Max-Planck-Institut

für

Astrophysik

Annual Report 2003

Contents

1 General Information

1.1 A brief overview of the MPA

The Max-Planck-Institut für Astrophysik, usually called the MPA for short, is one of the 80 autonomous research institutes within the Max-Planck-Gesellschaft (MPG). These institutes are primarily devoted to fundamental research. Most of them carry out work in several distinct areas, each led by a senior scientist who is a "Scientific Member" of the MPG. The MPA was founded in 1958 under the direction of Ludwig Biermann. It was an offshoot of the MPI für Physik which at that time had just moved from Göttingen to Munich. In 1979 the decision was made to transfer the headquarters of the European Southern Observatory (ESO) from Geneva to Munich. As part of the resulting reorganization the MPA (then under its second director, Rudolf Kippenhahn) moved to a new site in Garching, just north of the Munich city limits. The new building lies in a research park barely 50 metres from ESO headquarters and is physically connected to the buildings which house the MPI für Extraterrestrische Physik (the "MPE"). This park also contains two other large research institutes, the MPI für Plasmaphysik and the MPI für Quantenoptik, as well as many of the scientific and engineering departments of the Technische Universität München (the "TUM"). In 1996 the institute's management structure was altered to replace the third director, Simon White, by a board of directors, currently Wolfgang Hillebrandt, Rashid Sunyaev and Simon White, the Managing Directorship rotating every three years. Rashid Sunyaev has been acting as the Managing Director since January of 2003.

The MPA was founded specifically as an institute for theoretical astrophysics, intended to foster the development of basic theoretical concepts and effective numerical methods to master the challenges of stellar structure and evolution, the hydrodynamics of the interstellar medium , magnetic fields, hot plasmas, energetic particles, and the calculation of transition probabilities and cross-sections important for astrophysics. In later years these efforts also complemented the observational and instrumental activities carried out in other Max-Planck institutes.

Very soon this specialization grew to include strengths in numerical astrophysics using powerful supercomputers and computer clusters in Garching at the supercomputer facility of the MPG. These traditions have been strongly promoted in recent years and the MPA has also diversified to include a wide range of data analysis activities. Resources are specifically channelled into areas where new observational or computational capabilities are expected to lead to rapid developments. Current concentrations of interest include stellar evolution, stellar atmospheres, accretion phenomena, nuclear and particle astrophysics, supernova physics, astrophysical fluid dynamics, high-energy astrophysics, radiative processes, the structure, formation and evolution of galaxies, gravitational lensing, the large-scale structure of the Universe, and physical cosmology, including cosmic microwave background (CMB) research. Several of the earlier concentrations of interest, for example, solar and solar system physics, the quantum chemistry of astrophysical molecules, and General Relativity because of the foundation of the Albert Einstein institute in Golm have been very substantially reduced over the last decade.

Although MPA scientists are mainly working on problems in theoretical astrophysics, they also participate in a number of observational projects. The European cosmic microwave background satellite Planck Surveyor, scheduled for launch in 2007, is being planned and will be operated by a consortium of groups and institutions across Europe. The MPA represents Germany in this consortium. Specifically, part of the software system required for Planck data processing and information exchange within the consortium will be developed at MPA, the development and use of a data simulation pipeline for Planck is coordinated by MPA, and MPA will be the place where the final data products of the Planck mission will be prepared for release, documented, and finally released to the astronomical community. MPA is also involved in the overall management and coordination of the data-reduction software required for the mission, and in several of its scientific aspects.

In 2000, MPA became a partner of the "Sloan

Digital Sky Survey" (SDSS) project. This survey Aims to map one-quarter of the entire sky, determining the positions, brightnesses and colours of more than 100 million celestial objects. It is now 50% complete and has obtained spectra and so measured distances to more than 400,000 galaxies and quasars. SDSS is performing extremely well and MPA scientists are actively involved in the data analysis and interpretation. Much of the work is focused on using the very high quality spectra to understand the properties of the galaxies and the AGN in the survey.

Finally, on October 17, 2002, the European gamma-ray mission *Integral* was successfully launched on a Russian Proton rocket. INTEGRAL is addressing questions related to compact objects, stellar nucleosynthesis, the Galactic center and extragalactic astronomy. These scientific goals are attained by combining high-resolution spectroscopy with imaging and accurate astrometry of celestial sources of gamma-ray emission. The MPA is involved in this mission through Rashid Sunyaev and his affiliation with IKI in Moscow. INTEGRAL is producing interesting results on the hard X-ray population of the Galactic center field and on the brightness of the Galaxy in the electron-positron annihilation line and the gamma-ray line of radioactive ^{26}Al.

While most of the research at MPA addresses theoretical issues, the neighbouring institutes provide complementary expertise and there are many collaborative projects with them. Major research programmes at MPE are concerned with observational aspects of infrared, X-ray and gamma-ray astronomy, together with supporting theoretical work. ESO carries out a broad range of instrumental and observational projects in the optical and infrared, many of which make use of the VLT, the largest optical telescope in the world.

At any given time the MPA has about 44 scientists working on long-term positions at postdoctoral level and above, up to 7 foreign visitors brought in for periods of varying length under a vigorous visitor programme, and more than 30 graduate students. The students are mostly enrolled for degrees in one of the two large universities in Munich, the Technical University (TUM) and the Ludwig-Maximilian-Universität (LMU). A number of the senior staff at MPA have teaching affiliations with one or other of these universities. Ties with the German universities are also established via joint research projects, such as the special research programs ("Sonderforschungsbereiche") on particle astrophysics, which also includes the MPI für Physik, and on gravitational wave astronomy.

On initiative of the Max-Planck Society, an *International Max-Planck Research School on Astrophysics* was founded in 2000. The purpose of the School was to enhance the visibility of astronomy in Garching/Munich and to increase collaboration between the different institutions. It is open to students from all countries of the world. The school has since attracted more than 50 highly-qualified and motivated young scientists and the first students are now in their final year of study and will obtaing their degrees next year either from the LMU or from the TU.

Since 1996 the MPA is part of EARA, a European Association for Research in Astronomy which links it to the Institut d'Astrophysique de Paris, the Leiden Observatory, the Institute of Astronomy, Cambridge, and the Instituto Astrofisico de Canarias in a programme dedicated to fostering inter-European research collaborations. Such collaborations are also supported by membership in a number of EC-funded networks, some of which are coordinated by the MPA. The five European networks that MPA are involved in deal with the physics of the intergalactic medium, the cosmic microwave background, accretion onto compact objects, Type Ia supernovae explosions and gamma ray bursts.

Finally, in 1999, a proposal to establish a Max-Planck Cosmology Group at the the Shanghai observatory was realized. The group has approximately 8 to 10 researchers, mainly young postdocs and graduate students, and a very active exchange between that group and the MPA has continued in the following years.

1.2 Current MPA facilities

The MPA building itself is a major asset for its research activities. It was specially designed by the same architect as ESO headquarters, and the two buildings are generally considered as important and highly original examples of the architecture of their period. Although the unconventional geometry of the MPA can easily confuse first-time visitors, its open and centrally focused plan is very effective at encouraging interaction between scientists and makes for a pleasant and stimulating research environment.

The library facility is shared by the MPA and the MPE.

The fact that it has to serve the needs of two institutes with differing research emphases – predominantly theoretical astrophysics at MPA and observational/instrumental astrophysics at the MPE – explains its size. At present the library holds about 20000 books and conference proceedings, as well as reports, observatory publications and preprints, and it holds subscriptions for about 250 journals. The current holdings occupy about 1900 meters of shelf space. In addition the library maintains a pre– and reprint archive of MPA and MPE publications, two slide collections (one for MPA and one for the MPE) and keeps copies of the Palomar Observatory Sky Survey (on photographic prints) and of the ESO/SERC Sky Survey (on film). The MPA/MPE library catalogue includes books, conference proceedings, periodicals, doctoral dissertations, and habilitation theses. This catalogue and the catalogues of other MPI libraries on the Garching campus and elsewhere are accessible online via the Internet from the library and from every office terminal or PC. Internet access to other bibliographical services, including electronic journals and the SCI, is also provided. To serve the librarians' and users' needs the library has access to several copy machines, and is equipped with a microfiche and microfilm reader/printer, 2 X-terminals, 4 PCs, 2 laser printers and a fax machine.

An urgent need for more shelf space was alleviated in 2002. After the completion of the new MPE building in 2000, the library acquired a large archive room in the basement of the new MPE building and also obtained additional space in the new MPA basement. This room currently provides about 400 meters of shelf space and holds the MPA/MPE preprint and reprint archives, the observatory publications and the preprints. The available space in the basement will allow additional shelf space of up to 400 meters to be installed if necessary. Because the preprint and reprint archives and the observatory publications have moved, new space has become available in the main library room. This section has been redecorated and is used as office space for the librarians. A user help desk has also been installed.

Computational facilities

MPA has always placed considerable emphasis on computational astrophysics and has therefore ensured access to forefront computing facilities. The MPA computer centre consists of 8 powerful central workstations (IBM, SUN, and INTEL-based PCs) providing computer resources both for interactive work and for intermediate-scale numerical applications. All users have free access to all resources. User access is mainly through modern desktop PCs (with Linux as the operating system) for interactive work, which are also administered by the system managers. System software and the file system (AFS) are set up so that users always have the same computer environment independent of the machine they are actually working on. The total on-line disk space of several TByte resides on a few central fileserver systems with high data security. Data accessibility is virtually 100% throughout the year. Special requirements regarding CPU-power, memory and storage size are met as well. Several IBM-hosts and a recently acquired new Opteron-system provide 64-bit environment for memory requests of up to 8 GB per process. In addition to the general systems, the PLANCK and SDSS projects have their own dedicated workstations and PCs. An additional SUN-workstation cluster exists for the high energy astrophysics group. For travel and presentation purposes a number of laptops can be borrowed for a limited time. Private laptops are allowed, but form a separate, less secure network. MPA also supports a fully equipped and modern video-conferencing facility.

MPA scientists also have access to the RZG, the main computer centre of the MPG, and are among the top users of the facilities there. The most important resources provided by the RZG are parallel and vector supercomputers, PByte mass storage facilities, and the gateway to GWIN/Internet. The exchange of expert knowledge with RZG staff is also very valuable. Network connection to the RZG is via Gigabit-Ethernet and behind a campus-wide firewall, and by a structured 100 Mbit network in-house. WLAN has recently been introduced to MPA, too. The AFS file system ensures that the transfer of data among MPA machines and from MPA to the RZG is almost transparent to the user. An MPA-owned LINUX-PC-cluster, maintained by RZG, satisfies the increasing needs for cheap, but effective CPU-resources.

Further computing power is available at a second Max-Planck Society computer centre which is operated jointly with the University of Göttingen, and provides additional access to large parallel machines, services and expertise. Finally, MPA scientists can apply (and have applied successfully) for time on several other high-performance computers around Germany.

1.3 2003 at the MPA

The highlight of MPA public outreach activities in 2003 was our biennial "Open House" on Saturday, Oct. 25. It attracted about 1000 visitors to the Institute, including a large number of pupils and students, who enjoyed various presentations of MPA research work. Besides lectures by scientists on cosmology, galaxy evolution, element formation, and black hole physics, which filled the MPA lecture hall to its capacity limit, our "Cosmic Cinema" show of computer simulations attracted large crowds of visitors. A new collection of posters, which MPA researchers prepared for this event with the help of a Praktikum student, offered visitors a chance to get involved in conversations with presenting scientists. In the "Astro-Sprechstunde" in our coffee corner, staff members answered studentst' questions about internship possibilities and the career perspectives as a professional astrophysicist.

In 2003, MPA again hosted a number of visiting school classes, The students were informed about modern achievements in astrophysics by H.U. Schmidt and they responded enthusiastically. MPA researchers also supervised "Praktikum" works and internships of students and pupils gave talks at schools and public science events (see also section 4.4.3 "Public Talks").

Every year since 1997 the MPA has invited a world-class theoretical astrophysicist to give three talks over a one month period on a subject of his or her choice. The goal is to provide an opportunity for extended interactions between the visitor and the local astronomical community. This set of prize lectures, known as the Biermann Lectures, were given in 2003 by Lars Hernquist from the Harvard-Smithsonian Center for Astrophysics. Professor Hernquist have lecturs on three different subjects: *"New Puzzles from Neutron Stars", " Early Structure Formation and WMAP"* and *"Modeling Galaxy Formation and Evolution"*. This series of excellent talks consistently filled the MPA lecture theatre to its limits.

Several workshops and conferences were organized by MPA scientists in 2003. "The Physics of Type Ia Supernova Explosions" (March 10-15) RTN Workshop and Winter School, Ringberg Castle. "Thermonuclear Supernovae and Cosmology", (September 22 - October 4) ECT/RTN Workshop and School in Trento, Italy. "Stellar Populations 2003" (October 6 - 10), which was the MPA/ESO/MPE conference.

MPA's national and international cooperations and collaborations continued to flourish in 2003. A European COST project "Knowledge Exploration in Science and Technology" chaired by Geerd H. F. Diercksen, a RTN on "The Physics of Type Ia Supernova Explosions", coordinated by Wolfgang Hillebrandt, RTN on "Gamma-ray Bursts" led by Rashid Sunyaev, the "Intergalactic Gas" Network led by Simon White, and the CMB Network led by Rashid Sunyaev brought many new postdocs, students and visitors to MPA. A large international consortium involving several MPA scientists and with Simon White as PI has been carrying out an ESO Large Programme "The ESO Distant Cluster Survey". The consortium obtained substantial time on the VLT and NTT telescopes in 2003.

As a consequence of the various European TMR- and RTN- Networks involving MPA scientists, colleagues from all over Europe have been frequent visitors at MPA during 2003. As in previous years, a serious problem has been the quest for housing for such guests, as well as for new postdocs, and graduate students. The plans of the MPG to build a guest-house with 80 apartments on campus, mentioned in last year's report, still did not materialize. However, we will not give up: the joint discussions with the town council still give room for hope!

The research quality at MPA was recognized in 2003 by international prizes at both senior and junior level. Rashid Sunyaev was awarded both the 2003 Peter Gruber Cosmology prize and the Dannie Heinemann Astrophysics prize of the American Astronomical Society and American Institute of Physics, while Annette Ferguson won the Annie Jump Cannon award.

The partner group of the MPA at Shanghai Astronomical Observatory has developed very well in 2003. There has been growing international recognition of the research work by the leader of the group, Yipeng Jing, as well as his postdocs and students. They have received several invitations to give talks at major astrophysics conferences (such as the IAU meetings in Sydney) and have received offers of international collaborations by institutes in Canada, the USA, and in Europe. The partner group has been invited to join the European weak lensing project as the only non-European collaborator. The collaboration with the MPA is strong, as is the exchange program, At the moment 3 students from SHAO are visiting the MPA for one year.

The group has become a center for cosmological research in China with close connections to Beijing University and the University of Science and Technology in Hefei. At the end of 2003 the group consisted of 3 staff members, 7 PhD students, and 4 master students.

Finally, in 2003 construction work for the subway connecting the City of Munich to Garching has strongly influenced the environment around MPA. The present plans are to finish construction work by 2006/7. Until then everyone commuting between Munich and Garching will have to live with many inconveniences, but the direct connection to the city centre will no doubt be worth the long wait.

1.4 How to reach us

- Postal address:

  MPI für Astrophysik
  Postfach 13 17
  D-85741 Garching
  Germany

- Telephone (country code 49):

  89-30000-0 (switchboard)
  89-30000-2214 (secretary)
  89-30000-2235 (FAX)

- Electronic address:

  e-mail:
  user-id@mpa-garching.mpg.de
  (initial + last name
  will reach most people,
  e.g. mdepner for Maria Depner)

  World Wide Web:
  http://www.mpa-garching.mpg.de
  anonymous ftp:
  ftp.mpa-garching.mpg.de

- MPA (reference) library:

  phone: +49-89-30000-2305/6
  FAX: +49-89-30000-2378
  email: lib@mpa-garching.mpg.de
  URL: http://www.mpa-garching.mpg.de/libris.html
  homepage: only local access

2 Scientific Highlights

2.1 Neutron Stars as Cosmic Cannonballs

Scientists at the Max-Planck-Institute for Astrophysics in Garching and the University of Chicago have substantiated an explanation for the high space velocities of observed pulsars. Their computer models confirm the likely connection with asymmetries during supernova explosions.

Stars with more than ten times the mass of our Sun end their lives in spectacularly powerful supernova explosions. While the major part of the stellar gas is violently ejected, the core of the star collapses by its own gravity to form a neutron star. The latter has a mass of roughly 1.5 times the Sun, but its diameter is only about 20 kilometers. The matter in its interior is therefore more dense than in atomic nuclei.

Some of the known neutron stars are found inside the gaseous remnants of past supernova explosions. The most famous example is in the Crab Nebula (Fig. 2.1). Because it spins around its axis about 33 times per second, we receive on Earth characteristic, regular pulses. Such rotating neutron stars were therefore named pulsars. Other neutron stars, however, move away from the site of their formation with very high speed (Fig. 2.2). Typical velocities are several hundred kilometers per second, but some pulsars propagate through interstellar space with more than 1000 kilometers per second (Fig. 2.3). This is much faster than the motion of ordinary stars in our Galaxy. Therefore many neutron stars can escape from the gravitational pull of the Milky Way.

The orgin of the pulsar motions has long been a mystery. There is, however, no lack of ideas. Quite a number of theories have invoked speculative effects or exotic particle physics, but a connection with anisotropies of supernova explosions, which is suggested by observations, had so far not been demonstrated convincingly.

Now a team of scientists at the Max-Planck-Institute for Astrophysics in Garching and the ASCI Flash Center of the University of Chicago has found a natural explanation for such a connection. In computer simulations the team discovered that random, small perturbations in the star can amplify to huge anisotropies due to the rapid growth of fluid instablities during the launch of the explosion (Fig. 2.4). The explosion shock wave and the ejected matter therefore develop global deformation with a dominance of low modes, and the neutron star can be kicked to very high velocities of several hundred kilometers per second within just a second (Fig. 2.5).

For the first time the computer models allow one to understand the measured pulsar motions as a consequence of explosion asymmetries without making use of additional assumptions. Interestingly, the results seem to support a theory which has been favored for a long time to explain the beginning of the supernova explosion: The explosion is caused by the action of neutrinos. These neutral, weakly interacting elementary particles are radiated by the hot neutron star in huge numbers. They heat the gas in the stellar interior and can thus create the pressure by which the explosion is started. The viability of this neutrino-driven mechanism still awaits confirmation by hydrodynamic simulations with a detailed treatment of the microphysics and of the neutrino transport in the high-density core of the neutron star. Because of our incomplete understanding of the relevant physics, the dense interior of the nascent neutron star was replaced in the present computer simulations by an inner boundary condition where the luminosities and spectra of the emitted neutrinos were specified. The neutrino emission of the neutron star was assumed to be sufficiently powerful so that the neutrino-driven mechanism works. The neutrino heating leads to violent buoyancy until the expansion of the stellar gas occurs in a generically anisotropic manner. The mechanism of the explosion, the asymmetries observed in many supernovae, e.g. by polarization measurements, and the pulsar proper motions can thus all be linked to one effect. These results therefore give new credibility to the neutrino-heating mechanism for supernova explosions. (Hans-Thomas Janka, Konstantinos Kifonidis, Ewald Müller, Leonhard Scheck, Tomek Plewa)

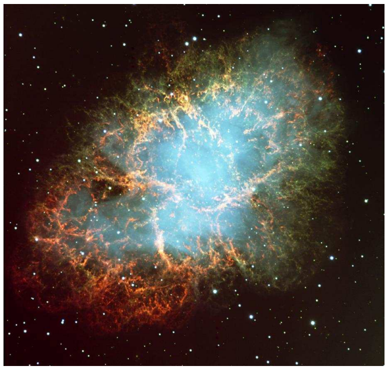

Figure 2.1: The Crab Nebula with the Crab Pulsar at its center (Credit: ESO).

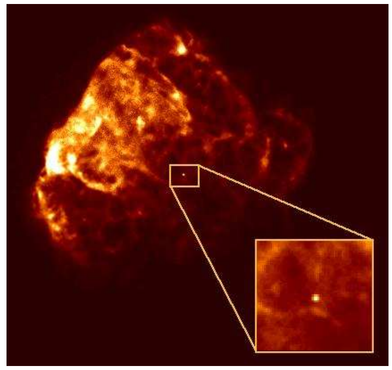

Figure 2.2: X-ray image of the PUPPIS A supernova remnant taken by the ROSAT satellite. In the inset close-up view, a faint pinpoint source of X-rays is visible which is most likely the young neutron star, moving with about 1000 km/sec in the opposite direction than the hot, bright gaseous relics of the supernova explosion. (Credit: S. Snowden, R. Petre (LHEA/GSFC), C. Becker (MIT) et al., ROSAT Project, NASA).

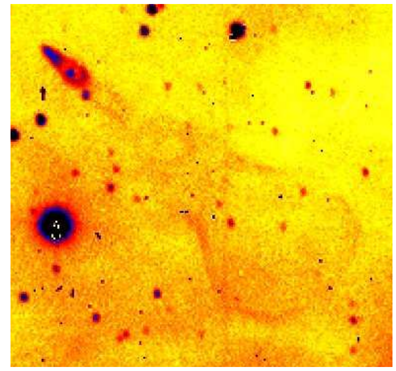

Figure 2.3: The Guitar Nebula. It is produced by the bow shock and the wake left behind by a neutron star which is travelling through the interstellar medium at an extraordinarily high speed of about 1600 km/sec. (Image taken with the 5-m Hale Telescope of the Palomar Observatory. Source: S. Chatterjee & J.M. Cordes, Astrophys.J. 575, 407 (2002)).

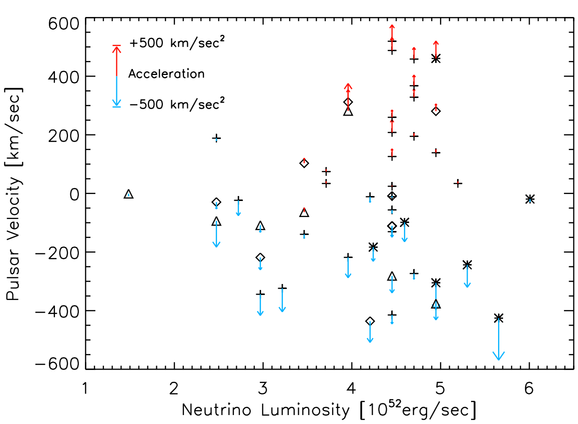

Figure 2.5: One second after the start of the supernova explosion the neutron star has gained a velocity up to more than 500 km/s. Because of the persistently large acceleration in some models (indicated by the length of the arrows) the final maximum speed can even be higher.

2.2 Flame Physics in Thermonuclear Supernova Explosions

Type Ia supernovae (SNe Ia) have recently received considerable attention because it appears that they can be used as distance indicators in cosmological measurements. These led to the conclusion that we are living in a universe that started to accelerate its expansion when it was about half its present age. The method applied in the distance measurements rests, however, primarily on phenomenological models which lack proper theoretical understanding so far.

A currently favored model describes SNe Ia as thermonuclear explosions of a white dwarf star close to the Chandrasekhar limit which consists of carbon and oxygen. From the star's center outward the thermonuclear reaction is mediated by a subsonic deflagration flame. The key ingredient to this model is the interaction of the flame front with turbulent motions which inevitably develop from instabilities stemming from the density contrast between nuclear fuel and processed material. Due to this mechanism the flame reaches velocities necessary to produce powerful SN Ia explosions. The

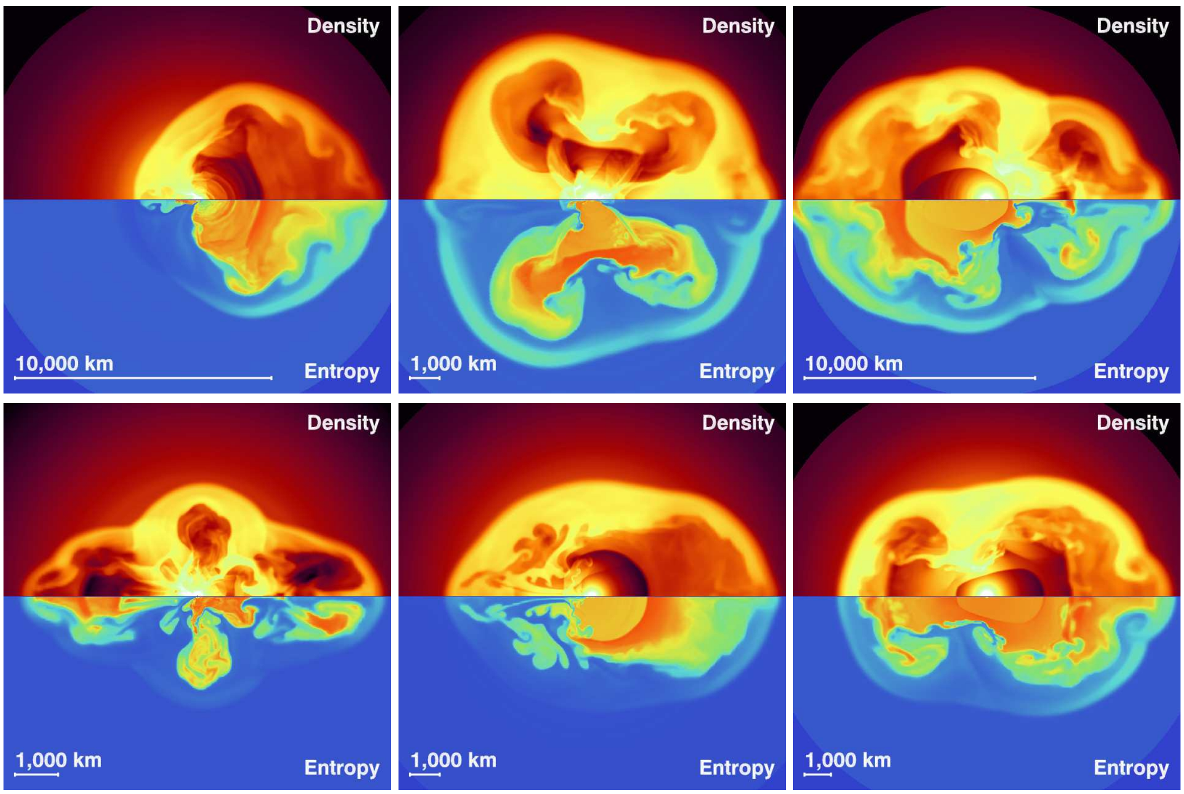

Figure 2.4: Asymmetric gas distribution in the interior of exploding stars one second after the start of the explosion. The pictures show the deformed supernova shock wave for a sample of six computer simulations. The neutron star is (not visible) at the center. Vortices and inhomogeneities in the gas flow have grown from random fluctuations in a highly nonlinear way and have produced a global morphology that is very different in every model.

difficulty to simulate this scenario emerges from the vast range of relevant length scales. From the viscous dissipation scale up to the largest turbulent eddies it covers more than 11 orders of magnitude. Moreover, the flame thickness is extremely small. There is very little hope to resolve this scale space in numerical simulations in the foreseeable future.

Therefore a simulation code for SNe Ia has been developed in the past years at MPA that resolves the upper part of the scale space but relies on assumptions on the physics on smaller (unresolved) scales. This scale separation is known as large-eddy simulation (LES). The numerical implementation is based on the level set method describing the mean position of the flame by the zero level set of a scalar field which is evolved appropriately. In order to corroborate this approach, the flame evolution has been simulated in a restricted domain at small scales. The goal of these studies was to verify the description of the effects of turbulence on unresolved scales by means of a subgrid scale (SGS) model and to check the assumption that the dynamically relevant instabilities are captured by the large-scale calculations and that stabilizing mechanisms hold on small scales.

Turbulent Burning in the Kolmogorov Regime

Although turbulence in SNe Ia is convectively driven, there must be a range of self-similar turbulent velocity fluctuations which obey the Kolmogorov scaling laws. Contrary to the largest scales which are dominated by buoyancy effects, the dynamics of the flow in this so-called inertial subrange is dominated by non-linear transfer of energy through a cascade of turbulent vortices. Assuming that the numerical cutoff is within the inertial subrange, one can formulate a dynamical equation for the kinetic energy associated with velocity fluctuations on scales smaller than the cutoff, i. e., the SGS turbulence energy. This equation supplements the hydrodynamical conservation laws which describe the dynamics of the flow on the numerically resolved scales. For simulations of SNe Ia, scaling arguments show that the cutoff indeed occurs in the inertial subrange.

The evolution of the burning process is significantly affected by turbulence, once the magnitude of velocity fluctuations exceeds the laminar burning speed, which is basically determined by the thermal conductivity of the fuel. Since turbulence folds and wrinkles the flames, the surface area increases and the rate of burning is enhanced. This mechanism is crucial for the deflagration model of SNe Ia. However, as a consequence of the limited resolution of numerical simulations, the computed flame front as represented by the level set method is smoother than the physical flame front. Thus, the burning rate would be underestimated, if one did not account for the effects of turbulence on unresolved scales. Now the key idea is that the numerical smoothing of the flame surface can be compensated by enhancing the flame propagation speed. This leads to the notion of a turbulent flame speed which is of the order of the unresolved turbulent velocity fluctuations. The magnitude of the fluctuations in the inertial subrange is given by a power law, which implies that the dynamics on the large scales becomes asymptotically independent of the numerical resolution. In essence, this is why the concept of a LES works. Locally, the turbulent flame speed is determined by the aforementioned SGS turbulence energy, for which a dynamical equation is known. However, the various terms in this equation cannot be evaluated either analytically or numerically due to the non-linearity of turbulent dynamics. Therefore one is bound to invoke putative approximations which amount to a SGS model.

There are many suggestions for such approximations, and a priori it is not clear which one should be chosen. For this reason, several options were investigated in 3D LES of turbulent thermonuclear burning in a simplified scenario: a cubic domain subject to periodic boundary conditions. Turbulence is produced artificially by means of a stochastic force field. The burning process is initially ignited in several small spheres and then is evolving while turbulence is developing. From the simulation data, the statistics of a number of dynamical quantities as well as the structure of the flow and the flames in 2D sections were investigated, and comparisons for different choices of SGS model parameters were performed. For example, the evolution of the total specific energy in a particular LES is illustrated in Fig. 2.6. Moreover, a snapshot of the flow in combination with contours of the ratio of the turbulent velocity scale q_{sgs} to the laminar burning speed s_{lam} is shown in Fig. 2.7. In this simulation, a SGS model was implemented which is based upon a *dynamical procedure*. Rather than making ad hoc assumptions, model parameters are estimated *locally* from structural properties of the resolved flow. It was found that the application of a dynamical procedure leads to significant changes in the evolution of the burning process compared to the more straight-forward model which has been used in supernova simulations so far. Whether observable consequences will arise if the new model is applied to the deflagration in thermonuclear supernova remains to be seen.

Investigation of the Cellular Burning Regime

The above described interaction between the flame and turbulent velocity fluctuations dominates its propagation only down to the so-called Gibson scale. Below that scale the flame burns faster through turbulent eddies than these can deform it. Here the flame evolution is determined by the (hydrodynamical) Landau-Darrieus (LD) instability and its counteracting nonlinear stabilization. In case of terrestrial flames this stabilization leads to a cellular steady-state pattern of the flame front giving rise to the *cellular burning regime*. In 1995 Niemeyer and Hillebrandt could show by means of hydrodynamical simulations that the LD instability acts under conditions of SNe Ia and the present study confirmed that also the cellular stabilization of the flame front holds for thermonuclear flames in white dwarfs. This was achieved in a series of 2D simulations. The stability of the cellular flame shape was tested for various fuel densities and for interaction of the flame with vortical flows. Two examples are given in the following.

Figure 2.8 shows the propagation of an initially perturbed flame into quiescent fuel. The initial perturbations grow and in the nonlinear regime the flame exhibits a cellular structure. For the given setup, however, the cellular pattern of the same wavelength as the initial perturbation is not a stable solution. The snapshots at later times (Fig. 2.8b,c) illustrate the "merging" of cells until the steady-state structure of a single domain-filling cusp has formed. In case of higher numerical resolutions, this fundamental flame structure may be superposed by a short-wavelength cellular pattern, which is advected toward the cusp and does not lead to a break-up of the domain-filling cell. This evolution is well in agreement with theoretical predictions. Simulations with different fuel densities ρ_u led to similar results. In the range of $\rho_u = 1 \times 10^7 \, \mathrm{g\,cm^{-3}} \ldots 1 \times 10^9 \, \mathrm{g\,cm^{-3}}$ no significant flame destabilization could be observed.

Flame interaction with a vortical fuel field is shown in Fig. 2.9. This is motivated by turbulent motions from the turbulent eddy cascade around the Gibson scale and from pre-ignition convective motions in the white dwarf. A parameter study with different fuel densities and various strengths of the velocity fluctuations in the fuel flow led to the result that a vortical flow of sufficient strength can break up the cellular pattern of the flame (cf. Fig. 2.9b,c). In this case, however, no drastic self-turbulization of the flame but rather a smooth adaptation of the flame structure to the imprinted flow was observed (see Fig. 2.9d).

These results corroborate the assumption of large scale models, that the generation of turbulence is dominated by large-scale effects. In the cellular burning regime, the flame surface is enlarged compared to a planar configuration. This leads to an additional acceleration of the flame, but no effects were found that drastically alter the explosion process. (F.K. Röpke, W. Schmidt and W. Hillebrandt)

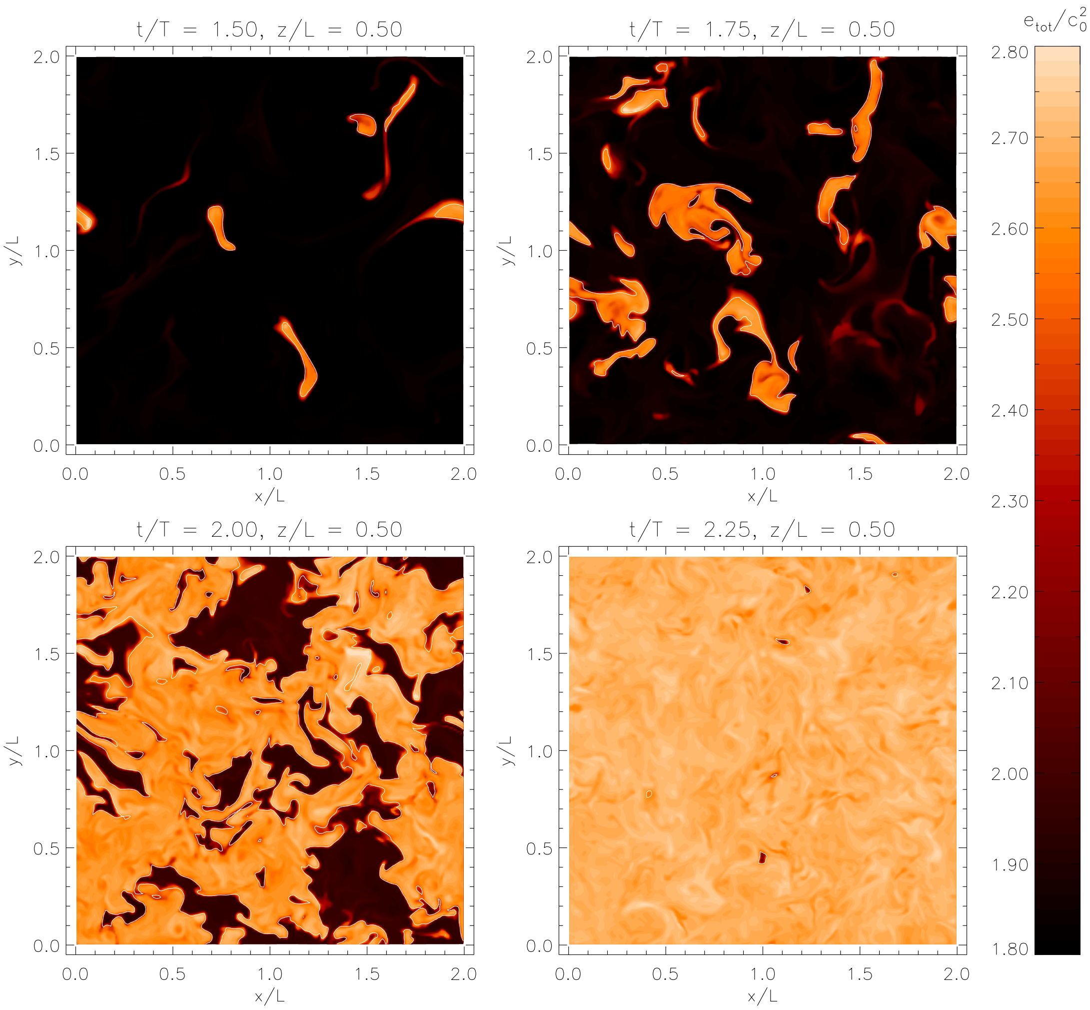

Figure 2.6: 3D LES of turbulent burning: 2D contour sections of the dimensionless total energy $\tilde{e} = e/c_0^2$. The mean mass density is $\rho_0 \approx 2.903 \cdot 10^8\,\mathrm{g\,cm^{-3}}$ and the initial sound speed $c_0 \approx 6.595 \cdot 10^8\,\mathrm{cm\,s^{-1}}$. Turbulence is produced by a stochastic solenoidal force field. The bright regions of high specific energy contain burned material, and the flame fronts are indicated by the thin white lines.

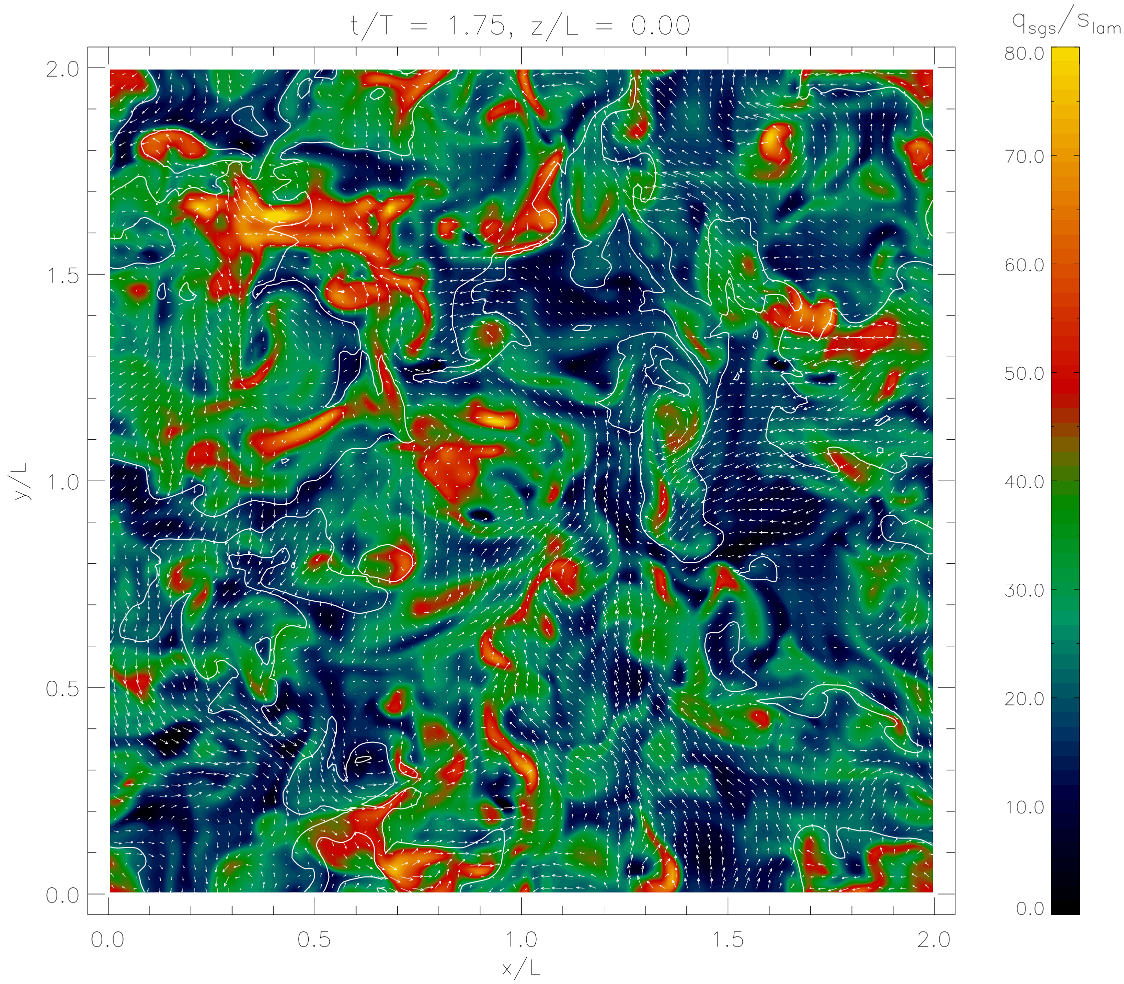

Figure 2.7: 3D LES of turbulent burning: Filtered flow map with contours of the SGS turbulence velocity $q_{\rm sgs}$ relative to the laminar burning speed $s_{\rm lam}$ in a 2D section at normalized time $\tilde{t} = 1.75$. The numerical resolution is $N = 216$.

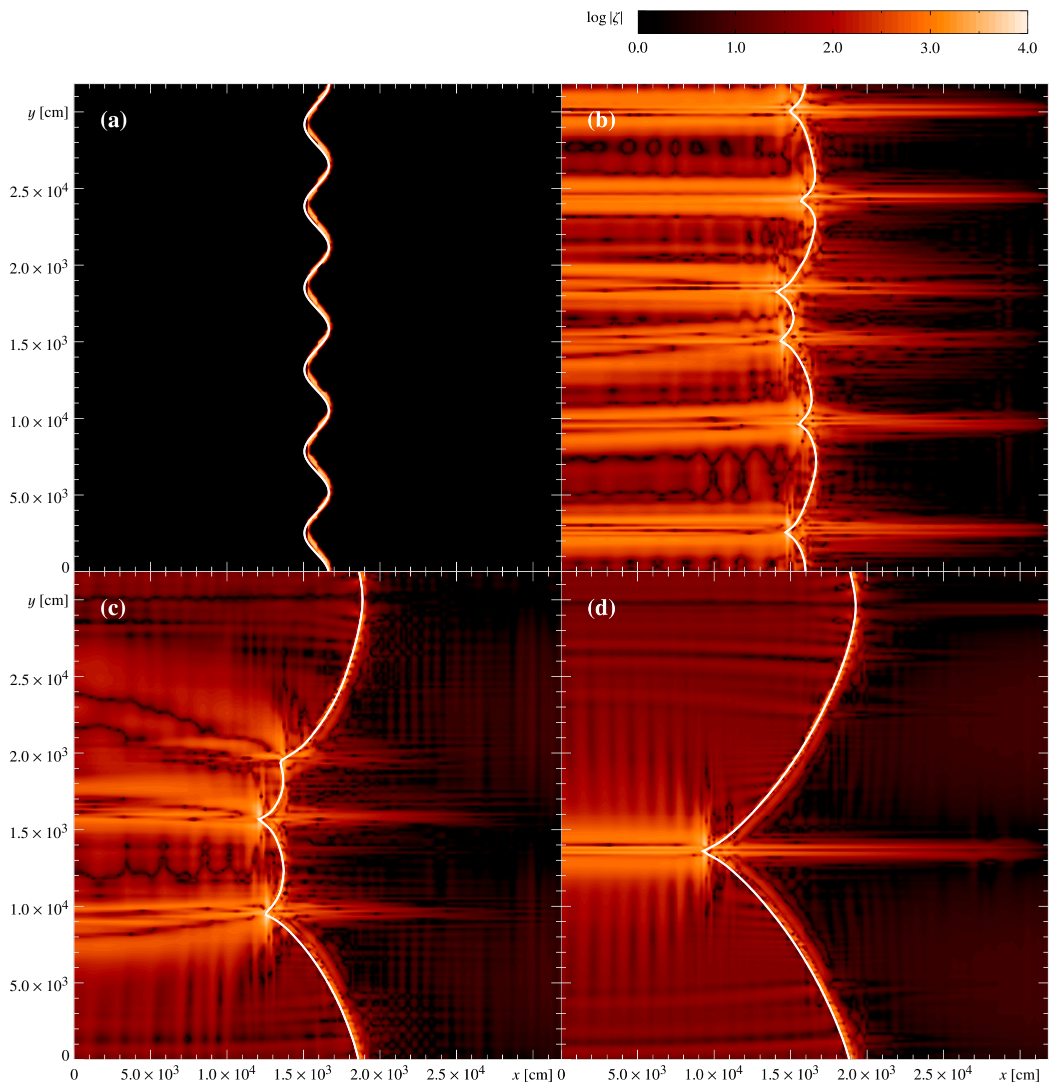

Figure 2.8: Flame propagation into quiescent fuel at $\rho_u = 5 \times 10^7\,\mathrm{g\,cm^{-3}}$, resolution: 200×200 cells, snapshots taken at **(a)** 0, **(b)** 7.5, **(c)** 15, and **(d)** 30 growth times τ_{LD} of a perturbation with $\lambda = 3.2 \times 10^4$ cm. Color-coded is the vorticity of the flow field.

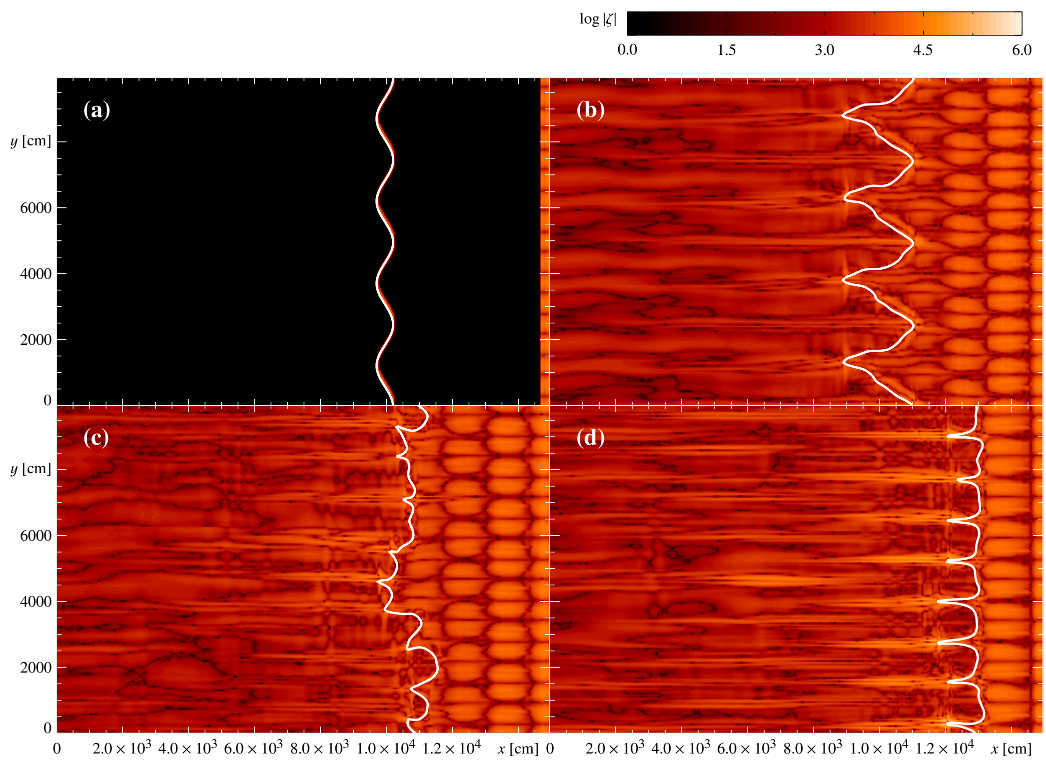

Figure 2.9: Flame propagation into vortical fuel at $\rho_u = 5 \times 10^7\,\mathrm{g\,cm^{-3}}$; velocity fluctuations at the right boundary: $v'/u_{\mathrm{lam}} = 2.5$; resolution: 300×200 cells; snapshots taken at **(a)** 0 s, **(b)** 8.0×10^{-3} s, **(c)** 1.6×10^{-2} s, and **(d)** 4.8×10^{-2} s. Color-coded is the vorticity of the flow field.

2.3 A stable magnetic field in a stellar interior

The magnetic fields of A-stars and magnetars

The origin of the strong magnetic fields observed in some A-stars, White Dwarfs and neutron stars has been an unsolved problem since more than 50 years. Are these fields 'fossils': remnants of magnetic fields present at the birth of the star? Or are they continuously created by some currently still operating process? With numerical MHD simulations of global magnetic fields in stars, we have now shown that the fossil hypothesis is in fact the most likely one.

A small percentage of hot stars are observed to have a strong magnetic field (300 G to 30 kG, or 0.03 to 3 Tesla) at the surface. Unlike the field at the surface of the Sun, these fields are static, no changes having been observed in the fields of any stars over the fifty years since their discovery. Also unlike the Sun, the fields are ordered, nearly dipolar.

These differences are not surprising, since these hot stars lack the convective envelope which is the source of the Sun's magnetic field. They do have small convective cores, however, and it has been suggested that a magnetic field is generated there by a dynamo process like that operating in the core of the Earth. The field which we observe at the surface would have migrated upwards from the core. This is called the 'core-dynamo' model.

An alternative to explain the magnetic fields of hot stars is the 'fossil-field' idea. This is the suggestion that the magnetic field was present when the star was formed, and has remained there ever since. It must be able to survive for hundreds of millions of years for this idea to work.

An arbitrary magnetic field residing in a sphere of conducting fluid will, in general, be unstable and decay on a short time-scale (the Alfvén travel time, of the order of a few years). This is because the magnetic field represents a positive energy which can be released by internal displacements of the fluid in the sphere. Unlike the case of a bar magnet, where the field is held in place by solid state forces, the fluid interior of a star provides little stability.

However, there has been speculation for many years that the force of gravity, acting in the radial direction, could provide enough of a constraint for certain special field configurations to be stable. Such a field would be able to survive for a long time, decaying only on the much longer time-scale determined by the finite resistivity of the fluid in

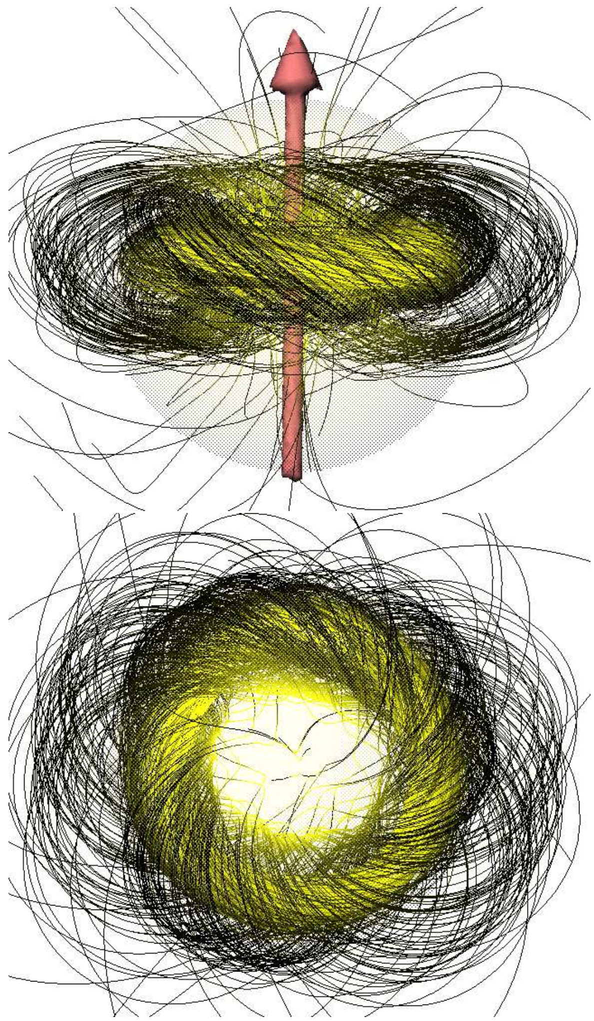

Figure 2.10: The field configuration resulting from the numerical simulations, viewed from the side (upper panel) and the top (lower panel). The black lines represent the magnetic field lines, the transparent sphere marks the stellar surface and the arrow in the upper panel marks the direction of the dipole moment of the field.

which it resides. For a star, this time-scale would be longer than the lifetime of the star itself, and consequently, if such a field were ever able to form inside a star, we should expect it to remain there, relatively static. However, no such stable field has ever been proven to exist.

Previous attempts to prove the existence of such a field have used analytical methods, i.e. pen and paper. Unfortunately, it turned out to be much easier to show that a magnetic field of a particular shape is unstable than to find stable ones.

Where analytic methods fail, numerical simulations can sometimes help. With a 3-D magnetohydrodynamic code, we have modelled a star as a self-gravitating ball of plasma with a temperature distribution comparable to that found in reality (a polytrope). Into this star we put a randomly generated magnetic field, and followed the evolution of this magnetic field in time. The idea was that this field would, being unstable, begin to decay but eventually find its way into a stable configuration, if it exists. This was indeed found to happen, and regardless of the precise shape of the initial field, a stable configuration of approximately the same shape was produced (Fig. 2.10).

The stable core of this configuration is a circular twisted torus buried below the surface of the star. To picture this shape, imagine drawing lines (representing magnetic field lines) on a piece of rubber tubing parallel to the length of the tube, twisting one end of the tube in relation to the other, and then bending the tube around into a loop, so that the lines at the two ends join up.

The torus is usually not exactly centered in the star, and slightly deformed. Another set of field lines passes through the center of this torus: these lines cross the surface of the star and give the field its external appearance of an approximate dipole. This solves one of the problems of the original fossil field model, since a purely dipolar field is about the most unstable of all configurations. It is the stable twisted torus below the surface that gives the configuration its overall stability.

In all cases where the evolution of the initial configuration yielded a stable end-product it looked like Fig. 2.10, suggesting either that no other stable field exists, or that other stable fields are difficult to reach from a random initial field of the type used.

Some understanding of these results is provided by considering the so-called *magnetic helicity*, a global property of a magnetic configuration, given by the integral of the product of the magnetic field and its vector potential over the volume. It is a conserved quantity as long as magnetic diffusion and reconnection can be neglected. If the initial field configuration has a finite helicity, it can decay only to the lowest energy state with the same helicity; aparently it has the form shown in fig 1. In practice, helicity is not strictly conserved in our simulations but it still appears to plays an important role.

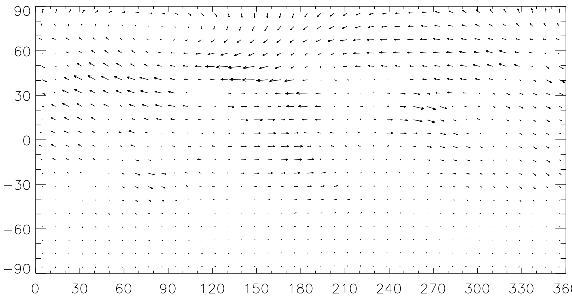

Figure 2.11: The horizontal component of the Lorentz force in the crust of a magnetar, with longitude and latitude making the x and y axes. The forces are predominantly of the kind that would produce rotational displacements when the crust yields in a cracking event.

The stable fields we have found could also explain the fields seen in White Dwarfs (WD). The fields in WD have aproximately the strengths resulting when the core of a magnetic main sequence star were to contract into a WD. In fact, since WDs have no convective cores, they provide a stronger case for the fossil field hypothesis than main sequence stars.

More recently, galactic objects have been observed which emit X-rays at high luminosity, both continuously and during outbursts. By far the most likely explanation is that these objects are neutron stars with an extremely strong magnetic field (10^{15} G, or 10^{11} T). The slow decay of the magnetic field provides the energy for the X-ray emission. This is called the *magnetar* model.

Neutron stars have a solid crust, which is able to fix a magnetic field in place which would be unstable in its absence. For the field strengths of most neutron stars (observed as pulsars) this is a sufficient explanation, but the field strength in magnetars is strong enough to break a neutron star crust. As in the case of the White Dwarfs, however, the core of a neutron star is a stably stratified fluid, and could hold the kind of field configurations discussed above. The gradual decay of this field as a result of the finite resistivity of the fluid would produce heat and account for the continuous X-ray emission. The changes in the magnetic field below the crust due to this decay would put stress on the crust, which would eventually crack ('starquakes'). In a cracking event, currents would be sent through the tenuous atmosphere and a large amount of energy released at once, producing the outbursts observed from magnetars.

We have modelled the evolution of the stable twisted torus field in a neutron star with a solid crust. As the field underneath the crust slowly changes, we measure the stresses which build up in the crust. These are illustrated in Fig. 2.11. Although we do not model the actual crust cracking process itself, it is possible to see where and a what way the crust is likely to crack, by looking at the stress forces. We find that the stress tends to produce the rotational crust displacements required by outburst models, as well as fault lines – lines separating regions in which the stress is in opposite directions. There are parallels here to the stresses in the Earth's crust before earthquakes. (J. Braithwaite)

2.4 Condensation in two-phase accretion flows in AGN and XRBs

The black holes at the centers of galaxies are often enormously energetic sources of radiation of all kinds; they are the ultimate power sources for quasars and other types of active galactic nuclei (AGN). However most of the nearby galactic centers, including the 3 Million solar mass black hole in our own galaxy, are surprisingly quiet. There is a large amount of hot gas in their large scale environment, which one would expect to accrete onto the hole and power a much larger X-ray flux than observed. Where is this gas going, if it does not accrete? As a new solution to this problem, we find that the gas can in fact 'condense' into a cool, invisible disk at some distance from the hole. Mass accumulates there instead of accreting, leading to long periods of quiescence seprated by relatively short active episodes in which the accumulated mass drops into the hole. The activity phase is then probably the time when these black holes are observed as bright AGN.

Observations, while not unambiguous at this point, suggest that both types of solutions may exist in reality. Low Luminosity AGN (LLAGN), inactive galaxies such as our own, and quiescent states of XRB transients are especially interesting in this regard. For example, LLAGN are classified as AGN because of their optical broad double-peaked emission lines. These lines clearly require a cool accretion disk to exist at $\sim 10^3 - 10^4$ Schwarzschild radii from the black hole. When the infrared-optical spectra of these objects are interpreted as the standard disk emission, one obtains an estimate of the accretion rate flowing through the disk. If this large scale accretion flow is continued down to the black hole, theoretically one would expect the flow to be brighter by one to four orders of magnitude than observed. One popular idea that solves the problem is that the accretion flow start off at large radii as the standard cold flow but then "evaporates" at few hundred to few thousand Schwarzschild radii to form an inner NRAF (see 2.12). Since the latter is radiatively inefficient, the expected luminosity is strongly reduced and can be made to agree with the observations rather naturally.

Over the last 10 years, a considerable work has been expended here at MPA to understand the physics of such a transition. Meyer & Meyer-Hofmeister built a detailed model where the cold disk is evaporated via thermal conduction heating due to hot coronal electrons. Deufel, Dullemond & Spruit studied a similar process driven by hot ions. As any physical process, disk evaporation has its inverse process – i.e. condensation of the hot flow on the disk surface. We have undertaken a systematic study to determine the parameter space where the condensation process may be important. We discovered two physically distinct condensation regimes. The first one occurs when the density in the hot flow is large enough so that the thermal conductivity is well described by the classical Spitzer's formula. The physics of such flows is very similar to that studied by Meyer & colleagues. The only distinction is the higher density in the hot flow that makes the radiative cooling rate significant, forcing condensation. Roughly speaking, the latter condition is met by flows with accretion rate $\dot{m} > \alpha^2$, where $\alpha \leq 1$ is the viscosity parameter. Our results are in qualitative agreement with the most recent study of Liu, Meyer & Meyer-Hofmeister that indeed found condensation in their models for low enough values of α.

The second condensation regime occurs when the accretion rate of the hot flow is very low. In such flows the radiative cooling term is unimportant, and using the classical Spitzer's flux formula, one finds evaporation. However, when the mean free path of the hot electrons is large compared with the geometrical thickness of the hot flow, the classical heat flux formula is not valid. We used the "non-local" heat flux approach borrowed from the

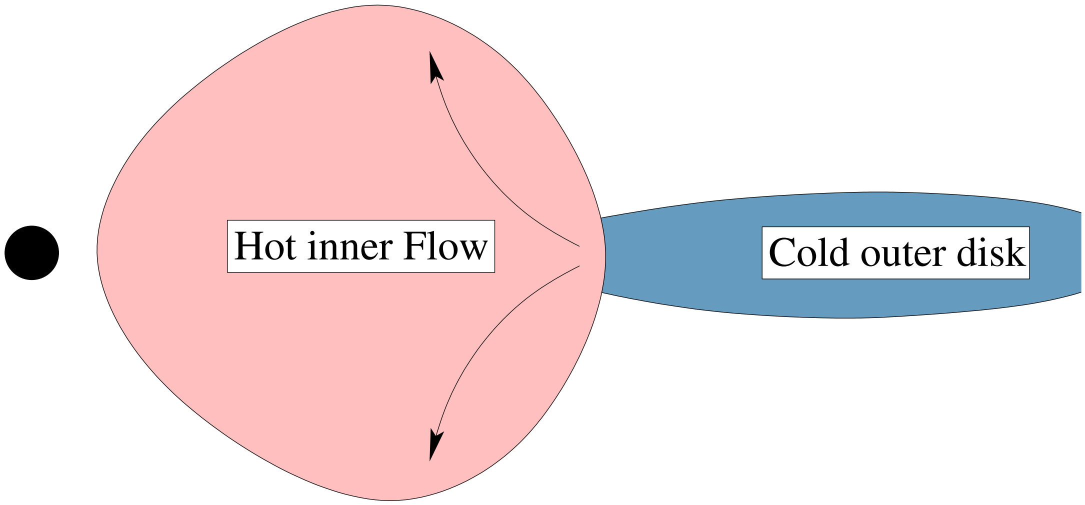

Figure 2.12: Cold accretion disk evaporating to form an inner hot flow. The latter is very hot and tenuous and is thus radiatively inefficient. This geometry has been suggested in the past to explain the low radiative output of LLAGN.

terrestrial laser heated plasma experiments to deal with this complication. We find that, due to their very large mean free path, the hot particles penetrate deep into the cold disk where the radiative losses are significant enough to balance the incoming heat flow.

Our results suggest an alternative explanation for the LLAGN phenomenon. Accretion disks of LLAGN are believed to be very cold, i.e. $T \lesssim 10^3$ K. In analogy to the X-ray binary stars, it is quite likely that LLAGN disks may be in the "inactive" or quiescent phase. In X-ray binaries, this state follows a major outburst produced by a strong accretion event. At the end of the event, the inner accretion disk is highly depleted of mass ("emptied"). The accretion rate through the inner parts, i.e. directly on the black hole, is thus very small, yielding a very small luminosity. However the outer disk regions, continuously fed from the companion star, are accumulating mass until they become massive and hot enough for the next outburst.

We thus suggest that LLAGN accretion flows have a two-phase geometry shown in 2.13. The hot flow above the disk is the stellar winds or the hot ISM captured by the black hole gravity. This gas is responsible for the X-ray emission of the LLAGN, and in some nearby galactic centers is actually spatially resolved (e.g. in our own galaxy, and the nucleus of M87). As the hot gas condenses, the gravitational energy released per unit mass of hot gas is very small if this process occurs at $R \sim 10^3 - 10^5$ Schwarzschild radii. As long as the cold disk is inactive, the luminosity of such a flow would be quite small. Estimates show that the mass storage process may have to be very long to refuel the disk – e.g. $10^7 - 10^8$ or more years.

The two different geometries for the LLAGN (2.12 and 2.13) can be observationally distinguished in the future. The presence of the cold disk in the inner part may manifest itself through X-ray and near infra-red flares (such flares are observed in Sgr A*), and reprocessing of the stellar radiation of the closest stars into the near infrared band. This new view on the LLAGN appears theoretically attractive since it puts onto an evolutionary sequence all the galactic nuclei, from the brightest quasars that radiate at about the Eddington limit to the dimmest sources such as Sgr A* (S. Nayakshin, J. Cuadra and R. Sunyaev).

2.5 Studying Galaxy Formation with the Local Universe Fossil Record

Understanding the way in which galaxies form and evolve remains an outstanding task for modern astrophysics. Our theoretical understanding of structure formation has progressed enormously over the past decade leading to the now 'standard picture' of hierarchical assembly within a cold dark matter (CDM) universe dominated by dark energy. Within this framework, large disc galaxies, like the Milky Way, are thought to arise from the merger and accretion of many smaller subsystems, as well as from the smooth accretion of intergalactic gas. While this theory has met with much success

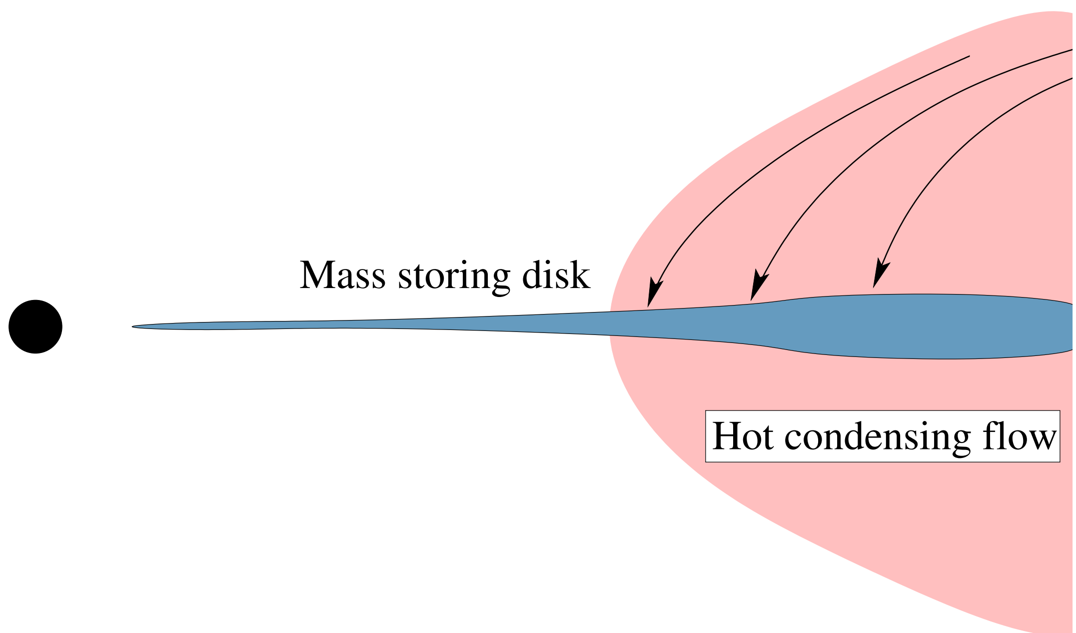

Figure 2.13: A possible alternative geometry of the accretion flow in LLAGN. The cold disk is shown very thin in the innermost regions to reflect the fact that, compared to the standard accretion disks, the inactive disks are nearly empty in the inner regions. The disk is refilled by the hot condensing flow. The X-ray luminosity in this scenario comes from the hot condensing gas settling onto the disk at large radii.

on large scales, there are worrying discrepancies between predictions and observations on smaller 'galactic-sized' scales. Determining whether this is a signature that the cosmological model is incorrect, or simply that the poorly-understood astrophysical processes which dominate on these scales – namely star formation, feedback and chemical enrichment – have not yet been properly implemented in numerical models, is of utmost importance. Knowledge of the star formation and mass assembly histories of massive galaxies provides a key to resolving this issue.

In CDM models, galactic stellar halos are predicted to contain the most visible signatures of hierarchical assembly, namely tidal debris from merged former satellite companions. As these small systems disrupt, their stars get pulled out into long tidal tails which trace out the satellite's orbit. The tidal debris eventually disperses, with constituent stars merging into the background stellar halo. Due to their extreme faintness, very little has been known until now about the properties of stellar halos beyond the Milky Way. A. Ferguson (MPA), in collaboration with R. Ibata (Strasbourg), M. Irwin, A. McConnachie (Cambridge), G. Lewis (Sydney) and N. Tanvir (Herts), has been exploring the spatial distribution, ages, metallicities and kinematics of old and intermediate-age stellar populations (the "fossil record") in the outer regions of our two most massive galactic companions, the Local Group spirals M31 and M33. Their approach has been to use resolved star counts to probe extremely low surface brightness emission over very large areas. This is currently the best technique to search for the occurence of stellar streams and other faint structure around galaxies and to characterise their halo properties.

The Isaac Newton Telescope Wide Field Camera has been used to map a contiguous area of $\gtrsim$ 40 square degrees around M31, allowing uninterrupted study of the luminous stellar population (resolved red giant branch (RGB), aysmptotic giant branch (AGB) and main sequence stars). A spectacular result from the survey was the discovery of a giant stream of stars stretching out to at least 70 kiloparsecs in the halo, likely associated with the ongoing accretion of a dwarf companion galaxy, as well as evidence for significant spatial density and metallicity substructure at various locations throughout the stellar halo and in the outer disk (2.14). Over the past year, work has focused on characterising the nature and origin of this substructure. Deep observations with the Canada-France-Hawaii 3.6 m telescope were used to map out the three dimensional structure of the

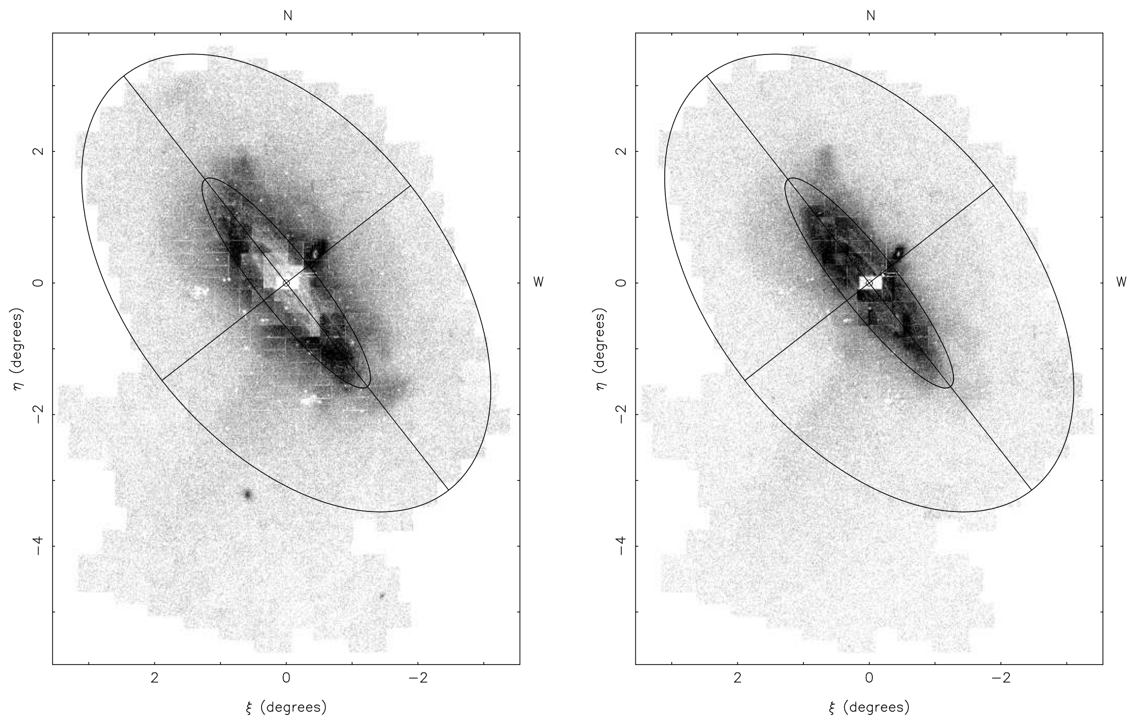

Figure 2.14: Surface density of blue RGB stars (left) and red RGB stars (right) as mapped by the Isaac Newton Telescope Wide Field Camera survey (163 individual pointings, corresponding to more than 40 square degrees of contiguous coverage). These maps correspond to 100x125 kpc at the distance of M31. The dwarf elliptical companions M32 and NGC 205 lie at 0.00°, −0.4° and −0.5°,0.4° respectively. Various substructures are apparent, however the prominence of features varies substantially between the two maps indicating the colour dependence of the substructure. Notable features include the giant stellar stream projecting south-east of the main galaxy ($\xi = +0.5, \eta = -2.0$), the clump of stars along the south-western major axis ($\xi = -1.7, \eta = -1.7$), the north-eastern spur ($\xi = +0.7, \eta = +1.8$), the south-western spur ($\xi = -1.4, \eta = -0.8$), the loop emanating north of NGC 205 ($\xi = -0.4, \eta = +1.5$) and the very faint northern fragment ($\xi = +1.5, \eta = +2.9$).

giant stream, finding it to lie more than 100 kpc *behind* M31 along the line-of-sight at its southermost extreme. Through a collaboration with S. Chapman (Caltech), spectra for more than 5000 individual RGB stars in M31 were obtained using the DEIMOS spectrograph on the Keck II 10 m telescope. Analysis of radial velocities of stars at various locations along the stellar stream were used in conjunction with the stream distance to constrain the mass of the M31 dark matter halo. The inferred orbit for the progenitor of the stream was also calculated and it was found that simple scenarios connecting the giant stellar stream to either of the bright dwarf elliptical companions M32 and NGC 205 could be ruled out. It is presently unclear which, if any, of the known satellite companions around M31 is producing the giant stellar stream. Additional constraints are coming from a Cycle 11 program with the Advanced Camera for Surveys on the Hubble Space Telescope. This program is obtaining deep colour-magnitude diagrams (CMDs) of many of the stellar overdensities around M31, from which inferences can be made about the detailed nature of the stellar populations and the star formation histories of the individual clumps. The first results are very intriguing: the substructure observed is characterised by a variety of CMD morphologies, indicating that the M31 stellar halo is truly inhomogeneous on large scales. Together, these different datasets are providing strong support for the idea that M31 has been assembled from many smaller pieces.

Surprisingly, a completely different picture emerges from the study of the lower mass system, M33. A similar survey with the Isaac Newton Telescope, covering $\sim$ 7 square degrees, has failed to reveal any halo substructure at all and limits the luminosity of a smooth stellar halo – if one even exists – to be less than a few percent of the disk luminosity. M33 therefore appears to be a pure disk galaxy which, in contrast to M31, has evolved *without* significant satellite accretion for much of its life.

The differences observed between the M31 and M33 stellar halos are intriguing but hard to interpret given the small sample size. Does the role of satellite accretion in galaxy assembly depend so strongly on mass that these observations can be reconciled? Do most galaxies experience a prolonged period of satellite accretion, like M31, or do they evolve more quiescently, like M33? Future work will involve extending this type of study to other massive galaxies, the closest of which reside just beyond our Local Group, and which span a range in morphological type, luminosity and local environment. With this larger dataset, it will be possible to determine the 'typical' properties of galactic stellar halos and to start to address systematic trends between stellar halo/thick disk properties and those of the host galaxy (A. Ferguson.)

2.6 The reionization history of the IGM and its observability through the 21cm emission line

Despite much recent theoretical and observational progress in our understanding of the formation of early cosmic structure in the high redshift universe, many fundamental questions remain only partially answered. For example, what were the first luminous objects, when did they form, and what was their impact on the surrounding intergalactic gas?

In the standard cosmological scenario, the primordial plasma was in a highly ionized state from the initial Big Bang until the recombination redshift, $z \sim 1100$, when its temperature fell to about 3000K. Thereafter it remained almost entirely neutral until the first sources of ultraviolet radiation formed and reionized it. Although increasing attention has been given to reionization of the intergalactic medium (IGM) over the past few years, only recently have observations of very distant quasars and of the Cosmic Microwave Background (CMB) radiation allowed quantitative studies of the high-redshift IGM and its reionization. Neutral hydrogen along the line-of-sight to distant quasars absorbs radiation emitted at wavelengths shorter than the Lyman-α. Measuring the optical depth corresponding to such absorption places a limit on the abundance of neutral hydrogen at each intervening redshift. Recent high-resolution spectra show near complete absorption in $z \sim 6$ quasars and have been interpreted as mapping the trailing edge of the cosmic reionization epoch. However, analysis of the first maps of CMB anisotropy from the `WMAP` satellite suggests that reionization must have begun at much higher redshift. Whatever the exact history of reionization, it is clear that much of the IGM was ionized at redshifts well beyond 6.

The nature of the sources responsible for reionization is still the subject of a lively debate. Several authors have claimed that known populations of quasars and galaxies provide only 10% of the UV photons needed to explain the observed ionization of the IGM. Thus additional sources are required at high redshift, the most promising being early galaxies and quasars. No evidence for quasars beyond $z = 6.5$ has yet been found, and recent observations of temperature and metal abundance in low density regions of the IGM suggest that an early population of stars may be responsible for its reionization and enrichment. For this reason, most recent models of reionization assume stellar sources. It is commonly believed that the `WMAP` observations require production of ionizing photons to be more efficient at high than at low redshift, with recent papers suggesting that the first stars (*Pop III* stars) were metal-free and massive, resulting in an enhanced UV luminosities. Nevertheless, no observation rules out the presence of high-redshift quasars, so an additional contribution to the UV photon budget could come from miniquasars powered by intermediate-mass black holes, perhaps the remnants of the first generation of stars.

In order to interpret the `WMAP` and $z \sim 6$ quasar data, MPA scientists, in collaboration A. Ferrara (SISSA), have run high-resolution reionization simulations that follow the formation of galaxies and the propagation through the IGM of the ionizing photons they produce. These simulations were carried out for a typical region of comoving diameter $\sim$ 30 Mpc, and for a region in which a massive rich cluster developed at lower redshift. These are the largest regions ever used to study the reionization process. To study the impact of varying assumptions about star formation and UV photon production these simulations were repeated several times. Fig. 2.15 shows slices cut through our "typical" region. The evolution of the ionized regions (dark) is illustrated for cases where the formation of massive stars is favored (the so-called Larson Initial Mass Function, IMF; upper panels) and where more 'standard' stars are formed (Salpeter IMF; lower panels). As expected, when more ionizing photons are produced, reionization proceeds faster and is completed earlier, $z \sim 13$ rather than $z \sim 8$. Our protocluster simulation makes it possible to assess the impact of environment on the reionization process. In typical regions high density peaks are uncommon and ionized regions break easily into the diffuse IGM; in the proto-cluster densities are higher, ionization is more difficult and recombination is faster. Many photons are needed to ionize the high density gas immediately surrounding the sources. As a result, although early formation of massive sources causes reionization to start earlier in this region, it is completed later. Filaments of neutral gas are still present after our typical region is fully ionized.

In collaboration with P. Madau (UC Santa Cruz), MPA scientists used the above simulations to assess the detectability of the reionization epoch at radio wavelengths. It has long been known that neutral gas in the IGM and in gravitationally collapsed systems may be detectable in emission or absorption against the CMB at the frequency corresponding to the redshifted 21 cm line, the line associated with the electron spin-flip transition in the ground state of the hydrogen atom.

The emission of the 21 cm line is governed by the spin temperature, T_S. In the presence of the CMB radiation, T_S quickly reaches thermal equilibrium with $T_{\rm CMB}$ and some mechanism is required to decouple the two temperatures if the gas is to be observable. At epochs when the IGM is mainly neutral, early galaxy population may provide enough Lyα photons to produce such decoupling. These photons heat the IGM, so the 21 cm line should be seen in emission. By following the evolution of reionization in our simulations, the expected fluctuations caused by the 21 cm emission can be calculated. These are induced by inhomogeneities both in the gas density and in its ionization state. Our second figure shows the *rms* value of this apparent temperature fluctuation, $\langle \delta T_b^2 \rangle^{1/2}$ as predicted by our simulation of a typical region (assuming a Larson IMF) as a function of the bandwidth, $\Delta\nu$, and angular size $\Delta\theta$ of the observation and for the redshift when several high density neutral regions are still present but ionized regions occupy roughly half the total volume (see Figure 2.16) . Broad-beam observations at frequencies $\sim$ 100 MHz with the next generation of low-frequency radio telescopes should be sensitive enough to measure angular fluctuations at the level of 5–20 mK on scales $<$ 5 arcmin. Thus we may soon be able to study the structure of the reionization process directly. (B. Ciardi, F. Stoehr and S. White).

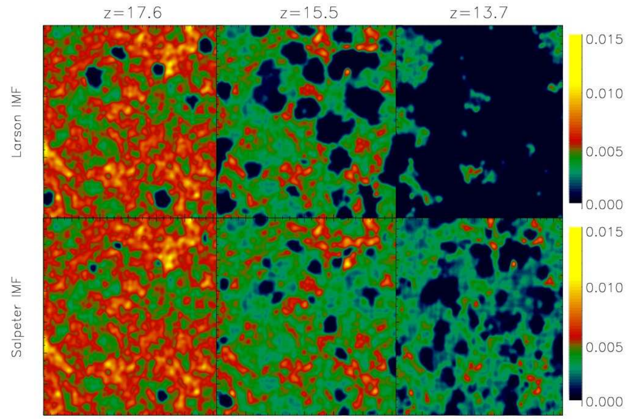

Figure 2.15: The panels show the neutral hydrogen number density in slices cut through the simulation box, at redshift, from left to right, $z = 17.6, 15.5$ and 13.7, for a Larson (upper panels) and a Salpeter (lower panels) IMF.

2.7 Dark Matter Annihilation in the halo of the Milky Way

Today there is evidence for an as yet unidentified form of dark matter on scales ranging from dwarf galaxies up to galaxy clusters. The latest measurements of the cosmic microwave background (from the WMAP satellite) agree with arguments based on Big Bang nucleosynthesis, on the dynamics of large-scale structure and on the statistics of gravitational lensing in indicating that this dark matter makes up about 80% of all clustered matter in the Universe and about a quarter of its total current energy density. Since its presence was first demonstrated in 1933 by the Swiss astronomer Fritz Zwicky, identifying the nature of dark matter has been one of the greatest challenges in cosmology.

Many candidates for the dark matter have been suggested over the years, from axions through neutrinos and snowballs to massive black holes. The total mass range spanned is about 75 orders of magnitude! One elegant solution might be a particle known as the neutralino. This is currently considered one of the most probable elementary particle candidates, and arises naturally in supersymmetric extensions of the standard model of particle physics. These theories introduce a new symmetry - supersymmetry - which assigns to each known boson a new corresponding supersymmetric fermion particle and vice versa. Although the new symme-

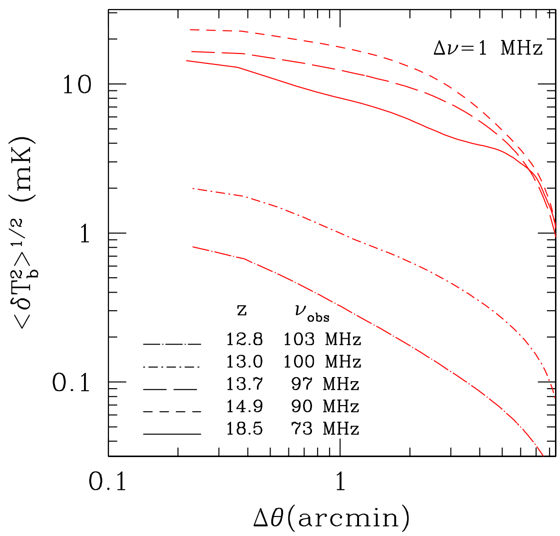

Figure 2.16: Expected rms brightness temperature fluctuations, $\langle \delta T_b^2 \rangle^{1/2}$ predicted by a simulation of reionization in a typical region of the Universe. Fluctuations are plotted as a function of beam size $\Delta\theta$ for fixed observing bandwidth $\Delta\nu = 1$ MHz. Each curve corresponds to a different emission redshift or, equivalently, to a differfent observed frequency ν_{obs}.

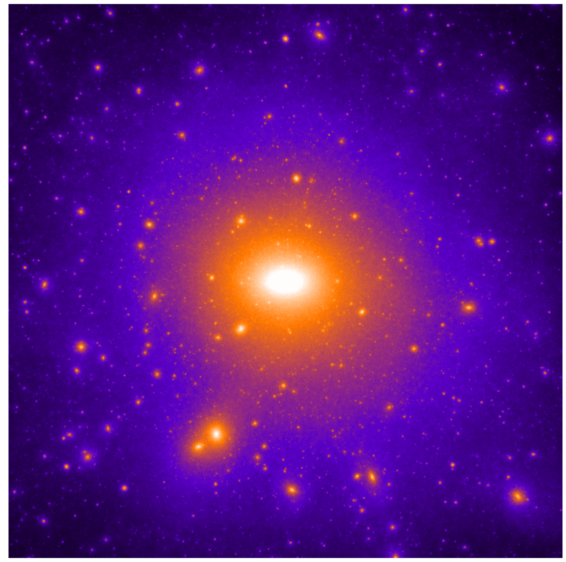

Figure 2.17: Dark matter density distribution of a simulated Milky Way halo. The image shown is 540 kpc on a side and thus shows the whole virial region. If future experiments detect annihilation radiation it will likely be from inner Galaxy, a region about 0.1% of the size of the one shown here.

try introduces a large number of free parameters it helps to solve some severe problems in the standard model. So far none of the predicted supersymmetric partners has been detected. They are supposed to have energies too high to be probed with current particle accelerators but should be within the reach of the Large Hadron Collider (LHC) planned to start operating at CERN in 2007.

The lowest mass supersymmetric particle, the neutralino, is stable if the new symmetry (called R-Parity) is conserved. It is supposed to have a mass between 50 GeV and a few TeV and to interact only weakly and through gravity. With its large mass it makes a perfect candidate for the cold dark matter that is currently favoured by microwave background and large-scale structure observations.

Although the dark matter does not normally emit or scatter light, there might nevertheless be a way to "see" it directly. If neutralinos are Majorana particles they can self-annihilate when they collide, emitting, among other particles (e.g. Z0-bosons, pions and positrons) gamma-rays of high energy. The mean annihilation rate per particle depends on the local density of potential collision partners, so annihilation will occur primarily in the regions with the highest dark matter density. A positive detection of the annihilation radiation would confirm the nature of the dark matter and place constraints the neutralino mass and annihilation cross-section.

The Milky Way is the prime target for detecting annihilation radiation, especially its centre which is only 8 kpc away from the Sun. A second strong annihilation source could be substructure within the dark matter distribution in the halo of the Milky Way. Simulations predict the presence of many dense substructure lumps, the most massive of which are thought to host the observed dwarf satellite galaxies (LMC, SMC, Sag A, ...) (Fig. 2.17).

F. Stoehr, S. D. M. White, V. Springel (all MPA) and G. Tormen (Osservatorio di Padova) used the new IBM Regatta-supercomputer at the Max Planck Society's Garching Supercomputer Centre to carry out a series of simulations of the assembly of a dark matter halo very similar to the Milky Way's. Their largest model is the highest resolution such simulation ever carried out, with more than 10 million simulation particles inside the final galaxy halo and a spatial resolution better than 250 pc. These simulations made possible detailed

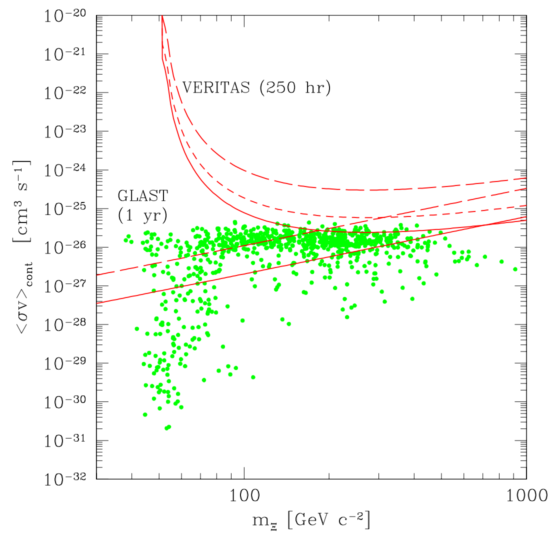

Figure 2.18: This figure shows the detectability of various supersymmetric models. Each point corresponds to a valid model, consistent with accelerator data and the cosmological density of dark matter, and with a specific mass and interaction cross-section for the neutralino particle. Lines show the detectability limits for typical observations with GLAST and VERITAS. Points lying above the lines indicate models that would be detected. The lowest solid line corresponds to an observation of the inner Galaxy with GLAST, the long dashed line to an observation of a Milky Way satellite galaxy like the Large Magellanic Cloud (LMC). Whereas there are many models that could be detected by GLAST, very few models would produce enough gamma-rays to allow a detection with VERITAS.

predictions for the annihilation flux from the inner regions of the Galaxy as well as from its closest and most massive substructure haloes. These predictions depend, of course, on the masses and cross-sections assumed for the neutralinos, which are also constrained by accelrator experiments and by the total observed density of dark matter in the Universe. They were compared to the detection capabilities of next-generation gamma-ray telescopes, in particular, GLAST (the Gamma Ray Large Area Space Telescope, a satellite mission) and VERITAS (Very Energetic Radiation Imaging Telescope Array System, a ground based Air-Shower-Čerenkov telescope).

These comparisons showed, that few neutralino models that are consistent with accelerator experiments will produce enough annihilation flux to be detected with VERITAS. On the other hand, the possibilites for GLAST are much more promising because of its very large field of view (almost half the sky). This makes possible a detection strategy which searches for gamma-rays within a large solid angle centred ten or twenty degrees both from the Galactic Centre and from the Galactic Plane. The background is relatively low in these directions, and there is a good chance that GLAST will detect annihilation radiation from the inner halo of the Milky Way (see Figure 2.18). This new strategy avoids contamination by high-energy gamma-rays produced when cosmic rays collide with interstellar gas. In addition, in these regions the theoretical prediction is relatively insensitive to the quality and resolution of the simulation. This is in strong contrast to the densest regions near the Galactic Centre and in substructures, where the exact structure of the density distribution is still very much a matter of debate.

These models suggest that there are many possible neutralino models that would produce enough annihilation flux for GLAST to detect individual substructures, although the radiation from substructure is expected to make up only about 15% of the total from the Galaxy's halo as a whole.

If the dark matter is, in fact, made of the lightest supersymmetric particle, then it might well be possible to "see" it with GLAST and so finally to unveil its true nature. (F. Stoehr)

2.8 A fundamental plane of black hole activity

The ultimate observational evidence of a celestial body being a black hole comes from dynamical studies, by measuring the gravitational influence of the central object on neighboring stars and gas. However, there are a number of distinctive signatures of black hole-powered activity that are usually regarded as proxy of black hole existence. Objects as diverse as X-ray binaries, radio galaxies, quasars, and even our Galactic center, are now believed to be powered by the gravitational energy released by the process of accretion onto a central black hole. Apart from copious radiation, one of the manifestations of this accretion energy release is the production of relativistic jets, emitting synchrotron radiation in the radio band.

The complicated physics of jet acceleration and collimation close to a black hole is still a mystery. Yet, the observed similarity (in morphology and spectrum) of radio and X-ray emission from black holes of different mass suggests that they share a common physical origin. This fact can be formalized in mathematical terms by introducing a *scale invariance* assumption ensuring that the innermost jet structure and dynamics are invariant under changes of black hole mass and dimensionless accretion rate (see Fig. 2.19 for schematic view).

A. Merloni, S. Heinz and T. Di Matteo, all from MPA, have followed this lead and investigated the consequences of considering all astrophysical black holes, from stellar mass to supermassive ones, to be members of one single class. In particular, they have examined the disc–jet connection by investigating the properties of their compact emission in the X-ray and radio bands. They have compiled a sample of ∼100 active galactic nuclei with measured black hole mass, 5 GHz core emission, and 2-10 keV luminosity, together with 8 galactic black holes with a total of ∼ 50 simultaneous observations in the radio and X-ray bands.

A careful study of multivariate correlations between mass and luminosities led to the discovery of a "fundamental plane" of black hole activity. In practice, if we define the instantaneous state of activity of a black hole of mass M (in units of solar masses), by the radio and hard X-ray luminosity of its compact core, and represent such an object as a point in the three-dimensional space $(\log L_{\rm R}, \log L_{\rm X}, \log M)$, all black holes (either of stellar mass or supermassive) will lie preferentially on a plane, described by the following equation:

$$\log L_{\rm R} = \xi_{\rm RX} \log L_{\rm X} + \xi_{\rm RM} \log M + 7.33^{+4.05}_{-4.07}, \quad (2.1)$$

where the best fit correlation coefficients are given by: $\xi_{\rm RX} = 0.60^{+0.11}_{-0.11}$ and $\xi_{\rm RM} = 0.78^{+0.11}_{-0.09}$. Figure 2.20 shows an edge-on view of this plane (an animated 3D version of the same plot can be found on the MPA website, on the August 2003 issue of the Research Highlights).

There are two main reasons why such a long sought-after correlation has been discovered just now. The first is the importance of having large numbers of accurately measured black hole masses, which only became available in the *HST* era thanks to the exquisite spatial resolution needed for this kind of dynamical studies. Moreover, the tight empirical correlation between black hole mass and central velocity dispersion of the host's bulge now allows to infer the values of those masses from larger scale galactic properties, greatly increasing the number of reliable estimates available, at least in the local universe. The second crucial factor is the identification of the hard (2-10 keV) X-ray spectral range as the best suited to unveil accretion activity, because absorption is unimportant in that band (with the exception of heavily obscured, so called "Compton thick", sources). However, the search for hard X-ray emission in all but the brightest galactic nuclei had to wait until the launch of

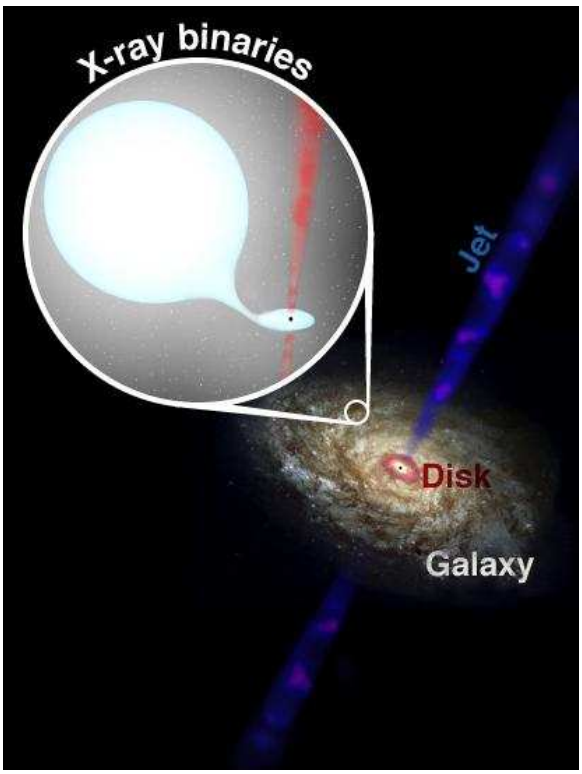

Figure 2.19: Artist's impression of black hole - accretion disk - jet systems in galactic nuclei and X-ray binaries. The appearance and physical properties of the inner regions around the black hole are very similar in both cases, though one is about 10^8 times smaller than the other.

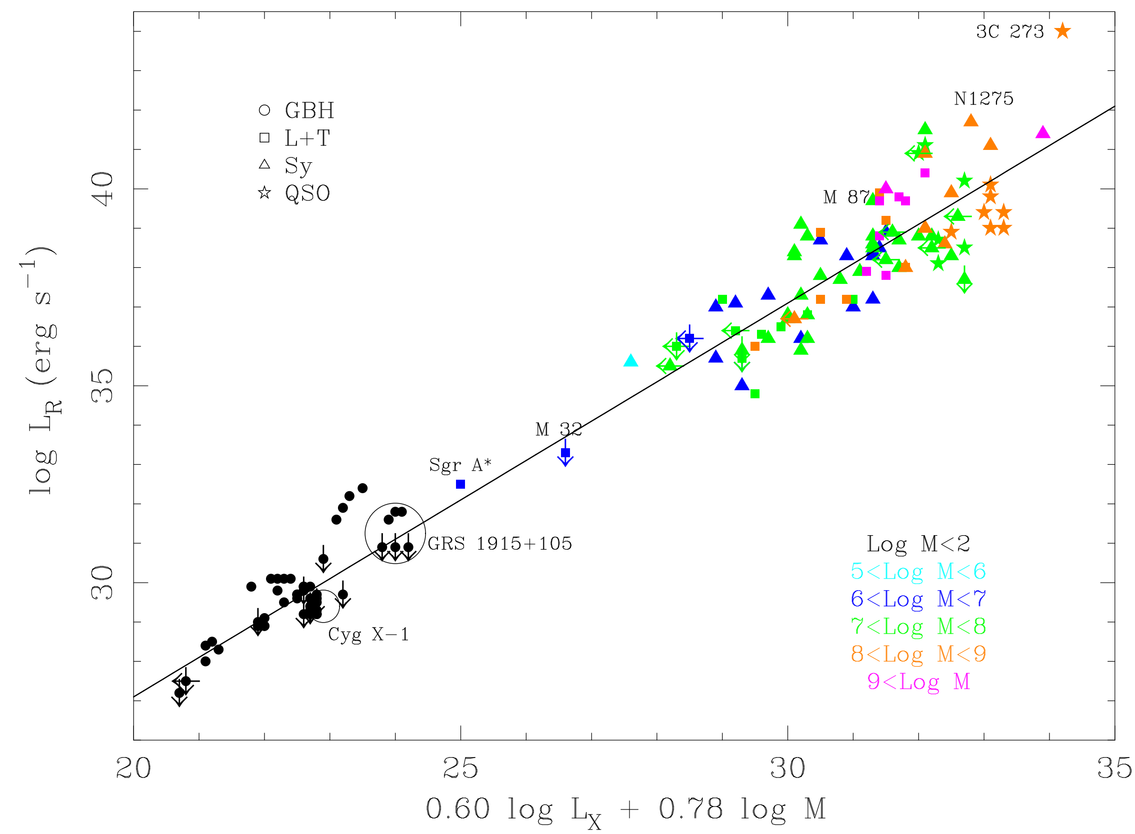

Figure 2.20: The edge-on view of the "fundamental plane of black hole activity". The solid line shows the best fitting function (2.1). Some well known sources are indicated with their most common astronomical name.

the *Chandra* satellite, with its high spatial resolution, before it could be carried on in a systematic fashion.

From a theoretical point of view, these results clearly suggest that the *ansatz* of scale invariance for the disc–jet coupling captures the main physical properties of such systems. Thus, a universal theoretical scaling between the radio flux at a given frequency and both mass and accretion rate can be derived, *independently of the jet model* (this was done in a separate paper by Sebastian Heinz & Rashid Sunyaev), with scaling indices that depend only on the (observable) spectral slope of the synchrotron emission in the radio band, $\alpha_{\rm R}$, on the jet electron distribution power-law index, p, and on the accretion mode. Also, it is possible to predict the correct amount of scatter for any such relationship.

For example, let us consider the case of flat spectrum radio sources ($\alpha_{\rm R} = 0$), and assume the standard value for the electron distribution index $p = 2$. If the X-rays are produced in the accretion flow, the general theoretical expression for the *observable* correlation coefficients for any specific disc-jet coupling model in which the relativistic particle pressure at the injection radius is a fixed fraction of the total pressure are given by: $\xi_{\rm RM} = 2.83[1 + (\partial \ln \phi_B/\partial \ln M) - (\partial \ln \phi_B/\partial \ln \dot{m})/q]$ and $\xi_{\rm RX} = 2.83(\partial \ln \phi_B/\partial \ln \dot{m})/q$. Different accretion models imply different values of q. In general, radiatively inefficient accretion models will correspond to $q \simeq 2$ and radiatively efficient ones to $q \simeq 1$. On the other hand, different scalings of the magnetic energy density at the base of the jet, ϕ_B, with mass, M, and accretion rate, $\dot{m}$, result in different values of $\partial \ln \phi_B/\partial \ln M$ and $\partial \ln \phi_B/\partial \ln \dot{m}$. Once again, each specific accretion model predicts a different scaling for such a quantity.

If, instead, X-rays are produced by optically thin synchrotron emission in the jet itself, for the same correlation coefficients we get $\xi_{\rm RM} = 0.40$ and $\xi_{\rm RX} = 0.81$.

By comparing the observationally derived correlation coefficients ($\xi_{\rm RX}$ and $\xi_{\rm RM}$) to the theoretically predicted ones, A. Merloni, S. Heinz and T. Di Matteo were able to put constraints on accretion models and on the disc–jet coupling. In Figure 2.21 the theoretically predicted values of the correlation coefficients are over-plotted on the χ^2 density distribution for the correlation coefficients obtained by fitting the data. Circles, diamonds and squares represent the radiatively inefficient, jet and standard disc models respectively. This demonstrates that the X-ray emission from black holes accreting at less than a few per cent of the Eddington rate cannot be produced by radiatively efficient accretion, while radiatively inefficient flows agree well with the data. The optically thin X-ray jet synchrotron emission model is only marginally consistent with the observed correlation (A. Merloni).

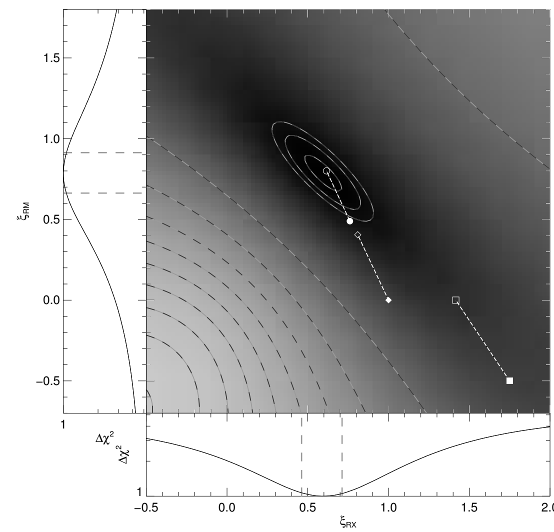

Figure 2.21: Shaded areas show the χ^2 density distribution, and dashed lines the χ^2 contours for the observed correlation coefficients $\xi_{\rm RM}$ and $\xi_{\rm RX}$. The inner 3 contours show the formal 1,2 and 3 sigma confidence levels, the remaining contours further out show levels of $\Delta\chi^2_{\rm red} = 10$. Over-plotted are the theoretically predicted values of the correlation coefficients where circles, diamonds and squares represent the ADAF, jet and standard disc models respectively. Empty symbols show the values for $\alpha_{\rm R} = 0$ and filled ones for $\alpha_{\rm R} = 0.5$. The lines connecting the points represent the tracks of $\xi_{\rm RX}$ and $\xi_{\rm RM}$ traced out by variation of $\alpha_{\rm R}$.

3 Research Activities

3.1 Stellar Physics

A. Weiss investigated various aspects of the evolution of low-mass stars, includings the violent core helium flash in Pop. II stars with very thin hydrogen envelopes (project in collaboration with M. Salaris and H. Schlattl, Liverpool, and S. Cassisi, Teramo), deep mixing physics in cluster red giants (with P. Denissenkov, Victoria) and the age of old open clusters (with M. Salaris, Liverpool). A. Weiss and collaborators also worked on intermediate mass stars. In particular, P. Marigo and C. Chiosi (Padua), L. Girardi (Trieste) and A. Weiss developed the first thorough theoretical model for the Planetary Nebulae Luminosity Function.

A. Büning, a PhD student supervised by H. Ritter, continued numerical calculations of the long-term evolution of compact binaries. When the irradiation of the donor star by the accretion luminosity of the compact star was taken into account, the long-term mass transfer rate was destabilized and there were mass transfer cycles on the thermal timescale of the donor. A. Büning found that these cycles were regulated by 2 parameters: the driving time scale (which is given by the nuclear timescale of the donor and/or the angular momentum loss timescale) and an irradiation efficiency parameter. For cataclysmic variables (CVs) with unevolved donors, and orbital periods of around 3 hours cycles can occur for reasonable assumptions about both parameters. This was in agreement with earlier results. For CVs with highly evolved donors, the cycles were much less pronounced than expected. For CVs with giant donors, the system became more stable with increasing core mass. Under certain circumstances low-mass X-ray binaries with main sequence donors could also undergo cycles.

L. Dessart, in collaboration with J. Hillier (Univ. Pittsburgh), adapted the model atmosphere code CMFGEN to supernovae conditions. A wide parameter space was covered to test the behavior of the code, includingg hydrogen-rich and helium-rich compositions. This work was in preparation for a future project that will use inputs from explosion calculations to model the entire photospheric phase of well observed supernovae using UV, optical and near-infrared spectra (e.g. SN1999em). Dessart also plans to extend the current simulations to a higher dimensionality in order to account for deviations from sphericity.

R. Buras, a PhD student supervised by H.-Th. Janka, and M. Rampp simulated stellar core collapse and post-bounce evolution of progenitor stars with masses between 11 $M_\odot$ and 15 $M_\odot$. The simulations were carried out in two dinesnions and assumed spherical symmetry, but they included the effects of stellar rotation. They were performed with the new neutrino-hydrodynamics codes VERTEX (for 1D simulations) and MuDBaTH (for multi-dimensional ones), which employ a Boltzmann solver for the neutrino transport, a state-of-the-art description of neutrino-matter interaction processes, and correction terms for general relativistic gravity. No supernova explosions were obtained, although the models were relatively close to explosions driven by neutrino heating in combination with convective overturn in the layer between neutron star and stalled supernova shock.

In a Diploma Thesis supervised by H.-Th. Janka and R. Buras, F. Kitaura computed stellar core collapse and post-bounce evolution for the 1.28 $M_\odot$ O-Ne-Mg core of a $\sim 9\,M_\odot$ progenitor star, provided by K. Nomoto. The simulations were performed using the VERTEX code. The simulations did not confirm previous claims that such cores explode by the prompt, hydrodynamic mechanism, nor did the calculations support other simulations, where explosions by the delayed, neutrino-heating mechanism were found. Instead, neutrino-heating between the neutron star and the supernova shock caused mass outflow similar to the neutrino-driven winds obtained for accretion-induced white dwarf collapse to neutron stars by Woosley and Baron (1992).

In a Diploma Thesis, supervised by H.-Th. Janka, A. Arcones investigated the conditions for supernova shock revival by neutrino heating using a semi-analytic toy model for the accretion atmosphere of the nascent neutron star. This allowed her to calculate the radius of the stationary accretion shock for a variety of parameters, such as the neutron star mass and radius, the neutrinospheric luminosity, and the rate of mass accretion by the shock. In contrast to previous attempts, the model determines the neutrinospheric temperature as a solution of the set of equations instead of imposing it as a boundary condition. Calculations for steady-state and non-stationary accretion showed that a more compact neutron star or higher mass accretion rate can favor neutrino-driven supernova explosions, because a catastrophic increase of the energy transfer by neutrinos occurs and destabilizes the accretion atmosphere for a lower value of the neutrinospheric luminosity.

E. Müller, M. Rampp, R. Buras, H.-T. Janka and D.H. Shoemaker (LIGO Laboratory, MIT) computed the gravitational wave signal from supernova core collapse using state-of-the-art progenitor models of rotating and non-rotating massive stars. These models integrated the equations of axisymmetric hydrodynamics together with the Boltzmann equation for the neutrino transport and included an elaborate description of neutrino interactions as well as a realistic equation of state. Using the Einstein quadrupole formula, the wave amplitudes resulting both from non-radial mass motion and anisotropic neutrino emission were obtained. They found that the dominant contribution to the gravitational-wave signal was produced by neutrino-driven convection behind the supernova shock. For stellar cores rotating at the extreme of current stellar evolution predictions, the core-bounce signal was detectable with LIGO II for a supernova up to a distance of ~ 5 kpc, whereas the signal from post-shock convection was observable up to a distance of ~ 100 kpc, and even with LIGO I to a distance of ~ 5 kpc. If the core wass non-rotating its gravitational wave emission could be measured with LIGO II up to a distance of ~ 15 kpc, while the signal from the Ledoux convection in the deleptonizing, nascent neutron star could be detected up to a distance of ~ 10 kpc. Both kinds of signals were generically produced by convection in any core collapse supernova.

L. Scheck in his PhD work, supervised by H.-Th. Janka, K. Kifonidis and E. Müller, performed two- and three-dimensional simulations of the evolution of convective overturn processes in the neutrino-heated region behind the supernova shock. Using a fast characteristics-based neutrino transport solver by H.-Th. Janka it was possible to run more than 50 two-dimensional simulations with different progenitor stars, explosion energies and rotation velocities. These computations demonstrated that for slowly varying core luminosities (imposed at the inner grid boundary at the edge of the proto-neutron star) the convective bubbles had sufficient time to merge to large-scale structures and that low order modes dominated after several 100 milliseconds. The resulting aspherical mass distribution below the shock led to a strong gravitational acceleration of the nascent neutron star. This mechanism could provide a natural explanation for the observed high pulsar velocities. A first three-dimensional simulation also showed a dominance of low-order convective modes.

In a continuation of their earlier collaboration, K. Kifonidis, T. Plewa (ASCI FLASH Center, Chicago), H.-Th. Janka and E. Müller investigated the long-time evolution of globally anisotropic supernovae, in which neutrino-driven convection gives rise to low-order convective modes within the first second of the explosion (see the PhD project of L. Scheck). They computed 2D hydrodynamic models using HERAKLES and the adaptive mesh refinement code AMRA which extend over several hours, covering the entire phase of shock propagation through a 15 $M_\odot$ progenitor. The models are being used to investigate the development of matter fall-back, the long-time evolution of the asphericity of the explosion, the resulting neutron star kick, and the polarization of the ejecta.

Compact binaries, i.e. binary systems in which at least one of the two components is a compact star (white dwarf, neutron star, black hole), are of considerable astrophysical interest. One of the ongoing activities in the theory of stellar structure and evolution concerns the formation and evolution of such binaries. In this context H. Ritter, in collaboration with A. King (Univ. of Leicester) investigated the the X-ray luminosity of accretion disks around black holes where the mass flow rate through the outer parts of the disk is highly super-Eddington (either because the donor is a massive star in a phase of thermal time scale mass transfer or because the disk is very extended, transient and in a high state). It was found that such disks can reach X-ray luminosities of up to 10 times the calssical Eddington limit, thereby making the hypothetical intermediate mass black hole no longer a necessity.

As an ongoing service to the community working on compact binaries, H. Ritter continued compiling the data for the semi-annual update of the "Catalogue of Cataclysmic Binaries, Low–Mass X–Ray Binaries and Related Objects" which is now available only on-line. In collaboration with U. Kolb (Open Univ., Milton Keynes, two releases (as of 1 January 2003 and 1 July 2003) of this catalogue were issued (with the next release due 1 January

2004). H. Ritter and U. Kolb (Open Univ., Milton Keynes) have also continued compiling data for the semi-annual updates of the web-based living version of the Catalog and Atlas of Cataclysmic Variables, which is provided in collaboration with R. Downes (Space Telescope Science Intitute, Baltimore), R. Webbink (Univeristy of Illinois, Urbana), M. Shara (American Museum of Natural History, New York), and H. Duerbeck (Free Univ. Brussels, Brussels).

In collaboration with M.H. Montgomery (Univ. of Cambridge, England), F. Kupka applied a fully non-local model of convection to the case of envelopes of DA and DB white dwarfs. For envelopes with non-adiabatic convection the model predicts large overshooting below the convection zone (containing ten times the mass of the unstable zone) and photospheric velocities of several km s^{-1}. Both predictions are in qualitative agreement with numerical simulations by B. Freytag (Univ. of Uppsala, Sweden). From a comparison with models used in the literature, the temperature structure of the lower photospheric was found to be in agreement with spectroscopic observations. The parameters of the non-local model were taken unaltered from previous studies. Local mixing length theory requires changes of its scale height parameter by a factor of 4 to recover the temperature structure in different cases and cannot predict photospheric velocity fields or overshooting. The applicability of the non-local model to deep convection zones is now being studied.

As part of the MACHO Survey work, P. Popowski participated in frequency analysis of 6391 variables classified earlier as fundamental-mode RR Lyrae (RR0) stars in the Large Magellanic Cloud (LMC). The overwhelming majority (i.e., 96%) of these variables have been proved to be indeed RR0 stars. Among those, 731 stars were Blazhko variables showing either a doublet or an equidistant triplet pattern at the main pulsation component in their frequency spectra. This sample overwhelmingly exceeds the number of Blazhko stars known in all other systems combined. The incidence rate of the Blazhko variables among the RR0 stars in the LMC is 11.9%, which is 3 times higher than their rate among the first-overtone RR Lyrae stars. The detailed characteristics of the frequency patterns put in question the validity of the magnetic oblique rotator model and provide stringent constraints on models based on mode-coupling theories.

P. Popowski was also involved in another analysis of variable star data from the MACHO Project. Fourier coefficients were derived for the V and R light curves of 785 overtone RR Lyrae variables (RR1) in 16 MACHO fields near the bar of the LMC. The following characteristics of 330 bona fide RR1 stars were derived: $\log L$ in the range 1.6 to $1.8 L_\odot$, $\log T_{eff}$ between 3.85 and 3.87, and a mean color excess $E(V-R) = 0.08$ mag. The 80 M5-like variables were used to determine a LMC distance of $\mu = 18.43 \pm 0.06$ (statistical) ± 0.16 (systematic) mag. The large systematic error arises from the difficulties of correcting for interstellar extinction and for crowding.

U. Anzer and P. Heinzel (Ondrejov, Czech Rep.) developed a model for extended EUV filaments which is based upon a magnetic arcade consisting of many individual twisted flux tubes. They tested their model with existing SoHO EUV observations and also applied a new spectroscopic model for EUV lines to the lines of MgX, SiXII and OV obtained with SoHO/CDS. For one particular filament, they determined the full 3D geometry of the EUV extensions and estimated the total mass associated with it.

3.2 Nuclear and Neutrino Astrophysics

C. Travaglio, K. Kifonidis and E. Müller continued their investigations of shock-induced nucleosynthesis in Eulerian simulations of neutrino-driven core collapse supernova explosions. One and two-dimensional supernova simulations with a marker particle integrator coupled to the parallel, Eulerian hydrodynamics code HERAKLES were performed for this purpose. The temperature and density histories of the marker particles, which are passively advected with the flow in the course of an Eulerian simulation, were used to compute the nucleosynthesis in a post-processing step. First results show that for cases in which the explosion develops very rapidly (and hence neutrino heating does not have sufficient time to lead to strong convection and a strong shock deformation) the nucleosynthetic yields between 2D and corresponding 1D models do not deviate appreciably. Furthermore, resolution studies indicate that significantly higher numerical resolution than heretofore employed appears to be required to obtain converged yields.

To handle these computational requirements, K. Kifonidis, in a collaboration with F.-K. Thielemann (Univ. Basel), developed a vectorized and parallelized nucleosynthesis code that employs the state-of-the-art Bader-Deuflhard and Kaps-Rentrop stiff differential equation integrators. The code can be used as a stand-alone post-processing tool for nuclear networks with hundreds of nuclear species, but was also used within HERAKLES to efficiently evolve a 32 species network online with the multidimensional hydrodynamics. The method is able to consistently treat the transition into and out of the regime of nuclear statistical equilibrium (NSE) as well as the high-temperature NSE regime. It is currently being coupled to the equations of state implemented in HERAKLES to obtain a fully consistent treatment of the energy source term due to nuclear transmutations.

In his Diploma Thesis, supervised by H.-Th. Janka and R. Buras, A. Marek performed core-collapse and post-bounce simulations of massive stars with three different nuclear equations of state, namely the ones of Lattimer and Swesty (1991), Hillebrandt and Wolff (1984), and Shen et al. (1998). The calculations were done in spherical symmetry, using the new neutrino-hydrodynamics program VERTEX. Significant differences in the shock formation position, the shock propagation and stagnation radius, and in the prompt electron-neutrino burst were found. Although supernova explosions were not obtained, the differences were large compared to other relevant effects and can be of importance for the development of post-shock convective overturn and convection inside the nascent neutron star.

Based on 3D computer simulations of thermonuclear (type Ia) supernova explosions, C. Travaglio, W. Hillebrandt, M. Reinecke and F.-K. Thielemann (Univ. Basel) computed elemental and isotopic nuclear abundances for a sample of ignition conditions and metallicities. The method used was the marker-particle approach. They showed that the model predictions agree well on average with earlier parameter studies, with the exception of a larger fraction of unburned carbon and oxygen in the 3D models. This finding might be in conflict with observed late-time nebular spectra. Explanations and ways out are under investigation.

In collaboration with the Hot-Star-Group (A. Pauldrach) at the Universitätssternwarte München, D. Sauer calculated synthetic spectra for type Ia supernovae from NLTE radiative transfer models on the basis of hydrodynamic explosion models. These models describe the interaction of the gas with radiation in the ejecta and explain the characteristic observed spectrum of these objects. Although the first results were encouraging,it was found that the standard approach for calculating radiative transfer in stars has significant shortcomings if applied to supernovae. In particular, scattering processes in deep layers and effects arising from sphericity have to be treated in more detail to improve the quality of the models and make them a useful tool for the analysis of observed spectra.

PhD student M. Stehle Supervised by W. Hillebrandt and P. Mazzali (Triest)) worked on the analysis of spectra of type Ia supernovae in the early phase. The data was provided by observations of the RTN network. A very fast and efficient Monte Carlo code was used to calculate synthetic spectra and allowed the physical properties of the expanding envelope of the supernova to be studied. The code was improved to derive the abundance distribution of the SN for complete sets of SN spectra. Analyzing one spectrum after the other leads to an "abundance tomography" of the SN ejecta. This was tested with SN 2002bo and the results are now in press.

M. Stritzinger, working with B. Leibundgut of the European Southern Observatory and W. Hillebrandt, investigated the nature of Type Ia supernovae using bolometric lightcurves constructed from well observed events. Additionally, in collaboration with N. Suntzeff from the Cerro Tololo Inter-American Observatory, he has completed a spectrophotometric standard star project, which will soon be made available to the astronomical community. Most of this work is also part of a European Research Training Network, whose goal is a better understanding of Type Ia supernovae. The Network brings together theorists and observers from six European Countries and Australia. In the past 18 months the RTN, which is coordinated by W. Hillebrandt, has collected a very detailed time series of spectra and excellent multi-colour light curves for 6 very nearby supernovae, making use of up to 14 different telescopes world wide. These data will provide the basis for a case-by-case comparison between theory and observations.

C. Travaglio has studied the role of Asymptotic Giant Branch stars (AGB) in Galactic chemical evolution. The chemical enrichment of the Galaxy was followed using a detailed evolutionary model. Travaglio studied the astrophysical origin of the s-process nuclei with atomic mass number $A > 90$, and focused on the fact that s-process has not a unique nature, the abundance distribution in the solar system being the outcome of all previous generations of AGB stars of different masses and metallicities. One highlight of the analysis was the s-process contribution by the Galactic chemical evolution to Sr, Y, and Zr. Travaglio compared theoretical predictions with recent spectroscopic observations in very low-metallicity stars.

3.3 Numerical Hydrodynamics

In his PhD work supervised by M.A. Aloy and E. Müller, T. Leismann developed a 2D special relativistic magneto-hydrodynamics (RMHD) code for the simulation of relativistic magnetized jets. The code uses staggered grids for the magnetic field components in order to avoid the numerical generation of magnetic monopoles. The numerical fluxes of the RMHD equations are evaluated using an approximate Riemann solver. The code successfully passed a set of 1D and 2D test problems, and has been used to simulate the evolution of magnetized jets. Leismann studied the morphology and dynamics of jets having pure toroidal or pure poloidal magnetic fields of different strength and compared the results with non-magnetized jets. He found that the presence of even very small magnetic fields can trigger substantial dynamical differences with respect to non-magnetized models. He also addressed the long-time evolution of powerful magnetized jets, simulating a jet with a (beam) toroidal magnetic field of equipartition strength. The evolution and global properties are very similar to those of non-magnetized jets, i.e. it is very difficult to distinguish them observationally.

In a PhD project supervised jointly by M.A. Aloy, W. Brinkmann (MPE) and E. Müller, P. Mimica developed the synchrotron radiation code ”R-GENESIS” as an extension of the relativistic hydrodynamics code ”GENESIS”. The code treats the injection of ultra-relativistic electrons at relativistic shock fronts, their synchrotron radiation and radiative losses (the back-reaction on the hydrodynamics is also considered), and the spatial advection by the thermal fluid. Several simulations of colliding relativistic shells within a blazar jet have been performed, and the X-ray light curves and spectra have been computed. The results agree well with observations of Mkn 421, a typical high-energy peaked blazar.

M.A. Aloy and E. Müller in collaboration with J.M. Martí and J.M. Ibáñez (Univ. of Valencia) and J.L. Gómez (Instituto de Astrofísica de Andalucía) have performed numerical simulations of relativistic jets in order to disentangle the effects of curvature, helical motions and light travel time delays on the morphologies observed in parsec scale jets. A comparison of synthetic radio maps obtained from the simulations with those of observed superluminal sources showed that the variability of the jet emission is the result of a complex combination of phase motions, viewing angle selection effects, and non–linear interactions between perturbations and the underlying jet and/or the external medium. These results question the hydrodynamic properties inferred from observed apparent motions and radio structures, and indicate that shock-in-jet models may be overly simplistic.

M.A. Aloy, H.-T. Janka and E. Müller have been studying the viability of neutron star mergers as progenitors of gamma–ray bursts. They explored the conditions under which a successful ultra-relativistic jet or wind is formed in this scenario, and whether these jets explain the properties of short-lived gamma–ray bursts. They assume that the jet (or wind) is initiated by the release of energy due to the annihilation of neutrinos and anti–neutrinos in the outer shells of the merger. Their preliminary results indicate that a large variety of collimated outflow morphologies can be obtained, from ultra-relativistic winds to moderately relativistic, knotty jets. Jet-like outflows result for energy deposition rates below $\approx 10^{51}\,\mathrm{erg\,s^{-1}}$. However, in this case, the signature of the outflow will not be a short gamma–ray burst, because the head of the jet propagates at mildly relativistic speeds as a consequence of the large amount of mass swept up by the jet during its propagation. Wind–like outflows in low–density environments may produce gamma–ray bursts, because the baryonic pollution is then sufficiently small to allow propagation at ultra-relativistic speeds.

Motivated by this result, M.A. Aloy and J.D. Salmonson (Lawrence Livermore National Laboratory) are computing synthetic light curves and spectra using a simplified model of a ultra-relativistic wind in a low–density environment. Their preliminary findings are that the so–called uniform models (used widely by observers to interpret the gamma-ray burst phenomenology) are too simplistic. The angular distribution of the Lorentz factor of the gamma-ray emitting region (infered from breaks in the light curves) is not monotonic, but has a local minimum at small angles with respect to the symmetry axis and peaks at angles of $\approx 15°$.

M.A. Aloy and P. Hardee (Univ. of Alabama) have studied the applicability of linear stability analysis for relativistic jets using numerical simulations. In particular, they want to test whether instabilities saturate during the transition from the linear to the non–linear regime. According to the linear analysis, this ought to lead to the destruction of the jet. One would then infer that relativistic jets could survive the most disruptive normal modes, and hence the range of applicability of the linear stability analysis might be reduced.

The numerical simulation of astrophysical phenomena leading to the formation of compact objects like neutron stars and black holes has been the focus of the research of H. Dimmelmeier, E. Müller and J.A. Font (Univ. of Valencia). In a collaboration with J. Novak (Meudon Observatory) they improved their general relativistic hydrodynamics code by implementing numerical spectral methods. This so-called grid wedding (*mariage des maillage*) between the spectral and finite difference grids in a dynamic evolution code is an important step towards stable and efficient 3-dimensional simulations of compact objects.

Together with N. Stergioulas (Univ. of Thessaloniki) and J.A. Font (Univ. of Valencia), H. Dimmelmeier also simulated axisymmetric rotating neutron stars. In a parameter study, neutron star models were perturbed and evolved with a numerical code in order to extract their characteristic oscillation frequencies, and to investigate their dependence on the star's rotation rate and rotation profile. Using the simulation results in astroseismology studies, observers will be able to gain more insight into the structure of these objects.

H. Dimmelmeier finished a long-term project with J.M. Martin Garcia (Consejo Superior de Investigaciones Científicas, Madrid) and J.A. Font (Univ. of Valencia) on critical collapse phenomena which arise close to the threshold of black hole formation. For certain matter models, an initial configuration can either disperse or collapse to a black hole depending on the fine tuning of the initial degrees of freedom. In their study, H. Dimmelmeier, J.M. Martin Garcia and J.A. Font included rotation in numerical simulations of critical collapse for the first time. H. Dimmelmeier was also involved in a collaboration with P. Cerdá, J.A. Font (both Univ. of Valencia), G. Faye (Universität Jena) and E. Müller to apply a flexible and stable approximation of Einstein's general relativistic field equations called CFC+ in simulations of supernova core collapse. The quality of this approximation will be tested against simulations using the community code Cactus. H. Dimmelmeier has begun these test calculations together with B. Zink, and in close collaboration with I. Hawke and C. Ott (both AEI, Golm).

The line-driven instability mechanism is of paramount importance for hot star wind structure and dynamics. It was implemented by L. Dessart into the publicly available hydrodynamical code ZEUS3D and the code has now been parallelized. 2D numerical simulations of the Smooth Source Function formalism were performed to study the time-evolution of a non–Sobolev hot star wind. L. Dessart and S.P. Owocki found that wind structures develop but their lateral extent goes down to the azimuthal grid size. This was an artifact resulting from the neglect of the lateral contribution of the radiation on the wind dynamics. They are now developing a numerical method that accounts for such lateral radiative acceleration.

In a collaboration with M. Liebendörfer (CITA, Toronto) and A. Mezzacappa (Oak Ridge Nat. Lab., Tennessee), M. Rampp and H.-Th. Janka tested their new neutrino-hydrodynamics program (VERTEX) against the Oak Ridge-Basel code AGILE-BOLTZTRAN. Both codes use very different methods to solve the hydrodynamics equations and the neutrino transport. Applying them to well defined one-dimensional core collapse problems with Newtonian and relativistic gravity, good agreement was found for all phases of the supernova evolution. The results of this first comparative code validation in the field of supernova simulations have been provided to the community so that other codes can be tested.

R. Oechslin investigated the influence of numerical uncertainties (resolution, artificial viscosity, interpolation schemes) and different equations of state on binary neutron star merger dynamics using a semi-relativistic SPH hydrodynamics code. He is also developing a SPH-based hydrodynamics module for the Cactus toolkit (Albert Einstein-Institut, Golm).

V. Springel developed GADGET-2, a new, extensively modified version of the massively parallel TreeSPH simulation code GADGET. A more accurate, symplectic time-integration scheme was implemented in the new version. Using a fractal Peano-Hilbert order for the mass distribution, a novel algorithm for the domain decomposition has been devised while allowing simultaneously for much improved cache utilization of microprocessors, resulting in substantially better computational performance. A TreePM algorithm, a hybrid between the particle-mesh and tree methods, has been added to the code, allowing substantial performance gains of up to factors $\sim 5-10$ in collisionless cosmological simulations. Numerous additional physics modules and simulation options have been added as well, increasing the overall flexibility of the code. Finally, a special *lean* version of the code has been developed. It is heavily memoryoptimized to the extent that, on the new Regatta supercomputer at RZG, the particle number can be pushed to well beyond 10^{10} using this code. In preparation of large production runs, massively parallel postprocessing algorithms for group finding and power spectrum measurement have been added to the code as well.

F. Röpke investigated the stability of thermonuclear flames in Type Ia Supernova explosions at scales below the Gibson length. This was done in the course of a PhD work supervised by W. Hillebrandt and in collaboration with J. Niemeyer (Univ. of Würzburg). The flame evolution under the influence of the Landau-Darrieus instability was modeled numerically for propagation into quiescent fuel as well as for interaction with turbulent motions of the fuel. The study corroborated fundamental assumptions of large-scale Type Ia supernova models. The doctoral thesis was accepted by the Technical Univ. of Munich in June 2003.

A major difficulty of treating turbulent burning in simulations of thermonuclear supernova stems from the fact that it is impossible to resolve the whole range of dynamical scales, even with the most powerful of currently available computers. This restriction leads to the concept of a large-eddy simulation, in which only the largest scales are numerically resolved. As the burning process is highly susceptible to turbulent velocity fluctuations on scales smaller than the numerical resolution, a model which accounts for these effects is indispensable. The investigation of several options for such a subgrid scale model is the subject of ongoing research by W. Schmidt. As it would be hard to systematically test and compare different subgrid scale models in full supernova simulations, a simplified scenario was chosen, where turbulence is artificially produced by a stochastic force field in a cubic domain.

In a PhD project supervised by W. Hillebrandt and J.C. Niemeyer (Univ. of Würzburg), L. Iapichino has performed multi-dimensional simulations of SN Ia ignition. The Chicago "FLASH" Adaptive Mesh Refinement code was used in order to explore the conditions inside the white dwarf prior to the thermal runaway. Temperature perturbations in degenerate matter and their evolution as seeds of subsequent flame propagation were studied.

3.4 High Energy Astrophysics

In a collaboration with W. Forman, C. Jones (CfA) and H. Böhringer (MPE), E. Churazov and R. Sunyaev studied the role of resonant scattering on the flux ratios of X-ray emission lines for the Perseus cluster of galaxies. For pure thermal broadening some of the strong lines should be suppressed in the core region because of opacity effects. However, the observed ratios (XMM-Newton data) are consistent with the optically thin plasma emission models. The lack of evidence for resonant scattering effects implies gas motion in the core with a range in velocities of at least half of the sound velocity. If this motion has the character of small scale turbulence, then its dissipation would provide enough energy to compensate for radiative cooling of the gas. The activity of the supermassive black hole at the center of the cluster may be the driving force of the gas motion.

The formation of cold fronts in the gas of galaxy clusters was studied by S. Heinz and E. Churazov in collaboration with W. Forman, C. Jones (CfA) and U.G. Briel (MPE). Chandra and XMM-Newton observations of many clusters reveal sharp discontinuities in the X-ray surface brightness, which, unlike shocks, have lower gas temperature on the X-ray brighter side of the discontinuity. For this reason, these features are called 'cold fronts'. It is believed that cold fronts are formed when a subcluster merges with another cluster and the ram pressure of gas flowing outside the subcluster gives the contact discontinuity the characteristic curved shape. Simple analysis shows that the flow of gas past the merging subcluster induces slow motions inside the cloud. These motions transport gas from the central parts of the subcluster towards the interface. Because in a typical cluster or group (even an isothermal one) the entropy of the gas in the central regions is significantly lower than in the outer regions, the transport of the low entropy gas towards the interface and the associated adiabatic expansion makes the gas temperature immediately inside the interface lower than in any other place in the system, thus enhancing the temperature jump across the interface and making the 'tip' of the contact discontinuity very cool.

A new model for the prompt emission mechanism of gamma-ray bursts was proposed by S. Inoue and A. Janiuk (Copernicus Astronomical Center, Warsaw), based on photospheric emission from radiation-dominated fireballs. Taking into account Compton upscattering processes in magnetic reconnection regions outside the photosphere, as well as time variable and/or spatially inhomogeneous baryon loading, they showed that the model can reproduce the observed spectra of gamma-ray bursts, with some advantageous properties compared to the more popular internal shock models. This picture may also lead to observable cyclotron absoption features in the low energy spectra and can thus provide crucial constraints on the nature of the central engine. J. Chluba in collaboration with S.Y. Sazonov and R.A. Sunyaev studied in detail the double Compton emission in an isotropic, mildly relativistic plasma. Analytic expressions for the double Compton emissivity have been obtained for a very broad range of plasma temperatures and for various incoming photon distributions.

The population low mass X-ray binaries in nearby galaxies and its relation to the mass of the host galaxy was studied by M. Gilfanov. Using Chandra observations of old stellar systems in nearby galaxies of various morphological types, and the census of LMXBs in the Milky Way, he showed that radial distribution of LMXBs closely follows that of the near-infrared light. In a broad mass range, $\log(M_*) \sim 9 - 11.5$, the total number of LMXBs and their combined luminosity are proportional to the stellar mass of the host galaxy. The luminosity distributions of LMXBs observed in different galaxies are similar to each other and are consistent with the 'universal' XLF derived from all data. The 'universal' LMXB XLF has a complex shape, significantly different from that of HMXBs. It follows a power law $dN/dL \propto L^{-1}$ at low luminosities, gradually steepens at $\log(L_X) \gtrsim 37.0 - 37.5$ and has a rather abrupt cut-off at $\log(L_X) \sim 39.0 - 39.5$. This value of the cut-off luminosity is lower by an order of magnitude, than found for high mass X-ray binaries.

P. Shtykovskii (Space Research Institute, Moscow) and M. Gilfanov studied the X-ray luminosity function of HMXBs in the Large Magellanic Cloud, based on data from a large number of XMM-Newton observations. They showed that in a broad luminosity range ($\log(L_x) \sim 33.5 - 36.5$) the HMXB XLF follows a power law with differential slope $\alpha \sim 1.6$ and the normalization is consistent with the value predicted from the star formation rate in LMC. This results extend the validity of the "universal" HMXB XLF, derived by Grimm, Gilfanov & Sunyaev (2003) by 3 orders of magnitude towards lower luminosities.

There are a number of distinctive signatures of black hole-powered activity that are usually regarded as proxy of black hole existence. Relativistic jets emitting synchrotron radiation in the radio band are one such signature, the second most common being the presence of strong, compact power-law X-ray emission commonly associated with the inner part of an accretion disc. Andrea Merloni, Sebastian Heinz and Tiziana Di Matteo, have examined the disc–jet connection in stellar mass and supermassive black holes by investigating the properties of their compact emission in the X-ray and radio bands. First they compiled a sample of ∼100 active galactic nuclei and 8 galactic black holes with simultaneous observations in the radio and X-ray bands. Using this sample, they have studied the correlations between the radio ($L_{\rm R}$) and the X-ray ($L_{\rm X}$) luminosity and the black hole mass (M). The sample of sources is found to define a 'fundamental plane' in the three-dimensional ($\log L_{\rm R}, \log L_{\rm X}, \log M$) space, given by $\log L_{\rm R} = (0.60^{+0.11}_{-0.11}) \log L_{\rm X} + (0.78^{+0.11}_{-0.09}) \log M + 7.33^{+4.05}_{-4.07}$. This empirical correlation has an elegant theoretical interpretation in terms of scale invariant jet models and can be directly used to constrain the dynamics of the accretion flow. A. Merloni, S. Heinz and T. Di Matteo have also demonstrated that the observed scaling relations between $L_{\rm R}$, $L_{\rm X}$ and M imply that the X-ray emission from black holes accreting at less than a few per cent of the Eddington rate is unlikely to be produced by radiatively efficient accretion, and is marginally consistent with optically thin synchrotron emission from the jet. On the other hand, models for radiatively inefficient accretion flows seem to agree well with the data. In a subsequent work, A. Merloni has explored some of the consequences of such a fundamental relationship for the cosmological evolution of supermassive black holes. He showed that given a local black hole mass function, a local AGN radio luminosity function, and the evolution of the X-ray luminosity function up to redshift 3, it is possible to use the fundamental plane relationship to infer directly the mass and accretion rate history of supermassive black holes.

F. Miniati, T. Ensslin (MPA) and G. Sigl (IAP) have used a large scale structure simulation which includes matter and magnetic field distributions to study the origin and propagation of ultra high energy cosmic rays (UHECRs). They find that the highly structured magnetic field distributions resulting from the simulation, combined with the observed degree of isotropy of UHECRs events, put severe constraints on the source distribution and therefore, the nature of the acceleration process. By comparing various scenarios, they find that the best fit to the available data seems to require "cosmological structure" in both the distribution of UHECR sources and magnetic fields similar to those produced in the simulation.

In the direction Cygnus OB2 association lies a strong unidentified source of TeV gamma-rays. F. Miniati with Y. Butt, T. Dame, J. Drake (Harvard-Smithsonian Center for Astrophysics), P. Benaglia, J. A. Combi, M. Kauffman-Bernardo, G. Romero (Instituto Argentino de Radioastronomia), M. Corcoran (Univ. Space Research Ass., NASA Goddard Space Flight Center) P. Milne (Los Alamos National Laboratory) M. Pohl, O. Reimer (Ruhr-Universitaet Bochum), and M. Rupen (National Radio Astronomy Observatory) have made a detailed multifrequency model for this source, showing that the existing radio data and X-ray upper limit are only compatible with emission from secondary electron-positrons. This implies that the TeV gamma-ray must be of hadronic origin making Cygnus OB a likely acceleration site for CR protons up to PeV energies. They have been awarded Chandra telescope time to observe the predicted X-ray synchrotron from secondary electron-positrons. This is one of the most promising sources for studying the origin of Galactic CRs.

If gamma-ray bursts (GRBs) are located in molecular clouds, a substantial fraction of their prompt and early afterglow X-ray radiation should be scattered into our line of sight (S. Sazonov and R. Sunyaev). The scattered flux provides a direct measure of the typical density of the GRB ambient medium. If the primary emission is beamed, the scattered X-ray flux will gradually decrease for several months to years before falling off rapidly. Therefore, it should be possible to estimate the collimation angle of a burst from the light curve of its X-ray echo and a measured value of the line-of-sight absorption column depth. This study shows that for the brightest GRBs such echos should be detectable already with Chandra and XMM-Newton.

A sample of approximately 100 AGN detected in the RXTE nearly all-sky ($|b| > 10°$) hard X-ray (3–20 keV) survey was used by S. Sazonov and M. Revnivtsev to infer the statistical properties of the local ($z < 0.1$) population of AGN. The proportion of unobscured and obscured (10^{22} cm^{-2} $<$ $N_{\rm H} < 10^{24}$ cm^{-2} was found to depend dramatically on the luminosity. While the obscured objects amount to two thirds of low-luminosity AGN ($L_{\rm X-ray} < 10^{43.5}$ erg s^{-1}), their fraction drops to below 15% at higher luminosities. The reconstructed luminosity function implies that the local energy release by accretion onto supermassive black holes is distributed nearly equally between AGN in the luminosity range 10^{41}–$10^{43.5}$ erg s^{-1}. Taking into account the available estimate of the total volume X-ray emissivity in the local Universe, the above results also imply that active and non-active galaxies with $L_{\rm X-ray} < 10^{41}$ erg s^{-1} might provide a similar contribution.

3.5 Accretion

Recent NIR observations at MPE have mapped out the orbits of several stars around Sgr A*, the supermassive black hole in the center of our Galaxy. J. Cuadra, under the supervision of S. Nayakshin and R. Sunyaev, studied the constraints set by these new data on the properties of an inactive accretion disk. An optically thick disk could eclipse, reflect and reprocess the stellar radiation, which is not observed. Cuadra, Nayakshin & Sunyaev (2003) thus concluded that the disk either has a relatively large inner hole or is optically thin in the near infrared bands. Interestingly however, the excess L' emission of the star S2 could potentially be explained by the reprocessed disk emission.

M. Gilfanov, M. Revnivtsev and S. Molkov (Space Research Institute, Moscow) studied the short term variability in luminous LMXBs. Based on the data of RXTE/PCA observations of 4U1608–52 and GX340+0, they showed that aperiodic and quasi-periodic variability on $\sim$ sec – msec time scales is caused primarily by variations of the luminosity of the boundary layer. The emission of the accretion disk is less variable on these time scales and its power density spectrum follows $P_{\rm disk}(f) \propto f^{-1}$ law, contributing to observed flux variation at low frequencies and low energies only. The kHz QPOs have the same origin as variability at lower frequencies, i.e. independent of the nature of the "clock", the actual luminosity modulation takes place on the neutron star surface. The boundary layer spectrum remains nearly constant in the course of the luminosity variations, depends weakly on the global mass accretion rate, and in the limit $\dot{M} \sim \dot{M}_{\rm Edd}$ is close to Wien spectrum with $kT \sim 2.4$ keV. The accretion disk spectrum is significantly softer and is well described by the relativistic disk models.

S. Heinz and R. Sunyaev showed how the scale invariance of jet physics can be used to derive the mathematical relation between the jet luminosity and the mass and accretion rate of the black hole that produces the jet. This relation is independent of the unknown details of jet formation, which can all be absorbed into the observed spectral properties of the jet. This relation can be used to explain the 'fundamental plane' of black hole mass, radio-X-ray luminosity (Merloni, Heinz and di Matteo) mentioned above.

Merger between neutron stars or neutron stars and black holes produces a black hole surrounded by a massive accretion torus. M. Aloy, H.-Th. Janka and E. Müller have investigated the formation of relativistic jets and winds by the deposition of thermal energy (for example, due to neutrino-antineutrino annihilation) above the poles of such tori. The relativistic hydrodynamic simulations show that the flow is collimated by the interaction with the dense accretion torus. Provided the environmental density is sufficiently low, ultra-relativistic polar winds with typical opening angles around 20 degrees are obtained. These winds are highly structured in the radial and lateral directions and can account for important observational properties of short gamma-ray bursts – energies of 10^{50} erg/steradian or more emitted in only fractions of a second, and burst durations up to a few seconds. The simulations confirm that merger models of compact objects and energy release by neutrinos together form a viable scenario for explaining the class of short gamma-ray bursts.

The evolution of the accretion tori involved in this process was studied by H.-Th. Janka in collaboration with M. Ruffert and S. Setiawan (both Univ. of Edinburgh, Scotland). The three-dimensional simulations include a shear viscosity in the torus in order to take into account the effect of black hole rotation on the location of the innermost stable circular orbit. A pseudo-Newtonian potential is used to describe the gravity of the black hole. The neutrino emission and energy deposition by neutrino-antineutrino annihilation was found to increase sensitively with the disk mass, with the black hole spin in the case of a disk in corotation, and with the value of the α-viscosity.

There is accumulating observational evidence that relativistic jets may play an important role as sinks of energy in accretion flows. In collaboration with J. Malzac and A.C. Fabian (both Institute of Astronomy, Cambridge) A. Merloni studied the rapid correlated UV/optical/X-ray variability of the galactic black hole XTE J1118+480 (see MPA Annual report 2001) as a signature of the coupling between the X-ray corona and a jet emitting synchrotron radiation in the optical band. A new scenario has been proposed, in which the jet and the corona are fed by the same energy reservoir where large amounts of accretion power are stored before being channelled into either the jet or the high energy radiation. A strong requirement of the model is that the total jet power should be at least a few times larger than the observed X-ray luminosity, implying a radiative efficiency for the jet $\epsilon_{\rm j} \lesssim 3 \times 10^{-3}$. This would be consistent with the overall low radiative efficiency of the source. Independent arguments show that the jet probably dominates the energetic output of all accreting black holes in the low-hard state.

Understanding the physics of accretion flows towards black holes is important for X-ray binaries and Active Galactic Nuclei. U. Anzer, G. Börner, I. Kryukov (Moscow) and N. Pogorelov (Moscow) continued their numerical investigation of accretion flows. They included different types of radiative cooling functions as well as the effects of Compton heating and cooling. They found that both steady state flows and flows with strong temporal variations can occur under these circumstances.

The vertical structure of the corona above a cool geometrically thin accretion disk was computed with a new method developed by F. Meyer and E. Meyer-Hofmeister. The model is based on the same physics as their earlier one-zone model, but now modified to include inflow and outflow of mass, energy, and angular momentum from and towards neighboring zones. With this model B.F. Liu, E. Meyer-Hofmeister, and F. Meyer have investigated the structure of a corona above a possible cool disk around the galactic center. For large viscosity parameter α, evaporation of the disk dominates over the accretion rates inferred from observation of the surrounding gas. For low α, the accreted gas can condense into the cool disk. In both cases, however, the predicted coronal bremsstrahlung emission would significantly exceed observational limits. This argues against the presence of a cool disk around the back hole at the center of our galaxy.

Cool disks are universally present in accreting black holes in binaries. X-ray observations of these binaries in their 'hard' X-ray states are most easily understood if the cool disk terminates at some distance (5-100 $r_{\rm g}$) from the hole. Inside resides the optically thin 2-temperature plasma s that produces the X-rays (the 'truncated disk' model). The mechanism that allows the accretion flow to make this dramatic change from a cold to a very hot state (reported in previous years' Annual reports) has now been investigated with time-dependent numerical calculations by C. Dullemond. There are indications that the interaction of the hot and cold components may lead to interesting time-variability.

F. Meyer investigated a fragmentation instability of accretion disks around black holes as a model for ultraluminous X-ray sources. The model allows the escape of radiation at a true super-Eddington rate from magnetically confined fragments through the gaps that formed between them and seems capable of resolving the apparent inconsistencies of conventional models. The conditions at the outer rim of accretion disks in Z Cam systems were studied by F. Meyer and Y. Osaki (Nagasaki Univ.) in order understand why this subclass of cataclysmic variables shows both modes of accretion – a steady hot disk accretion and a dwarf nova type acretion where the disk alternates between a cool quiescent state and a hot outburst state.

3.6 Interaction of radiation with matter

Numerous physical problems require a detailed understanding of the radiative transfer of photons into different environments, ranging from intergalactic and interstellar medium to stellar or planetary atmospheres. The full solution of the seven dimension radiative transfer equation is still beyond our computational capabilities. For this reason, an increasing effort has been devoted to the development of radiative transfer codes based on a variety of approaches and approximations. B. Ciardi, in collaboration with A. Ferrara (SISSA, Trieste) and A. Maselli (OAA, Florence), has developed the code CRASH, based on a Monte Carlo scheme, to follow the propagation of ionizing photons into a given density field. The code includes the treatment of both hydrogen and helium.

Hot star winds are driven *via* the scattering of continuum star light by optically thick lines of metals. Such driving is extremely unstable and leads to the natural formation of shocks and associated structures in outflows from luminous hot stars. In the directions intersecting the stellar core, this instability is found to be moderated by the momentum contribution from scattered photons, a mechanism named the line–drag. However, away from the star's direction, such scattered photons have a net stabilizing effect, which acts as a radiative viscosity damping lateral oscillations occurring below the lateral Sobolev length. L. Dessart and S.P. Owocki are developing formalisms to address the importance of such a lateral line-drag on the lateral scale of wind structures, with relevance for X-ray production, clumping and acceleration of hot star winds.

S. Sazonov, J. Ostriker (Institute of Astronomy, Cambridge, UK) and R. Sunyaev computed the characteristic spectrum and the Compton equilibrium temperature, T_c, of the emission from the average quasar in the Universe. Using information on the cumulative AGN light, composite quasar spectra and the estimated local mass density of supermassive black holes, T_c was constrained to a narrow range around 2×10^7 K. This value is interestingly close to typical temperatures of cooling flows in elliptical galaxies and above the virial temperatures of lower mass galaxies. These results were next applied by S. Sazonov, J. Ostriker and L. Ciotti (Bologna Univ., Italy) to explore the possibility that accretion growth of the central black holes of early-type galaxies could be regulated by radiative feedback from the hole to the galactic X-ray halo. It was shown that under certain assumptions, the observed tight correlation between black hole mass and galactic properties can be explained by this model.

3.7 Galaxy evolution and the Intergalactic Medium

Galaxy properties of low z**.** S. Charlot, in collaboration with G. Bruzual (CIDA Venezuela), has developed a new model of the spectral evolution of galaxies that has 10-times higher spectral resolution than achieved in previous models. In collaboration with H. Mathis (Oxford), A. Gallazzi, G. Kauffmann and S. White (MPA), this model was used to develop new spectral diagnostics of the star formation history, stellar metallicity and dust content in galaxies using several different techniques. The high-resolution model also allows precise measurements of emission-line fluxes through the accurate subtraction of the stellar continuum in galaxies containing significant nebular emission. In a project led by J. Brinchmann, the group has been using the emission lines in the SDSS spectra to derive star formation rates, metallicities and dust attenuation strength for samples of hundreds of thousands of galaxies. This has led to the most detailed characterization so far of the properties of star-forming galaxies in the local Universe.

X. Kong, S. Charlot, J. Brinchmann (MPA) and M. Fall (STScI) also combined the new spectral evolution model above with a simple but physically motivated model for the transfer of starlight through the interstellar medium in galaxies. They developed new diagnostics of the star formation history and dust attenuation in high-redshift galaxies, for which only the rest-frame ultraviolet emission but not the optical nor infrared emission can be observed at present.

P. Popowski in collaboration with Kem Cook (IGPP/LLNL) and Andrew Becker (Bell Labs) presented a $(V-R)$-based reddening map of about 43 square degrees toward the Galactic bulge/bar, constructed using photometry from the MACHO microlensing survey. They used the novel method of estimating the reddening that is based on $(V-R)$-color averages of the entire color-magnitude diagrams. Their $(V-R)$-colors correlate very well with extinction maps based on other methods and allow them to identify several low-extinction windows. A dusty disk obeying a $\csc|b|$ extinction law well describes gross properties of the extinction toward the bulge/bar fields. The reddening/extinction map is available on the World Wide Web.

G. Kauffmann has been studying the properties of the host galaxies of 22,000 active galactic nuclei (AGN) in the Sloan Digital Sky Survey in collaboration with T. Heckman (JHU, Baltimore), C. Tremonti (Steward Observatory), J. Brinchmann, S. Charlot and S. White. AGN are found to reside in massive galaxies with structural properties that are very similar to ordinary early-type galaxies, but with stellar populations that are typically much younger. The group has been using the [OIII] luminosity as a way of estimating how much material is being accreted by black holes in the local Universe. The group finds that low mass black holes ($< 3\times10^7 M_\odot$) are currently accreting at relatively high rates. The SDSS results show that the growth time for this population is of order a Hubble time. Massive black holes are experiencing much less accretion at the present day indicating that these objects were already in place at high redshifts.

Finally, the same group led by G. Kauffmann has also been using the SDSS to study how the environment of a galaxy affects its properties. It is found that at fixed stellar mass, both star formation and nuclear activity in galaxies depend strongly on local density, but the sizes and structural properties of galaxies are independent of it. The group also highlighted a striking similarity in the changes in galaxy properties as a function of density and as a function of redshift and discussed how this could be understood.

A. Ferguson (along with Ibata (Strasbourg), I., McConnachie (Cambridge), Lewis (Sydney), Tanvir (Herts) continued to study the fossil record in our nearest giant neighbours, M31 and M33. Deep wide-field imagery with the Canada France Hawaii Telescope was used to probe line-of-sight distance variations towards the giant stellar stream in the halo of M31, revealing the southernmost extreme to be more than 100 kpc behind M31. Along with S. Chapman (CalTech), radial velocities of stream red giant branch stars were obtained with Keck/DEIMOS and used to constrain the origin of the stream as well as the mass of M31. The radial velocity of the stream proved inconsistent with the simplest scenarios linking it to either of the known satellities, M32 and NGC205. Unlike M31, M33 was found to have no halo substructure but a smooth extended disk which was well-characterised by an exponential decline out to 5 radial scalelengths. The maximum $R^{1/4}$ stelar halo which could exist in M33 and be consistent with the observed surface brightness profile was constrained to be $\lesssim 5\% L_{disk}$. The distance to M33 was re-evaluated using a large sample of red giant branch stars and found to be ≈ 800 kpc, consistent with previous determinations based on Cepheid variable stars. Along with Tüllman, Elwert, Bomans, Dettmar (Bochum) and Rosa (ESO), Ferguson analysed observations of another nearby galaxy, the Sculptor Group system NGC 55, which led to the spectroscopic confirmation of several extraplanar star formation sites.

F. Miniati with A. Finoguenov (MPE), W. Pietsch (MPE), B. Aschenbach (MPE) have investigated the case of M86 elliptical galaxy. They identify a possible reverse shock with Mach number of 1.4 in the process of crushing the galaxy. The latter is ascribed to the presence of a dense X-ray emitting filament, previously revealed in the ROSAT all Sky Survey data. The shock is not associated with other previously identified features of the M86 X-ray emission. Finally, the mere existence of the large scale gas halo around the M86 group, suggests that the disruption of the M86's X-ray halo may be caused by small-scale types of interactions such as galaxy-galaxy collisions.

Quasars. In collaboration with a summer student W. Weinzierl, P. Popowski developed a test for the origin of quasar redshifts based on proper motions. It is commonly accepted that quasar redshifts have a cosmological origin. However, there are some cases where several quasars with completely different redshifts and a nearby active galaxy are aligned, is claimed by some authors to be unlikely to happen by chance. P. Popowski and W. Weinzierl showed that quasars ejected from local AGNs at velocities close to the speed of light would have proper motions which would easily be measurable with future astrometric missions such as GAIA and SIM.

In a non-microlensing application of the MACHO Project data, M. Geha (UC Santa Cruz) with P. Popowski and other MACHO members presented 47 spectroscopically confirmed quasars discovered behind the Magellanic Clouds. These quasars were identified via photometric variability in the MACHO database, more than tripling the number of quasars previously known in this region.

Galaxy evolution. T. Di Matteo, in collaboration with R. Croft (Carnegie Mellon Univ.), V. Springel (MPA) and L. Hernquist (Harvard Univ.) has coupled state-of-art cosmological simulations of galaxy formation in the Λ–Cold Dark Matter (CDM) model with a model for black hole growth and activity. In the prescription they have developed, the black hole fueling rate is regulated by its interplay with star formation and associated feedback processes in the gas. This establishes a link between star formation and the quasar phase in host galaxies, which in turn can broadly reproduce the observed slope of the relation between black hole mass and stellar velocity dispersion, as well as the properties of the X-ray and optical quasar luminosity functions. Using the simulations and the measured quasar metal abundances, they have shown that it is possible to construct self-consistent models for the locations where massive galaxies are being assembled, vigorously forming stars and building central black holes.

S. Recchi studied in detail the effect of single and multiple bursts of star formation on the dynamical and chemical evolution of Blue Compact Dwarf galaxies. 2-D hydrodynamic codes are used to investigate the evolution of a model galaxy similar to IZw18 (the most metal-poor galaxy locally known) under different star formation histories. The next step will be to run accurate 3-D simulations by means of the adaptive-mesh hydrodynamic code FLASH.

With K. Dolag, M. Meneghetti, G. Tormen (OAP Padova), F. Perrotta, C. Baccigalupi (SISSA Trieste) and L. Moscardini (Univ. of Bologna), M. Bartelmann used numerical simulations to study how dark-energy cosmologies with constant and time-varying equation of state affect halo parameters. Analytic models based on the assumption that halo core densities reflect the mean cosmic density at their formation time were found to correctly describe halo concentrations, once properly calibrated. The change of the mean halo concentration in dark-energy models could be traced back to the behaviour of the growth factor at very early times.

V. Springel, in collaboration with S. White and L. Hernquist (Harvard Univ.), developed a novel, more robust method to measure the shape of dark matter halos using their gravitational isopotentials directly. The shapes of dark matter halos were then measured in collisionless cosmological simulations, as well as in corresponding simulations that also account for gasdynamics, including radiative cooling and star formation. The baryonic inflow that results from the dissipation was found to modify the shapes of the innermost parts of dark matter halos substantially, making the highly elongated shapes of halos found in collisionless simulations much rounder. Intriguingly, the projected shape distribution of the inner parts of dark halos found in the dissipative simulations agrees with the 2D shape distribution of isophotal lines of luminous elliptical galaxies.

G. Börner, D.H. Zhao(Shanghai), Y.P. Jing (Shanghai), and H.J. Mo (since March 1st, UMass at Amherst, USA) have investigated the growth and structure of dark matter halos. They found that the structural properties of a halo at any time can be predicted from its mass accretion history. The scaling law relating an inner scale radius r_s of the halo with the mass contained within r_s is the reason for this. The build-up of dark halos in CDM models consists of an early phase of of fast accretion, and a late phase of slow accretion. During the fast accretion phase the mean concentration of halos, i.e. the ratio of halo radius to r_s, is constant and about 3. This has the interesting consequence that galaxies at high redshift, and clusters at the present time have the same structure.

X. Kang together with Y.P. Jing (Shanghai) and G. Börner has used the semi-analytic approach to model galaxy formation in a series of high resolution cosmological simulations. The simulations range from cluster to cosmic volumes and can predict systematic properties of galaxies in a variety of environments. The models are compared to a number of data sets including the luminosity functions of the SDSS and 2dF survey, the composite cluster luminosity function, color-magnitude relations, and mass to light ratios.

Lyman alpha absorption. V. Springel, in collaboration with K. Nagamine and L. Hernquist (both Harvard Univ.), has investigated the properties of damped Lyman-α absorbers (DLA) in cosmological hydrodynamic simulations of structure formation. Using a subresolution model for the interstellar medium and detailed convergence studies, they showed that previous numerical work on the DLA abundance was affected by numerical overcooling, lack of resolution, and insufficient treatment of stellar feedback processes. The new simulations match the observed abundance of DLAs well in the redshift range $z = 1$ to $z = 4.5$, and account for their estimated star formation rates. However, the mean median metallicity of simulated DLAs is higher than the values typically estimated from observations, by nearly an order of magnitude.

In collaboration with S. Furlanetto (CalTech), J. Schaye (IAS), and L. Hernquist (Harvard Univ.), V. Springel investigated the Ly-α emission from diffuse, optically thin gas in the intergalactic medium (IGM) of the low-redshift universe. Using hydrodynamic simulations, they found that galaxies are surrounded by Ly-α coronae with surface brightness moderately above the expected background. The space-density of these Ly-α emitters is quite high, and they trace the filamentary structure of the IGM, so that they potentially provide a new way to map out the cosmic web. In related work, they also studied the line emission of metals in the diffuse IGM, focusing on two ultraviolet doublet transitions, OVI and CIV. Filaments of low overdensity were found to emit substantially below the expected background, but enriched dense regions of the IGM can be detected above the background. Particularly regions that have recently been influenced by galactic winds are found to be luminous in metal lines, suggesting that the enrichment processes of the IGM can be probed by observations of metal lines in the diffuse IGM.

Reionization S. Inoue discussed the unique potential of using dispersion delay in the low frequency radio emission of very high redshift gammaray bursts for probing the reionization history of the universe. The prospects can be particularly promising with facilities such as the *Low Frequency Array*, if gamma-ray bursts emit strong coherent radio emission. Interesting constraints may also be obtainable for the warm-hot intergalactic medium and the molecular cloud environments of gammaray bursts at low redshifts.

S. Inoue and B. Ciardi calculated the broadband afterglow emission of very high redshift gammaray bursts including the reverse shock component, showing that they are brightest in the millimeter to infrared band a few hours after the burst, with milli-Jansky flux levels even from redshifts as high as 30. Such spectra may reveal interesting atomic and molecular absorption lines, observable by facilities such as the *Atacama Large Millimeter Array.* Although primordial molecules such as H_2, HD or LiH are difficult to detect, the rotational lines of molecules such as CO, as well as atomic forbidden lines of metals such as C and O should be detectable, offering a unique probe of individual star forming regions in early galaxies where metal enrichment is starting to take place.

N. Sugiyama (NAOJ), S. Zaroubi (MPA) and J. Silk (Oxford) developed an alternative hypothesis to explain the high optical depth observed by the WMAP CMB satellite. The model invokes as an additional component a non-scale-free isocurvature power spectrum which combines with the standard scale-free adiabatic power spectrum for inflation-motivated primordial density fluctuations. Such a component is constrained by the Lyman alpha forest observations, can account for the small-scale power required by spectroscopic gravitational lensing, and yields a source of early star formation that can reionise the universe at $z \sim 20$ yet becomes an inefficient source of ionizing photons by $z \sim 10$. The model thus allows the conventional adiabatic fluctuation component to reproduce the late thermal history of the intergalactic medium.

At $z \sim 1100$ the IGM is expected to recombine and remain neutral until the first sources of ionizing radiation form and reionize it. The nature of these sources is the subject of a lively debate, the most promising ones being early galaxies and quasars. B. Ciardi, A. Ferrara (SISSA, Trieste), F. Stöhr and S. White have followed the reionization process produced by an early population of pregalactic stellar objects. This is obtained combining the high-resolution simulations run at the MPA, for the galaxy distribution and emission properties, with the code CRASH, for the radiative transfer of photons. The process has been studied for a variety of parameters, and has been tested against the effect of the environment, the mass and grid resolution.

New observational probes of the reionization epoch have been actively searched for in the last few years. It has long been known that neutral hydrogen in the IGM may be directly detectable in emission or absorption against the CMB radiation at the frequency corresponding to the redshifted 21 cm line. In general, 21 cm spectral features will display angular structure as well as structure in redshift space due to inhomogeneities in the gas density field, hydrogen ionized fraction and spin temperature. In collaboration with P. Madau (Santa Cruz, OAA Florence), B. Ciardi has estimated the radio emission expected from the neutral hydrogen distribution derived by the above simulations. They find that the warm, neutral IGM produces brightness temperature fluctuations relative to the average that could be detected by the planned telescope SKA or LOFAR at $z > 10$. While the 21 cm tomography could allow us to map the topology of the reionization process and constrain the nature of the ionizing sources, this remains a challenging project due to foreground contamination. B. Ciardi, T. Di Matteo and F. Miniati have studied the contribution to the extragalactic foregrounds from unresolved radio sources, free-free emission from ionizing sources, cluster radio relics and radio halos.

In exciting future probe of the epoch of reionization will be 21cm tomography of the neutral hydrogen in the IGM and in gravitationally collapsed systems. T. Di Matteo with B. Ciardi and F. Miniati, is modeling the contaminating foregrounds to the primary 21 cm radiation due to extragalactic point source and extended sources. Point sources are the galaxies which produce radio emission and free-free emission. Extended sources include radio halos and relics and free-free amission from the IGM. We are using cosmological simulations and are producing simulated sky maps for the upcoming *Lofar* and *PAST* facilities.

Intergalactic Medium. F. Miniati and S. D. M. White in collaboration with A. Ferrara (SISSA, Trieste) and S. Bianchi (Arcetri, Florence) have investigated the contribution from thermal emission produced by gas shock heated during cosmic structure formation to the cosmic ultraviolet background. Their main calculation was based on an updated version of Press-Schechter formalism but was in agreement with a empirical estimate based on the observed properties of galaxies and the observed cosmic star formation history. They computed a composite UVB spectrum made of QSO, stellar and thermal components and accounted for radiative transfer effects. They found that thermal emission is not negligible in general and that it is particularly important at photon energies above 54.6 eV, which is relevant for HeII reionization. According to their calculations, thermal emission is the dominant contribution at these energies for redshifts above 4 and at redshift 6 provides enough photons to drive HeII reionization. In addition those calculations allowed a constraint on the escape fraction of ionizing photons from galaxies to less than a few percent.

Observations of QSOs and galaxies at $z > 6$ and more recently WMAP observations of CMB temperature and polarization anisotropies have reignited interest in the formation and the evolution of the first structures in the universe, and their effects on the IGM and the subsequent structure formation process. B. Ciardi, in collaboration with A. Ferrara (SISSA, Trieste), is collecting the available studies into a Review paper on the subject.

3.8 Cosmic structure from z=0 to the Big Bang

Galaxy Clusters. M. Brüggen (Bremen), T.A. Enßlin, and F. Miniati estimated the luminosity function of cluster radio relics, which are former radio cocoons that have been revived by shock waves. The statistics of shock wave strengths were derived by analysing a large-scale structure simulation. The estimated radio luminosity function is compatible with current observations. Furthermore, the work explains very naturally the observed locations of radio relics on the outskirts of clusters, because this is where the cosmic shock waves mainly occur.

T.A. Enßlin, C. Vogt, T.E. Clarke (Charlottsville), G.B. Taylor (NRAO Socorro) investigated whether Faraday rotating magnetic fields are local to intracluster radio galaxies, or if they belong to the foreground intracluster medium. In the first case, spatial correlations between structures in Faraday rotation maps and polarisation angle maps can be expected, since these are tracers of line-of-sight parallel and perpendicular magnetic field components, respectively. In the second case such correlations are impossible due to the spatial separation of radio emitting and Faraday rotating components. Statistical tests were performed on the co-alignment of gradients in these maps. It was shown that claimed co-spatial structures in earlier publications were due to map-making artefacts and were not of astrophysical nature. A more solid basis for detailed statistical analysis of Faraday rotation maps was established, and a tool to quantitatively characterise the quality of Faraday rotation maps was developed.

C. Vogt and T. Enßlin developed a statistical analysis for Faraday rotation measure maps of extended polarised radio sources in order to extract properties of cluster magnetic fields. They reanalysed Faraday rotation maps of extended radio sources located in the Abell 400, Abell 2634 and the Hydra A cluster. They successfully determined magnetic power spectra from the maps and derived magnetic field strengths for the non-cooling flow clusters (Abell 400 and Abell 2634) of about 3-6 μG and for the cooling flow cluster (Hydra A) of about 12 μG. They realised that small scale pixel noise and map making artefacts influence strongly the shape of the power spectra, however the above mentioned results should be robust. In collaboration with K. Dolag (Univ. of Padua), they developed a new algorithm (PACMAN - Polarisation Angle Correcting rotation Measure ANalysis) to calculate accurate Faraday Rotation maps from multi-frequency polarisation data.

S. Heinz, E. Churazov, B. Forman (CfA, Harvard), C. Jones (CfA, Harvard), and U. Briel (MPE) performed hydrodynamic simulations of cold fronts in galaxy cluster mergers. They show that ram pressure stripping can induce strong vorticity in the core of the merging sub-cluster, which transports the lowest entropy, coldest material from the core of the sub-cluster to the tip of the contact discontinuity. Their analysis of XMM data of the galaxy cluster A3667 shows that the edge of the cold front is indeed the place where the coldest gas resides.

S. Inoue and N. Sugiyama (National Astronomical Observatory, Japan) investigated the integrated flux of ultra-high energy cosmic ray protons accelerated in the accretion shocks of galaxy clusters. Accounting for cosmological evolution of the cluster mass function and merger/accretion rate using the extended Press-Schechter formalism, they found that these can make a significant or even dominant contribution to the observed ultra-high energy cosmic rays, depending on the efficiency of acceleration.

G. De Lucia, G. Kauffmann, V. Springel and S. White have been using high resolution N-body simulations to models the effects of feedback and the transport of heavy elements on the properties of galaxies and on the state of the intracluster and intergalactic medium. This work is part of G. De Lucia's PhD thesis. They show that if the baryon fraction favoured by WMAP observations of the microwave background is adopted, feedback processes must be extremely efficient in order to prevent too much gas from cooling and forming galaxies. In the models that works best, a significant fraction of the baryons and hence the metals in the Universe are ejected outside virialized dark matter halos and are never able to fall back in. The group has also used the same set of simulations to study the properties of substructure in dark matter halos.

C. Pfrommer and T. Enßlin studied non-thermal properties of clusters of galaxies in order to put constraints on the population of cosmic ray protons (CRp). They developed an analytic formalism which describes the induced radio synchrotron and γ-ray emission from hadronic interactions of CRp with ambient thermal protons. Comparing the γ-ray flux to EGRET upper limits, they constrained the CRp energy density in nearby cooling flow clusters such as Perseus and Virgo to $< 20\%$ relative to the thermal energy density. Radio surface brightness profiles of the Perseus mini-halo matched the expected emission by this hadronic scenario well on all scales. Considering the small amount of energy density in CRp (2% relative to the thermal energy density) needed to account for the observed radio emission, this is a strong indication for the hadronic origin of these radio mini-halos.

As an extention of this work, C. Pfrommer and T. Enßlin estimated magnetic field strengths of radio emitting galaxy clusters by minimising the non-thermal energy density contained in cosmic ray electrons, protons, and magnetic fields. They developed a minimum energy criteria together with theoretically expected tolerance regions for observed synchrotron emission which is generated by a cosmic ray electron population originating from hadronic interactions of CRp. Application to the radio halo of the Coma cluster and the radio mini-halo of the Perseus cluster yielded equipartition between cosmic rays and magnetic fields within the expected tolerance regions. Furthermore, C. Pfrommer and T. Enßlin studied the cosmic ray proton (CRp) population within the giant elliptical galaxy M 87 using the TeV γ-ray detection of the HEGRA collaboration. Within the considered scenario, the γ-rays are produced by decaying pions which result from hadronic CRp interactions with thermal gas of the interstellar medium of M 87. Both the expected radial γ-ray profile and the required amount of CRp support this hadronic scenario.

G. Hütsi in collaboration with J. Einasto, M. Einasto, E. Saar (Tartu Observatory) studied the properties of clusters and superclusters of galaxies and their dependence on local environment using data from the SDSS Early Data Release and from the LCRS. Clusters/superclusters were identified as peaks in the high/low resolution density field, respectively. Properties of these objects were studied and compared with the properties of Abell clusters and superclusters. A significant dependence of cluster properties on their environment was detected. So for example the most luminous clusters in high-density environments are about an order of magnitude brighter than most luminous clusters in low-density environments.

M. Jubelgas, as part of his PhD thesis supervised by V. Springel, developed a novel numerical method to treat thermal conduction in thin astrophysical plasmas within the parallel structure formation code GADGET. Thermal conduction has been proposed as a possible explanation for the apparent suppression of strong cooling flows in rich clusters of galaxies. In collaboration with K. Dolag (Univ. of Padova), he carried out the first cosmological hydrodynamic simulations of cluster formation that account self-consistently for thermal conduction, as well as for processes of radiative cooling and star formation. While thermal conduction was found to significantly modify the radial temperature and entropy profiles of simulated rich clusters, the total mass deposition rate in the center due to cooling was hardly changed, suggesting that thermal conduction is unlikely to provide a complete solution to the cooling flow problem.

B. M. Schäfer, C. Pfrommer and S. Zaroubi have proposed a new method for estimating redshifts of galaxy clusters based solely on resolved Sunyaev-Zel'dovich (SZ) images. Given a high resolution SZ cluster image (with FWHM of 1), the method indirectly measures its structure related parameters (amplitude, size, etc.) by fitting a model function to the higher order wavelet moments of the cluster's SZ morphology. The relationship between these parameters is used in order to measure the cluster redshift.

Large scale structure. P. Erdogdu (IoA) O. Lahav (IoA), S. Zaroubi (MPA) and the 2dFGRS team, have reconstructed the underlying density field of the 2 degree Field Galaxy Redshift Survey (2dFGRS) for the redshift range $0.035 < z < 0.200$ using the Wiener Filtering method. Maps of the density field in 2 different resolutions have been presented: $5h^{-1}$ Mpc and $10h^{-1}$ Mpc. All major superclusters and voids in the survey have been identified. A. Eldar, Y. Hoffman (Jerusalem) S. Zaroubi (MPA), E. Branchini (Roma III), and A. Dekel (Jerusalem) have also expanded the reconstructed 3d velocity field in terms of its multipoles. They used this information to put constraints on the large scale structure outside the observed volume.

V. Springel, together with S. Borgani, L. Tornatore, P. Tozzi (all three Trieste), G. Murante, A. Diaferio (both Torino), K. Dolag, G. Tormen (both Padova), and L. Moscardini (Bologna), carried out a very large cosmological hydrodynamic simulation of structure formation in the ΛCDM model, using 2×480^3 dark matter and SPH particles, respectively, in a box of $192\,h^{-1}$Mpc. The simulation accounted for radiative cooling of gas, star formation, and associated feedback processes by supernova explosions as well as for weak galactic winds. In a first analysis, they studied the X-ray properties of clusters and groups of galaxies. The X-ray temperature distribution function, and the relation between mass and temperature were found to be consistent with observations. For massive clusters with temperatures $T > 2\,\mathrm{keV}$, the relation between luminosity and temperature also agrees with observations, but does not exhibit the pronounced break at the group-scale which is observed for real clusters. While the simulations clearly show evidence for entropy injection into the intracluster medium by the included feedback processes, these effects are apparently too weak to bring the thermodynamic properties of the simulated intracluster medium on the group-scale into agreement with observations, suggesting that in reality further non-gravitational heating mechanisms are at work here.

G. Börner and Y.P. Jing (Shanghai) have measured the three point correlation function for the 2dF catalog of optical galaxies. They found good agreement with their earlier analysis of the Las Campanas Survey, and the same type of discrepancy with CDM model predictions: A simulation modeled according to the WMap parameters showed amplitudes about a factor of 2 higher than the data.

D.N. Chen together with Y.P. Jing (Shanghai) continued the study of the angular momentum distribution of dark matter and hot gas within halos using simulations generated by Y.P. Jing and K. Yoshikawa (Tokyo).

3.9 Gravitational Lensing

Together with M. Meneghetti (Padova) and L. Moscardini (Bologna), M. Bartelmann studied the impact of cD galaxies on the strong-lensing cross sections of galaxy clusters. Their effect was found to be small to moderate, increasing the probability for the formation of large arcs typically by not more than 50%. The same authors compared arc cross sections of numerically simulated clusters to their analytic approximations, finding the latter inadequate for computing absolute arc probabilities because cluster asymmetries, substructures, and surrounding tidal fields strongly affect arc cross sections in a way which is hard to capture in reasonable analytic models. M. Bartelmann, M. Meneghetti, F. Perrotta, C. Baccigalupi (Trieste) and L. Moscardini analytically estimated the relative change of arc abundance due to earlier structure growth in dark-energy cosmologies with constant equation-of-state parameter w. Halos growing earlier are more compact and thus more efficient strong lenses, but the increased integrated Sachs-Wolfe effect requires the normalisation of density fluctuations to be lowered. The net effect is an increase of the arc optical depth by up to a factor two as w increases from -1 to -0.6, followed by a steep decrease.

M. Bartelmann and M. Meneghetti investigated into the validity of the claim made by a group at Caltech that constraints from radial and tangential arcs in galaxy clusters, together with the velocity dispersion of the central cluster galaxy, required rather flat central density profiles and thus contradicted the density profiles consistently found in CDM simulations. Based on axisymmetric lens models for the clusters, the claim turns out to be incorrect in presence even of little cluster asymmetry.

B. Ménard (now IAS Princeton), M. Bartelmann, T. Hamana (IAP Paris and NAO Tokyo) and N. Yoshida (CfA Cambridge and NAO Tokyo) investigated the improvement of cosmic magnification statistics achieved by including second-order terms into the analytic computation, and tested their results with numerical simulations. Second-order terms contribute significantly to the autocorrelation function of cosmic magnification on arcminute scales, but higher-order terms are negligible. B. Ménard, M. Bartelmann and Y. Mellier (IAP Paris) investigated how well cosmological parameters like Ω_0 can be constrained with cosmic-magnification statistics. Wide-area surveys like the SDSS promise results comparable in accuracy to cosmic-shear measurements, but the main strength of cosmic-magnification statistics is the possibility to constrain galaxy biasing.

B. Ménard and Céline Péroux use 2dF data in order to investigate the gravitational lensing effects of MgII absorbers on background quasars. They found that quasars having a strong MgII absorption lines are significantly brighter.

G.L. Li together with M. Bartelmann (Tübingen), and and Y.P. Jing (Shanghai) has worked on the question, why there is a discrepancy between the number of giant arcs observed and predicted in CDM models. In his model calculations he has included about 200 galaxy clusters, and 10 redshift intervals for lensing sources. This is the largest sample used for the arc ststistics up to now. G.L. Li with Y.P. Jing (Shanghai) also has considered the flux-ratio anomalies observed in strong lensing, especially the relation to substructures in high resolution simulations.

3.10 Cosmic Microwave Background Studies

Foreground Studies. In collaboration with C. Dickinson, R. D. Davies, and R. Davis (Jodrell Bank, UK) and K. M. Górski (NASA-JPL, USA), A. J. Banday has reinvestigated the contribution of foregrounds to the COBE-DMR data. The new ingredient to the study has been the inclusion of a full-sky map of H_α emission as a tracer of the free-free diffuse foreground in the microwave frequency range. Such emission can then be disentangled from an apparent anomalous component of Galactic dust-correlated emission. This now unambiguously identified anomalous dust-correlated component has been determined to have a frequency spectral dependence of the form $\nu^{-2.5}$. A physical interpretation is more problematic; the result implies the presence of an emission component with a dust-like morphology but a synchrotron-like spectrum, in substantial agreement with the WMAP results.

Non-Gaussianity Studies. Work has continued on methods to investigate and quantify putative non-Gaussian signals present in CMB data. Together with H. K. E. Eriksen and P. Lilje (Oslo, Norway) and K. M. Gorski (NASA-JPL, USA), an algorithm to rapidly determine the 3- and 4-point correlation functions for various geometries of spherical triangles or quadrilaterals has been developed and applied to the first year WMAP data release. Interestingly, local estimates of these n-point correlation functions determined from discs of approximately 10 degree radius arranged to maximally cover the celestial sphere indicate an asymmetry in the distribution of CMB power on the sky. Extending the analysis to hemispheres indicates that a region close to the Northern ecliptic pole demonstrates a remarkable lack of large-scale power. In continuing companion work with F. Hansen (Rome II, Italy), utilising the Gabor transform to regularise local power spectrum estimates, this asymmetry is observed with even stronger statistical significance. In the absence of compelling explanations due to Galactic foregrounds or instrumental systematic artefacts, an intrigiung possibility remains that fundamentally new physics is required on these large scales.

J. Chluba in collaboration with S.Y. Sazonov and R.A. Sunyaev examined analytically and numerically the thermalization of spectral distortions of the cosmic microwave background after energy injection in the very early universe including relativistic corrections to Compton and double Compton scattering. Relativistic effects lead to corrections of the order of a few percent for energy injection at redshifts $z > 2 \cdot 10^6$. J. Chluba in collaboration with R.A. Sunyaev studied the spectral distortions of the cosmic microwave background (CMB) arising from the superposition of Planck spectra with different temperatures. Due to the finite resolution of CMB experiments and the existence of CMB fluctuations on the level of $\Delta T/T \sim 10^{-5}$ this type of distortion appears for any observation of the CMB. It has been shown that the distortion is indistinguishable from a y-type distortion. The CMB dipole due to the motion of the sun with respect to the CMB induces a full sky distortion with y-parameter $y_{\rm d} = 2.6 \cdot 10^{-7}$.

Component Separation Studies. A method for component separation based on the Fast Independent Component Algorithm (FastICA) has been developed and applied to the COBE-DMR data by a group comprising A. J. Banday in collaboration with D. Maino (Univ. of Milan, Italy), C. Baccigalupi and F. Perrotta (SISSA, Italy) and K. M. Górski (NASA-JPL, USA). With application to real data, we have found that the method is sensitive to differences in the noise properties of the input data sets. By including other data, specifically maps of Galactic dust emission from the COBE-DIRBE instrument, synchrotron measurements at 408 MHz and a tracer of the free-free emission based on surveys of the H_α spectral line, convolved to the DMR beam resolution, a reasonable separation of the CMB signal can be achieved. In particular, the derived CMB signal is consistent with previous model fits to the data, and the presence of an anomalous dust-correlated component has been established with a spectral dependence of the form $\nu^{-2.5}$, in excellent agreement with the work of Banday et al. (2003). Work is now proceeding to extend the method for application to the WMAP first year data.

A flexible maximum entropy based method for foreground separation has also been developed with R. B. Barreiro and P. Vielva (IFCA, Spain), M. P. Hobson, A. N. Lasenby and V. Stolyarov (Cambridge, UK) and K. M. Górski (NASA-JPL, USA). As applied to the COBE-DMR data, a robust reconstruction of the CMB signal has been derived, although extraction of the spectral behaviour of the Galactic components is difficult to achieve unambiguously because of the low signal-to-noise of the data. The maps of the CMB determined from both FastICA and Flexible MEM are in excellent agreement at high Galactic latitudes.

C. Hernández–Monteagudo and R. Sunyaev have studied the correlation of different signals seeded by cosmological perturbations in the context of the CMB. They focused their analysis on the amplitude and the angular scale at which those correlations show up. This study provides a way to search for weak signals in the power spectrum of the CMB, under the requirement that the weak and the dominant signals have different spectral dependence.

Software Development. A. J. Banday, M. Bartelmann and M. Reinecke in collaboration with K. M. Gorski (NASA-JPL, USA) and E. Hivon (NASA-IPAC, USA) continue to maintain and develop the HEALPix software package for the simulation and analysis of CMB anisotropy maps. Version 1.2 was publicly released in early 2003. Work is currently focussed on diversifying the support for various programming environments. Toolkits in C++, Java and C# are expected in the coming year. Studies are also underway in the utilisation of HEALPix as a standard spatial database scheme for Virtual Observatory applications.

In an extension of the database activity in the context of the German Astrophysical Virtual Observatory A. J. Banday has collaborated with G. Lemson (MPE, Garching) and P. Dowler (CADC, Canada) to propose a unified domain model for astronomy. Such a model is an essential ingredient for the development of a Virtual Observatory (VO). It will provide a common grammar and vocabulary for expressing the varied data products existing in distributed astronomical databases. Further, it will define the set of concepts that a user of the VO can use in queries to these archives. Without such a common data model it will not be possible to achieve true interoperability between different archives.

Radiative transfer. K. Basu has studied the effect of line emission and scattering from atoms and molecules on the Cosmic Microwave Background (CMB) temperature anisotropy, in collaboration with C.Hernandez-Monteagudo and R.Sunyaev. Part of this work has appeared in a recent paper where he has used the scattering of CMB photons by the fine-structure transitions of various atoms and ions to constrain the ionization and enrichment history of the universe. It has been shown that with the tremendous sensitivity of present and future CMB experiments, a very strong constraint ($10^{-4} - 10^{-2}$ solar fraction) can be put on the abandances of different heavy elements in the redshift range $z = 5 - 30$.

C. Hernández–Monteagudo and J.A. Rubiño–Martín have cross-correlated the first year WMAP CMB maps with templates built from optical and X-ray based catalogues of clusters and superclusters of galaxies. This cross-correlation should unveil the presence of anisotropies induced by the thermal Sunyaev-Zel'dovich (tSZ) effect. For the BCS, NORAS and de Grandi cluster catalogues a typical tSZ decrement of $15 - 35$ μK per cluster was found ($2\sigma - 5\sigma$ detection level, no beam deconvolution applied). For supercluster templates derived from Einasto's supercluster catalogues no evidence of correlation could be reported, ($y_{SC} < 2.18 \times 10^{-8}$ at the 95% confidence limit).

J.A. Rubiño-Martín, C. Hernández-Monteagudo and T. Enßlin have studied the Rees-Sciama signature induced in the CMB from a merger of galaxy clusters. They have developed an analytical approximation to compute this effect, which can be easily included in numerical simulations. They also have proposed a method to extract this signal from a sample of clusters. Currently, and in collaboration with M. Maturi (Univ. of Padua), they are obtaining realistic simulations of this effect using hydrodynamic simulations of cluster mergers.

J.A. Rubiño-Martín have visited twice the VSA group in Tenerife, and he has participated in the data processing of this experiment, and in deriving the cosmological implications of the measured power spectrum.

3.11 Quantum mechanics of atoms and molecules, astrochemistry

The long-term efforts to study basic exothermic binary reactions of possible astrophysical relevance were continued. In this context various reactions relevant for modelling of the primordial Lithium chemistry were investigated by rigorous quantum-mechanical calculations. Reaction constants for the formation and destruction of diatomic Lithium compounds such as LiH and the ionic species LiH^+ and $HeLi^+$ were evaluated in order to establish the appropriate theory level which is required to obtain reliable results. In case of the hydrides LiH and LiH^+ the present results were found to be in perfect agreement with recently calculated accurate literature values. On the corresponding theory level the full three-dimensional potential energy hypersurfaces of the lower electronic states of the weakly bound LiH_2^+ complex were calculated for future studies of the reaction dynamics of various binary processes such as radiative association, radiative charge-transfer, or exothermic hydrogen abstraction reactions. These calculations led to the first complete spectroscopic characterization of the ground electronic state of the LiH_2^+ ion. All bound rotation-vibration energy levels and their linestrengths and transition probabilities were predicted and in addition the low-lying quasibound resonance states, which are expected to play an important role in low-temperature collisional processes, were determined. Similar calculations for the first excited electronic state of the triatomic ion were started. The potential energy surface of this state has a much more complicated topology with two energy minima of comparable well depths, separated by a medium-sized energy barrier.

Apart from the light LiH_2^+ complex, studies of the strongly bound triatomic HCO^+/HOC^+ and HN_2^+ ions were continued. The recently developed computational approach on a two-reference-configuration coupled-cluster level was applied to calculate the three-dimensional potential energy hypersurfaces for the protonation/hydrogenation reactions of CO and N_2, or CO^+ and N_2^+, respectively. One-dimensional models to approximate the corresponding reaction dynamics were developed but were found to be inadequate.

As an extension of the previous work on the spectroscopy of interacting electronic molecular states the Renner-Teller $\tilde{A}\ ^1B_1 \rightarrow \tilde{X}\ ^1A_1$ emission spectra of SiH_2 were calculated and used to interpret features obtained in dispersed fluorescence spectroscopy measurements (W.P. Kraemer together with V. Špirko (Prague), P. Soldan (Durham), P. Neogrady (Bratislava), P.R. Bunker (Ottawa), P. Jensen (Wuppertal)).

Semiconductor technology allows the construction of quantum systems consisting of electrons confined in potential wells, referred to as *artificial atoms* or *quantum dots*, as *double dot artificial molecules* or *double quantum dots*, and as *quantum dot molecules*, respectively. Experimental techniques permitting the manipulation of single molecules have opened the field of $single-molecule\ physics$. In chemistry systems with nanostructures have been used to isolate molecules and to treat each single molecule individually with the other components opening the field of *nanochemistry* or $single-molecule\ chemistry$. Studies of quantum objects confined by different forms of external potentials have attracted the attention of both physicists and quantum chemists since the early days of quantum mechanics. The development of new technologies and experimental techniques has triggered new intensive theoretical research on modeling spatially confined quantum systems.

In a series of studies, quantum-chemical models of atoms and molecules were applied to investigate the effects of spatial confinement on the properties and reactions of quantum systems. The confined object is described by the Hartree-Fock (HF) and configuration interaction (CI) methods. The spatial confinement is defined by an external one-particle potential introduced to the N-electron Hamiltonian. Studies have been performed of the spectral properties and of the dipole polarizability, respectively, of few electron systems, namely the 2- and 3-electron quantum dot, the hydrogen negative ion, the helium atom, the lithium atom, and the lithium molecule confined by anisotropic harmonic oscillator potentials of different geometry and strength. (G. H. F. Diercksen and T. Sako, Tokyo, Japan)

4 Publications and Invited Talks

4.1 Publications in Journals

4.1.1 Publications that appeared in 2003

Abazajian, K., G. Kauffmann, L. Tasca, S. Zibetti et al. (SDSS Collaboration): The first data release of the Sloan Digital Sky Survey. Astron. J. **126**, 2081–2086 (2003).

Alencar, S.H.P., C.H.F. Melo and C.P. Dullemond: The pre-main sequence spectroscopic binary AK Scorpii revisited. Astron. Astrophys. **409**, 1037–1053 (2003).

Alcock, C., D. Alves, P. Popowski et al.: The MACHO Project Large Magellanic Cloud variable star inventory. XI. Frequency analysis of the fundamental mode RR Lyrae stars Astrophys. J. **598**, 597–610 (2003).

Aloy, M.A., J.Mª., Martí, E. Müller et al.: Three-dimensional simulations of relativistic precessing jets probing the structure of superluminal sources. Astrophys. J. **585**, L109–L112 (2003).

Anzer, U. and P. Heinzel: On the nature of extended EUV filaments. Astron. Astrophys. **404**, 1139–1144 (2003).

Arp, H.: Research with Fred. Astrophys. and Space Science, **285**, 451–457 (2003).

Asada, H., T. Hamana and M. Kasai: Images for an isothermal ellipsoidal gravitational lens from a single real algebraic equation. Astron. Astrophys. **397**, 825–829 (2003).

Banday, A.J., C. Dickinson, R.D. Davies et al.: Reappraising foreground contamination in the COBE-DMR data. Mon. Not. R. Astron. Soc.. **345**, 897–911 (2003).

Baraffe, I., G. Chabrier, T.S. Barman et al.: Evolutionary models for cool brown dwarfs and extrasolar giant planets. The case of HD 209458. Astron. Astrophys. **402**, 701–712 (2003).

Barrio, F.E., C. Done and S. Nayakshin: On the accretion geometry of Cyg X-1 in the low/hard state. Mon. Not. R. Astron. Soc. **342**, 557–563 (2003).

Bartelmann, M. and S. D. M. White: Stacking clusters in the ROSAT All-Sky Survey. Astron. Astrophys. **407**, 845–854 (2003).

Bartelmann, M., F. Perrotta and C. Baccigalupi: Halo concentrations and weak-lensing number counts in dark energy cosmologies. Astron. Astrophys. **400**, 19–19 (2003).

Bartelmann, M., M. Meneghetti, F. Perrotta, C. Baccigalupi and L. Moscardini: Arc statistics in cosmological models with dark energy. Astron. Astrophys. **409**, 449–457 (2003).

Bi, H. G., L. Z. Fang, L. Feng and Y. Jing: Hydrogen clouds before reionization: a lognormal model approach. Astrophys. J. **598**, 1–12 (2003).

Brüggen, M.: Equilibrium models of galaxy clusters with cooling, heating, and conduction Astrophys. J. **593**, 700–704 (2003).

Brüggen, M.: Simulations of buoyant bubbles in galaxy clusters Astrophys. J. **592**, 839–845 (2003).

Bruzual, G. and S. Charlot.: Stellar population synthesis at the resolution of 2003. Mon. Not. R. Astron. Soc. **344**, 1000–1028 (2003).

Buras, R., M. Rampp, H.T. Janka and K. Kifonidis: Improved models of stellar core collapse and still no explosions: What is missing? Phys. Review Lett. **90**, 241101 (2003).

Buras, R., H.T. Janka, M.T. Keil, G. Raffelt and M. Rampp: Electron neutrino pair annihilation: A new source for muon and tau neutrinos in supernovae. Astrophys. J. **587**, 320–326 (2003).

Burbidge, E.M., G. Burbidge, H.C. Arp and S. Zibetti: QSOs associated with M82. Astrophys. J. **591**, 690–694 (2003).

Burbidge, E.M., G. Burbidge and H.C. Arp: The nature of the ultraluminous X-ray sources inside galaxies and their relation to local QSOs. Astron. Astrophys. **400**, L17–L19 (2003).

Burenin, R. A., R.A. Sunyaev, M.N. Pavlinsky et al.: The First Hours of the Optical Afterglow from the Cosmic Gamma-Ray Burst 030329. Astron. Lett. **29**, 573–578 (2003).

Butt, Y.M., P. Benaglia, F. Miniati et al.: Chandra/Very Large Array follow-up of TeV J2032+4131, the only unidentified TeV gamma-ray source. Astrophys. J. **597**, 494–512 (2003).

Candia, P., K. Krisciunas, J. Cuadra et al.: Optical and infrared photometry of the unusual Type Ia supernova 2000cx. Publ. Astron. Soc. Pac. **115**, 277–294 (2003).

Casas-Miranda, R., H.J. Mo and G. Börner: Testing theoretical models for the higher order moments of dark halo distribution. Mon. Not. R. Astron. Soc. **339**, 872–880 (2003).

Cassisi, S., M. Salaris and A.W. Irwin: The initial helium content of Galactic globular cluster stars from the R-parameter: Comparison with the cosmic microwave background constraint. Astrophys. J. **588**, 862–870 (2003).

Cassisi, S., H. Schlatti, M. Salaris and A. Weiss: First full evolutionary computation of the helium flash-induced mixing in population II stars. Astrophys. J. **582**, L43–L46 (2003).

Cayón, L., E. Martínez-González, F. Argüeso, A. J. Banday and K. M. Górski: COBE-DMR constraints on the non-linear coupling parameter: a wavelet based method. Mon. Not. R. Astron. Soc. **339**, 1189–1194 (2003).

Chen, D.N., Y.P. Jing and K. Yoshikaw: Angular momentum distribution of hot gas and implications for disk galaxy formation. Astrophys. J. **597**, 35–47 (2003).

Cherepashchuk, A.M., R.A. Sunyaev, E.V. Seifina et al: INTEGRAL observations of SS433, a super-critically accreting microquasar with hard spectrum. Astron. Astrophys. **411**, L441–L445 (2003).

Churazov, E., W. Forman, C. Jones and H. Böhringer: XMM-Newton observations of the Perseus Cluster. I. The temperature and surface brightness structure. Astrophys. J. **590**, 225–237 (2003).

Ciardi, B. and P. Madau: Probing beyond the epoch of hydrogen reionization with 21 centimeter radiation. Astrophys. J. **596**, 1–8 (2003).

Ciardi, B. A. Ferrara and S.D.M. White: Early reionization by the first galaxies. Mon. Not. R. Astron. Soc. **344**, L7–L12 (2003).

Ciardi, B., F. Stoehr and S.D.M. White: Simulating intergalactic medium reionization. Mon. Not. R. Astron. Soc. **343**, 1101–1109 (2003).

Cora, S.A. and S.D.M. White: Chemical enrichment of the intra-cluster medium. Astrophys. and Space Science **284**, 425–428 (2003).

Cuadra, J. Nayakshin, S., and R. Sunyaev: Bright stars and an optically thick inactive disk in Sgr A* and other dormant galaxy centers. Astron. Astrophys. **411**, 405-416 (2003).

Daddi, E., H.J. A. Rottgering, G. Rudnick et al.: Detection of strong clustering of red K-selected galaxies at $2 < z(phot) < 4$ in the Hubble Deep Field-South. Astrophys. J.. **588**, 50–64 (2003).

Denis, P.A., M. Kieninger, O.N. Ventura, R.E. Cachau and G.H.F.Diercksen: Complete basis set and density functional determination of the enthalpy of formation of the controversial HO3 radical. A discrepancy between theory and experiment. Chem. Phys. Lett. **377**, 483–484 (2003).

Dessart, L. and S.P. Owocki: Two-dimensional simulations of the line-driven instability in hot-star winds. Astron. Astrophys. **406**, L1–L4 (2003).

Dessart, L., N. Langer and J. Petrovic: The impact of radiation and wind momenta on mass transfer in massive close binary systems. Astron. Astrophys. **404**, 991–996 (2003).

Di Matteo, T., R.A.C. Croft, V. Springel and L. Hernquist: Black hole growth and activity in a Lambda cold dark matter universe. Astrophys. J.. **593**, 56–68 (2003).

Di Matteo, T., S.W. Allen and A.C. Fabian: Accretion onto the supermassive black hole in M87. Astrophys. J. **582**, 133–140 (2003).

Diaferio, A., A. Nusser, N. Yoshida and R. A. Sunyaev: Superclusters with thermal Sunyaev-Zel'dovich effect surveys. Mon. Not. R. Astron. Soc. **338** 433–442 (2003).

Dominik, C., C.P. Dullemond, L.B. Waters and S. Walch: Understanding the spectra of isolated Herbig stars in the frame of a passive disk model. Astron. Astrophys. **398**, 607–619 (2003).

Dominik, C., C.P. Dullemond, J. Cami and H. van Winckel: The dust disk of HR 4049 - Another brick in the wall. Astron. Astrophys. **397**, 595–609 (2003).

Dullemond, C.P., M.E. van den Ancker, B. Acke and R. van Boekel: Explaining UX Orionis star variability with self-shadowed disks. Astrophys. J. **594**, L47–L50 (2003).

Dullemond, C.P. and A. Natta: The effect of scattering on the structure and SED of protoplanetary disks. Astron. Astrophys. **408**, 161–169 (2003).

Dullemond, C.P. and A. Natta: An analysis of two-layer models for circumstellar disks Astron. Astrophys. **405**, 597–605 (2003).

Durret, F. G.B.L. Neto, W. Forman and E. Churazov: An XMM-Newton view of the extended "filament" near the cluster of galaxies Abell 85. Astron. Astrophys. **403**, L29–L32 (2003).

Enßlin, T.A.: Does circular polarisation reveal the rotation of quasar engines? Astron. Astrophys. **401**, 499–504 (2003).

Enßlin, T.A.: On the escape of cosmic rays from radio galaxy cocoons. Astron. Astrophys. **399**, 409–420 (2003).

Enßlin, T.A. and C.Vogt: The magnetic power spectrum in Faraday rotation screens. Astron. Astrophys. **401**, 835–848 (2003).

Enßlin, T.A., C. Vogt, T.E. Clarke, and G.B. Taylor: Are the Faraday Rotating Magnetic Fields Local to Intracluster Radio Galaxies? Astrophys. J. **597**, 870–877 (2003).

Franx, M., I. Labbe, G. Rudnick et al.: A significant population of red, near-infrared-selected high-redshift galaxies. Astrophys. J. **587**, L79–L82 (2003).

Furlanetto, S., J. Schaye, V. Springel and L. Hernquist: Mapping the Cosmic Web with Lyα Emission. Astrophys. J. **599**, L1–L4 (2003).

Gallino, R., E. Arnone, C. Travaglio et al.: Minute steps on the quest of the s-process. Nuclear Phys. A. **718**, 181C–188C (2003).

Geha, M., C. Alcock, P. Popowski et al.: Variability-selected quasars in MACHO project Magellanic Cloud fields Astron. J. **125**, 1–12 (2003).

Gilfanov, M., M. Revnivtsev and S. Molkov: Boundary layer, accretion disk and X-ray variability in the luminous LMXBs. Astron. Astrophys. **410**, 217–230 (2003).

Grainge, K., P. Carreira, J.A. Rubino-Martin et al.: The cosmic microwave background power spectrum out to l=1400 measured by the Very Small Array. Mon. Not. R. Astron. Soc. **341**, L23–L28 (2003).

Grimm, H.J. M. Gilfanov and R. Sunyaev: High mass X-ray binaries as a SFR indicator. Astron. Nachrichten **324**, 171–171 (2003).

Grimm, H.J. M. Gilfanov and R. Sunyaev: High-mass X-ray binaries as a star formation rate indicator in distant galaxies. Mon. Not. R. Astron. Soc. **339**, 793–809 (2003).

Hamana, T., I. Kayo, N. Yoshida, Y. Suto and Y.P. Jing: Modelling peculiar velocities of dark matter haloes. Mon. Not. R. Astron. Soc. **343**, 1312–1318 (2003).

Heinz, S.: The interaction of relativistic jets with their environment. New Astron. Reviews **47**, 565–567 (2003).

Heinz, S., E. Churazov, W. Forman et al.: Ram pressure stripping and the formation of cold fronts. Mon. Not. R. Astron. Soc. **346**, 13–17 (2003)

Heinz, S and R.A. Sunyaev: The non-linear dependence of flux on black hole mass and accretion rate in core-dominated jets. Mon. Not. R. Astron. Soc. **343**, L59–L64 (2003).

Heinzel, P., U. Anzer and B. Schmieder: A spectroscopic model of EUV filaments. Solar Phys. **216**, 159–171 (2003).

Helmi, A, Z. Ivezic, F. Prada et al.: Selection of metal-poor giant stars using the Sloan Digital Sky Survey photometric system. Astrophys. J. **586**, 195–200 (2003).

Helmi, A., S.D.M. White and V. Springel: The phase-space structure of cold dark matter haloes: insights into the Galactic halo. Mon. Not. R. Astron. Soc. **339**, 834–848 (2003).

Hernquist, L. and V. Springel: An analytical model for the history of cosmic star formation. Mon. Not. R. Astron. Soc. **341**, 1253–1267 (2003).

Hillebrandt, W., J.C. Niemeyer, M. Reinecke, F. Röpke and C. Travaglio: Multidimensional simulations of type Ia supernova explosions and nucleosynthesis. Nuclear Phys. A. **718**, 229C–238C (2003).

Hillebrandt, W., J.C. Niemeyer, M. Reinecke, C. Travaglio: The physics and astrophysics of type Ia supernova explosions. Mem. Soc. Astron. Italiana **74**, 942–948 (2003)

Inogamov, N. A. and R. A. Sunyaev: Turbulence in clusters of galaxies and X-ray line profiles. Astronomy Lett. **29**, 791–824 (2003).

Inoue, S., N.Iwamoto, M. Orito and M. Terasawa: Nucleosynthesis in baryon-rich outflows associated with gamma-ray bursts. Astrophys. J. **595**, 294–303 (2003).

Inoue, S and T.K. Suzuki: Cosmic ray production of Li-6 by structure formation shocks in the early Galaxy. Nuclear Phys. A. **718**, 69C–72C (2003).

Inoue, S., D. Guetta and F. Pacini: Precursor plerionic activity and high-energy gamma-ray emission in the supranova model of gamma-ray bursts. Astrophys. J. **583**, 379–390 (2003).

Janka, H.T., R. Buras and M. Rampp: The mechanism of core-collapse supernovae and the ejection of heavy elements. Nuclear Phys. A. **718**, 269C–276C (2003).

Jensen, P., W.P. Kraemer and P.R. Bunker: Transition moments and NH2 cometary spectra. Mol. Phys. **101**, 613–622 (2003).

Kauffmann, G., T.M. Heckman, S. White et al.: Stellar masses and star formation histories for 10(5) galaxies from the Sloan Digital Sky Survey. Mon. Not. R. Astron. Soc. **341**, 33–53 (2003).

Kauffmann, G., T.M. Heckman, S. White et al.: The dependence of star formation history and internal structure on stellar mass for 10(5) low-redshift galaxies. Mon. Not. R. Astron. Soc. **341**, 54–69 (2003).

Kauffmann, G., T.M. Heckman, S. White et al.: The host galaxies of active galactic nuclei. Mon. Not. R. Astron. Soc. **346**, 1055–1077 (2003).

Kaviani, A., M. Haehnelt and G. Kauffmann: Modelling SCUBA sources in a Lambda CDM cosmology: hot starbursts or cold extended galactic dust? Mon. Not. R. Astron. Soc. **340**, 739–746 (2003).

Keil, M.T., G. Raffelt and H.-T. Janka: Monte Carlo study of supernova neutrino spectra formation. Astrophys. J. **590**, 971–991 (2003).

Keshet, U., E. Waxman, A. Loeb, V. Springel and L. Hernquist: Gamma rays from intergalactic shocks. Astrophys. J. **585**, 128–150 (2003).

Kifonidis, K., T. Plewa, H.-T. Janka and E. Müller: Non-spherical core collapse supernovae - I. Neutrino-driven convection, Rayleigh-Taylor instabilities, and the formation and propagation of metal clumps. Astron. Astrophys. **408**, 621–649 (2003).

Kobayashi, C.: The origin of elliptical galaxies inferred from their metallicity gradients Astrophys. Space Sci. **284**, 853–856 (2003).

Kobayashi, C. and K. Nomoto: Lifetime of Type Ia Supernovae and chemical evolution of Galaxies Nuclear Phys. A. **718**, 680C–682C (2003).

Kong, X.: Empirical population synthesis for 74 blue compact galaxies. Astrophys. Space Sci. **284**, 905–908 (2003).

Kong, X., S. Charlot, A. Weiss and F.Z. Cheng: Spectroscopic study of blue compact galaxies - III. Empirical population synthesis. Astron. Astrophys. **403**, 877–887 (2003).

Kong, X., W.H. Zhang, C. Li, F.Z. Cheng and A. Weiss: A population synthesis study of the galaxy NGC5018. Chinese Astron. and Astrophs. **27**, 28–36 (2003).

Kraft, R.P., E. Vazquez, E. Churazov et al.: X-ray emission from the hot interstellar medium and southwest radio lobe of the nearby radio galaxy Centaurus A. Astrophys. J. **592**, 129–146 (2003).

Kryukov, I.A., N.V. Pogorelov, U. Anzer, G.S. Bisnovatyi-Kogan, and G. Börner: The influence of radiative effects on the accretion onto stellar magnetospheres. Astron. Astrophys. **402**, 13–28 (2003).

Labbé, I., G. Rudnick, M. Franx et al.: Large disklike galaxies at high redshift. Astrophys. J. **591**, L95–L98 (2003).

Labbé, I., G. Rudnick, M. Franx et al.: Ultradeep near-infrared ISAAC observations of the Hubble Deep Field South: Observations, reduction, multicolor catalog, and photometric redshifts. Astron. J. **125**, 1107–1123 (2003).

Langanke, K., G. Martinez-Pinedo, H.-T. Janka et al.: Electron capture rates on nuclei and implications for stellar core collapse Phys. Review Lett. **90** 241102 (4) (2003).

Lin, W.P., Y.P. Jing and L.W. Lin: Formation time-distribution of dark matter haloes: theories versus N-body simulations. Mon. Not. R. Astron. Soc. **344**, 1327–1333 (2003).

Lin, W.P., X. Zhou, X. Kong et al.: H alpha plus [N II] observations of the HII regions in M81. Astron. J. **126**, 1286–1294 (2003).

Lutovinov, A.A and M. Revnivtsev: RXTE observations of X-ray transients IGRJ17091–3624 and IGRJ18539–0727. Astron. Lett. **29**, 719–723 (2003).

Lutovinov, A.A, S. Molkov and M. Revnivtsev: First results observations of transient pulsar SAXJ2103.5+4545 with the INTEGRAL observatory. Astron. Lett. **29**, 713–719 (2003).

Maino, D., A. J. Banday, K. M. Górski, C. Baccigalupi and F. Perrotta: Astrophysical component separation of CPBE-DMR 4-yr data with FastICA. Mon. Not. R. Astron. Soc. **344**, 544–552 (2003).

Malzac, J., T. Belloni, H.C. Spruit and G. Kanbach: The optical and X-ray flickering of XTE J1118+480. Astron. Astrophys. **407**, 335–345 (2003).

Mandal, S., P.K. Mukherjee and G.H.F. Diercksen: Two electrons in a harmonic potential: an approximate analytical solution. J. Phys. B: At. Mol. Opt. Phys. **36**, 4483–4494 (2003)

Marri, S. and S.D.M. White: Smoothed particle hydrodynamics for galaxy-formation simulations: improved treatments of multiphase gas, of star formation and of supernovae feedback. Mon. Not. R. Astron. Soc. **345**, 561–574 (2003).

Maselli, A., A. Ferrara and B. Ciardi: CRASH: a radiative transfer scheme. Mon. Not. R. Astron. Soc. **345**, 379–394 (2003).

Mashonkina, L., T. Gehren, C. Travaglio and T. Borkova: Mg, Ba and Eu abundances in thick disk and halo stars. Astron. Astrophys. **397**, 275–284 (2003).

McConnachie, A.W., J.J.,Irwin, R.A. Ibata, A. Ferguson et al.: The three-dimensional structure of the giant stellar stream in Andromeda. Mon. Not. R. Astron. Soc. **343**, 1335–1340 (2003).

Ménard, B. and C. Peroux: Investigating lensing by absorbers in the 2dF-quasar survey Astron. Astrophys. **410**, 33–46 (2003).

Ménard, B., T. Hamana, M. Bartelmann and N. Yoshida: Improving the accuracy of cosmic magnification statistics. Astron. Astrophys. **403**, 817–828 (2003).

Ménard, B., M. Bartelmann and Y. Mellier: Measuring Ω_0 with higher-order quasar-galaxy correlations induced by weak lensing. Astron. Astrophys. **409**, 411–421 (2003).

Meneghetti, M., M. Bartelmann and L. Moscardini: Cluster cross-sections for strong lensing: analytic and numerical lens models. Mon. Not. R. Astron. Soc. **340**, 105–114 (2003)

Merloni, A. and A.C. Fabian: Iron K alpha line profiles and the inner boundary condition of accretion flows. Mon. Not. R. Astron. Soc. **342**, 951–961 (2003).

Merloni, A.: Beyond the standard accretion disc model: coupled magnetic disc-corona solutions with a physically motivated viscosity law Mon. Not. R. Astron. Soc. **341**, 1051–1056 (2003).

Merloni, A., Heinz, S. and di Matteo, T.: A Fundamental Plane of black hole activity. Mon. Not. R. Astron. Soc. **345**, 1057–1076 (2003).

Meyer-Hofmeister, E. and F. Meyer: The formation of the coronal flow/ADAF. Astron. Astrophys. **402**, 1013–1019 (2003).

Miller, J.M., H.L. Marshall, R. Wijnands, T. Di Matteo et al.: Chandra and RXTE spectroscopy of the Galactic microquasar XTE J1550-564 in outburst. Mon. Not. R. Astron. Soc. **338**, 7–13 (2003).

Miniati, F.: Numerical modelling of gamma radiation from galaxy clusters. Mon. Not. R. Astron. Soc. **342**, 1009–1020 (2003).

Mrugala, F, V. Spirko and W. Kraemer: Radiative association of HeH2+. J. Chem. Phys. **118**, 10547–10560 (2003).

Mukherjee, P., A. J. Banday, A. Riazuelo, K. M. Górski and B. Ratra: COBE-DMR-Normalized Dark Energy Cosmogony. Astrophys. J. **598**, 767–778 (2003).

Mukherjee, P, T. Souradeep, B. Ratra, N. Sugiyama and K.M. Gorski: OVRO CMB anisotropy measurement constraints on flat-Lambda and open CDM cosmogonies. Modern Phsy. Lett. A. **18**, 1145 – 1155 (2003).

Munshi, D. and Coles, P. Error estimates for measurements of cosmic shear. Mon. Not. R. Astron. Soc. **338**, 846–856 (2003).

Nadyozhin, D.K.: Explosion energies, nickel masses and distances of Type II plateau supernovae. Mon. Not. R. Astron. Soc. **346**, 97–104 (2003).

Nayakshin, S and R. Sunyaev: Close stars and an inactive accretion disc in Sgr A*: eclipses and flares. Mon. Not. R. Astron. Soc. **343**, L15–L19 (2003).

Ohno, H., M. Takada, K. Dolag, M. Bartelmann and N. Sugiyama: Probing Intracluster Magnetic Fields with Cosmic Microwave Background Polarization. Astrophys. J. **584**, 599–607 (2003).

Osaki, Y. and F. Meyer: Is evidence for enhanced mass transfer during dwarf-nova outbursts well substantiated? Astron. Astrophys. **401**, 325–337 (2003).

Pascucci, I. D. Apai, T. Henning and C. P. Dullemond: The first detailed look at a brown dwarf disk. Astrophys. J. **590**, L111–L114 (2003).

Perrotta, F., M. Magliocchetti, C. Baccigalupi, M. Bartelmann et al.: Predictions for statistical properties of forming spheroidal galaxies. Mon. Not. R. Astron. Soc. **338**, 623–636 (2003)

Pfrommer, C. and T.A. Enßlin: Probing the cosmic ray population of the giant elliptical galaxy M 87 with observed TeV gamma-rays. Astron. Astrophys. **407**, L73–L77 (2003).

Pierini, D. and C. S. Möller: Dust emission in the far-infrared as a star formation tracer at z= 0: systematic trends with luminosity. Mon. Not. R. Astron. Soc. **346**, 818–824 (2003).

Popowski, P., K.H. Cook and A.C. Becker: Large-Scale Extinction Map of the Galactic Bulge from the MACHO Project Photometry. Astron. J. **126**, 2910–2921 (2003).

Power, C., S.D.M. White, V. Springel et al.: The inner structure of Lambda CDM haloes - I. A numerical convergence study. Mon. Not. R. Astron. Soc. **338**, 14–34 (2003).

Reifarth, R., C. Arlandini, C. Travaglio et al.: Stellar neutron capture on promethium: Implications for the s-process neutron density. Astrophys. J. **582**, 1251–1262 (2003).

Revnivtsev, M.: Distribution of the Galactic bulge emission at vertical bar b vertical bar > 2 degrees according to the RXTE Galactic Center scans. Astron. Astrophys. **399**, 699–702 (2003).

Revnivtsev, M.: RXTE observations of the strongly absorbed sources IGR J16318-4848 and IGR J16358-4726. Astron. Lett. A. J. of Astron. and Space Sci. **29**, 644–648 (2003).

Revnivtsev, M.: A weak outburst of the millisecond X-ray pulsar SAX J1808.4-3658 in October 1996 as detected from RXTE slew data. Astron. Lett. A. J. of Astron. and Space Sci. **29**, 383–386 (2003).

Revnivtsev, M. and R. Sunyaev: A possible 38 day X-ray period of KS 1731-260. Astron. Astrophys. **399**, 699–702 (2003).

Revnivtsev, M., M. Gilfanov, R. Sunyaev, K. Jahoda and C. Markwardt: The spectrum of the cosmic X-ray background observed by RTXE/PCA. Astron. Astrophys. **411**, 329–334 (2003).

Revnivtsev, M.G., S.Y. Sazonov, M.R. Gilfanov and R.A. Sunyaev: IGR J16318-4848: An X-ray source in a dense envelope? Astron. Lett. A. J. of Astron. and Space Sci. **29**, 587–593 (2003).

Ritter, H. and U. Kolb: Catalogue of cataclysmic binaries, low-mass X-ray binaries and related objects (Seventh edition). Astron. Astrophys. **404**, 301–303 (2003).

Röpke, F.K., J.C. Niemeyer and W. Hillebrandt: On the small-scale stability of thermonuclear flames in Type Ia supernovae Astrophys. J. **588**, 952–961 (2003).

Rubino-Martin, J.A. and R.A. Sunyaev: Discriminating between unresolved point sources and 'negative' Sunyaev-Zel'dovich clusters in cosmic microwave background maps. Mon. Not. R. Astron. Soc. **344**, 1155–1174 (2003).

Rudnick, G., Rix, H.-W., Franx, M. et al.: The Rest-Frame Optical Luminosity Density, Color, and Stellar Mass Density of the Universe from z=0 to z=3. Astrophys. J. **599**, 847-864 (2003).

Rudnick, G., S. White, A. Arago‘n-Salamanca et al.: Studying high redshift galaxy clusters with the ESO Distant Cluster Survey. The Messenger, **112**, 19–24 (2003).

Sako, T. and G.H.F. Diercksen: Confined quantum systems: dipole polarizability of the two-electron quantum dot, the hydrogen negative ion and the helium atom. J. Phys. B. Atomic Mol. and Optical Phys. **36**, 3743–3759 (2003).

Sako, T. and G.H.F. Diercksen: Confined quantum systems: spectral properties of two-electron quantum dots. J. of Phys. Cond. Matter **15**, 5487–5509 (2003).

Sako, T. and G.H.F. Diercksen: Confined quantum systems: spectral properties of the atoms helium and lithium in a power series potential. J. Phys. B. Atomic Mol. and Optical Phys. **36**, 1433–1457 (2003).

Sako, T. and G.H.F. Diercksen: Confined quantum systems: a comparison of the spectral properties of the two-electron quantum dot, the negative hydrogen ion and the helium atom. J. Phys. B. Atomic Mol. and Optical Phys. **36**, 1681–1702 (2003).

Sazonov, S.Y. and R.A. Sunyaev: Observing scattered X-ray radiation from gamma-ray bursts: A way to measure their collimation angles. Astron. Astrophys. **399**, 505–509 (2003).

Schäfer, B.M. and N. Kawai: A Fourier-based algorithm for modelling aberrations in HETE-2's imaging system. Nucl. Instr. and Methods Phys. Res. Section. A. **500**, 263–271 (2003).

Schirmer, M., T. Erben, P. Schneider et al.: GaBoDS: The Garching-Bonn Deep Survey - I. Anatomy of galaxy clusters in the background of NGC 300. Astron. Astrophys. **407**, 869–888 (2003).

Schneider, P. and M. Lombardi: The three-point correlation function of cosmic shear - I. The natural components Astron. Astrophys. **397**, 809–818 (2003).

Schwope, A.D., H.C. Thomas, K.H. Mantel, R. Haefner and A. Staude: Cyclotron spectroscopy of HU Aquarii Astron. Astrophys. **402**, 201–209 (2003).

Shen, S.Y., H.J. Mo, S. White et al.: The size distribution of galaxies in the Sloan Digital Sky Survey. Mon. Not. R. Astron. Soc. **343**, 978–994 (2003).

Siebel, F., J.A. Font, E. Müller and P. Papadopoulos: Axisymmetric core collapse simulations using characteristic numerical relativity. Phys. Rev. D. **67**, 124018-16 (2003).

Sigl, G., F. Miniati and T.A. Enßlin: Ultrahigh energy cosmic rays in a structured and magnetized universe. Phys. Rev. D. **68**, 043002-10 (2003).

Šindelka, M., V. Špirko and W.P. Kraemer: Vibrational linestrengths for the ground and first excited electronic states of HeH_2^+. Theor. Chem. Acc. **110**, 170 – 175 (2003).

Smith, R.E., J.A. Peacock, A. Jenkins, S. White et al. Stable clustering, the halo model and non-linear cosmological power spectra. Mon. Not. R. Astron. Soc. **341**, 1311–1332 (2003).

Sokasian, A., T. Abel, L. Hernquist and V. Springel: Cosmic reionization by stellar sources: Population II stars. Mon. Not. R. Astron. Soc. **344**, 607–624 (2003).

Springel, V. and L. Hernquist: Cosmological smoothed particle hydrodynamics simulations: a hybrid multiphase model for star formation. Mon. Not. R. Astron. Soc. **339**, 289–311 (2003).

Springel, V. and L. Hernquist: The history of star formation in a Lambda cold dark matter universe. Mon. Not. R. Astron. Soc. **339**, 312–334 (2003).

Spruit, H.C.: Origin of the torsional oscillation pattern of solar rotation. Solar Phys. **213**, 1–21 (2003).

Stoehr, F., S.D.M. White, V. Springel, G. Tormen and N. Yoshida: Dark matter annihilation in the halo of the Milky Way. Mon. Not. R. Astron. Soc. **345**, 1313–1322 (2003).

Suleimanov, V., F. Meyer and E. Meyer-Hofmeister: High efficiency of soft X-ray radiation reprocessing in supersoft X-ray sources due to multiple scattering Astron. Astrophys. **401**, 1009–1015 (2003).

Sunyaev, R. A., M.L. Norman and G.L. Bryan: On the Detectability of Turbulence and Bulk Flows in X-ray Clusters. Astron. Lett.. **29**, 783–790 (2003).

Swaters, R.A., B.F. Madore, F.C. van den Bosch and M. Balcells: The central mass distribution in dwarf and low surface brightness galaxies Astrophys. J. **583**, 732–751 (2003).

Terekhov, O.V., A.G. Kuzmin, S.Y. Sazonov et al. Localization of the solar flare SF900610 in X-rays with the WATCH instrument of the GRANAT observatory. Astron. Lett. A. J. of Astron. and Space Sci. **28**, 853–856 (2003).

Tornatore, L., S. Borgani, V. Springel et al.: Cooling and heating the intracluster medium in hydrodynamical simulations. Mon. Not. R. Astron. Soc. **342**, 1025–1040 (2003).

Tremonti, C. A., T. Heckman, G. Kauffmann et al.: The Stellar Mass, Metallicity, and AGN content of SDSS Galaxies as a Function of Local Environment. American Astr. Soc. **202** 5102– (2003).

Tuüllmann, R., M. R. Rosa, A. Ferguson et al: Star formation in gaseous galaxy halos. VLT spectroscopy of extraplanar HII-regions in NGC 55. Astron. Astrophys. **412**, 69–80 (2003).

van Bemmel, I. M. and C.P. Dullemond: New radiative transfer models for obscuring tori in active galaxies. Astron. Astrophys. **404**, 1-19 (2003).

van Boekel, R., L.B. Waters, C.P. Dullemond et al.: Grain growth in the inner regions of Herbig Ae/Be star disks. Astron. Astrophys. **400**, L21–L24 (2003).

van den Bosch, F. C., T. Abel and L. Hernquist: The angular momentum of gas in protogalaxies - II. The impact of pre-heating. Mon. Not. R. Astron. Soc. **346**, 177–185 (2003).

van den Bosch, F.C., H.H. Mo and X.H. Yang: Towards cosmological concordance on galactic scales. Mon. Not. R. Astron. Soc. **345**, 923–938 (2003).

van den Bosch, F.C., H.H. Mo and X.H. Yang: Linking early- and late-type galaxies to their dark matter haloes. Mon. Not. R. Astron. Soc. **340**, 771–792 (2003).

van Dokkum, P.G., N.M. Schreiber, G. Rudnick et al.: Spectroscopic confirmation of a substantial population of luminous red galaxies at redshifts z greater than or similar to 2. Astrophys. J. **587**, L83–L87 (2003).

Vogt, C. and T.A. Enßlin: Measuring the cluster magnetic field power spectra from Faraday rotation maps of Abell 400, Abell 2634 and Hydra A Astron. Astrophys. **412**, 373–385 (2003).

Wandelt, B.D., F.K. Hansen: Fast, exact CMB power spectrum estimation for a certain class of observational strategies. Phys. Rev. D. **67**, 023001-9 (2003).

Winkler, C., S. Grebenev, R. Sunyaev et al.: The INTEGRAL mission. Astron. Astrophys. **411**, L1–L6 (2003).

Xu, K., Z. Wen-haoa, L. Chenga, C. Fu-zhen and A. Weiss: A population synthesis study of the galaxy NGC5018. Chinese Astron. and Astrophys. **27**, 28–36 (2003).

Yamamoto, K.: Optimal Weighting Scheme in Redshift-space Power Spectrum Analysis and Prospect for Measuring the Cosmic Equation of State. Astrophys. J. **595**, 577–588 (2003).

Yamamoto, K.: Measuring cosmological parameters with the SDSS QSO spatial power spectrum analysis to test the cosmological principle. Mon. Not. R. Astron. Soc. **341**, 1199-1204 (2003).

Yang, X.H., H.J. Mo, G. Kauffmann and Y.Q. Chu: Understanding the results of galaxy-galaxy lensing using galaxy-mass correlation in numerical simulations. Mon. Not. R. Astron. Soc. **339**, 387–396 (2003).

Yang, X. , H. J. Mo and F. C. van den Bosch: Constraining galaxy formation and cosmology with the conditional luminosity function of galaxies. Mon. Not. R. Astron. Soc. **399**, 1057–1080 (2003).

Yoshida, N., A. Sokasian, L. Hernquist and V. Springel: Early structure formation and reionization in a warm dark matter cosmology. Astrophys. J. **591**, L1–L4 (2003).

Yoshida, N., A. Sokasian, L. Hernquist and V. Springel: Early Structure Formation and Reionization in a Cosmological Model with a Running Primordial Power Spectrum. Astrophys. J. **598**, 73–85 (2003).

Yoshikawa, K., Y.P. Jing and G. Börner: Spatial and dynamical biases in velocity statistics of galaxies. Astrophys. J. **590**, 654–663 (2003).

Zahn, O. and M. Zaldarriaga: Probing the Friedmann equation during recombination with future cosmic microwave background experiments. Phys. Rev. D. **67**, 063002-11 (2003).

Zdziarski, A.A., P. Lubinski, M. Gilfanov and M. Revnivtsev: Correlations between X-ray and radio spectral properties of accreting black holes. Mon. Not. R. Astron. Soc. **342**, 355–372 (2003).

Zhao, D.H., Y.P. Jing, H.J. Mo and G. Börner: Mass and redshift dependence of dark halo structure. Astrophys. J. **597**, 9–12 (2003).

Zhao, D.H., Y.P. Jing, H.J. Mo and G. Börner: The growth and structure of dark matter haloes. Mon. Not. R. Astron. Soc. **339**, 12–24 (2003).

Zhao, D. H., Y. P. Jing and G. Börner: Mass and redshift dependence of dark halo structure. Astrophysical J. **581**, 876–885 (2003).

4.1.2 Publications accepted in 2003

Alcock, C., D. Alves, P. Popowski et al.: The MACHO Project Large Magellanic Cloud Variable Star Inventory. XIII. Fourier Parameters for the First Overtone RR Lyrae Variables and the LMC Distance. Astron. J.

Aloy, M.A., J.Mª., Martí, and J.Mª. Ibáñez: Numerical Simulations of Relativistic Jets. Boletín de la Sociedad Española de Astronomía.

Arp, H., E. M. Burbidge and G.R. Burbidge: The double radio source 3C343.1: A galaxy-QSO pair with very different redshifts. Astron. Astrophys.

Barton, E.J., R. Dave, J.D.T. Smith, C. Papovich, L. Hernquist and V. Springel: Searching for Star Formation Beyond Reionization. Astrophys. J.

Basu, K., C.Hernandez-Monteagudo and R.A.Sunyaev: CMB Observations and the Production of Chemical Elements at the End of the Dark Ages. Astron. Astrophys.

Benetti, S., P. Meikle, M. Stehle et al.: Supernova 2002bo: inadequacy of the single parameter description. Mon. Not. R. Astron. Soc.

Bicker, J., Fritze-v. Alvensleben, U., Möller, C.S. and Fricke, K.J.: Chemically consistent evolution of galaxies: II. Spectrophotometric evolution from zero to high redshift. Astron. Astrophys.

Boehm, C., T.A. Enßlin and J. Silk: Can annihilating Dark Matter be lighter than a few GeV? Journal of Physics G: Nuclear and Particle Physics.

Borgani, S., G. Murante, V. Springel et al.: X-ray properties of galaxy clusters and groups from a cosmological hydrodynamical simulation. Mon. Not. R. Astron. Soc.

Churazov, E., W. Forman, C. Jones, R. Sunyaev and H. Böhringer: XMM-Newton observations of the Perseus Cluster. II. The temperature and surface brightness structure. Mon. Not. R. Astron. Soc.

Civiš, S., J. Šebera, V. Špirko, J. Fišer, W.P. Kraemer and K. Kawaguchi: New rotation-vibration band and potential energy function of NeH^+ in the ground electronic state. J. Molec. Spectrosc.

De Lucia, G., G. Kauffmann, V. Springel et al.: Substructures in Cold Dark Matter Haloes. Mon. Not. R. Astron. Soc.

De Lucia, G., G. Kauffmann and S. White: Chemical enrichment of the intra-cluster and intergalactic medium in a hierarchical merger model. Mon. Not. R. Astron. Soc.

Denissenkov, P. and A. Weiss: Globular Cluster Archaeology: Nucleosynthesis and Extra Mixing in Extinct Stars. Astrophys. J.

Dewangan G.C., R. Griffiths, T. Di Matteo and N. Schurch: Iron Kα emission from the low-luminosity Active Galaxies M81 and NGC 4579, Astrophys. J.

Di Matteo T., R. Croft, V. Springel and L. Hernquist: The cosmological evolution of metal enrichment in quasar host galaxies. Astrophys. J.

Dolag, K., M. Bartelmann, F. Perrotta et al.: Numerical study of halo concentrations in dark-energy cosmologies. Astron. Astrophys.

Eriksen, H. K., F. K. Hansen, A. J. Banday, K. M. Górski and P. B. Lilje: Asymmetries in the CMB anisotropy field. Astrophys. J.

Eriksen, H. K., P. B. Lilje, A. J. Banday and K. M. Górski: Estimating N-Point Correlation Functions from Pixelized Sky Maps. Astrophys. J. Suppl. Ser.

Finoguenov, A., W. Pietsch, B. Aschenbach and F. Miniati: XMM-Newton Witness of M86 X-ray metamorphosis. Astron. Astrophys.

Furlanetto, S., J. Schaye, V. Springel and L. Hernquist: Ultraviolet Line Emission from Metals in the Low-Redshift Intergalactic Medium. Astrophys. J.

Gilfanov, M., H.J. Grimm and R. Sunyaev: Lx–SFR relation in star forming galaxies. Mon. Not. R. Astron. Soc.

Gilfanov, M.: Low mass X-ray binaries as a stellar mass indicator for the host galaxy. Mon. Not. R. Astron. Soc.

Hernández-Monteagudo, C. and J. A.Rubiño-Martín: On the Presence of Thermal SZ Induced Signal in First Year WMAP Temperature Maps. Mon. Not. R. Astron. Soc.

Hernández-Monteagudo, C., Kashlinsky, A. and F. Atrio-Barandela: Using peak distribution of the cosmic microwave background for WMAP and Planck data analysis: formalism and simulations. Astron. Astrophys.

Inoue, S.: Probing the cosmic reionization history and local environment of gamma-ray bursts through radio dispersion. Mon. Not. R. Astron. Soc.

Kentaro, N., V. Springel and L. Hernquist: Abundance of damped Lyman-alpha absorbers in cosmological SPH simulations. Mon. Not. R. Astron. Soc.

Kentaro, N., V. Springel and L. Hernquist: Star formation rate and metallicity of damped Lyman-alpha absorbers in cosmological SPH simulations. Mon. Not. R. Astron. Soc.

Kobayashi, C.: GRAPE-SPH Chemodynamical Simulation of Elliptical Galaxies I: Evolution of Metallicity Gradients. Mon. Not. R. Astron. Soc.

Kong, X., S. Charlot, J. Brinchmann and S.M. Fall: Star formation history and dust attenuation in galaxies drawn from ultraviolet surveys. Mon. Not. R. Astron. Soc.

Kraemer W. and V. Špirko: Bound and low-lying quasibound rotation-vibration levels of the ground electronic state of LiH_2^+. J. Chem. Phys.

Krisciunas K., M., Phillips, M. Stritzinger et al.: Optical and infrared photometry of the nearby Type Ia supernova 1999ee, 2000bh, and 2001ba. Astron. J.

Lutovinov, A. A., S.S. Tsygankov, S. Grebenev, R. Sunyaev et al.: Two Years of Observations of the X-ray Pulsar SMC X-1 with the ART-P Telescope onboard the Granat Observatory. Astron. Lett.

Meneghetti, M., M. Bartelmann and L. Moscardini: CD Galaxy Contribution to the Strong Lensing Cross Sections of Galaxy Clusters. Mon. Not. R. Astron. Soc.

Miniati, F., A. Ferrara, S. White and S. Bianchi: Ultraviolet Background Radiation from Cosmic Structure Formation. Mon. Not. R. Astron. Soc.

Müller, E., M. Rampp, R. Buras, H.-Th. Janka and D.H. Shoemaker: Towards gravitational wave signals from realistic core collapse supernova models. Astrophys. J.

Navarro, J.F., E. Hayashi, S.D.M. White, V. Springel et al.: The Inner Structure of LCDM Halos III: Universality and Asymptotic Slopes. Mon. Not. R. Astron. Soc.

Nayakshin, S., J. Cuadra and R.A. Sunyaev: X-ray flares from Sgr A*: star-disk interactions? Astron. Astrophys.

Pfrommer, C. and T.A. Enßlin: Constraining the Population of Cosmic Ray Protons in Cooling Flow Clusters with Gamma-Ray and Radio Observations: Are Radio Mini-Halos of Hadronic Origin? Astron. Astrophys.

Popowski, P. and W. Weinzierl: A Test for the Origin of Quasar Redshifts. Mon. Not. R. Astron. Soc.

Rocha, G., L. Cayón, J. Banday et al.: Topology of the universe from COBE-DMR; a wavelet approach. Mon. Not. R. Astron. Soc.

Salaris, M., A. Weiss and S.M. Percival: The age of the oldest Open Cluster. Astron. Astrophys.

Salaris, M., M. Riello, S. Cassisi and G. Piotto: The Initial Helium Abundance of the Galactic Globular Cluster System. Astron. Astrophys.

Sazonov, S.Yu., Ostriker, J.P. and R.A. Sunyaev: Quasars: the characteristic spectrum and the induced radiative heating. Mon. Not. R. Astron. Soc.

Scheck, L., T. Plewa, H.-Th. Janka, K. Kifonidis and E. Müller: Pulsar recoil by large-scale anisotropies in supernova explosions. Phys. Rev. Lett.

Torri, E., M. Meneghetti, M. Bartelmann et al.: The impact of cluster mergers on arc statistics. Mon. Not. R. Astron. Soc.

Travaglio, C., R. Gallino, E. Arnone et al.: Galactic evolution of Sr, Y, Zr: a multiplicity of stellar neutron capture components. Astrophys. J.

Travaglio, C., K. Kifonidis and E. Müller: Multi-dimensional nucleosynthesis in SNII. New Astronomy Reviews.

Viel, M., S. Matarrese, A. Heavens, M.G. Haehnelt, T.-S. Kim, V. Springel and L. Hernquist: The bispectrum of the Lyman-alpha forest at z 2-2.4 from a Large sample of UVES QSO Absorption Spectra (LUQAS). Mon. Not. R. Astron. Soc.

Yurchenko, S. N., P.R. Bunker, W.P. Kraemer and P. Jensen: The spectrum of singlet SiH_2. Canad. J. Chem.

Zibetti, S., S. White and J. Brinchmann: Haloes around edge-on disc galaxies in the Sloan Digital Sky Survey. Mon. Not. R. Astron. Soc.

4.2 Publications in proceedings and monographs

4.2.1 Publications in proceedings that appeared in 2003

Alencar, S. H. P. , L. Alencar, C. Dullemond et al.: The pre-main sequence spectroscopic binary AK SCO. In: Open issues in local star formation , (Eds.) Lépine, Jacques; Gregorio-Hetem, Jane Astrophysics and space science library 299, Kluwer Academic Publishers, Dordrecht 2003, 107–114.

Aloy, M.A., Martí, J.Mª., Gómez, J.L., Agudo, I., Müller, E. and Ibáñez J.Mª.: Simulations of precessing jets. In: Highlights of Spanish Astrophysics III Proc. V Scientific Meeting of the Spanish Astronomy Society, Toledo, 2002. Eds. J. Zamorano, J. Gorgas, J. Gallego. Kluwer Academic Publishers 2003, 23–26.

Arnone, E., C. Travaglio, R. Gallino and O. Straniero: Galactic chemical contribution to CNO and Ne isotopes by AGB stars. In: CNO in the Universe. Eds. C. Charbonnel, D. Schaerer and G. Meynet. ASP Conf. Ser., Vol. 304, p. 327–329

Balastegui, A., P. Ruiz-Lapuente and R. Canal: Measuring O?, O? and the SFR with class III GRBs. In: Gamma-ray burst and afterglow astronomy 2001 . A Workshop celebrating the first year of the HETE Mission , (Eds.) Ricker, G.R. and R.K. Vanderspek. AIP Conference Proceedings 662, American Institute of Physics, Melville 2003, 438–445.

Bartelmann, M., K. Dolag and H. Lesch: The evolution of magnetic fields in galaxy clusters. In: Astrophysical supercomputing using particle simulations Proc. IAU Symposium 208, Tokyo, 10-13 July 2001. Eds. Makino, J. and P. Hut ASP, 2003, 189–198.

Bartelmann, M.: Strong and weak lensing by galaxy clusters. In: Matter and energy in clusters of galaxies. Proc. conf. at National Central University, Chung-Li, Taiwan, 23-27 April 2002. Eds. Bowyer, S. and Hwang, C.-Y. ASP Conference Series Volume 301, 2003, 255–270.

Börner, G., Y.P. Jing, K. Yoshikawa. The Low Relative Velocities of Late-Type Galaxies and Galaxy Bias. In: The Formation, Evolution and Large Scale Distribution of Galaxies Proc. Fifth China-Germany Workshop on Cosmolgy and Galaxy Formation, Beijing, September 15-22, 2002. Eds.: Jing, Y.P., Deng, Z.G., Börner, G. Progress in Astronomy, 21 (Suppl.), 7–17.

Burkert, A. , F. C. van den Bosch and R. A. Swaters: The origin of the correlation between the spin parameter and the Baryon fraction of galactic disks. In: The mass of galaxies at low and high redshift: Proceedings of the ESO/USM München Workshop, Eds. Bender, R.; Renzini, A. ESO astrophysics symposia , Springer, Berlin 2003, 119-123.

Chen, D. and Y. Jing: The Angular Momentum Distribution within Dark Matter Halos. In: The Proceedings of the IAU 8th Asian-Pacific Regional Meeting, Volume II, held at National Center of Sciences, Hitotsubashi Memorial Hall, Tokyo, July 2 - 5, 2002, (Eds.:) by S. Ikeuchi, J. Hearnshaw, and T. Hanawa. The Astronomical Society of Japan, ASP Conference Series, Vol. 289, 2003, p. 247-248.

Churazov, E.: Quasi-stationary cooling flows with small mass deposition. In: Matter and energy in cluster of galaxies, Eds. Bowyer, Stuart; Hwang, Chorng-Yuan Astronomical Society of the Pacific Conference Series 301, Astronomic al Society of the Pacific, San Francisco, CA (US) 2003, 295-404.

De Lucia, G., G. Kauffmann and S.D.M. White: Evolution of galaxies in clusters: semi-analytic models and observations In: Multiwavelength Cosmology, Mykonos Conference Proceedings. (Eds.: Manolis and Plionis) in press

Di Matteo, T , W. Allen , A. C. Fabian and A. S. Wilson: Low-luminosity black holes: The case of M87. In: Active galactic nuclei : From central engine to host galaxy290, , Eds. Collin, S.; Combes, F.; Shlosman, I. Astronomical Society of the Pacific Conference Series , Astronomical Society of the Pacific, Vol. 290, San Fransisco 2003, 391-392.

Di Matteo T., R. Croft, V. Springel and L. Hernquist: The cosmological evolution of quasars and their enviroments, In: AGN Physics with the Sloan Digital Sky Survery, Princeton, USA, 27-30 July 2003, Proc. Astronomical Society of the Pacific Conference Series Eds. G.T.Richard and P.B. Hall, in press

Dolag, K.: Modeling magnetic fields in galaxy clusters. In: Matter and energy in cluster of galaxies, Eds. Bowyer, Stuart; Hwang, Chorng-Yuan Astronomical Society of the Pacific Conference Series 301, Astronomical Society of the Pacific, San Francisco, CA (US) 2003, 193-200.

Dominik, C. , C. P. Dullemond , L.B. Waters and A. Natta: Models of passive disks with inner holes : evidence for disks around intermediate mass pre-main-sequence stars. In: Galactic star formation across the stellar mass spectrum, Eds. De Buizer, J.M.; van der Bliek, N. S. Astronomical Society of the Pacific Conference Series 287, Astronomical Society of the Pacific, San Franscisco 2003, 313-318.

Enßlin, T. A.: The fate of intracluster radio plasma. In: Matter and energy in cluster of galaxies, Eds. Bowyer, Stuart; Hwang, Chorng-Yuan Astronomical Society of the Pacific Conference Series 301, Astronomical Society of the Pacific, San Francisco, CA (US) 2003, 159-166.

Enßlin, T. A.: Is the long-term persistency of circular polarisation due to the constant helicity of the magnetic fields in rotatinng quasar engines?. In: Astrophysics and Space Science, 288, 1-2, (Eds.) Fender, R. and J.P. Macquart, (2003) 183–191.

Girardi, L., G. Bertelli, A. Weiss et al.: Theoretical isochrones in several photometric systems. In: Proceedings of the XLVI Congresso Nazionale della Società Astronomica Italiana. Eds.: Corsini, E.M. and Barbieri, C., Mem. Soc. Astr. Italiana, vol. 74, 2003, 474–475.

Górski, K. M., A. J. Banday, E. Hivon and B. D. Wandelt: HEALPix – a Framework for High Resolution, Fast Analysis on the Sphere. In: Astronomical Data Analysis Software and Systems XI, ASP Conference Proceedings, Vol. 281. Eds. D. A. Bohlender, D. Durand and T. H. Handley. Astronomical Society of the Pacific, San Francisco, 2002, 107–111.

Heckman, T. M. and G. Kauffmann: The host galxies of 26,000 AGN. In: Star formation through time : A conference to honur Roberto J. Terlevich, Eds. Pérez, Enrique; González Delgado; Rosa M.; Tenorio-Tagle, Guillermo Astronomical Society of the Pacific Conference Series 297, Astronomical Society of the Pacific, San Fransisco 2003, 341-343.

Heinz, S. and R. Sunyaev: Cosmic rays from micrrquasars. In: New View on microquasars : Proceedings of the fourth microquasar workshop, Eds. Durouchoux, Philippe; Fuchs, Yaël; Rodriguez, Jérôme , Center for space physics, Kolkata, Indien 2003, 140-143.

Heinzel, P., U. Anzer, B. Schmieder and P. Schwartz: EUV-filaments and their mass loading. In: Solar Variability as an Input to the Earth's Environment, Ed. Wilson, A. ESA SP-535 , ESA Publications Division, ESTEC, Noordwijk, The Netherlands 2003, 447-457.

Heinzel, P. and U. Anzer: 2D radiative transfer in magnetically confined structures. In: Stellar atmosphere modeling, Eds. Hubeny, Ivan; Mihalas, Dimitri Astronomical Society of the Pacific Conference Series 288, Astronomical Society of the Pacific, San Franscisco 2003, 441-444.

Helmi, A.: The phase-space struture of CDM halos and dark-matter direct detection experiments. In: Galaxy evolution: theory and observationsn 17, Eds. Avila-Reese, Vladimir; Firmani, Claudio; Frenk, Carlos S.; Allen, Christine Revista mexicana de astronomia y astrofisica: Serie de conferencias , UNAM, Mexico, DF(MEX) 2003, 24-25.

Janka, H.-T. , R. Buras , K. Kifonidis , T. Plewa and M. Rampp: Core collapse and then? The route to massive star explosions. In: From twilight to highlight: The physics of Supernovae / Proceedings of the ESO/MPA/MPE Workshop, Eds. Hillebrandt, W. and B. Leibundgut, ESO Astrophysics Symposia , Springer, Berlin 2003, 39-52.

Jing, Y. P.: An ellipsoid model for the halo density profile. In: The proceeding of the IAU 8th Asian-Pacific regional meeting Volume I, Eds. S. Ikeuchi, J. Hearnshawa and T. Hanawa. Astronomical Society of the Pacific Conference Series 289, Astronomical Society of the Pacific, San Fransisco 2003, 259-262.

Kauffmann, G.: Perspectives on galaxy formation. In: Star formation through time : A conference to honur Roberto J. Terlevich, Eds. E. Pérez, D. González, M. Rosa, G. Tenorio-Tagle. Astronomical Society of the Pacific Conference Series 297, San Fransisco 2003, 439-445.

Keil, M. T. , G. G. Raffelt and H.-Th. Janka: Supernova neutrino spectra formation. In: Nuclear physics B. Proceedings supplements, 118, Eds. F. von Feilitzsch and N. Schmitz. 2003, 506-506.

Kleinheinrich, M. , T. Erben , K. Meisenheimer , H.-W. Rix , M. Schirmer , P. Schneider and C. Wolf: The relativity of shape measurements. In: Galaxy evolution: theory and observationsn17, , Eds. V. Avila-Reese, C. Firmani, C. Frenk, C. Allen. Revista mexicana de astronomia y astrofisica: Serie de conferencias , UNAM, Mexico, DF(MEX) 2003, 36-36.

Kobayashi, C. and K. Nomoto: Type Ia supernova progenitors lifetime, and cosmic supernova rate. In: From twilight to highlight: The physics of Supernovae / Proceedings of the ESO/MPA/MPE Workshop, Eds. Hillebrandt, W. and B. Leibundgut, ESO Astrophysics Symposia , Springer, Berlin 2003, 379-383.

Labbé, I., Franx, M., Rudnick, G. et al.: Ultradeep near-infrared imaging of the HDF-South: rest-frame optical properties of high redshift galaxies. In: Discoveries and Research Prospects from 6- to 10-Meter-Class Telescopes II. Ed. P. Guhathakurta. Proceedings of the SPIE, Volume 4834, 195–202.

Labbé, I., Franx, M., Rudnick, G. et al.: Ultradeep Near-Infrared ISAAC Observations of the Hubble Deep Field South: Selecting High-Redshift Galaxies in the Rest-Frame Optical. In: The Mass of Galaxies at Low and High Redshift. Proceedings of the ESO Workshop held in Venice, Italy, 24-26 October 2001, p. 256–261.

Malzac, J. , T. Belloni and H. C. Spruit: Correlated optical/X-ray variability in XTE J1118+480. In: New View on microquasars : Proceedings of the fourth microquasar workshop, Eds. P. Durouchoux, Y. Fuchs, J. Rodriguez. Center for space physics, Kolkata, Indien 2003, 49-42.

Menard, B. , T. Erben and Y. Mellier: Weak lensing study of Abell 2029. In: Matter and energy in cluster of galaxies, Eds. S. Bowyer and C.Y. Hwan. Astronomical Society of the Pacific Conference Series 301, Astronomical Society of the Pacific, San Francisco, CA (US) 2003, 537-541.

Merloni, A.: Microquasars in the low/hard state: strong coranae, compact jets, and the high frequency. In: New View on microquasars : Proceedings of the fourth microquasar workshop, Eds. P. Durouchoux, Y. Fuchs, J. Rodriguez. Center for space physics, Kolkata, Indien 2003, 113-116.

Merloni, A. and Fabian, A. C.: Iron Kα line profiles and inner boundary condition for magnetized accretion flows. In: Active Galactic Nuclei: from Central Engine to Host Galaxy. Proc. of meeting held in Meudon, France, July 23-27, 2002. Eds.: S. Collin, F. Combes and I. Shlosman. Astron. Soc. Pac. Conf. Ser, Vol. 290, p. 117–118.

Mimica, P. and K. Pavlovski: Eclipse mapping of hyperactive Algols. In: Interplay of Periodic, Cyclic and Stochastic Variability in Selected Areas of the H-R Diagram. Proc. ASP Conf. Ser. 292. San Francisco: Astronomical Society of the Pacific, 2003, p. 405–411.

Nadyozhin, D.: Physical properties of SNe IIP derived from comparsion of theoretical models with observations. In: From twilight to highlight: The physics of Supernovae / Proceedings of the ESO/MPA/MPE Workshop, Eds. Hillebrandt, W. and B. Leibundgut, ESO Astrophysics Symposia , Springer, Berlin 2003, 241-245.

Nayakshin, S.: Models of photo-ionized X-ray reflection in AGN. In: Active galactic nuclei : From central engine to host galaxy290, , Eds. Collin, S.; Combes, F.; Shlosman, I. Astronomical Society of the Pacific Conference Series , Astronomical Society of the Pacific, San Fransisco 2003, 55-58.

Nayakshin, S.: The frozen (inactive) disk in Sgr A*: freezing the accretion of the hot gas too?. In: Astronomische Nachrichten, (Eds.) Cotera, A., H. Falcke, T.R. Geballe and Markoff, S. (2003) 483–489.

Niemeyer, J., M. Reinecke, C. Travaglio and W. Hillebrandt: Small steps toward realistic explosion models of type Ia supernovae. In: From twilight to highlight: The physics of Supernovae / Proceedings of the ESO/MPA/MPE Workshop, Eds. Hillebrandt, W. and B. Leibundgut, ESO Astrophysics Symposia , Springer, Berlin 2003, 151-157.

Niemeyer, J. C., M. Reinecke and W. Hillebrandt: Models of type Ia supernova explosions. In: High performance computing in science and engineering - Munich 2002 : Transactions of the first joint HLRB and KONWIHR staturs and result workshop, Eds. Wagner, S. and W. Hanke. Springer, Berlin 2003, 105-112.

Nomoto, K., T. Uenishi, C. Kobayashi et al.: Type Ia supernova: Progenitors and diverties. In: From twilight to highlight: The physics of Supernovae / Proceedings of the ESO/MPA/MPE Workshop, Eds. Hillebrandt, W. and B. Leibundgut, ESO Astrophysics Symposia , Springer, Berlin 2003, 115-127.

Pogorelov, N., I. Kryukov, U. Anzer, G. Bisnovatyi-Kogan and G. Börner: Radiative effects in the modelling of accretion onto stellar magnetospheres. In: Astronomy, cosmology and fundamental physics : Proceedings of the ESO/CERN/ESA Symposium, Eds. Shaver, P.A.; DiLella, L. and A. Giménez. ESO astrophysics symposia , Springer, Berlin 2003, 473-474.

Ruffert, M. and H.-Th. Janka: Merging neutron star - Black hole binaries. In: Gamma-ray burst and afterglow astronomy 2001 . A Workshop celebrating the first year of the HETE Mission, Eds. Ricker, G.R. and R.K. Vanderspek. AIP Conference Proceedings 662, American Institute of Physics, Melville 2003, 193–198.

Ruiz-Lapuente, P. , F. Comeron , S. Smartt , R. L. Kurucz , J. Mendez , R. Canal , A. Filippenko and R. Chornock: Search for the companions of galctic SNe Ia. In: From twilight to highlight: The physics of Supernovae / Proceedings of the ESO/MPA/MPE Workshop, Eds. Hillebrandt, W. and B. Leibundgut, ESO Astrophysics Symposia , Springer, Berlin 2003, 140–147.

Schlattl, H., M. Salaris, S. Cassisi, A. Weiss The He flash in ultra metal-poor stars In: 3D Stellar Evolution Proc. LLNL workshop, Livermore, 22-26 July 2002. Eds.: Turcotte. S., Keller and S., Cavallo. ASP Conf. Series, vol. 293, 2003, 314–320

Schwartz, P., P. Heinzel, B. Schmieder and U. Anzer: Determination of the 3D–topology of an EUV–filament observed by SoHO/CDS, SoHO/SUMER and VTT/MSDP. In: Solar Variability as an Input to the Earth's Environment, Ed. Wilson, A. ESA SP-535 , ESA Publications Division, ESTEC, Noordwijk, The Netherlands 2003, 495-498.

Smith, N. J. T., G. E. Kalmus, C. S. Frenk and S. D. M. White: The search for dark matter and dark energy in the Universe - Papers of a Discussion Meeting Held at the Royal Society, January 22-23, 2003. In: Philosophical transactions of the Royal Society of London A, 361, 1812, 2003 2425–2425.

Springel, V. and L: Hernquist: A multi-phase model for simulations of galaxy formation. In: Astrophysical supercomputing using particle simulations: Proceedings of the 208th symposium of the International Astronomical Union, Eds. Makino J. and P. Hut. IAU Symposium 208, Astronomical Society of the Pacific, San Francsisco, CA (US) 2003, 273-282.

Spruit, H.C.: A dynamo in the radiative interior. In: Turbulence, Waves and Instabilities in the Solar Plasma. Proc. NATO ASI Budapest September 2002. Eds.: R. Erdelyi et al. Kluwer, 2003, 3–21.

Travaglio, C., K. Kifonidis, K. and E. Mueller: C and O explosive nucleosynthesis in SNII coupled to multidimensional hydrodynamics. In: CNO in the Universe. Eds. C. Charbonnel, D. Schaerer and G. Meynet. ASP Conf. Ser., Vol. 304, 352–357.

van Boekel, R., S. Cabañero Rodriguez, C. P. Dullemond et al.: Probing the structure of circumstellar disks surrounding Herbig Ae stars with VLTI. In: Galactic star formation across the stellar mass spectrum, Eds. De Buizer, J.M. and N.S. van der Bliek. Astronomical Society of the Pacific Conference Series 287, Astronomical Society of the Pacific, San Franscisco 2003, 478-483.

van den Bosch, F. C.: Measuring the virial masses of disk galaxies. In: The mass of galaxies at low and high redshift: Proceedings of the ESO/USM München Workshop, Eds. Bender, R.; Renzini, A. ESO astrophysics symposia , Springer, Berlin 2003, 250-255.

Yoshida, N. , T. Hamana , Y. Suto and A. Edvard: Clustering of dark halos on the lightcone. In: Astrophysical supercomputing using particle simulations: Proceedings of the 208th symposium of the International Astronomical Union, Eds. Makino J. and P. Hut. IAU Symposium 208, Astronomical Society of the Pacific, San Francsisco, CA (US) 2003, 467-468.

4.2.2 Publications available as electronic file only

Arp, H.: Research with Fred. In: Astrophysics and space science, 285, 2, Eds. Wickramasinghe, C., G. Burbridge and J. Narlikar: 2003, 451-457, Sequ. No.: 5138615.
`http://ipsapp009.kluweronline.com/content/getfile/4525/88/20/abstract.htm`

Bikmaev, I., R. Sunyaev, M. Gilfanov et al.: GRB030329: RTT150 optical observations.. GRB Circular Network **2220**
`http://gcn.gsfc.nasa.gov/gcn/gcn3_archive.html`

Cora, S. A. and S. D. White: Chemical enrichment of the intra-cluser medium. In: Astrophysics and Space Science, 284, 2, Eds. Hensler, G.; Stasinska, G.; Harfst, S.; Kroupa, P.; Theis, Chr. (2003) 425-428.
`http://ipsapp008.kluweronline.com/content/getfile/4525/85/25/abstract.htm`

Downes, R.A., R.F. Webbink, M.M. Shara, H. Ritter, U. Kolb and H.W. Duerbeck: A catalog and atlas of cataclysmic variables: The living edition.
http://www-int.stsci.edu/ downes/cvcat/

Enßlin, T.A., C. Vogt and C. Pfrommer: Magnetic Fields and Cosmic Rays in Galaxy Cluster Cooling Flows Proceedings of The Riddle of Cooling Flows in Galaxies and Clusters of Galaxies, held in Charlottesville, VA, May 31 - June 4, 2003, Eds. T. Reiprich, J. Kempner, and N. Soker.
http://www.astro.virginia.edu/coolflow/

Frenk, C. S., G.E. Kalmus, N. J. Smith and S.D.M. White: The search for dark matter and dark energy in the Universe - Papers of a Discussion Meeting Held at the Royal Society on 22 and 23 January 2003. (The search for dark matter and dark energy in the Universe, January 22–23, London, GB) In: Philosophical transactions of the Royal Society of London A 361, 1812.
http://www.catchword.com/rsl/1364503x/v361n1812/contp1-1.htm

Grimm, H.-J., M. Gilfanov and R. Sunyaev: High mass X-ray binaries as a SFR indicator. In: Astronomische Nachrichten, 324, 1-2, (Ed.) Barcons, X. 2003, 171-171.
http://www3.interscience.wiley.com/cgi-bin/abstract/102531376/START

Heinz, S.: The interaction of relativistic jets with their environment. In: The physics of relativistic jets in the CHANDRA and XMM era, 6-7, , 2003, 565-567 In: New Astronomy Reviews, 47, 6-7, Eds. Brunetti, G.; Harris, D.E.; Sambruna, R. M.; Setti, G. 2003, 565-567.
http://www.sciencedirect.com/science

Heinz, S. and T.A. Enßlin: The Interaction of Jets with the Intracluster Medium Conference Note: A Taxonomy of Extended Radio Sources in Clusters of Galaxies Proceedings of The Riddle of Cooling Flows in Galaxies and Clusters of Galaxies, held in Charlottesville, VA, May 31 - June 4, 2003, Eds. T. Reiprich, J. Kempner, and N. Soker.
http://www.astro.virginia.edu/coolflow/

Hillebrandt, W., J. C. Niemeyer, M. Reinecke, F. Röpke and C. Travaglio: Multidimensional simulations of type Ia supernova explosions and nucleosynthesis. In: Nuclear physics A, 718, Eds. Kubono, S.; Teranishi, T.; Kajino, T.; Nomoto, K.; Tanihata, I. 2003, 229C-238C.
http://www.sciencedirect.com/science

Inoue, S. and T. K. Suszuki: Cosmic ray production of 6Li by structure formation shocks in the early Galaxy. In: Nuclear physics A, 718, Eds. Kubono, S.; Teranishi, T.; Kajino, T.; Nomoto, K.; Tanihata, I. 2003, 69C-72C.
http://www.sciencedirect.com/science

Kempner, J.C., E.L. Blanton, T.E. Clarke, T.A. Enßlin, M. Johnston-Hollitt, L. Rudnick: Conference Note: A Taxonomy of Extended Radio Sources in Clusters of Galaxies Proceedings of The Riddle of Cooling Flows in Galaxies and Clusters of Galaxies, held in Charlottesville, VA, May 31 - June 4, 2003, Eds. T. Reiprich, J. Kempner, and N. Soker.
http://www.astro.virginia.edu/coolflow/

Khamitov, I., R. Sunyaev, M. Gilfanov et al.: GRB030329: RTT150 optical observations and upper limit for a host. GRB Circular Network **2198**
http://gcn.gsfc.nasa.gov/gcn/gcn3_archive.html

Khamitov, I., R. Sunyaev, M. Gilfanov et al.: GRB030329: RTT150 optical observations and upper limit for a host. GRB Circular Network **2204**
http://gcn.gsfc.nasa.gov/gcn/gcn3_archive.html

Khamitov, I., R. Sunyaev, M. Gilfanov et al.: GRB030429: RTT150 optical observations, a possible host galaxy. GRB Circular Network **2208**
http://gcn.gsfc.nasa.gov/gcn/gcn3_archive.html

Khamitov, I., R. Sunyaev, M. Gilfanov et al.: GRB030429: RTT150 optical obs., correction to GCN 2208. GRB Circular Network **2213**
http://gcn.gsfc.nasa.gov/gcn/gcn3_archive.html

Kobayashi, C. and K. Nomoto: Lifetime of type Ia supernovae and chemical evolution of galaxies. In: Nuclear physics A, 718, Eds. Kubono, S.; Teranishi, T.; Kajino, T.; Nomoto, K.; Tanihata, I. 2003, 680C-682C. Kobayashi, C.: The origin of elliptical galaxies inferred from their metallicity gradients. In: Astrophysics and Space Science, 284, 2, Eds. Hensler, G.; Stasinska, G.; Harfst, S.; Kroupa, P.; Theis, Chr. 2003, 853-856, Sequ. No.: Article ID: 5119483.
http://ipsapp007.kluweronline.com/content/getfile/4525/85/112/abstract.htm

Kong, X.: Empirical population synthesis for 74 blue compact galaxies. In: Astrophysics and Space Science, 284, 2, Eds. Hensler, G.; Stasinska, G.; Harfst, S.; Kroupa, P.; Theis, Chr. 2003, 905-908.
http://ipsapp007.kluweronline.com/content/getfile/4525/85/123/abstract.htm

Marti, J.M. and E. Müller: Numerical Hydrodynamics in Special Relativity.
http://www.livingreviews.org/Articles/

Revnivtsev, M., Gilfanov, M., Churazov, E., Sunyaev, R.: IGR J17091-3624 in archival data of MIR/KVANT/TTM. The Astronomer's Telegram **150**
http://www.astronomerstelegram.org/

Ritter, H. and U. Kolb: Catalogue of cataclysmic binaries, low-mass X-ray binaries and related objects (Edition 7.1).
http://www.mpa-garching.mpg.de/RKcat/
http://vizier.cfa.harvard.edu/viz-bin/VizieR source=V/113A
http://vizier.u-strasbg.fr/viz-bin/VizieR source=V/113A

4.3 Popular articles and books

Arp, H. Catalogue of Discordant Redshift Associations. Apeiron, Montreal, 2003, 234 pages.

Bartelmann, M.: Der polarisierte Hintergrund. Sterne und Weltraum, **42/5**, 26–28 (2003)

Bartelmann, M.: Galaxien vom Urknall bis heute. Teil 2: Kosmologie. Sterne und Weltraum Special, **2/03**, 44–49.

Börner, G.: The Early Universe–Facts and Fiction. (4th Edition). Springer Verlag, 2003, 586 pages.

Börner, G.: "Vom Urknall zum Weltall". National Geographics Deutschland, Dezember 2003.

Börner, G.: "Kosmologie". Spektrum der Wissenschaft, Dezember 2003.

Börner, G.: "Schwarze Löcher", Zeitschrift 'Ausblicke' (LMU München) 15, 17–25 (2003).

Burkert, A., M. Bartelmann and M. Steinmetz: Galaxien vom Urknall bis heute. Sterne und Weltraum Special 1, 22–49 (2003).

Heinz, S. and R. Sunyaev: Cosmic Ray Beschleunigung in Mikroquasaren. In: Max-Planck-Gesellschaft - Jahrbuch 2003, K.G Saur Verlag K. G., München (2003) 51–55.

Hillebrandt, W. and B. Leibundgut (Eds.): From Twilight to the Highlight: The physics of supernovae, Proceedings of the ESO/MPA/MPE Workshop. The physics of Supernovae, 29–31.7. 2002 Garching, Germany. In: ESO Astrophysics Symposia. Springer, Berlin XVII, 414 p.

Kifonidis, K. , T. Pewa , H.-T. Janka and E. Müller: Typ Ib supernovae und der Explosionsmechanismus massereicher Stern. In: Max-Planck-Gesellschaft - Jahrbuch 2003, K.G Saur Verlag K. G., München (2003) 45–50.

Springel, V.: Die Enstehung der Galaxien. Physik Journal, **6/12**, 31–37 (2003).

Stoehr F. and S. D. M. White: Ballet des galaxies, Pour la Science, Dossier 38: La Gravitation, 66-71 (2003)

4.4 Invited-, Colloquia- and Public talks

4.4.1 Invited and review talks

H. Arp: "Ejection from Active Galaxies", Manchester Astronomical Society, England (22.11.)

H. Arp: Conference on Cosmology, Univ. (Pavia, Italy, 22.–23.6.)

H. Arp: Science and Democracy, (Naples, Italy, 11. – 12.6)

M. Bartelmann: "Numerical Methods in Gravitational Lensing" (Aussois, 05.01.–08.01.)

G. Börner: "The Threepoint Correlation Function of the Galaxy distribution" (Univ. of Tokyo, 06.11.)

G. Börner: Workshop on "Atomic clocks and fundamental constants" (Bad Honnef, 16.6.)

S. Charlot: MPA/MPE/ESO Conference "Stellar Populations" (Garching, 6.10.–10.10.)

E. Churazov: Conference "The Riddle of Cooling Flows in Galaxies and Clusters of Galaxies", (Charlottesville, USA 31.5.–04.06.)

E. Churazov: Workshop "Fundamental Atomic Spectroscopy", (Zvenigrad, Russia 1.12.–5.12.)

E. Churazov: Workshop "High Energy Astrophysics 2003", (Moscow, Russia 24.12.–26.12.)

B. Ciardi: Workshop "Workshop on the Topology of Reionization" (Tucson, 20.3.–22.3.)

T. Di Matteo: University of California, Physics & Astronomy Colloquium "Black hole growth and activity throughout cosmic history" (Irvine, USA, 27.2.)

T. Di Matteo: The Tenth Marcel Grossmann Meeting on General Relativity "Black Holes and Galaxy Formation" (Rio de Janeiro, Brazil, 20.7.–26.7.)

H. Dimmelmeier: Tenth Anniversary of The Center for Gravitational Physics and Geometry, "Gravitation: A Decennial Perspective", 1993 – 2003 (Penn State University, State College, PA, U.S.A., 8.6.–12.6.)

M. Gilfanov: "Stellar-Mass, Intermediate-Mass, and Supermassive Black Holes" (Kyoto, Japan, 28.10.–21.10.)

M. Gilfanov: "High Energy Astrophysics 2003" (Moscow, Russia, 24.12.-25.12.)

H.-J. Grimm: Frascati Workshop 2003 "Multiwavlength Behaviour of High Energy Cosmic Sources" (Vulcano, 246.05.–31.05.)

S. Heinz: "Particle Acceleration in Astrophysical Objects" (Cracow, Poland, 24.6.–28.6.)

S. Heinz: "Cooling Flows in Galaxies and Clusters of Galaxies" (Charlottesville, VA, USA, 31.5.–4.6.)

W. Hillebrandt: The Physics of Supernova Explosions (Ringberg Castle, Germany, 10.3.–15.3.)

W. Hillebrandt: IAU Symposium 192 "Supernovae" (Valencia, Spain, 22.4.-26.4.)

W. Hillebrandt: Workshop on Supernovae and Dust (Paris, France, 16.5.–17.5.)

W. Hillebrandt: The Future Astronuclear Physics (Brussels, Belgium, 20.8.–22.8.)

W. Hillebrandt: Thermonuclear Supernovae and Cosmology (Trento, Italy, 22.9.–4.10.)

W. Hillebrandt: Ten Years of ECT*: Achievement and Vision (Trento, Italy, 11.10.–12.10.)

H.-Th. Janka: IAU 25th General Assembly (Sydney, 13.7.–26.7.)

H.-Th. Janka: International Conference "The Future Astronuclear Physics" (Brussels, 20.8.–22.8.)

H.-Th. Janka: Workshop "Astroteilchenphysik in Deutschland" (Karlsruhe, 16.9.–18.9.)

H.-Th. Janka: IAU Colloqium 192 (Valencia, Spain, 22.4.–26.4.)

H.-Th. Janka: Universitätsseminar über aktuelle Themen aus Kosmochemie und Astrophysik (Mainz, 27.1.)

H.-Th. Janka: Universitätsseminar (Aarhus, Denmark, 14.5.)

H.-Th. Janka: Seminar am Forschungszentrum (Karlsruhe, 2.12.)

H.-Th. Janka: Workshop on Numerical Methods for Multidimensional Radiative Transfer Problems (Heidelberg, 24.9.–26.9.)

G. Kauffmann: Carnegie Observatories Centennial Symposium III: "Clusters of Galaxies: Probes of Cosmological Structure and galaxy Evolution" (Pasadena, 26.1.–31.1.)

G. Kauffmann: "Physical Cosmology" (Blois, 15.6.–20.6.)

G. Kauffmann: IAU Symposium 216 "Maps of the Cosmos" (Sydney, 14.7.–17.7.)

G. Kauffmann: "From First Light to the Milky Way" (Zürich, 18.8.–22.8.)

G. Kauffmann: "Multiwavelength Mapping of Galaxy Evolution" (Venice, 13.10.–16.10.)

A. Merloni: "A fundamental plane of black hole activity" (Amsterdam, 29.8.)

F. Miniati: "Modeling the Intergalactic and Intracluster Medium" (Vulcano, 1.10.–4.10.)

F. Miniati: "GLAST-LAT International Collaboration Meeting" (Rome, 15.9.–18.9.)

F. Miniati: "Science with 5@5" (Ringberg Castle, 10.11.–15.11.)

E. Müller: RTN Workshop and Winter School on "The Physics of Type Ia Supernova Explosions" (Ringberg Castle, 10.3.–15.3.)

E. Müller: Workshop on "The Physics of Compact Stellar Objects" (Valencia, 8.9.–11.9.)

E. Müller: 27th Spanish Relativity Meeting on "Gravitational Radiation" (Alicante, 11.9.–13.9.)

E. Müller: International Conference on "Virtual Astrophysical Jets" (Dogliani, 2.10.–4.10.)

P. Popowski: International Conference "Gravitational Lensing: A Unique Tool For Cosmology" (Aussois 5.1.–11.1.).

G. Rudnick: Astron. Seminar, "Bright Lights, Big City: The Rest-Frame Optical Luminosity Density, Color, and Stellar Mass density to z 3", New York University, (New York, U.S.A., 8.1.)

G. Rudnick: Astron. Seminar, "Bright Lights, Big City: The Rest-Frame Optical Luminosity Density, Color, and Stellar Mass density to z 3", University of Wisconsin, (Madison, U.S.A., 15.1.)

G. Rudnick: "The Formation and Evolution of Galaxies" conference, "The Cosmically Averaged Universe to z 3", (Kloster Irsee, 3.7.)

G. Rudnick: Astron. Seminar, "The Cosmically Averaged Universe to z 3", (Heidelberg, 20.11.)

V. Springel: “Multiwavelength Cosmology” (Mykonos, Greece, 17.6.–20.6.)

V. Springel: IAU Symposium 220 “Dark Matter in Galaxies” (Sydney, Australia, 21.7.–25.7.)

V. Springel: Workshop “Galaxy Formation: A Herculean Challenge” (Banff, Canada, 1.11.–6.11.)

V. Springel: Workshop “Computational Cosmology and Astrophysics” (Courant-Institute, New York, USA, 15.11.)

H.C. Spruit: Conference on X-ray Bursts; Institute for Advanced Study, (Princeton, 11.-15.3.)

H.C. Spruit: Solar Physics Division American Astronomical Society (Baltimore, 17.-22.6.)

H.C. Spruit: Conference on High-Energy Astrophysics (Cracow, 23.-29.6.)

H.C. Spruit: GRB minisymposium, JENAM (Budapest, 28.-31.8.).

R. Sunyaev: 25 General Assembly of the IAU, Joint Discussion 18, ”Quasar Cores and Jets”, (Sydney, 13.7.–26.7.)

R. Sunyaev: IAU Symposium 216 “Maps of the cosmos”, Gruber Cosmology Prize lecture, Hot gas in clusters of galaxies, (Sydney, 13.7.–26.7.)

R. Sunyaev: Villa Mondragone International School on Gravitation and Cosmology “The Polarization of the Cosmic Microwave Background”, (6.9.–11.9.)

R. Sunyaev: Workshop ’Cosmology with Sunyaev-Zel’dovich Surveys’, (University of Chicago, 17.9.–20.9.)

R. Wegmann: ”X-rays in the Solar System”, (Leiden, The Netherlands 7.–9.4.)

A. Weiss: “Stellar Population Synthesis” (Garching, 6.10.–10.10.)

A. Weiss: Joint Discussion 4 at the XXVth General Assembly of the IAU “Astrophysical impact of abundances in globular cluster stars” (Sydney, Australien, 16.7.–17.7.)

S. White: 3rd Carnegie Symposium, Clusters of Galaxies (Pasadena, 12.10.–19.10.)

S. White: Satellites and Tidal Streams, (La Palma, 26.5.–30.5.)

S. White: 2nd Annual Thinkshop, (Potsdam, 12.6.–15.6.)

S. White: IAU Symposium No. 211, Maps of the Cosmos, (Sydney, 14.8.–25.8.)

S. White: IAU Joint Discussion No. 8, Virtual Observatory, (Sydney, 14.8.–25.8.)

S. White: IAU Joint Discussion No. 10, Clusters of Galaxies, (Sydney, 14.8.–25.8.)

S. White: IAU Symposium No. 220, Dark Matter in Galaxies, (Sydney, 14.8.–25.8.)

S. White: Star and Structure formation, (Zürich, 18.8.–22.8.)

S. White: Multiwavelength Mapping of Galaxy Formation, Evolution, (Venice, 13.10.–16.10.)

4.4.2 Colloquia talks

M. Bartelmann: Physical Colloquium (SISSA, Trieste, 13.01.–15.1.).

M. Bartelmann: Physical Colloquium (IAP, Paris, 24.1.).

M. Bartelmann: Physical Colloquium (Unversität Tübingen, 09.5.).

M. Bartelmann: Physical Colloquium (Universität Essen, 22.10.).

M. Bartelmann: Physical Colloquium, (Magnus-Haus, Berlin, 10.11.).

M. Bartelmann: Physical Colloquium, (Universität Stuttgart, 11.11.).

G. Börner: Physical Colloquium, (Universität Augsburg, 19.2.).

B. Ciardi: Universita' dell'Insubria (Como, 27.3.).

B. Ciardi: Universita' la Sapienza (Rome, 17.10.).

W. Hillebrandt: Physical Colloquium, (Ulm, 10.11.).

E. Müller: Physical Colloquium (Würzburg, 7.4.).

E. Müller: Physical Colloquium (Bonn, 4.7.).

V. Springel: Astrophysical Colloquium (Bonn, 28.3.).

V. Springel: Astrophysical Colloquium (New York University, USA, 14.11.).

V. Springel: Astrophysical Colloquium (Turino, Italy, 2.12.).

R. Sunyaev: Special Invited lecture, (University of Tokyo, Japan 12.6.)

R. Sunyaev: Invited lecture, ISAS, Tokyo, (University of Tokyo, Japan 11.6.)

R. Sunyaev: Institute for Advanced Study, Princeton, Colloquium, (Princeton, 23.9.)

R. Sunyaev: Harvard-Smithsonian Center for Astrophysics, Special Seminar, (Harvard, 25.9.)

R. Sunyaev: Special Invited lecture, Institute of Theoretical and Experimental physics, (Moscow, 8.10.)

A. Weiss: Astronomy Colloquium, (Heidelberg, 24.6.).

S.D.M. White: Colloque de physique, (ENS Lyon, 26.3.).

S.D.M. White: Sackler Lecture, (Princeton University, 3.4.).

S.D.M. White: Astronomy Colloquium, (Bochum 7.6).

S.D.M. White: Abendvortrag fuer Graduiertenkolleg, (Blaubeuren 1.10.).

S.D.M. White: Physical Colloquium, (Göttingen 3.11.).

4.4.3 Public talks

M. Bartelmann: Studium Generale, Tübingen (13.5.)

M. Bartelmann: Volkshochschule Ingolstadt (9.10.)

G. Börner: LMU München, Seniorenstudium (27.1.)

G. Börner: EBZ Otzenhausen (8.4.)

G. Börner: Evangelische Kirche Ludwigshafen (6.5.)

G. Börner: Schloss Thurnau/Bayreuth; Evang. Akademie Tutzing und Univ. Bayreuth (10.10.)

T.A. Enßlin: Gymnasium Erding, (24.7)

E. Müller: MPG-Hauptversammlung Hamburg, (4.6.)

E. Müller: Auricher Wissenschaftstage 2003, Aurich (11.11.)

H. Ritter: Volkssternwarte, München (4.7.)

G. Rudnick: MPA Tag der offenen Tür (25.10.).

G. Rudnick: Montefiore Elementary School, Chicago, U.S.A., (16.1.)

V. Springel: Volksternwarte Bonn, (27.3.)

A. Weiss: MPG-Hauptversammlung, Hamburg, (4.6.)

S.D.M. White: Wissenstransfer Abendvortrag, Tübingen (20.5.)

S.D.M. White: Vortrag am Tag der offenen Tür, Garching (25.10)

5 Personnel

5.1 Scientific staff members

Directors

W. Hillebrandt, R. Sunyaev (managing), S.D.M. White.

External Scientific Members

R. Giacconi, R.-P. Kudritzki, W. Tscharnuter.

Staff

M.A. Aloy, A. Arbey (since Sept. 1), A.J. Banday, M. Bartelmann (till Sept. 30.), G. Börner, S. Charlot, E. Churazov, L. Dessart (since Jan. 1.), H. Dimmelmeier, K. Dullemond, T. Enßlin, M. Gilfanov, S. Heinz (till Sept. 30.), S. Inoue, H.–T. Janka, G. Kauffmann, K. Kifonidis, C. Kobayashi, W.P. Kraemer (till Sept. 30), F. Kupka (since Oct. 1.), A. Merloni, H.J. Mo (till April 30), E. Müller, S. Nayakshin, R. Oechslin (since April 1.), P. Popowski, M. Rampp (till Febr. 28.), M. Reinecke, M. Revnivtsev, H. Ritter, F. Röpke (since July 1.), G. Rudnick, S. Sazonov, V. Springel, H.C. Spruit, C. Travaglio (till Sept. 30.), F. van den Bosch (till Sept. 30.), A. Weiß, S. Zaroubi.

Emeriti

H. Billing, R. Kippenhahn, F. Meyer, H.U. Schmidt, E. Trefftz.

Scientists associated:

U. Anzer, H. Arp, G. Diercksen, W. Kraemer (since Oct. 1), E. Meyer–Hofmeister, J. Schäfer, H.-C. Thomas, R. Wegmann.

Sofja Kovalevskaja Programm

J. Brinchmann (till Nov. 30.), S. Charlot (awardee) C. Möller

Alexander von Humboldt fellowships

Xu Kong (USTC, China, till Oct. 31), Bifang Liu (since July 1.)

DAAD–fellowships

C. Scannapieco (IAFE, Argentina) 1.9.–31.12.

EC–fellowships

N. Bouche (since Sept. 1.), B. Ciardi, S. Cora (till Sept. 30.), A. Ferguson (since Febr. 10.), D. Giannios (until Sept. 30.), C. Hernandez-Monteagudo, F. Miniati, P. Ocvirk (since Oct. 1.), J.A. Rubiño-Martín, A. Serenelli (1.2.–31.7.), A. Wozna (till Sept. 30).

Ph.D. Students

R. Barmina (till Aug. 31), S. Bertone, J. Braithwaite, A. Büning (till Oct. 31.), R. Buras, M. Flaskamp (till Jan. 30.), L. Gao, H.-J. Grimm (till Aug. 30.), L. Iapichino, M. Jubelgas, M. Kitzbichler (since Nov. 1.), T. Leismann, B. Menard (till April 30.), A. Nickel, C. Pfrommer, F. Röpke (till June 30.), D. Sauer, B. M. Schäfer, L. Scheck, W. Schmidt, M. Stehle, F. Stoehr (till July 31.), B. Zink (since April 1.).

IMPRS Ph.D. Students

K. Basu, J. Chluba, D. Croton, J. Cuadra, G. De Lucia, A. Gallazzi (since Febr. 1.), G. Hütsi, T. Jaffe (since Sept. 1.), P. Mimica, P. Rebusco (since Oct. 1.) M. Stritzinger, L. Tasca, C. Vogt, R. Voss (since May 1.), S. Zibetti.

Diploma students

A. Arcones (till Dec. 31.) T. Behrens (till Febr. 28), M. Gieseler (since March 1.), V. Heesen (till March 30.), F. Kitaura (till Dec. 31.), A. Marek (till Dec. 31.), M. Obergaulinger (since June 1.), S. Taubenberger (since Nov. 1.), O. Zahn (till April 30.).

5.1.1 Staff news

M. Bartelmann: accepted C4 appointment at Theoretische Astrophysik, Universität Heidelberg.

A. Ferguson: received the 2003 Annie Jump Cannon Award in Astronomy.

J. Niemeyer: accepted C3 appointment at the Institut Theoretische Physik und Astrophysik, Universität Würzburg.

R. Sunyaev: received the 2003 Dannie Heineman Prize for Astrophysics from American Institute of Physics American Astronomical Union; the Cosmology Prize and Gold Medal of the Peter Gruber Foundation and International Astronomical Union for 2003.

5.1.2 Ph.D. theses 2003

R. Banerjee: Evolution of primordial magnetic fields in the early universe. Ludwig-Maximilians-Universität, München.

A. Büning: "Langzeitentwicklung kompakter Doppelsternsysteme mit Bestrahlungsrückkopplung" Ludwig-Maximilians-Universität, München.

M. Flaskamp: "Nichtlokale und zeitabängige Konvektion in Sternen" Technische Universität München.

H.-J. Grimm: "X-ray in the Milky Way and other galaxies" Ludwig-Maximilians-Universität, München

A. M. Lisewski: "Turbulent Combustion in Type Ia Supernovae" Technische Universität, München

B. Menard: "Cosmic Magnification", University of Paris.

F.K. Röpke: "On the Stability of Thermonuclear Flames in Type Ia Supernovae Explosion" Technische Universität, München.

S. Shen: "The statistical research of the size distribution of galaxies" Graduate School of Chinese Academy of Sciences.

F. Stoehr: "Simulations of Galaxy Formation and Large Scale Structure", Ludwig-Maximilians-Universität, München.

5.1.3 Diploma theses 2003

A. Arcones: "Studies of neutrino-heating and shock-revival phase in a supernova core by using an analytic toy model"; Technische Universität, München.

T. Behrens: "Lichtkurven-Systematik von Typ Ia Supernovae im Falle gemischter Explosionsklassen"; Technische Universität, München.

F. Kitaura: "Hydrodynamical simulation of the stellar collapse of O/Ne/Mg cores with Boltzmann neutrino transport"; Technische Universität, München.

A. Marek: "The effects of the nuclear equation of state on core collapse and supernova evolution"; Technische Universität, München.

5.2 Visiting scientists

Name	home institution	Duration of stay at MPA
G. Bruzual	(Mérida, Venezuela)	1.10.–31.10.
S. Blinnikov	ITEP, Moscow	15.9.–31.10.
D. Chen	(Shanghai, China)	since 4.10.
R. Chang	(Shanghai, China)	since 20.11.
J. Comerford	Univ. of California, Berkeley U.S.A.	15.6.–13.8.
R.A.C. Croft	(Carnegie Mellon Univ. USA)	1.6.–30.6.
Z.G. Deng	(Beijing, China)	25.6.– 21.9.
P. Denissenkov	(Victoria, Canada)	1.9.–1.10.
S. Grebenev	(Moscow, Russia)	6.11–6.12.
L. Girardi	(Triest, Italy)	4.10.–3.11.
C. Halliday	(Padova, Italy)	1.1.–30.4.
P. Heinzel	(Ondrejov, Czech Rep.)	1.– 16.5.
L. Hernquist	(CfA Harvard, USA)	23.6.–22.7.
C.J. Horowitz	(Indiana, USA)	1.9.–30.9.,
Y. Hou	(Shanghai, China)	1.3.–31.5.
A. Janiuk	(Warsaw, Poland)	10.11.–10.12.
N. Inogamov	(Moscow, Russia)	5.5.–5.6.
		6.10.–30.11.
Y.P. Jing	(Shanghai, China)	2.4.–11.6.
X. Kang	(Shanghai, China)	since 5.10
V. Kelló	(Bratislava, Slovak Republic)	04.08.–31.08.,
I. Kryukov	(Moscow, Russia)	1.– 31.7.
G. Li	(Shanghai, China)	since 5.10.
A. Lutovinov	(INTEGRAL, Switzerland)	28.5.–27.6.
P. Marigo	(Padua, Italy)	4.10.–3.11.
M. Matturi	(Padua, Italy)	since 1.10.
P. Mazzali	(Trieste, Italy)	26.5.–13.7.
D. Nadyozhin	(ITEP, Moscow)	1.4.–30.4.
M. Pieri	(Blackett Lab. London, U.K.)	1.10.–30.12.
T. Plewa	(Chicago, USA)	5.4.–3.5.
S. Recchi	(Univ. Kiel)	since 13.9.
P. Ruiz-Lapuente	(Barcelona, Spain)	27.3.–26.5.
M. Salaris	(Liverpool, U.K.)	11.7.–11.8.
A. Serenelli	(La Plata, Argentina)	1.2.–1.8.
N. Shakura	(Moscow, Russia)	1.9.–30.9.
Z. Shao	(Shanghai, China)	until 22.1.
S. Shen	(Shanghai, China)	1.1.–31.12.
P. Shtykovskii	(Moscow, Russia)	26.7.–5.9.,
		10.11.–20.12.
C. Shu	(Shanghai, China)	until 31.1.
E. Sorokina	(ITEP, Moscow)	15.9.–31.10.

Name	home institution	Duration of stay at MPA
A. Tolstov	(ITEP, Moscow)	15.9.–15.10.
M. Urban	(Bratislava, Slovak Republic)	04.08.–31.08.
V. Utrobin	(ITEP, Moscow)	1.11.-31.12.
W. Weinzierl	(Berlin)	1.5.–30.6.
X.Y. Xia	(Tianjin, China)	25.6.– 21.9.
S. Yamamoto	(Nagoya, Japan)	26.07.–07.09.
Y. Zhang	(Beijing, China)	1.19.–31.10.
D. Zhao	(Shanghai, China)	1.3.–31.5.