Max-Planck-Institut

für

Astrophysik

Annual Report 2010

Contents

1 General Information

1.1 A brief history of the MPA

The Max-Planck-Institut für Astrophysik, called the MPA for short, was founded in 1958 under the directorship of Ludwig Biermann. It was first established as an offshoot of the Max-Planck-Institut für Physik, which at that time had just moved from Göttingen to Munich. In 1979, in the course of plans to move the headquarters of the European Southern Observatory from Geneva to Garching, Biermann's successor, Rudolf Kippenhahn, relocated the MPA to its current site. The MPA became fully independent in 1991. Kippenhahn retired shortly thereafter and this led to a period of uncertainty, which ended in 1994 with the appointment of Simon White as director. The subsequent appointments of Rashid Sunyaev (1995) and Wolfgang Hillebrandt (1997) as directors at the institute, together with adoption of new set of statutes in 1997, allowed the MPA to adopt a system of collegial leadership by a Board of Directors. The Managing Directorship rotates every three years, with Wolfgang Hillebrandt in post for the period 2009-2011. In 2007 Martin Asplund arrived as a new director. The institute also has three external Scientific Members: Riccardo Giacconi, Rolf Kudritzki and Werner Tscharnuter.

The MPA was founded specifically as an institute for theoretical astrophysics. Its original goal was to develop the theoretical concepts and numerical algorithms needed to study the structure and evolution of stars (including the sun), the dynamics and chemistry of the interstellar medium, the interaction of hot, dilute plasmas with magnetic fields and energetic particles, and the calculation of transition probabilities and cross–sections for astrophysical processes in rarefied media. These efforts led to broad international cooperation and were clearly differentiated from the observational and instrumental activities carried out in other Max-Planck institutes. From its inception the MPA has also had an internationally-recognized numerical astrophysics program that is unparalleled by any other institution of similar size.

In recent years, activities at the MPA have diversified. They now address a much broader range of topics and include a variety of data analysis activities while still maintaining a substantial emphasis on numerics. Resources are channeled into areas where new instrumental or computational capabilities are expected to lead to rapid developments. Active areas of current research 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. Several previous research areas (solar system physics, the quantum chemistry of astrophysical molecules, general relativity and gravitational wave astronomy) have been substantially reduced over the last two decades.

Various aspects of the MPA's structure have historical origins. Its administration (which at present is housed primarily in the main MPA building but will move to a new extension building in early 2013) is shared with the neighboring, but substantially larger MPI für extraterrestrische Physik (MPE). The library in the MPA building also serves the two institutes jointly. All major astronomical books and periodicals are available. The MPA played an important role in founding the Max-Planck Society's Garching Computer Centre (the RZG; the principal supercomputing centre of the Society as a whole). MPA scientists have free access to the RZG and are among the top users of the facilities there. Ten posts at the computing centre, including that of its director, are formally part of the MPA's roster. This arrangement has worked well and results in a close and productive working relationship between the MPA and the RZG.

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 (for example at the now traditional morning "scientific coffee") and makes for a pleasant and stimulating research environment.

During the past ten years the steady growth of MPA's personnel has caused severe problems. There is no longer enough office space available, and the lecture room is now much too small even for the "house seminars", let alone for special events such as the Biermann lectures. In its earlier stages, the expansion in numbers could be accommodated by conversion of laboratory space into offices and by removal of rarely used library holdings to a remote store. The institute's capacity for such adaptation is now exhausted, however, and in 2007 a request was submitted the MPG's President and Central Administration for a building extension to relieve the problem.

Finally in 2009 the request received a positive answer. MPA got the permit to plan for a new extension building with a total of about 900 m^2 usable space. The detailed planning started in fall of 2009. The aim was to provide a significantly bigger lecture hall ($\sim$ 130 seats), plus office space for MPA's computer support group as well as room for their computer hardware, and offices for the MPA/MPE administration, the idea being that the administration/support groups would be located within easy reach of both institutes and, at the same time, all offices in MPA's "old" building would again be used by scientists only. According to present plans the construction work will start in June 2011 and will be finished by spring of 2013. By then the MPA site will look as shown in Figures 1.1.

Library

The library is a shared facility of the MPA and the MPE and therefore has to serve the needs of two institutes with differing research emphases – predominantly theoretical astrophysics at MPA and observational/instrumental astrophysics at the MPE. At present the library holds a unique collection of about 45000 books, conference proceedings, and journals (22629) about 7200 reports and observatory publications, as well as subscriptions for about 200 journals and manages online subscriptions for about 400 periodicals. The current holdings occupy about 1900 meters of shelf space. In addition the library maintains an archive of MPA and MPE publications, two slide collections (one for MPA and one for the MPE), a collection of approximately 400 CDs and videos, and it stores 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 and links to other online publications. This catalogue and the corresponding 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.

Additional technical services such as several PCs and terminals in the library area, copy machines, a colour bookscanner, two laser printers, and a fax machine are available to serve the users' and the librarians' needs.

The "Max Planck Digital Library" (MPDL) keeps campus licenses for online electronically accessible journals whereas individual institutes subscribe only to print copies of selected journals at a reduced price. The online journals are accessible via the institute's library homepages or Library Catalogue.

In 2010 the MPDL launched the "PubMan" system in which all institute publications (MPA and MPE) are archived electronically and made accessible internally from the library homepage. The administration and maintenance of this system is carried out by the library staff (about 1100 publications in 2010).

For lack of office space elsewhere in the institute four guest desks with PCs are available in the library's reading hall.

The library is run by three people who share the tasks as follows: Mrs. Chmielewski (full time; head of the library, administration of books and reports), Mrs. Hardt (full time; interlending and local loans of documents, "PubMan", and publications management for both institutes), and Mrs. Blank (half time; administration of journals).

Computational facilities

Because of the heavy emphasis on numerical astrophysics at MPA, the provision of suitable computers and network connections is a critical element in achieving the institute's scientific goals. In practice, computing needs are satisfied by providing both extensive in-house computer power and access to the supercomputers and the mass storage facilities at the Max Planck Society's Garching Computer Centre (the RZG) and the Leibniz Computer Centre of the state of Bavaria (the LRZ). Scientists

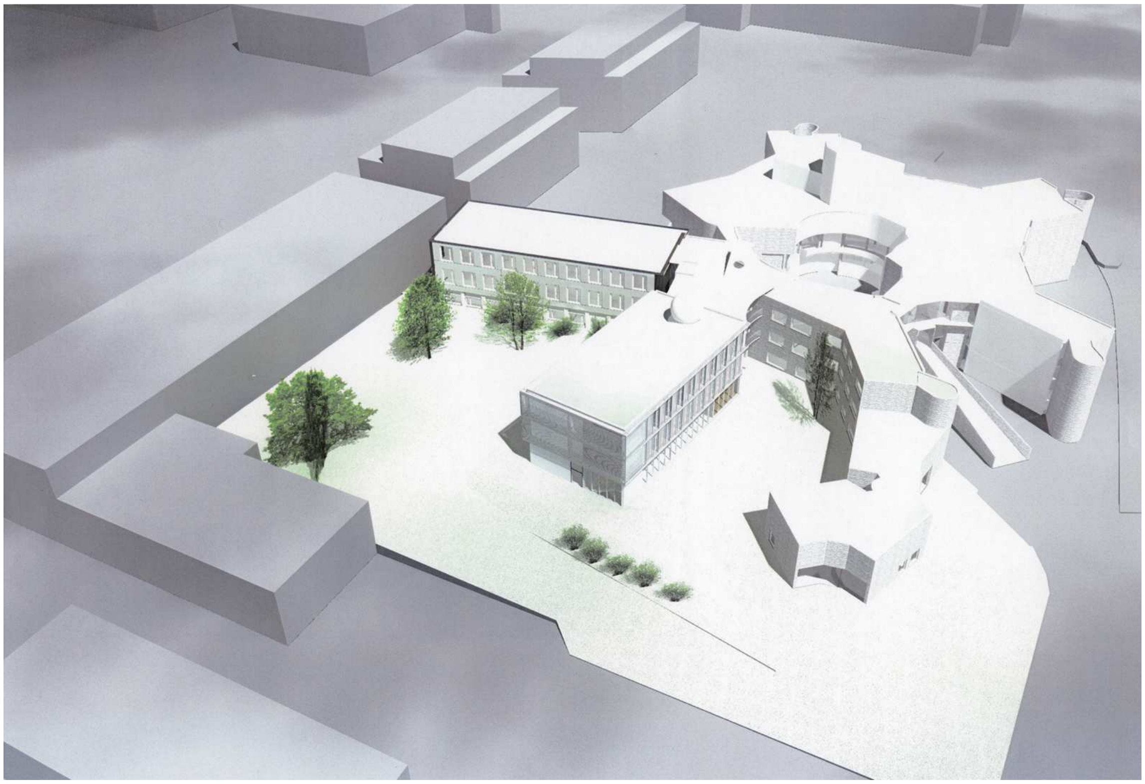

Figure 1.1: This is how MPA may look in early 2013

at MPA are also very successful in acquiring additional supercomputing time at various additional computer centers.

The design, usage and development of the MPA computer system is organized by the Computer Executive Committee in close consultation with the system administrators. This group also evaluates user requests concerning resources or system structure, with scientific necessity being the main criterion for decisions. In addition the committee meets RZG representatives on a regular basis to discuss issues concerning MPA's requirements at the Computer Center Garching (RZG). RZG and MPA coordinate their development plans to ensure continuity in the working environment experienced by the users. Furthermore, MPA participates actively in discussions of potential major investments at the RZG. Common hardware acquisitions by the two institutions are not unusual. Presently, MPA has two Linux-clusters with several hundred processors each located at RZG. The most important resources provided by the RZG are parallel supercomputers, PByte mass storage facilities (also for backups), and the gateway to GWIN/Internet.

MPA's computer system guarantees that every user has full access to all facilities needed, and that there is no need for users to perform maintenance or system tasks. All desks are equipped with modern PCs, running under one operating system (Linux) and a fully transparent file system, with full data security and integrity guaranteed through multiple backups, firewalls, and the choice of the operating system.

With this approach MPA is achieving virtually uninterrupted, continuous service. Data loss over the past few years is below the detection limit, and duty cycles are well beyond the 95% level. Since desktop PCs are not personalized, hardware failures are quickly repaired by a complete exchange of the computer.

In addition to the desktop systems, which, to the larger part are younger than 5 years and which (in 2010) amount to more than 180 fully equipped working places, users have access to central number crunchers (about 20 machines, all 64-bit architecture; with up to 16 processor cores and 96 GB memory), mainly through a batch system. The total on-line data capacity is beyond 500 Terabyte, individual user disk space ranges from a mere GB to several TB, according to scientific need.

All MPA scientists and PhD students may also get a personal laptop for the duration of their presence at the institute. These and private laptops may be connected to the in-house network, but to a subnet well separated from the crucial system components by a firewall. Apart from the standard wired network (Gb capacity up to floor level, and 100 Mb to the individual machine), access through a protected WLAN is possible, too.

The basic operating system is relying on Open-Source software and developments. One MPA system manager is actively participating in the Open-Source community. The Linux system is an in-house developed special distribution, including the A(dvanced) F(ile) S(ystem), which allows completely transparent access to data and a high flexibility for system maintenance. For scientific work licensed software, e.g. for data reduction and visualization, is in use, too. Special needs requiring Microsoft or Macintosh PCs or software are satisfied by a number of public PCs and through servers and emulations.

The system manager group comprises two full-time and two part-time system administrators; users have no administrative privileges nor duties, which allows them to fully concentrate on their scientific work.

In addition to the central MPA computer services, both the Planck Surveyor project and the SDSS group operate their own computer clusters. The former installation is designed in a similar fashion as the general system, and is maintained by an MPA system manager. The SDSS system is MS Windows based, and administered both by an MPA- and an additional SDSS-manager.

1.3 2010 at the MPA

Planck Surveyor

Planck Surveyor is a medium-sized ESA satellite mission to map the Cosmic Microwave Background. It was launched in May 2009 and has been operating nominally on station at L2 since late August 2009. 'First light' was in September 2009. Already in July 2010 the international consortium released the first all-sky image of the microwave sky, using data spanning the full frequency range of Planck from 30 to 857 GHz, and in September Planck has obtained its very first images of galaxy clusters.

Operations are currently expected to continue until the beginning of 2012, with proprietary data analysis continuing until the end of that year. The MPA is the only German participant in this effort with co-Investigators on each of the two instruments. Our role within the project was originally planned to be the development of a distributed processing system to be used as the backbone both for simulation of the mission and later for the data analysis itself. In addition MPA was charged with preparing the final mission products for release to the astronomical community. These goals have shifted in response to developments elsewhere in the distributed Planck software effort. Support of data release to the collaboration and to the broader public has now been de-emphasised in favour of extended support both for mission simulation activity and for the operation of the Trieste data centre for the Low Frequency Instrument. Funding for this work, which will occupy 12 programmers and scientists at peak, comes from the DLR and from internal MPA resources. The DLR request is already funded in full through the end of March 2012. MPA scientists are playing a leading role within the Planck consortia in science associated with galaxy clusters and secondary, we continue to maintain the mission simulation pipeline which is used to validate most new developments in the data processing.

Since 1999, the MPA has participated in the Planck Surveyor Mission. Simon White and Rashid Sunyaev are project Co-Investigators. The MPA Planck group was first managed by Matthias Bartelmann until 2003, and since then by Torsten Enßlin. Its role is to provide software infrastructure for the Planck data analysis, namely the Planck simulation package, the ProC workflow engine, and a Data Management Component (see also the article by T. Ensslin on first results obtained by the mission (Section 2.1).

LOFAR's first all-sky image

LOFAR is an innovative low-frequency radio interferometer project based primarily in the Netherlands. It is the first large facility instrument in the world for which beam construction is carried out entirely in software. This instrument strategy implies a very large computational requirement and in addition several of LOFAR's prime science drivers, particularly the search for redshifted 21 cm radiation from the epoch of reionization and studies of the structure of extended radio sources, are also focal points of research at MPA. Thus when the German Long Wavelength consortium (GLOW) was formed to negotiate German participation in the project, it was natural for MPA to join. The main body of the telescope is currently under construction in the Netherlands and consists of a scatter of antenna fields, each containing 96 "high-frequency" and 96 "low-frequency" antennae. German (and also UK, French and Swedish) participation consists in the construction of additional antenna fields which extend the baseline of the interferometer, together with broadband data links to transfer all data to Holland for processing. The first of 6 German antenna fields has already been built at Effelsberg and the second (MPA's) was completed on a site 40 km north of Munich in June 2010. Already on 12 February the LOFAR station in Unterweilenbach has taken a first low-band all-sky image (Fig. 1.2). First usable data from a large fraction of the array (including the German stations) became available in early 2011.

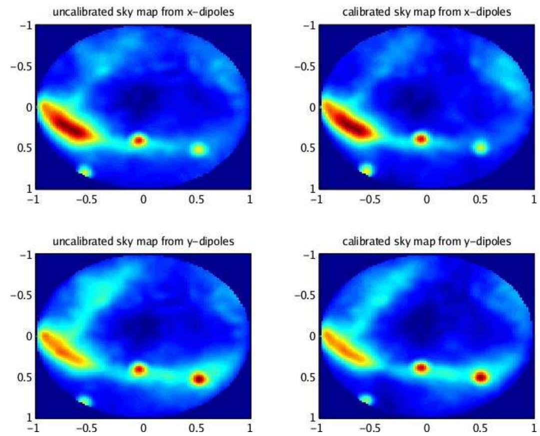

Figure 1.2: First all-sky radio image with LOFAR antennas near Garching

The MPA scientist in charge is Benedetta Ciardi, who also chairs the Science Working Group of the German LOng Wavelength (GLOW) Consortium. In addition, she is a core member of the LOFAR Epoch of Reionization Working Group.

Biermann lectures on extrasolar planets

The very successful Biermann lectures at the MPA continued with an exciting topic: Professor Sara Seager from the Massachusetts Institute of Technology spent several weeks at the institute and gave a series of lectures about different aspects of extrasolar planets. A pioneer in this young astronomical field – the first confirmed observation happened less than 20 years ago – Sara Seager is one of the leading figures in theoretical and computational studies of exoplanet atmospheres, interiors and how to identify signs of life on distant planets.

The Biermann lectures aim at stimulating scientific activities across the Munich astronomical community and have been a huge success in previous

Figure 1.3: Sara Seager (Biermann lecturer 2010)

years. World-class scientists working on topics in theoretical and computational astrophysics are invited to spend one month in Garching, give a series of prize lectures and interact with colleagues from the various surrounding institutes. While several previous visitors shared the MPA's research interests, topic of 2010 broadened the scope to a new and exciting field. Sara Seager was the first female Biermann lecturer and also the youngest scientist to receive this honour, in recognition of her early involvement and seminal contributions to this dynamic field.

As always the lectures were very well attended, only MPE's big lecture theatre offering a barely sufficient number of seats. Also as always, her lecture series offered another opportunity for a "beer and pretzel" party in MPA's backyard in the end.

Rudolf-Kippenhahn-Prize for Ákos Bogdan

End of May, the Rudolf-Kippenhahn-Prize for the best scientific paper written by a student at the MPA was awarded to Ákos Bogdan for his publication 'Unresolved X-ray emission in M31 and constraints on progenitors of Classical Novae'. The prize is awarded jointly by the institute and its former director, after whom it is named, to recognize originality, a large impact on science but also the quality of writing for a publication to which students themselves made substantial contributions.

The prize committee accorded the prize to him in appreciation of the comprehensive nature of his investigation, its novel approach and style of employing simple but physically justified analytical calculations. In his paper Ákos studied the appearance of the Andromeda galaxy in X-rays and demonstrates that three main components shape the X-ray surface brightness of the galaxy: numerous faint unresolved sources associated with an old stellar population, hot gas and protostars in star-forming regions, and a galactic scale wind that is driven by supernovae. Using these observations, he derived important constraints on the nature and properties of classical novae.

Public Outreach

The MPA engages with the wider public in many different ways. As every year, our scientists were involved in educational programmes for school teachers and presented public talks as well as lectures to school classes. They served as guides both for groups visiting the institute and at the temporary cosmology exhibition on the "Evolution of the Universe" at the Deutsches Museum, which has been jointly developed and financed by the MPA, MPE, ESO, MPP, and the Excellence Cluster for Fundamental Physics at the TUM and LMU during the International Year of Astronomy 2009. At the institute the scientists also supervised undergraduates and high school students on small research projects during internships, wrote articles for popular science media, and acted as interview partners for newspaper, radio and television journalists for both international and German national media.

On the **Girls' Day** in April MPA welcomed some 50 girls ages 12-16 to a day full with information about a career in astrophysics. The programme was organised jointly with the MPE and all available places were taken in just a couple of weeks. Women students and scientists gave lectures, presented the "cosmic cinema" in 3D, and discussed with the girls about a career in science, so they could learn about different aspects related to astronomy first hand (see also Figure 1.5). The Girls'Day is an initiative throughout Germany to encourage girls to learn more about occupational areas that are still male dominated and that girls consider only seldom when it comes to choosing a career path. And even if some girls probably participated because it amounted to a day out of the classroom, most of the group was very interested in the work of the female scientists.

In addition to regular science highlights on the

MPA webpages, the public outreach office issued a number of press releases about important scientific findings and milestones for the Planck and LOFAR projects, which were taken up by numerous (mainly online) media. This information was complemented by event announcements and news about prizes and awards for MPA scientists.

Figure 1.4: Rudolf Kippenhahn Prize ceremony: Former MPA-director Rudolf Kippenhahn presented Ákos Bogdan with the prize certificate.

Figure 1.5: During the Girls'Day, the girls could - among other activities - watch the Cosmic Cinema in 3D and observe the solar surface.

2 Scientific Highlights

2.1 14 billion years of cosmic history in one: Planck mission presents first results

From the start of the mission was very promising: Following 10 years of preparation, the Planck collaboration, which includes a team at the Max Planck Institute for Astrophysics, observed a textbook launch on May 14th, 2009. Later that summer as the satellite reached its operating position some 1.5 million kilometres outside the Earth's atmosphere, the moste sensitive instruments had been cooled down to their working temperature of in some cases only 0.1 degrees above absolute zero. This means that they are able not only to observe the 2.7 Kelvin emission of the very early universe, right after the Big Bang, but also to produce precise maps of its tiny temperature variations of just a few millionths of a degree. These temperature variations are the first indicators of all observable structure in the universe, stars, galaxies and galaxy clusters. Even though Planck can only look back to a time about 380 000 years after the Big Bang, from its data the scientists glean insights into the first few fractions of a second, when the cosmic structures were seeded, some 14 billion years ago.

Planck's primary aim is the measurement of these temperature fluctuations with unprecedented accuracy. Planck scans the sky at nine frequencies, ranging from high-frequency radio waves at 30 gigahertz (GHz) to the far infrared with 857 GHz. The scientists need this broad frequency range as Planck observes not only the primordial emission but also noise from galaxies. This interfering signal, however, has a different spectral distribution, which can be identified, measured and subtracted thanks to the multi-frequency measurements with Planck. While this foreground signal is an annoyance to cosmologists who want to look back to the cosmic nursery, for those stadying galaxies it provides valuable information.

The largest part of this foreground light comes from our own galaxy, the Milky Way (See Fig. 2.1). From within the galactic disk, we see the interstellar medium all around us, either due to the thermal radiation of dust clouds at high frequencies or due to the radio emission of electrons moving nearly with the speed of light in the galactic magnetic field.

So far, Planck has produced three complete scans of the whole sky, and therefore fulfilled its primary objective. However, since it continues to function perfectly, it will probably continue to provide data until 2012. The results gained from the first year of Planck data were first presented on January 11th, 2011 many of them based on the "Early Release Compact Source Catalogue" with some 15. 000 compact sources (see Fig. 2.2). The early release of this data enables scientists to arrange for detailed follow-up observations with other telescopes such as the Herschel space telescope that operates at similar wavelengths.

Along with the catalogue, 25 scientific papers were published with topics ranging from studies of individual objects in the catalogue and analyses of galactic emission to the first cosmological results on galaxy clusters and the light of early galaxies. Highlights of these papers include:

- confirmation of the galactic anomalous microwave radiation that is probably due to the fast rotation of small, electrically charged dust particles;
- a map of a dark gaseous component in our galaxy, only visible in microwaves;
- the precise measurement of 189 galaxy clusters and the discovery of 30 new galaxy clusters with the Sunyaev-Zeldovich effect, arising from the interaction of the cosmic background radiation with the hot gas (up to 100 million degrees) in the atmosphere of galaxy clusters (See Fig. 2.3);
- the first measurement of the theoretically predicted Suyaev-Zeldovich effect also in smaller galaxy clusters, which now allows for a nearly complete inventory of the previously invisible gas in the universe;
- a detailed measurement of the far infrared emission of all star forming galaxies in the universe (See Fig. 2.4). The scientists can now

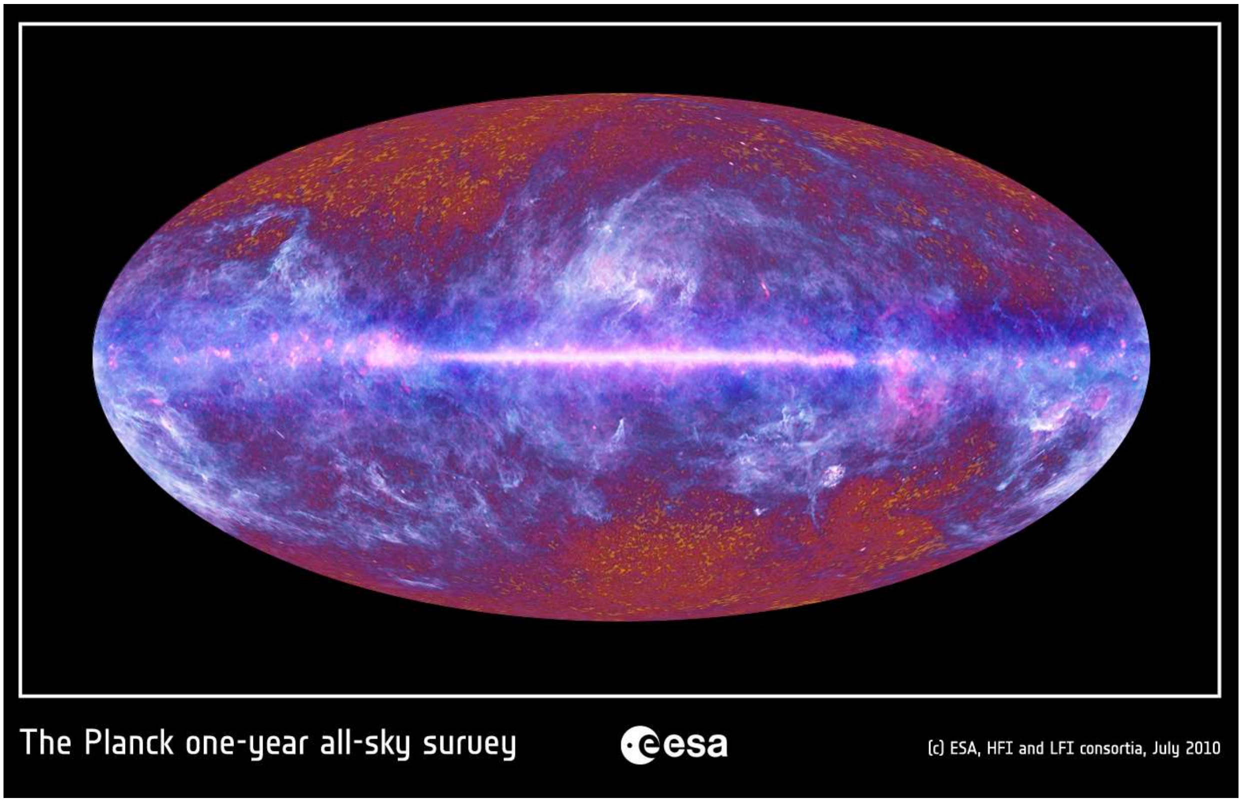

Figure 2.1: Planck image of the sky in microwaves. The dust emission of the Milky Way is visible as broad, horizontal band. Near the galactic north and south pole, at the top and bottom of this sky projection, the temperature variations of the cosmic background radiation are visible. With a detailed measurement and characterization of the galactic foreground emission, this signal can be subtracted from the map to reveal light from the early universe.
Image: ESA / Planck Collaboration

observe the history of galaxy formation, looking back to an epoch when the universe was only 2 billion years old, just one seventh of its present age.

The results presented at this Planck conference mainly cover the astrophysical by-products of the Planck mission. The data related to Planck's primary goal, the cosmic microwave background, and the resulting conclusions regarding the age, structure and composition of the universe as well as insights into its origin will probably be published in 2013. Until then, the noise signal from space as well as from the instruments has to be understood in more detail. The team at the Max Planck Institute for Astrophysics will contribute to this effort – their software for simulating and processing the data will continue to be in daily use. At the same time, others in the institute, in particular the Planck co-investigators Simon White and Rashid Sunyaev, (who predicted the Sunyaev-Zeldovich effect in 1969) as well as Torsten Enßlin, the head of the German contribution to Planck, and their groups, will help to increase the scientific gain of the mission.

2.2 The First Stars in the Universe

The first stars in the Universe, so-called Population III stars, formed a few hundred million years after the Big Bang in dark matter 'minihalos' with about one million solar masses. These early progenitors of more massive objects like the Milky Way confined the intergalactic gas within their gravitational potential wells, where it became dense enough to form molecular hydrogen – the simplest molecule in the Universe. The gas then cooled by activating the internal degrees of freedom of H_2 and underwent runaway collapse down

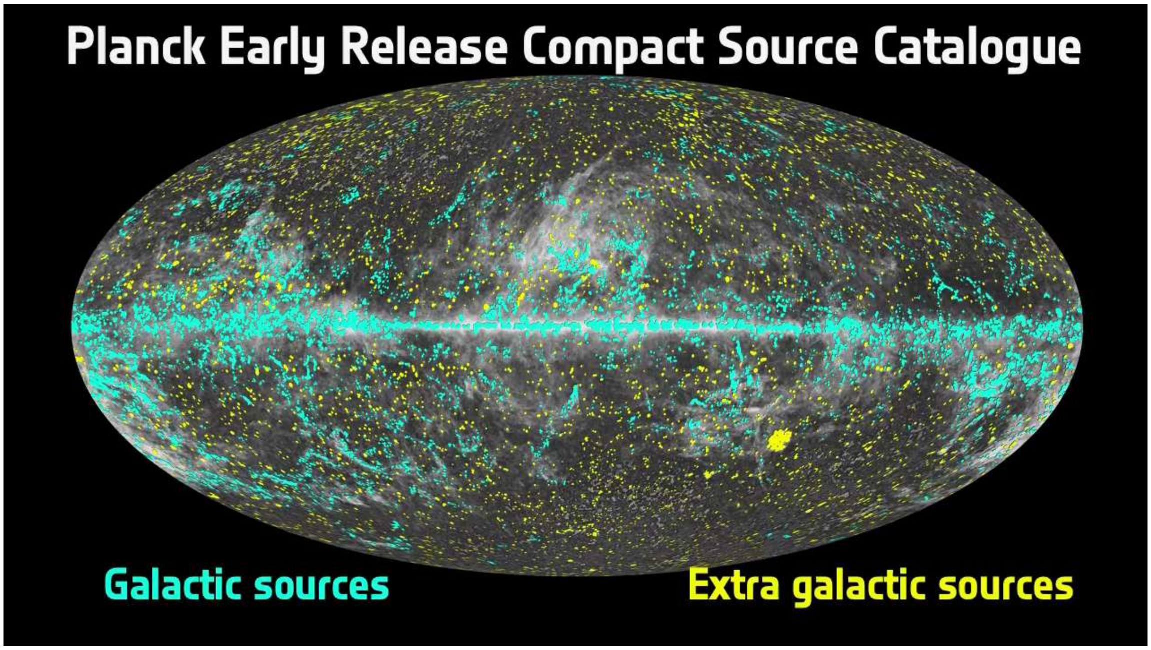

Figure 2.2: The 15 000 objects in the “Early Release Compact Source Catalogue”, where galactic objects – mainly compact dust clouds – are shown in green, and extragalactic objects – mainly radio galaxies and galaxies with a large thermal emission from dust – are shown in yellow. The larger yellow blob to the lower right is the Large Magellanic Cloud, a dwarf galaxy orbiting the Milky Way.

Image: ESA / Planck Collaboration

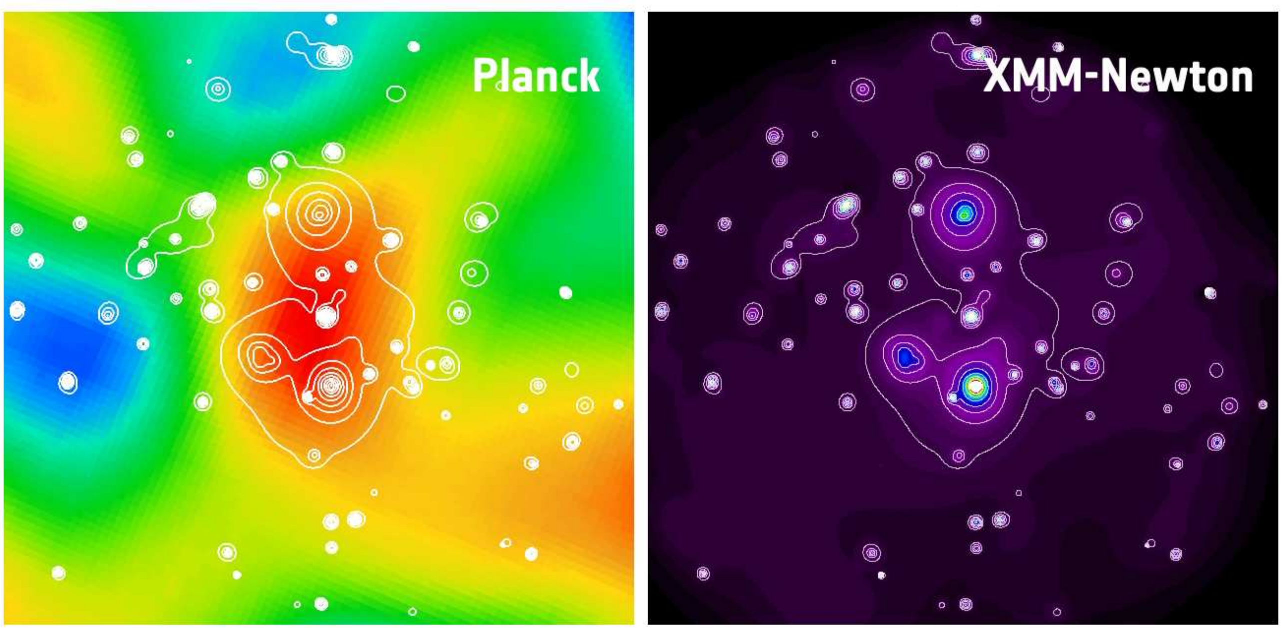

Figure 2.3: A galaxy super cluster discovered (using the Sunyaev-Zeldovich effect by PLANCK) (left) and its confirmation in X-ray emission of the hot gas in the galaxy cluster with the XMM-Newton X-ray telescope (right).

Image: ESA / Planck Collaboration

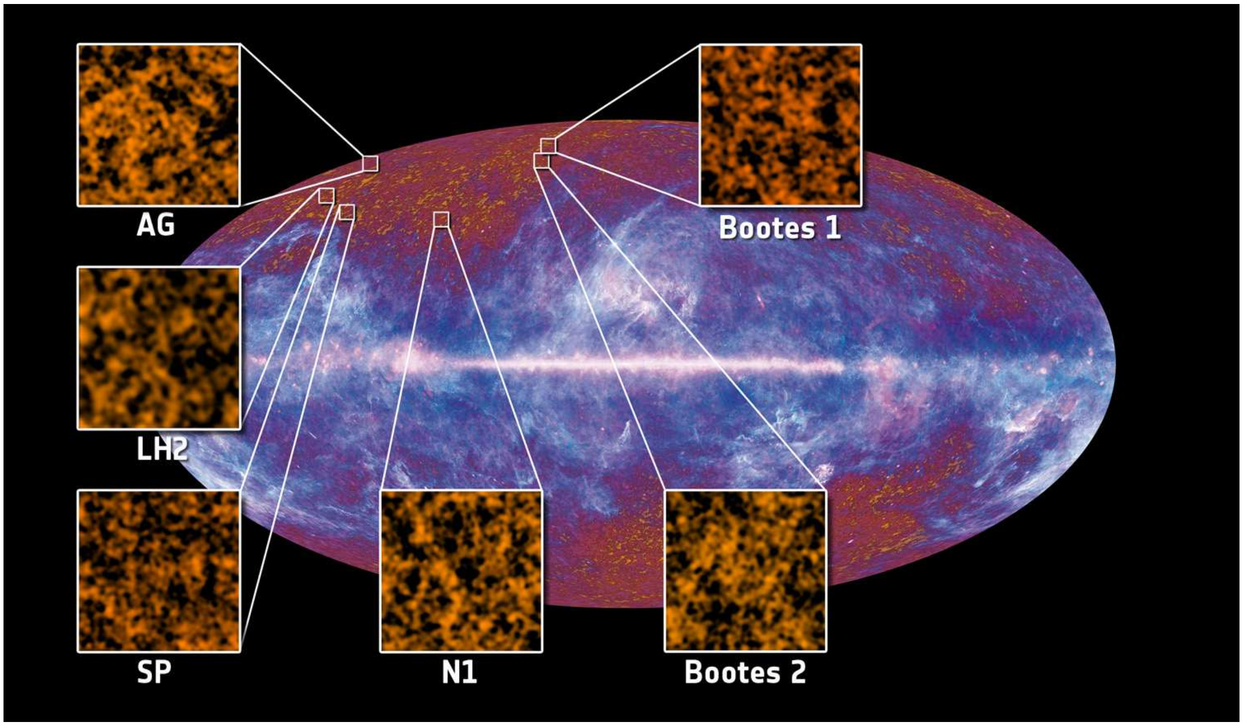

Figure 2.4: In the enlarged regions, the cosmic far infrared background was studied, as the galactic foreground emission there is weak. Each small image shows the grainy emission due to myriad contributing galaxies. In part this emission is from epochs when the universe was only 2 billion years old, its present age is about 14 billion years.

Image: ESA / Planck Collaboration

to parsec scales, followed by a second quasi-static collapse phase to extremely high densities, comparable to the density of the Sun. During the final stages of the collapse, a protostar with a thousandth of a solar mass formed and began to grow through further accretion.

Numerical simulations performed over the last decade have found little evidence for fragmentation during the initial collapse phase, indicating that the first stars formed in isolation. Assuming that all the mass of the surrounding envelope accreted onto the first protostar, simple one-dimensional calculations show that Population III stars will grow to about one hundred times the mass of the Sun. This extreme mass scale results in the emission of many more ionizing photons than is the case for normal stars, and could leave a distinct imprint on the 21 cm background and the reionization of the Universe. Furthermore, such massive stars give rise to extremely energetic supernova explosions, perhaps even to so-called pair-instability supernovae (PISNe), which disrupt the entire progenitor star and leave no compact remnant behind.

In recent work, a team of scientists from the MPA as well as from the Universities of Heidelberg and Texas have used a revolutionary new simulation technique to investigate the evolution of the gas beyond the formation of the first protostar (see Fig. 2.5). These simulations are the first scientific application of the moving mesh code AREPO to be submitted for publication. AREPO is a finite volume method that solves the Euler equations based on a piece-wise linear reconstruction of flow variables and on use of an exact Riemann solver to calculate hydrodynamical fluxes between cells. The cells themselves are an evolving Voronoi tessellation generated from a set of points which can be advected with the flow, making the mesh automatically adaptive in a Lagrangian fashion. The accuracy of mesh-based hydrodynamics is thus combined with the natural adaptivity and Galilean invariance usually associated with the smoothed particle hydrodynamics (SPH) technique. The simulations were augmented by a time-dependant primordial chemical network, as well as a prescription for the replacement of self-gravitating regions with

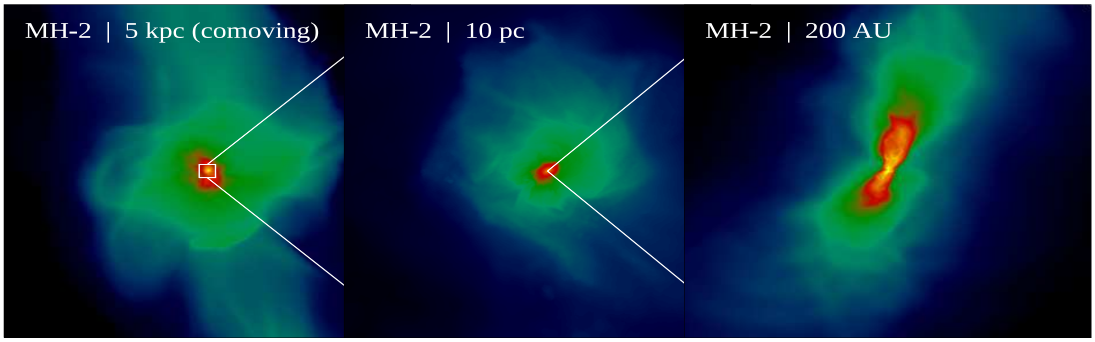

Figure 2.5: A zoom-in on the gas in one of the minihalos studied. The hydrogen density is color-coded from black (most underdense) to yellow (densest). The left panel shows the virialization of the minihalo on cosmological scales, followed by the runaway collapse of the central 10 pc, where the gas becomes self-gravitating and decouples from the dark matter (middle panel). In the final stages of the collapse, a fully molecular core with an extent of a few hundred AU forms (right panel). Taken together, this simulation spans more than twenty orders of magnitude in density.

point masses, termed sink particles.

In these AREPO simulations, as the protostellar gas reaches the highest densities, it becomes rotationally supported in a disk in which spiral structure transfers angular momentum outward, thus allowing accretion onto the central object (see Fig. 2.6). However, after a few tens of years, accretion onto the disk raises its mass so that it becomes gravitationally unstable, fragmenting into a handful of protostars. After this initial burst of star formation, the gas again becomes gravitationally unstable several times, forming new protostars over the entire duration of the simulations. After only 1000 years, a small cluster with about 10 protostars has formed in all the minihalos studied. The masses of the protostars range from 0.1 to $10\,\mathrm{M}_\odot$ with a relatively flat mass function, indicating that most of the mass is locked up in high-mass protostars (see Fig. 2.7).

Although the simulations are terminated well before the protostars have grown to their final masses, they suggest a very different picture of primordial star formation. Instead of forming a single object, the gas in minihalos fragments vigorously into a number of protostars with a range of masses. It is an open question as to how this early mass function will be mapped into the final mass function of Population III, after accretion, fragmentation and merging have finally stopped. However, if a flat, broad mass function persists, a number of lower-mass Population III stars will have formed which will survive to the present day if their mass remains below $\sim 0.8\,M_\odot$. Although this possibility is speculative because of uncertainties in the treatment of sink particles and the fact that we follow the protostellar accretion only for the first 1000 out of 10^5 or 10^6 yr, it is worth noting that such Population III fossils might be found in ongoing and planned large surveys of metal-poor stars in the Milky Way.

Furthermore, the presence and mutual competition of multiple accretors in a given minihalo will act to limit the growth of the most massive objects. Population III stars are therefore less likely to reach masses in excess of $\sim 140\,\mathrm{M}_\odot$, the threshold for triggering extremely energetic PISNe. A reduced PISN rate is more easily compatible with the absence of their distinct nucleosynthetic signature in any of the extremely metal-poor halo stars observed so far. Population III stars could still have given rise to numerous extremely luminous supernova explosions, if they had masses of a few tens of $\mathrm{M}_\odot$ and if they were rapid rotators, as suggested by recent studies. They would then have exploded as core-collapse hypernovae, with explosion energies similar to those of PISNe. Our results may also challenge models of so-called 'dark stars', which are Population III stars powered by dark matter self-annihilation heating. These models invoke an increased DM interaction rate at the center of the Population III star which itself lies at rest at the center of its minihalo. The complex dynamics of a protostellar cluster at the center of the minihalo may preclude such efficient DM capture and heating.

In a second application of AREPO, we investigated the implications of a recently discovered mismatch between the dark matter and baryon velocities predicted by the linear theory of structure growth up until recombination. The residual velocity offset at the time of first star formation is a few km/s, which is comparable to the sound speed of the gas. This offset acts like an addi-

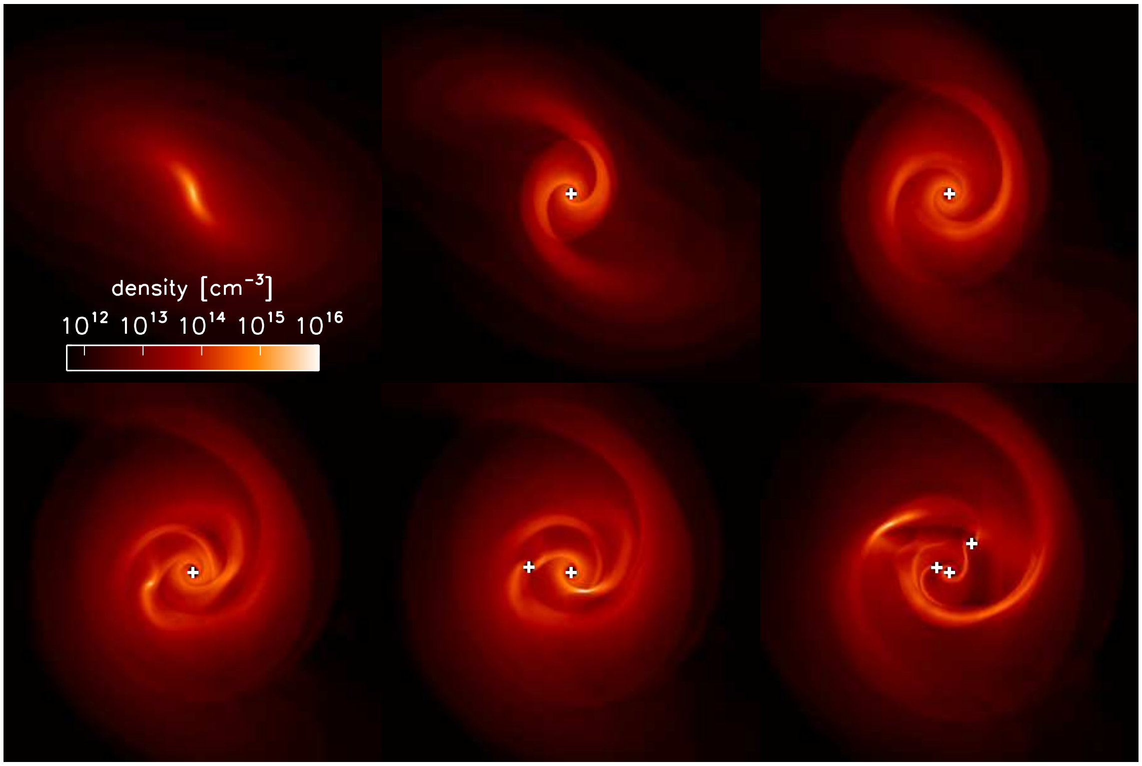

Figure 2.6: Density evolution in a 120 AU region around the first protostar in a minihalo, showing the build-up of the protostellar disk and its eventual fragmentation. We also see 'wakes' in the low-density regions, produced by the previous passage of the spiral arms.

tional source of pressure that increases the Jeans mass of the gas (see Fig. 2.8). Our simulations show that in regions where the offset takes its *rms* value, the halo mass required for runaway collapse is increased by a factor of $\simeq 3$. This delays the onset of star formation in minihalos by $\Delta z \simeq 4$. Since offset velocities are Maxwellian distributed with a spatial coherence length corresponding to many Mpc in the present universe, the formation of the first stars is expected to be modulated on large scales. This modulation might be inherited by the distribution of more massive objects forming at later times, thereby biasing large-scale structure estimates of cosmological parameters such as those related to the properties of Dark Energy. (Thomas Greif, Volker Springel, Simon White, Paul Clark, Simon Glover, Rowan Smith, Ralf Klessen, Volker Bromm). *For further details, see Greif et al., ApJ, 2011a, b; Clark et al., Science, 2011; Smith et al., MNRAS, 2011.*

2.3 What is the Matter with Dwarf Galaxies?

Dwarf galaxies are the most numerous galaxies in our Universe, and our Milky Way is surrounded by dozens of them. While dwarfs come in different shapes and sizes, they have one thing in common. Most of their mass seems to be contributed not by the stars and gas we can see, but by so-called dark matter, identified only through its gravitational pull. Confirmation of a direct detection of dark matter is still eagerly awaited since it appears to have played a crucial role in the formation of structure in the Universe. As part of his PhD thesis MPA student Till Sawala has carried out computer simulations of the formation and evolution of dwarf galaxies, which challenge present assumptions about the nature of dark matter.

In the current picture of galaxy formation, dark matter collapses into so-called haloes, within which galaxies condense and evolve. The distribution of galaxies is thus expected to follow the distribution of dark matter closely. By matching a model of the dark matter distribution to the observed dis-

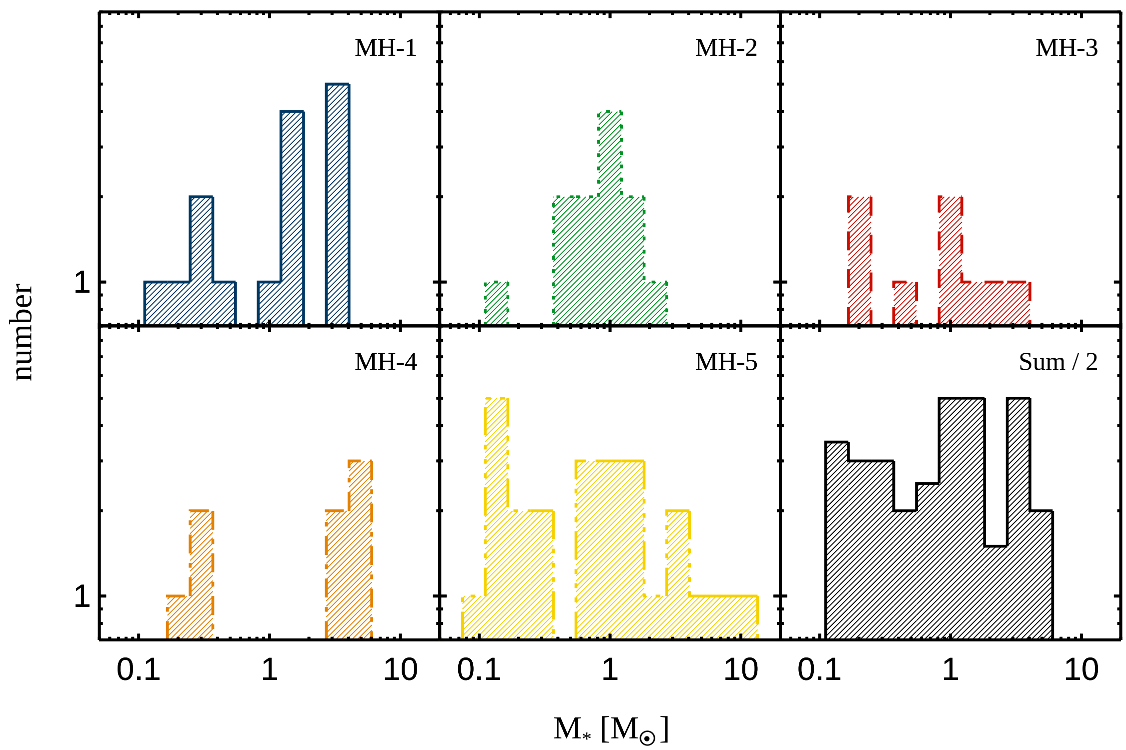

Figure 2.7: The protostellar mass function obtained in all five minihalos after 1000 years of continued fragmentation and accretion. A small cluster of protostars has formed in every case. In the bottom right panel, we also show the cumulative mass function obtained by summing up the contributions from the individual minihalos, and renormalized for better visibility. The resulting distribution is relatively flat between ~ 0.1 and $\sim 10\,M_\odot$, which shows that most of the mass is locked up in high-mass protostars.

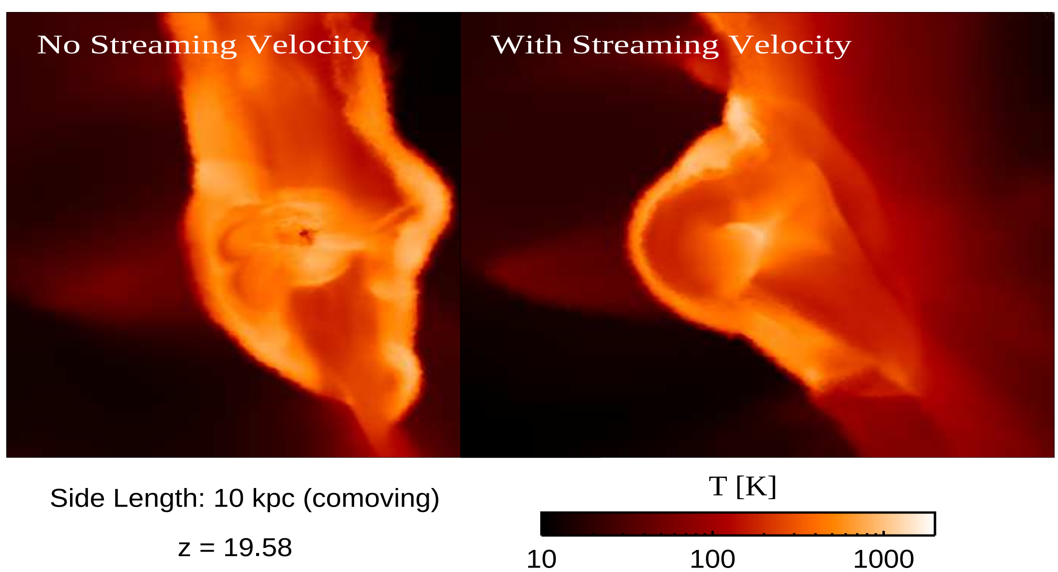

Figure 2.8: Comparison of the virialization of a cosmological minihalo in the absence of streaming velocities (left panel), and with an initial streaming velocity of $3\,\mathrm{km\,s^{-1}}$ at $z = 99$ (right panel, gas moves from left to right). In the left panel, the gas at the center of the halo has become dense enough to cool, while in the right panel this has been prevented due to the additional energy input by gas streaming into the halo with a velocity comparable to the sound speed of the gas.

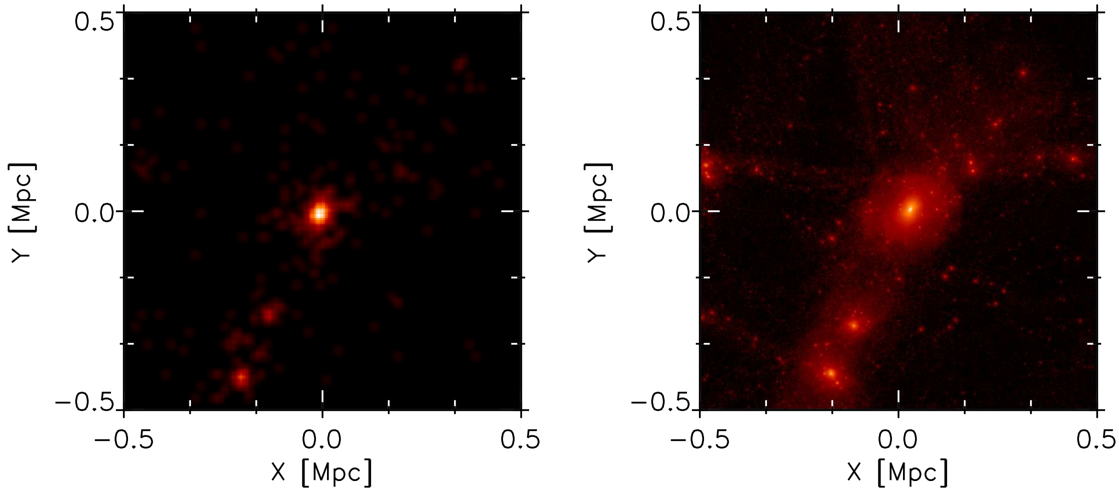

Figure 2.9: A slice through the Millennium-II Simulation (left) and through the resimulation (right), centered on the halo of a dwarf galaxy. Its location and mass are identical between the two simulations. The increased resolution of the resimulation compared to the parent simulation also reveals additional structure.

tribution of galaxies, one can deduce the law which determines which galaxies form in which haloes.

To understand the formation of individual galaxies in detail, high resolution computer simulations are needed, which attempt to follow all the relevant astrophysical processes. Till Sawala and his co-authors selected six Dark Matter haloes with different formation histories from the "Millennium-II" simulation, a high resolution representation of the growth of dark matter structure in the current standard Cold Dark Matter model, and carried out detailed re-simulations at very high resolution. All six haloes grow to a mass about 10 billion times that of the Sun, corresponding to a central dwarf galaxy containing about one million stars, according to the statistical "law" mentioned above. The simulations produced galaxies with stellar masses 50 to 100 times larger, however, pointing to serious problems with the simulations themselves or with the assumptions underlying the standard picture (See Fig. 2.9).

Comparing the selected haloes to others in the Millennium-II Simulation showed that they are indeed representative, so that the discrepancy in stellar mass is not due to peculiarities of the systems simulated. It must reflect a real disagreement between the virtual world simulated and the real world we observe.

Three explanations could resolve this discrepancy. The observational picture could be incomplete, and there could be many more dwarf galaxies than are found in our current surveys. Alternatively, the abundance of dark matter haloes could be lower than predicted by the Cold Dark Matter model, so that lower mass haloes would have to host the observed galaxies. Finally, if both the dwarf galaxy count and the Cold Dark Matter model are correct, then we must conclude that current simulations over-predict the real star formation rates in dwarf galaxies by more than a factor of 10.

All three of these possible solutions would have far-reaching consequences, if correct. Current observational counts of galaxies are claimed to be sufficiently complete and their incompleteness to be well enough understood that an explanation of the discrepancy is not possible without overturning our observational picture of the nearby Universe.

Possible alternatives to Cold Dark Matter are obtained by changing assumptions about the nature of the dark matter particle. Sawala and his colleagues showed that their simulations could match the stellar mass - halo mass relation expected in a Warm Dark Matter universe where less structure forms on small scales. However, full consistency seems to require structure suppression at a level which is inconsistent other observations, in particuar with the small-scale structure observed in high-redshift intergalactic gqas through the absorption it causes in the spectra of background quasars.

If the observed count of dwarf galaxies is in-

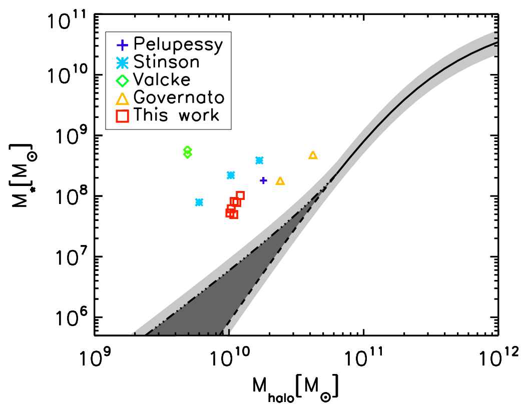

Figure 2.10: This plot compares the predicted relation between stellar mass and halo mass (black curve) and the simulations of individual dwarf galaxies (coloured symbols). The grey area shows the maximum uncertainty from observations. The results from the new simulations are shown as red squares; other symbols show results of previous studies.

deed complete, and the Cold Dark Matter model correctly predicts the abundance of haloes, then the simulations must be wrong about the efficiency with which stars are formed. All published simulations predict similar efficiencies despite different assumptions and simulation methods, so this problem is unlikely to be due to numerical problems. A more likely explanation is that some important physical process is responsible for inhibiting star formation in real galaxies, but has not yet been included in simulations.

Only one thing appears certain. Current censuses of dwarf galaxies, the standard Cold Dark Matter picture for structure formation, and current simulations of the galaxy formation process cannot all be correct. Some aspect of our standard picture needs major revision.
(Till Sawala and Simon White)

2.4 Observational Studies of Gas in Galaxies at MPA

An international team of astronomers [Key members: Barbara Catinella (MPA), Silvia Fabello (MPA), Reinhard Genzel (MPE), Tim Heckman (JHU), Guinevere Kauffmann (MPA), Carsten Kramer (IRAM), Sean Moran (JHU), Amelie Saintonge (MPE), David Schiminovich (Columbia University), Linda Tacconi (MPE), Jing Wang (MPA)] have been carrying out two ambitious surveys (GASS and COLD GASS) to measure the atomic and molecular gas content of around 1000 galaxies with stellar masses greater than $10^{10} M_\odot$ using two of the largest radio telescopes in the world. The results of this programme will yield precious insight into how the interplay between gas and star formation shapes the evolution of galaxies in the local Universe.

Galaxies are well known to divide into two large families: red, old ellipticals and blue, star-forming spirals. While this distinction has been known for a long time, recent work based on the Sloan Digital Sky Survey (SDSS) has shown that in the local Universe, the division into these two large families occurs abruptly at a particular mass and density. Theoreticians have postulated a diverse set of mechanisms to explain the characteristic scales evident in the galaxy population. Most of these mechanisms involve processes that either eject substantial amounts of gas from the galaxy (often referred to as "quenching"), or that regulate the rate at which gas is able to accrete onto the galaxy from its external environment.

The aim of the surveys being carried out by the MPA/MPE groups is to gain new insight into the physical processes that regulate the present-day growth of galaxies with stellar masses greater than $10^{10} M_\odot$ by surveying their gas content. Neutral hydrogen (HI) is the source of material that will *eventually* form stars; it thus may represent a key ingredient in understanding the rate at which galaxies are gaining mass by accretion. The molecular gas, as traced by Carbon Monoxide (CO) emission, probes "birth clouds" in which stars are currently forming. By studying the interplay between atomic gas, molecular gas and young stars, one hopes to gain insight into internally-driven processes that regulate the conversion of gas to stars in galaxies (see Figure 2.12).

In order to understand how such processes operate across the galaxy population as a whole, one requires large, *unbiased* samples of galaxies. The galaxies in the GASS and COLD GASS surveys have been selected from the SDSS. The survey was one of the most ambitious optical surveys of the sky ever undertaken. Over 8 years of operation, it obtained multi-color images covering more than a quarter of the sky and created 3-dimensional maps containing around a million galaxies.

The data obtained by the SDSS provide a wealth of information about stellar content of nearby galaxies. Multi-colour images yield information about stellar ages and masses, while the emission and absorption lines in the spectra allow astronomers to derive estimates of metallicities and

Figure 2.11: Four observational facilities the form the cornerstones of the GASS project: a) the Arecibo radio telescope (top left), b)The Galaxy Evolution Explorer (GALEX) satellite (top right), c) The IRAM 30m radio-mm telescope at Pico Veleta (bottom left), d) The Sloan Digital Sky Survey telescope at Apache Point, New Mexico (bottom right).

star formation rates, and to assess whether or not material was accreting onto central supermassive black holes. Although this data provided a wealth of new information about stellar populations in nearby galaxies, lack of information about the associated gas has prevented real progress in disentangling accretion and quenching processes.

GASS probes the relationship between stars (*(http://www.mpa-garching.mpg.de/GASS)*) and gas by linking SDSS observations (which probe the visible light from galaxies), with those from the space-based Galaxy Evolution Explorer satellite (which probes light from the youngest stars) and from Arecibo and IRAM, two of the large radio telescope in the world (see Fig. 2.11). The Arecibo observations started in 2008 and are on-going. A thousand targets will be observed until they are detected or an HI gas mass fraction limit of few percent is reached. A subset of these targets are being followed up by the IRAM 30m telescope in Granada, Spain, in order to measure molecular gas mass fractions down to the same limit (see *http://www.mpa-garching.mpg.de/COLD_GASS/)*.

The two surveys have already yielded a number of interesting new results, which have been written up in a series of 9 papers. One of the first striking results was that HI gas fraction can be predicted accurately from two optically-derived parameters. The HI fraction increases in proportion to color/star formation rate, but it also decreases as a function of stellar density (Catinella et al. 2010).

Disk galaxies are believed to form from gas that cools within massive dark matter halos. As gas cools, it loses pressure support and falls to the center of the halo until it becomes rotationally supported. The smaller the initial angular momentum of the gas, the more it contracts. Because the star formation rate in a galaxy increases in proportion to the density of the gas in its interstellar medium, denser galaxies use up their available fuel quickly and become gas-poor. Red, high density galaxies are thus expected to have low HI fractions, as observed.

Although the majority of galaxies in the sample lie on a tight “plane” defined by color and density, around 10% of the sample deviate significantly in having higher HI content than inferred from their optical properties. These unusually gas-rich galax-

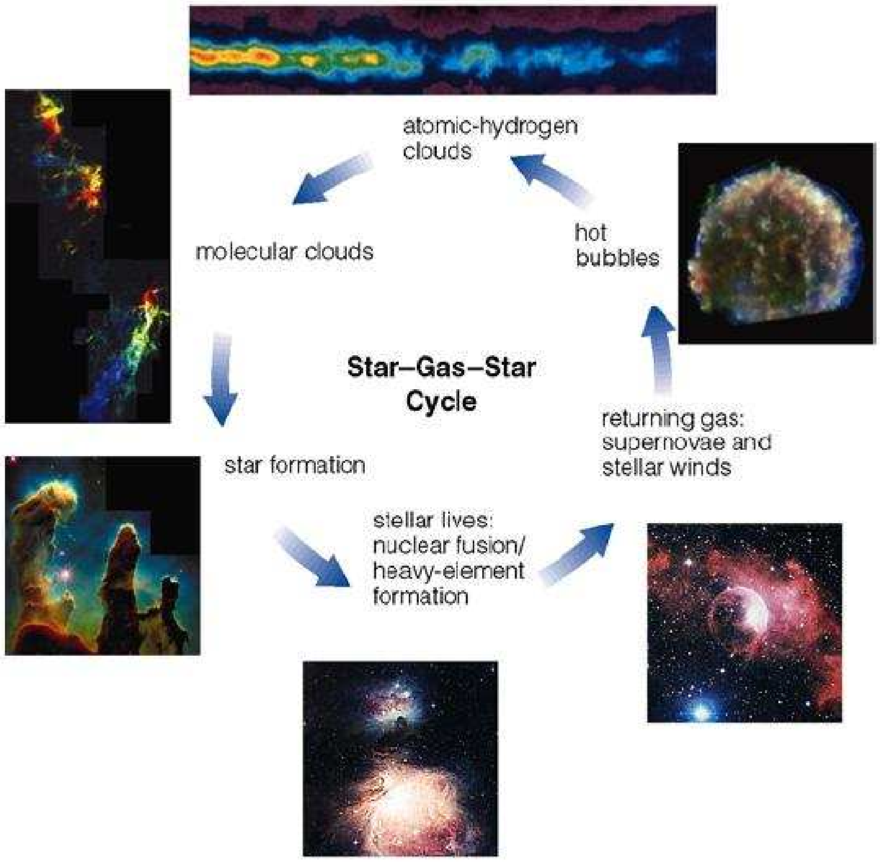

Figure 2.12: The star-gas-star cycle in galaxies.

ies are of considerable interest, because they may have recently accreted HI from their surroundings. GASS team members have carried out extensive investigations of the properties of these objects. One interesting finding is that unusually HI-rich galaxies have unusually blue *outer* disks (Wang et al. 2011).

Follow-up long slit spectroscopy on the Multi-Mirror Telescope in Arizona reveals that the blue outer disks harbour young ($<$ 1 Gyr), metal-poor stellar populations (Moran et al. 2010) (see Fig. 2.13). This lends credence to the idea that present-day disk galaxies are forming from the "inside out". According to theory, high angular momentum gas accretes later than low angular momentum gas. Although this paradigm has commonly served as the basis of semi-analytic models of the formation of disks in the context of Cold Dark Matter cosmologies, this is the first time that direct supporting evidence has been found.

Unusually HI rich galaxies have regular rotation curves and light profiles that are symmetric. Their star formation rates are on average no higher than similar galaxies without excess gas (Schiminovich et al. 2010). This suggests that most of the gas is accreted smoothly, and not in the form of condensed satellites, which would strongly perturb the disk, drive gas into the central regions of the galaxy and result in "bursts" of star formation. In normal spirals, HI gas in the outer disks is probably transported inwards over timescales of many Gyrs. As gas flows inwards, its density increases until the ultraviolet radiation produced by young stars is no longer able to penetrate into the densest regions. These are the conditions under which H_2 molecules begin to assemble, leading to the formation of giant molecular cloud complexes, which are the nurseries in which stars are born.

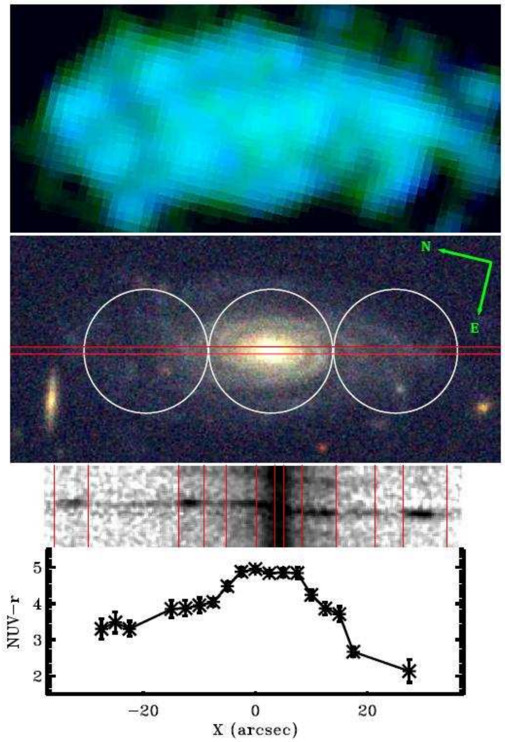

Figure 2.13: An example of a galaxy with very high HI content and a young, blue outer disk. The top image shows the galaxy in ultraviolet light as imaged by GALEX, the image below shows the galaxy in optical light as imaged by the SDSS telescope, and the bottom panel shows the UV/optical colour profile of the galaxy. This galaxy contains more than $10^{10} M_\odot$ of HI gas, comparable to its total mass in stars.

Are the stellar nurseries of all galaxies alike? What is the fraction of the available molecular gas that is turned into stars before the birth cloud is destroyed by energetic output from hot young stars in the form of radiation and outflows? Does this fraction differ from galaxy to galaxy in the local Universe, and was it different in galaxies in the early Universe? These are some of the most topical questions facing astrophysicists who attempt to understand the physical processes that regulate the rate at which galaxies form their stars.

Recent results from the COLD GASS survey indicate that the molecular gas depletion time (defined as the time taken for a galaxy to exhaust its supply of molecular gas at its current rate of star formation) may not be constant, but may vary systematically from one galaxy to another (Saintonge et al 2011). More actively star forming galaxies harbour molecular clouds in which star formation is more efficient. For many years, this was understood to apply only to the most extreme starbursting galaxies known, the so-called Luminous Infrared Galaxy population. Most of these galaxies exhibit signs of recent or continuing interactions. It was thus hypothesized that their interstellar medium properties could be quite different from those of quiescent spirals like our own Milky Way. The COLD GASS results now link these two populations by showing that molecular gas depletion times vary smoothly as gas surface density and star formation increase.

The main fascination of galaxies since the time of Edwin Hubble has been the intricately interwoven system of correlations or "scaling laws" that relate properties such as mass, size, age and metallicity to each other. The GASS and COLD GASS surveys are currently extending this knowledge to the *global* interplay between gas and stars in nearby galaxies. The challenge for the future will be to link phenomena that operate on vastly different physical scales: from the dense cores of molecular clouds to the diffuse ionized gas between galaxies. Meeting this challenge will undoubtedly require new technologies and new surveys. Our experience in the construction of GASS and COLD GASS has prepared us well for many new discoveries to come! (Guinevere Kauffmann, Barbara Catinella and Amelie Saintonge)

2.5 Exploring the history of the Milky Way

In a clear night the spectacular band of the Milky Way stretches over the whole sky. As we are sitting right in its disc the Galaxy has not only earned special interest to explore the history of our home, but it offers the by far most ample data to understand the history and dynamics of spiral galaxies in general. A team of scientists at the Max Planck Institute for Astrophysics devotes its work to simultaneously elaborate our models of the Galaxy and gather more data to constrain them. The group around Martin Asplund, Luca Casagrande and Ralph Schönrich has now re-analysed the light from 16,000 stars in the solar neighbourhood. Their study showed in particular that the stars in the so-called thick disc, whose orbits protrude farther from the galactic plane, can naturally be explained as immigrants from the inner galactic disc.

Stars are both drivers of the evolution of our Galaxy and witnesses of its past. At their centres, during most of their life they burn hydrogen and helium via nuclear fusion reactions into heav-

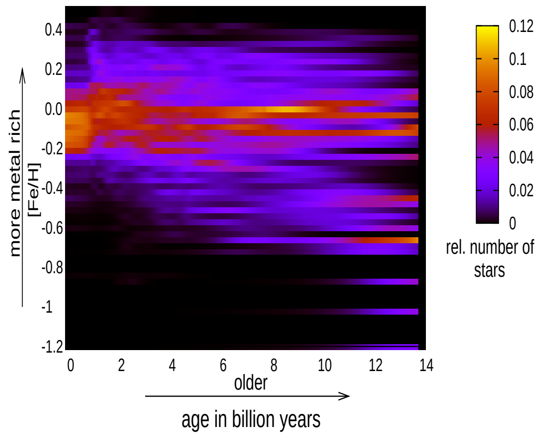

Figure 2.14: The relationship between age and metal content [Fe/H] for the stars in our sample, where the colour coding indicates the number of stars. The peak of the metallicity distribution hardly shifts with age, but the width of the distribution increases significantly. This signature can be ascribed to radial migration.

ier elements, which astronomers broadly refer to as metals. The most massive stars burn their nuclear fuel very quickly on a cosmic timescale: they live only millions of years, while our Galactic disk already exists for about 10 billion years. During their violent death they expel most of their nuclear processed products. These mix with the pristine gas clouds, from which new stars are continuously being formed, and enrich them with metals. Stars with masses similar to our Sun act as witnesses to this history: a star's outer layer hardly mixes with the material at their cores and so the stellar atmosphere largely reflects the chemical composition of the gas from which the star was formed. Their longer lifetimes, of the order of several billions of years, make them fossils of early cosmic epochs.

The enrichment of the star-forming interstellar gas is not a sudden process, metals will accumulate with time. Moreover, the relative composition of the metals changes: very old stars, i.e. stars that have been born during the youth of our Galactic disk, carry a surplus of so called "alpha elements" compared to iron. These alpha elements are multiples of helium nuclei such as oxygen, magnesium, silicon and calcium. The ratio of alpha elements to iron serves as a natural time indicator hinting at when a star was born. Not only time affects the ingredients of a star, but also geography that thus helps to follow up the origin of an object: There is an abundance gradient within the Galaxy. The star forming gas in the dense inner disk develops more quickly and is more metal rich than in the outskirts, and so the metal content of a star is linked to where it was born. Until recently, it was thought that nearby stars could be regarded as a book from which to read the local history of star formation and enrichment. This information alone is, however, not enough to fully characterize the history of the Milky Way disk: as shown by researchers at MPA and James Binney (University of Oxford), stars migrate heavily within the disk. They do not orbit around the centre of the Galaxy with a roughly constant radius but can shift both further-in and further-out with time, making the chemical signature very difficult to interpret. Stars found today in the solar neighbourhood did not necessarily form there; they can be immigrants from other regions of the disk.

Taking migration of stars into account greatly modifies the interpretation of the history of the Milky Way. The xenophobic view without migration needs to invoke catastrophic happenings in the Galactic history, such as the impact of a smaller galaxy or at least a period when star formation almost completely ceased. In contrast, the new models with migration explain observations with a quite calm and simple Galactic history. The two models also imply very different relationships between the age of the stars and their metal content ("metallicity"): the classical perspective needs a pronounced change in the local metal content over time to build up the observed broad distribution of metallicities in the solar vicinity. The migration models do not require this as diversity is imported with the immigrants. So, while the classical perspective demands a strong evolution of the metal content over time, i.e. a significantly lower metallicity for older stars, combined with no significant development of the width of the metallicity distribution, our new models can allow for a nearly constant average metal content over large spans of time, but predict instead an increased spread of metallicity with age.

Exactly this prediction could now be confirmed on the new data. As can be seen from Figure 2.14, the peak of the metallicity distribution hardly moves with age of the objects, but the width of the distribution increases. This is in conflict with the classical view, while it is naturally explained in the radial migration model. For this the MPA scientists embarked upon a revision of the stellar

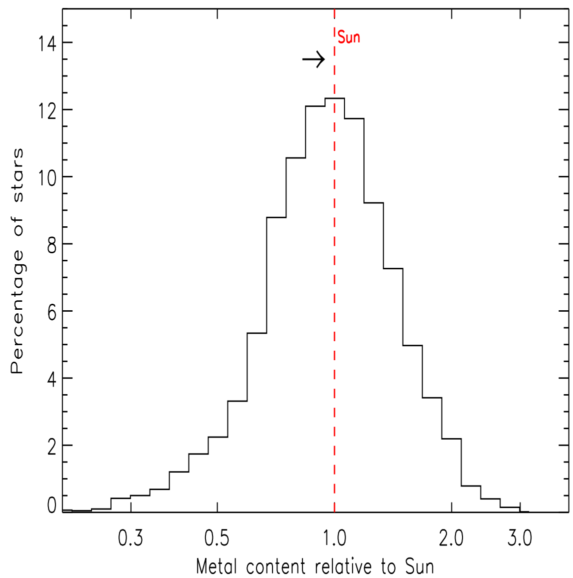

Figure 2.15: Metallicity distribution of stars relative to the Sun. The black arrow indicates the shift of the sample mean compared to older determinations. Here the peak coincides almost exactly with the metal content of the Sun.

parameters in the Geneva-Copenhagen survey, the most comprehensive catalogue of the solar neighbourhood, containing some 16,000 stars. Most commonly the metal content of stars is derived by studying the stellar spectra and comparing them with model spectra. As this approach is very time-consuming it is not feasible when dealing with thousands of stars. Some abundance information can, however, be retrieved directly from colours: just as tiny amounts of dye can colour wine red, the presence of metals in a stellar atmosphere alters the star's colours. Using an improved scheme to derive stellar physical parameters from colours, the researchers at MPA have shown that the average metallicity of stars in the vicinity of the Sun is higher than previously thought, thus making the Sun a more common object (see Fig. 2.15).

The model developed at MPA and the University of Oxford is the first analytical model that can relate chemical information to the motions of stars. The explanations for observed relationships are easy and straightforward in this model, while classical models fail to explain them. Further correlations can be predicted, such as the mean rotational velocity in the solar neighbourhood as shown in Figure 2.16. The mixing is not complete, i.e. stars get scattered around in the Galaxy, but some information, e.g. in rotational velocity, on their origin still remains in the concerned populations. Old stars with a content of alpha-elements are at the top, young stars at the bottom. Superimposed on this distribution is the velocity information: stars from the inner disk rotate more slowly (blue) and are less metal rich (right) than stars from the outer disk. This prediction was confirmed by observational data for young stars (the predictions for old stars are more complex).

This bears an interesting side effect: An important value in Galactic kinematics is the relative motion of our Sun through the Galactic disk (the local standard of rest), which must be determined by the motions of the surrounding stars. Understanding these trends between metallicity and kinematics in addition to having created better tools for understanding data selection effects an international research group led by MPA could detect a significant systematic error in the standard determination of solar motion. The new value also reduces the tension between the accepted local standard of rest with other measurements of our Galaxy. To further discriminate the new model from the classical view and to improve our understanding of the mixing process in the disk, more information is required. As noted above, the amount of alpha element is related to the age of a star. The MPA astronomers have been able for the first time to estimate the content of alpha elements from colours. Thus they could explore the subtle links between the detailed chemistry and the movements of stars in the Galaxy with an unprecedented large sample.

Excitingly, the new radial migration model also provides a natural explanation for the so called thick disk, a puffed up stellar population in the disk. Rather than postulating a cosmic collision between the Milky Way and another galaxy as in the classical view, the migration model explains its existence with the immigration of relatively old stars from the inner Galactic disk. In most definitions, stars with slow rotation are predominantly ascribed to this thick disk, which is linked to the stars' origin in the inner disk, while stars with higher rotation velocity are linked to an origin from the outer, more metal poor disk (see Figure 2.17). The slowly rotating stars clearly have a higher average content in alpha elements, which points to their higher age. At the same time, they are also more metal rich than the fast rotating population. This again points to a problem in the classical picture without migration. (Ralph Schönrich)

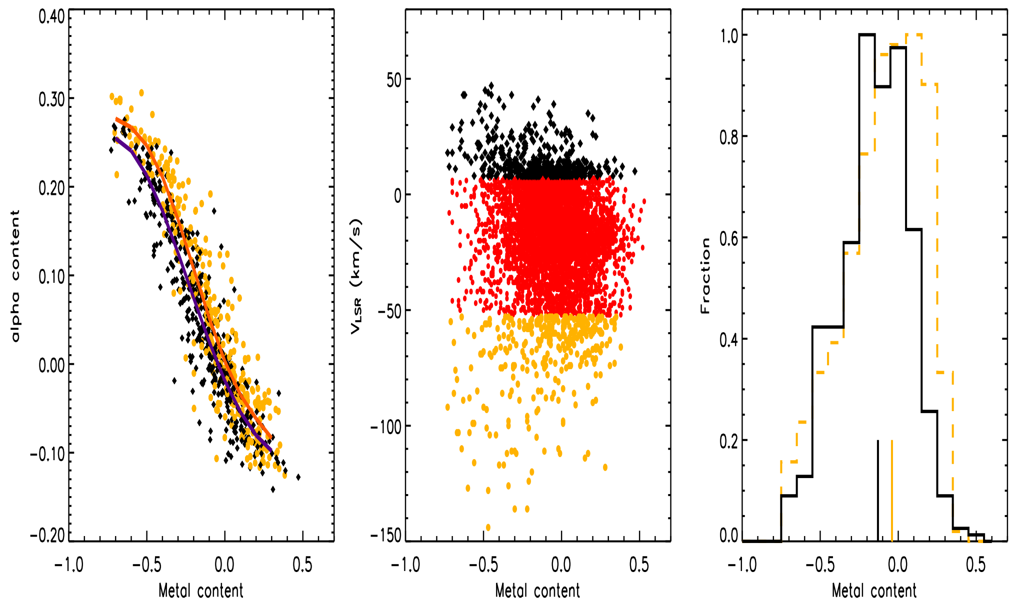

Figure 2.17: These plots show various properties versus metal content. In the central panel, stars are selected that have higher (black) or lower (yellow) rotational velocity relative to the Sun (v = 232 km/s). The left panel shows the amount alpha elements for slow stars (yellow) and fast stars (black), the coloured lines show the mean trends of both populations. Slower stars (the "thick disk") have a higher abundance in alpha elements, which points to a higher age. The right panel shows the distribution of metal content in the slow (yellow) and fast (black) stars; slow stars have a higher metal content on average. In contrast to the classical belief, where older and thick disk stars should be more metal poor, this can naturally be explained in the migration model.

2.6 Solving the mystery of the Sun's low lithium abundanc

Lithium is an enormously important element in astronomy and cosmology. This stems partly from it being a very fragile element that can easily be destroyed in stellar interiors by proton capture reactions if the temperature is high enough. Thus if lithium is transported from the surface to deeper lying hotter regions through convection or other mixing processes, the atmospheric Li abundance will decrease with time. Our own Sun must have destroyed most of its Li over its 4.5 billion year lifetime since the solar surface Li abundance today is only 1% of what is measured in the most pristine meteorites. Also the Sun has a lower Li content than is observed in many solar-type stars in the solar neighborhood. There has been a long-standing but as yet unresolved debate whether the Sun's Li abundance is unusual compared with stars of otherwise identical properties.

Furthermore, standard models of the Sun's evolution does not predict any significant Li destruction since the convection zone is predicted not to extend deep enough into the solar interior for Li burning to take place. Thus there must be an extra mixing below the convection zone but the physical process(es) responsible for this has not yet been identified. Given the large spread (factor of >100) in Li abundances in stars in the solar neighborhood, this mixing and corresponding Li destruction likely depend sensitively on the exact properties of the star, such as the age, mass, effective temperature, surface gravity and metallicity.

Recently, the issue of the Li content of solar-type stars received renewed attention as a Spanish research group led by Garik Israelian claimed in an article in Nature that stars with planets tend to have less Li than stars without a confirmed planetary companion. Thus they argued that the presence of planets can somehow influence the amount of Li destruction in the stars. If confirmed this would open the intriguing possibility of identifying stars likely to host planets solely from determining the stellar Li content, a vastly easier undertaking than painstakingly observing stars over time to look for tiny variations in their motion or brightness indicating the presence of an orbiting planet.

The low solar Li abundance, the Spanish group argued, is a consequence of the Sun having planets. A team of astronomers at the MPA (Patrick Baumann, Ivan Ramirez, Martin Asplund, and Karin Lind) together with Jorge Melendez from the Uni-

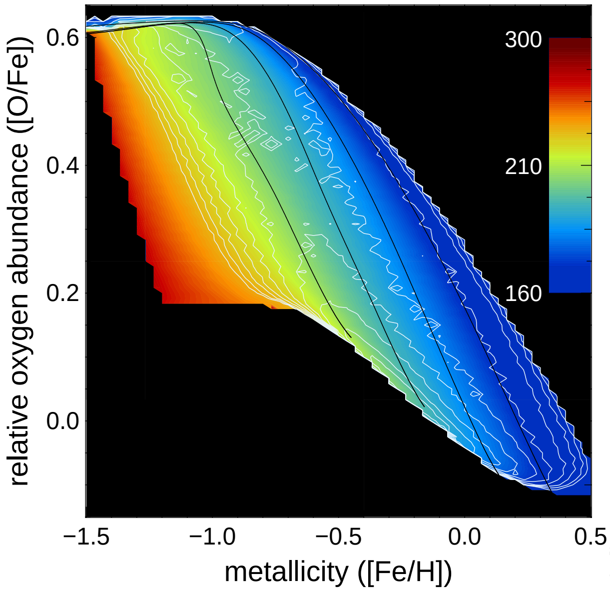

Figure 2.16: Mean rotational velocity of stars with different chemical composition in the theoretical model. The horizontal axis gives the metal content of stars, the vertical axis the relative amount of the alpha-element oxygen (O) compared to iron (Fe). Objects high in oxygen (top) are generally the oldest. The colours indicate the mean rotational velocity of the objects. There is a clear contrast between metal rich and metal poor stars. Black lines indicate the origin of stars in the model; they trace the evolution of the star forming gas in distances of 10 kpc (outer disk), 7.5 kpc (about our Sun), 5 kpc and 2,5 kpc (inner disk) from the centre.

versity of Sao Paulo has taken a fresh look at the issue but reached the opposite conclusion: planet-host stars have very similar Li abundances as other stars and instead the Li content is dictated by the mass, metallicity and age of the star.

For the analysis, the MPA team selected 117 stars from the Hipparcos catalog using the star's color, brightness, and distance. Those objects were observed with several telescopes, including the 3.6 meter ESO telescope at La Silla and the 6.5 meter Magellan Clay telescope at Las Campanas. The very high quality of the data enabled very accurate measurements of the fundamental parameters of the stars such as mass, age, metallicity, and temperature as well as the surface lithium abundance.

With this dataset, they were able to connect the different parameters to the surface lithium abundance in a very consistent way. One of the most important findings is the fact that the lithium abundance in solar-type stars is strongly age-dependent, that means the lithium abundance in those stars decreases monotonically with increasing age of the star. Another very interesting finding is that the

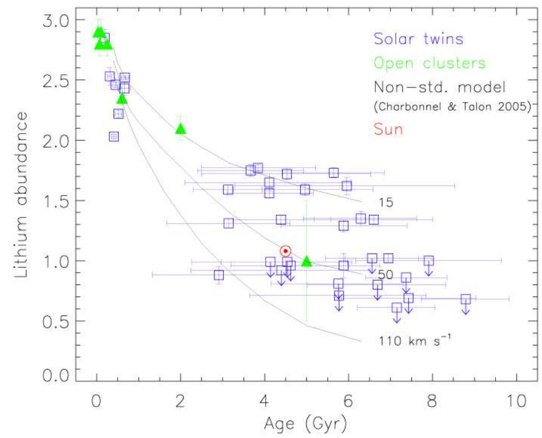

Figure 2.18: Evolution of lithium abundance with age in solar twin stars. Field solar twins are shown by open squares, while filled triangles represent solar twins in open clusters. The Sun is shown as the red circle. Non-standard stellar models, which include rotation and internal gravity waves, (solid lines) can explain both the decrease in lithium with increasing age and the scatter seen in the sample; the three different curves are the results for a selection of (assumed) initial rotational velocities of the stars (indicated by the numbers next to the curves).

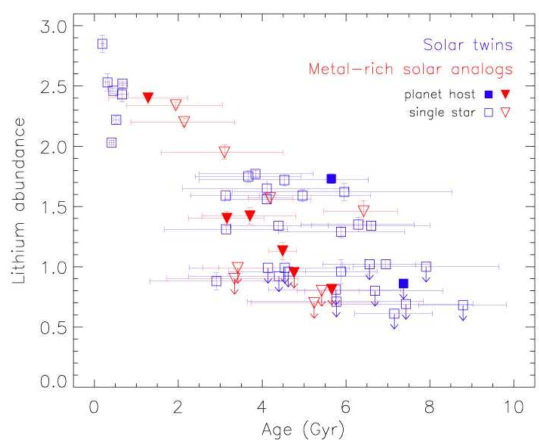

Figure 2.19: Evolution of lithium abundance with age for solar twins and metal-rich solar analogs. The solar twin sample is represented by open squares, those which are known to host planets by filled squares. Metal-rich solar analogs with and without detected giant planets are shown with filled and open triangles, respectively. The metal-rich solar analogs seem to follow a lithium versus age trend as well, similar to the solar twins, independently of hosting planets or not, but their lithium content is somewhat smaller than in solar twins at a given age, at least in the 3 to 6 Gyr age range. This difference is expected from the higher metal content, as predicted by stellar models.

Sun fits this trend perfectly, which leads to the conclusion that the Sun does not have an abnormally low lithium abundance compared to stars of similar age, mass, and metallicity: the Sun is perfectly normal (see Fig. 2.18).

The reason why standard stellar models can not correctly predict the solar Li abundance is that most of those models do not contain the whole diversity of transportation mechanisms and therefore predict a too small lithium depletion. When the team applied more realistic, non-standard models, the Sun agrees perfectly with the predictions. In Fig. 2.18 solar twins from open clusters are also shown, because their ages are known with a very high precision. They, too, agree with the observed trend of stars in the field perfectly.

The team also compared their findings with information about planets around the stars. They could not confirm the findings by the Spanish group, who predicted a stronger lithium depletion in planet-hosting solar-type stars. In that case the age effect was simply not properly accounted for, which led to the incorrect conclusion regarding dependence on planet properties; their sample of stars with planets tended to be older than the stars without planets

The MPA group also analyzed a sample of metal-rich solar analogs, stars that are very similar to the Sun but have an overall metal content that is up to 80% larger than the Sun's. This selection was made because stars known to have planets are in general more metal-rich than stars where no planets have been detected. Also the comparison of those stars' lithium-age-relation for stars with and without known planets does not show any significant difference (see Fig. 2.19).

Thus the reasons for the previous findings of a lithium-planet-connection can be traced to selection effects: metal-rich analogs are on average more lithium depleted than their solar-type siblings, regardless of whether the star is hosting a planet or not. This stronger lithium depletion in more metal-rich stars is explained by stellar evolution models, which predict a deeper convection zone for more metal-rich stars, thus enhancing the amount of depleted lithium. Since the planet-hosting subsample is biased towards higher metallicities, an incautious sample selection lead to the conclusion that the planets are responsible for the stronger lithium depletion.

The new MPA study has convincingly demonstrated that a low lithium abundance can be naturally explained as a combined effect of metallicity and age and does not imply the presence of planets. Solar-type stars show a strong decrease in lithium with age, supporting non-standard stellar models. More metal-rich stars are slightly more lithium

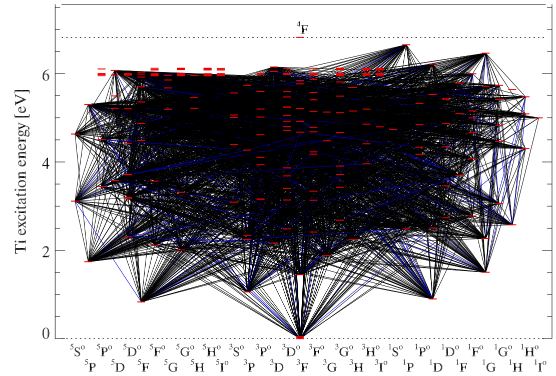

Figure 2.20: Term diagram for the neutral Ti atom; the ionization energy is 6.82 eV. The plot shows atomic energy levels and radiatively allowed transitions between them, which are included in the simultaneous solution of radiative transfer and statistical equilibrium equations.

poor than solar-metallicity stars of the same mass and age, but that is regardless of whether the stars are hosting planets or not. (Patrick Baumann)

2.7 Fe-peak elements in metal-poor stars

Chemical composition of late-type stars provides major observational constraints for studies of stellar nucleosynthesis and chemical evolution of stellar populations in our Galaxy. Surface of main-sequence stars preserves pristine composition of the ISM from which the stars were once formed, thus tracing continuous enrichment of the ISM by elements produced in short-lived stars, such as that exploding as supernovae type II or Ia. In contrast, atmospheres of evolved stars are polluted by the products of nucleosynthesis occurring in their interiors. Detailed abundance patterns can be determined from stellar spectra. In this respect, analysis of FGK stars is particularly advantageous, because, due to relatively cool surfaces, their spectra are rich in lines of various atomic and molecular in the UV optical and infrared.

Late-type stars are found in all Galactic substructures (halo, disk, and bulge), and span a huge range of metallicities and ages. Combinations of different elements and the variation in their abundances with metallicity are widely used to verify and calibrate models of the Galactic chemical evolution (GCE). This allows to constrain such impor-

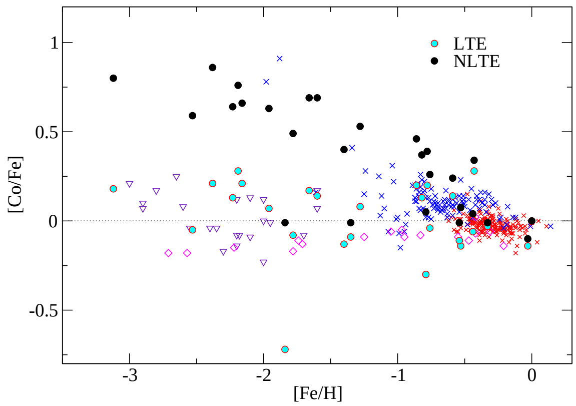

Figure 2.21: Abundance ratios [Co/Fe] computed under NLTE (filled black circles) and LTE approach (filled blue circles) for a sample of metal-poor Galactic stars as a function of their metallicity [Fe/H]. LTE-based abundance ratios for other Galactic field stars from the literature are also shown for comparison (open symbols and crosses).

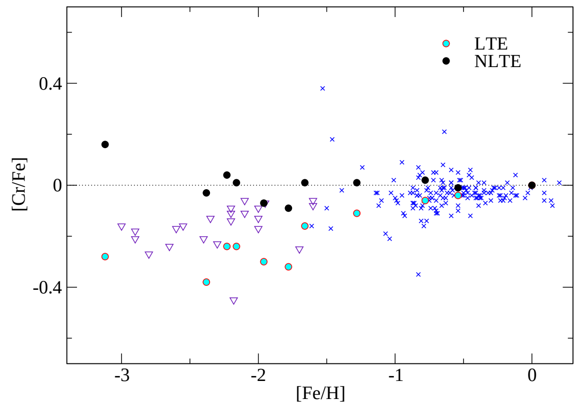

Figure 2.22: [Cr/Fe] vs [Fe/H] ratios in metal-poor stars. Symbols as in Fig. 2.21

tant parameters as star formation history, initial mass function, and efficiency of mixing in the ISM. Since stellar yields are also a part of these models, the abundances observed in late-type stars also test the theories of stellar nucleosynthesis and evolution and highlight any of their intrinsic problems.

One intriguing problem that has been occupying theoreticians and observers for a long time now, is the discrepancy between observed abundance distributions of different iron peak elements in Galactic metal-poor stars and predictions of GCE models. The theory of stellar nucleosynthesis predicts that odd-Z nuclei (V, Mn, Co) must be suppressed relative to their even-Z neighbors (Ti, Cr, Fe, Ni) in a low-metallicity environment. Thus, the odd-Z elements should be less abundant than Fe in low-metallicity stars compared to the Sun.

Whereas, the ratio of even-Z elements to Fe is expected to be roughly solar and independent of the metal content of a star. Neither of these theoretical expectations have been confirmed by observations of FGK stars. In particular, spectroscopic studies report decreasing [Cr/Fe] (square brackets denote logarithmic abundance ratio of two elements in a star relative to their ratio in the Sun) and increasing [Ti/Fe] ratios with decreasing metallicity, while the [Co/Fe] ratio remains solar down to the lowest metallicities.

Although most studies attribute this problem to deficiencies of the GCE models, we became concerned about the accuracy of spectroscopically-determined abundances in stars. In fact, all previous abundance estimates for iron peak elements contain a systematic error, since they did not consider the true kinetic equilibrium of an element throughout a stellar atmosphere. The latter is also known as non-local thermodynamic equilibrium (NLTE) and is one of the key aspects of the radiative transfer theory. NLTE calculations take into account the interaction of atoms with the radiation field explicitly by solving radiative transfer and statistical equilibrium equations for each of the atomic energy levels and ionization stages.

We constructed complete atomic models for several iron peak elements (Fig. 2.20) and performed, for the first time, calculation of NLTE spectral line formation for their neutral and singly-ionized atoms using models of stellar atmospheres. The synthetic spectra were compared to observed spectra of field Galactic metal-poor stars and of the globular cluster Omega Centauri to derive element abundances.

Unlike earlier studies, we find that Galactic metal-poor stars are over abundant in the odd-Z element cobalt (Fig. 2.21), but have nearly solar proportions of the even-Z element chromium (Fig. 2.22), and the odd-Z manganese relative to iron. The titanium abundances in Galactic metal-poor stars mimic the well-known trend of alpha-process elements (Mg, Ca) with [Fe/H]. Now, the trend of [Cr/Fe] with [Fe/H] can be reproduced by GCE models without the need to invoke additional assumptions, such as peculiar conditions in the ISM. However, the models are still fully inadequate to represent the halo trends of [Mn/Fe], [Co/Fe], and [Ti/Fe].

These abundance ratios are largely insensitive to majority of parameters in GCE models, except for stellar nucleosynthesis, which is expressed through theoretically computed element yields from stars of various masses and metallicities.

Iron group elements are produced in explosive burning of silicon, which occurs in massive stars, exploding as SN II, and in exploding white dwars in binary systems. Thus, our results are very useful to constrain models of supernovae and properties of their progenitors.

An interesting pattern of manganese abundances was obtained for giants of the globular cluster Omega Centauri. The [Mn/Fe] values in the metal-poor populations of Omega Centauri ([Fe/H] $\sim -1.5 \ldots -1.8$) overlap those of Milky Way halo stars. However, unlike in Galactic disk stars, Mn/Fe declines in two more metal-rich stars in the red giant branch of Omega Centauri. These results suggest that low-metallicity supernovae of either Type II or Type Ia dominated the enrichment of the more metal-rich stars in this globular cluster.

The potential of using abundances of iron group elements in old metal-poor stars is very large. They are useful not only as a diagnostic tool for physical conditions in stellar atmospheres, but also for understanding nucleosynthesis in supernovae, chemical enrichment of the galactic ISM, and, hence, chemical evolution of the Galaxy. (Maria Bergemann)

2.8 Are the progenitors of Type Ia supernovae less massive than previously thought?

Stellar explosions give rise to the temporary appearance of bright new stars in the sky. Among these so-called supernovae is a particular class of objects that is characterized by the absence of hydrogen but strong evidence of silicon in their spectra. These “Type Ia” supernovae are of particular interest to modern astrophysics. Their importance originates from the fact that their luminosity can be obtained from observations using an empirically derived relationship between their light curve shape and peak luminosity. Since objects of known luminosity can be used to measure distances, this makes Type Ia supernovae the most important beacons to measure the expansion rate of the Universe. Despite their importance, however, we still lack a good understanding of the physical origin of these explosions or of the astrophysical systems in which they occur.

In the widely-accepted standard model, Type Ia supernovae result from thermonuclear explosions of a White Dwarf star composed of carbon and oxygen. Isolated White Dwarfs, which represent the final stages of relatively low-mass stars like our Sun, are eternally stable. Having exhausted their nuclear energy supply, these stars simply cool down and fade over billions of years. Many stars, however, are part of a binary system. In such a case it is possible for the two stars to interact with each other and some such interaction is most likely the reason why explosions of White Dwarfs occur. Several evolutionary scenarios for binary star systems that could lead to Type Ia supernova explosions have been proposed, but, despite considerable effort, we still do not know which ones are realized in nature.

In the currently favoured scenario the White Dwarf accretes hydrogen-rich material from a companion star until it grows to a critical mass (the Chandrasekhar mass). At that point, the density in the core of the White Dwarf grows sufficiently high that thermonuclear reactions start and the White Dwarf explodes. Although this scenario is capable of reproducing the observed diversity of normal Type Ia supernovae, there are severe problems in explaining the observed rate of Type Ia supernovae within this scenario.

The mergers of two White Dwarfs in a close binary were suggested as an alternative to trigger Type Ia supernovae. However, it has long been unclear whether these systems could really produce thermonuclear explosions. Only recently a team of MPA researchers has shown that this is indeed possible under certain conditions. However, they concluded that this progenitor channel will produce most likely a peculiar faint sub-class of the Type Ia supernovae.

A third option, which has received relatively little attention so far, is that of a White Dwarf which accretes helium-rich material from a companion star. This leads to the build-up of a helium layer on the White Dwarf, which may eventually become unstable and ignite, ultimately leading to an explosion of the underlying White Dwarf. In contrast to the other scenarios outlined above, this would happen when the mass of the White Dwarf is lower than the Chandrasekhar limit. Since low-mass White Dwarfs are more common than White Dwarfs that grow to the Chandrasekhar limit, this model may do much better than the standard model in accounting for the observed rate of Type Ia supernovae. However, it had been largely discarded since the presence of a thick helium-rich layer leads to a composition of the explosion ejecta which differs from that seen in observations. New

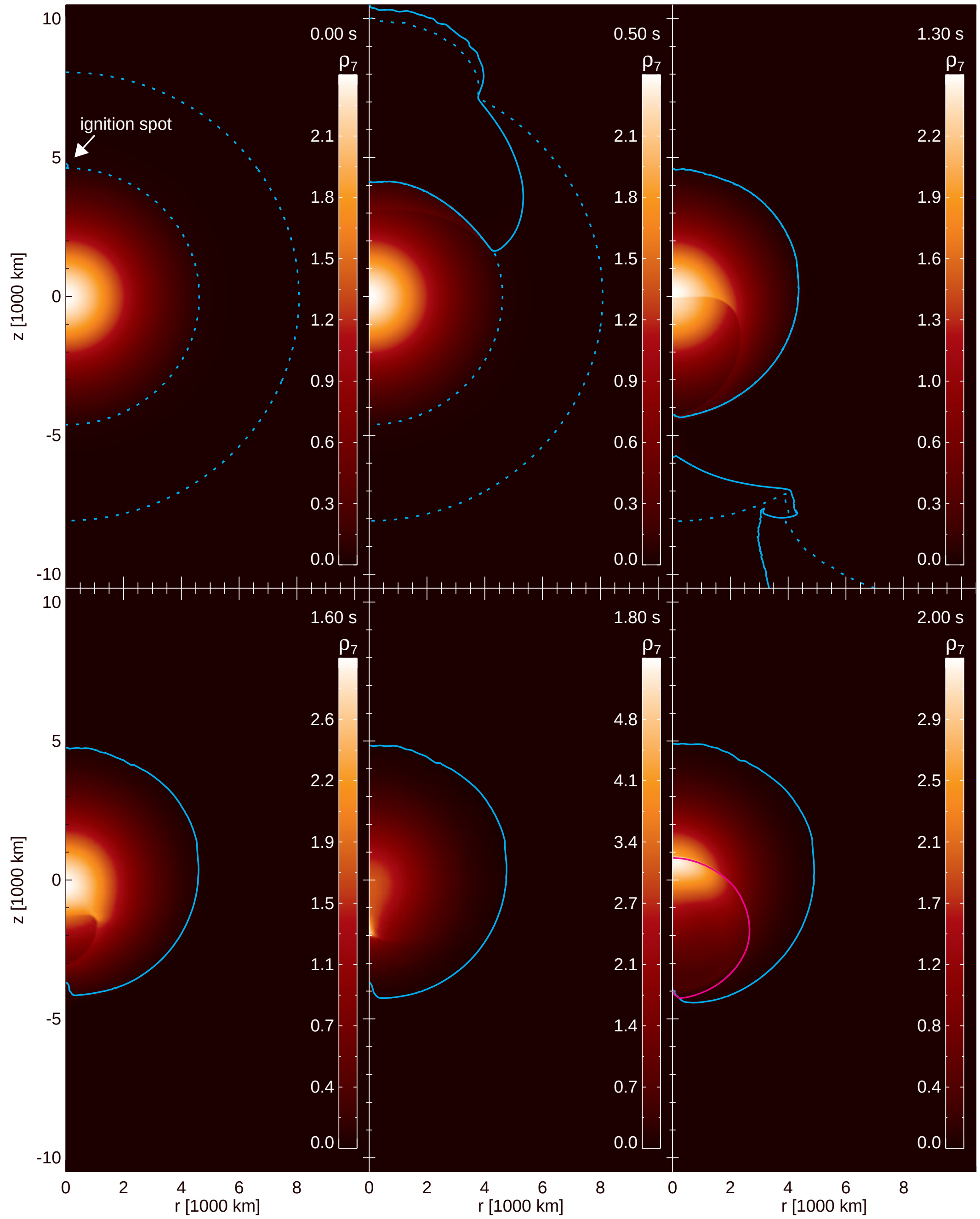

Figure 2.23: Explosion evolution for a double detonation of a 1.004 $M_{\odot}$ White Dwarf (from top left to bottom right). After igniting a helium detonation at the bottom of the helium shell (top left panel; dashed lines in cyan mark the border of the helium shell) a helium detonation flame (solid cyan line) wraps around the carbon-oxygen core thereby driving a shock wave into it. At 1.8 s after the ignition of the shell detonation this shock converges and ignites a secondary detonation of carbon-oxygen material which then propagates through the core (magenta lines) and unbinds the White Dwarf. The colour coding shows the density structure of the White Dwarf (in 10^7 gcm^{-3}).

calculations by Bildsten and Shen (University of California, Santa Barbara) of the properties of the helium shell, however, have indicated that ignition might occur for much thinner shells than previously thought. This led a team of MPA scientists to re-investigate this model in more detail.

In a first study, led by Michael Fink, they investigated whether an assumed surface helium detonation is capable of triggering a subsequent detonation in the core even for the new minimum he-

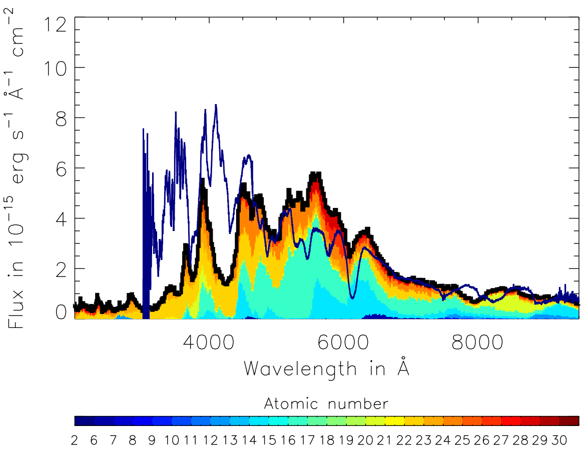

Figure 2.24: Synthetic spectrum at 3 days before maximum brightness as obtained from our radiative transfer calculations for a double detonation of a 1.08 $M_\odot$ White Dwarf (thick black line). For comparison the blue line shows the observed spectrum of the Type Ia supernova SN 2004eo at the corresponding epoch. The colour coding below the spectrum indicates the contribution of each chemical element to the emission in the corresponding wavelength bin.

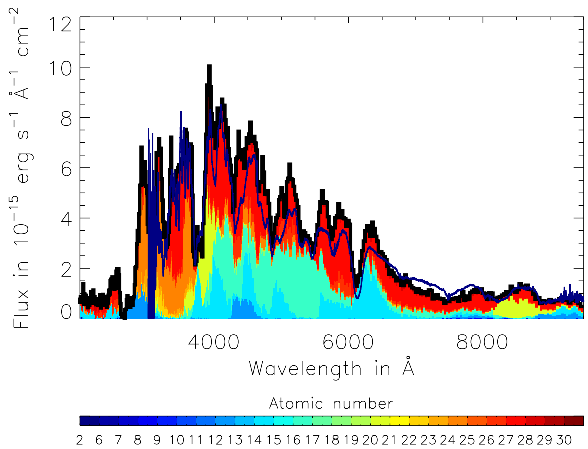

Figure 2.25: As Figure 2.24, but here the synthetic spectrum is for an idealized toy model of a "naked" carbon-oxygen White Dwarf with a total mass of 1.06 $M_\odot$.

lium shell masses of Bildsten and Shen. Performing hydrodynamic simulations coupled to a simplified scheme for nuclear reactions to simulate the propagation of the detonation through the helium shell (see Figure 2.23), they have shown that such a core detonation is virtually inevitable for a wide range of core and corresponding minimum helium shell masses thus leading to a complete disruption of the White Dwarf.

In a follow-up study, led by Markus Kromer, the MPA scientists used radiative transfer simulations to predict synthetic observables for these explosion models. These differ strongly from those found in earlier simulations of sub-Chandrasekhar-mass explosions in which more massive helium shells were considered. The new models predict light curves that cover both the range of brightnesses and the rise and decline times of observed Type Ia supernovae. However, their colours and spectra do not match the observations (cf. Figure 2.24). This discrepancy is mainly due to the composition of the burning products of the helium shell of the Fink et al. models which contain significant amounts of iron group material. However, it is also shown that the burning products of the helium shell depend crucially on its initial composition thus leaving some space to find a model in which the shell material is less dominant.

To investigate the potential which such models might have in explaining observed Type Ia supernovae, the MPA scientists finally investigated an idealized case where the influence of the layer of accreted helium is negligible. For this study, led by Stuart Sim, they hydrodynamically simulated artificial explosions of a set of "naked" sub-Chandrasekhar-mass carbon-oxygen White Dwarfs and derived synthetic observables for their explosion models from radiative transfer simulations. The light curves and spectra obtained from those simulations are in astonishingly good agreement with observed properties of Type Ia supernovae (see Figure 2.25). Thus, the MPA scientists conclude that explosions of sub-Chandrasekhar-mass White Dwarfs might be a viable model of Type Ia supernovae if the optical display is dominated not by the products of burning in the helium-shell but by the ejecta produced in the explosion of the underlying White Dwarf.

Moreover, the sub-Chandrasekhar-mass model has another appealing property: Since the mass of the exploding White Dwarf is not fixed to the Chandrasekhar limit, the initial mass of the exploding carbon-oxygen White Dwarf provides a simple physical parameter to account for the range of observed brightnesses of Type Ia supernovae. Thus, this scenario has the potential to give a simple physical explanation for the range of properties of Type Ia supernova. The race is now on to answer the critical question: can real explosions simultaneously meet conditions for igniting the helium shell whilst not giving rise to an outer ejecta layer which is incompatible with observations? (Markus Kromer and Michael Fink)

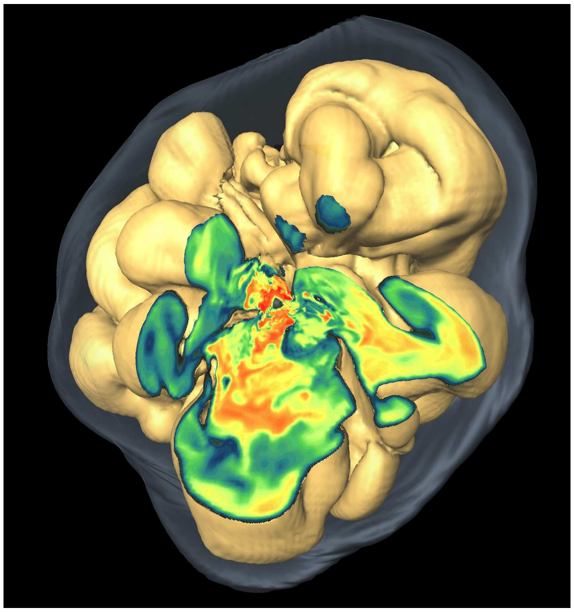

Figure 2.26: Three-dimensional explosion simulation about 0.5 seconds after core bounce. The bluish, nearly transparent surface is the shock front with an average radius of 1900 km. *Copyright: Max Planck Institute for Astrophysics*

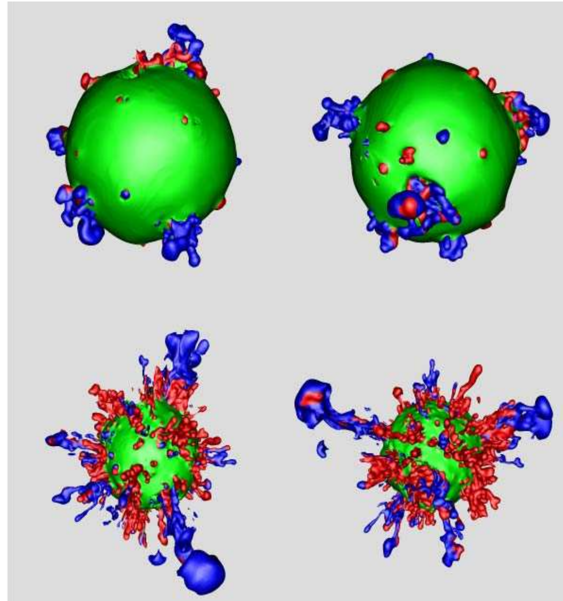

Figure 2.27: These snap-shots show the outward mixing of certain elements in a supernova explosion from two different viewing directions, 350 seconds after core bounce in the upper two panels and after 9000 seconds in the lower two panels, when the shock has broken out of the stellar surface. The surfaces denote the radially outermost locations of carbon (green), oxygen (red), and nickel (blue) with a constant mass fraction. *Copyright: Max Planck Institute for Astrophysics*

2.9 How a supernova obtains its shape

Researchers of the Max Planck Institute for Astrophysics in Garching managed for the first time to reproduce the asymmetries and fast-moving iron clumps of observed supernovae by complex computer simulations in all three dimensions. To this end they successfully followed the outburst in their models consistently from milliseconds after the onset of the blast to the demise of the star several hours later. (Astrophysical Journal, 10 May 2010)

Massive stars end their lives in gigantic explosions, so called supernovae, and can become – for a short time – brighter than a whole galaxy, which is made up of billions of stars. Although supernovae have been studied theoretically by computer models for several decades, the physical processes happening during these blasts are so complex that astrophysicists until now could simulate only parts of the process and so far only in one or two dimensions. Researchers at the Max Planck Institute for Astrophysics in Garching have now carried out the first fully three-dimensional computer simulations of a core collapse supernova over a timescale of hours after the initiation of the blast. They thus could answer the question how initial asymmetries, which emerge deep in the dense core during the very early stages of the explosion, fold themselves into inhomogeneities observable during the supernova blast.

While the great energy of the outburst makes these stellar explosions visible far out into the Universe, they are relatively rare. In a galaxy of the size of our Milky Way, on average only one supernova will occur in 50 years. About twenty years ago, a supernova could be seen even with the naked eye: SN 1987A in the Tarantula Nebula in the Large Magellanic Cloud, our neighbouring galaxy. This relative closeness – only about 170 000 light years away – allowed many detailed observations in different wavelength bands over weeks and even months. SN 1987A turned out to be a core-collapse supernova, a so-called Type II event. It occurs when a massive star, which is at least nine times heavier than the sun, has burned almost all its fuel. The fusion engine in the centre of the star begins to stutter, triggering an internal collapse and thus a violent explosion of the entire star. In the case of SN 1987A the star had about 20 solar masses at its birth.

SN 1987A is probably the best studied supernova and it is still a great challenge to develop and refine models of what was happening inside the dying star to produce its emission of radiation. One of the astonishing and unexpected discoveries in SN 1987A and many subsequent supernovae was the fact that nickel and iron – heavy elements that are formed near the centre of the explosion – are mixed outward in big clumps into the hydrogen shell of the disrupted star. Nickel bullets were observed to propagate at velocities of thousands of kilometres per second, much faster than the surrounding hydrogen and much faster than predicted by simple hydrodynamic calculations in one dimension (1D), i.e., only studying the radial profile from the centre outwards.

In fact, it turned out that the brightness evolution (the so-called light curve) of SN 1987A and of similar core-collapse supernovae can only be understood if large amounts of heavy core material (in particular radioactive nickel) are mixed outwards into the stellar envelope, and light elements (hydrogen and helium from the envelope) are carried inwards to the core.

The details of supernova explosions are very difficult to simulate, not only because of the complexity of the physical processes involved but also because of the duration and range of scales – from hundreds of metres near the centre to tens of millions of kilometres near the stellar surface – that need to be resolved in ultimately three-dimensional (3D) computer models. Previously conducted simulations in two dimensions (2D, i.e., with the assumption of axial symmetry) indeed showed that the spherical shell structure of the progenitor star is destroyed during the supernova blast and large-scale mixing takes place. But the real world is three-dimensional and not all observational aspects can be reproduced by 2D models.

The new computer models of the team at the Max Planck Institute for Astrophysics now simulate for the first time the complete burst in all three dimensions, from the first milliseconds after the explosion is triggered in the core (see Fig. 2.26) to a time three hours later, when the shock breaks out of the progenitor star. The researchers found substantial deviations in the 3D models compared to previous work in 2D especially in the growth of instabilities and the propagation of clumps. These are not just minor variations; these effects determines the long-time evolution and ultimately the extent of mixing and observable appearance of core-collapse supernovae.

In the 3D-simulations, metal-rich clumps have much higher velocities than in the 2D case. These "bullets" expand much more rapidly, overtaking material from the outer layers (see Fig. 2.27). Using a simple analytic model the scientists could demonstrate that the different geometry of the bullets, toroidal versus quasi-spherical, can explain the differences observed in the simulations. While the differences between the 2D- and 3D-models found are probably generic, many features will depend strongly on the structure of the progenitor star, the overall energy and the initial asymmetry of the blast.

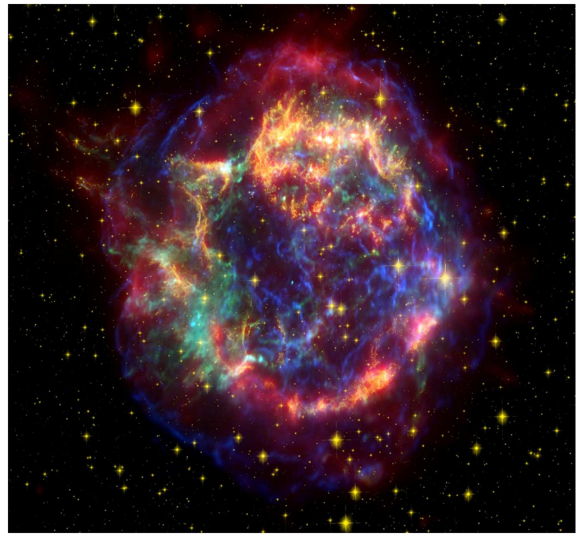

Figure 2.28: The Cassiopeia A nebula is the gaseous remnant of a supernova explosion whose light reached the Earth around the year 1680. The asymmetries and filamentary structure of this expanding cloud of stellar debris are a consequence of the clumping and mixing processes that also played a role in Supernova 1987A and that were simulated for the first time in all three dimensions by the team at the Max Planck Institute for Astrophysics. *Credit: X-ray: NASA/CXC/SAO; Optical: NASA/STScI; Infrared: NASA/JPL-Caltech/Steward/O.Krause et al.*

The scientists hope that their models, in comparison to observations, will help them to understand how stellar explosions start and what causes them. Investigating a wider variety of progenitor stars and initial conditions will therefore be the focus of future simulation work. In particular, a detailed model that reproduces all observational features of SN 1987A still remains a challenge.

(Please note that Fig. 2.28 shows the remnant of another, older supernova explosion that also exhibits large-scale asymmetries as observed in SN 1987A.)

Original publication: N.J. Hammer, H.-Th. Janka, E. Müller, "Three-dimensional simulations of mixing instabilities in supernova explosions", The Astrophysical Journal 714 (2010) 1371-1385

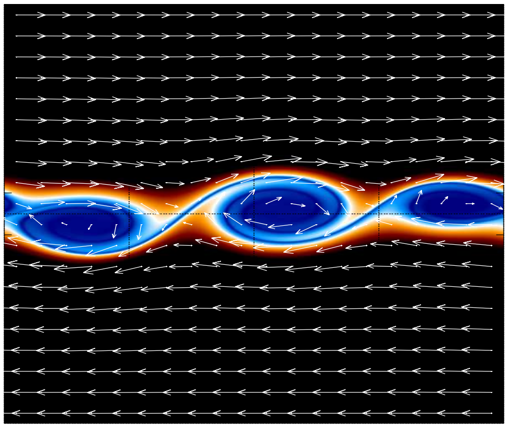

Figure 2.29: An unstable shear flow with gas in the upper and lower half of the domain flowing to the right and left, respectively (arrows indicate the flow velocity). A series of vortices has formed in the midplane (colours indicate the vorticity, i.e., a measure of the circulation of the flow).

2.10 Magnetic fields in merging neutron stars

According to Einstein's General Theory of Relativity, binary systems of two neutron stars emit a part of their orbital kinetic energy and angular momentum in the form of gravitational waves. Therefore, the stars spiral in towards each other until they finally merge. A black hole forms, swallowing most of the matter immediately. However, for a short period of time a small fraction (of the order of a tenth of a solar mass) of the gas forms a torus revolving rapidly around the black hole. In less than a second, this remnant falls onto the black hole. A fraction of the gravitational energy liberated by the gas accretion is used to accelerate narrowly collimated plasma jets, which are later an intense source of gamma radiation, a so-called short gamma-ray burst (GRB).

Most neutron stars possess a magnetic field, which can be directly detected in pulsars. In principle, the magnetic field could affect the merger. Dramatic effects occur, however, only if the magnetic field energy becomes comparable to the kinetic or internal energy of the gas. This corresponds to a field strength exceeding by far all observed values, stronger even than the fields of 10^{14} Gauss observed for the strongest magnetised neutron stars, the so-called magnetars. Somewhat smaller effects can occur for weaker field strengths though if the field is amplified during the merger.

Consisting of several distinct dynamical phases, the merger offers various possible sites of field amplification. Among them, one of the most promising is the contact layer forming as the neutron stars begin to touch each other. At this instance, a thin layer forms along which the gas is flowing in opposite directions. This contact layer is unstable against the shear instability. After some time, a roughly circular vortex develops. Magnetic field lines embedded in the gas are stretched by the vortex flow, leading to an amplification of the field similar to the tension of a rubber band increasing when the band is stretched. In previous works, D. Price and S. Rosswog estimated that the magnetic field reaches values in excess of 10^{15} Gauss by this mechanism. If this holds, merging neutron stars would be, by far, the most intense magnets in the universe.

To simulate the interaction between the gas and the magnetic field, one has to model fine structures accurately, requiring high computational costs. To follow, on the other hand, the motion of the two neutron stars requires to simulate a large domain covering both stars. Though the extremely high accuracy is needed only in a small part of the domain, simulations of the entire merger able to describe the magnetized turbulence in the contact layer in detail are currently not feasible.

Therefore, large scale modeling of the merger, including the final approach and the eventual contact of the neutron stars cannot determine an accurate value of the expected field strength though it provides a very good description of the merger process in many other respects. To circumvent this problem, scientists at the Max- Planck-Institute for Astrophysics and the University of Valencia have performed simulations of magnetized shear flows resembling those in merging neutron stars. They limited themselves to regions of a few hundred meters around the contact layer, hence simulating only a small part of the entire merger encompassing a few tens of kilometers.

This configuration is unstable. Initially, the magnetic field grows along with the shear instability very rapidly. After a short time, roughly circular vortices form at the shear interface and the growth of the shear instability terminates. We show the resulting flow in Fig. 2.29. Though the shear instability saturates when the vortices are established, the magnetic field continues to grow due to the vortex flow stretching the field lines. In Fig. 2.30, we show the complex geometry of the field developing as the magnetic field is wrapped

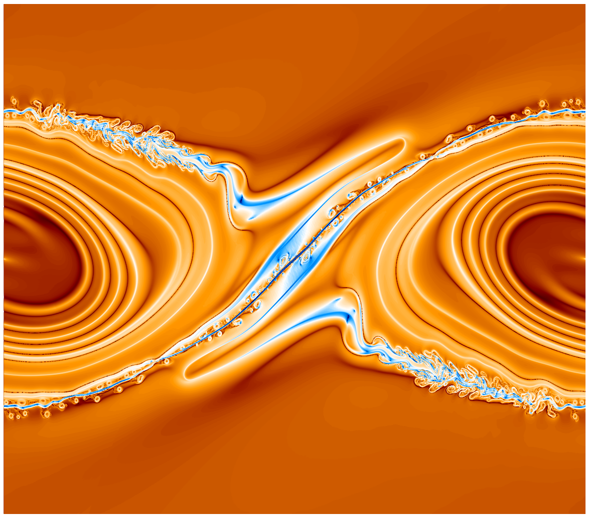

Figure 2.30: The distribution of the magnetic field in an unstable shear flow. The field strength is shown colour-coded ranging from dark red (weakest) via white to dark blue (strongest fields). The field is strongest in a thin sheet wrapped around the vortex multiple times. The dissipation of the field by secondary instabilities is already visible where the field sheet is twisted in a complex pattern.

around the center of the vortex multiple times.

The magnetic field can affect the gas flow only appreciably if its energy is comparable to the kinetic energy of the gas. In this case, the magnetic field is sufficiently strong to resist further stretching and exert forces onto the matter. This resistance decelerates the rotation of the vortex and field amplification ceases. In extreme cases, the vortex can be disrupted completely. In this stage, the magnetic field decreases again, partly because its energy is used to decelerate the flow, partly due to dissipation by a second generation of hydromagnetic instabilities. An early stage of the development of these instabilities is displayed in Fig. 2.30, while Fig. 2.31 shows the same model at a later time when the instabilities have already disrupted the vortex.

As the field ceases to grow once its energy locally equals the kinetic energy of the gas, the maximum field achievable depends only on the shear flow but not on the initial field strength. However, the growth of the magnetic field is not uniform throughout the unstable shear layer. Only in small and localised parts of the layer a huge magnetic field may be built up. The rest of the layer retains the initial (weak) field. On average, one finds that the mean value of the field is smaller the weaker the initial field is, and the back-reaction of the field onto the flow is significantly slower.

These results imply that we can indeed expect extremely strong magnetic fields, for shear flows in merging neutron stars, even if both neutron stars are only weakly magnetised. The impact of the field, is limited, however, because only a small fraction of the gas is threaded by a strong field, and because the magnetic field starts to decrease quickly again once it reaches its maximum value. (Martin Obergaulinger)

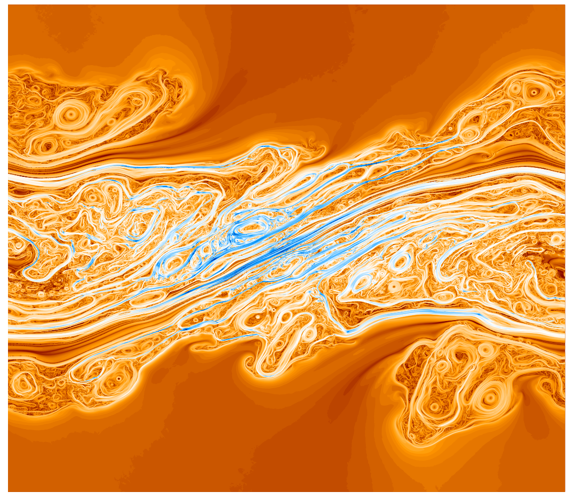

Figure 2.31: The same model at a later time when the vortex is already completely disrupted and the field has assumed a very complex shape of tangled field sheets.

2.11 Polarization as a way to measure transverse velocities of gas motions in galaxy clusters

While very in hot intergalactic medium (IGM) is optically thin to continuum radiation, the optical depth in resonant lines can be of order unity or larger. Resonant scattering in the brightest X-ray emission lines can cause distortions in the surface brightness distribution, spurious variations in the abundance of heavy elements, changes in line spectral shapes and even polarization of line emission.

The magnitude of these effects not only depends on the density, temperature and ionization state of the gas, but is also sensitive to the characteristics of the gas velocity field. Polarization signal is in particular sensitive to the gas motions perpendicular to the line of sight. This opens the unique possibility to study the transverse component of

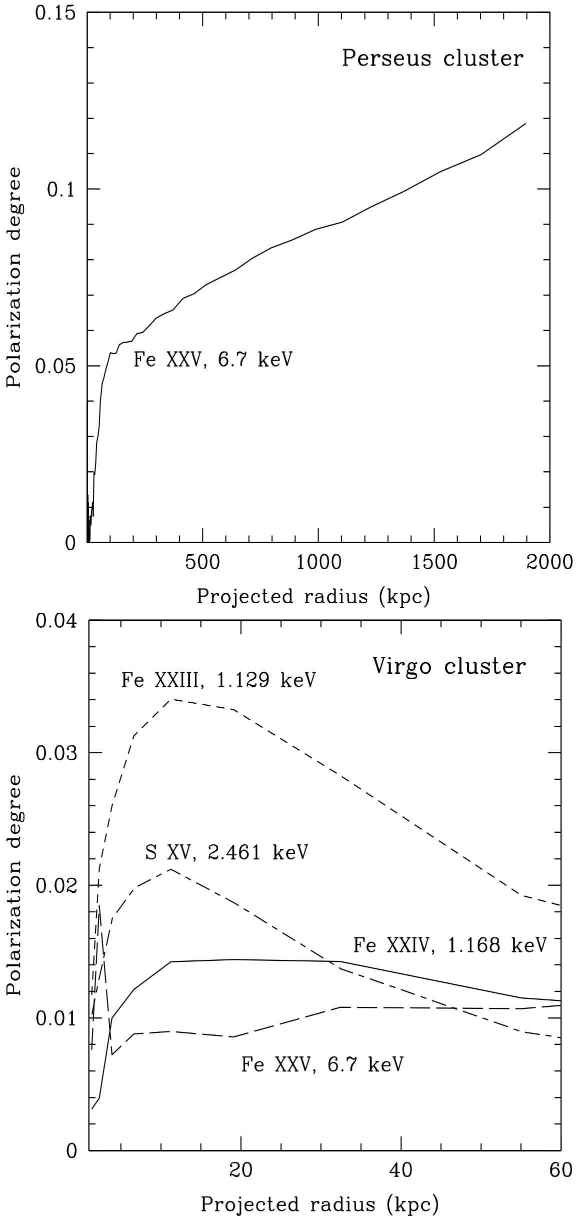

Figure 2.32: Right panel: polarization degree as a function of projected distance from the center of the Perseus cluster in the most prominent resonant line of Fe XXV with energy 6.7 keV. Left panel: polarization degree as a function of projected distance from the center of the Virgo/M87 cluster in the most prominent resonant lines.

the velocity field in clusters of galaxies.

Hot gas (10^7 - 10^8 K) in galaxy clusters emits X-rays in continuum and in emission lines of ionized heavy elements. Since iron is the most abundant element, the resonant lines of ionized iron are especially strong and bright. In these lines the cross section of scattering is much larger than the cross section in continuum and the optical depth in lines can be of order unity or even larger. For instance, the optical depth of the He-like iron line at 6.7 keV in the brightest clusters in the sky A426 (Perseus) and Virgo is ~ 3 and ~ 1.4 respectively.

The atomic structure of the ions define the process of line scattering (absorption and re-emission of the photon) as a combination of two components: isotropic and Rayleigh scattering. It is well known that Rayleigh component leads to the polarization (just like in the case of Thomson scattering) if there is a quadrupole moment in initial radiation field.

In galaxy clusters such quadrupole moment arises naturally if (i) scattering takes place far from the bright central core of the cluster and/or (ii) if there are gas motions. The expected degree of polarization is high: in the Perseus cluster it reaches ~ 7 per cent in the He-like iron line at 6.7 keV. In the Virgo cluster it is about several per cent in the most promising lines (Fig. 2.32).

Transverse gas motions can change the expected degree and direction of polarization, since along the direction of motions the cross section of scattering in the line is decreasing. Using modern full 3D simulations of galaxy clusters the polarization degree we calculated degree of the X-ray line polarization taking into account gas motions.

In Fig. 2.33 one can see that polarization degree in the He-like iron line reaches ~ 25 per cent within the distance of 500 kpc from the core, if the cluster gas is at rest. The inclusion of gas motions decreases the polarization down to ~ 10 per cent and causes rotation of the polarization plane.

A new era of high resolution X-ray spectroscopy and polarimetric studies is coming, driven by progress in development of new generation of X-ray detectors. The first polarimetric mission, based on photo-effect principle, is already approved and funded and will be launched in the nearest future. More missions are under discussions. The measurement of the polarization degree of the bright X-ray emission lines would provide us with new information on the bulk and turbulent gas motions in clusters of galaxies. (I. Zhuravleva, E. Churazov, S. Sazonov, R. Sunyaev and K. Dolag)

Further Readings: Zhuravleva I.V., Churazov E.M., Sazonov S.Y., Sunyaev R.A., Forman W., Dolag K., *'Polarization of X-ray lines from galaxy clusters and elliptical galaxies - a way to measure the tangential component of gas velocity'*, 2010, Mon. Not. R. Astron. Soc., 157.

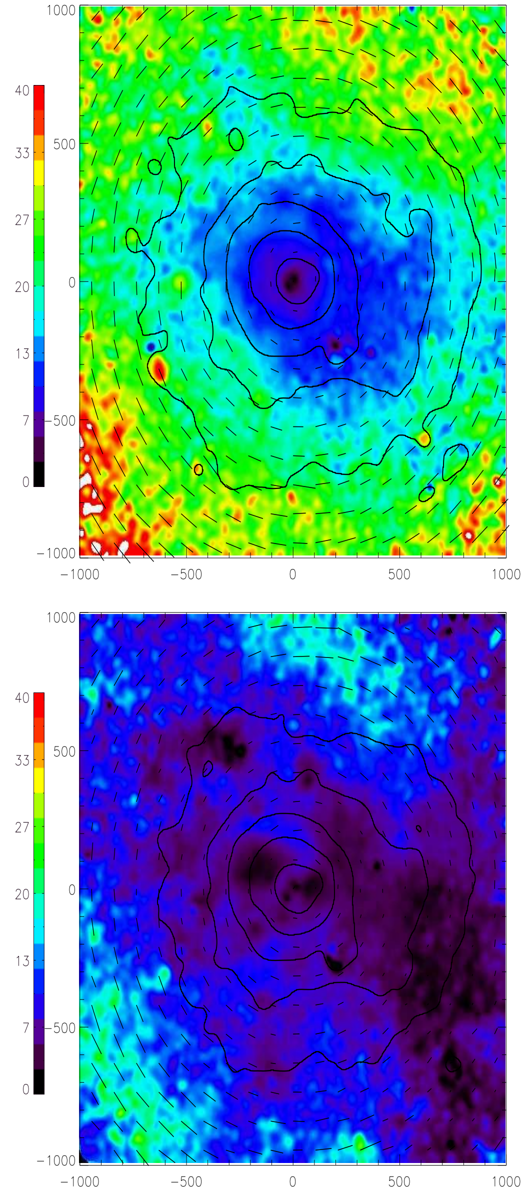

Figure 2.33: Polarization degree of the simulated cluster in the line of Fe XXV at 6.7 keV. The colors in the images show polarization degree (in per cent), the short dashed lines show the orientation of the electric vector. The contours of the X-ray surface brightness are superposed. The left panel shows the case when gas is at rest, the right panel shows results when gas motions are included.

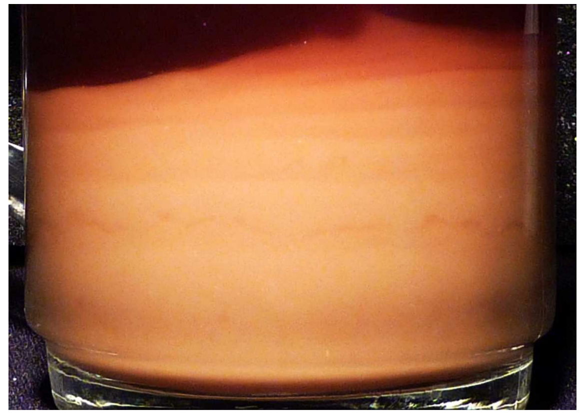

Figure 2.34: Layered convection in a glass of coffee with milk.

2.12 Stars and latte macchiato

What do these have in common? Inquisitive coffee drinkers of may have noticed a pretty 'layering' phenomenon that sometimes occurs in a glass of latte macchiato (Fig. 2.34). A series of recently completed numerical simulations demonstrates how the same layering process happens inside stars. The results of the simulations settle an issue in the theory of stellar evolution that has been open for half a century.

The coffee in your glass (not in a mug, since you want to see what's happening inside) cools at the top, sinks down, and is replaced by rising hot fluid: it sets up a *convective* flow. (The flow is nicely visible in the pattern of rising and sinking flakes if the milk added is slightly off.)

If you do not stir the coffee after adding milk, the flow pattern is interrupted: convection is not strong enough to lift the milk (heavier than water) from the bottom. This is not the end, however: after a few minutes the transition between the milk and the coffee above has developed thin layers (this works especially well with low-fat condensed milk). Convection now continues again, but only inside each of the layers separately, without mixing between them. This phenomenon is called *double diffusive* convection. It happens in nature, for example in the ocean under the arctic ice sheet and in the volcanic lakes of East Africa.

It can also happen in stars, as Hydrogen at their center burns into Helium. Convection driven by the heat from nuclear fusion is impeded by accumulation of the heavier Helium 'ashes'. It interferes with convective mixing of Helium outward through the star.

Over the long life of the star, even a very minor amount of mixing can become important, however. The detailed distribution of Helium through the star has a strong effect on the further evolution of the star, so the question is how much of a residual mixing might take place.

With an extensive set of numerical simulations of the layering phenomenon, this rate of mixing has now been measured. Like in the geophysical

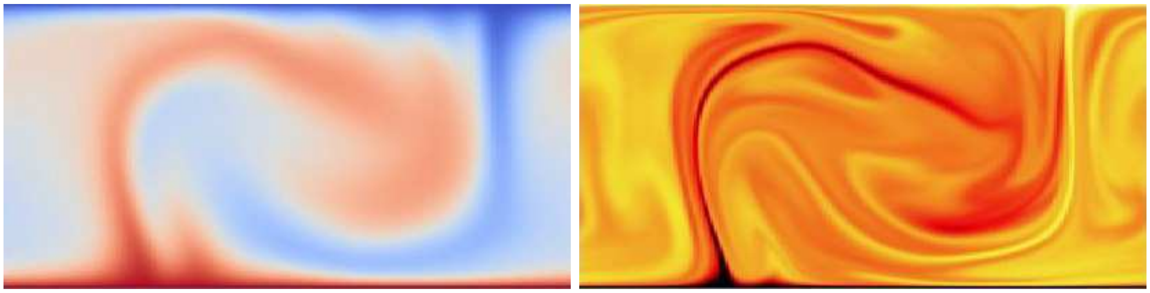

Figure 2.35: Convective flow pattern inside a double-diffusive layer. The top image shows the temperature distribution (red is warm, blue is cold), the bottom image the helium concentration (dark means high concentration). The flow structures in the temperature image appear wider than those seen in the helium. This blurring is due to thermal conduction (movie: http://www.mpa-garching.mpg.de/mpa/research/current-research/hl2010-12/movie.avi).

Figure 2.36: Flow structures at the interface between two layers of a double-diffusive set of layers

examples mentioned, it is found to be quite low, much lower than the mixing usually assumed in theories of stellar evolution. Its effects are probably negligible even over the star's life time. (Florian Zaussinger and Henk Spruit)

3 Publications and Invited Talks

3.1 Publications in Journals

3.1.1 Publications that appeared in 2010 (274)

Abbas, U., S. De La Torre, et al. (incl. L. Guzzo): The VIMOS-VLT deep survey: evolution in the halo occupation number since z $\sim$ 1. Mon. Not. R. Astron. Soc. **406**, 1306 - 1317 (2010).

Abdikamalaov, E. et al. (incl. A. Marek and H.-T. Janka): Axisymmetric general relativistic simulations of the accretion-induced collapse of white dwarfs. Physical Review D, **81**, 044012 (2010).

Aleksic, J., L.A. Antonelli et al. (incl. T. Ensslin): MAGIC gamma-ray telescope observation of the Perseus cluster of galaxies: implications for cosmic rays, dark matter, and NGC 1275. Astrophys. J. **710**, 634 - 647 (2010).

Angulo, R.E. and S.D.M. White: The birth and growth of neutralino haloes. Mon. Not. R. Astron. Soc. **401**, 1796 - 1803 (2010).

Angulo, R.E. and S.D.M. White: One simulation to fit them all - changing the background parameters of a cosmological N-body simulation. Mon. Not. R. Astron. Soc. **405**, 143 - 154 (2010).

Aumer, M., A. Burkert, P. Johansson and R. Genzel: The structure of gravitationally unstable gas-rich disk galaxies. Astrophys. J. **719**, 1230 - 1243 (2010).

Baldi, M., V. Pettorino, G. Robbers and V. Springel: Hydrodynamical N-body simulations of coupled dark energy cosmologies. Mon. Not. R. Astron. Soc. **403**, 1684 - 1702 (2010).

Baumann, P., I. Ramirez, J. Melendez et al.: Lithium depletion in solar-like stars: no planet connection. Astron. Astrophys. **519**, A87 (2010).

Bauswein, A., H.-Th. Janka and R. Oechslin: Testing approximations of thermal effects in neutron star merger simulations. Physical Review D, **82**, 084043 (2010).

Bauswein, A., R. Oechslin and H.-Th. Janka: Discriminating strange star mergers from neutron star mergers by gravitational-wave measurements. Phys. Rev. D **81**, 1 - 21 (2010).

Behara, N.T, P. Bonifacio et al. (incl. L. Sbordone): Three carbon-enhanced metal-poor dwarf stars from the SDSS. Chemical abundances from CO5BOLD 3D hydrodynamical model atmospheres. Astron. Astrophys. **513**, A72 (2010).

Bedding, T.R., D. Huber et al. (incl. A. Weiss): Solar-like oscillations in low-luminosity red giants: first results from Kepler . Astrophys. J. Lett. **713**, L176 - L181 (2010).

Bensby, T., M. Asplund, J. Johnson et al.: Chemical evolution of the galactic bulge as traced by microlensed dwarf and subgiant stars - III. Detection of lithium in the metal-poor bulge dwarf MOA-2010-BLG-285S. Astron. Astrophys. **521**, L57 (2010).

Belczynski, K., T. Bulik et al. (incl. A. J. Ruiter): On The Maximum Mass of Stellar Black Holes. Astrophys. J. **714**, 1217 - 1226 (2010).

Bergemann, M., Pickering and T. Gehren: NLTE analysis of Co i /Co ii lines in spectra of cool stars with new laboratory hyperfine splitting constants. Mon. Not. R. Astron. Soc. **401**, 1334 - 1346 (2010).

Bergemann, M. and G. Cescutti: Chromium: NLTE abundances in metal-poor stars and nucleosynthesis in the Galaxy. Astron. Astrophys. **522**, A9 (2010).

Bernardi, M., F. Shankar, J.B. Hyde et al.: Galaxy luminosities, stellar masses, sizes, velocity dispersions as a function of morphological type. Mon. Not. R. Astron. Soc. **404**, 2087 - 2122 (2010).

Bernardi G., A. de Bruyn et al. (incl. B. Ciardi): Foregrounds for observations of the cosmological 21 cm line: II. Westerbork observations of the fields around 3C196 and the North Celestial Pole. Astron. Astrophys. **522**, A67 (2010).

Bersanelli, M., N. Mandolesi et al. (incl. A. Banday): Planck pre-launch status: design and description of the low frequency instrument. Astron. Astrophys. **520**, A4 (2010).

Bertone, S., J. Schaye et al. (incl. R. Wiersma): Metal-line emission from the warm-hot intergalactic medium - I. Soft X-rays. Mon. Not. R. Astron. Soc. **407**, 544 - 566 (2010).

Bertone, S., J. Schaye et al. (incl. R. Wiersma): Metal-line emission from the warm-hot intergalactic medium: II. Ultraviolet. Mon. Not. R. Astron. Soc. **408**, 1120 - 1138 (2010).

Boehringer, H., G.W. Pratt et al. (K. Dolag): Substructure of the galaxy clusters in the REXCESS sample: observed statistics and comparison to numerical simulations. Astron. Astrophys. **514**, A32 (2010).

Bogdan, A. and M. Gilfanov: Soft band X/K luminosity ratios for gas-poor early-type galaxies. Astron. Astrophys. **512**, A16 (2010).

Bogdan, A. and M. Gilfanov: Unresolved X-ray emission in M31 and constraints on progenitors of classical novae. Mon. Not. R. Astron. Soc. **405**, 209 - 218 (2010).

Bois, M., F. Bournaud et al. (incl. T. Naab): Formation of slowly rotating early-type galaxies via major mergers: a resolution study. Mon. Not. R. Astron. Soc. **406**, 2405 - 2420 (2010).

Bonafede, A., L. Feretti et al. (incl. K. Dolag): The Coma cluster magnetic field from Faraday rotation measures. Astron. Astrophys. **513**, A30 (2010).

Bonoli, S., F. Shankar, S.D.M. White et al.: On merger bias and the clustering of quasars. Mon. Not. R. Astron. Soc. **404**, 399 - 408 (2010).

Bottino, M., A. Banday and D. Maino: New insights into the foreground analysis of the WMAP 5-year data using FASTICA. Mon. Not. R. Astron. Soc. **402**, 207 - 225 (2010).

Boylan-Kolchin, M., V. Springel, S.D.M. White and A. Jenkins: There's no place like home? Statistics of Milky Way-mass dark matter haloes. Mon. Not. R. Astron. Soc. **406**, 896 - 912 (2010).

Bragaglia, A., E. Carretta et al. (incl. S. Lucatello): Helium in first and second-generation stars in globular clusters from spectroscopy of red giants. Astron. Astrophys. **519**, A60 (2010).

Bragaglia, A., E. Carretta et al. (incl. S. Lucatello): X-shooter observations of main-sequence stars in the globular cluster NGC 2808: first chemical tagging of a He-normal and a He-rich dwarf. Astrophys. J. Lett. **720**, L41 - L45 (2010).

Brasseur, C. M., P.B. Stetson et al. (incl. L. Casagrande): Fiducial Stellar Population Sequences for the VJKS Photometric System Astrophys. J. **140**, 1672 - 1686 (2010).

Brown, P.J. P. Roming et al. (incl. P. Mazzali): The Absolute Magnitudes of Type Ia Supernovae in the Ultraviolet. Astrophys. J. **721**, 1608 - 1626 (2010).

Caffau, E., L. Sbordone, H.-G. Ludwig et al.: Sulphur abundances in halo stars from multiplet 3 at 1045 nm. Astron. Nachrichten, **331**, 725 - 730 (2010).

Campisi, M.A., L.-X. Li and P. Jakobsson: Redshift distribution and luminosity function of long gamma-ray bursts from cosmological simulations. Mon. Not. R. Astron. Soc. **407**, 1972 - 1980 (2010).

Cappelluti, N., M. Ajello et al. (incl. S. Bonoli): Active Galactic Nuclei Clustering in the Local Universe: An Unbiased Picture from Swift-BAT. Astrophys. J. Lett. **716**, L209 - L213 (2010).

Carretta, E., A. Bragaglia et al. (incl. S. Lucatello): The radial distribution of stars of different stellar generations in the globular cluster NGC 3201. Astron. Astrophys. **519**, A71 (2010).

Catinella, B., D. Schiminovich, G. Kauffmann et al.: The GALEX Arecibo SDSS Survey - I. Gas fraction scaling relations of massive galaxies and first data release. Mon. Not. R. Astron. Soc. **403**, 683 - 708 (2010).

Cerda-Duran, P.: Numerical viscosity in hydrodynamics simulations in general relativity. Classical and Quantum Gravity **27**, 1 - 14 (2010).

Chaplin, W., T. Appourchaux et al. (incl. Serenelli): The asteroseismic potential of Kepler: first results for solar-type stars. Astrophys. J. Lett. **713**, L169 - L175 (2010).

Chen, Y.M., C. Tremonti et al. (incl. G. Kauffmann): Absorption-line probes of the prevalence and properties of outflows in present-day star-forming galaxies. Astron. J. **140**, 445 - 461 (2010).

Chiavassa, A., Lacour, F. Millour et al.: VLTI/AMBER spectro-interferometric imaging of VX Sagittarii's inhomogenous outer atmosphere. Astron. Astrophys. **511**, A51 (2010).

Chiavassa, A., X. Haubois, J.S. Young, et al.: Radiative hydrodynamics simulations of red supergiant stars. II. Simulations of convection on Betelgeuse match interferometric observations. Astron. Astrophys. **515**, A12 (2010).

Chiavassa, A., R. Collet, L. Casangrande and M. Asplund: Three-dimensional hydrodynamical simulations of red giant stars: semi-global models for interpreting interferometric observations Astron. Astrophys. **524**, A93 (2010).

Chluba, J.: Could the cosmological recombination spectrum help us understand annihilating dark matter? Mon. Not. R. Astron. Soc. **402**, 1195 - 1207 (2010).

Chluba J. and R.A. Sunyaev: Ly alpha escape during cosmological hydrogen recombination: the 3d-1s and 3s-1s two-photon processes. Astron. Astrophys. **512**, A53 (2010).

Chluba J. and R.A. Sunyaev: Cosmological recombination: feedback of helium photons and its effect on the recombination spectrum. Mon. Not. R. Astron. Soc. **402**, 1221 - 1248 (2010).

Chluba, J., G. Vasil and L. Dursi: Recombinations to the Rydberg states of hydrogen and their effect during the cosmological recombination epoch. Mon. Not. R. Astron. Soc. **407**, 599 - 612 (2010).

Christlein, D., D. Zaritsky and J. Bland-Hawthorn: A spectroscopic study of the Hα surface brightness profiles in the outer discs of galaxies. Mon. Not. R. Astron. Soc. **405**, 2549 - 2560 (2010).

Churazov, E., S. Tremaine, W. Forman et al.: Comparison of approximately isothermal gravitational potentials of elliptical galaxies based on X-ray and optical data. Mon. Not. R. Astron. Soc. **404**, 1165 - 1185 (2010).

Ciardi, B., R. Salvaterra and T. Di Matteo: Lyman alpha versus X-ray heating in the high-z intergalactic medium. Mon. Not. R. Astron. Soc. **401**, 2635 - 2640 (2010).

Cohen, J., A. Gould, et al. (incl. M. Asplund): A Puzzle Involving Galactic Bulge Microlensing Events. Astrophys. J. Lett. **711**, L48 - L52 (2010).

Cooper A.P. et al. (incl. S. White and V. Springel): Galactic stellar haloes in the CDM model. Mon. Not. R. Astron. Soc. **406**, 744 - 766 (2010).

Cucciati, O., C. Marinoni et al. (incl. S. Charlot): The VIMOS-VLT deep survey: the group catalogue. Astron. Astrophys. **520**, A42 (2010).

Cunha, K., V. Smith, M. Bergemann et al.: Manganese Abundances in the Globular Cluster Centauri. Astrophys. J. **717**, 333 - 341 (2010).

D'Angelo, C. and H. Spruit: Episodic accretion on to strongly magnetic stars. Mon. Not. R. Astron. Soc. **406**, 1208 - 1219 (2010).

D'Onghia, E., V. Springel, L. Hernquist and D. Keres: Substructure Depletion in the Milky Way Halo by the Disk. Astrophys. J. **09**, 1138 - 1147 (2010).

Das, P., O. Gerhard, E. Churazov and I. Zhuravleva: Steepening mass profiles, dark matter and environment of X-ray bright elliptical galaxies. Mon. Not. R. Astron. Soc. **409**, 1362 - 1378 (2010).

De Lucia, G., M. Boylan-Kolchin, A. Benson et al.: A semi-analytic model comparison - gas cooling and galaxy mergers. Mon. Not. R. Astron. Soc. **406**, 1533 - 1552 (2010).

Decarli, M. Dotti, C. Montuori and C. Liimets: The peculiar optical spectrum of 4C+22.25: Imprint of a massive black hole binary? Astrophys. J. Lett. **720**, L93 - L96 (2010).

Degraf, C., T. Di Matteo and V. Springel: Faint-end quasar luminosity functions from cosmological hydrodynamic simulations. Mon. Not. R. Astron. Soc. **402**, 1927 - 1936 (2010).

Di Cecco, A., R. Becucci et al. (incl. A. Weiss): On the absolute age of the globular cluster M92. Astronomical Society of the Pacific **122**, 991 - 999 (2010).

Docenko, D. and R.A. Sunyaev: Fine-structure infrared lines from the Cassiopeia A knots. Astron. Astrophys. **509**, 1 - 20 (2010).

Dolag, K., G. Murante and S. Borgani: Dynamical difference between the CD galaxy and the diffuse, stellar component in simulated galaxy. Mon. Not. R. Astron. Soc. **405**, 1544 - 1559 (2010).

Donnert, J., K. Dolag, Brunetti et al.: Radio haloes from simulations and hadronic models - I. The Coma cluster Mon. Not. R. Astron. Soc. **401**, 47 - 54 (2010).

Donoso, E., Ch. Li, G. Kauffmann, et al.: Clustering of radio galaxies and quasars. Mon. Not. R. Astron. Soc. **407**, 1078 - 1089 (2010).

Dotti, M. and M. Ruszkowski: AGN pairs: chance superpositions or black hole binaries? Astrophys. J. Lett. **713**, L37 - L40 (2010).

Elsner, F., B. Wandelt and M.D. Schneider: Probing local non-Gaussianities within a Bayesian framework. Astron. Astrophys. **513**, A59 (2010).

Elsner, F. and B. Wandelt: Local non-Gaussianity in the cosmic microwave background the bayesian way. Astrophys. J. **724**, 1262 - 1269 (2010).

Enke, H., M. Steinmetz, et al. (incl. T. Ensslin): AstroGrid-D: Grid technology for astronomical science. New Astron. **16**, 79 - 93 (2010).

Ensslin, T. and C. Weig: Inference with minimal Gibbs free energy in information field theory. Phys. Rev. E. **882**, 051112, 1 - 13 (2010).

Fabjan, D., S. Borgani et al. (incl. K. Dolag): Simulating the effect of active galactic nuclei feedback on the metal enrichment of galaxy clusters. Mon. Not. R. Astron. Soc. **401**, 1670 - 1690 (2010).

Fakhouri, O., Ch-P. Ma, and M. Boylan-Kolchin: The Merger Rates and Mass Assembly Histories of Dark Matter Haloes in the Two Millennium Simulations. Mon. Not. R. Astron. Soc. **406**, 2267 - 2278 (2010).

Faltenbacher, A.: The impact of environment on the dynamical structure of satellite systems. Mon. Not. R. Astron. Soc. **408**, 947 - 960 (2010).

Faltenbacher, A. and S.D.M. White: Assembly Bias and the Dynamical Structure of Dark Matter Halos. Astrophys. J. **708**, 469 - 473 (2010).

Faltenbacher, A., A. Finoguenov and N. Drory: The halo mass function conditioned on density from the millennium simulation: insights into missing baryons and galaxy mass functions. Astrophys. J. **712**, 484 - 493 (2010).

Faucher-Giguere, C.A., D. Keres, M. Dijkstra et al.: Lyα cooling emission from galaxy formation Astrophys. J. **725**, 633 - 657 (2010).

Fink, M., F. Röpke, W. Hillebrandt et al.: Double-detonation sub-Chandrasekhar supernovae: can minimum helium shell masses detonate the core? Astron. Astrophys. **514**, A53 (2010).

Fowler, J.W., V. Acquaviva et al. (incl. C. Hernandez-Monteagudo): The Atacama cosmology telescope: a measurement of the $600 < l < 8000$ cosmic microwave background power spectrum at 148 GHz. Astrophys. J. **722**, 1148 - 1161 (2010).

Fraser, M., K. Takats, et al. (incl. S. Taubenberger): On the Progenitor and Early Evolution of the Type II Supernova 2009kr. Astrophys. J. Lett. **714**, L280 - L284 (2010).

Frommert, M. and T.A. Enßlin: The axis of evil - a polarization perspective. Mon. Not. R. Astron. Soc. **403**, 1739 - 1748 (2010).

Frommert, M., D. Pflueger, T. Riller et al.: Efficient cosmological parameter sampling using sparse grids. Mon. Not. R. Astron. Soc. **406**, 1177 - 1189 (2010).

Fryer, C.L., A. J. Ruiter et al. (incl. P. Mazzali): Spectra of Type Ia Supernovae from Double Degenerate Mergers Astrophys. J. **725**, 296 - 308 (2010).

Fu, J., Q. Guo, G. Kauffmann and M. Krumholz: The atomic-to-molecular transition and its relation to the scaling properties of galaxy discs in the local universe. Mon. Not. R. Astron. Soc. **409**, 515 - 530 (2010).

Gadotti, D. M. Baes and S. Falony: Radiative transfer in disc galaxies - IV. The effects of dust attenuation on bulge and disc structural parameters. Mon. Not. R. Astron. Soc. **403**, 2053 - 2062 (2010).

Galametz, A., J. Vernet et al. (incl. R. Overzier): Galaxy protocluster candidates at $1.6 < z = 2$. Astron. Astrophys, **522**, A58 (2010).

Gandhi, P., V.S. Dhillon et al. (incl. H. Spruit): Rapid optical and X-ray timing observations of GX339-4: multicomponent optical variability in the low/hard state. Mon. Not. R. Astron. Soc. **407**, 2166 - 2192 (2010).

Gao, L., T. Theuns, et al. (incl. V. Springel and S. White): The earliest stars and their relics in the Milky Way. Mon. Not. R. Astron. Soc. **403**, 1283 - 1295 (2010).

Gawryszczak, A., J. Guzman, T. Plewa and K. Kifonidis: Non-spherical core collapse supernovae - III. Evolution towards homology and dependence on the numerical resolution. Astron. Astrophys. **521**, A38 (2010).

Genel, S., N. Bouche, T. Naab et al. The growth of dark matter halos: evidence for significant smooth accretion. Astrophs. J. **719**, 229 - 239 (2010).

Gilfanov, M. and A. Bogdan: An upper limit on the contribution of accreting white dwarfs to the type Ia supernova rate. Nature, **463**, 924 - 925 (2010).

Giuffrida, G., L. Sbordone, S. Zaggia et al.: A wide angle view of the Sagittarius dwarf Spheroidal Galaxy. I: VIMOS photometry and radial velocities across Sgr dSph major and minor axis. Astron. Astrophys. **513**, A62 (2010).

Gizon, L., A.C. Birch and H.C. Spruit: Local He- lioseismology: Three Dimensional Imaging of the Solar Interior. Ann. Rev. Astron. Astrophys. **48**, 289 - 338 (2010).

Gjerlow, E., H.K. Erikson, A.J. Banday et al: The two- and three-point correlation functions of the polarized five-year WMAP sky maps. Astrophys. J. **710**, 689 - 697 (2010).

Goncalves, T. S., A. Basu-Zych, R. Overzier et al: The Kinematics of Ionized Gas in Lyman-break Analogs at z $\sim$ 0.2. Astrophys. J. **724**, 1373 - 1388 (2010).

Goodger, J., M. Hardcastle et al. (incl. M. Gilfanov): Long-Term Monitoring of the Dynamics and Particle Acceleration of Knots in the Jet of Centaurus A. Astrophys. J. **708**, 675 - 697 (2010).

Graziani, L, L. Barletti, S. Aiello and C. Cecchi-Pestellini: Radiative transfer modelling in protoplanetary disks with the P-N approximation and Monte Carlo techniques. Math. Meth. Appl. Sci. **33**, 1263 - 1273 (2010).

Grebenev, S.A. and R. A. Sunyaev: New fast X-ray transient IGR J18462-0223 discovered by the INTEGRAL observatory. Astron. Lett. **36**, 533 - 539 (2010).

Greif, T.H., S.C. Glover, V. Bromm and R. Klessen: The First Galaxies: Chemical Enrichment, Mixing, and Star Formation. Astrophys. J. **716**, 510 - 520 (2010).

Grevesse, N., M. Asplund, A. Sauval and P. Scott. The chemical composition of the Sun. Astrophys. and Space Science **328**, 179 - 183 (2010).

Gritschneder, M., A. Burkert, T. Naab and S. Walch: Detailed Numerical Simulations on the Formation of Pillars Around H II Regions. Astrophys. J. **723**, 971-984 (2010).

Gualandris, A., S. Gillessen and D. Merritt: The Galactic Centre star S2 as a dynamical probe for intermediate-mass black holes. Mon. Not. R. Astron. Soc. **409**, 1146 - 1154 (2010).

Gunar, S., P. Schwartz et al. (incl. U. Anzer): Statistical comparison of the observed and synthetic hydrogen Lyman line profiles in solar prominences. Astron. Astrophys. **514**, 1 - 11 (2010).

Guo, Qi, S. White, Ch. Li, and M. Boylan-Kolchin: How do galaxies populate dark matter haloes? Mon. Not. R. Astron. Soc. **404**, 1111 - 1120 (2010).

Gustafsson, B., J. Melendez, M. Asplund and D. Yong: The chemical composition of solar-type stars in comparison with that of the Sun. Astrophys. and Space Science **328**, 185 - 191 (2010).

Hammer, N., H.-Th. Janka and E. Müller: Three-dimensional Simulations of Mixing Instabilities in Supernova Explosions. Astrophys. J. **714**, 1371 - 1385 (2010).

Harker, G., S. Zaroubi et al. (incl. B. Ciardi): Power spectrum extraction for redshifted 21-cm Epoch of Reionization experiments: the LOFAR case. Mon. Not. R. Astron. Soc. **405**, 2492 - 2504 (2010).

Haurberg, N., G. Lubell et al. (incl. A. Serenelli): Ultraviolet-bright Stellar Populations and Their Evolutionary Implications in the Collapsed-core Cluster M15. Astrophys. J. **722**, 158 - 177 (2010).

Hayek, W., M. Asplund et al. (incl. R. Collet): Radiative transfer with scattering for domain-decomposed 3D MHD simulations of cool stellar atmospheres. Astron. Astrophys. **517**, A49 (2010).

Heinzel, P., U. Anzer and S. Gunar: Solar quiescent prominences. Filamentary structure and energetics. Mem. S.It. **81**, 654 - 662 (2010).

Hennawi, J., A.D. Myers et al. (incl. F. Shankar): Binary quasars at high redshift. I. 24 new quasar pairs at z $\sim$ 3-4. Astrophys. J. **719**, 1672 - 1692 (2010).

Henning, P.A., C.M. Springob et al. (incl. B. Catinella): The Arecibo L-band Feed Array Zone of Avoidance Survey. I. Precursor Observations Through the Inner and Outer Galaxy. Astron. J. **139**, 2130 - 2147 (2010).

Herbert-Fort, S., D. Zaritsky, D. Christlein and S. Kannappan: The surface mass density and structure of the outer disk of NGC 628. Astrophys. J. **715**, 902 - 907 (2010).

Hernandez-Monteagudo, C.: Revisiting the WMAP-NVSS angular cross correlation. A skeptic's view. Astron. Astrophys. **520**, A101 (2010).

Hernandez-Monteagudo, C. and R.A. Sunyaev: Galaxy clusters as mirrors of the distant Universe. Implications of the blurring term for the kSZ and ISW effects. Astron. Astrophys. **509**, 1 - 9 (2010).

Hess, S. and V. Springel: Particle hydrodynamics with tessellation techniques. Mon. Not. R. Astron. Soc. **406**, 2289 - 2311(2010).

Hilbert St. and S.D.M. White: Abundances, masses and weak-lensing mass profiles of galaxy clusters as a function of richness and luminosity in ΛCDM cosmologies. Mon. Not. R. Astron. Soc. **404**, 486 - 501 (2010).

Hirschmann, M., S. Khochfar et al. (incl. T. Naab): On the evolution of the intrinsic scatter in black hole versus galaxy mass relations. Mon. Not. R. Astron. Soc. **407**, 1016 - 1032 (2010).

Hosford, A., A.E. Garcia Perez, R. Collet et al.: Lithium abundances of halo dwarfs based on excitation temperatures. II. Non-local thermodynamic equilibrium. Astron. Astrophys. **511**, 1 - 12 (2010).

Hou, Z., A.J. Banday, K. Gorski et al.: Frequentist comparison of CMB local extrema statistics in the five-year WMAP data with two anisotropic cosmological models. Mon. Not. R. Astron. Soc. **401**, 2379 - 2387 (2010).

Hou, Z., A.J. Banday, et al. (incl. F. Elsner): The primordial non-Gaussianity of local type (f'local'NL) in the WMAP 5-year data: the length distribution of CMB skeleton. Mon. Not. R. Astron. Soc. **407**, 2141 - 2156 (2010).

Hüdepohl, L., B. Müller, H.-T. Janka et al.: Neutrino Signal of Electron-Capture Supernovae from Core Collapse to Coolin. Phys. Rev. Lett. **104**, 251101 (2010).

Inoue, S., R. Salvaterra et al. (incl. B. Ciardi): Probing intergalactic radiation fields during cosmic reionization through gamma-ray absorption. Mon. Not. R. Astron. Soc. **404**, 1938 - 1943 (2010).

Irrgang, A., N. Przybilla et al. (incl. F. Nieva): The nature of the hyper-runaway candidate Hip 60350. Astrophys. J. **711**, 138 - 143 (2010).

Jackson, N., S. Bryan, S. Mao and Ch. Li: Satellites in the field and lens galaxies: SDSS/COSMOS versus SLACS/CLASS. Mon. Not. R. Astron. Soc. **403**, 826 - 837 (2010).

Jaffe, T., J. Leahy, A. Banday et al.: Modelling the galactic magnetic field on the plane in two dimensions. Mon. Not. R. Astron. Soc. **401**, 1013 - 1028 (2010).

Jasche, J., F.S. Kitaura, B. Wandelt and T. Ensslin: Bayesian power-spectrum inference for large-scale structure data Mon. Not. R. Astron. Soc. **406**, 60 - 85 (2010).

Jasche, J. and F. Kitaura: Fast Hamiltonian sampling for large-scale structure inference. Mon. Not. R. Astron. Soc. **407**, 29 - 42 (2010).

Jasche, J., F.S. Kitaura, Ch. Li and T. Ensslin: Bayesian non-linear large-scale structure inference of the sloan digital sky survey data release 7. Mon. Not. R. Astron. Soc. **409**, 355 - 370 (2010).

Jennings, E., C. Baugh, R. Angulo and S. Pascoli: Simulations of quintessential cold dark matter: beyond the cosmological constant. Mon. Not. R. Astron. Soc. **401**, 2181 - 2201 (2010).

Jofre-P., B. Panter, C.J. Hansen and A. Weiss: Stellar atmosphere parameters with MA_{Ξ}, a MAssive compression of Xi2 for spectral fitting. Astron. Astrophys. **517**, 1 - 17 (2010).

Karl, S., T. Naab, P. Johansson et al.: One moment in time - modeling star formation in the antennae. Astrophys. J. Lett. **715**, L88 - L93 (2010).

Kauffmann, G., Ch. Li, and T.M. Heckman: The Accretion of Gas onto Galaxies as Traced by their Satellites. Mon. Not. R. Astron. Soc. **409**, 491 - 499 (2010).

Kawabata, K. S., K. Maeda, et al. (incl. S. Taubenberger): A massive star origin for an unusual helium-rich supernova in an elliptical galaxy. Nature, **465**, 326 - 328 (2010).

Kitaura, F.S., J. Jasche and B. Metcalf: Recovering the non-linear density field from the galaxy distribution with a Poisson-lognormal filter. Mon. Not. R. Astron. Soc. **403**, 589 - 604 (2010).

Kotarba, H., et al. (incl. K. Dolag and F. Stasyszyn): Simulating Magnetic Fields in the Antennae Galaxies. Astrophys. J. **716**, 1438 - 1452 (2010).

Kraemer, W. and V. Spirko: Statistical properties of the energies and electric dipole moments of the bound vibrational states of the system HCO+/COH+. Chemical Physics **373**, 170 - 180 (2010).

Krivonos, R., M. Revnivtsev, S. Tsygankov et al.: INTEGRAL/IBIS 7-year All-Sky Hard X-Ray Survey. Part I: Image Reconstruction. Astron. Astrophys. **519**, A107 (2010).

Krivonos, R., S. Tsygankov, M. Revnivtsev et al.: INTEGRAL/IBIS 7-year All-Sky Hard X-Ray Survey. Part II: Catalog of Sources. Astron. Astrophys. **523**, A61 (2010).

Kromer, M., S.A. Sim, M. Fink et al.: Double-detonation Sub-Chandrasekhar Supernovae: Synthetic Observables for Minimum Helium Shell Mass Models. Astrophys. J. **719**, 1067 - 1082 (2010).

Kuiper, E., N.A. Hatch, et al. (incl. R. Overzier): A galaxy populations study of a radio-selected protocluster at $z \sim 3.1$. Mon. Not. R. Astron. Soc. **405**, 969 - 986 (2010).

Landau, S.J. and G.C. Scoccola: Constraints on variation in alpha and me from WMAP 7-year data. Astron. Astrophys. **517**, 1 - 4 (2010).

Ledo, H., M. Sarzi, M. Dotti and S. Khochfar: A census of nuclear stellar discs in early-type galaxies. Mon. Not. R. Astron. Soc. **407**, 969 - 985 (2010).

Lee, J. and V. Springel: A scaling relation of the evolving tidal fields in a Lambda-CDM cosmology. J. of Cosmology and Astrop. Phys. **05**, 031-042 (2010).

Li, Z.Y., L.R. Spitler et al. (incl. M. Gilfanov): X-ray Emission from the Sombrero Galaxy: Discrete Sources Astrophys. J. **721**, 1368 - 1382 (2010).

Li, Ch. and S.D.M. White: Autocorrelations of stellar light and mass in the low-redshift Universe. Mon. Not. R. Astron. Soc. **407**, 515 - 519 (2010).

Liu, L., X.H. Yang, et al. (incl. V. Springel): The Stellar Mass Components of Galaxies: Comparing Semi-Analytical Models with Observation. Astrophys. J. **712**, 734 - 745 (2010).

Ludlow, A. D., J.F. Navarro, V. Springel et al.: Secondary Infall and the Pseudo-Phase-Space Density Profiles of Cold Dark Matter Halos. Mon. Not. R. Astron. Soc. **406**, 137 - 146 (2010).

Lund T., A. Marek, et al. (incl. H.-T. Janka): Fast time variations of supernova neutrino fluxes and their detectability. Physical Review D. **83**, 1 - 13 (2010).

Maeda K., et al. (incl. F. Röpke and S. Taubenberger): An asymmetric explosion as the origin of spectral evolution diversity in type Ia supernovae. Nature, **466**, 82 - 85 (2010).

Maeda K., S. Taubenberger et al. (incl. P. Mazzali): Nebular Spectra and Explosion Asymmetry of Type Ia Supernovae. Astrophys. J. **708**, 1703 - 1715 (2010).

Maeda, K., F. Röpke, M. Fink, W. Hillebrandt et al.: Nucleosynthesis in Two-Dimensional Delayed Detonation Models of Type Ia Supernova Explosions. Astrophys. J. **712**, 624 - 638 (2010).

Magic, Z., A. Serenelli, A. Weiss and B. Chaboyer: On Using the Color-Magnitude Diagram Morphology of M67 to Test Solar Abundances. Astrophys. J. **718**, 1378 - 1387 (2010).

Maio, U., B. Ciardi, K. Dolag et al.: The transition from population III to population II-I star formation. Mon. Not. R. Astron. Soc. **407**, 1003 - 1015 (2010).

Malec, E. and T. Rembiasz: General Relativistic versus Newtonian: a universality in radiation hydrodynamics. Physical Review D. **82**, 124005 (2010).

Mandolesi, N. et al. (incl. MPA PLANCK group): Planck pre-launch status: the Planck-LFI programme. Astron. Astrophys. **520**, A3 (2010).

Maurer I. and P.A. Mazzali: Oxygen recombination in the nebular phase of supernovae 1998bw and 2002ap. Mon. Not. R. Astron. Soc. **408**, 947 - 960 (2010).

Maurer, I., P. Mazzali et al. (incl. S. Taubenberger): Characteristic velocities of stripped-envelope core-collapse supernova cores. Mon. Not. R. Astron. Soc. **402**, 161 - 172 (2010).

Maurer, I., P. Mazzali, S. Taubenberger and S. Hachinger: Hydrogen and helium in the late phase of supernovae of Type IIb Mon. Not. R. Astron. Soc. **409**, 1441 - 1454 (2010).

Mazzali, P. A., I. Maurer, S. Valenti et al.: The Type Ic SN 2007gr: a census of the ejecta from late-time optical-infrared spectra. Mon. Not. R. Astron. Soc. **408**, 87 - 96 (2010).

McCarthy, I.G., J. Schaye et al. (incl. R. Wiersma): The case for AGN feedback in galaxy groups. Mon. Not. R. Astron. Soc. **406**, 822 - 839 (2010).

Mead, J.M.G, L.J. King et al. (incl. E. Puchwein): The impact of AGN feedback and baryonic cooling on galaxy clusters as gravitational lenses. Mon. Not. R. Astron. Soc. **406**, 434 - 444 (2010).

Melendez, J., I. Ramirez, L. Casagrande, et al.: The solar, exoplanet and cosmological lithium problems. Astrophys. and Space Science, **328**, 193 - 200 (2010).

Melendez, J., L. Casagrande, I. Ramirez et al.: Observational evidence for a broken Li Spite plateau and mass-dependent Li depletion. Astron. Astrophys. Lett. **515**, 1 - 7 (2010).

Melendez, J., et al. (incl. I. Ramirez and L. Casagrande): UV by-beta photometry of solar twins: the solar colors, model atmospheres, and the Teff and metallicity scales. Astron. Astrophys. **522**, A98 (2010).

Menanteau, F., J. Gonzalez et al. (incl. C. Hernandez-Monteagudo): The Atacama cosmology telescope: physical properties and purity of a galaxy cluster sample selected via the Sunyaev-Zel'dovich effect. Astrophys. J. **723**, 1523 - 1541 (2010).

Meneghetti, M., E. Rasia et al. (incl. K. Dolag): Weighing simulated galaxy clusters using lensing and X-ray. Astron. Astrophys. **514**, 1 - 23 (2010).

Metcalf, R.B.: Neutrino masses, dark energy and the gravitational lensing of pre-galactic H i. Mon. Not. R. Astron. Soc. **401**, 1999 - 2004 (2010).

Metcalf, T.S., M. Monteiro et al. (incl. V.A. Silva): A precise asteroseismic age and radius for the evolved sun-like star KIC 11026764. Astrophys. J. **723**, 1583 - 1598 (2010).

Milne, P.A, P. Brown et al. (incl. P. Mazzali): Near-ultraviolet Properties of a Large Sample of Type Ia Supernovae as Observed with the Swift UVOT. Astrophys. J. **721**, 1627 - 1655 (2010).

Mocak, M., S. Campbell, E. Müller and K. Kifonidis: The core helium flash revisited. III. From Population I to Population III stars. Astron. and Astrophys. **520**, A114 (2010).

Moll, R.: Large jets from small-scale magnetic fields. Astron. Astrophys. **512**, A5 (2010).

Monaco, L., P. Bonifacio, L. Sbordone et al.: The lithium content of omega Centauri. New clues to the cosmological Li problem from old stars in external galaxies. Astron. Astrophys. **519**, L3 (2010).

Montero, P., J. Font and M. Shibata: Influence of Self-Gravity on the Runaway Instability of Black-Hole-Torus Systems. Phys. Rev. Lett. **104**, 191101 (2010).

Moradi, H., C. Baldner, et al. (incl. H. Spruit): Modeling the Subsurface Structure of Sunspots. Sol. Phys. **267**, 1 (2010).

Moran, S.M., G. Kauffmann, et al. (incl. B. Catinella): UGC8802: A Massive Disk Galaxy in Formation. Astrophys. J. **720**, 1126 - 1135 (2010).

Moriya, T., N. Tominaga, et al. (incl. P. Mazzali): Fallback Supernovae: A Possible Origin of Peculiar Supernovae with Extremely Low Explosion Energies. Astrophys. J. **719**, 1445 - 1453 (2010).

Müller, B., H.-Th Janka and H. Dimmelmeier: A New Multi-dimensional General Relativistic Neutrino Hydrodynamic Code for Core-collapse Supernovae. I. Method and Code Tests in Spherical Symmetry. Astrophys. J. Suppl. **189**, 104 - 133 (2010).

Muthsam, H.J., F. Kupka, B. Loew-Baselli et al.: ANTARES - A Numerical Tool for Astrophysical RESearch with applications to solar granulation. New Astron. **15**, 460 - 475 (2010).

Navarro, J. F., Ludlow, A., V. Springel, et al.: The diversity and similarity of simulated cold dark matter haloes. Mon. Not. R. Astron. Soc. **402**, 21 - 34 (2010).

Nayakshin, S. and C. Power: Simulations of momentum feedback by black hole winds. Mon. Not. R. Astron. Soc. **402**, 789 - 802 (2010).

Neistein, E., A. Maccio and A. Dekel: Universal merger histories of dark-matter haloes. Mon. Not. R. Astron. Soc. **403**, 984 - 995 (2010).

Neistein, E. and S. Weinmann: The degeneracy of galaxy formation models. Mon. Not. R. Astron. Soc. **405**, 2717 - 2736 (2010).

Noebauer, U., K.S. Long, S. Sim and C. Knigge: The Geometry and Ionization Structure of the Wind in the Eclipsing Nova-like Variables RW Tri and UX UMa. Astrophys. J. **719**, 1932 - 1945 (2010).

Nuza, S., K. Dolag and A. Saro: Photometric and clustering properties of hydrodynamical galaxies in a cosmological volume: results at z = 0. Mon. Not. R. Astron. Soc. **407**, 1376 - 1386 (2010).

Obergaulinger, M., M.A. Aloy and E. Müller: Local simulations of the magnetized Kelvin-Helmholtz instability in neutron-star mergers. Astron. Astrophys. **515**, 1 - 25 (2010).

Oser, L., J. Ostriker, T. Naab et al.: The Two Phases of Galaxy Formation. Astrophys. J. **725**, 2312 - 2323 (2010).

Overzier, R.A., T.M. Heckman, D. Schiminovich et al.: Morphologies of Local Lyman Break Galaxy Analogs. II. A Comparison with Galaxies at $z = 2 - 4$ in ACS and WFC3 Images of the Hubble Ultra Deep Field. Astrophys. J. **710**, 979 - 991 (2010).

Padilla, N., D. Christlein, E. Gawiser et al.: Clustering and descendants of MUSYC galaxies at $z < 1.5$. Mon. Not. R. Astron. Soc. **409**, 184 - 198 (2010).

Pakmor, R., M. Kromer, F.K. Röpke et al.: Sub-luminous type Ia supernovae from the mergers of equal-mass white dwarfs with $M \sim 0.9\ M_{\odot}$. Nature, **463**, 61 - 64 (2010).

Pastorello, A., M.T. Botticella, et al. (incl. S. Taubenberger): Multiple major outbursts from a restless luminous blue variable in NGC 3432. Mon. Not. R. Astron. Soc. **408**, 181 - 198 (2010).

Pedrosa, S., P. Tissera and C. Scannapieco: The joint evolution of baryons and dark matter haloes. Mon. Not. R. Astron. Soc. **402**, 776 - 788 (2010).

Perets, H. B., A. Gal-Yam, P. Mazzali et al.: A faint type of supernova from a white dwarf with a helium-rich companion. Nature, **465**, 322 - 325 (2010).

Perets, H. B. and A. Gualandris: Dynamical constraints on the origin of the young B-stars in the galactic center . Astrophys. J. **719**, 220 - 228 (2010).

Poggianti, B., G. De Lucia et al. (incl. S.D.M. White): The evolution of the density of galaxy clusters and groups: denser environments at higher redshifts. Mon. Not. R. Astron. Soc. **405**, 995 - 1005 (2010).

Portinari, L., L. Casagrande and C. Flynn: Revisiting Δ Y/Δ Z from multiple main sequences in globular clusters: insight from nearby stars. Mon. Not. R. Astron. Soc. **406**, 1570 - 1582 (2010).

Prézeau, G. and M. Reinecke: Algorithm for the Evaluation of Reduced Wigner Matrices Astrophys. J. Suppl. **190**, 267 - 274 (2010).

Przybilla, N., M. Firnstein, F. Nieva et al.: Mixing of CNO-cycled matter in massive stars. Astron. Astrophys. **517**, 1 - 6 (2010).

Puchwein, E., V. Springel, D. Sijacki and K. Dolag: Intracluster stars in simulations with AGN feedback. Mon. Not. R. Astron. Soc. **406**, 936 - 951 (2010).

Ramirez, I., M. Asplund, P. Baumann et al. A possible signature of terrestrial planet formation in the chemical composition of solar analogs. Astron. Astrophys. **521**, A33 (2010).

Ramirez, I., Collet et al. (incl. M. Asplund): Granulation signatures in the spectrum of the very metal-poor red giant HD122563. Astrophys. J. Lett. **723**, L223 - L227 (2010).

Reid, B., L. Verde, K. Dolag et al.: Non-Gaussian halo assembly bias. J. Cosmol. Astropart. Phys. **7**, 1 - 21 (2010).

Ritter, H.: Formation and evolution of cataclysmic variables: Mem. Soc. Astron. It. **81**, 849 - 862 (2010).

Roncarelli, R., L. Moscardini et al. (incl. K. Dolag): Imprints of primordial non-Gaussianities in X-ray and SZ signals from galaxy clusters. Mon. Not. R. Astron. Soc. **402**, 923 - 933 (2010).

Ruffert, M. and H.-Th. Janka: Polytropic neutron star - black hole merger simulations with a PaczyÅĎski-Wiita potential. Astron. Astrophys. **514**, A66 (2010).

Ruiter, A. J., K. Belczynski, M. Benacquista, et al.: The LISA Gravitational Wave Foreground: A Study of Double White Dwarfs. Astrophys. J. **717**, 1006 - 1021 (2010).

Ryde, N., B. Gustaffson, et al. (incl. M. Asplund): Chemical abundances of 11 bulge stars from high-resolution, near-IR spectra. Astron. Astrophys. **509**, A20 (2010).

Saglia, R.P., P. Sanchez-Blazquez et al. (incl. S.D.M. White): The fundamental plane of EDisCS galaxies. The effect of size evolution. Astron. Astrophys. **524**, A6 (2010).

Sako, T., J. Paldus and G. Diercksen: Origin of Hund's multiplicity rule in quasi-two-dimensional two-electron quantum dots. Phys. Rev. A. **81**, 022501 (2010).

Sales, L., J. Navarro et al. (incl. V. Springel): Feedback and the structure of simulated galaxies at redshift z = 2. Mon. Not. R. Astron. Soc. **409**, 1541 - 1556 (2010).

Saracco, F., M. Pietroni et al. (incl. G. Robbers): Nonlinear matter spectra in coupled quintessence. Phys. Rev. D. **82**, 1 - 14 (2010).

Saro, A., G. De Lucia, S. Borgani, and K. Dolag: Gas cooling in semi-analytic models and smoothed particle hydrodynamics simulations: are results consistent? Mon. Not. R. Astron. Soc. **406**, 729 - 743 (2010).

Sawala, T., C. Scannapieco, U. Maio and S.D.M. White: Formation of isolated dwarf galaxies with feedback. Mon. Not. R. Astron. Soc. **402**, 1599 - 1613 (2010).

Sbordone, L., P. Bonifacio, E. Caffau et al.: The metal-poor end of the Spite plateau. I. Stellar parameters, metallicities, and lithium abundances. Astron. Astrophys. **522**, A26 (2010).

Scannapieco, C., D.A. Gadotti, P. Jonsson and S.D.M. White: An observer's view of simulated galaxies: disc-to-total ratios, bars, and (pseudo-) bulges. Mon. Not. R. Astron. Soc. Lett. **407**, 41 - 45 (2010).

Schäfer, J.: Transport Coefficients of dilute hydrogen gas, calculations and comparisons with experiments. Chemical Physics **368**, 38 - 48 (2010).

Schäfer, J.: Calculated cross sections for transport coefficients of H2 dilute in He and HI gas. Chemical Physics **374**, 15 - 21 (2010).

Schiminovich, D., B. Catinella, G. Kauffmann, et al.: The GALEX Arecibo SDSS Survey - II. The star formation efficiency of massive galaxies. Mon. Not. R. Astron. Soc. **408**, 919 - 934 (2010).

Schmidt, W., F. Ciaraldi-Schoolmann, J. Niemeyer et al.: Turbulence in a Three-Dimensional Deflagration Model For Type Ia Supernovae. II. Intermittency and the Deflagration-to-Detonation Transition Probability. Astrophys. J. **710**, 1683 - 1693 (2010).

Schönrich, R., J. Binney and W. Dehnen: Local kinematics and the local standard of rest. Mon. Not. R. Astron. Soc. **403**, 1829 - 1833 (2010).

Schrabback, T., J. Hartlap, et al. (incl. S. Hilbert): Evidence of the accelerated expansion of the Universe from weak lensing tomography with COSMOS. Astron. Astrophys. **516**, A63 (2010).

Sehgal, N., P. Bode, et al. (incl. C. Hernandez-Monteagudo): Simulations of the microwave sky. Astrophys. J. **709**, 920 - 936 (2010).

Seitenzahl, I., F. Röpke, M. Fink and R. Pakmor: Nucleosynthesis in thermonuclear supernovae with tracers: convergence and variable mass particles. Mon. Not. R. Astron. Soc. **407**, 2297 - 2304 (2010).

Semboloni, E., T. Schrabback et al. (incl. S. Hilbert): Weak lensing from space: first cosmological constraints from three-point shear statistics. Mon. Not. R. Astron. Soc. **410**, 143 - 160 (2010).

Serenelli, A.: New results on standard solar models. Astrophysics and Space Science **328**, 13 - 21 (2010).

Serenelli, A. and S. Basu: Determining the Initial Helium Abundance of the Sun. Astrophys. J. **719**, 865 - 872 (2010).

Shankar, F., F. Marulli, M. Bernardi et al.: Sizes and ages of SDSS ellipticals: comparison with hierarchical galaxy formation models. Mon. Not. R. Astron. Soc. **403**, 117 - 128 (2010).

Shankar, F., F. Marulli, et al. (incl. M. Boylan-Kolchin): Further constraining galaxy evolution models through the size function of SDSS early-type galaxies. Mon. Not. R. Astron. Soc. **405**, 948 - 960 (2010).

Shankar, F., D.H. Weinberg and Y. Shen: Constraints on black hole duty cycles and the black hole-halo relation from SDSS quasar clustering. Mon. Not. R. Astron. Soc. **406**, 1959 - 1966 (2010).

Shankar, F., G. Sivakoff, M. Vestergaard and X.Y. Dai: The relative growth of optical and radio quasars in SDSS. Mon. Not. R. Astron. Soc. **401**, 1869 - 1881 (2010).

Shen, Y., J. Hennawi, F. Shankar et al.: Binary quasars at high redshift. II. Sub-Mpc clustering at z 3-4. Astrophys. J. **719**, 1693 - 1698 (2010).

Sheth, K., M. Regan et al. (D. Gadotti): The Spitzer survey of stellar structure in galaxies (S4G). Publ. Astron. Soc. Pac. **122**, 1397 - 1414 (2010).

Shtykovskiy, P. and M. Gilfanov: Thermal diffusion in the intergalactic medium of clusters of galaxies. Mon. Not. R. Astron. Soc. **401**, 1360 - 1368 (2010).

Silva, A.V., M. Catelan and A. Weiss: Pulsation period changes as a tool to identify pre-zero age horizontal branch stars. Astrophys. and Space Science, **328**, 123 - 127 (2010).

Silva Aguirre, V., J. Ballot, A. Serenelli and A. Weiss: Semiconvective mixing in low-mass stars. Astrophysics and Space Science **328**, 129 - 133 (2010).

Sim, S.A., L. Miller, K.S. Long et al.: Multidimensional modelling of X-ray spectra for AGN accretion disc outflows - II. Mon. Not. R. Astron. Soc. **404**, 1369 - 1384 (2010).

Sim, S.A, D. Proga, L. Miller et al.: Multidimensional modelling of X-ray spectra for AGN accretion disc outflows - III. Application to a hydrodynamical simulation. Mon. Not. R. Astron. Soc. **408**, 1396 - 1408 (2010).

Sim, S.A., F. Röpke, W. Hillebrandt et al.: Detonations in Sub-Chandrasekhar-mass C+O White Dwarfs: Astrophys. J. Lett. **714**, L52 - L57 (2010).

Simionescu, A., N. Werner et al. (incl. E. Churazov): Metal transport by gas sloshing in M87. Mon. Not. R. Astron. Soc. **405**, 91 - 99 (2010).

Springel, V.: E pur si muove: Galilean-invariant cosmological hydrodynamical simulations on a moving mesh. Mon. Not. R. Astron. Soc. **401**, 791 - 851 (2010).

Spruit, H., G.B. Scharmer and M.G. Loefdahl: Striation and convection in penumbral filaments. Astron. Astrophys. **521**, A72 (2010).

Stasyszyn, F., S. Nuza, K. Dolag et al.: Measuring cosmic magnetic fields by rotation measure-galaxy cross-correlations in cosmological simulations. Mon. Not. R. Astron. Soc. **408**, 684 - 694 (2010).

Stello, D., et al. (incl. A. Serenelli, V. Silva and A. Weiss): Detection of solar-like oscillations from Kepler photometry of the open cluster NGC 6819. Astrophys. J. Lett. **713**, L182 - L186 (2010).

Strigari, L., C. Frenk and S.D.M. White: Kinematics of Milky Way satellites in a Lambda cold dark matter universe. Mon. Not. R. Astron. Soc. **408**, 2364 - 2372 (2010).

Suyu, S.H, P. Marshall et al. (incl. S. Hilbert): Dissecting the Gravitational lens B1608+656. II. Precision measurements of the Hubble constant, spatial curvature, and the dark energy equation of state. Astrophys. J. **711**, 201 - 221 (2010).

Tanaka, M., K. Kawabata et al. (incl. P. Mazzali): Spectropolarimetry of extremely luminous type Ia supernova 2009dc: nearly spherical explosion of super-Chandrasekhar mass white dwarf. Astrophys. J. **714**, 1209 - 1216 (2010).

Tauber, J. A. et al. (incl. MPA PLANCK Group): Planck pre-launch status: The Planck mission. Astron. Astrophys. **520**, A1 (2010).

Thöne, C., D. Kann et al. (incl. R. Sunyaev): Photometry and spectroscopy of GRB 060526: a detailed study of the afterglow and host galaxy of a z = 3.2 gamma-ray burst. Astron. Astrophys. **523**, A70 (2010).

Tissera, P., S.D.M. White, S. Pedrosa and C. Scannapieco: Dark matter response to galaxy formation. Mon. Not. R. Astron. Soc. **406**, 922 - 935 (2010).

Tornatore, L., S. Borgani, M. Viel and V. Springel: The impact of feedback on the low-redshift intergalactic medium. Mon. Not. R. Astron. Soc. **402**, 1911 - 1926 (2010).

Tsygankov, S. S., A.A. Lutovinov and A.V. Serber: Completing the puzzle of the 2004-2005 outburst in V0332+53: the brightening phase included. Mon. Not. R. Astron. Soc. **401**, 1628 - 1635 (2010).

Tsygankov, S. S. and E.M. Churazov: Search for outbursts in the narrow 511-keV line from compact sources based on INTEGRAL data. Astronomy Lett. **36**, 237 - 247 (2010).

Turk, M., P. Clark et al. (incl. T. Greif): Effects of varying the three-body molecular hydrogen formation rate in primordial star formation. Astrophys. J. **726**, 1 - 11 (2010).

Utrobin, V., N. Chugai and M. Botticella: Type IIP supernova 2009kf: Explosion driven by black hole accretion? Astrophys. J. Lett. **723**, L89 - L92 (2010).

Utsumi, Y., T. Goto et al. (incl. R. Overzier): A Large Number of z > 6 Galaxies Around a QSO at z = 6.43: Evidence for a Protocluster? Astrophys. J. **721**, 1680 - 1688 (2010).

Van den Berg, D.A., L. Casagrande and P. Stetson: An Examination of Recent Transformations to the BV(RI) C Photometric System from the Perspective of Stellar Models for Old Stars. Astrophys. J. **140**, 1020 - 1037 (2010).

Viel, M., M.G. Haehnelt and V. Springel: The effect of neutrinos on the matter distribution as probed by the intergalactic medium. J. of Cosmology and Astrop. Phys. **06**, 015 - 053 (2010).

Volonteri, M., K. Gültekin, and M. Dotti: Gravitational recoil: effects on massive black hole occupation fraction over cosmic time. Mon. Not. R. Astron. Soc. **404**, 2143 - 2150 (2010).

von der Linden, A., V. Wild, G. Kauffmann, et al.: Star formation and AGN activity in SDSS cluster galaxies. Mon. Not. R. Astron. Soc. **404**, 1231 - 1246 (2010).

Wang, J., R. Overzier, G. Kauffmann et al.: The UV-optical colours of brightest cluster galaxies in optically and X-ray selected clusters. Mon. Not. R. Astron. Soc. **401**, 433 - 444 (2010).

Wang, J.Y., H. Xu et al. (incl. Z. Zhang): How to identify and separate bright galaxy clusters from the low-frequency radio sky. Astrophys. J. **723**, 620 - 633 (2010).

Wang, Y., H.G. Xu et al. (incl. Z. Zhang): Central gas entropy excess as direct evidence for AGN feedback in galaxy groups and clusters. Res. Astron. Astrophys. **10**, 1013 - 1022 (2010).

Weig, C. and T.A. Enßlin: Bayesian analysis of spatially distorted cosmic signals from Poissonian data. Mon. Not. R. Astron. Soc. **409**, 1393 - 1411 (2010).

Weinmann, S., G. Kauffmann, A. von der Linden and G. De Lucia: Cluster galaxies die hard. Mon. Not. R. Astron. Soc. **406**, 2249 - 2266 (2010).

Werner, N., A. Simionescu, et al. (incl. E. Churazov): Feedback under the microscope-II. Heating, gas uplift and mixing in the nearest cluster core. Mon. Not. R. Astron. Soc. **407**, 2063 - 2074 (2010).

Wiersma, R., J. Schaye, C. Dalla Vecchia et al.: The enrichment history of cosmic metals. Mon. Not. R. Astron. Soc. **409**, 132 - 144 (2010).

Wongwathanarat, A., N. Hammer and E. Müller: An axis-free overset grid in spherical polar coordinates for simulating 3D self-gravitating flows. Astron. Astrophys. **514**, A48 (2010).

Wongwathanarat, A., H.-Th. Janka and E. Müller: Hydrodynamical Neutron Star Kicks in Three Dimensions. Astrophys. J. Lett. **725**, L106 - L110 (2010).

Xu, H.G., J.H. Gu et al. (incl. Z.L. Zhang): Clumpy metal concentrations in elliptical galaxies NGC 4374 and NGC 4636. Res. Astron. Astrophys. **10**, 220 - 226 (2010).

Xu, D. D., S. Mao et al. (incl. V. Springel): Substructure Lensing: Effects of Galaxies, Globular Clusters and Satellite Streams. Mon. Not. R. Astron. Soc. **408**, 1721 - 1729 (2010).

Zavala, J., M. Vogelsberger and S.D.M. White: Relic density and CMB constraints on dark matter annihilation with Sommerfeld enhancement. Physical Review D, **81**, 083502 (2010).

Zavala, J., V. Springel and M. Boylan-Kolchin: Extragalactic gamma-ray background radiation from dark matter annihilation. Mon. Not. R. Astron. Soc. **405**, 593 - 612 (2010).

Zhang, Y., V. Springel and X. Yang: Genus statistics using the Delaunay tessellation field estimation method - I. Tests with the millennium simulation and the SDSS DR7. Astrophys. J. **722**, 812 - 824 (2010).

Zhuravleva, I. V., E. M. Churazov, S. Sazonov et al.: Polarization of X-ray lines from galaxy clusters and elliptical galaxies - a way to measure the tangential component of gas velocity. Mon. Not. R. Astron. Soc. **403**, 129 - 150 (2010).

3.1.2 Publications accepted in 2010 (63)

Alves-Brito, A., J. Melendez, M. Asplund et al.: Chemical similarities between Galactic bulge and local thick disk red giants: O,Na, Mg, Al, Si, Ca and Ti. Astron. Astrophys.

Arcones A. and H.-Th. Janka Nucleosynthesis-relevant conditions in neutrino-driven supernova outflows. II. The reverse shock in two-dimensional simulations. Astron. Astrophys.

Bell, M.E., T. Tzioumis et al.(incl. P. Arevalo): X-ray and radio variability in the low luminosity Active Galactic Nucleus NGC 7213. Mon. Not. R. Astron. Soc.

Benetti, S., M. Turatto, et al. (incl. S. Taubenberger): The Type Ib SN 1999dn: one year of photometric and spectroscopic monitoring. Mon. Not. R. Astron. Soc.

Bernardi, M., N.Roche, F. Shankar and R. Sheth: Evidence of major dry mergers at Msun from curvature in early-type galaxy scaling relations? Mon. Not. R. Astron. Soc.

Bernardi, M., N. Roche, F. Shankar and R. Sheth Curvature in the color-magnitude relation but not in color-sigma: Major dry mergers at Msun? Mon. Not. R. Astron. Soc.

Biffi, V., Dolag, K. and Boehringer, H.: Velocity structure diagnostics of simulated galaxy clusters. Mon. Not. R. Astron. Soc.

Bogdan, A. and M. Gilfanov: Soft band X/K luminosity ratios in late-type galaxies and constraints on the population of supersoft X-ray sources. Mon. Not. R. Astron. Soc.

Buerzle, F. et al. (incl. F. Stasyszyn, T. Greif, K. Dolag: Protostellar collapse and fragmentation using an MHD GADGET. Mon. Not. R. Astron. Soc.

Casagrande, L., I. Ramirez, J. Melendez et al.: An absolutely calibrated effective temperature scale from the InfraRed Flux Method. Astron. Astrophys.

Chiavassa, A., E. Pasquato, A. Jorissen, et al.: Radiative hydrodynamics simulations of red supergiant stars. III. Spectro-photocentric variability, photometric variability, and consequences on Gaia measurements. Astron. Astrophys.

Churazov, E., S. Sazonov, S. Tsygankov et al.: Positron annihilation spectrum from the Galactic Centre region observed by SPI/INTEGRAL, revisited: annihilation in a cooling ISM? Mon. Not. R. Astron. Soc.

Churazov, E., I. Zhuravleva, S. Sazonov and R. Sunyaev: Resonant scattering of X-ray emission lines in the hot intergalactic medium. Space Science Reviews.

Colpi, M. and M. Dotti: Massive binary black holes in the cosmic landscape. Advanced Science Lett.

Decarli, R., M. Dotti and A. Treves: Geometry and inclination of the broad line region in blazars. Mon. Not. R. Astron. Soc.

DeGraf, C., T. Di Matteo and V. Springel Quasar Clustering in Cosmological Hydrodynamic Simulations: Evidence for mergers. Mon. Not. R. Astron. Soc.

Durant, M., T. Shahbaz, et al. (incl. H. Spruit): High time resolution optical/X-ray cross-correlations for X-ray binaries: anticorrelations and rapid variability. Mon. Not. R. Astron. Soc.

Ensslin, T., C. Pfrommer, F. Miniati and K. Subramanian: Cosmic ray transport in galaxy clusters: implications for radio halos, gamma-ray signatures and cool core heating. Astron. Astrophys.

Fabello S., B. Catinella, et al. (incl. G. Kauffmann): ALFALFA HI Data Stacking I. Does the Bulge Quench Ongoing Star Formation in Early-Type Galaxies? Mon. Not. R. Astron. Soc.

Freudling, W., L. Staveley-Smith, B. Catinella et al.: Deep 21-cm HI Observations at z 0.1: The Precursor to the Arecibo Ultra Deep Survey. Astrophys. J.

Gabler, M., P. Cerda-Duran et al. (incl. E. Müller): Magneto-elastic oscillations and the damping of crustal shear modes in magnetars. Mon. Not. R. Astron. Soc. Lett.

Gadotti, D.: Secular Evolution and Structural Properties of Stellar Bars in Galaxies. Mon. Not. R. Astron. Soc.

Gao, L., C. Frenk, M. Boylan-Kolchin et al.: The statistics of the subhalo abundance of dark matter haloes. Mon. Not. R. Astron. Soc.

Govoni, F., K. Dolag, M. Murgia et al. Rotation Measures of Radio Sources in Hot Galaxy Clusters. Astron. Astrophys.

Guo, Q., S. White, M. Boylan-Kolchin, et al.: From dwarf spheroidals to cDs: Simulating the galaxy population in a LCDM cosmology. Mon. Not. R. Astron. Soc.

Gvaramadze, V.V. and A. Gualandris: Very massive runaway stars from three-body encounters. Mon. Not. R. Astron. Soc.

Hatch, N. A.; C. De Breuck, et al. (incl. R. Overzier): Galaxy protocluster candidates around z 2.4 radio galaxies. Mon. Not. R. Astron. Soc.

Johnson, J.L, S. Khochfar, T.H. Greif, F. Durier: Accretion onto black holes formed by direct collapse. Mon. Not. R. Astron. Soc.

Khatri, R. and R. Sunyaev: Time of primordial Be-7 conversion into Li-7, energy release and doublet of narrow cosmological neutrino lines. Astron. Lett.

Maciejewski, M., M. Vogelsberger, S. White and V. Springel: Bound and unbound substructures in Galaxy-scale Dark Matter haloes. Mon. Not. R. Astron. Soc.

Maio U., Koopmans L. E. and B. Ciardi: The impact of primordial supersonic flows on early structure formation, reionization and the lowest-mass dwarf galaxies. Mon. Not. R. Astron. Soc.

Marriage, T.A., J.B. Juin et al (incl. C. Hernandez-Monteagudo): Atacama Cosmology Telescope: Extragalactic Sources at 148 GHz in the 2008 Survey. Astrophys. J.

McCarthy, I., J. Schaye, et al. (incl. V. Springel): Gas expulsion by quasar-driven winds as a solution to the over-cooling problem in galaxy groups and clusters. Mon. Not. R. Astron. Soc.

Meyer-Hofmeister, E., and F. Meyer: Broad iron emission lines in Seyfert galaxies re-condensation of gas onto an inner disk below the ADAF. Astron. and Astrophys.

Mineo, S., M. Gilfanov and R. Sunyaev: The collective X-ray luminosity of HMXB as a SFR indicator. Astron. Nachrichten.

Mocak, M. and E. Müller: Rayleigh-Taylor finger instability mixing in hydrodynamic shell convection models. Astron. Astrophys.

Montuori, C., M. Dotti, M. Colpi, R. Decarli, F. Haardt: Search of sub-parsec massive binary black holes through line diagnosis. Mon. Not. R. Astron. Soc.

Neistein, E., S. Weinmann, C. Li and M. Boylan-Kolchin: Linking haloes to galaxies: how many halo properties are needed? Mon. Not. R. Astron. Soc.

Pace, F., L. Moscardini et al. (incl. K. Dolag: A numerical study of the effects of primordial non-Gaussianities on weak lensing statistics. Mon. Not. R. Astron. Soc.

Petkova, M. and V. Springel: Simulations of galaxy formation with radiative transfer: Hydrogen reionisation and radiative feedback. Mon. Not. R. Astron. Soc.

Reinecke, M.: Libpsht - algorithms for efficient spherical harmonic transforms. Astron. Astrophys.

Rest, A., R.J. Foley et al. (incl. P. Mazzali): Direct Confirmation of the Asymmetry of the Cas A SN Explosion with Light Echoes. Astrophys. J.

Revnivtsev, M., S. Potter, et al. (incl. E. Churazov): Observational evidence for matter propagation in accretion flows. Mon. Not. R. Astron. Soc.

Revnivtsev, M., K. Postnov, A. Kuranov and H. Ritter: On the nature of the break in the X-ray luminosity function of low-mass X-ray binaries: Astron. Astrophys.

Roediger, E., M. Brueggen et al. (incl. E. Churazov): Gas sloshing, cold front formation, and metal redistribution: the Virgo cluster as a quantitative test case. Mon. Not. R. Astron. Soc.

Sawala, T., Q. Guo, et al. (incl. S.D.M. White): What is the (Dark) Matter with Dwarf Galaxies? Mon. Not. R. Astron. Soc.

Schnerr, R.S. and H.C. Spruit: The brightness of the magnetic field in the quiet Sun. Astron. Astrophys.

Sijacki, D., V. Springel and M.G. Haehnelt: Gravitational recoils of supermassive black holes in hydrodynamical simulations of gas rich galaxies. Mon. Not. R. Astron. Soc.

Starling, R., K. Wiersema, et al. (incl. P. Mazzali): Discovery of the nearby long, soft GRB 100316D with an associated supernova Mon. Not. R. Astron. Soc.

Tanaka, M., P. Mazzali, et al. (incl. I. Maurer): Abundance stratification in Type Ia supernovae - III. The normal SN2003du. Mon. Not. R. Astron. Soc.

Taubenberger, S. et al. (incl. S. Hachinger, W. Hillebrandt et al.): High luminosity, slow ejecta and persistent carbon lines: SN 2009dc challenges thermonuclear explosion scenarios. Mon. Not. R. Astron. Soc.

Tepper-Garcia, T., P. Richter et al.(incl. R. Wiersma): Absorption signatures of warm-hot gas at low redshift: OVI. Mon. Not. R. Astron. Soc.

Vogelsberger, M. and S.D.M. White: Streams and caustics: the fine-grained structure of LCDM haloes. Mon. Not. R. Astron. Soc.

Vogelsberger M., R. Mohayaee and S.D.M. White: Nonspherical similarity solutions for dark halo formation. Mon. Not. R. Astron. Soc.

Wadepuhl, M. and V. Springel: Satellite galaxies in hydrodynamical simulations of Milky Way sized galaxies. Mon. Not. R. Astron. Soc.

Waldman, R., D. Sauer et al. (incl. P. Mazzali): Helium Shell Detonations on Low Mass White Dwarfs as a Possible Explanation for SN 2005E. Astrophys. J.

Wanajo, S., H.-Th. Janka and S. Kubono: Uncertainties in the nu p-process: supernova dynamics versus nuclear physics. Astrophys. J.

Wanajo, Sh., H.-Th. Janka and B. Müller: Electron-capture supernovae as the origin of elements beyond iron. Astrophys. J. Lett.

Wang J., et al (incl. S. White, V. Springel): Assembly History and Structure of Galactic Cold Dark Matter Halos. Mon. Not. R. Astron. Soc.

Wang, J., G. Kauffmann, R. Overzier, B. Catinella et al.: The GALEX Arecibo SDSS survey: III. Evidence for the Inside-Out Formation of Galactic Disks. Mon. Not. R. Astron. Soc.

Yamila, Y., C.M. Baugh, and R.E. Angulo: Are the 2dFGRS superstructures a problem for hierarchical models? Mon. Not. R. Astron. Soc.

Zhuravleva I., E. Churazov, S. Sazonov et al.: Resonant Scattering in Galaxy Clusters with Anisotropic Gas Motions on Different Spatial Scales, Astron. Lett.

3.2 Publications in proceedings

3.2.1 Publications in proceedings appeared in 2010 (89)

Alves-Brito, J. Melendez and M. Asplund: Chemical similarities between the galactic bulge and local thick disk red giant stars: analysis from optical data. In: Chemical Abundances in the Universe: Connecting First Stars to Planets. Eds. Cunha, K., M. Spite and B. Barbuy. IAU Symposium **265**, Cambridge University Press, 342-343.

Asplund, M. and K. Lind: The light elements in the light of 3D and non-LTE effects. In: Titel: Light Elements in the Universe, Eds. Charbonnel, C. et al. IAU Symposium **268** Cambridge University Press, 191-200.

Athanassoula, E., D. Gadotti, L. Carrasco et al.: Barred galaxy photometry: comparing results from the Cananea sample with N-body simulations. In: Long Walk Through Astronomy: A Celebration of Luis Carrasco's 60th Birthday. Revista mexicana de astronomia y astrofisica - serie de conferencias **37**, 79-82.

Bauswein, A. and H.-Th. Janka: Relativistic simulations of neutron star and strange star mergers. In: High Performance Computing in Science and Engineering, Garching/Munich 2009: Transactions of the Fourth Joint HLRB and KONWIHR Review and Results Workshop. Eds. Wagner, S., M. Steinmetz et al., Springer Verlag 2010, 347-358.

Bensby, T., S. Feltzing et al. (incl. M. Asplund): Elemental abundances in the galactic bulge from microlensed dwarf stars. In: Chemical Abundances in the Universe: Connecting First Stars to Planets. Eds. Cunha, K., M. Spite and B. Barbuy. IAU Symposium **265**, Cambridge University Press, 346-347.

Bergemann, M., and T. Gehren: Fe-peak element abundances in disk and halo stars In: Chemical Abundances in the Universe: Connecting First Stars to Planets. Eds. Cunha, K., M. Spite and B. Barbuy. IAU Symposium **265**, Cambridge University Press, 346-347.

Bonifacio, P., L. Monaco, L. Sbordone et al.: Lithium in a metal-poor external galaxy: Omega Centauri In: Titel: Light Elements in the Universe, Eds. Charbonnel, C. et al. IAU Symposium **268** Cambridge University Press, 269-274.

Bosma, A., D.A. Gadotti, W.J. de Blok and E. Athanassoula: Kinematics of the barred spiral galaxy NGC 1291. In: Galaxies in isolation: exploring nature versus nurture. Eds. Verdes-Montenegro, L., A. del Olmo and J. Sulentic. San Francisco. Astronomical Society of the Pacific **421**, 53-56.

Casagrande, L., L. Portinari and C. Flynn: Revisiting the helium abundance in globular clusters with multiple main sequences. In: Titel: Light Elements in the Universe, Eds. Charbonnel, C. et al. IAU Symposium **268** Cambridge University Press, 129-134.

Catinella, B., D. Schiminovich, and G. Kauffmann: HI and Star Formation Properties of Massive Galaxies: First Results from the GALEX Arecibo SDSS Survey. In: Hunting for the Dark: The Hidden Side of Galaxy Formation. Eds. Debattista, V. P. and Popescu, C.C. AIP Conference Proceedings, Vol. **1240**, 95-98.

Churazov E., Zhuravleva I., Sazonov S., Sunyaev R.: Resonant Scattering of X-ray Emission Lines in the Hot Intergalactic Medium. In: Space Science Reviews, "X-ray Spectroscopy", Eds. J. Kaastra and F. Paerels, 104-122.

Clarke, T.E., A. Cohen, T.A. Enßlin et al.: Tracing Diffuse Emission in Galaxy Clusters at Low Frequencies. In: American Astronomical Society, AAS Meeting 215, 436.31. Bulletin of the American Astronomical Society, **42**, 389.

Cooper, A.P. et al. (incl S. White and V. Springel): Galactic stellar haloes in the CDM model. In: Hunting for the Dark: The Hidden Side of Galaxy Formation. Eds. Debattista, V. P. and C.C. Popescu. AIP Conference Proceedings, Melville.American Institute of Physics. Vol. **1240**, 293-294.

Cordero-Carrion, I., P. Cerda-Duran and J.M. Ibanez: Numerical evolution and gravitational radiation in Fully Constrained Formulation. In: 8th Edoardo Amaldi Conference on Gravitational Waves. Proceedings of the 8th Edoardo Amaldi Conference on Gravitational Waves. Journal of Physics: 2010 Conference Series **228**, IOP Publishing 012055.

Cordero-Carrion, I., J.M. Ibanez and J.A. Morales Lladosa: On the local existence of maximal slicings in spherically symmetric spacetimes. In: XXXII Spanish Relativity Meeting (ERE 2009) 'Gravitation in the Large' (Bilbao, 7-11 September 2009). Proceedings of the Spanish Relativity Meeting, ERE 2009. (Eds: R. Lazkoz and R. Vera). Journal of Physics: 2010, Conference Series **229**, 012029.

Creech-Eakman, M., J. Young et al. (incl. A. Chiavassa): Imaging simulations of selected science with the Magdalena Ridge Observatory Interferometer. In: Optical and Infrared Interferometry II Eds. Danchi, W., F. Delplancke and J. Rajagopal. Proceedings of SPIE Bellingham, Washington, USA. Society of Photo-Optical Instrumentation Engineers **7734**, 1-7.

Cuadra, J.: Black hole binary mergers within gas discs. In: Hunting for the Dark: The Hidden Side of Galaxy Formation. Eds. Debattista, V. P. and Popescu, C.C. AIP Conference Proceedings, Melville. American Institute of Physics, Vol. **1240**, 231-234.

Das, P., O. Gerhard et al. (incl. E. Churazov): The outer haloes of massive, elliptical galaxies. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 92.

De Gouveia Dal Pino, E., P. Piovezan, L. Kadowaki et al.: On the role of magnetic reconnection in jet/accretion disk systems. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, 247-248.

Docenko, D., and R. Sunyaev: Possibility of measuring the amount of intergalactic metals with 14N VII HFS line. In: Chemical Abundances in the Universe: Connecting First Stars to Planets. Eds. Cunha, K., M. Spite and B. Barbuy. IAU Symposium **265**, Cambridge University Press, 167-170.

Docenko, D., and R. Sunyaev: Hyperfine structure radio lines from hot ISM in elliptical galaxies. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 278.

Dolag, K.: Magnetic fields and cosmic rays in galaxy clusters. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, 461-463.

Dotti, M., M. Colpi, L. Maraschi, et al.: A Path to Radio-Loudness through Gas-Poor Galaxy Mergers and the Role of Retrograde Accretion. In: Accretion and Ejection in AGN: a Global View. Proceedings of a conference held June 22-26, 2009 in Como, Italy. Eds. Maraschi, L., G. Gisheline et al. p.19

Ensslin, T.A., T. Clarke et al. (incl. A. Waelkens): Magnetic turbulence in clusters of galaxies. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 456.

Fabello, S., B. Catinella, K. Guinevere et al.: Exploiting HI surveys with stacking. In: Proceedings of the ISKAF2010 Science Meeting. Assen, the Netherlands. 2010, 16-28.

Fabjan, D., S. Borgani et al. (incl. K. Dolag): AGN feedback effect on intracluster medium properties from galaxy cluster hydrodynamical simulations. In: AGN Feedback in Galaxy Formation: Proceedings of the Workshop held in Vulcano, Eds. Antonuccio-Delogu, V. and J. Silk. Cambridge, UK. Cambridge University Press **15**, 175-182.

Font, J.A., P. Cerda-Duran and N. Stergioulas: Relativistic MHD simulations of Alfven QPOs in magnetars. In: Numerical Modeling of Space Plasma Flows: ASTRONUM-2009. Eds. Pogorelov, N., E. Audit and G. Zank. San Francisco. Astronomical Society of the Pacific. **429**, 72-78.

Forman, W., E. Churazov, S. Giacintucci et al.: 3C28 in Abell 115- a radio source with a twist. In: X-Ray Astronomy 2009. Present Status, Multi-Wavelength approach and future perspectives. Eds. Comastri, A., M. Cappi and L. Angelini. Melville, NY, USA. American Institute of Physics. AIP Conference Proceedings, 2010, Vol. **1248**, 273-276.

Frailis, M., A. Zacchei, et al. (incl. MPA PLANCK group): The Planck/LFI data processing:. real-time analysis, data management and scientific workflows. In: Astroparticle, particle and space physics, detectors and medical physics applications. Eds. Leroy C. et al., World Scientific Publishing Co. Pte. Ltd., 2010, 709-718.

Fu, J., Q. Guo and G. Kauffmann: Semi-analytic models on the molecular and neutral gas in galaxies. In: Hunting for the Dark: The Hidden Side of Galaxy Formation. Eds. Debattista, V. P. and Popescu, C.C. AIP Conference Proceedings, 2010, Vol. **1240**, 177-178.

Fulton, C., H. Arp and J. Hartnett: Analyses of the 2dF deep field. In: Frontiers of Fundamental and Computational Physics: 10th International Symposium. Eds. Hartnett, J.G. and P.C. Abbott. Melville, NY, USA. American Institute of Physics **1246**, 131-135.

Gandhi, P., V.S. Dhillon et al. (incl. H. Spruit): Rapid timing studies of black hole binaries in optical and X-rays: correlated and non-linear variability. In: X-Ray Astronomy 2009. Present Status, Multi-Wavelength approach and future perspectives. Eds. Comastri, A., M. Cappi and L. Angelini. AIP Conference Proceedings, Melville, NY, USA. American Institute of Physics 2010, Vol. **1248**, 119-122.

Gilfanov, M.: X-Ray Emission from Black-Hole Binaries. In: The Jet Paradigm - From Microquasars to Quasars. Ed. T. Belloni. Lecture Notes in Physics, Berlin Springer Verlag, 2010 **794**, 17-51.

Gilfanov, M. and A. Bogdan: Warm ionized ISM in the bulge of Andromeda galaxy. In: Highlights of Astronomy as presented at the XXVII IAU General Assembly, 2009 Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 296.

Gvaramadze, V.V., A. Gualandris, S. Portegies Zwart: High-velocity runaway stars from three-body encounters. In: Star clusters: basic galactic building blocks throughout time and space, Proceedings of the International Astronomical Union, IAU Symposium, **266**, 413-416.

Hammer, N., H.-Th. Janka and E. Mueller: 3D simulations of large-scale mixing in core collapse supernova explosions. In: High Performance Computing in Science and Engineering, Garching/Munich 2009: Transactions of the Fourth Joint HLRB and KONWIHR Review and Results Workshop. Eds. Wagner, S., M. Steinmetz et al., Springer Verlag 2010, 335-346.

Heald, G., J. McKean et al. (incl. F. de Gasperin): Progress with the LOFAR imaging pipeline. In: Proceedings of Science, ISKAF2010 Science Meeting Trieste, SISSA 2010, 1 - 11.

Hummels, C. B., D. Schiminovich, B. Catinella et al.: The GALEX Arecibo SDSS Survey (GASS): First Results. American Astronomical Society, AAS Meeting 215, Bulletin of the American Astronomical Society, Vol. **42**, 561.

Inoue, S., R. Salvaterra et al. (incl. B. Ciardi): Deciphering the ancient universe with high-energy gamma-rays from gamma-ray bursts. In: Deciphering the Ancient Universe with Gamma-Ray Bursts AIP Conference Proceedings. Eds. Kawai, N. and S. Nagataki. Melville. American Institute of Physics, 2010 **1279**, 128-131.

Irrgang, A., N. Przybilla et al. (incl. F. Nieva): HIP 60350: A supernova ejected hyper-runaway star? In: 11th Symposium on Nuclei in the Cosmos - NIC XI. Proceedings of Science, Trieste. SISSA 2010, 1-5.

Janka, H.-Th.: Stellar evolution and death models and modeling. In: 11th Symposium on Nuclei in the Cosmos - NIC XI. Proceedings of Science, Trieste. SISSA 2010, 1-114.

Jennings, E., C.M. Baugh, R.E. Angulo and S. Pascoli: How BAO measurements can fail to detect quintessence. In: International Conference on the Invisible Universe, Invisible Universe International Conference, Eds. Alimi, J.-M. and A. Füzfa. AIP Conference Proceedings. Melville, NY, USA. American Institute of Physics, 2010, **1241**, 945-954.

Jones, C., E. Churazov, S. Giacintucci et al.: Hot gas in clusters, groups and galaxies: from SMBH outbursts to cosmology. In: X-Ray Astronomy 2009. Present Status, Multi-Wavelength approach and future perspectives. Eds. Comastri, A., M. Cappi and L. Angelini. AIP Conference Proceedings, Melville, NY, USA. American Institute of Physics 2010, Vol. **1248**, 253-260.

Krivonos, R., M. Revnivtsev, S. Tsygankov and S. Sazonov: INTEGRAL all-sky survey: deep inside galaxy and beyond In: The Extreme sky: Sampling the Universe above 10 keV (extremesky2009), Proceeding of Science, SISSA, Trieste, 1 - 8.

Krivonos, R. and M. Revnivtsev: The X-Ray AGN Bias Factor at Zero Redshift. In: Co-Evolution of Central Black Holes and Galaxies, Proc. of the International Astronomical Union, IAU Symposium 2010, Cambridge University PressVolume **267**, p. 462.

Krivonos, R. and M. Revnivtsev: Large Scale structure of the local Universe traced by hard X-ray emitting AGNs. In: X-Ray Astronomy 2009. Present Status, Multi-Wavelength approach and future perspectives. Eds. Comastri, A., M. Cappi and L. Angelini. AIP Conference Proceedings, Melville, NY, USA. American Institute of Physics 2010, Vol. **1248**, 399-402.

Krivonos, R., M. Revnivtsev, S. Tsygankov et al.: Broad view on hard X-ray background emission of the Galaxy. Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. **15**, p. 810-810.

Kupka, F., H. Muthsam, F. Zaussinger et al.: Solar surface flow simulations at ultra-high resolution. In: High Performance Computing in Science and Engineering, Garching/Munich 2009: Transactions of the Fourth Joint HLRB and KONWIHR Review and Results Workshop. Eds. Wagner, S., M. Steinmetz et al., Springer Verlag 2010, 415-425.

Le Fevre, O., D. Maccagni et al. (incl. B. Ciardi): DIORAMAS: a wide-field visible and near-infrared imaging multi-slit spectrograph for the EELT. In: Proceedings of the SPIE, Ground-based and Airborne Instrumentation for Astronomy III. Eds. McLean, Ian S., S. Ramsay et al. Volume 7735, pp. 773528-773528-11 (2010).

Lind K., F. Primas et al. (incl. M. Asplund): Observational signatures of lithium depletion in the metal-poor globular cluste. NGC6397. In: Titel: Light Elements in the Universe, Eds. Charbonnel, C. et al. IAU Symposium **268** Cambridge University Press, 263 - 268.

Lutovinov, A., M. Revnivtsev and R. Krivonos: Galactic plane structure in hard X-rays. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 809.

Maeda, K., K. Kawabata et al. (inc. P. Mazzali): Similarity and difference in GRB-associated SN Ic 1998bw and other type Ib/c supernovae. In: Deciphering the Ancient Universe with Gamma-Ray Bursts AIP Conference Proceedings. Eds. Kawai, N. and S. Nagataki. Melville. American Institute of Physics, 2010 **1279**, 366-368.

Malbet, F., W. Cotton et al. (incl. A. Chiavassa): The 2010 interferometric imaging beauty contest. In: Optical and Infrared Interferometry II Eds. Danchi, W., F. Delplancke and J. Rajagopal. Proceedings of SPIE Bellingham, Washington, USA. Society of Photo-Optical Instrumentation Engineers **7734**, 1 - 12.

Melendez, J., L. Casagrande, I. Ramirez et al.: Observational signatures for depletion in the Spite plateau: solving the cosmological Li discrepancy? In: Titel: Light Elements in the Universe, Eds. Charbonnel, C. et al. IAU Symposium **268** Cambridge University Press, 211 - 214.

Melendez, J., L. Casagrande, I. Ramirez et al.: Precise Li abundances in metal-poor stars: depletion in the Spite plateau. In: Chemical Abundances in the Universe: Connecting First Stars to Planets. Eds. Cunha, K., M. Spite and B. Barbuy. IAU Symposium **265**, Cambridge University Press, 71 - 72.

Melendez, J., M. Asplund, B. Gustafsson et al.: Unprecedented accurate abundances: signatures of other Earths? In: Chemical Abundances in the Universe: Connecting First Stars to Planets. Eds. Cunha, K., M. Spite and B. Barbuy. IAU Symposium **265**, Cambridge University Press, 412 - 415.

Melendez, J., I. Ramirez, M. Asplund and P. Baumann: Lithium in other suns: no connection between stars and planets. In: Titel: Light Elements in the Universe, Eds. Charbonnel, C. et al. IAU Symposium **268** Cambridge University Press, 341 - 342.

Mei, S., B. Holden et al. (incl. R. Overzier): Stellar populations and morphology on the red sequence at z $\approx$ 1. In: International Conference on the Invisible Universe, Invisible Universe International Conference, Eds. Alimi, J.-M. and A. Füzfa. AIP Conference Proceedings. Melville, NY, USA. American Institute of Physics, 2010, **1241**, 236-243.

Mocak, M. and E. Müller: The core helium flash: 3D hydrodynamic models. In: High Performance Computing in Science and Engineering, Garching/Munich 2009: Transactions of the Fourth Joint HLRB and KONWIHR Review and Results Workshop. Eds. Wagner, S., M. Steinmetz et al., Springer Verlag 2010, 323-334.

Müller, B., A. Marek, and H.-Th. Janka: The SuperN-Project: current advances in understanding core collapse supernovae. In: High Performance Computing in Science and Engineering '09: Transactions of the High Performance Computing Center Stuttgart (HLRS) 2009 Eds. Nagel, W., D. Kröner and M. Resch. Springer Verlag, 17 -32.

Müller, B., L. Hüdepohl, A. Marek et al.: The SuperN-Project: an update on core-collapse supernova simulations. In: High Performance Computing in Science and Engineering '09: Transactions of the High Performance Computing Center Stuttgart (HLRS) 2009, Eds. Nagel, W., D. Kröner and M. Resch. Proceedings, Springer Verlag, 69 - 83.

Nieva, M.F. and N. Przybilla: Improving stellar parameter and abundance determinations of early B-type stars In: Hot and Cool: Bridging Gaps in Massive Star Evolution. Eds. Leitherer C., P. Bennet et al. Astronomical Society of the Pacific Conference Series 2010, **425**, 146-151.

Nunes, N., T. Dent, C. Martins and G. Robbers: Reconstructing the evolution of dark energy with variations of fundamental parameters. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 303.

Obergaulinger, M., P. Cerda-Duran, E. Müller and M.A. Aloy: Simulations of the magneto-rotational instability in core-collapse supernovae. In: Numerical Modeling of Space Plasma Flows: ASTRONUM-2009. Eds. Pogorelov, N., E. Audit and G. Zank. San Francisco. Astronomical Society of the Pacific. **429**, 136-141.

Overzier, R.: Massive dense nuclei in young starbursts: progenitors of early-type galaxy cusps? In: Co-Evolution of Central Black Holes and Galaxies, Proc. of the International Astronomical Union, IAU Symposium 2010, Cambridge University Press Volume **267**, p.128.

Patru, F., A. Chiavassa, D. Mourard and N. Tarmoul. Direct imaging with a hypertelescope of red supergiant stellar surfaces. In: Optical and Infrared Interferometry II Eds. Danchi, W., F. Delplancke and J. Rajagopal. Proceedings of SPIE Bellingham, Washington, USA. Society of Photo-Optical Instrumentation Engineers **7734**, 1 - 14.

Pedrosa, S., P. Tissera and C. Scannapieco: Baryons and dark matter halo distributions in ΛCDM cosmology. In: Stellar Populations - Planning for the Next Decade. Eds. Bruzual G. and S. Charlot. IAU Symposium **262**, Cambridge University Press, 404-405.

Predehl, P., H. Böhringer et al. (incl. E. Churazov and R. Sunyaev): eROSITA on SRG. In: X-Ray Astronomy 2009. Present Status, Multi-Wavelength approach and future perspectives. Eds. Comastri, A., M. Cappi and L. Angelini. AIP Conference Proceedings, Melville, NY, USA. American Institute of Physics 2010, Vol. **1248**, 543-548.

Predehl, P., et al. (incl. E. Churazov and R. Sunyaev): eROSITA on SRG. In: Space Telescopes and and Instrumentation 2010: Ultraviolet to Gamma Ray. Eds. Arnaud, M., St. Murray and T. Takahashi. Proceedings of SPIE **7732**, San Diego, CA, USA 2010, 1-10.

Primas, F., K. Lind et al. (incl. M. Asplund): The lithium history of NGC 6397. In: Star clusters: basic galactic building blocks throughout time and space. Eds. de Grijs, R., and J.R. Lepine. IAU Symposium **266**, Cambridge University Press, 143 - 148.

Przybilla, N., M. Firnstein and M.F. Nieva: Tepid supergiants: chemical signatures of stellar evolution and the extent of blue loops. In: Hot and Cool: Bridging Gaps in Massive Star Evolution. Eds. Leitherer C., P. Bennet et al. Astronomical Society of the Pacific Conference Series 2010, **425**, 134-139.

Reisenegger, A., P. Jofre-Pfeil and R. Fernandez: Constraining a possible time-variation of the gravitational constant through 'gravitochemical heating' of neutron stars. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 314.

Röpke, F., W. Hillebrandt, D. Kasen and S. Woosley: Modeling the diversity of type Ia supernova explosions In: Numerical Modeling of Space Plasma Flows: ASTRONUM-2009. Eds. Pogorelov, N., E. Audit and G. Zank. San Francisco. Astronomical Society of the Pacific. **429**, 142-147.

Ruiter, A. J., K. Belczynski, S. A. Sim et al.: Type Ia Supernovae and Accretion Induced Collapse In: International Conference of binaries: In celebration of Ron Webbink's 65th Birthday. Eds. Kologera, V. and M. van der Sluys. AIP Conference Proceedings, Vol. **1314**, 233-238.

Sbordone, L., P. Bonifacio, E. Caffau et al. The metal-poor end of the Spite plateau: gravity sensitivity of the HęÁ wings fitting. In: Titel: Light Elements in the Universe, Eds. Charbonnel, C. et al. IAU Symposium **268** Cambridge University Press, 355 - 356.

Schönrich, R.: Physics and structure of the galactic disc(s) In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 185.

Scoccola, C., S. Landau and H. Vucetich: WMAP 5-year constraints on α and me. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 307.

Seitenzahl, I., F. Röpke, R. Pakmor and M. Fink: Nucleosynthetic post-processing of type Ia supernovae with variable tracer masses. In: Proceedings of Science, 11th Symposium on Nuclei in the Cosmos - NIC XI, SISSA Trieste 2010, 1-5.

Shankar, F.: Merger-induced quasars, their light curves, and their host halos. In: Co-Evolution of Central Black Holes and Galaxies, Proc. of the International Astronomical Union, IAU Symposium 2010, Cambridge University PressVolume **267**, 248-253.

Sijacki, D., V. Springel and M. Haehnelt: Growing supermassive black holes in cosmological simulations of structure formation. In: Co-Evolution of Central Black Holes and Galaxies, Proc. of the International Astronomical Union, IAU Symposium 2010, Cambridge University PressVolume **267**, 445-450.

Sim, S., M. Kromer, F. Röpke et al.: Monte Carlo radiative transfer simulations: applications to astrophysical outflows and explosions. In: Numerical Modeling of Space Plasma Flows: ASTRONUM-2009. Eds. Pogorelov, N., E. Audit and G. Zank. San Francisco. Astronomical Society of the Pacific. **429**, 148-153.

Spruit, H.C.: Theory of Magnetically Powered Jets. In: The Jet Paradigm - From Microquasars to Quasars. Ed. T. Belloni. Lecture Notes in Physics, Berlin Springer Verlag, **794**, 2010, 233-262.

Tanaka M., K. Kawabata et al. (incl. P. Mazzali): Multi-dimensional explosion geometry of supernovae: spectropolarimetric study with Subaru. In: Deciphering the Ancient Universe with Gamma-Ray Bursts AIP Conference Proceedings. Eds. Kawai, N. and S. Nagataki. Melville. American Institute of Physics, 2010 **1279**, 433-435.

Wanajo, Sh. and H.-Th. Janka: The r-process in black hole winds. In: The 10th International Symposium on Origin of Matter and Evolution of Galaxies, Eds. Tanihara, I., T. Shima et al. AIP Conference Proc. Melville, New York. American Institute of Physics **1269**, 120 - 125.

Wang, J., G. Kauffmann and R. Overzier: The relation between gas accretion and resolved star formation in galaxies. In: Hunting for the Dark: The Hidden Side of Galaxy Formation. Eds. Debattista, V. P. and Popescu, C.C. AIP Conference Proceedings, Vol. **1240**, 177-178.

Werner, N., I. Zhuravleva, E. Churazov et al.: Constraints on turbulent pressure in the X-ray halos of giant elliptical galaxies from resonant scattering. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 297.

White, S.D.M.: ID 3 evolution of structure in the universe. In: Highlights of Astronomy, Ed. I.F. Corbett Intern. Astron. Union 2010. Cambridge, UK. Cambridge University Press **15**, p. 45.

Zavala, J., V. Springel and M. Boylan-Kolchin: Mapping extragalactic dark matter structures through gamma-rays. In: 2009 Fermi Symposium, Washington, DC, USA, 1 - 7.

Zhuravleva, I., E. Churazov, S. Sazonov: Polarization of X-ray lines from galaxy clusters and elliptical galaxies. In: The Coming of Age of X-ray Polarimetry. Eds. Bellazzini, R., E. Costa et al. Cambridge University Press **22**, 146 - 149.

3.2.2 Publications available as electronic file only

Chiavassa, A., E. Pasquato, A. Jorissen et al. Photocentric variability of red supergiant stars and consequences on Gaia measurements.
http://adsabs.harvard.edu/abs/2010sf2a.conf..339C

Fabello, S., B. Catinella, G. Kauffmann et al. Exploiting HI surveys with stacking.
http://adsabs.harvard.edu/abs/2010iska.meetE..16F

Krivonos, R., S. Tsygankov, M. Revnivtsev et al.: INTEGRAL all-sky survey of hard X-ray sources (Krivonos+, 2010) *http://adsabs.harvard.edu/abs/2010yCat..35239061K*

Milone, A.,P., G. Piotto et al. (incl. A. Marino): Multiple stellar populations in Galactic globular clusters: observational evidence.
http://adsabs.harvard.edu/abs/2010sf2a.conf..319M

Ritter, H. and U. Kolb: Catalogue of cataclysmic binaries, low-mass X-ray binaries and related objects (Editions 7.13 and 7.14).
http://www.mpa-garching.mpg.de/RKcat/
http://physics.open.ac.uk/RKcat/
http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=B/cb
http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=B/cb

Seitenzahl, I., F. Roepke, R. Pakmor and M. Fink: Nucleosynthetic post-processing of Type Ia supernovae with variable tracer masses.
http://adsabs.harvard.edu/abs/2010arXiv1012.4641S

Zavala, J., V. Springel and M. Boylan-Kolchin: Mapping extragalactic dark matter structures through gamma-rays.
http://adsabs.harvard.edu/abs/2010arXiv1001.3307Z

3.3 Invited review talks at international meetings

M. Asplund:
– “Galactic Archeology with HERMES”, Sydney, Australia, Sept. 28-29
– “ILL 2020 Vision”, Grenoble, France, Sept. 15-17
– “Cool Stars 16”, Seattle, USA, Aug. 29 - Sept. 2
– “Galaxies and their masks”, Soussevlei, Namibia, April 11-17

A. Bauswein:
– Sino-German Frontiers of Science Symposium, (Qingdao, China, 20.5.-23.5.)

E. Churazov:
– “215th AAS Meeting”, (Washington, DC, 3.1-7.1)
– “Physics and Astrophysics of Neutron Stars and Black Holes”, (Bremen, 16.7-17.7)
– “High-resolution X-ray spectroscopy: past, present, and future”, (Utrecht, 15.3-17.3)
– “Formation and evolution of black holes, galaxies and their environment”, (Potsdam, 20.9-24.9)
– “SPIE Symposium”, (San Diego, 27.6-2.7)
– “Galaxy clusters: observations, physics and cosmology”, (Garching, 26.7-30.7)

B. Ciardi:
– “The First Galaxies, Quasars, and Gamma-Ray Bursts” (State College, USA 7.6–10.6)

– “Cosmological Reionization” (Allahabad, India 16.2–20.2)
– “Evolution of galaxies, their central black holes and their large-scale environment” (Potsdam, Germany 20.9.-24.9)
– “Cosmic Radiation Fields - Sources in the early Universe” (Hamburg, Germany 10.11–12.11)

M. Dotti:
– “LISA Astro-GR@Paris” workshop, (Paris, France, 13.9.-17.9.)

T. Enßlin:
– “Rotation Measure Analysis of Magnetic Fields in and around Radio Galaxies”, (Riccione, Italy, 10.5.-14.5.)
– “Magnetic fields on scales from kiloparsecs to kilometers: properties and origin”, (Krakow, Poland, 17.5-21.5)
– “Cosmic magnetism”, (Kiama, Australia, 7.6.-11.6.)
– “Theory and observations of extragalactic magnetic fields”, (Paris, France, 13.12.-15.12)

H. Junklewitz:
– “Large Scale Magnetic Fields in the Universe”, (Bern, Switzerland, 1.3.-5.3.)

M. Gilfanov:
– “Ultra-luminous X-ray sources and middle weight black holes” (ESAC, Madrid, Spain, 24.05.-26.05.)
– “Frontiers of non-linear physics” (Nizhnii Novgorod, 11.07.-20.07.)
– “Astrophysics of neutron stars” (Cesme, Turkey, 2.08.-6.8.)
– “New methods in space research” (Kazan, Russia, 6.10.-10.10.)
– “GRAVITAS science workshop” (Garching bei Muenchen, 25.10.-26.10.)
– “High energy astrophysics - 2010” (Moscow, 21.12.-24.12.)

A. Gualandris:
– “Central Massive Objects: The Stellar Nuclei - Black Hole Connection” (ESO garching, 22.6-25.6)

W. Hillebrandt:
– 15th Ringerg Workshop on Nuclear Astrophysics (Tegernsee, 22.3. - 26.3.)
– DEISA-PRACE Conference, (Barcelona 10.5.-12.5.)
– Annual Meeting of the Astronomische Gesellschaft, (Bonn, 13.8.-17.8.)

H.-Th. Janka:
– INPC 2010 – International Nuclear Physics Conference (Vancouver, Canada, 4.7.–9.7.)
– Workshop on Neutrinos from Supernovae (Paris, France, 16.12.–17.12.)
– “Science Week”, The Annual Cluster Science Meeting (Garching, Germany, 11.10.–14.10.)

P. Mazzali:
– Summary talk “Observational Signatures of Type Ia Supernovae” (Leiden, The Netherlands 20.9.-24.9.)

E. Müller:
– “Simulating the explosion of massive stars: computational challenges and recent results” SECAM Workshop, (ENS Lyon, France, 11.10.-15.10.)

F. Röpke:
– Erice School on “Particle and Nuclear Astrophysics” (Erice, Italy, 16.9.–24.9.)

H.C. Spruit:
– Plenary talk, “Theory of magnetically powered jets”, 25$^{\text{th}}$ Texas conference, (Heidelberg, 6.12.-10.12.)

A. Weiss: “Red giants as probes of the structure and evolution of the milky way” workshop, (Rome, Italy, 15.11.-17.11.)

S.D.M. White:
– Dynamics from the Galactic Center to the Milky Way Halo, (Cambridge, USA 2010)
– The Theory of the Universe and Everything in it, (Toronto, 2010)
– GGI Conference on The Dark Matter Connection: Theory and Experiment (Florence 2010)
– A Universe of dwarf galaxies: Observations, Theories, Simulations (Lyon 2010)
– CCP 2010 Conference on Computationsl Physics (Trondheim, Norway 2010)
– Darkness Visible: Dark Matter in astrophysics and particle physics (Cambridge, UK 2010)
– Kavli Prize Symposium on Astrophysics (Oslo, 2010)
– Evolution of Galaxies, their central black holes and their large-scale environment, (Potsdam, Germany 2010)
– IAU Symposium No. 277 "Tracing the Ancestry of Galaxies, Ouagadougou, Burkina Faso 2010

R. Wiersma:
– Metal Enrichment from Hydrodynamical Simulations, (El Escorial, Spain, 16.9.-17.9.)

3.4 Public talks

G. Börner:
– Ökumenischer Kirchentag München (13.5.)
– G. Börner: Evang. Akademie Meissen (13.11.)

T. Enßlin:
– Ludwig-Maximilian-Universität München (17.6)
– Technische Universität München (22.7)

W. Hillebrandt:
– Planetarium Nürnberg (27.1.)
– Planetarium Hamburg (15.10.)

P. Mazzali:
– High Schools of Liguria, Sarzana, Italy (18.10.)

B. Müller:
Volkssternwarte Winzer (24.4.)

E. Müller:
– Tag der offenen Tür, Schloss Ringberg (26.6.)

3.5 Lectures

W. Hillebrandt: SS10, TU München

H.-Thomas Janka: SS10 und WS10/11, TU München

P. Mazzali: Scuola Normale Superiore, Pisa, Italy (Academic year 2010-2011)

E. Müller, WS10/11, TU München

H. Ritter, WS09/10 und WS10/11, LMU München

F. Röpke: WS09/10, SS10 and WS 10/11TU München

A. Weiss, SS10, LMU München

Short lectures

G. Börner: ”Kosmologie” (Univ. Konstanz, February)

W. Hillebrandt: University of Pisa (January and October)

H.-Th. Janka: “Entwicklung massereicher Sterne und Supernovae” (Univ. Konstanz, 20.1.–21.1.)

H.-Th. Janka: “Stellar Evolution and Death – Models and Modeling” (GSI Darmstadt, 12.7.–17.7.)

F. Röpke: ”Introduction to Computational Astrophysics” (Universität Heidelberg, 06.04.–09.04.)

4 Personnel

4.1 Scientific staff members

Directors

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

Research Group Leader

E. Churazov, B. Ciardi, M. Gilfanov, H.-Th. Janka, G. Kauffmann, T. Naab, E. Müller.

External Scientific Members

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

Emeriti

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

Staff

R. Angulo, P. Arevalo (until 30.6.), A. Bauswein (since 1.2.), M. Bell (since 1.7.), M. Bergemann, A. Bogdan (since 1.2.), M. Boylan-Kolchin (until 31.8.), L. Casagrande, B. Catinella, P. Cerda-Duran, Y.M. Chen (until 29.3.), A. Chiavassa (until 24.9.), B. Ciardi, D. Christlein (until 30.6.), E. Churazov, R. Collet, A. Cooper (since 15.10.), J. Cuadra (until 31.7.), K. Dolag (until 31.10.), M. Dotti, M. Egger (since 1.6.), T. Enßlin, M. Fink (since 1.12.), M. Gilfanov, T. Greif, M. Grossi (since 1.8.), A. Gualandris, B. Henriques (since 1.9.), C. Hernandez-Monteagudo, J. Hu (until 31.8.), H.–T. Janka, P. Jofre-Pfeil (since 1.9.), G. Kauffmann, R. Khatri (since 1.8.), K. Kovac (since 1.10.), R. Krivonos, Ch. Li (until 30.9.), K. Lind (since 1.12.), S. Lucatello (until 31.7.), A. Marino (since 1.9.), I. Maurer (since 1.11.), P. Mazzali, B. Metcalf, P. Montero, B. Moster (since 1.12.), B. Müller, E. Müller, M. Obergaulinger (until 31.10.), R. Overzier, E. Puchwein (until 30.9.), I. Ramirez (until 30.9.), M. Reinecke, H. Ritter (until 31.5.), F. Röpke, G. Ruchti (since 1.10.), A. Ruiter, A. Saintonge, L. Sales (since 1.9.), L. Sbordone, C. Scoccola, I. Seitenzahl, A. Serenelli (until 1.9.), F. Shankar, S. Sim (until 31.10.), V. Springel (until 28.2.), H.C. Spruit, S. Taubenberger, S. Tsygankov, S. Weinmann (until 31.8.), A. Weiss, J. Zavala-Franco (until 31.10.), L. Wang (until 31.8.), R. Wiersma.

Associated Scientists:

U. Anzer, H. Arp, G. Börner, G. Diercksen, W. Kraemer, E. Meyer–Hofmeister, H. Ritter (seit 1.6.), J. Schäfer, H.-C. Thomas, R. Wegmann.

Minerva Fellow

E. Neistein (until 30.9.)

DAAD Fellow

S. Nuza (until 31.3.)

Ph.D. Students

[1] M. Alves-Cruz*, P. Baumann, A. Bauswein (until 31.1.), V. Biffi*, R. Birkl (till 30.11.), A. Bogdan* (till 31.1.)*, S. Bonoli* (till 28.5.), M.-P. Bottino* (till 22.10.), M.A. Campisi*, F. Ciaraldi-Schoolmann, C. D'Angelo (until 30.9.)*, F. De Gasperin, J. Donnert, F. Elsner (till 31.10.), S. Fabello*, M. Fink (30.11.), M. Frommert, M. Gabler, L. Graziani*, M. Grossi (till 31.1.)*, S. Hachinger, F. Hanke (since 15.10.), W. Hayek (till 31.8.), M. Herzog, S. Hess, L. Hüdepohl, F. Ianuzzi*, J. Jasche (till 15.4.), A. Jeeson-Daniel*, P. Jofre-Pfeil* (till 30.8.), O. Just, N. Krachmalnikoff* (since 1.9.), M. Kromer, C. Laporte* (since 1.9.), N. Lyskova* (since 1.9.), T. Mädler, Z. Magic* (since 1.9.), I. Maurer (till 31.10.), F. Miczek, S. Mineo*, R. Moll (till 28.1.), R. Pakmor (till 30.9.), M. Petkova*, L. Porter*, T. Rembiasz*, T. Sawala* (till 31.12.), R. Schönrich, V. Silva*, F. Stasyszyn*, M. Ugliano*, M. van Daalen* (since 1.9.), M. Vogelsberger (till 30.4.), J. von Groote (since 1.12.), M. Wadepuhl, J. Wang, A. Wongwathanarat*, R. Yates (since 1.9.), F. Zaussinger (till 31.8.), Z. Zhang*, I. Zhuraleva*.

Diploma students

Ph. Edelmann (till 30.1.), E. Gall (since 15.11.), F. Hanke (till 30.9.), H. Junklewitz (till 28.2.), S. Lutter (since 15.11.), Z. Magic (till 30.6.), U. Nöbauer (since 1.2.), M. Selig (since 20.9.), M. Uhlig (since 22.11.), J. von Groote (till 30.5.), C. Weig (till 30.1.), H. Weingartner (since 22.11.), R. Yates (till 30.8.)

Technical staff

Computational Support: H.-A. Arnolds, B. Christandl, N. Grüner, H.-W. Paulsen (head of the computational support)
PLANCK group: M. Bell, U. Dörl, T. Enßlin (group leader), W. Hovest, J. Knoche, J. Rachen, M. Reinecke, T. Riller, G. Robbers
Secretaries: M. Depner, S. Gründl, G. Kratschmann, K. O'Shea, C. Rickl (secretary of the management).
Library: E. Blank, E. Chmielewski (head of the library), C. Hardt.

4.1.1 Staff news

Gerhard Börner: won the CAS Award (Chinese Academy of Sience) for International Cooperation in Science and Technology and received the "Friendship Award" of the Chinese government (October 2010).

Akos Bogdan: received the Rudolf-Kippenhahn-Prize for the best scientific paper written by a student.

Marat Gilfanov: – Professor of astrophysics (the title awarded by the High Commission of the Ministry of Science and Education of Russian Federation)
– Honorary member of Tatarstan Academy of Sciences

Guinevere Kauffmann: received the German Federal Order of Merit.

Roderik Overzier: Tinsley Visiting Scholar Award, University of Texas

Fritz Röpke: ARCHES award for German-Israeli collaboration
– Professorship in Astrophysics at the Univeristy of Würzburg (starting 01.01.2011)

Rashid Sunyaev: received the German Federal Order of Merit.

Simon White: received the Max-Born Preis 2010 by the Institute of Physics (IOP) and German Physical Society (DFG)
– Honorary Citizenship of the City of Padua 2010

[1]*IMPRS Ph.D. Students

4.2 PhD Thesis 2010/Diploma thesis 2010

4.2.1 Ph.D. theses 2010

Andreas Bauswein: Relativistic simulations of compact object mergers for nucleonic matter and strange quark matter. Technische Universität München (defense: 9.2.2010).

Reiner Birkl: Stationary, axisymmetric neutron stars with meridional circulation in General Relativity. Technische Universtität München (defense: 13.1.2010).

Akos Bogdan: X-ray emission from nearby early-type galaxies and origin of Type Ia Supernovae. Ludwig-Maximilians-Universität, München (defense: 25.2.2010).

Silvia Bonoli: The Role of Galaxy Mergers in the Evolution of Supermassive Black Holes. Ludwig-Maximilians-Universität München (defense: 28.5.2010).

Maria Paola Bottino: Component separation methods for Cosmic Microwave Background studies. Ludwig–Maximilians–Universität, München (defense: 3.12.2010).

Caroline R.X.M. D'Angelo: Truncated accretion discs around stellar-mass objects. University of Amsterdam, (submitted).

Emilio Donoso: Evolution of radio galaxies across cosmic time. Ludwig-Maximilians-Universität München (defense: 10.3.2010).

Franz Elsner: Search for Non-Gaussian signatures in the cosmic microwave background radiation. Ludwig-Maximilians-Universität München (defense: 19.11.2010).

Michael Fink: Modeling detonations in Type Ia supernovae. Technische Universität München (defense: 3.12.2010).

Mona Frommert: Temperature and Polarization Studies of the Cosmic Microwave Background. Ludwig-Maximilians-Universität, München (defense: 11.2.2010).

Margherita Grossi: Probing Early Dark Energy and primordial non-Gaussianity with cosmological simulations. Ludwig-Maximilians-Universität, München (defense: 5.2.2010).

Jens Jasche: Bayesian methods for analyzing the large scale structure of the universe. Ludwig-Maximilians-Universität München (defense: 15.4.2010).

Paula Jofre Pfeil: The age of the Milky Way halo stars - Implications for galaxy formation. Ludwig-Maximilians-Universität München (10.12.2010).

Immanuel Maurer: Gamma Ray Bursts and their Super Novae. Technische Universität, München (defense: 30.11.2010).

Rainer Moll: Magnetic acceleration and instabilities of astrophysical jets. Universität Amsterdam (defense: 28.1.2010).

Ruediger Pakmor: Progenitor systems of Type Ia Supernovae: mergers of white dwarfs and constraints on hydrogen-accreting white dwarfs. Technische Universität, München (defense: 16.12.2010).

Marco Pierleoni: CRASHa coupling continuum and line radiative transfer. Ludwig-Maximilians-Universität München (defense: 17.9.2010).

Mark Vogelsberger: The internal structure of Cold Dark Matter Haloes. Ludwig-Maximilians-Universität, München (defense: 23.4.2010).

Florian Zaussinger: Numerical simulation of doulbe-diffuse convection. Universität Wien (submitted).

4.2.2 Diploma theses 2010

Phillip Edelmann: Modeling of Thermonuclear Reaction Fronts in White Dwarfs. Technische Universität München

Florian Hanke: Studien zum neutrinogetriebenen Explosionsmechanismus von Kernkollapssupernovae mit Simulationen in ein, zwei und drei Dimensionen. Technische Universität München.

Henrik Junklewitz: Imprints of magnetic power and helicity spectra on radio polarimetry statistics. Ludwig-Maximilians-Universität München.

Zazralt Magic: Impact of the new solar abundances on the analysis of galactic clusters and binaries. Ludwig-Maximilians-Universität München.

Janina von Groote: Modelling signatures of outflow in X-ray spectra of Active Galactic Nuclei. Universität Regensburg.

Cornelius Weig: Information field theory applied to a spatially distorted log-normal field with Poissonian noise. Ludwig-Maximilians-Universität München.

Robert Yates: Analysis of the diffracted light around a coronagraphic external occulter. University di Padova, Italien.

4.2.3 PhD Thesis (work being undertaken)

Monique Alves-Cruz: S-process in extremely metal-poor stars. LMU. *Abstract: In the last two decades a large number of stars from the Galactic halo has been observed in high-resolution. These observations, motivated by the search for metal-poor stars in surveys such as HK and Hamburg/ESO, brought to light intriguing nucleosynthesis signatures. One of them is the overabundance of s-process elements observed in several extremely metal-poor stars (EMPS - [Fe/H]<-3.0). The goal of this project is to verify the role of s-process nucleosynthesis in primordial AGB stars as a source of the s-enrichment in EMPS.*

Michael Aumer: Simulations of Disk Galaxy Evolution. LMU. *Abstract: The aim of this thesis is to study the evolution of Milky-Way like disk galaxies in a fully cosmological framework predicted by the LambdaCDM scenario. Two aspects of this topic we would like to address, are: A) The stability of thin, galactic disks against dynamical heating imposed by substructure predicted for LambdaCDM halos. B) The mixing of metals ejected from disk galaxies in supernova-driven winds and its effect on the metal enrichment of the IGM. For these purposes we use and update the multiphase SPH galaxy formation code by Scannapieco et al 2005/2006.*

Patrick Baumann: Chemical composition of solar-type stars and its impact on planet-hosting. LMU. *Abstract: Work on elemental abundances in solar-like stars. We want to fins out, if there is any connection between the chemical composition of a star and whether it's hosting a planet or not. Preliminary results indicate that the Sun has different abundances of refractory elements compared to solar-type field stars, which might be due to terrestrial planet formation.*

Sandra Benitez: Model-Independent Reconstruction of the Expansion History of the Universe. TUM. *Abstract: Type Ia supernovae are the best (relative) distance indicators out to z 1 and it was by means of their luminosity distances that the notion of an accelerated expansion of the Universe was established a decade ago . Based on the largest sample of these objects available today, we have reconstructed the expansion history of the Universe in an model-independent way. Our method is purely geometric and does not make any assumptions on the matter/energy content of the Universe. This approach allow us to obtain H(z) in a straightforward way directly from the data. Also we are able to yield constrains on very different Dark Energy models and non-standard cosmologies based in very different physical assumptions.*

Veronica Biffi: Studying the physics of galaxy clusters by simulations and X-ray observations. LMU. *Abstract: Clusters of galaxies are optimal targets to study the large–scale structure of the Universe as well as the complex physical processes on the smaller scales. It is therefore vital to unveil cluster intrinsic structure, precisely estimate their total gravitating mass, and accurately calibrate scaling relations between observable quantities. A promising approach to achieve a more detailed picture of such complicated objects is found in the comparison between hydrodynamical numerical simulations of galaxy clusters and X–ray observations*

Franco Ciaraldi-Schoolmann: Stochastic modeling of Type Ia supernovae explosions in Large Eddy Simulations. TUM. *Abstract: The focus of my work is on explosions of Chandrasekharmass white dwarfs in the delayed detonation scenario. Here, an open question is how to implement the transition of the thermonuclear burning front from a subsonic deflagration toa supersonic detonation (DDT). For this a subgrid scale model for DDTs is developed which models the relevant parameters for a DDT on unsresolved scales in Large Eddy Simulations. The goal is to find out to what extend these simulations can explain the observed variances in brightness in Type Ia supernovae.*

Francesco De Gasperin: Cosmological Evolution of Supermassive Black Holes With LOFAR. LMU. *Abstract: Work on the framework of LOFAR commissioning. LOFAR is the new radio telescope that has been built in the Netherlands and throughout Europe. With its revolutionary capabilities and by means of more well-known devices, I study the interaction between AGN (Active Galactic Nuclei) and ICM (Intra-Cluster Medium), putting constraints on galaxy evolution paradigms.*

Julius Donnert: On the non-thermal emission in galaxy clusters. LMU. *Abstract: We investigate the transient phenomenon of radio haloes - Mpc sized, diffuse radio sources found exclusively in a fraction of merging galaxy clusters. The non-thermal spectrum suggests that in the intra cluster medium Cosmic Ray electrons interact with magnetic fields to emit Synchrotron radiation. Using the cosmological MHD SPH code Gadget3 we investigate Secondary and, for the first time, Reacceleration models as sources for the short lived cosmic ray electrons.*

Philipp Edelmann: Hydrodynamical simulations coupled to nuclear reaction networks in stellar astrophysics. TUM. *Abstract: The aim of this thesis is to investigate problems in stellar astrophysics which require simultaneous treatment of hydrodynamics and nuclear burning. To this end an existing low Mach number hydrodynamics code is extended with a nuclear reaction network and different methods of coupling these source terms are tested. Verifying prescriptions used in one-dimensional stellar evolution simulations with multi-dimensional simulations is the main application. This may provide new insights into critical stages of stellar evolution.*

Silvia Fabello: HI properties of nearby galaxies from ALFALFA data stacking. LMU. *Abstract: The neutral gas (HI) in galaxies is crucial to understand their evolution, as it fuels future star formation. Currently on-going blind HI surveys, such as ALFALFA (Arecibo Legacy Fast ALFA) survey, will produce HI data over a cosmologically significant volume, but will not detect a large fraction (80%) of the high mass, gas-poor galaxies. This high mass range is the regime where galaxies seem to make a transition between blue and star-forming and red and passively-evolving. I have developed a software tool to co-add ALFALFA HI data that allows one to recover the average neutral gas content of a population of galaxies, even if individual sources are not detected. Using this technique I can characterize the HI content of nearby high mass galaxies, eg. by studying HI scaling relations or analyzing the dependence on nuclear and environmental properties. This will give us a better insight into current models of galaxy formation.*

Michael Gabler: Coupled crust-core-magnetosphere oscillations of magnetars. TUM. *Abstract: The aim of this project is to study torsional oscillations of mangetized neutron stars in order to obtain an explanation of quasi-periodic oscillations (QPOs) in soft gamma-ray repeaters. Therefore, a general-relativistic ideal magneto-hydro dynamic code MCoCoA has to be extended by including the effects of a solid crust. With this numerical tool at hand the magneto-elastic oscillations of the magnetar can be described. The second part of the project is concerned with a description of the magnetosphere in terms of a force-free configuration, which is coupled to the evolution of the star. It is necessary to understand this interaction to have a possible mechanism to modulate the emission, which is supposed to occur outside of the magnetar, and hence understand how the oscillations of the star cause the observed QPOs.*

Luca Graziani: Cosmological Radiative Transfer through metals in CRASH. LMU. *Abstract: Radiative transfer (RT) in cosmology is a useful technique to investigate the IGM status at the epoch of galaxy formation and to constraint the efficiency of the primordial radiative processes. The inclusion of metal ionization states in the CRASH radiative transfer simulations is obtained coupling the code with the sophisticated photo-ionization engine Cloudy and applied to constraint QSO spectra observations with theoretical models, to study the physical status of the IGM and finally to constraint the cosmic UV background fluctuations at $z{\sim}2$-3.*

Stephan Hachinger: Analysis of photospheric spectra of supernovae. TUM. *Abstract: In this thesis we analyse abundances and densities within thermonuclear and hydrogen-deficient core-collapse supernovae. We show that extreme Type Ia supernovae have progenitors and explosion mechanisms different from normal objects. Furthermore, we give constraints on the progenitor stars for low-mass Type IIb, Ib and Ic supernovae based on helium abundances. Our analyses are based on a spectrum synthesis code which we extended significantly to simulate selected ions in non - LTE (local thermodynamic equilibrium).*

Florian Hanke: Three-dimensional simulations of core-collapse supernovae using a detailed neutrino transport description. TUM. *Abstract: 3D simulation of core-collapse supernovae using a detailed* *neutrino transport description are crucial for understanding the explosion mechanism of massive stars in detail. They will allow us to study convection and hydrodynamical instabilities in a satisfactory manner. In particular this effects should facilitate the explosion of massive stars. Due to extremely high demands of computer time of such 3D calculations our simulation tool must make use of massively parallel machines and a new efficient neutrino transport description will be coupled to the three-dimensional hydrodynamics code to determine the true systematics of core-collapse supernovae.*

Matthias Herzog: Dynamical Simulations of Phase Transitions in Compact Stars. TUM. *Abstract: We perform multi-dimensional hydrodynamical simulations of the conversion of a hadronic neutron star to a strange quark star. Following the example of thermonuclear burning in white dwarfs, we model the conversion process as a combustion. First results show that the combustion becomes turbulent and the resulting star is a hybrid star containing a atrange quark matter core and a hadronic outer layer.*

Steffen Hess: Particle hydrodynamics with tessellation techniques. LMU. *Abstract: A number of recent studies have emphasized inaccuracies of SPH in the treatment of fluid instabilities. The origin of these numerical problems can be traced back to spurious surface effects across contact discontinuities. We present a new fluid particle model where the density estimate is carried out with the help of a Voronoi tessellation. This approach improves the ability of the scheme to represent sharp contact discontinuities and eliminates spurious surface tension effects present in SPH and that play a role in suppressing certain fluid instabilities.*

Michael Hilz: Evolution of Elliptical Galaxies. LMU. *Abstract: We use a set of N-body simulations of one- and two-component galaxy models to show how consecutive galaxy mergers affect the scaling relations of elliptical galaxies. Analyzing the dynamical processes during equal-mass and minor mergers we find that especially the latter scenario is very efficient by growing a galaxy's size and decreasing its velocity, which might solve the 'compactness problem' of early-type galaxies at a redshift of* ~ 2.

Francesca Iannuzzi: Studying the survival of galaxies in hydrodynamical simulations of clusters. LMU. *Abstract: The project aims at investigating galaxy cluster formation and evolution by means of numerical simulations performed with a modified version of the TreeSPH code GADGET-3. This new version of the code employs adaptive softening to describe the gravitational interaction between the simulation particles; having this quantity variable in space and time, as opposed to having it fixed at the beginning of the simulation, allows to increase the spatial resolution in overdense regions whilst keeping particle-particle noise under control in less dense environments. Simulations involving gravitational as well as gas dynamics are likely to considerably benefit from the adoption of this scheme: the adaptive behaviour of the resolution scale should allow to follow the collapse of dark matter and particularly gas down to scales which are currently unachievable in standard simulations at comparable mass resolution, thus providing a more reliable representation of the behaviour of galaxy-like substructures.*

Akila Jeeson-Daniel: Lyman Alpha Emitters around the Epoch of Reionization. LMU. *Abstract: LAEs are one of the important tools to study the Epoch of Reionization. I simulate LAEs between z=6-10 to compare them to observations. LAEs are simulated using cosmological hydrodynamical simulations by a modified version of Gadget-II and the radiative transfer of ionizing and lyman alpha radiation is done using CRASH-alpha.*

Oliver Just: Numerical models of hyper-accreting post-merger accretion tori. TUM. *Abstract: Remnant accretion discs around black holes created after compact object mergers are favored candidates for the central engines of short gamma-ray bursts and potential sites for the production of r-process elements. Using numerical simulations including detailed microphysics coupled to a neutrino transport scheme we calculate the energy deposition due to annihilation and absorption of neutrinos and analyze the dynamic outflow of radiation and matter as a function of the global parameters of these systems.*

Simon Karl: The Antennae Galaxies - a key to galactic evolution. LMU. *Abstract: We are using Gadget 3 major merger simulations to investigate the Antennae Galaxies (NGC 4038/39). The Antennae Galaxies are one of the best-studied major merger systems of two gas-rich spirals in the local Universe, providing an ideal laboratory for detailed comparison with numerical simulations. In my thesis, we have developed a numerical model with a close match to both the global morphology and kinematics as well as to some of the key aspects of the on-going star formation (e.g. the off-nuclear starburst) in the Antennae. We now use this fiducial model for further studies on the interaction-induced star formation and the formation history of star clusters in the system.*

Nicoletta Krachmalnicoff: Studying the Epoch of Reionization with LOFAR. LMU. *Abstract: One of the Key Science Project of the LOFAR radio telescope is to carry out observational studies of The Epoch of Reionization (EoR) which one of the least understood epochs of the Universe's evolution. My work is focused on the LOFAR data analysis and the main goal in to mapping the neutral gas fraction in the Universe as a function of redshift through the detection of the hydrogen 21 cm line. This kind of measurement is very challenging due to the low power of the signal compared to the Galactic and extragalactic foregrounds and the noise.*

Natalya Lyskova: Physics of hot gas in elliptical galaxies. LMU. *Abstract: While density and temperature of the hot gas in early type galaxies are routinely measured, other properties, such as magnetic fields or microturbulence are not know, We investigate various observational signatures of these properties, in particular their effect on the apparent mass measurements based on X-ray data.*

Zazralt Magic: Theoretical models for cool stars including multidimensional atmospheres. LMU. *Abstract: Stellar evolution models fail to reproduce correctly the surface of stars due to crude approximations of the atmosphere and the superadiabatic regime. In the course of my PhD thesis I will compute a grid of realistic 3D atmosphere models, which will resolve the above mentioned issues by nature. Later on, I will implement these accurate atmosphere models into a 1D stellar evolution code, in order to produce more precise evolutionary models.*

Fabian Miczek: Simulation of low Mach number astrophysical flows. TUM. *Abstract: Stellar interiors often contain fluid motions at very low Mach number, for example convective motions or meridional circulation in rotating stars. However, an efficient and accurate numerical simulation of these flows is very challenging because of the large disparity of the fluid speed compared to the speed of sound. Therefore, the objective of this thesis is to develop a new simulation code with implicit time stepping and an improved spatial discretization technique in order to study the impact of these flows on the evolution of stars.*

Stefano Mineo: X-ray emission from star-forming galaxies. LMU. *Abstract: Based on a homogeneous set of X-ray, infrared and ultraviolet observations from Chandra, Spitzer and GALEX archives, we study the properties of populations of high-mass X-ray binaries in a sample of star-forming galaxies. In particular we investigate the relation between the star formation activity and both the X-ray binary population and the diffuse gas emission of the host galaxy. A significant part of this work is the study of luminosity functions of X-ray binaries.*

Niels Oppermann: Non-Gaussianities in Cosmology. LMU. *Abstract: The reconstruction of non-Gaussian signal fields is an important and non-trivial step in answering many astrophysical and cosmological questions. Non-Gaussianities are present in the cosmic microwave background radiation in the form of signatures of foregrounds, secondary effects, and the primordial quantum fluctuations themselves. They also play a prominent role in the cosmic matter distribution and in the properties of the Milky Way itself. Sophisticated inference techniques are needed to deduce statements about those fields from uncertain measurement data. We develop such techniques in the framework of Information Field Theory and apply them in a variety of different contexts.*

Ludwig Oser: Galaxy Formation and Evolution. LMU. *Abstract: We are using hydrodynamical cosmological 'zoom-in' simulations to study the formation and evolution of massive galaxies. The simulations are performed with the help of the TreeSPH Code Gadget-2 and include star formation, radiative cooling, SN feedback and a uniform UV background. We find that galaxy formation* *appears to show a 'two-phase' character, with a rapid early phase ($z > 2$) during which "in-situ" stars are formed within the galaxy from infalling cold gas followed by an extended phase since $z < 3$ during which "ex-situ" stars are primarily accreted. We find that the ratio of in-situ to accreted stars is dependent on the galaxy mass and explains several observed properties of massive galaxies.*

Margarita Petkova: Numerical radiative transfer and the hydrogen reionization of the Universe. LMU. *Abstract: It is the goal of this thesis to develop a numerical solver for the radiative transfer equation and implement it into an accurate and robust cosmological simulation code in order to study cosmological reionization. We have introduced two schemes - a moment method with a variable Eddington tensor and a modified Boltzman equation solver in the form of an advection equation. We have implemented the methods in the cosmological simulation codes GADGET and AREPO, respectively.*

Laura Porter: Modelling dust in cool stellar and substellar atmospheres. LMU. *Abstract: Dust is manifestly a 3D phenomenon, like convection, with the two processes inextricably linked in cool stars and substellar objects. At present 1D models simulate dust by prescribing convection via a characteristic mixing timescale, but intrinsically are unable to reproduce the inhomogeneous surface structures and the observed L-T transition at the cool end of the main sequence. By including 3D dust formation, growth and transport within an existing stellar surface convection code, I plan to investigate the interplay between dust and gas with particular emphasis on investigating the L-T transition.*

Tomasz Rembiasz: Non-ideal MHD instabilities and turbulence in core collapse supernovae. TUM. *Abstract: The magnetorotational instability (MRI) is one of the most promising mechanisms for the amplification of the magnetic field and the subsequent transport of angular momentum and the extraction of rotational energy from the proto-neutron star in core collapse supernovae. Since simulations of the MRI and MRI-driven turbulence require extremely fine grids that cannot be afforded in global models, the goal of this project is to study them in local simulations. One has to extract quantities characterizing the turbulent transport coefficients such as average Maxwell and Reynolds stresses and correlate them with simulation parameters, eg. different rotation profiles, hydrodynamic stratifications, hydrodynamic and magnetic Reynolds numbers. The final step is to apply the most promising turbulence models in global simulations and investigate their influence on the evolution of supernovae.*

Ralph Schoenrich: Chemistry and dynamics of the Milky Way. LMU. *Abstract: We combine models of kinematics and dynamics for the Galaxy with chemical evolution codes. Having a full population synthesis at hand we can thus produce representations of Galactic surveys and by this fully interpret their results. The modelling has yielded so far a decent model of the Galactic disc, a new and simple explanation for the origin of the Galactic thin and thick discs and a large correction of the solar motion. We also re-examined a sample for the Galactic halo, discarding recent claims of a proven bimodality.*

Victor Silva: Asteroseismic Probes of Mixing Processes in Stellar Interiors. LMU. *Abstract: Asteroseismology, the only tool capable of piercing the outer layers of stars and directly probe their interiors, has entered a golden era with the data currently being obtained by the Kepler mission. We can use it to constrain mixing processes in stellar interiors by comparing the theoretical frequencies obtained with modern stellar evolution and pulsation models to the observational data. The results have implications in the study of stellar populations and the formation of our galaxy.*

Federico Stasyszyn: Smoothed particle magneto-hydro-dynamics for cosmological applications. LMU. *Abstract: We study novel implementations of MHD in SPH, constraining and understanding the effects of non divergentless magnetic field. We apply this methods in non-radiative cosmological simulations that allow us to study the large scale effects of magnetic fields and we found limits in detectability for current instrumental capabilities.*

Irina Thaler: Solar magnetohydrodynamics. Uni Amsterdam. *Abstract: Study of the structure of magnetic fields at the solar surface, and their effect on long-term variations in the Sun's brightness.*

The methods will include analytic models, realistic 3-D radiative magnetohydrodynamic simulations of sunspots and small magnetic structures, acquisition and analysis of high-resolution polarimetric observations with the Swedish 1- Solar telescope.

Marcella Ugliano: Explosion and remnant systematics for neutrino-driven supernovae. TUM. *Abstract: The currently favored scenario for the collapse and explosion of massive stars and the formation of neutron stars predicts a delayed explosion triggered by neutrino heating. In this thesis, this scenario is investigated with numerical simulations in one dimension for a wide range of progenitor stars and in two dimensions for a smaller subset of the 1D sample, in order to link the masses of the compact remnants and the explosion properties (like explosion energy and ejected nickel mass) to variations of the progenitor models. The calculations are performed with PROMETHEUS-HOTB, an Eulerian code with approximate gray neutrino transport, and carried out until the shock emerges from the stellar surface.*

Marcel van Daalen: Correlation functions from the Millennium XXL simulation. LMU. *Abstract: We will use the Millennium XXL simulation, together with the original Millennium simulation, to reliably determine the theoretical galaxy correlation function out to scales of hundreds of Mpc, with the largest statistical sample to date. Along the way, we will estimate the effects of, for example, randomizing the positions of satellite galaxies within their parent haloes and reshuffling galaxies with the same mass. To obtain the correlation function for a given cosmology within a reasonable amount of time, a method will have to be devised with which it can be determined within some fixed maximum uncertainty, using a carefully picked subset of the full sample available.*

Janina von Groote: Hydrodynamic modelling of the accretion-induced collapse of white dwarfs with detailed neutrino transport. TUM. *Abstract: O/Ne/Mg White Dwarfs may undergo accretion induced collapse, if they exceed the Chandrasekhar-mass, by accreting matter from a binary companion. This will lead to an event similar to an electron capture supernova. The goal is to simulate the collapse and get information about the conditions for nucleosynthesis.*

Markus Wadepuhl: Simulations of the formation of a Milky Way like galaxy. TUM. *Abstract: Hydrodynamical cosmological simulations have so far in general not been able to successfully form realistic disc galaxies. This work is intended to investigate some of the detailed processes happening during galaxy formation and to analyze their influence on the main galaxy and the population of satellite galaxies. This is done by utilizing extremely high resolution simulations and different numerical schemes.*

Jing Wang: The relation between morphology, star formation rate and gas fraction in galaxies. Univ. of Science and Technology of China. *Abstract: I measure consistent broad band SED from images of galaxies and measure the SFR with the standard SED fitting method. I measure morphology feature of galaxies, including distribution in of light in the bright part of galaxy, existence and strength of bars, shape and amount of diffuse light around galaxies. I study the relation between star formation, gas fraction and morphology in galaxies.*

Annop Wongwathanarat: Multidimensional simulations of core collapse supernovae using a two-patch overset grid in spherical coordinates. TUM. *Abstract: Three-dimensional (3D) core-collapse supernova simulations are computationally very demanding. To this end, we adopt and implement a new type of overset grid for spherical geometry called the "Yin-Yang" grid developed for geophysical applications, however, have never been applied to astrophysical flows before. The Yin-Yang grid allows us to perform high-resolution 3D simulations with significant time step gains compared to the usual latitude-longitude grid. Using the Yin-Yang grid technique we perform a set of 3D self-consistent core-collapse supernova simulations starting from approximately 15 ms after bounce until the supernova shock wave breaks out from the progenitor star including an approximate neutrino transport and nuclear burning network. We study the hydrodynamical neutron star kick mechanism, the formation and distribution of heavy elements synthesized during the explosion, and its connection to the neutron star kick direction.*

Zhongli Zhang: Low-mass X-ray binaries in early-type galaxies. LMU. *Abstract: The aim of the thesis is to study properties of low-mass X-ray binaries in nearby early-type galaxies. This study is based primarily on the archival data of Chandra observations. The unprecedented sub-arcsec angular resolution of Chandra telescopes capable of resolving individual compact sources in nearby galaxies makes it possible to study populations of accreting black holes and neutron stars in external galaxies. The specific goal of this study is to compare formation and evolution of populations of low-mass X-ray binaries in different environments - in globular clusters, in galactic nuclei and in the fields of galaxies, and investigate their dependence on the star-formation history and the age of the stellar population.*

Irina Zhuravleva: Radiative transfer in hot gas of galaxy clusters. LMU. *Abstract: While hot gas in galaxy clusters is optically thin to continuum radiation, the optical depth in resonant lines can be of order unity or larger and radiative transfer processes start to be important. Resonant scattering (RS) in the brightest X-ray emission lines in clusters, which firstly affect the surface brightness profiles and line shapes, can be used as powerful tool to study ICM properties. In particular we are focusing on investigations of anisotropic gas motions using RS and caused by scattering polarization, which is sensitive to the transverse velocities of gas motions.*

4.3 Visiting scientists

Name	home institution	Duration of stay at MPA
Tom Abel	Stanford Univ.	5.12.–31.12.
Pavel Abolmasov	Moscow University	3.9.–16.9.
Tony Banday	Univ. Toulouse	22.3.–4.4.
		and 3.8.-18.8.
Altan Baykal	Univ. of Ankara	13.7.–22.8.
Sergey Blinnikov	ITEP Moscow	18.3.-31.3.
		and 12.7.–31.8.
Yan Mei Chen	Chin. Acad. Beijing	10.6.–13.7.
Jens Chluba	CITA, Toronto, Canada	22.2.–15.3.
Nikolay Chugai	Inst. of Astron. Moscow	15.3.–15.4.
Weiguang Cui	Shanghai Obs.	till 18.2.
Marc Davis	Astro, Univ. Berkeley	1.5.–30.6.
Tolga Dincer	Faculty of Science, Istanbul	15.7.–15.9.
Dunja Fabjan	Univ. Trieste	31.1.–26.2.
Ryan Foley	CfA Harvard Univ.	6.9.–19.9.
Jian Fu	Shanghai Obs.	till 15.2.
		and 13.10.-9.11.
Dimitrios Giannios	Princeton Univ.	5.7.–18.7.
Liang Gao	NAO, Beijing	21.8. – 2.9.
Hong Guo	Shanghai Observatory	till 31.8.
Qi Guo	Durham Univ.	15.1.-31.1.
Oliver Hahn	Stanford Univ	5.12.–22.12.
Nail Inogamov	Landau Inst. Moscow	16.8.–12.10.
Anatoly Iyudin	Moscow State Univ.	3.6.–2.8.
		and 7.12.–20.12.
Jinrong Li	Univ. Hefei, China	5.12.-20.12.
Li-Xin Li	Peking Univ.	16.8.–13.9.
Sean Moran	JHU, Baltimor USA	24.1.-5.2.
Dmitrij Nadyozhin	ITEP Moscow	1.3.–30.4.
Yuchiro Nakada	Santa Barbara	11.7.–8.8.
Ramesh Narayan	CfA Harvard Univ.	19.9.–20.10.
Eyal Neistein	Racah Inst. Jerusalem	15.9.-30.9.
Zhizheng Pan	Hefei Univ.	till 20.3.
Francesca Perotta	Trieste	1.7.–31.7.
Laura Portinari	Turku Univ. Finland	5.4.–15.5.
Karine Sagnard	ENSPS Strasbourg	1.3.–1.9.
Maurizio Salaris	Liverpool John Moore Univ.	21.7.-21.8.
Alexander Saro	Trieste Univ.	27.6.–10.7.
Sergey Sazonov	IKI Moskow	31.1.–7.4.
		and 1.7.–22.8.
Sara Seager	Cambridge Univ. USA	5.7.–26.7.
Nikolai Shakura	Sternberg Astron. Moscow	16.8.–16.9.
Pavel Shtykovskiy	High Energy Dept., Moscow	24.7.-26.8.
Elena Sorokina	Sternberg Inst. Moscow	1.7.–31.7.
Victor Utrobin	ITEP, Moscow	1.10.-30.11.
Wenting Wang	Shanghai Observatory	since 16.11.
Osorio Yiesson	Uppsalla Univ.	18.10.–6.11.
Heling Yan	Peking Univ.	till 30.1.
Wei Zhang	NAOC, Beijing	1.6.–30.6.
Youcai Zhang	Shanghai Obs.	till 28.2.
Gang Zhao	NOOC, Beijing	2.5.–31.5.
Jie Zhou	Nat. Astron. Obs. Peking	till 4.11.