Max-Planck-Institut

für

Astrophysik

Annual Report 1994

The front page shows the result of a simulation of the gravitational lens effect exerted by a cluster of galaxies on the images of numerous elliptical background galaxies. Shown are contours of the convergence acting on light ray bundles passing through the cluster. The convergence traces the surface mass distribution of the cluster and gives an impression of the total (dark and luminous) matter distribution. The colored structures are the images of the background galaxies, which can be distorted drastically into so-called giant luminous arcs. Such structures are indeed observed, and real clusters compare very well to these simulations, both in their mass distribution and the images of the background galaxies, a very fine example being the cluster A2218. (From Bartelmann, Steinmetz and Weiss, 1995)

Annual Report of the Max-Planck-Institut für Astrophysik,
Postfach 1523, D–85740 Garching, Federal Republic of Germany.

Editors: A. Weiss and S.D.M. White..

Printed by Dokumentationsstelle of the MPI für Astrophysik, Garching.

ISSN 0948–9525

Contents

1 General Information

1.1 A brief overview of the MPA

The Max-Planck-Institut für Astrophysik, usually called the MPA for short, is one of more than 50 autonomous research institutes within the Max-Planck Society. These institutes are primarily devoted to fundamental research. Most of them carry out work in several distinct areas, each led by a senior scientist who is a "Scientific Member" of the Max-Planck Society. The MPA was founded in 1958 under the direction of Ludwig Biermann. It was an offshoot of the MPI für Physik which at that time had just moved from Göttingen to Munich. In 1979 the headquarters of the European Southern Observatory (ESO) came to Munich from Geneva, and as part of the resulting reorganisation the MPA (then under its second director, Rudolf Kippenhahn) moved to a new site in Garching, just north of the Munich city limits. The new building lies in a research park barely 50 metres from ESO headquarters and is physically connected to the buildings which house the MPI für Extraterrestrische Physik (the "MPE"). This park also contains two other large research institutes, the MPI für Plasmaphysik and the MPI für Quantenoptik, as well as many of the scientific and engineering departments of the Technische Universität München (the "TUM"). The current director of the MPA is Simon White who took up the post in 1994.

Research at MPA is devoted to a broad range of topics in theoretical astrophysics. Major concentrations of interest lie in the areas of stellar evolution, stellar atmospheres, supernova physics, astrophysical fluid dynamics, galaxy structure and evolution, the large-scale structure of the Universe, and cosmology. The MPA has traditionally been strong in studies of General Relativity, but in mid-1995 most of the relativity group will move to the newly founded MPI für Gravitationsphysik in Potsdam near Berlin. Their departure is expected to allow a consolidation of MPA activities in extragalactic astrophysics, as well as a possible expansion into new areas. While most MPA research addresses theoretical issues, the neighbouring institutes provide complementary expertise and there is a variety of collaborative projects between these institutes. The major research programmes at MPE are concerned with instrumental and observational aspects of infrared, X-ray and gamma-ray astronomy, together with supporting theoretical work, while ESO groups carry out a broad range of instrumental and observational projects in the optical and infrared wavebands.

At any given time the MPA has about 30 scientists working on long-term positions at post-doctoral level and above, up to 10 foreign visitors brought in for periods of varying length under a vigorous visitor programme, and about 20 graduate students. The students are almost all enrolled for degrees in one of the two large universities in Munich, the TUM and the Ludwig-Maximilians-Universität (LMU). A number of the senior staff at MPA have teaching affiliations with one or other of these universities. Ties with the Institute of Astronomy and the Observatory of the LMU are particularly close because the observatory director (Rolf Kudritzki) is also a Scientific Member of the MPA.

A recent development which should also enhance interactions with other local institutions is the approval by the German Science Foundation of a large long-term research programme on astro-particle physics (a "Sonderforschungsbereich der Deutschen Forschungsgemeinschaft"). Funding starts in 1995 and is expected to continue for up to ten years. Participants in the programme include the physics departments of the two universities, the observatory of the LMU, the MPI für Physik, and the MPA.

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 focussed plan is very effective at encouraging interaction between scientists and makes for a pleasant and stimulating research environment. Part of the ground floor and most of the basement of the building is currently occupied by the infrared group of the MPE, and this proximity significantly enhances the possibilities for interaction with this large and active observational/instrumental group.

The MPA and the MPE share a large and fully stocked astronomical library which is housed in the MPA building. All major astronomical books and periodicals are available. The library staff can also provide access to a variety of online archives and are currently extending this capability. Further library material is available at ESO which in addition maintains a complete collection of optical sky maps and photographic sky surveys. Other large data analysis facilities are available at the MPE which is the European data centre for the ROSAT satellite and will provide a data centre for the ISO satellite when this is launched next year.

The MPA has always placed considerable emphasis on computational astrophysics and has therefore ensured access to forefront computing facilities. The current in-house system is based on a central cluster of about 10 IBM RS6000 workstations, with additional SGI graphics workstations for graphics applications. Users have free access to all workstations and are in general connected via large-screen X-window terminals or desk-top workstations. For larger computing tasks MPA scientists use the facilities of the central computing centre of the Max-Planck Society (known as the RZG). This is part of the MPI für Plasmaphysik and is located a few hundred metres from the MPA. Current facilities at the RZG include a 4-processor Cray YMP, a 16-processor Cray Jedi, a large cluster of high-end workstations and a Terabyte mass storage system. A large parallel machine will be purchased in 1995. MPA scientists have free access to the RZG and are among the top users of the facilities there. As a result of the recent installation of an AFS file system the transfer of data among the MPA machines and from MPA to the RZG is now almost transparent to the user. Additional computing power is available at a second Max-Planck Society computer centre which is operated jointly with the University of Göttingen. This centre provides additional access to large parallel machines.

1.3 1994 at the MPA

1994 was a busy year at the MPA which saw a number of changes. One of the MPA's Scientific Members, Hermann Ulrich Schmidt, officially retired and a colloquium in his honour, was arranged on May 9. It was attended by many colleagues from Europe and from the US. The invited speakers M. Stix (Freiburg), J.H. Thomas (Rochester), N.O.Weiss (Cambridge), and H. Rauer (Lindau) gave talks on topics from solar physics and cometary magnetohydrodynamics.

The institute is lucky that despite his retirement H.U. Schmidt still takes part in most of its activities and remains as happy as ever to give younger scientists the benefit of his expertise. A new Scientific Member, Simon White, also arrived in 1994 and took up the post of Director in succession to Rudolf Kippenhahn. This ended an extended and sometimes difficult interim period during which the MPA was very ably and vigorously led by Wolfgang Hillebrandt. These changes, together with the departure of the Relativity Group led by Jurgen Ehlers to the newly founded MPI für Gravitationsphysik in Potsdam and the likely appointment in the near future of another new Scientific Member, are expected to result in a significant reshaping of the overall research programme at the MPA over the next few years.

May 1994 also saw one of the biennial visits of the Visiting Committee of the MPA, currently J. Audouze (Paris; chairman), I. Appenzeller (Heidelberg), R. Blandford (Pasadena), R. Penrose (Oxford), J. Truran (Chicago) and N. Weiss (Cambridge, UK). The group reviewed the scientific accomplishments of the previous two years and discussed the planned reorientation of research at MPA (which was much influenced by their earlier advice). Their final report expressed considerable satisfaction both with the current state of MPA research and with its plans for the future. They were able to convey these opinions directly to the President of the Max-Planck Society in a final discussion before they left Munich.

In December 1994 the 17th Texas Symposium on Relativistic Astrophysics was held in Munich and many MPA scientists took part as speakers or organisers. The meeting brought more than 500 astrophysicists to Munich and its impact on the local community was enhanced by a 3-day joint MPA/MPE workshop on "The Mass and Composition of Galaxy Clusters" which was held at the MPA just before the main meeting. This workshop attracted a strong international group of speakers and filled the MPA seminar room to bursting point. Just after the Texas meeting a second, smaller international workshop on "Stellar Dynamics and Cosmology" brought together scientists interested in using special-purpose hardware produced by a group of Japanese researchers (the so-called GRAPE boards) to carry out N-body and hydrodynamical simulations of the dynamics of star clusters, of galaxies, and of galaxy clusters.

The arrival of a new director also resulted in a number of organisational changes within the MPA during 1994. All longer-term posts are now widely advertised on a regular yearly timetable, and appointments are made according to the advice of formally constituted appointments committees. The permanent scientific staff, together with representatives of the temporary postdoctoral staff and the graduate students, meet regularly as a "Wissenschaftliche Institutsrat" to discuss all issues affecting the scientific life of the institute. Finally, a less formal meeting of the institute occurs each morning at 10:30 in order to exchange scientific and other views, and to consume free coffee currently provided by a timely infusion of funds from the Royal Astronomical Society.

1.4 How to reach us

- Postal address:

  MPI für Astrophysik
  Postfach 1523
  85740 Garching
  Germany

- Telephone (country code 49):

  89-3299-00 (switchboard)
  89-3299-3214 (secretary)
  89-3299-3235 (FAX)

- Electronical:

  e-mail:
  user-id@mpa-garching.mpg.de

  World Wide Web:
  http://www.MPA-Garching.MPG.DE

  anonymous ftp:
  ftp.mpa-garching.mpg.de

2 Research Abstracts

2.1 How round are Wolf-Rayet stars?

Massive stars are generally known to be rapid rotators, with O-stars showing maximum rotational speeds of over 400 km/s, which is about 50% of their breakup velocity. Wolf-Rayet stars, however, the descendants of O-stars, have extremely dense stellar winds which prevent a direct spectroscopic determination of their rotation rates. Recently, a model for the effect of rotation on stellar winds has been worked out and its application to Wolf-Rayet stars has shown that even moderate rotation may cause considerable deviations of the stellar wind from spherical symmetry. Here, we report on the first time-dependent and self-consistent calculations of rotating mass losing stars in the Wolf-Rayet phase. We predict the evolution of their surface velocities and the corresponding wind geometries and arrive at two surprising conclusions. Firstly, the majority of the Wolf-Rayet stars should be absolutely spherical, but secondly, a noticeable fraction of them are expected to be severely flattened, i.e. appearing with the shape of a discus rather than a sphere.

The effects of rotation on the evolution of massive stars have been debated for a long time, but despite numerous hints of their importance, they have not yet been systematically investigated. Recently, it has been proposed that mass loss may trigger the mixing of matter and angular momentum in the interior of massive stars, with the consequence of the formation of core hydrogen burning Wolf-Rayet stars. Here, we follow this idea by means of time-dependent stellar structure calculations. The centrifugal force is included by using equipotential surfaces instead of concentric spheres as independent coordinate. Time dependent, rotationally induced mixing of matter and angular momentum is treated in a diffusion approximation.

In the following, we describe the evolution of a star with an initial mass of 40 $M_\odot$ and an initial equatorial rotation velocity of 420 km/s. Due to the O star wind mass loss and rotationally induced internal mixing, the model turns into a Wolf-Rayet star during core hydrogen burning. This is in contrast to Wolf-Rayet models originating from calculations without rotation. The Wolf-Rayet phase is marked by a substantial increase in the surface helium and nitrogen abundances and a corresponding increase in the luminosity-to-mass ratio. It is reached at an age of 4 million years. Fig. 2.1 shows that the model maintains a high rotational velocity until the Wolf-Rayet stage is reached. It then begins a rapid spin down due to the coupling of the intense Wolf Rayet mass loss (for which we adopt empirical determined rates) and internal mixing of angular momentum: The stellar interior is kept close to rigid body rotation and angular momentum is thus continuously shuffled from the core to the surface layers and blown off by the stellar wind. The efficient spin down of the whole star is thus a specific feature of our model.

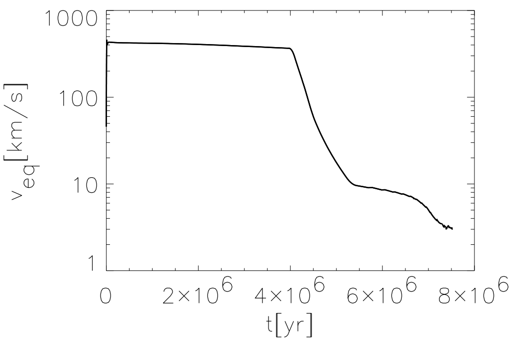

Figure 2.1: Evolution of the equatorial rotation velocity of our stellar model during core hydrogen burning. Rapid rotation is maintained until a spin down occurs when the Wolf-Rayet stage is reached.

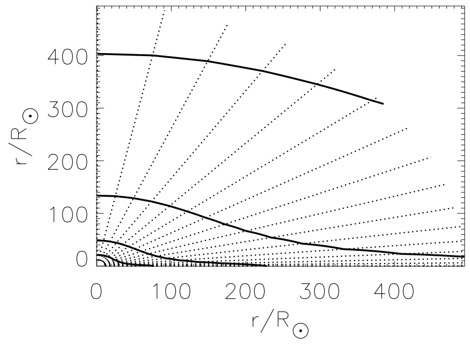

Figure 2.2: Streamlines of wind particles (dashed) and wind density contours (solid) for our model during the Wolf-Rayet Phase at a rotation rate of 150 km/s. Contour lines are given for densities of $10^{-15}, 10^{-14}, 10^{-13}$ and 10^{-12}g/cm^3.

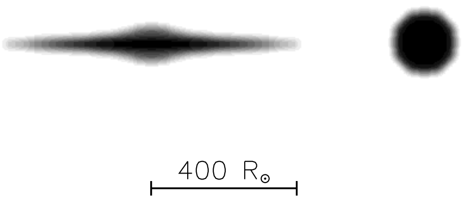

Figure 2.3: The photospheric shape corresponding to the model shown in Fig. 2.2. viewed from within the equatorial plane (left), and from the pole (right).

For the effects of rotation on the wind of a Wolf-Rayet star, we applied the model recently proposed by Bjorkmann and Cassinelli. This model allows us to calculate the geometry of the optically thick stellar wind as a function of the rotational velocity and to connect it to observables. The trajectory of a wind particle is determined by the rotational velocity, the accelerating radiative forces and the gravitational force. For fast acceleration, its streamline will be nearly radial. If the wind velocity is comparable to the rotation speed, conservation of angular momentum leads to trajectories converging towards the equatorial plane.

When our model develops an optically thick and slowly accelerated Wolf-Rayet wind, the effects of rotation on the wind geometry are much stronger due to the lower wind velocities near the star. Initially, a disk is formed. Since the strong mass loss causes the rotational velocity to decrease rapidly, after some time the disk vanishes and a strongly distorted wind remains.

Fig. 2.2 shows the trajectories, Fig. 2.3 the photosphere as seen in the equatorial plane and from the pole. At this time, the equatorial velocity is still about 150 km/s. The extension in the equatorial plane is abouta 800 solar radii and ratio of the axes about 1:7, while the (hidden) hydrostatic part of the star with its radius of about 8 solar radii is almost spherical. The density contrast from the pole to the equator is about 30.

Due to the decreasing rotation, the wind becomes more and more spherical. The axis ratio of the photosphere is decreased to 0.5 after $5.4\,10^6$ yr. The density contrast decreases to a factor of 2 after $5.68\,10^6$ yr, corresponding to a rotational velocity of 42 km/s. By comparing to the duration of core hydrogen burning, we infer the existence of a significantly aspherical photosphere during 5% of the time.

Since the mean life time of Wolf-Rayet stars is $\sim$20% of the hydrogen burning life time of their O star progenitors, the numbers above indicate that a substantial fraction of the known Wolf-Rayet stars may actually have a discus-like shape. These still rapidly rotating stars could be recognized by a high degree of polarization of their radiation if seen equator-on, which may be related to the discovery of polarization in some Galactic Wolf-Rayet stars. Furthermore, photospheric absorption components may be observable from the polar region of the star, where the wind density is much lower compared to that at the equator; this interpretation has actually been proposed by Koenigsberger for the Galactic Wolf-Rayet star WR 138. The objects with the largest equatorial extensions might even be resolvable by means of optical speckle interferometry, especially given the fact that the region which produces the emission lines is considerably more extended than the photosphere. On the other hand, the rapid spin-down seen in our models leads to the prediction that most Wolf-Rayet stars should have very small rotational velocities and thus spherically symmetric winds and photospheres. This is in remarkable agreement with the absence of polarization in the majority of Wolf-Rayet stars, and with flat-topped and almost rectangular emission line profiles observed in a couple of cases, which indicate spherical symmetry. (J. Fliegner & N. Langer).

2.2 Late-type Dwarfs and the Lithium Puzzle

Modern spectroscopic techniques allow us to study the light emitting layers of stars in considerable detail. From such observations one can obtain quantitative information about the chemical composition of these layers. The surface abundances of the various chemical species challenge our knowledge of the structure and evolution of stars since they are the imprint of the numerous physical processes which generate, destroy, and transport the constituents during the stellar lifetime. Since the first theoretical models including hydrogen burning were made by Gamov in 1938, great progress has been achieved understanding stars as nuclear reactors transforming their chemical composition. Despite much effort less progress has been made in overcoming the idealized concept of stars as hydrostatic configurations. In current standard models hydrodynamical effects are incorporated through a simple description, designed primarily to give an estimate of the energy transport associated with convective gas flows. In view of this crude approach it is not surprising to find stars where the surface abundances hint at internal transport processes that standard models cannot account for.

A prominent example is the lithium abundance of the Sun. During its evolution over 4.6 billion years the Sun has managed to reduce the amount of the trace element lithium in its visible layers by a factor of 140. Lithium is a fragile element — lithium nuclei are already destroyed by reaction with thermal protons at just 2.5×10^6 K. While usually nuclear reactions take place only near the center of stars, where the highest temperatures and densities are encountered, lithium can be processed far out in the stellar envelope. Solar models predict that an outer shell of 29% in radius — the hydrogen convection zone — is rapidly mixed by turbulent gas motions which are responsible for the energy and mass transport there. This suggests, as explanation of the lithium deficit, that material from the cool visible layers is brought down into hotter layers where lithium can be burned and subsequently brought back to the surface again. But even at the base of the convection zone the temperatures are thought to be so low that lithium remains essentially unaffected. This problem persists if one considers the evolutionary changes of the solar structure. Only during a short period in the pre-main sequence phase is there the possibility of burning lithium in the convective envelope; but the predicted overall depletion amounts to a factor of 2 to 3 only. The solar lithium deficit is just one example of the situation in the class of F and G main sequence stars. These objects show a complex pattern of lithium depletion depending on age, metallicity, rotation rate, or even more parameters (cf. Fig. 2.4). Clearly one has to invoke additional processes which can account for an extended mixing and enhanced burning of lithium.

Processes related to macroscopic gas flows which are usually ignored are prime candidates. In the course of projects pursued at the Max-Planck-Institute for Astrophysics the authors considered "convective overshooting" and shearing instabilities due to differential rotation as potential culprits. The term "convective over-

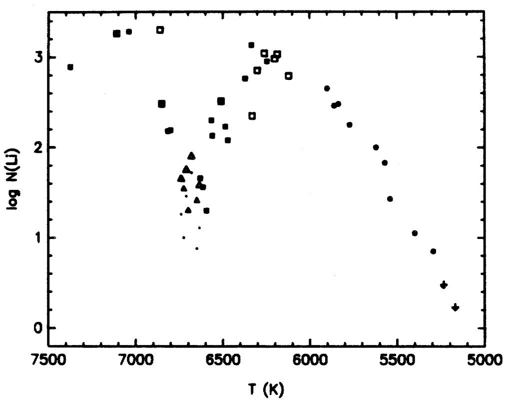

Figure 2.4: The observed Li-temperature profile for the Hyades F and G dwarfs. The most obvious patterns are the dip around 6700 K and the decrease of the Li-abundance for stars cooler than 6200 K. While the so called lithium dip can not be explained by means of simple diffusive processes, the Li-depletion towards cooler stars and therefore deeper convective envelopes gives strong evidence for an extra mixing below the convective region. Only for stars with effective temperatures below $\approx$5000 K the convection zone itself extends into the lithium burning region.

shooting" describes the phenomenon that convectively driven fluid motions are not strictly confined to unstable regions but penetrate to some extent into their stable surroundings. The large difference between evolutionary and hydrodynamical time scales allows a splitting of the coupled problem. In practice, a suitable prescription for the hydrodynamical process characterizing the situation in a quasistatic stellar background model is incorporated into the evolutionary calculations. The derivation of such a prescription is by no means an easy task due to the lack of a reliable theory of turbulent flows. In the present case we obtained a representation for the overshooting from hydrodynamical simulations, and for the rotationally induced mixing from a parametrized analytical approximation. It turns out that with an appropriate choice of the free parameters in rotating models without overshooting one can simultaneously fit the evolution of lithium in the Sun as well as in F and G stars. Non-rotating models of the Sun including overshooting show that it significantly affects the lithium evolution. Although the results still suffer from some arbitrariness in the choice of free parameters, and uncertainties related to the difficulties inherent to hydrodynamical simulations of flows in stellar interiors, they clearly show the importance of these processes. Thus, we have encountered a common situation in science: things look promising but also demand further consideration. (H.-G. Ludwig & J. Fliegner)

2.3 Thermonuclear Explosions of White Dwarfs

Supernova explosions are by far the most energetic events in our cosmic neighbourhood. For a short period of time they can be as bright as their entire host galaxy. However, they are rare events: In our own Galaxy we expect there to be a few supernovae per century, but many of them are hidden behind galactic gas and dust. Therefore, it is not so surprising that the last local supernova was observed in 1604, and the only supernova of this century which could be seen from Earth with the naked eye for a while was discovered in the Large Magellanic Cloud some 50 kpc away in 1987.

Astronomers classify supernovae with respect to their spectral properties. Those showing Balmer lines of hydrogen in their spectra are named to be of type II, all others are of type I. A subclass of type I supernovae has lines of intermediate-mass elements like silicon in their early spectra, and at later times lines of iron and cobalt appear, but they show no indication for the presence of oxygen. They are now called type Ia supernovae or classical type I's, because most of the previously known type I's seem to have belonged to that subclass. Moreover, they are surprisingly similar in most of their observable properties. Most members of this group seem to have the same luminosity at maximum light, and their light curves have almost always the same shape. Although deviations from these rules have been found in some cases, the overall homogeneity of type Ia supernovae is still astonishing. Moreover, there seem to exist correlations between the form of the light curve and the maximum luminosity. Because supernovae are so bright and can be detected even in very distant galaxies, all these properties make them ideal candidates for measuring cosmic distances.

A key question is, however, why this subclass of supernovae appears to be so homogeneous, because we can use them as distance indicators with some confidence only if we understand the underlying physics. Of course, the simplest explanation would be if the same kind of stars would always explode by the same mechanism. This leads us to a model which is in general favoured today. It is believed that type Ia supernovae are exploding white dwarfs with a common mass, i.e. a mass close to the critical Chandrasekhar mass. In this model the explosion energy is liberated by thermonuclear fusion of carbon and oxygen into iron-group elements in the interior of the white dwarf. At temperatures above about 5×10^9 K radioactive nickel forms first and then decays via cobalt into stable iron. The energy released from radioactive decay determines the light curve of the supernova and, if the same amount of nickel is always formed, this could explain the homogeneity of the class. Although the general scheme seems convincing and has been considerd very successful in the past, doubts have emerged recently which cannot easily be overcome.

There are, in principle, two ways by which thermonuclear fusion can propagate inside the degenerate matter of a white dwarf. Either the nuclear fuel is heated to ignition temperature by heat conduction and convection or it is compressed by a shock wave. The former mode of propagation is a (subsonic) deflagration wave whereas the latter is a (supersonic) detonation. The problem with pure detonations is that at high densities they do not produce the intermediate-mass elements seen in type Ia explosions, making the simple version of this scenario rather unlikely. Deflagrations, on the other hand, can account more easily for the observed spectra but they suffer from other problems which will be discussed in what follows, together with some ideas how these problems may be cured.

One of the basic assumptions of all deflagration models is that in a few seconds most of the white dwarf is incinerated by the thermonuclear burning front. This requires that the velocity of the front be similar to the sound speed because otherwise the white dwarf would have time to expand and to cool down to temperatures below the ignition temperature. Consequently, most of the nuclear fuel would remain untouched. It has been demonstrated that a front propagating at the nonturbulent or "laminar" velocity, which is less then a percent of the sound speed, would at best turn a tenth of the mass of the white dwarf into nickel, not enough to give an explosion. On the other hand, it is very unlikely that the burning front is laminar. In contrast, the viscosity of the white dwarf's material is so low that small inhomogeneities in the velocity field should be enough to lead to vorticity and turbulence. The burning front will then propagate at the turbulent velocity which may be considerably higher.

Processes leading to perturbations of the velocity field are in fact known. One is the buoyancy (or Rayleigh-Taylor) instability. The burned gas of the white dwarf is hotter and lighter than the surrounding unburned material. It therefore experiences a buoyancy force driving blobs of hot gas upwards into the unburned fuel. Shear instabilities then cause vorticity, and both are the origin of turbulence. Alternatively, instabilities generated by the nuclear burning itself may couple to larger scales and may also be the cause of turbulence. As a net effect, it is expected that in a given interval of time more carbon and oxygen is fused into iron-group elements than is predicted by just laminar nuclear burning.

Unfortunately, it is very difficult to convert these ideas to a quantitative (numerical) model which then can be compared with observations. In fact, a numerical simulation would have to include a huge span of scales, ranging from the order of magnitude of the thickness of the burning front (a fraction of a millimeter) to the radius of the white dwarf (several thousand kilometers), and they would have to resolve all these scales. It is obvious that this problem cannot be solved by means of direct numerical simulations, even on the most powerful supercomputers. A way out of this difficulty may be found in methods which are widely used in meteorology (where a similar problem is encountered) and in modelling laboratory fluids and combustion, but which has not become popular in astrophysics so far. These methods are called "large eddy simulations". They solve the hydrodynamic equations directly on large scales, but treat the unresolved small scales by means of simple statistical models. For the case of interest here this task is not too difficult. We deal with turbulent velocities safely below sound speed, and for this kind of turbulence the scaling laws for turbulent velocity fluctuations are known since the work of Kolmogorov in 1941. Moreover, laboratory combustion experiments with chemical flames indicate that turbulent burning velocities can be descibed by similar scaling laws. These scaling laws depend only on the smallest scale down to which turbulence still persists, and on a fractal dimension.

A model of this type was used to simulate combustion processes inside white dwarfs. Nuclear burning was ignited near the center of the white dwarf where the temperature and the density adopt their highest values. The propagation of the burning front was computed for a variety of initial conditions and different parameters of the subgrid model. A typical result is given in Fig. 2.5, showing the position of the burning front after the nuclear fuel has burned for a little more than a second. It can be seen that the shape of the front is very complicated, with no indication of any symmetry. The large scale structure of the front is dominated by the Rayleigh-Taylor instability, and shear flows have led to turbulence at the interface between fuel and ashes, and behind the front. At the time when this snapshot was taken about 30 percent of the matter of the white dwarf had been incinerated to radioactive nickel, but the front velocity had never exceeded a few percent of the local sound speed. In fact, the front is slowing down, the star is beginning to expand, and nuclear burning is close to being extinguished. In this particular simulation, as well as in most others with similar initial conditions, turbulence has led, as was hoped, to an acceleration of nu-

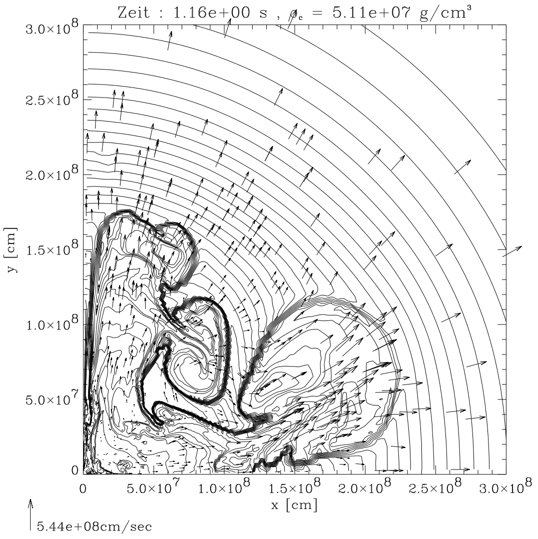

Figure 2.5: The thermonuclear burning front propagating through the interior of a Chandrasekhar-mass white dwarf. It can clearly be recognized by the sharp gradient in the material density, represented by the contour lines. The front separates hot, burned matter in the center from cold, dense carbon and oxygen further outside. In addition, the velocity field is shown by arrows at the respective grid points.

clear burning. Unfortunately, the effect is still too small. Although the star is unbound in the end and would explode, its expansion velocity would be too small to resemble the observed features of type Ia supernova explosions.

Is it now proven that thermonuclear explosions of white dwarfs cannot explain type Ia supernovae? It is certainly too early to draw such far reaching conclusions from the set of numerical simulations discussed here. First of all, the physics of turbulent flames is still far from being fully understood and is subject to intensive research in many laboratories all over the world. On the other hand, the key to the supernova problem may also be found in astrophysics. For example, the structure of the white dwarf at the onset of the thermonuclear runaway may be more complicated than was assumed in our simple models. In particular, the front would propagate differently if nuclear burning was ignited off-center in one or several blobs. Other modifications could include convection prior to the runaway or rotation which seems to be unavoidable if the white dwarf's mass is brought to the Chandrasekhar limit either by accretion or by merging of two low-mass white dwarfs. In any case, it appears that the physics of type Ia supernova explosions is much more complicated than had been anticipated. (J.C. Niemeyer & W. Hillebrandt)

2.4 Do low-mass black holes form in Type II supernovae?

In our galaxy more than 150 clouds of gas and dust are known to be the dilute remnants of violent stellar explosions. Most of these fuzzy shells should have originated from explosions of Type II supernovae which are the catastrophic disruptions of stars with masses larger than about eight times the mass of the Sun. During their "quiet" lives of 10 million years or more these stars consume all the nuclear fuel in their central regions by converting hydrogen into successively heavier elements, first helium, then carbon, oxygen, neon, magnesium, silicon, and finally iron. This chain of nuclear reactions releases the energy and produces the pressure which the star needs to be stabilized against the enormous inward pull of its own gravitational attraction. Iron as the most tightly bound atomic nucleus does not allow to gain energy by further nuclear fusion processes. Yet, although the star's vital source of energy has disappeared, the dense central core of the star continues to lose energy by the escape of neutrinos, elementary particles that are copiously produced under the conditions in the core but which leave the star nearly unhindered. This ongoing energy loss has catastrophic consequences: The stellar core collapses within only a fraction of a second after the nuclear flame has been extinguished.

The inward motion is not stopped before the density reaches or even surpasses the density present in atomic nuclei. It is then that thermal motions of neutrons and protons and the repulsive nuclear forces between these nucleons become strong enough to balance gravity again. This moment marks the birth of the most compact object known, a neutron star. In a neutron star the nucleons are packed so densely that the mass of 1.5 Suns is compressed into a sphere with the diameter of only about 20 km. The hot stellar gas that falls onto the nascent neutron star "bounces off" and expands outward again, thereby disrupting the star in a gigantic supernova explosion. The violent ejection of most of the star's material into the interstellar space is accompanied by an extremely bright outburst of light that can become more luminous than a whole galaxy for several weeks.

On February 23, 1987, the first flash of light from such a supernova explosion was discovered by Ian Shelton. Supernova SN 1987A went off in the Large Magellanic Cloud, only 150000 light years away, and has been the closest supernova for more than 300 years. Its observation could confirm the theoretical picture described above in a spectacular way. The capture of 19 neutrinos in two terrestrial water tanks proved the emission of a huge number of these extremely rarely interacting particles. This indirectly testified the collapse of a stellar core and the formation of a neutron star. The outburst of light provided evidence of the very fast ejection of material of more than 10 times the mass of the Sun, thus showing that a very massive star ended its life in being disrupted. However, an important aspect in the theoretical picture is still missing: Even more than eight years after the explosion no neutron star has been found yet. As is well known from many observed pulsars such a compact remnant should signal its existence by a characteristic emission of electromagnetic radiation and of energetic particles.

What happened to the neutron star in SN 1987A? How could it disappear or hide itself from observation? Interestingly, also in most of the other 150 supernova shells no pulsar is visible. Have the neutron stars left the explosion clouds as one might speculate because many pulsars are discovered to move through the interstellar space with high velocities? Yet, this can hardly be the solution to the puzzle in case of SN 1987A. What else might have happened? An exiting possibility is that instead of a neutron star a black hole was formed in SN 1987A and in many other Type II supernovae. The emission from the material falling into the black hole would be well below currently measurable signal strengths. The detection of neutrinos from SN 1987A over a time interval of several seconds, however, excludes that the black hole emerged immediately from the stellar collapse. Instead, a neutrino-emitting neutron star must have existed as an intermediate state which has become unstable against further collapse to a black hole.

Performing detailed numerical simulations to follow the evolution of the neutron star in SN 1987A from the moment of formation to the instant when it collapsed to a black hole, we could demonstrate that such a scenario is not mere speculation. During the first seconds of a neutron star's life the evolution is driven by the loss of neutrinos. Although these particles interact with matter only once in the time a photon experiences 10^{20} scatterings, they cannot leave the neutron star immediately. At the extreme densities present in the interior of the neutron star even a neutrino scatters 10000 to 100000 times before it finally reaches the surface and escapes a few seconds after its creation. The neutrinos do not only carry away energy to cool the star. They also mediate a gradual transformation of the iron material that makes up the central region of the pre-supernova star. Iron contains neutrons and protons in similar numbers while the matter in the neutron star is proton-depleted. The most elaborate equations of state for the density regime above nuclear matter density do not only predict a large abundance of neutrons but also of other particles, so-called hyperons and mesons, which are produced in reactions between energetic neutrons. The occurrence of such new particles has severe consequences for the behavior and the properties of the star.

The production of hyperons and mesons near the center of the neutron star consumes energy and reduces the pressure, i.e., it "softens" the equation of state. Driven by the loss of neutrinos, more and more neutrons and therefore hyperons and mesons are created in the neutron star. The corresponding softening of the equation of state leads to a contraction of the star and to an increase of the density, which again favors further hyperon production. When a new, stable balance can be achieved, the resulting "hadron star" will be more compact than an ordinary neutron star. However, if the mass of the young neutron star is high enough, the gravitational pull is so strong that the chain of reactions speeds up and leads to a runaway situation quite similar to the events that triggered the collapse of the stellar iron core – a final recollapse of the star is inescapable. In Fig. 2.6 the two possibilities are shown in a schematic way. The solid line gives the mass of the newborn neutron star (sum of the rest masses of all particles in the star) which varies with the density at the center of the star. The dashed line displays the corresponding mass-density relation in case of hadron stars, i.e., when hyperons and mesons are present in the star. The two

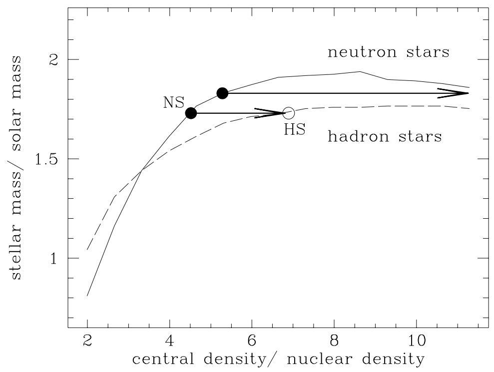

Figure 2.6: Evolution from a newly formed neutron star (NS) to a hadron star (HS). The central density of the star is measured in units of the nuclear density (about $2.5 \cdot 10^{14}\,\mathrm{g/cm^3}$), the stellar mass is defined as the sum of the (vacuum) masses of all particles in the star

arrows mark paths along which the nascent neutron star can evolve as its central density slowly increases due to the emission of neutrinos. Either the star leaves its position on the solid line to find a new stable position on the dashed curve (lower arrow), or it misses the dashed line and the density at its center will increase beyond all limits (upper arrow).

We found that hadron stars remain stable for a measurable mass of at most 1.58 solar masses. Our simulations revealed that, if the neutron star in SN 1987A became unstable, the re-collapse has happened 5 to 10 seconds after the neutron star was born in the stellar core collapse. At the time of re-collapse the hadron star was still a very hot object. Future investigations will have to clarify whether the neutrinos observed from SN 1987A are compatible with this scenario or rule it out. Also, unless the improbable case is true that SN 1987A was the only Type II supernova where a black hole with a mass only slightly larger than the mass of the Sun was formed, then observation is challenged to find evidence for a large number of low-mass black holes in our Galaxy. (W. Keil & H.-Th. Janka)

2.5 Irradiation–induced mass transfer cycles in cataclysmic variables

Cataclysmic variables are close binary stars in which a white dwarf accretes matter from a low–mass companion star. One of the side effects of the mass transfer to the white dwarf consists in the transformation of potential and kinetic energy of the transferred matter into accretion luminosity, most of which is generated near the white dwarf. Part of that luminosity, in turn, is radiated in the direction of the companion star, thereby heating those parts of its surface which "see" the light source. In the following we shall examine the consequences of irradiating the companion star for the long–term evolution of such systems. That the reaction of the mass losing star to external irradiation could have important consequences for binary evolution was first noticed only rather recently in a much more extreme context, namely the low–mass X–ray binaries, i.e. systems similar to cataclysmic variables but with a neutron star or a black hole in place of the white dwarf. Because in such systems the accreting object is much more compact than a white dwarf, the accretion luminosity and with it the irradiating fluxes exceed those in cataclysmic variables by many orders of magnitude. Nevertheless, we shall restrict ourselves to the discussion of the more modest cataclysmic variables. Before going to describe the evolution of such systems with irradiation let us briefly recall the basic effects resulting from irradiating a low–mass star.

In this context, low mass means a mass less than that of the Sun. Only for such stars which have a relatively deep outer convective envelope is the internal structure strongly dependent on the surface boundary conditions and thus sensitive to irradiation. Let us now examine what happens if such a star, which we assume to be in thermal equilibrium, is suddenly exposed to an external radiation field. Thermal equilibrium means that the star's energy loss through its surface is exactly balanced by nuclear energy generation in its interior, i.e. that its luminosity L is equal to the nuclear luminosity L_{nuc}. For this to be the case, the temperature has to decrease from the center to the surface in a unique way. Now, if the star is suddenly irradiated from outside over part or all of its surface with radiation which penetrates into the photosphere, the photospheric temperature has to rise. As a result, the temperature gradient below the surface of the irradiated parts is lowered and therefore the loss of energy through these layers is partially or totally blocked, i.e. luminosity gets trapped in the star. Thus, immediately after the onset of irradiation, the star finds itself in a situation where $L - L_{\rm nuc} < 0$. What happens now? Contrary to naïve expectations, a star does not heat up if energy gets trapped in its interior. Rather, as is well known from the Virial theorem, ordinary stars have a negative gravo–thermal specific heat (a consequence of self–gravitation) which means that in response to energy storage the interior of the star cools and expands, thereby lowering $L_{\rm nuc}$. In this way the star can regain a new state of thermal equilibrium. The change of radius necessary to reach new thermal equilibrium depends very sensitively on whether irradiation is isotropic or not. If irradiation is isotropic and sufficiently strong, the star must swell considerably and become fully radiative. If, on the other hand, a sizeable fraction of the stellar surface remains unaffected by irradiation, the stars swells only relatively little and does not become fully radiative. What is most important for the following is that the effect of irradiation on the stellar radius saturates in amplitude (because no more than the total luminosity L can be blocked) and in time, where the relevant time scale on which the star adjusts to changes of the surface conditions is of the order of the thermal time scale of the convective envelope.

Let us now turn back to cataclysmic variables in which such a low–mass star is transferring mass to a white dwarf companion and is irradiated by the accretion luminosity generated in the vicinity of the accretor. Because of the strong tidal interaction the donor star is likely to be in (or near) synchronous rotation with the orbital motion. Thus one side of the star is always facing the accretor and is irradiated whereas the rest always remains in the shadow. Now we must ask ourselves whether mass transfer in such a binary is stable if we take into account the donor's reaction to irradiation. This is not a trivial question because in response to an increased mass transfer more accretion luminosity is generated. The star is thus more strongly irradiated, as a result of which it expands further and amplifies mass transfer even more. A proper stability analysis of the situation just described yields the following result: cataclysmic variables having a donor star with a mass $M \gtrsim 0.65 M_\odot$ are likely to be unstable against irradiation–induced runaway mass transfer, whereas the systems are stable if $M \lesssim 0.65 M_\odot$.

Now it is time to recall that the effect of irradiating a star saturates in amplitude and in time. Because of this, in systems which are unstable, the mass transfer rate cannot run away to arbitrary high values. Rather, such a system is forced to evolve through a limit cycle during which phases of high mass transfer alternate with phases of very low or no mass transfer. During the high state mass transfer is driven by the expansion of the donor star which, in turn, is caused by irradiation. Because of the saturation of the irradiation effect, such a high state cannot persist, because after some time the donor star no longer grows sufficiently fast. When, in response to lowering the mass transfer rate, energy begins to leak more efficiently out of the star, it starts shrinking again, thereby reducing the mass transfer even more. The system goes into a low state during which the star initially shrinks faster than its Roche radius, inside of which matter is gravitationally bound and outside of which it can flow onto its companion. In the long run, however, the Roche radius must catch up again. (This is a consequence of the loss of orbital angular momentum which drives the long–term evolution of such systems in the first place.) This means that after some time mass transfer sets in anew thus bringing the system back to the high state.

As we mentioned above, this limit cycle mechanism does not work if the donor star has less than $\sim 0.65 M_\odot$. There are two main reasons for this: First, with decreasing mass the thermal inertia of the convective envelope increases rapidly (a consequence of the growing mass of the convective envelope and of the mass luminosity relation) and second, below $\sim 0.65 M_\odot$ convection is adiabatic almost up to the photosphere with the result that energy outflow is almost totally blocked even for very small irradiating fluxes. If this is the case over most of the irradiated hemisphere the star's energy loss no longer depends sufficiently sensitively on the irradiating flux.

The fact that the above–described mechanism cannot produce mass transfer cycles in cataclysmic variables with a donor star of less than $\sim 0.65 M_\odot$, i.e. with an orbital period of less than $\sim 6^h$, means it is unlikely that it is the cause of the large scatter of the observed mass transfer rates, in particular for systems in the period range of interest, i.e. $3^h \lesssim P \lesssim 6^h$. However, we must realize that the model we have studied so far is still a rather simple one. Therefore more work needs to be done before we may draw firm conclusions about the importance of irradiation–induced mass transfer cycles for the evolution of cataclysmic variables. (H. Ritter)

2.6 Lop-sided Galaxies?

Galaxies are assemblies of typically several billion stars, which constitute one of the most important units in the hierarchical structure of the universe. Each star in a galaxy orbits in the gravitational potential provided by all others stars and possibly by hitherto unidentified, "dark" matter. The research field of galaxy dynamics deals with making a quantitative connection between the *sources* of gravity, the stellar and dark mass, and the *effects* of the gravity, the induced orbital motions of the stars.

In the most important type of galaxies, so-called spiral galaxies, the majority of stars is arranged in a disk. It has been known for a long time that these galaxies are not perfectly axisymmetric, but exhibit bars near the center and spiral arms at larger radii (see e.g. the galaxy, NGC 4440 in Fig. 2.7). One generic problem in studies of galaxy dynamics is that one would like to know the spatial distribution of the *mass* density, but only can observe directly the two-dimensional, projected density of the stellar *light*. If the stellar population had a mass-to-light ratio which were constant throughout the galaxy, the mass distribution could be determined directly from the observations up to a proportionality constant.

In most spiral galaxies, this problem of measuring mass through measuring light, turns out to be as difficult as if we were forced to infer the distribution of the earth's population from optical satellite pictures taken at night. On the one hand the highly industrialized areas could appear much brighter than it would correspond to their population fraction, on the other hand important population centers could be covered by clouds and thus remain invisible. Analogously, there are areas in galaxies where newly formed stars dominate the surface brightness. As a population, these stars are much brighter than older stellar populations of the same (total) mass. Galaxies, however, do not only contain stars, but also dust and gas. Such dust may absorb most of the light from the stars behind it and make these areas appear less luminous than expected from their true mass-to-light ratio.

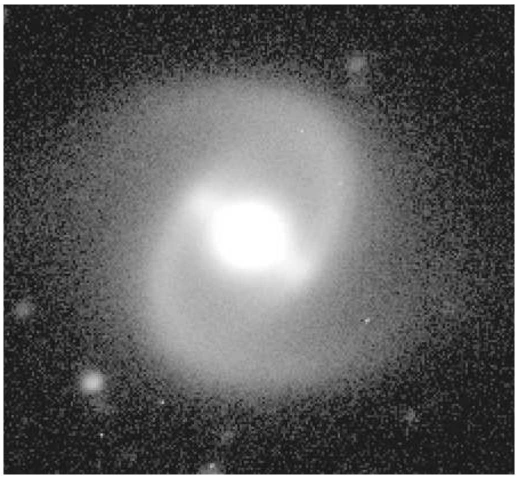

Figure 2.7: The disk galaxy NGC 4440, where we look almost perpendicularly onto the disk plane, presents a good example of the two most common, non-axisymmetric structures: a bar at the center and two strong spiral arms at larger radii. This galaxy is, however, a rare example where such structures are clearly seen in images taken at visual wavelengths, without beeing distorted by the light of young stars or by dust.

The development of near infrared detectors has made it possible in the last years to obtain galaxy images in which the light distribution is a much better approximation to the stellar mass distribution. Infrared images have two key advantages over observations in the optical wavelength region: First, young stellar populations have a higher mean surface temperature than older populations and therefore radiate a larger portion of their total energy at ultraviolet and visual wavelengths. Consequently, young stellar populations, of little *total* mass, are less overrepresented in the infrared light than in the visual. Second, infrared radiation can penetrate galactic dust much better than optical radiation. Therefore, dusty regions are less underrepresented in the infrared light than in the optical.

This new type of observations is now being used to study the mass distribution in bars and spiral arms (and the resulting orbits) more reliably. As always when astronomical objects are studied in a new part of the electromagnetic spectrum, one finds unexpected results. One of these surprises is that many galaxies are "lop-sided". If one imagines any galaxy disk divided in half by a line through the center, then one finds in one third of all galaxies that there are 25% more stars in one sector than the other. This apparent tendency of galaxies to develop lopsidedness is surprising, because linear stability analyses showed that galactic disks should be stable against such perturbations. There are (at least) two possible explanations for this lopsidedness. First, we know that galaxies often develop symmetric instabilities, such as bars and spiral arms (Fig. 2.7). We know further, that galaxy disks are commonly warped, i.e. the outer parts are slightly tilted with respect to the central disk plane. Using a strongly simplified model, it is possible to show, that the asymmetric warp perpendicular to the disk plane can interact with the symmetric distortions in the disk plane and produce asymmetries within the disk plane. Whether this mechanism can explain the lop-sidedness as observed, still needs to be verified in detail.

An alternative explanation for lop-sided disks is based on the fact that galaxies are not completely isolated entities in space. There are clear indications that several times during its life the internal structure of every galaxy is distorted significantly by the gravitational interaction with another, passing galaxy. It is possible that such encounters lead to the complete merger of the two galaxies into a new, more massive galaxy. But it is much more common that these encounters only lead to a transient distortion of the potential in which the galaxy disk moves.

Fig. 2.8 shows a pair of galaxies which is most likely undergoing such an encounter. In its passage the smaller galaxy has apparently distorted the disk of the larger galaxy. In particular, this process seems to have induced strong lopsidedness in the disk. Simple estimates show that it will take several billion years (about one quarter the age of the universe), until this asymmetry disappears. It is possible to check quantitatively how efficient this process is in inducing lop-sidedness, by simulating such encounters on the computer. Most existing simulations have concentrated on strong encounters, lading to the merger of the participating galaxies. Simulations of less violent encounters are now being carried out and will show how important galaxy fly-bys are in producing disk asymmetries. If this latter effect is indeed the most important reason for disk asymmetries, one can in turn use the observed frequency of lop-sidedness to constrain the galaxy-galaxy interaction rate. (H.-W. Rix)

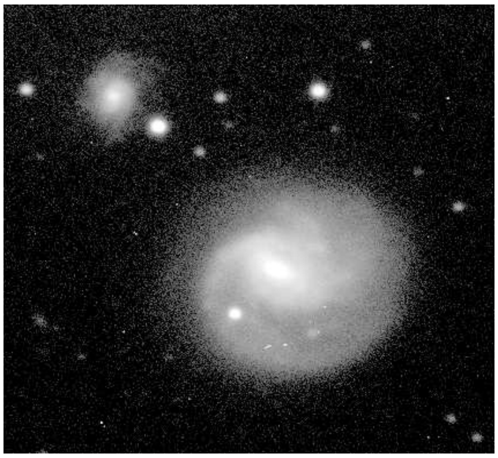

Figure 2.8: NGC 4430, a lop-sided galaxy. In this galaxy the the mean position of the outer disk is shifted with respect to the nucleus. The picture suggests one of the possible explanations for this phenomenon: Passing by, the small galaxy has distorted the internal structure of the bigger galaxy and has created the disk asymmetry. Estimates show that the asymmetry will last much longer than duration of the galaxy passage.

2.7 The Isophotes of Elliptical Galaxies: A Clue to their Formation History?

To explain the origin of the two different types of galaxies, ellipticals and spirals, is still a major issue of current research. Almost twenty years ago, Toomre argued that ellipticals may be formed by the merging of spiral galaxies. Though different aspects of the merging hypothesis are still a matter of debate and though it is unlikely that *all* ellipticals are formed by merging spirals, the merging scenario is still the most attractive theory for the formation of ellipticals. Within the last decade, two observations

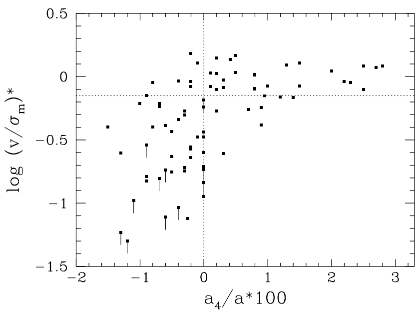

Figure 2.9: $(v/\sigma)^*$ as a function of a_4/a for observed elliptical galaxies. a_4/a is a measure of the deviation of the isophotes from an ideal ellipse. Positive a_4/a corresponds to disky isophotes, negative a_4/a to boxy isophotes. The parameter $(v/\sigma)^*$ compares the rotational velocity with that required in order to explain the observed flattening by rotation. All disky ellipticals are found above the horizontal solid line (corresponding to $(v/\sigma)^* = 0.7$) and are clearly flattened by rotation, whereas the boxy ellipticals lie below it and rotate too slowly.

have shed new light on the origin of ellipticals. R. Davies and collaborators observed that there exist two dynamically different classes of ellipticals: less massive ones are moderately rotators and are flattened by their rotation; more massive ellipticals rotate very slowly and their ellipticity can only be explained by an anisotropic inner velocity distribution. R. Bender demonstrated that the isophote shape (i.e. the shape of contours of constant surface brightness) of ellipticals depends strongly on their rotation properties (Fig. 2.9): the isophotes of rotationally flattened ellipticals deviate from an ideal ellipse towards a more disk-like shape (*disky* ellipticals), that of slowly rotating ellipticals to a more box like shape (*boxy* ellipticals). It is intriguing, that all signs of a recent merging event, like, e.g., a kinematically decoupled core, can be found in boxy ellipticals. They also show the most prominent X-ray halos and are radio loud whereas disky ellipticals do not. These observations also militate against theories which try to explain diski- and boxiness as a simple projection effect.

N–body simulations provide a way to test, whether boxy isophotes are a hint that an elliptical has been formed in a merging event. To do this we set up a stable model for a disk galaxy with a mass similar to the Milky Way. The disk galaxy is embedded in a six times more massive halo of dark matter. Two of such galaxies are set on a parabolic orbit (Fig. 2.10; top). They approach each other, collide, merge (Fig. 2.10; middle), and relax into an ellipsoidal object whose mass distribution and kinematics are very similar to those of observed elliptical galaxies (Fig. 2.10; bottom). Since the isophote deviations are small, very high particle numbers have to be used in the numerical simulations in order to overcome the statistical noise. Only recently have numerical simulations involving such high particle numbers become possible using special

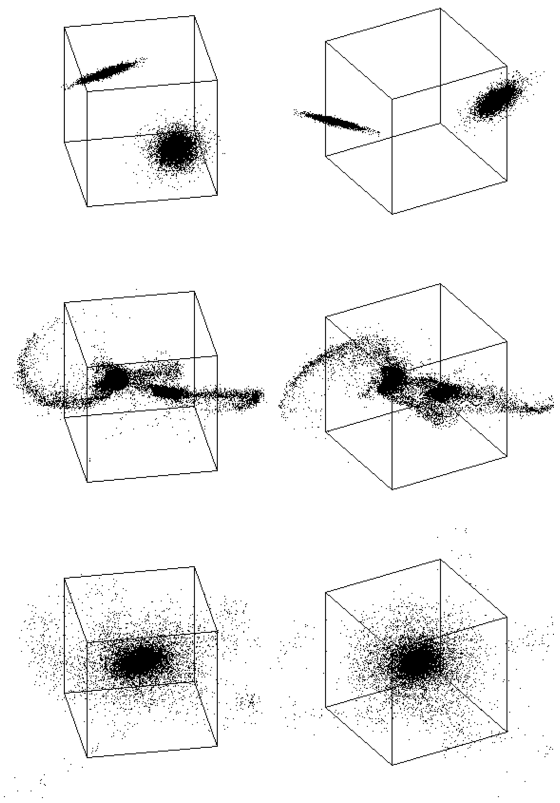

Figure 2.10: Three-dimensional view of the evolution of two merging spirals. The left and right columns correspond to two different viewing angles. Top: The intial orbital geometry. The spirals are inclined to the orbital plane by 30°. Middle: The merging of the galaxies. The two spirals are partially disrupted due to their tidal interaction. Bottom: the relaxed, ellipsoidal shaped merger remnant.

purpose computers.

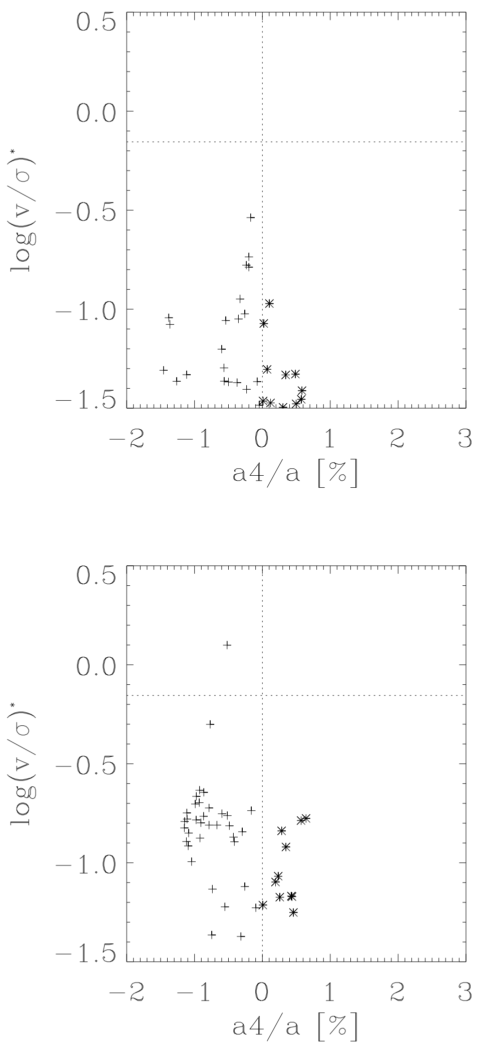

Figure 2.11: $(v/\sigma)^*$ as a function of a_4/a for two merger remnants seen from 48 different viewing angles each. Obviously they preferably exhibit boxy isophotes and are slow rotators.

After a simulation has finished, we can make artificial CCD images of the remnants taken from many different viewing angles. These images can then be analyzed with standard astronomical image processing software. The data analysis is then very similar to that of real galaxy images. It turns out that all our merger remnants are slow rotators, almost all the orbital angular momentum of the visible stars is dumped into the dark halo. Their isophote shape tends to be boxy; we found no disky ellipticals (Fig. 2.11). Thus, our merger remnants are remarkably similar to observed boxy ellipticals, but neither their isophote shapes nor their kinematics are consistend with what is observed for disky ellipticals. The simulations, therefore, favour those models, in which the differences between disky and boxy ellipticals are interpreted as a dichotomy in their origin. (Stefan Buchner & Matthias Steinmetz)

2.8 QSO Absorption Line Systems and Galaxy Formation

It is generally believed that large-scale structure in the universe formed by gravitational instability from primordial fluctuations in a cosmological background. In the hierarchical clustering scenario, a dominant dissipationless component of dark matter is assumed to aggregate into dark matter clumps or dark haloes, galaxies then form by the cooling and condensation of gas within them. In such a scenario, it is impossible to understand galaxy formation without first understanding the physical state of the gas from which galaxies form. The gas which forms galaxies must settle to the centre of dark matter haloes and in so doing may produce absorption lines in the spectra of background quasars. Recent observations of QSO absorption line systems that are associated with galaxies provide a unique opportunity to study the gaseous structure of galactic haloes. Absorbing gas can be observed at a wide range of column densities and to high redshifts, making it possible to study the formation and evolution of the gas haloes of galaxies.

A group of scientists at the MPA have been working on a project to understand how the observations on QSO absorption line systems can be fitted into our general picture of galaxy formation, and what constraints these observations can pose on current models of galaxy formation.

One constraint on galaxy formation models can be obtained from the total amount of gas contained in damped Lyman alpha absorption systems. These systems have the highest column density of neutral hydrogen and are usually assumed to arise in protogalactic discs. Observations show that the mass of neutral hydrogen contained in these systems at redshift $z \sim 3$ is comparable to the total mass of stars in present-day normal galaxies. This means that the building material of normal galaxies may have already been assembled in galactic haloes at $z \sim 3$. It turns out that the amount of gas predicted to lie in galactic haloes at high redshift depends sensitively on cosmological model and on the amplitude of initial density fluctuations on galactic scales. Indeed the currently popular mixed dark matter model, with parameter values preferred by other observations, actually predicts too few galactic haloes at $z \sim 3$ to be able to account for the total mass observed in damped Lyman alpha systems. The observed evolution of the mass in these systems may also provide constraints on the history of star formation in protogalaxies.

More information about galaxy formation and evolution can be obtained from observations of the relation between the properties of absorption line systems and those of their parent galaxies. Direct imaging of QSO MgII absorption line systems at redshift $z < 1$ has demonstrated that these systems do indeed arise in gaseous haloes around galaxies. There are also indications that at low redshift some Lyman alpha forest systems (with much lower column density of neutral hydrogen) are also associated with large gas haloes around galaxies. To understand these observations, we have proposed a model for the gas structure in galactic haloes. The accretion of gas from the intergalactic medium results in a halo of hot gas around every galaxy. In general, a two-phase structure develops, in which a hot phase at about the virial temperature of the halo is in pressure balance with a cold phase that stays in the form of small clouds photoionized by a background of UV radiation. Such a model is compatible with current observational results, and allows the physical properties of the 'halo gas' uncovered by absorption line studies to be integrated into a global picture of galaxy formation. Our model predicts that, while MgII systems are mostly associated with normal bright galaxies, most CIV systems should be found in association with smaller systems.

In the near future, deep imaging and high-resolution spetroscopy from the *Hubble Space Telescope* and the Keck 10m telescope will provide much more information about how the absorption line properties are related to those of their parent galaxies. On the theoretical side, a better understanding of the processes determining the gaseous structure of galactic haloes can be obtained by combining physical modelling with direct numerical simulations. Such work will tell us how to recognize galaxies in the act of formation. (H.J. Mo)

2.9 Reconstruction of the mass distribution in clusters of galaxies – an application of gravitational lensing

The propagation of light rays – as that of particles – is affected by gravitational fields. This prediction of General Relativity, verified by the deflection of light rays from distant stars by the Sun, leads to observable phenomena which are of interest for astrophysics and cosmology. For example, if the deflecting mass is sufficiently strong, a source lying behind that deflector can be seen in different directions on the sky. In fact, in recent years about 15 such systems have been found where a quasar is multiply imaged (or even deformed into a ring-like image) by a galaxy along its line-of-sight. Such so-called gravitational lens systems have the great potential for measuring the mass of the deflector (in one case, the by far most accurate mass determination of the inner part of a galaxy has been made), and cosmological distances, with the aim of determining the Hubble constant.

Gravitational lensing not only leads to a deflection of a light bundle as a whole, but such bundles are also deflected differentially. Hence, if the light bundle corresponding to a circular source is deflected, it will appear distorted on the sky; for weak distortion, a circular source will appear as an elliptical image. For strong distortions, the resulting images can have a very spectacular shape, and in the center of many clusters of galaxies, such so-called luminous arcs have been found, which are 'banana-shaped' with length-to-width ratios of up to 20. In several cases, such arcs have been spectroscopically verified as being due to galaxies in the background of the cluster. In the outer parts of clusters, the distortion is weaker and is thus not readily seen in individual galaxy images.

Fortunately, the currently available observational techniques allow very deep exposures of the sky, up to a level where several hundred-thousand galaxies per square degree can be identified. This population of 'faint blue galaxies' are believed to have a mean redshift of order unity and are thus ideal targets to investigate the weak distortion effects caused by clusters of galaxies with redshift less than ~ 0.5. Since these galaxies can be assumed to be randomly oriented intrinsically, a weak lensing distortion shows up in a locally coherent alignment of these galaxies near a cluster. Hence, the effect of weak distortion can be measured using statistical methods.

The distortion is due to the differential deflection, or in other words, due to the tidal gravitational field of the deflector. This tidal field depends (linearly) on the projected mass distribution of the cluster. It turns out that this relation between distortion and surface mass density can be inverted, i.e., the surface mass density can be calculated from the tidal field, which in turn can be obtained from the weak distortion of galaxy images. This cluster mass reconstruction, an example of which is shown in the figure, is at the very edge of current astronomical possibilities due to the faintness and smallness of the galaxy images. Together with the fact that the estimate of the local distortion requires statistical methods this implies that the techniques for analyzing data and for the inversion must be optimized for making full use of the observations and for avoiding artifical noise or systematic effects. The development and testing of such techniques is one of the main reasearch areas in the gravitational lens group at the MPA.

The cluster mass reconstruction from weak image distortions has been tested with a handful of clusters already. In at least one case, the results have been very surprising: One galaxy cluster has been found to have an enormously high mass-to-light ratio, implying that this cluster contains a large fraction of dark matter. The fact that the mass determination from gravitational lensing is sensitive to all kind of matter makes it an ideal tool for investigating the dark matter distribution in clusters and even on larger scales.

In the near future, this research field will develop quickly, due to the developments of large CCD arrays on big telescopes, the construction of several 8 meter-class telescopes at extremely good sites (in particular the VLT built by ESO), and the progress currently being made on data analysis techniques. It will then be possible to measure not only the total mass of clusters, but also their mass distribution and substructures; furthermore, this weak lensing technique provides the most promising method to study

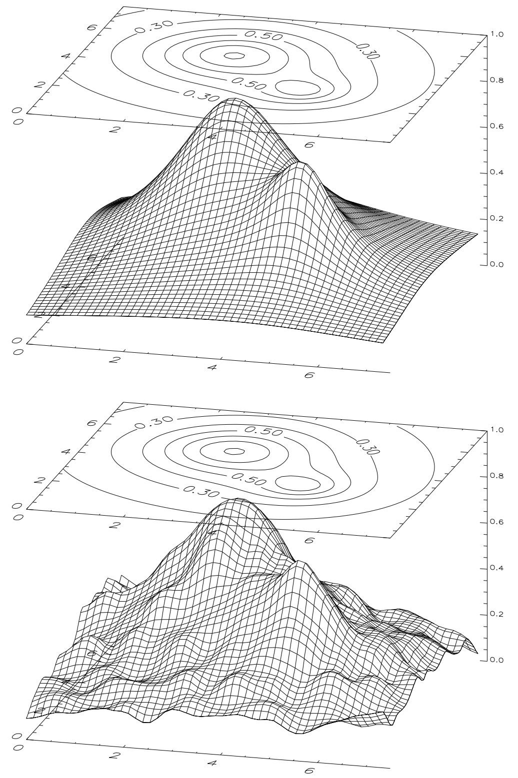

Figure 2.12: The mass distribution of a simulated cluster as displayed in the upper panel was used to generate synthetic galaxy images, accounting for the intrinsic ellipticity distribution of the source galaxies, which in turn were then used to reconstruct the mass density profile as shown in the lower panel. Plotted are the surface mass density against angular position and surface mass density contour lines. Note the good overall agreement and in particular the successful reconstruction of the two cluster mass centers.

the redshift distribution of the faintest galaxies which by no means can be determined spectroscopically. And, perhaps most important and exciting, gravitational lensing can detect large cosmic mass concentrations which are 'too dark' to be detected by conventional means, as optical or X-ray sources in surveys – indeed, a double quasar which has been supected to be due to gravitational lensing has been verified as a gravitational lens system, since the deflecting mass concentration has also led to a coherent distortion of weak galaxy images around the quasar positions. (P. Schneider)

2.10 Radial and nonradial adiabatic stellar oscillations: a mathematically rigorous investigation of their spectra

A crucial assumption for the linearized stability analysis of a spherical star is the "completeness" of its radial as well as nonradial normal modes. In a mathematical formulation this is equivalent to the assumption that the operators governing these oscillations have pure point spectra.

Radial adiabatic oscillations, which were considered already in 1919 by Eddington, lead to Sturm–Liouville operators. In 1958 Ledoux and Walraven observed that these operators are singular and hence that it is not obvious that they have discrete spectra. Strangely enough this problem was never considered in the mathematical literature.

Apparently the only mathematical paper on *non–radial adiabatic oscillations* is one by Eisenfeld (1969) which, however, considers only the very special cases that the density and the pressure of the unperturbed star are analytic both at the center as well as at the surface of the star. For polytropic background models this is true only for the polytropic indices $n = 1, 2, 3$ and 4.

The main results of our work concern background models which are polytropic with $0 < n < 5$ only near the center and the boundary of the star:

For radial oscillations it was proved that the oscillation spectrum is not only a pure point spectrum but moreover purely discrete, i.e., consists of countably main (simple) eigenvalues, which have no finite accumulation point.

For nonradial spheroidal (or "poloidal") oscillations it was proved that the spectrum is a (unbounded) pure point spectrum consisting of zero as well as of countably many non–vanishing eigenvalues of multiplicity ≤ 2. Moreover, it was shown that it contains an eigenvalue of infinite multiplicity and/or a finite accumulation point. These results are all in agreement with numerical calculations. The latter suggest for spheroidal oscillations that zero is the only accumulation point of the spectrum, a fact which we did not show. (B. Schmidt, H. Beyer)

3 Research Activities

3.1 Sun and interplanetary matter

R. Wegmann and H. U. Schmidt in collaboration with H. Rauer und K. Jockers (both MPAe Lindau) investigated by means of time-dependent, three-dimensional magnetohydrodynamic model calculations the effect of solar wind disturbances on the plasma tail of a comet. A change in the flow direction deflects the tail. A sudden change in the orientation of the interplanetary magnetic field by 90° forms tail rays. R. Wegmann was able to calculate with his MHD program the transit of interplanetary shock waves through a comet. Part of the tail is blown off. The calculated phenomena resemble closely observed tail disconnection events. The asymmetric plasma flow in a comet between adjacent tangential discontinuities in the solar wind was the subject of the thesis work of R. Reinberger supervised by H.U. Schmidt. — K. Jahn (Univ. of Warzawa) and H.U. Schmidt have completed a series of triparticle sunspot models for umbra, penumbra and quiet sun in hydrostatic and mutual magnetostatic equilibrium. In collboration with A.M. Rucklidge and N.O. Weiss (Univ. of Cambridge, U.K.) H.U. Schmidt investigated the loss of stability of a growing pore model at a bifurcation where a sudden transition to an overlapping stable spot model with penumbra must occur.

H.-G. Ludwig carried on with work concerning the solar lithium problem. Together with J. Fliegner the effects of transport due to overshooting have been investigated for the depletion of lithium during main sequence evolution (see Sect. 2.2).

3.2 Stellar structure and evolution; supernovae; nucleosynthesis

The PhD thesis of H. Braun, which is guided by N. Langer, concerns accretion processes in massive close binary systems, as well as mixing processes thereby induced (e.g. thermohaline convection or semiconvection), the development of numerical methods to deal with these, and the development of a selfconsistent binary evolution code. — J. Fliegner's thesis, which is also guided by N. Langer, investigates the time dependent evolution of rotating massive stars, including the action of the centrifugal force and rotationally induced mixing processes (see Sect. 2.1). — N. Langer, H. Braun and J. Fliegner determined, as a function of the relevant physical parameters, the rate of production of the radionuclide ^{26}Al in massive single and binary stars. This is being used for the interpretation of the observed galactic 1.8 MeV γ-ray line, in collaboration with R. Diehl and U. Oberlack (both MPE, Garching).

In collaboration with G. Garcia-Segura (IAC, Tenerifa) and M.-M. MacLow (Chicago), N. Langer has computed the formation and evolution of circumstellar nebulae and envelopes around massive stars, by coupling a hydrodynamic stellar evolution code to multidimensional explicit gasdynamical calculations. — Together with S.E. Woosley (Santa Cruz, CA) and T.A. Weaver (Livermore, CA), N. Langer has developed models for the evolution of progenitor systems and explosions of Typ Ib/c supernovae, including detailed predictions for the accompanying nucleosynthesis. — Together with W.-R. Hamann (Kiel), and M. Lennon, F. Najarro, A. Pauldrach and W. Puls (all Sternwarte München), N. Langer developed a hypothesis for the origin of Wolf-Rayet type winds, and a new scenario for the evolution of massive stars by detailed numerical models, incorporating their pulsational properties. A. Heger, in his Diploma thesis with N. Langer, is investing the structure and forces occurring in Wolf-Rayet stellar winds.

The evolution of low mass stars on the Asymptotic Giant Branch was the subject of the thesis work of J. Wagenhuber, supervised by Achim Weiss. In this context an improved numerical method was developed that now allows the investigation of questions like the stability of the envelope or the dependence of the evolution on various detailed formulations of convection theory. — G. Raffelt (MPI für Physik, München) and Achim Weiss continued earlier work on the brightness of the Red Giant Branch tip as a function of standard and non-standard plasma neutrino emission rates (together with M. Haft, MPI für Physik, München) and on supposed axion emission, thereby constraining the axion-electron coupling. — Achim Weiss also searched for periodicities in the lightcurves of R CrB stars that were observed by his collaborators R. Fried (Braeside Obervatory, Arizona) and E. Olson (Univ. of Illinois). — With respect to the evolution of massive stars, the influence of rotation on the chemical composition and consequently on the position in the Hertzsprung-Russell-Diagram was the subject of a collaboration with scientists at the Middle East Technical University at Ankara (Eryurt, Kirbiyik, Kiziloglu, Civelek).

R. Stehle, U. Kolb and H. Ritter have investigated the problem, why, apart from a brief initial phase after the onset of mass transfer, the long-term evolution of cataclysmic binaries is practically independent of the initial mass of the donor star. They have shown that this property is the consequence of an attractor which characterizes the reaction of low-mass stars upon mass loss. — H. Ritter and U. Kolb, in cooperation with J. Frank (Louisiana State University) and A. King (University of Leicester) have investigated the conditions under which mass transfer in cataclysmic binaries (and similar systems) can undergo a limit cycle which, in turn, could result in alternating phases of high and low rates of mass transfer. They have shown that the most likely mechanism for driving such a limit cycle is irradiation of the donor star by the accretion luminosity liberated in the vicinity of the compact component (a white dwarf or a neutron star). H. Ritter, Z.-Y. Zhang and U. Kolb have studied the reaction of low-mass stars upon weak anisotropic irradiation and its consequences for the stability of mass transfer in cataclysmic binaries. They found that low-mass stars are very susceptible to even low irradiating fluxes and that, therefore, cataclysmic binaries can suffer from an irradiation-driven mass transfer instability which, in turn, could lead to a limit cycle in the mass transfer of such systems. Numerical calculations of the long-term evolution, using the bipolytrope approximation for modelling the donor star, confirm the existence of such a limit cycle if the donor's mass is in the range $0.6M_\odot \lesssim M_2 \lesssim 1.0M_\odot$ (see Sect. 2.5). — H. Ritter has practically completed the preparations for the publication of the 6th edition of the "Catalogue of Cataclysmic Binaries, Low-Mass X-Ray Binaries and Related Objects" which is due to appear in 1995.

U. Kolb, M. de Kool, H. Ritter and A. King (University of Leicester) applied de Kool's Monte Carlo based binary scenario code to compute collective properties of post common envelope (CE) binaries and compared these with observed systems thought to represent such post CE binaries. The models showed that the absence of magnetic stellar wind braking does not produce an upper magnetic field limit for AM Her stars, as it was discussed recently. — Further work aimed at the understanding of interrelations of classical novae and cataclysmic variables (CVs): K. Schenker considered in his diploma thesis, supervised by U. Kolb, the change of orbital parameters in CVs caused by friction of the secondary orbiting in the nova envelope; the corresponding change of the mean mass transfer rate influences the long-term evolution. U. Kolb constructed distribution functions for Galactic novae by combining recent population models for cataclysmic variables with a description for the conditions at the onset of a thermonuclear runaway. U. Kolb and M. Politano (Arizona State University) improved estimates of the contribution of oxygen-neon-magnesium novae to the ^{26}Al production in the Galaxy. They derived limits on the amount of mixing of white dwarf material into the accreted envelope by a comparison with recent COMPTEL observations of the Galactic 1.8 MeV emission.

Results of hydrodynamical simulations of convection in the envelopes of ZZ Ceti white dwarfs have been analysed by H.-G. Ludwig. In collaboration with M. Steffen and B. Freytag (both Univ. of Kiel) the detailed structure and the mean properties of their convective zones have been studied. The main issues concern the capabilities of the classical mixing-length approach to give quantitative description, and spectroscopic effects due to lateral temperature inhomogeneities.

A comprehensive parameter study of the collapse of rotating polytropes was the subject of the thesis work of T. Zwerger, supervised by E. Müller. The aim of the work was to determine the strength, form and frequency of the gravitational wave signal produced in such events. Varying the initial amount and distribution of angular momentum, and the adiabatic index of the polytrope a set of 81 models have been computed ranging from almost rigidly rotating models to strongly differentially rotating ones. The results show that the amount of energy radiated in form of gravitational waves during axisymmetric core collapse lies in the range $2\ 10^{-10} M_{\odot} c^2 \leq E_{GW} \leq 2\ 10^{-7} M_{\odot} c^2$. The corresponding dimensionless wave amplitudes are in the range $4\ 10^{-23} \leq h \leq 2\ 10^{-22}$ for a source at a distance of 10 Mpc.

H.-Th. Janka and E. Müller have performed single- and multi-dimensional hydrodynamical simulations of the post-bounce evolution of collapsed stellar cores. They studied the sensitivity of the explosion to variations of the neutrino luminosity from the protoneutron star and investigated the effects and importance of convection and convective overturn during the early phase of the explosion. In particular, the recoil motions obtained by the newly formed neutron star by anisotropic neutrino emission and turbulence in and around the nascent neutron star were analysed.

K. Takahashi, J. Witti and H.-Th. Janka have continued to compute nucleosynthesis associated with type-II supernovae. Based on single- and multi-dimensional hydrodynamical simulations by H.-Th. Janka and E. Müller, the possibility of heavy element nucleosynthesis after the core collapse was systematically explored. A mapping of the most appropriate sites for the r-process nucleosynthesis onto the electron concentration - entropy plane has also been attempted by Takahashi in a semi-analytic manner.

Hydrodynamic instabilities on microscopic scales in type Ia supernovae were studied by means of 2-dimensional numerical simulations by J. Niemeyer in a diploma-thesis, supervised by W. Hillebrandt. It was shown that on linear scales not much larger than the width of the burning front the Landau-Darrieus instability leads to a growth of perturbations, wrinkling the flame, and increasing its surface area. It is expected that this instability will accelerate the front on small scales beyond its laminar velocity. A numerical scheme was developed which allows to compute numerically the coupling between large scale motions and unresolved turbulent scales for thermonuclear burning fronts in carbon-oxygen white dwarfs. As a first test case this subgrid model was applied to the nuclear burning in a Chandrasekhar mass white dwarf but only a marginal explosion was observed. It seems possible that this failure of the model originates from poorly understood highly dynamical nonlinear coupling processes in turbulent flows which are investigated in collaboration with S.I. Blinnikov, P.V. Sasorov (ITEP, Moscow) and S.E. Woosley (UC Santa Cruz). Under the assumption that the flow patterns are described by the potential approximation the flame propagation can be obtained from the Frankel equation. First numerical studies show that at least in the outer layers of the white dwarf the burning front is significantly accelerated (see Sect. 2.3).

M. de Kool, in collaboration with Paul J. Green (Harvard Center for Astrophysics), has studied the formation rate of stars that have peculiar abundances because of accretion from the wind of a companion star on the AGB. The results were compared with the observed properties of binaries containing dwarf carbon stars and barium stars.

A numerical study of the dynamics of the core helium flash was the subject of the diploma work of K. Achatz, supervised by E. Müller. The aim of this work in progress is to check the validity of the results of previous multi-dimensional simulations, which used less accurate numerical techniques and significantly cruder zoning. The results of K. Achatz, which were obtained with the hydrodynamic code PROMETHEUS, do not confirm the earlier findings of Cole & Dupree. In particular, no violent helium flash is found. The results show instead a non-stationary convective pattern outside the off-center temperature maximum, and no significant overall temperature increase in the helium burning layer during a period of more than 1000 dynamical time scales. — Y. Eriguchi (Univ. of Tokyo), M. Hashimoto (Kyushu Univ.) and E. Müller computed the equilibrium structure of self-gravitating Keplerian disks of arbitrary thickness surrounding a gravitating central object (star), which is approximated by a point mass. These equilibrium models adequately approximate quasi-equilibrium evolutionary stages of accretion disks encountered during proto-star formation as well as describing a black hole surrounded by a thick disk (e.g., in systems like SS 433).

The joint problem of stationary circulation and differential rotation in a radiative star (as formulated by J.-P. Zahn) was solved numerically by V. Urpin, D. Shalybkov (Ioffe Institute, St. Petersburg) and H. Spruit. — D.P. Denissenkov together with Achim Weiss studied the effect of deep diffusive mixing in metal-poor red giants. The calculated changes of the atmospheric abundances due to diffusive mixing and the CNO–, NeNa– and MgAl–burning cycles were compared with the abundances observed in globular cluster red giants.

R.P. Kudritzki, A. Fullerton, K. Venn and T. Soffner continued their work on the quantitative spectroscopic analysis of hot stars. The focus of this year's research was time-dependent radiation-hydrodynamics of stellar winds and the use of supergiants and Planetary Nebulae as distance indicators. This work is performed at the Institute for Astronomy at the University of Munich.

3.3 Accretion onto white dwarfs and neutron stars; accretion disks

F. Meyer and E. Meyer-Hofmeister investigated together with Liu Fukun (Yunnan Observatory, Kunming, China) the evaporation of the cool inner disk in dwarf novae and the resulting accretion onto the white dwarf. The structure of the hot corona above the disk and of the white dwarf boundary layer determine the spectra which can be compared with ROSAT data. F. Meyer and E. Meyer-Hofmeister modelled the effect of a secondary star magnetic field on dwarf nova outbursts and analysed light curves, together with N. Vogt (Universidad Catolica de Chile, Santiago). In addition, E. Meyer-Hofmeister and F. Meyer determined the visual luminosity of the accretion disk and the irradiated secondary star for the supersoft X-ray source CAL87. Comparison with the optical eclipse curve points to an extended source of X-rays and also visual light, which might be a scattering corona above the accretion disk. — Transition fronts in accretion disks and their numerical treatment in the quasistationary approximation were investigated by K. Ludwig.

S. Chakrabarti has fitted the observed spatially-resolved emission lines profiles in the center of M87 with a theoretical model of spiral shock waves in accretion disks, which improves the fit relative to a simple Keplerian disk model and leads to a significantly higher mass of the central black hole.

Using the model of the coronal winds causing the warp of accretion disks, Susanne Schandl investigated the detailed dip structure in the X-ray lightcurve of the X-ray binary HZ Her/Her X-1. As a consequence of the interaction between the accretion stream and the warped precessing disk a thickening of the disk and a spray of matter were simulated to model the observed anomalous and preeclipse dips. At later times the optical lightcurve is interpreted as a composition of the light of the single components of the system, their heating by illumination with X-rays and by shading and covering effects based on the results of the coronal wind model.

U. Kolb and A. King (University of Leicester) investigated the effect of consequential angular momentum loss (CAML) on mass transfer in semi-detached compact binaries. As an application they showed that CAML in the form of an accretion disk wind cannot account for the observed width of the period gap in cataclysmic variables. — The program to identify new AM Herculis binaries at high galactic latitude based on the ROSAT All Sky Survey, a collaboration between the MPE für Extraterrestrische Physik (W. Voges), the Universitäts-Sternwarte Göttingen (K. Beuermann, K. Reinsch, V. Burwitz), the Astrophysikalisches Institut Potsdam (A. Schwope) and H.-C. Thomas, led to the discovery of 26 new objects of this type. Time-resolved spectroscopy and photometry was performed in order to determine orbital periods and estimate magnetic field strengths (from modelling cyclotron emission and/or Zeeman absorption) for a number of these sources. Accretion of matter onto a white dwarf at the limit of stable nuclear burning and reprocessing of radiation at the surface of its companion have been invoked to explain the observations of a galactic supersoft X-ray source in a collaboration headed by K. Beuermann from the Universitäts-Sternwarte Göttingen and including H.-C. Thomas and scientists from 6 other institutions.

H. Spruit studied interchange instabilities of poloidal magnetic fields in accretion disks. With S. Lubow (STScI) a strong stabilisation of interchanges by differential rotation was found. In collaboration with J. Papaloizou (QMW, London) and R. Stehle, H. Spruit showed that this instability is essentially an incompressible one. R. Stehle started his graduate research under supervision of H. Spruit with the development of a code for 2-D magnetohydrodynamics of a poloidal magnetic field in an accretion disc. He also developed a numerical formulation for 2-D hydrodynamics in disks in which the vertical dynamics is treated in a one-zone approximation. With J. van Paradijs and E. Martín (Astronomical Institute 'Anton Pannekoek', Amsterdam) H. Spruit studied the energetic consequences of the observed Lithium abundance in secondaries of X-ray transients, in a model in which the Lithium is produced by nuclear processes in the inner disk.

3.4 The Galaxy, external galaxies, Active Galactic Nuclei and galaxy formation

Together with C. Henkel and T.L. Wilson (both MPIfR, Bonn), Y.-N. Chin (Univ. Bonn), and U. Ott (MPI für Chemie, Mainz), N. Langer studied the spatial distribution of the CNO-Isotopes in the Milky Way, and their relative abundances in starburst galaxies. N. Langer has, with A. Maeder (Geneva Obs.), investigated the reasons for the variations of the relative frequency of red supergiants in galaxies with different metallicities.

Constructing self-consistent models for the Galactic bar is the thesis of HongSheng Zhao (under the supervision of D. Spergel and R. Rich). The models are built numerically with a revised Schwarzschild technique. The mass on 10000 randomly launched orbits in the bar potential are assigned with quadratic programming to reproduce the COBE infrared intensity map of the Galactic bulge region and to reproduce the model potential. The model also fits the velocity data towards the bulge, making it the first model that is consistent with both observations of light and velocity of the bulge/bar. As an application of this model, Zhao, Spergel and Rich computed the microlensing events distribution towards the bulge, and find the event duration and optical depth as observed by OGLE is consistent with most of the lenses being ordinary stars in the bar.

H. Velazquez and S.D.M. White made dynamical models to interpret the nature of the newly discovered dwarf galaxy in Sagittarius. They found that this object is probably a dwarf spheroidal system which was tidally disrupted by the Milky Way during its previous pericentric passage. The observational data require the dwarf to be on a highly eccentric orbit with a period of about one billion years. — New 3-dimensional hydrodynamical models on the fragmentation of gravitationally unstable molecular clouds have been computed by A. Burkert, in collaboration with P. Bodenheimer (Santa Cruz, USA). The formation of dense molecular cores which subsequently condense into protostars, core-core merging and the interaction of these cores with the surrounding gas cloud is investigated in detail. — The formation of globular clusters through efficient star formation and self-enrichment of giant molecular clouds has been studied in detail as a function of the protogalactic environment by A. Burkert, in collaboration with J. Truran and J. Brown (University of Chicago, USA). The effect of the disruptive galactic tidal field and the confining ambient hot gas component on the formation of gravitationally bound globular clusters is explored.

In an extensive project embracing stellar evolution (represented by Achim Weiss), galactochemical evolution (F. Matteucci; ESO and Triest) and spectroscopy of the integrated light of elliptical galaxies (R. Peletier; ESO and Groningen), synthetic metal line strengths were computed and compared with observations. The results substantiate earlier claims that the stellar population of ellipticals consists of old low-mass stars with an at least solar abundance of metals and an overabundance of oxygen and other α-elements. — As part of his thesis work, R. Andersen, supervised by A. Burkert, developed a 3-dimensional chemodynamical code. In a first application, this program was used for investigating the self-regulated, 3-dimensional formation and evolution of disk-like dwarf galaxies inside dark matter haloes.

The kinematic properties and isophote shapes of numerically simulated merger remnants were investigated in the diploma thesis of S. Buchner, supervised by M. Steinmetz. It turns out that merger remnants are slow rotators. An anisotropic velocity dispersion is required in order to explain their flattening. Furthermore, merger remnants tend to have boxy isophotes. Thus, the merger remnants exhibit the properties typically observed for ellipticals with boxy isophotes, but not of those with disky isophotes, which are flattened by their rotation. Since the observed boxy ellipticals often show signatures for a recent merging event, this work strengthens the hypothesis that disky and boxy ellipticals might be of different origin and that boxy ellipticals are formed by mergers (see Sect. 2.7).

H.H. Fink (MPE für Extraterrestrische Physik) and H.-C. Thomas analyzed ROSAT spectra of a sample of 26 BL Lacertae objects at low interstellar absorption and derived parameters for the inhomogeneous jet model. D. Grupe (Universitäts-Sternwarte Göttingen), K. Beuermann (Universitäts-Sternwarte Göttingen) and H.-C. Thomas studied the X-ray and optical properties of a number of X-ray soft Seyfert 1.5 galaxies, in which the softness of the X-ray spectrum appears to be correlated with the narrowness of the Balmer lines.

F. Meyer and W.J. Duschl (University of Heidelberg) investigated the connection between coronal and disk accretion in AGN. — M. de Kool, in collaboration with Mitchell C. Begelman (JILA, University of Colorado), has been developing a model for the QSO Broad Absorption Line Region. In this model cool clouds are accelerated out of an accretion disk by radiation pressure, flowing along magnetic field lines that are responsible for the cloud confinement. The radiation pressure acting on the outflowing matter can compress the magnetic field in such a way that the observed scaling of ionization parameter with velocity is obtained. — H. Spruit and T. Foglizzo started work on the poloidal collimation and stability of magnetically accelerated jets and winds.

The statistical distribution of the spin parameters of dark–matter halos was investigated by M. Steinmetz and M. Bartelmann. It could be shown that an analytical approximation based on the linear theory of gravitational collapse can reproduce not only the statistical averages of the spin parameters of halos, but also their probability distribution with a surprisingly good accuracy. Furthermore it turns out that within this approximation, the spin parameter depends only weakly on Ω_0, Λ and the type of power spectrum.

The formation and evolution of disk galaxies was studied by M. Steinmetz and E. Müller. Starting from Cold Dark Matter (CDM) like initial conditions, numerical simulations were performed including the effects of gas dynamics, radiative cooling, star formation, supernova feedback and metal enrichment. A galaxy forms which shows the main properties of observed spiral galaxies: a rotationally supported exponential disk which consists of young stars with solar metallicity, a slowly rotating halo of old metal poor stars, a bulge of metal rich stars, and a slowly rotating extended halo of dark matter. Bulge, stellar and dark halo are supported by an anisotropic velocity dispersion and have a de Vaucouleurs surface density profile. The flattening of the dark matter and stellar halos is too large to be explained by rotation only. The stellar disk is cold and thin.

The influence of a UV background on the formation of galaxies was investigated by M. Steinmetz. A UV background suppresses the cooling by collisional excitation, the dominant cooling process for a gas of primordial composition. Furthermore, the gas is heated up by absorption of background photons. Highly resolved gasdynamical simulations were performed using Smoothed Particle Hydrodynamics. The time-dependent network equations for the ions of hydrogen and helium were simultaneously solved. It turns out that for commonly used assumptions for the UV background and for the power spectra, the distribution of halo masses is very similar to that without a UV background. Even the formation of halos with masses as low as 10^7 solar masses (in baryons) is only marginally affected. Most of the small mass objects are already collapsed before the UV background becomes sufficiently strong. Only in case of a intense and hard UV background already present at hight redshift, a remarkable depletion of objects with masses smaller than a few $10^8\,\mathrm{M}_\odot$ can be observed. The influence of the background radiation becomes even weaker if absorption effects on the spectrum of the background radiation are taken into account.

The role of momentum transfer ("radiation pressure") due to an internal source of ionizing radiation for the formation of baryonic structures was investigated by M. Haehnelt. It was found that fully ionized self-gravitating objects can be radiation-pressure supported on a characteristic length scale $D_{\mathrm{rp}} \approx 100\mathrm{pc} - 3\mathrm{kpc}$. On smaller scales momentum transfer due to ionizing radiation will be the dominant force, and for spherical collapsing objects of mass $\lesssim 10^{10} M_\odot$ a complete bounce is possible. This will have important implications for the thermal and dynamical evolution of the intergalactic medium.

In collaboration with S. White, A. Burkert investigated the origin and structure of isothermal dark matter cores in DDO-galaxies which have been proposed as an indication that dark matter must be baryonic. Scaling relations for the global parameters of dark matter cores are derived which show that dark matter need not be baryonic and provide important information for cosmological models. — The process of collisionless violent relaxation of stellar systems has been studied by A. Burkert. The effect of an external tidal field on the relaxation process and the initial conditions required for explaining the universal surface density profiles, observed in giant ellipticals, is explored.

3.5 Gravitational Lensing, Clusters of Galaxies, Large Scale Structure, Cosmology

M. Bartelmann, P. Schneider and G. Hasinger (MPI für Extraterrestrische Physik, Garching; now Institut für Astrophysik, Potsdam) showed with the help of the ROSAT *All Sky Survey* that high-redshift, radio-loud background sources are highly significantly correlated with diffuse X-ray emission which is emitted in the foreground of these sources. This may be a result of gravitational lensing by the foreground objects. M. Bartelmann demonstrated that such lensing may allow the amplitude and the spectrum of cosmic density perturbations and the cosmic density parameter Ω_0 to be determined from the cross-correlation function between high-redshift sources and foreground galaxies. — S. Seitz and P. Schneider have shown that there exists a statistically significant overdensity of high-redshift 1-Jy quasars around (foreground) Zwicky clusters, which can be understood qualitatively in terms of gravitational magnification; in contrast, low-redshift radio galaxies from the 1-Jy catalog strongly avoid Zwicky clusters, which is most likely an environmental effect. — C. Seitz, J. Wambsganss and P. Schneider have studied the statistical properties of microlensing lightcurves, in particular their autocorrelation function and the magnification fluctuations, and applied these results to the quadruple QSO 2237+0305, for which a relatively small mass ($\sim 10^{-4} M_\odot$) of the microlenses was deduced preliminarily.

S. Seitz, P. Schneider and J. Ehlers have investigated the propagation of light bundles in arbitrary spacetimes; in particular, their behaviour near caustics was studied. A new derivation of the gravitational lens equation was obtained from the resulting propagation laws, and the relation of the multiple deflection equation to the Jacobi propagation law was clarified. Furthermore, a 'relative focusing theorem' was formulated and proven. A new and simplified proof of the magnification theorem in multiple deflection gravitational lensing was given by S. Seitz and P. Schneider, and the general analytic solution of the Dyer-Roeder transport equation for light bundles, and its non-linear generalization, was derived.

Using numerically simulated galaxy clusters, M. Bartelmann, A. Weiss and M. Steinmetz pursued the question of how asymmetries and substructures of these clusters influence their properties as gravitational lenses. Emphasis was laid on the frequency and the shape of strongly distorted images of background galaxies (so-called arcs). Based on these results, M. Bartelmann quantified an effect which may cause cluster masses, as determined from the strong lens effect, to be systematic and significant overestimated.

The method to determine the mass distribution in clusters of galaxies from observations of gravitationally-sheared images of background galaxies was generalized to strong (and critical) clusters by C. Seitz and P. Schneider. A global invariance transformation of the mass distribution was found which leaves all image shapes unchanged; in addition, a local degeneracy for critical clusters was derived. Several non-linear methods to obtain the local lens distortion parameter from observed galaxy images were developed, and three different reconstruction procedures for spherical clusters were tested. A fully non-linear, parameter-free iterative reconstruction technique for clusters was derived and successfully tested on numerical cluster models (simulated by M. Steinmetz); in particular, the mass of the inner region of model clusters could be determined with an accuracy of a few percent. To avoid boundary artefacts contained in these mass profile reconstructions due to the finiteness of the data fields (i.e., CCDs), P. Schneider has developed a cluster inversion procedure which is exact for finite data fields, i.e. which is free of boundary artefacts (also see Sect. 2.9). – M. Bartelmann further pursued the question of the reliability of cluster masses derived from the weak lensing effect which manifests itself as weak distortions of the images of background galaxies (so-called arclets) in the fields of galaxy clusters. R. Narayan (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA) and M. Bartelmann suggested how lensing can be used to determine the as yet unknown redshift distribution of the so-called faint blue galaxies.

Using the Zeldovich approximation for the evolution of cosmological density perturbations, P. Schneider and M. Bartelmann have derived an analytical form of the power spectrum, which is accurate well into the non-linear regime of density fluctuations.

The formation of dark halos and galaxy clusters in different cosmogonies was the subject of the diploma thesis of A. Huss, supervised by M. Steinmetz. By means of N–body simulations, four different models were investigated, two models with cold dark matter (CDM) but different normalization, one with hot dark matter (HDM), and one with a 7:3 mixture of CDM and HDM (CHDM). All models are based on an Einstein-de Sitter universe. Special emphasis was put on the time evolution of the power spectrum, of the correlation function and of the cumulative mass function. In order to perform the numerical simulations, the existing binary treecode was extended to include periodic boundary conditions by means of the Ewald summation technique, known from solid state physics. Furthermore, a method was developed to identify gravitationally bound objects. It turns out that the CHDM model seems to exhibit the best agreement with observations, though structures like halos and galaxy clusters probably form too late. — The large-scale structure in a universe dominated by cold and hot dark matter was simulated using a P3M code by Y.P. Jing, H.J. Mo, G. Börner and L.Z. Fang. In addition, the substructures that form in galaxy clusters in different dark matter models and with different cosmological parameters were investigated and it was shown how velocity dispersion profiles in dark matter simulations of galaxy clusters depend on the sampling.

H.J. Mo and S.D.M. White have developed a simple analytic model for the gravitational clustering of dark haloes. This model allows the autocorrelation function of haloes and the cross-correlation between haloes and mass to be evaluated from the linear power spectrum of density fluctuations. Tests against N-body simulations show good agreement, and the model allows an analytic understanding of how the spatial distribution of dark haloes is biased with respect to that of the mass.

The problem of reconstructing cosmic density fields from peculiar–velocity measurements has been approached by T. Buchert in collaboration with M. Susperregi (Astrophysics Institute, Oxford, U.K.) and A. Dekel (University of Jersusalem, Israel). For this purpose a reconstruction model based on the Lagrangian perturbation theory to second order has been investigated; the quality of the reconstruction is currently being studied in comparison with other models and numerical simulations. — Solutions of the Lagrangian perturbation theory have been generalized in various ways in a diploma thesis by M. Vanselow supervised by T. Buchert: solutions for nonparabolic background models have been found; solutions with the presence of primordial vorticity in the velocity field as well as solutions for nonvanishing average shear flow are currently being investigated.

Robust statistical measures for the analysis of the morphology of large–scale structure in the Universe have been investigated by a statistics group at the university (H. Wagner, K.R. Mecke, LMU) in collaboration with T. Buchert. The investigation and application of these measures for the diagnostics of models for large–scale structure has been pursued by M. Platzöder in his diploma thesis, supervised by H.J. Mo and T. Buchert in collaboration with S. Gottlöber (Astrophysik Institut, Potsdam). As a next step these statistics are used for the diagnostics of galaxy catalogs.

The density field of large–scale structure in the Universe has been realized for various classes of initial data by evolving them with a third–order Lagrangian perturbation solution of the Euler–Poisson system as the topic of a Ph.D.–thesis by A.G. Weiss in collaboration with T. Buchert and A. L. Melott (Lawrence University, Kansas, U.S.A.). These density fields have been compared with numerical simulations by means of various statistical methods. It was found that Lagrangian perturbation schemes display an excellent agreement with numerical simulations down to galaxy group mass scales even for hierarchical structure formation models, if the Lagrangian schemes are optimized by suitable filtering of the initial data. — Density fields for different symmetric and generic cluster models in the framework of Lagrangian perturbation schemes have been realized with high–spatial resolution in comparison with numerical simulations (PM, P^3M, Tree–code) as a topic of a Ph.D. thesis by G. Karakatsanis, supervised by G. Börner in collaboration with T. Buchert; the perturbation potentials of the Lagrangian schemes have been analytically constructed for this purpose to achieve maximal precision of the results. It has been found that the best agreement with numerical simulations is obtained for the third–order Lagrangian approximation even after shell–crossing singularities have developed. — A complete class of singularities of Lagrangian mappings has been analyzed by T. Buchert and A.G. Weiss in collaboration with S.F. Shandarin (Lawrence University, Kansas, U.S.A.) in order to identify and classify morphological building blocks of large–scale structure in the Universe. The aim is to determine abundance statistics of singularities of a given type in Lagrangian perturbation solutions, and to relate them to observable objects.

The properties of Ly-α absorbing clouds in quasar spectra have been investigated by H.J. Mo in a model where the clouds are confined by the pressure of ambient hot gas in galactic haloes (see Sect. 2.8). In addition, constraints on galaxy formation in dark matter models were discussed with J. Miralda-Escudé (Institute for Advanced Study, Princeton) using the observations of damped Ly-alpha systems. — The implications of recent measurements of the sizes of Lyα absorbers were studied by M. Haehnelt in collaboration with M. Rauch (Observatories of the Carnegie Institution of Washington, Pasadena). It was found that the measured large sizes of $250\mathrm{kpc} - 1\mathrm{Mpc}$ indicate that a major fraction of all baryons might be contained in low column density Lyα absorbers, and that the neutral hydrogen must be contained in significantly flattened structures.

3.6 Gravitation theory

The work begun last year by U. Brauer, A. Rendall and O. Reula (University of Cordoba, Argentina) on the nonlinear stability of homogeneous Newtonian cosmological models with a perfect fluid as matter model was completed. U. Brauer continued to work on his PhD thesis, supervised by A. Rendall, concerning the formation of singularities in relativistic and self-gravitating fluids. — P. Chruściel and A. Rendall studied the nature of singularities in spatially homogeneous solutions of the Einstein vacuum equations, showing in particular cosmic censorship for spacetimes of the Bianchi IX class. A. Rendall also obtained various results on the nature of the singularities in solutions of the Einstein equations with matter under strong symmetry assumptions. The existence of crushing singularities in spacetimes with spherical or plane symmetry was shown under rather general conditions and more detailed information on the singularities was obtained for spatially homogeneous solutions with general matter and for plane-symmetric solutions with a massless scalar field as matter model.

H. Beyer and B. G. Schmidt investigated spectral properties of the linear operator governing Newtonian, adiabatic stellar oscillations. For the first time radial as well as non–radial oscillations were treated in a rigorous mathematical setting. As expected, the spectrum of radial oscillation is purely discrete; whereas in the non–radial case the eigenfrequencies accumulate and hence the spectrum is only a pure point spectrum. — B.G. Schmidt studied systematically the Cauchy problem for relativistic linearly oscillating fluid shells of matter and their Newtonian limit (see Sect. 2.10).

A systematic approximation method has been developed by J. Ehlers within Newtonian cosmology to study nonlinear perturbations of density and velocity which covers vertical motions. The iteration scheme is shown to work at arbitrary order. The relation of this scheme to general relativity has been clarified in part. This work has been done with Thomas Buchert. — T.Futamase has developed a general relativistic model of an inhomogeneous universe using the 3+1 formulation of GR and averaging quantities on spatial hypersurfaces according to Isaaccson. — M. Kasai has found a relativistic generalisation of the Zel'dovich approximation and Lagrangian perturbations, and has used it to describe inhomogeneous cosmological models. — H. Friedrich discussed the conformal structure of Einstein's field equations in terms of conformal Cartan connections. Furthermore he investigated the asymptotic behaviour of anti-de Sitter-type solutions to Einstein's field equations near space-like and null infinity. — In collaboration with G. Sparling (University of Pittsburgh, USA), J. Frauendiener examined linear spinor equations on curved manifolds. They proved existence and uniqueness of solutions for a certain class of such equations. A further research subject was the connection between spin-(3/2) fields on Ricci-flat manifolds and twistor theory. Further together with C. Klein (Max-Planck AG, Jena) the collision of two spherically symmetric dust shells was examined in a general relativistic context. — The Euler–Poisson system for describing the evolution of self–gravitating continua has been represented in terms of exact integrals for the gravitational field strength in Lagrangian space by T. Buchert. Implications of this new representation for the construction of solutions and approximations for the evolution of large–scale structure in the Universe have been investigated. These models extend the validity of analytical approximations into the highly nonlinear regime of the structure formation process. —

3.7 Physical processes

Theoretical and experimental aspects of weak-interaction rates of long-lived nuclear species under high pressure have been scrutinized by K. Takahashi in collaboration with C. Harper, Jr (Harvard), which are of key importance for solving a long-standing geological problem associated with the depth of the surface convection of the Earth, and particularly with plume islands. — I. Borzov (Obninsk) has continued to calculate nuclear beta-decay rates from a self-consistent model of finite Fermi systems, the results of which are being applied, in collaboration with K. Takahashi, to electron capture processes that are of interest in supernova studies.

Using the method of multiply nested refined grids, M. Ruffert was able to simulate three-dimensional hydrodynamic Bondi-Hoyle-type accretion, for the first time with sufficiently high resolution to address unanswered questions pertaining to the occurrence of the flip flop flow. Not only was the parameter space (flow velocity, accretor size, etc.) scanned in order to delimit under which circumstances unstable flow occurs, but the simulations were also applied to a possible candidate: the black hole at the center of our Galaxy. The latter was done in collaboration with F. Melia (Univ. of Arizona). Inclusion of a velocity gradient into the flow and application of the results to wind-fed X-ray sources was done together with U. Anzer. — V. Utrobin (guest of E. Müller from ITEP, Moscow) studied the effects of nonthermal ionization and excitation on the light curve of the type IIb supernova SN1993J. Hydrodynamical models clearly show that both effects dominate after maximum light and play a decisive role in reproducing both the smooth tail of the light curve and the emergence of He lines in the spectrum.

Continuing work based on his diploma work, supervised by H.-Th. Janka, W. Keil performed general relativistic simulations of the Kelvin-Helmholtz neutrino cooling phase of newly formed neutron stars for a large number of models with different masses, different supranuclear equations of state, and different initial temperature profiles. The effects of the creation of additional hadronic states like hyperons at several times nuclear matter density were looked into. In particular, the scenario of a delayed collapse of the proto-neutron star to a black hole due to the corresponding softening of the equation of state was investigated, and the proposed scenario was discussed in the context of constraints from the observed SN 1987A neutrino signal (see Sect. 2.4). In a collaboration with G. Raffelt (MPI für Physik, Munich), W. Keil and H.-Th. Janka used the compatibility of the predicted neutrino signal characteristics with the SN 1987A data to deduce limits on a suppression of the neutrino opacity in dense matter relative to its "standard" value due to nucleon-nucleon interactions and many-body effects. These cannot be calculated in simple perturbative terms and are not taken into account in the cross sections generally used for neutrino interactions with isolated target particles. The studies have implications for the axion emission rate from neutron stars and for the bounds on axion parameters derived from SN 1987A.

M.M. Sharma and W. Hillebrandt (in collaboration with G.A. Lalazissis and P. Ring from the TU München) have investigated shell effects in nuclei near the neutron-drip line based on the relativistic mean-field theory for applications to r-process nucleosynthesis. They found that in contrast to predictions obtained previously from Skyrme-type interactions, shell effects remain strong at the neutron-magic number $N = 82$ even far from stability. They also investigated the possibility of determining the compressibility of the nuclear equation of state from empirical data, and in particular from the measured charge radii of finite nuclei (in collaboration with M.A. Nagarajan from the Univ. of Sevilla, Spain). Other work of M.M. Sharma included applications of the relativistic mean-field theory to the nuclear breathing modes (with M.V. Stoitsov, M.-L. Cescato, and P. Ring), and to the anomalous isotope shifts in Pb nuclei (with G.A. Lalazissis, J. König, and P. Ring) and ground state properties of exotic nuclei (with G.A. Lalazissis).

3.8 Numerical methods

A convergence criterion for the Richardson-Lucy deconvolution method was developed and tested with ROSAT photon fields (H.G. Bi,G. Börner) — The steadily growing requirements on the precision of solar models motivated work by J. Reiter and L. Walsh (TU Munich) together with Achim Weiss. They compared two stellar evolution programs based on different numerical schemes to find limitations on the intrinsic numerical accuracy. — In a common project W.F. Thor (University of Amsterdam), R. Dgani (Caltech), L.J. van den Horn (University of Amsterdam) and H.-Th. Janka have developed a spectral, flux-limited neutrino diffusion scheme that is momentum conserving. The method was applied and tested in a hydrodynamical situation that is representative of a collapsing stellar core and type-II supernova explosion. — D.P. Denissenkov found a numerical solution for the problem of the interaction of meridional circulation with turbulent diffusion in rotating massive stars for the stationary case.

3.9 Quantum mechanics of atoms and molecules; astrochemistry

The research activities of the molecular physics group are concentrated on (i) the theoretical study of atomic and molecular processes and properties and (ii) on the development of the necessary theoretical methods, algorithms and software.

The study of atomic and molecular processes and properties includes such different subjects as (i) the stability, structure and spectroscopy of Rydberg molecules, Van der Waals clusters and hydrogen-bonded systems, (ii) photochemical processes in crystals and (iii) the mechanism of the photodynamic therapy of cancer. These studies require reliable calculations of properties of excited electronic states of systems in the gas, the liquid and the solid phase.

Of particular interest to experimentalists and theoreticians alike are the properties of Rydberg molecules which are energetically unstable in the electronic ground state but stable in electronically excited Rydberg states. As an example the clusters H(He)n, n=1,2 are being studied in some detail. The preliminary results show that both clusters form stable Rydberg molecules, that the electronic excitation is localized at the hydrogen atom, and that the distribution of the excited electron completely encloses the cluster. More and refined calculations are required to reliably and quantitatively verify the present results. These studies are to be extended in order to investigate the stability, structure, spectra and dynamics of Rydberg molecules as functions of the cluster size, the central atoms (such as Li, K, Na, ... and transition metals) and the rare-gas ligands (such as Ne, Ar, Kr, ...). Further studies will be performed in close cooperation with the experimental laboratories of Dr. V.E. Bondebey (TU Munich) and Dr. K. Yamanouchi (The University of Tokyo; DFG Schwerpunktprogramm: Molekulare Cluster, E.W. Schreiner).

Of similar experimental and theoretical interest are the properties of the electronically excited states of Van der Waals clusters which, contrary to Rydberg molecules, are bound in the ground state but only by the very weak Van der Waals forces. As an example the energetically low lying excited states of the beryllium dimer, Be_2, are being studied. The investigation includes all states which correlate with the first excited singlet and triplet states of the dissociated beryllium atoms. In agreement with experiment both bound and unbound electronically excited states have been found. These studies are to be extended in order to determine the electronic spectrum with an accuracy sufficient for comparison with experiment and to investigate the distribution of the density of the excited electron as a function of the interatomic distance (P. Graf). Preliminary studies have been performed for the electronically excited states of the hydrogen-bonded hydrogen fluoride dimer, $(HF)_2$. So far, no stable excited hydrogen-bonded states have been found (E.W. Schreiner).

The theoretical studies of excited electronic states have been extended to classical and quantum mechanical studies of highly excited Rydberg electrons in crossed electric and magnetic fields. Guided by an approximate Hamiltonian, the structure of the phase space has been explained in terms of invariant tori, periodic orbits, chaotic motion, chaos/order transitions and Arnold diffusion (J.R. von Milczewski, T. Uzer, Atlanta, USA).

The photodynamic therapy (PDT) of cancer is based on the use of light sensitive molecules, called photosensitizers. Clinical tests of the photodynamic therapy of cancer using 5-aminolevulinic acid-induced (ALA) photosensitizers have been very successful and encouraging. While there are different speculations about the (re)action of photosensitizers in biochemical environments leading to the damage and death of cells, little is known in detail about the physical and chemical process(es) involved in the reaction. A concerted experimental, theoretical and clinical effort is being started to understand the photodynamic therapy of cancer. The primary emphasis of this concerted effort will be on the study of the interaction of protoporphyrin species with light and of the properties of electronically exited states of these photosensitizers and their photoproducts (NSERC Canada Strategic Project (in preparation): R. Pottier and V.H. Smith, Kingston, Canada).

Recently, for the first time, excited states have been characterized experimentally in molecular crystals by x-ray crystallography. At low temperatures these states have practically infinite lifetimes. Very little is known about the formation, stability and electronic structure of these states. Theoretical studies have been started in order to explain the processes of formation and depletion and the structure of these states (NSERC Canada Cooperative Project: P. Coppens, Buffalo, USA, V.H. Smith and Jiahu Wang, Kingston, Canada).

For the studies of the properties and processes of atoms and molecules in excited electronic states outlined above the development and implementation of new quantum mechanical methods was found to be necessary. The configuration interaction (CI) method has been chosen as the standard tool. It has been shown that the symmetric group formulation of the CI method is superior to the unitary group formulation because of transparency and simplicity. The emphasis is on the development of the CI method for spin-dependent Hamiltonian operators for the approximate treatment of relativistic effects (M. Barysz, Katowice, Poland, N. Flocke, J. Karwowski, Torun, Poland).

The reliable and accurate calculation of electronic transition probabilities, in particular of highly excited Rydberg states, by using quantum mechanical ab-initio methods is difficult and requires a considerable amount of computer time. Therefore, the quantum orbital defect (QDO) method, which was developed originally for studying these properties of atoms, has been successfully extended to study electronic transition probabilities of the Rydberg molecules H_3, FH_2 and NH_4 (I. Martin, Valladolid, Spain).

Atomic and molecular properties and processes in the gas phase and in the condensed phase, in general, differ considerably. Most chemical processes, in particular industrially important processes and all biological processes, take place in the condensed phase. Therefore it is most important to study the properties and processes interacting with the surrounding media. For such studies a combined quantum mechanical/classical model which treats the solute quantum mechanically and the solvent as a classical dielectric continuum has been developed. But in most cases the physical interaction between solute and solvent is not satisfactory in this model. Therefore this approach is being replaced by a model in which the solvent is described through a classical dynamic simulation (P. Graf, A. Nitzan, Tel Aviv, Israel).

Except for some simple problems, the Schroedinger equation can only be solved approximately. Therefore the most important steps involved in studying atomic and molecular properties and processes by quantum mechanical methods are (i) to select or to construct a model which describes correctly the essential physics of the property or process and which permits the numerical solution of the associated Schroedinger equation and (ii) to interpret correctly the computed results within the framework and limitations of the chosen model. Computational quantum mechanical methods are applied more and more by non-expert users, both in the academic and in the industrial environment. Therefore it is most important to provide reliable support for these critical tasks for the non-expert user. For this reason the concept of a knowledge-based, stepwise evolutionary, open software environment has been developed: the OpenMol program. The development of the OpenMol progam concentrates on (i) the development of appropriate knowledge structures, cases and rules for knowledge representation and processing (xOpenMol: E.W. Schreiner; N.S. Scott, Belfast, Northern Ireland), (ii) the development of the required numerical methods, algorithm and software (M. Barysz, Katowice, Poland; P. Graf, N. Flocke, E.W. Schreiner; I. Cernusak, V. Kello, M. Urban, Bratislava, Slovak Republic) and (iii) the development of appropriate user interfaces (gOpenMol; L. Laaksonen, Espoo, Finland).

Within the general research project of W. Krämer to explore the limitations and possible extended applications of the Born-Oppenheimer approximation in molecular calculations, (i) in a collaboration with V. Špirko (Academy of Sciences of the Czech Rep.) the concept of adiabatic separations was applied to nuclear motions with strongly different vibrational amplitudes in order to facilitate predictions of the rotation-vibrational dynamics of larger molecules, and (ii) in another collaboration with P. Jensen (University of Giessen) and P.R. Bunker (Herzberg Institute of Astrophysics, Ottawa) the coupling between electronic and nuclear motions (vibronic coupling) was studied in the special case of Renner-Teller coupled electronic states of triatomic molecules (CH_2^+).

In addition, previous studies on the dynamics of dissociative recombination processes in molecular clouds were continued: A new algorithm to determine the electron capture width in electron-ion interactions developed recently by P.Å. Malmqvist (University of Lund, Sweden) was implemented and tested.

4 Publications

4.1 Publications in journals

The following publications appeared in (almost exclusively) refereed journals during 1994. For work completed and submitted, but not printed in 1994, see the section "Preprints".

AKSENOV, A.G., BLINNIKOV, S.I.: A Newton iteration method for obtaining equilibria of rapidly rotating stars. A&A 290, 674–681 (1994)

ARP, H.: Observations which contradict the hypothesis of a Big Bang Universe, European Review 2, 165-172 (1994)

ARP, H.: ROSAT x-ray survey of an area 10 degrees square around the active galaxy Centaurus A, A&A 288, 738-745 (1994)

ARP, H.: Companion galaxies: a test of the assumption that velocities can be inferred from redshifts, Ap.J. 430, 74-82 (1994)

BARTUNOV, O.S., BLINNIKOV, S.I., PAVLYUK, N.N., TSVETKOV, D.YU.: A model for Supernova 1993J. A&A 281, L53–L55 (1994)

BI, H.G., ARP, H., ZIMMERMAN, H.U.: X-ray observations of NGC 3077, A&A 282, 386-400 (1994)

BLINNIKOV, S.I., DUNINA-BARKOVSKAYA, N.V.: The cooling of hot white dwarfs: a theory with non-standard weak interactions and a comparison with observations. MNRAS 266, 289–304 (1994)

BARTELMANN, M., SCHNEIDER, P.: Large-scale correlations between QSOs and IRAS galaxies. A&A 284, 1–11 (1994)

BARTELMANN, M., WEISS, A.: Arc statistics with realistic cluster potentials. I. Method and first results. A&A 287, 1–14 (1994)

BARTELMANN, M., SCHNEIDER, P., HASINGER, G.: Diffuse X-ray emission around high-redshift, radio-loud QSOs. A&A 290, 399–411 (1994)

BARWIG, H., RITTER, H., BÄRNBANTNER, O.: 1H1752+081: a new eclipsing probable AM Her type binary. A&A 288, 204–212 (1994)

BOFFIN, H.M.J., ANZER, U.: Numerical studies of wind accretion using SPH. I.2D simulations. A&A 284, 1026–1036 (1994)

BRAUER, U., RENDALL, A., REULA O.: The cosmic no–hair theorem and the nonlinear stability of homogeneous Newtonian cosmological models. Classical and Quantum Gravity 11, 2283–2296 (1993)

BUCHERT, T., MELOTT, A.L., WEISS, A.G.: Testing higher–order Lagrangian perturbation theory against numerical simulations – I. Pancake models. A&A 288, 349–364 (1994)

BUCHERT, T.: Lagrangian theory of gravitational instability of Friedman-Lemaître cosmologies - a generic third–order model for nonlinear clustering. MNRAS 267, 811–820 (1994)

BURKERT, A.: On the formation of compact ellipticals. MNRAS 266, 877–885 (1994)

CAO, X.W., SPRUIT, H.C.: Magnetically driven wind from an accretion disk with low-inclination field lines. A&A 287, 80–86 (1994)

DE KOOL, M., MEURS, E.J.A.: PG 1416-129: A broad absorption line QSO with low intrinsic X-ray absorption. A&A 281, L65–L68 (1994)

DENISSENKOV, P.A.: Turbulent diffusive mixing in early B-type main sequence stars. A&A 287, 113–130 (1994)

DENISSENKOV P.A.: Double-zone model with diffusive mixing and the mass and helium discrepancies in OB-stars. Space Science Reviews 66, 405–408 (1994)

DIERCKSEN, G.H.F., KARELSON, M., TAMM, T., ZERNER, M.C.: Multicavity SCRF Calculation of Ion Hydration Energies. Int. J. Quantum Chem., Quantum Chem. Symp. 28, 339–348 (1994)

DUCH, W., DIERCKSEN, G.H.F.: Size-extensivity corrections in configuration interaction methods. J. Chem. Phys. 101, 3018–3030 (1994)

DUCH, W., DIERCKSEN, G.H.F.: Neural networks as tools to solve problems in physics and chemistry. Comput. Phys. Commun. 82, 91–103 (1994)

ERYURT, D., KIRBIYIK, H., KIZILOGLU, N., CIVELEK, R., WEISS, A.: The evolution of a 20 $M_\odot$ rotating star: abundance anomalies in OBN stars in LMC. A&A 282, 485–492 (1994)

FRAUENDIENER, J.: The Bach equations are an exact set of spinor fields. Twistor Newsletter 36, 33–36 (1993)

FRAUENDIENER, J.: A higher spin generalization of the Dirac equation to arbitrary curved manifolds. Twistor Newsletter 37, 10–13 (1994)

FRAUENDIENER, J.: Another view at the spin (3/2) equation. Twistor Newsletter 37, 7–9 (1994)

FRAUENDIENER, J., SCHMIDT, B.G.: Numerical evolution – linear and nonlinear – of spherically symmetric deviations from an isotropic universe. Gen. Rel. Grav. 25, 373–397 (1993)

FRAUENDIENER, J., SPARLING, G.: An algebraic treatment of certain classes of spinor equations and an application to general relativity. Proc. Roy. Soc. London 443, 409–428 (1993)

GOMEZ, R., WINICOUR, J., SCHMIDT, B.G.: Newmann–Penrose constants and the tails of self-gravitating waves. Physical Review D, 49, 2828–2836 (1994)

GREINER, J., HASINGER, G., THOMAS, H.-C.: Another supersoft X-ray source in the LMC. A&A 281, L61–L64 (1994)

HAEHNELT, M.G.: Low-frequency gravitational waves from supermassive black holes. MNRAS 269, 199 (1994)

HAFT, M., RAFFELT, G.G., WEISS, A.: Standard and non-standard plasma neutrino emission revisited. ApJ 425, 222–230 (1994)

JAHN, K., SCHMIDT, H.U.: Thick penumbra in a magnetostatic sunspot model. A&A 290, 295–317 (1994)

JANKA, H.-TH., MÜLLER, E.: Neutron star recoils from anisotropic supernovae. A&A 290, 496–502 (1994)

JING, Y.P, MO, H.J., BÖRNER, G., FANG, L.Z.: The large-scale structure in a universe dominated by cold plus hot dark matter. A&A 284, 703–718 (1994)

KEIL, W.: Neutrinos and the evolution of newly born neutron stars. Prog. Part. Nucl. Phys. 32, 105 (1994)

KING, A.R., KOLB, U., DE KOOL, M., RITTER, H.: The initial periods of cataclysmic variables and the maximum field strength in AM Herculis systems. MNRAS 269, 907 (1994)

KORMANN, R., SCHNEIDER, P., BARTELMANN, M.: Isothermal elliptical gravitational lens models. A&A 284, 285–299 (1994)

KORMANN, R., SCHEIDER, P., BARTELMANN, M.: A gravitational lens model for B1422+231. A&A 286, 357–364 (1994)

KRAEMER, W.P., JENSEN, P., BUNKER, P.R.: An ab initio calculation of the vibronic energies of the CH_2^+ molecule. Can. J. Phys. 72, 871–878 (1994)

KRAEMER, W.P., ŠPIRKO, V., BLUDSKY, O.: Extended ab initio Study of the Vibrational Dynamics of H_5^+ and D_5^+ Including All Vibrational Modes. J. Mol. Spectrosc. 164, 500–509 (1994)

LANGER N.: Presupernova evolution of the most massive stars. Space Sci. Rev. 66, 365–372 (1994)

LANGER N., HAMANN W.-R., LENNON M., NAJARRO F., PULS J., PAULDRACH A.: Towards an understanding of very massive stars. A&A 290, 819–833 (1994)

LUDWIG, H.-G., JORDAN, S., STEFFEN, M.: Numerical simulations of convection at the surface of a ZZ Ceti white dwarf. A&A 284, 105–117 (1994)

LUDWIG, K., MEYER–HOFMEISTER, E., RITTER, H.: Systematics of dwarf nova outbursts: a parameter study in the framework of the disk–instability model. A&A 290, 473–486 (1994)

MARASCHI, L., GRANDI, P., URRY, C.M., WEHRLE, A.E., MADEJSKI, G.M., FINK, H.H., GHISELLINI, G., HARTMAN, R.C., KORATKAR, A.P., VON MONTIGNY, C., PIAN, E., THOMAS, H.-C., TREVES, A., ALLER, M.F., ALLER, H.D., BAYLIN, C.D., BALONEK, T.J., BOCK, H., COLLMAR, W., GLASS, I.S., LITCHFIELD, S.J., MCHARDY, I.M., MÉNDEZ, R., PESCE, J., REUTER, H.P., ROBSON, E.I., STEPPE, H., STEVENS, J.A., TERASRANTA, H., WAGNER, S.J.: The 1993 multiwavelength campaign on 3C 279: the radio to gamma-ray energy distribution in low state. ApJ 435, L91–L95 (1994)

MARTI, J.Mª., MÜLLER, E.: The analytical solution of the Riemann problem in relativistic hydrodynamics. J. Fluid Mechanics 258, 317–333 (1994)

MARTI, J.Mª, MÜLLER, E., IBÁÑEZ, J.Mª.: Hydrodynamical simulations of relativistic jets. A&A 281, L9–L12 (1994)

MARTIN, E.L., SPRUIT, H.C., VAN PARADIJS, J.: Energy implications of Li production in X-ray transients. A&A 291, L43–L46 (1994)

MECKE, K.R., BUCHERT, T., WAGNER, H.: Robust morphological measures for large–scale structure in the Universe. A&A 288, 697–704 (1994)

MO, H.J.: Lyman alpha absorption at low redshifts and hot gas in galactic haloes. MNRAS 269, L49 (1994)

MO, H.J., MIRALDA-ESCUDÉ, J.: Damped Lyman alpha systems and galaxy formation. ApJ 430, L25–L28 (1994)

MOLES, M., MÁRQUEZ, I., MASEGOSO, I., DEL OLMO, A., PEREA, J., ARP, H.: Testing for interaction between the galaxies NGC 450 and UGC 807, Ap.J. 432, 135-147 (1994

MOSZYNSKI, R., JEZIORSKI, B., DIERCKSEN, G.H.F., VIEHLAND, L.R.: Symmetry-adapted perturbation theory potential for the HeK+ molecular ion and transport coefficients of potassium ions in helium. J. Chem. Phys. 101, 4697–4707 (1994)

MÜLLER, E., HÖFLICH, P.: A comparison of calculated and observed monochromatic type Ia supernova light curves. A&A 281, 51–65 (1994)

REINSCH, K., BURWITZ, V., BEUERMANN, K., SCHWOPE, A.D., THOMAS, H.-C.: RX J0531.5-4624: A new ROSAT discovered AM Herculis binary in the 'period gap'. A&A 291, L27–L30 (1994)

RUDAK, B., RITTER, H.: The line of death, the line of birth. MNRAS 267, 513–517 (1994)

RUFFERT, M.: Three-dimensional Hydrodynamic Bondi-Hoyle Accretion. III. Mach 0.6, 1.4 and 10; $\gamma = 5/3$. A&A 106, 505–522 (1994)

RUFFERT, M., MELIA, F.: Hydrodynamical 3D Bondi-Hoyle Accretion onto the Galactic Center Blackhole Candidate Sgr A*. A&A 288, L29–L32 (1994)

SCHAEFER, J.: Empirical corrections of the rigid rotor interaction potential of H_2 - H_2 in the attractive region; dimer features in the FIR absorption spectra. A&A 284, 1015–1025 (1994)

SCHANDL, S., MEYER, F.: Herculis X-1: coronal winds producing the tilted shape of the accretion disk. A&A 289, 149–161 (1994)

SEITZ, C., SCHNEIDER, P.: Variability of microlensing lightcurves. I. Autocorrelation method and the calculation of the correlated deflection probability. A&A 288, 1–18 (1994)

SEITZ, C., WAMBSGANSS, J., SCHNEIDER, P.: Variability of microlensing lightcurves. II. Magnification fluctuations, autocorrelation functions, and applications to QSO 2237+0305. A&A 288, 19–29 (1994)

SEITZ, S., SCHNEIDER, P.: Some remarks on multiple deflection gravitational lensing. A&A 287, 349–360 (1994)

SEITZ, S., SCHNEIDER, P., EHLERS, J.: Light propagation in arbitrary spacetimes and the gravitational lens approximation. Class. Quantum Grav. 11, 2345–2383 (1994)

SHARMA, M.M., LALAZISSIS, G.A., HILLEBRANDT, W., RING, P.: Shell effects in nuclei near neutron drip line. Phys. Rev. Lett. 72, 1431–1434 (1994)

SHARMA, M.M., LALAZISSIS, G.A., HILLEBRANDT, W., RING, P.: Reply to comment on shell effects in nuclei. Phys. Rev. Lett. 73, 1870 (1994)

SPRUIT, H.C.: Fast Eclipse Mapping. A&A 289, 441–448 (1994)

STEINMETZ, M., MÜLLER, E.: The formation of disk galaxies in a cosmological context: Populations, metallicities and metallicity gradients. A&A 281, L97–L100 (1994)

STOITSOV, M.V., CESCATO, M.L., RING, P., SHARMA, M.M.: Nuclear breathing mode in the relativistic mean-field theory. J. Phys. G: Nucl. Part. Phys. 20, L149 (1994)

STOITSOV, M.V., RING, P., SHARMA, M.M.: Generator coordinate calculations for breathing-mode giant monopole resonance in the relativistic mean-field theory. Phys. Rev. C50, 1445–1455 (1994)

TAKAHASHI, K., JANKA, H.-TH., WITTI, J.: Nucleosynthesis in neutrino–driven winds from protoneutron stars II. The r-process. A&A 286, 857–869 (1994)

VON MILCZEWSKI, J., DIERCKSEN, G.H.F., UZER, T.: Classical Dynamics of Rydberg electrons in crossed fields: the structure of phase space and chaos-order alternations. Int. J. Bifurcation Chaos 4, 905 (1994)

VON MILCZEWSKI, J., DIERCKSEN, G.H.F., UZER, T.: Intramanifold chaos in Rydberg atoms in external fields. Phys. Rev. Lett. 73, 2428–2431 (1994)

WAGENHUBER, J., WEISS, A.: Termination of AGB-evolution by hydrogen recombination. A&A 290, 807–814 (1994)

WAGENHUBER, J., WEISS, A.: Numerical methods for AGB evolution. A&A 286, 121–135 (1994)

WEGMANN, R.: Crowding for analytic functions with elongated range. Constr. Approx. 10, 179 (1994)

WEISS, A.: Evolution of initially mixed massive main sequence stars. A&A 284, 138–144 (1994)

WITTI,J., JANKA, H.-TH.,TAKAHASHI, K.: Nucleosynthesis in neutrino–driven winds from protoneutron stars I. The α-process. A&A 286, 841–856

4.2 Proceedings and publications in monographs

ANZER,U.: Remarks on Two-Dimensional Magnetic Arcade Models of Coronal Structures. In Rusin, V., Heinzel, P. and Vial, J.-C. (eds.), IAU Colloq. 144 "Solar Coronal Structures" VEDA Publishing Company, Bratislava, p. 309–314 (1994)

ANZER, U., BÖRNER, G., and NAGASE, F.: Tests of Wind Accretion Models. In Makino, F., and Ohashi,T. (eds.), New Horizon of X-Ray Astronomy- First Results from ASCA Universal Academy Press, Inc., Tokyo, p. 611–612 (1994)

ARP, H: Galaxy creation in a non Big Bang Universe In: E. Rudolph, L.-O. Stomatescu (eds.), Philosophy, Mathematics and Modern Physics, Springer Verlag, Heidelberg, 132-143 (1994)

BARTELMANN, M.: Large-scale QSO-galaxy associations due to gravitational lensing. In Surdej, J, Fraipont–Caro, D., Gosset, E., Refsdal, S., Remy, M. (eds.), Gravitational Lenses in the Universe, Proceedings of the 31st Liège International Astrophysical Colloquium, Liège, p. 275–283 (1994)

BORZOV, I.: Beta-decay half-lives of neutron-rich nuclides in Fe-Co-Ni region. In Somorijai, E., and Fulop, Z. (eds.), Nucleosynthesis of Heavy Elements, INR, Debresen, p. 115 (1994)

BRAUN H., LANGER N.: New massive close binary models and the ^{26}Al yield of the Wolf-Rayet binary component γ^2 Velorum. In K.A. van der Hucht et al. (eds.), IAU-Symp. No. 163 on Wolf-Rayet Stars: Binaries, Colliding Winds, Evolution, Kluwer, p. 305–308 (1994)

BUCHERT, T., WEISS, A.G.: Third–order Lagrangian perturbation theory – realization at high–spatial resolution. In: Bouchet, F., Lachièze-Rey, M. (eds.), 9th. IAP conference "Cosmic Velocity Fields", Editions Frontières, Paris, p. 517-519 (1994).

BURKERT, A., THEIS, C., HENSLER, G.: The chemodynamical evolution of dwarf galaxies. In Meylan, G., and Prugniel, P. (eds.), Dwarf galaxies, ESO/OHP, p. 545 (1994)

BURKERT, A., TRURAN, J.W.: On the formation of compact ellipticals. In In Hensler, G., Theis, C., and Gallagher, J.S. (eds.), Panchromatic View of Galaxies – their Evolutionary Puzzle, Editions Frontièrs, Gif–sur–Yvette, p. 123–133 (1994)

BURKERT, A.: On the formation of elliptical galaxies. In Klare, G. (eds.), Reviews in Modern Astronomy 7, Astronomische Gesellschaft, Hamburg, p. 191–205 (1994)

DENISSENKOV, P.A.: Rotationally induced turbulent diffusion in early B-type stars: theory and observations. In L.A.Balona, M.F.Henrichs, and J.M.Le Contel (Editors), "Pulsation, Rotation and Mass Loss in Early-Type Stars", Proceedings of the 162nd Symposium of the IAU, held in Antibes-Juan-les-Pins, France, October 5-8, 1993, Kluwer Academic Publishers, p.145-146 (1994)

DIERCKSEN, G.H.F., HALL, G.G.: Intelligent software: The OpenMol program. Computers in Physics, 8, 215-222 (1994), W. Gentzsch and U. Harms (eds.). In Lecture Notes in Computer Science 796, Springer-Verlag, Berlin, p. 219-222 (1994)

FLIEGNER, J., LANGER, N.: Effects of Rotation on the Main Sequence Evolution of a $5M_{\odot}$ Star. In Balona, L.A., Henrichs, A.F., Le Contel, J.M. (eds.), IAU Symp. 162, Pulsation, Rotation and Mass Loss in Early-Type Stars. Kluwer, Dordrecht, p. 147–148 (1994)

FRAUENDIENER, J.: Numerical evolution – linear and nonlinear – of spherically symmetric deviations from an isotropic universe. In R. Kerr and Z. Perjés (eds.), Relativity Today: Proceedings of the Fourth Hungarian Workshop Akadémiai Kiadó, Budapest, p. 107–115 (1994)

HENKEL C., WILSON T.L., LANGER N., CHIN Y.-N., MAUERSBERGER R.: Interstellar CNO isotope ratios. T.L. Wilson, K.J. Johnston, eds., The Structure and Content of Molecular Clouds, Springer (Lecture Notes in Physics 439), Berlin, p. 72–88 (1994)

HENSLER, G., SAMLAND, M., THEIS, C., BURKERT, A.: Chemodynamical approach to galactic evolution. In In Hensler, G., Theis, C., and Gallagher, J.S. (eds.), Panchromatic View of Galaxies – their Evolutionary Puzzle, Editions Frontièrs, Gif–sur–Yvette, p. 341–363 (1994)

HILLEBRANDT, W.: Neutrino physics and supernovae. In Faessler, A. (ed.), Proc. Intern. School of Nuclear Physics, Prog. Part. Nucl. Physics, 32, p. 75–109 (1994)

KOLB, U., DE KOOL, M.: The period distribution of AM Her stars. In Shafter, A.W. (ed.), Interacting Binary Stars, ASP Conf. Ser. 56, Astron. Soc. Pacific., San Francisco, p. 338–341 (1994)

KOLB, U., DE KOOL, M.: CV population synthesis: application to CVs evolving without magnetic braking. In D'Antona, F., Caloi, V., Maceroni, C., and Giovanelli, F. (eds.), Evolutionary Links in the Zoo of Interacting Binaries, Mem. Soc. Astron. It. 65, p. 205–208 (1994)

KRAEMER, W.P.: Dissociative Recombination of $C_2H_2^+$: Some Basic Information from Electronic Structure Calculations. In Rowe, B.R., Mitchell, J.B.A. B.R., and Canosa, A. (eds.), Dissociative Recombination: Theory, Experiment, and Applications. Plenum Press, London, p. 67–74 (1994)

LANGER N.: Evolution of massive stars. In R. Clegg et al. (eds.), 34^{th} Herstmonceux Conf. on Circumstellar Media in the Late Stages of Stellar Evolution, Cambridge University Press, Cambridge, p. 1–14 (1994)

LUDWIG, H.-G.: Numerical simulations of overshoot at the base of the solar convection zone. In M. Schüssler and W. Schmidt (eds.), Solar Magnetic Fields, Eds.Cambridge University Press, Cambridge, p. 149–151 (1994)

MEYER, F.: Ap-stars: A new look at holding and confining their magnetic fields. In Lynden-Bell, D. (ed.), Cosmical Magnetism, Kluwer Academic Publishers, Dordrecht (Boston) London, p. 67 (1994)

MÜLLER, E.: Fundamentals of Gas-Dynamical Simulations. In Contopulous, G., Spyrou, N.K., and Vlahos, N. (eds.), Galactic Dynamics and N-Body Simulations (Proc. of the EADN Astrophysics School VI, Thessaloniki, Greece, 1993), Lecture Notes in Physics 433, Springer Verlag, Berlin, Springer Verlag, Berlin, p. 313–364 (1994)

MÜLLER, E.: Multidimensional Hydrodynamical Simulations of Supernova Explosions. In Bludman, S.A., Mochkovitch, R., and Zinn-Justin, J. (eds.), Supernovae (Proc. of the Les Houches Summer School, Course X, Session LIV, Les Houches, 1990), Elsevier Science B.V., Amsterdam, p. 393–488 (1994)

MÜLLER, E., JANKA, H.-TH.: Multi-dimensional Simulations of Neutrino-driven Supernovae. In Klare, G. (ed.), (Proc. of the International Scientific Conference of the Astronomische Gesellschaft, Bochum, Germany, 1993), Reviews of Modern Astronomy 7, Astronomische Gesellschaft, Hamburg, p. 103–128 (1994)

RITTER, H.: Secular Evolution of Compact Binaries: Tema Con Variazioni. In D'Antona, F., Caloi, V., Maceroni, C., and Giovanelli, F. (eds.), Evolutionary Links in the Zoo of Interacting Binaries, Mem. Soc. Astron. It. 65, p. 173–181 (1994)

RUFFERT, M.: Mehrfachgitter in Simulationen der Akkretion und des protostellaren Kollapses. In Konrad-Zuse-Zentrum für Informationstechnik, Technical Report 94-1, Deutsche Mathematiker Vereinigung, ISSN 0933-789X, p. 14 (1994)

SCHAEFER,J.: Dimer features of H_2 - H_2 and isotopomeres at low temperatures. In G.C.Tabisz and M.N.Neuman (eds.), Collision- and Interaction-Induced Spectroscopy, Kluwer Academic Publishers, printed in the Netherlands, p. 485–494 (1994)

SCHMIDT, B.G.: On quasinormal modes. In Kerr, R.P., and Perjés, Relativity today, Proceedings of the fourth Hungarian Relativity Workshop, Akademiai Kiado, Budapest, p. 77–88 (1994)

SCHNEIDER, P.: Unsolved puzzles with gravitational lenses. In Surdej, J, Fraipont–Caro, D., Gosset, E., Refsdal, S., Remy, M. (eds.), Gravitational Lenses in the Universe, Proceedings of the 31st Liège International Astrophysical Colloquium, Liège, p. 41–52 (1994)

SCHNEIDER, P.: Concluding Remarks. In Surdej, J, Fraipont–Caro, D., Gosset, E., Refsdal, S., Remy, M. (eds.), Gravitational Lenses in the Universe, Proceedings of the 31st Liège International Astrophysical Colloquium, Liège, p. 657–669 (1994)

SEITZ, C.: Autocorrelation Properties of Microlensing Lightcurves. In Surdej, J, Fraipont–Caro, D., Gosset, E., Refsdal, S., Remy, M. (eds.), Gravitational Lenses in the Universe, Proceedings of the 31st Liège International Astrophysical Colloquium, Liège, p. 429–434 (1994)

SEITZ, S.: The generalized magnification theorem. In Surdej, J, Fraipont–Caro, D., Gosset, E., Refsdal, S., Remy, M. (eds.), Gravitational Lenses in the Universe, Proceedings of the 31st Liège International Astrophysical Colloquium, Liège, p. 579–586 (1994)

SPRUIT, H.C.: Theoretical interpretation of solar and stellar irradiance variations. In J. Pap, C. Fröhlich, H. Hudson, S. Solanki (eds.), (IAU Coll. 143), The Sun as a variable star: solar and stellar irradiance variations, Cambridge University Press p. 270–290 (1994)

SPRUIT, H.C.: Magnetic winds from stars and disks. In D. Lynden-Bell (ed.), Cosmical Magnetism, Kluwer, Dordrecht, p. 33–44 (1994)

SPRUIT, H.C.: Accretion Disks. In A. Alpar, N. Kiziloğlu and J. van Paradijs (eds.), Lives of Neutron stars, Kluwer, Dordrecht, p. 355–376 (1994)

SPRUIT, H.C.: Theory of Radius and Luminosity Variations. In E. Nesme-Ribes, (ed.), The solar engine and its influence on terrestrial atmosphere and climate, Kluwer, Dordrecht, p. 107–127 (1994)

SPRUIT, H.C.: Cyclic accretion from a disk onto a neutron star magnetosphere. In A. Alpar, N. Kiziloğlu and J. van Paradijs (eds.), Lives of neutron stars, Kluwer, Dordrecht, p. 377–386 (1994)

STEHLE, R., KOLB, U., RITTER, H.: Population Synthesis for Population II Cataclysmic Variables. In Shafter, A.W. (ed.), Interacting Binary Stars, ASP Conf. Ser. 56, Astron. Soc. Pacific., San Francisco, p. 311–314 (1994)

STEHLE, R., KOLB, U., RITTER, H.: Evolutionary Aspects of Population II Cataclysmic Variables, In D'Antona, F., Caloi, V., Maceroni, C., and Giovanelli, F. (eds.), Evolutionary Links in the Zoo of Interacting Binaries, Mem. Soc. Astron. It. 65, p. 415–416 (1994)

STEINMETZ, M.: The formation of Galaxies: A Challenge for Supercomputers – a Simple Task for GRAPE? In High–Performance Computing and Networking, Vol. I: applications, Lecture Notes in Computer Science, 796, Springer Verlag, Berlin, p. 358–364 (1994)

STEINMETZ, M., MÜLLER, E.: Galaxy Formation in a Cluster Environment: First Steps to a Consistent Descritption. In In Hensler, G., Theis, C., and Gallagher, J.S. (eds.), Panchromatic View of Galaxies – their Evolutionary Puzzle, Editions Frontièrs, Gif–sur–Yvette, p. 34–38 (1994)

THOMAS, H.-C., FINK, H.H.: ROSAT spectra and lightcurves of bright BL Lacertae objects at low interstellar absorption. In Courvoisier, T.J.-L., and Blecha, A. (eds.), Multi-wavelength Continuum Emission of AGN, Kluwer Acad. Publ., Dordrecht, p. 384 (1994)

TRURAN, J.W., BURKERT, A.: Metal abundances and the stellar component of the Galaxy. In In Hensler, G., Theis, C., and Gallagher, J.S. (eds.), Panchromatic View of Galaxies – their Evolutionary Puzzle, Editions Frontièrs, Gif–sur–Yvette, p. 389–400

EHLERS, J., FRIEDRICH, H. (eds.): Canonical Gravity: From Classical to Quantum. Springer-Verlag, Heidelberg; Lecture Notes in Physics, vol. 434 (1994)

4.3 Popular articles

EHLERS, J., FAHR, H.J.: Urknall oder Ewigkeit. Bild der Wissenschaft 6, 84 (1994)

EHLERS, J.: Ein Universalgenie der Wissenschaft; zum hundertsten Todestag des Naturforschers Hermann von Helmholtz. Berliner Tagesspiegel, Berlin, 7.9., S.27, (1994)

JANKA, H.-TH., MÜLLER, E., RUFFERT, M.: Simulations of Turbulent Convection in Supernova Explosions of Massive Stars. In Forschung und wissenschaftliches Rechnen. Max-Planck-Gesellschaft, Berichte und Mitteilungen 1/1994, p. 151 (1994)

SCHANDL, S.: Die verbogene Akkretionsscheibe von Her X-1. SuW 33, 270 (1994)

STEINMETZ, M.: Entstehung und Morphologie der Galaxien. In Jahrbuch der Max–Planck–Gesellschaft 1993, Hubert & Co., Göttingen, p. 349 (1994)

4.4 Preprints ("Green Reports")

The following preprints appeared in 1994 as official MPA "Green Reports":

AKSENOV, A.G., S.I. BLINNIKOV: A Newton iteration method for obtaining equilibria of rapidly rotating stars. MPA 779 (1994).

ANZER, U., G. BÖRNER: Random variations of the pulse period of X–ray binaries with wind accretion: MPA 824 (1994).

BARTELMANN, M.: Cosmological parameters from angular correlations between QSOs and galaxies. MPA 818 (1994).

BARTELMANN, M., P. SCHNEIDER, G. HASINGER: Diffuse X–ray emission around high–redshift, radio–loud QSOs. MPA 796 (1994).

BARTELMANN, M., M. STEINMETZ, A. WEISS: Arc statistics with realistic cluster potentials. II. Influence of cluster asymmetry and substructure. MPA 826 (1994).

BARWIG, H., H. RITTER, O. BÄRNBANTER: 1H1752+081: a new eclipsing probable AM Her type binary. MPA 790 (1994).

BERGER, B.K., P.T. CHRUSCIEL, V. MONCRIEF: On "asymptotically flat" space–times with G_2–invariant Cauchy surfaces. MPA 797 (1994).

BEYER, H.R., B.G. SCHMIDT: Newtonian stellar oscillations. MPA 811 (1994).

BEYER, H.R.: The spectrum of radial adiabatic stellar oscillations. MPA 811 (1994).

BEYER, H.R.: The spectrum of adiabatic stellar oscillations. MPA 811 (1994).

BEYER, H.R.: On some vector analogues of Sturm–Liouville operators. MPA 811 (1994).

BI, H., G. BÖRNER: When does the Richardson–Lucy deconvolution converge? MPA 809 (1994).

BISNOVATYI–KOGAN, G., M. MURZINA: Burst propagation through interstellar gas. Self–similar solutions. MPA 785 (1994).

BRAUER, U., A. RENDALL, O. REULA: The cosmic no–hair theorem and the nonlinear stability of homogeneous Newtonian cosmological models. MPA 800 (1994).

BRAUN, H., N. LANGER: New massive close binary models and the ^{26}Al yield of the WR binary component γ^2 Vel. MPA 813 (1994)

BRAUN, H., N. LANGER: Effects of accretion onto massive main sequence stars. MPA 827 (1994).

CHAKRABARTI, S.K.: Velocity profile of the ionized disk in M87 and the mass of the black hole. MPA 820 (1994).

CHRUSCIEL, P.T.: "No Hair" theorems — folklore, connectures, results. MPA 792 (1994).

FLIEGNER, J., N. LANGER: Models of rotating Wolf–Rayet stars. MPA 813 (1994)

FRIEDRICH, H.: Einstein equations and conformal structure: existence of anti–de Sitter–type space–times. MPA 808 (1994).

GARCIA–SEGURA, G., M.–M. MAC LOW, N. LANGER: The imprint of massive stellar evolution on circumstellar gas. MPA 813 (1994)

HAEHNELT, M.G.: Momentum transfer by an internal source of ionizing radiation — an important feedback process during galaxy formation?! MPA 837 (1994).

HASER, S.M., D.J. LENNON, R.–P. KUDRITZKI, J. PULS, A.W.A. PAULDRACH, L. BIANCHI, J.B. HUTCHINGS: The stellar wind of on O8.5I(f) star in M31. A determination of mass loss rate and metallicity. MPA 830 (1994).

HERRERO, A., R.–P. KUDRITZKI, R. GABLER, J.M. VILCHEZ, A. GABLER: Fundamental parameters of galactic luminous OB stars. II. A spectroscopic analysis of HDE 226868 and the mass of Cygnus X–1. MPA 835 (1994).

HERRERO, A., D.J. LENNON, J.M. VILCHEZ, R.–P. KUDRITZKI, R.H. HUMPHREYS: Spectroscopic observations of AB–supergiants in M31 and M33. MPA 783 (1994).

JAHN, K., H.U. SCHMIDT: Thick penumbra in a magnetostatic sunspot model. MPA 801 (1994).

JANKA, H.–TH., E. MÜLLER: Neutron star recoils from anisotropic supernovae. MPA 788 (1994).

KADZHAN, Ya.M., M. MURZINA: Self–similar spherical accretion in the gravitational field of a constant point mass. MPA 778 (1994).

KEIL, W., H.–TH. JANKA: Hadronic phase transition at supranuclear densities and the delayed collapse newly formed neutron stars. MPA 816 (1994).

KEIL, W., H.–TH. JANKA, G. RAFFELT: Reduced neutrino opacities and the SN1987A signal. MPA 834 (1994).

KING, A.R., U. KOLB, M. DE KOOL, H. RITTER: The initial periods of cataclysmic variables and the maximum field strength in AM Herculis systems. MPA 795 (1994).

LANGER, N., W.–R. HAMANN, M. LENNON, F. NAJARRO, A.W.A. PAULDRACH, J. PULS: Towards an understanding of very massive stars. A new evolutionary scenario relating O stars, LBVs and Wolf–Rayet stars. MPA 803 (1994).

LALAZISSIS, G.A., M.M. SHARMA: Ground state properties of exotic nuclei near Z=40 in the relativistic mean–field theory. MPA 822 (1994).

LALAZISSIS, G.A., M.M. SHARMA, J. KÖNIG, P. RING: Anamalous isotope shifts in Pb nuclei in RMF theory. MPA 819 (1994).

LANGER, N.: Structure and evolution of massive single stars and their relevance for close binary systems. MPA 813 (1994).

LANGER, N., C. HENKEL: The Synthesis of Helium and CNO Isotopes in Massive Stars. MPA 839 (1994).

LANGER, N., A. MAEDER: The problem of the blue–to–red supergiant ratio in galaxies. MPA 829 (1994).

LIU, F.K., F. MEYER, E. MEYER–HOFMEISTER: Dwarf novae in quiescence: the relation of disk evaporation and accretion onto the white dwarf. MPA 836 (1994).

LUDWIG, K., E. MEYER–HOFMEISTER, H. RITTER: Systematics of dwarf nova outbursts: a parameter study in the framework of the disk–instability model. MPA 802 (1994).

MARTI, J.Mª., E. MÜLLER: Extension of the piecewise parabolic method to one–dimensional relativistic hydrodynamics. MPA 815 (1994).

MELOTT, A.L., T. BUCHERT, A.G. WEISS: Testing higher–order Lagrangian perturbation theory against numerical simulations — 2. Hierarchical models. MPA 799 (1994).

MEYER, F., E. MEYER–HOFMEISTER: Instability in a braking disk: Her X–1 in the interactive state. MPA 786 (1994).

MEYER–HOFMEISTER, E., N. VOGT, F. MEYER: The influence of a magnetic field of the secondary star on dwarf nova outbursts. MPA 843 (1994).

MO, H.J.: Lyman α absorption at low redshifts and hot gas in galactic halos. MPA 810 (1994).

MO, H.J., J. MIRALDA–ESCUDE: Damped Lyman Alpha systems and galaxy formation. MPA 804 (1994).

MÜLLER, E.: Fundamentals of gasdynamical simulations. MPA 780 (1994).

NIEMEYER, J.C., W. HILLEBRANDT: Microscopic instabilities of nuclear flames in type Ia Supernovae. MPA 840 (1994).

NIEMEYER, J.C., W. HILLEBRANDT: Turbulent nuclear flames in type Ia Supernovae. MPA 841 (1994).

PAULDRACH, A.W.A., A. FELDMEIER, J. PULS, R.–P. KUDRITZKI: Radiation driven winds of hot stars — the theory of O–star atmospheres as a spectroscopic tool. MPA 781 (1994).

RUFFERT, M.: Three–dimensional hydrodynamic Bondi–Hoyle accretion. III. Mach 0.6 and 10; $\gamma = 5/3$. MPA 789 (1994).

RUFFERT, M., U. ANZER: Bondi–Hoyle accretion simulations including velocity gradients. MPA 814 (1994).

SCHANDL, S., F. MEYER: Her X–1: coronal wind producing the titled shape of the accretion disk. MPA 798 (1994).

SCHNEIDER, P.: Cluster lens reconstruction using only observed local data. MPA 832 (1994).

SCHNEIDER, P., M. BARTELMANN: The power spectrum of density fluctuations in the Zel'dovich approximation. MPA 806 (1994).

SCHNEIDER, P., C. SEITZ: Steps towards nonlinear cluster inversion through gravitational distortions. I. Basic considerations and circular clusters. MPA 807 (1994).

SEITZ, C., P. SCHNEIDER: Steps towards nonlinear cluster inversion through gravitational distortions. II. Generalization of the Kaiser & Squires method. MPA 823 (1994).

SEITZ, S., P. SCHNEIDER: The density of 1–Janksy sources around Zwicky clusters. MPA 828 (1994)

SEITZ, S., P. SCHNEIDER, J. EHLERS: Light propagation in arbitrary spacetimes and the gravitational lens approximation. MPA 787 (1994).

SHARMA, M.M., W. HILLEBRANDT, M.A. NAGARAJAN: Skyrme mean–field theory and properties of finite nuclei and nuclear matter. MPA 805 (1994).

SHARMA, M.M., G. LALAZISSIS, J. KÖNIG, P. RING: Isospin dependence of the spin orbit force and effective nuclear potentials. MPA 833 (1994).

SPRUIT, H.C.: Fast eclipse mapping. MPA 782 (1994).

SPRUIT, H.C.: Theories of radius and luminosity variations. MPA 784 (1994).

STEFFEN, M., H.–G. LUDWIG, B. FREYTAG: Synthetic spectra computed from hydrodynamical model atmospheres of DA white dwarfs. MPA 842 (1994).

STEINMETZ, M., M. BARTELMANN: On the spin parameter of dark–matter halos. MPA 794 (1994).

STEINMETZ, M., E. MÜLLER: The formation of disk galaxies in cosmological context: structure and kinematics. MPA 817 (1994).

STOITSOV, M.V., M.–L. CESCATO, P. RING, M.M. SHARMA: Nuclear breathing mode in the relativistic mean–field theory. MPA 791 (1994).

STOITSOV, M.V., P. RING, M.M. SHARMA: Generator coordinate calculations for breathing–mode giant monopole resonance in the relativistic mean–field theory. MPA 793 (1994).

UTROBIN, V.P., N.N. CHUGAI, A.A. ANDRONOVA: Asymmetry of SN 1987A: fast ^{56}Ni clump. MPA 838 (1994).

WAMBSGANSS, J., B. PACZYNSKI: Parameter degeneracy in models of the quadrupole lens system Q2237+0305. MPA 821 (1994).

WEGMANN, R.: MHD model calculations for the effect of interplanetary shocks on the plasma tail of a comet. MPA 825 (1994).

WHITE, S.D.M.: Formation and Evolution of Galaxies: Lectures given at Les Houches, August 1993. MPA 831 (1994).

WOOSLEY, S.E., N. LANGER, T.A. WEAVER: The presupernova evolution and explosion of helium stars that experience mass loss. MPA 812 (1994).

5 Personnel

5.1 Scientific Staff Members

U. Anzer, M. Bartelmann (on leave of absence since Aug. 7), H. Beyer (since April 1), G. Börner, T. Buchert (since Oct. 1), A. Burkert (till Dec. 31), M. de Kool (on leave of absence Jan. 15 – May 15), G.H.F. Diercksen (on leave of absence since Sept. 22), J. Ehlers, J. Frauendiener (on leave of absence till April 30), T. Foglizzo (since Oct. 1), H. Friedrich, A. Gautschy (till Sept. 30), M. Haehnelt (since Feb. 1), W. Hillebrandt (on leave of absence since Oct. 12), D.G. Hummer (till Aug. 31), D. Husfeld (till June 30), B. Jain (since Nov. 1), H.–T. Janka (on leave of absence since Oct. 17), P. Kafka, U. Kolb (on leave of absence since Oct. 15), W.P. Kraemer, R.–P. Kudritzki, H.–G. Ludwig (since Jan. 1), R.H. Mendez (April 1 – June 30), E. Meyer–Hofmeister, F. Meyer, H. Mo (since Jan. 15), E. Müller, R. Reinberger (July 1 – Aug. 31), A.D. Rendall (till Aug. 31), H. Ritter, H.–W. Rix (since Sept. 1), M. Ruffert, J. Schäfer, S. Schandl, B.G. Schmidt, P. Schneider, H.C. Spruit (on leave of absence since May 1), M. Steinmetz, K. Takahashi, H.–C. Thomas, J. Villumsen (since Nov. 1), J. Wambsganß (till Sept. 30), R. Wegmann, Achim Weiß, R. van de Weygaert (since Nov. 1), S.D.M. White (since Sept. 1), H.S. Zhao (since Nov. 1).

Emeriti: H. Billing, R. Kippenhahn, H.U. Schmidt (since June 1), E. Trefftz.

Heisenberg–grant: N. Langer (Göttingen)

Ph.D. students: R.–P. Andersen, U. Brauer, H. Braun, H. Dünhuber (till April 30), P. Englmaier, H. Erdl, J. Fliegner, P. Graf, A. Huss (since Aug. 1), G. Karakatsanis, W. Keil, R. Klessen (since Nov. 1), R. Kneissl (since Oct. 1), A. Körner (till Sept. 9), C. Kronberg (till Oct. 31), K. Ludwig, J. von Milczewski, J. Niemeyer (since July 1, on leave of absence since Oct. 1), R. Reinberger (till May 31) C. Seitz, S. Seitz, E. Schreiner, T. Soffner, R. Stehle (since April 1, on leave of absence since May 1), O. Ullmann (since Oct. 1), J. Wagenhuber, Arno Weiß, T. Zwerger.

Diploma students: K. Achatz (since Aug. 1), A. Bartsch (since March 1), S. Buchner (till Aug. 31), N. Deiser (till Nov. 1), B. Geiger (since May 1), A. Heger (since June 1), A. Huss (till July 19), R. Klessen (till Sept. 16), R. Kneissl (till July 26), G.–H. Lescow (since April 1), J. Niemeyer (till May 28), M. Platzöder (since May 1), K. Schenker (since March 1), R.H. Stehle (till March 9), M. Vanselow (since Jan. 1).

5.2 Staff News

J. Ehlers was appointed Scientific Member and Director at the newly founded MPI for Gravitational Physics, Potsdam. J. Ehlers was also elected Member of the Berlin–Brandenburg Academy of Sciences.

H.U. Schmidt retired on May 31.

M. Steinmetz was awarded the Otto Hahn Medal 1993 during the General Assembly of the Max–Planck Society at Göttingen.

S.D.M. White was appointed Director of the MPA and Scientific Member at the Institute. He took up his directorship on Sept. 1.

5.3 Visiting scientists

Name (home institution, duration of stay at MPA)

MPG fellowships:
N.V. Ardelyan (Moscow, Russia) March 1 – April 15; R. Beig (Wien, Austria) March 1–31; H.G. Bi (Hefei, China) till Feb. 28; J. Bicak (Prag, Czech Republic) Jan. 20 – April 1 and June 28 — July 27; S. Blinnikov (Moscow, Russia) March 20 – June 19; T. Bonev (Sofia, Bulgaria) May 1 – July 31; I. Borzov (Obninsk, Russia) Feb. 1 – March 14; I. Cernusak (Bratislava, Slowak Republic) May 6 – June 5 and July 25 – Sept. 24; P. Denissenkov (St. Petersburg, Russia) March 1 – April 30; W. Duch (Torun, Poland) Jan. 24 – Feb. 13 and Aug. 1 – Sept. 7; W. Dziembowski (Warsaw, Poland) Jan. 11 – Feb. 10; I. Forcada (Cambridge, UK) since Oct. 1; A. Fullerton (Newark, USA), since May 11; T. Futamase (Hirosaki, Japan) July 15 – Sept. 15; T. Gan–Baruch (Tel Aviv, Israel) May 15 – Nov. 15; W. Groom (Cambridge, UK) seit Oct. 1; K. Irving (Montevideo, Uruguay) Aug. 8 – Sept. 30; K. Jahn (Warsaw, Poland) June 1 – Aug. 31; J. Karwowski (Torun, Poland) July 3 – Aug. 30; M. Kasai (Hirosaki, Japan) Nov. 1 – Dec. 31; V. Kellö (Bratislava, Slowak Republic) April 17 – May 16 and July 25 – Sept. 24: A. Kritsuk (St. Petersburg, Russia) Aug. 1 – Oct. 20; L. Laaksonen (Espoo, Finland) June 1–30; F. Liu (Kunming, China) till Nov. 6; P.–Å. Malmqvist (Lund, Sweden) Sept. 19 – Oct. 15; S.G. Moiseenko (Moscow, Russia); N. O'Murchada (Cork, Ireland) March 16 – April 15; T. Plewa (Warsaw, Poland) since Nov. 19; R. Price (Salt Lake City, USA) June 15 – July 14; J. Pullin (Pennstate, USA) June 17 – July 16; W. Rindler (Dallas, USA) July 1–31, M.M. Sharma (Kuwait) till Jan. 31 and July 1 – Aug. 31; V. Spirko (Prag, Czech Republic) May 1 – July 31; R. Sunyaev (Moscow, Russia) June 19 – Aug. 31; M. Urban (Bratislava, Slovak Republic) July 25 – Sept. 24; V. Utrobin (Moscow, Russia) since Nov. 1; H. Velasquez (Cambridge, UK) since Oct. 1; K. Venn (Austin, USA) since Aug. 1, J. Vojtik Oct. 17 – Dec. 10; Z. Zhang (Beijing, China); Y Zhugzhda (Moscow, Russia) Aug. 1 – Sept. 30.

Alexander von Humboldt–Research Awards and fellowships:

Alexander von Humboldt–Awards: P. Bodenheimer (Santa Cruz, USA) July 15 – Sept. 25; W. Kolos (Warsaw, Poland) since Oct. 1; J.W. Truran (Chicago, USA) May 12 – Aug. 12; M. Zerner (Gainesville, USA) June 27 – Aug. 18.

Alexander von Humboldt–fellowships: P. Denissenkov (St. Petersburg, Russia) till Feb. 28; Y. Jing (Triest, Italy) since March 1; S. Scott (Belfast, Northern Ireland) March 1 to Sept. 24; O. Ventura (Montevideo, Uruguay) July 1 – Sept. 30.

DAAD–fellowship:
J. Kannar (Budapest, Hungary) since Oct. 1.

DFG–fellowships:
G. Bisnovatyi–Kogan (Moscow, Russia) Jan. 15–31; S. Chakrabarti (Bombay, India) July 1–31; D. Shalybkov (St. Petersburg, Russia) Oct. 1 – Nov. 30; V. Urpin (St. Petersburg, Russia) Oct. 1 – Nov. 30.

EC–fellowships:
D. Dyl (Torun, Poland) Jan. 14 – July 2; K. Grudzinski (Torun, Poland) June 15 – Aug. 25; M. Karelson (Tartu, Estonia) June 6–15; D. Krause (Edmonton, Canada) July 7 – Aug. 12; J.M. Marti (Valencia, Spain); R. Sosa (Montevideo, Uruguay) May 2–31; F. Vila (Montevideo, Uruguay) Aug. 8 – Sept. 29.

ESF–fellowships:
M. Barysz (Katowice, Poland) July 18 – Oct. 17; I. Martin (Valladolid, Spain) June 2–21.

Other Visitors:
M. Barysz (Katowice, Poland) June 18 – July 17; T. Baumgarte (Ithaca, USA) June 27 – July 22; G. Carraro (Padova, Italy) Nov. 6 – Dec. 11; G. Garcia–Segura (Teneriffa, Spain) Dec. 5–20; S. Gottlöber (Potsdam, Germany) March 15 – April 15, Oct. 18 – Nov. 22 and Nov. 30 – Dec. 10; S. Grebenev (Moscow, Russia) July 22 – Aug. 15; P. Jensen (Wuppertal, Germany) Sept. 11–24; A. King (Leicester, UK) July 15 – Aug. 11; Y. Jing (Triest, Italy) Feb. 7–28; A. Petters (Princeton, USA) June 8–30; P. Ruiz–Lapuente (Barcelona, Spain) since Oct. 1; V.H. Smith (Kingston, Canada) June 23 – July 7; M.M. Sharma (Kuwait) Feb. 1 – March 8; S. Sosa (Montevideo, Uruguay) May 2–31; E. Tchourazov (Moscow, Russia) July 22 – Aug. 15; J. Thomas (Rochester, USA) April 26 – May 13; K. Thornton (Chicago, USA) July 24 – Aug. 8; S.B. Trickey (Gainesville, USA) Aug. 6–24; B. Wybourne (Torun, Poland) June 15 – July 6.

5.4 Diploma, Ph.D. and Habilitation Theses

Diploma theses:

S. Buchner: "Struktur und Dynamik wechselwirkender Galaxien", Technical University Munich;

A. Huss: "Die Bildung von dunklen Halos und Galaxienhaufen in Kosmogonien mit kalter und heißer dunkler Materie", Technical University Munich;

R. Klessen: "Über die Natur der Dicken Scheibe unserer Milchstraße", Technical University Munich;

R. Kneissl: "Anisotropie der kosmischen Mikrowellen–Hintergrundstrahlung", Ludwig–Maximilians–University Munich;

J. Niemeyer: "Turbulente thermonukleare Brennfronten in Weißen Zwergen", Technical University Munich;

R. Stehle: "Langzeitentwicklung von kataklysmischen Doppelsternen der Population II", Ludwig–Maximilians–University Munich.

Ph.D. theses:

H. Dünhuber: "Intrinsische und beobachtbare kollektive Eigenschaften von Kataklysmischen Doppelsternen", Ludwig–Maximilians–University Munich;

R. Reinberger: "Asymmetrische Plasmaströmung in Kometen unter Berücksichtigung von Tangentialdiskontinuitäten im Sonnenwind. Ein Lagrangesches MHD–Modell", Ludwig–Maximilians–University Munich.

Habilitation theses:

T. Buchert: "Inhomogeneous Newtonian Cosmogony", Ludwig–Maximilians–University Munich;

E. Müller: "Mehrdimensionale Hydrodynamische Simulationen von Supernovaexplosionen", Technical University Munich.