predict a declining rotation velocity if the only mass in the system were provided by the observed stars. The observations thus suggest that an unseen “halo” of dark matter extends well beyond the visible galaxy and contributes most of the mass at large radii. This idea that disk galaxies are embedded in extended and massive dark haloes is also supported by other observations, for example, of the motions of small satellite galaxies in orbit around them, and is almost universally accepted. We have no direct indication, however, what this dark matter might be.

The present-day population of galaxy disks possesses a number of interesting regularities. One of the most striking is the so-called Tully-Fisher relation; the level of the flat part of a galaxy's rotation curve is tightly related to its intrinsic brightness – brighter galaxies rotate faster. This relation is much used to measure the distance of galaxies. The rotation speed can be measured directly, the intrinsic brightness can then be inferred, and a comparison with the apparent brightness allows the distance to be inferred from the inverse square law. A second regularity relates the size of a disk to its rotation speed and so to its intrinsic brightness. The average exponential scalelength of disks of a given rotation speed increases in direct proportion to the rotation speed. In contrast to the Tully-Fisher relation, at each rotation speed there is a substantial variation in size about the mean value. Clearly such regularities tell us something important about how disks were formed. New data from the Hubble Space Telescope and the Keck telescopes also provide important clues by allowing us to see whether the regularities were the same when disk galaxies were young as they are today.

MPA work on disk galaxies has focussed on understanding whether these regularities can be understood in the general framework of hierarchical structure formation. This is currently the standard picture for the growth of structure. Small inhomogeneities generated very shortly after the Big Bang (perhaps by quantum fluctuations during an early period of accelerated expansion) are gravitationally amplified as the Universe expands. They are first visible as weak variations in maps of the microwave background radiation; these give us a picture of the Universe when it was only 300,000 years old. Further amplification at later times causes overdense regions of the Universe to stop expanding and collapse back onto themselves. Small objects form first and so become the building blocks for the larger systems which form later. Collapsing objects contain both gas and dark matter, with the latter contributing most of the mass. After collapse the dark matter rapidly relaxes to form a quasi-equilibrium dark halo. The gas, however, cannot maintain a similar equilibrium. It cools through radiation, loses its pressure support, and falls inwards under the gravitational influence of the dark matter. This infall is finally halted when the gas settles into a thin rotationally-supported disk, reflecting the angular momentum induced by tidal forces during the pre-collapse evolution. Stars form within this disk, producing a rotationally-supported stellar disk at the centre of a much more massive dark halo.

Many aspects of this picture can now be calculated quite reliably. For example, inhomogeneities produced by early quantum fluctuations can be shown to capable both of matching the measured variations in microwave background maps and of making present-day dark halos with the abundance, mass and internal structure inferred observationally for the halos of galaxies and galaxy clusters. MPA work shows that gas sinking to the centres of these halos can produce a population of disks with stellar masses, sizes and rotation curves quite similar to those of real galaxies, and with a similar dependence of brightness and size on rotation speed. Even the fact that the Tully-Fisher relation is very tight while the size-brightness relation shows considerable scatter turns out to be simply explained in these hierarchical models.

Such models also determine the evolution of galactic disks. The most robust prediction is that disks of a given rotation velocity should typically be smaller at earlier times. Recent observational data from the Keck telescope do appear to show a trend which is close to that predicted, but inconsistent at high significance with older models which assume that disks were assembled at early times and have evolved only in brightness since then.

Some aspects of this work remain highly idealised and raise a number of questions about physical processes during disk formation. First, the fraction of the total mass of a galaxy-halo system in the form of ordinary matter (almost all in the stars of the galaxy) appears to be much smaller than corresponding fraction for massive

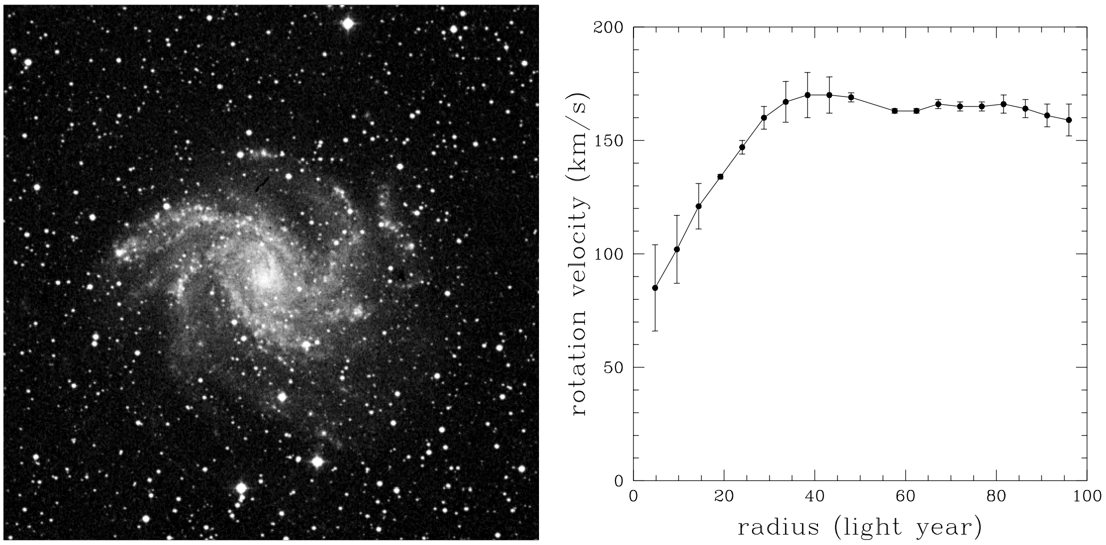

Figure 2.12: The left panel shows a face-on disk galaxy, NGC 6946. The side-length of the box is about one hundred thousand light years. The galaxy would appear as a thin disk if viewed edge-on. The right panel shows the run of circular velocity (inferred from radio observations of neutral hydrogen) with radius. Notice the rotation curve remains approximately flat to the last measured data point.

galaxy clusters (where most of the ordinary matter is in the gas between the galaxies). This may mean that a lot of gas was blown out of the system during galaxy formation. Second, the MPA models assume that the disk material has the same angular momentum per unit mass as the dark halo; an assumption which appears needed to reproduce the observed sizes of disks. This is in sharp contrast to what is seen in numerical simulations of disk formation, where the gas transfers most of its angular momentum to the dark matter and the final disk ends up too small. This suggests that the simulations do not yet correctly include all of the physics; the processes of star-formation and of galactic winds are particularly difficult to treat realistically. Third, both observations and numerical simulations suggest that giant elliptical galaxies can form by the merger of disk systems. Interestingly, elliptical galaxies also follow relations similar to the disk Tully-Fisher and size-luminosity relations. It is important to understand if the merger model allows these to be understood as a *consequence* of the analogous disk relations.

Clearly much theoretical work remains to be done. With more and better observational data pouring in, the formation and evolution of galaxies will remain an exciting area of research for years to come. (Shude Mao, H.J. Mo, Simon White)

2.7 X-ray observations of distant lensing clusters

Typical clusters of galaxies consist of several hundreds of galaxies. Between the galaxies is a gas atmosphere at temperatures of $10^7 - 10^8$K, which is almost completely ionized and emits X-rays primarily through bremsstrahlung. The temperature reflects the depth of the gravitational potential well. The gas is an important component of the clusters as it provides $10-30\%$ of the cluster mass. In comparison the galaxies themselves provide only about $3-5\%$. The rest of the cluster consists of dark matter of unknown nature.

X-ray observations reveal much about clusters which cannot be obtained from optical data alone. For example, clusters are easier to identify in X-rays. One observes extended X-ray emission filling the cluster while optical observations show only a somewhat enhanced number of galaxies (see Fig. 2.13). The X-ray emission is much less likely to be a chance projection effect than the enhanced galaxy density. Another example is that the X-ray morphology reveals the dynamical state of the cluster. While a cluster in equilibrium is symmetric, a cluster in the process of forming looks irregular, showing indications of the formation mechanism. Tell-tale features show up both in the X-ray emission and in the gas temperature distribution. Further-

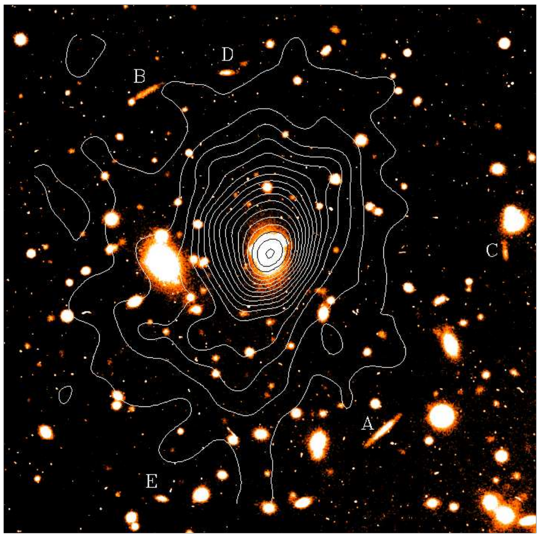

Figure 2.13: ROSAT/HRI contours of the galaxy cluster RXJ1347-1145 superposed on an optical image. The X-ray emission is strongly peaked towards the centre. In the optical image several arcs produced by gravitational lensing are visible. They are marked with letters.

more, in more regular clusters the distribution and temperature of the emission allow one to estimate the amount and distribution of the dark matter. X-ray spectra show that the gas consists not only of hydrogen and helium, but also of heavier elements. The abundances of these elements are approximately three times smaller than in the Sun. This means the gas cannot be primordial but must have been processed by stars, presumably in the cluster galaxies. The ratios of the abundances of different heavy elements give information about how this processing occurred.

A great deal of detailed X-ray data on clusters has been collected recently by the ROSAT and ASCA satellites. Here we consider a particularly interesting selection of clusters – distant, massive objects – studied at MPA. A comparison of these clusters with nearby objects gives hints about the evolution of structure and certain cosmological parameters, in particular the mean density of the Universe: in a universe with low density, structure formation is completed earlier than in a universe where there is enough matter to eventually halt the expansion and perhaps even cause recollapse to a Big Crunch.

The three clusters – RXJ1347-1145, Cl0939+4713 and Cl0500-24 – discussed here are especially massive. We know this because they either show high X-ray luminosity or contain a large number of galaxies. In addition, they all produce easily measurable distortions of the images of background galaxies by gravitational lensing (see the following article by Stella Seitz). The three clusters have similar redshifts (z=0.32–0.45) and so are seen at the same age. Despite these similarities, however, they show some very different properties.

RXJ1347-1145 is the most luminous X-ray cluster found so far, with a bolometric luminosity of 2×10^{46}erg/s. This is quite surprising because in the optical it is not a spectacular object. The X-ray image (Fig. 2.13) shows the emission to be strongly peaked towards the centre, which usually indicates a relaxed state. X-ray spectra show the cluster to be hot (9 keV) and to have a relatively high metallicity. All these properties suggest that this cluster has had plenty of time to accrete gas and other matter and to evolve to an equilibrium state. Apparently RXJ1347-1145 is an example of an old, well-virialized cluster.

Cl0939+4713 shows opposite properties to RXJ1347-1145. In the optical it is perhaps the richest cluster known, while its X-ray luminosity is an order of magnitude smaller than that of RXJ1347-1145. Its temperature and metallicity are both also smaller. The most striking difference, however, is in the X-ray image (Fig. 2.14). The X-ray emission is not spherically symmetric but has two maxima which may even have further internal structure. Cl0939+4713 appears to consist of several smaller units in the process of merging. It is then effectively a young cluster, still far from equilibrium.

Cl0500-24 is an optically rich cluster with X-ray luminosity two orders of magnitude lower than that of RXJ1347-1145. From optical observations it is known that Cl0500-24 consists of two subclusters superposed on each other, but only one of these subclusters is X-ray luminous. The X-ray morphology shows pronounced substructure. Obviously, Cl0500-24 is also a young cluster.

A comparison of these clusters with a sample of nearby clusters shows no clear differences. The nearby clusters have metallicities, temperatures and luminosities in the same range and some of them also show substructure. These results may indicate early completion of evolution (by a redshift around 0.5) which would then argue against a high density universe because in this case strong evolution is expected between $z = 0.5$ and today.

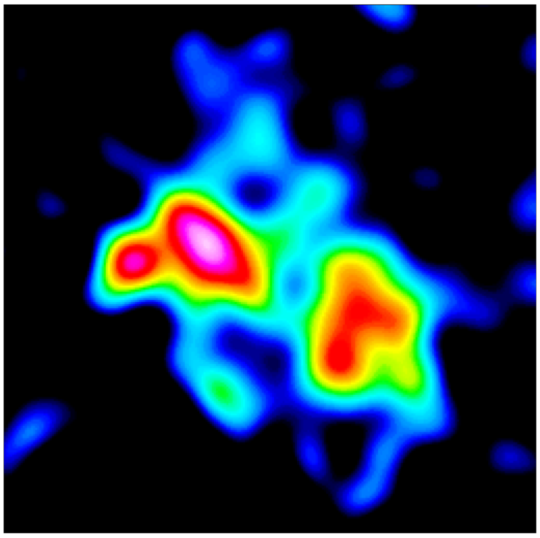

Figure 2.14: ROSAT/HRI image of the galaxy cluster Cl0939+4713. The X-ray emission shows two maxima which may even have some internal structure. Note that this figure is about three times larger on a side than the image of RXJ1347-1145.

This is a very preliminary result which must be confirmed by further observation. The three selected clusters show the difficulties of such a study. The scatter in their properties is so huge that either a large sample of distant clusters or a sample of extremely distant clusters will be needed if we are to detect an unambiguous shift in cluster properties with redshift. The coming generation of X-ray satellites (e.g. AXAF, XMM) should provide such samples and so may answer many open questions about the evolution of clusters. (Sabine Schindler)

2.8 Clusters of galaxies as natural telescopes

In 1937, F. Zwicky predicted that massive objects like galaxies or clusters of galaxies can serve as natural – and cheap – telescopes, allowing a deeper 'look' into the Universe behind them. He expected this because light bundles are focused by a deflecting mass, and this focusing increases the apparent size and brightness of background light sources. One therefore sees the same objects behind a cluster as one would see without it, but extended sources appear larger (magnified) and the sources become brighter. Even multiple images of the same source are possible. In the past, some observed multiply-imaged quasars (quasi-stellar point sources) have been recognized as being strongly magnified by the lens effect. As will be discussed below, the lens magnification effect is particularly important when a distant galaxy is lensed by a massive foreground cluster. The last year has witnessed several spectacular examples of this effect.

The investigation of lensed structures in foreground clusters has revealed additional very high-redshift galaxies behind the cluster CL 0939+47. Due to the lens effect, the shapes of these galaxies become distorted and from the pattern of this distortion the projected mass distribution of the cluster can be calculated. This mass map allowed the MPA lensing group and their collaborators to predict that two galaxies are strongly lensed, i.e. magnified and stretched severely or mapped into multiple images. Spectroscopy of the lensed sources at the Keck telescope subsequently confirmed this prediction and showed that both galaxies have a redshift of about 4. In addition, a third galaxy with redshift 3.3 was identified. Although these galaxies could have been discovered without the lensing cluster, the magnification made it possible to obtain detailed spectra which yielded precise redshifts, metallicities and star-formation rates.

Another example is the discovery of two lensed galaxies at redshift $z \sim 4$ behind the cluster A2390 by French and American astronomers. A detailed model of the cluster mass distribution, based on the observed multiple image geometry, had predicted the high redshifts before the spectroscopic confirmation. It is clear that detailed imaging of strong lensing clusters provides an alternative window on the high-redshift Universe.

A particularly spectacular case is the object 'cB58'. It was discovered in a survey of medium-redshift clusters by the CNOC (Canadian Network for Observational Cosmology) collaboration which took spectra of galaxies in order to measure the relative velocity distribution of cluster members. Rather than being a member of the $z = 0.37$ cluster MS1512+36 (see Fig. 2.15), cB58 turned out to be at the much higher redshift $z = 2.72$. Although much farther away than the cluster, cB58 appears brighter than most cluster galaxies, suggesting that it must be extremely luminous. cB58 is located close to the cluster center, but ground-based images did not indicate the distortion characteristic of a galaxy image mapped into a giant arc. As a result, the lensing hypothesis was originally

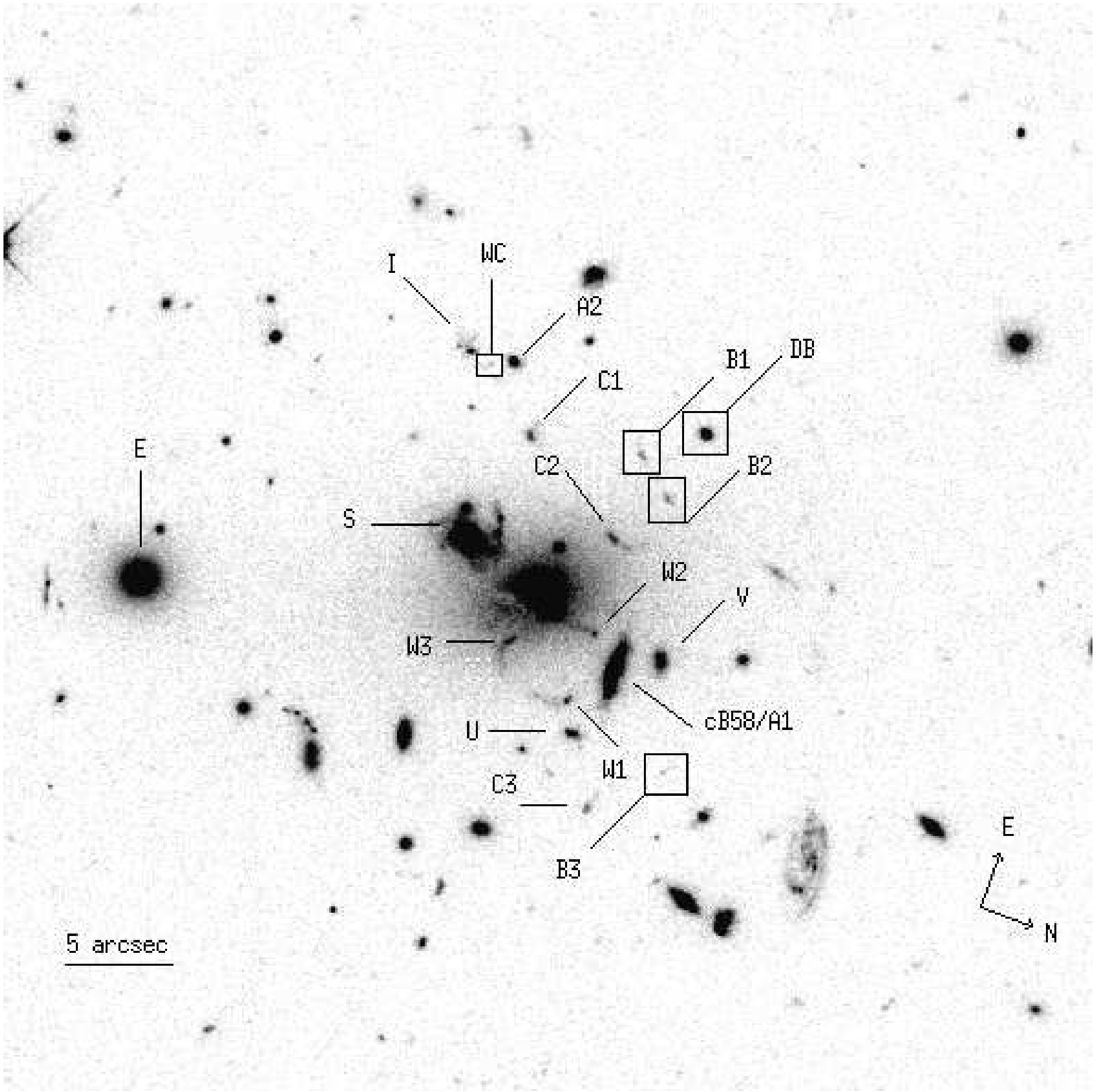

Figure 2.15: Image of the core of the cluster MS1512+36 using coadded V- and R-data. Close to the central galaxy in the center is a face-on spiral S to its left. The galaxy cB58 is on the opposite side at $5''$ distance with an inclination angle of $71.6°$ relative to the x-axis. The compact bright object A2 at $(r, \phi) \approx (11'', 97°)$ is the counterimage of the gravitational arc cB58. Left to the upper and lower end of cB58 are two shrimp-like objects (W1 & W2) with their heads pointing towards cB58. They are also lensed, with a counterimage WC left of A2, and a fourth image at W3. Near the upper right diagonal of the field there is the galaxy pair B1 & B2. The third image B3 of that system is marginally visible in this figure. The three galaxies C1, C2 and C3 also have a common source.

discarded, and the observed size and brightness of cB58 were considered to reflect its intrinsic properties, requiring it to be by far the most strongly star-forming galaxy ever found.

It became clear that this conclusion was premature after an image of the cluster was obtained in two filters with the WFPC2 camera on the Hubble Space Telescope. cB58 turned out to be very elongated in the direction tangential to the cluster center, as expected for a giant arc, with an axis ratio of about 1:7. Furthermore its flux distribution (Fig. 2.16) is mirror symmetric relative to the dashed line in Fig. 2.16, as expected if two images of a source are merging perpendicular to that line to form the giant arc. The lensing hypothesis then became the most plausible interpretation of the huge brightness of the image. In order for cB58 to be a typical high-redshift galaxy, it was already known that its magnification would have be of order 40, and so the question arose whether the HST data could determine the magnification precisely: is cB58 a particularly luminous and somewhat magnified high-redshift galaxy, or is it a normal but highly magnified galaxy?

To answer this question, the lensing geometry of the cluster must be understood in great detail. According to the information from the velocities of cluster galaxies and the X-ray temperature and luminosity of the intracluster gas, this cluster is not particularly massive. This was confirmed by an investigation of the distortion of background galaxies. Unfortunately, the observation of the cluster was not very deep (i.e. the observing time was not extremely long), and so a reconstruction of the projected mass distribution similar to that for the cluster CL 0939 was not possible. Further progress required an additional image of the source of cB58 or additional multiply imaged objects to be found. At this stage the color information from the two WFPC-2 filters (Visual and Red filters) helped tremendously: cB58 is extremely blue, and there is only one other image in the field with similar color (A2 in Fig 2.15). It is thus tempting to interpret this image as a second image of the galaxy corresponding to cB58.

A simple mass model of the cluster, with an ellipticity similar to that of the central cluster galaxy and a mass as expected from the galaxy velocity dispersion, can easily account for cB58 (or A1) and A2 as multiple images of the same source A. Comparing the prediction of this simple model with the image (Fig. 2.15) and taking into account the colors of the galaxies, three additional multiple image sets were found iteratively: C1,C2,C3 and B1,B2,B3 are each three images of a single source, B and C respectively, and W1,W2,W3,WC are four out of 5 images of another source W.

To get full agreement the lens model had to be refined. Several cluster galaxies had to be explicitly considered as lens components. The final mass model then reproduces all the multiple image systems in this cluster; in addition, it can account for the strength of the distortion pattern of the remaining background galaxies. This model implies that cB58 is magnified by

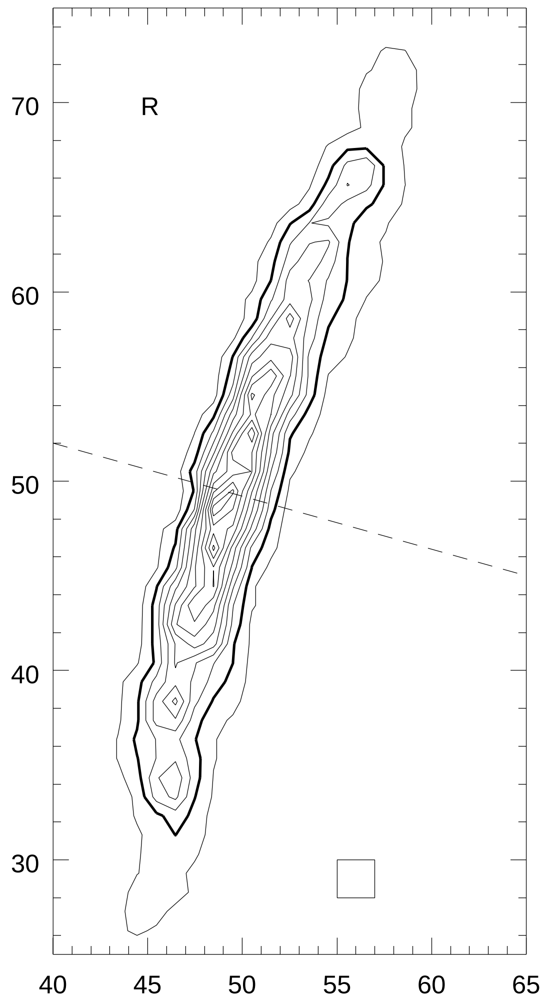

Figure 2.16: R-band image of the galaxy cB58. One unit in the horizontal and vertical direction equals one pixel of size $\approx 0\farcs05$. Contours are spaced by 5 counts per pixel; the thick line corresponds to 10 counts per pixel. The square indicates the size of that part of the source which is lensed into cB58. It demonstrates the usefulness of clusters as natural telescopes.

about a factor of 50. The unlensed source A can be reconstructed using the lens model and the image A2. The dramatic stretching of cB58 relative to its source can be inferred from Fig. 2.16; the source of cB58 is smaller than the region covered by the small square in that figure. We conclude that the source of cB58 corresponds to a typical high-redshift galaxy. Nevertheless, one which, due to its high magnification, can be studied in much more detail than any other known redshift ~ 3 galaxy.

The redshifts of the sources B, C and W are not yet known. Our lens model predicts that they should have a redshift very close to that of cB58. We threfore tentatively conclude – and eagerly await spectroscopic confirmation – that this study (which was done as a close collaboration between the MPA and the Universitätssternwarte München) has discovered a high-redshift cluster behind a foreground cluster. (Stella Seitz)

2.9 Cosmic structure in the dark ages

In the modern picture of cosmology our Universe is believed to have originated in a very hot and dense initial state, the so-called Hot Big Bang. From then on the Universe has expanded and cooled. The initially opaque fireball became transparent to radiation approximately 300.000 years after the Big Bang. Most of this light has not been absorbed or scattered since then and was observed for the first time by Penzias and Wilson in 1967 as the Cosmic Microwave Background Radiation (CMBR). In the early 1990s, the Cosmic Microwave Background Explorer (COBE) satellite measured minute fluctuations in the otherwise isotropic CMBR. This provided evidence for an important hypothesis: namely that astronomical objects such as galaxies, clusters of galaxies, and the large scale structure of the Universe were formed by gravitational instability. In fact, Stephen Hawking called this discovery "the most important discovery of all time". The ripples in the microwave sky are believed to originate from slightly overdense regions which, as the Universe expanded further, started to contract and collapse to form the objects we see today. Today's ground– and space–based telescopes directly image the radiation that has been emitted by quasars and galaxies up to approximately 15 billion years ago. Between the emission of the CMBR and these observed cosmological objects there is an epoch that lasts roughly 1 billion years about which little is known. Since we have no direct observations of this era (yet) it is currently referred to as the Dark Ages. Clearly it is in these Dark Ages where the first cosmological objects form and the first stars switch on. It is in this epoch, when the Universe starts its transformation from a rather dull "gas with ripples" phase into today's fascinating array of objects of seemingly limitless diversity.

How did the first objects in the Universe form? Were they clusters of stars? Were they massive black holes like the ones believed to power quasars? These are truly fundamental questions, which are difficult to answer but are addressed by recent MPA work. Of course, it would be best to observe these early objects directly and fortunately there is considerable effort underway to achieve this. The proposed Next Generation Space Telescope for example, an eight meter class telescope in space that may be launched within the next ten years, could help to answer these questions. But do we know what to look for? Can we already now predict what we will find?

Current models of structure formation have been successful in matching the observed properties of astrophysical objects on a vast range of scales, such as X-ray clusters, galaxies, and quasar absorption line systems. All these models assume that most of the matter in the Universe is dark collisionless matter, i.e. matter that only interacts through gravity. Furthermore, these models assume that initially (shortly after the Big Bang) there were density fluctuations in the gas and in the dark matter on a large range of scales. i.e. there are small and large regions that have higher densities than the average density. The models differ in their assumptions about the spectrum of initial density fluctuations. This spectrum specifies how much denser a typical region of given size is in comparison with the mean mass density of the Universe. The most promising models assume that smaller regions have typically larger overdensities than larger regions. As the Universe expands, the denser a region was initially, the earlier it will turn around and collapse. Hence, in the most promising models small systems will form first and later merge into larger ones. Due to this hierarchy of objects that form these models are called Hierarchical Models of Structure

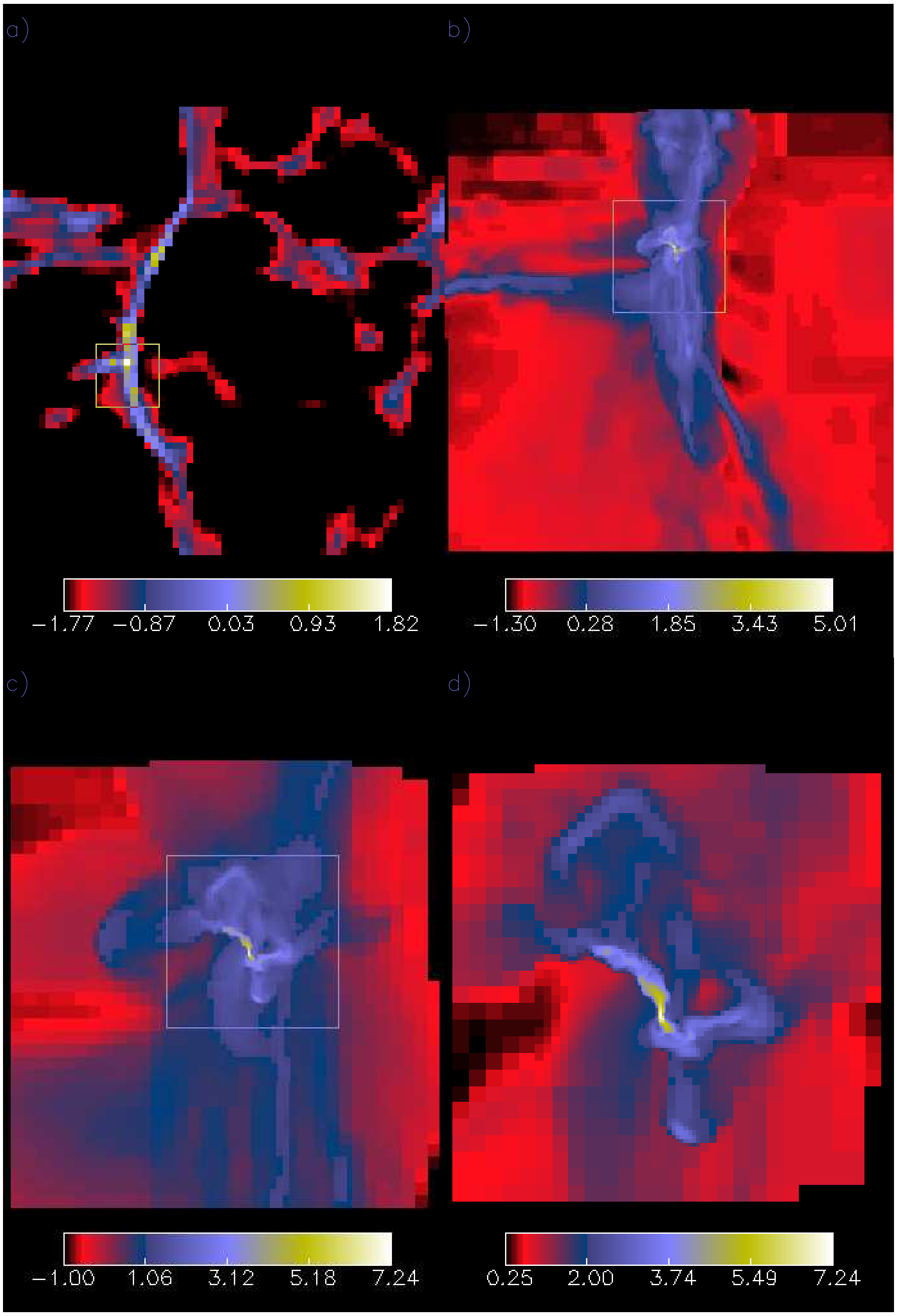

Figure 2.17: Logarithm of gas overdensity (i.e., 7 stands for 10^7 times the mean density) on different scales. Panel a) depicts the largest grid at the given redshift (z=17) it has 28 kpc ($\sim$ 900.000 light years) on a side. Panels b) through d) zoom further in (illustrated by the yellow squares in the preceeding panel) and have 4, 1, and 0.4 kilo parsec side lengths, respectively. The slice cuts through a cool (20 K $<$ T $<$ 2000 K) high density disk like structure. The finest resolution element in this simulation is 1.4 parsec on a side; 20.000^3 times smaller than the simulation volume.

Formation.

So small things are believed to form first. But how small were these first objects? Could there be a density fluctuation with one solar mass that directly collapses to form a star like the Sun? When an overdense region of gas contracts its central density and temperature rise. Hence also the central pressure (which is simply the product of density and temperature) increases. As a consequence an outward force is established which counteracts gravity. Only if gravity exceeds these pressure forces will the "cloud" be able to contract. However, as the cloud contracts pressure forces will typically increase more rapidly than gravity. Hence, even if gravity exceeds pressure forces initially, the collapse will be halted eventually. However, it is possible to reduce the pressure by cooling the gas. If for example hydrogen molecules are present in the gas, a collision with a neutral hydrogen atom may cause the molecule to rotate or vibrate, leaving the neutral hydrogen atom with less kinetic energy. If now the molecule stops rotating (vibrating) it will emit a photon and this energy is lost from the cloud. As a consequence the temperature, and hence the pressure, of the gas is reduced. In collaboration with researchers from around the world, MPA scientists have studied in detail the chemistry of molecule formation and cooling of the gas under the relevant physical conditions. They found that the first objects must have had masses exceeding 100.000 times the mass of our Sun, such that they can contract to high densities, form molecules, cool, and collapse further.

With a computer program that solves the relevant laws of physics, with initial conditions specified by the structure formation model, and with a supercomputer, one can simulate what must have happened in the Dark Ages. This is what MPA researchers, in collaboration with American scientists from the National Center of Supercomputing Applications and Princeton Observatory, are trying to achieve. They have developed new numerical methods specifically for this project which allow them to follow the time-dependent reactive flow of the primordial gas. In these calculations the dynamics are computed on a grid, i.e., at discrete times and x,y, and z positions one calculates the density, temperature, velocity, and chemical composition of the gas. During the course of the simulation, if one finds an overdense region that starts to collapse, one can introduce a new grid centered on this region and resolve the dynamics more accurately. This technique, called adaptive mesh refinement, allows one to "zoom in" on the places of interest. This way it is possible to study the formation and evolution of molecular clouds on physical scales down to less than 1 parsec (parsec $\approx$ 3 light years) within a more than 10^{13} times larger simulation volume. An illustration of these new results is given in Fig. 2.17. The figure shows four zooms of the same slice through the simulation volume. The color encodes the logarithm of the gas overdensity (i.e. 7 stands for 10^7 times the average density of the Universe). The calculation followed the collapse of a density fluctuation of mass 10 million times that of our Sun. A disk–like structure with 100 thousand solar masses of cooled gas is found. Its diameter is roughly 50 parsec with a typical height of 10 parsec. The gas temperature within the disk ranges from 20 to a few thousand Kelvin, and is a few hundred Kelvin at the dense center. The surrounding infalling gas has a temperature of $\sim 10^4$ Kelvin. These calculations give quantitative predictions not only for the hydrodynamic quantities but also for the chemical composition of the gas. The fact that rotating disks are formed in such small objects is surprising. Further simulations are currently being carried out to follow the collapsing structures to the yet higher densities required for star formation. Future studies will be crucial in predicting the nature of the first objects in the Universe, thus providing future observers with some idea of what to look for. (Tom Abel)

2.10 Black holes formed in the early Universe: could they be the dark matter?

The nature of the dark matter in the Universe is one of the outstanding questions in cosmology at the present time. There is evidence for the existence of as yet unidentified matter throughout the Universe, matter which does not emit light, and probably is not the material humans and stars are made of, i.e. baryons. This dark matter is believed to have been detected through its gravitational interaction with ordinary matter. It is thought to explain the large rotation velocities of disk galaxies, the motions of small galaxies around larger galaxies, the velocities of galaxies within clusters of galaxies, and the evolution of the expansion rate of the Universe. It appears that the total mass in dark matter is much larger than the mass in stars and gas. There have been many suggestions for the origin and nature of this dominant mass component of the Universe, for example, weakly interacting massive particles (WIMP's). WIMP's would have very weak interactions with ordinary matter, their existence may be supported by new particle physics theories, and they may be a natural and abundant leftover from the evolution of the early Universe. Nevertheless, WIMP's have so far eluded detection in all of the many particle detectors built to look for them.

Dark matter also surrounds our own Galaxy, the Milky Way. Recently, a large-scale observational program has been carried out to search for massive compact halo objects, or MACHO's, in the Milky Way's halo. Such objects are another possible candidate for the unseen dark matter. The stimulus for the program was the idea that dark matter might be in the form of planets or brown dwarfs. (A brown dwarf is a ball of gas held together by its own gravitational force but not massive enough to start nuclear reactions and so become a star.) Millions of stars were repeatedly observed in a satellite galaxy of the Milky Way, the Large Magellanic Cloud or LMC. If a halo MACHO moves directly between the observer's telescope and a star in the LMC, the light from the star is focussed by the gravity of the MACHO and it appears brighter for a short time. Although this program failed to find halo brown dwarfs, it did detect apparently more massive MACHO's. The results indicate that a substantial fraction of the dark matter in our Galactic halo consists of objects roughly half as massive as our Sun. If made from baryons these objects would have to be stars (red dwarfs) or would once have to have been stars (white dwarfs).

Nevertheless, searches with the Hubble Space Telescope failed to find red dwarfs or white dwarfs in our halo in sufficient abundance to explain the MACHO's. Recent MPA work asks whether these MACHO's are black holes. Black holes would also cause light to bend but would be invisible unless lit up by ordinary matter falling into them. It is commonly argued that black holes can be made from ordinary massive stars, but only with masses about four times greater than those inferred for MACHO's from the lensing experiments.

However, black holes can be made from anything, baryons, light, or even WIMP's. The only requirement for making a black hole is to compress any form of mass, or energy, to such high densities that even light is unable to escape the immense gravitational force at the surface of the dense region. Black holes can have almost any mass, depending on the environment they are formed in.

When the Universe was young, it was hot and dense. At very early times the dominant contribution to its energy density was not baryons, or even dark matter, it was electromagnetic radiation, referred to as light, and many other particle species produced from this electromagnetic radiation. The residual radiation from this early state is observed today as the cosmic microwave background radiation. If only a tiny fraction of this radiation were converted into black holes at early times those black holes could provide the dark matter in the present Universe.

Black hole formation in the early Universe is possible if regions containing more radiation than the average cease to expand and recollapse under their own self-gravity. However, collapse can only proceed if the region's self-gravity exceeds the countervailing pressure forces. This can be the case for regions approximately twice as dense as the remainder of the Universe provided these regions are sufficiently large. How large? They must be so large that a signal starting at the very beginning of time and traveling at the speed of light could just have traversed them. The distance light can travel from the beginning of the Universe to some later epoch is called the horizon length. If overdense regions are much smaller than the current horizon length, pressure effects smooth them out, if they are much larger they are disconnected from their environment and would not be part of our Universe

How massive would black holes formed in the early Universe be? They would have the mass (or energy) of the radiation and particles within the over-dense region. This is approximately the mass in radiation within a sphere of diameter the horizon length, referred to as the horizon mass. The horizon mass is initially very small but it increases with time as the horizon length grows. Black holes formed in the early Universe could be a few times the mass of Mt. Everest, if the overdense region was very small and formed very early. On the other hand, black hole masses could be as large as thousands of times the mass

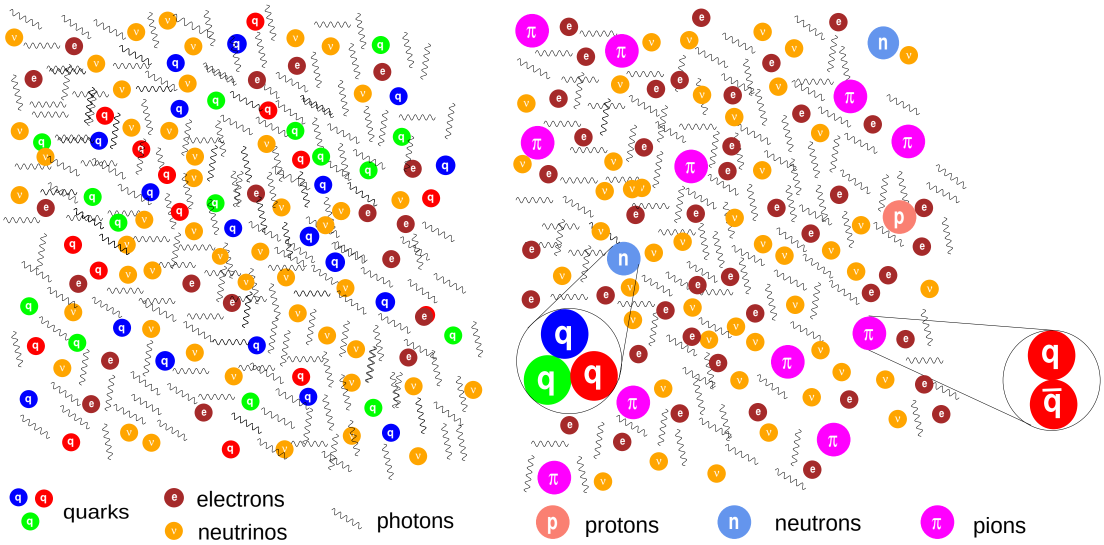

Figure 2.18: Schematic representation of regions of the Universe before (left) and after (right) the QCD phase transition. The different symbols indicate the abundant existence of elementary particles (photons, electrons, neutrinos, and quarks) and composite particles (pions, neutrons, and protons). Quarks combine due to their strong interactions to form pions and a few protons and neutrons during the QCD phase transition. These strong interactions between quarks also yield a substantial reduction in pressure forces at the QCD transition.

of the Sun for large overdense regions and late formation times.

Why should black holes formed at the beginning of the Universe have the masses of the compact objects observed in our halo? It could be that the Universe had overdense regions just big enough to form black holes with about half the mass of the Sun, but it seems unsatisfactory to believe in such cosmic accidents. Rather one would like to explain the present state of the Universe as the result of the action of physical laws. Generic theories for the formation of overdense regions in the early Universe predict that the probability of having fluctuations with a certain length scale ought to be roughly the same for all length scales. Thus they do not help to explain the “accident”.

Nevertheless, the horizon mass is close to the mass of the detected MACHO’s during a very special period of the early Universe. This is about one hundredth of a millisecond after the Big Bang when the Universe underwent a phase transition. Before this time many different particle species were present. These included photons (light), electrons and positrons, neutrinos, and quarks. Quarks are the elementary particles which turn into pions, protons and neutrons when the temperatures and densities are low, or, equivalently, when the Universe is old, just as electrons, protons and neutrons form atoms at even lower temperatures and later times. The formation of pions from quarks occurred at this particular epoch in what is called the cosmic quantum-chromodynamic (QCD) phase transition (Fig. 2.18). During this transition the pressure of the Universe is altered because of the conversion of quark interaction energy into kinetic energy of the pions. Whereas the energy associated with the random motions, i.e. the kinetic energy, contributes positively to the pressure, interaction energy contributes negatively. Regions with more quarks and higher energy density may exist in pressure equilibrium with regions of fewer quarks and lower energy density because the interaction between quarks contributes negatively to the pressure. Fluctuations in the energy density may therefore form black holes during the QCD transition without having to fight pressure forces, a situation which arises at no other time in cosmic history. It is intriguing, therefore, that the mass scale for black holes formed during the QCD transition is approximately that of the observed MACHO’s.

Current MPA work on black hole formation during the cosmic QCD transition is focussed on attempting to quantify how much easier it is to form black holes at this epoch than at other epochs in the early Universe, and how massive these black holes would actually be. To address these questions it is necessary to model not only the gravitational physics of black hole formation but also the particle physics of a quark-pion plasma. Another topic of interest is whether accretion of material onto the black holes at later times might give rise to electromagnetic radiation which could leave observable signatures. Only through such characteristic signatures are we likely to find compelling evidence for or against such black holes as a solution to the dark matter problem. (Karsten Jedamzik)

3 Research Activities

3.1 Sun and interplanetary matter

R. Wegmann and H.U. Schmidt in collaboration with C. M. Lisse (Goddard Space Flight Center), K. Dennerl and J. Englhauser (both MPE) investigated in detail the process of X-ray emission by charge exchange of heavy solar wind ions in a comet. The spectrum consists of more than 100 lines. For an instrument with low energy resolution like the X-ray satellite ROSAT it looks like the spectrum of bremsstrahlung of 200 eV electrons in good agreement with observation.

R. Wegmann used his new improved MHD model for the plasma flow around a comet to investigate the distribution of water ions. For small comets up to 11% of the water molecules are ionized before they dissociate. For large comets this fraction is only about 3%. The theoretical results about the water ion distribution are used to interpret ground based observations of H_2O^+ column densities. In particular, one can determine in several ways the total gas production rate of a comet from images of the H_2O^+ tail.

U. Anzer and P. Heinzel (Astronomical Institute Ondrejov) studied the equilibrium of solar quiescent prominences. They considered one-dimensional slab models both for the magnetic and for the radiative equilibrium. When these two types of models are applied to observations they give very different results. Based upon this discrepancy it is argued that the fine structure will play an important role in prominence models.

N.A. Inogamov (Landau Institute of Theoretical Physics, Chernogolovka) studied the turbulent processes in the convective zone of the Sun, the upper cascade near the surface and the lower cascade near the boundary between the convective and radiative zones. He also investigated high frequency acoustic oscillations at the boundary between the chromosphere and the upper convective zone.

H. Spruit clarified with Å. Nordlund (Copenhagen Observatory) the origin of the power spectrum of length scales in stellar granulation, showing that almost all power at small scales is caused by the sharp edges of granules rather than by small scale turbulence.

O.V. Terekhov (Space Research Institute, Moscow) analysed the physical processes during high energy solar flares, especially the associated deuterium synthesis.

3.2 Stellar structure and evolution

The evolution of rotating massive single stars (i.e., $8\,M_\odot < M < 25\,M_\odot$) of solar composition was studied by A. Heger, supervised by N. Langer (MPA, now Univ. Potsdam). A spin-up effect of these stars at the transition from red supergiants to blue supergiants was found and investigated. Together with N. Langer and S.E. Woosley (UCSC/Lick Observatory, Santa Cruz and MPA) the late evolutionary stages of rotating massive stars were investigated and pre core-collapse models for type II a and type I b/c supernovae were obtained. The evolution of these stars was followed from the main-sequence until onset of core-collapse. In collaboration with I. Baraffe and L. Jennin (both ENS, Lyon) high-amplitude stellar pulsations, found in the most luminous of our evolutionary models, were studied.

M. Shindo, M. Hashimoto (both Kyushu University, Fukuoka), Y. Eriguchi (Univ. of Tokyo) and E. Müller investigated the structure of rapidly rotating, chemically inhomogeneous stars on the H and He main sequence. Nuclear burning, a realistic equation of state and realistic opacity were taken into account in the stellar models. Using two types of rotation laws several equilibrium sequences of massive stars were computed up to the point where mass shedding occurs at the equator. For uniformly rotating H burning stars the luminosity decreases by a 6.4% compared to a non-rotating star. Models, where the angular momentum is concentrated towards the center, develop highly flattened surface layers. Compared with non-rotating models their luminosity decreases by 16% at the point of mass shedding provided their total angular momentum is less than $10^{53}\,\mathrm{g\,cm^2\,s^{-1}}$ and their density stratification has no toroidal topology. For very differentially and rapidly rotating stars the decrease of the luminosity becomes significant.

A. McFadyen and S.E. Woosley (Univ. of California, Santa Cruz) investigated hydrostatic oxygen burning in massive stars by means of direct numerical simulations, based on SPH and finite volume codes.

M. Salaris and A. Weiss continued their work about the ages of globular clusters, using a new generation of stellar models, which include updated opacities and equation of state. After showing that the most metal-poor galactic clusters were not older than about Gyr (together with S. Degl'Innocenti, Pisa), they investigated a sample of 25 halo clusters both for their absolute and relative ages. It turned out that, if the new models together with a careful application of different age determination methods are used, the metal-poor clusters form a surprisingly homogeneous group in age with differences less than of order 1 Gyr, while with increasing metallicity (up to 25% of the solar value), the ages are anti-correlated with metal content and clusters get as young as 7 Gyr. Due to updates in the observational results, the oldest clusters now appear to be 11 ± 1Gyr old. In connection with this work M. Salaris and S. Cassisi (Teramo) studied the tip of the Red Giant Branch using it as a distance indicator. Based on the same models employed for the cluster dating they derived a value for the Hubble constant of $64^{\pm}10$ km/(sMpc), which results in an age for the Universe of about 12 Gyr ($\Omega = 0.3$), in agreement with the cluster ages.

P. Denissenkov (St. Petersburg) investigated globular cluster abundance anomalies in globular cluster stars (with A. Weiss). After applying additional diffusive mixing below the convective envelope of red giant stars, they furthermore take into account the effects of stellar winds from an earlier generation of Asymptotic Giant Branch stars experiencing thermal flashes, hot-bottom burning and diffusive mixing themselves. The observational evidence for abundance anomalies requires more and more complicated theoretical scenarios to account for them. On the theoretical side the nuclear reaction network had to be expanded to include all hydrogen-cycles as well as α-reactions and neutron captures for burning-shells in Asymptotic Giant Branch stars and s-process nucleosynthesis (with J. Norris & G. Da Costa, MSSSO, Australia).

The study of Asymptotic Giant Branch (AGB) stars in the Magellanic Clouds was continued. M. Groenewegen, in collaboration with C. Loup (ESO, IAP, Paris), A.A. Zijlstra (ESO) and R. Waters (Amsterdam), published an inventory of known and candidate AGB stars, supergiants and planetary nebulae detected by IRAS in the LMC. In addition, near-infrared photometry and optical spectroscopy of IRAS sources in the Small Magellanic Cloud and a study about obscured AGB stars in the Magellanic Clouds were completed. Coworkers were van Loon (Amsterdam), Whitelock (SAAO, Capetown, South-Africa), Loup (ESO) and others. — M. Groenewegen modelled the circumstellar dust shell of the most famous carbon star IRC +10 216. Compared to previous modelling a much larger set of observational data was used as constraints, including interferometric data. This allowed determination of the dominant grain size (found to be 0.16 micrometer), and inner dust radius, and the dust mass loss rate. Together with W. van der Veen (Columbia), B. Lefloch (IRAM Granada) and A. Omont (IAP) he mapped the circumstellar shell of this star in the 1.3 mm continuum. The emission is clearly extended and is detected out to 50 arcseconds. The contribution of molecular line emission in the broad-band 1.3mm filter is important, and estimated from modelling this emission. The resulting dust emission as a function of radial offset clearly indicates that there was a phase of enhanced mass loss in the past. — Together with R. Oudmaijer (Imperial College, London) and H.-G. Ludwig (TAC, Copenhagen) he also studied the only two known mass losing carbon stars in the galactic halo. They obtained optical spectra, detected CO (2-1) emission in one star, and modelled the spectral energy distribution and the CO emission. The two stars are at very large distances from the galactic plane.

From the one CO detection plus the model they find that the star is metal poor. It is suggested that both objects may be related to the Sagittarius dwarf galaxy. — Together with P. Whitelock (SAAO), C. Smith (ADFA) and F. Kerschbaum (Univ. of Vienna) M. Groenewegen modelled the spectral energy distributions of about 40 carbon Mira variables. The advantage of using Miras variables is that luminosities can be estimated from the periods, via the P-L-relation. A relation between mass loss rate and luminosity was established. Full radiation-hydrodynamical calculations including dust formation predict expansion velocities which are significantly too large. This is related to the fact that these models need to be calculated – contrary to observational evidence – with a large C/O ratio to get an outflow in the first place. It indicates that a principle physical ingredient in these radiation-hydrodynamical calculations is still missing. Possibly the winds are "clumpy" which may lead to dust formation on a local scale, or there is an additional outwards directed force, possibly radiation pressure on molecules.

A theoretical aspect of AGB stars concerns the carbon, oxygen, nitrogen yields of AGB stars, i.e. the mass of these elements per unit initial mass shed to the interstellar medium. Such data are important in chemical evolution models of galaxies. M. Groenewegen, together with L.B. van den Hoek (University of Amsterdam, The Netherlands) calculated a new dataset superseding the work of Renzini & Voli of 1981. — Leo Girardi studied the synthetic evolution of near-infrared colours of single stellar populations, in collaboration with G. Bertelli (University of Padova, Italy). Near-infrared colours change greatly if different prescriptions for the mass-loss rates in AGB stars are assumed, or if the models include the effect of hot-bottom burning on the luminosity. The same uncertainties hold for the initial-final mass relation and the maximum luminosity of these evolved stars as a function of age and metallicity. Comparison with the data for star clusters in the Large Magellanic Cloud pointed to efficient hot bottom burning to be occurring in AGB stars of initial mass higher than about 3 solar masses.

The results of the Diploma thesis by H. Schlattl about a new solar model have appeared in a publication by him and A. Weiss and H.-G. Ludwig (now Kobenhavn). The new model features in particular a more realistic stratification of the superadiabatic layers. Based on 2d-hydrodynamical models (by H.-G. Ludwig, TAC, Kobenhavn) of the solar sub-photosphere and theoretical atmosphere calculations a variable mixing-length parameter has been used to obtain the same structure. The agreement with observed p-mode frequencies tracing these layers could be improved by that approach.

H. Spruit, with E.S. Phinney (Caltech), studied the origin of rotation of neutron stars and white dwarfs and concluded that in both cases it is likely to be acquired in the late stages of stellar evolution, rather than being a remnant of the original angular momentum of the progenitor stars.

Coalescing neutron stars are currently the most popular model to explain the central engins of gamma-ray bursts. M. Ruffert and H.-Th. Janka have simulated a variety of models, in order to shed light on the accessible physical conditions during the mergers, on the amount of matter dynamically ejected during the merging, on the timescales of mass accretion by the (forming) black hole, on the conversion of energy into neutrino emission, on the amount of energy deposited by $\nu\bar{\nu}$-annihilation, and on the baryon loading of the created pair-plasma fireball. To this end, the masses and mass ratios as well as the initial spins of the neutron stars were varied, the impact parameter was changed to consider spiral-in orbits and direct collisions, a black hole (vacuum sphere) was included in the simulations, and the dynamical evolution of the accretion torus around the black hole was studied. While the neutrino emission during the dynamical phases of the mergings is definitely too small to power gamma-ray bursts (GRBs), the masses, lifetimes, and neutrino luminosities of the accretion tori have values that might explain short ($\mathcal{O}(0.1\text{–}1\,\mathrm{s})$) and relatively low power ($\sim 10^{50}/(4\pi)\,\mathrm{erg}/(\mathrm{s}\cdot\mathrm{sterad})$) gamma-ray bursts.

Together with R. Oudmaijer (Imperial College) and H. Schrijver (SRON) the so-called Lutz-Kelker bias in trigonometric parallaxes was investigated by M. Groenewegen comparing the best Hipparcos parallaxes with previous ground-based observations. Empirical evidence for the presence of this bias is indeed found. Reanalysing the 26 best Cepheids in the Hipparcos catalogue, which previously had been used by Feast & Cathpole to derive a distance modulus to the LMC of 18.70, but taking into account, and correcting for the Lutz-Kelker bias, they found a distance modulus of 18.56, in agreement with other determinations.

3.3 Supernovae and nucleosynthesis

W. Keil, H.-Th. Janka, and E. Müller continued their studies of convection in nascent neutron stars. Besides investigating the influence of stellar rotation and post-collapse mass accretion on the development of the convection, the grid size and grid resolution were tested concerning their effects on the results of the two-dimensional hydrodynamic simulations. The gravitational wave emission (luminosities, spectra, waveforms) was computed and the numerical models were evaluated for the recoil acceleration of the neutron star caused by the convectively enhanced anisotropic neutrino emission.

S. Hardy examined a new proposal for the regeneration of the stalled shock in a core collapse supernova based on the quasi-linear interactions between the neutrinos produced in the core and the plasma turbulence generated near the shock. It was shown that while low energy neutrinos (below 1 keV) may be scattered, this interaction is not strong enough to scatter the bulk of the neutrinos sufficiently to effect the dynamics of the explosion.

A close comparison of simulations of neutrino transport in proto-neutron stars with a Boltzmann solver, the Monte Carlo method and the multi-group flux-limited diffusion method has been accomplished by Th.-H. Janka and H. Suzuki (KEK, Tsukuba, Japan). It is found that the Boltzmann solver works very well for both the energy spectrum and the luminosity but not for the flux and the Eddington factor. The Boltzmann solver underestimates them while the commonly used flux limiters tend to overestimate them. This shortcoming of the Boltzmann solver can be remedied by the implementation of the variable angular mesh method. This code is planned to be used extensively for studying the effect of uncertain neutrino-nucleon scattering rates on the energy spectra and luminosities of neutrinos.

Explosive oxygen burning triggered by the aspherical shock wave resulting from neutrino driven non-spherical core collapse supernovae is being studied in the Ph.D. thesis of K. Kifonidis supervised by E. Müller. The two-dimensional simulations require locally fine resolution in a large spatial domain, which is obtained by using the adaptive mesh refinement technique. This technique was implemented into the PROMETHEUS hydrodynamic code in collaboration with T. Plewa (Nicolaus Copernicus Center, Warsaw).

In collaboration with S. Nagataki (University of Tokyo, Tokyo), M. Hashimoto (Kyushu Univ., Fukuoka, Japan), Katsuhiko Sato (Univ. of Tokyo), and Y. Mochizuki (RIKEN, Saitama, Japan), S. Yamada (Univ. of Tokyo) studied the explosive nucleosynthesis in asymmetric type II supernovae. They found that stronger alpha-rich freeze-out occurs near the rotational axis in which a jet-like shock wave propagates, leading to larger yield of ^{44}Ti which otherwise tends to be under-produced in spherically symmetric models.

J.C. Wheeler (Univ. of Texas, Austin), J.J. Cowan (Univ. of Oklahoma, Norman), and W. Hillebrandt have investigated the possibility that the site of the r-process might be the collapsing cores of stars around 8 $M_\odot$.

The light curves of Type Ia supernovae are analyzed and their diversity is studied in a Ph.D. thesis by G. Contardo, supervised by E. Müller and B. Leibundgut (ESO). Bolometric light curves have been constructed from observations for comparison with theoretical models.

A. Aksenov, S. Blinnikov and V. Utrobin (all ITEP, Moscow) have continued their work on supernova light curves and spectra, using a novel radiation hydrodynamic code. S. Blinnikov and V. Imshennik (ITEP, Moscow) also continued their work on thermonuclear detonation fronts in exploding stars in collaboration with W. Hillebrandt, and on pulsational thermonuclear explosions and non-adiabatic convection in accreting carbon-oxygen white dwarfs.

P. Ruiz-Lapuente (Univ. of Barcelona) and H. Spruit have studied the effect of the expansion on the magnetic field in a Type Ia supernova envelope and concluded that the field strength can become so low that energetic positrons travel freely through the envelope. This effect can have noticeable consequences for the late-time light curves.

M. Lisewski uses the so-called “one dimensional turbulence” model of A. Kerstein to investigate statistical properties of nuclear flames in the distributed regime. This work, a thesis supervised by W. Hillebrandt, is carried out in collaboration with S.E. Woosley (Univ. of California, Santa Cruz) and J.C. Niemeyer (MPA and Univ. of Chicago).

F. Meyer further investigated structure formation in the wind from the red supergiant stage of the progenitor of SN 1987A by ionization and heating during the subsequent final blue supergiant stage.

In a common project, K. Thornton, J.W.Truran (Univ. of Chicago), H.-Th. Janka, M. Gaudlitz, and M. Steinmetz (Univ. of Arizona, Tucson) have investigated the input of kinetic and thermal energy from supernova explosions to their environment. To this end, hydrodynamic simulations of the evolution of supernova remnants were performed for different explosion energies and for different densities and metallicities of the interstellar medium.

K. Sumiyoshi (RIKEN, Saitama, Japan) , S. Yamada (Univ. of Tokyo) and W. Hillebrandt, in collaboration with H. Suzuki (KEK, Tsukuba, Japan), have computed the dynamical evolution of a neutron star at its minimum stable mass by means of an implicit hydrodynamical code and with up-to-date nuclear input physics. They found that these objects first expand on the time-scale of slow nuclear β-decays but then explode violently. In addition, the decompression of cold neutron star matter was identified as a possible site for r-process nucleosynthesis.

3.4 Close binaries and accretion

U. Anzer and G. Börner together with T. Matsuda (Kobe University), E. Shima (Kawasaki Heavy Industries) and H. Boffin (University of Cardiff) continued their investigation of wind accretion flows. They studied two- dimensional isothermal models as approximations to flows with strong radiative cooling. They found that these flows are very similar to the corresponding adiabatic flows computed earlier for gamma=4/3 and gamma=5/3. M. Ruffert continued his investigations on Bondi-Hoyle-Lyttleton accretion using a multiply nested refined grid code. The aim is to find dependencies of the unstable flow patterns on physical parameters. The question of how much angular momentum is accreted together with mass still is an open one.

U. Kolb studied the formation of neutron star low–mass X–ray binaries, in collaboration with V. Kalogera (CfA, Harvard) and A. King (Leicester). Transient behaviour in short–period systems requires that the donor is close to the end of core hydrogen burning. This and the observed transient fraction constrain the mean kick velocity imparted to the neutron star at birth and the strength of orbital angular momentum losses. Population synthesis models show that small kicks and weak braking are preferred. In collaboration with A. King, U. Kolb (both Univ. of Leicester) and J. Frank (Louisiana State Univ., Baton Rouge), H. Ritter investigated the evolutionary state of the black hole X–ray transient source GRO J1655–40 Using standard evolutionary calculations it could be shown that the observed binary and stellar parameters must correspond to a rather short–lived evolutionary phase during which the secondary's expansion accross the Hertzsprung gap comes almost to a halt. U. Kolb further investigated various aspects of soft X–ray transients (SXTs). He calculated the evolution of black hole binaries with donor stars in the intermediate–mass range and identified a narrow parameter range where systems with a secondary in the Hertzsprung gap would appear as SXTs. In collaboration with A. King (Leicester) the effect of superluminal jets on the evolution of black hole binaries and the black hole spin has been considered. High effective Lorentz factors can reduce the mass transfer rate sufficiently to allow SXT behaviour. U. Kolb and A. King (Leicester) critically examined a method to determine the primary mass in SXTs which applies a theoretical criterion for transient behaviour. They proposed an improved mass estimate based on the spectral type of the secondary.

R. Stehle (Astronomy Department, Leicester) finished the work for his PhD at MPA (supervised by H. Spruit). In 2-D simulations of accretion disks with strong magnetic fields he found a new form of global instability which effectively redistributes angular momentum. At lower field strength (magnetic support against gravity small) the disks appear to be essentially stable.

H. Ritter together with A. King (Univ. of Leicester) presented a semi–analytical model for the light curves of soft X–ray transients. In this model the observed light curves follow naturally from the disc instability picture, if irradiation by the central X–ray source during an outburst is taken into account. Irradiation prevents the disk from returning to the cool state until central accretion is greatly reduced, thereby accounting for the long duration of the outburst and the subsequent quiescence.

K. Ludwig concluded his Ph.D. thesis on fine mesh calculations of dwarf nova outbursts (supervised by F. Meyer). In this work he followed the vertical and radial disk evolution simultaneously, which is essential for determining formation, structure and propagation of transition fronts. B.F. Liu (MPA and Yunnan Observatory, Kunming), F. Meyer and E. Meyer-Hofmeister continued the studies of disk evolution during the quiescence interval of dwarf novae and found, that the evaporation of the inner disk leads to significantly different accumulation of matter in the disk and outburst cycles. As a consequence other values have to be chosen for the viscosity parameter α. Based on the new results the evolution of WZ Sge was reinvestigated together with B.F. Liu and S. Mineshige (Kyoto Univ.)

Cao (Shanghai Observatory) and H. Spruit started a study of the stability of a magnetically driven wind coupled to an accretion disk, using a WKB expansion to reduce the global problem to a problem along individual field lines.

H. Ritter and U. Kolb completed their work on the sixth edition of the "Catalogue of cataclysmic binaries, low–mass X–ray binaries and related objects", the tabular material of which is going to be published in electronic form only.

In response to recent criticism by several authors, H. Ritter together with A. King and U. Kolb (both Univ. of Leicester) reassessed the reality of the period gap observed among cataclysmic binaries and the viability of the disrupted braking hypothesis put forward to account theoretically for it. Not only is it shown that the observed gap is real, but also that the disrupted braking model is currently the only one consistent with the observed distribution over orbital period of different subtypes of cataclysmic variables.

H.-C. Thomas together with V. Burwitz, K. Beuermann and K. Reinsch (Universitäts-Sternwarte Göttingen), A.D. Schwope (Astrophysikalisches Institut Potsdam) and several collaborators from other institutes provided follow-up studies for polars with high magnetic field strength and one polar near the lower period limit. These polars were discovered in a sample of bright soft high galactic latitude sources from the ROSAT All-Sky Survey. Together with F.V. Hessman, K. Beuermann and A. van Teeseling (Universitäts-Sternwarte Göttingen) and R.W. Romani (Stanford) H.-C. Thomas started a search for black holes among classical novae. In collaboration with R. Neuhäuser and R. Danner (MPE), S. Peschke (MPI für Kernphysik), and F.M. Walter (State Univ. of New York, Stony Brook) H.-C. Thomas studied the neutron star candidate RX J1856.3-3754 discovered in the ROSAT All-Sky Survey. ROSAT and IUE observations of the eclipsing, low field polar V2301 Ophiuchi were analyzed by H.-C. Thomas, F.V. Hessman, K. Beuermann and V. Burwitz (Universitäts-Sternwarte Göttingen), and D. de Martino (VILSPA).

H. Spruit continued the study of the X-ray spectra produced by the interaction of a hot ion torus with an embedded cool disk and found that heating of the surface layers of the disk by the energetic ions produces a Comptonizing medium with approximately the right properties.

In a collaboration of M. Gilfanov, R. Sunyaev and the GRANAT/SIGMA team variability and spectral properties of several black hole candidates were studied. Important constraints on the hard X-ray luminosity function of X-ray transients were derived. Experimental results were compared with the predictions based on the assumption that Comptonization is the dominant mechanism in black hole binaries. S. Grebenev (Space Research Institute, Russian Academy of Sciences, Moscow) studied the Comptonization of X-rays in accretion disks around black holes and the effect on the broadband spectrum. He also investigated radiation viscosity effects.

S. Sazonov (Space Research Institute, Russian Academy of Sciences, Moscow) continued his thesis work on X-ray transients (under supervision of M.Gilfanov). S. Trudolyubov's work also concerns the nature of the galactic transient sources as well as physical processes in the innermost parts of active galactic nuclei.

M. Gilfanov in collaboration with J. Nevalainen (CfA), O. Vilhu (Univ. of Helsinki), J. Poutanen (Univ. of Uppsala) and R. Narayan (CfA) studied the applicability of advection dominated accretion flow and two phase models to the X–ray spectra of the black hole candidate 1E1740.7–2942 (based on ASCA, GRANAT/SIGMA and CGRO/BATSE data).

F. Meyer and E. Meyer-Hofmeister considered the evolution of the innermost disk region in our Galaxy in connection with instabilities and the mass supply for the advective flow towards the Galactic Center.

N. Inogamov (Landau Institute for Theoretical Physics, Chernogolovska) carried out an analysis of spreading of the boundary layer on the neutron star during disk accretion. N. Sibgatullin (Moscow State University, Moscow) computed for disk accretion the ratio of energies released in the disk and on the surface of the fast rotating neutron star including effects of general relativity.

S. Sazonov analyzed the results of high-luminosity X-ray pulsar observations with GRANAT/WATCH and other instruments. A theoretical interpretation based on the accretion column model by Basko and Sunyaev is in progress. M. Revnivtsev (Space Research Institute, Russian Academy of Sciences, Moscow) finished his studies of properties of the hard X-ray emission of galactic X-ray novae and X-ray bursters on the basis of GRANAT/SIGMA, EXOSAT, ASCA and RXTE observational results. These will make up a PhD thesis on the interpretation of high-energy observations of accreting neutron stars and hard X-ray transients (under the supervision of R. Sunyaev).

M.Gilfanov studied properties of X-ray emission from X-ray bursters in collaboration with M.Revnivtsev (Space Research Institute, Moscow, Russia) E.Churazov and R.Sunyaev. Study of ASCA archival data of observations of bursters in the low spectral state (luminosity $\leq 10^{37}$ erg/sec) yielded strong restrictions on the parameters of the boundary layer and the accretion disk. In particular, it was shown that observed low state spectra are incompatible with the simple picture of an optically thick viscous boundary layer. Furthermore, the inner radius of the optically thick, geometrically thin part of the accretion disk cannot be less than $15-30R_g$.

E. Müller and W. Brinkmann (MPE) have continued the numerical study of the precessing twin jets of the binary system SS433, using the parallelized three-dimensional version of the PPM based hydrodynamic code PROMETHEUS. In order to be able to analyze the huge (~ 10 Gbyte per simulation) three dimensional data sets produced by the simulations they have developed graphical tools based on the NAG Explorer software package. The propagating helical jet exhibits pronounced instabilities, which are presently being analyzed in detail. Within five precession periods the jet is slowed down by about 50% by the "snow plough" effect. This deceleration leads to violent interactions between jet material passing through the nozzle (at the inner grid boundary) in the same direction but at different epochs (i.e. at the same precession phase).

E. Meyer-Hofmeister, S. Schandl (Institut für Astronomie und Astrophysik, Tübingen) and F. Meyer analysed together with B. Deufel and H. Barwig (both Universitätssternwarte München) their new observational data for the galactic supersoft X-ray source RX J0019.8. The night-to-night variations of the lightcurve indicate, that the amount of radiation from the elevated disk rim changes. A further understanding of the supersoft binaries was developed in collaboration with V. Suleimanov (Kazan State Univ.) by the determination of spectra of the irradiated star and disk. It could be shown that the efficiency of reprocessing of the X-rays to optical and ultraviolet light is low, ≈ 0.05, for the irradiated stellar atmosphere and disk atmosphere, but high, ≈ 0.5, for the irradiated spray matter at the disk rim, due to its different atmospheric layering. This agrees with the lightcurve modelling which suggests the structure of the disk rim is elevated at the stream impact point.

F. Meyer and E. Meyer-Hofmeister continued their collaboration with M. Kato (Keio Univ., Yokohama) and I. Hachisu (Univ. of Tokyo) on the explanation of the changes between the high and low luminosity state of the supersoft X-ray source RX J0513.9.

A. Kercek, in a thesis supervised by W. Hillebrandt and in collaboration with J.W. Truran (Univ. of Chicago) continued his 3-dimensional numerical simulations of thermonuclear burning of hydrogen-rich matter accreted onto a white dwarf. The aim of the study is to explain the mixing of carbon and oxygen into hydrogen. The statistical properties of thermonuclear combustion in the well stirred regime are studied in 2 and 3 spatial dimensions.

M. Ruffert and H.-Th. Janka have extended their three-dimensional hydrodynamic computations to neutron star collisions and the merging of unequal-mass binary neutron stars. In addition, the use of nested cubic grids allowed both finer resolution at the center and a larger computational volume. A more reliable calculation of the gas temperature was achieved by the use of an entropy equation (instead of an equation for the total energy) to follow the time evolution of the thermodynamic variables. In order to investigate the implications for the production of cosmic gamma-ray bursts, the development of the accretion torus was simulated. This forms from gas with large angular momentum after most of the mass of the merged binary has collapsed into a central black hole. The effects of general relativity were estimated by comparative simulations which employed a Paczyński-Wiita description of the gravitational potential of the central black hole. Effects on the neutrino-antineutrino annihilation in the vicinity of the accretion torus were calculated analytically. In a Diploma Thesis, supervised by H.-Th. Janka and M. Ruffert, T. Eberl has started to simulate the merging of a neutron star with a black hole.

3.5 The Galaxy, external galaxies, and Active Galactic Nuclei

M. Gilfanov and R. Sunyaev studied the properties and the origin of the diffuse X–ray emission from the Galactic Center region. The spatial distribution of the emission in the iron 6.4 keV fluorescent line is compatible with the assumption that it might have been produced by the activity of the supermassive black hole in the Galactic Center about 250 – 300 years ago at a luminosity level of $\sim 10^{39}$ erg/sec. For several Galactic Center giant molecular clouds their location along the line of sight was determined and their iron abundances were estimated. For the two brightest regions evidence was found for a Compton shoulder in the 6.4 keV line profile. An upper limit of $10^4 M_\odot$ was derived for the amount of neutral gas in the immediate vicinity (≈ 2 pc radius) of the Sgr A* compact radio and X–ray source at the dynamical Center of the Galaxy.

D. Syer and H-S. Zhao (Leiden) studied restrictions on non-axisymmetric models of galactic nuclei. Galactic nuclei are now generally thought to have density cusps in their centres, and the evidence is mounting that as a consequence they are unlikely to be triaxial. Self-consistent stellar dynamical models of non-axisymmetric cusps would be an interesting counter-argument to this conclusion. 2-d analogues of triaxial cusps were considered: a sequence of non-axisymmetric, cuspy discs first described by Sridhar & Touma (1997). Scale-free models with potential $\Phi \propto r^\alpha$ were examined in detail. It was shown analytically for $0 < \alpha < 0.43$ that self-consistent models with positive phase-space density *do not* exist. Numerical solutions of the combined Vlasov and Poisson equations suggested that the *whole* sequence of models with $0 < \alpha < 1$ is also unphysical. Together with existing work on cusps, it was concluded on purely theoretical grounds that galactic nuclei are not expected to be triaxial.

A. Ulmer, with B. Paczyński (Princeton) and J. Goodman (Princeton), investigated the possibility that optically-thick envelopes may form following the tidal disruption of a star by a massive black hole. Such envelopes would reprocess hard radiation from accretion close to the black hole into the UV and optical bands producing AGN-luminosity flares with duration ~ 1 year. They discussed relativistic effects which make the envelopes convective and showed that the photospheric radius of the envelope is very sensitive to the luminosity at the envelope base, suggesting that either the envelope collapses or the envelope expands to a maximum radius at which point a wind may set in. They described the evolution of such envelopes based on simple energy arguments.

T. Plewa (Nicolaus Copernicus Center, Warsaw), J.M$^{\underline{a}}$. Martí (Univ. Valencia, Spain) E. Müller, M. Różyczka and M. Sikora (Nicolaus Copernicus Center, Warsaw) have performed simulations of relativistic jets propagating into a non-uniform medium. In particular, they have studied the bending of jets propagating obliquely to the galactic disk of NGC 4258. The jet is bent on a scale comparable to the density scale height of the disk, the magnitude of the bending effect being largest for light jets with low Lorentz factors. The predicted direction of bending is consistent with the observations.

J. Schäfer continued calculations of two-component fits of FIRAS-COBE spectra measured in three selected regions of Galactic longitude. The cold gaseous component has been found to be closely correlated with HI column densities distributed at large scales.

In collaboration with K. Beuermann and K. Reinsch (Univ. Göttingen), A.D. Schwope (AIP, Potsdam), and J. Trümper and W. Voges (MPE), H.-C. Thomas completed the identification program for a sample of bright, soft, high galactic latitude sources from the ROSAT All-Sky Survey. The Active Galactic Nuclei from this sample were investigated by D. Grupe and H.H. Fink (MPE), K.Beuermann and K.

Mannheim (Univ. Göttingen) together with H.-C. Thomas.

Xia X.Y., Deng Z.G., Boller Th., Börner G. investigated cross-correlations of ultraluminous IRAS galaxies and ROSAT sources. The dwarf galaxy Mrk273x was identified as a strong X-ray source with an AGN type spectrum in the optical.

K. Beuermann (Univ. Göttingen) and H.-C. Thomas studied the space distribution of polars and the mean hydrogen column densities derived from their X-ray spectra.

Identification of X-ray quasars has continued during 1997. Spectroscopic confirmation and redshift determinations have been accomplished by H. Arp (MPA) in collaboration with Prof. E. Margaret Burbidge (Univ. Calif., San Diego) and Prof. Yaoquan Chu (Univ. of Science and Technology, Hefei). Empirical sequences of objects evolving from quasars to normal companion galaxies have been established. The physical nature of the intrinsic redshift of the younger objects has been analyzed, principally in collaboration with Prof. Jayant Narlikar (Inter Univ. Center for Astronomy and Astrophysics, Pune).

3.6 Gravitational lensing

S. Mao, in collaboration with D. Lennon, M. Fuhrmann, T. Gehren (USM, Munich), L. Yan and A. Renzini (ESO), carried out a real-time spectroscopic program to observe bright microlensing events toward the Galactic Bulge using the NTT at ESO. A preliminary analysis of the microlensing events observed in 1997 was completed which provided detailed information on the intrinsic properties of the source stars: radial velocities, atmospheric parameters, distances and abundances. A high priority objective of this campaign is to obtain spectra of highly magnified cool dwarfs and subgiants in order to investigate their chemical composition and by implication, the formation and evolution of the bulge.

M. Bartelmann and A. Loeb (CfA, Cambridge) investigated gravitational lensing by spiral galaxies, including the lensing effect of the disk, putting special emphasis on multiple-imaging cross sections. Main results are that overall magnification cross sections are only weakly changed by disks, but that image statistics are strongly influenced by dust in the disks. The influence of lensing on the interpretation of damped Lyman-alpha lines in QSO spectra was also discussed.

With H.J. Witt (AIP, Potsdam), S. Mao studied a general class of elliptical potentials with shear as models for multiply-imaged gravitational lenses. A minimum additional shear is needed even to reproduce the observed image positions alone. A general relation also exists between the potential axial ratio and its major axis orientation. These results are valid almost independent of the radial profile of the potential. They found that some observed systems require highly significant shear, and for one lens, HST 12531–2914, there is very likely a misalignment between the major axis of light and that of potential (mass). Therefore detailed modelling of quadruple lenses can yield valuable quantitative information about the shape of lensing galaxies and their dark matter halos.

S. Mao and P. Schneider studied whether multiply imaged QSOs can be understood with 'simple' lens models. Whereas for many lens systems they yield a remarkably good description of the observed properties, some systems are notoriously difficult to understand quantitatively. It is argued that at least for one lens, B1422+231, these difficulties are not due to a 'wrong' parametrisation of the lens model, but that the discrepancy between observed and model-predicted flux ratios is due to substructure in the lens. Such substructure can distort the flux ratios predicted by 'simple' mass models, in particular for highly magnified images, without appreciably changing image positions and time delays, and therefore has little effect on the determination of the Hubble constant. A strategy to model lens systems with substructure is also proposed.

The four months observing campaign of the multiple image system B0218+357 by I. Browne, P. Wilkinson, S. Nair (Jodrell Bank), A. Patnaik (MPIfR), R. Perley (NRAO), P. Schneider and B. Geiger has been successfully completed, and the time delay can be obtained from two independent frequency data and from the total flux and the polarization of the images. A preliminary analysis of the data yields a time delay of $\sim$11 days, which, combined with the mass model derived by B. Geiger, yields an estimate of the Hubble constant of ~ 65 km/s/Mpc.

M. Bartelmann and T.S. Kolatt (UC Santa Cruz) developed a method that combines gravitational lensing and X-ray data for galaxy clusters in order to reconstruct the structure of clusters along the line-of-sight. It was shown with simulated data that substructured clusters can be detected at high significance, and that the proposed method yields more robust and reliable cluster parameters than other commonly employed techniques.

S. Seitz investigated strong lensing signatures in the cluster MS 1512+36 in collaboration with R.P. Saglia, R. Bender, U. Hopp, P. Belloni and B. Ziegler (USM, Munich Observatory). From multi-color images with the Hubble Space Telescope, it could be shown that the extremely bright high-redshift galaxy cB58 ($z = 2.72$) in that field is lensed into a gravitational fold arc by the cluster, and a counterimage could be identified. The detailed mass properties of the inner part of the cluster derived from several multiple image systems and a weak lensing analysis are in agreement with dynamical estimates and X-ray data.

A new algorithm for reconstructing the surface mass density of clusters of galaxies from weak lensing was developed by S. Seitz and P. Schneider. Though mathematically equivalent to their previously developed noise-filter reconstruction, the new algorithm is more convenient since it reduces the reconstruction to the numerical solution of a Neumann boundary value problem. Extensive tests show that this algorithm is the best direct inversion method known, and that it is ideally suited also for mass reconstructions on irregularly-shaped data fields, such as that of the Wide-Field Planetary Camera 2 on board the Hubble Space Telescope.

T.S. Kolatt (UC Santa Cruz) and M. Bartelmann studied how supernovae of type Ia can be used to remove the so-called mass-sheet degeneracy that is inherent in all weak-lensing cluster reconstruction techniques based on galaxy distortion measurements alone.

M. Bartelmann, J. Colberg, A. Huss, A.R. Jenkins (Durham) and F.R. Pearce (Durham) used numerical cluster simulations in different cosmologies to demonstrate that the statistics of gravitationally lensed arcs is a very sensitive probe of the cosmological model. By comparison with the already known number of giant luminous arcs, the numerical results rule out a cluster-normalized standard cold dark matter universe and favour a low-density cosmological model with vanishing cosmological constant.

In his diploma thesis, supervised by P. Schneider, T. Erben has studied several aspects of galaxy-galaxy lensing, the weak lensing effect where foreground galaxies impose a distortion on the images of background galaxies. He showed that with a modest amount of observational data, galaxy-galaxy lensing can constrain the mass scale and halo size of medium-redshift field galaxies with very little statistical uncertainty. In particular, the maximum-likelihood determination of the mass parameters of galaxies is nearly unaffected by an ellipticity distribution of these mass profiles. Wide angular field surveys will provide an upper bound to the dark halo size, reaching physical scales unprobed by most other methods. Galaxy-galaxy lensing can also be used to probe the dark halo mass properties of galaxies in clusters and thus to investigate whether cluster galaxies have smaller halo sizes than their counterparts in the field. B. Geiger and P. Schneider have developed a method for investigating this effect, by separating the lens effect due to the cluster as a whole from that of individual cluster galaxies. Simulating data with clusters modelled by N-body simulations, populated by cluster galaxies, it was shown that the galaxy parameters can be accurately recovered with a maximum likelihood analysis.

The image distortion of high-redshift galaxies by the large-scale distribution of dark matter (cosmic shear) can be used to study the statistical properties of the dark matter distribution in the Universe. P. Schneider, L. van Waerbeke, B. Jain and G. Kruse have developed a new statistics for measuring cosmic shear. Their 'aperture mass' yields a very localized estimate of the power spectrum of the projected mass density. Being a scalar, the aperture mass allows one to study higher-order moments of the probability distribution; it was shown that the skewness is a sensitive probe of the cosmic density parameter. The tail of the distribution directly probes the number density of collapsed objects and thus allows one to define a mass-selected sample of dark matter halos.

P. Schneider studied the correlation between the aperture mass and the number density of foreground galaxies, weighted with the same angular filter. This provides a first-order measure of the cosmic shear and is proportional to the bias factor. This correlation can be observed even with relatively shallow observations, like the ongoing ESO Imaging Survey, provided they cover sufficient solid angle. L. van Waerbeke extended this study to account for the fully non-linear evolution of the power spectrum of the density fluctuations. The signal-to-noise ratio of this correlation coefficient is larger than estimated from the linear evolution of the power spectrum. He showed that the angular dependence of the properly normalized correlation coefficient is a very sensitive measure of the scale dependence of the bias factor.

The angular correlation function between distant QSOs and foreground galaxies resulting from gravitational lensing by the large-scale structure was studied analytically by K. Dolag in a Diploma thesis, supervised by M. Bartelmann. The main results were that the nonlinear evolution of density fluctuations in the Universe is crucial, enhancing the correlation amplitude by at least an order of magnitude, and that the change of the correlation amplitude with cosmological parameters depends sensitively on the chosen normalisation of the power spectrum of density fluctuations.

Simulating cosmic shear measurements, L. Van Waerbeke, F. Bernardeau (CEA Saclay, Paris) and Y. Mellier (IAP, Paris) studied the noise propagation and the cosmic variance of the reconstructed map of large scale structures from simulated weak lensing data, including the noise due to intrinsic ellipticities of the galaxies. Using a maximum likelihood reconstruction method, they show that the noise in the reconstructed map closely approximates white noise, with no propagation to large scales. It may be calculated from the intrinsic ellipticities of the galaxies and removed from the observed power spectrum, allowing a direct and simple estimate of the projected mass power spectrum. The particular usefulness of the aperture mass has been demonstrated explicitly.

Together with several colleagues from ESO and the ST-ECF, T. Erben, P. Schneider, S. Seitz and S. White have started to analyze data from the HST-STIS parallel survey to detect cosmic shear on angular scales below one arcminute. In addition, an ESO Key Program for the measurement of cosmic shear on somewhat larger scales was launched by Y. Mellier (IAP), F. Bernardeau (IAP), L. da Costa (ESO), W. Freudling (ESO), B. Jain, P. Schneider, S. Seitz, L. van Waerbeke and S. White

Cosmic shear also acts along the lines-of-sight to multiple imaged QSOs, and thus adds a statistical uncertainty to the parameters of the corresponding lens models. P. Schneider has shown that the influence of this cosmic shear on the lens model is considerably less than previously thought. In particular, the determination of the Hubble constant from time-delay measurements in multiply imaged QSO systems is not more affected by cosmic shear than by the mass-sheet degeneracy always present in such models.

3.7 Clusters of galaxies and large scale structure

The galaxy cluster Cl0939+472 was studied by X-ray observations with the ROSAT/HRI and ASCA by S. Schindler, P. Belloni (Universitätssternwarte München), Y. Ikebe (MPI für extraterrestrische Physik), M. Hattori (Tôhoku University, Sendai), J. Wambsganss (Astronomisches Institut Potsdam) and Y. Tanaka (MPI für extraterrestrische Physik). The cluster was found to have pronounced substructure, low X-ray luminosity and low metallicity, which is unexpected for such an optically rich cluster. Furthermore, a comparison with an earlier ROSAT/PSPC observation revealed a strongly variable source with a change in luminosity by more than a factor of ten. In collaboration with W. Forman (CFA, Cambridge), C. Jones (CFA) and H. Donnelly (CFA), M. Gilfanov has continued work on the gas temperature distribution in clusters of galaxies using ASCA data. Evidence for an ongoing merger was found in a number of clusters including A1367, Perseus, Centaurus and others. It was also suggested that X–ray observations of the fluorescent iron K_α line with good spectral resolution may provide important constraints on the amount of cold gas accumulated in the cooling flow regions.

Combined N-body/hydrodynamic simulations of the dynamics of galaxy clusters were carried out in a diploma-thesis by K. Kulp (MPI für extraterrestrische Physik), supervised by S. Schindler. From these models a catalogue of temperature maps was calculated, which can be compared directly with observed temperature maps. They show that each stage of the merging of clusters is characterized by a particular temperature distribution.

Using a set of high resolution cosmological N-body simulations G. Tormen, C. Frenk (Durham) and S.D.M. White have studied the merging history of galaxy clusters in a cold dark matter (CDM) universe. They have found that the infall of dark matter haloes onto a forming cluster is identical in universes with critical density ($\Omega_0 = 1$) and in open ones ($\Omega = 0.3$). Using similar simulations, G. Tormen, A. Diaferio, and

D. Syer investigated the survival of dark matter satellites falling into larger halos. Satellites with less than a few per cent the mass of the main halo may survive for several billion years against dynamical friction, tidal forces, and collisions with other satellites. These authors found that the fraction of satellites undergoing close encounters is similar to the fraction of interacting or merging galaxies in clusters at moderate redshift. They also predict that roughly 40% of cluster galaxies have their dark matter halos disrupted by the present time.

A. Diaferio investigated a new method to estimate the mass of galaxy clusters. This method can be applied both to the cluster central region and to its outskirts, where the usual dynamical equilibrium assumption is not valid. The method requires knowledge of galaxy redshifts and positions on the sky alone. A. Diaferio applied this method to the dark matter particles of clusters extracted from the N-body simulations of Cold Dark Matter universes. He also applied this method to catalogs of galaxies formed and evolved with the semi-analytic procedure designed by G. Kauffmann (the GIF project). The method recovers the actual mass profile within a factor of two. This error originates from projection effects, sparse sampling and contamination of foreground and background objects. In collaboration with M.J. Geller (CfA, Cambridge), A. Diaferio applied this method to the Coma cluster: in the cluster central region, where other methods can be applied, this method yields a mass in agreement with X-ray estimates.

In collaboration with Y.P. Jing (RESCEU, Japan), H.J. Mo and G. Börner have analysed the spatial correlation function and pairwise velocity dispersion of galaxies in the Las Campanas Survey. They showed, with the help of large N-body simulations, that the real-space two-point correlation function and pairwise velocity dispersion of galaxies can now both be measured reliably from the Las Campanas Redshift Survey. They found that the observed two-point correlation function is significantly flatter than the mass correlation function in current CDM models on small scales. The observed pairwise velocity dispersion is also lower than that of dark matter particles in these models. They proposed a bias model to explain these discrepancies. They concluded that CDM models with cluster-abundance normalization are consistent with the observed correlation function and pairwise velocity dispersion of galaxies. In collaboration with L. da Costa and W. Freudling (ESO), A. Nusser compared the SFI and IRAS redshift survey velocity fields finding overall consistency.

G. Börner and Y.P. Jing investigated the three-point correlation function of matter in second-order perturbation theory and in numerical simulations for several models. They found that the dependence on triangle shapes can be used to discriminate between different models. The data of the Las Campanas Survey were analysed, and the peculiar velocity dispersion as well as the 2-point and 3-point correlation functions were calculated.

V. Springel and S.D.M. White have developed new techniques for analysing the luminosity function of galaxies. These are designed to be insensitive to galaxy clustering and to be able to detect evolution of the luminosity function with redshift. They applied these techniques to the IRAS 1.2 Jy redshift survey and to the new Point Source Catalog Redshift Survey (PSCz), finding the two to be consistent and to show evidence for rapid evolution of FIR-emitting galaxies. V. Springel and S.D.M. White together with the PSCz collaboration carried out an extensive analysis of the topology of large-scale structure in the 15000-galaxy PSCz, which is currently the survey with the largest available number of resolution elements for such analysis. The data are fully consistent with the kind of structure predicted by standard hierarchical clustering theories of cold dark matter type. Together with the Virgo Consortium, V. Springel and S.D.M. White developed new methods to extend such topological analyses to a wider range of scales. They applied these techniques to large simulations carried out by the Virgo Consortium, as well as to the IRAS 1.2Jy Survey. Again structure in the real data appears consistent with that seen in the simulations.

J. Colberg and S.D.M. White have continued as active members of the Virgo Consortium, a grouping of scientists from the UK, Canada and Germany which is dedicated to carrying out simulations of large-scale structure and galaxy formation using the current generation of large parallel supercomputers, primarily CRAY T3D's and T3E's at the Edinburgh Parallel Computing Centre and the Max-Planck-Society's computer centre in Garching. Papers completed in 1997 studied: (i) the spatial and velocity correlations of the dark matter in models from the cold dark matter family with unprecedented accuracy and dynamic range – none of these models can be consistent with current observational data without scale-dependent biasing of the galaxy distribution; (ii) the formation and evolution of galaxy clusters in these same cosmologies – with well observed samples of 20 to 30 clusters it appears possible to distinguish between an Einstein-de Sitter cosmology and a low-density universe; (iii) the morphology of cluster formation and its link to the surrounding large-scale structure – the primary elements of the large-scale structure are established early and matter flows into clusters primarily along these elements.

R. Sheth developed models based on Brownian random walks to provide approximate descriptions of the evolution of nonlinear gravitational clustering. A random-walk-based model for the evolution of clustering of initially Poisson seeds with a range of masses, was shown to be identical to a model described by the additive coagulation equation. An extension of this sort of model, previously used to estimate the number density of collapsed halos, was developed. The extension allows one to describe the spatial distribution of halos as well. It provides a framework within which the evolution of clustering of dark matter, as well as of collapsed dark matter halos, can be computed self-consistently.

H. Russ (Tübingen) in his Ph.D. Thesis, supervised by G. Börner, and in collaboration with M. Kasai (Hirosaki, Japan), M. Soffel (Dresden) investigated the influence of inhomogeneities on the global expansion factor of different cosmological models. O. Ullmann in his Ph.D. Thesis, supervised by G. Börner, analysed assumptions usually made in an analysis of cosmological magnitude-redshift data. He was able to show that the much debated analysis by I. Segal is a non-parametric method which properly corrects for the Malmquist bias, but misses other effects which must be considered.

3.8 Galaxy formation, intergalactic medium and physical cosmology

D. Syer, S. Mao and H.J. Mo have examined the global stability of an exponential stellar disk embedded in a dark matter halo and constrained the mass-to-light ratio of observed disks in the I-band, Υ_I. Assuming only that the radial surface density distribution of disks is exponential, they derived an analytic upper limit: $\Upsilon_I < 2.4h$, for a Hubble constant of $100h$ km s^{-1}Mpc^{-1}. Using N-body simulations they derived a stability criterion significantly different from that of previous authors. Using this criterion they argue that, almost independent of the concentration of the halo, $\Upsilon_I < 1.9h$. They discussed this result in relation to other independent determinations of Y_I, its limitations and its implications for theories of disk formation and barred galaxies.

S. Mao, H.J. Mo and S.D.M. White used recent observations of the rotation curves of high-redshift galaxies to study the evolution of galactic disks over the redshift range $0 < z \lesssim 1$. They found that the data are inconsistent at high significance with models in which disks were already assembled at $z = 1$ and have evolved only in luminosity since that time, but they are consistent with recent data on the evolution of disk galaxy abundance as a function of size and luminosity. The evolution of galaxy disks in both size and abundance are close to the predictions of hierarchical models for galaxy formation.

S. Mao and H.J. Mo suggested that the observed galaxy population can be classified into two broad sequences which are likely to reflect their formation mechanism. The 'main sequence', consisting of spirals, irregulars and all dwarf galaxies, is probably produced by gas settling within dark matter haloes. The 'giant branch', consisting of giant ellipticals and bulges, is probably produced by the merging of disk galaxies. They discussed the connections of different populations of galaxies expected in such a scenario.

The hydrodynamics and stability of cooling flows in galaxies was investigated by A. Kritsuk (Univ. of St. Petersburg), H. Böhringer (MPE) and E. Müller. Using an explicit direct Eulerian implementation of the PPM algorithm they probed the stability of hydrostatic equilibrium recycling models of hot gaseous coronae of giant elliptical galaxies with respect to a variety of perturbations. In the absence of heat conduction the equilibria are unstable due to radiative cooling. If heat conduction is taken into account, the equilibria are stable provided the perturbations are of low ($< 10\%$) amplitude. They have also studied the cooling instability for the first time in two spatial dimensions. Using axisymmetric random velocity perturbations the instability manifests itself by a set of narrow cooling gas streams flowing towards the center of the galaxy against a global subsonic galactic wind. The characteristic averaged X-ray observables of such hybrid gas flows do not deviate significantly from those of the initial equilibrium state, although the equilibrium conditions are considerably violated.

The origin of the colour-magnitude relation of elliptical galaxies was studied by G. Kauffmann and S. Charlot (IAP,Paris). A prescription for chemical evolution was included in Kauffmann's semi-analytic models of galaxy formation, as well as the new metallicity-dependent spectral synthesis models of Bruzual and Charlot. It was demonstrated that that it is possible to obtain a good fit to the slope and scatter colour-magnitude relation of cluster ellipticals, both at present and at high redshift, in a scenario where ellipticals form from the mergers of disk systems.

The evolution of a sample of brightest cluster galaxies from a redshift of one to the present day was studied by A. Aragon-Salmanca (IoA, Camridge), C. Baugh (Durham) and G. Kauffmann. They found that these galaxies exhibit very little luminosity evolution over this range, implying that their masses have grown by a factor of 2–5. This is in good agreement with predictions from semi-analytic models.

G. Lemson (Hebrew University, Jerusalem) and G. Kauffmann have used large N-body simulations to study the correlation of dark matter halo properties, such as masses, formation times, shapes, concentrations and spins, with their environment. Only halo mass is found to correlate with local overdensity, implying that clustering differences between galaxies of different types and luminosities must arise because they occur preferentially in halos of different mass.

G. Kauffmann, J. Colberg, A. Diaferio and S.D.M. White have implemented a new scheme to include semi-analytic prescriptions for how galaxies form into large N-body simulations of dissipationless gravitational clustering. These simulations were run on the T3E parallel supercomputer at the Rechenzentrum in Garching. This scheme allowed the clustering of galaxies of different luminosities and Hubble types to be followed as a function of redshift. An important result was that although galaxies followed the underlying dark matter distribution fairly closely at the present day, star-forming galaxies were predicted to be highly-clustered relative to dark matter at high redshifts. The clustering amplitude of galaxies on small scales was found to be very sensitive to the detailed assumptions about star formation and feedback processes in galaxies, but at scales greater than $\sim 5h^{-1}$ Mpc, the predictions of the models were quite insensitive to these assumptions.

G. Lemson (Hebrew University, Jerusalem), A. Dekel (HU, Jerusalem), J. Colberg, G. Kauffmann and S.D.M. White have also used the same simulations to study the evolution of the bias relation between galaxies and dark matter in detail.

H.J. Mo, S. Mao, and S.D.M. White studied the population of galactic disks expected in current hierarchical clustering models for structure formation. They found that with reasonable assumptions on how gas settles into dark matter haloes, the predicted population can match the sizes, luminosities, rotation curves and abundances of present-day disks, as well as the damped Lyman alpha absorbers in high redshift QSO spectra.

Observations of the distribution of cold gas in damped Lyman-alpha systems have been employed by K. Jedamzik, in collaboration with J.X. Prochaska (UC, San Diego), to infer about the properties of galaxies at high redshift. Using semianalytic tools of structure formation they have shown that existing observational data on damped Lyman-alpha systems may not easily be reconciled with a population of *regular* disks within protogalactic halos of abundances and masses predicted by currently popular structure formation models.

M. Haehnelt in collaboration with M. Steinmetz (Steward Observatory, Tucson) and M. Rauch (Caltech, Pasadena) used hydrodynamic simulations of galaxy formation in a cosmological context to investigate the nature of the physical structures giving rise to damped Lyman alpha absorption systems at high redshift. It was demonstrated that rapidly rotating large disks – a long standing conjecture for the nature of damped Lyman alpha absorption systems – are not the only viable explanation for the characteristic observed asymmetric profiles. Irregular protogalactic clumps can reproduce the observed velocity width distribution and asymmetries of the absorption profiles equally well. The velocity broadening in the simulated clumps was shown to be due to a mixture of rotation, random motions, infall and merging. It was further demonstrated that most standard hierarchical structure formation scenarios can easily account even for the largest observed velocity widths.

T. Abel and H.J. Mo studied the population of QSO Lyman limit absorption systems observed at high redshifts. They proposed that many of these systems may have originated from gas trapped in minihalos that form prior to reionization. They showed that the observed number density of Lyman limit systems at high redshifts can well be reproduced by minihalos predicted in hierarchical clustering models. They discussed the properties of these systems in connection to reionization and chemical enrichment of the intergalactic medium.

M. Haehnelt in collaboration with M. Steinmetz (Steward Observatory, Tucson) used hydrodynamic simulations in a cosmological context to investigate the thermal and ionization history of the intergalactic medium. Artificial absorption spectra were produced and the Doppler parameter distribution of Lyman alpha absorption lines was calculated for a set of different reionization histories. It was shown that the best agreement with the observed Doppler parameter distribution between redshift two and four is found if hydrogen and helium are reionized simultaneously at or before redshift five with a quasar-like spectrum.

M. L. Norman, P. Paschos (UIUC/ Urbana), and Tom Abel (MPA) have developed a formalism for incorporating radiative transfer into cosmological simulations. This is of interest for (1) expansion and percolation of cosmological ionization zones (inhomogenous reionization), and (2) self-shielding effects in the He II Lyman alpha forest. Assuming an isotropic radiation field, an elliptic equation for the monochromatic energy density of the radiation field is derived, which is solved in 3D using a parallel multigrid method.

In collaboration with K.M. Górski (TAC, Copenhagen), B. Ratra (Kansas State University, Kansas), R. Stompor (IoA, Cambridge) and N. Sugiyama (Kyoto University, Kyoto), A.J. Banday considered the viability of various cosmological models in the context of CMB observations, and particularly with a normalisation determined by the COBE-DMR experiment.

H. Noh studied the evolution of cosmological gravitational waves and the vorticity in a gravity theory with quadratic order curvature couplings with J. Hwang (Kyungpook National Univ., Korea).

K. Jedamzik in collaboration with V. Katalinic (U. of Chicago) and A. Olinto (U. of Chicago) has studied the evolution of primordial magnetic fields from very early epochs until the epoch of recombination. They have shown that finite photon (neutrino) shear viscosity and heat conductivity result in the efficient damping of pre-existing primordial magnetic fields.

The formation of primordial black holes during radiation dominated eras of the Universe has been studied by K.Jedamzik in collaboration with J.C. Niemeyer (MPA/U. of Chicago). They were able to derive a cosmic initial mass function for primordial black holes.

J.B. Rehm, supervised by K. Jedamzik, has investigated the Big Bang nucleosynthesis process for the production of light-elements in the presence of segregated matter/antimatter domains.

3.9 Physical processes

In a collaboration of E. Churazov, R. Sunyaev and L. Vainshtein (Lebedev Physical Inst., Moscow) differential cross-sections for scattering of astrophysically important X-ray lines by a helium atom were calculated. In comparison with scattering by a hydrogen atom the twice larger energy “gap” (due to the structure of the energy levels) and the significantly shallower “Compton profile” (due to broader distribution of the electron momentum) provide in principle the possibility to distinguish helium and hydrogen contributions, by observing scattered spectra of X-ray emission lines. It was also shown that the value of the equivalent width and the shape of the 6.4 keV iron K_α line, emerging from neutral matter, illuminated from inside or outside by the X–ray continuum spectrum, contains information on the time history of the illuminating continuum flux.

G. Golitsyn (Inst. of Atmospheric Physics, Moscow) was working on the theory of acceleration of cosmic rays in turbulent media.

D. Uskov’s (Lebedev Physical Inst., Moscow) research was devoted to the development of a model for line emission of Fe ions. The spectral characteristics of the lines were evaluated taking into account the mechanism of charge-exchange pumping of highly-excited ion states.

In a collaboration of H.-Th. Janka and G. Raffelt (MPI Physik, München), parity violating contributions to the neutrino opacities were investigated concerning their effects on the transport of neutrinos through magnetized protoneutron star matter. For this purpose, H.-Th. Janka has developed a new Monte Carlo code that simulates the transport of all neutrino and anti-neutrino flavors and takes into account the feedback of the neutrino transport on the stellar background. The developing global anisotropy of the neutrino emission was found sufficiently large to explain observed pulsar velocities of several 100 km/s to 1000 km/s if the interior magnetic field of nascent neutron stars has a directed component of a few 10^{13}–10^{14} G.

3.10 Numerical methods

K.M. Górski (TAC, Copenhagen), E. Hivon (TAC, Copenhagen), R. Stompor (IoA, Cambridge) and A.J. Banday have studied various schemes for the pixelisation of CMB full-sky observations for next generation very high resolution satellite projects. Simulations of such CMB skies are being studied in order to assess various important issues for the instrumental design and scanning strategy of the ESA-PLANCK satellite mission. Methods of component separation and power spectrum estimation are being implemented.

M. Reinecke has been implementing a novel front-tracking scheme into the multi-dimensional hydrodynamic code PROMETHEUS. His diploma thesis under the supervision of W. Hillebrandt is aiming at better tools for numerical simulations of thermonuclear supernovae. The method is developed in collaboration with R. Klein (Humboldt-Univ., Berlin) and J.C. Niemeyer (MPA and Univ. of Chicago).

In order to study the stability of powerful axisymmetric relativistic jets a 3D relativistic high-resolution shock-capturing hydrodynamic code has been developed by M.A. Aloy, J.Mª Martí, José Mª. Ibáñez (Univ. Valencia, Spain) and E. Müller. The code is parallelized for shared and virtually shared memory machines (e.g., CRAY JEDI and SGI Origin 2000). A CRAY T3E version is presently under development.

K. Kifonidis, T. Plewa (Nicolaus Copernicus Center, Warsaw) and E. Müller have extended the two-dimensional adaptive mesh refinement code AMRA in order to handle two-dimensional reactive flows. In particular, they have used AMRA in combination with the hydrodynamic code PROMETHEUS to model explosive nuclear burning the latter being described by a 13 species nuclear reaction network.

T. Plewa (Nicolaus Copernicus Center, Warsaw) and E. Müller have been working on extending the 2D version of the adaptive mesh refinement code AMRA to three spatial dimensions. A well tested version of AMRA-3D is expected to be ready in the middle of 1998.

3.11 Quantum mechanics of atoms and molecules; astrochemistry

Accurate and reliable theoretical studies are required, among other reasons, to assist in the interpretation of the Rydberg spectra of atoms and molecules, of their complexes with rare gas atoms and with other molecules, as well as of atoms and molecules embedded into small clusters and into the condensed phase. Corresponding investigations are being persued in close cooperation with experimental spectroscopists (R.J. Donovan, K.P. Lawley; Edinburgh, UK; K. Yamanouchi, Tokyo, Japan). Theoretical studies of clusters involving the iodine or iodine-bromine molecule as cromophores and different rare gas and diatomic ligands are of particular interest for understanding the changes on the chromophore due to the interction with different environments. The interpretation of recent experimental observations of the Rydberg spectra of the cations HCl+ and HBr+ require, in particular, theoretical studies of the structure and stability of doubly and of higher charged cations. Rigorous quantum chemical studies using the coupled-cluster method have been performed for the doubly and triply charged cation of the sulphur molecule and confirm the existence of metastable electronic ground and excited states (M. Urban; Bratislava, Slovak Republic). Challenging theoretical studies are being performed in order to investigate the proposed formation of cavities around the Rydberg states of atoms like gold and silver and molecules like carbonmonoxide in liquid helium. (G.H.F. Diercksen, E.W. Schreiner).

The photodynamic therapy of cancer is based on the use of light sensitive molecules, called photosensitizers. A concerted experimental, theoretical and clinical effort is being persued to understand the molecular processes involved in this therapy. The photophysical properties of potentially highly effective carcinolytic agents - the push-pull porphyrins - have been studied. The results predict a substantial redshift in the long wavelength electronic spectra of substituted free-base porphyrins. Therefore the respective compounds are suggested as favorable candidates for deep-penetrating photodynamic therapeutic agents. (R. Pottier, V.H. Smith; Kingston, Canada; S. Yamamoto; Toyota, Japan, M. Karelson, Tartu, Estonia; G.H.F. Diercksen).

Recent rigorous quantum mechanical state-to state studies of the radiative association formation process of diatomic molecular ions have been continued by investigating the formation of He_2^+ (W.P. Kraemer). For this small, weakly bound ion the reliability of the *ab initio* calculations can be directly assessed by comparing with the results of high-resolution spectroscopical measurements of transitions between highly excited rotation-vibrational levels in the region of the dissociation limit. Further calculations have been performed for the "atmospheric" molecular ions O_2^+, N_2^+, und CO^+ (W.P. Kraemer; M Juřek, Prague, Czeck Republic). Partition functions for He_2^+ and the rare gas hydride ions XH^+ (X=He, Ne, Ar) have been determined over a wide temperature range (W.P. Kraemer; P. Soldán, Prague, Czeck Republic). The extension of the *ab initio* state-to state studies of the radiative association formation process to general triatomic molecules is still a major problem due to the high density of highly excited rotation-vibrational levels close to the dissociation limit and due to the resulting strong couplings among these states. A new method has been devised by applying the concept of the adiabatic separation of the vibrational motions and using high-order Rayleigh-Schrödinger perturbation theory to evaluate the non-adiabatic coupling effects (V. Špirko, Prague, Czeck Republic). This new method has been applied to the triatomic model system HeH_2^+. For this weakly bound small complex improved potential energy hypersurfaces for the ground and the first excited electronic states have been calculated together with their dipole transition moments (W.P. Kraemer). The new perturbational approach has been tested also for the special case of the Coulomb potential in the positronium ion (W.P. Kraemer; V. Špirko and P. Soldán, Prague, Czeck Republic).

The recently developed method for calculating electronic resonances in low-energy electron-molecule collisions has been extended to include also vibronic couplings between Rydberg levels close to the ionization limit (P.-Å. Malmqvist, Lund, Sweden).

The computer code for calculating rotation-vibrational spectra of triatomic molecules with Renner-Teller coupled electronic states has been extended to permit also the computation of transition probabilities and intensities (P. Jensen and G. Osmann, Wuppertal) and has been applied to calculate the rovibronic spectra of CH_2^+ and NH_2^+ (P.R. Bunker, Ottawa, Canada; W.P. Kraemer).

A revised data set of collision induced H_2 - H_2 absorption coefficients for any ortho-/para-ratio of H_2 at frequencies ≤ 400 cm^{-1} and temperatures up to 300 - 400 K has been prepared. It will be used in model calculations of the outer atmospheres of the Heavy Planets (J. Schäfer).

The progress in computer hardware and in software engineering has made it possible to apply methods of quantum theory to study chemical and physical phenomena of molecules in complex solute-solvent systems. However, many industrial processes and almost all biomedical important processes are characterized by such high complexity that there is little hope that they will become accessible to quantum chemical studies in foreseeable future. Therefore the development and use of alternative theoretical approaches for describing properties of increasingly complex molecular systems is of high practical relevance. A most interesting and promising direction for the theoretical description of molecular properties and reactivity in condensed media is emerging from the efficient combination of the methods of quantum theory with the search for theoretical quantitative structure-activity/property relationships (M. Karelson, Tartu, Estonia; G.H.F. Diercksen).

In science and technology large amounts of data are generated, mostly in electronic form, by observations, experiments, and computer simulations. In the computational sciences large amounts of data are generated routinely as result of simulating physical and chemical properties. Surprisingly little attention has been paid to discovering and using hidden knowledge in data generated in research and technology. This seems primarily due to the fact that, in general, the data describing a case, like an observation, an experiment or a simulation, are large and of increasing complexity. For discovering new knowledge it is necessary to define objects and to develop classification schemes and similarity measures. In general, in science the object is an arbitrary complete study and is referred to (by us) as a Case. It is important to note that instances of a Case may serve a manifold of different purposes. Most important, they may serve for defining, organizing, performing and documenting observations, experimental studies and computer simulations. Case bases containing the evaluated results of completed studies may serve as basis for machine learning, case-based reasoning, knowledge discovery (data mining) and computer based learning. It is easily recognized that the concept of a Case and its formal definition have been developed originally for use within the framework of case based reasoning with the aim of developing intelligent scientific software in computational chemistry. But it is easily recognized that a Case can be processed by different software tools, possibly residing on remote hosts, each performing a specific task. This provides the possibility to perform a case study by sending the Case in the appropriate order to different software tools, possibly connected to an observation or experiment, for processing. This concept of a Case forms the basis of the OpenMol project developed by an international cooperation involving groups from Estonia (M. Karelson; Tartu), Finland (L. Laaksonen; Espoo), Germany (G.H.F. Diercksen, E.W. Schreiner), Japan (S. Yamamoto; Toyota), Northern Ireland (S. Bates, P Kilpatrick), Poland (W. Duch, J. Karwowski; Torun) and the Slovak Republic (V. Kellv, M. Urban; Bratislava).

3.12 Observational projects and review talks

3.12.1 Observational projects

I. Aretxaga (MPA), R. Terlevich (RGO), I. Salamanca (RGO), L. Ho (CfA), A. Filippenko (Berkeley): Nov. 5 – Nov. 6, William Herschel Telescope, La Palma, Spain, ISIS, Busqueda de variabilidad en AGNs de baja luminosidad;

R. Terlevich (RGO), I. Aretxaga (MPA), I. Salamanca (RGO), L. Ho (CfA), A. Filippenko (Berkeley): Nov. 7 – Nov. 8, William Herschel Telescope, La Palma, Spain, ISIS, Search for LLAGN variability;

M.A.T. Groenewegen, R.D. Oudmaijer (Imperial College): Jan. 15 – Jan. 16, IRAM, Pico Veleta, Spain, 30m telescope, spectrometers, CO observations of two red carbon stars in the galactic halo;

F. Kerschbaum (Vienna), M.A.T. Groenewegen, C. Lazaro (IAC), H. Habing (Leiden), J. Hron (Vienna): Feb. 17 – Feb. 18, IAC, Tenerife, Spain, 1.5m TCS, IR photometer, A search for long-period carbon Mira variables;

M.A.T. Groenewegen, W.E.C.J. van der Veen (Columbia), H. Habing (Leiden), A. Omont (IAP): March 20 – March 21, IRAM, Pico Veleta, Spain, 30m telescope, bolometer, The recent mass loss history of highly evolved stars;

M.A.T. Groenewegen, H.-G. Ludwig: April 2 – April 4, IRAM, Pico Veleta, Spain, 30m telescope, spectrometers, A CO blob ejected by IRC +10 216 ?

F. Kerschbaum (Vienna), M.A.T. Groenewegen, C. Lazaro (IAC), H. Habing (Leiden), J. Hron (Vienna): Aug. 29 – Aug. 31, IAC, Tenerife, Spain, 1.5m TCS, IR photometer, A search for long-period carbon Mira variables;

M.A.T. Groenewegen: Sept. 20 – Sept. 21, ESO, La Silla, Chile, SEST, 15m telescope, spectrometers, Do short period Miras lose mass, or how effective is radiation pressure on dust?

M.A.T. Groenewegen, A. Omont (IAP), H. Habing (Leiden), M. Sevenster (Leiden): Oct. 18 – Oct. 22, IRAM, Pico Veleta, Spain, 30m telescope, spectrometers, The dynamical behaviour of infrared carbon stars;

Stone R.E.S (Lick Obs.), M.A.T. Groenewegen, C. Barnbaum (STScI): Nov. 11 – Nov. 12, Lick Observatory, Mt. Hamilton, U.S.A., 3m Shane telescope, Kast spectrograph, Optical spectroscopy of infrared carbon stars;

H.E. Matthews (JCMT), W.E.C.J. van der Veen (Columbia), M.A.T. Groenewegen: Dec. 3, James Clark Maxwell Telescope, Mauna Kea, Hawaii, SCUBA, The recent mass loss rate history of highly evolved stars;

F. Kerschbaum (Vienna), M.A.T. Groenewegen, C. Lazaro (IAC), H. Habing (Leiden), J. Hron (Vienna): Dec. 26 – Dec. 28, IAC, Tenerife, Spain, 1.5m TCS, IR photometer, A search for long-period carbon Mira variables;

H. Barwig (Univ. Sternwarte Munich), B. Deufel (Univ. Sternwarte Munich), S. Schandl (Univ. Tübingen), E. Meyer-Hofmeister: Oct. 27 – Oct. 30, Calar Alto, Spain, MPI für Astronomie Heidelberg, Doppler tomography of the supersoft X-ray source RX J0019+2156;

I. Browne, P. Wilkinson, S. Nair (Jodrell Bank), A. Patnaik (MPIfR), R. Perley (NRAO), P. Schneider, B. Geiger: Oct. 96 – Jan. 97, VLA snapshots für die Vermessung der Lichtkurve des Gravitationslinsensystems B0218+35.7;

J.-P. Kneib (Toulouse), Y. Mellier (IAP), P. Schneider, L. van Waerbeke (Toulouse), B. Fort (DEMIRM), H.-W. Rix (Steward Observatory): May 23 – May 25, Canadian-French-Hawaii-Telescope, Mouna Kea, Hawaii, UH8K, Measuring the mean mass profile of field galaxies using galaxy-galaxy lensing;

Y. Mellier (IAP), F. Bernardeau (IAP), L. da Costa (ESO), W. Freudling (ESO), B. Jain, P. Schneider, S. Seitz, L. van Waerbeke, S. White: ESO Key Program, 180 hours NTT/SUSI, Probing cosmological scenarios from cosmic shear measurements;

H.-W. Rix (Steward Observatory), S. Seitz, M. Bartelmann, P. Schneider: April 9 – April 15, University of Arizona Observatories, AGN magnification by large-scale structure in the foreground;

T. Augusteijn (Santiago), H.C. Spruit: April 21 – April 22, ESO 3.5m, La Silla, Chile, Spectroscopy of new southern CVs;

H.-C. Thomas: Feb. 28 – March 6, ESO, La Silla, Chile, 2.2m Telescope, EFOSC 2, zeitaufgelöste Spektroskopie neuer magnetischer CVs;

H.-C. Thomas, F.V. Hessman (Göttingen), R.W. Romani (Stanford), K. Beuermann (Göttingen), A. van Teeseling (Göttingen): June 19 – June 24, Calar Alto Observatory, Spain, 2.2m Telescope, MAGIC, Schwarze Löcher unter den klassischen Novae?

3.12.2 Review talks

M. Bartelmann: Theoretical Physics Seminar, Zürich University (Zürich, Jan. 6);

M. Bartelmann: SFB Workshop on “Neutrino Astrophysics” (Ringberg Castle, Rottach–Egern, Germany, Oct. 20 – Oct. 24)

M. Gilfanov: Nordic Symposium in “Theoretical High Energy Astrophysics” (Copenhagen, Sept. 14 – Sept. 16)

M.A.T. Groenewegen: Third Euroconference on “The impact of near-infrared surveys on Galactic and extragalactic astronomy” (Meudon, France, June 19 – June 20)

M.A.T. Groenewegen: “ISO’s view on stellar evolution” (Noordwijkerhout, Netherlands, July 1 – July 4)

W. Hillebrandt: Int. Conf. on “Supernova Explosions: Their Causes and Consequences” (ITP, Univ. of California, Santa Barbara, Aug. 4 – Aug. 9)

W. Hillebrandt: SFB Workshop on “Neutrino Astrophysics” (Ringberg Castle, Rottach–Egern, Germany, Oct. 20 – Oct. 24)

H.-Th. Janka: 5th CTIO/ESO/LCO Workshop “SN1987A: Ten Years After” (La Serena, Chile, Feb. 22 – Feb. 28)

H.-Th. Janka: Colloquium in Honor of Prof. G. Tammann “Supernovae and Cosmology” (Augst, Switzerland, June 13)

H.-Th. Janka: ITP Workshop on “Supernova Explosions: Their Causes and Consequences” (Santa Barbara, USA, Aug. 5 – Aug. 9)

H.-Th. Janka: Erice International School on Nucl. Physics, 19th course “Neutrinos in Astro-Particle and Nuclear Physics” (Erice, Sicily, Sept. 16 – Sept. 24)

H.-Th. Janka: SFB Workshop on “Neutrino Astrophysics” (Castle Ringberg, Rottach-Egern, Germany, Oct. 20 – Oct. 24)

K. Jedamzik: SFB Workshop on "Neutrino Astrophysics" (Ringberg Castle, Rottach-Egern, Germany, Oct. 20 – Oct. 24)

G. Kauffmann: STScI Workshop on the "Hubble Deep Field" (Baltimore, USA, May 6 – May 9)

G. Kauffmann: Workshop on "Dark Halos of Galaxies" (Santa Cruz, USA, Aug. 11 – Aug. 15)

G. Kauffmann: IAU Symposium 186: "Galaxy Interactions at Low and High Redshift" (Kyoto, Japan, Aug. 26 – Aug. 30)

G. Kauffmann: IAU Symposium 187: "Cosmic Chemical Evolution" (Kyoto, Japan, Aug. 26 – Aug. 30)

G. Kauffmann: "The Young Universe" (Rome, Italy, Sept. 29 – Oct. 3)

U. Kolb: "13th North American Workshop on CVs" (Wyoming, USA, June 14 – June 19)

H.J. Mo: Workshop on "Dark Halos of Galaxies" (Santa Cruz, USA, Aug. 11 – Aug. 15)

E. Müller: 2nd Edoardo Amaldi Conference on "Gravitational Waves" (CERN, Switzerland, July 1 – July 4)

E. Müller: ITP Workshop on "Supernova Explosions: Their Causes and Consequences" (Santa Barbara, USA, Aug. 5 – Aug. 9)

E. Müller: Crafoord Symposium on "Late Stellar Evolution and Nucleosynthesis" (Stockholm, Sept. 30 – Oct. 1)

P. Schneider: Jodrell-Bank Workshop on "Golden Lenses: The Hubble Constant and galaxies at high redshift" (Jodrell Bank, USA, June 23 – June 25)

P. Schneider: Annual Meeting of the Brazilian Astronomical Society "New Trends in Astronomy in the Transition of the Century" (Angra dos Reis, Brazil, Aug. 3 – Aug. 7)

P. Schneider: "General Relativity and Cosmology" (Kyoto, Oct. 27 – Oct. 30)

P. Schneider: Joint ESO/Australian Conference "Looking Deep in the Southern Sky" (Sydney, Dec. 10 – Dec. 12)

H.C. Spruit: IAU Symposium 185 "New Eyes to See Inside the Sun and Stars" (Kyoto, Aug. 23 – Aug. 27)

R. Sunyaev: Nordic Symposium in Theoretical High–Energy Astrophysics, "Exploiting SPECTRUM–XG and INTEGRAL" (Copenhagen, Sept. 14 – Sept. 16)

R. Sunyaev: "Particle Physics and the Early Universe" in connection with the centenary of the discovery of the electron by J.J.Thomson; Cavendish Laboratory (Cambridge, UK, April 7 – April 15)

R. Sunyaev: Joint European and National Astronomical Meeting for 1997 "JENAM - 97" (Thessaloniki, Greece, July 2 – July 5)

R. Sunyaev: "Galactic Dynamics", (Princeton, USA, May 19 – May 21)

R. Sunyaev: Conference in honour of Riccardo Giacconi; (Rome, Italy, Oct. 24 - Oct. 25)

R. Sunyaev: SFB Workshop on "Neutrino Astrophysics" (Ringberg Castle, Rottach–Egern, Germany, Oct. 20 – Oct. 24)

R. Sunyaev: III International Conference on CosmoParticle Physics "COSMION-97" (Moscow, Russia, Dec. 8 – Dec. 13)

D. Syer: Pune Workshop "Dynamics of the Centres of Galaxies: Massive Black Holes in Galactic Nuclei" (Pune, India, July 3 – July 5)

S.D.M. White: Workshop on "Gravitational Lensing" (Ringberg Castle, Rottach–Egern, Germany, Jan. 20 – Jan. 24)

S.D.M. White: Workshop on "Science with the New Generation Space Telescope" (GSFC, Baltimore, USA, April 7 – April 9)

S.D.M. White: Workshop on "Cosmic Microwave Background" (Cambridge, UK, April 8 – April 11)

S.D.M. White: Workshop on "The Hubble Deep Field" (Baltimore, USA, May 7 – May 9)

S.D.M. White: Workshop on "Radio cosmology" (Ringberg Castle, Rottach–Egern, Germany, May 12 – May 16)

S.D.M. White: Workshop on "The Microwave Background" (Copenhagen, Denmark, May 29 – May 31)

S.D.M. White: NAS/GAAC Symposium "The Frontiers of Science" (Munich, Germany, June 19 – June 22)

S.D.M. White: IAP Astrophysics Colloquium "Structure and evolution of the Intergalactic Medium from Quasar Absorption Lines" (Paris, France, June 30 – July 5)

S.D.M. White: International Workshop LTD-7 on "Low Temperature Detectors" (Munich, Germany, July 29 – Aug. 1)

S.D.M. White: Workshop on "Dark Halos of Galaxies" (Santa Cruz, USA, Aug. 11 – Aug. 15)

S.D.M. White: IAU Symposium 186: "Galaxy Interactions at Low and High Redshift" (Kyoto, Japan, Aug. 26 – Aug. 30)

S.D.M. White: IAU Symposium 187: "Cosmic Chemical Evolution" (Kyoto, Japan, Aug. 26 - Aug. 30)

S.D.M. White: International Cosmology Workshop "Large–Scale Structure Tracks and Traces" (Potsdam, Germany, Sept. 15 – Sept. 20)

S.D.M. White: International Workshop on "The Young Universe" (Rome, Italy, Sept. 29 – Oct. 3)

S.D.M. White: Workshop on "Galaxy Clusters" (Ringberg Castle, Rottach–Egern, Germany, Oct. 6 – Oct. 10)

S.D.M. White: Austrian Science Day 1997 (Semmering, Austria, Oct. 23 – Oct. 25)

S.D.M. White: Conference on "The Non-Sleeping Universe" (Porto, Portugal, Nov. 27 – Nov. 29)

4 Publications

4.1 Publications in journals

4.1.1 Publications that appeared in 1997:

Alonso, A., M. Salaris, C. Martinez-Roger, O. Straniero and S. Arribas: CCD photometry of the metal-rich halo cluster NGC6366. Astron. Astrophys. **323**, 374–381 (1997).

Arp H., J. Narlikar and H.-D. Radecke: High energy radiation from the center of the Local Supercluster. Astro Particle Physics **6**, 387–394 (1997).

Arp. H.: Discordant comments on compact groups. Astrophys. J. **474**, 74–83 (1997).

Arp, H.: Pairs of X-ray sources across Seyferts: the NGC4235 field. Astron. Astrophys. **328**, L17–L20 (1997).

Arp, H.: Concentration of quasars around the active extragalactic object 3C345. Astron. Astrophys. **327**, 479–482 (1997).

Arp, H.: Identification of X-ray sources $l1$ degree from Seyfert Galaxies. Astron. Astrophys. **319**, 33–44 (1997).

Arp, H.: New evidence on the excess redshift of companion galaxies. Astrophys. and Space Science **250**, 163–170 (1997).

Banday, A.J., K.M. Górski, C.L. Bennett, G. Hinshaw, A. Kogut, C.L. Lineweaver, G.F. Smoot and L. Tenorio: Root Mean Square Anisotropy in the COBE DMR Four-Year Sky Maps. Astrophys. J. **475**, 393–398 (1997).

Bartsch, A., P. Schneider and M. Bartelmann: Reanalysis of the association of high-redshift 1-Jansky quasars with IRAS galaxies. Astron. Astrophys. **319**, 375–393 (1997).

Böhringer, H., D.M. Neumann, S. Schindler and J.P. Huchra: Stripped spiral galaxies as ideal targets for the determination of the Cepheid distance to the Virgo cluster. Astrophys. J. **485**, 439–446 (1997).

Burbidge, G., F. Hoyle and P. Schneider: Very close pairs of quasi-stellar objects. Astron. Astrophys. **320**, 8–12 (1997).

Burwitz, V., K. Reinsch, K. Beuermann, H.-C. Thomas: Two new ROSAT discovered high field polars: RX J2022.6–3954 in Sagittarius and RX J0132.7–6554 in Hydrus. Astron. Astrophys. **327**, 183–190 (1997).

Cassisi, S., S. Degl'Innocenti and M. Salaris: The effect of diffusion on the red giant luminosity function 'bump'. Mon. Not. R. Astron. Soc. **290**, 515–520 (1997).

Cassisi, S. and M. Salaris: A critical investigation on the discrepancy between the observational and the theoretical red giants luminosity function 'bump'. Mon. Not. R. Astron. Soc. **285**, 593–603 (1997).

Davis, M., A. Miller and S.D.M. White: A galaxy–weighted measure of the relative peculiar velocity dispersion. Astrophys. J. **490**, 63–71 (1997).

Denissenkov, P., A. Weiss and J. Wagenhuber: Could intermediate-mass AGB stars produce star-to-star abundance variations in globular-cluster red giants? Astron. Astrophys. **320**, 115–124 (1997).

Diaferio, A. and M. J. Geller: Infall regions of galaxy clusters. Astrophys. J. **481**, 633–643 (1997).

Dolag, K. and M. Bartelmann: QSO-galaxy correlations in arbitrary Friedmann-Lemaitre cosmologies. Mon. Not. R. Astron. Soc. **291**, 446–454 (1997).

Flocke, N., M. Barysz, J. Karwowski and G.H.F. Diercksen: Symmetric group approach to relativistic CI. II. Reduction of matrices in the spin space. Intern. J. Quantum Chem. **61**, 11–20 (1997).

Flocke, N., M. Barysz, J. Karwowski and G.H.F. Diercksen Symmetric Group Approach to Relativistic CI. III. Matrix elements for spin-dependent operators. Intern. J. Quantum Chem. **61**, 21–34 (1997).

Gan-Baruch, Z., R. Wegmann, A. Eviatar and H.U. Schmidt: A two ion fluid model with gyrotropic pressures for the comet interaction with the solar-wind, Computer Phys. Comm. **103**, 131–144 (1997).

Gänsicke, B.T., K. Beuermann, H.-C. Thomas: EK TrA, a close relative of VW Hyi. Mon. Not. R. Astron. Soc. **289**, 388–392 (1997).

Gosset, E., O. Moreau, J. Surdej, J.-P. Swings and H. Arp: Surveys of ultraviolet-excess quasar candidates in large fields. Astron. Astrophys. Suppl. Ser. **123**, 529–568 (1997).

Groenewegen, M.A.T., van der Veen W.E.C.J., Lefloch B. and Omont A.: The extended 1.3 mm continuum emission around CW Leo. Astron. Astrophys. **322**, L21–L24 (1997).

Groenewegen, M.A.T., Oudmaijer R.D., Ludwig H.-G.: Two mass losing carbon stars in the galactic halo. Mon. Not. R. Astron. Soc. **292**, 686–694 (1997).

Hameury, J.–M. and H. Ritter: Illumination in binaries. Astron. Astrophys., Suppl. Ser. **123**, 273–277 (1997).

Hattori, M., Y. Ikebe, I. Asaoka, T. Takeshima, H. Böhringer, T. Mihara, D.M. Neumann, S. Schindler, T. Tsuru and T. Tamura: A dark cluster of galaxies at z=1. Nature **388**, 146–148 (1997).

Hessman, F.V., K. Beuermann, V. Burwitz, D. de Martino, H.-C. Thomas: The eclipsing AM Herculis binary V2301 Ophiuchi. I. ROSAT & IUE observations. Astron. Astrophys. **327**, 245–251 (1997).

Ivezić, Z., Groenewegen M.A.T., Men'schchikov A. and Szczerba R.: Benchmark problems for dust radiative transfer. Mon. Not. R. Astron. Soc. **291**, 121–124 (1997).

Juřek, M. V. Špirko, and W.P. Kraemer: *Ab initio* calculated rotation-vibration linestrengths for HeH_2^+. J. Molec. Spectrosc. **182**, 364–370 (1997).

Kauffmann, A., A. Nusser and M. Steinmetz: Galaxy formation and large-scale bias. Mon. Not. R. Astron. Soc. **286**, 795–811 (1997).

Keil, W., H.-Th. Janka, D.N. Schramm, G. Sigl, M.S. Turner and J. Ellis: A fresh look at axions and SN 1987A. Physical Review D **56**, 2419–2432 (1997).

King, A.R., J. Frank, U. Kolb and H. Ritter: Mass transfer cycles in close binaries with evolved companions. Astrophys. J. **482**, 919–928 (1997).

King, A.R., J. Frank, U. Kolb and H. Ritter: Transients among binaries with evolved low–mass companions. Astrophys. J. **484**, 844–847 (1997).

Klobukowski, M. G.H.F. Diercksen and J. M. Garcia de la Vega: Electron affinity of SF6. Advan. Quantum Chem. **28**, 189–203 (1997).

Kolb, U. and M. Politano: The contribution of O-Ne-Mg novae to the Al-26 production in the Galaxy. Astron. Astrophys. **319**, 909–922 (1997).

Kolb, U., A.R. King, H. Ritter and J. Frank: The transient nature of GRO J1655–40 and its evolutionary state. Astrophys. J., Lett. **485**, L33–L36 (1997).

La Dous, C., F. Meyer and E. Meyer-Hofmeister: UV observations of dwarf novae in quiescence - effects of evaporation? Astron. Astrophys. **321**, 213–219 (1997).

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White, S.D.M.: The physical origin of galaxy scaling relations. In: Galaxy Scaling Relations, Eds. L. da Costa, A. Renzini. Springer 1997, 3–14.

White, S.D.M.: Hierarchical clustering and galaxy formation. In: The Evolution of the Universe, Eds. G. Börner, S. Gottlöber. Wiley 1997, 227–244.

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4.3 Popular articles and books

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Börner, G.: Astronomen im Jagdfieber. Süddeutsche Zeitung (9. 1. 1997).

Börner, G.: Ist das kosmologische Standardmodell in Gefahr? Physik in unserer Zeit **28**, 6–16 (1997).

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Börner, G. and S. Gottlöber (Eds.): The Evolution of the Universe. Dahlem Workshop Report. John Wiley & Sons, Chichester 1997, 308p.

Janka, H.-Th. and S.D.M. White (Eds.): Annual Report of the Max-Planck-Institut für Astrophysik 1996. Max-Planck-Institut für Astrophysik, Garching 1997, 74p.

Kafka, P.: Zwei Dinge. In: Atlas der Sternbilder, Eds. E. Slawik und U. Reichert. Spektrum Akademischer Verlag, Heidelberg 1997, 196–207.

Kauffmann, G.: The case of the missing ellipticals. News and Views, Nature **390**, 346–347 (1997).

Meyer-Hofmeister, E. and H. Spruit (Eds.) Accretion Disks – New Aspects. Lecture Notes in Physics, vol. 487. Springer Verlag, Heidelberg 1997, 356p.

Ruffert, M. and H.-Th. Janka: Kosmische Gammastrahlenblitze — dem Rätsel auf der Spur. In: Forschung und wissenschaftliches Rechnen – Beiträge zum Heinz-Billing-Preis 1996, GWDG-Bericht Nr. **44**, Eds. T. Plesser, P. Wittenburg. Gesellschaft für wissenschaftliche Datenverarbeitung, Göttingen 1997, 125–143.

Ruffert, M. and H.-Th. Janka: Wenn Neutronensterne miteinander verschmelzen. In: MPG Spiegel 3/1997, 64–68.

4.4 Preprints ("Green Reports")

The following preprints appeared in 1997 as official MPA "Green Reports":

Anzer, U., P. Heinzel: Prominence parameters derived from magnetic-field measurements and NLTE diagnostics. MPA 1022

Aretxaga, I., R.J. Terlevich, B.J. Boyle: Multicolour imaging of z=2 QSO hosts. MPA 1055

Bartelmann, M., A. Huss, J.M. Colberg, A. Jenkins, F.R. Pearce: Arc statistics with realistic cluster potentials. IV. Clusters in different cosmologies. MPA 1037

Bartelmann, M., A. Loeb: Effects of disks on gravitational lensing by spiral galaxies. MPA 1068

Bartelmann, M., T.S. Kolatt: Resolving the light-of-sight structure of galaxy clusters by combining X-ray and lensing date. MPA 1028

Blinnikov, S., R. Eastman, O. Bartunov, V. Popolitov, S. Woosley: A comparativemodeling of supernova 1993J. MPA 1049

Blinnikov, S., R. Moessner: Expansions for nearly Gaussian distributions. MPA 1051

Colberg, J.M., S.D.M. White, A. Jenkins, F.R. Pearce: Linking cluster formationto large scale structure. MPA 1047

Davis, M., A. Miller, S.D.M. White: A galaxy-weighted measure of the relative peculiar velocity dispersion. MPA 1015

Denissenkov, P.A., G.S. Da Costa, J.E. Norris, A. Weiss: The puzzling MgAl anticorrelation in globular-cluster red giants: primordial plus deep mixing scenario? MPA 1039

Dolag, K., M. Bartelmann: QSO-galaxy correlations due to weak lensing in arbitrary Friedmann-Lemaitre cosmologies. MPA 1020

Forcada-Miró, M.I., S.D.M. White: Radiative shocks in galaxy formation. I. Cooling of a primordial plasma with no sources of heating. MPA 1071

Forcada-Miró, M.I.: II. Effects of a metagalactic UV background. MPA 1071

Gan-Baruch, Z., R. Wegmann, A. Eviatar, H. U. Schmidt: A two ion fluid model with gyrotropic pressures for the comet interaction with the solar-wind. MPA 1019

Gan-Baruch, Z., R. Wegmann, A. Eviatar, H.U. Schmidt: Results from a gyrotropic two ion fluid model for the comet interaction with the solar-wind. MPA 1018

Geiger, B., P. Schneider: Constraining the mass distribution of cluster galaxies by weak lensing. MPA 1030

Groenewegen, M.A.T., J.A.D.L. Blommaert: Near-infrared photometry and optical spectroscopy of IRAS sources in the small Magellanic Cloud. MPA 1066

Groenewegen, M.A.T., P.A. Whitelock, C.H. Smith, F. Kerschbaum: Dust shells around carbon Mira variables. MPA 1040

Groenewegen, M.A.T., R.D. Oudmaijer, H.-G. Ludwig: Two mass losing carbon stars in the galactic halo. MPA 1038

Haehnelt, M.G., M. Steinmetz, M. Rauch: Damped Lyα absorbers at high redshift - large disks or galactic buiding blocks?. MPA 1029

Haehnelt, M.G., M. Steinmetz: Probing the thermal history of the intergalactic medium with Lyα absorption lines. MPA 1033

Haser, S.M., A.W.A. Pauldrach, D.J. Lennon, R.-P. Kudritzki, M. Lennon, J. Puls, S.A. Voels: Quantitative UV spectroscopy of early O stars on the Magellanic Clouds. The determination of the stellar metallicities. MPA 1052

Heger, A., L. Jeannin, N. Langer, I. Baraffe: Pulsations in red supergiants with high L/M ratio. Implications for the stellar and circumstellar structure of supernova progenitors. MPA 1021

Huss, A., B. Jain, M. Steinmetz: The formation and evolution of clusters of galaxies in different cosmogonies. MPA 1013

Janka, H.-Th., W. Keil: Perspectives of core-collapse supernova beyond SN 1987A. MPA 1043

Jenkins, A., C.S. Frenk, F.R. Pearce, P.A. Thomas, J.M. Colberg, S.D.M. White, H.M.P. Couchman, J.A. Peacock, G. Efstathiou, A.N. Nelson: Evolution of structure in cold dark matter universes. MPA 1048

Jing, Y.P., H.J. Mo, G. Börner: Spatial correlation function and pairwise velocity dispersion of galaxies: CDM models versus the Las Campanas Survey. MPA 1044

Kauffmann, G., S. Charlot: Chemical enrichment and the origin of the colour-magnitude relation of elliptical galaxies in a hierarchical merger model. MPA 1064

Keil, W., H.-Th. Janka, D.N. Schramm, G. Sigl, M.S. Turner, J. Ellis: A fresh look at axions and SN 1987A: MPA 1005

King, A.R., J. Frank, U. Kolb, H. Ritter: Mass transfer cycles in close binaries with evolved companions. MPA 1008

King, A.R., J. Frank, U. Kolb, H. Ritter: Transients among binaries with evolved low-mass companions. MPA 1009

Kneissl, R., R.A. Sunyaev, S.D.M. White: A deep ROSAT PSPC observation toward the CMB decrement close to PC1643+4631 A+B: no cluster X-ray emission. MPA 1067

Kudritzki, R.-P., U. Springmann, A.W.A. Pauldrach, M. Lennon: Stellar wind momentum in galaxies and a new parametrization of the radiative line force. MPA 1053

Kudritzki, R.P.: Quantitative spectroscopy of the brightest blue supergiant stars in galaxies. MPA 1023

Langer, N.: The Eddington limit in rotating massive stars. MPA 1006

Lemson, G., G. Kauffmann: Environmental influences on dark matter halos and consequences for the galaxies within them. MPA 1065

Liu, B.F., E. Meyer-Hofmeister: The influence of new opacity data on the vertical structure of accretion disks. MPA 1014

Liu, B.F., F. Meyer, E.Meyer-Hofmeister: Evaporation of the accretion disk in dwarf novae during quiescence. MPA 1017

Ludwig, K., F. Meyer: Fine mesh calculations of dwarf nova outbursts. MPA 1061

Mao, S., H. Mo: On the physical connections between galaxies of different types. MPA 1070

Mao, S., P. Schneider: Evidence for substructure in lens galaxies? MPA 1035

Meyer-Hofmeister, E., S. Schandl, B. Deufel, H. Barwig, F. Meyer: The short-time variability of the supersoft X-ray source RXJ0019.8+2156. MPA 1062

Mo, H.J., S. Mao, S.D.M. White: The formation of galctic disks. MPA 1031

Müller, E.: Simulation of astrophysical fluid flow. MPA 1060

Nadyozhin, D.K., I.V. Panov, S.I. Blinnikov: The neutrino-induced neutron source in helium shell and r-process neutrosynthesis. MPA 1012

Niemeyer, J.C., A.R. Kerstein: Burning regimes of nuclear flames in SN Ia explosions. Numerical investigation of the scaling properties of turbulent premixed flames. MPA 1032

Oudmaijer, R.D., M.A.T. Groenewegen, H. Schrijver: The Lutz-Kelkler bias in trigonometric parallaxes. MPA 1063

Rampp, M., E. Müller, M. Ruffert: Simulations of non-axisymmetric rotational core collapse. MPA 1054

Rauch, M., M.G. Haehnelt, M. Steinmetz: QSO metal absorption systems at high redshift and the signature of hierarchical galaxy formation. MPA 1007

Ritter, H., U. Kolb: Catalogue of cataclysmic binaries, low-mass X-ray binaries and related objects (Sixth edition). MPA 1045

Ruiz-Lapuente, P., H. Spruit: Bolometric light curves of supernovae and post-explosion magnetic fields. MPA 1072

Salaris, M., A. Weiss: Chronology of the Halo globular cluster system formation. MPA 1011

Schneider, P., L. van Waerbeke, B. Jain, G. Kruse: A new measure for cosmic shear. MPA 1042

Schneider, P., L. Waerbeke, Y. Mellier, B. Jain, S. Seitz, B. Fort: Detection of shear due to weak lensing by large-scale structure. MPA 1026

Schneider, P.: Cosmic shear and biasing. MPA 1041

Schneider, P.: The cosmological lens equation and the equivalent single-plane gravitational lens. MPA 1034

Seitz, S., R.P. Saglia, U. Hopp, P. Belloni, B. Ziegler: The z=2.72 galaxy cB58: a gravitational fold arc lensed by the cluster MS 1512+36. MPA 1025

Springel, V., S.D.M. White, J.M. Colberg, H.M.P. Couchman, G.P. Efstathiou, C.S. Frenk, A.R. Jenkins, F.R. Pearce, A.H. Nelson, J.A. Peacock, P.A. Thomas: Genus statistics of the Virgo N-body simulations and the 1.2-Jy redshift survey. MPA 1046

Springel, V., S.D.M. White: Estimates for the luminosity function of galaxies and its evolution. MPA 1016

Sumiyoshi, K., S. Yamada, H. Suzuki, W. Hillebrandt: The fate of a neutron starjust be the minimum mass: does it explode? MPA 1036

Syer, D., H. Zhao: Density cusps: restrictions on non-axisymmetric models. MPA 1058

Syer, D., S. Mao, H. Mo: Global stability and the mass-to-light ratio of galactic disks. MPA 1059

Thomas, H.-C., K. Beuermann, K. Reinsch, A.D. Schwope, J. Trümper, W. Voges: Identification of soft high galactic latitude RASS X-ray sources: I. A complete count-rate limited sample. MPA 1069

Ulmer, A., B. Paczynski, J. Goodman: Tidal disruption Eddington envelopes around massive black holes. MPA 1057

Van Waerbeke, L.: Scale dependence of the bias investigated by weak lensing. MPA 1050

Velázquez, H., S.D.M. White: Sinking satellites and the heating of galaxy discs. MPA 1056

Weiss, A., H. Schlattl: The age of the most nearby star. MPA 1027

White, S.D.M.: The physical origin of galaxy scaling relations. MPA 1010

Woosley, S.E., A. Heger, T.A. Weaver, N. Langer: SN 1987A – presupernova evolution and the progenitor star. MPA 1024

5 Personnel

5.1 Scientific staff members

U. Anzer, A. Banday, M. Bartelmann, G. Börner, E. Churazov, G.H.F. Diercksen, M. Gilfanov, M. Groenewegen, W. Groom (March 1 – May 31), M. Haehnelt (till Sep. 30), W. Hillebrandt, B. Jain (till Aug. 31), H.–T. Janka, K. Jedamzik, P. Kafka, G. Kauffmann, K.–M. Knie (since Aug. 1), W. Keil (since March 1), U. Kolb (since May 15), W.P. Kraemer, R.–P. Kudritzki, M. Lennon (April 1 – Dec. 31), S. Mao, E. Meyer–Hofmeister, H.J. Mo, R. Mößner (till Sept. 30), P. Monger (July 5 – Aug. 31), E. Müller, J.C. Niemeyer (on leave of absence since Oct. 1), A. Nusser, R. Popham (since Sept. 1), H. Ritter, M. Ruffert (till Oct. 31), P. Schneider, S. Seitz (Aug. 1 – Dec. 31), R. Sheth, H.C. Spruit, M. Steinmetz (on leave of absence till May 15, left Aug. 14), R. Sunyaev, D. Syer, H.–C. Thomas, O. Ullmann (Oct. 1 – Dec. 31), A. Ulmer (since Sept. 15), H. Velazquez (Aug. 25 – Nov. 24), J. Wagenhuber (till June 30), R. Wegmann, A. Weiß, S.D.M. White.

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

Heisenberg–grant: N. Langer (Göttingen) till Jan. 31.

Ph.D. students: T. Abel (since Jan. 1), R. Casas (since Nov. 12), J.M. Colberg, G. Contardo (till Sept. 30), C. Cramphorn (since Jan. 1), K. Dolag (since March 15), I. Forcada, B. Geiger (on leave of absence since Feb. 1), W. Groom (till Feb. 28), A. Heger (on leave of absence till March 10), A. Huss (till Dec. 31), W. Keil (till Feb. 27), A. Kercek, K. Kifonidis (since March 1), R. Kneissl (till Dec. 18), A. Kopf (March 1 – Nov. 30), G. Kruse (since April 1), M. Lisewski (since June 1), K. Ludwig (till Feb. 28), N. Przybilla (since Sept. 1), M. Rampp (since March 15), K. Reblinsky (since Jan. 15), J. Rehm, H. Schlattl, J. Schmalzing, S. Seitz (till July 28), V. Springel, R. Stehle (till Nov. 3), G. Taresch (till Feb. 28), O. Ullmann (till July 14), H. Velazquez (till Aug. 6).

Diploma students: K. Dolag (till Feb. 11), T. Eberl (since June 20), T. Erben (till April 15), M. Rampp (till Jan. 3), R. Reinecke (since May 2), W. Salzmann (since March 1), O. Stranner (since Sept. 20).

5.2 Staff news

A. Diaferio received the Livio Gratton Prize in recognition of the best Italian Ph.D. thesis submitted during the period Jan. 1995 to Dec. 1996.

G. Kauffmann was awarded the Otto Hahn Medal 1996 during the General Assembly of the Max–Planck–Society at Bremen.

S.D.M. White was elected Fellow of the Royal Society of London.

5.3 Visiting scientists

Name (home institution) duration of stay at MPA

MPG fellowships:

A. Adamczak (Torun, Poland) Oct. 12 – Dec. 11; A. Aksenov (Moscow, Russia) Oct. 1 – Nov. 30; M.A. Aloy (Valencia, Spain) Nov. 10 – Nov. 22; I. Baraffe (Lyon, France) Oct. 6 – Nov. 8; S. Bates (Belfast, Northern Ireland) July 15 – Dec. 31; J. Bhatt (Ahmedabad, India) Nov. 18 – Dec. 4; S. Blinnikov (Moscow, Russia) Oct. 1 – Oct. 31; R. Bowens (Berkeley, USA) Aug. 31 – Sept. 28; X. Cao (Shanghai, China) Oct. 1 – Dec. 31; S. Cassisi (Teramo, Italy) June 6 – July 5; L. Chen (Shanghai, China) June 28 – July 27; Z. Deng (Peking, China) since Sept. 11; P.A. Denissenkov (St. Petersburg, Russia) Jan. 12 – Feb. 23; W. Duch (Torun, Poland) Aug. 4 – Sept. 4; A. Evrard (Ann Arbor, USA) Feb. 3 – March 2; C. Fryer (Santa Cruz, USA) June 6 – 29 and Oct. 19 – Nov. 3; G. Golitsyn (Moscow, Russia) July 16 – Aug. 15; S.A. Grebenev (Moscow, Russia) Nov. 3 – Dec. 3; S. Hardy (Sydney, Australia) since Oct. 1; P. Heinzel (Ondrejov, Czech Republic) April 6 – April 19; M. Hernanz (Barcelona, Spain) Nov. 17 – Dec. 16; J. Hwang (Koegu, Korea) since Dec. 13; V. Imshennik (Moscow, Russia) Nov. 3 – Dec. 2; N.A. Inogamov (Moscow, Russia) Nov. 18 – Dec. 18; P. Jensen (Wuppertal, Germany) March 3 – March 15 and Sept. 14 – Sept. 26; B. Jeziorski (Warsaw, Poland) July 9 – Aug. 8; Y. Jing (Tokyo, Japan) June 10 – June 24; T. Jyrimae (Tartu, Estonia) May 26 – June 23; M. Karelson (Tartu, Estonia) May 28 – June 19 and Oct. 19 – Nov. 18; J. Karwowski (Torun, Poland) Sept. 11 – Oct. 10; M. Kato (Yokohama, Japan) July 25 – Aug. 10; V. Kellö (Bratislava, Slovak Republic) Aug. 14 – Oct. 14; P. Kilpatrick (Belfast, Northern Ireland) July 10 – Aug. 15; A. Kritsuk (St. Petersburg, Russia) April 2 – May 1 and Nov. 2 – Dec. 31; B. Liu (Kunming, China) till May 31; P.–Å. Malmqvist (Lund, Sweden) July 1 – July 31 and Dec. 1 – Dec. 12; A. McFadyen (Santa Cruz, USA) Sept. 4 – Nov. 10; B. Metcalf (Berkeley, USA) Aug. 31 – Sept. 28; S. Mineshige (Kyoto, Japan) May 5 – July 4; H. Noh (Daejon, Korea) since Dec. 1; T. Plewa (Warsaw, Poland) Oct. 1 – Oct. 31; R.E. Pudritz (Hamilton, Canada) March 15 – Aug. 31; M. Revnivtsev (Moscow, Russia) April 15 – May 14 and since Nov. 29; P. Ruiz–Lapuente (Barcelona, Spain) since Dec. 12; S.Y. Sazonov (Moscow, Russia) April 15 – May 14 and Sept. 26 – Oct. 25; N. Sibgatoullin (Moscow, Russia) April 7 – May 6, July 10 – Aug. 10 and Oct. 31 – Nov. 30; J. Silk (Berkeley, USA) Aug. 31 – Sept. 30; P. Soldán (Prague, Czech Republic) May 1 – May 31 and Oct. 20 – Nov. 19; V. Špirko (Prague, Czech Republic) June 9 – Aug. 8 and Oct. 13 – Dec. 12; K. Subramanian (Pune, India) since Nov. 24; K. Tanaka (Tokyo, Japan) Sept. 1 – Sept. 30; O. Terekhov (Moscow, Russia) since Nov. 27; A. Timokhin (Moscow, Russia) since Dec. 15; G. Tormen (Cambridge, UK) till Dec. 31; S.P. Trudolyubov (Moscow, Russia) April 15 – May 14, July 15 – Aug. 16 and since Nov. 29; M. Urban (Bratislava, Slovak Republic) August 14 – Sept. 14; D. Uskov (Moscow, Russia) Nov. 10 – Dec. 17; V. Utrobin (Moscow, Russia) Oct. 1 – Nov. 30; L. Vainshtein (Moscow, Russia) March 11 – April 10; L. van Waerbeke (Toulouse, France) March 1 – Dec. 31; R. van de Weygaert (Groningen, Netherlands) April 5 – July 5; X. Xia (Tianjin, China) since Sept. 11; S. Yamada (Tokyo, Japan).

Alexander von Humboldt–research awards and fellowships

Alexander von Humboldt awards: D. Micha (Gainesville, USA) May 5 – June 1; M. Norman (Urbana, USA) since Aug. 1; J. Paldus (Waterloo, Canada) June 2 – Nov. 28; S.E. Woosley (Santa Cruz, USA) July 2 – Dec. 15;

Alexander von Humboldt–fellowships: L. Girardi (Porto Alegre, Brazil) since Oct. 1; K. Sumiyoshi (Hirosawa, Japan) till April 9; S. Yamamoto (Toyota, Japan) till March 31.

DAAD–fellowships:

A. Kudlicki (Warsaw, Poland) since Oct. 1; S. Pistinner (Beer–Sheba, Israel) till Oct. 31; V. Suleimanov (Kazan, Russia) Sept. 22 – Dec. 21.

DFG–fellowships:

A. Hernandez (Carracas, Venezuela) Aug. 4 – Aug. 17; H. Noh (Daejon, Korea) Sept. 1 – Nov. 30.

EC–fellowships:

I. Aretxaga; A. Diaferio; J. Perez–Jorda (till Oct. 16); M. Salaris (since March 14); E.W.Schreiner (Jan. 1 – Dec. 31)

5.4 Diploma and Ph.D. theses

Diploma theses:

K. Dolag: "Korrelationsfunktion von Galaxien und Quasaren in beliebigen Friedmann-Lemaitre-Kosmologien", Technical University Munich;

T. Erben: "Die Bestimmung von Galaxieneigenschaften durch Galaxy–Galaxy–Lensing", Technical University Munich;

M. Rampp: "Berechnung des Gravitationswellensignals bei Entstehung und Verschmelzung von Neutronensternen", Technical University Munich.

Ph.D. theses:

W. Groom: "The Formation and Evolution of Galaxies in a Cold Dark Matter Universe", University of Cambridge, UK;

W. Keil: "Konvektive Instabilitäten in entstehenden Neutronensternen", Technical University Munich;

R. Kneissl: "Beobachtungen und theoretische Modelle zu sekundären Anisotropien der kosmischen Mikrowellenstrahlung", Ludwig–Maximilians–University Munich;

K. Ludwig: "Hydrodynamische Berechnung eines Zwergnovaausbruchs im Rahmen des Scheibeninstabilitätsmodells", Ludwig–Maximilians–University Munich;

S. Seitz: "Untersuchungen zum schwachen Linseneffekt auf Quasare und Galaxien", Ludwig–Maximilians–University Munich;

R. Stehle: "Magneto–Hydrodynamics of Mass Accretion in Close Binary Systems and Protostars", University of Amsterdam;

O. Ullmann: "Analyse und Korrektur von Fehlern bei der Anwendung von Entfernungsindikatoren auf Extragalaktische Objekte ", Ludwig–Maximilians–University Munich;

H. Velazquez: "Dynamics of Disc Galaxies and Their Satellites", University of Cambridge, UK.