MPA 50 years

50th Anniversary Brochure
of the Max Planck Institute for Astrophysics

Max-Planck-Institut für Astrophysik

MAX-PLANCK-GESELLSCHAFT

Welcome Note from the Managing Director, Simon White

Dear Reader,

Fifty years is a long time, for institutions as for people, and yet maybe not so long. For most MPA graduate students, this is the time since their parents were born, thus most of history. On the other hand, the institute's anniversary party included a number of scientists who could recall the founding of the MPA and the hopes that went with it. Over five decades most people develop from children to grandparents, and most institutions go through several cycles of consolidation and renewal. The MPA is no exception, but while it is now very different from the way it was conceived, it still retains the core attributes which define its identity.

Our institute was born because of the conviction of a few people, most notably Ludwig Biermann, that astrophysics is a field which offers unique scientific challenges and opportunities, that understanding astronomical phenomena requires insight from the most diverse branches of physics, and that the astronomical world can teach us new physics. This vision has been confirmed in the most dramatic way possible by the explosive growth of astrophysics over the last half-century. When MPA was founded, planetary exploration was still a far-off dream, black holes were an esoteric and purely theoretical construct, pulsars, quasars and the cosmic microwave background were yet to be discovered, and the most distant known object was less than 10 % of the way back to the Big Bang. Indeed, the Big Bang itself was far from established.

Today, astronomical questions such as the nature of dark matter and dark energy, the origin of structure, or processes near black hole horizons, motivate research at the forefront of physics. Together with the discovery of other worlds, they have made astronomy the most present of all the physical sciences in the mind of the educated general public.

Not only the content of astronomy, but also its practice has been through several revolutions during MPA's lifetime. Astronomical observations have been extended from the traditional optical domain to all parts of the electromagnetic spectrum, and even beyond, to neutrinos, energetic particles and, perhaps soon, to gravitational waves. Telescopes, traditionally sited at university or institute observatories, evolved first into national facilities on remote sites, and then into global and often space-based facilities. At the same time, astronomical data changed from the property of the individual observer to a resource archived for the community as a whole. In 1958, astronomical results were published in a variety of languages and in often inaccessible periodicals. Now almost all appear in globally and electronically available journals, and can be accessed in advance through electronic preprints or conference talks. New computing technology has radically altered not only the way we take, store, analyse and publish our data, but also the way in which we seek to understand them. Numerical simulation and data modelling play a critical role in today's astrophysics, mediating between the traditional poles of theory and observation. Leadership in this exponentially growing area has been one of MPA's defining characteristics since its inception.

The growth and the globalisation of astronomy have also brought major sociological changes to the institute. The permanent staff are now a small minority of the scientists; they are outnumbered two to one by fixed term postdoctoral workers, and three to one by PhD students. In 1958 both these groups were minorities. These changes have been accompanied by a dramatic internationalisation of the institute, as well as by a substantial reduction in the mean age of its scientists. Coping with them has required a complete redesign of the MPA's management structure, and an expansion of its goals to promote research mentoring and international career promotion, in addition to pursuing forefront research. The research itself is now often carried out within national or international collaborations to an extent which was unimaginable even 25 years ago, and which leads some senior MPA scientists to be concerned that the intellectual tradition of independent individual theoretical research may be endangered.

I do not believe this danger to be real. While the way in which we pursue our science has changed, the most important drivers of research are the same at MPA today as when it was founded. They are a fascination with the extraordinary Universe revealed to us by astronomical observations; a conviction that understanding does not come from data alone, but requires a theoretical framework to order them; a belief that forefront computing can advance understanding throughout astrophysics; an emphasis on technical expertise and quality of work as a guarantor of long-term worth; and, most importantly, a curiosity about unexplained or inadequately explained phenomena which is the source of new insight into the physics of the astronomical world. The MPA has grown and evolved throughout its first half-century, making its mark at the forefront of several areas of astrophysics. The evolution will continue, and I'm firmly convinced that the next half-century will at least be the equal of that which has passed.

Garching, October 2008

50 Years of MPA –
50 Years of Theoretical Astrophysics

The Founding Years under Ludwig Biermann

The Max Planck Institute for Astrophysics (MPA) was founded in 1958 as an independent sub-institute within the Max Planck Institute for Physics and Astrophysics. The first director of this new sub-institute was Ludwig Biermann, who in the preceding years had used all his power to convince the Max Planck Society that theoretical astrophysics needed its own research facility.

International Astronomical Union (IAU) Symposium No. 22, "Stellar and solar magnetic fields", Tegernsee, 1963. From left to right: Reimar Lüst, Ludwig Biermann and the American astrophysicist Thomas Gold.

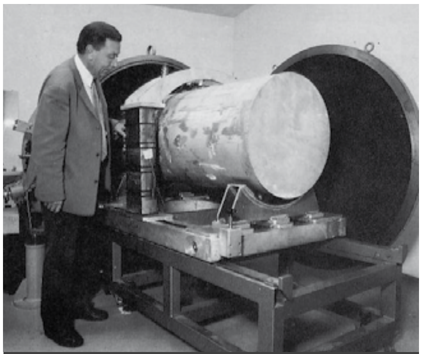
Like all of the 80 or so institutes which make up the Max Planck Society, the Institute for Astrophysics is principally dedicated to basic research. From the beginning, a strong emphasis on theoretical questions was the MPA's distinguishing feature: most other Max Planck Institutes also have major divisions doing experimental work.

The MPA's foundation was accompanied by a relocation. The former Aerodynamics Laboratory in Göttingen had become too small for the expanding scientific activity, so the Institute for Physics, then directed by Werner Heisenberg, moved with the MPA to Munich to a new building on the north side of town. Under Biermann's direction, the newly founded MPA concentrated on four main areas, each led by a Scientific Member of the Max Planck Society: Theoretical Astrophysics (Reimar Lüst), Quantum Mechanics (Eleonore Trefftz), Numerical Computing Machines (Heinz Billing) and Theoretical Plasma Physics (Arnulf Schlüter). These areas continued themes that were already active in Göttingen, and over the years they were broadened by the addition of new topics.

The Theoretical Astrophysics group dealt with the theory of comets, with cosmic rays, with solar physics and the structure of stars, and with the formation of the Solar System. Another important research topic was the propagation of magnetohydrodynamic shock waves, produced, for example, by the collision of two galaxy clusters, in the solar atmosphere, or in interplanetary space.

The foundation of a quantum mechanics group at MPA resulted from the realisation that atomic and molecular physics were becoming increasingly important for the understanding of new astronomical observations. Initially, this group was concerned with astrophysically relevant calculations of wave functions, but it soon extended its work to

Opening of the Max Planck Institute for Physics and Astrophysics in Munich/Freimann on May 9, 1960. Front row: State Secretary Staudinger (rightmost), to his left Ludwig Biermann, next Siegfried Balke, Minister of Nuclear Industry, right-hand behind him Adolf Butenandt, MPG president from 1960 to 1972, to Balke's left Otto Hahn, then-president of the MPG and Nobel prize winner, third person from the left Werner Heisenberg, leftmost Ernst Telschow, secretary general of the MPG.



The aluminium cylinder of Joseph Weber's gravitational wave experiment, which was repeated in Munich. In front Heinz Billing, supervisor of the experimental setup at the MPA.

Ludwig Biermann in a conversation with the then-president of the MPG, Adolf Butenandt, at the housewarming party of the Institute for extraterrestrial Physics on Februar 15, 1965

quantum chemistry, which is important for the physics of cometary nuclei.

The Numerical Computing Machines group developed new switching elements and storage units for a program-controlled electronic computing machine named G3. It was based on two previous machines, G1 and G2, which had been built in the Institute for Physics in Göttingen. The G3 turned the MPA into a German centre for computer development, but the demand for computation kept growing. More and more people at the Munich universities learned of the possibilities of high-level computation, so finally, after industrial production of computers began in the 1960's, the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) financed the acquisition of two big transistor computers for the two Munich computing centres. Up to that point, the G3 was probably the most powerful German computer ever, and Heinz Billing is confident even today that it was the finest vacuum tube computer ever built. In 1972 the G3 ceased operation and was switched off ceremonially over the customary glass of champagne.

About ten years after the completion of the G3 the scientists of the Computing group addressed themselves to a completely new project, which could put their electronic expertise to good use: an attempt to repeat Joseph Weber's famous gravitational wave experiment at the University of Maryland. Weber was convinced that his instruments, which were big metal cylinders with attached, hypersensitive strain detectors, had unambiguously registered gravitational waves, and so proven their existence. Einstein's theory of gravity predicts that such waves should be created when very strong gravitational fields change rapidly, for example, when black holes merge or stars explode. Perhaps Weber had seen such events and his detectors would provide astrophysicists with a direct way to study them.

The MPA theorists used equipment in the institute basement to develop new methods to repeat and analyse Weber's experiment. In spite of all their efforts, they were unable to reproduce the sensational Maryland results. Even today there is still no direct evidence for the space-time waves predicted by Einstein's theory. Nevertheless, early MPA efforts were essential for the later development of instrumentation in this field, and they were continued and greatly extended at the Max Planck Institute of Quantum Optics in Munich and at the Max Planck Institute for Gravitational Physics in Potsdam (the Albert Einstein Institute) which was founded in 1995 as an MPA off-shoot.

The fourth department of the original MPA, Theoretical Plasma Physics, dealt with the characteristics of ionised gases, the significance of which had become apparent during the preceding years. An important research topic from the beginning was cosmic magnetic fields, found in stars, accretion discs, galaxies and galaxy clusters. The corresponding theories of plasma physics also play an important role in sustaining controlled nuclear fusion. This led to the first fully independent spin-off from the Max Planck Institute for Physics and Astrophysics. In 1960 the Institute for Plasma Physics was founded and was incorporated into the Max Planck Society in 1971.

Arnulf Schlüter took over the theory department of the new institute. Since the characteristics of magnetic fields in ionised plasmas can be studied in detail on our Sun, the scientists of his group concentrated on solar physics. Basic insights into the so-called solar prominences – magnetic structures in the solar atmosphere, recognisable as large bright features extending outward from the Sun's surface – had already come from Rudolf Kippenhahn, Arnulf Schlüter and Ulrich Anzer. Studies of sunspots had also contributed a lot to the better understanding of cosmic magnetic fields.

A separate development also led to the foundation of another new institute. As early as 1950, Ludwig Biermann had suggested that the bending of the plasma tails of comets is caused by a particle flow emanating from the Sun, the so-called solar wind. Because the associated processes are very complicated, the idea came up to generate an artificial comet tail. This 1963 experiment was the origin of the Max Planck Institute for extraterrestrial Physics (MPE), led by Reimar Lüst. In its early years the MPE investigated extraterrestrial plasmas and the magnetosphere of the earth; later the institute concentrated on astrophysical observations in the infrared, X-ray, gamma and optical bands.

After Reimar Lüst left MPA, Rudolf Kippenhahn took over as leader of the Theoretical Astrophysics group. At that time the first big computing machines were becoming available, and Kippenhahn used them to investigate the structure and evolution of stars. Together with his collaborators Emmi Hofmeister and Alfred Weigert he was able to identify the main features of stellar evolution using new code they wrote themselves. In 1965 he was appointed professor at the University of Göttingen, but he remained closely connected to the MPA. Hermann Schmidt and Friedrich Meyer took over leadership of Theoretical Astrophysics at MPA.

The discovery in the 1960s of the cosmic microwave background and of previously unknown objects like quasars and pulsars stimulated new interest in cosmology and relativistic astrophysics. In 1971 Jürgen Ehlers was appointed Scientific Member at the MPA in order to lead research in relativistic astrophysics aimed at fundamental questions of gravitation theory as well as at applications to neutron stars, black holes and gravitational lenses. This research line eventually led to the founding of the MPI for Gravitational Physics, and in 1995 Ehlers moved to Potsdam as its founding director, together with most of his collaborators.

April 1st 1975 saw the retirement of Ludwig Biermann, the MPA's founding director who had built up the institute and led it for 17 years. He nevertheless continued working until several weeks before his death on January 12th, 1986. With him the MPA lost a wholehearted scientist, who, when immersed in the structure of stars, could forget the world around him. His ground-breaking scientific achievements won numerous awards, notably the Gold Medal of the Royal Astronomical Society (1974) and, posthumously, the Cospar Award (1986).

Hermann Ulrich Schmidt

Friedrich Meyer and Jürgen Ehlers

Jürgen Ehlers

Celebration of the 60th birthdays (1986) of Hermann Ulrich Schmidt and Rudolf Kippenhahn at the Ringberg castle, conference site of the MPG. From left to right: Rudolf Kippenhahn, Eleonore Trefftz and Wolfgang Hillebrandt.

Housewarming party in the new institute building on the Garching campus in 1980: Rudolf Kippenhahn's speech from the "pulpit" in the mezzanine floor of the staircase

Unexpected Challenges and a Crisis

Rudolf Kippenhahn succeeded Biermann as director of the MPA. He brought a new style of leadership which emphasised the autonomy of the scientist, valuing individual research profiles above those of the group as a whole. With his pioneering work in the field of stellar evolution, he laid the foundations for a long tradition at MPA.

Kippenhahn's last PhD student Achim Weiss followed in his footsteps and is still investigating the evolution of stars and binaries at MPA today. Over the years this group has shown how observations of star clusters allow their ages and their chemical compositions to be measured. By linking modern calculations of stellar evolution with observations of very old stars it has been possible to identify the amount of lithium produced by the Big Bang itself, and, from this, to constrain the total amount of ordinary matter in the Universe.

In 1978 Wolfgang Hillebrandt came to the institute to lead a new group studying nuclear astrophysics. With Ewald Müller he set out to develop models for exploding stars, the so-called core-collapse supernovae. They studied the influence of rotation and magnetic fields, and they calculated the gravitational wave signal and the production of heavy elements in these explosions. In 1985 Wolfgang Hillebrandt became a Scientific Member of the Society.

In 1979 the institute, which had grown markedly over the years, moved into a new building on the Garching campus north of Munich, next door to the new headquarters of ESO (the European Southern Observatory). Both buildings were purpose-designed by the architects Fehling and Gogel. Over the following decades this Garching site has developed into one of the leading research centres of Europe, and ESO, MPA and MPE are today the largest agglomeration of front-ranked astrophysical research facilities in Europe.

Since Biermann's early work on the interaction between plasma tails and the solar wind, the MPA had been very engaged in the physics of comets. As a result, the institute participated in the preparation and data analysis for the Giotto mission. In 1985 the European Space Agency (ESA) launched Giotto to study Halley's Comet, and on March 14, 1986 it passed the comet successfully at a distance of only 600 km, surviving despite being hit by a number of small particles. Giotto was the first spacecraft to provide pictures of a cometary nucleus and analysis showed the comet to have formed 4.5 billion years ago from ice that had condensed onto interstellar dust particles. The spacecraft's instruments confirmed the existence and the position of the flow discontinuities which Biermann's MPA group had predicted in 1962.

Magnetohydrodynamics and solar physics continued to be important research topics at the institute. New observations of oscillations of the solar surface opened up the field of he-

MPA staff in the inner courtyard of the institute building in Garching: The photo was taken in 1980 as a present for Rudolf Kippenhahn, who had fallen seriously ill, and sent to him in the hospital.

lioseismology, and the MPA stellar structure group could test their understanding of the solar interior from measurements of wave propagation through it, just as the Earth's interior can be probed using the waves caused by earthquakes. Cosmic magnetic fields were studied both on the solar surface, where Henk Spruit showed how they regulate the structure and the thermal properties of sunspots and their surroundings, and further afield where they play an important role in understanding how gas spirals onto newly forming stars and onto black holes. Such accretion often occurs in thin disks which can give rise to strong and directed outflows known as jets. Accretion disks are an important stage in the formation of planetary systems and provide our principal window on black hole growth. Their structure and their observable properties were worked out in 1973 by future MPA director Rashid Sunyaev and his Russian colleague Shakura in one of the most famous articles in all of astrophysics. The magnetic structure of the disks was studied at MPA by Friedrich Meyer, and the way they produce jets was simulated in ever increasing detail by Ewald Mueller.

At the beginning of the 1980's China began to open up to the outside world after the Cultural Revolution and Gerhard Börner went about building collaborations between the institutes of the Max Planck Society and the Chinese Academy of Sciences. In 1982 the first joint conference took place in Nanking, China. This initial contact led to a regular series of workshops and to an ever intensifying exchange programme between China and MPA. This culminated in 2000 with the founding of an MPA partner group at the Shanghai Astronomical Observatory led by cosmologist Yipeng Jing, a previous MPA scientist and one of Boerner's long-term collaborators. When this group reached the end of its term in 2005 its evident success resulted in an intensified joint programme and the founding of a second MPA/SHAO partner group.

Another productive off-shoot of MPA stellar evolution expertise was a programme on the formation and evolution of close pairs of stars. Material can be transferred from one star to the other in such systems, often producing dramatic effects. MPA research led by Hans Ritter and Henk Spruit emphasised cataclysmic variables, stars which increase rapidly in brightness by a large factor before dropping back to their original brightness.
Since 1982 Hans Ritter has published and continuously updated a catalogue of such compact binary stars. Many of these harbor Shakura-Sunyaev accretion disks which can be very bright at X-ray wavelengths. X-ray telescopes built by the MPI for extraterrestrial Physics and others, have produced very detailed information about such systems over the years, posing a continuing challenge to MPA theorists, who try to understand the physical processes at work in these objects.

MPA supernova studies got a great boost in 1987 when a star exploded in our small neighbour galaxy, the Large Magellanic Cloud. At the time, Wolfgang Hillebrandt was breaking new ground in developing models for thermonuclear combustion which could be used directly to interpret observational data. Supernova 1987A greatly stimulated this programme and set it on a track towards ever closer comparison with observation which developed over the next twenty years through a Europe-wide network to collect data from supernova explosions and several national Collaborative Research Centres. Over the same period supernova modelling at MPA was greatly strengthened by the addition of Thomas Janka who concentrated on a particularly critical part of the problem: how neutrino losses from a forming neutron star are ultimately responsible for the explosion of objects like 1987A. These developments in the 1980's brought MPA supernova research to the forefront world-wide, and laid the foundation for it to remain there until the present day.

In 1991 the Institute for Physics and Astrophysics was finally divided into three fully independent Max Planck Institutes: the Institutes for Physics (MPP), Astrophysics (MPA) and extraterrestrial Physics (MPE). In the same year Rudolf Kippenhahn retired. According to the Max Planck Society's Harnack Principle, institutes are supposed to be built around the research programmes of their directors, and these should normally be hired from the outside, rather than promoted from within. Since no successor for Kippenhahn had been identified ahead of time, his retirement cast a shadow over the MPA's future. During the search for a solution, Wolfgang Hillebrandt took over as acting director. This was just after German reunification, and the Max Planck Society was very active founding new institutes in Eastern Germany. This could only be funded through money saved at other institutes, and the MPA became a target for savings. Options discussed included merging with the Astrophysical Institute Potsdam, or even closing the MPA and dispersing its staff to the other astronomically oriented MPIs. In this situation all MPA staff were forced to rally in support of their institute and many realised for the first time how much it meant to them.

Rudolf Kippenhahn and his assistant Cornelia Rickl at Kippenhahn's retirement party

A new Start under altered Circumstances

At last light came at the end of the tunnel. In 1994 the British cosmologist Simon White came to the MPA as its new director. The uncertainty of the preceding years had taught a hard lesson, and White immediately set about installing a new management system, collegial leadership by a Board of Directors rather than management by a single director.

Hans-Christoph Thomas, for over 40 years working in stellar astrophysics at the MPA

In 1995 Rashid Sunyaev was appointed director at the MPA and moved from Moscow to Munich, and in 1997 Wolfgang Hillebrandt became the third member of the MPA's Board.
With the arrival of White and Sunyaev the MPA's research programme also broadened dramatically to include much of physical cosmology and high-energy astrophysics.

Simon White's arrival not only provided a new perspective for the stricken MPA, but also resulted in a radical internationalisation of the then still very German, patriarchal institute. At that time there were no institutionalised international collaborations, there were hardly any foreign PhD students, and the common working language was German. Another typically German phenomenon was that there were very few women among the scientists. Simon White strove towards a leaner structure, flattened hierarchies, better gender balance, greater clarity and participation in management, and strengthened international contacts. He set up the institute's Scientific Council, which includes all permanent scientists as well as representatives of the postdocs, PhD students and support staff; it has now met more than 70 times to discuss all aspects of institute policy. He also insisted that all institute postdoctoral positions be filled for fixed terms through an annual internationally advertised competition, and that promotion and tenure should be based on procedures similar to those followed in U.S. research universities.

Today MPA research from the students up to the directors is thoroughly international. The institute has links with institutions all over the world, and all jobs are advertised both in Germany and abroad. A third of the scientists are women. While theoretical and computational research still dominate institute activity, data analysis and interpretive research have also come to play a major role. Since 1997 the institute has hosted the German data centre (led initially by Matthias Bartelmann and now by Torsten Ensslin) for ESA's Planck satellite mission to study the cosmic microwave background and we all eagerly anticipate launch in 2009. Since 2003 the MPA has been a fully paid-up partner in the U.S.-led Sloan Digital Sky Survey, making particularly strong impact with Guinevere Kauffmann's studies of the systematic properties of the low-redshift galaxy population and their active nuclei. The high-energy group has made use of their Russian connections (while at MPA, Rashid Sunyaev has remained division head at the Institute for Space Research, Moscow) to gain access to about one quarter of all the data currently coming from ESA's Integral gamma-ray observatory, and has used this to build up an entirely new understanding of sources of X- and gamma-radiation within our own Galaxy. Finally, under the leadership of Benedetta Ciardi, the MPA has even become a radio observatory, joining the Dutch-led LOFAR (Low Frequency Array) project in 2007. An antenna-field is currently under construction in Aresing, a small village 40 km north of Garching.

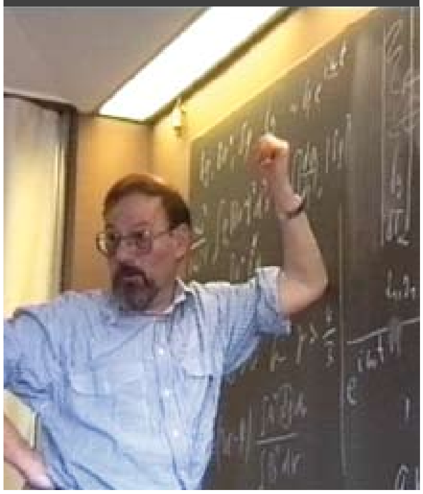
In recent years MPA's computational research has become just as international as its interpretive programmes. Since 1994 Simon White has co-led the Virgo Consortium, a group with partners in the UK, Canada, the USA, the Netherlands and Japan dedicated to simulating the growth of cosmic structure on supercomputers. Thanks largely to Volker Springel's remarkable ability to design, implement and deploy robust new algorithms, the consortium has repeatedly been able to use Garching supercomputers to open new frontiers in this field.

Their 1997 work on the structure of dark matter halos has become the most cited paper ever published by a German institute, and the 2005 public data release for their Millennium Simulation has so far led to the publication of more than 150 research papers. On slightly smaller scale, the relativistic jet and supernova programmes of the hydrodynamics group are carried out in close contact with collaborators in Spain and the USA, while Eugene Churazov's simulations of the heating of galaxy clusters by their central galaxy (most MPA researchers remember his striking visual analogy between a radio image of a central galaxy, an atmospheric nuclear weapons test and his simulation results) were carried out with US collaborators.

The most dramatic internationalisation of MPA's atmosphere undoubtedly came about through the founding in 2000 of the International Max Planck Research School on Astrophysics at the Ludwig-Maximilians University of Munich (IMPRS for short!). This was a joint initiative of the MPE, the MPA, the LMU observatory and ESO, and it now has a steady state population of about 70 PhD students following a joint set of courses and carrying out research projects in the four institutes. This has led to an increase in the doctoral student population at MPA by more than a factor of 3 and a situation where the most common nationality among the students is Italian rather than German, with more than 15 countries represented all together.

While large groups concentrate on the three core areas of institute activity – stellar astro-

Lecture by Bernd Schmid, member of the MPA relativity group



physics, high-energy astrophysics, extragalactic astronomy/cosmology – there are MPA scientists working in most areas of modern astrophysics. Individuals are not rigidly bound to specific projects, but have considerable freedom in choosing their research direction. Interaction between groups is emphatically encouraged, and most decisions affecting institute research are reached democratically by institute-wide committees. A central core of permanent staff has stuck to the MPA over the years, but junior scientists and visitors come and go, providing a continual turnover in the faces one sees at coffee or wandering the corridors. Many young MPA scientists have gone on to more senior research positions in Germany and abroad, and form a network of alumni who often maintain collaborative ties with the institute. Several now lead institutes of their own.

From left to right: Rashid Sunyaev, Wolfgang Hillebrandt and Emmi Meyer at Kippenhahn's retirement party

Staying at the forefront requires constant renewal, and in 2007 the MPA was pleased to welcome Martin Asplund as its first new director of the next generation. Both Wolfgang Hillebrandt and Rashid Sunyaev will retire in the next few years, and Asplund, a Swede who was previously working in Australia, will effectively be Hillebrandt's successor as leader of stellar astrophysics research at the institute. His expertise in studying the atmospheres of stars and determination of their chemical composition will bring new research directions to the MPA while reinforcing both the computational and the interpretational strands of its programme.

The success of the now 50-year-old Institute for Astrophysics rests upon the world-class research activity and cooperative partnership of many individuals. Over the years the institute has become bigger and bigger, and it has become difficult to fit into the existing accommodation or to know every MPA scientist. Nevertheless, guests, students and long-term members agree: the work climate at MPA is characterised by cosmopolitanism, tolerance and dynamism. Today, 50 years after its foundation, MPA people are working with the same enthusiasm, and to a perhaps even higher level, as in the beginning.

Simon White, Mrs. and Mr. Sunyaev, Mrs. Hillebrandt at the celebration of Rashid Sunyaev's 65th birthday

“Changes keep Science alive”: an Interview with Rudolf Kippenhahn

Rudolf Kippenhahn (born in 1926) headed the Theoretical Astrophysics Department of the Max Planck Institute for Physics and Astrophysics from 1963 to 1965, before taking up a chair at the University of Goettingen. In 1975 he returned as director to the Max Planck Institute for Astrophysics, and led it until his retirement in 1991. Today he works as an author of popular-science books on astronomy and other scientific topics.

Rudolf Kippenhahn's speech at his 70th birthday on June 14th, 1996 in the MPA

Heinz Billing and Rudolf Kippenhahn at the house-warming party of the Institute for extraterrestrial Physics in 1963

Which part of your work do you think had the most consequences?

I had the good fortune to start my scientific career at a time when bigger and more powerful computing machines were becoming available. Around 1963 I began working with my collaborators Emmi Hofmeister and Alfred Weigert to calculate the structure and evolution of stars. A new method from the United States made it possible to calculate not only the structure of stars, but also their long-term evolution. Soon we were able to take the lead in this area and to achieve great international success, but it wasn't long before others came and did even better. Yet later we began to study interactions between stars, and in particular the evolution of binary stars. Our stellar evolution code is still widely used by the international scientific community.

Which important changes has the MPA passed through since its formation in 1958, and how do you judge them?

The institute arose from Biermann's group and so was considerably shaped by Ludwig Biermann: individual freedom was regarded as very important. According to the requirements of current projects, ad hoc groups formed and after some time broke up again. I started in Biermann's department in Goettingen in 1975 as a member of the plasma physics group. Where you belonged was never fixed, and I maintained this approach during my own term of office. Ludwig Biermann was a very versatile researcher. Besides the gravitational group, the relativity group and the comet group, he had groups working on chemistry and mathematics. Many of his groups gave rise to other institutes, for example, the Institute for Plasmaphysics (IPP), the Institute for extraterrestrial Physics (MPE) and the Institute for Gravitational Physics (Albert Einstein Institute, AEI). Members of his mathematics group filled three mathematic chairs; another group was taken over by the Institute of Quantum Optics (MPQ). The succession from Biermann to me passed without problems, and indeed I took Biermann as an example in many respects, bringing Wolfgang Hillebrandt to the institute in order to include nuclear astrophysics in our scientific programme. The arrivals of Simon White, and later Rashid Sunyaev and Martin Asplund, brought about a further broadening of the programme and, more importantly, a substantial internationalisation of the institute. Modern communication media such as internet and email have globalised science markedly in the last two decades. I regard this as a positive trend; in the past scientific publications were often not as easily noticed as today, especially when they were not written in English. The down side of this development, however, is the enormous publication stress, which young scientists feel today. Since we all are in competition with each other on an international level, this trend seems unavoidable to me. It's the same in the economy. Today, young scientists only get fixed-term contracts, while in former times nearly everyone was engaged for life. For the individual, fixed-term contracts mean more uncertainty, but the institute as a whole would become inflexible if it committed itself to all its scientists on a long-term basis. Changes are necessary to keep a scientific institute alive. In the former East Germany, for example, everybody had a permanent contract, and so when you took over an institute, you could not bring your own people along with you. To the unions fixed-term contracts are anathema, but for the institute or the concern they make sense.

Since your retirement you commit yourself to public relations and make laypersons and children understand astronomy. Which medium do you think is the most effective?

When you write books you pull the strings, whereas when you give public talks, everything depends on the audience. You can prepare a talk perfectly and learn your text completely by heart, but when you hear from the audience, for example, the interjection: "I have been in contact with aliens for years!", everything develops in an unintended direction. Once, I had just started a talk at the children's university when a power failure occurred. Instantaneously a deafening clamour started. After a while the light went on again, but the clamour remained. Until the very end I was unable to quieten them again. When I was young, a very attractive young lady in the front row put me completely off my stride. All the time she shook her head disgustedly, obviously wanting to leave no doubt how little she thought of what I was saying. Later, however, it turned out that she had been persuaded to come to the talk against her will, and had actually planned something else for the evening. That was the reason why she was so annoyed, and not my talk. Another time I gave a speech in a hall where dinner was served, and suddenly a waiter dropped a tray with a bang. How best to react to such unexpected situations never ceases to be a challenge to my imagination. In a way, I returned to my roots by writing articles and books, because as a student I worked as a journalist to pay for my education. While I was an active researcher I wrote two specialized books, and afterwards I have written 15 popular-science books. When I have concentrated all my energy on one book for years, and then I see that books like "In search of an impotent man" or "Wetlands" generate sales figures more than a hundred times as high, I do get a little annoyed. I am 82 years old, and the fascination with this topic does not knock my socks off anymore. Which medium? Books or talks? Talks are more exciting, because when you start you never know how it will end. But talks are connected with travelling, with carrying suitcases and climbing stairs. That becomes increasingly exhausting as you grow older. When you write books, you work along unhurriedly over several years, and between times you occasionally get so disheartened that you are tempted to give up. I actually did give up when I was writing my book on infinity. After failing to write anything for months, I grew depressive. Only starting another book on a different topic, cheered me up again. I resumed the first project five years later and finished it successfully. When you hold the first copy of your book in your hands, you are overjoyed. This elation lasts one to two hours. Then you detect the first typo, which you overlooked in spite of repeated proof-reading, and which is now documented in thousands of elaborately designed books.

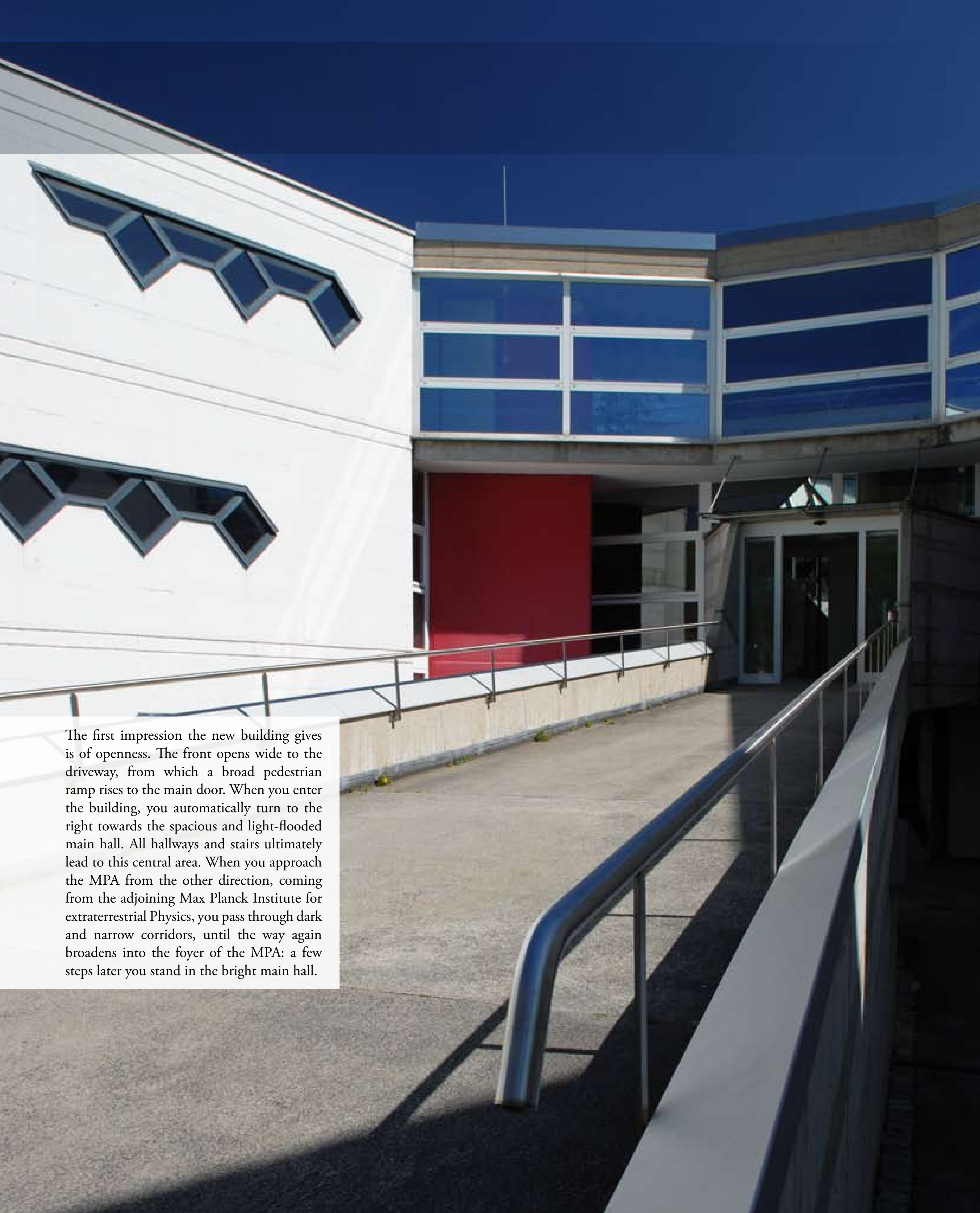
Dedicated to Communication: On the Architecture of the MPA Building

The need for a new home for theoretical astrophysics arose in the early 1970's from lack of space in the Foehringer Ring buildings in the north of Munich which housed the institutes for physics and astrophysics. In June 1974 the Board of the Max Planck Society decided to relocate the institute for astrophysics next to the planned headquarters of ESO (the European Southern Observatory) on the southern edge of a research campus just outside the town of Garching.

The MPG commissioned the architects Hermann Fehling and Daniel Gogel with the new building, based mainly on good impressions of the extraordinary building they had designed for the Max Planck Institute for Human Development in Berlin. The same team was also commissioned to design the ESO building.

To get an impression of what was required, the architects came to Foehringer Ring to talk to the scientists. At the time, the astrophysicists were sitting in offices, whose size varied with seniority, arranged in a line along one side of a long corridor. Experience had shown that good science requires not only the possibility of concentrated work in the privacy of one's room, but also much better opportunities for informal exchange of information with colleagues than was offered by this arrangement. There was a strong feeling that the new building should facilitate such contacts without disturbing the individual in his or her work.

Further wishes of the astrophysicists which the architects adopted as their own were: short routes to the library and to supercomputer service points from all offices, and the preservation of a magnificent (but ultimately ill-fated) old willow in the middle of the rather limited building site. Last but not least the scientists wanted a building which would look different from its neighbours.



The first impression the new building gives is of openness. The front opens wide to the driveway, from which a broad pedestrian ramp rises to the main door. When you enter the building, you automatically turn to the right towards the spacious and light-flooded main hall. All hallways and stairs ultimately lead to this central area. When you approach the MPA from the other direction, coming from the adjoining Max Planck Institute for extraterrestrial Physics, you pass through dark and narrow corridors, until the way again broadens into the foyer of the MPA: a few steps later you stand in the bright main hall.

Dedicated to Communication: On the Architecture of the MPA Building

Every morning at 10.30 the now traditional “scientific coffee” takes place in this space, an informal meeting where scientists exchange experiences and new ideas and meet visitors and colleagues from other groups. During this coffee break, but also by walking casually through the circular building, you quickly get an overview of who is currently at the institute. “If you want to ask someone something, you first look for him at the scientific coffee”, explains MPA director Wolfgang Hillebrandt, who has been at MPA for nearly 30 years.

Not only the main hall and its associated discussion niches, but also the coffee/lunch area in the mezzanine which overlooks it, the library and its reading room, the main lecture hall, and the newer seminar and meeting rooms in the basement provide important common working areas. From the main hall and from the offices of the scientists, they are reached over the central open stairway and adjoining galleries and bridges. During parties or receptions, these provide excellent podia for speeches.

The basic shape of the building is a rotunda with star-shaped external tentacles. This sometimes makes it hard for visitors and new inmates to find their way. Triangular and tilted windows and the general avoidance of right angles symbolically support unorthodox ways of thinking.

Centred on the public spaces and distributed over the first three floors, the offices of the scientists are very different from those in the old institute building at Foehringer Ring. Each room has an individual plan, and scientists have an opportunity to pick the kind of room they want. Some prefer to look south, some north; some want to be near the action in the central area, while others prefer to be cloistered far down a corridor; some like a single office, others like to share a larger space. The institute’s success in recent years has steadily increased the number of scientists, resulting in a reduction of freedom of choice, but a wide variety of possibilities still remain.

The MPA is built ringlike around an inner courtyard. A row of columns in the patio recall a monastic colonnade, and is perhaps conducive to contemplation and deep thinking. An important role in the choice of circular form was played by a 50 year-old willow tree. The building surrounded this tree, much as, according to the Max Planck Society’s Harnack Principle, Max Planck Institutes are established to support the research of individual forefront researchers. As a result, MPA scientists nicknamed this the “Harnack tree”. In the end, however, the tree fell victim to the astrophysicists: efforts by the MPA’s Numerical Computing Machines department, led by Heinz Billing, to shoe-horn its gravitational waves experiments into the basement, ultimately led to the premature demise of the willow, which like retiring directors has since had to be regularly replaced.

The spacious wooded areas surrounding the MPA and the adjacent MPE building are regularly used by the two institutes for festivities and public events like our biennial Open House. If you leave the MPA in a southward direction, you get to ESO headquarters, built by the same architects as MPA in a different but equally idiosyncratic style. Two other Max Planck Institutes, the MPI of Quantum Optics and the MPI for Plasma Physics are located within a few hundred meters, and many other institutes and departments of the two major Munich universities are also nearby on the Garching Campus.

From the very first day, MPA staff members felt at home in their new institute building. They find its unconventional and rambling shape (sometimes compared to that of the Crab Nebula) very inspiring for their work. “Architects in the 1970’s wanted to rebel against traditional architectural concepts, and our mission as scientists is also to forge new perspectives which can replace those that have proven inadequate: it is a good match”, says Hans-Thomas Janka, who has been studying supernovae and gamma-ray bursts at the MPA for almost twenty years.

We all have come to the conclusion that our building responds to our way of doing theoretical astrophysics extremely well. Our only reservation is that it has become too small to house all the scientific activities of the current, much expanded, MPA staff. Over its thirty year lifetime, the building has itself become a research object for architecture students. The many interested questions and positive comments of visitors who we guide through MPA repeatedly confirm that form and purpose have here been successfully welded into a homogeneous whole.

People at MPA

The MPA is not only an internationally renowned research institute, but also the daily meeting point of diverse personalities from nearly all countries of the world, a place where they exchange their everyday experiences and collaborate with each other. Some of these persons introduce themselves below.

Shoichi Yamada
Visiting Scientist

"I've been fascinated with astrophysics, since I read a Japanese book on the special theory of relativity at the age of 14. The second most important experience in my career was my first stay at the MPA in the mid-90ies. Together with Hans-Thomas Janka I wrote a paper on the simulation of supernovae: discussions with him broadened my mind considerably, even though he was very critical in the early phases.
Since this stay I have returned repeatedly to the MPA as a visiting scientist or in the context of sabbaticals. I love the research atmosphere here: you can concentrate for a long time on one topic. This is very different than in Tokyo, where everything is very hectic and I am often overwhelmed by teaching and supervising duties. Every area of physics interests me. I dream of the opportunity to become acquainted with nuclear physics, elementary particle physics and the physics of condensed matter. All these disciplines are necessary to understand astrophysical phenomena. To be able someday to study my objects of research, neutron, hyperon and quark stars, from an entirely new angle; that's my scientific ideal."

Hans-Werner Paulsen
System administrator

"After my studies in mathematics, with astronomy as subsidiary subject, the MPA was my first place of employment, and I have stayed here ever since.
When I started in 1983, there was only one computer at the institute, and it drove a line printer. Larger calculations were carried out at the Garching computer centre, and the results were only printed here. In order to illustrate the results of our calculations, we connected a graphics system to the computer. I was in charge of this system: it was my first duty at the MPA and it brought me into close collaboration with the scientists.
The graphics system was gradually upgraded, and more powerful processors were set into operation. It finally became possible to handle other tasks such as email and word processing at the MPA. As a result, the number of users of our system grew, and it often happened that a scientist had to wait for a free terminal in front of the computer room; at the time there were no monitors in individual offices. By rapidly developing the network and PC sectors we were finally able to provide each employee with their own workstation, at the same time as offering central services such as data backup, email and high-performance computing. Computing has become ever more important for the institute over the last decades, and I am proud that my work has facilitated the success of the scientists."

"The MPA is a theoretical institute, and my scientific background is in theory, too. As project manager for the LOFAR station in Aresing, however, I broke new ground. LOFAR is the largest networked radio telescope worldwide. It is operated by the Netherlands, but there are antenna fields in many European countries, amongst others in Germany.

I'm responsible for the acquisition and positioning of a remote antenna field in Aresing and I'm a member of LOFAR's Epoch of Reionization working group. During this epoch in the Universe's childhood, a few hundred million years after the Big Bang, the first stars started to make heavy elements, the ingredients for the chemistry of life, and simultaneously heated up pregalactic gas. As soon as LOFAR is set into operation, I will work primarily as an observational astrophysicist and check the latest theories on the reionization of the intergalactic medium.

In my opinion, theoretical and observational work complement one another very well. If you work only theoretically, you tend to lose contact to reality because of too much freedom. On the other hand, for me it is too restricting and one-sided to work exclusively as an observational astrophysicist.

LOFAR has aroused much interest in the public and the media. In the beginning, there was anxiety in Aresing until we clarified that we will not broadcast any radio waves, but only receive them. Now we get support from all sides, and the citizens of Aresing are very enthusiastic and proud about the contribution of their community to the LOFAR project. I hope that through LOFAR we will, in a few years, be able to observe for the first time ever the birth of the first stars."

Benedetta Ciardi
LOFAR Project manager

Cornelia Rickl
Assistant to the Managing Director

"I came to MPA in 1977, at the age of 19. I have worked for Kippenhahn, Hillebrandt, Sunyaev and White – each director was completely different. Over the years, I identified more and more with the institute. It feels good to be part of such an important and renowned institution and to have witnessed the development from the small, familiar institute up to today's success.

In the crisis at the beginning of the 90's, when, after Kippenhahn's retirement, no director was found and the MPG considered closing down the institute, we all grew closer together. In this situation I realised for the first time how dear the institute, with its special working atmosphere, had become to my heart. We all stuck together at that time and acted in concert to fight for the institute. The day, when we finally got the information that Simon White would come to us and that the institute would continue, was for me one of the highlights in the history of this institute.

In light of the experiences of this hard time and at the recommendation of White, a collegial leadership by a Board of Directors was introduced, with the managing directorship rotating every three years. Now the retirement of a director can no longer precipitate a crisis, and it has been very interesting for me to experience the different management styles of my alternating bosses."

Social Events

In order to support communication between institute members, to facilitate daily coexistence and to integrate new colleagues, there are quite a number of social events and celebrations at MPA. These range from outdoor summer fêtes with beer, pretzels and barbecue via carnival and Christmas parties to all-inclusive hiking in the mountains and other athletic activities by individual groups.

♪ **All My Papers**
Beatles: All My Loving

Close your eyes and don't worry
Tomorrow this story
Will appear in a journal for you
And although it's just mist
It's a paper for the list
And nothing at all may be true

Don't pretend to be repelled
It's the way all o'er the world
Remember this obvious clue
Thousand papers on the list
People think that you're the best
No matter if anything's true

All my papers
I will send to you
All my papers
Maybe they'll be true

Nearly legendary is the annual carnival party of the MPA with the bestowal of the Golden Pitchfork. This "award" was introduced in the 80's by students, in response to the start of the publication glut in the sciences at that time. Their consideration was that if there are so many publications there must be a lot of nonsense to be found among them. The pitchfork was to be granted annually to the scientist with the most meaningless publication in the previous year. The first laureate was Gerhard Boerner, until the present day (also in other respects) a leading cosmologist at the MPA.

Since that time the selection criteria have been extended considerably, honouring also other brilliant achievements: Laureate Simon White, for example, distinguished himself by the heroic deed of running over his laptop with his car. From time to time, however, we have scientists at the MPA who are so otherworldly (and clumsy) that the Golden Pitchfork is not given to them as a matter of principle – for the simple reason that otherwise they would be awarded it every year. Some years ago an additional version of this prize was introduced for younger scientists: the Junior Pitchfork. Those who win one of the pitchforks are responsible for passing it on, with a suitable speech, to the most worthy candidate in the following year.

A small social activity takes place every day at the MPA, namely the daily scientific coffee. Every morning from half ten to eleven, a buzz of voices and laughter sounds through the institute building. If you approach the main hall from the staircase, you can look down onto an impressive throng of some dozens of scientists, who, engrossed in (not exclusively scientific) conversations, stand together in small groups and have a cup of coffee. Simon White introduced this coffee break when he came to the institute in 1994, and pays for it using his editorial fee from the Royal Astronomical Society.

Social Events

The annual MPA mountain hike is sometimes referred to as the mountain race, because some MPA members take a very competitive approach to the event. While the top athletes compete to be first to the top, others amble behind unhurriedly and finally find time to get to know their colleagues, which is indeed considerably closer to the original intent of this social event. Normally there are no serious incidents during this outing. Nevertheless, an Australian guest researcher once managed to get lost in the mountains. When the police wanted to know what the missing person looked like, the best answer his MPA colleagues could think of was: “Like Quasimodo!” This turned out to be sufficient for identification, and after some anxious waiting the Australian was returned to the MPA intact and fit for work.

Since the beginning of the 80’s the MPA has had its own football team. They are able to look back on some notable successes, not least thanks to a good idea of today’s MPA director Wolfgang Hillebrandt: He proposed to join forces with a small, but successful football team from Berlin. The plan worked, and the MPA twice won the cup of the German Astronomical Society (Astronomische Gesellschaft, AG). In more recent times, the pressure to publish quickly and frequently has become increasingly noticeable in the athletic performance of the scientists. Inevitably, perhaps, it has now been a while since the last cup was won. Anyway, the MPA people can’t be put off so easily and just hold on to their goal. Undeviatingly they just compete again and again: Winning is not so important for the theorists, taking part is everything!

MPA Soccer Songs (after beer)
Chuck Berry: Rock And Roll Music

Just let me hear some of that MPA music
Any old way you choose it
It's got a back beat, you can't lose it
Any old time you use it
It's gotta be MPA music

If you wanna dance with me
If you wanna dance with me

I've got no kick against MPE
Unless they try to make a theory
About the universal melody
'Cause it will end up in a tragedy
That's why I go for that MPA music…

I do not keep my mind on ESO
Although they have a splendid telescope
They all observe the southern hemisphere
But never saw a jug of Bavarian beer
So I am keen on that MPA music…

Please, don't remind me of IPP
Unless computing time on Cray is free
They heat their plasma with a laser beam
But cannot win against our soccer team
And I'm in love with that MPA music…

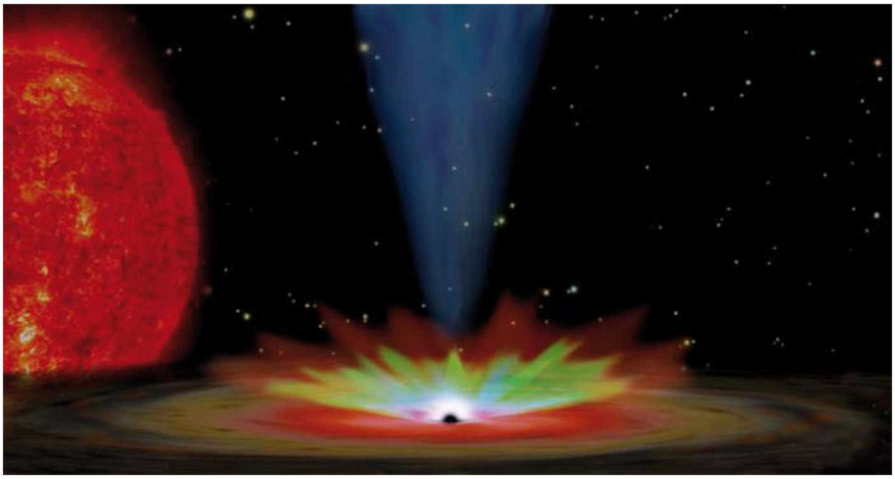
I've got no job here at the institute
Maybe my head is built of worthless wood
But since like others I would like to stay
I have to seek out for another way
That's why I started playing MPA music…

Working at MPA

International Top Level Research on German soil

The MPA aims to carry out theoretical, computational and interpretive astrophysics at the highest international level. The institute places great emphasis on high-end numerical astrophysics, using supercomputers at the Planck Society's Garching computer centre (the RZG), at the computing centre of the State of Bavaria (the LRZ, also in Garching) and at other major installations in Germany and throughout the world.

At MPA 15 long-term scientists currently work with around 30 postdocs, almost 40 PhD students, and up to 50 guest scientists at any given time. Since theoretical work tends to be synthetic and cross-disciplinary, the institute discourages any rigid division of its science into groups. Each of its directors is nevertheless responsible for a range of science topics which together form an identifiable "group of subgroups". The boundaries are overlapping and fluid, however, adjusting as needed for specific projects. PhD students and postdocs are selected by institute-wide ad hoc committees according to their scientific merit and the overlap of their interests with those of senior MPA scientists.



Artist's impression of a black hole X-ray transient. Mass drawn from a secondary star (left) forms an accretion disk which feeds mass to the hole (dark reddish and brown colours). During the infall X-rays (white region) as well as plasma outflows in the form of jets are emitted. An additional slow outflow produces, after typically half a second time-of-flight delay, strong ultraviolet (purple), optical (green) and infrared (red) emissions. The blue fuzz indicates the base of the much faster jet that produces radio emission, but at distances well outside the scale of this image.

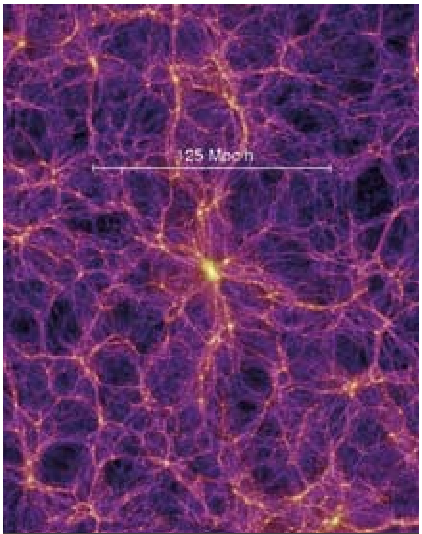
Cosmology: the Content, Structure and Evolution of our Universe

Problems associated with the larger questions of cosmology and extragalactic astronomy are studied in all the MPA research groups, although only the Cosmology Group led by Simon White is almost exclusively occupied with such problems.

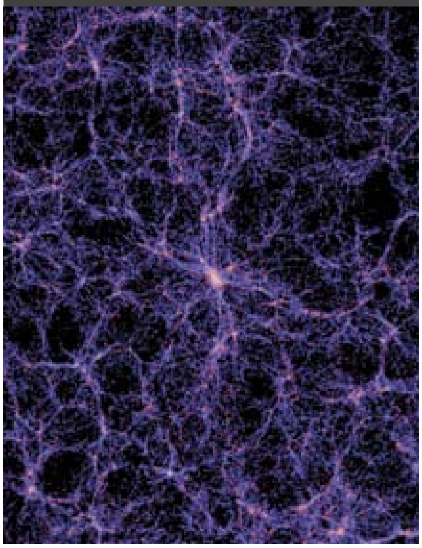
"During my working life cosmology has developed from a speculative and peripheral field to a central pillar of contemporary astrophysics.
New telescopes allow us to see back beyond the birth of galaxies, while new computers allow us to replay that birth at will in order to explore the physics which drives it. Truly we live in Golden Times for astronomy."
Simon White

The questions include: What is the Universe made of? How did it come to take its present form? Is it finite or infinite? Will it last for ever? What was the origin of all structure? How did galaxies form out of the primordial soup? What is the evolutionary link between galaxies and the extremely massive black holes at their hearts?

One of the hottest problems in physics was posed by the discovery, a decade ago, of the accelerated expansion of the Universe. Careful mapping of cosmic history using a particular kind of supernova showed that the Universe is expanding faster today than it was when it was half its present age. This seems to require most of the content of today's Universe to be in "Dark Energy", an unanticipated form with bizarre properties unlike any other known form of matter or energy. MPA supernova theorists have been clarifying the nature of the particular supernovae providing apparent evidence for acceleration, while MPA high energy theorists and structure formation simulators have been exploring how additional information about the Dark En-



Two pictures from the Millennium simulation: The first picture shows the predicted distribution of Dark Matter, the second one the illuminated galaxies in the same section.



ergy could be obtained from observations of gas in distant galaxy clusters and from observations of the evolution of galaxy clustering, respectively.

Dark Energy also seems required to explain the properties of observed structure in the Cosmic Microwave Background (CMB). This is an almost uniform sea of microwaves, first discovered in 1964, which turns out to be the left-over heat from the Big Bang itself. The CMB provides us with a direct image of the Universe when it was only 400,000 years old. At that time, there were no stars, galaxies or elements heavier than lithium; just a near-uniform hot plasma filled with weak sound waves from which all later structure has developed. Detailed studies of these sound waves over the last 15 years have provided great insight into the geometry and content of our Universe and the origin of all structure within it. The next great advance in this field is expected to come from the European Space Agency's Planck Satellite, to be launched at the beginning of 2009, which will map the whole microwave sky at 9 different frequencies and provide the most precise measurements so far of the CMB. Both Simon White and Rashid Sunyaev are Co-Investigators on this project, and the MPA hosts a pipeline development group led by Torsten Ensslin which is spear-heading Germany's contribution to Planck.

The CMB sky provides evidence not only for Dark Energy, but also for Dark Matter, a new form of matter, yet to be observed directly on Earth, which contributes about five times as much mass to the present Universe as the ordinary atomic matter we are familiar with. The need for unseen "Dark Matter" in the largest astronomical objects, for example galaxy clusters, has been known for 70 years, but its nature remains a mystery. Most astronomers are betting that it will turn out to be a new kind of elementary particle, perhaps soon to be discovered at the Large Hadron Collider in Geneva. Simon White and many scientists in his MPA cosmology group have spent much of their careers trying to understand how the Dark Matter influences the formation of galaxies and the pattern of galaxy clustering in the Universe. This so-called large-scale structure can then, perhaps, be used to read off the nature of the Dark Matter.

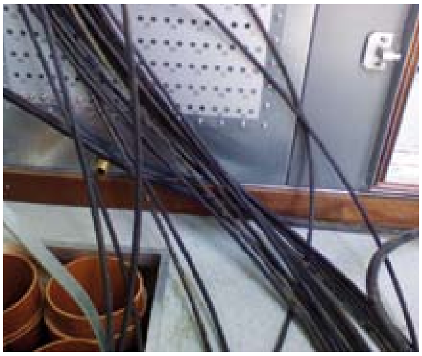
Sloan Digital Sky Survey Telescope at Apache Point Observatory in Sunspot, New Mexico

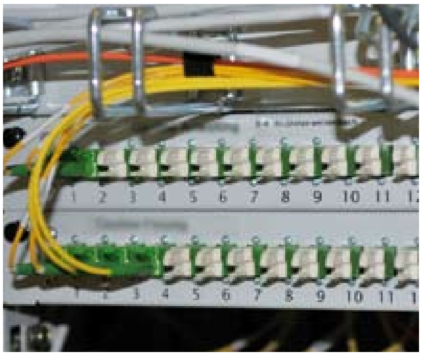
Detailed work of this kind is carried out through supercomputer simulations of the growth of cosmic structure. These produce virtual universes which can be compared directly with the real one we see around us. The code development group led by Volker Springel has positioned the MPA as the leading institute world-wide for simulation work of this kind, driving the development of new numerical techniques and carrying through many of the largest and highest impact calculations. Much of this research has been carried out in the context of the Virgo Consortium, a large international collaboration (co-led by Simon White) of scientists from Germany, the UK, the Netherlands, Canada and Japan, and dedicated to pooling resources for large programmes of simulations in this field. Together with insights from the CMB, Virgo Consortium simulations have done much to establish our current picture for the formation of galaxies and galaxy clusters.

Better understanding of how galaxies form and evolve comes not only from theoretical work, but also (and more importantly) from better observations of galaxy properties, both nearby and in the distant universe. Perhaps the most ambitious astronomical survey project ever undertaken is the Sloan Digital Sky Survey (SDSS). In its just completed second phase (SDSS-II) it was managed by a consortium of 25 institutions around the globe, including the MPA. It has mapped one quarter of the entire sky, measuring the position, brightness and colour of more than 100 million celestial objects. More importantly for the MPA, it has taken high-quality spectra for more than 700,000 galaxies and about 50,000 quasars, improving on previous studies not only by a factor of 100 in number, but also in the quality and uniformity of the data. This has allowed the MPA/SDSS galaxy analysis group led by Guinevere Kauffmann to carry out qualitatively new analyses of the physical properties of galaxies and of the black holes at their centres. This work led to the award of a Leibniz Prize to Dr. Kauffmann in 2007, which has in turn allowed MPA to participate in the third phase of SDSS which started in July 2008.

The MPA cosmology group has also just started a new initiative, led by Benedetta Ciardi, to participate in the Low Frequency Array (LOFAR), a new radio-telescope project led from the Netherlands. LOFAR consists of a large number of antenna fields which are connected to a central high-performance computing facility where the radio images are synthesized in real time. LOFAR will allow the astronomers to observe the sky with unprecedented resolution in an almost unexplored part of the electromagnetic spectrum. MPA scientists are interested in using it to study structure in the Universe before the formation of galaxies. The telescope should be able to detect emission from neutral hydrogen at the time when the first stars formed and the bulk of the matter in the Universe was ionised again by the effects of their radiation. The MPA contribution to LOFAR will be a remote observing station of two antenna fields located near Aresing, about 50 km north of Garching.

MPA Technicians set up the cabinet that will host the electronics for the LOFAR antennas on a field near Aresing.





"With the aid of the cosmological background radiation we can look back into the past of the Universe – as far as to the Big Bang, 13.7 billions of years ago. It is exciting that in this way we can gain clues to how the Universe was created and evolved to its present structure."
Rashid Sunyaev

High-Energy Astrophysics: Observing the violent Universe

The MPA High-Energy Astrophysics group, led by Rashid Sunyaev, deals with the interaction of matter with radiation under extreme physical conditions, where temperatures are hundreds of millions of degrees, where matter is very rarefied, or where magnetic fields are very strong. In particular, phenomena occurring at the end of the stellar lifetimes and close to stellar black holes are often observable primarily at high photon energies.

The research topics of the MPA High-Energy Astrophysics Group are the Universe as a whole (here their work has many overlaps with the Cosmology Group), clusters of galaxies, supermassive black holes and jets in AGN, accreting black holes and neutron stars in galactic binaries and their observational signatures. Regarding these objects the work of the group is mostly concerned with the theory of accretion onto compact objects and boundary layers around accreting neutron stars, gamma-ray bursts, as well as with non-thermal processes in astrophysical plasmas, and the theory of comptonization (the decrease in wavelength of a photon when it interacts with hot electrons).

High-Energy Astrophysicists at the MPA participate actively in the analysis and interpretation of observational data from the currently operating space observatories INTEGRAL, XMM-Newton, Chandra and RXTE. They maintain strong ties with experimental groups at the MPE, the Space Research Institute (IKI) in Moscow and the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts. Via their Russian connections, the MPA High-Energy Group is especially strongly involved in the analysis of data from the ESA mission INTEGRAL, launched by the Russian rocket.

The High-Energy Astrophysics Group at the MPA is active in four subareas:

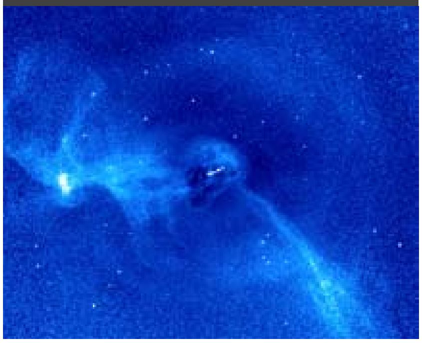
Interaction of Matter and Radiation including the Cosmic Microwave Background: Radiative transfer effects in the Universe are studied. Special emphasis is placed on anisotropies and spectral distortions in the Cosmic Microwave Background which can be due to various effects, e.g. first star formation, large-scale structure growth or cosmological recombination. Understanding the Cosmic Microwave Background is important to study the origin and evolution of the Universe as a whole.

Accretion Physics for Stellar Mass and Supermassive Objects: Scientists in this group work on the physics of accretion onto various kinds of objects, from newly born stars, to neutron stars and stellar mass black holes, to the supermassive black holes that power AGN. These studies cover a wide range of subjects, like the general properties of the accretion flow itself, the evolution of the accreting object and feedback processes between AGN and gas in their environment.

X-Ray Binaries: Work here concentrates, on the one hand, on properties of single objects, like X-ray brightness, variability and spectral behaviour, on the other hand, on the dependence of the global properties of a population of X-ray binaries on their host galaxy. X-ray binaries are a class of binary stars that are bright in X-rays, which are produced by matter falling from one star (usually a relatively normal star) to the other, which is a white dwarf, neutron star, or black hole.

Non-thermal processes in the Universe: Some of the most extreme and most interesting objects in the Universe such as supernovae, gamma-ray bursts and active galaxies with a black hole of several 100 million solar masses in their centre emit a lot of radiation with nonthermal spectra. Activity in this area concentrates on galaxy clusters and large-scale structure.

Supermassive black hole in elliptical galaxy M87 pumping energy to the hot gas (NASA's Chandra observatory image)



"The fact that the elements we consist of were created in the fiery interiors of stars never ceases to amaze me – we are all star-dust. Analysing star-light enables us to unravel the lives and deaths of generations of stars and the history of galaxies like our Milky Way."
Martin Asplund

Stellar Astrophysics and Galactic Archeology: Origin of the Elements

The research group "Stellar Astrophysics and Galactic Archeology" was created in 2007 with the arrival of Martin Asplund as a new MPA director. The group has a two-fold goal: to understand the physical processes in stars and how they evolve with time as well as to use stars as probes of the cosmos, from the Big Bang and the distant Universe to our Galactic neighbourhood and our own Sun.

A common thread of much of the work done in the research group is the study of the origin of the elements – when, where and how the different chemical elements were produced in the Universe. Within the first few minutes after the Big Bang the temperature and density were sufficiently high to enable nuclear reactions, creating hydrogen and helium as well as a smattering of lithium. All other elements have been forged by nuclear reactions in the fiery interiors of stars, the exact same processes that generate the energy enabling stars to shine. When stars die they eject some of their nuclear-processed material to the interstellar medium from which subsequent generations of stars are born. For each round of this cosmic recycling the amount of atoms heavier than hydrogen thus steadily increases. Each element has its own characteristic origin. For example, the oxygen we breathe has been generated by stars some ten times more massive than the Sun, the carbon in our bodies is believed to come from stars like our own Sun, while most of the iron in our blood comes from the catastrophic nuclear explosions of compact stellar embers called white dwarfs. This research is thus intimately linked with the theoretical and modelling efforts aimed at understanding lives and deaths of stars carried out by the Stellar Evolution and Hydrodynamics group at MPA.

A critical ingredient for this endeavour is how to decipher the light emitted by stars in terms of stellar properties such as masses, temperatures, ages and chemical compositions. Indeed most of our knowledge of the Universe stems directly or indirectly from the analysis of star-light. In order to interpret the stellar spectra correctly requires having realistic models of the stellar atmospheres from which the radiation originates. The group at MPA has pioneered developing sophisticated computer simulations of stellar atmospheres to address one of the main challenges for stars similar to the Sun, namely how to properly take into account convection that reaches up to the surface. This is done through time-dependent hydrodynamical calculations coupled with detailed radiative transfer, which requires supercomputers. The group is also world-leading in making detailed predictions of stellar spectra based on these atmosphere models and to infer the chemical compositions of stars from the elemental fingerprints in the form of spectral absorption lines.

One of the more surprising outcomes of the improved modelling work done within the group is a drastic revision of the solar chemical composition – the Sun contains only about half as much of elements like carbon, nitrogen and oxygen as previously thought. This finding has far-reaching consequences for most areas of astronomy since the content of the chemical elements in the Sun functions as an astronomical yardstick against which the compositions of all other stars, gas clouds and galaxies in the cosmos are referenced. Among other things these elements are very important in shaping the interior structure of stars and therefore how the stars will evolve with time.

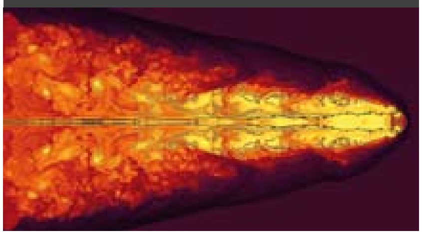
A major driver for the group is to understand the formation and evolution of galaxies like our own Milky Way, which is one of the main outstanding problems in astronomy today. One way of addressing this is to study stars born at different locations and with varying ages in the galaxy and thereby piece together its history, an approach which has been dubbed Galactic archeology. Within the standard framework of cold Dark Matter cosmology, galaxies are formed by continuous merging of smaller building blocks like dwarf galaxies. The signatures of this process should be visible in the elemental abundances and motions of stars. The chemical compositions of the stars reveal differences between the various stellar populations in the Galaxy in terms of the star formation rate, initial mass function and the amount of gas infall and outflow as a function of space and time. The MPA Stellar Astrophysics and Galactic Archeology group is actively involved in the two most ambitious Galactic surveys – the US-led Sloan Digital Sky Survey (SDSS) and the Chinese-led LAMOST project – which both will obtain spectra of millions of stars over the next five years. These will be true treasure-troves to disentangle the complicated history of our Milky Way. Much of the important follow-up work will be carried out using the ESO Very Large Telescope and led by MPA astronomers.

The SDSS and LAMOST surveys will also be harvested for finding the very oldest stars in the Galaxy. These first stars in the Universe were born within the first billion years after the Big Bang. Theoretically one expects them to have been very different from the stars of today in terms of their evolution and spectral properties. Will we one days be able to discover one of those elusive first stars containing only primordial matter from the Big Bang? Even if none of them are still around now, their nucleosynthetic signatures should be imprinted in the subsequent stellar generations. Unfortunately those stellar survivors are extremely rare today, which necessitates very large surveys to find them. These very old stars are extremely important since they hold clues to the conditions in the Big Bang itself and the earliest epochs of our Galaxy.

Our own Milky Way Galaxy is a spiral galaxy like the here shown Andromeda galaxy.
By determining the elemental abundances for stars of different ages born in different locations in a galaxy it is possible to piece together the evolutionary history of the whole galaxy from its formation some 10 – 13 billion years ago to the present day, a technique dubbed Galactic archeology. In particular the group is trying to understand the different stellar populations in the Milky Way – the central bulge, the thick and thin disks and the surrounding old halo – and how they interrelate.

"It fascinates me that it is possible to develop plausible models on the basis of few facts, and surprisingly often these models fit into reality. Supernova explosions fall under this category."
Wolfgang Hillebrandt

Simulation of a relativistic jet: the colour coding marks the density.



Life and Death of the Stars: Stellar Evolution and Hydrodynamics

With the aid of the methods of numerical hydrodynamics, the group led by Wolfgang Hillebrandt is developing computer models for stellar explosions and for collisions between binary stars. They also simulate relativistic outflow (jets) from black holes, and study convection (one of the major modes of heat transfer) and turbulent flows in stellar plasmas.

While Martin Asplund's group "Origin of the Elements and Stellar Atmospheres" concentrates on the quiet stages of star evolution, the "Stellar Evolution and Hydrodynamics" group puts its emphasis on the dynamic final phases of the stellar life cycle, and on nuclear astrophysics. However there are many overlaps both in methods and in research topics: hydrodynamics, radiation transport, massive or metal-poor stars.

The theory of stellar evolution has a long history at MPA, starting with the pioneering work by Kippenhahn, Meyer-Hofmeister and Weigert in the 1970s. Their stellar evolution code has continuously been updated, reshaped and extended until the present day, and is still among the best codes available. It is used for the calculation of solar models as well as for studying the evolution of single stars of all masses.

Current projects in the field of stellar evolution deal with the classification of stars into populations, with the development and testing of stellar models, and with Planetary Nebulae.

Planetary Nebulae consist of a glowing shell of gas and plasma formed by certain types of stars at the end of their lives. They are the outer layers of the stars which are expelled via pulsations and strong stellar winds, while the remains of the stars form hot and faint objects at their centres. Planetary Nebulae play an important role in the chemical evolution of galaxies. By means of their luminosity the distance of the galaxy can be measured. MPA models are being used to determine the exact relationship between luminosity and distance in different populations of planetary nebulae.

Important projects in the field of hydrodynamics deal with relativistic outflows, mergers of compact objects, the physics of thermonuclear supernovae and the explosion mechanism of core-collapse supernovae.

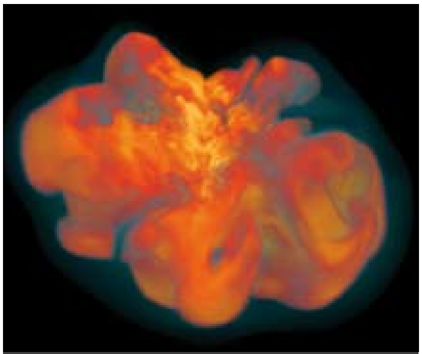
In relativistic hydrodynamics the collapse of rotating stellar cores to neutron stars is studied, and the resulting gravitational wave signal is calculated. Neutron stars are the final stage of stars of a specific mass range, and consist mostly of neutrons at very high density.

The MPA simulates relativistic outflows (so-called jets) and their emission properties in gamma-ray bursts and active galactic nuclei. Non-radial neutron star oscillations (periodic or irregular changes in luminosity which alter the spherical symmetry of the star) are studied in the context of General Relativity.

Supernovae are explosions of stars at the end of their lifetime, which can be observed as short and extremely luminous flashes. Stars of higher mass end their days with a core collapse, from which a pulsar or a black hole emerges. Stars of low mass, which are part of a binary star and accrete matter from their companion, explode as thermonuclear supernovae, by far the brightest supernovae, also referred to as Type Ia supernovae.

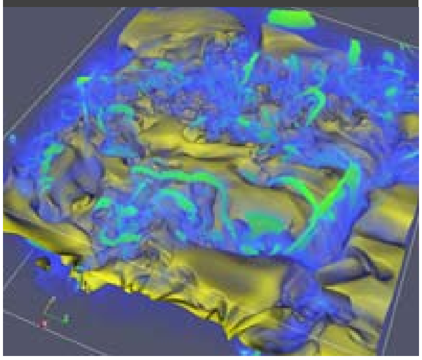
In their temporary final stage as part of a binary, these stars are called white dwarfs. The MPA group Hydrodynamics studies the incineration of white dwarfs by thermonuclear burning, using 3D hydrodynamics simulations. The resulting nucleosynthesis and the spectral signature of the events are calculated. Many overlaps between the research of the Hydrodynamics and Cosmology groups result from their joint study of Type Ia supernovae, which are used as cosmic distance meters and have led to the discovery of Dark Energy. For these studies the Hydrodynamics Group also runs extensive observational programmes.

Core-collapse supernovae are studied mainly with regard to details of their explosion mechanism. According to the generally accepted theory, a supernova of this type occurs at the end of life of a massive star after it has used up its nuclear fuel for stellar nucleosynthesis. The iron, the “ashes” of the nuclear combustion, remains in the core of the star. The loss of free electrons and the energy loss by photodisintegration lead to a heavy reduction of pressure in the core, and the core collapse ensues. The MPA Hydrodynamics group studies the role of neutrino heating and flow instabilities in the explosion of core-collapse supernovae by means of multi-dimensional radiation hydrodynamics simulations.



Numerical simulation of a core-collapse supernova, half a second after in its interior a new neutron star was born

Solar granulation in a numerical simulation: the granules on the photosphere of the Sun are caused by convection currents of plasma.



Imprint

Publisher	Max Planck Institute for Astrophysics Karl-Schwarzschild-Str. 1 D-85741 Garching Phone +49 89 30000-0 Fax +49 89 30000-2235 info@mpa-garching.mpg.de www.mpa-garching.mpg.de
Concept and Textedition	Mona Clerico
Image Credit	Heinz-Ado Arnolds et al., MPA; Tobias Krieg, MPG; Robert Gendler; ESO; NASA
Design	padma eck

October 2008