Max-Planck-Institut
für
Astrophysik

ANNUAL REPORT 2014

Contents

1 General Information

1.1 A brief history of the MPA

The Max-Planck-Institut für Astrophysik, usually called MPA for short, was founded in 1958 under the directorship of Ludwig Biermann. It was established as an offshoot of the Max-Planck-Institut für Physik, which at that time had just moved from Göttingen to Munich. In 1979, as part of plans to move the headquarters of the European Southern Observatory from Geneva to Garching, Biermann's successor, Rudolf Kippenhahn, relocated the MPA to its current site. The MPA became fully independent in 1991. Kippenhahn retired shortly thereafter and this led to a period of uncertainty, which ended in 1994 with the appointment of Simon White as director. The subsequent appointments of Rashid Sunyaev (1995) and Wolfgang Hillebrandt (1997) as directors at the institute, together with adoption of new set of statutes in 1997, allowed the MPA to adopt a system of collegial leadership by a Board of Directors. The Managing Directorship rotates every three years, with Simon White in post for the period 2012-2014.

In 2007 Martin Asplund arrived as a new director but, for personal reasons, decided to return to The Australian National University in 2011. He remains linked to the institute as external Scientific Member, joining the other external Scientific Members: Riccardo Giacconi, Rolf Kudritzki and Werner Tscharnuter. Eiichiro Komatsu arrived in 2012 from the University of Texas to take up a directorship, bringing new impetus to the institute's research into the early universe and the growth of structure. This generational change continued in 2013 when the MPA's own Guinevere Kauffmann was promoted to a directorship, thereby ensuring that the institute will remain a centre for studies of the formation and evolution of galaxies. Finally, a search is currently underway for another new director, active in some area of theoretical or numerical subgalactic astrophysics, to succeed Wolfgang Hillebrandt who retired in 2012.

The MPA was originally founded as an institute for theoretical astrophysics, aiming to develop the theoretical concepts and numerical algorithms needed to study the structure and evolution of stars (including the sun), the dynamics and chemistry of the interstellar medium, the interaction of hot, dilute plasmas with magnetic fields and energetic particles, and the calculation of transition probabilities and cross–sections for astrophysical processes in rarefied media. From its inception the MPA has had an internationally-recognized numerical astrophysics program that was long unparalleled by any other institution of similar size.

Over the last 20 years, activities at the MPA have diversified considerably. They now address a much broader range of topics, including a variety of data analysis and even some observing projects, although there is still a major emphasis on theory and numerics. Resources are channeled into directions where new instrumental or computational capabilities are expected to lead to rapid developments. Active areas of current research include stellar evolution, stellar atmospheres, accretion phenomena, nuclear and particle astrophysics, supernova physics, astrophysical fluid dynamics, high-energy astrophysics, radiative processes, the structure, formation and evolution of galaxies, gravitational lensing, the large-scale structure of the Universe, and physical and early universe cosmology. Several previous research themes (solar system physics, the quantum chemistry of astrophysical molecules, general relativity and gravitational wave astronomy) have been substantially reduced since 1994.

Since 2001 the MPA has been part of the International Max-Planck Research School in Astrophysics, a joint initiative between the Max Planck Society and the Ludwig-Maximilians University of Munich. About 70 PhD students participate in the school at any given time, most of them at the MPE or the MPA. This has subtantially increased and internationalised the graduate student body at MPA over the last decade and has resulted in productive social and professional links between MPA students and those at other local institutions. Currently about 25 students at MPA participate in the IMPRS.

MPA policy is effectively set by the Wissenschaftliche Institutsrat (WIR) which has met regularly about 6 times a year since 1995 to discuss all academic, social and administrative issues affecting the institute. This consists of all the permanent scientific staff, as well as elected representatives of the postdocs, doctoral students and support staff. It acts as the main formal conduit for discussion and communication within the institute, advising the directorate on all substantive issues. Ad hoc subcommittees of the WIR carry out the annual postdoc and student hiring exercises, monitor student progress, oversee the running of the computer system, and, in recent years, have carried out the searches for new directions and directorial candidates.

Other aspects of the MPA's structure have historical origins. Its administrative staff (which moved to a new extension building in early 2013) is shared with the neighboring, but substantially larger MPI für extraterrestrische Physik (MPE). The library in the MPA building also serves the two institutes jointly. All major astronomical books and periodicals are available. The MPA played an important role in founding the Max-Planck Society's Garching Computer Centre (the RZG; the principal supercomputing centre of the Society as a whole). MPA scientists have free access to the RZG and are among the top users of the facilities there. Ten posts at the computing centre, including that of its director, are formally part of the MPA's roster. This arrangement has worked well and results in a close and productive working relationship between the MPA and the RZG. At the end of 2014 the management of the RZG was transferred fully to the MPA/MPE administration.

1.2 Current MPA facilities

Computational facilities

Computer and network facilities are a crucial part of everyday institute life, with different needs for theoreticians, numerical simulators and data analysts. At MPA, computing needs are satisfied both by providing extensive in-house computer power and by ensuring effective access to the supercomputers and the mass storage facilities at the Max Planck Society's Garching Computer Centre (the RZG) and the Leibniz Computer Centre of the state of Bavaria (the LRZ). Scientists at MPA are also very successful obtaining additional supercomputing time at various other supercomputer centres at both national and international level.

The design, usage and development of the MPA computer system is organized by the Computer Executive Committee. This group of scientists and system managers also evaluates user requests concerning resources or system structure, with scientific necessity being the main criterion for decisions. RZG and MPA coordinate their activities and development plans through regular meetings to ensure continuity in the working environment experienced by the users.

The most important resources provided by the RZG are parallel supercomputers, PByte mass storage facilities (also for backups), and the gateway to the German high-speed network for science and education. MPA participates actively in discussions of major investments at the RZG, and has provided several benchmark codes for the evaluation of the next generation supercomputer options. RZG also hosts a number of mid-range computers owned by MPA. Presently, two Linux-clusters (with 756 and over 2600 processor cores, up to 10∼TB of core memory and 890∼TB disk storage capacity) are located at RZG, and are used for moderately parallel codes. In addition, MPA is operating a core node of the Virgo (the Virgo supercomputer consortium) data center at the RZG. The node will host the full results from all important Virgo simulations (e.g. Millennium XXL, Eagle) and provide web access to the world-wide community via the Millenium database. This system consists of 2∼PB disk storage and a fat-node server with 48 cores and 1∼TB RAM for data access and memory-intensive parallel data analysis.

MPA's computer system guarantees that every user has full access to all facilities needed, and that there is no need for users to perform maintenance or system tasks. All desks are equipped with modern PCs, running under one operating system (Linux) and a fully transparent file system, with full data security and integrity guaranteed through multiple backups, firewalls, and the choice of the operating system. With this approach MPA is achieving virtually uninterrupted service. Since desktop PCs are not personalized, hardware failures are quickly repaired by a complete exchange of the computer.

In addition to the desktop systems, which amount to more than 170 fully equipped workplaces, users have access to central number crunchers (about 20 machines, all 64-bit architecture; with up to 32 processor cores and 96 GB memory). The total on-line data capacity at MPA is approaching the Petabyte range; individual users control disk space ranging from a mere GB to several TB, according to scientific need. Energy consumption and cooling has become A crucial aspect of IT-installations. At MPA, we are concentrating on low power-consumption hardware and efficient, environmental-friendly cooling.

All MPA scientists and PhD students may also get a personal laptop for the duration of their presence at the institute. These and private laptops may be connected to the in-house network through a subnet which is separated from crucial system components by a firewall. Apart from the standard wired network (Gb capacity up to floor level, and 100 Mb to the individual machine), access through a protected WLAN is provided. MPA is also a partner in the eduroam-consortium, thus allowing its members unrestricted access to WLAN at all participating institutions.

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

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

Library

The library is a shared facility of the MPA and the MPE and therefore has to serve the needs of two institutes with differing research emphases – predominantly theoretical astrophysics at MPA and predominantly observational/instrumental astrophysics at MPE. At present the library holds a unique collection of about 50000 books and journals and about 7200 reports and observatory publications, as well as print subscriptions for about 180 journals and online subscriptions for about 500 periodicals. In addition the library maintains an archive of MPA and MPE publications, two slide collections (one for MPA and one for the MPE), a collection of approximately 800 non print media and it stores copies of the Palomar Observatory Sky Survey (on photographic prints) and of the ESO/SERC Sky Survey (on film). The MPA/MPE library catalogue includes books, conference proceedings, periodicals, doctoral dissertations, and habilitation theses, reports (print and online). Additional technical services such as several PCs and terminals in the library area, copy machines, a colour book-scanner, two laser printers, and a fax machine are available to serve the users' and the librarians' needs. The library is run by three people who share the tasks as follows: Mrs. Chmielewski (full time; head of the library, administration of books and reports), Mrs. Hardt (full time; interlending and local loan of documents, "PubMan", and publications management for both institutes - about 1200 publications 2014), and Mrs. Blank (half time; administration of journals)

1.3 2014 at the MPA

In 2014 the institute finally got back its guest-house. This had had to be closed for major renovation because mould had got so deeply into the building structure, that everything except the main load-bearing walls and the roof needed to be torn down to foundation level and renewed. We took advantage of this enforced work to redesign the interior layout, and as a result the guest-house now contains four double rooms and one single room, all with en-suite bathroom facilities, television and network connections. This rearrangement entailed the loss of all communal space, so the institute is currently considering conversion of a nearby (ex-)computer room in the main building to provide a common-room and small kitchen for guests. Past experience shows that the guest-house is particularly useful for guests visiting the MPA (or MPE) for periods from a few days week to a couple of weeks, and as result such communal space can be helpful for them to prepare food and to meet each other.

MPA scientific meetings in 2014

As usual, MPA scientists organised a number of scientific workshops in Garching or nearby in 2014. For the first time in many years there was no joint MPA/MPE/ESO/Excellence Cluster conference in 2014, but in compensation the Excellence Cluster's new Munich Institute for Astro- and Particle Physics (MIAPP) started operation. MIAPP hosts several topical programmes in astrophysics, cosmology, nuclear- and particle physics per year, each lasting up to four weeks and serving as a centre for scientific exchange. Programmes are selected competitively by a high-ranking international committee from proposals submitted in response to a general advertisement, and are coordinated by a small group of scientists which usually includes at least one local. The very first programme, in

May/June 2014, was on the Cosmological Distance Scale, and included Wolfgang Hillebrandt and Rolf Kudritski among its coordinators. Eichiiro Komatsu was a coordinator for another programme “Cosmology after Planck”, which took place in August/September 2014, despite the vagaries of analysis of large space-based datasets delaying the release of Planck’s full mission cosmological results until December.

A number of other international workshops were organised by MPA during the year. The now traditional Nuclear Astrophysics workshop was held again at Schloss Ringberg early in the year, and the Virgo Supercomputing Consortium held one of its six-monthly collaboration meetings at the institute in December. In addition the Physical Cosmology group organised a small workshop on Linear Perturbation Theory and Markov Chain Monte Carlo methods, which brought experts in the technical aspects of these topics to the institute to give practical lectures on them to the local cosmology community.

Biermann lectures 2014

In 2014, Volker Springel (1.2) came to MPA as our annual Biermann Lecturer. His three lectures revolved around the development and application of advanced numerical techniques to study cosmic structure formation. Volker is currently Professor for Theoretical Astrophysics at Heidelberg University where he leads a research group dedicated to numerical simulations of galaxy formation at the Heidelberg Institute for Theoretical Studies (HITS). He is perhaps best known for the GADGET code he authored, which allowed him to carry out the Millennium and Aquarius simulations, two landmark projects of the international Virgo Consortium. More recently, he has developed a novel moving-mesh technique for cosmological hydrodynamics, which produced the largest and most sophisticated numerical model of galaxy formation on cosmological scales thus far, the “Illustris” simulation (See Fig. 1.1). This work promises new insights into the complex process of galaxy formation and facilitates important predictions for the impact of baryonic physics on the overall properties of galaxies. Volker has made important contributions to the physical modelling of feedback from star formation and accreting supermassive black holes, and his AREPO code aims to be equally useful as GADGET for the field. He is also well known for the iconic images of cosmic large scale structure he made from the Millennium simulation. These been a source of inspiration for professional astronomers and the public alike. Volker Springel was a PhD student at MPA and later came back as a postdoc, rising to be a permanent research group leader before taking up his current post in Heidelberg in 2010. He has received a number of awards, among them the the Klung-Wilhelmy-Weberbank Prize for Physics in 2009, the Heinz-Maier-Leibnitz Prize of the DFG in 2004, and the Otto-Hahn-Medal of the MPG in 2001.

Prizes and Awards

At the end of April 2014, the Rackham Graduate School at the University of Michigan announced that Mike Anderson had been awarded the ProQuest Distinguished Dissertation Award for his PhD thesis. These awards recognize “exceptional and unusually interesting” dissertations and are selected by the Michigan Society of Fellows. Mike’s dissertation was entitled “Hot Gaseous Halos Around Galaxies”. The existence and properties of such gaseous halos have been an important open issue in the field of galaxy formation for decades. At MPA, Anderson is continuing his research on “missing” baryons from a number of directions. He is involved in several new observations of hot gaseous halos, both targeted observations and stacking analyses. He is also working on observations and theoretical analysis of the interplay between supermassive black holes at the centres of massive galaxies and the hot gaseous halos around the galaxies. Finally, he intends to examine the baryon budget of galaxies in the early Universe as well.

On 4 August, Eugene Churazov received the “Sir Harrie Massey award” during the opening ceremony of the COSPAR Scientific Assembly with more than 2000 participants taking place in the Aula Magna of Moscow University. Every two years, the Committee on Space Research (COSPAR) of the International Council for Science recognizes with this award outstanding contributions to the development of space research. Eugene received it for his fundamental contribution to X-ray and Gamma-ray astronomy in both theory and observation. The official citation acknowledges his role in resolving a conundrum, which baffled the astrophysical community for a quarter century: why the hot gas in clusters of galaxies that have a short radiative cooling time is actually not cooling and forming stars at the predicted rate. Eugene developed key theoretical insights and applied these to ROSAT, XMM-Newton, and Chan-

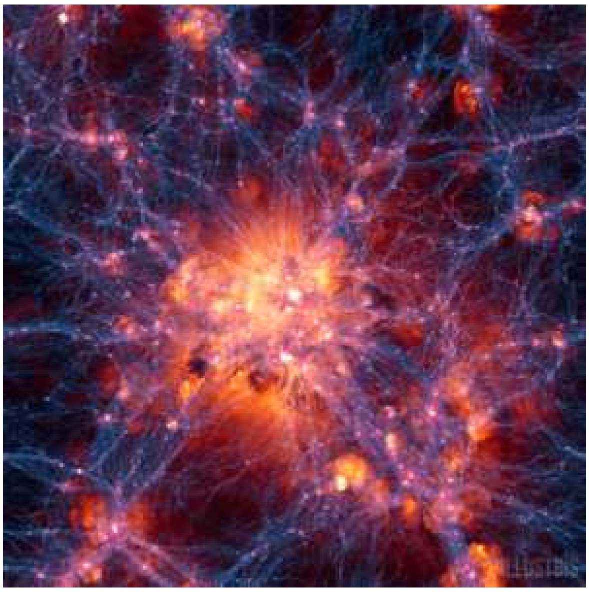


Figure 1.1: Snapshot image from the Illustris simulation, the currently largest and most sophisticated numerical model of galaxy formation. Copyright: Illustris Collaboration (CfA, MIT, HITS, Heidelberg University, IoA, STScI)

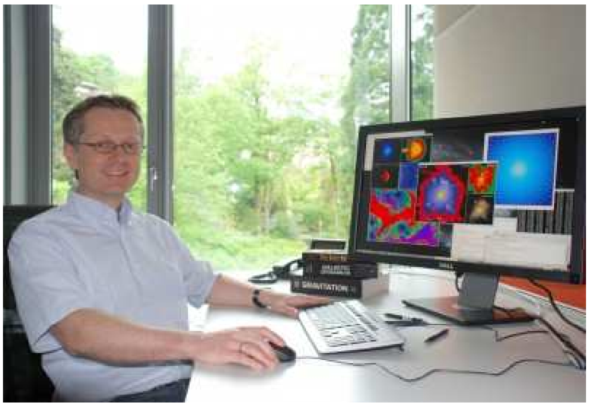


Figure 1.2: (Prof. Volker Springel is currently Professor for Theoretical Astrophysics at Heidelberg University. He has been the MPA Biermann Lecturer in 2014)

dra observations to show that the buoyant plasma bubbles, produced by outbursts from supermassive black holes, could deposit mechanical energy coming from radiatively inefficient accretion onto these black holes. He also showed that the bulk of the AGN power is captured within the cooling cores of cluster atmospheres. This is sufficient to re-heat the cooling gas and, hence, explain the relatively small observed amounts of star formation and cool gas.

Rudolf-Kippenhahn-Award for Tyrone Woods

In November, the MPA awarded Tyrone Woods with the annual Rudolf Kippenhahn Research Award for his paper *He II recombination lines as a test of the nature of SN Ia progenitors in elliptical galaxies*, which appeared in the journal Monthly Notices of the Royal Astronomical Society (see Fig. 1.4). The prize committee congratulated Tyrone for his novel approach and for the comprehensive nature of his investigation, noting that he conducted his project in an independent and self-driven manner. In his paper, Tyrone Woods proposed a new way to study the progenitors of Type Ia supernovae. The issue of which progenitor channel is responsible for the majority of Type Ia supernovae remains remains an open question, with single and double degenerate scenarios both appearing possible. The former would, however, imply a large population of hot, accreting white dwarf stars, which would contribute significantly to the ionizing UV radiation. Modelling their expected emission, Tyrone showed that one can constrain the contribution of the single degenerate channel to the SNIa rate in early-type galaxies using upper limits on the luminosity in certain helium recombination lines. This theoretical work triggered a major effort by a bigger group of scientists to search for this recombination line in the optical spectra of passive galaxies.

The Rudolf Kippenhahn Research Award is given annually in recognition of the best scientific paper written by an MPA student. In 2014, the committee had to appraise eight submissions – there were actually nine, but one will be eligible for 2015. The prize is awarded jointly by the institute and its former director, after whom it is named, based on originality, on significance of scientific impact, and on the quality of the writing in a publication to which students themselves made the dominant contribution.

Figure 1.3: The school girls were able to do some research themselves during the Girls'Day. In different experiments they "worked" on several astronomical topics.

Public Outreach

The public outreach work at MPA involves a broad range of activities and many scientists and staff contribute to present the scientific work at MPA to a wide audience. The public outreach office issued a number of press releases about important scientific results and new projects as well as news about awards and prizes for MPA scientists. These were published on the MPA website as well, complementing the popular monthly scientific highlight series.

In spring, MPA participated in the annual Girls'Day as in the previous years. The school girls could travel from the skies above Garching back to the very beginnings of the Universe. In the portable planetarium dome, junior scientists presented the digital planetarium show "Changing Skies", which not only deals with changes in stars and galaxies but also explains how some of these processes can be understood and modelled in simulations. In a complementary talk, the girls learned about some recent research findings. In addition, the girls were able to do some research themselves: In different experiments they "worked" on several astronomical topics (see Fig. 1.3). Throughout the half day, they also had the opportunity to discuss with the scientists at MPA about their work and their career.

Figure 1.4: Simon White presents the Certificate for the Kippenhahn-Award to Tyrone Woods *(copyright: H.-A. Arnolds, MPA)*

During the course of the year, the planetarium group also organized a number of visits (10 groups with a total of about 240 people) for both school pupils and students, both from German and abroad (Malta, Sweden, India), as well as special visitor groups from the Max Planck Society, who held their annual general assembly in Munich. About half the planetarium shows were complemented by popular talks about various scientific topics. In addition, MPA scientists were also involved in educational programmes for school teachers and gave public talks outside the institute. They supervised interns, wrote articles for popular science media and acted as interview partners for journalists.

2 Scientific Highlights

2.1 Superfluid Effects in Neutron Star Oscillations

The state of matter of neutron stars is largely unknown. However, "starquakes" of neutron stars with extremely strong magnetic fields (Fig. 2.1) shed light into their exotic interior structure (Fig. 2.2). Recent numerical simulations of the magneto-elastic oscillations of neutron stars strongly suggest that their liquid interior, which mainly consists of extremely compressed neutrons and some protons and electrons, is in a superfluid state. When including superfluidity in the models the predicted frequencies of the oscillations agree better with observations and the magnetic field strength estimates agree with alternative estimates. Moreover, the oscillations should live longer than in models without superfluidity.

Neutron stars are a very particular class of stars: they are the most compact stars and they posses the strongest magnetic fields ever observed. They are the final state of the evolution of massive normal stars, i.e. once the fusion process ceases in the centre of such a star, it explodes as a supernova and leaves a neutron star as a compact remnant (Fig. 2.1). But despite this fact, these stars cannot be considered to be “dead”. Instead, they show high activity related to their strong magnetic fields: emission of the most stable electromagnetic pulses (radio pulsars) and repeated flares in X- and gamma-rays (soft gamma-ray repeater/magnetars). Therefore, they are of major interest for astrophysicists.

While the structure of the solid crust of neutron stars is well constrained from terrestrial experiments, little is known about the state of the matter in their interiors. Various theories predict a different behavior of the core matter. (Fig. 2.2) Because neutron stars are held together by very strong gravity their interior is so dense that these conditions cannot be reproduced in any laboratory on Earth. Therefore, observations of neutron stars provide the only opportunity to help us understand the complex nuclear physics of very dense matter, and in particular the interaction of fundamental particle under these conditions.

"Starquakes" of neutron stars with extremely

Figure 2.1: The Soft Gamma-Ray Repeater SGR1900+14 is surrounded by a ring of material that was expelled in the stellar explosion leading to the collapsed star. Credit: NASA/JPL-Caltech

Figure 2.2: Neutron star structure: A solid crust with a thickness of about 1km surrounds a liquid core of about 10km whose state of matter is largely unknown. Credit: Illustration of Cassiopeia A: NASA/CXC/M.Weiss

strong magnetic fields (magnetars) may shed light into their exotic interior structure. In past years, two giant flares were detected in the so-called soft gamma-ray repeaters SGR 1806-20 (2004) and SGR1900+14 (1998). During these events the emitted gamma-ray emission was modulated at different frequencies. Some of the lower oscillation frequencies discovered approximately match the frequencies of magneto-elastic oscillations of magnetars. These pulsations of neutron stars arise from the interaction of the magnetic field in the core with elastic shear oscillations in the solid crust that are similar to earthquakes. However, in this magneto-elastic model the observed high frequencies could not be explained.

With recent numerical simulations, carried out by a collaboration between researchers from the MPA, the University of Valencia and the University of Thessaloniki, it is now possible to identify both low and high frequencies consistently as magneto-elastic oscillations or "starquakes". The crucial ingredient to match all observations at once is another exotic property of the core matter: superfluidity. In this state, there exists no viscosity in the fluid and it has infinite thermal conductivity. On Earth, superfluidity can only be observed at extremely low temperatures, and for just a few elements such as liquid helium.

If one includes superfluid effects in recent neutron star models, only a fraction of the matter (mainly the non-superfluid protons and electrons) is participating in the magneto-elastic oscillations that need to be matched to the observed frequencies. This decoupling leads to a better agreement of our estimates of the magnetic field strength of magnetars with alternative estimates. Moreover, a new family of oscillations appears that is crucial for a complete interpretation of the observed frequencies: a high-frequency shear mode in the crust (that was damped in previous models without superfluidity) resonates with a high overtone of the Alfvén oscillations in the core (Fig. 2.3). (Alfvén oscillations are magnetohydrodynamic waves that are caused by the magnetic field acting as restoring force.) Additionally, superfluid magneto-elastic oscillations should live longer than the oscillations described by previous models, which is important for their detectability.

In future studies the new model can be used to further constrain the state of the matter in neutron stars in general and its superfluid properties in particular. (Michael Gabler, Ewald Müller, Toni Font, Pablo Cerdá-Durán, Nikolaos Stergioulas)

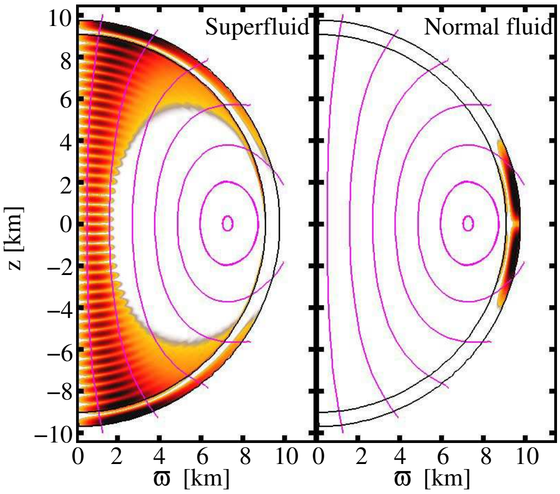


Figure 2.3: These simulations show a new family of oscillations that is present in superfluid models (left panel) and absent in non-superfluid models (right panel). The new oscillations appear as resonances between a high-frequency shear mode in the crust and a high Alfvén oscillation overtone in the core.

Reference:

Gabler, M., P. Cerdá-Durán, N. Stergioulas, J.A. Font, J.A. and E. Müller:P Imprints of Superfluidity on Magnetoelastic Quasiperiodic Oscillations of Soft Gamma-Ray Repeaters. Phys. Rev. Lett. **111**, 211102 (2013)

2.2 Connecting the formation of monster black holes to streaming motions in the early Universe

The origin of supermassive black holes in the centres of large galaxies is one of the most interesting unsolved problems in astrophysics. Recently, scientists at MPA investigated how the motions between ordinary matter and dark matter in the early Universe could have affected the formation of supermassive black holes alongside the first galaxies.

A supermassive black hole with a mass several million or even billion times the mass of the Sun lies at the centre of every massive galaxy. Observations of quasars – supermassive black holes in luminous, gas-eating states – show that they must have formed at around the same time as the first stars and galaxies, during the first few hundred million years after the Big Bang. The origin of these gravitational monsters remains one of the major unsolved problems in astrophysics.

The first stars and galaxies formed more than 13 billion years ago, when the mixture of primordial gas (mostly hydrogen and helium) and dark matter in the early Universe started to build up in dense pockets. There, the gas formed hydrogen molecules, and collapsed due to its own gravity to form the first stars.

Figure 2.4: Artist's rendering of a quasar ingesting matter from its surroundings. Such a supermassive black hole shines very brightly and can therefore be observed at vast distances.*credit: ESO/UKIDSS/SDSS*

Astrophysicists believe that the first super-sized black holes formed shortly afterwards, by one of two possible processes. The first possibility is that massive stars left behind black holes when they ran out of fuel. These then consumed matter from their surroundings and fused together with each other until they became supermassive. The second possibility is that extra-massive black holes formed from the direct collapse of very massive clumps of hot gas (about 8000 Kelvin, hotter than the surface of the Sun) that did not form hydrogen molecules – gas without hydrogen molecules would not have collapsed into ordinary stars, but instead much more massive objects.

As mentioned above, galaxies formed from – and consist of – a mixture of dark and ordinary matter. While ordinary matter is made of the familiar protons, electrons and neutrons, the dark matter interacts with normal, atomic matter only gravitationally. Actually, most of the mass inside a galaxy is in the form of this mysterious component. In a typical galaxy today, the union of the two types of matter – ordinary and dark – is peaceful, but this was not the case at the time when the first stars and galaxies formed.

Recent studies have shown that in the early Universe, ordinary matter and dark matter did not move in unison – much as fish do not always swim with the current of water. Because of the fact that there were relative motions between ordinary and dark matter – that they "streamed" against each other – they cannot have gravitationally collapsed in the same way. The dark matter, being more abundant, collapsed first, and gravity pulled in the ordinary matter only after the motions had slowed down. This means that because of the primordial streaming motions, the first stars and galaxies formed somewhat later than previously thought (See Figure 2.5 and 2.6). (Takamitsu Tanaka, Miao Li and Zoltan Haiman)

References:

Tanaka, T., Miao Li and Z. Haiman: The effect of baryonic streaming motions on the formation of the first supermassive black holes. M.N.R.A.S. **435**, 3559 (2013).

Tanaka T. and Miao Li: The formation of massive black holes in z∼30 dark matter haloes with large baryonic streaming velocities. M.N.R.A.S. (2014).

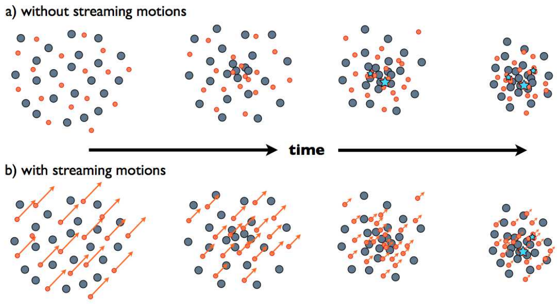


Figure 2.5: A schematic cartoon of how the first structures form without (top) and with (bottom) streaming motions. Dark matter is represented by grey circles, while ordinary matter is represented by orange ones. If there are streaming motions (represented by arrows) between ordinary and dark matter, the clumps of ordinary matter form less quickly, resulting in a delay in the formation of the very first stars (depicted as blue symbols).

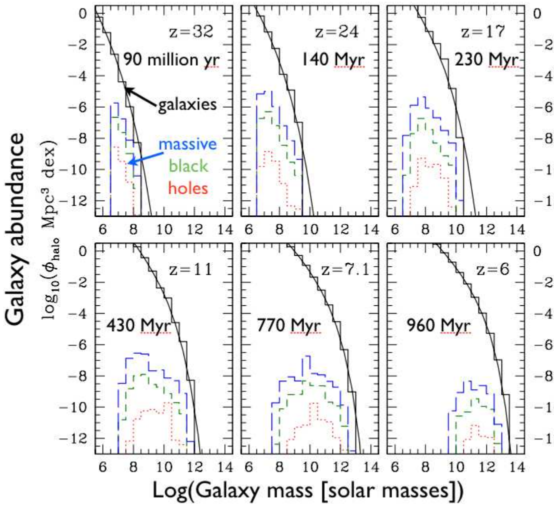


Figure 2.6: The plot on the left shows the theoretical abundances of all galaxies (black lines) and only those galaxies with massive black holes (coloured histograms) when the universe was just 90 million years old. Streaming motions could help to form massive black holes much earlier than previously thought. (The different colours represent different interpretations of high-resolution simulations on how effectively the streaming motions delay star formation.) The plot on the right is similar to the one on the left but at a later epoch. With the new scenario involving streaming motions, the prediction for the abundance of massive black holes is roughly consistent with the observed value (about 10^{-9} per cubic Megaparsec).

2.3 An observational and theoretical view of the atomic gas distribution in galaxies

How is cold gas accreted in galaxies? Observers and theorists from MPA have joined their efforts to investigate the radial distribution of atomic gas in unusually gas-rich nearby galaxies. They found a universal shape for the radial profiles of the gas in the outer regions of the observed galaxies, and obtained remarkable agreement with simulations. In half the galaxies, the atomic gas may have been accreted in the form of “rings”.

Every astronomy student learns that in galaxies stars form from huge gas clouds. However, the details of the accretion and distribution of gas in galaxies is still unclear. Therefore, an international group of scientists at MPA and ASTRON in the Netherlands joined forces and carried out the Bluedisk project to map neutral hydrogen in a sample of 25 very gas-rich galaxies as well as a similar-sized sample of “ontrol”galaxies with similar masses, sizes and distances, but normal gas content. Their main tools were the Westerbork Synthesis Radio Telescope (WSRT) as well as elaborate computer simulations.

There have been many efforts over the past three decades to map the distribution of cold, atomic gas in galaxies using radio synthesis telescopes. The first analyses showed that the atomic gas exhibits a wide variety of detailed features. These can be attributed to irregularities in the galaxy such as spiral arms, rings, bars, warps etc. Studies of larger samples revealed basic scaling relations that provide hints of the mechanisms regulating the evolution of galaxies.

In contrast to the stellar surface density, which peaks in the centre of the galaxy and drops steeply with radius, the radial distribution of the atomic gas often flattens or even declines near the centre of the galaxy. In the outer regions, the gas disks usually extend to a larger distance from the centre than the stellar disks, and are well-fit by exponential functions.

Thanks to improvements in the WSRT instrumentation and data analysis, the observations by the Bluedisk team reached significantly lower column densities than previous surveys, i.e. they were able to map the gas in regions where the gas has low density. This sample is thus also well-suited for direct comparison with theoretical models. Ob-

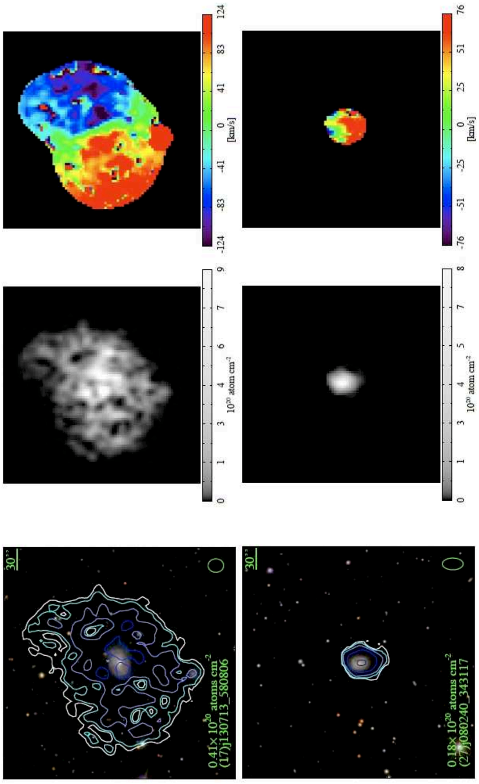


Figure 2.7: The top and bottom rows show two galaxies with very different gas disk morphologies. From left to right: the column density contours for neutral hydrogen overlaid on optical images from the Sloan Digital Sky Survey, the neutral hydrogen itself, and the velocity maps of the neutral hydrogen.

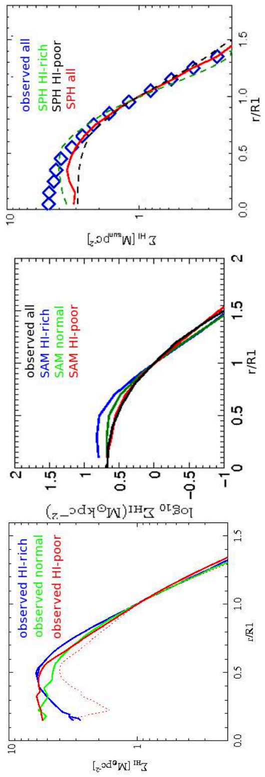


Figure 2.8: The median radial profiles of different galaxies (blue: gas rich, green: normal, red: gas poor). For all galaxies, the radius has been scaled to R1, where the gas surface density reaches 1 solar mass / square parsec. The observed profiles in the left plot are compared to results from semi-analytical models (SAM, middle) and results from smoothed particle hydrodynamical simulations (SPH, right).

servers and theorists worked together closely to improve their understanding of the radial distribution of the cold, atomic gas and to find a physical explanation for its structure.

The study revealed an interesting observational phenomenon: in the outer regions of all the galaxies, the gas exhibits a homogeneous surface density profile (if the sizes of the gas disks are properly scaled). This profile is well-fit by an exponential function with a universal scale-length. This universal profile appears to hold for all galaxies, irrespective of their stellar properties, gas masses, sizes, or morphologies (for an example see figure 2.7). This is remarkable, because the gas-rich galaxies contain on average 10 times more gas than the control sample.

In addition, the team found surprising agreement between their universal profile and results from simulations, both for smoothed-particle hydrodynamical simulations and for semi-analytic models of disk galaxy formation (see figure 2.8). It remains something of a mystery why the agreement with the smoothed-particle hydrodynamical simulations is quite so good.

In the semi-analytic models, the universal shape of the outer radial profiles is a direct consequence of the assumption that infalling gas is always distributed exponentially. However, there are observational indications that the atomic gas could be accreted in the form of “rings” Therefore, more work is underway on the theoretical side using smoothed particle hydrodynamical simulations to try and understand how gas settles onto the simulated galaxies in more detail (see figure 2.9). (Jing Wang and Guinevere Kauffmann)

Reference:

Wang, J.; Fu, J., Aumer, M., Kauffmann, G., et al.: An observational and theoretical view of radial distribution of HI gas in galaxies. MNRAS (2014).

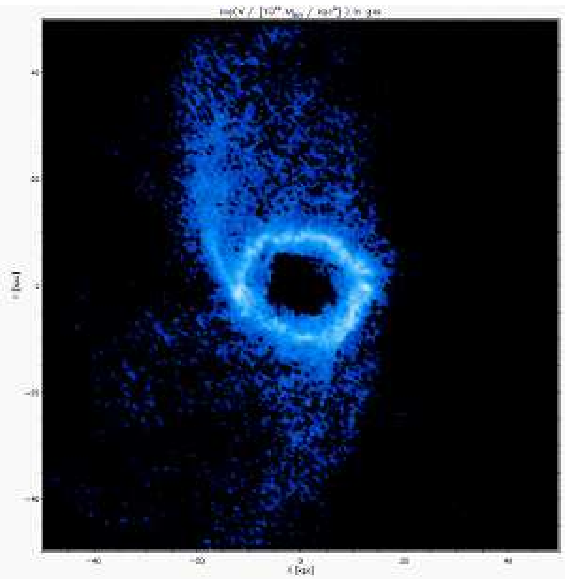


Figure 2.9: An extreme case of gas accretion in a ring-shape. This simulated galaxy at a redshift z∼0.5 was the result of smoothed particle hydrodynamical simulations. *Image provided by Michael Aumer*

2.4 New analytical model for turbulence pressure in galaxy clusters

Mass determinations of galaxy clusters based on observations of the hot intracluster gas often neglect non-thermal processes, most importantly intracluster turbulence. This introduces a systematic error in the estimate. A group of scientists at MPA has therefore developed an analytical, one-dimensional model for the non-thermal pressure contribution, which combines the growth of galaxy clusters in a cosmological context and the physics of turbulence. If further tests against both observations and simulations confirm the initial positive results, this new model could improve the determination of cluster masses and thus make galaxy clusters a more accurate cosmological tool.

The expansion of the present-day Universe is accelerating, and the origin of this acceleration is unknown. It indicates either the presence of “Dark Energy” - a mysterious energy component in the Universe with negative pressure, or a breakdown of Einstein’s General Relativity - how gravity works on cosmological scales. In order to distinguish between these two explanations, we must measure how structures in the Universe evolve over time.

Galaxy clusters (see Fig. 2.10) grow in mass by accreting material from their surroundings over cosmic history. They are the largest known gravitationally bound objects in the Universe and therefore are an excellent probe of the growth of large-scale structures – and thus of the origin of the cosmic acceleration. If we want to use galaxy clusters as a probe of the acceleration, we need to accurately determine their masses. Although these giants are dominated by invisible “dark matter”, we can infer their total mass from observations of the intracluster gas under the assumption of a hydrostatic equilibrium between the gravitational pull and the gas pressure, or more accurately the gradient of the gas pressure.

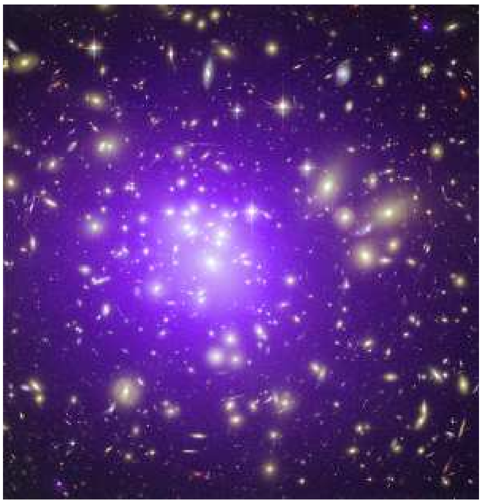


Figure 2.10: The galaxy cluster Abell 1689, one of the biggest and most massive galaxy clusters known. Most of the mass is in the form of dark matter, so astronomers need to use indirect methods such as gravitational lensing, the SZ-effect or X-ray observations of the hot intracluster gas to determine the mass of a galaxy cluster. Credit: X-ray: NASA/CXC/MIT/E.-H Peng et al; Optical: NASA/STScI

Observations of the intracluster gas, however, typically measure only the thermal pressure of the gas. Non-thermal pressure, especially from turbulent gas motion, has been recognized to provide an additional pressure gradient and therefore has to be taken into account as well. Neglecting this contribution would result in a deviation of the inferred cluster mass from the true mass and in consequence this would influence the study of cosmic acceleration.

So far, the amplitude of the turbulence pressure has mainly been estimated with large-scale hydrodynamical numerical simulations. These state-of-the-art simulations, however, yield quantitatively different results when using different numerical methods. Moreover, they are computationally expensive and do not lead to a direct physical understanding of what is happening in the galaxy clusters.

Therefore, we took a different approach to this problem by gathering physical insights about how turbulence arises and dissipates in the intracluster gas. From this input, we formed a one-dimensional analytical model of the non-thermal pressure contribution, which describes the velocity dispersion due to turbulence at each radius as the galaxy cluster grows in mass (Fig. 2.11).

This new analytical model predicts that the non-thermal fraction of the gas pressure increases towards cluster outskirts as it takes significantly longer for turbulence to dissipate at larger distances from the cluster centre. Another prediction is that the non-thermal fraction is larger in clusters with higher masses and in clusters observed at higher redshift (i.e. at earlier cosmic times), since they grow faster which triggers more turbulence.

$$\frac{\mathrm{d}\sigma^2_{\mathrm{nth}}}{\mathrm{d}t} = -\frac{\sigma^2_{\mathrm{nth}}}{t_{\mathrm{d}}} + \eta\,\frac{\mathrm{d}\sigma^2_{\mathrm{tot}}}{\mathrm{d}t}$$

Figure 2.11: This analytical equation is at the heart of the new method: it describes the evolution of pressure due to turbulence in galaxy clusters.

With the help of an existing model of the total pressure, the new model also gives the thermal pressure as well as the biased mass estimate derived from this thermal pressure gradient. If we compare our results with observations of a population of galaxy clusters, the predicted thermal pressure profile is in excellent agreement with the data (Fig. 2.12).

Thus, our model has passed an important observational test; in addition we found qualitative agreement with simulation data. More specific tests on the predicted mass and redshift dependence will be performed both against observations and numerical simulations. If all the tests are passed successfully, the physical understanding provided by the new model will lead to a better determination of the cluster masses. We can then use galaxy clusters as a competitive probe of the origin of cosmic acceleration. (Xun Shi and Eiichiro Komatsu)

Reference:
Xun Shi and Eiichiro Komatsu: Analytical model for non-thermal pressure in galaxy clusters, M.N.R.A.S. **442**, 521 (2014).

2.5 Resolving the radio sky

Radio astronomers obtain extremely high resolution sky images by using interferometers, instruments where several single radio telescopes are linked together. However, optimal data analysis procedures for such an instrument are significantly more involved than for a single telescope. Scientists from the Max Planck Institute for Astrophysics have now developed the algorithm RESOLVE (“Radio Extended Sources Lognormal De-

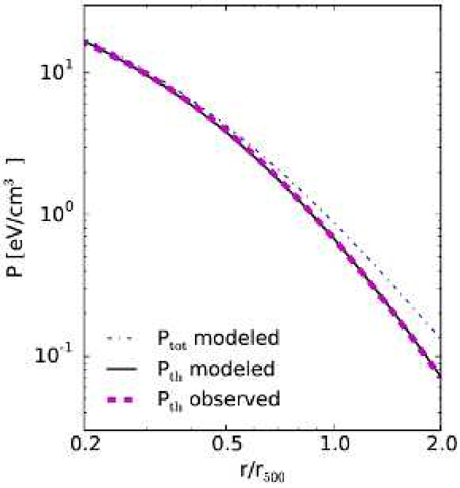


Figure 2.12: The predicted total (dash-dotted) and thermal (solid) pressure profiles calculated with the new model. The calculations were performed for a group of clusters at a mean redshift z=0.1 with a average mass of 300 trillion solar masses. The thick dashed line shows the profile derived from X-ray and SZ observations.

Figure 2.13: The Very Large Array (VLA) is a collection of 27 radio antennas located on the plains of San Augustin near Socorro, New Mexico, each with a dish 25 meters in diameter and weighing more than 200 tons. The data from all antennas can be combined electronically so that the array effectively functions as one giant antenna. *Credit: NRAO/AUI*

convolution Estimator") which solves a number of outstanding problems in radio imaging.

Using radio interferometers, scientists look into the deepest depths of the Universe. These instruments deliver high-resolution images of many different celestial objects, ranging from the Sun, over pulsars, and the interstellar gas in the Milky Way, to distant sources such as radio galaxies or quasars. The high-resolution radio images of such objects often reveal their complex and extended structure.

Indeed, most of the radio emission from celestial sources originates in extended cosmic plasma clouds, glowing only faintly to the observer on Earth. In consequence, such extended regions of emission are difficult to detect, since they have to be separated from unwanted interferences as e.g. electronic noise from terrestrial technical equipment or atmospheric effects.

Furthermore, imaging in radio interferometry is inherently more complicated as for a single telescope. This is because an interferometer does not detect the celestial sources directly, instead the signals from different detectors are electronically superimposed. To reconstruct the original signal from the data, a so called Fourier transformation needs to be applied, usually implying complex calculations on the computer. Unfortunately, standard imaging methods have the drawback that they often only produce unreliable results for weak and extended emission. Moreover, due to the complex nature of the interferometric observation, in general an estimation of the measurement uncertainty was unreliable so far as well.

In two recent publications, the new imaging algorithm RESOLVE is presented to solve exactly these problems of current methods. RESOLVE employs a statistical approach, estimating the most probable image reconstruction compatible with the measured data. In this process, the algorithm uses the vague prior knowledge of the observer on the source – namely that it is an extended object – to differentiate between likely and unlikely reconstructions. To this end, RESOLVE assumes that the radio intensity does not change abruptly from one place to the next, but instead that the source is comprised of statistically similar structures, connected over several pixels, and not necessarily exactly known prior to an observation. Mathematically, this is expressed by a so-called spatial correlation function, unknown at the beginning of the reconstruction process.

RESOLVE can roughly be divided into two major steps. In the first part, the statistically most probable image reconstruction, compatible with an extended source, is estimated. In this step, the spatial correlation function is assumed to be known by the algorithm and thus influences the reconstruction process. In the second part, the correlation function is estimated using the intermediate image reconstruction obtained in the first step. RESOLVE iterates this two-step process until a statistically optimal reconstruction has been obtained.

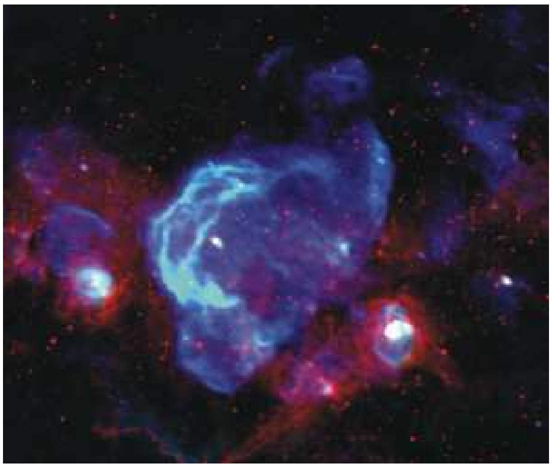


Figure 2.14: This is a false colour image of the region surrounding the W28 supernova remnant with the radio emission detected with the VLA shown in blue. The more compact objects north and south of W28 are regions of ionized hydrogen not directly related to the remnant. The new image reconstruction method will make it much easier to reconstruct interferometry images of such extended sources. *Credit: NRAO/AUI/NSF and Brogan et al.*

Finally, from the last reconstruction, a map of the measurement uncertainty is calculated.

This procedure can be extended to observations at different wavelengths. For this, in addition, the spectral dependence of the radio emission in every pixel is estimated using a very similar method as just described.

Simulated reconstructions using RESOLVE show that from high quality interferometric data, it is indeed possible to computationally reverse the complicated measurement process of the interferometer with high precision and to estimate the structure of an extended radio source with high precision. In addition, the noise is removed from the measured signal and a measurement uncertainty is estimated during this process.

Possible areas of application in observational radio astronomy range from single objects in the Milky Way like e.g. remnants of exploding stars, to distant radio galaxies and large galaxy clusters. The new image reconstructions will allow for a deeper and better resolved view into the radio sky. (Henrik Junklewitz, Michael Bell and Torsten Enßlin)

References:

Junklewitz, H., M. Bell, M. Selig and T. Enßlin: RESOLVE: A new algorithm for aperture synthesis imaging in radio astronomy. Astron. Astrophys.

Junklewitz, H., M. Bell, and T. Enßlin: A new approach to multi-frequency imaging in radio interferometry. Astron. Astrophys.

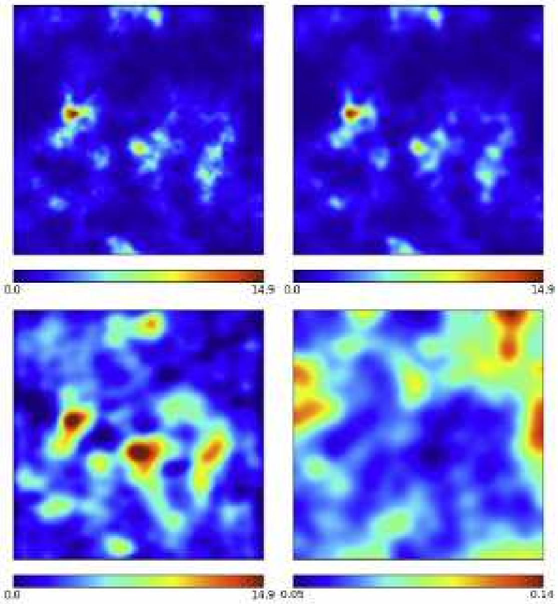


Figure 2.15: A simulated observation of a galaxy cluster with the VLA. The image on the top left shows the (real) input signal. The top right image shows the reconstruction using the RESOLVE algorithm. The image on the bottom left shows a reconstruction with a standard algorigthm (CLEAN) while the image on the bottom right gives the relative uncertainty of the reconstruction, note the different scale on this map.

2.6 Stellar halos reveal galactic accretion: Big fish eat small fish

Galaxies contain not only “home-made” stars, but also quite a large fraction of stars that were accreted from other galaxies, as a new analysis of SDSS images has recently shown. The scientists at the MPA “stacked” a large number of individual galaxy images to reveal the faint light of the stellar halo of distant galaxies. For the most massive, early-type galaxies the fraction of accreted stars in the stellar halo can be up to 70%.

In recent years, deep photometric observations of the local universe have revealed that galaxies are surrounded by a "stellar halo", a group of stars that extend to a distance of up to 100 kpc and more from the centre of the galaxy. This stellar halo consists of field stars, older globular clusters, and stars stripped from in-falling satellite galaxies. Too often, this stellar halo is too faint to observe with present day imaging.

For our own galaxy, the individual stars of the stellar halo have been resolved with the help of the SDSS survey up to a distance of 50 kpc from the galactic centre. In addition, deep integrated light studies have revealed the stellar halo of neighbouring galaxies in the local universe. However, for large-scale studies of these stellar halos, many more observations are required. Unfortunately, with present telescopes and reasonable integration times, we can only detect the stellar halos of nearby galaxies.

An alternative approach to deep observations of individual galaxies would be to stack a large number of images of similar galaxies. SDSS with nearly 60,000 galaxies in its spectroscopic sample, for which accurate redshifts and stellar masses are available, is just the right survey for the job. Even though the stellar halos of individual galaxies cannot be directly observed in the photometric images, by stacking these images we can increase the signal-to-noise (S/N) ratio, and thus study the average stellar halos of the galaxies as a function of various galaxy properties.

The theory of galaxy formation through hierarchical merging predicts not only that galaxies grow in size and mass through minor mergers, but also that these minor mergers give rise to the stellar halo. This implies that the stellar halos of galaxies consist of stars which are not born in the same galaxy (in-situ stars) but rather of stars which are born in smaller galaxies that have been accreted (the accreted component).

Studying the stellar halos of galaxies gives us vital clues to further constrain the theory of galaxy formation. For example, the fraction of stellar material accreted from other galaxies is an important physical constraint in the theory of galaxy formation. In addition, the local over-densities in the stellar halo of a galaxy often contain vital clues of the accretion history of the individual galaxy, since the low density and large relaxation times of stars in the stellar halo preserves information from the distant past.

A variety of theoretical simulations have been carried out that help us to better understand the formation of stellar halos. In particular, the particle-tagging simulations done here at MPA have predicted the stellar halos of a large range of galaxies and their accreted fractions. Although the exact properties of the stellar halos of galaxies depend on the individual accretion history of a galaxy, one can predict the average stellar halo properties of galaxies as a function of the dark matter halo mass, of the stellar mass, or as a function of other properties of the galaxy.

To constrain these theories, we require observations of the stellar halos of a large number of galaxies, or alternatively stacked images as mentioned above. In this work, we have used SDSS images of galaxies in various bins of stellar mass and divided them into late-type and early-type galaxies. In each stack, we have an average of nearly 3000 galaxies. Before stacking, each image of a galaxy was transformed to a common redshift (z=0.1) and oriented along the major axis. Other galaxies and stars in the image are masked out.

The stacked images of the galaxies reveal extra light out to nearly 100 kpc (see Fig. 2.16) and we find that the amount of extra light in the stellar halo is a strong function of stellar mass: Larger galaxies have more extended stellar halos than smaller galaxies. Similarly, early-type galaxies have larger stellar halos than late-type galaxies. Also, the ellipticity of the stellar halo is a function of stellar mass and the haloes of early-type galaxies are more elliptical than those of late-type galaxies.

To characterize the stellar halo of the galaxy stacks in more detail, we model the two-dimensional light distribution with a ”Sersic” profile (first published in 1963), a general mathematical function to describe the radial light intensity distribution of a wide variety of galaxy types. While this provided a good fit in the past, deviations from the Sersic profile have often been found, as deeper high-resolution data became available with newer telescopes and instruments.

For our stacked images, we find that the two-dimensional light distribution cannot be fit by a single Sersic profile, but rather needs multiple components: a double Sersic profile is needed for early-type galaxies, and a triple Sersic profile is required for late-type galaxies.

Each Sersic component traces a different physical and dynamical component of the galaxy. Under the assumption that the inner Sersic profile fits the in-situ component, and that the outer Sersic profile fits the accreted stellar component, we obtain an observational measure of the average accreted stellar light fraction of the galaxy. For early-type galaxies, the fraction of accreted stellar light rises from 30% to 70% while for late-type galaxies it is much smaller, increasing from 2% to 25% over the same mass range (See Figures 2.17 and 2.18). This provides important observational constraints for a range of galaxy masses and types, which can help differentiate between various theories of the formation of stellar halos and of the galaxies themselves. (Richard D’Souza, Guinevere Kauffmann,

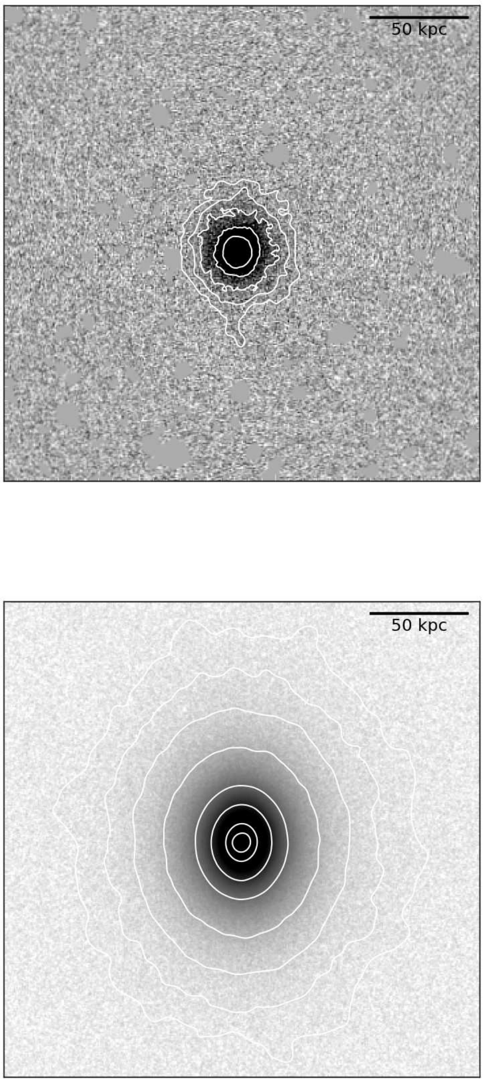


Figure 2.16: Up: Image of a single SDSS galaxy which goes into a stack. Below: The stack of early-type galaxies in the highest mass range. The contours indicate the ellipticity measured at various distances from the centre. For the individual galaxy image only the central, high surface brightness regions are visible, the outer areas are dominated by noise. While a typical single SDSS image allows one to go to a depth of 26 mag arcsec^{-2}, in our stacked image we can achieve a depth of nearly $\mu_r \sim 32$ mag arcsec^{-2}.

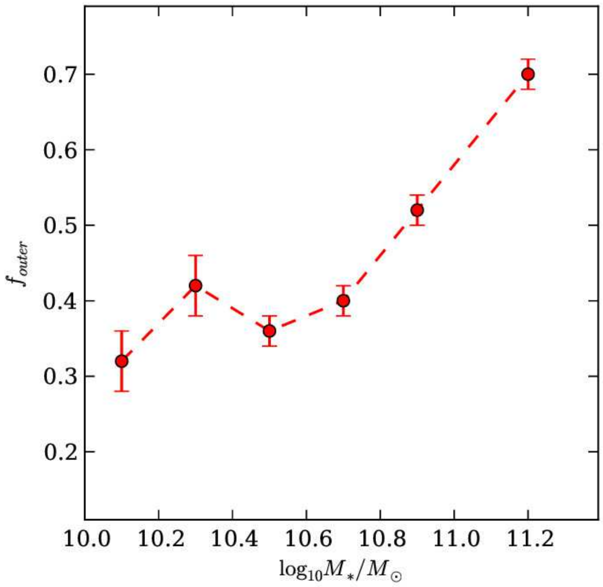


Figure 2.17: Fraction of accreted stellar light for early-type galaxies as a function of galaxy mass.

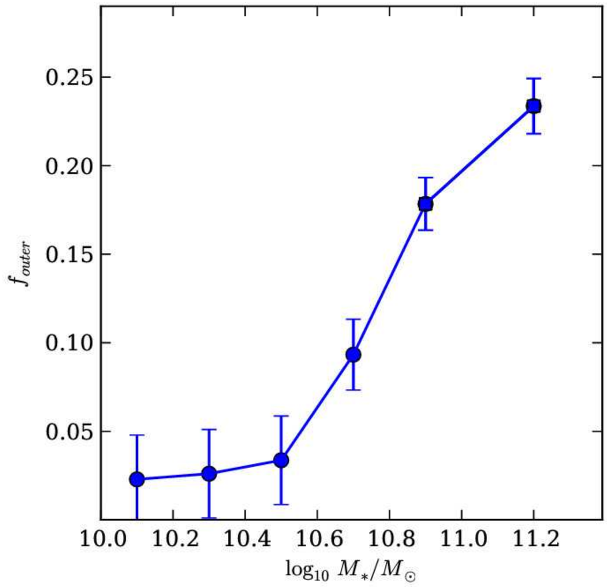


Figure 2.18: Same as Fig. 2.17 for late-type galaxies. Here the same trend can be seen, although the fraction of accreted stellar light is much smaller.

Jing Wang, Simona Vegetti)

Refernces:

D'Souza R., G. Kauffmann, J. Wang and S. Vegetti: Parametrizing the stellar haloes of galaxies. M.N.R.A.S, **443**, 1433 (2014).

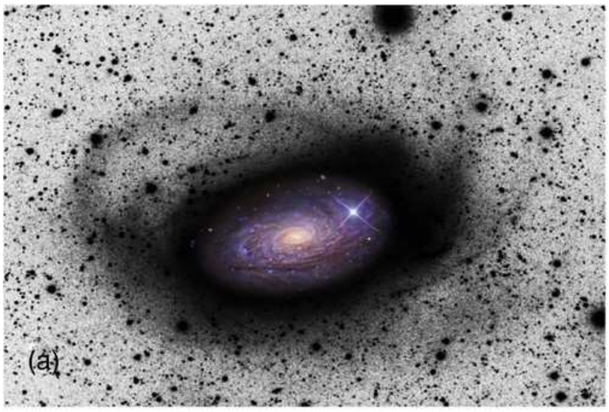


Figure 2.19: The stellar halo with a Sagitarius-like stream of Messier 63 from Martinez-Delgado et al. 2010, The Astronomical Journal, 140, 962

2.7 New light on the origin of the Galactic ridge X-ray emission

While previous studies found that most of the apparently diffuse galactic X-ray emission is actually due to point sources, researchers at the Max Planck Institute for Astrophysics have now predicted that on the Galactic plane 10-30% of this radiation should be truly diffuse. This diffuse component should originate from the interstellar gas, where X-ray radiation produced by luminous X-ray binary sources is being reprocessed. Studies of this component could provide valuable information on Galactic X-ray binaries and the history of the X-ray activity in our Milky Way.

The Galactic disk of the Milky Way can be seen from Earth as a band of stars across the night sky interrupted by narrow dark 'dust lanes'. There the dust in the gaseous disk blocks the visible light of the background stars. Thus, many of the most interesting features of our Milky Way can only be observed in X-rays. Along with the point X-ray sources which populate the Milky Way, we observe an apparently diffuse X-ray emission concentrated in the Galactic plane, known as the Galactic Ridge X-ray emission (GRXE).

The origin of this emission has puzzled astrophysicists ever since it was first identified by Diana Worrall and collaborators in 1982. Because of the difficulty in resolving the GRXE into point sources, it was initially believed that its nature might be truly diffuse, and that its origin might actually be a Galactic plasma rather than discrete stellar sources.

It was soon realised, however, that the temperature of the gas producing such an emission would have to be close to tens of millions of degrees - a temperature far too high for the gas to be gravitationally bound to the Galaxy. It was therefore suggested that the GRXE might be composed of a large number of stars fainter in X-rays than accreting black holes and neutron stars (but still more luminous than our Sun). Although it was not possible to actually see them at the time, the hope was that with the increasing sensitivity of new X-

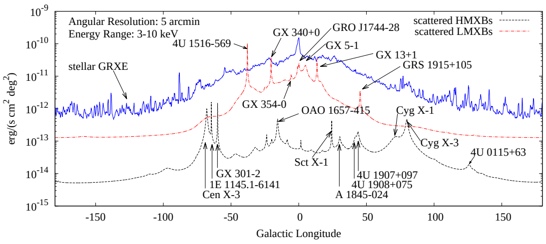


Figure 2.20: Components of the GRXE on the plane of the Galaxy in the 3-10keV range. The scattered GRXE component is shown separately for two types of XBs, low-mass XBs (LMXBs) and high-mass XBs (HMXBs). The labels indicate the names of the individual sources giving rise to the peaks in the scattered GRXE profile.

ray satellites, one day a multitude of faint X-ray sources could be fully resolved.

For decades, attempts were made to resolve this emission, yet most of it still appeared to be diffuse. Finally in 2009, M. Revnivtsev, S. Sazonov and collaborators pointed the Chandra X-ray observatory towards a very small region of the sky near the Galactic centre for 12 entire days and could resolve over 80% of the emission in this region. Along with this direct observation of the sources, other indirect probes have strengthened the case for a discrete origin of the GRXE in the last few years. In particular, the large-scale morphology of the emission closely follows that of the Galactic stellar population, and the GRXE spectrum shows good agreement with the combined spectra of the sources expected to directly contribute to the emission.

Thus it seemed that a general consensus on the discrete nature of the emission had been reached, and that the mystery of the origin of the GRXE had been conclusively solved.

This, however, may not be the whole story. Recent work by researchers at the Max Planck Institute for Astrophysics suggests that the GRXE might have an additional, truly diffuse component after all. This would arise not from the thermal emission of a very hot plasma but rather from the reprocessing by the interstellar gas of the X-ray radiation produced by luminous X-ray binary sources located in the Galaxy.

X-ray binaries are the most luminous sources of X-rays in galaxies such as the Milky Way. These binary systems emit X-ray radiation when material from a so-called donor star falls into the strong gravitational field of a compact object, such as a neutron star or a black hole. This X-ray radiation illuminates the atoms and molecules in the Galactic interstellar gas, which then scatter the incoming photons in different directions and at different energies. Thanks to this reprocessing of the original radiation, the resulting emission appears truly diffuse to the observer.

The contribution of this component would closely follow the distribution of the gas in the Galaxy. Therefore the large-scale morphology of the diffuse component should be characteristically different from that of the stellar component. In particular, the diffuse component would be 'thin' compared to the stellar one, since the gas distribution does not reach as far out of the Galactic plane as does the stellar population. Additionally, very dense regions of gas such as molecular clouds would produce very prominent features in the scattered GRXE component. If a high enough angular resolution is available, variations in the strength of the GRXE emission will then be observable close to these regions.

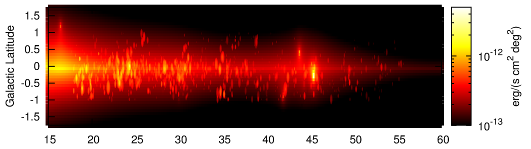


Figure 2.21: Map of the scattered GRXE emission on the sky. The emission is expected to closely follow the distribution of interstellar gas: indeed, the map shows that the intensity tends to be stronger on the plane of the Galaxy, where most of the interstellar gas is concentrated. Very dense regions of gas, such as dense molecular clouds, are also clearly visible as prominent bright features in the map.

It was found that on the Galactic plane, where most of the interstellar gas is concentrated, the scattered GRXE can contribute at least 10-30%. The interest in studying the diffuse component of the GRXE however goes beyond the sole purpose of determining its origin. This radiation also tells us about the distribution and luminosity of the X-ray binaries themselves.

Direct, exhaustive studies of the Galactic X-ray binary population are extremely diffcult even if one considers only the recent history. This is due to two main effects: on the one hand, severe uncertainties in determining the distance to these systems and instrumental flux limitations limit our view of this population beyond the Galactic centre; on the other hand, these sources are transient. This means that any time only a few of these sources are active and visible. Nevertheless, if we directly compare the fraction of the unresolved emission observed in different regions of the sky with the scattered component obtained from observed or simulated Galactic X-ray binary populations, we will be able to indirectly obtain constraints on the properties of the population of X-ray sources in the Galaxy.

Because the scattered light travels a longer path to reach the observer compared to light directly contributed by point sources, the scattered GRXE component also depends on the overall X-ray ac-

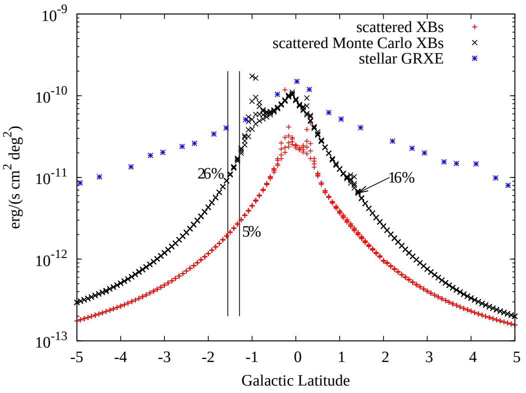


Figure 2.22: Latitude profiles for the scattered GRXE for two models of X-ray binary populations in the Galaxy, motivated by observations in our own Galaxy ("scattered XBs", red crosses) and in other galaxies ("scattered Monte Carlo XBs", black crosses). Both profiles follow the gas distribution, while the stellar distribution (blue stars) is much broader. Both models are consistent with the limits of 10-20% on unresolved GRXE from Revnivtsev et al 2009 in the region shown by the vertical bars.

tivity of the Galaxy in the past 10,000 to 30,000 years. Studies of the relative contribution of the scattered component to the GRXE therefore will allow us to look back at the history of the Galactic X-ray output over this period of time.

This research therefore highlights a new way in which the GRXE, whose origin might be even more diverse than initially thought, can provide us with a wealth of information on the X-ray sources, both faint and luminous, which populate our galaxy.

Radiation produced by X-ray binaries is of course not only scattered, but also absorbed by atoms and molecules, and therefore contributes to the heating of the interstellar gas.

The lower energy ultra-violet photons are usually the dominant source of heating in diffuse interstellar clouds. The X-ray photons can however penetrate deep inside the dense molecular clouds where the ultra-violet photons cannot reach, since they are absorbed by the outer layers.

The contribution of the X-ray binary sources to the heating rate in the interstellar medium was in fact found to be significant, suggesting that these sources may play a crucial role in determining the multiphase structure of the interstellar medium. (Margherita Molaro, Rishi Khatri, Rashid Sunyaev)

References:

Revnivtsev, M., Sazonov, S., Churazov, et al.: Discrete sources as the origin of the Galactic X-ray ridge emission., Nature, **458**, 7242, 1142-1144 (2009).

Molaro, M., Khatri, R., Sunyaev, R.: A thin diffuse component of the Galactic ridge X-ray emission and heating of the interstellar medium contributed by the radiation of Galactic X-ray binaries. Astron. Astrophys, **564**, A107, (2014).

2.8 X-ray diagnostics of the donor star in ultra-compact X-ray binaries

Low mass X-ray binaries (LMXBs) are stellar systems consisting of two stars, one of which is a relativistic object - a neutron star or a black hole - and the other is a normal low-mass star, like our Sun, for example (Fig. 2.23). If the separation between the two objects is comparable to the size of the normal star (which is hundreds thousands to millions of times larger than its relativistic companion), it may overfill it's Roche lobe - the region of space where dynamics of matter are dominated by the gravitational attraction of the star. Consequently, it will start losing its outer layers under the gravitational pull of the second star. Material is predominantly lost through the so called inner Lagrangian point - the point on the line connecting the two stars where the forces of gravity and the centrifugal force balance each other out. The material of the donor star will flow through this point and will fall into the gravitation potential well of the relativistic star, initiating the process which is called accretion. Due to its large angular momentum, the infalling matter will form an accretion disk around the relativistic object (Fig. 2.23). The classical theory of accretion disks around black holes and neutron stars was developed by Nikolai Shakura and Rashid Sunyaev in 1972. Due to the small size of the relativistic object (≈15 km for a neutron star) the gravitational energy released during accretion constitutes a significant fraction of the rest mass energy of the accreting material, typically about 5-20%. This makes these systems very luminous sources of X-ray emission.

There is a small but fascinating subclass of low-mass X-ray binaries, called Ultra-compact X-ray binaries (UCXBs) in which the donor star is a white dwarf - a remnant of a moderately massive normal star. These systems are extremely compact (hence their name) and have orbital periods shorter than 40 minutes, the fastest one having a period as short as 11 minutes.

An interesting feature of these systems is that

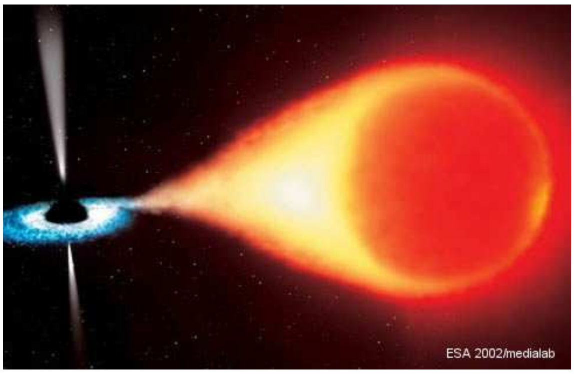
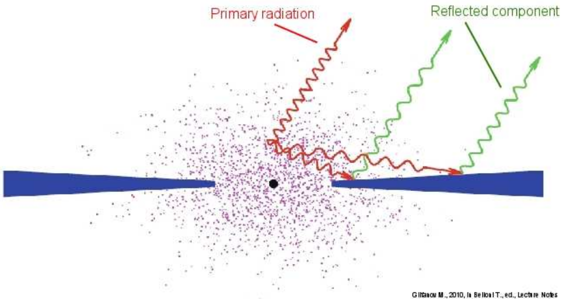


Figure 2.23: An artist's impression of an accreting Low Mass X-ray Binary. The donor star fills its Roche lobe and its material overflows the inner Lagrangian points and accretes on the relativistic star (in this case a black hole). Due to the large angular momentum of the infalling material an accretion disk is formed around the compact object. *Credit: ESA 2002/medialab*



Gilfanov M., 2010, in Belloni T., ed., Lecture Notes
X-Ray Emission from Black-Hole Binaries. Springe
p. 17

Figure 2.24: A sketch of the innermost part (≈ 1000 gravitational radii) in a low mass X-ray binary in the so called hard state. The inner part of the accretion flow is filled with hot and tenuous, optically thin plasma. Comptonization of the low frequency radiation in the plasma cloud is the main mechanism of the spectral formation in this state. Some fraction of this radiation illuminates the surface of the accretion disk and of the donor star. It is reprocessed by the material of the accretion disk and of the donor star giving rise to the so called 'reflected component', depicted in Fig.3. Credit: Gilfanov M., 2010, in Belloni T., ed., Lecture Notes in Physics, Vol. 794, The Jet Paradigm. Springer-Verlag, Berlin, p. 17

the chemical composition of the donor star is dramatically different from the composition of the donor star in 'normal' low-mass X-ray binaries. While donor stars in normal LMXBs have chemical composition similar to our Sun, i.e. are made of mostly hydrogen and helium with small admixture of metals, UCXBs feature donors that are depleted of hydrogen. They can be made of the ashes of nuclear burning of hydrogen (mostly helium and nitrogen), of helium (mostly carbon and oxygen) or carbon (mostly oxygen and neon).

Depending on the particular evolutionary path through which UCXBs form, they may have a variety of donors ranging from non-degenerate helium stars to white dwarfs. It is critically important to distinguish between these possibilities, in order to understand the processes that lead to UCXB formation and control their evolution. So far this task has been performed using methods of optical astronomy, with various degrees of success.

MPA scientists have recently proposed and tested a principally new method of diagnostics of the nature of the donor star in UCXBs by the means of X-ray spectroscopy.

The method is using the phenomenon called X-ray reflection. A fraction of the emission produced near the compact objects illuminates the surface of the accretion disk and the donor star (Fig. 2.24) and is reprocessed by this material. In the jargon of high energy astrophysics this reprocessed emission is called "reflected component". An example of its spectrum is shown in Fig. 2.25.

On top of the continuum produced by the Compton scatterings off electrons in the accretion disk, the reflected component also contains a number of characteristic lines. These lines (called emission lines) are due to the different chemical elements present in the accreting material. They are produced by the process called fluorescence and have well known energies, unique for each chemical element. Their shape and relative strength carry information about the geometry of the accretion flow and chemical composition of the accreting material.

The reflected component is heavily diluted by the primary emission, therefore the fluorescent lines of most of the elements are very weak and difficult to detect. Except for the fluorescent line of iron, which in the case of neutral iron is located at 6.4 keV. Thanks to the high fluorescent yield and abundance of iron, this is the brightest spectral feature in an otherwise relatively smooth continuum. All normal LMXBs have this line easily observable in their X-ray spectra.

While the reprocessing of X-ray radiation by the accretion disc and particularly the shape and strength of the iron line has been thoroughly investigated since 1970s, all prior work concentrated on accretion disks of nearly solar abundance of elements, with only moderate variations of the element abundances considered in a few papers. MPA scientists have now taken the first step in modeling X-ray reflection off hydrogen poor material with anomalous abundances, as expected in the accretion disks in Ultra-compact X-ray binaries. The model developed using the Monte Carlo technique is the first simulation of reflection spectra of C/O, O/Ne/Mg or helium rich disks.

Using these simulations, MPA scientists came to a paradoxical conclusion: The strongest and most easily observable effect of the hydrogen poor, C/O rich material is not an appearance of strong fluorescent lines of carbon and oxygen - as one might expect - but nearly complete disappearance of the fluorescent line of iron! This is caused by the screening of iron by the much more abundant carbon and oxygen.

In a neutral material of solar abundance, the most likely process for a photon with energy exceeding 7.1 keV - the photoionisation threshold of K-shell electrons in iron (so called K-edge) - is absorption by iron due to the photoionisation of its atoms. Photoionisation of iron is followed in about one-third of the cases by the emission of a 6.4 keV fluorescent photon. Consequently, the majority of photons with energies above this threshold will be absorbed by iron and will, therefore, contribute to its fluorescent line.

In the case of a C/O (or O/Ne) white dwarf though, the overwhelming overabundance of oxygen makes it the dominant absorbing agent even at energies far beyond its own K-edge, leaving only a few photons to fuel the iron fluorescent line. Although the fluorescent line of oxygen produced in the process is significantly boosted, it is still strongly diluted by the primary continuum and therefore is difficult to detect. A much more visible effect is the significant attenuation or complete disappearance of the iron line.

Helium, on the other hand, is not capable of screening iron, due to its smaller charge and, correspondingly smaller absorption cross-section at the iron K-edge. Therefore in the case of a helium-rich donor reflection proceeds 'as usual' and the iron line has its nominal strength.

This opens an exciting possibility to discriminate between helium and oxygen rich donors by means of X-ray spectroscopy. MPA scientists calibrated the method using extensive Monte-Carlo simulations, investigated its luminosity dependence and proposed observational tests of the picture. They used the data of XMM-Newton satellite to verify results of theoretical calculations using observations of UCXB systems with a donor star of known composition. Furthermore, they provided tentative identifications of the donor star in several ultra-compact binaries, where its nature remained so far unknown. (Filippos Koliopanos and Marat Gilfanov)

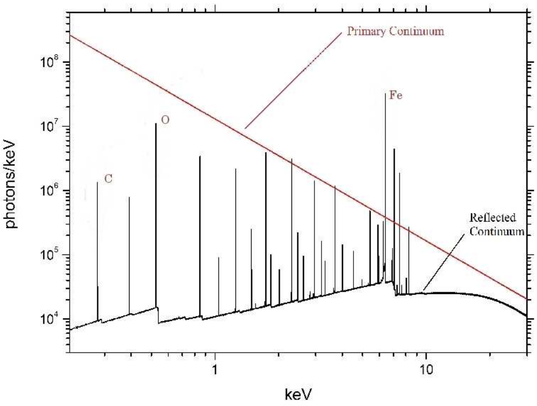


Figure 2.25: The spectrum of the reflected component for an accretion disk of solar abundance. Superposed on top of the reflected continuum produced by Compton scatterings on electrons, are absorption edges and fluorescence lines of various elements. Also shown is the Comptonized continuum produced by the hot plasma cloud in the vicinity of the compact object (see Fig.2.24). An observer near the Earth will observe the sum of the two components.

References:

Koliopanos F., Gilfanov M., Bildsten L., Trigo M.: X-ray diagnostics of chemical composition of the accretion disc and donor star in UCXBs - II. XMM-Newton observations., M.N.R.A.S., **442**, 2817 (2014)

Koliopanos F., Gilfanov M., Bildsten L.: X-ray diagnostics of chemical composition of the accretion disc and donor star in ultra-compact X-ray binaries, M.N.R.A.S., **432**, 1264 (2013).

2.9 Detailed gravitational lens modelling of the galaxy cluster MACS J1149.5+2223

At large scales, the cold dark matter model has been very successful in describing the observed properties of the Universe. With the use of N-body numerical simulations, detailed predictions have been made on the formation and evolution of the dark matter distribution at various scales. In particular, cold dark matter haloes are expected to be self-similar over a wide range of masses and to have a well-defined mass density distribution.

Gravitational lensing is a powerful tool to precisely measure the total mass distribution over a wide range of distances from the cluster centre.

In combination with other measurements it therefore allows the scientists to study the interaction between the dark matter and the baryons in the cluster. In this work they focused on the galaxy cluster MACS J1149.5+2223 with the aim of providing a robust total mass model over a wide range of distances.

The galaxy cluster MACS J1149.5+2223 (located at redshift 0.544) was initially discovered by the Massive Cluster Survey and acts as a strong gravitational lens for at least 5 galaxies (with redshifts between 1.4 and 3.0), which are lensed in as many as 15 different images. One of the lensed galaxies is an impressive triply-imaged grand-design face-on spiral galaxy, which is also strongly lensed in two distinct Einstein rings by two cluster galaxies (see Figure 2.26).

Previous gravitational lens models of this cluster were based on the reconstructions of a relatively limited number of image positions of the multiply lensed bright clumps and on simple scaling relations for the lensing contribution of the cluster member galaxies. Because of these limitations, many details of this lens system were reproduced only approximately.

In this work, they used a more sophisticated approach instead. They modelled all five cluster galaxies in the cluster centre that are close to multiply lensed images by using individual mass profiles. From the lensed background galaxies, they identified twice as many constraints as in previous models. Their advanced lens modelling technique uses not only the information on the positions of the multiply lensed images, but also their full surface brightness distribution.

The unique configuration of this lens system allowed them to reconstruct in particular the surface brightness distribution of the large central spiral galaxy in great detail. In addition, we were able to measure the mass profiles for several other individual cluster members and to determine the overall mass profile for the galaxy cluster as whole from its centre to a distance of up to 33 arcseconds (from 8 to 80 kpc) from the brightest cluster galaxy.

Our model indicates a large core (about 12 arcseconds) in the dark matter distribution of the cluster and we find that the total mass profile at the very centre is dominated by the brightest cluster galaxy. The inferred slope of the dark matter profile of MACS J1149.5+2223 is therefore shallower than the profile expected from pure dark matter simulations (the Navarro Frenk White (NFW) profile). This suggests that the baryons at the cluster centre have influenced the dark matter distri-

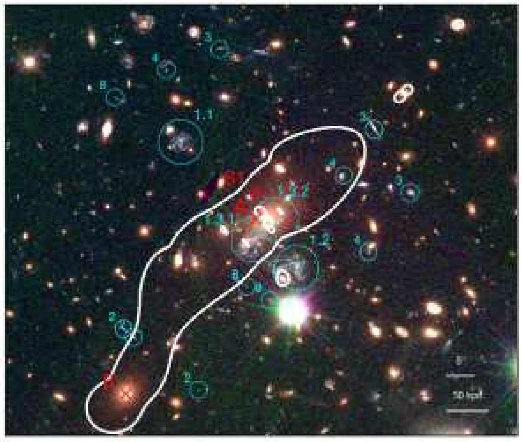


Figure 2.26: Image of the galaxy cluster MACS J1149.5+2223, observed with the Hubble Space Telescope. Several background images are multiply imaged (marked by circles). There is one particularly striking example of a face-on spiral galaxy; zoomed images of this galaxy are enlarged as insets.

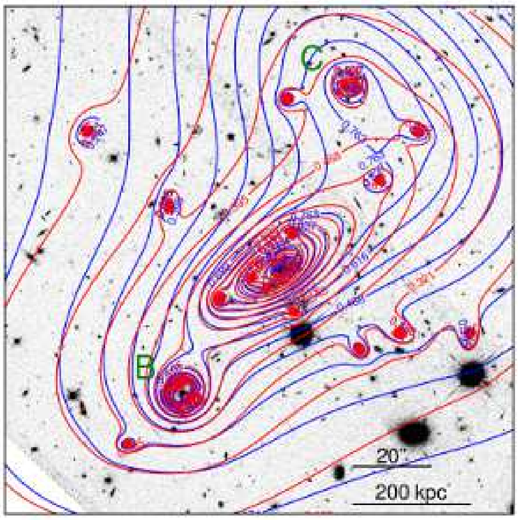


Figure 2.27: Contours of the cluster mass distribution including scaled cluster galaxies for two different models (blue: position based modelling; red: hybrid modelling). The grey background shows the same observation as in figure 1, but in just one colour filter (F555W).

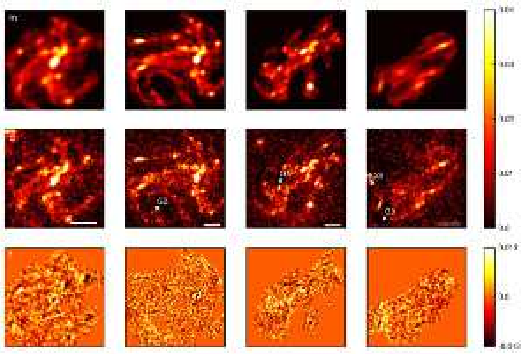


Figure 2.28: Results for the surface brightness modelling of the multiply imaged face-on galaxy. Images from left to right are the main images 1.1, 1.2, 1.3.1 and 1.3.2. The top row shows the model reconstruction, the middle row the observed data and the bottom row the residual (i.e. the difference between model and data).

bution. (Stefan Rau, Simona Vegetti and Simon White)

Reference:

Rau, S., S. Vegetti, and S. White: Lensing model of MACS J1149.5+2223 - I. Cluster mass reconstruction. M.N.R.A.S.**443**, 957-968 (2014).

2.10 A new neutrino-emission asymmetry in forming neutron stars

The neutron star that is born at the center of a collapsing and exploding massive star radiates huge numbers of neutrinos produced by particle reactions in the extremely hot and dense matter. Three-dimensional supercomputer simulations at the very forefront of current modelling efforts reveal the stunning and unexpected possibility that this neutrino emission can develop a hemispheric (dipolar) asymmetry. If this new neutrino-hydrodynamical instability happens in nature, it will have important consequences for the formation of chemical elements in stellar explosions, for imparting kicks to the neutron star, and for the perspective of detecting neutrinos from a future galactic supernova.

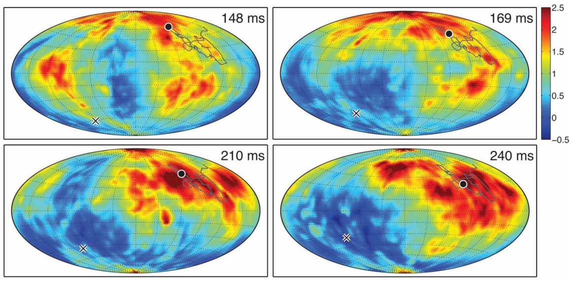


Figure 2.29: Evolution of the neutrino emission asymmetry in a collapsing star of 11.2 solar masses. The ellipses represent the whole surface of the nascent neutron star (analog to world maps as planar projections of the Earth's surface). Red and yellow mean a large excess of electron neutrinos compared to electron antineutrinos normalized to the average, blue means a low excess or even deficit of electron neutrinos. The images show the merging of smaller patches that are present at 0.148 seconds (upper left panel) to a clear hemispheric (dipolar) anisotropy at 0.240 seconds (lower right panel). The dot and cross indicate the emission maximum and minimum, the dark-grey line marks the path described by a slow motion of the dipole direction.

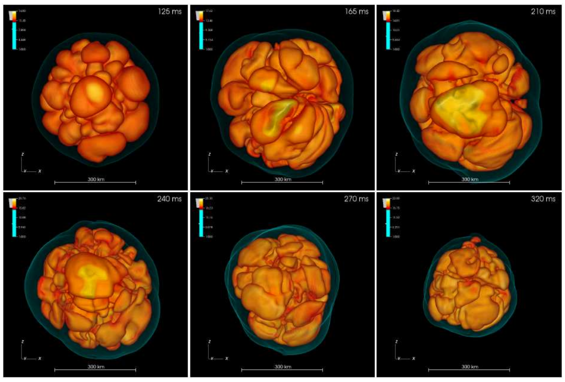


Figure 2.30: Bubbles of "boiling" gas surrounding the nascent neutron star (invisible at the center). Despite the highly time-variable and dynamical pattern of plumes of hot, rising gas surrounded by inflows of cooler matter, the neutrino emission develops a hemispheric asymmetry that remains stable for periods of time much longer than the life time of individual bubbles.

Stars with more than roughly eight times the mass of our sun end their lives in gigantic explosions, so-called supernovae. These spectacular events belong to the most energetic and brightest phenomena in the universe and can outshine a whole galaxy for weeks. Supernovae are not only the cosmic sources of chemical elements like carbon, oxygen, and silicon, which are fused over millions of years of quiescent stellar evolution and disseminated into circumstellar space by the blast wave. Supernovae are also important producers of iron and heavier trans-iron elements, which can be freshly assembled during the explosion.

While supernovae eject most of the material of the dying star, the stellar core of iron collapses under the influence of its own gravity within fractions of a second to an extraordinarily exotic, ultra-compact remnant, a neutron star. Such an object contains about 1.5 times the mass of our Sun, compressed into a sphere with the diameter of Munich.

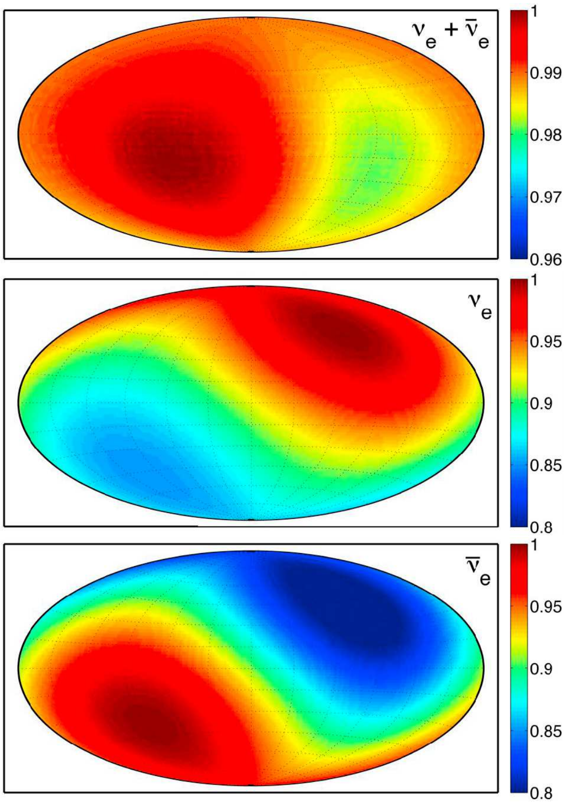


Figure 2.31: Neutrino emission asymmetry as observable over a period of 0.1 seconds. Analog to Fig. 2.29 the ellipses show all possible viewing directions. Observers in the red regions see the highest emission whereas those in the blue areas receive lower emission. While the hemispheric difference of the emission of electron neutrinos plus antineutrinos is only one to two per cent (top), the differences of electron neutrinos (middle) and antineutrinos (bottom) individually amount to up to 20 per cent of the maximum values with extrema on opposite sides.

The central density of a neutron star exceeds that in atomic nuclei, gigantic 300 million tons (the weight of a mountain) in the volume of a sugar cube.

The matter in newly born neutron stars is extremely hot, up to temperatures of more than 500 billion degrees. At such conditions particle reactions involving neutrons, protons, electrons and positrons (the anti-particles of electrons) create huge numbers of neutrinos. Cooling neutron stars thus radiate a total of 1058 of these uncharged, nearly massless elementary particles, which interact extremely rarely with matter on earth. Only one of a billion neutrinos coming from a supernova (or from the sun, which also produces neutrinos in the nuclear fusion “reactor” that burns at its center) hits a particle somewhere inside the earth, all the others cross through the whole of the earth’s body without a single collision.

Neutron stars release neutrinos and their antiparticles in three different flavors, corresponding to the three known families of charged leptons: electron neutrinos, muon neutrinos and tau neutrinos. These neutrinos are expected to be radiated equally in all directions, because neutron stars are nearly perfectly spherical objects due to their extremely strong gravitational fields. Most previous computer models of neutron star formation therefore assumed spherical symmetry. Only recently the first three-dimensional simulations with a detailed treatment of the complex neutrino physics have become possible due to the increased power of modern supercomputers.

As expected, the neutrino emission starts out to be basically spherical except for smaller variations over the surface (see Fig. 2.29), upper left panel). These variations correspond to higher and lower temperatures associated with violent “boilin” of hot matter inside and around the newly formed neutron star, by which bubbles of hot matter rise outward and flows of cooler material move inward (Fig. 2.30). After a short while and gradually growing, however, the neutrino emission develops clear differences in two hemispheres. The initially small patches merge to larger areas of warmer and cooler medium until the two hemispheres begin to radiate neutrinos unequally. A stable dipolar pattern is established, which means that on one side more neutrinos leave the neutron star than on the other side. Observers in different directions will thus receive different neutrino signals. While the directional variation of the summed emission of all kinds of neutrinos is only some per cent (Fig. 2.31 top), the individual neutrino types (for example electron neutrinos or electron antineutrinos) show considerable contrast between the two hemispheres with up to about 20 per cent deviations from the average (Figs. 2.31 middle and bottom). The directional variations are particularly pronounced in the difference between electron neutrino and antineutrino fluxes (Fig. 2.29, lower right panel), the so-called lepton number emission.

The possibility of such a global anisotropy in the neutrino emission was not predicted and its finding in the first-ever detailed three-dimensional simulations of dynamical neutron-star formation comes completely unexpectedly. The phenomenon exhibits astonishing properties: In spite of ongoing violent bubbling motions of the “boiling” hot and cooler gas, which lead to rapidly changing structures in the flow around and inside the neutron star (Fig. 2.30), the dipolar neutrino emission asymmetry establishes itself in a stable state. It thus exists for long periods of time, during which only a slow and moderate drift of its orientation can be observed (cf. the thin, dark-grey line in Fig. 2.29. The team of astrophysicists named this new phenomenon "LESA" for Lepton-Emission Self-sustained Asymmetry, because the emission dipole seems to stabilize and maintain itself through complicated feedback effects: Interactions with the asymmetric neutrino flow affect the collapse of the stellar core such that a hemispheric asymmetry develops in the matter falling inward to the nascent neutron star. This accretion asymmetry then continues to feed additional anisotropic emission of neutrinos. These findings suggest that the spherical collapse of a stellar core to a neutron star is not stable but the system wants to rearrange itself into a dipolar asymmetry mode.

If LESA happens in collapsing stellar cores, it will have important consequences for observable phenomena connected to supernova explosions. Neutrinos radiated from the nascent neutron star interact with the innermost material that gets ejected by the supernova blast wave. In doing so, neutrinos determine the ratio of neutrons to protons in the expelled plasma, which is a crucial requisite for the subsequent formation of heavy elements when the outflow cools. A directional variation between electron neutrino and antineutrino emission will thus lead to differences of the chemical element production in different directions. Moreover, a global dipolar anisotropy of the neutrino emission carries away momentum and thus imparts a kick to the nascent neutron star in the opposite direction. Because of the huge number of escaping neutrinos, an emission asymmetry of only one per cent, if lasting for several seconds, could account for a neutron-star recoil of 100 kilometers per second. Also the neutrino signal arriving at Earth from the next supernova event in our Milky Way must be expected to depend on the angle from which we observe the supernova. Detailed predictions of measurements with big underground facilities like the IceCube detector at the South Pole and the SuperKamiokande experiment in Japan therefore need to take into account the directional variations found in the new three-dimensional models.

However, the stunning neutrino-hydrodynamical instability that manifests itself in the LESA phenomenon is not yet well understood. Much more research is needed to ensure that it is not an artefact produced by the highly complex numerical simulations. If it is physical reality, this novel effect would be a discovery truly based on the use of modern supercomputing possibilities and not anticipated by previous theoretical considerations. (Hans-Thomas Janka)

References:

Tamborra I., F. Hanke F., H.-Th. Janka et al.: Self-sustained asymmetry of lepton-number emission: A new phenomenon during the supernova shock-accretion phase in three dimensions. Astrophys. Journal **792**, 96 (2014)

Tamborra I., Hanke F., et al. (incl. H.-Th. Janka): Neutrino signature of supernova hydrodynamical instabilities in three dimensions. Physical Review Letters **111**, 121104 (2013).

Tamborra I., Raffelt et al. (incl. H.-Th. Janka): Neutrino emission characteristics and detection opportunities based on three-dimensional supernova simulations. Physical Review **D 90**, 045032 (2014).

2.11 Stars influence the central distribution of dark matter in galaxy clusters

The Cosmic Microwave Background provides important information on how dark matter was distributed in the early Universe. Cosmological N-body simulations can be used to follow this distribution as it evolves forward in time, ultimately giving rise to today's cosmic web, made up of voids, filaments and the halos in which the galaxies live. It is an important task to characterise, both theoretically and observationally, the internal structure of these halos, since this constrains both the nature of the dark matter particle and the way galaxies form and evolve. Already in the 1990s, cosmological N-body simulations were able to characterise the density profiles of dark matter halos, showing that, to a good approximation, these have a universal shape from the scales of dwarf galaxies to those of galaxy clusters. The physical origin of this universal profile remains a mystery to this day. An important task in modern astronomy is to infer the distribution of dark matter in galaxies in order to test this prediction of the standard LCDM paradigm for halo structure.

Galaxy clusters are objects of prime interest to study dark matter because they give astronomers the largest number of independent probes of halo structure (stellar kinematics, strong gravitational lensing, weak gravitational lensing, X-ray emission from hot gas, galaxy motions). This helps considerably in obtaining robust and precise results which can put firm constraints on total mass profiles. Recent observations of galaxy clusters and of their central galaxies (Brightest Cluster Galaxies or BCGs) have combined a number of probes, revealing that the clusters' total density profiles are well described by the "universal" profile found in cosmological dark-matter-only simulations. However, their dark matter profiles are systematically shallower in the innermost regions (well inside the visible BCG).

As gas cools and condenses near the centre of a dark matter halo and begins to form stars, simple arguments suggest the dark matter should be pulled inwards, thus steepening its density profile. While this appears to contradict the observations, this is not the full story for BCGs because their growth can be more complicated than that of more typical galaxies. It was proposed in the 1970s that BCGs may grow through multiple mergers of preformed galaxies which will occur preferentially at the centres of clusters. This suggestion seems to hold up according to current detailed simulations of the formation of galaxies and clusters in the LCDM paradigm. However, previous work did not investigate whether this picture could explain the observed structural evolution of BCGs in detail (e.g. their stellar masses, sizes, shapes, surface brightness profiles and dark matter content, all as a function of redshift). A year ago, a team of scientists at the MPA and the National Astronomical Observatories in China have provided further support for this formation channel by comparing observations at low and high redshift with sophisticated methods for "painting" the stars onto cosmological dark matter N-body simulations of galaxy cluster formation.

More recently, MPA scientists conducted N-body simulations which explicitly and self-consistently followed the evolution of both stars and dark matter in clusters. These high-resolution simulations began with a dark matter distribution consistent with LCDM expectations and a galaxy population consistent with that observed in the z 2 universe (about 3 billion years after the Big Bang) and they followed evolution down to the present day. This required a new scheme to insert equilibrium galaxies of a prescribed structure into dark matter halos that had already formed in a cosmological simulation, while mimicking the contraction of the dark-matter halos induced by baryon condensation at their centres.

While the earlier conclusions on BCG evolution held up, the new simulations showed that the cen-

Figure 2.32: A composite optical and X-ray image of Abell 383, one of the 7 relaxed rich clusters considered in the study by Newman et al. 2013a,b. This image shows the X-ray emission of the hot electron gas in the cluster (in purple), its member galaxies and its central Brightest Cluster Galaxy which exhibits an extended diffuse envelope of stars around it. *Credits: X-ray: NASA/CXC/Caltech/A.Newman et al/Tel Aviv/A.Morandi & M.Limousin; Optical: NASA/STScI, ESO/VLT, SDSS*

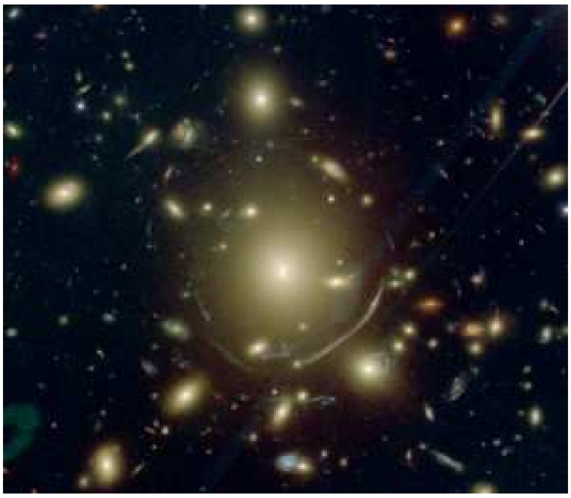


Figure 2.33: A zoom on the BCG in Abell 383 taken with the Hubble Space Telescope. The central BCG is surrounded by an extended envelope of stars and the numerous distorted images around it are background galaxies which are getting lensed by the cluster. Because of their high masses, galaxy clusters can act as gravitational lenses: the background galaxies close to the line of sight of the cluster get multiply imaged or distorted into large arcs like the one visible south of the BCG. Some of the cluster galaxies (e.g. the bright elliptical galaxy one on the south-east of the BCG) act as additional lenses which further distort some of the multiple images. *Credits: NASA/STScI*

tral mass re-distributes itself significantly as mergers proceed. By the present day, the mixture of dark and stellar matter in the BCGs had the same total mass density profiles as in test simulations which included dark matter alone. This demonstrated that evolution tends to drive the total mass density profile (stars and dark matter) towards the "universal" shape. Since the stars contribute most of the mass near the middle of the final BCGs, this meant that their dark matter density profiles were actually less centrally concentrated than in the dark-matter-only simulations, even though they started out more concentrated in the initial galaxies. As a result, the simulated BCGs appear to have dark matter profiles consistent with those inferred observationally.

The simulated BCGs typically experienced 6 or 7 mergers which, in real galaxies, would be accompanied by a merger of the central supermassive black holes. Such mergers pump energy into the innermost regions, causing the stars and dark matter to move outwards. Estimates of the size of this effect based on the simulations suggest that it might explain the large stellar cores often observed in BCGs. So far, the effects of supermassive black holes in BCGs cannot be directly simulated in a full cosmological context, so the current simulations offer realistic initial conditions for simplified numerical studies of supermassive black hole merging in the central regions of BCGs.

This study suggests that observations of the mass distribution in the centres of galaxy clusters can be understood if BCG evolution is primarily driven by dissipationless mergers. Within the standard LCDM paradigm, such an evolutionary path naturally explains a total density profile similar to those found in dark-matter-only simulations, together with a shallower dark matter density profile. There seems no need to appeal to the more radical explanations proposed in some recent papers such as new physics in the dark matter sector or dynamical effects driven by star and black hole formation which are much more violent than any observed. (Chervin Laporte and Simon White)

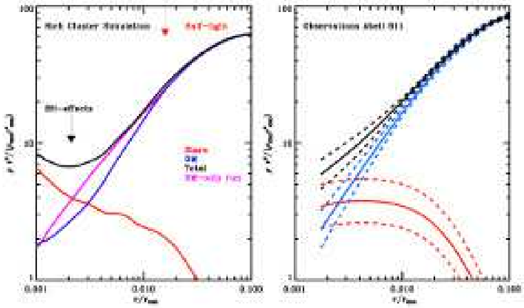


Figure 2.34: Density profiles of simulated and real clusters. Left Panel: Density profile for one of the re-simulated galaxy cluster. The black, red and blue lines represent the distribution of total (stars+dark matter), dark matter and stellar mass. The magenta line corresponds to the distribution of matter in a dark-matter-only run of the cluster (where the contribution of stars in galaxies was completely neglected). The total mass profile as a whole is very similar to the dark-matter-only run except where the density of stars overtakes that of the dark matter. The final dark matter profile on the other hand is shallower than the original dark-matter-only run already at the half-light radius of the BCG marked by the red arrow. The black arrow shows the radius where effects from black hole mergers would significantly affect the distribution of stars and dark matter in the BCG core. Right Panel: Density profile for one of the clusters in the Newman et al. (2013) sample, Abell 611. Black, red and blue lines represent the contributions from total, stellar and dark matter respectively. The dashed lines mark the 1-sigma error on the modelling. The mass distribution in this cluster is quite similar to one of the simulated clusters in the left panel. *Credits: Laporte and White 2014*

2.12 A new standard ruler: Measuring angular diameter distances using time-delay strong lenses

Observing the universe has a fundamental limitation: the 3-dimensional universe is projected onto the 2-dimensional observation plane, which makes it hard to know the 'depth' of the universe (in other words, how far an object is from us). As a consequence, astronomers rely on indirect methods to measure cosmological distances.

There are two methods to achieve this goal: One is the so-called 'standard candle' method, where the apparent luminosity of an object is compared to its intrinsic brightness that is assumed to be known. Using Type Ia supernovae as a standard candle, the method has led to the discovery of the accelerating expansion of the universe and the existence of dark energy. The other method is the 'standard ruler' method, which compares the apparent size of an object to its intrinsic size. For example, large-scale galaxy surveys allowed astronomers to use the so-called Baryonic Acoustic Oscillations as a standard ruler.

However, both existing methods have limitations. We still do not know the progenitors of Type Ia supernovae, and thus using them to infer distances may be limited by our physical understanding of supernovae. The resources required to measure Baryonic Acoustic Oscillations are large, as we need to take spectra of millions of galaxies, and a given project takes many years and tens of millions of euros (or more) to complete. Therefore, there is a strong desire to find another candle or ruler, which is well understood physically and demands less observational resources.

Recently, MPA scientists have substantially improved upon a method to use strong gravitational lens systems with measured time delays to infer the distance to the lens. The method was first proposed in 2009 by Paraficz and Hjorth, but no further study has been done since then. Strong gravitational lensing happens when a massive galaxy is almost, but not exactly, aligned to a source quasar that is located behind the galaxy. The light emitted from the source quasar passes through the gravitational field of the galaxy and is slightly bent towards the galaxy, according to General Relativity.

Each photon passing through a different part of the galaxy experiences a different gravitational potential: As a result, the galaxy acts like an optical lens and the photons taking separate paths produce multiple images around the galaxy (see Figure 2.35). As each photon takes a different path to reach the observer, the path lengths and thus the arrival times of the photons differ, allowing the observer to measure the delay between each path as the source quasar changes its brightness in time (see schematic in Figure 2.36). The time difference between images is called the time delay.

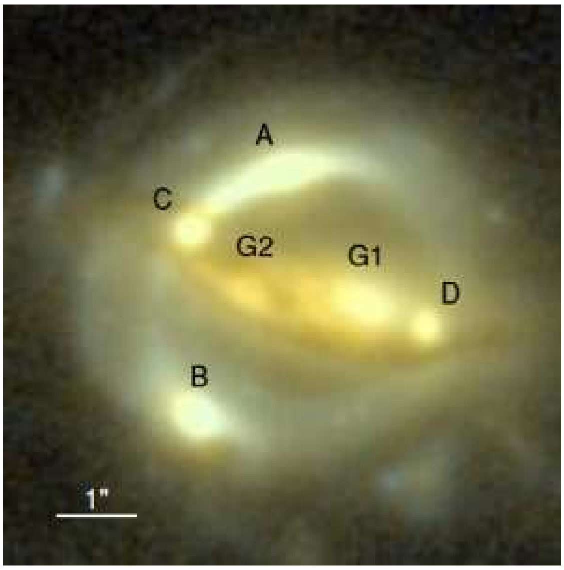


Figure 2.35: Image of a strong lensing time delay system, B1608+656, taken by the Hubble Space Telescope (from Suyu et al. 2010). The centre of the lens galaxy (G1) and a satellite galaxy (G2) are surrounded by images of a background source (A, B, C and D). The ordering of the images follows the arrival time. credit: HST/NASA

The physics behind the new ruler method is simple. The measured time delay is proportional to the mass of the galaxy. The measured velocity dispersion of the galaxy gives the gravitational potential of the lens. Combining both measurements yields the physical size of the lens. Then, by comparing the physical size of the lens that has been calculated and the angular size of the lens that has been observed, we can obtain the distance to the lens.

The angular diameter distance to the lens galaxy measured in this way can be expressed in terms of several observables such as the time delay, velocity dispersion, lens redshift, and image positions. It also depends on the steepness of the mass profile of the lens, which can be determined by analysing the shape and brightness distributions of the lens and images.

One big advantage of this new method, which

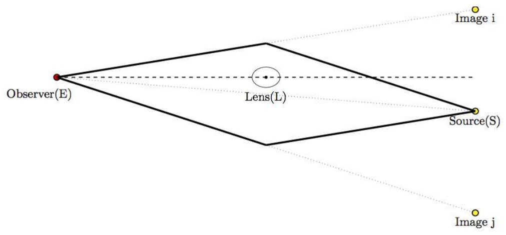


Figure 2.36: Configuration of a strong gravitational lensing system. The thick solid line shows the two different paths that photons emitted from the source could take. The dotted lines show the angular positions where images and the source appear on the sky. The position of the source, however, is usually not observable as it is very close to the lens. Note that the plot is not to scale: The distance photons travel is much longer than the size of the lens or the source. Credit: Jee, Komatsu and Suyu 2014

was found by scientists at MPA, is that the effect of the external mass that lies along the line-of-sight between the observer and the source, which is called the 'external convergence', cancels out. In other words, the angular diameter distance does not change under the presence of external mass that causes extra bending of light rays. In principle, the external convergence acts like another lens added to the lens system, and adds uncertainty to the traditional cosmological measurements using strong lenses. A good analogy exists in the classical optics: It is impossible to tell the difference between a single lens system with a given focal length, and a multiple lens system consisting of lenses with different focal lengths which collectively form a system with the same effective focal length as that of the single lens. Likewise, gravitational lens systems with a single lens and multiple lenses cannot be distinguished by observables.

However, in our case the resulting angular diameter distance does not depend on the external convergence, since the time delay and the velocity dispersion are both determined solely by the properties of the lens. Applying this method to one of the existing lens systems, B1608+656 (2.35), the researchers find that the distance can be measured with 15% accuracy (2.37).

This new method requires precise estimation of the mass and the potential of the system from data. Challenges lie both in the observation and the modelling of the lens: Assuming that the lens galaxy (which is a massive elliptical galaxy in most cases) has reached dynamical equilibrium, the random motion of matter particles inside the galaxy counteracts the gravitational force so that the galaxy neither collapses nor expands. This is measured by the velocity dispersion of stars with respect to the centre of the galaxy. The Jeans equation relates the radial component of the velocity dispersion to the gravitational potential; however, it is impossible to observe just the radial component of the velocity dispersion. The measurement is done using the Doppler shift of stellar light, which means that only the line-of-sight component of the velocity dispersion is measurable. The fact that only the luminous tracers (such as stars) can be measured results in the observation of projected, luminosity weighted velocity dispersion. When the velocity dispersion is anisotropic, the situation becomes even more complicated. Moreover, the measured velocity dispersion is usually a quantity that is averaged over an aperture of size few tenth of arc seconds. In the end, it is not easy to relate the value we observe to the potential itself.

To overcome this complication, we use spatially resolved spectroscopy of the lens galaxy to obtain the radial profile of the velocity dispersion. Then, we use a radius at which the scatter between different anisotropic profiles is minimised, the “sweet spot”, which was derived previously by other researchers at MPA (Churazov et al.). With this method, the uncertainty from the anisotropic velocity dispersion is minimised and the accuracy in the determination of the angular diameter distance improves to 12%.

This study demonstrates that, using a strong lens galaxy with measured time delays, the angular diameter distance can be measured accurately, providing a powerful, new way to chart our universe. (Inh Jee, Eiichiro Komatus and Sherry H. Suyu)

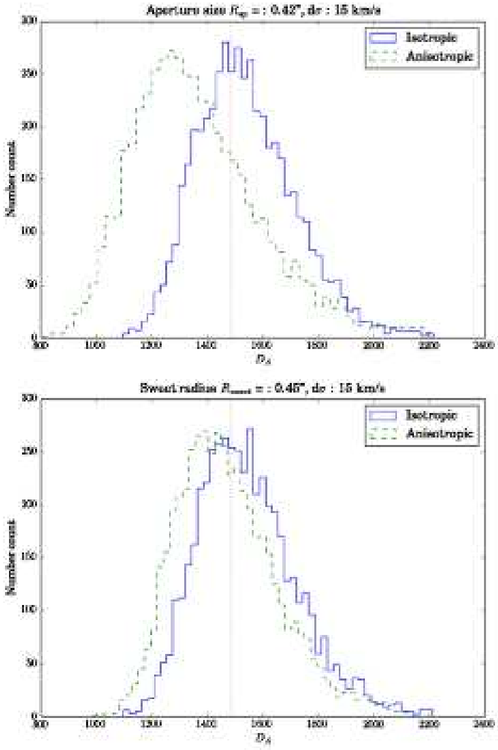


Figure 2.37: Distribution of angular diameter distances calculated from (top) the simulated aperture-averaged velocity dispersion of the lens system B1608+656, and (bottom) the velocity dispersion measured at the sweet-spot radius (see Figure 1). In both plots, the blue solid line shows the distribution when the input model is isotropic, whereas the green dashed line is the distribution when the simulated velocity dispersion is anisotropic. In the upper case, the distance can be determined to an accuracy of about 15%. If the radial profile of the velocity dispersion is taken into account (using the "sweet spot", see text), as the bottom panel shows, the uncertainty decreases to 12% Credit: Jee, Komatsu and Suyu 2014

3 Publications and Invited Talks

3.1 Publications in Journals

3.1.1 Publications that appeared in 2014 (254)

Ahn, C. P., R. Alexandroff, et al. (incl. S. White): The tenth data release of the Sloan Digital Sky Survey: first spectroscopic data from the SDSS–III Apache Point Observatory Galactic Evolution Experiment. Astrophys. J. Suppl. **211**, 17 (2014).

Alatalo, K., K. Nyland et al. (incl. Th. Naab): NGC 1266 as a local candidate for rapid cessation of star formation. Astrophys. J. **780**, 186 (2014).

Algorry, D.; J. Navarro et al. (incl. L. Sales): Counterrotating stars in simulated galaxy discs. Mon. Not. R. Astron. Soc., **437**, 3596–3602 (2014).

Anderson, M. E., and J.N. Bregman: Modeling X–ray emission around galaxies. Astrophys. J. **785**, 67 (2014).

Ando, S., A. Benoit–Levy, and E. Komatsu: Mapping dark matter in the gamma–ray sky with galaxy catalogs. Phys. Rev. D, **90** 023514 (2014).

Angulo, R., S. White, V. Springel and B. Henriques: Galaxy formation on the largest scales: the impact of astrophysics on the baryonic acoustic oscillation peak. Mon. Not. R. Astron. Soc. **442**, 2131–2144 (2014).

Arcavi, I., A. Gal–Yam, et al. (incl. A. Sternberg): A continuum of H– to He–rich tidal disruption candidates with a preference for E+A galaxies. Astrophys. J. **793**, 38 (2014).

Arnett, W. D., C. Meakin and M. Viallet: Chaos and turbulent nucleosynthesis prior to a supernova explosion. AIP Advances, **4**, 041010 (2014).

Ashall, C., P. Mazzali, D. Bersier et al.: Photometric and spectroscopic observations, and abundance tomography modelling of the type Ia supernova SN 2014J located in M82. Mon. Not. R. Astron. Soc. **445**, 4427–4437 (2014).

Augustovičová, L., P. Soldán, W.P. Kraemer and V. Špirko: Potential microwave probes of the proton-to-electron mass ratio at very high redshifts. Mon. Not. R. Astron. Soc. **439**, 1136–1139 (2014).

Augustovicova, L., W. Kraemer, and P. Soldan: Depopulation of metastable helium by radiative association with hydrogen and lithium ions. Astrophys. J.**782**, 46 (2014).

Augustovicova, L., W. Kraemer, and P. Soldan: Depopulation of metastable helium He(2(1)S) by radiative association with hydrogen and lithium cations. Journal of Quant. Spectroscopy **148**, 27–37 (2014).

Aumer, M., S. White and Th. Naab: The diverse formation histories of simulated disc galaxies. Mon. Not. R. Astron. Soc. **441**, 3679–3695 (2014).

Bally, J., M. Rathborne et al. (incl. D. Kruijssen): Absorption filaments toward the massive clump G0.253+0.016. Astrophys. J. **795**, 28 (2014).

Barai, P., Viel, et al. (incl. M. Gaspari): Kinetic or thermal AGN feedback in simulations of isolated and merging disc galaxies calibrated by the M–ω relation. Mon. Not. R. Astron. Soc. **437**, 1456–1475 (2014).

Bauswein, A., R. Ardevol, H.–T. Janka and S. Goriely: Nucleosynthesis constraints on the neutron star–black hole merger rate. Astrophys. J. Lett. **795**, L9 (2014).

Bauswein, A., N. Stergioulas and H.–T. Janka: Revealing the high–density equation of state through binary neutron star mergers. Phys. Rev. D, **90** 023002 (2014).

Behrens, C., M. Dijkstra and J. Niemeyer: Beamed Ly α emission through outflow–driven cavities. Astron. Astrophys. **563**, A77 (2014).

Beifiori, A., D. Thomas, et al. (incl. J. Johansson): Redshift evolution of the dynamical properties of massive galaxies from SDSS–III/BOSS. Astrophys. J. **789**, 92 (2014).

Belyaev, A.K., L. Augustovičová, P. Soldán and W.P. Kraemer: Non-radiative inelastic processes in lithium-helium ion-atom collisions. Astron. Astrophys. **565**, A106 (2014).

Ben–Ami, S., Gal–Yam, A., Mazzali: SN 2010mb: direct evidence for a supernova interacting with a large amount of hydrogen–free circumstellar material. Astrophys. J. **785**, 37 (2014).

Benetti, S., M. Nicholl, et al. (incl. S. Taubenberger): The supernova CSS121015:004244+132827: a clue for understanding superluminous supernovae. Mon. Not. R. Astron. Soc. **441**, 289–303 (2014).

Beutler, F., S. Saito, et al. (incl. C. Wagner): The clustering of galaxies in the SDSS–III Baryon Oscillation Spectroscopic Survey: signs of neutrino mass in current cosmological data sets. Mon. Not. R. Astron. Soc. **444**, 3501–3516 (2014).

Bizzocchi, L., M. Filho et al. (incl. B. Henriques): Bulgeless galaxies at intermediate redshift: sample selection, color properties, and the existence of powerful active galactic nuclei. Astrophys. J. **782**, 22 (2014).

Bogdan, A., R. J.van Weeren et al. (incl. E. Churazov): Young AGN outburst running over older X–ray cavities. Astrophys. J. Lett. **782**, L19 (2014).

Boselli, A., L. Cortese, et al. (incl. B. Catinella): Cold gas properties of the Herschel Reference Survey – II. Molecular and total gas scaling relations. Astron. Astrophys. **564**, A66 (2014).

Boselli, A., L. Cortese, et al. (incl. B. Catinella): Cold gas properties of the Herschel Reference Survey – III. Molecular gas stripping in cluster galaxies. Astron. Astrophys. **564**, A67 (2014).

Bufano, F., G. Pignata, et al. (incl. P. Mazzali): SN 2011hs: a fast and faint type IIb supernova from a supergiant progenitor. Mon. Not. R. Astron. Soc. **439**, 1807–1828 (2014).

Chen, H.–L., T. Woods, et al. (incl. M. Gilfanov): Next generation population synthesis of accreting white dwarfs – I. Hybrid calculations using bse + mesa. Mon. Mon. Not. R. Astron. Soc. **445**, 1912–1923. (2014).

Chiavassa, A., R. Ligi, Z. Magic et al.: Planet transit and stellar granulation detection with interferometry – Using the three–dimensional stellar atmosphere Stagger–grid simulations. Astron. Astrophys. **567**, A115 (2014).

Choi, E., Th. Naab, et al. (incl. B. Moster): Consequences of mechanical and radiative feedback from black holes in disc galaxy mergers. Mon. Not. R. Astron. Soc. **442**, 440–453 (2014).

Churazov, E., R. Sunyaev, J. Isern et al.: Cobalt–56 Γ–ray emission lines from the type Ia supernova 2014J. Nature, **512**, 406–408 (2014).

Coenen, T., J. van Leeuwen et al. (incl. B. Ciardi): The LOFAR pilot surveys for pulsars and fast radio transients. Astron. Astrophys. **570**, A60 (2014).

Corsi, A., Ofek, et al. (incl. A. Sternberg): A multi–wavelength investigation of the radio–loud supernova PTF11qcj and its circumstellar environment. Astrophys. J. **782**, 42 (2014).

D'Souza, R., G. Kauffmann, J. Wang and S. Vegetti: Parametrizing the stellar haloes of galaxies. Mon. Not. R. Astron. Soc. **443**, 1433–1450 (2014).

Dall'Ora, M., et al. (incl. S. Taubenberger and S. Benitez): The type IIP supernova 2012aw in M95: hydrodynamical modeling of the photospheric phase from accurate spectrophotometric monitoring. Astrophys. J. **787**, 139 (2014).

Davis, J. H., T. Enßlin, and C. Böhm: New method for analyzing dark matter direct detection data. Physical Review D, **89**, 043505 (2014).

Davis, T. A., L.M. Young et al. (incl. Th. Naab): The ATLAS3D Project – XXVIII. Dynamically driven star formation suppression in early–type galaxies. Mon. Not. R. Astron. Soc. **444**, 3427–3445 (2014).

De Lucia, G., L. Tornatore et al. (incl. S. White): Elemental abundances in Milky Way–like galaxies from a hierarchical galaxy formation model. Mon. Not. R. Astron. Soc. **445**, 970–987 (2014).

de Souza, R. S., E. Ishida, D. Whalen et al.: Probing the stellar initial mass function with high–z supernovae. Mon. Not. R. Astron. Soc. **442**, 1640–1655 (2014).

de Souza, R. S., U. Maio, V. Biffi and B. Ciardi: Robust PCA and MIC statistics of baryons in early minihaloes. Mon. Not. R. Astron. Soc. **440**, 240–248 (2014).

Deheuvels, S. et al. (incl. L. Casagrande and X.H. Yang): Seismic constraints on the radial dependence of the internal rotation profiles of six Kepler subgiants and young red giants. Astron. Astrophys. **564**, A27 (2014).

Dennison, K. A., T. Baumgarte and P. Montero: Trumpet slices in Kerr spacetimes. Phys. Rev. Lett. **113**, 261101 (2014).

Dijkstra, M.: Lyα emitting galaxies as a probe of reionisation. Publ. of the Astron. of Australia, **31**, 040 (2014).

Dijkstra, M., S. Wyithe, Z. Haiman et al.: Evolution in the escape fraction of ionizing photons and the decline in strong Lyα emission from z $>$ 6 galaxies. Mon. Not. R. Astron. Soc. **440**, 3309–3316 (2014).

Dijkstra, M., A. Ferrara, and A. Mesinger: Feedback–regulated supermassive black hole seed formation. Mon. Not. R. Astron. Soc. **442**, 2036–2047 (2014).

Dorn, S., E. Ramirez, et al. (incl. T. Enßlin): Generic inference of inflation models by non–Gaussianity and primordial power spectrum reconstruction. J. of Cosmology and Astropart. Phys. **6**, 1475–7516 (2014).

Dunkel, J., and S. Hilbert: Consistent thermostatistics forbids negative absolute temperatures. Nature Phys. **10**, 67–72 (2014).

Eckert, D., Molendi et al. (incl. M. Gaspari): The stripping of a galaxy group diving into the massive cluster A2142. Astron. Astrophys. **570**, A119 (2014).

Enßlin, T. A., H. Junklewitz, L. Winderling et al: Improving self–calibration. Phys. Rev. E, **90**, 043301 (2014).

Ergon, M., Sollerman, J., et al. (incl. S. Taubenberger): Optical and near–infrared observations of SN 2011dh – the first 100 days. Astron. Astrophys. **562**, A17 (2014).

Fernandez, R., B. Müller, T. Foglizzo and H.–T. Janka: Characterizing SASI– and convection–dominated core–collapse supernova explosions in two dimensions. Mon. Not. R. Astron. Soc. **440**, 2763–2780 (2014).

Filho, M. E., P. Brochado et al. (incl. B. Henriques): A multiple dry merger at z = 0.18: witnessing the assembly of a massive elliptical galaxy. Mon. Not. R. Astron. Soc. **443**, 288–298 (2014).

Fink, M., M. Kromer, I. Seitenzahl et al.: Three–dimensional pure deflagration models with nucleosynthesis and synthetic observables for type Ia supernovae. Mon. Not. R. Astron. Soc. **438**, 1762–1783 (2014).

Foley, R. J., Fox, et al. (incl. W. Hillebrandt): Extensive HST ultraviolet spectra and multiwavelength observations of SN 2014J in M82 indicate reddening and circumstellar scattering by typical dust. Mon. Not. R. Astron. Soc. **443**, 2887–2906 (2014).

Forero–Romero, J. E., S. Contreras, and N. Padilla: Cosmic web alignments with the shape, angular momentum and peculiar velocities of dark matter haloes. Mon. Not. R. Astron. Soc. **443**, 1090–1102 (2014).

Förster Schreiber, N. M., R. Genzel et al. (incl. Th. Naab): The Sins/zC–Sinf survey of z ∼2 galaxy kinematics: evidence for powerful active galactic nucleus–driven nuclear outflows in massive star–forming galaxies. Astrophys. J. **787**, 38 (2014).

Gabler, M., P. Cerda–Duran et al. (incl. E. Müller): Modulating magnetar emission by magneto–elastic oscillations Astronomische Nachrichten, **335**, 240–245 (2014).

Gabler, M., P. Cerda–Duran et al. (incl. E. Müller): Modulating the magnetosphere of magnetars by internal magneto-elastic oscillations. Mon. Not. R. Astron. Soc. **443**, 1416-1424 (2014).

Garcia–Berro, E., S. Torres et al. (incl. M. Biller–Bertolami): The white dwarf cooling sequence of 47 Tucanae. Astron. Astrophys. **571**, A56 (2014).

Gaspari, M., E. Churazov, D. Nagai et al.: The relation between gas density and velocity power spectra in galaxy clusters: high–resolution hydrodynamic simulations and the role of conduction. Astron. Astrophys. **569**, A67 (2014).

Gaspari, M., F. Brighenti, P. Temi and S. Ettori: Can AGN feedback break the self–similarity of galaxies, groups, and clusters? Astrophys. J. Lett. **783**, L10 (2014).

Genovali, K. et al. (incl. M. Bergemann and R.–P. Kudritzki): On the fine structure of the Cepheid metallicity gradient in the galactic thin disk. Astron. Astrophys. **566**, A37 (2014).

Genzel, R., N. Förster Schreiber, et al. (incl. Th. Naab): Evidence for wide–spread active galactic nucleus–driven outflows in the most massive z ∼ 1–2 star–forming galaxies. Astrophys. J. **796**, 7 (2014).

Genzel, R., N. Förster Schreiber, et al. (incl. Th. Naab): The SINS/zC–SINF survey of z ∼ 2 galaxy kinematics: evidence for gravitational quenching. Astrophys. J. **785**, 75 (2014).

Gil–Marin, H., C. Wagner, J. Norena et al: Dark matter and halo bispectrum in redshift space: theory and applications. J. Cosmology and Astr. Phys. **12**, 029 (2014).

Gilfanov, M. R., and R. A. Sunyaev: Radiation–dominated boundary layer between an accretion disc and the surface of a neutron star: theory and observations. Physics Uspekhi, **57**, 377–388 (2014).

Gilfanov, M., and A. Merloni: Observational appearance of black holes in X–ray binaries and AGN. Space Science Reviews, **183**, 121–148 (2014).

Girichidis, P., L. Konstandin, A. Whitworth and R. Klessen: On the evolution of the density probability density function in strongly self–gravitating systems. The Astrophys. J. **781**, 91 (2014).

Gómez–Vargas, G., A. Cuoco, et al. (incl. E. Komatsu) Dark matter implications of Fermi–LAT measurement of anisotropies in the diffuse gamma–ray background. NIMA **742**, 149–153 (2014).

Goudfrooij, P., and D. Kruijssen: Color–magnitude relations within globular cluster systems of giant elliptical galaxies: the effects of globular cluster mass loss and the stellar initial mass function. Astrophys. J. **780**, 43 (2014).

Grimm–Strele, H., F. Kupka, and H. Muthsam: Curvilinear grids for WENO methods in astrophysical simulations. Comp. Physics Comm. **185**, 764–776 (2014).

Guilet, J., and G. Ogilvie: Global evolution of the magnetic field in a thin disc and its consequences for protoplanetary systems. Mon. Not. R. Astron. Soc. **441**, 852–868 (2014).

Guilet, J. and R. Fernandez: Angular momentum redistribution by SASI spiral modes and consequences for neutron star spins. Mon. Not. R. Astron. Soc. **441**, 2782 (2014).

Guo, H., C. Li, Y.P. Jing and G. Börner: Stellar mass and color dependence of the three–point correlation function of galaxies in the local universe. Astrophys. J. **780**, 139 (2014).

Guo, Q., and S. White: Numerical resolution limits on subhalo abundance matching. Mon. Not. R. Astron. Soc. **437**, 3228–3235 (2014).

Haas, M., C. Leipski et al. (S. Vegetti): 3C 220.3: a radio galaxy lensing a submillimeter galaxy Astrophys. J. **790**, 46 (2014).

Heinzel, P., J.C Vial, and U. Anzer: On the formation of MgII h and k lines in solar prominences. Astron. Astrophys. **564**, A132 (2014).

Hernandez–Monteagudo, C., A. Ross, A. Cuesta, et al.: The SDSS–III Baryonic Oscillation Spectroscopic Survey: constraints on the integrated Sachs-Wolfe effect. Mon. Not. R. Astron. Soc. **438**, 1724–1740 (2014).

Hirschmann, M., K. Dolag, A. Saro et al.: Cosmological simulations of black hole growth: AGN luminosities and downsizing. Mon. Not. R. Astron. Soc. **442**, 2304–2324 (2014).

Hoffmann, K., S. Planelles et al. (incl. M. Maciejewski): Subhaloes gone Notts: subhaloes as tracers of the dark matter halo shape. Mon. Not. R. Astron. Soc. **442**, 1197–1210 (2014).

Hu, C.–Y., T. Naab, S. Walch, et al.: SPHGal: smoothed particle hydrodynamics with improved accuracy for galaxy simulations. Mon. Not. R. Astron. Soc. **443**, 1173–1191 (2014).

Huang, M.–L., and G. Kauffmann: The variation in molecular gas depletion time among nearby galaxies: what are the main parameter dependences? Mon. Not. R. Astron. Soc. **443**, 1329–1338 (2014).

Hütsi, G., M. Gilfanov, A. Kolodzig and R. Sunyaev: Probing large–scale structure with large samples of X–ray selected AGN I. Baryonic acoustic oscillations. Astron. Astrophys. **572**, A28 (2014).

Hütsi, G., M. Gilfanov and R. Sunyaev: Linking X–ray AGN with dark matter halos: a model compatible with AGN luminosity function and large–scale clustering properties. Astron. Astrophys. **561**, A58 (2014).

Jeeson–Daniel, A., B. Ciardi and L. Graziani: Clumping factors of H II, He II and He III. Mon. Not. R. Astron. Soc. **443**, 2722–2732 (2014).

Jelic, V., A.G. de Bruyn et al. (incl. B. Ciardi): Initial LOFAR observations of epoch of reionization windows – II. Diffuse polarized emission in the ELAIS–N1 field. Astron. Astrophys. **568**, A101 (2014).

Jeon, M., A. Pawlik, V. Bromm, and M. Milosavljevic: Radiative feedback from high–mass X–ray binaries on the formation of the first galaxies and early reionization. Mon. Not. R. Astron. Soc. **440**, 3778–3796 (2014).

Jofre, P., U. Heiter et al. (incl. M. Bergemann): Gaia FGK benchmark stars: metallicity. Astron. Astrophys. **564**, A133 (2014).

Johansson, J., T. Woods, M. Gilfanov et al.: Diffuse gas in galaxies sheds new light on the origin of type Ia supernovae. Mon. Not. R. Astron. Soc. **442**, 1079–1089 (2014).

Joseph, R., F. Courbin et al. (incl. M. Petkova): A PCA–based automated finder for galaxy–scale strong lenses. Astron. Astrophys. **566**, A63 (2014).

Kauffmann, G.: Quantitative constraints on starburst cycles in galaxies with stellar masses in the range 10(8)–10(10). Mon. Not. R. Astron. Soc. **441**, 2717–2724 (2014).

Keller, S., M. Bessell et al. (incl. Z. Magic): A single low-energy, iron-poor supernova as the source of metals in the star SMSS J031300.36-670839.3. Nature, **506**, 463–466 (2014).

Kerzendorf, W., S. Taubenberger, I. Seitenzahl and A. Ruiter: Very late photometry of SN 2011fe. Astrophys. J. Lett. **796**, L26 (2014).

Khabibullin, I., and S. Sazonov: Stellar tidal disruption candidates found by cross–correlating the ROSAT Bright Source Catalogue and XMM-Newton observations. Mon. Not. R. Astron. Soc. **444**, 1041–1053 (2014).

Khabibullin, I., S. Sazonov and R. Sunyaev: SRG/eROSITA prospects for the detection of stellar tidal disruption flares. Mon. Not. R. Astron. Soc. **437**, 327–337 (2014).

Khedekar, S., E. Churazov, S. Sazonov, et al.: Scattering of emission lines in galaxy cluster cores: measuring electron temperature. Mon. Not. R. Astron. Soc. **441**, 1537–1544 (2014).

Kim, J.–H., T. Abel et al. (incl. F. Iannuzzi): The AGORA high–resolution galaxy simulations comparison project Astrophys. J. Suppl. **210** 14 (2014).

Krone-Martins, A., E. Ishida and R. de Souza: The first analytical expression to estimate photometric redshifts suggested by a machine, Mon. Not. R. Astron. Soc. Lett. **443**, L34–L38 (2014).

Koliopanos, F., M. Gilfanov, L. Bildsten and M.D. Trigo: X–ray diagnostics of chemical composition of the accretion disc and donor star in UCXBs – II. XMM-Newton observations. Mon. Not. R. Astron. Soc. **442**, 2817–2825 (2014).

Komarov, S. V., E. Churazov, A. Schekochihin and J. ZuHone: Suppression of local heat flux in a turbulent magnetized intracluster medium. Mon. Not. R. Astron. Soc. **440**, 1153–1164 (2014).

Komatsu, E., C. Bennett, (on behalf of the WMAP science team): Results from the Wilkinson Microwave Anisotropy Probe. Progress of Theor. and Exp. Phys., **06B102** 1–24 (2014).

Kruijssen, J. M. D.: Globular cluster formation in the context of galaxy formation and evolution. Classical and Quantum Gravity, **31**, 24 (2014).

Kruijssen, J. M. D., S.N. Longmore, B.G. Elmegreen et al.: What controls star formation in the central 500 pc of the galaxy? Mon. Not. R. Astron. Soc. **440**, 3370–3391 (2014).

Kruijssen, J. M. D. and S.N. Longmore: n uncertainty principle for star formation – I. Why galactic star formation relations break down below a certain spatial scale lar mass and star formation rate. Mon. Not. R. Astron. Soc. **439**, 3239–3252 (2014).

Kunze, K., and E. Komatsu: Constraining primordial magnetic fields with distortions of the black–body spectrum of the cosmic microwave background: pre– and post–decoupling contributions. J. of Cosmology and Astrop. Phys. **009**, 1–25 (2014).

Li, M., R. Angulo, S. White, and J. Jasche: Matched filter optimization of kSZ measurements with a reconstructed cosmological flow field. Mon. Not. R. Astron. Soc. **443**, 2311–2326 (2014).

Lomax, O., A. Whitworth et al. (incl. S. Walch): Simulating star formation in Ophiuchus. Mon. Not. R. Astron. Soc. **439**, 3039–3050 (2014).

Ludlow, A. D., J. Navarro et al. (incl. S. White): The mass-concentration-redshift relation of cold dark matter haloes. Mon. Not. R. Astron. Soc. **441**, 378–388 (2014).

Lyskova, N., E. Churazov, A. Moiseev et al.: Stellar kinematics of X–ray bright massive elliptical galaxies. Mon. Not. R. Astron. Soc. **441**, 2013–2033 (2014).

Maguire, K., M. Sullivan, Y.–C. Pan et al.: Exploring the spectral diversity of low–redshift type Ia supernovae using the Palomar Transient Factory. Mon. Not. R. Astron. Soc. **444**, 3258–3274 (2014).

Marino, A. F., A. Milone, et al. (incl. M. Bergemann): Helium enhanced stars and multiple populations along the horizontal branch of NGC 2808: direct spectroscopic measurements. Mon. Not. R. Astron. Soc. **437**, 1609–1627 (2014).

Mazumdar, A., M.J. Monteiro, et al. (incl. V. Silva): Measurement of acoustic glitches in solar-type stars from oscillation frequencies observed by Kepler. Astrophys. J. **782** 18, (2014).

Mazzali, P. A., A. McFadyen, S. Woosley et al.: An upper limit to the energy of gamma-ray bursts indicates that GRBs/SNe are powered by magnetars. Mon. Not. R. Astron. Soc. **443**, 67–71 (2014).

Mazzali, P. A., M. Sullivan, S. Hachinger et al.: Hubble Space Telescope spectra of the type Ia supernova SN 2011fe: a tail of low-density, high–velocity material with $Z < Z$. Mon. Not. R. Astron. Soc. **439**, 1959-1979 (2014).

McDermid, R. M., M. Cappellari et al. (incl. Th. Naab): Connection between dynamically derived initial mass function normalization and stellar population parameters. Astrophys. J. Lett. **792**, L37 (2014).

McQuinn, K. B. W.; M. J. Cannon, et al. (incl. A. Saintonge): Distance determinations to SHIELD galaxies from Hubble Space Telescope imaging. Astrophys. J. **785**, 3 (2014).

Medvedev, P., M. Gilfanov, S. Sazonov and P. Shtykovskiy: Impact of thermal diffusion and other abundance anomalies on cosmological uses of galaxy clusters. Mon. Not. R. Astron. Soc. **440**, 2464-2473 (2014).

Melandri, A., E. Pian et al (incl. P. Mazzali): Diversity of gamma–ray burst energetics vs. supernova homogeneity: SN 2013cq associated with GRB 130427A. Astron. Astrophys. **567**, A29 (2014).

Meyer–Hofmeister, E., and F. Meyer: The relation between radio and X-ray luminosity of black hole binaries: affected by inner cool disks? Astron. Astrophys. **562**, A142 (2014).

Milisavljevic, D., R. Margutti, et al (incl. P. Mazzali): Interaction between the broad–lined type Ic supernova 2012ap and carriers of diffuse interstellar bands. Astrophys. J. Lett. **782**, L5 (2014).

Miller Bertolami, M., B. Melendez, L. Althaus and J. Isern: Revisiting the axion bounds from the Galactic white dwarf luminosity function. J. of Cosmology and Astrop. Phys. **10**, 069 (2014).

Miller Bertolami, M. M.: Limits on the neutrino magnetic dipole moment from the luminosity function of hot white dwarfs. Astron. Astrophys. **562**, A123 (2014).

Mineo, S., S. Rappaport, A. Levine et al.: A comprehensive X-ray and multiwavelength study of the colliding galaxy pair NGC 2207/IC 2163. Astrophys. J. Lett. **797**, 91 (2014).

Mineo, S., M. Gilfanov, B. Lehmer et al.: X–ray emission from star-forming galaxies – III. Calibration of the LX-SFR relation up to redshift z $\approx$1.3 non-degenerate set of optical line indices. Mon. Not. R. Astron. Soc. **437**, 1698-1707 (2014).

Molaro, M., R. Khatri, and R. Sunyaev: A thin diffuse component of the galactic ridge X-ray emission and heating of the interstellar medium contributed by the radiation of galactic X-ray binaries. Astron. Astrophys. **564**, A107 (2014).

Molenda-Zakowicz, J., K. Brogaard et al. (incl. M. Bergemann): Spectroscopic study of the open cluster NGC 6811. Mon. Not. R. Astron. Soc. **445**, 2446-2461 (2014).

Moll, R., C. Raskin, D. Kasen, and S. Woosley: Type Ia supernovae from merging white dwarfs. I. Prompt detonations. Astrophys. J. **785**, 105 (2014).

Montero, P. J., T. Baumgarte and E. Müller: General relativistic hydrodynamics in curvilinear coordinates. Phys. Review D. **89**, 084043 (2014).

Morales-Garoffolo, A. et al. (incl. S. Taubenberger and M. Klauser): SN 2013df, a double–peaked IIb supernova from a compact progenitor and an extended H envelope. Mon. Not. R. Astron. Soc. **445**, 1647-1662 (2014).

Morel, T., N. Castro, et al. (incl. H. Spruit): The B fields in OB stars (BOB) survey. The ESO Messenger, **157**, 27-31 (2014).

Morokuma, T., N. Tominaga, et al. (incl. P. Mazzali): Kiso supernova survey (KISS): survey strategy. Publ. of the Astron. Soc. of Japan, **66**, 114 (2014).

Morosan, D. E., P.T. Gallagher et al. (incl. B. Ciardi): LOFAR tied–array imaging of type III solar radio bursts. Astron. Astrophys. **568**, A67 (2014).

Moster, B. P., A.V. Maccio and R.S. Somerville: Numerical hydrodynamic simulations based on semi-analytic galaxy merger trees: method and Milky Way-like galaxies. Mon. Not. R. Astron. Soc. **437**, 1027-1044 (2014).

Mulcahy, D. D., A. Horneffer et al. (incl. T. Enßlin): The nature of the low-frequency emission of M51 - First observations of a nearby galaxy with LOFAR. Astron. Astrophys. **568**, A74 (2014).

Naab, T., L. Oser, E. Emsellem et al.: The ATLAS3D project – XXV. Two-dimensional kinematic analysis of simulated galaxies and the cosmological origin of fast and slow rotators. Mon. Not. R. Astron. Soc. **444**, 3357-3387 (2014).

Nakamura, T., Kashiyama, et al. (incl. Y. Suwa): Soft X-ray Extended Emissions of Short Gamma-Ray Bursts as Electromagnetic Counterparts of Compact Binary Mergers; Possible Origin and Detectability. Astrophys. J. **796**, 13 (2014)

Newman, S. F., P. Buschkamp et al. (incl. Th. Naab): Nebular excitation in z $\sim$ 2 star–forming galaxies from the SINS and LUCI surveys: the influence of shocks and active galactic nuclei. Astrophys. J. **781**, 21 (2014).

Nielsen, M. T. B., M. Gilfanov et al. (incl. T. Woods): Upper limits on the luminosity of the progenitor of type Ia supernova SN 2014J. Mon. Not. R. Astron. Soc. **442**, 3400-3406 (2014).

Nielsen, M. T. B., G. Nelemans, R. Voss, and S. Toonen: On double-degenerate type Ia supernova progenitors as supersoft X-ray sources – a population synthesis analysis using SeBa. Astron. Astrophys. **563**, A16 (2014).

Obergaulinger, M., H.-T. Janka, and M. A. Aloy: Magnetic field amplification and magnetically supported explosions of collapsing, non–rotating stellar cores. Mon. Not. R. Astron. Soc. **445**, 3169-3199 (2014).

Ohlmann, S. T., M. Kromer, et al. (incl. I. Seitenzahl): The white dwarf's carbon fraction as a secondary parameter of type Ia supernovae. Astron. Astrophys. **572**, A57 (2014).

Oonk, J. B. R., R. van Weeren et al. (incl. B. Ciardi): Discovery of carbon radio recombination lines in absorption towards Cygnus A. Mon. Not. R. Astron. Soc. **437**, 3506-3515 (2014).

Patil, A. H., S. Zaroubi, et al. (incl. B. Ciardi): Constraining the epoch of reionization with the variance statistic: simulations of the LOFAR case. Mon. Not. R. Astron. Soc. **443**, 1113-1124 (2014).

Pawlik, A. H.; V. Bromm, and M. Milosavljevic: Assembly of the first disk galaxies under radiative feedback from the first stars. Memorie della Societa Astron. Italiana, **85**, 565 (2014).

Pentericci, L., E. Vanzella, et al. (incl. M. Dijkstra): New observations of z $\sim$ 7 galaxies: evidence for a patchy reionization. Astrophys. J. **793**, 113 (2014).

Planck Collaboration (incl. MPA Planck group): Overview of products and scientific results. Astron. Astrophys. **571**, A1 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results - II. Low Frequency Instrument data processing. Astron. Astrophys. **571**, A2 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. III. LFI systematic uncertainties. Astron. Astrophys. **571**, A3 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. V. LFI calibration. Astron. Astrophys. **571**, A5 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. VI. High Frequency Instrument data processing. Astron. Astrophys. **571**, A6 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. VII. HFI time response and beams. Astron. Astrophys. **571**, A7 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. VIII. HFI photometric calibration and mapmaking. Astron. Astrophys. **571**, A8 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. IX. HFI spectral response. Astron. Astrophys. **571**, A9 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. X. HFI energetic particle effects: characterization, removal, and simulation. Astron. Astrophys. **571**, A10 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XI. All-sky model of thermal dust emission. Astron. Astrophys. **571**, A11 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XII. Diffuse component separation. Astron. Astrophys. **571**, A12 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XIII. Galactic CO emission. Astron. Astrophys. **571**, A13 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XIV. Zodiacal emission. Astron. Astrophys. **571**, A14 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XV. CMB power spectra and likelihood. Astron. Astrophys. **571**, A15 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XVI. Cosmological parameters. Astron. Astrophys. **571**, A16 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XVII. Gravitational lensing by large-scale structure. Astron. Astrophys. **571**, A17 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XVIII. The gravitational lensing-infrared background correlation. Astron. Astrophys. **571**, A18 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XIX. The integrated Sachs-Wolfe effect. Astron. Astrophys. **571**, A19 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XX. Cosmology from Sunyaev–Zeldovich cluster counts. Astron. Astrophys. **571**, A20 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXI. Power spectrum and high-order statistics of the Planck all-sky Compton parameter map. Astron. Astrophys. **571**, A21 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXIII. Isotropy and statistics of the CMB. Astron. Astrophys. **571**, A23 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXIV. Constraints on primordial non-Gaussianity. Astron. Astrophys. **571**, A24 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXV. Searches for cosmic strings and other topological defects. Astron. Astrophys. **571**, A25 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXVI. Background geometry and topology of the Universe. Astron. Astrophys. **571**, A26 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results - XXVII. Doppler boosting of the CMB: Eppur si muove. Astron. Astrophys. **571**, A27 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXVIII. The Planck Catalogue of Compact Sources. Astron. Astrophys. **571**, A28 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXIX. The Planck catalogue of Sunyaev-Zeldovich sources. Astron. Astrophys. **571**, A29 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXX. Cosmic infrared background measurements and implications for star formation. Astron. Astrophys. **571**, A30 (2014).

Planck Collaboration (incl. MPA Planck group): Planck 2013 results. XXXI. Consistency of the Planck data. Astron. Astrophys. **571**, A31 (2014).

Planelles, S., S. Borgani, et al. (incl. K. Dolag): On the role of AGN feedback on the thermal and chemodynamical properties of the hot intracluster medium. Mon. Not. R. Astron. Soc. **438**, 195-216 (2014).

Pollack, J. E., R. Smith and C. Porciani: A new method to measure galaxy bias. Mon. Not. R. Astron. Soc. **440**, 555-576 (2014).

Prat, V., and F. Lignieres: Shear mixing in stellar radiative zones - I. Effect of thermal diffusion and chemical stratification. Astron. Astrophys. **566**, A110 (2014).

Prokhorov, D. A. and E.Churazov: Counting gamma rays in the directions of galaxy clusters. Astron. Astrophys. **567**, A93 (2014).

Prokhorov, D. A. and S. de Jong: A morphological analysis for searches of possible extended Γ-ray sources associated with dark matter annihilation. Mon. Not. R. Astron. Soc. **441**, 2200-2207 (2014).

Prokhorov, D. A.: An analysis of Fermi-LAT observations of the outskirts of the Coma cluster of galaxies. Mon. Not. R. Astron. Soc. **441**, 2309-2315 (2014).

Rahmati, A., and J. Schaye: Predictions for the relation between strong H I absorbers and galaxies at redshift 3. Mon. Not. R. Astron. Soc. **438**, 529-547 (2014).

Raicevic, M., A. Pawlik, J. Schaye, and A. Rahmati: The effect of recombination radiation on the temperature and ionization state of partially ionized gas. Mon. Not. R. Astron. Soc. **437**, 2816-2830 (2014).

Rasia, E., E.T. Lau, et al. (incl. K. Dolag): Temperature structure of the intracluster medium from smoothed–particle hydrodynamics and adaptive–mesh refinement simulations. Astrophys. J. **791**, 96 (2014).

Rathborne, J. M., S.N. Longmore, et al. (incl. D. Kruijssen): Turbulence sets the initial conditions for star formation in high-pressure environments. Astrophys. J. Lett. **795**, L25 (2014).

Rathborne, J. M., S.N. Longmore, et al. (incl. D. Kruijssen): G0.253+0.016: a centrally condensed, high–mass protocluster. Astrophys. J. **786**, 140 (2014).

Rau, S., S. Vegetti, and S. White: Lensing model of MACS J1149.5+2223 – I. Cluster mass reconstruction. Mon. Not. R. Astron. Soc. **443**, 957-968 (2014).

Revnivtsev, M. G., R. Sunyaev, R. Krivonos et al.: Broadband spectrum of the total X–ray emission from the galaxy M31. Astron. Lett.–A J. of Astron. and Space Astrophys. **40**, 22-28 (2014).

Revnivtsev, M. G., S. Tsygankov, E. Churazov and R. Krivonos: Hard X-ray emission of Sco X-1. Mon. Not. R. Astron. Soc. **445**, 1205-1212 (2014).

Rosotti, G. P. et al. (incl. D. Kruijssen and S. Walch): Protoplanetary disc evolution affected by star–disc interactions in young stellar clusters. Mon. Not. R. Astron. Soc. **441**, 2094-2110 (2014).

Röttgers, B., T. Naab and L. Oser: Stellar orbits in cosmological galaxy simulations: the connection to formation history and line-of-sight kinematics. Mon. Not. R. Astron. Soc. **445**, 1065-1083 (2014).

Roychowdhury, S., J.N. Chengalur, S.S. Kaisin and I. D. Karachentsev: The relation between atomic gas and star formation rate densities in faint dwarf irregular galaxies. Mon. Not. R. Astron. Soc. **445**, 1392-1402 (2014).

Sako, T., J. Paldus and G. Diercksen: Angular correlation in He and He-like atomic ions: a manifestation of the genuine and conjugate Fermi holes. Physical Review A. **89**, (6) (2014).

Salazar-Albornoz, S., A. Sanchez, N. Padilla and C. Baugh: Clustering tomography: measuring cosmological distances through angular clustering in thin redshift shells. Mon. Not. R. Astron. Soc. **443**, 3612-3623 (2014).

Sales, L. V., F. Marinacci, V. Springel and M. Petkova: Stellar feedback by radiation pressure and photoionization. Mon. Not. R. Astron. Soc. **443**, 2990-3006 (2014).

Sanchis-Gual, N., P. Montero, et al. (incl. E. Müller): Fully covariant and conformal formulation of the Z4 system in a reference-metric approach: comparison with the BSSN formulation in spherical symmetry. Physical Review D. **89**, 104033 (2014).

Sanders, J. S., A. Fabian, et al. (incl. E. Churazov): The X-ray coronae of the two brightest galaxies in the Coma cluster. Mon. Not. R. Astron. Soc. **439**, 1182-1192 (2014).

Sasdelli, M., P. Mazzali, E. Pian, et al.: Abundance stratification in type Ia supernovae – IV. The luminous, peculiar SN 1991T. Mon. Not. R. Astron. Soc. **445**, 711–725 (2014).

Scaloz, R. et al. (incl. M. Kromer and S. Taubenberger): Type Ia supernova bolometric light curves and ejected mass estimates from the Nearby Supernova Factory. Mon. Not. R. Astron. Soc. **440**, 1498-1518 (2014).

Scalzo, R. A., Childress, et al. (incl. S. Taubenberger): Early ultraviolet emission in the type Ia supernova LSQ12gdj: no evidence for ongoing shock interaction. Mon. Not. R. Astron. Soc. **445**, 30–48 (2014).

Scalzo, R. A., A. Ruiter, and S. Sim: The ejected mass distribution of type Ia supernovae: a significant rate of non-Chandrasekhar-mass progenitors. Mon. Not. R. Astron. Soc. **445**, 2535-2544 (2014).

Schmidt, F., E. Pajer, and M. Zaldarriaga: Large-scale structure and gravitational waves - III. Tidal effects. Physical Review D. **89**, (8): 083507 (2014).

Schönrich, R., and M. Bergemann: Fundamental stellar parameters and metallicities from Bayesian spectroscopy: application to low- and high-resolution spectra. Mon. Not. R. Astron. Soc. **443**, 698-717 (2014).

Seitenzahl, I. R., A. Summa, et al.: 5.9-keV Mn K-shell X-ray luminosity from the decay of 55Fe in Type Ia supernova models. Mon. Not. R. Astron. Soc. **447**, 1484 (2014).

Serra, P., L. Oser, et al. (incl. T. Naab): The ATLAS3D project – XXVI. HI discs in real and simulated fast and slow rotators. Mon. Not. R. Astron. Soc. **444**, 3388-3407 (2014).

Shi, X., B. Joachimi, and P. Schneider: How well do third-order aperture mass statistics separate E- and B-modes? Astron. Astrophys. **561**, A68 (2014).

Shi, X., and E. Komatsu: Analytical model for non-thermal pressure in galaxy clusters. Mon. Not. R. Astron. Soc. **442**, 521-532 (2014).

Shiraishi, M., E. Komatsu and M. Peloso: Signatures of anisotropic sources in the trispectrum of the cosmic microwave background. J. of Cosmo and Astrop. Phys. **4**, 027 (2014).

Shirazi, M., J. Brinchmann and A. Rahmati: Stars were born in significantly denser regions in the early universe. Astrophys. J. **787**, 120 (2014).

Shirazi, M., S. Vegetti, N. Nesvadba, et al.: The physical nature of the 8 o'clock arc based on near-IR IFU spectroscopy with SINFONI. Mon. Not. R. Astron. Soc. **440**, 2201-2221 (2014).

Silva Aguirre, V., G. Ruchti, et al. (incl. A. Jendreieck): Old puzzle, new insights: a Lithium-rich giant quietly burning Helium in its core. Astrophys. J. Lett. **784**, L16 (2014).

Smiljanic, R., A.J. Korn, M. Bergemann, et al.: The Gaia-ESO Survey: the analysis of high-resolution UVES spectra of FGK-type stars. Astron. Astrophys. **570**, A122 (2014).

Smith, R. E., D.S. Reed, D. Potter et al.: Precision cosmology in muddy waters: cosmological constraints and N-body codes. Mon. Not. R. Astron. Soc. **440**, 249-268 (2014).

Sousa, S. G., N.C. Santos, et al. (incl. M. Bergemann): A new procedure for defining a homogenous line-list for solar-type stars. Astron. Astrophys. **570**, A21 (2014).

Spiniello, C., S. Trager, L. Koopmans, and C. Conroy: The stellar IMF in early-type galaxies from a non-degenerate set of optical line indices. Mon. Not. R. Astron. Soc. **438**, 1483-1499 (2014).

Spiro, S., A. Pastorello, et al. (incl. S. Taubenberger): Low luminosity type II supernovae – II. Pointing towards moderate mass precursors. Mon. Not. R. Astron. Soc. **439**, 2873-2892 (2014).

Stacy, A., A. Pawlik, V. Bromm, and A. Loeb: The mutual interaction between Population III stars and self–annihilating dark matter. Mon. Not. R. Astron. Soc. **441**, 822-836 (2014).

Sternberg, A., A. Gal-Yam et al. (incl. W. Hillebrandt): Multi-epoch high-spectral-resolution observations of neutral sodium in 14 type Ia supernovae. Mon. Not. R. Astron. Soc. **443**, 1849-1860 (2014).

Stringer, M. J., F. Shankar, et al. (incl. B. Moster): Galaxy size trends as a consequence of cosmology. Mon. Not. R. Astron. Soc. **441**, 1570-1583 (2014).

Surman, R., et al. (incl. O. Just, and H.-T. Janka): Production of 56Ni in black hole-neutron star merger accretion disc outflows. J. of Phys. G: Nuclear and Particel Physics, **41(4)**, 044006 (2014).

Suwa, Y.: From supernovae to neutron stars. Publ. Astron. Soc. Japan, **66**, L1 (2014).

Suwa, Y. and Enoto, T.: Anisotropic neutrino effect on magnetar spin: constraint on inner toroidal field. Mon. Not. Roy. Astron. Soc., **443**, 3586–3593 (2014).

Suyu, S. H. et al. (incl. S. Hilbert and C. Spiniello): Cosmology from gravitational lens time delays and Planck data. Astrophys. J. Lett. **788**, L35 (2014).

Takats, K., M. L. Pumo et al. (incl. S. Taubenberger): SN 2009N: linking normal and subluminous type II-P SNe. Mon. Not. R. Astron. Soc. **438**, 368-387 (2014).

Takiwaki, T., K. Kotake, and Y. Suwa: A Comparison of Two- and Three-dimensional Neutrino-hydrodynamics Simulations of Core-collapse Supernovae. Astrophys. J. **786**, 83 (2014).

Tanaka, M., Morokuma, et al. (incl. P. Mazzali): Discovery of dramatic optical variability in SDSS J1100+4421: A peculiar radio-loud narrow-line Seyfert 1 galaxy? Astrophys. J. Lett. **793**, L26 (2014).

Tanaka, T. L.: Driving the growth of the earliest supermassive black holes with major mergers of host galaxies. Classical and Quantum Gravity. **31**, 24 (20014).

Tanaka, T. L., and M. Li: The formation of massive black holes in z $\sim$30 dark matter haloes with large baryonic streaming velocities. Mon. Not. R. Astron. Soc. **439**, 1092-1100 (2014).

Thaler, I., and H. Spruit: Brightness of the Sun's small scale magnetic field: proximity effects. Astron. Astrophys. **566**, A11 (2014).

Toonen, S., J. Claeys, N. Mennekens, and A. Ruiter: PopCORN: hunting down the differences between binary population synthesis codes. Astron. Astrophys. **562**, A14 (2014).

Travaglio, C., R. Gallino et al. (incl. W. Hillebrandt): Radiogenic p-isotopes from type Ia supernova, nuclear physics uncertainties, and galactic chemical evolution compared with values in primitive meteorites. Astrophys. J. **795**, 141 (2014).

Übler, H., T. Naab, T., L. Oser et al.: Why stellar feedback promotes disc formation in simulated galaxies. Mon. Not. R. Astron. Soc. **443**, 2092-2111 (2014).

Valenti, S. et al. (incl. S. Taubenberger and S. Benitez): PESSTO monitoring of SN 2012hn: further heterogeneity among faint type I supernovae. Mon. Not. R. Astron. Soc. **437**, 1519-1533 (2014).

van Daalen, M. P., J. Schaye, I. McCarthy et al.: The impact of baryonic processes on the two-point correlation functions of galaxies, subhaloes and matters functions in dense environments. Mon. Not. R. Astron. Soc. **440**, 2997-3010 (2014).

van Weeren, R. J. et al. (incl. Th. Enßlin and B. Ciardi): LOFAR low-band antenna observations of the 3C 295 and Boötes fields: source counts and ultra-steep spectrum sources. Astrophys. J. **793**, 22 (2014).

Vedantham, H. K., L. Koopmans et al. (incl. B. Ciardi): Chromatic effects in the 21 cm global signal from the cosmic dawn. Mon. Not. R. Astron. Soc. **437**, 1056-1069 (2014).

Vegetti, S., L. Koopmans, M. Auger, et al.: Inference of the cold dark matter substructure mass function at $z = 0.2$ using strong gravitational lenses. Mon. Not. R. Astron. Soc. **442**, 2017-2035 (2014).

Vegetti, S., and M. Vogelsberger: On the density profile of dark matter substructure in gravitational lens galaxies. Mon. Not. R. Astron. Soc. **442**, 3598-3603 (2014).

Velliscig, M., M. van Daalen, J. Schaye: The impact of galaxy formation on the total mass, mass profile and abundance of haloes. Mon. Not. R. Astron. Soc. **442**, 2641-2658 (2014).

Vera-Ciro, C. A., L. Sales, A. Helmi and J. Navarro: The shape of dark matter subhaloes in the Aquarius simulations. Mon. Not. R. Astron. Soc. **439**, 2863–2872 (2014).

Vikhlinin, A. A. et al. (incl. E. Churazov and R. Sunyaev): Clusters of galaxies. Physics Uspekhi, **57**(4), 317-341 (2014).

Walker, E. S., P. Mazzali, E. Pian et al. Optical follow-up observations of PTF10qts, a luminous broad-lined type Ic supernova found by the Palomar Transient Factory. Mon. Not. R. Astron. Soc. **442**, 2768-2779 (2014).

Wang, J., J. Fu, M. Aumer, G. Kauffmann et al.: An observational and theoretical view of the radial distribution of HI gas in galaxies. Mon. Not. R. Astron. Soc. **441**, 2159-2172 (2014).

Wang, W., L. Sales, B. Henriques and S. White: Satellite abundances around bright isolated galaxies – II. Radial distribution and environmental effects. Mon. Not. R. Astron. Soc. **442**, 1363-1378 (2014).

Weijmans, A.-M., P. de Zeeuw et al. (incl. Th. Naab): The ATLAS 3D project – XXIV. The intrinsic shape distribution of early-type galaxies. Mon. Not. R. Astron. Soc. **444**, 3340-3356 (2014).

Woods, T. E., and M. Gilfanov: UV emission lines in passively evolving galaxies can reveal the progenitors of type Ia supernovae. Astrophys. and Space Science, **354**, 69-74 (2014).

Woods, T. E., and M. Gilfanov: Emission-line diagnostics to constrain high-temperature populations in early-type galaxies. Mon. Not. R. Astron. Soc. **439**, 2351-2363 (2014).

Wu, X., et al. (incl. T. Naab, and L. Oser): The mass and angular momentum distribution of simulated massive early-type galaxies to large radii. Mon. Not. R. Astron. Soc. **438**, 2701-2715 (2014).

Wuyts, E., J. Kurk, et al. (incl. T. Naab): A consistent study of metallicity evolution at $0.8 < z < 2.6$: Astrophys. J. Lett. **789**, L40 (2014).

Yates, R. M., and G. Kauffmann: Dilution in elliptical galaxies: implications for the relation between metallicity, stellar mass and star formation rate. Mon. Not. R. Astron. Soc. **439**, 3817-3834 (2014).

Yates, R.M., B. Henriques et al. (incl. G. Kauffmann and S.D.M. White): Reconciling the chemical properties of star-forming galaxies, the Milky Way, and local ellipticals. Memorie della Societa Astronomica Italiana **85**, 430 (2014).

Young, L. M., N. Scott, et al. (incl. T. Naab): The ATLAS3D project – XXVII. Cold gas and the colours and ages of early-type galaxies. Mon. Not. R. Astron. Soc. **444**, 3408-3426 (2014).

Zhuravleva, I., E. Churazov et al. (incl. R. Sunyaev): Turbulent heating in galaxy clusters brightest in X-rays. Nature, **515**, 85-87 (2014).

Zhuravleva, I., E. Churazov et al. (incl. M. Gaspari): The Relation between Gas Density and Velocity Power Spectra in Galaxy Clusters: Qualitative Treatment and Cosmological Simulations. Astrophys. J. Lett. **788**, L13 (2014).

3.1.2 Publications accepted in (21)

Augustovičová, L., W.P. Kraemer, V. Špirko and P. Soldán: The role of molecular quadrupole transitions in the depopulation of metastable helium.

Bahé, Y. M. and I.G. McCarthy: Star formation quenching in simulated group and cluster galaxies: when, how, and why. Mon. Not. R. Astron. Soc.

Cooper, A.P., L. Gao et al. (incl. S. White): Surface photometry of BCGs and intracluster stars in Lambda-CDM.

Dorn, S., R. Erandy et al. (incl. T. Enßlin): Generic inference of inflation models by non-Gaussianity and primordial power spectrum reconstruction, JCAP.

Greiner, M. and T. Ensslin: Log-transforming the matter power spectrum Astron. Astrophys.

Greiner, M. and T. Ensslin: Log-transforming the matter power spectrum.

Guilet, J., E. Müller and H.-Th. Janka: Neutrino viscosity and drag: impact on the magnetorotational instability in proto-neutron stars. Mon. Not. R. Astron. Soc.

Henriques, B.; White, S.D.M.; Thomas, P. et al.: Galaxy formation in the Planck Cosmology I - Matching the observed evolution of star-formation rates, colours and stellar masses.
`eprint arXiv:1410.0365 (2014)`

Inserra, C. et al. (incl. S. Taubenberger): OGLE-2013-SN-079: A Lonely Supernova Consistent with a Helium Shell Detonation. Astrophys. J. Lett.

Jerkstrand, A. et al. (incl. S. Taubenberger): Late-time spectral line formation in Type IIb supernovae, with application to SN 1993J, SN 2008ax, and SN 2011dh. Astron. Astrophys.

Kruijssen, J. M. D., Dale, J. E. and Longmore, S. N.: The dynamical evolution of molecular clouds near the Galactic Centre - I. Orbital structure and evolutionary timeline. Mon. Not. R. Astron. Soc.

Nielsen, M. T. B., Gilfanov et al. (incl. T. Woods): Upper limits on the luminosity of the progenitor of Type Ia supernova SN 2014J. Mon. Not. R. Astron. Soc.

Oppermann, N., H. Junklewitz, M. Greiner, et al.: Estimating extragalactic Faraday rotation. Astron. Astrophys.

Paldus, J., T. Sako, and G.H.F. Diercksen: Link On the cluster structure of linear-chain fermionic wave functions. J. Math. Chem.

Planck Collaboration et al. (incl. MPA Planck group): Planck intermediate results. XXX. The angular power spectrum of polarized dust emission at intermediate and high Galactic latitudes. Astron. Astrophys.

Sasdelli, M., W. Hillebrandt et al. (incl. S. Taubenberger): A metric space for Type Ia supernova sprectra. Mon. Not. R. Astron. Soc.

Sawala, T., C. Frenk et al. (incl. S.D.M. White): Local Group galaxies emerge from the dark.

Selig, M. and T.A. Enßlin: D3PO 8722, Denoising, Deconvolving, and Decomposing Photon Observations. Astron. Astrophys.

Shao, L., C. Li, G. Kauffmann and J. Wang: The nature of obscuration in AGN: II. insights from clustering properties. Mon. Not. R. Astron. Soc.

Taubenberger, S. et al.: Spectroscopy of the Type Ia supernova 2011fe past 1000 d. Mon. Not. R. Astron. Soc. Lett.

Tartaglia, L., A. Pastorello, T. Taubenberger, et al.: Interacting supernovae and supernova impostors. SN 2007sv: the major eruption of a massive star in UGC 5979. Mon. Not. R. Astron. Soc.

3.2 Publications in proceedings

3.2.1 Publications in proceedings appeared in (40)

Barnabe, M., Spiniello, C., and L. Koopmans: Dissecting the 3D structure of elliptical galaxies with gravitational lensing and stellar kinematics. In: B. L. Ziegler, F. Combes, H. Dannerbauer, and M. Verdugo (Eds.), Galaxies in 3D across the Universe (IAU Symposium 309). Cambridge, UK: Cambridge University Press. p. 77-80 (2014).

Bugli, M., Del Zanna, L., and N. Bucciantini: Mean field dynamo in thick disks around Kerr black holes: high order axisymmetric simulations. In: F. A. Aharonian, F. M. Rieger, J. M. Paredes, and G. E. Romero (Eds.), Proceedings of the 4th High Energy Phenomena in Relativistic Outflows (HEPRO IV) Meeting (p. 1460203-1-1460203-5 (2014).

Cirasuolo, M., Afonso, et al. (incl. G. Kauffmann): MOONS: the Multi-Object Optical and Near-infrared Spectrograph for the VLT. In: Ground-based and Airborne Instrumentation for Astronomy V Eds. S. K. Ramsay, I. S. McLean and H. Takami. 1-13 (2014).

Cordero-Carrion, I., and P. Montero: BSSN equations in spherical coordinates without regularization. In: A. Garcia-Parrado, F. C. Mena, F. Moura, and E. Vaz (Eds.), Progress in Mathematical Relativity, Gravitation and Cosmology, Berlin, Springer, p. 205-209 (2014).

Cristini, A., R.. Hirschi, et al. (M. Viallet): Linking 1D stellar evolution to 3D hydrodynamic simulations. In: G. Meynet, C. Georgy, J. Groh, and P. Stee (Eds.), New Windows on Massive Stars, Asteroseismology, Interferometry and Spectropolarimetry (IAU Symposium 307). Cambridge, UK: Cambridge University Press. p. 98-99 (2014).

D'Souza, D., and A. Weiss: Radiative levitation in massive stars: a self-consistent approach. In: G. Meynet, C. Georgy, J. Groh, and P. Stee (Eds.), New Windows on Massive Stars, Asteroseismology, Interferometry and Spectropolarimetry (IAU Symposium 307) (pp. 213-214). Cambridge, UK: Cambridge University Press. p. 213-214 (2014).

Davis, T. A., Alatalo, K., et al. (incl. T. Naab): Spatially resolved molecular gas in early-type galaxies. In: T. Montmerle (Ed.), Highlights of Astronomy as presented at the XXVIII IAU General Assembly, 2012. p. 122-123 (2014).

Enßlin, T.: Astrophysical data analysis with information field theory. In:: Bayesian Inference and Maximum Entropy Methods in Science and Engineering, MaxEnt. Eds. R. K. Niven, B. Brewer, D. Paull et al. p. 49-54 (2013).

Feroci, M., J. den Herder et al. (incl. M. Gilfanov): The Large Observatory for x-ray timing. In: T. Takahashi, J.-W.-A. den Herder, and M. Bautz (Eds.), Space Telescopes and Instrumentation 2014: Ultraviolet to Gamma Ray p. 1-20, (2014).

Gatto, A., Fraternali, F., Marinacci, F. et al.: Estimating the galactic coronal density via ram-pressure stripping from dwarf satellites. In: A. Adamson, J. Davies, and I. Robson (Eds.), The Labyrinth of Star Formation - Conference dedicated to Prof. Anthony Whitworth. p. 167-169 (2014).

Girichidis, P. and R. Banerjee: Impact of tangled magnetic fields on star formation. In: A. Adamson, J. Davies, and I. Robson (Eds.), The Labyrinth of Star Formation - Conference dedicated to Prof. Anthony Whitworth. p. 105-108 (2014).

Hansen, C. J., Caffau, E., and M. Bergemann: Strontium in the era of Gaia and LAMOST. In: S. Feltzing, G. Zhao, N. A. Walton, and P. A. Whitelock (Eds.), Setting the Scene for Gaia and LAMOST - The current and next Generations of Surveys and Models. IAU Symposium 298. Cambridge, UK: Cambridge University Press. p. 409-409 (2014).

Hirschmann, M., and T. Naab: The origin of metallicity gradients in massive galaxies at large radii. In: B. L. Ziegler, F. Combes, H. Dannerbauer, and M. Verdugo (Eds.), Galaxies in 3D across the Universe (IAU Symposium 309) . Cambridge, UK: Cambridge University Press. p. 117-120 (2014).

Holman, K., Walch, S. K., Goodwin, S., and A. Whitworth: Mapping the present-day prestellar core mass function into the stellar IMF. In: A. Adamson, J. Davies, and I. Robson (Eds.), The Labyrinth of Star Formation - Conference dedicated to Prof. Anthony Whitworth. p. 309-315 (2014).

Kolodzig, A., Gilfanov, M., Hütsi, G., and R. Sunyaev: Large-scale structure studies with AGN in the eROSITA/SRG all-sky survey. In: A. M. Mickaelian, and D. B. Sanders (Eds.), Multiwavelength AGN Surveys and Studies (IAU Symposium 304) Cambridge, UK: Cambridge University Press. p. 422-425 (2014).

Kruijssen, J. M. D.: A galactic-scale origin for stellar clustering. In: A. Adamson, J. Davies, and I. Robson (Eds.), The Labyrinth of Star Formation - Conference dedicated to Prof. Anthony Whitworth. p. 437-441 (2014).

Lomax, O., Whitworth, A. P. et al. (incl. S. Walch): Modelling star formation in Ophiuchus. In: A. Adamson, J. Davies, and I. Robson (Eds.), The Labyrinth of Star Formation - Conference dedicated to Prof. Anthony Whitworth. p. 109-113 (2014).

Longmore, S. N., Kruijssen, J. M. D., Bastian, et al.: The formation and early evolution of young massive clusters. In: H. Beuther, R. S. Klessen, C. P. Dullemond, and T. Henning (Eds.), Protostars and Planets VI Tucson, Arizona, USA: University of Arizona Press. p. 291-316 (2014).

Magic, Z., Collet, R., and M. Asplund: The Stagger-grid: a grid of 3D stellar atmosphere models. In: G. Alecian, Y. Lebreton, O. Richard and G. Vauclair (Eds.), New Advances in Stellar Physics: From Microscopic to Macroscopic Processes. p. 367-371 (2014).

Marek, A., Rampp, M., Hanke, F., and H.-T. Janka: Towards petaflops capability of the VERTEX supernova code. In: M. Bader, A. Bode, H.-J. Bungartz, M. Gerndt, G. R. Joubert, and F. Peters (Eds.), Paralell Computing: Accelerating Computational Science and Engineering (CSE) Amsterdam IOP Press. p. 712-721 (2014).

Marino, A. F.: Multiple stellar populations in the massive clusters M22 and Omega Centauri. In: T. Montmerle (Ed.), Highlights of Astronomy as presented at the XXVIII IAU General Assembly. p. 234-236 (2014).

Martins, F., M. Bergemann, J. M. Bestenlehner, et al.: SpS5 - II. Stellar and wind parameters. In: T. Montmerle (Ed.), Highlights of Astronomy as presented at the XXVIII IAU General Assembly, 2012. p. 420-428 (2014).

Melendez, B. E., Miller Bertolami, M. M., and L.G. Althaus: New axion bounds from the white dwarf luminosity function. Revista Mexicana de Astronomia y Astrofisica, 44, 48-48 (2014).

Mitchell, J. P., Braithwaite, J., et al. (incl. H. Spruit, H.): Search for stable magnetohydrodynamic equilibria in barotropic stars. In: P. Petit, M. Jardine, and H. C. Spruit (Eds.), Magnetic Fields throughout Stellar Evolution (IAU Symposium 302). Cambridge, UK: Cambridge University Press. p. 441-444 (2014).

Morel, T., Castro, N., et al. (incl. H. Spruit): The B fields in OB stars (BOB) survey. In: G. Meynet, C. Georgy, J. Groh, and P. Stee (Eds.), New Windows on Massive Stars, Asteroseismology, Interferometry and Spectropolarimetry (IAU Symposium 307). Cambridge, UK: Cambridge University Press. p. 342-347 (2014):

Obergaulinger, M., Just, O., Janka, H.-T., et al: A new two-moment scheme with algebraic closure for energy-dependent multi-flavor neutrino transport in supernovae. In: N. V. Pogorelov, E. Audit, and G. P. Zank (Eds.), 8th International Conference of Numerical Modeling of Space Plasma Flows (ASTRONUM 2013) p. 255-260 (2014).

Pavlinsky, M., et al. (incl. E. Churazov, M. Gilfanov, R. Sunyaev): Status of ART-XC/SRG instrument. In: T. Takahashi, J.-W.-A. den Herder, and M. Bautz (Eds.), Space Telescopes and Instrumentation 2014: Ultraviolet to Gamma Ray, p. 1-11 (2014).

Prat, V., Lignieres, F., and G. Lesur: New prescriptions of turbulent transport from local numerical simulations. In: G. Meynet, C. Georgy, J. Groh, and P. Stee (Eds.), New Windows on Massive Stars, Asteroseismology, Interferometry and Spectropolarimetry (IAU Symposium 307). Cambridge, UK: Cambridge University Press. p. 70-75 (2014).

Predehl, P., R. Andritschke, et al. (incl. R. Sunyaev): eROSITA on SRG. In: T. Takahashi, J.-W.-A. den Herder, and M. Bautz (Eds.), Space Telescopes and Instrumentation 2014: Ultraviolet to Gamma Ray (p. 1-6 (2014).

Remus, R.-S., Dolag, K., Bachmann, L. K., et al.: Disk galaxies in the magneticum pathfinder simulations. In: B. L. Ziegler, F. Combes, H. Dannerbauer, and M. Verdugo (Eds.), Galaxies in 3D across the Universe (IAU Symposium 309) Cambridge, UK: Cambridge University Press. p. 145-148 (2014).

Roychowdhury, S., Huang, M.-L., Kauffmann, G., and J. Chengalur:Kennicutt-Schmidt relation in the HI dominated regime. In: B. L. Ziegler, F. Combes, H. Dannerbauer, and M. Verdugo (Eds.), Galaxies in 3D across the Universe (IAU Symposium 309) . Cambridge, UK: Cambridge University Press. p. 341-341 (2014).

Sales, L. V.:Origins of disks in simulations of spiral galaxies. In: M. S. Seigar, and P. Treuthardt (Eds.), Structure and Dynamics of Disk Galaxies. p. 97-104 (2014).

Selig, M.: The NIFTy way of Bayesian signal inference. In: Bayesian Inference and Maximum Entropy Methods in Science and Engineering, MaxEnt. Eds. R. K. Niven, B. Brewer, D. Paull et al. p. 68-73 (2013).

Shao, L.: A study of optical/IR selected AGNs with SDSS and WISE. In: A. M. Mickaelian, and D. B. Sanders (Eds.), Multiwavelength AGN Surveys and Studies (IAU Symposium 304)Cambridge, UK: Cambridge University Press. p. 213-216 (2014).

Spruit, H.: Accretion disks. In: I. Gonzalez Martinez-Pais, T. Shabaz, and J. Casares Velazquez (Eds.), Accretion Processes in Astrophysics, New York, Cambridge University Press, p. 1-44 (2014).

Teklu, A., Remus, R.-S., Dolag, K., and A. Burkert: The angular momentum dichotomy. In: B. L. Ziegler, F. Combes, H. Dannerbauer, and M. Verdugo (Eds.), Galaxies in 3D across the Universe (IAU Symposium 309). Cambridge, UK: Cambridge University Press. p. 349-349 (2014).

Walch, S. K.: Star formation triggered by feedback from massive stars. In: A. Adamson, J. Davies, and I. Robson (Eds.), The Labyrinth of Star Formation - Conference dedicated to Prof. Anthony Whitworth. p. 173-179 (2014).

White, S. (2014). The influence of halo evolution on galaxy structure. In: T. Montmerle (Ed.), Highlights of Astronomy as presented at the XXVIII IAU General Assembly, 2012. p. 371-371 (2014).

Yates, R. M., Kauffmann, G., Thomas, et al: Reconciling the chemical properties of star-forming galaxies, the Milky Way, and local ellipticals. Memorie della Societa Astronomica Italiana, 85(2), 430-433 (2014).

Yates, R. M., and G. Kauffmann: Dilution in massive, elliptical galaxies. Memorie della Societa Astronomica Italiana, 85(2), p. 426-429 (2014).

3.2.2 Publications available as electronic file only

de Souza, R. S., Elliott, J., Krone-Martins, A., Ishida, E. E. O., Hilbe, J., Cameron, E.: CosmoPhotoz: Photometric redshift estimation using generalized linear models.
`http://ascl.net/1408.018`

Feroci et al.: The Large Observatory for x-ray timing Proceedings of the SPIE, Volume 9144, id. 91442T 20 pp. (2014)
`http://proceedings.spiedigitallibrary.org/proceeding.aspx?articleid=1893955`

Mills, E. A. C., A. Ginsburg, D. Kruijssen et al.: VLASSICK: The VLA Sky Survey in the Central Kiloparsec.
`http://adsabs.harvard.edu/abs/2014arXiv1401.3418M`

Ritter, H. and U. Kolb: Catalogue of cataclysmic binaries, low-mass X-ray binaries and related objects (Editions 7.21 and 7.22)
`http://www.mpa-garching.mpg.de/RKcat/`
`http://physics.open.ac.uk/RKcat/`
`http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=B/cb`
`http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=B/cb`

Selig, M., V. Vacca, N. Oppermann and T. Enßlin: The Denoised, Deconvolved, and Decomposed Fermi gamma-ray Sky – An Application of the D3PO Algorithm
`http://arxiv.org/abs/1412.7160`

3.3 Talks

3.3.1 Invited review talks at international meetings

B. Ciardi: The first billion years of galaxies and black holes (Sexten, Italy, 30.6-4.7)
– The Formation and Growth of Galaxies in the Young Universe (Obergurgl, Austria, 26.-30.4)

T.A. Enßlin: Gas in and around galaxies (Ringberg Castle 12.5.-16.5.)
– Quantum Cosmology (Bad Honneff 28.7.)
– Turbulence: in the Sky as on the Earth (Natal, Brazil 6.10.)

Gaspari, M.: The X-ray Universe Symposium (Dublin, Ireland - 16.06.14)
– Clusters 2014 conference (Paris, France - 23.06.14)
– 3rd ICM Theory and Computation workshop (Copenhagen, Denmark - 12.08.14)

M. Gilfanov: Binary SMBHs, (Las Cruces, Chile, 4.3.-7.3)
– The Unquiet Universe, (Cefalu, Italy, 2.6-13.6.)
– Zel'dovich-100 Conference (Moscow, 16.6.-20.6.)
– Quenching and quiescence, (Heidelberg, Germany, 14.7-18.7)
– NuSTAR First Science, COSPAR-2014, (Moscow, Russia, 4.8-8.8)
– Outflows and Accretion from White Dwarfs to Supermassive Black Holes,
COSPAR-2014, (Moscow, Russia, 4.8-8.8)
– Transients' Unsolved Mysteries, (Eilat, Israel, 20.10-23.10)

W. Hillebrandt: IAS SNe Ia workshop, (Princeton, 10.2. - 12.2.)
– "Explosions I have known" Stirling Colgate's Legacy in Science, (Los Alamos, 11.8. - 13.8.)
– Type Ia Supernovae: progenitors, explosions, and cosmology, (Chicago, 15.9. - 19.9.)

H.-Th. Janka: Formation and Evolution of Neutron Stars (Bonn, 5.3.)
– The Structure and Signals of Neutron Stars, from Birth to Death (Florence, 24.3.–28.3.)
– Symposium on Selected Topics in Astroparticle Physics (Garching, 7.11.)
– INT workshop on the r-process (INT Seattle, 28.7.–1.8.)

– Conclusion Workshop of SFB/TR7 “Gravitational Wave Astronomy” (Jena, 1.12.–5.12.)
– MIAPP Program “Neutrinos in Astro- and Particle Physics” (Garching, 30.6.–25.7.)
– SN2NS Workshop (Paris, 3.2.–5.2.)
– 17th Workshop on Nuclear Astrophysics (Ringberg Castle, 7.4.–12.4.)
– Swift: 10 Years of Discovery (Rome, 2.12.–5.12.)
– ECT Workshop “Future Directions in the Physics of Nuclei at Low Energies”
(ECT* Trento, 21.5.–23.5.)
– International Conference “Explosions I have known: Stirling Colgate’s Legacy in Science”
(Los Alamos, 11.8.–13.8.)

G. Kauffmann : Ringberg Workshop on Galaxy Formation, (Tegernsee, 18.5-22.5)

E. Komatsu: Zel’dovich-100 Conference (Moscow, 16.6.-20.6.)
– The 18th Paris Cosmology Colloquium (Paris, 23.7.-25.7.)

J. M. D. Kruijssen: A Critical Look at Globular Cluster Formation Theories: (Sexten, Italy, 14.7.-18.7.)
– Star Clusters and Black Holes in Galaxies across Cosmic Time (Beijing, China, 25.8.-29.8.)

Thorsten Naab: Galaxies in 3D across the Universe, (Vienna, 7.7. -11.7.)
– Evolving galaxies in evolving environments, (Bologna, 15.9. - 19.9.)

V. Prat: Contributed talk (IAU Symposium 307, Geneva, 23.6.)

C. Spiniello: Unveiling the Formation of Massive Galaxies (Aspen 3.2. - 7.2.)
– NAM2014, The Initial Mass Function of Galaxies: Myth & Facts (Porthsmouth, 23.6. - 26.6.)
– IAU Symposium 311 (Oxford, 21.7. - 25.7.)
– The universe of digital sky surveys (Naples, 24.11. - 28.11.)

H. Spruit: Gamma-ray burst, Supernova & magnetar thinkshop (Bormio, IT, 20.–24.1.)

R. Sunyaev: The 10th Sino-German Workshop on Galaxy Formation and Cosmology,
From Dark Matter to Galaxies’, (Xi’an, China 18.5.-23.5.)
– The 2014 Shanghai Particle Physics and Cosmology Symposium SPCS2014,
(Jiao Tong University, China 28.5.-31.5.)
– conference “Zeldovich-100”, (Moscow, 16.6.-20.6.)
– IAU Symposium 308: The Zeldovich Universe: Genesis and Growth of the Cosmic Web,
(Tallinn, 23.6.-28.6.)
– IKI Moscow, High Energy Astrophysics today and tomorrow, (Moscow, IKI, 23.12.-25.12.)
– Colloquium of A.F. Ioffe Physical-Technical Institute, (St-Petersburg, 7.9.-9.9.)
– Annual conference of Spanish Astronomers, (Teruel, Spain 11.9.-13.9.)
– Conference: PLANCK 2014 - The microwave sky in temperature and polarization,
(Ferrara, Italy, 1.12.-5.12.)

S. White: Unveiling the Formation of Massive Galaxies (Aspen, 2.-7.2.)
– The Formation and Growth of Galaxies in the Young Universe - (Ogergurgl, Austria, 26.4.-30.4.)
– Ringberg Workshop ”Gas in and around galaxies” (Tegernsee, Germany, 12.-16.5.)
– Amsterdam Meeting (Amsterdam, 22.6.-25.6.)
– IAU Symposium 311 (Oxford, 20.7. - 25.7.)
– Potsdam Conference (Potsdam, 25.8.-29.8.)
– Solvay Conference (Brussels, 8.10.-11.10.)

T. E. Woods: Quenching and Quiescence (Heidelberg, Germany, 14.7.-18.7.)

A. Weiss: Symposium “SYSE”, during DPG annual meeting, (Berlin, 18.-19.3)
– Workshop “GaiaCal2014”, (Ringberg Castle, 9.7.)

3.3.2 Colloquia talks

B. Ciardi: Invited Colloquium (Osservatorio Astrofisico di Firenze, Florence; 27.2)
– Invited Colloquium (Ossevatorio Astronomico di Roma, Monte Porzio; 18.2)

T.A. Enßlin: Invited Colloquium (Universe Cluster LMU; 17.2.)
– Invited Colloquium (University Hamburg; 11.12)
– Invited Colloquium (Karlsruhe Institute for Technology; 18.12)

M. Gaspari: Invited Colloquium (LMU, Munich - 14.04.)

M. Gilfanov: Invited Colloquium (Technion, Haifa - 27.10.)

J. Guilet: Invited seminar (IPAG Grenoble; 16.10.)
– Invited seminar (SAp CEA-Saclay, 16.12.)

W. Hillebrandt: University of Basel (8.5.)

H.-Th. Janka: Invited Colloquium (Astronomy Inst./GRAPPA Amsterdam; 2.7.)
– “PRISMA and GK” Seminar (JG Univ. Mainz, 5.11.)
– Invited Colloquium (AEI Potsdam/Berlin, 15.10.)
– “Astro-/Kernphysikalische Kolloquium” (FIAS Frankfurt, 30.1.)
– Joint Astronomy Colloquium (ESO Garching, 9.10.)

G. Kauffmann: Invited Colloquium (Princeton University; 1.5.)
G. Kauffmann: Invited Colloquium (Rutgers University; 2.5.)
G. Kauffmann: Invited Colloquium (Garching; 3.7.)

E. Komatsu: Invited Colloquium (Univ. of Heidelberg; 14.1.)
– Invited Colloquium (Leibniz-Inst. f. Astrophysik, Potsdam; 14.3.)
– Invited Colloquium (Univ. of Kyoto; 26.3.)
– Invited Colloquium (MPI für Physik, Munich; 1.4.)
– Invited Colloquium (ICTP, Trieste, Italy 22.10.)

J. M. D. Kruijssen: Invited Colloquium (ARI Heidelberg; 23.10.)

S. Mineo: Invited Seminar (INAF/Bologna University; 11.12.)

M. Selig: Excellence CLuster Workshop (Garching; 17.2.)

C. Spiniello: Invited colloquium (Copenhagen, 26.2.)
– Invited colloquium (Oxford, 13.5.)

H. Spruit: Invited Colloquium (Pontificia Universidad Catolica de Chile, Santiago, 26.5.)
– Invited Colloquium (ESO Vitacura, Santiago, 11.6.)

R. Sunyaev: Physics Colloquium (TU Berlin, 17.1.)

A. Weiss: Invited Colloquium (Observatoire Midi-Pyrnenees Toulouse; 3.4.)

T. E. Woods: Invited Colloquium HEAD Lunch Talk (Harvard-Smithsonian CFA) 24.9.
Invited Colloquium Astro Seminar (University of Alberta) 11.9.

3.3.3 Public talks

G. Börner: Universität Regensburg (30.9.)

T.A. Enßlin: Kolpingfamilie Gersthofen, Augsburg (14.6.)
  – Lehrerfortbildung “Das frühe Universum”, Bad Honneff (21.7.)
  – Summerschool on “Aspects of String- and Fieldtheories”, LMU München (19.8.)
  – Astronomische Gesellschaft Buchloe e.V. (19.9)
  – “Wissenschaft für jedermann” im Deutschen Museum (19.11.)

M. Gilfanov: Kazan Federal University (20.9.)

J. Guilet: Palais de la d’couverte, Paris (2.2.)

W. Hillebrandt: Förderkreis Planetarium Göttingen 4.11.)

H.-Th. Janka: Universität Frankfurt (30.1.)

E. Komatsu: Yamanashi Prefectural Science Center, Yamanashi, Japan (8.11.)
  – Chienkan High School, Saga, Japan (14.11.)
  – Roppongi Art College, Tokyo, Japan (2.12.)

H. Spruit: Volkssternwarte Laupheim (14.3.)

A. Weiss: Gymnasium Weilheim (6.5.)

3.4 Lectures and lecture courses

3.4.1 Lectures at LMU and TUM

T. Enßlin, SS 2014, LMU München

W. Hillebrandt WS 2013/2014 and WS 2014/2015, TU München

H.-Th. Janka, WS 2013/2014 and SS 2014, TU München

G. Kauffmann , WS 2013/2014 and SS 2014 LMU, München

E. Müller, WS 2013/2014 and SS 2014, TU München

H. Ritter, WS 14/15, LMU München

A. Weiss, SS 2014, LMU München

3.4.2 Short lectures courses

M. Gilfanov: “High Energy Processes and Objects” (IMPRS on Astrophysics, Garching, 7.4.–11.4.)

E. Komatsu: “Dark Energy Probes” (School on “Challenges in Modern Cosmology: Dark Matter and Dark Energy,” International Institute of Physics, Natal, Brazil, 9.5.-9.5)
  – “Recent Results from the CMB experiments” (Schule für Astroteilchenphysik 2014, 8.10-16.10)

H. Spruit: “Probability, chance, risk: statistics in daily life and in science” (Pontificia Universidad Catolica de Chile, Santiago, 27.5.–11.6.)

R. Sunyaev: - short lectures at different Univ. in China (9.5.-1.6.):
  – Institute of High Energy Physics, CAS, Beijing
  – Kavli Institute of Astronomy and Astrophysics at Peking University
  – Tsinghua University, Beijing
  – National Astronomical Observatory of China, Beijing
  – Shanghai Astronomical Observatory, CAS, Shangai
  – Lodewijk Woltjer Lecture, European Astronomical Society, EWASS, (Geneva 1.7.-4.7.)

A. Weiss: “Stellar Structure and Evolution” (IMPRS on Astrophysics, Garching, 20.–24.1.

4 Personnel

4.1 Scientific staff members

Directors

E. Komatsu (managing director since 1.1.2015), G. Kauffmann, R. Sunyaev, S.D.M. White (managing director until 31.12.2014)

Research Group Leaders

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

External Scientific Members

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

Emeriti

H. Billing, W. Hillebrandt, R. Kippenhahn, F. Meyer, E. Trefftz.

Staff/Postdoc

M. Anderson, Y. Bahe, A. Bauswein (until 31.12.) G. Di Bernardo (since 20.10.), A. Ford (since 1.9.), M. Gabler, M. Gaspari, P. Girichidis, F.A. Gomez (since 8.10.), J. Guilet, H. Hämmerle, K. Helgason (since 1.10.), B. Henriques, S. Hilbert, G. Hütsi (until 30.9.), J. Johansson (until 26.9.), A. Jones (since 1.12.), O. Just, R. Khatri, S. Khedekar (until 20.9.), Jaiseung Kim, D. Kruijssen, T.Y. Lam (until 31.8.), G. Lemson (until 30.9.), N. Lyskova (sine 21.2.), Z. Magic (15.5.-31.8.), M. Miller-Bertolami, S. Mineo (since 1.9.) R. Moll (until 31.10.), A. Monachesi (since 8.10.), P. Montero, B. Müller (until 31.1.), M. Nielsen, U. Nöbauer (since 1.7.), L. Oser (since 1.10.), A. Pawlik, Th. Peters (since 1.10.), V. Prat, D. Prokhorov (until 30.9.), A. Rahmati (until 31.7.), M. Reinecke, T. Rembiasz (1.6.-30.9.), S. Roychowdhury, F. Schmidt, X. Shi, R. Smith (until 30.9.), C. Spiniello, H. Spruit (untl. 28.2.), A. Sternberg (until 15.3.), A. Summa (since 1.4.), T. Tanaka (until 31.8.), S. Taubenberger, V. Vacca (since 1.1.) S. Vegetti, M. Viallet, J. von Groote (since 1.12.), C. Wagner (until 30.9.), J. Wang (until 30.4.), A. Weiss, A. Wongwathanarat (until 31.7.).

Ph.D. Students

[1] A. Agrawal* (since 1.9.), R. Andrassy*, H. Andresen*, A. Arth (until 31.7./terminated), M. Aumer* (until 31.5.), V. Böhm*, R. Bollig, M. Bugli*, H.L. Chen, C.T. Chiang, A. Chung*, B. Ciambur* (terminated 31.3.), M. Compostella (since 1.11.), D. D'Souza*, R. D'Souza*, S. Dorn, P. Edelmann (until 31.12.), T. Ertl, A. Gatto*, M. Greiner, F. Hanke (until 31.5.), W. Hao*, N. Hariharan*, S. Heigl* (since 10.9.), C.H. Hu*, M.L. Huang, H.Y. Ip* (since 1.9.), I. Jee, A. Jendreieck* (until 30.9.), S. Jia (since 1.1.), K. Kakiichi*, F. Koliopanos*, A. Kolodzig*, S. Komarov*, C. Laporte* (until 31.5.), T. Lazeyras (since 7.10.), N. Lyskova* (until 20.2.), Q. Ma, Z. Magic* (until 31.8.), G. Mazur (since 1.9.-30.11./terminated), T. Melson, M. Molaro*, U. Nöbauer (until 30.6.), D. Oliveira* (terminated 30.6.), A. Pardi*, E. Pllumbi*, S. Rau (until 14.5.), B. Röttgers, M. Rybak*, M. Sasdelli*, A. Schmidt (since 1.11.), M. Selig, Shi Shao (until 14.10.), M. Soraism*, T. Steininger (since 1.10.), I. Thaler* (until

---

[1] *IMPRS Ph.D. Students

30.4.), J. von Groote (until 31.5.), D. Vrbanec*, M. Wadepuhl, G. Wagstaff* (since 1.9.) T. Woods*, P. Wullstein* (until 31.12./terminated), R. Yates (until 28.2.), Luo Yu.

Diploma students

A. Agrawal (until 31.8.), R. Ardevol (until 31.3.), T. Denk (until 28.2.), M. Eisenreich (until 30.9.), A. Gessner (until 28.2.), T. Pangerl (until 30.9.), V. Rozov (until 30.9.), A. Schmidt (until 30.9.), N. Schwarz (since 1.5.)

Technical staff

Computational Support: H.-A. Arnolds, B. Christandl, N. Grüner (retired 31.10.), H.-W. Paulsen (head of the computational support), A. Weiss (since 1.6.)

PLANCK group: U. Dörl (until 31.12.), W. Hovest (until 31.12.), J. Knoche,
MPDL: J.W. Kim (until 30.6.) *Galformod:* M. Egger (until 31.12.)
Press Officer: H. Hämmerle (MPA/MPE).
Secretaries: M. Depner, J. Dreher (since 1.5.) S. Gründl, G. Kratschmann, K. O'Shea (retired 1.3.), C. Rickl (secretary of the management).
Library: E. Blank, E. Chmielewski (retired 31.12.), C. Hardt (head of the library since 1.12.).

Associated Scientists:

U. Anzer, G. Börner, G. Diercksen, W. Kraemer, E. Meyer–Hofmeister, H. Ritter, J. Schäfer, H. Spruit (since 1.3.), R. Wegmann.

4.1.1 Staff news

Mike Anderson received the ProQuest Distinguished Dissertation Award for his PhD thesis by the Rackham Graduate School at the University of Michigan.

Eugene Churazov received the "Sir Harrie Massey award" during the opening ceremony of the COSPAR Scientific Assembly.

Marat Gilfanov has been appointed professor by special appointment at the University of Amsterdam's (UvA) Faculty of Science.

Rashid Sunyaev received the Lodewijk Woltjer Award of the European Astronomical Society.

A. Weiss: Honorarprofessur Univ. München

Tyrone Woods received the Kippenhahn Prize for his paper *He II recombination lines as a test of the nature of SN Ia progenitors in elliptical galaxies* appeared in M.N.R.A.S.

4.2 PhD Thesis 2014 and Diploma thesis 2014

4.2.1 Ph.D. theses 2014

Michael Aumer: Simulating the formation and evolution of disc galaxies in a ΛCDM universe. Ludwig-Maximilians-Universität München.

Philipp Edelmann: Coupling of nuclear reaction networks and hydrodynamics for application in stellar astrophysics. Technische Universität München.

Florian Hanke: Two- and three-dimensional simulations of core-collapse supernova explosions of massive stars applying neutrino hydrodynamics. Technische Universität München.

Lorenz Hüdepohl: Neutrinos from the formation, cooling, and black hole collapse of neutron stars. Technische Universität München.

Henrik Junklewitz: Statistical inference in radio astronomy. Ludwig-Maximilians-Universität München.

Chervin Laporte: Evolution of clusters and large-scale structures of galaxies. Ludwig-Maximilians-Universität München.

Natalya Lyskova: Mass determination of elliptical galaxies. Ludwig-Maximilians-Universität München.

Zazralt Magic: Theoretical stellar atmosphere models for cool stars. Ludwig-Maximilians-Universität München.

Ulrich Nöbauer: A Monte Carlo approach to radiation hydrodynamics in stellar outflows. Technische Universität München.

Laura Porter: Towards modelling ultracool dwarfs. Ludwig-Maximilians-Universität München.

Irina Thaler: Solar magnetohydrodynamics. University of Amsterdam.

Marcel van Daalen: Correlation functions from the Millennium XXL simulation. Ludwig-Maximilians-Universität München.

Janina von Groote: General Relativistic Multi Dimensional Simulations of Electron Capture Supernovae. Technische Universität München.

Stefan, Rau: Gravitational lensing studies of galaxy cluster halos. Ludwig-Maximilians-Universität München.

Marco Selig: Information Theory Based High Energy Photon Imaging. Ludwig-Maximilians-Universität München (submitted).

Rob Yates: The chemical evolution of galaxies in semi-analytic models and observations. Ludwig-Maximilians-Universität München.

4.2.2 Diploma theses 2014

Aniket Agrawal: Towards an Analytical Model for Redshift Space Distortions. Ludwig-Maximilians-Universität München.

Ricard Ardevol: Constraining the BH-NS merger rate by r-process element production. Technische Universität München.

Tobias Denk: Runaway instability in accretion discs: numerical simulations in spherical polar coordinates. Technische Universität München.

Maximilian Eisenreich: Black Hole Feedback in Elliptical Galaxies. Technische Universität München.

Alexandra Gessner: Constraining the Crab Progenitor: Multidimensional Simulations of Neutron Star Kicks in Electron-Capture Supernovae. Ludwig-Maximilians-Universität München.

Andreas Schmidt: Feedback from Supernova and Active Galactic Nuclei in Gas-Rich Discs at High Redshift. Ludwig-Maximilians-Universität München.

4.2.3 PhD Thesis (work being undertaken)

Aniket Agrawal: An Analytical Model for Redshift Space Distortions. Ludwig-Maximilians-Universität München.

Robert Andrassy: Convective overshooting in stars. University of Amsterdam.

Haakon Andresen: Gravitational waves from core collapse supernova. Ludwig-Maximilians-Universität München.

Ricard Ardevol: Nucleosynthesis in Neutron Star-Neutron Star and Black Hole-Neutron Star mergers. Technische Universität München.

Vanessa Böhm: Gravitational Lensing of the Cosmic Microwave Background: Reconstruction of Deflection Potential and unlensed Temperature Map using Information Field Theory. Ludwig-Maximilians-Universität München.

Robert Bollig: Long term cooling studies of proto-neutronstars with full neutrino flavour treatment and muonisation. Technische Universität München.

Matteo Bugli: Study of viscous accretion disks around Kerr black holes. Technische Universität München.

Chi-Ting, Chiang: Sparse sampling and position-dependent power spectrum: new and efficient approaches to galaxy redshift surveys and searches for non-Gaussianity. Ludwig-Maximilians-Universität München.

Andrew Chung: High-redshift Lyman-α945; Emitters. Ludwig-Maximilians-Universität München.

Durand D'Souza: Radiative levitation and other processes in massive stars. Ludwig-Maximilians-Universität München.

Richard D'Souza: Stellar Halos of Galaxies. Ludwig-Maximilians-Universität München.

Maximilian Eisenreich: The wondrous multi-phase ISM of elliptical galaxies. Ludwig-Maximilians-Universität München.

Thomas Ertl: Progenitor-remnant connection of core-collapse supernovae. Technische Universität München.

Sebastian Dorn: Non-Gaussianity and inflationary models. Technische Universität München.

Andrea Gatto: The impact of stellar feedback on the formation and evolution of molecular clouds. Ludwig-Maximilians-Universität München.

Mahsa Ghaempanah: Information field theory for INTEGRAL gamma ray data. Ludwig-Maximilians-Universität München.

Maksim Greiner: Galactic tomography. Ludwig-Maximilians-Universität München.

Wei Hao: Supermassive black hole binaries in Galaxy centres. Ludwig-Maximilians-Universität München.

Nitya Hariharan: Numerical Developments of the Radiative Transfer code CRASH. Technische Universität München.

Chia-Yu, Hu: A new star formation recipe for large-scale SPH simulations. Ludwig-Maximilians-Universität München.

Mei-Ling Huang: Radially resolved star formation histories of disk galaxies. Ludwig-Maximilians-Universität München.

Hiu Yan Sam Ip: Testing Gravity with Large-Scale Structure. Ludwig-Maximilians-Universität München.

Inh Jee: Measuring angular diameter distances of strong gravitational lenses. Ludwig-Maximilians-Universität München.

Andressa Jendreieck: Stellar Parameter Estimation for Kepler Stars. Ludwig-Maximilians-Universität München.

Kakiichi Koki: The high redshift universe: galaxy formation and the IGM. Ludwig-Maximilians-Universität München.

Filippos Koliopanos: Radiation processes in compact X-ray sources. Ludwig-Maximilians-Universität München.

Alexander Kolodzig: Large-scale structure studies using AGN in X-ray surveys – Challenges from XBOOTES and prospects for eROSITA. Ludwig-Maximilians-Universität München.

Sergey Komarov: Physics of Intracluster Medium. Ludwig-Maximilians-Universität München.

Titouan Lazeyras: Investigations into galaxy and halo bias. Ludwig-Maximilians-Universität München.

Tobias Melson: Implementation of a two-moment closure scheme for neutrino transport into the Yin-Yang grid environment for three-dimensional simulations of core-collapse supernovae with the Prometheus-Vertex code. Technische Universität München.

Margherita Molaro: X-ray binaries' contribution to the Galactic ridge X-ray emission. Ludwig-Maximilians-Universität München.

Anabele Pardi: The Dynamics and Evolution of the Interstellar Medium Ludwig-Maximilians-Universität München.

Else Pllumbi: Nucleosynthesis studies for supernova and binary merger ejecta. Technische Universität München.

Bernhard Röttgers: AGN feedback in cosmological simulations and the comparison to observations. Ludwig-Maximilians-Universität München.

Michele Sasdelli: Principal Components Analysis of type Ia supernova spectra. Ludwig-Maximilians-Universität München.

Andreas Schmidt: Simulation of the large-scale Lyman-alpha forest. Ludwig-Maximilians-Universität München.

Li Shao: Understanding the connection between AGNs and their host galaxies. Ludwig-Maximilians-Universität München.

Shi Shao: Disk dynamics in live halos. NAOC, China

Monika Soraism: Progenitors of Type Ia Supernovae. Ludwig-Maximilians-Universität München.

Theo Steininger: Reconstruction of the Galactic magnetic field. Ludwig-Maximilians-Universität München.

Dijana Vrbanec: Cross-correlation of Lyman Alpha Emitters & 21-cm signal from the Epoch of Reionization. Ludwig-Maximilians-Universität München.

Graham Wagstaff: Structure of coolster envelopes and atmospheres. Ludwig-Maximilians-Universität München.

Tyrone Woods: The Progenitors of Type Ia Supernovae. Ludwig-Maximilians-Universität München.

4.3 Visiting scientists

Name	home institution	Duration of stay at MPA
Raul Angulo	(CEFCA, Spain)	6.8.-6.9.
Lucie Augustovicova	(IOC, Prague)	7.7.-19.7.
Eliana Amazo-Gomez	(Univ. Nacional Columbia)	until 28.2.
Patricia Arevalo	(Univ. Cat. de Chile)	1.7.–31.7.
Thomas W. Baumgarte	(Bowdoin Coll. Brunswick USA)	1.6.–4.7.
Alexander Beck	(USM, Munich)	1.7.-31.12.
Andrei Beloborodov		1.7.-12.7.
Andrey Belyaev	(St. Petersburg, Russia)	8.1.–8.2.
		and 1.11.-30.11.
Sandra Benitez	(Cidade Univ. Brazil)	19.10.–9.11.
Sergey Blinnikov	(ITEP, Moscow)	31.3.–13.4.
Mia Bovill	(Santiago, Chile)	14.1.–31.1.
Pavel Denissenkov	(Victoria, Canada)	6.6.–5.7.
Ivan de Martino	(Salamanca University Spain)	1.2.–30.4.
Rafael De Souza	(KASI, Korea)	8.3.–8.4.
		and 7.7.-27.8.
Eliana Amaso Gomez	(Univ. of Bogota)	until 28.2.
Hannes Grimm-Strele	(TU Wien Austria)	15.1.–30.4.
Jian Fu	(Shanghai, Obs.)	5.3.–14.5.
Kumar Hazra	(APCTP, Korea)	24.8.–6.9.
Tobias Heinemann	(KITP Santa Barbara)	1.9.–30.9.
Michaela Hirschmann	(IAP, Paris)	13.10.–24.10.
Nail Inogamov	(Landau Inst. Moscow, Russia)	15.7.–31.8.
Emille Ishida	(Sao Paulo, Brazil)	1.1.–31.12.
Iyudin, Anatoli	(Moscow Russia)	2.2.–16.2.
Shi Jia	(Yunnan Obs. China)	1.1.-31.12.
Yipeng Jing	(Shanghai Observatory)	13.6.–8.8.
Ildar Khabibullin	(IKI Moscow, Russia)	30.1.–28.2.
		and 10.7.–18.8.
Damian Kwiatkowski	(Univ. Warsaw, PL)	1.7.–31.8.
Li-Xin Li		1.8.-31.8.
Yu Luo	(Purple Mountain Observatory, China)	until 30.4.
Paolo Mazzali	(Univ. of Liverpool)	4.9.–4.10.
Pavel Medvedev	(IKI Moscow, Russia)	30.1.–28.2.
		and 10.7.–22.8.
Ilya Mareminskiy	(IKI, Moscow)	10.7.–18.8.
Vassili Mewes	(Univ. of Valencia)	7.1.-7.2.
Alejandro Munoz	(PUC Santiago, Chile)	12.5.–12.6.
Yoshiaki Naito	(Univ. Tokio)	25.10.-10.11.
Atsushi Naruko	(Kyoto University Japan)	26.5.-8.6.
Julio Navarro	(Victoria, Canada)	1.10.-31.12.

Name	home institution	Duration of stay at MPA
Joshua Dominik Orth	(Uni Würzburg)	1.9.–26.9.
Nelson Padilla	(PUC, Santiago, Chile)	until 31.3.
Dante Paz	Osserv. Astron. Cordoba, AR)	10.1.–10.3.
Andre Ruiz	Osserv. Astron. Cordoba, AR)	10.1.–10.3.
Sergei Sazonov	(IKI, Moscow, Russia)	10.7.–15.8.
Nicholas Sanchez	(Univ. of Valencia)	6.1.–31.1.
Nikolai Shakura	(Sternberg Astron. Inst. Moscow)	1.8.–30.8.
Volker Springel	(HITS, Heidelberg)	2.6.–2.7.
Yudai Suwa	(JSPS, Tokyo)	since 1.4.
Assaf Sternberg	(Cluster guest)	since 15.3.
Bryan Terrazas	(Univ. of Michigan)	4.8.–16.8.
Scott Tremaine	(IfA, Princeton USA)	29.5.–26.6.
Paulina Troncoso	(PUC Santiag, Chile)	6.1.–22.1. and 16.2.–16.3.
Victor Utrobin	(ITEP, Moscow, Russia)	23.10.–22.12.
Naito Yoshiaki	(Tokyo University Japan)	25.10.–17.11.
Lev Yungelson	(RAS, Moscow, Russia)	26.03.-25.04.