

ASTRON

Annual report 2009

Image on front cover:

The image shows the so-called 'superterp' in the centre of the core LOFAR area between the villages of Exloo and Buinen in Drenthe, the Netherlands. On the superterp six LOFAR stations are placed.

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Preface

It is my pleasure to introduce the ASTRON Annual Report for 2009. This year the ASTRON foundation celebrated its 60th anniversary – the last 60 years have been exciting indeed, but the next 60 still to come promise even more in my opinion! In particular, I am delighted by the progress the exciting LOFAR project has made this year. LOFAR will in the first place enable us to explore the early universe, but with its underground sensors also allows for research in areas such as geophysics and precision agriculture, while the ICT backbone to synchronize data from so many remote sensors is also unprecedented.

Despite a late start in the rollout process due to poor weather, more than 20 LOFAR stations had been successfully deployed before the end of the year. The rapid deployment of LOFAR stations across the country, and in addition the completion of two international stations in Germany, represents a remarkable achievement and I commend the efforts of the staff at ASTRON that have made all of this possible. But ASTRON has also made excellent progress in other areas of our mission. This includes the completion of the first prototype phased array feed for the Westerbork telescope (APERTIF) and the on-going construction of the EMBRACE dense aperture array as part of our Square Kilometre Array (SKA) research and development programme. During this very busy period, I am delighted that the expansion of the Astronomy Group continues to make good progress, partly fueled by significant external funding from the EC and via NWO Vici and Vidi awards.

The initial definition of a potential governance model for the new International LOFAR Telescope has also been a major undertaking for staff at ASTRON. This is a very difficult task, as the needs and requirements of the various stakeholders are wide-ranging. Nevertheless, we are confident that the model proposed by ASTRON will permit a collaboration agreement to be agreed upon with the aim of signing this early next year.

No need to say that all this has been made possible by the efforts of the highly motivated and dedicated team of ASTRON and the LOFAR consortium, with the help of NWO, European agencies (incl. the EC) and the regional SNN, and with the support of an incredible number of companies and organizations that see the unprecedented potential of LOFAR and the future SKA. The future prospects of the institute are excellent indeed. The financial situation is stable and the recent success with European and national funding awards, bodes well in terms of ASTRON's continued capacity to attract a large fraction of its resour-

ces from external sources. Additional funding for the WSRT-APERTIF project is now being sought at national level, and there are indications that future funding opportunities at regional level will permit us to further develop the concept of smart sensor networks as part of our SKA R&D programme. For ASTRON, the SKA very much represents the long-term future of the institute. Next year, NWO and ASTRON will jointly host the International SKA Forum 2010 in the Netherlands. We're looking forward to this immensely, and we see this initiative as a very visible sign that the Netherlands as a whole wishes to play a central role in the project. At the same time, our plan is to formally inaugurate the LOFAR telescope. We look forward to 2010 with quite some anticipation!

*Prof. Henk Zijm
Chairman, ASTRON board.*

Directors Report

2009 has certainly been a year to remember! The progress with the roll-out and commissioning of LOFAR is just one of many highlights this year. Although things got off to a slow start with unusually wet and freezing weather conditions, by the springtime conditions had improved and the fields around the core area in Exloo-Odoorn could at last be flattened.

With a substantial amount of hardware in storage, the first "production" LOFAR station was quickly assembled and by the end of April the first production LOFAR station (RS302) was complete. By the beginning of the summer we were celebrating "first fringes" to half a dozen stations, and the generation of the first wide-field images began to appear – exciting times for us all! Around this time it looked as though all this progress might have to come to a halt because of possible restrictions on construction due to the breeding season for birds. Fortunately common sense prevailed, and with local government taking the lead, ASTRON staff ensured that various strict safeguards and regulations were put in place to protect the birds and their eggs.

The densely packed LOFAR "super-terp" was also completed this year, packing six LOFAR stations into a region that spans almost 400 metres across. Aerial images around the core area in Exloo (see front cover) give a good impression of the scale of the project. I'm happy to report that the data quality produced by the first stations is quite outstanding, leaving astronomers around the world dribbling at the mouth for much more!

The first meeting of ASTRON's Science Advisory Committee (chaired by Prof. Steve Rawlings, Oxford) was held in January, and by December the SAC met again for the second time this year. They were impressed by the progress that we had made in the intervening ten months – “amazing progress” was the adjective used to describe the status of LOFAR. The SAC were also impressed by all other aspects of our activities, including our revamped outreach and diversity programme.



The Science Advisory Committee convened at ASTRON

First fringes between the Dutch LOFAR stations and the International LOFAR station at Effelsberg is another major milestone this year, and we are clearly on the right path towards realising the International LOFAR Telescope (now known as the “ILT”). Two international stations are complete – one at Effelsberg and the other at Tautenburg, Germany. ASTRON has taken the lead in initiating discussions that are beginning to define the way in which the ILT will organise itself as an independent organisation, and how it will serve and interact with the astronomical community. Towards the end of 2009, intensive bi-lateral discussions had taken place between ASTRON and several key stakeholders, including the ASTRON board, the LOFAR Council, NL-LAC (NL LOFAR Astronomical Committee), IWG (International Working Group) and the LOFAR consortium itself. There are many different views to satisfy and constraints to meet, but we're confident that the process is converging towards a model in which a new ILT foundation will be formed, governed by an ILT board with executive day-to-day authority vested in an ILT director. Our hope is that the ILT collaboration agreement can be formally signed by all the partners in early 2010.

At the end of September 2009, we received over 90 proposals for the commissioning phase of the ILT with an associated over-subscription

rate in excess of a factor of ten! As the rollout progresses apace, a larger fraction of our efforts must now focus on commissioning the telescope. Fortunately, the continued expansion of the Astronomy Group, and the imminent appointment of several new Support Scientists in the Radio Observatory, means that we are in good shape to support these developments. In order to properly support our astronomers, in 2009 we appointed an astronomical application software coordinator – a function that has been desperately needed for some time. Related to these developments, it is indeed a pleasure to report that our bid to receive extra-funding via NWO's “dynamising” programme has been successful. We have been awarded 1.85M€ over the next three years on top of our base budget, and we have chosen to use this to strengthen our activities in the area of fundamental research. Our intention is to use the money to support the scientific exploitation of the ILT, and to strengthen all facets of our SKA activities. A significant part of the programme will support PhD students jointly supervised by ASTRON and University staff. Hopefully this initiative will help, at least to some extent, in dealing with the avalanche of data that LOFAR is already beginning to generate. The “dynamising” award also permits us to support a more ambitious short and long-term Visitors Programme. If you are at all interested in being closely involved in LOFAR, APERTIF or EMBRACE commissioning activities, drop us a note!

While much of the attention within ASTRON in 2009 has naturally focused on LOFAR, the APERTIF project has also been making excellent progress. APERTIF aims to kit-out the WSRT antennas with focal plane array (FPA) systems, increasing the field of view of the array by a factor of 30. At the end of August, APERTIF passed its first PDR (Project Design Review) with flying colours. To say that there is quite some excitement both here at ASTRON and in the wider international SKA community with respect to the results that the APERTIF group has achieved over the last year is a bit of an understatement! However, while funding is already in place to develop FPA's for the WSRT array, more resources are required in order to realise appropriate correlator and data processing facilities. A team led by Tom Oosterloo, Marc Verheijen (Kapteyn Inst., Groningen) and Wim van Cappellen, recently submitted a proposal to the NWO-G programme, aiming to secure the necessary funding to complete the final part of the project. The name of the proposal is APROPOS - APERTIF Processing Pipeline & Online System. The results of the evaluation will be known around February 2010 – fingers crossed.

Towards the end of the year, the EMBRACE Aperture Array telescope (a collaboration under the SKADS international consortium) successfully achieved “first light” just a few days in advance of the final FP6

SKADS workshop in Belgium. Together with the commissioning results now flowing from LOFAR, the opportunity to finally demonstrate the maturity of sparse and dense aperture arrays (AA) as an enabling technology for the SKA is now upon us. This comes at exactly the right time for the SKA project, as the process of converging on a final design for Phase 1 picks up speed. As a result, in 2009 ASTRON took the lead in establishing the Aperture Array Verification Programme (AAVP). This new project is expected to kick-off next year, and in 2009 sources of funding at the regional level were being pursued. AAVP will also include participants from other European countries with the aim of amassing around 10M€ of combined funding. AAVP will explicitly build upon the results of LOFAR and EMBRACE, pushing the AA technology to the next stage of development.

In 2009, ASTRON took over the coordination of the RadioNet FP7 project. The EC proposal, submitted by ASTRON on behalf of a consortium of more than twenty different partners has been funded to the tune of 10M€ over the next three years. ASTRON is involved in most of the RadioNet activities and benefits substantially via the telescope transnational access programme. A significant involvement in the RadioNet Uniboard project is also of keen relevance to the back-end correlator that will be required by WSRT-APERTIF in 2012.

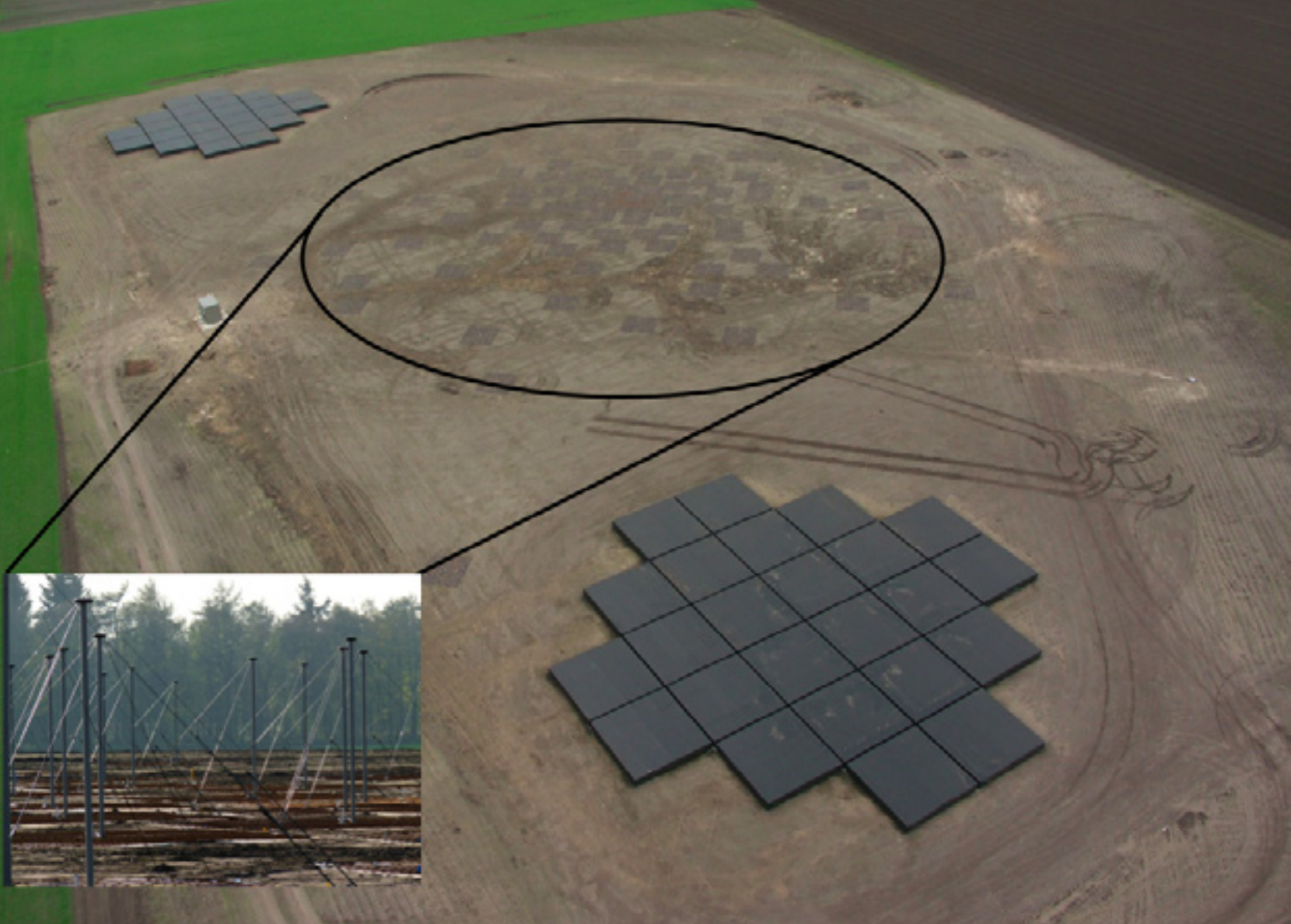
next year and have everything in place by the end of the summer 2012. We shall see!

Prof. Mike Garrett
General Director



The RadioNet FP7 kick off

Finally, after several iterations, the design of the extension to our existing buildings in Dwingeloo has now been largely settled. The new design is exciting and will allow for a significantly larger colloquium room, a new library, a Science Support Centre and a state-of-the-art telescope control room. Our aim is to start construction at the end of



Radio Observatory

In 2009, balancing acts were the order of the day for most of the people in the Radio Observatory, and indeed throughout ASTRON: pushing ahead towards a fully functional LOFAR telescope, simultaneously in many different areas of development and rollout, while also supporting commissioning and busy weeks, conducting test observations, and of course in addition staying on top of Westerbork Synthesis Radio Telescope (WSRT) operations and maintenance.

The Westerbork Synthesis Radio Telescope in 2009

Driven by an ambitious high-yield schedule of astronomical observing, WSRT operations have proceeded routinely from the control room in Dwingeloo; this includes e-VLBI, and, on a test basis, recorded VLBI as well now, with TADUmax in full use and producing excellent data. Future VLBI sessions will use TADUmax exclusively, for operational robustness.

Override observations of several new gamma-ray bursts have kept the operators and the overall scheduler, Gyula Józsa, on their toes, but with good results: two very interesting gamma-ray burst sources were detected with the WSRT.

In 2009, WSRT proposal deadlines yielded some very ambitious requests for the semesters ahead, resulting in some tough choices for the Programme Committee. The resulting telescope calendar was dominated by several very large programmes, which make use of the great sensitivity and also the excellent stability of the WSRT systems.

The projects also needed more movements of the telescopes than has been experienced for a long time, requiring significant attention from the crew in the summer of 2009. Scientists, inside and outside ASTRON, felt an urgency to carry out these programmes before moving on to the even grander plans they have with Apertif. The range of first-class science that such a focal plane array would bring, was brought home vividly during the Panoramic Radio Astronomy conference in June 2009, organised largely by the Astronomy Group. With technical work on both the frontend and the backend continuing full steam ahead,

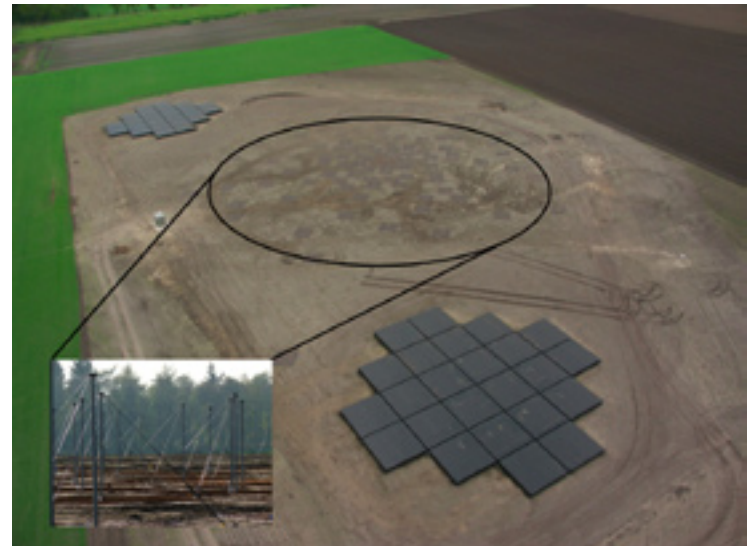


Focal plane arrays in the focus of one of the Westerbork dishes

astronomers worked hard on funding proposals that can make Apertif a reality a few years from now. In May 2010, we received the news that Apertif is fully funded. With this funding for the correlator, calibration/ reduction pipeline and the data archive, the WSRT will continue to be one of the most advanced radio telescopes in the world for many years to come.

LOFAR in 2009

The progress with LOFAR continued very satisfactorily. LOFAR station CS302 has become the first to be formally taken on by the Radio Observatory for operational use, pending some outstanding issues. Michael Wise and Antonis Polatidis kept an eye out for the proper balance between progress with development, bug- fixing and feedback to engineers, and access for astronomers eager to prepare (themselves and their software) for first science observing.



The first LOFAR station that was completed: cs302. The picture shows the High Band Antennas and the Low Band Antennas (inset). Copyright: ASTRON.

Observing with LOFAR

Along with the preparations for the new ASTRON website, there has been a lot of activity to assemble and produce adequate LOFAR user documentation, geared initially at the first announcement of opportunity for observing, that revolved mostly around astronomical commissioning and preparations for future large projects.

As many as 94 LOFAR observing proposals, submitted at the end of September 2009, gave a vivid demonstration of just how eager the astronomical community is to participate in using LOFAR as soon as

possible. The deadline clearly worked as a catalyst, sparking new ideas, forging new collaborations, and leading to write-ups of specific, well-defined project goals in a way that we did not have available before. The scientific review, by the independent Programme Committee, and the technical review, mostly by internal people, will lead to a cohesive shared-risks commissioning package, and to clarification of many scientific and technical issues.

Dialogue with the technical experts at ASTRON is essential: together we need to work on the LOFAR capabilities that are highest on the priority lists, after determining jointly the bottlenecks, tradeoffs and choices to be made. This review and iteration takes time, but will pay off in the form of well-understood milestones and priorities for commissioning observing, with tasks that specific people at ASTRON and from the astronomical community will work on. It will allow expectations and preparations in the astronomical research groups to be founded on our best-effort estimates of how to bring the remarkable capabilities of LOFAR to life in the coming months and years.



Discussing the International LOFAR Telescope

LOFAR data processing school

Another highlight for LOFAR occurred in February 2009: the first LOFAR data processing school, organised by Michael Wise (ASTRON), with the help of many people. It was widely seen as a great success by the many participating astronomers from the Netherlands and abroad who filled the meeting rooms to the brim. Further schools will follow as the commissioning proceeds and the set of available LOFAR applications and (pipeline) tools expands.



LOFAR called and they all came: approximately 40 participants from the LOFAR community gathered at ASTRON for the "LOFAR Data Processing School". The aim of this school was to introduce new members of the collaboration, who will be involved in the commissioning effort, to LOFAR. Copyright: Lars Bahren.



Astronomers can request observing time with LOFAR using the web-based proposal tool Northstar.

International LOFAR Telescope

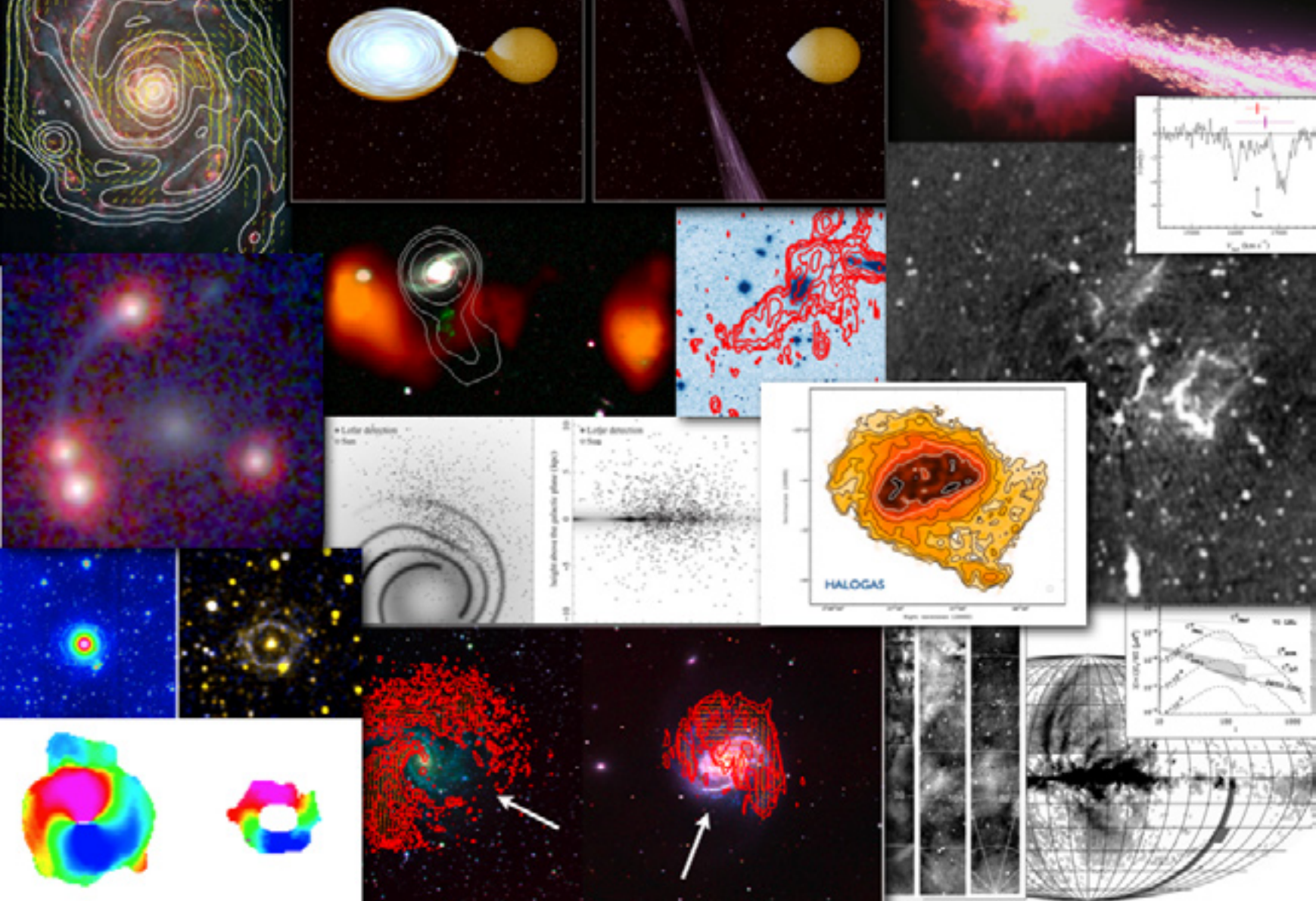
In our dialogue with the institutions and users groups in the Netherlands and around Europe, balancing acts of a somewhat different kind led to a good understanding of the kind of consortium we need to run the International LOFAR Telescope as an integrated facility, with no strong distinctions between the operational use of LOFAR stations in Exloo, Coevorden, Onsala (Sweden), or wherever else they may be. ILT formalities were completed in June 2010.

The International Year of Astronomy

Last but not least, the Radio Observatory was very much involved in the International Year of Astronomy 2009. The “100 hours of astronomy” on 3, 4 and 5 April 2009 with a live webcast and many quite varied activities at NEMO, were a big success thanks to the tireless efforts of many individuals at ASTRON.



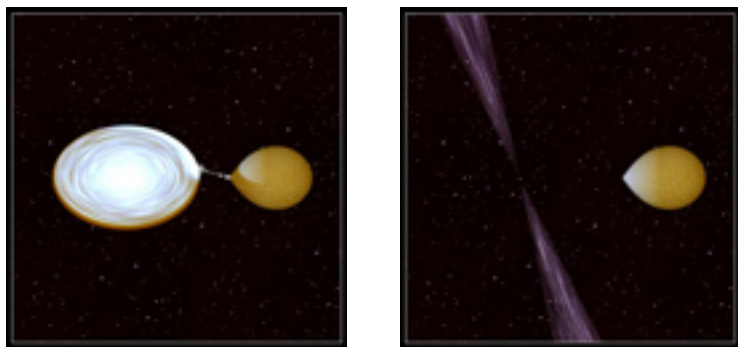
Marijke Haverkorn (ASTRON) giving a presentation about astronomy in NEMO, Amsterdam. Credit: Herve Jamin, ASTRON.



Astronomy Group

Like every year, the astronomers at ASTRON have covered a wide range of scientific topics in their research. Here is a short summary of some of the main results.

Pulsar astronomy has been, as always, one of the central themes. This year the highlight in this field was the discovery of a radio millisecond pulsar that has suddenly turned on. Interestingly, it was found that up to a few years ago this system contained an accretion disk. This source is thought to be the missing link that shows that millisecond radio pulsars are spun up by mass transfer from a companion star. This result appeared in Science magazine.



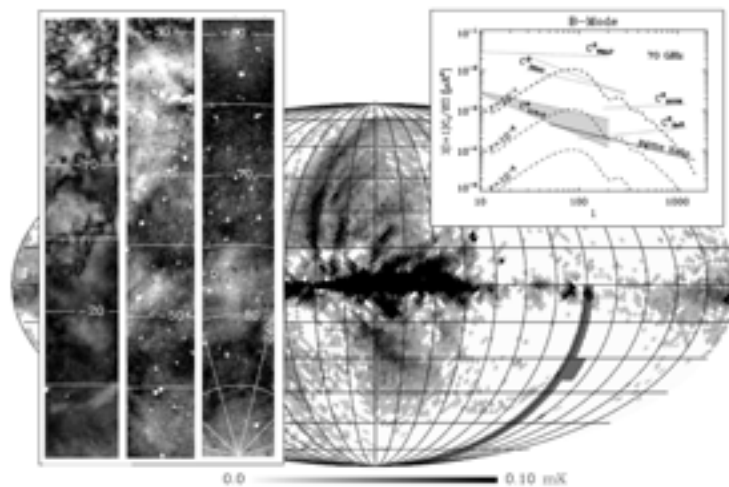
Discovery of the missing link between accreting binaries (left) and millisecond pulsars (right) – Archibald, Stairs, Ransom et al. 2009, Science, 324, 1411.

The Westerbork Synthesis Radio Telescope (WSRT) has continued to produce interesting results. The WSRT campaign on the powerful gamma-ray burst GRB080319B, together with unparalleled data from satellites and observatories around the globe, has helped to show that the jet this object is aimed almost directly at the Earth. GRB events are associated with sharp asymmetries that quickly develop in the relativistic outflows that occur when massive stars use up all their nuclear fuel, almost instantaneously collapse and then explode on rebound. It is estimated that this GRB was so bright that it would have been briefly observable to the naked eye, being 7.5 billion light-years away! The results of the observations were published in Nature. The WSRT is still active in the follow up monitoring of GRB events.

As the data from the first LOFAR observations are becoming available, it has been interesting to see the predictions on the number and type of pulsars that will be discovered with LOFAR. An all-sky Galactic survey can find approximately 1000 new pulsars, probing the local pulsar population to a deep luminosity limit. Giant pulses from extragalactic pulsars can be detected out to over a Mpc.

The study of the interstellar medium and magnetic fields in galaxies is becoming more and more relevant in the group because of the implications for LOFAR observations which will start very soon. In the meantime other available radio telescopes are used to make progress in this

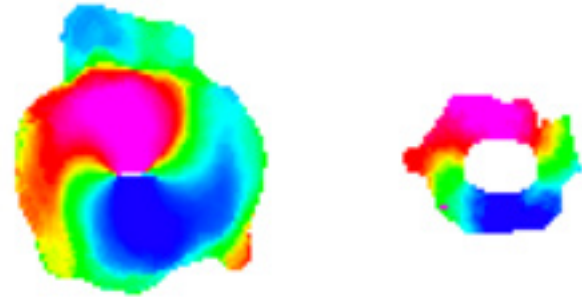
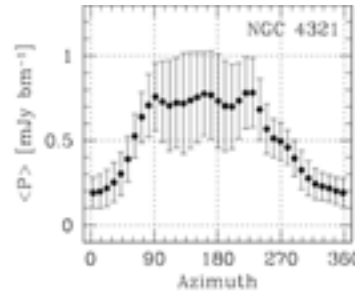
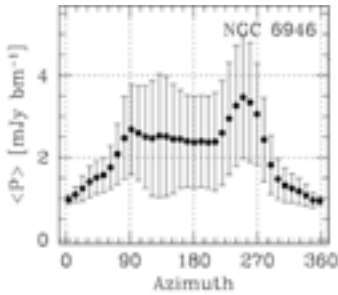
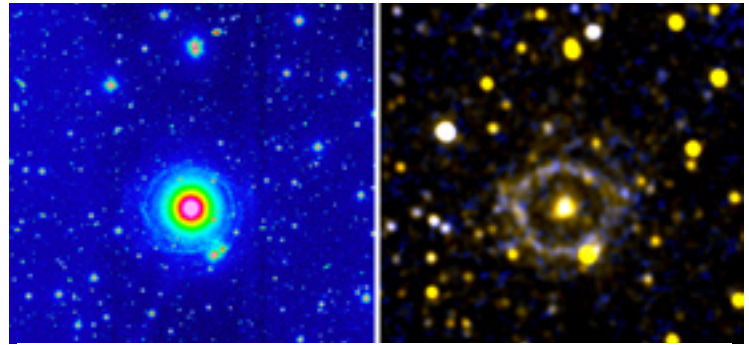
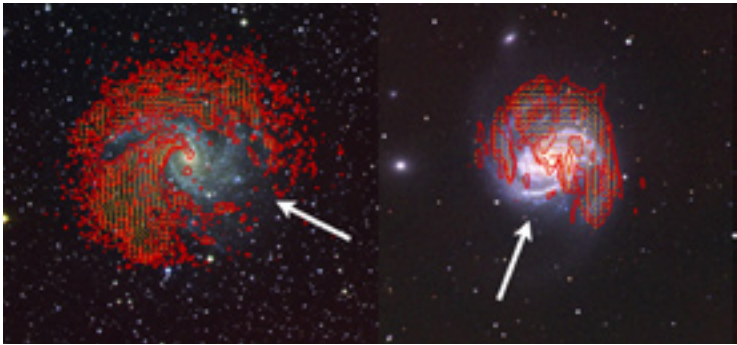
field. The precision attainable in polarized Cosmic Microwave Background (CMB) radiation studies depends on the much stronger Galactic foreground radiation. A project that makes use of the Parkes Galactic Meridian Survey (PGMS) has tried to determine limits on the Galactic synchrotron contamination at CMB frequencies. Compared to the theoretical estimates of B-mode spectra, the new results show stronger limits, which may have consequences for the preferred frequency to look for the B-mode.



Polarized Galactic synchrotron emission – Carretti, Haverkorn, McConnell et al. 2009, ArXiv:0907.4861.

Interesting results have been obtained in the study of magnetic field in nearby spiral galaxies, using WSRT data. It has been found that all galaxies with extended polarized emission have a minimum in polarized intensity near the kinematically receding major axis. Moreover, galaxies with compact nuclei show polarization structure in the nucleus which points to Faraday-thin/thick media. Identifying magnetic field structures in nearby galaxies narrows down the mechanisms for creation and amplification of magnetic fields in the early Universe.

One of the “niche” applications of the WSRT is extremely deep observations of nearby galaxies in the neutral hydrogen (HI) emission line at 1.4 GHz. Not only are the images produced by the WSRT beautiful, but more importantly, they have taught us a great deal about the interface between galaxies and the intergalactic medium. Because of this, a large WSRT survey called HALOGAS (Hydrogen Accretion in Local GALaxies) has started and the first results are becoming available now. The WSRT observations reveal a vast, extended network of HI fila-



Two trends in spiral galaxies discovered – Heald, Braun & Edmonds 2009, A&A, 503, 409

Optical and UV images (top) and velocity fields (bottom) of ESO 381-47 – Donovan, Serra, van Gorkom et al., 2009, AJ, 137, 5037.

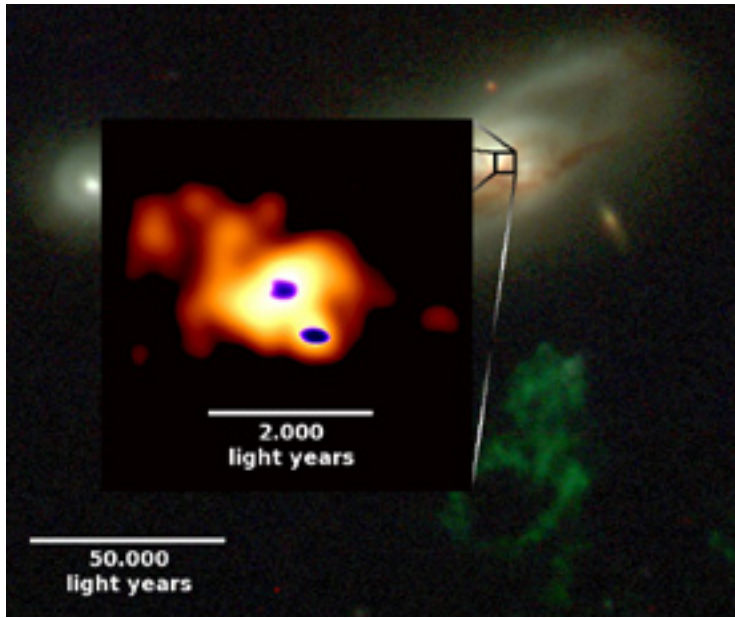


Another large programme with the WSRT is the observation of neutral hydrogen in early-type galaxies. This is the deepest, statistically most complete HI survey of early-type galaxies to date. Preliminary results confirm earlier reports of a high detection rate and indicate that there is a continuum of HI properties of early-type galaxies as a function of environment. Detailed studies of single objects are, however, also important. In the case of the S0/a galaxy ESO 381-47, deep observations have been used to study the formation of the HI and UV ring and test scenarios involving a bull's eye collision, accretion of cold IGM gas and tightly wound spiral-arms.

The WSRT has also contributed to the study of Active Galactic Nuclei. The intriguing “Hanny’s Voorwerp” has been confirmed to be ionized by an AGN at the centre of IC 2497, thanks to observations with the WSRT and with the European Very Long Baseline Interferometry Network (e-EVN). The observations also show that the emission nebula is part of a huge gas cloud.

ments in the outer regions of galaxies. Observations like this will help to characterize faint gas in the outskirts of the general spiral galaxy population, and to gain a far better understanding of the importance of gas accretion.

Extremely broad 21-cm HI absorption (FWZI ~ 1600 km/sec) has been discovered with the WSRT in the radio source 4C37.11 (B2 0402+379). This object has been claimed to host a super-massive binary black hole. The main features in the absorption profile are two components, sepa-



Two very compact sources are detected at the heart of IC2497 with the EVN, signalling the presence of an active galactic nucleus. The surrounding smooth and extended radio emission, arises from a so-called “nuclear starburst” – Rampadarath, Garrett, Józsa et al. arXiv:1006.4096.

rated by ~ 1100 km/sec. Given the large width of the absorption, it has been suggested that the extreme properties of the HI absorption are the kinematic signature of a binary massive black hole.

Gravitational lensing provides powerful tests of dark-matter predictions. John McKean and collaborators studied the group-scale lens B2108+213 in detail, using Keck, Chandra, HST and VLBI. They were able to determine the mass of the system in two ways and found that the baryonic component in the centre of the group dominates over the dark matter component. Also, studies of substructure within galaxy-scale dark matter haloes were carried out using gravitational lensing. It was found that the level of substructure in lens MG J 2016+112 is higher when compared to what is expected from simulations. Using the magnification from a gravitational lens, a water maser from the distant lensed quasar MG J0414+0534 at $z = 2.64$ was found using the Effelsberg telescope and the EVLA. It was found that the maser is associated with the quasar’s relativistic jet. This result has appeared in Nature. The water maser has since been monitored with the Arecibo telescope every six weeks.

Clusters of galaxies have been in the centre of cosmological research for many decades. The powerful radio sources in them interact with

the cluster medium and influence the growth of dominant central galaxies. Using the WSRT, two clusters were studied. These observations revealed a wide range of structures, many of which lie at the periphery of the cluster.

In the Abell 2255 cluster, large-scale relic features were found and, using the polarized emission, 3-D maps were made of this cluster. For the Perseus cluster, new WSRT observations have produced high dynamic range total and polarization images, revealing features never seen before. At the end of the high-brightness tail of NGC1265 a giant (150 kpc half-circle) loop is revealed which is more than 50% polarized.

In 2009, members of the group have been involved in the (co-)supervision in collaboration with staff at the universities (inside and outside the Netherlands) of more than 10 PhD students and a number of Master students. Three PhD students successfully defended their thesis this year. The group has also hosted five summer students, two of them involved in the commissioning of the very first data obtained by LOFAR.



The summer students of 2009

In addition to the highlights of the science, many outreach activities were carried out as part of the International Year of Astronomy. ASTRON was also present with its booth at the exhibition at the XXVII General Assembly of the International Astronomical Union in Rio de Janeiro. Visitors had the chance to talk to ASTRON staff and pick up brochures about ASTRON’s core activities.

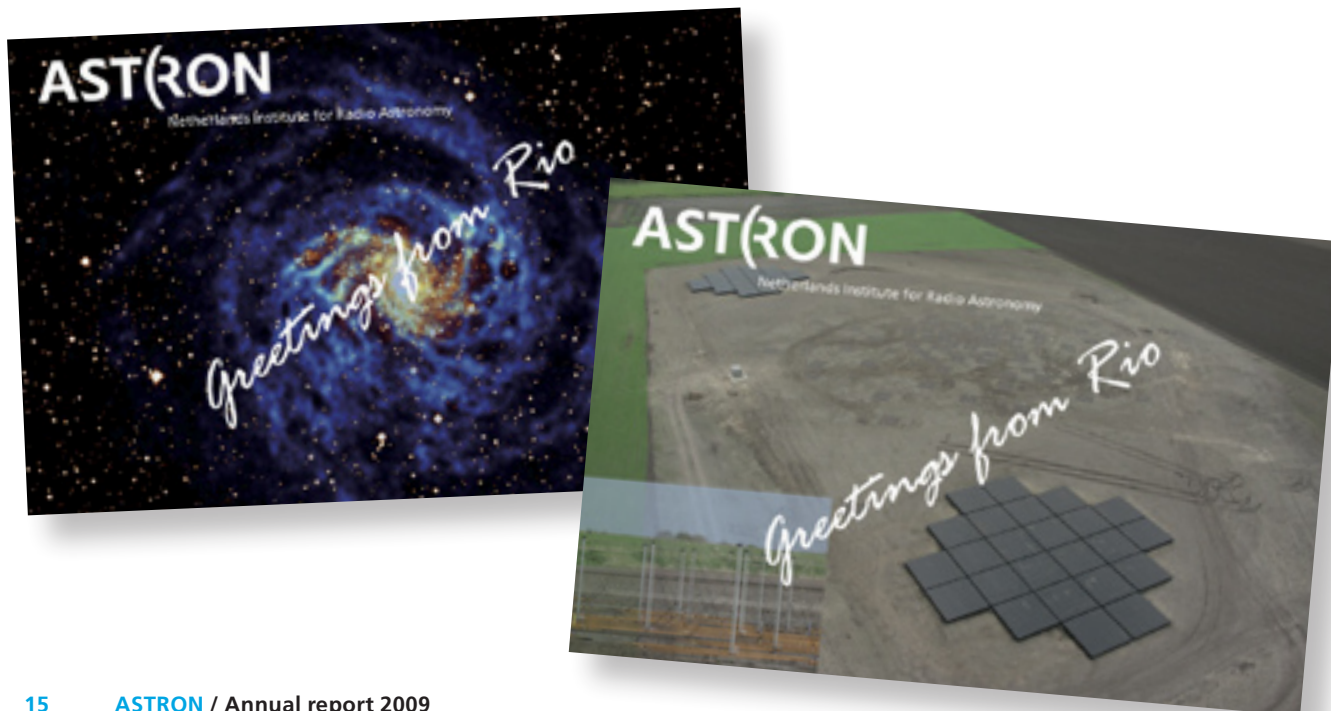


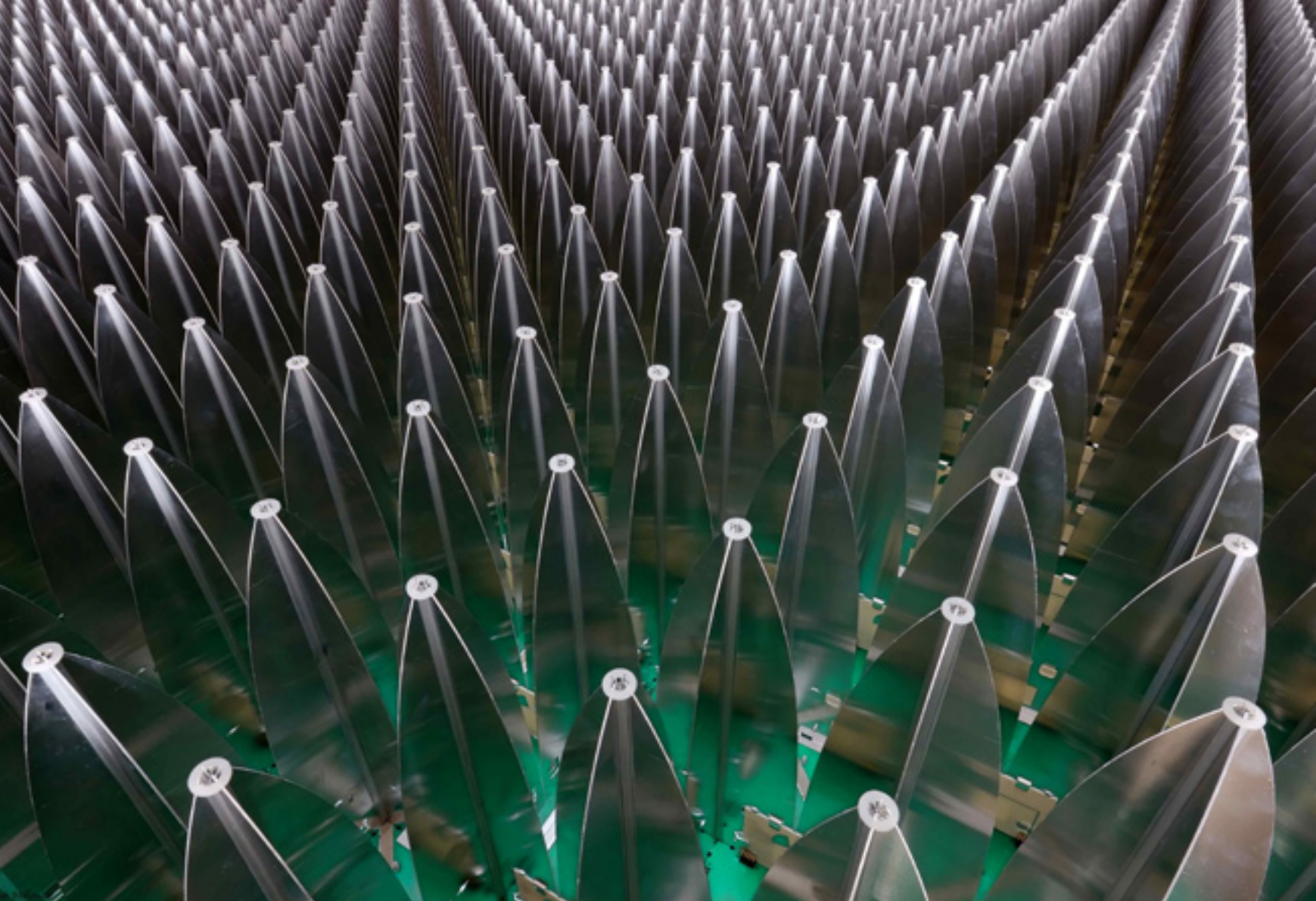
The ASTRON booth at the General Assembly in Rio de Janeiro in August 2009



Impression of the Stromfest organised in honour of Richard Strom

Finally, it is also worth mentioning the three international meetings that have been organized: "Panoramic Radio Astronomy", a workshop to celebrate the work of Richard Strom who had recently retired and "Powerful Radio Galaxies: Triggering and Feedback", a workshop organized at the Lorentz Center.





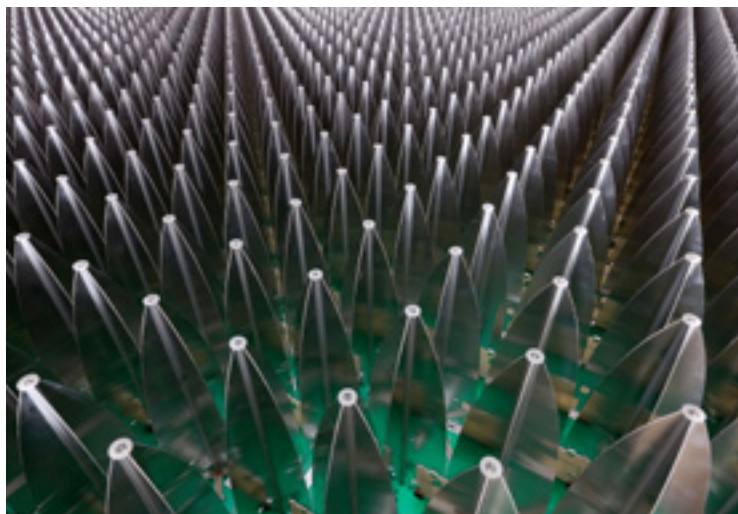
Research and development

The R&D programme in 2009 was dominated by LOFAR, SKADS and APERTIF. The EC FP6 SKA Design Study, coordinated by ASTRON, was successfully completed in 2009. The construction of EMBRACE was a major milestone in SKADS. APERTIF designed and constructed the second prototype and conducted a successful Preliminary Design Review. LOFAR was full in roll-out phase, which required an effort from all ASTRON divisions and external partners, both for hardware installation and software development. LOFAR is in an extremely challenging phase, as it is now starting to produce exciting scientific results.

Alongside these large projects, some ten smaller technology research projects were conducted, ranging from a fundamental study in EM antenna modeling to the development of pattern-recognition concepts for digital diagnosis.

Highlight - EMBRACE and beyond

The EC FP6 funded SKA (Square Kilometre Array) Design Study (SKADS) was successfully completed in 2009. A major component of SKADS is the EMBRACE demonstrator. EMBRACE stands for Electronic Multi-beam Radio Astronomy Concept. This system uses new receiver technology. Unlike the traditional mechanically moveable telescope, this system consists of a large number of flat antennas without movable parts, which track the radio source electronically. Together, the antennas form a large surface, which can be extended flexibly to reach the necessary sensitivity.



EMBRACE: an impressive field of Vivaldi antennas stretched out under the radome near the Westerbork array. Copyright: ASTRON, Rob Millenaar.

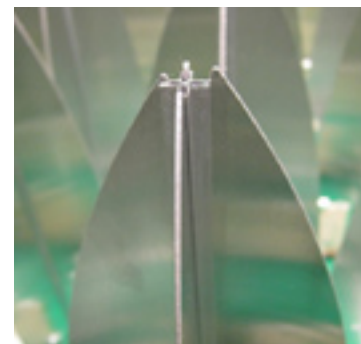
EMBRACE consists of 144 aperture array tiles at the WSRT and 80 at the Nançay decametric array. EMBRACE was in production, test and integration phase during 2009, and tiles were being used at both sites.

Mass production

Optimisation for mass production is crucial for the Square Kilometre Array (SKA). Even the null-series antennas for EMBRACE consisted of 2500 pieces. During the production of this series, small effects became apparent due to the large number statistics. Solutions for them could be found, in many cases in a straightforward way, but the null-series was essential for discovering them. E.g. a small nylon ring had to be



Installation of the null-series tiles in the radome at Westerbork



The devil is in the details... Plastic rings added on top of the Vivaldi elements to prevent occasional minor displacements during transport.

added on the top of the four antenna elements in the dual-pole dipole to prevent small movements during assembly and transport. For the final production, a small slot was made in each antenna to hold this nylon ring in position.



Members of the ministry of Education, Culture and Science visit ASTRON.



Students at the EMBRACE radome in Westerbork.

LOFAR Back-ends

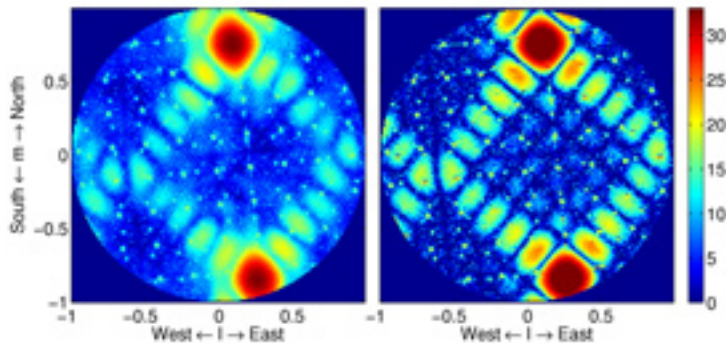
EMBRACE uses LOFAR back-ends for digitisation and signal processing. In 2009, most of this equipment and cables were available at the WSRT and Nançay.



Installation of the back-end cabinets at the WSRT.

First results for EMBRACE

An impressive result with EMBRACE was achieved during the Christmas break of 2009. EMBRACE measured the first signals of supernova remnant Cassiopeia A. A first analysis of these observations shows the system meets the design goals well.



Nine modified tiles were used to scan the sky at 1475 MHz, observing Afristar, which is a geostationary satellite positioned at 21 degrees East. Using a clever signal-processing scheme, the maximum achievable signal-to-noise ratio per tile for each direction was obtained, without calibrating the array itself. Since Afristar is the single dominant radio source at this frequency, this reveals the average tile beam pattern for a 3x3-array of uncalibrated tiles. This image shows Afristar close to the south-eastern horizon, the grating response of the system in the north and the side lobe pattern.

Beyond EMBRACE – the Aperture Array Verification Programme

EMBRACE and the other design studies in SKADS were completed and verified in 2009. The in-depth characterisation and usage of EMBRACE is beyond the scope of SKADS. The next phase beyond SKADS, is the

European Aperture Array Verification Programme (AAVP), a coordinated effort to design and verify the aperture array system for the Square Kilometre Array, and develop a full, technologically mature system design for the SKA Low-frequency and Mid-frequency Aperture Array system from 70 MHz to 1GHz. AAVP is essential for demonstrating the technical readiness of the aperture array technology. AAVP is a collaboration of nine European countries and Australia.



Highlight – Progress with Apertif

With Apertif, ASTRON shows in a measurable and verifiable way how well focal plane arrays work and what its advantages and limitations are. On 25-26 August, the Preliminary Design Review for Apertif took place. An international panel concluded that the project team demonstrated the feasibility of this innovative technology and delivered both a well-developed design and impressive initial results on astronomical sources.



The second prototype of APERTIF ready to be mounted in the WSRT dish RT5. The main improvement is that the system noise is about 75 K, 50 K better than that of the first prototype. The system has been assembled after thoroughly testing each of the 144 elements.

Highlight - Distributed Aperture Array for Radio Astronomy In Space

The DARIS project is an ESA study in which ASTRON, EADS ASTRIUM, Radboud Universiteit Nijmegen, and ALTRAN participate.

With large apertures in space at frequencies below 30 MHz, many interesting science cases can be studied. These range for example from surveys of the extragalactic low-frequency sky, coronal mass ejection mapping and research, investigation of planetary radio bursts, to detection of cyclotron maser emission from extra-solar planets.

In DARIS the feasibility of large aperture arrays in space for radio astronomy observations is studied. Given the required very large apertures, an interferometric aperture synthesis array would be the preferred telescope concept. Studies of the interstellar plasma and interplanetary plasma indicate that baselines up to 100 km are optimal for the frequency range 0.03-30 MHz. Longer baselines seem not to be useful as the plasma would distort the interferometric phases, thus limiting the angular resolution. As the distribution and density of the plasma is not accurately known, these numbers are estimates.

Several mission concepts are studied. Formation flying, such as in-orbit around the earth, in-orbit around the moon, at L2, or a distributed aperture moon-based systems will be considered. Because of strong interference of Earth-bound long-wave HF transmitters, an in-orbit distributed satellite system around the moon or a system at the back side of the moon would be preferable. Moon-based systems have been considered, DARIS however limits itself to space-based formation flying systems.



Possible top-level architecture for a low-frequency antenna array in space.

Technology Transfer

ASTRON carried out several consultancy and support services for commercial partners ranging from RF-consultancy and remote diagnosis of plant diseases using pattern recognition and distributed data networks to Finite Element Analysis on Aluminium tubes used in high-speed skating.

For a company dedicated to the development of professional mobile communications systems for mission-critical applications based on Trunked Radio systems, we executed an extensive Development and Test and Measurement support contract.

Education

The ASTRON course on *Applied RF Technology* received a serious amount of attendees, both courses in 2009 were fully booked (numbers are limited to sixteen in order to achieve a high quality of hands-on training support during this course). In 2009, ASTRON has developed an additional course, filling the gap between basic RF-theory and hands-on to RF.



Special projects

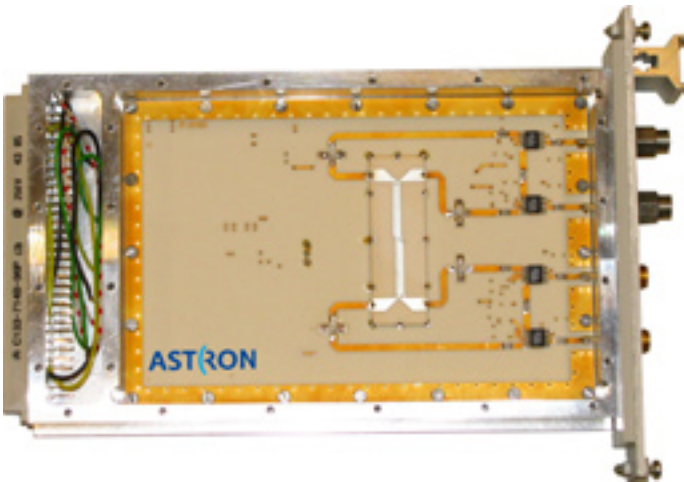
The Galsee project is the In-Orbit Validation part of the Galileo program for European satellite navigation. The Galsee project is managed by Thales-Alenia Space (TAS) from Rome. The Galsee-SMF project (SMF =Signal-in-space Monitoring Facility) performs detailed measurements on signal and data quality transmitted by the Galileo satellites.

The Galileo signal has a wide bandwidth and the power levels are low, therefore large dish antennas are necessary to perform the measurements with the required accuracy. ASTRON, with its WSRT, is uniquely equipped to perform this task.

Since the WSRT's front-end is dual-linear polarized and the Galileo signals are circular polarized, a converter was made to convert the linear polarization into dual orthogonal circular signals.

ASTRON benefits from knowledge about the Galileo (and GPS) signals for calibrating the ionosphere effects for LOFAR. In this context it is of particular interest that Galileo uses three frequencies rather than two.



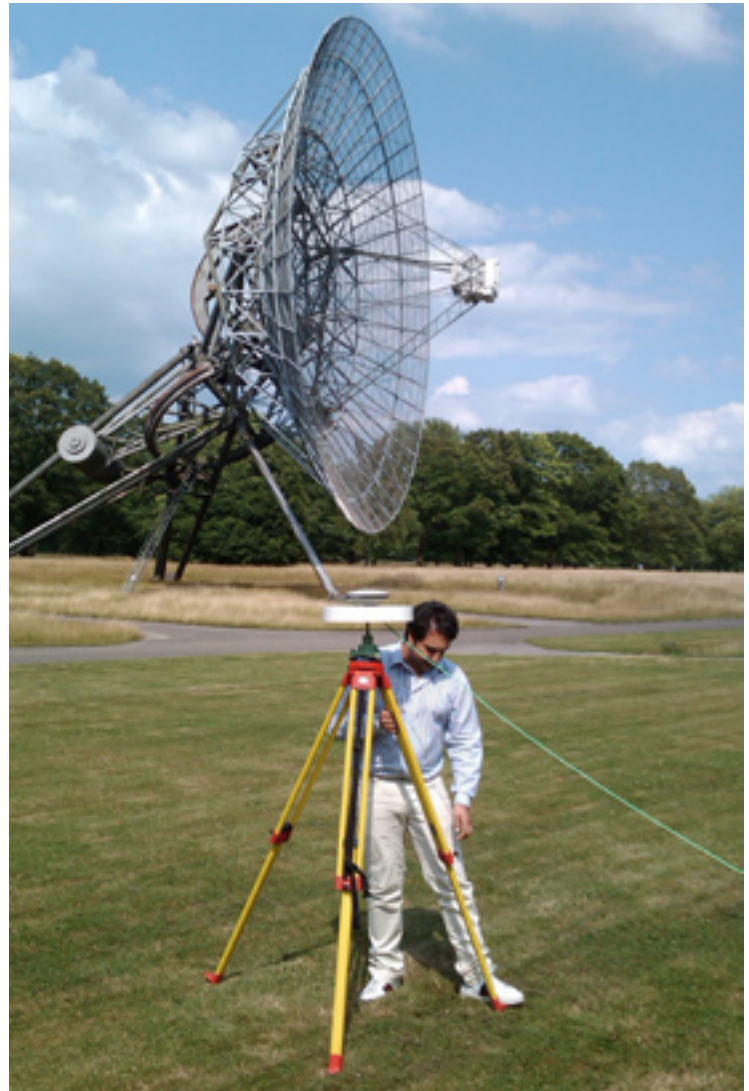


Milling the enclosure (top), and the final converter for linear polarization to circular polarization (bottom).

During 2009, the project has finished the Critical Design Review, the Preliminary Design Review and the Test Readiness Review meaning all hardware and software including calibration is in place for the final acceptance tests. These tests are planned for 2010 and after successful completion the Galsee-SMF can be used for Galileo in-Orbit Validation by TAS-Rome.

NOVA Optical/Infrared instrumentation group

In 2009, the programme of the NOVA Optical/IR group, hosted at ASTRON, saw the completion and delivery of the flight hardware of



Simultaneous measurement of Giove-B just above the horizon using an omni-antenna and one of the Westerbork dishes.

the spectrometer main optics for JWST-MIRI, the near-IR spectrometer for X-Shooter, and all 72 sets of mirror blocks for the ALMA Band-9 receiver cartridges.

The NOVA group at ASTRON consists of ten experienced people with expertise ranging from optical, mechanical, and cryogenic design, system engineering, CNC and optical production capabilities, instrument integration, and verification. Several staff within ASTRON's R&D division are involved in supporting these activities. Over the last decade this group carried out the optical-IR instrumentation projects for

which NOVA had final responsibility towards ESO, ESA, and international partners. Current arrangements between NOVA, ASTRON, and NWO concerning the Optical-IR instrumentation group are concluded in a contract that covers the period 2008-2011.

In the near term, the Optical-IR group will undertake the work packages on SPHERE-Zimpol and Matisse which are of major Dutch astronomical interest and for which NOVA has contractual obligations towards ESO and international partners. Furthermore, the group is involved in the hardware part of four Phase A studies on E-ELT instruments, and carries out some technical R&D for future instrumentation. From 2011 onwards, the group is expected to take on the Phase-B work for one E-ELT instrument with ongoing R&D for a second E-ELT instrument. Head of the group is Ramon Navarro. ASTRON provides in-kind systems engineering support through Lars Venema.

Programme and funding

NOVA leads the national efforts on the E-ELT participation. The projects are undertaken in collaboration with ASTRON, SRON, technical universities, TNO, and several industrial partners.

In November 2008, the Ministry of OC&W and NWO allocated a grant of 18.8 M€ to NOVA and its national partners for work on E-ELT instrumentation projects. The (instrumentation for the) E-ELT was one of the five projects that got national funding out of eight ESFRI projects that were identified as Dutch priorities by the national roadmap committee for large-scale European research facilities. The grant includes 8.8 M€ for conceptual and preliminary design studies, Phase A and B, and technology development, and 10 M€ for participation in the final design and construction of one instrument. The latter part is conditional to ESO's decision to go ahead with the construction of the E-ELT and to select instruments in which NOVA has a leading role. Payment is spread over the period 2009-2018.



LOFAR

The construction of the LOFAR stations finally started in the spring of 2009 after months of delay due to heavy rainfall and frost. Preparations for the construction of Core Station 302 – on the edge of the central region near the village of Exloo in Drenthe – got underway in March 2009. Before the antennas could be placed, the field had to be prepared. The requirements on the flatness are quite strict (level to within +/- 6 cm for the Low Band Antenna field and +/- 3 cm for the High Band Antennas). Under favourable weather conditions, this is well within the capabilities of the contractor that carries out such work, but not in the relatively soft ground and under the extremely wet conditions that ASTRON encountered since October 2008.

In early March 2009, conditions improved, and we finally had a prolonged spell of dry weather. Flattening started in late March, after which markers that indicate the antenna positions were placed in the field. The antennas are distributed in a roughly circular area, 70 metres in diameter. Erecting a field of LOFAR LBA's takes no more than a week under normal weather conditions, once the preparations (flattening of the field and laying of the cables) have been completed.



Discussing the building of LOFAR at the head office in Dwingeloo

The placement of the High Band Antenna (HBA) tiles (which operate between 120 and 250 MHz) is a considerably more complicated procedure. The antennas are pre-assembled at a production facility in Exloo and transported one by one to the field on a trailer. A crane then hoists the tiles, which weigh 150 kg each and measure 5m x 5m, into place. The tiles are fixed to the ground with deep anchors, to ensure that they can resist high winds. Each of the 'black boxes' actually contains sixteen antenna elements, laid out in a 4x4 grid, whose signals are combined in a time-delay beamformer inside the tile. The HBA's are covered by a uv-resistant flexible polypropylene foil that protects the interior of the tile from the elements. The stations in the Netherlands will each have 48 HBA tiles. The international LOFAR stations each have 96 HBA's.

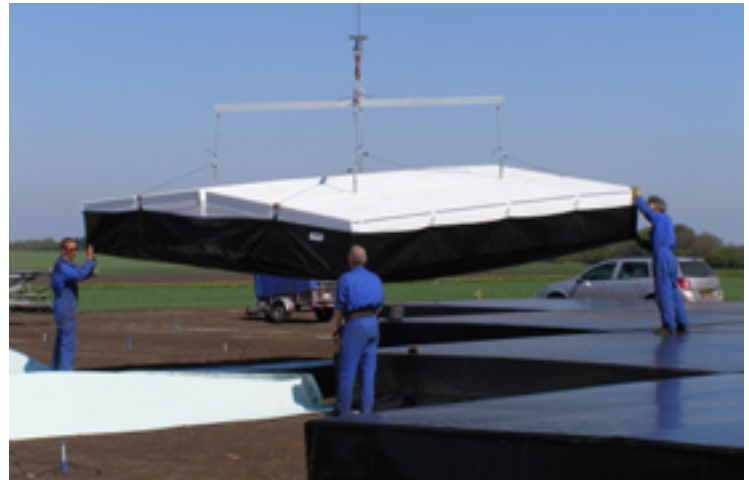
Construction of the first station was completed in early May. This was the starting point for the testing and commissioning effort, which verified that the station performed as expected. Once complete, control of a station is handed over to ASTRON's Radio Observatory division. This in turn marked the start of an extensive period of testing and verification – involving astronomers from all the major stakeholders in the



Netherlands and our international partners. In parallel with these tests, construction of the other stations proceeded as planned.

After the delays encountered earlier, the construction of LOFAR stations got underway in earnest in the summer. Since completion of the first station, the building progressed at great pace. By the end of October 2009, 19 stations had been completed, with a further five stations awaiting only the installation of the High Band Antennas (HBA's).

One of the most characteristic features of LOFAR is the concentration of six stations that are located at the heart of the array, and can be seen very clearly in aerial photographs.



The superterp under construction. Credit: Aerophoto Eelde.

Top: The LOFAR Low Band Antennas in the field. Credit: Henri Meulman, ASTRON

Bottom: The placement of one of the High Band Antennas. Credit: Jan Pieter de Reijer, ASTRON

These stations have been built on what is being referred to as the “superterp”. A circular island – about 340 metres in diameter, which was created in 2008. After giving the ground a year to settle, construction of the stations started in August. The photographs show personnel from one of our contractors erecting the low band antennas (top right) and a view from the superterp with three of the twelve 24-tile High Band Antenna fields (bottom right).

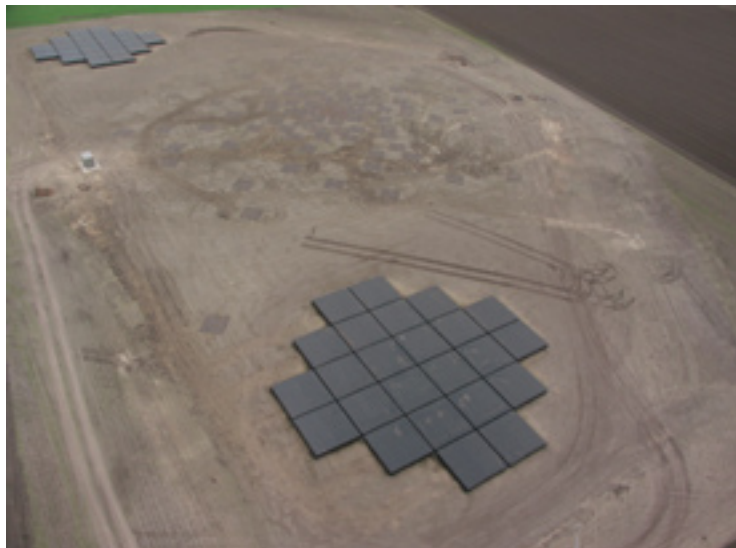
Construction of International LOFAR stations also continued. July saw the delivery and installation of the first HBA field at the Max Planck Institut für Radioastronomie’s station in Effelsberg, Germany.

In August, the first fringes between the Effelsberg station and LOFAR stations in the Netherlands were detected. In October, the HBA part of the Tautenburg station of the Thüringer Landessternwarte was completed. Meanwhile construction of the stations in Potsdam (Germany), Nançay (France) and Chilbolton (UK) was underway. In total, eight international stations are certain to be built in Germany (5), France, Sweden and the UK (1 each). Colleagues in Poland and Italy are working hard to secure funding for further stations, which would extend LOFAR’s baselines even further and add to its capabilities.

In addition to the antenna stations for radio astronomy, the LOFAR project also realised a geophysical and infrasound observatory. Detectors for all three applications can be found on a number of the stations and they share parts of the network infrastructure. Construction of these stations was also well underway in 2009, and set to be completed in the first half of 2010.



The placement of a cabinet filled with electronics at the edge of the first LOFAR station CS302. Credit: Henri Meulman, ASTRON



Aerial photograph of the first LOFAR station CS 302. The two fields of High Band Antenna tiles and the cabinet filled with electronics (top left) are clearly visible. The Low Band Antennas are more difficult to make out amidst the tracks that have been left on the field during construction. Credit: TopFoto, Assen



Networks and telescopes used for IYA2009 24-hr e-VLBI. Image by Paul Boven (boven@jive.nl).
 Satellite image: Blue Marble Next Generation, courtesy of NASA Visible Earth (visibleearth.nasa.gov <<http://visibleearth.nasa.gov>>).

JIVE

In the early months of 2009, JIVE was very visible in the events associated with the International Year of Astronomy (IYA). Together with international VLBI partners and supported by the EXPRoS project, a global e-VLBI campaign was organised that featured prominently at the opening ceremony in Paris. By showing not just detections but even images during the observations, the real-time aspect of e-VLBI proved to be a very powerful way to catch the attention of the public at this event. Also the truly world-spanning nature of the collaboration connected very well with the spirit of the IYA. Later in the year, the EVN and JIVE also featured in the webcast and national events during the 100 hours of astronomy.



EVN representatives explain real-time VLBI at the IYA opening ceremony in Paris.

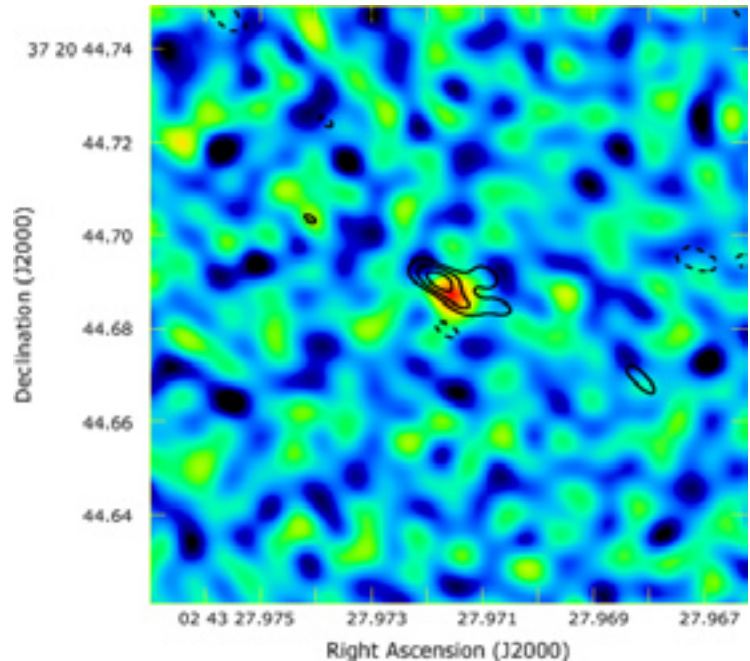
In the course of 2009, e-VLBI became a mature scientific facility. Not only the number of telescopes continued to increase, but also the bandwidth available to user programmes reached the target 1024 Mbps data-rate. With these competitive features, the pressure on the observing opportunities grew, and most notably the number of proposals for the so-called Target-of-Opportunity observations increased, requiring fast allocation of telescopes and correlator facilities. In the middle of 2009, the EXPReS project was formally concluded with a large-scale science and technology conference in Madrid. After that the EXPReS management could wrap up the project and close the books. This was followed by a formal review in which the relevance of EXPReS for the future of radio astronomy, in particular the SKA was high-



Participants of the 8th e-VLBI workshop, Science and Technology of Long Baseline Real-Time Interferometry, in front of the Yebes telescope, which connected to the e-EVN in the course of 2009.

lighted. In these processes new desired features were identified which accumulated in the promising NEXPReS proposal, which was submitted to the EC by JIVE on behalf of fifteen partners by the end of 2009.

Besides the exciting progress with e-VLBI the EVN was also enhanced with the joining of telescopes in Russia and new dishes in China. In order to accommodate the larger number of telescopes and proposed higher bandwidths, JIVE has a strong program to develop more correlator capacity. On the short term, the software correlator program can specifically accommodate more technically demanding proposals by being more flexible for spectral processing and pulsar binning. Originating from JIVE's successful Space applications program, this work matured to the level that JIVE started to implement new hardware to accommodate prospective user proposals. In addition, a large NWO funded program has started to investigate the deployment of FPGA based correlators for both VLBI and applications at ASTRON. This program was boosted by the start of the UniBoard program in the EC funded RadioNet collaboration. In the same program JIVE runs the ALBiUS software project, the EVN access program and contributes to the management activities that are based at ASTRON.

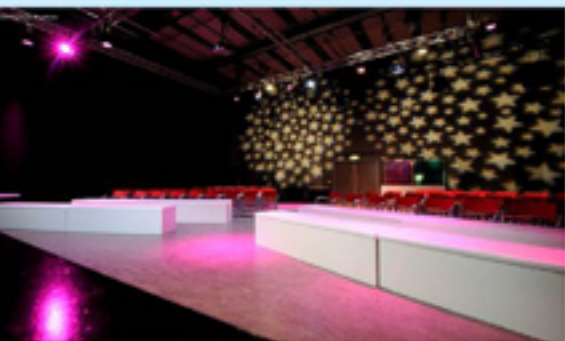


Fast response e-VLBI (colours) and follow-up with high sensitivity VLBI two months later (contours), demonstrate that the weak radio-emission from SN2007gr originates from a rapidly expanding explosion. The observed source evolution indicates that some of the material in this otherwise ordinary normal type Ic supernova must be entrained in relativistic expansion (Paragi et al, Nature. #463, 2010).

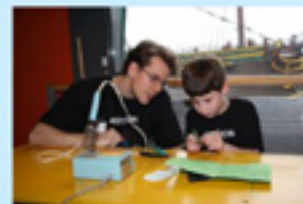
New telescopes, the e-VLBI activities and the advent of new correlator options are a few aspects that impact on the complexity of the operations of the correlator team. Nevertheless, the support group continues to keep up with the recording rate of the EVN and delivers a perfect data-product. The astronomers in the group are also the main source of scientific output at JIVE. By using new, innovative observing options, the way is paved for the user community to deploy new VLBI opportunities for the most exciting astrophysics.



ASTRON



The Clue of the author
 Een boek is het resultaat van een proces van ontdekking en onderzoek. Het is een reis van ideeën naar een verhaal dat de lezer fascineert en inspireert. Het is een reis die vaak jaren duurt en waarbij de auteur zijn best doet om de lezer te betoveren en te raken. Het is een reis die vaak eindigt in een boek dat de wereld verrijkt en de lezer inspireert.



Management and communications

Public relations and outreach

The International Astronomical Union (IAU) launched 2009 as the International Year of Astronomy (IYA2009) under the theme: *The Universe, Yours to Discover*. IYA2009 marks the 400th anniversary of the first astronomical observation through a telescope by Galileo Galilei. It was a global celebration of astronomy and its contributions to society and culture, with a strong emphasis on education, public engagement and the involvement of young people, with events at national, regional and global levels throughout the whole of 2009. The aim of the Year was to stimulate worldwide interest, especially among young people, in astronomy and science under the central theme 'The Universe, Yours to Discover'. ASTRON initiated and participated in many IYA2009 activities.

International year of Astronomy 2009

During 2009, ASTRON organised and participated in regional, national and international activities.



3 April: live webcast during the international Cornerstone Project 100 Hours of Astronomy

The 100 Hours of Astronomy Cornerstone Project was a worldwide event consisting of a wide range of public outreach activities, one of which was the live 24-hour research observatory webcast on 3 April. ASTRON participated in this event with the Westerbork Telescope and the LOFAR telescope. People worldwide could follow, live on the internet, the work of the astronomers at ASTRON in Dwingeloo and hear about their fields of research.

4 and 5 April 2009: the Weekend of the Stars in NEMO, Amsterdam
7,570 people visited the science centre NEMO in Amsterdam on 4 and 5 April 2009. During this Museum weekend, the event called 'Be seduced by the stars' was organised in honour of the International Year of Astronomy 2009. ASTRON participated heavily in this weekend, which marked the biggest event of 2009 for the institute. All weekend, NEMO was freely accessible for everyone to enjoy a



Michiel Brentjens (ASTRON, on the right) was interviewed during a live webcast, organised by the European Southern Observatory.

heavenly programme. People could listen live to pulsars made by ASTRON's Westerbork Telescope. The signals could also be seen on big screens.

Astronomers of ASTRON also showed visitors the new LOFAR telescope. With live observations people could see the spectacular research that can be done with LOFAR.

Another popular activity was the workshop Make your own pulsar, in which children could make their own pulsar and personalise it. The success of this workshop could be seen by the large number of kids walking around in NEMO all weekend with a 'knutselpulsar' in their hand!



Pulsars in the making!



A young boy proudly holds his self-made pulsar.



A girl is concentrating highly on welding her electronic package.



Top & bottom: ASTRON staff show visitors the inner workings of a pulsar.

Besides this, ASTRON organised its famous 'Pretlab' (or Electrolab), where children made their own electronic packages and turn it into a disco light or a broche.

Honorary guest of ASTRON this weekend was Hanny van Arkel, a school teacher from Heerlen and also amateur astronomer. She discovered Hanny's Voorwerp, a mysterious green gas cloud. She explained visitors how to search for objects in the universe and classify them themselves in the GalaxyZoo project.

For very small kids there was also enough to do. On Sunday, the Spacegirls organised a drawing contest. These seven girls, from the



Hanny van Arkel explains Galaxy Zoo to visitors in NEMO.

Nassau College in Assen, participated in the national CanSat project, a space competition for high school students, where they made a satellite out of soda can. In NEMO, the most beautiful colourings were awarded chocolate bunnies, chocolate eggs and, of course, a soda can!



Kids working hard on their drawings during the drawing context in NEMO.

Girlsday 2009

On Thursday 23 April, 33 girls from the 4th year of the high school Nassau College in Assen attended the Girlsday 2009 organised by ASTRON & JIVE. Girlsday is one of the initiatives taken by ASTRON's Diversity Committee to help promote science and technology under young women.



Girls descending from the Dwingeloo Telescope after a tour to show them the inner workings of this national monument.



During Girlsday 2009, two of the Spacegirls showed the inner workings of the CanSat, a satellite in a soda can, they designed themselves.

With all the great help and efforts of ASTRON's Diversity Committee, several people from CAMRAS and the Spacegirls, it was a very successful day for everyone and hopefully we will see some of these girls back as scientists!

From Earth to the Universe

With one of its most eye catching and beautiful images, ASTRON participated in the IYA2009 cornerstone project From Earth to the Universe. With images taken from both ground- and space-based telescopes, From Earth to the Universe (FETTU) showcases the incredible variety of astronomical objects that are known to exist.



The image of NGC6946 shown on the streets in Bolivia.....

FETTU is being shown in non-traditional public venues such as parks and gardens, shopping malls, metro stations and airports in major cities across the world. The FETTU images have been selected for their stunning beauty to engage members of the general public who might normally ignore or avoid astronomy. With short, but informative captions on each panel, FETTU introduces some basics of the science involved once an individual has been drawn to the image. The picture shows the image ASTRON submitted, galaxy ngc6946 in Bolivia and Slovenia.



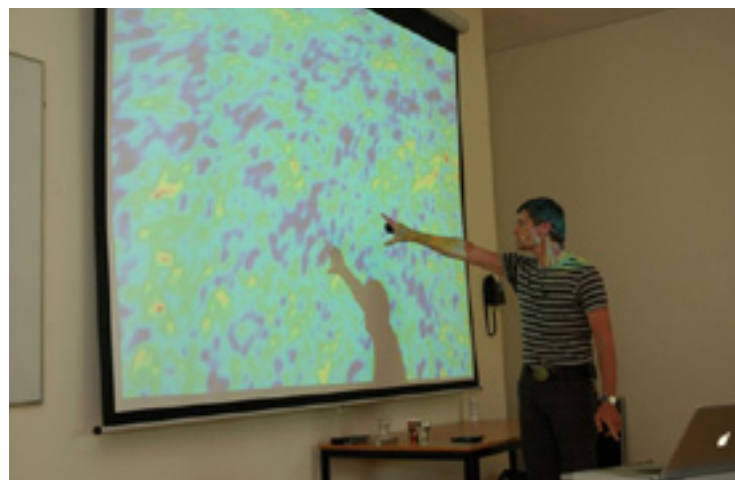
..... and in Slovenia.

The worldwide response to the FETTU project continues to be astounding. As of May 2009, over 55 countries around the world signed to host FETTU exhibits in more than 200 separate locations ranging from Brazil to Bulgaria and from Uruguay to the United States.

ASTRON turned 60 in 2009

In 2009, ASTRON celebrated its 60th anniversary. Although this is not a special 50th or 75th anniversary moment, with IYA2009 in mind, ASTRON marked this occasion with some special colloquia. First up on the list of speakers was the ever-popular Prof. Vincent Icke, professor of theoretical astronomy at Leiden University and a frequent guest on various national TV shows.

The second colloquium organised in honour of ASTRON's birthday presented Prof. Harry van der Laan as speaker. For 60 minutes, Prof Harry van der Laan riveted a spell-bound audience with reminiscences of his 20 years (1967-1987) at the helm of our Foundation, or rather of Dutch astronomy.



Vincent Icke presenting at ASTRON in honour of ASTRON's 60th anniversary.



Prof. Harry van der Laan spoke during the second colloquium of ASTRON's 60th birthday.

Spacegirls blew ASTRON away

During 2009, ASTRON sponsored a very special project: the Spacegirls and their participation in the national CanSat competition for high school students. Seven girls of the Dr. Nassau college in Assen, the Netherlands, also known as the Spacegirls, participated in a Dutch contest called CanSat. In this competition, organised by the Technical University Delft and space agency ISIS (Innovative Solutions In Space), high school teams from all over the Netherlands made a satellite out of a soda can, a 'CanSat'. This CanSat had to perform two missions: it had to determine its height during its flight and it had to land safely. For this second mission the girls designed and made an airbag in the form of a parachute. ASTRON sponsored the seven girls, who were



The Spacegirls on the ASTRON terrace with their trophee, won in the CanSat competition.

also the only all-girls team (including two twins!) participating in the project and eventually won the contest. This was celebrated with a party at ASTRON.

Press releases

Below is an overview of the press releases ASTRON has issued in 2009. The complete press releases, with accompanying high resolution images, can be found on the ASTRON webpages: www.astron.nl.

2 January 2009

SKA essential facility for future of European astronomy

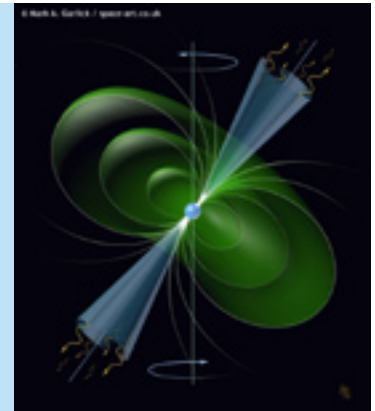
16 January 2009

Westerbork telescope participates in marathon observation

12 February 2009

Three pulsars discovered with the Westerbork radio telescope

*Impression of a pulsar.
Credit: Mark A. Garlick / space-art.
co.uk*



31 March 2009

Ten million euro for RadioNet FP7!

9 April 2009

Over 7500 people visit science centre NEMO during astronomy weekend

Rene Vermeulen, director of the Radio Observatory, explaining aperture array technology to visitors of NEMO.



23 April 2009

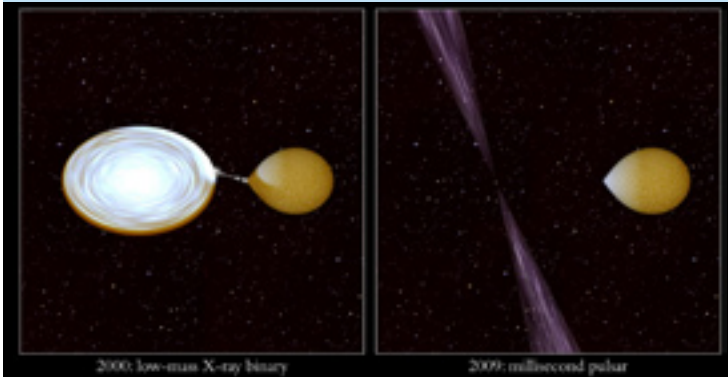
Most distant detection of water in the Universe

*The image is made from Hubble Space Telescope (HST) data and shows the four lensed images of the dusty red quasar, connected by a gravitational arc of the quasar host galaxy. The lensing galaxy is seen in the centre, between the four lensed images.
Credit: John McKean/HST Archive data*



21 May 2009

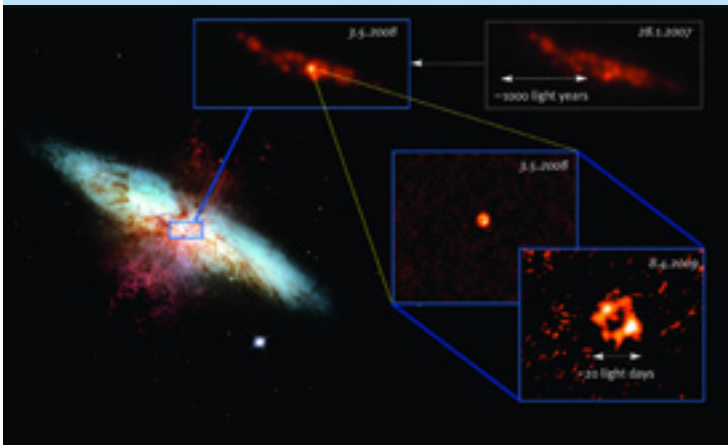
'Missing link' reveals birth of a radio millisecond pulsar



Impression of the radio millisecond pulsar. Credit: Archibald/ van Leeuwen.

28 May 2009

An exploding star in an exploding galaxy



Zooming into the center of the galaxy M82, one of the nearest starburst galaxies at a distance of only 12 Million light years. The left image, taken with the Hubble Space Telescope (HST), shows the body of the galaxy in blue and hydrogen gas breaking out from the central starburst in red. The VLA image (top left) clearly shows the supernova (SN 2008iz), taken in May 2008. The high-resolution VLBI images (lower right) shows an expanding shell at the scale of a few light days and proves the transient source as the result of a supernova explosion in M82.

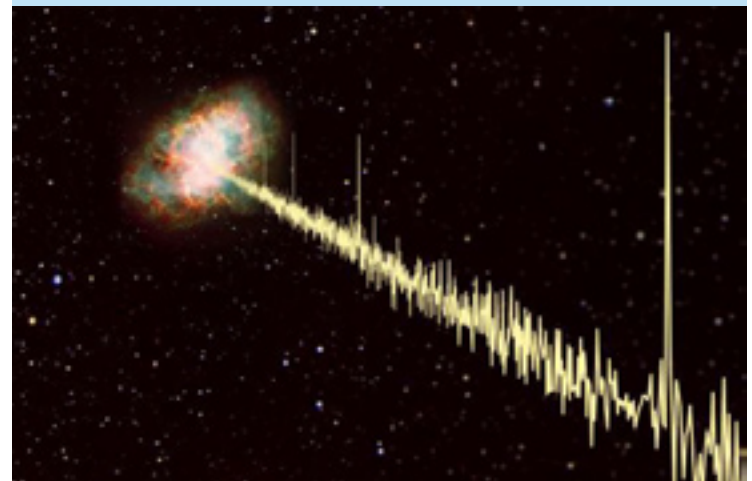
Graphics: Milde Science Communication, HST Image: INASA, ESA, and The Hubble Heritage Team (STScI/AURA); Radio Images: A. Brunthaler, MPIfR.

8 July 2009

Spacegirls win Dutch space competition CanSat

9 July 2009

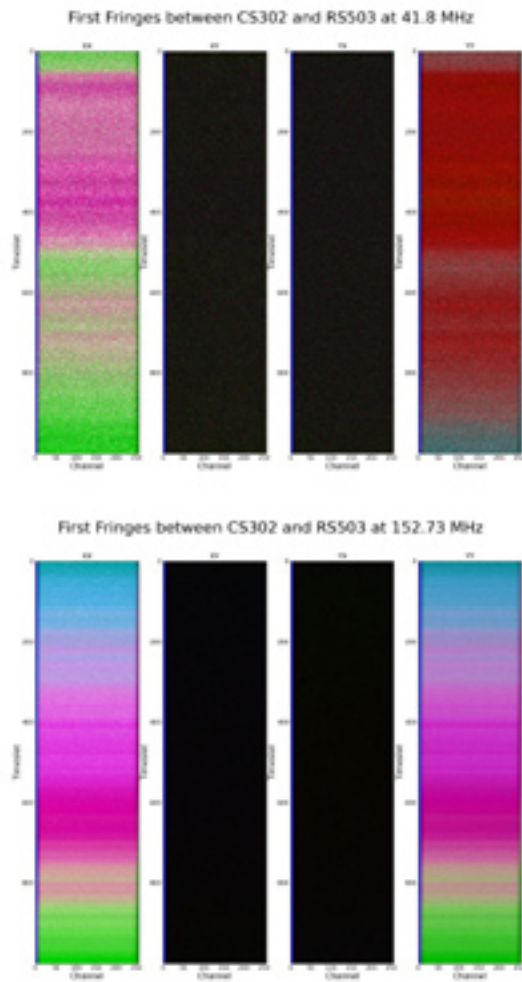
ASTRON astronomers make light work of pulsars!



The remains of the last nearby supernova: a ring of gas and dust, once the outer layers of the old star, but now spun outward. In the middle of this nebula is a radio pulsar. The peaks on the right side are the radio pulses observed by the Westerbork telescope.

20 July 2009

ASTRON's new LOFAR telescope shows first fringes



During the night of July 8/9, a team of ASTRON engineers and astronomers successfully detected correlated radio signals -- fringes -- from the sky with the first three full-scale LOFAR stations. The Low Band Antenna (LBA) stations were pointed at Cygnus A, a very powerful radio source associated with an ultra massive black hole at a distance of approximately 200 Mpc. The team observed the entire frequency band from 30 to 78 MHz at a spectral resolution of 763 Hz. A day later, the experiment was successfully repeated using the High Band Antennas (HBAs) between 120 and 168 MHz resulting in the images seen here. The stations that were used were between 5 and 20 km apart. Once completed, LOFAR will consist of more than 50 stations distributed across Europe with baselines ranging from 30 m up to 1500 km.

2 September 2009

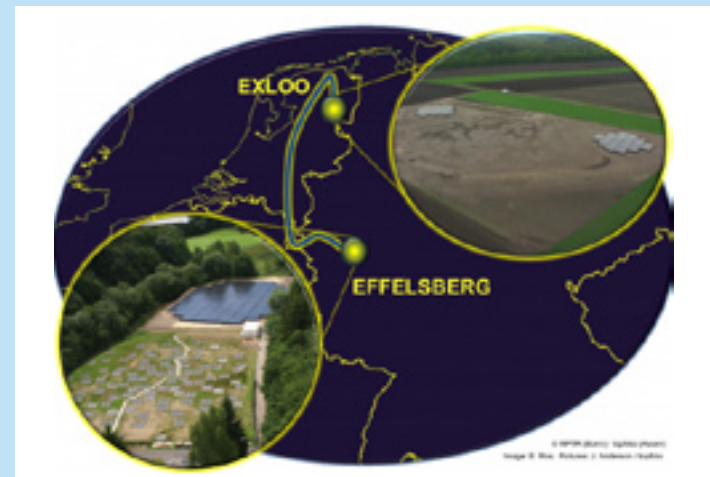
ASTRON creates new nature reserve in Drenthe

9 September 2009

Spacegirls present extraordinary space project at ASTRON

23 September 2009

LOFAR observes across borders



LOFAR stations in Effelsberg, Germany (left) and the Netherlands (right). Credit: MPIfR (Bonn, left) and TopFoto, Assen (right). Image: E. Ros/J. Anderson.

26 October 2009

Over 800 people visited Astronomy Day Dwingeloo

30 October 2009

Special prize for radio astronomy's contribution to WiFi



John O'Sullivan. Credit: Bearcage Productions.

24 November 2009

VIDI grant for ASTRON astronomer Marijke Haverkorn

18 December 2009

LOFAR maps the radio sky at Effelsberg

Major group visits in 2009

- Tue 17 Feb 2009 Students Masterclass University of Groningen (Kapteyn Institute)
- Wed 01 Apr 2009 Recognition of the Veder Award 2009 to CAMRAS
- Mon 06 Apr 2009 Board of the University of Amsterdam
- Wed 08 Apr 2009 Mayor of Midden-Drenthe and council members visit ASTRON
- Wed 06 May 2009 City council of Eemsmond
- Fri 08 May 2009 Dutch society for Space (NVR)
- Fri 15 May 2009 Province of Drenthe and ambassadors worldwide



Prof. Michael Garrett gives a presentation during the ambassador's visit



Dr. Tom Oosterloo explains ambassadors about radio astronomy and the Apertif project

- Tue 26 May 2009 Master of Science students University of Leiden
- Mon 08 Jun 2009 Students of the physics olympiad 2009
- Thu 11 Jun 2009 IYA 2009: primary school kids visit Dwingeloo and Westerbork
- Mon 15 Jun 2009 Environmental federation of Drenthe
- Mon 05 Oct 2009 NOVA Fall school 2009
- Tue 25 Aug 2009 High school students from the Aletta Jacobs College in Hoogezand
- Thu 27 Aug 2009 Neighbourhood union Lhee/Lheebroek
- Tue 01 Sep 2009 Teachers of the Leiden instrument making school
- Fri 11 Sep 2009 Visit of several members of the ministry of Education, Culture and Science: mw. drs. B.J. van den Bergh en dhr. dr. J.A.C. van de Donk
- Wed 07 Oct 2009 Students Hanze Institute of Technology
- Sat 10 Oct 2009 VVD, Senate
- Fri 30 Oct 2009 Hanny van Arkel and local Galaxy Zoo participants visit ASTRON
- Thu 26 Nov 2009 NXP Semiconductors
- Tue 01 Dec 2009 High school students of the Celeanum Gymnasium in Zwolle visit ASTRON



Personnel & Organisation

Diversity

2009 was the year that diversity started to become a significant issue for ASTRON. In a previously held external evaluation one of the main conclusions was that within ASTRON a discrepancy existed between the numbers of male and female scientists and engineers. The evaluation panel also pointed out that ASTRON can and should set an example for the scientific community in the Netherlands in this regard. The board of ASTRON initiated a diversity committee. Their goal was to investigate possibilities to attract more female scientists and engineers.

Examples of diversity committee activities are the Helena Kluyver programme and the Girls day. The Helena Kluyver programme offers financial support to female scientists and engineers so they can visit ASTRON and JIVE for a short period to work in Dwingeloo together with staff from both institutes. Girls day is a programme set up to introduce high school girls to science and engineering through workshops.

In all recruitment the diversity committee has stimulated gender equity by encouraging women to apply and in offering assistance with regard to partner careers amongst others.

The focus of the diversity committee has been expanded to other minority groups as well like handicapped and ethnic minorities. A new aspect of the diversity committee is that young handicapped people are offered the possibility to gain work experience.



High school girls looking at antenna elements during Girlsday 2009

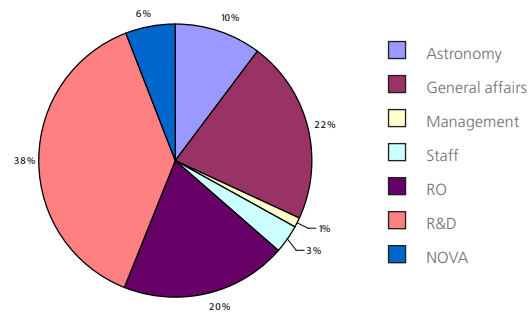
Absenteeism

In 2009 the absenteeism rate was 3,7%. This is an increase compared to 2008 (1,9%), mainly due to a few employees who became ill for a longer period of time.

Number of employees

Department	Number of people
Astronomy	16
General affairs	34
Management	2
Staff	5
Radio Observatory	31
Research & Development	60
NOVA*	9
	157

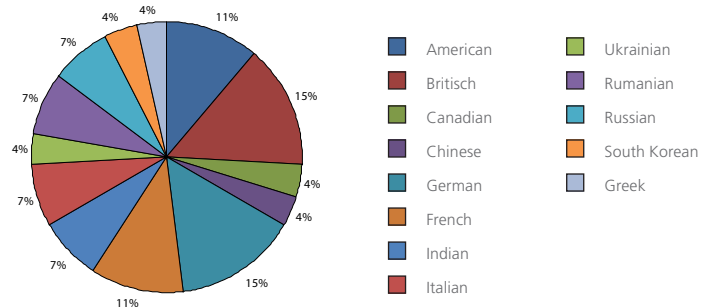
* NOVA is a separate entity but all personnel is employed by ASTRON (NWO)



Note: The staff under NOVA is ASTRON staff working for the NOVA group

Nationalities

ASTRON has 157 staff members. 130 staff members have the Dutch nationality. The 27 foreign employees have thirteen different nationalities.



Financial report 2009

Financial report 2009 compared with 2008.

	2009 Budget	2009 Actual	2009 Difference	2008 Actual
REVENUES				
Government Grants-Ministry of Education, Culture & Science	10,513,857	10,746,857	-233,000	9,782,941
Subsidies / Contributions	3,613,356	7,390,814	-3,777,458	10,625,558
Release to provision	0	1,063,219	-1,063,219	400,467
Other Income	602,500	660,171	-57,671	435,986
Cash management	150,000	78,143	71,857	393,166
<i>Subtotal</i>	<u>14,879,713</u>	<u>19,939,204</u>	<u>-5,059,491</u>	<u>21,638,118</u>
Results Subsidiaries				
Subsidiary ATH	0	0	0	17,393
<i>Subtotal</i>	<u>0</u>	<u>0</u>	<u>0</u>	<u>17,393</u>
Special Income				
Special Income	0	253,127	-253,127	321,077
<i>Subtotal</i>	<u>0</u>	<u>253,127</u>	<u>-253,127</u>	<u>321,077</u>
Total Income	<u>14,879,713</u>	<u>20,192,331</u>	<u>-5,312,618</u>	<u>21,976,588</u>
EXPENDITURES				
Grants / Expenditures				
Operations	25,451,806	26,632,777	1,180,971	31,441,105
Allocation to Projects	-10,176,528	-8,059,883	2,116,645	-9,320,731
<i>Subtotal</i>	<u>15,275,278</u>	<u>18,572,894</u>	<u>3,297,616</u>	<u>22,120,374</u>
Results Subsidiaries				
Subsidiary ATH	0	114,423	114,423	0
<i>Subtotal</i>	<u>0</u>	<u>114,423</u>	<u>114,423</u>	<u>0</u>
Other Expenditures				
Other Expenditures	0	62,974	62,974	290,708
<i>Subtotal</i>	<u>0</u>	<u>62,974</u>	<u>62,974</u>	<u>290,708</u>
Total Expenditures	<u>15,275,278</u>	<u>18,750,291</u>	<u>3,475,013</u>	<u>22,411,082</u>
BALANCE	<u>-395,565</u>	<u>1,442,040</u>	<u>-1,837,605</u>	<u>-434,494</u>

ASTRON/ JIVE colloquia

- Thu 08 Jan 2009 Speaker: **Rowin Meijerink (University of California Berkeley)**
Title: **Chemistry and Excitation of Molecular Gas in the Planetforming Region of Young Circumstellar Disks.**
- Thu 15 Jan 2009 Speaker: **Jason Hessels (ASTRON)**
Title: **Millisecond Pulsars**
- Thu 22 Jan 2009 Speaker: **Chris Ormel (MPIA Heidelberg)**
Title: **The first stages of planet formation: how to grow from small to large**
- Thu 29 Jan 2009 Speaker: **Jim Ulvestad (NRAO)**
Title: **Young Supernovae in Arp 299 and Related Starbursts**
- Thu 05 Feb 2009 Speaker: **Frank Israel (University of Leiden)**
Title: **Centaurus A - the nearest AGN**
- Mon 09 Feb 2009 Speaker: **Marijke Haverkorn (ASTRON)**
Title: **Unraveling the magnetized interstellar medium**
- Thu 05 Mar 2009 Speaker: **Leon Koopmans (University of Groningen)**
Title: **Strong Gravitational Lens Modeling:**
Sub-title: **The Structure & Evolution of Early-type Galaxies to $z=1$ and beyond**
- Thu 12 Mar 2009 Speaker: **Jan David Mol (ASTRON)**
Title: **Load Balancing in Peer-to-Peer Video Distribution**
- Thu 19 Mar 2009 Speaker: **Gemma Janssen (University of Amsterdam)**
Title: **High Precision Radio Pulsar Timing**
- Mon 23 Mar 2009 Speaker: **Andrew Fletcher (Newcastle University)**
Title: **Random fluctuations in the diffuse interstellar medium**
- Thu 02 Apr 2009 Speaker: **Davor Krajnovic (University of Oxford)**
Title: **Internal structure of galaxies along the red sequence**
- Thu 09 Apr 2009 Speaker: **Robert Langenhuisen and Paul Boven (CAMRAS / JIVE)**
Title: **What is happening in our backyard?**
- Thu 16 Apr 2009 Speaker: **Marcel ter Brake (University of Twente)**
Title: **Cryo-cooling developments at UT, relevant to Astronomy**
- Thu 23 Apr 2009 Speaker: **Martin Asplund (Max-Planck-Institute for Astrophysics, Garching)**
Title: **The surprising Sun: Does the Sun have a sub-solar metallicity?**
- Tue 12 May 2009 Speaker: **Vincent Icke (Universiteit Leiden)**
Title: **Kosmologie op ASTRONs 120ste verjaardag**
Sub-title: **Colloquium ter ere van 60 jarig bestaan ASTRON:**
- Tue 19 May 2009 Speaker: **Amir Leshem (Bar-Ilan University)**
Title: **Array processing and its application to radio astronomy**
- Thu 28 May 2009 Speaker: **Pascal Wolkotte (University of Twente)**
Title: **An Automated Design-flow for FPGA-based Sequential Simulation**
Location:
- Tue 09 Jun 2009 Speaker: **Michael Kramer (Univ. Manchester/Max-Planck-Inst. for RA Bonn)**
Title: **Studying Fundamental Physics with Radio Astronomy**
- Thu 11 Jun 2009 Speaker: **Harry van der Laan (Leiden/ESO/Utrecht)**
Title: **SRZM 1967 - 1987 Exciting but turbulent years**
Sub-title: **2e colloquium ter ere van 60 jarig bestaan ASTRON**
- Thu 18 Jun 2009 Speaker: **Rens Waters (University of Amsterdam)**
Title: **The direct detection of exo-planets**
- Thu 25 Jun 2009 Speaker: **Georg Fischer (Institut für Weltraumforschung, Graz)**
Title: **Five years of Saturn lightning observations with Cassini**
- Thu 02 Jul 2009 Speaker: **Lyndsay Fletcher (Glasgow University)**
Title: **Energy release and particle acceleration in solar flares and coronal mass ejections**
- Wed 26 Aug 2009 Speaker: **Peter Hofstee (IBM Austin Research laboratory, STI design center)**
Title: **The next 25 years of computer architecture?**
- Thu 03 Sep 2009 Speaker: **Anne-Marie Weijmans (Universiteit Leiden)**
Title: **Dark matter in early-type galaxies: mapping dark haloes with integral-field spectrography**
- Tue 08 Sep 2009 Speaker: **Miguel de Avillez (University of Evora)**
Title: **High-Resolution Modelling of the Interstellar Medium in Spiral Galaxies**
- Thu 10 Sep 2009 Speaker: **The Spacegirls**
Title: **De spacegirls en de CanSat competitie**
- Tue 15 Sep 2009 Speaker: **Doug Johnstone (Herzberg Institute of Astrophysics)**
Title: **Contemplating the Low Mass Star Formation Road Map to ALMA**

- Thu 24 Sep 2009 Speaker: **Naomi McClure-Griffiths (ATNF)**
 Title: **GASS in the lower Milky Way halo**
- Thu 08 Oct 2009 Speaker: **Helmut Lammer (Institut für Weltraumforschung, Graz)**
 Title: **Determining the mass loss limit for close-in exoplanets**
- Thu 15 Oct 2009 Speaker: **Tobia Carozzi (University of Glasgow)**
 Title: **Aspects of precision polarimetry in radio astronomy**
- Tue 27 Oct 2009 Speaker: **Sander Weinreb (California Institute of Technology)**
 Title: **Wideband Very Low Noise Amplifiers and Antenna Feeds**
- Thu 29 Oct 2009 Speaker: **Mehreen Mahmud (JIVE)**
 Title: **Searching for Helical Magnetic Fields in Active Galactic Nuclei**
- Thu 05 Nov 2009 Speaker: **Alexi Glover (ESA/ESTEC)**
 Title: **Space Weather: An Applications Perspective**
- Thu 12 Nov 2009 Speaker: **Anna L. Watts (University of Amsterdam)**
 Title: **Stars under stress - new results from neutron star seismology**
- Thu 19 Nov 2009 Speaker: **Paola di Matteo (Observatoire de Paris)**
 Title: **Galaxy interactions and their impact on the observed properties of galaxies**
- Thu 26 Nov 2009 Speaker: **Roy Smits (University of Manchester/ ASTRON)**
 Title: **Pulsar science with the SKA**
- Thu 03 Dec 2009 Speaker: **Wouter Vlemmings (Argelander Institut, Bonn)**
 Title: **Maser measurements of magnetic fields during Massive Star-formation**
- Thu 10 Dec 2009 Speaker: **Alan Harris (DLR Berlin-Adlershof)**
 Title: **The Astrobiological Implications of Near-Earth Asteroids**
- Tue 15 Dec 2009 Speaker: **Valeriu Tudose (ASTRON)**
 Title: **The disc-jet coupling in X-ray binary systems**



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Publications 2009

Astronomy Group and Radio Observatory

Astronomical publications in refereed journals 2009

1. O. Scholten, S. Buitink, J. Bacelar, R. Braun, **A. G. de Bruyn, H. Falcke**, K. Singh, B. Stappers, **R. G. Strom**, R. Al Yahyaoui: *Improved Flux Limits for Neutrinos with Energies above 10^{22} eV from Observations with the Westerbork Synthesis Radio Telescope*, 2009, Physical Review Letters, 103, 191301
2. J. S. Deneva, J. M. Cordes, M. A. McLaughlin, D. J. Nice, D. R. Lorimer, F. Crawford, N. D. R. Bhat, F. Camilo, D. J. Champion, P. C. C. Freire, S. Edel, **V. I. Kondratiev, J. W. T. Hessels**, F. A. Jenet, L. Kasian, V. M. Kaspi, M. Kramer, P. Lazarus, S. M. Ransom, I. H. Stairs, B. W. Stappers, **J. van Leeuwen**, A. Brazier, A. Venkataraman, J. A. Zollweg, S. Bogdanov: *Arecibo Pulsar Survey Using ALFA: Probing Radio Pulsar Intermittency And Transients*, 2009, Astrophysical Journal, 703, 2259-2274
3. Anne M. Archibald, Ingrid H. Stairs, Scott M. Ransom, Victoria M. Kaspi, **Vladislav I. Kondratiev**, Duncan R. Lorimer, Maura A. McLaughlin, Jason Boyles, **Jason W. T. Hessels**, Ryan Lynch, **Joeri van Leeuwen**, Mallory S. E. Roberts, Frederick Jenet, David J. Champion, Rachel Rosen, Brad N. Barlow, Bart H. Dunlap, Ronald A. Remillard: *A Radio Pulsar/X-ray Binary Link*, 2009, Science, 324, 1411-
4. J.L. Donovan, **P. Serra**, J. H. van Gorkom, S. C. Trager, **T. Oosterloo**, J. E. Hibbard, **R. Morganti**, D. Schiminovich, J. M. van der Hulst: *ESO 381 - 47: An Early-Type Galaxy with Extended H I and a Star-Forming Ring*, 2009, Astronomical Journal, 137, 5037-5056
5. **G. I. G. Józsa, M. A. Garrett, T. A. Oosterloo**, H. Rampadarath, Z. Paragi, H. van Arkel, C. Lintott, W. C. Keel, K. Schawinski, E. Edmondson: *Revealing Hanny's Voorwerp: radio observations of IC 2497*, 2009, Astronomy and Astrophysics, 500, L33-L36
6. **G. I. G. Józsa, T. A. Oosterloo, R. Morganti**, U. Klein, T. Erben: *Kinematic modeling of disk galaxies. III. The warped "Spindle" NGC 2685*, 2009, Astronomy and Astrophysics, 494, 489-508
7. **V. Tudose**, J. C. A. Miller-Jones, R. P. Fender, Z. Paragi, C. Sakari, A. Szostek, **M. A. Garrett**, V. Dhawan, A. Rushton, R. E. Spencer, M. van der Klis: *Probing the behaviour of the X-ray binary Cygnus X-3 with very long baseline radio interferometry*, 2009, Monthly Notices of the Royal Astronomical Society, , 1682
8. **R. Morganti**, A. B. Peck, **T. A. Oosterloo**, G. van Moorsel, A. Capetti, R. Fanti, P. Parma, H. R. de Ruiter: *Is cold gas fuelling the radio galaxy NGC 315?*, 2009, Astronomy and Astrophysics, 505, 559-567
9. Geraint Harker, Saleem Zaroubi, Gianni Bernardi, **Michiel A. Brentjens, A. G. de Bruyn**, Benedetta Ciardi, Vibor Jelic, Leon V. E. Koopmans, Panagiotis Labropoulos, Garrelt Mellema, André Offringa, V. N. Pandey, Joop Schaye, Rajat M. Thomas, Sarod Yatawatta: *Non-parametric foreground subtraction for 21-cm epoch of reionization experiments*, 2009, Monthly Notices of the Royal Astronomical Society, 397, 1138-1152
10. B. H. C. Emonts, C. N. Tadhunter, **R. Morganti, T. A. Oosterloo**, J. Holt, E. Brogt, G. van Moorsel: *The disc-dominated host galaxy of FR-I radio source B2 0722+30*, 2009, Monthly Notices of the Royal Astronomical Society, 396, 1522-1536
11. G. B. Taylor, P. Charlot, **R. C. Vermeulen, N. Pradel**: *Monitoring the Bidirectional Relativistic Jets of the Radio Galaxy 1946+708*, 2009, Astrophysical Journal, 698, 1282-1291
12. H. Rampadarath, **M. A. Garrett, A. Polatidis**: *Observations of 44 extragalactic radio sources with the VLBA at 92 cm. A list of potential calibrators and targets for LOFAR and RadioAstron*, 2009, Astronomy and Astrophysics, 500, 1327-1336
13. G. Bernardi, **A. G. de Bruyn, M. A. Brentjens**, B. Ciardi, G. Harker, V. Jelic, L. V. E. Koopmans, P. Labropoulos, A. Offringa, V. N. Pandey, J. Schaye, R. M. Thomas, S. Yatawatta, S. Zaroubi: *Foregrounds for observations of the cosmological 21 cm line. I. First Westerbork measurements of Galactic emission at 150 MHz in a low latitude field*, 2009, Astronomy and Astrophysics, 500, 965-979
14. A. More, **J. P. McKean**, S. More, R. W. Porcas, L. V. E. Koopmans, **M. A. Garrett**: *The role of luminous substructure in the gravitational lens system MG 2016+112*, 2009, Monthly Notices of the Royal Astronomical Society, 394, 174-190
15. Geraint J. A. Harker, Saleem Zaroubi, Rajat M. Thomas, Vibor Jelic, Panagiotis Labropoulos, Garrelt Mellema, Ilian T. Iliev, Gianni Bernardi, **Michiel A. Brentjens, A. G. de Bruyn**, Benedetta Ciardi, Leon V. E. Koopmans, V. N. Pandey, Andreas H. Pawlik, Joop Schaye, Sarod Yatawatta: *Detection and extraction of signals from the epoch of reionization using higher-order one-point statistics*, 2009, Monthly Notices of the Royal Astronomical Society, 393, 1449-1458
16. **R. Morganti**, B. Emonts, **T. Oosterloo**: *Broad H I absorption in the candidate binary black hole 4C37.11 (B2 0402+379)*, 2009, Astronomy and Astrophysics, 496, L9-L12
17. Rajat M. Thomas, Saleem Zaroubi, Benedetta Ciardi, Andreas H. Pawlik, Panagiotis Labropoulos, Vibor Jelic, Gianni Bernardi, **Michiel A. Brentjens, A. G. de Bruyn**, Geraint J. A. Harker, Leon V. E. Koopmans, Garrelt Mellema, V. N. Pandey, Joop Schaye, Sarod Yatawatta: *Fast large-scale reionization simulations*, 2009, Monthly Notices of the Royal Astronomical Society, 393, 32-48
18. **R. Morganti**, R. Emonts, J. Holt, C. Tadhunter, **T. Oosterloo, C. Struve**: *Gas and stars in compact (young) radio sources*, 2009, Astronomische Nachrichten, 330, 233

19. **V. Tudose**, R. P. Fender, M. Linares, D. Maitra, M. van der Klis: *The disc-jet coupling in the neutron star X-ray binary Aquila X-1*, 2009, Monthly Notices of the Royal Astronomical Society, 400, 2111-2121
20. K. Kovac, **T. Oosterloo**, J. M. van der Hulst: *A blind HI survey in the Canes Venatici region*, 2009, Monthly Notices of the Royal Astronomical Society, 400, 743-765
21. J. Holt, C. N. Tadhunter, **R. Morganti**: *The ionization of the emission-line gas in young radio galaxies*, 2009, Monthly Notices of the Royal Astronomical Society, 400, 589-602
22. C. C. Kirkpatrick, M. Gitti, K. W. Cavagnolo, B. R. McNamara, L. P. David, P. E. J. Nulsen, **M. W. Wise**: *Direct Evidence for Outflow of Metal-Enriched Gas Along the Radio Jets of Hydra A*, 2009, Astrophysical Journal, 707, L69-L72
23. D. Maitra, S. Markoff, **H. Falcke**: *A time-dependent jet model for the emission from Sagittarius A**, 2009, Astronomy and Astrophysics, 508, L13-L16
24. C. Fedeli, **A. Berciano Alba**: *On the abundance of gravitational arcs produced by submillimeter galaxies at radio and submm wavelengths*, 2009, Astronomy and Astrophysics, 508, 141-160
25. M. A. Pérez-Torres, C. Romero-Cañizales, A. Alberdi, **A. Polatidis**: *An extremely prolific supernova factory in the buried nucleus of the starburst galaxy IC 694*, 2009, Astronomy and Astrophysics, 507, L17-L20
26. R. F. Pizzo, **A. G. de Bruyn**: *Radio spectral study of the cluster of galaxies Abell 2255*, 2009, Astronomy and Astrophysics, 507, 639-659
27. **M. Serylak**, B. W. Stappers, P. Weltevrede: *S2DFS: analysis of temporal changes of drifting subpulses*, 2009, Astronomy and Astrophysics, 506, 865-874
28. Paolo Soleri, **Valeriu Tudose**, Rob Fender, Michiel van der Klis, Peter G. Jonker: *Linking jet emission and X-ray properties in the peculiar neutron star X-ray binary Circinus X-1*, 2009, Monthly Notices of the Royal Astronomical Society, 399, 453-464
29. **R. Smits**, D. R. Lorimer, M. Kramer, R. Manchester, B. Stappers, C. J. Jin, R. D. Nan, D. Li: *Pulsar science with the Five hundred metre Aperture Spherical Telescope*, 2009, Astronomy and Astrophysics, 505, 919-926
30. H.-R. Klöckner, A. Martínez-Sansigre, S. Rawlings, **M. A. Garrett**: *High-redshift obscured quasars: radio emission at sub-kiloparsec scales*, 2009, Monthly Notices of the Royal Astronomical Society, 398, 176-188
31. **V. I. Kondratiev**, M. A. McLaughlin, D. R. Lorimer, M. Burgay, A. Possenti, R. Turolla, S. B. Popov, S. Zane: *New Limits on Radio Emission from X-ray Dim Isolated Neutron Stars*, 2009, Astrophysical Journal, 702, 692-706
32. J. Abraham, ..[126 authors collapsed].., **H. Falcke** and [345 authors collapsed] : *Atmospheric effects on extensive air showers observed with the surface detector of the Pierre Auger observatory*, 2009, Astroparticle Physics, 32, 89-99
33. J. Welch, D. Backer, L. Blitz, D. C.-J. Bock, G. C. Bower, C. Cheng, S. Croft, M. Dexter, G. Engargiola, E. Fields, J. Forster, C. Gutierrez-Kraybill, C. Heiles, T. Helfer, S. Jorgensen, G. Keating, J. Lugten, D. MacMahon, O. Milgrome, D. Thornton, L. Urry, **J. van Leeuwen**, D. Werthimer, P. H. Williams, M. Wright, J. Tarter, R. Ackermann, S. Atkinson, P. Backus, W. Barott, T. Bradford, M. Davis, D. Deboer, J. Dreher, G. Harp, J. Jordan, T. Kilsdonk, T. Pierson, K. Randall, J. Ross, S. Shostak, M. Fleming, C. Cork, A. Vitouchkine, N. Wadefalk, S. Weinreb: *The Allen Telescope Array: The First Widefield, Panchromatic, Snapshot Radio Camera for Radio Astronomy and SETI*, 2009, IEEE Proceedings, 97, 1438-1447
34. **G. Heald**, R. Braun, R. Edmonds: *The Westerbork SINGS survey. II Polarization, Faraday rotation, and magnetic fields*, 2009, Astronomy and Astrophysics, 503, 409-435
35. P. Soleri, S. Heinz, R. Fender, R. Wijnands, **V. Tudose**, D. Altamirano, P. G. Jonker, M. van der Klis, L. Kuiper, C. Kaiser, P. Casella: *A parsec scale X-ray extended structure from the X-ray binary Circinus X-1*, 2009, Monthly Notices of the Royal Astronomical Society, 397, L1-L5
36. M. A. Walker, **A. G. de Bruyn**, H. E. Bignall: *Extremely anisotropic scintillations*, 2009, Monthly Notices of the Royal Astronomical Society, 397, 447-452
37. **Richard Strom**, Marteen Roos, Pieter-Rim de Kroon: *DVD review: Barred Spiral - De Melkweg Ontrafeld (Roos and de Kroon)*, 2009, Journal of Astronomical History and Heritage, 12, 171-171
38. J. Abraham, ..[122 authors collapsed].., **H. Falcke** and [336 authors collapsed] : *Upper limit on the cosmic-ray photon fraction at EeV energies from the Pierre Auger Observatory*, 2009, Astroparticle Physics, 31, 399-406
39. A. Horneffer, L. Bähren, S. Buitink, **H. Falcke**, J. R. Hörandel, J. Kuijpers, S. Lafebre, A. Nigl, O. Scholten, K. Singh: *Air shower measurements with LOFAR*, 2009, Nuclear Instruments and Methods in Physics Research A, 604, 20
40. K. Dodds-Eden, D. Porquet, G. Trap, E. Quataert, X. Haubois, S. Gillissen, N. Grosso, E. Pantin, **H. Falcke**, D. Rouan, R. Genzel, G. Hasinger, A. Goldwurm, F. Yusef-Zadeh, Y. Clenet, S. Trippe, P.-O. Lagage, H. Bartko, F. Eisenhauer, T. Ott, T. Paumard, G. Perrin, F. Yuan, T. K. Fritz, L. Mascetti: *Evidence for X-Ray Synchrotron Emission from Simultaneous Mid-Infrared to X-Ray Observations of a Strong Sgr A* Flare*, 2009, Astrophysical Journal, 698, 676-692

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44. Peter L. Biermann, Julia K. Becker, Laurentiu Caramete, Alex Curutiu, Ralph Engel, **Heino Falcke**, László Á. Gergely, P. Gina Isar, Ioana C. Maris, Athina Meli, Karl-Heinz Kampert, Todor Stanev, Oana Tascu, Christian Zier: *Active Galactic Nuclei: Sources for ultra high energy cosmic rays?*, 2009, *Nuclear Physics B Proceedings Supplements*, 190, 61-78
45. Sebastian Jester, **Heino Falcke**: *Science with a lunar low-frequency array: From the dark ages of the Universe to nearby exoplanets*, 2009, *New Astronomy Review*, 53, 1-26
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