

# ASTRON

*Annual Report 2005-2006*



ASTRON

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## Preface

Once every six years our parent organization, the Netherlands Organisation for Scientific Research (NWO), carries out an “existential” evaluation of its scientific institutes. The year 2005 was such a year for ASTRON. On June 6th and 7th an international panel of experts under the chairmanship of Jos Engelen, Chief Scientific Officer and Deputy Director-General at CERN, visited Dwingeloo to see our activities first hand and pass judgment on the quality of our program. At the end of the summer, we were most pleased to receive an overall evaluation of EXCELLENT.

ASTRON management and board defined a set of priorities for the coming six years. Highest priority will be to ensure that our new radio telescope, LOFAR, is properly completed and commissioned, and that the scientific exploitation of the facility is adequately financed and supported. High priority is given to preparations for the Square Kilometre Array radio telescope, both as regards technology development and the international organization of the project. Next, equal priorities will be to strengthen our optical instrumentation program, and to continue harvesting scientific results with the Westerbork radio telescope and JIVE.

The LOFAR project is in the design and development phase. Most sub-systems had been prototyped and during the year, they could be subjected to critical sub-system design reviews. Even scientific results using prototype hardware could be reported, including a Nature paper by H. Falcke and collaborators demonstrating that ultra-high energy cosmic rays can be studied effectively with LOFAR. Our collaboration with IBM Research took a big step forward with the delivery and successful commissioning of the 12000 processor BlueGene/L central computing machine. The Province of Drenthe formally put the telescope into its land use planning documents, and then, to acquire the necessary 320 ha of ground for the central core of antennas, we arranged one of the largest land reallocation procedures in many years

in the north-east Netherlands. The EADS-Space company approached us about using LOFAR as a platform for testing ideas about a mission to place a similar kind of radio telescope on the Moon. LOFAR will be a research facility not only for astronomy, but also for applications in geophysics, precision agriculture and other areas for which a wide-area sensor network will provide innovative research possibilities. Each of the applications communities is investing substantial funds in the project. To ensure transparent decision-making, and to facilitate future commercial applications, a formal limited partnership (commanditaire vennootschap) was formed, with a separate LOFAR foundation as a managing body.

ASTRON was increasingly successful in technology transfer and valorization. AstroTec, our wholly owned holding company, set up a joint venture to bring our sensor networking technologies to market in the area of fire prevention systems. The ministry of Economic Affairs recognized the intelligent sensor networks involved in LOFAR as a “Peak in the Delta”. Consequently, ASTRON participated in several regional initiatives, in particular IDL Sensor Solutions and Sensor Universe, to further strengthen this peak. Our importance to the regional economy was given a prominent place in the policy planning document “Strategic Agenda for North Netherlands 2007-2013”.

The Square Kilometre Array radio telescope project has been conceived as a global cooperation. It received a major boost during the past two years as a formal, €38M design study got under way. The effort is being led by ASTRON and is being financed by the European Commission together with 29 organizations in 11 countries, making it very much a global collaboration. To ensure its management would receive the expert attention required, Arnold van Ardenne, previously ASTRON director R&D, agreed to guide the project through to its completion in 2009. Marco de Vos, previously system engineering manager for LOFAR, took over as director R&D.



In recognition of our role in promoting European astronomy, the European Commission selected JIVE (hosted by ASTRON) for a Europe-wide media event, held on July 6 and 7, 2005. Press from across the continent visited Dwingeloo and the Westerbork telescope, learned about the various cooperative networks in astronomy financed by the Commission, and heard presentations about the three flagship projects of the community: the Square Kilometre Array radio telescope, the Extremely Large (optical-IR) Telescope and the astroparticle physics facility, Km<sup>3</sup>Net. The assembled guests were also treated to a demonstration of e-VLBI and to speeches on science policy from Euro-Commissioner for Research, Janez Potočnik, and from our own Minister Maria van der Hoeven.

Our program of optical-IR instrumentation involves collaborations with other European institutes to design and build frontier instruments for the most powerful telescopes in the world. We were involved in instrumentation projects in every stage of development: The VISIR mid-IR imager and spectrometer moved into routine science operation on the ESO Very Large Telescope; X-Shooter, a high-efficiency echelle spectrograph for the VLT that provides an exceptionally wide spectral coverage in a single integration, completed its detailed design and development phase and was prepared for manufacture; the Mid-IR Instrument (MIRI) for the James Webb Space Telescope moved into the phase of detailed design and development; and we participated in a conceptual design study for a future mid-IR instrument, christened MIDIR, for the planned European Extremely Large Telescope. Our astronomical research program focuses on use of the Westerbork Synthesis Radio Telescope but covers a very broad range of topics. During 2005-2006, studies were completed of the faint end of the galaxy luminosity function to test the predictions of the Cold-Dark-Matter scenario for large scale structure formation in the early

universe; the predicted cosmic web filament between M<sub>31</sub> and M<sub>33</sub> was imaged for the first time in neutral hydrogen; the diffusion of cosmic rays in galaxies was investigated by comparing WSRT and Spitzer satellite data; previously undetected outflows of energy from both galactic black holes and active galactic nuclei were discovered and shown to be of significance to the energy budgets of such systems; a new technique called rotation measure synthesis was developed and used to investigate the intergalactic medium in the Perseus cluster of galaxies; glitches in slow pulsars and sub-pulse drifting in pulsars were brought into focus with unprecedented sensitivity; etc. Other studies included a direct determination using VLBI techniques of the distance and proper motion of the M<sub>33</sub> galaxy, and extensive theoretical simulations were made of proposed observations with LOFAR in the new discipline of astroparticle physics. The annual report before you tries to provide a comprehensive overview of ASTRON's activities in 2005-2006. As we did last year, we choose a conversational style of presentation that we hope conveys to the general reader both the excitement of our program and its increasing breadth.

Prof. dr. Harvey Butcher, Director

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Rob van den Berg

## 1. Research and Development

### The new face of R&D

Listen to Marco de Vos talking about research at ASTRON, and you cannot help getting excited about astronomical research and its myriad of possibilities. In a way this is what you might expect from the new head of the R&D laboratory, a position he took over from Arnold van Ardenne in July 2005. After having worked on LOFAR for many years, developing its highperformance computing infrastructure, he has now become responsible for the whole of ASTRON's R&D – although his frequent mentioning of LOFAR makes it abundantly clear that he still has a soft spot for this project. When I ask him about his new responsibility, he immediately refers to ASTRON's mission: "To enable astronomical discoveries by supplying innovative technology. In R&D we have to look ahead. The wonderful thing about astronomy is that it pushes technology to its limits: astronomy makes things happen."

Judging from the R&D website, most of the work occurs within the scope of some project, often with a fancy acronym like PHAROS, X-SHOOTER and MASSIVE. Sitting in his office the new R&D director explains what development path is followed by each of these projects, and especially how they come about: "Smaller projects are the responsibility of the scientists and project leaders. In that case the management team only checks whether it fits into the overall programme, and whether we want to make a commitment to match any external funds. Sometimes there is a specific scientific problem that needs to be solved, for instance by developing a new instrument. In that case we rather speak of r&D, with a small r and a large D. Then there are the so-called *enabling technologies*, which represent research with a clear eye to the future. These are much more risky – often long shots – but also that kind of research neatly fits ASTRON's mission." De Vos: "Finally, we have *Technology Transfer* projects, a relatively recent development, where we

apply existing technologies to other areas or for commercial purposes. Politicians really value technology transfer, especially here in the northern part of the Netherlands. In this way others can make use of our knowledge, which is great. In 2005, a wireless sensor network was set up together with the Agricultural University in Wageningen to monitor relative humidity and temperature at 150 positions in a potato field. This information will allow farmers to better guard their crops against fungous diseases." Technology transfer also benefits from so-called *innovation vouchers*, where small companies get the opportunity to farm out an R&D problem at a major research institution: a great stimulus for innovation. But ASTRON also stands to benefit in another way. De Vos: "By establishing relationships with (local) companies, we create the opportunity to mass produce critical parts for our big projects and thus reduce investment costs and increase reliability. A project like SKA can only survive when we cooperate with industry."

Developing a project is a constant struggle to fit the available budget with the requirements. Even for a Big Science project like LOFAR, initial budgets were small, but as the project grows, funding should follow, and once it reaches maturity, a sudden switch occurs and the whole organisation gets involved. De Vos: "LOFAR really was a prime example of how this process can and should be handled." Also in 2005, ASTRON submitted a seven million euro NWOgroot proposal for APERTIF (*APERTure Tile In Focus*), a project to develop focal plane arrays. De Vos: "They really represent state-of-the-art technology development in receiver and antenna design. They allow us to increase the survey capacity of the WSRT, and at the same time they act as a pathfinder facility at GHz frequencies for SKA. We want to lift the technology from the concept stage to a level where we have a sound understanding of all elements of the system." Even though the board of NWO has not officially made a decision, the signs are positive and

De Vos acknowledges that he has put the champagne on ice: "But the cork is still on!", he hastens to add.

De Vos: "It would be wrong, though, to only consider ASTRON's project portfolio, we are also a knowledge organisation. In that sense we rely heavily on the dedication of the close to hundred people that work in R&D. When I started this job, I went by everyone to learn about people's motivation, to find out what drives them. Partly it is astronomy, which is a fascinating science, but also the work itself should be interesting; people should get the opportunity and time to carefully study a problem down to its smallest details. My main priority therefore, is to enable them to keep on developing their knowledge, because only in that way can we work on technologies which lie ten years ahead. A large involvement in technology transfer projects may be good for fund raising, but would adversely affect the knowledge build-up. That is the balancing act we face, as 'only' one quarter of our funding is guaranteed by NWO." It certainly requires a tight focus on strategy and planning. De Vos: "Within the management team we have to decide which projects should be pushed ahead. Another priority I have set myself is to get a better control on scope changes in projects. Things never go as planned, so changes are inevitable. But by better analysing risk in the various stages of a project you can make it easier to take decisions and ultimately you may prevent undesirable budget overruns."

*Early 2006, corks were unscrewed as NWO granted 5 million euro to the APERTIF project. Design activities are well underway, and a first prototype (appropriately called Digestif) will be in operation at the WSRT in mid-2007.*

In the years 2005 and 2006, the R&D division had an unprecedented load of activities. The radio portfolio was still dominated by LOFAR when the developments for the Square Kilometre Array Design Study (SKADS) were rapidly ramping up. By the end of 2006, LOFAR had successfully completed its subsystem Critical Design Reviews and was getting initial results from the first Core Station (CS1). The SKADS team had produced the first aperture array tile for the EMBRACE demonstrator and was completing the design for the ten-tile prototype. Both LOFAR and SKADS are important stepping stones towards an aperture array solution for the mid-frequencies of the Square Kilometer Array. SKADS will demonstrate the feasibility of this architecture in terms of noise and cost figures. LOFAR plays an important role in demonstrating the calibratability of aperture arrays. The calibration of the LOFAR station data, which was successfully demonstrated at the LOFAR Calibration Review, is also a major step forward in providing the evidence that aperture arrays can be calibrated to a sufficient dynamic range.

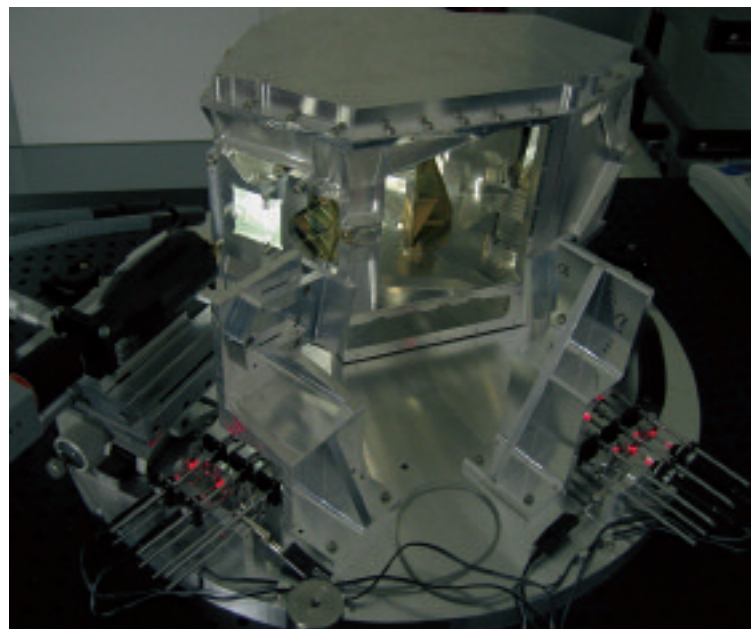
The program on Focal Plane Array (FPA) systems, which is complementary to the aperture array studies, culminated in the APERTIF proposal. The aim of APERTIF is to provide the WSRT telescopes with FPA front-ends, thus dramatically increasing their survey capabilities. A significant amount of APERTIF funding was granted in 2006 in the NWO-G program. APERTIF build on the experience in earlier a projects (FARADAY, PHAROS). In addition to the science case, it will allow us to establish the merits of Focal Plane Array technology for the SKA.

In the optical portfolio, two large projects MIRI and XShooter were proceeding in parallel. Both projects operate in a complex international environment, and passed important milestones in the course of 2005 and 2006. Both projects are scheduled for completion in 2007.

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In 2006, NOVA and NWO-M granted funding for the polarimetric imager for SPHERE (the Spectro-Polarimetric High-contrast Exoplanet REsearch instrument, a second generation instrument for the VLT). SPHERE consists in an extreme adaptive optics common path including a coronagraphic unit and feeding three focal instruments: an infrared dual beam imager with spectroscopic capabilities (IRDIS), an infrared integral field spectrograph (IFS) and a visible polarimetric imager (ZIMPOL). ASTRON will work on the design and production of ZIMPOL. ASTRON also contributed to pre-studies for a mid-infrared spectrometer, MIDIR, for the Extremely Large Telescope. A consortium of Dutch astronomical institutes and industrial parties was invited to submit a proposal for MIDIR related research in the SmartMix program.

As LOFAR moves into roll-out phase, the R&D division will increasingly put the focus on the SKA. ASTRON will make a significant contribution to the SKA Preparatory Phase study, expected to be submitted to the EC in early 2007. The main focus will be on innovative Wide- Field-of-View front-ends for the SKA, in particular Aperture Arrays, building on SKADS/EMBRACE, and on the RFI mitigation, software and calibration for the SKA, applying the knowledge and experience built up for LOFAR to the higher frequency regimes of the SKA.



*This picture shows the Alignment inspection on the Spectrometer Main Optics of MIRI, the Mid Infrared Instrument for the James Webb Space Telescope. Six laser beams are traced inside the light path. The Alignment inspection is performed to validate the requirements of vibration during launch of the JWST satellite, where MIRI will be part of.*



*The test cryostat, designed for qualification tests of MIRI (Mid Infrared Instrument for the James Webb Space Telescope) is integrated for the first cold run. The picture shows ASTRON test and support engineer Eddy Elswijk mounting the cold screen (50K).*

## The instrument that shoots faster than its shadow

Astronomers never get tired of pushing telescopes to their observational limits. They want to look further, deeper, faster. That is why ever-larger telescopes are being designed and built, to be equipped with ever-more sensitive instruments and detectors. It is not surprising then that only a few odd years after operations had started at the 2600 meters high Paranal VLT site in Chile, its operator, the *European Southern Observatory*, sent out a call already for a new, second generation of instruments: to aid in discovering planets around other stars, to allow multi-object searches and to be able to quickly follow rare events such as the afterglow of Gamma Ray Bursts. As a potential way to answer this last question X-SHOOTER was proposed. This spectrograph, destined for the Cassegrain focus of one of the four unit telescopes at Paranal, got its name from its capability to observe faint sources with an unknown flux distribution in a *single exposure*: a single-shot solution. It is supposed to cover the spectral range from the UV to the near infrared. By being able to look at various wavelength ranges in one fell swoop, the observations could be done much faster, much cleaner, and be much less dependent on disturbances.

This year the instrument passed its *Final Design Review*, and development is now going fullsteam ahead. According to project manager Lars Venema, the astronomical community really needed some time, though, to get used to the idea: "What we proposed was initially considered to be far overdone. But as the project progressed and especially when the instrument was more and more taking shape, it turned out that people were actually eagerly awaiting its deployment. And even more so, there are already proposals for upgrades!" And he concludes: "There is nothing new under the sun, this really is a healthy project." Since X-SHOOTER is supposed to cover the full wavelength range from 350 to 2500 nm, with maximum efficiency and sensitivity, different detector technologies are

required. And a Dutch consortium -comprising groups from ASTRON and the Universities of Amsterdam and Nijmegen led by principal investigator Lex Kaper- was made responsible for the development of the Near Infrared (NIR) spectrograph. The incoming light is split into three wavelength ranges using special dichroic mirrors. Using interference in a multilayer coating, these mirrors are able to reflect 95% of the light above a certain threshold, while passing 95% of the light below that threshold. Venema: "These are curious beasts: while seeing through them in red you can see someone standing behind you in blue."

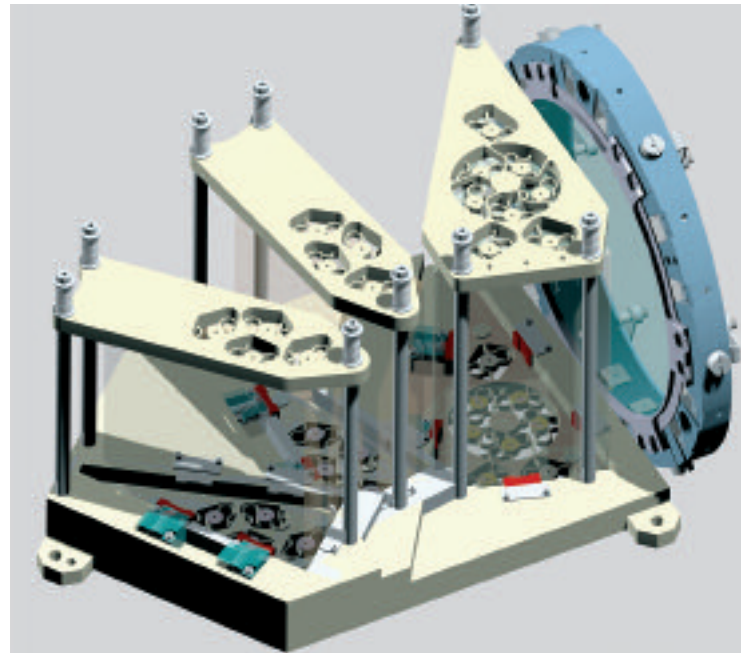
At the outset a number of design requirements were formulated. The spectral resolution of the instrument had to be sufficient to resolve the strong atmospheric hydroxyl-lines, which form a messy background. Venema: "We had to be able to see through them. The spatial resolution on the other hand is of less importance, as the telescope suffers from atmospheric disturbances anyway. In that sense it is similar to a 45 cm telescope, but its light-collecting power is infinitely better." The main design difficulties arose from the requirement that not only the detector needed to be cooled to some 60-80 Kelvin to keep its noise level low, but also the whole instrument, in order not to drown the signal in the background. A setback was the ESO ban on closed cycle coolers, as these were considered to induce unacceptable vibrations on the telescope. This required a full rethinking of the cooling concept and put more severe restrictions on the shielding of the detector from the rest of the instrument. Venema: "Also it became even more difficult to comply with a number of other requirements: the optical alignment needed to be guaranteed at low temperature, so we had to find ways to limit heat losses, and moreover, it must remain intact during cool down. This sets contradictory requirements. On the one hand the construction needs to be very stiff and thus tightly connected to the telescope, while at the same time you would like it to almost float freely, without any connection to the outside world." To address stiffness requirements "...tougher than those in



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space applications", Venema and his team were the first to apply the extreme light-weighting technique that has been developed at ASTRON. Using modern 5-axis milling machines, the inside of a single block of material is hollowed out for more than 95%, leaving walls as thin as three tenths of a millimetre, with heights of up to one hundred millimetres! In this way a 50% weight reduction compared to traditional light-weighting is obtained without losing stiffness in materials like aluminium, steel and ceramics.

And then there is the optical system, in which each part has its own, often-remarkable story connected to it. Sometimes, unexpected solutions popped up, for instance when making the wedge-like profile for each line on the echelle grating. These grooves had to be so deep, that they could not be properly machined, as the material that was chipped away could not be removed fast enough. This led to imperfections that reduce the efficiency of the grating and thus compromises the performance of the instrument. Fortunately, after making a negative replica of the grating, these turned out to be less of a nuisance! Then the optical design had to be adapted to accommodate unruly materials, such as the zincselenide for the prisms, which could not be made thicker than 60 mm, while a 100 mm thickness was required; so an extra prism was introduced. Also the team came up with nifty solutions to remedy nature's imperfections, such as the chromatic aberrations in the camera, which were compensated by similar negative aberrations in the collimator. Venema and his team even developed a way to polish aluminium mirrors, a trick they learnt from a 1953 handbook, thereby bypassing a NASA patent. With this kind of ingenuity and commitment, one can understand how in spite of the delay caused by the cooler problems, X-Shooter is still targeted to be the first second-generation instrument to be installed on the VLT.



*X-shooter's mechanically complex cross-dispersion prisms. Sufficient mechanical stiffness is required both at room temperature and cryogenic temperature. During the temperature transitions, the differential contraction should be properly handled and optimal thermal contact between metal and prisms should be maintained.*

X-SHOOTER's Final Design Review was held at ESO Garching on February 6-7, 2006. By the end of 2006, X-shooter had entered the Manufacture, Assembly, Integration and Test phase. Manufacturing was started for the most critical component: the Cold Optics Collimator Box, or "D-box" (after its shape). Manufacturing of solid aluminum mirrors, as needed for X-shooter is not straightforward, requiring many process steps to produce the required surface quality. For X-Shooter a unique polishing technique has been applied, resulting in a high accuracy mirror with peak to valley deformations of 150 nanometers, together with surface roughness in the range of 1 – 2 nm. With such extraordinary quality the mirror is suitable for use throughout the visible and into the near ultraviolet. After polishing, the mirror receives a thin gold coating for optimum reflectivity across the whole wavelength range. Hardware delivery of X-shooter to ESO is planned for the end of 2007.



*ASTRON optical engineers Rik ter Horst and Menno de Haan proudly show the X-shooter NIR main mirror, fabricated using a unique aluminum polishing technique.*

## Radio astronomy enters the 'CCD era'

Within the community of radio astronomers, phased array technology is enjoying everincreasing popularity. The reason for this is obvious, as it offers to radio telescopes the same performance leap that optical telescope systems have enjoyed in the past decades when they made the transition from a single photometer in the telescope focus to large-format CCD detector arrays. The imaging speed of a radio telescope depends on the number of beams creating the field of view and their position with respect to each other. Whereas traditional radio telescopes use either single dipole or horn antennas as feed systems, dense antenna arrays with a large number of elements can generate multiple beams by electronically summing the signals from different groups of elements. It is as if you can look in several directions at the same time. The multi-beam capabilities offer an increased field of view leading to a higher survey speed of the telescope, completely analogous to using a CCD on a optical telescope, with an individual CCD pixel as the equivalent of an antenna beam.

A *Focal Plane Array* (FPA) system is a combination of a reflector antenna with a smart feed. The latter greatly enhances the capabilities of the reflector by improving the illumination and expanding its field of view compared to conventional horn feeds. Different beams are furthermore synthesized electronically, and they can be dynamically controlled, improving bandwidth and allowing beam steering. Jan Geralt Bij de Vaate was one of the people at ASTRON who at an early stage recognised the potential of FPA systems for radio astronomy and started developing the technology with support from the European Commission some four years ago. Bij de Vaate: "Within the FARADAY project of the European Commission the potential of the concept was explored and demonstrated. In 2004, we installed an FPA feed on one of the WSRT telescopes and even though a lot of tinkering may have gone into its development, we were able to show it was possible to improve the aperture efficiency of a standard reflector.

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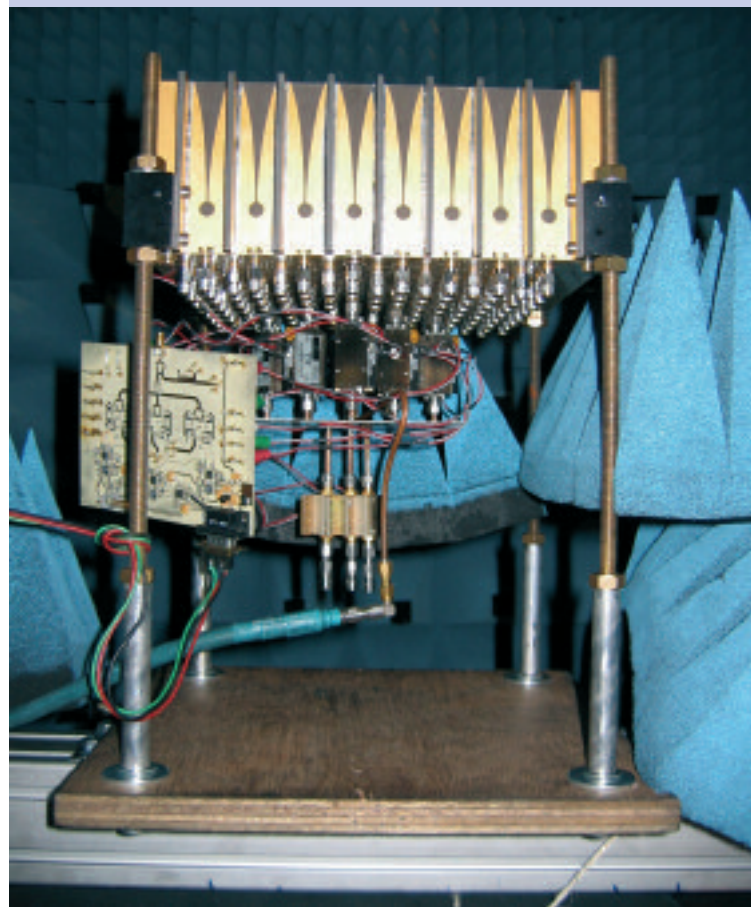
*ASTRON engineers Harm-Jan Stiepel and Kees Brouwer are mounting the FPA feed on one of the WSRT telescopes.*

However, the system was not cryogenically cooled, so we had a lot of trouble with the high system temperature. With the PHAROS demonstrator (*Phased Arrays for Reflector Observing Systems*) that will be realized in 2006, we will use better Low-Noise Amplifiers (LNAs) cooled to temperatures of 20 Kelvin, and will thus be able to extend the FARADAY results."

Whereas FARADAY consisted of two beams, the PHAROS demonstrator will have twice as many, operating in a frequency range of 4 to 8 GHz. The FPA will consist of 312 Vivaldi antenna elements of which twenty-four will be fitted with LNAs. These are the key elements from which the four RF output beams are assembled. This occurs in a so-called *RF beam former* section, which takes care of phase control, amplitude control and intermediate amplification. This beamformer section will be held at an intermediate 70 Kelvin, well-isolated from its room temperature surroundings. Bij de Vaate: "With such a large number of LNAs in the cryostat there is a large thermal leakage, because of the many cables that need to enter the cooled area. Therefore, we decided to also put the antennas in the cryostat, but to that end the cryostat had to be

equipped with a dome-shaped RF entry window. With a diameter of almost half a meter this really sets a new challenge for vacuum system design. In order to keep out any undesirable influx of infrared radiation heating up the antenna, the RF window is also fitted with filters."

*Significant funding for APERTIF was granted early 2006. Experiments with the FARADAY prototype on the WSRT in the course of 2006, significantly improved our understanding of the focal plane array technique. Apart from a series of scientific papers, they resulted in the specification for the first APERTIF prototype which will be in operation at the WSRT in mid-2007.*



*Prototype multi-beam Focal Plane Array system in ASTRON's antenna measurement room.*

PHAROS will be mounted on different radio telescopes of the various project partners, so that all can evaluate the new technology. Besides existing telescopes, future system such as the Square Kilometre Array (SKA) will benefit from focal plane arrays. Three SKA demonstrators are being developed based on FPA technology: xNTD (Australia), KAT (South-Africa) and APERTIF, which is the future successor of PHAROS.

## Optical processing of radio waves

Even though Moore's Law still reigns supreme, with the speed of integrated chips doubling every one and a half years or so, at ASTRON people are beginning to experience the limits that electronic data processing poses. In case a limited number of receivers are involved, such as for the WSRT, it is worthwhile to apply cryogenic techniques and use superconducting electronics. But for LOFAR with its multitude of receivers, this was no longer a viable option. An important consequence is that it is no longer possible to do the signal processing for all frequencies in its range of up to 250 MHz instantaneously. So even though LOFAR is based on an ultra-fast, highly parallel central processor -at 27.5 teraflop per second one of the fastest super-computers- the signals have to be chopped up in small bands, and processed separately. For phased array telescopes at even higher frequencies, such as SKA, the data processing costs would go sky high. And that's where optical signal processing comes in; the speed of light has no match. Optical bandwidths are much larger and moreover, optical processing will give a better frequency resolution and a higher dynamic range. The big question is: how? For two years now Peter Maat has been involved with the AMPHORA project, the *Advanced Microwave PHOTonic Receiver Array*, which aims to answer this crucial question. Maat: "AMPHORA starts with antennas that capture the radio signals and transform them into coherent optical signals confined in fibres. Combining these optical signals and forming intermediate images – based on holographic storage and read-out – is a different expertise for which we cooperate with other institutes such as the CNRS in France, the University of Colorado and the Office of Naval Research, which is the main sponsor of the work. At ASTRON we have been looking at the (analog) optical signal transport via amplitude modulation on an optical carrier, just like it is done for cable television systems." However, that would not be sufficient for astronomical applications, which have

much more stringent requirements in terms of phase stability and more importantly, cost. Because if there is one word that comes back time and again in our discussion it is 'cost'. Maat: "If you take SKA as an example, the costs of a one square meter tile are not to exceed 1000 euro. With one hundred antennas per tile, this means that there is only ten euro available for data transport and signal processing!" Maat hastens to add that whatever AMPHORA will look like, it will be too late for SKA phase 1, which will get its final design review in 2009. AMPHORA really is a long-term development.

With the help of two students doing an internship at ASTRON, Maat has studied how the way individual antennas are positioned influences the quality of the telescope image. Maat: "By looking at different configurations, we have found ways to suppress spurious peaks which do not belong to the main signal." Furthermore, attention was given to antenna development, or rather in finding the best way of arranging different VIVALDI antenna elements: co-planar, on a microstrip or a stripline. Whereas the latter was clearly superior, the relatively simple (and much cheaper) co-planar arrangement turned out to be fully acceptable to all project partners. Also the radio-frequent interface was studied, or, as Maat describes it, "...the best way to get the signal into a glass fibre." To this end, a phase front simulator was developed to simulate a parallel wavefront at different angles. Finally, the optical signal transport was studied in model experiments. Maat: "In that case the laser beam was modulated with an RF signal, but you could in principle also modulate the laser internally." Now all the pieces of the puzzle will have to fit together, and even then some further development is needed, as the holographic data storage still relies on a crystal at a temperature of 4 Kelvin. Maat: "We still have a long way to go." ■

*In 2006, an "Innovatie Samenwerkingssubsidie" was granted to a successor project in which photonic beamforming will be prototyped together with an industrial partner, Lionix, and Twente University. ASTRON also participates in the successful SmartMix MEMPHIS, where the SKA will drive the specifications of one of the demonstrators. An NWO-M subsidy allowed Peter Maat to properly equip a photonics lab. Although we still have a long way to go, the path was much better paved by the end of 2006.*

## 2. Science highlights of the Radio Observatory

Thirty-five years after its completion back in 1970, the Westerbork Synthesis Radio Telescope has vastly exceeded the scientific expectations of its initiators. The upgraded observatory, consisting of fourteen 25-metre radio dishes working in unison, has provided astronomers with unprecedented views of the universe, from extremely remote gamma-ray bursts at the edge of the observable universe to atmospheric static induced by cosmic ray particles raining down on Earth. New state-of-the-art hardware and revolutionary data analysis techniques have opened up completely novel areas of research, and as a result, Westerbork remains one of the most powerful and productive radio astronomy observatories in the world.

According to Observatory director René Vermeulen, Westerbork has a very high observing efficiency. 'Each quarter, we log about 1350 hours of real observing time,' he says, 'which amounts to about 62 percent of the total time of every day and night.' The remaining 38 percent is spent on development, maintenance, setup, calibration and slewing the telescopes. About half of the time is used to observe neutral hydrogen beyond our own Milky Way galaxy, and 25 percent is spent on pulsar observations, with the remaining quarter divided over a variety of astronomical objects and phenomena. Moreover, about three times per year Westerbork teams up with other radio telescopes in Europe and around the world for three-week sessions of very long baseline interferometry (VLBI).

One of the main hardware additions that became fully operational at the start of 2005 was the placement of the low-frequency backends in the focal planes of the radio dishes. They are sensitive to frequencies between 120 and 180 Mega Hertz, and provide ASTRON scientists with an opportunity to gain experience in this part of the electromagnetic spectrum which will be studied in more detail with LOFAR (LOW-Frequency ARray), the new facility



*The Westerbork Synthesis Radio Telescope.*

now under development in the northern part of the Netherlands. Also, in the high-frequency part of the spectrum, a 6 Giga Hertz-receiver has become operational on one of the radio antennas in 2005; it is used in observations of maser emissions in distant galaxies.

### Pulsar progress

As for new hardware, the inauguration of a new pulsar machine on 16 December 2005 was an important milestone for the observatory. PuMa II – the second-generation Dutch Pulsar Machine – is now the best of its kind in the world, according to ASTRON's Ben Stappers. PuMa II is a dedicated supercomputer used to sift through huge amounts of radio data in search of repetitive pulsar signals. It performs 385 billion operations per second, is 70 percent more sensitive than its predecessor and can detect pulse variations as brief as 10 microseconds. Says pulsar expert Shri Kulkarni of the California Institute of Technology in Pasadena: 'PuMa II puts Westerbork right in the league of the best pulsar

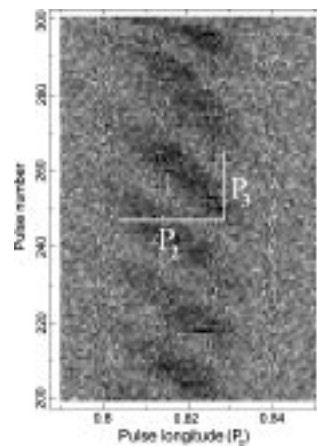
observatories in the world.’ Pulsar observations with the Westerbork array have also greatly benefited from a new observing strategy, called 8gr8 (‘eight-grate’). ‘The Westerbork synthesis array was never suited for the discovery of new pulsars,’ says ASTRON astronomer Robert Braun, ‘because it has a very narrowly focused effective field of view.’ The reason: the digital correlator – used to properly delay and subsequently combine the signals from the individual antennas – is ‘tuned’ to the very centre of the observed part of the sky. To realize interferometry for other parts of the field, a different time-delay would be necessary.

With the new eight-fold correlator at Westerbork, this is finally possible, explains Vermeulen. ‘We can now do eight varieties of interferometry simultaneously,’ he says, ‘so the complete field of view of the 25-metre antennas becomes available.’ According to Vermeulen, it turned out to be a relatively simple task to accomplish. ‘And it really works,’ adds Braun. ‘The first measurements were carried out in August 2005, and we have already discovered a few new pulsars.’ As a result, the Westerbork telescope is now the fastest pulsar survey instrument in the world, at least at relatively low frequencies.

‘In our search for new objects, we’re no longer looking for more run-of-the-mill pulsars,’ says Vermeulen. ‘Instead, we’re interested in the peculiar ones. The 8gr8 technique may be of help to find them.’ The high quality of the pulsar work carried out at Westerbork has been one of the motivations of the European Commission to award part (the prize was shared) of the one million euro Descartes Prize 2005 to PULSE, a European collaboration of pulsar researchers including Ben Stappers, who is affiliated both to ASTRON and to the University of Amsterdam.

### Single Pulse surveyed

The structure of observed pulses provides information on the emission mechanism and magnetic fields of radio pulsars. Using a new sensitive method, the WSRT has now surveyed 12%



*A pulse-stack of one hundred successive pulses of PSR B1819-22, one of the new drifters found in this survey. Two successive drift bands are vertically separated by P<sub>3</sub> and horizontally by P<sub>2</sub>. The pulse number is plotted vertically and the time within the pulses (i.e. the pulse longitude) horizontally, where P<sub>0</sub> is the pulse period.*

of the radio pulsar population for ‘drifting sub-pulses’ and discovered some interesting and important behavior. One hundred and fifty hours of data with the PuMa-I backend (at wavelengths of 21 and 92 cm) were analyzed using the new method as part of the PhD thesis of Patrick Weltevrede (Univ. Amsterdam) supervised by Ben Stappers (ASTRON) and in collaboration with Russell Edwards (ATNF). The survey doubled the number of known drifters and found a number of extremely interesting sources. Unexpectedly more pulsars were found to show this phenomenon than was expected.

What fraction of the pulsars has drifting sub-pulses? Of the 187 analyzed pulsars at 21cm, 68 show this phenomenon of which only 26 were previously known. And at 92cm 185 pulsars were analyzed and 76 showed drifting. In total 57 new drifters were found. Because drifting sub-pulses are now shown to be common in radio pulsars, the physical conditions required to produce them cannot be very different from the required conditions to produce the radio emission itself. It could be that drifting sub-pulses are always produced but are hard to detect in some cases.

# ASTRON

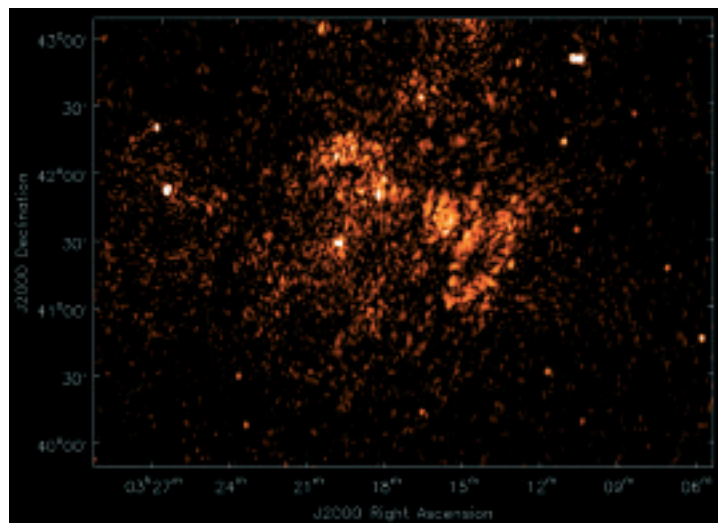
Drifting is independent of the magnetic-field strength, but the population of pulsars that show drifting sub-pulses is on average older than those that do not. Moreover, the drifting subpulse pattern is more stable and regular for older pulsars. It is claimed that the angle between the magnetic and the rotation axis is on average smaller for older pulsars. So as the pulsar gets older, the rotation axis and the magnetic axis grows more aligned, which appears to make the mechanism that drives the drifting phenomenon more effective and stable. By comparing the results at the two frequencies, drifting seems to be more pronounced at lower frequencies, and on average the modulation index of pulsars is higher at lower frequencies. These properties argue that pulsed radio emission is a combination of a drifting component and a quasi-steady component, and the former seems to be less dominant at the higher frequencies.

## Rotation magic

Another trick that was first successfully applied in 2005 goes under the name of rotation measure synthesis. As radio astronomer Michiel Brentjens of the University of Groningen explains, the technique makes it possible to detect extremely faint sources of polarized radio waves. A magnetic field between the source and the observer introduces a rotation of the polarization direction, and this Faraday rotation is strongly dependent on the wavelength. As a result, says Brentjens, if a faint source is observed in a broad wavelength band (necessary to collect enough signal), the observed polarization is effectively smeared out.

Rotation measure synthesis comes to the rescue. This data analysis technique is possible at Westerbork because the broad wavelength band is divided into hundreds of small channels. By just assuming a particular amount of wavelength-dependent Faraday rotation, a radio map of the sky for that particular amount of rotation can be synthesized. At most rotation measures, the resulting map remains noisy, but at certain values, new faint sources suddenly jump out. 'In 2005, using this technique, Westerbork astronomer Ger

de Bruyn and I serendipitously discovered extremely faint structures at the perimeter of the Perseus cluster of galaxies,' says Brentjens, who is now writing his PhD thesis on these observations. All in all, the Westerbork array is still one of the world's most versatile radio observatories. Although the American Very Large Array (VLA) in New Mexico has a larger total collecting area, a better angular resolution in some of its configurations, and more ability of producing instantaneous radio images, Westerbork has a much better correlator, making it more capable of mapping very tenuous clouds of neutral hydrogen. And although Westerbork cannot observe at very high radio frequencies, its low-frequency capabilities are unsurpassed by other large facilities.



*Some of the mysterious structures discovered in the direction of the Perseus cluster.*

## Imaginary journey

Seventy years after the accidental discovery of radio waves emanating from the centre of our Milky Way galaxy, radio astronomy has become an integral part of the continuing study of our universe. An imaginary journey through space, from exploding stars in remote galaxies back to phenomena in our immediate cosmic neighbourhood, serves as a tour

of a wide variety of exciting Westerbork science results that were published in the course of 2005. By far the most powerful explosions in the distant universe are the so-called gamma-ray bursts. Within a few seconds, they release more energy than the sun produces in its entire 10-billion-year lifetime. Gamma-ray bursts are the terminal explosions of very massive, rapidly rotating stars, whose extremely dense cores collapse into black holes. Jets of matter spew into space with almost the speed of light, and powerful shock waves produce the gamma rays that can be observed by spacecraft orbiting the Earth.

One of the most enigmatic gamma-ray bursts exploded on 29 March 2003 in the constellation Leo the Lion, at a distance of over 2.5 billion lightyears. The lingering afterglow of the explosion was observed for many weeks at various wavelengths with telescopes on the ground, including the Westerbork Synthesis Radio Telescope. What was surprising about the observations (carried out at centimeter wavelengths) is that the afterglow remained brighter than expected at the longest wavelengths. According to Alexander van der Horst (University of Amsterdam) and his colleagues, this suggests that the jets of GRB 030329 are structured or layered. Thus, the Westerbork observations provide a means of studying the details of the explosion mechanism.

## Outflows and plumes

A bit closer to home, ASTRON's Raffaella Morganti and her colleagues used the Westerbork telescope to study seven active galactic nuclei – extremely energetic galaxies that are powered by a supermassive central black hole. These quasar-like galaxies, at distances of many hundreds of millions of lightyears, also known as radio galaxies, which blow fast plasma into intergalactic space. Morganti's team discovered huge outflows of neutral hydrogen gas in these galaxies, with velocities on the order of 1000 kilometres per second. The large bandwidth available to the upgraded Westerbork array was a key factor in this discovery: because of the large spread of velocities

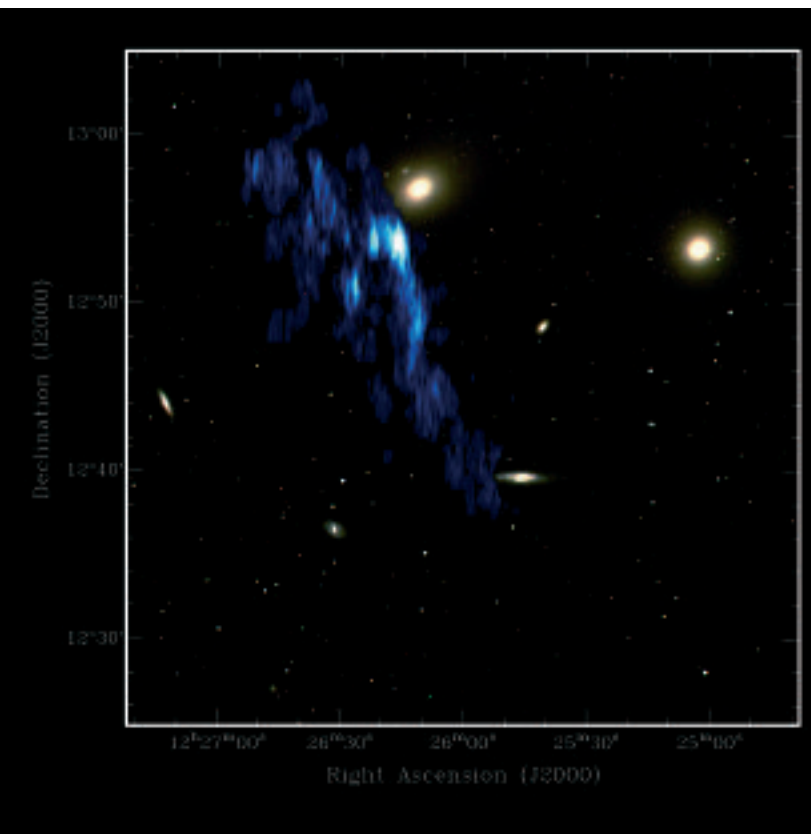
of the outflows, the characteristic 21-centimetre radiation of neutral hydrogen is doppler-shifted to a correspondingly large spread of wavelengths. According to Morganti and her colleagues, the hydrogen outflows are probably driven by the interaction of the radio jets with interstellar gas in the galaxy's core. Some of the outflows amount to some fifty solar masses per year, which makes them comparable to galaxy outflows caused by superwinds from huge bursts of star formation. The new Westerbork data suggest that jet-driven outflows in active galactic nuclei may have a large impact on galaxy evolution – maybe as large as starburst superwinds.

Galaxies may experience internal violence, but they can also influence each other, especially when they are close together in rich clusters. A striking example of this mutual interaction has been revealed by the Westerbork telescope in observations of the core of the Virgo cluster, at a distance of some 52 million lightyears. ASTRON astronomer Tom Oosterloo and Jacqueline van Gorkom (Columbia University, New York) discovered a huge elongated cloud of neutral hydrogen gas in the cluster core, weighing in at some 340,000 solar masses. The hydrogen plume extends over 350,000 lightyears, and appears to connect two galaxies in the cluster: NGC 4388 and M86.

According to Oosterloo and Van Gorkom, the cloud probably consists of interstellar gas that originally belonged to NGC 4388, the smaller of the two galaxies. The gas must have been stripped away when the galaxy moved through the extended halo of M86. Similar galactic 'strip acts' must have been performed before, and they are expected to contribute significantly to the reservoir of intracluster gas. Indeed, from the observed hydrogen density in the newly discovered plume, Oosterloo and Van Gorkom conclude that the ionized star-forming regions that have earlier been found in the space between the cluster members probably have formed from neutral gas that has first been stripped away from galaxies.



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*Total HI image of the cloud discovered in the Virgo cluster (blue) superimposed on an optical image based on the Digitized Sky Survey. The spiral galaxy at the bottom-right end of the cloud is NGC 4388, while the galaxy near the top of the cloud is the elliptical M86. The HI residing in NGC 4388 has been blotted out for clarity.*

## The Milky Way's neighbours

Our own Milky Way galaxy is located on the very edge of the Virgo cluster, and is one of the three large members of a small galaxy group. The other two large Local Group members are the Andromeda galaxy and the Triangulum galaxy, known to astronomers as M31 and M33, respectively. Because of their small distance (less than three million lightyears), they can be studied in great detail, and the Westerbork array has played a vital role in unraveling their mysteries. For instance, Westerbork carried out follow-up observations of high-velocity clouds in the neighbourhood of M31, which were first detected with the Green Bank

Telescope in the United States.

High-velocity clouds are relatively compact, fast-moving clouds, measuring a few thousand lightyears across, and containing a few hundred thousand solar masses of neutral hydrogen. Decades ago, they were first identified in the proximity of our own Milky Way galaxy, and astronomers were strongly divided on their origin: some thought they might represent the final stages of the process of galaxy accretion, others thought they were ejected out of the plane of the galaxy. According to the most recent insights, both types of clouds are actually present – a view that is supported by the Westerbork observations of Andromeda's high-velocity clouds.

According to a team of radio astronomers including Robert Braun, twelve of the sixteen clouds are close together, and they more or less coincide with a previously detected giant stream of stars, tens of thousands of lightyears away from the central disk of the Andromeda galaxy. This suggests that these clouds have a tidal origin, just like the stellar stream – they were probably drawn from M31 by tidal forces when a smaller satellite galaxy made a close pass to Andromeda. But some other high-velocity clouds appear to be more isolated. According to the team, these might represent primordial clouds, probably containing lots of dark matter.

## Imaging the Cosmic Web

Using the Westerbork telescope, Braun has also made the first 'image' of the so-called Cosmic Web – the filamentary large-scale structure of the universe in which galaxy groups and clusters are just the high-density regions and 'nodes'. The existence of the Cosmic Web had been predicted by computer simulations that showed how primordial matter in the expanding universe would first gravitationally collapse into thin sheets and narrow filaments. However, since the inter-cluster gas is extremely tenuous, it is very hard to detect, even though the Cosmic Web may contain most of the atomic and molecular matter in the universe. In some cases, ionized oxygen gas – a minor constituent of the Cosmic Web – has revealed itself

by absorbing particular wavelengths of the ultraviolet radiation of distant quasars, but Westerbork has for the first time been able to detect actual emission from a filament between M31 and M33. ‘Ninety-nine percent of the gas is ionized,’ says Braun, ‘but about one percent of the hydrogen atoms are neutral, and can be detected and mapped using a radio telescope like Westerbork.’ Since the two galaxies are currently moving toward each other, the filament can’t be due to tidal interaction, and Braun is confident that the gas represents the Cosmic Web. Incidentally, the Andromeda galaxy is also approaching our Milky Way galaxy. Details of the upcoming encounter are sketchy, however, since only the line-of-sight velocity of M31 is known very well, while the proper motion due to the traverse velocity (in the plane of the sky) is too small to be determined. But ASTRON’s Heino Falcke has been involved in a study using data from the Very Long Baseline Array in the United States to solve this problem. Using proper motion measurements of M33, and taking into account that M33’s disk has not been tidally disturbed by an encounter with M31, the team (led by Abraham Loeb of the Harvard-Smithsonian Center for Astrophysics) was able to constrain the traverse velocity of Andromeda and to predict that the dark halos of the Milky Way and the Andromeda galaxy will indeed pass through each other within five to ten billion years from now.

## Bubbles and clouds

Within our own galaxy, Westerbork not only observed pulsars – rapidly rotating and highly magnetized neutron stars that are the compact remnants of supernova explosions – but also stellar black holes. Although a black hole is invisible in principle, it reveals its presence indirectly. For instance, Cygnus X-1, a black hole orbiting a giant star at some 8000 lightyears away, sucks matter away from the star in a whirling accretion disk that gets hot enough to emit x-rays. Radio observations have revealed energetic jets – miniature versions of the jets produced by active galactic nuclei – that carry energy away from the black hole. Using the Westerbork telescope, Elena Gallo of the

University of Amsterdam and her colleagues have imaged the surroundings of Cygnus X-1, and detected a bubble with a diameter of fifteen lightyears that appears to be created by energy from the jet. In a paper in *Nature*, Gallo and her colleagues estimate that the amount of energy carried away by the relatively dark jets is comparable to the emitted x-ray power of the black hole binary. ‘In fact,’ she says, ‘we used the interstellar gas as a calorimeter: the energy of the jets could be deduced from the size and the radio luminosity of the bubble.’

But not everything in our cosmic backyard can be explained so readily. For instance, Robert Braun (ASTRON) and Nissim Kanekar (National Radio Astronomy Observatory, USA) have discovered a new and mysterious population of tiny hydrogen clouds in the nearby interstellar medium. This completely unexpected Westerbork find was the result of the most sensitive 21-centimetre absorption observations ever made. With this technique, the foreground cloudlets leave spectroscopic fingerprints in the radiation of distant radio beacons well beyond the Milky Way galaxy. According to Braun and Kanekar, the nearby hydrogen clumps (probably just a few hundred lightyears away) are less than 0.1 lightyears across (much smaller than the average distance between stars in the Milky Way), have core temperatures of about 50 degrees above absolute zero, and are much denser than the average interstellar medium. Their existence is a mystery: their lifetimes can’t be much higher than a few million years. Future observations will have to establish how numerous these clouds are, and whether or not they are formed by stellar winds from sun-like stars. For now, the tiny clouds defy explanation.

## Cosmic riddle

Talking of mysteries, radio observations may also help to tackle the riddle of ultrahigh-energy cosmic rays, as a large collaboration led by ASTRON’s Heino Falcke has demonstrated in another *Nature* paper. Cosmic rays are ultra-fast elementary particles (mostly protons and electrons) that have

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been accelerated by some cosmic process and constantly bombard the terrestrial atmosphere. Most of them probably arise from supernova explosions in distant galaxies, but the most energetic ones pose a problem: if they travel through space long enough, they would lose their energy by interactions with the omnipresent microwave photons of the cosmic background radiation. This implies that they must originate at distances of less than a few hundred million lightyears, and no viable candidate sources are known within that distance. Evidently, a much more precise characterisation of these ultrahigh-energy cosmic rays is needed to solve the enigma, but cosmic ray detectors have to be extremely large and expensive to capture enough of them. Radio observations may help. Falcke and his colleagues show that the interaction of a high-energy cosmic ray particle with the Earth's atmosphere not only produces a cascade of secondary particles, but also a brief flash of low-frequency radio waves. In other words: observations of radio waves generated just a few tens of kilometres above our heads may ultimately reveal information about cosmic accelerators at distances of hundreds of millions of lightyears.

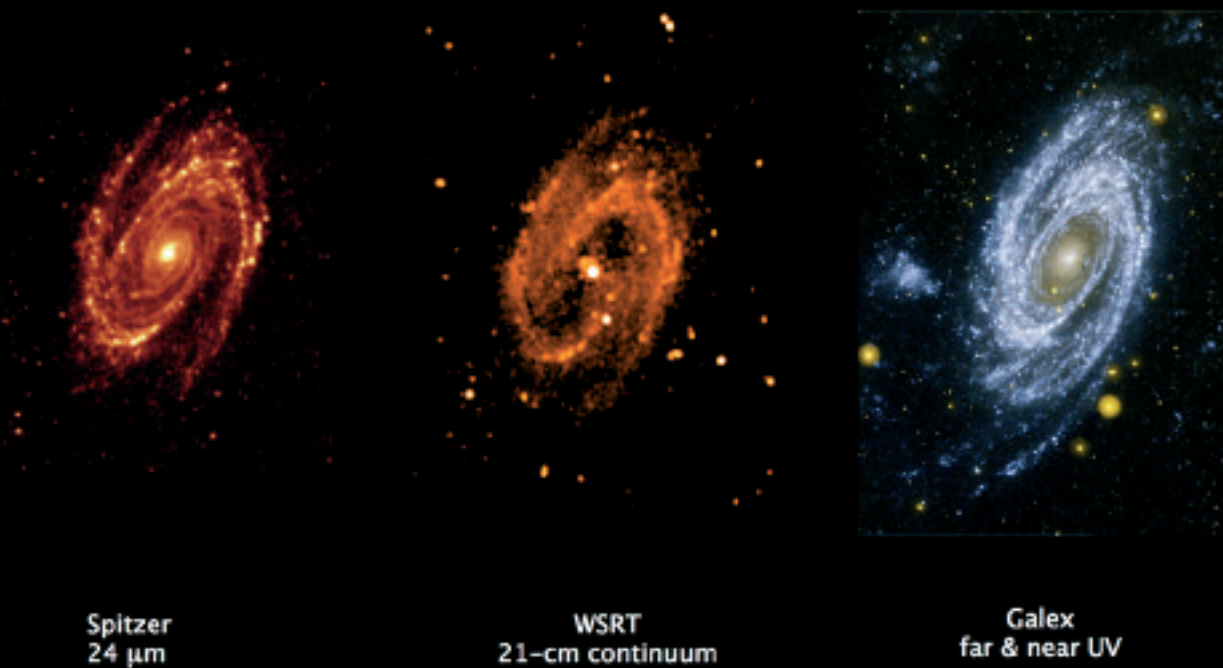
There's one catch, though: this type of observation cannot be carried out by a directional radio telescope like Westerbork, or the Very Large Array for that matter. Instead, omni-directional low-frequency antennas and receivers are needed to monitor the whole sky for these brief flashes. Falcke and his colleagues used the LOPES array in Karlsruhe, Germany – a prototype station of the LOFAR radio observatory now under construction in the Netherlands. But if this cosmic riddle will ever be solved by LOFAR, scientists will undoubtedly recognize the legacy of the venerable Westerbork Synthesis Radio Telescope, which has paved the way – both technologically and scientifically – for next-generation facilities. ■

## Westerbork SINGs

An understanding of the star formation process is critical to a wide range of astrophysical questions, from the phase and energy balance in the local Interstellar medium (ISM), to the circumstances surrounding the universal peak of star formation and merger activity that apparently typify the early universe. To achieve this, new sensitive radio continuum images of a sample of galaxies have been obtained with the WSRT to complement the SINGs (Spitzer Infrared Nearby Galaxy Survey) program. This study has been carried out by Robert Braun, Tom Oosterloo, Raffaella Morganti in collaboration with Uli Klein (Alfa) & Rainer Beck (MPIfR).

The traditional global tracers of current star formation in galaxies, like H $\alpha$  imaging, have led to some empirical descriptions of how star formation occurs. However, given the complexity of the many competing processes occurring in a galactic disk, it is clear that a coordinated effort, including multiple tracers of the interstellar medium, is needed to make substantial progress. Just such an initiative is currently underway with the Spitzer Nearby Galaxy Survey (SINGs, Kennicutt et al. 2003, Publ. ASP vol. 115, p. 928). This Spitzer Legacy program provides pixel-resolved data from the visible to 160  $\mu$ m for a sample of 75 galaxies nearer than 30 Mpc that spans a large range of Hubble types and (to a lesser extent) global star formation rates. In addition to the Spitzer data, the SINGs program will make a comprehensive set of broad-band optical BVRIJHK, narrow-band H $\alpha$ , as well as UV, CO and (in some cases) HI data available. An important supplement to the SINGs program is sensitive radio continuum imaging of the sample galaxies. The results are to be presented in the form of an image atlas for which a standard transfer function and image size are used throughout. The radio continuum, optical and integrated HI images are to be displayed side-by-side. Much as the Hubble Atlas has allowed a generation of astronomers to appreciate the diversity of the optical continuum appearance of nearby galaxies,

## M 81



*Spot the 7 differences: three images of the same nearby galaxy M 81 as observed with three different telescopes. Each image highlights different components of this galaxy. By analysing all these images, the processes that regulate the formation of new stars in M 81 can be studied in great detail. The image made with the Spitzer infra-red satellite shows the dust clouds that are heated to a few hundred Kelvin by stars that just formed or that are still forming. The WSRT image shows the hot gas that is ionised by young, massive stars, as well as the radio emission from very energetic particles (cosmic rays) that are created by stars that exploded in regions of star formation (supernovae). Finally, the blue light in the image from the Galex UV satellite shows the locations where stars have formed over the last 100 million years.*

the new atlas will provide a catalog of the rich diversity of radio continuum and HI appearances. The new data have the potential to help address some key questions on star formation in a wide range of nearby galactic environments: the Spitzer SINGS data and the WSRT-SINGS radio continuum

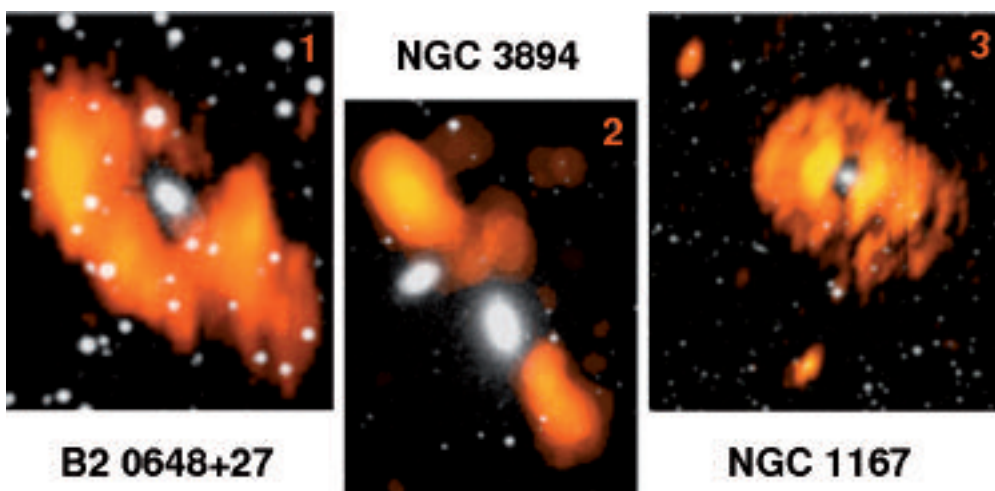
survey can be used to study the well-known farinfrared (FIR) to radio correlation, but now within galaxies to understand its origin. In the field of Galactic Magnetic Fields, it will now be possible to trace continuous variations of the RM and shed light on detailed magnetic field structures.

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## Fossil neutral hydrogen in radio galaxies

In 2006, the WSRT has revealed huge disks of neutral hydrogen around nearby radio galaxies. These structures are likely to be relicts of the way these galaxies formed and we can use them to understand the processes that feed the massive black hole in their centres. This work has been part of the PhD thesis of Bjorn Emonts (Groningen University) supervised by Raffaella Morganti and Tom Oosterloo. The power emitted by radio galaxies originates from a massive black hole in the centre of the galaxies. This makes them among the most powerfully luminous objects in the Universe. The material that feeds and keeps the black hole active (that is, stars and gas) is brought to the black hole by the effects of interactions and mergers between galaxies. In a merger between two gas-rich galaxies, part of the gas is transported to the central region, where it triggers a burst of star formation and where it may also feed the black hole, creating a so-called Active Galactic Nucleus (AGN). Another part of the gas is expelled from the galaxies into intergalactic space in large-scale tidal tails, arms, bridges, etc. These large-scale tidal features may - over a period of several Gyr - (partially) fall back

onto the newly formed host galaxy and eventually may settle in a regularly rotating disk or ring-like structure. Imaging the neutral hydrogen gas in radio galaxies may therefore be a method to study the age and history of these objects. The idea is that the more regular the gas in these objects appears, the more time has passed since the galaxy interaction occurred. Similarly, determining the properties of the stellar populations will also give indications about the formation history, as the presence of young stars indicates that a starburst triggered by an interaction occurred not so long ago. This technique was used to study a complete sample of 22 nearby, moderately-powerful, non-cluster radio galaxies. In 25% of the radio galaxies observed, large-scale disk- or ring-like HI structures (with diameters up to 190 kpc and masses up to about  $10^{10}$  solar masses) were detected, surrounding the early-type host galaxy. These HI disks/rings show regular rotation, although a varying degree of asymmetry is still visible in these structures. The observations show no evidence for ongoing gas-rich mergers in the form of large-scale tidal tails. Instead, the observed HI structures are old, indicating that it takes a long time from the start of an interaction to the onset of the current episode of radio-AGN activity.



Three nearby radio galaxies with a large-scale HI disk/ring. The neutral hydrogen emission is shown in red, while the optical image is in white (the radio source is very compact and not shown in these images).

## Towards a new observatory

In the course of 2006, the Radio Observatory took important preparatory steps towards its important new role for the operations of LOFAR. The “new observatory” will jointly operate the WSRT and LOFAR. The team will not only be responsible for the technical operations of both arrays, but also provide the necessary science support for the astronomical applications. Key to this support is a group of young Support Scientists that will form the

interface between the technical operations team and the users of the facilities. This model, which has been successfully used by JIVE, will allow for a closer interaction of users with the instrument by committed scientists that are, in addition to their support task, also driven by their own scientific interests. In the course of 2007, the Radio Observatory will take over the responsibility for the operations of the first LOFAR stations. By the end of 2006, observatory staff was already heavily involved in many aspects of LOFAR, in particular the roll-out.



*Every year, ASTRON and JIVE invite several students from around the world to come to Dwingeloo and work for a summer on research projects under the supervision of local staff members. The 2006 summer students were (from left to right): Ana Cabral, Maciej Serylak, Dana Vicas, Christian Struve, and Filomena Volino.*

## 3. LOFAR

### LOFAR gets going

**What was the most memorable day in 2005? LOFAR director Eugène de Geus doesn't need to think long. Without doubt, that must have been Tuesday, 26 April. Not only was LOFAR's proprietary supercomputer Stella officially inaugurated that day, but there also was a surprise party for ASTRON director Harvey Butcher. As one of the founding fathers of the revolutionary new radio telescope, Butcher received the insignia of the Order of the Dutch Lion. Not from the mayor of his hometown Roden, which would have been the standard procedure, but from Maria van der Hoeven, the Dutch minister of Education, who has always been a very strong political supporter of LOFAR. 'It was a very special occasion,' says de Geus.**

LOFAR (LOw-Frequency ARray) is indeed a very special project. The distributed radio telescope, which will be by far the largest in the world, will consist of tens of thousands of small antennas, clustered in fields that are scattered over an area 350 kilometres across, with a strong concentration towards the centre, in the Dutch province of Drenthe. Government funding for LOFAR was secured in late 2003, and construction is now in progress, with full completion expected later this decade. One of the main scientific goals of LOFAR is the study of the very early history of the universe, before the formation of the first stars and galaxies. The inauguration of Stella and the knighting of Butcher may have constituted LOFAR's major highlight in 2005, but it was certainly not the only one. Toward the end of the year, the project received important additional funding from the Northern Netherlands Assembly (Samenwerkingsverband Noord-Nederland, SNN), and in November and December, it passed the subsystem critical design review – a major milestone in program development. 'Carrying out such a review is an

achievement in itself,' says de Geus, 'because we are really working at the forefront of technology.' The principle of interferometry is not new to radio astronomy. Ever since the 1960's, signals from individual radio telescopes have been put together in phase to obtain a much sharper view of the universe at radio wavelengths. But in the case of LOFAR, the technology is vastly different. The telescope has no moving parts, no parabolic antenna dishes, no focal points and no pointing direction. Instead, simple copper wires in pyramid-shaped static antennas receive radio waves from all directions at once, and advanced software filters out the signals from one particular position on the sky.



*LOFAR low-band antennas at Core Station 1.*

To achieve the best combination of sensitivity and angular resolution, most of the antenna fields will end up in LOFAR's core area, while a number of remote stations have to be distributed along five giant spiral arms that extend all the way into Germany. A dedicated optical fibre network connects all antennas to each other and to the

central data processing facility in Groningen. The first observations with LOFAR's Initial Test Station (ITS) in the municipality of Borger-Odoorn were carried out in late 2003, and construction of the first Core Station (CS<sub>1</sub>) started in 2006, close to the ITS.

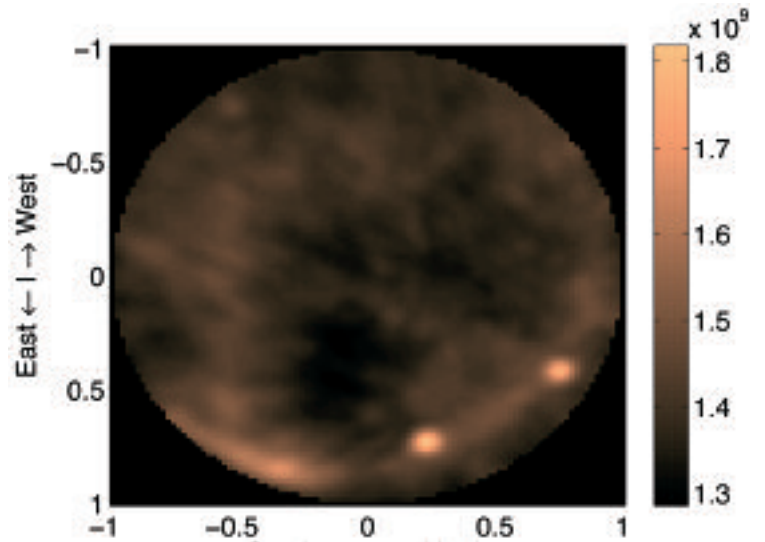


*In order to be able to maintain the LOFAR fields in a good way, the vegetation is replaced by a specially selected mixture of grass and flowers. In the picture, station CS-10 is prepared for the new vegetation.*

## Stella

From the very start, it was clear that LOFAR would require tremendous processing power, says ASTRON's Kjeld van der Schaaf, who is the project manager of the Stella supercomputer. 'The data rate that LOFAR will produce was estimated at some 300 to 400 gigabits per second, continuously,' he says. That's the content of sixty cd-roms every single second. 'Moreover,' says van der Schaaf, 'the computing power of the central processor would probably have to exceed 20 teraflops' – twenty trillion calculations per second. 'Back in 2003, when we started to discuss these requirements, no existing computer could provide that.'

It wasn't until 2004 that van der Schaaf and his colleagues learned about IBM's Blue Gene project – a novel-design supercomputer that was being developed at the company's Watson Research



*First image from LOFAR Core Station 1. This full sky image was made based on 43 subbands of 156 kHz (6.7 MHz total bandwidth) near 57 MHz (the resonance frequency of the low-band antennas). After flagging the visibility data was Fourier transformed to produce the image. No calibration, deconvolution or other method was applied. The image shows Cas A and Cyg A near the northeastern horizon. Along the horizon from north to south-east the galactic plane is visible with increasing intensity near the southeastern horizon where we're getting close to the galactic centre. A (rather vague) straight band is visible from south-east to south-west ending in a point source near the southwestern horizon, which may be identified as the north polar spur and Vir A respectively.*

Laboratories in New York Heights. As its name already suggests, Blue Gene was originally conceived as a computational tool for geneticists studying protein folding, but in the end, the design also turned out to be perfect for three-dimensional simulations of nuclear blasts and supernova explosions, carried out by the U.S. Department of Energy's Lawrence Livermore National Laboratory. 'We immediately visited the Blue Gene development team,' says van der Schaaf, 'and we were just in time to ask for a couple of important modifications that would make the new machine better suited for LOFAR.'

One single computer chip of a Blue Gene machine is equivalent to a full-fledged pc, and a large number of these chips (768 clusters of eight chips each, to be precise) constitute a giant network



# ASTRON



structure. Blue Gene's architecture also provides very powerful and flexible data exchange with the outside world, says van der Schaaf, which is of utmost importance for LOFAR. Stella (an acronym for Supercomputer TEchnology for Linked Lofar Applications) was the first Blue Gene computer to be installed in Europe, and with six racks and a grand total of 6144 chips, it is one of the largest in the world.

Of course, the giant machine consumes a huge amount of power, up to 120 kilowatts, and it produces a large amount of heat. Stella's six racks are actively cooled by air, which is forcefully blown through the computer. 'You definitely need ear protection when you enter the room where Stella is located,' says van der Schaaf. 'There's a tremendous noise, mainly from the cooling.' In the near future, this will only become worse when some 250 regular pc's for data input are added to the system.

Saving all the original LOFAR observations would cost around one thousand euros per day for data storage alone, but that won't be necessary.

According to van der Schaaf, a week worth of data can be stored in Groningen, but after calibrating and condensing, the final data products will be sent to and archived by the end users of LOFAR. As for unexpected power failures, batteries can keep Stella running for thirty seconds, after which a large generator will take over. Data loss through computer hacking is impossible, since Stella runs on a completely isolated network.

'The inauguration was an essential milestone,' says LOFAR director Eugène de Geus. 'Stella is a whole new aspect of LOFAR.' Around a hundred people attended the ceremony on 26 April 2005, including many top-level administrators from the northern part of the Netherlands. The obligatory red-button-push by Minister van der Hoeven initiated a brief and fancyful movie of the installation of Stella, and through a live connection with the headquarters in Dwingeloo, ASTRON personnel could witness the whole event, including the knighting of their director Harvey Butcher.



*Minister van der Hoeven bringing Stella to life.*

## SNN Grant

One other 2005 LOFAR milestone was the allotment of a new and important grant from the Northern Netherlands Assembly (Samenwerkingsverband Noord-Nederland, SNN). 'This has been a long and exciting process,' says LOFAR project manager Jan Reitsma, 'because so many conditions had to be met.' In late 2003, LOFAR received 52 million euros from the Dutch government, through the BSIK program (Besluit Subsidies Investerings in de Kennisinfrastuctuur – Decree Subsidies Investments in Knowledge Infrastructure), on the condition that at least the same amount of money would be found elsewhere. But, says Reitsma, the original BSIK grant application was for 74 million euros (half of the estimated total project cost of LOFAR), and there remained a gap of 22 million euros. That gap has now been filled by the new grant. The SNN funds are intended to stimulate the economic development of the three northern provinces of the Netherlands, so during the application process, it was very important to convince the SNN board of

potential LOFAR-related investments in this part of the country. ‘Basically, the SNN’s commandment was: Thou shalt *spend as much as possible in the north,*’ quips Reitsma.

As for the required funds to match the BSIK grant, says de Geus, Germany is likely to play a key role. In 2005, discussions with potential foreign partners commenced, and as a result, a dozen German institutes have set up the GLOW consortium (German LOng Wavelength), with the aim of building twelve LOFAR stations on German soil (two GLOW members were already part of the original LOFAR consortium). The first German station, at the Max-Planck-Institut für Radioastronomie (MPIfR) location in Effelsberg, was completed in late 2006. Meanwhile, a white paper has been produced by the GLOW consortium with the intent of participating at a level of 17 million euros. ASTRON’s Heino Falcke, a German-born astronomer, was instrumental in establishing the German connection, says de Geus.

Discussions with other countries also took off. The University of Uppsala in Sweden has always been involved in the LOFAR consortium, but France and Italy have also shown interest in taking part in the project. In particular, French astronomers are keen on LOFAR’s ability to study extrasolar planets, whose magnetospheres may emit low-frequency radio waves as a result of interactions with the stellar wind from their parent star. Moreover, University of Amsterdam astronomer Rob Fender moved to the University of Southampton in 2005, taking his LOFAR involvement with him, which has led to preliminary discussions on a possible collaboration with radio astronomers in the United Kingdom.

## Applications

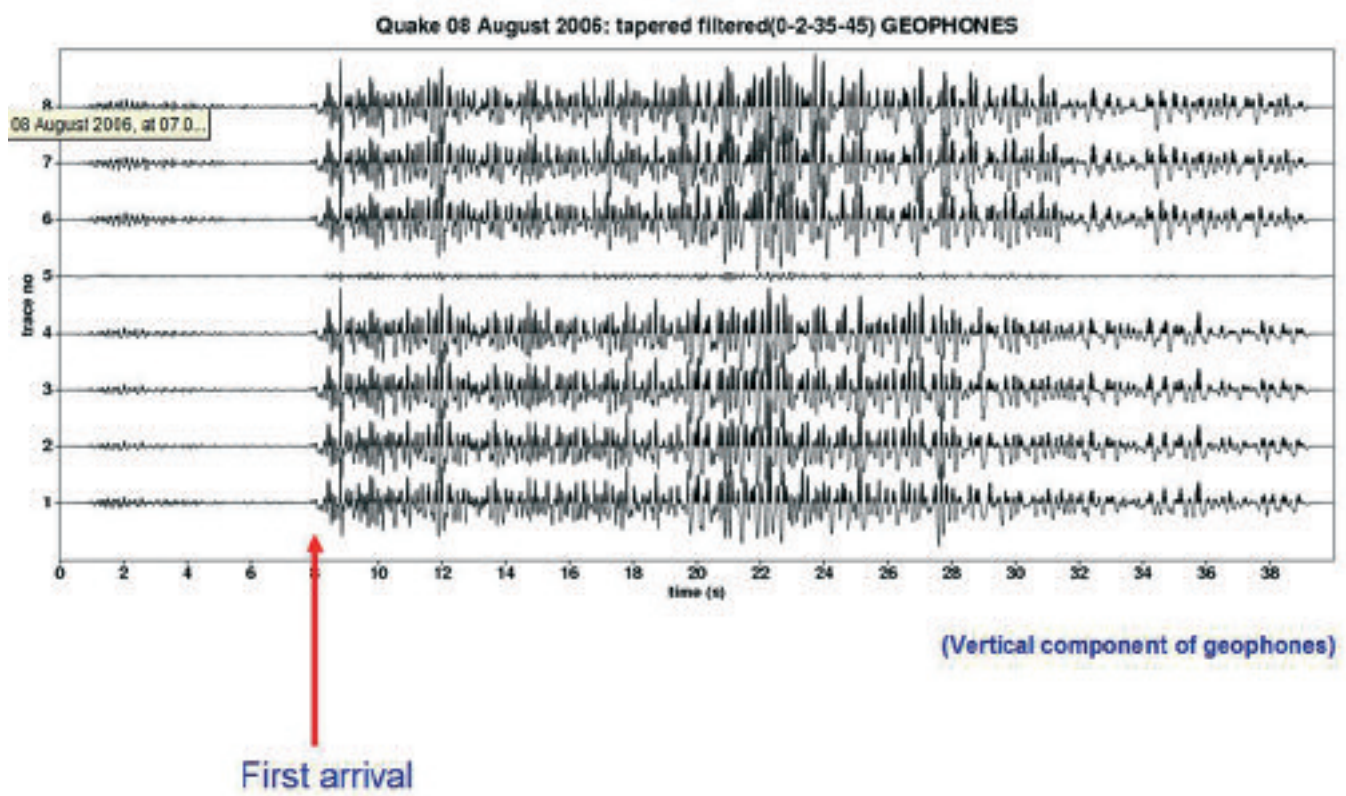
One thing that sets LOFAR apart from other radio observatories is the strong connection it has with non-astronomical science. Right from the start, the goal has been to create a much broader use of the antenna and sensor network, for instance in the field of geology, meteorology and precision



*The Westerbork High-band Antenna Test station at the WSRT site, where it functioned as a 15th telescope during low frequency LFFE measurements.*

agriculture. Indeed, without these additional applications, LOFAR would never have received the initial BSIK grant. ‘The list of possibilities has grown tremendously,’ says Joris van Enst, LOFAR’s director for science. A geologist by training, van Enst pursued a government career in science policy before Butcher invited him to ASTRON in 2004. ‘Scientists in other fields are generally enthusiastic about the possibilities of LOFAR,’ says van Enst, ‘provided they first understand the concept.’ While the existing network infrastructure can be very useful for some projects, like mapping sub-surface layering and movements using geophones, other applications might just use LOFAR’s advanced experience in ICT technology and software development. ‘In principle,’ says van Enst, ‘everything that’s big and uses a mathematical model can be approached in this way.’ According to van Enst, one of the most exciting future programs could be large-scale monitoring of the Waddenzee – an ecologically unique inlet of the North Sea – to study the relation between geophysical processes like sedimentation or mud

# ASTRON



Recording of the earthquake at 2006/08/08 07:04 through the geophones at the LOFAR test site.

flow and biological or environmental changes. ‘In 2005, we started promising discussions with many institutes,’ he says. ‘They would need to combine their specific knowledge in their own field with ASTRON’s experience’ in building and adapting models on the basis of the input of a large sensor network. If successful, such a program could well be of international importance.

## Review

Despite these ambitious multidisciplinary applications, astronomy remains the major scientific driver for LOFAR, and many new technologies had to be developed over the past few years to transform the new observatory from a promising concept into a working machine. That’s why the subsystem critical design review, carried

out in November and December 2005, was so important, says de Geus. ‘Every single element of LOFAR had to be submitted to the right tests, to check whether the design is really up to the task.’ According to program manager Jan Reitsma, the critical design review was a major proof of the pudding. ‘It revealed whether or not the engineers did a good job.’

For about six weeks, various aspects of LOFAR were thoroughly discussed in one- or two-day sessions, explains de Geus. Specially invited committees of astronomers and engineers, both from the Netherlands and from abroad, were to evaluate scientific requirements, technological choices, detailed designs, and prototype performance of a wide variety of subsystems, from antennas and low-noise amplifiers to calibration techniques and data handling. ‘It’s a very complex process,’ says

Reitsma, 'with the purpose of making sure that the design is capable of fulfilling the expectations of the end users of LOFAR.'

Of course, the LOFAR engineers have not been working in an intellectual vacuum for the past couple of years. According to de Geus, an informal trajectory of peer review at a wide variety of meetings and workshops also played a key role. 'It would be very strange if a passer-by, even someone who is very knowledgeable about radio astronomy, would be able to point out a fundamental design flaw.' Nevertheless, the 2005 subsystem critical design review was a major formal milestone in the project organisation. Moreover, says de Geus, the process enforces an extremely detailed documentation of the whole project, which in fact constitutes an important collective memory.

In the end, the subsystem critical design review turned up few unexpected surprises. 'Everyone emerged from the sessions with a new sense of confidence,' says de Geus. Still, two subsystems required further development, according to the respective committees. One was the electronics necessary to temporarily store LOFAR data to search for brief transient events; the other was the design of the high-band antennas. Originally, says de Geus, the high-band antennas would have been developed by LOFAR's American partners, so after 2003 ASTRON had to start more or less from scratch.

The subsystem critical design review was a demanding process for the LOFAR engineers. 'In many cases, the future end users of the telescope had very specific requirements and demands,' says Reitsma. 'I applaud the engineers for accepting comments and critique, and for working together with the scientists to explore the limits of what is technologically possible.' With the majority of subsystems having passed their individual examinations, de Geus is confident that the full system critical design review in January 2007 will proceed flawlessly. And although there has never been a formal relation between the review and the BISK grant, the positive result is of course relevant for the future funding of LOFAR.



*On November 1st 2006, the backbone of LOFAR was broken due to constructions along the A28 highway. All 144 fibers had to be welded on two places to restore the 65 kilometer fiber connection, after which LOFAR CS1 tests could be continued.*



*In the second half of 2006, LOFAR Core Station 1 was built. The picture shows LOFAR Roll out manager Mark Bentum, feeding the antenna cables to the electronics cabinet.*



## Outreach and outlook

Another positive development that became apparent in 2005 is the acceptance of LOFAR by the Dutch population. Because of the continuous debate about possible adverse health effects of UMTS antennas used for mobile telephony, many citizens were quite suspicious about the LOFAR antennas at first. 'We had to put a lot of effort into explaining the difference between transmitting and receiving,' says de Geus. The project received much media exposure, especially in the northern part of the Netherlands, and in general, people have become enthusiastic about the revolutionary facility. Part of LOFAR's 2005 public relations endeavour has focused on students, within the framework of the LOFAR@School project – a contest that provided talented highschool students with a unique opportunity to invent and explore new innovative applications for the sensor network. The winning team, carefully selected by a professional jury, even got to develop their idea in collaboration with IBM technicians, as part of IBM's Extreme Blue summer internship program. The contest winners were the Niftarlake College in Maarssen, with a project to monitor the relation between pollution and health, and the Philip van Horne Scholengemeenschap in Weert, with a proposal to use a sensor network for studies of the terrestrial magnetic field.

Ultimately, LOFAR could very well play an important role in getting young students in touch with science and technology, says de Geus. For instance, highschools throughout the country could be encouraged to set up a single LOFAR antenna at their premises, which would be connected to the array. Similar projects have already been undertaken by high-energy astrophysicists with cosmic ray detectors. Also, since LOFAR will have applications well beyond the somewhat esoteric field of radio astronomy, the unique Dutch facility could conceivably stimulate general interest in science among young children – something that requires serious attention, according to some studies. It is of course much too early to know whether or not LOFAR will transform the way Dutch students

will appreciate science and technology. But something that has transformed very much because of LOFAR is the institutional culture at ASTRON, says Eugène de Geus. 'We have changed beyond recognition. LOFAR has forced us to collaborate with very different scientific disciplines and with business companies. As a result, ASTRON is now much more embedded within the society, and we have become more aware and responsive to economic and political events.'

In the near future, the cultural change at ASTRON may help the institute to make a crucial contribution to the development of SKA, the Square Kilometre Array. This futuristic radio telescope, to be built either in Western Australia or in Southern Africa, will probably use a novel mix of 'classical' parabolic radio dishes and flat phased-array antennas that are more comparable to the antennas of LOFAR. Right now, says de Geus, it's very important for us to demonstrate the feasibility of the concept of a 'software telescope', since the international radio astronomy community isn't fully convinced yet. And of course, the current experience with LOFAR will give ASTRON a headstart in the development of SKA technology. Says de Geus: 'Everything that happens with LOFAR is relevant to SKA.' ■



*On June 5, 2006, the Laureates Class of 2006 were honored in Medal Ceremonies at the Andrew W. Mellon Auditorium in Washington D.C. ASTRON was nominated by IBM and belongs with the LOFAR project to the 5 most innovative ICT Science projects. ASTRON director Harvey Butcher had the honor to receive the medal (copyright CW honors).*

On June 5th, 2006, ASTRON and LOFAR were honored by the ComputerWorld magazine Honors Program event held at the Andrew W. Mellon Auditorium in Washington D.C. LOFAR was judged to belong to the 5 most innovative ICT Science projects in the world in the past year. On September 12th, the Internet Society of the Netherlands announced its annual awards for 2006. LOFAR and Gigaport Next Generation (the advanced academic internet in the Netherlands) were recognized as projects belonging to the absolute top in the areas of IT technology and innovation, and shown as examples of a strong Dutch vision on the future of IT research. The economic, scientific and technological spin-off of both projects promise to be significant and both will contribute substantially to the country's competitive knowledge base.

During the summer of 2006, four initial LOFAR stations were installed in the central core area. These four locations share the hardware of one full station: the middle location contains 48 low band antennas (50% of a complete station) and the three

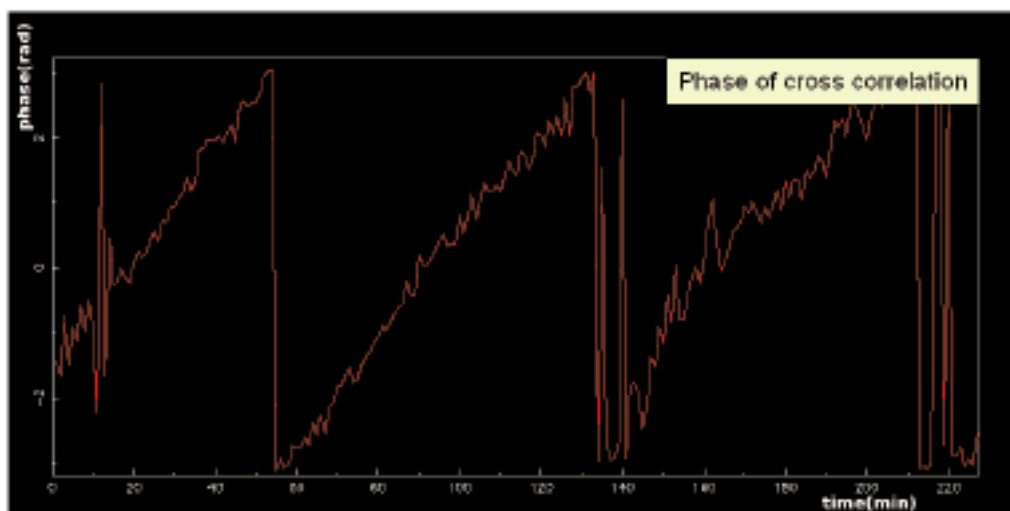
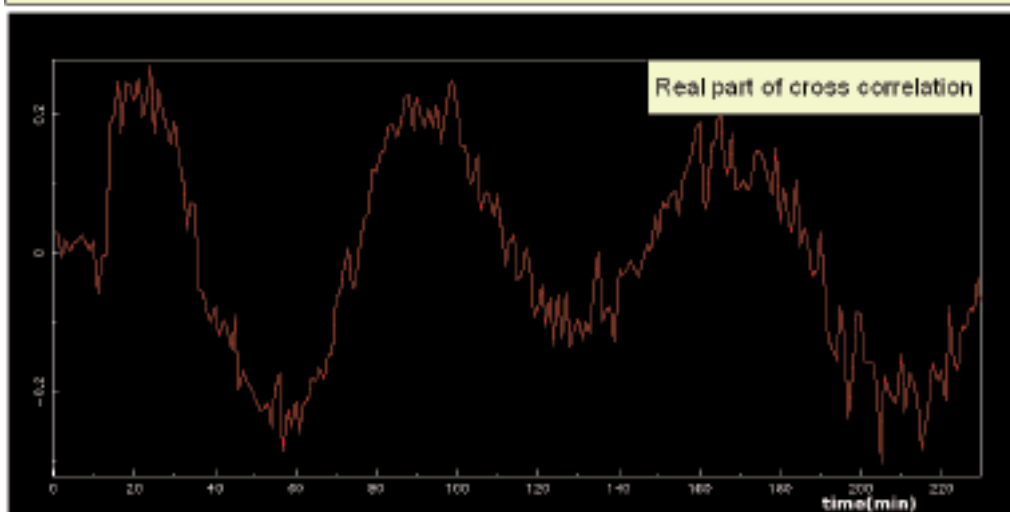
other locations each contain 16 low band antennas and corresponding signal processing chain. The signal processing chain is organized in clusters of 4 antennas, which can be operated as a "mini-station" with its own independent beam direction. In this mode the initial station configuration yields 276 baselines.

The installation and first commissioning efforts have resulted in a first observation of fringes between two "mini-stations" in the central location. The fringes of a strong sky source are observed as a gradual phase shift between the two dipole locations. These fringes prove the functioning of the integrated signal flow from the antennas and signal processing in Exloo through the fiber connection to Groningen and correlation on the Blue Gene supercomputer.

By the end of 2006, a steady stream of data was being produced by CS1 and commissioning of the full signal chain and software integration was proceeding quickly. LOFAR has entered the exciting phase where each new observation poses both new insights and new challenges!

#### Fringes observed with CS1

- observed in the night of 13-14 september from 23:00 till 3:00 (4 hours)
- cross correlation of two dipoles (XX)
- Fringes from dominating strong source passing through dipole beam



Cross correlation of two dipoles in CS1 over a period of 4 hours, measured in September 2007. The dipoles have an almost east-west baseline of 34 meters. Shown is a single frequency channel of 1 kHz around 60 MHz integrated over 1 minute. The top plot shows the real part of the correlation, nicely following a sine shape. The lower plot shows the phase angle rotating over three periods.



Rob van den Berg

## 4. Technology transfer

### **ASTRON: a *kennismotor* in the Northern part of the Netherlands**

We have only been talking for ten minutes, but the whiteboard is already fully covered in diagrams, acronyms and arrows showing relationships between the various organisations and people. It is typical for the way Arnold van Ardenne, head of the *Astrotec Holding* (ATH), explains what happened with his company. ATH is a company that is fully owned by ASTRON. Its mandate is to bring innovative and novel technology developed by ASTRON to the marketplace. "It was a fruitful year.", Van Ardenne concludes at the end of our interview, even though it did not go as fast as he would have wanted. A year of setting up joint ventures to capitalise on the developments that were started since ATH's birth in mid-2003, but also a year of waiting and clearing all kinds of red tape that stood in the way of fulfilling his plans and ideas.

But let's start with the good news. With the establishment of *NOFIQ Systems*, the first real application of the smart sensor technology developed at ASTRON, has come one step closer. NOFIQ will market an automated fire extinguisher for use in relatively small enclosures like switchboxes, where, according to Van Ardenne "...almost 8% of all fires start." This unique fire safety system consists of a number of 'smart', battery-driven temperature and CO sensors, which are connected via a two-way radio link to a central hub. Depending on the CO concentration in the surrounding air and the temperature level in the room various actions may be taken, from sending out a simple alert message, or turning off ventilation systems to cutting the power altogether. Van Ardenne: "This makes it possible to detect a fire at a very early stage, thereby potentially limiting damages. And in case a fire should break out anyway, a special aerosol is released, which extinguishes the flames not by removing oxygen or

by cooling, but by binding free radicals, that is by directly interfering with the combustion reactions at the molecular level." The micro-sized aerosol particles offer an extremely large – and therefore highly active – surface. The particles also remain in suspension for a relatively long time, allowing them to flow into the natural convection currents present in combustion. This further increases the efficiency of the extinguishing agent.

Van Ardenne: "This material is not new, and the system set-up may seem very obvious, but no one has ever done it. Moreover, there were specific conditions we had to fulfil such as a very low power consumption. Also the whole system had to comply with all applicable telecom and fire-directives. No one had ever done that before, so we basically helped develop the regulations. Finally, there is the integration of the fire extinguisher with a radio-frequency link, which proved to be a major challenge. But that is where ASTRON/ATH could really show its added value." Van Ardenne proudly shows the first brochure that has recently been printed, and he explains what further steps will be taken: "Soon the first generation will go out for field tests, a training module for installers will be made, and preparations have started for the first real 'production series' in 2006 at Variass BV, a company in Veendam."

NOFIQ really claimed a large part of his working hours, and there are more products 'with an ASTRON label' that may hit the market in a few years, so Van Ardenne has his work cut out for him: a joint venture called FUFA will develop a flat phased array antenna for the delivery of inflight entertainment in aeroplanes – based on the FAST-antenna that was successfully finished in 2004 –, and FILITRON will work on marketing a radio-frequency identification and antitheft system, for instance for application in libraries. Van Ardenne: "This all became possible because with projects like LOFAR, ASTRON has become a major *kennismotor*



*NOFIQ is an early-stage fire detection and source extinguishing system which, when sensing the early signs of a fire near fire extinguishing units, sends a alerting signal by a 2.4 GHz wireless connection network to the main control unit. Then the relevant extinguishing units will release autonomous a gas (harmless to electronics and humans) to extinguish the fire. (copyright Astrotec Holding B.V.)*

("knowledge engine") in the northern part of the Netherlands." To underline this, he mentions the two million euro support that the European Union has granted to the *Innovative Action Programme* of the province of Drenthe. With these funds eight highly innovative local projects in the area of sensor technology can be supported. Van Ardenne: "Using knowledge that has been developed at ASTRON!" For another pet project of Van Ardenne, the *Integrated Development Laboratory (IDL)*, 2005 was a year of waiting for funds to become available from SNN, *Samenwerkingsverband Noord Nederland (SNN)*, which is responsible for redistributing part of the money from the natural gas that is found here. Van Ardenne: "It was a year of setting up the organisation, of hiring people and finding the right program leaders. In the meantime IDL got involved in the *IJKDIJK* project, a kind of smart dike surveillance and monitoring system. With more than twenty partners, the contribution of ASTRON can only be minor, with some optical sensors from LOFAR, but this 'intelligent dike' in Bellingwolde is a unique project, which will make sophisticated

sensor technology available for water management. Continuous monitoring is important for the safety of our country, especially in view of the effects of climate change and rising sea levels."

To strengthen contacts between ASTRON/ATH and local manufacturing companies, Van Ardenne also organised a number of industry days. The ultimate goal is to use this kind of cooperation to create a source of cheap components for the large phased array telescopes like SKA (*the Square Kilometer Array*). SKA provided another highlight of 2005. Van Ardenne: "On the first of July and after two years of preparation, the European Commission decided to fund the *SKA Design Study (SKADS)*. In total 38 million euro was committed to the study including 10 million euro from the EC. The majority of the funding comes from the national governments across Europe. We have now started working on EMBRACE, (the *Electronic Multi-Beam Radio Astronomy Concept*) a technology demonstrator for SKADS. This four hundred square meter array should ultimately be able to equal the sensitivity of a 25 meter parabola. During this project we will have to make a convincing case regarding the use of phased arrays for radio astronomy. But that means we also have to face the cost issues." It is exactly in this respect where local companies will play an important role, with support from the Innovatieve Acties Programma Drenthe to stimulate local industrial participants.





Rob van den Berg

## 5. The Square Kilometre Array

### SKADS, a European reality

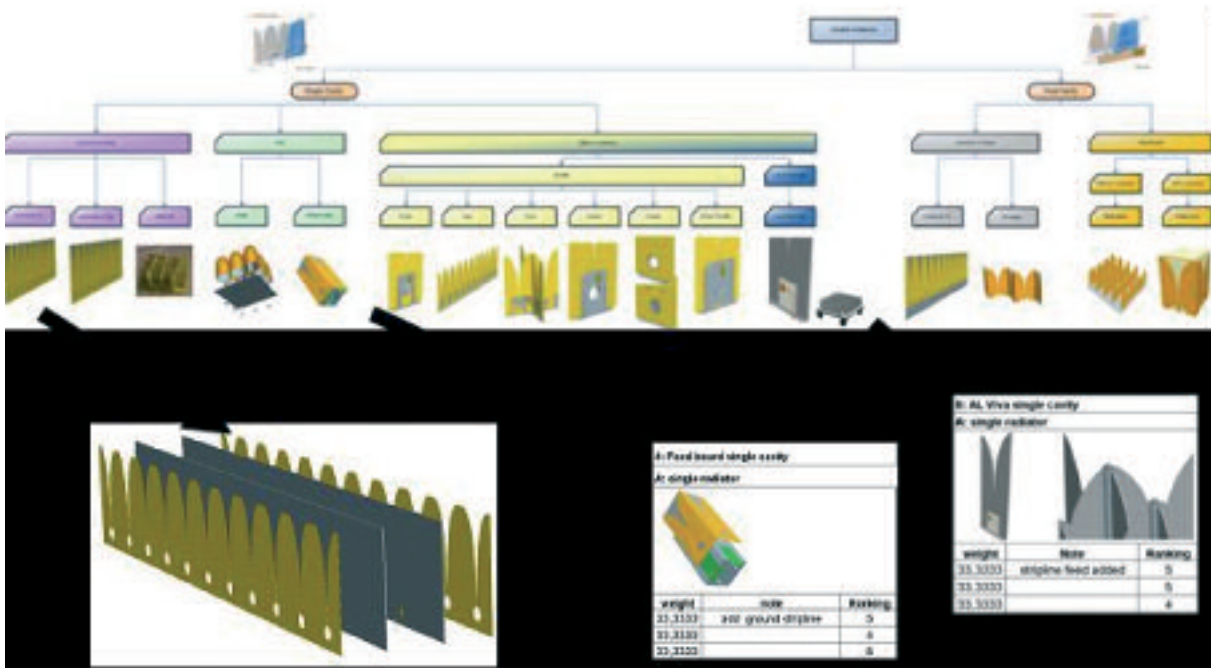
On the first of July the European Commission decided to fund the SKA Design Study (FP6 SKADS), an international effort to investigate and develop technologies, which should enable the design of an enormous radio astronomy telescope with a million square metres of collecting area, the Square Kilometre Array. Van Ardenne: "It took a lot of hard work in the preceding two years to get every one of the twenty-eight participants on board. In total 38 million euro was committed to the study and the SKADS office is located here in Dwingeloo, together with the SKADS co-ordinator and project manager." The project will run from 1 July 2005 to 30 June 2009. The first tangible results were a brochure and a website ([www.skads-eu.org](http://www.skads-eu.org)), but even well before the official start date of the project, work had already begun to work on EMBRACE, the Electronic Multi-Beam Radio Astronomy Concept, a technology demonstrator for SKADS. This four hundred square meter array will be built on the knowledge gained from THEA, the Thousand Element Array and should ultimately have comparable sensitivity of a 25 meter parabola. According to Van Ardenne some important steps were made in 2005 towards the electromagnetic modeling of such an antenna. Also the architecture of the array was carefully studied to determine which functionalities should be included in the tile, and which could just as well be kept 'outside', mainly for cost reasons. Van Ardenne: "During this project we will have to make a convincing case regarding the use of phased arrays for radio astronomy. But that means we also have to face the cost issues."

It is exactly in this respect where outside companies will play an important role, possibly involving companies from Drenthe with support from an EC development fund. To strengthen contacts between ASTRON and such companies like IBM, Philips,

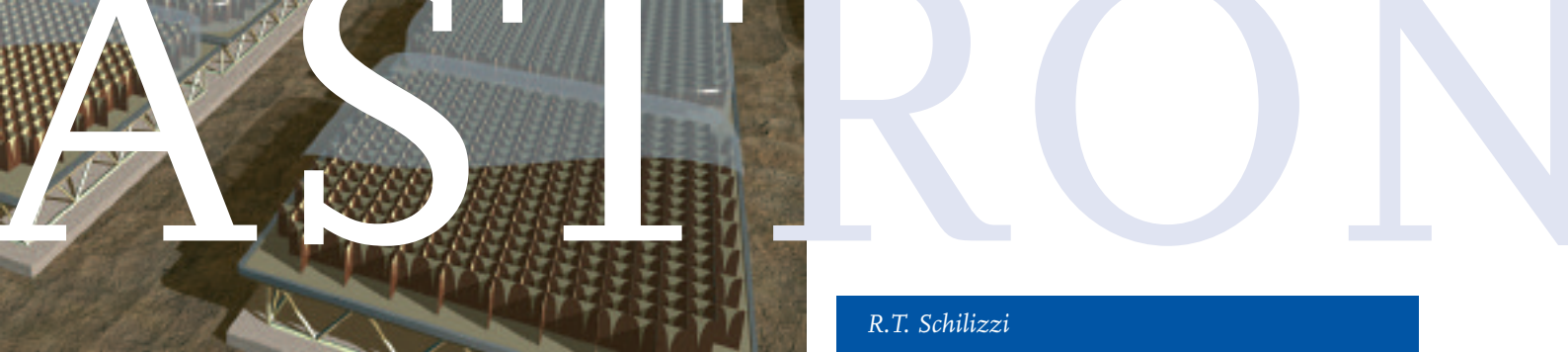
and Alcatel, Van Ardenne organised a number of industry days. The ultimate goal was to use this kind of cooperation to create a source of cheap components for the large phased array telescopes like SKA. This same problem is targeted within PACMAN, a collaboration between the University of Twente Technical University of Eindhoven, ASTRON and the industrial electronics company Thales Nederland leading the project, with financial support from the Ministry of Economic Affairs. PACMAN's goal is to research and develop integrated technology for the design and manufacturing of mass-market, low-cost phased array antennas that can be applied in various domains, such as telecom, wireless internet, satellite communication, radars, large area astronomic antennas as we are developing for SKADS, automotive and security. Van Ardenne: "The first results are now becoming available. Potential solutions involve printing technique applied e.g. for radio-frequency ID tags on a thin polymer foil. If we could do the same with VIVALDI antenna elements, we should be able to build tiles well below a cost price of a thousand euro." Of course, Van Ardenne realises that besides costs, testing EMBRACE will be extremely helpful to convince all partners in the project of the viability of these phased array systems.



The first EMBRACE tile, primarily used to verify the antenna patterns.



Decision-tree for the realization of the antenna elements. Based on a careful trade-off process the left-most (dual-pol) approach was selected for EMBRACE.



R.T. Schilizzi

## The International SKA Project Office

The Square Kilometre Array, the SKA, represents the next step forward in radio astronomy. It is a global project that aims to construct a radio telescope with a collecting area of one million square metres. The SKA will be an interferometric array of individual antenna stations, synthesizing an aperture with a diameter of up to several thousand kilometres.

The mission of the International SKA Project Office (ISPO) is to play the central coordinating and leadership role in realizing the global SKA project on behalf of the International SKA Steering Committee (ISSC). The Project Director, Project Engineer, and Project Scientist work together with the ISPO Working Groups and Task Forces and the national and regional projects to carry out this task. ISPO is hosted by ASTRON.

In 2005, the major issues tackled by the ISPO were the site short-listing process, supervision of RFI monitoring at the candidate sites, the selection of the Reference Design for the SKA, generation of the Project Plan, monitoring progress of the pathfinder projects, modeling the costs of the telescope, structuring contacts with potential industry partners, outreach, and finance.

### *Site short-listing: which country will host the SKA*

The ISPO issued several clarifications on the “Request For Proposals” and “Guidelines on Configuration Simulations” in response to questions from the site proposers. The clarifications were issued after consultation with the Site Evaluation Working Group and Simulations Working Group. Protocols on the site selection process were drafted by the ISPO and approved by the ISSC at its 15th meeting held in Pune, India. Preparations were made for the evaluation of the proposals by the Site Advisory Committee and the

ISPO Working Groups and Task Forces. Four proposals for hosting the SKA were submitted at the end of 2005, by Argentina & Brazil, Australia, China, and South Africa.

### *RFI monitoring*

The ASTRON RFI monitoring team completed its series of month-long measurements at each of the four candidate sites for the SKA. The local teams began their year-long monitoring campaigns in March. The ISPO supervised these activities and clarified questions on procedures after consultation with the RFI Assessment Task Force.

### *Project Plan*

A first version of the SKA Project Plan was prepared by the ISPO. It includes a timeline to Phase 1 construction starting in 2012, and full array operation by 2020. The Project Plan has served to focus attention on the steps needed world-wide to achieve these goals.

### *Reference design*

The ISSC approved a Reference Design for the SKA (see figure) which includes a small dish array with smart feeds, aperture array tiles in the core of the array for all-sky monitoring, and a low-frequency array to study the Epoch of Reionisation in detail.

### *Options for the SKA*

A first version of a paper was prepared by the ISPO outlining the options available to the international SKA Collaboration in the areas of technical design, site selection, cost, and governance, and the consequences of particular decisions that could be taken by the ISSC.

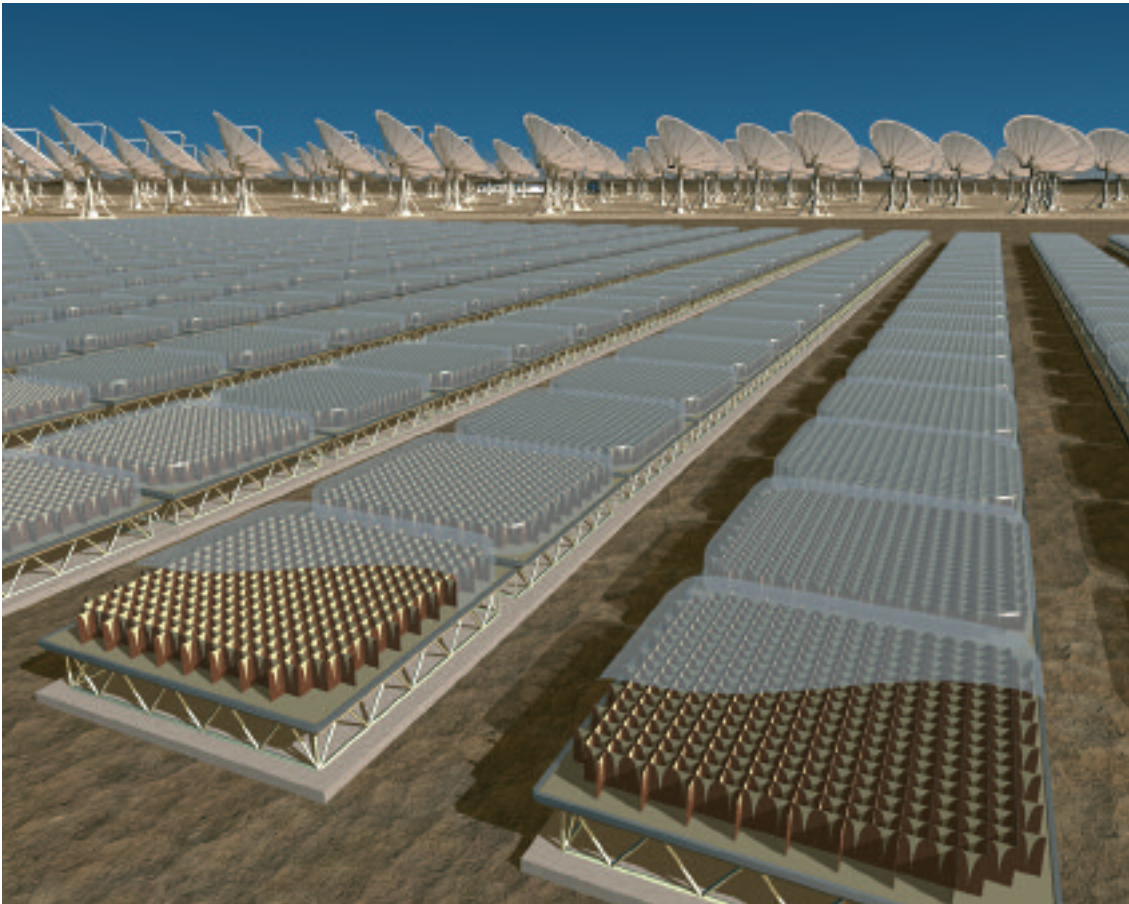
### *Contacts with industry, CERN*

Contacts with IBM, led by the International Project Engineer on the ISPO side, continued in 2005 and resulted in the drafting of a “Term Sheet” to act as template for interactions with IBM of SKA partners around the world.

In 2006, the major issues for the ISPO were coordinating the site proposal evaluation process which led to the short-listing by the Steering Committee of the Australian and Southern African sites, science-engineering tradeoffs on the SKA design, preparing sections of the seventh Framework Proposal on SKA Design and Additional Site Characterization, generating interim reports on Engineering Decisions for the SKA and on Site Infrastructure Deployment and Costs, monitoring

progress of the Pathfinder projects around the world, modeling the costs of the telescope, structuring contacts with potential industry partners, outreach at the IAU General Assembly, preparation of documents for Steering Committee meetings, and finance. In addition, the ISPO supported the Steering Committee in its contacts with Funding Agencies.

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*SKA Reference Design: aperture array tiles and dishes*



## 6. General information

### Public relations and Outreach

Contacts with the press and public outreach events are important for ASTRON in order for it to show its scientific excellence, as well as its relevance to society and the Dutch knowledge economy.

One of the most important events for ASTRON in 2005 was the opening of the LOFAR supercomputer Stella by the Minister of education, culture and science, Mrs. Maria van der Hoeven on 26 April. The supercomputer with a capacity of 27,5 teraflop per second is based at the Rekencentrum of the Rijksuniversiteit Groningen and is a collaborative achievement between ASTRON and IBM. At this occasion, ASTRON general director Harvey Butcher was awarded Ridder in de Orde van de Nederlandse Leeuw by the Minister.

Another important event in 2005 was the two-day press conference organized by the European Commission: "Astronomy looks into the future – the role of European Infrastructures". The event was hosted by JIVE, the Joint Institute for VLBI in Europe, in close collaboration with ASTRON. 60 Journalists from all over Europe attended the press conference. Both the Dutch Minister of education, culture and science, Mrs. Maria van der Hoeven and Mr. Janez Potočnik, the EC Commissioner for Science and Research held a keynote speech. They emphasized the importance of European funding and collaboration to establish successful large research infrastructures and to develop new large astronomical instruments.

The press heard presentations about the three flagship projects of the community: the Square Kilometre Array radio telescope, the Extremely Large (optical-IR) Telescope and the astroparticle physics facility, Km<sup>3</sup>Net. Research infrastructures in astronomy and astrophysics like RadioNet, OPTICON, EuroPlaNet and ILIAS presented their

networking research infrastructures to the press. JIVE showed new results of the VLBI tracking of the descent of the Huygens probe on Titan and also presented a live demonstration of e-VLBI. In addition to the press, a number of EC-officials and scientists involved in the research infrastructures were present. The press conference was very successful resulting in a considerable number of press articles and broadcasts and showed the importance of "the Dwingeloo campus" in the international field of astronomy.

On 18 April 2006, ASTRON celebrated the fiftieth anniversary of the opening by Queen Juliana (on 17 April 1956) of the Dwingeloo radio telescope. Two hundred guests came from far and wide to reminisce over the early days of Dutch astronomy. The April 2006 issue of the National Geographic featured an extensive article by Govert Schilling on the telescope and on Dutch radio astronomy. The Dwingeloo telescope is no longer used for research but the Society for Amateur Radio in the Netherlands (VERON) has a strong interest in making the facility available to amateurs, schools and the general public. At the anniversary ceremony, Thijs van der Hulst, chairman of the ASTRON Board, and Dick Harms, VERON chairman, signed a letter of intent to set up the "C.A. Muller Radio Astronomie Station" (CAMRAS) foundation, the purpose of which will be the restoration of the telescope to an operational state for use by the public.

In 2006, thirteen hundred local elementary school pupils descended on the LOFAR Initial Test Site in Exloo to see the prototype antenna array and help 'calibrate' the prototype geophone array. The geophones are buried about ten meters under the surface to eliminate the much unwanted surface noise. But they are still sensitive enough to detect footsteps directly overhead. For the calibration



*The 25-metre Dwingeloo telescope. The camera that took this nostalgic picture was supported by a prototype LOFAR antenna (see the shadow on the right).*



*School pupils helping to calibrate the prototype geophone array by jumping up and down.*

experiment the children were asked to jump up and down at some distance away from the sensors. They were then asked to look at the recorded vibrations and note the difference in arrival times across the array. Knowing the distance between the geophones, one could ‘calibrate’ the speed of travel of the vibration signal in the ground. Answer: 932 km/hour! The event also marked the start of ‘LOFAR week’ at 23 schools in the township Borger- Odoorn, which includes the town of Exloo. ASTRON and LOFAR staff members gave talks to pupils aged 5 to 12, who then did exercises on the planets and built models of LOFAR antennas.

Making our activities known to the outside world is a continuous activity. Apart from the selected events mentioned above, ASTRON received a lot of public attention and hosted several smaller events, including six international scientific workshops. Many staff members are involved in presenting our activities to various audiences like students, policy makers, politicians, business people and interested general public. Interaction with students and (occasionally) school children is considered to be important in order to raise their interest in science and technology. ASTRON continued to appear in the general and technical press at a regular basis.

In 2005 and 2006 ASTRON opened the institute for visitors on the Open Day in the national science and technology week. Each year, some 3000 visitors made their way to the ASTRON premises and enjoyed a series of demonstrations (for example, ‘How to make a comet’), lectures and tours of our facilities. Younger visitors could join in a technical workshop (“PretLab”), rolling up their sleeves to build a multi-color LED based temperature sensor or a LOFAR radio.

# ASTRON



2005

## Visits

20/1	Platform Metaal regio Noord
24/1	Ondernemende Staten Drenthe
24/1	Pre-university college students organized by Leiden
9/2	ESA staff
17/2	VWO students organized by Kapteyn Institute
21/2	NLTO South-East Drenthe
21/2	Council members municipality of Westerveld
2/3	Students physics Universiteit Twente
29/3	SRON Facility group
30/3	Pre-university college students organized by Leiden
7/4	Natuurwetenschappelijk Genootschap Assen
8/4	Wageningen University, chairgroup "Erosie en Bodem- en Waterconservering"
20/4	WSRT, Onderwijs Ontmoetingsdag gemeente Coevorden
13/5	Former students business administration TU Delft
1/7	Koninklijke Nederlandse Heidemaatschappij
8/7	Council members municipality of Assen
24/8	VSB Fonds en Drents Landschap
9/9	Algemeen Bestuur SBW
10/9	Students physics and astronomy Vrije Universiteit van Amsterdam
17/9	"Vereniging Oud-Sterrewachters" Leiden
22/9	INCOSE/NLD
27/9	KNVWS department Twente
7/10	Students Universiteit Twente
8/10	Former promovendi TU Delft
11/10	Working group Nationaal Park Dwingelderveld
18/10	Roelof van Echten College Hoogeveen, 4+5 VWO
19/10	Staatsbosbeheer Regio Noord
21/10	Ingenieursbureau Oranjewoud
21/10	Students Universiteit van Amsterdam
21/10	Rotary Club Emmen
8/11	Rotary Club Zuidlaren-Anloo
22/11	NGI Noord Nederland
24/11	Students TU Delft
7/12	Staff Kapteyn Instituut

2006

## Visits

13/1	Board ABOost
20/1	Raad van Toezicht & Board Scheper Ziekenhuis Emmen
24/1	Pre-university college students organized by Leiden
26/1	Studievereniging Sipke Wynia TU Delft
9/2	Connect Business club
9/2	Landinrichtingscommissie Borger-Odoorn
15/3	Physics excursion HAVO/VWO students
15/3	Pharos region Zwolle-Hoogeveen
22/3	Pre-university college students organized by Leiden
6/4	Studievereniging Marie Curie KUN
26/4	Studievereniging Electrotechniek TU Delft
2/5	Probus '88 Drachten
12/5	Junior Kamer
15/5	KNVWS and Flamish VVS
17/5	Municipality council Hoogeveen
18/5	Faculty Space Science University of Groningen
1/6	Stichting SURF
27/6	Mathematics & Information Technology faculty University of Groningen
7+8/9	Students mechanical technique Noorderpoort College Stadskanaal
11/9	Rotary Club Meppel
16/9	KNVWS meteors working group
22/9	Medical staff Bethesda hospital Hoogeveen
25/9	Municipality council Borger-Odoorn
29/9	Information technology students Leeuwarden
7/10	't Lantschap Drenth (reunion students University of Groningen)
19/10	Laser and Electro-Optics Society Benelux Student Chapter
1/11	Students Technische Universiteit Eindhoven
6/11	Students Universiteit van Amsterdam
16/11	Vereniging oud-directeuren Rabobank
1/12	Mrs. Danuta Hübner, European Commissioner for Regional Policy
19/12	Students (future teachers) physics and chemistry Hogeschool Windesheim





## Personnel and Organization

Division	2005	2006
General affairs	32 (♂) 16 (♀)	32 (♂) 17 (♀)
Radio Observatory	39 (♂) 4 (♀)	37 (♂) 3 (♀)
R&D	83 (♂) 10 (♀)	80 (♂) 9 (♀)
Total	184	178

Age	2005	2006
< 25	2	0
25-35	50	42
35-45	49	53
45-55	46	43
55-65	34	35
> 65	3	5

	2005	2006
Full time	159	154
Part time	25	24

Nationalities 2005 2006		
Dutch	156	153
French	3	2
British	3	4
Ukrainian	1	1
German	5	6
Russian	2	1
Japanese	1	0
Romanian	1	1
Swedish	1	0
American	2	3
New Zealanders	1	1
Canadian	3	2
Italian	1	1
Indian	2	2
Chinese	1	1
Bulgarian	1	0

Absence	2005	2006
Absence because of sickness	2,8%	3,4%

## Financial Report 2005

**ASTRON Institute**  
Financial Report of 2005,  
compared with 2004

	2005 Budget	2005 Actual	2005 Difference	2004 Actual
<b>INCOME</b>				
Government Grants-Ministry of Education, Culture & Science Subsidies / Contributions by by third parties	7.448.400	8.479.944	1.031.544	13.036.450
Cash Management	0	33.590	33.590	19.877
Other Income	786.292	1.056.188	269.896	482.340
<b>Total income</b>	<b>19.218.557</b>	<b>19.798.800</b>	<b>580.243</b>	<b>16.403.869</b>
<b>EXPENDITURES</b>				
Grants / Expenditures				
Projects	14.075.150	15.432.786	1.357.636	13.707.856
Radio Observatory	3.115.823	3.004.323	-111.500	2.857.268
Operations	12.965.375	13.313.425	348.050	11.441.291
Allocation to Projects	-10.947.323	-11.524.744	-577.421	-10.845.960
Other Expenditures	0	75.791	75.791	138.555
<b>Total Expenditures</b>	<b>19.209.025</b>	<b>20.301.581</b>	<b>1.092.556</b>	<b>17.299.010</b>
<b>BALANCE</b>	<b>9.532</b>	<b>-502.781</b>	<b>-512.313</b>	<b>-895.141</b>



## Financial Report 2006

### ASTRON Institute

Financial Report of 2006,  
compared with 2005

	2006 Budget	2006 Actual	2006 Difference	2005 Actual
<b>INCOME</b>				
Government Grants-Ministry of Education, Culture & Science Subsidies / Contributions by third parties	9.480.402	7.458.002	-2.022.400	8.479.944
Cash Management	5.750.130	4.187.110	-1.563.020	10.229.078
Other Income	0	86.432	86.432	33.590
	100.000	2.011.645	1.911.645	1.056.188
<b>Total income</b>	<b>15.330.532</b>	<b>13.743.189</b>	<b>-1.587.343</b>	<b>19.798.800</b>
<b>EXPENDITURES</b>				
Grants / Expenditures				
Projects	11.044.432	9.928.654	-1.115.778	15.432.786
Radio Observatory	2.941.613	2.736.787	-204.826	3.004.323
Operations	12.388.919	12.962.743	573.824	13.313.425
Allocation to Projects	-11.044.432	-11.358.992	-314.560	-11.524.744
Other Expenditures	0	19.550	19.550	75.791
<b>Total Expenditures</b>	<b>15.330.532</b>	<b>14.288.742</b>	<b>-1.041.790</b>	<b>20.301.581</b>
<b>BALANCE</b>	<b>0</b>	<b>-545.553</b>	<b>-545.553</b>	<b>-502.781</b>

## Board and Management Team

### ASTRON Board members:

Prof. Dr. J.M. van der Hulst (Chairman)	Kapteyn Astronomical Institute
Prof. Dr. Ir. J.H. Blom	Technical University of Eindhoven
Prof. Dr. J.H. van Gorkom	Columbia University, New York
Prof. Ir. P. Hoogeboom	TNO Defense and Security
Prof. Dr. C.U. Keller	Utrecht University (from May 2006)
Prof. Dr. K.H. Kuijken	Leiden University (from October 2005)
Prof. Dr. J.M.E. Kuijpers	Radboud University
Prof. H.J.G.L.M. Lamers	Utrecht University (until May 2006)
Prof. Dr. G.K. Miley	Leiden University (until October 2005)
Prof. Dr. L.B.F.M. Waters	University of Amsterdam

### ASTRON Management Team:

Prof. Dr. H.R. Butcher	Executive Director, Chair
Dr. E.J. de Geus	Director External Affairs
K.P.H. Determan	Director General Affairs a.i.
Ir. A. van Ardenne	Director Emerging Technologies
Dr. W.A. Baan	Director Radio Observatory
Dr. C.M. de Vos	Director R&D Division

### Invited to MT meetings:

Dr. M.A. Garrett	Director JIVE
Mrs. J.W. Roorda	Head of Human Resource Department



## 7. Publications and colloquia

### Publications by ASTRON astronomical staff 2005

1. Aars, C. E., Hough, D. H., Yu, L. H., Linick, J. P., Beyer, P. J., Vermeulen, R. C., Readhead, A. C. S.: "Optical Spectrophotometry of a Complete Sample of 3CR Lobe-dominated Quasars", 2005, *Astronomical Journal*, 130, 23A.
2. An, T., Goss, W. M., Zhao, Jun-Hui, Hong, X. Y., Roy, S., Rao, A. P., Shen, Z.-Q., "Simultaneous Multi-Wavelength Observations of Sgr A\*", 2005, *Astrophysical Journal*, 634, L49.
3. Baan, W. A., Klöckner, H.: Megamasers: "Molecular Diagnostics of the Nuclear ISM", 2005, *Astrophysics and Space Science*, 295, 263B.
4. Barbieri, C. V., Fraternali, F., Oosterloo, T., Bertin, G., Boomsma, R., Sancisi, R.: "Extra-planar gas in the spiral galaxy NGC4559", 2005, *Astronomy and Astrophysics*, 439, 947B.
5. Barvainis, R., Lehár, J., Birkinshaw, M., Falcke, H., Blundell, K. M.: "Radio Variability of Radio-quiet and Radio-loud Quasars", 2005, *Astrophysical Journal*, 618, 108B.
6. Bignall, H. E., de Bruyn, A. G., Jauncey, D. L.: "The variable extragalactic radio universe", *EAS Publications Series*, Volume 15, 2005, pp.157-176.
7. Boomsma, R., Oosterloo, T. A., Fraternali, F., van der Hulst, J. M., Sancisi, R.: "Extra-planar H I in the starburst galaxy NGC253", 2005, *Astronomy and Astrophysics*, 431, 65B.
8. Bower, G. C., Falcke, H., Wright, M. C., Backer, D. C.: "Variable Linear Polarization from Sagittarius A\*: Evidence of a Hot Turbulent Accretion Flow", 2005, *Astrophysical Journal*, 618L, 29B.
9. Braun, R.: "The Neutral Medium", 2005, *mpge.conf...23B*.
10. Braun, R., Thilker, D. A.: "Imaging the Low Red-shift Cosmic Web", 2005, *Astronomical Society of the Pacific*, 331, 121B.
11. Braun, R.: "Extra-Planar Gas", 2005, *Astronomical Society of the Pacific*, 331, B.
12. Braun, R., Kanekar, N.: Tiny H I clouds in the local ISM", 2005, *Astronomy and Astrophysics*, 436L, 53B.
13. Boomsma, R., Oosterloo, T. A., Fraternali, F., van der Hulst, J. M., Sancisi, R.: "High Velocity H I in NGC 6946 and Extra-planar Gas in NGC 253", 2005, *Astronomical Society of the Pacific*, 331, 247B.
14. Brentjens, M. A., de Bruyn, A. G.: "Faraday rotation measure synthesis", 2005, *Astronomy and Astrophysics*, 441, 1217B.
15. Britzen, S., Krichbaum, T. P., Strom, R. G., Witzel, A., Muxlow, T. W. B., Matveenko, L. I., Campbell, R. M., Alef, W., Hummel, C. A., Zensus, A.: "Large-scale motion, oscillations and a possible halo on the counter-jet side in 1803+784", 2005, *Astronomy and Astrophysics*, 444, 443B.
16. Brunthaler, A., Reid, M. J., Falcke, H.: "Atmosphere-Corrected Phase-Referencing", 2005, *Astronomical Society of the Pacific*, 340, 455B.
17. Brunthaler, A., Reid, M. J., Loeb, A., Falcke, H.: "The proper motion of M 33", 2005, *Astronomische Nachrichten*, 326R, 487B.
18. Brunthaler, A., Bower, G. C., Falcke, H.: "Radio linear and circular polarization from M81\*", 2005, *Astronomische Nachrichten*, 326, 541B.
19. Brunthaler, A., Falcke, H., Bower, G. C., Aller, M. F., Aller, H. D., Terasranta, H.: "The extreme flare in III Zw 2: evolution of a radio jet in a Seyfert galaxy", 2005, *Astronomische Nachrichten*, 326, 540B.
20. Brunthaler, A., Falcke, H., Bower, G. C., Aller, M. F., Aller, H. D., Teräsanta, H.: "The extreme flare in III Zw 2: Evolution of a radio jet in a Seyfert galaxy", 2005, *Astronomy and Astrophysics*, 435, 497B.
21. Brunthaler, A., Reid, M. J., Falcke, H., Greenhill, L. J., Henkel, C.: "The Geometric Distance and Proper Motion of the Triangulum Galaxy (M33)", 2005, *Science*, 307, 1440B.

22. de Bruyn, A. G., Brentjens, M. A.: "Diffuse polarized emission associated with the Perseus cluster", 2005, *Astronomy and Astrophysics*, 441, 931D
23. de Bruyn, A. G.: "RM structure in the polarized synchrotron emission from our galaxy and the Perseus cluster of galaxies", 2005, *Astronomische Nachrichten*, 326, 610D
24. Chatterjee, S., Gaensler, B. M., Vigelius, M., Cordes, J. M., Arzoumanian, Z., Stappers, B., Ghavamian, P., Melatos, A.: "PSR J2124-3358: A Bow Shock Nebula with an X-ray Tail", 2005, *American Astronomical Society Meeting 207*, #183.13C.
25. Doyle, M. T., Drinkwater, M. J., Rohde, D. J., Pimblet, K. A., Read, M., Meyer, M. J., Zwaan, M. A., Ryan-Weber, E., Stevens, J., Koribalski, B. S., and 30 coauthors: "The HIPASS catalogue - III. Optical counterparts and isolated dark galaxies", 2005, *Monthly Notices of the Royal Astronomical Society*, 361, 34D.
26. Emonts, B. H. C., Morganti, R., Oosterloo, T. A., Tadhunter, C. N., van der Hulst, J. M.: "Fast Outflow of Neutral and Ionized Gas from the Radio Galaxy 3C 293", 2005, *Astronomical Society of the Pacific*, 331, 353E.
27. Emonts, B. H. C., Morganti, R., Tadhunter, C. N., Oosterloo, T. A., Holt, J., van der Hulst, J. M.: "A jet-induced outflow of warm gas in 3C293", 2005, *Monthly Notices of the Royal Astronomical Society*, 362, 931E.
28. Falcke, H.: "The Low Frequency Array (LOFAR) - Status and prospects", 2005, *Astronomische Nachrichten*, 326, 612F.
29. Falcke, H., Apel, W. D., Badea, A. F., Bähren, L., Bekk, K., Bercuci, A., Bertaina, M., Biermann, P. L., Blümer, J., Bozdog, H., and 65 coauthors: "Detection and imaging of atmospheric radio flashes from cosmic ray air showers", 2005, *Nature*, 435, 313F.
30. Fraternali, F., Oosterloo, T. A., Sancisi, R., Swaters, R.: "The Extra-planar Neutral Gas in the Edge-on Spiral Galaxy NGC 891", 2005, *Astronomical Society of the Pacific*, 331, 239F.
31. Furlanetto, S. R., Carilli, C. L., Briggs, F. H., Jarvis, M., Rawlings, S., Falcke, H.: "Probing the Dark Ages with the Square Kilometer Array", 2005, *American Astronomical Society Meeting 207*, #137.05F.
32. Gallo, E., Fender, R., Kaiser, C., Russell, D., Morganti, R., Oosterloo, T., Heinz, S.: "A dark jet dominates the power output of the stellar black hole Cygnus X-1", 2005, *Nature*, 436, 819G.
33. Garrett, M. A., Wrobel, J. M., Morganti, R.: "21st Century VLBI: Deep Wide-Field Surveys", 2005, *Astronomical Society of the Pacific*, 340, 600G.
34. Garrett, M. A., Wrobel, J. M., Morganti, R.: "Deep VLBI Imaging of Faint Radio Sources in the NOAO Bootes Field", 2005, *Astrophysical Journal*, 619, 105G.
35. Hagiwara, Y., Baan, W. A., van Langevelde, H. J.: "Dense Molecular Gas around Protostars and in Galactic Nuclei", 2005, *fmhp.book.....H*.
36. Hagiwara, Y., Baan, W. A., Langevelde, H. J.: "Foreword", 2005, *Astrophysics and Space Science*, 295, 1H.
37. van der Horst, A. J., Rol, E., Wijers, R. A. M. J., Strom, R., Kaper, L., Kouveliotou, C.: "The Radio Afterglow of GRB 030329 at Centimeter Wavelengths: Evidence for a Structured Jet or Nonrelativistic Expansion", 2005, *Astrophysical Journal*, 634, 1166V.
38. Huege, T., Falcke, H.: "Radio emission from cosmic ray air showers: Simulation results and parametrization", 2005, *Astroparticle Physics*, 24, 116H.
39. Huege, T., Falcke, H.: "Radio emission from cosmic ray air showers. Monte Carlo simulations", 2005, *Astronomy and Astrophysics*, 430, 779H.
40. Iliiev, I. T., Shapiro, P. R., Scannapieco, E., Mellema, G., Alvarez, M., Raga, A. C., Pen, U.: "Ionisation fronts and their interaction with density fluctuations: implications for reionisation", 2005, *pgqa.conf*, 369I.

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41. Klein, U., Józsa, G., Kenn, F., Oosterloo, T.: “Galaxien und Dunkle Materie: neue Sichtweisen”, 2005, *Sterne und Weltraum*, 44i, 28K.
42. Klöckner, H., Baan, W. A.: “Understanding Extragalactic Hydroxyl”, 2005, *Astrophysics and Space Science*, 295, 277K.
43. Koopmans, L. V. E., de Bruyn, A. G.: “HI kinematics in a massive spiral galaxy at  $z=0.89$ ”, 2005, *Monthly Notices of the Royal Astronomical Society*, 360L, 6K.
44. Körding, E., Falcke, H.: “A Unifying Scheme for Low-Luminosity XRBs and AGN”, 2005, *Astrophysics and Space Science*, 300, 211K.
45. Körding, E., Colbert, E., Falcke, H.: “A radio monitoring survey of ultra-luminous X-ray sources”, 2005, *Astronomy and Astrophysics*, 436, 427.
46. Kovac, K., Oosterloo, T. A., van der Hulst, J. M.: “The faint end of the HI mass function”, 2005, in *Near-fields cosmology with dwarf elliptical galaxies*, IAU Colloquium Proceedings of the international Astronomical Union 198, Held 14-18 March, Switzerland, edited by Jerjen, H.; Binggeli, B. Cambridge: Cambridge University Press, 2005., pp.351-354.
47. Kovalev, Y. Y., Kellermann, K. I., Lister, M. L., Homan, D. C., Vermeulen, R. C., Cohen, M. H., Ros, E., Kadler, M., Lobanov, A. P., Zensus, J. A., and 3 coauthors: “Sub-Milliarcsecond Imaging of Quasars and Active Galactic Nuclei. IV. Fine-Scale Structure”, 2005, *Astronomical Journal*, 130, 2473K.
48. Labiano, A., O’Dea, C. P., Gelderman, R., de Vries, W. H., Axon, D. J., Barthel, P. D., Baum, S. A., Capetti, A., Fanti, R., Koekemoer, A. M., Morganti, R.: “ST/STIS low dispersion spectroscopy of three Compact Steep Spectrum sources. Evidence for jet-cloud interaction”, 2005, *Astronomy and Astrophysics*, 436, 493L.
49. Loeb, A., Reid, M. J., Brunthaler, A., Falcke, H.: “Constraints on the Proper Motion of the Andromeda Galaxy Based on the Survival of Its Satellite M33”, 2005, *Astrophysical Journal*, 633, 894L.
50. Lommen, A. N., Bilikova, J., Jenet, F. A., Portegies Zwart, S., Stappers, B. W.: “Using Pulsars to Detect Black Hole Binaries in Globular Clusters”, 2005, *Astronomical Society of the Pacific*, 328, 225L.
51. Lorente-Espin, O., Riera, A., Balick, B., Mellema, G., Xilouri, K., Terzian, Y.: “Abundance Analysis of a Sample of Bipolar Type I Planetary Nebulae”, 2005, *AIP Conference Proceedings*, 804, 61L.
52. Maoz, D., Nagar, N. M., Falcke, H., Wilson, A. S.: “The Murmur of the Sleeping Black Hole: Detection of Nuclear Ultraviolet Variability in LINER Galaxies”, 2005, *Astrophysical Journal*, 625, 699M.
53. McKean, J. P., Browne, I. W. A., Jackson, N. J., Koopmans, L. V. E., Norbury, M. A., Treu, T., York, T. D., Biggs, A. D., Blandford, R. D., de Bruyn, A. G., and 7 coauthors: “CLASS B2108+213: a new wide-separation gravitational lens system”, 2005, *Monthly Notices of the Royal Astronomical Society*, 356, 1009M.
54. Middelberg, E., Roy, A. L., Walker, R. C., Falcke, H.: “VLBI observations of weak sources using fast frequency switching”, 2005, *Astronomy and Astrophysics*, 433, 897M.
55. Morganti, R., Tadhunter, C. N., Oosterloo, T. A.: “Fast neutral outflows in powerful radio galaxies: a major source of feedback in massive galaxies”, 2005, *Astronomy and Astrophysics*, 444L, 9M.
56. Morganti, R., Oosterloo, T. A., Tadhunter, C. N., van Moorsel, G., Emonts, B.: “The location of the broad H i absorption in 3C 305: clear evidence for a jet-accelerated neutral outflow”, 2005, *Astronomy and Astrophysics*, 439, 521M.
57. Morganti, R., Oosterloo, T., Tadhunter, C. N.: “Outflows of Neutral (and Ionized) Gas in Radio Galaxies”, 2005, *Astronomical Society of the Pacific*, 331, 361M.
58. Nagar, N. M., Falcke, H., Wilson, A. S.: “Radio Sources in Low-Luminosity AGNs. IV (Nagar+, 2005)”, 2005, *yCat*, 34350521N.

59. Nagar, N. M., Falcke, H., Wilson, A. S.: "Radio sources in low-luminosity active galactic nuclei. IV. Radio luminosity function, importance of jet power, and radio properties of the complete Palomar sample", 2005, *Astronomy and Astrophysics*, 435, 521N.
60. Nigl, A., Timmermans, C., Schellart, P., Kuijpers, J., Falcke, H., Horneffer, A., de Vos, C. M., Koopman, Y., Pepping, H. J., Schoonderbeek, G.: "An outreach project for LOFAR and cosmic ray detection", 2005, *Astronomische Nachrichten*, 326, 619N.
61. Oosterloo, T., van Gorkom, J.: "A large H I cloud near the centre of the Virgo cluster", 2005, *Astronomy and Astrophysics*, 437L, 19O.
62. Oosterloo, T. A., Morganti, R.: "Anomalous HI kinematics in Centaurus A: Evidence for jetinduced star formation", 2005, *Astronomy and Astrophysics*, 429, 469O.
63. Oosterloo, T. A., Sadler, E. M., Morganti, R., van der Hulst, J. M.: "Extended HI Structures Around Early-Type Galaxies: Relics of Their Formation?", 2005, *mmgf.conf.*, 438O.
64. Orchiston, W., Bracewell, R., Davies, R., Denisse, J., Goss, M., Gunn, A., Kellermann, K., McGee, D., Morimoto, M., Slee, B., Strom, R., and 4 coauthors: "The IAU Historic Radio Astronomy Working Group. 2: progress report", 2005, *Journal of Astronomical History and Heritage*, 8, 65O.
65. Orienti, M., Garrett, M. A., Reynolds, C., Morganti, R.: "The nature of the Mid-IR faint radio sources from the Spitzer First Look Survey", 2005, *Memorie della Societa Astronomica Italiana*, v.76, p.166.
66. Pihlström, Y. M., Baan, W. A., Darling, J., Klöckner, H.: "High-Resolution Imaging of the OH Megamaser Emission in IRAS 12032+1707 and IRAS 14070+0525", 2005, *Astrophysical Journal*, 618, 705P.
67. Rijkhorst, E., Mellema, G., Icke, V.: "Blowing up warped disks in 3D. Three-dimensional AMR simulations of point-symmetric nebulae", 2005, *Astronomy and Astrophysics*, 444, 849R.
68. Roy, A. L., Goss, W. M., Mohan, N. R., Oosterloo, T., Anantharamaiah, K. R.: "Radio Recombination Lines from Starbursts: NGC 3256, NGC 4945 and the Circinus Galaxy", 2005, *AIP Conference Proceedings*, 783, 303R.
69. Roy, S., Rao, A.P., Subrahmanyan R.: "Extragalactic sources towards the central region of the Galaxy", 2005, *Monthly Notices of the Royal Astronomical Society*, 360, 1305.
70. de Ruiter, H. R., Parma, P., Morganti, R., Santantonio, L.: "Nuker law fits of radio galaxies (De Ruiter+, Capetti, A., Fanti, R., 2005)", 2005, *yCat*.34390487D.
71. de Ruiter, H. R., Parma, P., Capetti, A., Fanti, R., Morganti, R., Santantonio, L.: "Are radio galaxies and quiescent galaxies different? Results from the analysis of HST brightness profiles", 2005, *Astronomy and Astrophysics*, 439, 487D.
72. Siegel, M. H., Majewski, S. R., Gallart, C., Sohn, S. T., Kunkel, W. E., Braun, R.: "A Search for Stellar Populations in High-Velocity Clouds", 2005, *Astrophysical Journal*, 623, 181S.
73. Stappers, B. W.: "Recent X-ray Observations of PSR B1957+20", 2005, *Astronomical Society of the Pacific*, 328, 425S.
74. Strom, R. G.: "Shades of the goddess: Venus in transit", 2005, *tvnv.conf.*.498S.
75. Tadhunter, C., Robinson, T. G., González Delgado, R. M., Wills, K., Morganti, R.: "Starbursts and the triggering of the activity in nearby powerful radio galaxies", 2005, *Monthly Notices of the Royal Astronomical Society*, 356, 480T.
76. Thilker, D. A., Braun, R., Westmeier, T.: "H I Throughout the Circum-galactic Environment of Andromeda", 2005, *Astronomical Society of the Pacific*, 331, 113T.
77. Tilak, A., O'Dea, C. P., Tadhunter, C., Wills, K., Morganti, R., Baum, S. A., Koekemoer, A. M., Dallacasa, D.: "Resolving the Shocks in Radio Galaxy Nebulae: Hubble Space Telescope and Radio Imaging of 3C 171, 3C 277.3, and PKS 2250-41", 2005, *Astronomical Journal*, 130, 2513T.





78. Villar-Martín, M., Tadhunter, C., Morganti, R., Holt, J.: “The giant star forming halo associated with the radio galaxy PKS 1932-46”, 2005, Monthly Notices of the Royal Astronomical Society, 359L, 5V.
79. Weltevrede, P., Edwards, R. T., Stappers, B. W.: “Pulsar subpulse modulation properties at 21cm (Weltevrede+, 2006)”, 2005, yCat, 34450243W.
80. Westmeier, T., Braun, R., Bruens, C., Kerp, J., Thilker, D.: The high-velocity clouds of M 31: tracers of galactic evolution”, 2005, Astronomische Nachrichten, 326R, 520W.
81. Westmeier, T., Braun, R., Thilker, D.: “Westerbork H I observations of high-velocity clouds near M 31 and M 33”, 2005, Astronomy and Astrophysics, 436, 101W.
82. York, T., Jackson, N., Browne, I. W. A., Koopmans, L. V. E., McKean, J. P., Norbury, M. A., Biggs, A. D., Blandford, R. D., de Bruyn, A. G., Fassnacht, C. D., and 5 coauthors: “CLASS B0631+519: last of the Cosmic Lens All-Sky Survey lenses”, 2005, Monthly Notices of the Royal Astronomical Society, 361, 259Y.

## Publications Research and Development 2005

1. Alliot, S., “A performance/cost Estimation Model for the Large Scale Array Signal Processing System Specification”, IESJ International Embedded System Journal, Vol. 1, Issue 7, 2005.
2. Alliot, S., Deprettere, E., “The communication mechanism in a generic platform”, Proceedings ProRISC 2005, p332-337, Nov. 2005.
3. Ardenne, A. van, Wilkinson, P.N., Patel, P.D., Vaate, J.G. bij de, “Electronic Multi-Beam Radio Astronomy Concept: Embrace a demonstrator for the European SKA Program”, Experimental Astronomy, special issue on SKA2004, Vol. 17, pp. 65-77.
4. Boonstra, A.J., Wijnholds, S.J., Tol, S. van der, Jeffs, B., “Calibration, Sensitivity and RFI Mitigation requirements for LOFAR and SKA”, 2005 IEEE International Conference on Acoustics, Speech and Signal Processing, Special session “Towards a New Generation of Radio Astronomical Instruments”, Philadelphia, PA, USA, Vol. 5, pp. 869-872, March, 2005.
5. Boonstra, A.J., Radio Frequency Interference Mitigation in Radio Astronomy, thesis TU Delft, ASTRON, ISBN: 90-805434-3-8, June, 2005.
6. Boonstra, A.J., Tol, S. van der, “Spatial Filtering of Interfering Signals at the Initial LOFAR Phased Array Teststation”, Radio Science, Vol. 40, No. 5. August 10, 2005.
7. Boonstra, A.J., Wijnholds, S., “Implementation of the LOFAR Interference Mitigation Strategy, Considerations and Tradeoffs”, URSI-GA 2005, New Delhi, India, October 2005.
8. Bregman, J.D., “Het LOFAR Concept, op weg naar een nieuwe generatie radiotelescopen”, Tijdschrift van het NERG themanummer LOFAR, nr. 1-2005, pp. 4-13.
9. Bregman, J.D., “System optimisation of Multi-Beam Aperture Synthesis Arrays for Survey Performance”, Experimental Astronomy, special issue on SKA2004, Vol. 17, pp. 365-380.
10. Bregman, J.D., “Cost Effective Frequency Ranges for Multi-Beam Dishes, Cylinders, Aperture Arrays and Hybrids, Experimental Astronomy, special issue on SKA2004, Vol. 17, pp. 407-416.
11. Bregman, J.D., “LOFAR Approaching the Critical Design Review”, Proceedings URSI-GA 2005, New Delhi, India, October 2005.
12. Cappellen, W. van, Bregman, J.D., Arts, M.J., “Effective Sensitivity of a Non-Uniform Phased Array of Short Dipoles”, Experimental Astronomy, special issue on SKA2004, Vol. 17, pp. 101- 109.
13. Cappellen, W.A. van, Kant, G.W., Patel, P.D., “Antenna Development for EMBRACE, the European Demonstrator Program for SKA”, ANTEM 2005, St. Malo, France, June 2005.
14. Das U.C., “An Efficient Computation of Sommerfeld Integral Representing Green's Function in a Layered Medium”, Proceedings URSI-GA 2005, New Delhi, India, October 2005.
15. Escoffier, R.P., Comoretto, G., Webber, J.C., Baudry, A., Broadwell, C.M., Greenberg, J.H., Treacy, R.R., Cais, P., Quertier, B. and Gunst, A.W., “The ATACAMA Large Millimeter Array Correlator”, Proceedings URSI-GA 2005, New Delhi, India, October 2005.

16. Falcke, H., Butcher, H., de Vos, C. M., Kant, G. W., Koopman, Y., Pepping, H. J., Schoonderbeek, G., van Cappellen, W., Wijnholds, S., et al., "Detection and Imaging of Atmospheric Radio Flashes From Cosmic Ray Airshowers", *Nature*, Vol. 435, issue 7049, pp. 313-316, May 2005.
17. Gunst, A.W., Kant, G.W., "Signal Transport and Processing at the LOFAR Remote Stations", *Proceedings URSI-GA 2005*, New Delhi, India, October 2005.
18. Gunst, A.W., Bos, A., Escoffier, R.P., Comoretto, G., Webber, J.C., Baudry, A., Broadwell, C.M., Greenberg, J.H., Treacy, R.R., Cais, P., Quertie, B., "The Atacama Large Millimeter Array Correlator", *Proceedings URSI-GA 2005*, New Delhi, India, October 2005.
19. Hamaker, J., "Matrix-based Theory and Practice of Radio-Polarimetric Self-calibration", *Proceedings URSI-GA 2005*, New Delhi, India, October 2005.
20. Huiszoon, B., (Student Member IEEE), Jonker, R.J.W., Bennekom, P.K. van, Khoe, G.-D. (Fellow IEEE), Waardt, H. de, "Cost-Effective Up to 40 Gb/s Transmission Performance of 1310 nm Directly Modulated Lasers for Short- to Medium-Range Distances", *IEEE/OSA Journal of Lightwave Technology*, Vol. 23, no. 3, March 2005.
21. Ivashina, M.V., Vaate, J.G. bij de, Marel, H. van der, "Holographic Performance Verification of a Focal Plane Array Photo Type Designed with Conjugated Field Method", *28th Antenna Workshop on Space Antenna Systems and Technologies*, Noordwijk, May-June 2005.
22. Ivashina, M.V., Simons, J., Vaate, J.G. bij de, "Efficiency Analysis of Focal Plane Arrays in Deep Dishes", *Experimental Astronomy*, special issue on SKA2004, Vol. 17, pp.149-162.
23. Ivashina, M.V., Maaskant, R., Marel, H. van der, Vaate, J.G. bij de, "Holographic performance verification of a Focal Plane Array prototype", *Proceedings of the 28th ESA Antenna Workshop on Space Antenna Systems and Technologies "State of the art in a strategic area and creative ways forward"*, April 2005.
24. Ivashina, M.V., Vaate, J.G. bij de, "Focal Plane Arrays: Radio Astronomy enters the CCD area", *Proceedings URSI-GA 2005*, New Delhi, India, October 2005.
25. Kant, G.W., Patel, P.D., Houwelingen, J.A. van, Ardenne, A. van, "Electronic Multi-Beam Radio Astronomy Concept: Embrace The European Demonstrator for the SKA Program", *Noordam, Proceedings URSI-GA 2005*, New Delhi, India, October 2005.
26. Kroes, G., Oudenhuysen, A., Meijers, M., Pel, J.W., "MIRI-JWST Spectrometer Main Optics opto-mechanical design and prototyping", *Optics and Photonics 2005*, SPIE Conference, San Diego, USA, Vol. 5877, pp. 244-255, July-August 2005.
27. Lemaitre, J., Alliot, S., Deprettere, E., "Behavioral Specification of Control Interface for Signal Processing applications", in *Proc. IEEE 16th International Conference on Application-specific Systems, Architectures and Processors*, pp. 43-49, July 2005.
28. Li, B., "A L-band Cryogenic Low Noise Amplifier", *Annals of Shanghai Observatory (Chinese Journal)*, Vol. 25, 2004.
29. Maat D.H.P., Kant, G.W., "Fiber Optic Network Technology for Distributed Long Baseline Radio Telescopes", *Experimental Astronomy*, special issue on SKA2004, Vol. 17, pp. 213-220.
30. Marel, H. van der, Woestenburger, E.E.M., Bruyn, G. de, "Low Frequency Receivers for the WSRT. A window of opportunity", *Proceedings URSI-GA 2005*, New Delhi, India, October 2005.
31. Murakawa, K., Suto, H., Oya, S., Yates, J. A., Ueta, T., Meixner, M., " High resolution H band imaging polarimetry of IRC +10216. The obscured location of the central star", *A&A*, Vol.436, p p601, 06/2005.
32. Noordam, J.E., "Meqtree: Prototype Calibration Package for LOFAR", *Proceedings URSI-GA 2005*, New Delhi, India, October 2005.
33. Schaaf, K. van der, Overeem, R., "COTS Correlator Platform", *Experimental Astronomy*, special issue on SKA2004, Vol. 17, pp. 287-297.
34. Schaaf, K. van der, Broekema, C., Diepen, G. van, Meijeren, E. van, "The LOFAR Central Processing Facility Architectue", *Experimental Astronomy*, special issue on SKA2004, Vol. 17, pp. 43-58.



35. Simons, J., Ivashina, M., Vaate, J.G. bij de, Roddis, N., "Beamformer System Model of Focal Plane Arrays in Deep Dish Radio Telescopes", European Microwave Conference, Paris, pp. 2079-2082, October 2005.
36. Ueta, T., Murakawa, K., and Meixner, M., "HST/NICMOS imaging polarimetry of protoplanetary nebulae: probing of the dust shell structure via polarized light", *Astronomical Journal*, Vol. 129, pp 1625, 03/2005.
37. Vaate, J.G. bij de, "Very Large Microwave Arrays for Radio Astronomy and Space Communications", IEEE IMS2005 Array Workshop, Long Beach, June 2005.
38. Veen, A.J. van der, Leshem, A., Boonstra, A.J., "Signal Processing for Radio Astronomy", *Experimental Astronomy*, special issue on SKA2004, Vol. 17, pp. 231-249.
39. Wild, W., Graauw, Th. de, Helmich, F., Cernicharo, J., Baryshev, A., Bos, A., Herder, J.W. den, Gunst, A., Jackson, B., Langevelde, H.J., Maat, P., Martin-Pintado, J., Noordam, J., Quirrenbach, A., Roelfsema, P., Venema, L., Wesselius, P., Whyborn, N., Yagoubov, P., "Exploratory Submm Space Radio Interferometric Telescope (ESPRIT)", *Proceedings URSI-GA 2005*, New Delhi, India, October 2005.
40. Wijnholds, S.J., Bruyn, A.G. de, Bregman, J.D., Vaate, J.G. bij de, "Hemispheric Imaging of Galactic Neutral Hydrogen with a Phased Array Antenna System", *Experimental Astronomy*, special issue on SKA2004, Vol. 17, pp. 59-64.
41. Wijnholds, S.J., Bregman, J.D., Boonstra, A.J., "Sky Noise Limited Snapshot Imaging in the Presence of RFI with LOFAR's Initial Test Station", *Experimental Astronomy*, special issue on SKA2004, Vol. 17, pp. 35-42.
42. Wijnholds, S.J., "Confusion Limited All Sky Imaging With LOFAR's Initial Test Station Applying Wide Field Calibration Techniques", *Proceedings URSI-GA 2005*, New Delhi, India, October, 2005.
43. Woestenburg, E.E.M., Kuenen, J., "Low noise performance perspectives of wideband aperture phased arrays", *Experimental Astronomy*, special issue on SKA2004, Vol. 17, pp. 89-99.
44. Xu, J., Woestenburg, E.E.M., Vaate, J.G. bij de, Serdijn, W.A., "GaAs 0.5 dB NF Dual-Loop Negative Feedback Low-Noise Amplifier IC", *Electronics Letters*, July 7, Vol. 41, issue 14, 2005.

### Publications by ASTRON astronomical staff 2006

1. An, T.; Goss, W.M.; Zhao, Jun-Hui; Hong, X.Y.; Roy, S.; Rao, A.P.; Shen, Z.-Q., Simultaneous Multi-Wavelength Spectrum of Sgr A\* and Long Wavelength Cutoff at  $\lambda > 30$  cm, *Journal of Physics: Conference Series*, Volume 54, Issue 1, pp. 381-385 (2006).
2. Blazek, J.A.; Gaensler, B.M.; Chatterjee, S.; van der Swaluw, E.; Camilo, F.; Stappers, B.W., The Duck Redux: An Improved Proper-Motion Upper Limit for the Pulsar B1757-24 near the Supernova Remnant G5.4-1.2, *The Astrophysical Journal*, Volume 652, Issue 2, pp. 1523-1530.
3. Bertone, S.; Vogt, C.; Enlin, T., Magnetic field seeding by galactic winds, *Monthly Notices of the Royal Astronomical Society*, Volume 370, Issue 1, pp. 319-330.
4. Bower, G.C.; Goss, W.M.; Falcke, H.; Backer, D.C.; Lithwick, Y., The Intrinsic Size of Sagittarius A\* from 0.35 to 6 cm., *The Astrophysical Journal*, Volume 648, Issue 2, pp. L127- L130.
5. Braun, R., Book Review: EXTRA-PLANAR GAS/Astronomical Society of the Pacific, 2005, *The Observatory: A Review of Astronomy*, vol. 126, no. 1192, p. 221 (June 2006).
6. Brocksopp, C.; Fender, R.; Miller-Jones, J.C.A.; Stappers, B., A Highly Polarised Jet in XTE J1748-288, *Proceedings of the VI Microquasar Workshop: Microquasars and Beyond*. September 18-22, 2006, Como, Italy, p.18.1.
7. Brunthaler, A.; Henkel, C.; de Blok, W.J.G.; Reid, M.J.; Greenhill, L.J.; Falcke, H., Water masers in the Local Group of galaxies, *Astronomy and Astrophysics*, Volume 457, Issue 1, October 1 2006, pp.109-114.

8. Brunthaler, A.; Bower, G.C.; Falcke, H., Radio linear and circular polarization from M 81\*, *Astronomy and Astrophysics*, Volume 451, Issue 3, June I 2006, pp.845-850
9. de Bruyn, A.G.; Katgert, P.; Haverkom, M.; Schnitzeler, D.H.F.M., Radio polarization and RM structure at high Galactic latitudes, *Astronomische Nachrichten*, Vol.327, Issue 5/6, p.487-490.
10. de Bruyn, A.G.; Maxquart, J.-P., Diffractive interstellar scintillation of the quasar J1819+3845 at 121 cm, *Astronomy and Astrophysics*, Volume 446, Issue 1, January IV 2006, pp.185-200.
11. Chatterjee, S.; Gaensler, B.M.; Melatos, A.; Brisken, W.; Stappers, B.; Rakowski, C., Probing relativistic winds from neutron stars: bow shocks and the Double Pulsar, 36th COSPAR Scientific Assembly. Held 16 - 23 July 2006, in Beijing, China., p.3328.
12. Croft, S.; van Breugel, W.; de Vries, W.; Dopita, M.; Martin, C.; Morganti, R.; Neff, S.; Oosterloo, T.; Schiminovich, D.; Stanford, S.A.; van Gorkum, J., Minkowski's Object: A Starburst Triggered by a Radio Jet, *Revised*, *The Astrophysical Journal*, Volume 647, Issue 2, pp. 1040-1055.
13. Dallacasa, D.; Morganti, R.; Orienti, M.; HI absorption in high-frequency peaker galaxies, *Astronomy and Astrophysics*, Volume 457, Issue 2, October II 2006, pp.531-536.
14. Dohm, J.M.; Anderson, R.C.; Baker, V.R.; Barlow, N.G.; Miyamoto, H.; Davies, A.G.; Taylor, G.J.; Boynton, W.V.; Keller, J.; Kerry, K.; Janes, D.; Fairén, A.G.; Schulze-Makruch, D.; Glamoclija, M.; Marinangeli, L.; Ori, G.G.; Strom, R.G.; Williams, P.; Ferris, J.C.; Rodriguez, J.A.P.; De Pablo, M.A.; Karunatillake, S., Tharsis/Elysium Corridor: A Marker for an Internally Active Mars?, 37th Annual Lunar and Planetary Science Conference, March 13-17, 2006, League City, Texas, abstract no.1131.
15. En,lin, T.A.; Vogt, C., Magnetic turbulence in cool cores of galaxy clusters, *Astronomy and Astrophysics*, Volume 453, Issue 2, July II 2006, pp.447-458.
16. En,lin, T.A.; Waelkens, A.; Vogt, C.; Schekochihin, A.A., Futures magnetic field studies using the Planck surveyor experiment, *Astronomische Nachrichten*, Vol.327, Issue 5/6, p.626-631.
17. Emonts, B.H.C.; Morganti, R.; Tadhunter, C.N.; Holt, J.; Oosterloo, T.A.; van der Hulst, J.M.; Wills, K.A., Timescales of merger, starburst and AGN activity in radio galaxy B2 0648+27, *Astronomy and Astrophysics*, Volume 454, Issue 1, July IV 2006, pp.125-135.
18. Emonts, B.H.C.; Morganti, R.; Oosterloo, T.A.; van der Hulst, J.M.; Tadhunter, C.N.; van Moorsel, G.; Holt, J., Merger origin of radio galaxies investigated with HI observations, *Astronomische Nachrichten*, Vol.327, Issue 2/3, p.139-142.
19. Falcke, H.; van Haarlem, M.P.; de Bruyn, A.G.; Braun, R.; Röttgering, H.J.A.; Stappers, B.; Boland, W.H.W.M.; Butcher, H.R.; de Geus, E.J.; Koopmans, L.; Fender, R.; Kuijpers, J.; Miley, G.K.; Schilizzi, R.T.; Vogt, C.; Wijers, R.A.M.J.; Wise, M.; Brouw, W.N.; Hamaker, J.P.; Noordam, J.E.; Oosterloo, T.; Bähren, L.; Brenjens, M.A., A very brief description of LOFAR – the low Frequency Array, 2 pages, IAU GA 2006, Highlights of Astronomy, Volume 14, K.A. van der Hucht, ed.
20. Falcke, H.D.E., LOFAR – The Low Frequency Array, Long Wavelength Astrophysics, 26th meeting of the IAU, Joint Discussion 12, 21 August 2006, Prague, Czech Republic, JD12, #16.
21. Gurvits, L.I.; Falcke, H.; Yan, Y.; Huang, M., Very Long Wavelength Universe view from the Moon, 36th COSPAR Scientific Assembly. Held 16 - 23 July 2006, in Beijing, China., p.1618.
22. Hessels, J.W.; Vlemmings, W.; Deshpande, A.A.; Bhat, N.D.; Chatterjee, S.; Han, J.L.; Gaensler, B.M.; Kasian, L.; Deneva, J.S.; Reid, B.; Lazio, T.J.; Kaspi, V.M.; Crawford, F.; Lommen, A.N.; Backer, D.C.; Kramer, M.; Stappers, B.W.; Hobbs, G.B.; Possenti, A.; D'Amico, N.; Burgay, M., Using ALFA. II. The Young, Highly Relativistic Binary Pulsar, *The Astrophysical Journal*, Volume 640, Issue 1, pp. 428-434.
23. Holt, J.; Tadhunter, C.N.; Morganti, R., Outflows and shocks in compact radio sources, *Astronomische Nachrichten*, Vol.327, Issue 2/3, p.147-150.
24. Holt, J.; Tadhunter, C.; Morganti, R.; Bellamy, M.; González Delgado, R.M.; Tzioumis, A.; Inskip, K.J., The co-evolution of the obscured quasar PKS 1549-79 and its host galaxy: evidence for a high accretion

# ASTRON

- rate and warm outflow, *Monthly Notices of the Royal Astronomical Society*, Volume 370, Issue 4, pp. 1633-1650.
25. Homan, D.C., Kovalev, Y.Y., Lister, M.L., Ros, E., Kellermann, K.I., Cohen, M.H., Vermeulen, R.C., Zensus, J.A., Kadler, M., "Intrinsic Brightness Temperatures of AGN Jets", *The Astrophysical Journal*, Volume 642, Issue 2, pp. L115-L118.
  26. Huege, T.; Falcke, H.; Monte Carlo Simulations of Radio Emission from Cosmic Ray Air Showers, World Scientific Publishing Co., Pte. Ltd., Singapore, 2006, p.60.
  27. Hyman, S.D.; Pal, S.; Ray, P.S.; Lazio, T.J.; Kassim, N.E.; Roy, S., A Search for GCRT J1745-3009 and Other Galactic Center Radio Transients, *American Astronomical Society Meeting* 208, #48.05.
  28. Hyman, S.D.; Lazio, T.J.W.; Roy, S.; Ray, P.S.; Kassim, N.E.; Neureuther, J.L., A New Radio Detection of the Transient Bursting Source GCRT J1745-3009, *The Astrophysical Journal*, Volume 639, Issue 1, pp. 348-353.
  29. Janssen, G.H.; Stappers, B.W., 30 glitches in slow pulsars, *Astronomy and Astrophysics*, Volume 457, Issue 2, October II 2006, pp.611-618.
  30. Janssen, G.H.; Stappers, B.W., Glitch Observations In Slow Pulsars, On the Present and Future of Pulsar Astronomy, 26th meeting of the IAU, Joint Discussion 2, 16-17 August, 2006, Prague, Czech Republic, JD02, #47.
  31. Jozsa, G.I.G.; Kenn, F.; Oosterloo, T.A.; Klein, U., A case-study of grand-design warps in galactic disks, *Galaxy Evolution Across the Hubble Time*, International Astronomical Union. Symposium no. 235, held 14-17 August, 2006 in Prague, Czech Republic, S235, #211.
  32. Karuppusamy, R.; Stappers, B., Software Aspects of PuMa-II, On the Present and Future of Pulsar Astronomy, 26th meeting of the IAU, Joint Discussion 2, 16-17 August, 2006, Prague, Czech Republic, JD02, #50.
  33. K rding, E.; Falcke, H.; Corbel, S., Refining the fundamental plane of accreting black holes, *Astronomy and Astrophysics*, Volume 456, Issue 2, September III 2006, pp.439-450.
  34. Kovalev, Y. Y.; Kellermann, K. I.; Lister, M. L.; Homan, D. C.; Vermeulen, R. C.; Cohen, M. H.; Ros, E.; Kadler, M.; Lobanov, A. P.; Zensus, J. A.; Kardashev, N. S.; Gurvits, L. I.; Aller, M. F.; Aller, H. D., Erratum: "Sub-Milliarcsecond Imaging of Quasars and Active Galactic Nuclei. IV. Fine-Scale Structure", *The Astronomical Journal*, Volume 131, Issue 4, pp. 2361-2361.
  35. Labiano, A; O'Dea, C.P.; Barthel, P.D.; Vermeulen, R.C.: "Environment of compact extragalactic radio sources", 2006, *Astrophysics*, 11, 738L.
  36. Labiano, A.; Vermeulen, R. C.; Barthel, P. D.; O'Dea, C. P.; Gallimore, J. F.; Baum, S.; de Vries, W., H I absorption in 3C 49 and 3C 268.3. Probing the environment of compact steep spectrum and GHz peaked spectrum sources, *Astronomy and Astrophysics*, Volume 447, Issue 2, February IV 2006, pp.481-487.
  37. van Leeuwen, J.; Cordes, J.M.; Lorimer, D.R.; Freire, P.C.C.; Camilo, F.; Stairs, I.H.; Nice, D.J.; Champion, D.J.; Ramachandran, R.; Faulkner, A.J.; Lyne, A.G.; Ransom, S.M.; Arzoumanian, Z.; Manchester, R.N.; McLaughlin, M.A.; Hessels, J.W.T.; Vlemmings, W.; Deshpande, A.A.; Bhat, N.D.R.; Chatterjee, S.; Han, J.L.; Gaensler, B.M.; Kasian, L.; Deneva, J.S.; Reid, B.; Lazio, T.J.W.; Kaspi, V.M.; Crawford, F.; Lommen, A.N.; Backer, D.C.; Kramer, M.; Stappers, B.W.; Hobbs, G.B.; Possenti, A.; D'Amico, A.; Faucher-Gigu re, C.-A.; Burgay, M., Arecibo and the ALFA Pulsar Survey, *Chinese Journal of Astronomy and Astrophysics*, Supplement, Volume 6, Issue S2, Proceedings of the 2005 Lake Hanas International Pulsar Symposium. Editors: N. Wang, R. N. Manchester, B. J. Rickett and A. Esamdin., p.311-318.
  38. van Leeuwen, J.; Stappers, B., Pulsars Research With LOFAR, The First Next-Generation Radio Telescope, On the Present and Future of Pulsar Astronomy, 26th meeting of the IAU, Joint Discussion 2, 16-17 August, 2006, Prague, Czech Republic, JD02, #64

39. Leipski, C.; Falcke, H.; Bennert, N.; Hüttemeister, S., The structure of radio-quiet quasars, *Astronomy and Astrophysics*, Volume 455, Issue 1, August III 2006, pp.161-172
40. Lopes Collaborations; Apel, W.D.; Asch, T.; Badea, A.F.; Bähren, L.; Bekk, K.; Bercuci, A.; Bertaina, M.; Biemann, P.L.; Blümer, J.; Bozdog, H.; Brancus, I.M.; Buitink, S.; Brüggemann, M.; Buchholz, P.; Butcher, H.; Chiavassa, A.; Cossavella, F.; Daumiller, K.; dj Pierro, F.; Doll, P.; Engel, R.; Falcke, H.; Gemmeke, H.; Ghia, P.L.; Glasstetter, R.; Grupen, C.; Haungs, A.; Heck, D.; Hörandel, J.R.; Homeffer, A.; Huege, T.; Kampert, K.H.; Kolotaev, Y.; Krömer, O.; Kuijpers, J.; Lafebre, S.; Mathes, H.J.; Mayer, H.J.; Meurer, C.; Milke, J.; Mitirica, B.; Morello, C.; Navarra, G.; Nehls, S.; Nigl, A.; Obenland, R.; Oehlschläger, J.; Ostapchenko, S.; Over, S.; Petcu, M.; Petrovic, J.; Pierog, T.; Plewnia, S.; Rebel, H.; Risse, A.; Roth, M.; Schieler, H.; Sima, O.; Singh, K.; Stümert, M.; Toma, G.; Trichero, G.C.; Ulrich, H.; van Buren, J.; Walkowiak, W.; Weindl, A.; Wochele, J.; Zabierowski, J.; Zensus, J.A.; Zimmernann, D., Progress in air shower radio measurements: Detection of distant events, *Astroparticle Physics*, Volume 26, Issue 4-5, p. 332-340
41. Macquart, J.-P.; Bower, G.C.; Wright, M.C.H.; Backer, D.C.; Falcke, H., The Rotation Measure and 3.5 Millimeter Polarization of Sagittarius A\*, *The Astrophysical Journal*, Volume 646, Issue 2, pp. L111-L114
42. Malhotra, R.; Strom, R.G.; Ito, T.; Yoshida, F.; Kring, D.A., Bombardment History of the Inner Solar System, *American Astronomical Society, DPS meeting #38*, #67.01
43. Merloni, A.; Hörding, E.; Heinz, S.; Markoff, S.; Di Matteo, T.; Falcke, H., Why the fundamental plane of black hole activity is not simply a distance driven artifact., *New Astronomy*, Volume 11, Issue 8, p. 567-576
44. Morganti, R.; de Zeeuw, P.T.; Oosterloo, T.A.; McDermid, R.M.; Krajinovic, D.; Cappellari, M.; Kenn, F.; Weijmans, A.; Sarzi, M., Neutral hydrogen in nearby elliptical and lenticular galaxies: the continuing formation of early-type galaxies, *Monthly Notices of the Royal Astronomical Society*, Volume 371, Issue 1, pp. 157-169.
45. Morganti, R.; Oosterloo, T.; Sadler, E.M., The neutral hydrogen content of E and So galaxies, *Galaxy Evolution Across the Hubble Time*, International Astronomical Union. Symposium no. 235, held 14-17 August, 2006 in Prague, Czech Republic, S235, #344
46. Morganti, R., Neutral hydrogen in radio galaxies: Results from nearby, importance for far away, *Astronomische Nachrichten*, Vol.327, Issue 2/3, p.127-134
47. Murphy, E.J.; Braun, R.; Helou, G.; Armus, L.; Kenney, J.D.P.; Gordon, K.D.; Bendo, G.J.; Dale, D.A.; Walter, F.; Oosterloo, T.A.; Kennicutt, R.C. jr.; Calzetti, D.; Holenbach, D.J.; Jarrett, T.H.; Kewley, L.J.; Leitherer, C.; Li, A.; Meyer, M.J.; Regan, M.W.; Rieke, G.H.; Rieke, M.J.; Roussel, H.; Sheth, K.; Smith, J.D.T.; Thornley, M.D., An Initial Look at the Far-Infrared-Radio Correlation within Nearby Star-forming Galaxies Using the Spitzer Space Telescope, *The Astrophysical Journal*, Volume 638, Issue 1, pp. 157-175
48. Murphy, E.J.; Helou, G.; Braun, R.; Kenny, J.D.; Armus, L.; the SINGS team, The Effect of Star Formation Activity on the Far-Infared—Radio Correlation within Spiral Galaxies, 2007 AAS/AAPT Joint Meeting, American Astronomical Society Meeting 209, #198.07
49. Murphy, E.J.; Helou, G.; Braun, R.; Kenney, J.D.P.; Armus, L.; Calzetti, D.; Draine, B.T.; Kennicutt, R.C. jr.; Roussel, H.; Walter, F.; Bendo, G.J.; Buchalew, B.; Dale, D.A.; Engelbracht, C.W.; Smith, J.D.T.; Thomley, M.D., The Effect of Star Formation on the Far-Infared-Radio Correlation within Galaxies, *The Astrophysical Journal*, Volume 651, Issue 2, pp. L111-L115
50. Murphy, E.J.; Helou, G.; Armus, L.; Braun, R.; Kenney, J.D.P.; the SINGS team., Relating Diffusion Properties of Cosmic-Ray Electrons Star Formation Activity within Normal Galaxies, eprint arXiv:astro-ph/0609038

# ASTRON

51. Murphy, E.J.; Helou, G.; Armus, L.; Braun, R.; Kenney, J.D.P.; the SINGS team., Phenomenological Modeling of the FIR-Radio Correlation within Nearby Galaxies, 4 Pages, 2 Figures, to appear in "Infrared Diagnostics of Galaxy Evolution", ASP Conference Series, Pasadena, 14-16 November 2005
52. Ostorero, L.; Wagner, S.J.; Gracia, J.; Ferrero, E.; Krichbaum, T.P.; Britzen, S.; Witzel, A.; Nilsson, K.; Villata, M.; Bach, U.; Bamaby, D.; Bernhart, S.; Carini, M.T.; Chen, C.W.; Chen, W.P.; Ciprini, S.; Crapanzano, S.; Doroshenko, V.; Efimova, N.V.; Emmanoulopoulos, D.; Fuhrmann, L.; Gabanyi, K.; Gilitinan, A.; Hagen-Thom, V.; Hausser, M.; Heidt, J.; Hojaev, A.S.; Hovatta, T.; Hroch, F.; Ibrahimov, M.; Impellizzeri, V.; Ivanidze, R.Z.; Kachel, D.; Kraus, A.; Kirtanidze, O.; Lähtenmäki, A.; Lanteri, L.; Larionov, V.M.; Lin, Z.Y.; Lindfords, E.; Munz, F.; Nikolashvili, M.G.; Nucciarelli, G.; O'Connor, A.; Ohlert, J.; Pasanen, M.; Pullen, C.; Raiteri, C.M.; Rector, T.A.; Robb, R.; Sigua, L.A.; Sollanpää, A.; Sixtova, L.; Smith, N.; Strub, P.; Takahashi, S.; Takalo, L.O.; Tapken, C.; Tartar, J.; Tomikoski, M.; Tosti, G.; Tröller, M.; Walters, R.; Wilking, B.A.; Wills, W.; Agudo, I.; Aller, H.D.; Aller, M.F.; Angelakis, E.; Klare, J.; Körding, E.; Strom, R.G.; Teräsranata, H.; Ungerechts, H.; Vila-Vilaró, B., Testing the inverse-Compton catastrophe scenario in the intra-day variable blazar S5 0716+71. I. Simultaneous broadband observations during November 2003, *Astronomy and Astrophysics*, Volume 451, Issue 3, June I 2006, pp.797-807
53. Rottgering, H.J.A.; Braun, R.; Barthel, P.D.; van Haarlem, M.P.; Miley, G.K.; Morganti, R.; Snellen, I.; Falcke, H.; de Bruyn, A.G.; Stappers, R.B.; Boland, B.H.W.M.; Butcher, H.R.; de Geus, E.J.; Koopmans, L.; Fender, R.; Kuijpers, J.; Schilizzi, R.T.; Vogt, C.; Wijers, R.A.M.J.; Wise, M.; Brouw, W.N.; Hamaker, J.P.; Noordam, J.E.; Oosterloo, T.; Bähren, L.; Brentjens, M.A.; Wijnholds, S.J.; Bregman, J.D.; van Cappellen, W.A.; Gunst, A.W.; Kant, G.W.; Reitsma, J.; van der Schaaf, K.; de Vos, C.M., LOFAR – Opening up a new window on the Universe, 11 pages, 5 figures, to appear in the proceedings of the conference "Cosmology, galaxy formation and astroparticle physics on the pathway to the SKA", Oxford, April 10-12 2006
54. Roy, S.; Pramesh Rao, A., Low frequency studies of the Galactic Centre with GMRT, *Journal of Physics: Conference Series*, Volume 54, Issue 1, pp. 156-160 (2006).
55. Roy, S.; Bhatnagar, S., Confirmation of New Supernova Remnants near the Galactic Centre, *Journal of Physics: Conference Series*, Volume 54, Issue 1, pp. 152-155 (2006).
56. Rubio-Herrera, E.; Braun, R.; Janssen, G.; van Leeuwen, J.; Stappers, B.W., The 8gr8 Cygnus Survey for New Pulsars and RRATs, On the Present and Future of Pulsar Astronomy, 26th meeting of the IAU, Joint Discussion 2, 16-17 August, 2006, Prague, Czech Republic, JD02, #52
57. Schnerr, R.S.; Rygl, K.L.J.; van der Horst, A.J.; Oosterloo, T.A.; Miller-Jones, J.C.A.; Henrichs, H.E., Radio observations of candidate magnetic O stars, *Astrophysics*
58. Scholten, O.; Bacelar, J.; Braun, R.; de Bruyn, A.G.; Falcke, H.; Stappers, B.; Strom, R.G., Optimal radio window for the detection of Ultra High Energy cosmic rays and neutrinos off the moon, *Astroparticle Physics*, Volume 26, Issue 3, p. 219-229
59. Schulze-Machuch, D.; Dohm, J.M.; Fairen, A.G.; Baker, V.R.; Fink, W.; Strom, R.G., Sample Return Missions to Mars, Venus, and the Ices on Mercury and the Moon, 37th Annual Lunar and Planetary Science Conference, March 13-17, 2006, League City, Texas, abstract no.1324
60. Serra, P.; Trager, S.C.; van der Hulst, J.M.; Oosterloo, T.A.; Morganti, R., IC 4200: a gas-rich early-type galaxy formed via a major merger, *Astronomy and Astrophysics*, Volume 453, Issue 2, July II 2006, pp.493-506
61. Serra, P.; Trager, S.C.; van der Hulst, J.M.; Oosterloo, T.A.; Morganti, R., Line-strength indices in IC, VizieR On-line Data Catalog: J/A+A/453/493. Originally published in: 2006A&A...453..493S

62. Smits, J.M.; Stappers, B.W.; Edwards, R.T.; Kuijpers, J.; Ramachandran, R., Frequency dependence of orthogonal polarisation modes in pulsars, *Astronomy and Astrophysics*, Volume 448, Issue 3, March IV 2006, pp.1139-1148
63. Smits, R.; Mitra, D.; Stappers, B.; Kuijpers, J.; Weltevrede, P.; Jessner, A.; Gupta, Y., The geometry of PSR B0031-07, Proceedings of the 363. WE-Heraeus Seminar on: Neutron Stars and Pulsars (Posters and contributed talks) Physikzentrum Bad Honnef, Germany, May.14-19, 2006, eds. W.Becker, H.H.Huang, MPE Report 291, pp.161-164
64. Stappers, B.W., High Time Resolution Low-Frequency Pulsar Studies, On the Present and Future of Pulsar Astronomy, 26th meeting of the IAU, Joint Discussion 2, 16-17 August, 2006, Prague, Czech Republic, JD02, #51
65. Stappers, B.W.; Kramer, M.; Lyne, A.G.; D'Amico, N.; Jessner, A., The European Pulsar Timing, *Chinese Journal of Astronomy and Astrophysics*, Supplement, Volume 6, Issue S2, Proceedings of the 2005 Lake Hanas International Pulsar Symposium. Editors: N. Wang, R. N. Manchester, B. J. Rickett and A. Esamdin., p.298-303
66. Vermeulen, R. C.; Labiano, A.; Barthel, P. D.; Baum, S. A.; de Vries, W. H.; O'Dea, C. P., Atomic hydrogen in the one-sided "compact double" radio galaxy 2050+364, *Astronomy and Astrophysics*, Volume 447, Issue 2, February IV 2006, pp.489-498
67. Vogt, C.; En,lin, T.A., Magnetic turbulence in cool cores of galaxy clusters, *Astronomische Nachrichten*, Vol.327, Issue 5/6, p.595
68. Weltevrede, P.; Edwards, R.T.; Stappers, B.W., Statistics of the Drifting Subpulse, *Chinese Journal of Astronomy & Astrophysics*, Volume 6, Issue S2, Proceedings of the 2005 Lake Hanas International Pulsar Symposium. Editors: N. Wang, R. N. Manchester, B. J. Rickett and A. Esamdin., p.13-17
69. Weltevrede, P.; Wright, G.A.E.; Stappers, B.W.; Rankin, J.M., The bright spiky emission of pulsar B0656+14, *Astronomy and Astrophysics*, Volume 459, Issue 2, November IV 2006, pp.597-597
70. Weltevrede, P.; Wright, G.A.E.; Stappers, B.W.; Rankin, J.M., The bright spiky emission of pulsar B0656+14, *Astronomy and Astrophysics*, Volume 458, Issue 1, October IV 2006, pp.269- 283
71. Weltevrede, P.; Stappers, B.; Rankin, J.; Wright, G., Is PSR B0656+14 a very nearby RRAT source?, On the Present and Future of Pulsar Astronomy, 26th meeting of the IAU, Joint Discussion 2, 16-17 August, 2006, Prague, Czech Republic, JD02, #46
72. Weltevrede, P.; Stappers, B.W.; Rankin, J.M.; Wright, G.A.E., Is Pulsar B0656+14 a Very Nearby Rotation Radio Transient?, *The Astrophysical Journal*, Volume 645, Issue 2, pp. L149- L152
73. Weltevrede, P.; Edwards, R.T.; Stappers, B.W., The subpulse modulation properties of pulsars at 21 cm, *Astronomy and Astrophysics*, Volume 445, Issue 1, January I 2006, pp.243-272
74. Weijmans, A.; Krajinovic, D.; Oosterloo, T.A.; Morganti, R.; de Zeeuw, P.T., Dark Matter in NGC 2974: From 100 pc to 10 kpc Scales, *Galaxy Evolution Across the Hubble Time*, International Astronomical Union. Symposium no. 235, held 14-17 August, 2006 in Prague, Czech Republic
75. van Woerden, H.; Strom, R.G., The beginnings of radio astronomy in the Netherlands, *Journal of Astronomical History and Heritage* (ISSN 1440-2807), Vol. 9, No. 1, p. 3 - 20 (2006).
76. Xiang, L.; Reynolds, C.; Strom, R.G.; Dallacasa, D., European VLBI network observations of fourteen GHz-peaked-spectrum radio sources at 5 GHz, *Astronomy and Astrophysics*, Volume 454, Issue 3, August II 2006, pp.729-740
77. Zhao, F-Y.; Strom, R.G.; Jiang, S-Y., The Guest Star of AD185 must have been a Supernova, *Chinese Journal of Astronomy and Astrophysics*, Volume 6, Issue 5, pp. 635-640 (2006).





## Publications Research and Development 2006

1. Ardenne, A. van, "Antennas for Radio Astronomy", European Conference on Antennas & Propagation (EUCAP), Nice, France, November 6-10, 2006.
2. Brandl, B., Lenzen, R., Venema, L., Käufl, H.U., Finger, G., Glasse, A., Brandner, W., Stuik, R., „MIDIR/T-OWL: the thermal/mid-IR Instrument for the E-ELT”, SPIE proc. 6269, 2006.
3. Cappellen, W.A. van, Wijnholds, S.J., Bregman, J.D., "Sparse antenna Array configurations in large aperture synthesis radio telescopes", Proc. European Radar Conference, Manchester, UK, September 13-15, 2006, pp. 76 - 79.
4. Escoffier R.P., Comoretto G., Webber J.C., Baudry A., Broadwell C.M., Greenberg J.H., Treacy R.R., Cais P., Quertier B., Camino P., Bos A. and Gunst A.W., "The ALMA Correlator", for publication in *Astronomy & Astrophysics*.
5. Falcke, H., Haarlem, M.P. van, Bruyn, A.G. de, Braun, R., Rottgering, H.J.A., Stappers, B., Boland, W.H.W.M., Butcher, H.R., Geus E.J. de, Koopmans, L., Fender, R., Kuijpers, J., Miley, G.K., Schilizzi, R.T., Volgt, C., Wijers, R.A.M.J., Wise, M., Brouw, W.N., Hamaker, J.P., Noordam, J.E., Oosterloo, T., Bahren, L., Brentjes, M.A., Wijnholds, S.J., Bregman, J.D., Cappellen, W.A. van, Gunst, A.W., Kant, G.W., Reitsma, J., Schaaf, K. van der, Vos, C.M. de, "A very brief description of LOFAR - the Low Frequency Array", IAU GA, Prague, August 2006.
6. Graauw, Th. de, Cernacharo, J., Bos, A., Herder, J.-W. den, Gerin, M., Guilloteau, S., Gunst, A., Helmich, F., Jackson, B., Lange, G. de, Langevelde, H., Maat, P., Martin-Pintado, J., Noordam, J., Quirrenbach, A., Roelfsema, P., Venema, L., Wild, W., Yagoubov, P., "ESPRIT, an Exploratory Submm Space Radio-Interferometric Telescope", in: A. Wilson (Ed.), *ESA Conference Series: The Dusty and Molecular Universe: A Prelude to Herschel and ALMA*, Paris, France, October 27-29, 2004, p.320 (not in Q4 2004 or Q4 2005).
7. Hamaker, J.P., "Understanding Radio Polarimetry V: Making self-calibration work: Processing of a simulated observation", *Astronomy & Astrophysics* 456 (2006), pp. 395-404.
8. Lagage, P.O., Doucet, C., Pantin, E., Habart, E., Duch enne, G., M enard, F., Pinte, C., Charnoz, S., Pel, J.W., "Anatomy of a Flaring Proto-Planetary Disk Around a Young Intermediate-Mass Star", *Science* 314, p. 621, 2006.
9. Lema tre J., Alliot S., Deprettere E., "Requirements for interfacing IP components in reconfigurable platforms", *Journal of VLSI Signal Processing-Systems*, volume 43, number 2, May 2006.
10. Lema tre, J., Deprettere, E., "FPGA implementation of a Prototype Hierarchical Control Network for Large-Scale Signal Processing Applications", in Proc. of the ACM/IEEE European Conf. on Parallel Computing (Euro-Par'06), Dresden, Germany, Aug. 29-Sept. 1, 2006, p 1192-1203.
11. Lenzen, R., Brandl, B., Brandner, W., Finger, G., Glasse, A., K aufl, H.U., Venema, L., "Observational capabilities and technical solutions of a thermal and MIR instrument at E-ELT", SPIE proc. 6269, 2006.
12. Li, B., Woestenburg, E.E.M., Vaate, J.G., bij de, Serdijn, W.A., "A Broadband Indirect Feedback Power-to Current LNA", 2006 IEEE International Symposium on Circuits and Systems (ISCAS), May 2006.
13. Maaskant, R., Mitra, R., Huang, Neng-Tien, Yu, Wen, Ivashina, M., "Parallel FDTD Modeling of a focal Plane Array with Vivaldi Elements on the Highly Parallel LOFAR BlueGen/L Supercomputer", URSI, APS, Albuquerque, USA, July 2006. pp. 3861-3864.
14. Maaskant, R., Mitra, R., Cappellen, W. van, "Efficient Numerical Analysis of Prototype Antennas for the Square Kilometre Array (SKA) Using the Characteristic Basis Function Method (CBFM)", URSI, Albuquerque, USA, July 2006, pp. 608.

15. Maaskant, R., Popova, M., Brink, R. van den, "Towards the Design of a Low-Cost Wideband Demonstrator Tile for the SKA", European Conference on Antennas & Propagation (EUCAP), Nice, France, November 6-10, 2006.
16. Maaskant, R., Yang, B., "A Combined Electromagnetic and Microwave Antenna System Simulator for Radio Astronomy", European Conference on Antennas & Propagation (EUCAP), Nice, France, November 6-10, 2006.
17. Meijers, M., "Applied Systems Engineering in a Small Scale Project", Modeling, Systems Engineering, and Project Management for Astronomy II, Proc. 6271 SPIE Conference, 2006.
18. Navarro, R., Elswijk, E., Haan, M. de, Hanenburg, H., Horst, R. ter, Kleszcz, P., Kragt, J., Pragt, J., Rigal, F., Roelfsema, R., Schoenmaker, T., Tromp, N., Venema, L., Groot, P., Kaper, P., "X-shooter Near-IR Spectrograph Arm: Design and Manufacturing Methods", Proc. 6273 SPIE Conference, 2006.
19. Ng Mou Kehn, M., Ivashina, M.V., Kildal, P.S., Maaskant, R., "Control of Reflection and Mutual Coupling Losses in Maximizing Efficiency of Dense Focal Plane Arrays", European Conference on Antennas & Propagation (EUCAP), Nice, France, November 6-10, 2006.
20. Nijboer, R.J., Noordam, J.E., Yatawatta, S.B., "LOFAR Self-Calibration using a Local Sky Model", ADASS XV, Astr. Soc. Pacific Conference Series, vol. 351, pp 291-294, ISBN 1-58381-291-9, 2006 (already on web).
21. Patel, P.D., "Wideband Antennas for Radio Astronomy", European Conference on Antennas & Propagation (EUCAP), Nice, France, November 6-10, 2006.
22. Röttgering H.J.A., et al., "LOFAR - Opening up a New Window on the Universe", SKA Conference 2006, 10-12 April 2006. In: H.-R. Kloeckner, M. Jarvis, S. Rawlings (eds.), "Cosmology, Galaxy Formation and Astroparticle Physics on the Pathway to the SKA".
23. Romein, J.W., Broekema, C.P., Meijeren E. van, Schaaf, K. van der, Zwart, W.P., "Astronomical Real-Time Streaming Signal Processing on a Blue Gene/L Supercomputer", Proc. ACM Symposium on Parallel Algorithms and Architectures, July 2006, pp. 59-60.
24. Schaubert, D.H., Kasturi, S., Elsallal, M.W., Cappellen, W.A. van, "Wide Bandwidth Vivaldi Antenna Arrays - Some Recent Developments", European Conference on Antennas & Propagation (EUCAP), Nice, France, November 6-10, 2006.
25. Schreuder, F., Vaate, J.G. bij de, "Localized LNA cooling in vacuum", Proc. 12th International Workshop on THERMal INvestigations of ICs and Systems, Nice, France, 27-29 September 2006, pp. 175-179.
26. Simons, J., Vaate, J.G. bij de, Ivashina, M., Zuliani, M., Natale, V., Roddis, N., "Design of a Focal Plane Array System at Cryogenic Temperatures", European Conference on Antennas & Propagation (EUCAP), Nice, France, November 6-10, 2006.
27. Smirnov, O.M., Noordam, J.E., Implementing arbitrary Measurement Equations with the MeqTree system", ADASS XV 2005, Astr. Soc. Pacific Conference Series, vol. 351, pp 355-359, ISBN 1-58381-291-9, 2006.
28. Tanigawa, M., Wilhelmsson, T. and Meulman, H., "Low-cost Low Maintenance Phased Array Diagnostic Tool Using Broadcast Transmissions from Low Earth Orbit (LEA) Satellites", Proc. Antenna Measurement Techniques Association (AMTA) Europe Symposium, Germany, Munich, May 1-4, 2006., PID467, pp. 217-222.
29. Tanigawa, M., Wilhelmsson, T., Meulman, H., "Phased Array Antenna Measurements using Transmissions from Low Earth Orbit (LEO) Satellites", Proc. Antenna Measurement Techniques Association (AMTA) Europe Symposium, 2006.
30. Tol, S. van der, Wijnholds, S.J., "CRB Analysis of the Impact of Unknown Receiver Noise in Phased Array Calibration", 4th IEEE workshop on Sensor Array and Multichannel Processing (SAM-2006), Waltham, Massachusetts, USA, 12-14 July 2006, on web via IEEEExplore.

# ASTRON

31. Wells, M., Lee, D., Oudenhuisen, A., Hastings, P., Pel, J.W., Glasse, A., "The MIRI medium resolution spectrometer for the James Webb Space Telescope", SPIE Proc. 6265, 2006.
32. Wijnholds, S.J., Boonstra, A.J., "A multisource calibration method for phased array radio telescopes", Fourth IEEE Workshop on Sensor Array and Multi-channel Processing (SAM-2006), Waltham, Massachusetts, USA, July 12-14, 2006, on web via IEEEExplore.
33. Wijnholds, S.J., Veen, A.J. van der, "Effects of Parametric Constraints on the CRLB in Gain and Phase Estimation Problems", IEEE Signal Processing Letters, V13, no. 10, October 2006, pp. 620-623.
34. Wild, W., Graauw, Th. de, Helmich, F., Cernicharo, J., Gunst, A., Bos, A., Herder, J.W. den, Jackson, B., Langevelde, H.J., Maat, P., Martin-Pintado, J., Noordam, J., Quirrenbach, A., Roelfsema, R., Venema, L., Wesselius, P., Yagoubov, P., "ESPRIT – A space interferometer concept for the far-infrared", SPIE Proc. 6265, 2006.
35. Xiaolong Li, Woestenburg, E.E.M., Vaate, J.G. bij de, Serdijn, W.A., "A Broadband Indirect- Feedback Power-to-Current LNA", accepted for presentation at the 2006 IEEE International Symposium on Circuits and Systems, to be held in Kos, Greece, May 21-24, 2006.
36. Yarovoy, A.G., Aubry, P.J., Ligthart, L.P., Tanigawa, M., Boonstra, A.J., Cappellen, W. van, Boer, H.J., "GPR with an Electronically Steered Footprint", Proc. PIERS 2006 (Progress in Electromagnetics Research Symposium), pp. Tokyo, Japan, August 2-5, 2006.

## Joint ASTRON – JIVE colloquia 2005

Date	Speaker	Topic
January 14	Richard Strom	ASTRON, <i>The early history of Dutch Radio Astronomy: radio telephony, Hollandia, Paramaribo and the ionosphere.</i>
January 21	James Miller-Jones	'Anton Pannenkoek' Institute, Amsterdam, <i>Radio observations of Cygnus X-3.</i>
January 28	Mark Walker	Kapteyn Institute, Groningen, <i>Microarcsecond imaging of the ionized interstellar medium.</i>
February 9	Chung-Chi Lin + Ulf Klein	ESA, <i>Future ESA Radiometry Missions for Earth Observations, Tour of ASTRON and 2 short colloquia.</i>
February 11	Michiel Hogerheijde	Sterrewacht Leiden, <i>Molecular Views of Planet-Forming Disks.</i>
February 18	Chris Verhoeven	Technical University, Delft, <i>MISAT – a new satellite system.</i>
February 25	Charlotte Lemmens	ASTRON, <i>The LOFAR Visitor Centre.</i>
March 1	Michael Wise	MIT Kavli Institute for Astrophysics and Space Res, <i>Large-scale Heating and AGV Feedback in Clusters of Galaxies.</i>
March 4	Tom Maccarone	'Anton Pannenkoek' Institute, Amsterdam, <i>A unified picture of the disk-jet connection: foundations and applications.</i>
March 11	Bram Achterberg	Astronomy Institute, Utrecht, <i>The highest energy cosmic rays.</i>
March 31	Dr. H. Olthof	ESA-ESTEC, <i>Huygens and Titan, Introduction ESA, historical facts about Christiaan Huygens and his observations of Saturn and Titan, Cassini-Huygens mission.</i>
April 8	Frank Verbunt	Astronomical Institute, Utrecht, <i>The Earth- Moon system.</i>
April 15	Leon Koopmans	Kapteyn Institute, Groningen, <i>Dark &amp; Luminous Matter in Early-type Galaxies from Gravitational Lensing &amp; Stellar Dynamics.</i>
April 22	Subhashis Roy	ASTRON, <i>Radio Studies of the Galactic Centre.</i>
May 12	Harmut Gemmeke	IPE, <i>Forschungszentrum Karlsruhe, Low Frequency Antennas for Detecting Cosmic Rays.</i>
May 27	James Anderson	JIVE, <i>TBA</i>
June 2	Helio Takai	Physics Department, Brookhaven National Laboratory, <i>Detecting ultra High Energy Cosmic Ray showers with RADAR.</i>
June 10	Heinz Völk	MPI für Kernphysik, Heidelberg, <i>The nonthermal Universe in gamma rays – results of the H.E.S.S. experiment.</i>
June 17	Ignas Snellen	Sterrewacht Leiden, <i>Transiting Extrasolar Planets.</i>

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June 24	Ilian Lliev	CITA, TBA
September 1	Dharam Vir Lal	NCRA, Pune, <i>Study of X-shaped sources.</i>
September 8	Elena Gallo	'Anton Pannenkoek' Institute, Amsterdam, <i>Relativistic Jets from Stellar Black Holes.</i>
September 15	Jean-Pierre Macquart	NRAO, <i>Understanding the Radio Variability of Sgr A*.</i>
October 7	Dave Jauncy	CSIRO/ATNF, <i>Interstellar Scintillation and Radio Variability.</i>
October 20	Serena Bertone	University of Sussex, <i>The effect of galactic winds on the Ly-alpha forest.</i>
October 27	Scott Trager	Kapteyn Institute, Groningen, <i>Are Ols, Red Galaxies Death? (the Stellar Content of Earlytype Galaxies).</i>
November 3	Lisa Harvey-Smith	JIVE, <i>Studies of OH and methanol masers in regions of massive starformation.</i>
November 11	Martin Fullekrug	University of Bath, UK, <i>Thunder and Lighting: Global remote sensing of the atmospheric electromagnetic environment.</i>
November 17	Láslo Evers	KNMI, <i>Infrasound: Listening to inaudible sound.</i>
November 24	Gianni Bernardi	Inst. Di Astrof. Spaz. E Fis. Cosm., Bologna, <i>Observations of synchrotron polarized diffuse emission as foreground for the CMB.</i>
December 1	Jos Roerdink	Inst. For Math. And Comp. Science, Groningen, <i>Automated feature extraction and visualization of large data sets.</i>
December 8	Daan Goense	Wageningen University & Research Centre, <i>A wireless sensor network for precision agriculture, the case for Phytophthora decision support.</i>
December 11	Sebastian Jester	University of Southampton, <i>AGN Jets: Emission and Origins.</i>
December 15	Christoph Keller	Astronomy Institute, Utrecht, <i>Solar surface observations and what they can tell MHD simulations.</i>

## Joint ASTRON – JIVE colloquia 2006

Date	Speaker	Topic
January 3	George Heald	University of New Mexico, <i>Kinematics of Diffuse Ionized Gas Halos in Spiral Galaxies.</i>
January 12	Carl Kesselman	Information Sciences Inst, U South. California, <i>Pioneering the Grid.</i>
January 13	Laura Birzan-Rafferty	University of Ohio, <i>Radio Properties of Cavities in the ICM: Imprints of AGN Activity.</i>
January 16	Aeree Chung	Columbia University, <i>Virgo. a Laboratory for studying Galaxy Evolution.</i>
January 19	Paul de Groot	Radboud Universiteit, Nijmegen, <i>Optical Galactic Plane Surveys.</i>
January 20	Nan Rendong	Beijing Astronomical Observatory, <i>FAST and the Chinese SKA program.</i>
February 8	Guy Drijkoningen	Civil Engineering & Geosciences, TU Delft, <i>LOFAR and Seismology: Seismic imaging and monitoring.</i>
February 16	Nigel Douglas	Kapteyn Institute, <i>PN.S and beyond: Galaxy Dynamics with Planetary Nebulae.</i>
February 23	Rob Millenaar	Rob Millenaar (ASTRON), <i>Finding a site for the SKA - the RFI perspective.</i>
March 2	Remo Tilanus	NWO/Joint Astronomy Center, Hilo, <i>The Future Scientific Programme of the JCMT.</i>
March 9	Yuri Levin	Sterrewacht Leiden, <i>Young stars in the Galactic Center.</i>
March 21	Hermine Landt	CfA, Harvard, <i>A New Population of Blazars.</i>
March 30	Benedetta Ciardi	MPA, Garching bei München, <i>Reionization: simulations and predictions for 21cm observations.</i>
April 4	Steve Sheckman	Carnegie Institution of Washington, <i>The Giant Magellan Telescope.</i>
April 6	Sera Markoff	Anton Pannekoek Instituut, Amsterdam, <i>Inflow/Outflow Connections in Accreting Black. Holes.</i>
April 13	Rebeca Soria-Ruiz	JIVE, <i>The study of circumstellar SiO masers using VLBI.</i>
May 18	Marcus Brüngen	International University Bremen, <i>The Physics of the Intracluster Medium.</i>
June 1	Paul van der	Werf Sterrewacht Leiden, <i>Starburst galaxies at low and high redshift.</i>
June 8	Rhaana Starling	Astronomical Institute 'Anton Pannekoek', UvA, <i>Optical spectroscopy of gamma-ray burst afterglows</i>
June 16	Emil Lenc	Swinburne University, <i>Wide-field, High Spatial Resolution Radio Imaging of the Southern Starburst NGC 253.</i>
June 22	Floris van der Tak	SRON Groningen, <i>Submillimeter observations of Galactic high-mass star formation.</i>
June 30	Lolke Schakel	Faculty of Economics, University of Groningen, <i>LOFAR: Imaging Performance vs. Costs.</i>

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July 6	Gijs Verdoes	Kleijn Kapteyn Institute, Groningen, <i>ASTRO-WISE Science: A new approach to astronomical data analysis for the data-flooded era.</i>
August 24	Anish Roshi	Raman Research Institute, <i>Carbon Recombination Line as a Probe to Study the Environment of Ultra-compact HII regions.</i>
August 31	Enno Middelberg	CSIRO Australia Telescope National Facility, <i>ATLAS - A Very Deep Look into the Southern Radio Sky.</i>
September 5	Kurt Weiler	Naval Research Laboratory, <i>Low Frequency Radio Astronomy and the LWA.</i>
September 7	Alexander van der Horst	Astronomical Institute 'Anton Pannekoek', UvA, <i>Modeling Gamma-ray Burst Afterglows at Centimeter Wavelengths.</i>
September 14	Colin Norman	STScI/Johns Hopkins University, <i>What we have learned from the Chandra Deep Fields.</i>
October 5	Johan Hamaker	ASTRON, <i>Matrix-based Theory and Practice of Radio-Polarimetric Self-calibration.</i>
October 13	Atish Kamble	Raman Research Institute, <i>Multiband Modeling of Gamma Ray Burst Afterglows.</i>
October 19	Leonid Petrov	NVI, Inc. / NASA Goddard Space Flight Center, <i>Recent Fundamental VLBI Surveys.</i>
October 20	Matthew Bailes	Swinburne University, <i>Public Outreach in 3 Dimensions and the impact of software correlators in precision pulsar timing.</i>
November 2	Atul Deep	IUCAA, India, <i>The Design and Fabrication of Near Infrared PICNIC Imager (NIPi).</i>
November 9	Rick Perley	NRAO, <i>eVLA Status.</i>
November 16	Krisztina Gabanyi	MPIfR – Bonn, <i>Effects of the turbulent ISM on radio observations of quasars.</i>
November 24	Dan Stinebring	Oberlin College, Ohio, <i>Pulsar Scintillation: Structure in the ISM and its Effect on Gravitational Wave Detection.</i>
December 1	Maria Cunningham	University of New South Wales, <i>The Mopra G333 Multi-wavelength Survey: Massive Star Formation in the Southern Galactic Plane.</i>
December 7	Neeraj Gupta	NCRA, <i>Cold atomic gas in AGNs and intermediate-redshift protogalaxies.</i>
December 14	Stafford Withington	Cavendish Laboratory, Cambridge, <i>Optical. Physics of Phased Arrays and Bolometric Interferometers.</i>

## Colofon

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