ASTRON

Annual Report 2008

Netherlands Institute for Radio Astronomy

Image cover:

construction of the central mound that will house six LOFAR

stations at the heart of the LOFAR core area near Exloo in Drenthe.

Inset: one of the first images made with the prototype of the new APERTIF system.

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Preface

It is my pleasure to introduce the ASTRON Annual Report for 2008. I would like to congratulate ASTRON on the great progress that has been made this year.
Despite the many changes introduced within the organisation, ASTRON staff have remained focused on the work at hand. Good progress has been made in all areas – in particular with the development of LOFAR, APERTIF and EMBRACE. During this period of rapid change, the focus of the institute has also sharpened. The trend continues towards concentrating our efforts on radio astronomy. As a result, ASTRON is now officially the Netherlands Institute for Radio Astronomy. To mark this change, a new logo and house style has been introduced.

The internationalisation of LOFAR is also a very welcome development. With many countries across Europe now involved, the telescope will be able to produce images that are at least ten times sharper than the original concept. The central role ASTRON is playing in the further development of LOFAR is widely acknowledged, and provides an excellent point of departure for the challenge of the next decade: the Square Kilometre Array (SKA) project.

For that reason also, the decision to strengthen research in radio astronomy in Dwingeloo is an important stepping stone as well. While there is still a lot of progress to make in this area, the ASTRON board sees this as an essential development if ASTRON is to fully exploit its telescope facilities, and to play a prominent role in the SKA project.

The future prospects of the institute are excellent. ASTRON has built a solid reputation throughout the world as one of the leading institutes in radio astronomy, and is at the heart of exciting international developments. With the Square Kilometer Array as the logical follow-up of LOFAR, and observing that the SKA is now emerging as the joint top priority for the European astronomical community, ASTRON is perfectly placed to play a key role in these challenging developments.

Prof. Henk Zijm
Chairman, ASTRON board.

Directors Report

Over the last year, many changes have taken place in the governance of ASTRON. On the 1st of January 2008, a new board was appointed, chaired by Prof. Jos Engelen (then deputy general director and chief scientific officer of CERN). The new board is smaller than before - other board members include Sipke Swierstra, Prof. Wim Harder and Prof. Johan Bleeker. Our new board members bring a wealth of experience in the areas of science policy & political affairs, running complex organisations and exploiting large scientific facilities. While previous ASTRON boards included significant representation from national stakeholders, the new board operates 'at a distance' from the ASTRON director and management team. In the new model, the ASTRON director is now advised by a Scientific Advisory Committee (SAC). The SAC will offer advice to ASTRON on various strategic issues that are relevant to our main mission – making discoveries in radio astronomy happen. At the end of the year the SAC was appointed with Prof. Steve Rawlings (Oxford) as its first chairman. At the end of the year, Jos Engelen was appointed as chairman of the NWO General Board (effective 1 January 2008). Prof Henk Zijm (formerly rector magnificus, University of Twente) was appointed as chairman of the ASTRON board. Prof. Wim Harder suddenly passed away this year and was replaced by Prof. Jeff de Hosson (Dept. of Applied Physics, Groningen). Wim's contribution to ASTRON in this year was very much appreciated, especially in the area of financial oversight. He will be sadly missed.

In 2008 the main thrust of our activities have been to operate and exploit our major telescope facilities - the WSRT (Westerbork Synthesis Radio Telescope) and in the future LOFAR (Low Frequency Array), and to continue the leading role we play in the international development of new and novel technologies for the SKA (Square Kilometre Array). The pursuit of fundamental research across all our divisions is also a primary goal of our organisation. In this year, we

have taken important steps forwards in terms of re-building the astronomy group at ASTRON. With the appointment of top-talent to staff positions within the group, and the creation of new support scientists group at the Radio Observatory, ASTRON, together with JIVE, is emerging as a significant force in radio astronomy. Across all of ASTRON's divisions, 73 refereed publications were produced this year,

This year part of the infrastructure required to build the LOFAR radio telescope was put in place. Large-scale civil works were initiated within the LOFAR core area, located near Exloo, about 25 kilometres from Dwingeloo. In collaboration with various regional partners, this area will also be transformed into a nature reserve. In September, an elevated area of land was constructed that is more than 325 metres wide. This so-called 'super-terp', will be the location of six core stations, densely packed together in order to provide excellent uv-coverage on the shortest spacings. Unfortunately, the very wet and wintry weather experienced around the end of the year made the placement of stations impossible. However, around the country, hardware production for LOFAR was in full swing – the delay in actually putting kit on the ground required us to invest in substantial storage facilities. In addition, a decision was made to populate and test the electronic cabinets in a factory production environment, rather than in the field. With some pride, we can also report that around 75% of the contracted work has been placed with companies located here in North Netherlands. The LOFAR High Band Antenna (HBA) pre-production prototypes successfully generated deep images of the entire sky. The constructing of production LOFAR stations is expected to take place early in the spring next year.

In the international arena, interest in LOFAR continued to rise. Currently, there are five stations funded in Germany, one in the UK, one in France, and one in Sweden. There is strong interest to build more stations in these countries, and Italy, Austria/ Ukraine and Poland are actively seeking funds for their own stations. In Hamburg, the second international LOFAR astrophysics workshop was hosted by the German Long-wavelength consortium (GLOW). The meeting attracted over 140 participants from many different European countries, but also the Ukraine, Iran, Taiwan and Russia.

In 2008, an agreement between ASTRON and NOVA (the Dutch research school for astronomy) saw the formation of the NOVA Optcial/IR group. Largely funded by NOVA, the group's activities have begun to focus on E-ELT instrumentation studies. Hosted by ASTRON, the NOVA group retains access to our laboratory facilities, and to personnel in the rest of the institute with relevant expertise (e.g. cryogenics, mechanical design and software development). The new agreement between ASTRON and NOVA ensures that the Dutch astronomical community is well placed to play a major role in the development of instrumentation for the next generation of Optical/IR telescopes.

Looking towards the future, there can hardly be a better time for us to direct our efforts towards developing a more coherent programme in radio astronomy. An important link to SKA technology development is the Westerbork NWO-G funded APERTIF project. This seeks to replace the single receiver systems currently employed on each Westerbork telescope, by a focal plane array (FPA) "camera" system, expanding the field of view of Westerbork by a factor of 25! The development of this kind of technology is essential if the SKA is to meet its current science specification goals, and is subject to many different and novel R&D efforts around the world. In this year, experiments with a test FPA system (Digestif) installed on a single Westerbork telescope, produced the very first astronomical results and images using this new type of technology. In parallel to this development, the construction of the EMBRACE Aperture Array prototype made good progress under the auspices of FP6 SKADS. The prototype is expected to be complete by the middle of next year.

In this year, the Netherlands roadmap was published for large-scale research infrastructures. 25 infrastructures have been identified as being important for the future development of Dutch science. Sixteen of these are already identified within the ESFRI (European Strategy Forum on Research Infrastructures) list of opportunities, including the E-ELT and SKA.
The international SKA project continues to advance by leaps and bounds. In 2008, the FP6 SKA Design Study (SKADS) was in full swing, and in April the FP7 SKA Preparatory Phase activity (PrepSKA) also started. The enthusiastic engagement of the national funding agencies (including NWO) in the PrepSKA policy work packages is also very encouraging. Meanwhile, the SKA Project Development Office (and its Central Design and Integration Team) has started to expand. In the autumn of 2008, the priorities for future astronomical facilities in the

next decade was decided via the funding agencies led Astronet process. The SKA and E-ELT emerge as the joint priorities for the European astronomical community. Discussions on how these two large-scale facilities can be realized within the same time-frame are expected to take place later next year.

Prof. Mike Garrett
General Director

1. Radio Observatory

The formal organisation change within the Radio Observatory, that united several sub-groups into the Technical Operations Group, and created a new Science Support and a new Systems Engineer Group, took effect on 1 January 2008. The adaptation to the new formal situation went smoothly, as changes in tasks had already begun gradually for most people, and other changes in procedures and collaborations were still being gradually introduced throughout the year. However, hiring qualified personnel to fill the vacancies proved challenging, and at the end of the year a number of posts remained open.

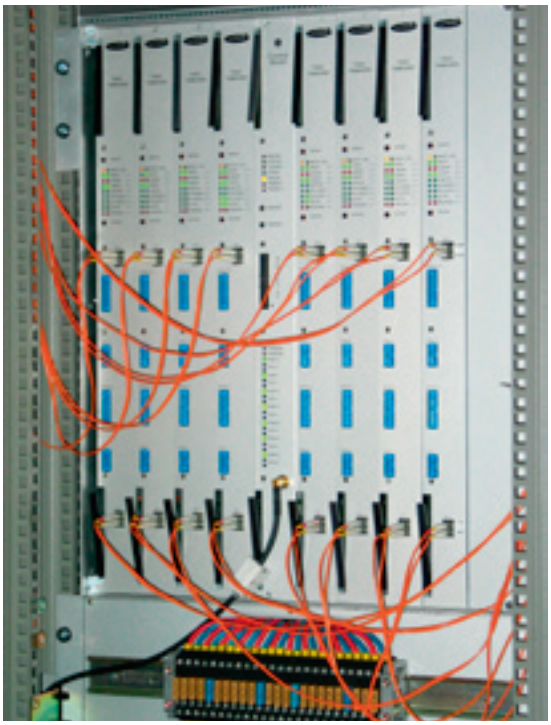
Since LOFAR operations involve a number of different parties both nationally (e.g., the CIT of the RUG) and internationally (the foreign consortia purchasing and installing stations), the Director, assisted by C. Vogt, started intensive preparations to formalise the various partnerships, and also to ensure that operational procedures will be in place. Workshops were convened in May and September with interested parties from Austria, Germany, France, Italy, Poland, Sweden, the Ukraine, and the United Kingdom; numerous other meetings were attended. The work will continue in 2009, aimed at respecting all interests and allowing LOFAR to function as a common-user observatory towards the community, in the same way as the WSRT.

Technical Operations

Since no internal candidate had been found to head the important Technical Operations group, the function was taken up ad interim by Bert Woestenburg (from the R&D division). Major changes were instituted in the working procedures, allowing an increasing focus on (future) LOFAR operations. By August, all RO-personnel formerly stationed at the WSRT were moved to offices in Dwingeloo. This optimises internal interactions, both around the focal point of the LOFAR/WSRT Control Room, and for participation in LOFAR development and rollout. The 'software pavilion', that hosts RO and R&D software engineers alike, for example, has worked out well. Priorities and work schedules within the Technical Operations group are now set on a weekly basis.

European science journalists visit the WSRT and have the chance to see Apertif and EMBRACE on 1 Oct 2008

The WSRT is now visited by crews for planned maintenance, typically every Tuesday, and for repairs to the extent that these can be fitted into the work schedules. Slippages in the LOFAR rollout schedule have allowed significant emphasis on preventive maintenance at the WSRT, that will be advantageous during the LOFAR roll-out period. Oversized top wheels were installed in the hour angle gear boxes of all telescopes. Mechanical, electronic and cryogenic maintenance and repair of the MFFEs occurred at routine levels; instabilities in the cryogenic temperature of two MFFEs were fixed. A hardware engineer who retired this year spent time transferring his expertise to other staff. Replacement and repairs took place as needed for faulty modules and circuit boards for both IVC and correlator; safeguarding relevant backend expertise in view of retirements also received attention. Remote monitoring and control capabilities for system hardware (controllable power switches, network enabled KVM switches, automated shutdown procedures) have been improved to minimize the need for on-site maintenance.



After a period of commissioning in 2007-2008, VLBI operations have made full use, from Session 2008/3 onwards, of the new digital Tied Array Distribution Unit (TADUmax) system, which in combination with a Mark5B recorder replaces the old analogue adding system, the field system and the Mark5A recording system. TADUmax is operationally more transparent and is producing better quality data. The new system has also performed up to expectations in a number of e-VLBI sessions, with the Mark5B under full control from JIVE. VLBI software,

procedures, and documentation were improved. The 34.4 km dark fibre between the WSRT and JIVE, used for e-VLBI, was upgraded to use multiple wavelengths (CWDM), with each wavelength able to carry 1 Gbps. Furthermore, FTP file transfers scheduled in EVN network monitoring experiments can now be done automatically.

The Pulsar Machine II, PuMa-II has taken over most of PuMa-I functionality; it is now supported by RO staff. The tape units were extended to 22 TB RAID 5 storage space - almost a fourfold increase. Pulsar observing also benefits from the flexibility of the TADUMax system. Changes to the cluster configuration have enabled remote management of PuMa-II with network controlled power units and a combination of virtual keyboard/mouse and serial terminal servers. In the last quarter of 2008 one of the tape loaders broke down and was replaced. Also, spare hardware was acquired for the PUMA-II cluster to ensure continued operation in the next two years.

The WSRT system software, including TMS, is stable. The code repository for the web applications (including MoM and NorthStar) has been moved from a CVS system to the Subversion (SVN) system also in use by the LOFAR software developers. The WSRT disk based data archive has been moved to Dwingeloo, with a full copy residing on a SAN at the CIT in Groningen. Just before the end of the year, a 24 TB archive server was installed at ASTRON, for the second copy of the WSRT archive. After some technical problems with the file server at the CIT, the service has been relocated to ASTRON for the time being.

Observations with the LOFAR test stations, including CEP if possible (the changeover to BlueGene/P led to major disruptions for test observing), were supported as much as the availability of the system allowed. The operators gained experience in setting up the system, even though not yet with the final software.

Site measurements have been performed at national and international candidate station sites, using the standard LOFAR monitoring setup. The properties of an LBA near a strong RFI source were also characterised. Groundwork starting in July in the core marked the formal start of participation in the LOFAR station rollout process. One of the test stations (CS8) had to be dismantled. To accommodate test systems with LCUs, two HBA-tiles of CS10 were removed. The rollout team for the core stations is headed by RO hardware engineer Jan-Pieter de Reijer; other RO staff are involved as well.

Throughout 2008, many contributions to the development of LOFAR Software and ICT systems were made. This included preparing the automated installation procedure for the LOFAR station Local Control Units, initial testing and use of the SAS/MAC/SHM systems, development of station based MAC software, development of the LOFAR CRAFT (Component Registration and Fault Tracking) system, offline pipeline development, and preparing central LOFAR services including the security setup. Remote desktop solutions were evaluated to allow operators to work securely and interactively with LOFAR internal applications from remote locations (including home) over low bandwidth connections. The design of the LOFAR Long Term Archive (LTA) was taken up by system engineer Hanno Holties who during the last quarter chaired the LOFAR LTA Working group, commissioned by LOFAR and BiG Grid management to provide a blue print for the LOFAR LTA in preparation for future acquisitions of archive systems. Michael Wise joined the RO as LOFAR Astronomy Coordinator in July, and is managing the crucial development and commissioning of LOFAR user (pipeline) software.

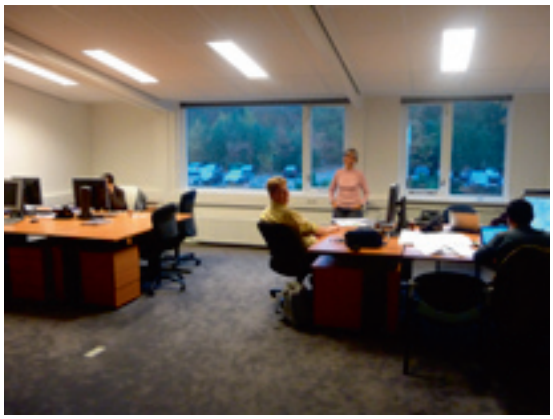
Support was given to Digestif testing for the Apertif system, to the Galileo SMF project, and to the construction of a platform for EMBRACE at the test location between telescopes 4 and 5, as well as for realisation of a shielded cabin for EMBRACE electronics and for experiments in the construction hall for the EMBRACE radome. In November the radome was placed, after which the shielded cabinet was located near the radome. Two apprentices from the KAT7 project were hosted in the Control Room to learn the ropes of interferometry.

Maintenance and development work on NorthStar were carried out by an externally hired JAVA developer from May onwards. With OPTICON support, functionality was delivered for the WHT, INT, and NOT telescopes. Support has been provided to the Joint Astronomy Center Hawaii, to the Jodrell Bank Observatory, and incidentally to other RadioNet facilities. Development continued on a generic version that has a high level of adaptability with respect to instrument configurations and allows functional behaviour to be changed through configuration files. For Dutch use, there are now separate NorthStar versions for the WSRT, for the ING tele-

scopes (with Opticon), and for the JCMT. Development of a LOFAR version of NorthStar was initiated in preparation for a first call for proposals in 2009.

Science Support; Observing Programme

As part of the gradual ramping up of science support activities within the Radio Observatory, new support scientists were hired in April (G. Józsa) and October (N. Pradel). An improved Science Support Centre was installed over the summer; it can now host six to eight visiting scientists in comfort.



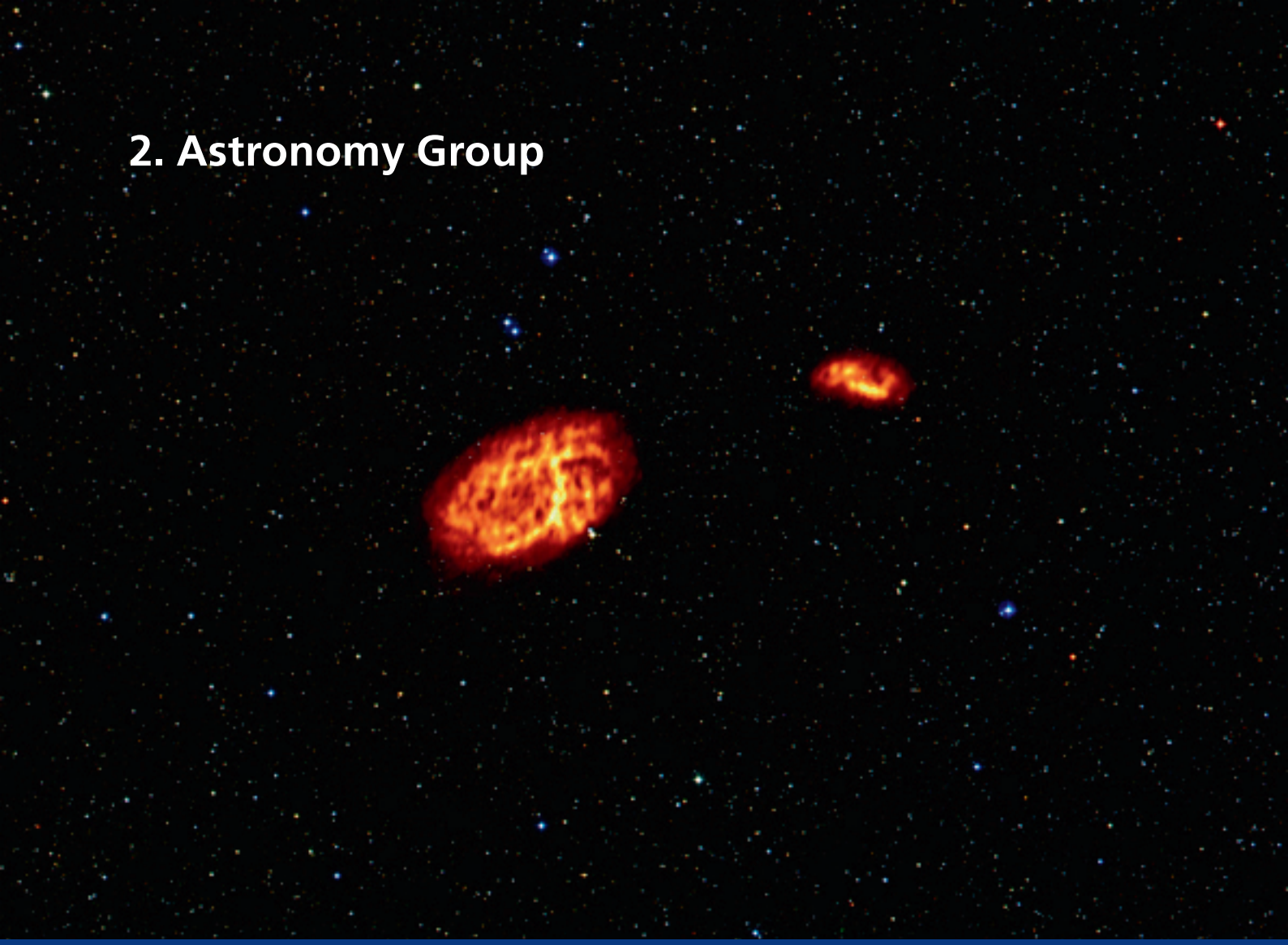
The scheduling of the WSRT is now an interaction between the operators and the science support group. The ironing out of project allocations that were unevenly spread in LST took much attention initially. A WSRT scheduling tool based on Excel was developed, that now allows rapid insight into the critical elements for the schedule, and has also proven to be very useful during the PC meetings.

The net scientific production was high, varying between 1322 hours in the second quarter (that saw impact from a failure of the cooling system in an early-season heat wave) to 1488 hours in the third quarter (which includes the traditionally smooth summer vacation period). Throughout the year, the observations were all done in maxi-short configuration, but campaigns to visit other spacings of the movable telescopes are expected again for 2009. The observations were predominantly with the L-band systems, but encompassed all bands, including the LFFEs, and all backends, including PUMA-II, and (e)VLBI observations. When the PUMA cluster was not used for observing, it was used for processing data from pulsar surveys carried out at the WSRT. Tests have shown that the transition of the ~10 year Pulsar Timing Program at the WSRT to the use of TADUmax did not impact timing residuals.

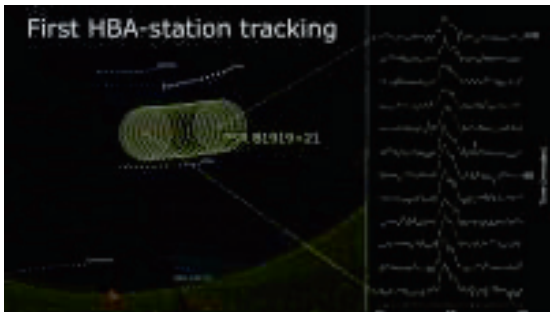
The possibility to apply during the course of a semester for 'service' or 'filler' observations, was extended to allow a total duration of 24 hours per project. This has led to a significant rise in the number of service proposals, now often five per quarter, and these are most useful in increasing productivity by filling empty gaps in the schedule, that fall inevitably between successive 12-hr synthesis observations.

The Radio Observatory was pleased to welcome more than thirty people to the WSRT Users Meeting held on 4 June 2008 in Amersfoort; the first such occasion since 2002. The community was brought up to speed with the current status and possible options for the future of the WSRT, and users presented some of their recent science highlights. Extensive discussion showed very broad interest in the potential new capabilities of Apertif, and fascinating options were mentioned for radio continuum, polarisation, HI line, and pulsar applications. Some concern was voiced about the loss of low frequency coverage for pulsar and polarisation work, and the loss of frequency agility that would result. The Observatory was urged, in particular, to explore options to continue participation in VLBI at other frequencies than L-band, even if perhaps with only with a single dish. Nevertheless, the assembled participants by and large agreed that the prospects of Apertif represent an opportunity that is not to be missed, and that will allow the WSRT to be a forefront facility for many years to come.

2. Astronomy Group



A wide range of science and activities has been covered by the Astronomy Group also this year. Some highlights are briefly presented below. Topics new to the group have been covered, such as Saturn lighting and the exoplanetary radio emission that Jean-Mathias Griessmeier has observed at low frequency using the UTR-2 radiotelescope. This work it is not only interesting in its own right, but is also highly relevant in preparation for LOFAR. Of course we have continued to be engaged in frontline research in 'classical' fields for the group, in particular the study of neutral hydrogen. Interesting are the first HI results on a large sample of nearby early-type galaxies obtained by Paolo Serra, Raffaella Morganti and Tom Oosterloo, who have shown how common neutral hydrogen is in these objects, as well as the variety of structures found. Important results, also highly relevant for LOFAR, have been obtained, by Ger de Bruyn, in the field of magnetism based on WSRT LFFE observations. These data have allowed, for the first time, a view of the diffuse polarised emission of the Milky Way at 2-m wavelength.



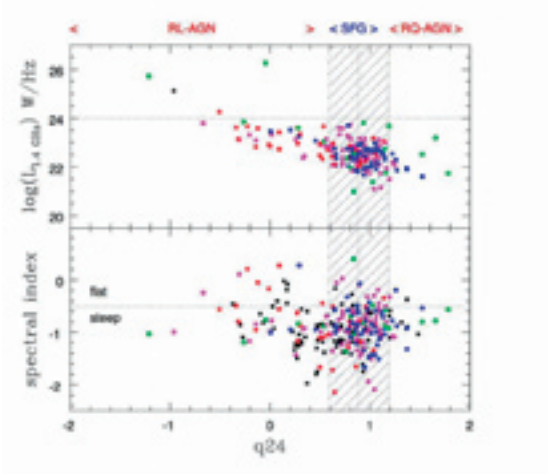
Preparation for LOFAR has been one of the high-priority activities of the group. In particular, it is worth mentioning the success of the 'LOFAR pulsar busy week', that have concentrated on the commissioning of beam-formed, i.e. non-imaging, modes. This week (in November the first of a regular series) brought together Jason Hessels and Joeri van Leeuwen from ASTRON, with the other LOFAR Pulsar Working Group members, the observers, and several developers and support scientists. Several known pulsars were detected for the first time with LOFAR and they will provide good test sources for future commissioning activities. Several important bugs were identified and fixed during the pulsar busy week, in particular the station tracking using a coherent sum of all the elements within a station (see figure).

Summer students

The astronomy group has hosted three students during the summer 2008. Martin Bell (a Ph.D. student at the University of Southampton) has worked under the supervision of Ger de Bruyn on the search for highly dispersed, single event, transient radio bursts (Lorimer et al. 2007) in archival low frequency Westorbork data. The motivation behind this project is to find new single-epoch high-energy burst events. The summer student Ana Guelbenzu (from Vienna University) worked, supervised by Raffaella Morganti and Eva Jütte, at WSRT mosaic observations to map the distribution of the HI in the Leo Ring. HI is known to be present in this region and it was considered particularly interesting as it did not appear to be associated to any particular galaxy in this field and, therefore, claimed to be primordial. The new WSRT observations show in much more detail and depth the complex kinematics of the HI and they reveal some faint connection with galaxies in the group. Zhiyu Zhang, a summer student from the Purple Mountain Observatory in Beijing, has worked under the supervision of Tom Oosterloo and Paolo Serra on the galaxy ESO 092-21. This is a small E/S0 galaxy that was observed in HI with the ATCA. ESO 092-21 is an interesting galaxy because it is surrounded by a very large disc of HI almost fifteen times larger than the stellar body. The disc is rotating extremely regularly and is therefore a nice object to perform dynamics studies. In addition to their research, the students have followed lectures on various topics (general introduction to radio interferometry, radio emission from planets and pulsars as well as extragalactic talks on neutral hydrogen, AGN variability and radio surveys).

Female Visitor programme

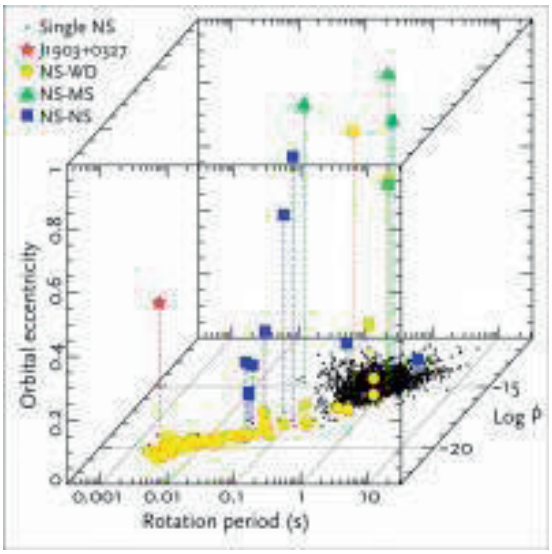
The astronomy group has enjoyed the visit of Isabella Prandoni (Inst. Radioastronomia, Bologna, Italy) as part of the Helena Kluyver female visitor programme that we have started at ASTRON. Isabella has worked together with Raffaella Morganti and Claudio Paulo (student from Univ. Western Cape, ZA) on understanding the characteristics of the radio sources in the Spitzer First Look Field. They used VLA 1.4GHz and GMRT 610MHz data to derive the spectral index of the sources. These sources were correlated with the list of optical information (spectra, redshift). Preliminary results are illustrated in the figure, where, for the radio sources in the FLS, we plot the 1.4 GHz luminosity (top) and the 0.61-1.4 GHz spectral index (bottom) as a function of the 24 micron over 1.4 GHz luminosity ratio (referred to as q24). The q24 parameter range typical for star-forming galaxies is shown by the blue shaded region.



Radio-loud and radio-quiet AGNs are respectively located at the left and right side of such a region (corresponding to an excess or deficit of radio emission with respect to the infrared). The figure clearly shows that the large majority of low power AGNs are radio-loud, possibly associated with low accretion rate systems. Very interestingly, however, we have here a first direct evidence of radio-quiet AGNs being present at sub-mJy flux levels. Such a result supports the idea that radio-quiet AGNs are not necessarily radio silent.

Science Highlights 2008

An Eccentric Binary Millisecond Pulsar



Binary pulsar systems are superb probes of stellar and binary evolution and the physics of extreme environments. In a survey with the Arecibo telescope, Joeri van Leeuwen, Jason Hessels and the PALFA collaboration have found PSR J1903+0327, a radio pulsar with a rotational period of 2.15 ms in a highly eccentric (e = 0.44) 95-day orbit around a solar mass companion. Infrared observations identify a possible main-sequence companion star. Conventional binary stellar evolution models predict neither large orbital eccentricities nor main-sequence companions around millisecond pulsars, and cannot explain the system that is observed. Alternative formation scenarios involve recycling a neutron star in a globular cluster then ejecting it into the Galactic disk or membership in a hierarchical triple system. A relativistic analysis of timing observations of the pulsar finds its mass to be 1.74+/-0.04 Msun, an unusually high value (Champion et al., Science 320, 2008).

The figure shows rotation periods, period derivatives, and orbital eccentricities (for binary pulsars) of pulsars in the disk of the Galaxy. The bottom face of the cube shows a plot of rotation period versus rotation period derivative for all Galactic pulsars. Colored points show the binary pulsars, projected upward from the bottom face in proportion to their orbital eccentricities. Square blue points are double neutron star systems, triangular green points are pulsars with main-sequence or massive companions, circular yellow points are pulsars with white dwarf or sub-dwarf companions, and the red star is PSR J1903+0327, which occupies a unique place in the diagram.

PSR J1856+0245: Arecibo Discovery of a Young, Energetic Pulsar

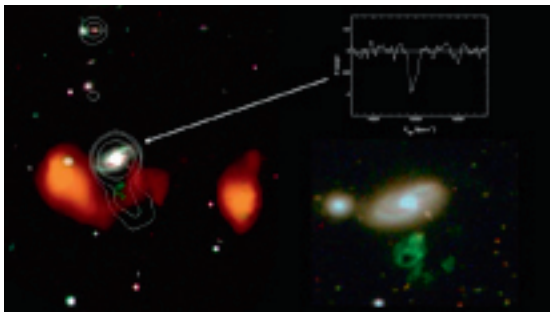
Also as part of the PALFA pulsar survey with Arecibo, Jason Hessels and Joeri van Leeuwen were part of a team that presented the discovery of the young, Vela-like pulsar J1856+0245, likely associated with the HESS TeV gamma-ray source J1857+026 (Hessels et al., ApJ, 682, L41, 2008). This pulsar likely solves the mystery of the nature of this high energy source. X-ray follow-up observations are currently being analysed.

Hanny's Voorwerp

Mike Garrett, Gyula Józsa (Radio Observatory) and Tom Oosterloo made WSRT and e-VLBI continuum, and WSRT HI observations of Hanny's voorwerp. The Voorwerp was discovered by Hanny van Arkel, a Dutch school teacher and an enthusiastic volunteer of the Galaxy Zoo project. While surfing through hundred's of images, Hanny noticed a huge green irregular cloud of gas of galactic scale, located about 60,000 light years from a nearby galaxy,

IC2497. The object has had astronomers scratching their heads for over a year now - the extent of the cloud is enormous and the gas is extremely hot (> 15000 Celsius) but paradoxically it is devoid of stars.

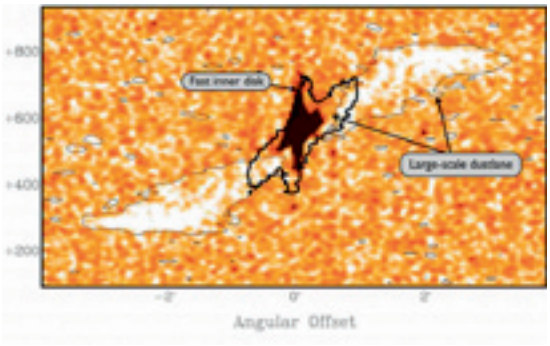
The new WSRT and VLBI observations have thrown new light on the true nature of this bizarre object. In particular, the data suggest that IC2497 is associated with a highly obscured AGN that presents a collimated radio jet on kpc scales. This jet clears a narrow path through the thick dust and gas that surrounds IC2497, permitting optical and uv radiation to ionise everything in its path.



WSRT observations reveal a radio jet (white contours) emanating from the centre of the nearby galaxy IC 2497, headed straight in the direction of Hanny's Voorwerp (green). The observations also reveal a huge reservoir of hydrogen gas (coloured orange) that probably arose from a previous encounter between IC2497 and another galaxy. The presence of strong neutral hydrogen absorption (top right plot) argues that the central regions of IC2497 are highly obscured. Credit: Main image left and top right hand corner, ASTRON. Hanny's voorwerp (bottom right) Dan Herbert, Isaac Newton Telescope.

The WSRT HI observations detect a huge stream of neutral gas that is in the vicinity of IC2497 and extended across ~ 100pc. Part of this is ionised by the path cleared by the radio jet, thus creating Hanny's voorwerp. The coherent velocity structure of the neutral gas strongly suggests it has arisen via a merger between IC2497 and other nearby galaxies. Indeed a group of galaxies lying about 100pc from IC2497 are located at the tip of the neutral gas stream. A paper (Gyula et al.) is in preparation and a press release (coinciding with a visit of Hanny van Arkel to ASTRON) drew wide attention from the national and international media.

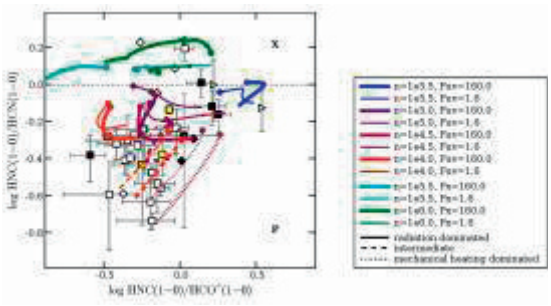
A circumnuclear disk of atomic hydrogen in Centaurus A



Raffaella Morganti, together with Tom Oosterloo and Christian Struve, has completed a Letter describing the HI absorption observed in the central region of Centaurus A. The observations were performed with the Australia Telescope Compact Array and are part of a larger project that will be described in the full paper that Struve is writing. Regarding the central region of Centaurus A, these new data show that the HI absorption covers a much larger velocity range than previously known. For the first time, absorption is detected against the radio core at velocities blueshifted with respect to the systemic velocity. Our data also indicate that the redshifted component is broader than reported before. Interestingly, a comparison of the HI with CO data shows a striking similarity. The molecular gas has been described as a circumnuclear disk. Thus, these results suggest that the central HI absorption is not, as was previously claimed, connected to infall into the AGN, but instead is due to a cold, circumnuclear disk.

Typical scales of turbulence in the Galactic plane
Marijke Haverkorn and collaborators studied the outer scale of structure in the magneto-ionised medium in the Galactic spiral arms and interarm regions by way of Faraday rotation of background sources behind the inner Galactic plane. It is believed that the dominant driver of turbulence in the inner Galaxy is supernova remnants, which input energy in the magneto-ionised medium at scales of about 100 pc. Haverkorn et al. (2008) show that the dominant scale of fluctuations in the spiral arms is only a few parsecs, indicating that either there is an additional source of structure in the spiral arms, or supernova remnants stir turbulence in the arms on scales much smaller than previously assumed.

Dense gas in luminous infrared galaxies



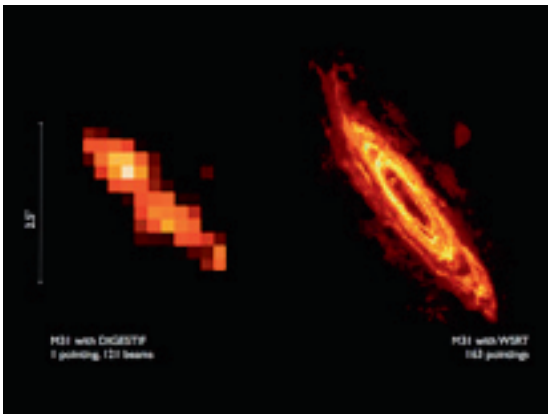
Understanding the properties of the molecular medium in the Galaxy and in the nuclei of active galaxies requires a combination of observational data and theoretical modeling. The molecular Inter-Stellar Medium ISM) is the location of the active star-formation, which serves as a source of energy for the most spectacular Galactic and extragalactic emission regions. Willem Baan, student Edo Loenen (RUG), and Marco Spaans (RUG) have worked on combining observation and theory to explain the observed molecular line emissions both in the Galaxy and in (Ultra-) Luminous InfraRed Galaxies.

Extensive physical and chemical modeling codes are employed to explain line emission properties and emission line ratios found in the star-formation regions. Rather than using a single molecular species to interpret, multiple molecular species in the ISM are being used because each molecular species reacts different to the local environment. Together these molecules are more sensitive to environmental changes and they may be used as diagnostic tools to understand the details of the physics and chemistry of the molecular environment. Each molecular species can also be individually analyzed using its higher excitation levels in order to obtain information on temperature and density.

As a first step the observed characteristics of the molecules HCN, HNC, and HCO^+ in extragalactic infra-red luminous galaxies (Baan et al., 2008) have been used to apply the theoretical models (Loenen, Spaans and Baan, 2008). The accompanying figure shows a diagnostic diagram using the line ratios. The color curves are predicted theoretical ratios that describe different environmental conditions (described by density 'n' and radiation density 'F'). It has been found that many of sources below the dotted line can be explained by PDR (Photon-Dominated Region) characteristics that result from massive star-formation in the galactic nucleus. A few sources above the dotted line have the characteristics of an X-ray Dominated Region (XDR) that would result from the presence of an Active Galactic Nucleus (AGN). However, more evolved (older) starbursts (group of data points towards lower left) cannot be explained by simple PDR characteristics and require 'feedback' from the intense star-formation process (dashed curves). Shocks resulting from Supernovae and Supernova Remnants provide mechanical heating of the medium that results in depletion of the HNC molecules and enhancement of HCO^+, which reduces the line ratios. The relative position of sources within such diagrams reveals the physical and chemical state of the molecular ISM in the galactic nucleus and the evolutionary state of the starburst activity. The yellow data points are nearby galaxies of particular interest that are subject of further study with interferometry.

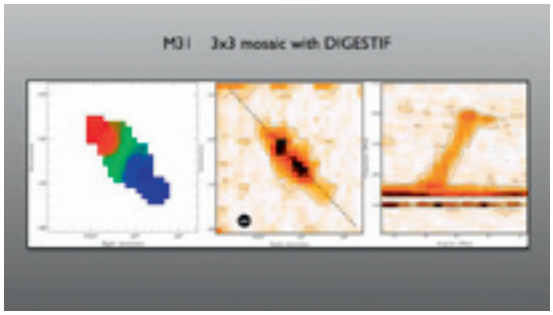
Apertif/Digestif related activities

A major milestone was reached with Digestif in the last week of February, namely the first astronomical image ever made with an FPA. At the moment of observation, Digestif was equipped with 36 active elements. Using a single telescope pointing with an integration time of 6.7 sec, 121 optimised beams were constructed on the sky with which an area of 2.5 by 2.5 degrees was imaged centred on Cygnus A, with a resolution of just over half a degree (see image). The on-axis beam has an Ae/Tsys of 2 and the beams with a small offset have a comparable sensitivity.



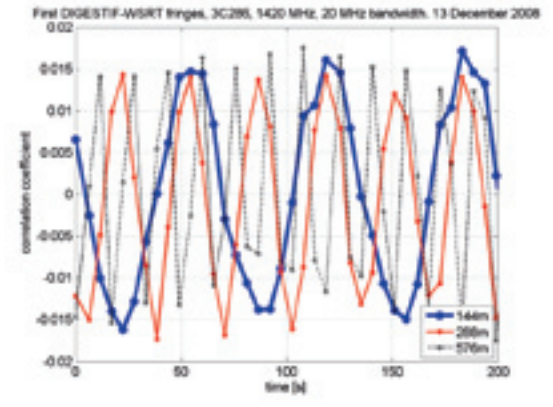
As expected, the sensitivity drops at the edges of the field of view due to the limited size of the array. Following this success, more objects were observed, among which M31. The figure shows on the left the integrated HI obtained from a single 6.7 sec integration. Also here, 121 compound beams were made, imaging an area of 2.5 x 2.5 degrees. For comparison, the total HI obtained from a full mosaic (involving 163 pointings) done by Robert Braun with the

WSRT is shown. Off course that looks better, but he cheated by also using the other thirteen WSRT dishes and by integrating much much longer…



Following this, a small 3×3 mosaic was done on M31, to cover a slightly larger area. The result is below, also showing the kinematics of the HI in M31. It shows that with FPA systems, large areas on the sky can be imaged quickly.

At the end of this already very exciting year, the APERTIF team proudly announced the first fringes between the DIGESTIF Focal Plane Array and multiple MFFE equipped dishes of the WSRT. The IF outputs of 3 MFFE dishes (RT1, RT3 & RT4) were connected to the DIGESTIF back-end at RT5. After a short but intense period of debugging, the first fringes were measured. The figure shows the measured fringes between one FPA element and multiple MFFE dishes at 144m and 288m and 576m baselines over a period of 200 seconds. As expected, the fringe frequency doubles when the baseline is doubled. All dishes were tracking 3C286. The data is taken at 1420 MHz with a bandwidth of 20 MHz and an integration time of 0.025 s per point. The possibility to measure correlations between DIGESTIF and other dishes will enable a more detailed evaluation of FPA performance and to test the performance of FPA's in interferometric imaging.



These great results have only been possible through the collaborative efforts of the APERTIF team, in particular Wim van Capellen, Tom Oosterloo, Laurens Bakker and Marianna Ivashina, while the efforts of Albert-Jan Boonstra, Hans van der Marel and Harm-Jan Stiepel should be also mentioned. A special word of thanks also to the great support of Gyula Józsa and the Observers Yuan Tang, Jurjen Sluman and Geert Kuper who used all their creativity to squeeze these observations in the WSRT schedule.

3. Research and Development

The Research & Development division went through a major change in 2008 as NOVA assumed full responsibility for the Optical/IR program. A new NOVA Optical/IR group was formed, combining expertise in optical and mechanical design, production and integration and systems engineering. The group reports separately elsewhere in this annual report.

The radio program continued to be dominated by LOFAR, SKADS and APERTIF. LOFAR and APERTIF are breakthrough science instruments in their own right. They also demonstrate technologies for the SKA, and thus form a complement to the SKA Design Study, SKADS. LOFAR in particular paves the way in a broad range of subsystems, including the low-frequency sparse aperture arrays, high performance computing and calibration, and operational concepts. APERTIF is a SKA PathFinder in demonstrating the capabilities of Phased Array Feeds on the existing WSRT dishes. Since SKADS will finish in 2009, preparations for a follow-up project were started. The Aperture Array Verification Program (AAVP) will make the next step in demonstrating the capabilities and imaging qualities of aperture array technologies at mid-SKA frequencies.

LOFAR R&D

Final subsystem CDRs were completed in 2008, and hardware activities mostly focused on the roll-out of LOFAR stations. Procurement processes for electronics systems were completed. The valorization approach used in the SNN funded program 'LOFAR Noordelijke componenten' proved successful as some 75% of the contracts resulting from these open tenders could be awarded to Northern companies. An unfortunate combination of nature protection rules and bad weather conditions caused a significant delay in the roll-out. In order to mitigate the effect of this delay it was decided to handle integration of subsystems, originally planned to take place at the fields, at the central storage facility instead. System check-out and acceptance procedures were established, using the European stations as a reference.

Major R&D activities continued in the areas of software and calibration. Activities focused on the completion of the production software needed to run the telescope, in particular the Monitoring and Control and On-line Application Pipeline. Algorithmic research continued in the MeqTree environment and the production-level Black-Board Selfcal pipeline. Results from Core Station 1 data gradually improved as the software matured. However, a major challenge still lies ahead in the further development of ionospheric modeling and calibration, as longer baselines are still lacking in the system.

APERTIF

The NWO-G funded APERTIF project ('APERture Tile In Focus') aims to substantially increase the field of view of the Westerbork Synthesis Radio Telescope (WSRT) using Focal Plane Array technology. With an enlarged field of view, it becomes feasible to survey the entire sky on short timescales with high sensitivity and at high spatial resolution. This will enable entirely new types of astronomical research.

ASTRON is currently developing the APERTIF receiver system. The traditional horn antenna, located in the focus of each Westerbork dish, will be replaced by a cluster of antennas, the Focal Plane Arrays, thus creating a radio 'camera' in every dish. The FPA system allows for a single telescope to observe in multiple directions at the same time, forming a continuous extended field of view which has not been possible before. Astronomers can now collect much more information in a shorter period of time and from a larger area of the sky. This transformational FPA technology has been pioneered and brought to maturity by ASTRON, enabling a huge leap forwards for astronomy and the development of radio-sensor systems.

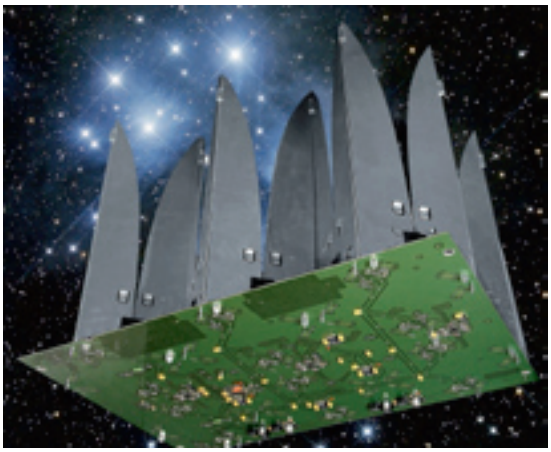
A prototype FPA system called DIGESTIF has been installed in one of the WSRT dishes. Early 2008, for the first time anywhere in the world, meaningful astronomical images were made with this type of receiver at such a high frequency as has described in chapter 2.
In December 2008, three MFFE equipped dishes (RT1, RT3 and RT4) have been connected to the DIGESTIF back-end at RT5. As described in chapter 2 of this annual report, after a short but intensive period of debugging, the first fringes have been measured.

SKA Design Study (SKADS)

The European SKA Design Study is a program of research activities that will lead to a preliminary design for the SKA, using Aperture Array technology for the Mid SKA array. Work packages cover science and system simulations, research on innovative technologies (including an innovation of the Italian BEST telescope) and the construction of two aperture array demonstrators: EMBRACE (lead by ASTRON) and 2-PAD (lead by University of Manchester). EMBRACE will demonstrate a high-volume, low-cost tile using both analogue and digital beamforming. The 2-PAD system will evaluate an all-digital beamforming approach. Together these demonstrators will provide the necessary input on performance and costing.

EMBRACE, (or SKADS/DS5, the fifth design study in SKADS), is concerned with the design and development of a large scale European SKA demonstrator based on the aperture array concept. The acronym literally means 'Electronic Multi-Beam Radio Astronomy ConcEpt'. More important though is the message it tries to convey that AA technology will be brought to a sufficient level of maturity that the worldwide SKA community can safely embrace it. EMBRACE will consist of 144 aperture array tiles at the WSRT and eighty at the Nançay decametric array. This physical scale is such that cost-figures can be established with sufficient confidence and that performance can be demonstrated with sufficient accuracy. In the course of 2008, the teams at ASTRON, Observatoire de Paris, MPIfR (Bonn) and INAF (Bologna) completed the designs for most EMBRACE subsystems. The procurement process was completed just before the end of the year, and roll-out will proceed with a pilot series early 2009.

Dion Kant (ASTRON R&D, left) and Jan Pieter de Reijer (Radio Observatory, right) overseeing the preparation of the 200 m2 EMBRACE site at the WSRT between RT5 and RT6.



Not an artist impression, but the celebration picture of the first EMBRACE receiver board. These so-called Hex-boards, placed together in groups of six, each contain 24 Vivaldi elements (dual-pol), low noise amplifiers and analogue beamformer chips (developed in France) and switchable True-time-delay lines. (Photograph: Jürgen Morawietz, ASTRON. background image: Albert van Duin, ASTRON).

In support of Design Study 2, SKA simultations, the MeqTree simultation and visualization environment was further extended and improved. Although MeqTrees originated at ASTRON, it is aimed to be developed in an open, distributed way. For that reason, the project was put on SourceForge, the open source software development repository. Two MeqTree workshops were organized and a strong partnership with the University of Oxford was established on the parallelization of the code to improve performance.

PrepSKA and AAVP

ASTRON participates in the EC FP7 Preparatory Action for the SKA (PrepSKA) at several levels. Three key areas where R&D will contribute are the SKA system design studies, the design of the mid-SKA Aperture Array systems and the software and calibration algorithms needed to get maximum dynamic range for SKA.

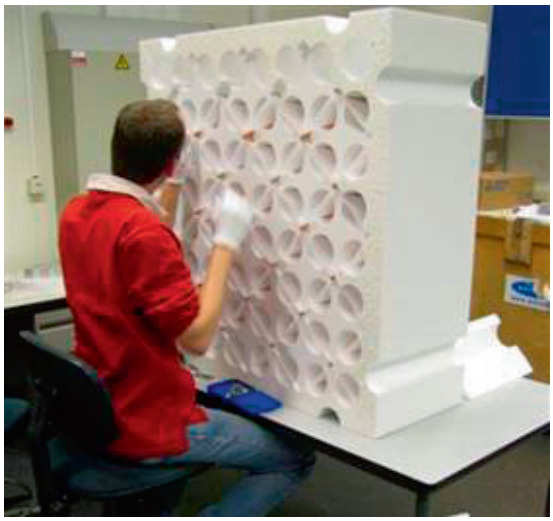
At the end of SKADS the aperture array technology will show remaining issues and 'hotspots', areas were major improvements can be made in cost or performance. In the PrepSKA era, a targeted effort will be executed to address these issues. The goal here is to bridge the gaps between prototype and production system on specific areas. This includes the overall system temperature and the performance of the back-end systems. But also the overall power dissipation (including optimized power sup-

plies and options for 'green energy') will have to be addressed, as well as often-neglected but highly critical items as connector technology.

The final step towards SKA Phase 1 systems is a full-scale verification system. The European SKA Consortium (ESKAC) asked SKADS coordinator Arnold van Ardenne to set up an Aperture Array Verification Program (AAVP). We see the AAVP as a natural next step beyond EMBRACE and 2PAD. The scale of the system remains to be decided, depending on available funding and the overall SKA timescales. Perhaps the most important aspect of AAVP is that it brings aperture arrays on the same track as the dishes for the higher frequencies. This will make it easier to demonstrate the performance gains to the community and will ensure the overall SKA system design (including back-end processing) is optimized for an integrated approach with dishes and aperture arrays ensuring maximum scientific return at a broad range of frequencies.

Technical Research Projects

Each of the currently seven competence groups in the R&D division carries out a technical research program to ensure that emerging technologies can be applied to future instruments in an adequate and timely fashion. Most of this research is conducted through partnerships with industry and technical universities. Three examples are highlighted below.



The PACMAN project aims at developing low-cost Phased Arrays for Mass market applications. ASTRON collaborates with Thales, Twente University of Technology and Eindhoven University of Technology.

A passive low-cost tile has been constructed and tested in October 2008. An active low-cost tile has been assembled and ready for testing. These tiles, branded FLOWPAD, consist mainly of foam structure with polyester foil with printed differential antenna and LNA. This technology has been made available to the 2PAD project. In 2009, the special low noise balanced LNA will be tested as a final action in the project.

The DARIS project was accepted by ESA in December 2008. The project looks into the feasibility of a distributed array of telescopes in space. As a first step the astronomic scientific benefits will be established and (partial) system requirements will be derived from it. On the technical side antenna concepts, potentially feasible array deployment locations (Moon orbit, earth-Moon L2 Lagrangian point, Sun-earth L4/L5 point, and Lunar far-side) will be studied. Several signal processing architectures (centralized/distributed correlation and beamforming) will be investigated to derive models for the signal processing load and communication bandwidth requirements. ASTRON is leading this collaboration with Radboud University, ASTRIUM and Altran.

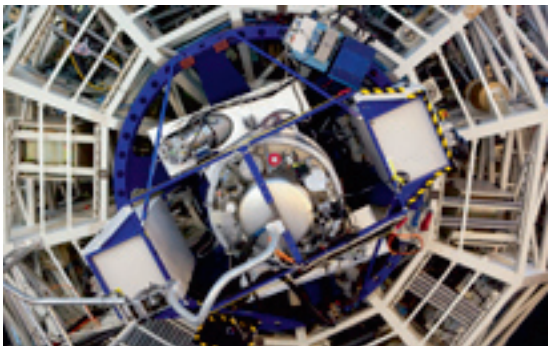
The ASTROStream project is a collaboration with Delft University of Technology on high performance computing architectures for astronomy. Five different many-core processor architectures have been compared as correlator platforms. Results will be presented at the ICS 2009 conference. The insights obtained in this study also contributed to the performance of the LOFAR software correlator. An extended review of correlators on multi-core processors will be published in IEEE Signal Processing Magazine.

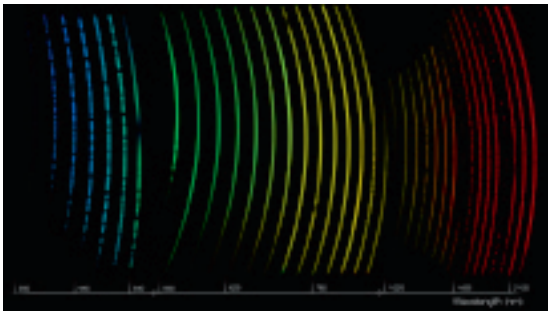
Technology Transfer

The valorization strategy of ASTRON has several layers, with different impact and risks involved. The cornerstone of the strategy is partnerships in projects. This allows companies to prepare for participation in large procurements, or to establish new product-market combinations in the slip-stream of breakthrough innovative developments. The success of this approach has been demonstrated with LOFAR. In 2007/2008 the same model was used in EMBRACE, through the Innovative Actions Program of the Province of Drenthe. Direct spin-offs are handled through the holding company ATH. Although this is a very visible aspect of valorization, it is only a relatively small component of the overall valorization strategy. The Bureau of Technology Transfer is increasingly active in negotiating short knowledge transfer projects, through innovation vouchers or otherwise. In 2009, the options for facility sharing will be further worked out and marketed.

NOVA-ASTRON Optical Infrared Instrumentation Group

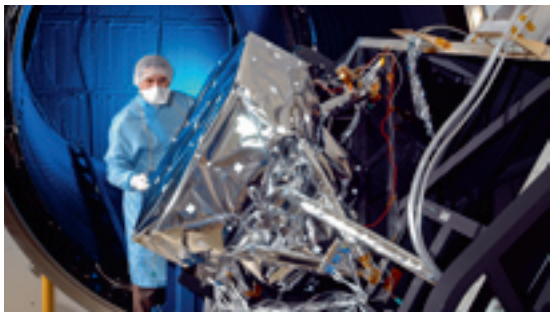
Since January 2008, NOVA has taken over control of the Optical Infrared Instrumentation group. While ASTRON is focusing on radio astronomy and radio instrumentation, NOVA ensures continuation of the optical and infrared instrumentation activities that are vital for the astronomical community in the Netherlands. The NOVA-ASTRON Optical Infrared instrumentation group is still based at the ASTRON premises in Dwingeloo and the people remain employees of NWO.
As always the activities of the NOVA-ASTRON Optical Infrared instrumentation group are dominated by the (many) running projects. In 2008, there was a break from the past as the main activities during the last few years. The X-shooter and MIRI projects were virtually finished, while new instrumentation projects for the E-ELT were started.

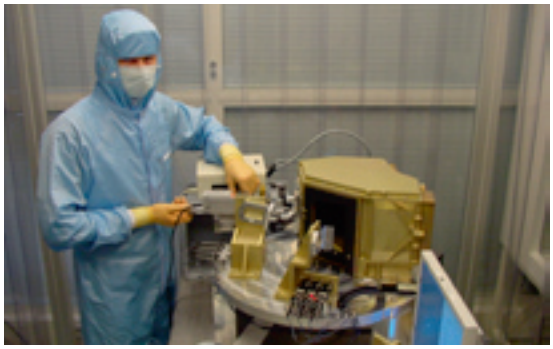




The X-shooter Near InfraRed Spectrometer has successfully passed the Preliminary Acceptance Test Europe in March 2008. The hardware has been delivered to ESO Garching for integration with the Backbone, electronics and UltraViolet and VISual spectrographs, accomplishing unprecedented simultaneous wavelength coverage from 300nm to 2500nm. The Dutch NIR spectrograph provides 70% of this wavelength range and is the most complicated part of the X-shooter instrument, because it needs to operate in vacuum at a temperature of about 100 Kelvin (-180° Celcius). Commissioning of the complete X-shooter instrument at the VLT in Chili is executed in the first quarter of 2009. Science observations start in October 2009.

In 2008, the MIRI activities were finished according to the planning and in budget. We are especially proud of this accomplishment, since this is the first space project that is executed at NOVA-ASTRON. Based on successful functional tests in Dwingeloo and vibration tests at ESA-ESTEC, the flight models of both MIRI grating wheels and both optical benches have been accepted by the JWST MIRI consortium. The hardware has been delivered to RAL in the UK for integration with the other MIRI sub-assemblies. Although not part of the Dutch work package, extreme precision (temperature controlled) CNC milling of the MIRI deck assembly was also done at ASTRON. The first mid infrared spectrum has been produced by the integrated instrument. Launch of the James Webb Space Telescope is scheduled for 2014.





The hardware team is also busy producing about 300 mirrors for the ALMA band-9 receivers. ESO plans to equip all ~70 ALMA antennas with the band-9 receiver that is developed by SRON. Although the sub-millimeter wavelengths are even longer than the infrared wavelengths we are used to, technical challenges remain in achieving optical tolerances directly from the CNC milling and in series production. The plan is to deliver the last batch of mirrors in 2009.

In 2008, design activities were focused on Sphere-ZIMPOL. Sphere is the exo-planet finder for the VLT and ZIMPOL is the polarisation based planet finder, a Dutch-Swiss contribution to the Sphere instrument. Sphere-ZIMPOL successfully passed the final design review at the end of 2008 and is starting the hardware manufacturing phase in 2009. Commissioning of Sphere-ZIMPOL at the VLT in Chili is planned for 2011.
A lot of progress has been made on the feasibility of Matisse, the first 4-telescope combiner for the VLT Interferometer, planned for first light in 2013. The current mid infrared VLT Interferometer MIDI combines 2-telescopes and was also designed, build and tested at ASTRON. The extension to 4 telescopes provides 6 baselines and phase closure, enabling imaging / image reconstruction. Also the wavelength coverage is extended with respect to MIDI, comprising L, M and N band (3 to 15 micrometer). The technical challenge is to operate hundreds of optical components at cryogenic temperatures. The preliminary design review is planned for 1 October 2009.

NOVA-ASTRON also performed the optical and system design for SPEX, the spectro-polarimeter that is intended to fly on a mars orbiting satellite in order to characterise dust storms. In 2009, a breadboard model of the instrument will be built with partners TNO, Dutch Space, SRON and the University of Utrecht.

ESO started 10 phase A studies for instrumentation for the European Extremely Large Telescope, the E-ELT. All studies finish end of 2009 or early 2010 in order to provide input to the E-ELT design before finalising the design. The plan is to select two instrument concepts for first light and some others for first generation instrumentation. NOVA-ASTRON participates in four ELT instrumentation phase A studies:

- EPICS, an exo-planet finder for the ELT, comparable to Sphere-ZIMPOL on the VLT. The Dutch work package is again the polarisation module.
- METIS, a mid infrared imager and spectrograph, comparable to part VISIR, part CRIRES and part NACO on the VLT. This instrument has a large Dutch contribution, including spectrographs, reimager, common structure and cryogenics, Adaptive Optics and more. The Consortium PI, PM and systems engineer are all based in the Netherlands.
- MICADO, a high resolution near infrared camera (VLT: HAWK-I / SINFONI). The Dutch work package consists of the data reduction software and the cryogenics - opto-mechanics.
- OPTIMOS, a fibre fed visual to near infrared multi object spectrograph, comparable to FLAMES-Giraffe-UVES on the VLT. This instrument has a Dutch Co-PI and Consortium PM. The Dutch work package is the Near Infrared Spectrograph.

At the end of 2008, 18.8 Million Euro of ESFRI money was granted to NOVA in order to develop technology needed for ELT instrumentation and to have an important Dutch contribution to an E-ELT instrument.

At SPIE Astronomical Telescopes and Instrumentation several oral and poster presentations by the NOVA-ASTRON group were received very well. For the first time NOVA-ASTRON also participated in the exhibition, where our stand drew quite a crowd, especially for the extreme light weighting, the aluminum mirror polishing and the qualification model for the JWST-MIRI optical bench.

4. LOFAR

At the end of 2007, and after many years of design and planning, the LOFAR project started the mass construction phase. By 2010, this will result in (at least) 36 astronomical stations, in addition to a number for the geophysical and infrasound applications and eight or more international stations.

Due to the investments involved, the project has to follow the European procurement guidelines, which regulate the process of selecting suppliers. The first call for tenders was issued on December 3rd 2007. This covered three categories of components: the printed circuit boards (PCB), cabinets and station hardware. Subsequent calls were also issued for network equipment (in January 2008) and Central Processing hardware (in May 2008). The first round of contracts was signed early in May and hardware started arriving over the summer, at the storage facility in Emmen where the parts are checked and gathered before being transported to the stations as soon as construction gets underway. ASTRON staff supervised the production process and performed tests of initial samples.

The LBA-LNA is the Low Noise Amplifier of the LOFAR Low Band Antenna. The picture shows a circuit board with two such amplifiers, one for each of the two polarizations of the incoming radio signals. The LNA has been optimized to work in the low frequency band from 30MHz to 80MHz. The four antenna wires will be soldered to the printed circuit board, forming two highly sensitive dipole antennas. Then the electronics will be sealed in, protected against wind, rain and sunshine (photograph Henri Meulman).

Production of the LOFAR Backplanes which will connect the analogue processing on one side (in particular the receivers) and the digital processing boards on the other side (photograph: Menno Norden, Gijs Schoonderbeek).

LOFAR cabinets in storage at Excel Assemblies in Emmen. The digital and analogue printed circuit boards and other equipment are placed inside these cabinets before they are shipped to the fields. The small inset image in the lower left shows the PVC pipes that are used in the Low Band Antenna.

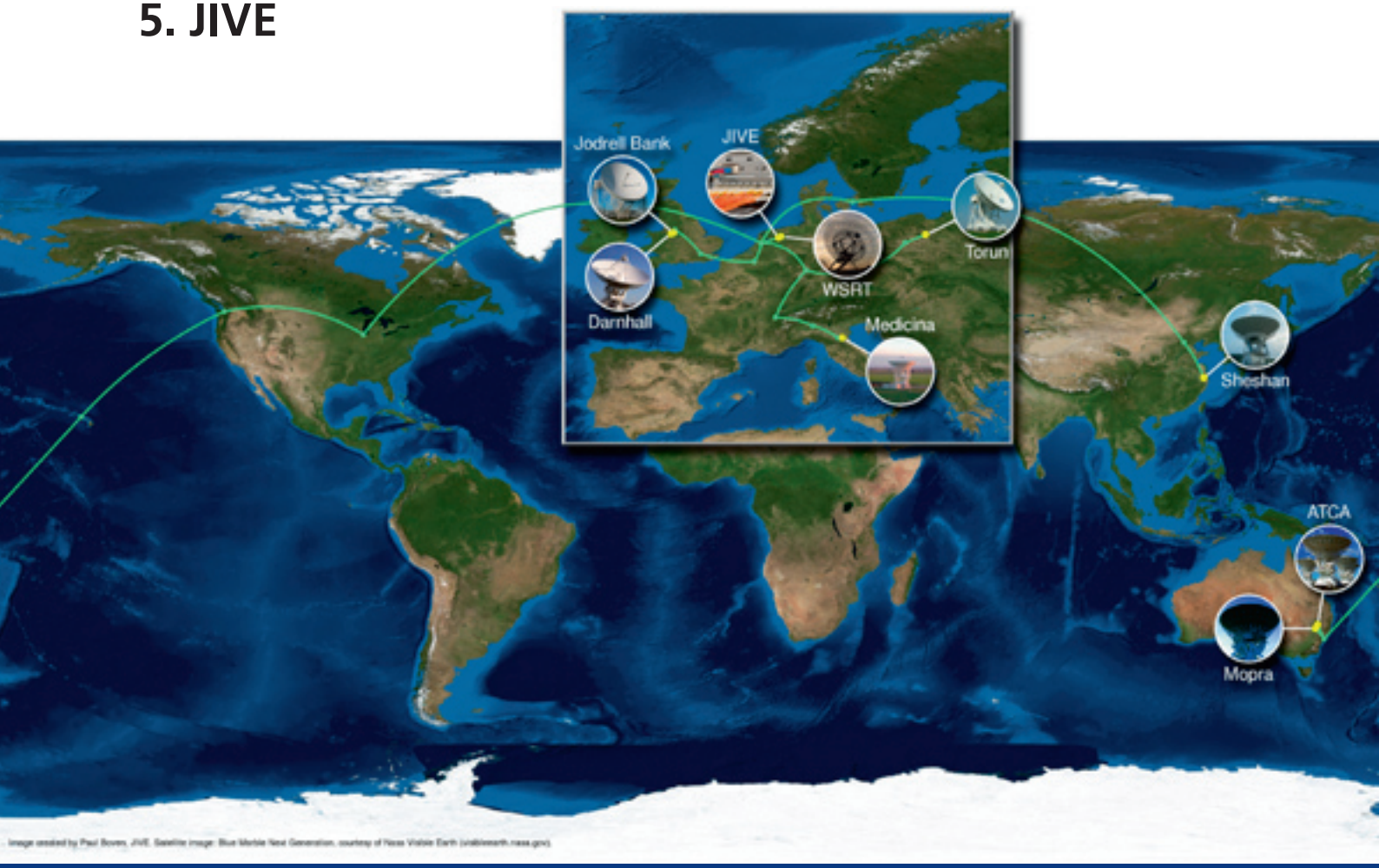
Half the LOFAR stations that will be built in the Netherlands will end up in a 400 hectare central core area between the villages of Exloo and Buinen in Drenthe. These stations will provide the necessary short baselines that are needed for some of LOFAR's key science projects, such as detection of the Epoch of Reionization and the Transient KSP's Radio Sky Monitor. Spectacular aerial photographs showed the progress that was made in developing this area throughout the summer and early autumn. At the heart of the core, six LOFAR stations will be placed on a central mound, some 350 meters in diameter. All other core stations will also be raised by between 60 and 90 cm relative to their original level. This is required because the central area will also be developed as a nature reserve – in addition to housing the LOFAR stations. The course of the river and other waterways that flow through the core will be changed to stimulate development of a wetland area with a wide variety of grasses and herbs which will attract many species of birds, butterflies and insects. Establishing a nature reserve will mean that future developments in the area other than the construction of LOFAR will be limited, ensuring lower levels of interference from nearby traffic and domestic appliances.

Construction of the central mound that will house 6 LOFAR stations at the heart of the core. This aerial photograph was taken in September and shows the company responsible for the groundwork in action. The prototype High Band Antenna tiles and some individual HBA antennas on the old prototype station CS-10 can be seen in the lower left of this photograph.

Initial delays in the production of some of the components were followed by bad weather (rain and frost) throughout most of the autumn and winter. Unfortunately this prevented the start of construction of the first LOFAR stations. The requirements on flatness of the antenna fields are quite strict (level to within +/- 6 cm for the Low Band Antenna field and +/- 3 cm for the High Band Antennas). Under favourable weather conditions, this is well within the capabilities of the contractor, but not in the relatively soft ground and under the extremely wet conditions that were encountered in the second half of the year. As it became clear that the start of the station roll-out would be pushed into 2009, indoor integration and assembly of the cabinets was started to speed up the construction process once the weather improved. Planning for the first observations also got underway. A Million Source Shallow Survey will produce the sources that make up the global sky model – essential in the calibration of the telescope. Software development also continued and will hopefully deliver initial pipelines for the processing of imaging, pulsar and cosmic ray data once observations start in the course of 2009.

Meanwhile, the internationalisation of LOFAR continued apace. Contracts were signed for stations near Jülich in Germany and Nançay in France, while funding was secured to build stations in Potsdam (Germany), Chilbolton (UK) and Onsala (Sweden). In September, over 140 members of the LOFAR community met in Hamburg for a second international conference organised this time by the Hamburg Observatory and the German Long-Wavelength Consortium (GLOW). Towards the end of the year, negotiations started for the formation of an international organisation in which the interests of all participating countries will be represented.

5. JIVE



The most important responsibility of the Joint Institute for VLBI in Europe (JIVE) is to make sure that high quality data from the European and Global VLBI Network is delivered in a timely fashion.

Despite the fact that the operational team was undergoing several changes in 2008, the group managed to keep up with the influx.

Many tributes to the scientific quality of the European VLBI Network (EVN) and the correlator at JIVE featured in the EVN Symposium in Bologna in September of 2008; indeed a wide range of very exciting results obtained with modern VLBI were presented.

Also new results from real-time e-VLBI experiments were obtained in 2008. During this year important steps were taken that make e-VLBI now competitive in sensitivity with recorded VLBI. Innovations were made to allow mixed bandwidth correlations, as well as various other solutions to fill the connectivity bandwidth to its full capacity. Moreover, the largest antenna of the EVN, the 100m Effelsberg dish, became available for VLBI. The scientific capabilities of the complete array were demonstrated during the dedication ceremony when the planned test observations were superseded by a campaign of the famous source SS433, which underwent a flare that triggered e-VLBI observations (Figure 1).

JIVE made quite a name for itself demonstrating the new e-VLBI technique at various conferences, often during live demonstrations. For the network community especially the long-haul intercontinental observations are impressive. In 2008 connectivity milestones to South Africa and South-America were reached, adding to the earlier experiments that included telescopes in Asia and Australia. These demos serve not only an outreach objective; they have also proven to be very efficient ways to focus the partners in EXPReS to reach the project objectives.

These global demos also show that e-VLBI is a viable option for the VLBI network of the future. The role of e-VLBI in the future has become more and more clear during the course of EXPReS. Initially its scientific aims were formulated as real-time astronomy, but it has become evident that e-VLBI will also operate more robustly than recorded VLBI, because the feedback loop with the stations can be closed instantaneously. Moreover, the network world provides off-the-shelve solutions for increasing bandwidth on the existing fibres (see for example Figure 2).

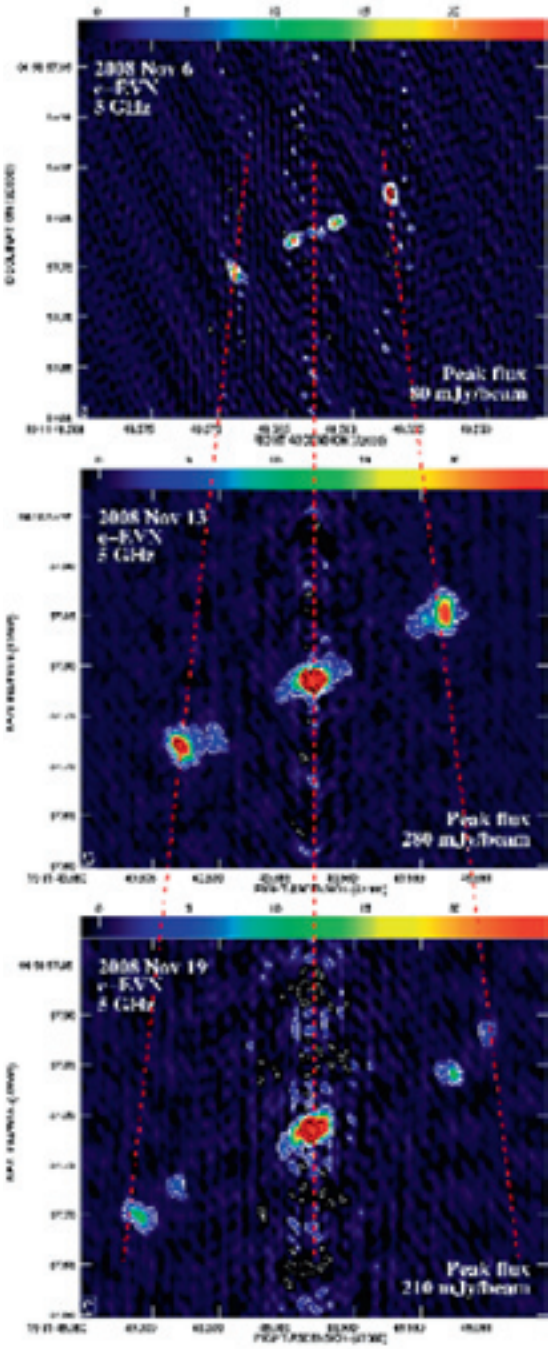


Figure 1: e-EVN images of a long-lived SS433 flare (Tudose et al.).

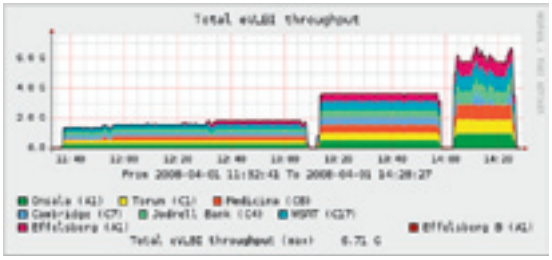


Figure 2: Data throughput reaching already 1 Gbps data-rates per telescope during the first e-VLBI observations with Effelsberg

During 2008 the scientific capabilities of the EVN were also improved by the addition of the new Yebes 40m telescope. First fringes were found in one of the so-called ftp tests and subsequently the powerful new telescope was deployed in an increasing number of user experiments. The JIVE correlator also received data for the first time from the Russian telescopes in the QUASAR network. Improvements were furthermore made to increase the number of MERLIN telescopes that can participate in EVN experiments, increasing the short baseline coverage of the array.

Looking at the future of the EVN and JIVE, it is clear that it will be feasible to increase the bandwidth of observations, first to a 4 Gbps standard, later to 10 or 64 Gbps. To continue its focal role in the EVN, JIVE will need a new correlator to accommodate the larger bandwidth, but also a larger number of antennas. Combining this with a demand for more flexibility for high spectral resolution (and pulsar) science, it is estimated that such a correlator should be a hundred times more powerful than the current Mk4 machine. In 2008 JIVE formulated its plans to construct a FPGA based data processor and submitted funding proposals to accommodate these plans. In the FP7 RadioNet program, which was prepared in JIVE will manage the new Uniboard program on FPGA components, in addition to the vital EVN Trans National Access and ALBUS programs.

Meanwhile important progress was also obtained with the software correlator, which is being constructed in the context of two projects, FABRIC (part of EXPReS) and SCARIe (funded by NWO). This software correlator is routinely used to do fringe checks on the incoming signals of the so-called ftp tests. In 2008 the interfaces were added to format the data to the commonly used astronomy interfaces and in this way first images were obtained. Progress was also made to deploy the software in a distributed fashion and this featured in several tests and demos of dynamic light-path allocation.

The activities on the next generation correlator should also have a lot of synergy with the application of the VLBI technique for space missions. Based on the results with the Huygens landing on Titan, the interest of this highly accurate technique to measure satellite trajectories is prominently on the agenda for future space missions, for example ESA's plans to visit the Jupiter system. As an interesting by-product of this planetary interest, JIVE scientists used new techniques on single dish antennas to detect water maser in the Saturn system (Figure 3). Remarkably, some of the same astronomers also reported VLBI emission from the most distant quasar (Figure 4), demonstrating that the staff has a wide interest in all aspects of radio-astronomy.

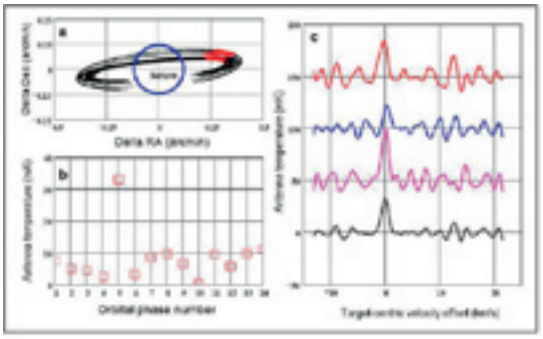


Figure 3: The 22 GHz water maser spectra reduced for the orbital motion of Atlas. Orbital phase 5, which has the highest SNR detection (6.5σ), corresponds to the orbital segment shown in red in the upper left panel. The high SNR of this detection and its persistence over one year of observation (as illustrated on the right panel) is indicative of a possible association of the maser emission with a spot lagging the position of Atlas by several thousand km along its orbit rather than Atlas itself. The emission might originate in the edge regions of rings A and F, disturbed by the Atlas's motion (Pogrebenko et al.).

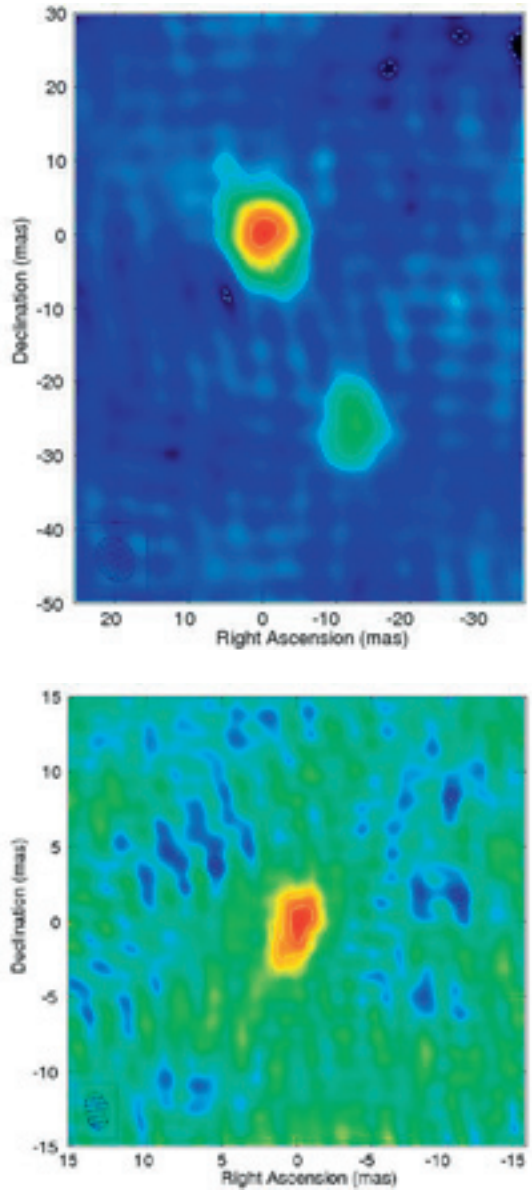


Figure 4 EVN images of the highest redshift radio quasar J1427+3312 at 18cm (top) and 6cm (bottom). The double morphology, steep spectrum and resolved components resemble the structure of CSO sources at much lower redshifts (Frey et al.).

6. Management & communications

PR & Outreach

In 2008, ASTRON was again clearly visible in the media on a number of occasions.

Open Day ASTRON & JIVE 2008

On Sunday 19 October, ASTRON and JIVE organised their annual Open Day. The activities were divided over a big tent, the building of ASTRON and the Dwingeloo Telescope behind the building. In the tent the comet show and the pretlab, where children could make their own electronic package, were a huge success. In the building the public visited the mechanical department of ASTRON, where blowing up chocolate marshmellows was a popular activity, especially for kids. Other activities included presentations about the universe, LOFAR and everything about ASTRON. Visitors could also take a look at the EVN correlator at JIVE.
The Dwingeloo Telescope was also a big object of interest. Over 500 people saw the inside of the control room and heard the enthousiastic volunteers of CAMRAS, the foundation that supports the telescope, talk about its history and their work on the telescope. Around 2,000 people visited ASTRON and JIVE on this Open Day.

'Hanny's Voorwerp' visited ASTRON

On 27 November, Hanny van Arkel visited ASTRON to speak about her discovery, 'Hanny's voorwerp', during a colloquium. In 2007, this Dutch school teacher discovered what is surely one of the most bizarre objects discovered via the GalaxyZoo.org website. This object, now known as 'Hanny's voorwerp' appears as an irregular cloud located about 60,000 light years from the galaxy IC 2497.

Since Hanny made her discovery she has become a bit of an international celebrity. Articles have appeared in the front pages of the international press, the national newspapers and tv here in the Netherlands and in the news sections of top journals like Nature, New Scientist etc. Hanny also appeared on the 'Sky at Night' with Patrick Moore, and has been touring the Netherlands giving talks to schools and societies - in September 2008, she also appeared on 'De Wereld Draait Door'.

On the 27th of October, Hanny van Arkel explained about the Galaxy Zoo project and her famous discovery. E-VLBI and WSRT results that shed new light on this mystery object were also briefly presented by ASTRON staff.

European science journalists visit ASTRON and JIVE

On 1 October 2008, 29 European science journalists visited ASTRON and JIVE. The Dutch Association of Science Journalists (VWN) organised this international excursion to the Netherlands in the autumn, focusing on Dutch activities in the fields of astronomy and space science. The excursion coincided with the 400th anniversary of the telescope.

The journalists received a varied programme at ASTRON and JIVE. Huib Jan van Langevelde, director of JIVE, presented an overview of JIVE, VLBI and e-VLBI. This was followed by an explanation of space applications of VLBI and a tour of the correlator. The visit to JIVE was followed by a trip to the Westerbork Synthesis Radio Telescope and concluded with a tour on the LOFAR field in Exloo.

ASTRON presents new logo

In 2008, ASTRON introduced its new house style for the institute. This included a new ASTRON logo as well as a change in institute name. 'Netherlands Foundation for Research in Astronomy' has been replaced by 'Netherlands Institute for Radio Astronomy'. This is also expressed in the new logo.

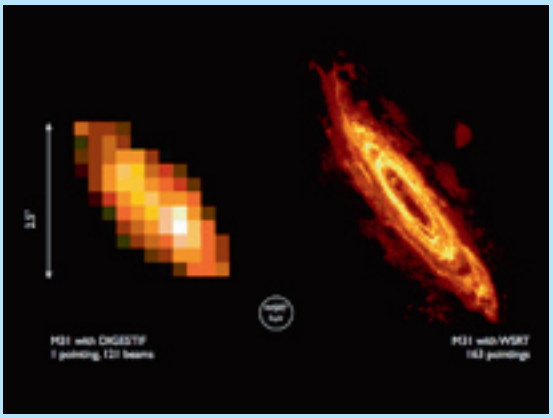
ASTRON
Netherlands Institute for Radio Astronomy

Press releases

Below an overview of the press releases ASTRON sent out in 2008. The complete press releases can be found on the ASTRON webpages.

27 March 2008

ASTRON performs first successful astronomical observations with a Focal Plane Array



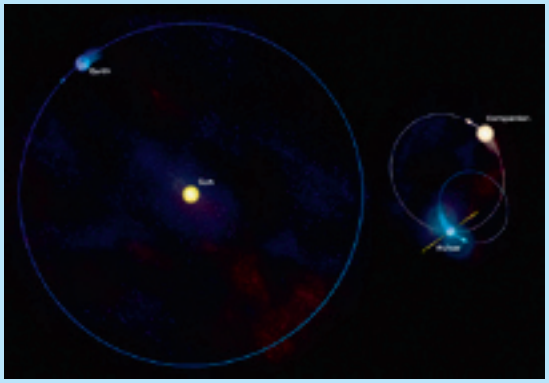
The picture shows one of the first images made with the prototype of the new APERTIF system.

22 April 2008

World's largest radio astronomy project gets serious

22 May 2008

Speedy pulsar discovered - culprit unknown



Pulsar orbit compared to the orbit of earth. Compared to earths orbit (left) the much heavier pulsar (right) moves in a very small and elliptical orbit. (NB: the size of the sun and its companion is exaggerated 10 times, the earth 1000 times and the pulsar 100,000 times). Credit: Bill Saxton, NRAO/AUI/NSF

23 May 2008

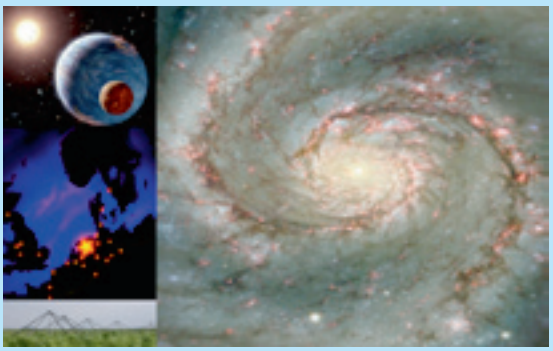
Networks create 11,000km real-time virtual telescope

26 May 2008

ASTRON receives signals for Dutch European navigation system

09 June 2008

SETI researchers gather at ASTRON



A typical galaxy like the milky way contains as many stars as there are grains of sand on all the worlds beaches. Most of these stars have planetary systems and many will have the right conditions for life to flourish. LOFAR can potentially search for artificial radio signals from intelligent civilisations in nearby stellar systems.

11 July 2008

ASTRON presents new logo

19 August 2008

Prestigious European research grant awarded to ASTRON researcher

10 September 2008

Westerbork detects radio waves of “naked-eye” gamma-ray burst

30 September 2008

Spectacular aerial photo’s show construction of LOFAR telescope

09 October 2008

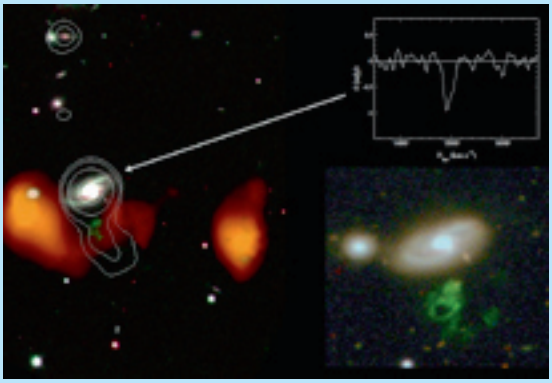
Sunday 19 October: Open Day at ASTRON and JIVE in Dwingeloo

21 October 2008

Open Day 2008 ASTRON and JIVE huge success!

21 November 2008

ASTRON intrigued by Hanny's Voorwerp



WSRT observations reveal a radio jet (white contours) emanating from the centre of the nearby galaxy IC 2497, headed straight in the direction of Hanny's Voorwerp (green). The observations also reveal a huge reservoir of hydrogen gas (coloured orange) that probably arose from a previous encounter between IC2497 and another galaxy. The presence of strong neutral hydrogen absorption (top right plot) argues that the central regions of IC2497 are highly obscured. Credit: Main image left and top right hand corner, ASTRON. Hanny's voorwerp (bottom right) Dan Herbert, Isaac Newton Telescope.

09 December 2008

SKA Identified as an essential facility for the future of European astronomy

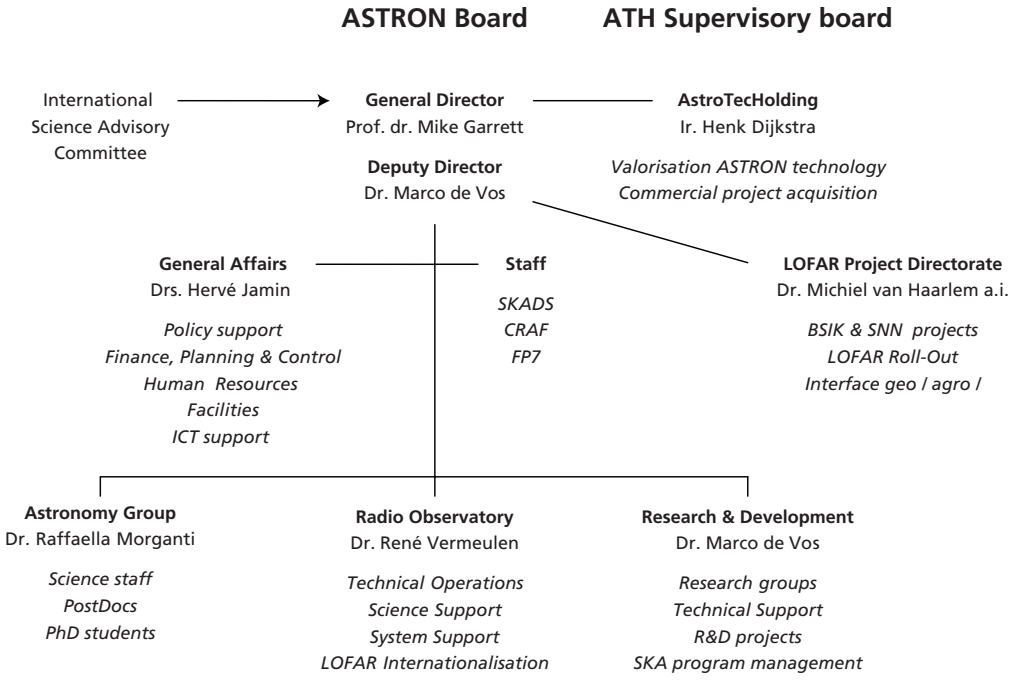
Major visits to ASTRON in 2008

9/1	Concluding meeting IAP-Embrace with partners (Excel, Major, Revamo, B&J Polyurethaantechniek)
28/1	Dutch ministry of Education, Culture and Science, and Senter Novem
31/1	Deans VMBO South West Drenthe
1/2	PvdA Statenfracties Groningen, Friesland, Drenthe
26/2	Masterclass Astronomy Groningen
25/3	Fysical-Mathematical faculty societies (University of Groningen and University of Leiden)
2/4	Pre-university College Leiden (Universiteit of Leiden)
8/4	Province of Drenthe and Gemeente Assen
27/5	LOFAR Internationalisation meeting (Various participants from abroad)
28/5	Norwegian Embassy and SNN
12/6	LOFAR SETI Workshop
9/8	Dutch Centre of Directors and Board members
18/9	Scientific council for government policy
18/9	Fonds Economische Structuurversterking
1/10	European science journalists
6-10/10	NOVA fall school 2008
30/10	Dutch ministry of Education, Culture and Science, and Senter Novem and NOW
31/10	Royal Dutch Meteorological Institute (KNMI)
19/10	Open Day ASTRON & JIVE
26/11	Leiden school of instrumentmaking

Personnel & Organisation

Organisation

The organisational changes initiated in 2007 still had some impact in 2008. A number of redundant employees was mediated to another job or continued their career outside ASTRON. It is expected that in 2009 a final solution is found for these employees.
In 2008, ASTRON was organised according to the following organisation chart:



Recruitment

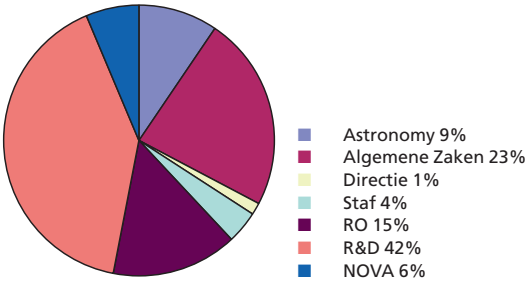
2008 was characterised by many recruitment activities: thirteen in total. Most of these activities were aimed at jobs in the Radio Observatory and the Astronomy Group. Many foreign employees were recruited, with many additional efforts by the organisation to ensure rapid integration into ASTRON and the Dutch society.

Internships and work experience

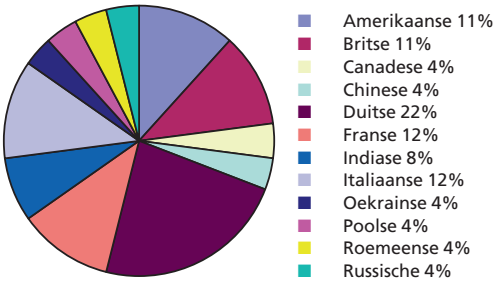
ASTRON has an active placement policy for all job levels. In 2008, a total of fifteen students had an internship or graduate position at ASTRON. This year, ASTRON also started some work experience places. In case of a positive evaluation, ASTRON will offer more opportunities to work with people with a weaker position in the labour market.

Staff

At the end of 2008, the number of employees at ASTRON counted 158 (including the NOVA group).



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



At ASTRON there are 13 different nationalities besides the Dutch nationality. Over 16% of the ASTRON employees are from abroad.

Absenteeism

The absenteeism rate in 2008 was 1.9%. Even in relation to comparable organizations this is relatively low.

Financial report 2008

Financial report 2008 compared with 2007	2008 Budget	2008 Actual	2008 Difference	2007 Actual
REVENUES				
Government Grants-Ministry of				
Education, Culture & Science	10.030.935	9.782.941	247.994	6.492.888
Subsidies / Contributions	4.038.947	10.625.558	-6.586.611	8.698.787
Release to provision	0	400.467	-400.467	1.964.090
Other Income	548.600	435.986	112.614	1.424.599
Cash management	0	393.166	-393.166	197.046
Subtotal	14.618.482	21.638.118	-7.019.636	18.777.410
Results Subsidiaries				
Subsidiary ATH	0	17.393	-17.393	0
Subtotal	0	17.393	-17.393	0
Special Income				
Special Income	0	321.077	-321.077	70.081
Subtotal	0	321.077	-321.077	70.081
Total Income	**14.618.482**	**21.976.588**	**-7.358.106**	**18.847.492**
EXPENDITURES				
Grants / Expenditures				
Operations	25.470.657	31.441.105	5.970.448	30.124.433
Allocation to Projects	-9.778.691	-9.320.731	457.960	-10.610.577
Subtotal	15.691.966	22.120.374	6.428.408	19.513.856
Results Subsidiaries				
Subsidiary ATH	0	0	0	289.428
Subtotal	0	0	0	289.428
Other Expenditures				
Other Expenditures	0	290.708	290.708	225.998
Subtotal	0	290.708	290.708	225.998
Total Expenditures	**15.691.966**	**22.411.082**	**6.719.116**	**20.029.282**
BALANCE	-1.073.484	-434.494	-638.990	-1.181.790

ASTRON/JIVE colloquia

Thu 17 Jan 2008	Speaker: **Filippo Fraternali (Bologna)** Title: **Accretion of gas onto nearby spiral galaxies**
Thu 31 Jan 2008	Speaker: **Megan Argo (Jodrell Bank Observatory)** Title: **Nearby Starburst Galaxies**
Wed 06 Feb 2008	Speaker: **Hayley Bignall (JIVE)** Title: **What makes quasars twinkle? Results from the MASIV Survey**
Thu 14 Feb 2008	Speaker: **Peter Jonker (SRON)** Title: **Low-mass X-ray binaries; what can we learn from them?**
Wed 20 Feb 2008	Speaker: **Richard Dodson (OAN)** Title: **MIF1-CT-2005-021873: Two years of a Marie Curie in the OAN**
Fri 29 Feb 2008	Speaker: **Joe Shields (Ohio University)** Title: **Recent Results on Star Clusters in Galaxy Nuclei**
Thu 06 Mar 2008	Speaker: **Renzo Sancisi (INAF & Kapteyn)** Title: **Cold Gas Accretion in Galaxies**
Thu 13 Mar 2008	Speaker: **Guido De Marchi (ESTEC)** Title: **Dissolving globular clusters**
Thu 20 Mar 2008	Speaker: **Yuri Kovalev (MPIfR Bonn)** Title: **Opacity in compact extragalactic radio sources and recent results on the inner radio jet in M87**
Thu 27 Mar 2008	Speaker: **Jean-Mathias Griessmeier (ASTRON)** Title: **The search for low frequency radio emission from extrasolar planets**
Thu 03 Apr 2008	Speaker: **Inga Kamp (Groningen)** Title: **Probing protoplanetary disk evolution** Sub-title: **How to make a Solar System**
Thu 10 Apr 2008	Speaker: **Dominic Schnitzeler (Leiden)** Title: **The large-scale magnetic field of the second Galactic quadrant**
Thu 17 Apr 2008	Speaker: **Ralf-Juergen Dettmar (Ruhr University Bochum)** Title: **Gaseous Halos of Spiral Galaxies and the Interstellar Disk-Halo Connection**
Tue 22 Apr 2008	Speaker: **Joerg Hoerandel (Radboud University Nijmegen)** Title: **Charged particle astronomy**
Tue 06 May 2008	Speaker: **Raj Mittra (Pennsylvania State University)** Title: **"Solving Antenna Problems with a Large number of Degrees of Freedom (DoFs)** Sub-title: **by Combining Domain Decomposition with Parallelization."**
Tue 06 May 2008	Speaker: **Craig Walker (NRAO)** Title: **The M87 43 GHz VLBA movie project**

Tue 13 May 2008	Speaker: **Jos Engelen (CERN)** Title: **The Large Hadron Collider project - status and prospectives**
Thu 15 May 2008	Speaker: **John McKean (MPIfR Bonn)** Title: **Probing galaxy formation with cosmic telescopes**
Fri 23 May 2008	Speaker: **Ed Elson** Title: **Astrolunch**
Thu 29 May 2008	Speaker: **Enno Middelberg (Ruhr University Bochum)** Title: **Recent progress of the ATLAS survey**
Thu 05 Jun 2008	Speaker: **Imke de Pater (University of California Berkeley)** Title: **Dusty Rings in our Solar System: Focussing on Observations of Uranus's Rings with the 10-m W.M. Keck**
Thu 12 Jun 2008	Speaker: **Dan Werthimer (University of California, Berkeley)** Title: **Searching for ET and Transients with Eight Million SETI@home Volunteers**
Mon 16 Jun 2008	Speaker: **Dmitrijs Docenko (Max Planck Institut fuer Astrophysik, Garching)** Title: **Hyperfine radio line of 14-N VII for studies of the warm-hot intergalactic medium**
Thu 19 Jun 2008	Speaker: **Yashwant Gupta (National Centre for Radio Astrophysics NCRA, Pune)** Title: **The Giant Metre-wave Radio Telescope : Recent Science Results and Future Upgrade Plans**
Thu 26 Jun 2008	Speaker: **Rainer Beck (Max-Planck-Institut fuer Radioastronomie, Bonn)** Title: **Magnetic Fields in the Milky Way and Spiral Galaxies**
Fri 27 Jun 2008	Speaker: **Raj Thilak Rajan** Title: **A Tracking Algorithm to detect Cosmic Muons for the CMS RPC based Technical Trigger**
Tue 01 Jul 2008	Speaker: **Simon Johnston (ATNF)** Title: **Science with the Australian Square Kilometre Array Pathfinder**
Thu 03 Jul 2008	Speaker: **Mark Walker (Manly Astrophysics Workshop)** Title: **Interstellar scintillation - progress and possibilities**
Mon 04 Aug 2008	Speaker: **Chanda Jog (Indian Institute of Science, Bangalore, India)** Title: **The Flattened Dark Matter Halo of M31 as deduced from Observed HI scale-heights**
Thu 07 Aug 2008	Speaker: **Robert Braun (Australia Telescope National Facility)** Title: **Opaque atomic gas and star formation rate density in the local group**
Thu 04 Sep 2008	Speaker: **Andrzej Marecki (Torun Centre for Astronomy)** Title: **Post-active galaxies - more ubiquitous than we thought before**
Thu 11 Sep 2008	Speaker: **Joeri van Leeuwen (ASTRON)** Title: **Radio pulsars and instrument innovation for supernovae/gravitational-wave research**

Thu 25 Sep 2008	Speaker: **Joachim Vogt (Jacobs University Bremen)** Title: **Effects of internal geomagnetic variation on the Earth's space environment and the middle atmosphere**
Thu 02 Oct 2008	Speaker: **Henny Lamers (University of Utrecht)** Title: **Stellar Winds and Mass Loss: mechanisms, stellar evolution, interstellar medium**
Thu 09 Oct 2008	Speaker: **Frank Helmich (SRON)** Title: **Observing in the far-infrared: Herschel-HIFI and beyond**
Thu 16 Oct 2008	Speaker: **Juergen Blum (Technical University Braunschweig)** Title: **Planet formation**
Thu 23 Oct 2008	Speaker: **Robert Wiersma (Sterrewacht Leiden)** Title: **The Trials and Transport of Cosmic Metals**
Mon 27 Oct 2008	Speaker: **Prof. Dmytro M. Vavriv (National Academy of Sciences of Ukraine)** Title: **Low-noise, high dynamic range digital receiver/spectrometer for radio astronomy applications**
Thu 06 Nov 2008	Speaker: **Bo Peng (National Astronomical Observatories, China)** Title: **Radio telescopes rooted in Miyun observatory: past, present and future**
Thu 13 Nov 2008	Speaker: **Alexander O. Kasyanov (Taganrog Institute of Technology)** Title: **Microstip phased arrays and reflective type antenna arrays**
Thu 13 Nov 2008	Speaker: **Gianfranco Gentile (Ghent University)** Title: **Dark matter and modified dynamics: observational clues**
Thu 27 Nov 2008	Speaker: **Hanny van Arkel** Title: **Galaxy Zoo and the discovery of Hanny's Voorwerp**
Thu 04 Dec 2008	Speaker: **Uwe Motschmann (Technical University Braunschweig)** Title: **Between Stars and Planets: Simulation of Particle and Energy Transport by the Cosmic Plasma**
Thu 18 Dec 2008	Speaker: **Rachel Osten (University of Maryland)** Title: **New Insights into the Physics of Stellar Flares**

7. Publications 2008

Astronomy Group and Radio Observatory

Astronomical publications in refereed journals 2008

1. R. Morganti, T. Oosterloo, C. Struve, L. Saripalli: *A circumnuclear disk of atomic hydrogen in Centaurus A,* 2008, Astronomy and Astrophysics, 485, L5-L8
2. P. Serra, S. C. Trager, T. A. Oosterloo, R. Morganti: *Stellar populations, neutral hydrogen, and ionised gas in field early-type galaxies*, 2008, Astronomy and Astrophysics, 483, 57-69
3. J. L. Racusin, ..[53 authors collapsed].., M. A. Garrett, N. Gehrels, S. Golenetskii, A. Gomboc, J. Gorosabel, G. Greco, A. Guarnieri, S. Immler, M. Jelinek, G. Kasprowicz, V. La Parola, A. J. Levan, V. Mangano, E. P. Mazets, E. Molinari, A. Moretti, K. Nawrocki, P. P. Oleynik, J. P. Osborne, C. Pagani, S. B. Pandey, Z. Paragi, M. Perri, A. Piccioni, E. Ramirez-Ruiz, P. W. A. Roming, I. A. Steele, R. G. Strom, V. Testa, G. Tosti, M. V. Ulanov, K. Wiersema, R. A. M. J. Wijers, J. M. Winters, A. F. Zarnecki, F. Zerbi, P. Mészáros, G. Chincarini, D. N. Burrows: *Broadband observations of the naked-eye gamma-ray burst GRB080319B*, 2008, Nature, 455, 183-188
4. A. F. Loenen, M. Spaans, W. A. Baan, R. Meijerink: *Mechanical feedback in the molecular ISM of luminous IR galaxies*, 2008, Astronomy and Astrophysics, 488, L5-L8
5. B. H. C. Emonts, R. Morganti, J. H. van Gorkom, T. A. Oosterloo, E. Brogt, C. N. Tadhunter: *From major merger to radio galaxy: low surface-brightness stellar counterpart to the giant H I ring around B2 0648+27*, 2008, Astronomy and Astrophysics, 488, 519-522
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