

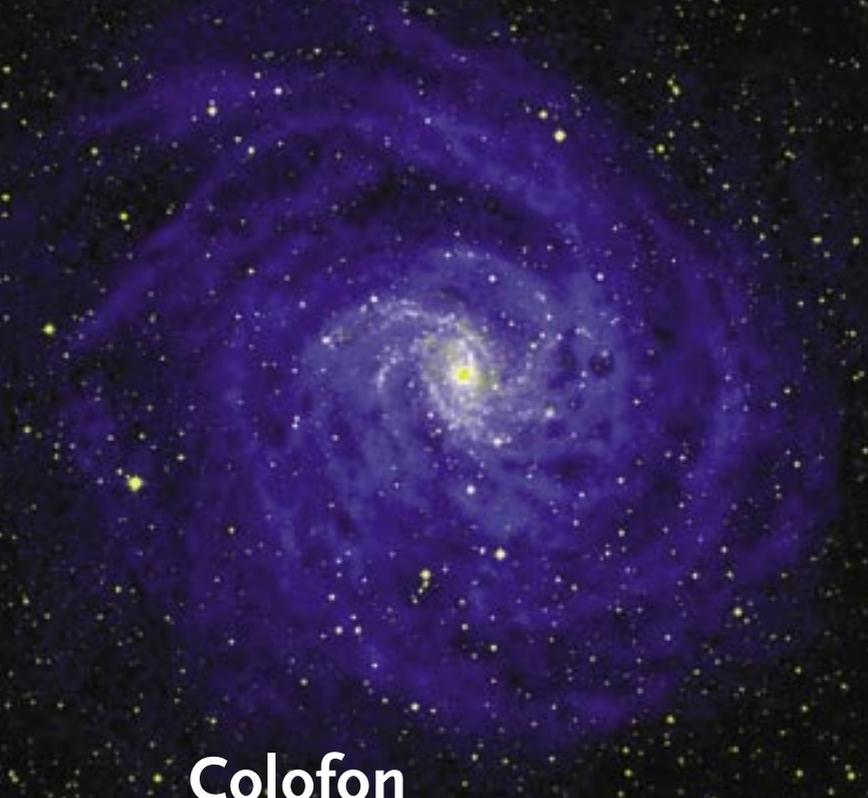
# Astronnews

december 2005

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- *New technique reveals Mega-parsec structures*
- *European astronomy celebrated in Dwingeloo*
- *Black Hole blows bubble*
- *Mars missions to use LOFAR technologies*
- *New back-end observes distant galaxy clusters*





## Colofon

### ASTRON

Netherlands Foundation for Research in Astronomy

Our goal is to enable discovery in astronomy through innovative instrumentation and facilities management

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### Published

Twice a year  
ISSN nr. 1871-6644

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## Note from editors

Welcome to this new issue of the ASTRONnews that covers a variety of items. Just before the summer, ASTRON went through an International Review and the results of this evaluation are summarized here by Thijs van der Hulst (chair of the ASTRON board).

With the Critical Design Review for LOFAR under way as we go to press, the LOFAR project is entering a crucial phase. Some of the aspects of LOFAR, like the station processing system or the “futuristic” system health management (by André Bos), are described in this issue.

Looking even more ahead, both the recently awarded FP6 SKA Design Study and the contribution to the design study of an ELT instrument have ASTRON heavily involved and will certainly get quite some attention in the coming issues of this newsletter.

While we get ready for these new facilities, a lot of exciting science is still coming out of the upgraded WSRT. The detection of neutral hydrogen in many galaxies in two distant clusters (by Verheijen and van Gorkom) is one of the application for which the broad band backend of the WSRT was planned. The capability of the backend has been used to develop a technique of rotation measure synthesis (described in the contribution by Brentjes and de Bruyn) while the improved image quality has allowed Gallo and collaborators to obtain to produce the beautiful image of the bubble around Cygnus X-1 and make a step forward in the understanding of stellar black holes.

We hope you will enjoy all this!  
Raffaella Morganti & Harvey Butcher

# Black Hole blows bubble

**A remarkable arcmin-scale ring-like radio structure has been discovered that is perfectly aligned with the milliarcsec-scale radio jet powered by Cyg X-1**

Deep 21-cm observations - five 12 hr runs - of the classical 10 solar mass black hole in Cyg X-1 were performed with the WSRT, resulting in the deepest map of that field to date and revealing the structure. Follow-up observations taken with the Isaac Newton Telescope Wide Field Camera using a  $\alpha$  filter detected the optical counter-part of the ring, indicating a thermal bremsstrahlung origin of the emission.

The direction of the proper motion of Cyg X-1 is roughly perpendicular to the jet direction, ruling out that the ring might be the low-luminosity remnant of the natal supernova of the black hole. Thus we interpret the ring of Cyg X-1 as the result of a strong shock that develops at the location where the collimated jet impacts on the ambient interstellar medium (ISM) – the Cyg X-1 black hole is blowing a bubble, if you will! This result is particularly important because it allows estimation of the jets' total power using the interactions of the jets with their surroundings.

The production of relativistic jets seems to be an almost ubiquitous consequence of accretion on to black holes on all mass scales; yet the importance of the jets for the energetics and dynamics of the accretion process, and as a potentially major source of energy input into the galactic interstellar medium (ISM), has yet to be well quantified. As the relativistic particles in the jets lose energy primarily via expansion, the radiative efficiency is likely to be very low, of the order of a few per cent, making it difficult to infer their total (radiated plus kinetic) power simply by measuring the emitted synchrotron radiation. Estimates of jets' total power are often based on assumptions of equipartition between the energy in the magnetic field and the relativistic particles, an assumption for which there is little a priori justification. Acting as an effective jet calorimeter, the ISM instead allows an estimate of the jet's power  $\times$  lifetime product that is, in principle, independent of the uncertainties associated with the spectrum and radiative efficiency.

In the case of Cyg X-1, the discovery of the ring-like structure shows that the jet particles inflate a synchrotron-emitting bubble which is over-pressured with respect to the surrounding gas; the lobe expands sideways forming a spherical shell of shock-compressed, bremsstrahlung-emitting gas, which we observe as a ring because of limb brightening effects.

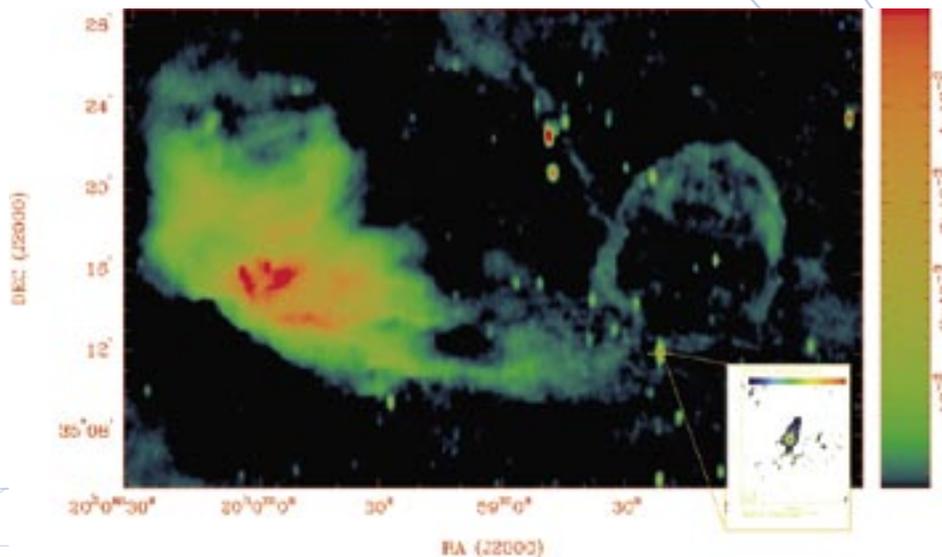


Figure – WSRT deep observation at 21 cm of the 10 solar mass black hole in Cyg X-1 (marked by a cross), yielding the deepest radio observation of that field to date. The observations show an arcmin-scale (corresponding to about 1 million AU at a distance of 2 kpc) ring of radio emission. The ring appears to draw an edge between the tail of the nearby HII nebula Sh2-101 and the position angle of the milliarcsec-scale radio jet of Cygnus X-1 (shown by the inset; VLBI map from Stirling et al. 2001).

Structures similar to the ring of Cyg X-1 have been found at the edges of the radio lobes of powerful radio galaxies hosting super-massive black holes, where the much higher temperatures of the intra-cluster medium compared to the ISM shift the bremsstrahlung emission to X-ray frequencies. Excepting the unique case of the W50 nebula surrounding the X-ray binary system SS 433 - where the interpretation is made difficult by the jet precession and uncertain contribution from the supernova remnant and disc wind - this is the first time that a similar structure is detected around a stellar black hole.

Applying a fluid model developed for extragalactic jet sources, we estimate that in order to sustain the observed ring emission the jet of Cyg X-1 has to carry a kinetic power that is a fraction  $f = 0.06$  of the bolometric X-ray luminosity of Cyg X-1 while in a hard X-ray state, i.e. while it is powering a the collimated jet.

This discovery has quite important consequences for low-luminosity stellar black holes as a whole. Since in these systems the jet power  $P_{\text{jet}}$  scales with the X-

ray luminosity  $L_x$  in a non-linear fashion ( $P_{\text{jet}} \propto L_x^{0.5}$ ; Fender, Gallo & Jonker 2003), this means that there exists a critical X-ray luminosity

$L_x$  below which the power output from accreting stellar black holes is jet-dominated.

By finding and measuring the ring of Cyg X-1, we have established the normalization of the above scaling, showing that the power output from the so called 'quiescent' black holes - those emitting X-rays below a few  $10^{-5}$  times the Eddington limit - would be dominated by the kinetic power of radiatively inefficient jets, rather than by the X-ray emitting inflow.

This work is presented in depth in Nature, Vol 436, p819, 2005. 



*Elena Gallo graduated in Physics at the University of Milan in 2001, then went to Amsterdam to do a PhD in astrophysics under Rob Fender's supervision.*

*Her research deals with accretion and jet production in stellar mass black holes; outside work, she likes reading, drawing, and playing with little Maya, her black & white cat who'll fly with her to Santa Barbara, where she is going to start with a Chandra Postdoctoral Fellowship in November 2005.*

## A new PuMa will soon be loose in the woods near Westerbork

On the 16th of December the new state-of-the art pulsar machine PuMa II will be taken into production at the WSRT. It is capable of Nyquist sampling and subsequently coherent dedispersing a total of 160 MHz of bandwidth. This doubles the bandwidth previously available for pulsar studies and provides an 8-fold increase in the bandwidth which can be coherently dedispersed.

The improved sensitivity and significantly higher time resolution the new machine affords will lead to greatly improved timing precision and enable high signal-to-noise, high time resolution single pulse studies.



*The data throughput board for PuMa II is shown. This board is responsible for acquiring and transporting 80 MBytes/s of digital data into the PuMa II system. There are in total 8 of these boards distributing a total of 160 MHz bandwidth to more than 80 processors for subsequent processing.*

# New technique reveals Mega-parsec structures

**Huge gaseous structures have been discovered in (or near) the Perseus cluster of galaxies. The structures were revealed by a novel technique called Faraday Rotation Measure Synthesis, developed at ASTRON and the Kapteyn Institute of the University of Groningen. These structures reside at distances of 1 to 2 Mpc from the cluster centre and measure between 200 kpc and over 3.5 Mpc in size.**

At the moment, the Westerbork Synthesis Radio Telescope is the only synthesis array in the world that can observe in more than a thousand full polarization channels at once. This unique capability, combined with a high instantaneous bandwidth (80 MHz at 340 MHz, 160 MHz at GHz frequencies), enabled the features to be revealed.

Simulations of large scale cosmic structure formation in recent years have suggested that structure in the universe formed bottom up. Clumping starts at the smallest scales and small structures merge into larger ones. The strong gravitational fields of these larger structures attracts other matter in their vicinity, making the larger structures grow even faster. These large, high density clouds become clusters of galaxies. The clusters are found in the simulations at the intersections of very long, relatively high density super cluster filaments, along which smaller clouds flow towards the clusters. The clusters and the filaments connecting them form the so-called 'cosmic web'. Outside of the clusters and filaments, the universe is very empty in the simulations.

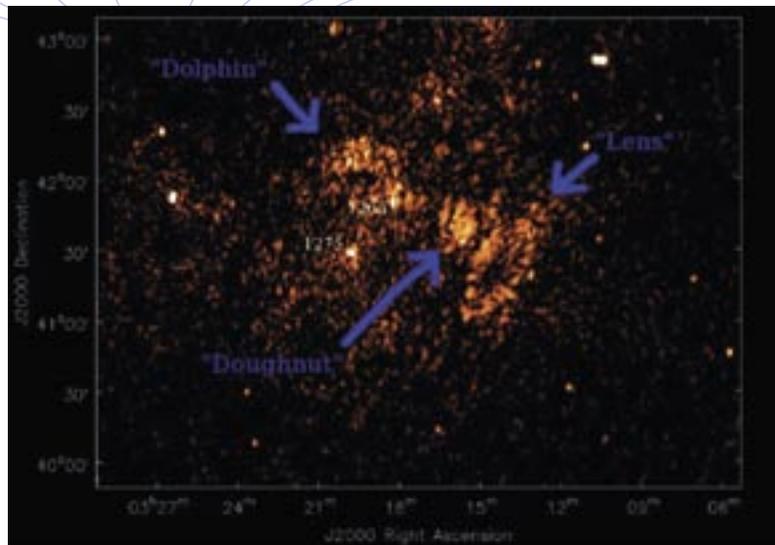
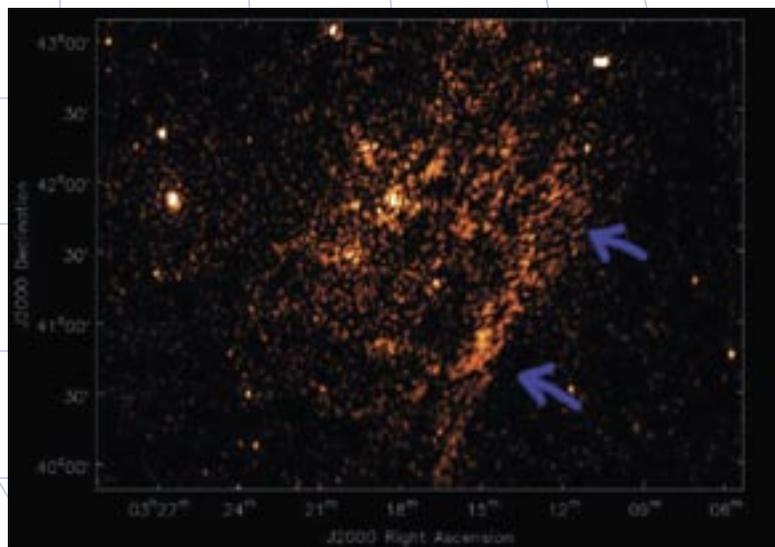
The central regions of clusters contain extremely hot gas that is easily observed in X-rays. However, the gas density and temperature drop with distance from the cluster centre, rendering the gas nearly invisible in even the most sensitive X-ray observations. Super cluster filaments only show up in the distribution of galaxies in surveys like the Sloan Digital Sky Survey (SDSS) and the 2dF redshift survey. But all cosmological simulations also show that there must be a significant amount of gas in these filaments. At the point where the gas flow from the super cluster impacts on the cluster inter galactic medium (IGM), there should be large Mpc scale shock fronts.

If there are magnetic fields at the outskirts of clusters and in super cluster filaments, the gas could emit radio synchrotron radiation. This emission could have a fairly steep spectrum, making it better visible at low radio frequencies. Provided the magnetic field reversal scales in the filaments are relatively large, this emission could be highly polarized. Shocks would compress and amplify the magnetic field, and re-energize the relativistic electron population, making the shock locations light up.

Using the Westerbork Synthesis Radio Telescope at frequencies between 310 and 370 MHz, we have managed to detect extremely large, diffuse, highly polarized structures at the periphery of the Perseus cluster (de Bruyn and Brentjens 2005). The largest structures are visible at the western side of the cluster, precisely where the Perseus-Pisces super cluster filament connects to the Perseus cluster.



*Michiel Brentjens is a PhD student at the University of Groningen, working on low frequency polarimetric observations of clusters of galaxies. The ultimate goal is to map gas structures in the cosmic web. Michiel is also involved in testing and developing the LOFAR self calibration system.*



This detection was made possible through the invention of a new data analysis technique, called Faraday Rotation Measure Synthesis, or RM-synthesis for short (Brentjens and de Bruyn 2005). This technique was designed to counter an effect called bandwidth depolarization. Linearly polarized radiation that propagates through a magnetized plasma has its polarization plane rotated proportional to (i)

the magnetic field strength along the line of sight, (ii) the electron density, and (iii) the wavelength squared. This effect is called Faraday Rotation. Typical values for the rotation measure (RM) are of the order of  $\pm 10$ -100 radians per square meter. That means that between 80 cm and 90 cm wavelength, the plane of polarization rotates several full circles around the origin and no polarization would remain. The simple solution is to reduce the bandwidth, but then one loses precious signal and the signal-

to-noise ratio becomes unfavourable.

But if one simply picks the correct rotation measure and de-rotates all polarization vectors in all channels before averaging, one will effectively compensate exactly the effect of this particular rotation measure. All pixels in a map that have this particular rotation measure then add constructively, while emission at different rotation measures adds only partly coherently. This way, one can use the full

bandwidth to detect emission with the chosen RM. If one now scans all plausible rotation measures, one acquires a RM-cube: a movie of the sky, where each frame is optimally sensitive to emission with one rotation measure only.

The picture at top is one frame from the RM-cube made of the Perseus cluster. It is the frame at a rotation measure of +42 rad/m<sup>2</sup>. The emission is located near or in the Perseus cluster. The long, straight feature on the right-hand side, indicated by the arrows, is at least 2.5 degrees long. That corresponds to a physical size of over 3.7 Mpc. For comparison: the distance to the Andromeda galaxy is only 710 kpc. The bottom picture, at a rotation measure of 52 rad/m<sup>2</sup>, shows a huge lenticular structure 500 kpc by 1 Mpc across ('lens'), and a smaller roundish feature ('doughnut'). North of NGC 1265 is an enormous curved feature, indicated with 'dolphin'. What are these things? A definitive answer to this question does not exist yet. There are nevertheless strong suspicions. The long, straight feature resembles a huge front. It is located at the point where the Perseus-Pisces super cluster filament connects to the Perseus cluster. Is this a large scale structure formation shock? Possibly. Recently, Govoni et al. (2004) found very similar structures at the outskirts of Abell 2255.

What about the other features? The 'lens' certainly looks like a severely compressed sphere. The major axis is oriented exactly parallel to the "front". Is that a coincidence? The 'dolphin' is situated directly north of the extended radio tail of NGC 1265. It even roughly follows the curve of the extended tail. Is this an ancient tail that detached from the radio

galaxy, rising buoyantly in the cluster IGM? Much smaller bubbles have been observed in X-ray observations very close to NGC 1275 (Fabian et al. 2003). It is suspected that radio relic sources, highly polarized structures at the periphery of clusters, are related to these smaller bubbles.

RM-synthesis has proved to be a powerful tool to discover extremely weak polarized emission. It may even be the first way to study gas at the periphery of clusters and beyond. Analysis of the RM structure in the objects we found will yield information on magnetic field strength and scale in the low density IGM of super cluster filaments. This is a regime in which cosmological simulations have hardly been tested before. The technique enables depth separation of Galactic foreground emission and distant cluster emission. RM-synthesis could even be used to study 3D structure of magnetic fields in supernova remnants and galaxies. [☞](#)



Picture by Isabella Gioia

The work on Faraday Rotation Measure Synthesis has been presented at the international conference 'Origin and evolution of Cosmic Magnetism' held in Bologna from Aug 29 to Sep 2, 2005, where Michiel and Ger received the "conference award" for the most discussed topic at the conference. The picture was taken at the conference dinner, soon after Rainer Beck (one of the organizers of the conference, on the right in the picture) gave the prize. The prize is in fact a magnetic construction toy that consists of small steel balls connected by highly magnetic rods that can be used to build all kinds of things. Sure Michiel will have a lot of fun with it!

## From the ASTRON Board

**This year turns out to be a very important year for ASTRON. The LOFAR project is starting up full swing and the Commanditaire Vennootschap LOFAR (Limited Partnership) and the LOFAR Foundation, which is formally in charge of the project on behalf of the CV are now officially in existence. At the participating university institutes the astronomers, geophysicists and other scientists are working hard to prepare for using the LOFAR infrastructure to do their science. At the same time the upgraded WSRT is producing great science, much of which will be presented in this and following issues of ASTRONnews.**

Early June ASTRON was visited by an international review panel chaired by Prof. J. Engelen of CERN and as members Prof. J. Bell Burnell (University of Bath), Prof. M. Longair (Cavendish Laboratory, Cambridge), Prof. J.H. Taylor (Princeton University), Prof. D.O. Williams (CERN). Their charter was to evaluate ASTRON's past performance and to assess ASTRON's potential for carrying out its mission in the future. The committee spent two days at Westerbork and Dwingeloo and had a very intensive and busy programme. Their final judgement was that ASTRON is excellent on all counts. They recommended that ASTRON takes great care in managing LOFAR and pays special attention to the ICT aspects of the project which as we all know are crucial and humongous.

The excellent evaluation of ASTRON is a tribute to all employees, from directorship to all the hardworking and enthusiastic people in the workshop, at the observatory, in the support area etc. The Board is proud of the accomplishment, but at the same time aware of the need to continue this performance to launch successfully such a complex project as LOFAR and, in parallel, continue work on the Square Kilometre Array developments. [☞](#)

# Summer students 2005

**This year's summer students at ASTRON and JIVE got a chance to experience life in the Netherlands as well as work with our scientific staff on various interesting topics in astronomical research.**



**Franz Kenn** - a PhD student at the Radio-astronomical Institute of Bonn, Germany - reduced HI data of early-type elliptical galaxies and specifically he developed a data reduction pipeline for those observations. On the basis of these observations

it is now possible to compare the galaxy's large-scale dynamics with the already available integral-field optical spectroscopic data of the central regions (part of the SAURON project).

**Daniele Biancu** - who is a researcher at the IRA-CNR in Bologna, Italy, worked on a project related to the motion of the parallax of HO maser star. He implemented a pipeline code for standard AIPS using ParselTongue.

**Birgitta Burggraf** - who just started her PhD at Bochum University, Germany, developed a pipeline within AIPS++ for the reduction of a WSRT point source sample. The scientific aim of her project was to measure the Faraday rotation of point sources behind the Perseus cluster region to study the magnetic field structure of this cluster.

**Brett Deaton** - who is about to finish his Bachelor's degree at Abilene Christian University in Texas, developed a specific software module for LOPES-Tools, a software package being built for analysis of data from the LOFAR-ITS and LOPES arrays. This module is a gain curve extraction routine to determine the underlying curve of a spectrum. This curve is then used to calibrate antenna gain, and can also be employed in RFI flagging.

**Juan Carlos Algaba** - a PhD student from Valencia, Spain – has been working on VLBI studies of the fast scintillating quasar PKS1257-326 which, unlike other fast scintillating quasars, has significant extended structure. The goal was to compare the VLBA data with ATCA data in order to probe the magnetic field and evolution of the inner radio jet.



The group not only enjoyed the scientific atmosphere at ASTRON and JIVE but went "Wadlopen" and bicycle riding through the beauty of Dwingelderveld national park surrounding the institutes.

Even the bad rainy weather - not unusual in the Netherlands! - during the summer student BBQ did not prevent them from having a good time. Many thanks to the overall organisation of Fritz Möller (in the picture with the blue cap). 

# New back-end observes distant galaxy clusters

**A pilot study with the WSRT's new backend of two clusters of galaxies at a redshift of  $z = 0.2$  has detected neutral hydrogen emission from more than 40 galaxies. Based on our detection rate and our knowledge of the range of H I masses in the local universe, planned deeper integrations will detect hundreds of galaxies and thus get the H I properties of galaxies at  $z = 0.2$  in a volume that is equivalent to the entire local universe out to 25 Mpc. The spatial distribution of the detected galaxies is very different in the two clusters. In Abell 963, one of the nearest Butcher-Oemler clusters, most of the gas rich galaxies are falling in from one side of the cluster. Abell 2192 is known to be a lower density cluster with much evidence for substructure. Here the gas rich galaxies are more uniformly spread over a large region centered on the cluster.**

It has long been known that galaxies have very different morphologies in the centers of clusters and in the field. In condensed clusters, elliptical and lenticular galaxies dominate, while in the field 80% of the galaxies are spirals. In the last twenty years a wealth of data has been gathered on clusters at intermediate redshift, up to  $z = 1$ , and it has become clear that the galaxy population in clusters evolves over relatively short cosmic timescales. Clusters at redshifts of  $z \geq 0.2$  have a larger fraction of blue galaxies, indicative of ongoing star formation, than would be expected based on passive stellar evolution of the galaxies. This is the so-called Butcher-Oemler effect.

Furthermore, the fraction of ellipticals remains unchanged from  $z = 1$  to 0, while clusters at a redshift of 0.5 have a significant fraction of spirals and hardly any lenticulars. At  $z = 0.2$  the situation is reversed: there are many lenticulars and few spirals. It has been

an ongoing debate whether it is the cluster environment that drives the morphological evolution of galaxies or whether it is the field population continuing to accrete onto clusters that evolves with redshift. Despite all these data nothing is known about the actual gas content of cluster galaxies beyond  $z \sim 0.1$ . The gas content is a critical parameter in environmentally driven galaxy evolution, since gas is the fuel for star formation. The main impediments to obtaining data on neutral hydrogen content at redshifts larger than 0.1 are the long integration times that are required and the occurrence of man-made interference at those frequencies.

It has long been realized that if one could use a wide field of view and observe many galaxies at once, it would be worth the long integration time. Radio synthesis telescopes with their large fields of view and sufficient angular resolution to resolve individual galaxies are

the ideal instruments for this. However, one limitation of most current synthesis instruments is that the instantaneous velocity coverage in such an observation can typically be no more than 1000 to 2000 km/sec, not enough to cover the range of velocities usually seen in clusters (3000-5000 km/sec).

This has now changed with the new backend of the WSRT. In a single observation one can cover up to 18000 km/sec!

Thus in one pointing one can not only probe the entire velocity range of the cluster, but also cover a very significant volume in front and behind the cluster. Such an observation provides the much needed gas content of each of the cluster galaxies and simultaneously the gas content of a control sample of galaxies in the field at about the same redshift. This last year we have performed a pilot study for just such a survey. We selected two clusters that are known to be very different in their dynamical state and star formation properties.

Abell 963, at  $z = 0.206$ , is one of the nearest Butcher-Oemler clusters with an unusual high fraction (19%) of blue galaxies. This massive, X-ray luminous cluster, is in a sample of X-ray selected clusters currently being studied at many wavelengths (Chandra, HST and NIT). Lensing studies show that 70% of the X-ray luminous clusters at  $z = 0.2$  are dynamically immature. However Abell 963 is unusually relaxed with less than 5% substructure.

Abell 2192, at  $z = 0.188$ , is less massive and is much more diffuse with significant substructure. So far it has not been detected in X-rays. Optical images of the central 1 Mpc of the two clusters are shown in Figure 1. We observed Abell 963 for 20x12 hours last February and Abell 2192 for 15x12 hours in July.

We used all eight IF channels, covering a frequency range from 1220 to 1160 MHz, resulting in a data cube with 1600 velocity channels. We have so far identified 20 H I selected galaxies with optical counterparts in Abell 963 and 21 in Abell 2192. The distribution of our detected galaxies is shown in Figure 2. In the case of Abell 963 nearly all of these are located to the NE of the cluster, while in the case of Abell 2192 the distribution is more diffuse, although some clumping seems to be present to the SW. Clearly we are beginning to map the large scale structure in which these clusters are embedded.

The fact that we see significant substructure around Abell 963 is very interesting. Although the core of this cluster is relaxed, it seems that this Butcher-Oemler cluster is, or soon will be, accreting a large group of gas-rich galaxies from its surroundings.

In Figure 3 we show examples of detected galaxies in the clusters together with some fore- and background galaxies. Note that many optical counterparts show disturbed morphologies. The position-velocity diagrams show that we have spatially resolved kinematic information as well. We will also be able to derive an HI-based Tully-Fisher relation for the galaxies at  $z=0.2$ .

Finally, from an optical redshift survey of optically selected galaxies in Abell 2192 we have identified 36 cluster members, of which 19 show emission lines in their spectra and 17 show no signs of star formation. Figure 4 shows the stacked HI spectra extracted from the data cube and shifted to the rest wavelength of each galaxy. The stacked spectrum of the emission line galaxies is shown in the top panel and of the non star forming galaxies in the bottom panel.

A clear H I emission signal is detected from the emission line galaxies.

Although our study was a pilot we have achieved a number of important results. First of all, at these low frequencies, we have managed to integrate down to the theoretical estimated noise level and we have demonstrated that we can deal with the interference

encountered. More importantly, we have shown the tremendous potential for science of deeper integrations (roughly 1000 hours per cluster). Our pilot survey was only sensitive enough to detect the largest H I masses ( $\geq 5 \times 10^9 M_{\odot}$ ). In the more distant future with the planned SKA telescope, we will be able to probe similar volumes at redshifts of 1 and beyond. [☞](#)

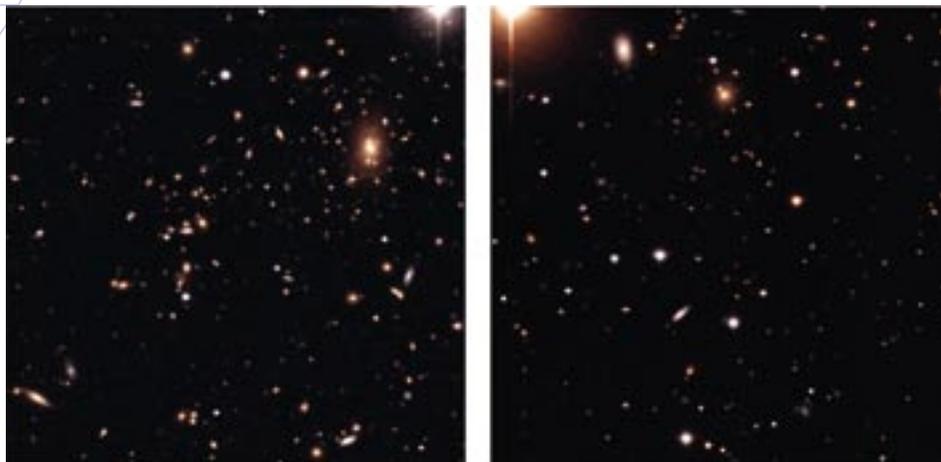


Figure 1: Optical images, 1 Mpc on a side, including the central regions of Abell 963 at  $z = 0.206$  on the left, and Abell 2192 at  $z = 0.188$  on the right.

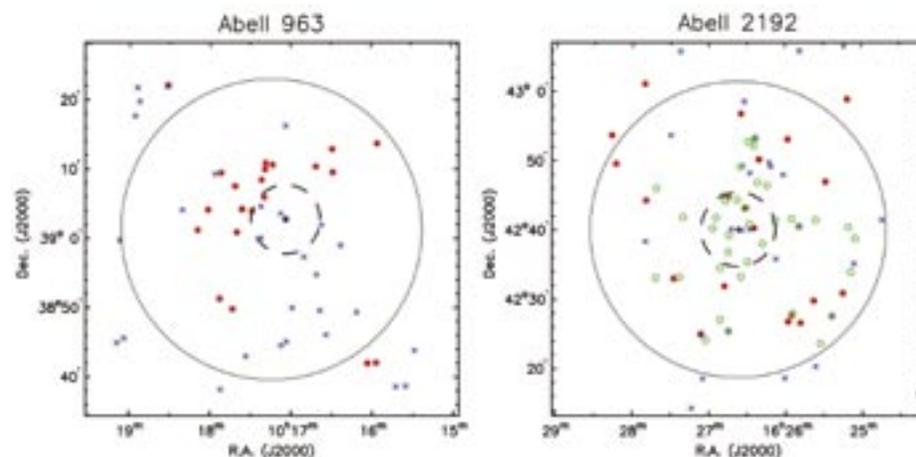


Figure 2: The distribution on the sky of galaxies with known redshifts. Red dots indicate the locations of HI detected galaxies. Blue crosses indicate galaxies with optical redshifts from the SLOAN survey. Green circles indicate the positions of galaxies with optical redshifts from our WIYN/Hydra survey. The full circle indicates the FWHM of the primary beam of the WSRT. The dashed circle has a radius of 1Mpc at the distances of these clusters.

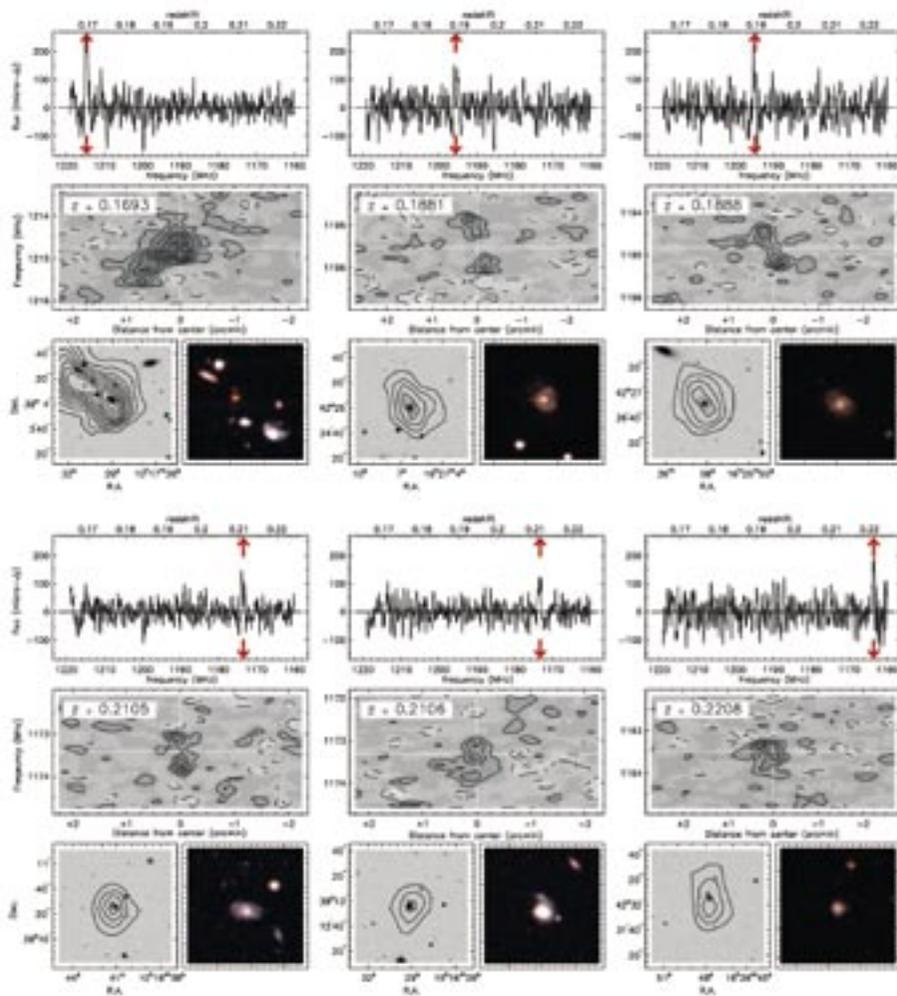


Figure 3: Examples of six galaxies at intermediate redshifts detected in H I with the WSRT. For each galaxy, the upper panel shows the entire H I spectrum with red arrows indicating the redshift and frequency of the H I signal. The middle panel shows the position-velocity diagram along the major axis of the galaxy. The lower left panel shows the integrated H I map on top of an optical image. The lower right panel shows a blow-up colour image of the H I detected galaxy.

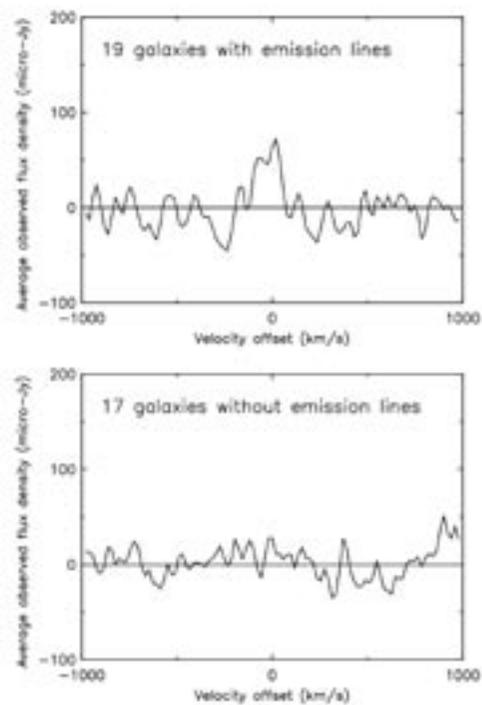
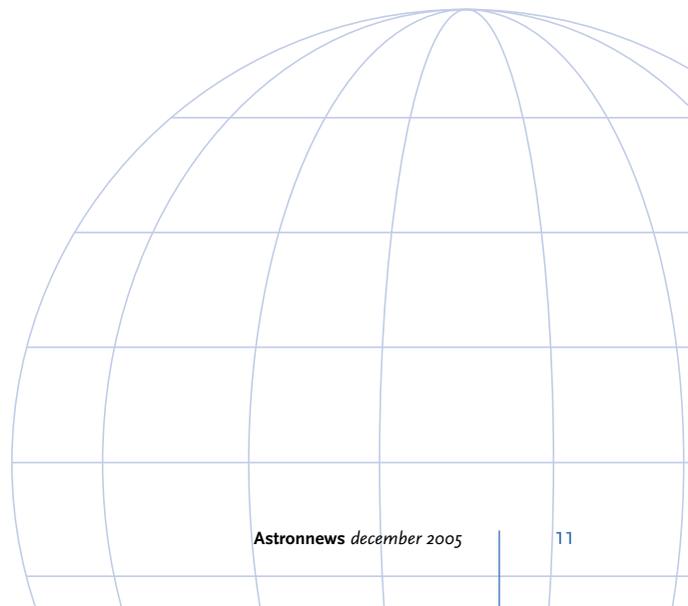


Figure 4: Stacked H I spectra of galaxies in Abell 2192 with optical redshifts, indicated with green circles in Figure 2. Galaxies with optical emission lines are forming stars and are detected in H I. In galaxies without optical emission lines, the formation of stars has halted and no H I has been detected in these galaxies.



# Postdocs at ASTRON: Corina Vogt



I am a Postdoctoral Researcher at ASTRON since October 2004. After my physics studies in Leipzig, I followed a childhood dream and turned to Astronomy. I did my PhD at the Max-Planck Institute for Astrophysics in Garching, Germany. I finally had the chance to visit a real telescope (the VLA) and even observe with it. However for my PhD thesis, my supervisor, Torsten Enßlin and me devised a novel method to statistically analyse Faraday rotation maps of extended radio sources to investigate the properties of cluster magnetic fields. The most exciting result of my thesis was the measurement of the magnetic power spectrum of the intra-cluster medium in the Hydra A cluster.

One clear goal for me is to apply this method to other clusters. Recently, I started to explore ways to extend these methods to Faraday rotation measurements of the galactic foreground.

Coming from a mainly theoretical institute learning there the beauty of maths, I enjoy now the other side and learn each day more about the pitfalls an observer is faced with. While I still actively study the properties of magnetic fields in clusters of galaxies and galaxies itself, I follow closely the exciting developments on the area of low frequency radio science which take place here at ASTRON. To be even closer to those developments, I started to get involved in the preparations for LOFAR in particular in the preparation for the detection of the 21cm signal from the epoch of Reionization, where I help with the coordination of the project tasks. Recently, I also started to support the coordination of all the LOFAR key science projects to make LOFAR an all-round success. ☺

# Working

**Stella, the IBM BlueGene/L processor at the heart of LOFAR, is a research machine. While the real-time streaming system is being developed, we need to learn as much as possible about the machine. To that end a number of different applications are being run. In this issue, we have asked Wim Mulder to provide a report on his experience with its use for geo-seismology.**

Subsurface imaging techniques are based on a number of physical processes, among them gravity anomalies, the electromagnetic response to natural or artificial sources, temperature anomalies, and wave propagation. The first three processes are governed by diffusion and therefore yield low spatial resolution. Wave propagation, however, is nearly non-diffusive and generally produces the highest resolution. For that reason, seismic data are heavily used for oil and gas exploration. Stella is well suited for testing algorithms on synthetic data generated by brute-force modelling of the governing wave equation.

Although the details of wave propagation in rocks are still a subject of active research, a fairly accurate description can be obtained by solving the system of anisotropic elastic wave equations. A seismic survey requires a sound source and geophones that record reflections from contrasts in the subsurface. Examples of man-made sound sources or shots are dynamite or vibroseis trucks. Earthquakes are a natural source. A synthetic survey requires a model of the subsurface in terms of density and P- and S-wave velocities and anisotropy parameters. A large number of shots must be fired for proper imaging. Each shot represents a separate computation.

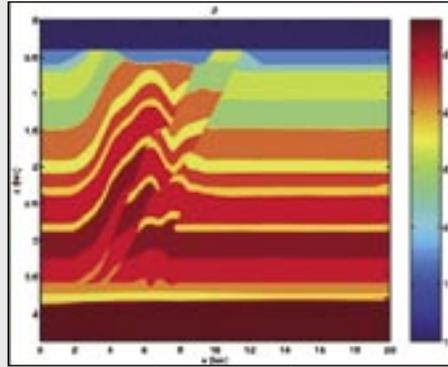
Realistic simulations require Peta-FLOP/s hardware, which is not yet available. Because the computational cost for an explicit time-stepping scheme scales with 4th power of the maximum frequency in the

# with Stella

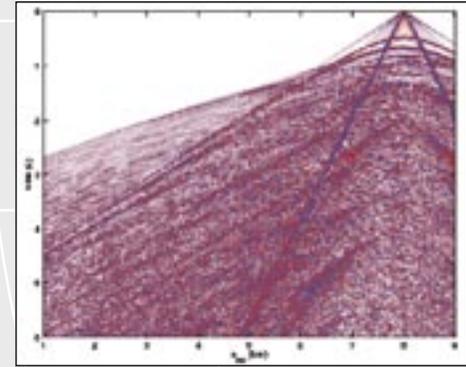
data, one can always sacrifice some realism to make the problem fit the available hardware. For Stella, some members of the EAGE, the European Association of Geoscientists & Engineers, have proposed a simplified 2D anisotropic model. Performing 3D computations in the 2D model reduces the number of shots and keeps the data volume down to about 60 Gbyte per line of 31 shots. This is sufficiently small to allow for on-line access on request, although the details of doing this still needs to be sorted out.

An existing modelling code was ported to Stella with surprisingly little effort. The code was written in C and uses MPI for communication between nodes. A single node was used for I/O and program control. This does not map in an optimal way to the BlueGene hardware, and caused jobs to fail when more memory was required than available. The code has an option for restarts, but we experienced crashes when this was used. Still, the overall performance is much better than on standard Linux clusters.

At the moment, one line with 31 shots spaced by 250 m on a computational grid with an 8-m mesh width has been completed, each shot requiring about 3 days of computation using almost 512 nodes. Three more lines are required with different types of



*The 2D density model*



*One line of seismic data for a single shot. The data have been weighted linearly in time and are strongly clipped to bring out the weaker reflections.*

sources, so that the symmetry properties of the wave fields can be used to generate much large surveys without additional simulations. The 8-m mesh width is too coarse by a factor 2 for realistic data frequencies. So far, only a single shot on a 4-m grid has been computed. This took about 3 weeks of computation on 1024 nodes.

The results should enable geophysicist to test and improve new algorithms. The synthetic data sets are expected to boost research in the field of imaging anisotropic elastic data. [🔗](#)

# Coffee and cake

Together with the technical and scientific adventures LOFAR has brought to ASTRON, there are also interesting sociological processes. Some of the most interesting have occurred while searching for locations for the remote LOFAR stations. Imagine the following, very typical scene:



*Frederiek Westra van Holthe and Peter Bennema*

Protesting farmers (and families) are sitting around the kitchen table of the largest farm in the area. The LOFAR team, consisting of Frederiek Westra van Holthe (Communications) and Peter Bennema (Land Use Planning), has been invited to listen to their objections to the installation of a LOFAR remote station nearby. Everyone is there (- everyone that is, except the farmer with whom LOFAR has already reached agreement: he has not been invited by the neighbours).

The first fifteen minutes are spent talking about this year's harvest and the weather, but after coffee and cake (Drents hospitality!) it's time to get down to business. The farmers oppose the erection of a LOFAR station in the area because it will bring limitations to their farming activities.

Some are afraid that the grounds of the LOFAR station will be badly maintained and weeds will migrate into their fields. But the most important argument seems to be that with the arrival of LOFAR it will no longer be possible to install large wind-turbines on their land for producing electricity, since these would generate too much interference for LOFAR.

The discussion is friendly and the farmers offer an alternative piece of land, about a kilometre further away. If LOFAR this is willing to buy this parcel (from the leader protesting farmers), they are willing to cease their opposition.

The LOFAR team refutes the objections about the negative effects on their farming activities as well as those relating to the bad maintenance of the LOFAR site. There will be no limitations for neighbouring areas as far as farming is concerned, and of course the stations will be well maintained.

It is however true that no wind-turbines can be built near a LOFAR station because of the interference they would generate. Anyway, it is difficult to imagine that in such a beautiful area somebody would be happy with the construction of such big wind-turbines.

One of the women present reacts to this and says decidedly, while looking sternly at her husband: "I don't want any windmills around here! I would rather have a hundred small LOFAR antennas than one big wind-mill!" What can he do? The husband has to agree...

And suddenly there are more women (and men) who prefer LOFAR and are not interested anymore in windmills.

The LOFAR team can relax, the battle is won. Nobody mentions the alternative piece of land anymore. The leader of the protest is disappointed; he would have liked to have sold his land to LOFAR.

This (or a similar) story is being repeated many times as we acquire the parcels of land for the LOFAR remote stations. In general, good information and open communication leads to acceptance. Sometimes a good chat around the kitchen table is needed to convince people.

Arranging enough physical space in order to make possible the realization of LOFAR is, however, proceeding well and according to plan. Roll-out of antennas can begin in the course of 2006.

# for LOFAR

As we go to press, about 80% of the land has been acquired in the Central Core (320 ha.), where a quarter of the antennas will be located. Part of this land has been designated by the Province as a future nature reserve. A close collaboration between LOFAR and the organisation that manages nature reserves (the foundation Het Drentse Landschap) has, therefore, been established. The plan is to locate the many antennas and other sensors of the Central Core such that nature can develop without compromising the technical demands of LOFAR.

So for example, the Achterste Diep, now a small, canalised stream that passes through the Central Core, will be allowed to return to the meandering brook it originally was. And research has shown that the bird population in the region is decreasing rapidly due to the intensive agriculture. By combining LOFAR and nature, the bird population will get a stimulus to recover. It will be possible to create a unique semi-wet natural area where the groundwater coming from the sandy regions higher up (such as the Hondsrug) can be collected. The plan is that

this will result in the development of a unique flora in the region. A project team composed of experts from several governmental bodies as well as Het Drentse Landschap and LOFAR is now working to make an integral plan for the entire region. This includes small-scale tourism and recreational spin-offs resulting from the combination LOFAR-nature. When designing the LOFAR antennas, the fact that these will be placed in an open landscape has been taken into account. Because of the materials used (a pole 160 cm high supported by four wires that also serve as the two dipoles), the Low-Band Antenna will be very inconspicuous in the rough landscape that will form after a few years. The High-Band Antenna will not exceed 70 cm and will hardly be visible in the landscape (see pictures). 



*LOFAR Low Band antennas*



*LOFAR High Band antennas*

# Computing at the edge

Each element antenna of LOFAR generates data at a rate of 2,4 Gbit/sec and the total data generation rate is about 35 Tbit/sec. To maintain maximum flexibility, one would like to transport all these data to the central processor for combination.

Unfortunately, technology has not yet advanced sufficiently to make this possible for an affordable price. Local data combination at each antenna station (cluster of antennas) is required to bring the volume of streaming data down to a level that it can be transported and centrally processed. In this case, LOFAR may be considered a hierarchical computational network with processing both at the 'edges' of the network and centrally.

The optimization problem is to distribute the required functionality while controlling for the loss of information and minimizing cost.

Last Astronnews, the central processor design was presented. This issue we tell about the 'edge' processing, that is, the digital embedded processing system that provides in total about three times the total processing power of Stella. Readers interested in more detail than we provide here should contact André Gunst (gunst@astron.nl).

The analog signals from the eight element antennas are amplified at the antennas and

transported to a local receiver unit, where they digitized and processed. A 12-bit, 200MHz ADC is employed in the receiver, operated in direct sampling mode such that aliasing may be used to mix the signal down in frequency as appropriate. The digitized signals are transformed to the frequency domain, filtered (into 512 sub-bands) with a polyphase (FPGA) filter bank, synchronized and time stamped, and are processed for interference suppression (deterministic spatial nulling during beamforming). The signals are routed to a digital beamformer that has a ring architecture (see figure).

This architecture minimizes the number of circuit boards and allows additional antennas to be coupled in easily. Because each processing unit may send data to the central processor the architecture also provides important redundancy in the system. Ethernet standard interfaces are used wherever possible, the main exception being the data pipes between processing boards. EMI has to be reduced to the minimum by using point-to-point low voltage differential signaling.

An innovative capability is provided by a circular RAM buffer at each unit, dimensioned to allow 1 sec of raw data to be retained (longer at reduced bandwidth or using partially processed data). This allows measurement beams to be formed after the



*The Team: (from left to right) Andre Gunst, Gijs Schoonderbeek, Jurgen Morawietz, Wietze Poiesz, Klaas Jan Wierenga, Sieds Damstra, Wessel Lubberhuizen, Arie Huijgen, Menno Norden, Yde Koopman (not in the picture: Andre van Houwelingen, Eric Kooistra, Stefan Wijnholds and Dion Kant)*

event, following an internal or external trigger. The initial LOFAR network connects 32 core stations and 45 remote stations. The core stations are distributed over a region 10 km in diameter and are dimensioned each to deliver 3 – 20 Gbit/sec. The remote stations are distributed over an area 160 km in diameter and are each specified to deliver 3 Gbit/sec. The aggregate (~ 580 Gbit/sec) is transported on a 738 Gbit/sec fiber backbone to Stella in Groningen, 65 km away. The technological challenge of this digital sub-system is substantial. Whenever that is the case we call in our Digital Embedded Processing team. Once again they have risen to the challenge: in October they passed their sub-system Critical Design Review, and as we go to press they have gone to formal procurement of this LOFAR sub-system. ☺



*Station beamformers operate in a ring configuration*

# LOFAR@School

**Two organizations, one mission. IBM Netherlands and LOFAR have recently joined forces to bring the excitement of astronomy and technology to high-school children. Plenty of innovative, young brainpower eager to come up with bright ideas, was the thought.**

This collaboration, which we have named LOFAR@School, challenged Dutch high-school kids to think of applications for a wide area sensor network like LOFAR. These applications might be relevant for young people or for schools, or for that matter might just be a good idea. Great prizes were of course on offer: every kid on the winning team would receive an i-Pod, the winning school would win an IBM laptop, and (possibly best of all) the winning idea would be worked out further toward a business case by a team of university students in the Extreme Blue program of IBM.

On 22 June last, an expert jury under the chairmanship of prof. Vincent Icke of the Leiden Observatory examined all the submissions, but had a very hard time choosing a winner. In the end they decided to appoint two winners.

One was the Niftarlake College in Maarssen, whose idea was to monitor aspects of the environment across a wide area and correlate these measures with local health records. The second winner was the Philips van Horne Scholengemeenschap in Weert, whose suggestion was to measure the Earth's magnetic field using student-built magnetometers.

Both winning teams had prepared their proposals very well. In fact one proposal was so well written according to the jury that it met the standards expected of professional research proposals. On 28 June, our Minister of Education, Culture and Science, Mrs. Van der Hoeven, awarded the prizes at a ceremony in The Hague.

Next, the winning ideas were presented to IBM's much admired summer program, Extreme Blue, in which university students work with IBM and one of its customers on an innovation challenge defined by the

customer and IBM. Four young and eager university students (three technical students and one business student) were given the task of turning one of the LOFAR@School ideas into a business case.

*continue on next page*

Members of the jury:

Prof. Vincent Icke (*professor theoretical astrophysics Leiden Observatory*)

Prof. Harvey Butcher (*ASTRON*)

Govert Schilling (*science journalist*)

Pieter Hogenbirk (*Educations Inspector*)

Djeevan Schiferli (*Innovation Officer IBM Global Services Europe*)



*Students Michel Wigbers, Joost Voordouw, Chris van Hinsbergen en Matia Bianchi*

# Learning



Prizes being awarded by Minister Van der Hoeven

The students selected were Michel Wigbers, Joost Voordouw, Chris van Hinsbergen and Mattia Bianchi. Could they design a kit of sensors and teaching materials of sufficient interest to sell to schools on a large scale? For the first time, an Extreme Blue team was given a challenge where the end result was not to make profit, but to achieve a low enough price that as many items as possible are sold. The students succeeded in estimating the development cost, the available subsidies, and the amount that schools might be willing to pay. Furthermore, they developed a prototype sensor package that can be put together at schools, and a user interface by which high-school students can access not just their own data but also data taken at other schools.

ASTRON and IBM are now planning to pursue this project further, so that as many high-school students as possible can be exposed to the excitement of being involved with the activities of LOFAR. 



Cover picture of report by  
Extreme Blue students

**The word GRID in the context of distributed computation and storage is supposed to evoke similarity to the power GRID. The user simply plugs a connector into the wall jack, not caring about where the computing power comes from. The GRID transparently provides the computational and storage resources to run large jobs. Sounds good, but does it work in practice?**

We are in fact counting on the availability of the national GRID infrastructure being developed at SARA in Amsterdam to process the very large amounts of WSRT and LOFAR data we are planning to generate. So it has been most important to develop experience with the GRID hardware and software under development in our country. This news item reports a demonstration of the usability of GRID hardware and software for astronomical data reduction. A large mosaic with 163 pointings (see the Figure) of the Andromeda galaxy has been successfully reduced on the NL-GRID processing environment.

The input measurement set was 10 GByte in size; the output 6°x5° images took up 50 GByte in total. A few years ago, the data were reduced on a 4-processor Dec-Alpha system, which took about half a year. At that time, it would have been useful to redo the reduction with different sets of parameters, but the extremely long processing time made this impossible.

To re-reduce the data now we have used an adapted version of Miriad, locally known as '4p', that exploits parallelism at several levels. All processors in a multi-processor machine collectively run a single task (through multithreading), and SIMD (vector) instructions are used if the processor supports them. On top of that, we exploited task parallelism by dividing independent tasks over multiple machines. First, this was done on a local PC cluster, later we moved to NL-GRID resources.

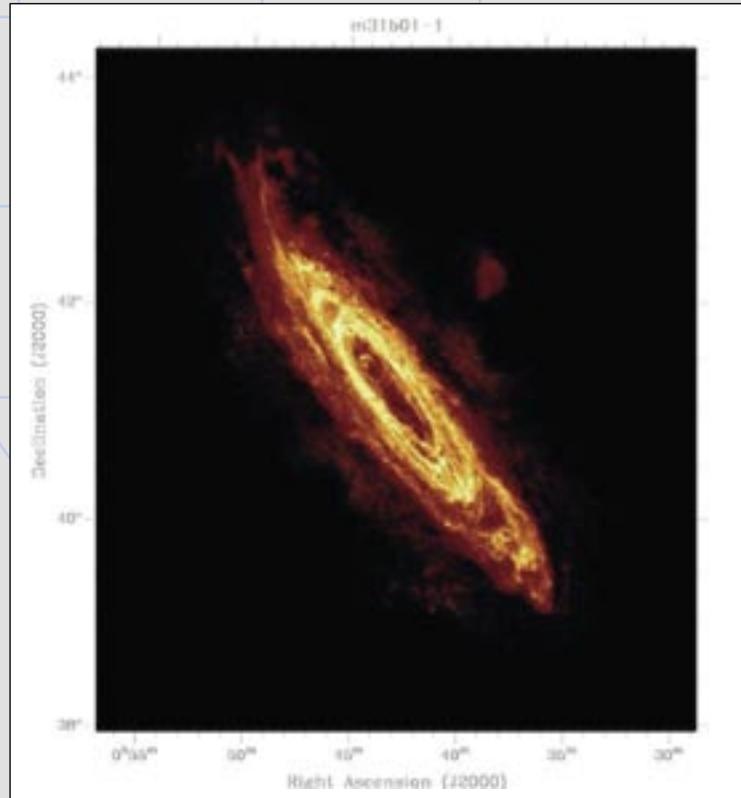
# to love the GRID

The time to process all data was reduced from a half year to approximately one and a half day, although execution times will be highly variable because available resources are variable, GRID resources being shared by many other users. Still, this decrease in the reduction time has made it possible to try a number of different sets of calibration parameters, and so determine the optimum reduction strategy for this data set.

From a user's point of view, the GRID provides Computing Elements (CEs) for processing purposes, Storage Elements (SEs) for persistent storage, and a User Interface (UI) from which the GRID can be accessed. From the UI, one can issue commands to transfer data to and from SEs, and submit jobs that are to be scheduled on CEs. The user does not know on which CE the job will be scheduled, but requirements like minimum memory size can be specified. A new Virtual Organization (VO) ASTRON was created to provide ASTRON users access to NL-GRID.

New users are welcome to apply for a user certificate, which is used for authentication and necessary for accessing NL-GRID. The author (romein@astron.nl) is the contact person for ASTRON and JIVE members but can help to redirect others to the right contact persons. Otherwise, interested people can check the site [www.sara.nl/userinfo/grid/description/index.html](http://www.sara.nl/userinfo/grid/description/index.html).

*M 31 mosaicked image processed using NL-GRID facilities. (Data set courtesy of Robert Braun)*



We can only conclude that the GRID may indeed be useful in practice for processing large astronomical data sets. It does take some time to learn to use the available GRID tools, which are quite low level. But with practice they are not really difficult to use. Especially for projects that involve incidental, large jobs that cannot readily be run on local work stations, the GRID is a useful resource of computational power. 

# Mars missions to use

**LOFAR commercial partner, Science and Technology bv, is responsible for the System Health Management of LOFAR. The project gave it the competitive edge necessary to win a development contract in preparation for future manned missions to Mars.**

Imagine a Martian base in the year 2025. Commander Carina is barely awake when she finds the alert light blinking on her Personal Digital Assistant (PDA)...

**Carina** What's wrong?

**PDA** Nothing serious. When you were sleeping I detected a malfunction in BioPlex number 3.

Carina knows all too well the importance of the BioPlex facilities; they are the prime life-support systems on the base. In the biosphere-like environment plants are grown for food and conversion of CO<sub>2</sub> to O<sub>2</sub>. On the base they have three of these facilities, but number 1 is already down because of maintenance. If number 3 is also giving trouble, things could get risky.

**Carina** Be specific, please...

**PDA** The CO<sub>2</sub> sensor of number 3 gave a reading that was too low, which triggered the alarm system. I know about the current limited availability of the other BioPlex systems, so I initiated a full automatic diagnostics procedure. Although the reading of the CO<sub>2</sub> sensor was low, the O<sub>2</sub> level looked normal. So, I decided to investigate the hypothesis that the CO<sub>2</sub>-sensor is faulty, especially since it's given us some problems before. Initial confidence level was conservatively set at 90%. To raise the confidence, I ran an additional test where I slightly increased the CO<sub>2</sub> injection level. The CO<sub>2</sub> sensor didn't respond at all, but the O<sub>2</sub> sensor showed the expected rise after a few minutes, which is fully consistent with the

hypothesis... So, that almost certainly proved that the CO<sub>2</sub> sensor was wrong. The confidence level of the diagnosis was better than 99.7%. I asked the astronaut on duty to replace the sensor. After that, all worked as expected, further raising the diagnosis confidence level to 99.997%.

The progress they have made in autonomous systems design still amazes Carina. It used to be that minor malfunctions grounded systems almost forever because the complex interactions between the system's components fooled the mechanics every time. But since these complex systems had been equipped with the state-of-the-art Self-Reflection unit, these problems were history. The system was now able to assess the impact of a malfunction, work out for itself what caused the problem, and suggest ways of solving it - sometimes even intercepting problems before they manifested itself. All this was possible because of its ability to reason about a behavioral model of itself, and the productivity at the colony had gone up tremendously because of it. But still, Carina is not assured that the problem is completely solved.

**Carina** What is your prognosis about the next failure of the replaced sensor? It looks like these things break down very often.

**PDA** Yes, these sensor's reliability numbers are worrying me as well. I have exchanged data with my peer systems at the other bases. They have similar problems with these sensors. I also know that since we launched the Bioplexes, new, more reliable, versions have been developed. So, I suggest we order these to be brought in from Earth with the next Kliper flight.

**Carina** Yes, and thank you for this.... What is on the agenda for today?

**PDA** Today we start with the commissioning of the instruments of Astronomy Experiment-42. AE-42 requires a fair amount of electrical power, so I suggest a rescheduling for Recreational Session RS-003 for tonight, in order to prevent hydrogen cell overload.

# LOFAR technologies

What has this Mars example to do with our work at ASTRON?

Well, just like the future Mars equipment, parts of LOFAR will fail on occasion as well. In order to cope with component failures, the LOFAR control system is being equipped with a “system health management” (SHM) subsystem. The high-level objective of this subsystem is to help maximize the measurement time of LOFAR, while minimizing operational maintenance costs. The SHM system uses the available sensor data to keep an eye on LOFAR’s performance. Due to the large number of components and the multiple ways of how these components may interact, it is a real challenge to detect a system failure and to identify the faulty component that causes it, without causing too many ‘false positives’. LOFAR’s system health management system will apply a range of techniques to tackle this problem. In order to determine the root cause of failure, LOFAR uses techniques originating from the ‘Artificial Intelligence’ field. While not as advanced as the self-aware SHM system from the Mars scenario sketched above, LOFAR will incorporate a number of techniques that were alluded to in that story. For example, LOFAR system health management also makes use of hypotheses about the health state of LOFAR and will test these hypotheses against the observed data and a model-based description of LOFAR’s normative behaviour. The model-based reasoning techniques are not only used for failure diagnosis, but can also be used to find out how the system can be reconfigured in case of a system failure, in order to realize graceful degradation behavior.

One of the objectives of the LOFAR project was to stimulate the technological impulse in embedded software design. We are happy to announce that the first signs of success in this area are already visible. Our company, S&T — together with TNO Human Factors, OKS from Spain, and EADS Space Transportation — has won a contract for Mission Execution Crew Assistant (MECA) project of the European Space Agency (ESA).

MECA will focus on developing new technology necessary to support ESA astronauts during future manned missions on Mars. Model-based health management, autonomous software components, and advanced human-computer interface design are some of the areas where the MECA project aims to make a significant contribution. Our experience with LOFAR will surely help to realize the MECA project goals, and hopefully a more advanced version of the LOFAR SHM system will actually make it to the surface of Mars, to support astronauts. 



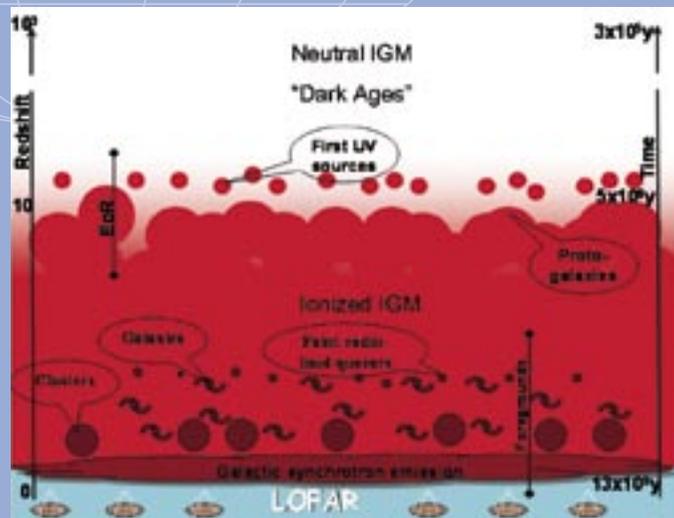
*S&T team (not in the Netherlands, obviously)*

Science and Technology b.v. (S&T) is an innovative company developing cutting edge information technology for high impact systems. S&T was founded in 2000 by Andre Bos, Erik Zoutman and Carina van Eijk. Carina holds a degree in Astronomy and spent many nights during her study at ASTRON.

Key player for the LOFAR project is Sidney Cadot (in the Atari shirt in the photo). Previously, Sidney developed software for remote sensing applications.

# Reionizing the Universe Conference

Perhaps the least understood process in the universe's evolution is the epoch of reionisation (EoR) of the intergalactic medium (IGM) when the first luminous objects formed. The physical processes that trigger this epoch and its ramifications on subsequent structure formation were the subject of this conference, held at the University of Groningen from June 27th to July 1st. The figure shows a cartoon with the three phases of the Universe covered by the conference discussions, pre-reionization IGM, EoR and post-reionization IGM. The figure also shows the types of objects that form the galactic and extra-galactic foreground for the planned LOFAR-EoR experiment.



So far we have a handful of observations that give rough constraints on the reionisation process, e.g., the WMAP polarisation data, the lower redshift  $L_{\gamma}$ - $\alpha$  emitters, the temperature of the IGM and Gunn-Peterson troughs seen in the spectra of  $z > 6$  quasars. In the near future, a few experiments - most notably the EoR-LOFAR project, PAST and MWA - are designed to measure the hydrogen neutral fraction of the IGM as a function of redshift and angular position through the hyper-fine 21cm spectral line. The goal is to study the nature of the first

objects and their UV spectra responsible for ionising the IGM and to answer many other questions like: How fast the reionisation spread? Which regions ionise first, the high or low density? How many HI reionisation epoch there are (e.g, single or double reionisation)? What can we learn from the 21 cm measurements about

the matter density fluctuations at these pristine conditions? Could there be detectable individual QSO ionised HII regions against a neutral background which constrain massive QSO luminosity function, and duty cycle? etc. In short these projects will provide a treasure trove for the study of the interplay between cosmology, structure formation and the intergalactic medium.

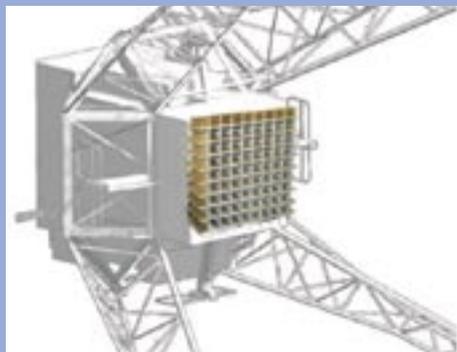
The conference was organised by the Kapteyn Astronomical Institute and LOFAR Epoch of Reionization key project and

financially supported by, KNAW, NOVA, NWO and funding provided by Prof. dr. Piet van der Kruit (associated with the Kapteyn chair). Beyond the scientific targets of the conference, the LOC had hoped also that it will, even in a modest way, to contribute the formation of this new community of people who study the Epoch of Reionization. The conference had 132 participants and a total of 70 oral Presentations, including 7 reviewers (from A.G. de Bruyn (ASTRON, Kapteyn), A. Ferrara (SISSA, Trieste), A. Loeb (Harvard), P. Madau (UC Santa Cruz), A. Meiksin (Univ. of Edinburgh), M.J. Rees (IoA, Cambridge) and W.L.W. Sargent (Caltech)) and 15 invited targeted speakers and 33 poster presentations. As one of the activities of the conference, the participants visited the ASTRON, Dwingeloo, where they had a tour in the Lab with an emphasis on LOFAR prototyping. They also had presentation on LOFAR and its promise for non-astronomy applications.

With the projected LOFAR schedules aiming at 2007 for the start of data collection of some of the experiments, the meeting brought together observers with theoreticians/simulators of the IGM and epoch of reionisation and helped focus the attention of both communities on the observational properties of the expected measurements and the various physical processes that might produce them, within the larger context of current cosmological models and physics of the IGM. [☞](#)

# Second International Focal Plane Array Workshop

On June 20-21 a large number of international experts on antenna and array technology attended the Second International Focal Plane Array Workshop in Dwingeloo. The more than 40 participants from 15 organizations discussed their technical progress in developing Focal Plane Arrays (FPA's) and presented the international plans for SKA Technology Demonstrators based on FPA's.



A Focal Plane Array system is a combination of a reflector antenna with a smart feed system. The smart feed greatly enhances the capabilities of the reflector by expanding its field of view when compared to conventional (multi)horn feeds. ASTRON recognized the potential of FPA systems for radio astronomy and started the FPA technology development four years ago. Within the EU FARADAY project the potentials of the FPA concept were explored and demonstrated. An FPA feed was installed on one of the WSRT telescopes and was used for drift scans and holographic measurements. These tests showed the feasibility of FPA's

and their capability to improve the aperture efficiency of reflectors. The FPA developments at ASTRON are being continued within the PHAROS project (part of RadioNet, see [www.radionet-eu.org](http://www.radionet-eu.org)). The PHAROS demonstrator that will be realized in 2006 extends the FARADAY results by demonstrating the FPA multi-beam capability in a cryogenically cooled system with a much lower system temperature.

Three SKA demonstrators are being developed based on FPA technology: xNTD (Australia), KAT (South-Africa) and APERTIF (The Netherlands). The development teams of these projects are collaborating intensively. The FPA workshop was therefore a very successful meeting. A first result of this collaboration is the SD-FPA whitepaper that has been written for the 2005 SKA meeting in Pune, India, from Oct. 31 - Nov 3.

The presentations of the workshop can be downloaded from: [www.astron.nl/fpaworkshop2005](http://www.astron.nl/fpaworkshop2005). 

## International center proposed

On June 10, representatives of governments and funding agencies from 11 countries met at Heathrow Airport to exchange information on the SKA project. They concluded they wish to receive a plan for international cooperation that could lead to an acceptable budget and implementation plan.

In early October, ASTRON and JIVE proposed to the Dutch government that a formal international center is needed to fulfill these requirements. As a working name, International Centre for Radio Astrophysics has been proposed. Such a center would develop remaining studies that are needed and prepare policy discussions that will be necessary for deriving a reliable project budget.

A decision on Dutch finance for the new center is expected in December and discussions with European, Chinese and other potential partners have been started.

A second meeting of governments and funding agencies is planned for February 6th in 2006 in the Netherlands to review developments. 

# European astronomy celebrated in Dwingeloo

On 7 July, Minister Van der Hoeven (Education, Culture and Science) joined EU Commissioner Potocnik (Research) in Dwingeloo to tell press representatives from across the continent about astronomy in Europe. More than 100 journalists and VIPs attended and all left with something to report: At the last count more than 100 international press articles have been published.

Attendees heard presentations of the research programs financed by the European Commission in optical and radio astronomy, and in astroparticle physics. Plans for future large facilities, including the ELT (optical-IR), SKA (radio) and KM<sub>3</sub>Net (astroparticles) were highlighted. A successful live demonstration of e-VLBI, in which the largest telescopes across the globe are connected in real-time to JIVE with high-speed fibre networks seemed to catch the imagination of many journalists, not to mention Commissioner Potocnik himself (see photo). It was particularly gratifying to hear the wide-recognition JIVE has achieved in many different areas, most recently its contribution to the ESA Huygens mission. 



Commissioner Potocnik revels in the symbolic decommissioning tape-based VLBI in Europe, launching the era of real-time e-VLBI

# OWL instruments studied



ASTRON has participated in concept studies of two projected instruments for ESO's OWL project. Finalized in October, the studies provide input for the 'Blue Book' on the feasibility of the 100-m OWL telescope concept that is favored by ESO staff as the next large optical telescope project in Europe. The Blue Book will provide the basis for a decision on starting the preliminary design phase, a decision which now is likely to be taken toward the end of next year.

The concept study for T-OWL, an instrument for imaging and spectroscopy in the thermal-IR and mid-IR wavelength regime (3 – 30 microns), was carried out jointly by groups in Heidelberg, Leiden and ASTRON, with input from more than 25 contributors at these and other institutions. A wide variety of new science would be possible with T-OWL, but among its main goals would be the study of extrasolar planets and their formation, and of the centers of active galaxies. The instrument would have a medium resolution spectral line sensitivity that surpasses that planned for JWST, and its imaging angular resolution would vary from 0,01 arcsec at 3,5 microns to 0,05 arcsec at 20 microns. Further studies of the T-OWL concept are planned as part of an FP6 ELT Design Study contract.

The concept study for EPICS – the Earth-like Planets Imaging Camera Spectrometer – was based at ESO and was informed by several working groups. ASTRON participated in the differential polarimetry working group. The primary science goal of EPICS, as its name suggests, is the detection and study of rocky planets around other stars. The technical challenge is to detect point sources at a level of  $2 \times 10^{-10}$  of the brightness of the star at 0,05 arcsec from the star. A 30-m telescope cannot even in principle achieve this performance, suggesting that OWL's 100-m aperture will ultimately be required for studying Earth-like planets around other stars.

One expects different polarization behavior of the light from the star and planets, hence differential polarization measurements may be important to achieve the necessary dynamic range. 

# Thirty organizations study SKA

Following over two years of preparation, a formal contract has now been signed with the European Commission to carry out an end-to-end design study of the SKA. On 17 and 18 November we met with our partners at the Chateau de Limelette outside Brussels – an ‘oasis of sophistication and tranquility’ according to the web-site and just the right venue both to kick-off the project and to have the contract signed. This four year project, going under the name ‘Square Kilometre Array Design Studies’ or ‘SKADS’ for short, addresses the technological readiness of the SKA project for financing in the 2010 time frame. It aims to analyze the whole SKA system, including critical studies of the Aperture-Array and Small-dish-plus-Focal-Plane-Array enabling technologies. An important goal will be to generate a reliable budget and a plausible project plan, which can be submitted with a proposal for construction financing.



*Speech of SKADS coordinator Arnold van Ardenne*

The contract brings thirty groups together from around Europe, Australia, Canada and South Africa to carry out the agreed program of work. Additional participants from the Chinese Academy of Sciences and the US SKA Consortium as well as from several commercial companies will join the effort without being formal contractual partners. ASTRON is the Commission’s formal contractual partner and our own Arnold van Ardenne ([ardenne@astron.nl](mailto:ardenne@astron.nl)) is coordinating the work. Project scientist is Steve Torchinsky from Paris Observatory ([steve.torchinsky@obspm.fr](mailto:steve.torchinsky@obspm.fr)) and Project Engineer is Andrew Faulkner from the University of Manchester ([andrew.faulkner@manchester.ac.uk](mailto:andrew.faulkner@manchester.ac.uk)). Our project officer at the Commission is ever-helpful Elena Righi-Steele ([elena.righi-steele@cec.eu.int](mailto:elena.righi-steele@cec.eu.int)). In total € 38M has been committed to the study. The main focus will be the front-end array antenna and signal processing technologies, to include system architecture, cost reduction strategies and demonstration prototyping. The feasibility and costing of the subsequent signal processing and data handling chains, through to delivery of data to the end user, will also be studied. Policy relating to intellectual property will be developed. A mid-term review of the work is scheduled for summer 2007 and a final

## Headquarters expansion

On November 16 our parent organization, NWO, approved our proposal for € 11,7M to extend our headquarters building in Dwingeloo. This will make possible the return of employees from temporary quarters in containers, the reduction of on-site staff in Westerbork and modest expansion of JIVE and ASTRON in the coming years. Knowing the extent of the possible expansion we will now start negotiations with the State Forestry Commission, from whom we lease our site in the Dwingelderveld National Park. 



*The meeting at the Chateau de Limelette*

review will take place in spring 2009. The project is large enough to have its own web site and, indeed, interested readers may keep themselves up to date on progress by surfing to [www.skads-eu.org/](http://www.skads-eu.org/). 

# VISIR 18 months later

**VISIR is installed permanently at the VLT-UT<sub>3</sub> (Melipal) of ESO in Chile. Since the installation in April 2004, VISIR has been in continuous operation without technical interruptions or servicing.**



The 'first light' of the instrument was on April 30 2004 and was the start of the first commissioning period. The commissioning went technically well, but in the end required 3 runs, due to the extreme bad weather during commissioning 2. There was hardly on-sky data during commissioning 2 and even rain was spotted on the mountain. Regular observations started at the end of 2004 with guaranteed time of the consortium and in the spring 2005 the 'open time' observations started. The instrument is used every full moon period, the 'dark time' of Melipal is being reserved for VIMOS. Some initial science results were described in the July issue of the Astronews.

In October 2005 the prime mirror of Melipal was scheduled for re-aluminisation. This was a good moment to do also some maintenance to VISIR. The closed cycle coolers for example require service every 1 to 1.5 year. Also the star-simulator needed some changes and a new thermal link for the spectrometer detector was installed. VISIR is ready again for a long period of operations, certainly to March 2006, when some additional servicing is scheduled. [🔗](#)

[www.eso.org/instruments/visir/](http://www.eso.org/instruments/visir/)

## Effelsberg first LOFAR outstation

At the end of October, the Max-Planck-Society granted funding for a LOFAR antenna station in Effelsberg (the radio observatory of the Max-Planck-Institut für Radioastronomie in Bonn). Together with an earlier pledge to provide a wide band data transport link to the observatory, the expansion of the LOFAR network outside the Netherlands is becoming reality.

A plan for a total six LOFAR stations at sites in Germany met an enthusiastic response at the annual autumn meeting of the Astronomische Gesellschaft in Cologne at the end of September. Discussions with various funding agencies in the country have started in earnest and additional grants are expected in the course of 2006. For more information see the German LOFAR White Paper at URL:

[www.mpifr-bonn.mpg.de/staff/wsherwood/LOFAR/white.paper.oct6.pdf](http://www.mpifr-bonn.mpg.de/staff/wsherwood/LOFAR/white.paper.oct6.pdf) [🔗](#)

## LOFAR CDR in progress

As we go to press, the Critical Design Review for LOFAR is under way. It is planned as a two phase process. First, roughly every two weeks starting in mid-September, a series of six critical reviews of the main sub-systems is being carried out: (1) Antennas, receivers, ADC; (2) Station digital processing; (3) Monitoring, control, specification and scheduling; (4) Wide area network and central processor; (5) Calibration; and (6) User software and key projects. Uncertainties resulting from these sub-system reviews are expected to be resolved by early in the New Year, when a final, full system level CDR will be held. Following the latter, a definitive construction budget can be finalized, and procurement and roll-out can begin. Land acquisition and planning permission for the central core and inner stations are proceeding well and are not expected to delay roll-out. 

## JIVE EXPReS

JIVE is leading the recently awarded FP6 EXPReS contract to connect European radio telescopes in real time to the correlator in Dwingeloo. ASTRON has joined the effort, which includes radio observatories across the world, and national and international networking organizations. The aim of the project is to move toward operational capability using existing 1 Gbit/sec connections and to prepare for future much higher capacity links. The project will also be important for the planned networking of new LOFAR antenna stations across the continent. 

# Photonics beam-formers studied

ASTRON's program of developing photonics processor technologies for use as array antenna beam-formers took a step forward in June with the award of an innovation subsidy grant from the Dutch Ministry of Economic Affairs. Partners in the project are the Telecommunications Engineering department of the University

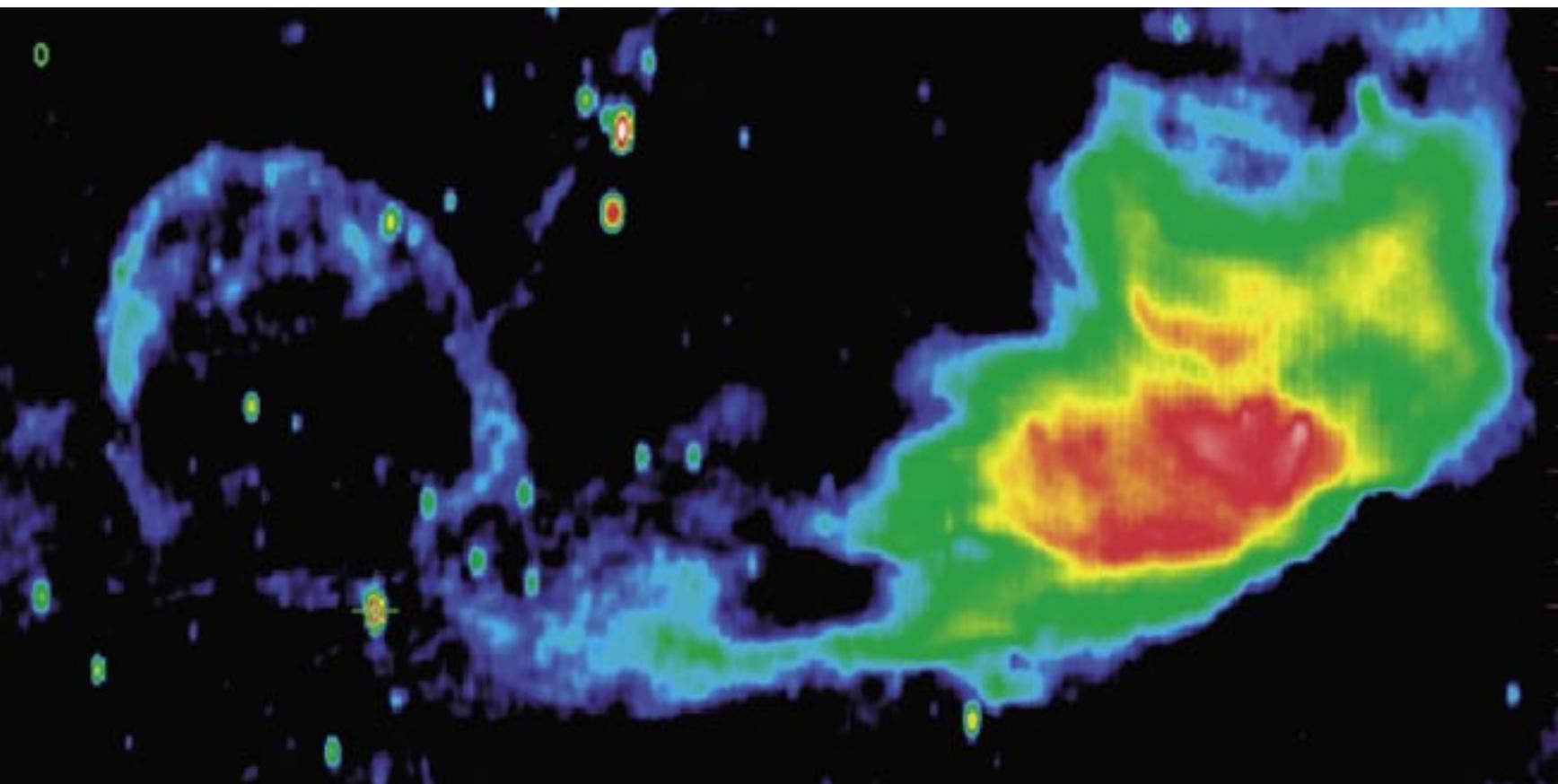
Twente and Lionix b.v., a local photonics component development and production company. The program will also be helped by a new subsidy program announced on 4 October by the Ministry for Innovative Research leading to the development of advanced photonic devices. 

## LOFAR an economic priority

The expertise built up by ASTRON and partners in the LOFAR project will be made available for innovative commercial applications. In a proposal to parliament on September 5, C. van Gennip, Dutch vice-minister for Economic Affairs, identified the

innovative potential of LOFAR technologies as a priority for further commercial development. Specific activities will be worked out during 2006 by representatives of national, provincial, and local governments together with local companies and ASTRON. 





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