LOFAR project explained...

Astronomical Institute ASTRON in Dwingeloo, The Netherlands, has been building and developing measuring instruments for astronomical research for over 50 years. A fine example of the know-how and expertise is the well-known Westerbork Radio Telescope. After a complete renewal in 2002, it is once again one of the most sensitive telescopes on Earth. Besides this radio telescope ASTRON also designs and constructs optical instruments. Built at the ASTRON facilities, these optical instruments are applied in the most advanced telescopes across our planet... and in space. At the Very-Large Telescope, the world's largest optical telescope in Chile's Atacama Desert, several instruments made by ASTRON have been installed, whereas the future James Webb Space Telescope, the successor of the Hubble Space Telescope, will use a highly advanced infrared spectrometer currently being developed at ASTRON.

Though the radio telescope in Westerbork is one of the most sensitive telescopes in the world, it can study galaxies only in the local universe. But astronomers would like to detect objects so far away that the signals have taken nearly the age of the universe to travel to us. For this, the new telescopes would have to be 100 times more sensitive. Questions such as 'what is the history of the universe' and 'which objects formed first after the birth of the universe' can therefore not now be answered. At the ASTRON laboratory in Dwingeloo enthusiastic astronomers and technicians are involved in developing an ultramodern new radio telescope. This new instrument is called LOFAR. It will open up new ways to do innovative, in-depth research.

Project objectives

This more sensitive telescope sees stars, galaxies, black holes and other objects that are farther away. Because the speed of light is limited, they also 'see' further back in time. This next generation of telescopes should be able for the first time to see the entire history of the Universe.

The basic technology of radio telescopes hasn't changed since the 1960's – large mechanical dish antennas collect signal before a receiver detects and analyses it. Half the cost of these telescopes lies in the steel and moving structure. A telescope 100x larger than existing instruments is therefore unaffordable (tens of billions of dollars). So new technology is required. LOFAR is the first telescope of this new sort.

LOFAR test facility, ca 200 m in diameter

ASTRON LOFAR

Software telescope?

Instead of 'mechanical signal processing' with a dish antenna, LOFAR detects the incoming signals using an array of simple omni-directional antennas, the electronic signals from which are digitised, transported to a central digital processor, and combined in software to emulate a conventional antenna. In essence, LOFAR is a large number of FM-radios, each tuneable in frequency and the signals from which combine in the central processor to produce a 'software telescope' having no moving parts (or in fact by copying the signals in software, any number of separate telescopes looking in separate directions). The cost is dominated by the cost of electronics and will follow Moore's law, becoming cheaper with time and allowing increasingly large telescopes to be built.

So LOFAR is an IT-telescope. The antennas are simple enough but there are a lot of them – 15000 in the LOFAR design.

A cluster of LOFAR antenna's

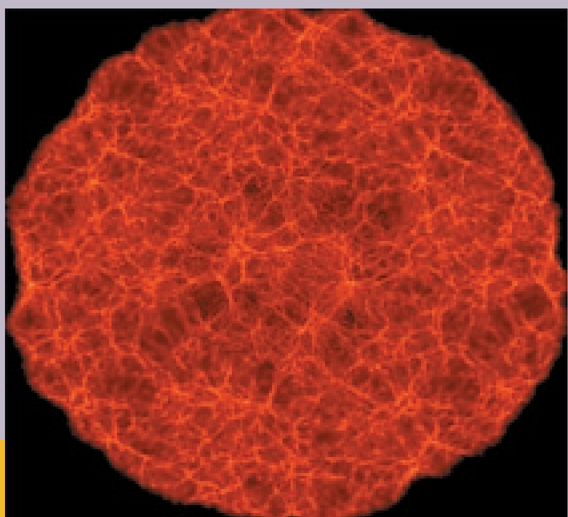
To make radio pictures of the sky with adequate sharpness, these antennas are to be arranged in clusters that are spread out over an area 350 km in diameter. Data transport requirements are in the range of many Tera-bits/sec and the processing power needed is tens of Tera-FLOPS. LOFAR is a challenge to realize with current technology but not impossibly so. Industrial R&D in the IT-sector is aiming to achieve similar performances. Direct connection to Internet for totally remote and distributed operation by groups of scientists around the world, each controlling its own software telescope (while sharing the same hardware), is the goal.

Looking back in time

LOFAR is designed to see objects so far away that their radio signals were emitted just after the Big Bang. One expects in fact to be able to detect the very first objects – were they stars, galaxies, black holes?

But it will also provide unique insights into magnetic storms on the Sun and the solar wind, and how they affect the climate on Earth. It will detect and study the highest energy cosmic rays single protons having the energy of a golf-ball on the driving range and the very existence of which theoreticians cannot explain.

And it will help interpret the signals from other telescopes, but providing essential physical information not otherwise available.



Theoretical modeling of objects condensing from BigBang fireball

Generic sensor array

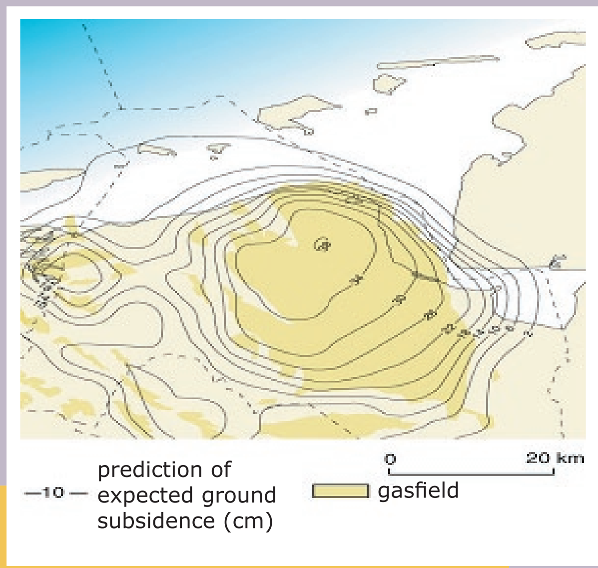
Thinking for a moment 'out of the box' leads one to the realization that these antennas are just sensors. Other sensors might also be attached and share use of the data transport and computational facilities. In the first instance, the Dutch LOFAR team at ASTRON would like to attach seismic geophones, bio-sensors and weather instruments. LOFAR would then become a sensor platform not only for astronomers but also for geophysicists and agricultural scientists. The challenge in this case is not so much technological as sociological – how to get very diverse groups of researchers to share the facility.

Imaging the underground

And it is sinking much faster than predicted. As natural gas is pumped out from under the northern Netherlands, the ground is sinking. The sea is also rising and together the country has a problem – how many new pumping stations are needed and when should the dikes be reinforced?

It could be important to understand in more detail how the underground gas reservoirs behave. High quality seismic imaging of reservoirs over long periods is required.

Theory says that dynamite or earthquakes are not necessary for seismic imaging, that naturally occurring acoustic rumblings should allow sharp pictures of the deep underground to be constructed, if only one can install a permanent, dense array of geophones and integrate for long periods. Siting LOFAR infrastructure appropriately will make that possible for the first time, and should allow the collapse behaviour of gas reservoirs to be studied during their production lifetime.



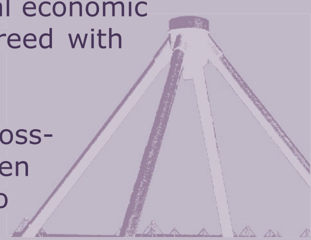
Ground subsidence in Northern Netherlands

Managing crop growth

Agriculture is one of the pillars of the Dutch economy. Green-house produce is and will remain a thriving industry even while reduced subsidies will cause traditional farming to decline. A natural extension of green-house farming is so-called 'precision agriculture' in which one maximizes production and profit by monitoring environmental factors and then optimising production on a very local scale. Required are accurate weather forecasts, not over areas of tens of kilometres but at the sub-km scale; growth models and sensors to monitor growth and pests; and integration of biological decision-making tools with dynamic market information. The LOFAR IT-infrastructure will serve as a platform for forward-thinking Dutch agricultural scientists to explore strategies for economically viable precision agricultur.

European dimension

ASTRON is also working with international groups to make LOFAR a reality. In Europe, groups at universities and research institutes in Germany, France, Sweden and the UK have been participating in defining and refining the science program. Centers of research expertise are being connected directly to LOFAR by the very broadband data transport fibers of the European Union's Géant project, and will be able to operate the sensor network of specific interest on-line from distributed control rooms. On the technology side, Lucent Technologies has been involved in R&D relating to the high capacity data transport network. IBM Research has joined with ASTRON to develop the central processor as part of the BlueGene development program. Plans for stimulating regional economic development based on the commercial spin-off from LOFAR have been agreed with local governments in the North Sea region.



The innovation proposed in the LOFAR project is substantial and the cross-disciplinary vision being promoted is unusual. The team at ASTRON has taken the lead in LOFAR and given the small size of the country is committed to realizing a distributed, fully international research platform.

How the project is financed

The LOFAR project has an overall budget of 148 million Euros. In order to finance the project, the Dutch provinces of Drenthe, Friesland and Groningen provided a start subsidy to allow the design of the facility to proceed. The parties participating in the project then requested the nation Dutch government to subsidize LOFAR within the framework of the Lisbon Strategy for promoting the knowledge infrastructure. At the end of 2003, the Dutch Cabinet agreed to provide a subsidy of € 52,000,000. Thanks to this subsidy and to the contributions of the 18 organizations (universities, research institutions and businesses) together forming the LOFAR consortium, LOFAR can now be built in the Netherlands.

The LOFAR site

A suitable location has been found for the centre core of LOFAR in the northern Dutch province of Drenthe, within the borders of the municipality of Borger-Odoorn. Since the end of the year 2003 a test facility is already active in this area. It consists of one hundred radio frequency sensors, and which provides the basis for further development of the underlying concepts of LOFAR. The area can be characterized as a large unpopulated agricultural area cut in two by a channelled stream.

Spread over an elliptical area of 320 ha approximately 4500 antennas with a maximum height of 2 metres will be positioned in clusters. It’s a challenge for LOFAR to fit into the overall landscape, in which natural development and agriculture play a prominent role. The area will also offer a chance for developing cycle and bridle paths and small-sized daytrip facilities.

New zoning regulations will enable the construction of the radio telescope. The enactment of the new zoning scheme will come into effect in 2005. The local population welcomes LOFAR being situated in their area. Farmers whose land is disowned will be provided with new land, which is sometimes even of a better quality for their purposes.

LOFAR testsite, Exloo

The sites for the approximately 45 separately situated antenna stations, each of approximately 4 hectares, will be placed along the 5 imaginary arms radiating from the central core, and will be selected on the basis of the technical requirements set by LOFAR and the local situations. And of course, these antenna stations too are positioned in such a way that the natural environment of the landscape will be disturbed as little as possible.

For more information:
www. lofar.org

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