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# A very brief description of LOFAR – the Low Frequency Array

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**Abstract.** LOFAR (Low Frequency Array) is an innovative radio telescope optimized for the frequency range 30-240 MHz. The telescope is realized as a phased aperture array without any moving parts. Digital beam forming allows the telescope to point to any part of the sky within a second. Transient buffering makes retrospective imaging of explosive short-term events possible.

The scientific focus of LOFAR will initially be on four key science projects (KSPs): 1) detection of the formation of the very first stars and galaxies in the universe during the so-called epoch of reionization by measuring the power spectrum of the neutral hydrogen 21-cm line (Shaver et al. 1999) on the  $\sim 5'$  scale; 2) low-frequency surveys of the sky with of order  $10^8$  expected new sources; 3) all-sky monitoring and detection of transient radio sources such as gamma-ray bursts, x-ray binaries, and exo-planets (Farrell et al. 2004); and 4) radio detection of ultra-high energy cosmic rays and neutrinos (Falcke & Gorham 2003) allowing for the first time access to particles beyond  $10^{21}$  eV (Scholten et al. 2006). Apart from the KSPs open access for smaller projects is also planned. Here we give a brief description of the telescope.

**Keywords.** instrumentation: interferometers, telescopes, cosmology: observations, cosmic rays

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## 1. LOFAR - how it works

In its first phase LOFAR will consist of 77 *stations* distributed within a ring of  $\sim 100$  km diameter. 32 stations will be clustered in a central core of  $\sim 2$  km diameter located in the North-Eastern part of the Netherlands near the village of Exloo. Each station has two antenna systems: the Low-Band and High-Band Antennas (LBA, HBA). The LBA system operates primarily in the frequency range 30-80 MHz with a switch to observe over a 10-80 MHz band as well. The HBA is optimized for the range 110-240 MHz with a possibility to observe up to 270 MHz with lower sensitivity. The LBA field is 60 m in

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diameter and contains 96 inverted-V crossed dipoles oriented NE-SW and SE-NW (i.e. dual polarization) in a randomized distribution with a slight exponential fall-off in density with radius. The HBA field consists of 96 tiles distributed in an as yet undetermined manner over roughly 50m. Each tile consists of a 4×4 array of bowtie-shaped crossed dipoles with an analog 5-bit beam former using true time delays. Radio waves are sampled with a 12-bit A/D-converter – to be able to cope with expected interference levels – operating at either 160 or 200 MHz in the first, second or third Nyquist zone (i.e., 0-100, 100-200, or 200-300 MHz band respectively for 200 MHz sampling). The data from the receptors is filtered in  $512 \times 195$  kHz sub-bands (156 kHz subbands for 160 MHz sampling) of which a total of 32 MHz bandwidth (164 channels) can be used at any time. Data from each receptor can be buffered in a transient buffer board (TBB) for as long as  $\sim 10\text{min}/(\Delta\nu/196\text{kHz})$ . Subbands from all antennas are combined on station-level in a digital beamformer allowing 8 independently steerable beams which are sent to the central processor via a glas fibre link that handles 0.7 Tbit/s data. The beams from all stations are further filtered into 1 kHz channels, cross-correlated and integrated on typical timescales of 1-10 seconds. The integrated visibilities are then calibrated on 10 second intervals to remove the effects of the ionosphere and images are produced. Channels with disturbing radio frequency interference (RFI) are dropped. For the correlation we use four of the six racks of an IBM Blue Gene/L machine in Groningen with a total of  $\sim 12000$  processors. We expect a typical input rate of  $\sim 0.5\text{Tbit/s}$  into the computer. Unix clusters are used as input and output nodes for pre- and postprocessing.

The expected  $3\sigma$  point source sensitivities of LOFAR for one hour integration over 4 MHz bandwidth dual-polarization are 2 mJy, 1.3 mJy, 70  $\mu\text{Jy}$ , and 60  $\mu\text{Jy}$  at 30, 75, 120, & 200 MHz respectively. The resolution will be 25", 10", 6", and 3.5" for the same frequencies. The field of view is  $3^\circ$  at 150 MHz (HBA) and  $7.5^\circ$  at 50 MHz (LBA).

The project is currently in discussions with consortia in Germany, UK, France, Italy, and Sweden to expand the baseline and increase the resolution by up to a factor of ten.

National funding of LOFAR has been obtained at a level of  $\sim 75$  MEuro plus various in-kind contributions. Construction of the first station was completed in September 2006. Further stations are expected to be rolled out in the course of 2007, so that commissioning and start of operation is foreseen for the year 2008.

## 2. Outlook and Conclusions

With its new concept (Bregman 2000) of a broad-band aperture array and digital beamforming LOFAR is expected to pave the way for a new generation of telescopes and to be an important pathfinder for the Square Kilometre Array. LOFAR will improve the resolution and sensitivity of previous telescopes for continuum observations by roughly two orders of magnitude over a wide frequency range. It will also provide instantaneous access to a large fraction of the sky at low frequencies at once, making serious and regular all-sky radio monitoring possible for the first time. With these unusual properties LOFAR promises a wealth of new discoveries.

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