



Polish LOFAR - a low frequency radio interferometer

Polish LOFAR Consortium (POLFAR)

1: Scientific justification

Polish astronomers are participating in the development and use of a radio astronomical instrument of new generation: Low Frequency ARray - LOFAR, exploring yet poorly studied range of low (<300 MHz) frequencies. It constitutes a European array of thousands of antennas - a challenge for data transfer and processing techniques. LOFAR studies objects in early Universe (like the high-redshift neutral hydrogen) and cosmic plasma in conditions unreachable in earth-based laboratories: densities either very high (pulsars) or extremely low, temperatures ranging from single Kelvins to millions of degrees and a wide range of magnetic field strengths. This research is important for Sun-Earth system plasma monitoring and for plasma technologies. To fulfill the conditions to participate in LOFAR Polish astronomers established the national consortium - POLFAR and plan to build three LOFAR stations in Poland, also hosting reference stations for the Global Navigation Satellite System (GNSS) and equipment for commercial programs: Soil, Water and Energy Exchange (SWEX), AGRO-FIZ and meteorological research.

Following research is planned by POLFAR members:

1. Jagiellonian University (main coordinator of POLFAR): turbulent, magnetized plasma in galaxies and in giant radio sources
2. Nicolaus Copernicus University in Toruń: violent plasma processes occurring near black holes in active galactic nuclei.
3. Space Research Center of Polish Academy of Sciences, Warszawa: solar outbursts and their influence near Earth plasma. Results are directly applicable in space weather nowcasting and forecasting thus, are important for ionospheric correction for LOFAR installation and for the satellite technology.
4. University of Zielona Góra: relativistic, extremely magnetized plasma around pulsars - a perfect laboratory of highly energetic plasma
5. Nicolaus Copernicus Astronomy Centre of Polish Academy of Sciences, dept. in Toruń: magnetospheres of giant solar planets - important for plasma physics in our Solar System.
6. University of Szczecin: participation in studies of high-redshift galactic nuclei, studying the activity of cool dwarf stars and of magnetospheres of their planets.
7. University of Warmia and Mazury, Olsztyn - participation in studies of pulsars, magnetospheres of extrasolar planets and of neutral hydrogen in early Universe as well as in GNSS and AGRO-FIZ projects, space weather services.
8. University of Environmental and Life Sciences in Wrocław will participate in the GNSS and AGRO-FIZ projects and in the geodynamical research.

2: Technical description

The LOFAR facilities in Poland will be distributed among three sites: Łazy (East of Kraków), Borówiec near Poznań and Bałdy near Olsztyn. All they will be connected via **PIONIER** dedicated links to Poznań. Each site will host one LOFAR station (96 high-band+96 low-band antennas). They will most time work as a part of European network, however, when less charged, they can operate as a national network. Stations will be maintained by institutes owning particular sites: Jagiellonian University (Łazy), Space Research Center of Polish Academy of Sciences (Borówiec) and University of Warmia and Mazury (Bałdy). From this point of view LOFAR will constitute a distributed network. It will be coordinated by the Polish Consortium POLFAR acting as a national centre. POLFAR will include also five other institutes (see Sect. 1) not involved in constructing the stations but contributing significantly to the scientific program of the LOFAR facility. POLFAR Consortium will also be the unique partner with relations to LOFAR Headquarters in the Netherlands and other national consortia performing common research projects with the use of all LOFAR stations, inside and outside of Poland. We expect at least 15 years of operational time for LOFAR intereferometer.

The development of astrophysical instruments constitutes a powerful driving force for modern technologies. This also holds for LOFAR - a network of elements (stations) with its core located in the Netherlands. LOFAR uses the most advanced technique of "phased array": the instrument's directional diagram (defining its resolution) is formed by combining signals from all individual antennas with a properly computed matrix of phase lags. While the antennas are mechanically simple (hence of a low costs), a proper combining of signals, focusing the array in the required direction is a challenge to contemporary techniques of data transfer and processing.

LOFAR consists of 36 stations in the Netherlands and at least 8 in other European countries. We plan to built till 2015 three more stations in Poland: in Łazy near Kraków, Borówiec near Poznań and Bałdy near Olsztyn. This is the smallest number enabling the operation of Polish stations as an independent interferometer when less heavily used in the whole system. Each station is a cluster of 96 high-frequency (120 - 240 MHz) and the same number of low-band (30 - 80 MHz) immobile antennas. This is a very important frequency range for the cosmic plasma physics. In this spectral domain we can observe for a first time the regions of normal and radio galaxies yet unseen at higher frequencies: their radio flux rapidly fades with frequency because of ageing population of high-energy relativistic electrons. This is also the optimum domain for observing the radio emission from magnetospheres of pulsars and giant (solar or extrasolar) planets. LOFAR will also give us chance for monitoring and diagnostic of different processes in space plasma. All this provides a trip to yet unexplored domains of the Universe. The data from all our stations will be sent online to Poznań via fast (GB/s) PIONIER network and then to the correlator in the Netherlands. This will be a good test for the PIONIER fast digital network. We also plan to set up our local POLFAR correlator in Poznań, enabling the aforementioned use of our local network.

To build the stations we are not expected to construct the hardware: the Dutch LOFAR centre offers the purchase of all the antennas, including their mounting and wiring. They will also sell us the receivers and digital equipment. We are expected to carry the costs of ground preparation, trenching and costs of further operation

Łazy - 20 km from Kraków, near Bochnia, Jagiellonian University, Institute of Geography and Spatial Management



Baldy - 20 km from Olsztyn, University of Warmia and Mazury



Borówiec near Poznań, Space Research Center of Polish Academy of Sciences. Astrogeodynamic Observatory. Fibre Internet connection to Poznań main node!



3. Status of LOFAR

In June 2010 the project of building 3 Polish LOFAR stations was placed on the list of the Polish Roadmap for Research Infrastructure

We applied for money to Ministry for 3 LOFAR stations and the decision was positive ...

Cycle observations last summer!

**MKSP LC0_043 Cycle 0 observations
(nearby galaxies)**

Target	Band	Coordinator	Proposed Observer	Actual Observer (1)	Requested Observation Date (2)	Possible Dates (3)	Total Observing Time (4)	Observed / Planned 10.5.2013
M31	HBA (110-190)	Beck	Giessuebel		New Time requested	Oct - Nov	8h	26-Sep
	LBA (30-88)	Beck	Giessuebel			Oct - Nov	8h	27-Sep
M33	HBA (110-190)	Heald	Paladino		New Time requested	Oct	8h	24-Oct
	LBA (30-88)	Heald	Paladino			Oct	8h	10-Oct
M51	HBA (110-190)	Heald	Horneter	Mulcahy	April 2013	Mar - May	8h	13th
M81/M82	HBA (110-190)	Detmar	Adebahr	Adebahr	February 2013	Dec - Apr	5h + 5h (c)	25th
	LBA (30-88)	Detmar	Adebahr	Adebahr	February 2013	Dec - Apr	5h + 5h (c)	25th
NGC891	HBA (110-190)	Beck	Mulcahy		Cycle 1	Oct - Dec	---	
	LBA (30-88)	Beck	Mulcahy			Oct - Dec	---	
NGC3079	HBA (110-190)	Detmar	Sotomayor	Sotomayor	Mar-Apr-2013	Dec - Apr	---	(e)
	HBA (110-190) d)	Conway	Varenius, Batejat			Dec - Apr	---	
NGC4531	HBA (110-190)	Beck	Sotomayor	Sotomayor	Mar-Apr 2013	Mar - Apr	8h	13th
NGC8946	HBA (110-190)	Chyzy	Jurusk	Jurusk	August 2013	1.8 - 20.10.	8h	15-Jul
IC342	HBA (110-190)	Beck	Mulcahy	Mulcahy, Adebahr / v. Eck, Pietka	Feb 2013	8h: 10.9 - 10.2.	5h + 5h (c)	25th
	LBA (30-88)	Beck	Mulcahy	Mulcahy, Adebahr	Feb 2013	Oct - Feb	5h + 5h (c)	25th
M101	HBA (110-190)	Heald	Torbio	Heald / Torbio	April 2013 (b)	Mar - May	8h	13th
NGC3627/3628	HBA (110-190)	Paladino	Drazdga	Paladino	March 2013	max 5h: now - 10.4	4h + 4h	29th
IC10	HBA (110-190)	Scaife	Haesen	Haesen	September 2013	Sep - Nov	8h	26-Aug
	LBA (30-88)	Scaife	Haesen	Haesen	September 2013	Sep - Nov	8h	26-Aug
Heinberg 124	HBA (110-190)	Chyzy / Bomans	Nikiel-Wroczyński	Nikiel-Wroczyński	September 2013	Dec - Apr	---	
Stephans Quintet	HBA (110-190)	Chyzy / Urbaniak	Nikiel-Wroczyński	Nikiel-Wroczyński	September 2013	Sep	8h	19-Aug
M33 Way 9999	HBA (110-190)	Havenkorn		Van Eck Jones				
Beck's HBA	HBA (110-190)	Havenkorn		Van Eck Jones				