EPSC Abstracts
Vol. 10, EPSC2015-920, 2015
European Planetary Science Congress 2015

Nanosats for a Radio Interferometer Observatory in Space

B. Cecconi (1), S. Katsanevas (2), D. Puy (3), M. Bentum (4) and team NOIRE.

(1) LESIA, CNRS-Observatoire de Paris, Meudon, France. (2) APC, Univ. Paris 7 Denis Diderot, Paris, France. (3) D. Puy, LUPM, Univ. de Montpellier, Montpellier, France. (4) Univ. Twente, Netherlands.

Email: baptiste.cecconi@obspm.fr

Abstract

During the last decades, astronomy and space physics changed dramatically our knowledge of the evolution of the Universe. However, our view is still incomplete in the very low frequency range (1- 30 MHz), which is thus one of the last unexplored astrophysical spectral band. Below 30 MHz, ionospheric fluctuations severely perturb ground-based observations. They are impossible below 10 MHz due to the ionospheric cutoff. In addition, man made radio interferences makes it even more difficult to observe from ground at low frequencies. Deploying a radio instrument in space is the only way to open this new window on the Universe.

Among the many science objectives for such type of instrumentations, we can find cosmological studies such as the Dark Ages of the Universe, the remote astrophysical objects, pulsars and fast transients, the interstellar medium. The following Solar system and Planetary objectives are also very important:

- Sun-Earth Interactions: The Sun is strongly influencing the interplanetary medium (IPM) and the terrestrial geospatial environment. The evolution mechanisms of coronal mass ejections (CME) and their impact on solar system bodies are still not fully understood. This results in large inaccuracies on the eruption models and prediction tools, and their consequences on the Earth environment. Very low frequency radio imaging capabilities (especially for the Type II solar radio bursts, which are linked with interplanetary shocks) should allow the scientific community to make a big step forward in understanding of the physics and the dynamics of these phenomena, by observing the location of the radio source, how they correlate with their associated shocks and how they propagate within the IPM.
- Planets and Exoplanets: The Earth and the fourgiant planets are hosting strong magnetic fields producing large magnetospheres. Particle acceleration are very efficient therein and lead to emitting intense low frequency radio waves in their auroral regions. These radio emissions are produced through the Cyclotron Maser Instability (CMI). Locating the radio sources and tracing back their path along magnetic field lines leads to the particle acceleration regions. This diagnostic is powerful remote sensing tool for studying the dynamics of planetary magnetospheres. Planetary lightnings are also a source electromagnetic radiation, which allows us to sound both planetary atmospheric and ionospheric properties. Finally, the potential observations of exoplanetary radio emissions at low frequencies are a very promising way of getting intrinsic properties of exoplanets such as their sidereal rotation period, the inclination of their rotation axis or magnetic axis, the intensity of their internal magnetic field, etc…

Current status

Dutch teams (Universities of Twente, Delft and Nijmegen, and the ASTRON institute in Dwingeloo) are leading a series of studies on space based radio interferometric instrumentation using miniaturized multiple platforms (swarms or constellations). These teams contributed to LOFAR instrument (30 MHz-250MHz), LOw Frequency ARray, which is the largest current low frequency instrument on Earth. Despite a limited space instrumentation expertise, these teams have built a serious road map towards a sapce based very low frequency radio interferometer (~1 kHz to ~100 MHz). Their archetypal project is OLFAR (Orbiting Low Frequency Array). This road map includes a series of technology demonstrators using cubesats (http://www.delfispace.nl). Many technical papers were published after their studies. Four PhD students are currently working on OLFAR at TU Twente, under the supervision of Mark Bentum. The OLFAR team is now seeking collaboration in Europe. Since the last two years, the NLAP (Netherland Low frequency Astromony Plateform) workshop is yearly organized and is dedicated to the study of very low frequency radio interferometry..

Within this collaboration platform, a space mission proposal was prepared for the ESA-CAS S2 call of 2015. The science objectives of the DSL (Discovering the Sky at the Longuest wavelengths) mission are those presented above. The proposal was unfortunately not selected by ESA, but other projects are in preparation.

Proposed Study

We are proposing to prepare a road map to guide the community towards a space based radio interferometer. The following points will be studied:

- identification of the main science objectives, with a possible scaling in time: Sun-Earth interactions, planetary magnetospheres, Galactic mapping, astrophysical objects, cosmology…
- Instrumental requirements after these science objectives: Interferometer (size and array configur-ation, temporal, angular and spectral resolutions) ; effective area (number of array nodes) ; instantaneous sensitivity (performance of the receiving chain) ; integrated sensitivity (mission duration, duty cycling)
- Translation in terms of platform constraints: constellation or swarm, need for a mother spacecraft ? measurments and computations on the same nodes or usage of various type of nodes ; pointing, location, ranging performance ; inter-satellite communication ; dimensioning of the TC/TM link ; power dimensioning
- State of the art of the radio detector part. (on the shelf instrumentation or R&D needed). Additional constraints on power or EMC.
- State of the art of the platform part. nanosatellite ? standard nanosatellite (cubesat) ; specific nanosatellite?
- Assesment studies (power, swarm, downlink, inter-node communication, computing power, sampling, calibration…),
- Identification of existing software or algoritmic technologies useable for such an instrument,
- identification technological hard points : plateform, instrumentation, software

This series of study has been proposed to CNES under the name of the NOIRE proposal (Nanosats pour un Observatoire Interférométrique Radio dans l'Espace).

Team NOIRE

Core Labs :

LESIA, Obs. Paris, France :
B. Cecconi, P. Zarka, L. Lamy, M. Moncuquet,
C. Briand, M. Maksimovic, R. Mohellebi,
A. Zaslavsky, Y. Hello, B. Mosser, B. Segret.

APC, Univ. Paris 7 Denis Diderot, France :
M. Agnan, M. Bucher, Y. Giraud-Heraud, H. Halloin,
S. Katsanevas. S. Loucatos, G. Patanchon,
A. Petiteau, A. Tartari

LUPM, Univ. Montpellier, France :
D. Puy, E. Nuss, G. Vasileiadis

Other Labs

CEA/SAp/IRFU , Saclay, France : J. Girard ;
ONERA/Toulouse, France : A. Sicard-Piet ;
IRAP, Toulouse, France : M. Giard ;
GEPI, CNRS-Obs. de Paris, France : C. Tasse ;
LPC2E, CNRS-Univ. d'Orléans, France :
J.-L. Pinçon, T. Dudok de Wit, J.-M. Griessmeier ;

C2S/TelecomParis, France : P. Loumeau, H. Petit, T. Graba, P. Desgreys, Y. Gargouri

Space Campuses

Centre Spatial Universitaire de Montpellier-Nîmes, Université de Montpellier : L. Dusseau ;
Fondation Van Allen, Institut d'Électronique du Sud, Université de Montpellier : F. Saigné ;
Campus Spatial Diderot, UnivEarthS, Sorbonne Paris Cité : M. Agnan ;
CERES, ESEP/PSL : B. Mosser, B. Segret