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Solar system radio emissions studies with the largest low-frequency radio telescopes

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Abstract

We describe the trends and tasks in the field of low-frequency studies of radio emission from the Solar system's objects. The world's largest decameter radio telescopes UTR-2 and URAN have a unique combination of sensitivity and time/frequency resolution parameters, providing the capability of the most detailed studies of various types of solar and planetary emissions.

1. Introduction

Study of Solar System objects becomes more and more relevant task. On the one hand, the safety of space missions, in terms of predicting the geomagnetic perturbations, requires a detailed and continuous study of the Sun, the solar wind and other factors of Solar-terrestrial relations. On the other hand, study of almost all planets of Solar System allows to generalize physical and chemical processes at their surfaces and in their atmospheres, such as e.g. thunderstorm activity. Its products are the non-equilibrium organic an non-organic chemical compounds, which could provide an insight to the origin of life.

2. Facility and methods

UTR-2 (Ukrainian T-shaped Radio telescope, 2 modification) [1, 2], URAN (Ukrainian Radio interferometer of Academy of scieNces), LOFAR (LOw Frequency ARray) have relatively large sensitivities. NDA (Nancay Decameter Array) and separate stations of LOFAR and GURT (Giant Ukrainian Radio Telescope) are more modest instruments which nevertheless provide full polarization capabilities and potential long duty cycles for large survey programmes. All these telescopes are equipped with powerful receivers (including spectropolarimeters and waveform capture receivers at 66...320 Msamples/second). They all have a common spectral range around 30...80 MHz, which allows for cross-calibrations and long baseline observations (VLBI, up to 3000 km baselines). VLBI observations with up to 2000 km baselines start to be regularly performed with e-LOFAR, and they can be extended by the use of UTR-2 or URAN when the frequency range permits. But even in different frequency ranges, simultaneous observations will increase the bandwidths of study, improve the Radio Frequency Interference (RFI) immunity and separate the ionospheric fluctuations and characteristic scintillation effects from the intrinsic time-frequency variations of the received emissions.

3. Trends and prospects of the low-frequency observations

The world's largest low-frequency (LF) radio telescopes such as UTR-2, LOFAR, LWA are operating in one of the most interesting and promising frequency ranges. It covers the maximum of radio emission of Jupiter-Io system, various signatures of thermal and non-thermal processes in the Solar corona, lightning in the planetary atmospheres etc. The achievements, already obtained in the low-frequency range [3, 4, 5] promise further results in the area of variable/pulsed/transient LF emissions study.
Scientific objectives include:
(1) detection and study of extremely diverse LF Solar radio emission, fine structure of radio bursts, coronal mass ejection and comparison between different types of radio emission mechanisms [6].
(2) the study of fine structure of Jovian decameter radio bursts includes the electric potential jumps

aligned with the Io-Jupiter field line, the microstructure of the bursts and its theoretical interpretation, the classification of time-frequency structures, and the source imaging [7]; waveform and time-frequency observations with exquisite sensitivity and resolution, provided by UTR-2 and URAN [8].
(3) the study of Saturn's lightning (fine structure, energetics, interplanetary propagation effects) with UTR-2 and LOFAR. This topic was initiated at UTR-2 and LOFAR, whereas first ground-based detections were made at UTR-2 [9]. Beyond the detailed study of Saturn's lightning we are planning to carry out the similar search in Uranus, Venus, and Mars atmospheres, providing unique insights to atmospheric physics and dynamics.
(4) the study of interplanetary scintillation (IPS) effects on radio sources such as Cas A, simultaneously with UTR-2, URAN and NDA in order to disentangle IPS and ionospheric effects.
Some of the aforementioned programmes will benefit from and provide complementary ground-based radio observations to the spacecrafts:
- STEREO for (1),
- JUNO for (2), which will explore Jovian decameter radio sources in situ while ground-based measurements will provide ultra-high time/frequency resolution observations, including full polarization; and
- CASSINI for (3), which already provides the reference detections and statistics from Saturn's orbit, until 2017.

Also, our LF expertise led us to get involved in preparatory projects and studies about radio astronomy from the (far side of the) Moon [10]. These prospective activities will extend to the scientific preparation of SOLAR ORBITER and JUICE missions.

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