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LOFAR Ionospheric Research Group - Advancing Ionospheric Studies through Radio Astronomy

Przepiórka-Skup Dorota[(1)], Mevius Maaijke [(2)], Dorrian Gareth[(3)], Beser Katarzyna[(4)], Kotulak Kacper[(5)], Jānis Šteinbergs[(6)], Matyjasiak Barbara[(1)], Pożoga Mariusz[(1)], Grzesiak Marcin[(1)], Rothkaehl Hanna[(1)], Spogli Luca[(7)], Ghidoni Rebecca[(7,8)], Woods Alan[(3)], Fallows Richard[(9)], Flisek Paweł[(5)], Froń Adam[(5)], Krankowski Andrzej[(5)], Forte Biagio[(10)], Boyde Ben[(3)], RapoportYuriy[(5)], Kinsler Paul[(10)], and Lu Tianchu[(10)]

(1) Centrum Badań Kosmicznych Polskiej Akademii Nauk, Bartycka 18A, 00-716, Warsaw, Poland, e-mail: dprzepiorka@cbk.waw.pl

(2) Astron, The Netherlands institute for Radio Astronomy, Dwingeloo, the Netherlands

(3) Space Environment and Radio Engineering (SERENE) group, University of Birmingham, United Kingdom

(4) New Jersey Institute of Technology, USA

(5) University of Warmia and Mazury, Poland

(6) Ventspils University of Applied Sciences, Engineering Research Institute "Ventspils International Radio Astronomy Center", Ventspils, Latvia

(7) INGV. Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy

(8) University of Bologna, Italy

(9) UK Research and Innovation (UKRI) Science & Technology Facilities Council (STFC) - Rutherford Appleton Laboratory (RAL) Space, United Kingdom

(10) Department of Electronic and Electrical Engineering, University of Bath, United Kingdom

The Earth's ionosphere, a dynamic ionised medium, plays a crucial role in radio wave propagation. While it enables radio communication, it also introduces distortions that impact both communication systems and astronomical observations. These effects become particularly pronounced at low frequencies, where ionospheric disturbances limit the resolution and accuracy of radio interferometry. In extreme cases, they can make observations nearly impossible. Understanding and mitigating these distortions is a shared objective of both radio astronomy and ionospheric research.

LOFAR (LOw Frequency ARray) is one of the most advanced radio interferometers in the world, operating in the 10-80 MHz (LBA – Low Band Antenna) and 110-240 MHz (HBA – High Band Antenna) frequency ranges. It consists of 52 stations, most of which are located in the Netherlands, with additional stations spread across several European countries, and more to come in the near future. Each station functions as an independent interferometer, and when combined, the array spans baselines ranging from 100 m to 2000 km. This configuration makes LOFAR not only a powerful instrument for radio astronomy but also an exceptional tool for studying the ionosphere.

Recognising LOFAR's unique capabilities for ionospheric research, the LOFAR Ionospheric Research Group (LIRG) was established to systematically investigate ionospheric dynamics and their effects on radio observations. The group brings together researchers working on ionospheric science and radio astronomy, facilitating cross-disciplinary collaboration. LIRG's research focuses on analyzing plasma velocities, ionospheric scintillations, and Traveling Ionospheric Disturbances (TIDs), as well as modelling atmospheric influences and studying extreme space weather events, including the May 2024 geomagnetic storm. Single-station studies further provide localised insights into ionospheric variability.

In addition to fundamental research, LIRG works on practical applications aimed at improving observational strategies and data calibration techniques. The group is developing dynamic scheduling methods to refine LOFAR's observation planning based on ionospheric conditions. It also explores the usability of bright extragalactic radio sources (3C sources) to probe ionospheric variations and advances Direction, Time, Amplitude, and Phase Calibration (DTAC) techniques to enhance ionospheric correction methods in radio astronomical data processing.

LIRG is also actively involved in the development of LOFAR 2.0, an upgrade that includes hardware improvements and enhanced operational procedures. These advancements will significantly enhance the real-time

monitoring and analysis of ionospheric conditions, further strengthening LOFAR's role as a dual-purpose tool for both radio astronomy and ionospheric research.

By bridging the gap between ionospheric science and radio astronomy, LIRG not only enhances our understanding of the ionosphere but also ensures the precision and reliability of low-frequency radio observations. These efforts are particularly relevant for the future of low-frequency radio arrays, including the Square Kilometre Array (SKA), where ionospheric effects must be both mitigated and leveraged as valuable sources of scientific information.