Intercontinental decametric VLBI

Jupiter DAM observations with KAIRA, LOFAR, LWA, NenuFAR

Olaf Wucknitz

MPIfR Bonn, Germany

`wucknitz@mpifr-bonn.mpg.de`

Max-Planck-Institut
für Radioastronomie

Abstract

We recently conducted a VLBI experiment with LOFAR, NenuFAR, KAIRA and several stations of the LWA to try transatlantic interferometry well below 50 MHz. Targets were decametric Jupiter bursts and bright pulsars. This poster describes preliminary results for Jupiter. We clearly detect fringes (modulated by interplanetary scintillation) on all baselines, even transatlantic at 8000 km length at frequencies of 30 MHz and below.

Introduction

VLBI is most difficult at very high and very low frequencies. At the low end, the limits are sensitivity (due to the bright Milky Way), the lack of bright compact calibrators, the ionosphere and potentially interplanetary scintillation (IPS). Known compact sources are pulsars (if not too scattered by the ISM) and decametric Jupiter bursts (see Fig. 1). The latter are not affected by the ISM and can reach millions of Jy.

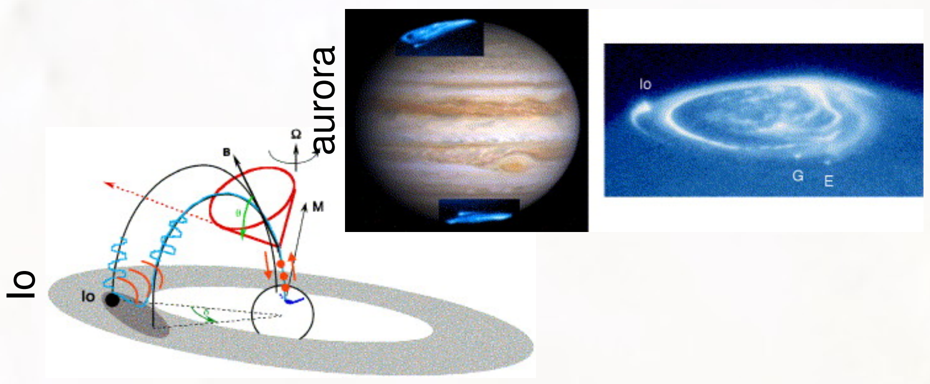

Fig. 1: Decametric emissions from Jupiter are caused by aurora and by interaction of the moon Io (background image of this poster) with the planet's magnetosphere (Zarka 2004, Planet. Space Sci., 52, 1455). The Io-induced bursts are semi-predictable and can be extremely strong.

Below 100 MHz, the optimal telescopes are LOFAR (with many stations in Europe), NenuFAR in France, and the LWA (with now four stations in New Mexico and California). Unfortunately all recording systems of UTR-2 in Ukraine were destroyed in the war. In 2013 we first tried to find transatlantic fringes in an observation of the pulsar B0809+74 with LOFAR, KAIRA in northern Finland and the first LWA station, unfortunately without success.

Observations

New experiments were conducted recently. In addition to pulsars, we also observed Jupiter, to allow for detections over very small ranges in time and frequency. Here we only report on one of the Jupiter observations on 2024-04-06, UTC 17:30–19:30 using NenuFAR, KAIRA, the international LOFAR stations DE602,603,604,605,609 in Germany, FR606 in Nançay next to NenuFAR, SE607 in Sweden, PL610,612 in Poland, IE613 in Ireland, LV614 in Latvia, a few Dutch RS stations, and four LWA stations (LWA1,LWA-SV,LWA-NA,LWA-OVRO). See Figs. 2–4.

Fig. 2: The two stations in Nançay: FR606 (left) and parts of NenuFAR (right).

Fig. 3: LWA antennas

Each station recorded a bandwidth of 40–75 MHz baseband data, which were processed at MPIfR. We corrected each stream for geometric delays and channelised to about one kHz. Data from two stations each were then multiplied (one complex conjugated), but averaging within pixels only took place at the plotting stage, to allow for more flexible resolutions in time and frequency. The correlated phases (using the dominant circular polarisation) still showed significant trends across the band, which were corrected to second order for the plots. Only about 5 seconds for a ca. 6 MHz wide band are shown here.

Fig. 4: The KAIRA station north of the Arctic circle in Finland is used for geoscience research and for astronomy (McKay-Bukowski et al. 2015, IEEE Trans. Geosci. Remote Sens., 53, 1440).

Fringes

Clear fringes are detected on all intra-European and intra-US baselines (Figs. 5, 6), even on the longest ones toward KAIRA.

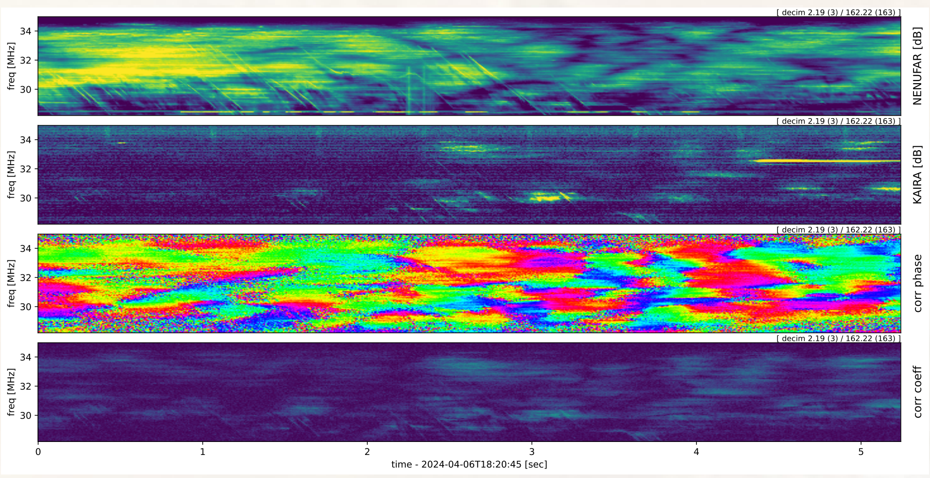

Fig. 5: Fringes on the NenuFAR–KAIRA baseline. The panels show (a) amplitude NenuFAR, (b) amplitude KAIRA, (c) correlated phase, (d) correlation coefficient computed per pixel. The patches in amplitude and phase are most probably caused by IPS. Intrinsic variations of these emissions are wider. The narrow diagonal streaks are intrinsic to the bursts. Apart from the IPS, the phases are quite stable over the relevant ranges.

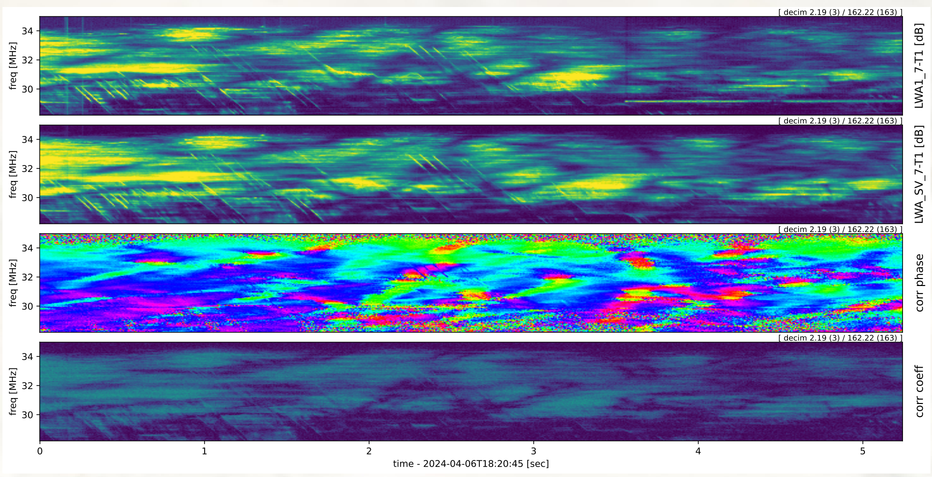

Fig. 6: Fringes on the LWA1–LWA-SV baseline, panels as in Fig. 2. We notice that the IPS variations are time-shifted between the stations, as expected. The narrow streaks have different phases than the diffuse emission, which may indicate positional offsets.

Even on transatlantic baselines we clearly detect fringes (Fig. 7). The phases are as stable as on shorter baselines, which is actually expected given the properties of IPS and the ionosphere. The correlation coefficients mostly depend on the station sensitivity, not on the baseline length, which indicates very compact (sub-arcsec) sources.

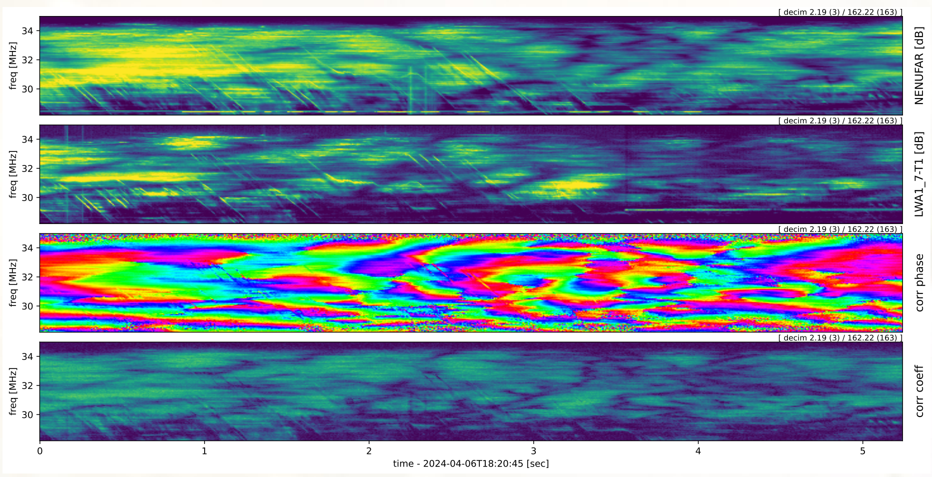

Fig. 7: Fringes on the transatlantic NenuFAR–LWA1 baseline, panels as in Fig. 2. To our knowledge, these are the first transatlantic fringes at 30 MHz.

Conclusions

We clearly detect fringes of Jupiter signals around 30 MHz across the Atlantic up to projected baseline lengths of 8000 km, proving the compact nature of the sources. These are preliminary results, and we still have to calibrate instrumental and ionospheric effects and separate the IPS signature from the intrinsic source properties, and study both. There are no external calibrators, but a variant of self-calibration is possible using Faraday rotation effects. We hope that we can detect, disentangle and 'map' the emission regions, as we have shown before with LOFAR-only data.

Acknowledgements

Help from the following colleagues (preparing/conducting observations, data transfer, discussions), is very much appreciated. In alphabetical order: **Krishnakumar Moochickal Ambalappat, Cees Bassa, Leszek Blaszkiewicz, Louis Bondonneau, Tobia Carozzi, Jesus Cazares, Jayce Dowell, Richard Fallows, Julien Girard, Jean-Mathias Griessmeier, Francesco Iraci, Evan Keane, Joern Kuensemoeller, Laurent Lamy, Alan Loh, Corentin Louis, Joe McCauley, Derek McKay, Mariusz Pozoga, Tomasz Sidorowicz, Bartosz Smierciak, Marian Soida, Janis Steinbergs, Sai Chaitanya Susarla, Greg Taylor, Philippe Zarka** ***Thank you!***