Realising the LOFAR Two-Metre Sky Survey

The LOFAR Two-Metre Sky Survey

The **LOw Frequency ARray (LOFAR)** is an unique radio interferometer comprising of 52 stations spread over 8 countries in Europe (see Fig. 1 and Fig. 2), operating at the lowest radio frequencies that can be observed with ground-based telescopes (10 - 250 MHz).

Fig. 1: The international LOFAR radio telescope (ASTRON).

Fig. 2: The LOFAR "Superterp" located at the core of the telescope array in Exloo (NL).

The **LOFAR Two-metre Sky Survey(LoTSS)**[1] uses the Dutch stations to produce an all-northern-sky continuum image at a central frequency of 144 MHz with an unprecedented sensitivity below 100 µJy beam^{-1} at a resolution of 6″, see Fig. 3.

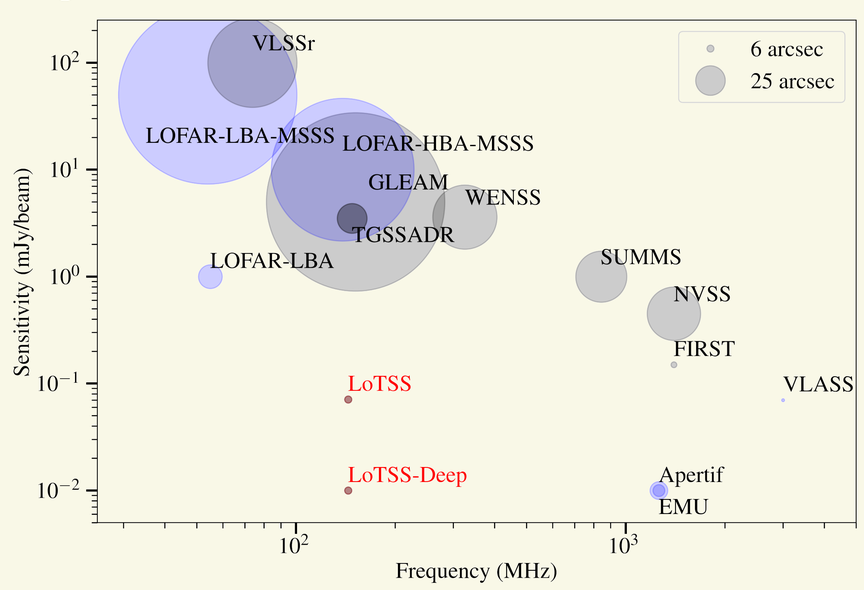

Fig. 3: Sensitivity versus frequency of selected recent (grey), forthcoming (blue), and LOFAR (red) radio sky surveys. The size of the dot resembles the square root of the resolution of the survey. Image by T. W. Shimwell.

The upcoming **LoTSS Data Release 3** will cover about 47% of the northern sky. LoTSS will ultimately provide a low-frequency radio map of 120 billion pixels, and will detect about 15 Million radio sources, thus providing the largest catalogue of radio sources to date.

The LOFAR Long-Term Archive

To cover the northern hemisphere, 25 000 hours of observations have to be carried out, requiring about 30 PB of capacity, stored at the federated LOFAR Long-Term Archive (LTA). The LTA at the Forschungszentrum Jülich (FZJ) stores half of all LoTSS data.

References

[1] T. W. Shimwell et al., A&A **659**, A1, 2022
[2] https://git.astron.nl/RD/LINC
[3] J .R. Callingham et al., Nature Astronomy **8**, 1359, 2024
[4] A. Botteon et al., A&A **649**, 37, 2021

Data Processing Framework at JSC

We have developed job management services and tools that serve as an interface between the LoTSS job database hosted at the University of Hertfordshire, the Jülich LTA and the facilities at the Jülich Supercomputing Centre (JSC). They organise the retrieval of data, the submission of the requested job to the SLURM queue of the Jülich Wizard for European Leadership Science (JUWELS) supercomputer, its monitoring, and the upload of the results to a data storage hosted at SURFsara in Amsterdam (see Fig. 4). The LOFAR software is packaged as a Docker container. Throughout the **computing proposal CHTB00** we have processed about 15 PB of LoTSS data stored at the Jülich LTA with the LOFAR Initial Calibration (LINC) pipeline[2]. With the compute site close to the storage at the Forschungszentrum Jülich (FZJ) we performed the processing with unparalleled speed and thus became an essential pillar in the realisation of the survey.

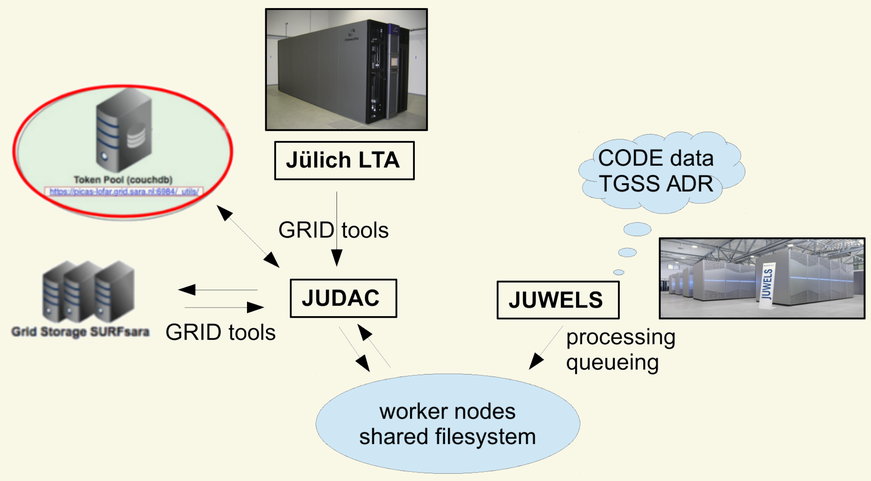

Fig. 4: Sketch of the automated processing scheme implemented on JUDAC and JUWELS. Interactions that require internet access (e.g., external databases) are run on JUDAC. The job preparation and submission is run on JUWELS.

Science Highlights

Due to its outstanding sensitivity and resolution, LoTSS is recovering an unprecedented number of radio sources and resolves the morphology of many radio galaxies. Since LOFAR operates at very low radio frequencies it allows the study of the distribution of fossil electron populations, i.e. the emitting plasma has undergone substantial radiative losses. Moreover, LOFAR's many short baselines enable the detection of very extended, low surface brightness sources. Recent scientific highlights include the detection of very extended, faint giant radio galaxies, the outflows of nearby galaxies, extragalactic peak-spectrum radio sources, quasars, the polarised sky, and radio signatures of star-planet interactions, exoplanets and space weather[3]. A spectacular example of fossil plasma has been recovered in the galaxy cluster Abell 1775 (see Fig. 5), more precisely, the observation shows how the fossil plasma is revived, revealing complex dynamics that caused the acceleration of electrons in the intra-cluster medium to relativistic energies on different scales. In total, LoTSS has already produced more than 388 journal papers.

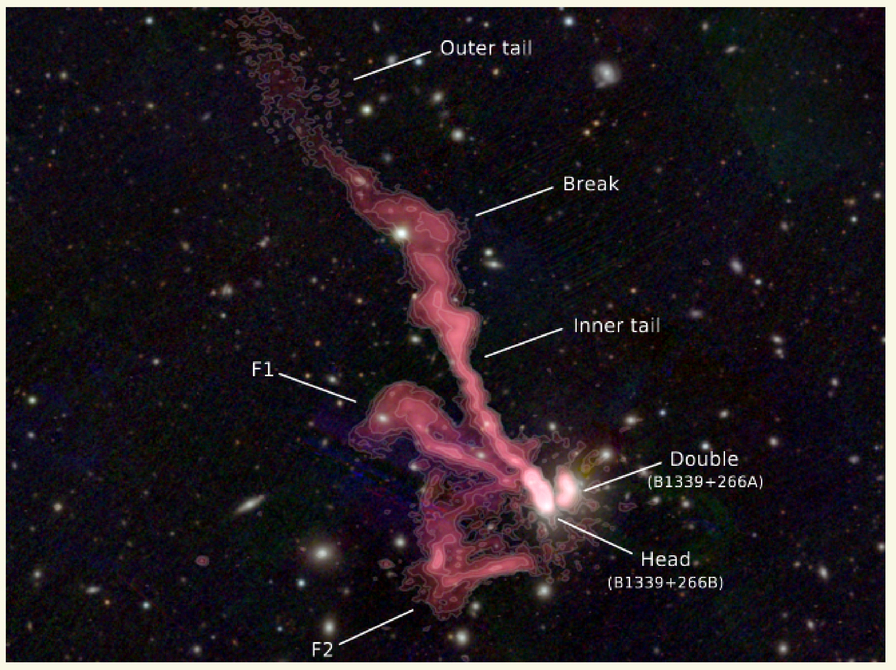

Fig. 5: LOFAR radio map centered at the galaxy cluster **Abell 1775**[4] (red) overlaid on top of a color composite image obtained from Pan-STARRS.

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