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Technosignature Searches with Very Long Baseline Interferometry (VLBI)

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1 Extended abstract

In recent years, advances in radio telescope technology and the increasing number of exoplanet discoveries from surveys have enabled a more precise and systematic search for extraterrestrial intelligence (SETI). In addition, the integration of machine learning techniques, advanced data pipelines, and dedicated observing programs has further accelerated progress in radio SETI research [1]. Looking ahead, next-generation instruments such as the Square Kilometre Array (SKA) and the next-generation Very Large Array (ngVLA) are expected to significantly enhance detection capabilities, broadening the scope and reach of SETI investigations.

However, SETI efforts continue to face challenges posed by the presence of numerous human-made radio frequency interference (RFI) signals. In this regard, SETI surveys utilizing Very Long Baseline Interferometry (VLBI) offer significant potential for both mitigating RFI and characterizing candidate SETI signals. In particular, VLBI provides an effective means of distinguishing nearby artificial signals from potential extraterrestrial sources. To facilitate a VLBI-based SETI program, we have conducted SETI observations using the Long Baseline Array (LBA). These efforts include the characterization of planetary satellite signals, wide-band VLBI SETI observations of exoplanets in habitable zones, and triggered follow-up VLBI observations of SETI candidates identified by ongoing Breakthrough Listen surveys.

Figure 1 shows the spectral signal of the Voyager-2 satellite, detected by the LBA at X-band on 20 May 2024. The phase and delay rates fluctuate over time, primarily due to the satellite's motion. By analyzing visibilities across different baselines, we can precisely determine the location and trajectory of these signals in the sky, effectively ruling out RFI sources within a few hundred astronomical units (AU) of Earth. To support VLBI-based SETI research, we have developed specialized data reduction and analysis pipelines tailored for the program. These pipelines will be utilized in dedicated VLBI SETI surveys in the coming years, paving the way for high-sensitivity observations that will advance the search for extraterrestrial intelligence with unprecedented precision and reliability.

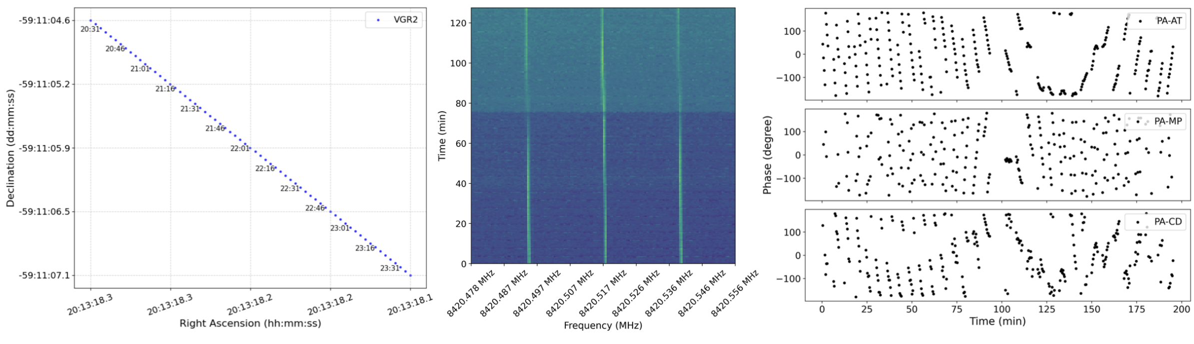

Figure 1. Left: Trajectory of the VGR2 satellite over a 2-hour period on May 20, 2024. Middle: Averaged cross-power spectrum of VGR2 detected by the LBA, showing three narrow lines persisting for 2 hours. Right: Visibility phases of the spectral signal for different LBA baselines (PA = Parkes, MP = Mopra, AT = ATCA, CD = Ceduna).

References

[1] Ma, P. X., "A deep-learning search for technosignatures from 820 nearby stars", Nature Astronomy, vol. 7, pp. 492–502, 2023. doi:10.1038/s41550-022-01872-z.