PROCEEDINGS OF SCIENCE

# Single-baseline interferometer for mJy observations

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The Ventspils International Radio Astronomy Centre (VIRAC) of Ventspils University of Applied Sciences (VeUAS) has developed an 800 m single-baseline interferometer consisting of 32 m (IR) and 16 m (IB) radio telescopes with 15 arcseconds of angular resolution. Irbene radio telescopes are operating at C/M/X-band (4.5-8.8 GHz). Raw telescope data are correlated with the Software FX Correlator (SFXC) [1] and output visibilities are calibrated with a ParselTongue* pipeline. Data processing techniques provide a velocity resolution of 0.088 $kms^{-1}$ and spectral resolution of 0.002 MHz and enabling observations to approach the theoretical sensitivity limit of the interferometer, at about 6 mJy for a 120 s integration. We propose to use the Irbene interferometer for discoveries in a new age of transient astrophysics. In this paper, we will show correlation and calibration schema and initial monitoring results.

Keywords: Galactic masers, VLBI observations, SFXC, ParselToung, high-mass protostars

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## 1. Introduction

Our goal is to use the two radio telescopes situated in Irbene, Latvia for the repurposing of a single-baseline interferometer capable of leading global research in the field of high-mass star formation variability. The two radio telescopes, of 32 m and 16 m diameters, are capable of interferometric observations under the operation of the VIRAC. The telescopes are separated by 800 meters, which provides an angular resolution of 15 arcseconds which matches well with the sizes of high-mass protostellar systems and their plasma formations. Data processing techniques provide a velocity resolution of 0.088 $kms^{-1}$ and spectral resolution of 0.002 MHz. Such a configuration of accessible radio telescopes is now uncommon due to the predominant focus on larger arrays, therefore giving rise to a unique opportunity to make novel progress and innovation in the research field. An in-house interferometer also has the benefit of flexible time allocation to provide the high-cadence monitoring observations necessary to detect activity on the day-to-year timescales of accretion events and their long-term evolution. Radio astronomical instruments are able to look into dense clouds of gas and dust where high-mass protostars are born, which are regions hidden to optical bands.

## 2. Observations and data processing

Observations are done in a typical European VLBI Network (EVN) setup: calibrator - target - calibrator. Each target source is observed twice in an observation (Strong sources 5 min. scans, week sources 8 min. scans) Calibrator sources have 3 min. scans. In observations 16 channels are used, 8 channels x 8 MHz for each of left and right polarisation. Correlation and calibration are done on VIRAC High Performance Computer (HPC). Correlation for each observation is done in two steps 1) continuum pass and 2) line pass. In both steps, 2-seconds integration time is used. In the continuum pass, all channels are correlated with 128 fast Fourier transform (FFT) points, the line-only channel containing the maser signal is correlated with 4096 FFT points.

Our source list contains two list of sources: 1) current and past flaring high-mass protostars and regularly variable sources from VIRAC maser single dish monitoring program [2], 2) High-mass proto-stars from the James Clerk Maxwell telescope transients survey [3]. Currently, the target source list includes about 30 sources.

Calibration is done using a ParselTongue pipeline which proceeds through the basic steps of calibration in a similar manner to VLBI data post-processing: 1) A-priori gain calibration using 'antab' files (gain curve and Tsys), 2) Bandpass, flagging and frequency definition of the 6.7 GHz methanol maser, 3) Manual phase-cal to remove delay and align polarisation's and BBCs in phase, 4) Calibration files are applied to the targets. 5) Phase and rates are determined on the maser emission and applied to the continuum emission of the high-mass proto-star, 6) Data are integrated in time and frequency and modelled to determine source flux, 7) Diagnostic plots are produced that allow quick inspection of the calibration quality.



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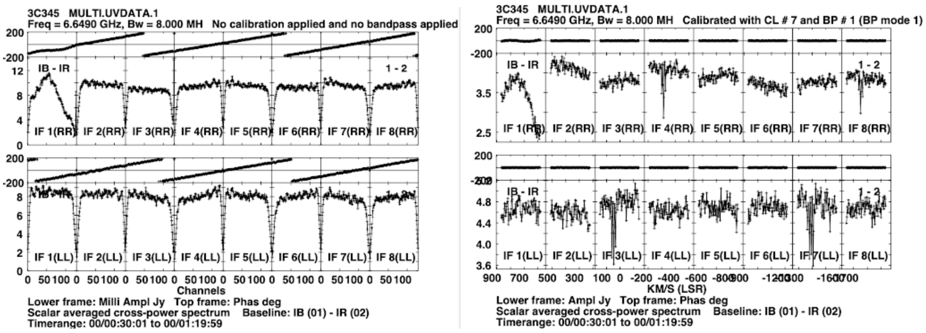
### 2.1 Example of data processing results

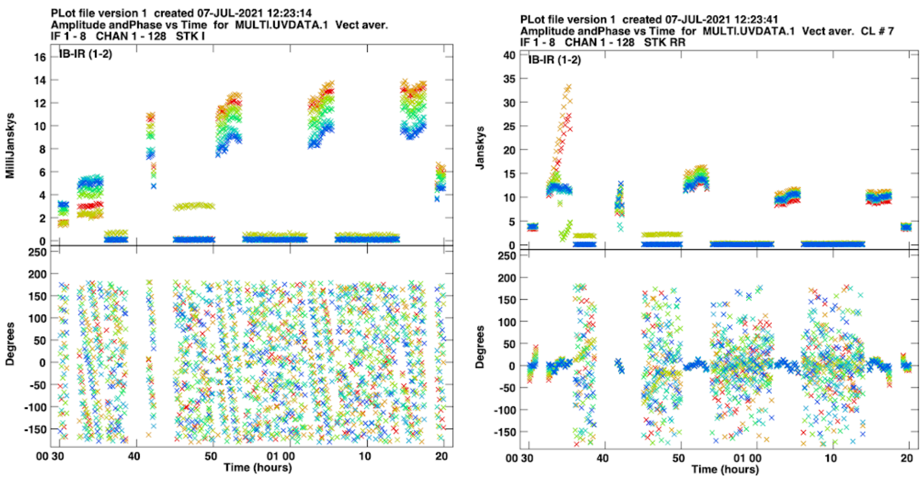
As a fringe finder and calibrator, the quasar 3C345 was used. It shows successful cross-correlation results and consistency across all Ifs. The plots of phase and amplitude vs frequency, before and after calibration procedure are presented on Figures 1a and 1b.




(a) (b)

Figure 1: The phase and amplitude vs frequency of calibrator source 3C345, before (a) and after (b) applied calibration. Shown as frequency channels and $kms^{-1}$.

Phase and amplitude vs time for all sources show that coherence is much improved, allowing full time integration across the scan as it is shown in the Figure 2.

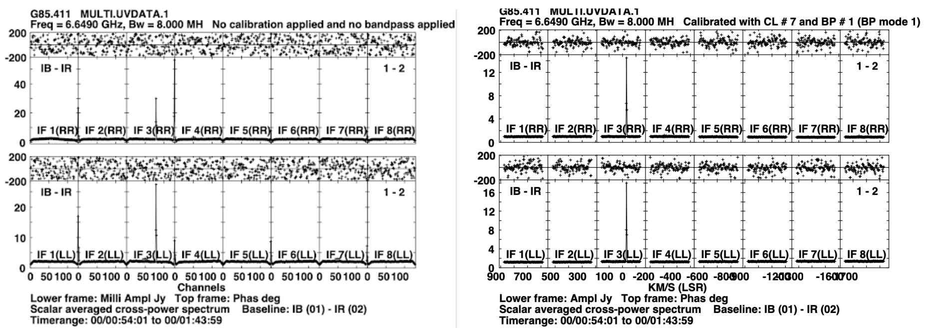



(a) (b)

Figure 2: Phase and amplitude vs time for all sources show that coherence is much improved, allowing full time integration across the scan (a) plot is before calibration, (b) plot is after calibration.

Phase and amplitude vs frequency for high-mass protostar G85.411+0.002 in which the maser emission (in IF 3) and radio continuum emission become clear upon calibration is shown in the Figure 3.

Calibrated cross-correlation spectrum of 6.7 GHz methanol maser in the source G85.411+0.002 is shown in the Figure 4.




(a) (b)

Figure 3: Phase and amplitude vs frequency for high-mass protostar G85.411+0.002 in which the maser (in IF 3) and radio continuum emission become clear upon calibration (a) plot is before calibration, (b) plot is after calibration. Shown as frequency channels and $kms^{-1}$.

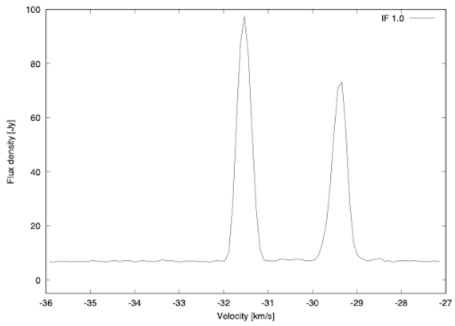



Figure 4: Calibrated cross-correlation spectrum of 6.7 GHz methanol maser in the source G85.411+0.002. The X axis velocity $[\frac{km}{s}]$, in the y axis flux density [Jy]

Preliminary results of monitoring proto-star G85.411+0.002. In the Figure 5 an example of monitoring results of proto-star G85.411+0.002 is shown. The individual spectra of each observation, light curves of spectral components and continuum emission are presented. Continuum emission is at 80 milliJansky level.

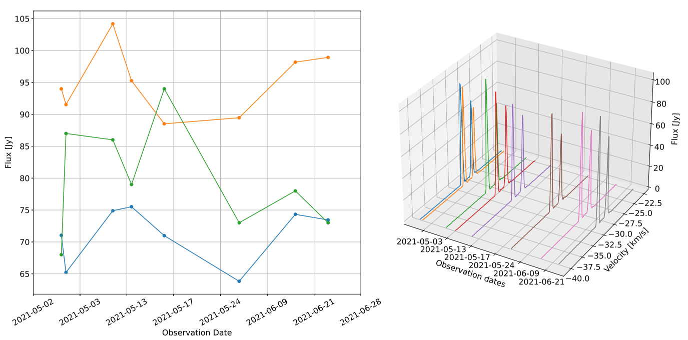



Figure 5: Left: Blue and orange lines trace time variation in radio line flux [Jy] of maser emission at velocities of -29.40 $kms^{-1}$ and -31.51 $kms^{-1}$, respectively. The green line traces radio continuum emission flux [Jy * 1000] from G84.411+0.002, monitored for the first time by our pre-science evaluation. Right: Demonstration monitoring of the 6.7 GHz maser spectra in high-mass protostar G85.411+0.002 using the VIRAC interferometer.

## 3. Conclusion

VIRAC has developed single-baseline interferometer with 800 m baseline, that allow monitoring of high-mass star formation variability. This interferometer has an angular resolution of 15 arcseconds (0.0042 degrees) which matches the size of high-mass protostellar systems and their plasma formations, data processing techniques allow provide a velocity resolution of 0.088 $kms^{-1}$ and spectral resolution of 0.002 MHz. Such a configuration of accessible radio telescopes is now uncommon due to the predominant focus on large arrays, therefore giving rise to a unique opportunity to make novel progress and innovation in the research field.

Our source list contains two groups of sources: 1) current and past flaring high-mass protostars and regularly variable sources from VIRAC maser single dish monitoring program [2], 2) High-mass proto-stars from the James Clerk Maxwell telescope transients survey [3]. Currently, the target source list includes about 30 sources.

## 4. Acknowledgements

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