The Orion Radio All-Stars:

Radio census and proper motions with the VLA and nonthermal variability with ALMA and the VLBA

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Summary

We are presenting a follow-up of our deep VLA radio survey in the central part of the Orion Nebula Cluster (ONC) at cm-wavelengths, now expanded to the outskirts of the cluster. We find strong evidence of the effect that the high-mass stars in the Trapezium have on the radio properties of nearby sources which most likely show free-free radio emission from external photoevaporation. We also compare our two sensitive VLA epochs of the central cluster, with a time baseline of just a few years, to measure fast proper motions of faint features related to the OMC1 explosion. In our continued variability study there are no new cases of extreme events (variability > an order of magnitude on short timescales), however it is within the expectations for these new and shorter observations. In addition to this analysis we expand our study of nonthermal YSO radio variability using ALMA and the VLBA, conducting a systematic monitoring in the millimeter range to constrain the occurrence of synchrotron flares which could have implications in disk mass measurements of insufficiently spatially resolved protoplanetary discs. The VLBA allows us to filter out any thermal emission making possible the study of the exclusively nonthermal population in the ONC at centimeter-wavelengths for which we present its variability in a greater detail.

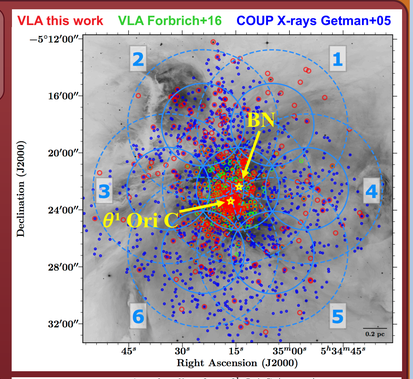
EXPANDED CATALOG OF COMPACT RADIO SOURCES IN THE ONC:

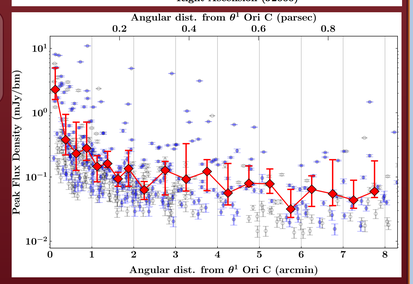
We have obtained high-sensitivity continuum maps (3-10 μJy/bm) from a total of ~30 h centimeter-wavelength observations using the C-band (4−8 GHz) with the Karl G. Jansky Very Large Array (VLA) in its high-resolution (~0.1″) A-configuration over an area of ~20′×20′ of the ONC covering the FOV of the X-ray survey COUP (Getman et al 2005).

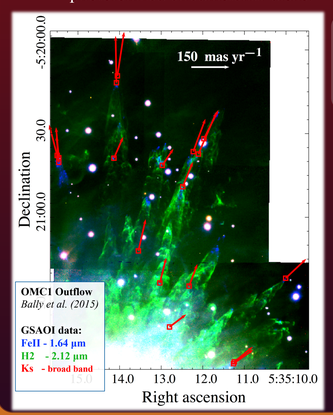
A total of 521 compact radio sources are detected (>5σ) of which 198 are new detections.

THE INFLUENCE OF MASSIVE STARS IN THE RADIO PROPERIES OF NEARBY YSOs:

The sample of sources that most likely represent the YSO population in the cluster shows a clear decreasing trend in their flux distribution as a function of projected distance to the massive Trapezium star θ^1 Ori C at the center of the ONC. This trend is expected for thermal free-free emission detected from externally photoionized circumstellar disks.







FIRST RADIO PROPER MOTION MEASUREMENTS OF THE ORION FINGERS:

The combination with our previous observations four years prior lead to the discovery of fast proper motions of up to ~373 km/s from faint radio sources associated with ejecta of the OMC1* explosion proving the sensitivity of these VLA observations to non-stellar radio emission and the utility of radio proper motions as a tool for source identification

*The OMC1 outflow has an explosive morphology of molecular material consequence of the dynamical encounter of stars which were ejected with speeds of a few tens of km/s more than 500 years ago (Bally & Zinnecker 2005; Rodríguez et al. 2005).

A NEWLY ENLARGED CENSUS OF **521 COMPACT RADIO SOURCES** IN THE ONC: **198 NEW SOURCES** NOT PREVIOUSLY REPORTED AT THESE FREQUENCIES.

HIGH PROPER MOTIONS (~370 km/s) ASSOCIATED TO **THE EXPLOSIVE STRUCTURE BN/KL** (OMC1 OUTFLOW).

VLA VARIABILITY: **CHANGE IN FLUX DENSITY** BY A **FACTOR >10** ON **LONG TIMESCALES** OF A FEW YEARS.

Vargas-González et al. 2021 (subm.)

ALMA: **FIRST CONSTRAINTS ON MILLIMETER RADIO FLARE RATE** FROM A LARGE SAMPLE.

VLBA SURVEY FOR NON-THERMAL EMISSION FROM YSOs: **FIRST LARGE SAMPLE OF LIGHT CURVES AT HIGH-TIME RESOLUTION** DIRECTLY FROM THE (u,v)-DOMAIN (NO IMAGING NEEDED).

Vargas-González et al. 2021 (in prep.)

References

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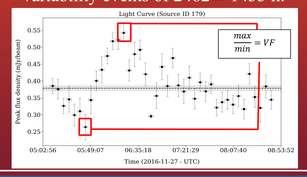
Vargas-González et al. 2021 (subm. to MNRAS)

VLA variability at cm-wavelengths

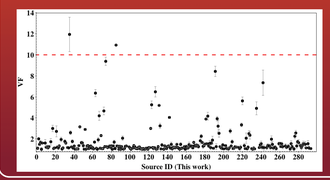
Short timescales

Radio light curves at high time resolution (5 min) for sources in the central pointing finding changes in flux density by a factor ≤5 on timescales of a few minutes to hours. Based on the cumulative observing time of YSOs from our two observations we find a mean time between extreme radio variability events of 2482± 1433 h.



Long timescales

Most of the sources have detections in the previous deep VLA observations, thus enabling the study of long term variability where we find only 2 sources with changes in flux density >10.

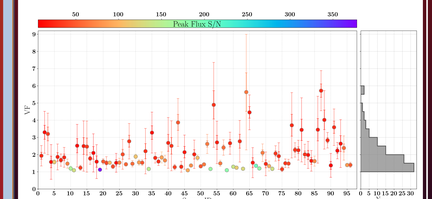


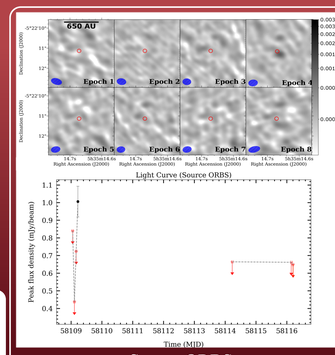
ALMA mm-variability constraints of YSOs

Millimeter-wavelengths observations from YSOs mostly traces the dust emission from disks (thermal free-free) but non-thermal mm-wave emission (synchrotron) can be detected from flaring sources (coronal type activity) but with only a few reported examples (eg. Bower+03, Massi+06).

We have obtained 3mm continuum in an area of ~1.5′×1.5′ (0.2 pc) around the BN/KL region in the inner ONC. A sample of 96 detected sources (>5σ) have been used to constrain the mm-wavelength variability of a large sample of YSOs for the first time.

Distribution of VF (maximum change in flux density on timescales of a few hours to days) in our sample:





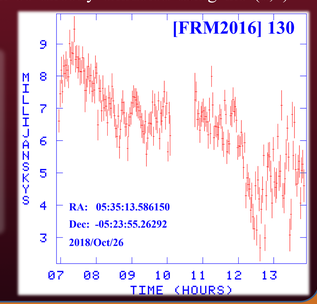
Source ORBS

A flare radio source with a strong outburst at 1.3 cm (VF>10) reported by Forbrich et al. (2008). Detected again at 6cm in Forbrich et al. (2016) with no variability and now detected at mm-wavelengths in only 1 out of the 8 ALMA epochs at ~8σ significance.

VLBA: non-thermal variability at cm-wavelengths

Following the VLBA non-thermal radio census of YSOs in the ONC at cm-wavelengths and milli-arcsec resolution reported in Forbrich et al. (2021) and Dzib et al. (2021) we are now extending these studies with a variability analysis of a large sample of non-thermal sources at high-time resolution (down to a few seconds) for the first time. Given the spatial filtering power of these obs. even moderate variability can be detected at these timescales. Additionally, the flux information for any source can be directly extracted using the (u,v) data with no imaging needed.

Source [FRM2016] 130 has X-ray (COUP 554) and NIR counterparts. This source was detected in the four VLBA epochs with a maximum S/N~145. The figure in the right shows its 2 minutes time resolution light curve from its brightest detection (epoch 4). It shows a change in peak flux density by a factor of ~3.8 on a period of time of ~ 5h



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