SMA imaging of protostars from OMC-1n to OMC3

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Abstract

We report Submillimeter Array (SMA) 1.3mm continuum observations of the OMC-1 northern filaments (previously identified from SCUBA JCMT 850 micron continuum and VLA ammonia observations), and 850μm continuum observations of OMC-3. We find 26 new compact sources along an extent of ~3′ within OMC-1n and 12 compact sources in OMC-3. The OMC-1n (OMC-3) sources range in mass from 0.5 to 2.8 M_{Sun} (0.3-5.7 M_{Sun}) and 9 of these are driving CO molecular outflows. The millimeter emission may be arising from the inner part of the envelope and circumstellar disk; these compact sources are therefore in the Class 0/I evolutionary phase. The spatial analysis of the protostars shows that these are divided into small groups in OMC-1n that are separated by a quasi-equidistant length of 30′ (0.06pc), consistent with the Jeans length, and therefore indicating the filament underwent thermal fragmentation. Within the protostellar groups, the typical separation is ~7″ (2800au). The protostars within OMC-1n show similar masses and sizes to those in OMC2/3, however their spatial separations are distinctly different and may point to how fragmentation propagated through the integral-shaped filament in Orion A.

Motivation

• filamentary structures are ubiquitous within molecular clouds (*see poster 1S036 by A. Hacar on filaments in Taurus*).
• how do these pc-scale structures convert gas and dust into sub-pc scale clumps and cores, and ultimately form clusters?
• fragmentation processes can be analyzed by a spatial analysis of protostars within filaments!

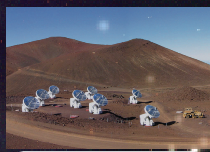

Fig. 1: The Submillimeter Array, SMA, located atop Mauna Kea, Hawai'i. The array consists of eight 6m antennas.

OMC-1n to OMC3

The Orion Molecular Cloud (OMC) A is the nearest (414+-7 pc, Menten et al., 2007) and one of the richest star-forming giant molecular clouds. It has an elongated structure ("Integral-shaped filement", Bally et al. 1987) spanning ~10pc and is composed of several large clouds to the north (OMC-1, OMC-2, and OMC-3) and south (OMC-4 and OMC-5). Here we present our analysis of the OMC-1n and OMC-3 clouds.

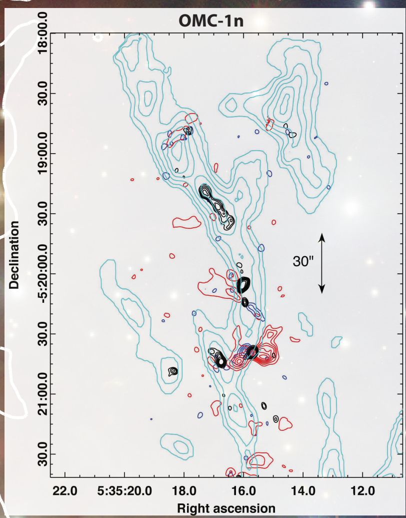

Fig. 2: OMC-1n at 1.3 mm revealing new protostars (black contours, ranging from 5 to 10σ). Red-shifted and blue-shifted CO(2-1) trace the protostellar outflows. The protostars are embedded within the dense NH3 (1,1) filamentary structure (cyan, Wiseman & Ho, 1998).

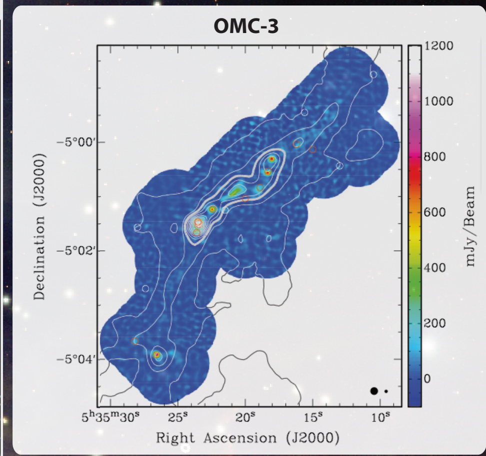

Fig. 3: OMC-3 SMA 850 μm continuum mosaic image (thin white contours in steps of 5 σ). Orange open circles and white open circles present the positions of protostars and T Tauri stars, respectively (Peterson & Megeath 2008). Thick white contours are from JCMT/SCUBA (Johnstone & Bally 1999), The contour starting at 0.3 Jy beam−1 with an interval of 0.6 Jy beam−1. Black filled circles in the bottom are the JCMT and SMA beam sizes of 14″ and 4.5″, respectively. **Published in Takahashi et al. (2013).**

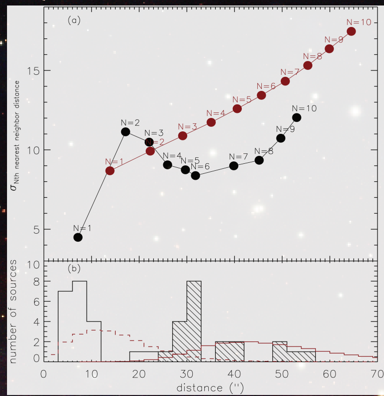

Fig. 4: (a)Median Nth nearest neighbor separations of the SMA sources vs. σNth nearest neighbor separation, where each data point (black filled symbol) is labeled from N = 1,... 10. The red symbols represent the median Nth nearest neighbor separations for a random spatial distribution for comparison purposes (see text). (b) Distribution of the 1st nearest neighbor separation (open black histogram), and the distribution of the 6th nearest neighbor separation (filled black histogram). The red dashed-line and the red solid-line histograms correspond to the 1st and 6th nearest neighbor separations for random spatial distributions, respectively. All the histogram bin widths correspond to the SMA beamsize, 3″.

Teixeira:

Takahashi:

Results

• We found 26 **new** protostellar sources in the OMC-1n dense filaments. These sources are distributed in groups that formed within dense clumps (identified by JCMT/SCUBA and VLA/NH_3) (see Fig. 2).

• We detected 12 protostars in OMC-3 (see Fig 3). The masses, sizes and densities between the OMC-3 and OMC-1n sources are similar. For OMC-1n to OMC-3, the protostellar masses range between 0.09 and 5.8 M_{Sun}, and median sizes is 2700 au.
See poster 1H038 by J. Forbrich on OMC-1/ONC protostellar variability.

• All the sources in OMC-1n and OMC-3 are distributed with quasi-periodical separations -- these separations can be interpreted as a fossil signature of the fragmentation scale of its paternal filaments.

• The spatial distribution of these protostars is characterized by two lengths (see Figs. 4 and 5): the shorter scale of ~9″ (3700 au / 0.02 pc) occurs mostly betwen the protostars in OMC-1n (= Jeans length$_{OMC-1n}$), whereas the longer scale of 26″ (10 800 au / 0.05 pc) occurs mostly for protostars in OMC-2 and OMC-3 (= Jeans length$_{OMC-2/3}$).

•The second scale is consistent with the separations of the clumps in OMC-1n, i.e., to the typical distance between the *groups* of protostars -- in OMC-1n we find evidence for hierarchical thermal fragmentation (see Fig. 4).

• A larger study of the spatial scaling with different size-scale structures in Orion, from > 10s pc to sub-pc (see Fig. 6) shows that thermal fragmentation is dominant on the scales from 1 to 0.1pc (Takahashi et al. 2013). *See poster 1H016 from C. Weber for protobinary separations!*

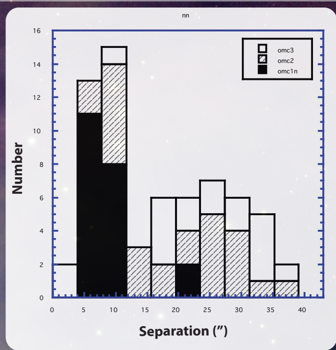

Fig. 5: Comparison of the nearest neighbor separation of protostars in the three different regions: OMC-1n, OMC-2 and OMC-3. Two distinct peaks are discernable, where OMC-1n contributes mostly to the peak of smallest separations, and where the second peak coincides with the grouping separations of OMC-1n (see Fig.4).

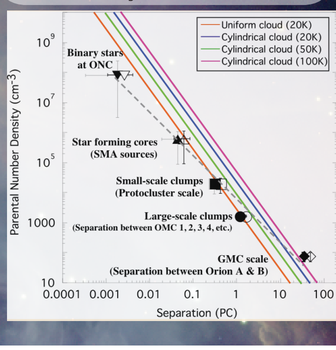

Fig. 6: Observed separations of clouds/large-scale clumps/small-scale clumps/cores in parsec as a function of the mean hydrogen number density of the parental cloud in cm^{-3}. The filled symbols show the separations assuming i = 90deg(filament in the plane of the sky), and the open symbols show the separation assuming i = 45deg. Data from GMC (Sakamoto et al. 1994; Wilson et al. 2005), large-scale clumps (Dutrey et al. 1991, 1993; Hanawa et al. 1993; Johnstone & Bally 1999), small-scale clumps (Cesaroni & Wilson 1994; Johnstone & Bally 1999), dense cores (Takahashi et al. 2013), and binaries (Reipurth et al. 2007) are denoted by diamonds, circles, squares, upright triangles, and inverted triangles, respectively. The color lines show the expected maximum instability size as a function of number density: uniform background density with a gas temperature of 20 K (orange), cylindrical cloud with a gas temperature of 20 K (blue line), 50 K (green), and 100 K (pink). **Published in Takahashi et al. (2013).**

Background:
- ESO/VISTA JHKs
- JCMT/SCUBA 850um (white contours, Johnstone et al. 1999)
- SMA 850μm and 1.3mm (black contours)

0.12pc or 24 840au