Circumbinary Molecular Rings around Young Stars in Orion‡

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Abstract

We present high angular resolution 1.3 mm continuum, methyl cyanide molecular line, and 7 mm continuum observations made with the Submillimeter Array and the Very Large Array, toward the most highly obscured and southern part of the massive star forming region OMC1S located behind the Orion Nebula. We find two flattened and rotating molecular structures with sizes of a few hundred astronomical units suggestive of circumbinary molecular rings produced by the presence of two stars with very compact circumstellar disks with sizes and separations of about 50 AU, associated with the young stellar objects 139-409 and 134-411. Furthermore, these two circumbinary rotating rings are related to two compact and bright *hot molecular cores*. The dynamic mass of the binary systems obtained from our data are >4 M_{sun} for 139-409 and > 0.5 M_{sun} for 134-411. This result supports the idea that intermediate-mass stars will form through circumstellar disks and jets/outflows, as the low mass stars do. Furthermore, when intermediate-mass stars are in multiple systems they seem to form a circumbinary ring similar to those seen in young, multiple low-mass systems (e.g., *GG Tau and UY Aur*).

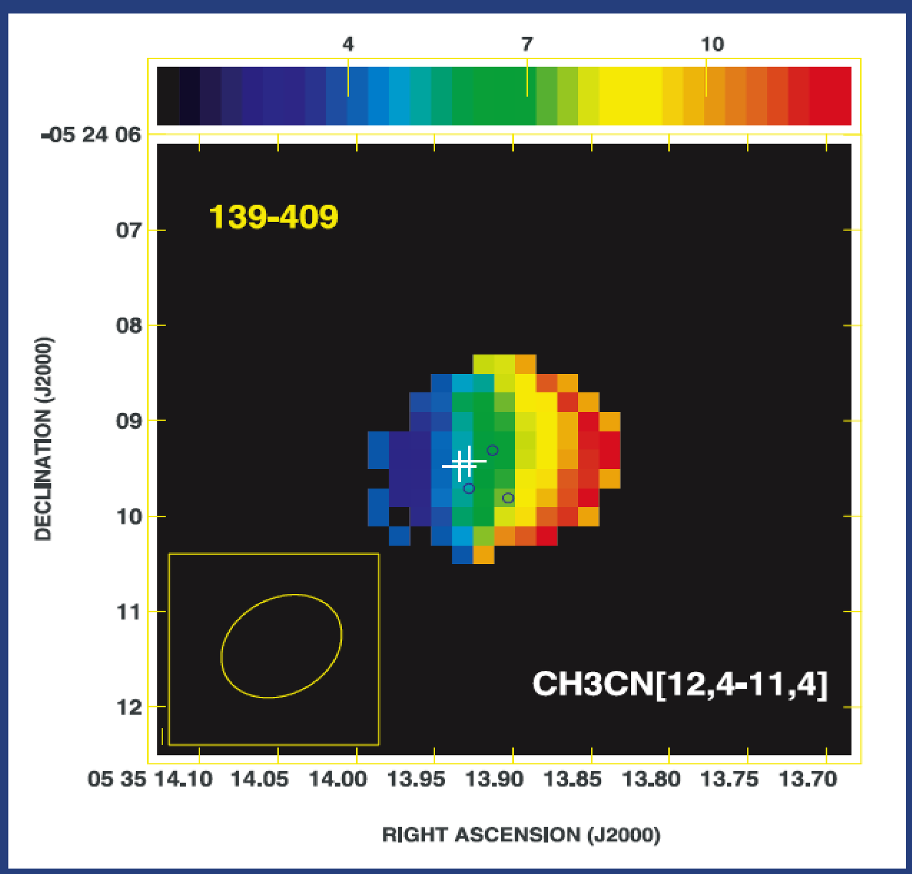

Figure 2 $CH_3CN[12_4-11_4]$ first moment maps of the molecular hot core 139-409 that is associated with compact intermediate-mass (proto)stars. The white crosses indicate the positions of the 7 mm compact radio binaries shown in Figure 1. The blue circles show the position of the water maser spots.

Introduction

The OMC1S or Orion-S is the ``twin'' dusty massive molecular core of the Orion BN-KL core. It is located almost at the same angular distance from the ``Trapezium'' as Orion BN-KL (~1'), but to the southwest of the former. The OMC1S region has a mass of about 100 M_{sun}, similar to that reported for BN-KL, but with a bolometric luminosity of ~10^4 L_{sun}, which is a factor of 10 less. This difference in luminosity might be attributed to OMC1S being less evolved than Orion BN-KL, as inferred if one compares the molecular line emission from both regions. With time, the massive stars forming in OMC1S might reach their final masses and shine with much larger luminosity than now. This possible evolutionary scheme has been also suggested to be taking place in the NGC6334I region.

In this poster we present the possible presence of two circumbinary molecular rotating rings located in the OMC1S region with sizes of a few hundred Astronomical Units (AU) around two very compact circumstellar disks and that are associated with intermediate-mass (proto)stars.

Observations

The observations were made with the *Submillimeter Array* (SMA: *The Submillimeter Array* is a joint project between the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics, and is funded by the Smithsonian Institution and the Academia Sinica) and *The Very Large Array* of the NRAO (The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.), centered at 1.3 mm and in the molecule line CH_3CN, and 7 mm, respectively.

Results

The SMA 1.3 mm continuum observations revealed a group of dusty and highly obscured objects in southern most region of OMC1S, while the molecular observations (CH_3CN) revealed two flattened and rotating molecular objects associated with the sources: 139-409 and 134-411, and that in addition are associated with groups of water masers (see Figures 1, 2 and 4). These sources are related with two strong *hot molecular cores (Zapata et al. in prep.)*. The physical parameters of these structures are given in Table 1.

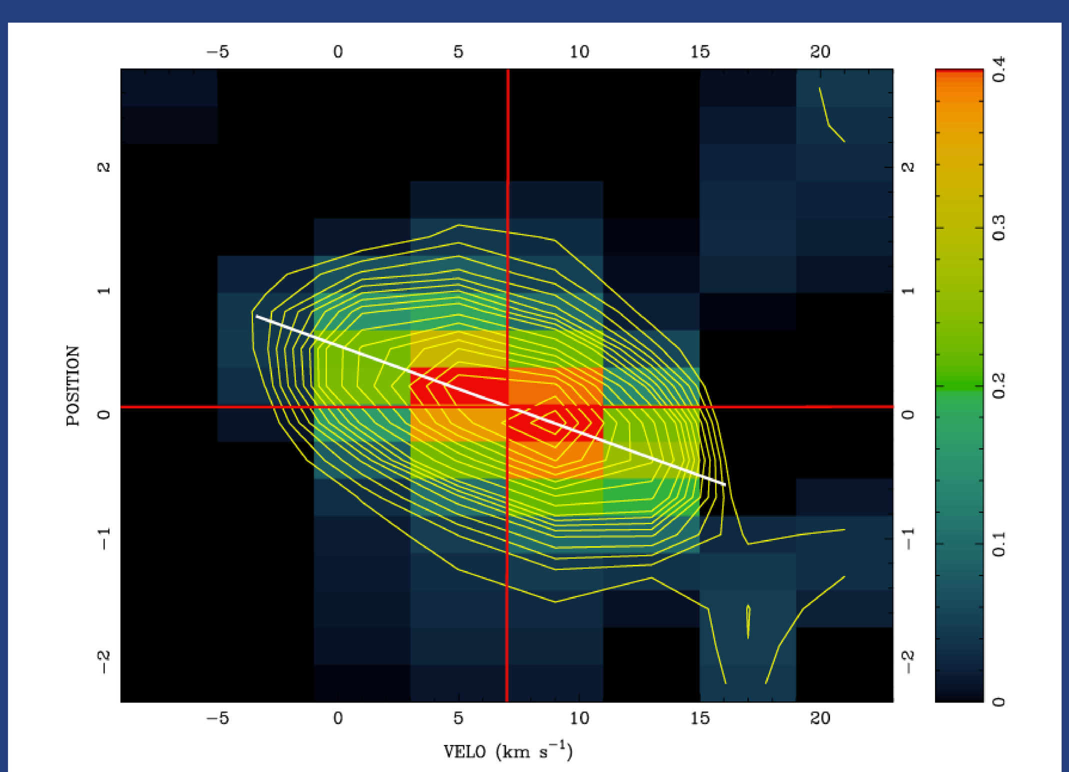

Figure 3 Position-velocity diagram of the $CH_3CN[12_4-11_4]$ molecular emission of 139-409 computed along the direction with PA=87º.

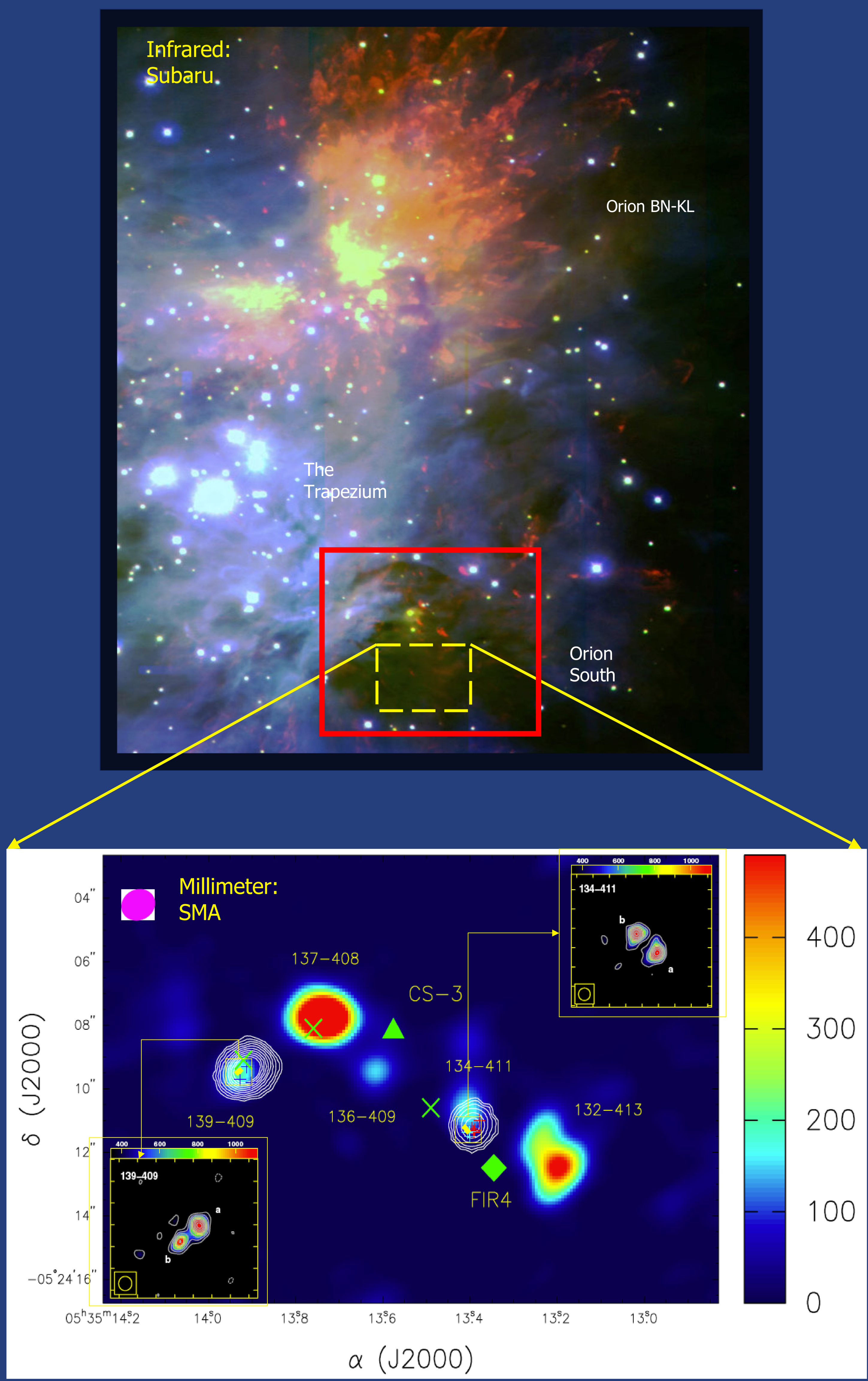

Figure 1 Upper: Infrared image of the Orion Nebula taken by the Subaru Telescope of the NAOJ. **Lower:** SMA 1.3 mm continuum color image of the southern most region of OMC1S, overlaying on the integrated molecular emission of the *hot molecular cores* 139-409 and 134-411 (white contours). The synthesized beam of the CH_3CN image is 1.13" X 0.93" with a P.A. = -73º and it is shown in the upper left corner. The scale bar indicates the 1.3 mm continuum emission in mJy $beam^{-1}$. The yellow rhombi indicate the positions of the 7 mm continuum compact radio binaries. The green rhombus and triangle denote the position of the source FIR 4 and the millimeter source CS 3 respectively. The blue and red crosses indicate the position of the blue- and red-shifted H_2O maser spots, respectively. Note that the masers associated with the hot molecular core (134-411) show a large velocity gradient, going from -20 to +45 km s^{-1}. The green `X' symbols indicate the position of the 3 mm BIMA continuum sources. In the left bottom and right upper corners we show the 7 mm continuum compact radio binaries located on the centers of the hot cores 139-409 and 134-411. The scale bar indicates the 7 mm continuum emission in 10^{-3}mJy $beam^{-1}$. on both images. The synthesized beam is shown in the bottom left corner of each box.

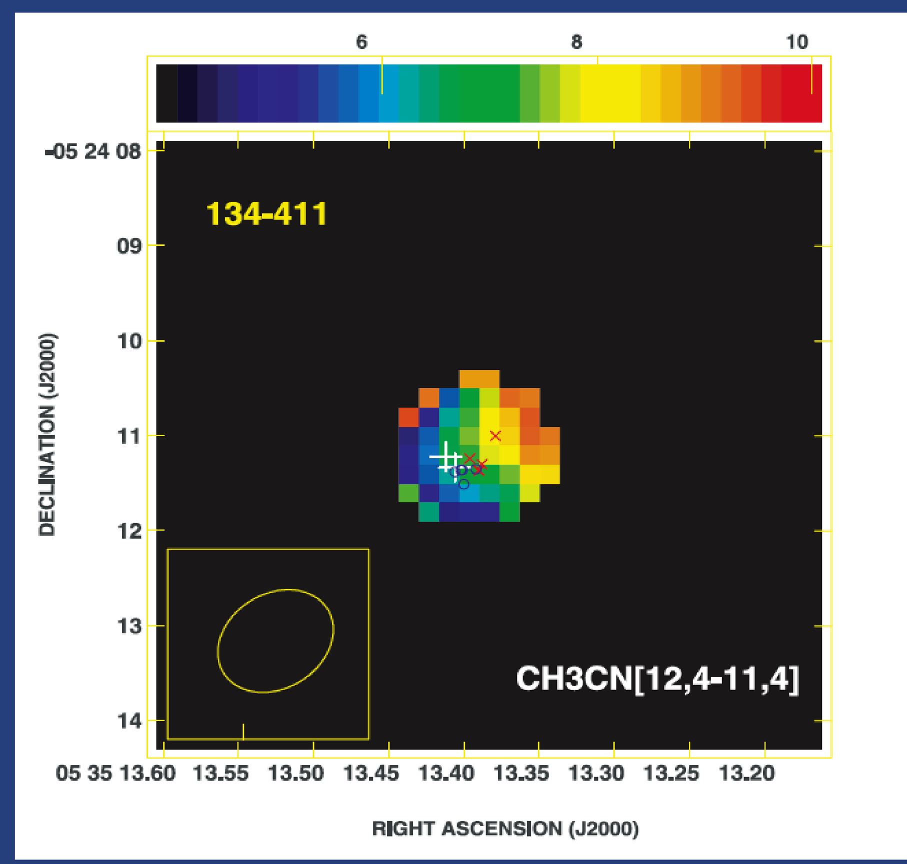

Figure 4 $CH_3CN[12_4-11_4]$ first moment maps of the molecular hot core 134-411 that is associated with intermediate-mass (proto)stars. The white crosses indicate the positions of the 7 mm compact radio binaries shown in Figure 1. The red and blue signs show the position of the water maser spots.

Table 1. Physical parameters of the circumbinary rings.

Name	RA [J2000]	Dec [J2000]	Deconv. Radius [AU]	Rot. Vel. [km s^{-1}]	Mass Dyn. [$M_\odot$]	Mass Gas[a] [$M_\odot$]
139-409	05 35 13.912	–05 24 09.40	147 ± 7	5	≥4	0.08
134-411	05 35 13.394	–05 24 11.15	83 ± 16	2.5	≥0.5	0.12

The circumstellar disks

Name	RA [J2000]	Dec [J2000]	Flux Density [mJy]	Undeconv. Radius [AU]	Mass of the Gas[a] [$M_\odot$]
139-409a	05 35 13.928	–05 24 09.41	2.5 ± 0.5	25	0.05
139-409b	05 35 13.933	–05 24 09.47	3.2 ± 0.5	20	0.06
134-411a	05 35 13.406	–05 24 11.33	3.3 ± 0.5	25	0.06
134-411b	05 35 13.412	–05 24 11.22	3.2 ± 0.5	25	0.06

(a) The masses of the gas were obtained assuming a dust temperature value of 100 K, an adopted value of $\kappa_{1.3\ mm}$ = 1.5 cm^2 g^{-1} (the average of the values of 1.0 cm^2 g^{-1}, valid for grains with thick dust mantles, and 2.0 cm^2 g^{-1}, valid for grains without mantles) and the flux densities at 1.3 mm of 180 mJy for 139-409 and of 270 mJy for 134-411.

The VLA 7 mm continuum observations revealed the presence of two very compact radio objects with sizes and separations of ~50 AU, toward the center of the molecular flattened structures (see Figures 1, 2 and 4). We interpret these compact central objects as very compact circumstellar disks. The physical parameters of these circumstellar disks are given in Table 1.

Since the CH_3CN molecule traces high-density gas the elongated structures traced by this molecule in 139-409 and 134-411 suggest two flattened circumbinary molecular rings observed in nearly edge-on. Moreover, the first moment of the CH_3CN[12-11] emission shows a total velocity gradient of about a few kilometers per second that seems to be aligned with the major axes of both structures, supporting also this interpretation (see Figures 2 and 4). Furthermore, in Figures 3 and 5 we show that the kinematics of the molecular gas in both cores, as computed along the major axes, seems to be consistent with a "rigid body law". This kinematics behavior also suggests that the molecular gas in both flattened structures seems to be only in a rotating ring.

In conclusion, we interpret the flattened molecular structures associated with the sources 139-409 and 134-411 as two circumbinary rings around binary systems traced by very compact 7 mm circumstellar disks associated with young intermediate-mass (proto)stars. However, we believe that more observations with higher angular and spectral resolution are necessary to confirm our interpretation. Finally, this result supports also the idea that intermediate-mass stars form through circumstellar disks and jets/outflows, as the low mass stars do.

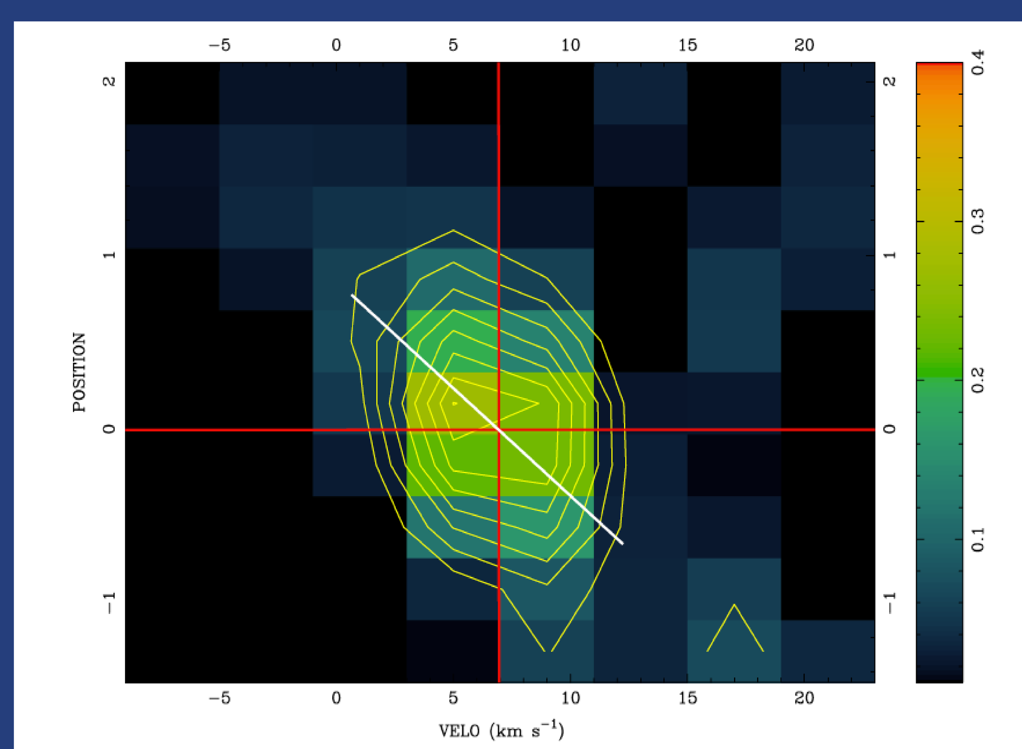

Figure 5 Position-velocity diagram of the $CH_3CN[12_4-11_4]$ molecular emission of 134-411 computed along the direction with PA=116º.

‡Based on the Letter: "Circumbinary molecular rings around young stars in Orion", Zapata,L.A., Ho,P.T.P., Rodriguez,L.F., Schilke,P., Kurtz,S. 2007, A&A, 471L, 59Z