# CO outflows in Orion: OMC-2/3

**N. Marcelino(1), J. Cernicharo(2), O. Berné(3)**

(1)NRAO (USA); (2)CAB, CSIC-INTA (Spain); (3)Leiden Obs., Leiden Univ. (The Netherlands)

## Introduction

The Orion molecular cloud is the closest (brightest) high-mass star forming region and, therefore, has become a prototypical source. The N-S molecular filament, known as the Integral-Shaped Filament (ISF, Bally ea. 1987), contains many protostellar sources (both low- and high-mass) at different stages of star formation. The youngest protostars, still deeply embedded in the cloud, can be detected in the near-IR or submm wavelengths. However in the mm range, the molecular gas surrounding these objects will show other signatures of the on-going star formation process. Among them, the blue and/or red wings in the $^{12}CO$ line profiles, constitute one of the most used methods to identify protostellar outflows. Detailed analysis of the CO data can also provide valuable information about the outflows and the driving source (mass, momentum and energy, accreted and ejected mass, etc.).
Using $^{12}CO$ J=2-1 large scale maps of Orion A (Berné ea. 2010; Marcelino ea. in prep.) we have identified CO outflow signatures. The used angular and velocity resolutions (11" and 0.4 km/s) are higher than previous extended CO maps, allowing the identification of small structures with its complex velocity distribution. In this poster we present the identified CO outflows towards the molecular clouds OMC-2/3, where many young low- to intermediate protostars have been observed.

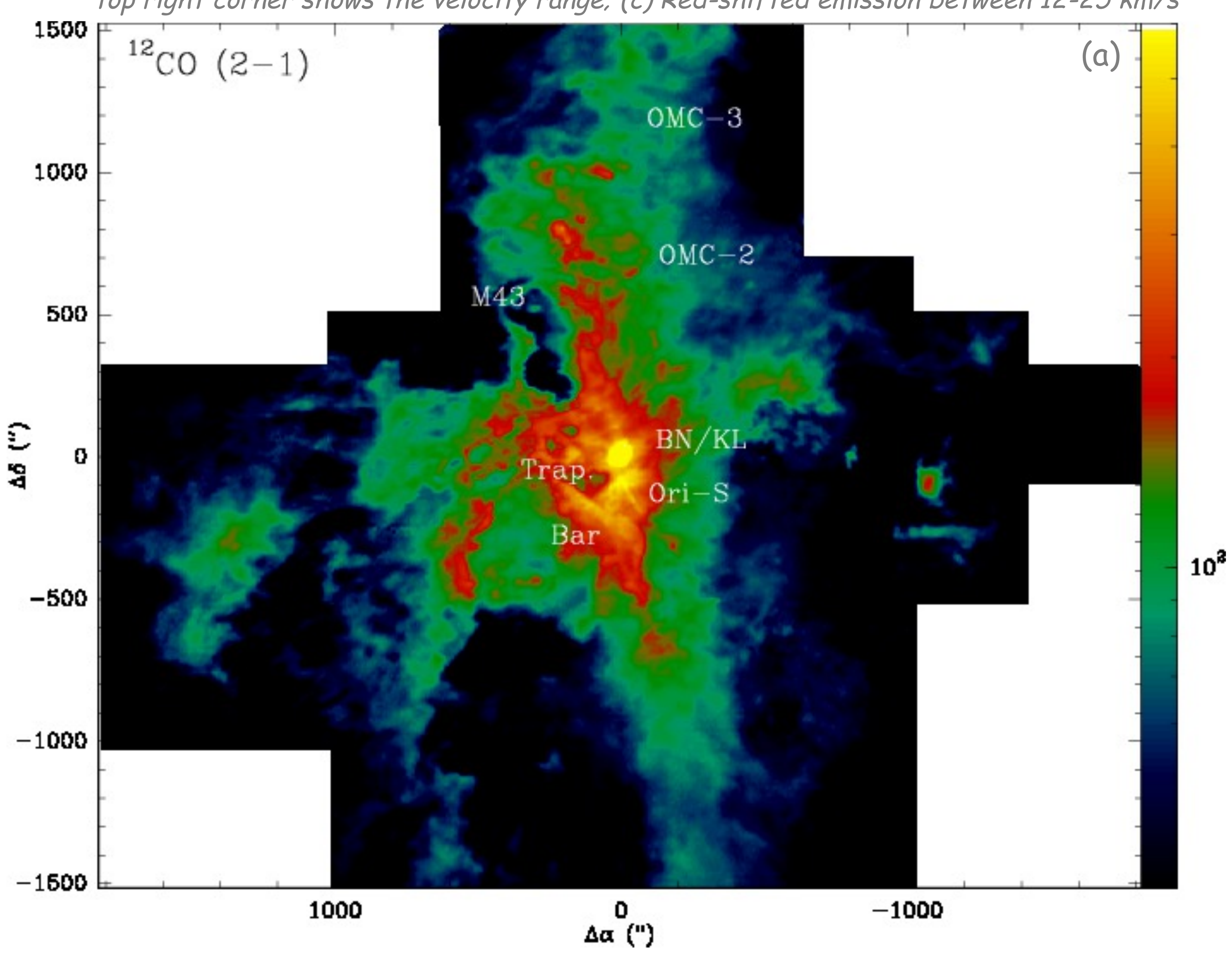
## Observations

The observations were performed at the IRAM 30m telescope (Spain) in 2008. We used the 3X3 HERA receiver array, each polarization tuned to $^{12}CO$ and $^{13}CO$ J=2-1 (230.5 and 220.4 GHz respectively). At these frequencies the beamwidth of the antenna is ~11", and the velocity resolution used is ~0.4 km/s. We observed in *On-The-Fly* (OTF) mapping mode and covered a region 1°x0.8°, at its largest extend, by the combination of 63 submaps. The central position of the map is that of the infrared source IRc2 ($\alpha_{J2000}$=05$^h$ 35$^m$ 14.5$^s$, $\delta_{J2000}$=-05° 22' 29.3").

## Results

Figure 1a shows the total integrated observed emission, where some of the main structures in Orion A are labeled. The morphology of the molecular gas, with many filaments, condensations and cavities, reveals the strong interaction of the newly formed stars –and their associated winds, HII regions, etc.– with the parental cloud. Figures 1b and 1c show the blue- and redshifted gas, where the interaction of the molecular gas with M42 is evident. In particular, the filaments to the E and SE in Fig 1b follow M42 ionization fronts. While the ionized material bubble push forward these structures, in Fig 1c we can also see the gas moving away from the observer due to this interaction. Besides this large scale interaction, outflow signatures are detected through the region. The most important being the high-mass forming regions Orion-KL and Orion-South. Also, the northern ISF shows multiple outflows as seen by the clumpy emission in Figs 1b and 1c, revealing star formation activity in the OMC-2/3 clouds.

*Fig 1: (a) Total $^{12}CO$ integrated intensity; (b) Blue-shifted emission only, numbers at the top right corner shows the velocity range; (c) Red-shifted emission between 12-25 km/s*



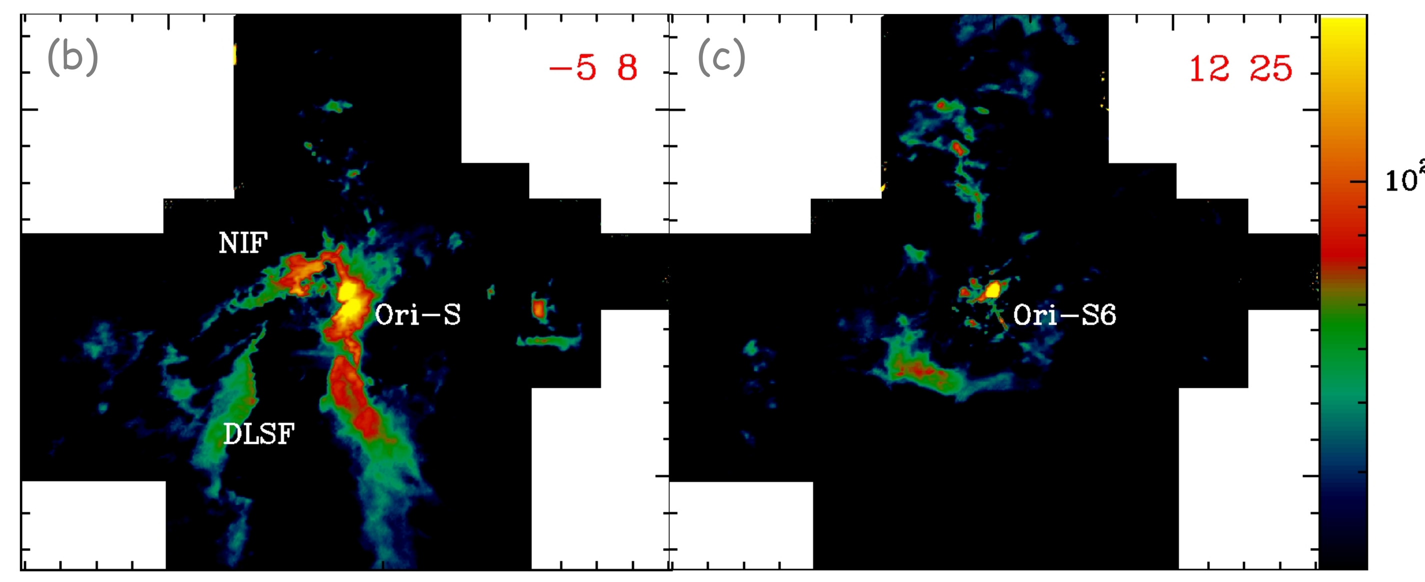




*Fig 2: OMC-3 northern region. Blue contours are 3 to 70 by 2 K km s$^{-1}$, while red ones are 6 to 70 by 2 K km s$^{-1}$. See text for more details.*

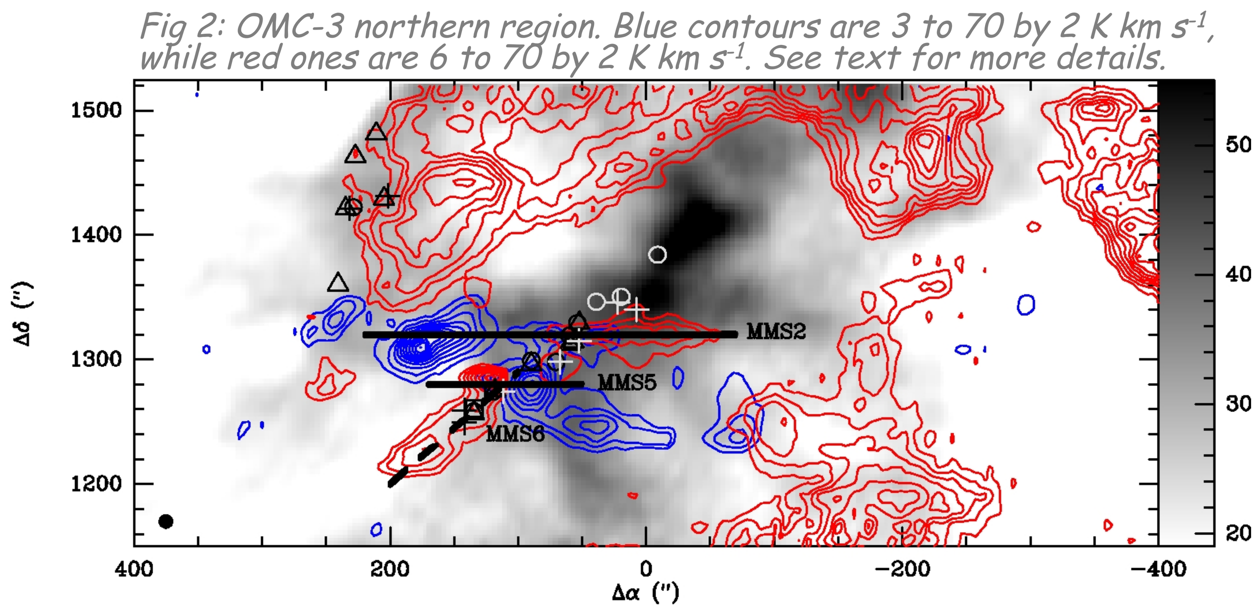



*Fig 3: OMC-2/3 region. Blue contours are 3.5 to 70 by 2.5 K km s$^{-1}$, while red ones are 8 to 70 by 3 K km s$^{-1}$. See text for more details.*

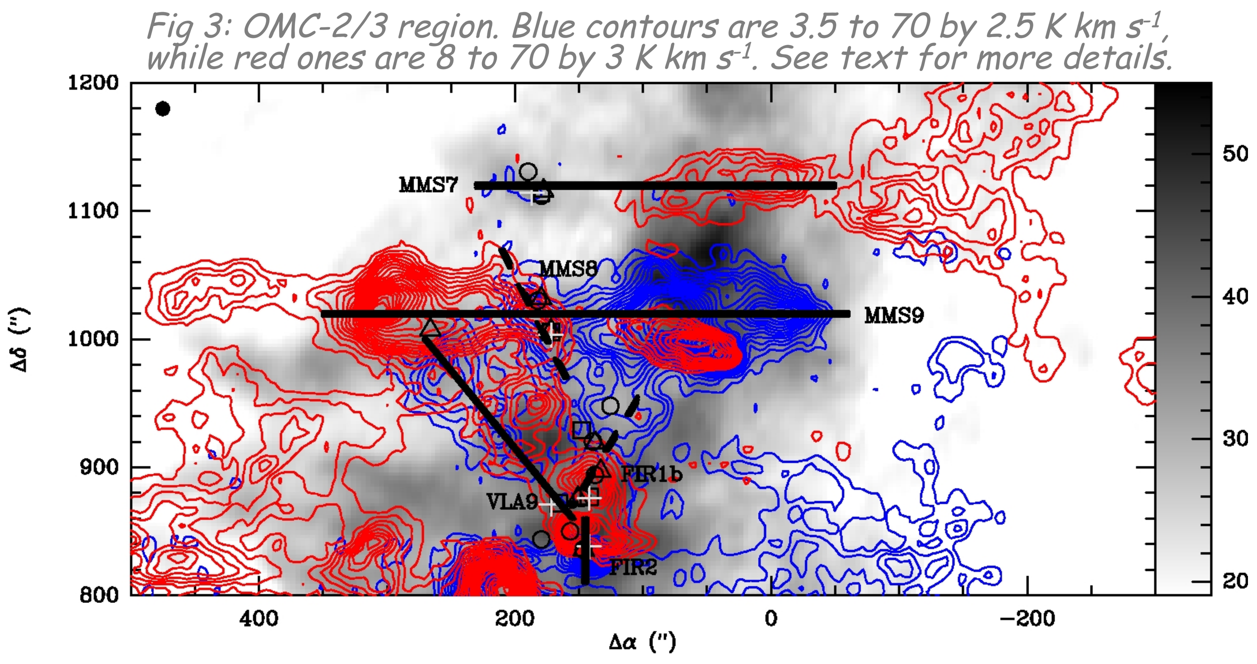
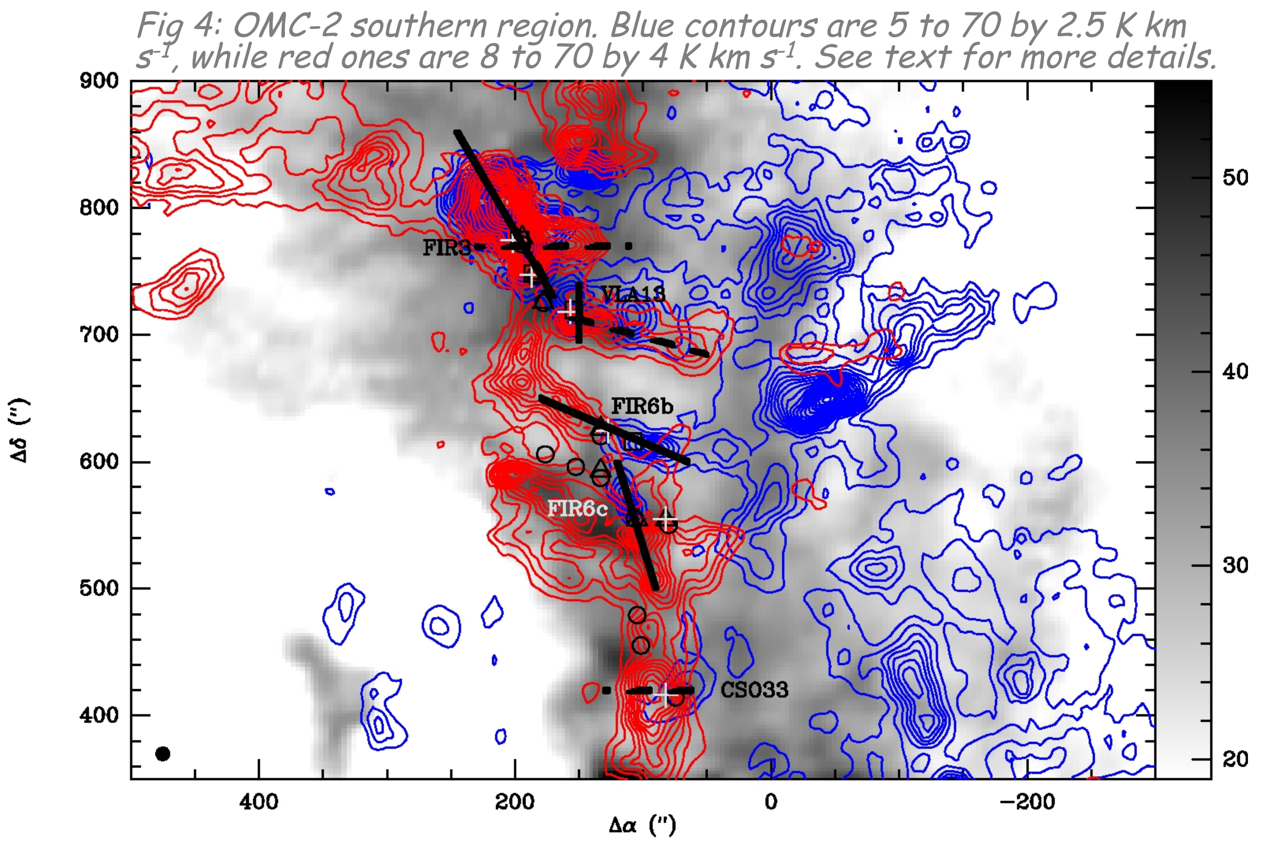



*Fig 4: OMC-2 southern region. Blue contours are 5 to 70 by 2.5 K km s$^{-1}$, while red ones are 8 to 70 by 4 K km s$^{-1}$. See text for more details.*




## Orion Molecular Clouds 2/3

At the northern end of the ISF several molecular peaks, known as the OMC-2/3 clouds appear. They are located ~15' and 25' North from BN/KL, and contain high density ($10^5$-$10^6$ cm$^{-3}$) and relatively low temperature (~20-25 K) gas (Castets & Langer 1995). Both are known to be very active in star formation, since many young low-mass protostars and outflows have been reported (see Peterson & Megeath 2008, for a review). Indeed Figs 1b and 1c show strong and turbulent emission at blue- and redshifted velocities. Most of the clumps seen at these velocities show strong wings in the $^{12}CO$ line profiles. We have used both CO emission morphology and the presence of such wings in the spectra to identify 16 outflows in OMC-2/3. This work is still on-going, a more detailed comparison with the IR and submm sources and the calculation of outflow properties will be published elsewhere (Berné, Marcelino, ea. in prep.).
Figures 2-4 show the OMC-2/3 region in which the detected outflows (and possible driving sources) are identified. Blue and red contours show low (-30 to 7 km/s) and high-shifted (13 to 50 km/s) velocities from $^{12}CO$ emission, while $^{13}CO$ emission at the mean velocities of the cloud (7-13 km/s) is shown in grey scale. Different symbols are used to mark the positions of Class 0/I protostellar objects. Open triangles show 1.3mm continuum sources (Chini ea. 1997; Nielbock ea. 2003), circles those detected at 350 µm (Lis ea. 1998), open squares mark 3.6 cm VLA sources (Reipurth ea. 1999), and crosses show the position of near-IR sources identified by Takahashi ea. (2008). Below, we discuss briefly the regions shown in the Figures.

<u>OMC-3 (north)</u>: Two outflows in the E-W direction are clearly identified in Fig 2, which possible driving sources are MMS2 and MMS5. The latter shows blue and red lobes close to the source, although a more extended blue lobe is seen to the SW. For both outflows, the detection of VLA sources and/or near-IR emission support their identification (Takahashi ea. 2008). A third possible outflow in the SE-NW direction is detected (MMS6). However, the only presence of a red lobe and the weaker wings makes this identification less clear.
<u>OMC-2/3</u>: The southern OMC-3 and northern OMC-2 clouds show clear outflow signatures, although the identification is difficult for some of them due to the high density of outflows and protostellar sources. MMS7 at the top of Fig 3, shows a large redshifted jet to the W, while only a small blue lobe is seen close E to the source. South to this outflow, a strong, bipolar one is seen in the E-W direction. The possible driving source is MMS9, which is associated with a 24µm source. Besides, close to the mm sources MMS8 and MMS9 there are coincident blue and red emissions in the NE-SW direction. This could be either coming from MMS8 or the result of a precessing outflow from MMS9. The origin of the red lobe to the W, which points back to MMS8 and MMS9, is not clear. Williams ea. (2003) considered this as part of the MMS9 instead of the blue lobe nearly coincident, since they did not detect blue wings on the spectra as we do.
In the northern OMC-2, a redshifted peak is detected close to FIR 1b. The extended low velocity emission at the N could be the blueshifted counterpart, although is not clear. East to FIR 1, a blue lobe in the NE-SW direction is seen, which is probably driven by VLA 9. Previously this emission was identified as arising from MMS10 (Williams ea. 2003), but the higher collimation and stronger wings are closer to VLA 9, pointing to the latter region as the origin of the outflow. At the bottom of Fig 3, a N-S bipolar outflow, with lobes close to FIR 2 is clearly detected.
<u>OMC-2 (south)</u>: Multiple blue and redshifted lobes are seen in the region FIR 3-5 (top in Fig 4). FIR 3 is the most probable source driving a NE-SW outflow with double-peaked and coincident lobes. This morphology has been interpreted as a pole oriented outflow (Takahashi ea. 2008). However, the presence of both blue and red emission toward W could also point to a criss-crossed jet since FIR 3 is a binary (Williams ea. 2003). To the SW and close to VLA 13, there are two blue and red small lobes, which could constitute a N-S outflow arising from this source. However, the extended emission to the W could point to a different orientation or another outflow driven by an undetected source. In the region FIR 6, two clear outflows are seen. FIR 6b is likely driving a NE-SW bipolar outflow. The 24 µm and VLA sources confirm this detection. To the south, FIR 6c powers a N-S outflow. At the bottom of Fig 4, there is a possible outflow in the E-W direction, close to CSO 33. However, the identification of the redshifted emission as part of this outflow is not clear, since it is lying in the molecular ridge close to M43 which could affect the gas close to this HII region.

**References**

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