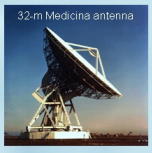
Intermediate-Mass Protostellar Outflows: the Puzzling L1641 case



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We have carried out observations at cm- and mm-wavelengths of the intermediate-mass star-forming region L1641 in several high-density gas and outflow tracers with the 32-m Medicina and Noto antennas, and with the 3-m KOSMA radiotelescope. The main goal we pursue is to clarify the complex molecular morphology in the L1641 region and to determine whether this complexity is due to the bending of the outflows or to the interaction of two intrinsic poorly collimated flows driven by IRAS 05375-0731 and IRAS 05380-0728 with the surrounding gas. We have mapped in $NH_3(1,1)$ and (2,2), and $HC_3N(5\text{-}4)$, the region towards the L1641-S3 cloud, where H_2 observations suggested a strong interaction between outflows and ambient material (Stanke et al. 2000). These observations have revealed the presence of several high-density clumps at different velocities surrounding the molecular outflows, traced using the J = 2-1 and 3-2 line emission of CO. The preliminary results seem to suggest that such clumps are tracing gas entrained within the surface of interaction between the outflows and the cloud hosting the star forming process.

2.12 μm image of the L1641-S and L1641-S3 region (Stanke et al. 2000), which is located at 460 pc. The contours show the distribution of high-velocity CO (1-0) (Morgan et al. 1991). Solid lines indicate redshifted gas, and dotted lines blueshifted. The systemic velocity in this region is about +5 km s^{-1}.

MB 40 (L1641-S)

RE 50 N

IRAS 05380-0728

RE 50

MB 41

L1641-S3 IRS

IRAS 05375-0731

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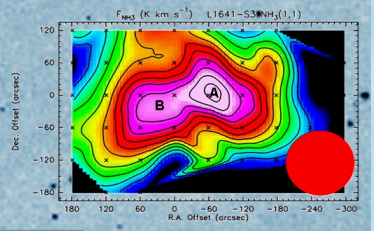
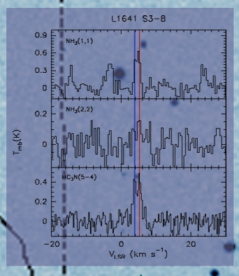
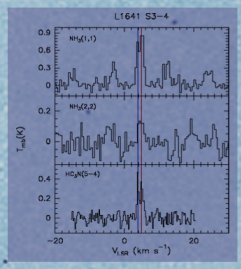
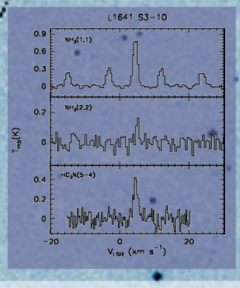
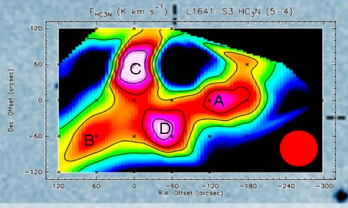
Integrated (K km s^{-1}) NH_3 (1,1) emission under the main line component, for a velocity interval [+1,+9] km s^{-1}, towards L1641-S3 taken with the 32-m Medicina antenna. Offsets are relative to the position of IRAS 05375-0731, $\alpha(2000) = 05^h\ 39^m\ 56.2^s$ $\delta(2000) = -07^o\ 30'\ 26.1''$. The frequency of the line is 23.7 GHz. The red circle indicates the antenna HPBW. Two clumps have been detected in NH_3, the western and strongest one called A, and the eastern one called B.











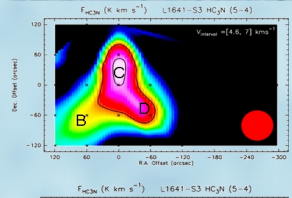
Integrated (K km s^{-1}) HC_3N (5-4) emission, for a velocity interval [+1,+9] km s^{-1}, towards L1641-S3 taken with the 32-m Noto antenna. Offsets are relative to the position of IRAS 05375-0731, $\alpha(2000) = 05^h\ 39^m\ 56.2^s$ $\delta(2000) = -07^o\ 30'\ 26.1''$. The frequency of the line is 45.5 GHz. The red circle indicates the antenna HPBW. Four clumps have been detected: clumps A and B (also detected in NH_3), and two additional clumps, C and D.

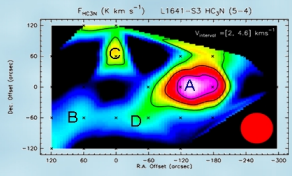
1 arcmin

0.13 parsec

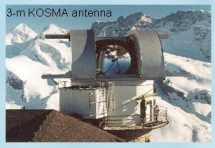
Spectra of NH_3 (1,1), NH_3(2,2), and HC_3N (5-4) have been taken towards the peak positions of clumps A and B (detected in both molecules), and clump C (detected only in HC_3N). The HC_3N spectra show clearly two spectral components, which cannot be disentangled by the complex NH_3 pattern. The first component peaks at a velocity of +3.9 km s^{-1} (*blue line*), while the second one peaks at +5 km s^{-1} (*red line*). The line widths of the components are in the 1-1.5 km s^{-1} range. From the (1,1) and (2,2) NH_3 spectra we have only been able to derive a rough estimate of $T_{kin} \sim 15$ K and $N_{NH3} \sim 2.5\ 10^{14}$ cm^{-2} for the gas towards clump B.

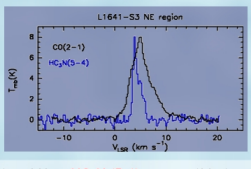
Overlay of the integrated NH_3 (1,1) emission (*red contours*) on the CO (1-0) high-velocity emission (*black contours*) (Morgan et al. 1991). The NH_3 (1,1) emission shows an elongated flattened structure, roughly perpendicular to the CO molecular outflow, with two clumps, A and B, located at both sides of the molecular lobes. This scenario suggests that the two clumps could be tracing gas entrained within the surface of interaction between the molecular outflow and the dense ambient core, resembling the scenario proposed for the other intermediate-mass outflow IC 1396N (Codella et al. 2001; Beltrán et al. 2002). Another possibility could be that the NH_3 emission is tracing a circumstellar envelope around the embedded YSO that is powering the CO outflow.

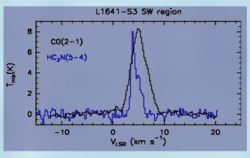




Integrated HC_3N (5-4) emission of the +3.9 km s^{-1} component, for a velocity interval [+2,+4.6] km s^{-1} (*upper panel*), and of the +5 km s^{-1} component, for a velocity interval [+4.6,+7] km s^{-1} (*lower panel*). Note that the two components are clearly tracing different clumps. The +5 km s^{-1} component clearly traces the clump A, which is the strongest one visible in NH_3, and it is also detected with much weaker emission towards clumps B, C, and D. On the other hand, the +3.9 km s^{-1} component peaks at the clump C position, traces clumps B and D as well, and shows no emission towards clump A. Therefore, the emission of HC_3N is different from the NH_3 one. Although one cannot exclude a sampling/resolution effect (note that the spatial resolution of the HC_3N observations is half of that of NH_3), this could indicate a different HC_3N/NH_3 ratio. In order to confirm this scenario further analysis and observations are required.







Overlay of the KOSMA CO (2-1) (*black*) and Noto HC_3N (5-4) spectra (*blue*) integrated over the NE and the SW lobes of the molecular outflow detected by Morgan et al. (1991). A preliminary analysis of the KOSMA observations indicates that the NE spectrum has a strong red wing, in agreement with the redshifted CO (1-0) lobe mapped by Morgan et al. (1991), plus some weaker blueshifted emission. The SW spectrum shows that there is still redshifted emission towards the south (not shown by the CO (1-0) map), as well as hints of a blue wing. Therefore, these preliminary results suggest that the outflow structure in L1641-S3 is more complex than the one shown by the CO (1-0) maps. However, in order to shed some light on the structure of this region, a further and more detailed analysis of the CO (2-1) and (3-2) data (the latter not shown here) is required.