Near infrared H2 outflows through IFU observations: peering into the massive star forming region IRAS 18264-1152

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Abstract

Since massive protostars are deeply embedded in their parental clouds, it is highly challenging to directly observe their immediate environment in the near-infrared (NIR). However, it is known that accretion and ejection processes are intrinsically related, thus observing the outflows in the NIR can provide crucial information about the processes governing massive star formation very close to the central engine. We analyse the morphology and chemical composition of the NIR jets of the IRAS 18264-1152 (G19.88-0.53) massive star forming region via K-band (1.9μm-2.5μm) observations obtained with the integral field units VLT/SINFONI and VLT/KMOS. We compute K-band magnitudes for seven point sources identified. One point source shows a rising continuum in the K-band, which may indicate its youth and potential jet driving source. The spectro-imaging analysis focuses on the H2 jets, for which we derived visual extinction, temperature, column density, area and mass. Other atomic species, such as [FeII] and BrG, are also detected, although weaker than H2. The intensity, velocity, and excitation maps based on H2 emission strongly support the existence of a protostellar cluster in this region, with at least two different large scale outflows. Furthermore, the NIR H2 morphology agrees extremely well with that found in the radio CO 2-1 outflows observed with SMA at a comparable sub-arcsecond resolution.

Motivation

When observing massive star-forming regions in the near-infrared (NIR), the central source and disc are usually highly obscured. Thus we turn our attention to the outflows driven by the high-mass young stellar objects (YSOs). The ejection and accretion processes are intrinsically related, so studying outflows can help us pinpoint the locations of the YSOs and gain insight into the mechanisms behind high-mass star formation.

Observations

We observe the IRAS 18264-1152 (also known as G19.88-0.53) region in the K-band (1.9μm - 2.5μm) using the integral field spectrograph VLT/SINFONI. The field of view is 8x8", the spectral resolution is ~ 4000, and the spatial sampling is 0.2".

We also analyse K-band archival data obtained with the integral field spectrograph VLT/KMOS. The total field of view of the mosaic image is about 40x65", the spectral resolution is ~ 4200, and the seeing limited spatial sampling is ~ 0.6".

Continuum and line emission in SINFONI

Figure 1 shows the K-band continuum emission observed with SINFONI, where we identify seven point sources. The data was flux calibrated, so we derived K-band magnitudes for these sources, which were in the range of 13-14 mag.

Source S4 shows a rising continuum spectrum in the K-band, and we detect the H I recombination line Brγ in its surroundings (in sources S5, S6, and S7). Brγ is an accretion and ejection tracer, and the emission we find seems extended and similar to the continuum, looking like scattered light in an outflow cavity. Thus this could indicate that S4 is a YSO (which has not been previously detected).

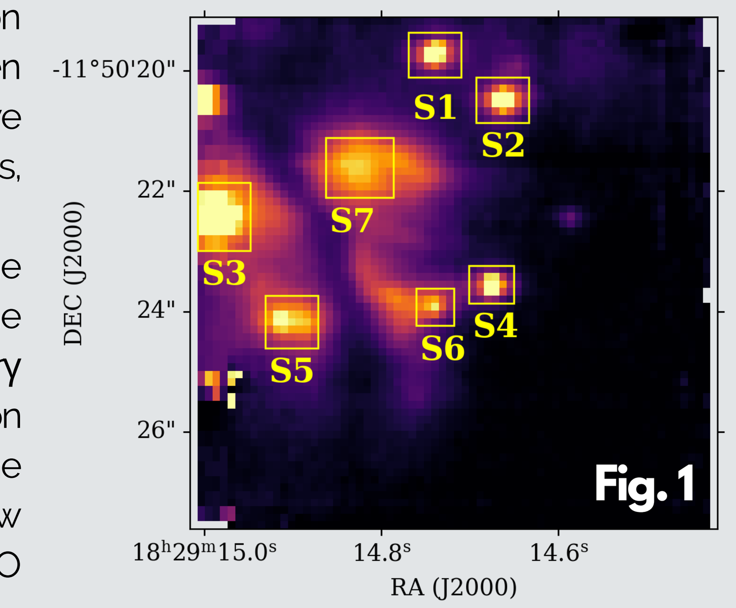

Fig. 1

H2 continuum-subtracted emission

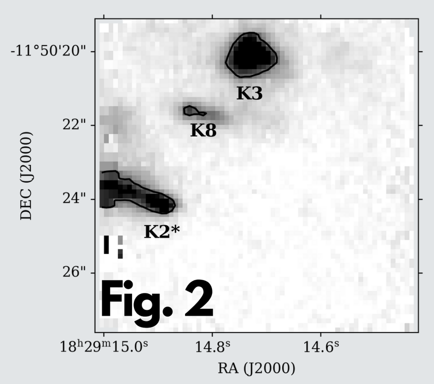

Fig. 2

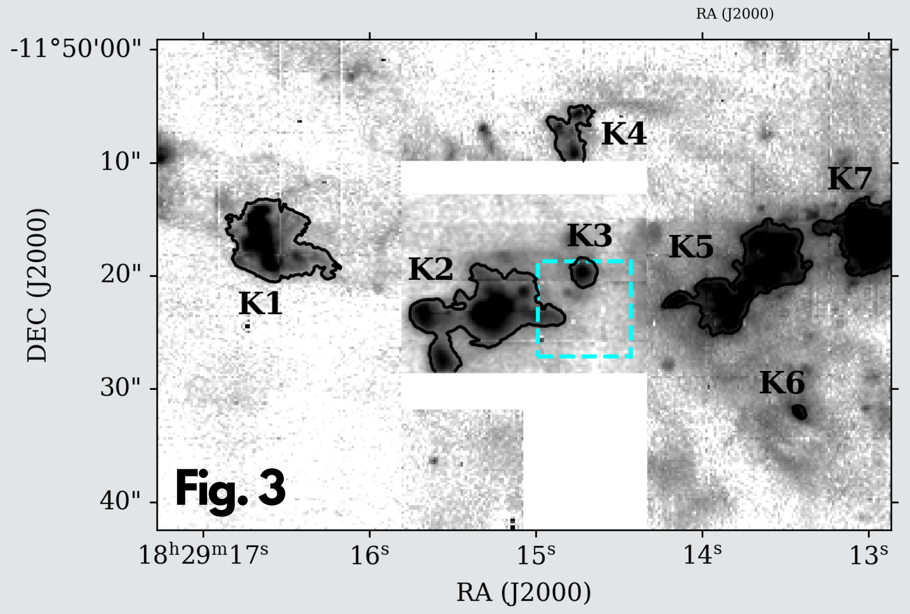

Fig. 3

Figures 2 and 3 show the H2 2.12μm continuum-subtracted emission captured with SINFONI and KMOS, respectively. We identify eight H2 knots by defining a 3-sigma threshold from local continuum regions.

We consider the scenario where one massive source (located between knots K2 and K5) is driving the E-W bipolar outflow. However, according to recent literature (e.g. Issac et al. 2020 and references within), there is evidence supporting the hypothesis that IRAS 18264-1152 hosts more than one protostar. The fact that both lobes are blueshifted (see section "Radial Velocity Map") and the presence of additional non-aligned knots lends support to the scenario of a protocluster in this region.

Radial velocity map

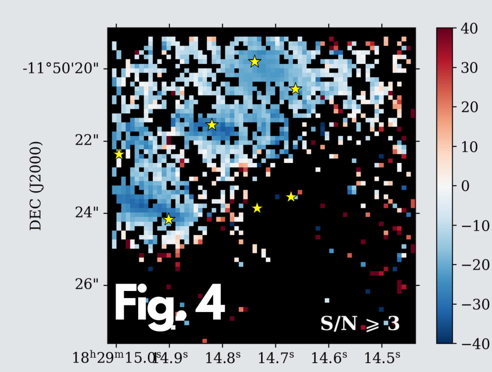

Fig. 4

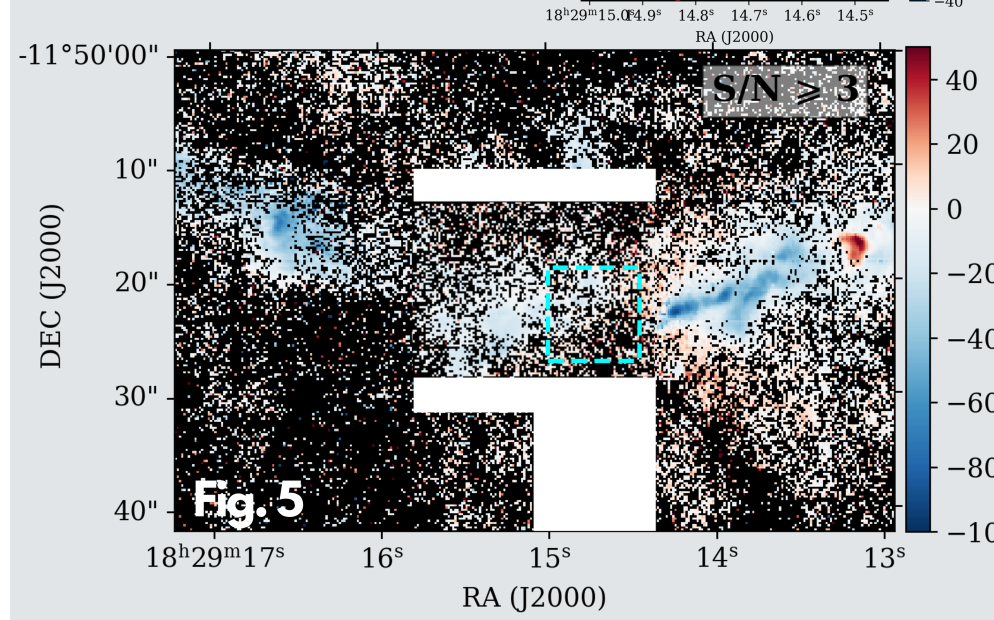

Fig. 5

We present the radial velocity maps as seen in SINFONI and KMOS in Figs. 4 and 5, respectively. The maps are produced by measuring the Doppler shift of the H2 1-0 S(1) line at 2.12μm and are corrected for the local standard rest and for the velocity of the cloud (43.7 +- 0.02 km/s, He et al. 2012).

The large scale bipolar outflows to the east and west are both blueshifted. This could be explained by the lobes belonging to two different outflows in the NE-SW and SE-NW directions, for which the red counterparts are obscured. The southwestern knot is redshifted and the northern knot is blueshifted.

We also obtained CO (2-1) outflow data from SMA (S. Leurini, private com.) which are consistent with the NIR results and which reveal the location of the red lobes.

Excitation map

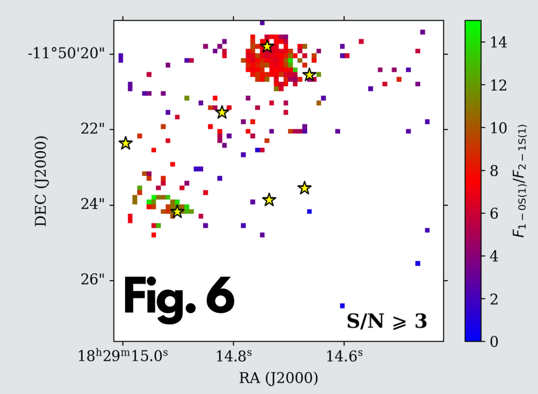

Fig. 6

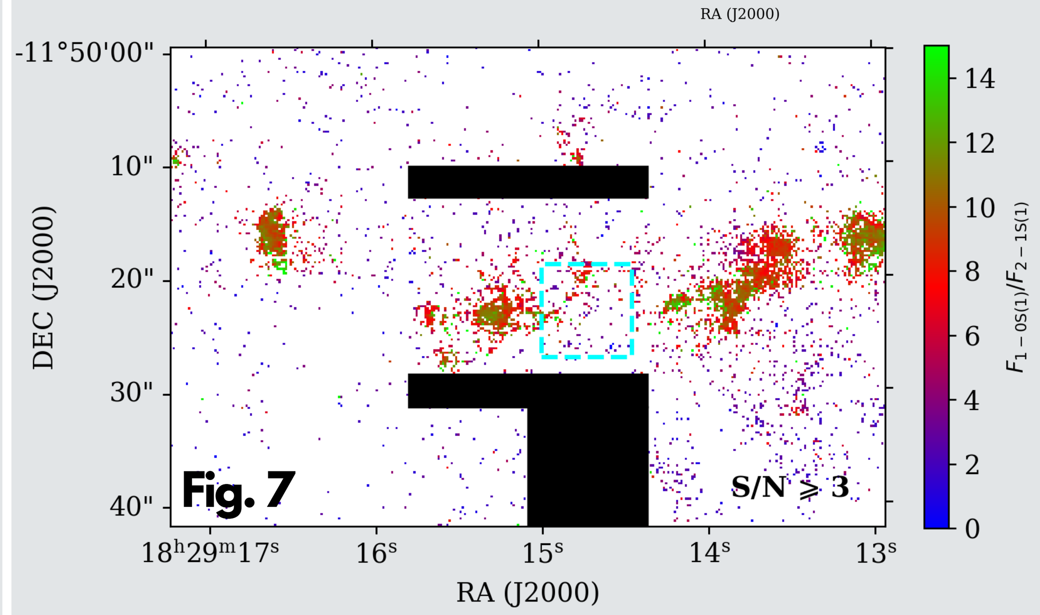

Fig. 7

The excitation maps of SINFONI and KMOS in Figs. 6 and 7, respectively, show the integrated flux ratio of two H2 lines: 1-0 S(1)/2-1 S(1).

The ratios have values of ~10. According to Burton (1992), these measurements are consistent with the H2 emission being shock driven, rather than produced by UV pumping.

These findings are consistent with the velocity maps and reinforce that the H2 is indeed tracing the jets driven by the massive protostar(s).

Extinction map

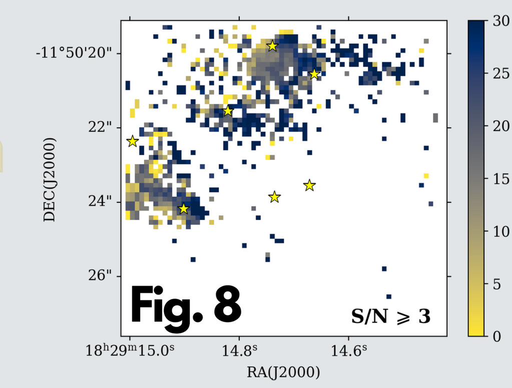

Fig. 8

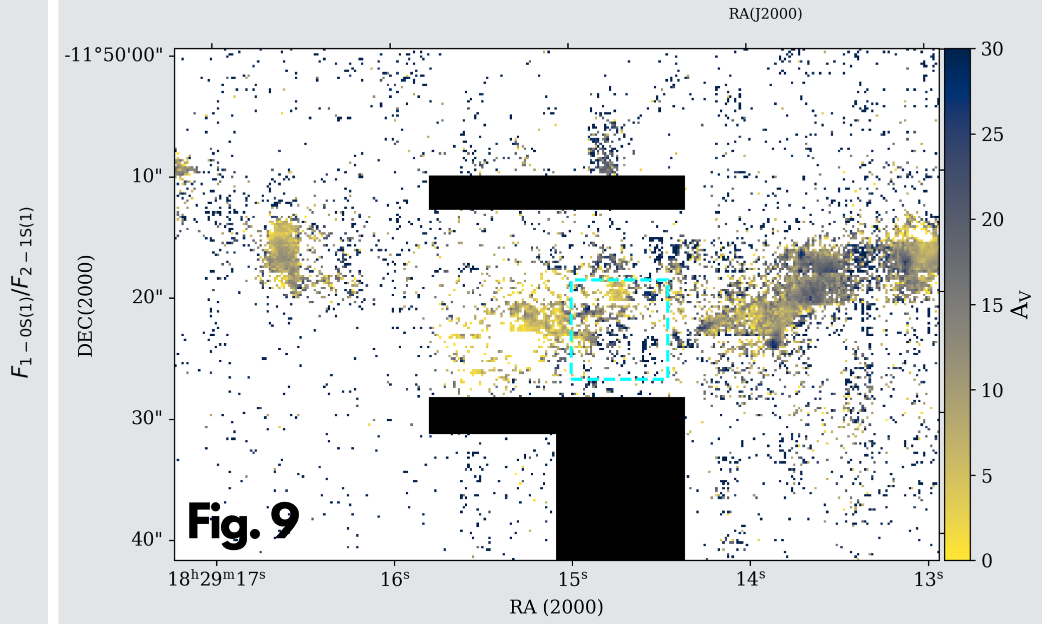

Fig. 9

Figures 8 and 9 depict the the visual extinction (Av) maps calculated with the SINFONI and KMOS data, respectively.

We calculated the Av using the extinction law from Rieke & Lebofski (1985). By choosing two H2 lines that come from the same upper level (here we use 1-0 S(1) and 1-0 Q(3)), the ratio of the extinction law is simplified and the Av becomes dependent only on the observed integrated fluxes, the Einstein coefficients, and the theoretical wavelengths of the lines. Av ranges from ~5 to 25 mag in our data.

We created ro-vibrational diagrams for each knot using the integrated line fluxes of the H2 lines, which were fitted (considering an average Av value) and yielded estimates of H2 temperatures of ~ 2500K and H2 column densities in the range of 10^16-10^19 cm^-2.

Summary

IRAS 18264-1152 is a complex star-forming environment. It shows several H2 emission lines through which we can probe deeper into the physical properties of the region.

We identify six H2 knots in the east-west direction, one to the north, and one to the southwest. The knots are consistent with shock driven emission.

The radial radial velocity map reveals that the main outflows in the east and west directions are both blueshifted, which could indicate the presence of at least two different bipolar outflows driven by different sources. The redshifted counterparts are probably obscured at these wavelengths. The northern knot is blueshifted and the southwestern knot in redshifted.

We consider the possibility of there being a single massive protostar driving the bipolar outflows. However, due to the blueshifted outflows in the east and west and the presence of additional non-aligned knots, we find it more likely that IRAS 18264-1152 hosts a protostellar cluster.

Lastly, we derive estimates of some physical properties for the jet knots in our field of view. The fitting of the ro-vibrational plots yields H2 temperatures of about 2500K and H2 column densities in the range of 10^16 to 10^19 cm^-2. These values are consistent with previous estimates for other high-mass driven outflows (e.g. Caratti o Garatti 2015).

Our results represent a great example of the usefulness of near-infrared observations in probing (or revealing) high-mass star-forming regions.

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Thank you for reading my poster.

Paper coming soon!
(Costa Silva et al., in prep)