W3 IRS 5: A Trapezium in its Making

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Abstract

Achieving a spatial resolution of ~0.35'' we resolve the inner ~4,000 AU of the high-mass star-forming region W3 IRS 5. In our PdBI 1.38 mm dust continuum map we find sources matching the positions of at least 3 of the 7 already detected near-infrared objects.

We also trace the compact SiO emission, detecting an outflow for each of the 2 main mm (and NIR) sources. Both outflows appear to be relatively close to the line-of-sight. This could explain why we can detect those 2 sources both in mm and NIR wavelengths, because we are observing the protostar directly through the cavity carved by the outflow.

Motivation

On spatial scales up to orders of a few 10^4 AU observations are showing that young massive stars are likely members of multiple systems, with separations between 10^4 AU to 1 AU, forming bound groups of several stars within larger clusters (Mermilliod & García 2001, in IAU Symposium, 191). Many of these systems are trapezia, unstable, non-hierarchical systems of three or more stars. The role such systems play in massive star formation is not yet understood, although it has been proposed that they could increase the mass accretion rate onto massive systems, or that binary accreting massive protostars could merge, forming even more massive systems.

Here we show our ongoing study of the very young star-forming cluster W3 IRS 5, which is believed to be a Trapezium system in its making.

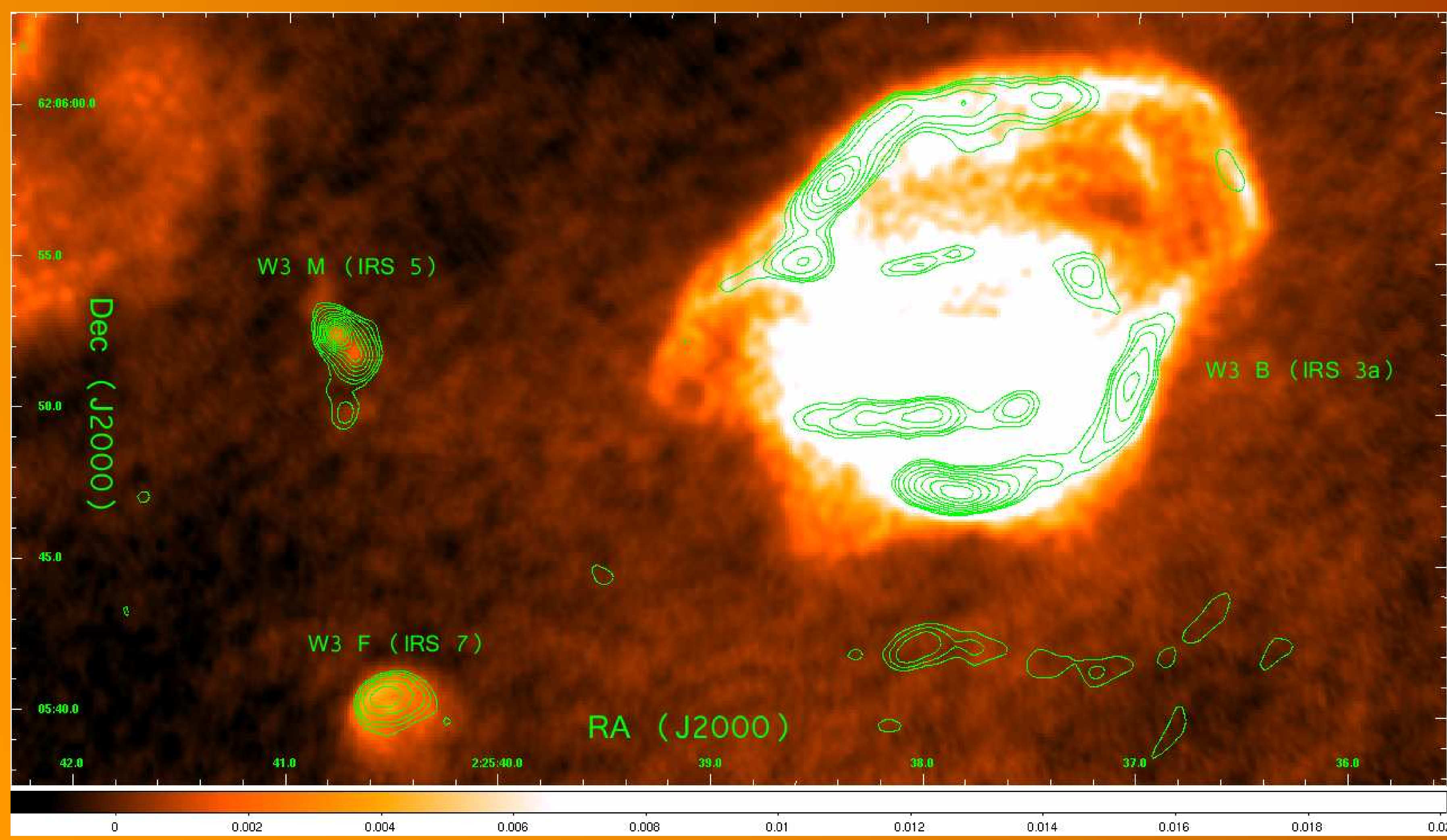

Figure 1: Continuum image of the W3 core at 4.9 GHz from Tieftrunk et al. (1997, A&A, 318, 931). Green contours trace the observed PdBI dust continuum emission at 3 mm. Shown are the compact HII region W3 B, the ultracompact HII region W3 F and the hypercompact HII region W3 M, subject of our study. In brackets are the main NIR sources associated to each region. W3 B lies at the border of our primary beam, thus the contours below W3 B are result of the deconvolution process, and do not have any physical meaning.

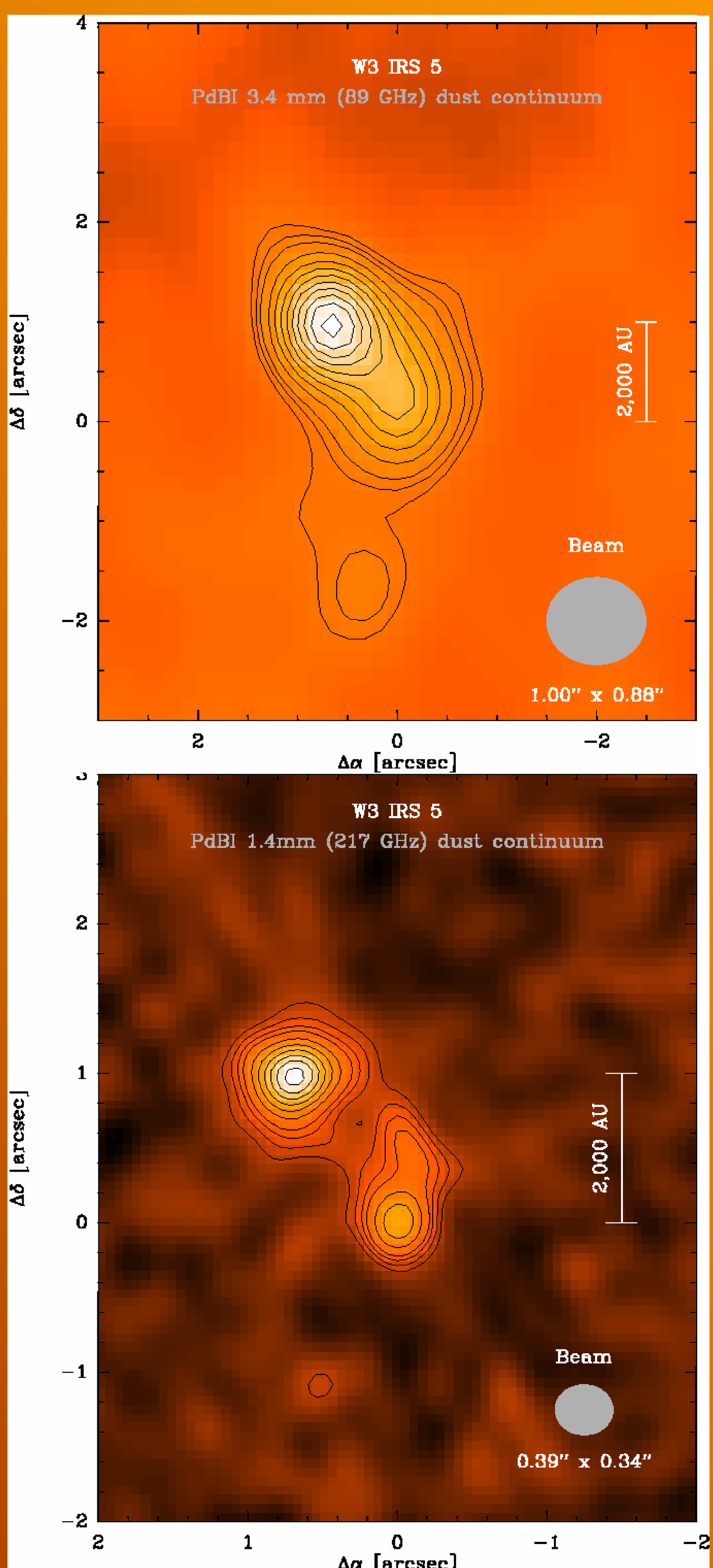

Figure 2: PdBI dust continuum maps of W3 IRS 5. Upper: 3 mm map, the contours are in 1σ steps between the 4σ level of 4 mJy/beam and 6 mJy/beam, and in 2σ intervals above that. Lower: 1.3 mm map, the contours are in 2σ steps between the 4σ level of 5 mJy/beam and 11 mJy/beam, and in 3σ intervals above that.

The proto-trapezium

The HII/molecular cloud complex W3, located at a distance of ~2 kpc, is a very active star forming region where all morphological classes of HII regions can be found (Tieftrunk et al. 1998, A&A, 340, 232). That suggests that different stages of massive star formation may be sequentially triggered by the pressure of the expanding HII regions (Figure 1).

Megeath et al. (2005, ApJ, 622, L141) observed 7 NIR sources in the region, 2 of which were previously known. Van der Tak et al. (2005, A&A, 431, 993) also detected several radio sources both in 43 GHz and 22 GHz.

We have mapped the region W3 IRS 5 with the Plateau de Bure Interferometer at 1.3 and 3 mm, imaging the dust continuum achieving an impressive spatial resolution, with a synthesized beam of 0.39'' x 0.34'' at 1.3 mm (Figure 2).

Considering a 4σ level sensitivity, we resolve 4 individual sources in the 1.3 mm continuum map. In Figure 3 we can see how each one of the mm sources matches a NIR source detected by Megeath et al. (2005), as well as a radio source form Van der Tak et al. (2005).

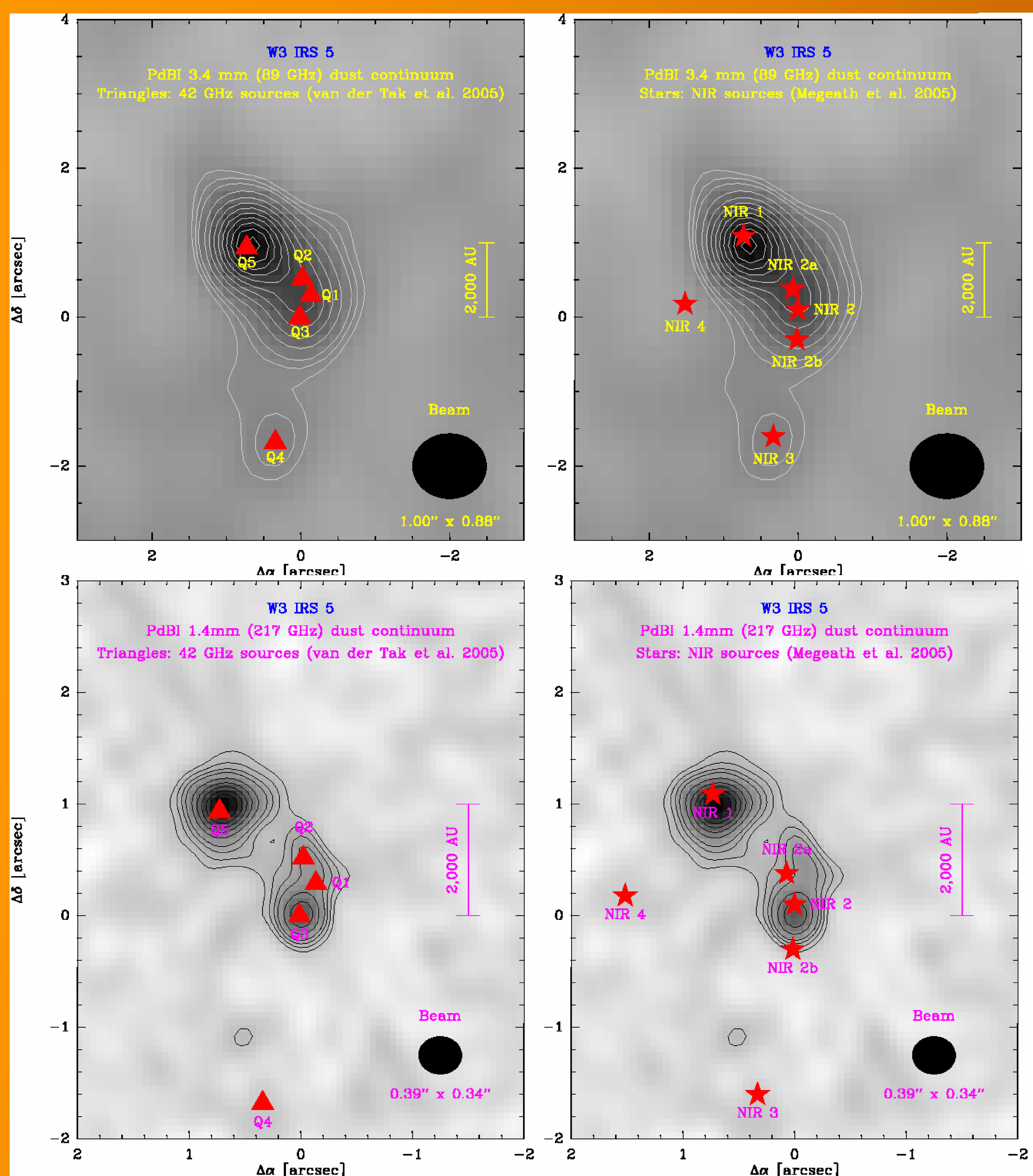

Figure 3: Positions of the NIR and Radio sources detected in the region, overlayed onto our PdBI dust continuum maps of W3 IRS 5. Left: Radio sources detected at 42 GHz by van der Tak et al. (2005), denoted by filled triangles, matching our dust continuum sources at 3 mm (upper panel) and 1.3 mm (lower panel). Right: NIR sources detected at 2.22 µm by Megeath et al. (2005), denoted by filled stars, matching our dust continuum sources at 3 mm (upper panel) and 1.3 mm (lower panel). In all cases, the contouring of the dust continuum is like in Figure 2.

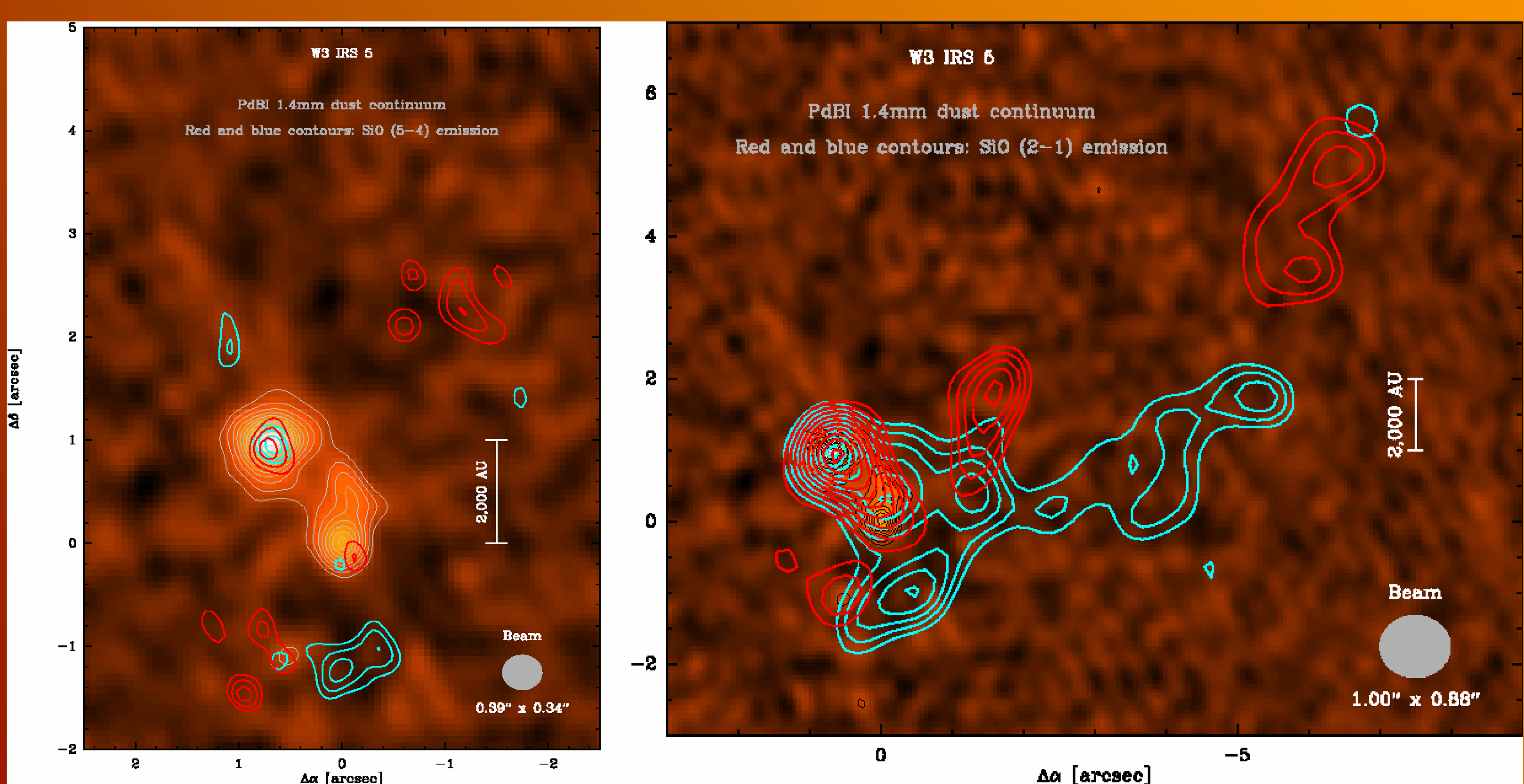

Figure 4: Blue- (cyan contours) and red-shifted (red contours) SiO (5 – 4) (1.3 mm, left) and SiO (2 – 1) (3 mm, right) emission detected in W3 IRS 5. Note in the left panel, how the blue- and red-shifted emission matches the position of the main continuum sources, apparently aligned close to the line-of-sight.

Compact Outflows

First analysis of the observed SiO (2 – 1) at 86.64 GHz and SiO (5 – 4) at 217.10 GHz lines revealed the presence of at least 4 outflows, shown in Figure 4. Two of these outflows match in position with the two main sources, and apparently are aligned close to the line-of-sight. This can explain why it is possible to observe these two sources both at NIR and mm wavelengths, because we would be observing the protostar directly through the cavity carved by the outflow.

We are still analyzing the obtained $C^{18}O$ (2 – 1) line emission at 219.64 GHz, as well as the SO_2 ($8_{3,5} - 9_{2,8}$) and SO_2 ($22_{2,20} - 22_{1,21}$) lines at 86.85 GHz and 216.64 GHz respectively.