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Cool, warm and hot outflows from CTTS
The FUV view of DG Tau

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Classical T Tauri stars drive strong outflows with temperatures from about 10^3 K up to a few 10^6 K. These outflows regulate the angular momentum balance and are therefore tightly related to the accretion process. However, the outflow driving and heating mechanisms are not well understood. We present new HST data of the prototypical jet-driving CTTS DG Tau tracing the low-temperature outflow with far-UV molecular hydrogen emission and the high-temperature part with C IV emission. We find that the low-temperature part shows a pronounced V-shape consistent with molecular disk-wind models. Low-velocity shocks are probably the pumping source for the FUV H2 lines. The hot plasma ($T>10^5$ K) is located close to the jet axis at a distance of 40 AU from the driving source and spatially offset from usual (optical) jet-tracers like [S II] or [O I]. It does not show any hints for proper-motion contrasting typical jet properties. The high-temperature plasma is unlikely to be caused by a hot stellar wind and we propose that the stationary heating is due to internal shocks or magnetic reconnection.

Cool:
Molecular hydrogen emission

The FUV molecular hydrogen line emission is fluorescently excited by Lya photons → traces the amount of molecular hydrogen at T~2000 K and the local Lya radiation field.

- Two bright rims with an opening-angle of 90 deg are clearly visible in the FUV and the near-IR.
- The H2 emission is located at greater distances from the jet axis than the faster [S II] λ6300.

➔The V-shaped H_2 Emission traces a warm disk wind probably heated predominately by ambipolar-diffusion (see models by [3]).

Warm:
Optical line emission (10^4 K)

- The forbidden line emission is concentrated in two knots within the innermost 140 AU (Fig. 2), but no (or very little) emission is present at the centroid position of the X-ray emission [1,2].
- The faster knot (0.3", 63 AU) is located further out than the X-ray emission. The slower one at 0.1" (21 AU) is located closer to DG Tau than the X-ray emission.
- The inner, low-velocity [O I] emission component appears stationary, but is much faster than predictions for photo-evaporating winds.

Hot:
FUV emission ($T\sim10^5$K, C IV)

The hot plasma is

- located co-spatially with the X-ray emission ($T>10^6$ K), but
- offset from the lower temperature optical emission.

→ C IV traces a different jet component than the lower temperature material. A stellar wind cools too rapidly to explain that the C IV emission peaks 40 AU from DG Tau so that we favour internal heating.

No emission is seen at the stellar position which demonstrates that a correlation between C IV luminosity and accretion rate might be indirect via the accretion-outflow relation in some objects.

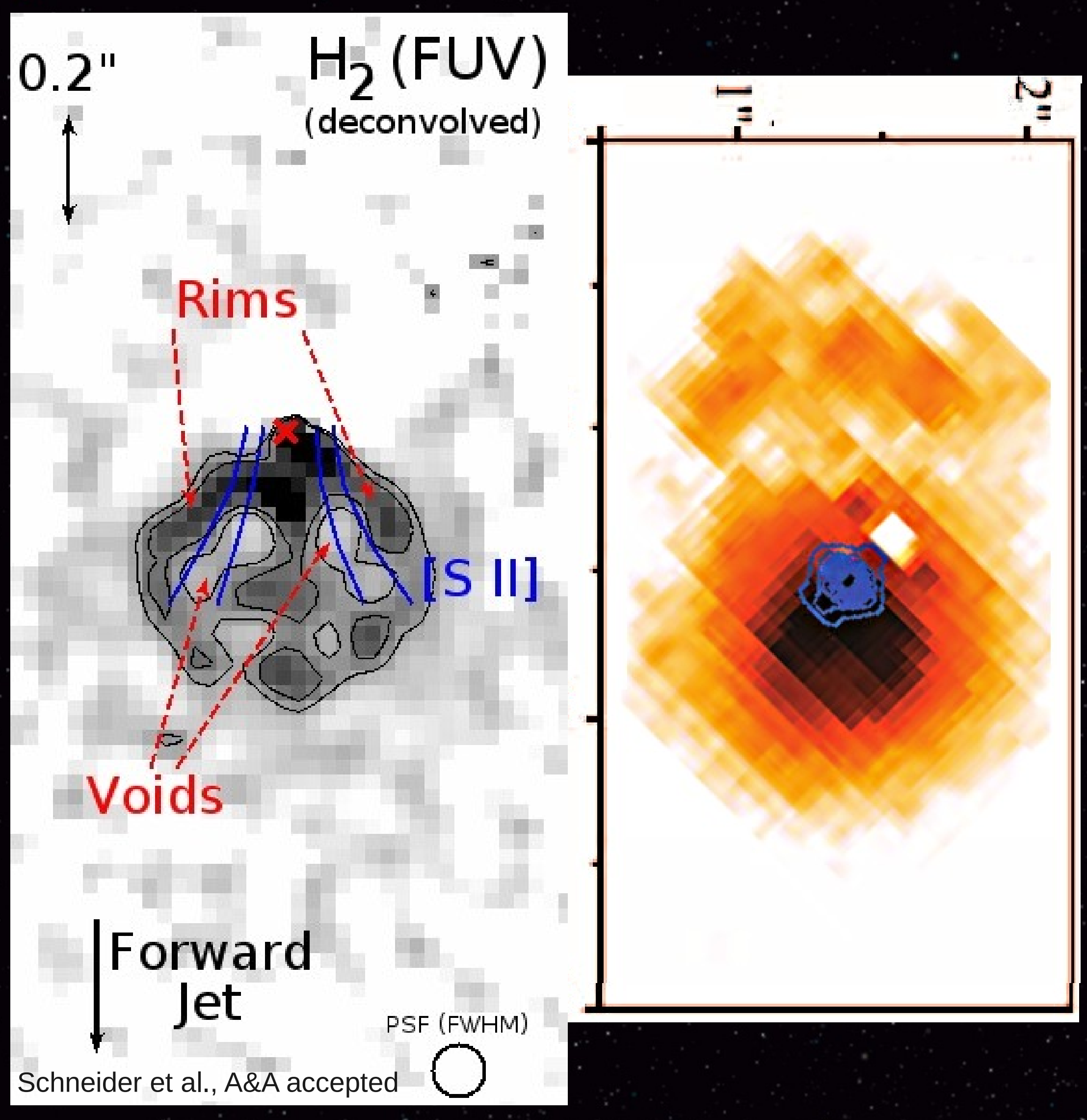

Fig.1 Left: FUV H2 emission from the DG Tau system. The forward jet direction is towards the right.
Right: Near-IR v=1-0 S(1) H2 emission from Beck et al. (2008, [6]). .

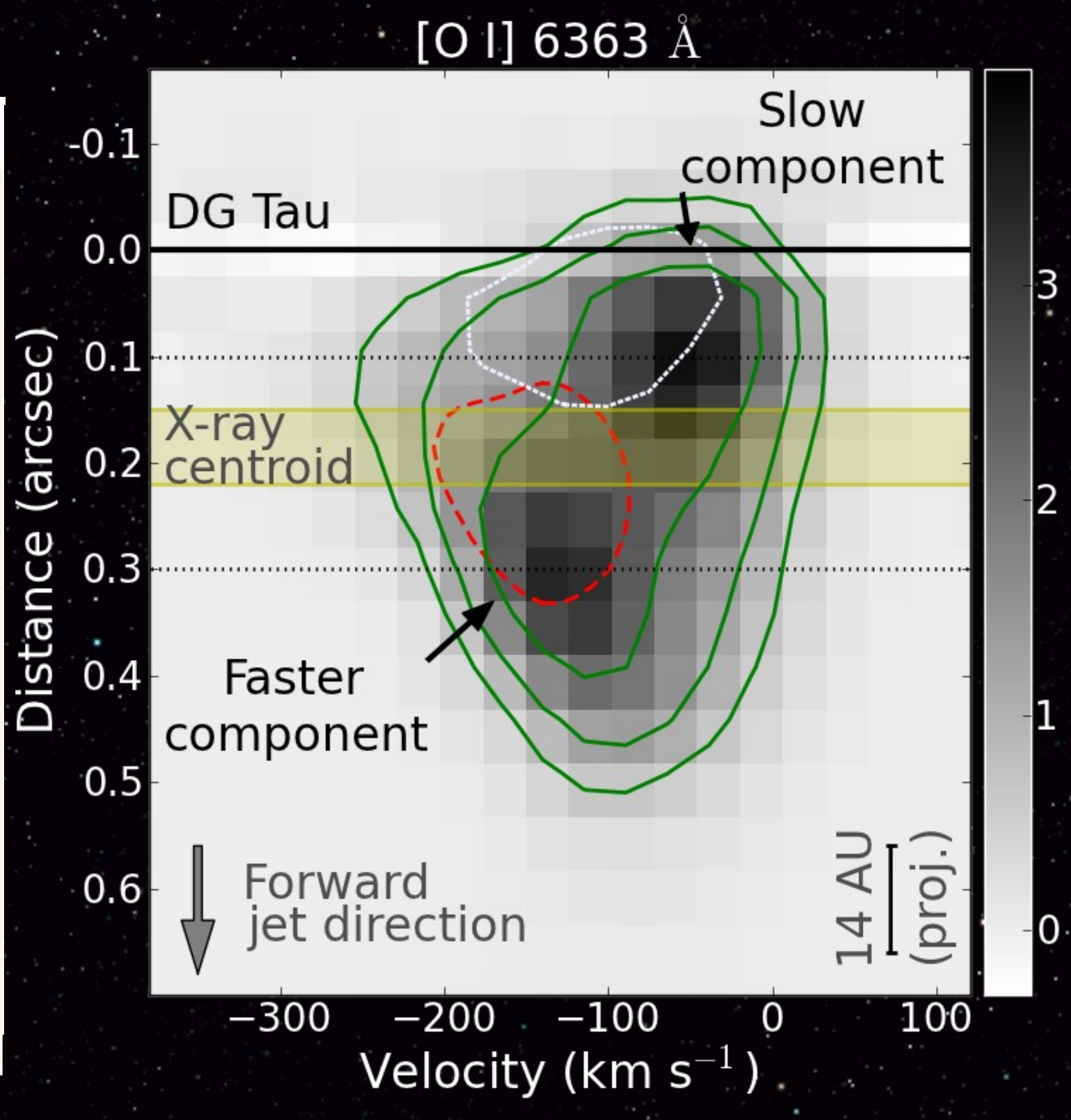

Fig.2: The [O I] emission (10^4 K) of the jet showing the two knots detected within the innermost 1". The stellar continuum has been removed by interpolating its distribution from nearby line-free regions.
Red contour: C IV emission (see Fig. 3).
White contour: [O I] emission (STIS in 1999) enclosing the same flux as the highest green contour.

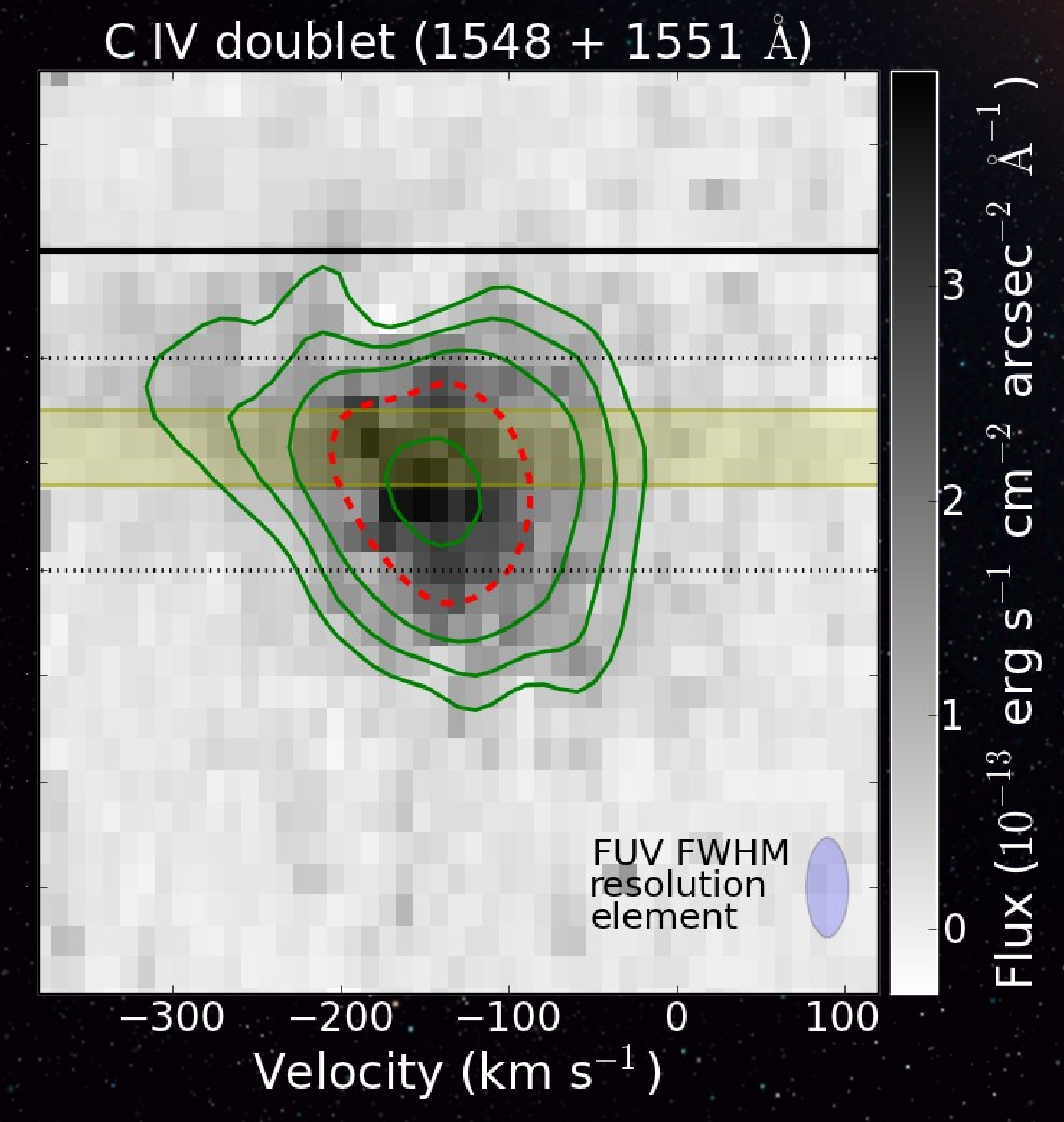

Fig.3: The C IV emission from the jet. Both lines of the doublet have been added. The molecular hydrogen contamination has been removed from the plot by subtracting the scaled distribution of other H2 lines within the same fluorescence route.

Conclusion

CTTS drive different kinds of outflows. The low-temperature part (10^3 – 10^4 K) is likely caused by the disk wind although probably different mechanisms are responsible for the excitation. The lowest temperature part (10^3 K) is heated by ambipolar-diffusion while the warm part (10^4 K) is heated by internal shocks and possesses clear proper-motion. This interpretation is consistent with the spatial morphology of the H2 emission and can explain the optical/near-IR emission. The emission from the high-temperature plasma is spatially offset from the low-temperature part; C IV and X-ray emission are co-spatial and likely stationary in position. This indicates that a different mechanism is responsible for their heating and that they are not associated with the stochastic shocks which are seen at lower temperatures. Alternatives to the internal shocks are a standing shock or magnetic re-connection events. The C IV data rule out an initially hot outflow, e.g., a stellar wind.

References: [1] **Schneider & Schmitt 2008, A&A, 488, L13; [2] Guedel et al. 2011, arXiv1101.2780G [3] Panoglou et al. 2012, A&A, 538, 2; [4] Schneider et al. 2013, A&A, 550, 1L [5] Beck et al. 2008, ApJ, 676, 472**

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