T Tauri Jet Rotation in the Near Infrared

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ABSTRACT

In recent years, there has been a number of detections of gradients in the radial velocity profile across jets from young stars. They may be interpreted as a signature of jet rotation about its symmetry axis, thereby supporting the theory that jets extract angular momentum from star-disk systems. However, this interpretation is undergoing active debate. Our group has deepened its investigation in recent years. In our latest study, we examine the inner jet region of RY Tau and DO Tau at high resolution to further constrain jet launch models.

OBSERVATIONS

AO-corrected IFU observations were taken of the inner jet from RY Tau and DO Tau, with GEMIN/NIFS in 2009 using the H-band filter/grating at slit position angles both parallel and anti-parallel to the jet axis. Additional arc lamp exposures were taken during observations to ensure high accuracy wavelength calibration. Velocity resolution was 57 km/s but, for signal-to-noise of 35, we can achieve a precision of 3 km/s, in emission line velocity centroids via Gaussian fitting. Spatial resolution with AO correction reached 0.1". Problems of uneven slit illumination do not affect our detection of transverse velocity gradients since the GEMINI slitlets have been aligned transverse to the jet axis.

TARGET

RY Tau is a 2 solar mass T Tauri star of spectral type F8 located at 140 pc, and is well known for its UX Ori type events. Recent studies include detection of a large scale Hα jet, Fig 1. Meanwhile, Skinner et al. (2012) detect x-ray emission at the jet base. Disk studies (Isella et al. 2010) reveal the disk structure, reporting disk inclination between 65-75° and an inner hole in the mm continuum emission with a radius of 15 AU. Polarimetric differential imaging (Takami et al. 2013) imply an extended scattering component above the disk atmosphere.

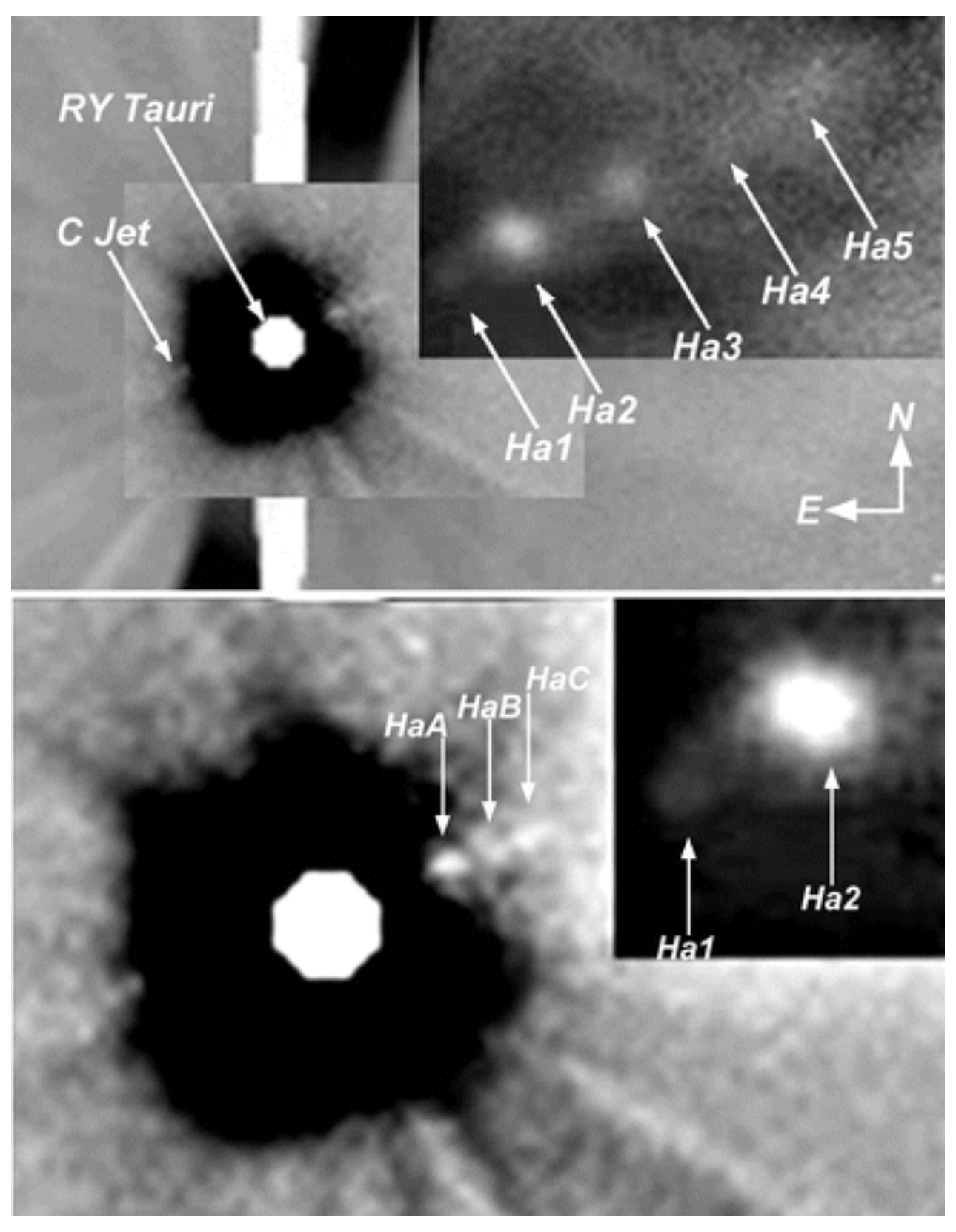

Fig 1. RY Tau (St-Onge & Bastien 2008)

RESULTS

1. Jet Structure

- Fig.2 illustrates the clumpy morphology and velocity field along the inner RY Tau blue-shifted jet, providing strong evidence for time variable ejection. It also highlights a slight mismatch in peak locations, with the radial velocity peak occurring before the intensity peak, hinting at the exciting possibility that the shock front is resolved!

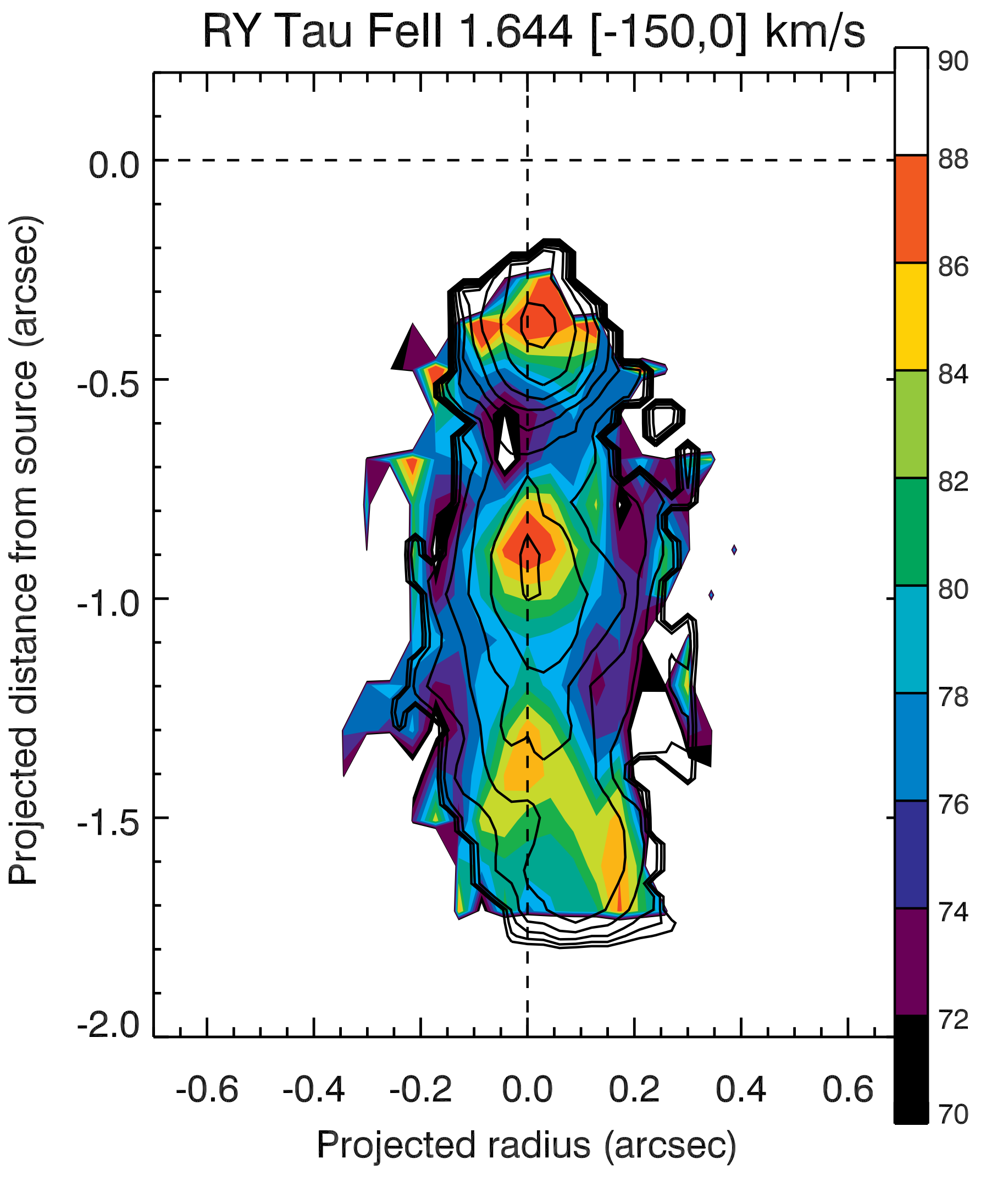

Fig 2. [Fe II] 1.644 line centroid velocity map with intensity contours overlaid. Line intensities integrated over a [-150, 0] km/s velocity interval.

- Three knots appear at distances of 0."4, 0."9 and 1."4. The velocity map suggests the opening of a V-shaped cavity after the 3rd knot. Assuming similar proper motions to the outer knots, 165 km/s (St Onge & Bastien 2008), we estimate an ejection variability timescale of 2-3 years.
- The velocity map shows a global decrease of centroid velocities of DeltaV=15-20 km/s towards the edges of the jet. This is also apparent in the transverse radial profiles shown in Fig. 4. This behavior is compatible with expectations of magneto-centrifugal disk wind models.
- We confirm that the jet position angle (PA) close to the source matches that on larger scales, i.e. PA=292-297 (St Onge & Bastien 2008)
- There is evidence of a small scale jet wiggling from Fig 2, both in the intensity and velocity map. There are suspicions of a companion (Bertout et al. 1999) although it has never been clearly detected.
- The jet width and opening angle are similar to other T Tauri jets, Fig 3, i.e. narrow inner jet widens by a factor 2 at a projected distance of 70-100 AU.

2. Jet Dust

The low velocity jet component close to the star does not appear in [Fe II] but does in published [O I] emission. This is possibly caused by stronger depletion of [Fe II] at low versus high velocities. We suggest that the low-velocity [O I] component may be tracing outer dusty streamlines in a disk wind, which could be also responsible for the extended scattering component seen by Takami et al. (2013).

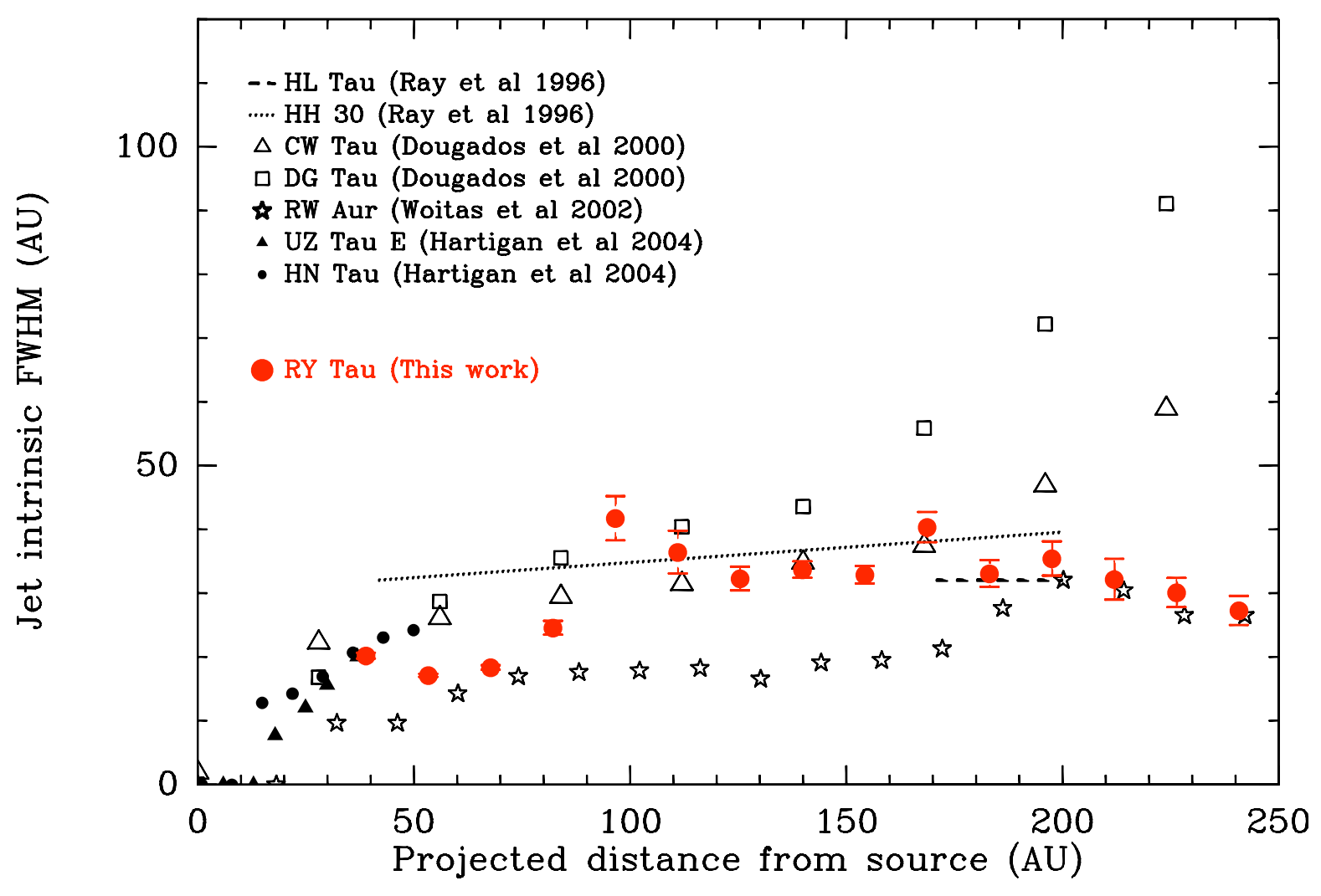

Fig 3. Deconvolved width of inner jet

3. Jet Rotation

Fig 4 shows transverse velocity profile at various distances from the source.

- No systematic radial velocity asymmetry (ΔVr) is apparent so, from the 3σ errorbars, we derive a 3σ upper limit on ΔVr ≈ 11 km/s, at 0.1" from the axis, which corresponds to upper limit of ≈ 6 km/s on toroidal velocity, Vϕ.
- Implications for jet launching: RY Tau is still compatible with disk wind models, but implies a small launching radius (≤ 0.5 AU) and small magnetic lever arm (≤ 7), Fig 5. The flow could still be dusty at these velocities since the dusty disk inner radius is 0.1 AU (Akeson et al 2005; Pott et al 2010)

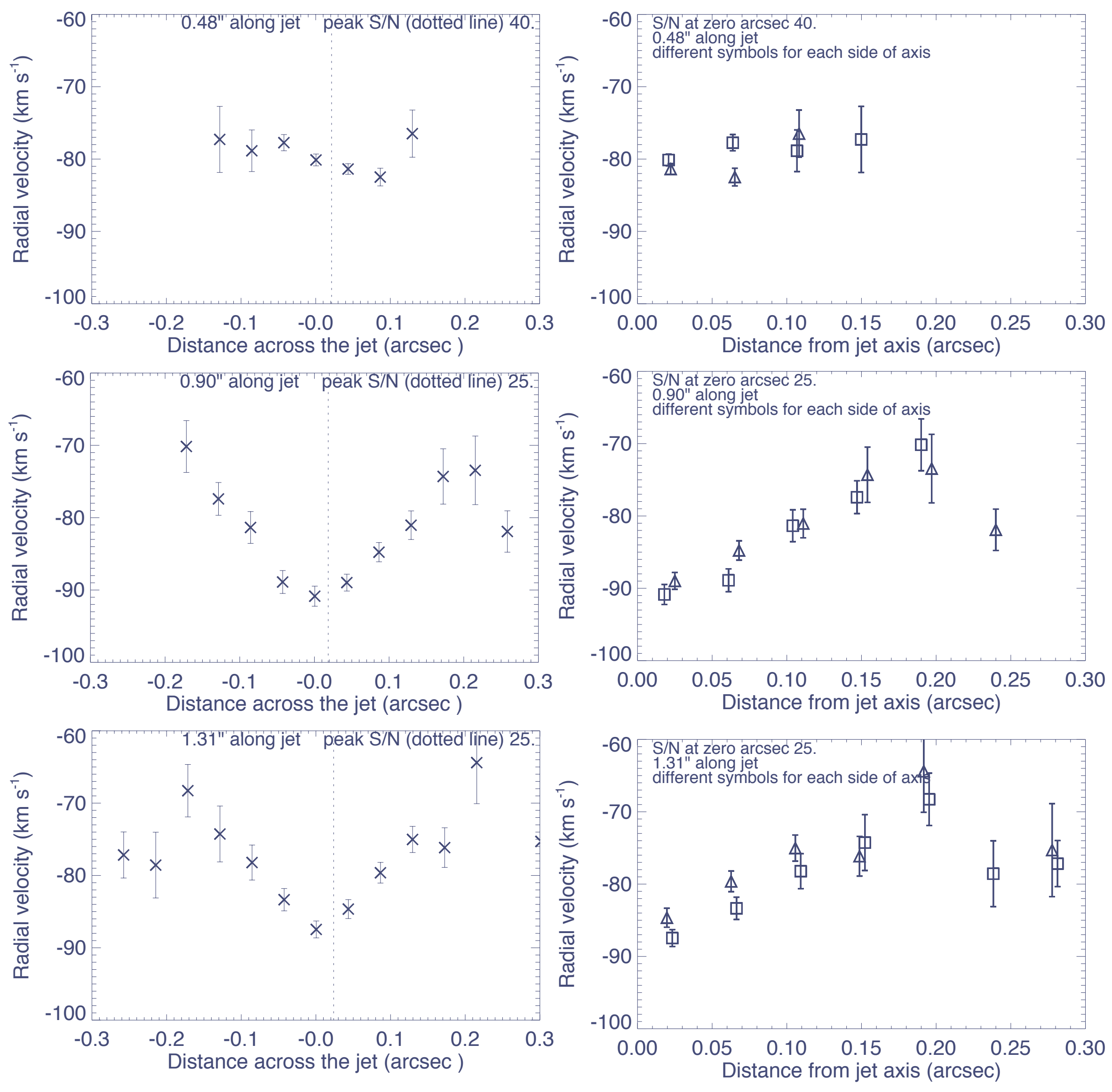

Fig 4.
Left panels: Transverse velocity profiles along the jet at various positions: 0.48", 0.9", 1.31"
Right panels: comparison of centroid velocities on either side of the jet axis. No systematic transverse velocity asymmetry is apparent.
Error bars are 3σ

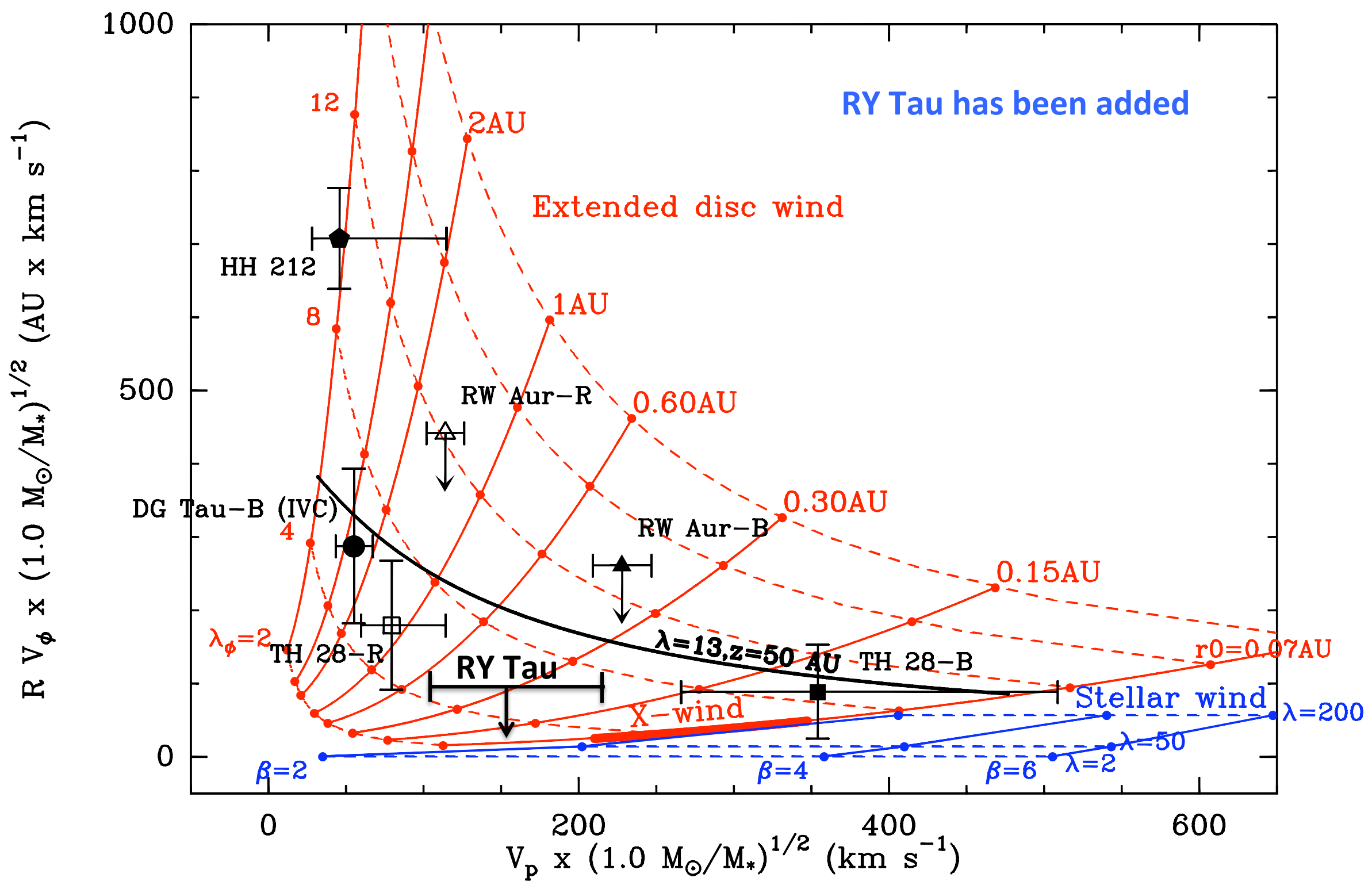

Fig 5. Comparison of launching mechanisms as a function of jet poloidal and toroidal velocity relationship. (Ferreira et al 2006, fig. 3)

CONCLUSIONS

High resolution observation of jets close to their base are critical in constraining the jet ejection mechanism (disk wind or stellar wind origin). We present preliminary results for RY Tau, via an IFU dataset of high resolution *both* spatially *and* spectrally. We report strong evidence of:

- ✓ time variable ejection, on time scales of 2-3 years
- ✓ resolved shocks
- ✓ an upper limit on any possible jet rotation, of Vϕ ≈ 6 km/s
- ✓ an upper limit for the jet ejection radius on the disk ≤ 0.5AU
- ✓ dust depletion in the low velocity jet component

REFERENCES - Akeson et al 2005 ApJ 635 1173; Bertout et al. 1999 A&A 352 574; Agra-Amboage et al 2009 A&A 493 1029; Ferreira et al 2006 A&A 453 785; Isella et al 2010 ApJ 174 1746; Pott et al 2010 ApJ 710 265; Skinner et al 2012 219 337.15; St-Onge & Bastien 2008 ApJ 674 1032; Takami et al 2013 arXiv:1306.1887