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The near-UV: the true window on jet rotation

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Abstract. High resolution observations of jet rotation in newly forming stars have the potential to support theories of magneto-centrifugal jet launching. We report a detection of a radial velocity difference across the blue-shifted jet from RY Tau, the direction of which matches the CO disk rotation sense. Now, in 3 of 3 cases, the sense of the near-UV jet gradient matches the disk rotation sense, implying that we are indeed observing jet rotation. It seems the jet core, probed at near-UV wavelengths, is protected by the outer jet layers from kinematic contaminations, and thus represents the only true window on jet rotation.

1. Introduction

The detection of jet rotation in newly forming stars would provide powerful support for theories of magneto-centrifugal jet launching (Pudritz et al 2007; Shang et al 2007). High resolution Hubble Space Telescope (HST) atomic spectra have revealed systematic differences in radial velocity across T Tauri jets close to the base, which were interpreted as jet rotation signatures (Bacciotti et al. 2002; Woitas et al. 2005; Coffey et al. 2004; 2007). However, subsequent observations (Coffey et al. 2012; White et al. 2014) and simulations (Sauty et al. 2012) suggest alternative interpretations, such as the outer layers of the jet being disrupted by shocks or instabilities.

While the high resolution of ALMA allows us to probe closer to the jet base, issues arise in trying to resolve the narrow jet width. Furthermore, it is not clear that molecular lines are appropriate tracers of launching kinematics, given that molecular flows are usually associated with tracing cavity walls, entrained gas and secondary flows. Indeed, molecules may not by able to survive the launching process. Hence, ALMA observations should be interpreted with caution (Coffey 2017).

As a result, it seems increasingly likely that the atomic jet core, which is probed at near-UV wavelengths, may be our true window on jet rotation, since it is protected by the outer jet layers from kinematic contaminations related to non-launching processes such as shocks and/or entrainment. This idea is supported by the fact that signatures of a possible near-UV jet rotation match the direction of the disk rotation in 2 of 2 cases examined so far, i.e. DG Tau (Coffey et al. 2007; Testi et al. 2002) and RW Aur (Coffey et al. 2012; Cabrit et al. 2006). This leads us to believe that observing the jet close to the base and also close to the axis may be the only way to probe the true jet rotation signature. Here, we present the

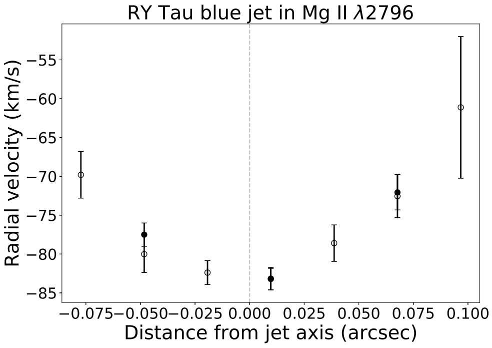

Fig. 1. Radial velocity profile across the jet base, illustrating an asymmetry which can be interpreted as jet rotation. Crucially, the latter matches the disk rotation sense. Errors are 3 sigma. Solid symbols represent binned emission (see text).

first results in a new high resolution near-UV study with HST/STIS.

2. Results

Using HST/STIS, we obtained spectra close to the base of the blue-shifted jet of RY Tau in the shock-excited Mg II doublet at 2796 angstroms. The jet width was found to be 0.″18, which was resolved with the two-pixel resolution of 0.″058 of the MAMA detector. Velocity resolution was 30 km/s, with an effective velocity resolution via Gaussian fitting of 1 km/s for our peak signal-to-noise of $\sim$ 30.

To identify jet rotation signatures, we compared radial velocities on one side of the jet axis to those of the other. An asymmetry in the transverse Doppler profile of the jet was identified (figure 1). To reduce the error bars on the velocity centroid fitting, we also binned the emission on each side of the jet axis, and compared the radial velocity of the binned emission. This improved confidence in our detection to beyond the 3 sigma level. A radial velocity difference of 5 ± 3 km/s (3 σ error) was determined at a position of 0.″4 (~50 au) from the star and in the region 0.03″-0.1″ (4-12 au) from the jet axis. The northern side of the jet is bluer than the southern side. Crucially, we find that the direction of the asymmetry matches the sense of CO disk rotation (Coffey et al. 2015). Hence, we interpret our observation as a signature of jet rotation in the high velocity core of the flow. Reassuringly, the direction of the asymmetry also matches that of a tentative detected at the same jet position but in near-IR Fe II lines (Coffey et al. 2015). Measurements imply a jet toroidal velocities of $\sim$ 2.6 km/s (for a jet inclination angle $\sim$ 20° w.r.t. the p.o.s.). This yields a jet launching radius of ~0.15 au, thus supporting a Disk-wind version of steady-state magneto-centrifugal jet ejection (Pudritz et al. 2007). These near-UV values match near-IR jet width (20 au), peak radial velocity (-80 km/s), toroidal velocity (<6km/s), and launching radius (0.5 au) for Fe II 1.644 um emission at 0.″1 (14 au) from the axis (Coffey et al. 2015).

While our observations emphasise yet again how observationally demanding this study is, it also seems to show that the inner core of the jet, close to the axis, which is traced by the higher velocity, higher excitation near-UV emission, preserves the kinematic signature of the jet launch mechanism.

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