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Hot Jets from Cool Stars

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FUV and X-ray observations of classical T Tauri stars (CTTSs) revealed that their jets contain plasma with temperatures reaching up to several million K. This is several orders of magnitude hotter than the well-known jets seen in optical/NIR forbidden emission lines (FELs, T~10^4 K) and unpredicted by established theories. We present HST observations simultaneously tracing the optical FEL emission and the hot plasma emitting C IV emission (10^5 K). The observations, performed with the slit aligned along the jet axis, spatially and spectrally resolve the jet emission, and reveal different kinematic structures: One/two(?) inner, stationary component at a few tens of au from the source and an outer, faster component moving slowly along the jets (ca. 80 km/s).

Warm (10^4 K)
Optical FEL emission

- Stationary, inner component (also seen in [N II] and [S II])
- Located closer to the source than the hotter C IV and X-ray emission
- Too fast for a photo-evaporating wind (see also Lavalley et al. 1997)
- Additional component showing clear proper motion of only 80 km/s
- Outer knots are 3-4x faster

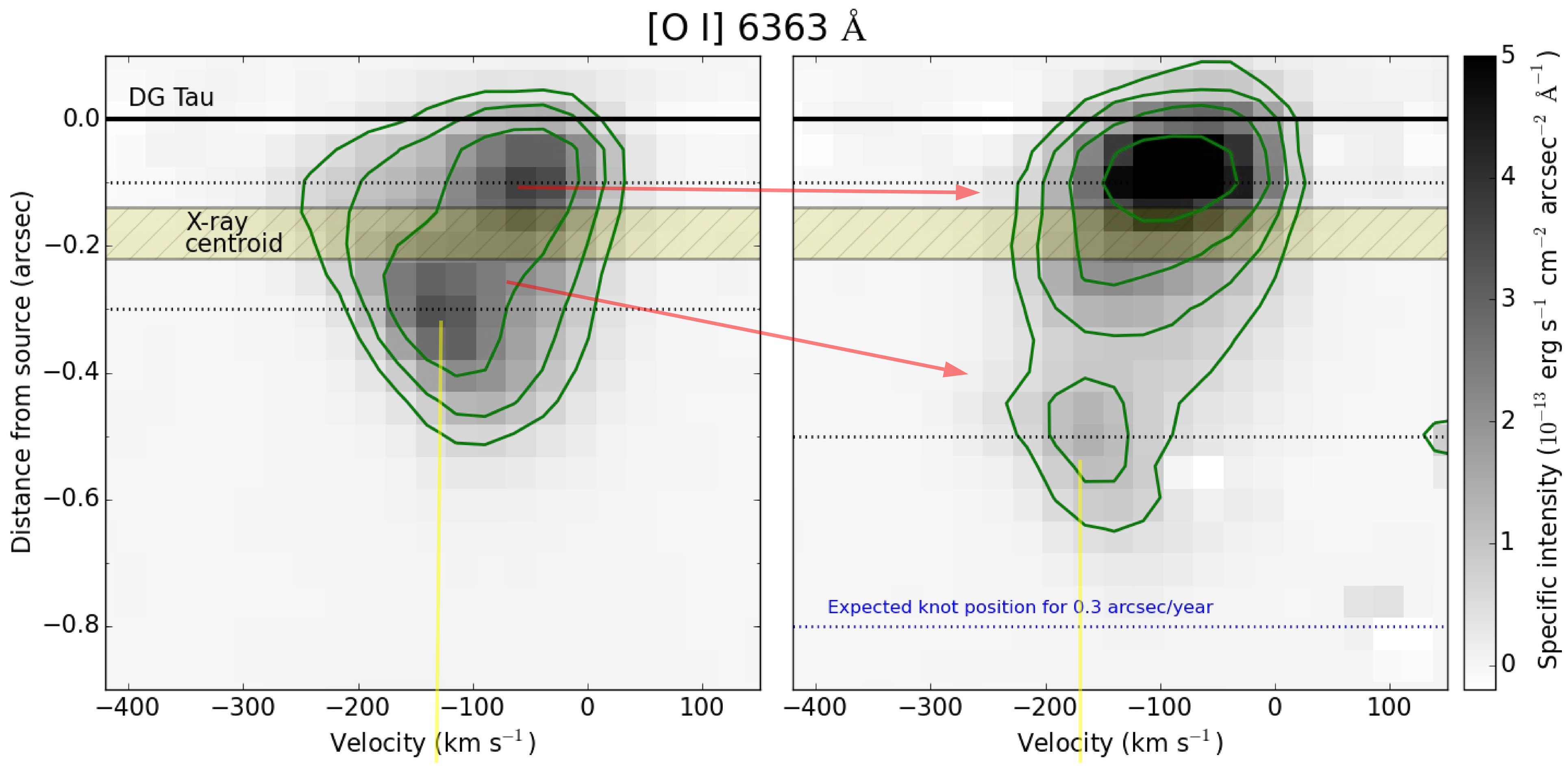

Fig. 1: Position velocity diagrams of [O I] emission observed with a separation of 1.7 years.

Hot (10^5 K)
FUV C IV emission

- Emission only from the jet (stellar emission absorbed)
- Inner, stationary component
- Compared to the inner, stationary [O I] component the inner C IV emission is
  - Faster (150 vs 60 km/s)
  - Further out (0.2 vs 0.1 arcsec)
- The outer, moving component has
  - similar velocity as the [O I] emission
  - similar proper motion

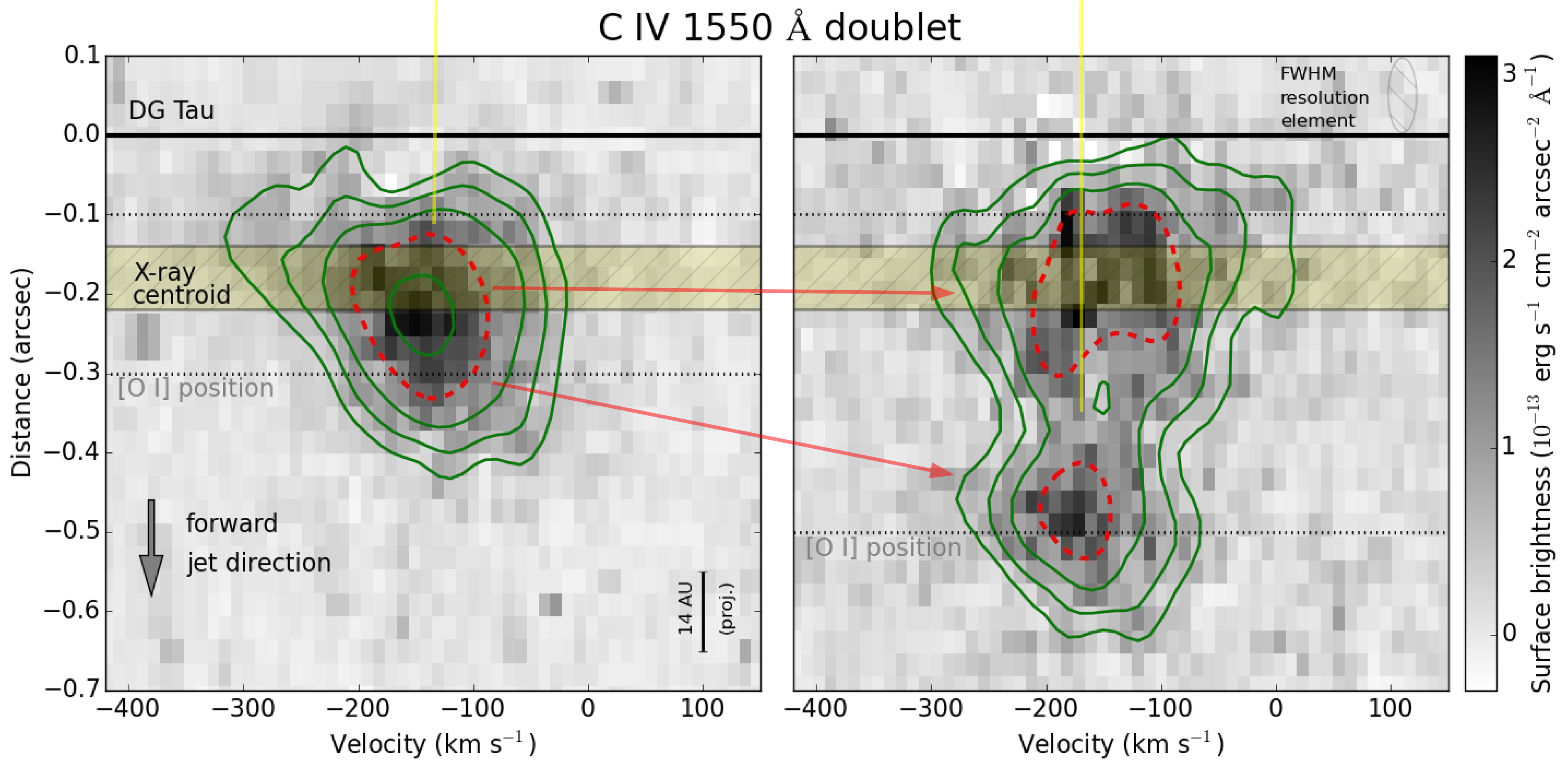

Fig. 2: Same as Fig. 1, but for the hotter C IV emission. Yellow lines indicate constant velocities, red arrows indicate motion (or lack thereof) between the two epochs. From Schneider et al. (2013, in prep.)

Very Hot (>10^6 K)
X-ray emission

- Hottest plasma detected so far
- Required shock velocities >300 km/s
- Bright, inner component:
  - overlaps spatially with the inner C IV emission
  - no proper motion over almost one decade
- Outer component likely shows proper motion

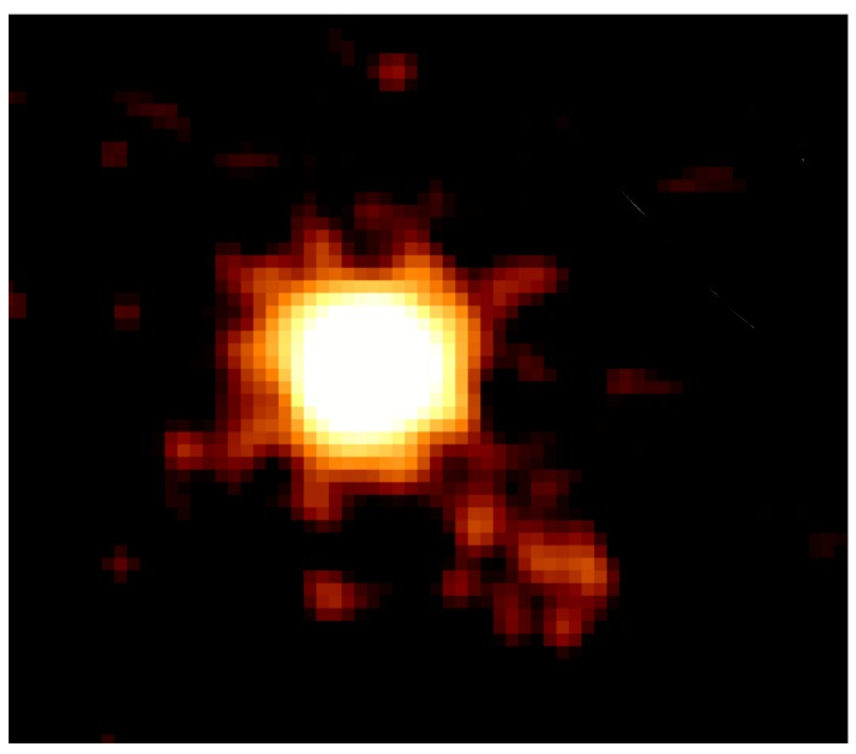

Fig. 3: Deconvolved soft X-ray image (0.3 -1.0 keV). Both, the bright, central component and the extended emission are the jet's X-ray emission. From Güdel et al (2011).

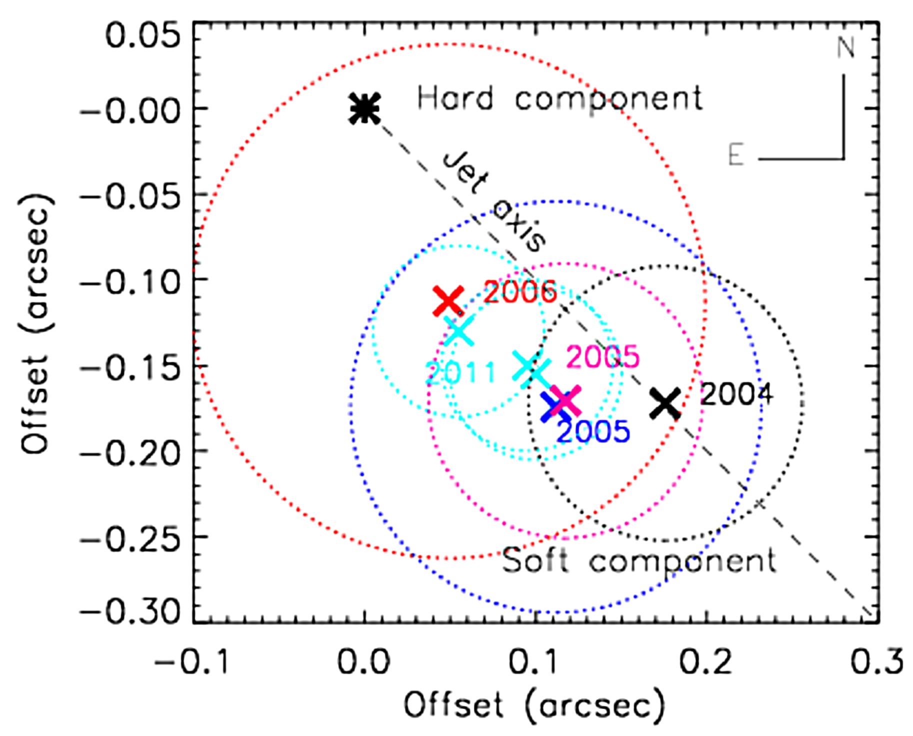

Fig. 4: Centroid of the X-ray emission measured at different epochs. Adapted from Schneider & Schmitt (2008).

Results & Questions

Hot jet plasma is
- constantly located close to the driving source in the jet acceleration/collimation region, where the magentic field is still strong
  → related to jet collimation?
  → magnetic reconnection events similar to the processes in stellar coronae?
- faster than the optical FEL emission
  → launched at smaller distances from the star than the well-known outflow?
  → Disk wind, inner disk rim, interaction of disk and stellar wind?
- Signature of an interaction between stellar and disk wind (Günther et al. 2014)?

References: *Güdel et al. 2011, arXiv1101.2780G, Günther, Li, Schneider 2014, ApJ, 795, 51; Lavalley et al. 1997, A&A, 327, 671;* Schneider & Schmitt 2008, A&A, 488, L13; Schneider et al. 2013, A&A, 550L, 1S