Long-Term Monitoring Observations of Jet Ejections and Mass Accretion for RW Aur A, RY Tau and DG Tau

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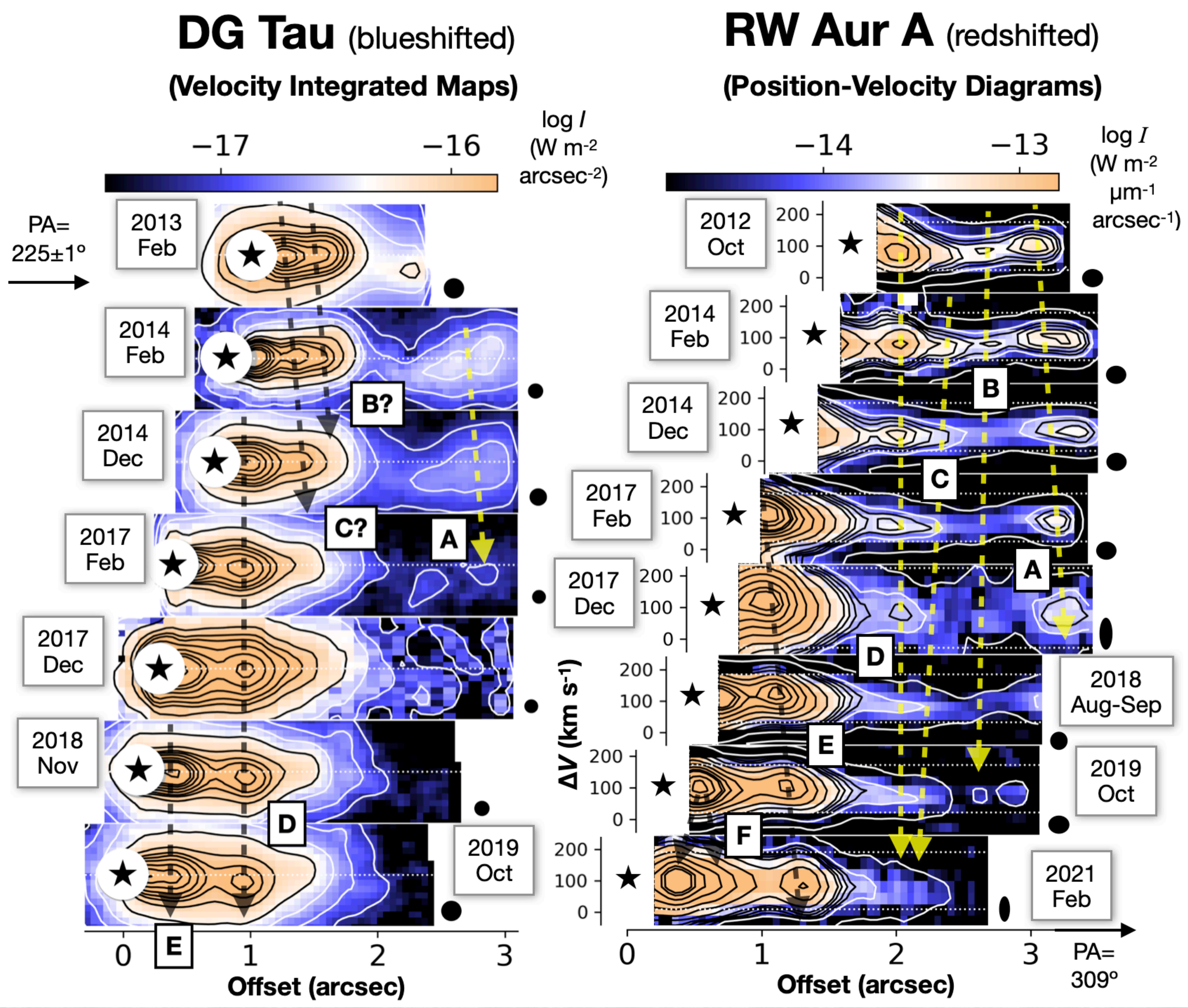
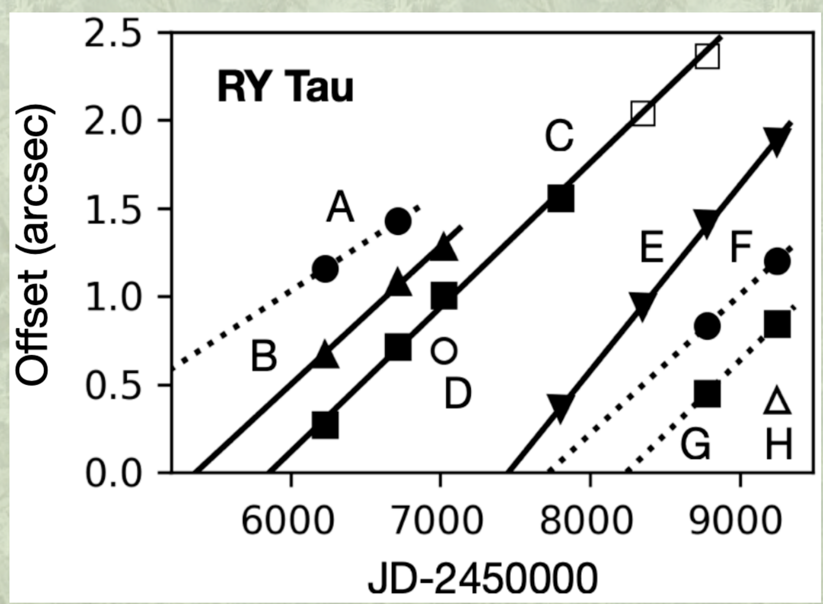
Understanding the mechanisms of mass accretion and jet ejection is one of the key issues of star formation theories. However, observational studies are hampered by the limited angular resolutions of current telescopes, which are not sufficient to resolve structure and kinematics in the jet launching region. Over the past ten years we have executed an alternative approach to tackle this important issue: that is, long-term monitoring of mass accretion and jet ejection for active pre-main sequence stars (RW Aur A, RY Tau, DG Tau). We summarize our achievements and analysis to date.

Jet Knot Ejections ([Fe II] 1.64 μm)

(Takami+ 2020[4], 2023[5]; Uyama+ 2022[6])



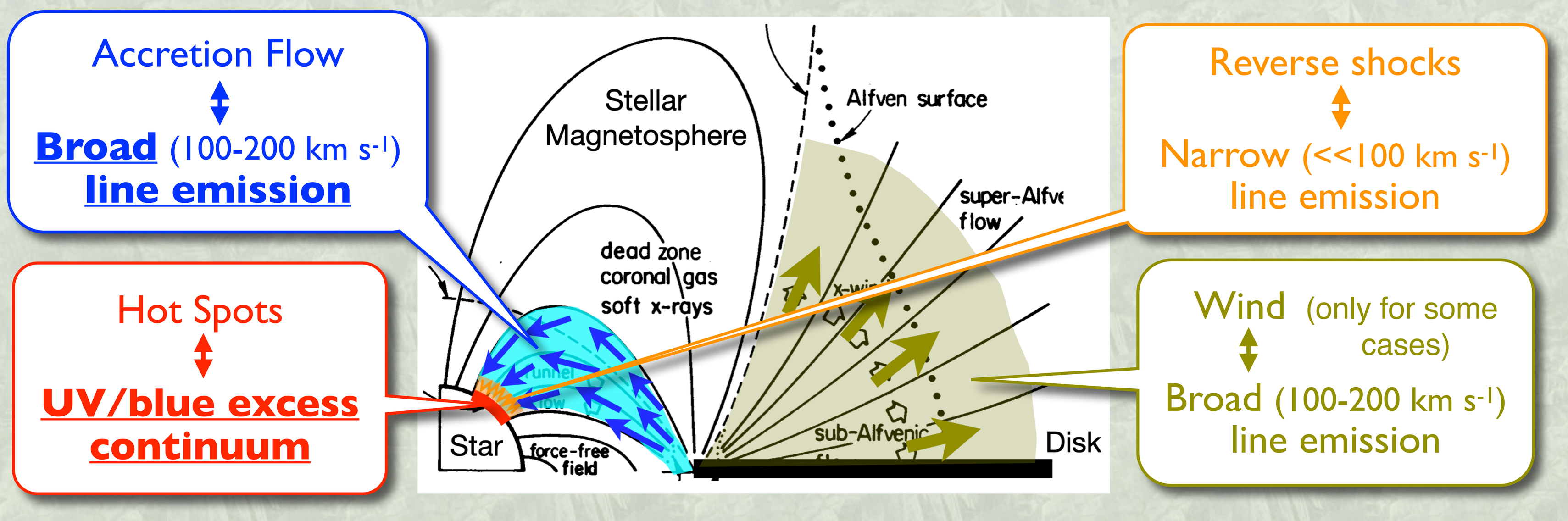


(***Top***) *Emission observed using Gemini-NIFS, VLT-SINFONI & Keck-OSIRIS (Angular resolution ~0".1; Velocity resolution δv=55-100 km s-1)*

(***Left***) *Positions at individual knots for the RY Tau jet. For each knot, linear fits are made using filled marks to measure the proper motion and the epoch of ejection at the star. The dashed and solid lines are for those with two and more than two epochs of the observations, respectively.*

- **Many jet knots** (if not all) **are moving away from the star**
  - $V_{tangential}$ *= 70-230 km s-1*
  - *Higher angular resolutions + better inner working angle required for confirming the presence of positionally stationary knots*
  - *Positions approximately match those in H emission*
- **Velocity variation between knots — up to ±10-20%**
- **Irregular time intervals of ejections from the star** (300–2000 days)
- **Knots = unresolved internal jet shocks?**
  - Variations in peak brightnesses and spatial extent are consistent with this idea, but the other possibilities are not excluded.

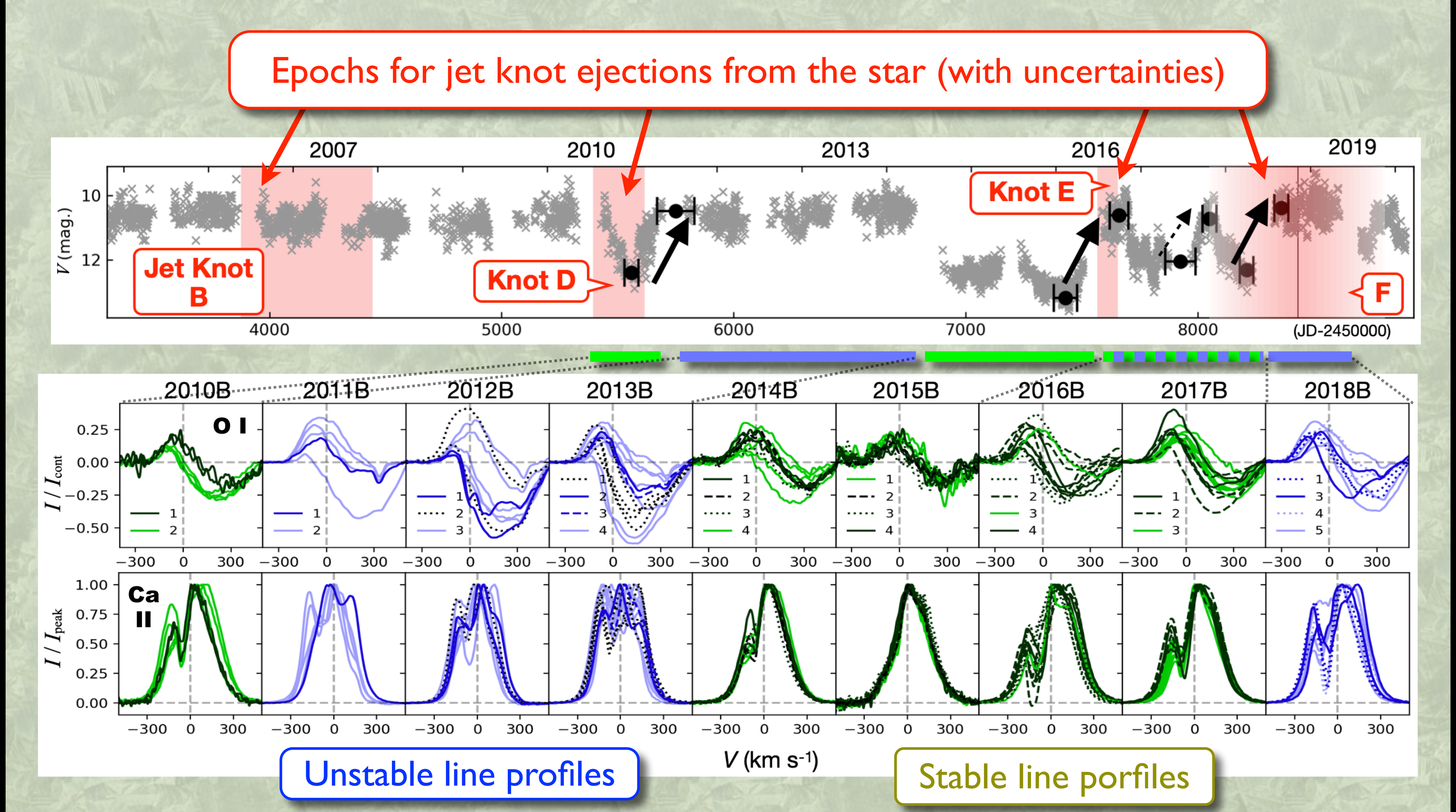
Signatures for Magnetospheric Accretion[1]



Possible Time Correlations with Jet Ejections & Magnetospheric Accretion (RW Aur A)

(Takami+ 2016[3], 2020[4] etc.)

- **Jet knot ejections tend to be associated with photometric rises**
  - … and therefore increases in mass accretion rates
  - Photometric variabilities match the stabilities of some optical line profiles that can be attributed to MHD instabilities in the accretion flow.
- **A photometric rise may occur within ~100 days of a jet knot ejection**
  - Suggesting that ejections occur from the inner disk edge or the disk surface at r ≤ 0.1 au



(***Top***) *V-band magnitudes obtained from the AAVSO archive and the CrAO 1.5-m telescope. Epochs of jet knot ejections from the star are marked in red.*

(***Bottom***) *Line profile variabilities for Ca II 8542 Å and [O I] 7772 Å observed using CFHT-ESPaDonS. The profiles in the individual boxes were obtained in the individual B semesters (August-January). In each box, the profiles with the same linestyle were obtained in a single observing run with intervals of 2-3 days. The blue and green colors are for the bright and dimming periods, respectively, in V-band.*

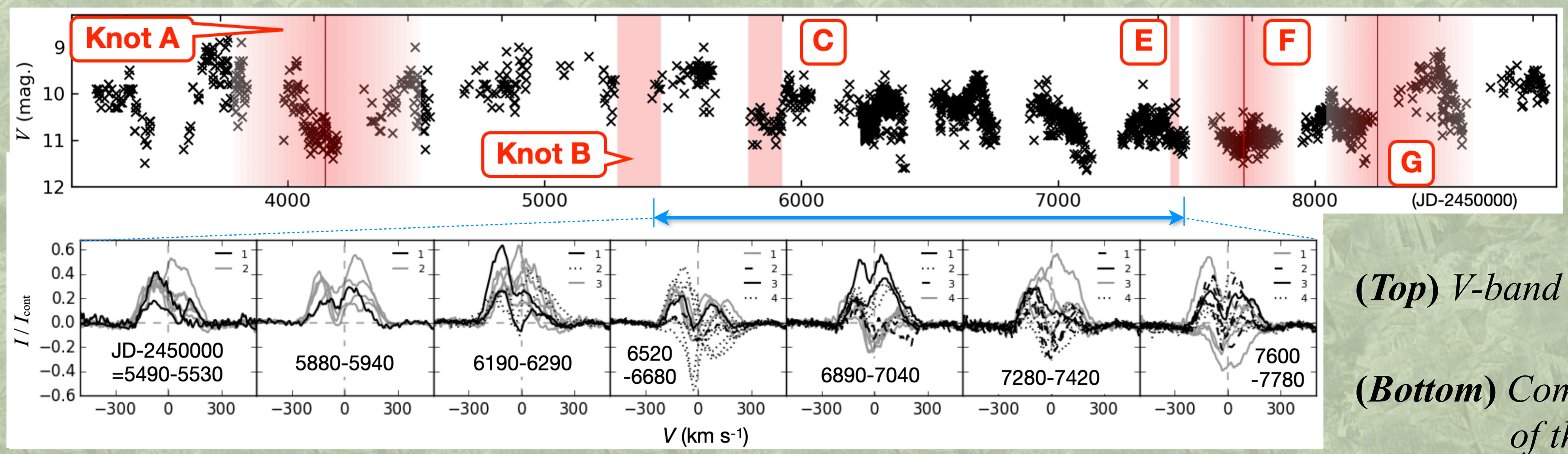
Jet ejections vs. mass accretion for the other stars

(Chou+ 2013[2]; Takami+, in prep)

vs. Photometry (RY Tau only)
- no clear correlation found so far

vs. Line profiles
- Detailed analysis in progress

Line profiles and variabilities are very different between stars



(***Top***) *V-band magnitude vs. jet knot ejections for RY Tau*

(***Bottom***) *Complicated line profile variabilities of the Ca II 8542 Å line for RY Tau*

References:-

[1] Calvet+/Najita+/Shu+, PPIV
[2] Chou+ (2013), ApJ, 145, 18
[3] Takami+ (2016), ApJ, 820, 139
[4] Takami+ (2020), ApJ, 901, 24
[5] Takami+ (2023), ApJS, 264, 1
[6] Uyama+ (2022), AJ, 163, 268