

Atomic and molecular study of the DG Tau microjet

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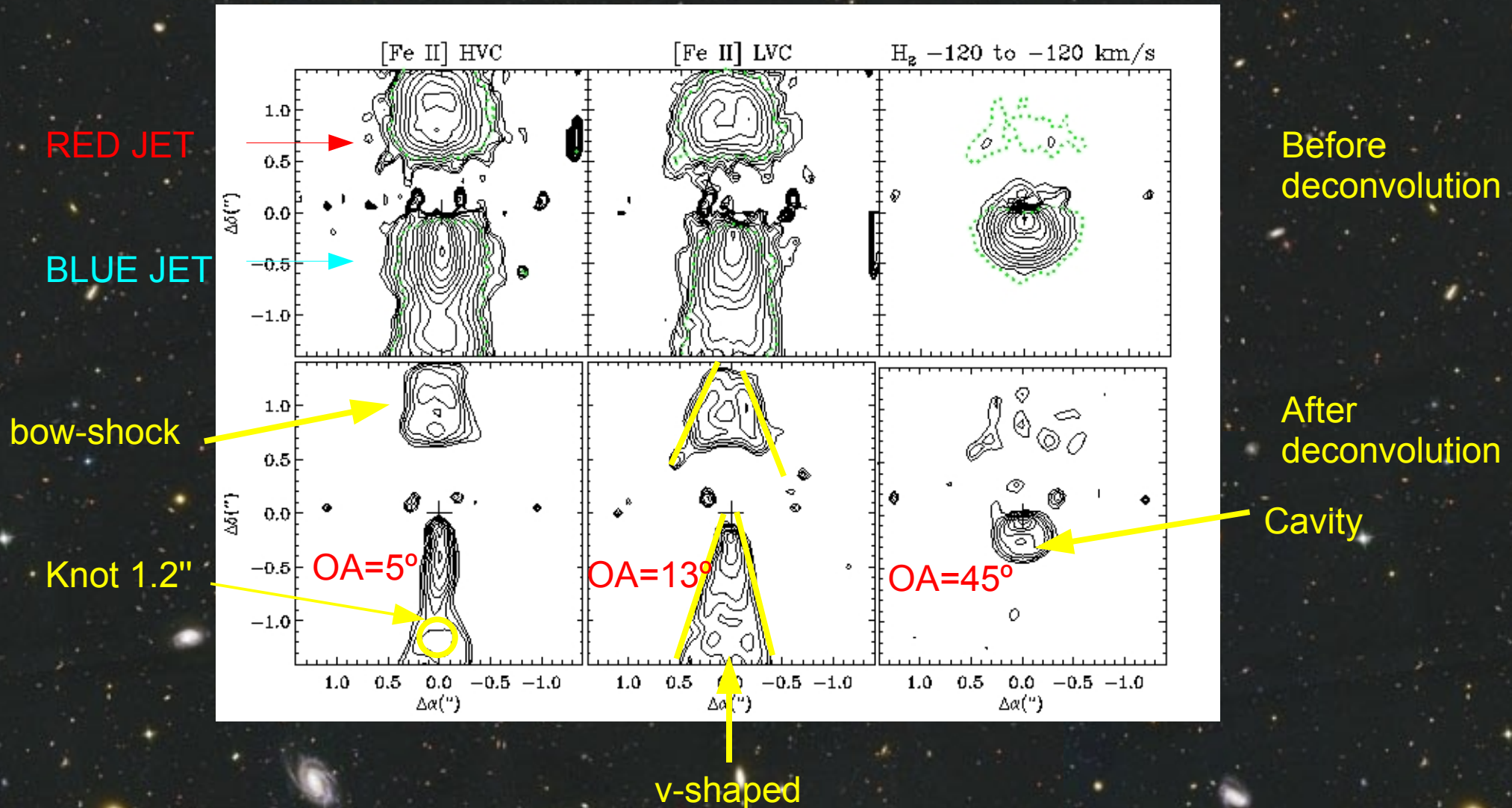
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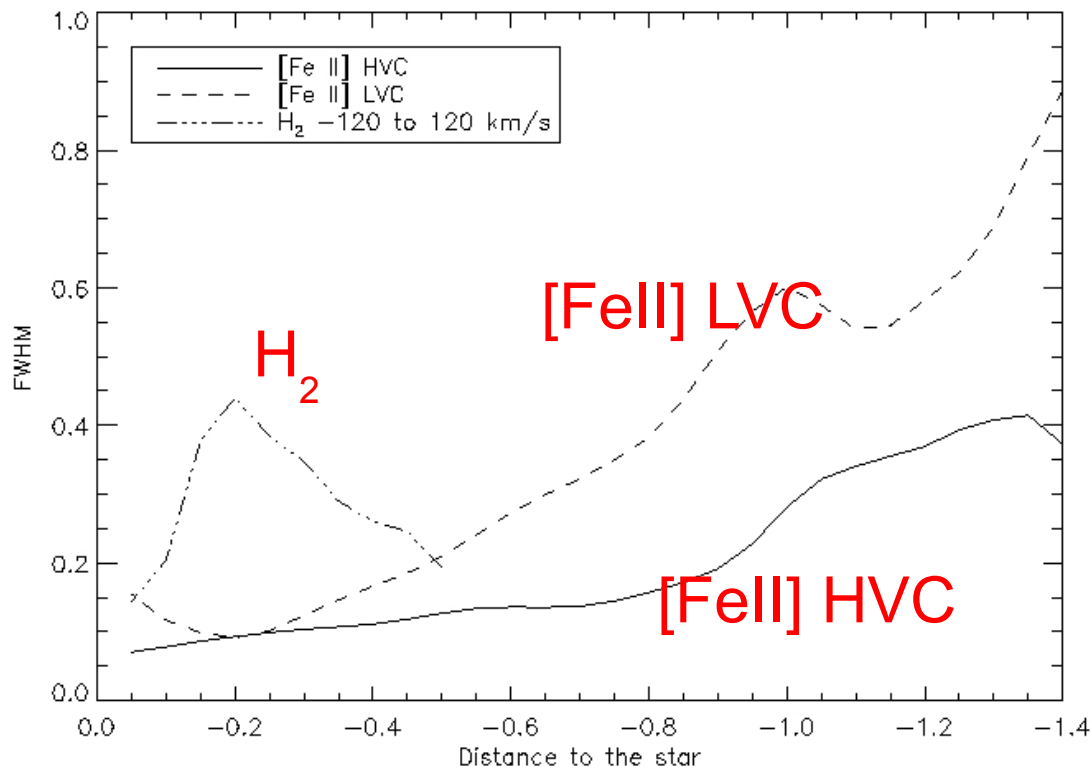
Introduction

- Aim:
 - Find observational constraints on the jet launching region \Rightarrow **constraints** on the **ejection** and collimation **mechanism**.
- SINFONI IR spectro-imaging observations
 - Compare the **atomic** ([FeII]) and **molecular** (H_2) jet
- spatial resolution 0.15"
- spectral resolution 100 km/s

Jet Morphology – Channel maps

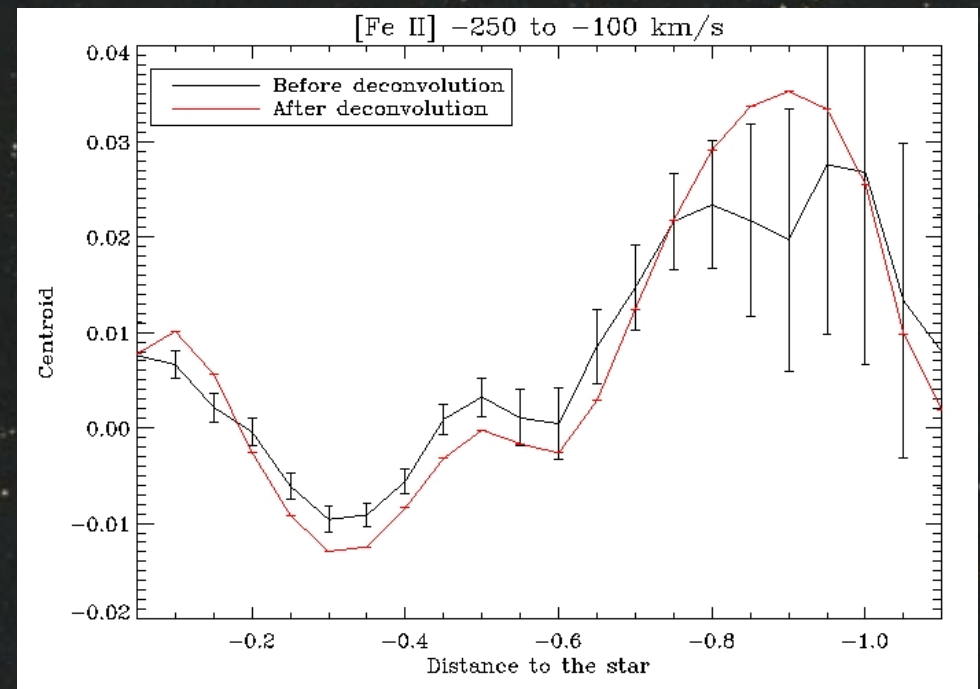
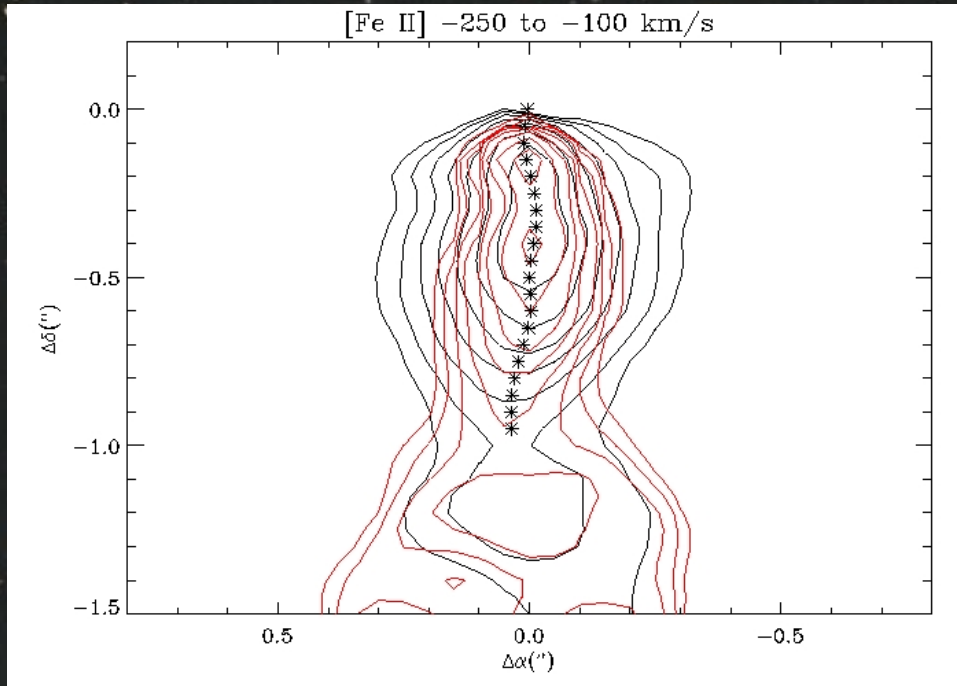


Jet Morphology - Collimation



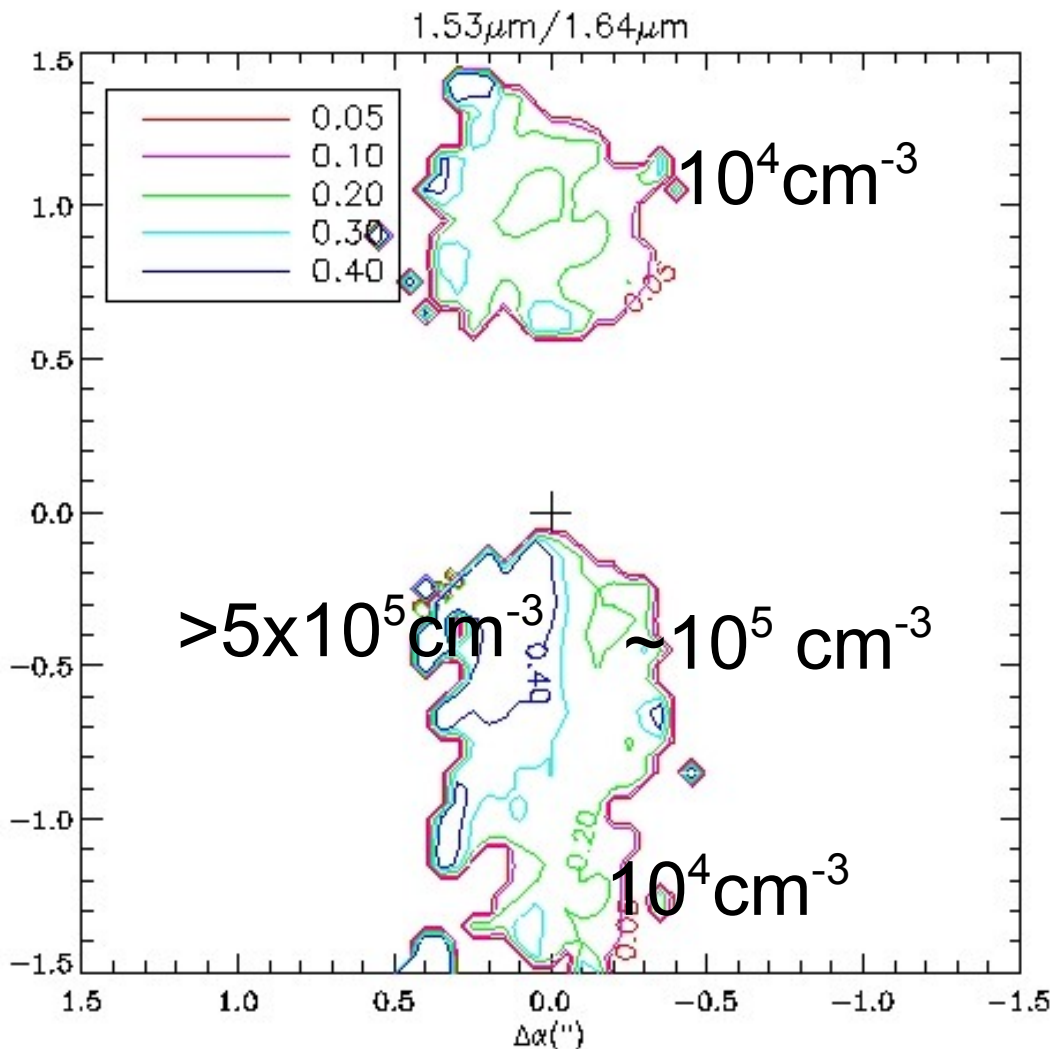
- **Launching radius from base width:**
 - [FeII] FWHM < 0.1" ⇒ launch radius < 7AU
 - H₂: < 0.15" ⇒ launch radius < 10 AU)
- Similar widths in [FeII] as in optical [Bacciotti et al, 2000](#)

Jet Morphology



- Hint of **wiggling** in HVB
- 1.2" at 300 km/s in Taurus cloud \Rightarrow period of **3 yr**

Atomic jet ($[F_{ell}]$) – electron density



- $F_{1.53\mu\text{m}} / F_{1.64\mu\text{m}}$ n_e indicator
- Density decreases with distance
- Asymmetries to the jet axis

Atomic jet ([FeII]) – mass flux

- Shock method:

- $F_{1.64} \propto n_H V_s$ (Hartigan et al, 2004)

$$\dot{M}_s = L_{1.64} \left(\frac{n_H V_s}{F_{1.64}} \right) \frac{1.4 m_H}{2}$$

- $\dot{M}_{jet} = \dot{M}_s v_j / v_s = \dot{M}_s 4$

- (Lavalley-Fouquet et al, 2000)

- Assuming 1 shock every 50AU (eg. HH30, Hartigan & Morse, 2007)

- $\dot{M}_j = 6 \cdot 10^{-9} - 2 \cdot 10^{-8} M_\odot / \text{yr}$

- Accretion rate from L_{Bry} (in sinfoni K-band)

- $L_{\text{Bry}} = 2.4 \cdot 10^{-4} L_\odot$

- $L_{\text{acc}} = 0.7 L_\odot$ (using relation of Muzerolle et al. 1998)

- $\dot{M}_{\text{acc}} = 10^{-7} M_\odot / \text{yr} \Rightarrow \dot{M}_{\text{ej}} / \dot{M}_{\text{acc}} = 0.06 - 0.2$

Molecular cavity (H_2) – Mass

- Molecular mass:

$$M_{1,3} = m_{H_2} L_{1-0S(1)} / h \nu_{ul} A_{ul} \quad M_{H_2} = M_{1,3} / 1.28 \cdot 10^{-2}$$

($T=2000K$, Beck et al 2008, Takami et al, 2004)

- $L_{H_2} = 1.6 \cdot 10^{-5} L_{\odot} \Rightarrow M_{H_2} = 3 \cdot 10^{-8} M_{\odot}$,
- Assuming $v \sim 15 \text{ km/s}$ over $0.5''$ then $t_{\text{cross}} = 20 \text{ yr}$
 $\Rightarrow \dot{M}_{\text{volume}}(H_2) \sim 1.5 \cdot 10^{-9} M_{\odot} / \text{yr}$
- $\dot{M}_{ej} / \dot{M}_{acc} = 0.02$
- D. Panoglou's predictions for H_2 in MHD disk winds:
 - $T \sim 2000 \text{ K}$ at $z > 10 \text{ AU}$ (ambipolar diffusion)
 - But $v_{H_2} \leq 20 \text{ km/s}$ and $r_0 < 10 \text{ AU}$: $\lambda < 3$

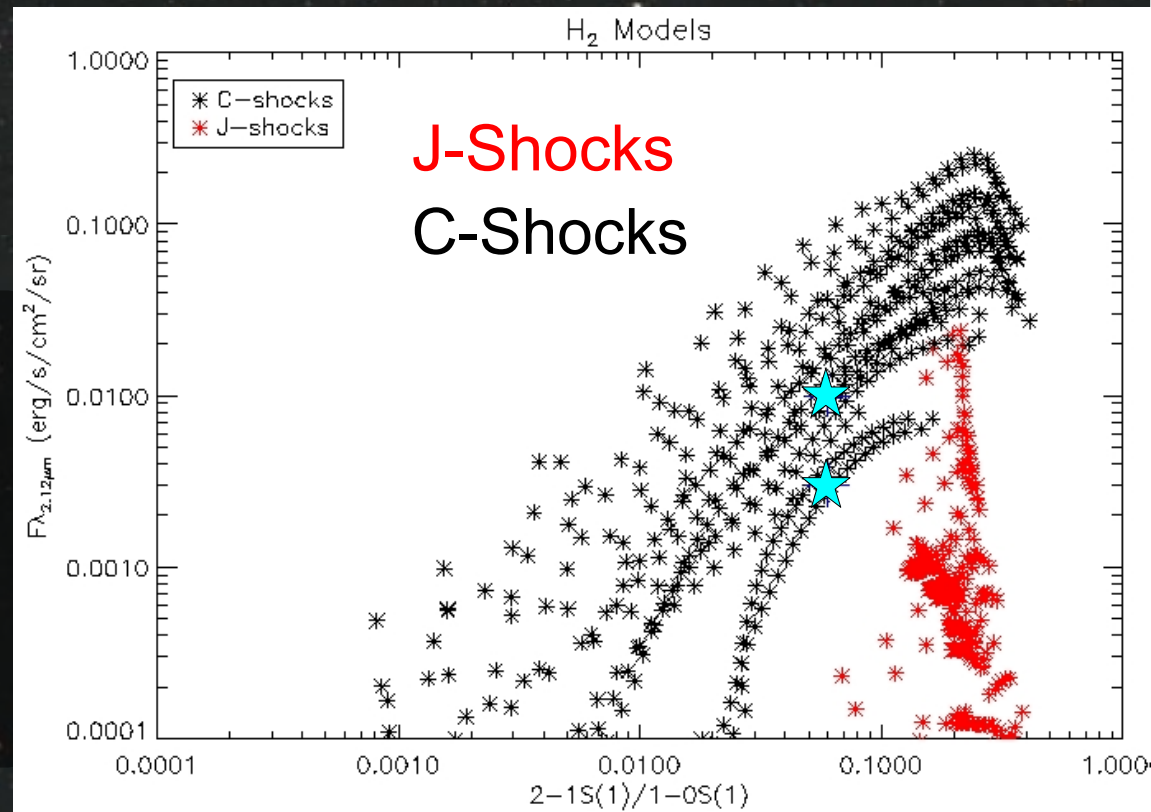
Molecular cavity (H_2) - Shocks

- H_2 brightness:
- at peak = $0.013 \text{ erg/s/cm}^2/\text{sr}$
- average = $0.003 \text{ erg/s/cm}^2/\text{sr}$
- $2-1 \text{ S}(1)/1-0 \text{ S}(1) = 0.06$ Beck et al, 2008

Models computed by
Kristensen et al, 2008 (in prep)

C-shocks

- $b = 0.5 \Rightarrow V_s = 16 - 19 \text{ km/s}$
- $b = 1.0 \Rightarrow V_s = 14 - 48 \text{ km/s}$
- $b = 2.0 \Rightarrow V_s = 19 - 55 \text{ km/s}$
($b \sim V_A \text{ (km/s)}$)



Molecular cavity (H_2) - C-Shocks

- Models: $F_{2.12\mu} \sim K 1.4 m_H n_H v_s^3 / 8 \pi$ with $K \sim 0.04$

$$\Rightarrow \dot{M}_s = \frac{L_{2.12\mu m}}{K} \frac{2}{v_s^2}$$

- $\dot{M}_s = 4 \cdot 10^{-9} - 4 \cdot 10^{-8} M_{\odot} / \text{yrs}$

- $\dot{M}_s / \dot{M}_{acc} = 0.04 - 0.4$ depending on b

\Rightarrow Slow Wide angle wind shocking against disk/envelope

Conclusions

- **Asymmetries** in the jet axis and in the e- density
 - instabilities ? jet precession?
- **Atomic** $\dot{M}_{ej} / \dot{M}_{acc} \sim 0.06 - 0.2$ (shocks)
- **Molecular**
 - a) slow molecular MHD wind heated by ambipolar diffusion, launched from $r_0 < 10$ AU with small magnetic lever arm $\lambda < 3$ $\dot{M}_{ej} / \dot{M}_{acc} \sim 0.02$
 - b) shocked slow wide angle wind at 45°
 $\dot{M}_{ej} / \dot{M}_{acc} \sim 0.04 - 0.4$
- Alternative: UV-Xrays irradiated disk ?
 - need models with high F_{uv} (100 times more than TW Hya model of [Nomura et al 2007](#))