Atomic and molecular study of the DG Tau microjet

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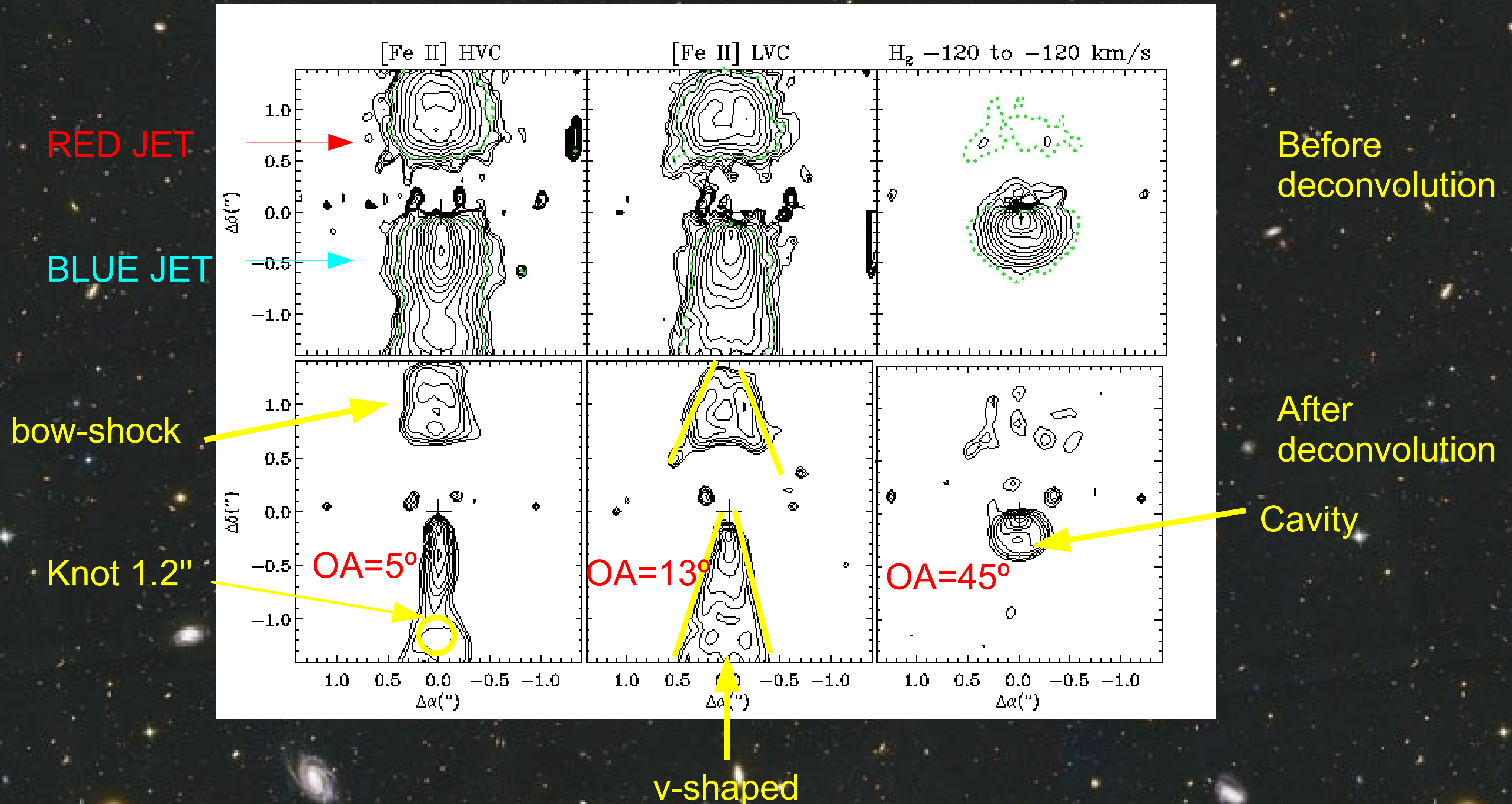
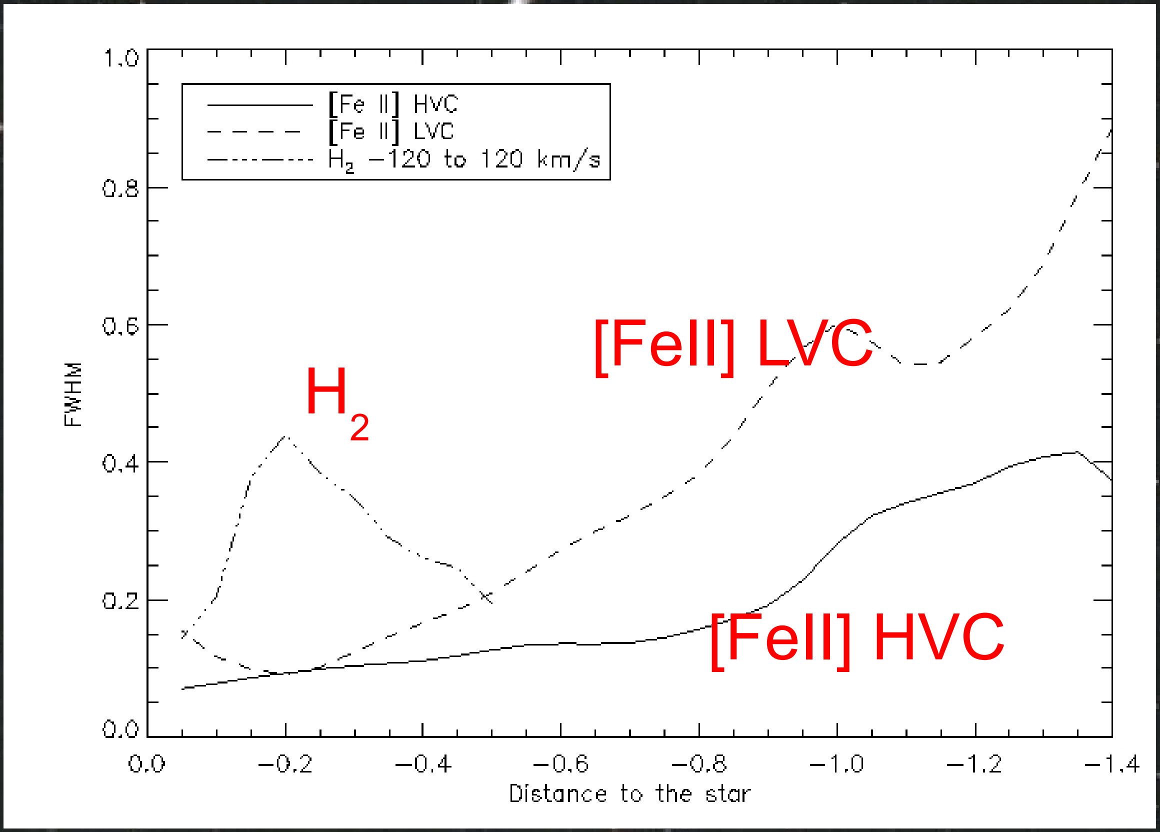
Introduction

- Aim:
  - Find observational constraints on the jet launching region ⇒ 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



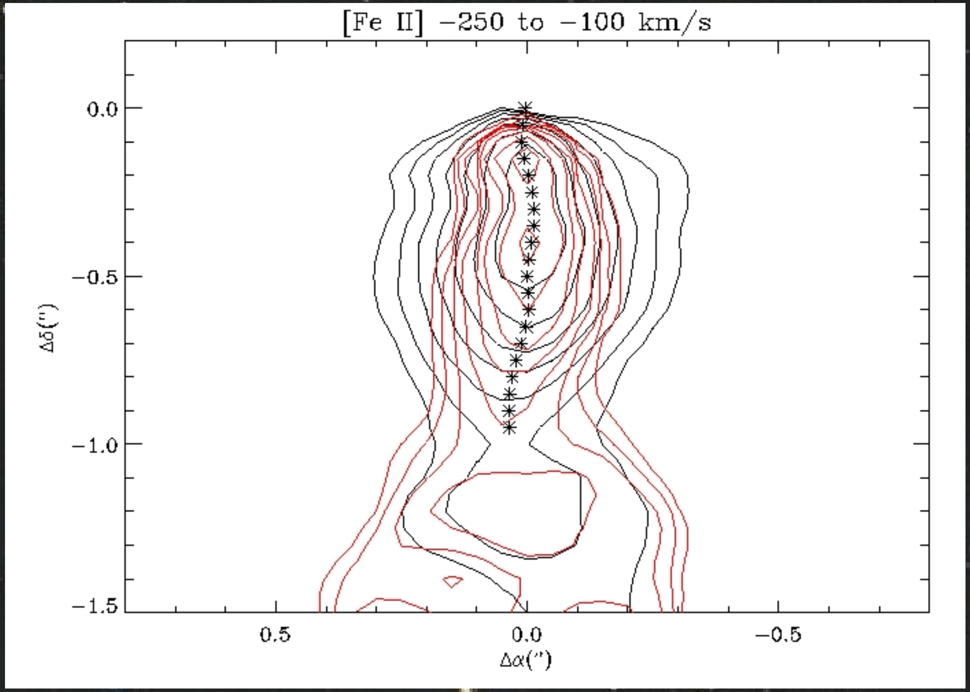
Jet Morphology - Collimation

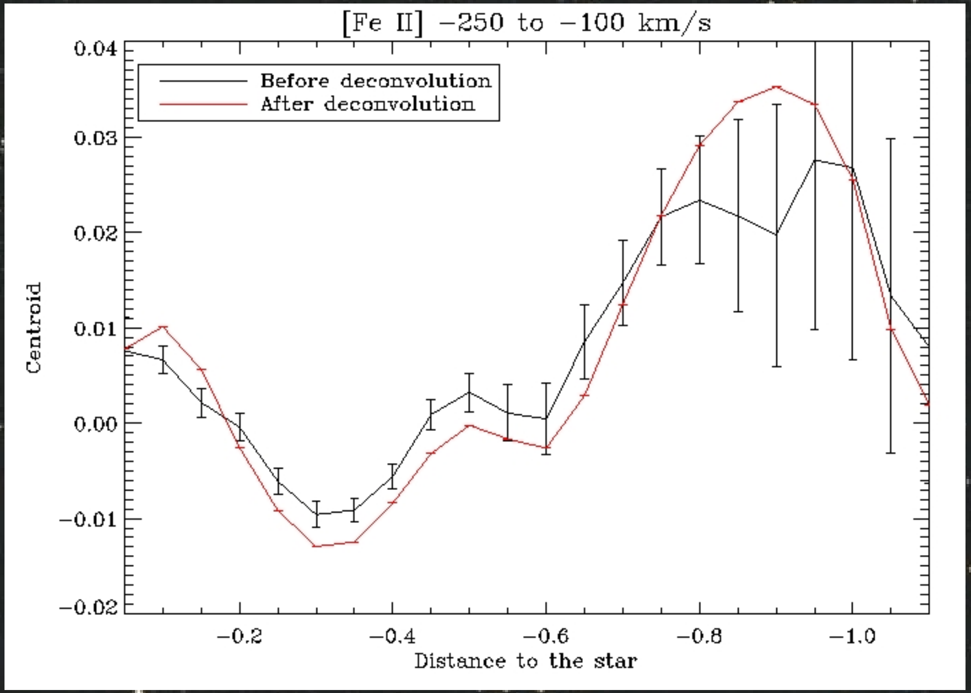


- Launching radius from base width:
  - [FeII] FWHM <0.1"
  ⇒ launch radius < 7AU
  - H_2: < 0.15"
  ⇒ launch radius < 10 AU)
- Similar widths in [FeII] as in optical

Bacciotti et al, 2000

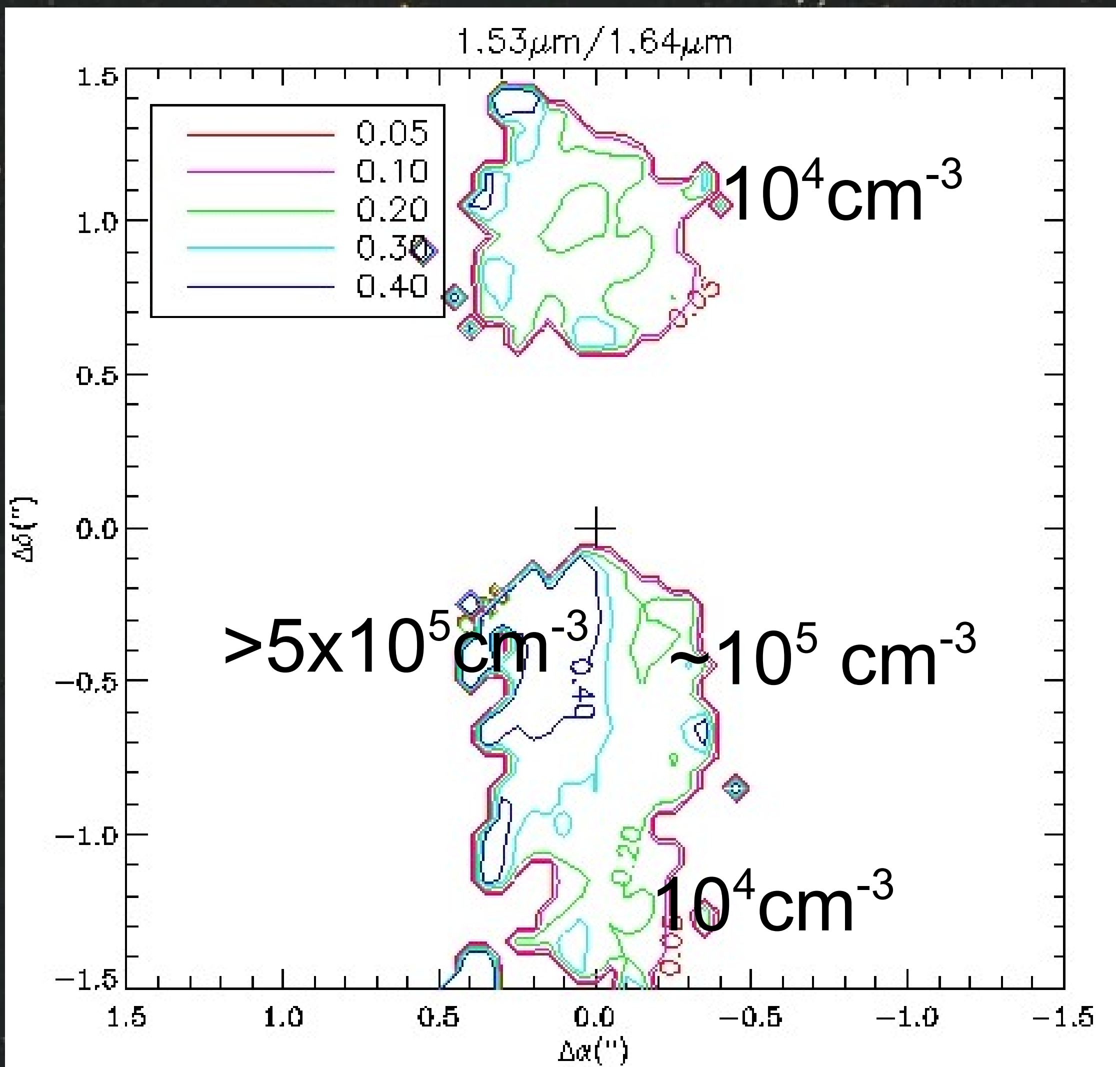
Jet Morphology





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

Atomic jet ([FeII]) – electron density



- $F_{1.53\mu m}/F_{1.64\mu m}$ 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)
  - $\dot{M}_{jet} = \dot{M}_s v_j / v_s = \dot{M}_s 4$
  - (Lavalley-Fouquet et al, 2000)
  - Assuming 1shock every 50AU (eg. HH30, Hartigan & Morse, 2007)
  - $\dot{M}_j = 6\ 10^{-9} - 2\ 10^{-8}\ M_\odot/yr$

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

- Accretion rate from $L_{Br\gamma}$ (in sinfoni K-band)
  - $L_{Br\gamma} = 2.4\ 10^{-4}\ L_\odot$
  - $L_{acc} = 0.7\ L_\odot$ (using relation of Muzerolle et al. 1998)
  - $\dot{M}_{acc} = 10^{-7}\ M_\odot/yr \Rightarrow \dot{M}_{ej} / \dot{M}_{acc} = 0.06 - 0.2$

Molecular cavity (H_2) – Mass

- Molecular mass:

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

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

- L_{H2} = 1.6 10^{-5} $L_{\odot}$ $\Rightarrow$ M_{H2} =3 10^{-8} $M_{\odot}$,
- Assuming v~15km/s over 0.5'' then t_{cross} = 20yr

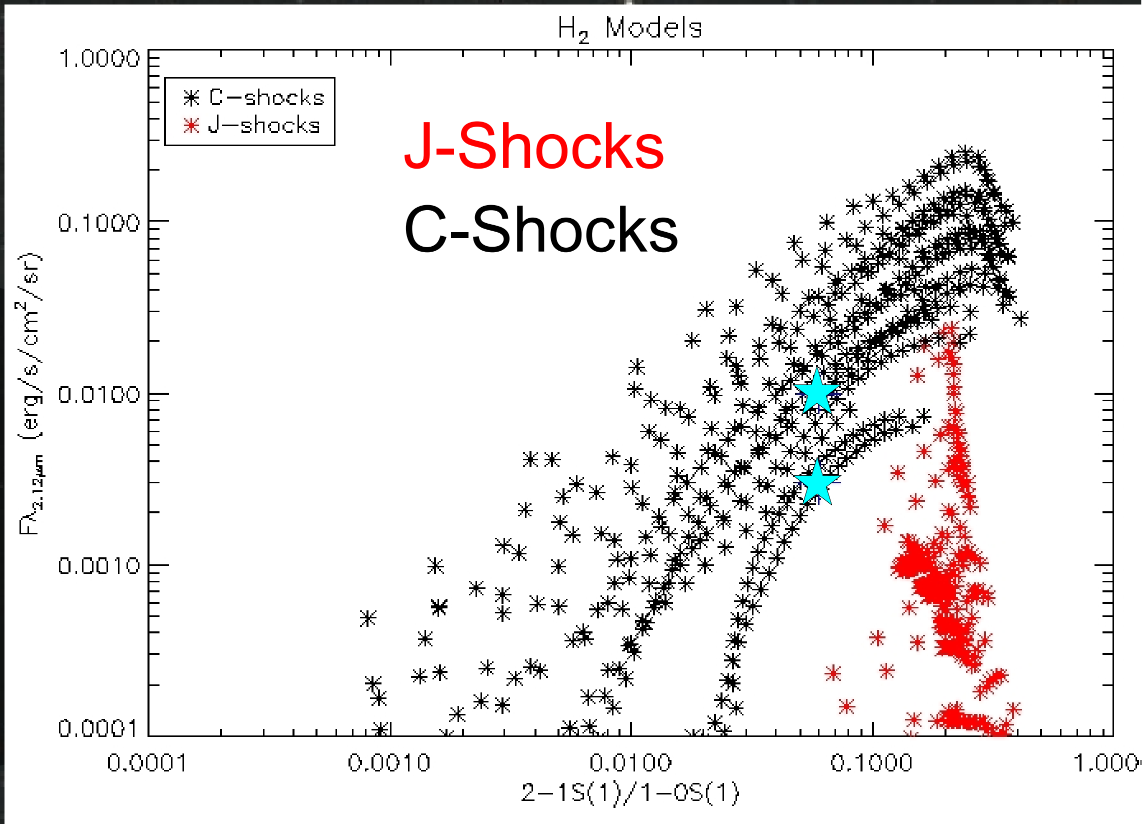
$\Rightarrow \dot{M}_{volume}(H_2)$ ~ 1.5 10^{-9} $M_{\odot}$/yr

- $\dot{M}_{ej} / \dot{M}_{acc}$ = 0.02
- D. Panoglou's predictions for H_2 in MHD disk winds:
  - T~2000 K at z > 10 AU (ambipolar diffusion)
  - But $v_{H2} \leq$ 20 km/s and r_0 < 10 AU: λ < 3

Molecular cavity (H_2) - Shocks

- H_2 brightness:
  - at peak = 0.013 erg/s/cm^{-2}/sr
  - average = 0.003 erg/s/cm^{-2}/sr
- 2-1 S(1)/1-0 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 km/s
- b= 1.0 $\Rightarrow V_s$ = 14 – 48 km/s
- b= 2.0 $\Rightarrow V_s$ = 19 – 55 km/s

(b ~ V_A (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 ~ 0.04

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

- $\dot{M}_s$ = 4 10^{-9} – 4 10^{-8} $M_\odot$/yrs
- $\dot{M}_s / \dot{M}_{acc}$ = 0.04 -0.4 depending on b

⇒ 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)