An alternative model for X-rays from jets

Hans Moritz Günther
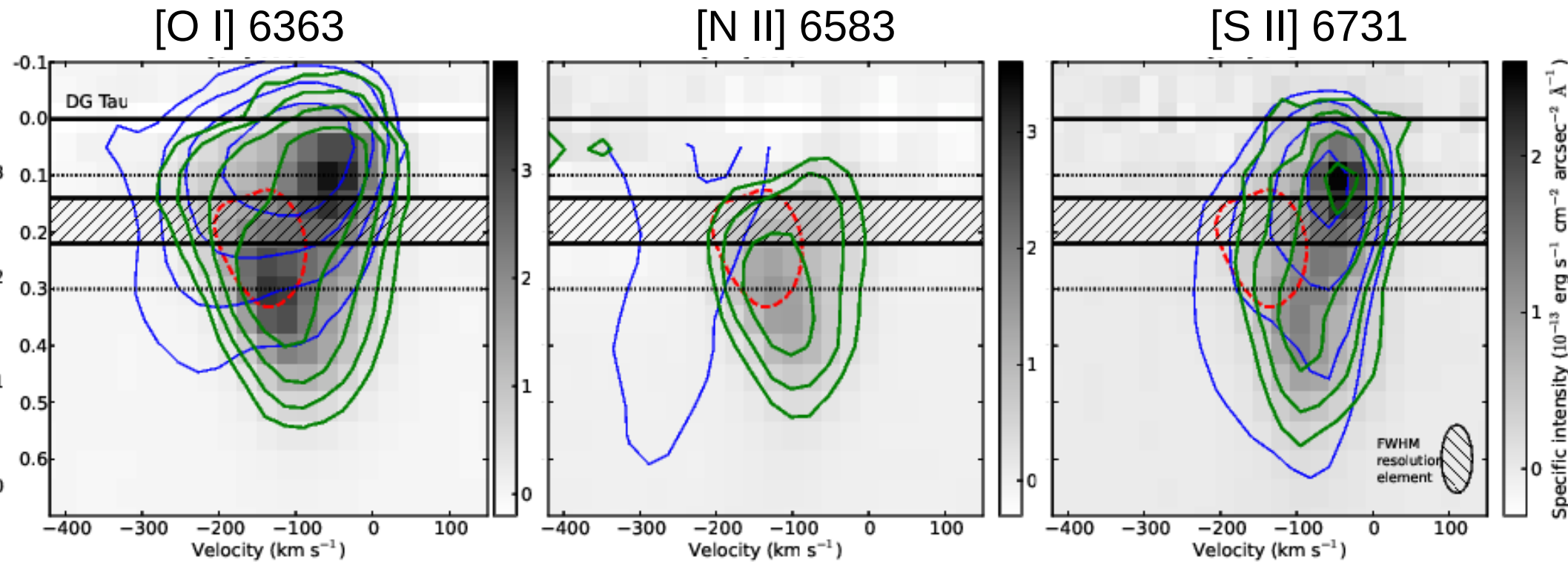## MIT

Zhi-Yun Li (University of Virginia),
Christian Schneider (ESA)

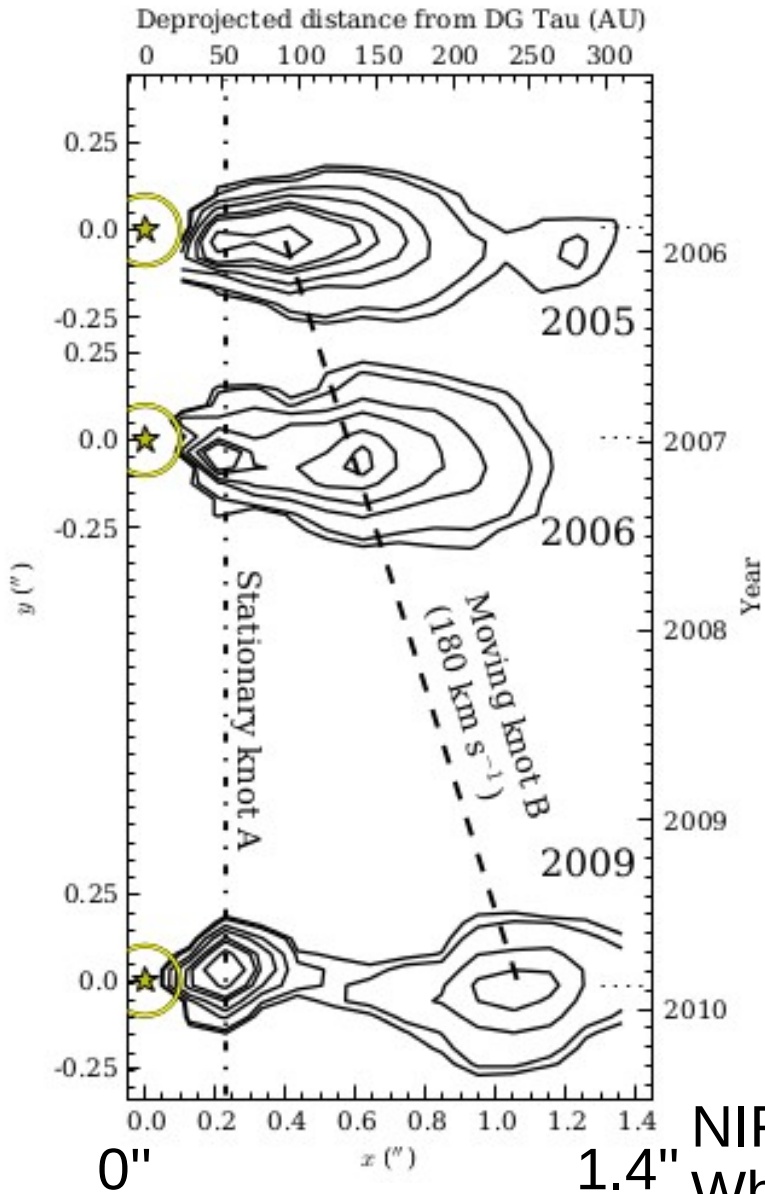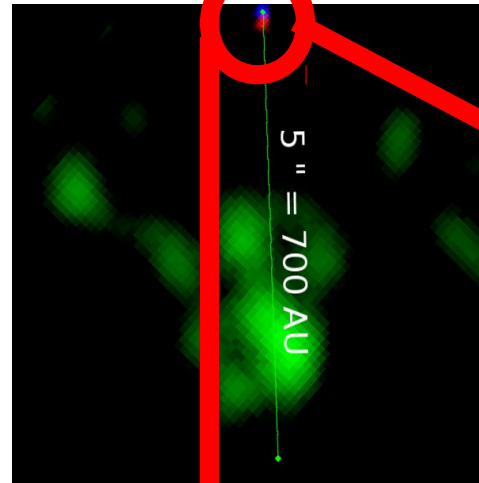# There is a stationary component in the jet.

[O I] 6363   [N II] 6583   [S II] 6731

Blue contours: 1999
Green contours: 2011

HST/STIS: DG Tau
Schneider, …, **Günther** et al. A&A (2013)

In IR and X-rays, too.

Deprojected distance from DG Tau (AU)

Stationary knot A

Moving knot B (180 km s^{-1})

2005
2006
2009
2010

0"   1.4"

NIFS: [Fe II]
White et al. (2014)

Chandra 450 ks
Güdel, …,
Günther et al.
(in prep)

5" = 700 AU

2004   2006   2012

2008
Year

Observed flux (10^{-14} erg/s/cm^2)
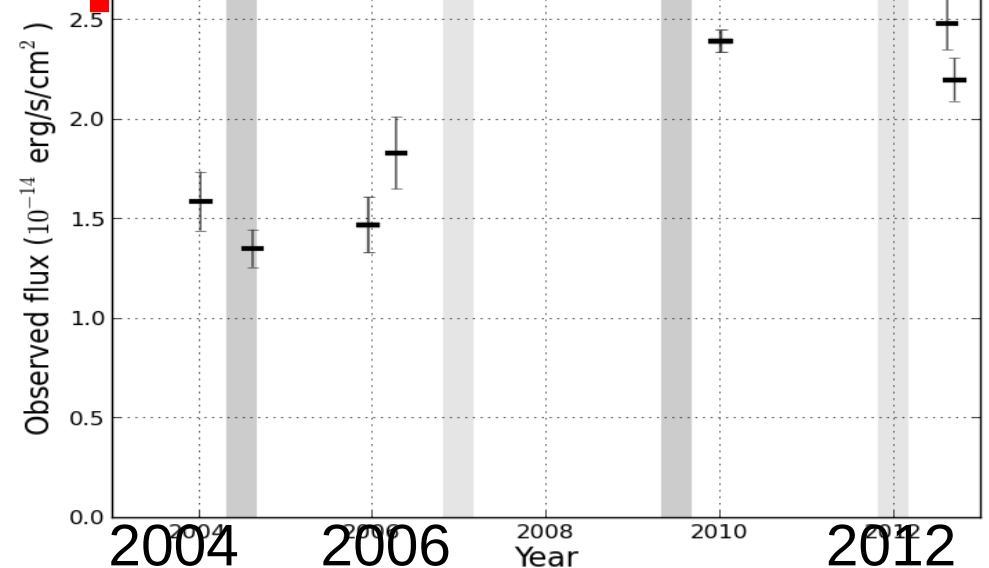
Schneider, **Günther** et al., in prep.

Mass flux through inner X-ray shock

X-rays   Forbidden optical lines   H2 lines (Near-IR)

R

d_{cool}

Shock

10-100 km/s   100-400 km/s   400-600 km/s

d_{cool} [AU]

10^{-9}
10^{-10}
10^{-11}

$\dot{M} = 10^{-9}$
$\dot{M} = 10^{-10}$
$\dot{M} = 10^{-11}$

R [AU]

Shock speed [km/s]
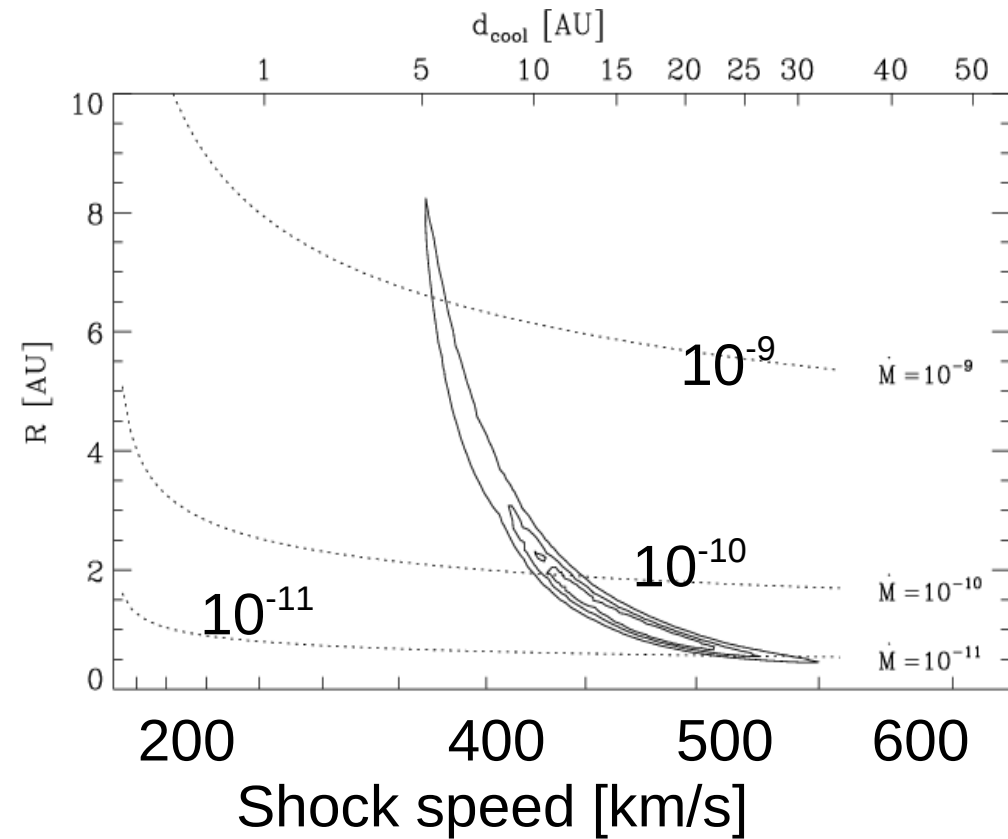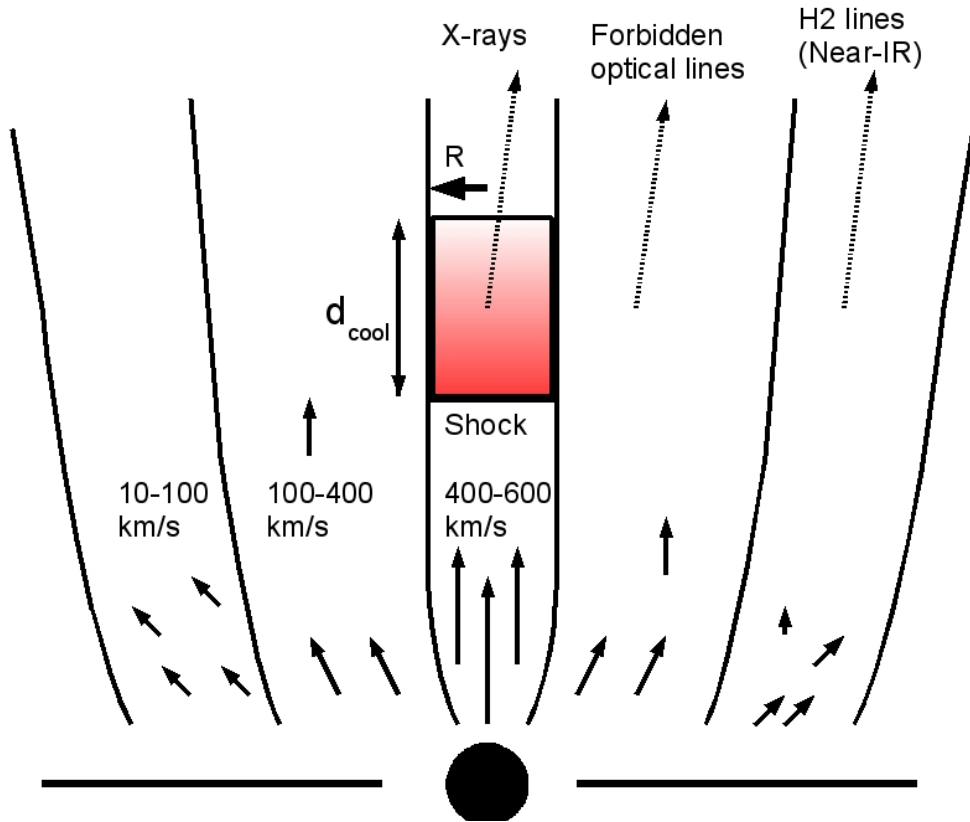
$$T = 4\,\mathrm{MK}\left(\frac{v_{\mathrm{shock}}}{500\ \mathrm{km\ s^{-1}}}\right)^2$$

$$\dot{M} = A_{\mathrm{jet}}\,\rho\,v_0$$

$$d_{\mathrm{cool}} = 20.9\,\mathrm{AU}\left(\frac{10^5\ \mathrm{cm^{-3}}}{n_0}\right)\left(\frac{v_{\mathrm{shock}}}{500\ \mathrm{km\ s^{-1}}}\right)^{4.5}$$
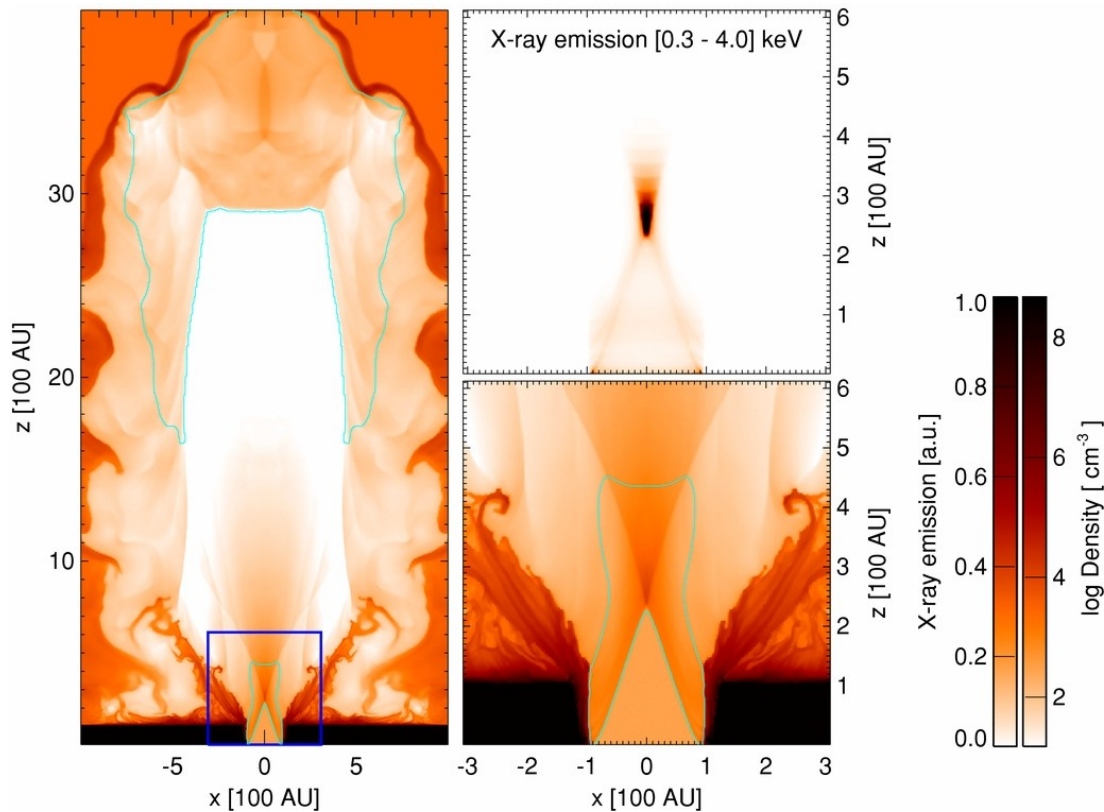
Model:
Günther, Matt & Li, A&A (2009)

Explanation 0: A new blob emerges

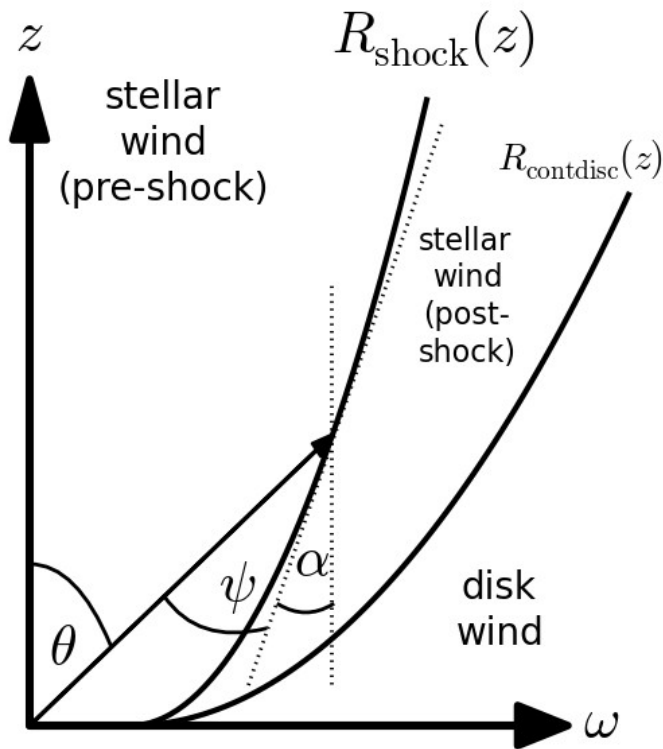Unlikely, given how constant the inner component appears.

Explanation I: Diamond shock

Bonito et al. (2010)

- Sophisticated model (MHD, conduction, …)

- Assume nozzele at base

- Numbers tuned to HH 154, but might work in DG Tau, too.

- This is a good model. But it might not be the *only* one.

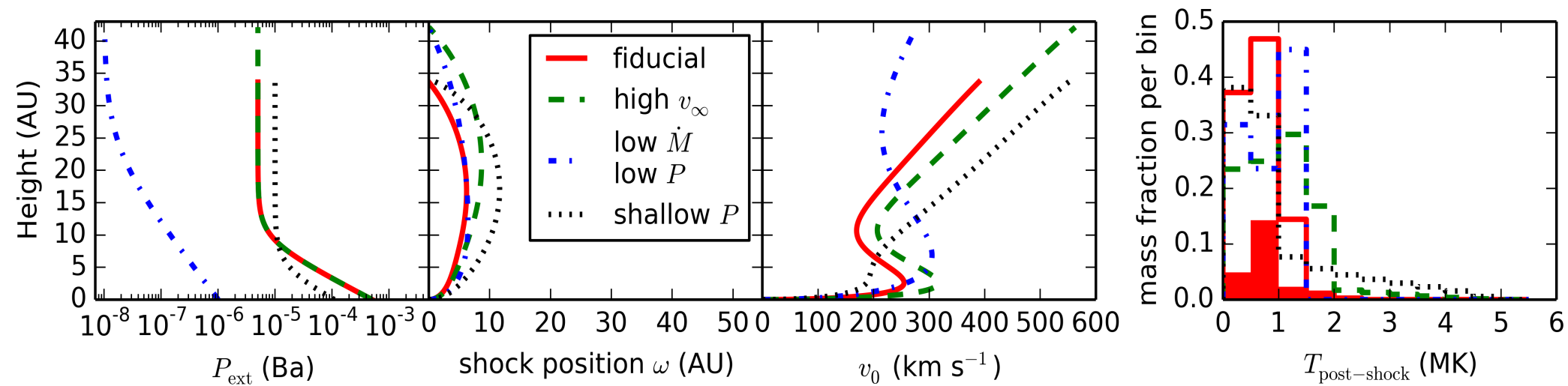# Explanation II: Stellar wind meets disk wind / disk field.

- Disk wind or stellar wind?
- Disk wind probably has higher mass flux, but lower velocity

Model
- Assume contact discontinuity between disk wind and stellar wind
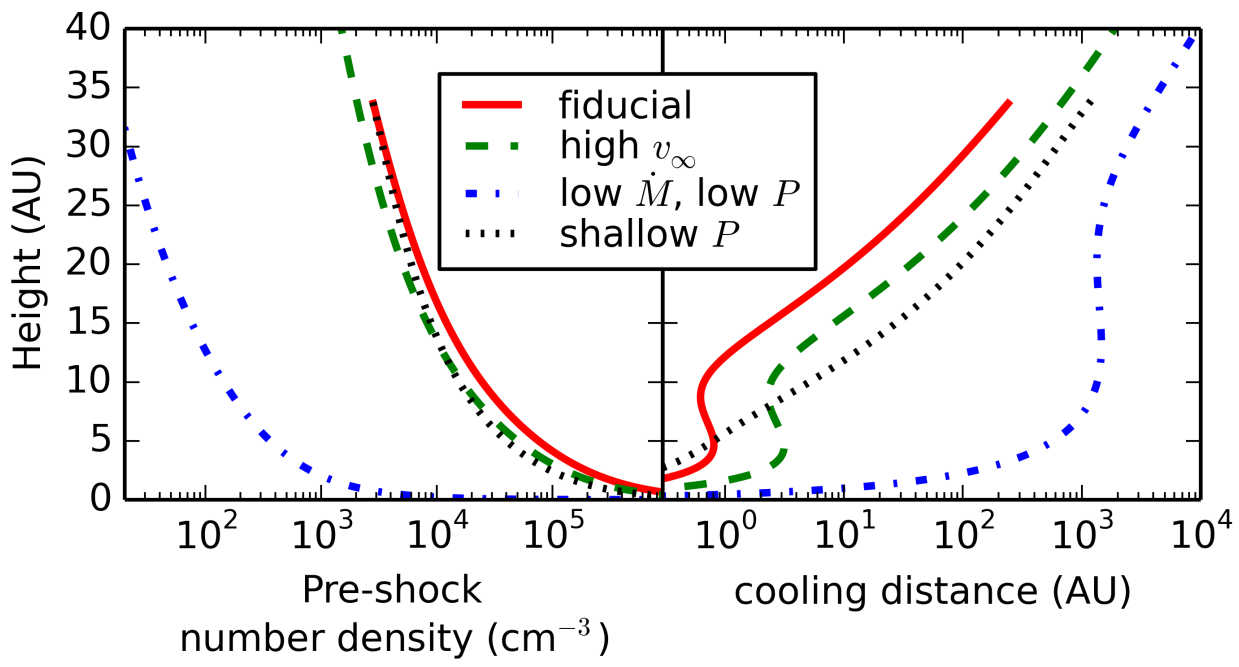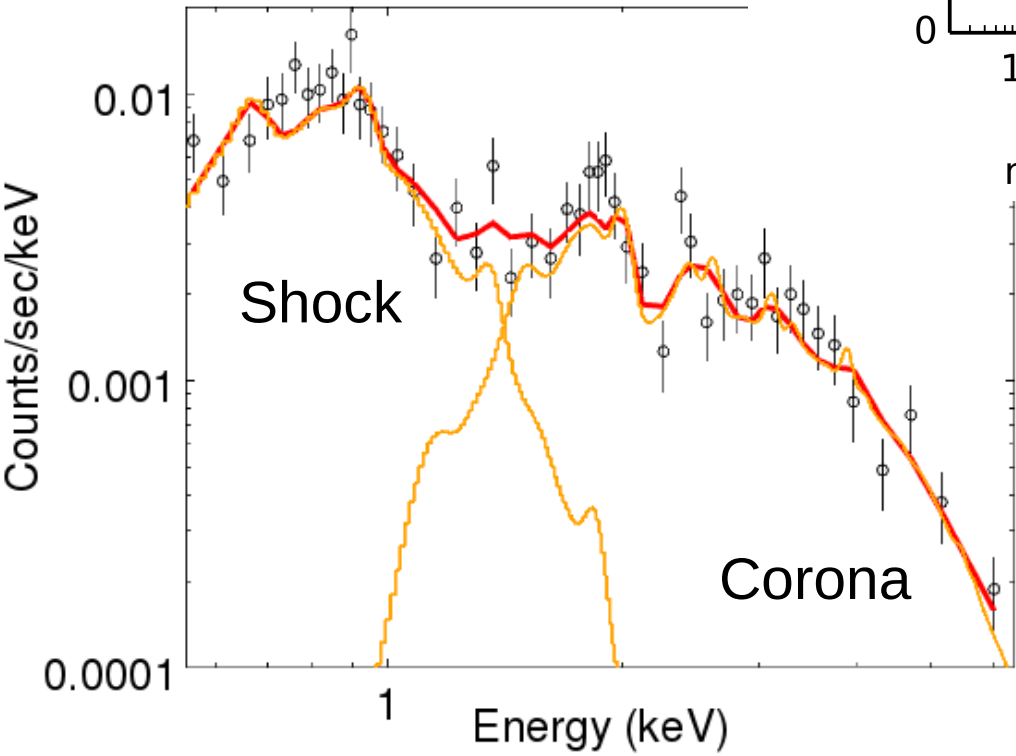- Collimation shock will form in stellar wind

$$\frac{d\omega}{dz} = \tan\left[\arctan\left(\frac{\omega}{z}\right) - \arcsin\left(\frac{\sqrt{z^2 + \omega^2}}{R_0}\right)\right]$$

How would such a shock look like?

- Stellar wind region thin and long

- Shock not resolved in optical obs

- High stellar mass loss

- 10^{-3} of jet mass sufficient to power X-rays

Shock properties and spectral fit

Fiducial model
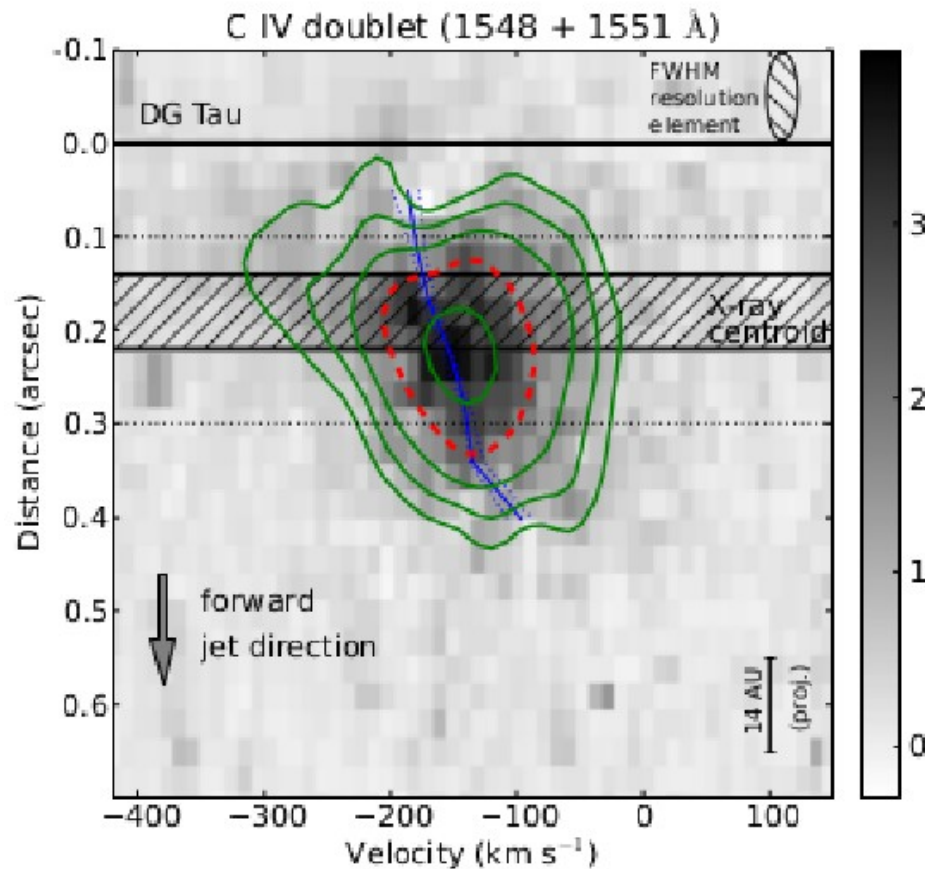- $5*10^{-10}$ M_{sun}/yr
- 800 km/s

DG Tau: X-ray and FUV emission

- Stationary inner component: Needs to be reheated continuously → Jet collimation

- At least two scenarios possible

  - ~~A new blob emerges~~

  - Diamond shock

  - Stellar wind – disk wind shock

- Need to explore more options, not just the first!

ApJ 795, 51 (2014)

https://github.com/hamogu/RecollimationXrayCTTS

C IV luminosity too large to be explained only by cooled X-rays

HST/STIS: DG Tau
Schneider, …, **Günther** et al. A&A (2013)