Chandra's First Decade of Discovery
Boston, MA
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Discovery of an Accretion-Fed Corona in a Young Star

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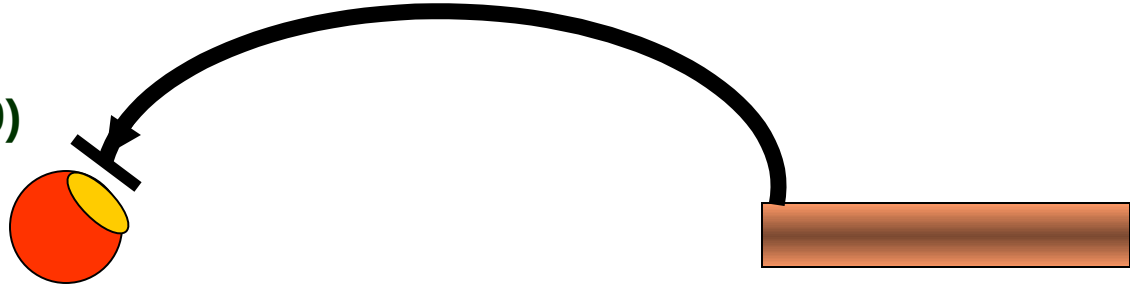
Accretion or Corona?

Chandra **Large Observing Program**
TW Hydrae (TW Hya)
High Energy Transmission Grating
~500 ks

- **Test argument for X-rays from accretion**
  (Kastner et al. 2002)
- **If accretion, test accretion-shock model**

(Brickhouse et al. 2009)



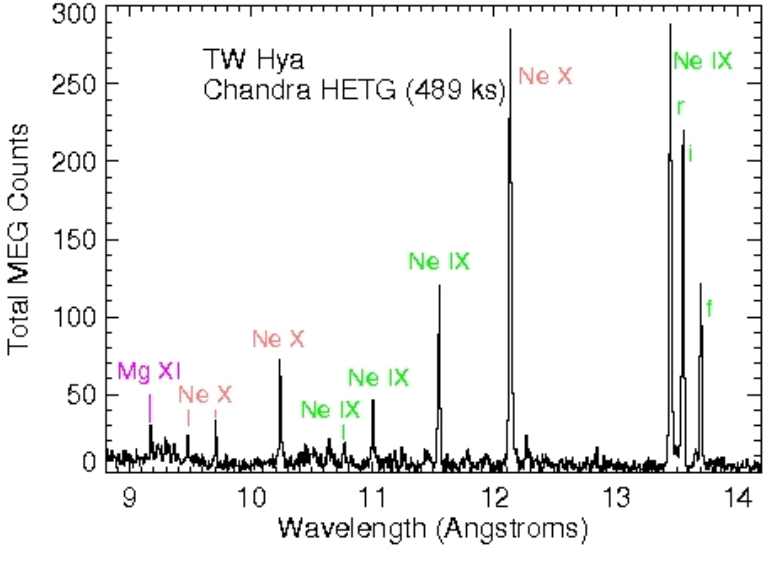
TW Hya

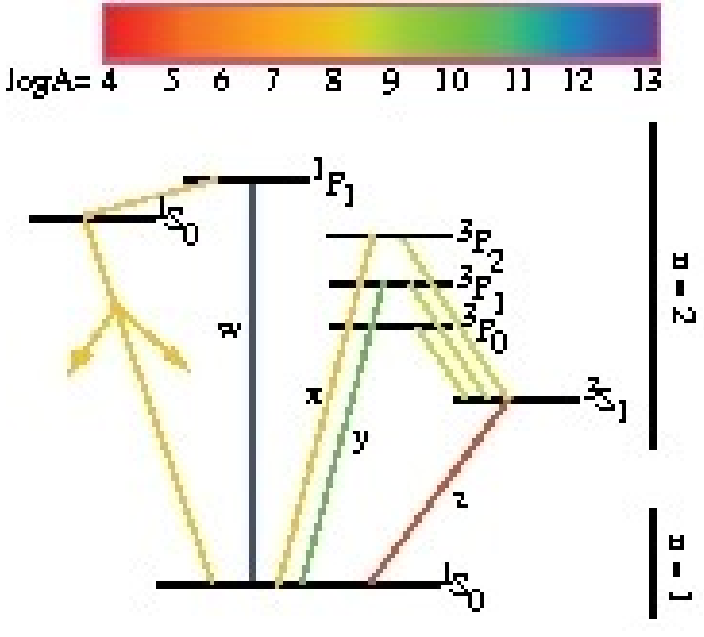
- Classical T Tauri star (accreting)
- 10 million yr old
- i=7^{o} (pole-on)
- M = 0.8 M_{Sun}
- R = 0.7 R_{Sun}
- Distance 57 pc

- X-ray plasma has high Neon abundance

  (Kastner et al. 2002; Drake et al. 2005)

Spectral Line Diagnostics



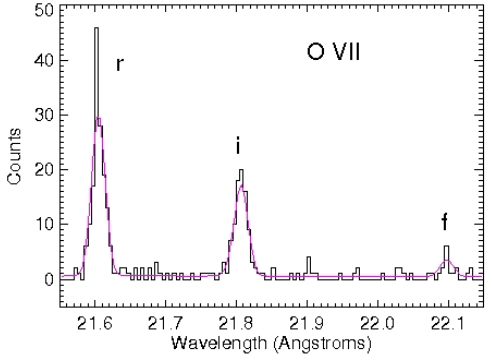


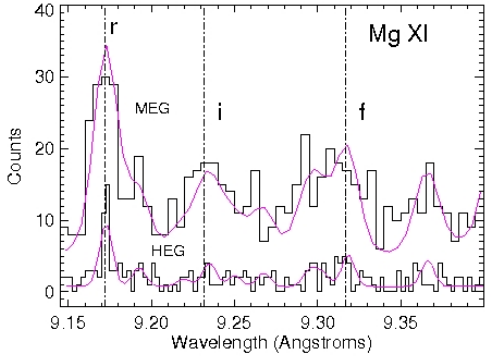
Segment of HETG spectrum showing H- and He-like Ne series

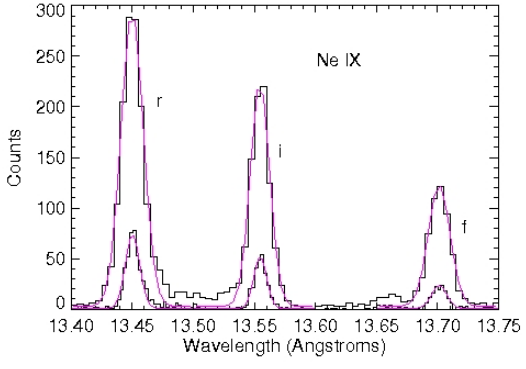
He-like Energy Levels (Smith et al. 2009)

Series lines are sensitive to absorption

He-like Ions:
O VII, Ne IX, and Mg XI

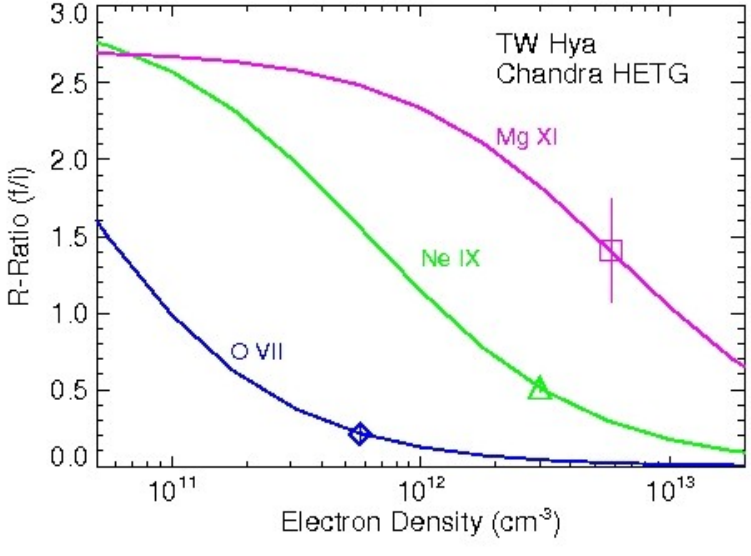


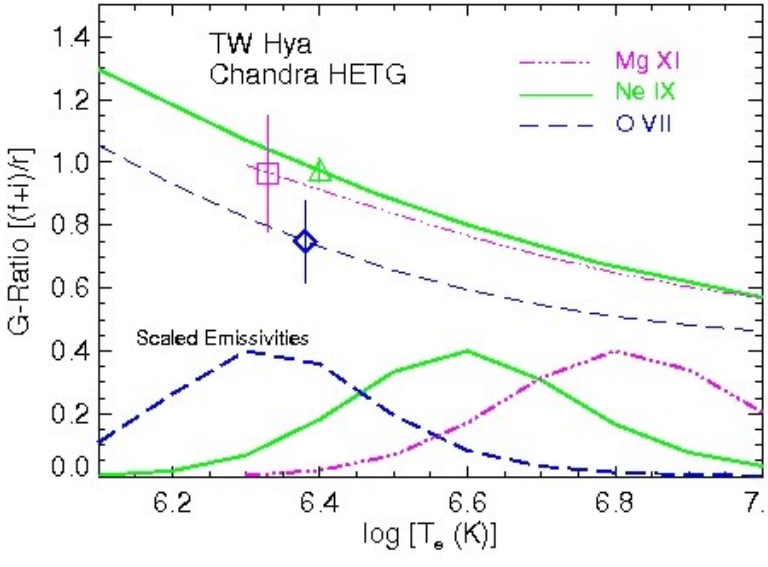




Diagnostics for T_e and N_e

X-Ray Line Ratio Diagnostics for Density and Temperature





$N_e = 6 \times 10^{12}$ cm^{-3} Mg XI

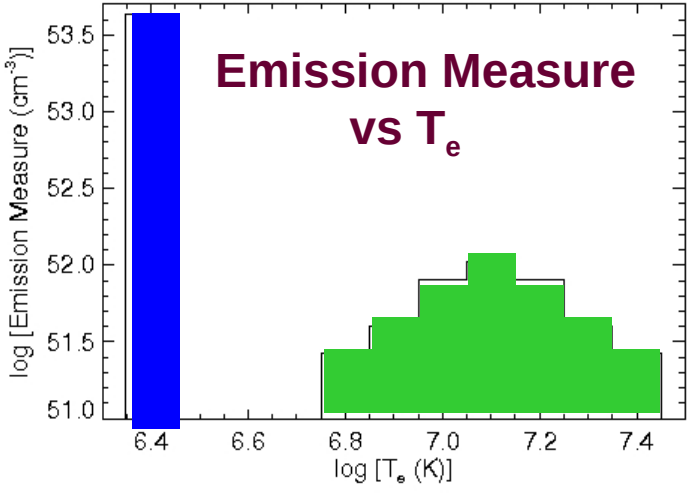
3×10^{12} Ne IX

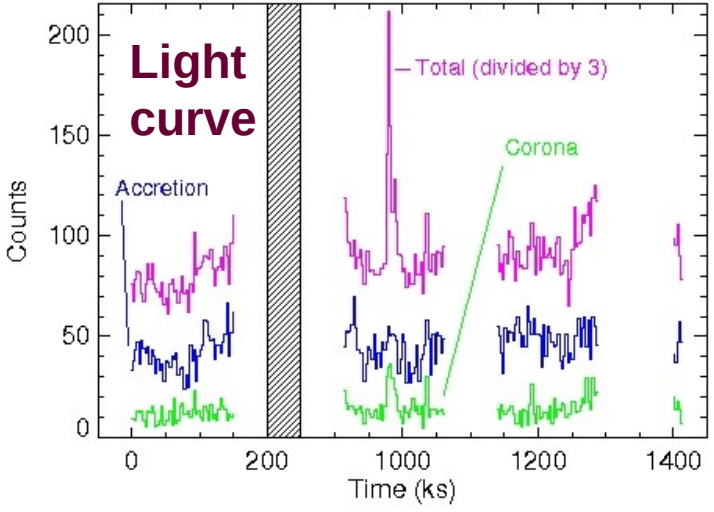
6×10^{11} O VII

$T_e = 2.50 \pm 0.25$ MK

This looks like the accretion shock!

Accretion and a Corona

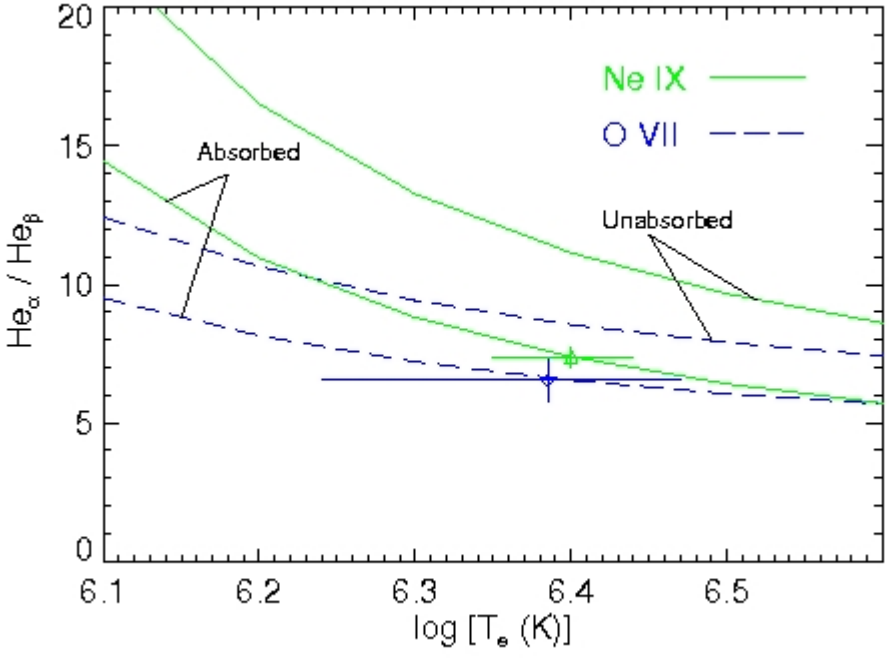




Hot "coronal" lines exhibit a large flare.
The "accretion" lines do NOT flare.
Variability occurs in both.

Complex absorption

- **O VII: $N_H = 4.1 \times 10^{20}$ cm^{-2}**
- **Ne IX: $N_H = 1.8 \times 10^{21}$ cm^{-2}**



Not resonance scattering:

Tau = g f λ, for a given ion

Series line ratios rule out

Testing the Accretion Shock Model

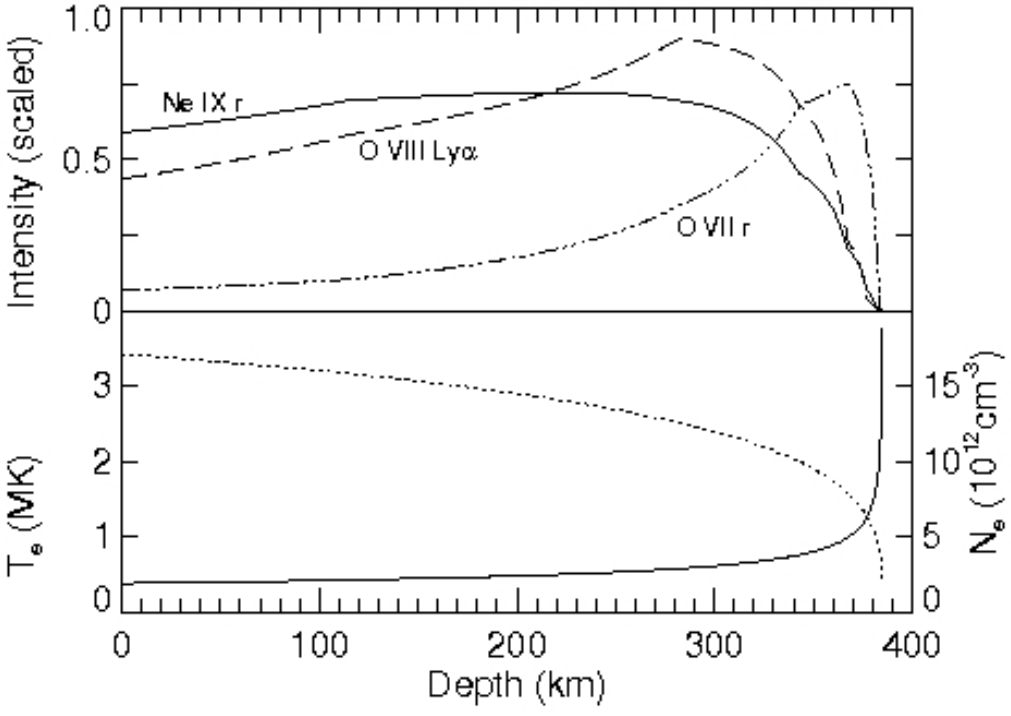
$$V_{ff} = \frac{2GM_*}{R_*} (1 - R^*/r_t)^{1/2}$$

~ 510 km/s

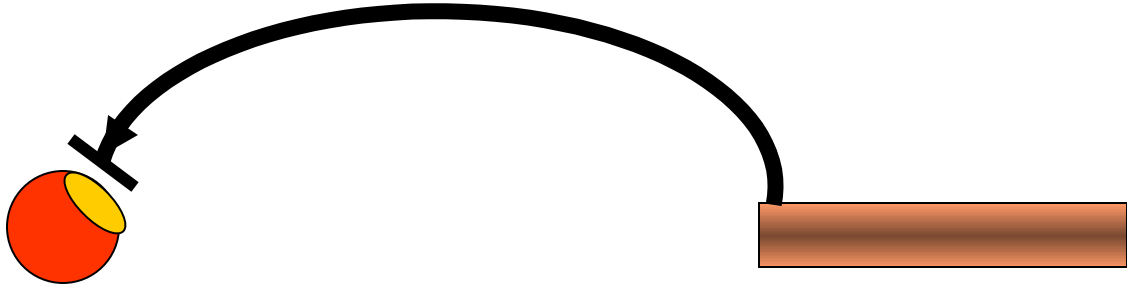
T_e = 3.4 MK

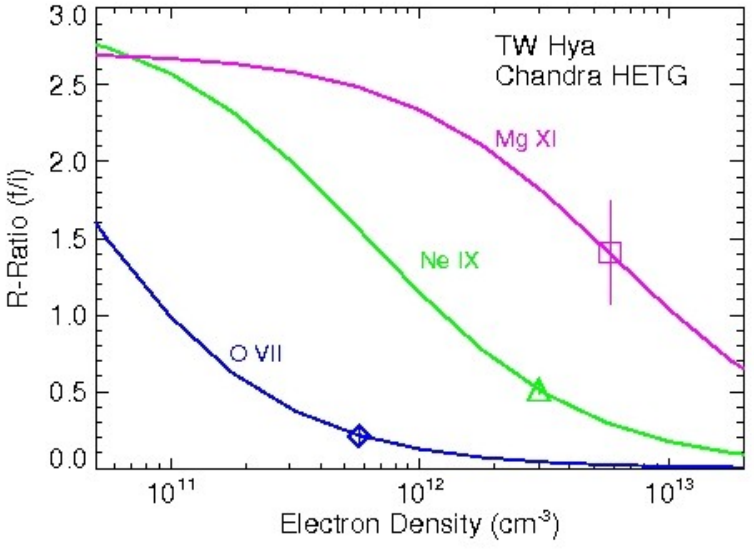
●

$M_{acc} = f A_* \rho_{pre} v_{ff}$



(Konigl 1991;
Calvet & Gullbring 1998;
Gunther et al. 2007;
Cranmer 2008)





- **Temperature and Density at Shock Front Agree with Model.**
- **Predicted density at O VII is 7 times larger than observed.**

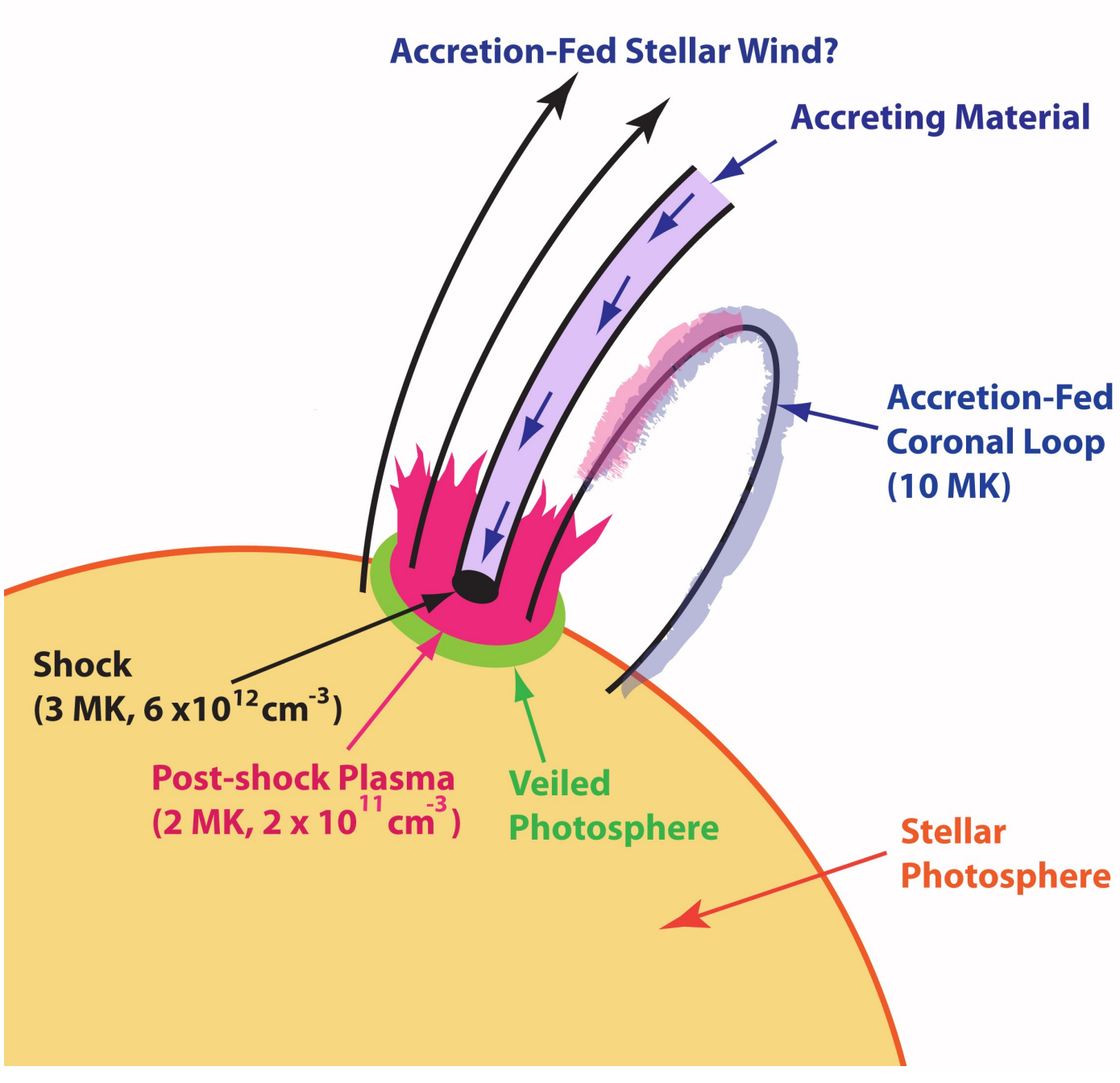
•Consider a new 2-Region model for the shock:
Region 1 = the shock front
Region 2 = the post-shock cooling region

•Each region has N_e , T_e, N_H, and V

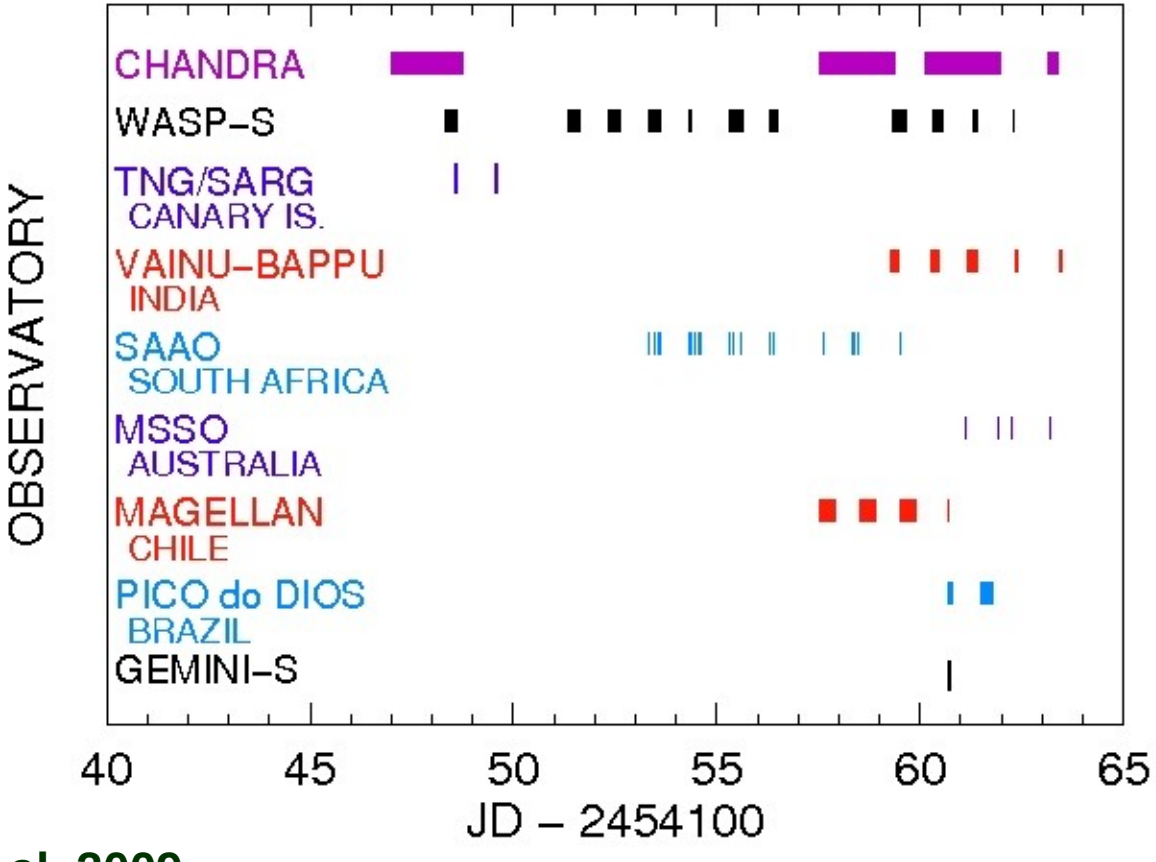
•Predict the r, i, and f lines of the He-like ions

•V2 = 300 x V1 => M2 = 30 x M1

Note Gudel et al. 2007
Gudel & Telleschi 2007


Accretion-Fed Stellar Wind?
Accreting Material
Accretion-Fed
Coronal Loop
(10 MK)
Shock
(3 MK, 6 x10^{12}cm^{-3})
Post-shock Plasma
(2 MK, 2 x 10^{11} cm^{-3})
Veiled
Photosphere
Stellar
Photosphere

TW Hya Campaign: Four Continents Plus Chandra



Dupree et al. 2009

Conclusions

- **High S/N, high resolution spectrum obtained with Chandra HETG shows 3 regions: a hot 10 MK corona, an accretion shock, and a post-shock cooling region.**
- **Diagnostics show excellent agreement with models of the shock itself.**
- **Diagnostics show that standard, one-dimensional models of the post-shock cooling plasma don't work.**
- **We need a new type of coronal structure, an "accretion-fed corona" to be heated and ionized by the shocked plasma.**
- **Accretion-fed coronae may be common in accreting young star systems.**