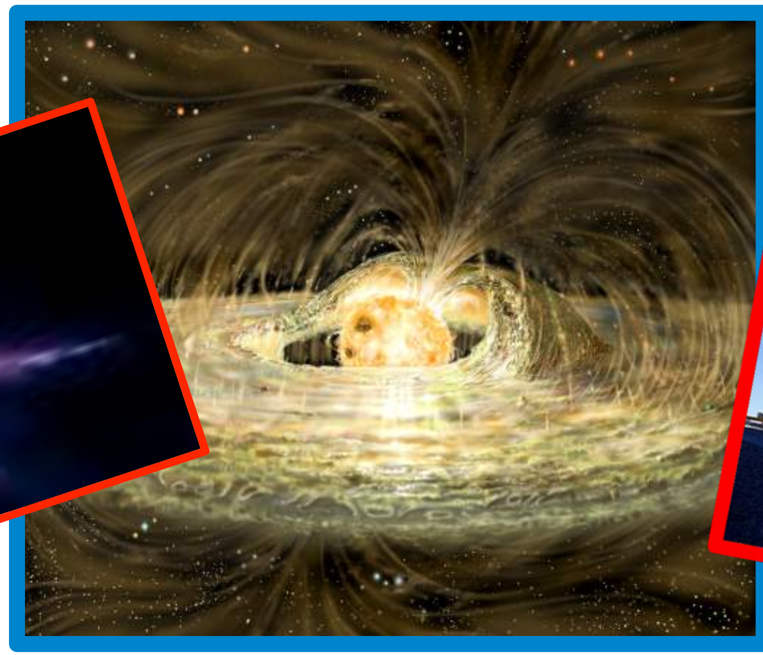
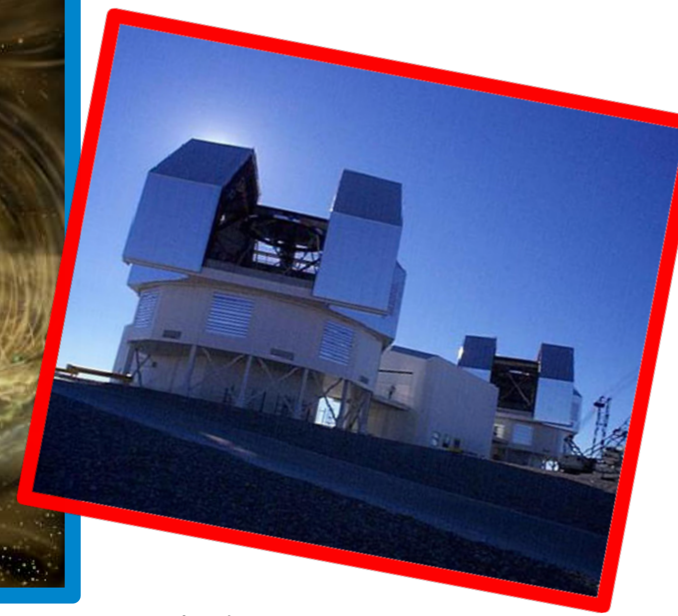
Probing Young Accreting Stars with X-Rays

Andrea Dupree, CfA

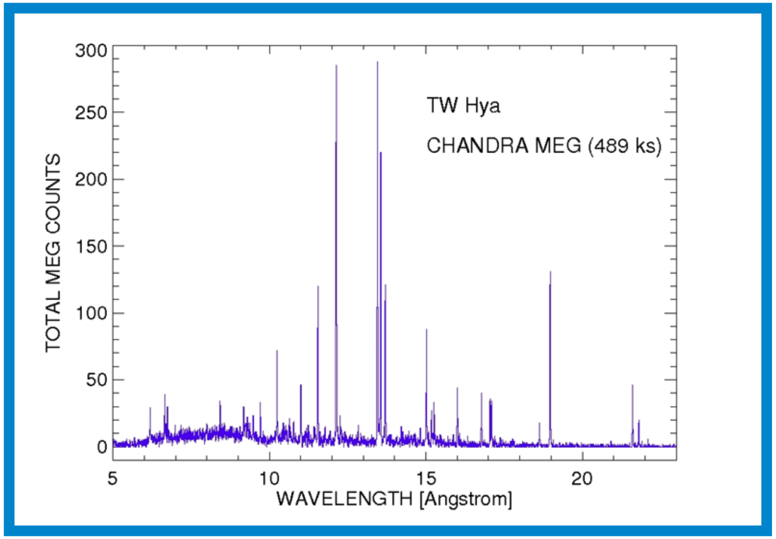




Collaboration with Nancy Brickhouse and Steve Cranmer (CfA)

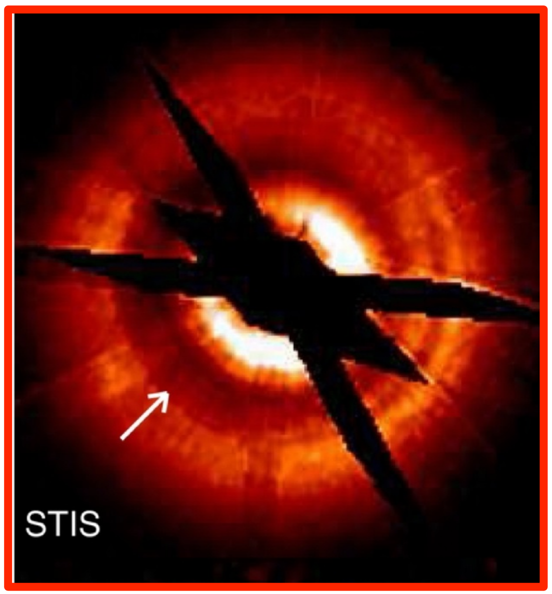
Einstein Symposium, October 28, 2014

CHANDRA Spectroscopy of Accreting Cool Stars

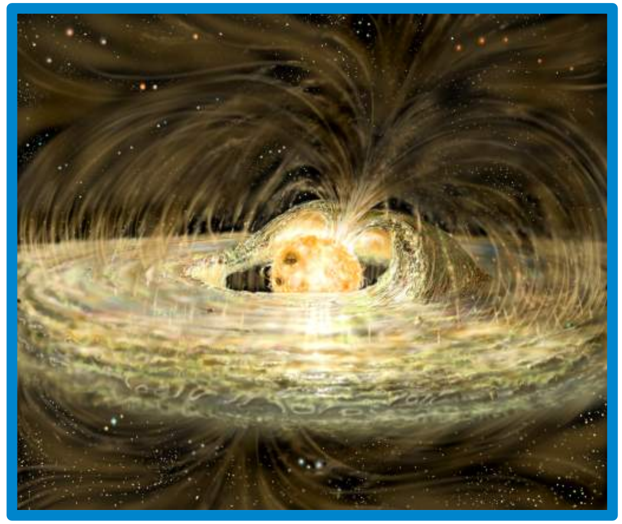


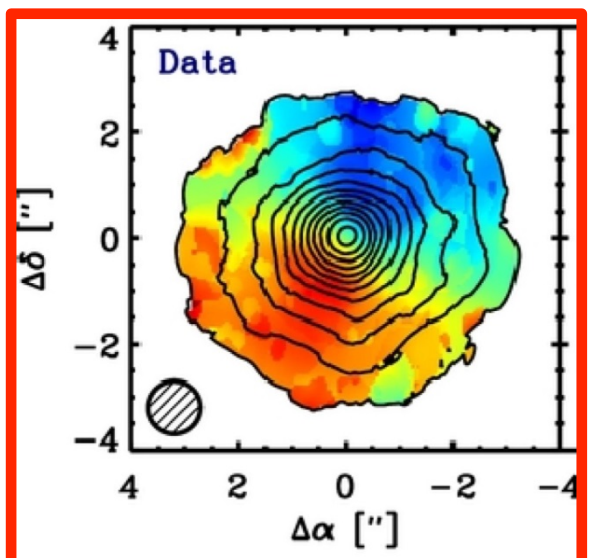
- Plasma diagnostics give parameters of accretion
- CHANDRA spectra define accretion models
- Time-domain spectroscopy (simultaneous multi-wavelength) changes accretion paradigm

TW Hya... closest accreting star

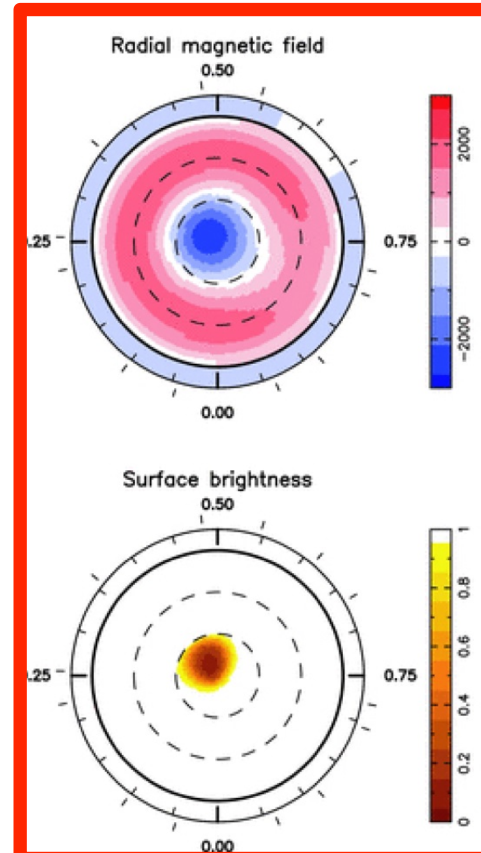


Optical
Debes+ 2013



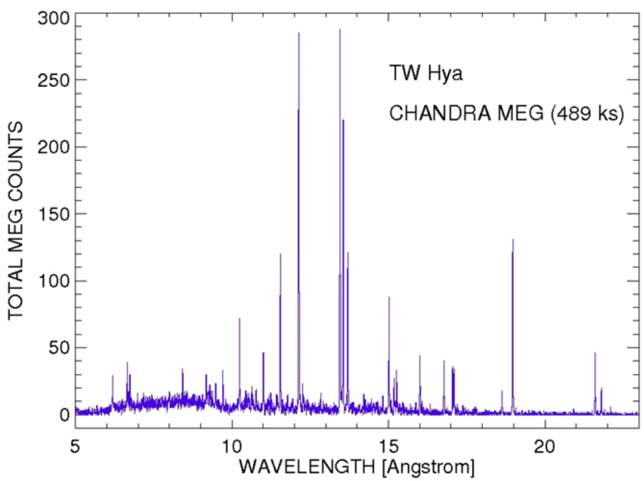


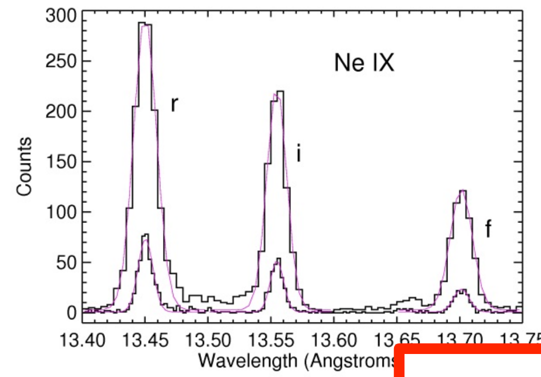
CO 3-2: Andrews+ 2012

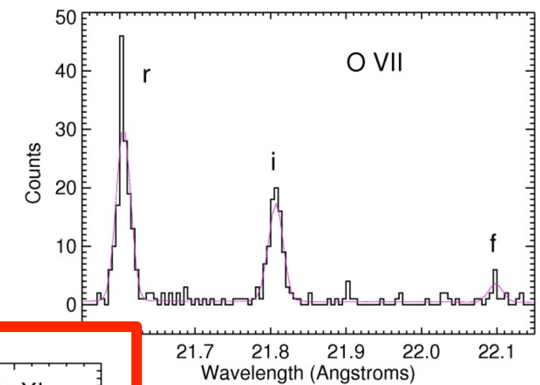


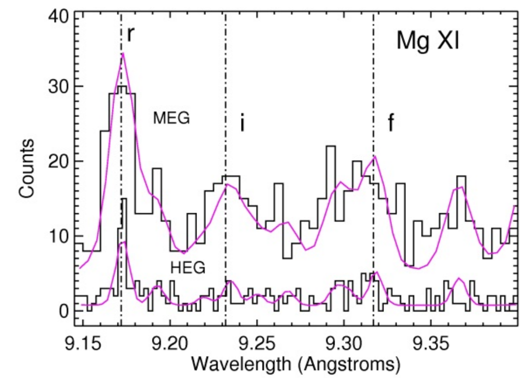
Donati+ 2011

Rich CHANDRA Spectrum



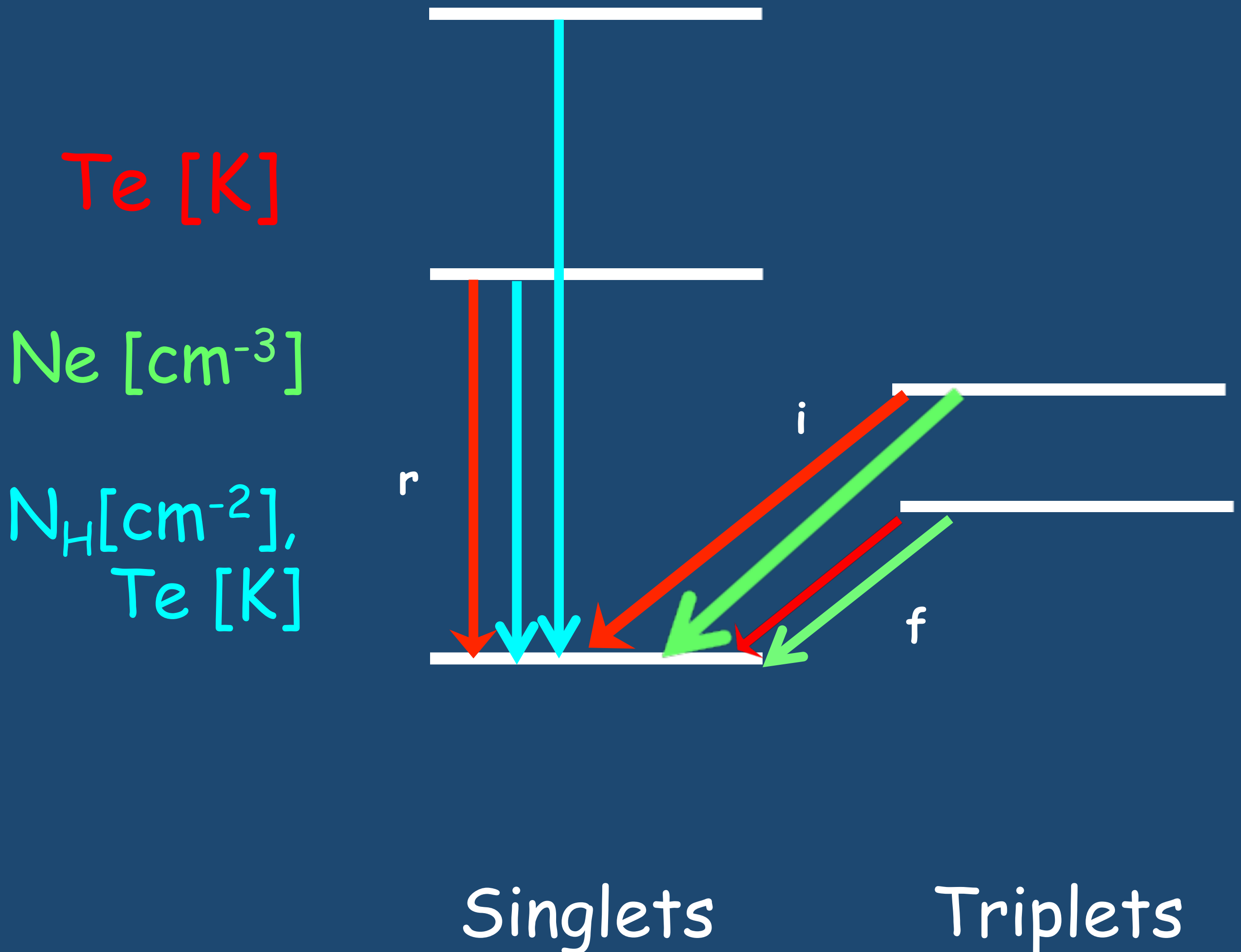




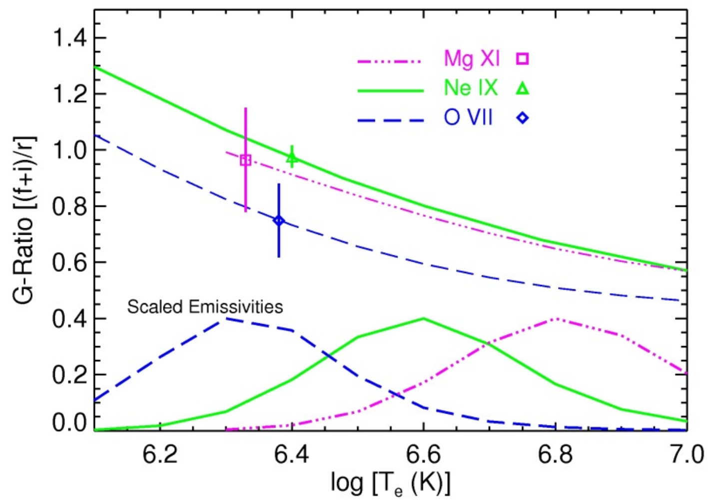


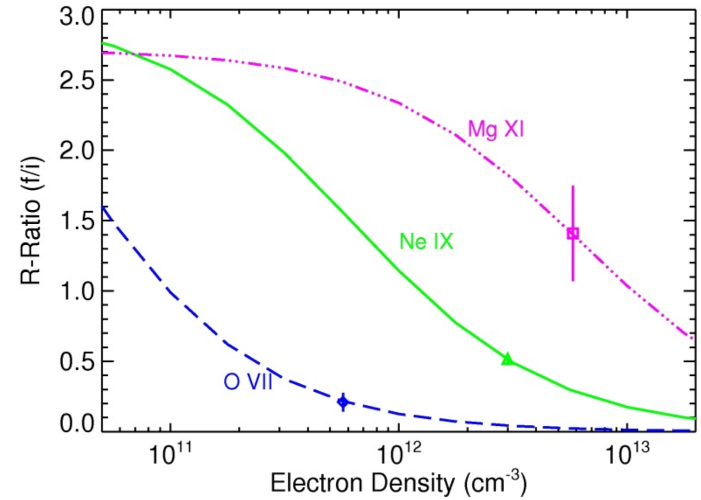
Brickhouse+ 2010

CHANDRA Plasma Diagnostics: Helium-like ions



Helium-ion diagnostics

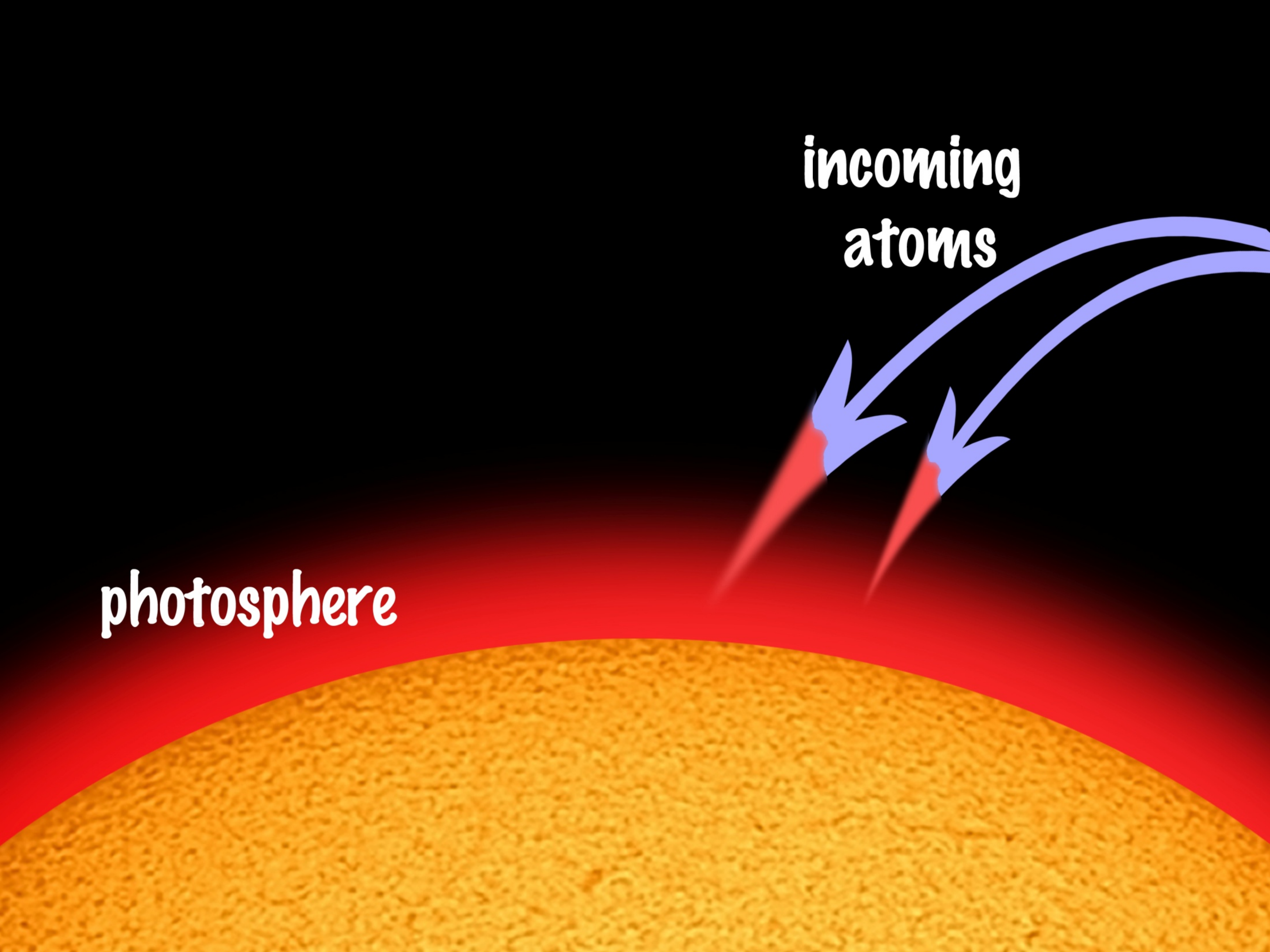


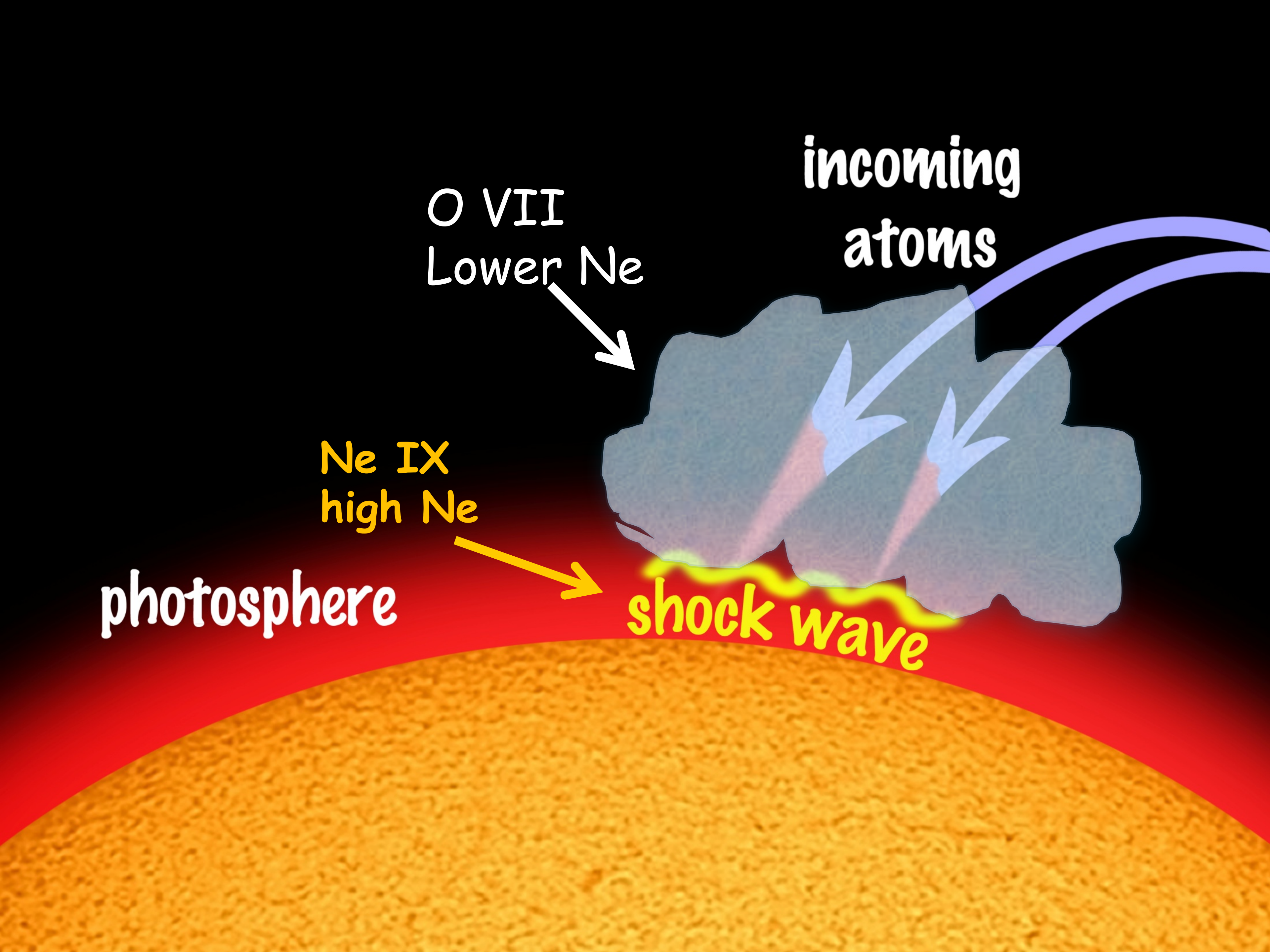


High Ne at Low T (3 MK) → Shock

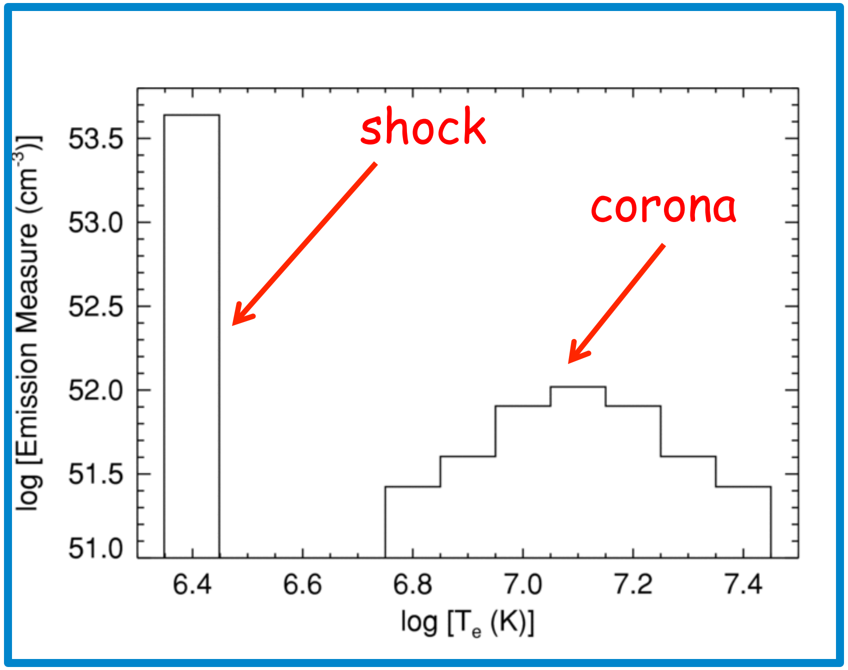
O VII indicates lower density(!)

Kastner+ 2002; Brickhouse+ 2010

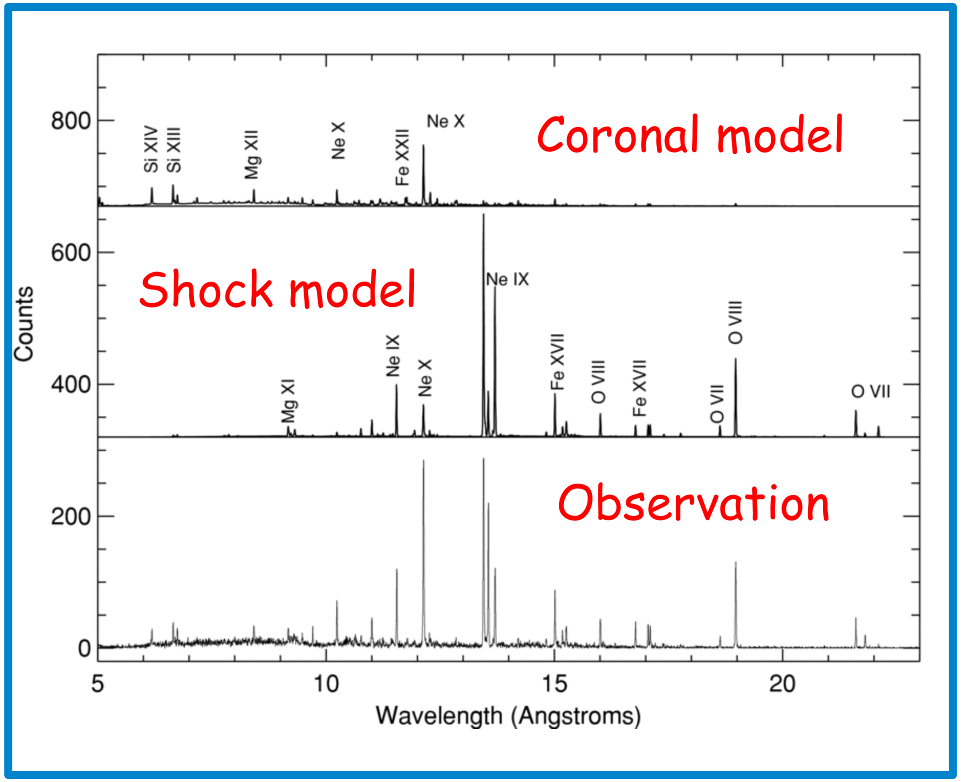

incoming
atoms
photosphere


incoming
atoms
O VII
Lower Ne
Ne IX
high Ne
photosphere
shock wave

Modeling the spectra



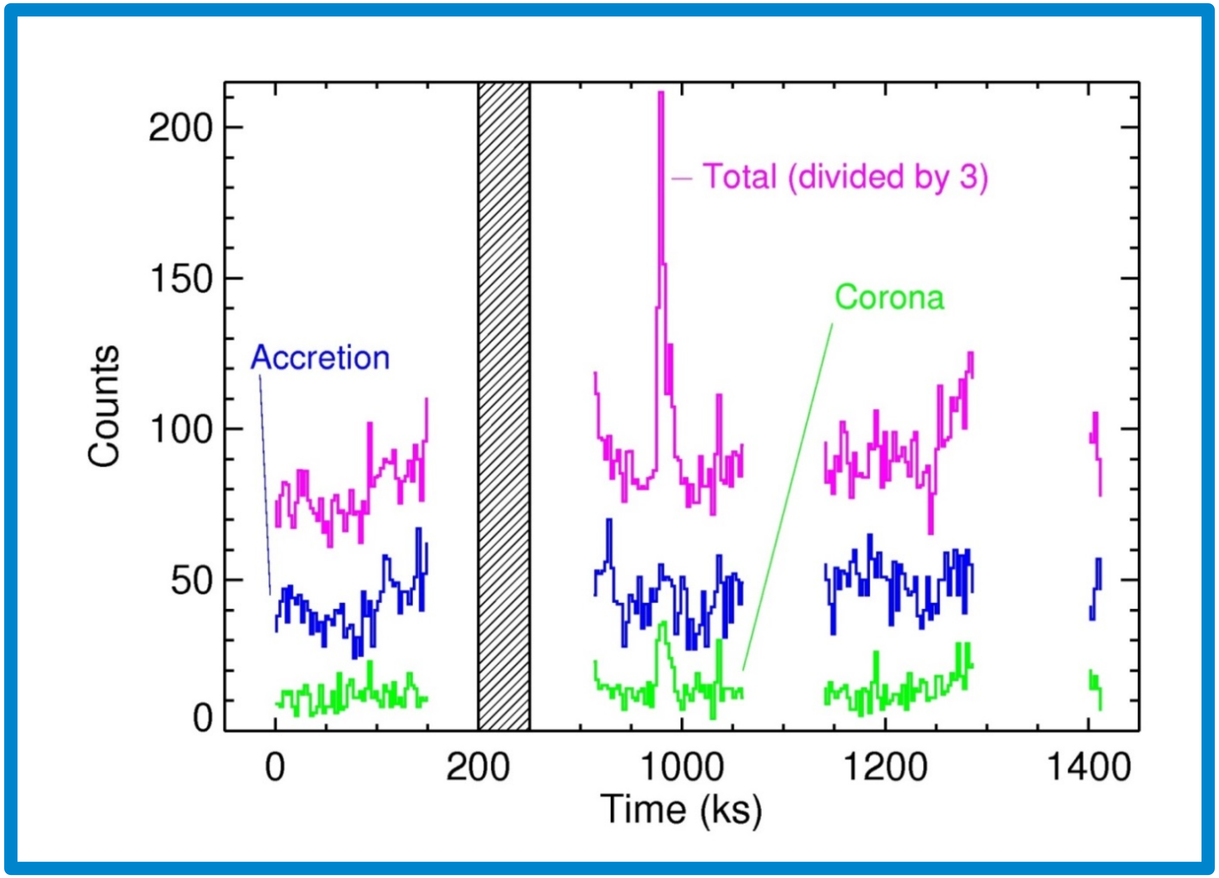
EMD model from continuum and line fits



Predicted and observed MEG spectra

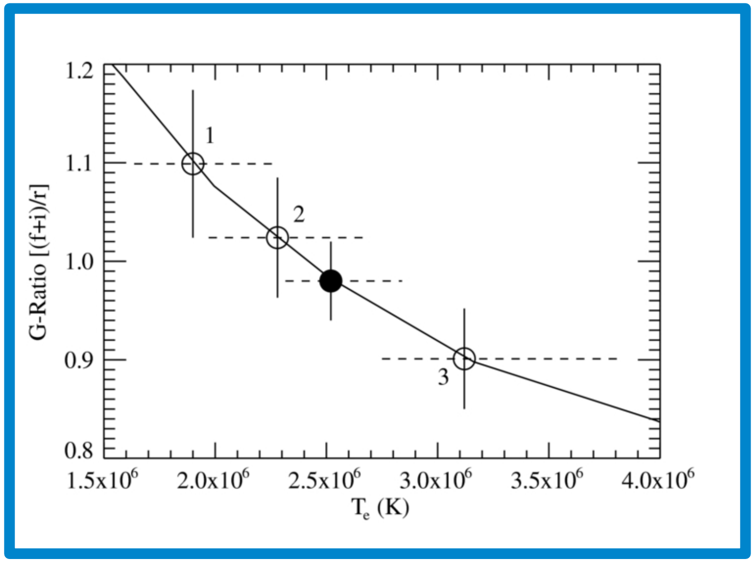
Brickhouse+ 2010

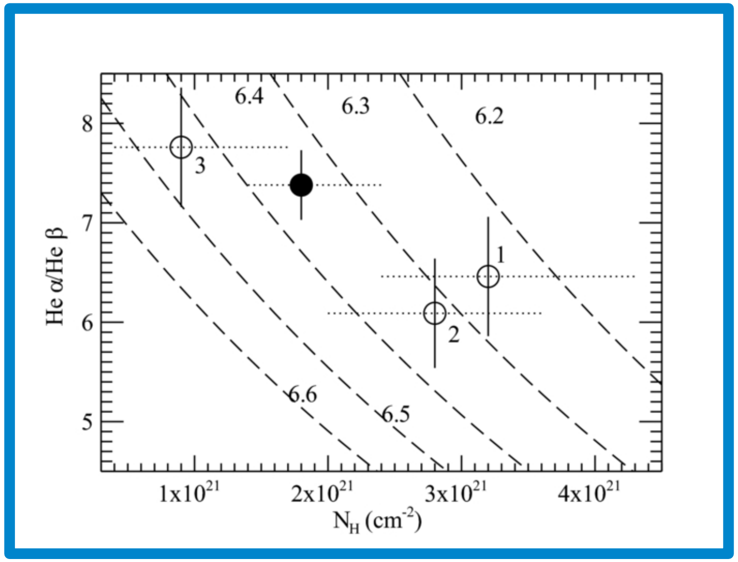
Accretion Lines vs Coronal Lines



Accretion Lines: N VII, O VIII, Ne IX, Fe XVII, Mg XI
Coronal Lines: Ne X, Mg XII, Si XIII, Si XIV, Fe XIII, FeXXII

3 pointings: Ne IX Diagnostics





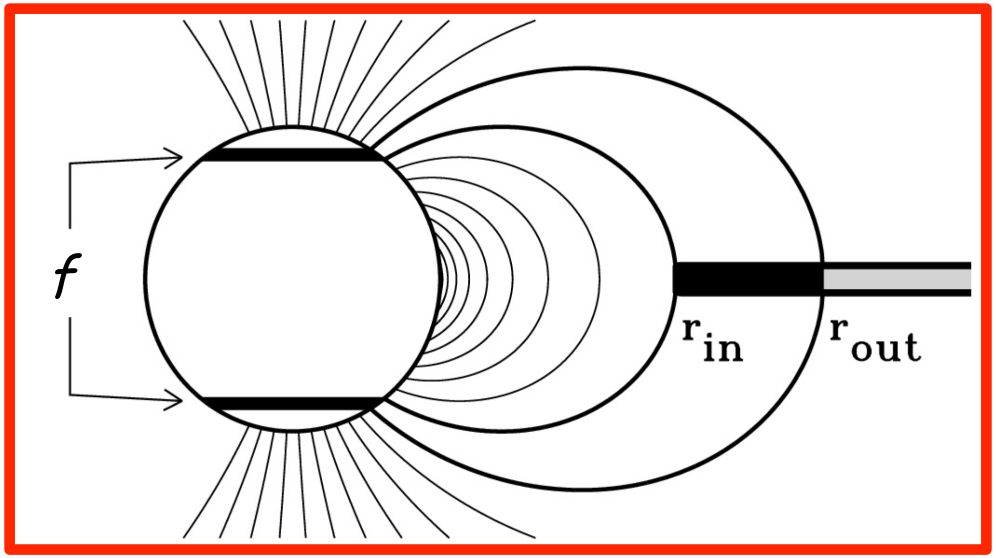
Shock Temperature changes => free-fall velocity changes

=> disk distance changes

Absorbing column changes (N_H) => path length changes

Brickhouse+ 2012

Toy model



Te → r_in,r_out

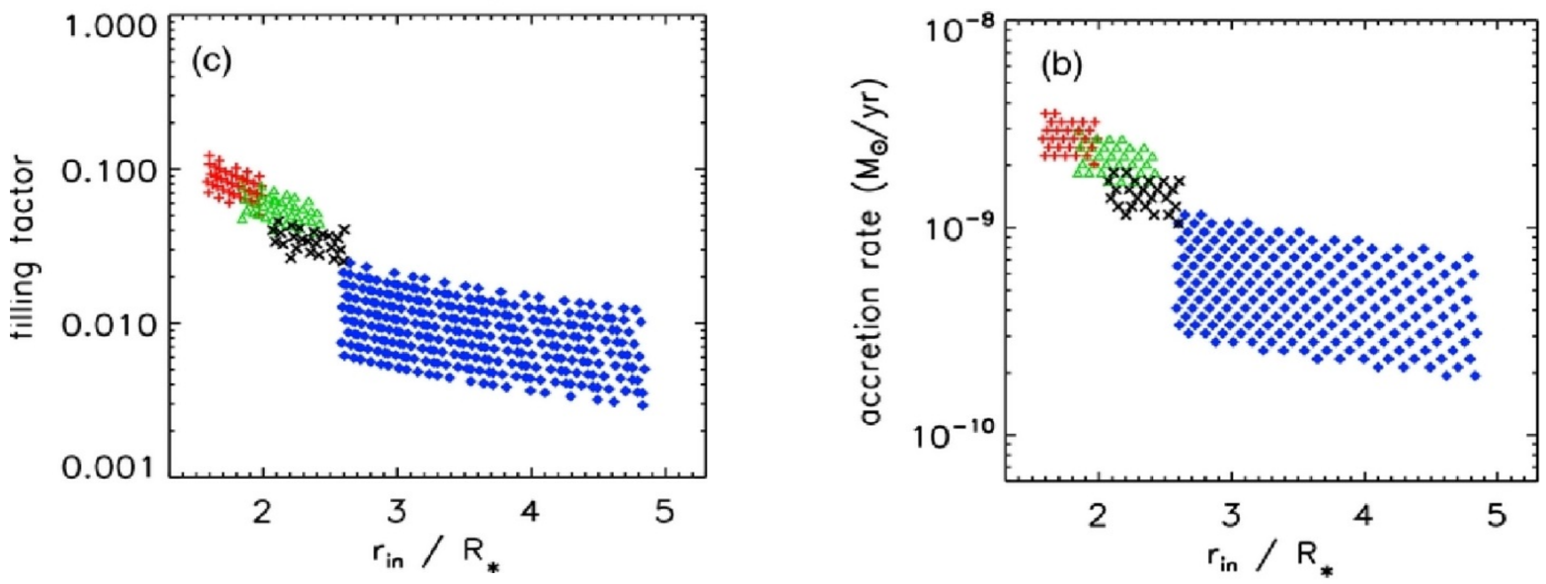
Ne → Ne/4 = preshock density

N_H → Accretion length

Cranmer 2008

Ne IX diagnostics constrain model

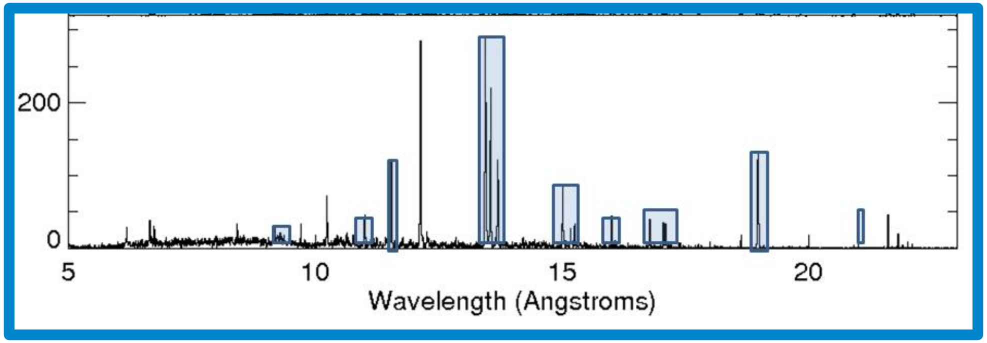
Te, Ne, N_H constrain M_dot, B, and f



Pointing: 1, 2, 3, average

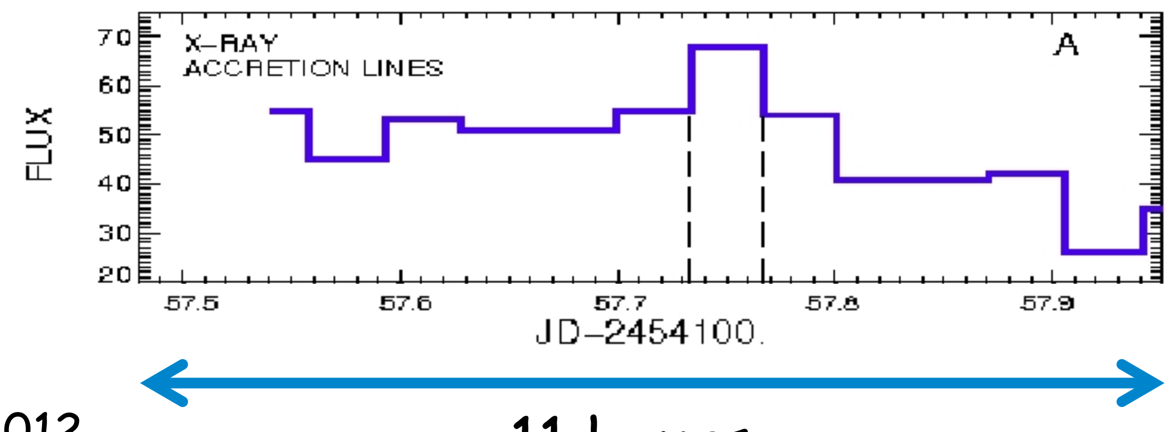
Brickhouse+ 2012

Accretion variability



X-Ray accretion lines:
N VII, O VIII, Ne IX,
Fe XVII, Mg XI

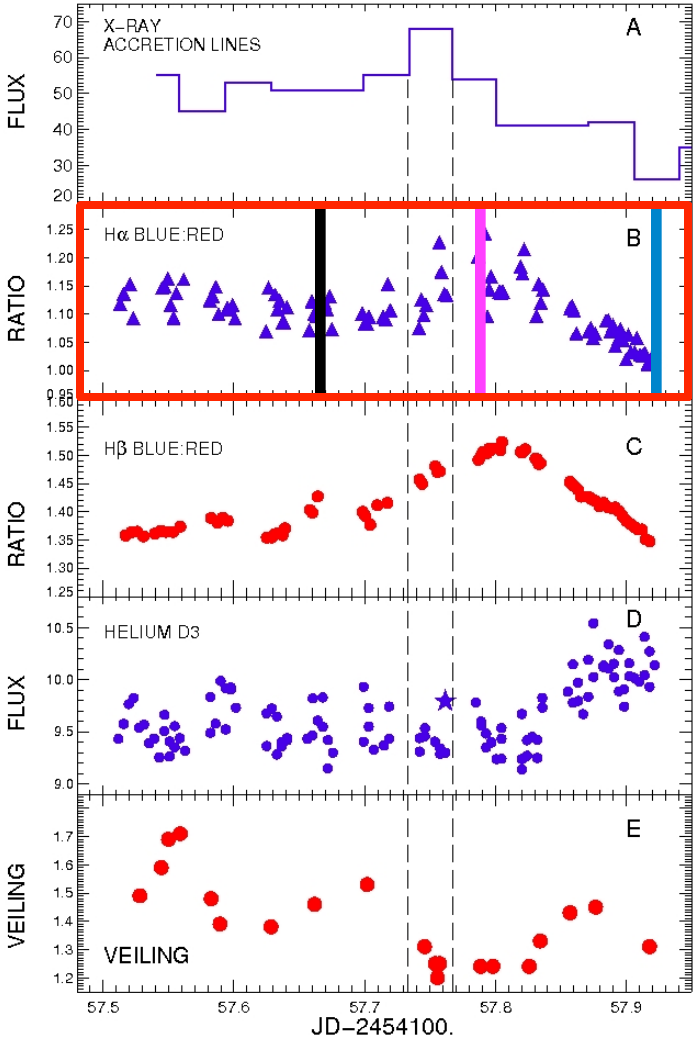
Accretion event

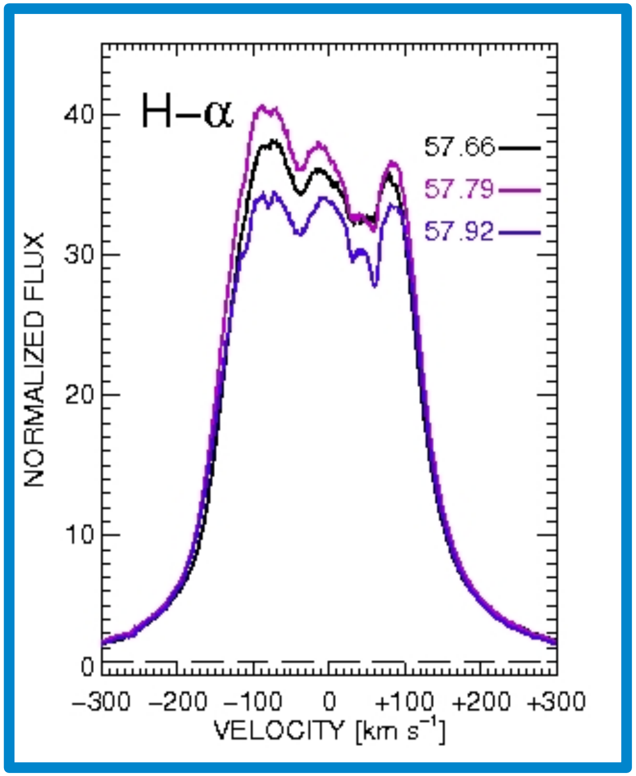


11 hours

Dupree+ 2012

H-alpha asymmetry change 9 minutes later ⟹ increased inflow for 1.5 hours





Optical spectra: Magellan/MIKE

Dupree+ 2012

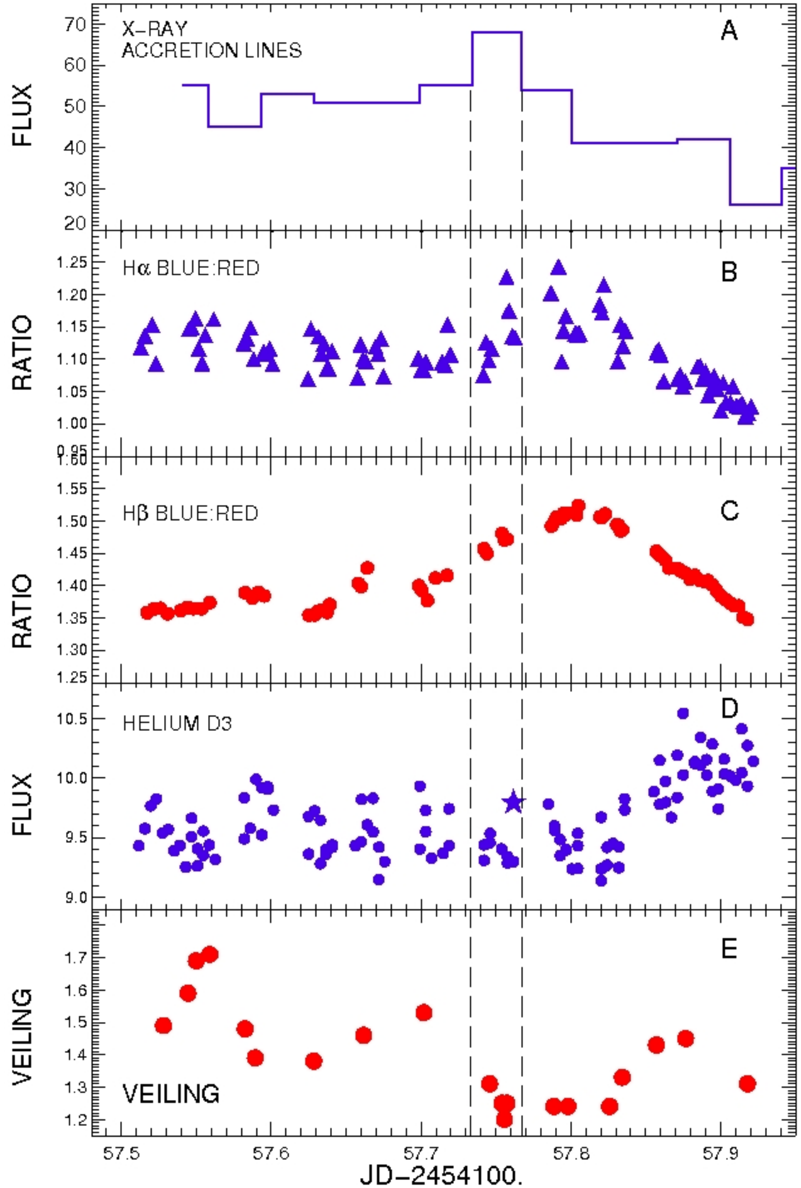
Accretion X-rays

H-alpha

H-beta

He D3

Optical Continuum Veiling



Delay after X-ray event

→ 9 minutes

→ 9+ minutes

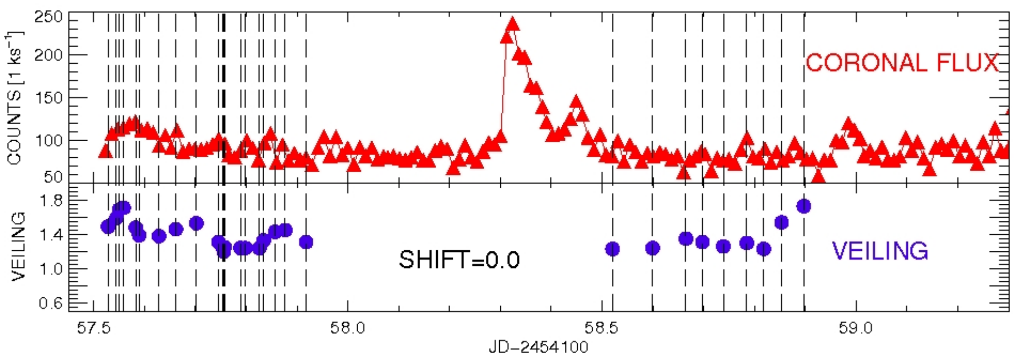
→ 30 minutes Broad component

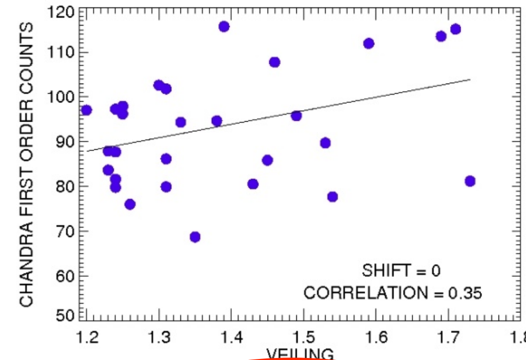
→ ~2 hours

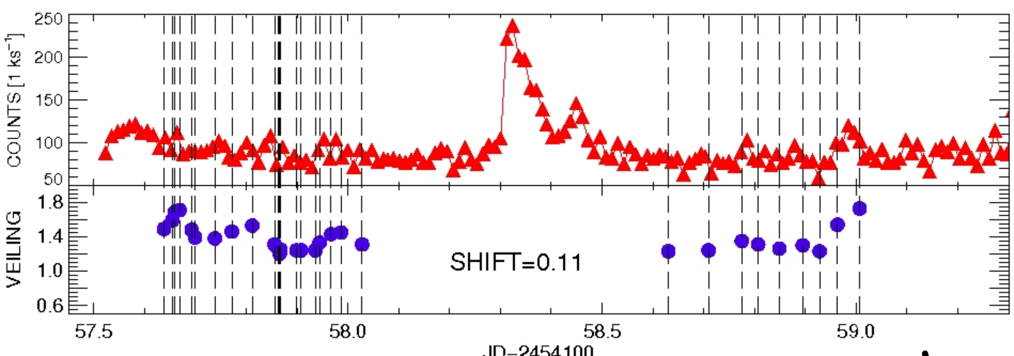
Suggests optical lines formed in postshock region

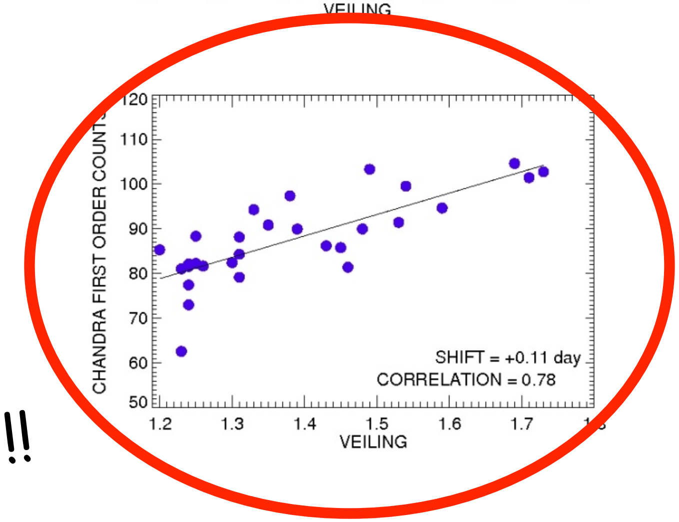
Dupree+ 2012

Coronal enhancements follow increase in veiling





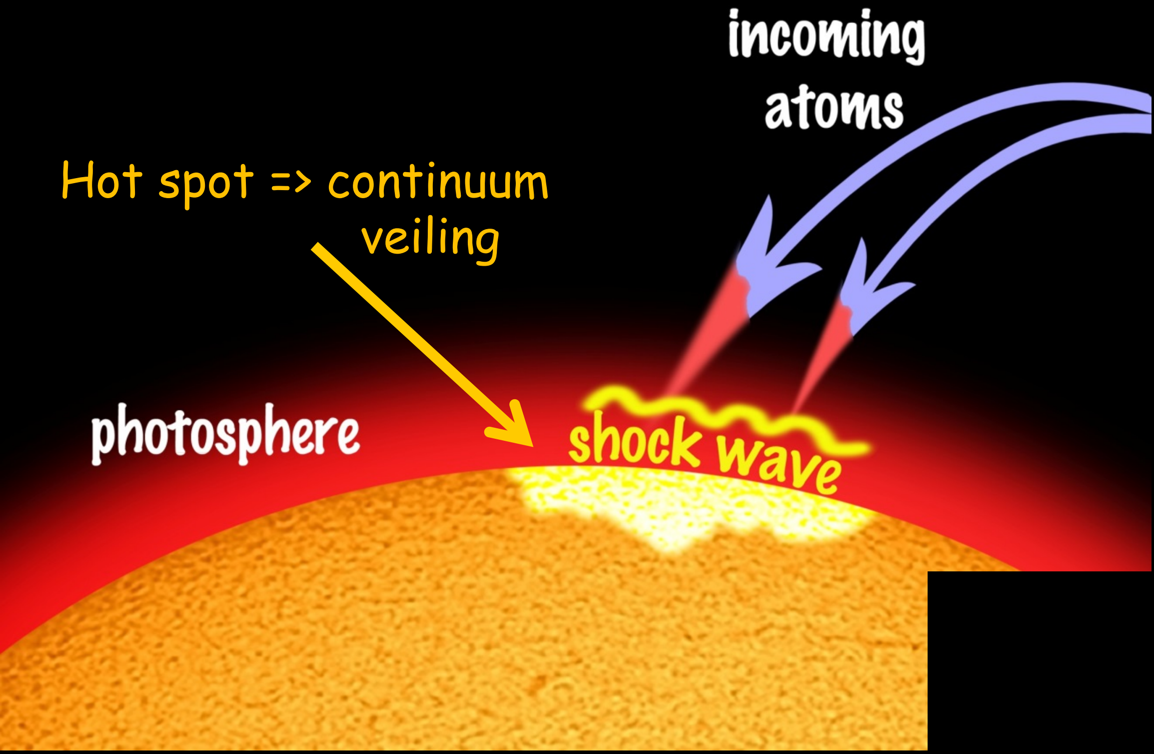


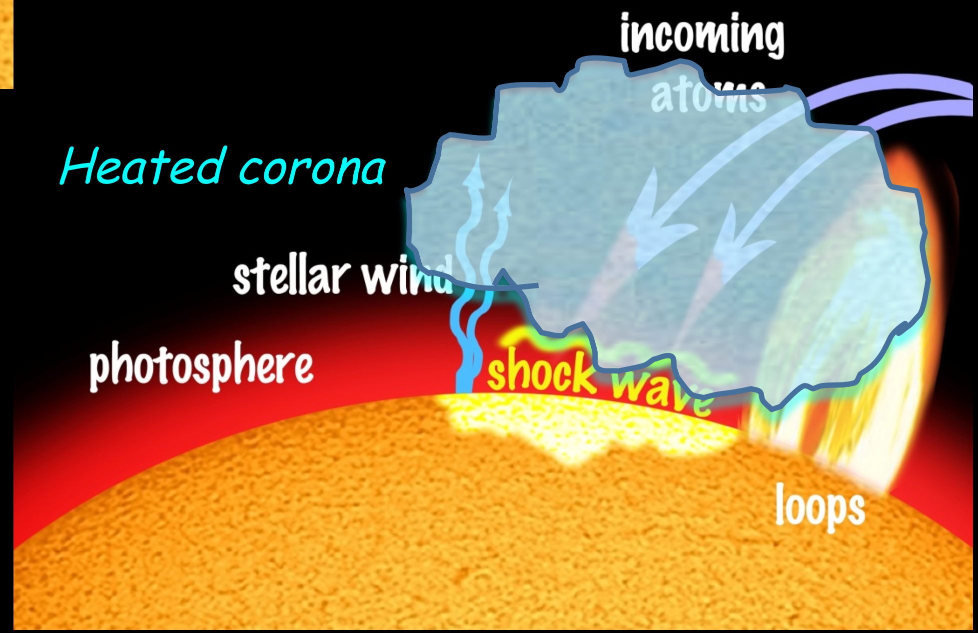


Best correlation: 2.5 hours !!

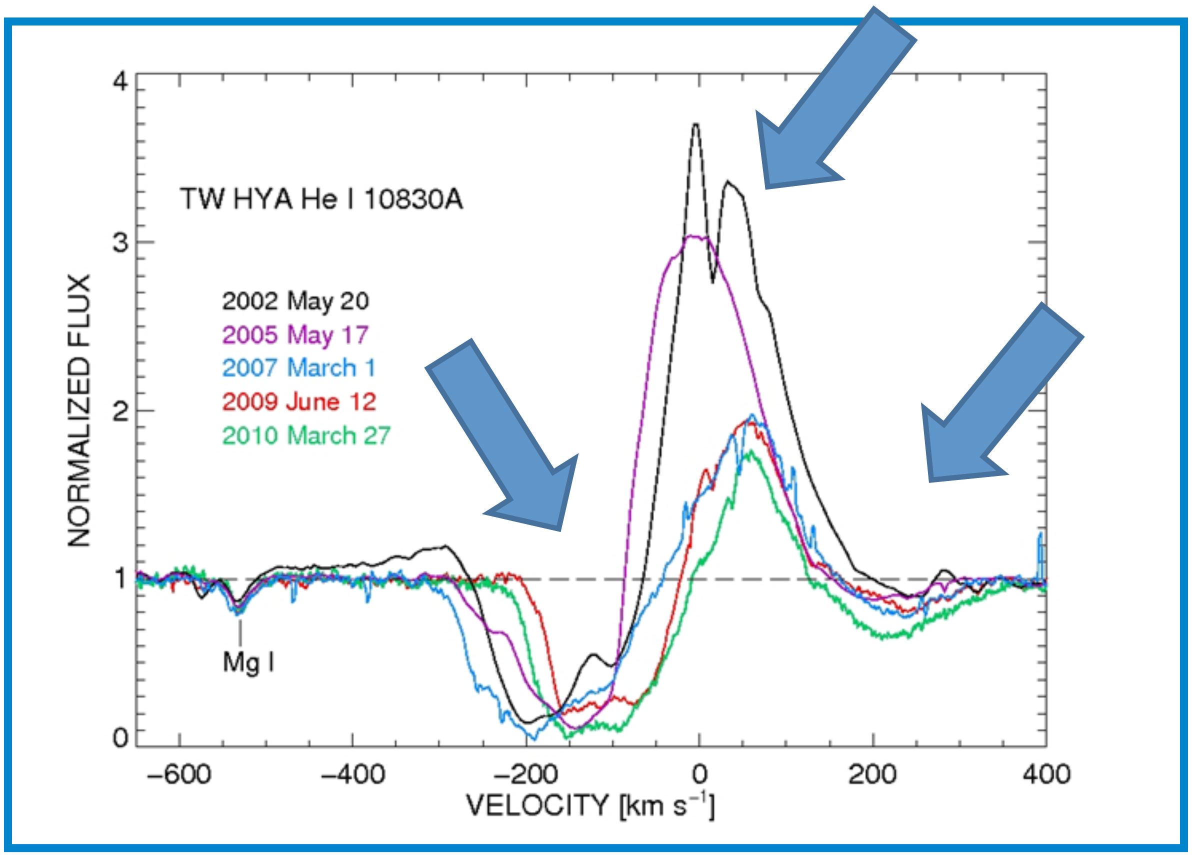
Suggests corona is heated by accretion

Dupree+ 2012


incoming
atoms
Hot spot => continuum
veiling
photosphere
shock wave


incoming
Heated corona
photosphere
loops

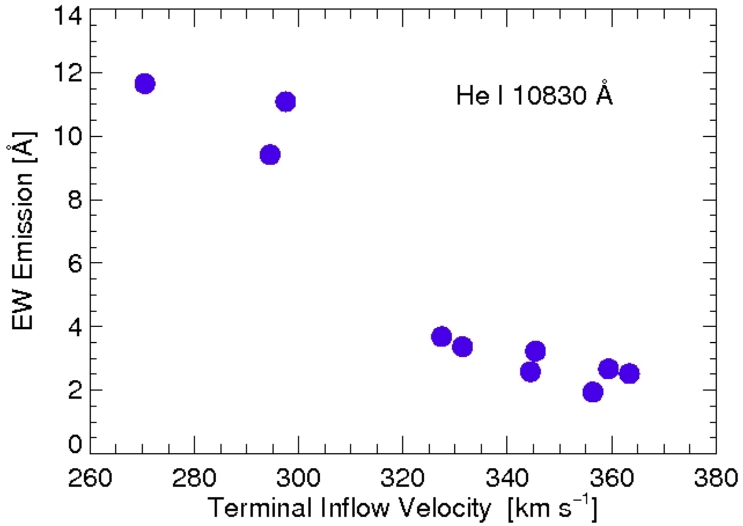
He I validates model....
with time-domain spectroscopy

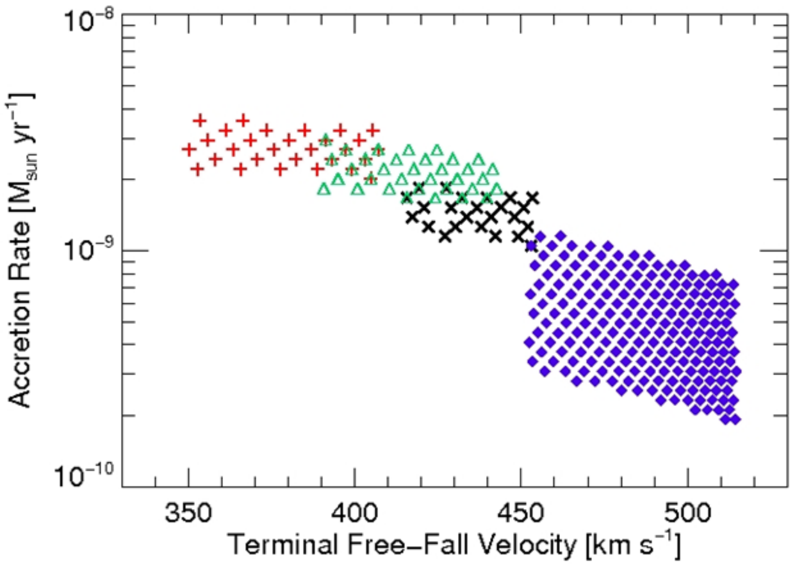


Dupree+ 2014

Observations

Model





Helium emission ↑ as inflow velocity ↑

M_dot ↑ as free-fall velocity ↓

Dupree+ 2014

CONCLUSIONS

- Combination of X-ray spectroscopy + optical/ near-IR spectra enable discoveries and understanding…(multi-wavelength/time domain)
- Broad emission lines (optical, UV, X-ray) arise in turbulent post-shock region (not 'accretion funnels') and are wind-scattered.
- These observations require a paradigm shift for accretion in young stars.
- Time delays suggest corona heated by accretion processes; possibly drive wind too.

What next?

- Address structure of post-shock cooling region
- Evaluate wind and mass loss
- Study accreting star at another orientation
- Increase time-domain observations....