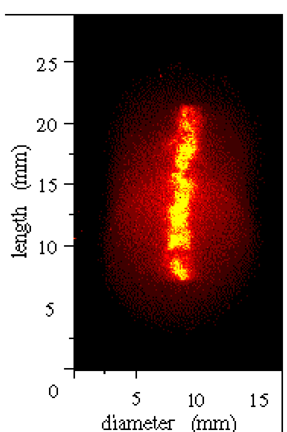
X-ray Spectroscopy
of Laboratory and Astrophysical Plasmas

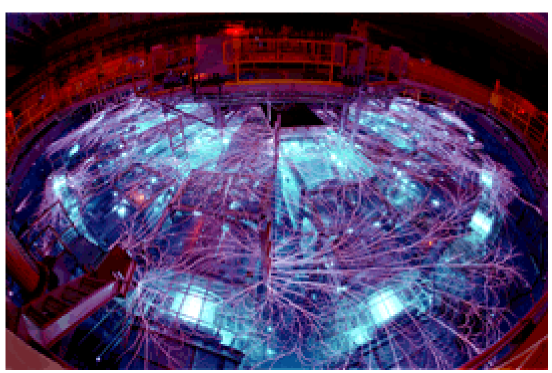
David Cohen

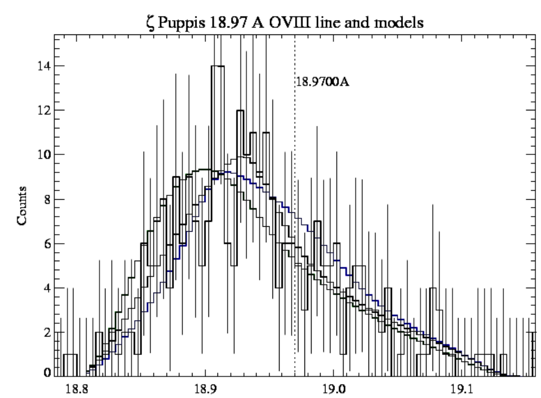
Department of Physics and Astronomy

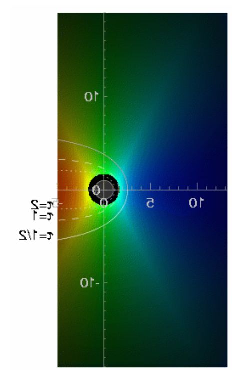
Swarthmore College

http://astro.swarthmore.edu/~cohen









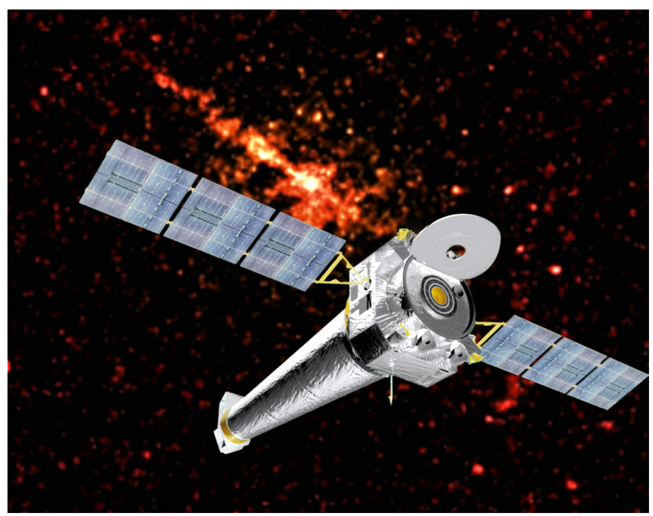
Broad Questions I'm Trying To Answer

1. How do hot stars produce X-rays?

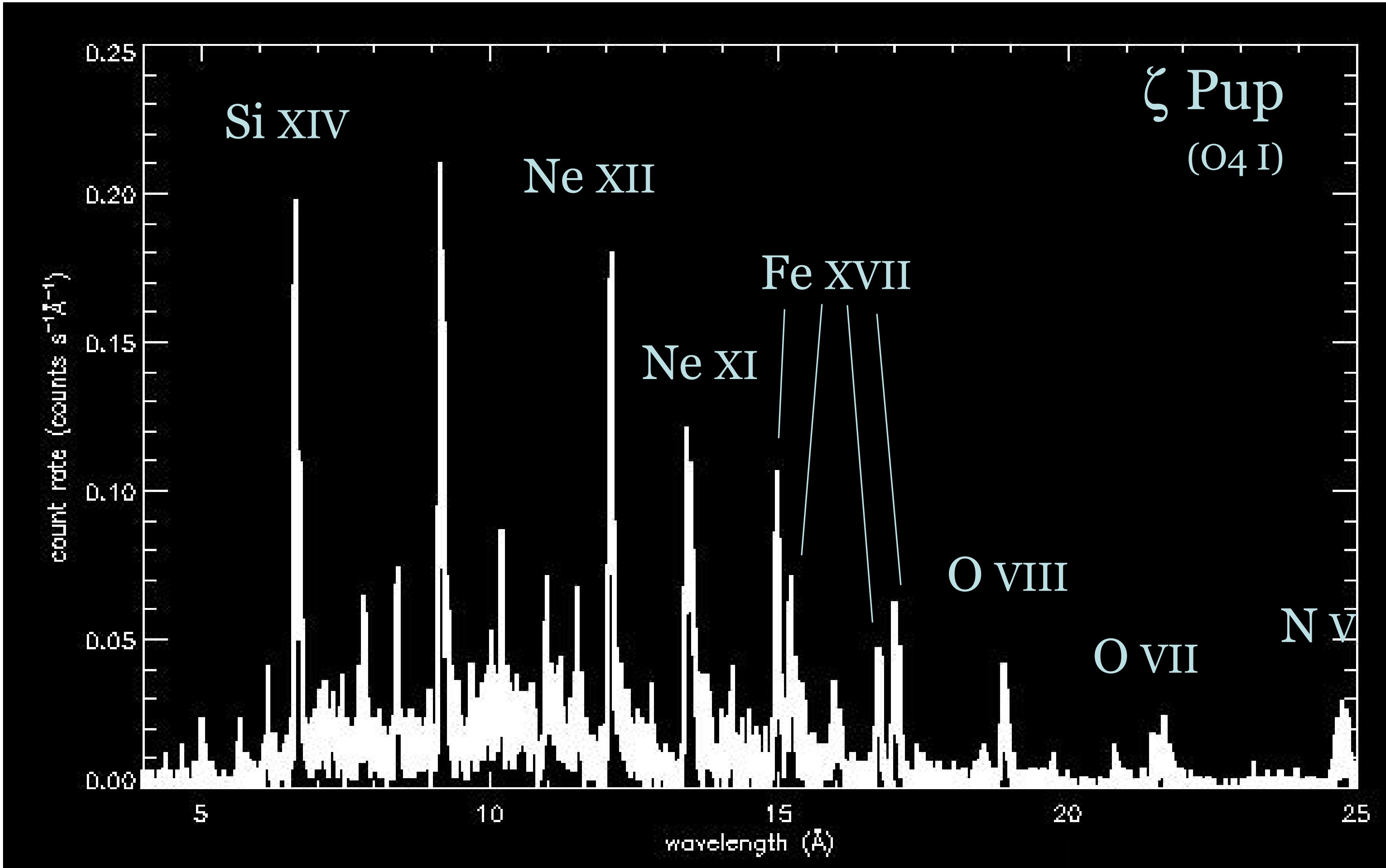
2. How does material near compact objects respond to accretion-driven X-ray emission?

With the launch of *Chandra* and *XMM* in 1999 high resolution spectroscopy is possible for the first time.

$\Rightarrow$ Quantitative diagnostics of plasma conditions



Topic #1: Hot Star X-rays - *Chandra* HETGS spectrum of the O star ζ Pup

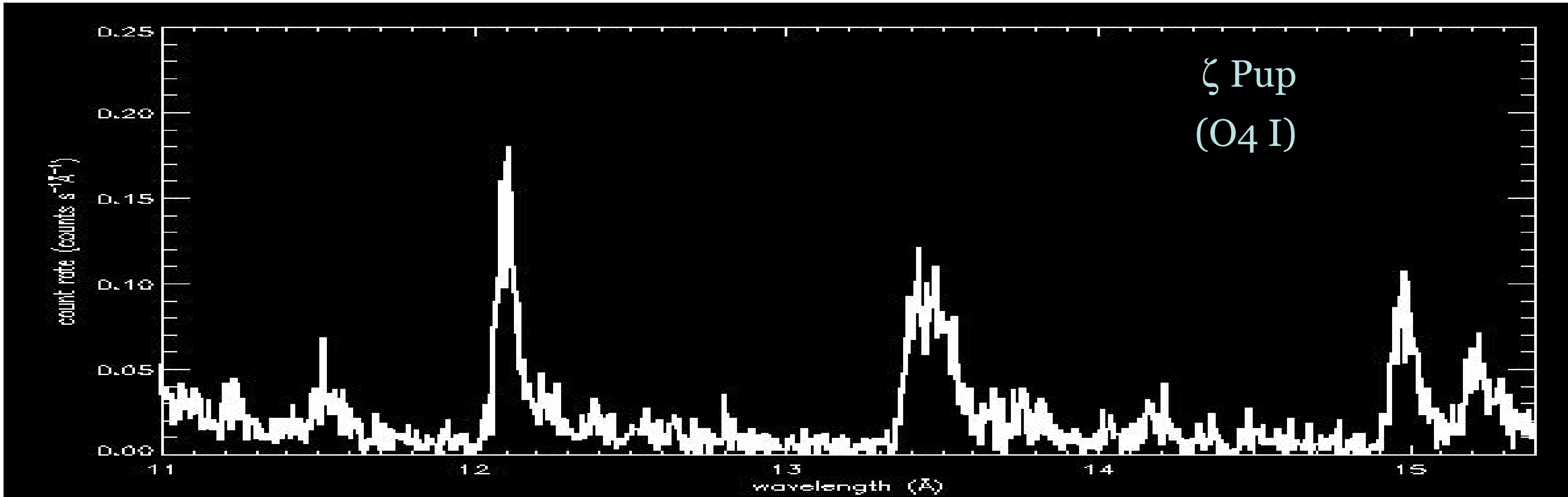


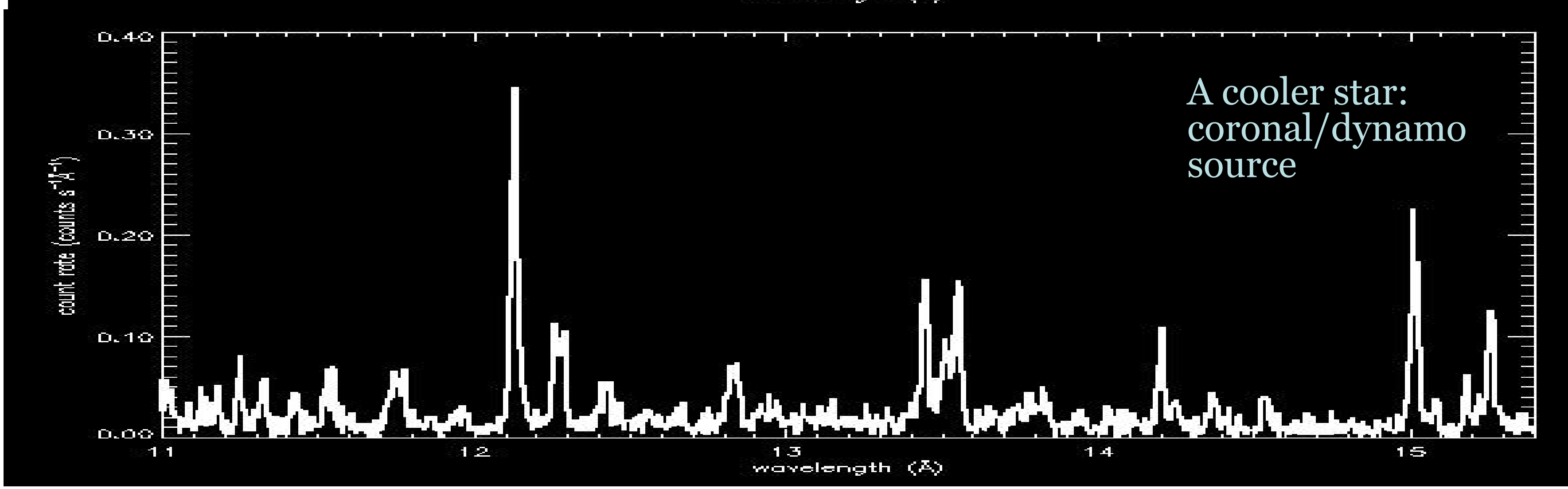
10 Å

20 Å

Focusing in on a characteristic portion of the spectrum

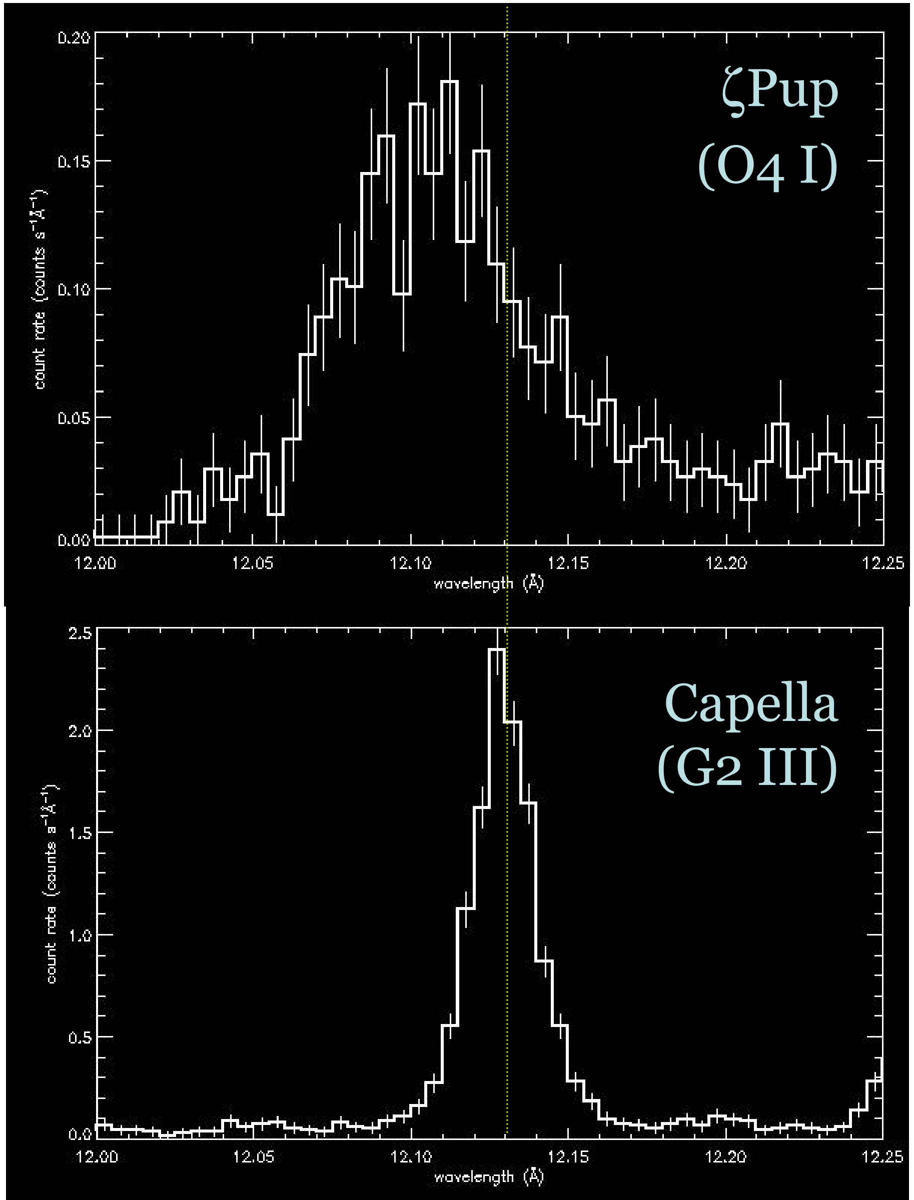
12 Å 15 Å





Ne X Ne IX Fe XVII

Differences in the line shapes become apparent when we look at a single line (here Ne X, Lyα)

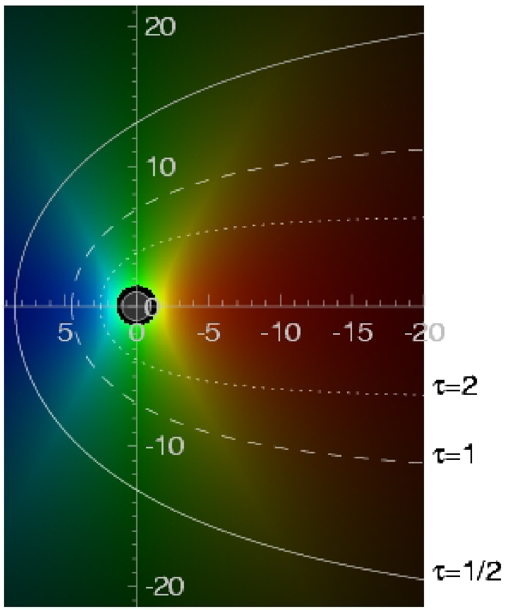


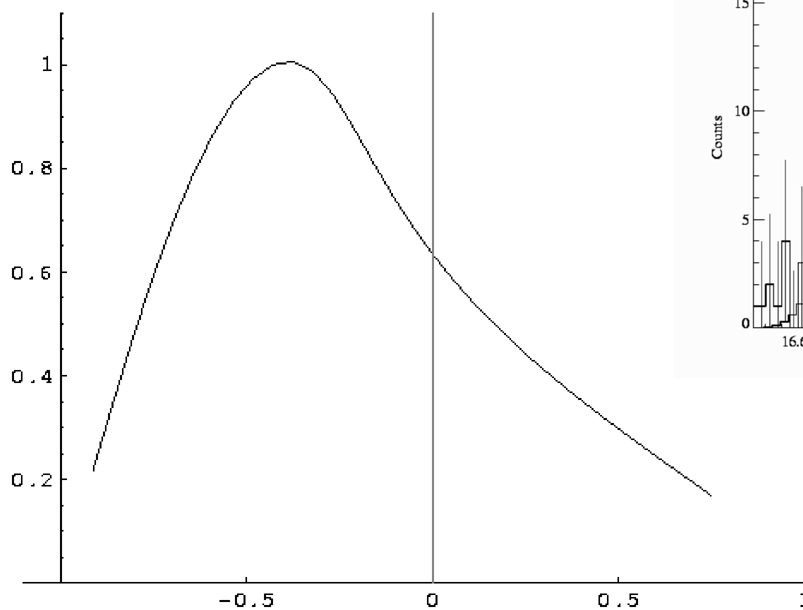
The O star's lines are *Doppler broadened*

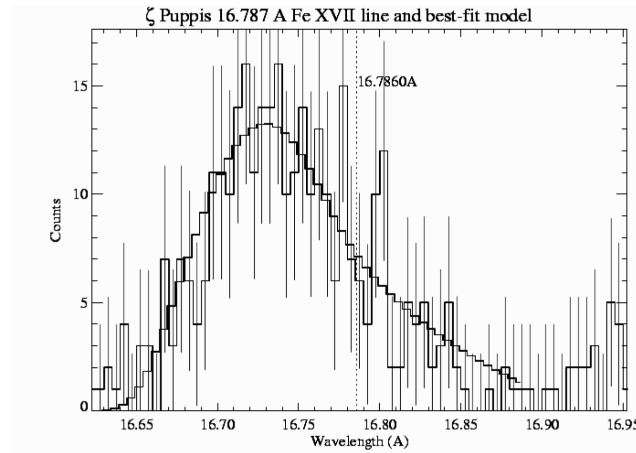
⇒ Unlike in cool stars, x-ray emission in hot stars has something to do with these stars' *stellar winds*

The shapes of these broadened lines tells us about the kinematics and spatial distribution of the x-ray emitting plasma

My students are fitting these x-ray line profiles with wind-shock models

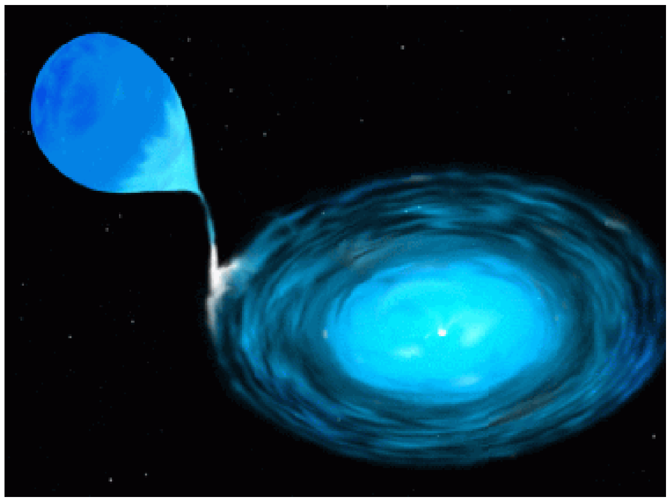


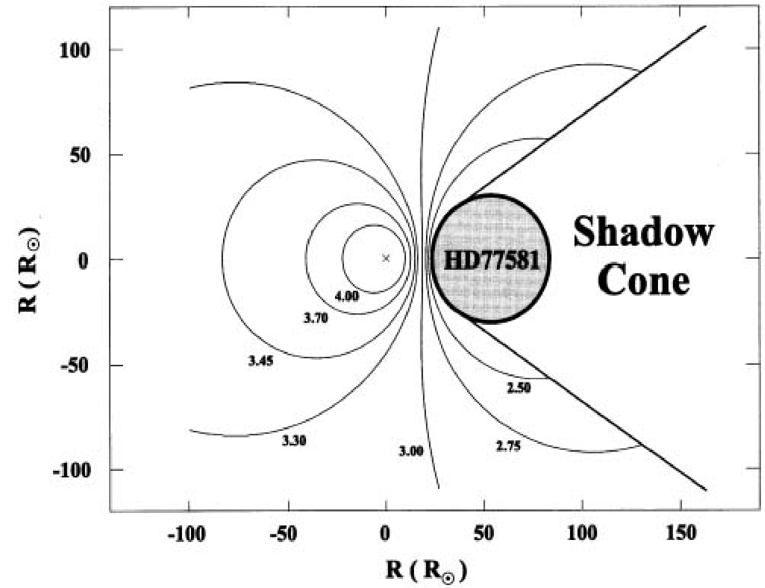




fit to data

The kinematics of the hot, wind-shocked plasma and the absorption by the cooler portion of the stellar wind reproduces the blueshifted, skewed line profiles.

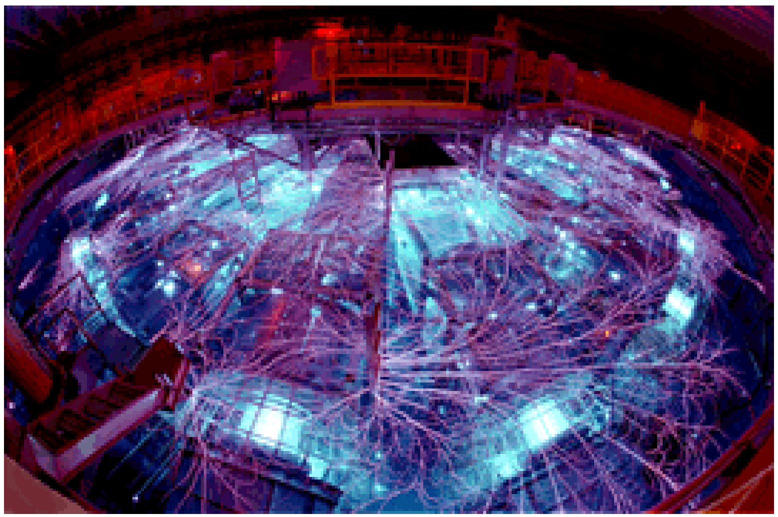




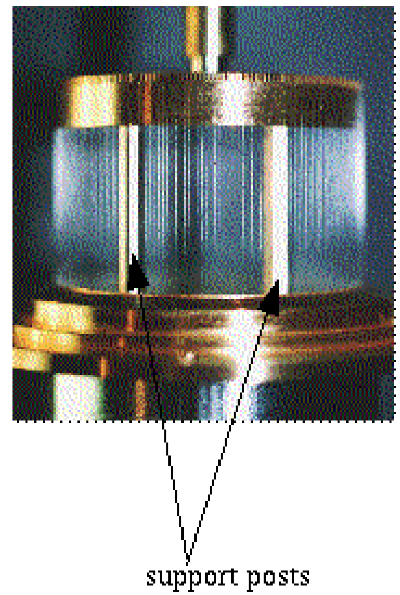
Topic #2: X-ray binaries and AGN have x-ray spectra that are characterized by *photoionization* (rather than by collisional processes, as is the case with stellar coronae and supernovae).

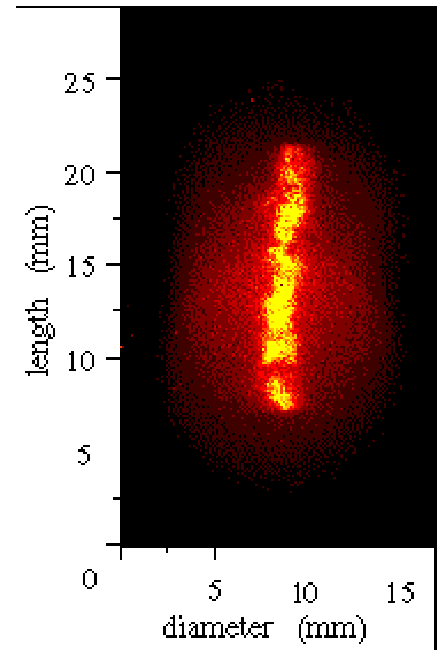
X-ray spectral modeling of photoionized plasmas needs to be *benchmarked by laboratory experiments*.

The **Z-Machine at Sandia** - world's most powerful x-ray source (2 MJ in 10 ns $\rightarrow$ 200 TW of X-ray power)



Capacitor bank discharges during a 'shot'.

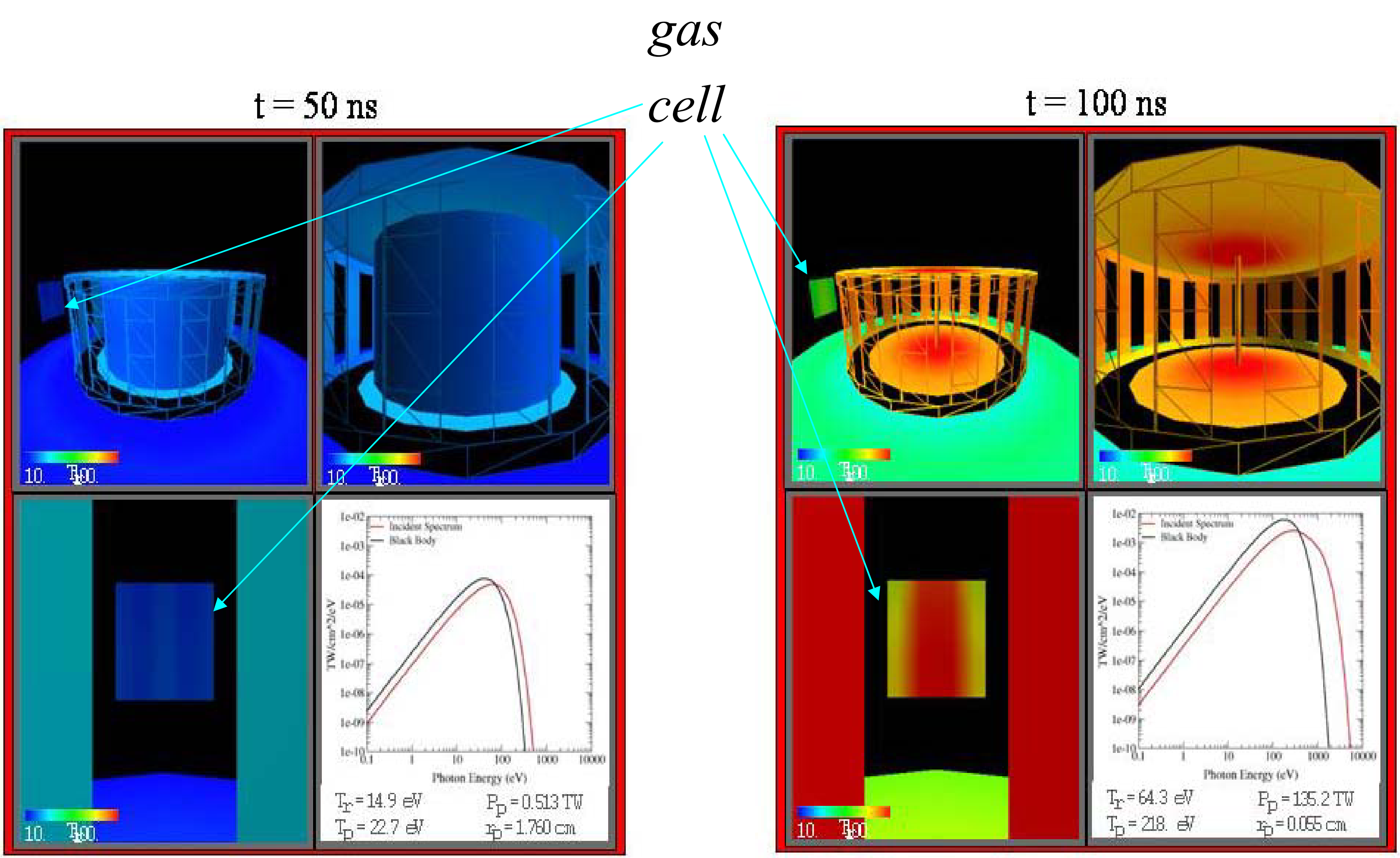




Current implodes a cylindrical wire array, producing x-rays.

We field a small container of gas (O, Ne, Ar, Fe...) near the pinch, exposing it to x-rays, and create an x-ray photoionized nebula, which we monitor spectroscopically.

Students of mine run simulations of the Z-pinch implosion and the irradiance of the gas cell. We also do hydro and spectral modeling of the gas.



We have obtained absorption spectra (to monitor the ionization balance in the gas); Soon we will also obtain emission spectra, which will be compared to *Chandra* spectra of XRBs and AGNs.

Ne IX between 10 Å and 11.5 Å

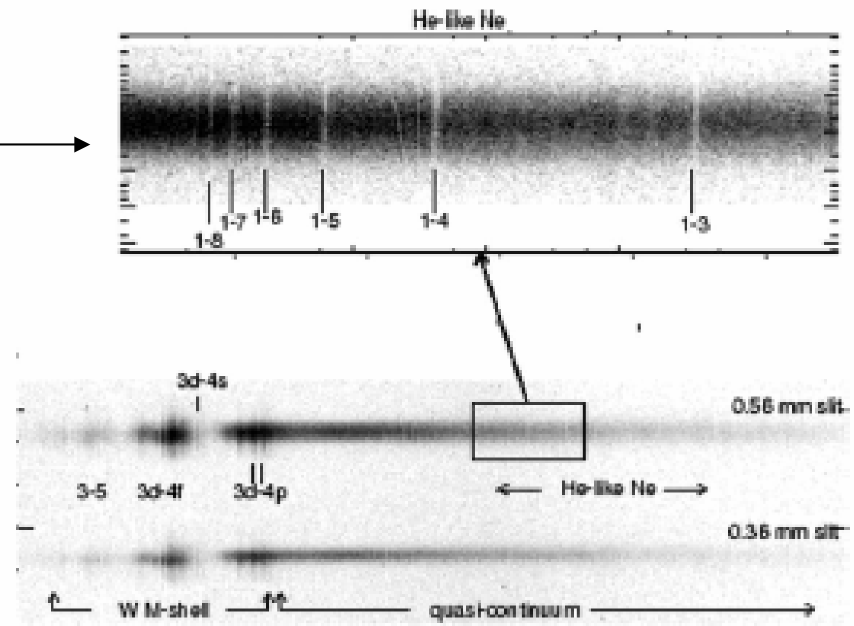


Fig. 4. Radially resolved absorption spectrum from Z experiment #543. Two slits are used to produce the spatially resolved spectra. The wavelength range covers approximately 4–15 Å. The inset is an enlarged view of the 10–11.5 Å region.

A section of our raw data (above). Note the very high principle quantum number lines of He-like neon.

There's a lot happening in astrophysical x-ray spectroscopy these days

Numerical modeling is required to get the most out of this new, high quality data.

Connections between astrophysics and laboratory physics are useful.