Cool star studies with IXO

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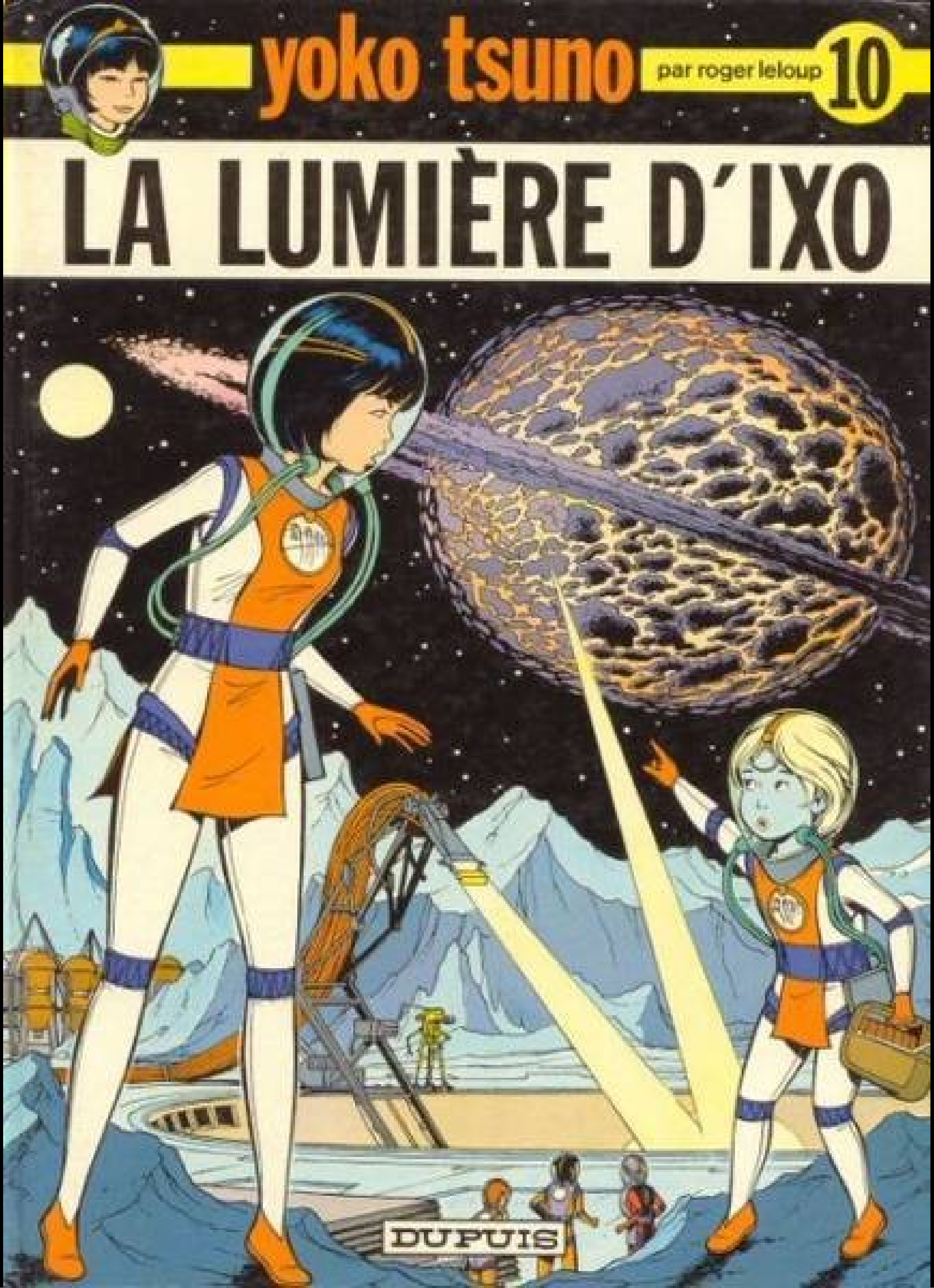
ESA IXO Conference, Munich 17-19 September 2008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LA LUMIÈRE D'IXO
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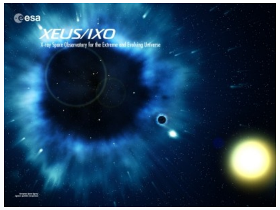
Introduction

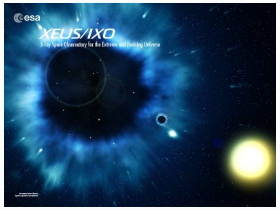


Beate's talk focused on imaging spectroscopy. This talk will focus on high-resolution spectroscopy topics with IXO using the NFI TES and the XGS

Why should we care about stellar science with IXO?

Stars are nearby cosmic plasmas ideal to study MHD physics, the importance of magnetic fields, winds, and X-ray photons on the surrounding environment (chemical enrichment, energy input; habitability of planets; irradiation of accretion disks)

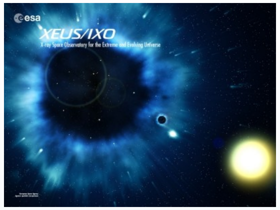
XMM-Newton/Chandra



The high-resolution grating spectra on-board XMM-Newton and Chandra have allowed excellent, new science to be done on stars:

- Abundance studies (FIP and inverse FIP effect)
- Average density & opacity measurements
- Eclipse & Doppler mapping of corona (limited by spectral resolution & resolution)
- Density measurements in a handful of young stars (excitement! Accretion may produce sufficient X-rays)
- Detection of Fe $K\alpha$ at 6.4 keV: information on source size, height, mechanism (but very limited!)
- Density variations during flares (rare! Low S/N)
- Etc...

Science with IXO

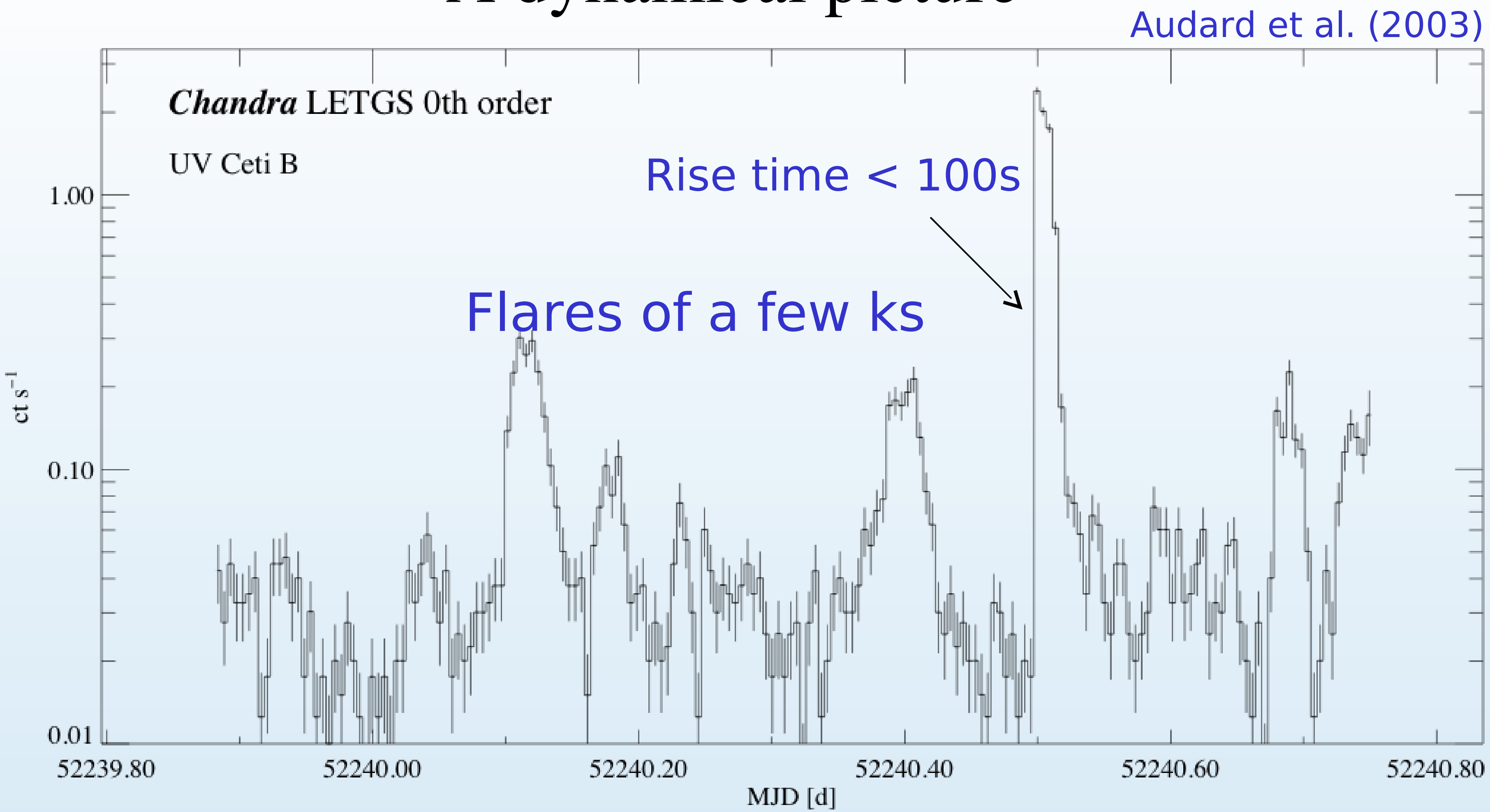


The large effective area of IXO will allow us to study, e.g.,

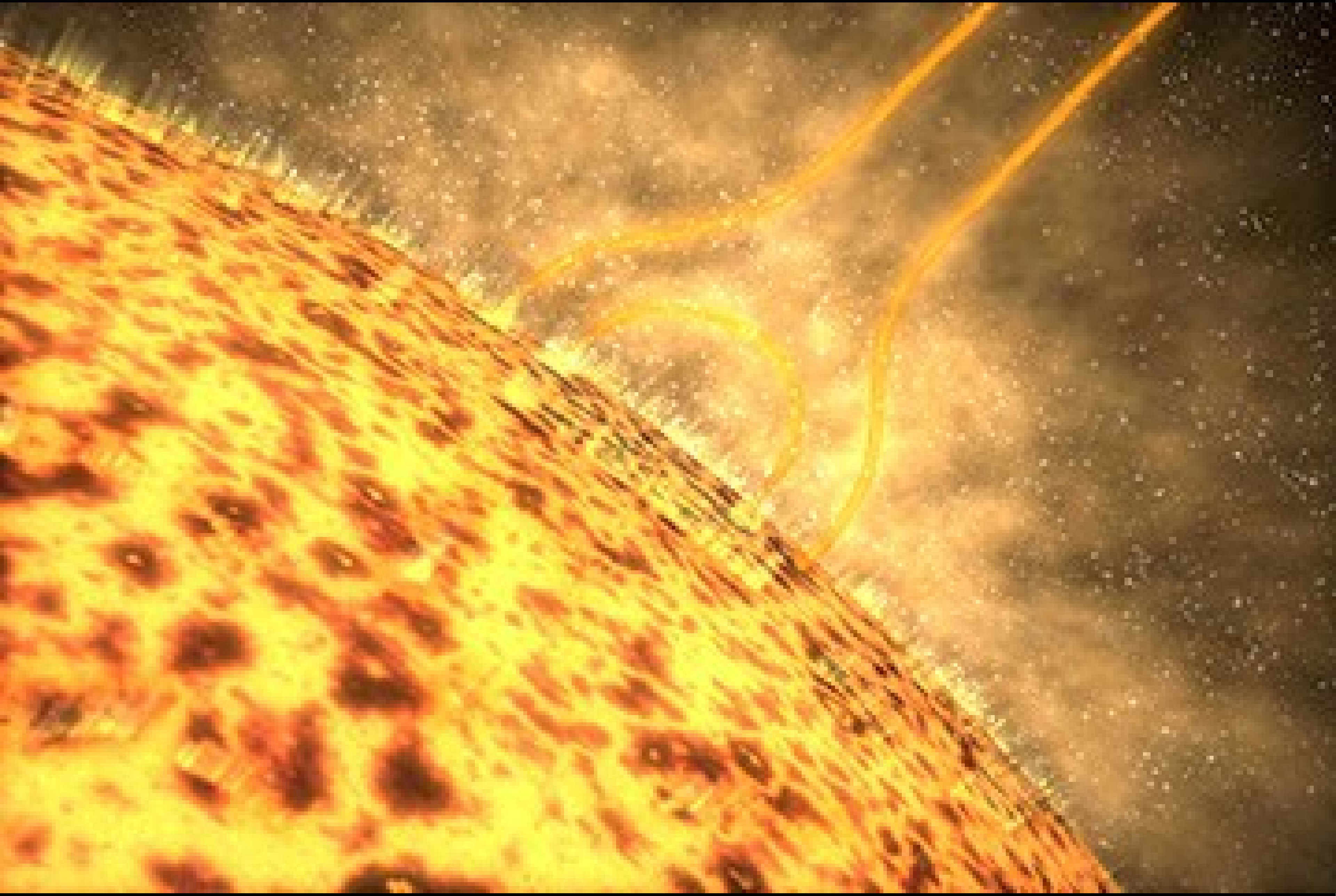
3)Dynamical MHD processes at the kilosecond time scale

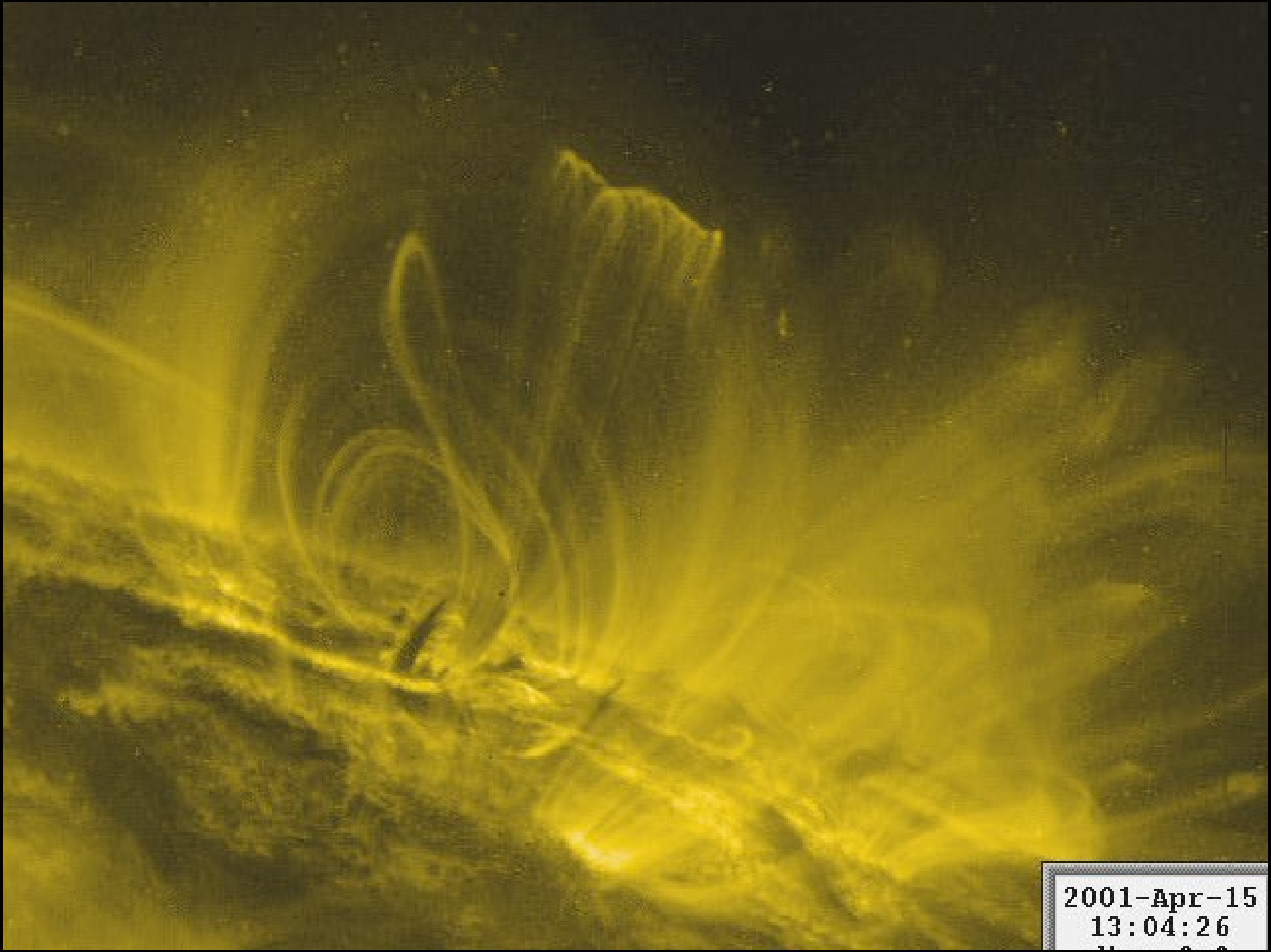
5)Go deeper and probe a much larger sample of stars in our Galaxy

A dynamical picture



- Chromospheric evaporation can lead to mass motions into the corona with speeds of a few 100 km/s
- Non-equilibrium conditions in the fast rise phase

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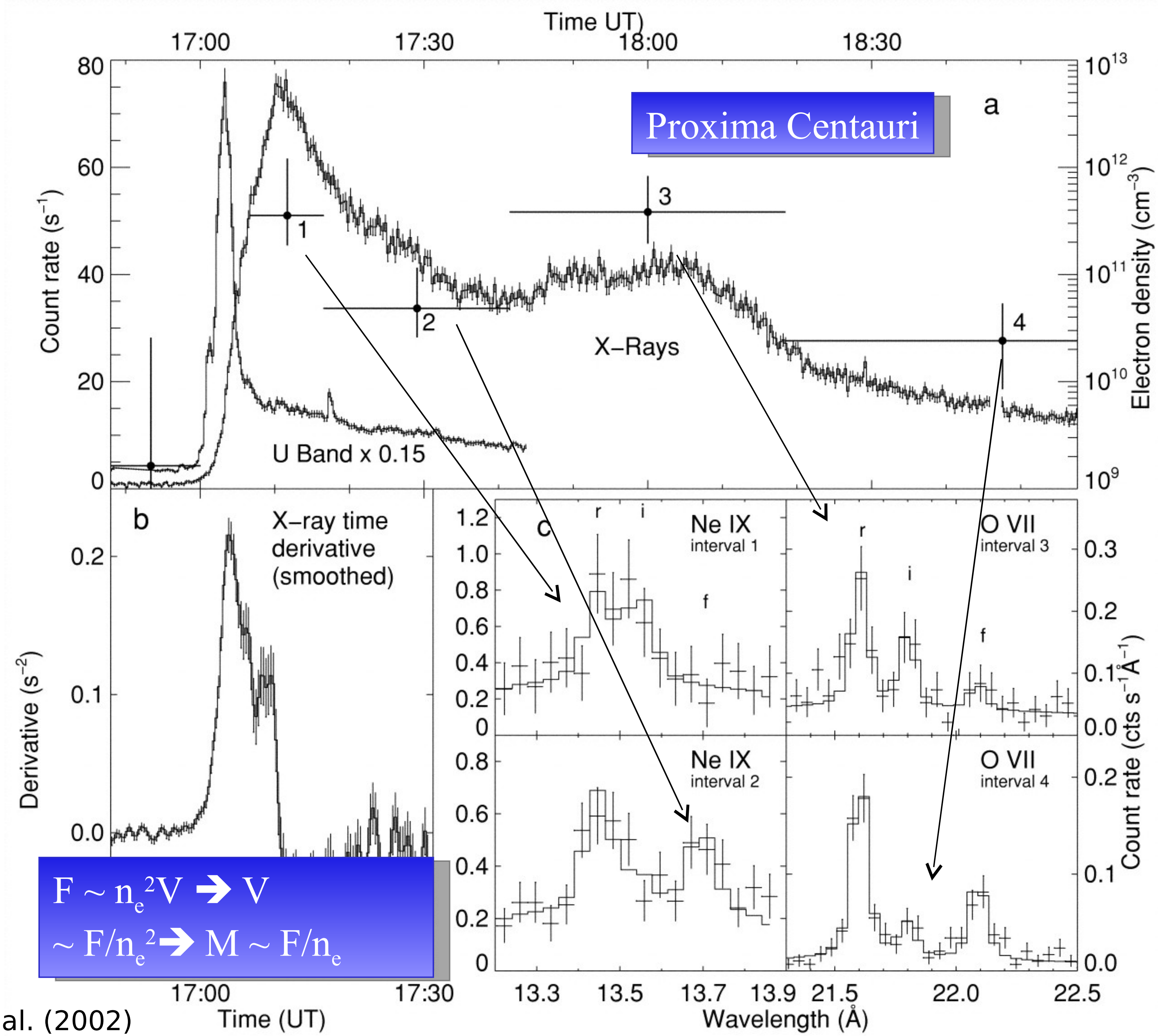
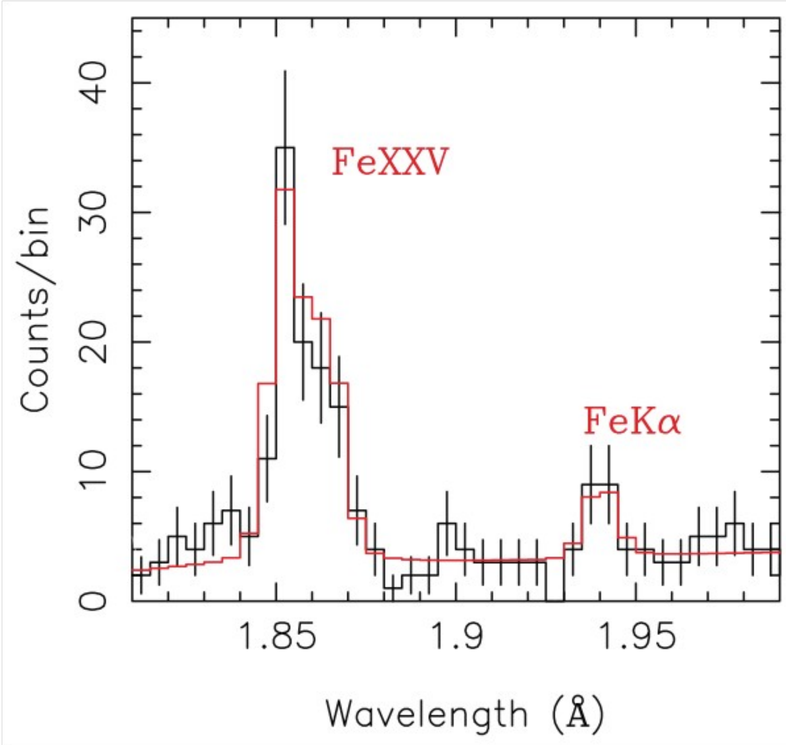
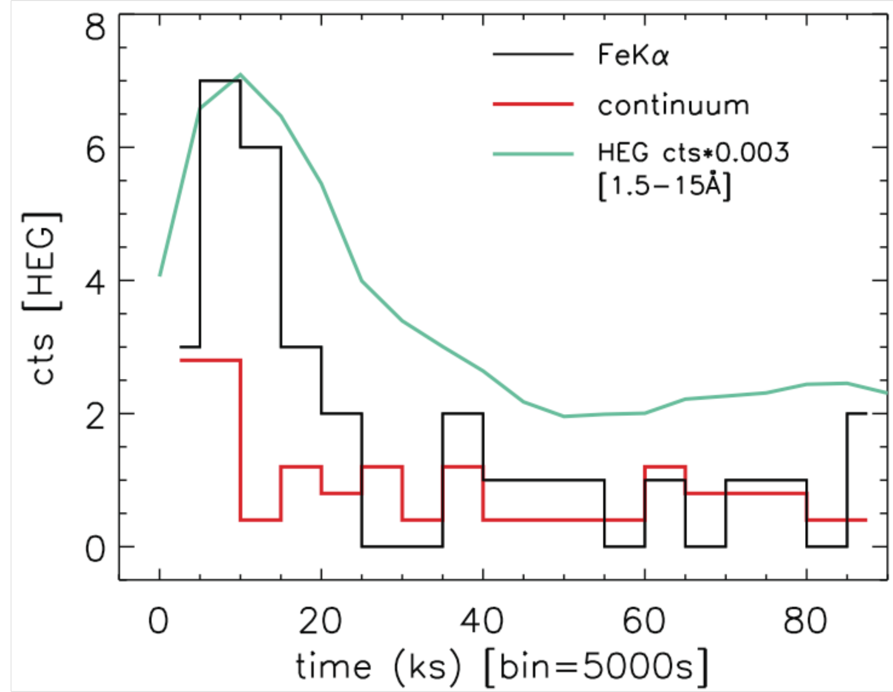
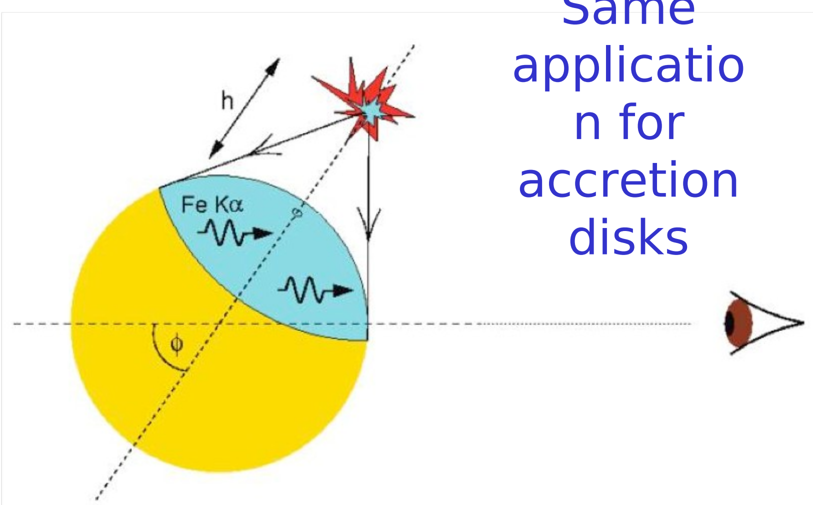


$F \sim n_e^2 V \rightarrow V \sim F/n_e^2 \rightarrow M \sim F/n_e$

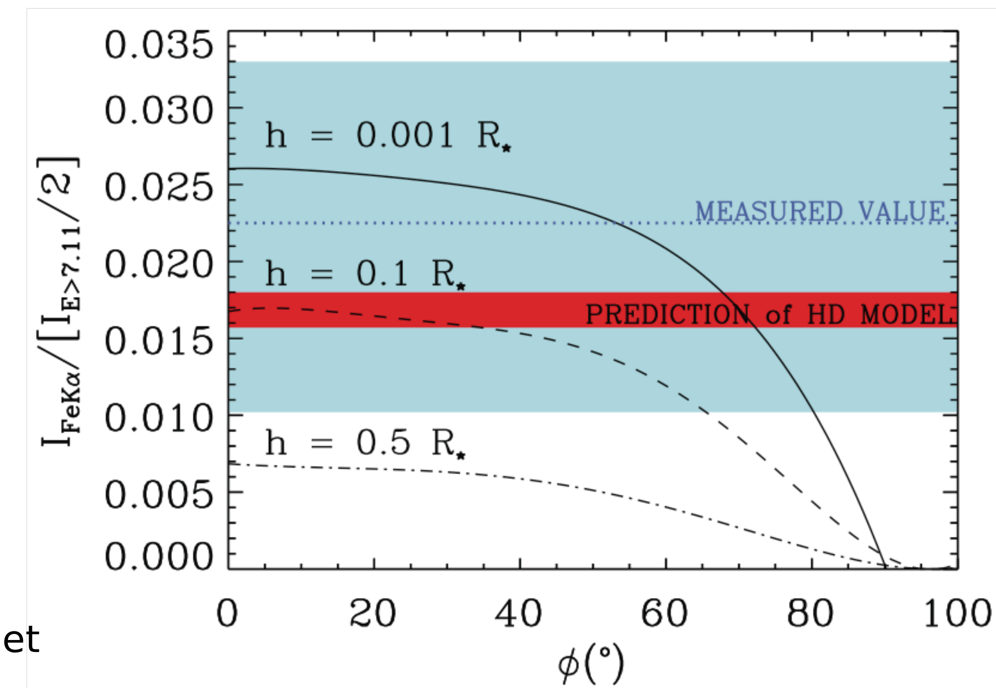
Güdel et al. (2002)



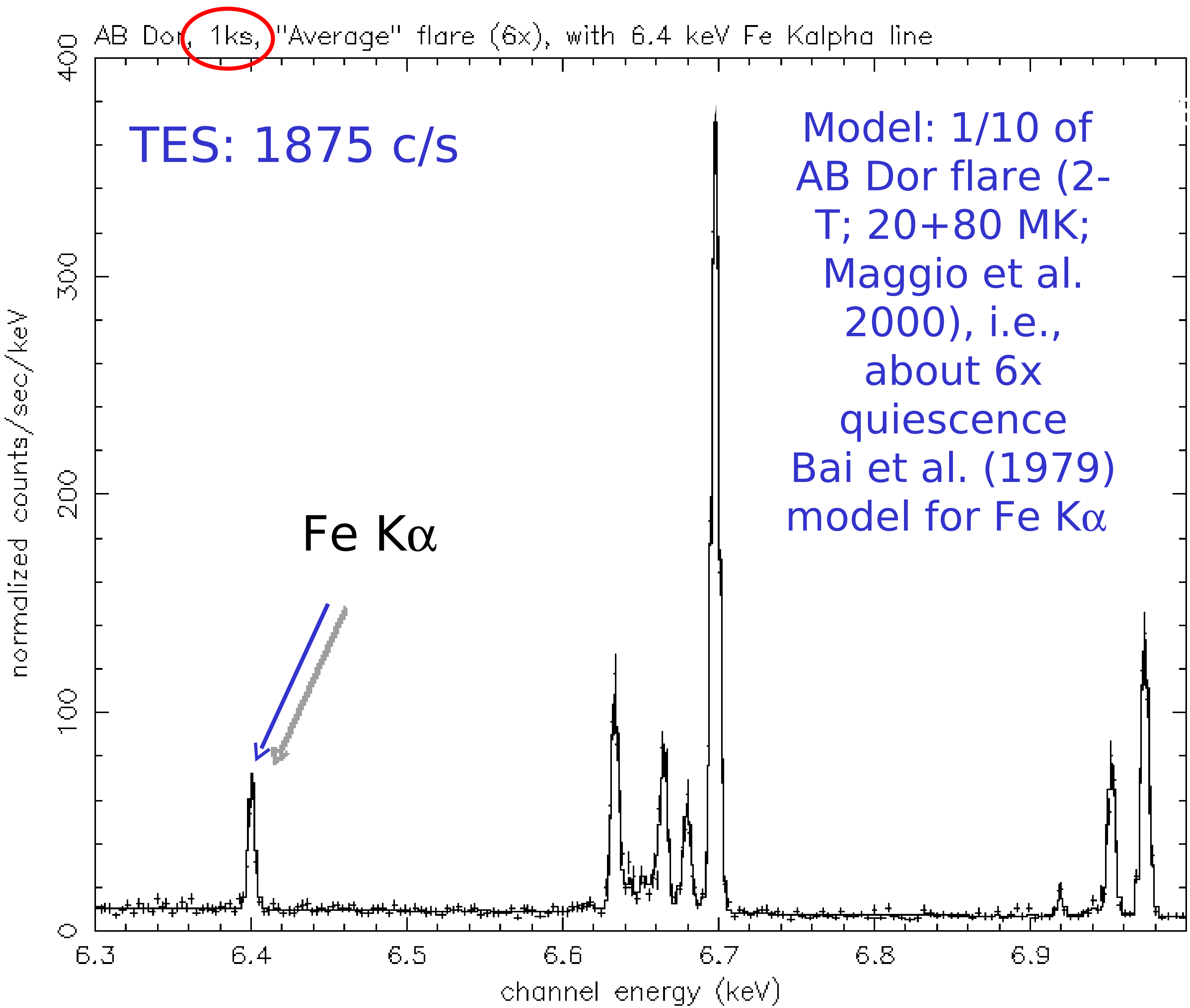


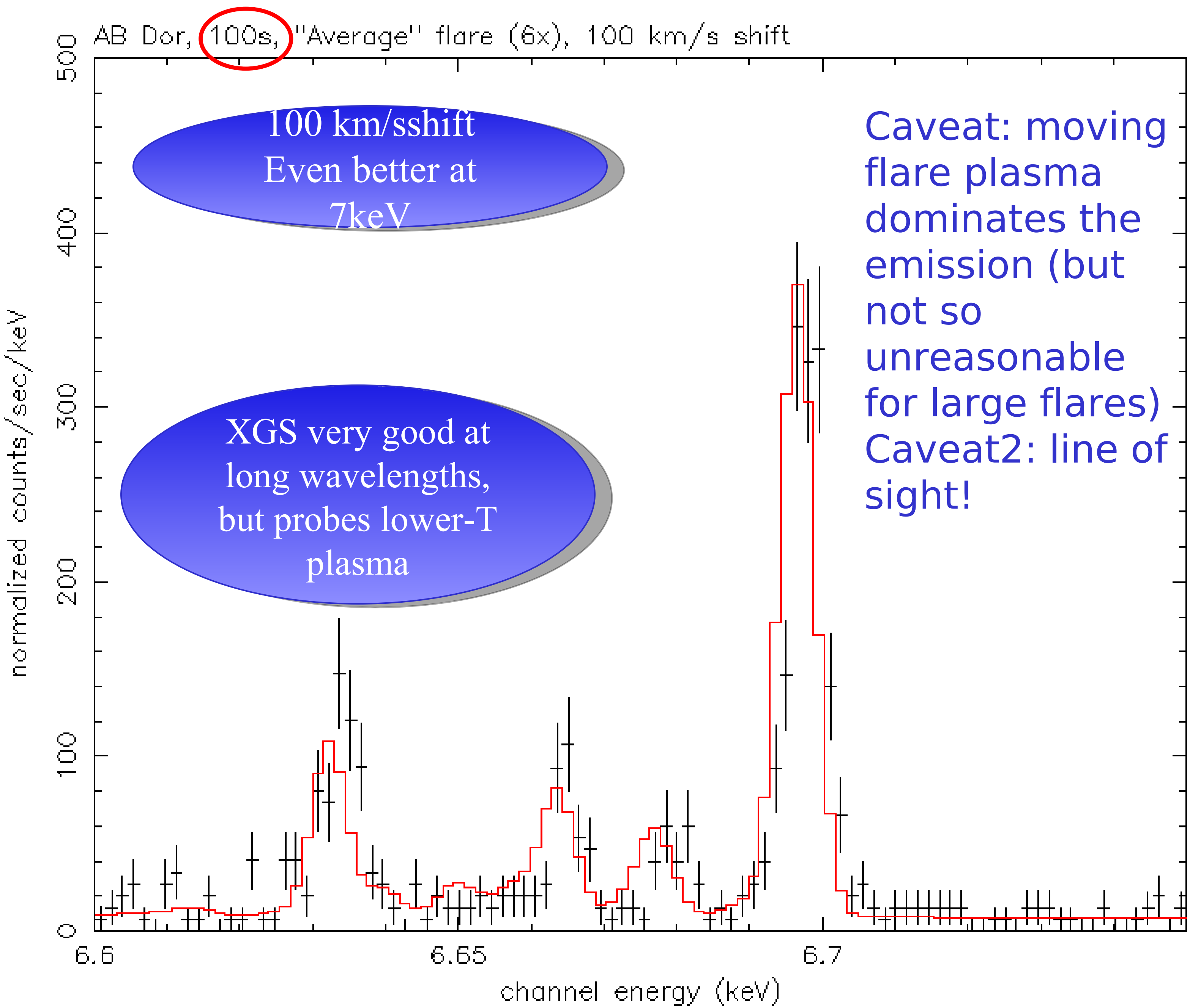


Same application for accretion disks

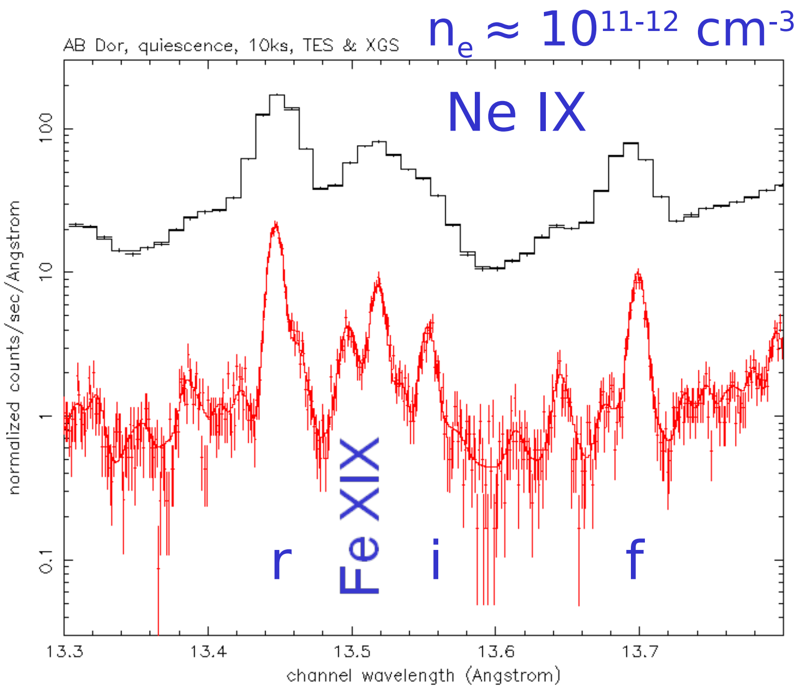


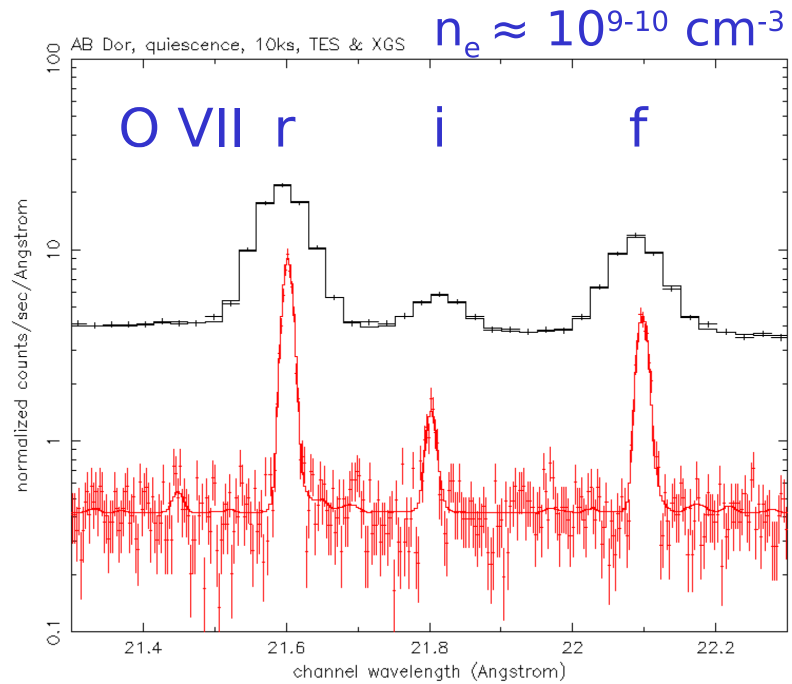
Testa et al. (2008). See also Osten et al. (2007), Giardino et al. (2007),

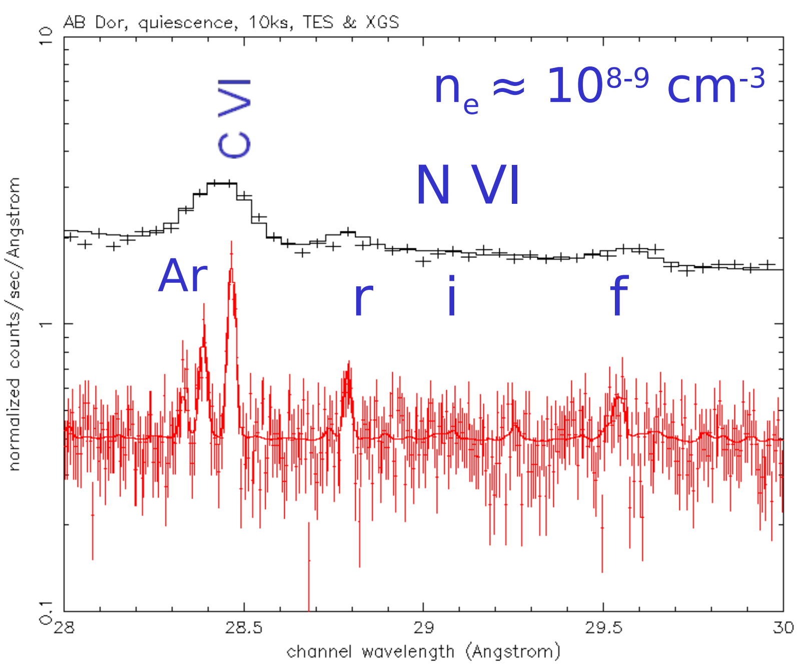

AB Dor, 1ks, "Average" flare (6x), with 6.4 keV Fe Kalpha line
TES: 1875 c/s
Model: 1/10 of AB Dor flare (2-T; 20+80 MK; Maggio et al. 2000), i.e., about 6x quiescence
Bai et al. (1979) model for Fe Kα
Fe Kα
normalized counts/sec/keV
channel energy (keV)
0
100
200
300
400
6.3
6.4
6.5
6.6
6.7
6.8
6.9



AB Dor, 100s, "Average" flare (6x), 100 km/s shift
100 km/sshift
Even better at
7keV
XGS very good at
long wavelengths,
but probes lower-T
plasma
Caveat: moving
flare plasma
dominates the
emission (but
not so
unreasonable
for large flares)
Caveat2: line of
sight!
normalized counts/sec/keV
0
100
200
300
400
500
6.6
6.65
6.7
channel energy (keV)







AB Dor in quiescence:
309 c/s (TES) 15 c/s (Con-X/XGS)

XGS clear advantage for blends, line shifts and broadening and picking up faint emission lines (e.g., N VI)

However, XGS count rate lower (but?), and no coverage below 12A?

Important for specific goals (line

High densities in accreting stars

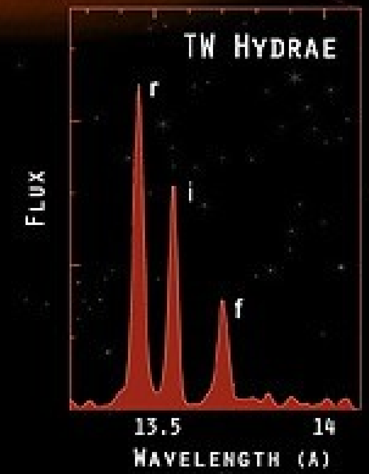
High i/f ratio in He-like triplets of TW Hya indicate $n_e \approx 10^{13}$ cm^{-3} (Kastner et al. 2002; Stelzer& Schmitt 2004). Also Fe XVII (Ness & Schmitt 2005)

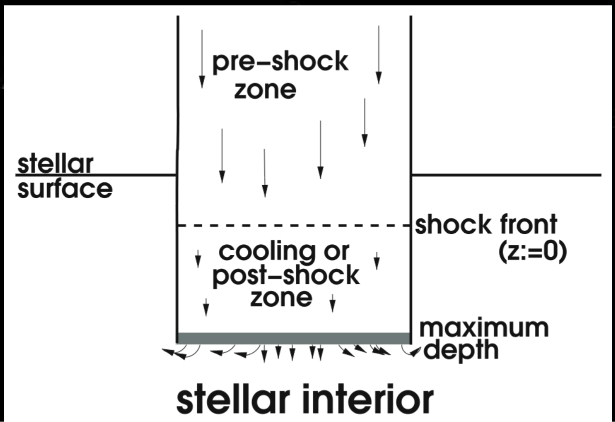
Plasma T≈3 MK consistent with adiabatic shocks from gas in free fall (v≈150-300 km s^{-1})

High densities in accreting young stars (Schmitt et al. 2005; Robrade& Schmitt 2006; Günther et al. 2006; Argiroffi et al. 2007), but not all (Telleschi et al. 2007; Güdel et al. 2007)

Very limited sample, with poor signal-to-noise ratio in grating spectra

$$T_s = \frac{3\mu m_{\mathrm{H}} v_s^2}{16k}$$

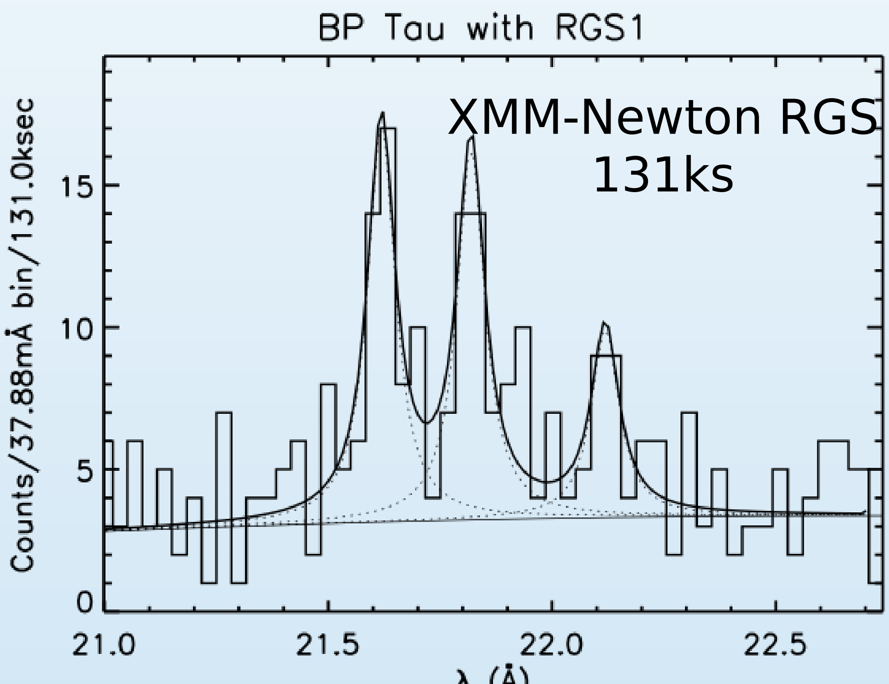




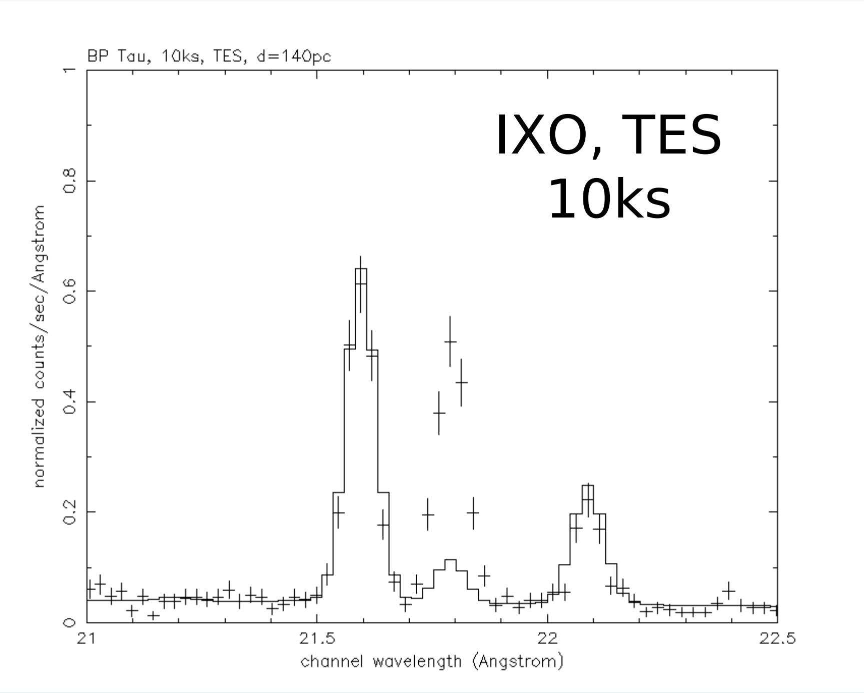
Günther et al. (2007

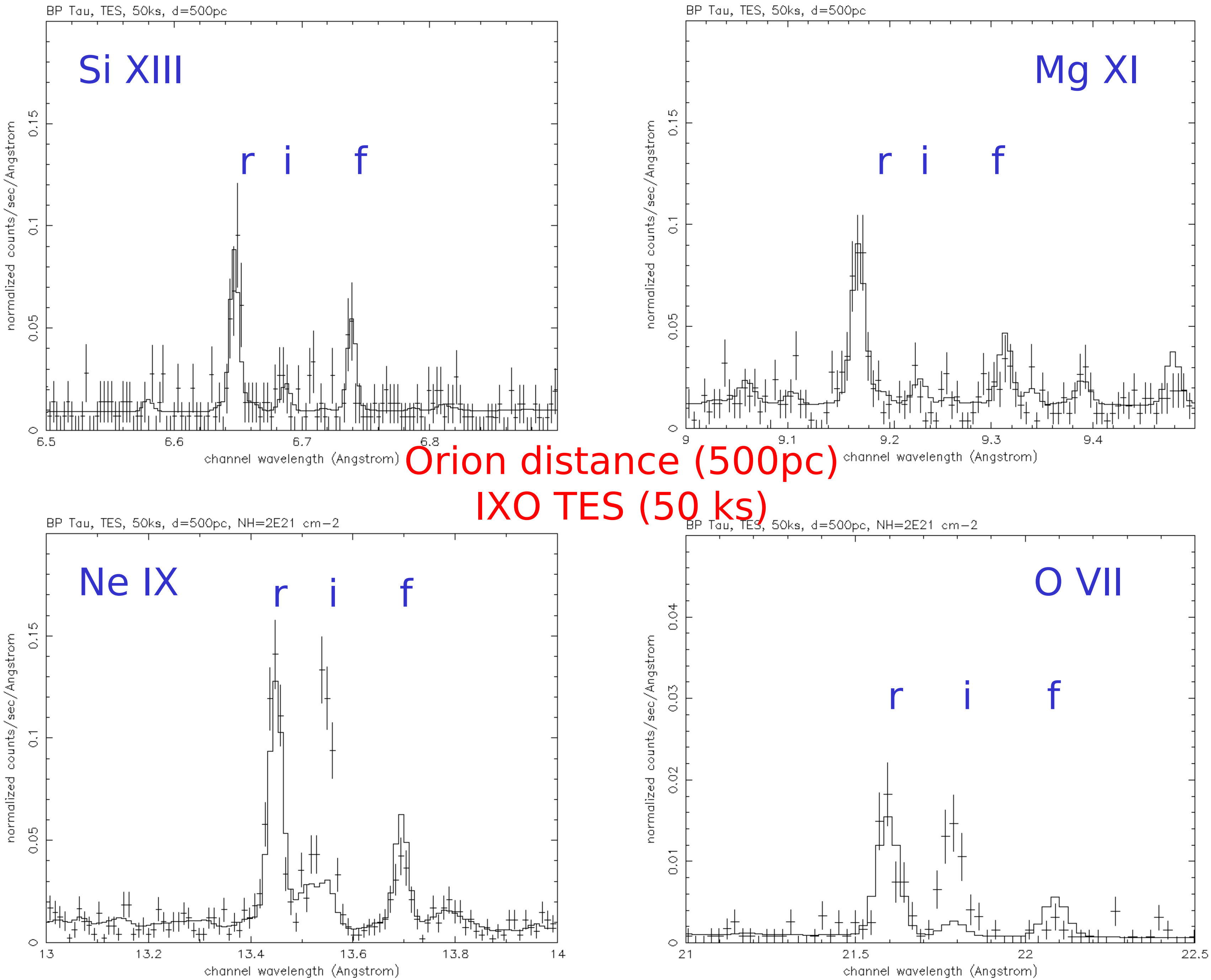
From present challenges to future observations

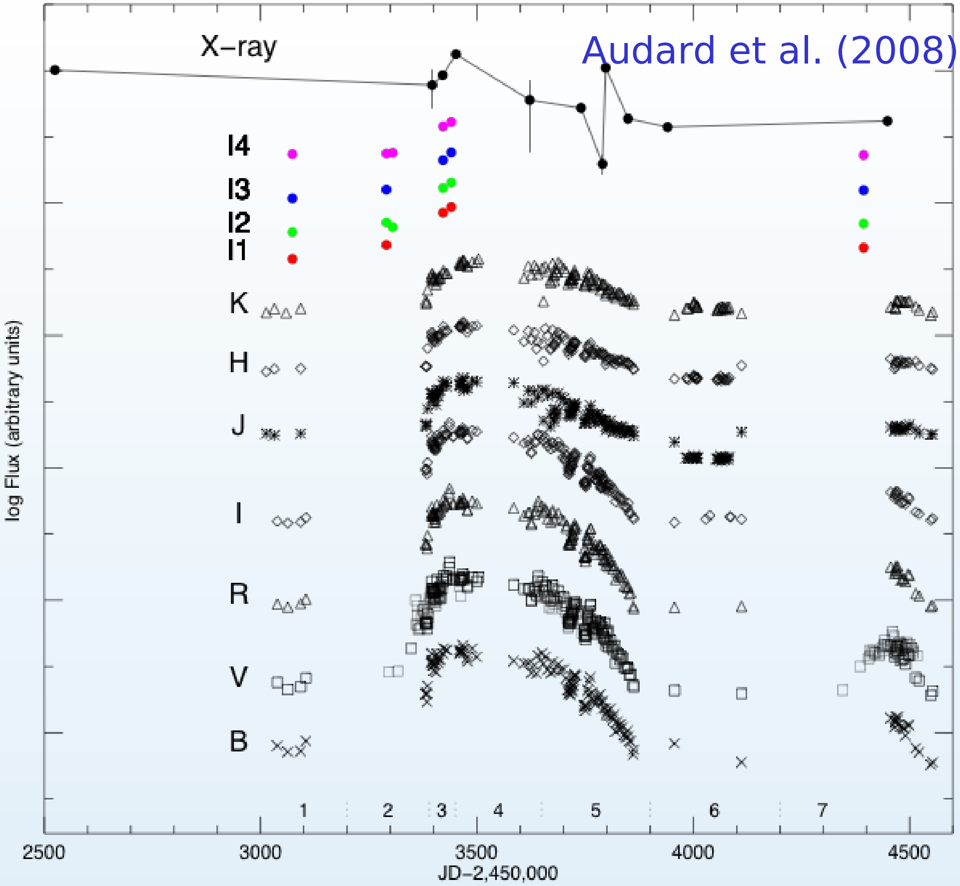
- Many grating spectra of magnetically active stars (esp. young pre-main sequence stars) suffer from low to average signal-to-noise ratios
- It will be possible to obtain densities in many sources within 500 pc relatively quickly (<50 ks, e.g., Taurus, Ophiuchus, Chamaeleon, Orion, etc)
- Access to low-T plasma from C VI and N VII as well (but N_H!)



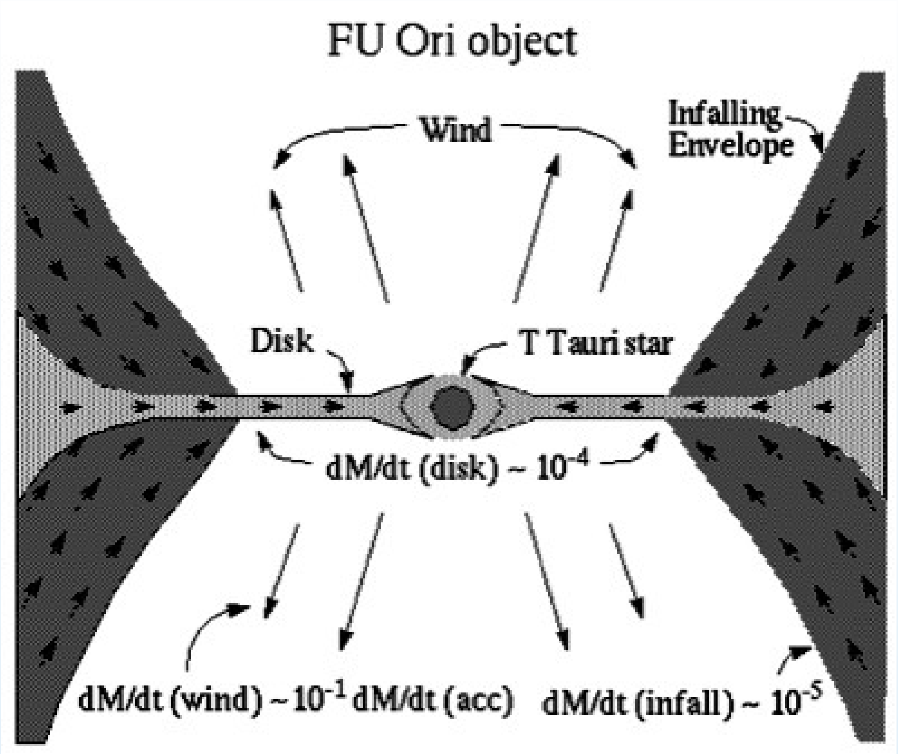
Schmitt et al. (2005)




Orion distance (500pc)
IXO TES (50 ks)
BP Tau, TES, 50ks, d=500pc
Si XIII
r i f
normalized counts/sec/Angstrom
channel wavelength (Angstrom)
BP Tau, TES, 50ks, d=500pc
Mg XI
r i f
normalized counts/sec/Angstrom
channel wavelength (Angstrom)
BP Tau, TES, 50ks, d=500pc, NH=2E21 cm−2
Ne IX
r i f
normalized counts/sec/Angstrom
channel wavelength (Angstrom)
BP Tau, TES, 50ks, d=500pc, NH=2E21 cm−2
O VII
r i f
normalized counts/sec/Angstrom
channel wavelength (Angstrom)

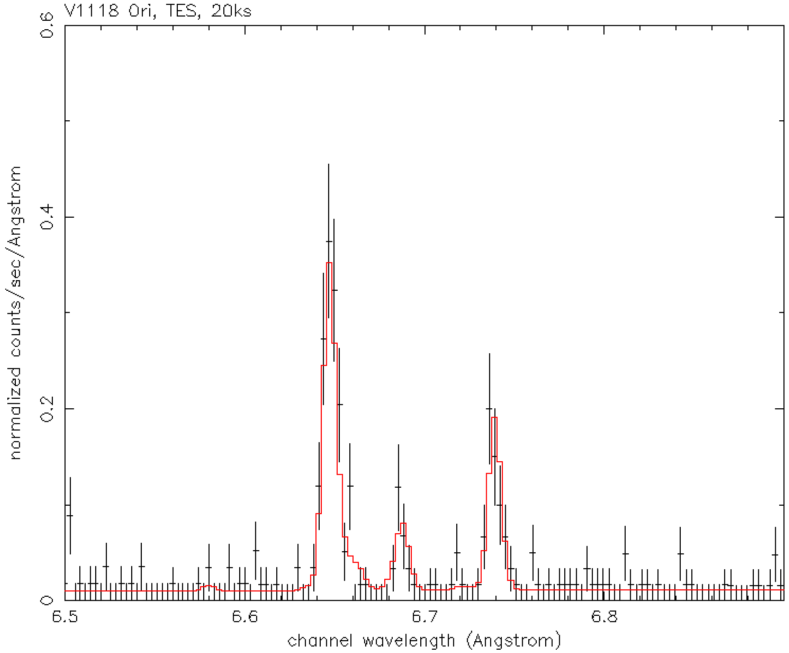


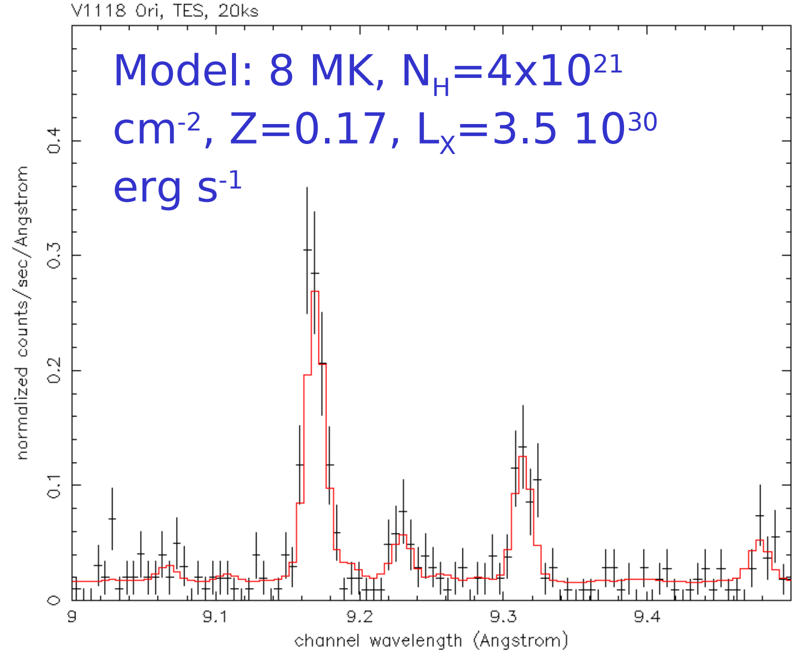
Audard et al. (2008) $F_x \approx 10^{-15}$-10^{-14} erg s^{-1} cm^{-2}

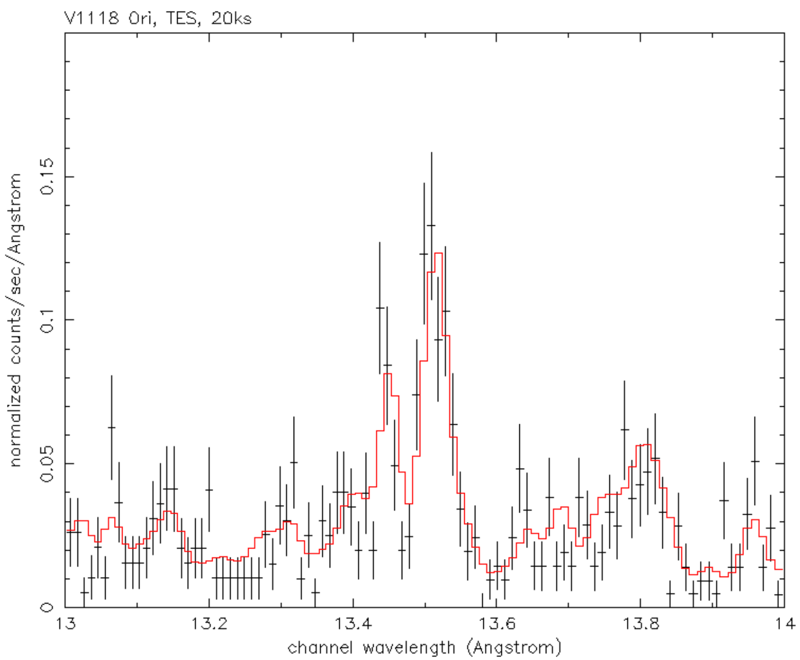


Hartmann (1997)

During outbursts in young stars, due to the increase in accretion rate in the outburst, the accretion disk closes in and may have disrupted the magnetic loops, modifying the magnetospheric configuration (Kastner et al. 2004; 2006; Grosso et al. 2005; Audard et al. 2005; 2008)



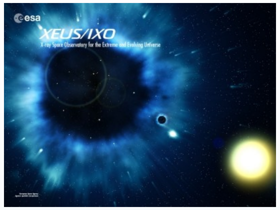




IXO TES: 0.3 c/s
Chandra & XMM-Newton: < 0.01 c/s

In addition to higher S/N spectra, the IXO TES data could, in similar exposures, help us obtain densities during the outburst

Conclusions



- Dynamical processes will (finally) be studied with a good to high S/N
- Stochastic processes, however, require some integration time (20-50 ks) to capture flares with sufficient energy and signal
- IXO will also probe deeper into the X-ray sky: routine plasma T and density measurements in reasonable amount of exposure time < 1 kpc
- TES polyvalent (spatial resolution, high count rates, good spectral resolution ➔ Integral Field Spectroscopy!), XGS for specific goals
- XGS' spectral resolution helpful for blends or to pick up faint emission lines, but lower count rates ➔ long integration times
- High count rates: need to avoid pile-up and deadtime (not as drastic as X-ray binaries, but still: flares can go to a few thousands c/s!)
- Spatial resolution: goal of 2" better than 5". TES: go to ≤2eV?
- Response at high energy useful to constrain high T plasma