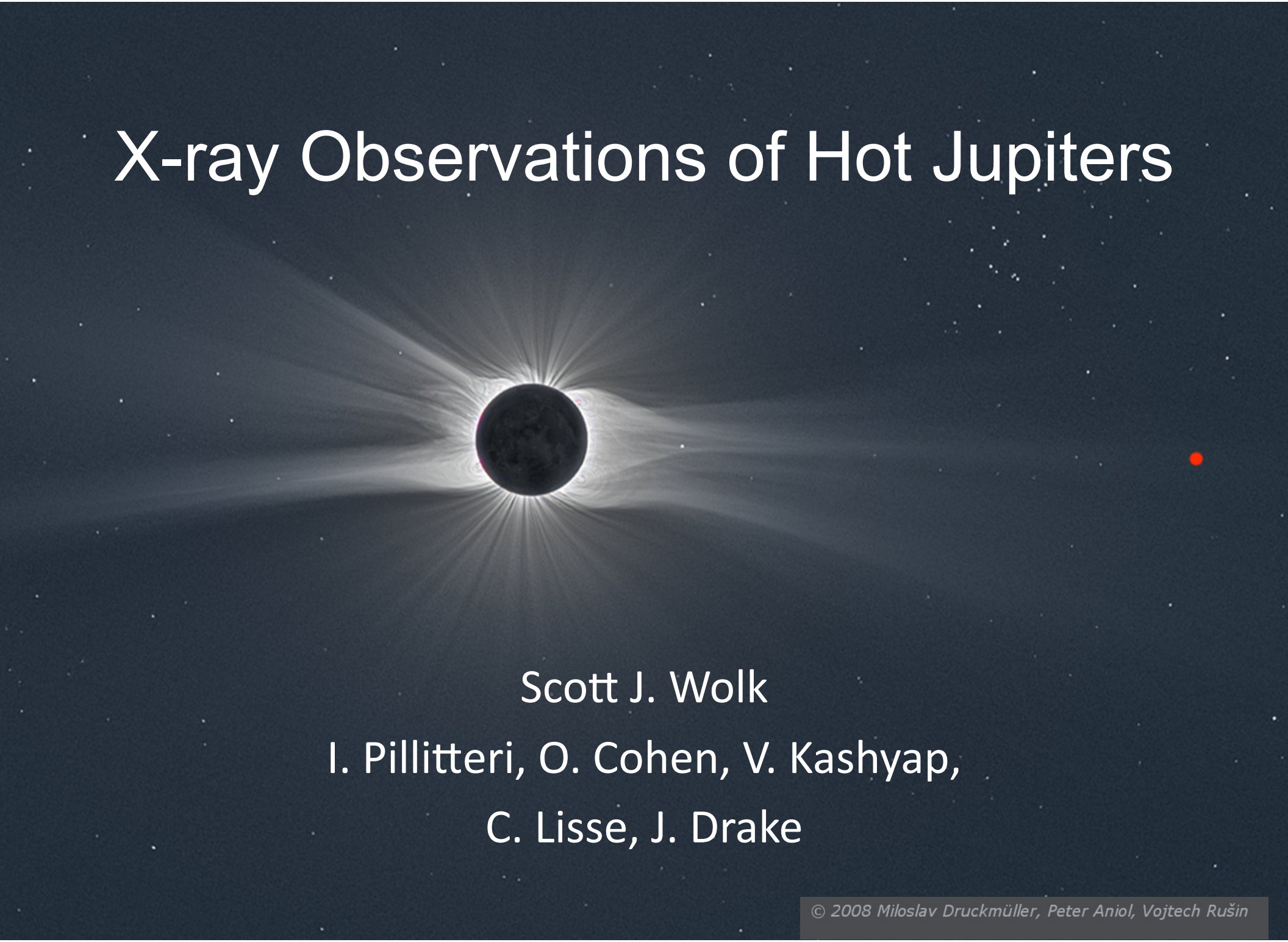
X-ray Observations of Hot Jupiters

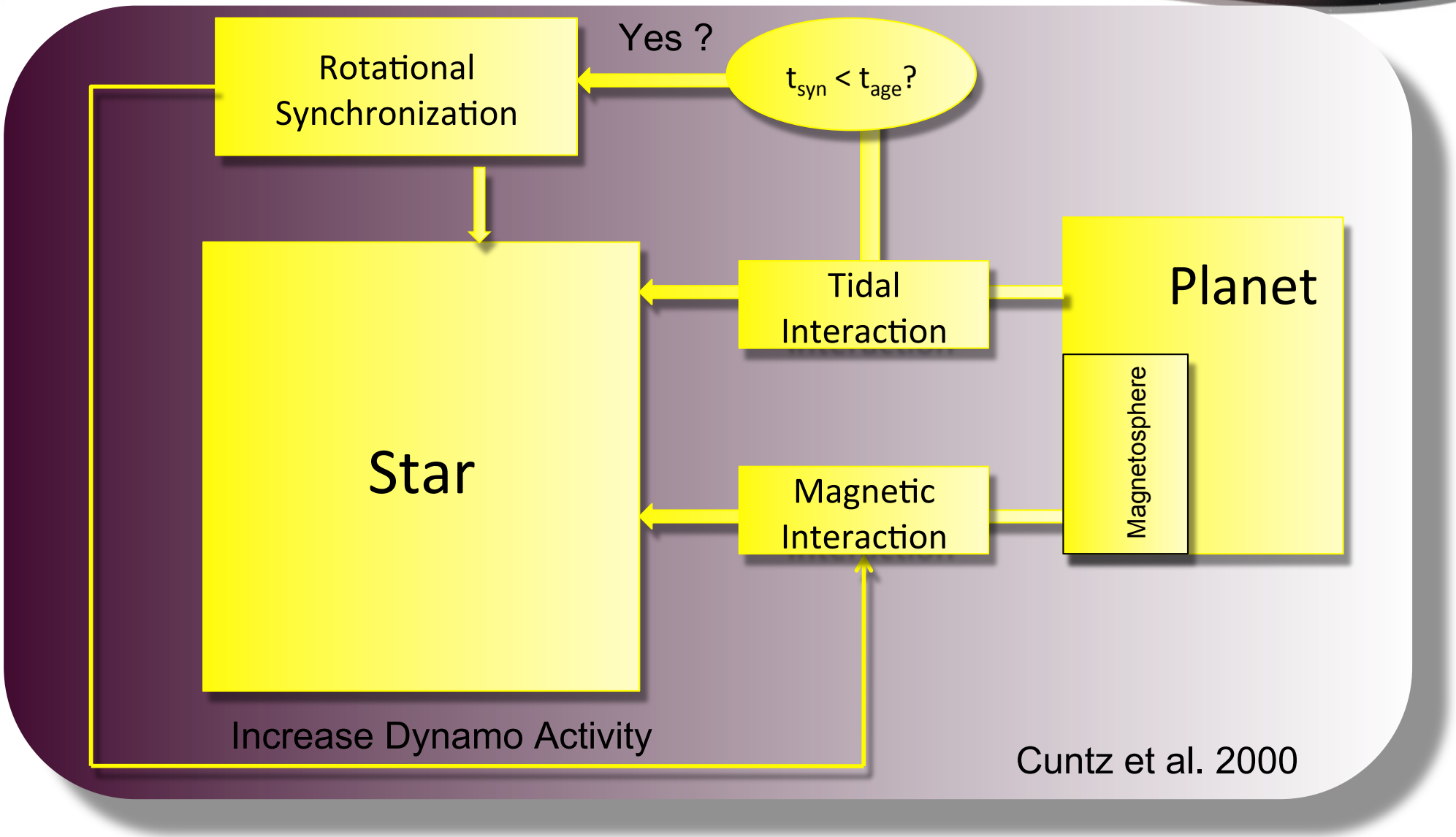


Scott J. Wolk

I. Pillitteri, O. Cohen, V. Kashyap,

C. Lisse, J. Drake

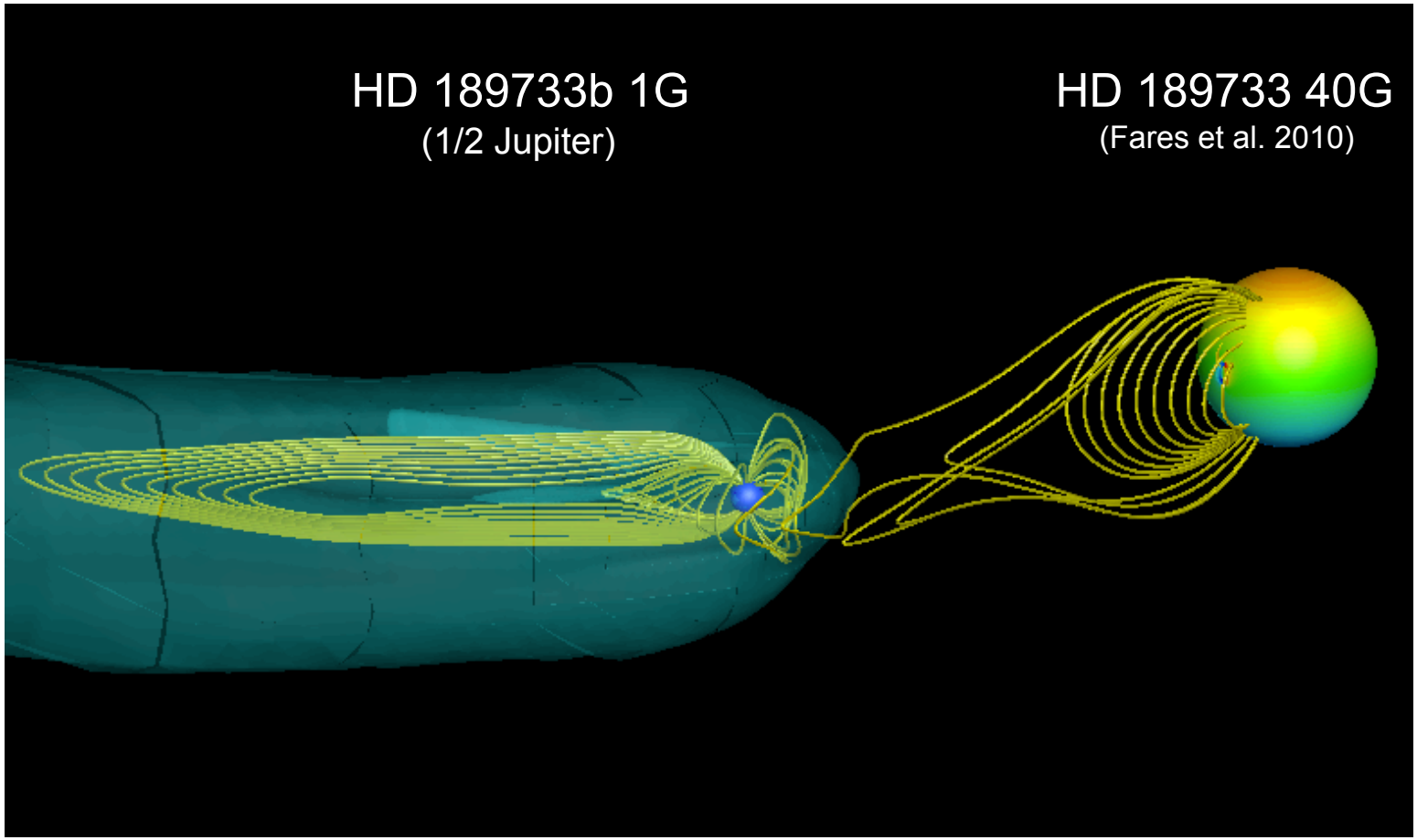
What is Star Planet Interaction?



Why do we care about SPI?

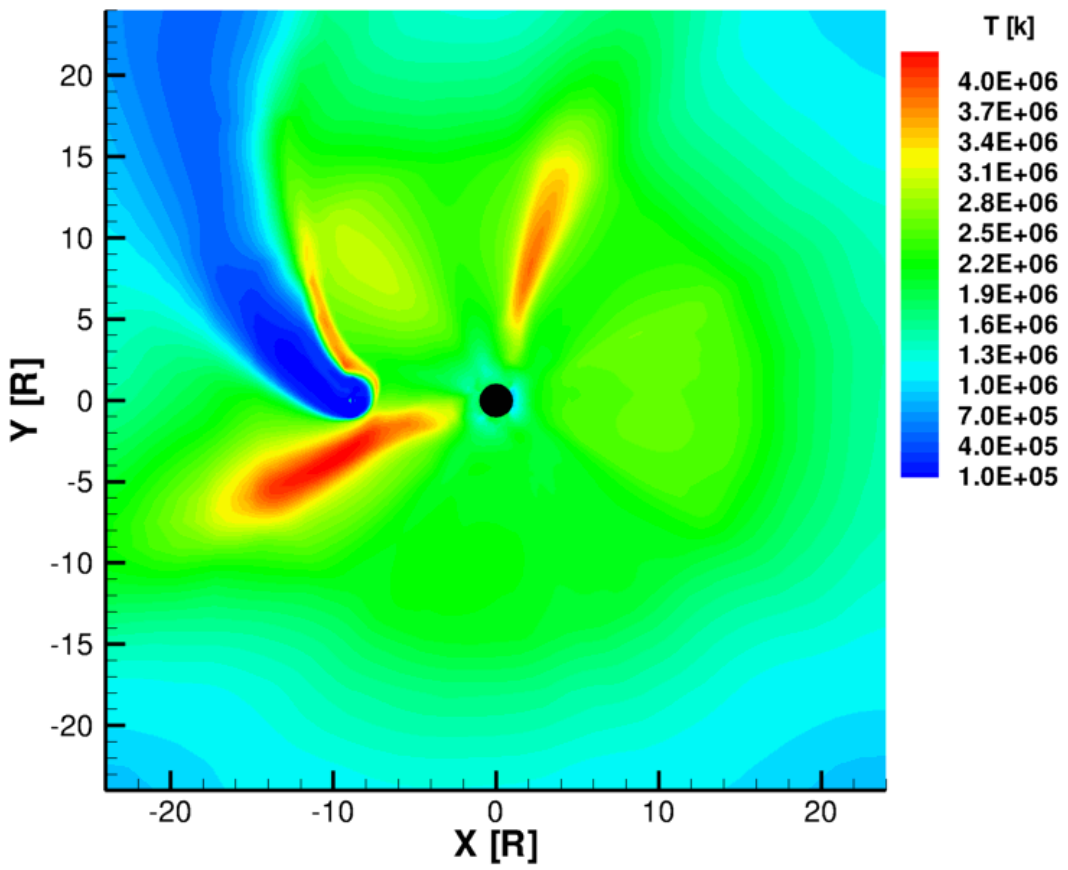
- X-rays from stars effect exoplanets…
  - Some hot Jupiters appear inflated beyond what the bolometric luminosity would predict.
  - X-Ray/UV flux ➔ atmospheric expansion (Lammier et al. 2003)
  - X-Ray flux ➔ photochemistry changing the thermal budget (Laing et al. 2004; Burrows et al. 2008)
- …Exoplanets may effect their host stars.
- Analytic Studies show ➔ $F_{recon} \alpha a_p^{-3}$ (Saar et al. 2004)
- Analytic models indicate field lines can connect the star to the planet, ruptures of the lines could give rise to flare-like activity.
- MHD simulations show strong feedback visible in X-rays

Could the Planet really Matter?



Cohen et al. 2011

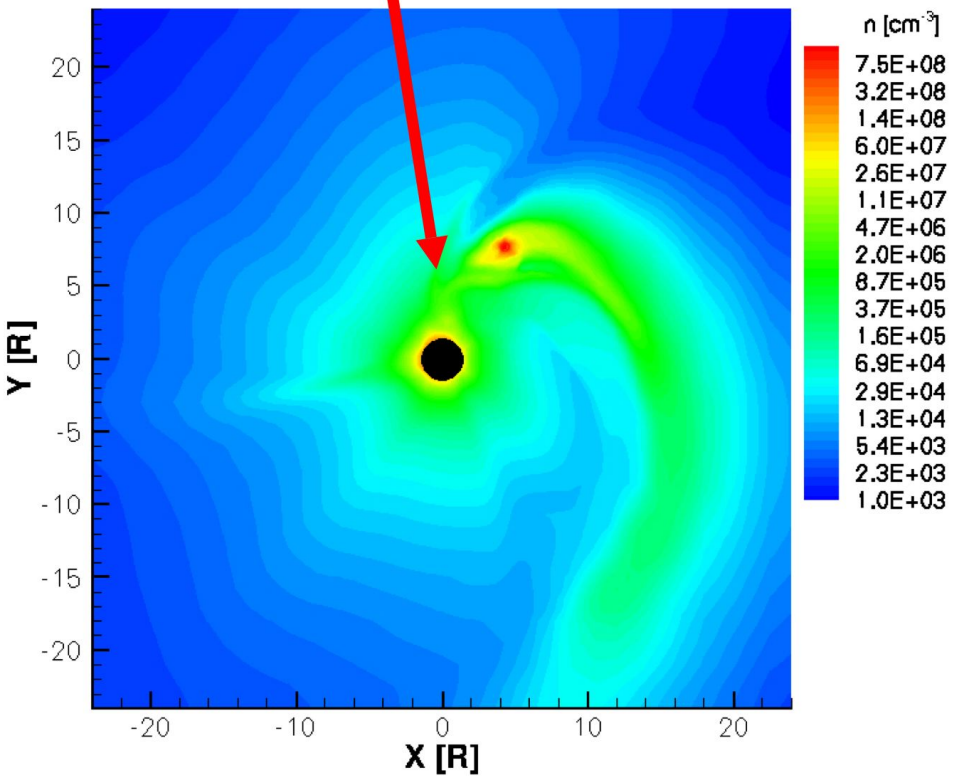
SPI induced flares?

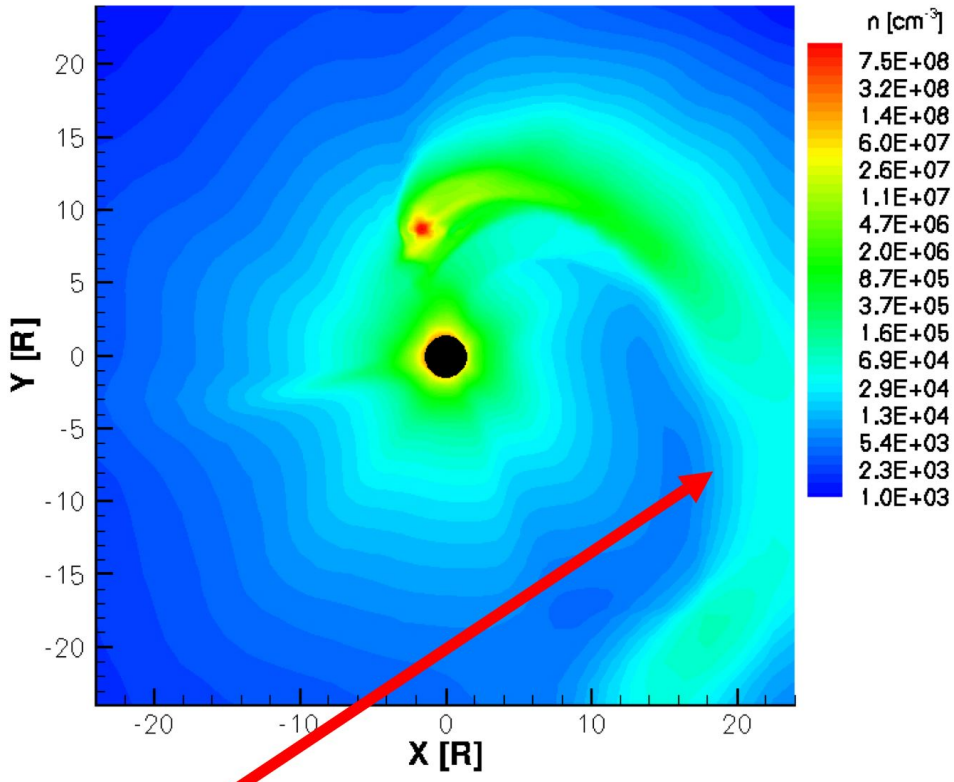


Cohen et al. 2011

A snapshot on a magnetic reconnection event

Material flowing from the planet



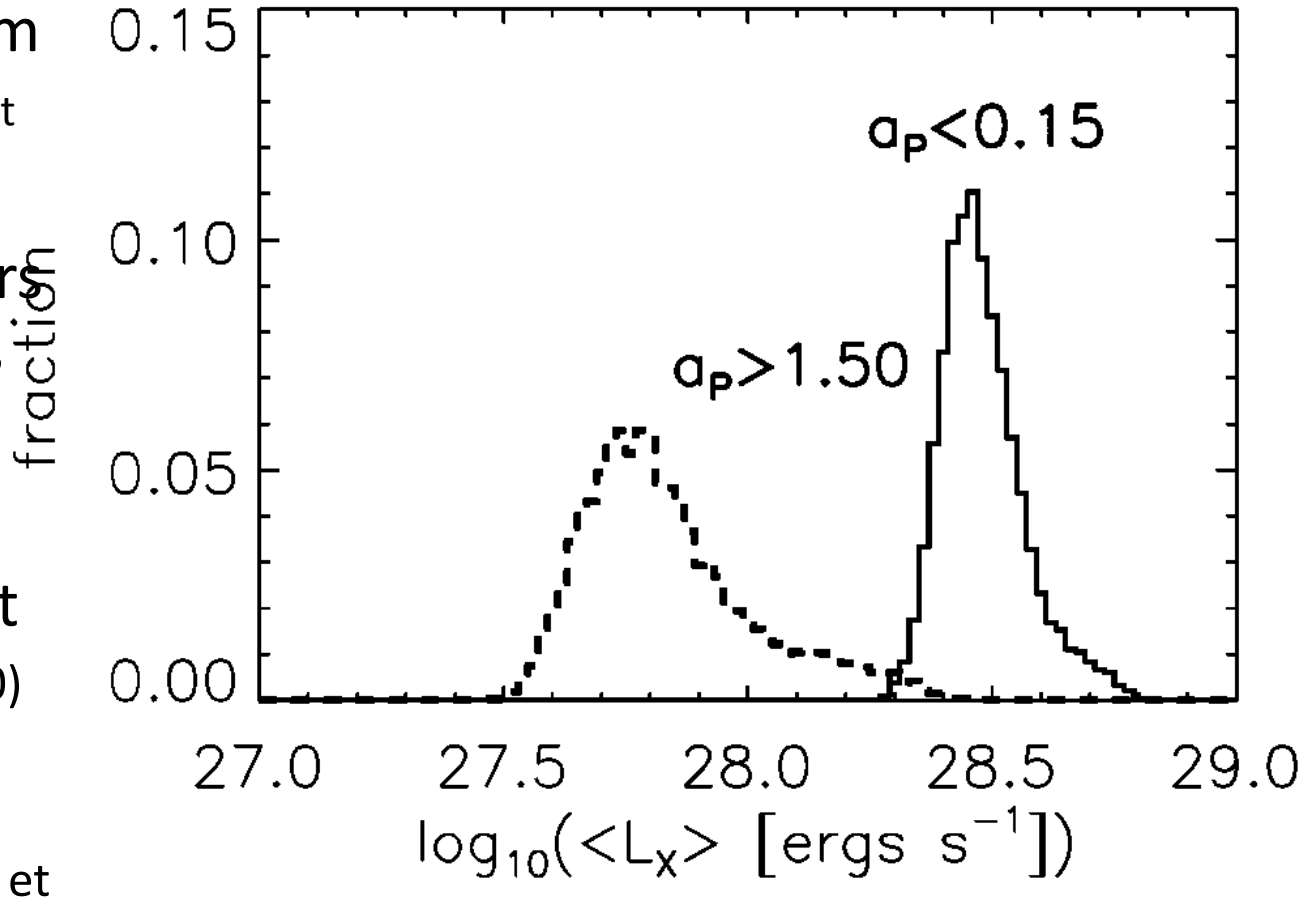


Plasmoid disconnection from the planetary tail

Cohen et al. 2011

What is the evidence exists for Star-Planet Interaction?

- Direct observation of phased emission from Ca II HK lines (Shkolnik et al. 2003, 2008)
- Stars with hot Jupiters are brighter in X-rays (Kashyap et al. 2009)
- Stellar Luminosity is propotional to Planet Mass? (Scharf et al. 2010)
- But these results are disputed. (Poppenhäger et al. 2010, 2011)



Kayshap et al. 2008

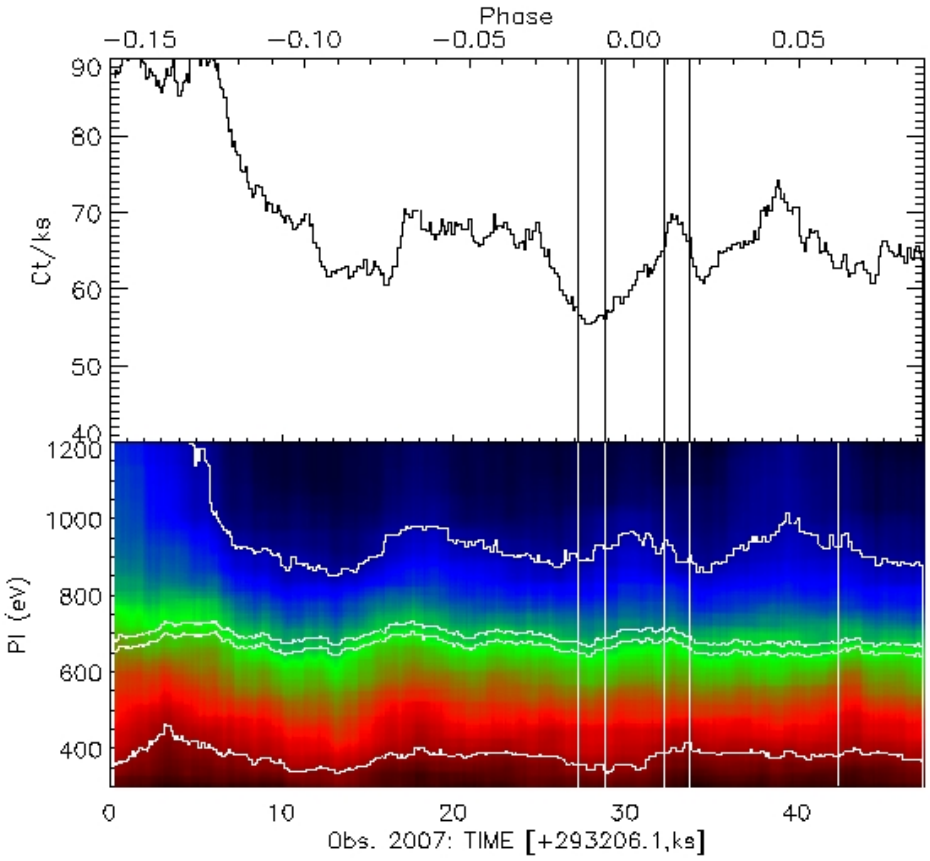
Evidence of SPI - HD 189733

	HD 189733A	HD 189733b	HD 189733B
Type	K 1.5V	planet	M4V
Mass	$0.81M_{\odot}$	$1.15M_{jup}$	$0.2M_{\odot}$
Radius	$0.76R_{\odot}$	$1.26R_{jup}$	–
Orbital Period	–	$2.219d$	$3200yr$
Mean orbital radius	–	0.003 AU	216 AU

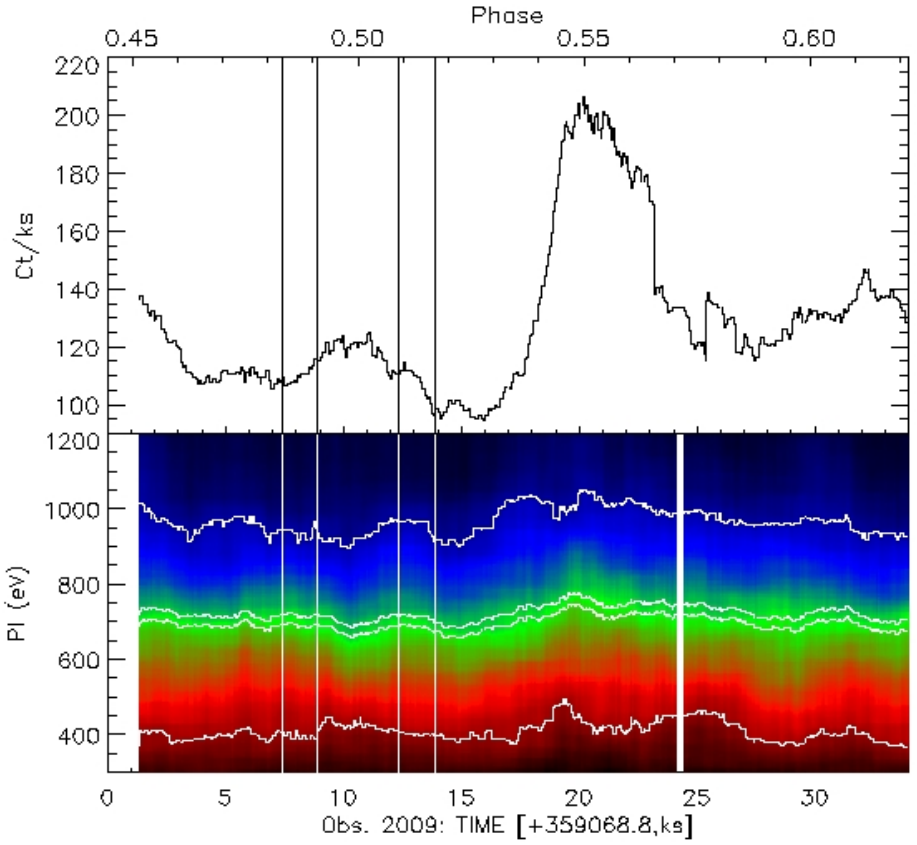
- At a distance of 19.3 pc it is one of the closest transiting planets.
- Somewhat X-ray active (L_x~$10L_{x\odot}$)
  - Age estimated at 0.6 Gyr
- XMM (Wheatley-PI) observed a planetary transit in April 2007
- We observed secondary eclipse with XMM in May 2009
- And observed a second eclipse with XMM in May 2011
  - However, this age is discrepant with an older-age inferred from the star's low Lithium-abundance (1/10 Solar; Santapaga et al 2010)
  - Secondary not detected in X-rays! This is highly unlikely for an M4 at 0.6 Gyr and implies the age is wrong

Results 2007-2009

Transit

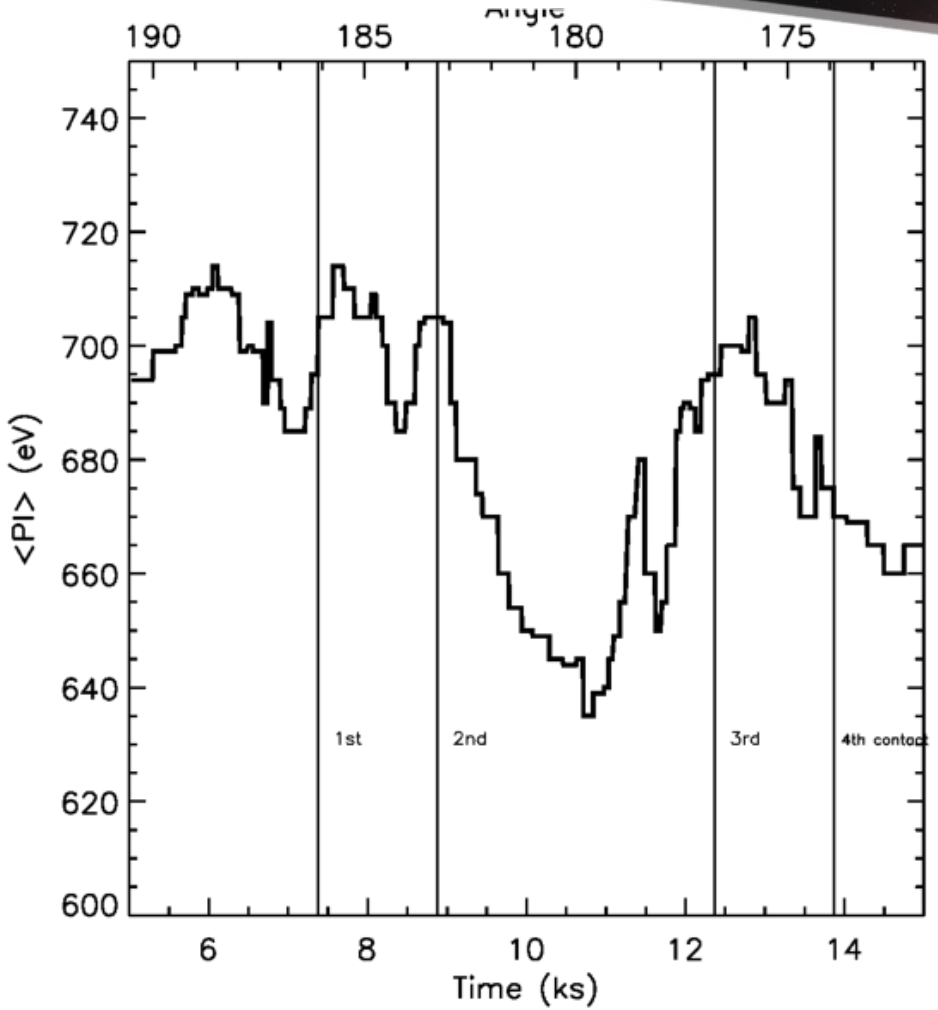


Eclipse



Pillitteri et al. 2010

X-Ray Softening

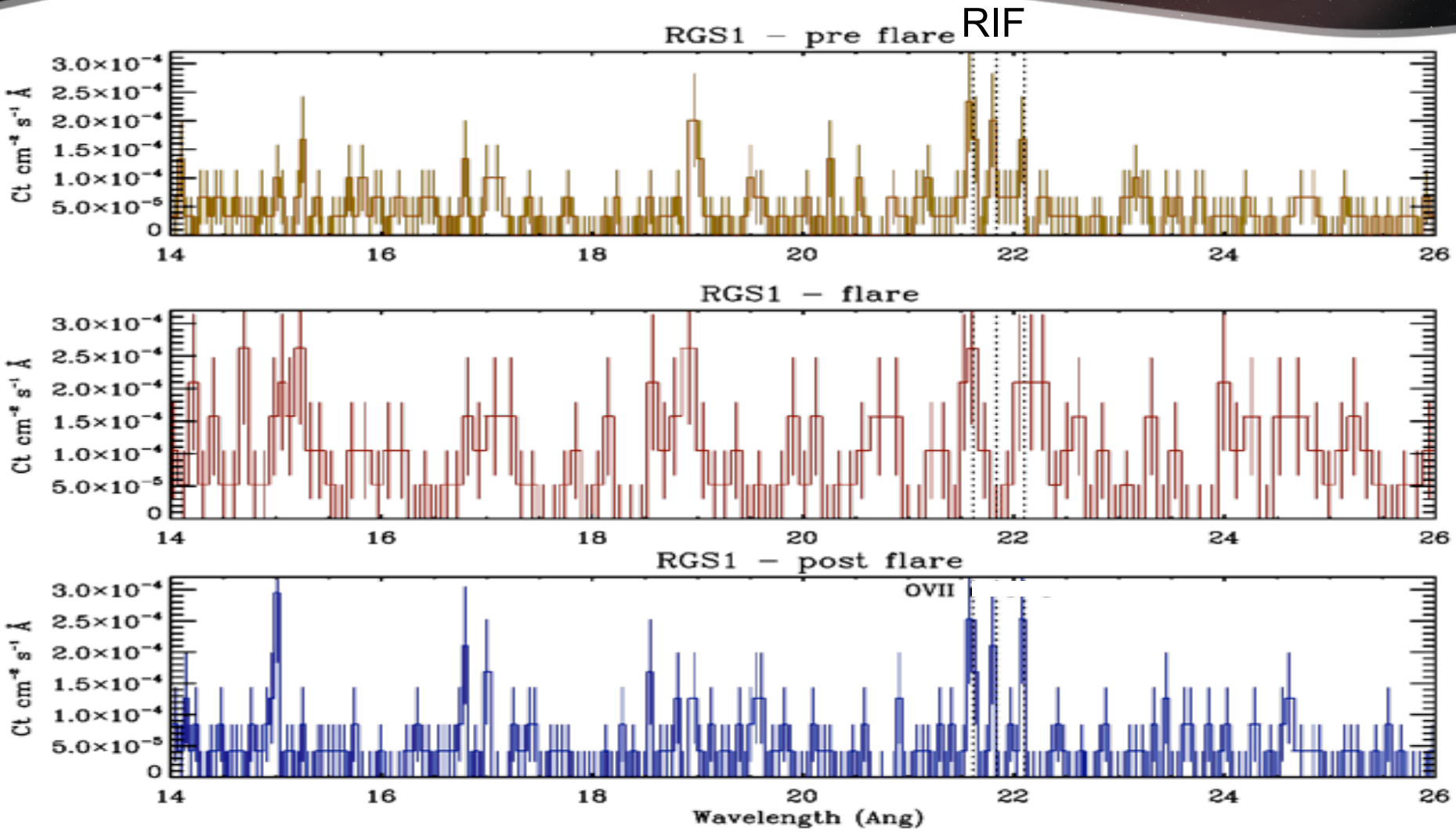


With XMM time resolution~ 1ks at 5 counts/ks

Pillitteri et al. 2010

Tantalizing evidence

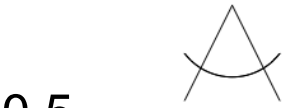
Blue shifted Oxygen lines?



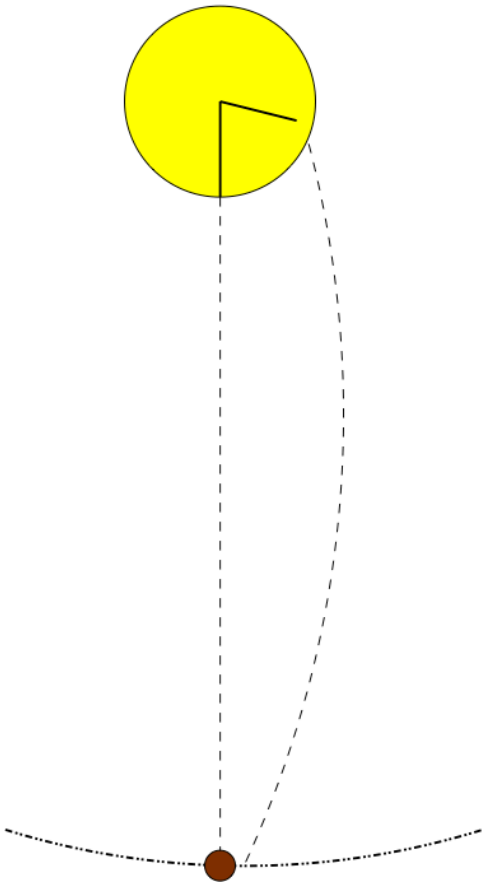
Pillitteri et al. 2010

Was the timing of the flare related to SPI?

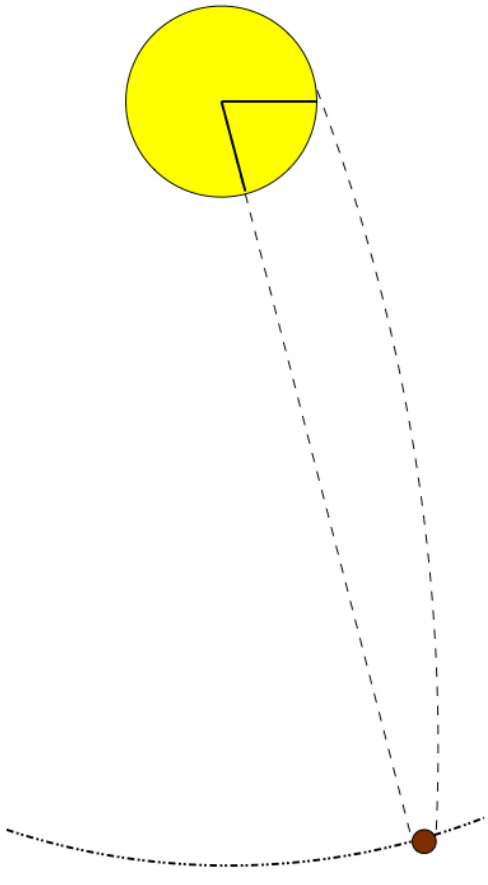
(Lanza 2008)



Phase 0.5



Phase 0.54

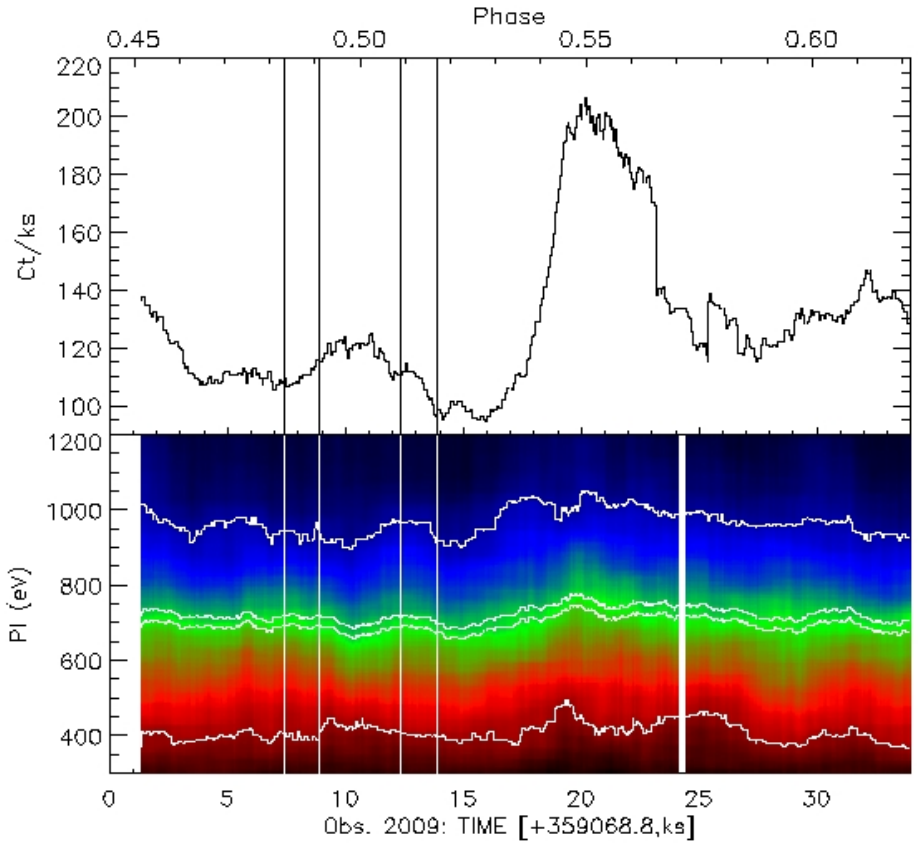


Results 2007-2009

Assigned 3 peculiarities to the eclipse:

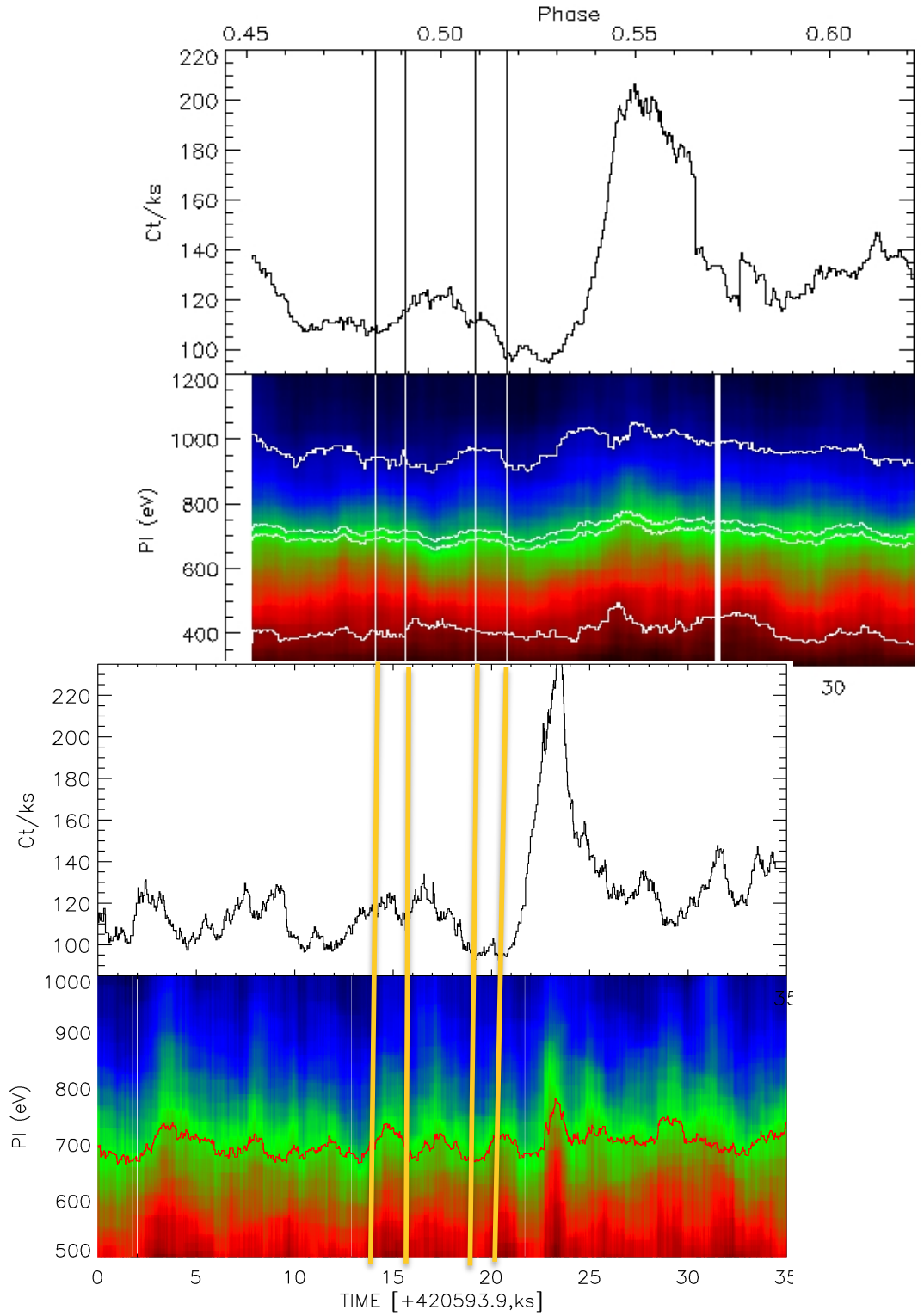
1. Softening of the spectrum during the eclipse.
2. The flare at phase 0.54
3. Blue-shifted features in the OVIII triplet

Eclipse



Are the 2009 and 2011 eclipses similar?

Smoothed lightcurves

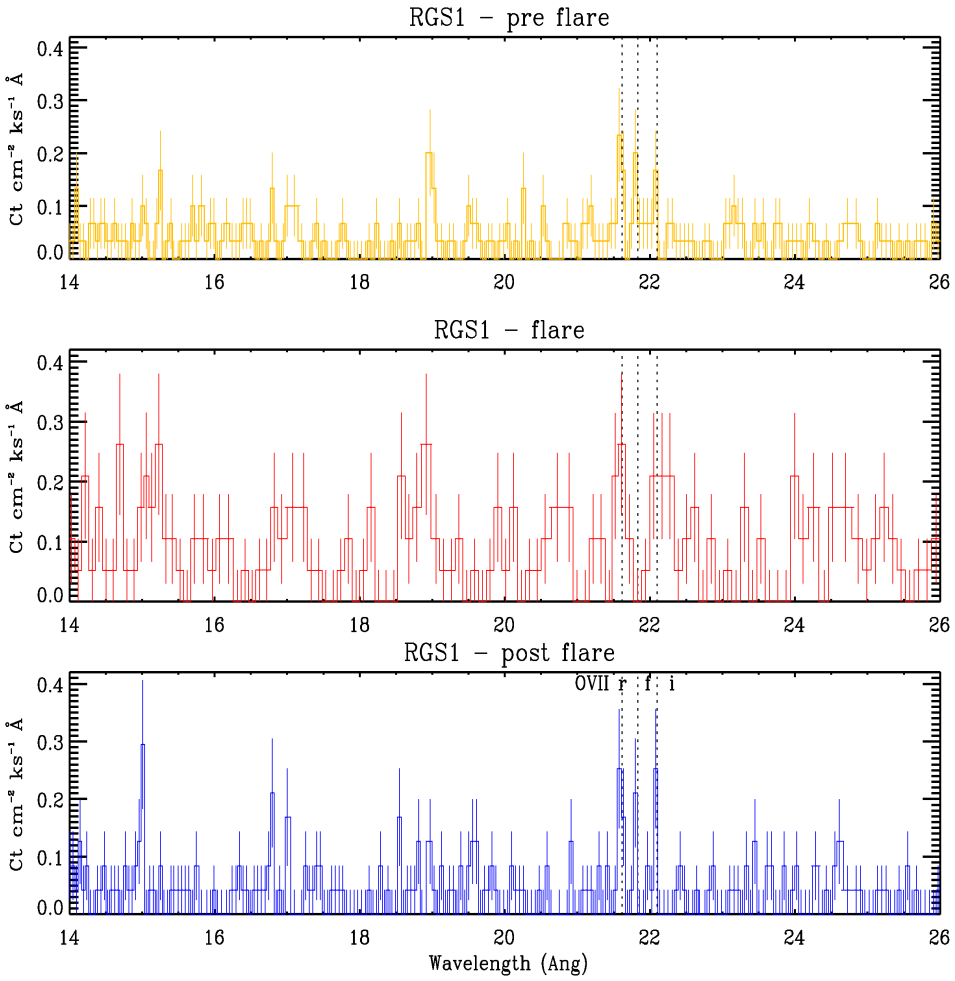


2009

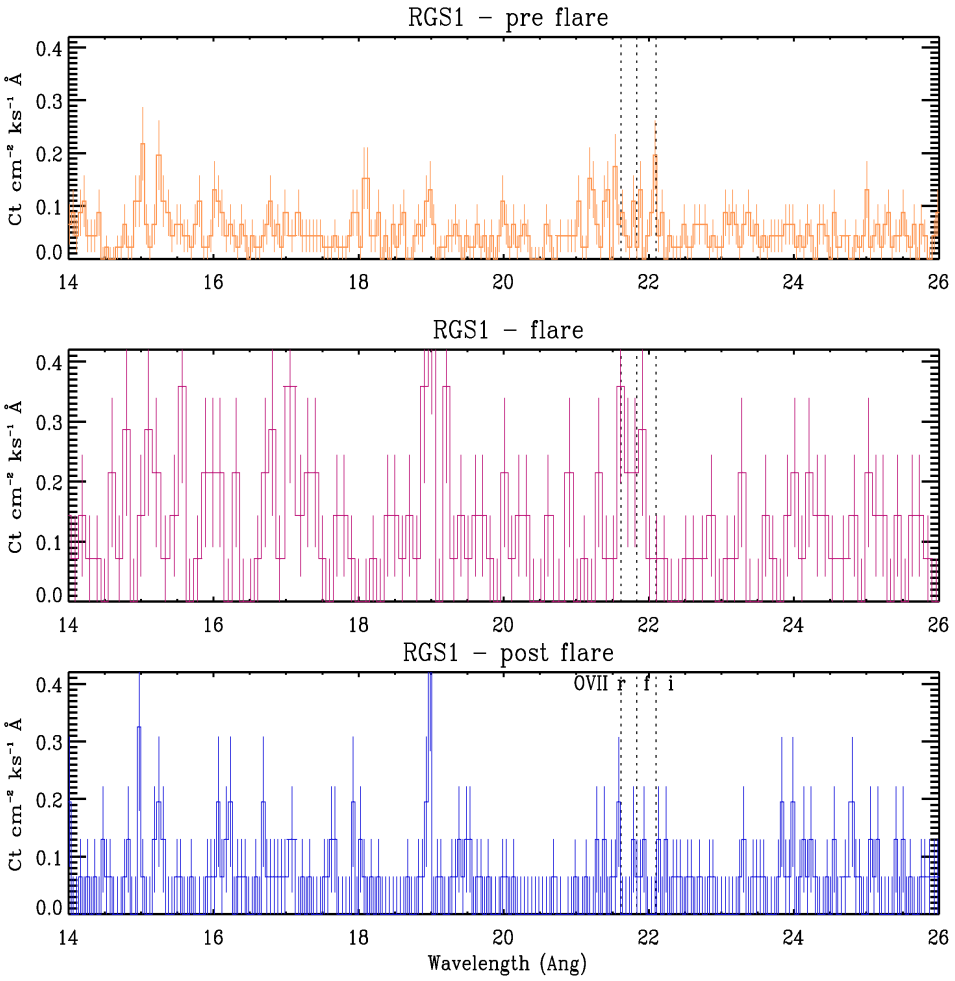
2011

Tantalizing evidence
more blue shifted Oxygen lines?

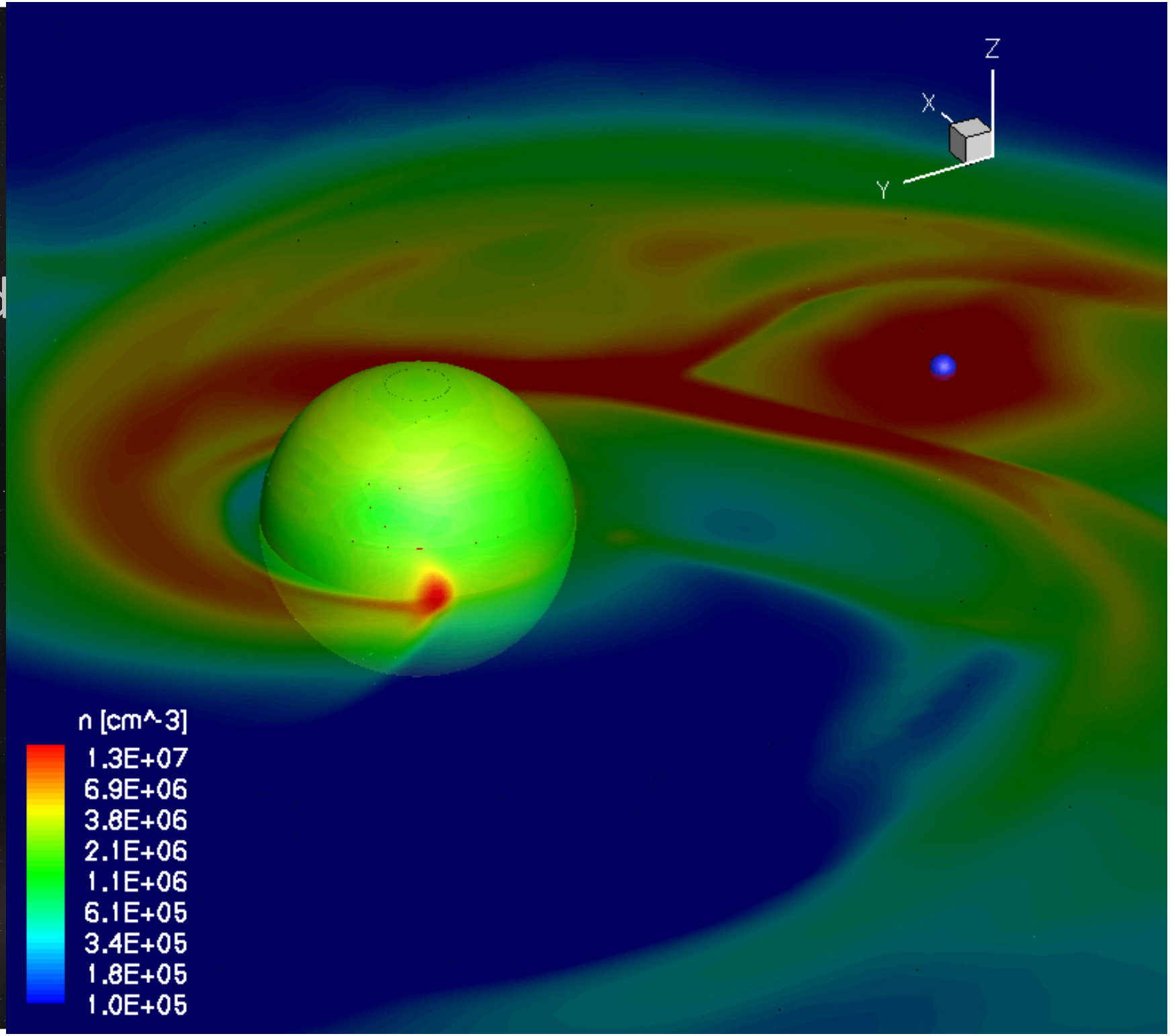
May 2009



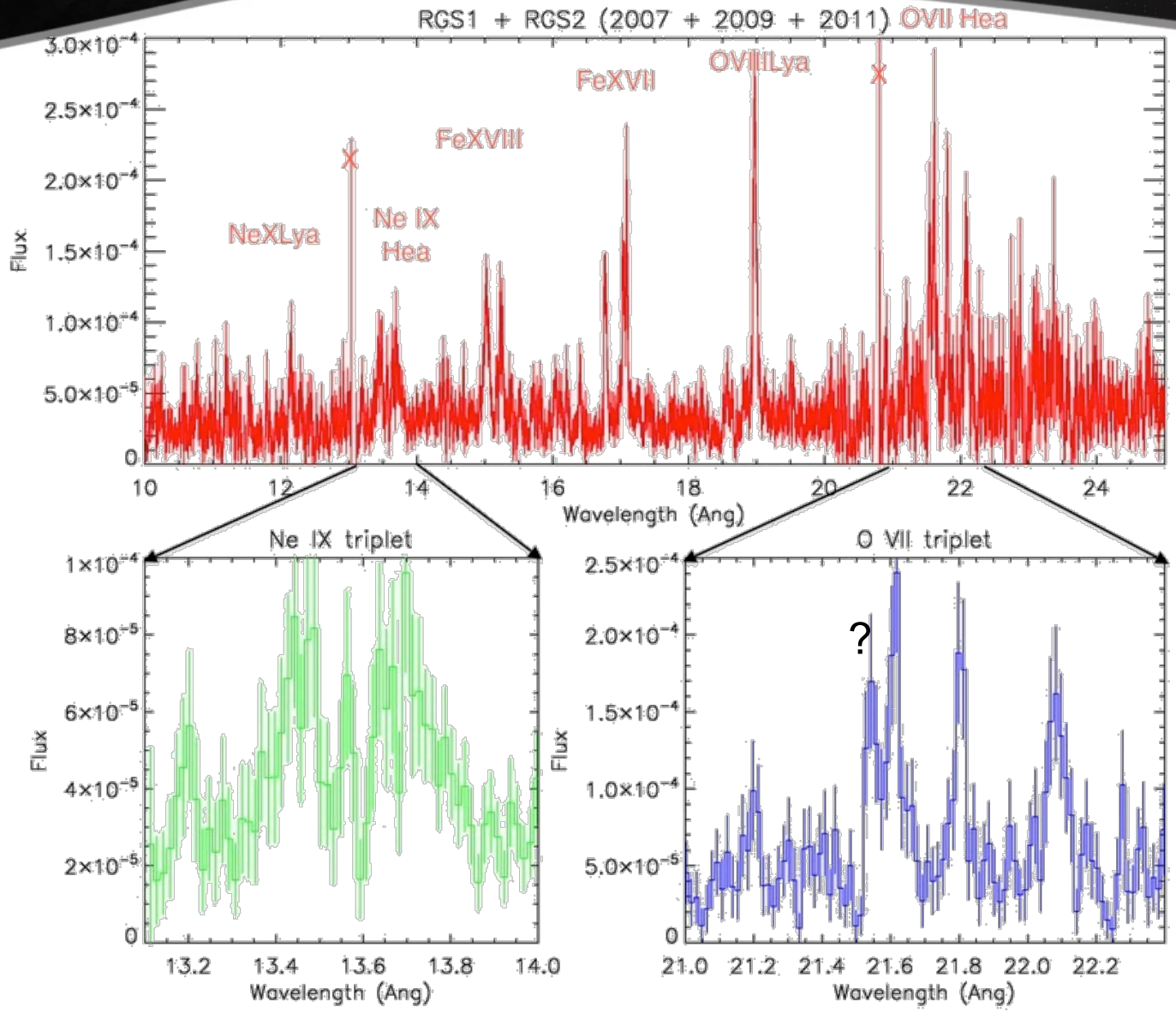
May 2011



MHD: Forward Flow



Tantalizing evidence
an unusual active corona



OVII f/I ratio~ 1

Ne IX f/I ~2

Both imply $n_e \sim 10^{11}$/cc

Similar to TW Hya density

Very cool ~ 400 eV

Summary 2011

- No effects noticed during the transit.
- We observed a softening of the spectrum during the first eclipse.
  - Possibly during the second eclipse.
- **TWICE** A peculiar flare was observed at phase 0.52-0.54.
  - Analytic models predicted a foot point 77^{o} forward of the sub-planetary point
  - But how does the flare "know" where the Earth is?
- The corona is cold and dense.
- It is possible we saw material flowing at ~ orbital velocity.
  - Possibly a torus of material.
- Still no detection of the M4 secondary
  - Corollary: **You cannot use activity to date stars with close in planets.**
- Future observation of HD189733 are planed as are observations of some highly eccentric systems.