TOWARDS OTHER EARTHS II
The Star-Planet Connection
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Effects of Star-Planet Interaction. HD 189733 and WASP-18.

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Introduction.

About 20% of known exo-planets are Hot Jupiters. These giant planets can significantly affect the activity of the host stars through tidal and magnetic interaction.

Some stars with hot Jupiters have shown variations of their activity phased with the planetary motion, due to **star-planet interaction (SPI)** of magnetic and tidal origin (e.g. μ And HD 179949, τ Boo and HD 189733, Shkolnik et al. 2003, 2005, 2008, Walker et al. 2008). Also, systems with hot Jupiters show evidence of spin-up or enhanced activity (Kashyap et al. 2008, Scharf 2010, Poppenhaeger and Wolk, 2014)

We investigated X-ray and FUV emission in HD 189733, and X-rays from WASP-18, and here we show how SPI can lead to the opposite effects on the stellar activity of host stars with different inner structure.

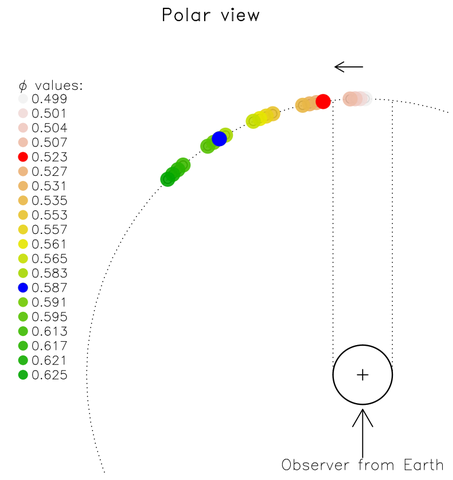
FUV observations of HD 189733.

HD 189733 is the best studied system with a transiting hot Jupiter. It is in a binary system with a quite inactive and old ($t > 5$ Gyr) M4 type star (see Table 1). The activity detected in the primary star is suspiciously high for an age of 5 Gyr (Pillitteri et al. 2010, Guinan 2013, Pillitteri et al. 2014, Poppenhaeger & Wolk 2014).

Table 1: HD 189733 by numbers

	HD 189733A	HD 189733b	HD 189733B
Type	K 1.5V	planet	M4V
Mass	$0.81 M_{\odot}$	$1.15 M_{jup}$	$0.2 M_{\odot}$
Radius	$0.76 R_{\odot}$	$1.26 R_{jup}$	–
Orbital Period	–	$2.219d$	$3200yr$
Mean orbital radius	–	0.003 AU	216 AU
Age	same as companion		$\simeq 5$ Gyr

We observed HD 189733 on Sept. 12th 2013 for a visit of five HST orbits to follow the egress of the planet from behind the star, and the same phases already observed three times with *XMM-Newton* (Pillitteri et al. 2010, 2011, 2014). We acquired high quality COS spectra in the wavelength range 1150-1450 Å. The schematic on the right (Fig. 1) shows the position of the planet during the HST exposures.



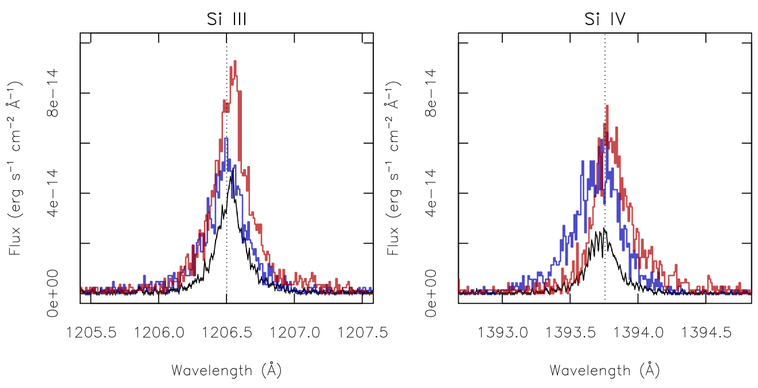


Figure 2: Si III and Si IV lines exhibit the strongest variability. At phases $\phi = 0.523$ (red spectrum) and 0.587 (blue spectrum) the lines shows an intensity enhancement and a centroid Doppler shift with respect to the average spectrum (black line).

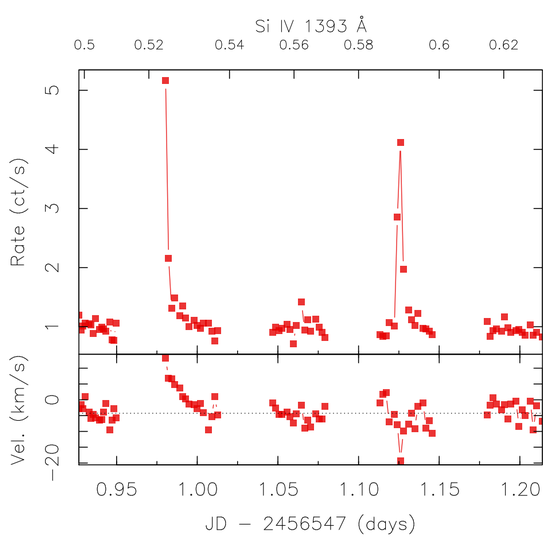


Fig. 3: the light curve of intensity and centroid shift of Si IV line at 1393Å. Two enhancements of profile intensity are seen in the spectrum of HD 189733. First event ($\phi = 0.523$) is interpreted as a limb brightening occurring at the end of the planetary eclipse. The atmosphere of the planet blown away along the line of sight in the direction opposite to the observer adds a red shifted component to the stellar spectrum, with a temperature probed by the formation temperature of Si IV lines ($\sim 80,000$ K).

The second enhancement is related to a chromospheric brightening, perhaps a flare occurring in an active region *co-moving* with the planet and emerging on the limb. A blue-shift of $\sim$ 20 km/s of the Si III and SI IV line centroids is very close to the speed of the planet projected on the stellar surface ($\sim$18 km/s).

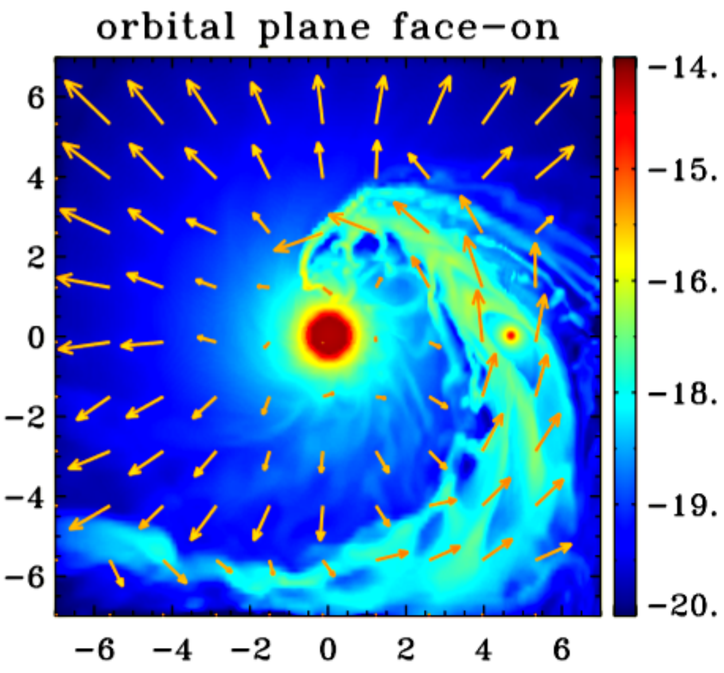
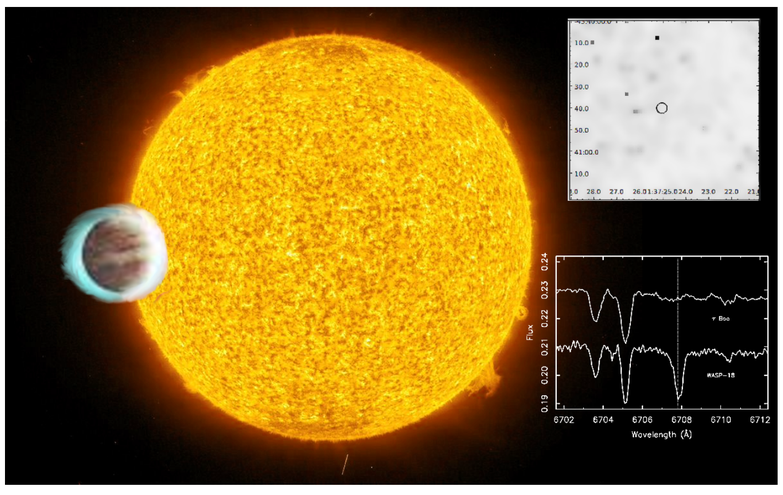


Fig. 4: detailed MHD simulations (Matsakos et al., A&A submitted) show that the magnetic field of the star+planet can drag the material evaporating from the planet and accrete it onto the star in a spot ahead of the sub-planetary point. The model explains the phased variability observed in X-rays and FUV at post eclipse phases ($\phi \sim 0.55 - 0.65$), occurring when the active spot emerges at the stellar limb. See also the poster from Matsakos et al. at this meeting, (MHD code: PLUTO, Mignone et al. 2007).

WASP-18: null activity.

Results published in Pillitteri et al. 2014, A&A 567, 128



Characteristics of the system:

	WASP-18	WASP-18b
Type	F6VI-V	planet
Mass	$1.23 M_{\odot}$	$10.4 M_{jup}$
Radius	$1.24\ R_{\odot}$	$1.16 R_{jup}$
Period	Rotation: $4 - 6d$	Orbital: $0.94d$
Separation	–	0.002 AU = 3.5 R_*
Distance	100±10 pc	–
X-ray Lumin.	$L_X \leq 10^{26.5}$ erg/s	–

Fig 5: WASP-18 has one of the fastest orbiting and most massive hot Jupiter. The estimate of the age for this system, based on isochrone fitting, is about 600 Myrs, similar to Hyades and M67. The strong Li absorption contraddicts the trend of Li depletion in planet host stars. It suggests both young age and inefficient mixing in the convective zone. The expected X-ray flux is 2 orders of magnitude higher than the *Chandra* upper limit. The tidal interaction with the planet must have a role in destroying the dynamo efficiency and the overall activity of the star. Tides on WASP-18 are of order of 500 km because of planet proximity and its mass.

Conclusions.

HD 189733 shows many signs of boosted X-ray activity due to magnetic and tidal SPI.

- **high flaring activity is detected in both X-ray and FUV bands after the planetary eclipse,**
- **FUV lines of ions show two increases of profile intensities,**
- **both X-ray and FUV phased variability support MHD simulations of a stream of planetary material flowing onto the star, ahead of the sub-planetary point, under the action of the global magnetic field.**

WASP-18 has a null activity at odds with its young age and rotation. A major role in the tidal SPI with its massive hot Jupiter is recognized to destroy the magnetic dynamo of the star.

SPI can manifest in two opposite ways in systems with different stellar structure and characteristics, enhancing activity in HD 189733 and destroying it in WASP-18.

Bibliography: • Guinan 2013, JAVSO 41, 153 • Kashyap et al. 2008, ApJ 687, 1339 • Mignone et al. 2007, A&A 170, 228 • Pillitteri et al. 2010, ApJ 722, 1216 • Pillitteri et al. 2011, ApJL 741, 18 • Pillitteri et al. 2014, ApJ 785, 145 • Poppenhaeger & Wolk 2014, A&A 565L, 1 • Scharf C. 2010, ApJ 722, 1547 • Shkolnik et al. 2003 ApJ, 597, 1092 • Shkolnik et al. 2005 ApJ, 622, 1075 • Shkolnik et al. 2008 ApJ, 676, 628 • Walker et al. 2008 A&A 482, 691