X-ray Observations of Hot Jupiters

Scott J. Wolk
I. Pillitteri, O. Cohen, V. Kashyap,
C. Lisse, J. Drake
What is Star Planet Interaction?

Cuntz et al. 2000

Rotational Synchronization

Yes?

$t_{\text{syn}} < t_{\text{age}}$?

Tidal Interaction

Planet

Magnetic Interaction

Star

Increase Dynamo Activity

Cuntz et al. 2000
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 $\rightarrow$ atmospheric expansion (Lammier et al. 2003)
  – X-Ray flux $\rightarrow$ photochemistry changing the thermal budget (Laing et al. 2004; Burrows et al. 2008)

• ...Exoplanets may effect their host stars.

• Analytic Studies show $\rightarrow F_{\text{reco}} \propto a_p^{-3}$ (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?

HD 189733b 1G
(1/2 Jupiter)

HD 189733 40G
(Fares et al. 2010)
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. (Poppenhäuser et al. 2010, 2011)
Evidence of SPI - HD 189733

<table>
<thead>
<tr>
<th>Type</th>
<th>HD 189733A</th>
<th>HD 189733b</th>
<th>HD 189733B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>K 1.5V</td>
<td>planet</td>
<td>M4V</td>
</tr>
<tr>
<td>Mass</td>
<td>$0.81M_{\odot}$</td>
<td>$1.15M_{\text{jup}}$</td>
<td>$0.2M_{\odot}$</td>
</tr>
<tr>
<td>Radius</td>
<td>$0.76R_{\odot}$</td>
<td>$1.26R_{\text{jup}}$</td>
<td>–</td>
</tr>
<tr>
<td>Orbital Period</td>
<td>–</td>
<td>$2.219d$</td>
<td>$3200yr$</td>
</tr>
<tr>
<td>Mean orbital radius</td>
<td>–</td>
<td>$0.003$ AU</td>
<td>$216$ AU</td>
</tr>
</tbody>
</table>

- At a distance of 19.3 pc it is one of the closest transiting planets.
- Somewhat X-ray active ($L_{x} \sim 10L_{x\odot}$)
  - 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)
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
Are the 2009 and 2011 eclipses similar?

Smoothed lightcurves
Tantalizing evidence
more blue shifted Oxygen lines?

May 2009

RGS1 - pre flare

RGS1 - flare

RGS1 - post flare

May 2011

RGS1 - pre flare

RGS1 - flare

RGS1 - post flare
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
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° 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.