Star-Planet Interactions:
State of the field and open questions

Dr Aline A. Vidotto
Royal Astronomical Society Fellow
University of St Andrews, UK
Which ‘interaction’ are we talking about?

- star-planet interaction → observable signatures on the star
  - tidal interaction
  - magnetic-magnetic interaction (needs to be sufficiently close-in)
- *stellar wind*-planet interaction → observable signatures on the planet
  - planetary radio emission (magnetic-magnetic interaction and/or kinetic-magnetic interaction)
  - formation of “sideways” bow shocks
  - planetary migration
- *radiative* SPI (?) → observable signatures on the planet
  - photo-evaporation of planetary atmosphere
  - inflated planets
Star-HJ Interaction $\rightarrow$ stellar activity enhancement

- Tidal interactions
  - only if $P_{\text{orb}} \neq P_{\text{rot}}$
  - expansion/contraction bulges $\rightarrow$ waves $\rightarrow$ non-radiative energy $\rightarrow$ enhanced heating, stellar activity

- Magnetospheric interactions
  - Magnetic interaction $\rightarrow$ enhanced heating, stellar activity
Star-HJ Interaction → stellar activity enhancement

- Notes:
  - activity signatures should be modulated by orbital period $P_{\text{orb}}$ or by beat period: $(1/P_{\text{orb}} - 1/P_{\text{rot}})^{-1}$.
  - largest effects for close-in planets
- stellar magnetic field: non-axisymmetric → phase lead in activity signal, largest effects with anti-parallel fields
  - important to characterise $B_{\text{star}}$. Only doable for bright, “fast” rotating stars.
- temporal variability → occasional detections (on/off)
  - multi-wavelength/technique observations: optical, X-ray, polarimetry,?
  - long-term monitoring?
  - best targets: orbiting inside the Alfvén surface (information can only travel upstream) → realistic stellar wind models (need to know the star)
Stellar wind-HJ interaction

• Planetary radio emission

• Planetary migration caused by wind torques on planets: perhaps important at early phases

• “Sideways” bow shock (absorption @ near-UV)

→ Need to understand stellar winds: challenging for low mass stars.

→ Solar wind scaling to other stars: is it a valid approach?

→ Interactions also affected by temporal variability. Best way to deal with that?
Extra slides
Fares et al 2010 - HD189733 (Jun/07)
Bow shocks around exoplanets: measuring planetary magnetic fields

Aline Vidotto (St Andrews)
M. Jardine, Ch. Helling, J. Llama, K. Wood (St Andrews)
L. Fossati (AlfA, Bonn)
C. Haswell (Milton Keynes)
Interaction between stellar wind and planetary magnetic field causes bow shock
Motivation: near-UV transit of WASP-12b

Light curve asymmetry = asymmetric distribution of material

Early ingress in the near-UV

No late egress in the near-UV
Transit technique: detection of exoplanets
Transit at near-UV: bow shock detection

Vidotto, Jardine & Helling 10

$\Delta \phi$

$B_{\text{planet}}$

$r_M$

Flux

Phase

optical

near-UV
Stellar wind-planet interactions in the near-UV

- **WASP-12b**: Hot-Jupiter with a 26 hour orbital period, ~1.83 times larger than Jupiter (Hebb+2009).

- **Early ingress**: Near-UV transit asymmetry in WASP-12b found by HST (Fossati+10).

- Potential detection of a magnetospheric bow shock (Vidotto+10) $\Rightarrow B_{\text{planet}} \approx 24G$.

- Modelled a simple bow shock using radiative transfer simulations and fit the data (Llama+11).
Stellar wind - planet interactions
Stellar wind - planet interactions

\[ \theta_0 = \arctan \left( \frac{u_{\text{wind},r}}{u_{\text{planet}} - u_{\text{wind},\varphi}} \right) \]
Stellar wind - planet interactions

\[ \frac{r_M}{R_P} = \left[ \frac{(B_{\text{planet}}/2)^2}{8\pi \left( \rho_{\text{wind}} \Delta u_{\text{wind}}^2 + \rho_{\text{wind}} \right) + B_{\text{wind}}^2} \right]^{1/6} \]
Wind modelling of HD189733

(Llama, Vidotto+ 13, submitted)

From observations (Fares+2010)

Simulated topology

Density @ planetary orbit

June/07

July/08
Predicted UV transit variations

HD189733: June/07
Density @ planetary orbit

assumption: $B_{\text{planet}} \approx B_{\text{jupiter}}$

(Llama, Vidotto+ 13, submitted)
Predicted UV transit variations

June 2007

July 2008
Predicted UV transit variations

• Confirmation that transits are variable: local stellar wind conditions around the planet influence the transit timing and depth (Vidotto, Jardine & Helling 11b).

• Repeated observations: allow us to study the varying environment around the planet.

• Simultaneous, multi-λ campaign: radio, X-ray, UV, spectropolarimetric observations → better description of the system

![Graphs showing predicted UV transit variations for June 2007 and July 2008.](image-url)