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

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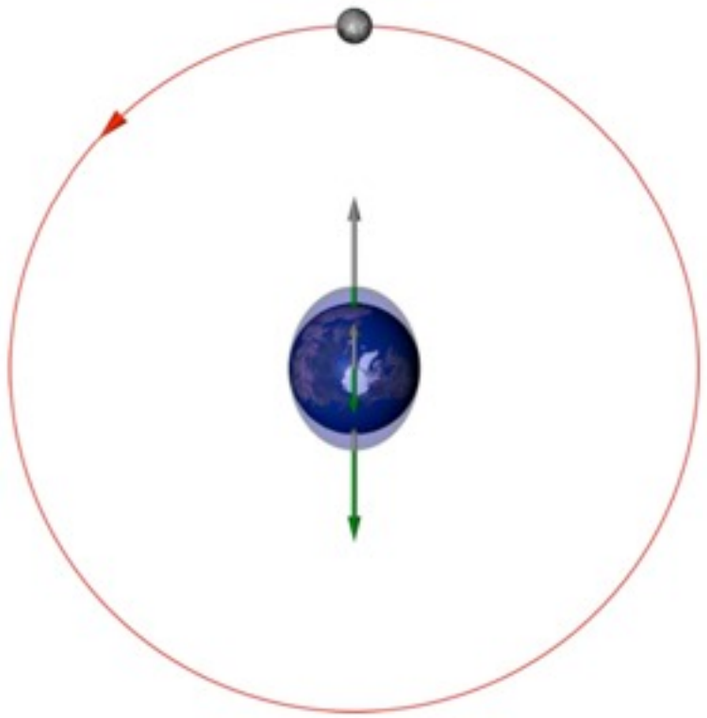
Which ‘interaction’ are we talking about?

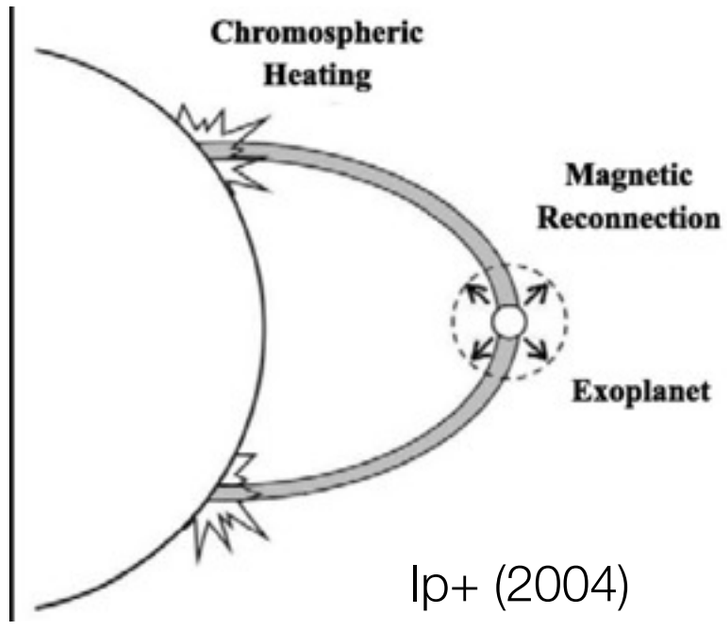
- star-planet interaction → observable signatures on the star
  - tidal interaction
  - magnetic-magnetic interaction (needs to be sufficiently close-in)
- *stellar wind*-planet interaction → observable signatures on the planet
  - planetary radio emission (magnetic-magnetic interaction and/or kinetic-magnetic 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 → stellar activity enhancement

- Tidal interactions



- Magnetospheric interactions



Ip+ (2004)

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

- Magnetic interaction → enhanced heating, stellar activity

Star-HJ Interaction → stellar activity enhancement

- Notes:
  - activity signatures should be modulated by orbital period P_{orb} or by beat period: $(1/P_{orb}-1/P_{rot})^{-1}$.
  - 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_{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 Alfven surface (information can only travel upstream) → realistic stellar wind models (need to know the star)

Stellar wind-HJ interaction

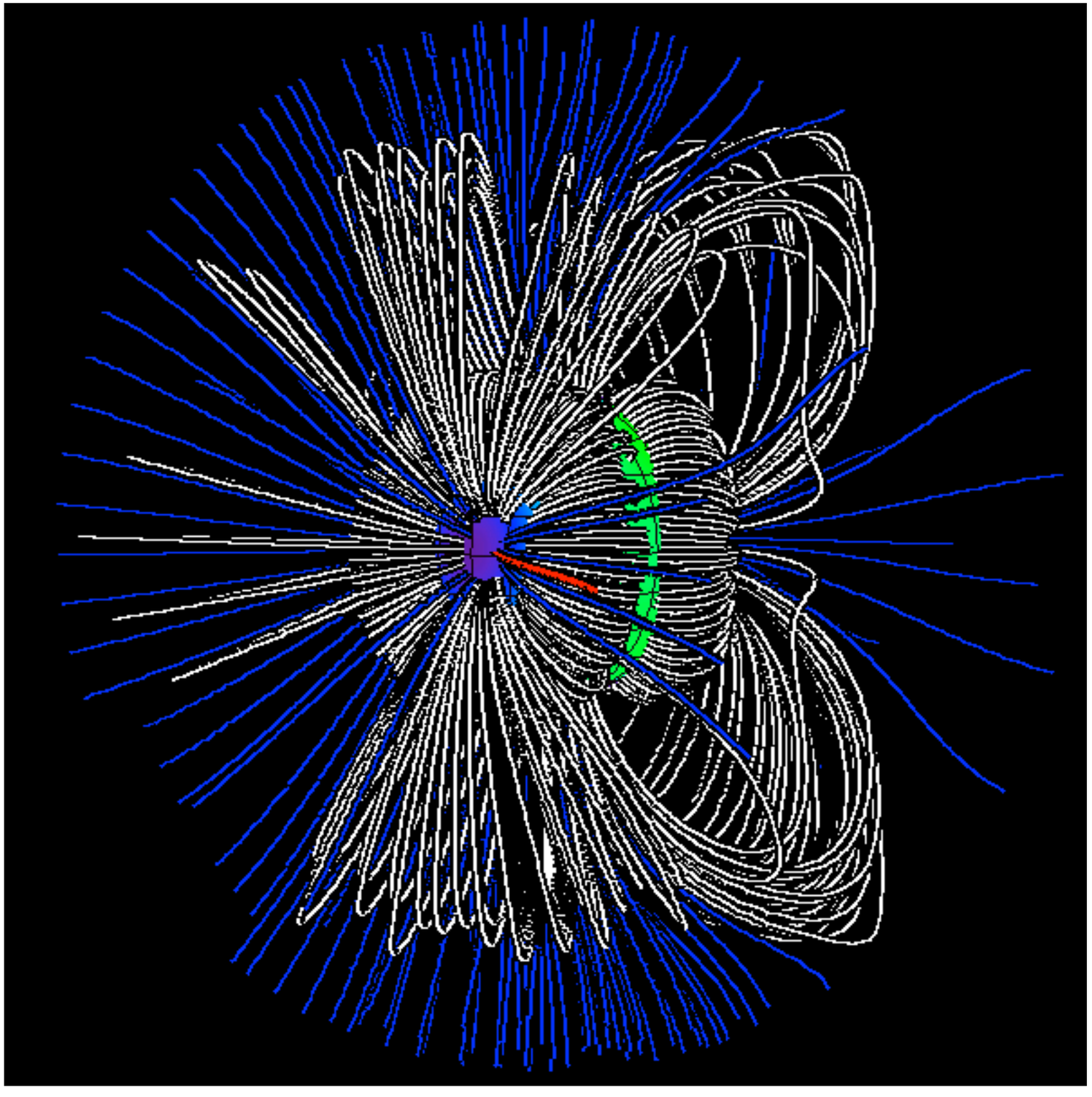
- Planetary radio emission
- Planetary migration caused by wind torques on planets: perhaps important at early phases
- “Sideways” bow shock (absorption @ near-UV)

➡ 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?

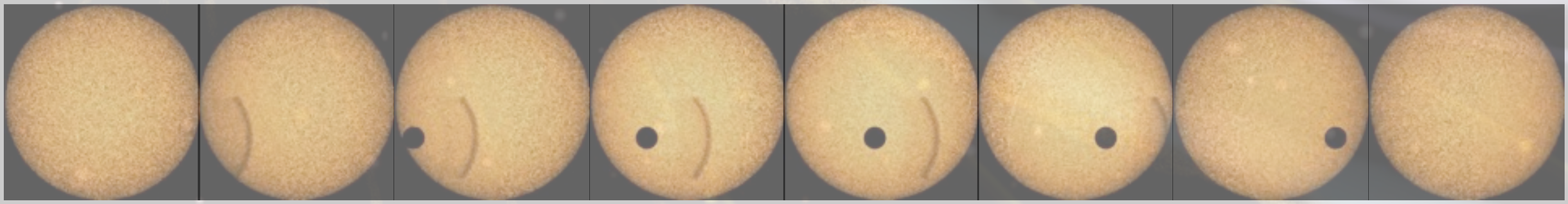
Extra slides



Fares et al 2010 - HD189733 (Jun/07)

Bow shocks around exoplanets: measuring planetary magnetic fields

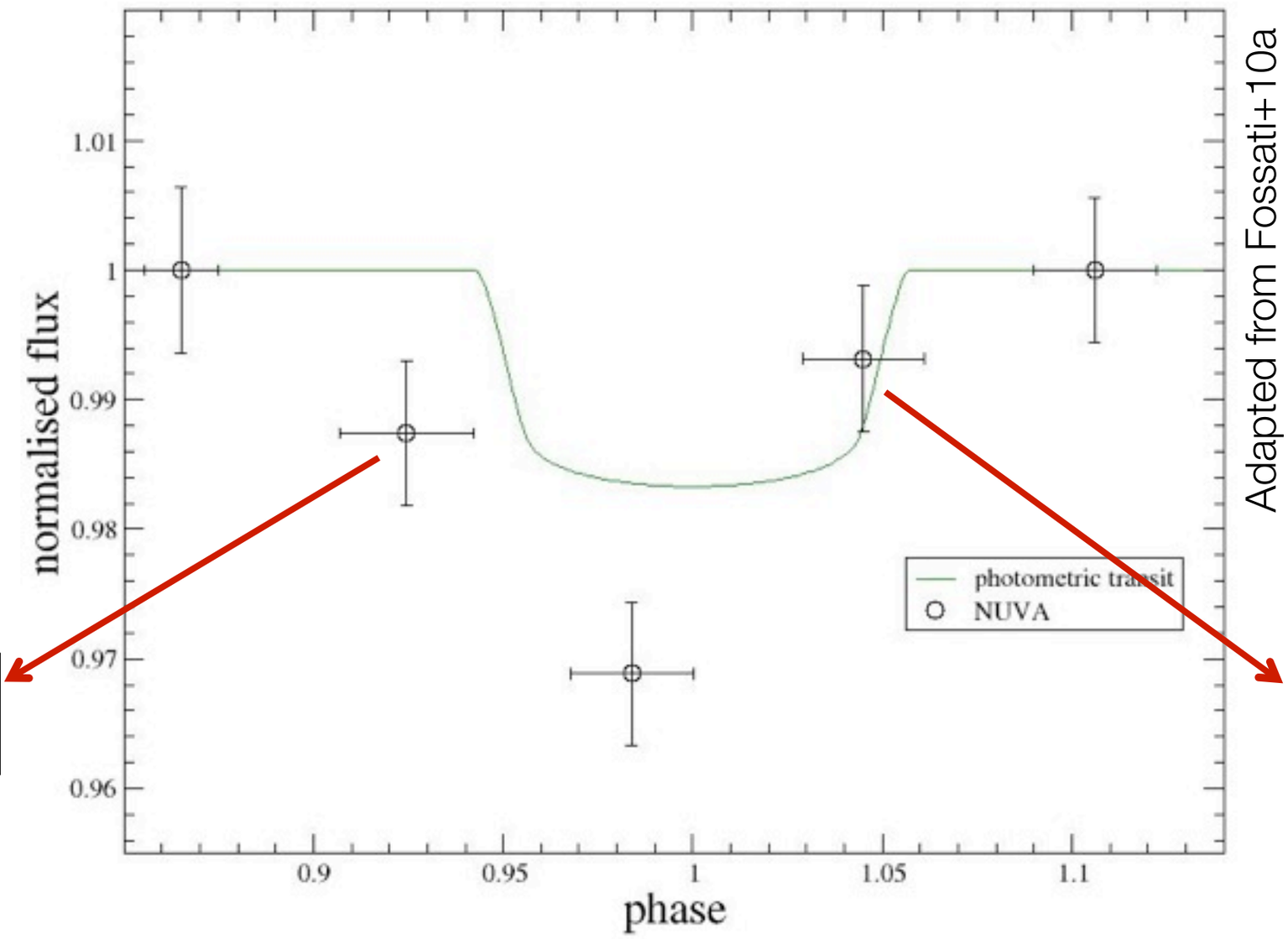
Aline Vidotto (St Andrews)
M. Jardine, Ch. Helling, J. Llama, K. Wood (St Andrews)
L. Fossati (AlfA, Bonn)
C. Haswell (Milton Keynes)



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

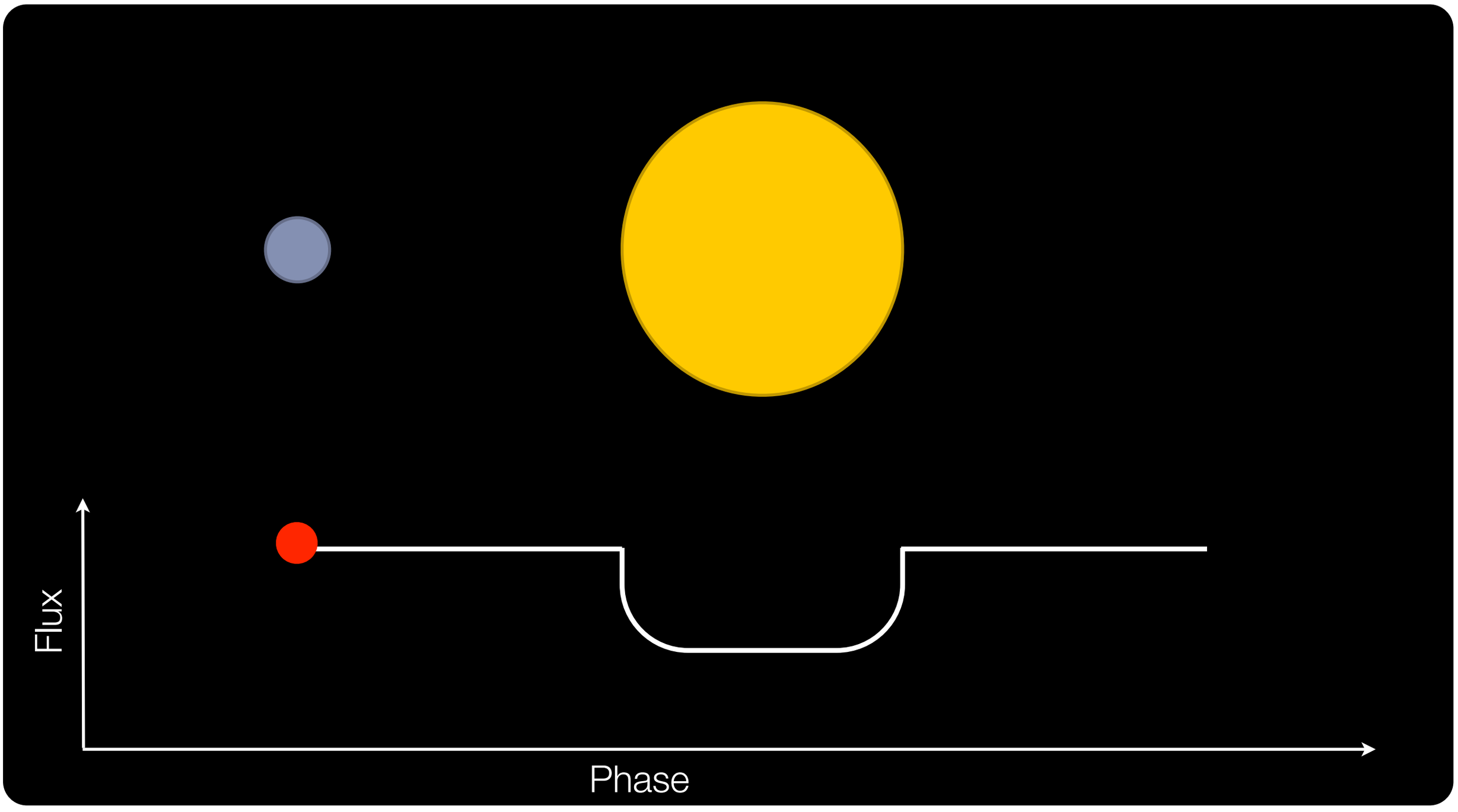


Adapted from Fossati+10a

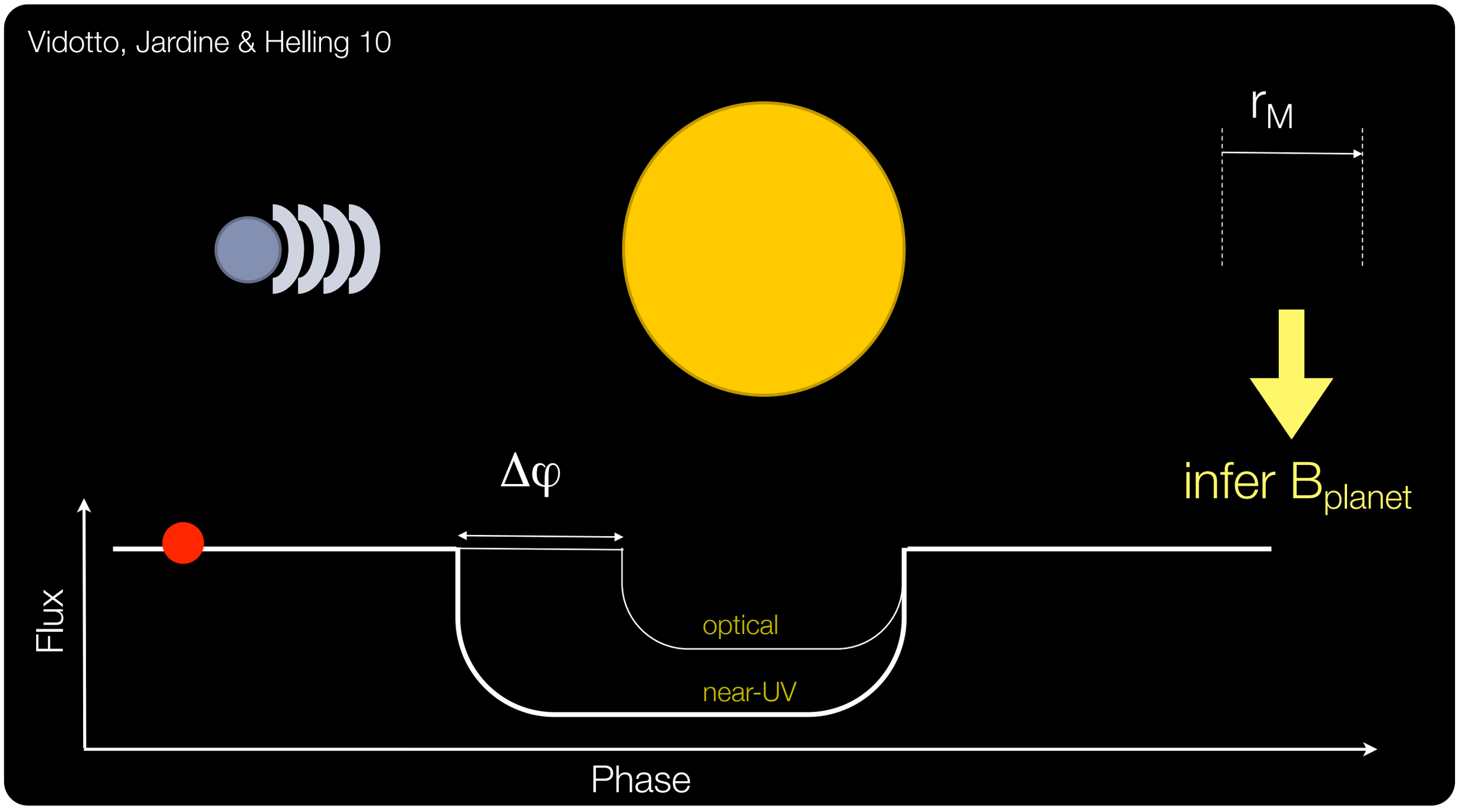
Early ingress in the near-UV

No late egress in the near-UV

Transit technique: detection of exoplanets

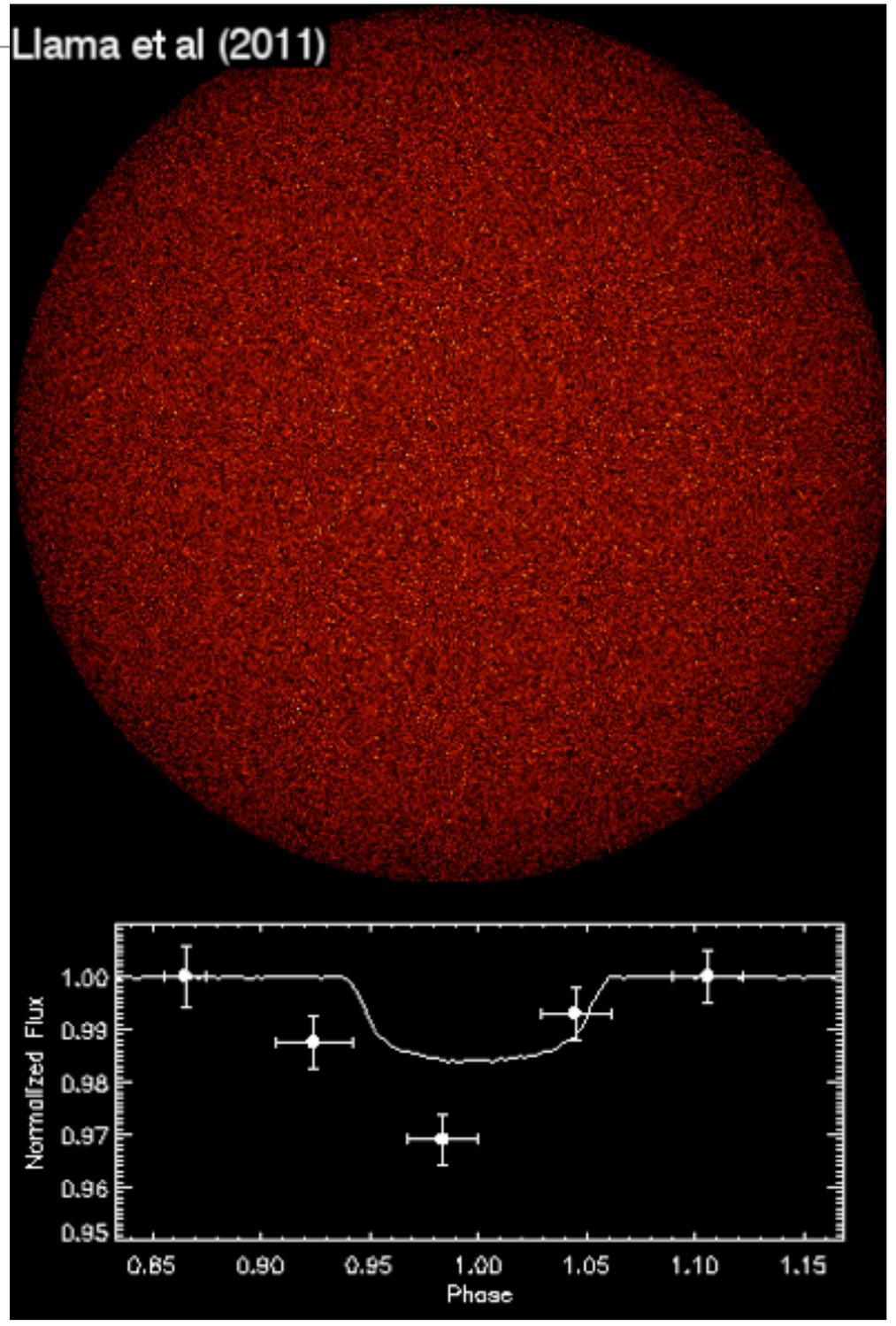


Transit at near-UV: bow shock detection

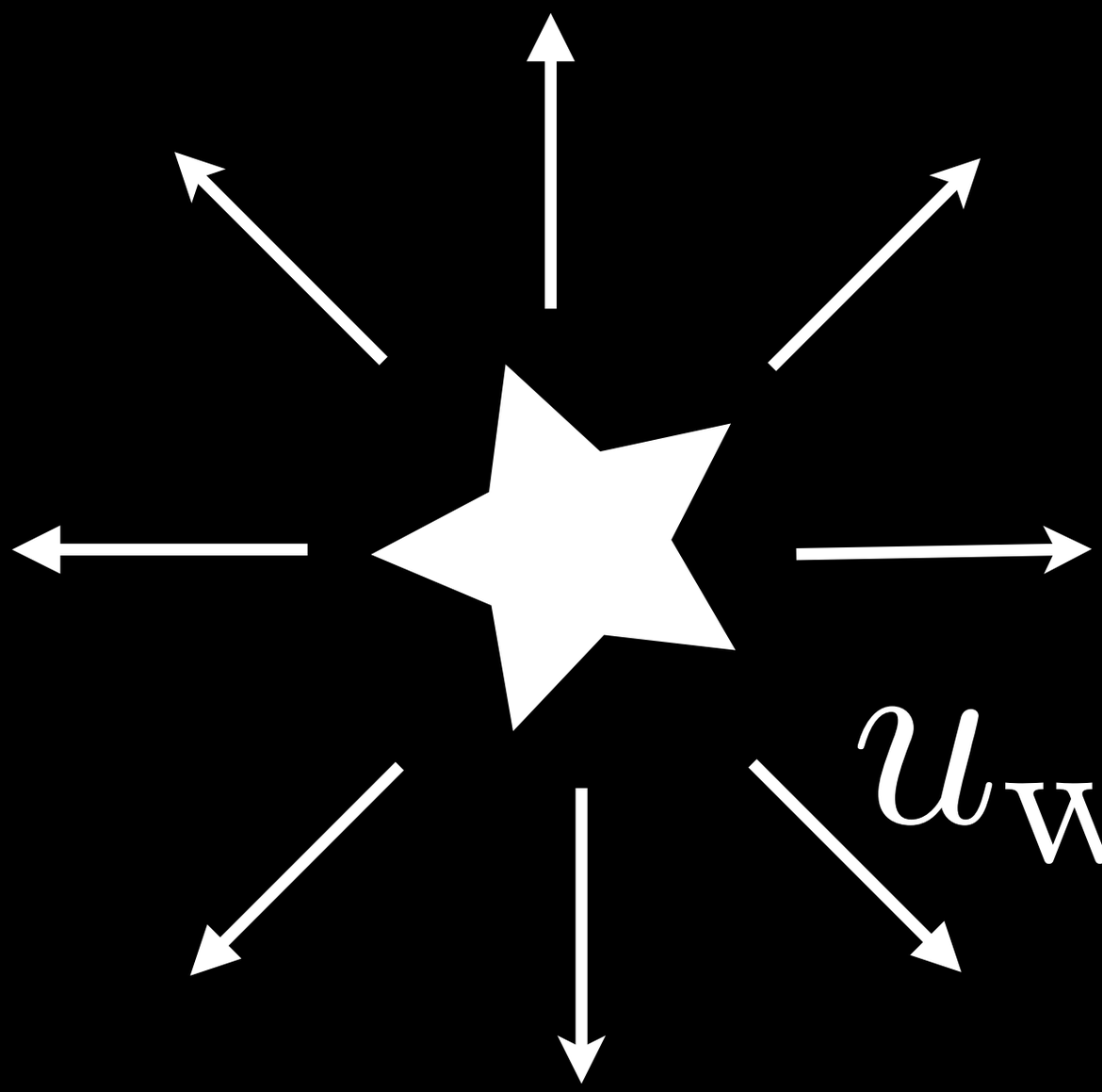


Stellar wind-planet interactions in the near-UV

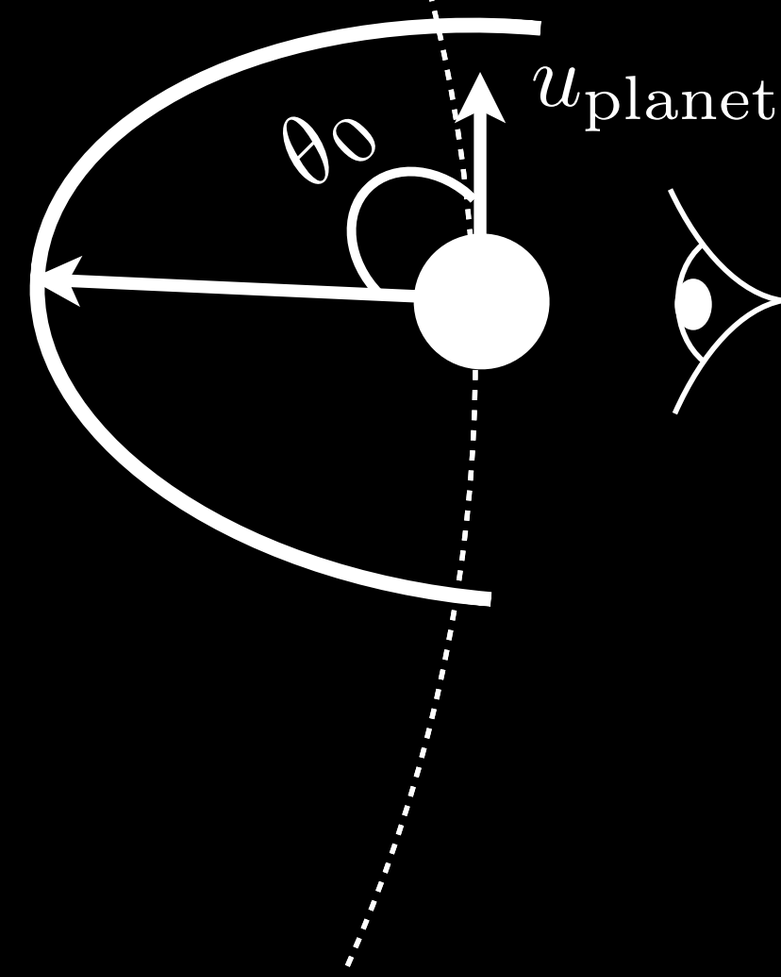
- WASP-12b: Hot-Jupiter with a 26 hour orbital period, ~1.83 times larger than Jupiter (Hebb+2009).
- Early ingress: Near-UV transit asymmetry in WASP-12b found by HST (Fossati+10).
- Potential detection of a magnetospheric bow shock (Vidotto+10) → $B_{planet} \lesssim 24G$.
- Modelled a simple bow shock using radiative transfer simulations and fit the data (Llama+11).



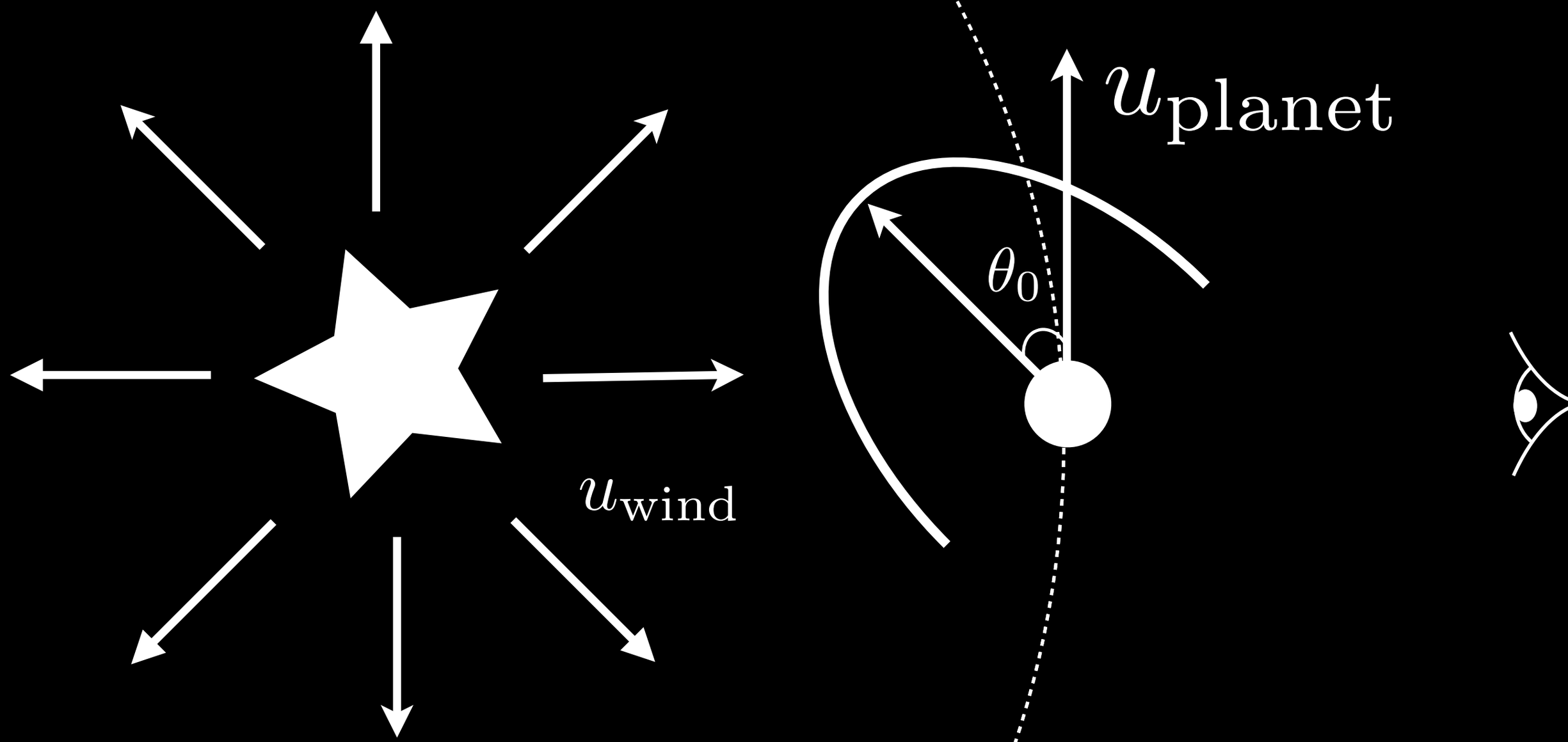
Stellar wind - planet interactions



u_{wind}

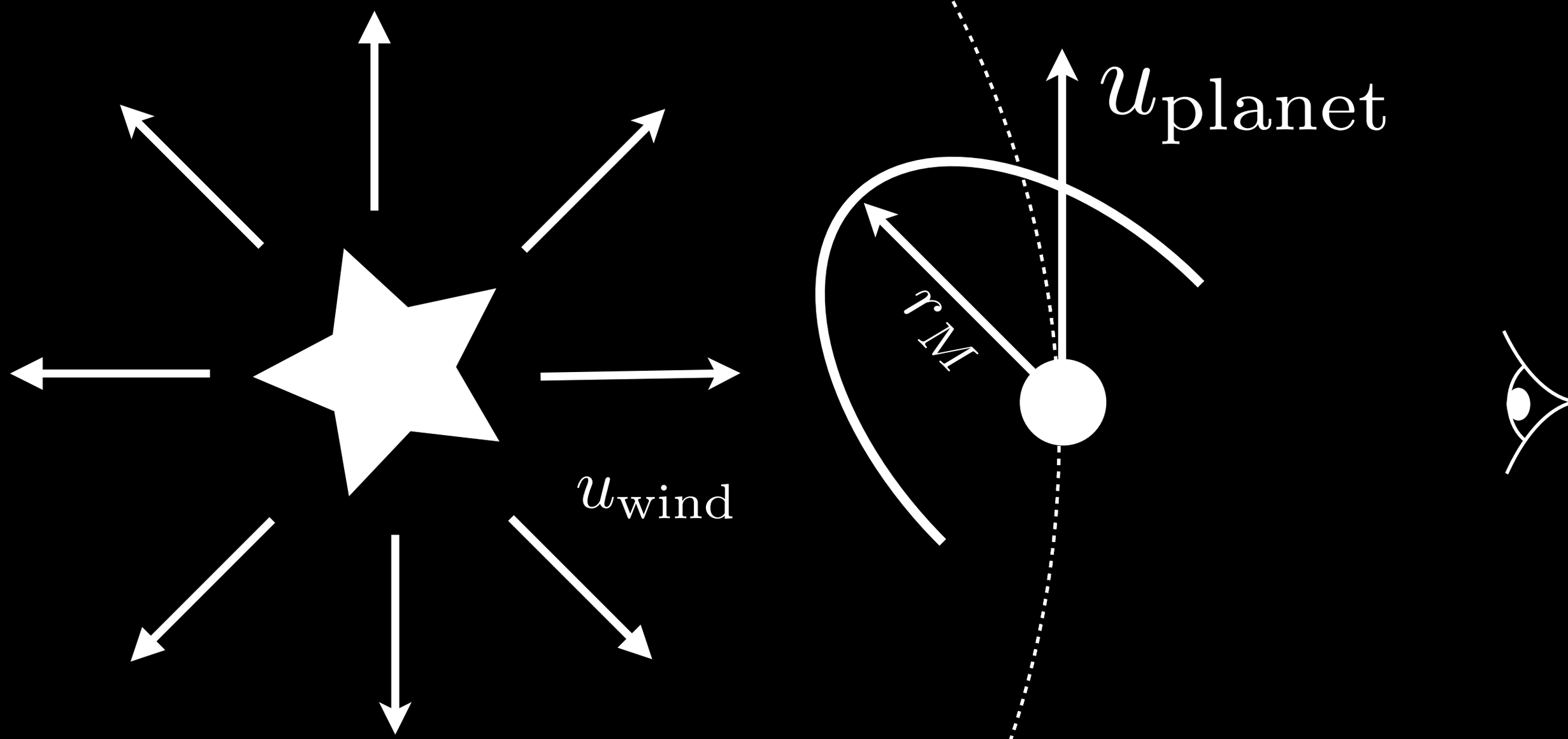


Stellar wind - planet interactions



$$\theta_0 = \arctan\left(\frac{u_{\mathrm{wind,r}}}{u_{\mathrm{planet}} - u_{\mathrm{wind},\varphi}}\right)$$

Stellar wind - planet interactions



$$\frac{r_M}{R_P} = \left[\frac{(B_{\mathrm{planet}}/2)^2}{8\pi(\rho_{\mathrm{wind}}\Delta u^2_{\mathrm{wind}} + p_{\mathrm{wind}}) + B^2_{\mathrm{wind}}} \right]^{1/6}$$

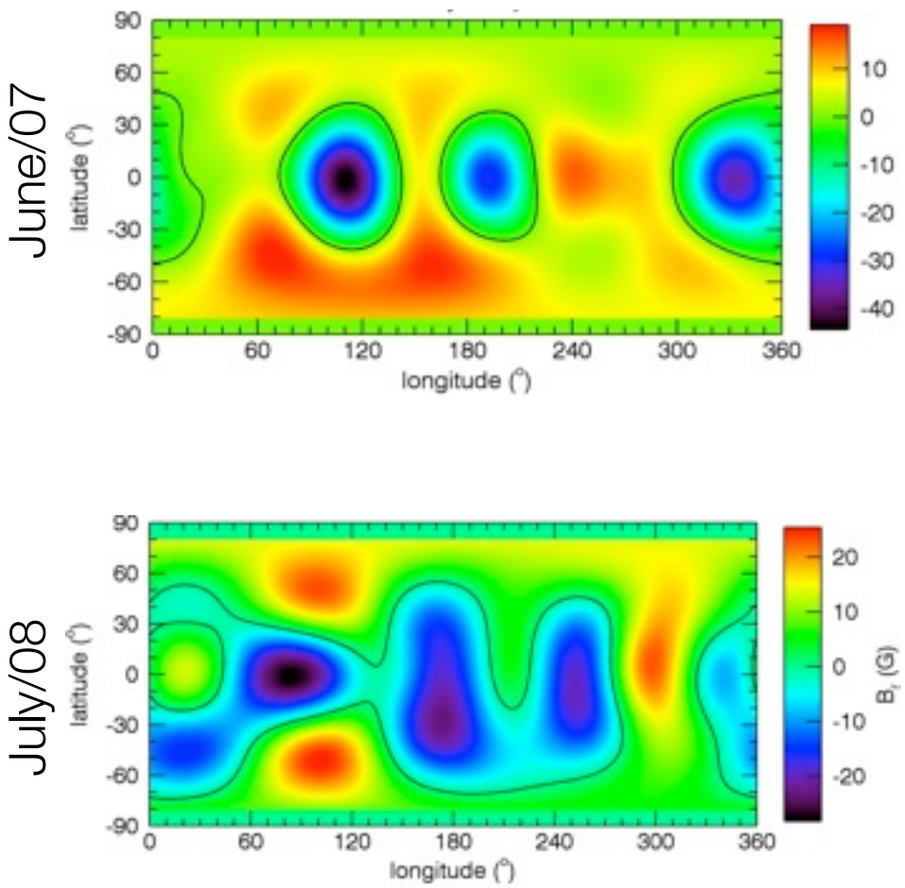
Wind modelling of HD189733

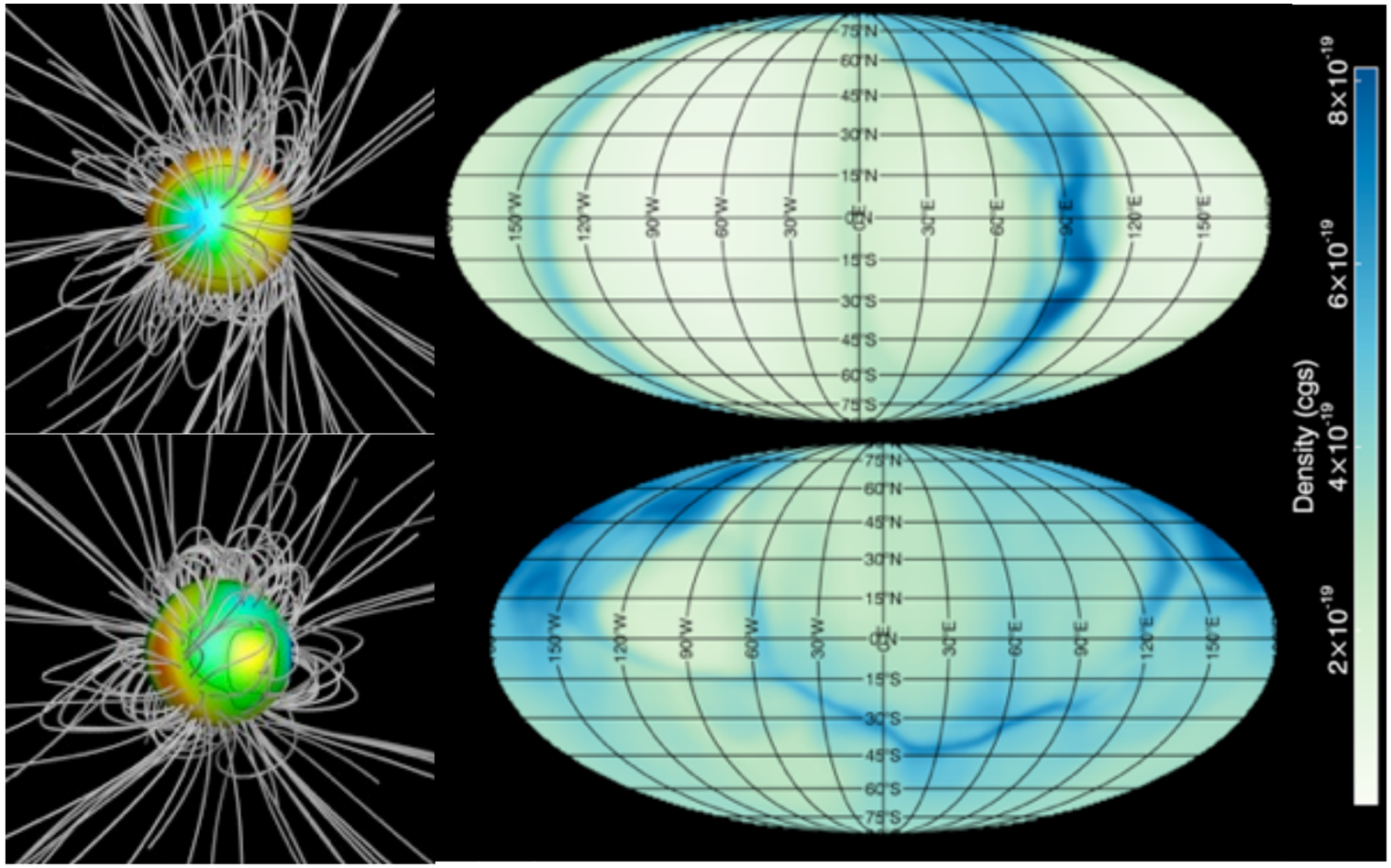
(Llama, Vidotto+ 13, submitted)

From observations
(Fares+2010)

Simulated topology

Density @ planetary orbit

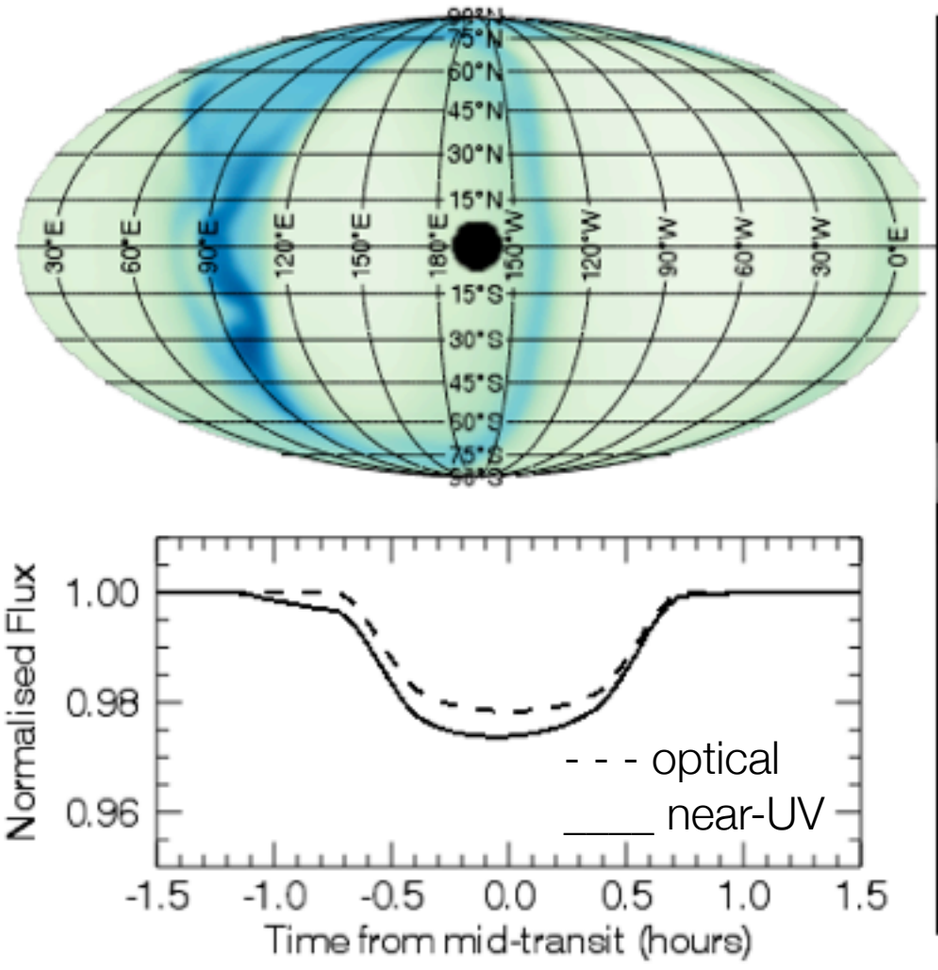




Predicted UV transit variations

HD189733: June/07
Density @ planetary orbit

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

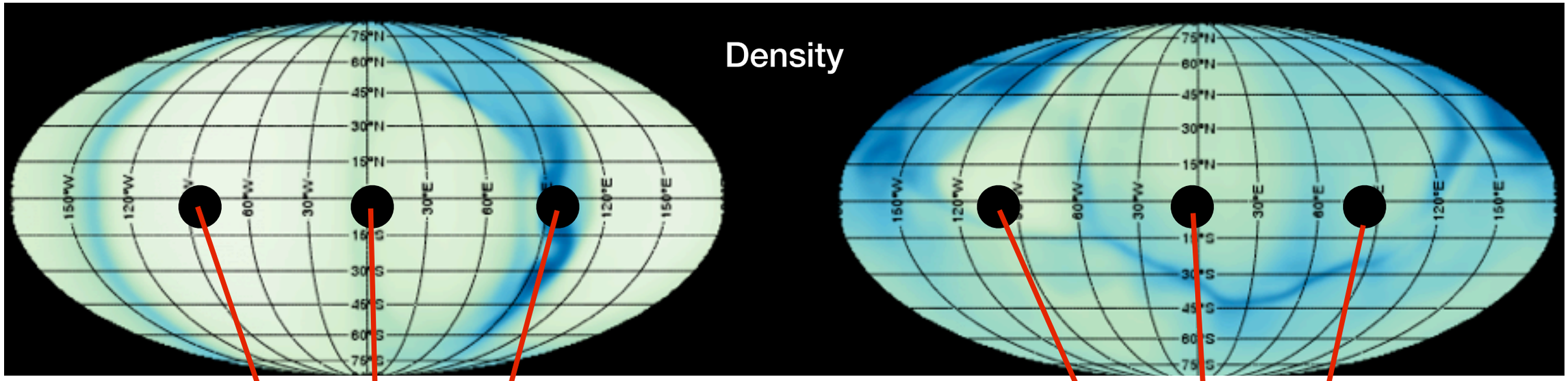


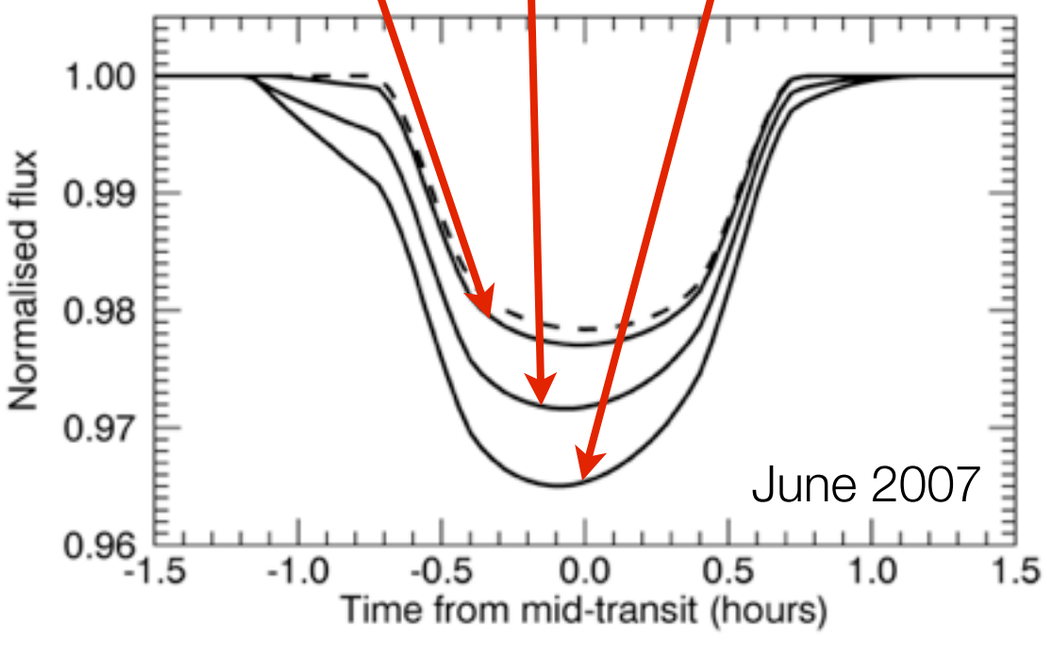
(Llama, Vidotto+ 13, submitted)

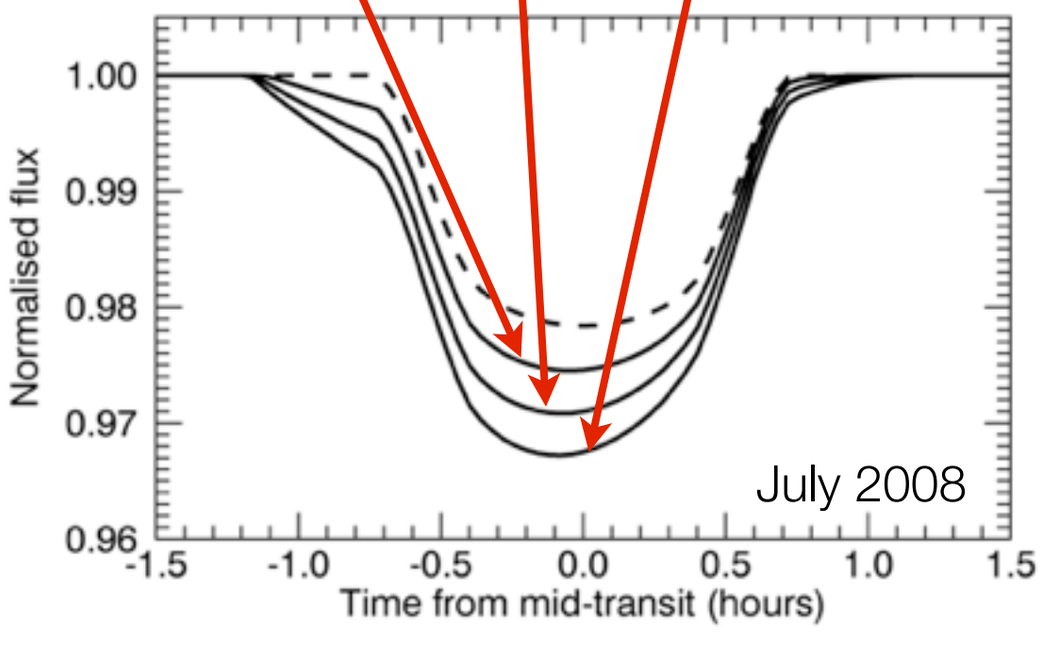
Predicted UV transit variations

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