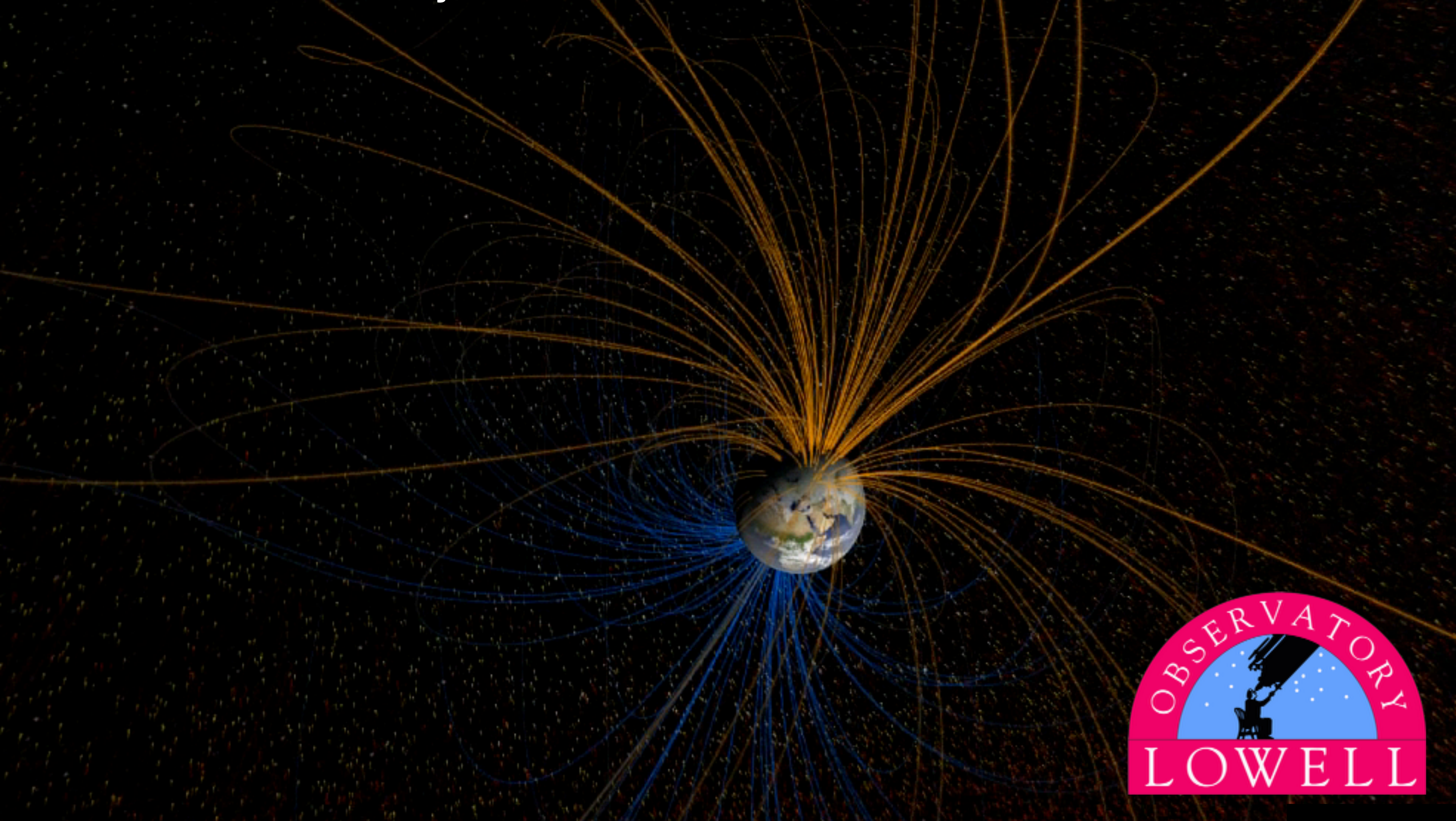
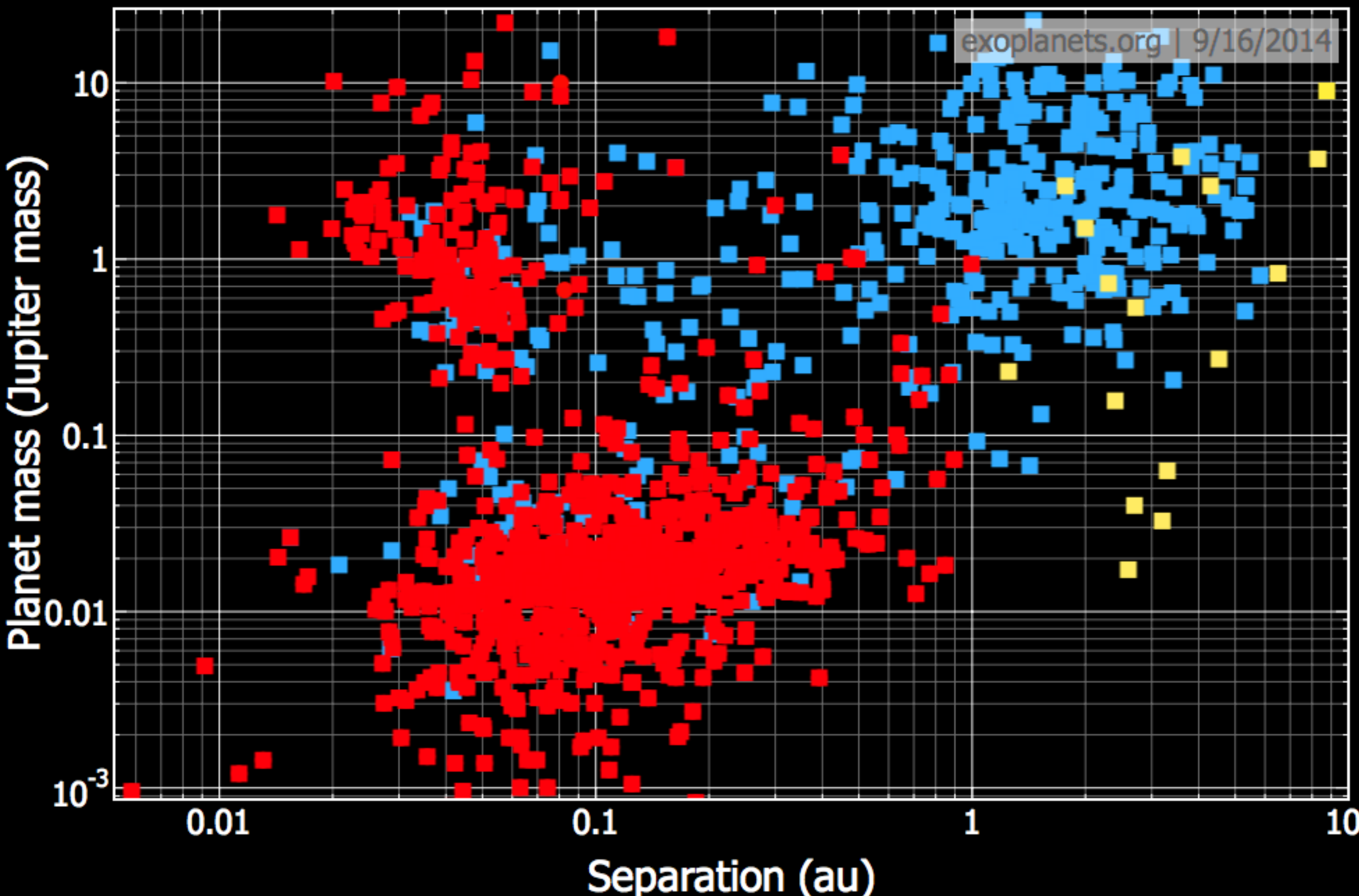
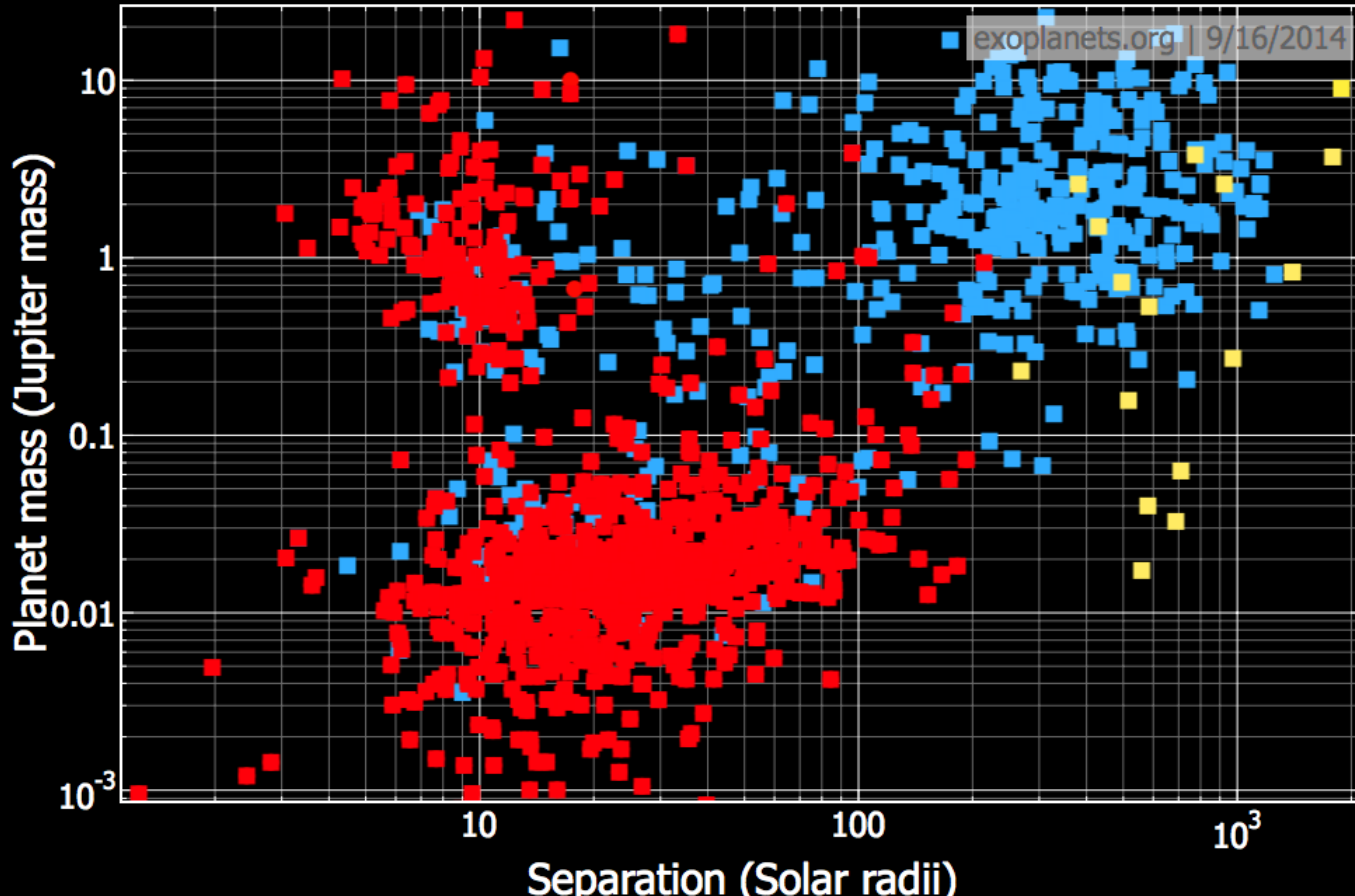
Detecting Exoplanetary Magnetic Fields

Joe Llama
joe.llama@lowell.edu

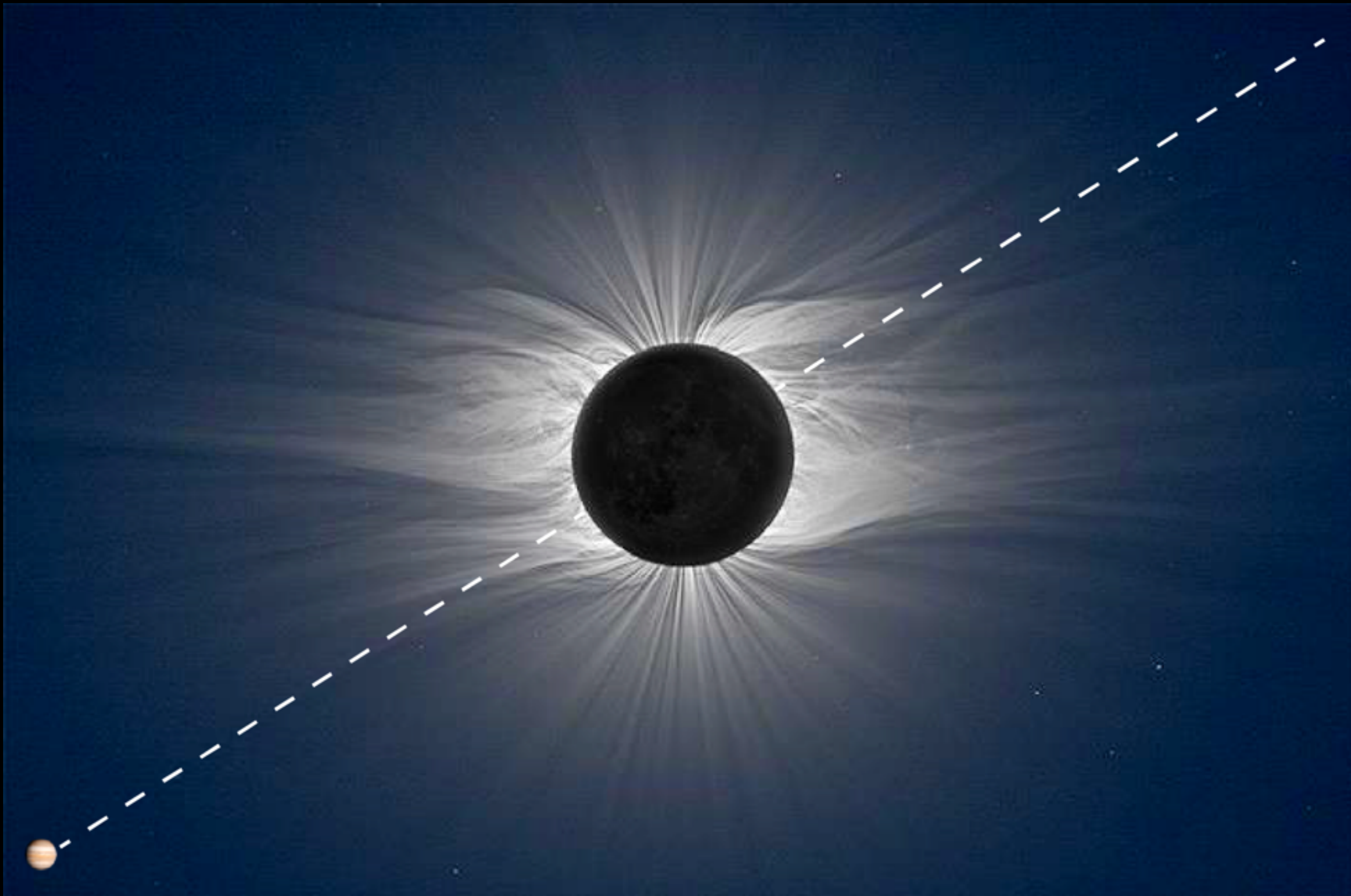


LOWELL OBSERVATORY


exoplanets.org | 9/16/2014
Planet mass (Jupiter mass)
10
1
0.1
0.01
10^-3
0.01
0.1
1
10
Separation (au)

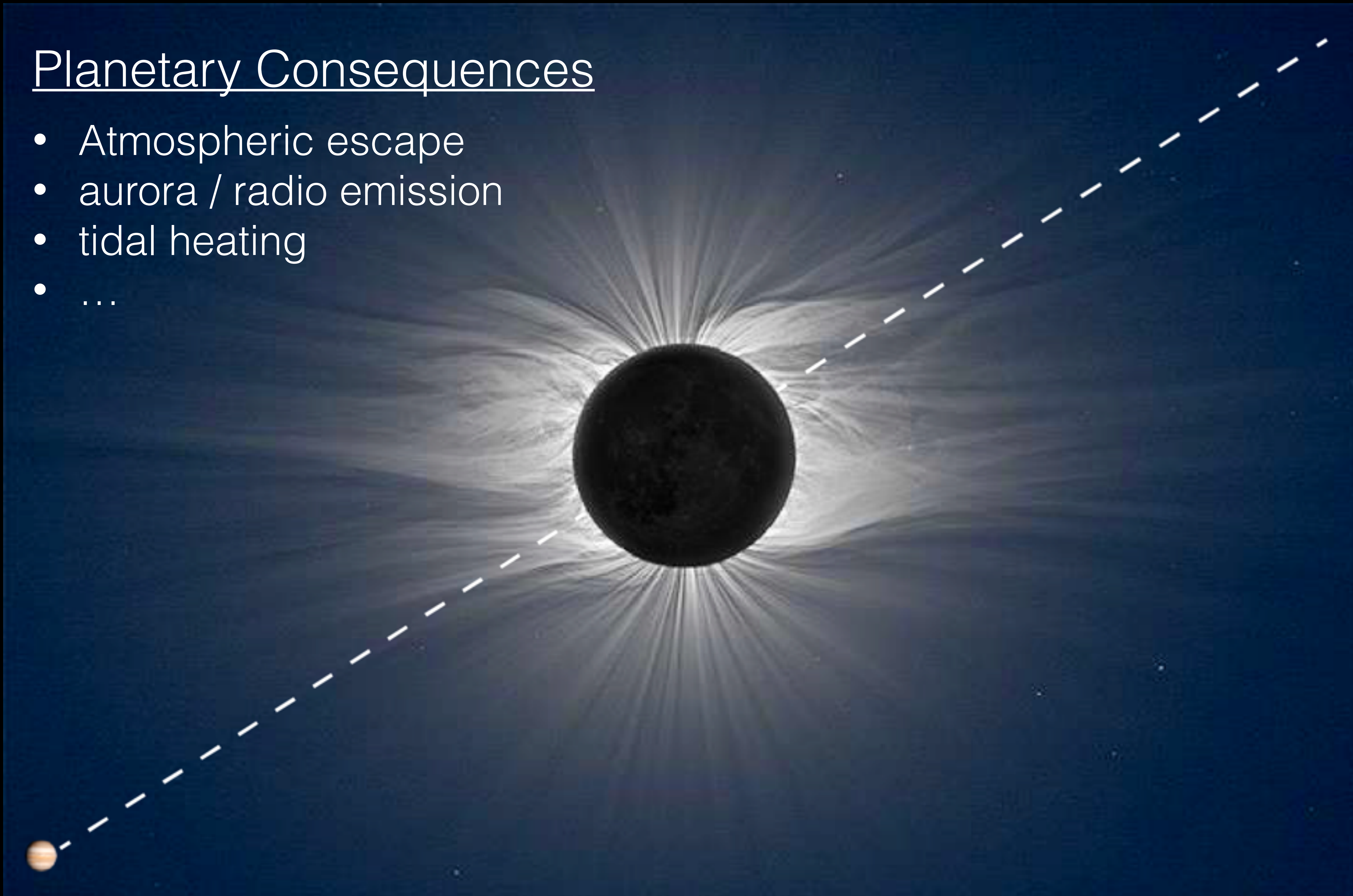


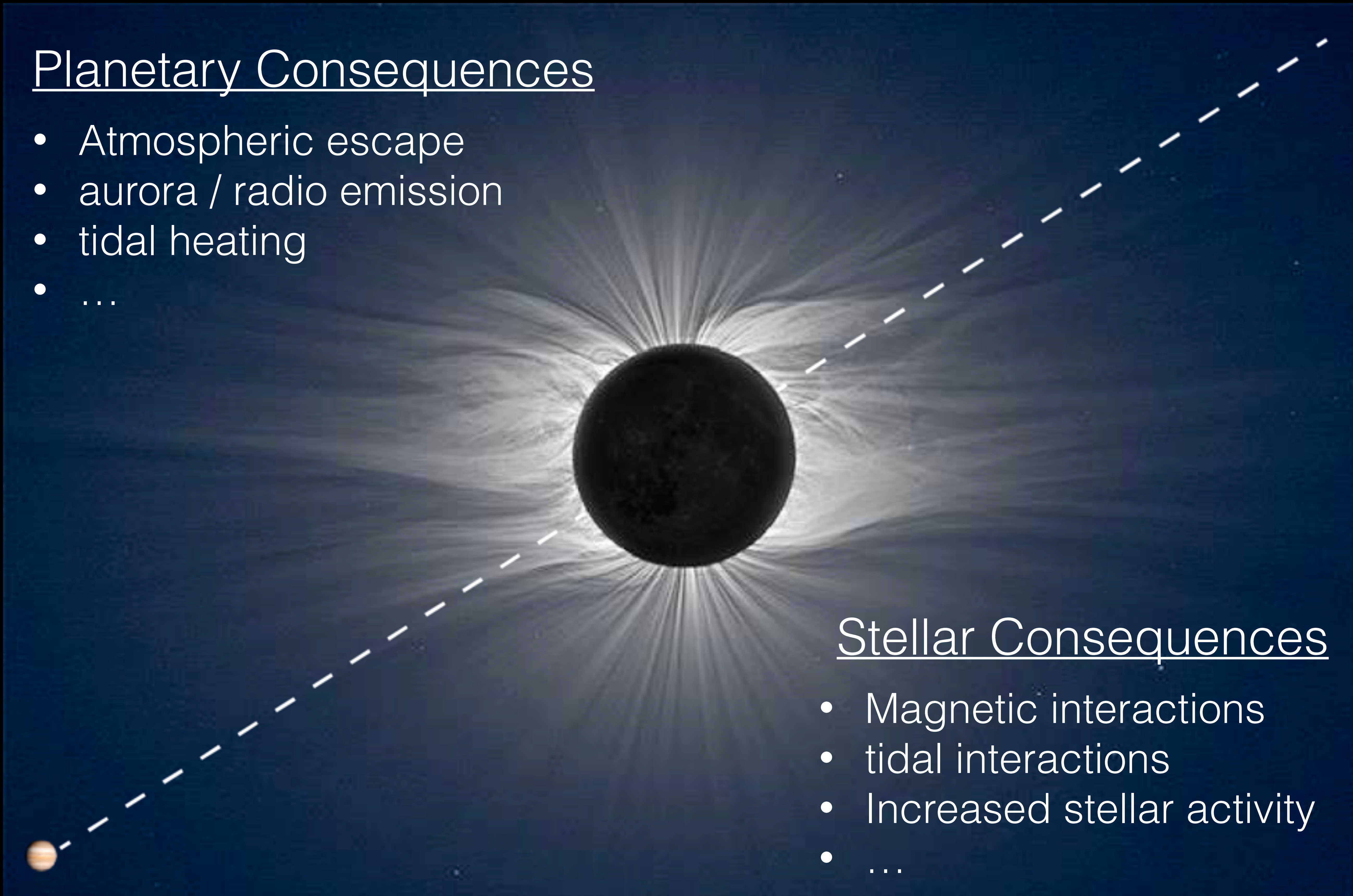
exoplanets.org | 9/16/2014
Planet mass (Jupiter mass)
10
1
0.1
0.01
10^{-3}
Separation (Solar radii)
10
100
10^{3}

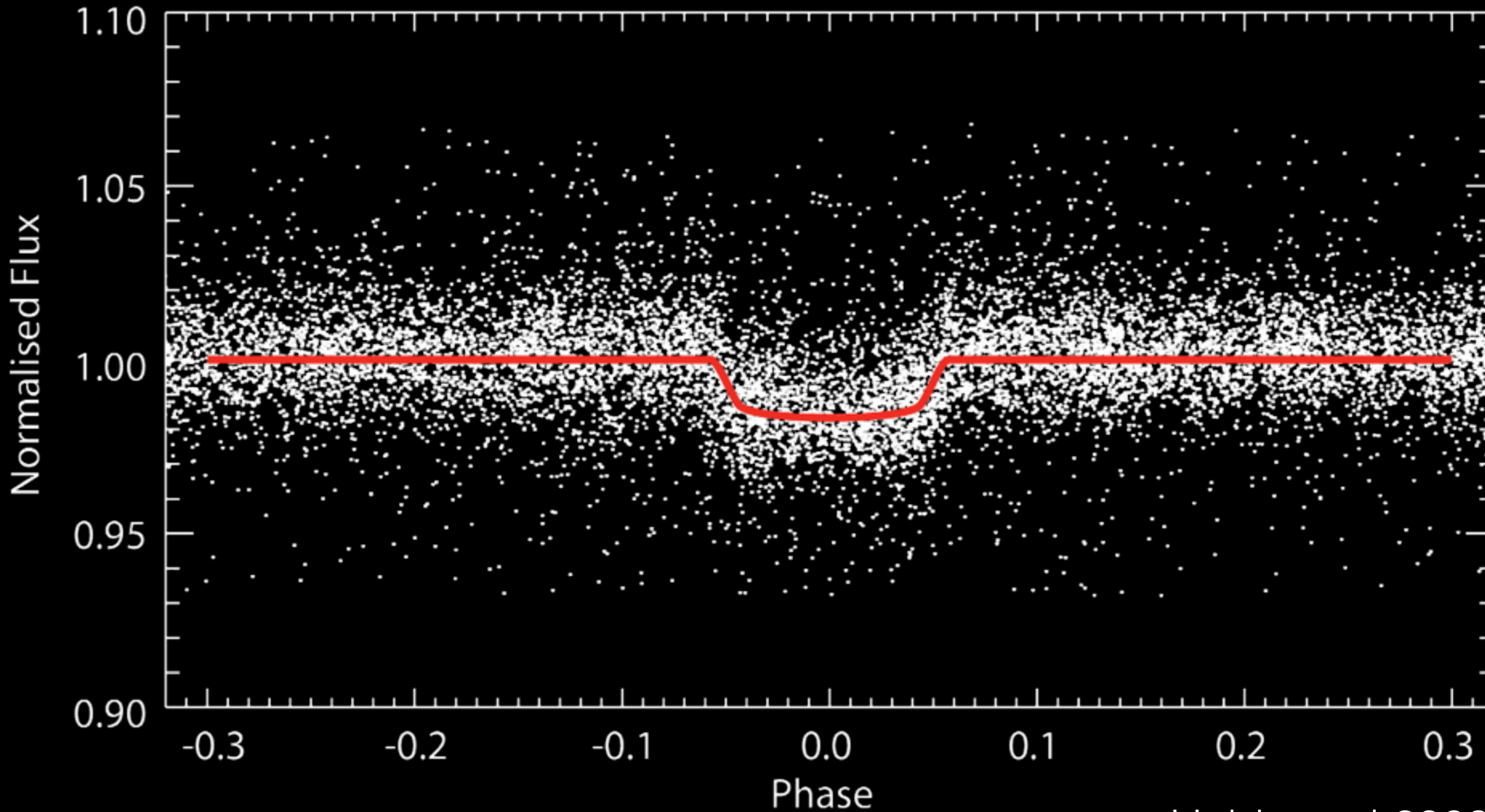


Planetary Consequences

- Atmospheric escape
- aurora / radio emission
- tidal heating
- …



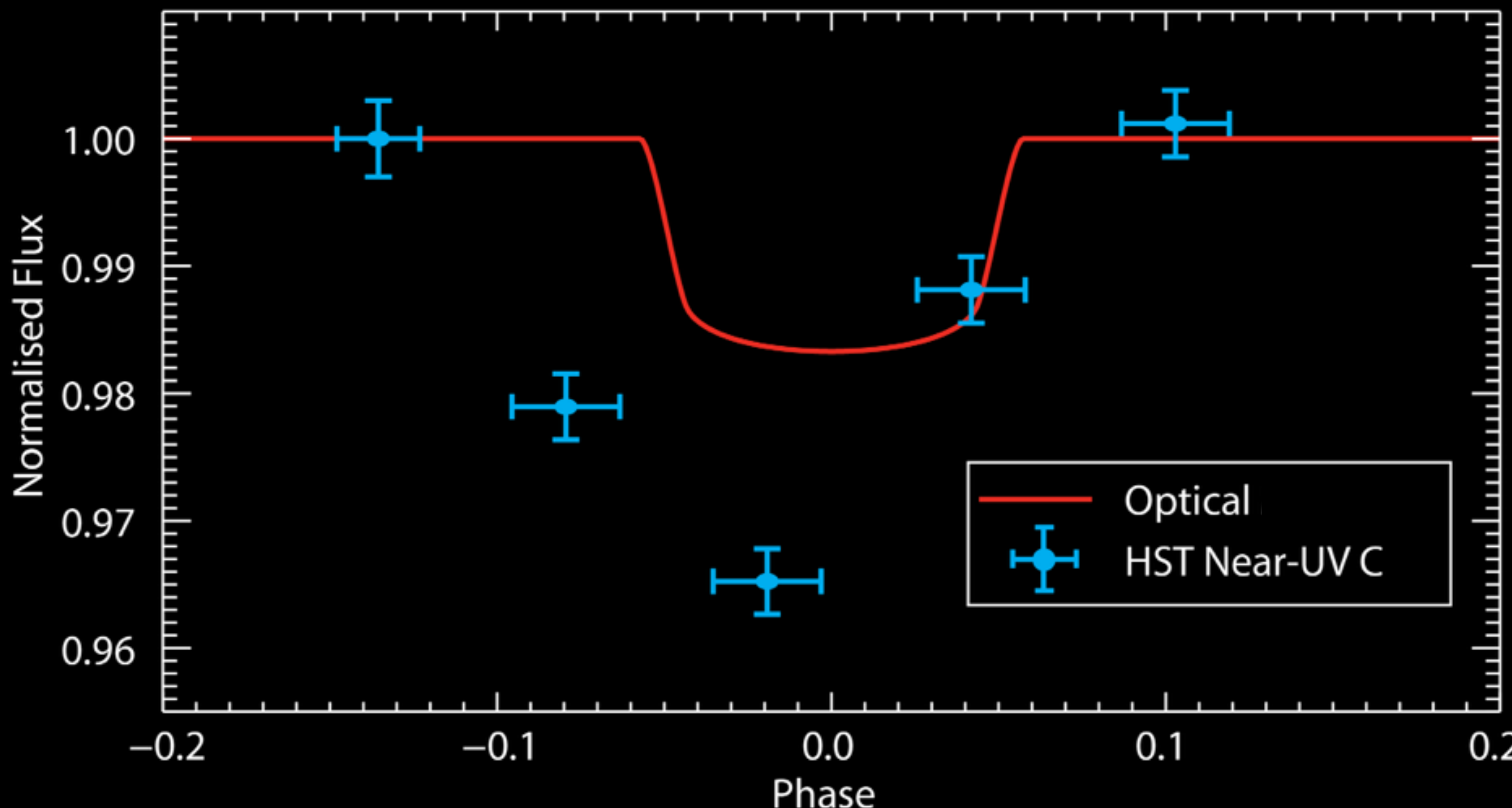

Planetary Consequences
• Atmospheric escape
• aurora / radio emission
• tidal heating
• …
Stellar Consequences
• Magnetic interactions
• tidal interactions
• Increased stellar activity
• …



Hebb et al 2009

WASP-12b

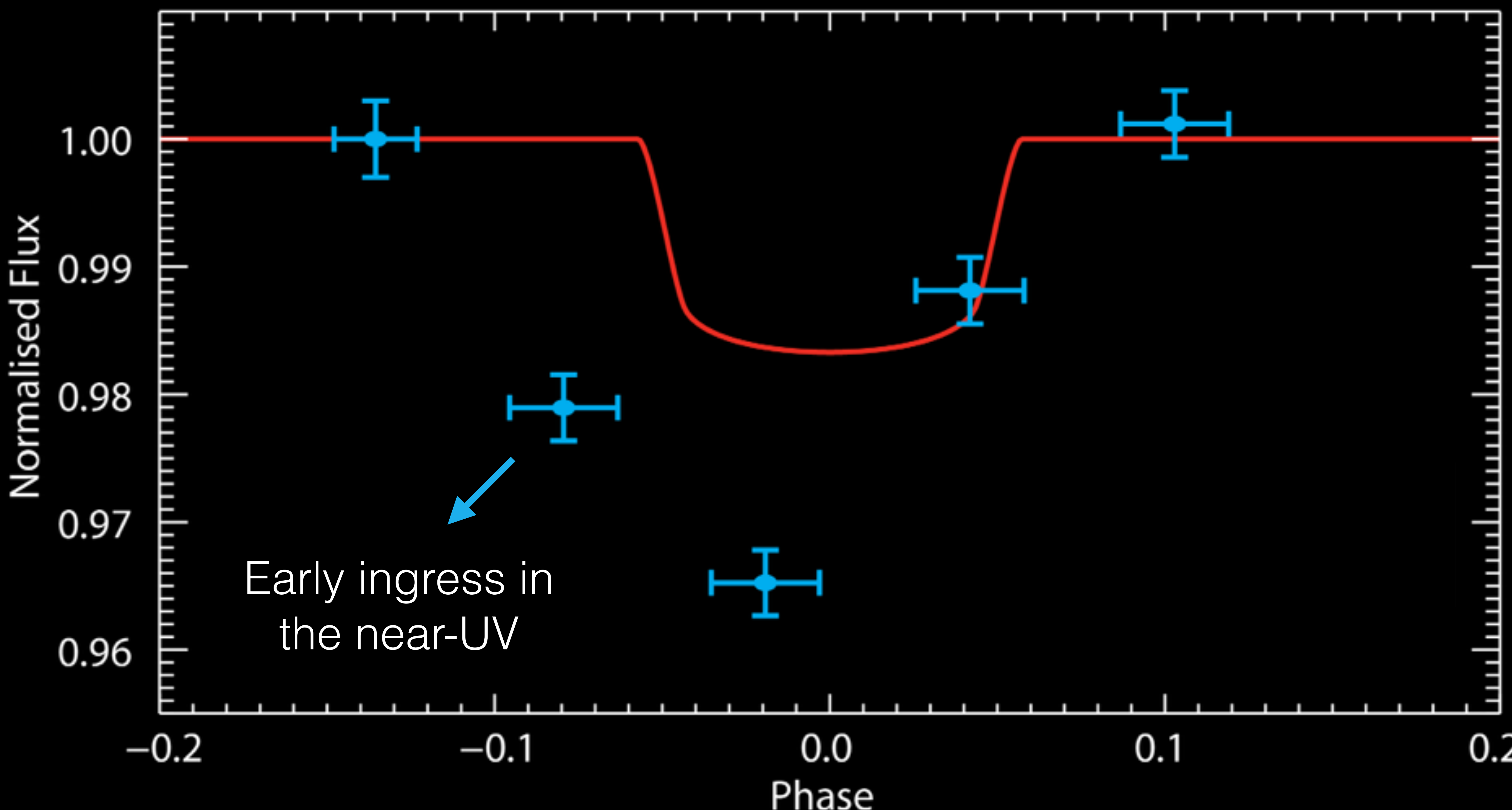
- $R_{planet} = 1.83\ R_{Jupiter}$
- $a = 3.134\ R_{\star}$ (~26 hours)



Fossati et al. 2010

WASP-12b

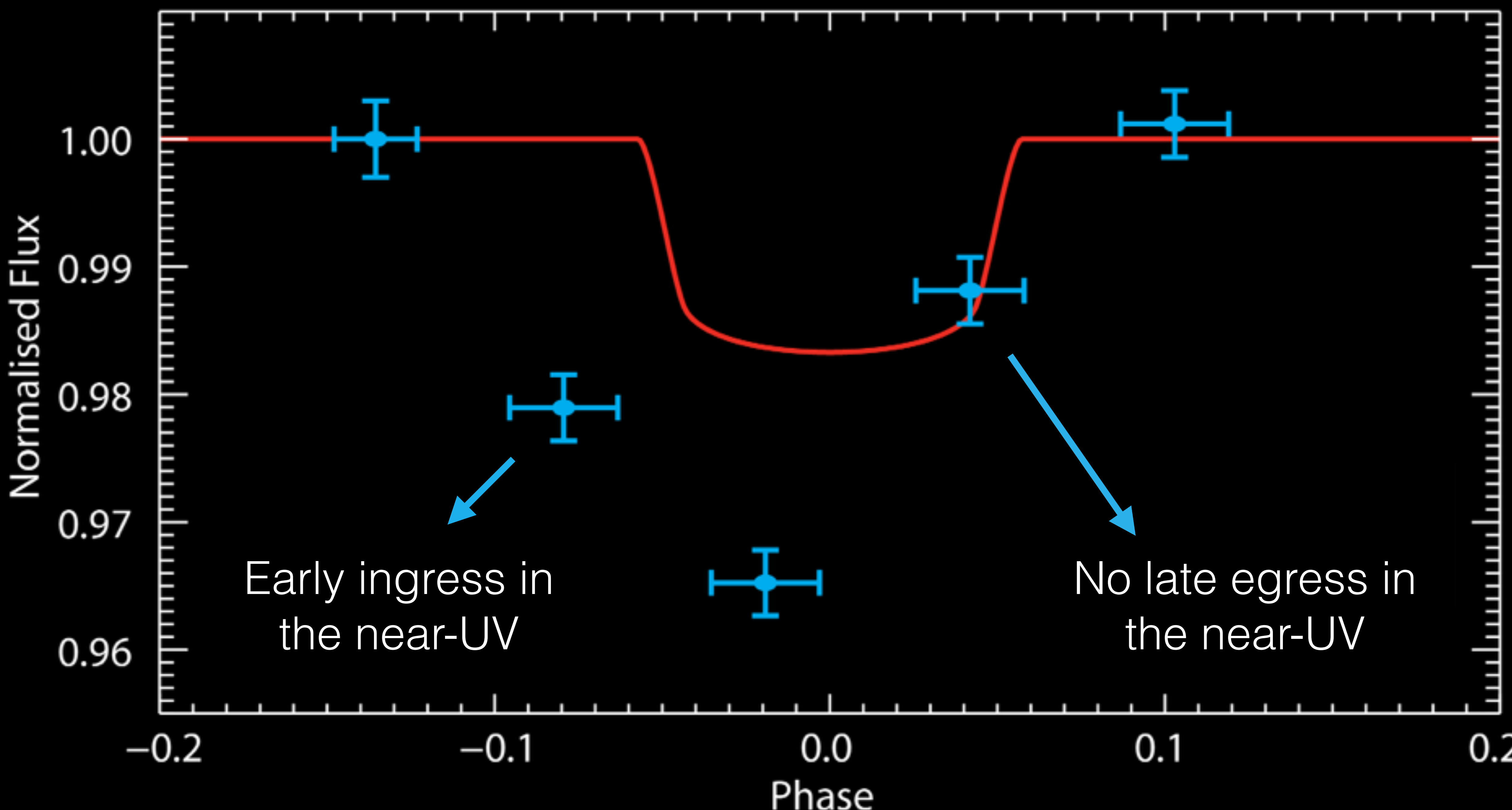
Near-UV light curve: Transit Asymmetry



Fossati et al. 2010

WASP-12b

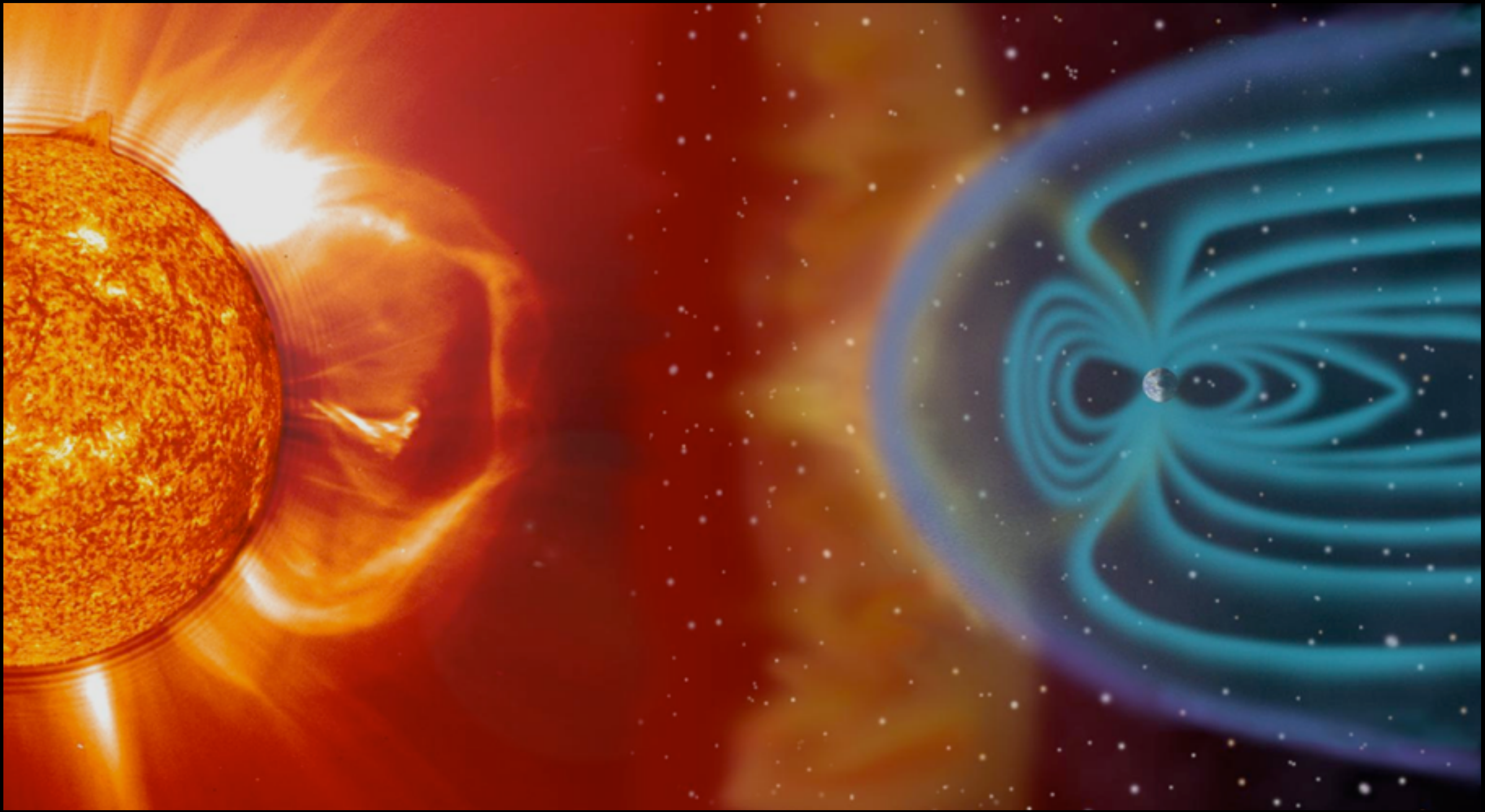
Near-UV light curve: Transit Asymmetry



Fossati et al. 2010

WASP-12b

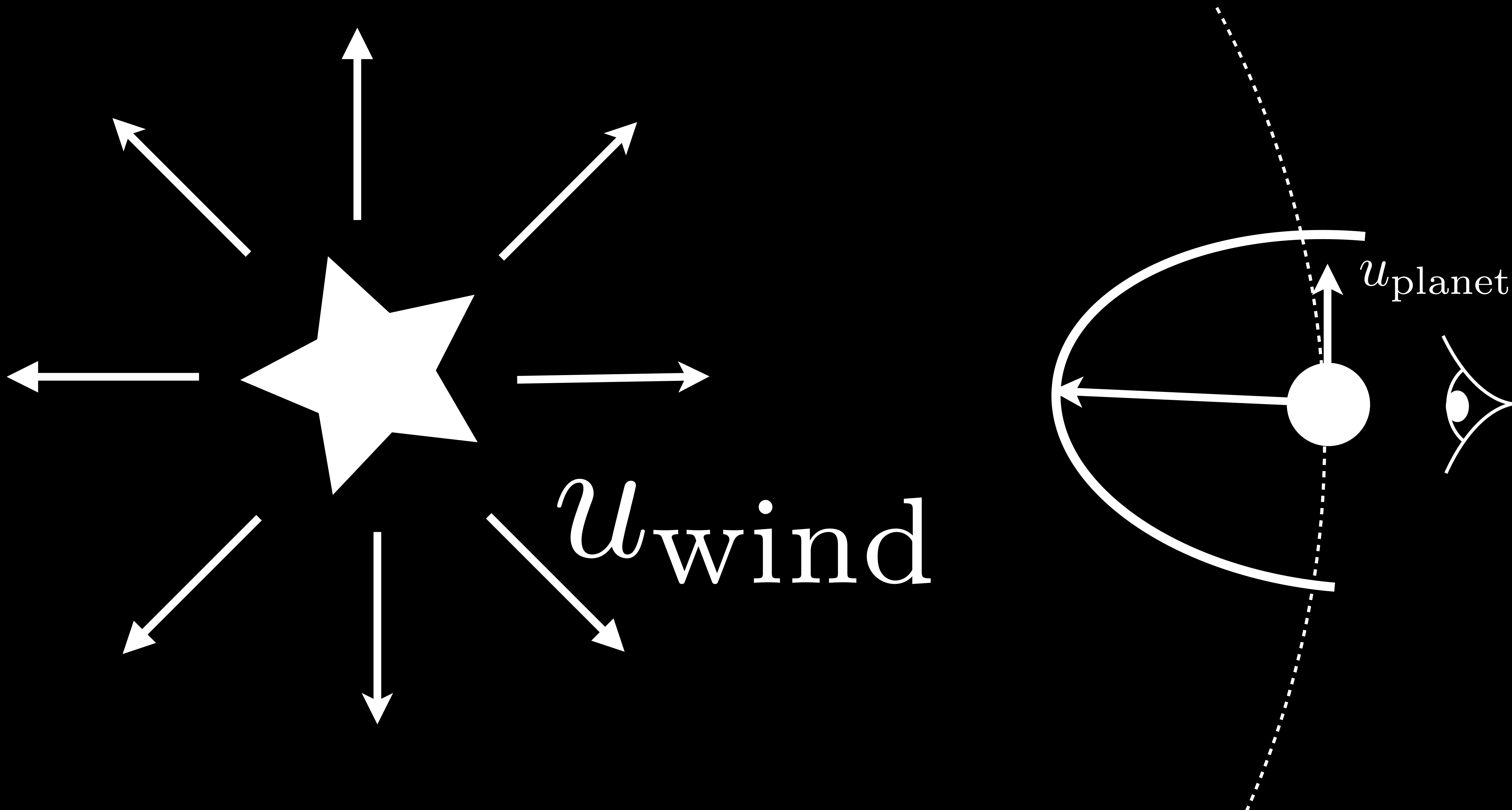
Near-UV light curve: Transit Asymmetry



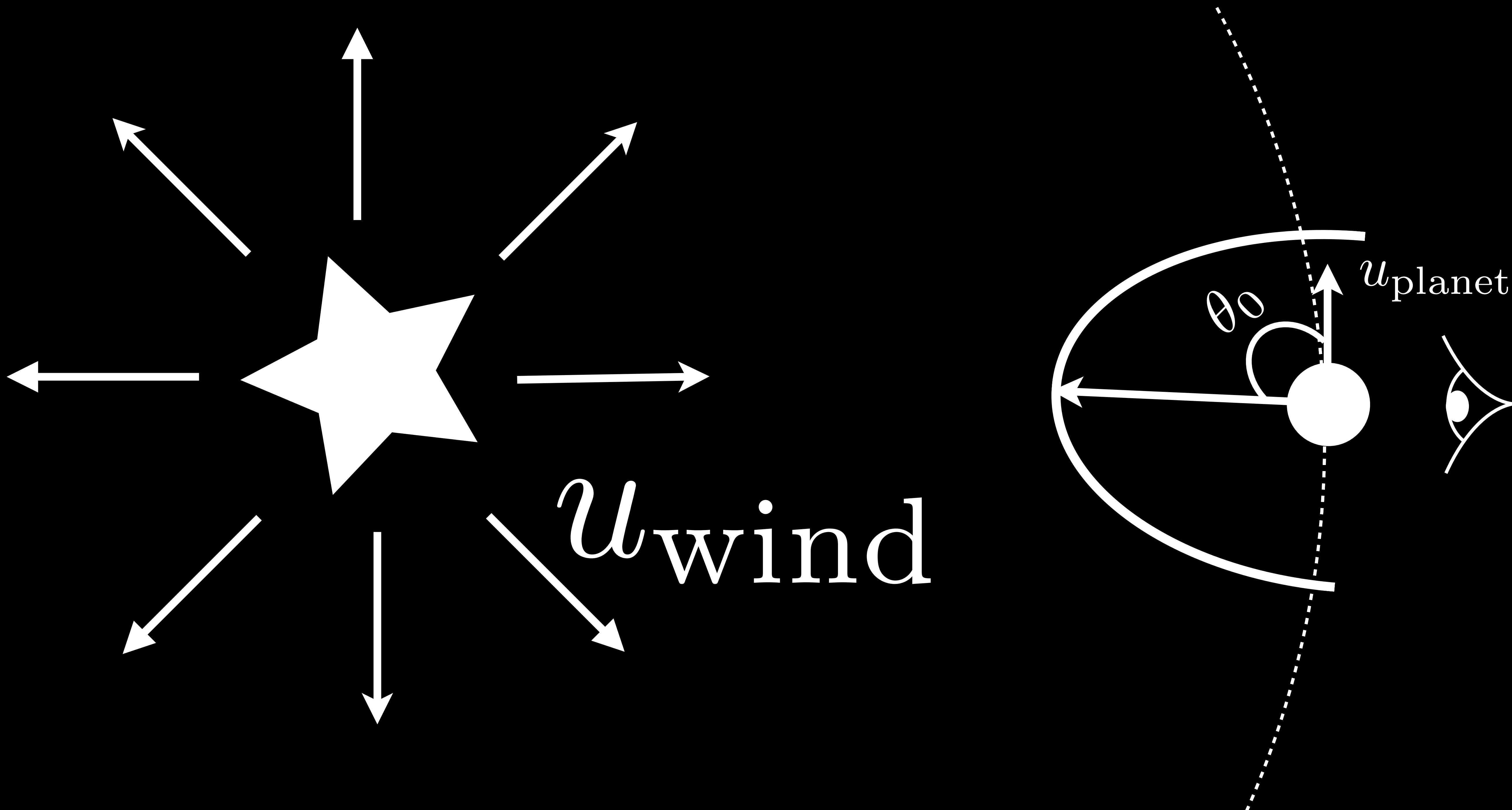
Stellar Wind

Vidotto et al. 2010: Interaction between stellar wind and planetary magnetic field causes compression.

Shock Model

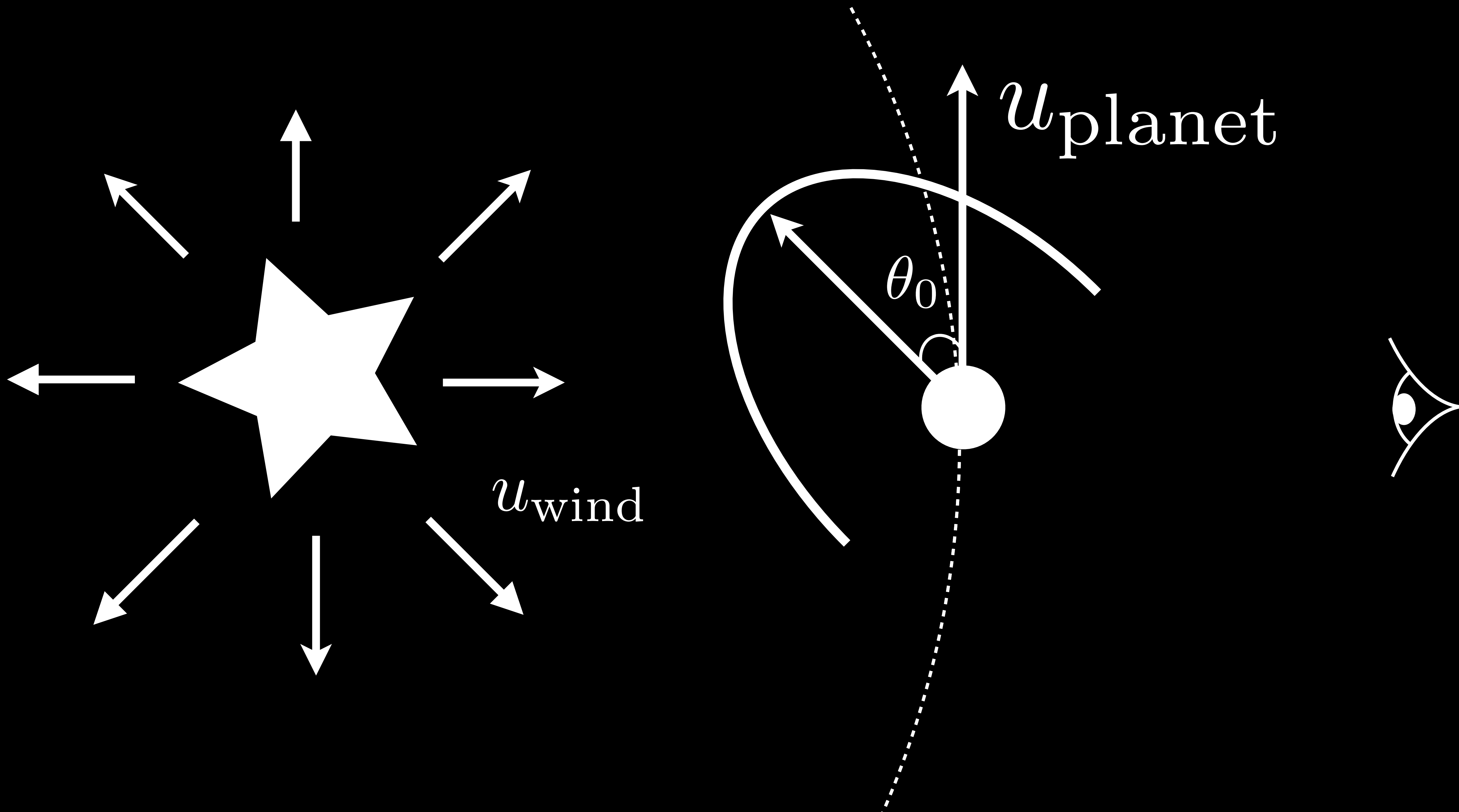


Shock Model



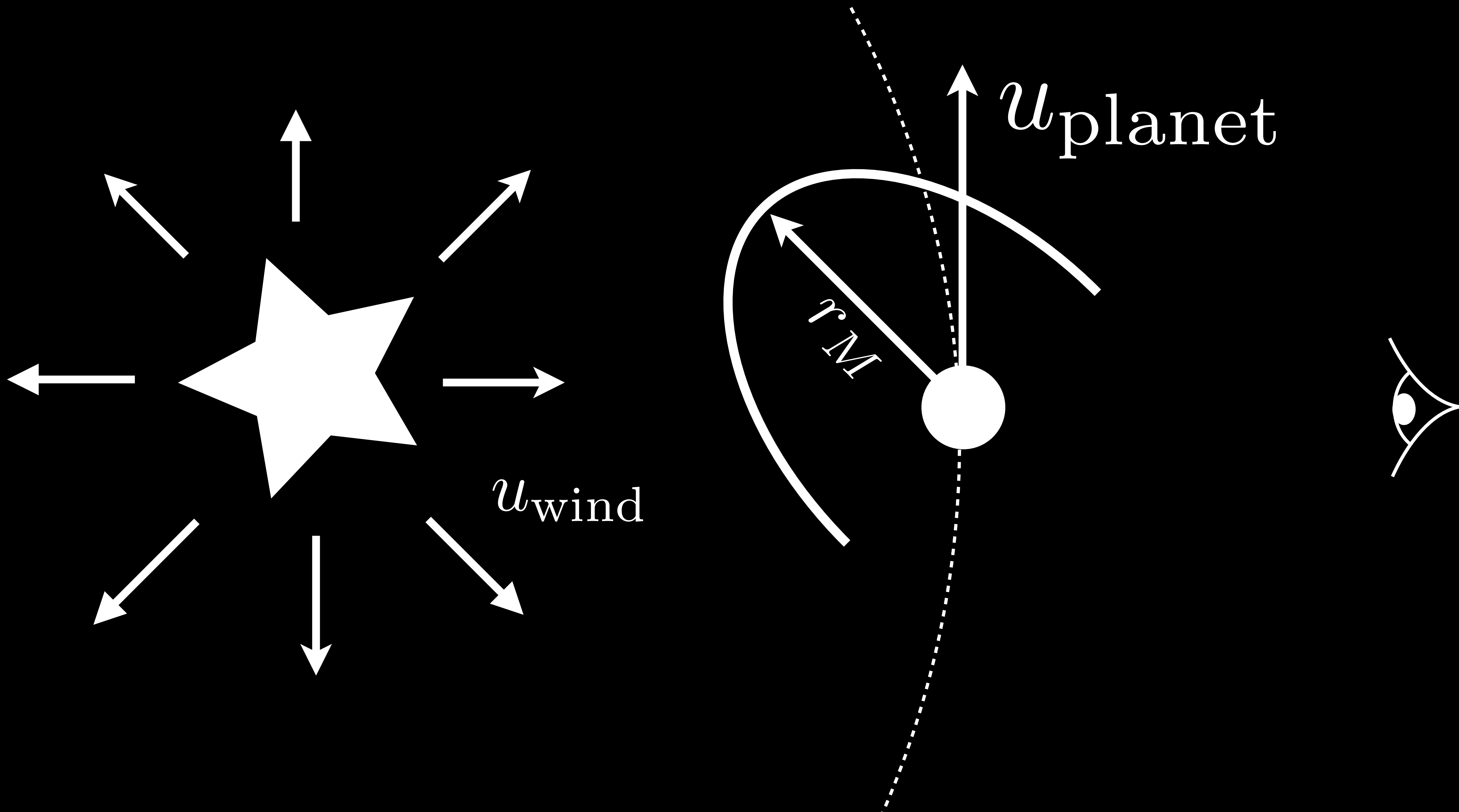
$$\theta_0 = \arctan\left(\frac{u_{\rm wind,r}}{u_{\rm planet} - u_{\rm wind,\varphi}}\right)$$

Shock Model



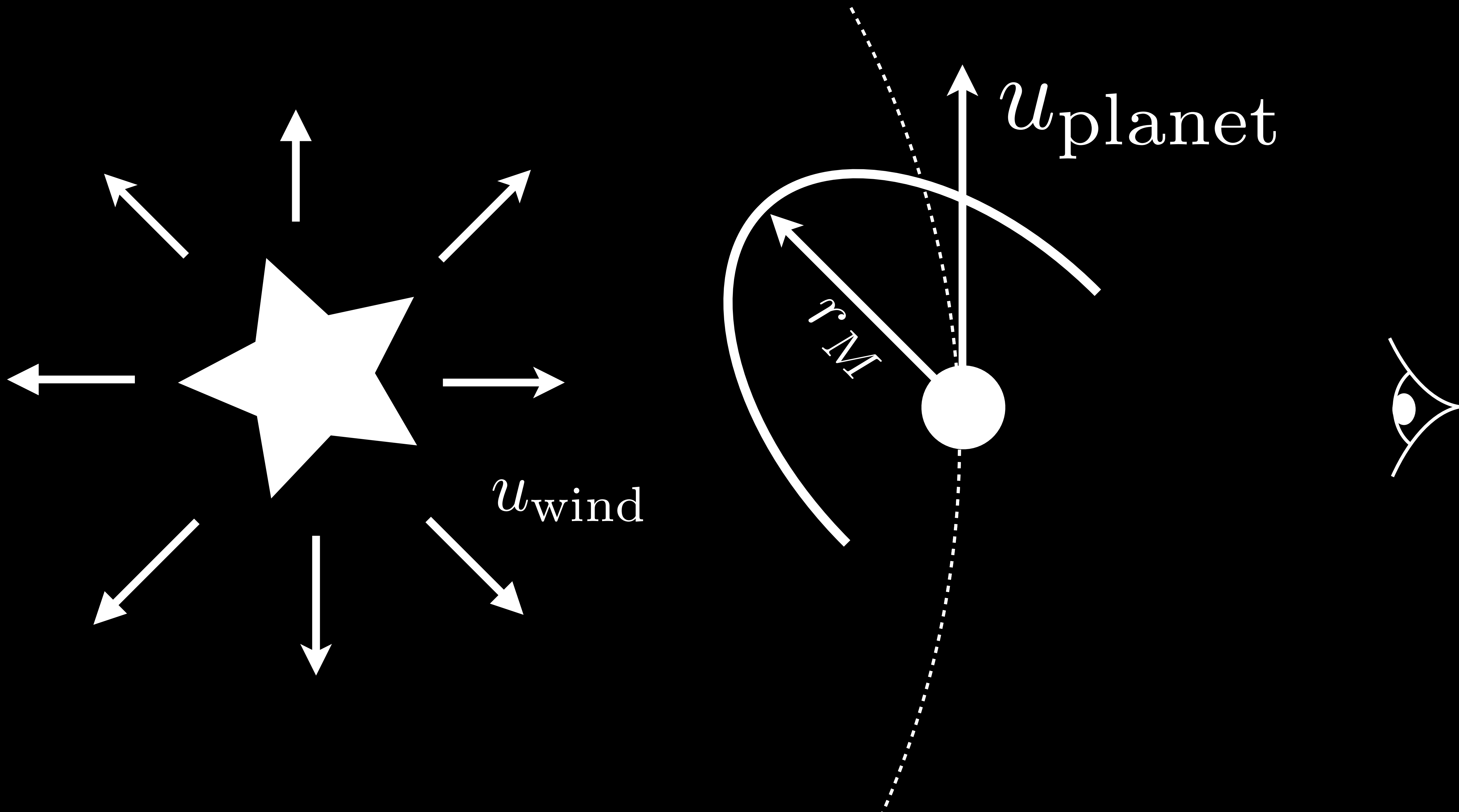
$$\theta_0 = \arctan\left(\frac{u_{\mathrm{wind,r}}}{u_{\mathrm{planet}} - u_{\mathrm{wind},\varphi}}\right)$$

Shock Model



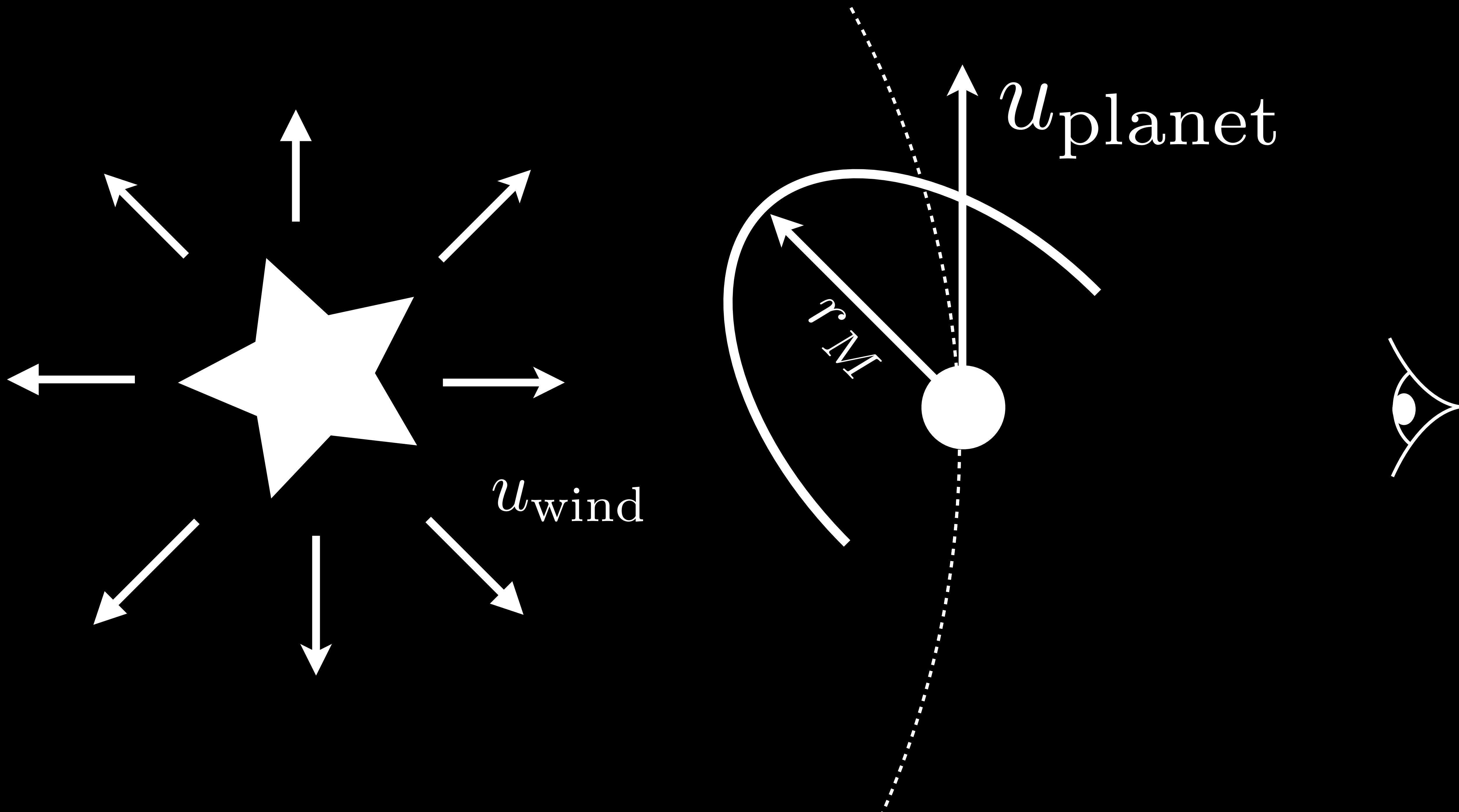
$$\rho_{\rm wind}\Delta u_{\rm wind}^2 + \frac{B_{\rm wind}^2(r_{\rm orb})}{8\pi} + p_{\rm wind} = \frac{B_{\rm planet}^2(r_{\rm M})}{8\pi} + p_{\rm planet}$$

Shock Model



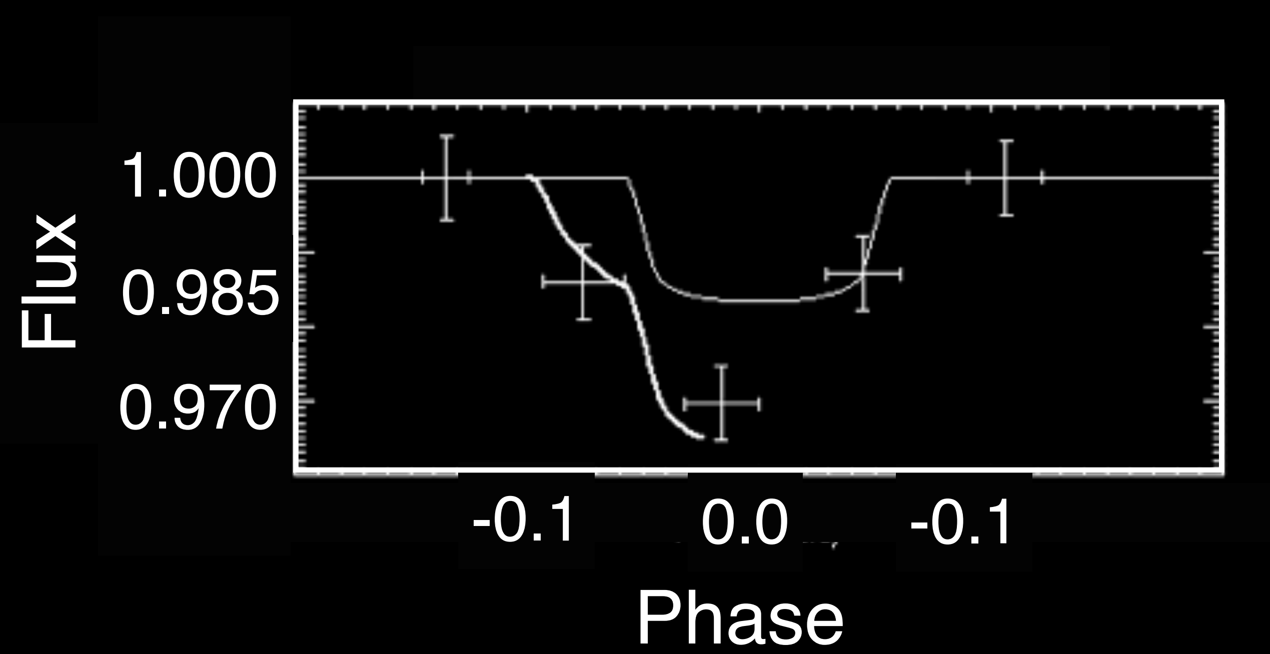
$$\rho_{\rm wind}\Delta u_{\rm wind}^2 + \frac{B_{\rm wind}^2(r_{\rm orb})}{8\pi} + \cancel{p_{\rm wind}} = \frac{B_{\rm planet}^2(r_{\rm M})}{8\pi} + \cancel{p_{\rm planet}}$$

Shock Model



$$B_{\rm planet}(r_M) = \frac{B_{\rm planet}}{2}\left(\frac{R_{\rm planet}}{r_M}\right)^3$$

WASP-12b In The Near-UV



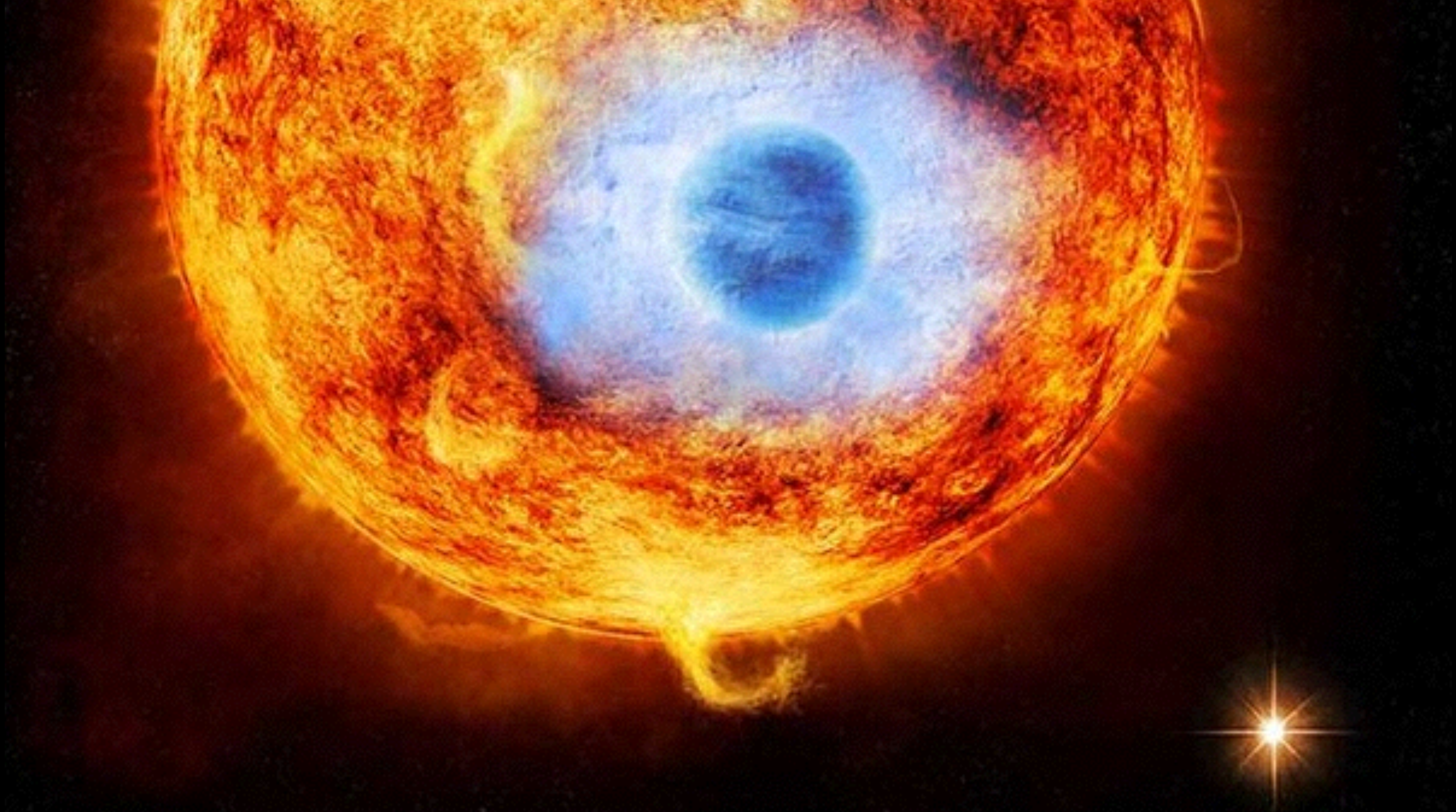
Llama et al. (2011):

Potential detection of a magnetic field around WASP-12b

Magnetosphere protects the atmosphere to ~5 Rp.

The magnetic field strength is Bp~ 24 Gauss.

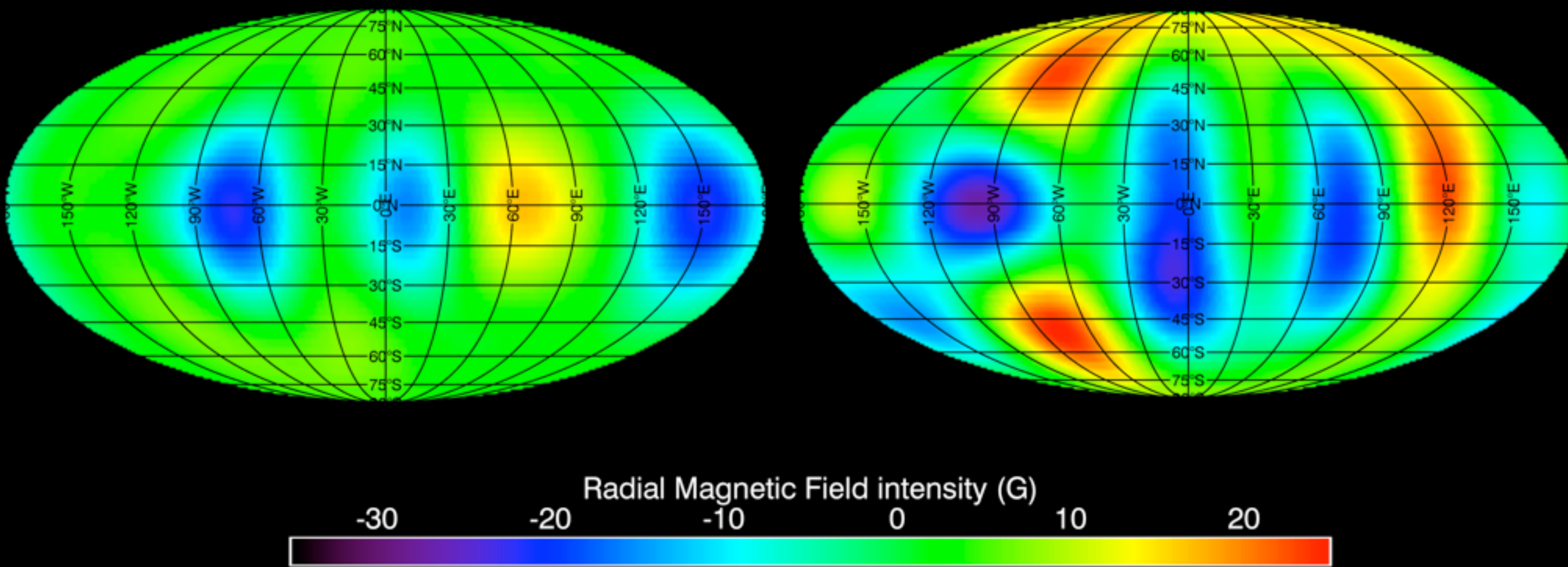
http://arXiv.org/abs/1106.2935



The HD 189733 System

An ideal target for magnetic imaging

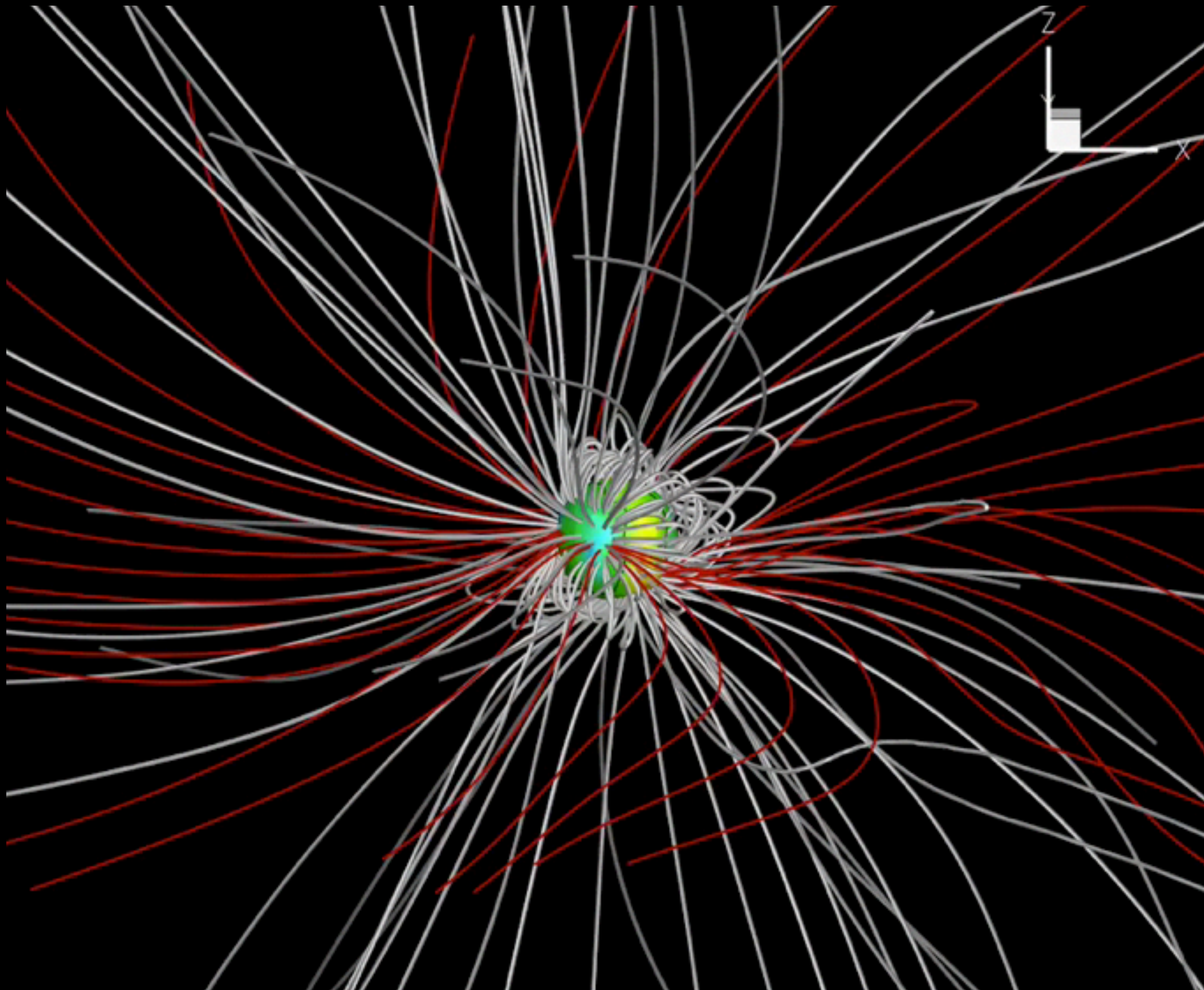
June 2007 July 2008



Fares et al 2010

Magnetic Geometry of HD 189733

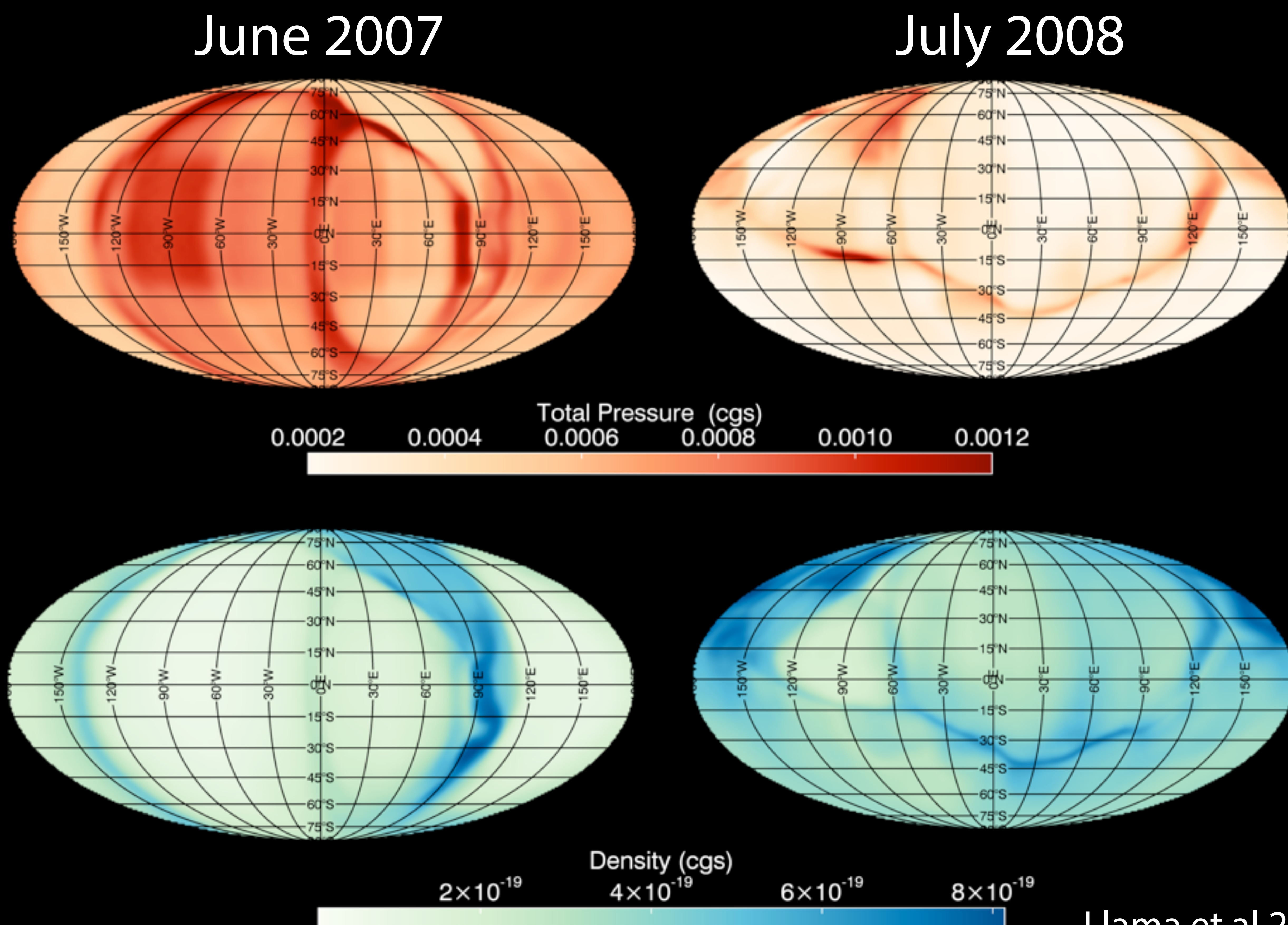
Zeeman-Doppler Imaging



Movie from Aline Vidotto

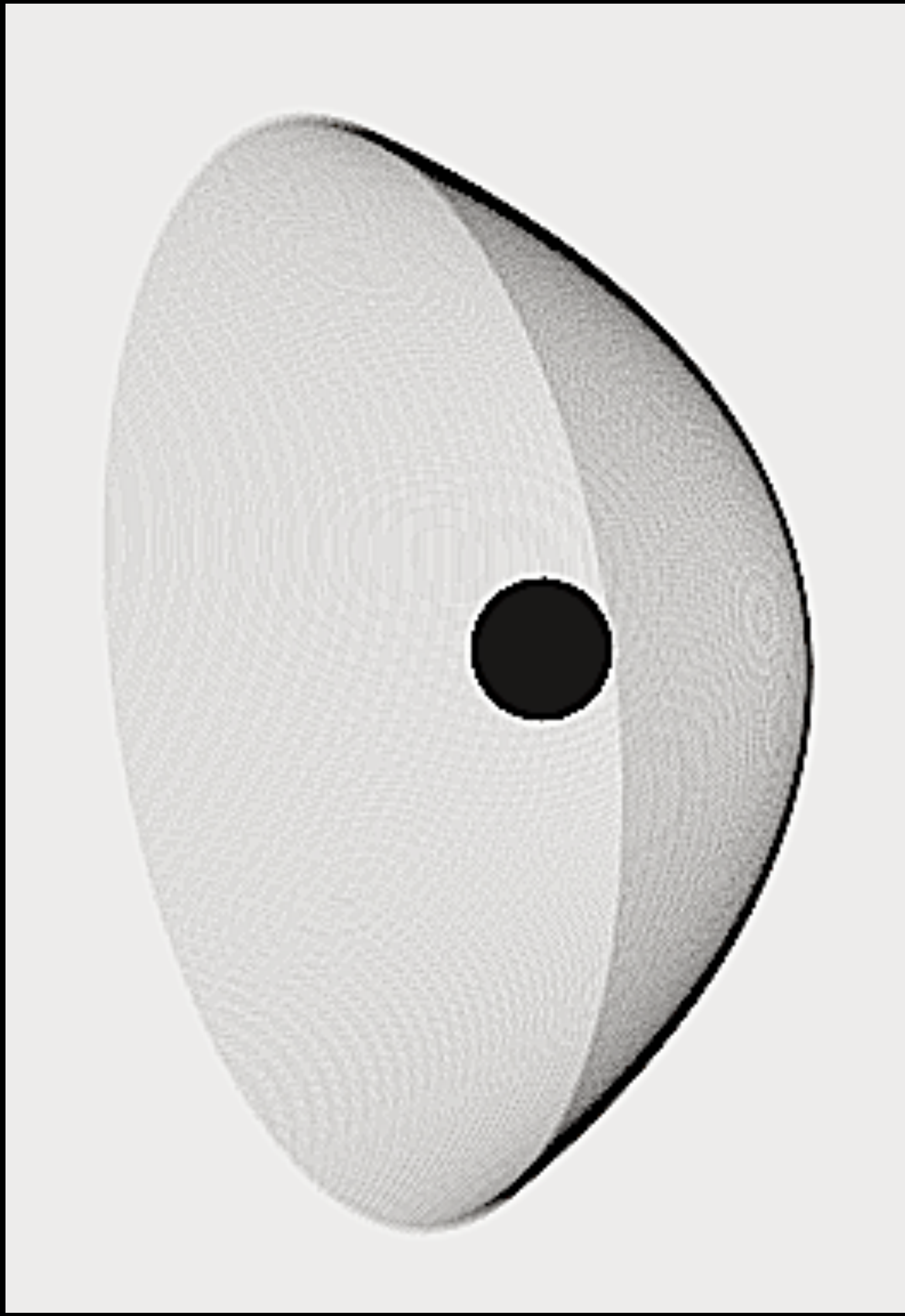
The Stellar Wind of HD 189733

Environment around HD 189733b



Llama et al 2013

Shock Model



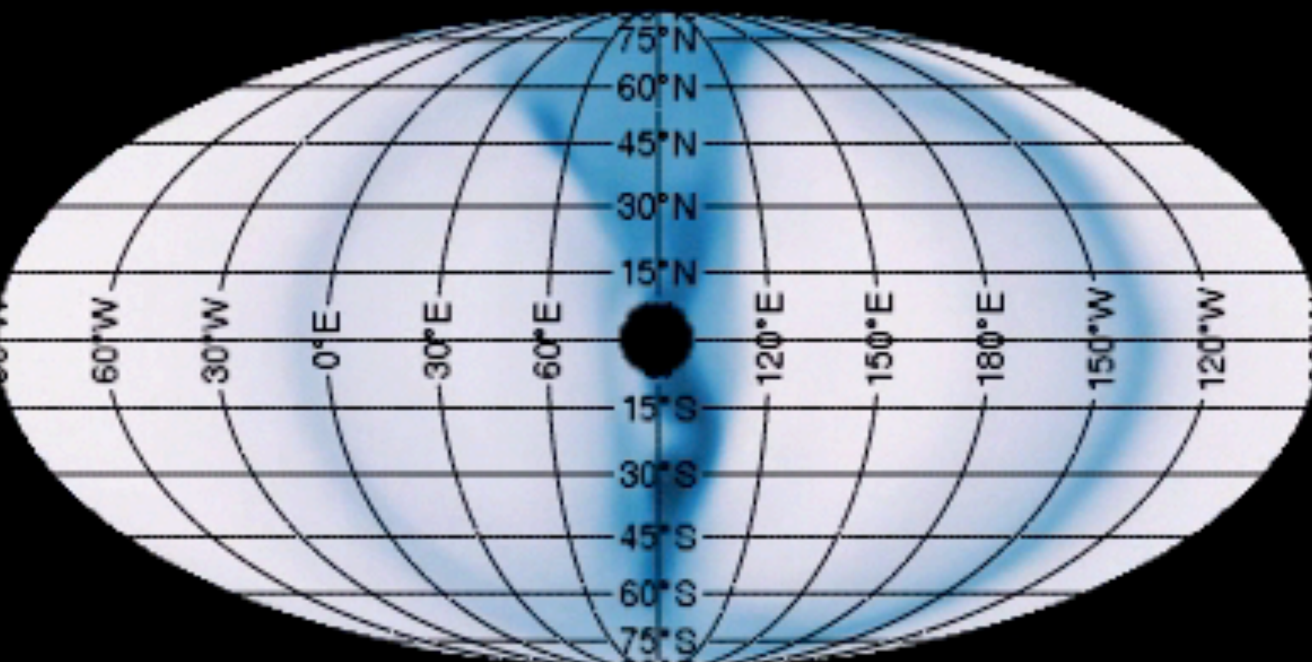
$B_{planet} = B_{Jupiter} = 14G.$

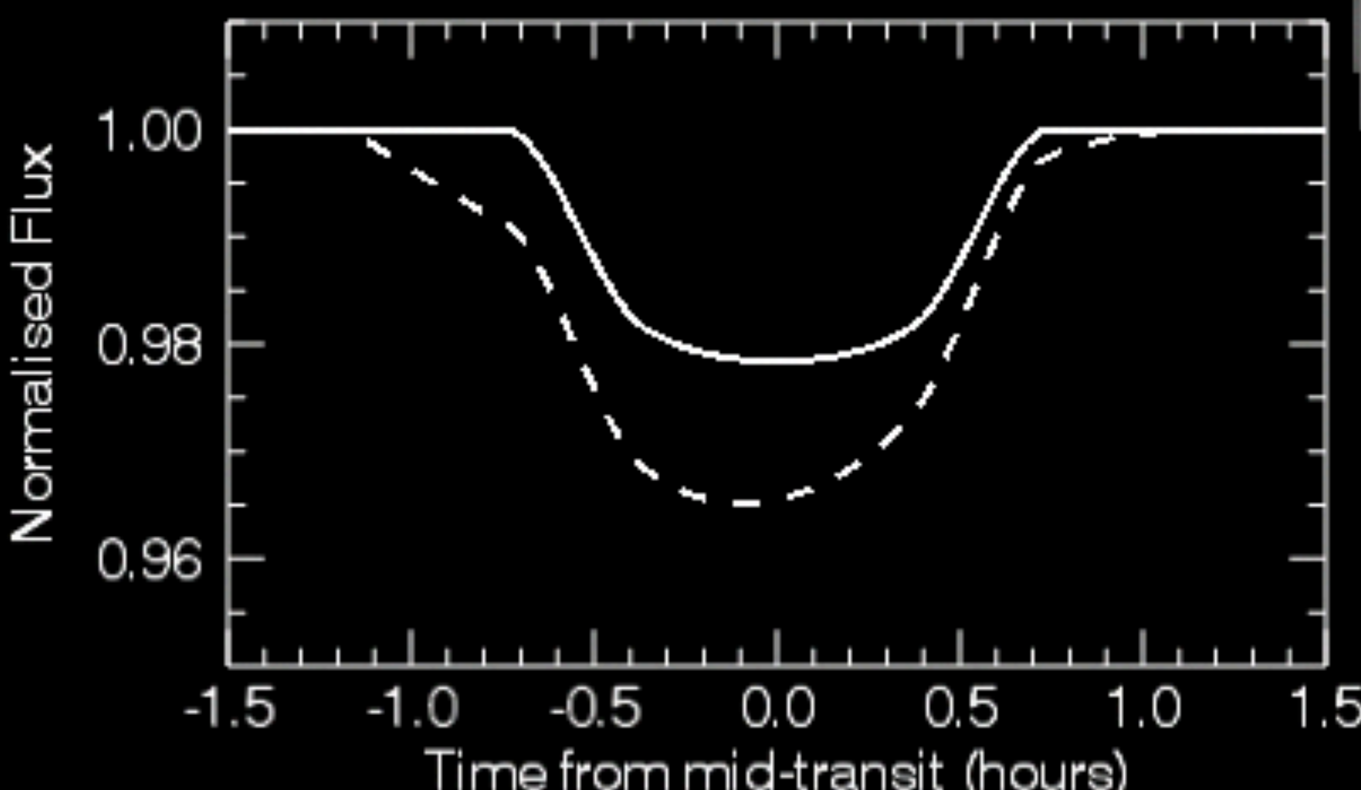
Dipolar planetary magnetic field.

Simulating near-UV transits.

Integrate along line-of-sight to create transit.

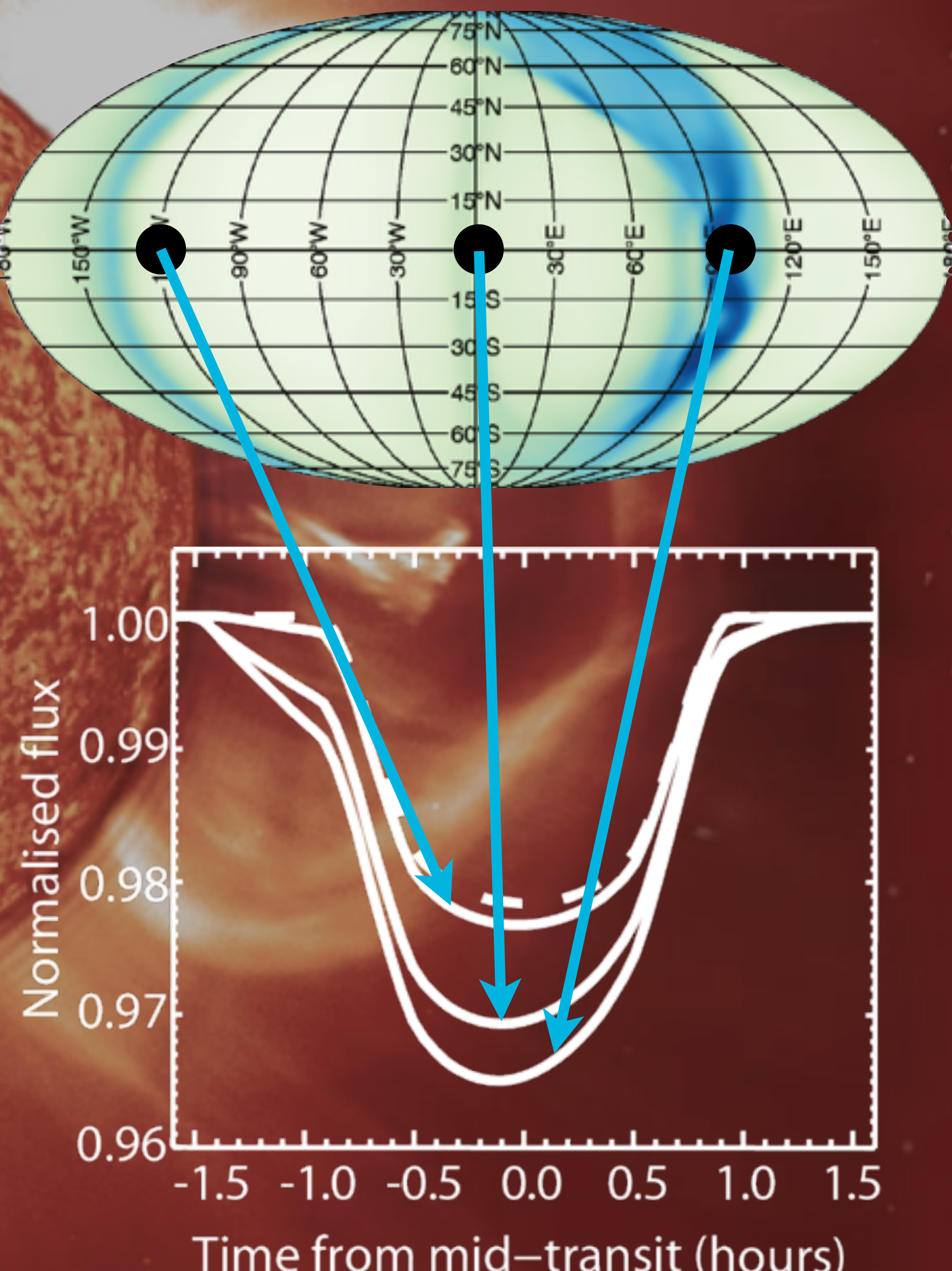
Simulated Near-UV Light Curves





Llama et al 2013:
http://arXiv.org/abs/1309.2938

Conclusions and Prospects



Near-UV transits provide a potential method for detecting exoplanetary magnetic fields.

Local stellar wind conditions around the planet influence the near-UV transit timing and depth.

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

Simultaneous multi-wavelength observations of HD 189733b: X-ray, UV, magnetic mapping underway.