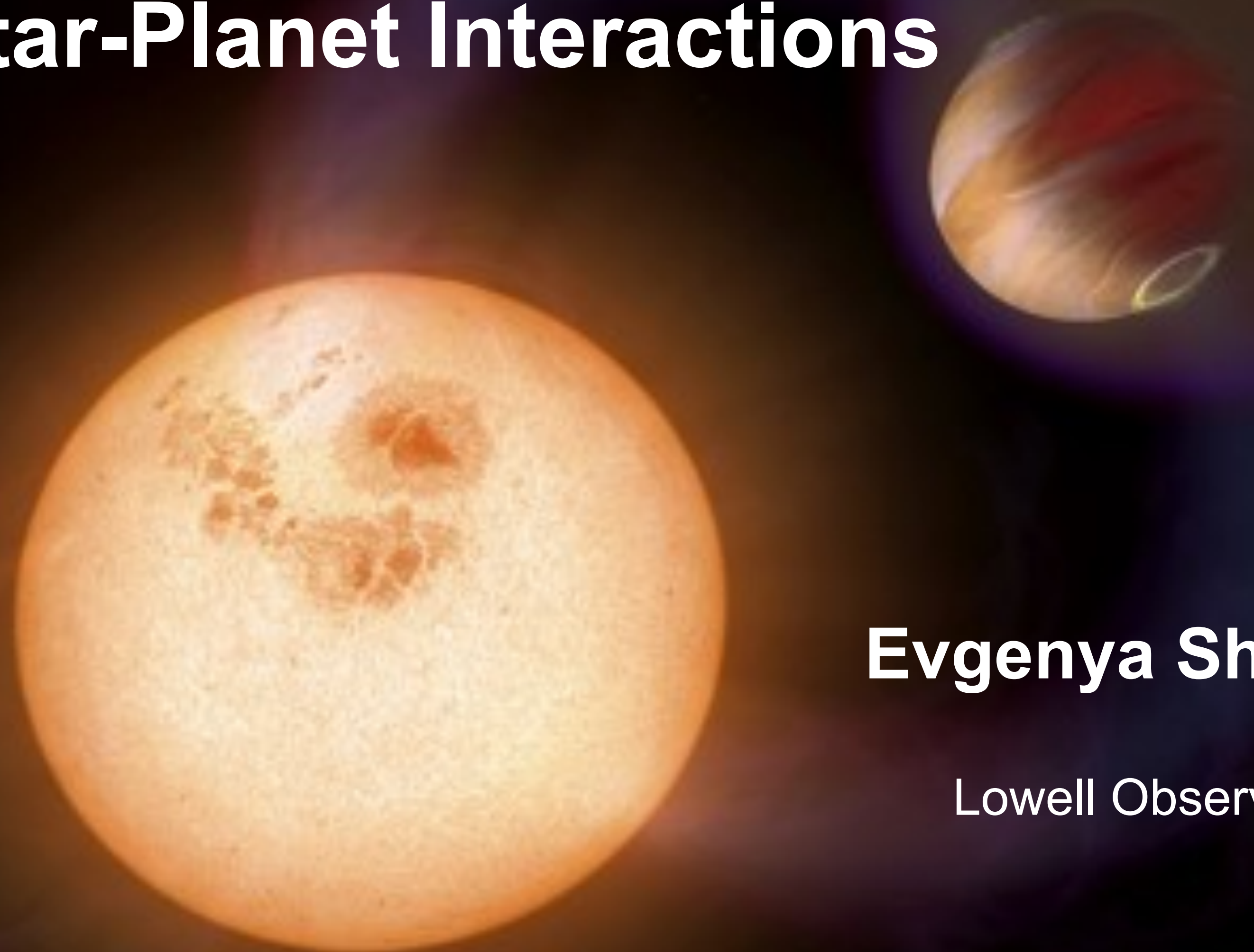
Detecting Exoplanetary Magnetic Fields with Star-Planet Interactions



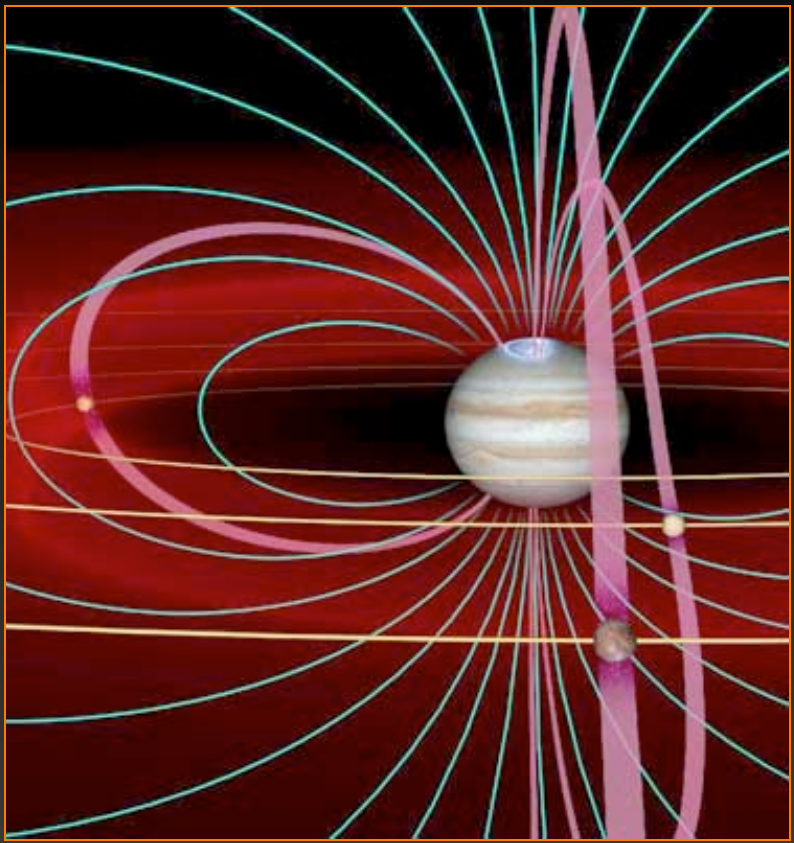
Evgenya Shkolnik

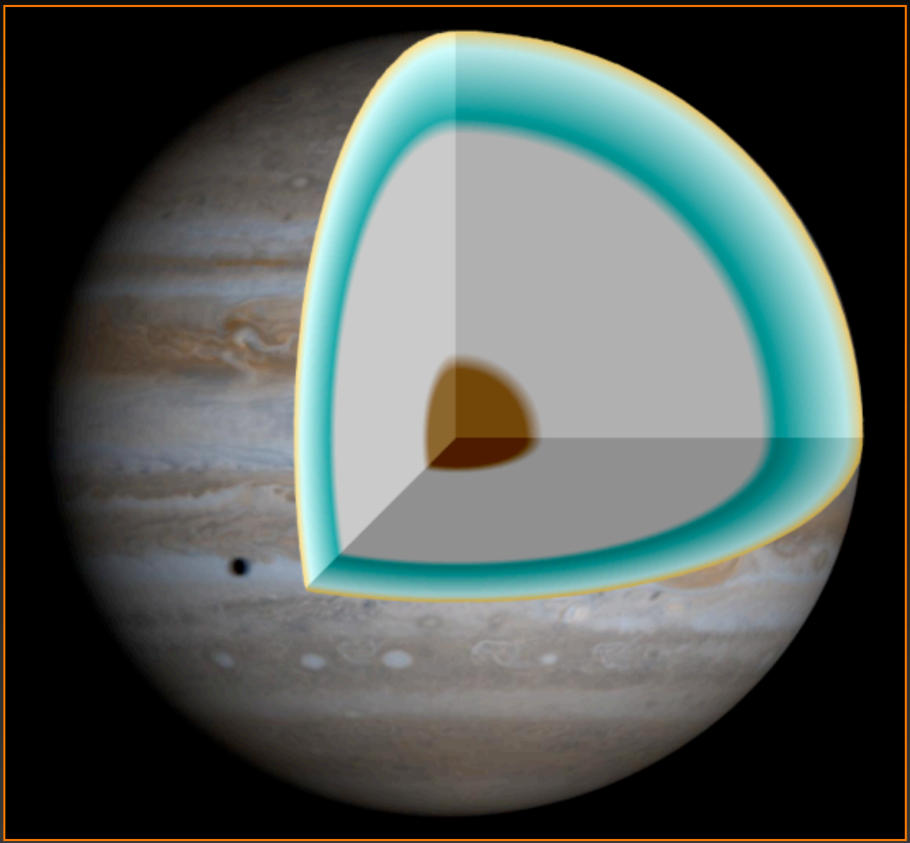
Lowell Observatory

Image: A. Schaller

Probing a Planet's Interior

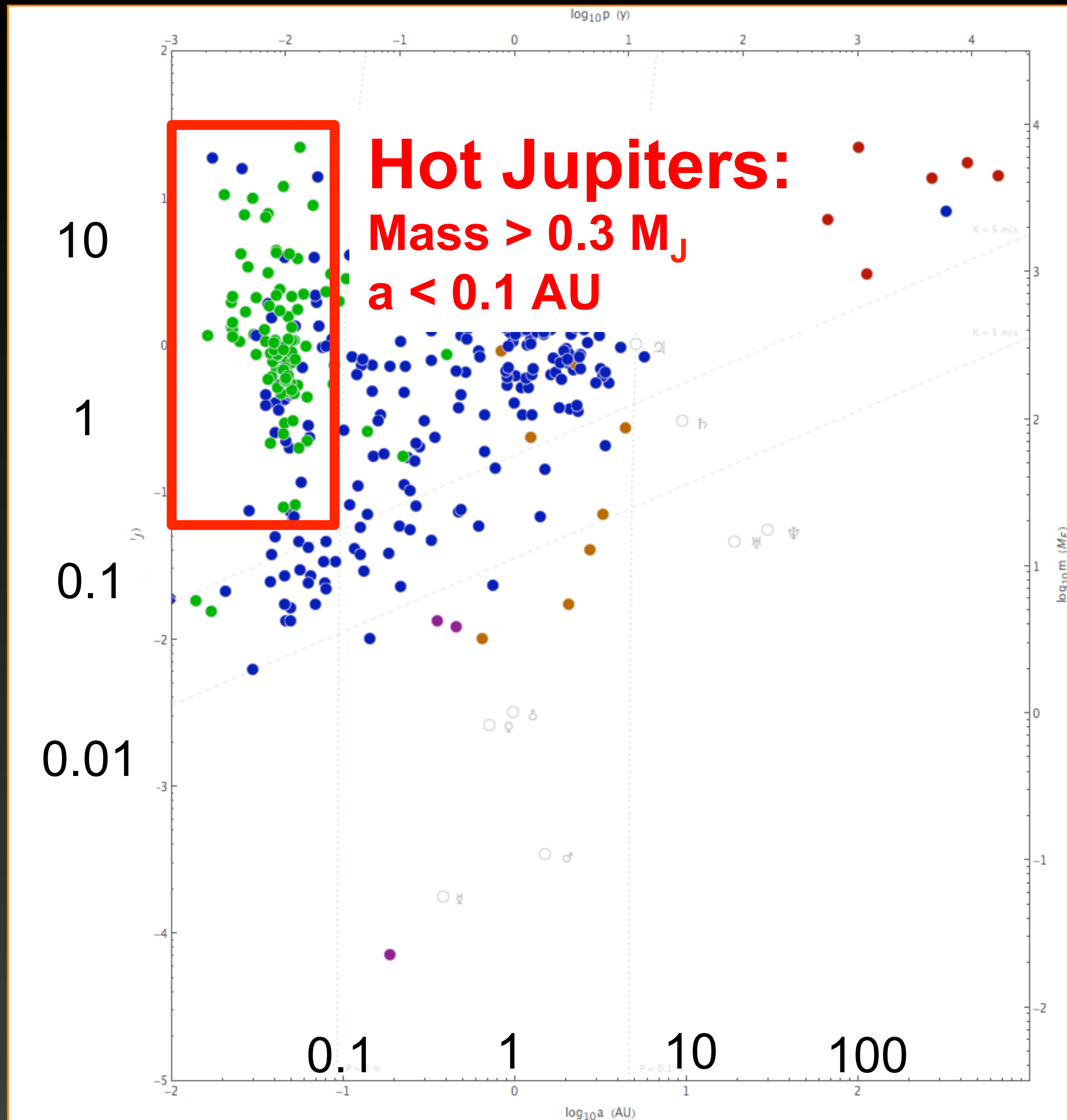
Jupiter's main constituent is metallic hydrogen.





NASA Images

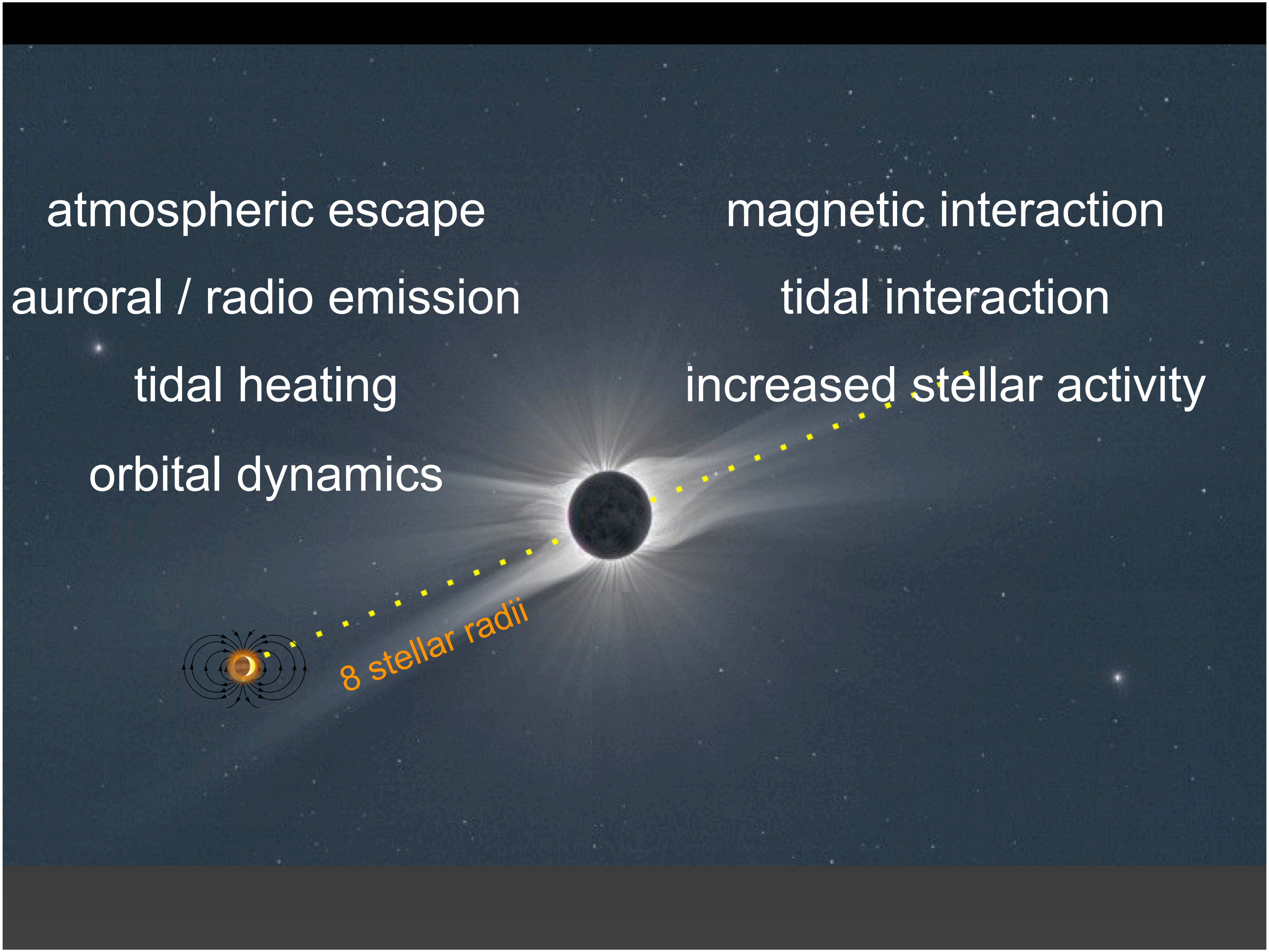
Extrasolar Planets



Planet Mass (M_{Jup})

Semi-major Axis (AU)

Credit: Aldaron


atmospheric escape
auroral / radio emission
tidal heating
orbital dynamics
magnetic interaction
tidal interaction
increased stellar activity
8 stellar radii

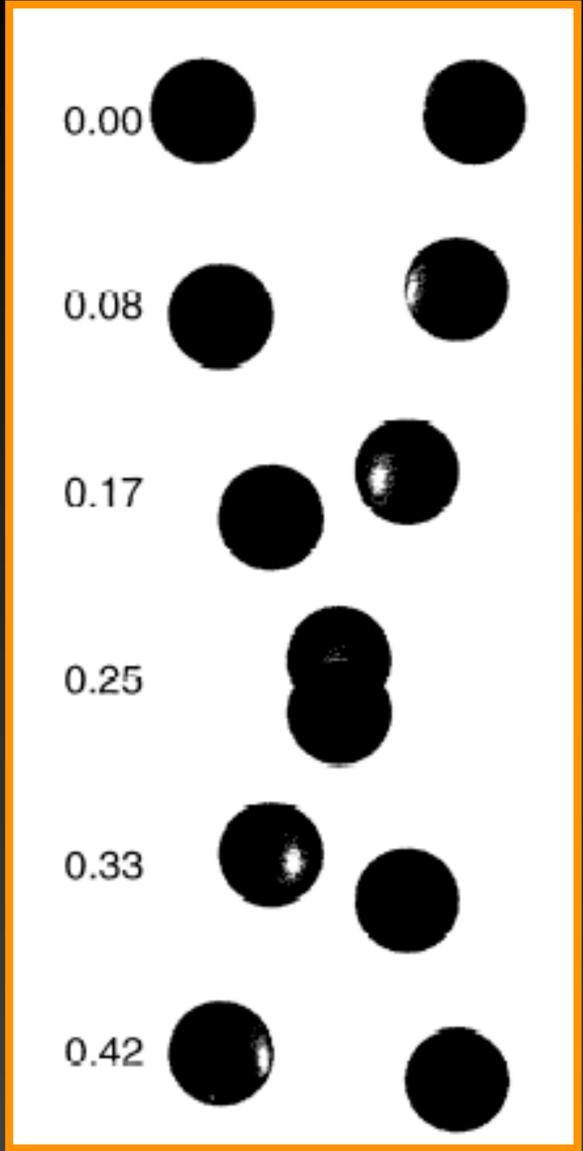
Magnetic Star-Planet Interactions → Planet-induced Stellar Activity

Magnetic heating

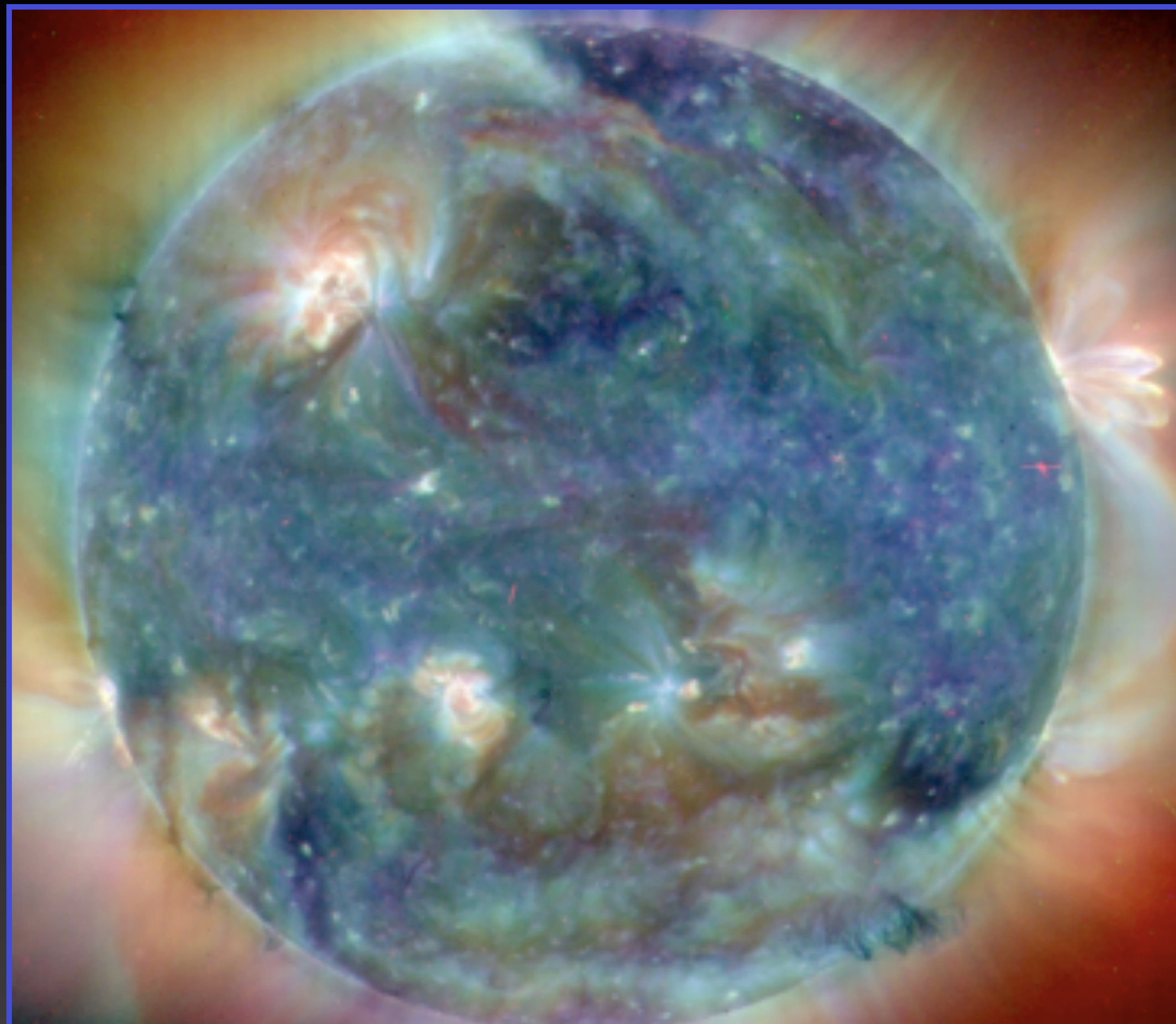
$$P_{activity} \approx P_{orbit}$$

with peak emission at sub-planetary point

Cuntz, Saar & Muzielak 2000



Piskunov 1996, Shkolnik et al. 2005a



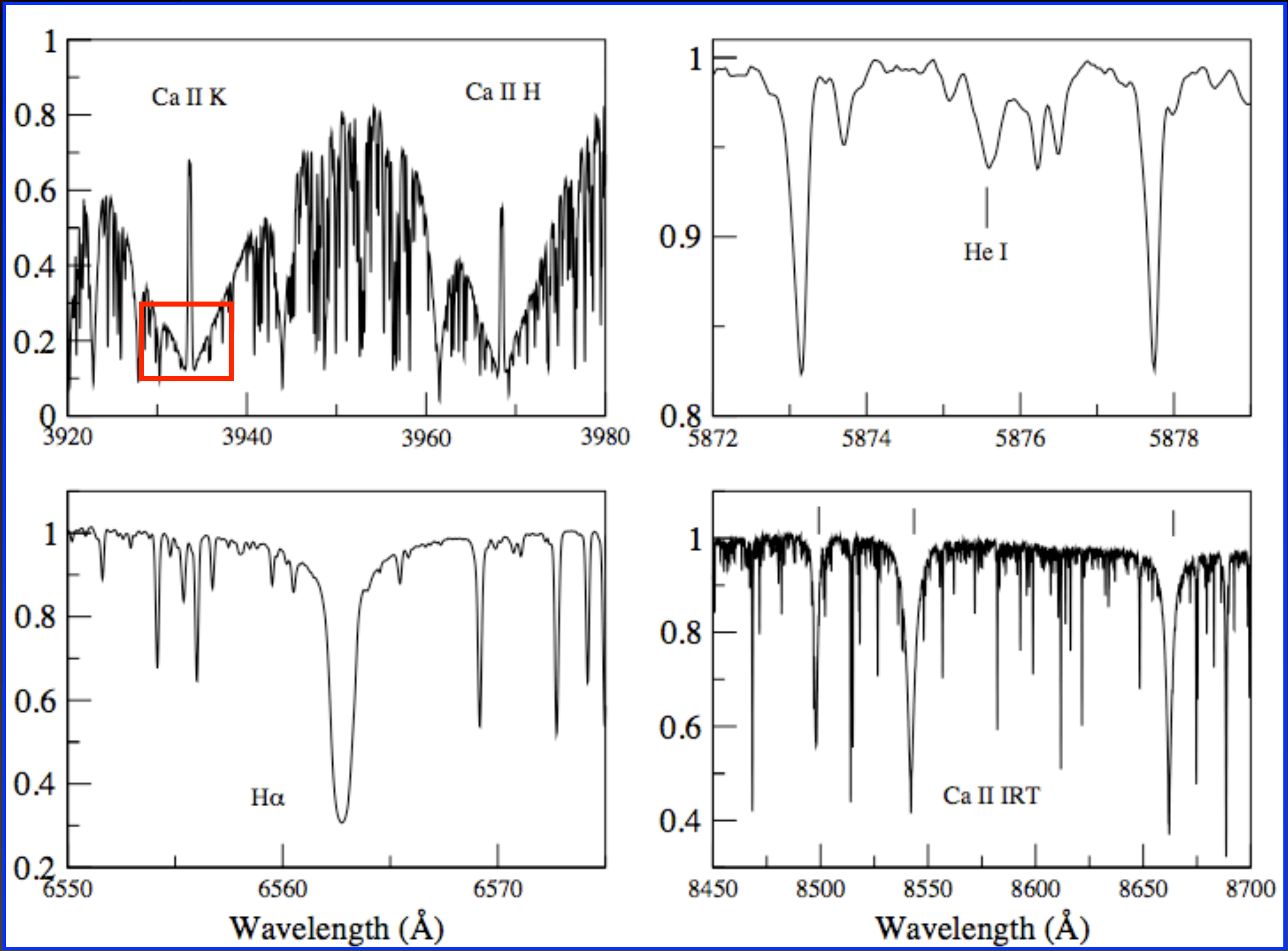
"If the Sun did not have a magnetic field, it would be as uninteresting a star as most astronomers believe it to be." - Robert B. Leighton

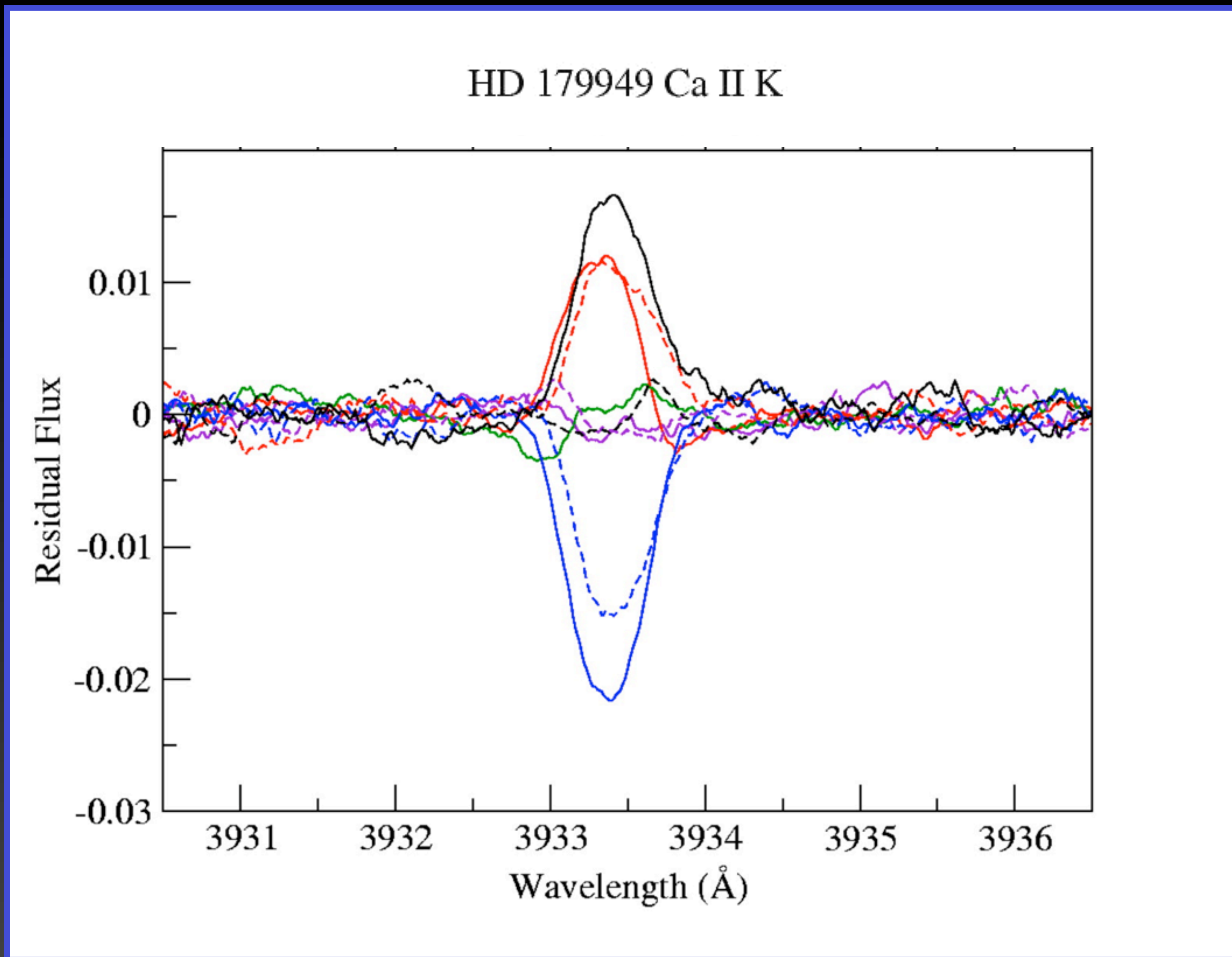
Monitoring stellar activity of

hot Jupiter hosts

Spectroscopy of Hot Jupiter Hosts

HD 189733

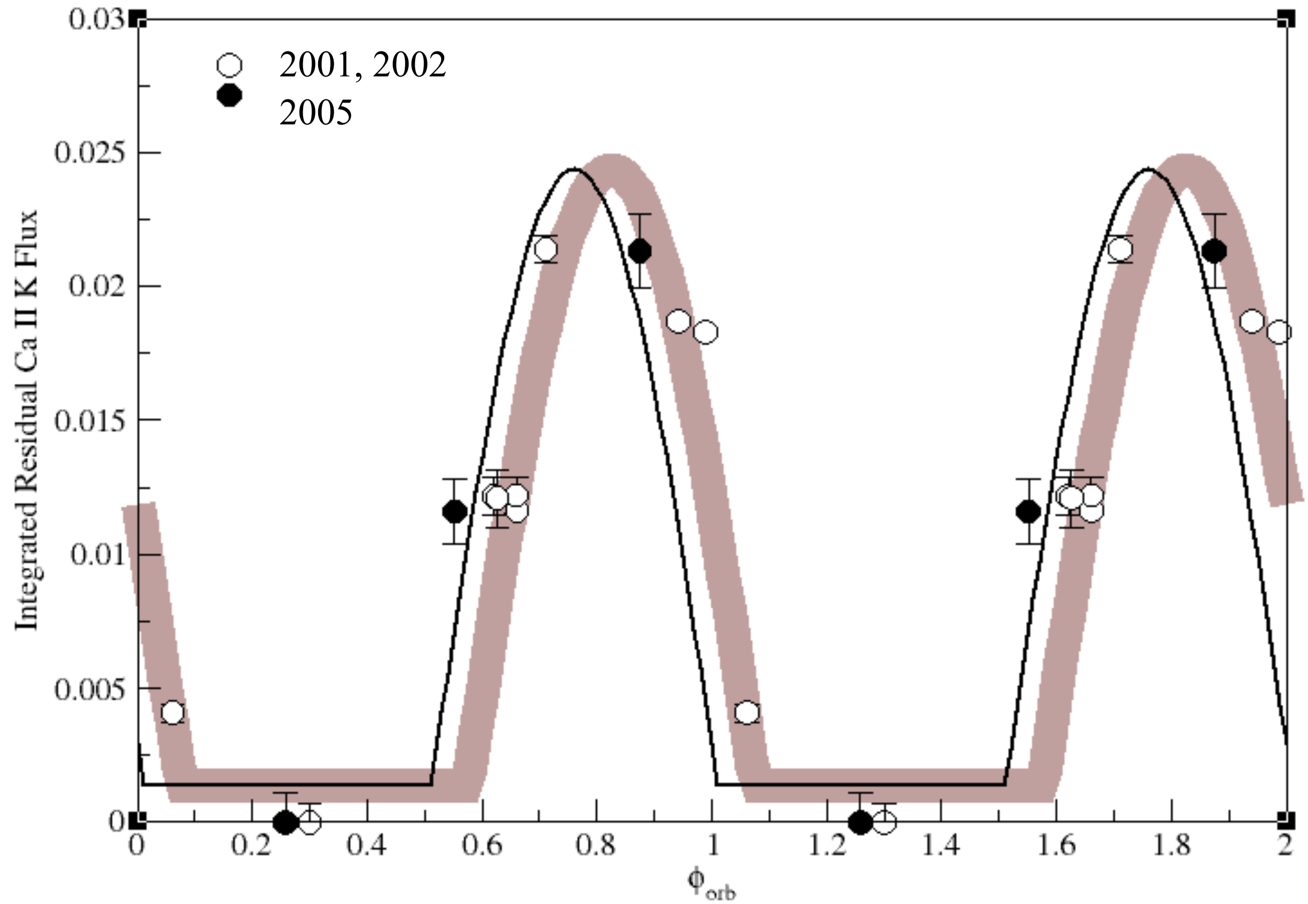



HD 179949 Ca II K
Residual Flux
0.01
0
-0.01
-0.02
-0.03
3931
3932
3933
3934
3935
3936
Wavelength (Å)

HD 179949

Shkolnik et al. 2005b, 2008

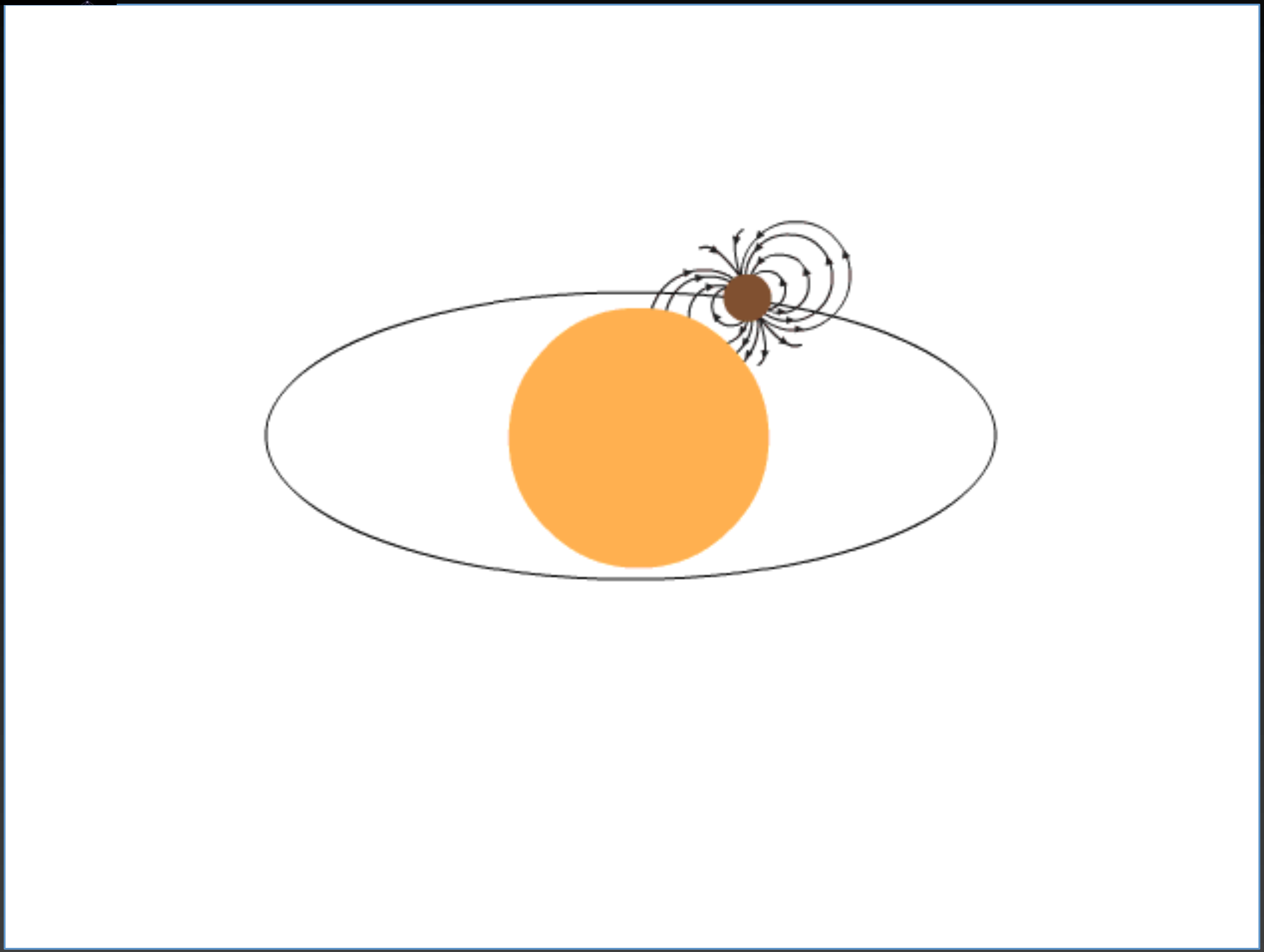
Stellar Activity



Orbital Phase, P_{orb}=3.09 days

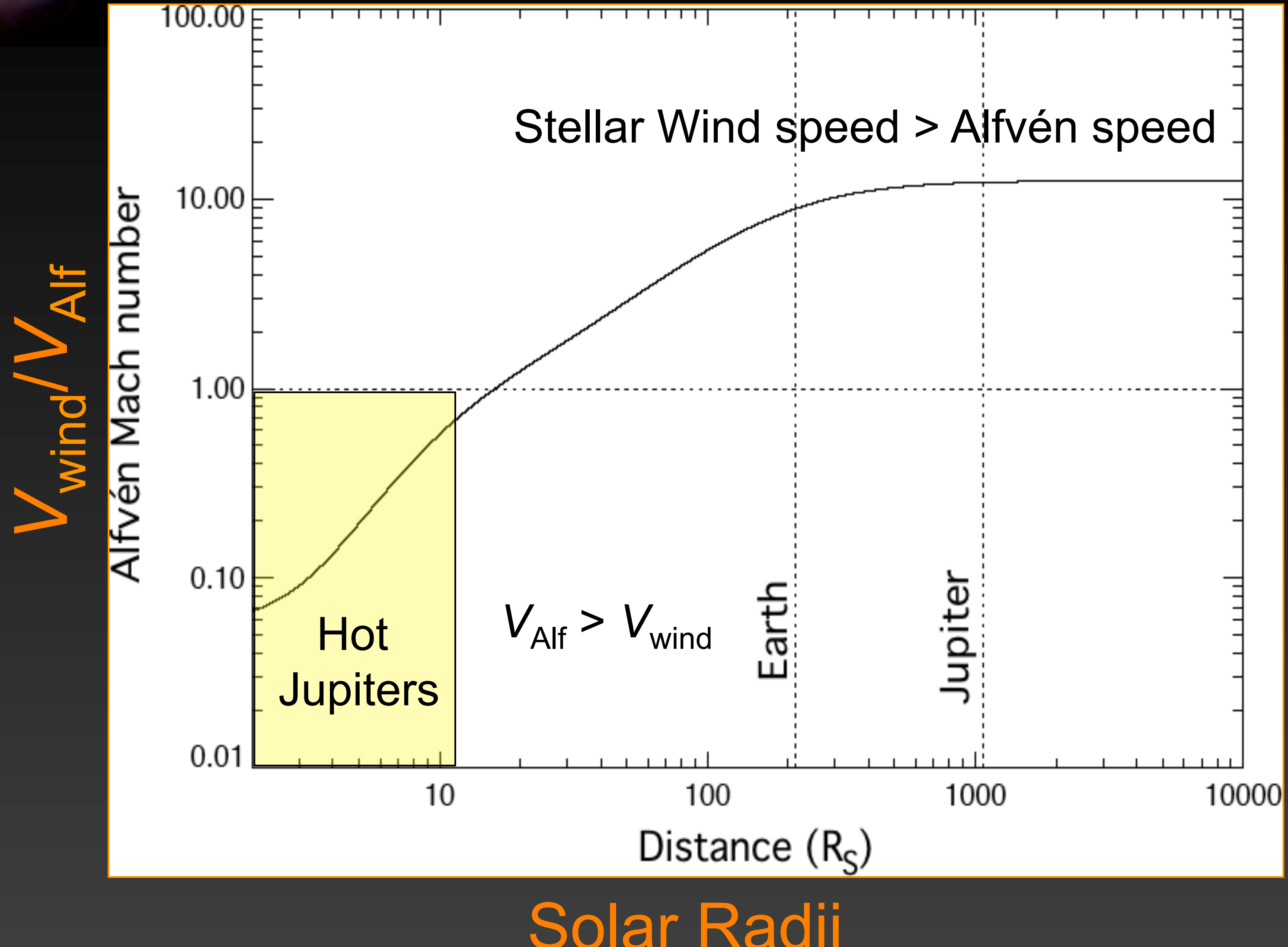
ϕ = 0 is the sub-planetary phase

Magnetic SPI

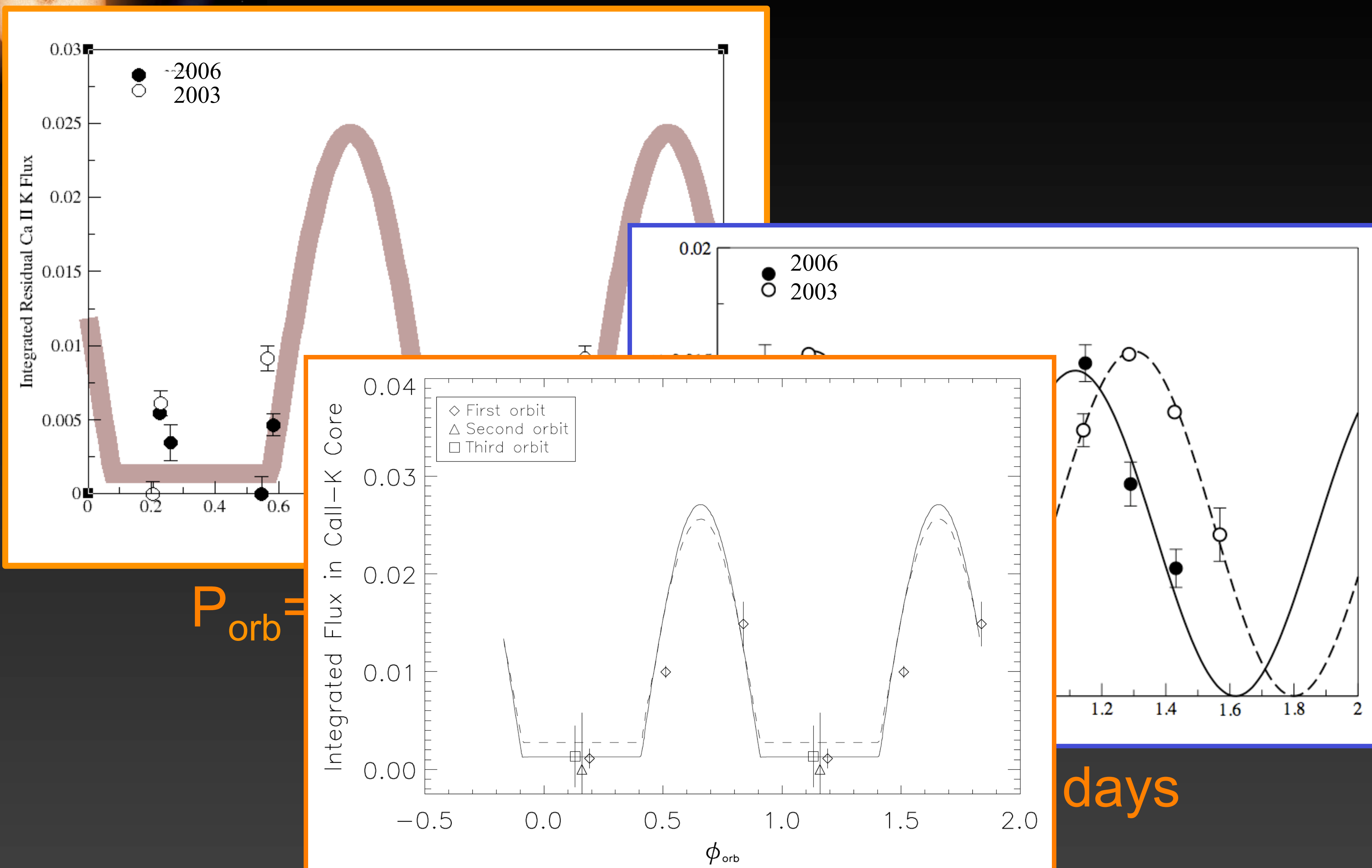


Sub-Alfvénic Regime

Zarka 2001



HD 179949

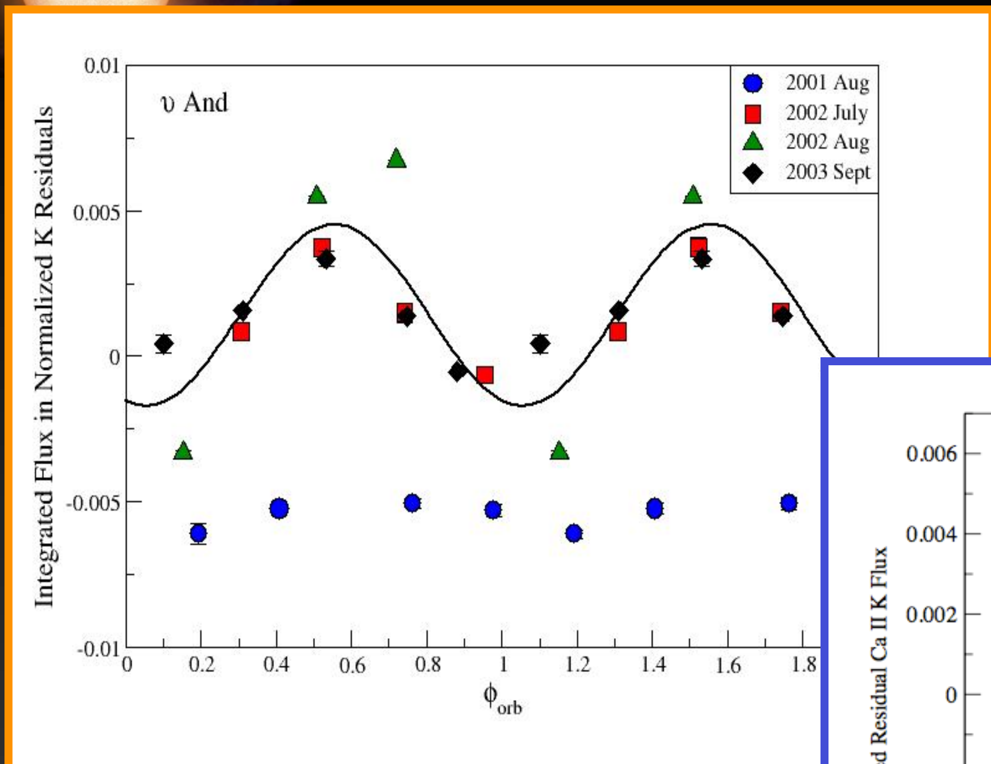


P_{orb}=

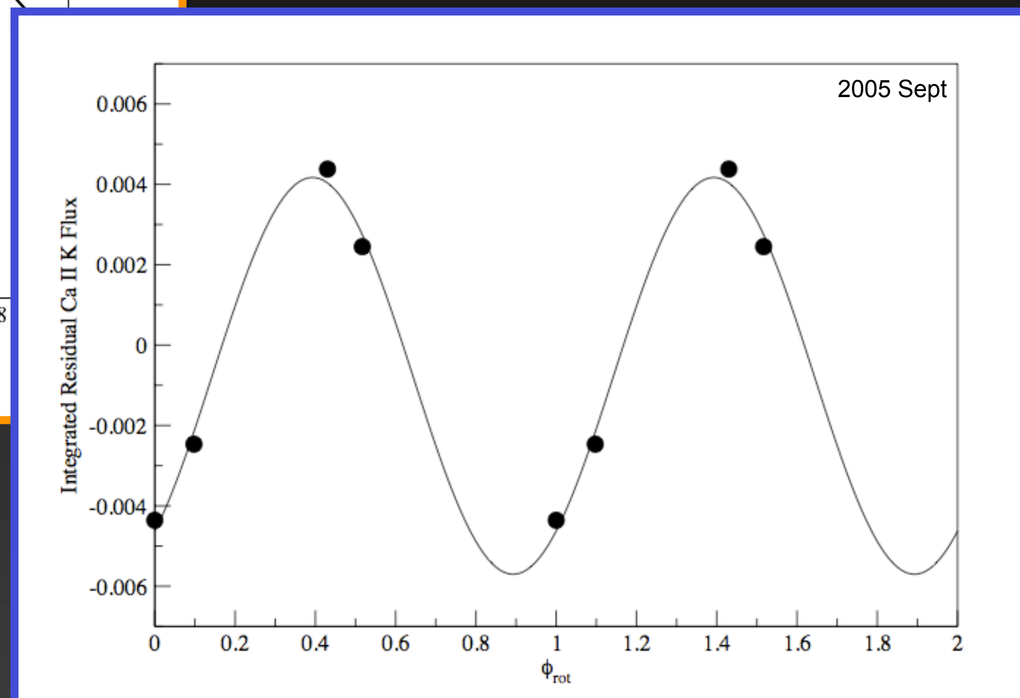
days

Gurdemir, Redfield & Cuntz, 2012

υ And



P_{orb}= 4.6 days

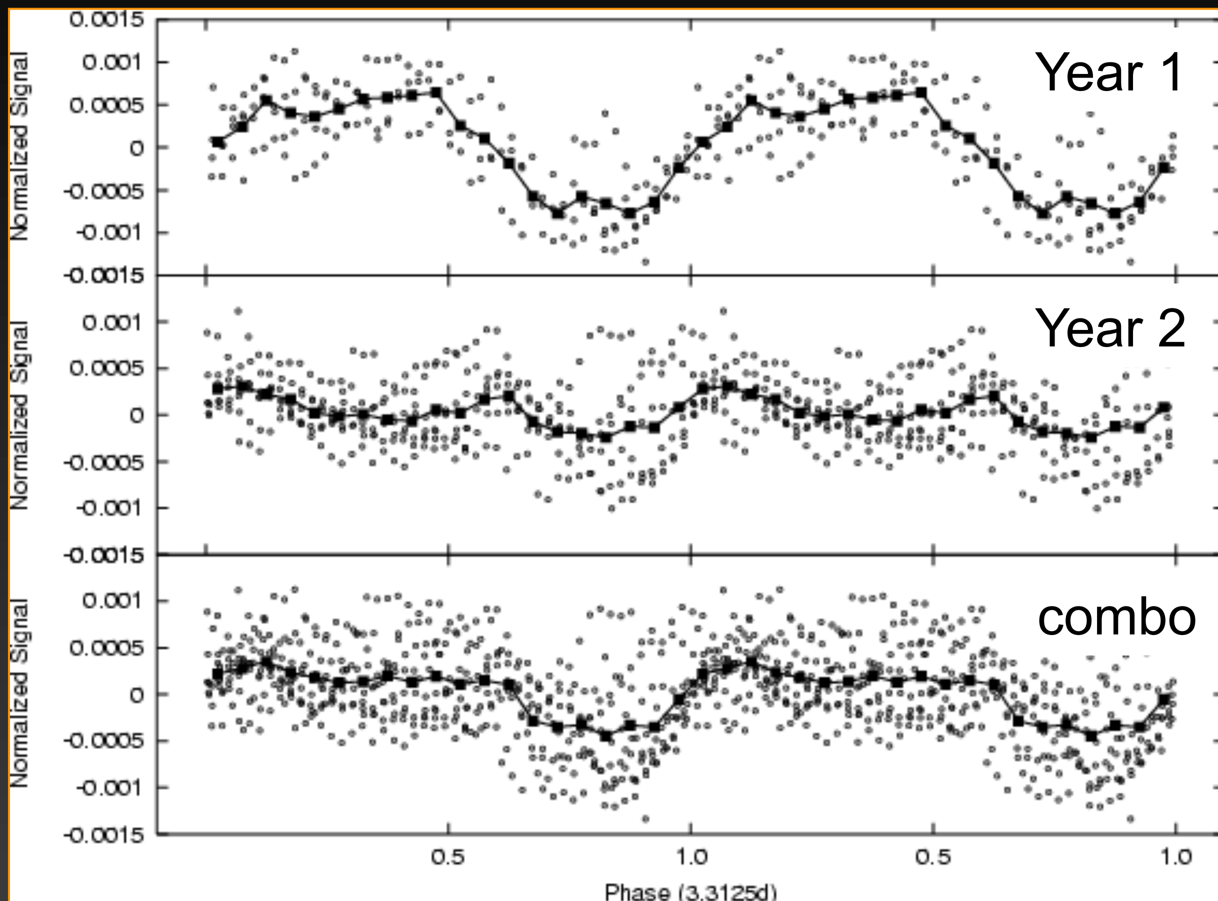


P_{rot}= 12 days

SPI Observations from Space

MOST photometry of stars with hot Jupiters

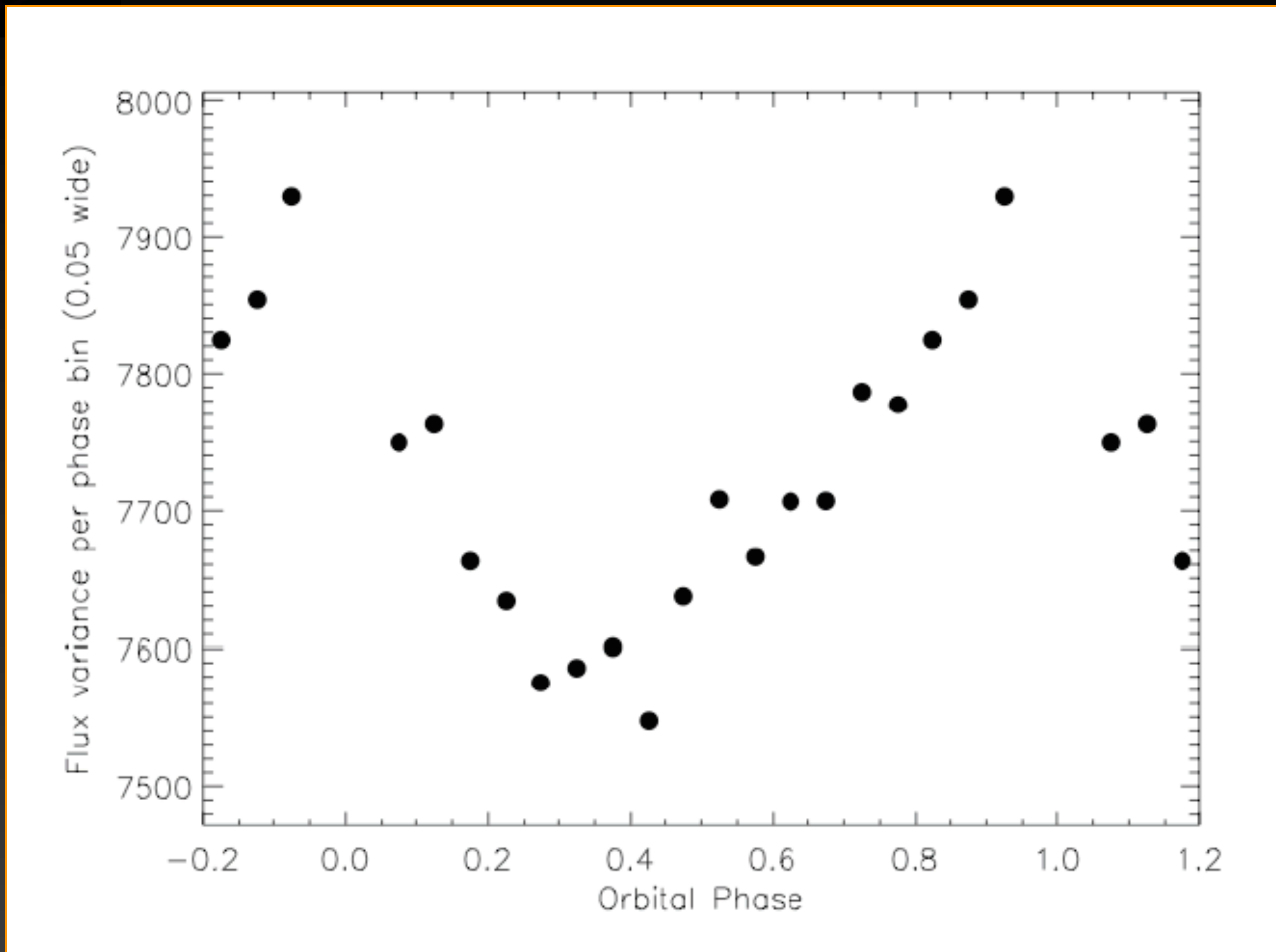
Normalized Signal



Orbital Phase

Walker et al. 2008

CoRoT photometry of CoRoT-2b (M_p=3.3M_J)

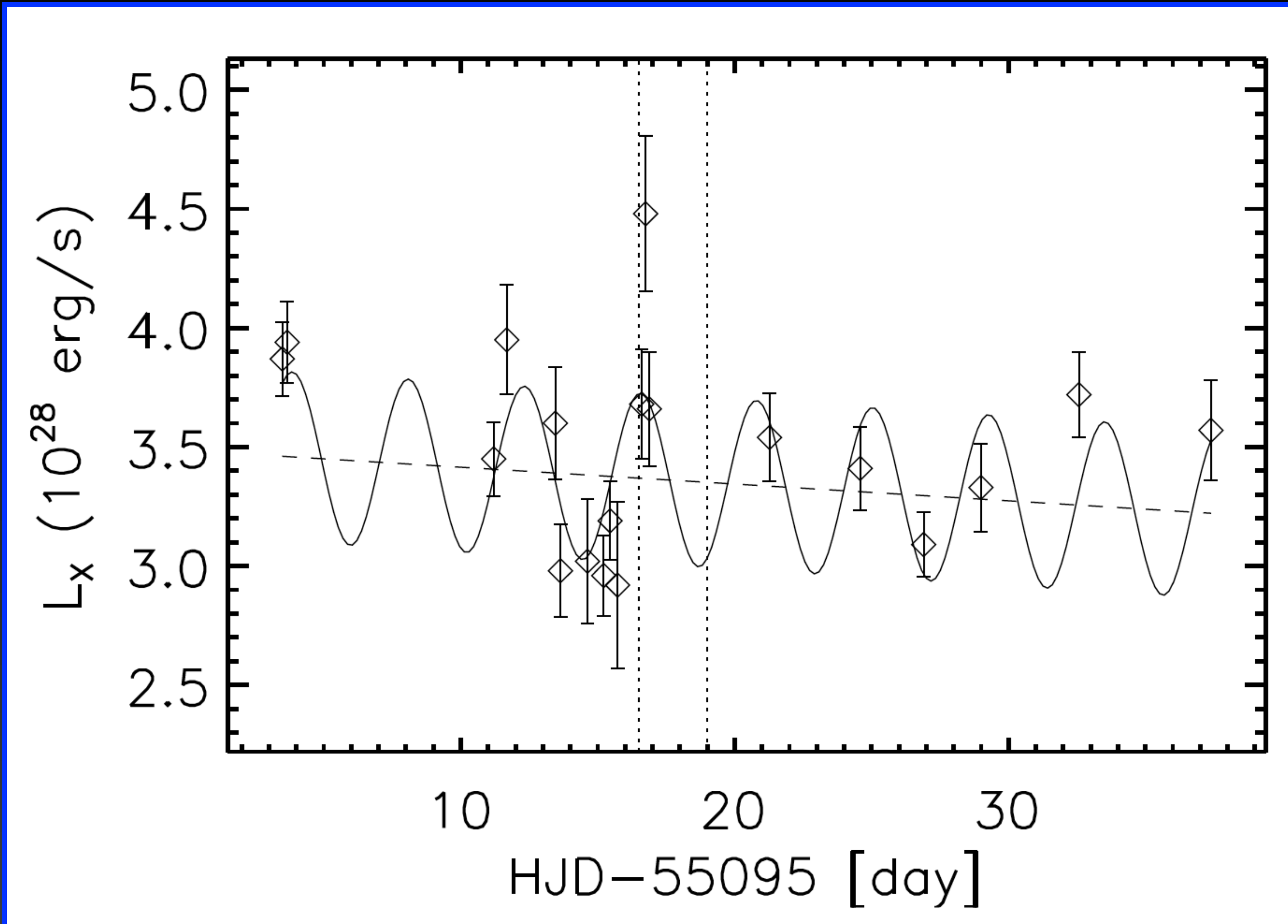


Flux Variance

Orbital Phase (P=1.74 d)

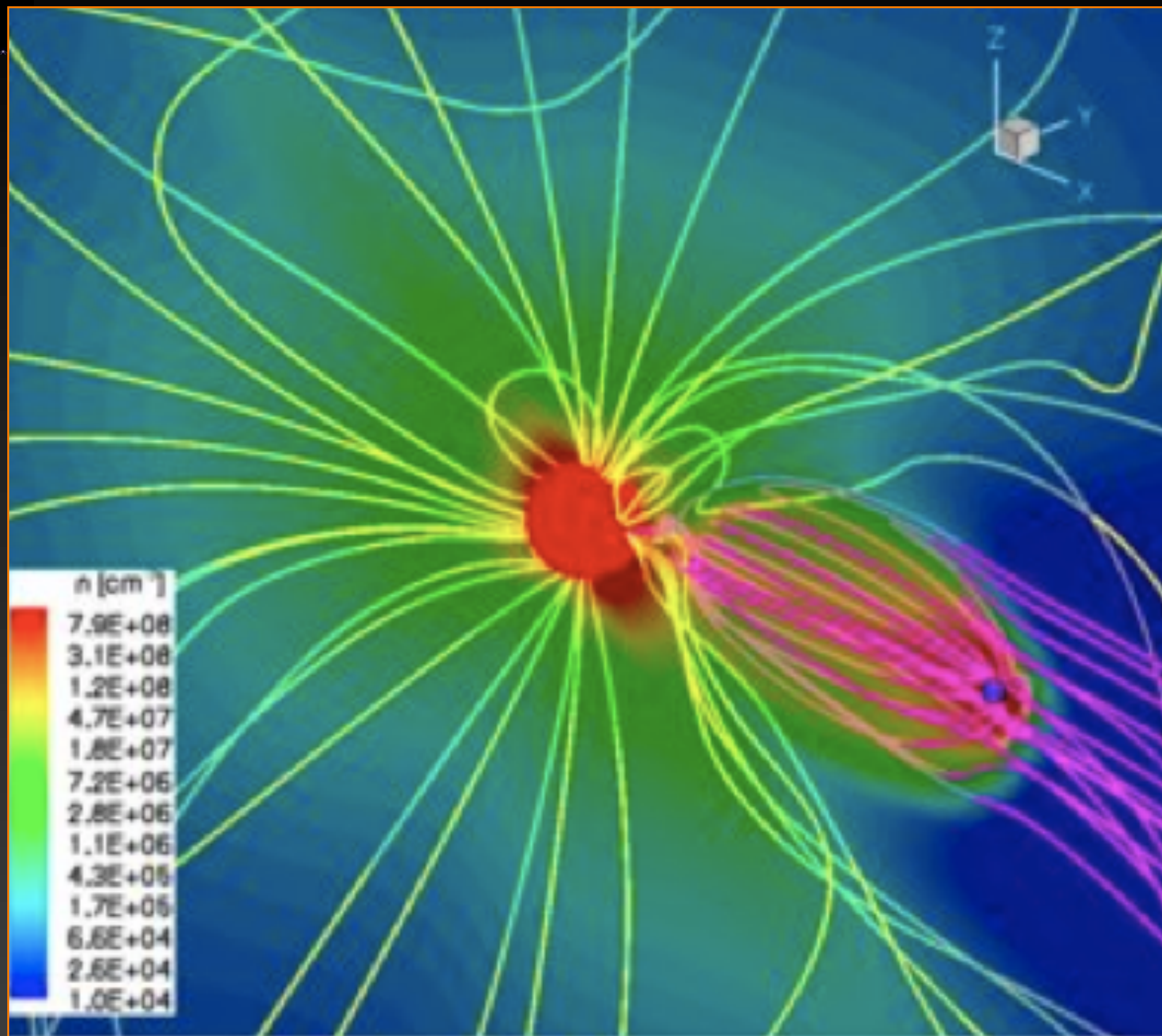
Pagano et al. 2009a

XMM Observations of HD 179949



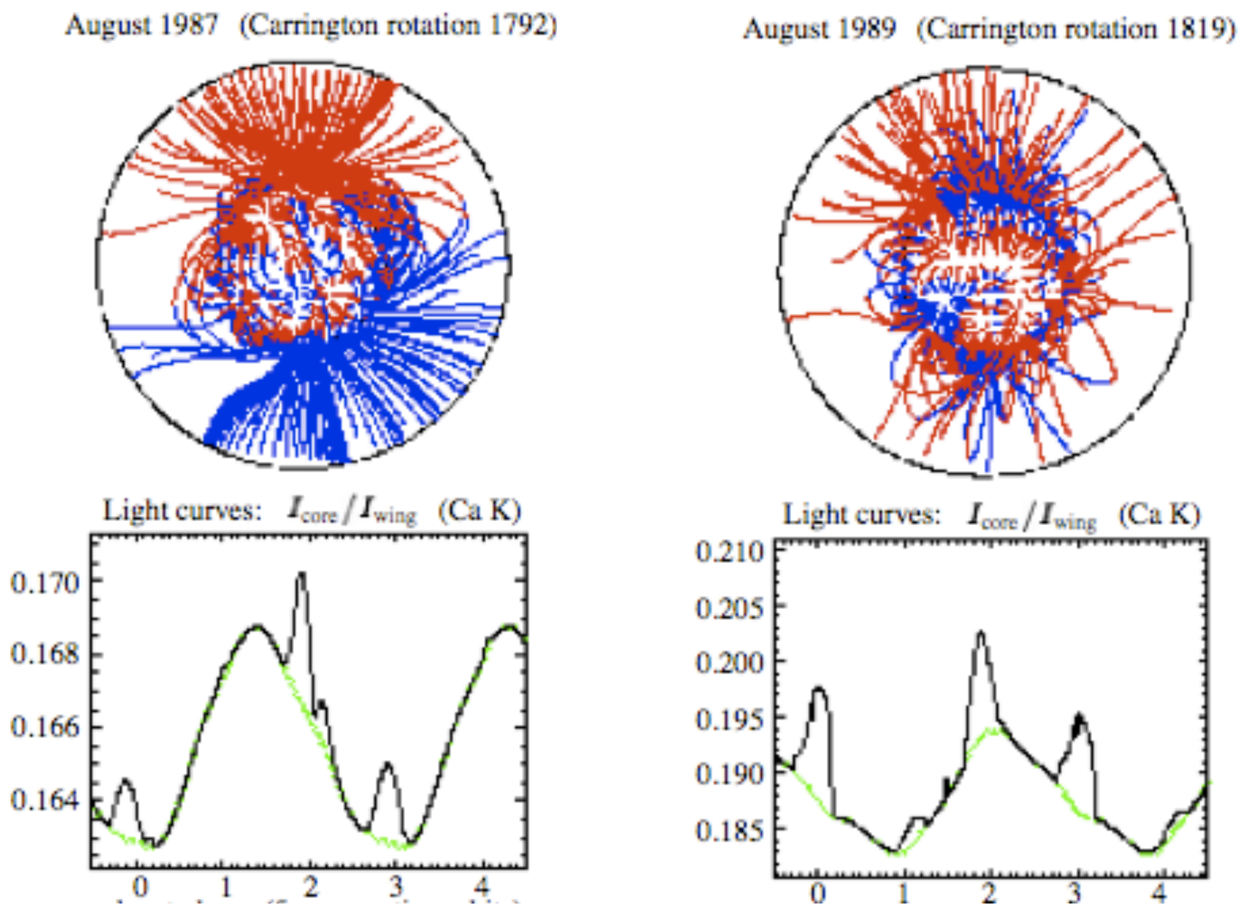
Scandariato et al. 2013

Full 3-D MHD Models for Magnetic SPI



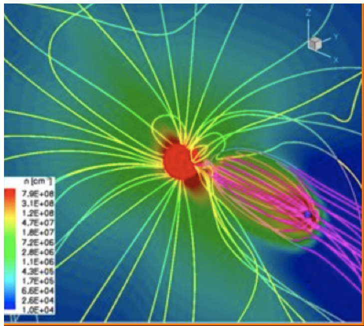
Cohen et al. 2009, 2010, 2011

Variable SPI due to Changing Stellar Fields



Ca II emission of 5 consecutive orbits

Cranmer & Saar 2007



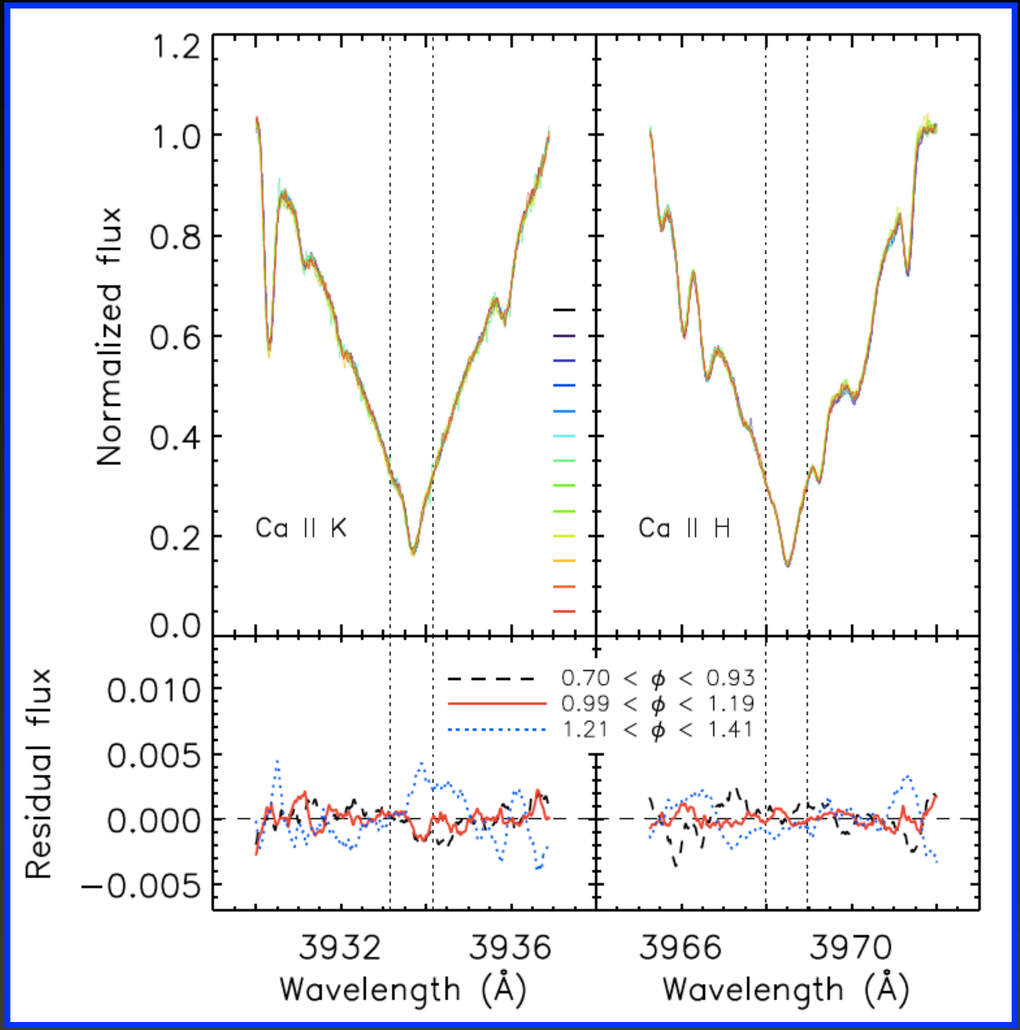
Know the star, know the planet.

$$\mathit{Power} \propto B_*^{4/3} B_p^{2/3} v_{rel}$$

Lanza 2009, 2012

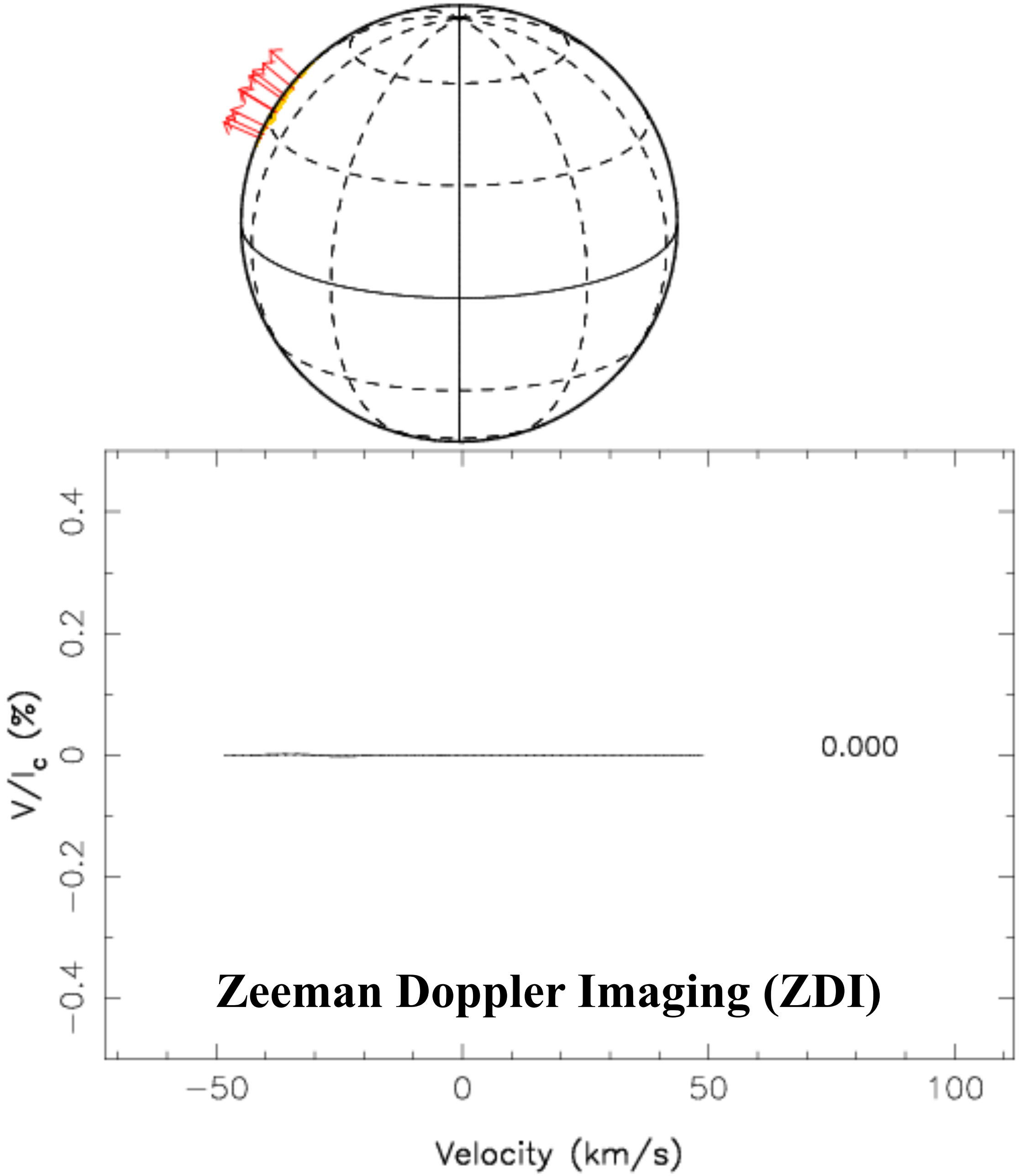
WASP-18: An Extreme case

Planet is 10 M_{Jup} with an orbital period of 0.94 days.



Miller et al. 2012

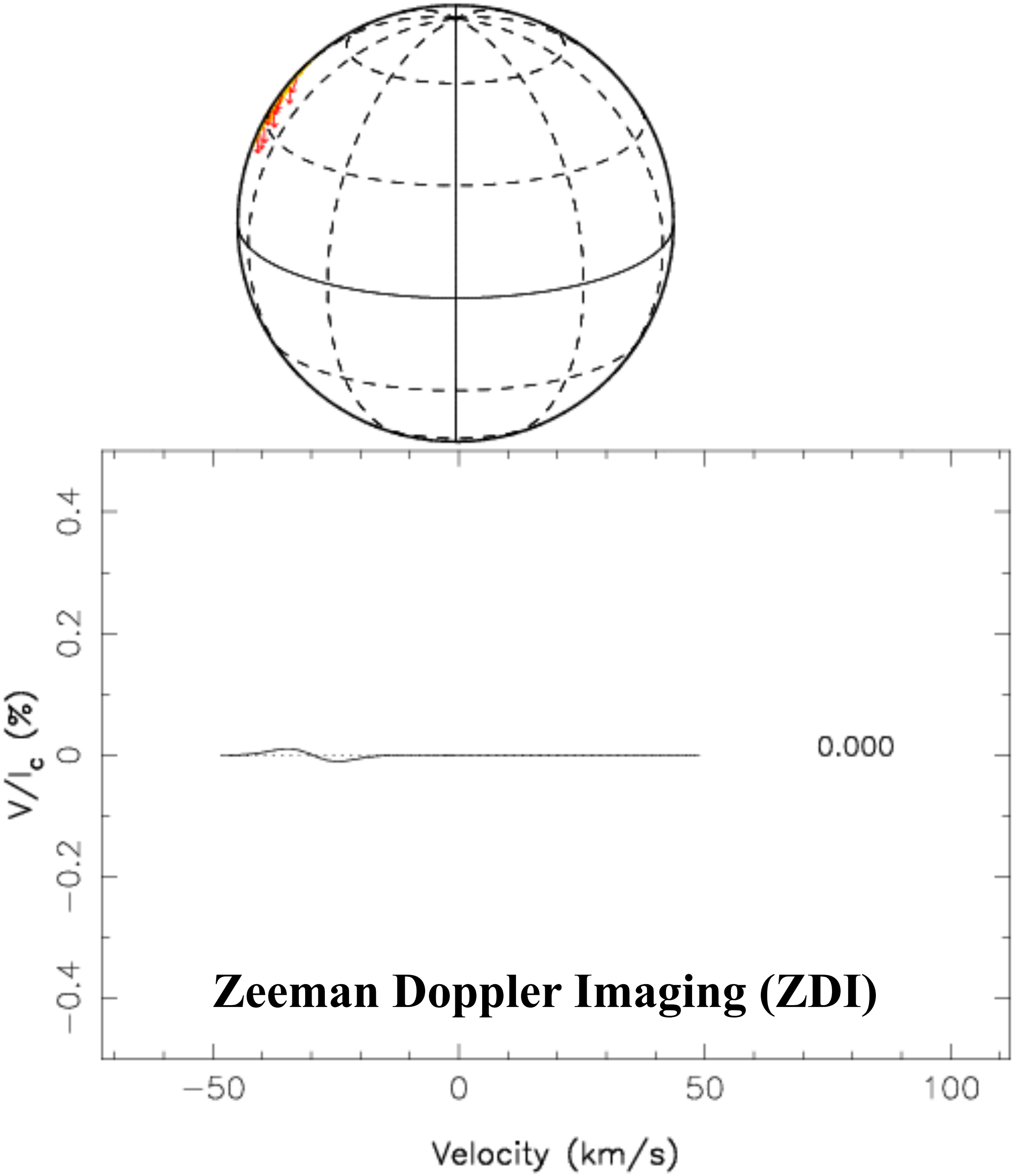
Radial Field



Zeeman Doppler Imaging (ZDI)

J.-F. Donati

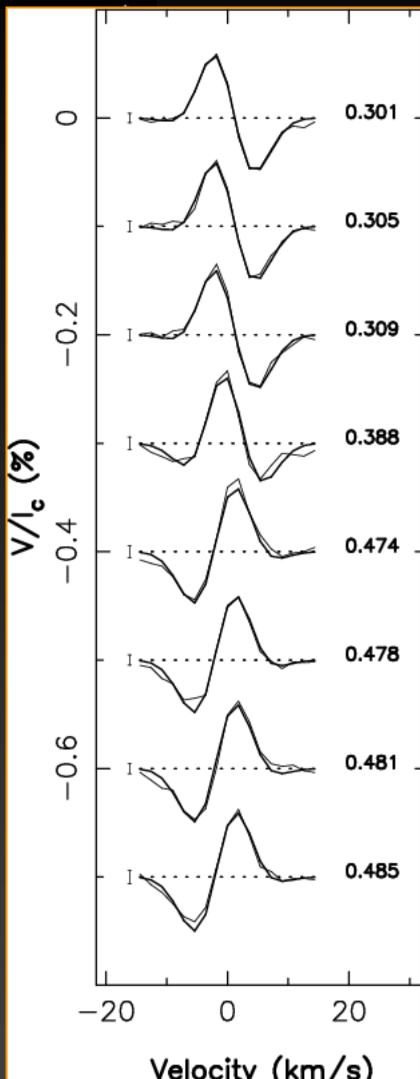
Azimuthal Field



J.-F. Donati

ZDI of HD 189733

Stokes V

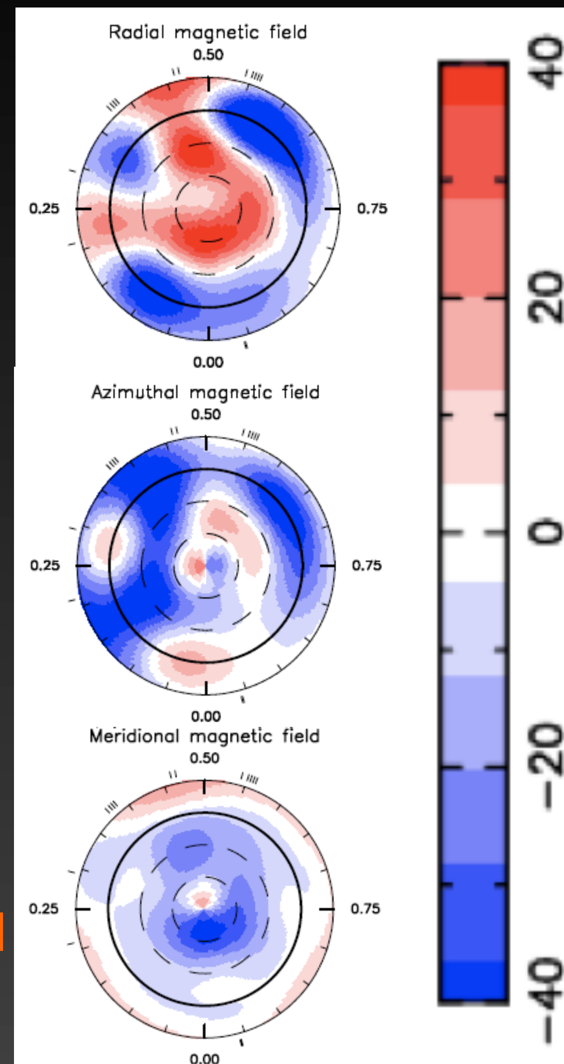


Magnetic Map

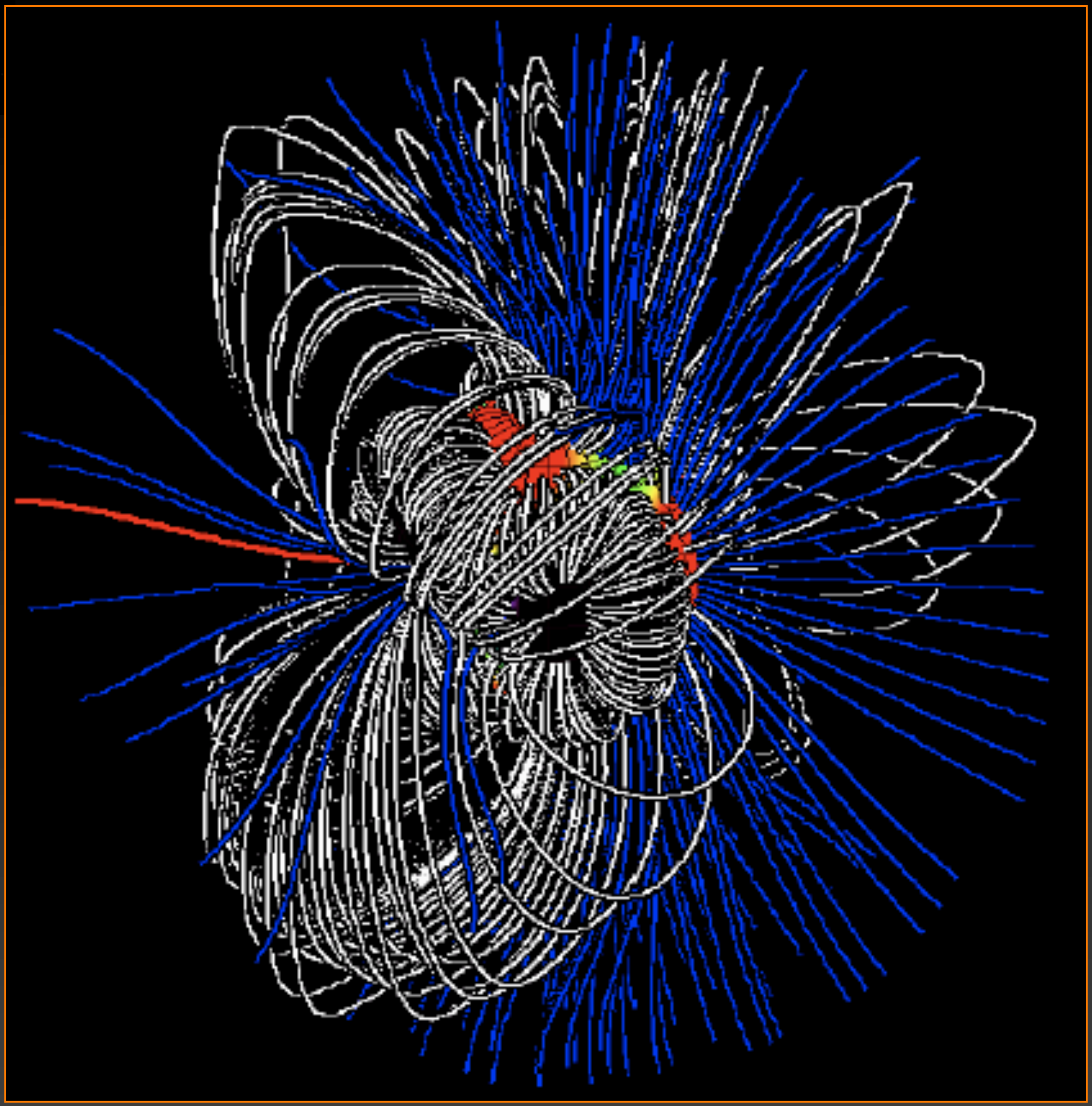
Radial

Azimuthal

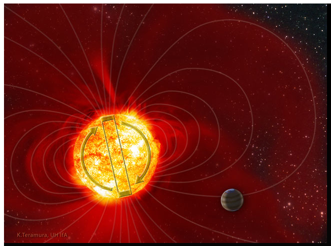
Meridional



Moutou et al. 2007, Fares et al. 2010

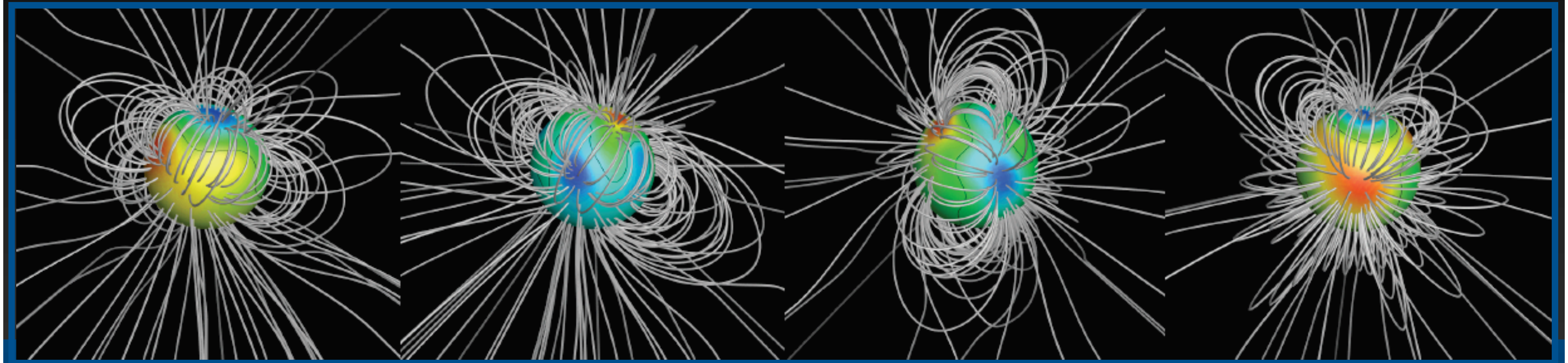


M. Jardine; Fares et al. 2010, 2012, 2013



Polarity Reversals of τ Boo

P_{orb} = 3.3 d, a = 7.1 R_*, $M_p \sin(40°)$=5.6 M_J

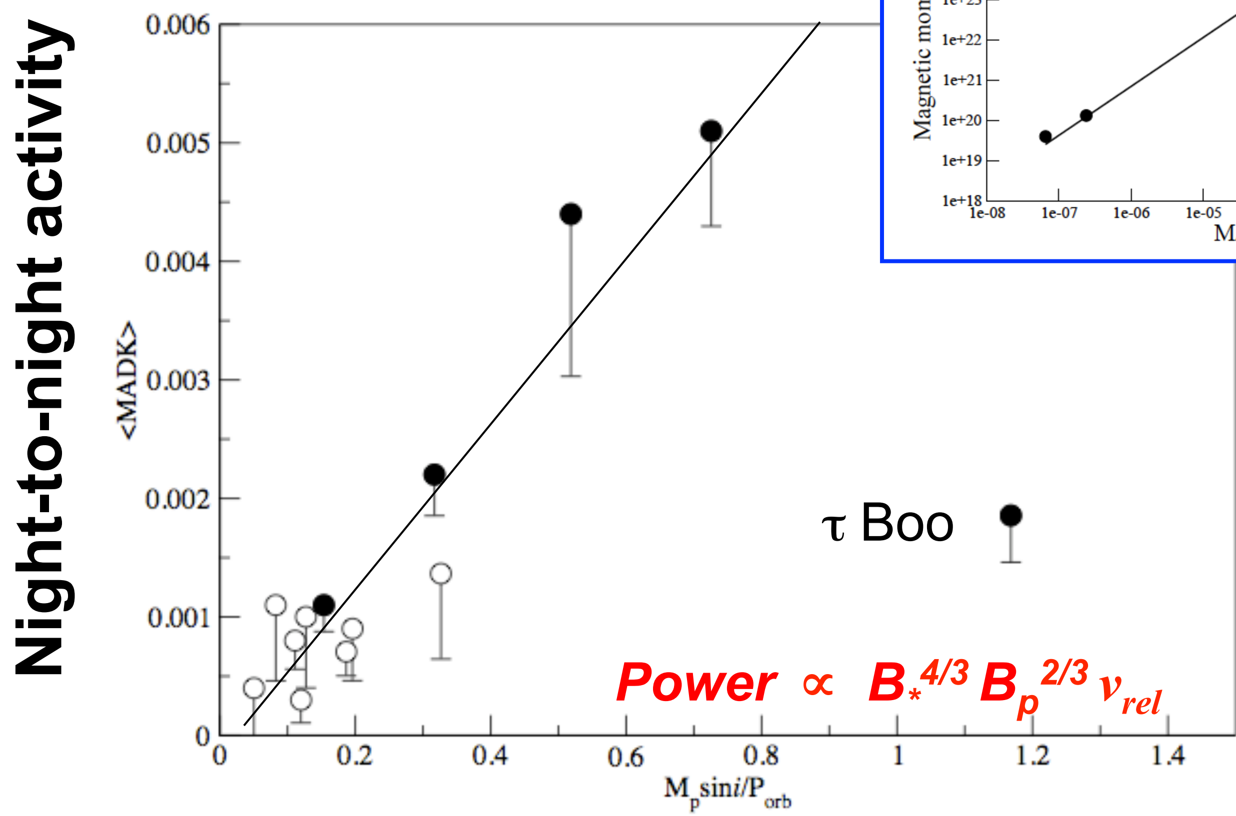


June 2006 (Catala et al, 2007) June 2007 (Donati et al, 2008) Jan 2008 June 2008

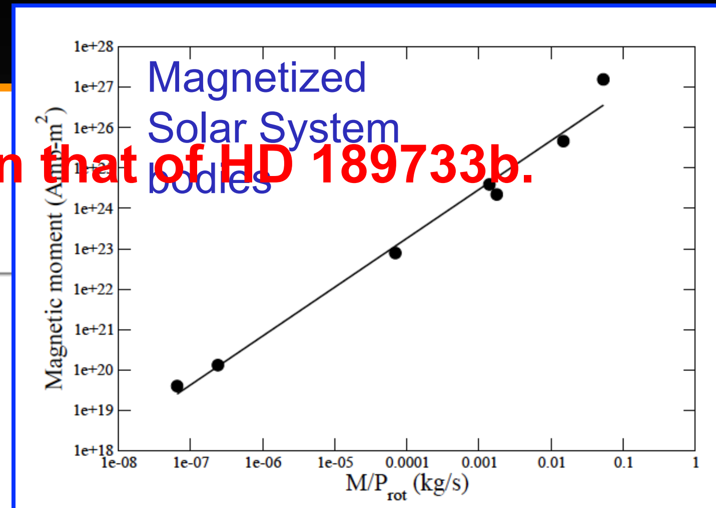
Catala et al. 2007, Donati et al. 2008, Fares et al. 2009, Vidotto et al. 2012

Probing Planetary B-fields?

HD 179949b has B_p 7× stronger than that of HD 189733b.



Power $\propto B_*^{4/3} B_p^{2/3} v_{rel}$



$M_p/P_{rot/orb}$ α planet's magnetic moment

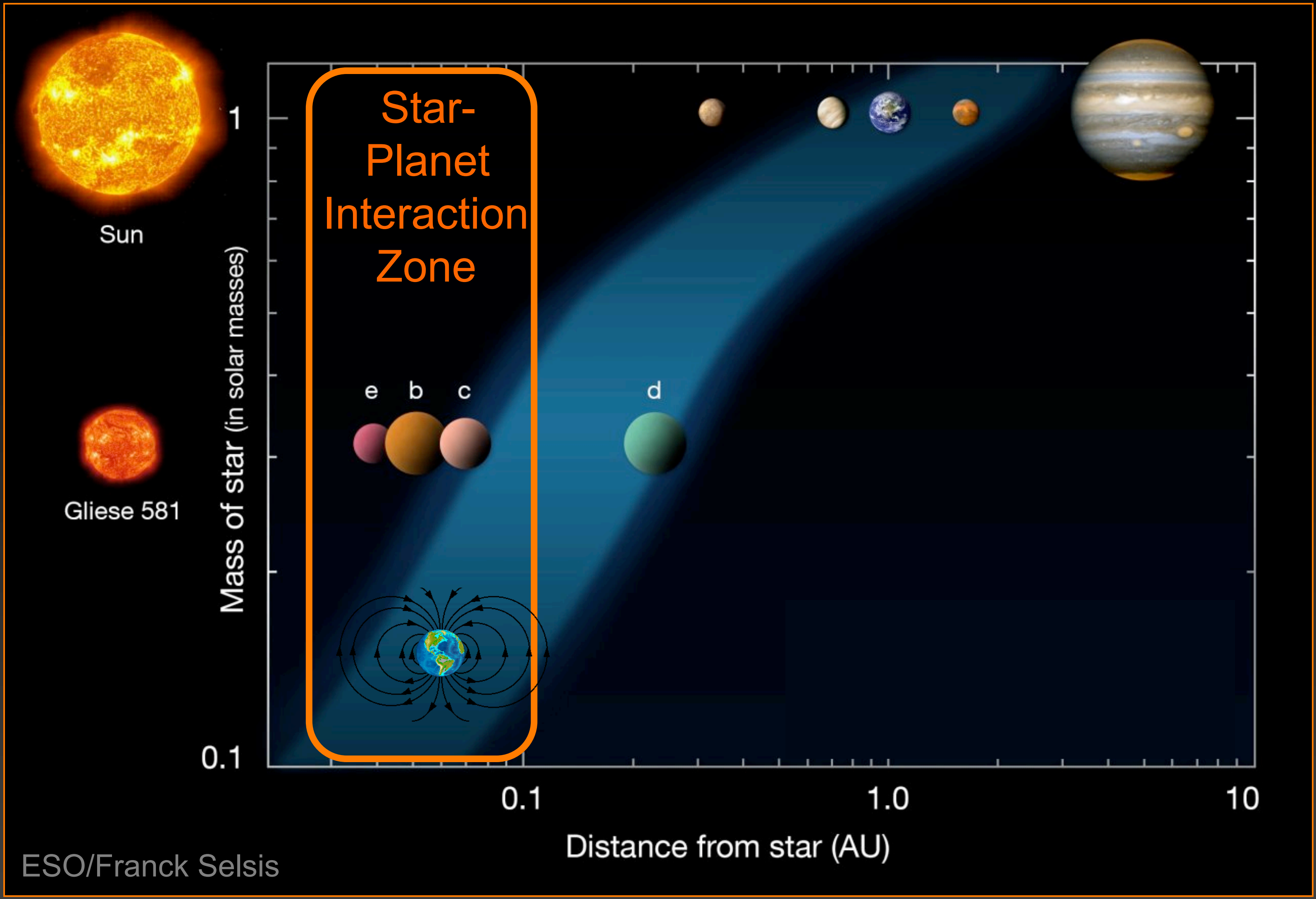
How can magnetic SPI inform us about habitable zone rocky planets?

Probing a Planet’s Interior and Potential for Habitability

The Earth’s magnetic field is generated by a fluid metallic iron-rich core.

E. Shkolnik, Lowell Observatory

Habitable Zone



Conclusion

Magnetic SPI is observable in close-in planetary systems, and provides a valuable probe exoplanetary magnetic fields.