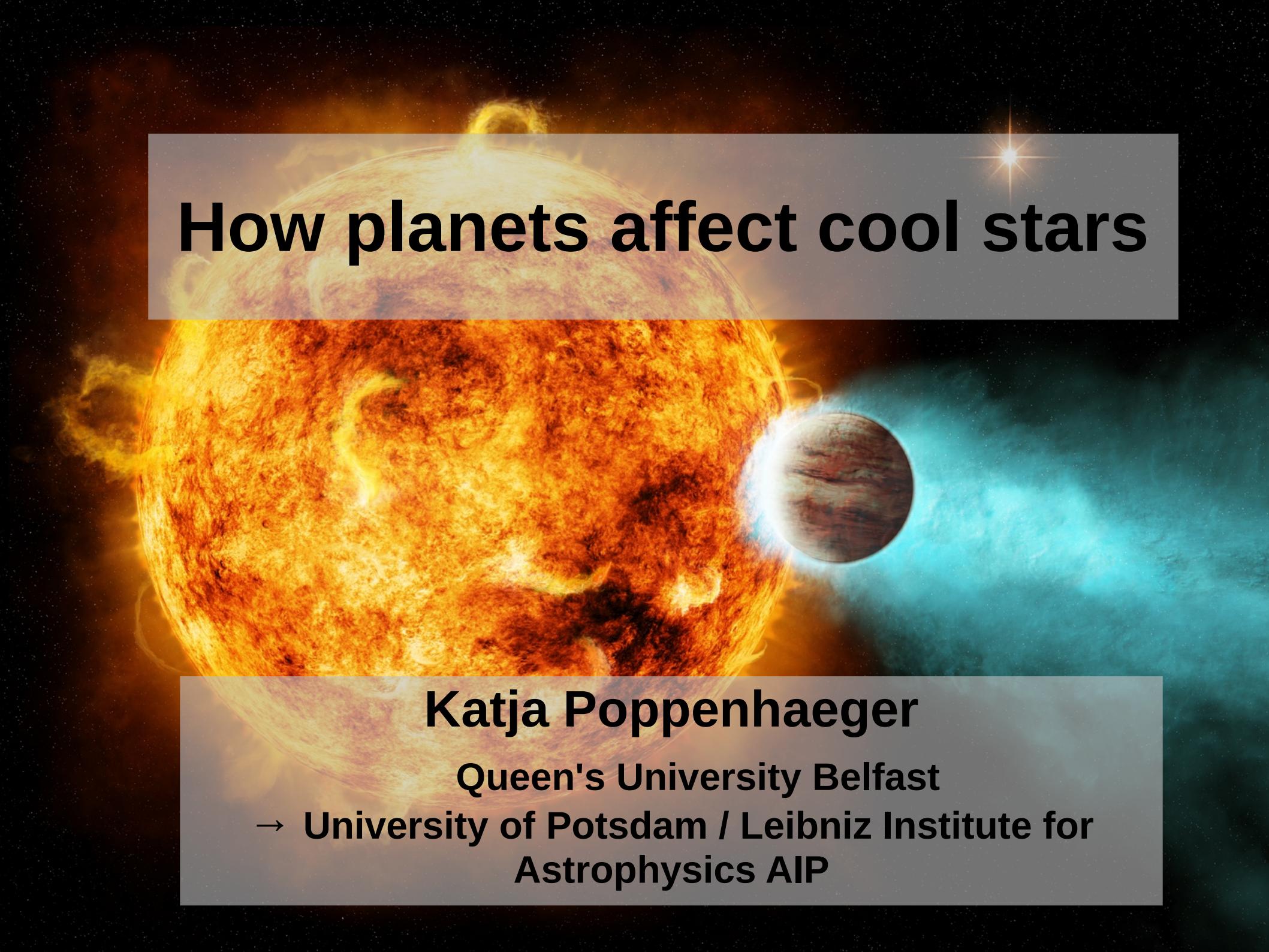


# How planets affect cool stars

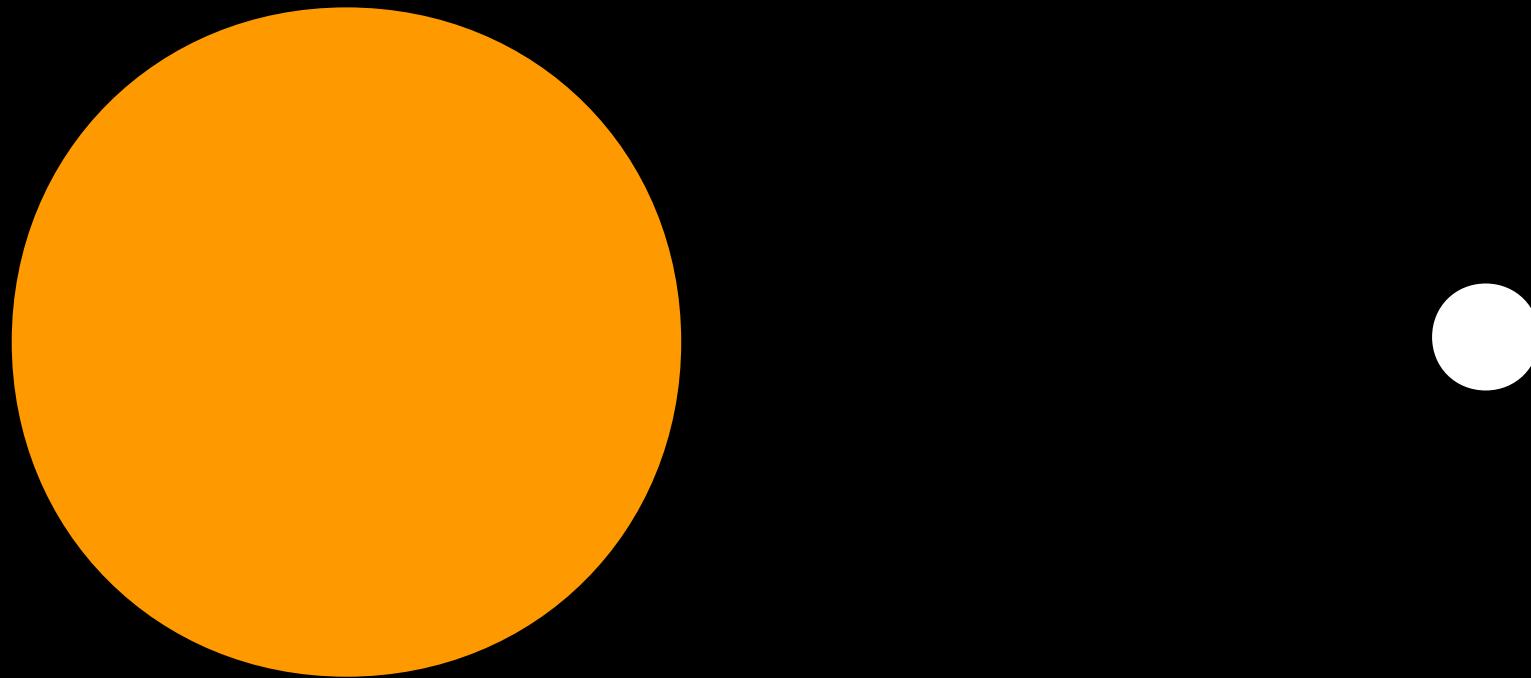


Katja Poppenhaeger

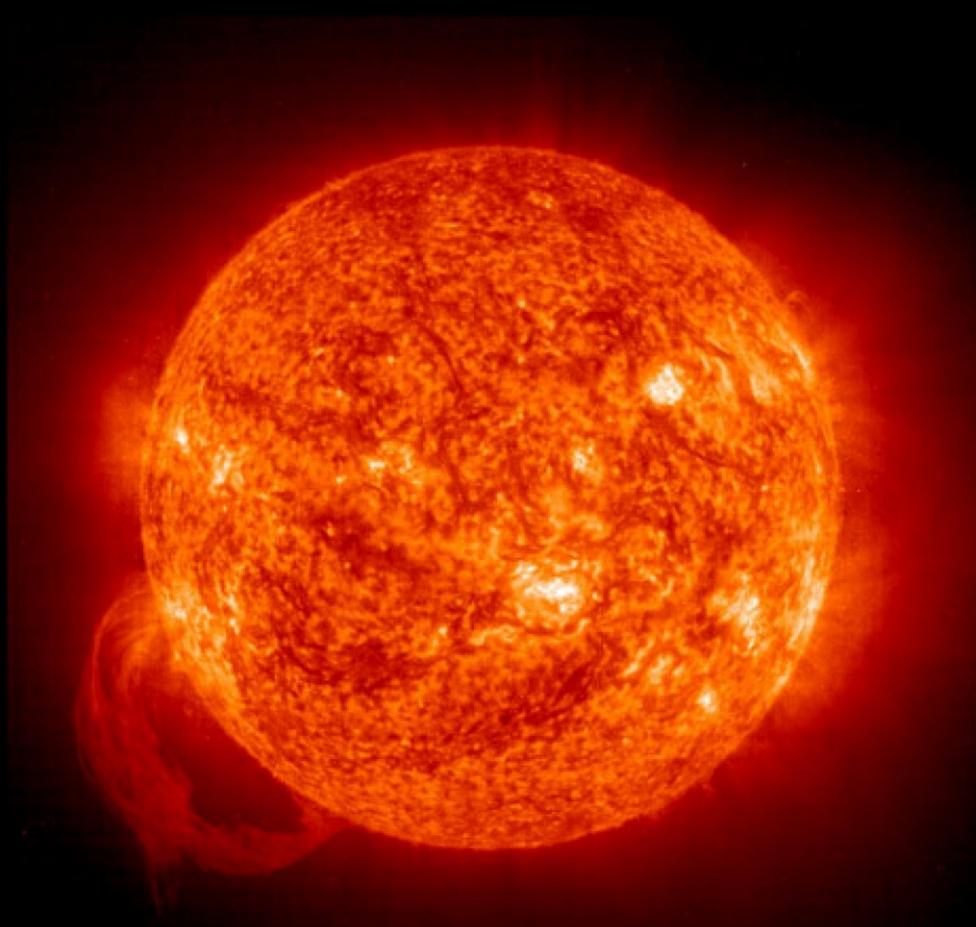
Queen's University Belfast

→ University of Potsdam / Leibniz Institute for  
Astrophysics AIP

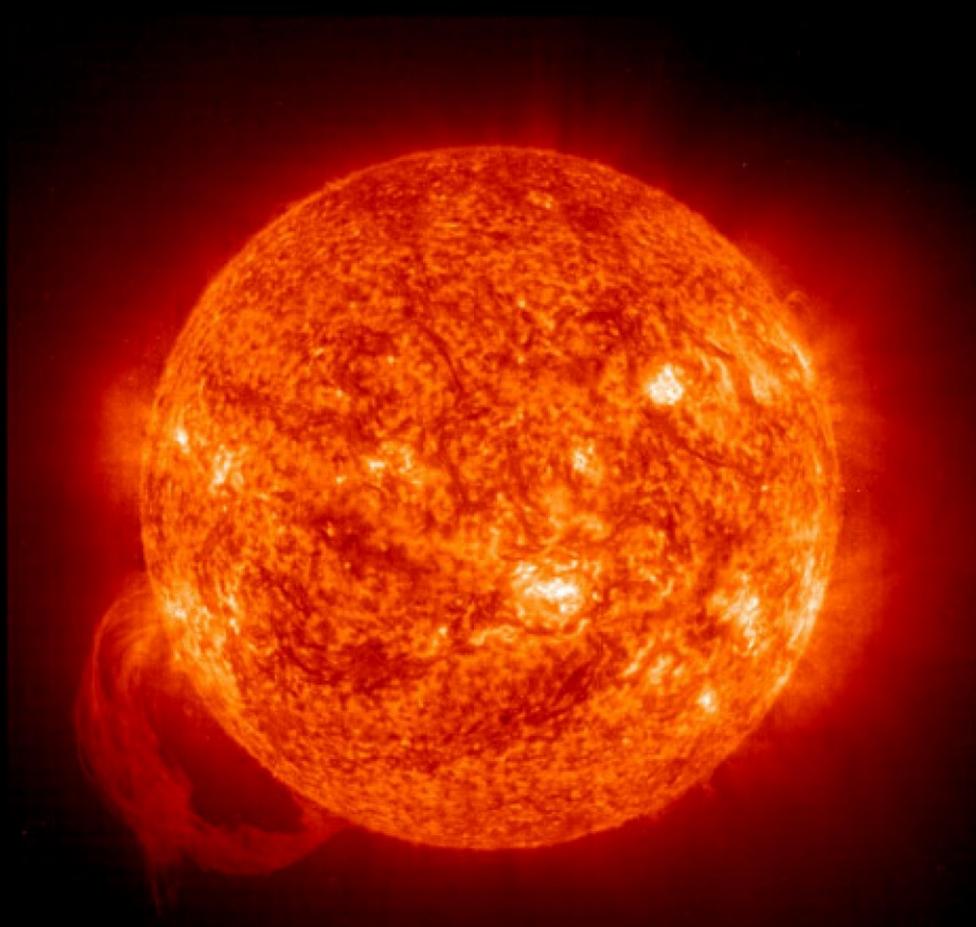
# Star-exoplanet systems



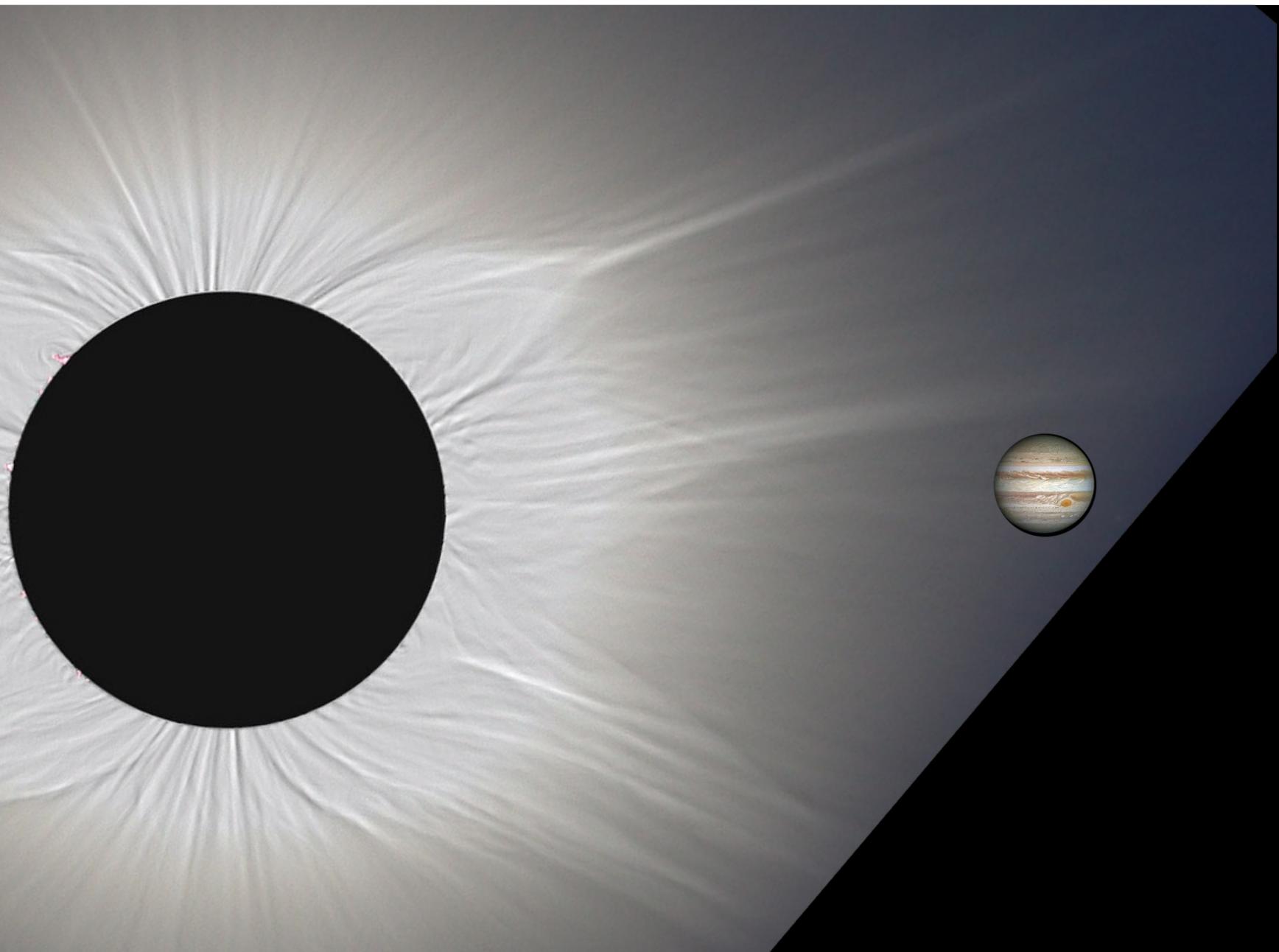
# Star-exoplanet systems



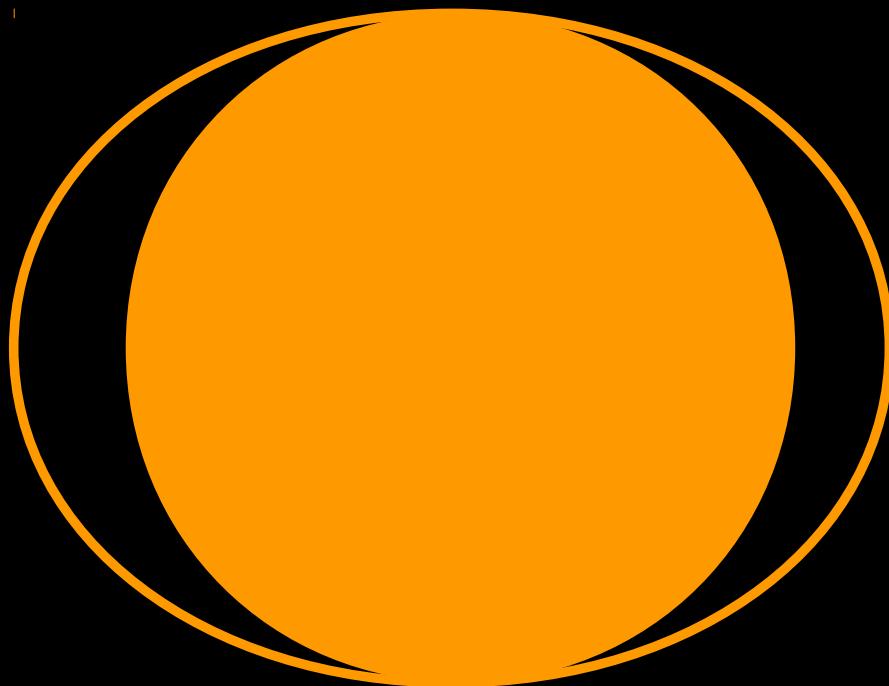
# Star-exoplanet systems



# Star-exoplanet systems



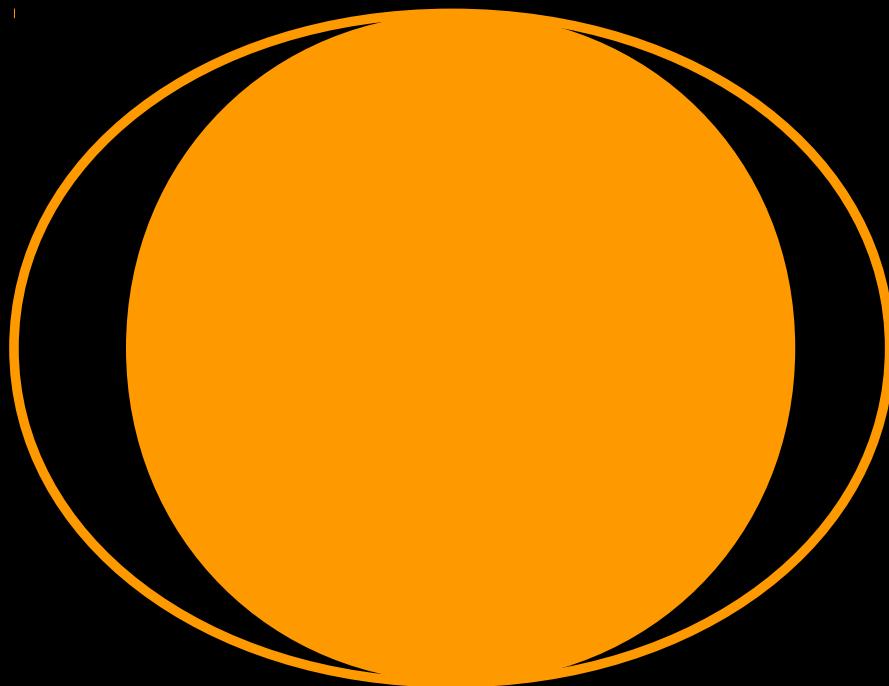
# Star-exoplanet systems



tidal  
interaction



# Star-exoplanet systems

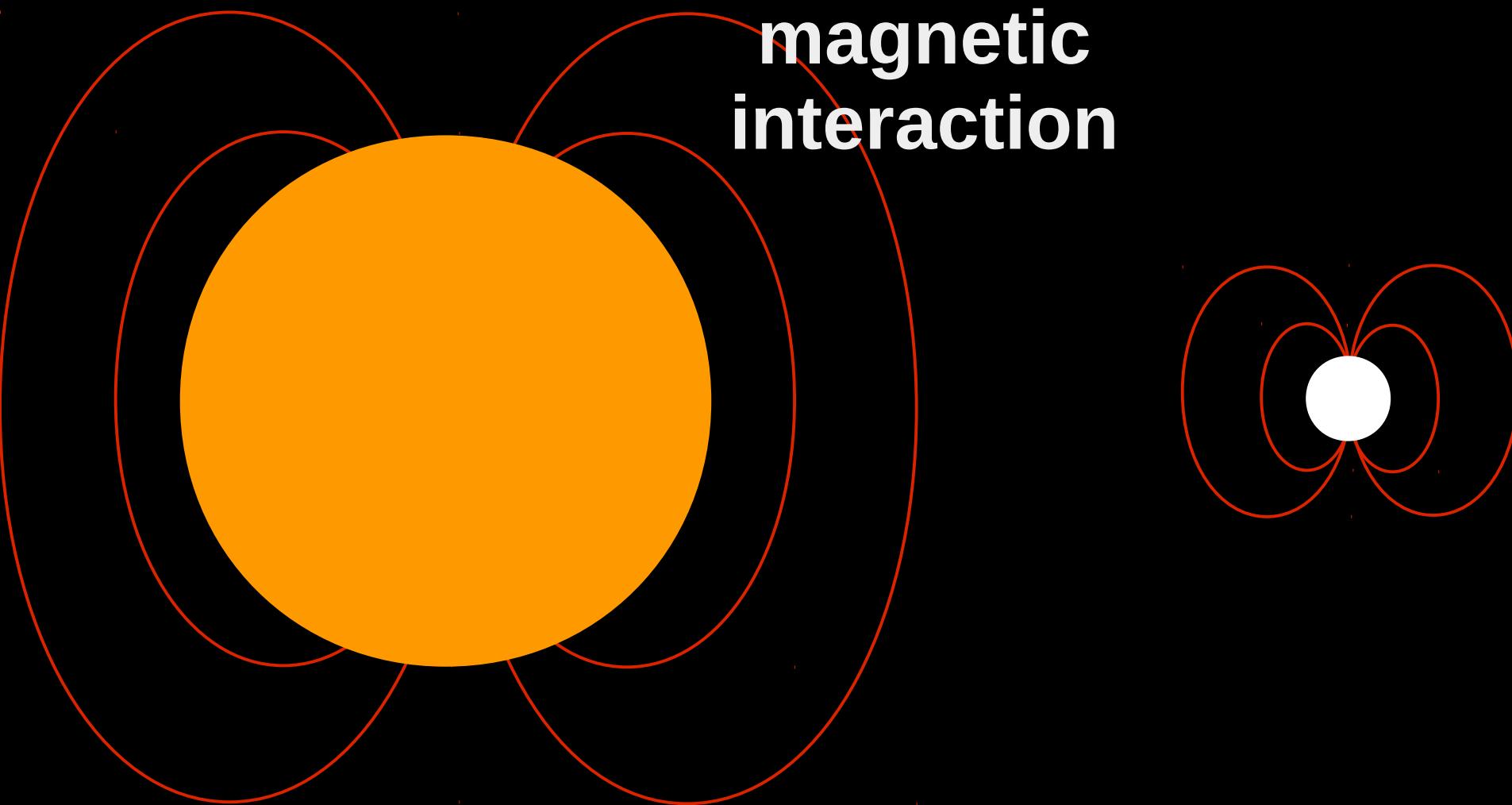


tidal  
interaction



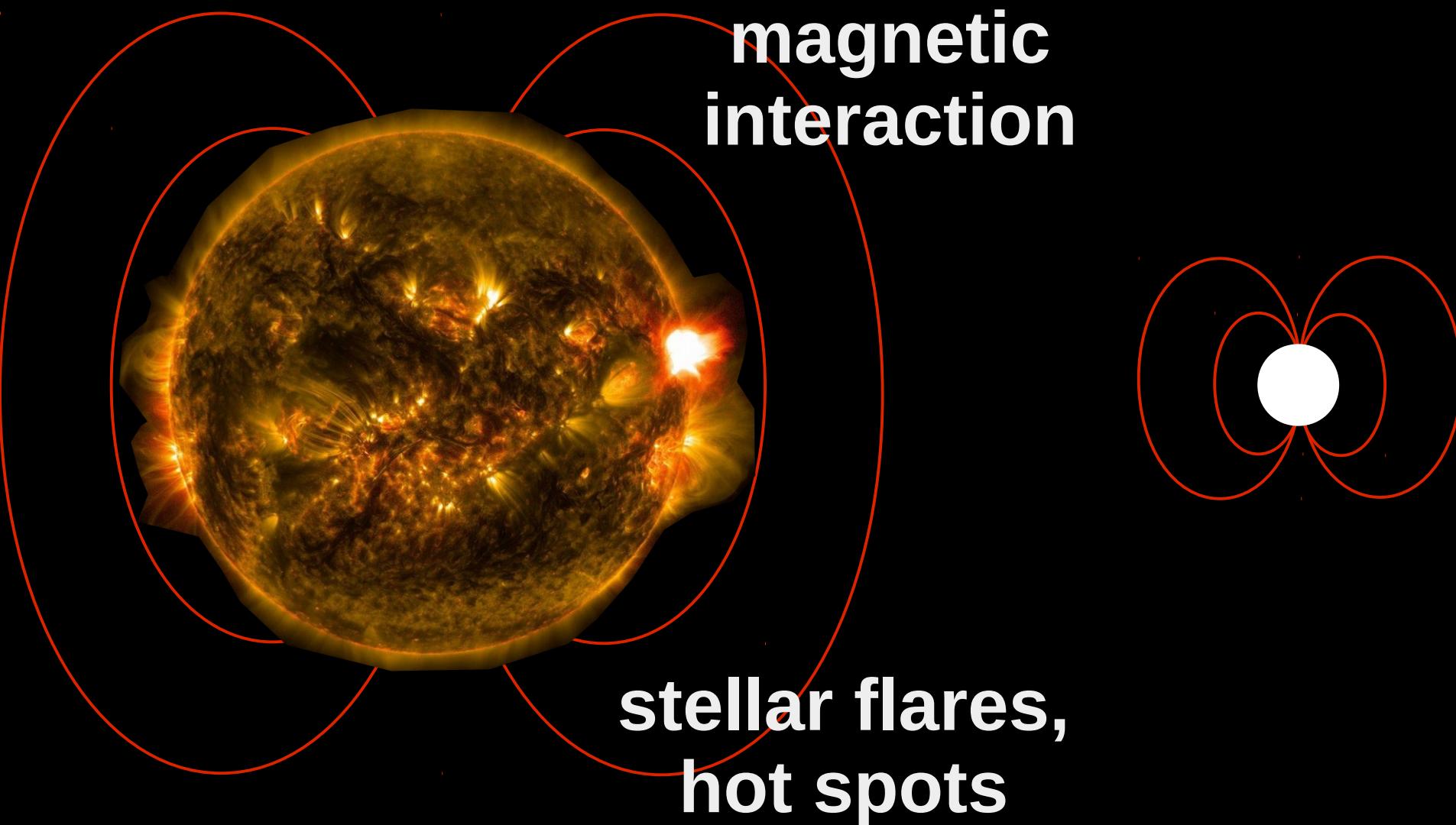
stellar spin

# Star-exoplanet systems



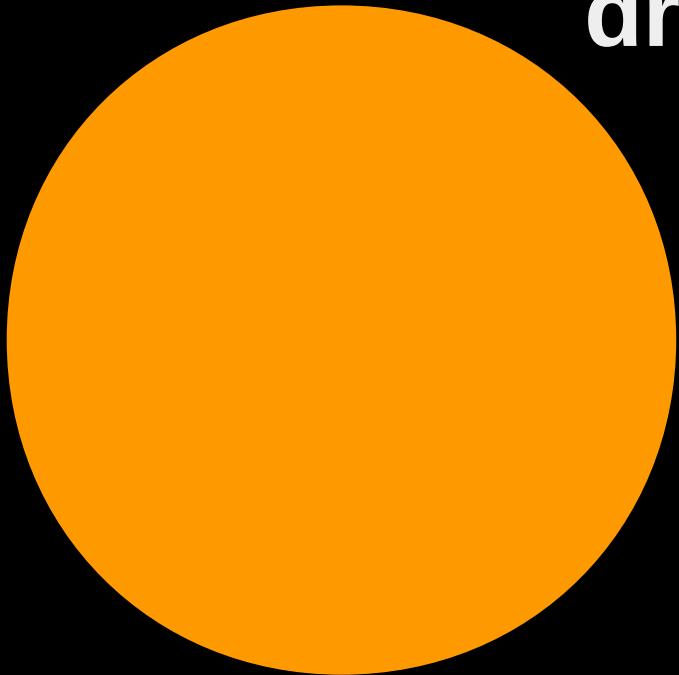
A diagram illustrating the magnetic interaction between a star and an exoplanet. On the left, a large orange circle represents the star, with several concentric red arcs extending from its right side, representing the star's magnetic field. On the right, a smaller white circle represents the exoplanet, with two red arcs extending from its left side, representing the planet's magnetic field. The text "magnetic interaction" is centered between the two celestial bodies.  
**magnetic  
interaction**

# Star-exoplanet systems



# Star-exoplanet systems

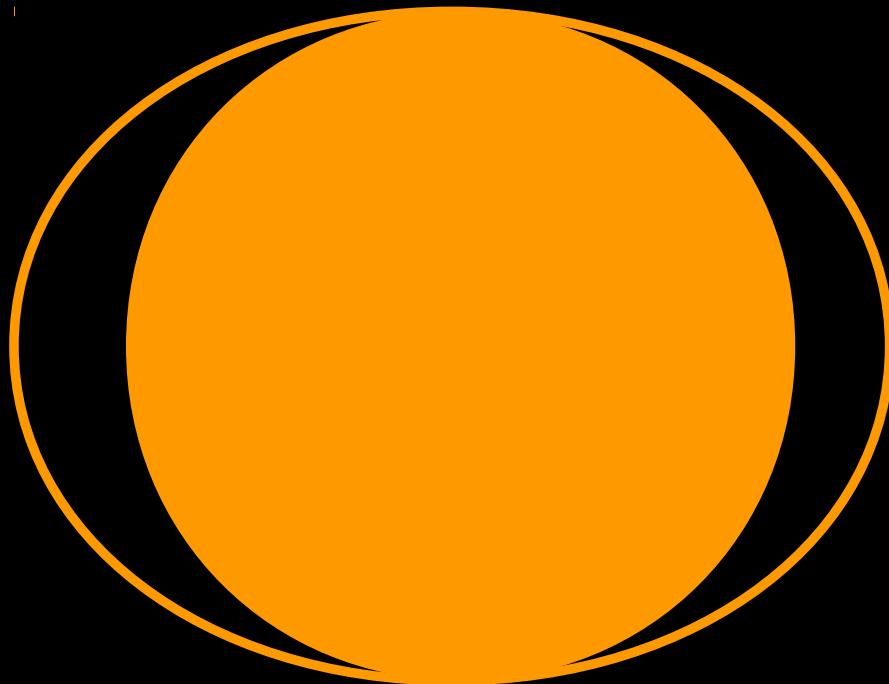
planetary  
effects  
driven by star



atmospheric  
blow-off



# Star-exoplanet systems

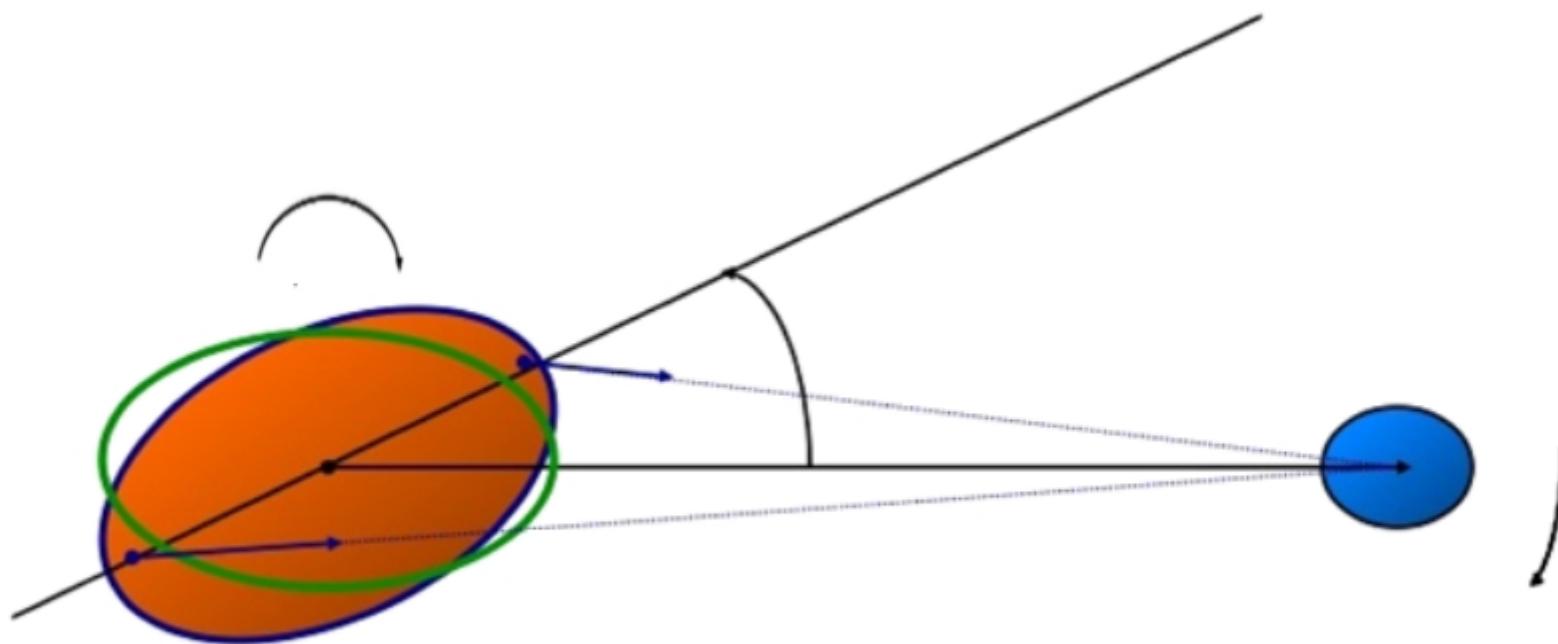


tidal  
interaction



stellar spin

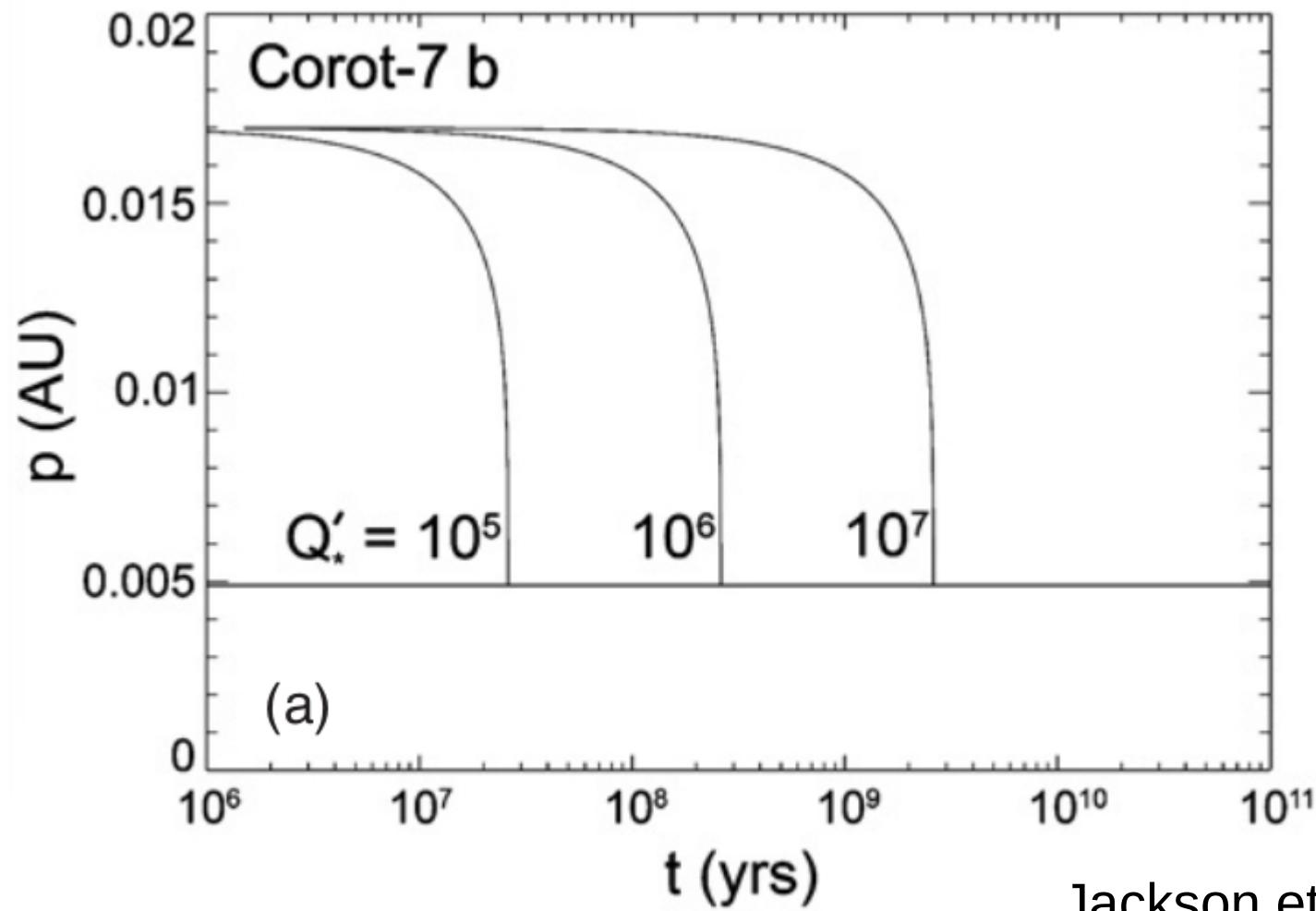
# Tidal interaction



Mathis & Remus (2013)

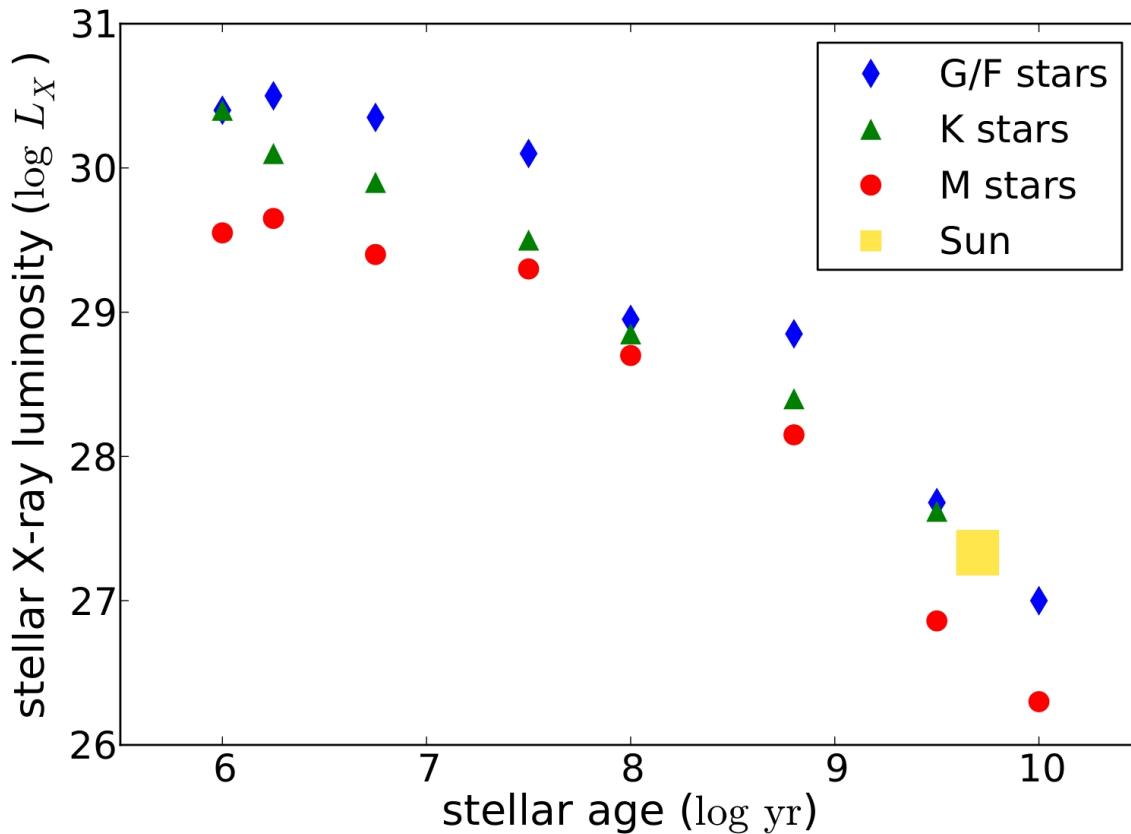
see also  
Lanza & Mathis (2016)

# Tidal interaction: inspiralling planets

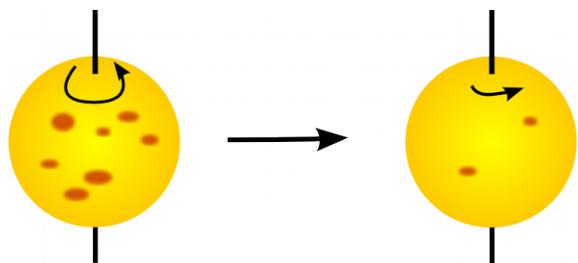


Jackson et al. (2009),  
Penev et al. (2012)

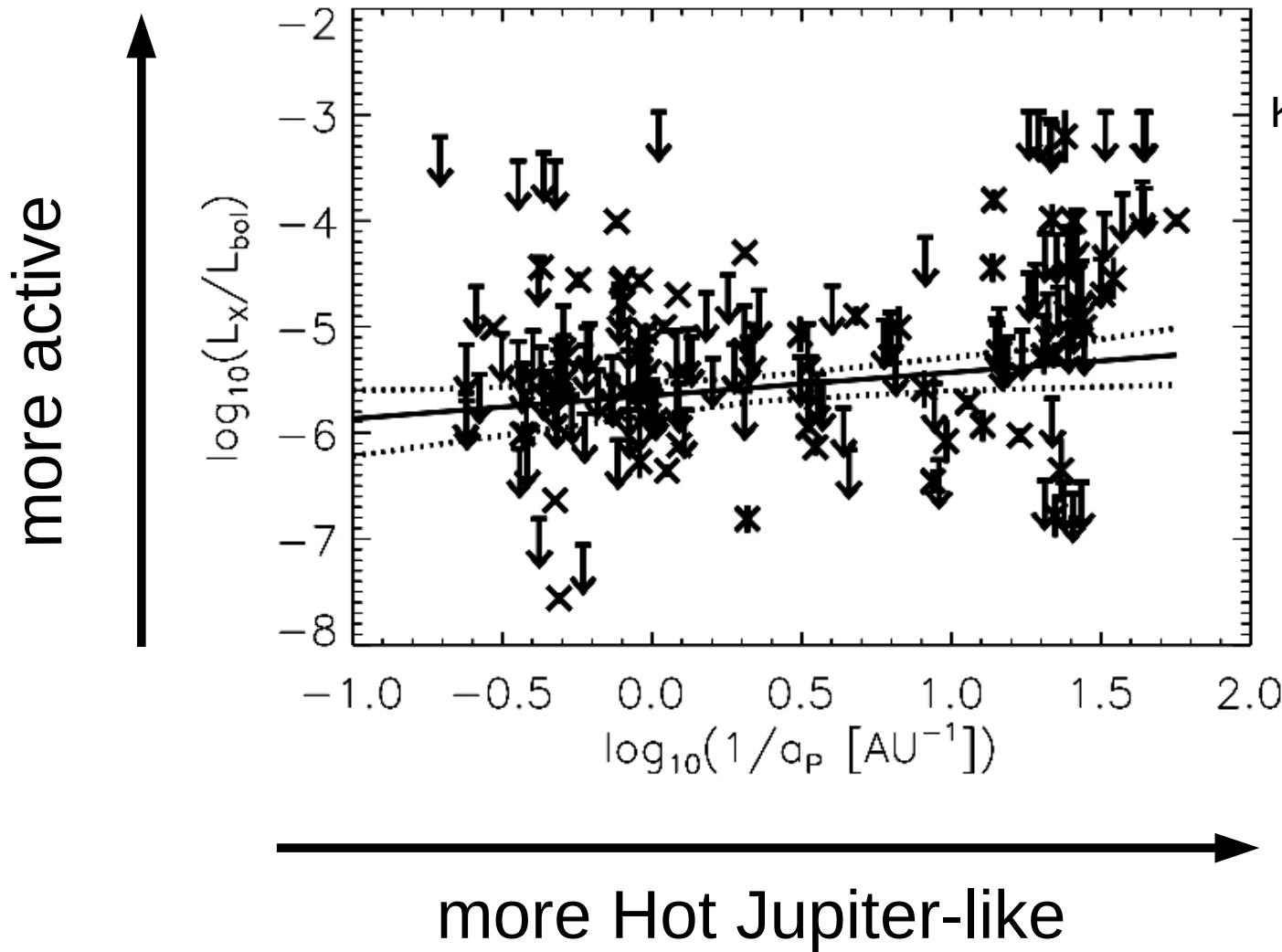
# How stars age on the main sequence



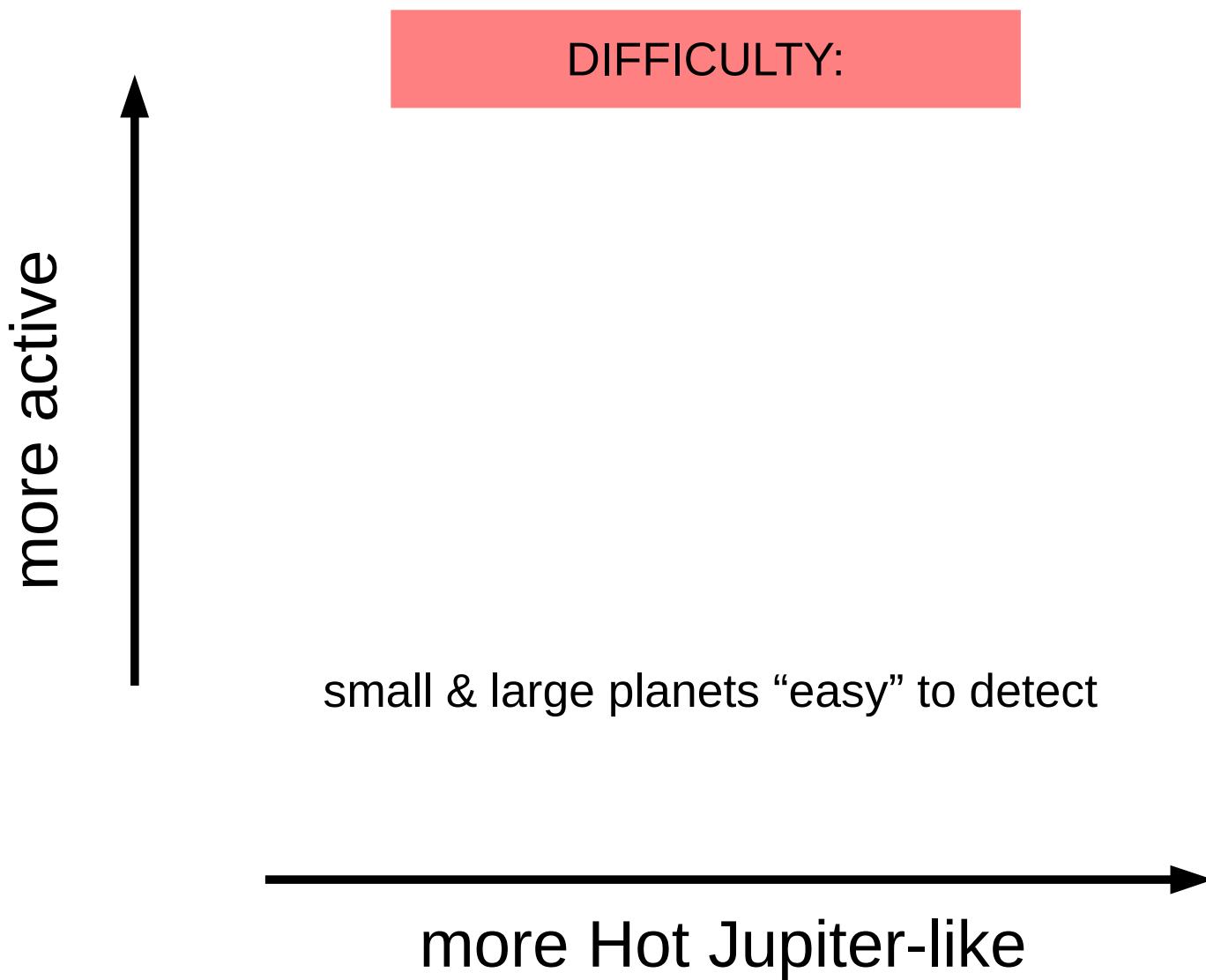
loss of angular  
momentum through  
stellar wind  
("magnetic braking")



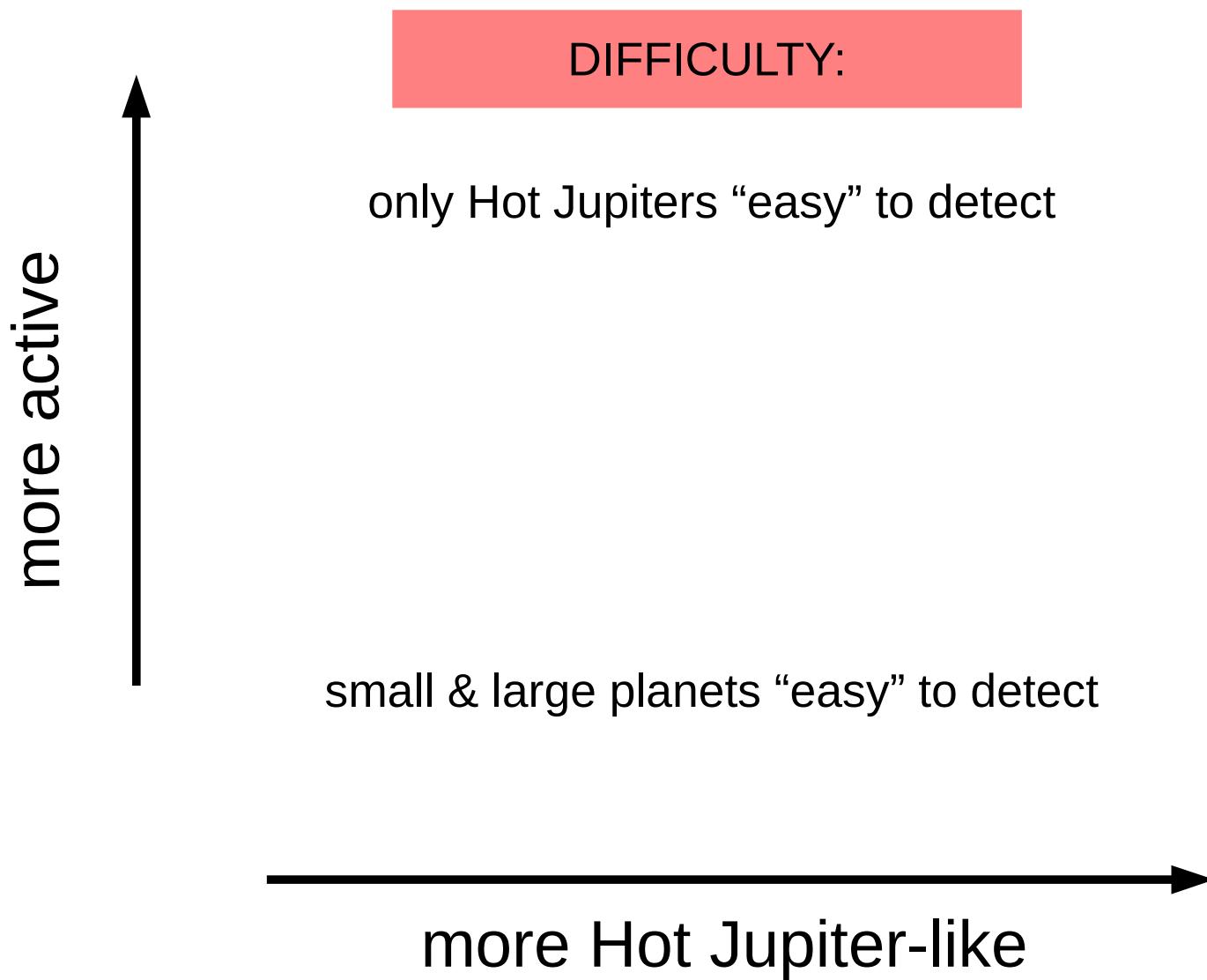
# Planet-induced activity: trends?



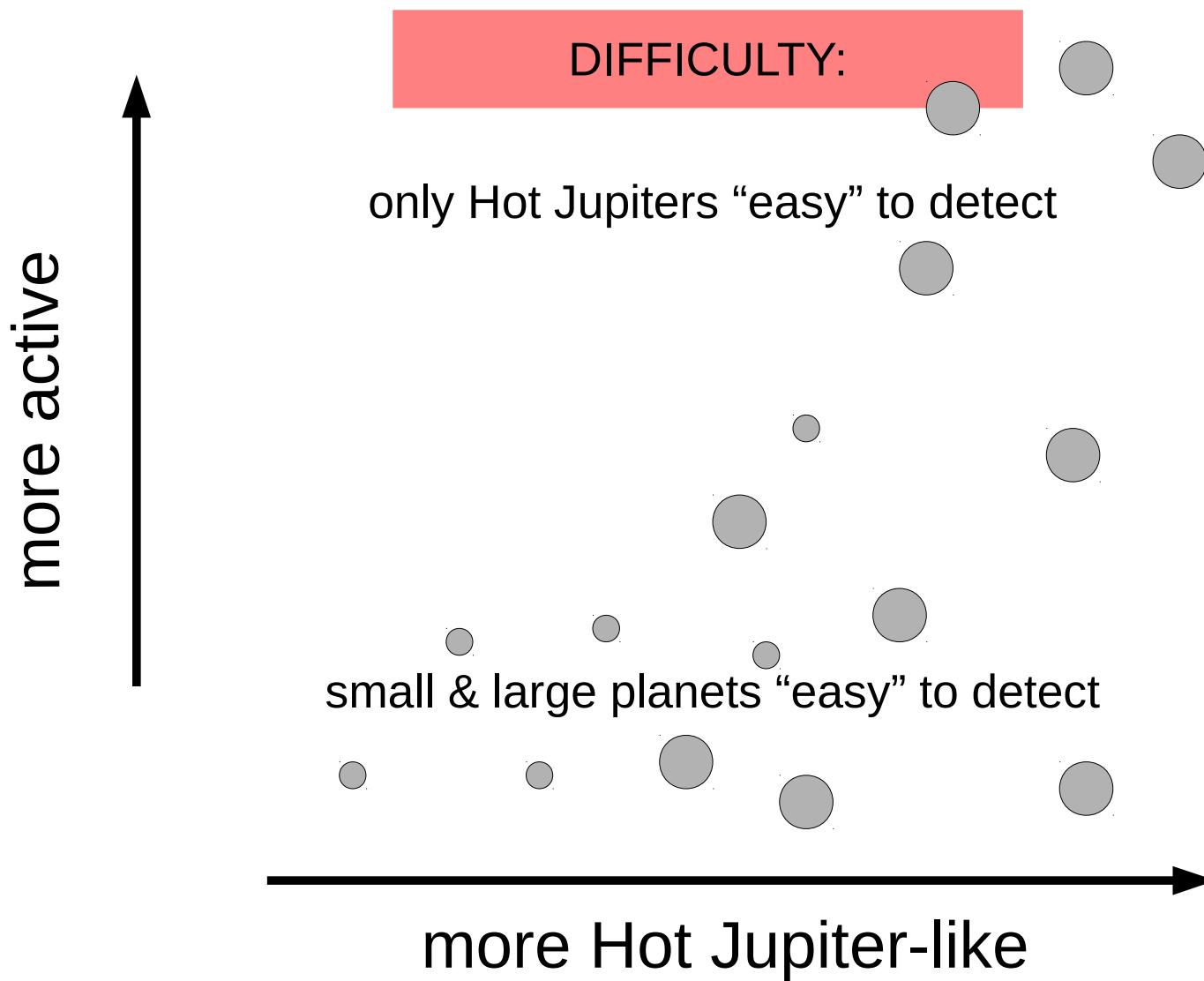
# Planet-induced activity: trends?



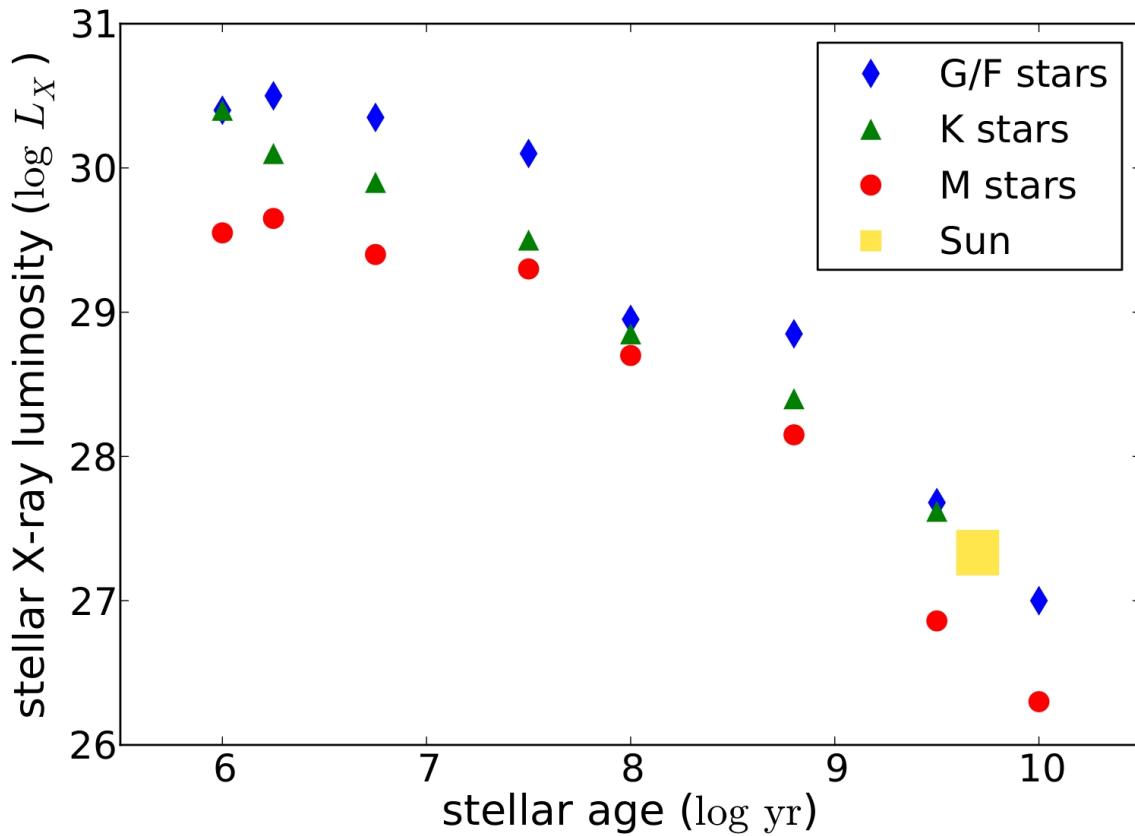
# Planet-induced activity: trends?



# Planet-induced activity: trends?

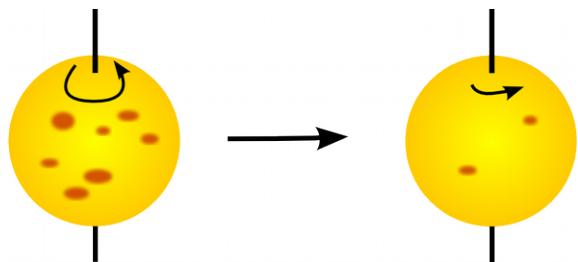


# How stars age on the main sequence



loss of angular momentum through stellar wind (“magnetic braking”)

Star overactive / over-rotating:  
planetary influence or just younger star?



# Some over-spinning or over-active stars

Host stars of close-in planets:

WASP-19, G8V star

$P_{\text{rot}} = 10.5 \text{ d}$

age =  $\sim 5 \text{ Gyr}$  (isochrones)

Hebb et al. (2010)

HATS-18, mid-G star

$P_{\text{rot}} = 9.8 \text{ d}$

age =  $\sim 5 \text{ Gyr}$  (isochrones)

Penev et al. (2016)

See also Maxted et al. (2015) for discrepancies in gyro- and isochrone ages of host stars;  
Morris et al. (2017) for over-activity of HAT-P-11

# Planet-hosting wide binaries

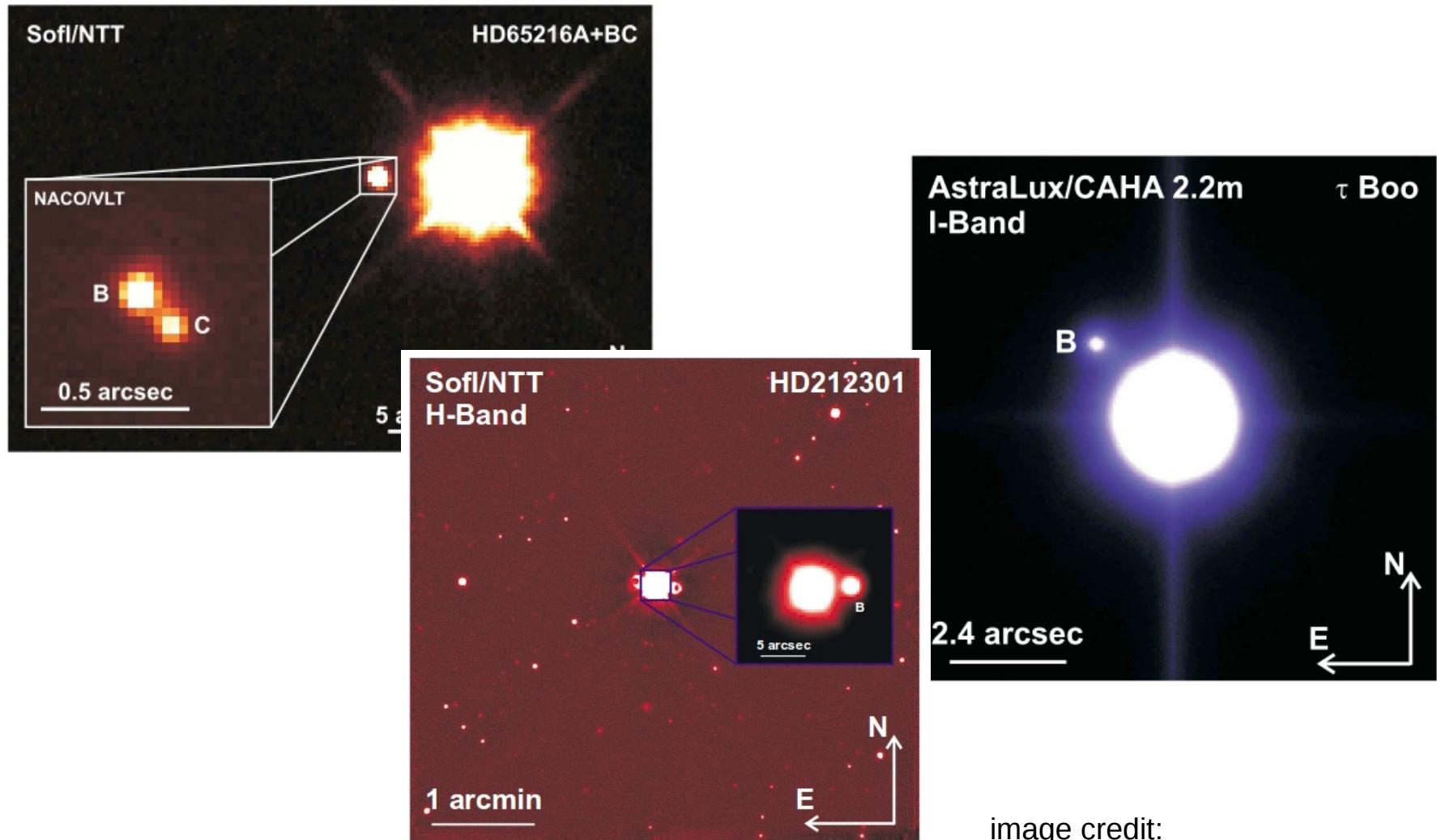
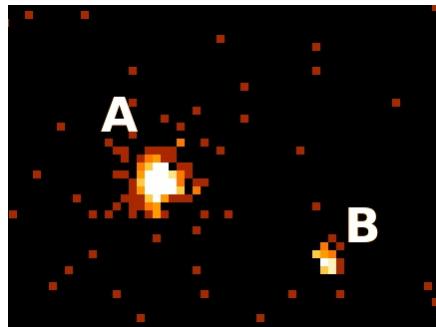
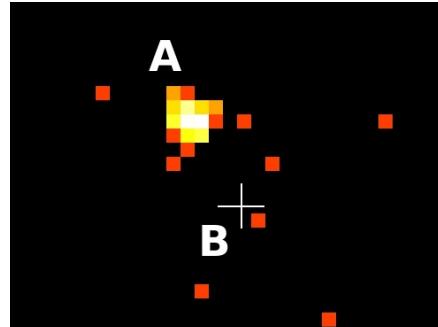


image credit:  
Mugrauer et al. (2007);  
see also Raghavan (2006)

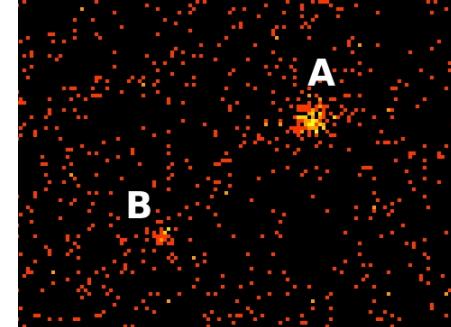
# Planet-hosting wide binaries



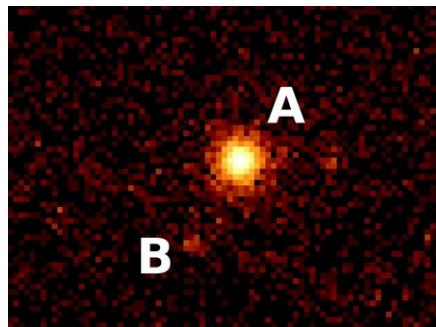
HD 189733 Ab B



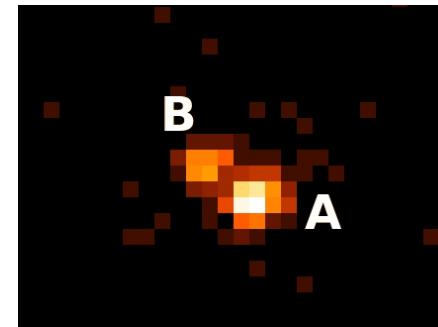
CoRoT-2 Ab B



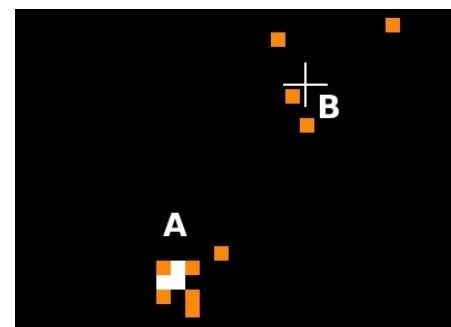
55 Cnc Abcde B



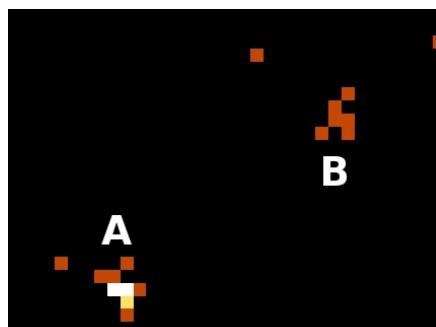
epsilon And Ab B



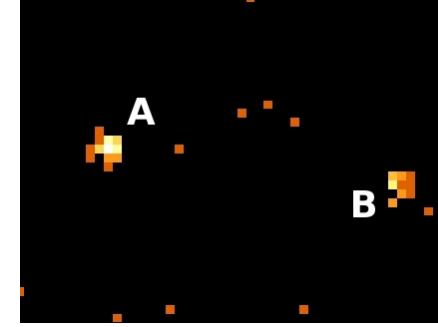
tau Boo Ab B



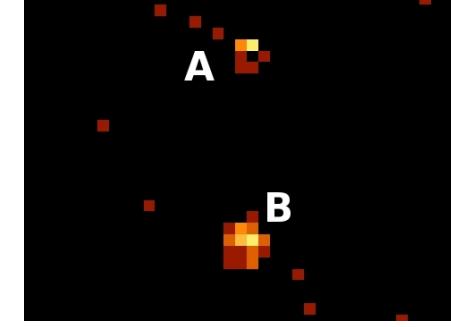
HAT-P-20 Ab B



HD 46375 Ab B



HD 178911 A Bb



HD 109749 Ab B

Poppenhaeger et al. (2014),  
Poppenhaeger et al. in prep.

# Planet-hosting wide binaries

strong tidal interaction



**CoRoT-2**



**HD 189733**

weak tidal interaction



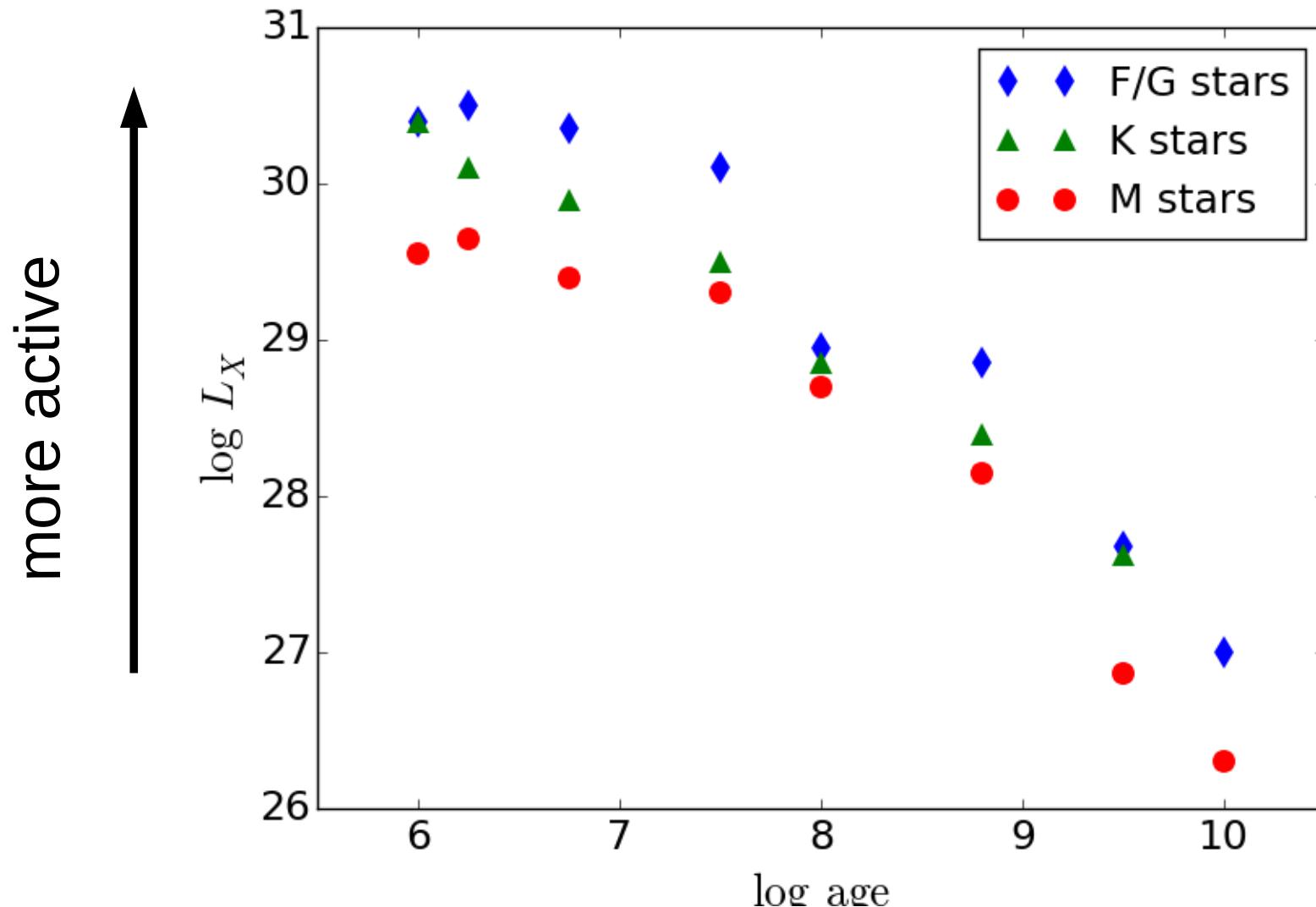
**ups And**



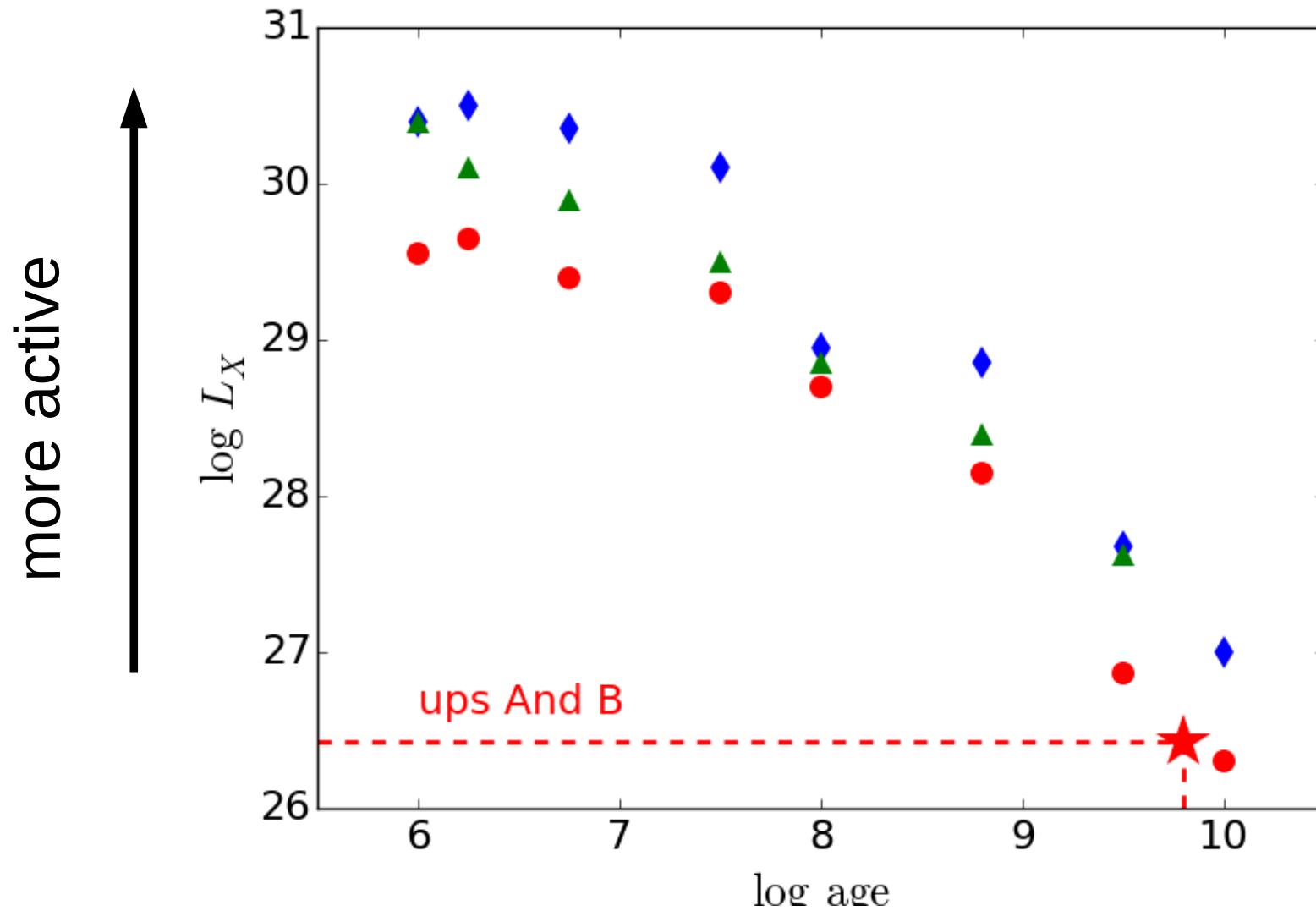
**55 Cnc**

•

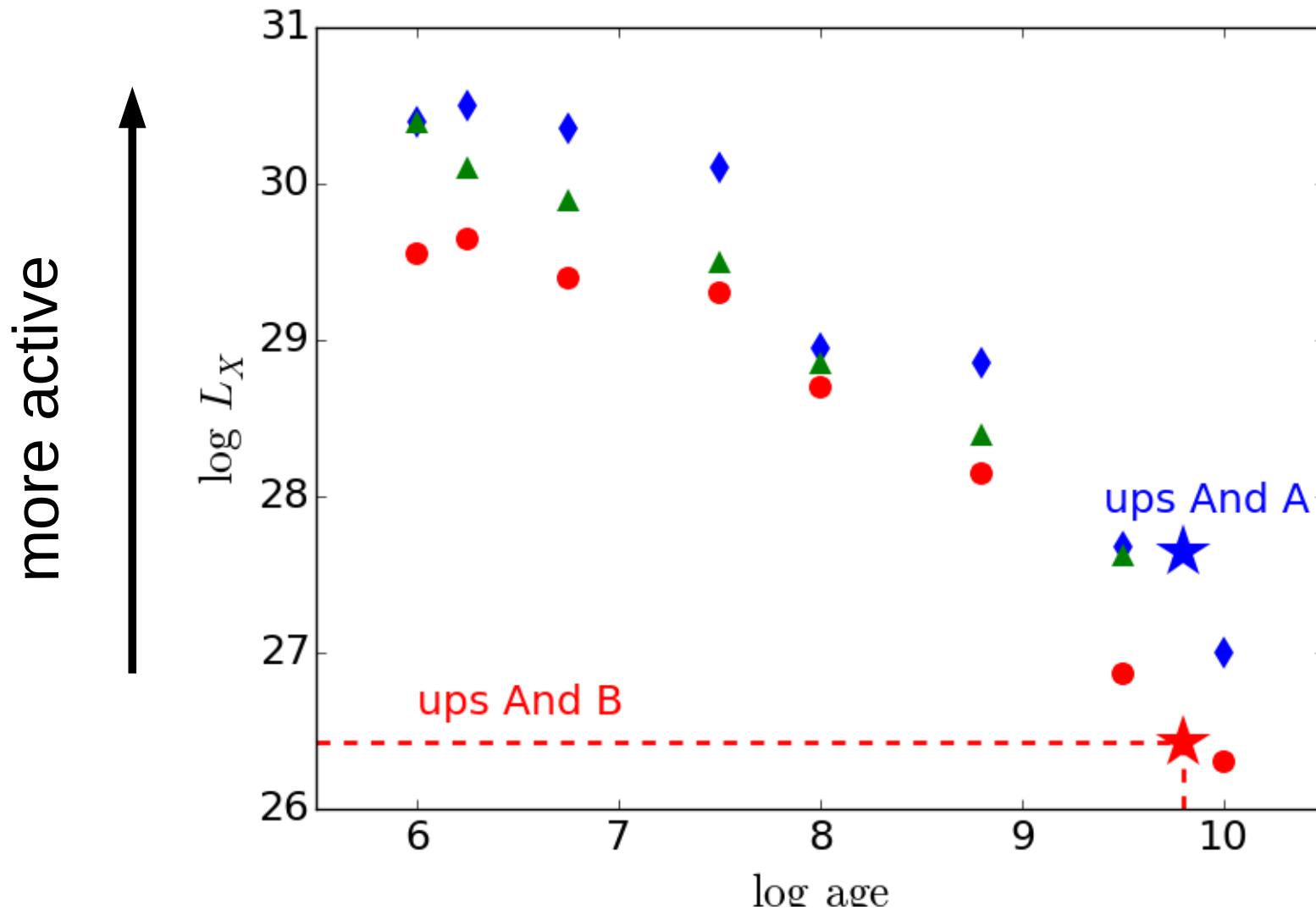
# Planet-hosting wide binaries



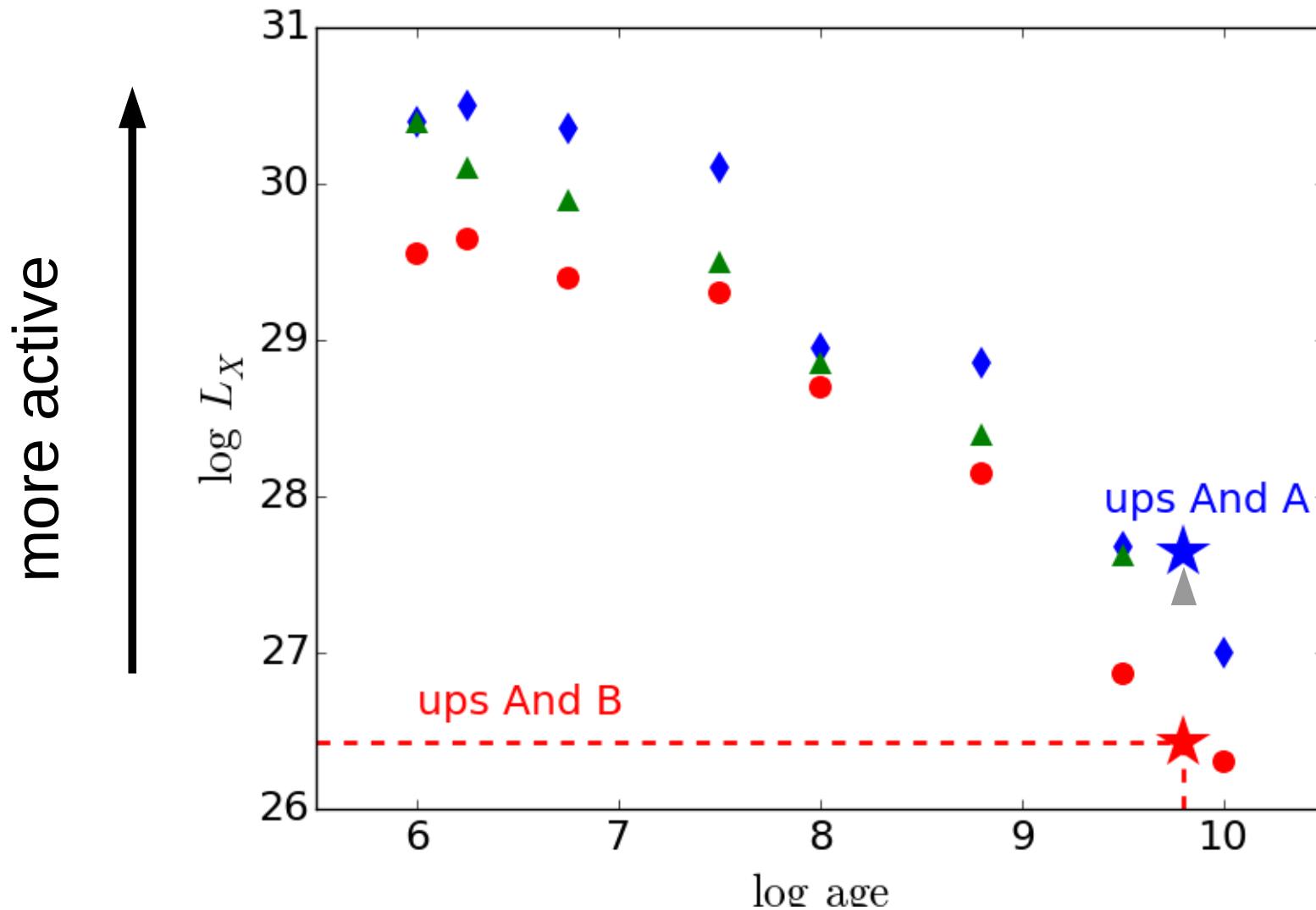
# Planet-hosting wide binaries



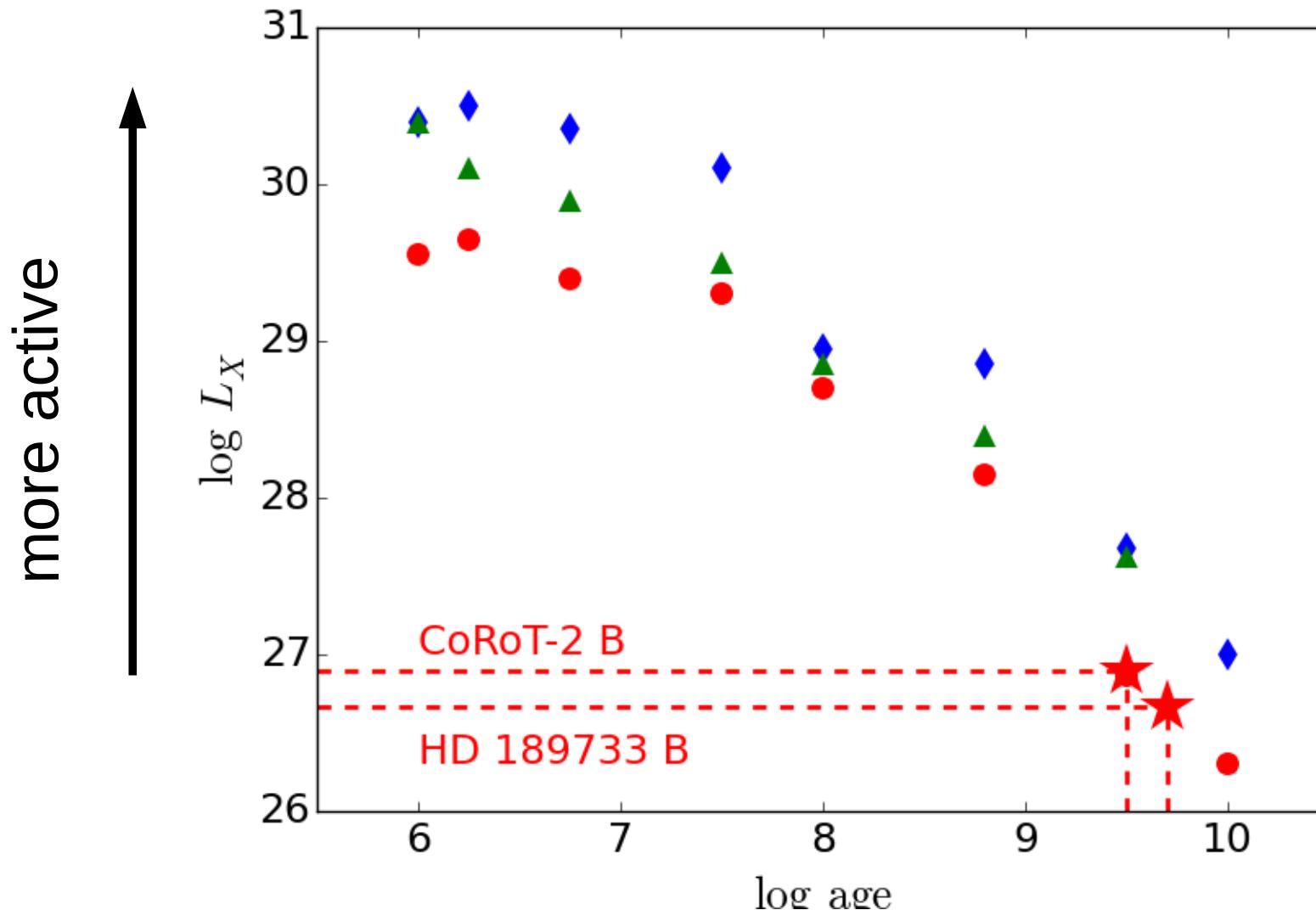
# Planet-hosting wide binaries



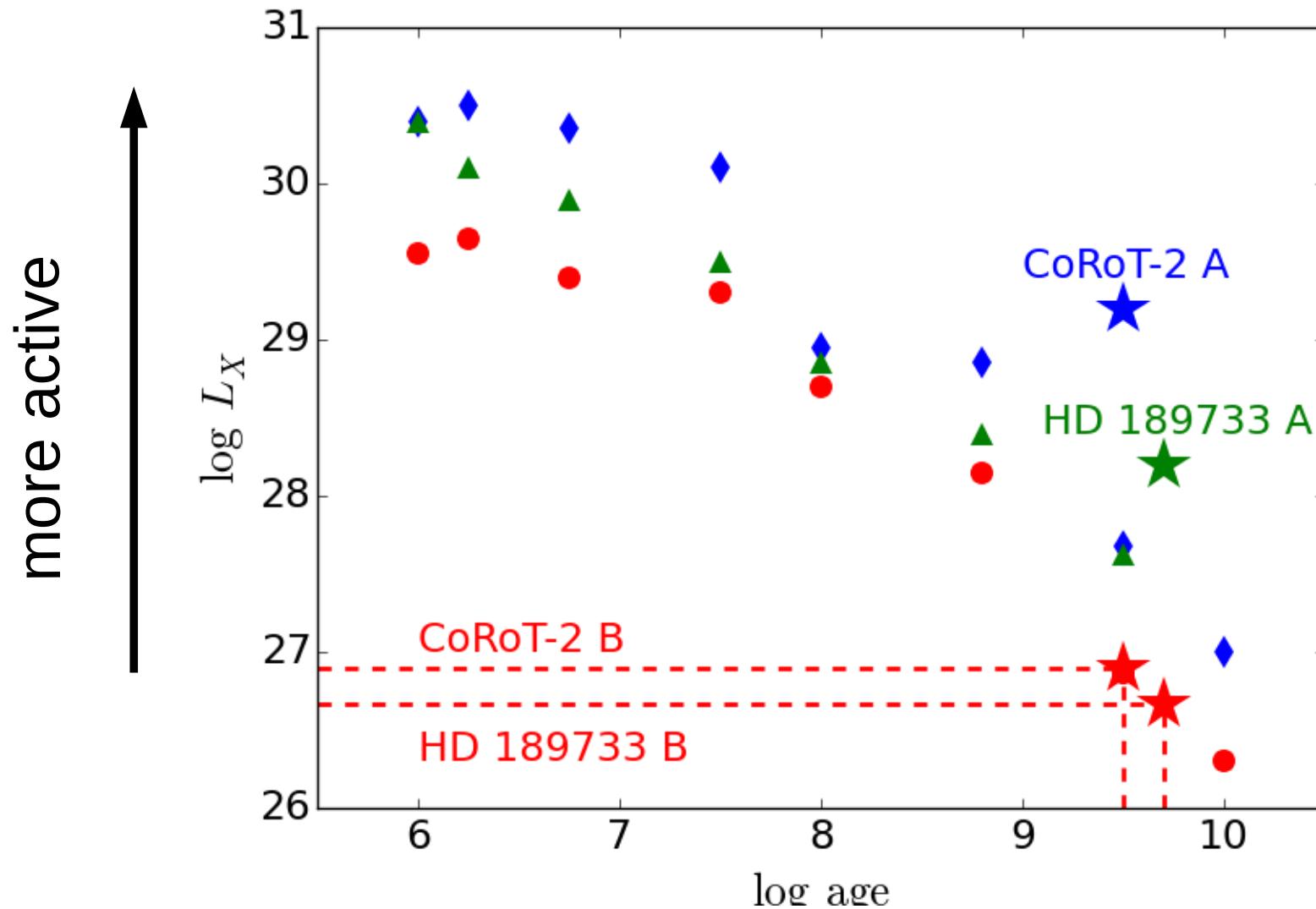
# Planet-hosting wide binaries



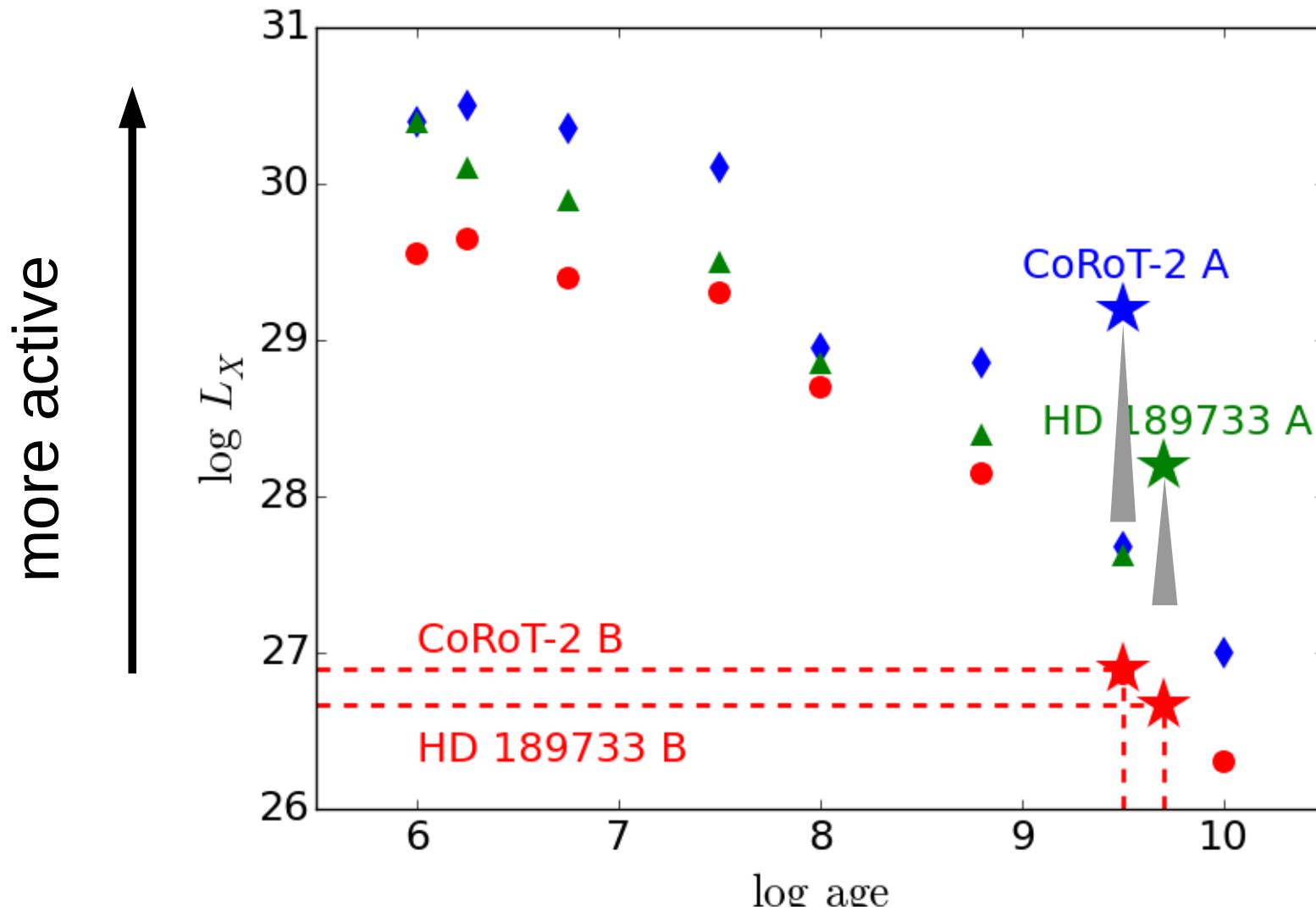
# Planet-hosting wide binaries



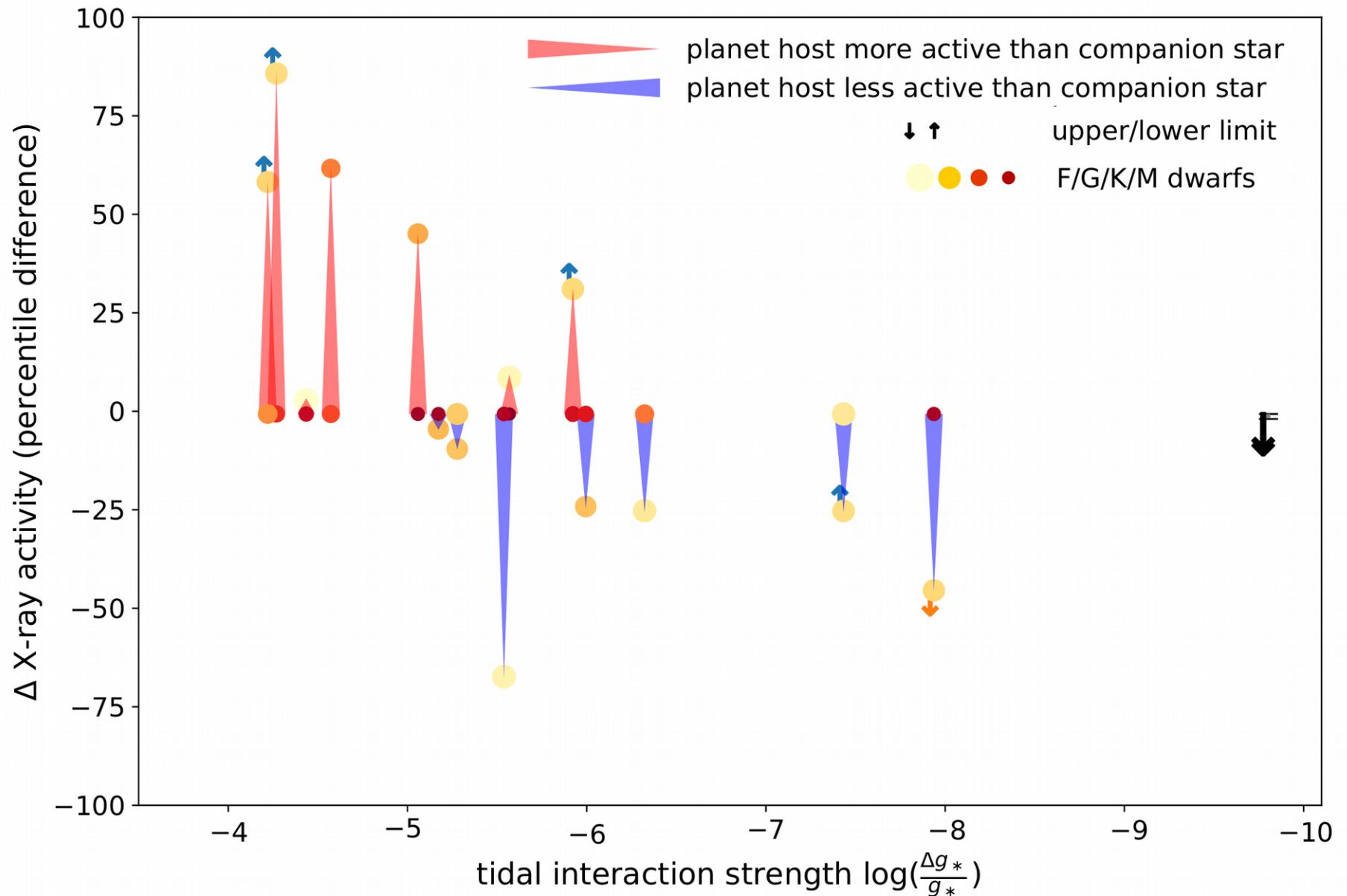
# Planet-hosting wide binaries



# Planet-hosting wide binaries



# Several over-active systems



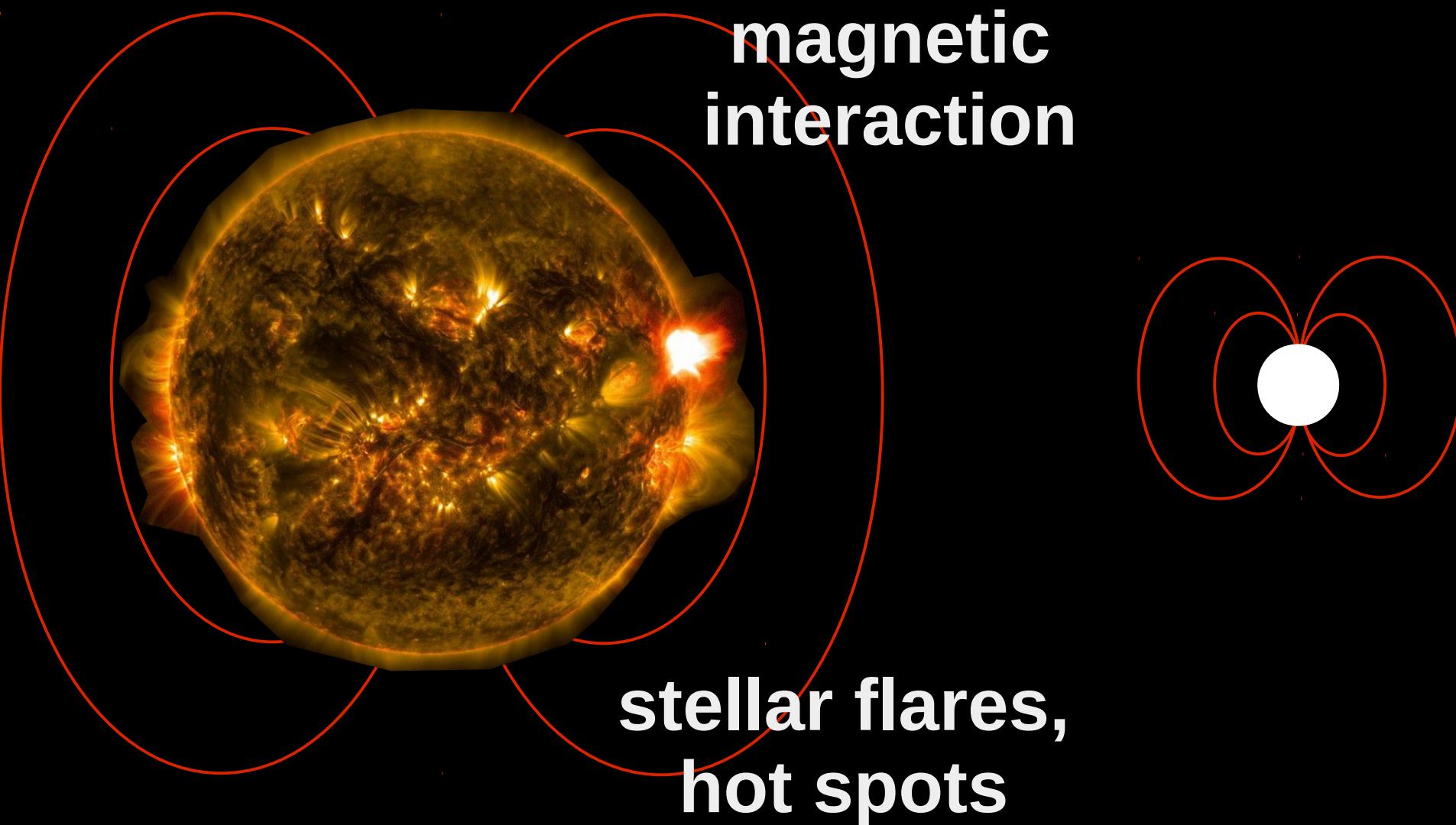
Poppenhaeger et al. (2014),  
Poppenhaeger et al. to be submitted

# Tidal spin-up of host stars

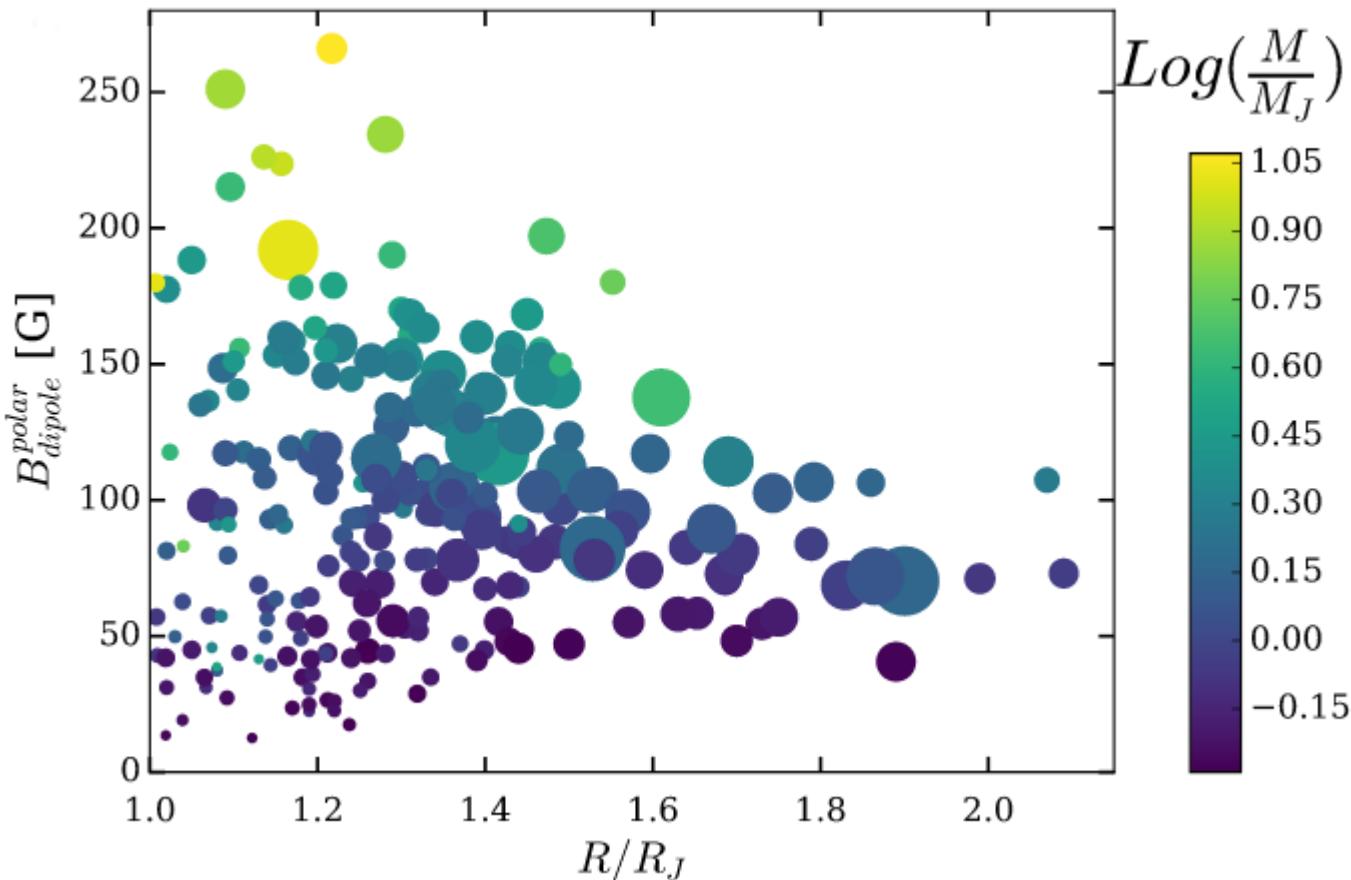
Need to be careful with selecting samples:  
detectability of exoplanets related to stellar  
activity

Compare stellar activity to reasonable  
expectation: through stellar ages or stellar  
companions

# Star-exoplanet systems



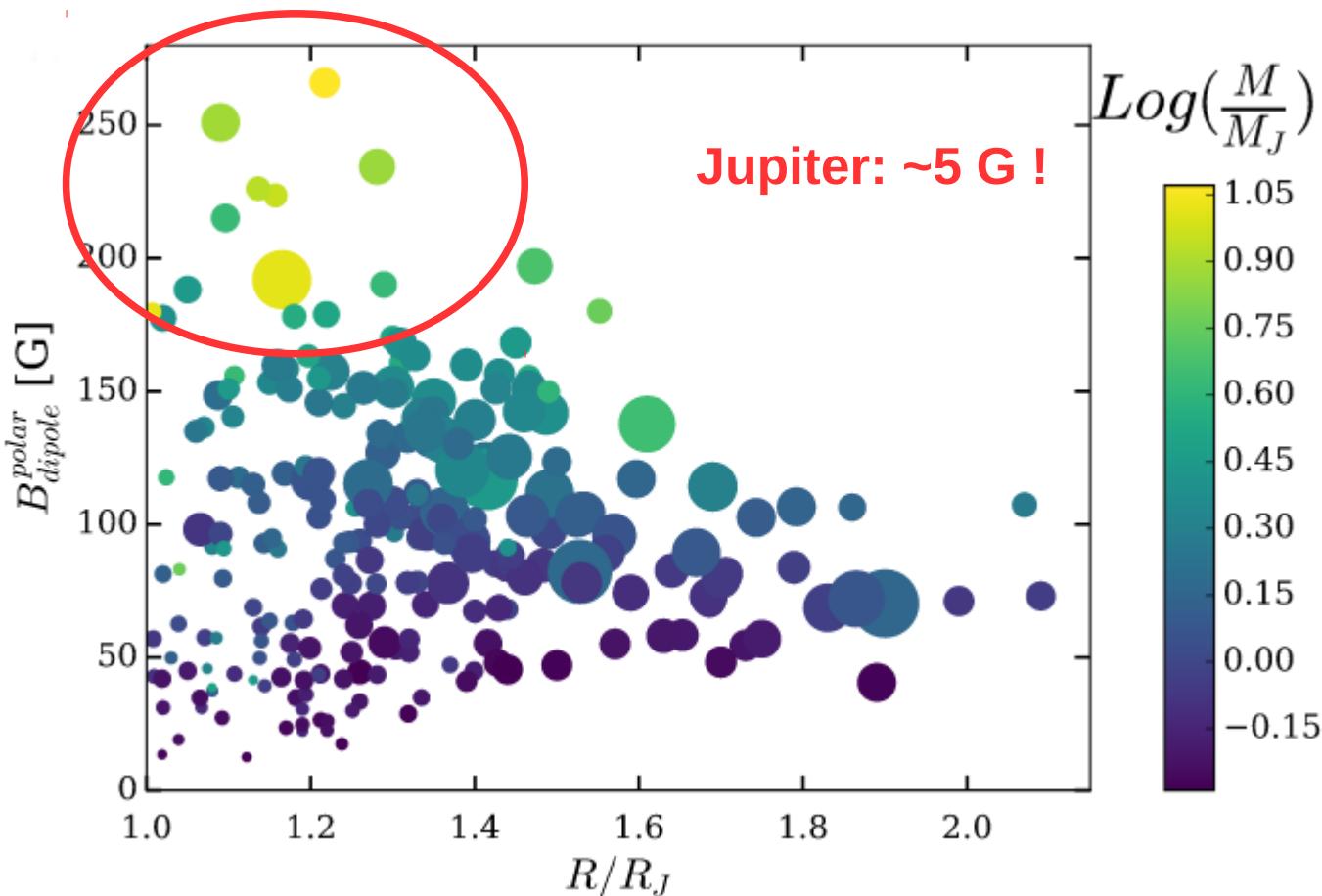
# Strong magnetic fields for very hot exoplanets



Simulations:  
strongly irradiated Hot Jupiters can have strong magnetic fields powered through enhanced dynamo processes

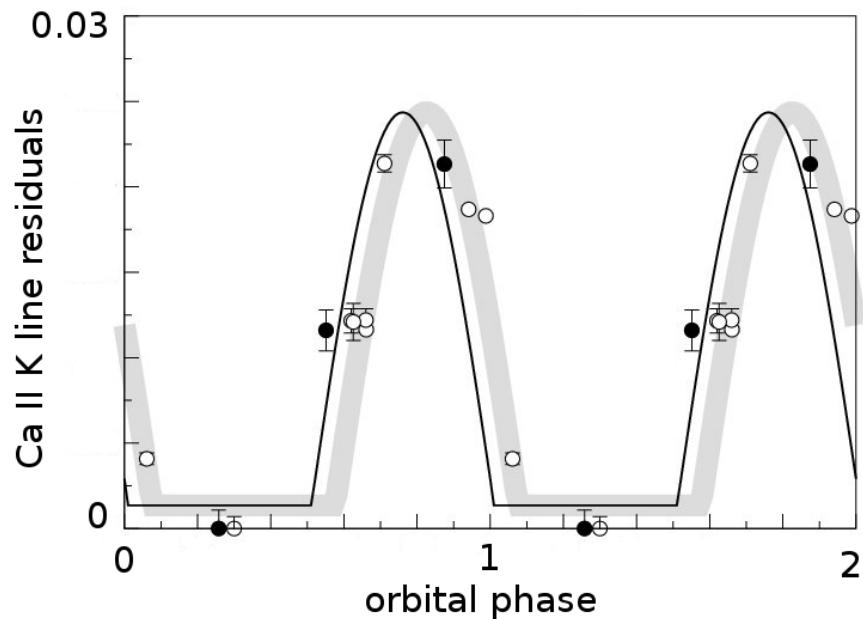
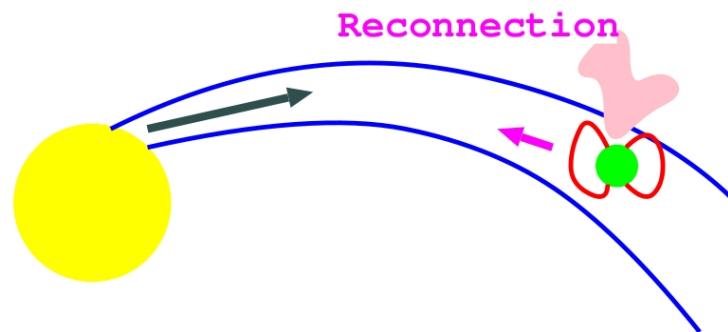
Rogers & McElwaine (2017)  
Yadav & Thorngren (2017)

# Strong magnetic fields for very hot exoplanets

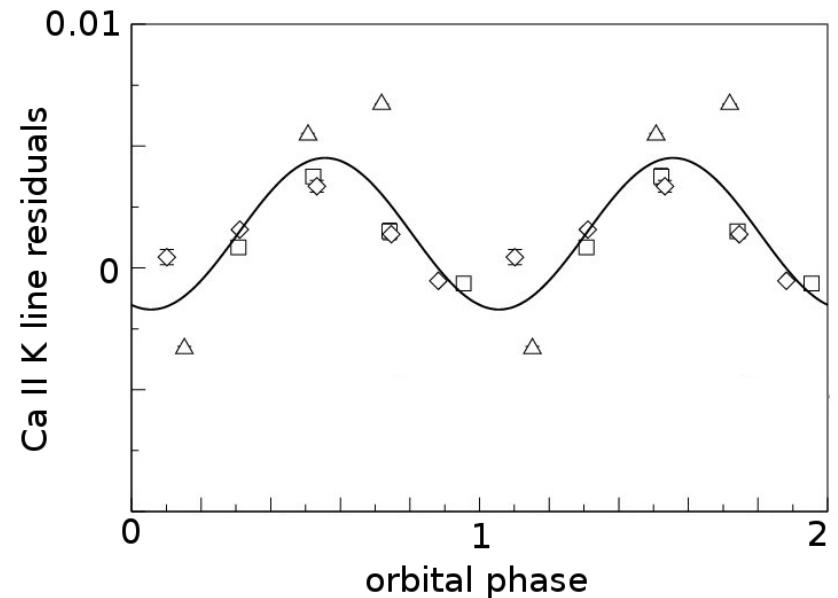


Simulations:  
strongly irradiated Hot Jupiters can have strong magnetic fields powered through enhanced dynamo processes

# Planet-induced hot spots?



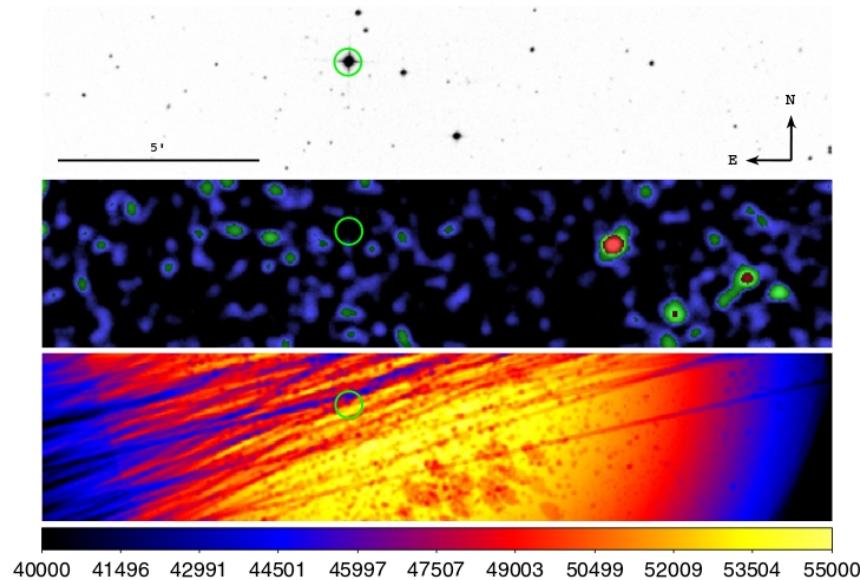
HD 179949  
 $P_{\text{orb}} = 3.1$  d  
 $P_{\text{rot}} = 11$  d



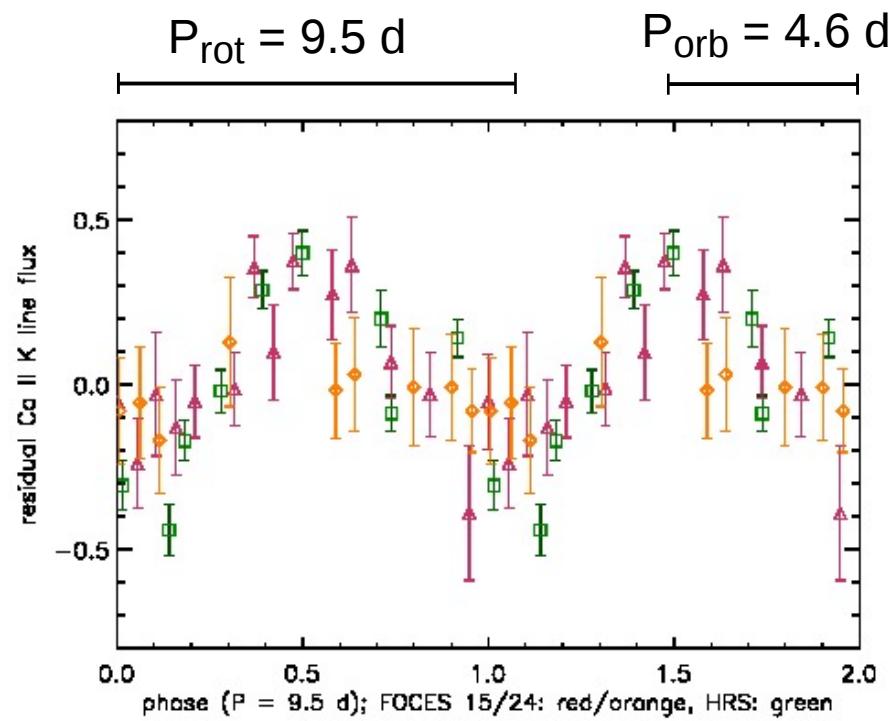
upsilon And  
 $P_{\text{orb}} = 4.6$  d  
 $P_{\text{rot}} = 9.5$  d

Shkolnik et al. (2005, 2008)

# But also: absence of magnetic effects



Miller et al. (2012),  
Pillitteri et al. (2014)

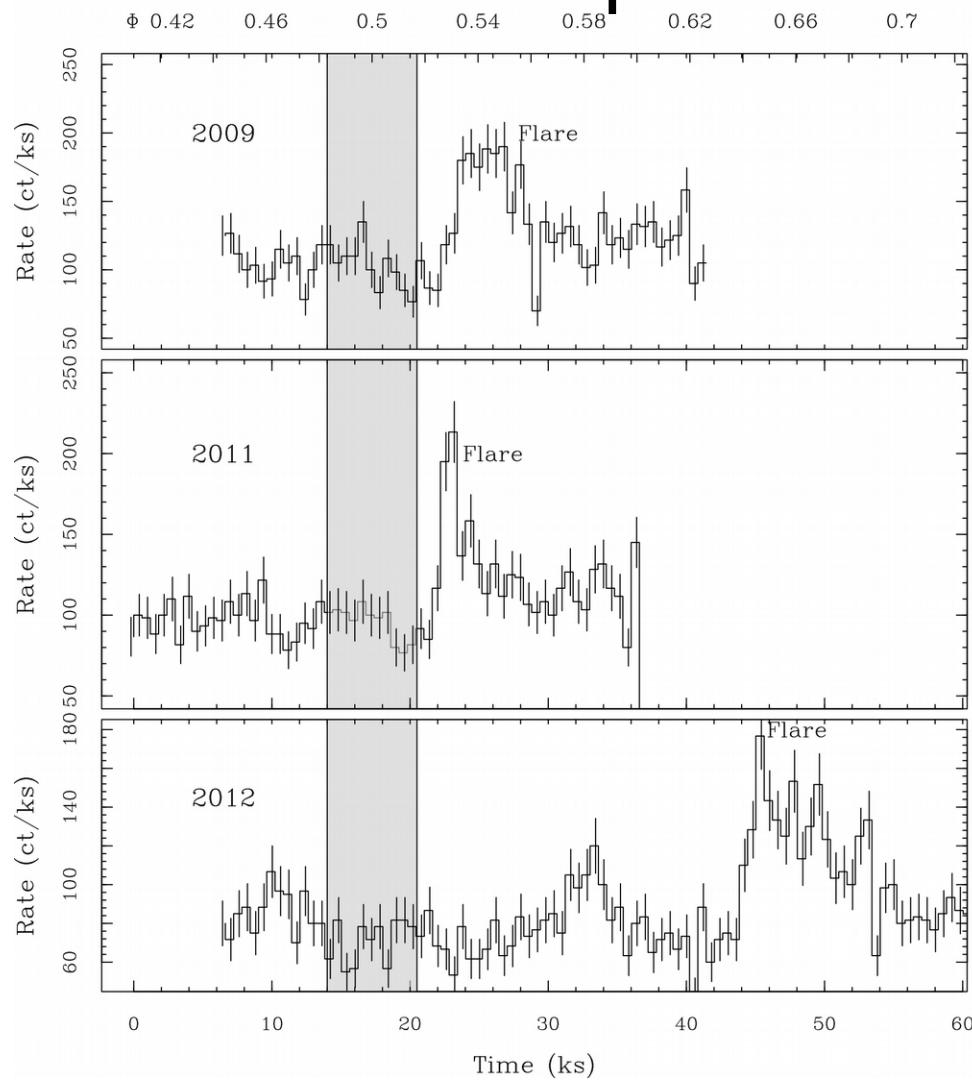


upsilon And (1.3 M<sub>Sun</sub>): varies with stellar rotation, not with Hot Jupiter orbit

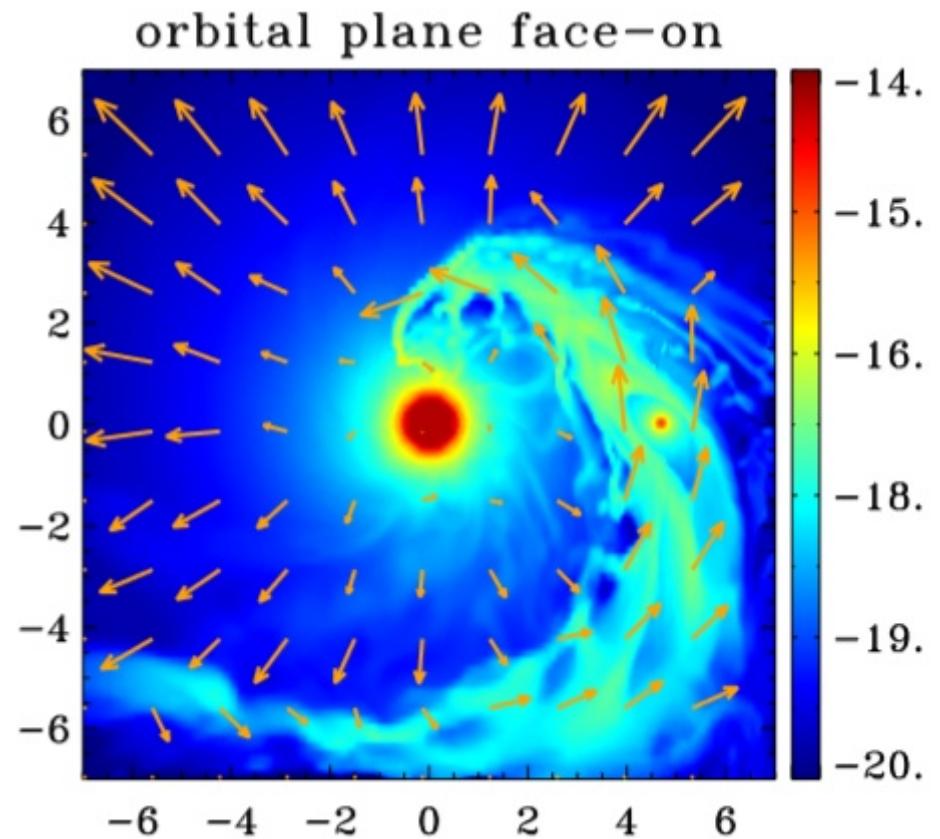
Poppenhaeger et al. (2010)

# Planetary / coronal rain

## HD 189733 - eclipse



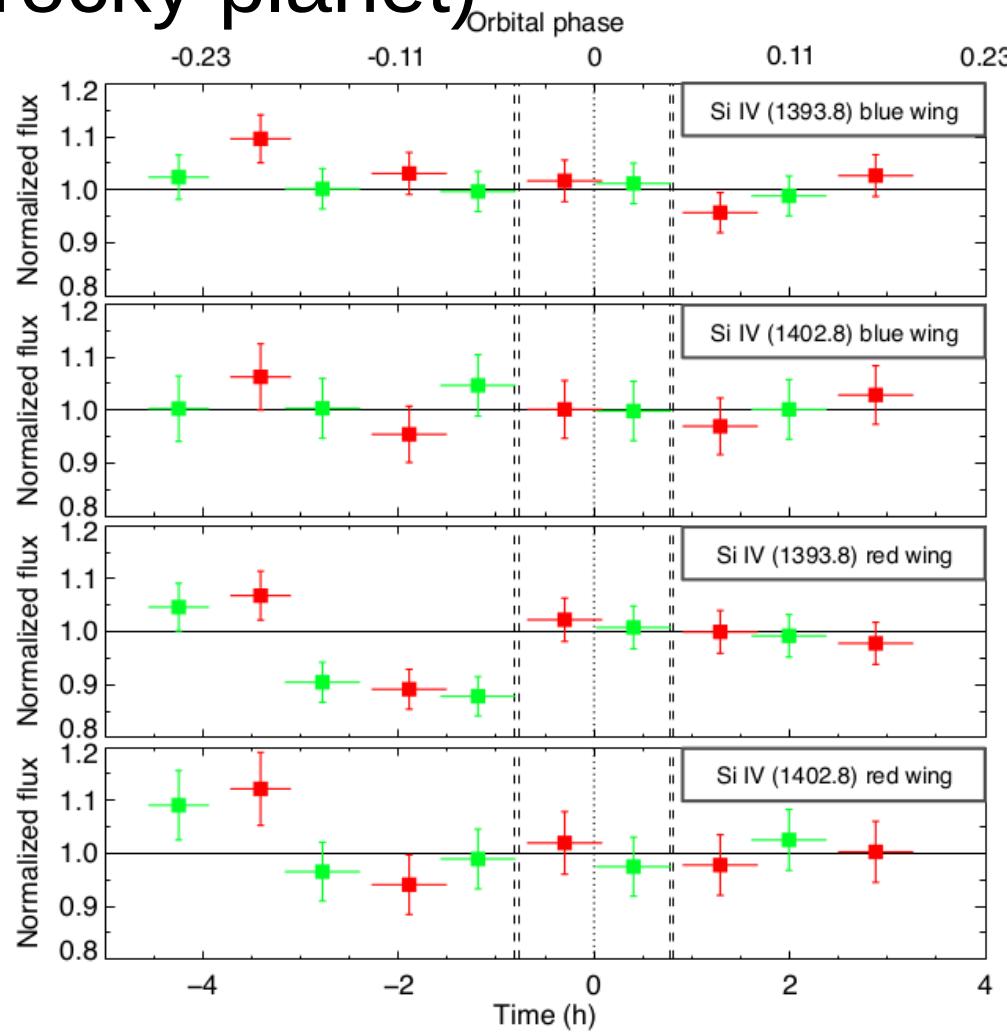
Pillitteri et al. (2015)



planetary material  
falling onto star?

# Planetary / coronal rain

55 Cnc transit  
(e: rocky planet)



Bourrier et al. (2018)

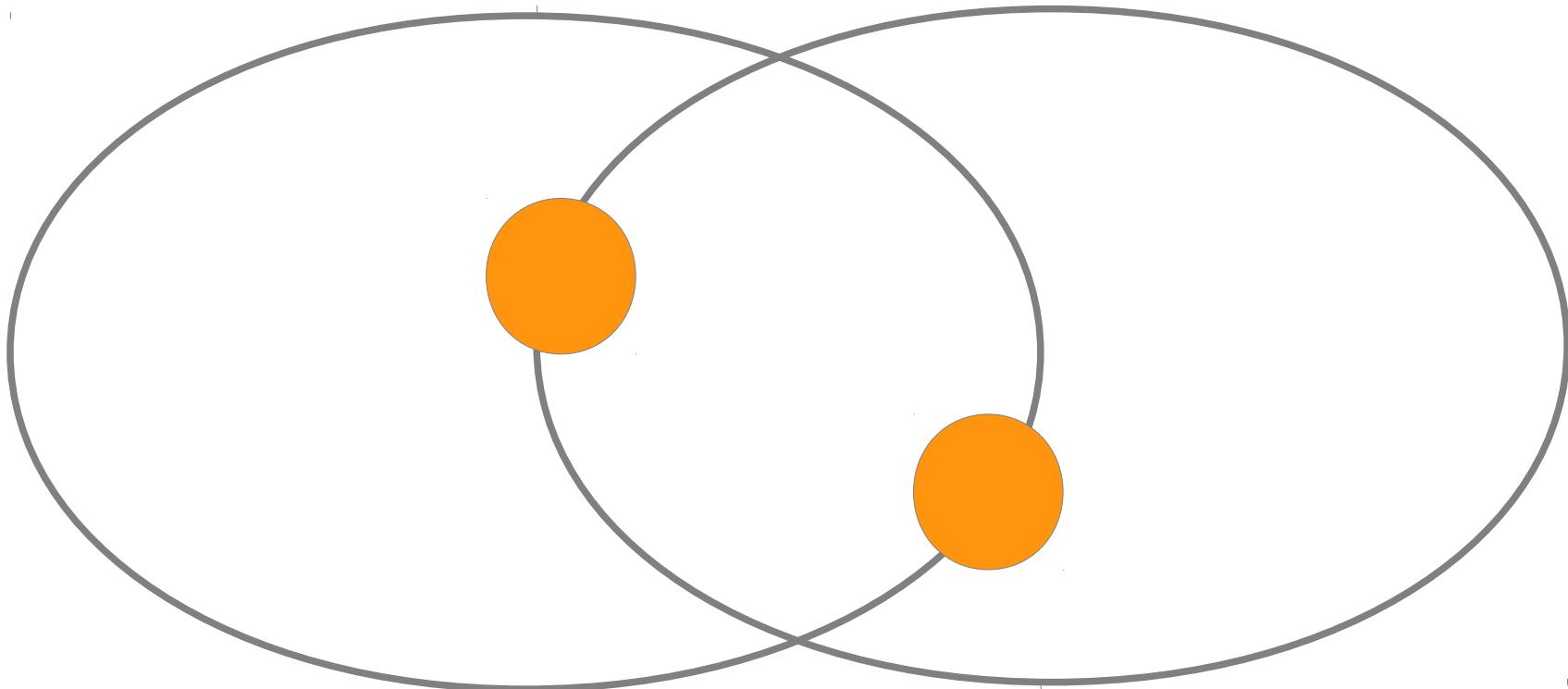
First indications: FUV  
line absorption in red  
wings of lines, not in  
blue wings

planet-triggered  
coronal rain?

other works:  
Lanza (2013)  
Scandariato et al. (2013)  
Strugarek et al. (2014),  
Matsakos et al. (2015)

# Planets in eccentric orbits

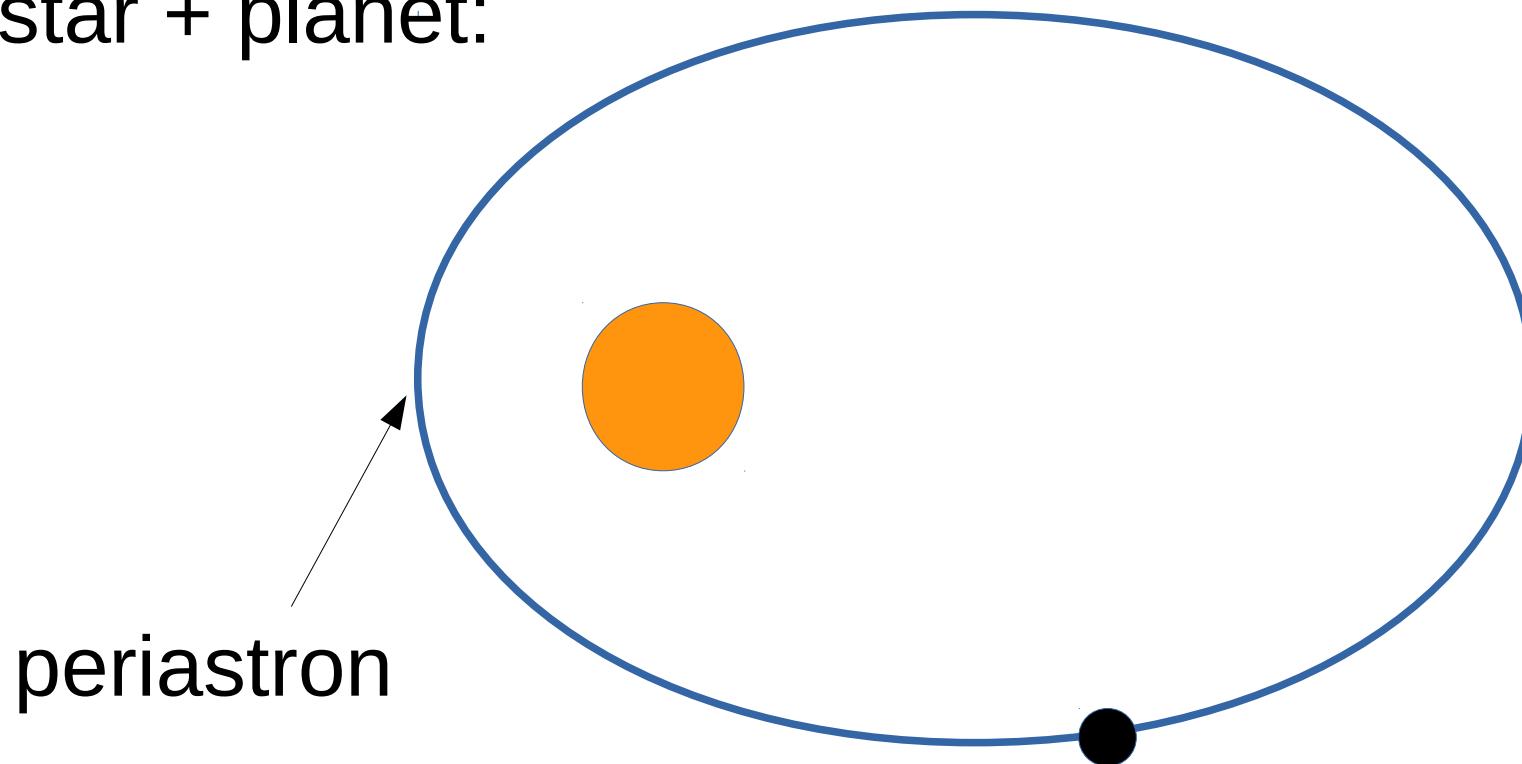
2 stars:



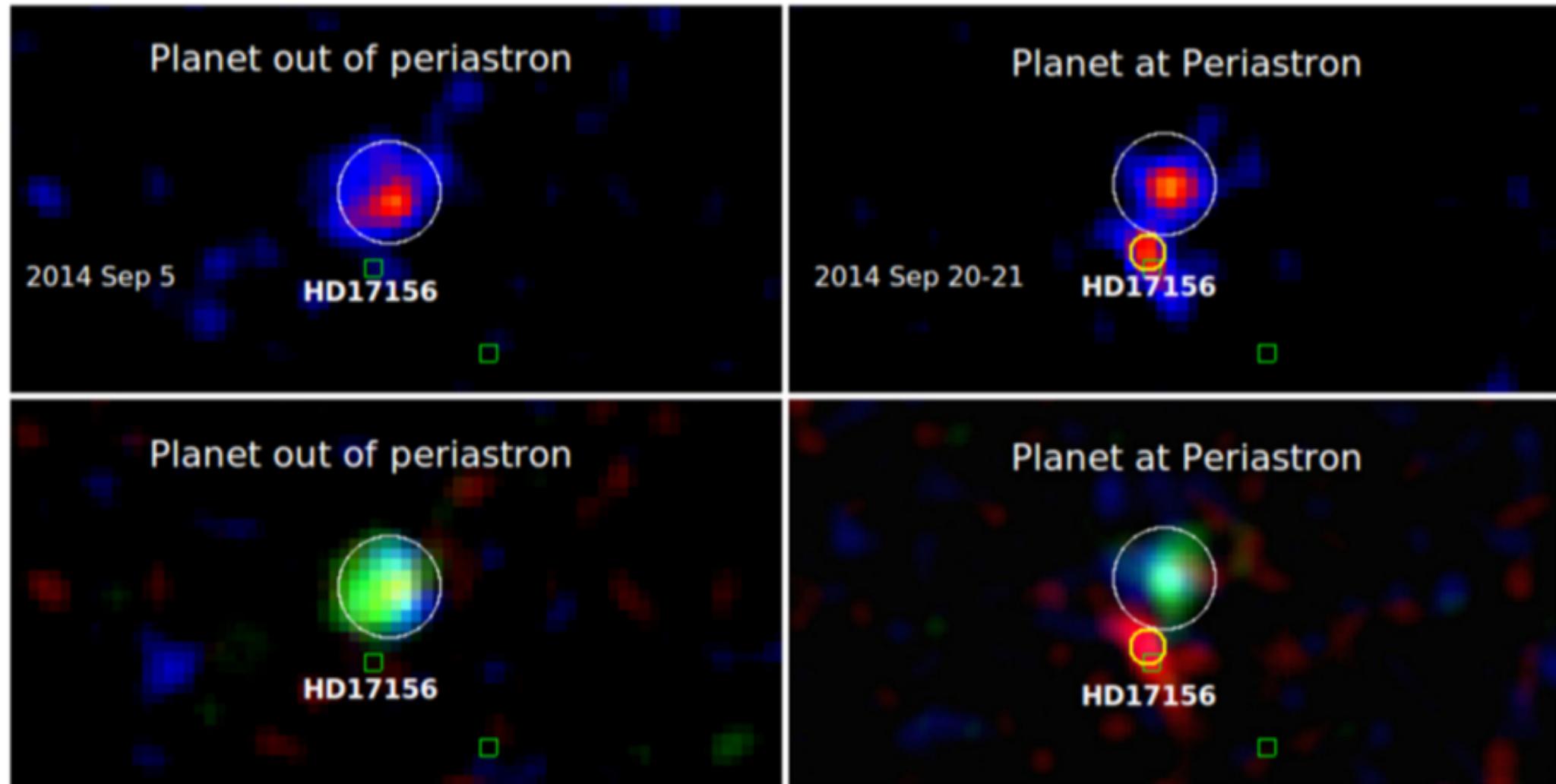
Flares from colliding  
magnetospheres:  
Getman et al. (2011);  
but: Getman et al. (2016)

# Planets in eccentric orbits

star + planet:



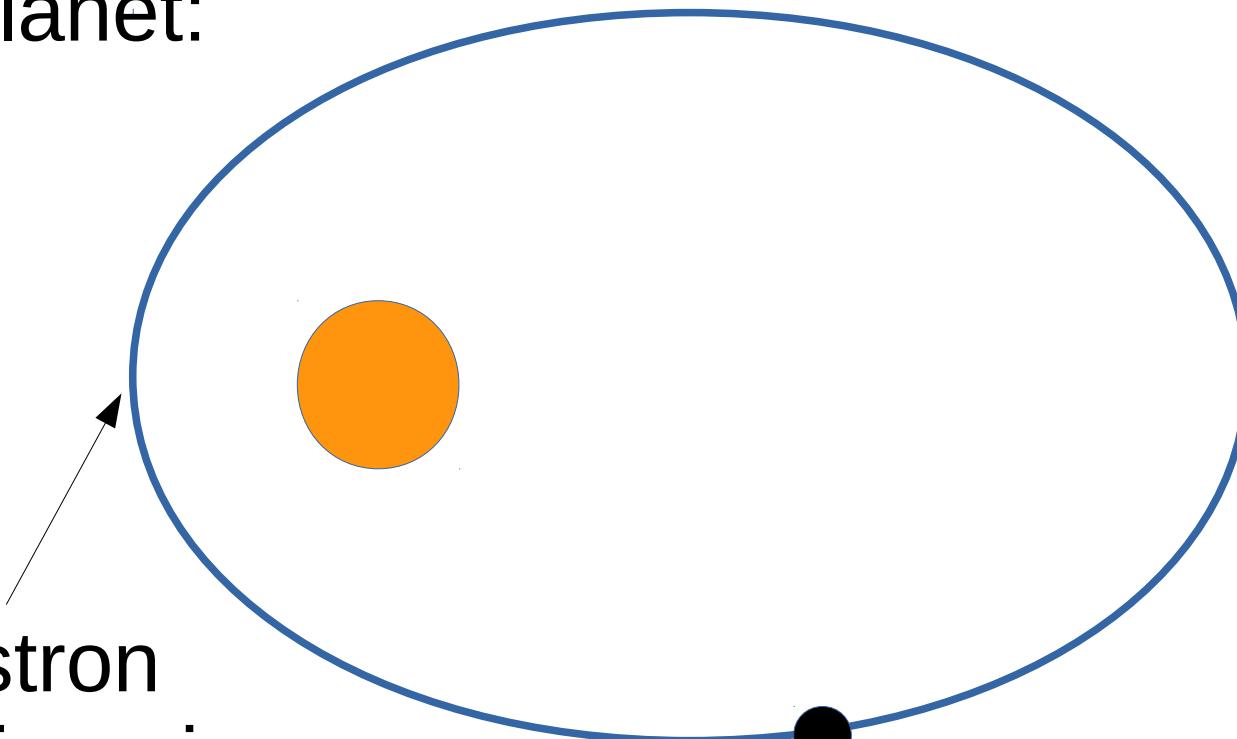
# Planets in eccentric orbits



Maggio et al. (2015)

# Planets in eccentric orbits

star + planet:

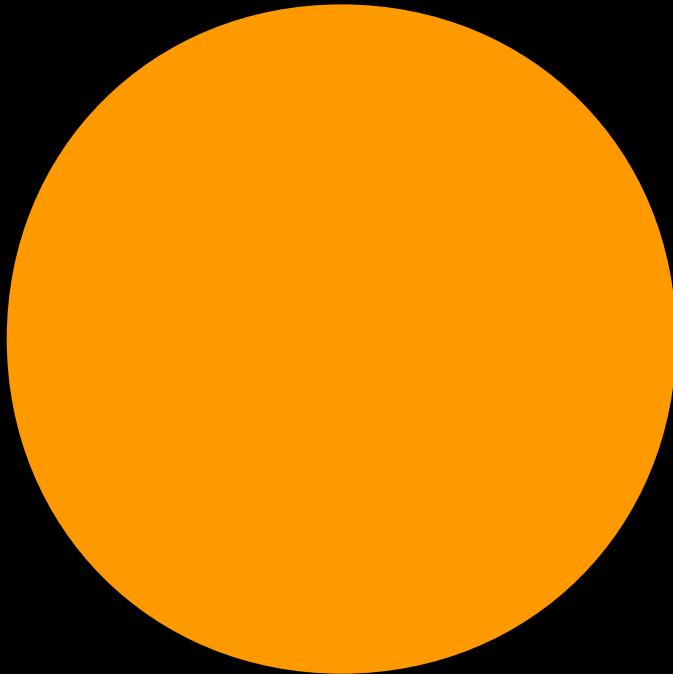


periastron  
-> flare triggering

This should depend on  
the planet's magnetosphere!

# Star-exoplanet systems

planetary  
effects



atmospheric  
blow-off



# Atmospheres and high-energy photons

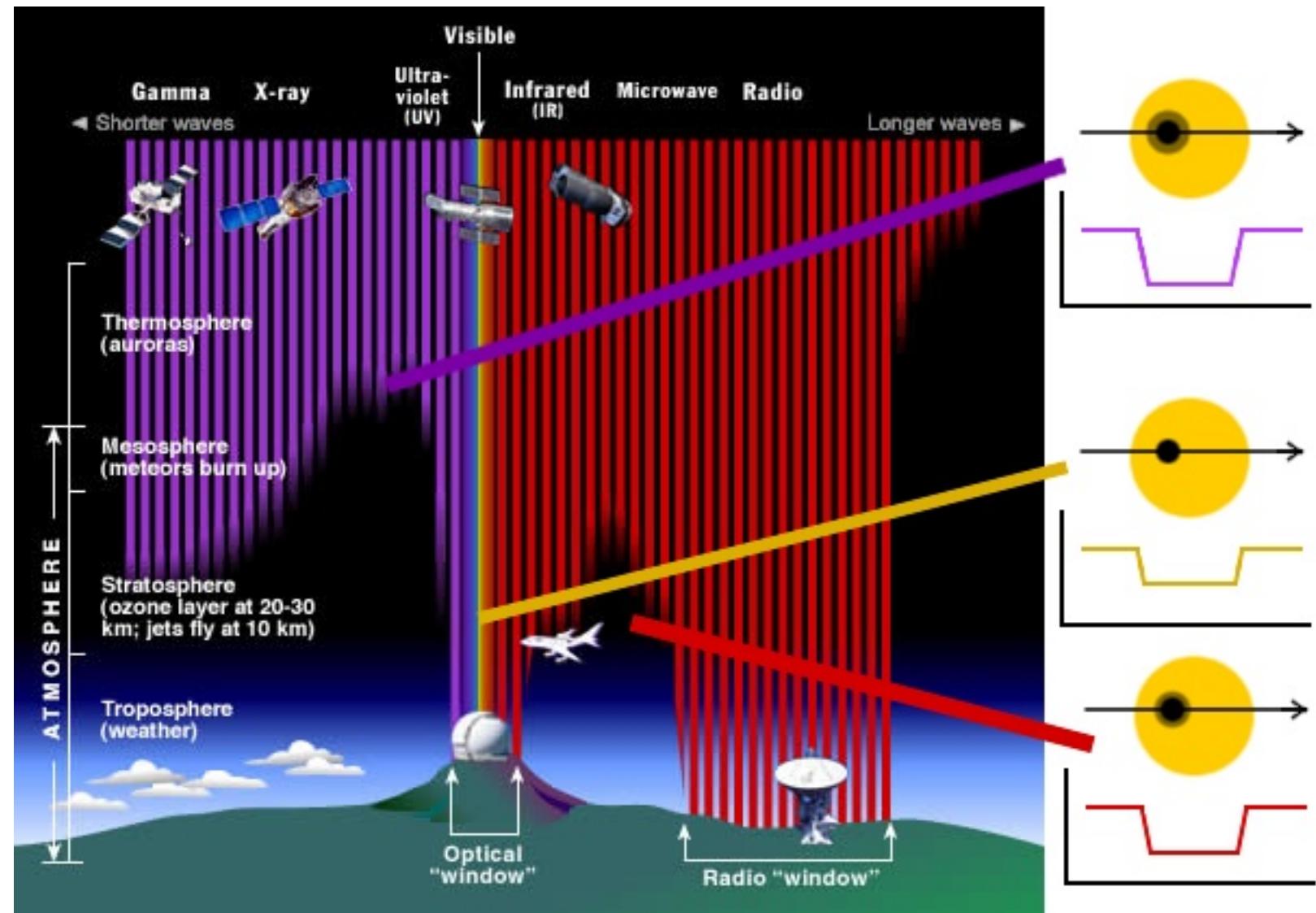
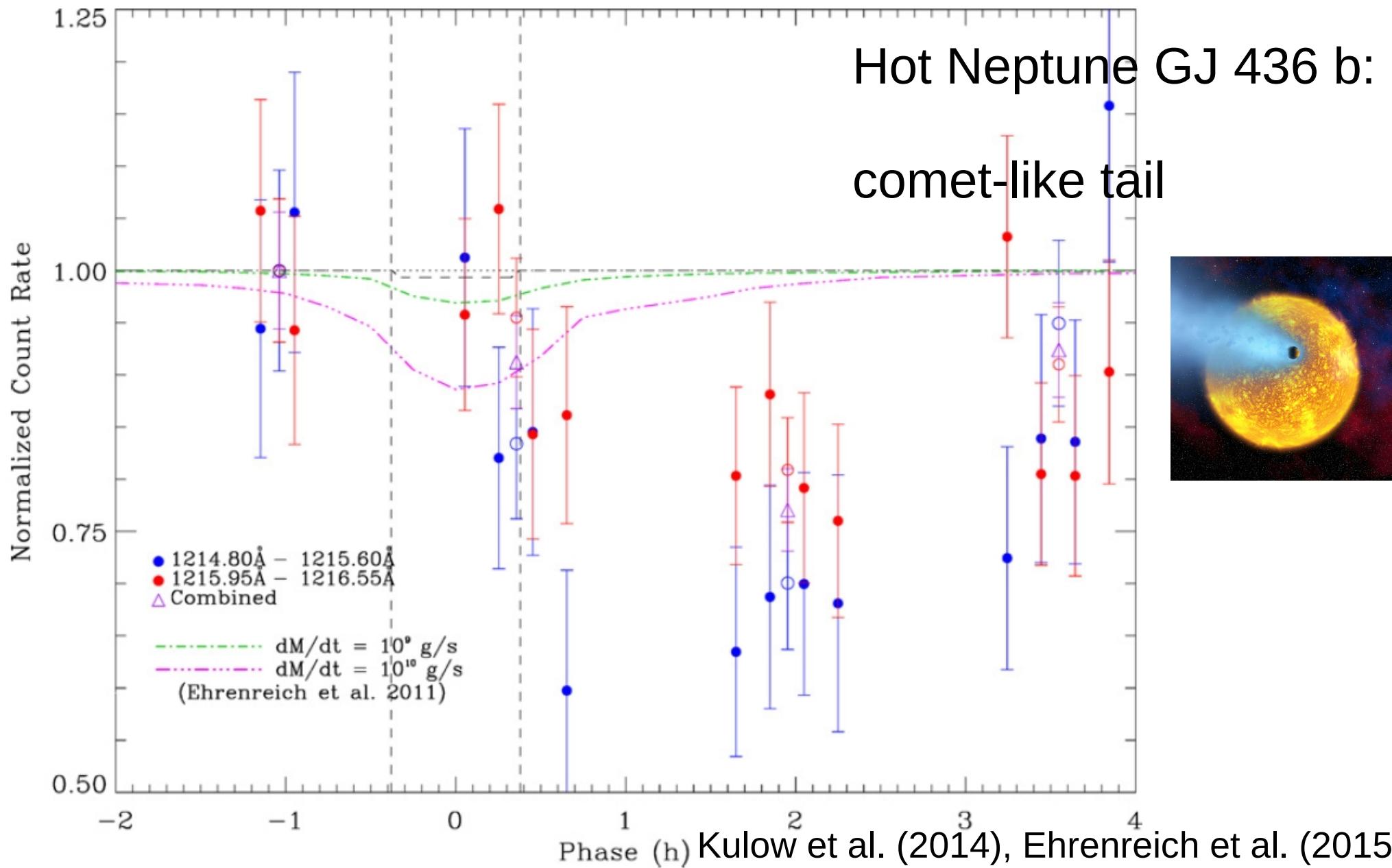
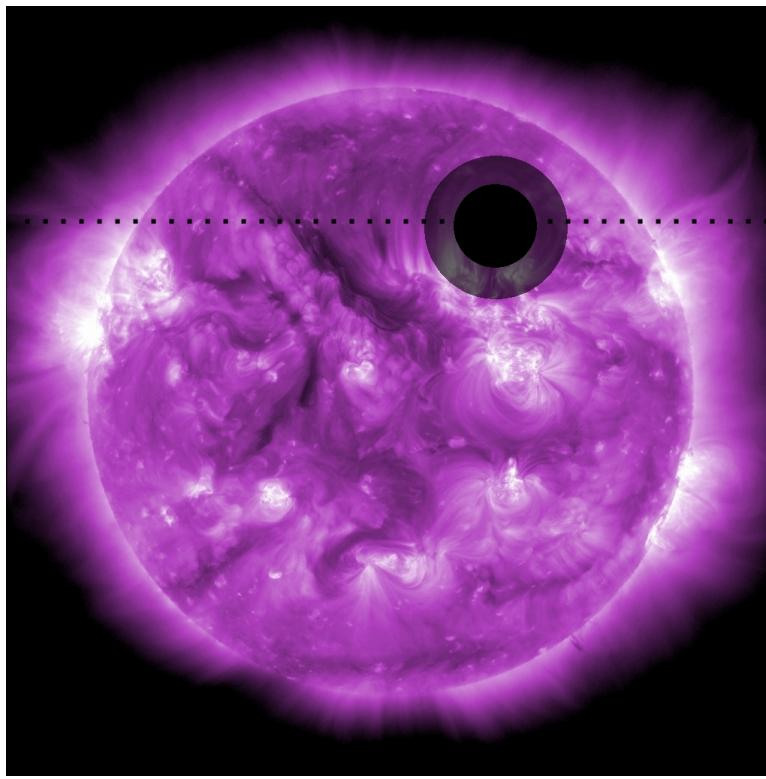


image credit: NASA

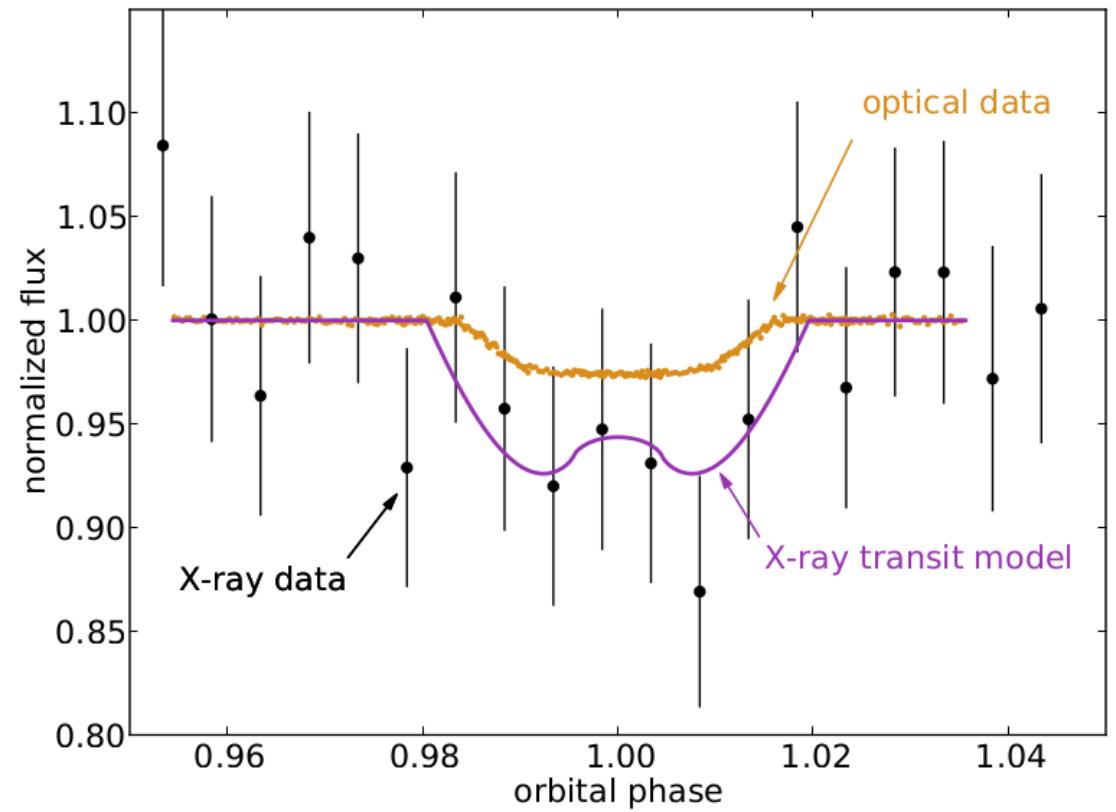
# Extended atmospheres in UV/X-ray



# X-ray transits: extended atmospheres



HD 189733 b



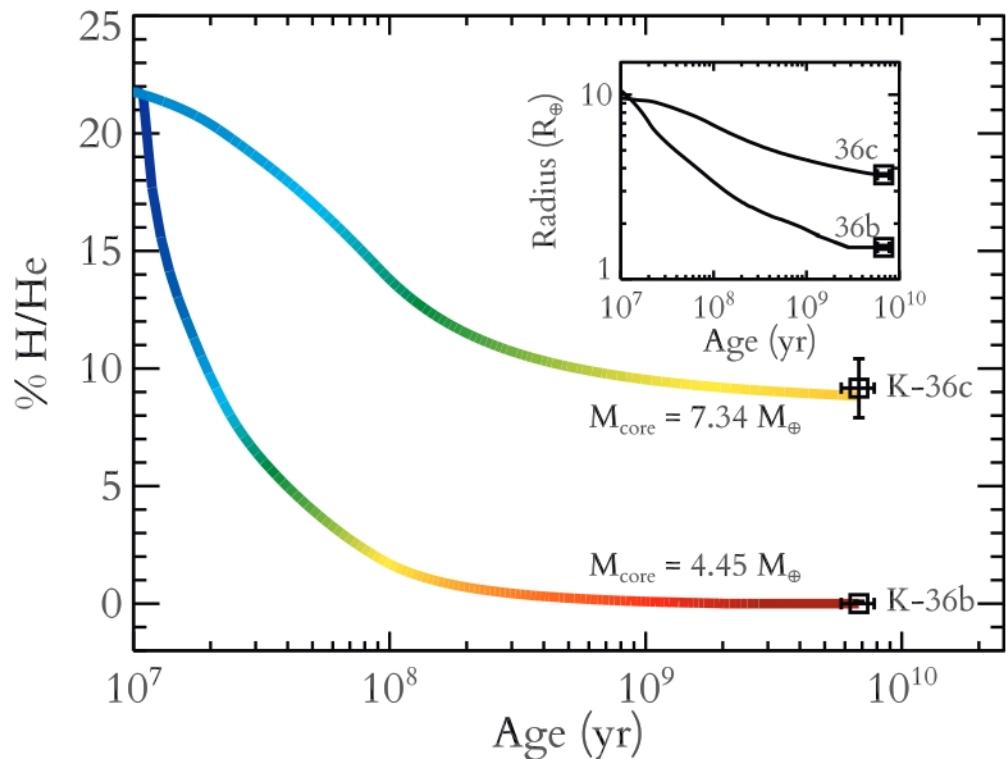
Poppenhaeger et al. (2013)

# Atmospheric evaporation

driven by X-ray and extreme UV photons

e.g. Murray-Clay et al. (2009), Lecavelier des Etangs (2004)

total estimated mass loss: small for Jupiters (few %),  
but substantial for small (Neptune-like) exoplanets



Kepler-36 system

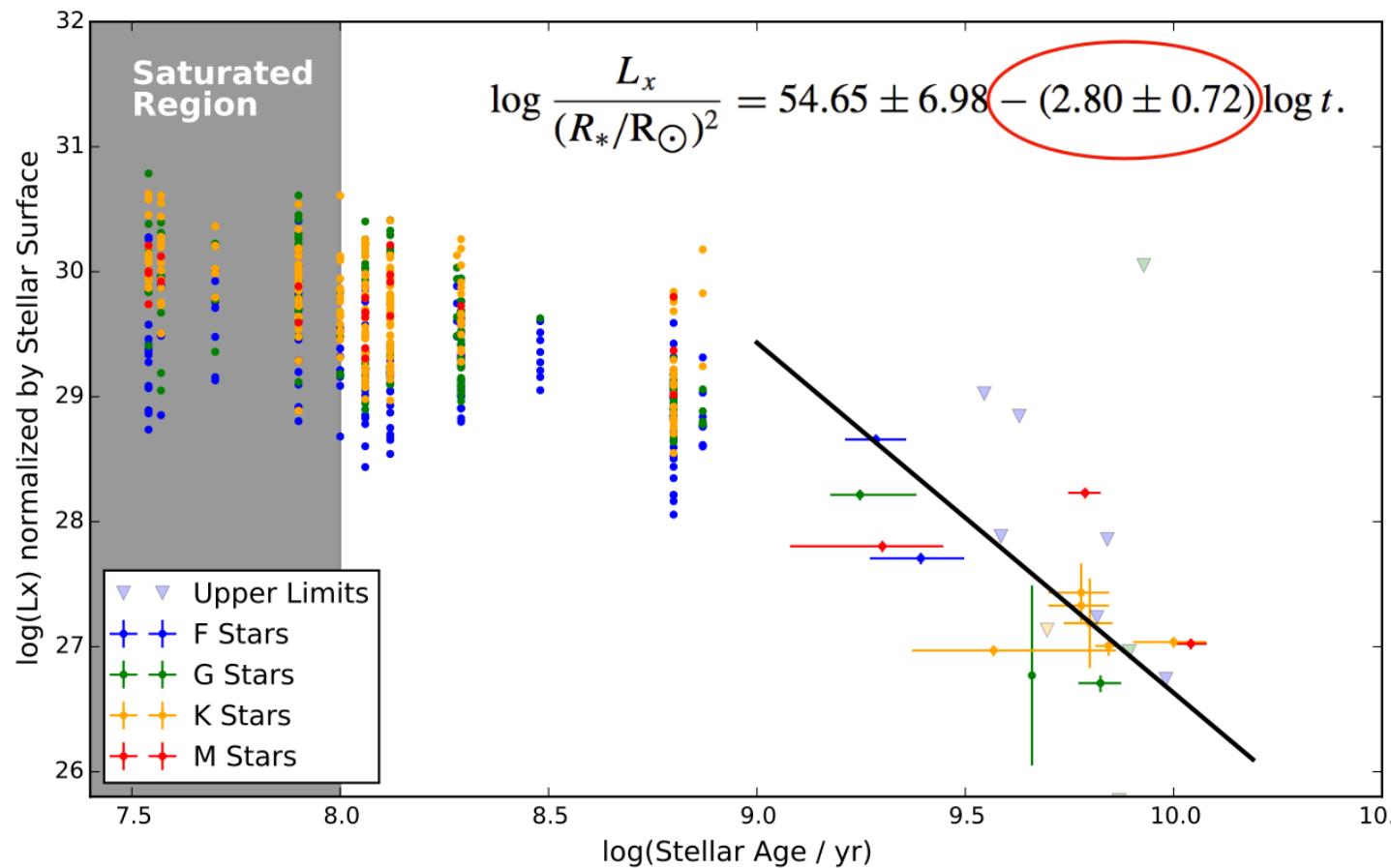
Lopez et al. (2013)

see also

Lecavelier des Etangs (2004)  
Sanz-Forcada et al. (2011)

# Survival of exoplanet atmospheres

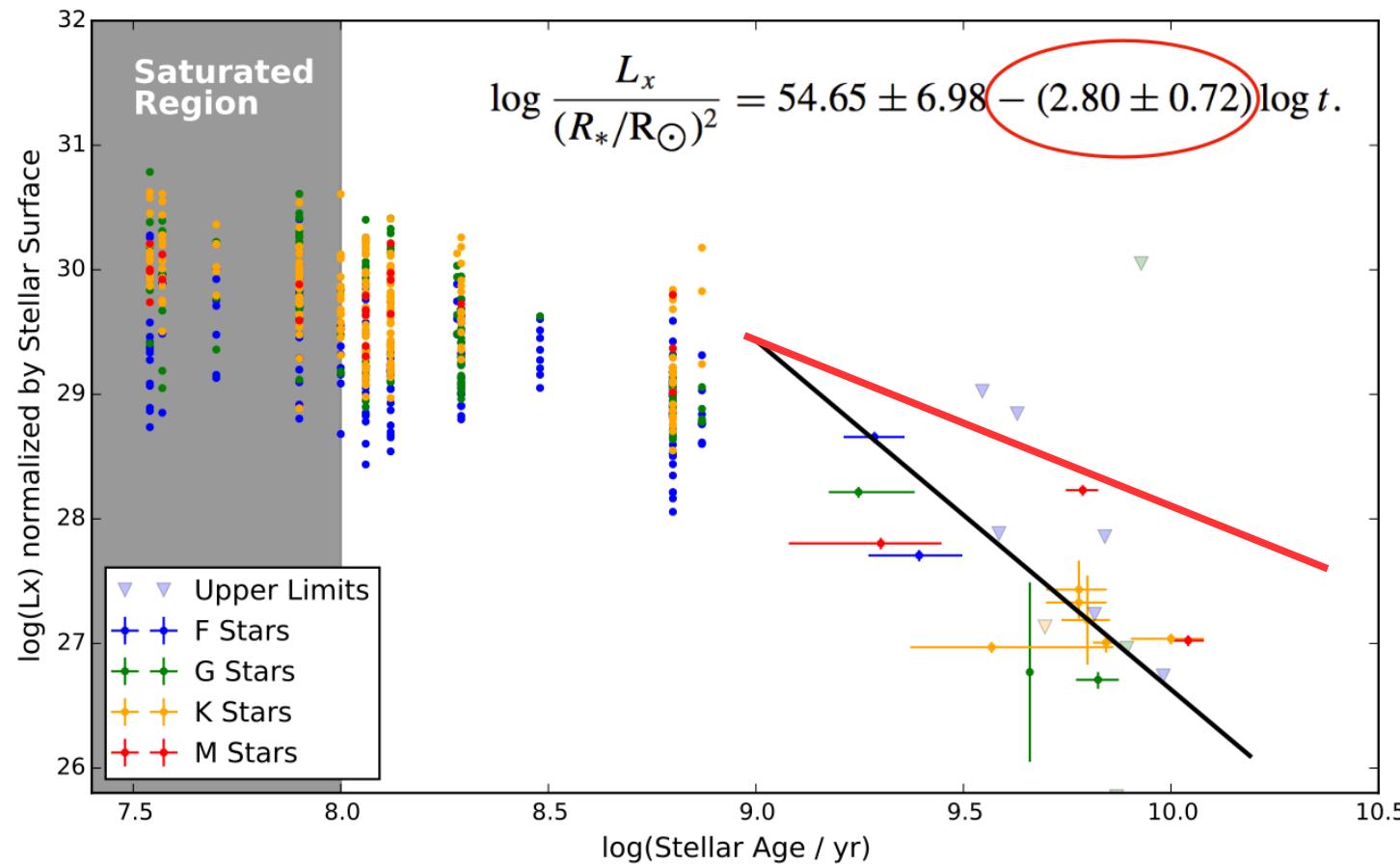
Erosion by high-energy irradiation:  
time-limited because cool stars spin down.  
Strong spin-down/X-ray dimming at old ages:



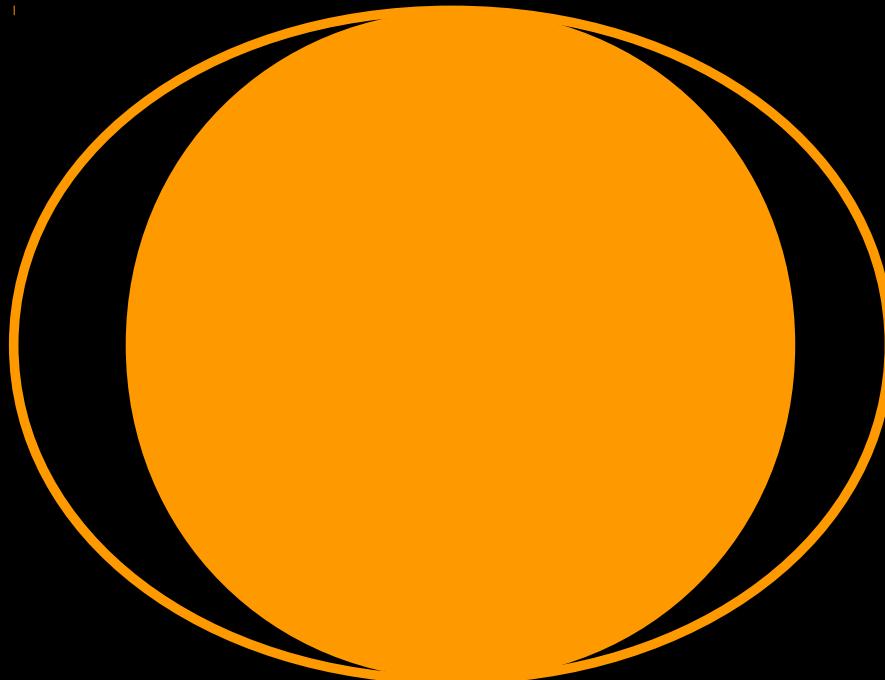
**slope of -2.8  
instead of  
canonical -1 for  
younger stars!**

# Survival of exoplanet atmospheres

If stellar high-energy output altered by Hot Jupiters:  
changes atmosphere survival time for all planets in system!



# Star-exoplanet systems

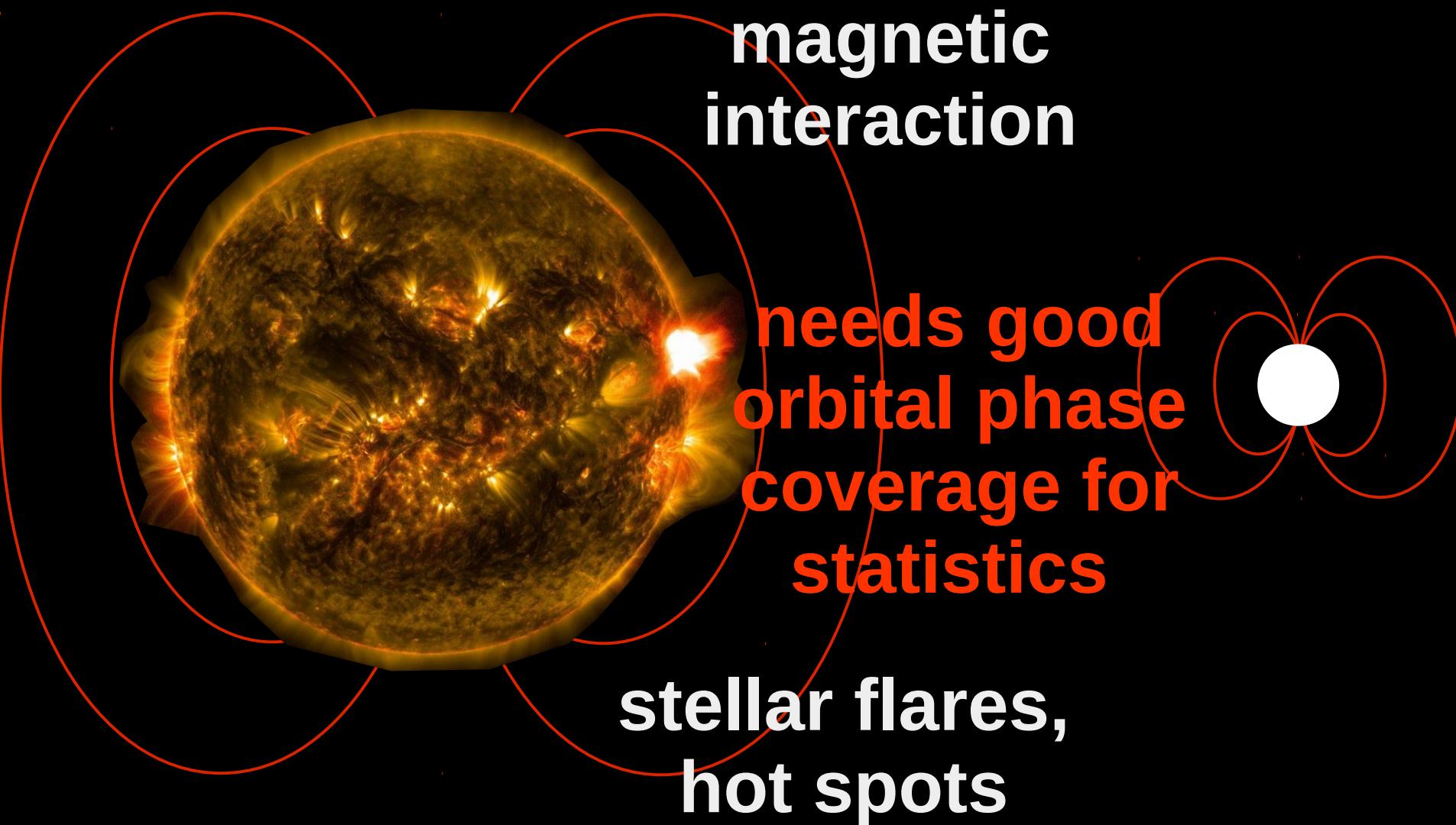


tidal  
interaction



**measurable  
when stellar  
age (proxy)  
available**

# Star-exoplanet systems

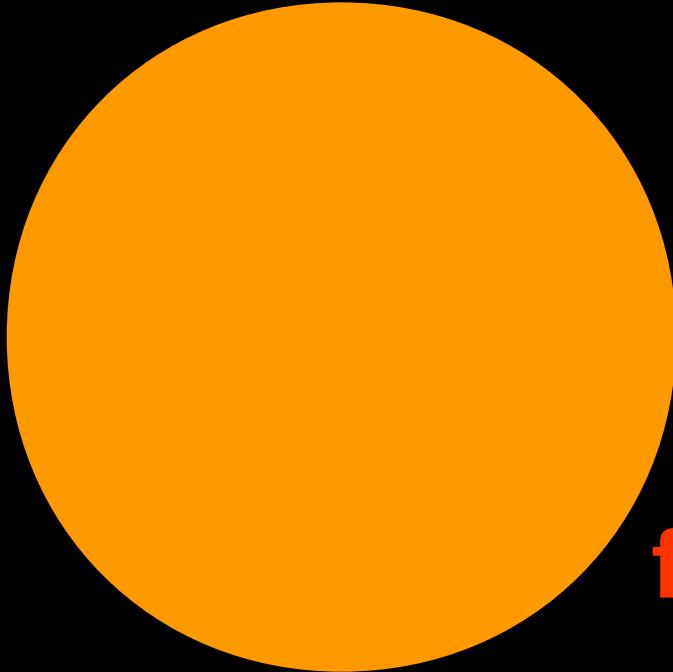


# Star-exoplanet systems

planetary  
effects

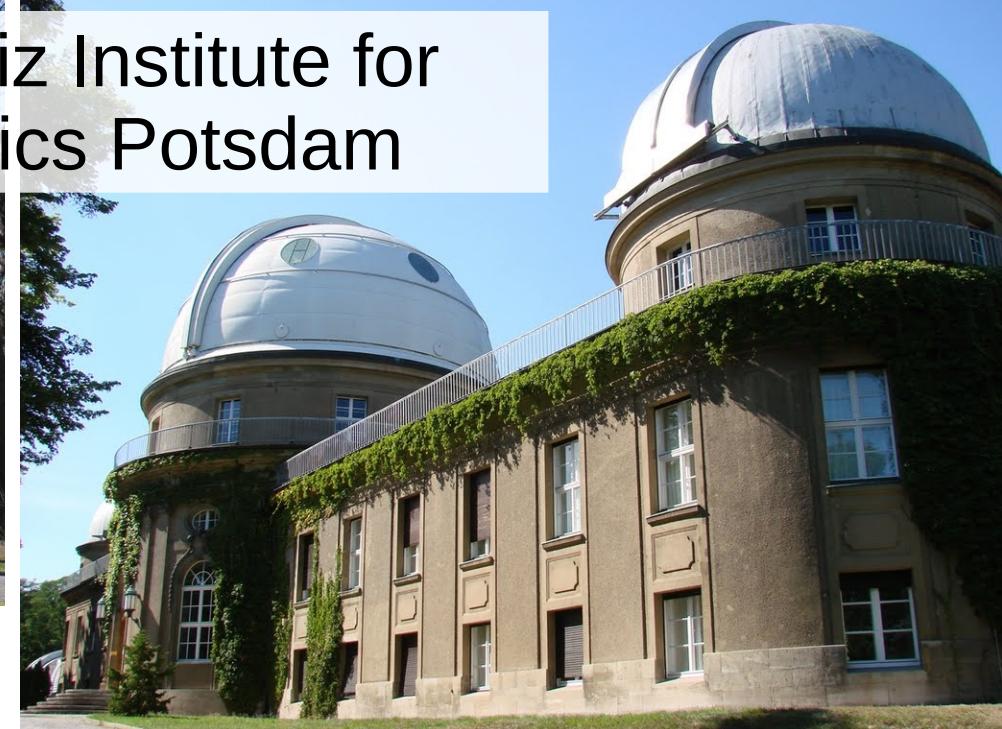
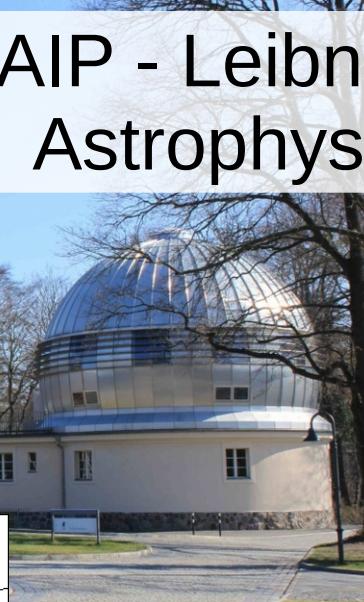
**common in  
short-period  
systems;  
potential  
feedback effects**

atmospheric  
blow-off



# I'm hiring!

AIP - Leibniz Institute for  
Astrophysics Potsdam



I'm looking for postdocs and  
PhD students to join my group -  
come and talk to me if you're  
interested!