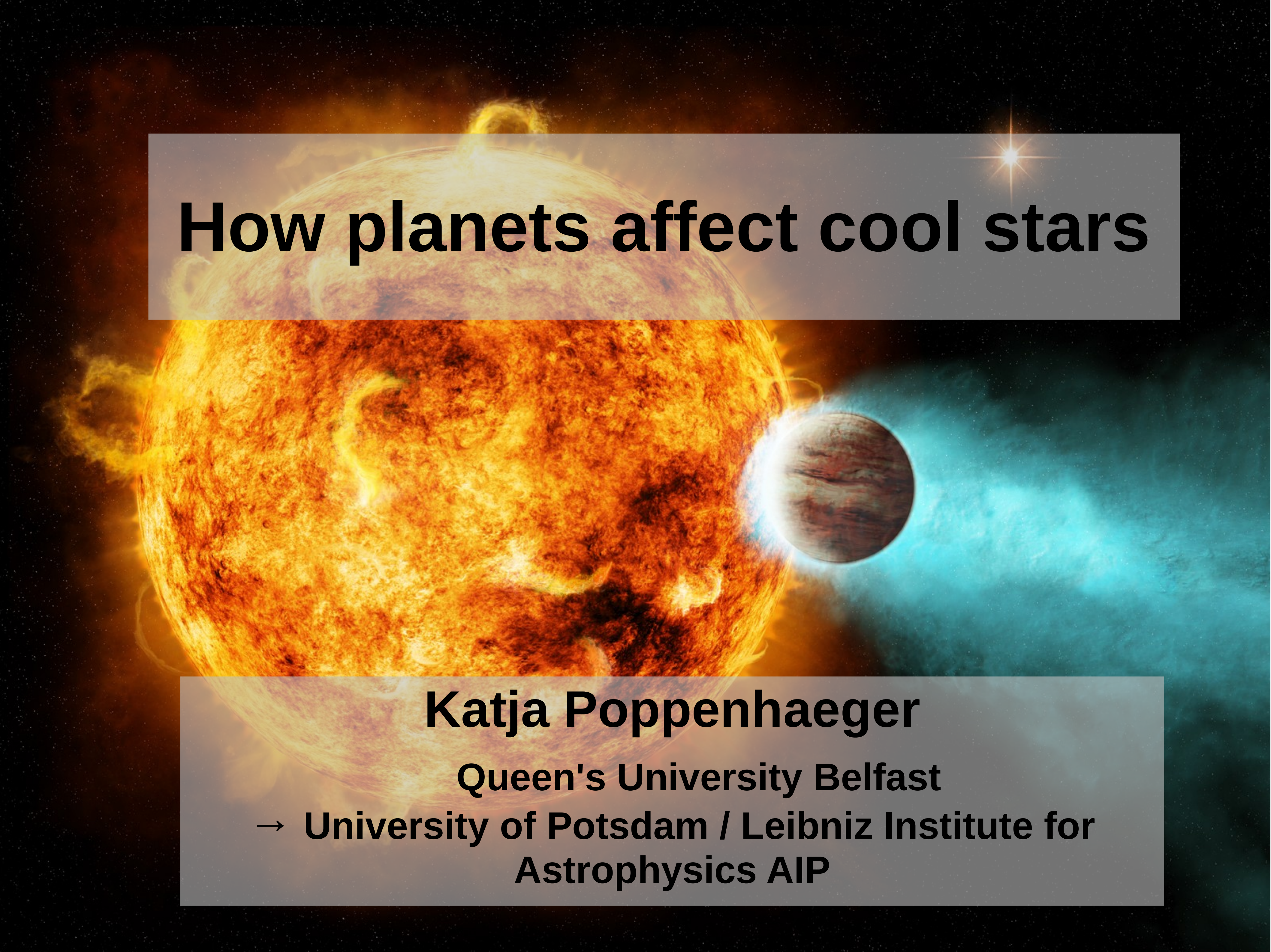
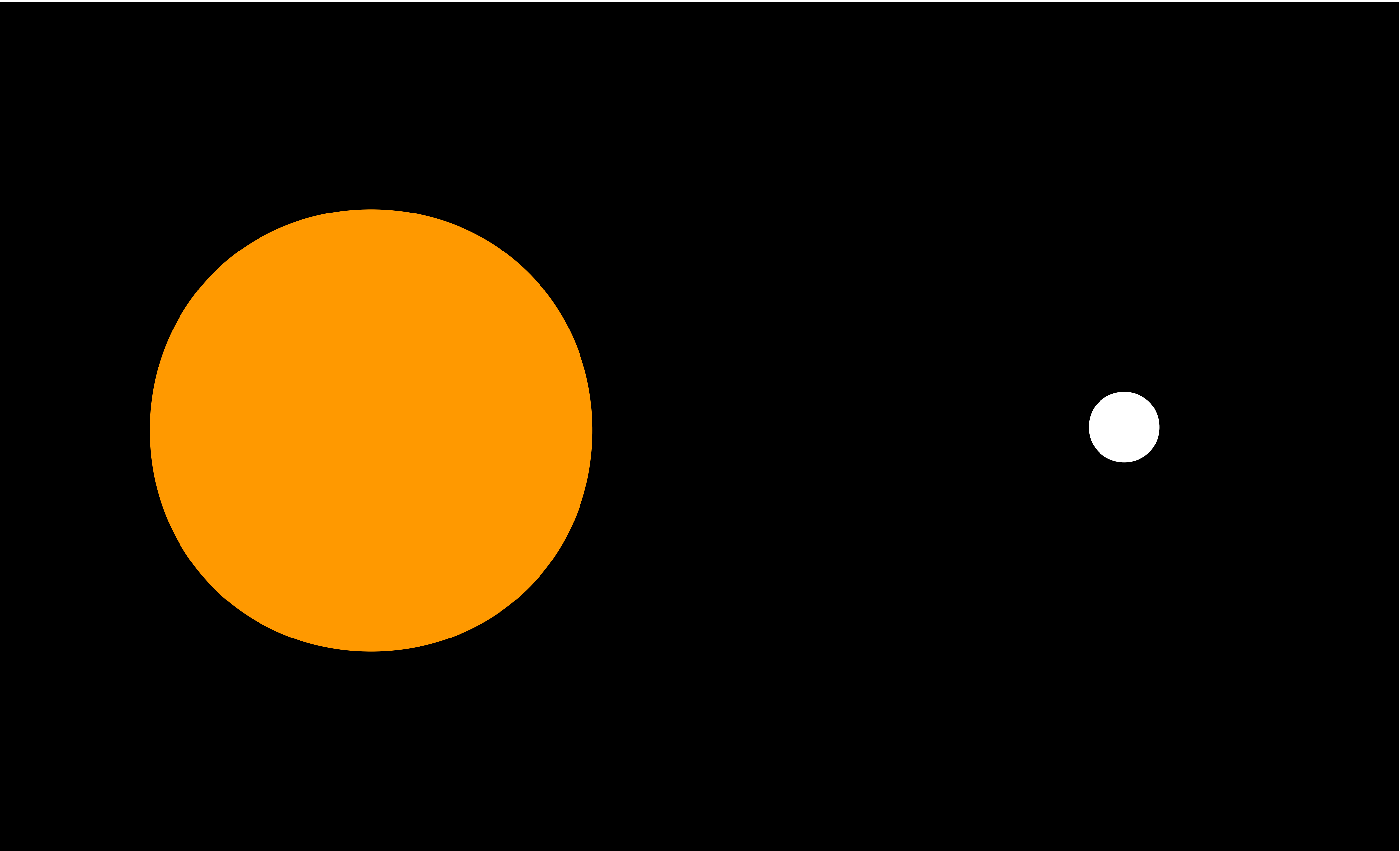


How planets affect cool stars

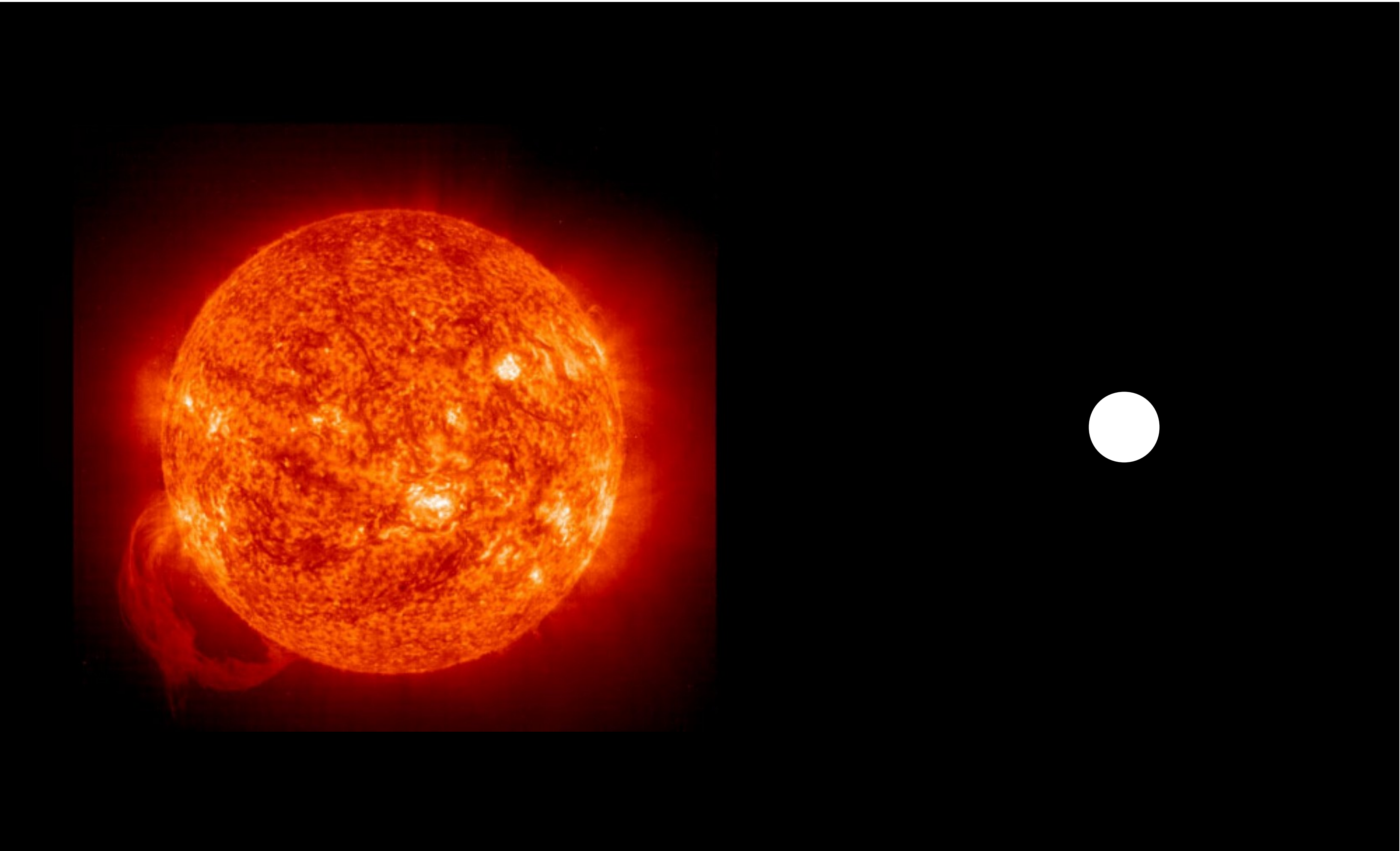
Katja Poppenhaeger

Queen's University Belfast
→ University of Potsdam / Leibniz Institute for Astrophysics AIP

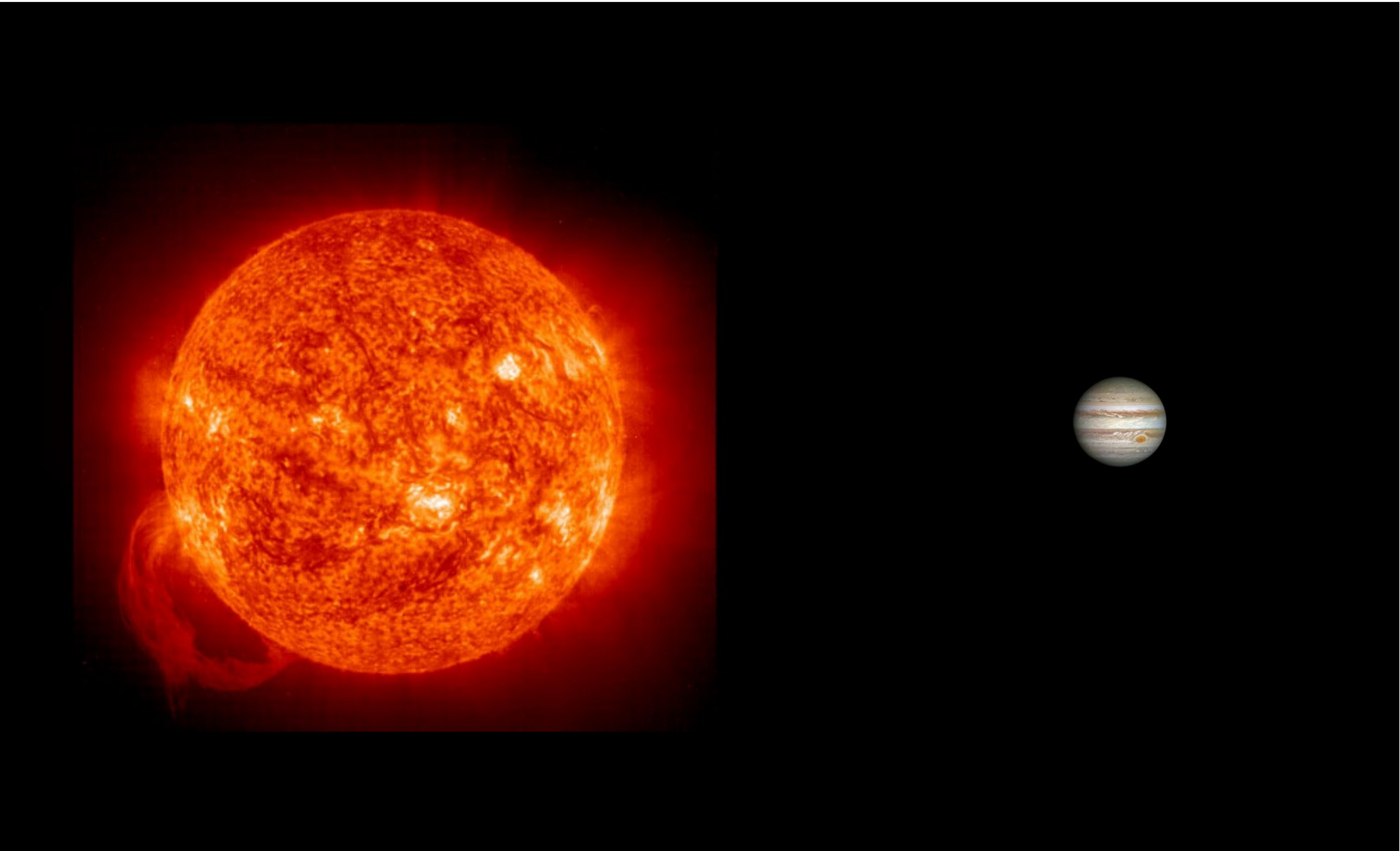
Star-exoplanet systems



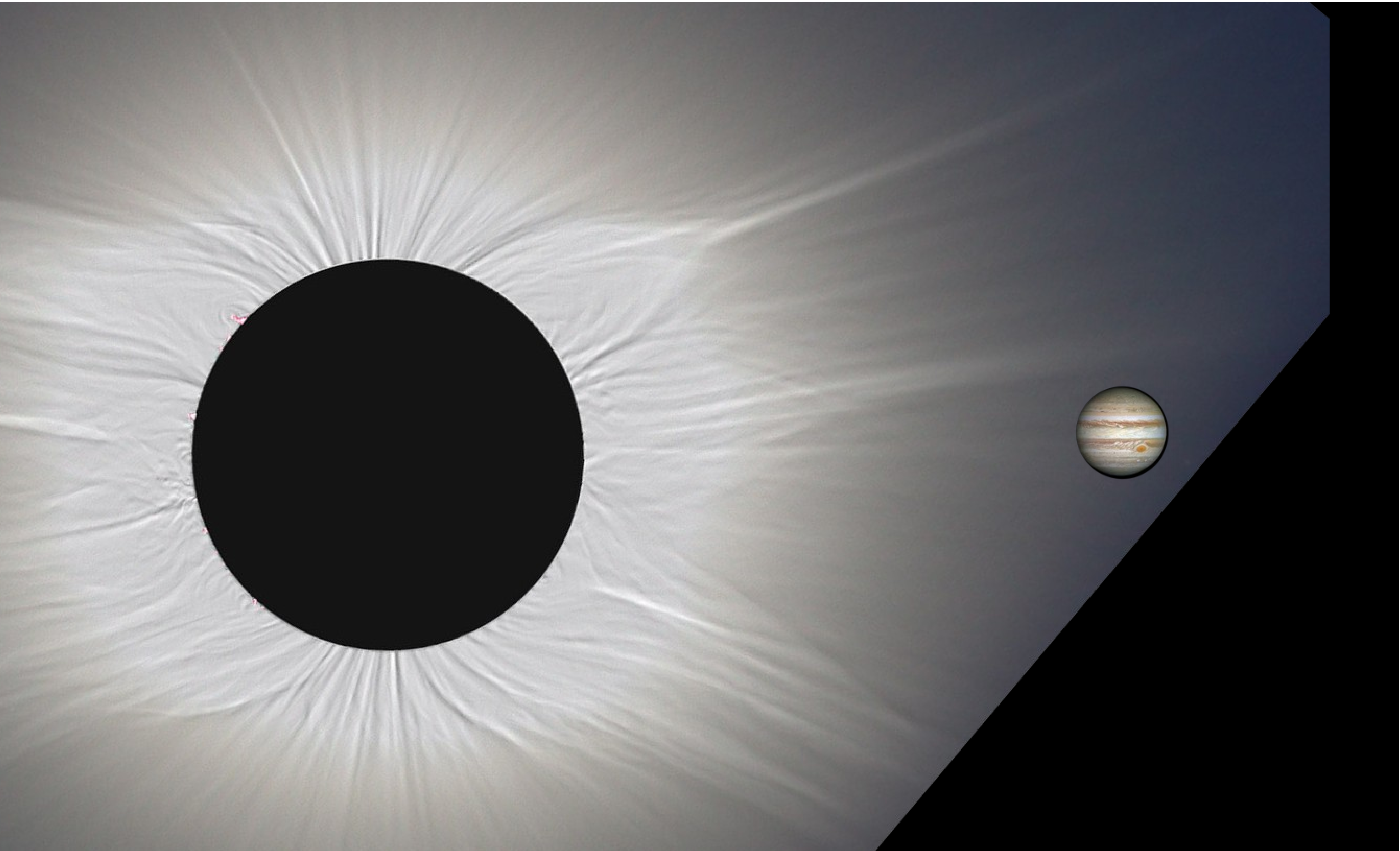
Star-exoplanet systems



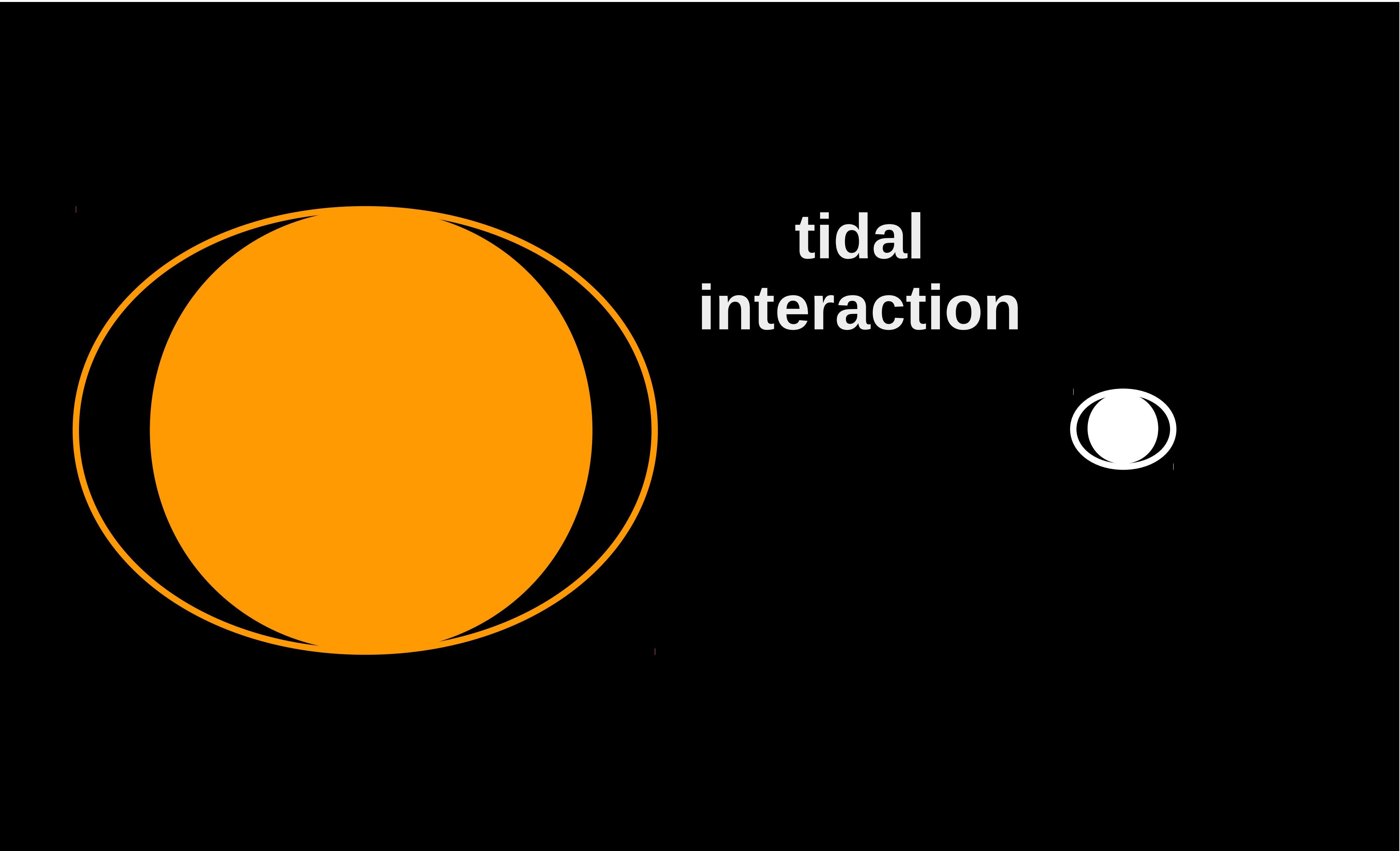
Star-exoplanet systems



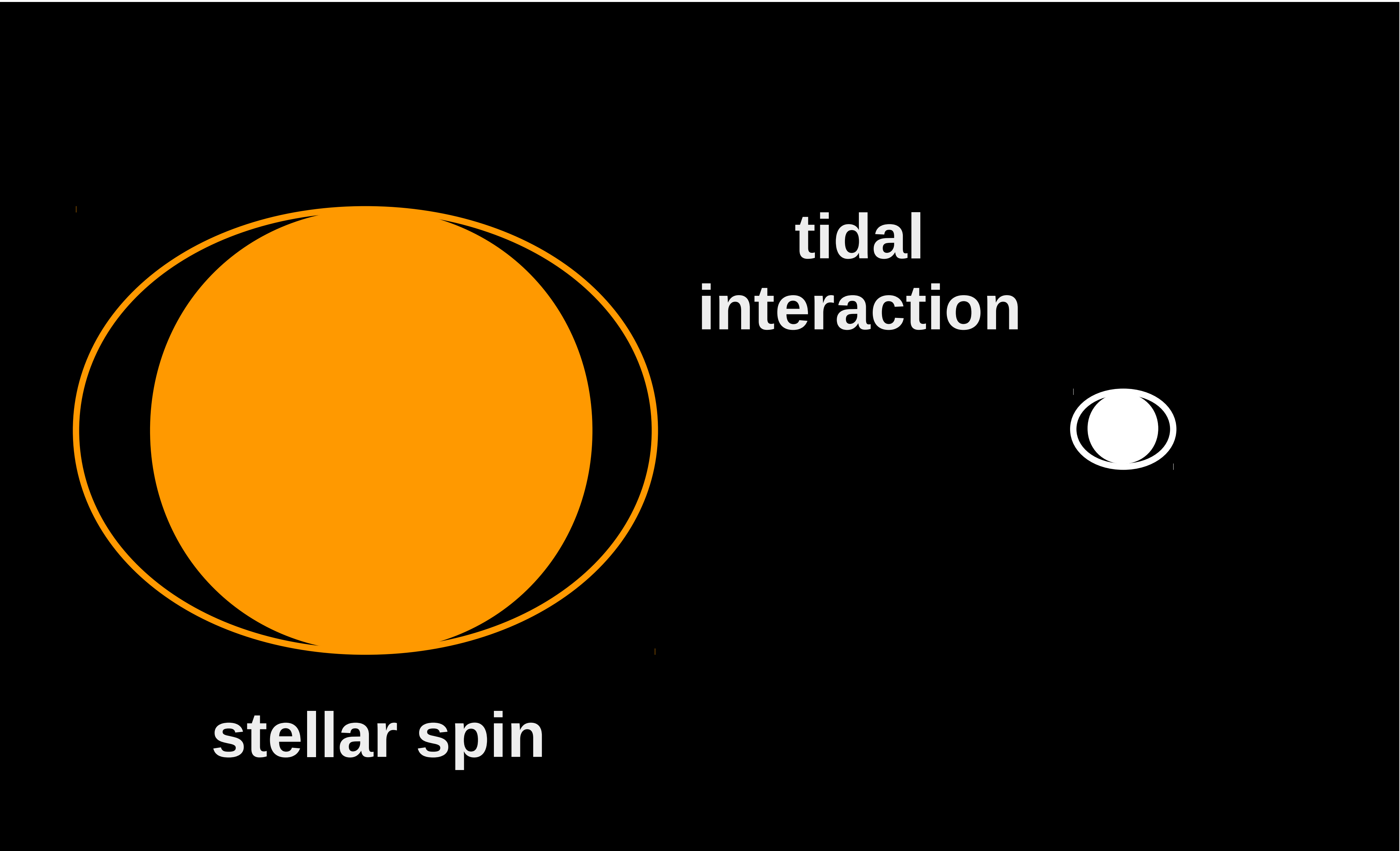
Star-exoplanet systems



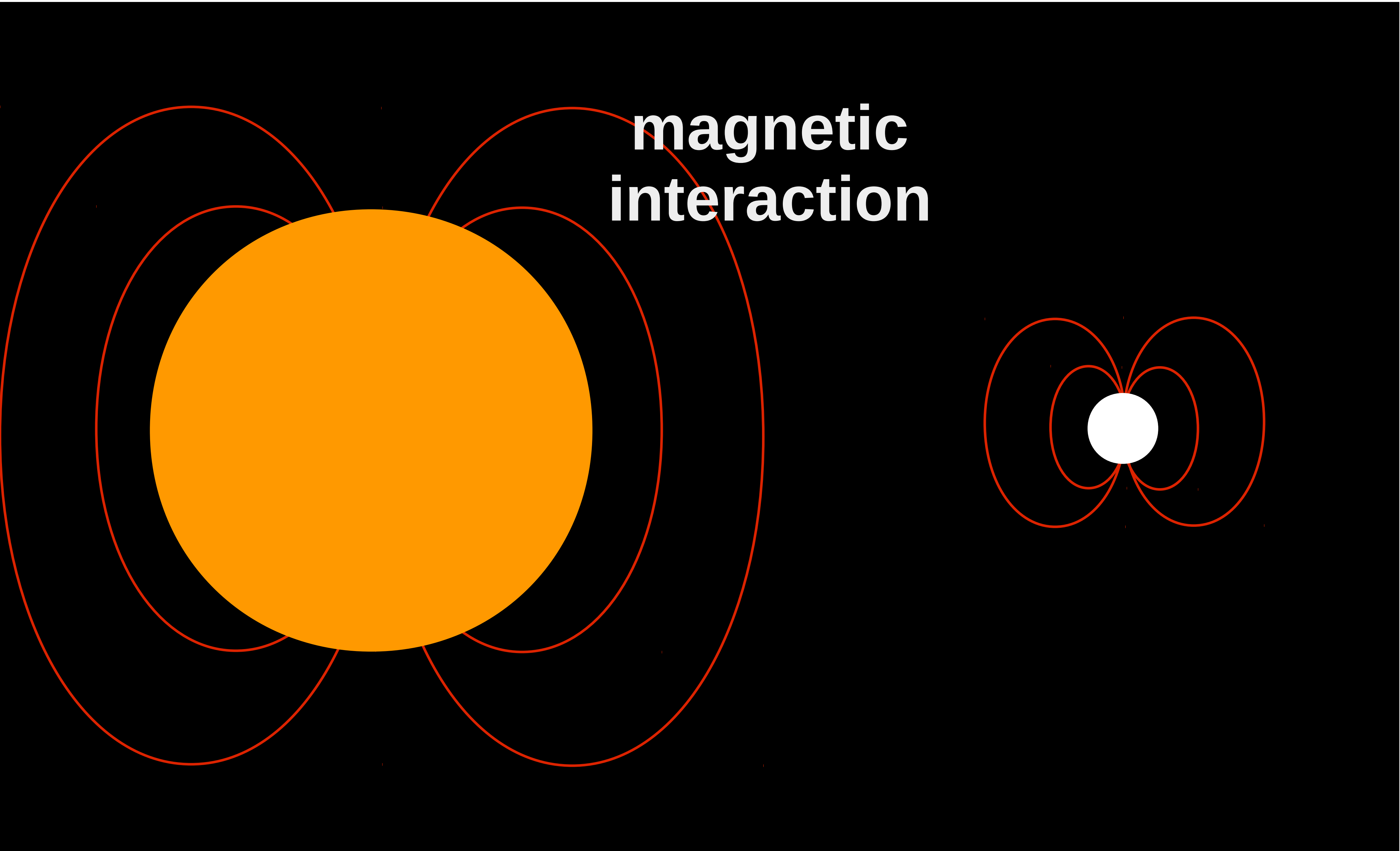
Star-exoplanet systems



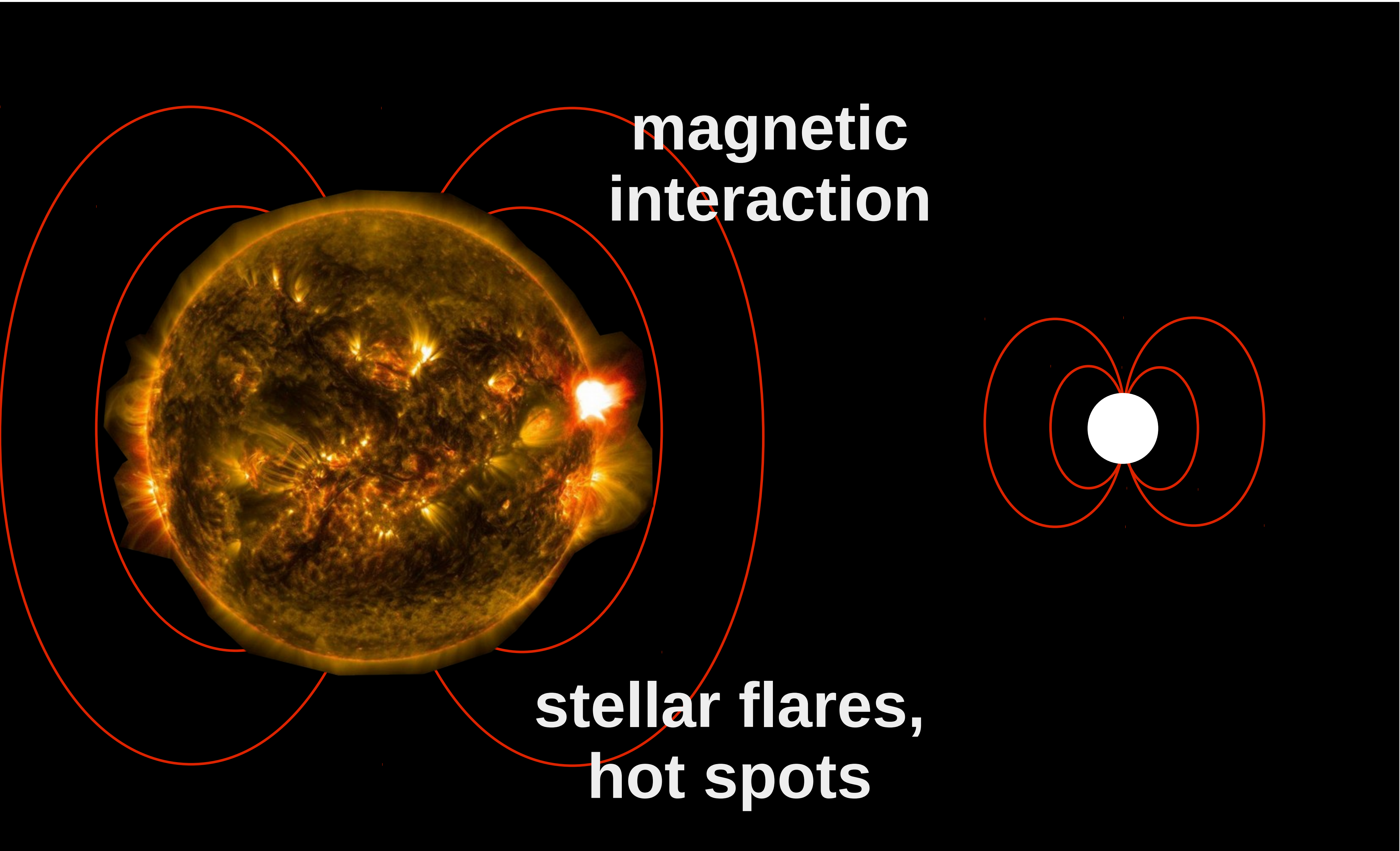
Star-exoplanet systems



Star-exoplanet systems

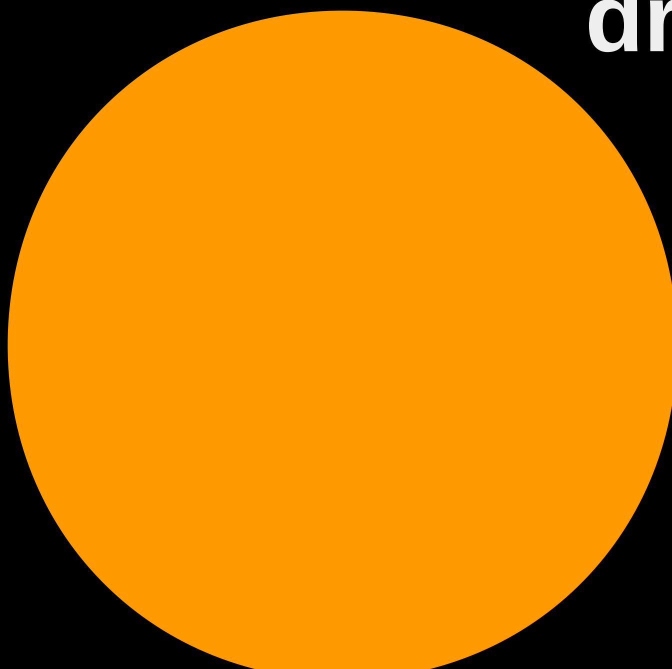


Star-exoplanet systems



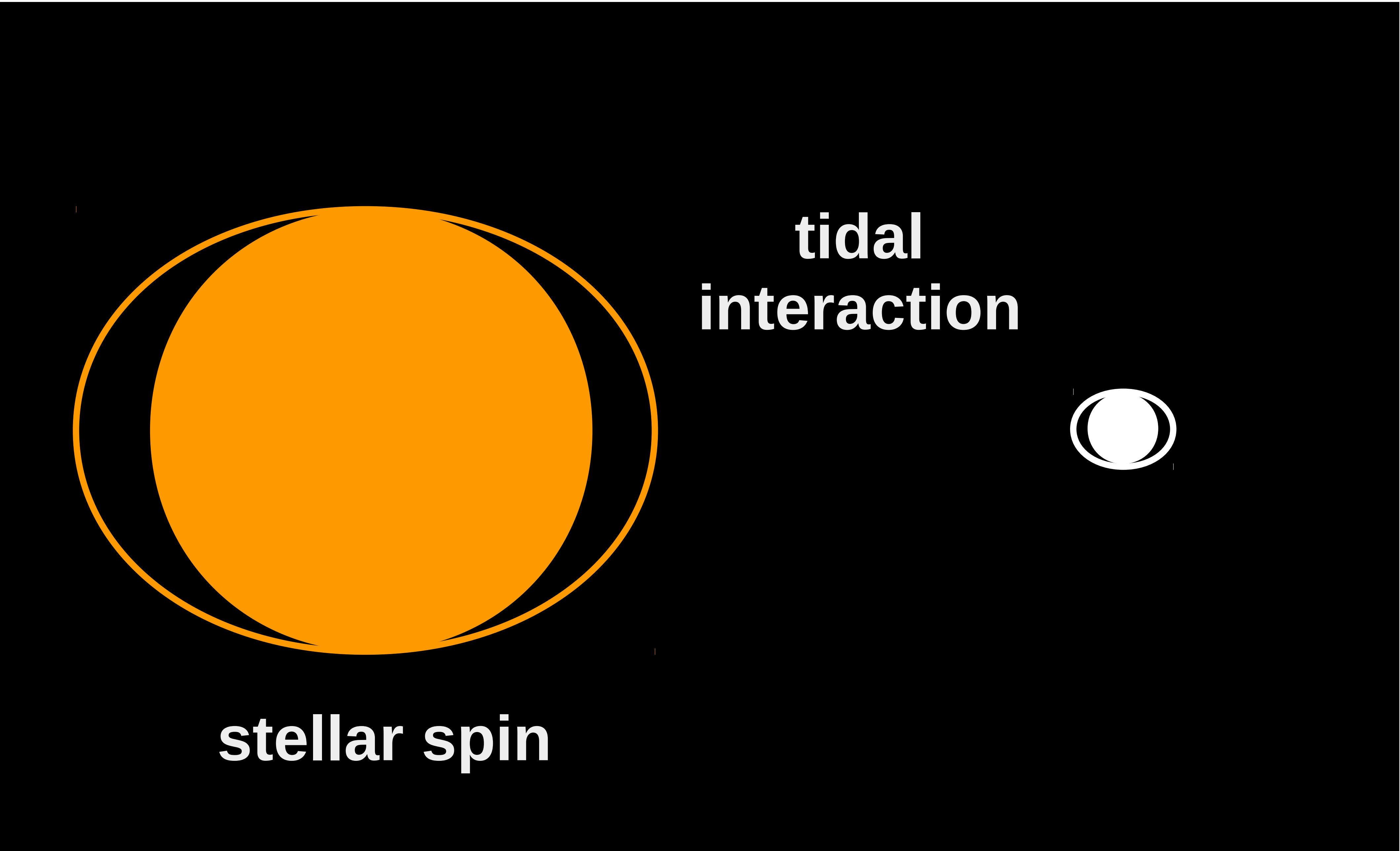
Star-exoplanet systems

planetary effects driven by star

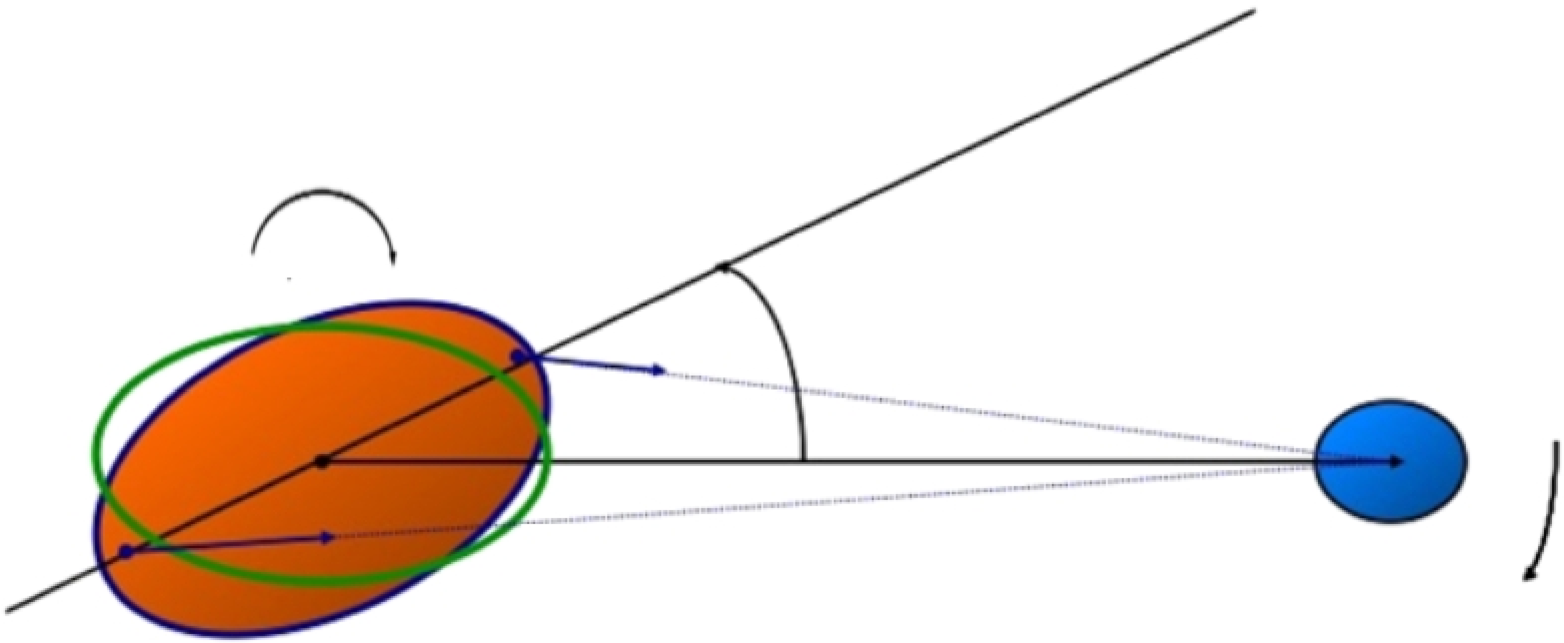


atmospheric blow-off

Star-exoplanet systems



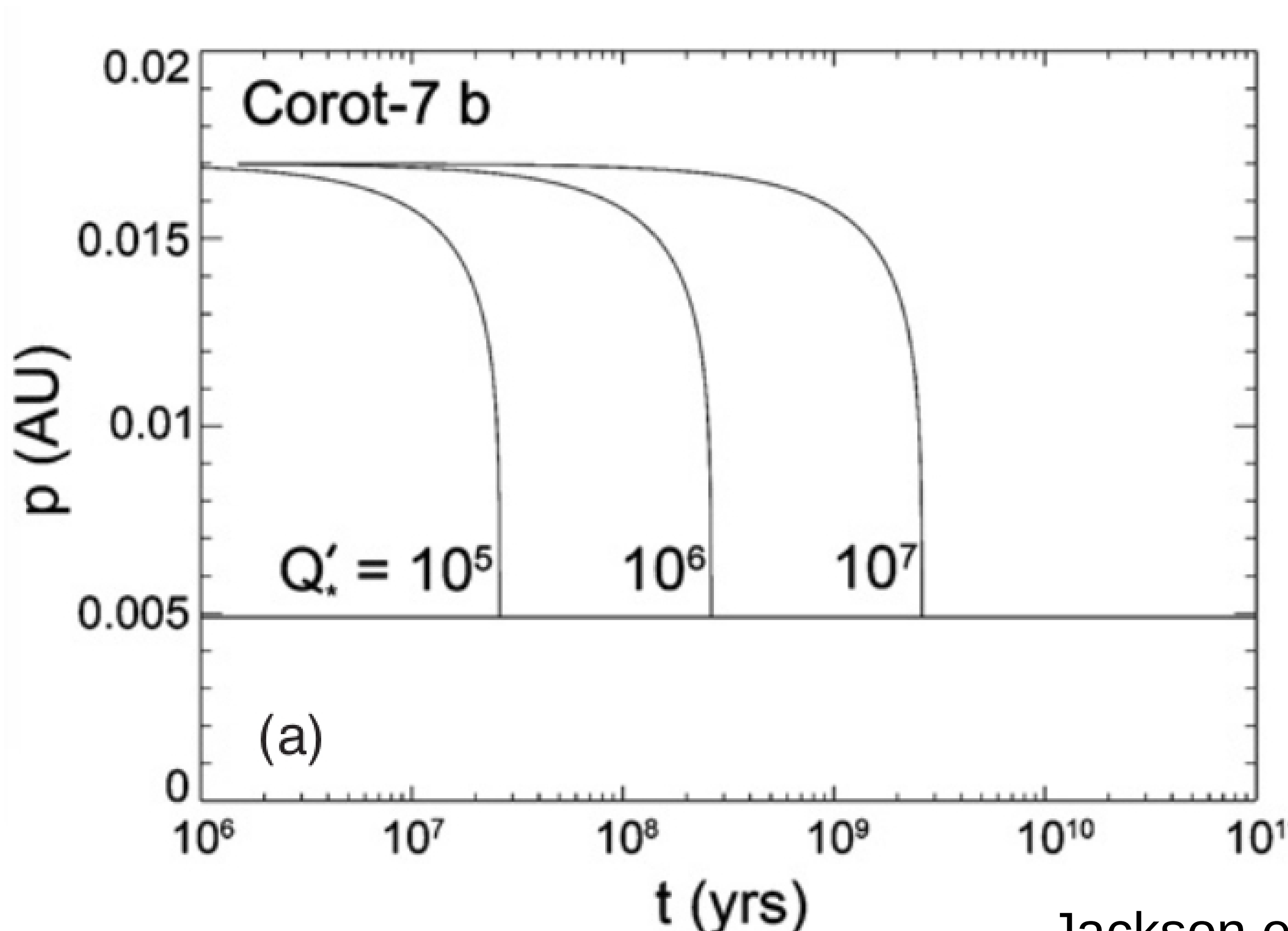
Tidal interaction



Mathis & Remus (2013)

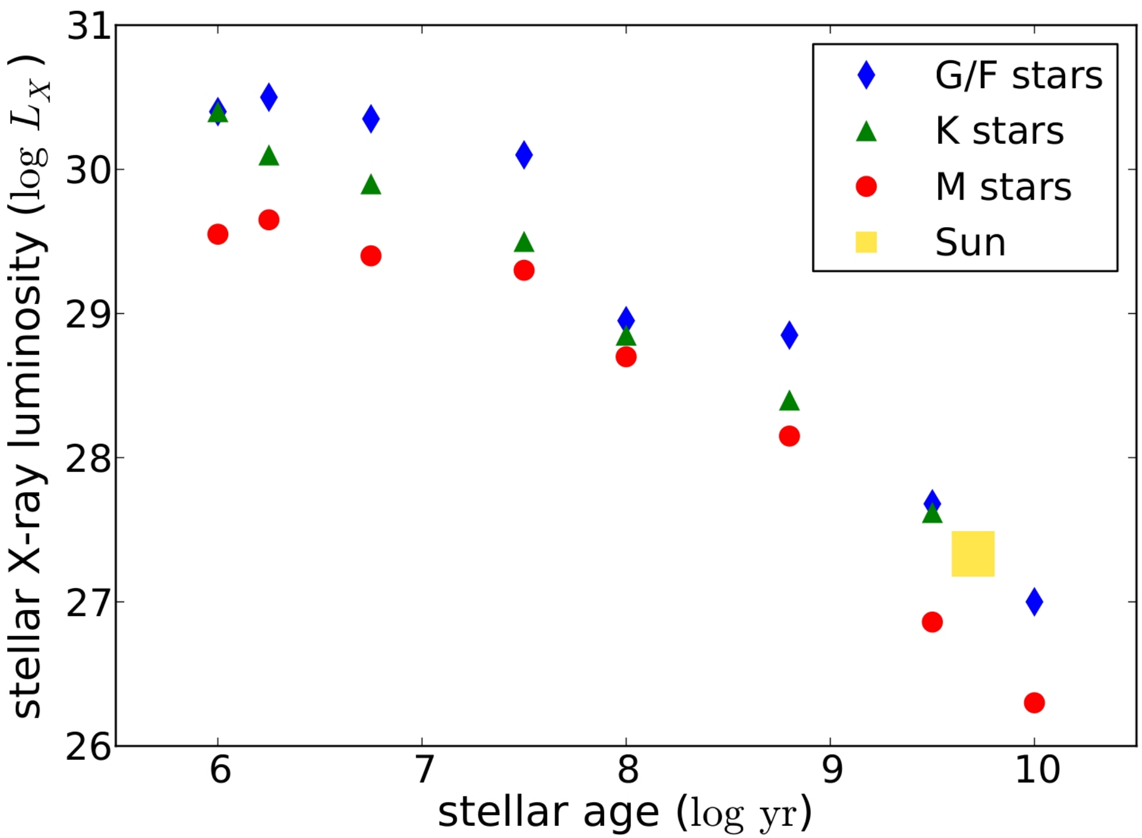
see also
Lanza & Mathis (2016)

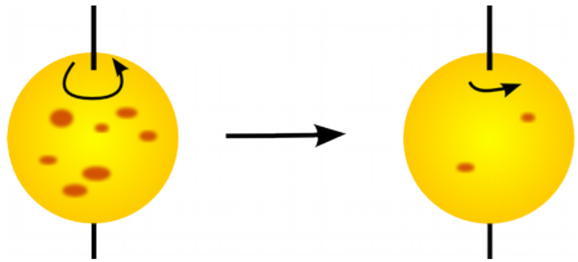
Tidal interaction: inspiralling planets



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

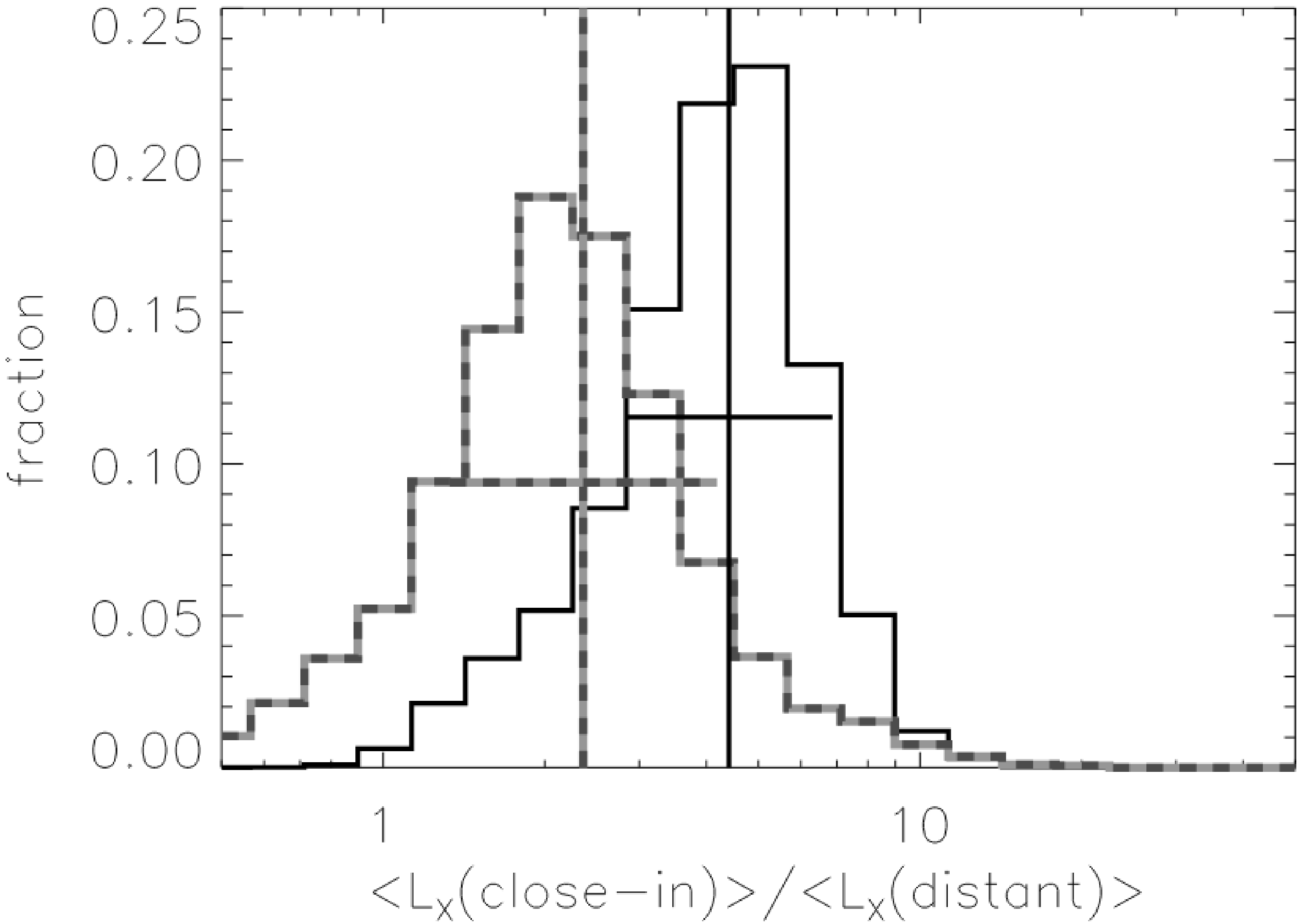
How stars age on the main sequence





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

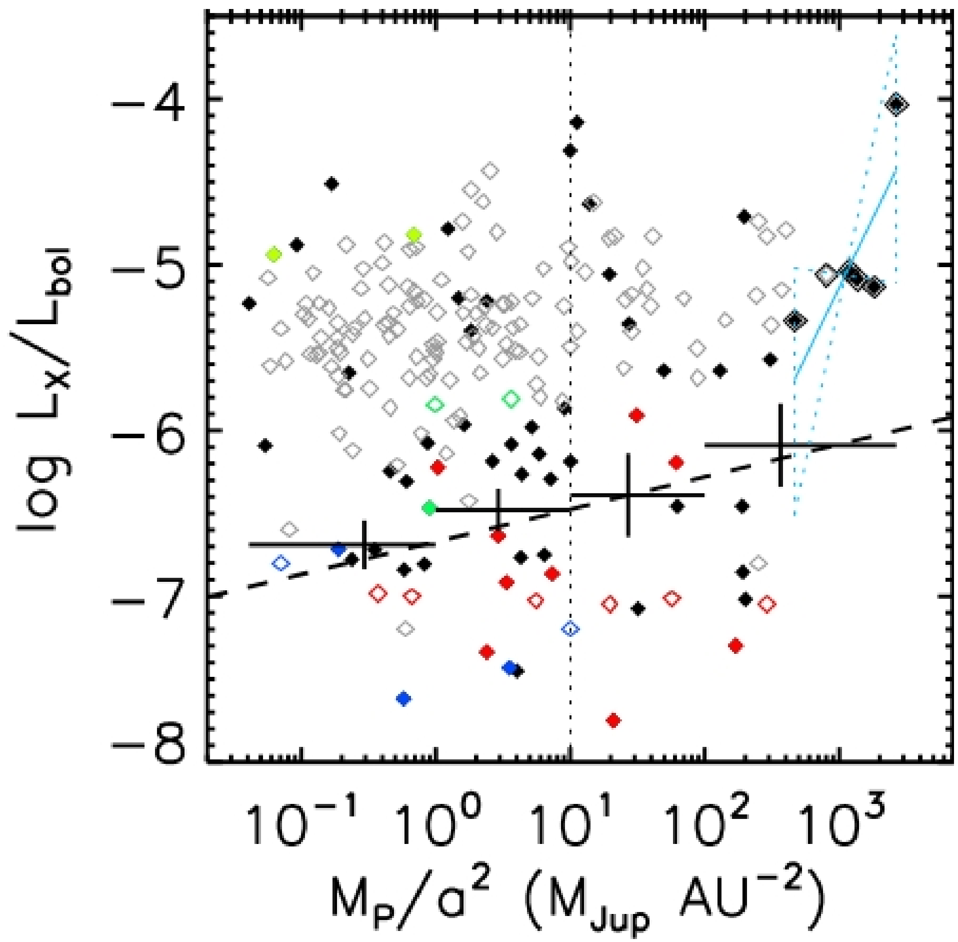
Planet-induced activity: trends?



Kashyap et al. (2008);
see also
Shkolnik (2013),
Miller et al. (2014)

Stars with Hot Jupiters 2-3 times X-ray brighter than stars with far away planets

Planet-induced activity: trends?



more active

more Hot Jupiter-like

Miller et al. (2015)

Planet-induced activity: trends?

DIFFICULTY:

more active

small & large planets “easy” to detect

more Hot Jupiter-like

Planet-induced activity: trends?

DIFFICULTY:

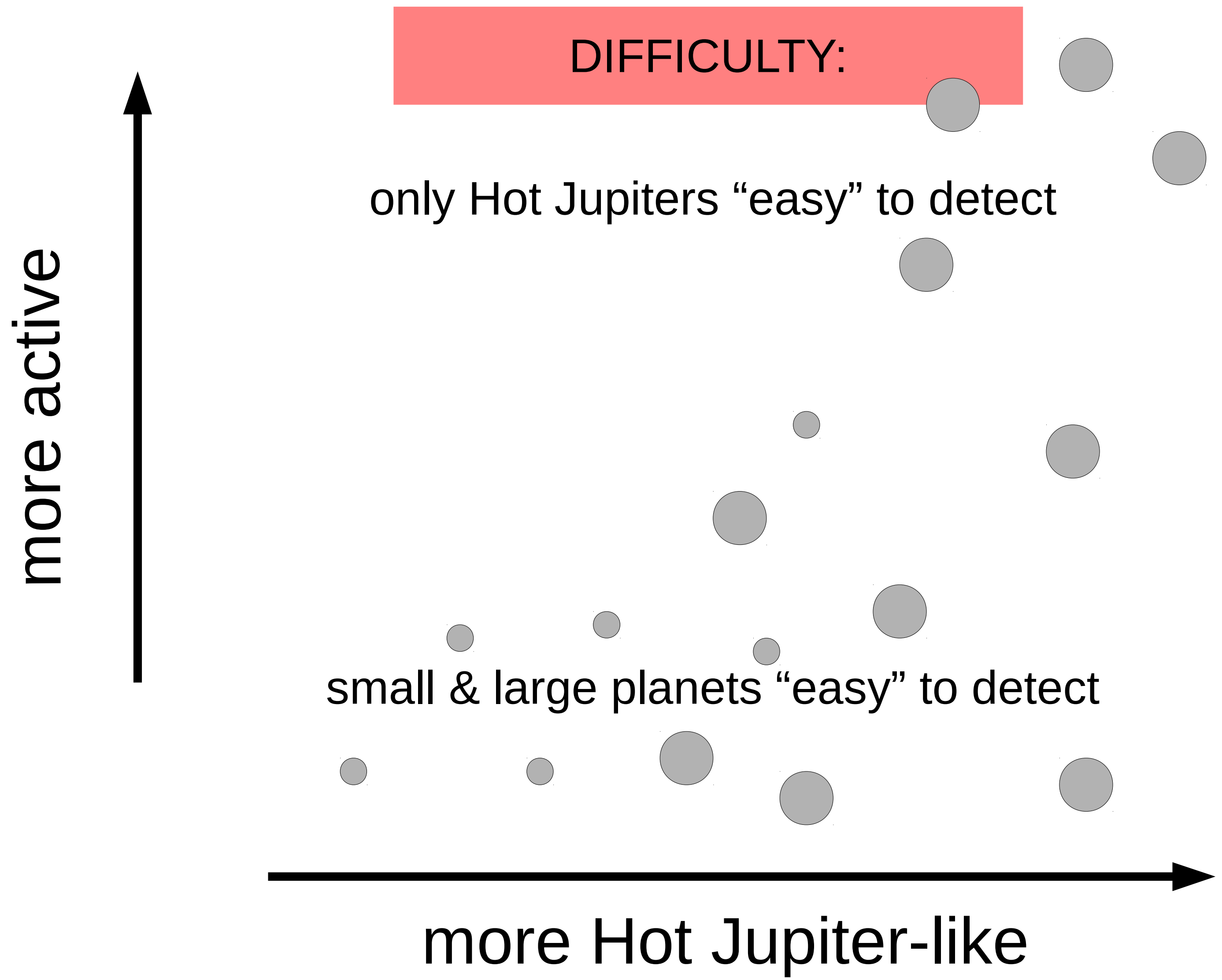
only Hot Jupiters “easy” to detect

more active

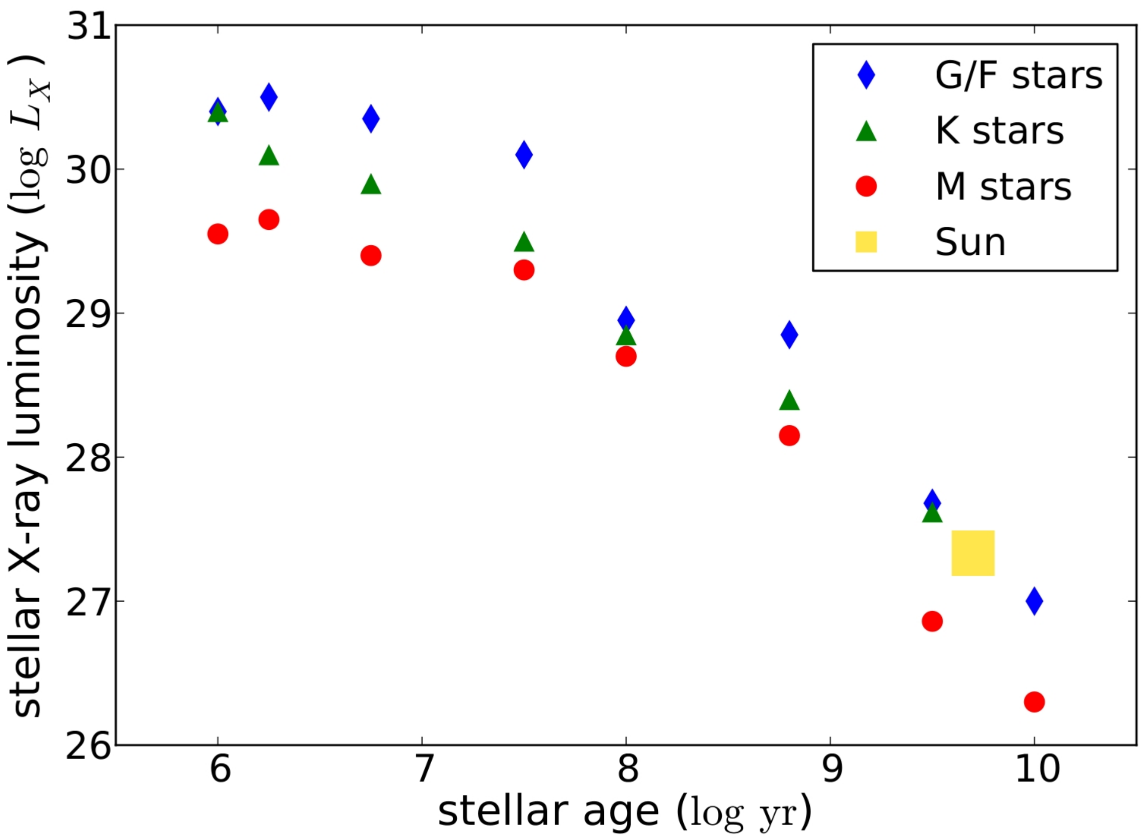
small & large planets “easy” to detect

more Hot Jupiter-like

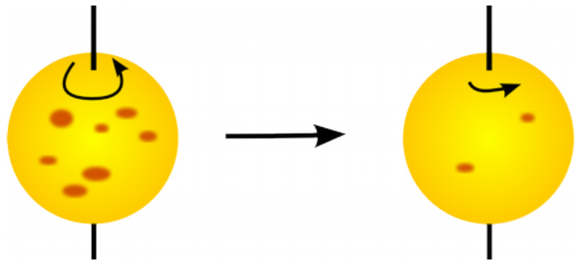
Planet-induced activity: trends?



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 stars

Hot Jupiter hosts:

WASP-19, G8V star

P_{rot} = 10.5 d

age = ~5 Gyr (isochrones)

Hebb et al. (2010)

HATS-18, mid-G star

P_{rot} = 9.8 d

age = ~5 Gyr (isochrones)

Penev et al. (2016)

See also Maxted et al. (2015) for discrepancies in gyro- and isochrone ages

Planet-hosting wide binaries

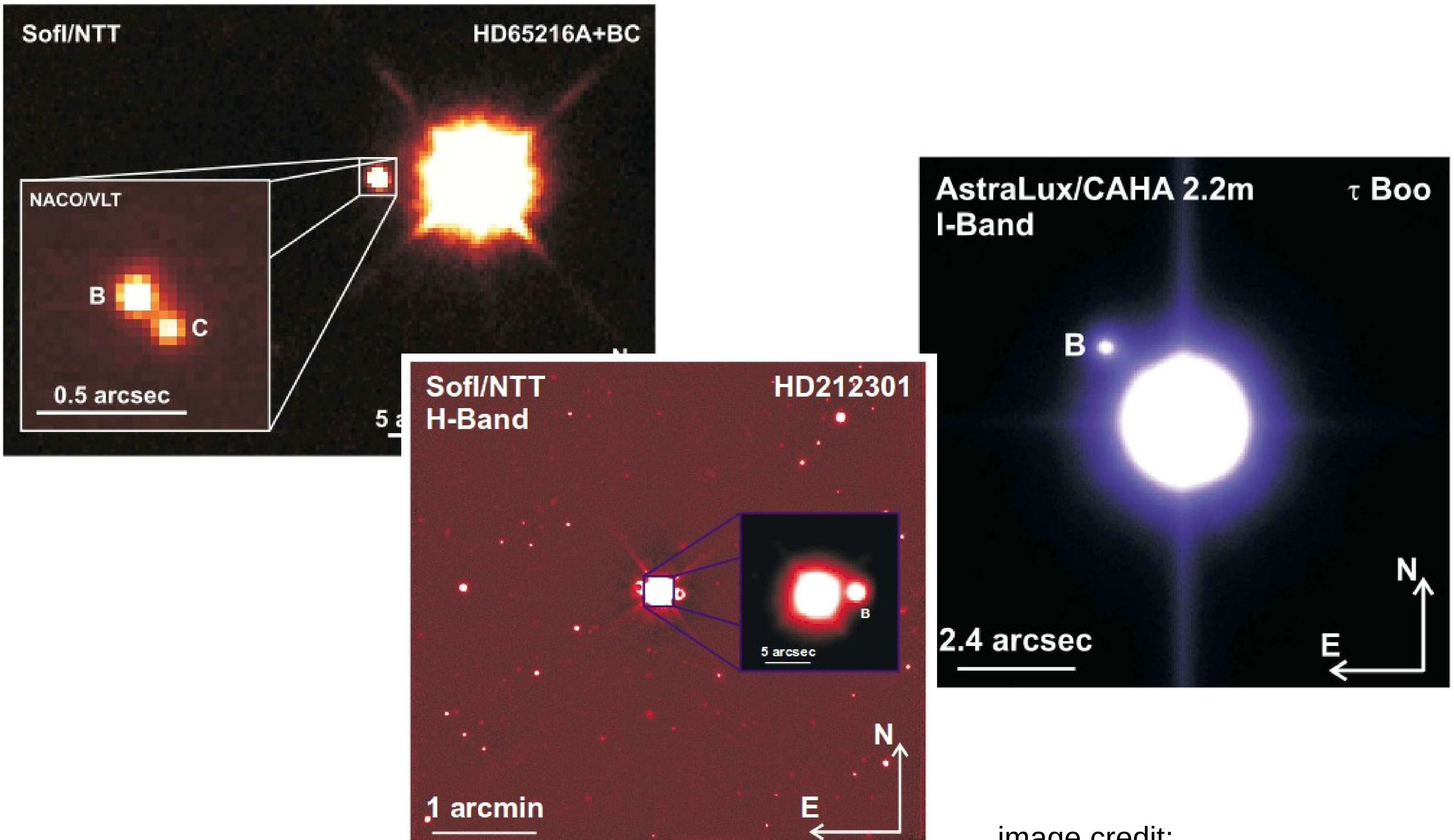
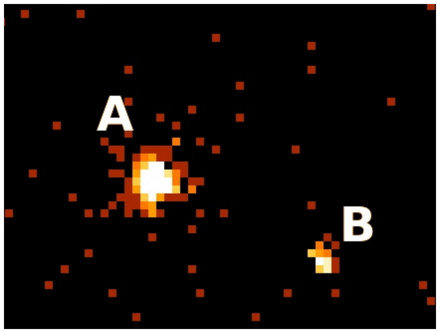
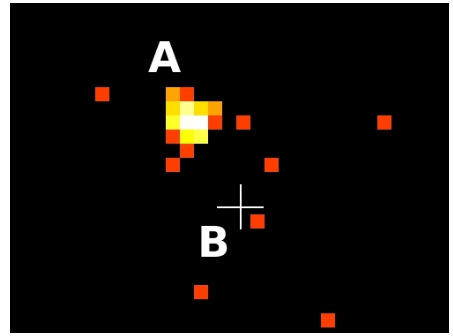


image credit:
Mugrauer et al. (2007);
see also Raghavan (2006)

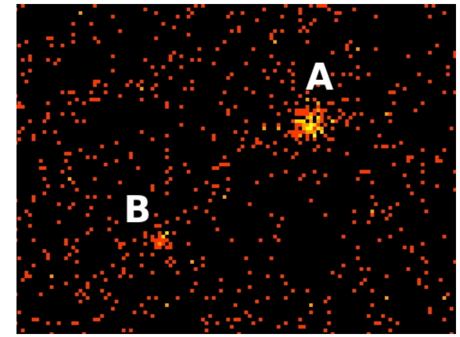
Planet-hosting wide binaries



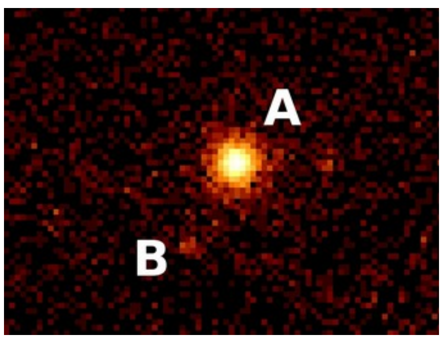
HD 189733 Ab B



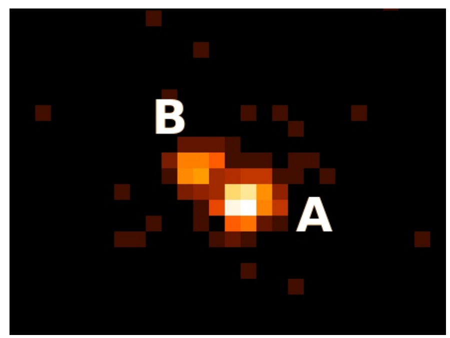
CoRoT-2 Ab B



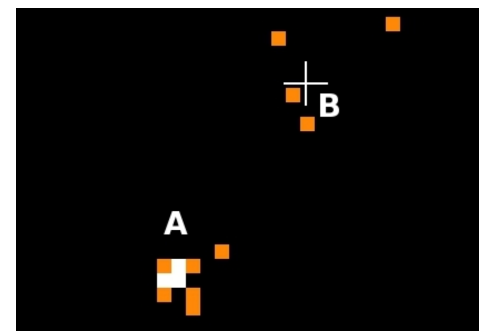
55 Cnc Abcde B



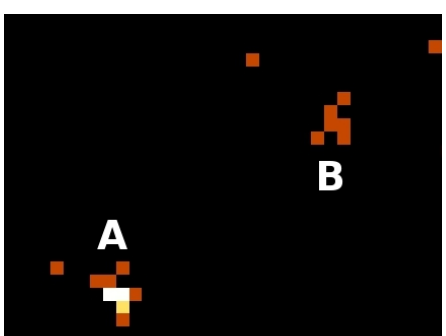
upsilon And Ab B



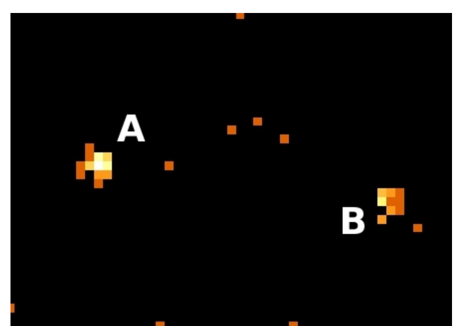
tau Boo Ab B



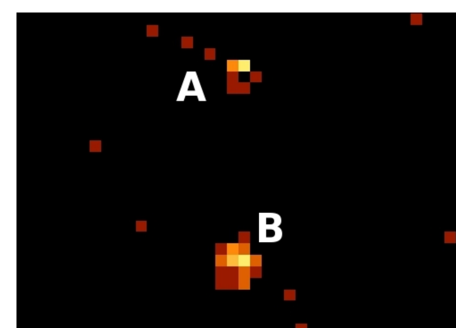
HAT-P-20 Ab B



HD 46375 Ab B



HD 178911 A Bb

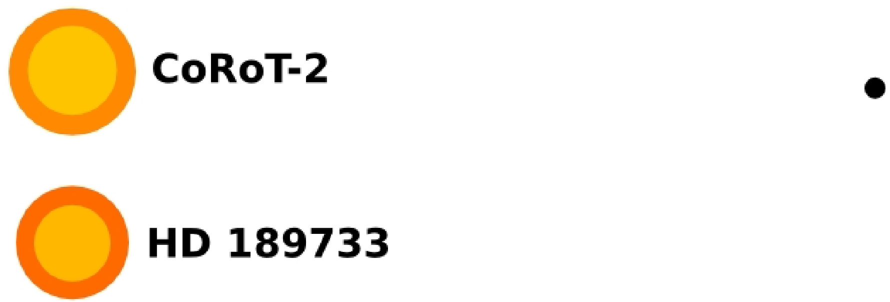


HD 109749 Ab B

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

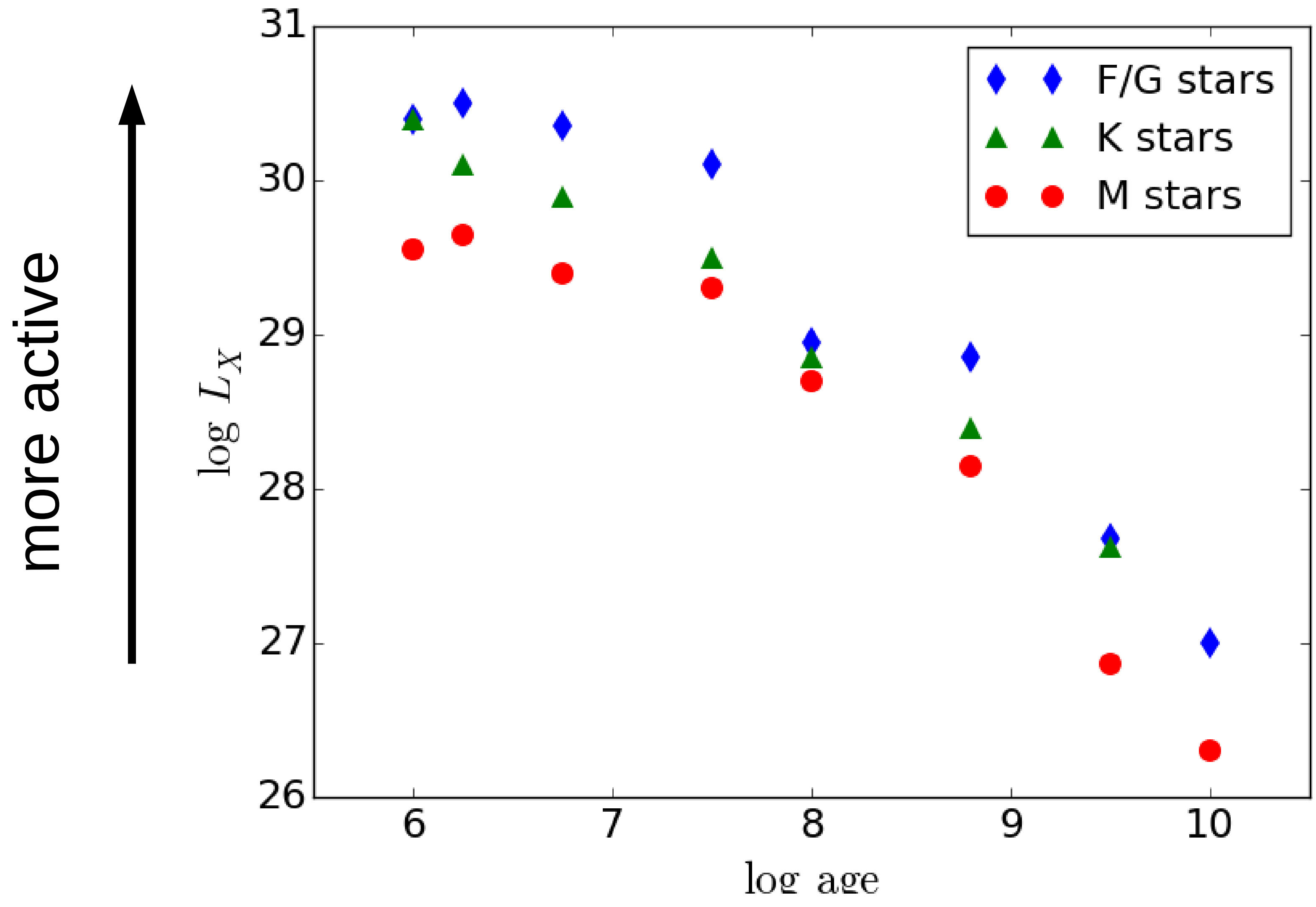
Planet-hosting wide binaries

strong tidal interaction

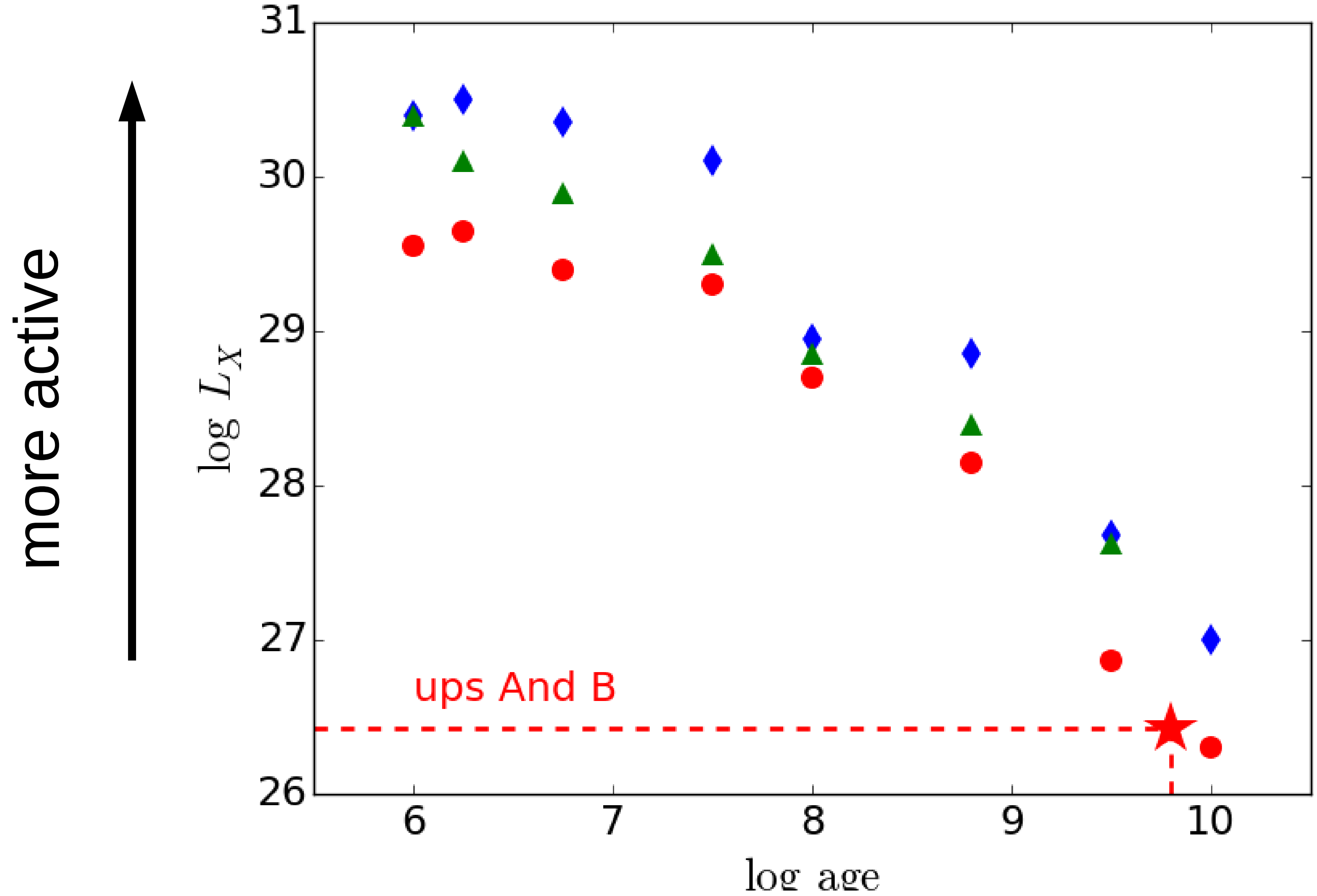


weak tidal interaction

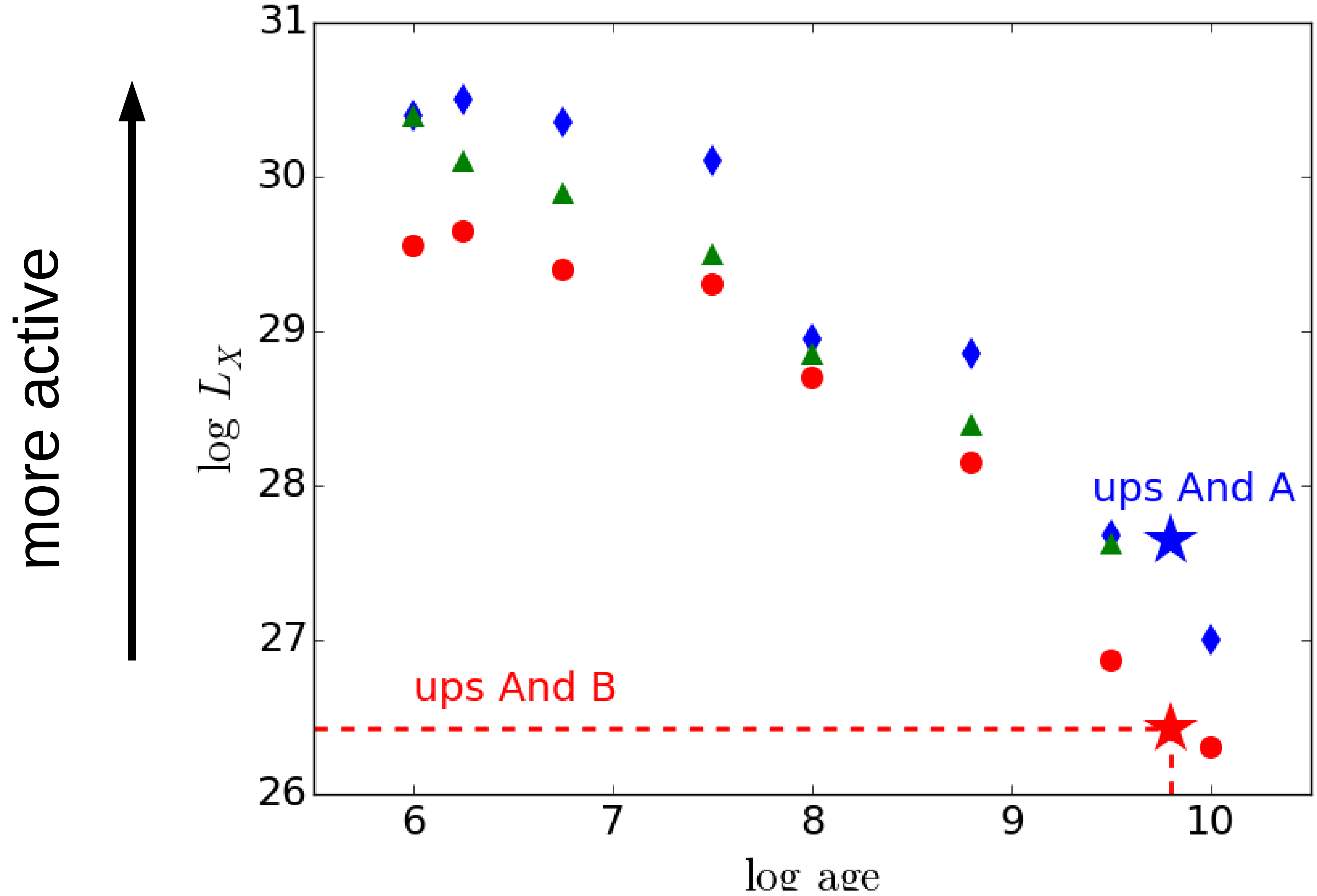
Planet-hosting wide binaries



Planet-hosting wide binaries

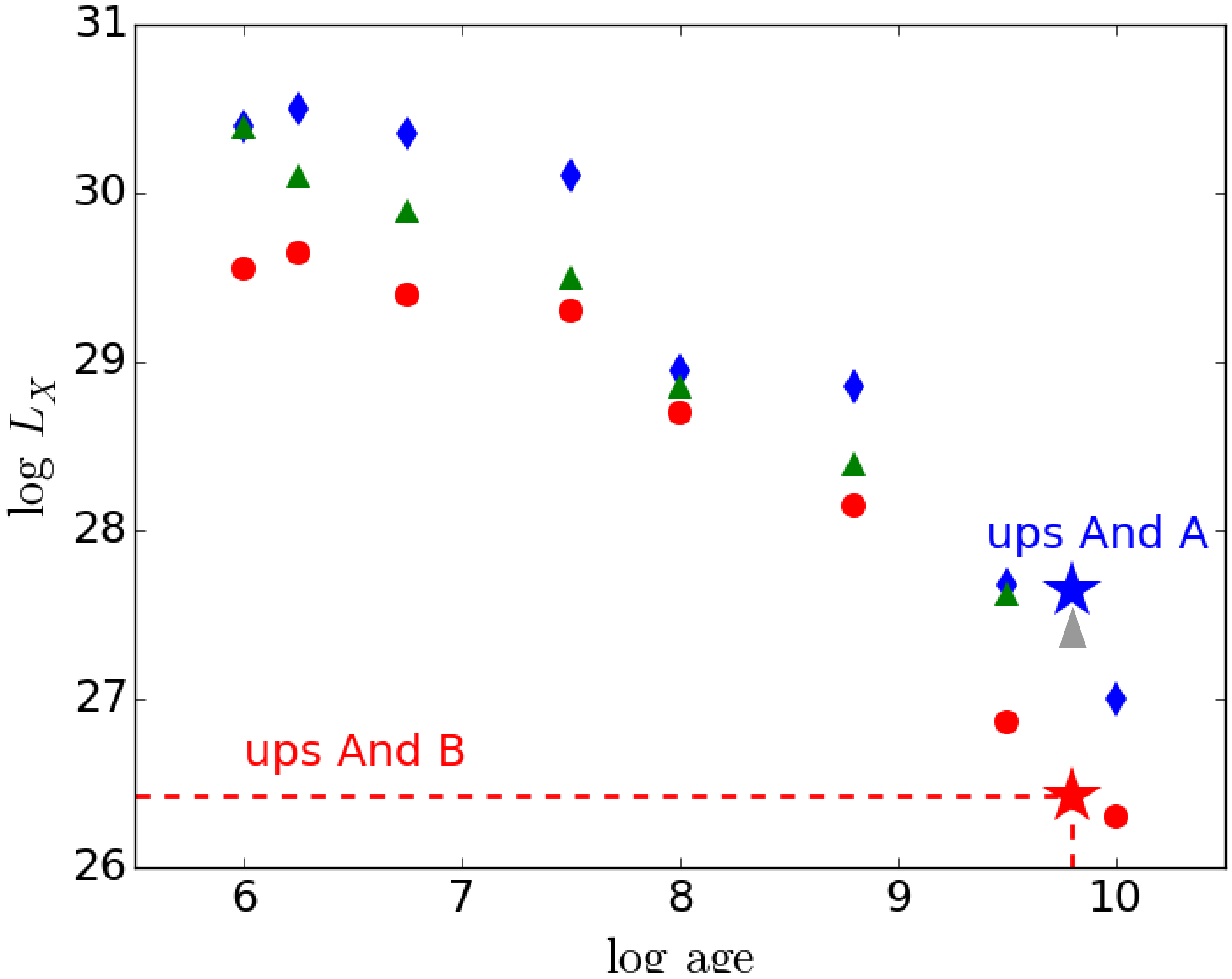


Planet-hosting wide binaries

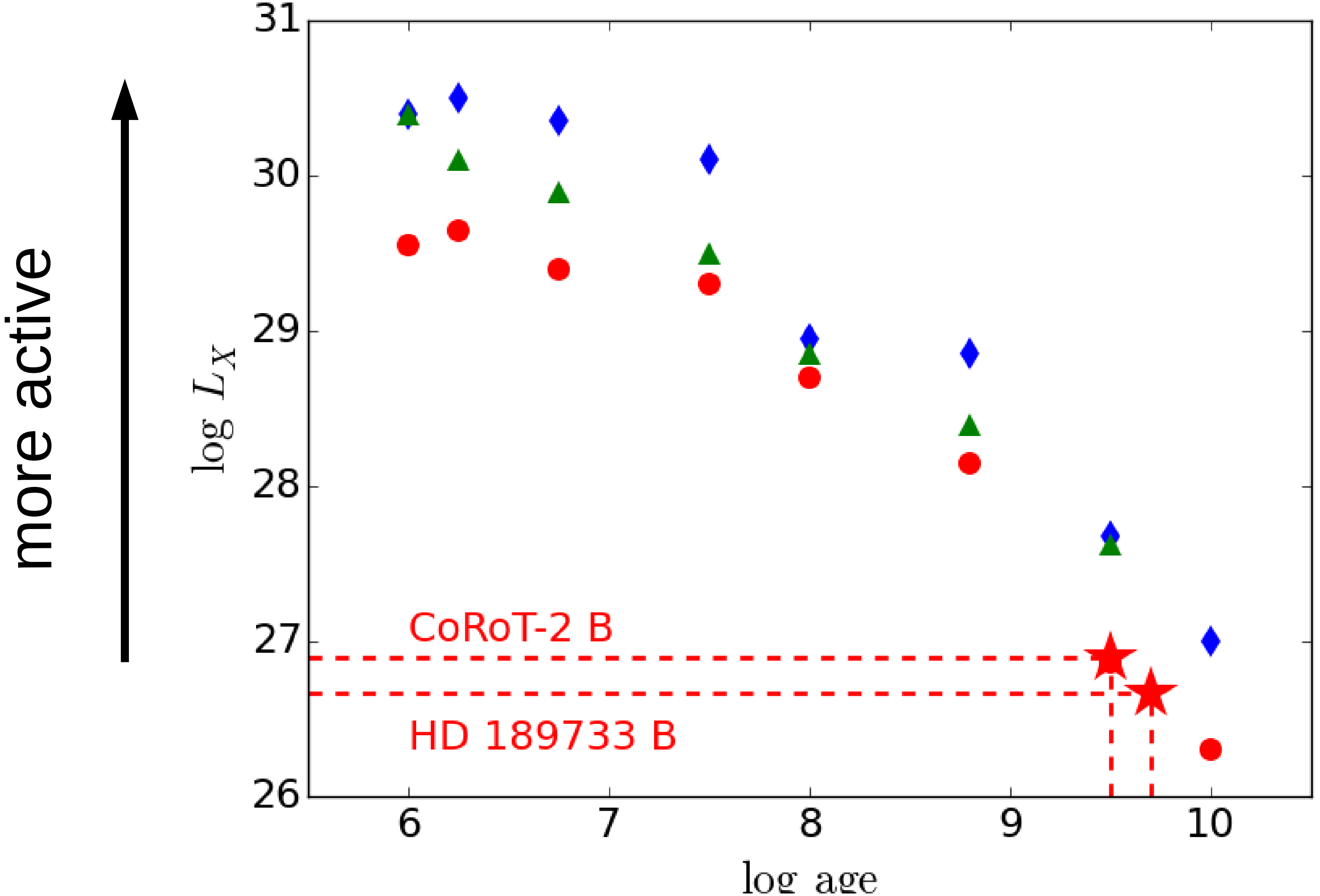


Planet-hosting wide binaries

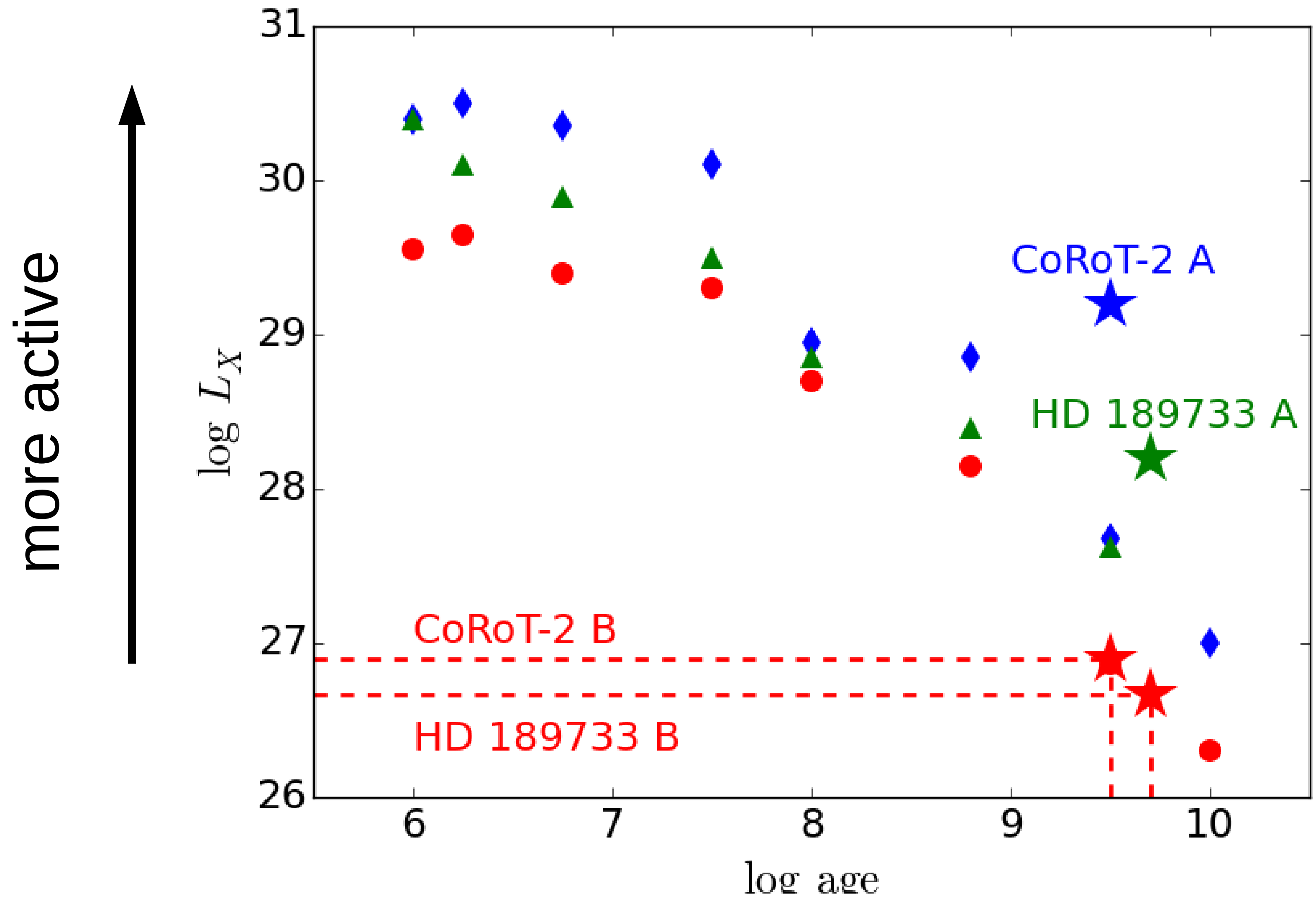
more active



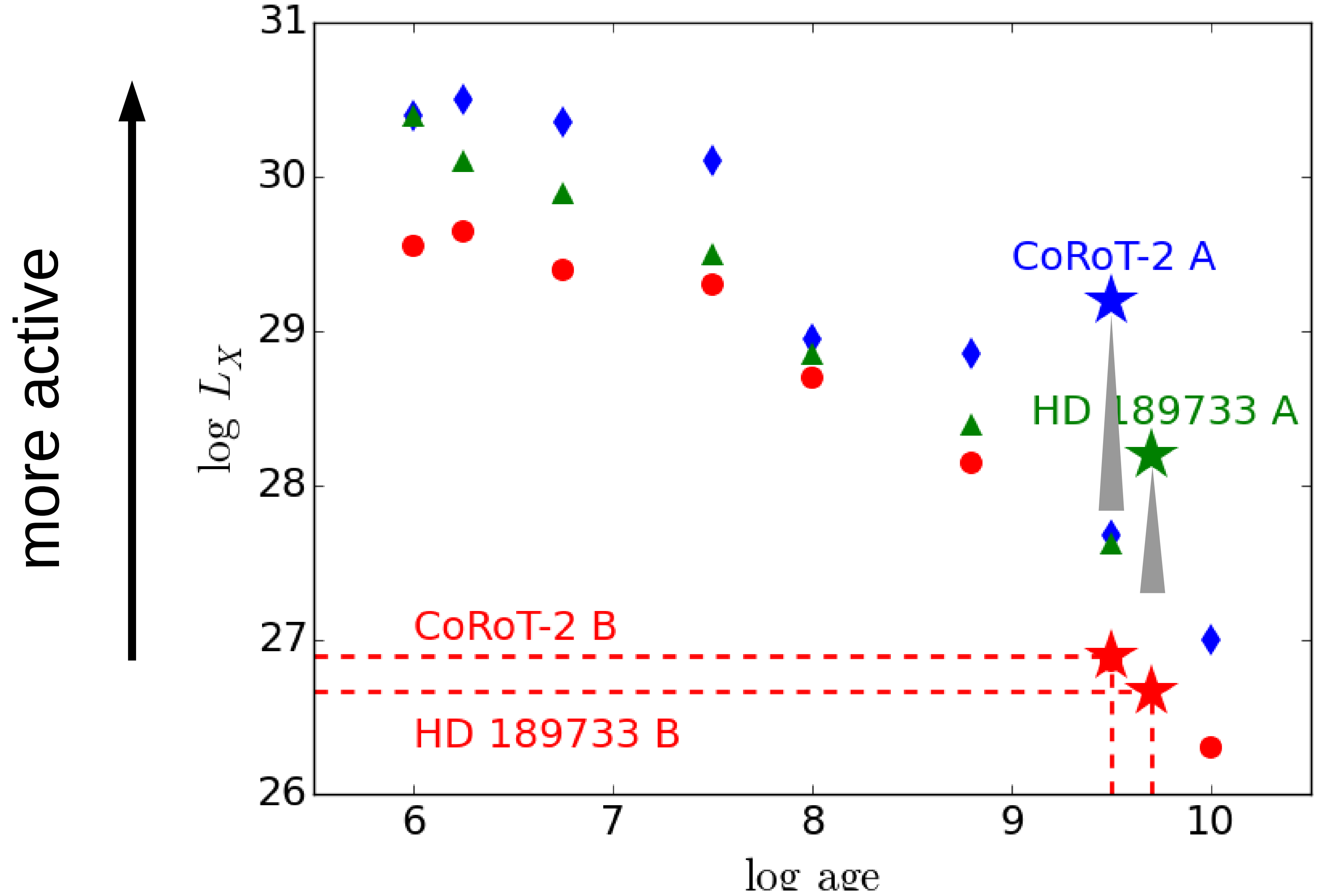
Planet-hosting wide binaries



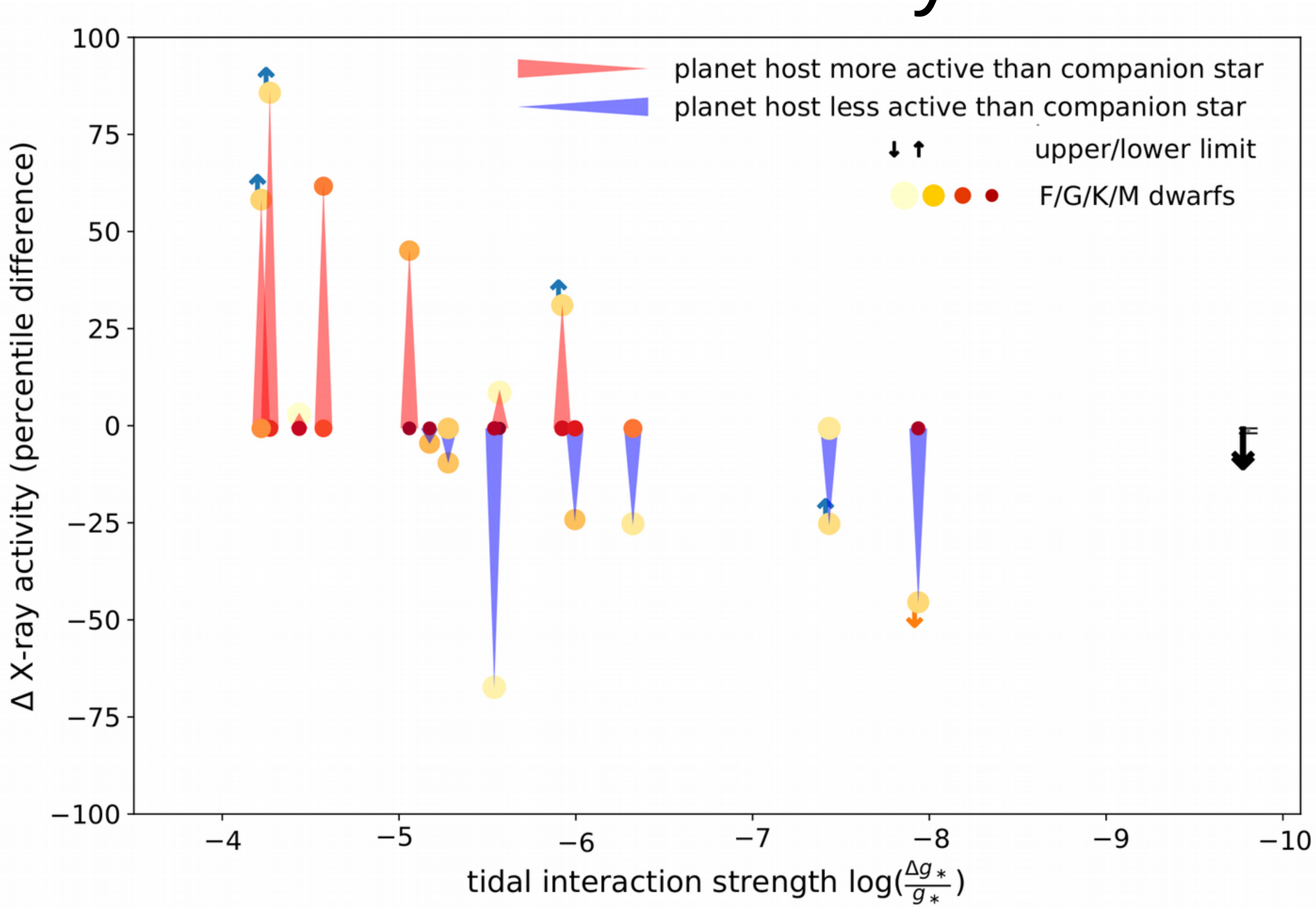
Planet-hosting wide binaries



Planet-hosting wide binaries



Several over-active systems



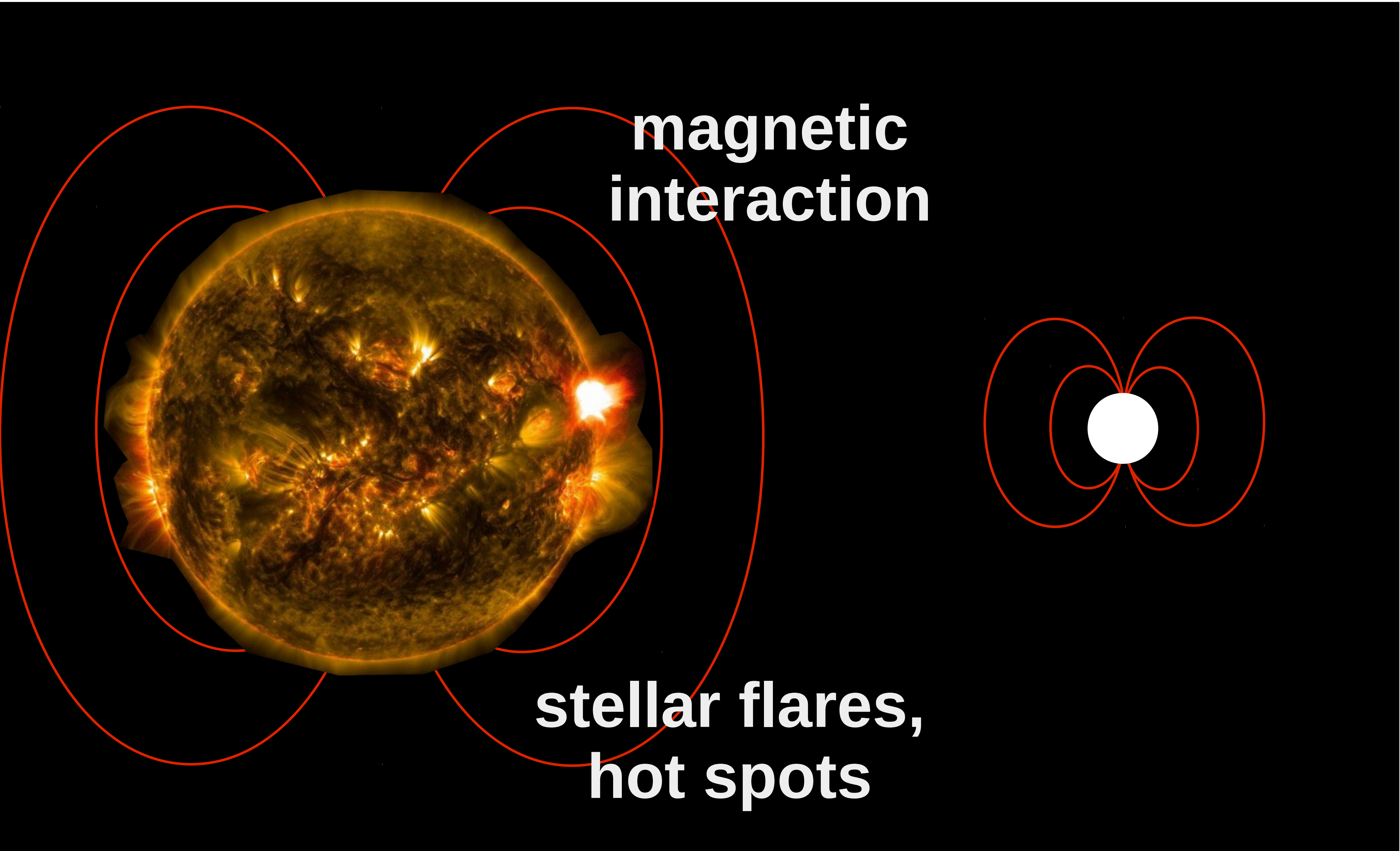
Poppenhaeger et al. (2014),
Poppenhaeger et al. to be submitted

Tidal spin-up of host stars

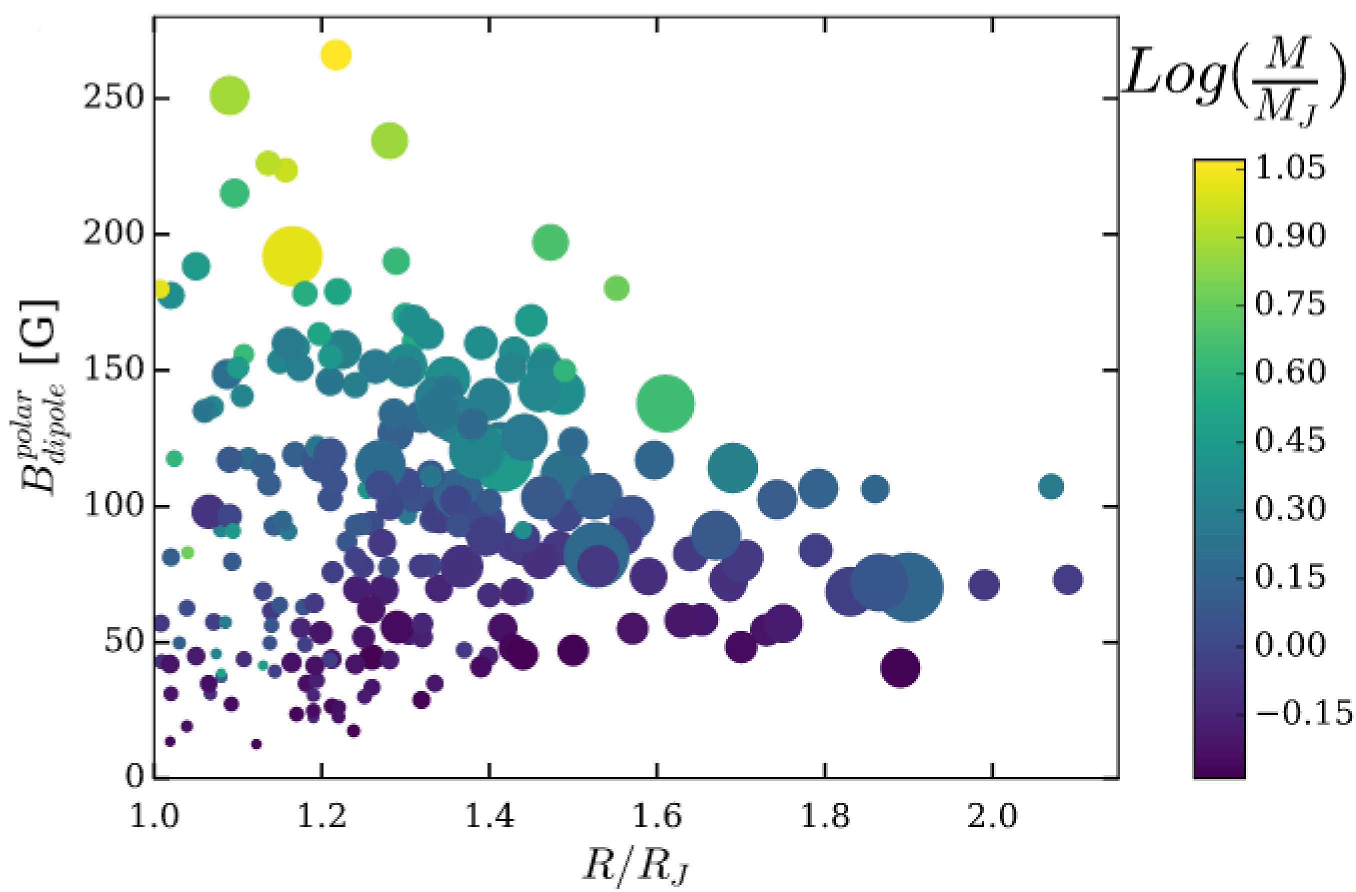
Need to be careful with selecting samples: detectability of exoplanets related to stellar activity

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

Star-exoplanet systems



Strong magnetic fields for very hot exoplanets

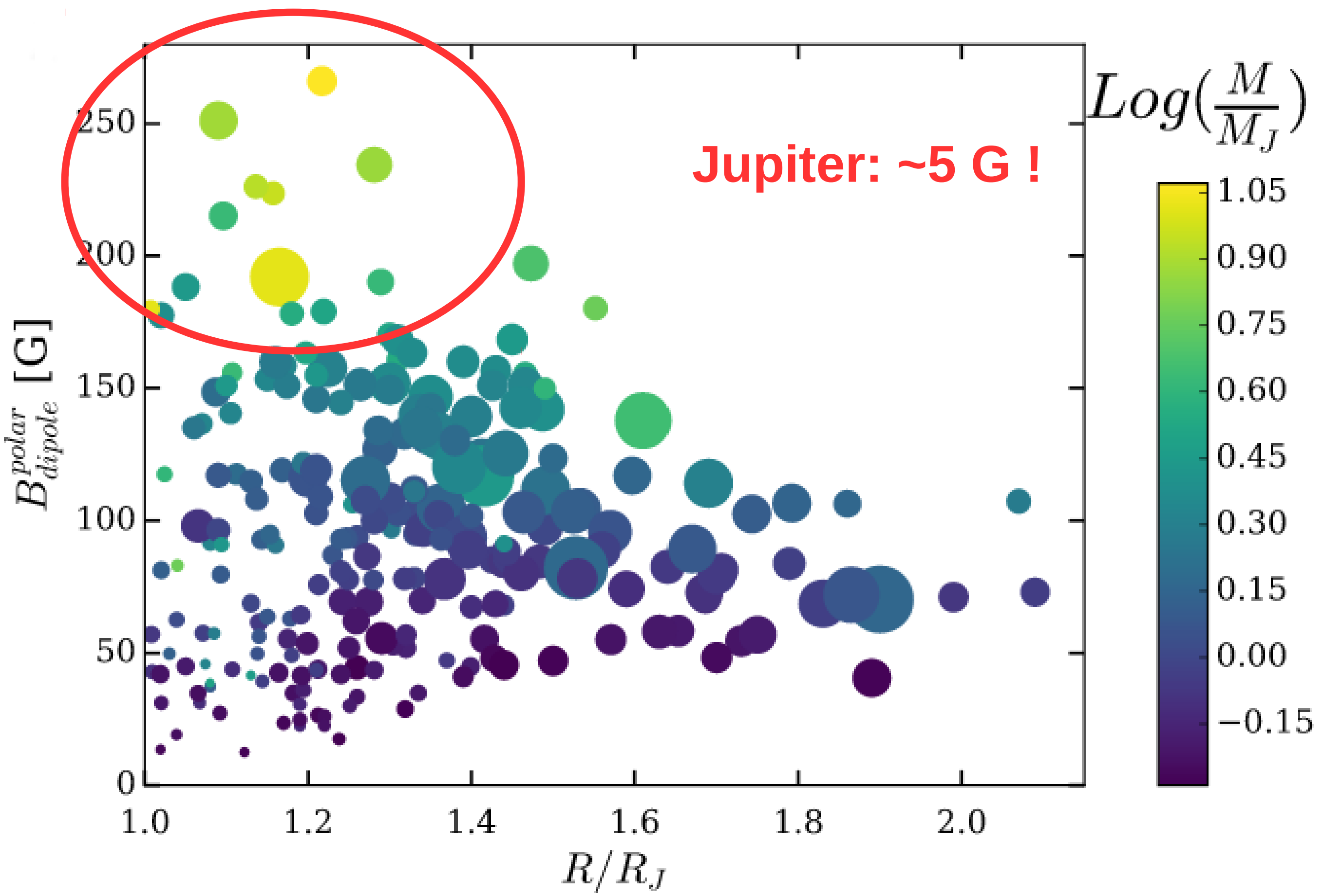


Simulations:

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

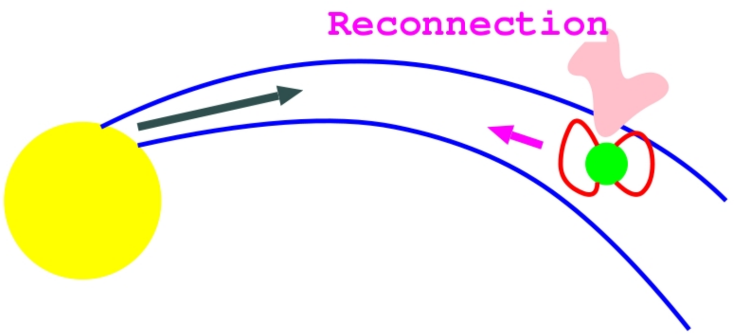


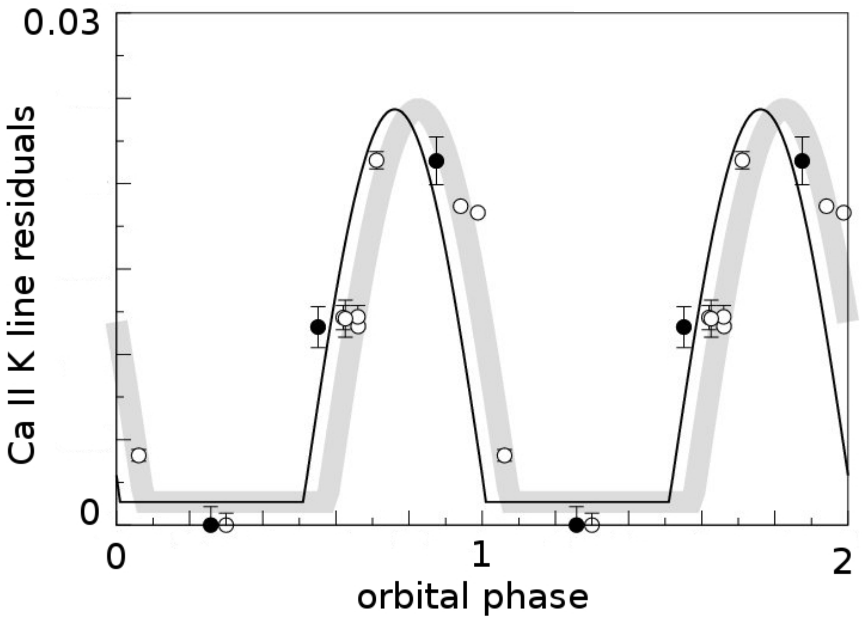
Simulations:

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

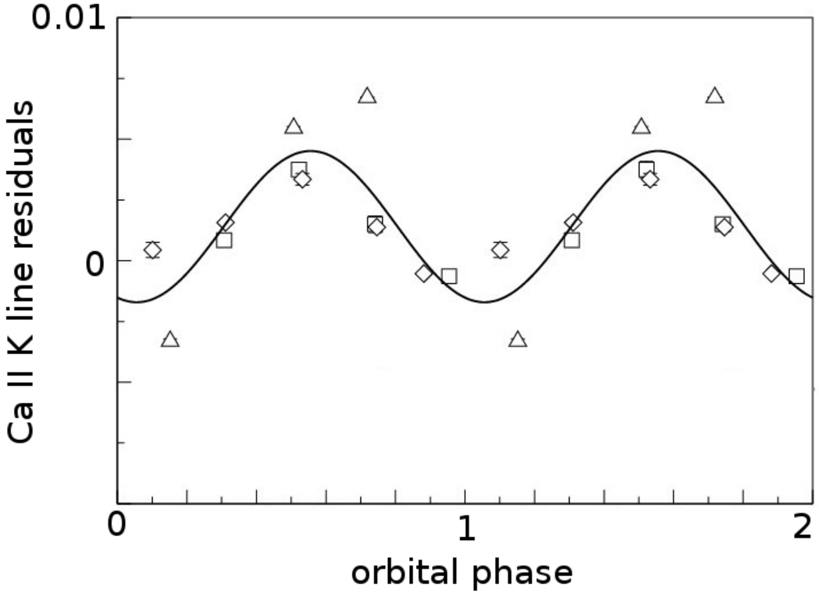
Rogers & McElwaine (2017)
Yadav & Thorngren (2017)

Planet-induced hot spots?





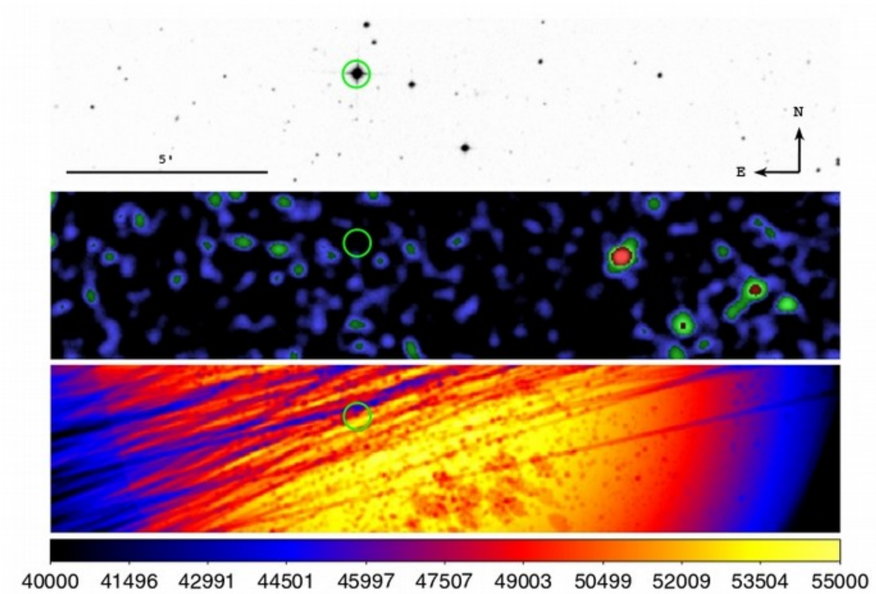
HD 179949
P_{orb} = 3.1 d
P_{rot} = 11 d



upsilon And
P_{orb} = 4.6 d
P_{rot} = 9.5 d

Shkolnik et al. (2005, 2008)

But also: absence of magnetic effects

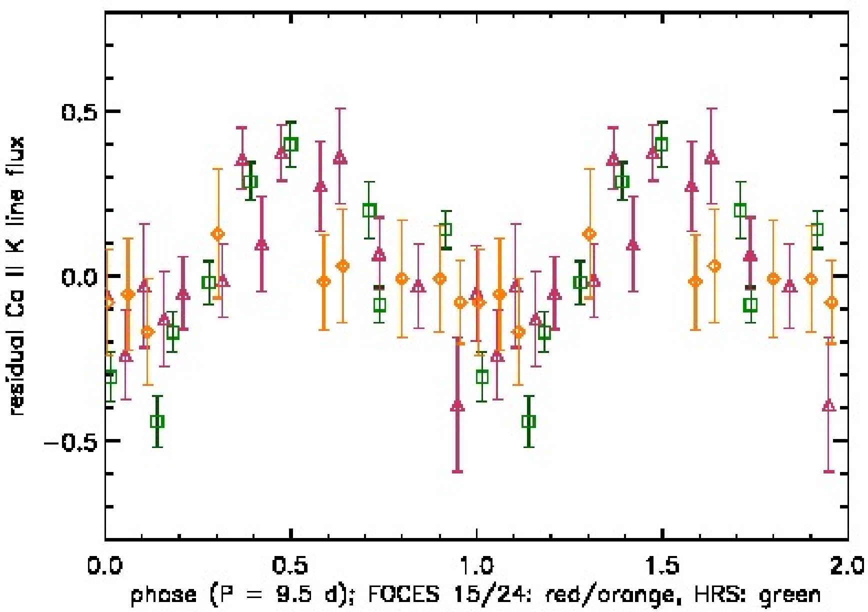


WASP-18 (1.2 M_{Sun}): completely X-ray dark!

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

P_{rot} = 9.5 d

P_{orb} = 4.6 d

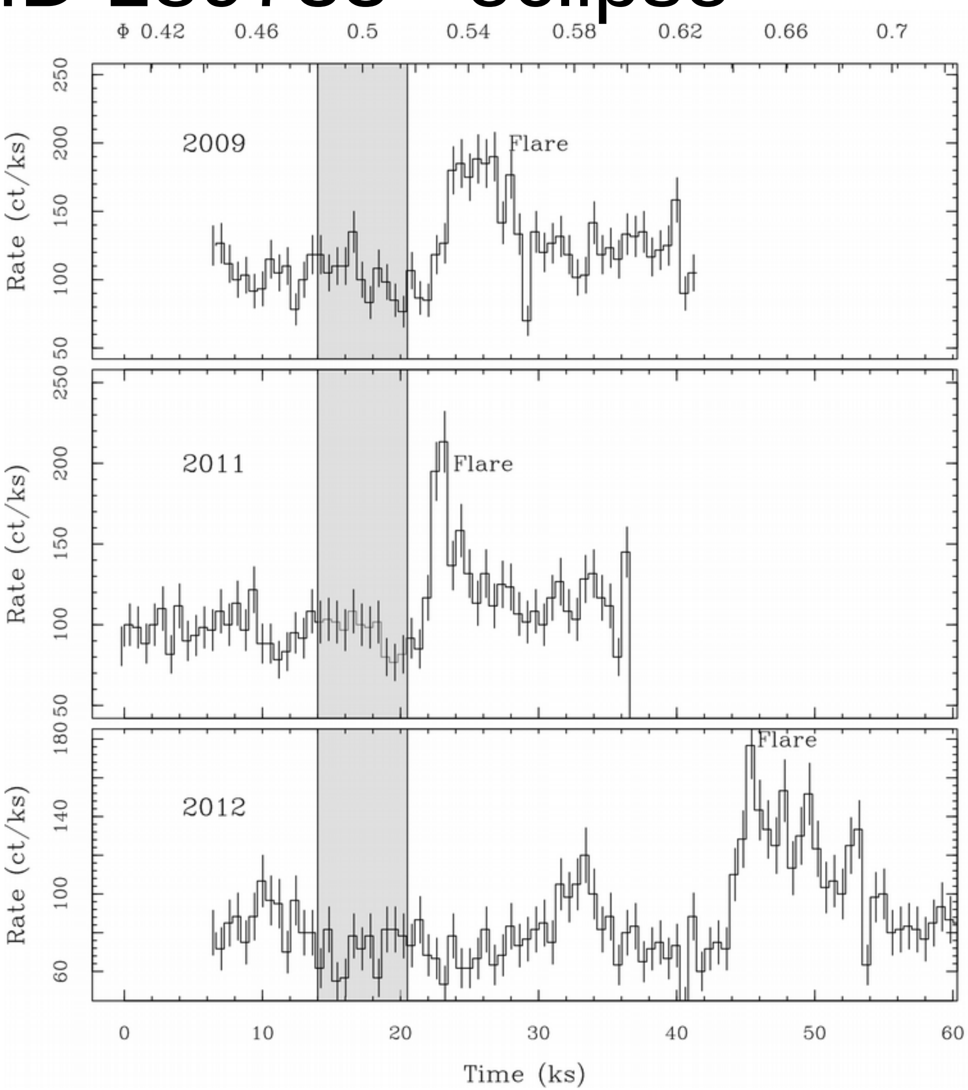


upsilon And (1.3 M_{Sun}): varies with stellar rotation, not with Hot Jupiter orbit

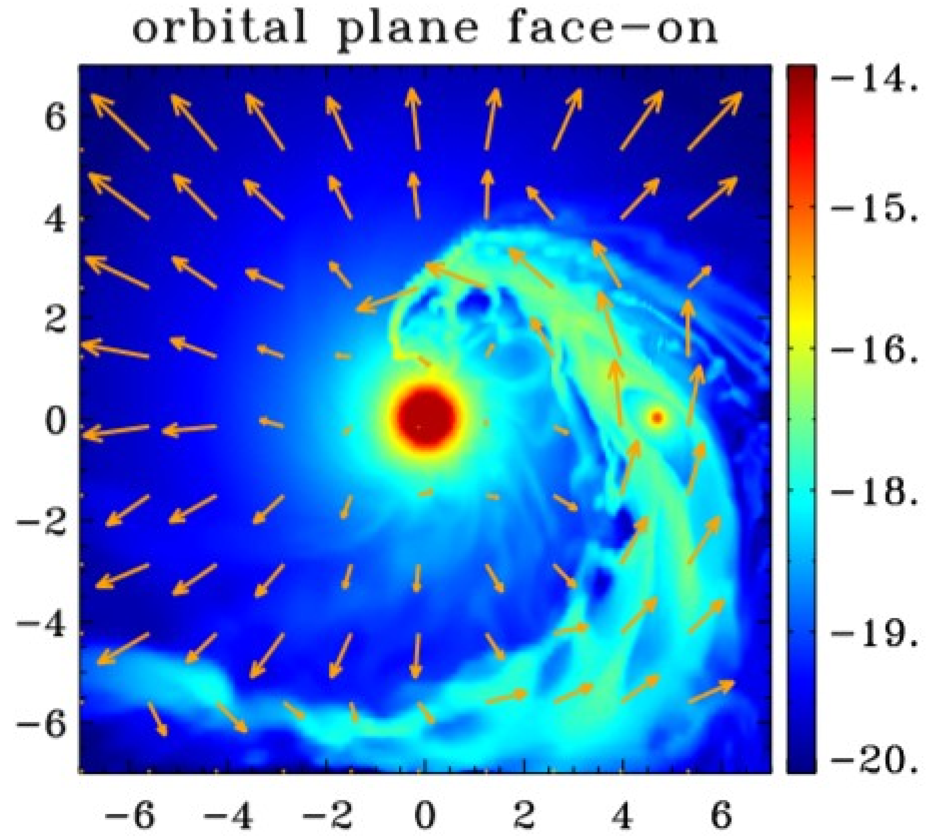
Poppenhaeger et al. (2011)

Planetary / coronal rain

HD 189733 - eclipse



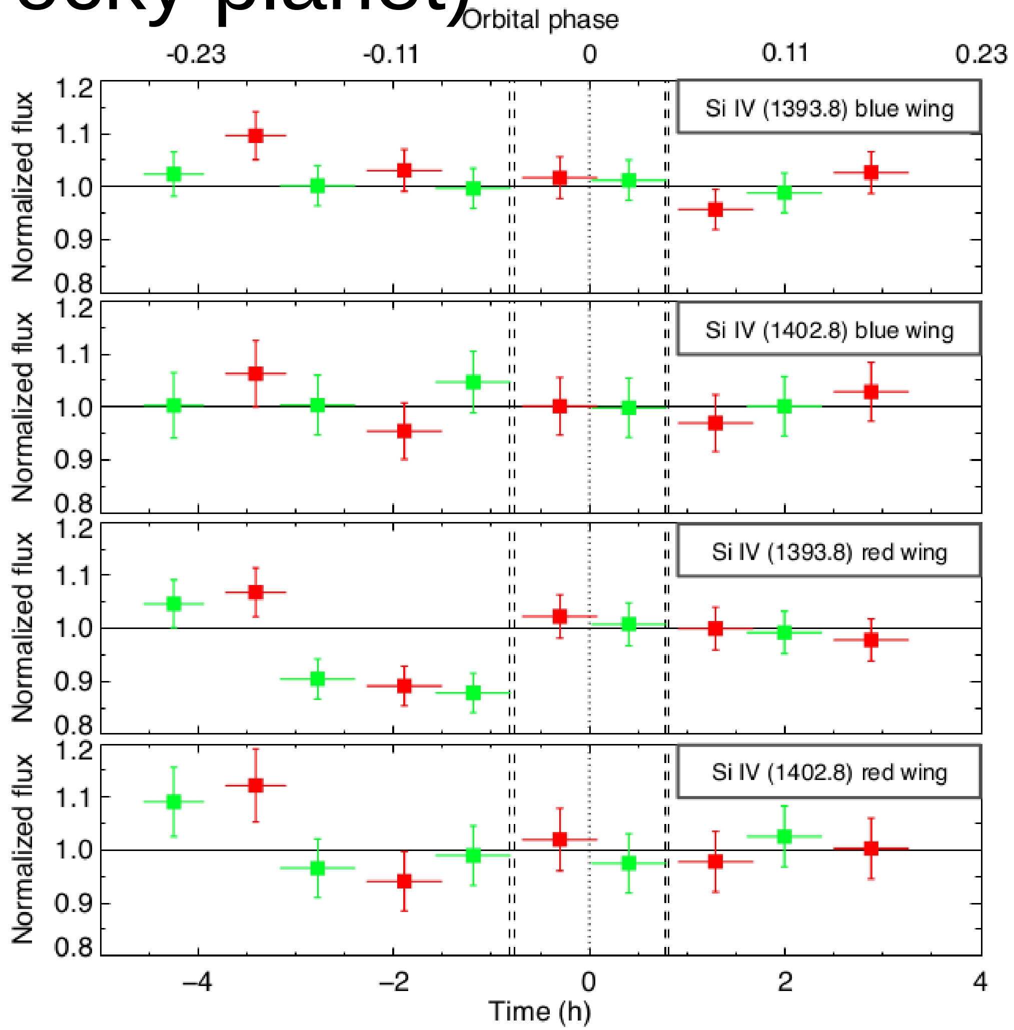
Pillitteri et al. (2015)



planetary material
falling onto star?

Planetary / coronal rain

55 Cnc transit
(e: rocky planet)



Bourrier et al. (2018)

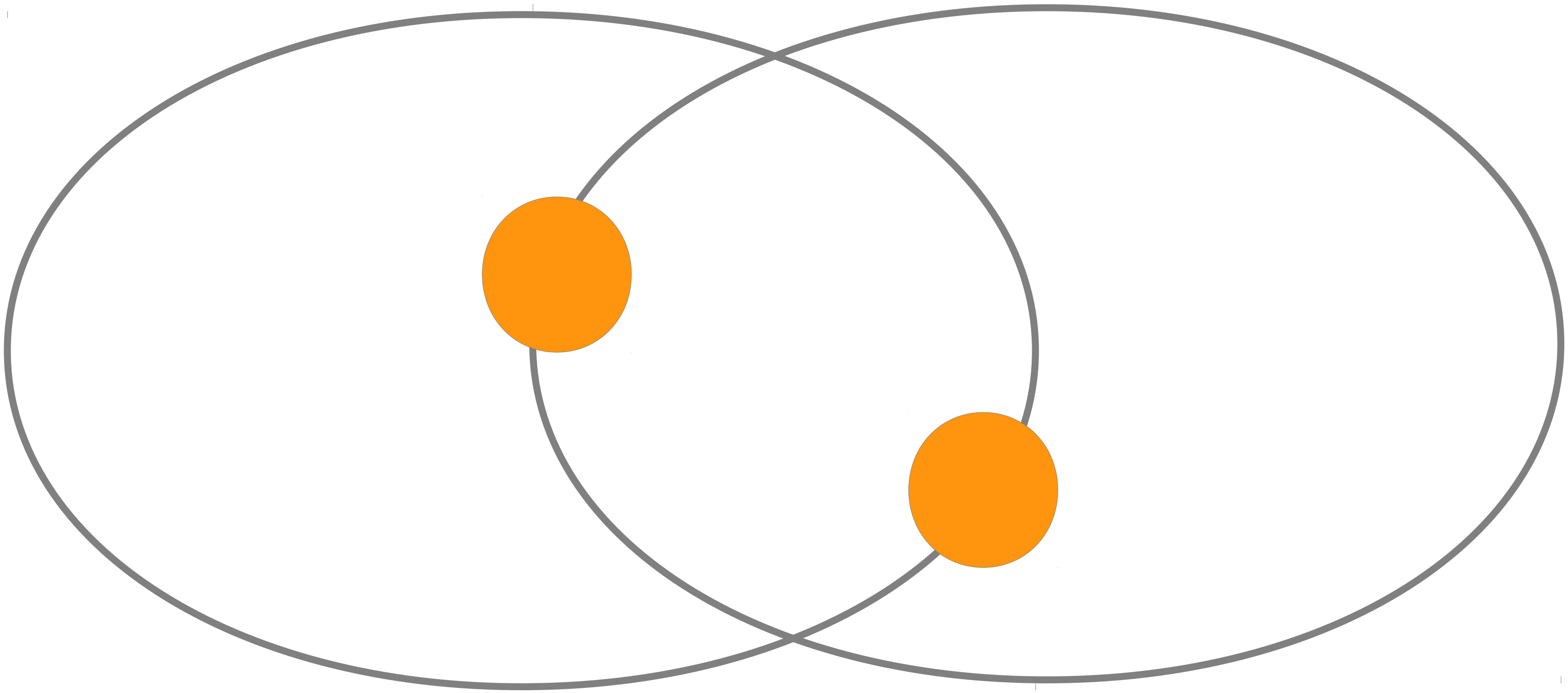
First indications: FUV line absorption in red wings of lines, not in blue wings

planet-triggered coronal rain?

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

Planets in eccentric orbits

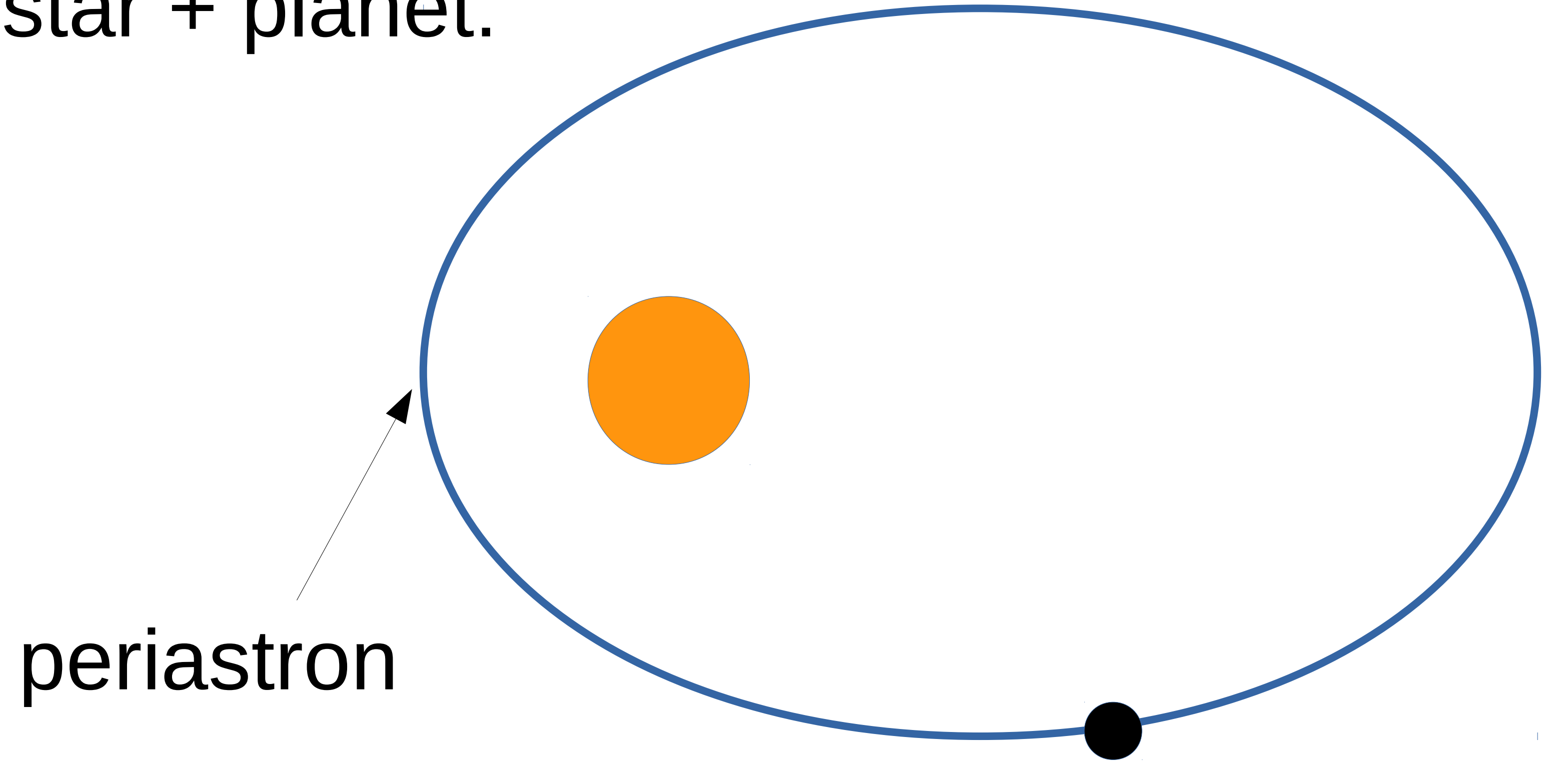
2 stars:



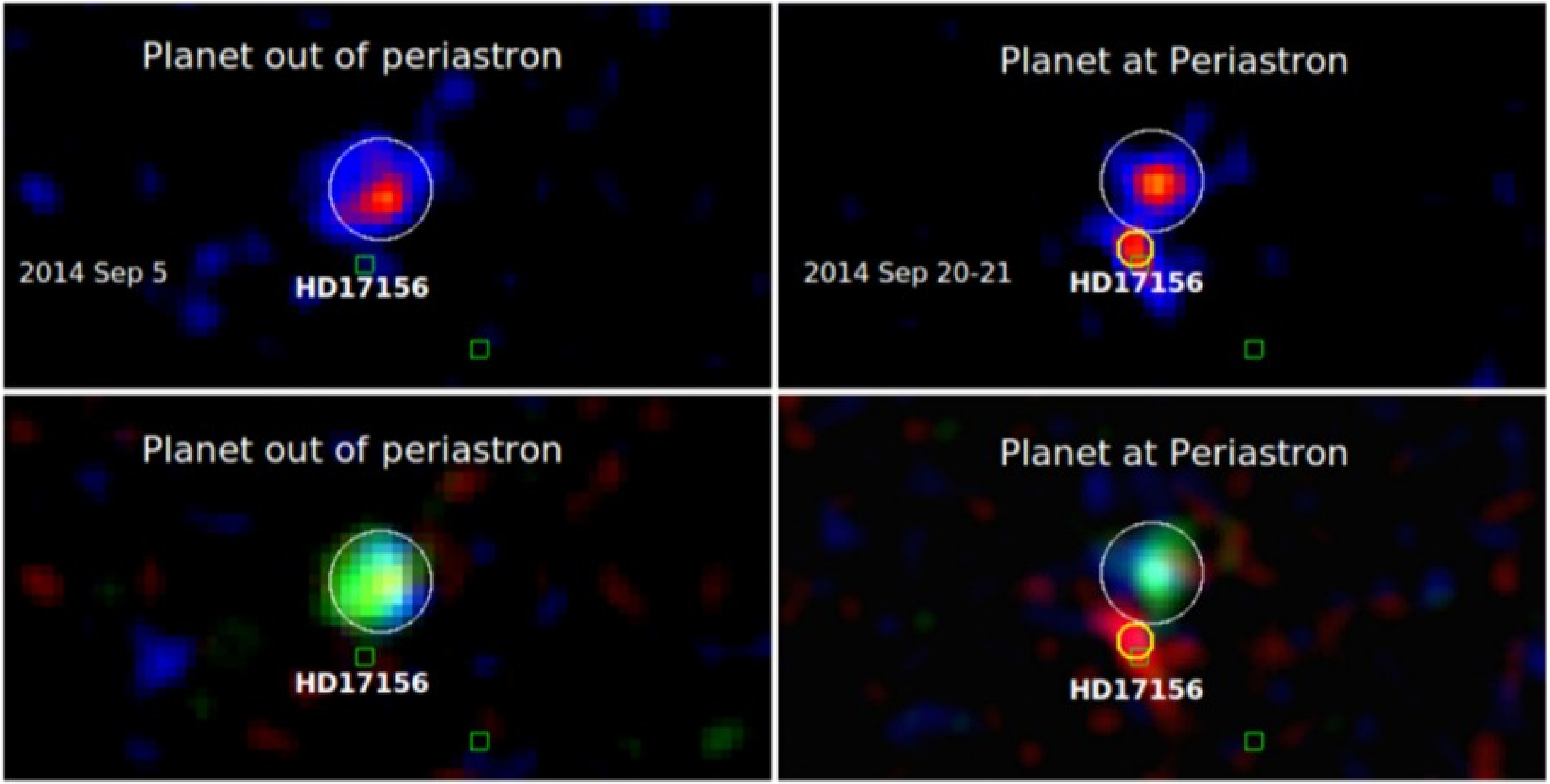
Flares from colliding magnetospheres:
Getman et al. (2011);
but: Getman et al. (2016)

Planets in eccentric orbits

star + planet:



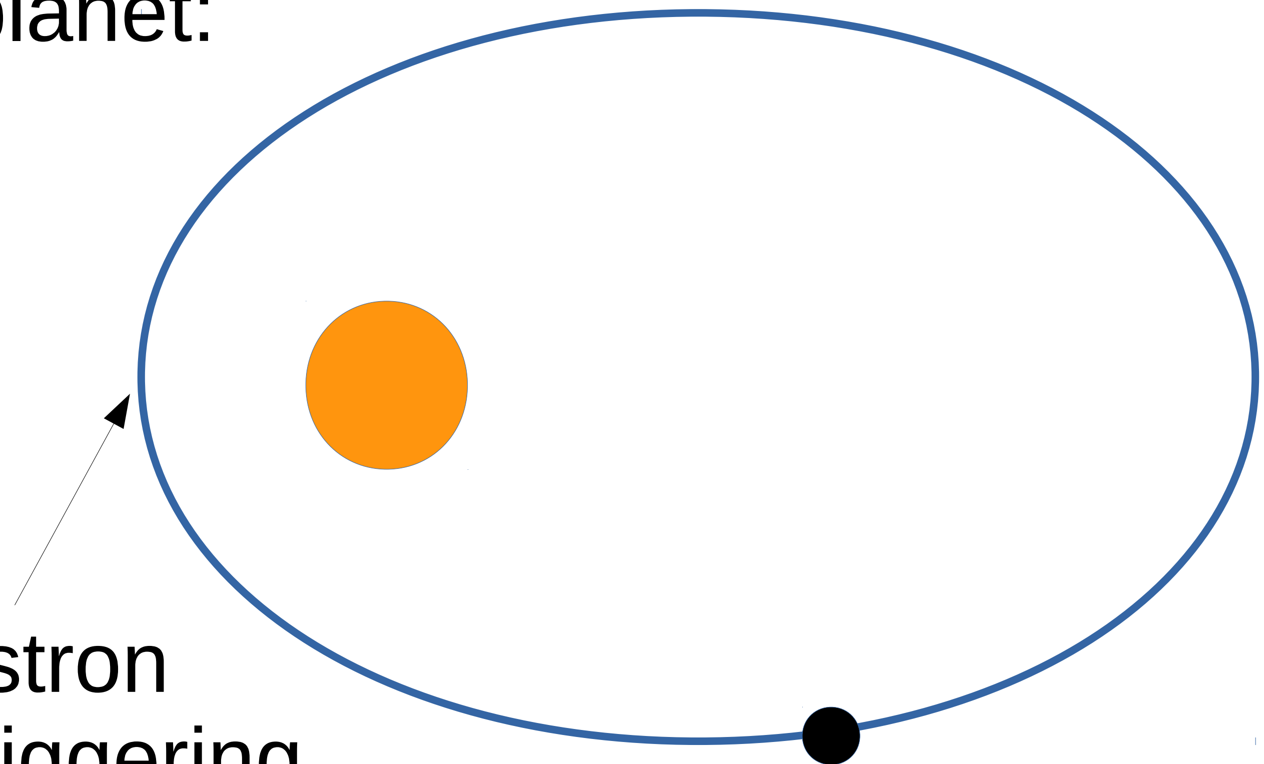
Planets in eccentric orbits



Maggio et al. (2015)

Planets in eccentric orbits

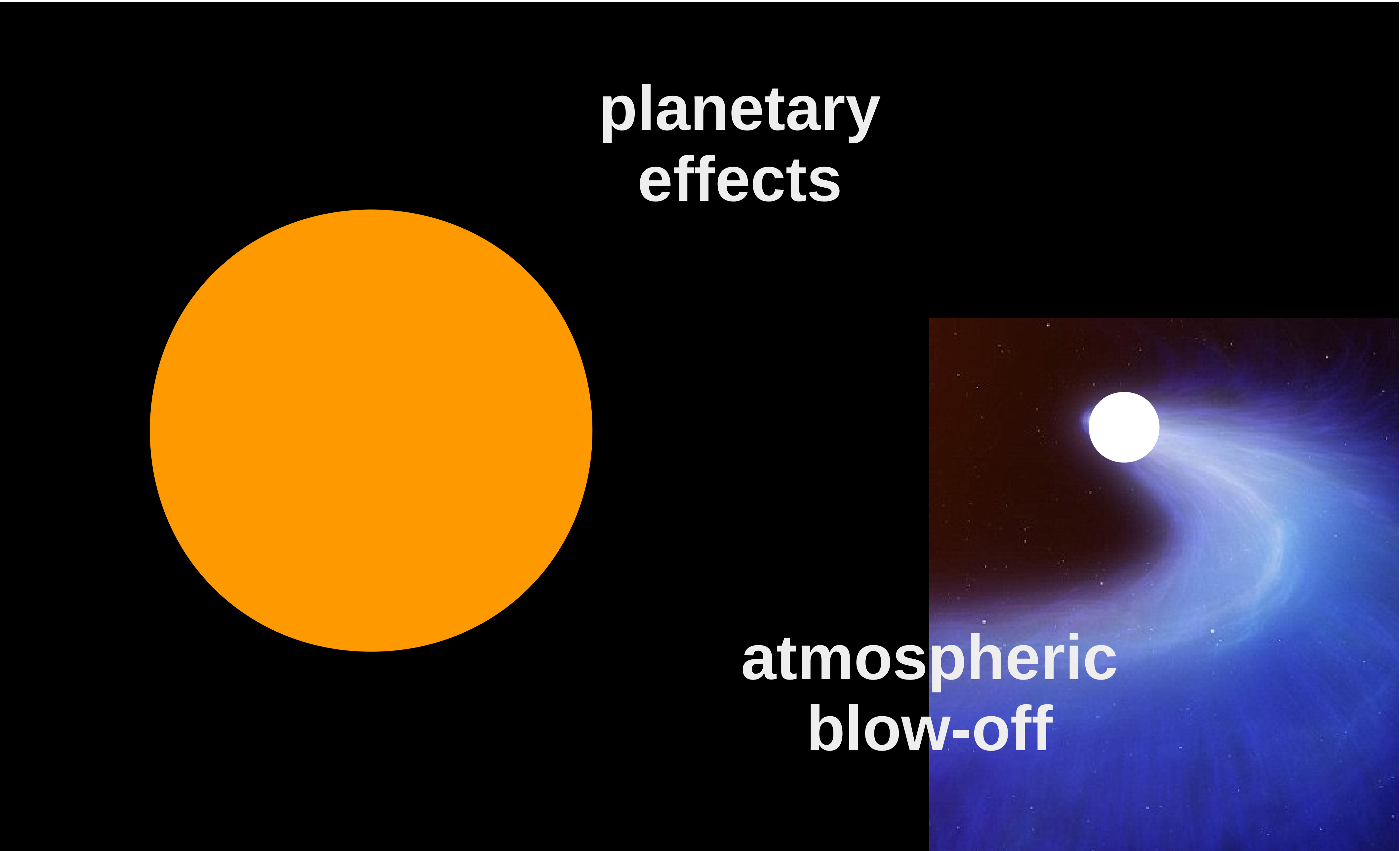
star + planet:



periastron
-> flare triggering

This should depend on
the planet's magnetosphere!

Star-exoplanet systems



Atmospheres and high-energy photons

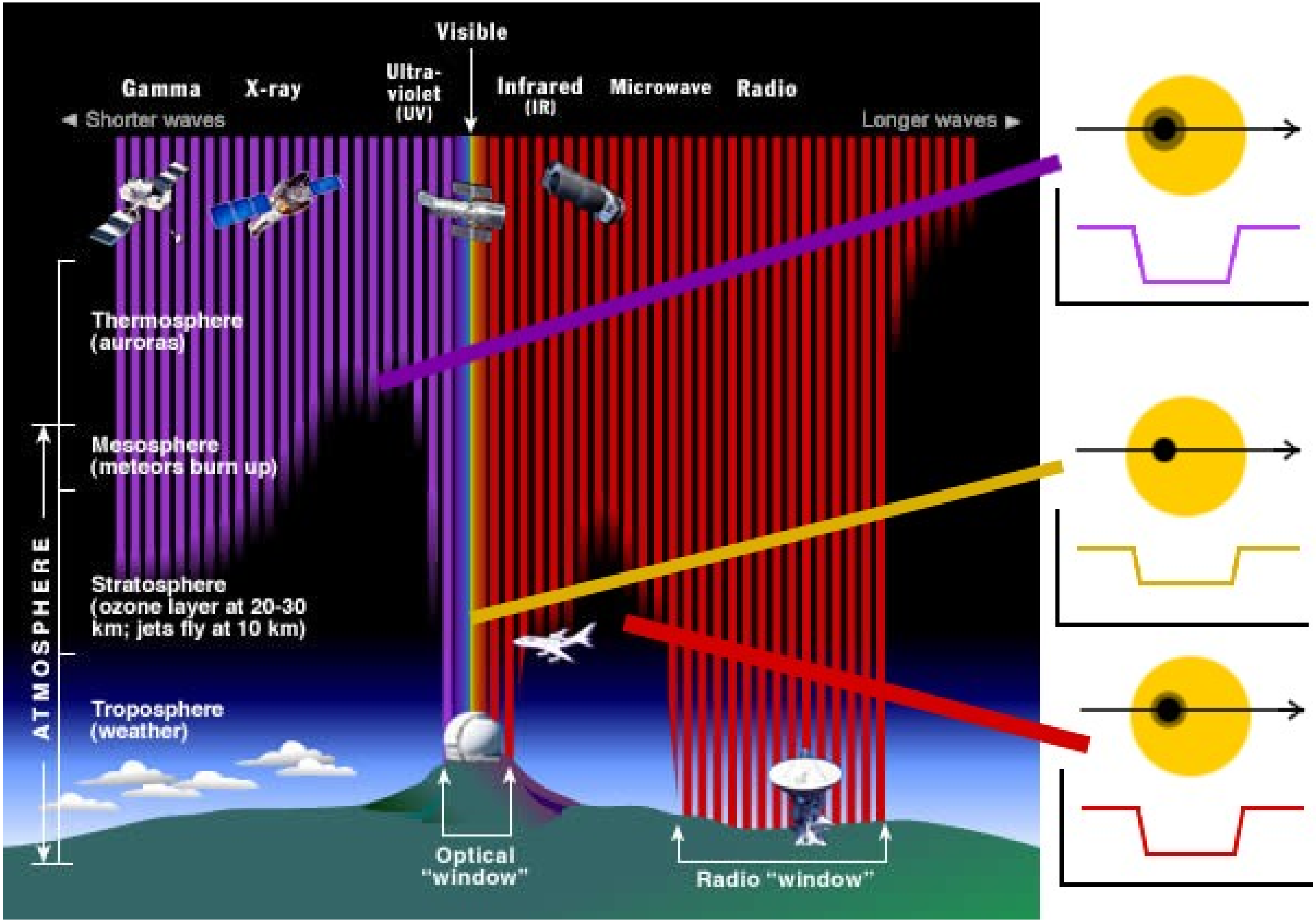
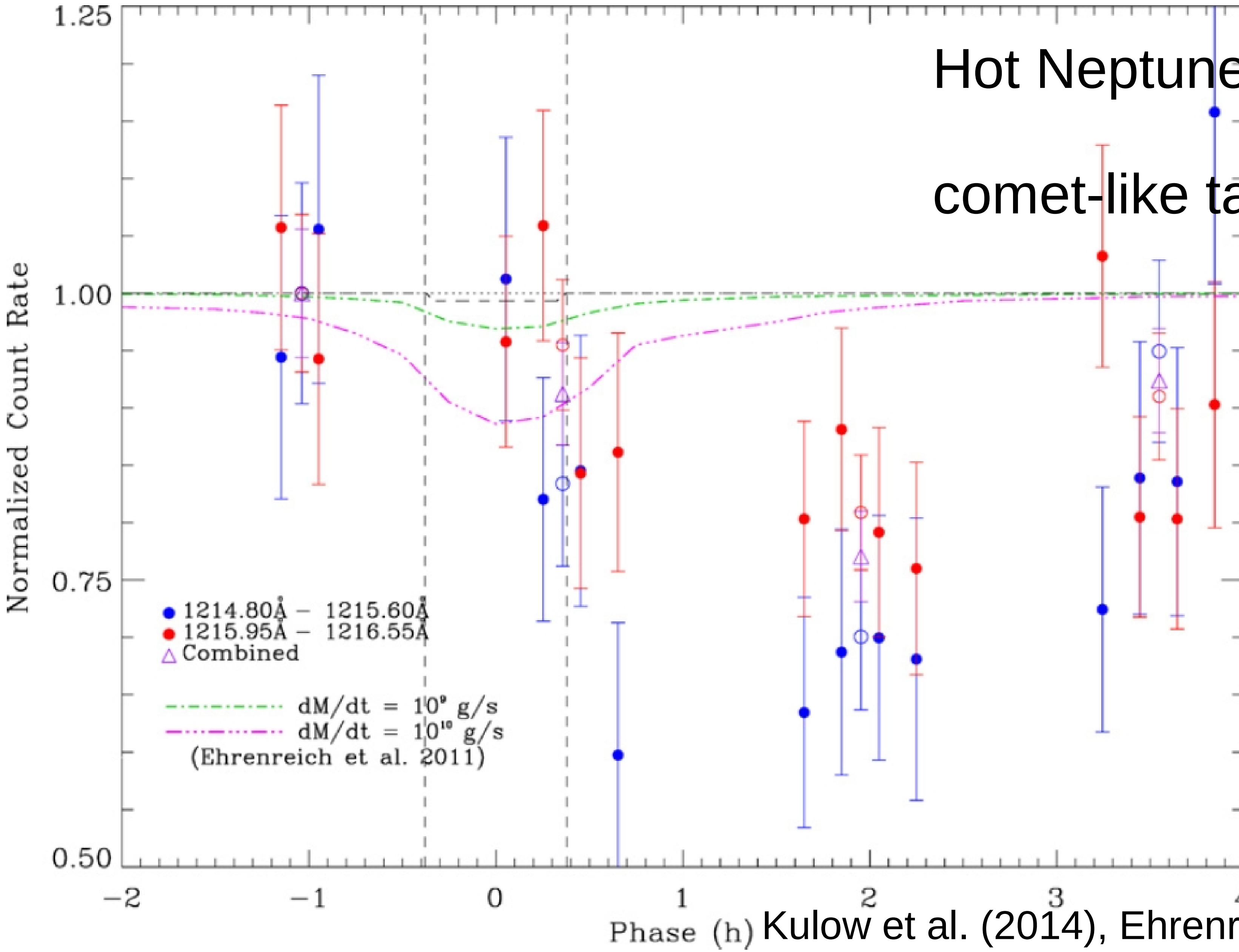


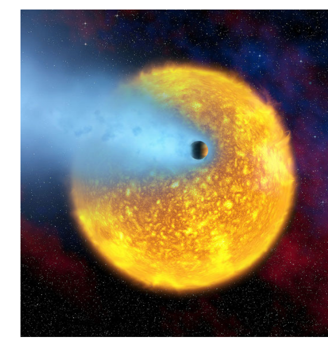
image credit: NASA

Extended atmospheres in UV/X-ray



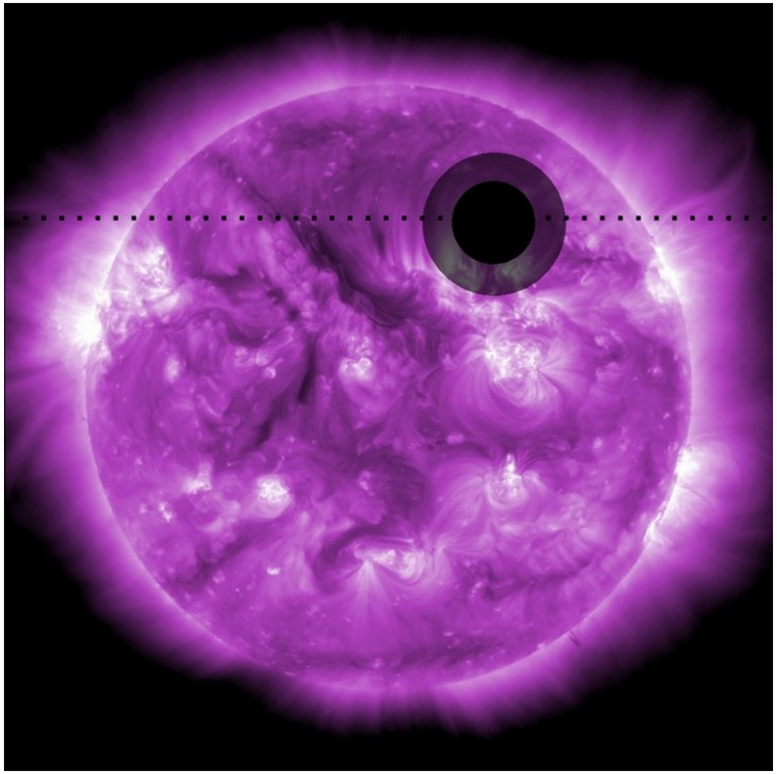
Hot Neptune GJ 436 b:

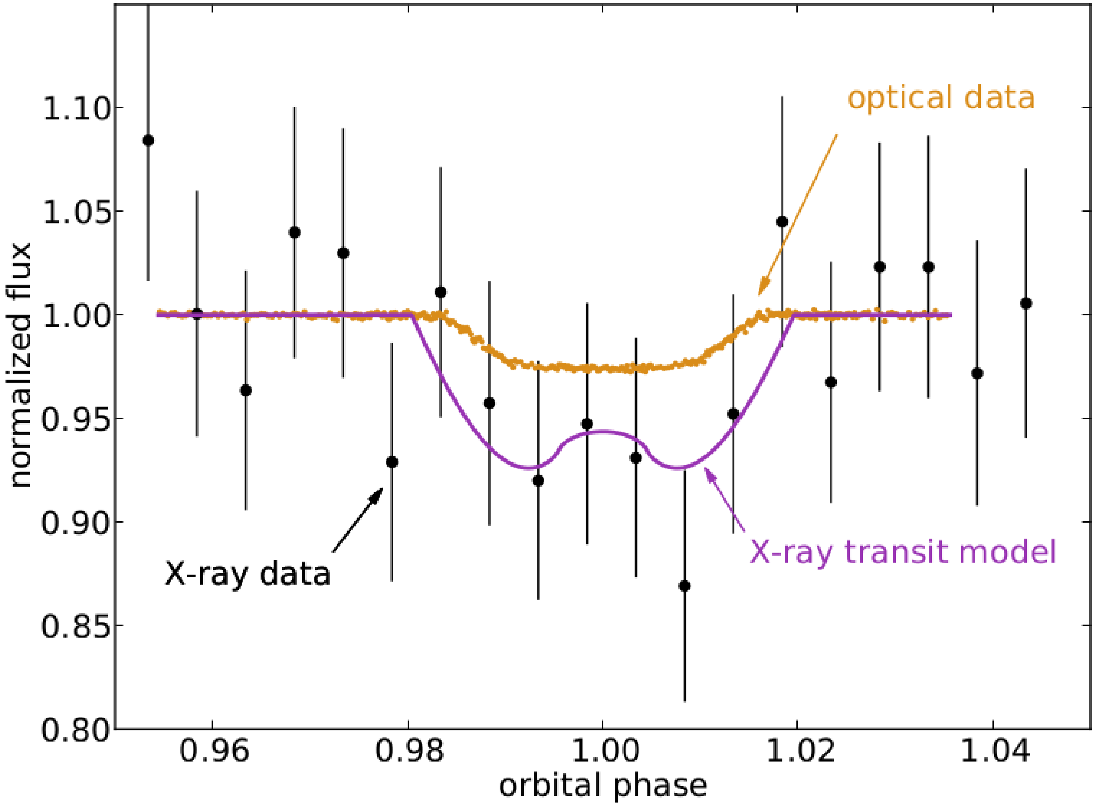
comet-like tail



Kulow et al. (2014), Ehrenreich et al. (2015)

X-ray transits: extended atmospheres





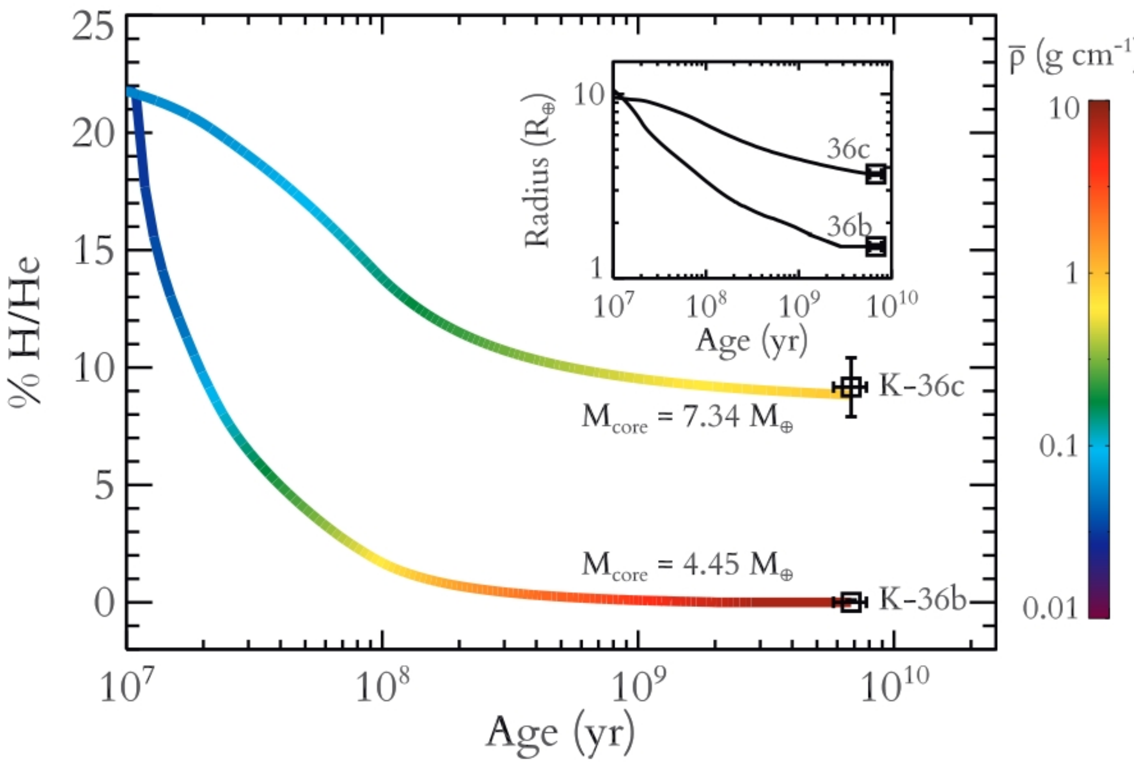
HD 189733 b

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



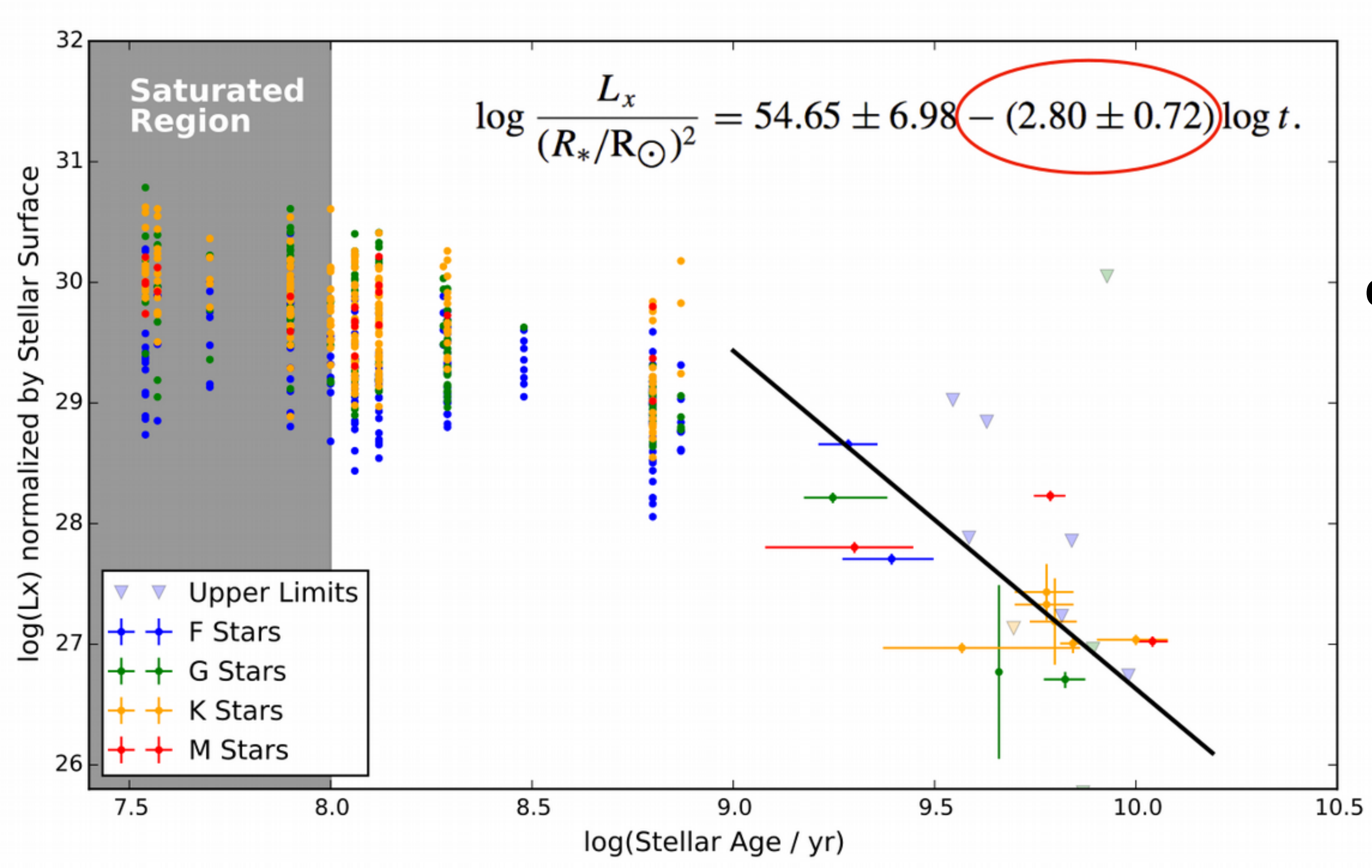
Kepler-36 system

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:

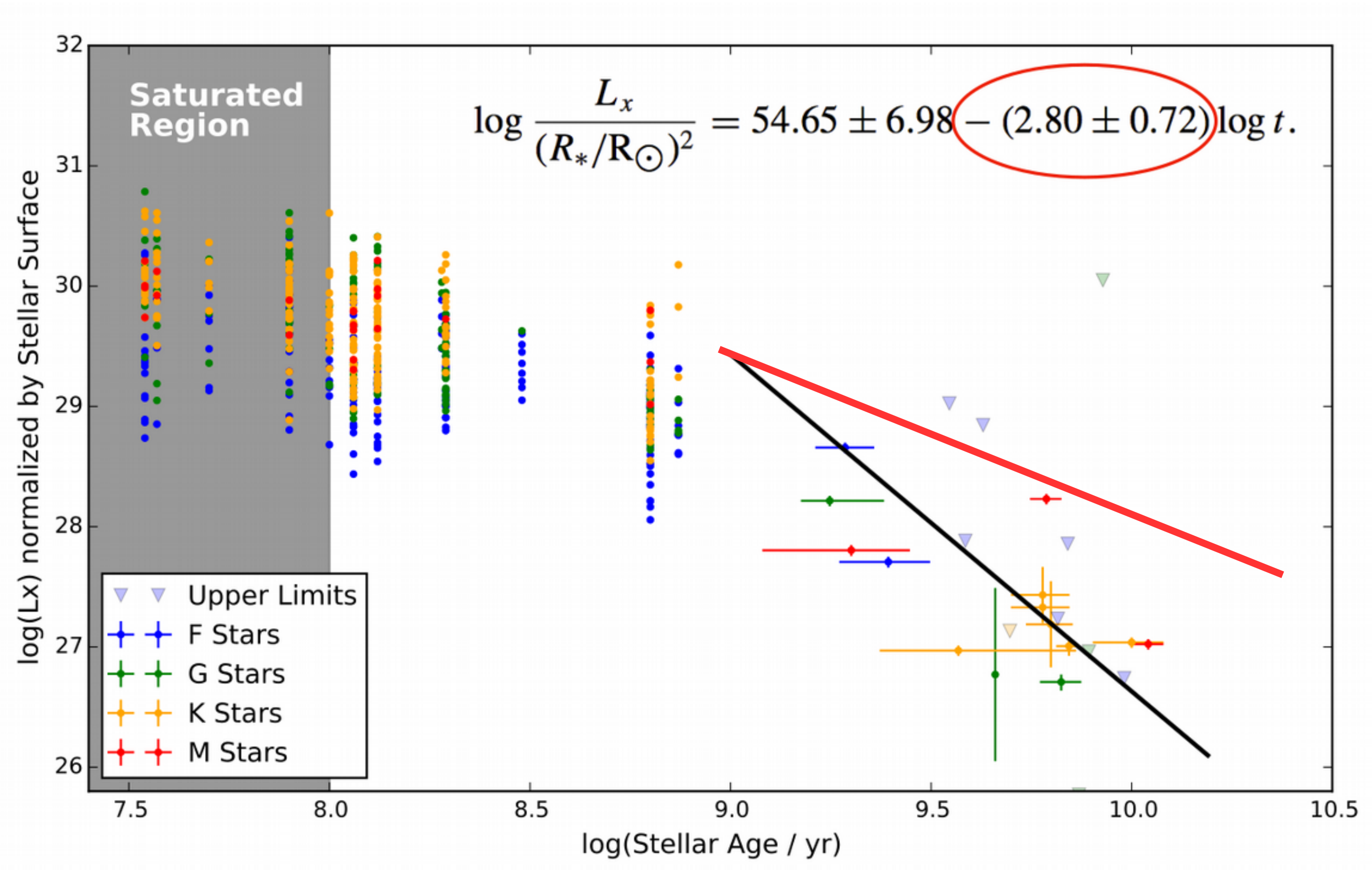


slope of -2.8 instead of canonical -1 for younger stars!

Booth, Poppenhaeger et al. (2017)

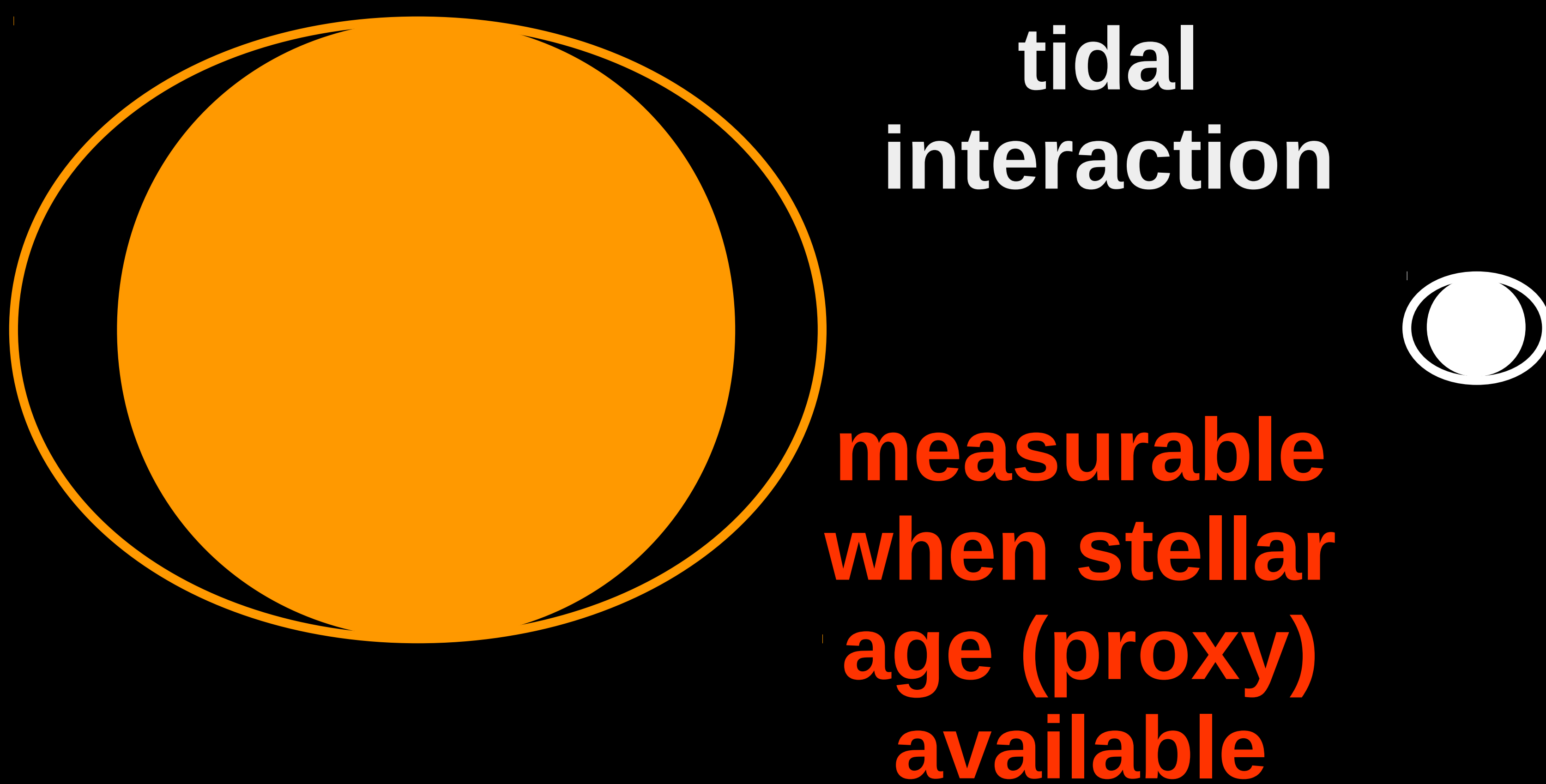
Survival of exoplanet atmospheres

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

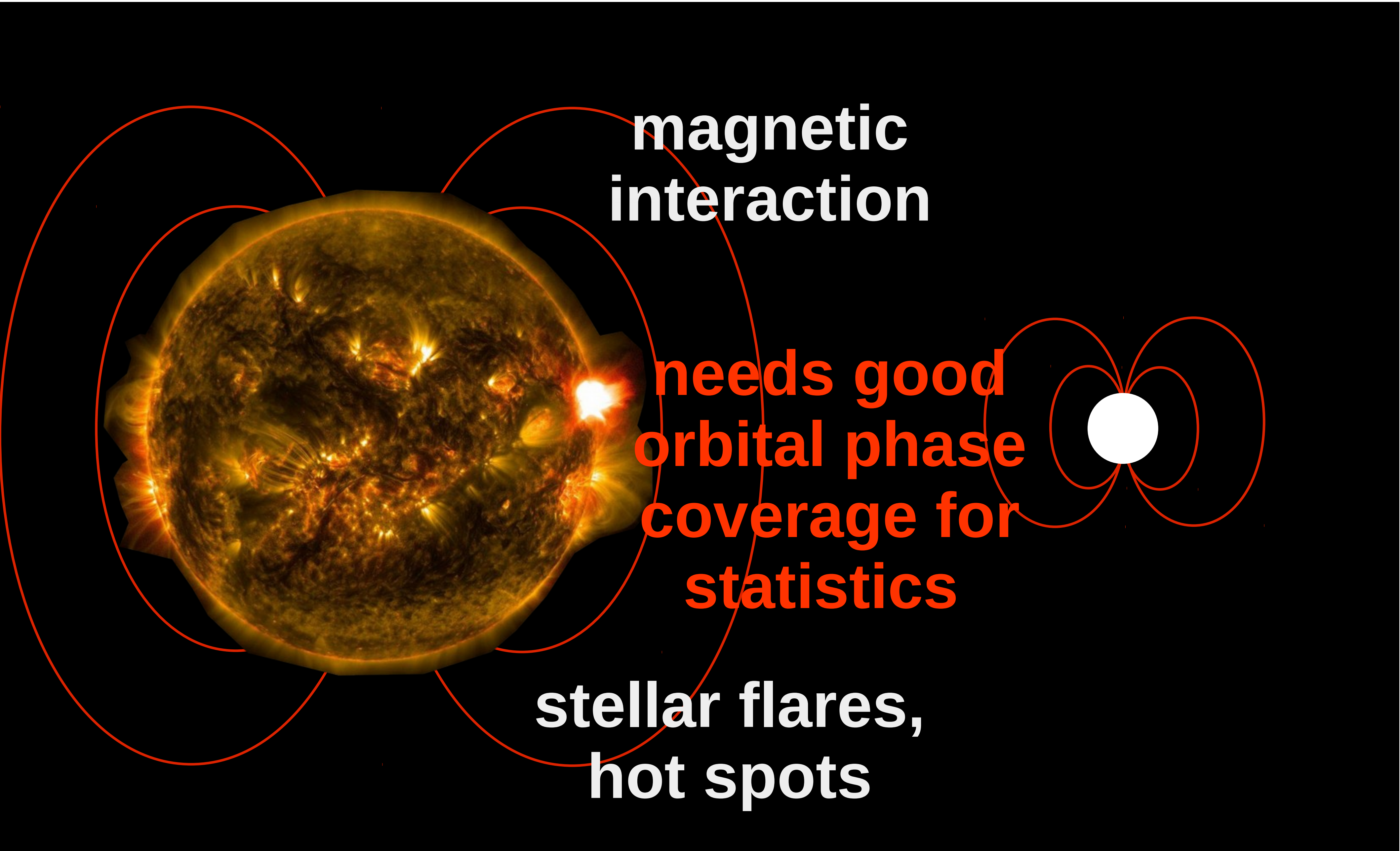


Booth, Poppenhaeger et al. (2017)

Star-exoplanet systems



Star-exoplanet systems



Star-exoplanet systems