Stellar magnetic activity
–
Star-Planet Interactions

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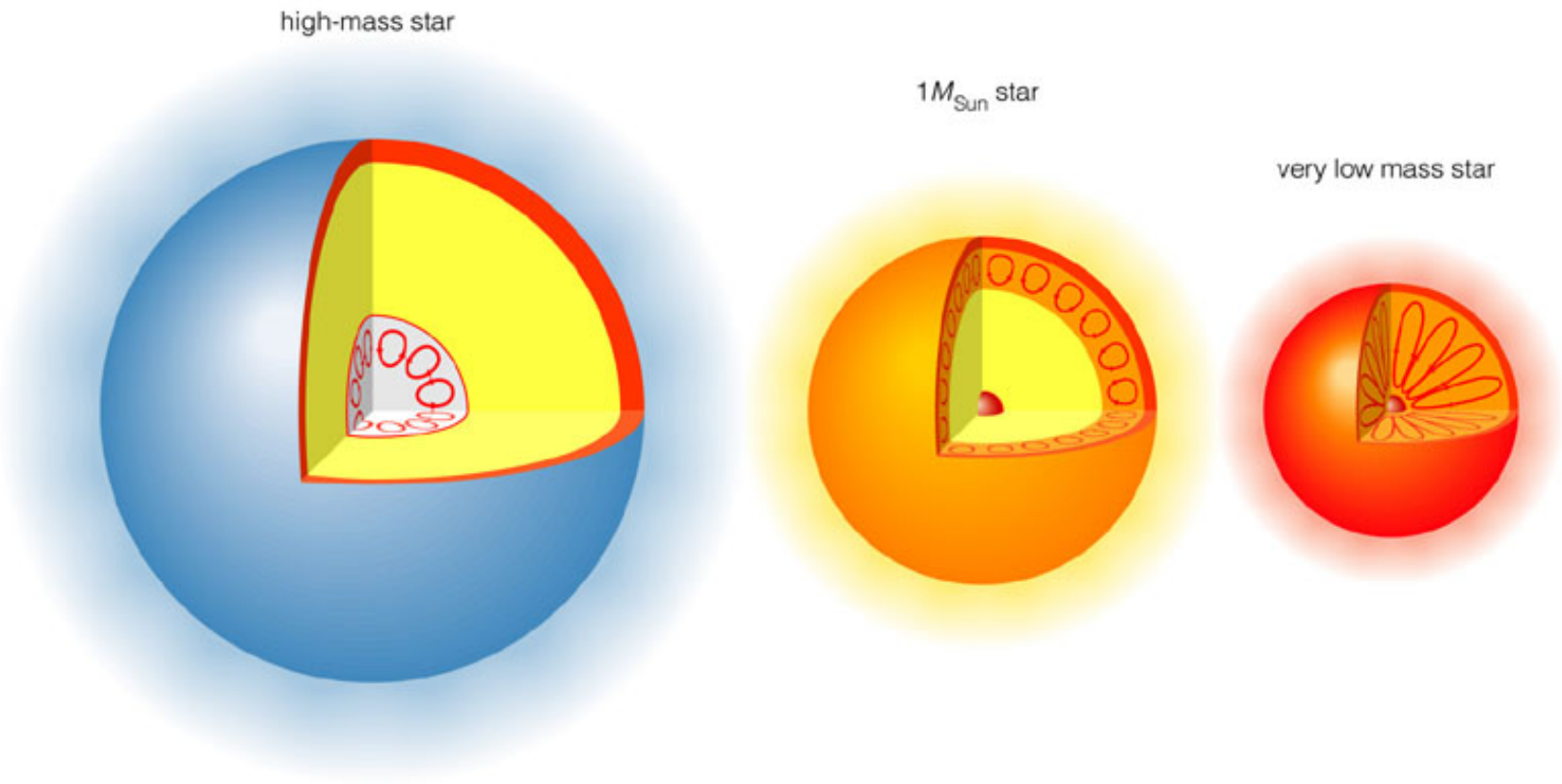
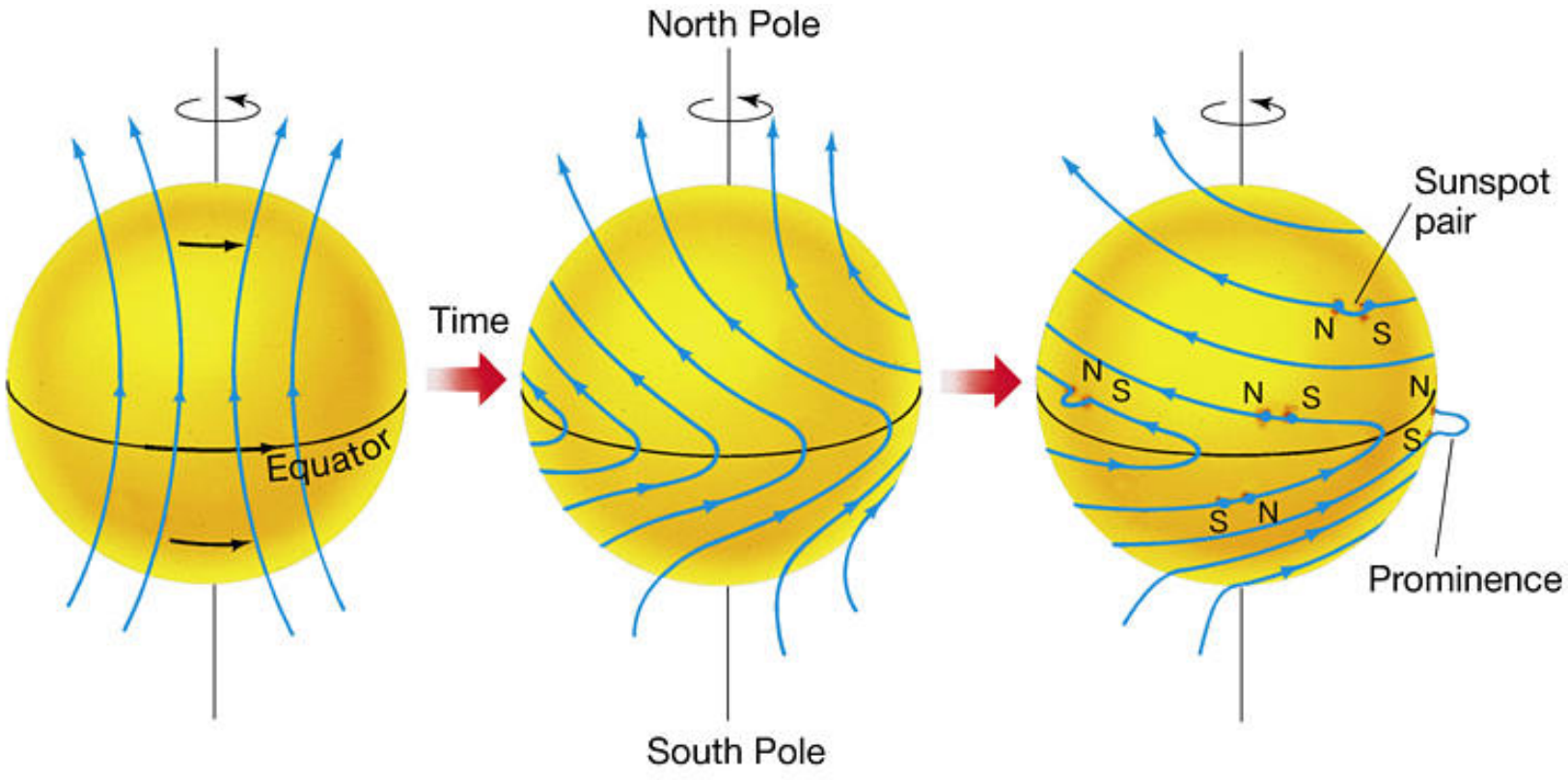
Collaborators: Scott Wolk, Moritz Günther, Ofer Cohen, Ignazio Pillitteri, Jürgen Schmitt, Birgit Fuhrmeister, Stefan Czesla, Frederic Hessman, Simon Albrecht, Carolina von Essen & KOINet, ...

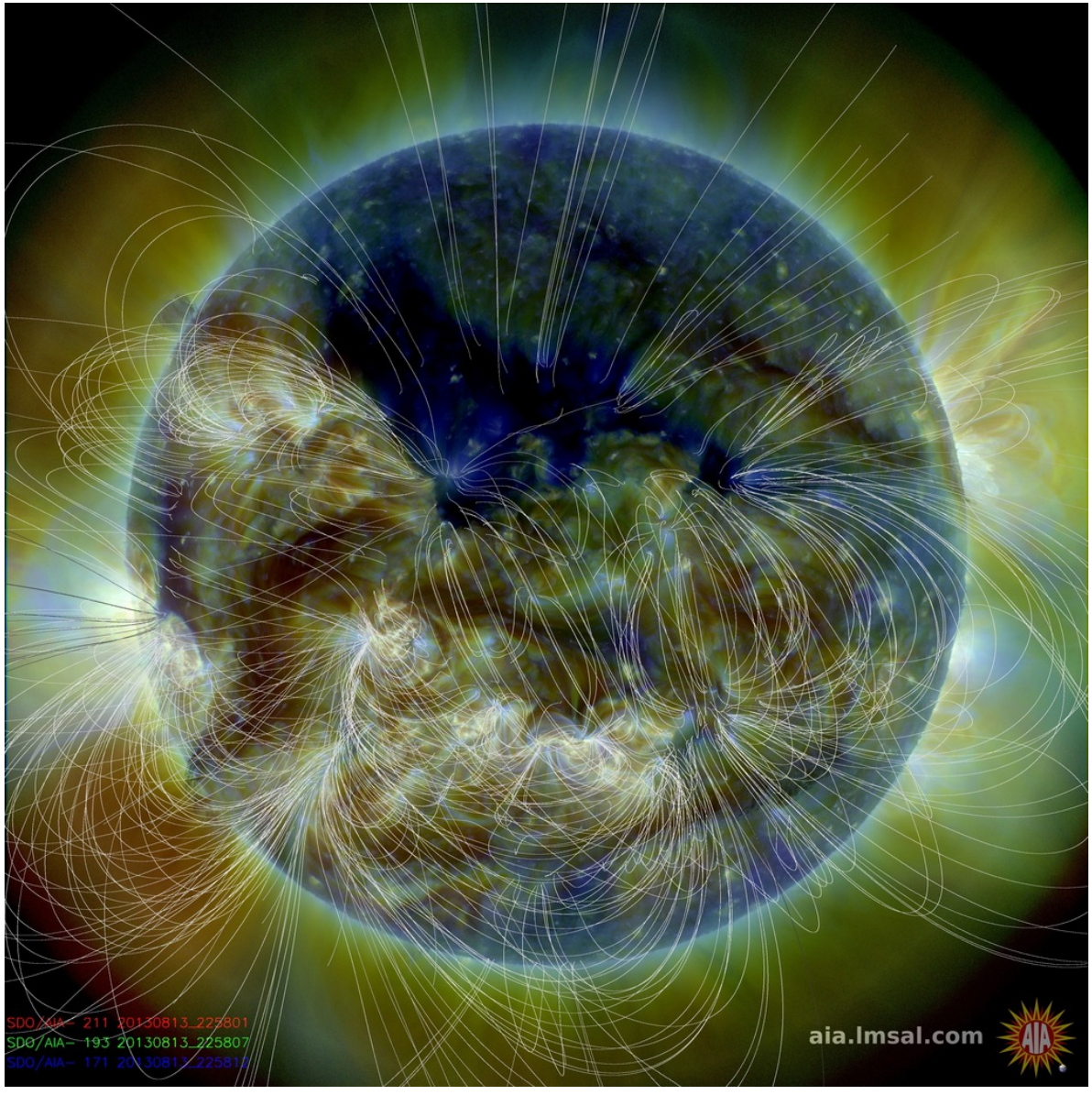
Hot and cool stars



Magnetic dynamo of cool stars

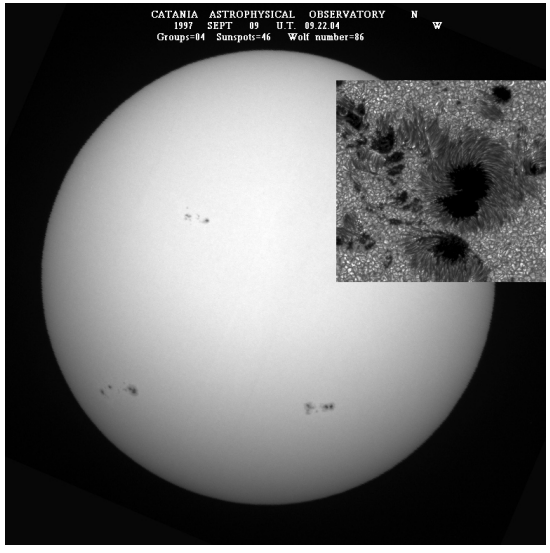


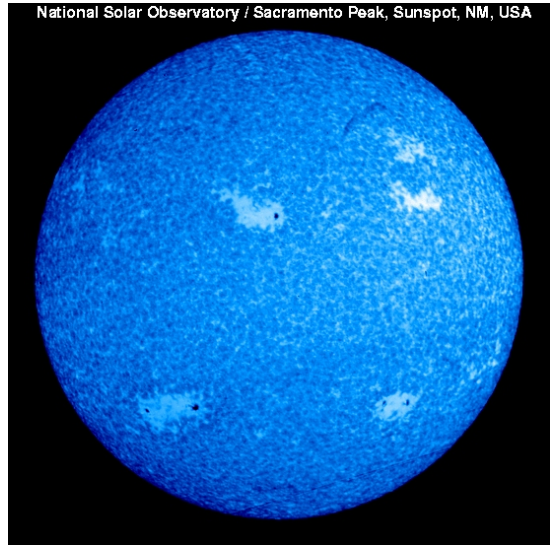
Magnetic activity and field lines on the Sun

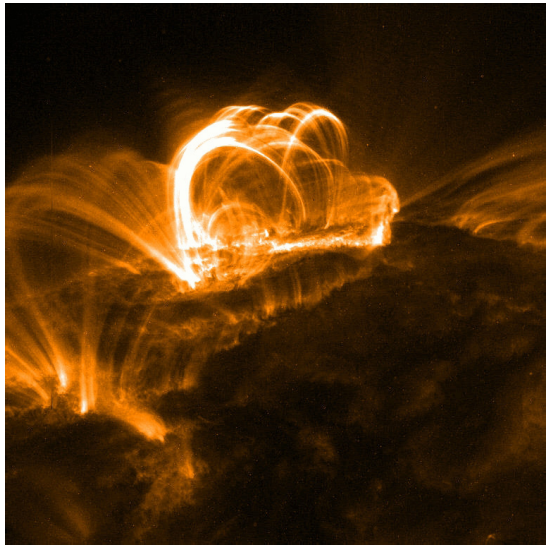


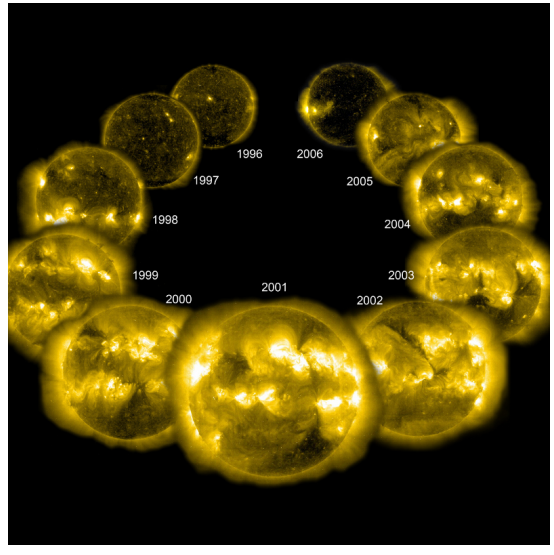
picture credit: SDO

Magnetic activity from optical to X-rays

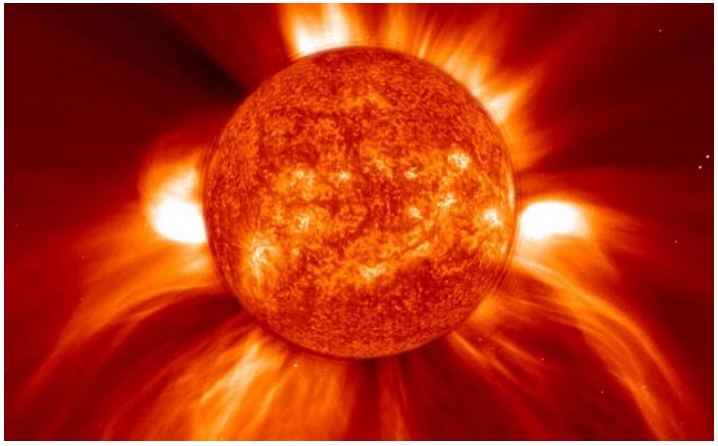




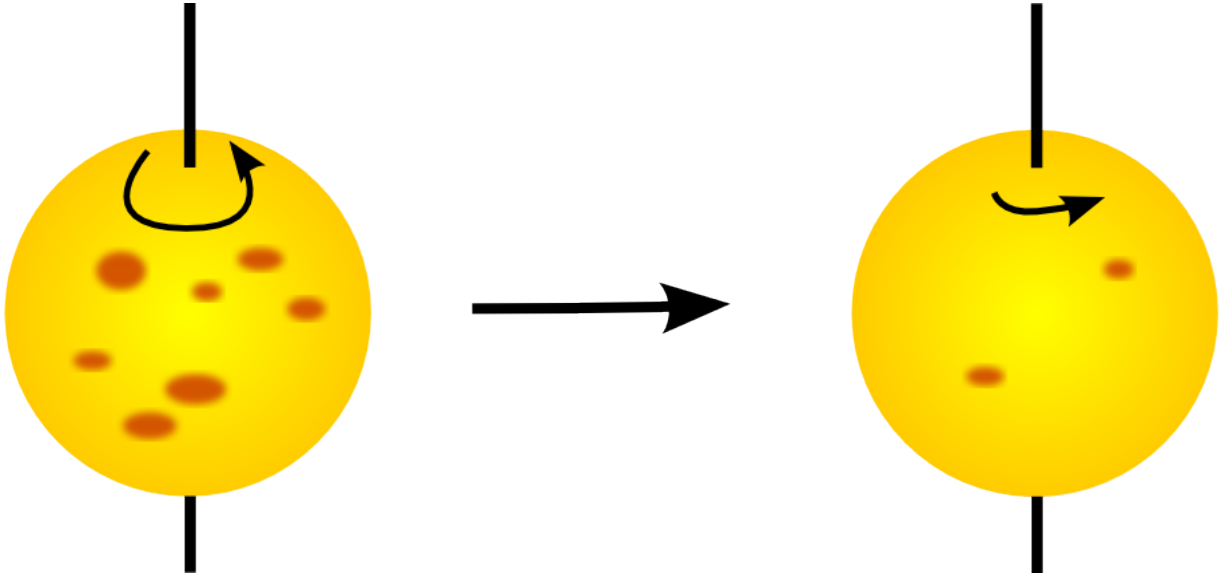




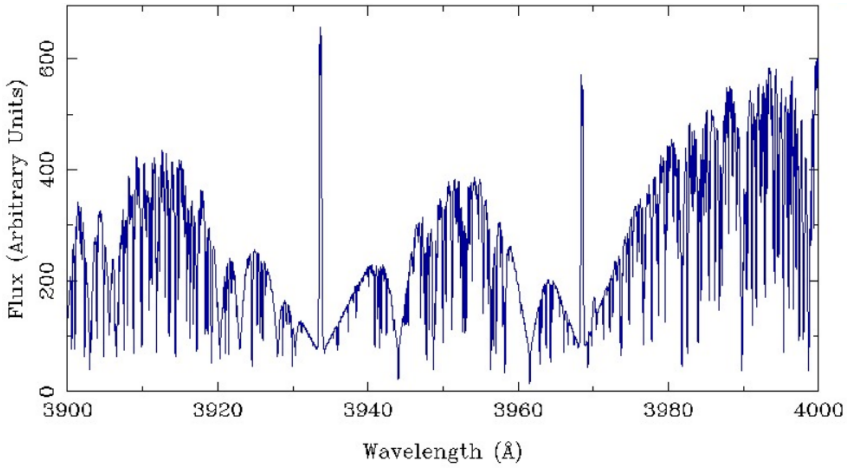
Decline of magnetic activity: magnetic braking

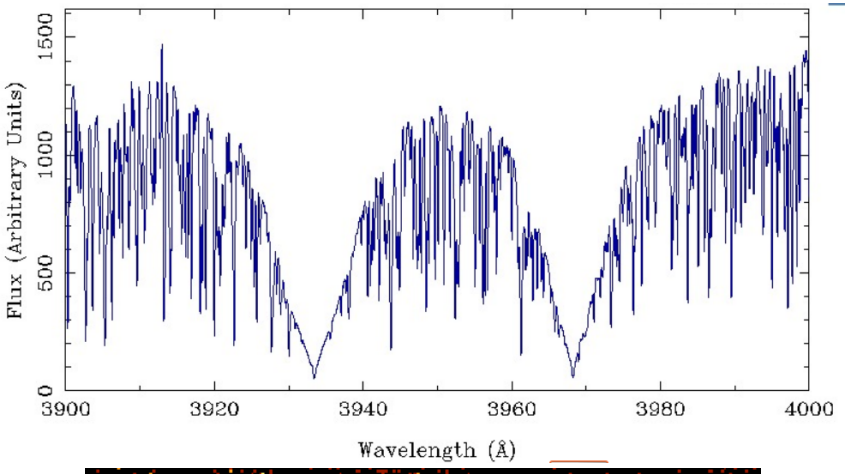


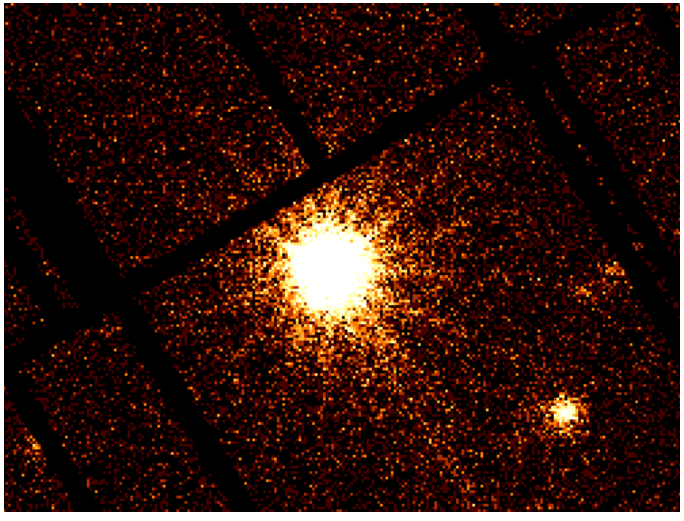
loss of angular momentum through stellar wind

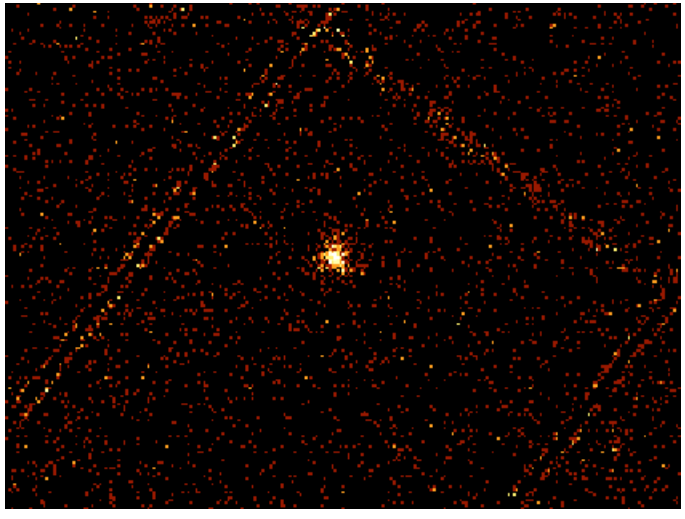


Activity decline with stellar age

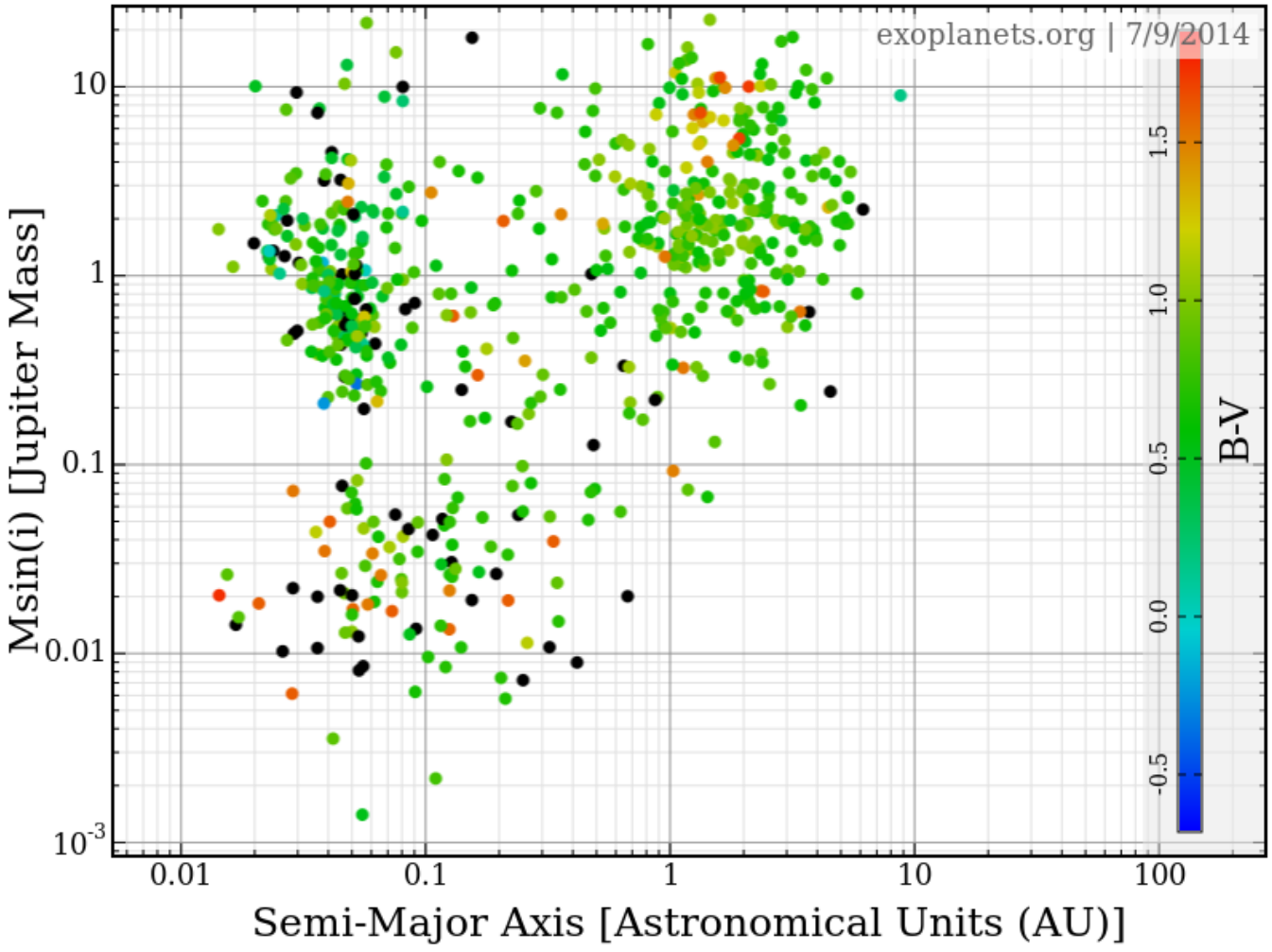




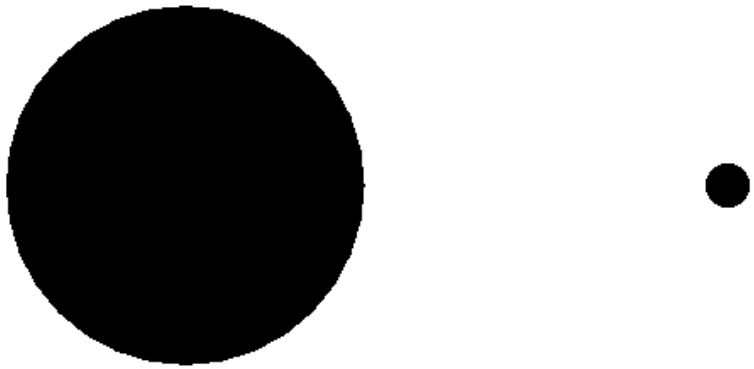




The exoplanet zoo



Hot Jupiter system to scale

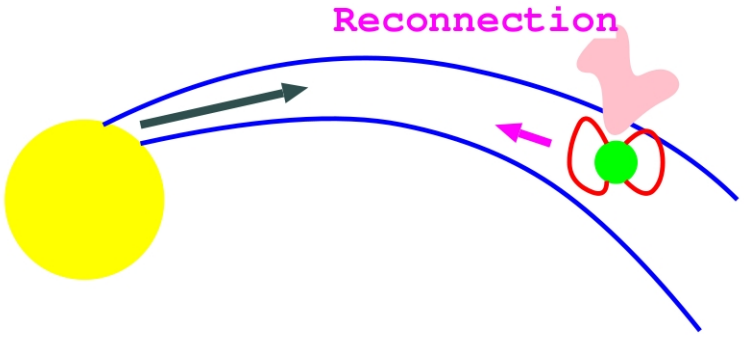


WASP-12 system

(G0 star + Hot Jupiter in 1 d orbit)

- planetary orbits within few stellar radii
- strong irradiation of planets ($\sim 100\,000\times$ flux at Earth)

Interaction of exoplanets and their host stars



picture credit: E. Shkolnik

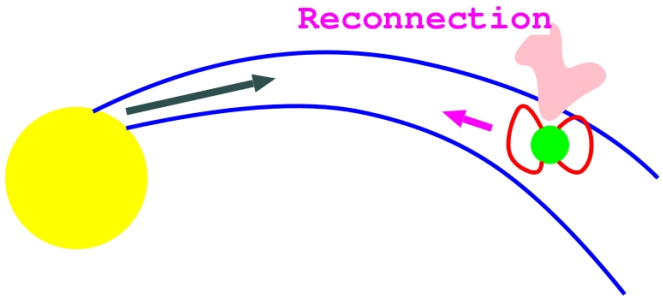
planets influencing stellar activity:
Star-Planet Interaction

picture credit: NASA

stellar activity influencing planets:
evaporation, habitability

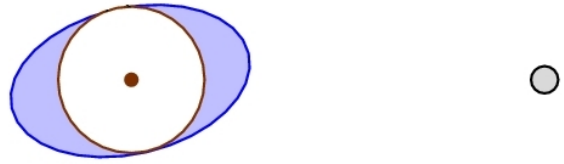
Star-planet interaction

2 basic scenarios:



magnetic

discovery papers:
Shkolnik et al. 2005, 2008
for 2 individual systems

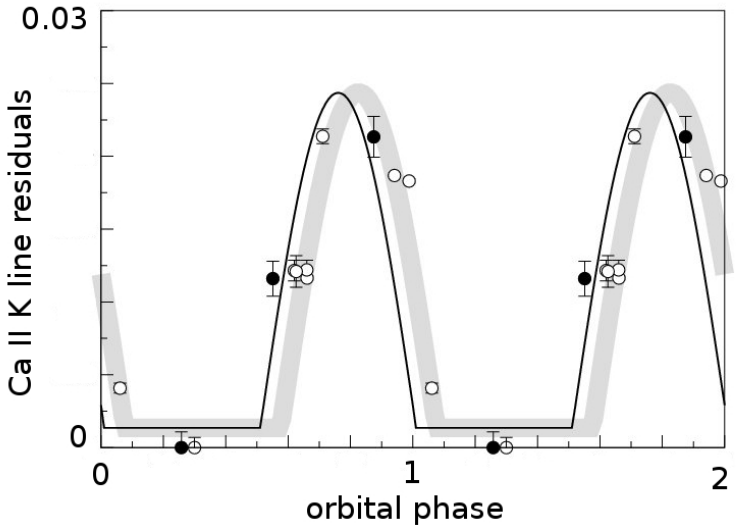


tidal

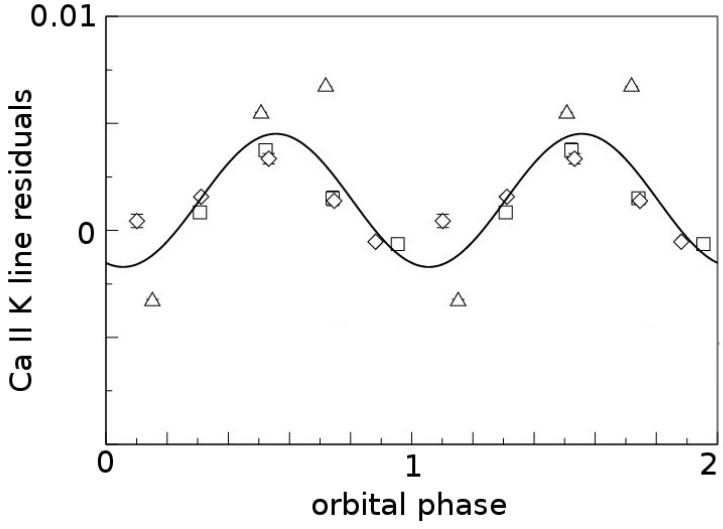
spin-up (inhibited spin-down) of host star; stronger for thick outer convection zones

picture credit: E. Shkolnik

Individual planet-host stars



HD 179949

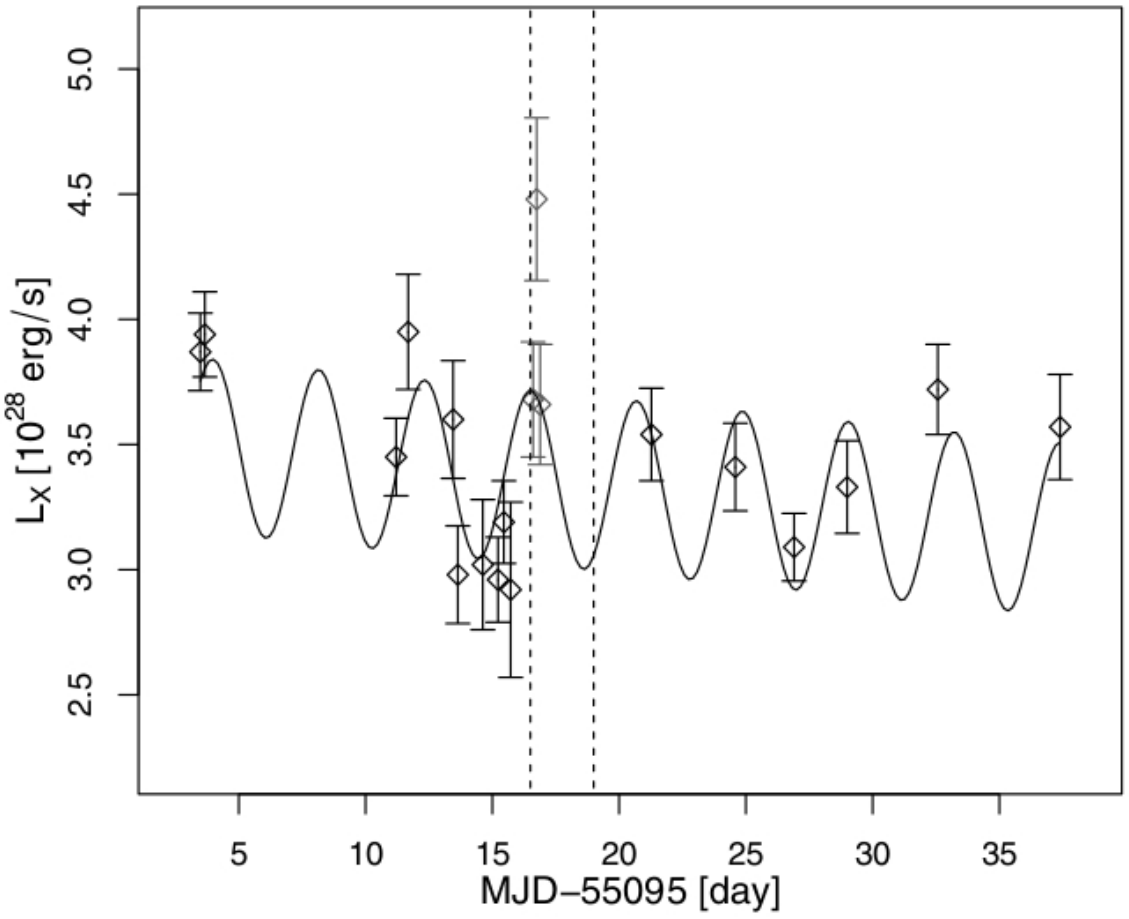


υ And

(Shkolnik at al. 2005)

Individual planet-host stars

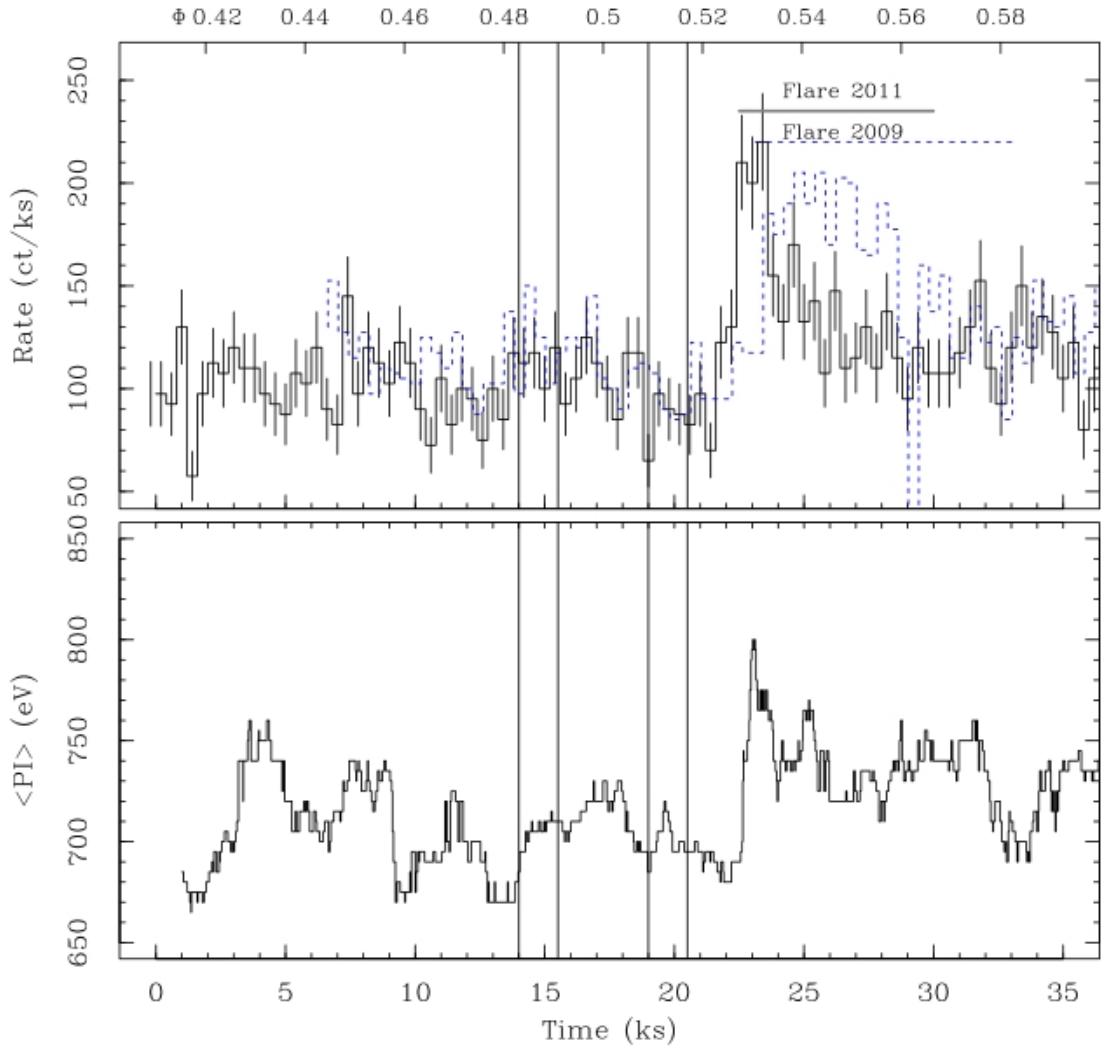
HD 179949 (hot Jupiter host)
$P_{rot} = 7.6 - 10.3$ d (differential), $P_{orb} = 3.1$ d



Scandariato et al. 2013

Individual planet-host stars: Flare triggering?

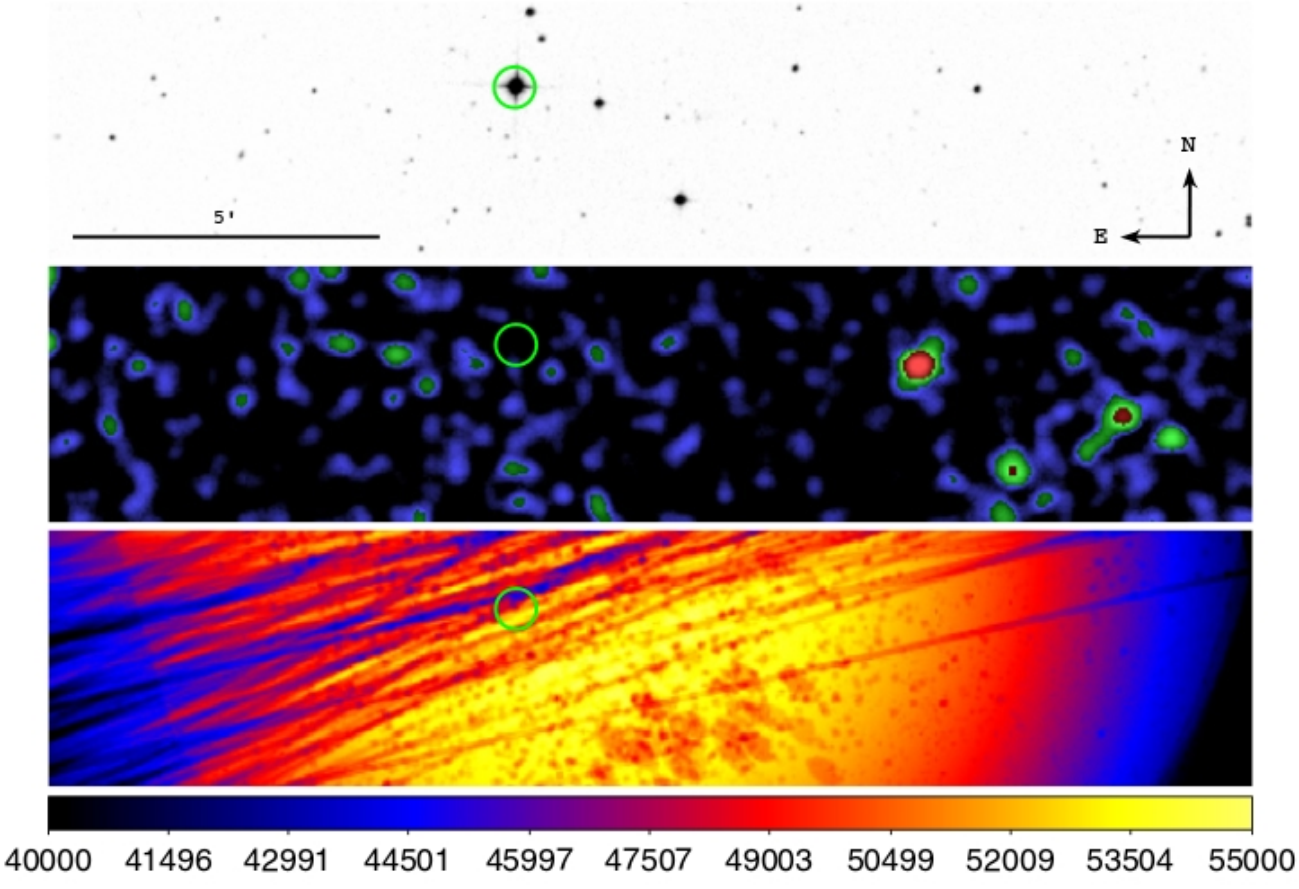
HD 189733 (hot Jupiter host)



Pillitteri et al. 2011

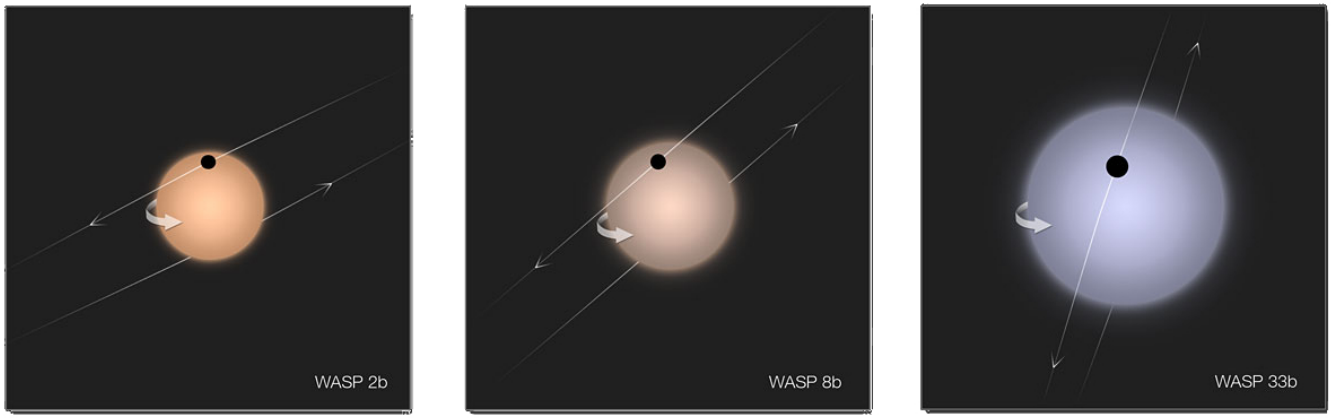
Individual planet-host stars: ultra-weak activity?

WASP-18 (hot Jupiter host, F6 star)

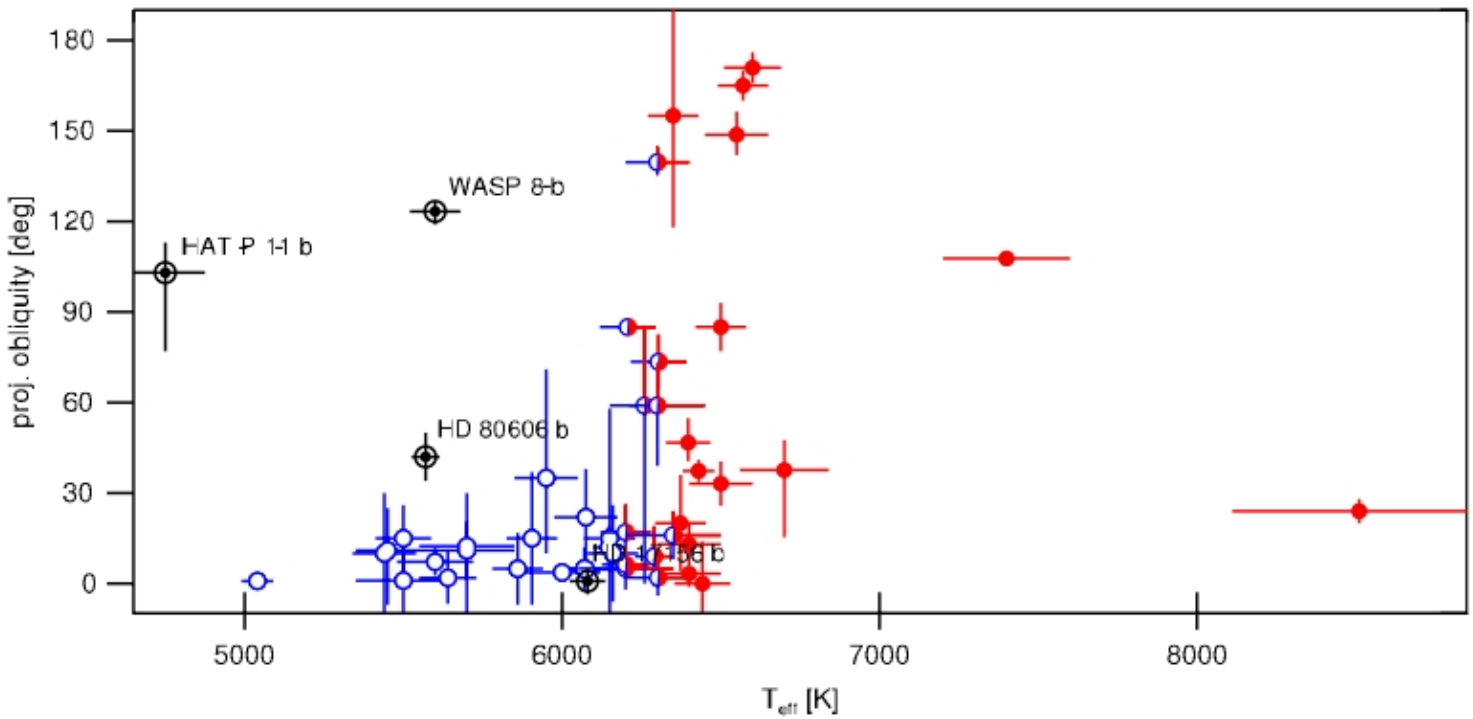


Miller et al. 2012, Pilliterri et al. 2014

Tidal interaction and orbital obliquities

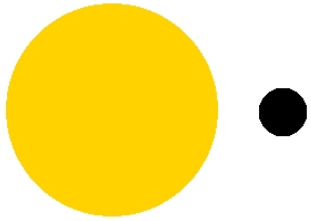


(picture credit: ESO)



(Albrecht et al. 2012)

Stellar samples: planet-induced activity enhancements?

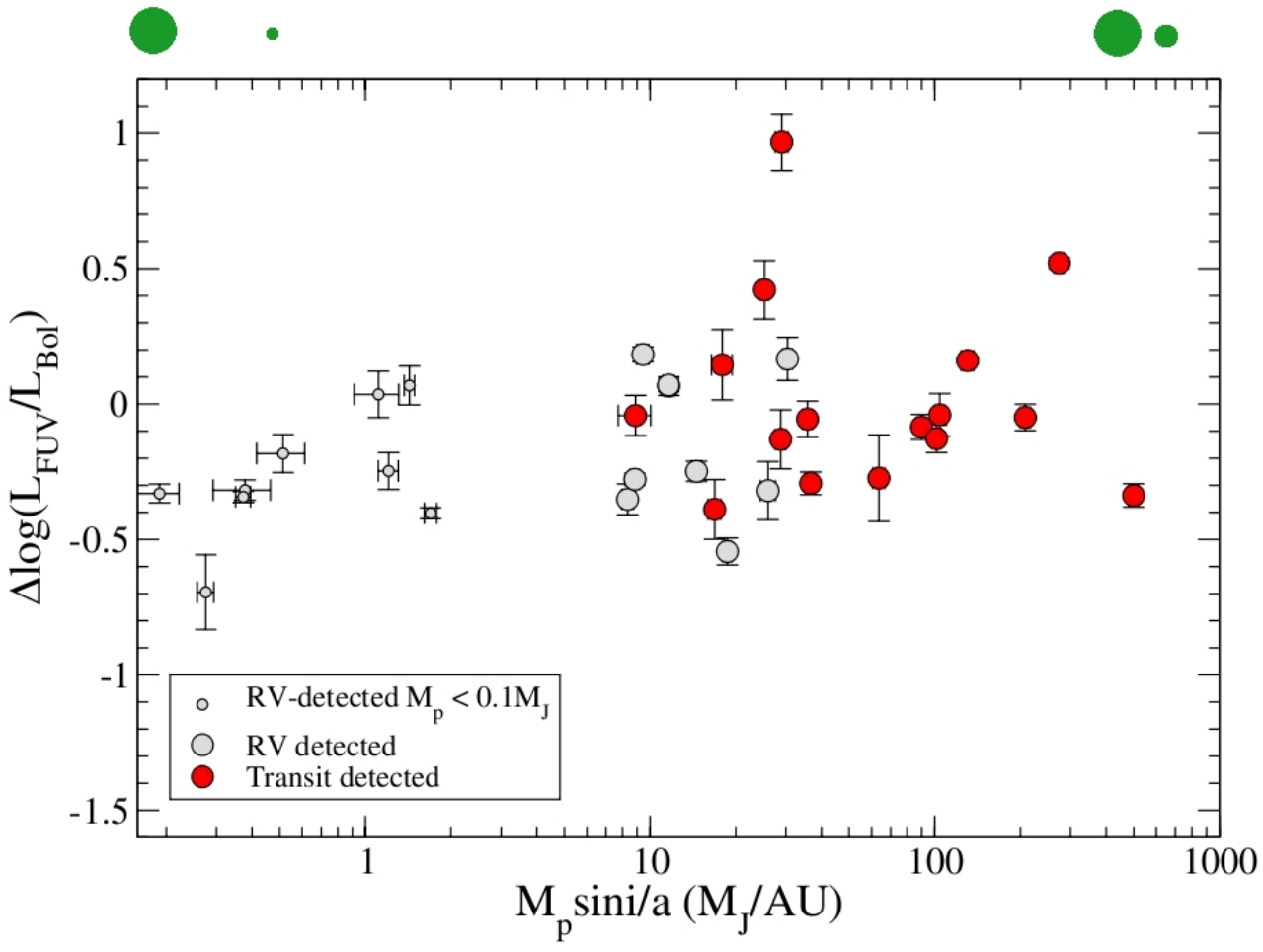


high activity?

low activity?

- searching for trends in samples of planet-hosting stars: Kashyap et al. 2010, Poppenhaeger et al. 2010, 2011, Lanza 2011, Shkolnik 2013, Miller et al. 2012, 2013, and others
- caveat: stellar activity biases against planet detection!

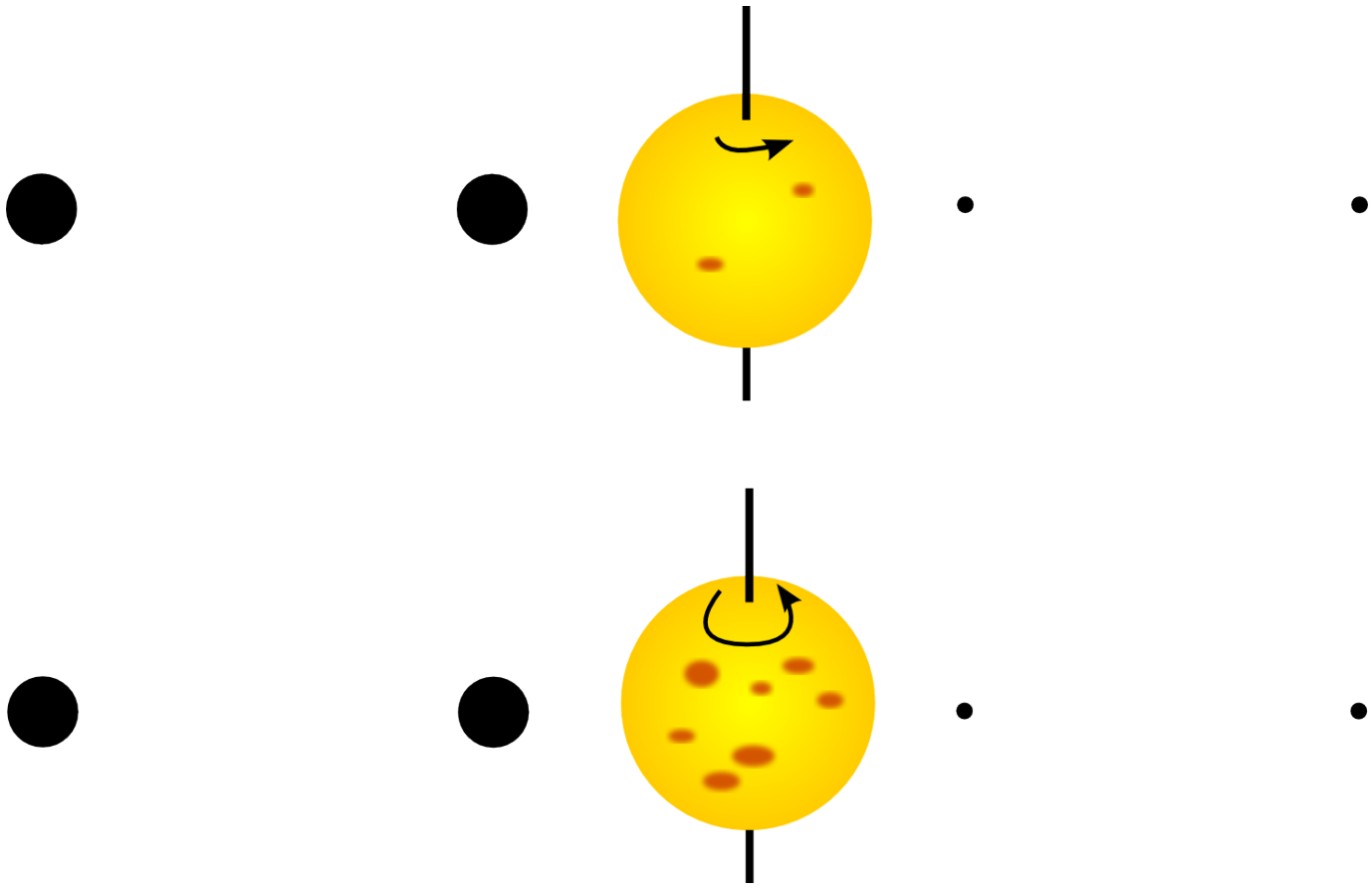
Searching for stellar activity enhancements



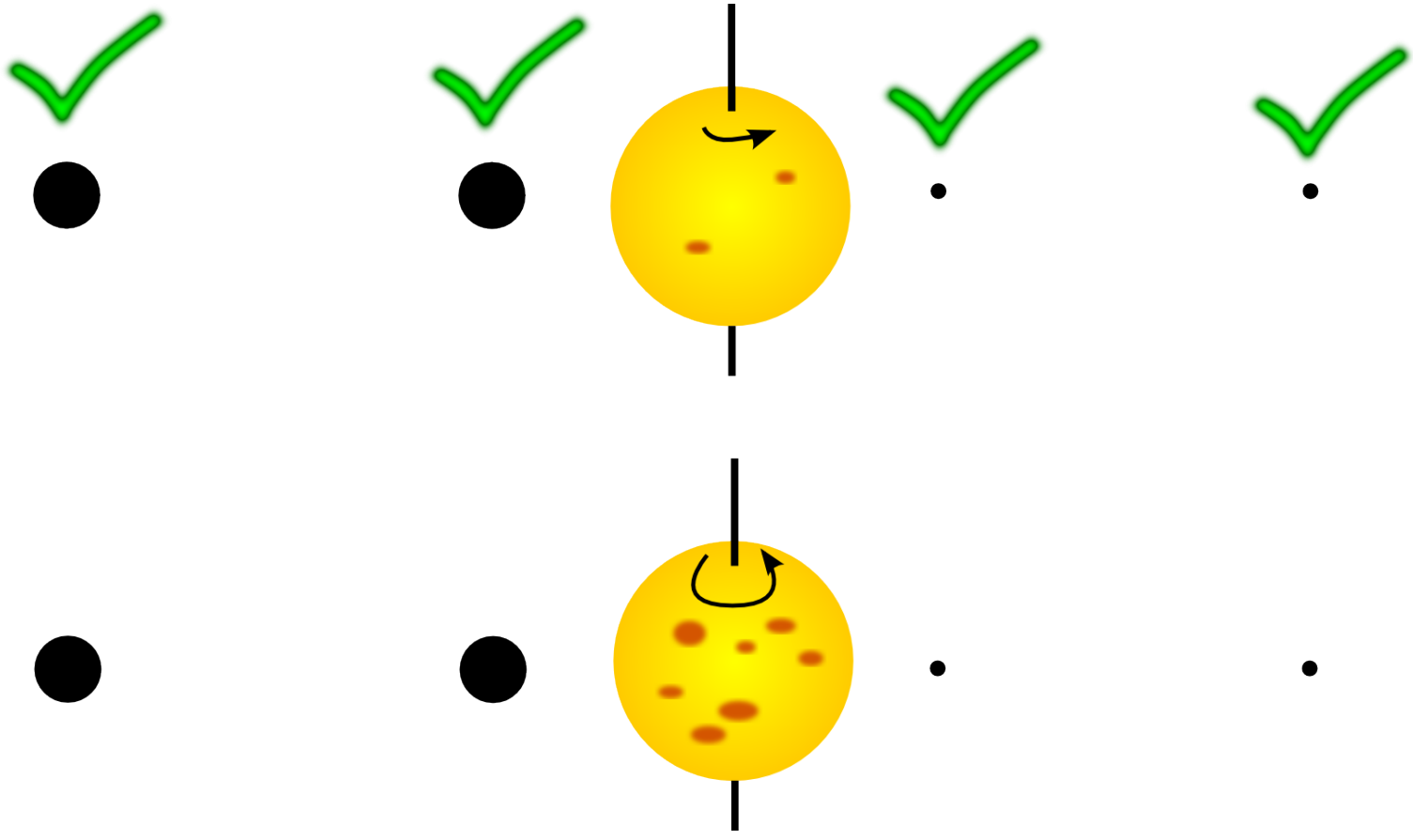
(Shkolnik 2013)

also: Kashyap et al. 2008, Scharf 2010

Dealing with selection effects



Dealing with selection effects



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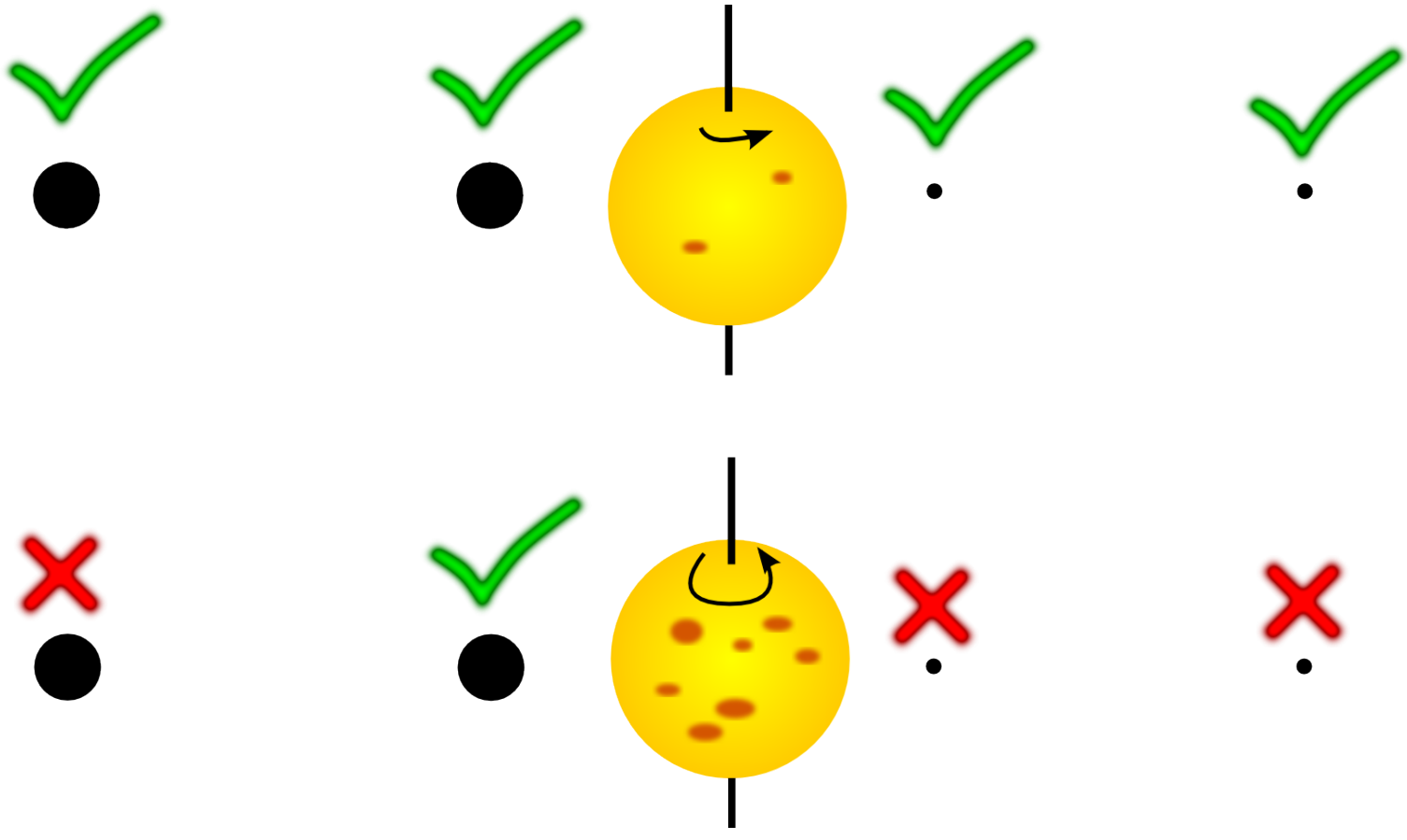
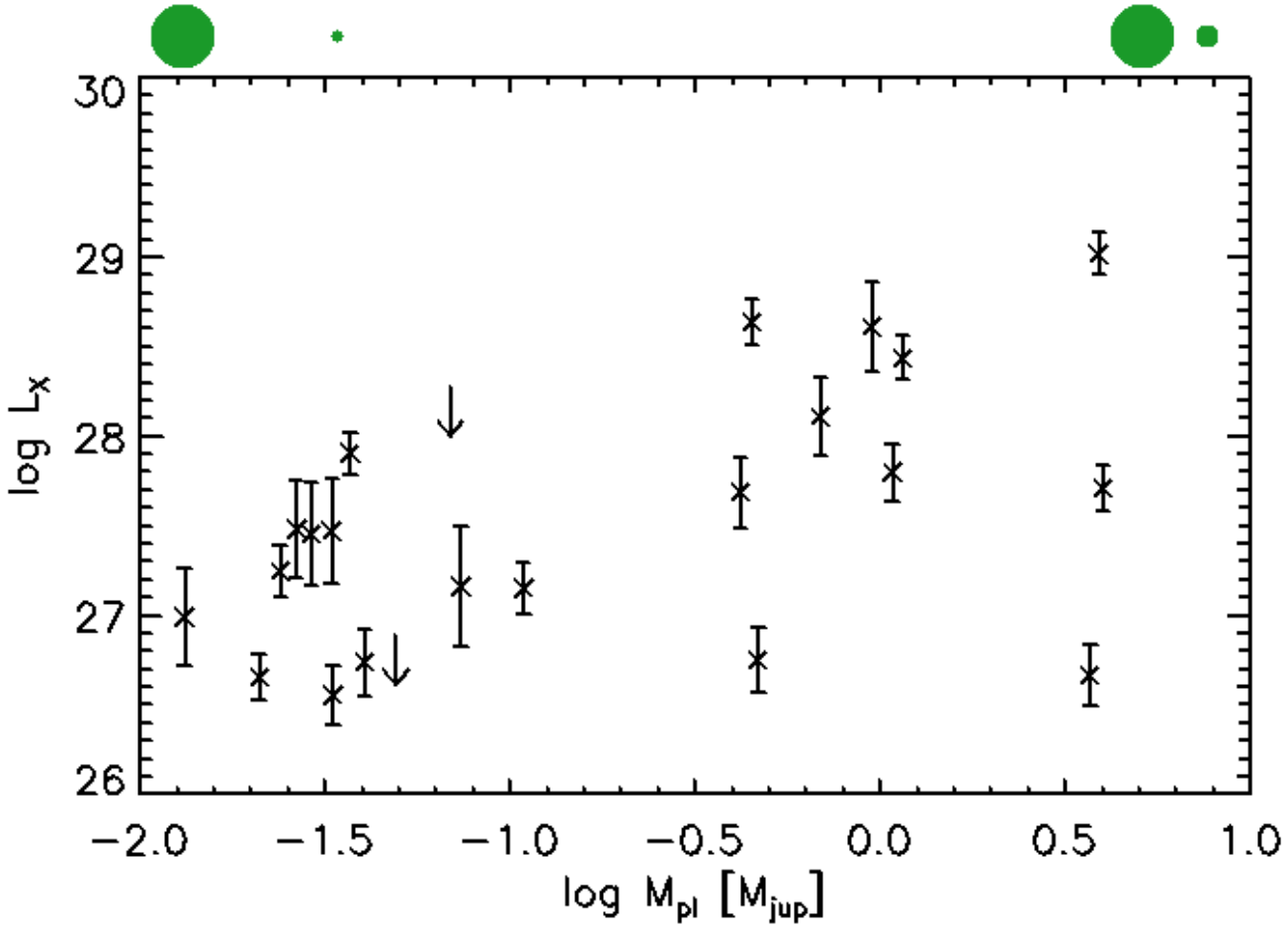


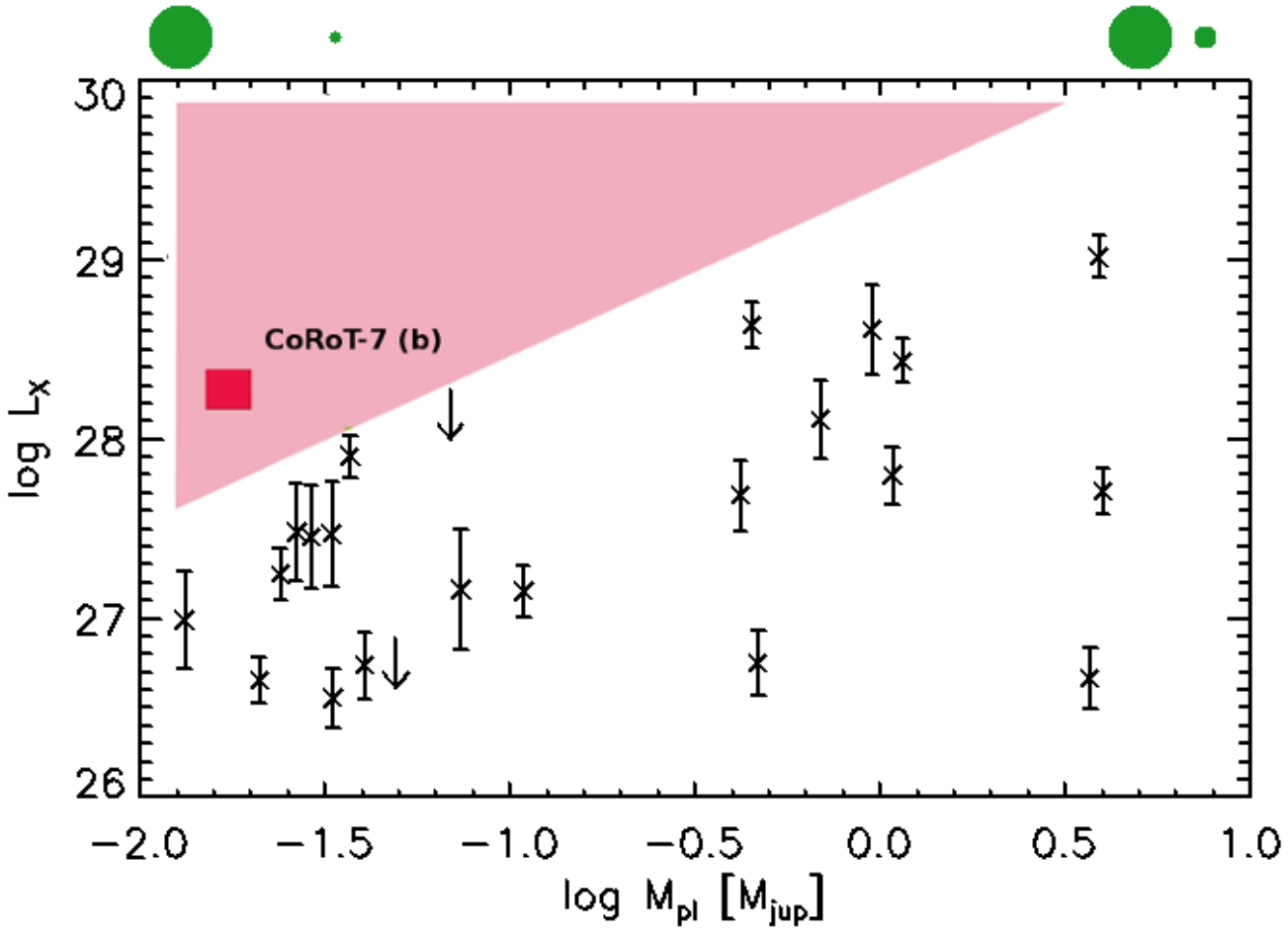
Dealing with selection effects



(Poppenhaeger & Schmitt, 2011)

strong selection effects from RV detections!

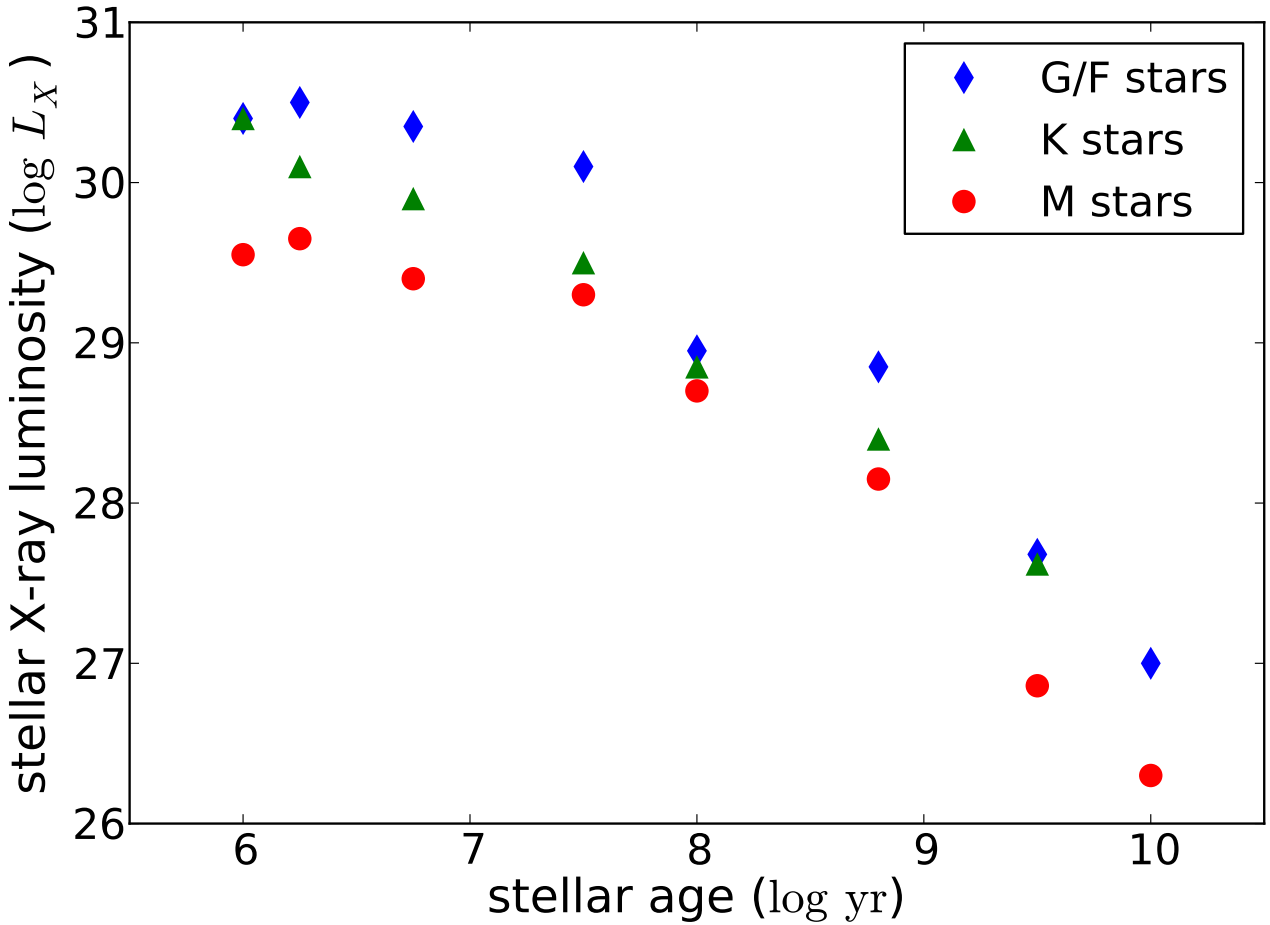
Dealing with selection effects



(Poppenhaeger & Schmitt, 2011)

strong selection effects from RV detections!

Activity decline with stellar age



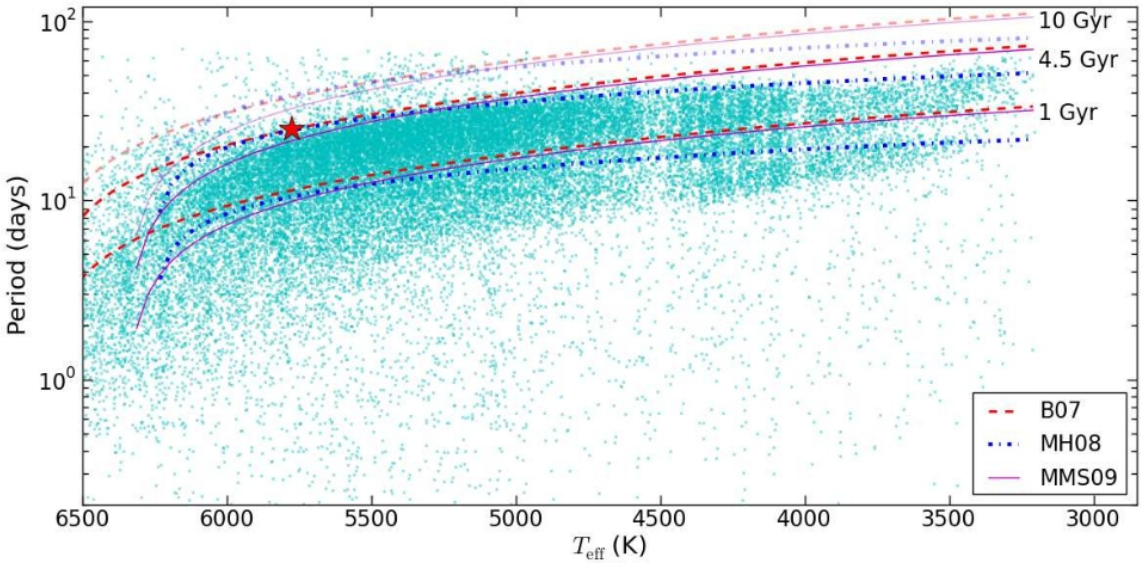
Data from Preibisch et al. 2005, Jeffries et al. 2006, Schmitt et al. 1995, Schmitt 1997, Maggio et al. 1987, Hawley et al. 1994

Chromospheric activity vs. age: for example Mamajek & Hillenbrandt 2008

Pinning down stellar ages to find activity outliers

Asteroseismic ages can help us to find planet hosts with unusual activity properties:

- Rotation

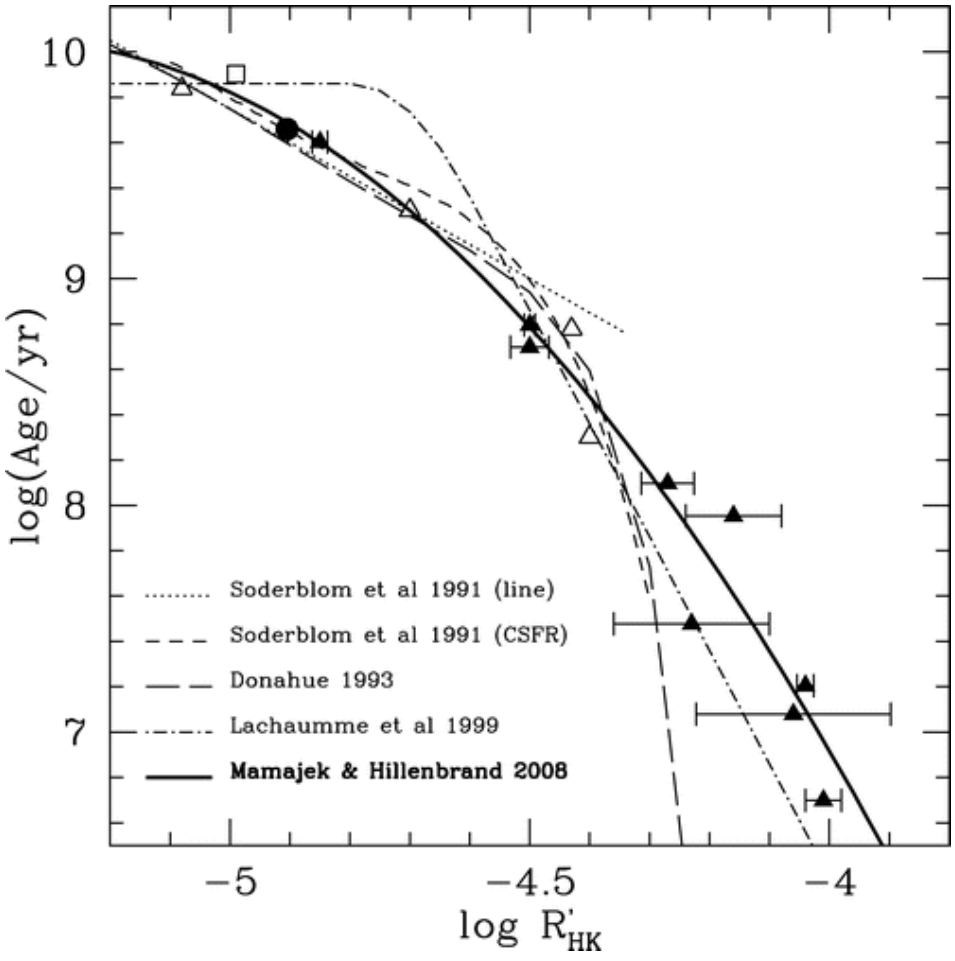


(McQuillan et al. 2014; see also Reinhold et al. 2013)

Pinning down stellar ages to find activity outliers

Asteroseismic ages can help us to find planet hosts with unusual activity properties:

- Rotation
- Activity (chromosphere)

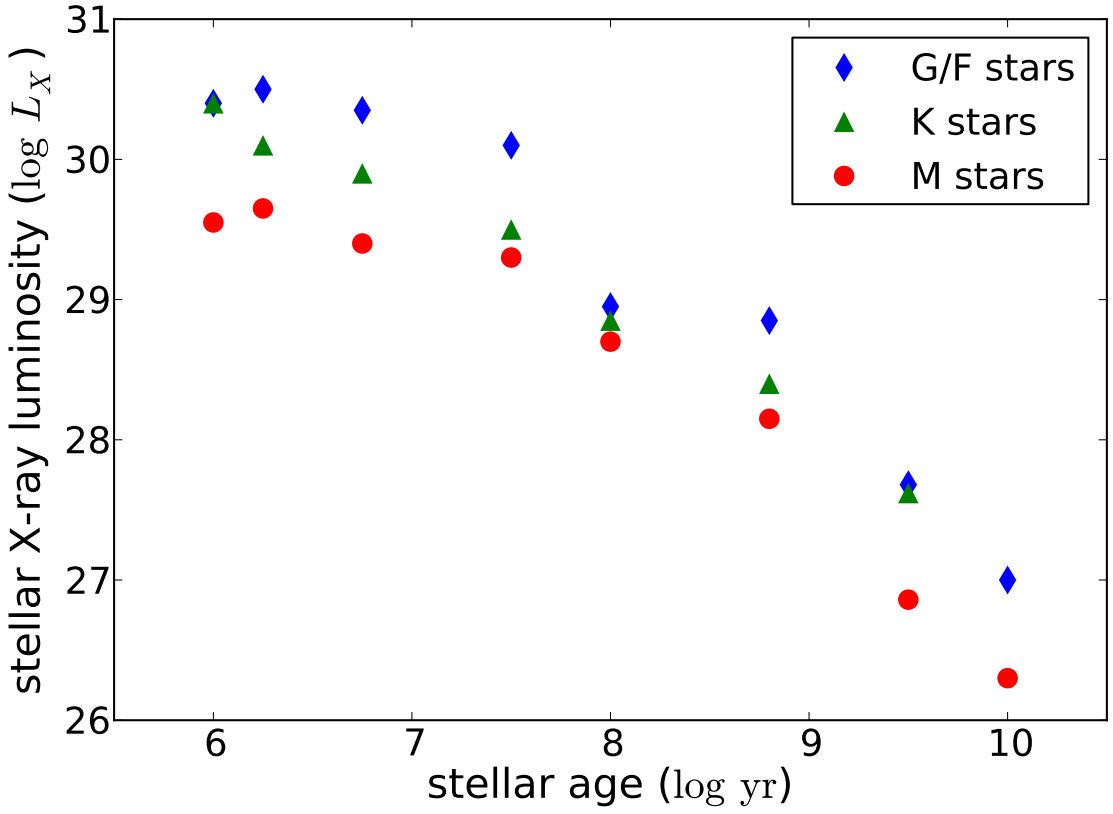


(Mamajek & Hillenbrand 2008)

Pinning down stellar ages to find activity outliers

Asteroseismic ages can help us to find planet hosts with unusual activity properties:

- Rotation
- Activity (chromosphere)
- Activity (corona)

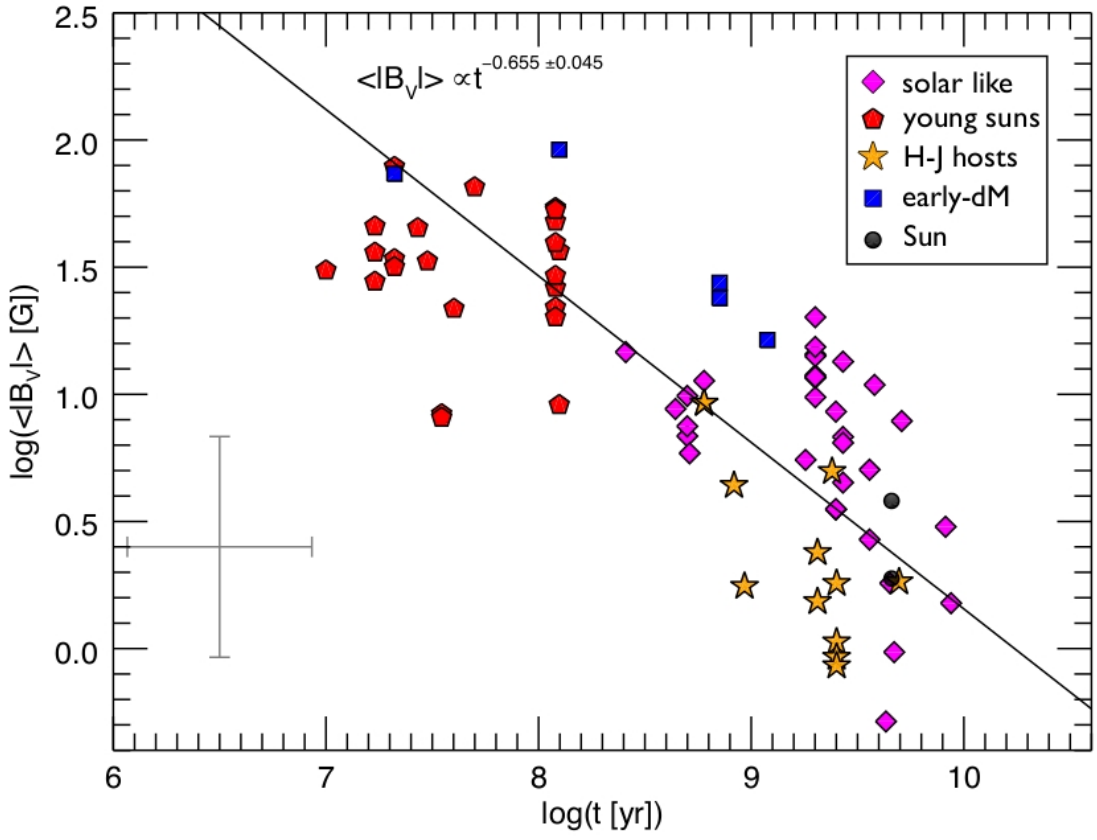


(data from Preibisch et al. 2005 and others)

Pinning down stellar ages to find activity outliers

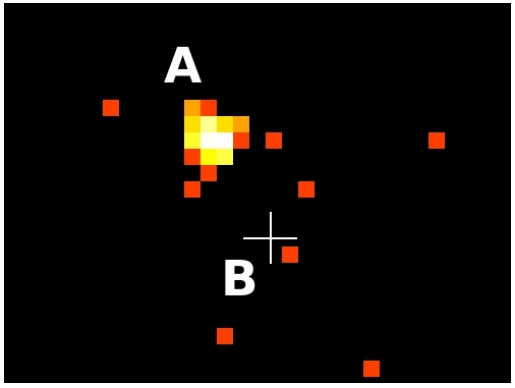
Asteroseismic ages can help us to find planet hosts with unusual activity properties:

- Rotation
- Activity (chromosphere)
- Activity (corona)
- Magnetic field strength

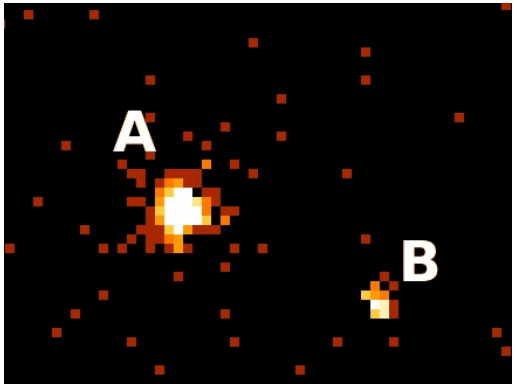


(Vidotto et al. 2014)

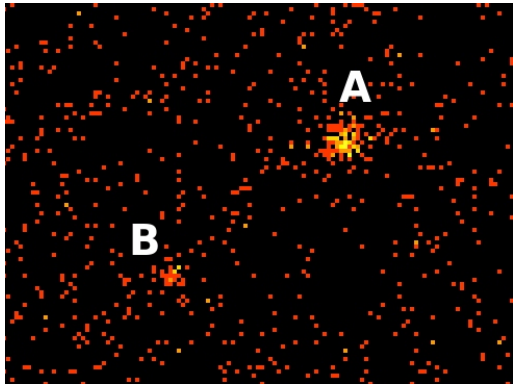
X-ray observations of 5 candidate systems



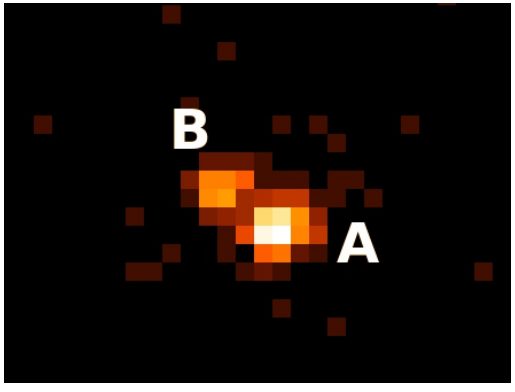
CoRoT-2 AB



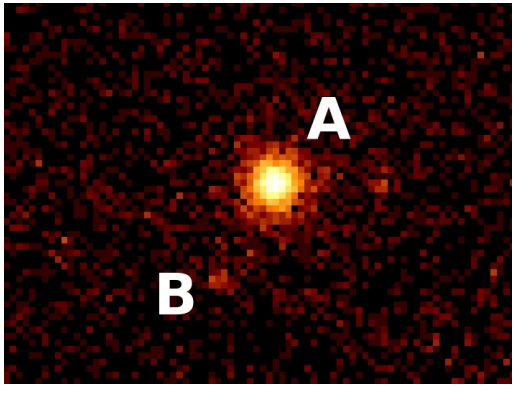
HD 189733 AB



55 Cnc AB

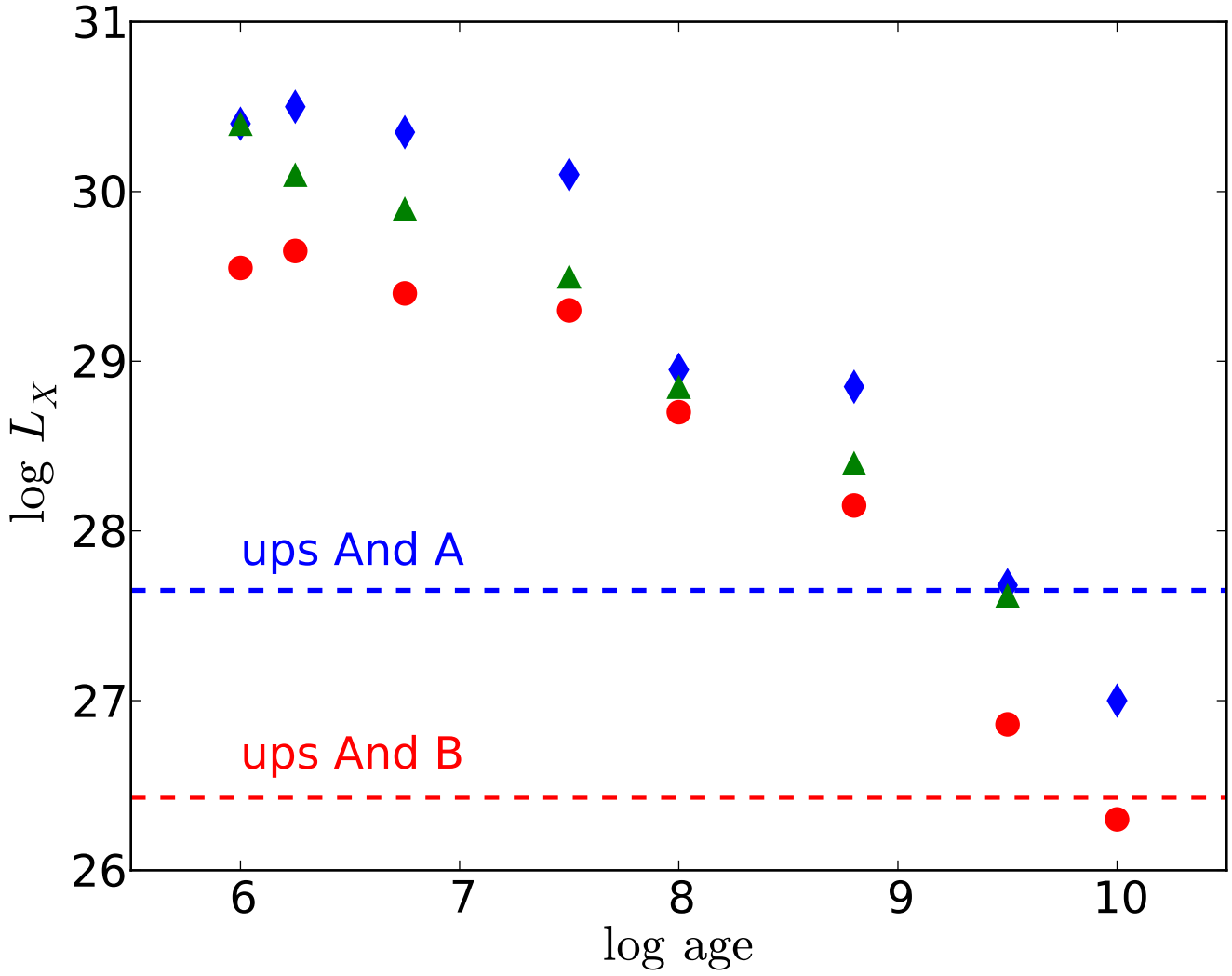


τ Boo AB

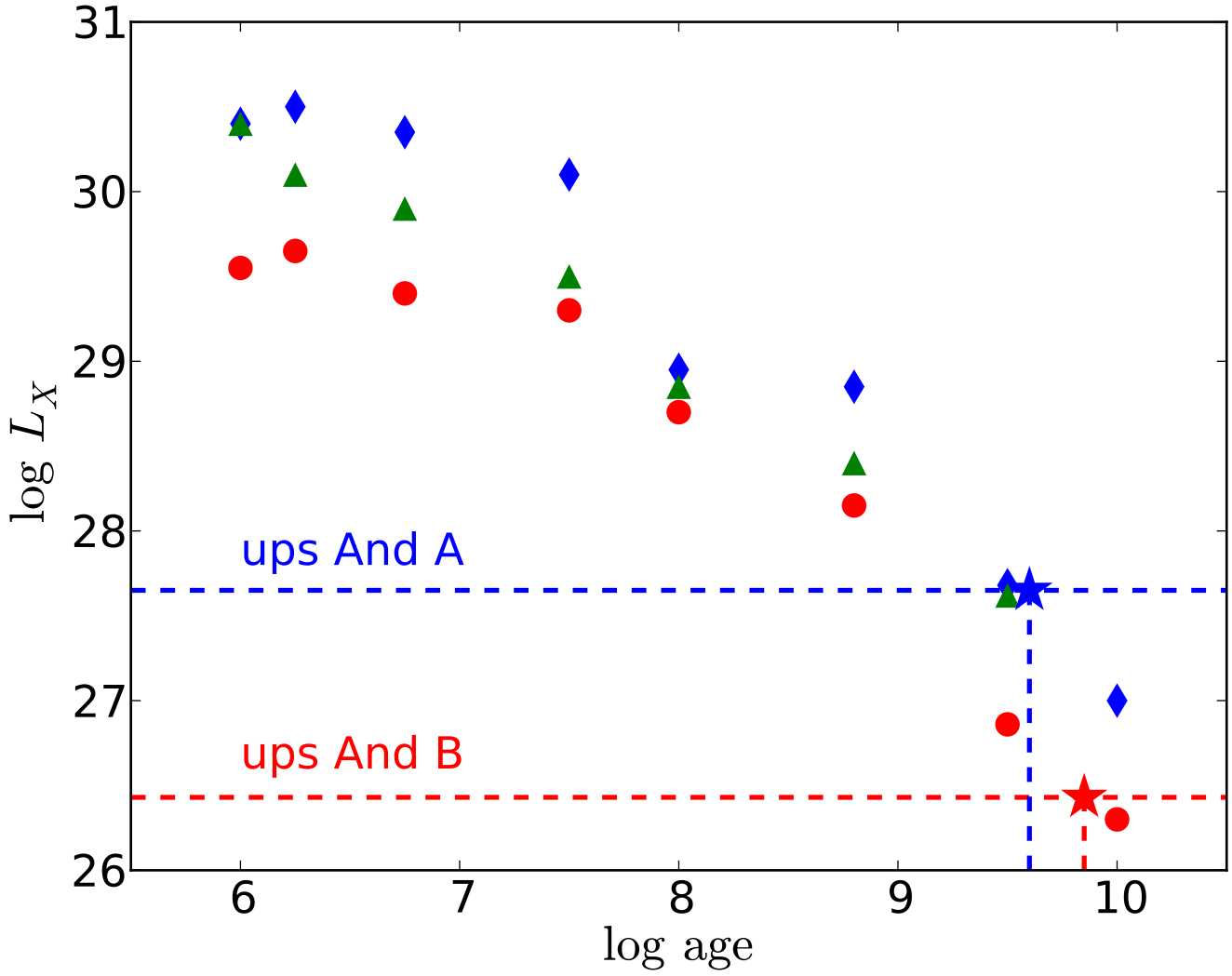


υ And AB

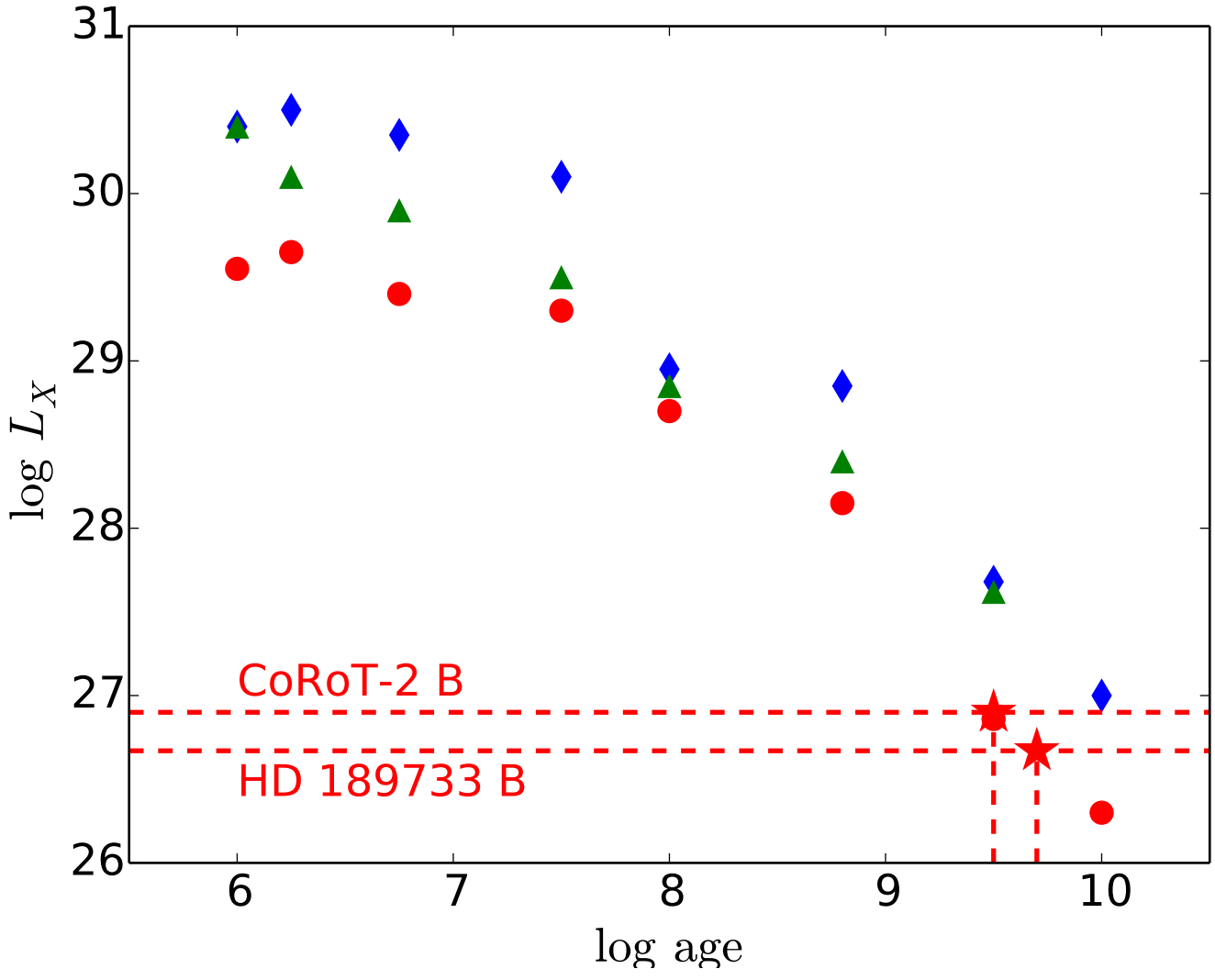
Age/activity for weak tidal interaction



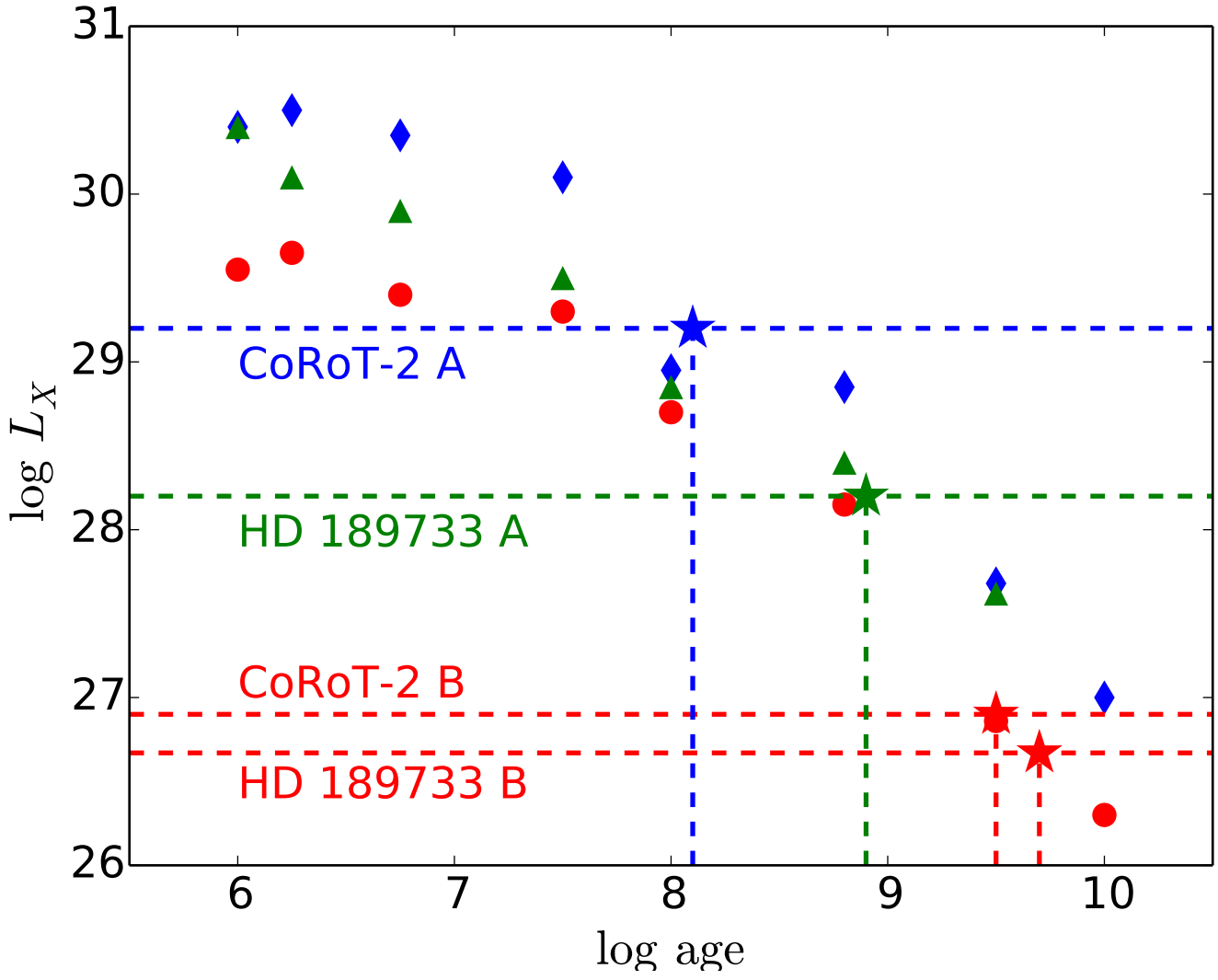
Age/activity for weak tidal interaction



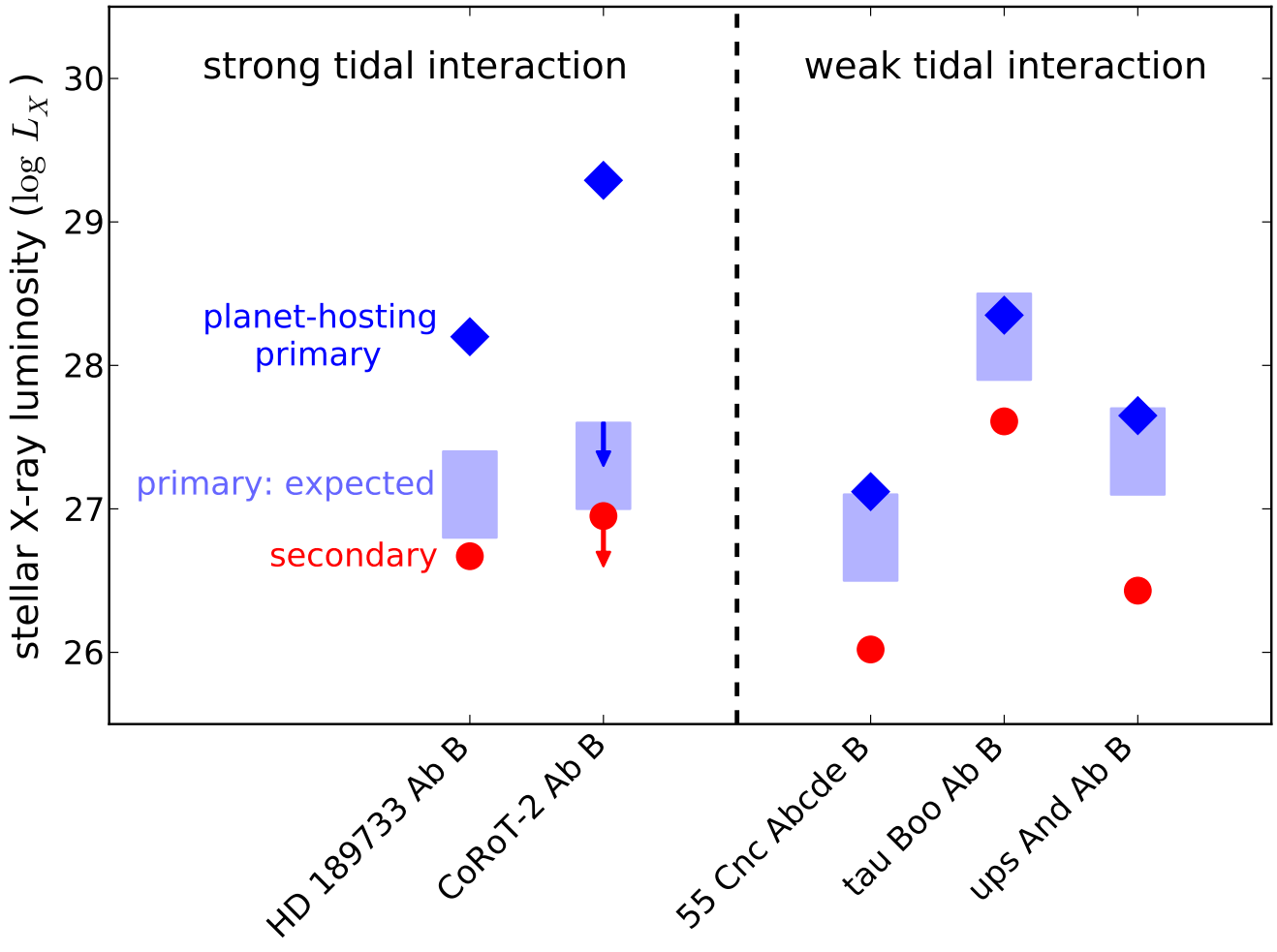
Age/activity for strong tidal interaction



Age/activity for strong tidal interaction



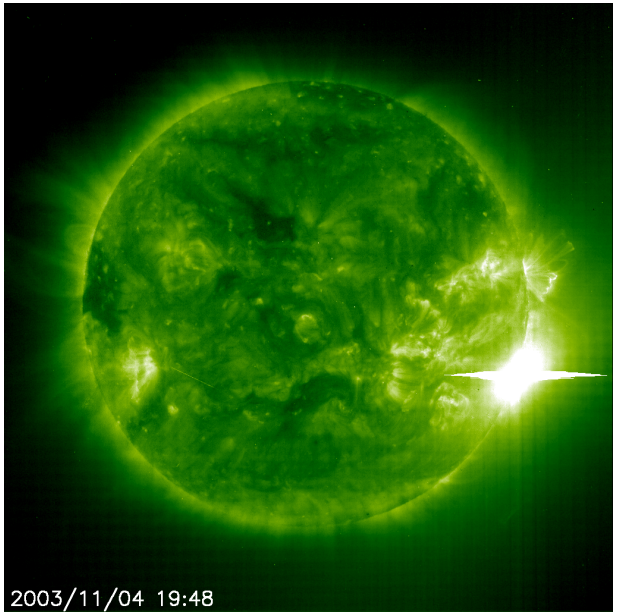
X-ray activity for 5 systems



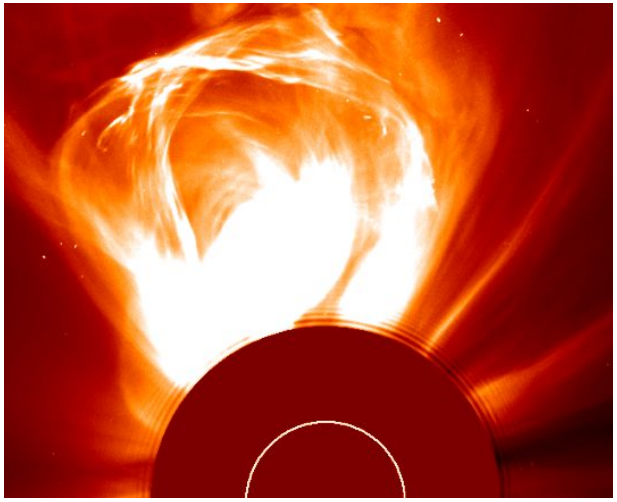
see Poppenhaeger et al. 2014, A&A Letters

Stellar activity affects exoplanets

flares



coronal mass ejections



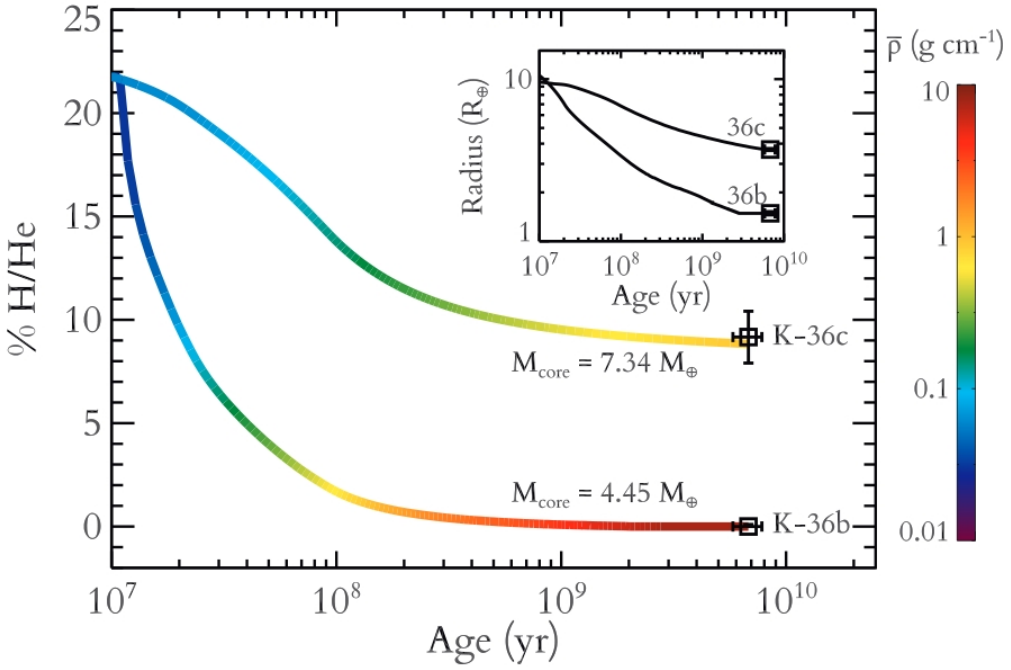
heating of high-altitude atmosphere

planetary mass loss

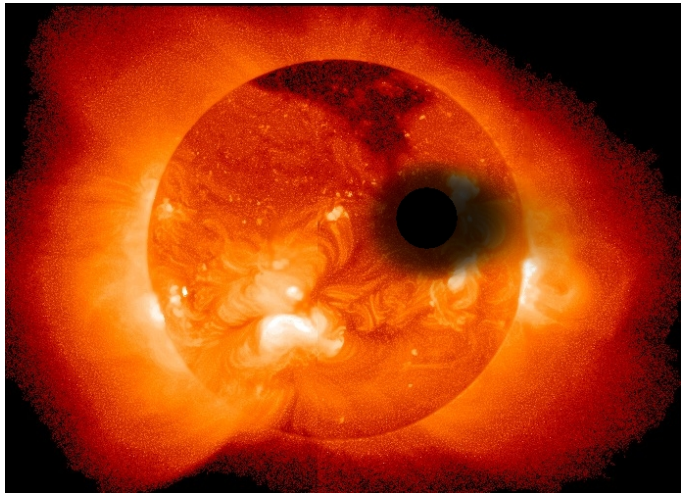
Atmospheric evaporation, driven by X-rays and UV

Evaporation of gaseous envelope

for example Murray-Clay 2009, Lecavelier des Etangs et al. 2004, Erkaev et al. 2007

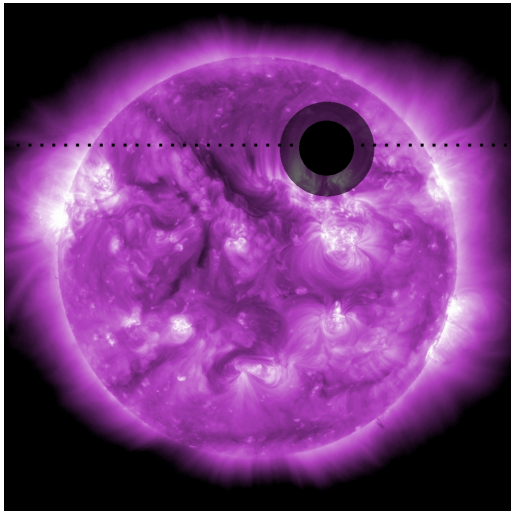


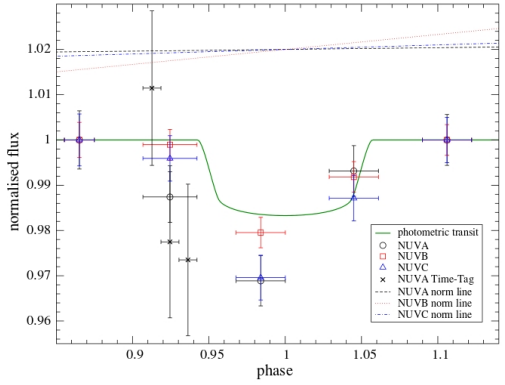
Lopez et al. 2013



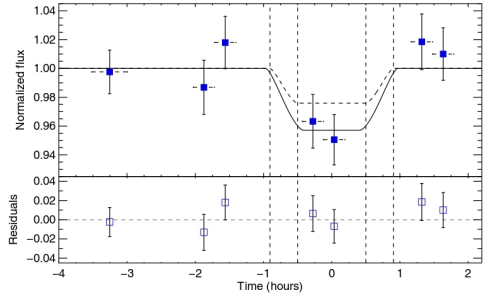
YOHKOH/modified by K.P.

X-rays and UV absorption in exoplanetary exospheres

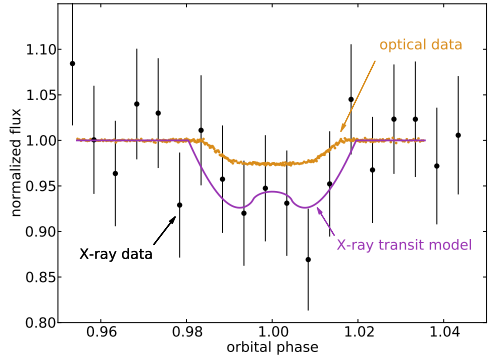




WASP-12b, NUV, Fossati et al. 2010



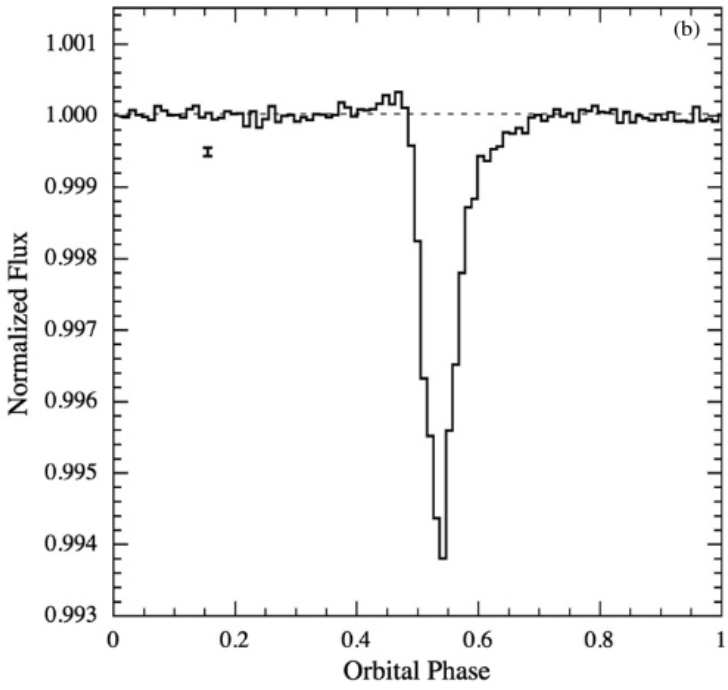
HD 189733b, Ly-α, Bourrier et al. 2013



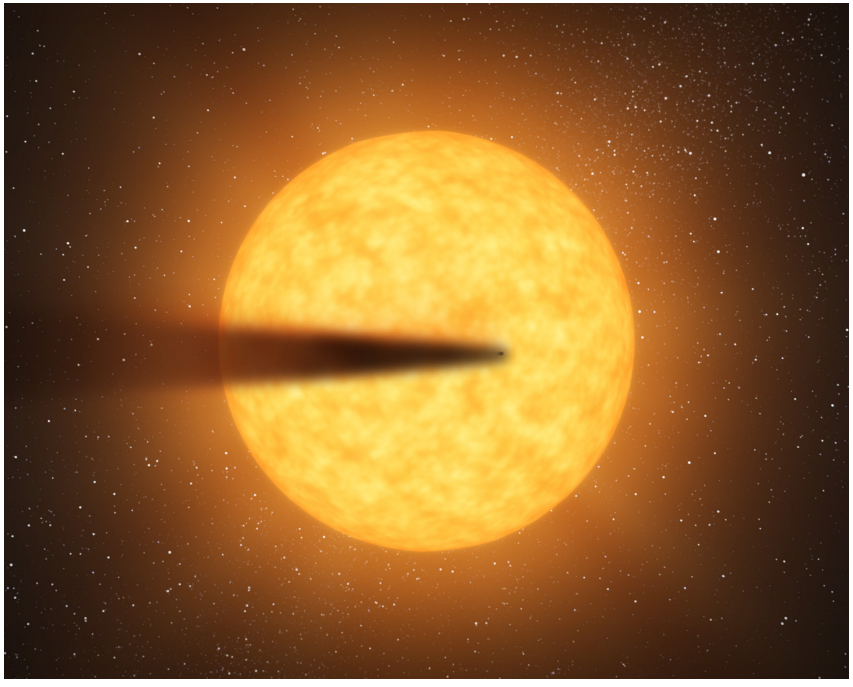
HD 189733b, X-rays, Poppenhaeger et al. 2013

Evaporating planets - transit profiles

KIC 12557548, dusty tail?



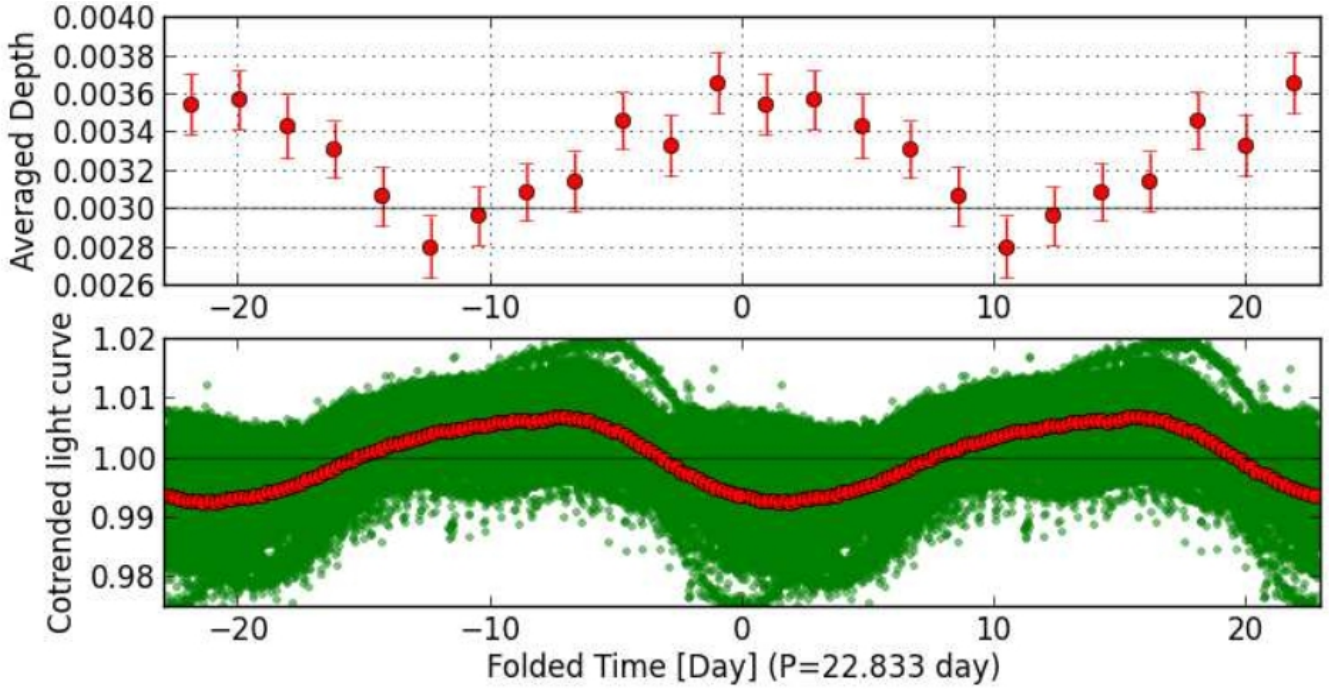
Rappaport et al. 2012



picture credit: NASA/JPL/Caltech

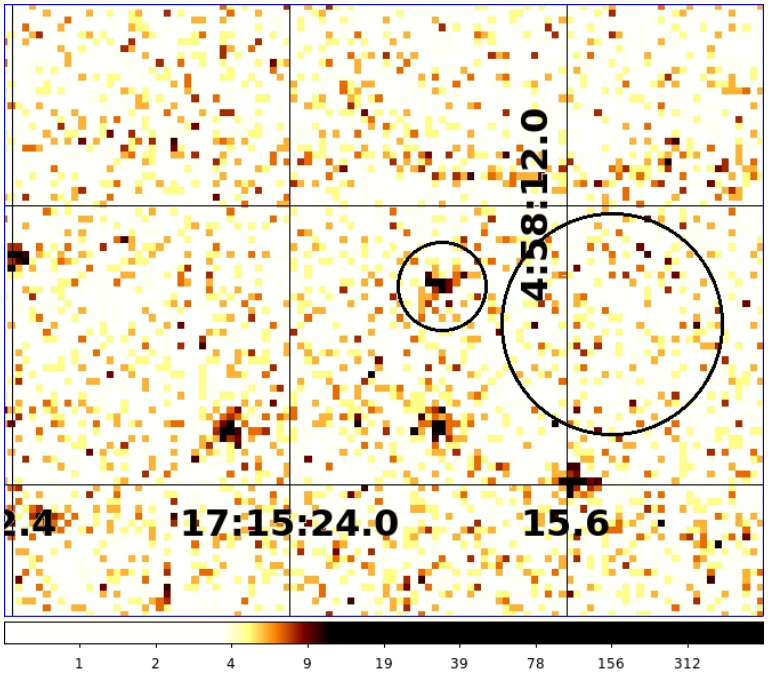
Evaporating planets - transit profiles

KIC 12557548

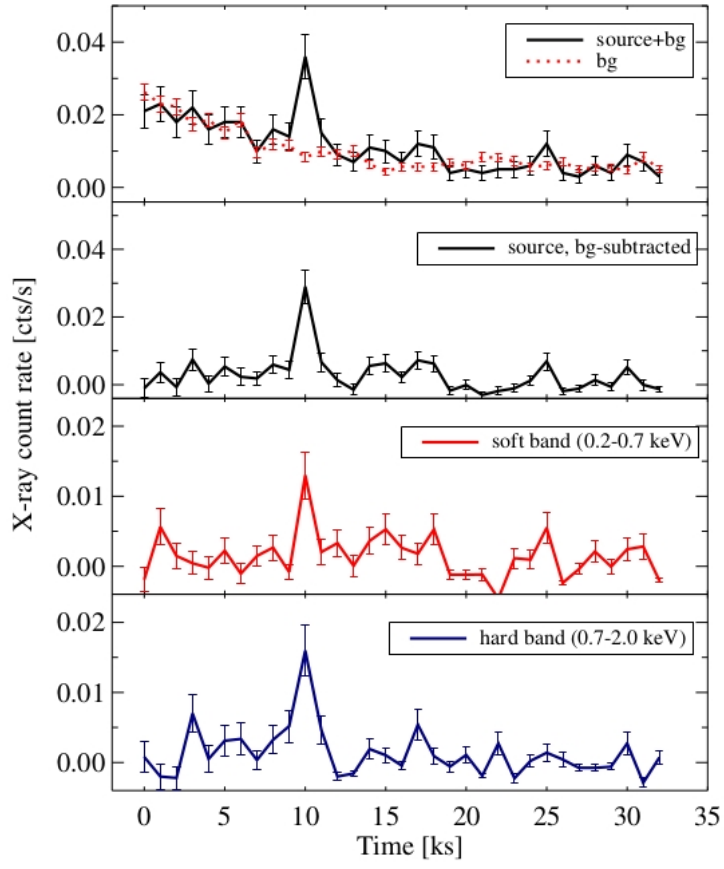


Kawahara et al. 2013

X-ray irradiation of GJ 1214 b

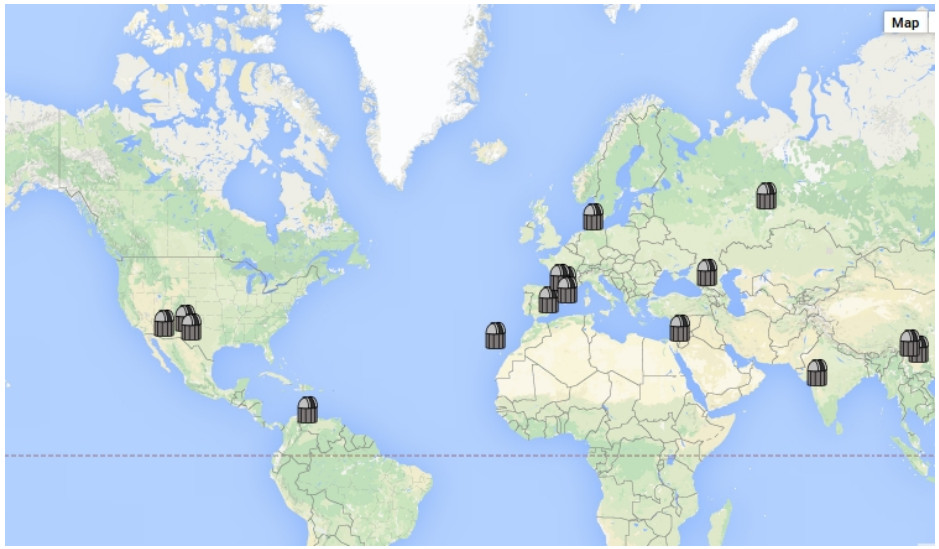


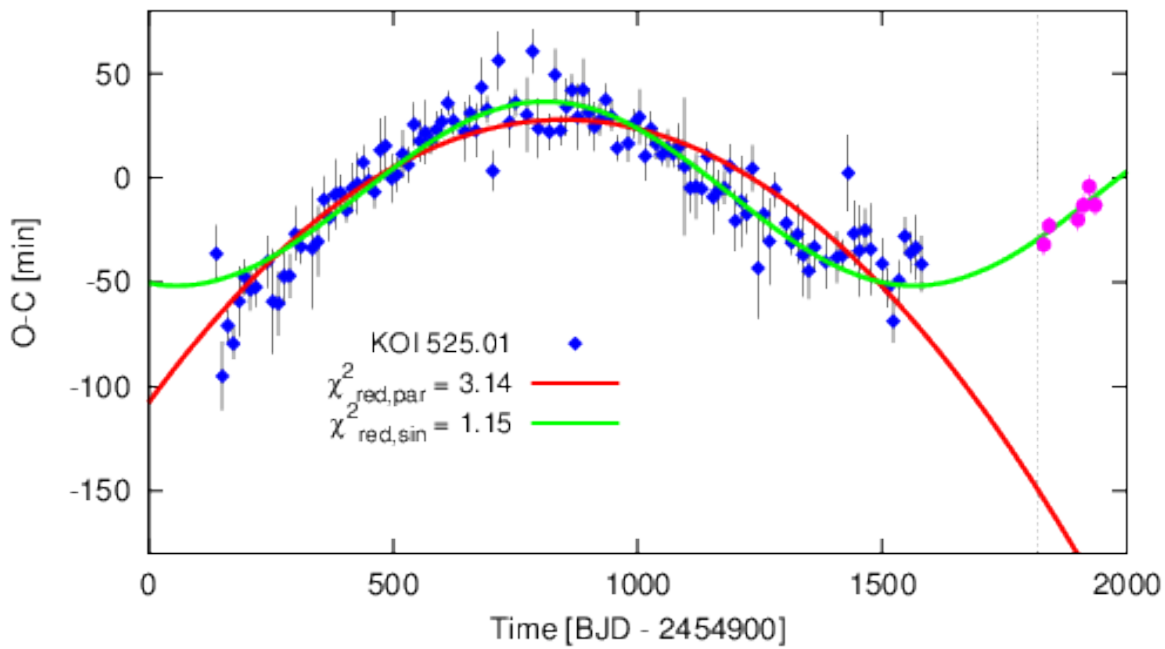
Lalitha, Poppenhaeger et al. 2014



XUV flux at planetary orbit: $\approx$ 2000 erg/s/cm^2
at least 5 times higher than for evaporating Hot Jupiter HD 209458 b!

Constraining exoplanet masses: KOINet

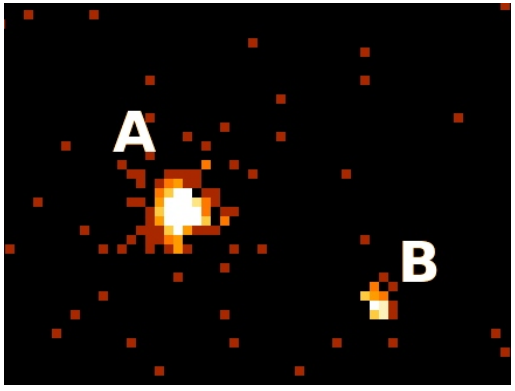


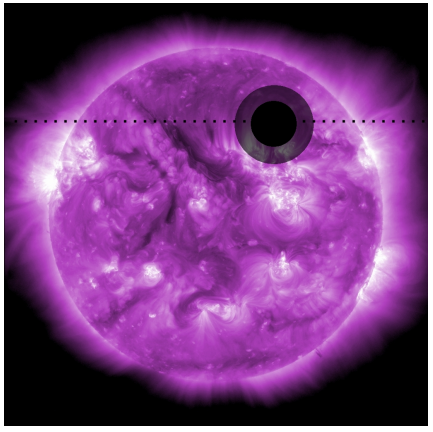


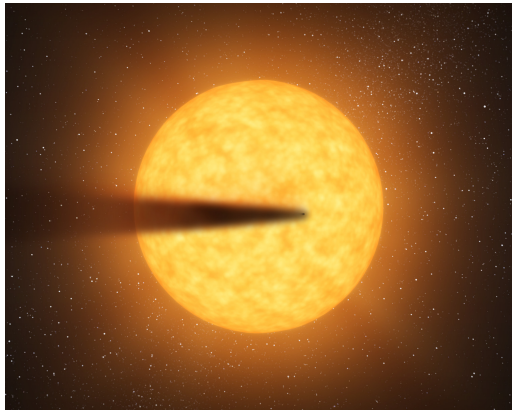
PI: C. von Essen, Aarhus University

http://koinet.astro.physik.uni-goettingen.de

Stellar magnetic activity and exoplanets







- activity biases in exoplanet host star samples
- tidal / flare triggering interactions of planets and stars?
- need activity-independent age estimates to identify outliers
- exoplanets: X-ray/UV-driven evaporation