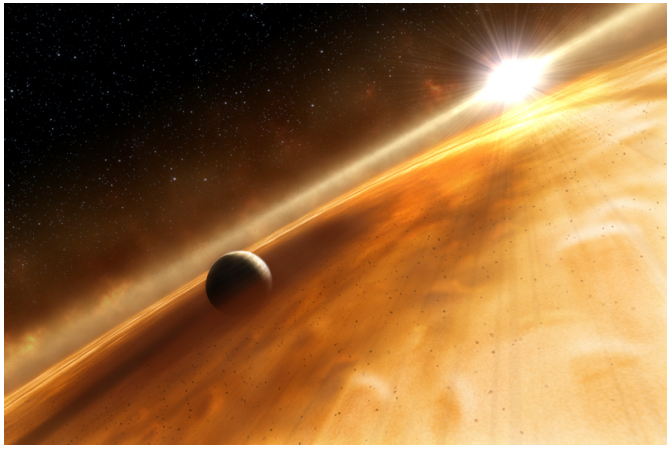
Extrasolar planets and their hosts:

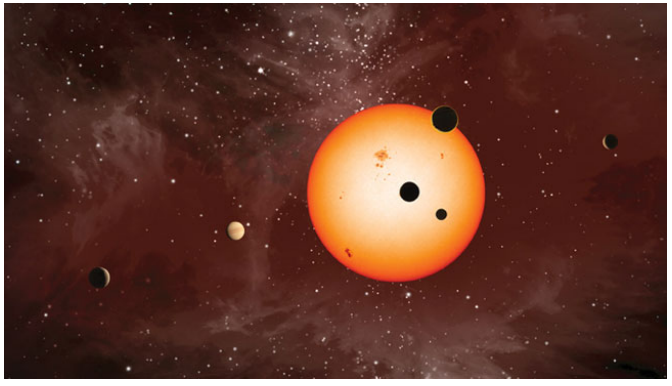
Why exoplanet science needs X-ray observations

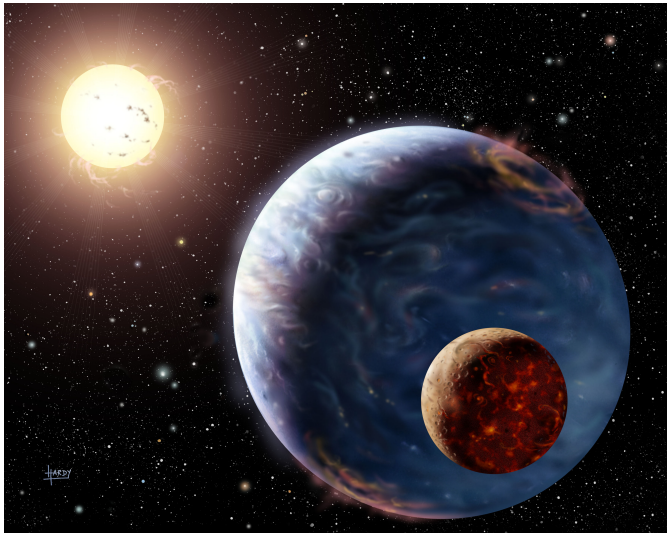
Dr. Katja Poppenhaeger
Sagan Fellow

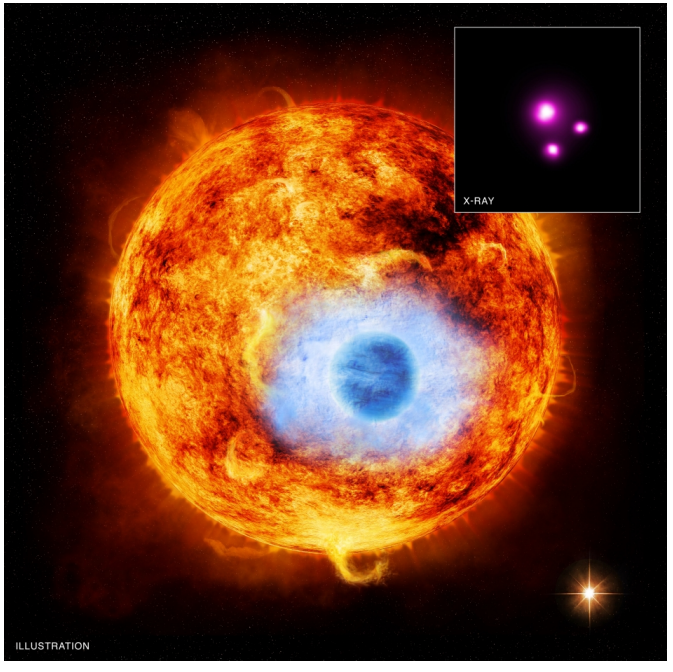
Harvard-Smithsonian Center for Astrophysics

Exoplanets

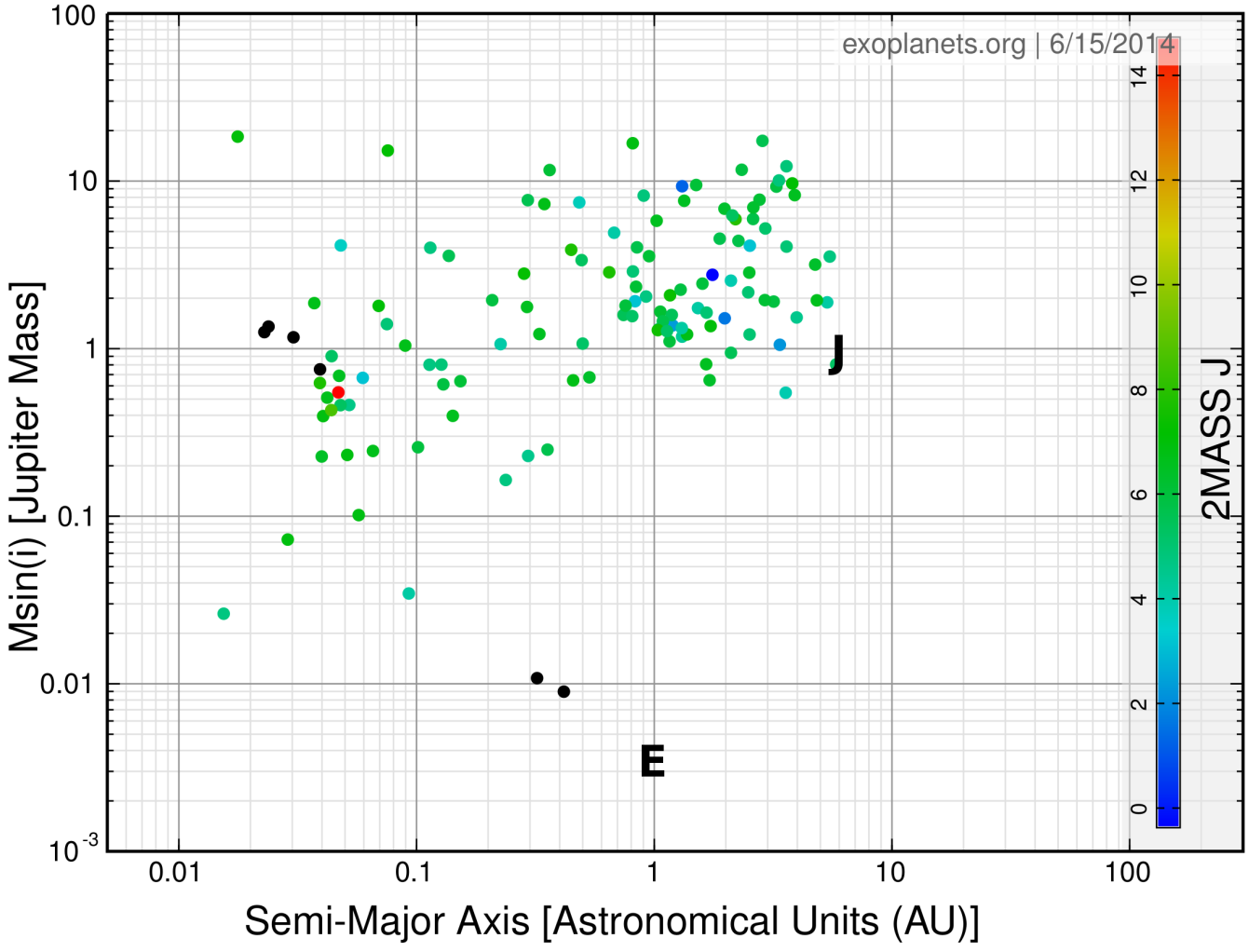






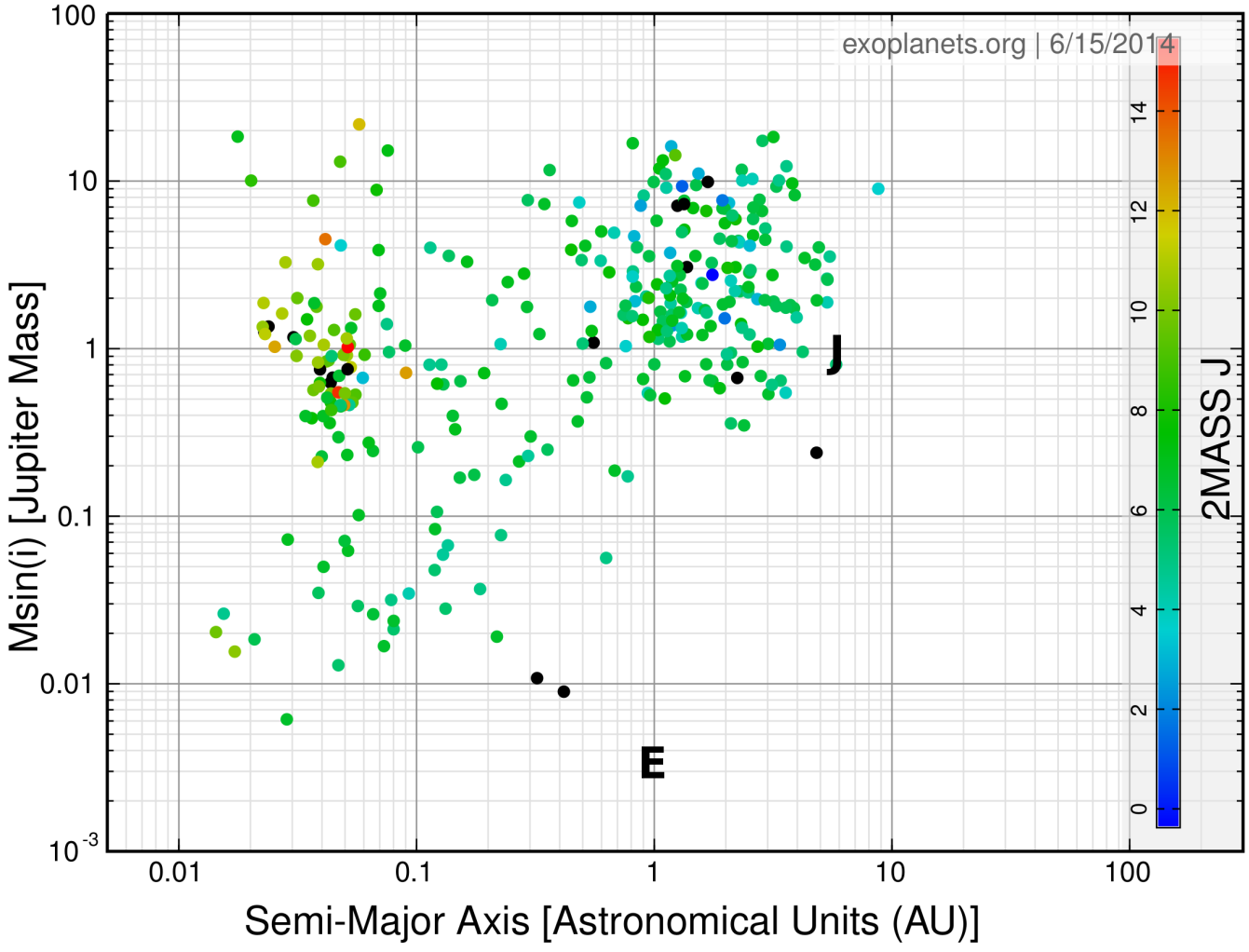


Exoplanets in 2005



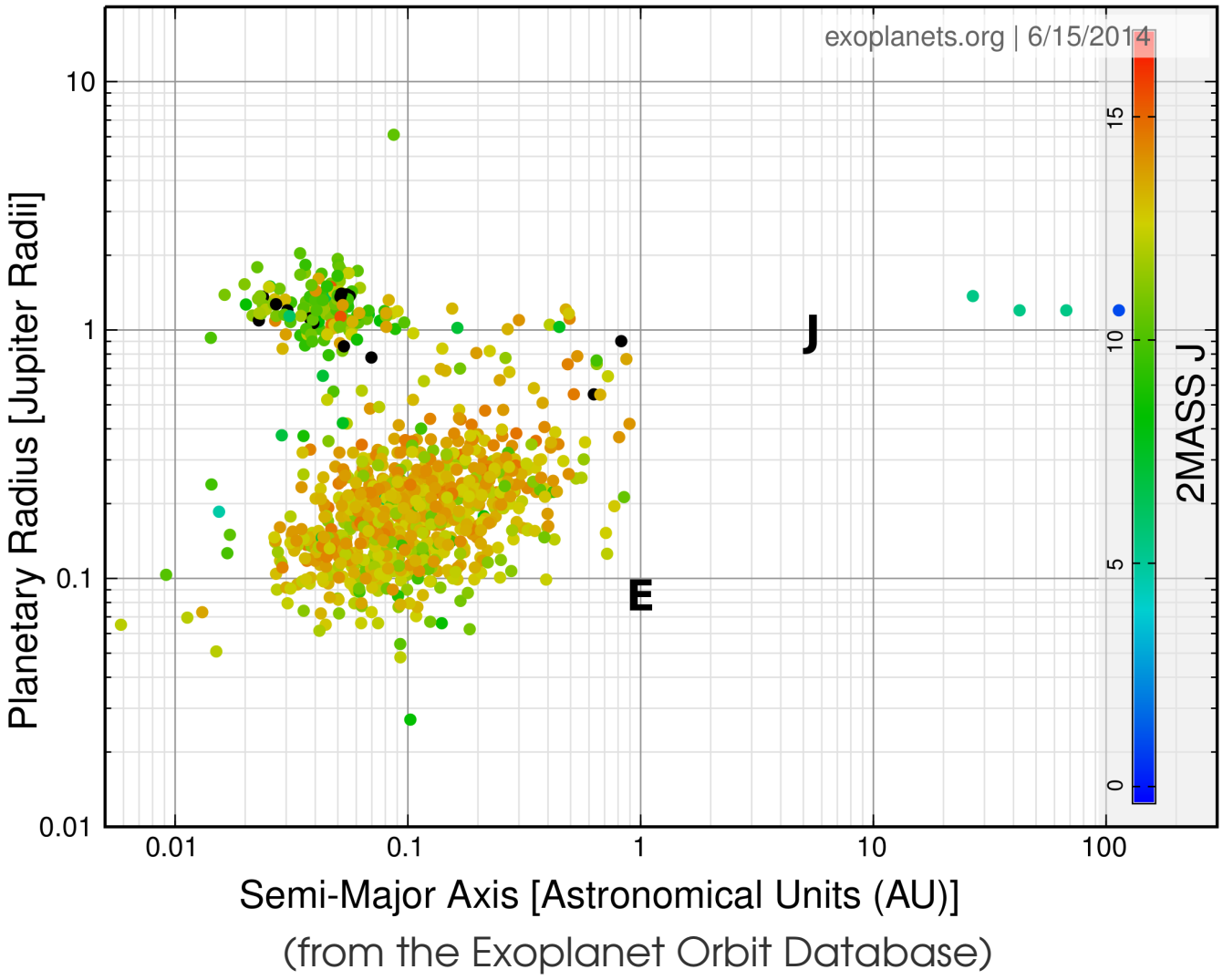
(from the Exoplanet Orbit Database)

Exoplanets in 2010



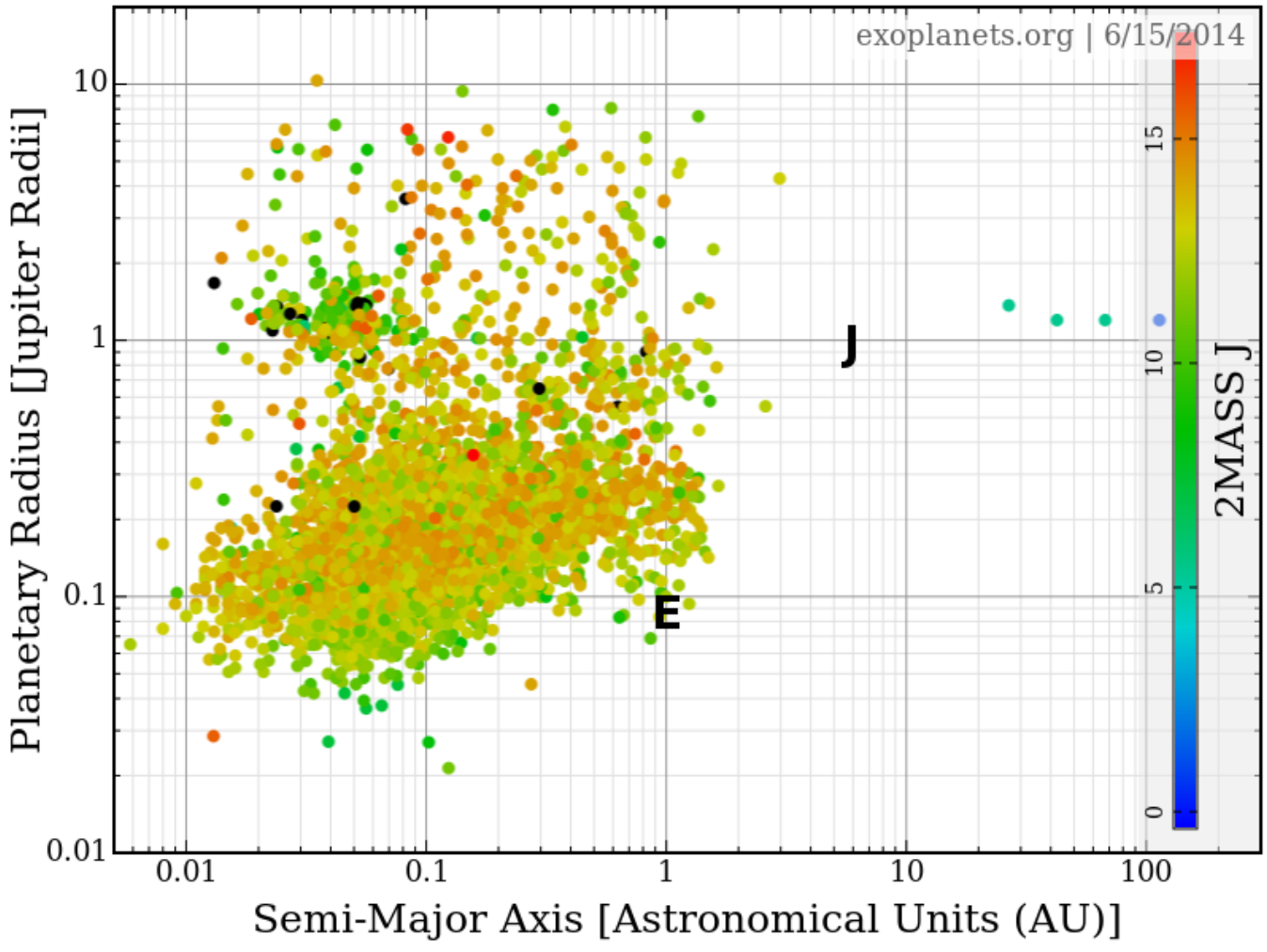
(from the Exoplanet Orbit Database)

Exoplanets in 2014



(from the Exoplanet Orbit Database)

Exoplanets in 2014, including Kepler candidates



(from the Exoplanet Orbit Database)

Exoplanets at AAS

Winter meetings of the American Astronomical Society:
press releases:
exoplanets vs. everything else

AAS 2011 Seattle:	11% (4/38)
AAS 2012 Austin:	12% (4/34)
AAS 2013 Long Beach:	29% (13/45)
AAS 2014 National Harbor:	31% (9/29)

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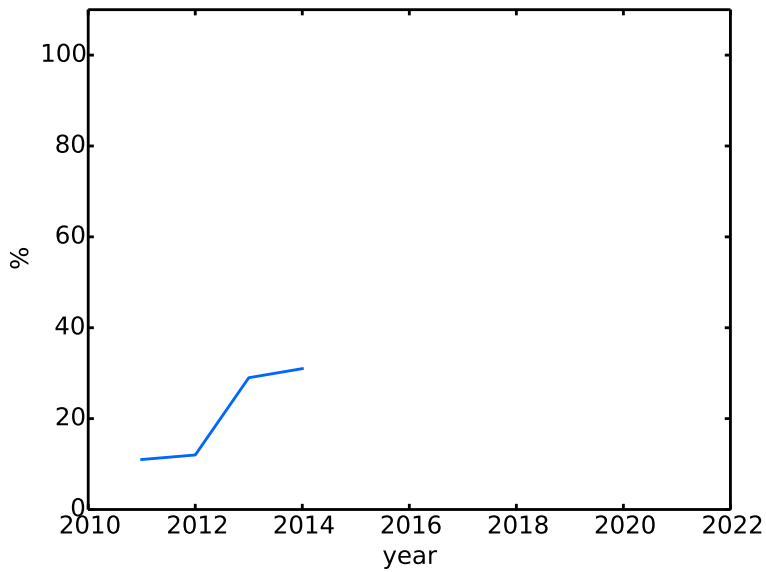

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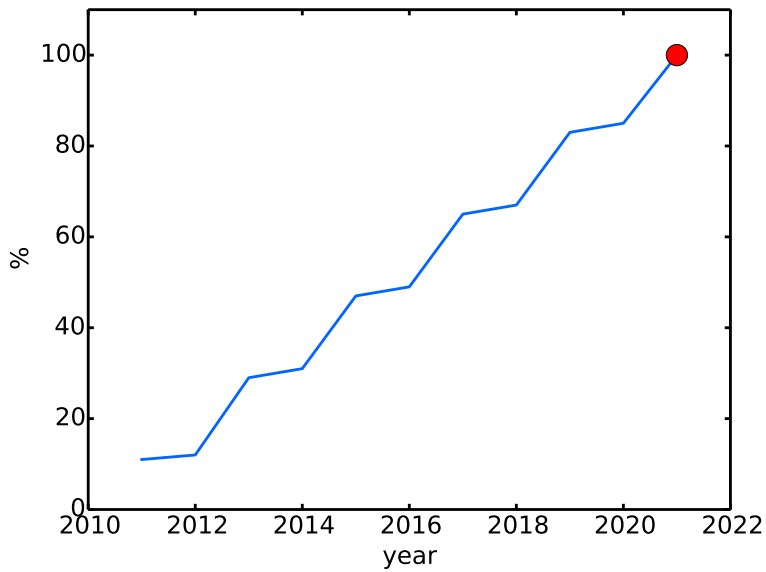
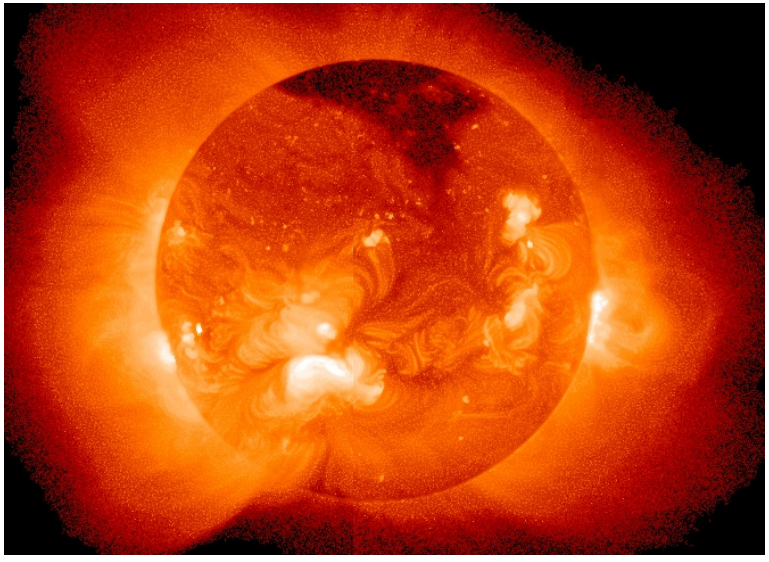
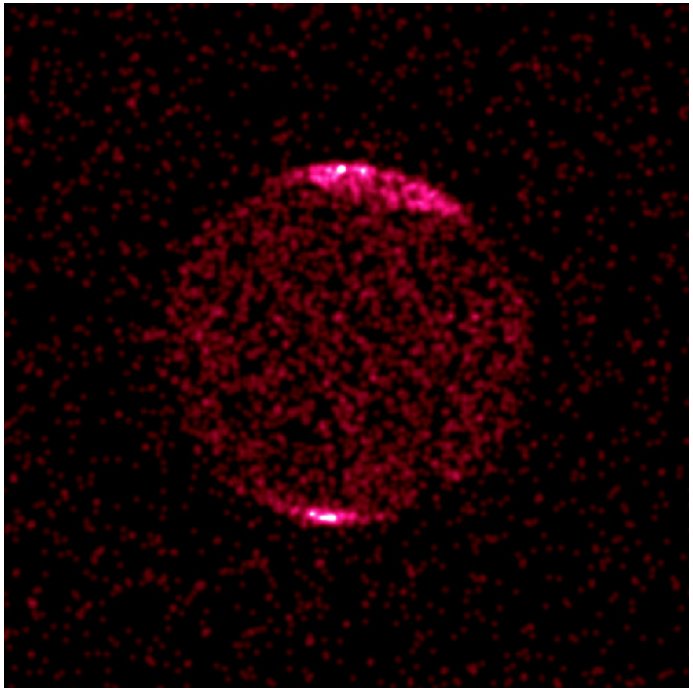


X-ray emission in exoplanet systems

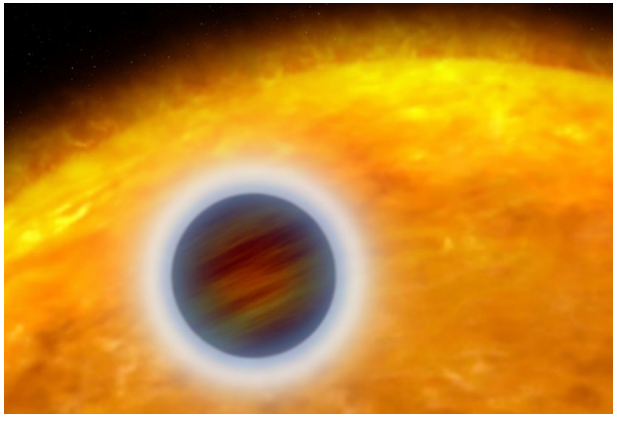


central star (if cool star):
magnetic activity, flares



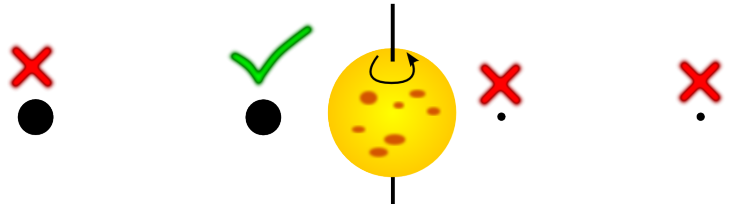
planets:
aurorae, charge exchange

Stellar high-energy emission

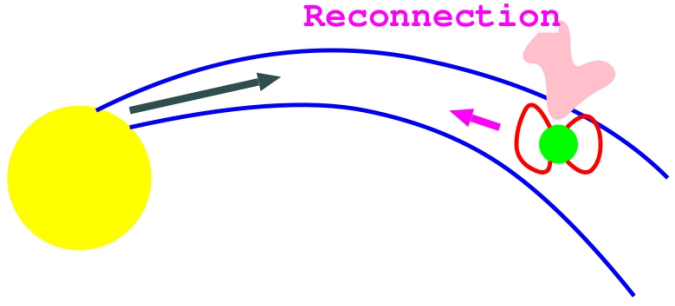


planetary atmospheres: use star as background candle

planetary mass loss: stellar high-energy emission is driver for evaporation

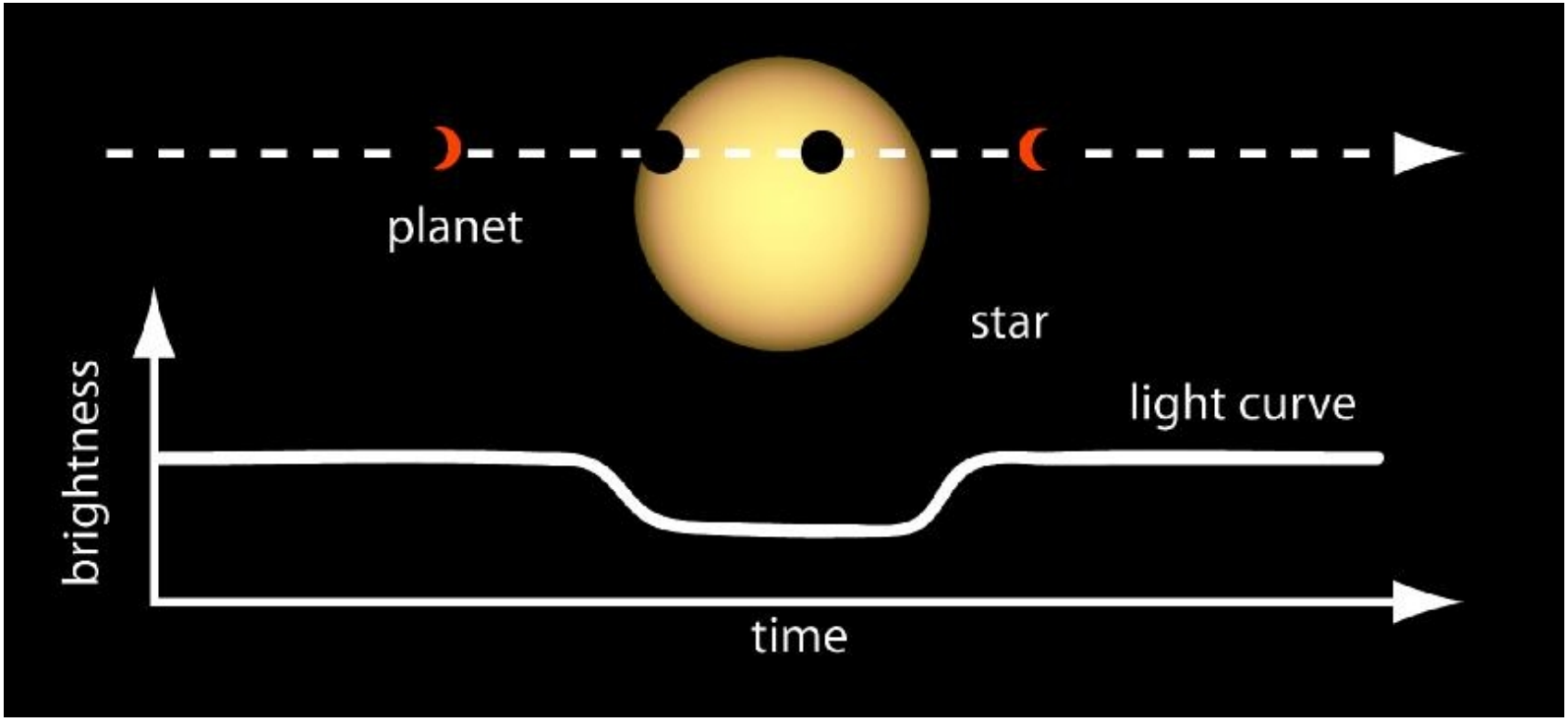


stellar magnetic activity biases planet detections



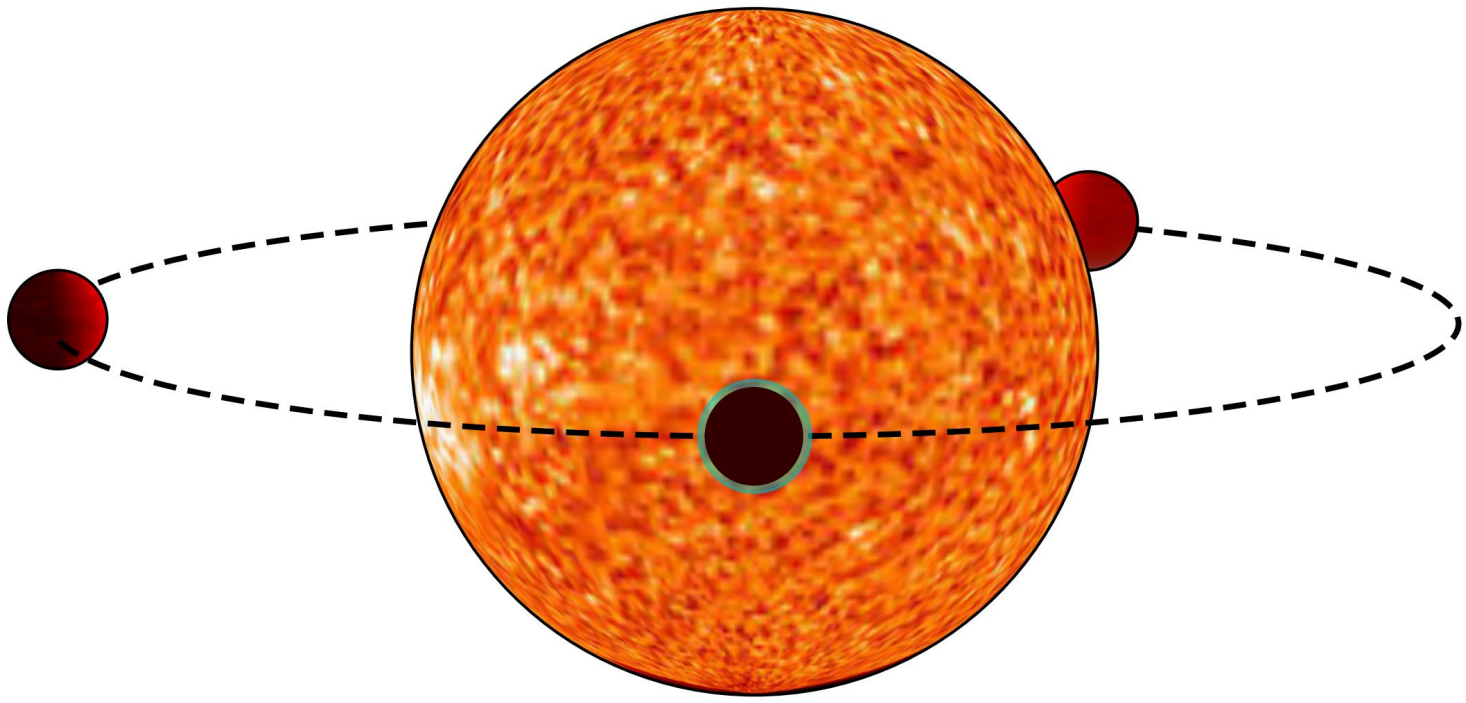
interactions of planets with stellar rotation/activity

Exoplanets: transits



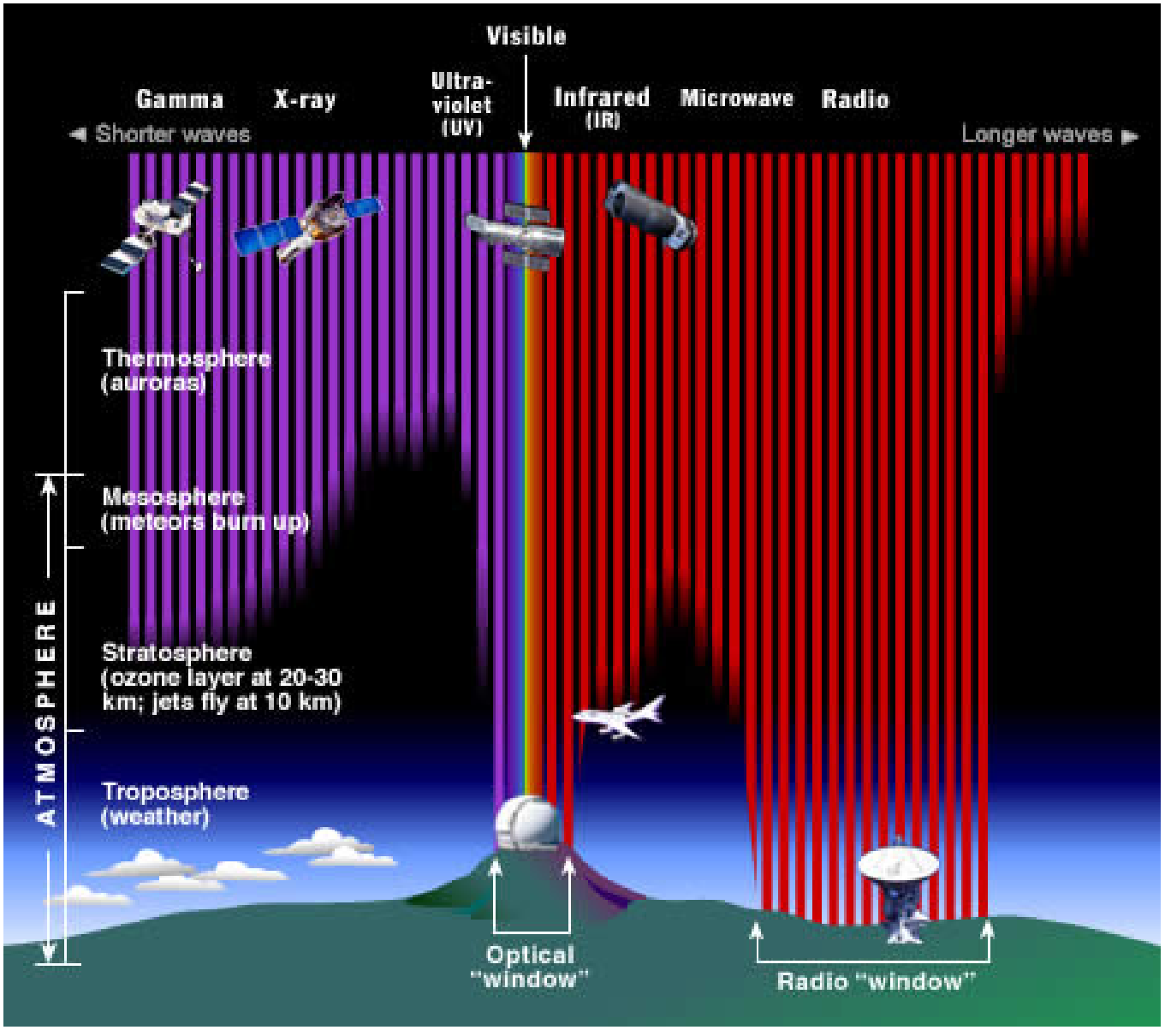
picture credit: NASA

Exoplanet atmospheres: transmission spectroscopy



K. B. Stevenson

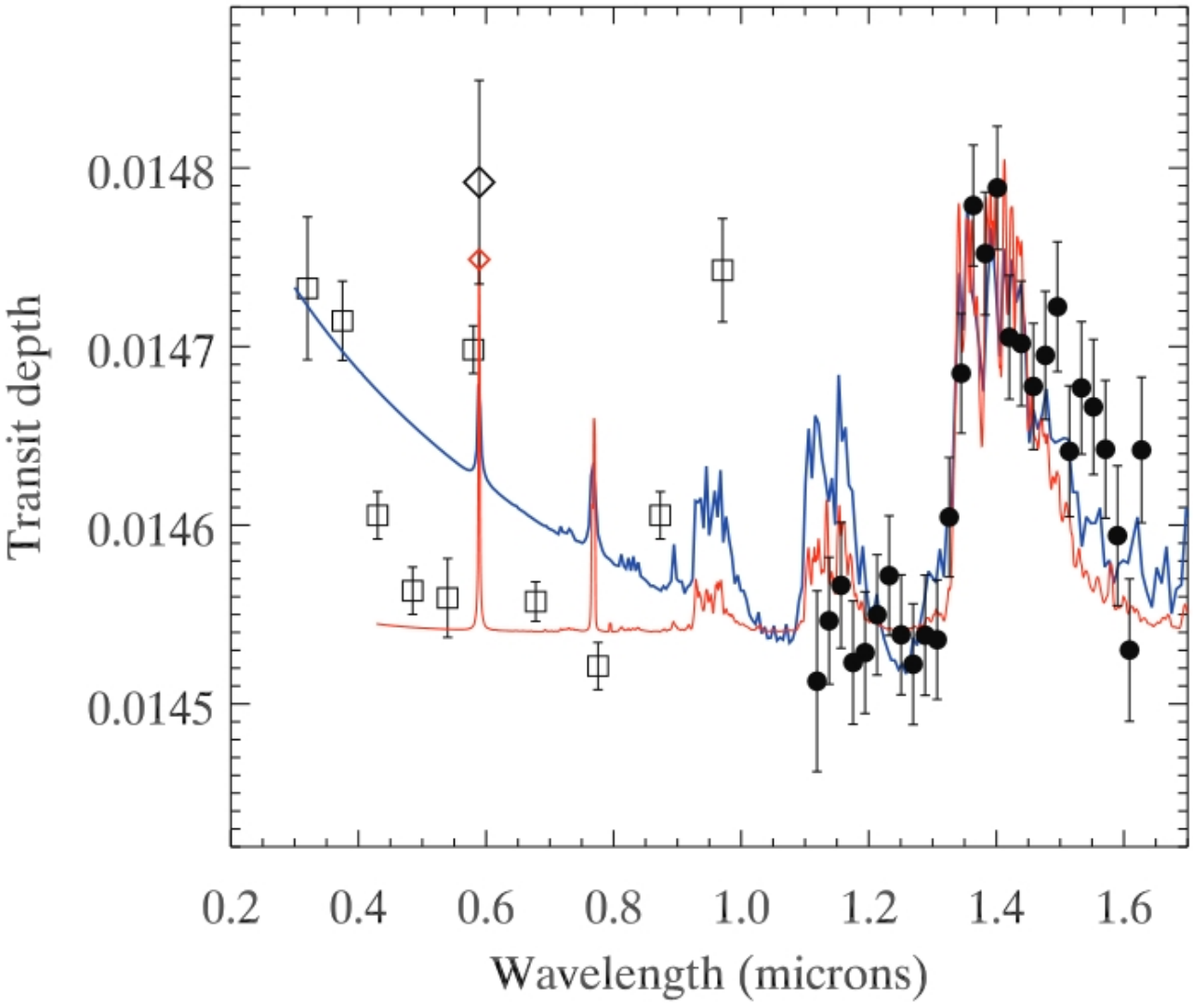
Exoplanet atmospheres: transmission spectroscopy



picture credit: NASA

Exoplanet atmospheres: transmission spectroscopy

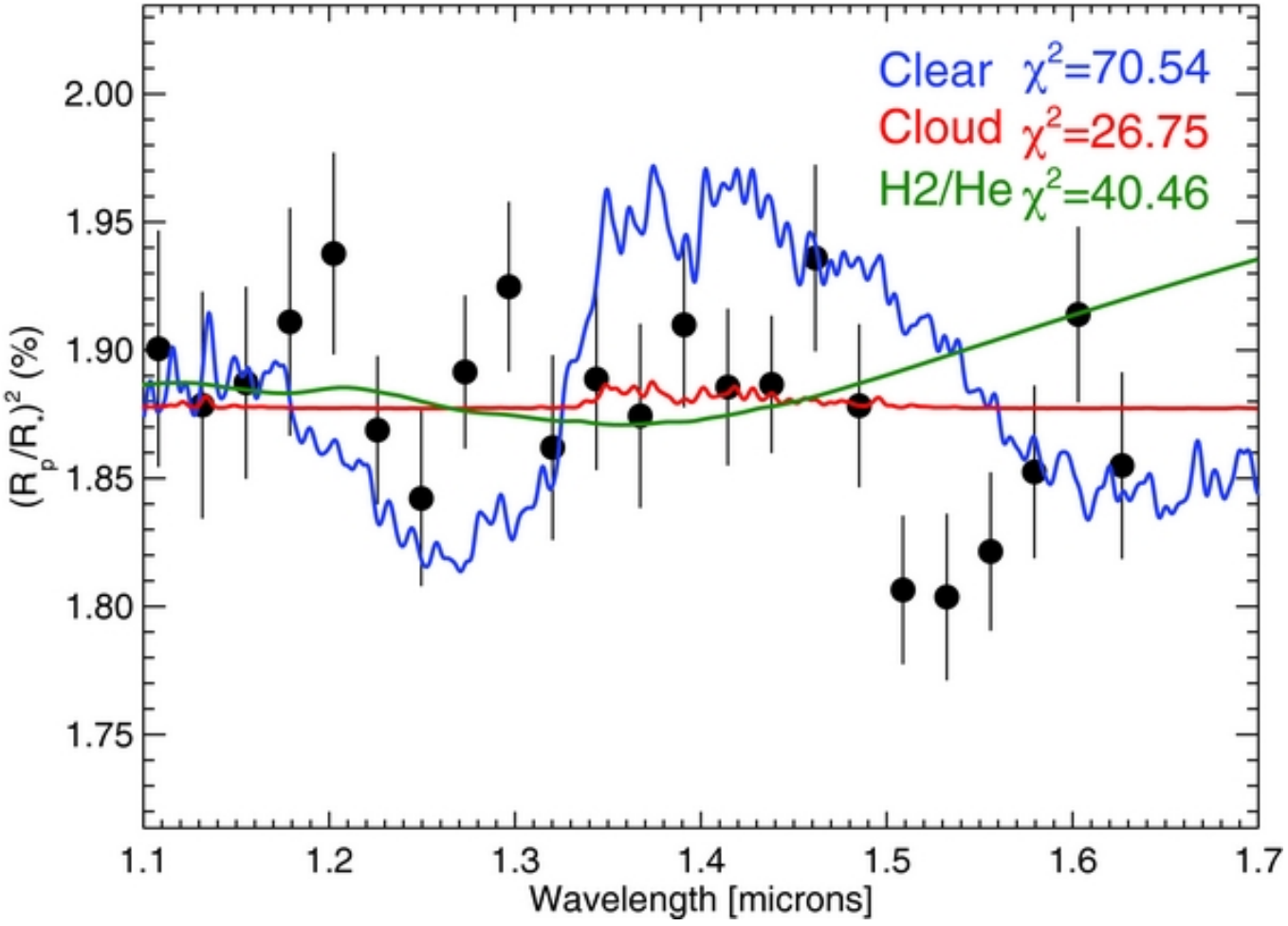
HD 209458b (hot Jupiter)



Deming et al. 2013

Exoplanet atmospheres: cloud layers

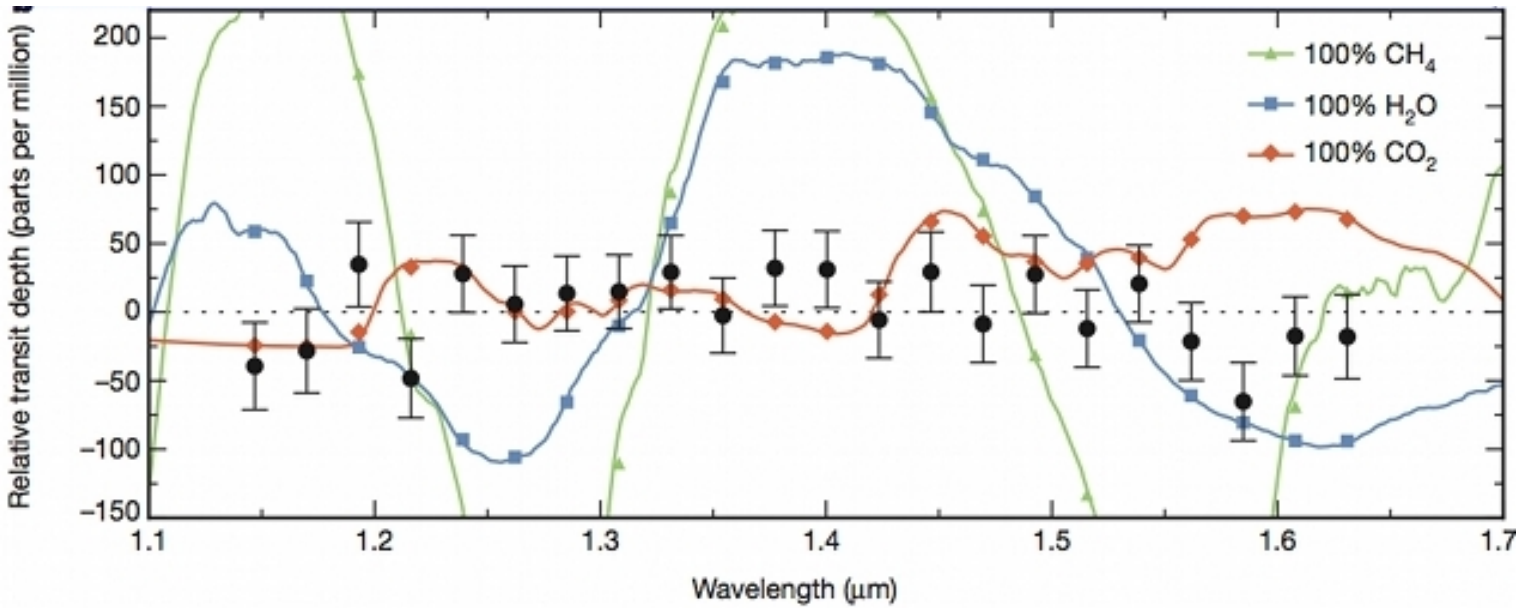
HAT-P-12b (warm Saturn)



Line et al. 2013

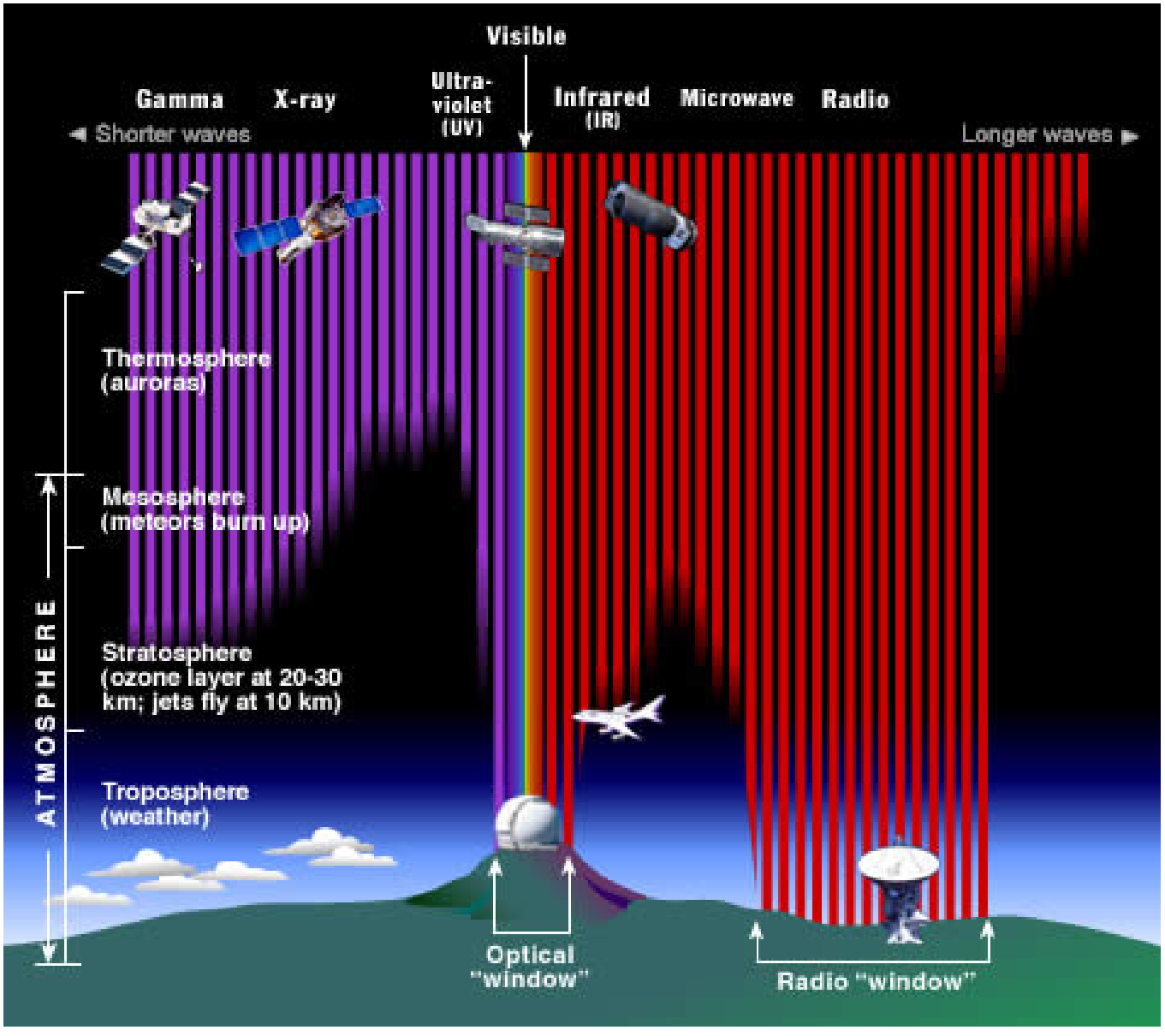
Exoplanet atmospheres: cloud layers

GJ 1214b (super-earth)



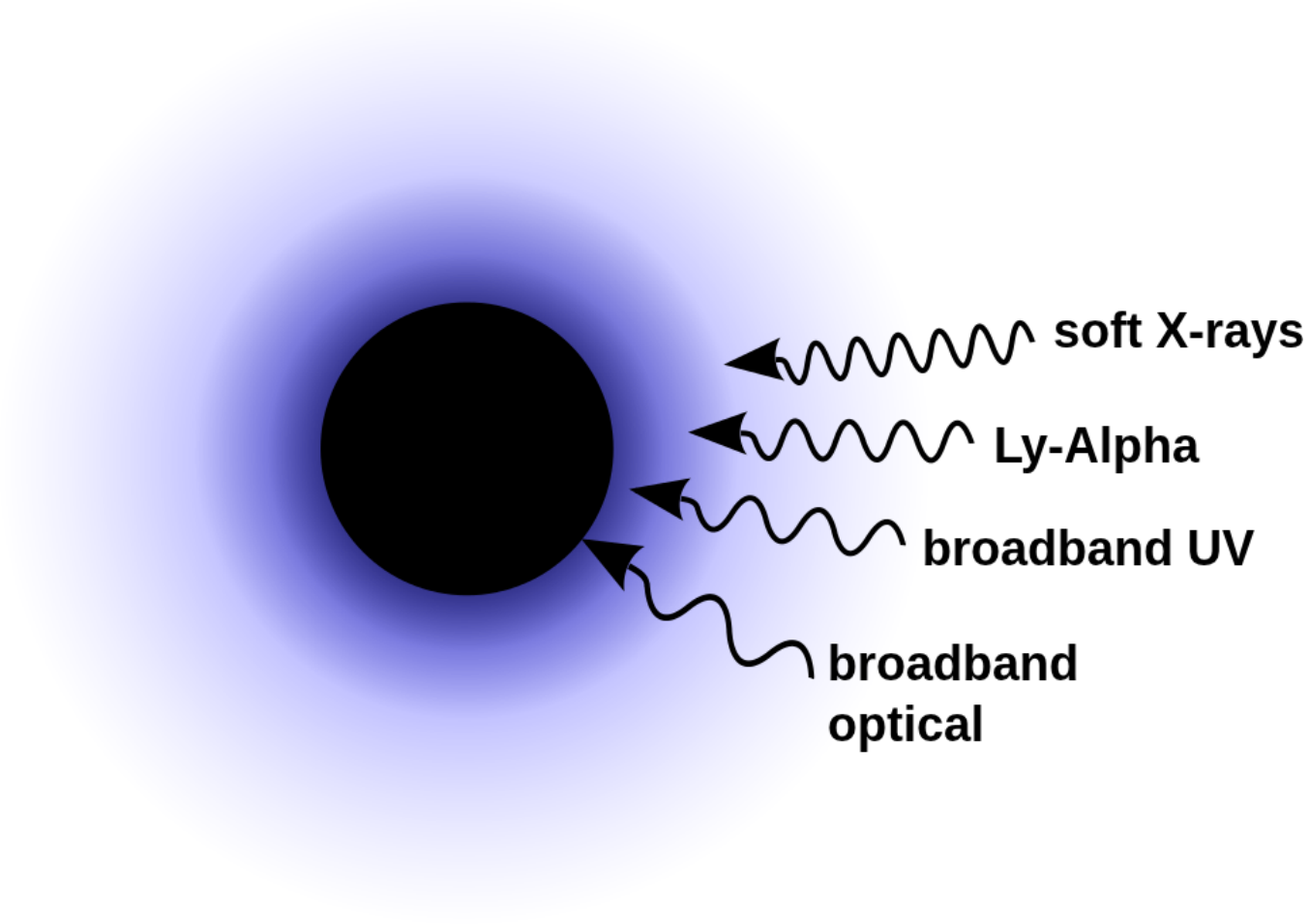
Kreidberg et al. 2014

Exoplanet atmospheres: transmission spectroscopy



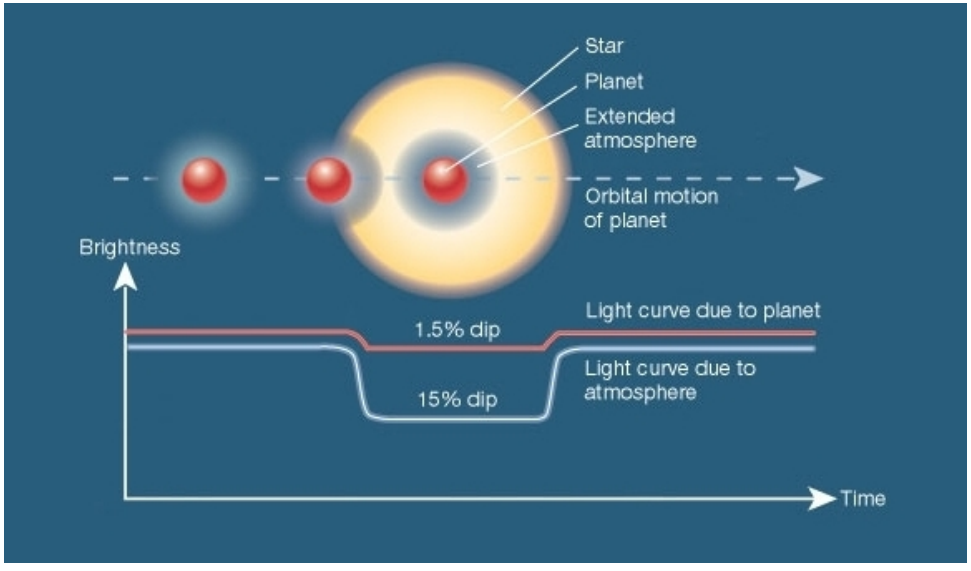
picture credit: NASA

Exoplanet atmospheres: outer layers



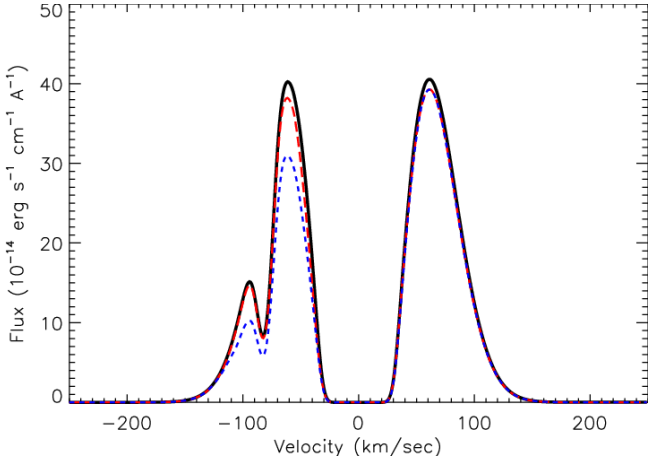
Poppenhaeger et al. 2013

Exoplanet atmospheres: outer layers



picture credit: D. Charbonneau / Nature

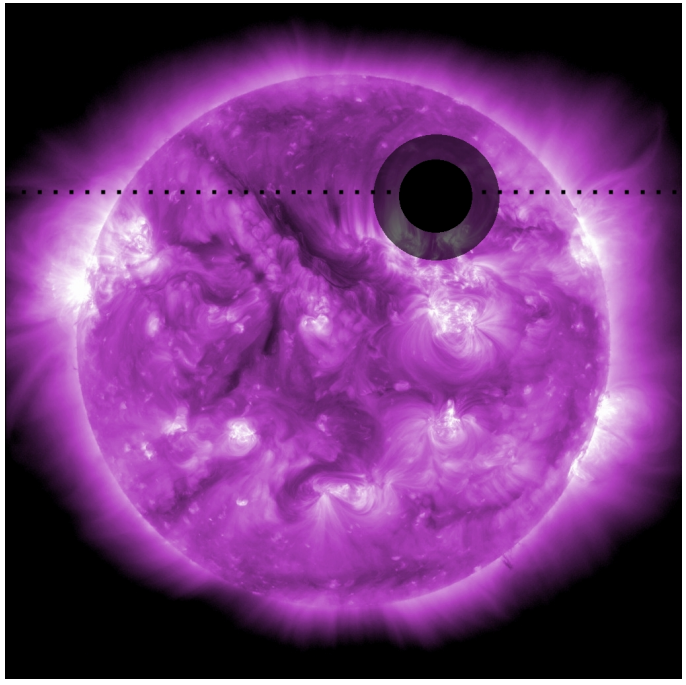
deeper transits

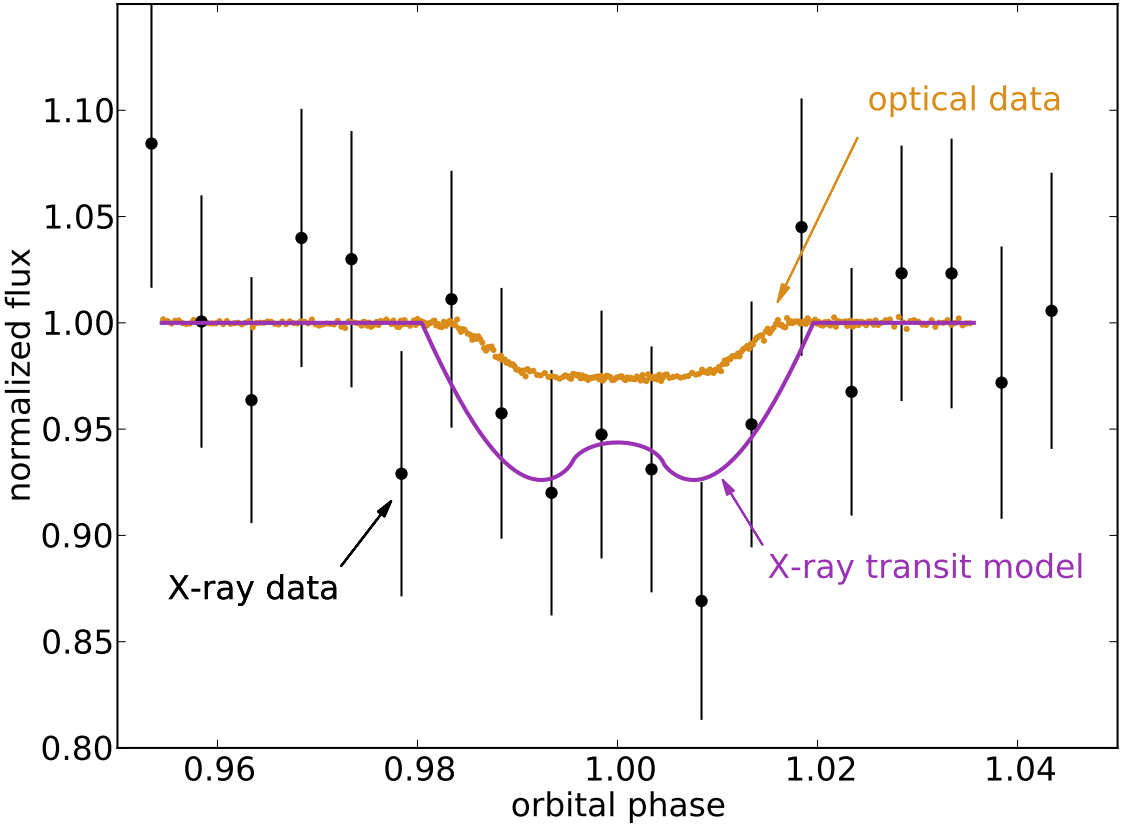


Lecavelier des Etangs et al. 2010

moving (evaporating) atmosphere: line profiles

X-ray transits (hot Jupiter HD 189733b)

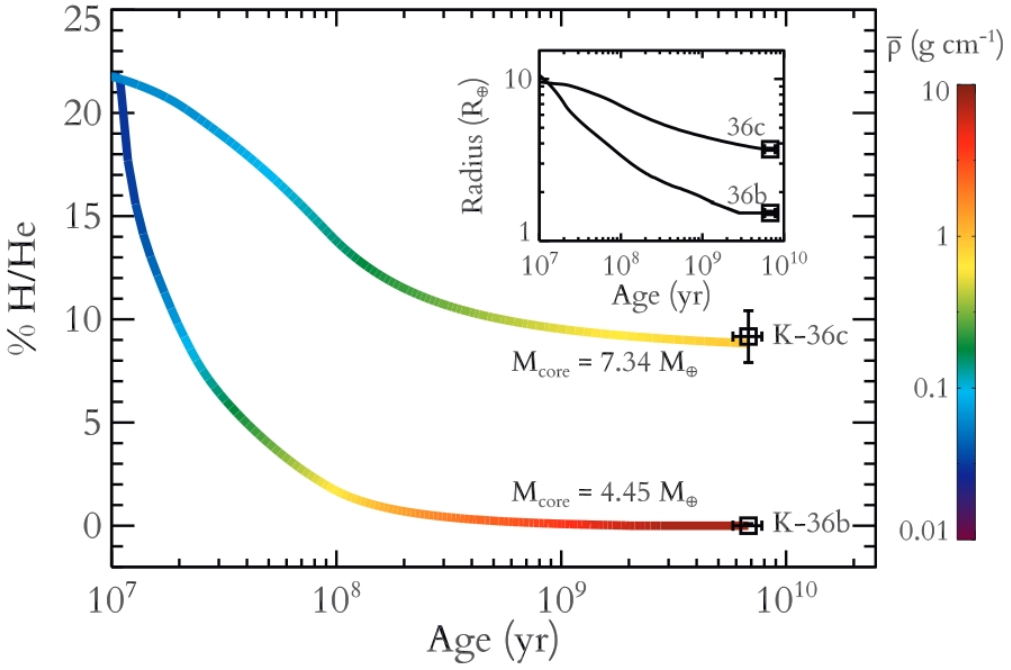




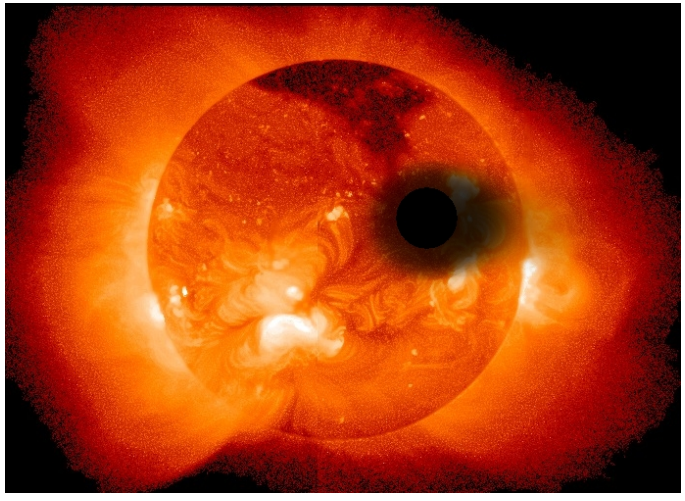
5 X-ray observations co-added, 0.2-2 keV
Poppenhaeger et al., ApJ 2013

Atmospheric evaporation, driven by X-rays and UV

Evaporation of gaseous envelope

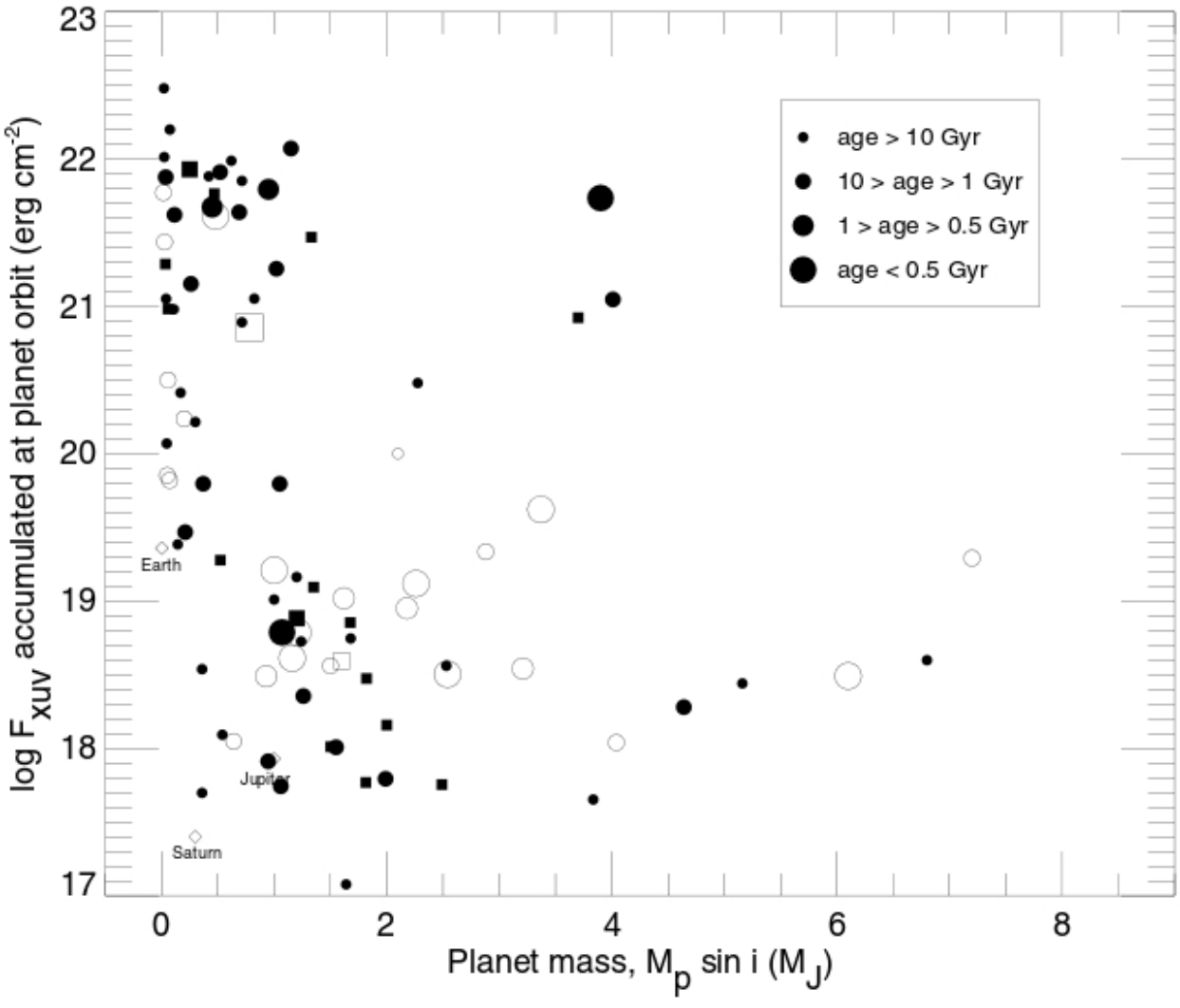


Lopez et al. 2013



YOHKOH/modified by K.P.

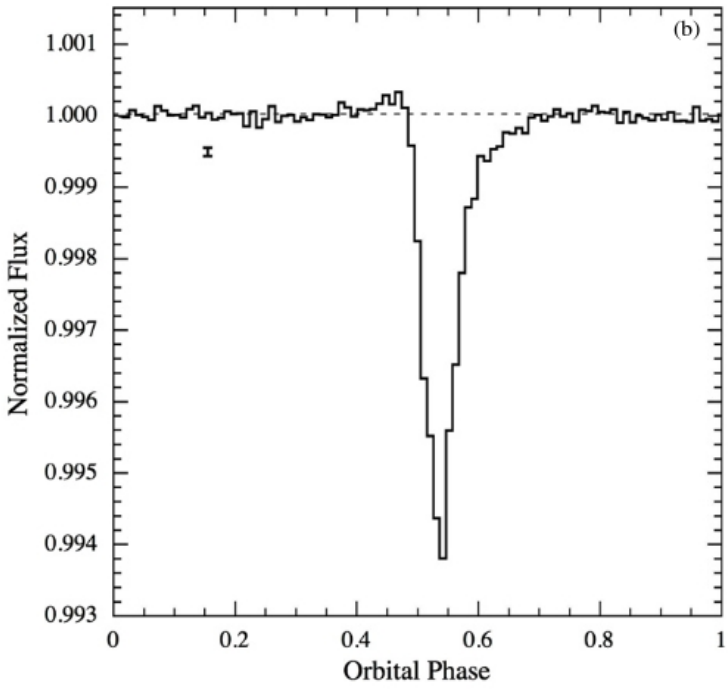
Imprints of evaporation in observed exoplanet population



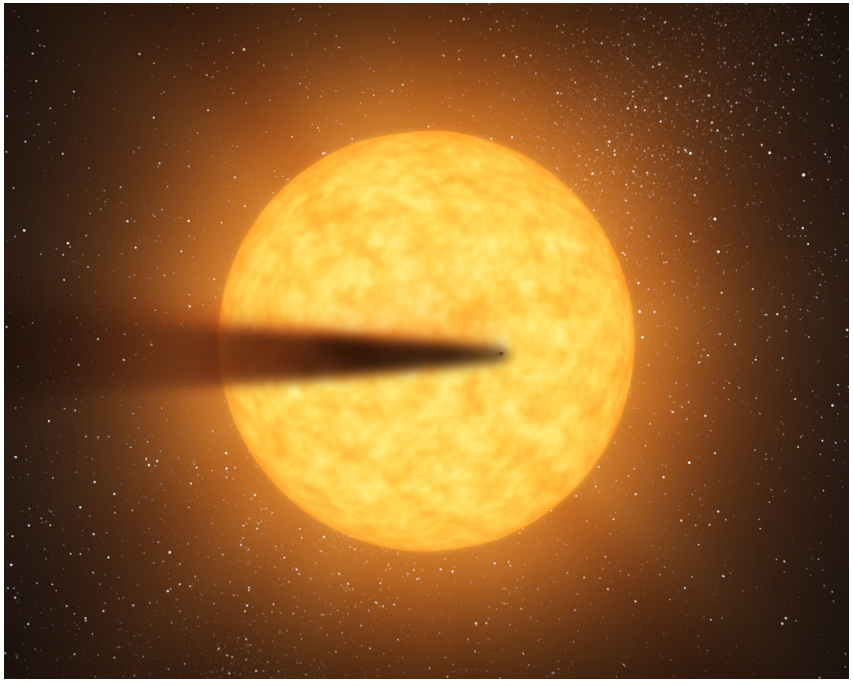
Sanz-Forcada et al. 2011

Evaporating planets - transit profiles

KIC 12557548, dusty tail?

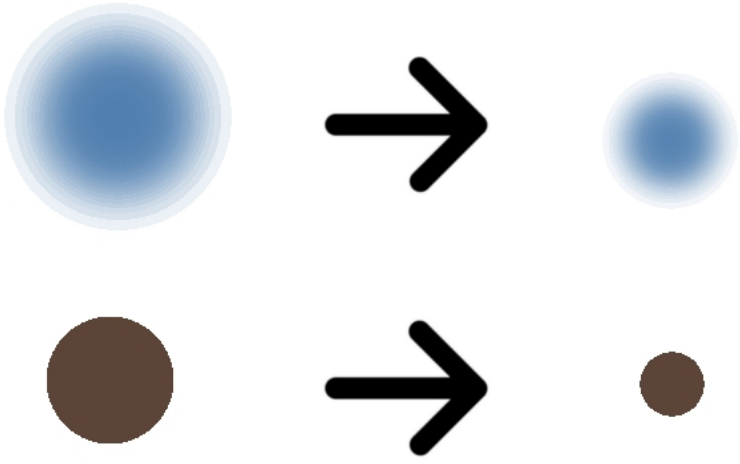


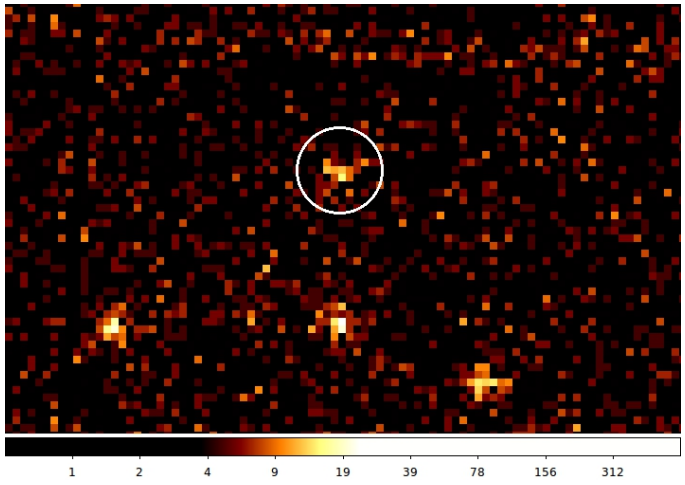
Rappaport et al. 2012



picture credit: NASA/JPL/Caltech

Small planets can lose lots of mass



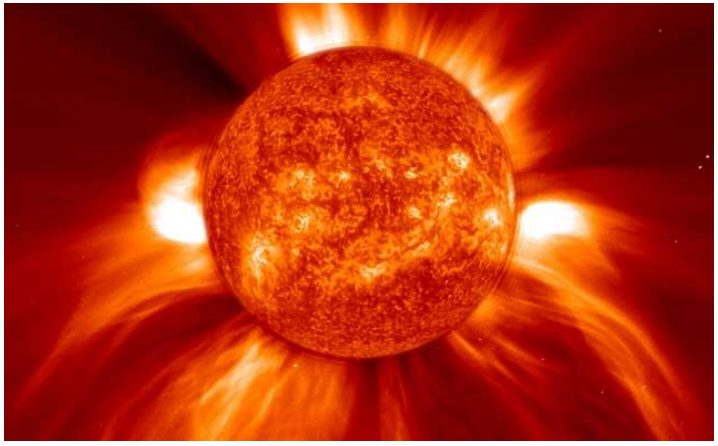


XMM detections of host stars:

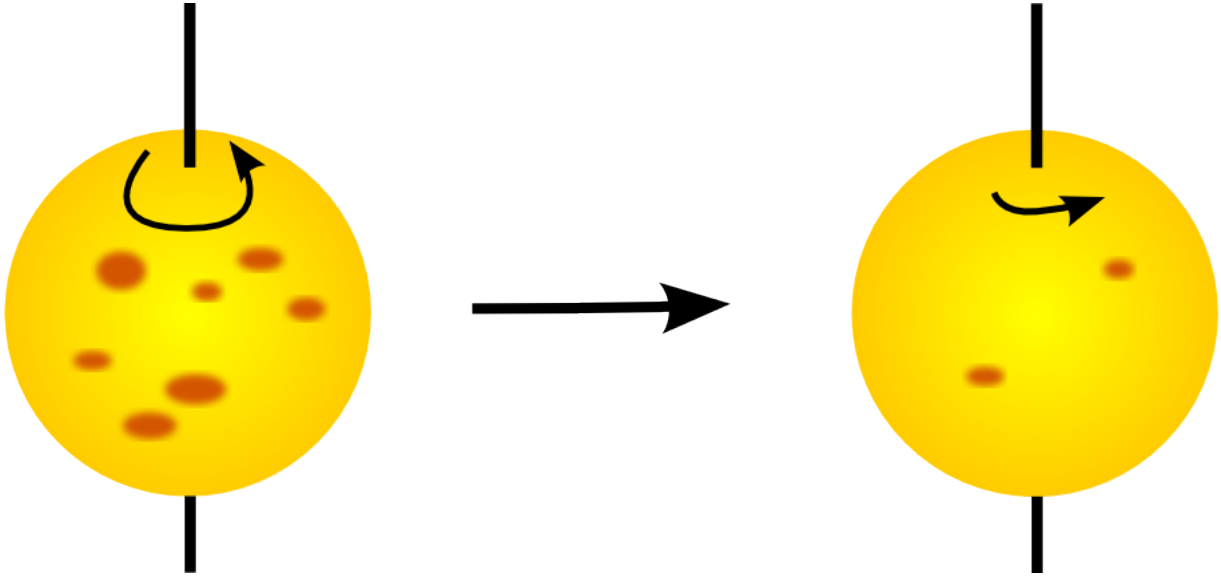
water-planet GJ 1214 b (Lalitha et al. 2014 submitted),
rocky planet CoRoT-7 b (Poppenhaeger et al. 2012)

$\rightarrow$ mixed systems like KOI-314?

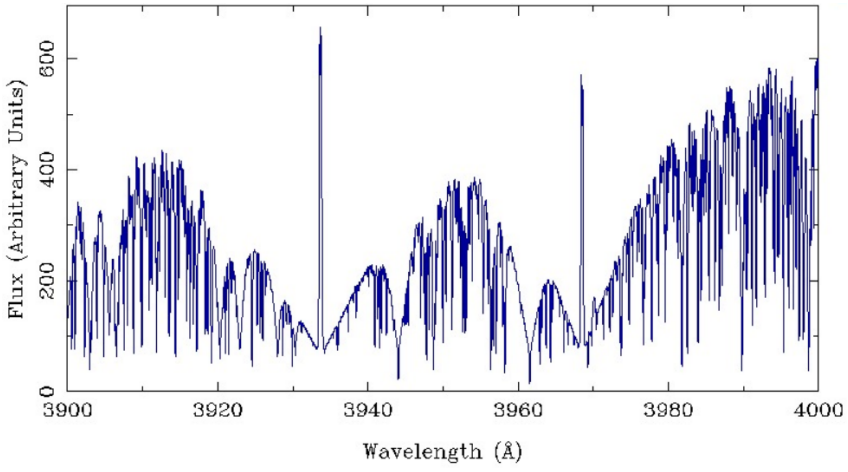
Decline of magnetic activity: magnetic braking

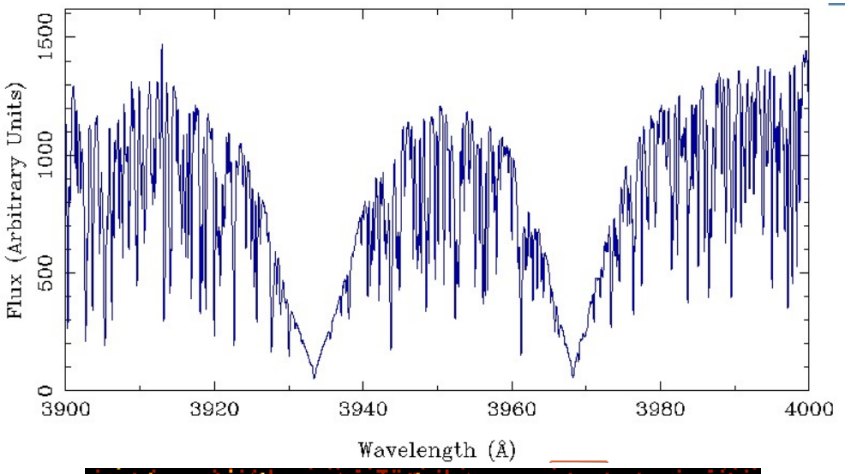


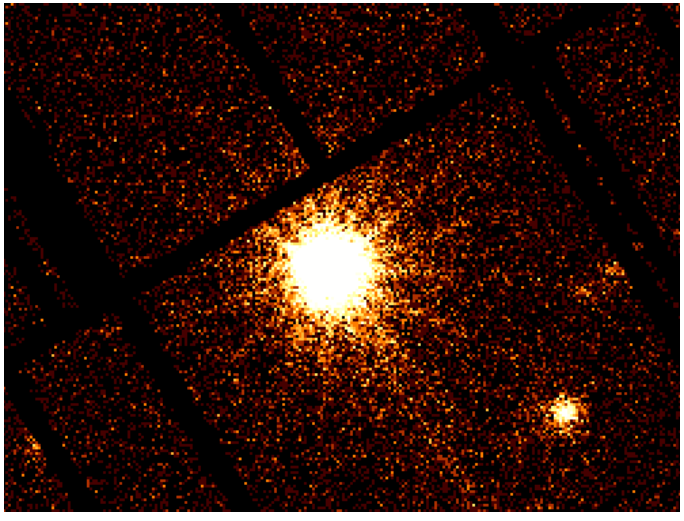
loss of angular momentum through stellar wind

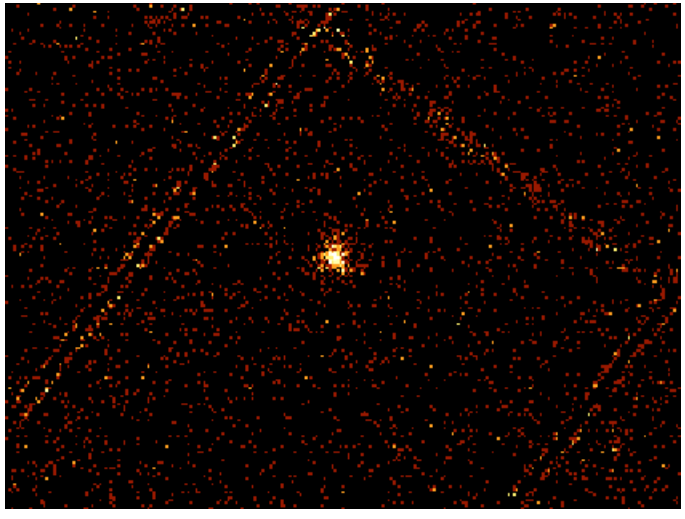


Activity decline with stellar age



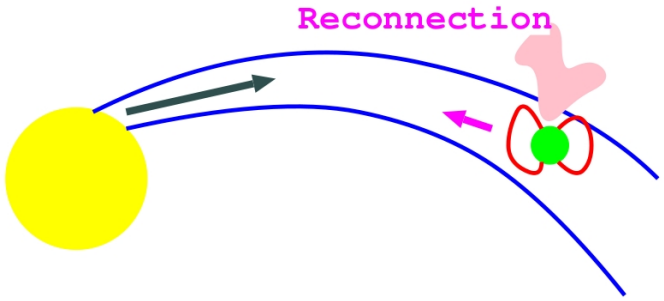






Star-planet interaction
(template: star-star interaction in close binaries)

2 basic scenarios:



magnetic

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

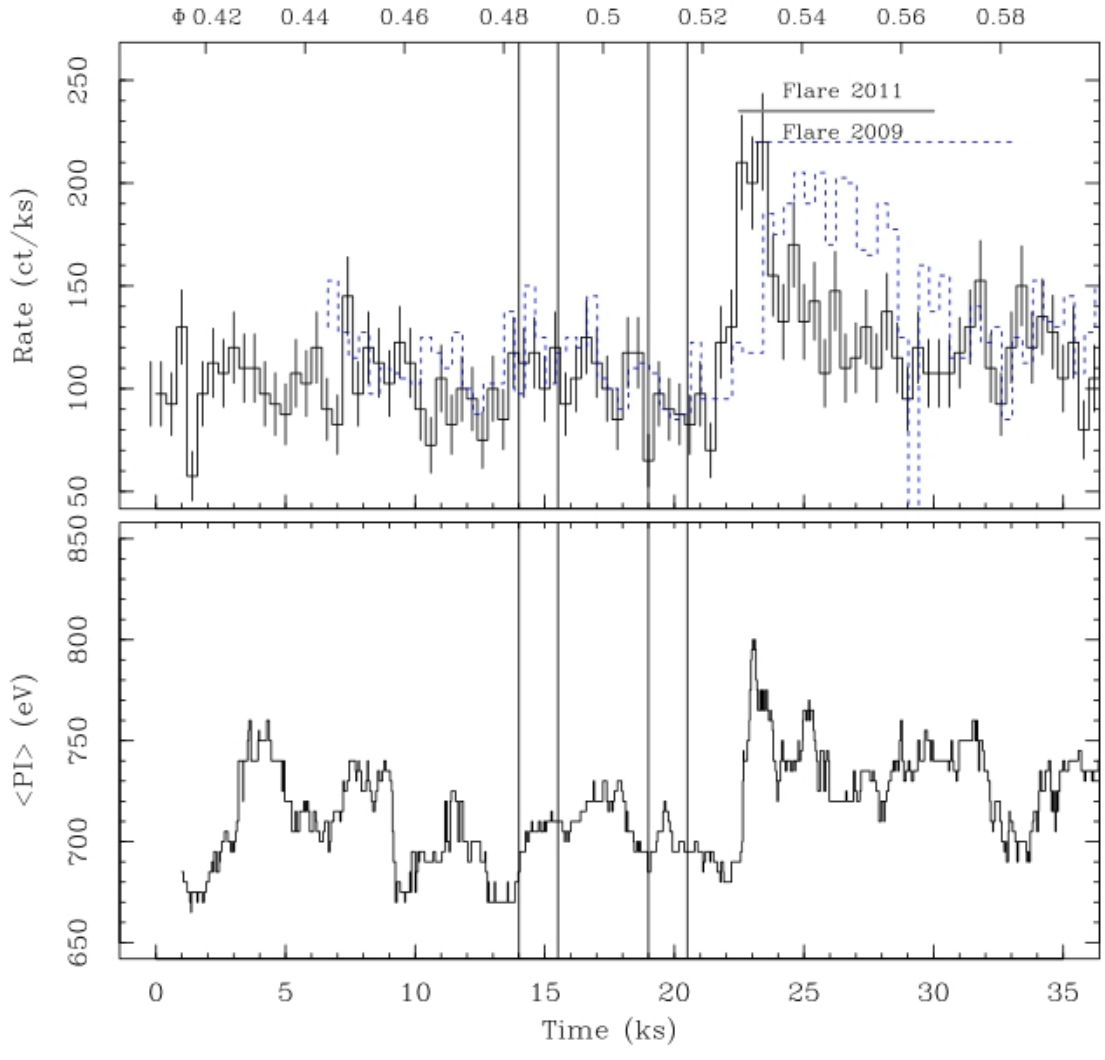
tidal

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

picture credit: Shkolnik et al. 2009

Individual planet-host stars: Flare triggering?

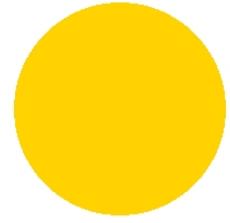
HD 189733b (hot Jupiter)



Pillitteri et al. 2011

Stellar samples: planet-induced activity enhancements?

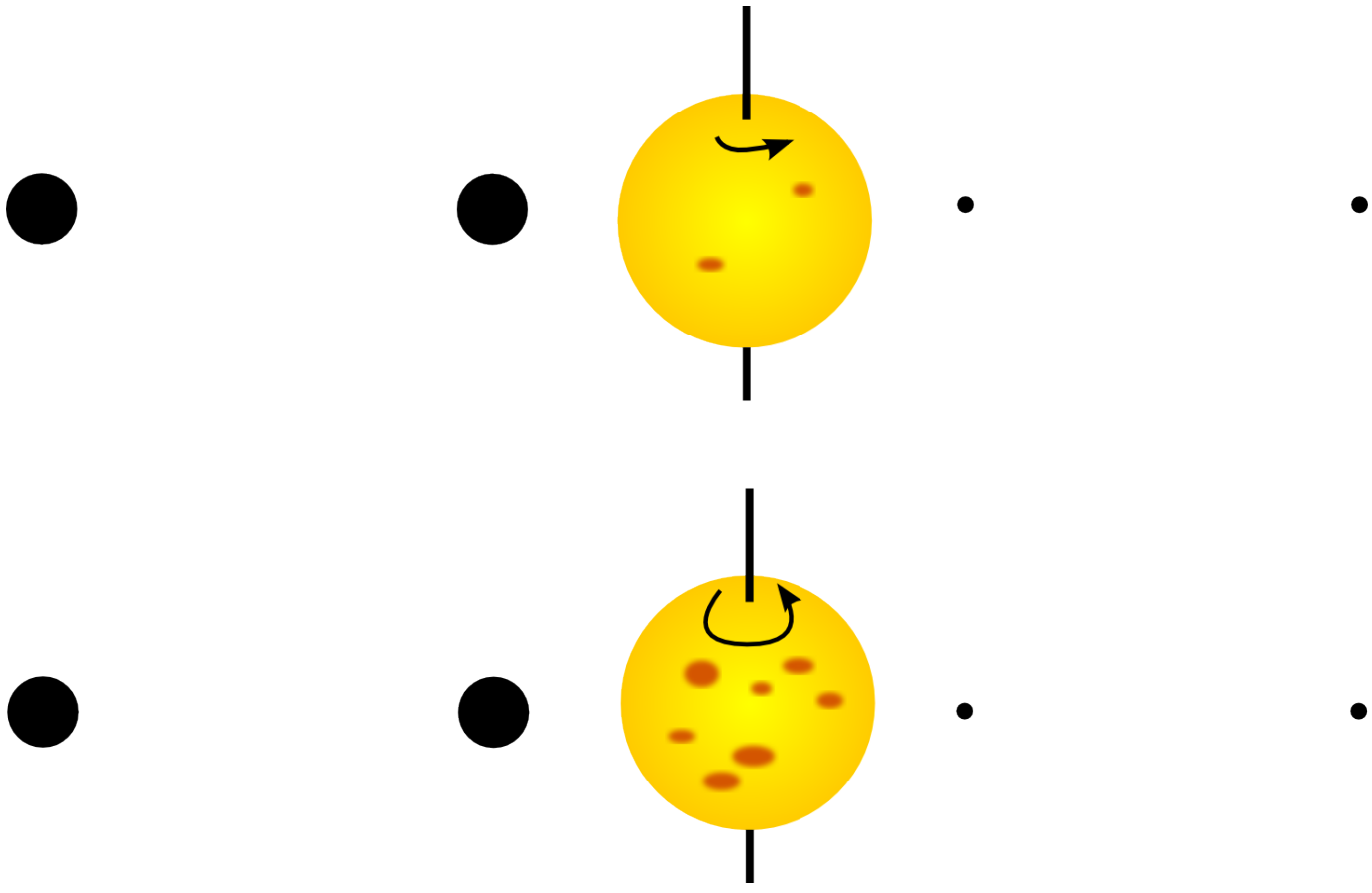
high activity?



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!

Dealing with selection effects



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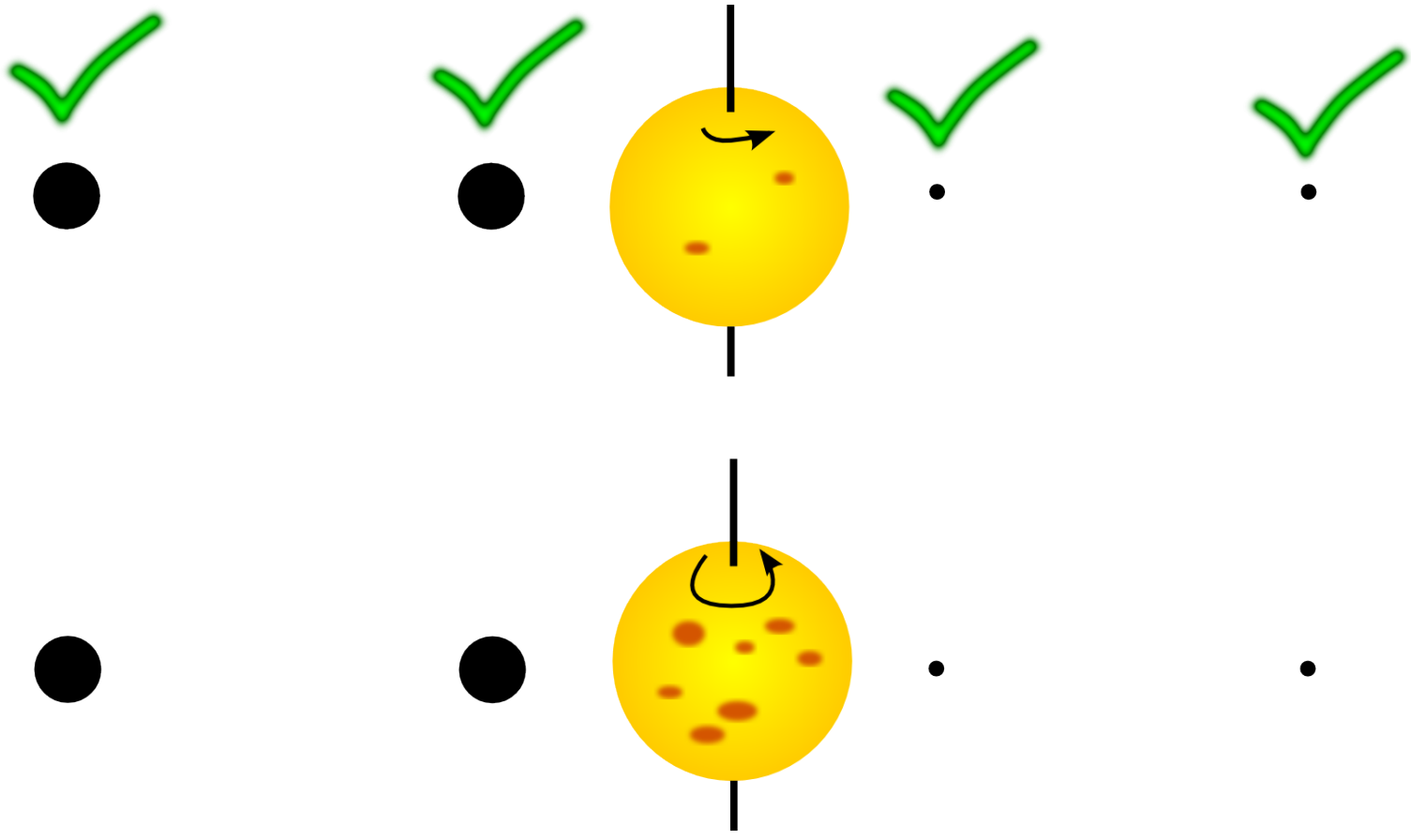

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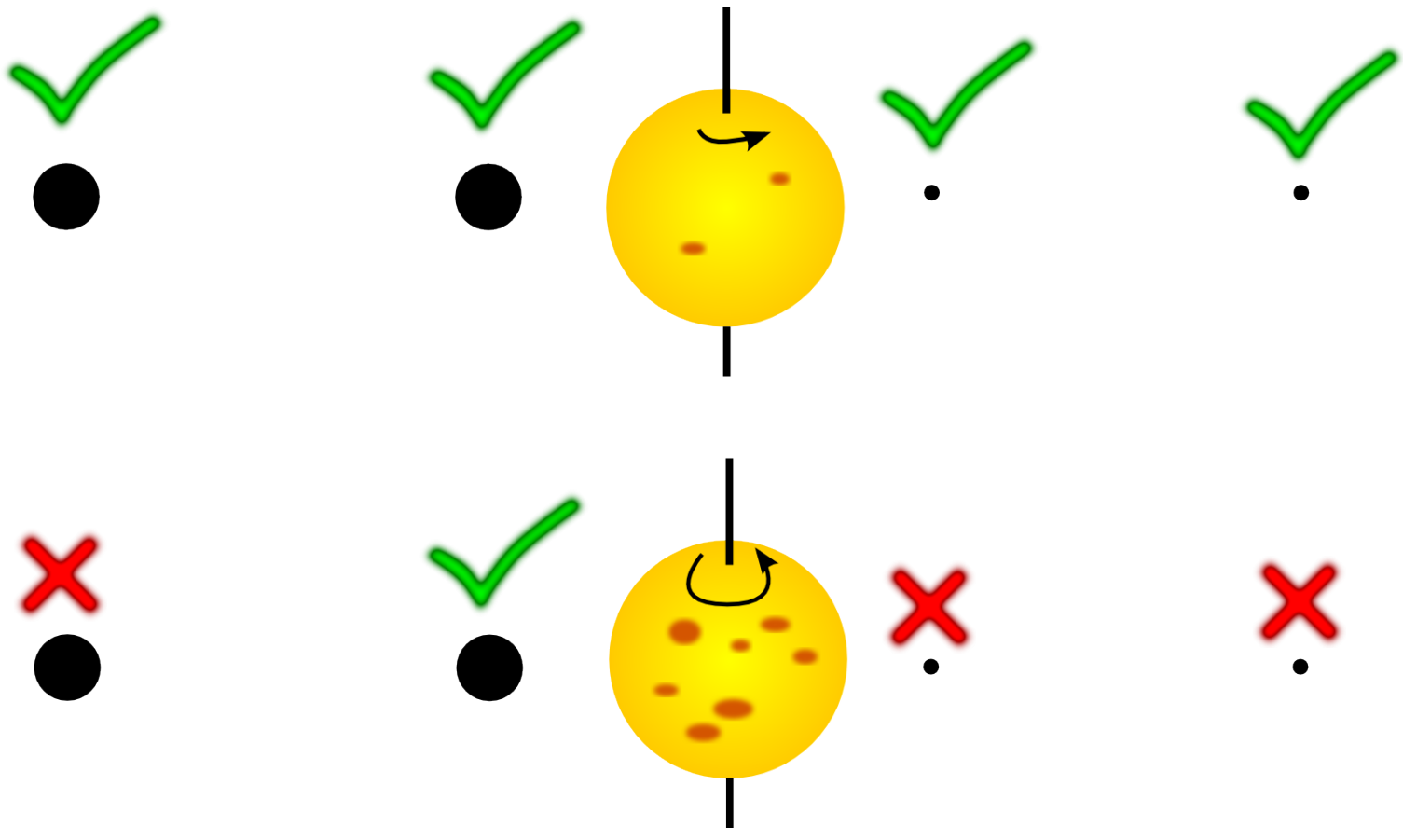
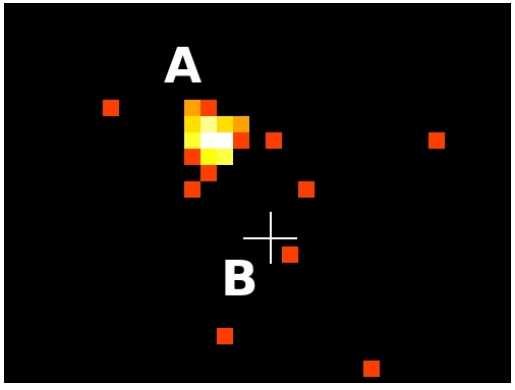
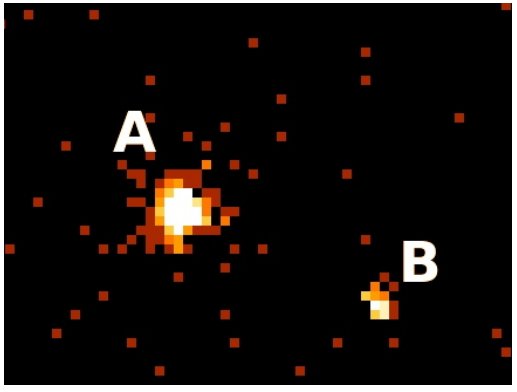


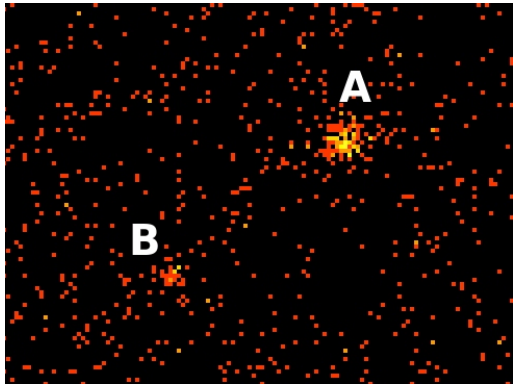
Systems with a built-in negative control: Planet-hosting stars with stellar companions



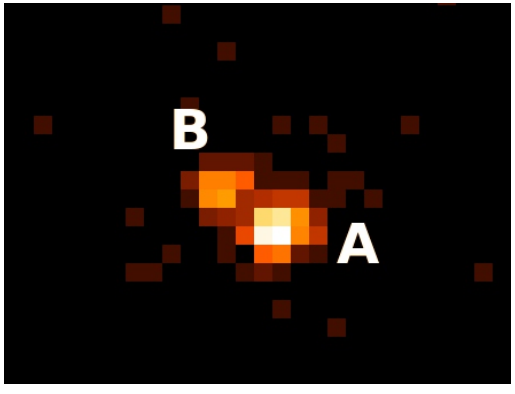
CoRoT-2 AB



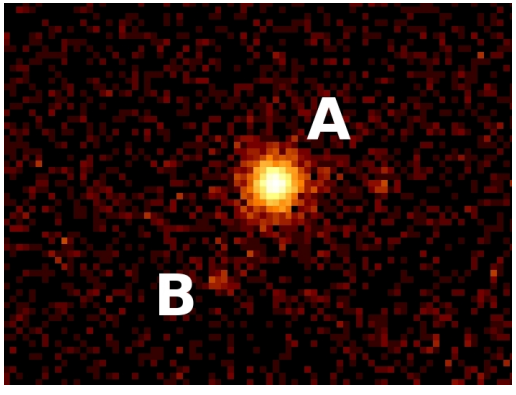
HD 189733 AB



55 Cnc AB

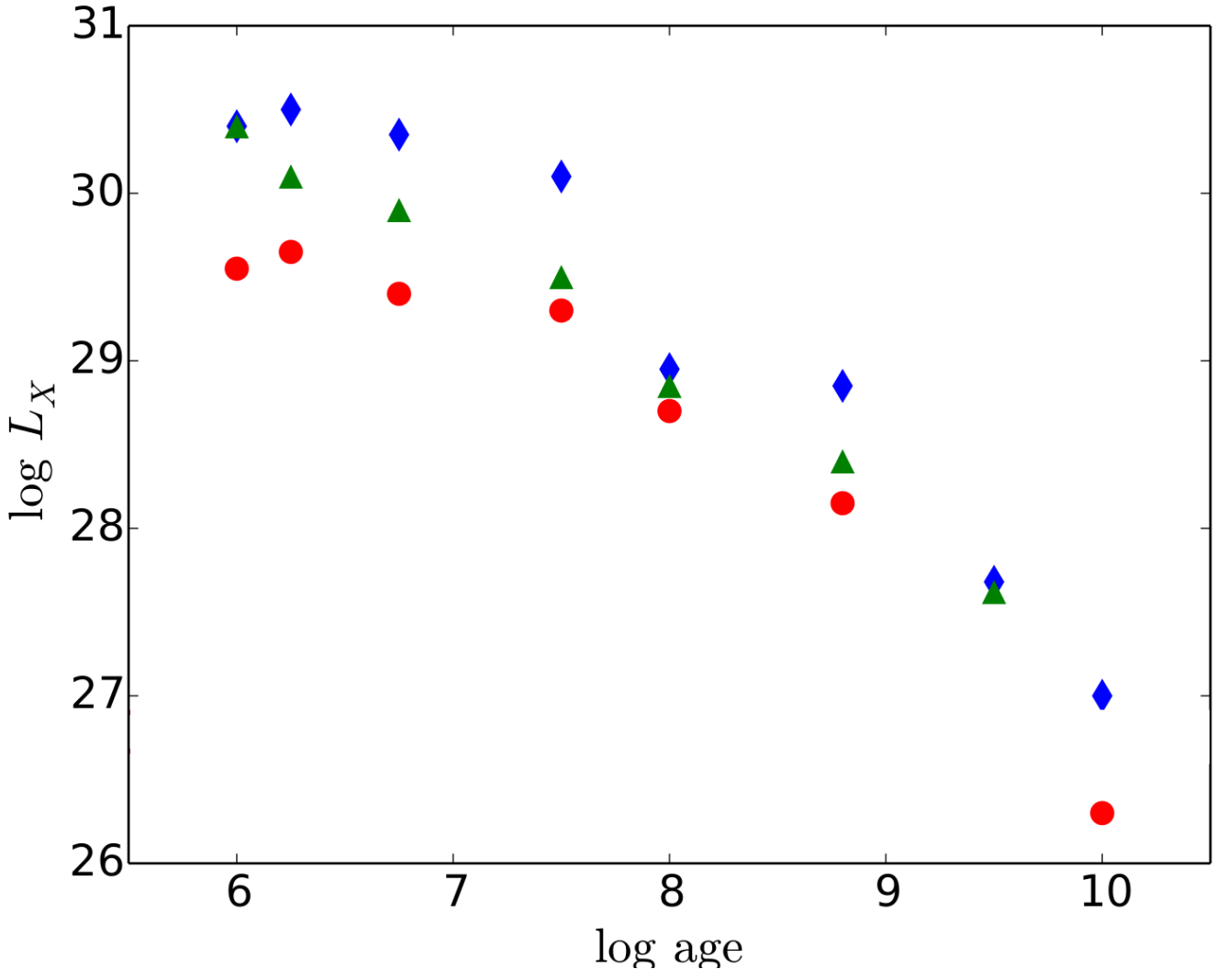


τ Boo AB

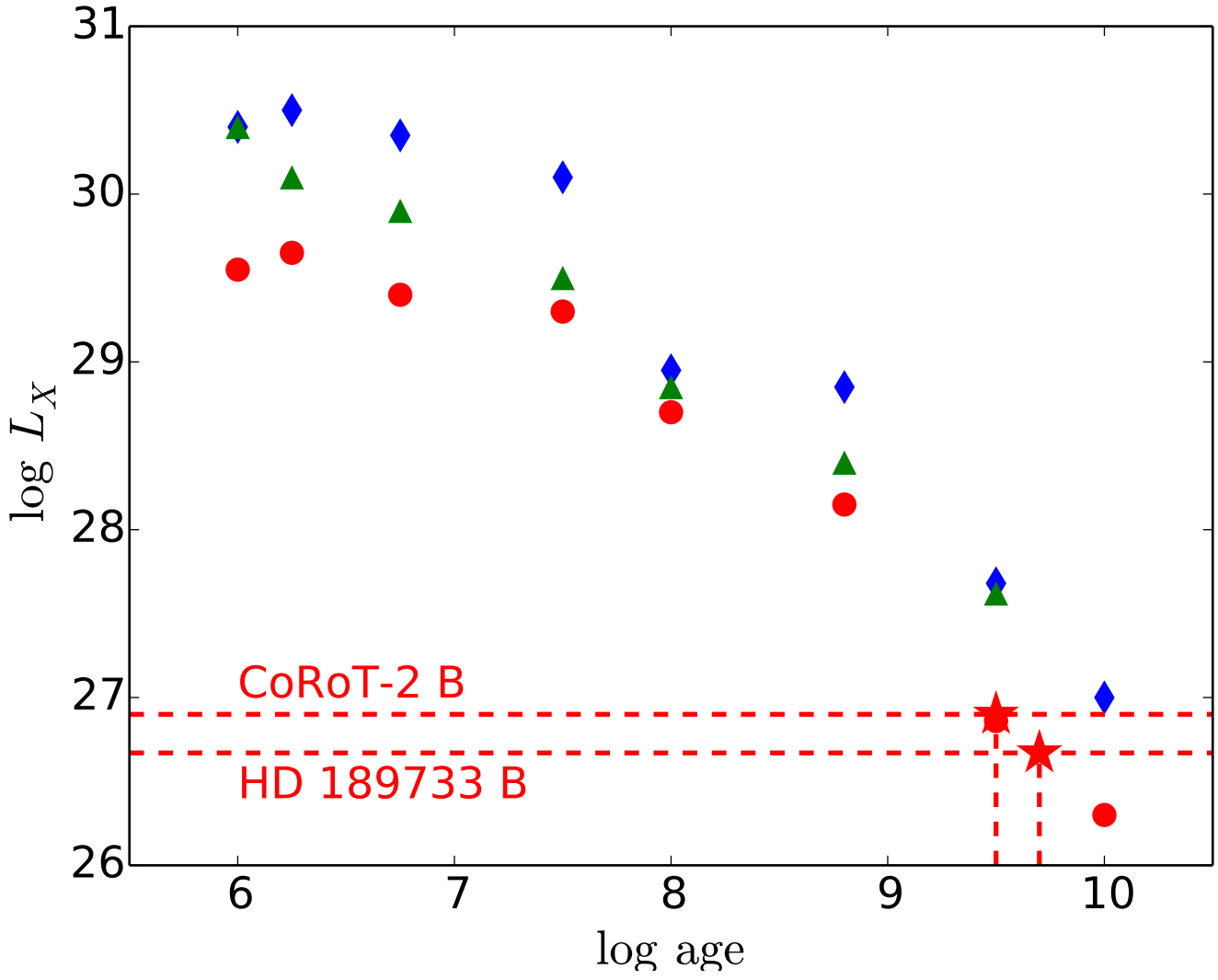


υ And AB

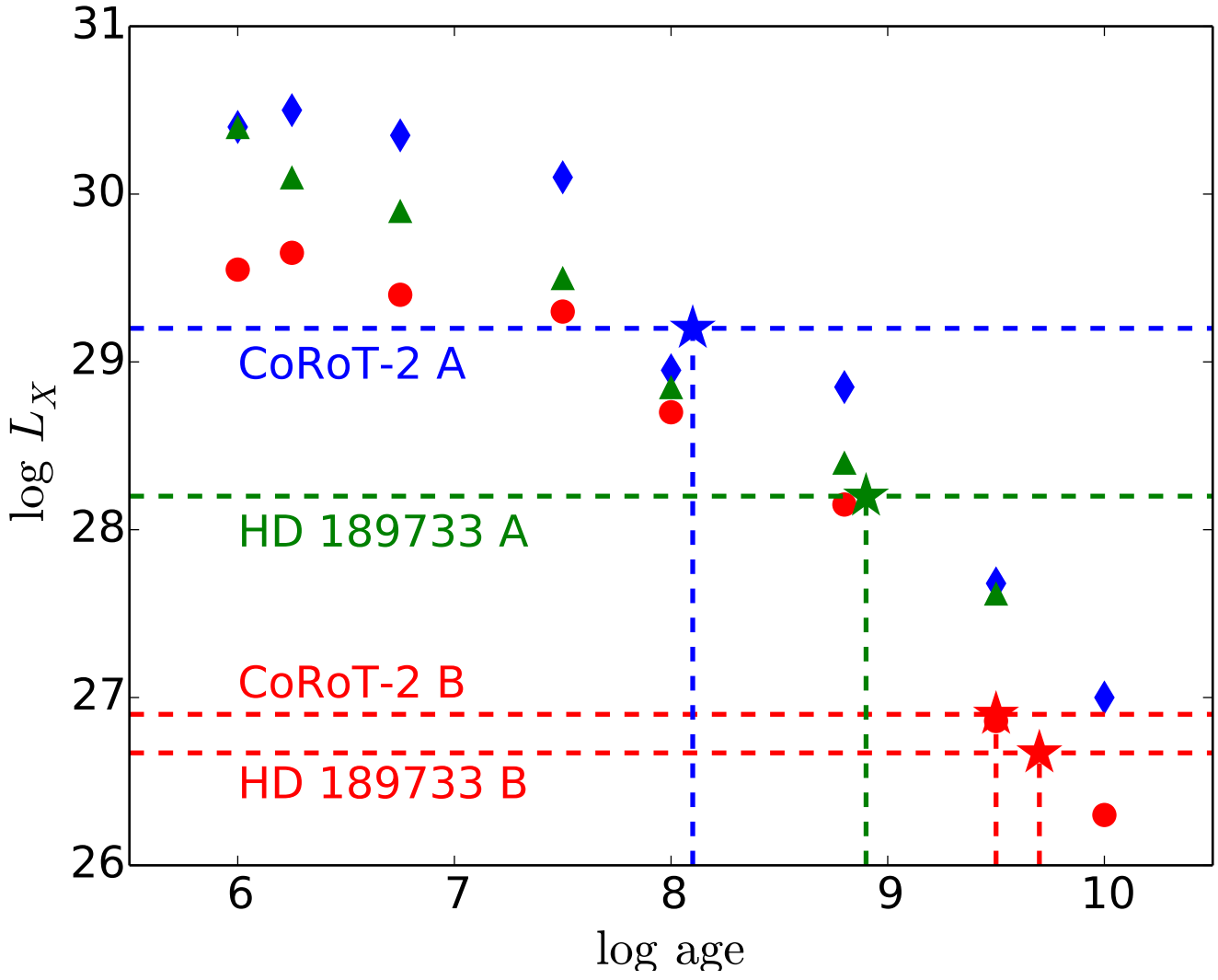
Stellar age and X-ray luminosity



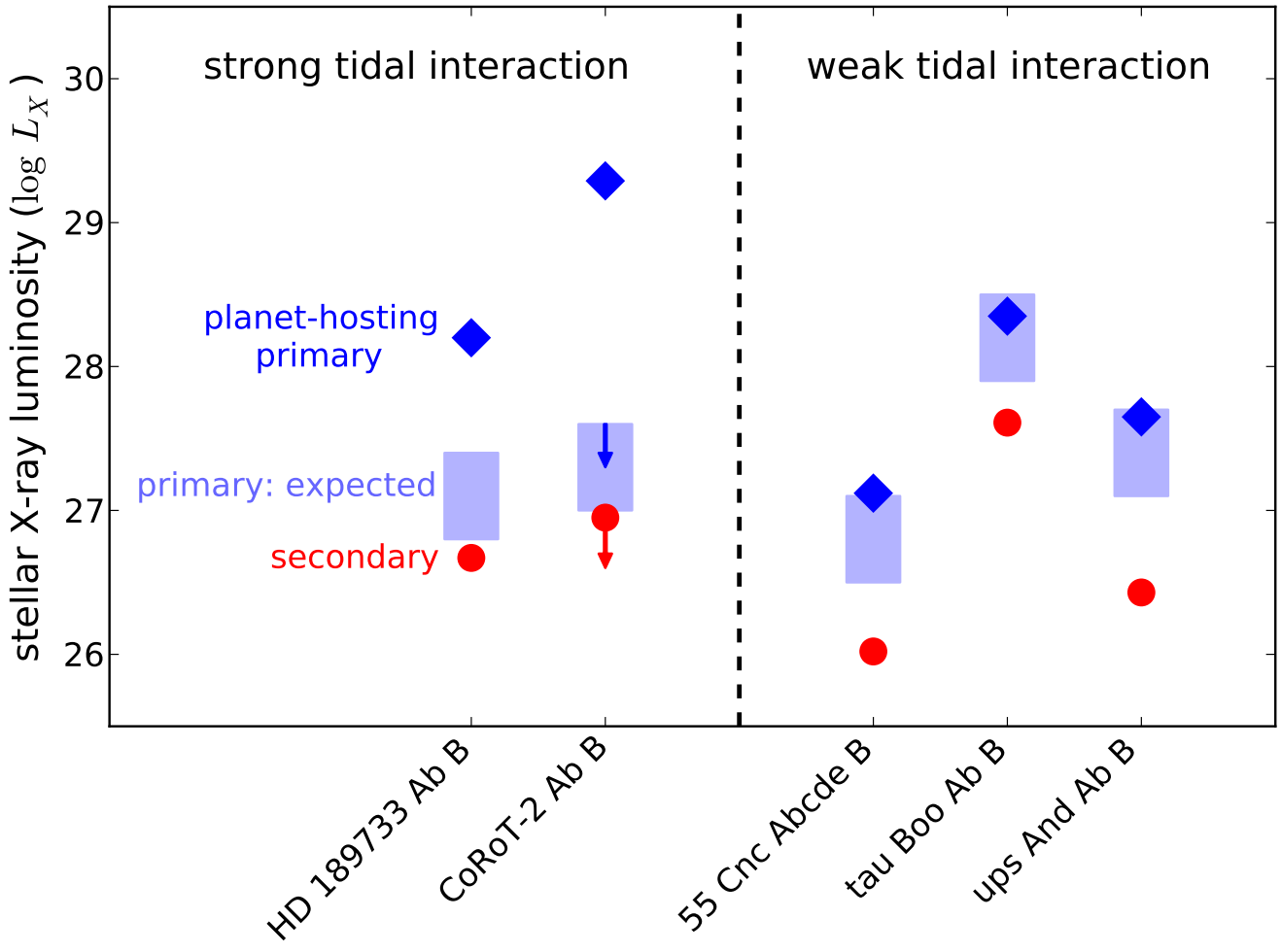
Stellar age and X-ray luminosity



Stellar age and X-ray luminosity

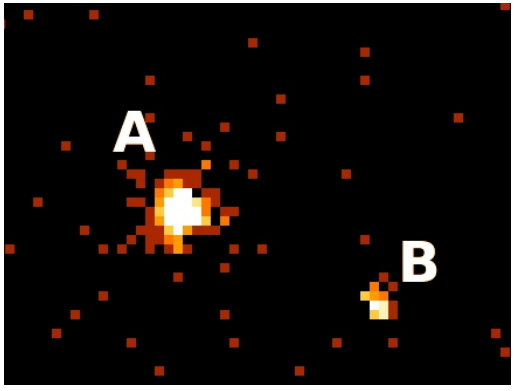


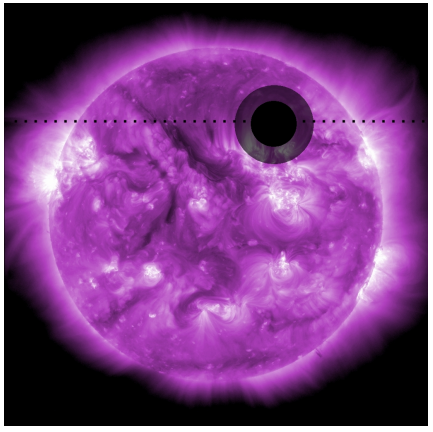
X-ray activity for 5 systems

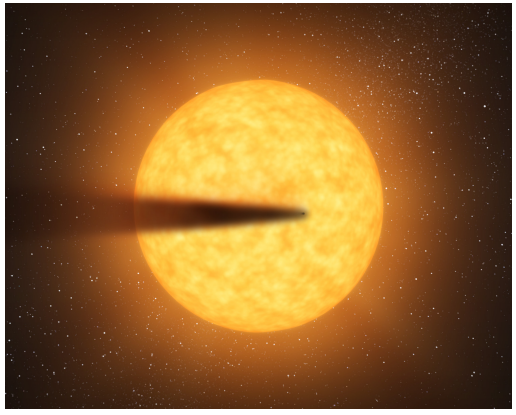


Poppenhaeger et al. 2014, A&A Letters

X-rays: exoplanets & host stars







- stars: activity biases in exoplanet samples
- stars: tidal / flare triggering interactions of planets and stars
- exoplanets: short wavelengths probe outer atmospheres, via transit depths or line profiles
- exoplanets: X-ray/UV-driven evaporation
- upcoming opportunities: Athena+, Astro-H, eRosita
- Arcus: X-ray grating!

NASA SMEX proposal: X-ray spectrograph Arcus