How planets affect cool stars

Katja Poppenhaeger
Queen's University Belfast
→ University of Potsdam / Leibniz Institute for Astrophysics AIP
Star-exoplanet systems
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tidal interaction
Star-exoplanet systems

stellar spin

tidal interaction
Star-exoplanet systems

magnetic interaction
Star-exoplanet systems

magnetic interaction

stellar flares, hot spots
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?

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

Kashyap et al. (2008); see also Shkolnik (2013), Miller et al. (2014)
Planet-induced activity: trends?

Miller et al. (2014)
Planet-induced activity: trends?

DIFFICULTY:

more active

small & large planets “easy” to detect

more Hot Jupiter-like
Planet-induced activity: trends?

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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
\[ P_{\text{rot}} = 10.5 \text{ d} \]
\[ \text{age} = \sim 5 \text{ Gyr (isochrones)} \]
Hebb et al. (2010)

HATS-18, mid-G star
\[ P_{\text{rot}} = 9.8 \text{ d} \]
\[ \text{age} = \sim 5 \text{ Gyr (isochrones)} \]
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

Poppenhaefer et al. (2014), Poppenhaefer 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

![Diagram showing the relationship between log age and log L_x for different types of stars: F/G stars (diamonds), K stars (triangles), and M stars (circles). The x-axis represents log age, ranging from 6 to 10, and the y-axis represents log L_x, ranging from 26 to 31. The diagram illustrates that F/G stars are more active than K stars and M stars across the range of ages.]
Planet-hosting wide binaries

![Graph showing the relationship between log L_X and log age for planet-hosting wide binaries. The graph includes symbols for different data points, with one set marked as 'ups And B'.]
Planet-hosting wide binaries
Planet-hosting wide binaries

![Graph showing the relationship between log age and log L_X, with markers for ups And A and ups And B, indicating more active stars.](image)
Planet-hosting wide binaries

![Graph showing the relationship between log L_x and log age for systems with different X-ray luminosities. The graph includes symbols for CoRoT-2 B and HD 189733 B, indicating their positions along the log age axis.]
Planet-hosting wide binaries

![Graph showing log LX vs. log age for CoRoT-2 A, CoRoT-2 B, HD 189733 A, and HD 189733 B. The graph indicates that more active stars tend to have lower log LX values.]
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

magnetic interaction

stellar flares, hot spots
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

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Rogers & McElwaine (2017)
Yadav & Thorngren (2017)
Planet-induced hot spots?

Shkolnik et al. (2005, 2008)

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

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

Shkolnik et al. (2005, 2008)
But also: absence of magnetic effects

WASP-18 (1.2 \(M_{\text{Sun}}\)): completely X-ray dark!
Miller et al. (2012), Pillitteri et al. (2014)

\(P_{\text{rot}} = 9.5\) d
\(P_{\text{orb}} = 4.6\) d

upsilon And (1.3 \(M_{\text{Sun}}\)):
varies with stellar rotation, not with Hot Jupiter orbit
Poppenhaeger et al. (2010)
Planetary / coronal rain

HD 189733 - eclipse

Pillitteri et al. (2015)
Planetary / coronal rain

55 Cnc transit (e: rocky planet)

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:

periastron
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

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

Hot Neptune GJ 436 b:
comet-like tail
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
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:

Booth, Poppenhaeger et al. (2017)

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!

\[ \log \left( \frac{L_x}{(R_*/R_{\odot})^2} \right) = 54.65 \pm 6.98 - (2.80 \pm 0.72) \log t. \]

Booth, Poppenhaeger et al. (2017)
Star-exoplanet systems

tidal interaction

measurable when stellar age (proxy) available
Star-exoplanet systems

- Magnetic interaction
- Needs good orbital phase coverage for statistics
- Stellar flares, hot spots
Star-exoplanet systems

Planetary effects seem 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!