

Planet-star tidal interactions with precise transit timing

Gracjan Maciejewski

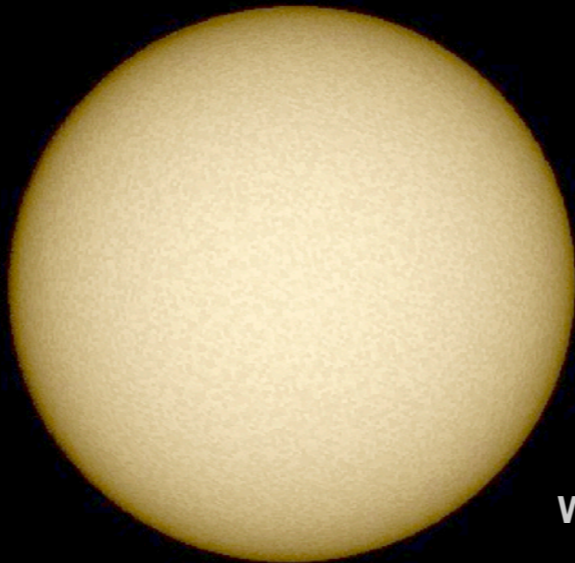
Centre for Astronomy, Nicolaus Copernicus University

This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

The WASP-12 system



SuperWASP
(Wide Angle Search for Planets)

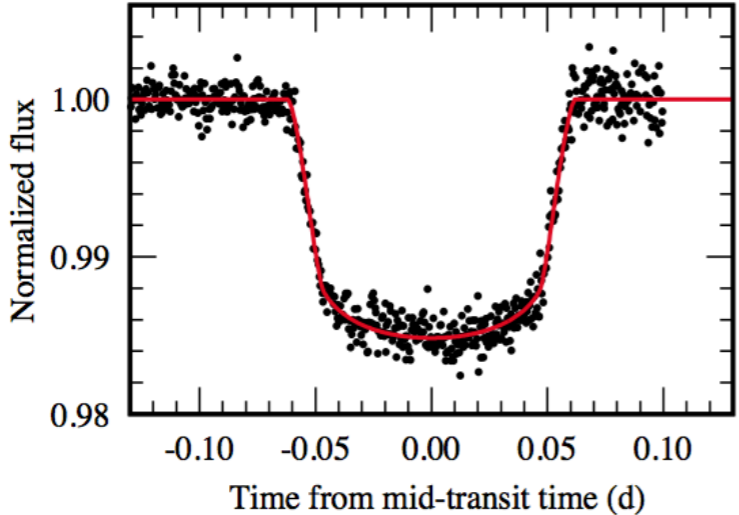


WASP-12



WASP-12 b

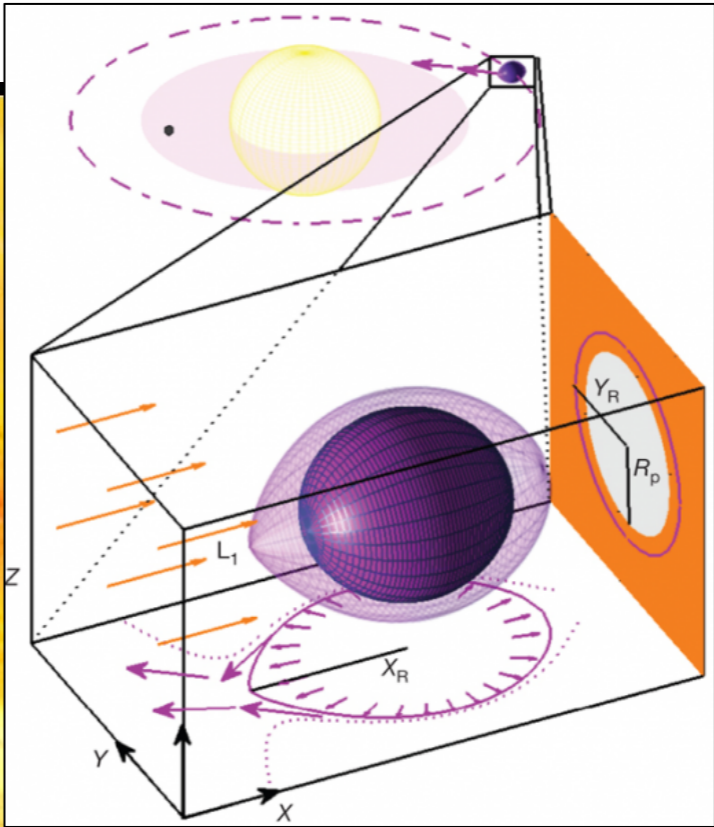
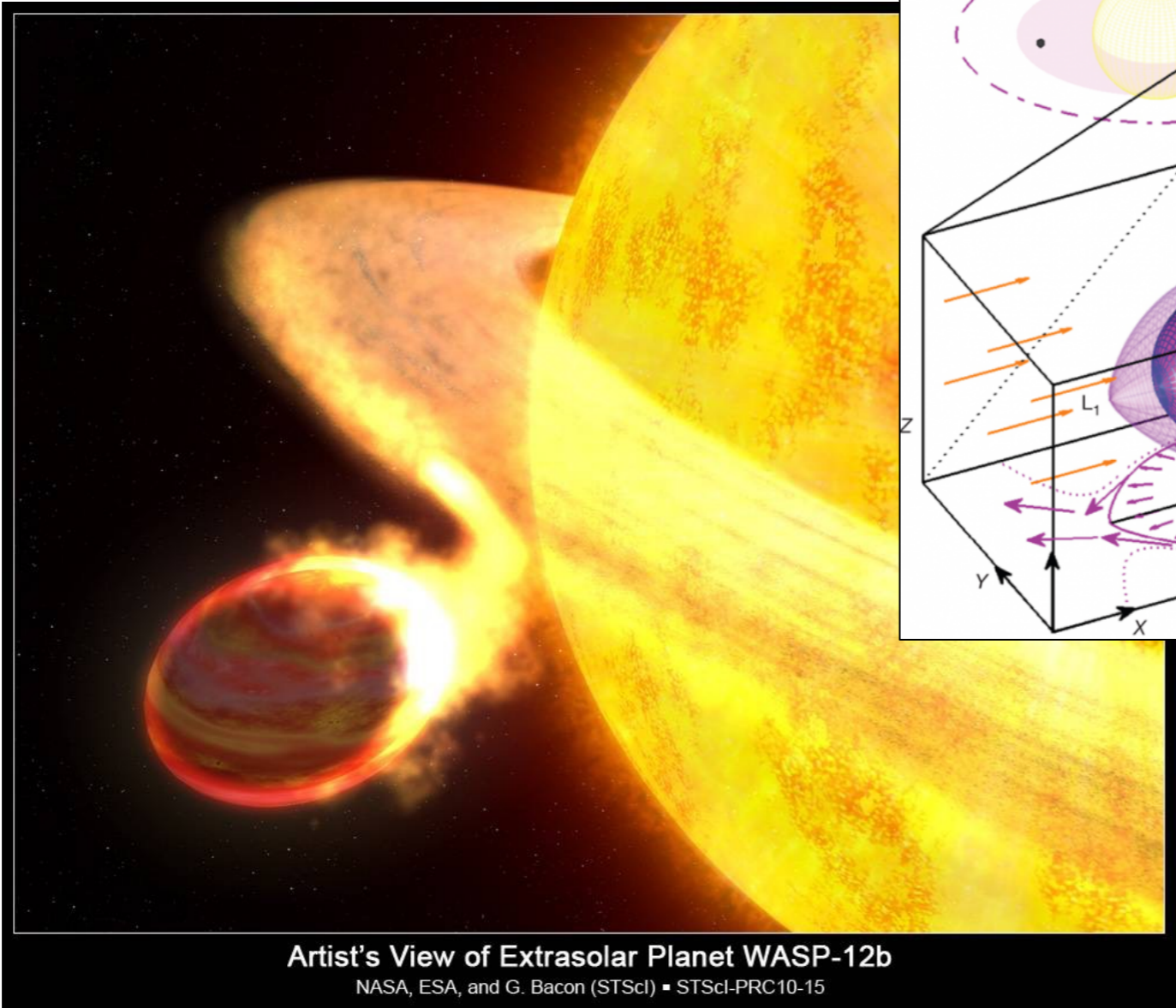
Mass: $1.4 M_{Jup}$
Radius: $1.8 R_{Jup}$
Orbital period: 1.09 d
S-major. axis: 0.0226 AU
Temp.: 2600 K



Mass: $1.3 M_{sun}$
Radius: $1.6 R_{sun}$
Spectral type: G0
Effective temp.: 6350 K
Apparent brightness: 11.3 mag

Hebb et al. 2009, ApJ, 693, 1920

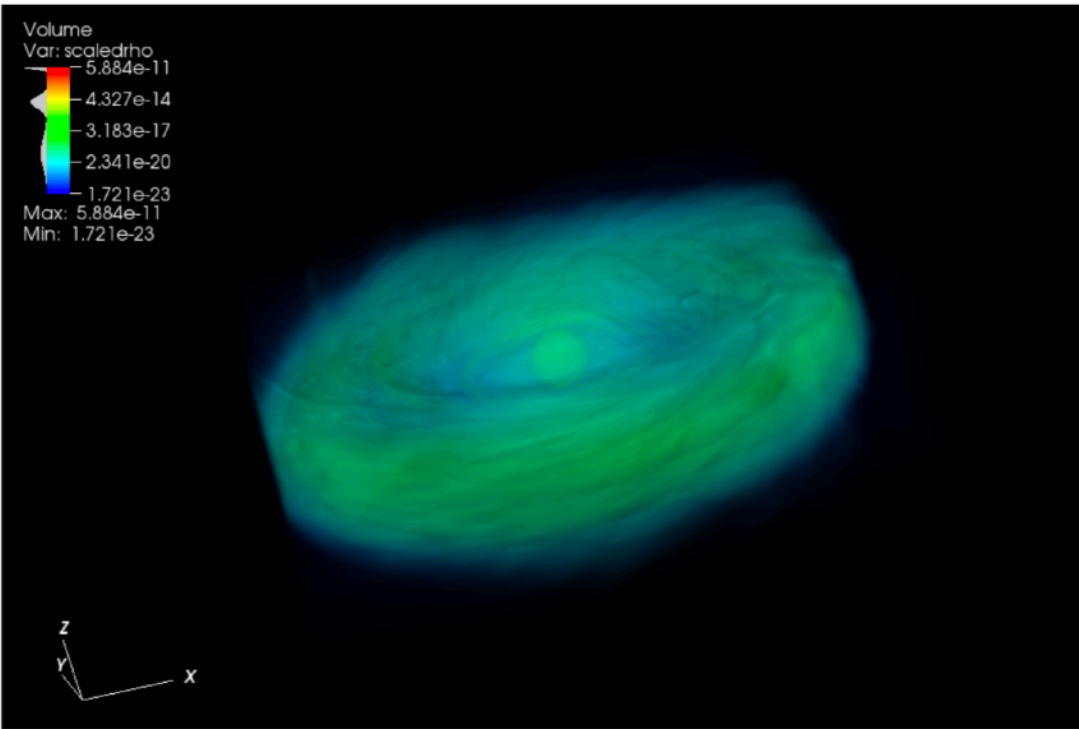
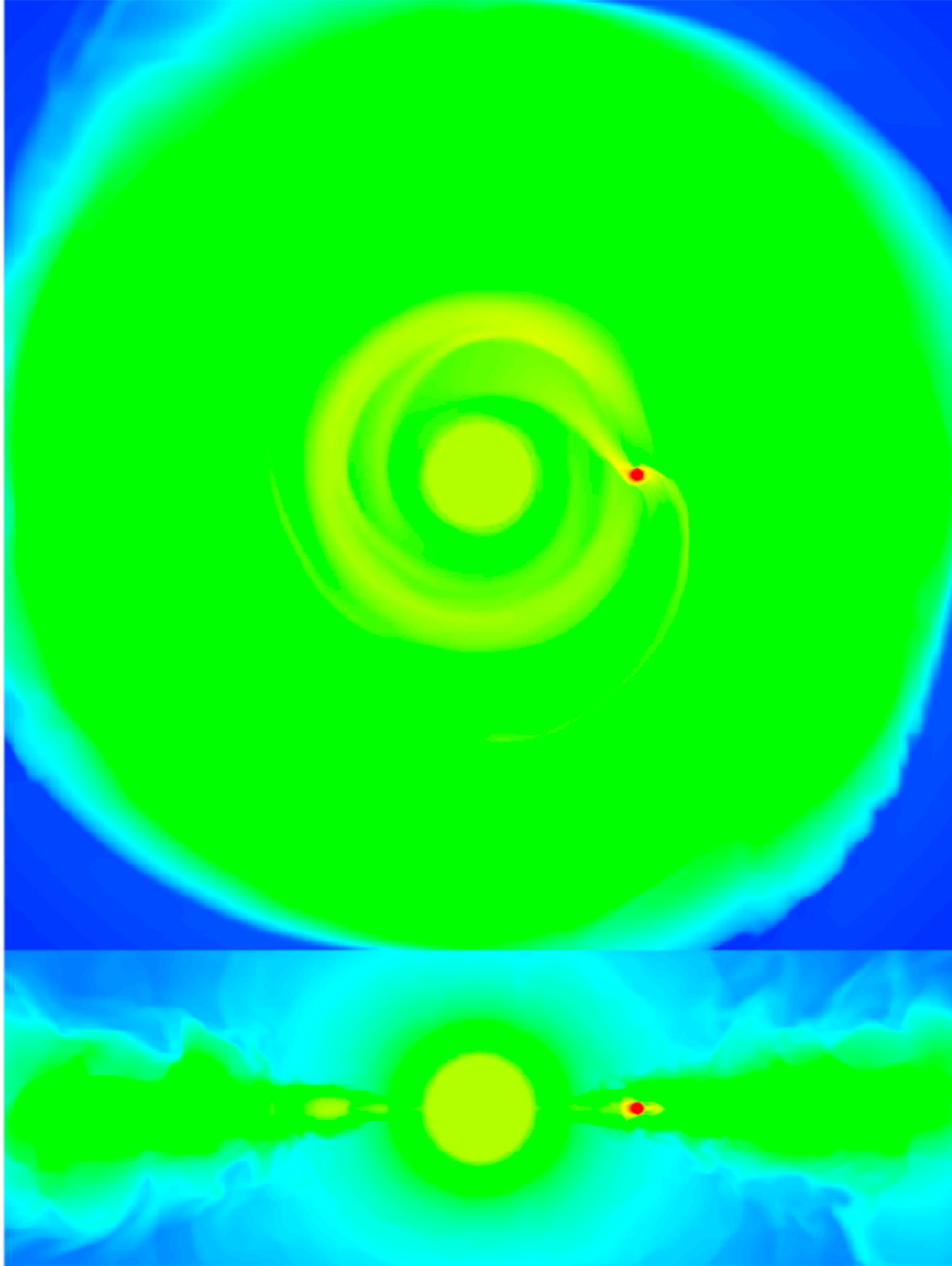
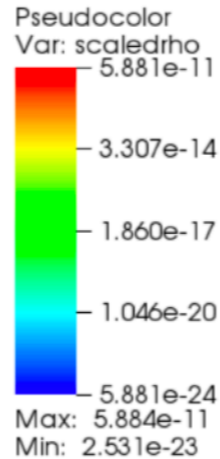
The WASP-12 system



Li et al. 2010, Nature, 463, 1054

This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

The WASP-12 system

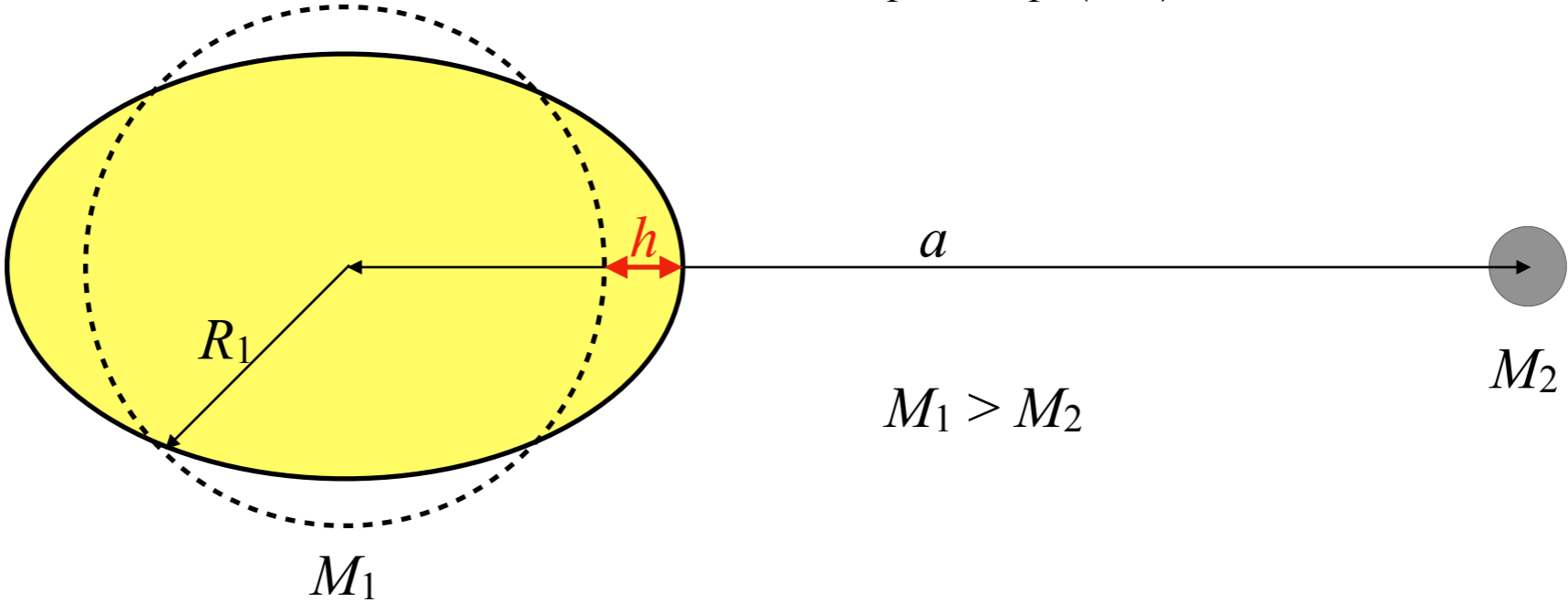


Debrecht et al. 2018

This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

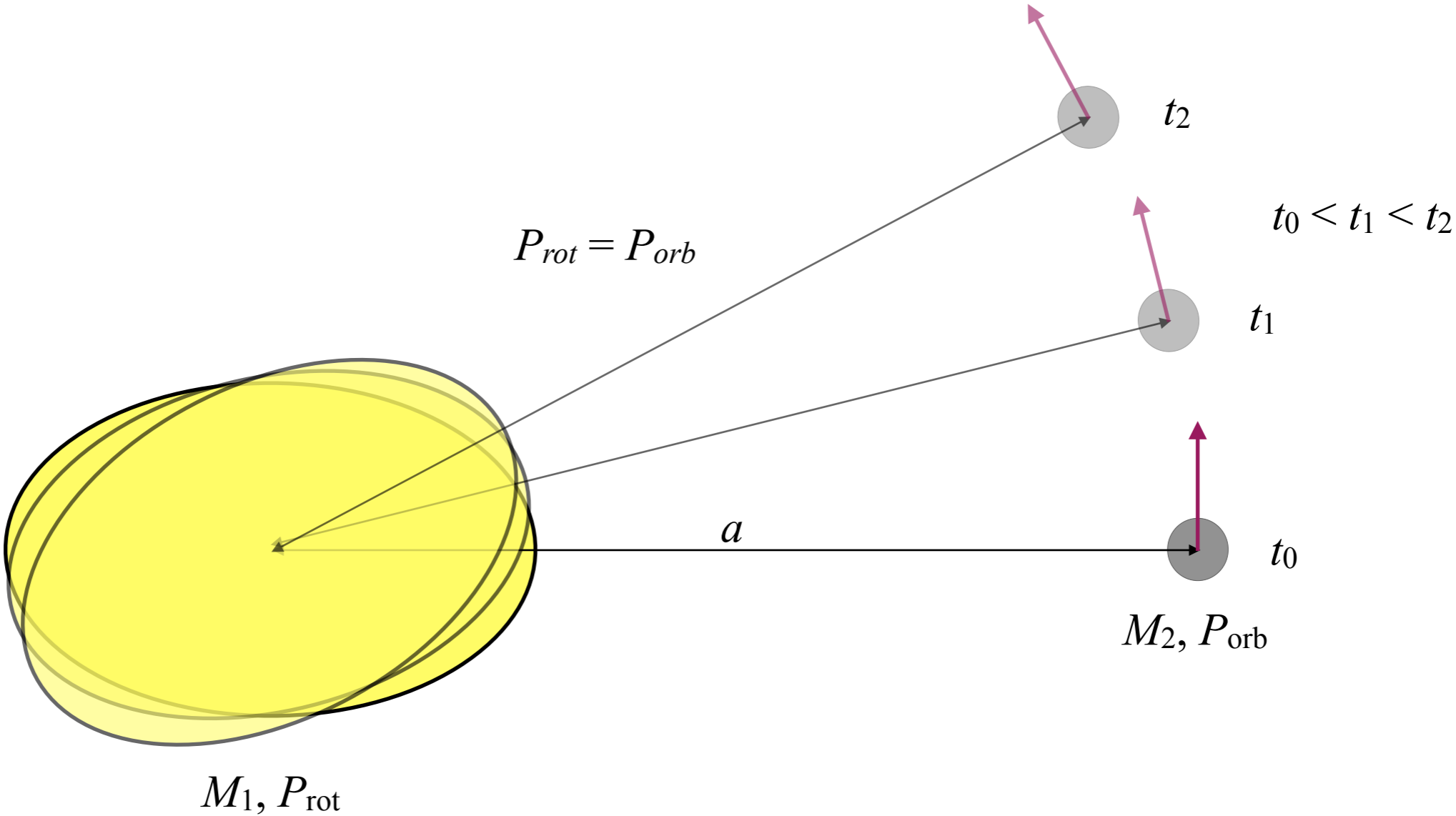
Tidal interactions

$$\frac{h}{R_1} = \frac{M_2}{M_1} \left(\frac{R_1}{a} \right)^3$$



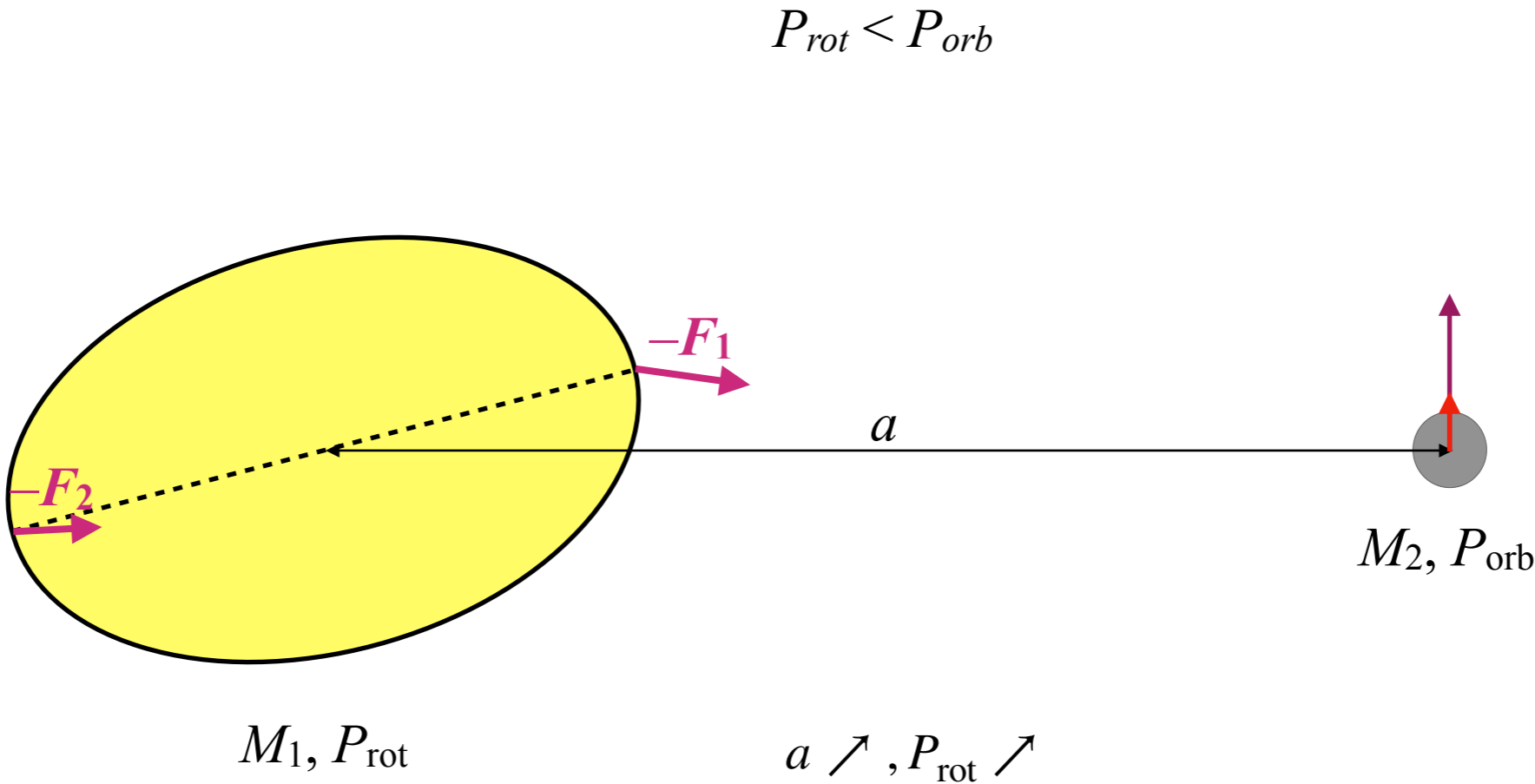
This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

Tidal interactions



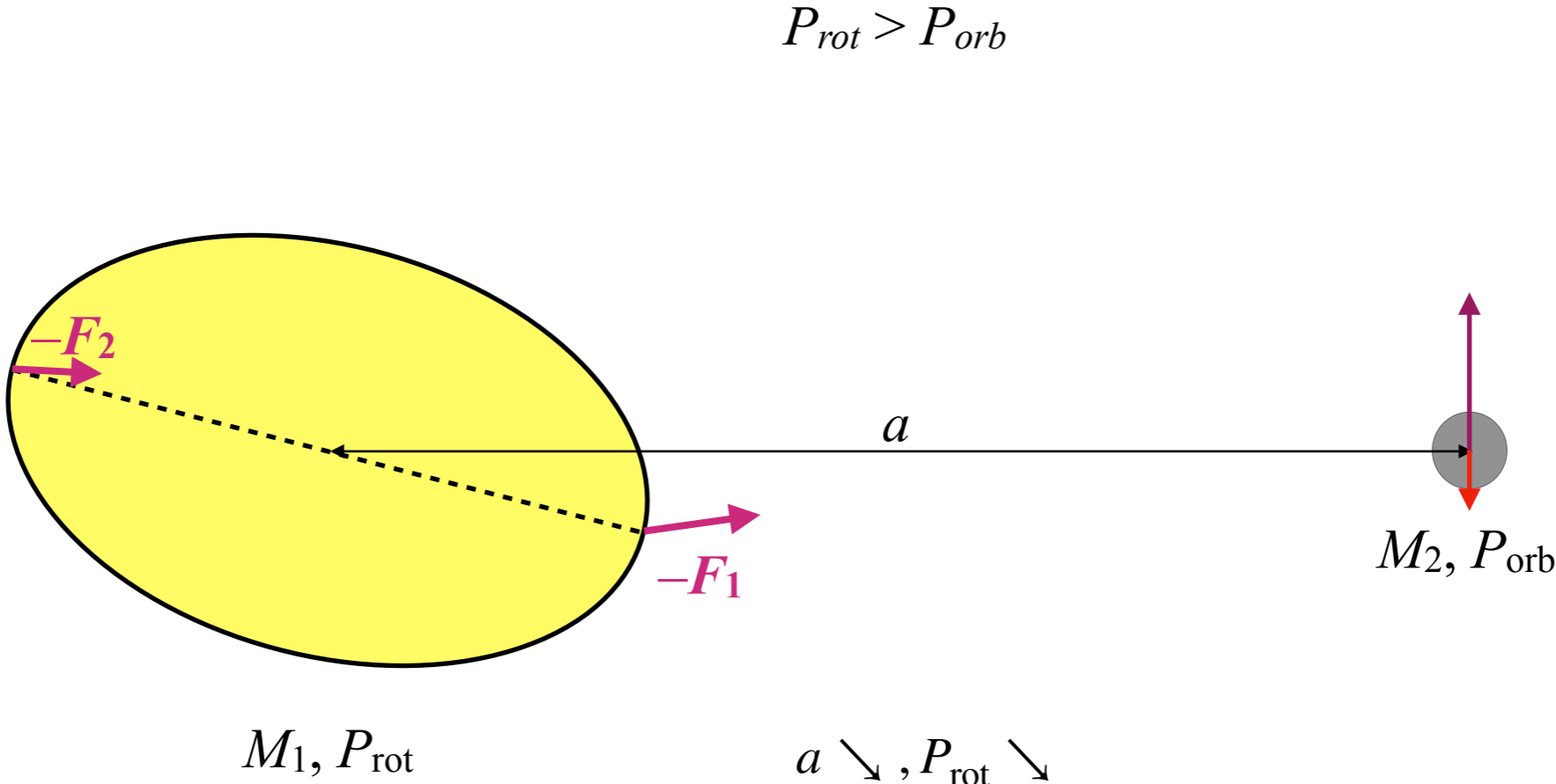
This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

Tidal interactions



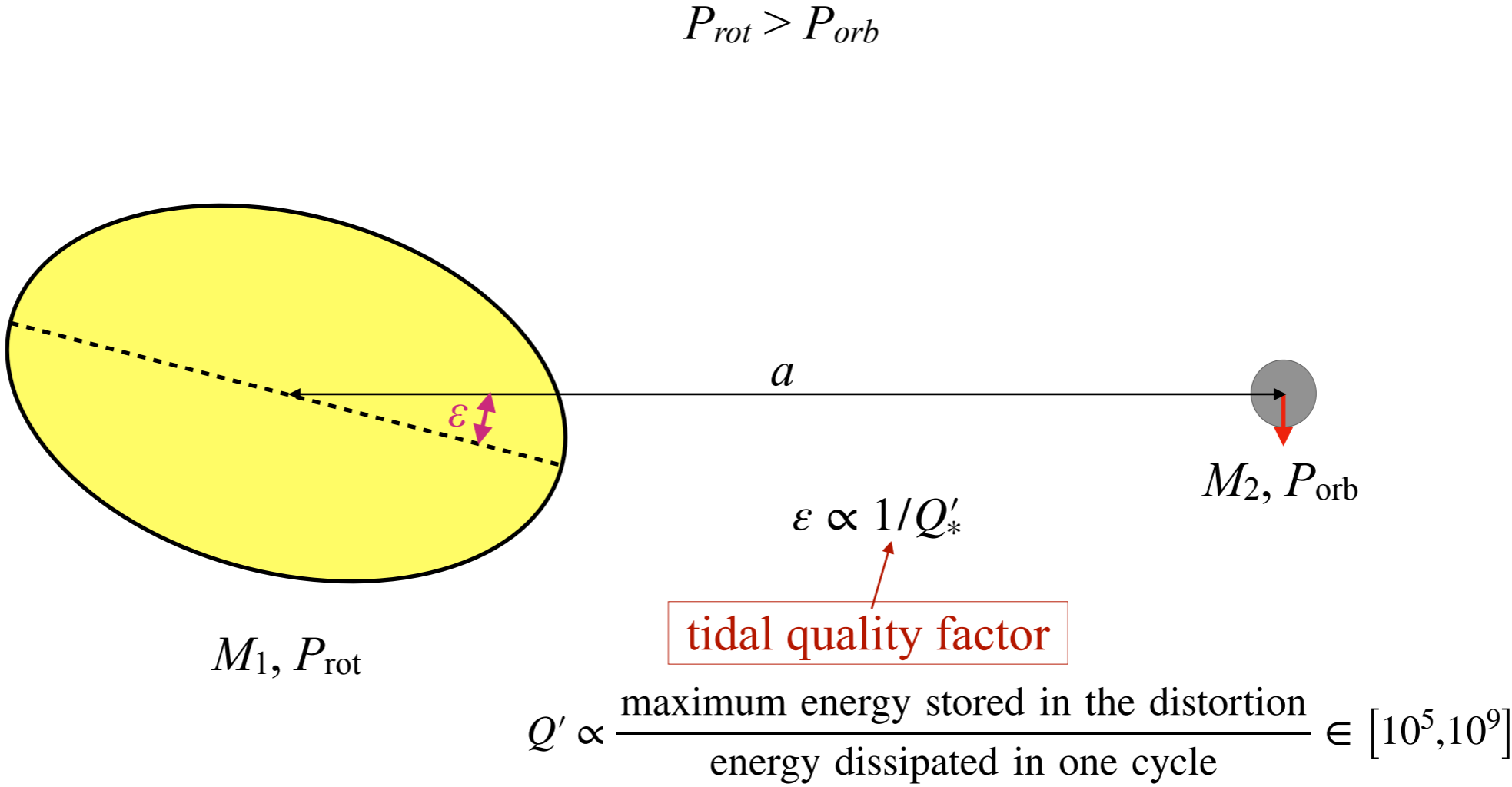
This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

Tidal interactions



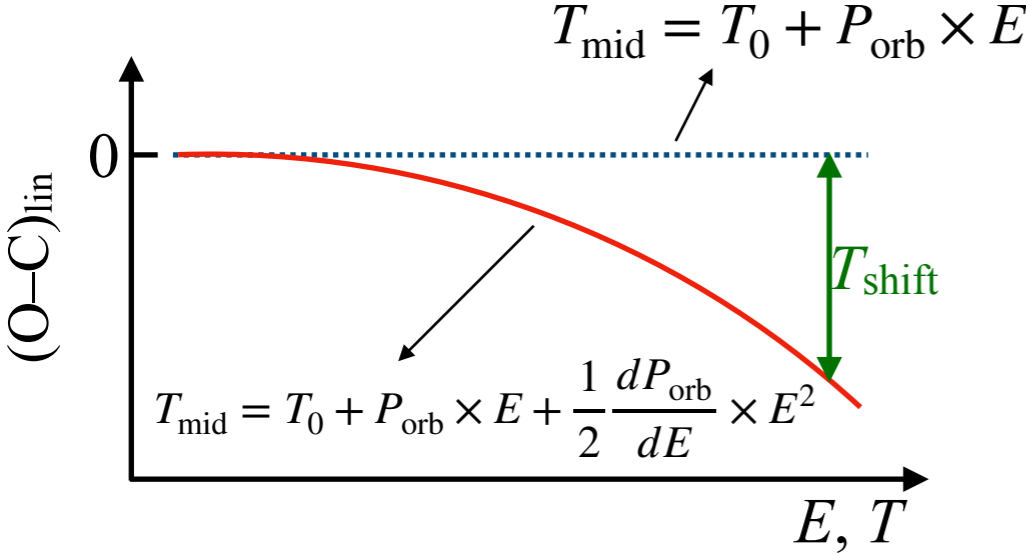
This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

Tidal interactions

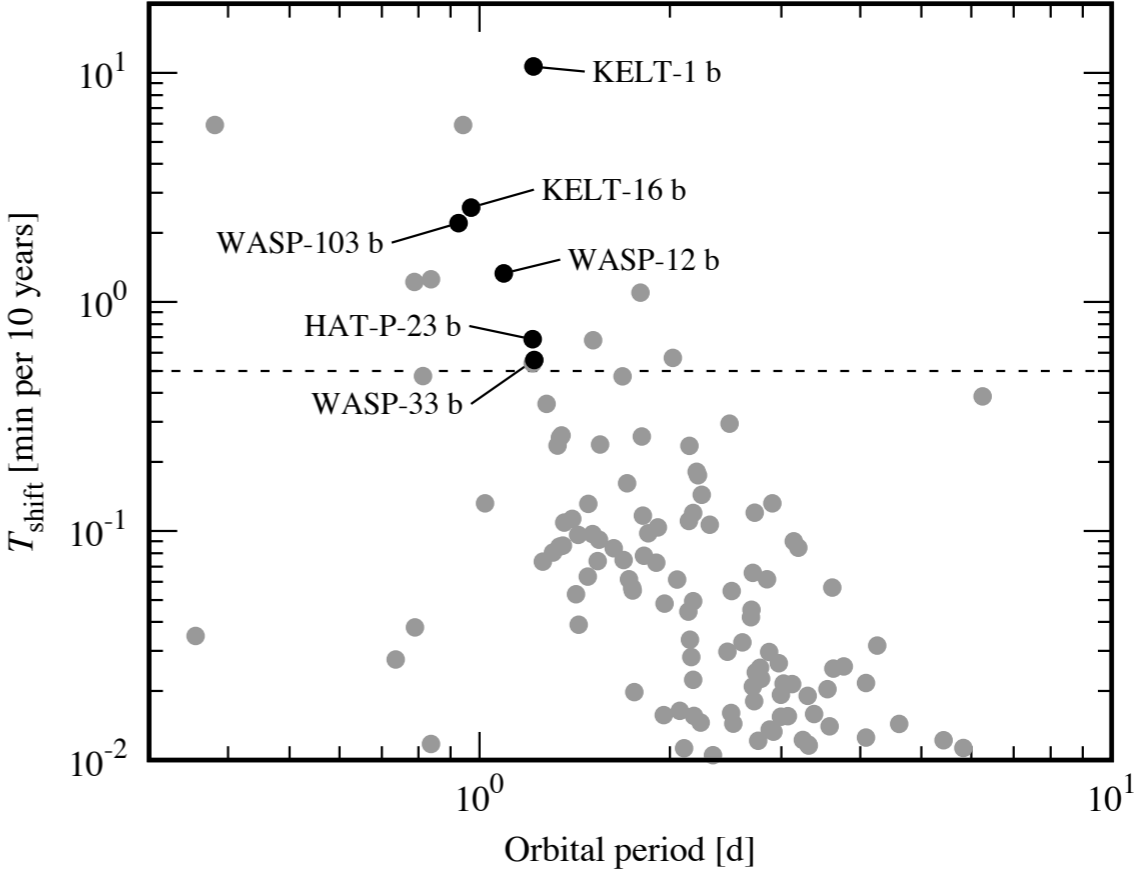


This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

Search for orbital decay due to tides



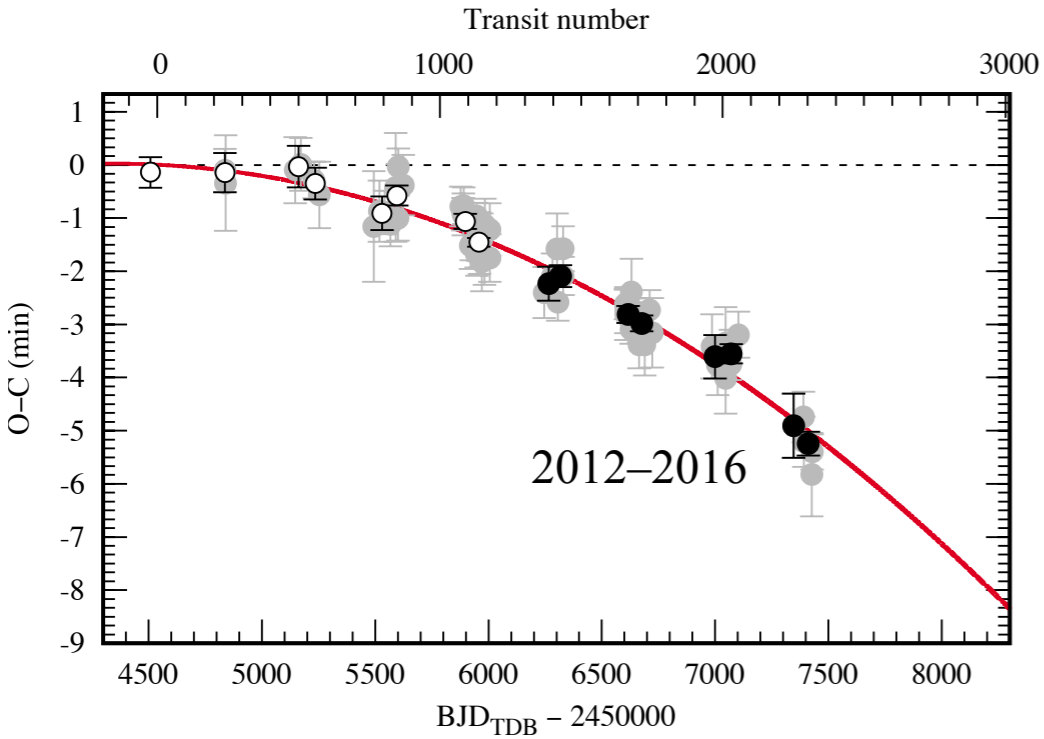
$$T_{\text{shift}} = -\frac{27}{4} \frac{\pi}{Q'_*} \left(\frac{M_p}{M_*}\right) \left(\frac{R_*}{a}\right)^5 \frac{1}{P_{\text{orb}}} T^2$$



Maciejewski *et al.* 2018, submitted

This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

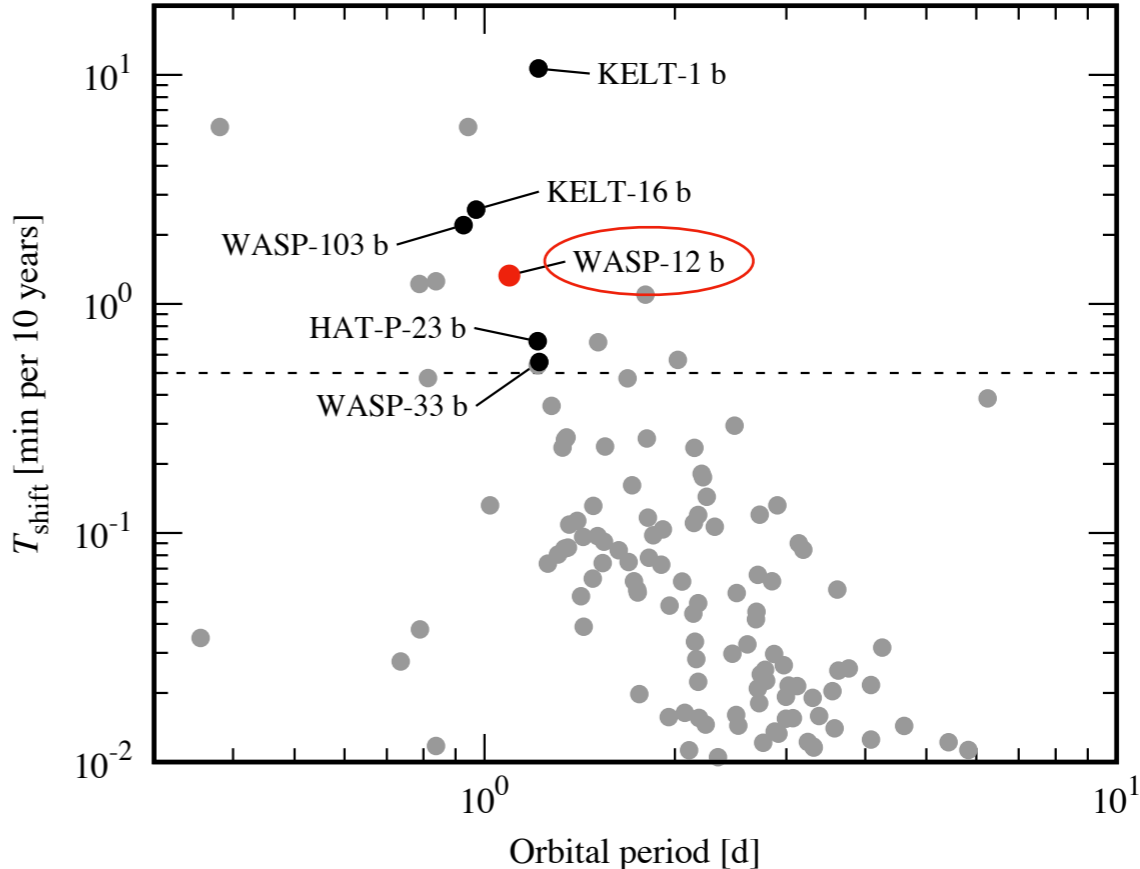
Search for orbital decay due to tides – WASP-12



Maciejewski et al. 2016, A&A, 588, L6

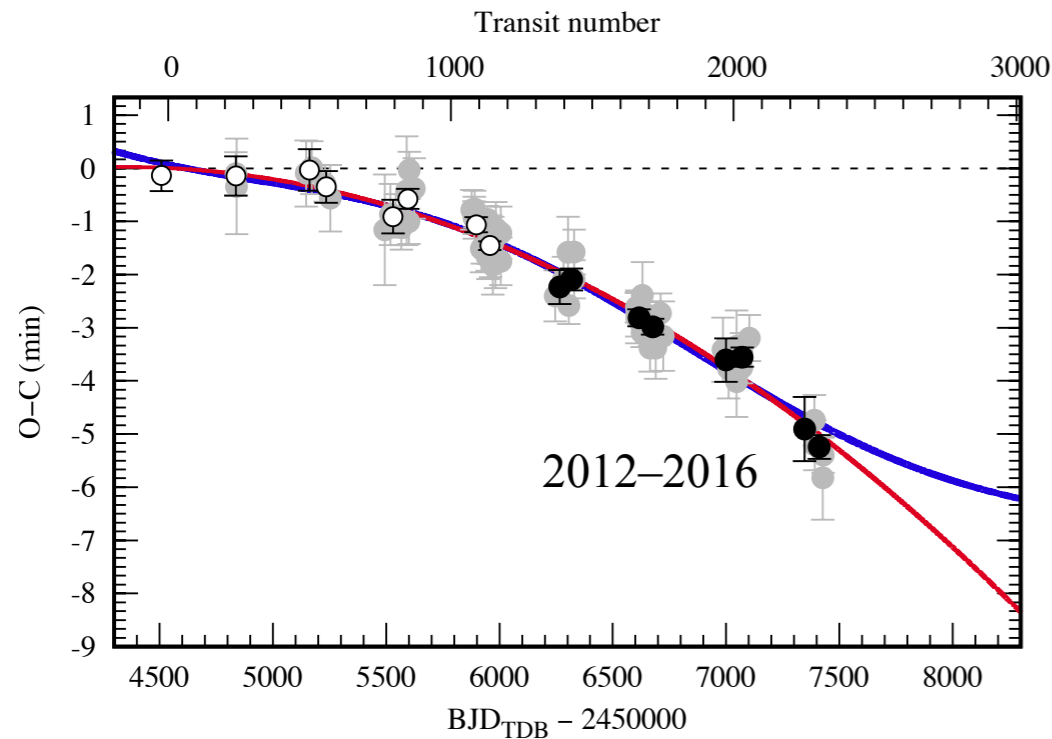
Orbital decay

- P_{orb} decreases by **26 milliseconds per year**
- the orbital distance shrinks by **600 meters a year**
- the planet will fall onto the host star in less than **10^6 yr**



Maciejewski et al. 2018, submitted

Search for orbital decay due to tides – WASP-12



Maciejewski et al. 2016, A&A, 588, L6

Apsidal precession of slightly eccentric orbit
(precession of the orbit due to the nonpoint-mass component of the gravitational field)

- e_{orb} of about **0.001**
- period of precession of about **10 yr**

Apsidal precession might be caused by:

- tidal deformations of the star and planet

$$\begin{aligned}\dot{\omega}_{\text{tidal}} &= \dot{\omega}_{\text{tidal},*} + \dot{\omega}_{\text{tidal},p} \\ &= \frac{15}{2} k_{2*} \left(\frac{R_*}{a} \right)^5 \frac{M_p}{M_*} f_2(e) n \\ &\quad + \frac{15}{2} k_{2p} \left(\frac{R_p}{a} \right)^5 \frac{M_*}{M_p} f_2(e) n,\end{aligned}$$

- rotation bulges

$$\begin{aligned}\dot{\omega}_{\text{rot}} &= \dot{\omega}_{\text{rot},*} + \dot{\omega}_{\text{rot},p} \\ &= \frac{k_{2*}}{2} \left(\frac{R_*}{a} \right)^5 \frac{v_*^2 a^3}{GM_*} g_2(e) n \\ &\quad + \frac{k_{2p}}{2} \left(\frac{R_p}{a} \right)^5 \frac{v_p^2 a^3}{GM_p} g_2(e) n,\end{aligned}$$

- general relativity

$$\dot{\omega}_{GR} = \frac{3GM_* n}{ac^2(1-e^2)}.$$

The total apsidal rotation is

$$\dot{\omega}_{\text{tot}} = \dot{\omega}_{\text{tid},p} + \dot{\omega}_{GR} + \dot{\omega}_{\text{rot},p} + \dot{\omega}_{\text{rot},*} + \dot{\omega}_{\text{tid},*}.$$

For typical very hot Jupiters

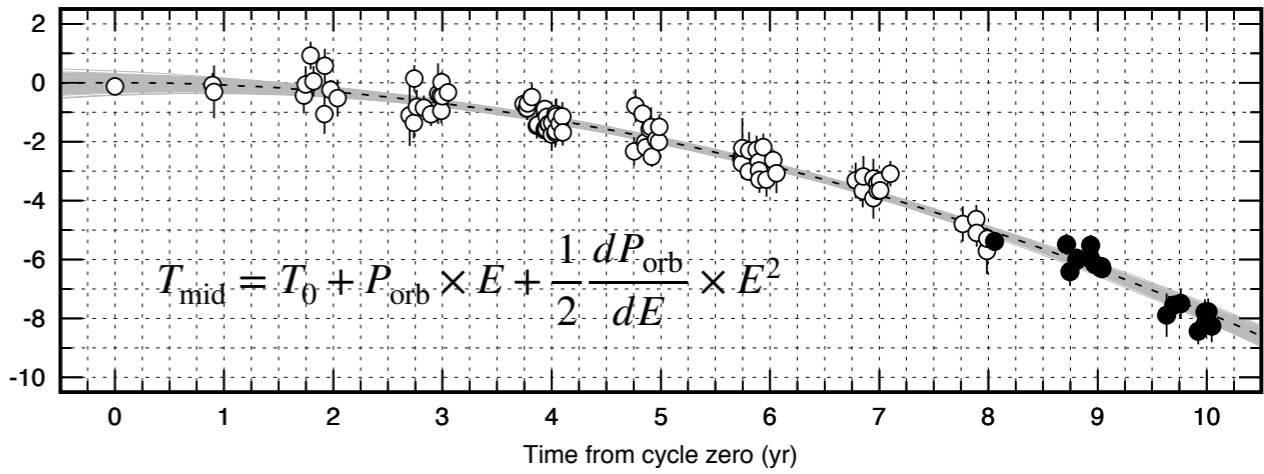
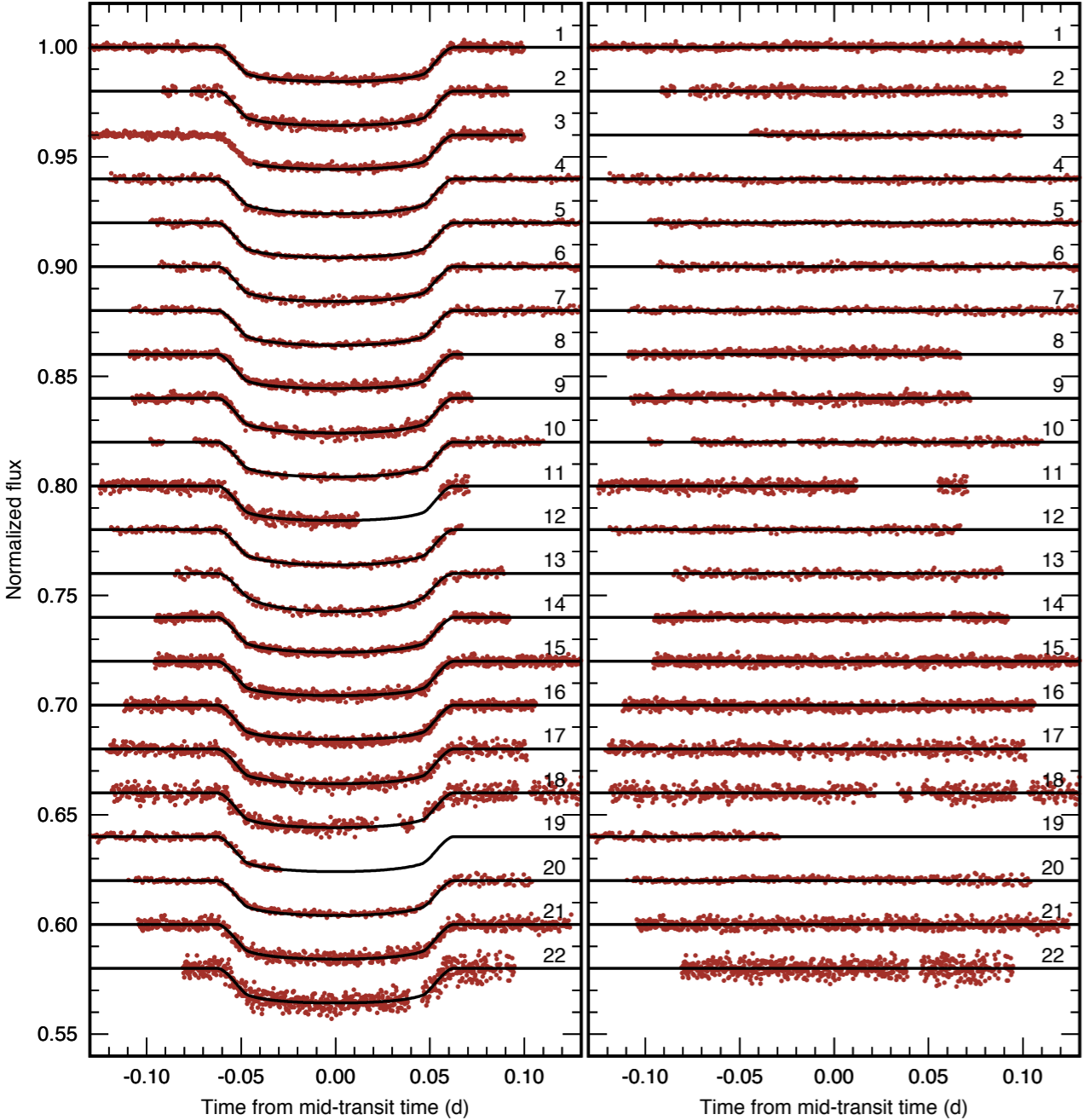
$$\dot{\omega}_{\text{tot}} \approx \dot{\omega}_{\text{tidal},p}$$

so the planetary Love number k_{2p} would be accessible *via* observations

Ragozzine & Wolf 2009, ApJ, 698, 1778

Search for orbital decay due to tides – WASP-12

2016–2018



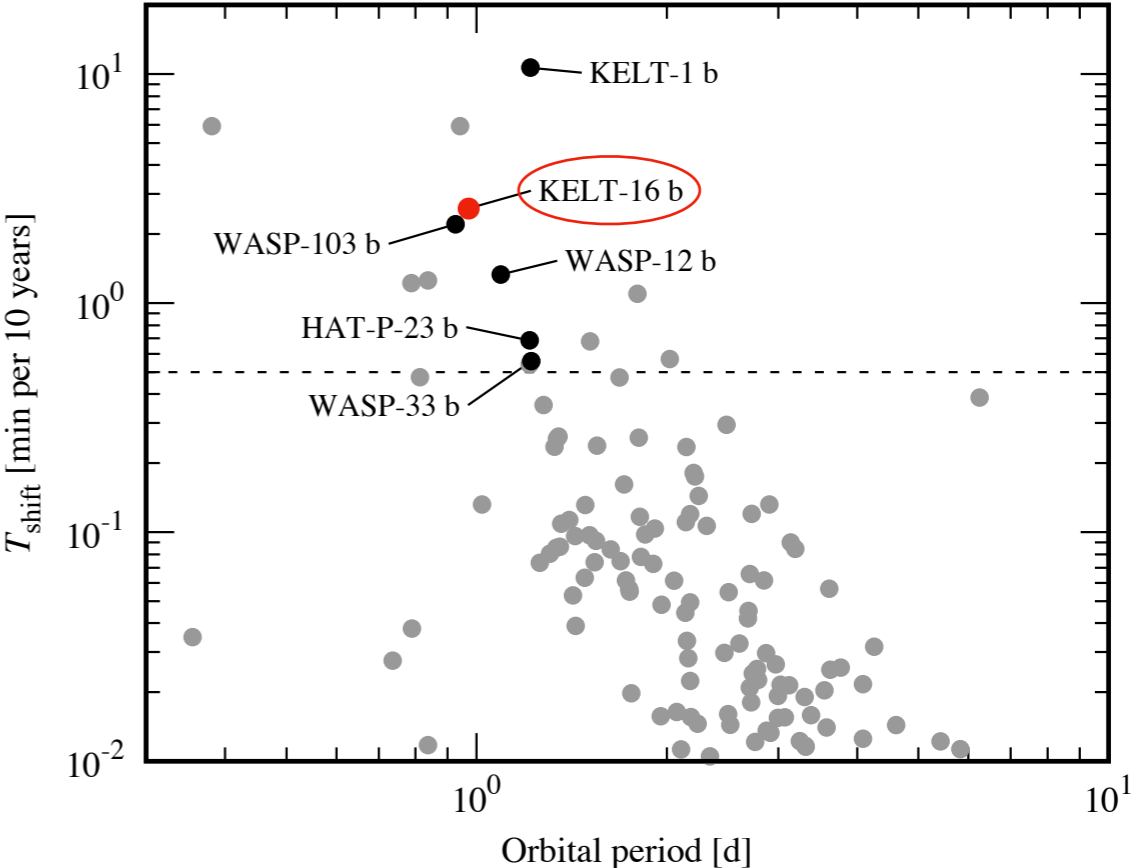
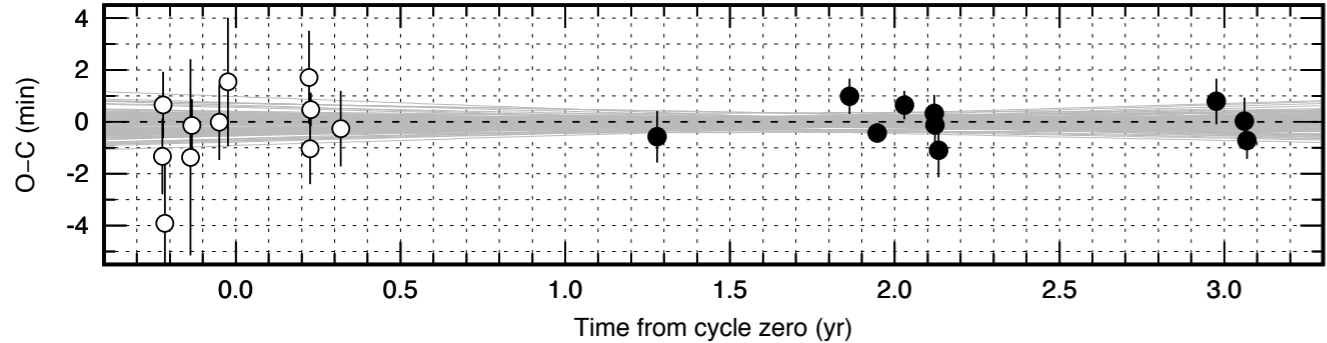
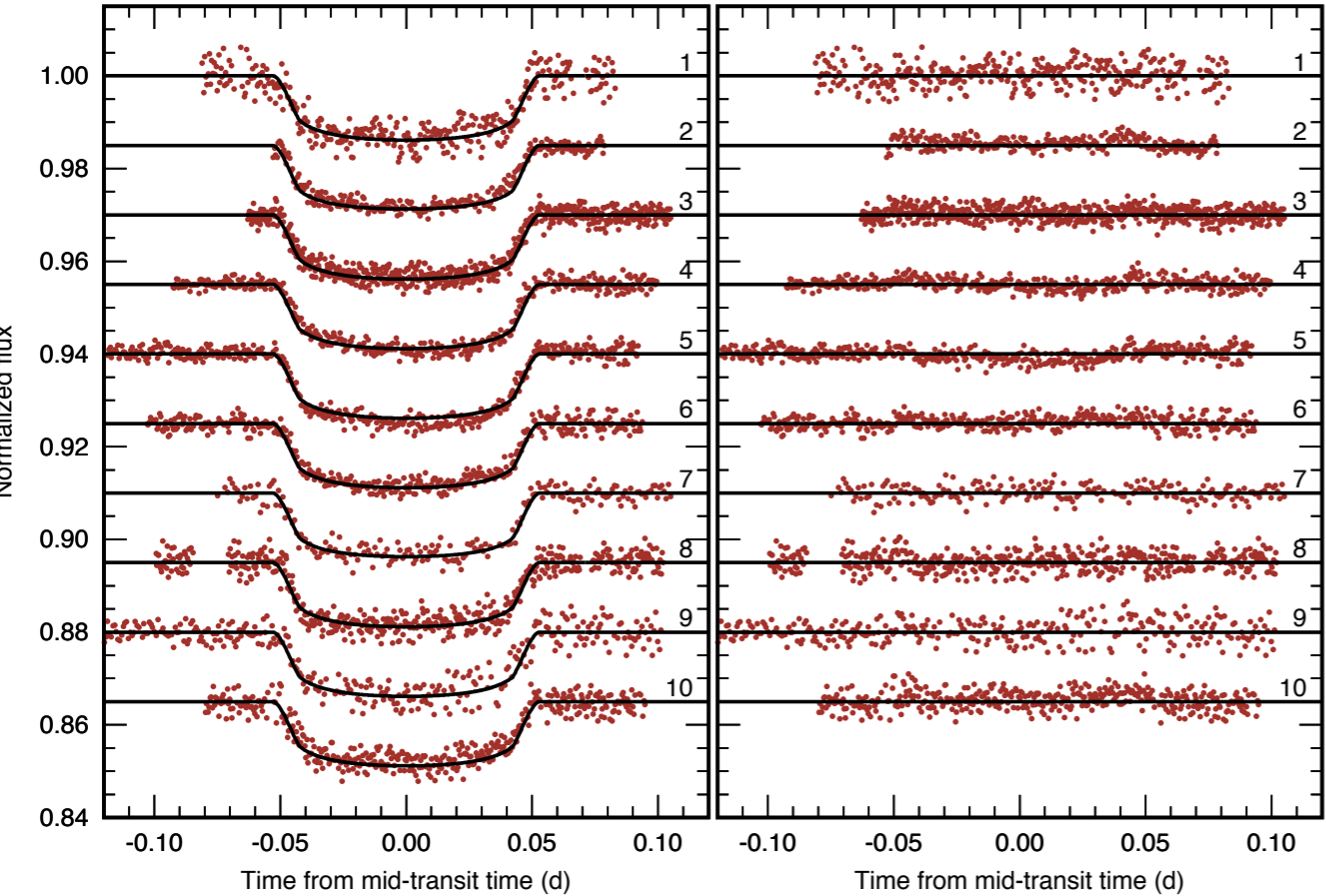
$$Q'_* = -\frac{27}{2} \pi \left(\frac{M_p}{M_*} \right) \left(\frac{a}{R_*} \right)^{-5} \left(\frac{dP_{\text{orb}}}{dE} \right)^{-1} P_{\text{orb}}$$

↓

$$Q'_* = (1.82 \pm 0.32) \times 10^5$$

Search for orbital decay due to tides – KELT-16

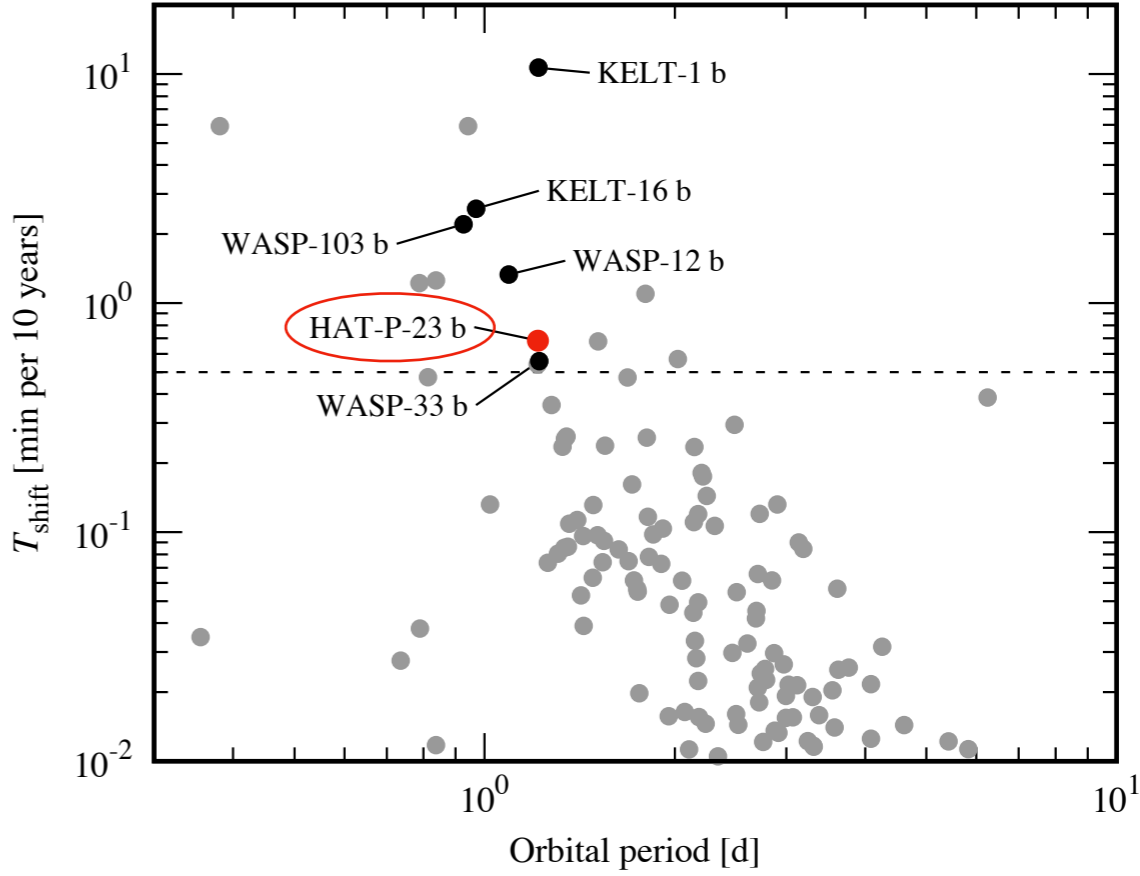
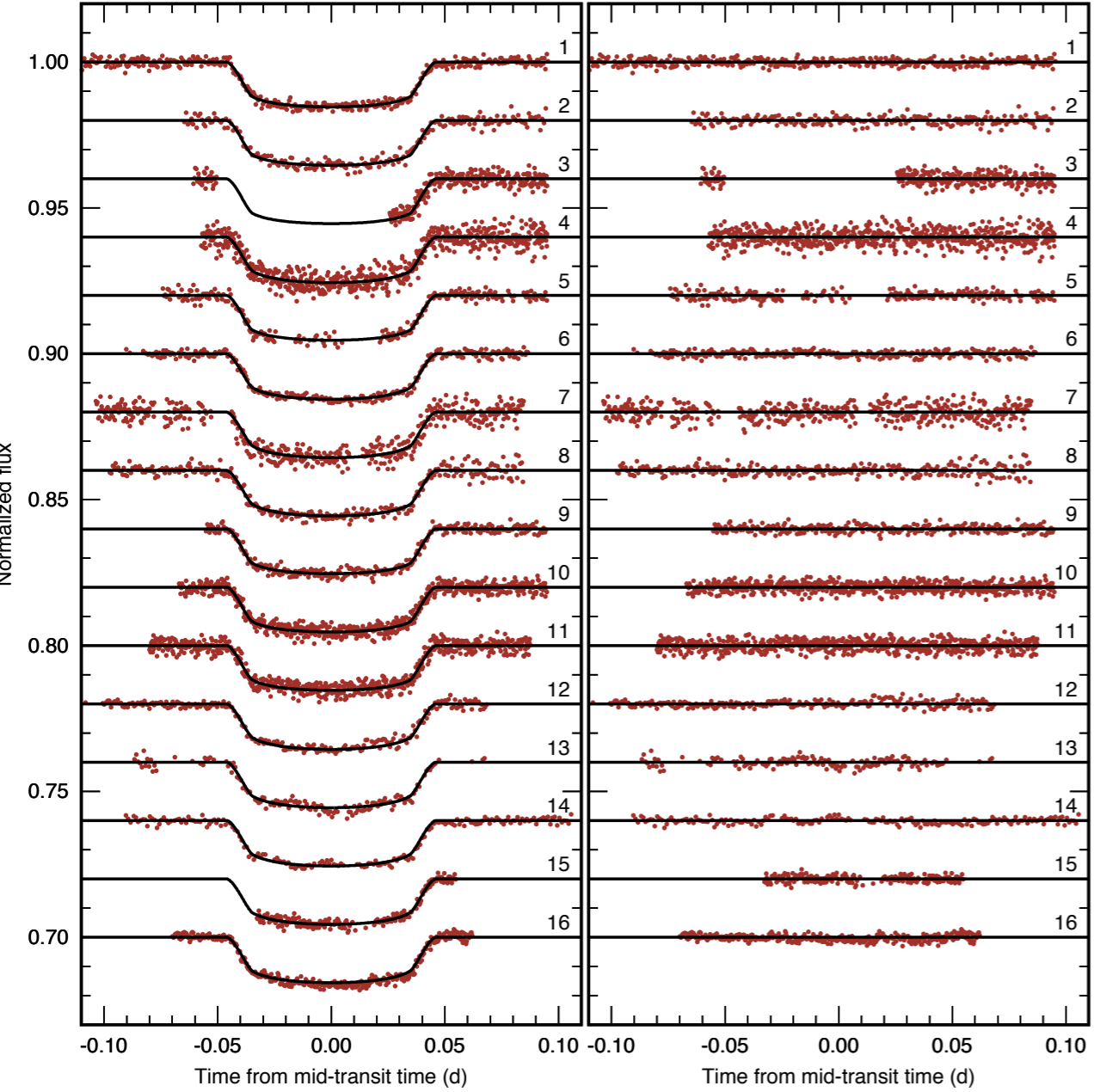
2016–2018



$Q'_* > 6.2 \times 10^4$ at the 95 % confidence level

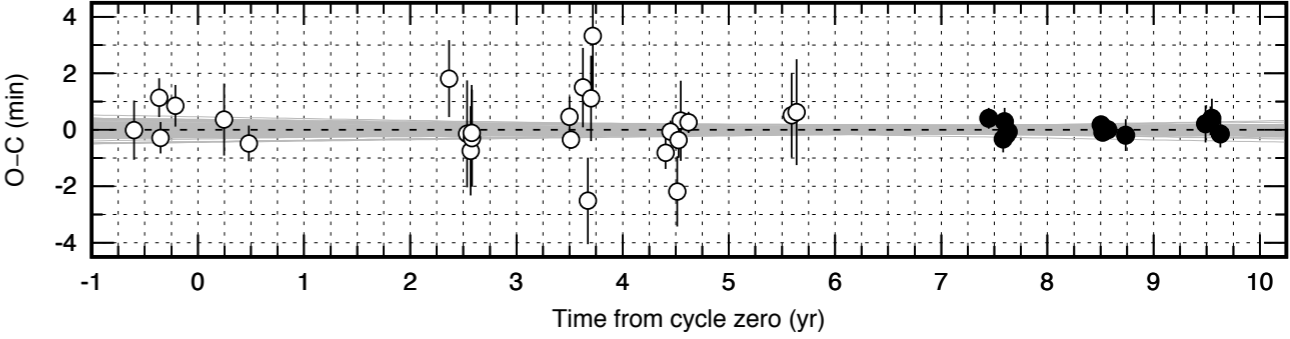
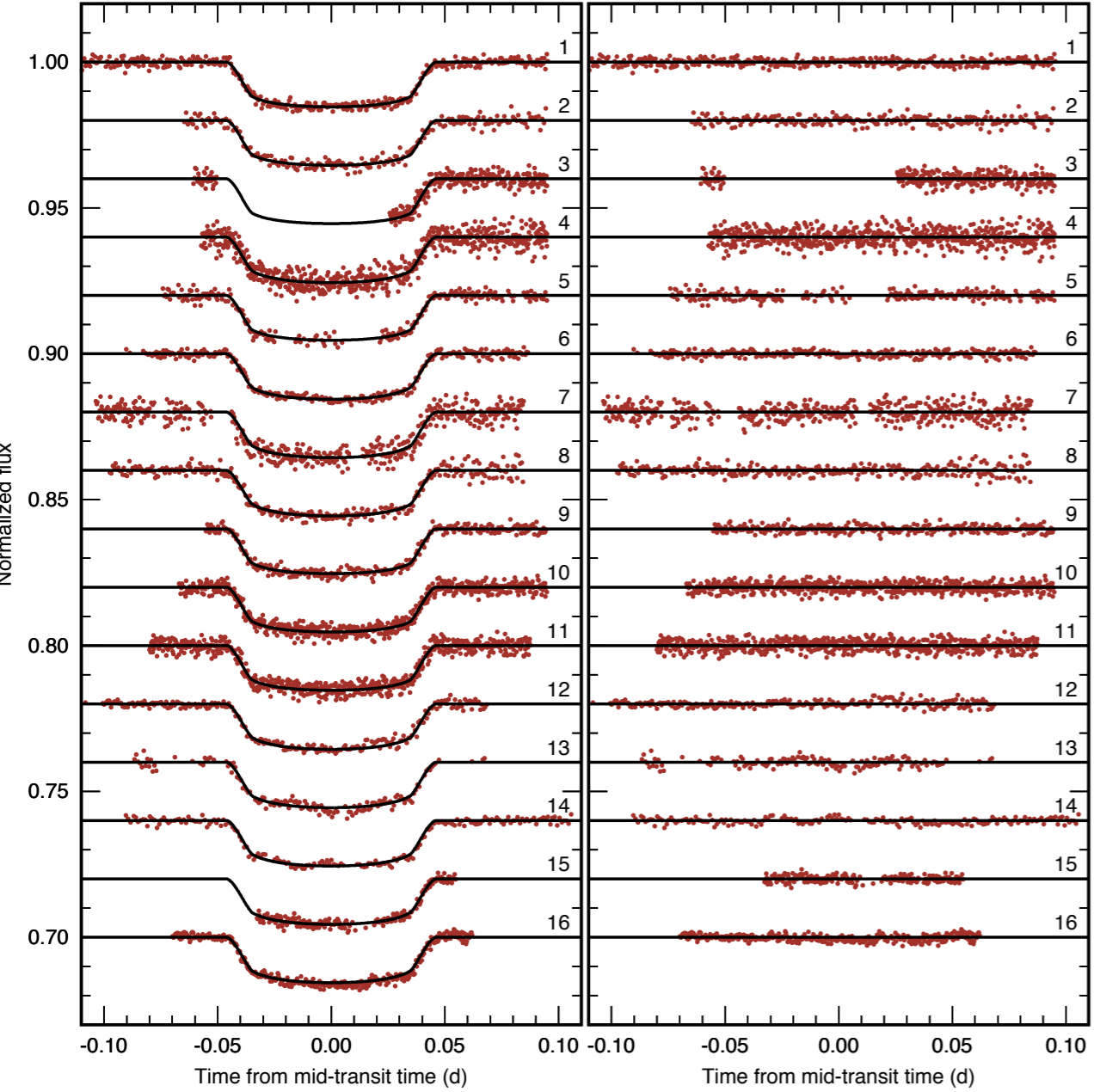
Search for orbital decay due to tides – HAT-P-23

2016–2018



Search for orbital decay due to tides – HAT-P-23

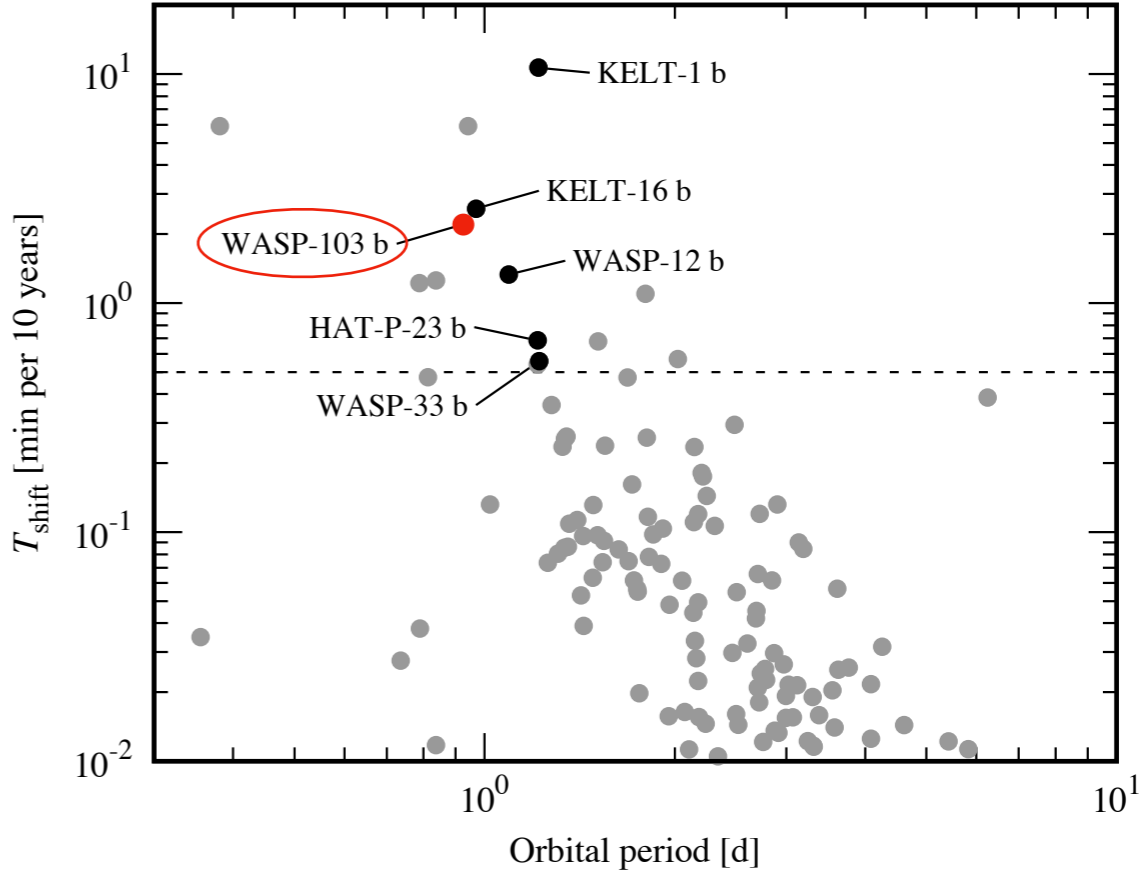
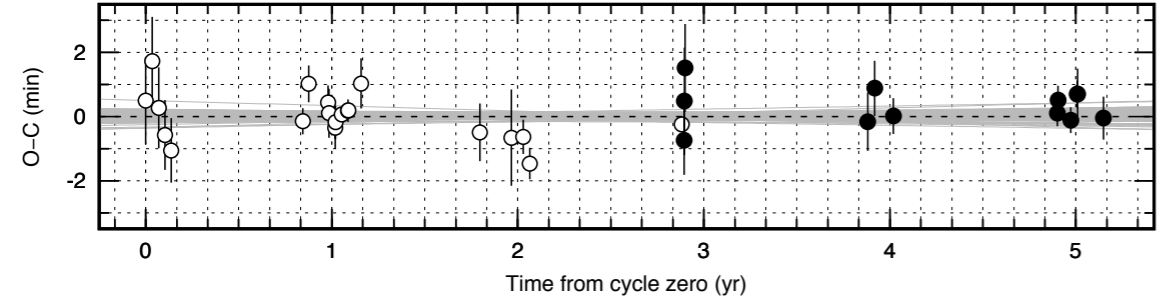
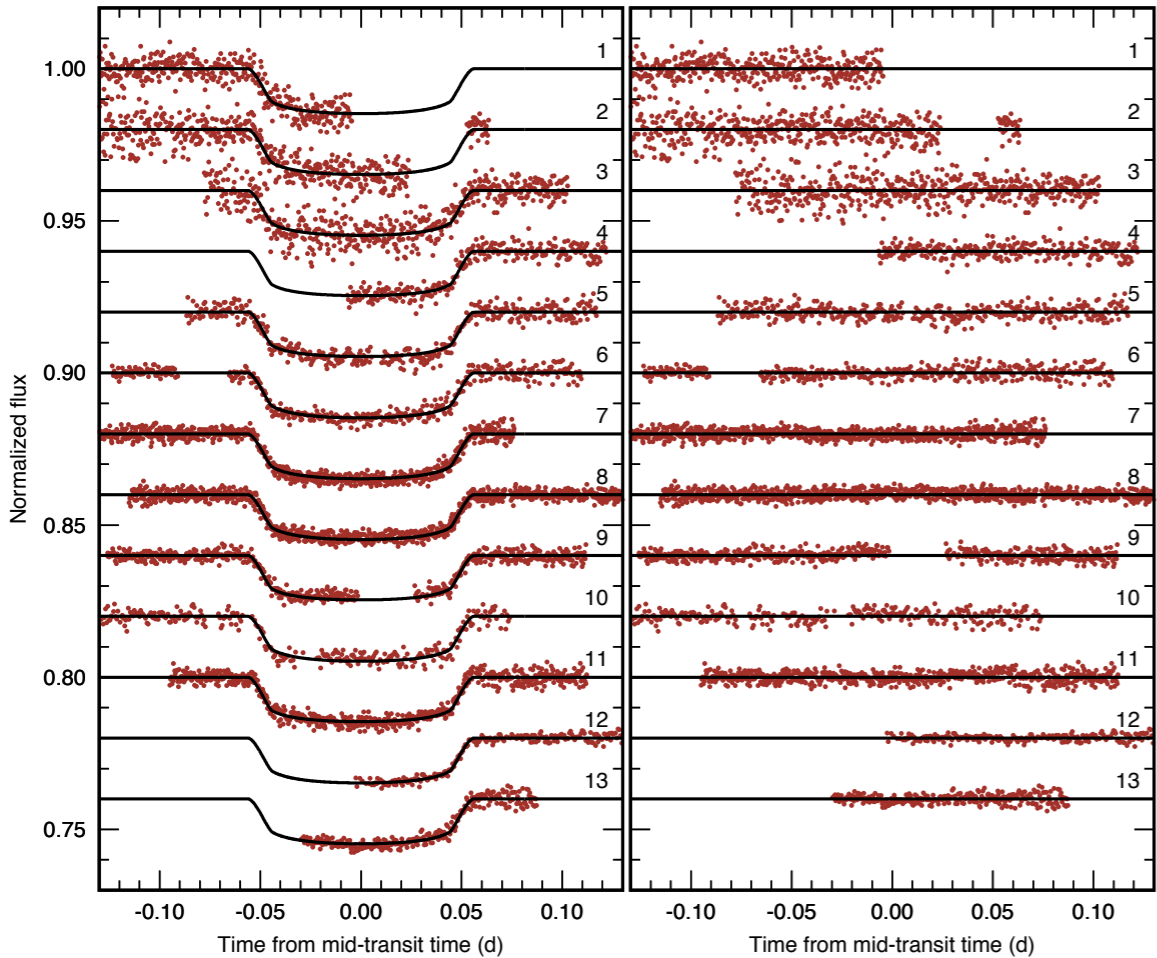
2016–2018



$Q'_* > 5.6 \times 10^5$ at the 95 % confidence level

Search for orbital decay due to tides – WASP-103

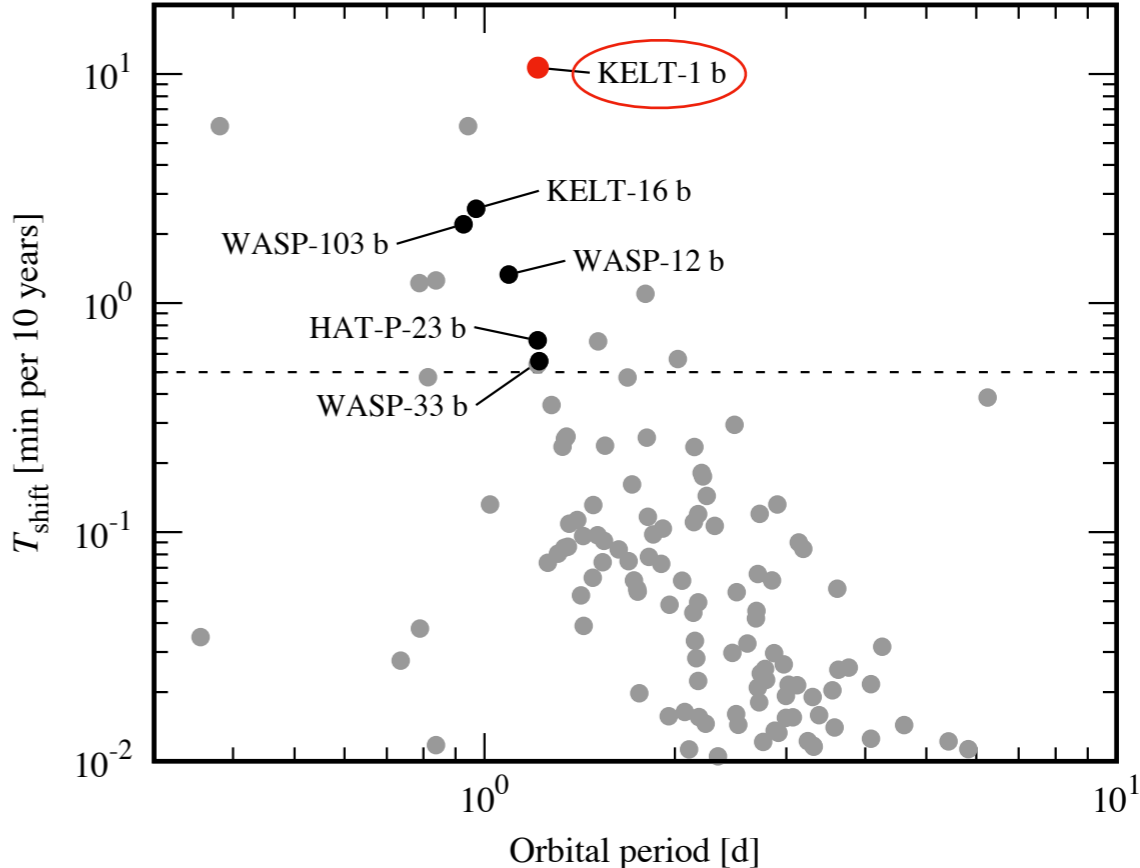
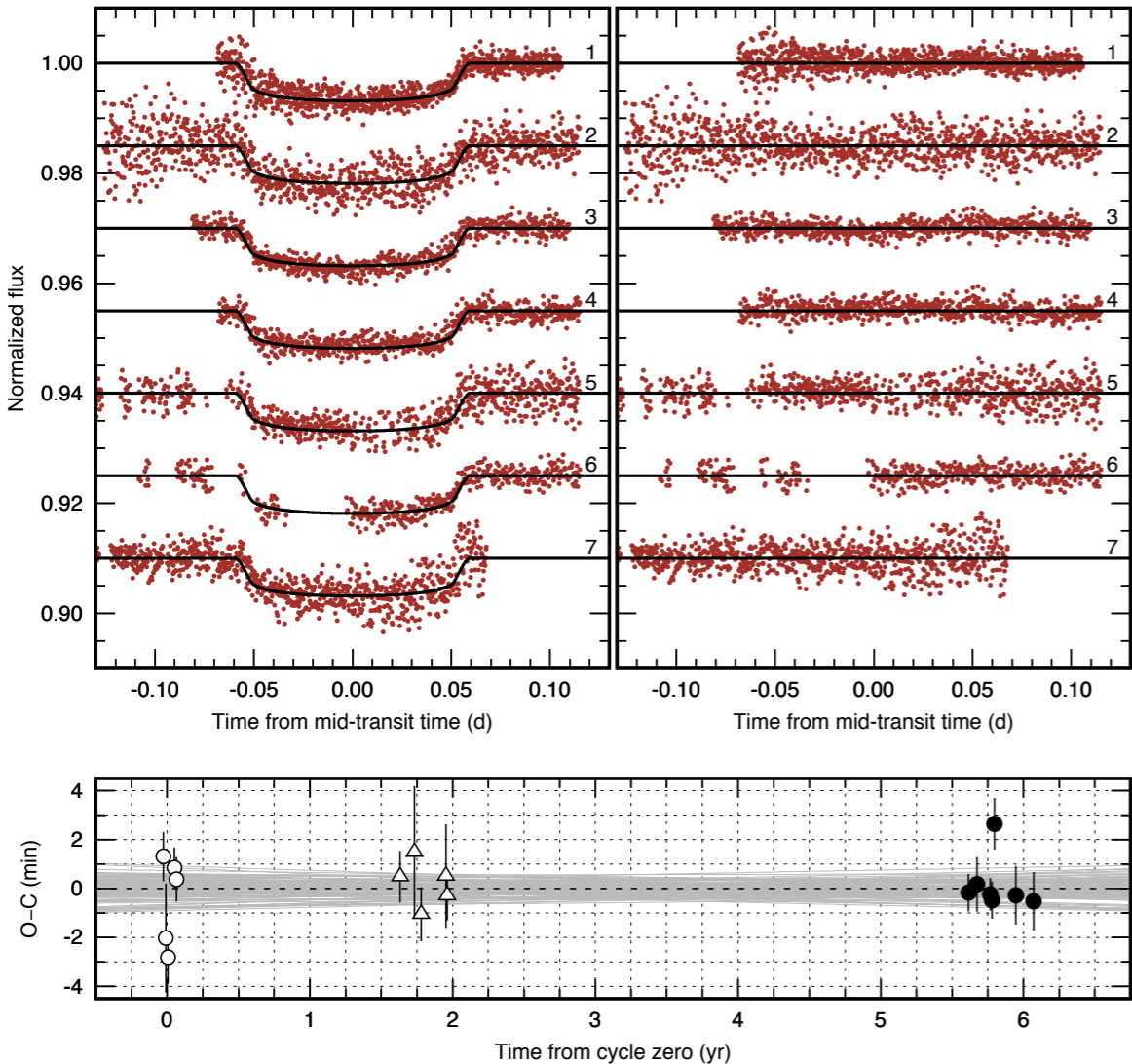
2016–2018



$Q_*' > 10^6$ at the 99.97 % confidence level

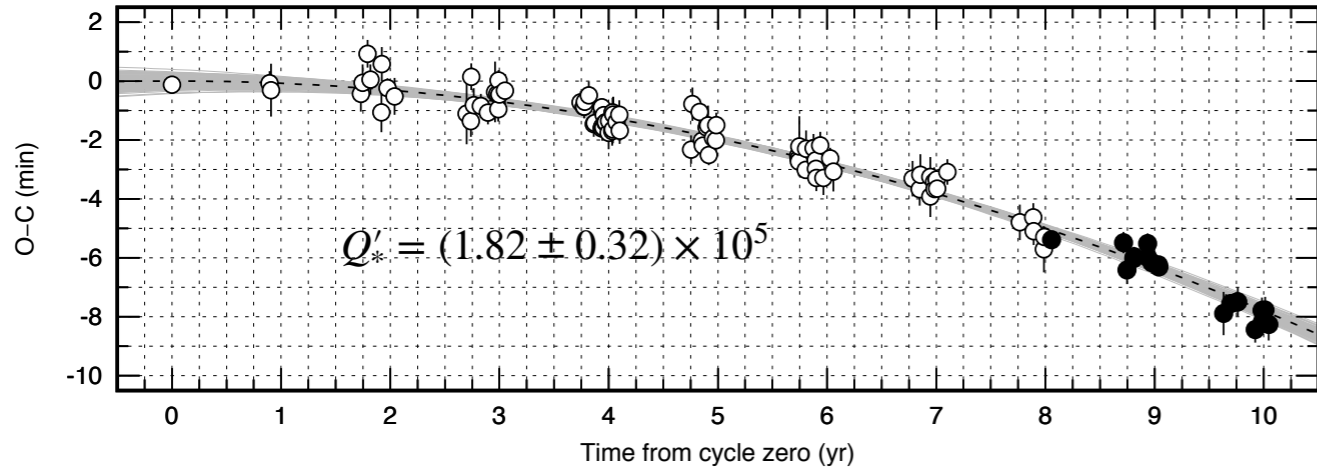
Search for orbital decay due to tides – KELT-1

2017

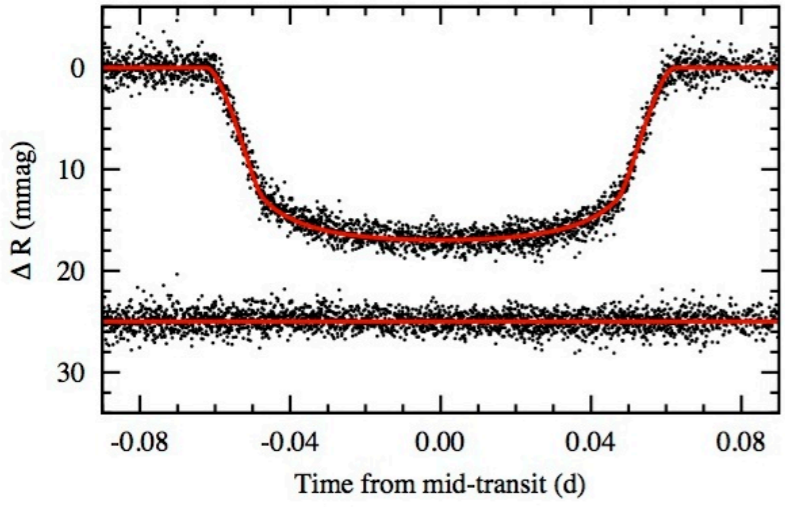


$Q'_* > 7.4 \times 10^5$ at the 95 % confidence level

Search for orbital decay due to tides – WASP-12

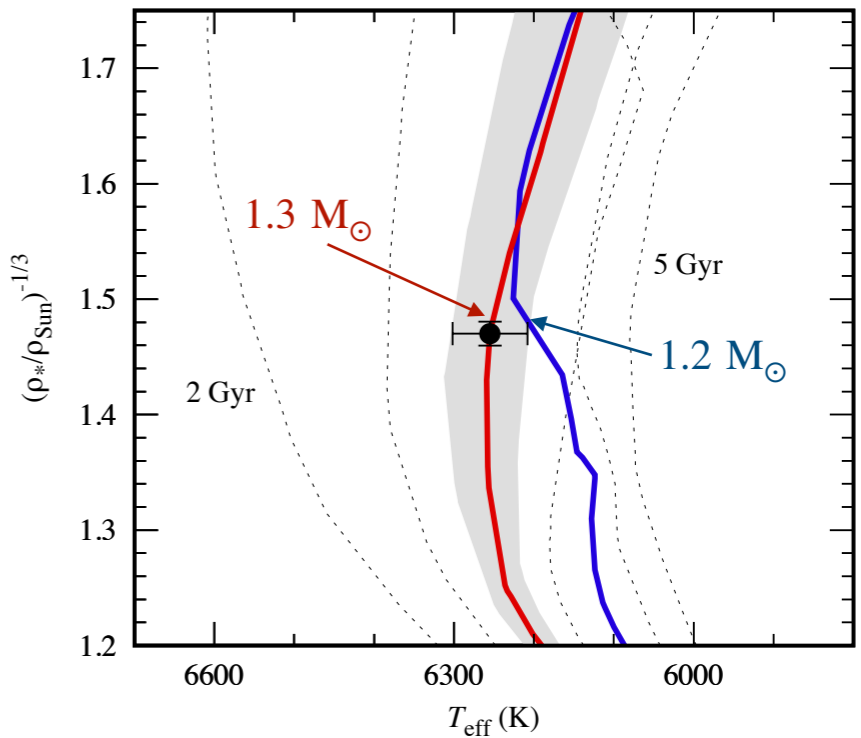


Maciejewski *et al.* 2018, submitted



Maciejewski *et al.* 2013, A&A, 551, 108

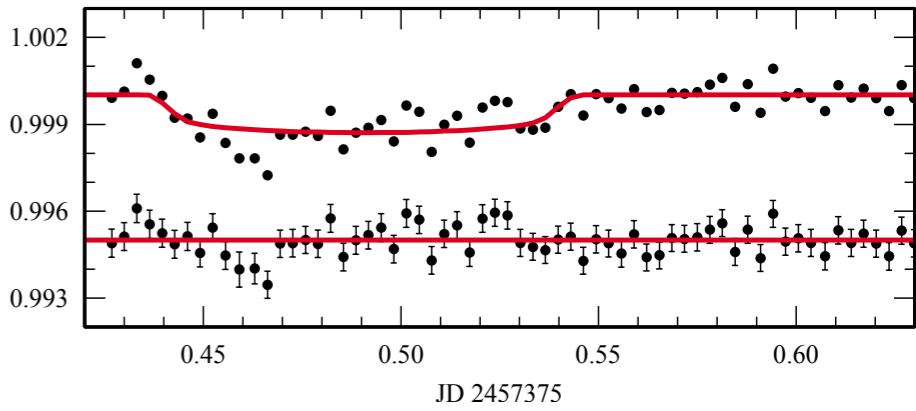
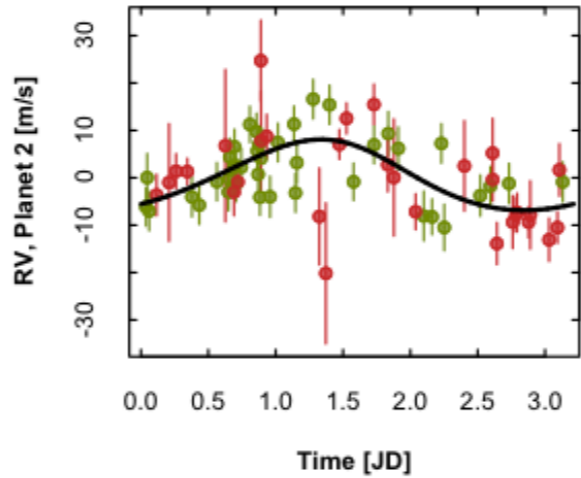
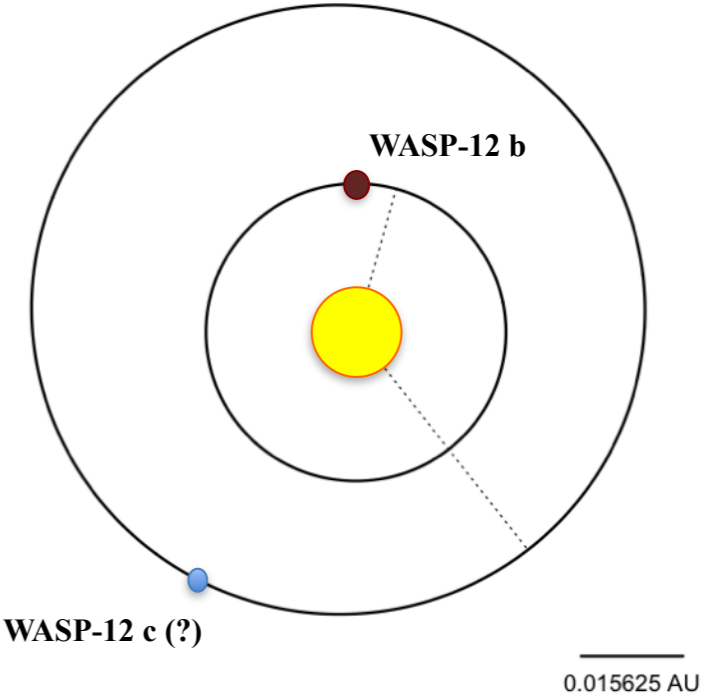
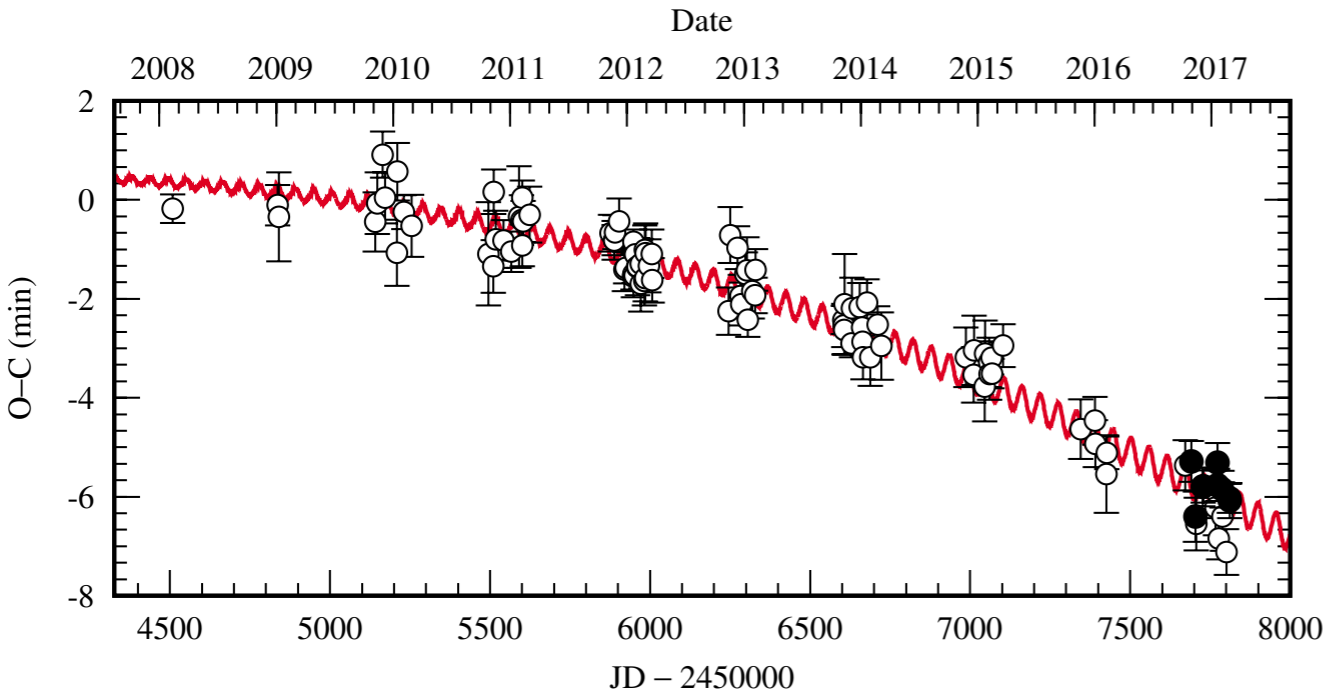
$$\rho_* = \frac{3\pi}{GP_b^2} \left(\frac{a_b}{R_*} \right)^3$$



Maciejewski *et al.*, in prep.

If WASP-12 is a subgiant star then theoretical models predict $Q'_* \approx 1.9 \times 10^5$

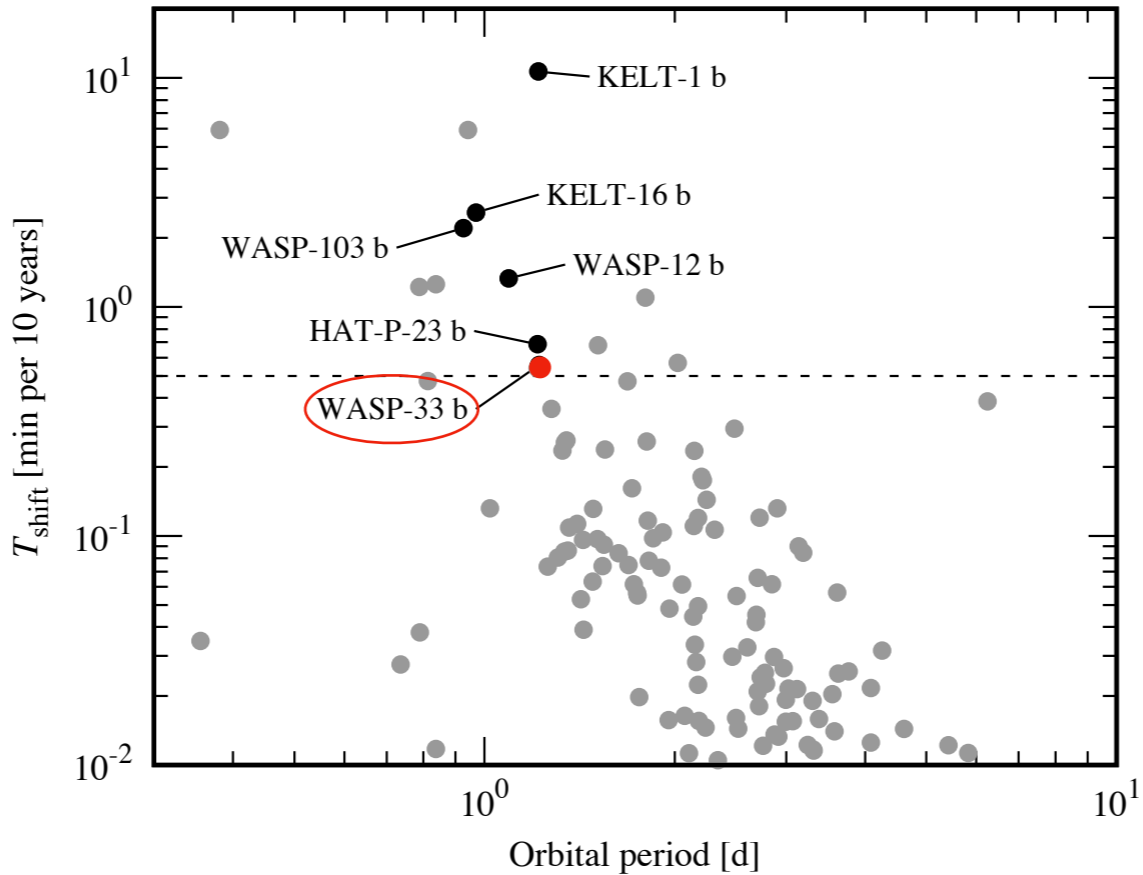
WASP-12 b – transit time variations of the perturbative nature



Maciejewski G., 2018, Proceedings of the Polish Astronomical Society, Vol. 7, p.113

This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

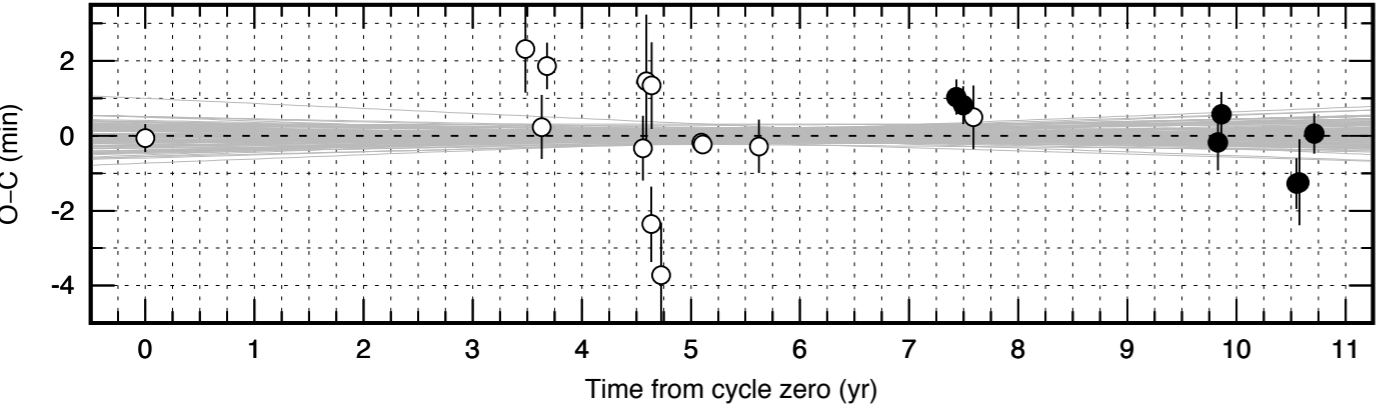
Search for orbital decay due to tides – WASP-33



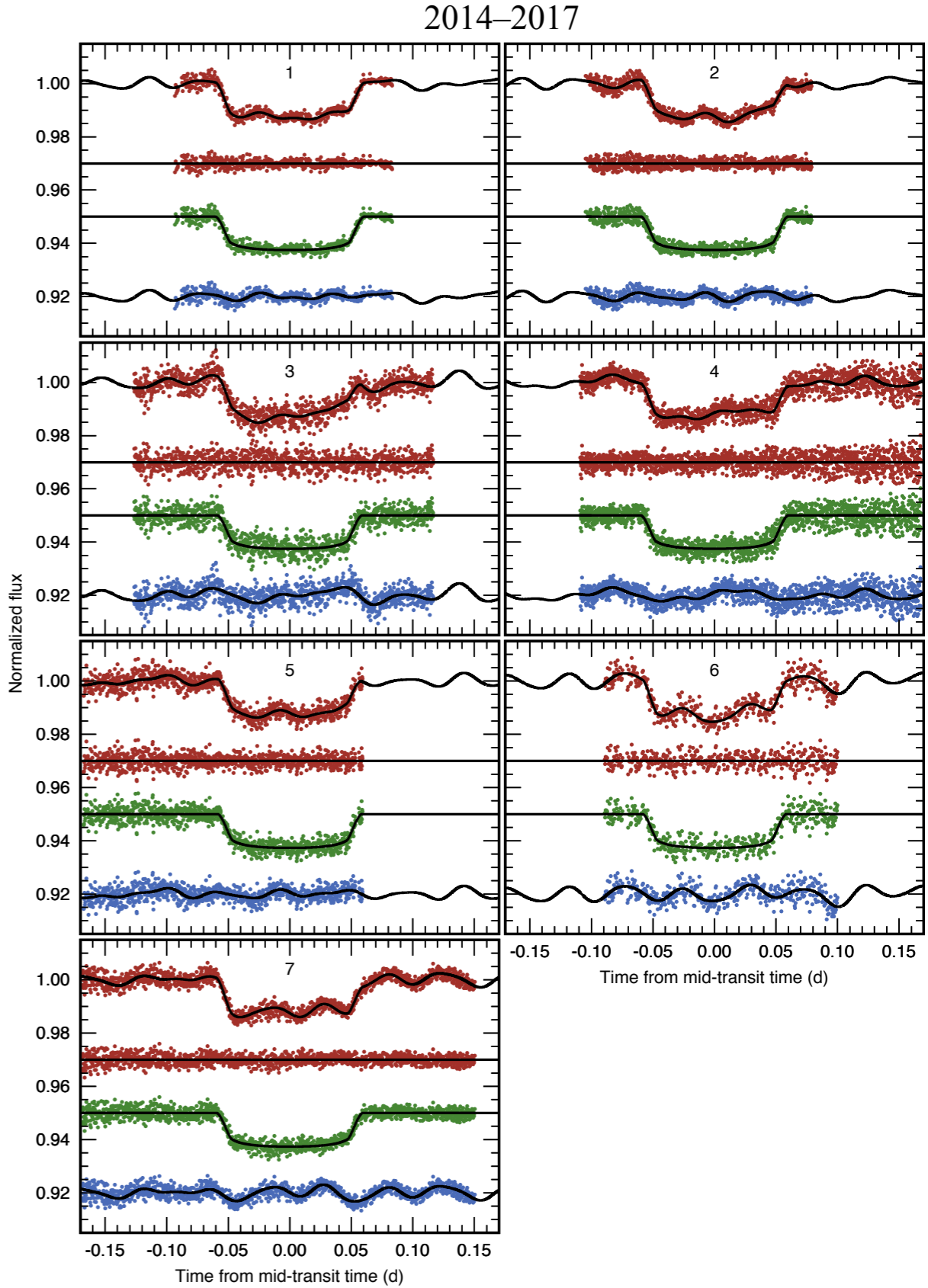
Maciejewski *et al.* 2018, submitted

This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

Search for orbital decay due to tides – WASP-33



$Q'_* > 5.0 \times 10^5$ at the 95% confidence level



Maciejewski *et al.* 2018, submitted

This research has been supported by the National Science Centre, Poland through grant no. 2016/23/B/ST9/00579.

<http://www.home.umk.pl/~gmac/TTV>

The screenshot shows a web browser window with the URL `www.home.umk.pl/~gmac/TTV/doku.php`. The browser's address bar and search bar are visible. The website has a blue header with the title "TRANSIT TIMING VARIATIONS @ YETI" and navigation tabs for "About the Project", "Strategy", "Results & Data", "Campaigns", and "Recent Changes". Below the header, a breadcrumb trail reads "Trace: starplanet • migration • hat4 • download • campaigns • backups • start" and the user is logged in as "ttv admin (admin)".

ABOUT THE PROJECT

In 2009 we launched international observing campaigns which are dedicated to detecting and characterising signals of transit timing variation for carefully selected transiting exoplanets. We base on collaboration within the framework of the [Young Exoplanet Transit Initiative \(YETI\)](#). The programme is realised by collecting data from 0.4–2.6-m telescopes spread worldwide at different longitudes. Observers or teams of observers, who contribute or try to contribute, become co-authors of a paper ending each campaign.

How to contribute?

Just try to observe a complete transit light curve during our campaign. A complete light curve is: at least 1 hour of out-of-transit monitoring + ingress + flat bottom + egress + again at least 1 hour of out-of-transit monitoring. Observations should be collected in a band in which an instrument is most sensitive. R and I bands are recommended to minimise atmospheric extinction and limb darkening effects. Exposure times should be not shorter than 20–30 s, recommended value is 40–50 s. Telescope defocusing may be used to avoid saturation. The exposure time should be the same during a run or at least during ingress and egress. Make sure that time survey from a clock of a CCD controlling computer is correct (± 1 s). Any web time software is enough to synchronise clocks before starting observing.

How to prepare observations?

The [Exoplanet Transit Database](#) offers a great tool which allows you to list transits available from your observatory. Just go to *Transit Prediction* and enter east longitude and latitude or click on the planet at the left and then *Show transit predictions for next 365 days*. Do not forget to add 1 hour before and after a transit for out-of-transit observations. In the case of any problems, a PI of a given campaign will be happy to assist you.

Contact

If you wish to join our project, please contact us for details:

- ✉ Gracjan Maciejewski
- ✉ Ralph Neuhaeuser

start.txt · Last modified: 2017/02/21 10:23 (external edit)

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