The peculiar transit signature of CoRoT-29b

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introduction

the Team

Transiting exoplanets from the CoRoT space mission ⋆

XXVIII. CoRoT-28b, a planet orbiting an evolved star, and CoRoT-29b, a planet orbiting an oblated star

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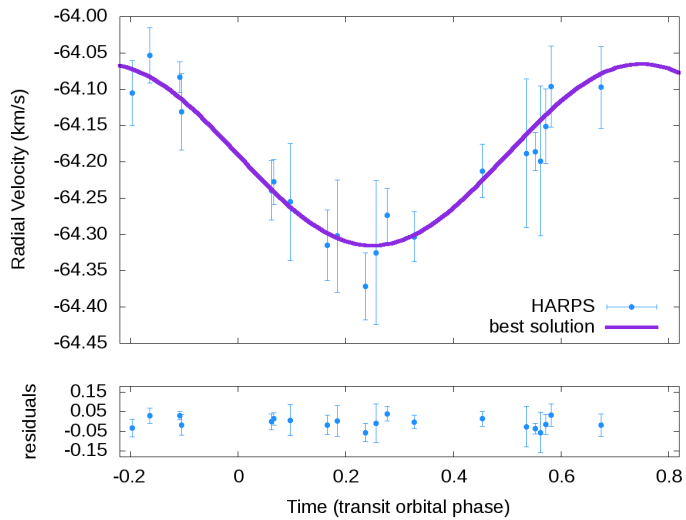
introduction

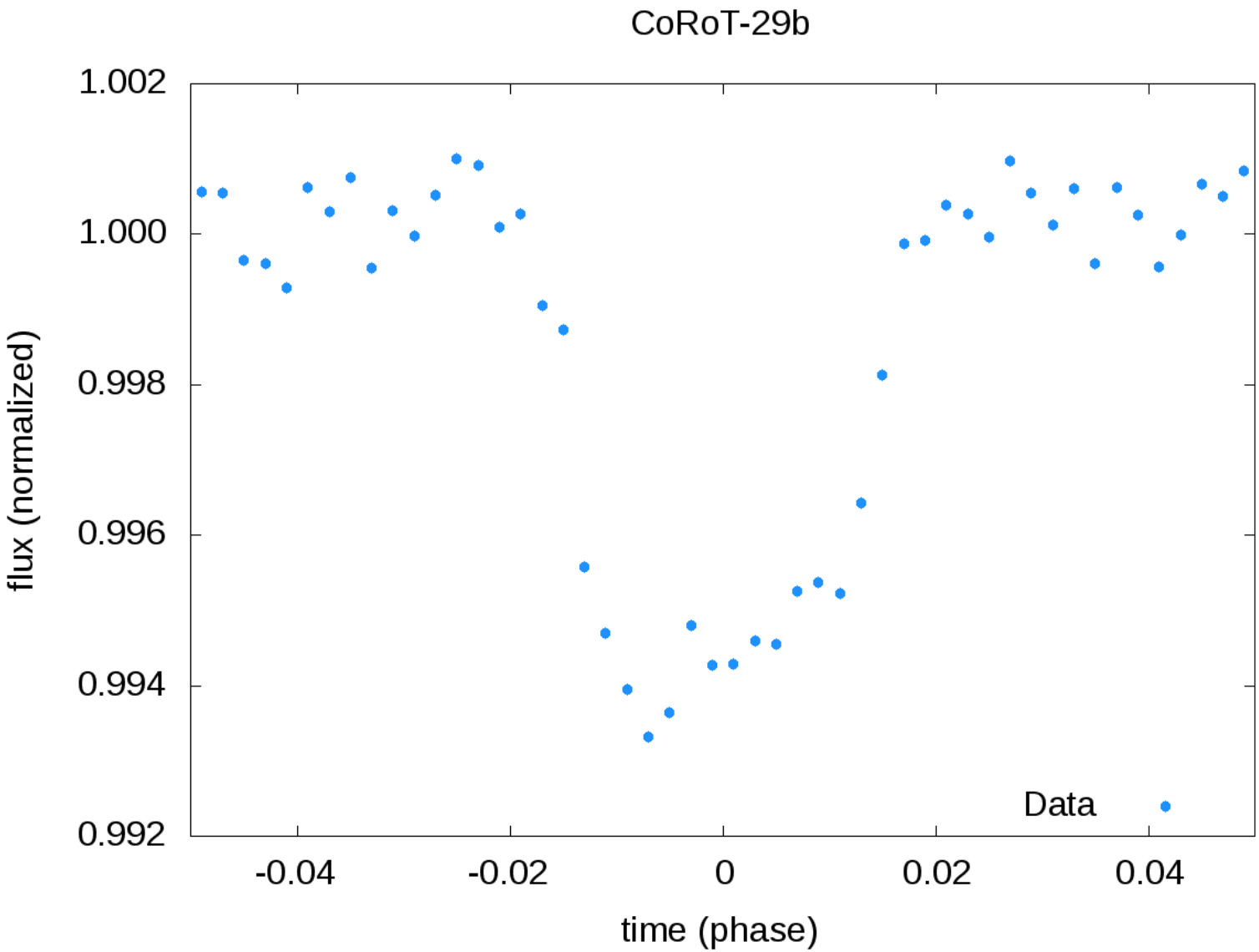
fact sheet

- planetary parameters
  - mass: $0.85 \pm 0.20\ M_{Jupiter}$
  - radius: $0.90 \pm 0.16\ R_{Jupiter}$
  - density: $1.45 \pm 0.74\ g\,cm^{-3}$
  - $\log g$: 3.42 ± 0.19 (cgs)
- stellar parameters
  - mass: $0.97 \pm 0.14\ M_{Sun}$
  - radius: $0.90 \pm 0.12\ R_{Sun}$
  - T_{eff}: $5\,260 \pm 100$K
  - $\log g$: 4.52 ± 0.19 (cgs)
  - age: $1 - 8$ Gyr
  - K0V
- orbital parameters
  - P: $2.850\,522 \pm 0.000\,076$ d
  - a: 0.0386 ± 0.0059 AU
  - K: $125 \pm 17\ m\,s^{-1}$
  - i: $87.3 \pm 2.7°$
  - e: 0.082 ± 0.081



CoRoT-29b: the asymmetry of the transit

the CoRoT observations



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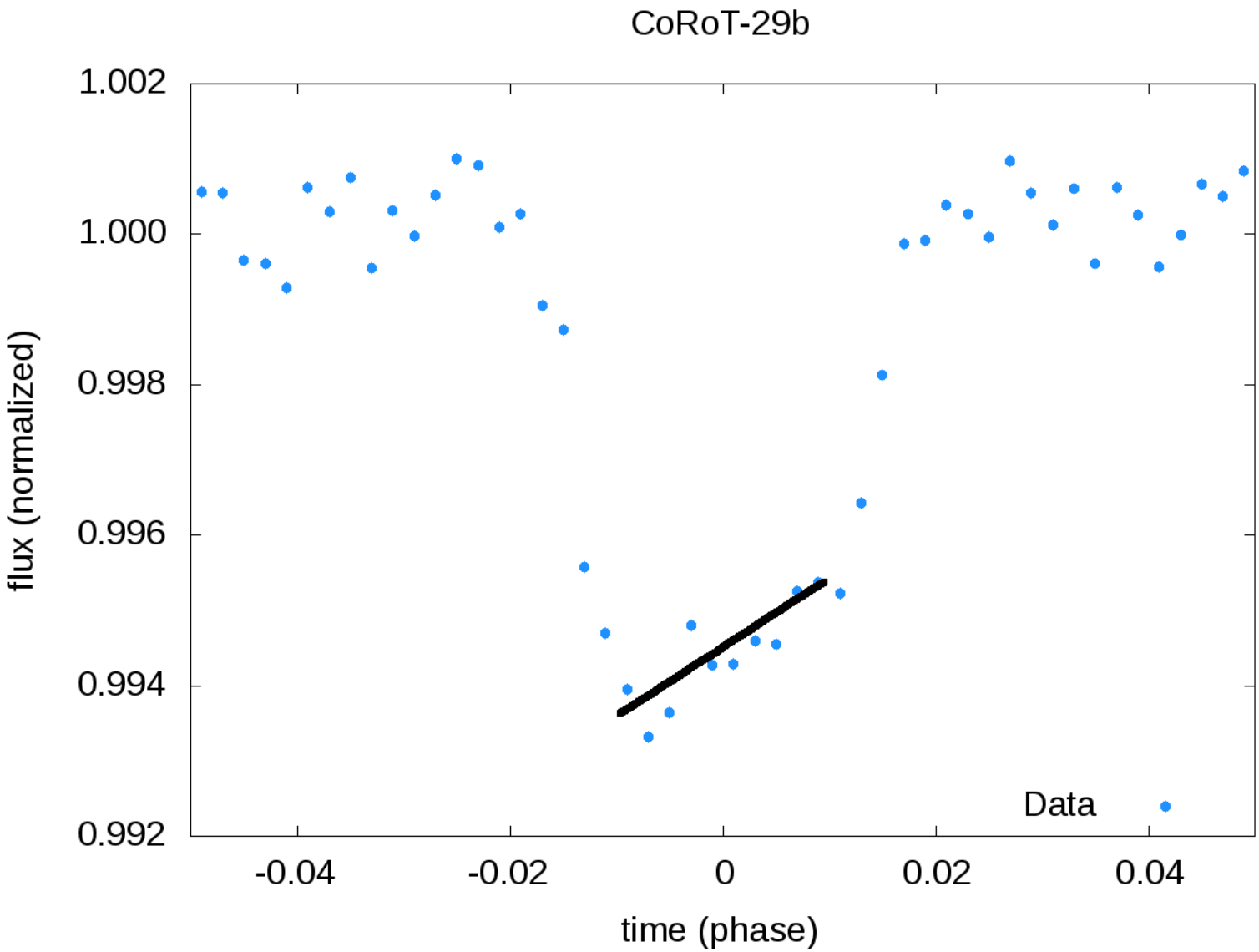

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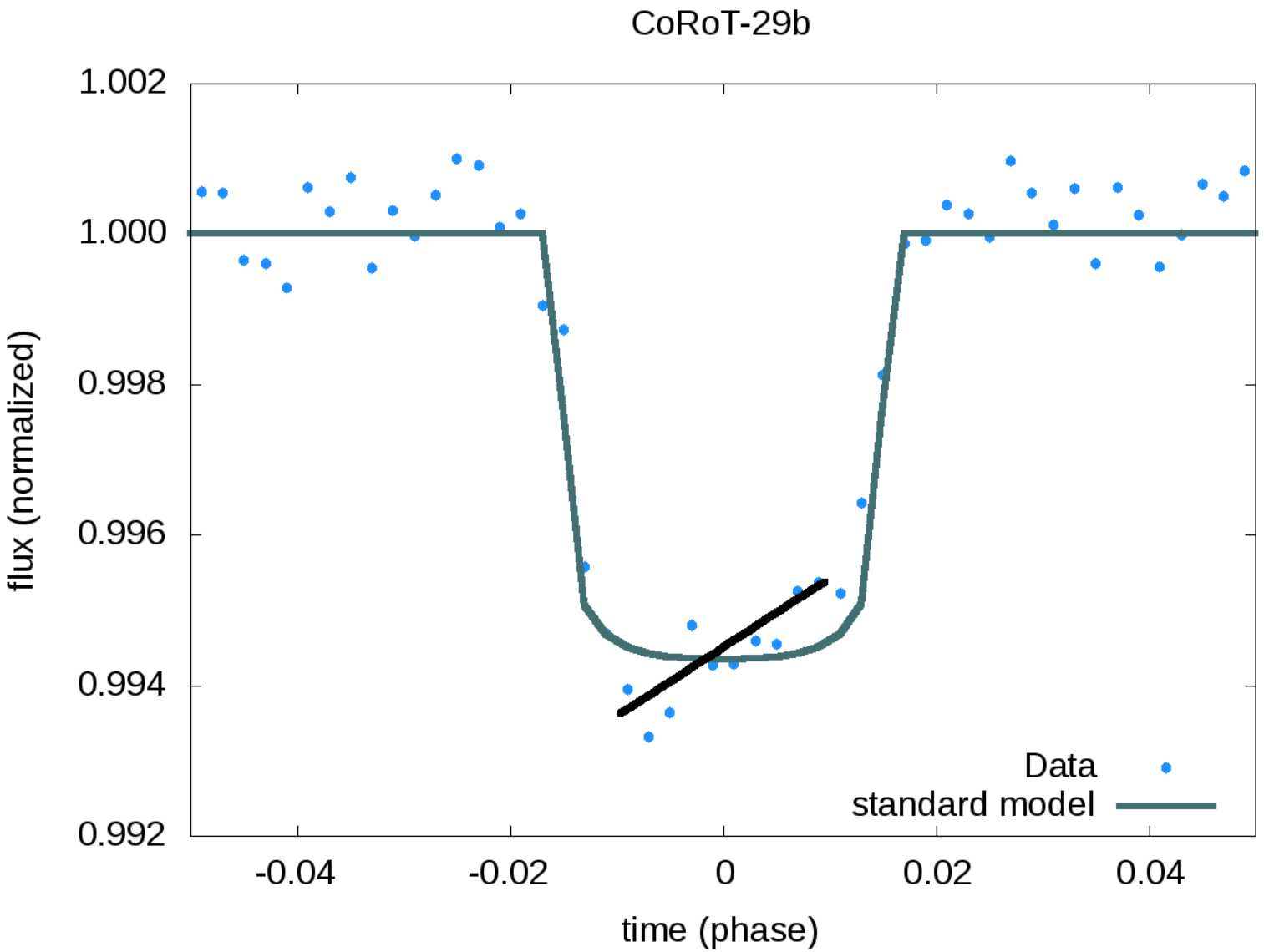

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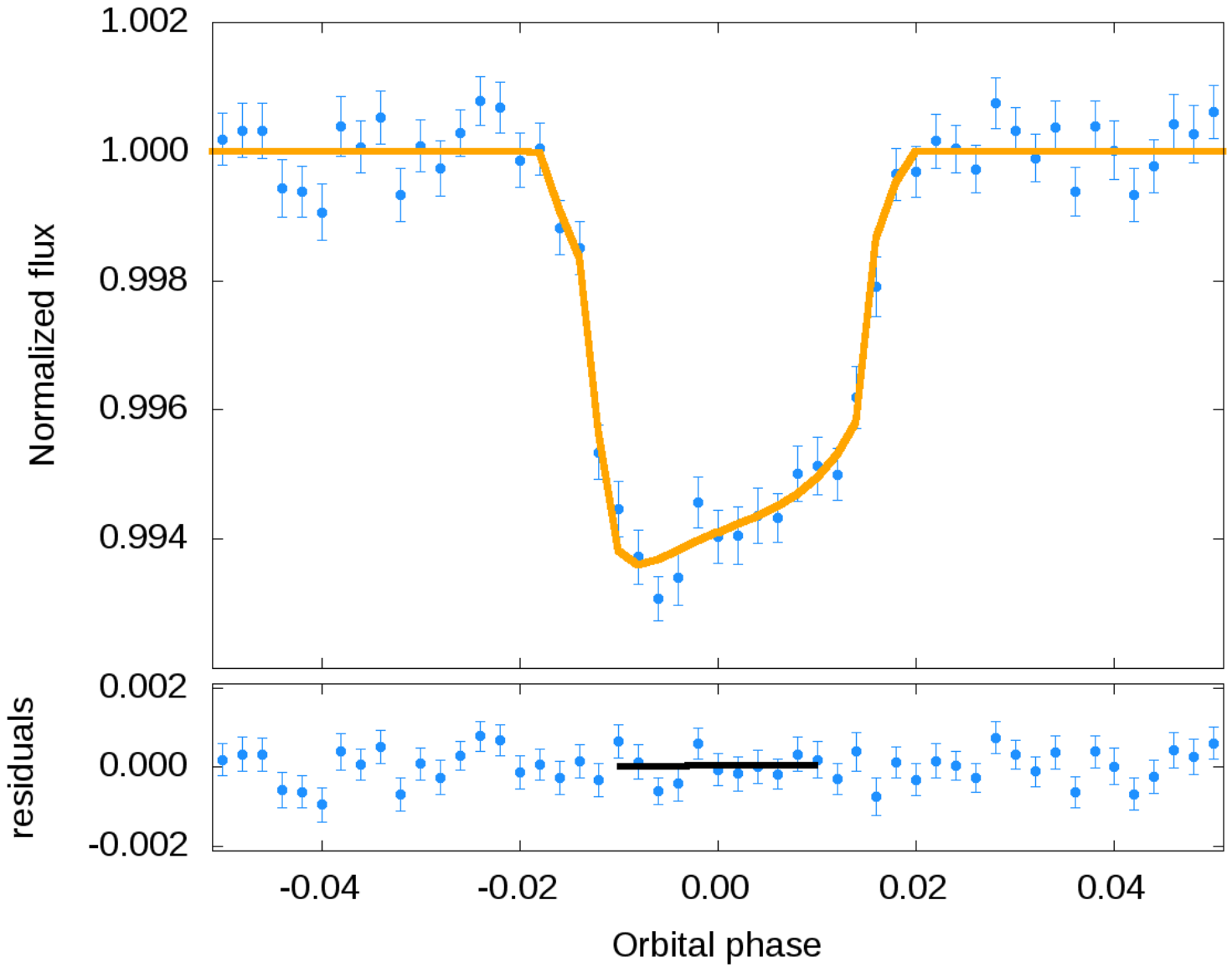
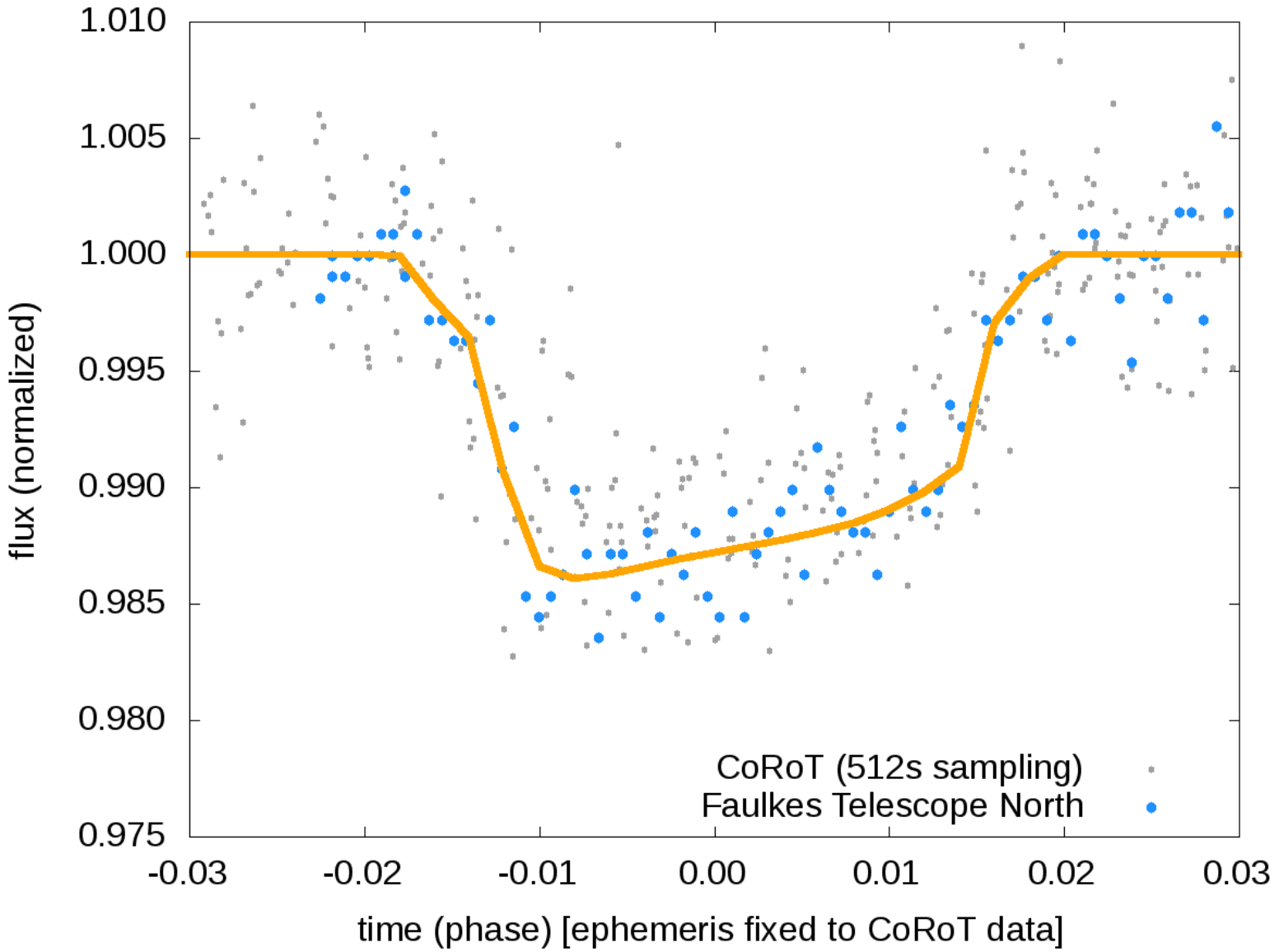


CoRoT-29b: the asymmetry of the transit

confirmation from ground-based observations



CoRoT-29b: the asymmetry of the transit

confirmation from ground-based observations

- the transit is significantly asymmetric
- confirmed from ground

CoRoT-29b: the origin of the asymmetry

the planet

- tidal distortion of the planet

$$J_2 = \frac{k_2}{3}\left(q_r - q_t\right);\ q_r = \frac{\Omega^2 R_p^3}{GM_p};\ q_t = -3\left(\frac{R_p}{a}\right)^3\left(\frac{M_p}{M_s}\right) \qquad (1)$$

see Ragozzine & Wolf (2009); Leconte et al. (2011)

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- disk

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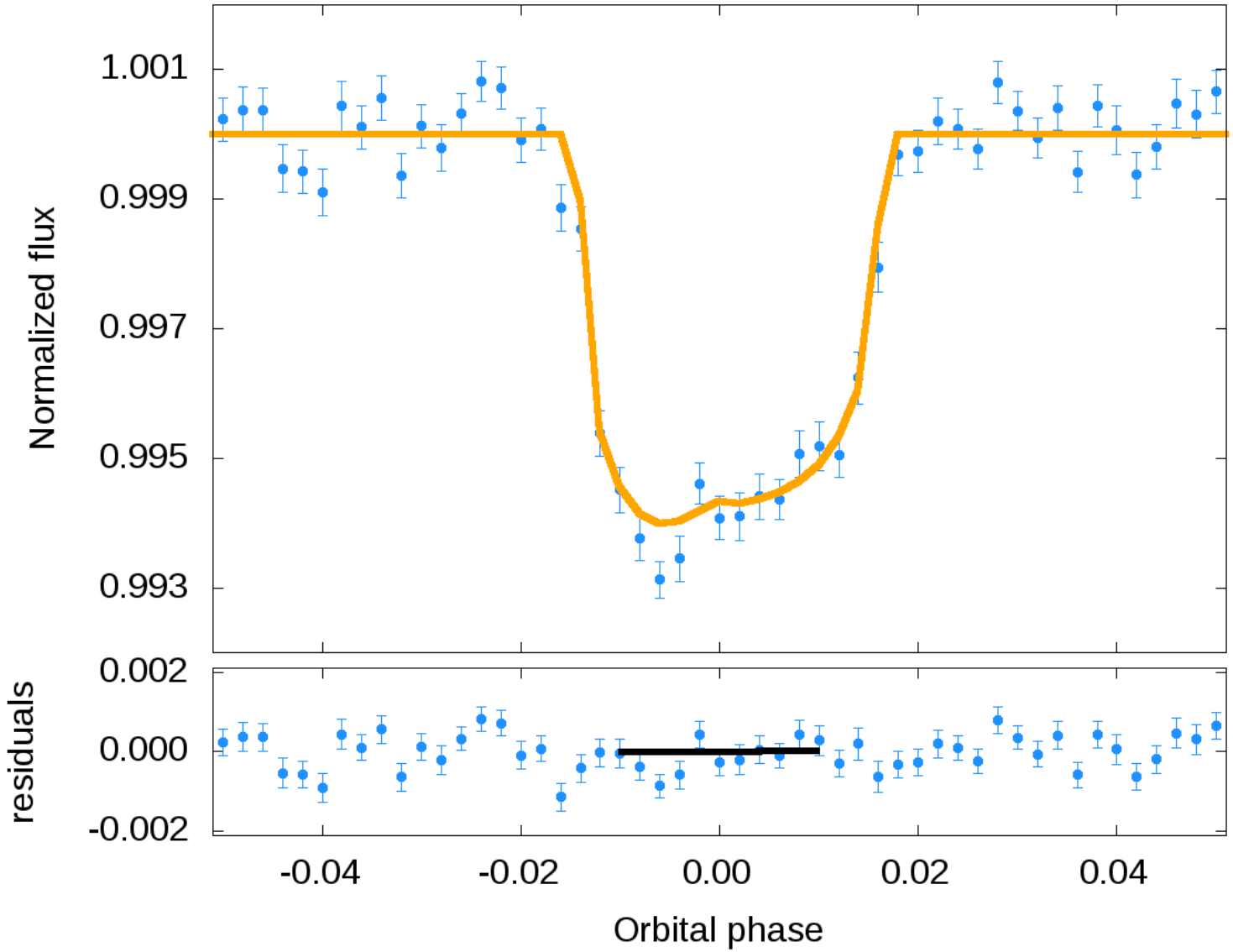
- disk
- rings, moons...

  discarded by the data

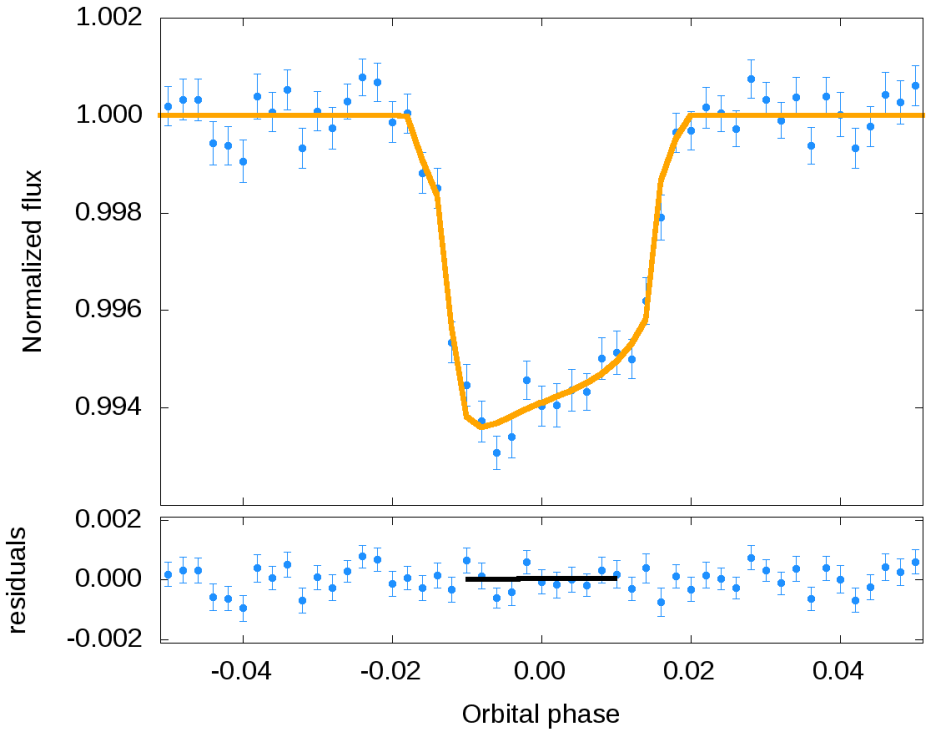
CoRoT-29b: the origin of the asymmetry

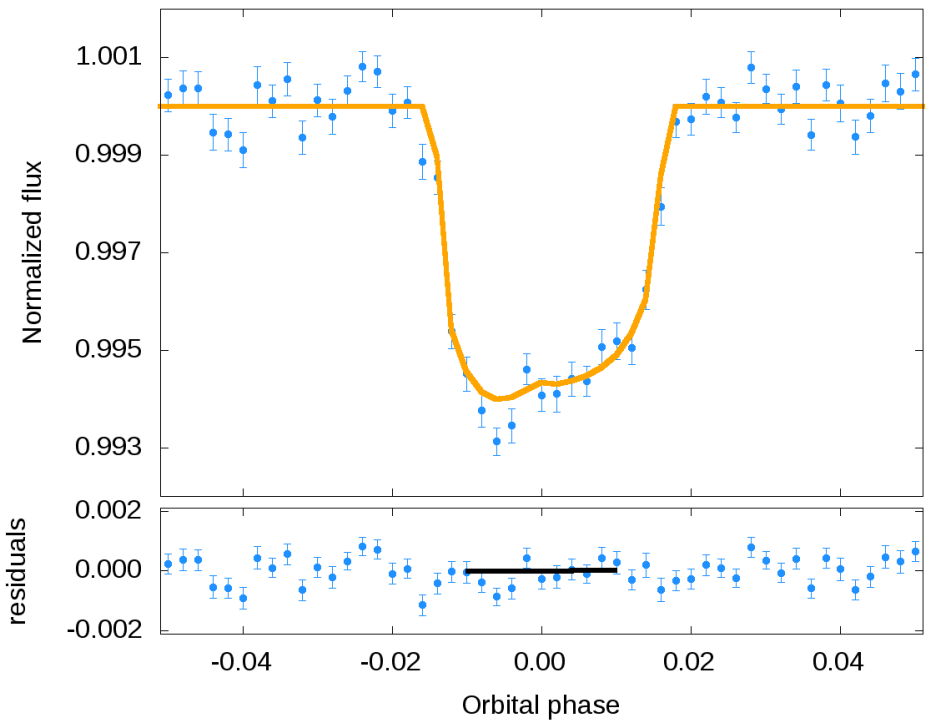
stellar spots



CoRoT-29b: the origin of the asymmetry

stellar spots





- gravity darkening

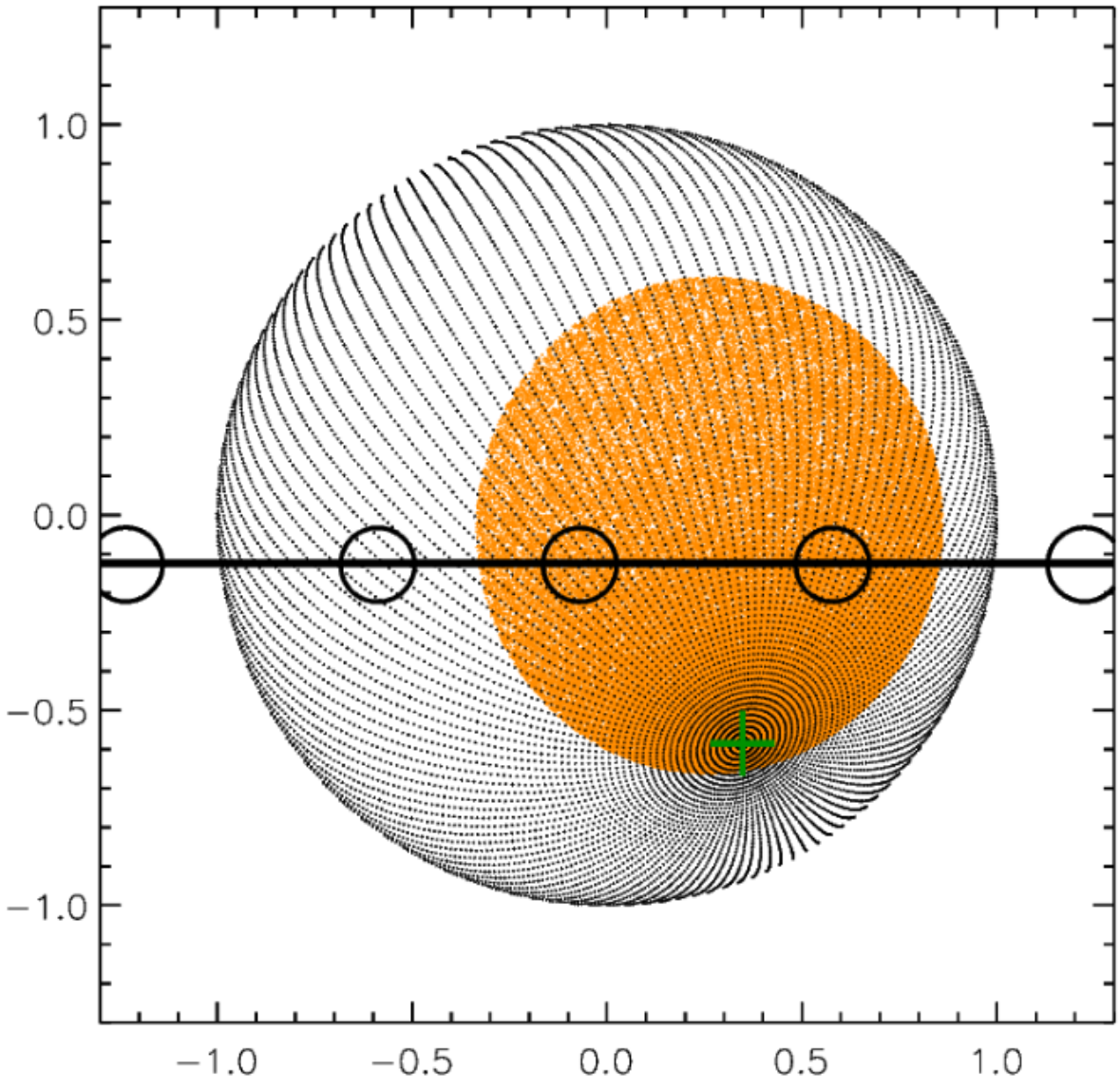
  $\chi^2 = 71$ (62 p; 12 f; $\chi^2_r = 1.4$)

- spot

  $\chi^2 = 84$ (60 p; 12 f; $\chi^2_r = 1.8$)

CoRoT-29b: the origin of the asymmetry

stellar spots



CoRoT-29b: the origin of the asymmetry

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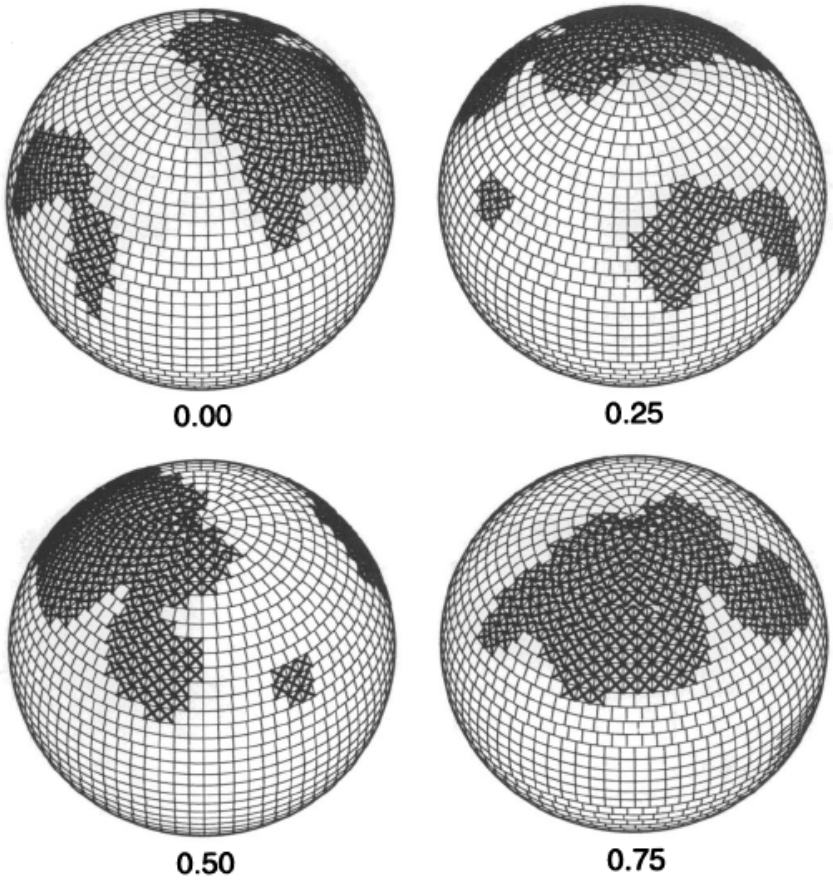

FIG. 13.—The average Doppler image of V410 Tau shown in stereographic projection at four rotation phases (ϕ = 0.0, 0.25, 0.50, and 0.75). All pixels with a temperature less than 500 K below the photospheric value are shown as spotted regions (*crosses*). All other image pixels are displayed as photosphere (*white*).

V410 Tau by Hatzes (1995)

CoRoT-29b: the origin of the asymmetry

stellar spots

- the spot scenario is *ad hoc*
- stability over 1 yr required (ground-based observations)
- polar spot (and misaligned orbit)
- slow rotating, main sequence star

CoRoT-29b: the origin of the asymmetry

stellar spots

- the spot scenario is *ad hoc*
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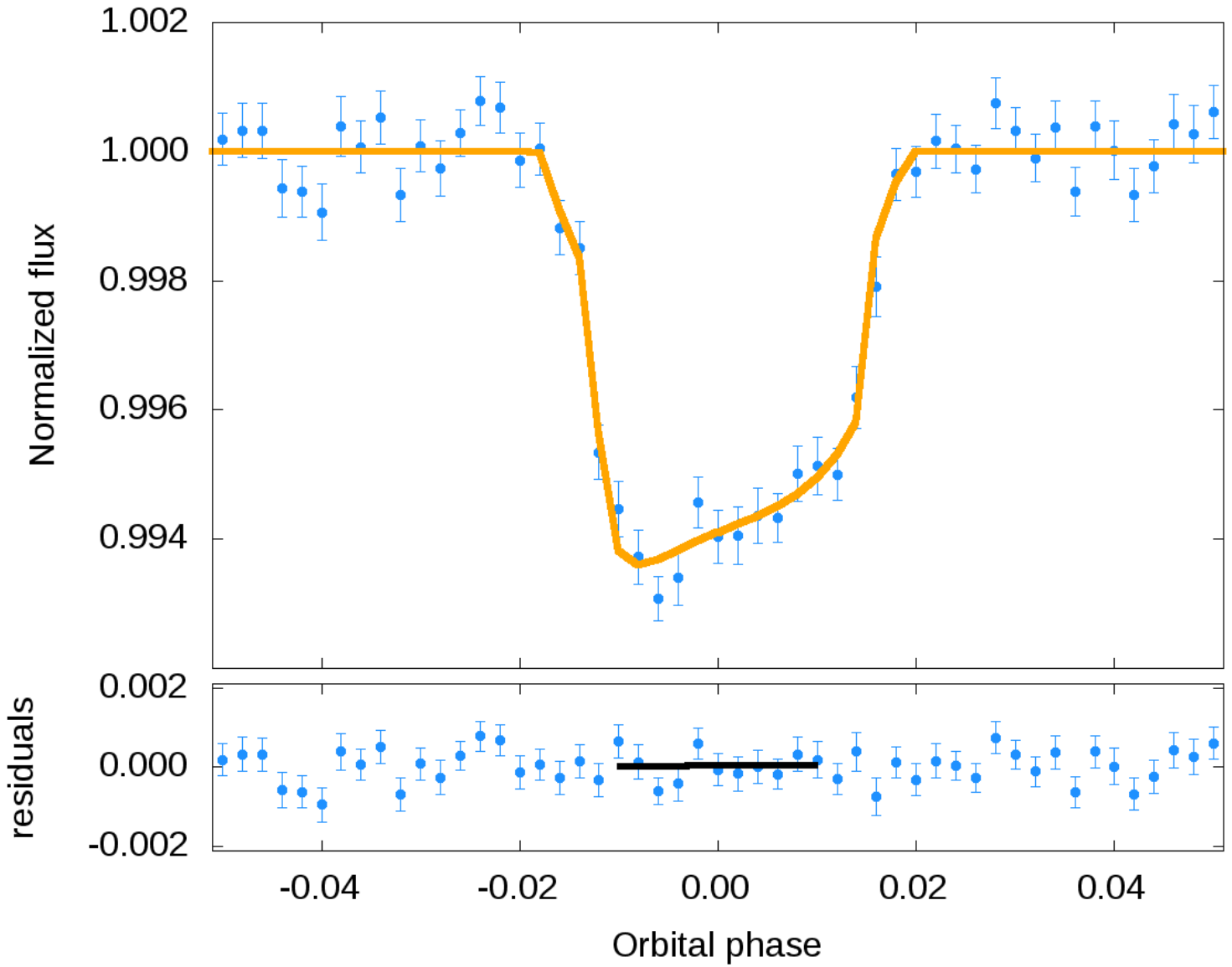
- polar spot (and misaligned orbit)
- slow rotating, main sequence star
- discarded by the data

CoRoT-29b: the origin of the asymmetry

gravity darkening



CoRoT-29b: the origin of the asymmetry

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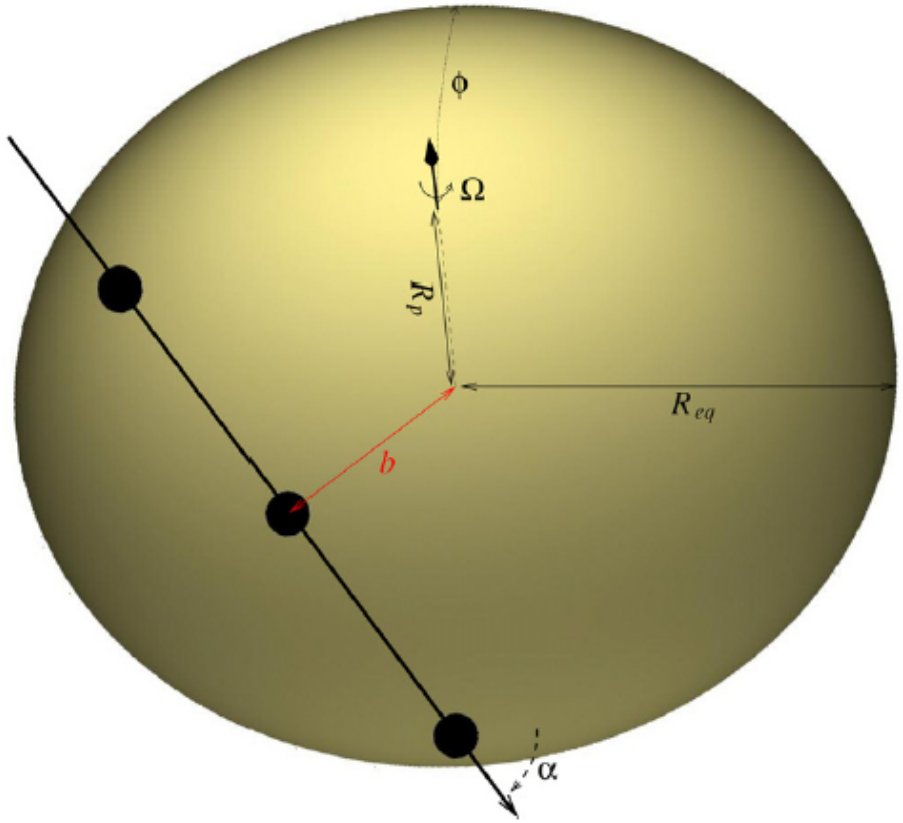
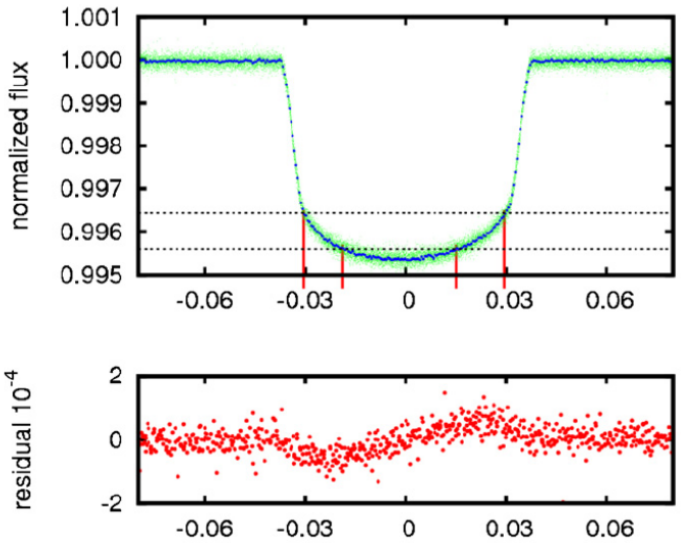


Figure 1. Schematic showing transit geometry along with some of the parameters referred to in the text such as planet orbit azimuth α, transit impact parameter b, stellar obliquity φ, stellar rotation rate Ω, equatorial radius R_{eq}, and polar radius R_p.

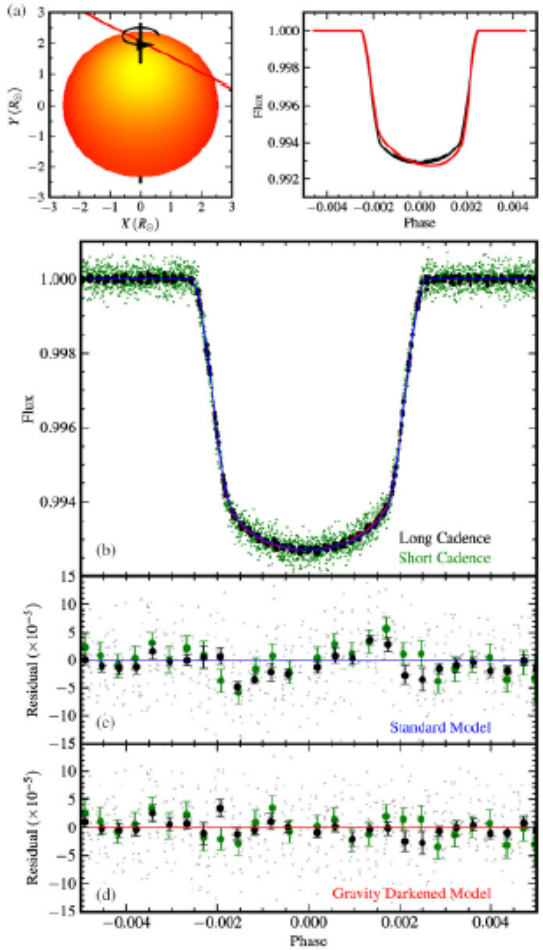
Barnes (2009) ApJ, 705

CoRoT-29b: the origin of the asymmetry

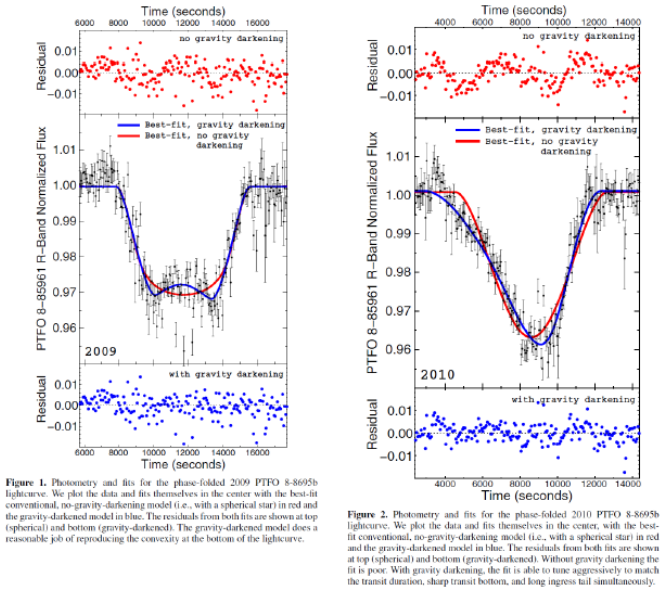
gravity darkening



Szabó et al. (2011) ApJ, 736



Zhou & Huang (2013) ApJ, 776



Barnes et al. (2013) ApJ, 774

CoRoT-29b: the origin of the asymmetry

gravity darkening

- effective gravitational potential

$$V = -\frac{GM_{\rm s}}{R(b)}\left(1 - J_2\left(\frac{R_{\rm s,eq}}{R(b)}\right)^2 P_2(\sin b)\right) - \frac{1}{2}{\Omega_{\rm rot}}^2 R^2(b)\cos^2 b \quad (2)$$

(see, for example, Zahn et al. 2010)

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- $J_2^{\odot} = (1.7 \pm 0.4) \cdot 10^{-7}$ (Lang 1999)

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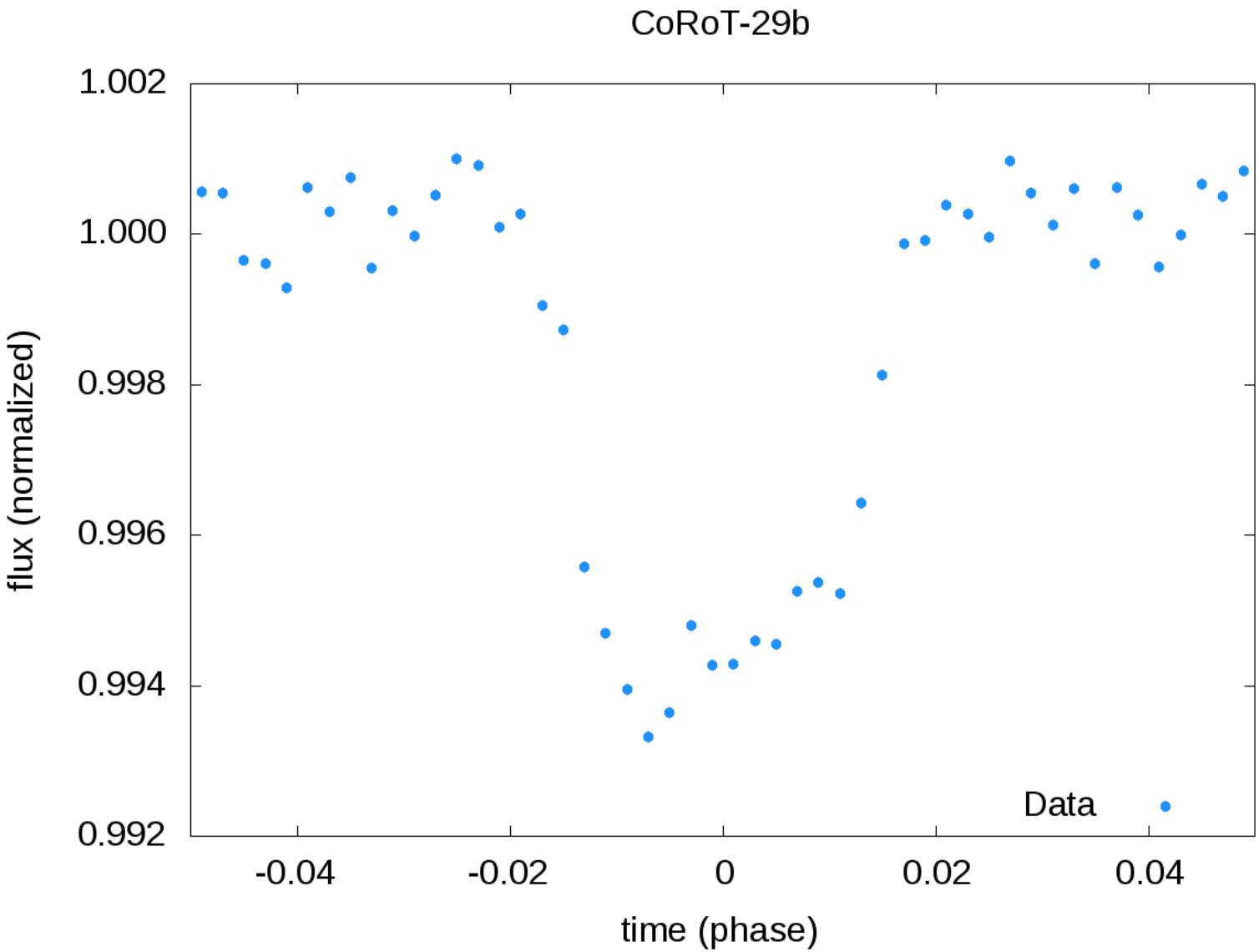
- $J_2 = 0.028 \pm 0.019$
- $J_2^{\odot} = (1.7 \pm 0.4) \cdot 10^{-7}$ (Lang 1999)
- WASP-33 $J_2 = 3.8 \cdot 10^{-4}$ (Iorio 2011)
- star has solar radius and is not rotating fast ($v \sin i = 3.5 \pm 0.5\,\mathrm{km\,s^{-1}}$)

CoRoT-29b: the origin of the asymmetry

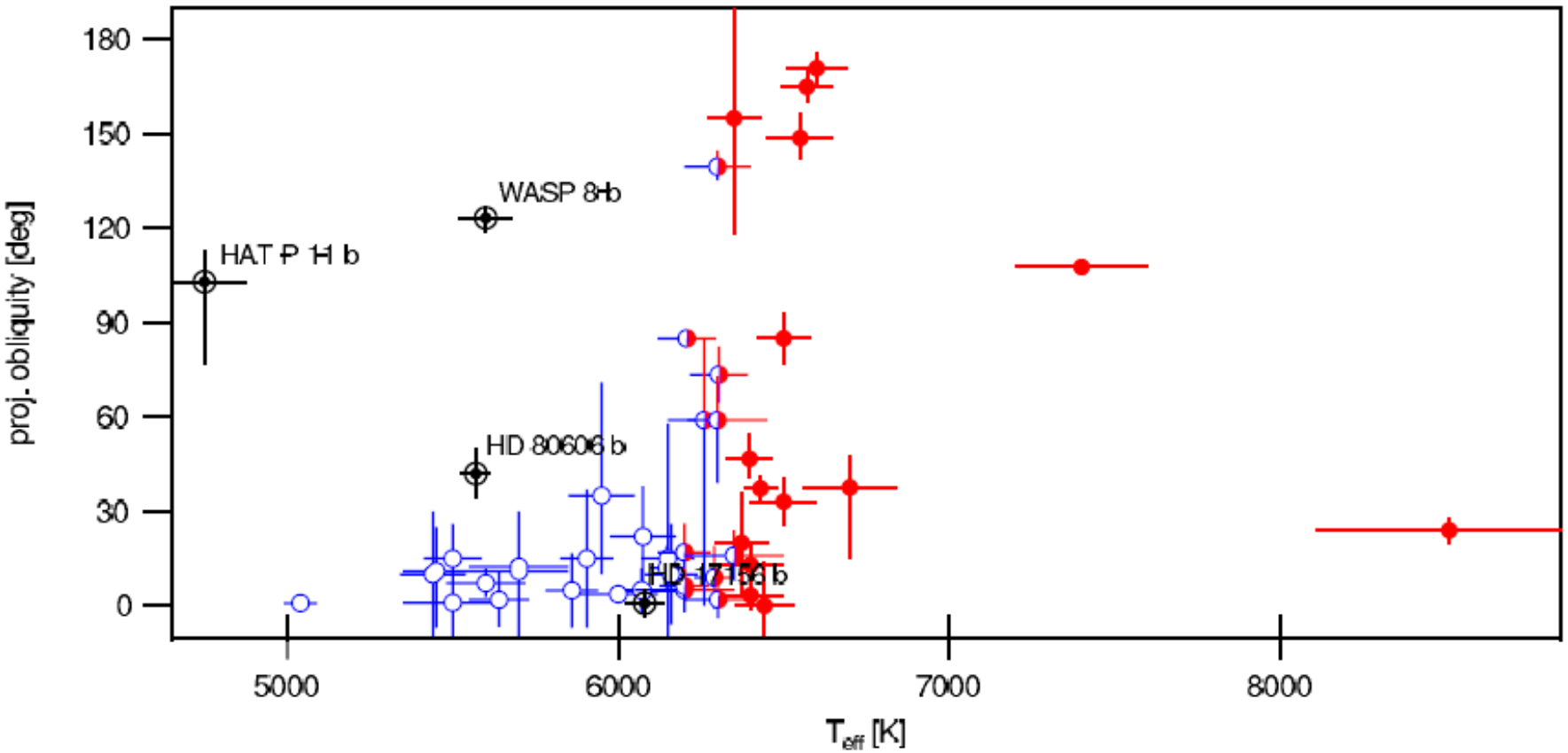
gravity darkening



CoRoT-29b: the origin of the asymmetry

gravity darkening

- planetary orbit is misaligned



Albrecht et al. (2012) ApJ, 7757

CoRoT-29b: the origin of the asymmetry

gravity darkening

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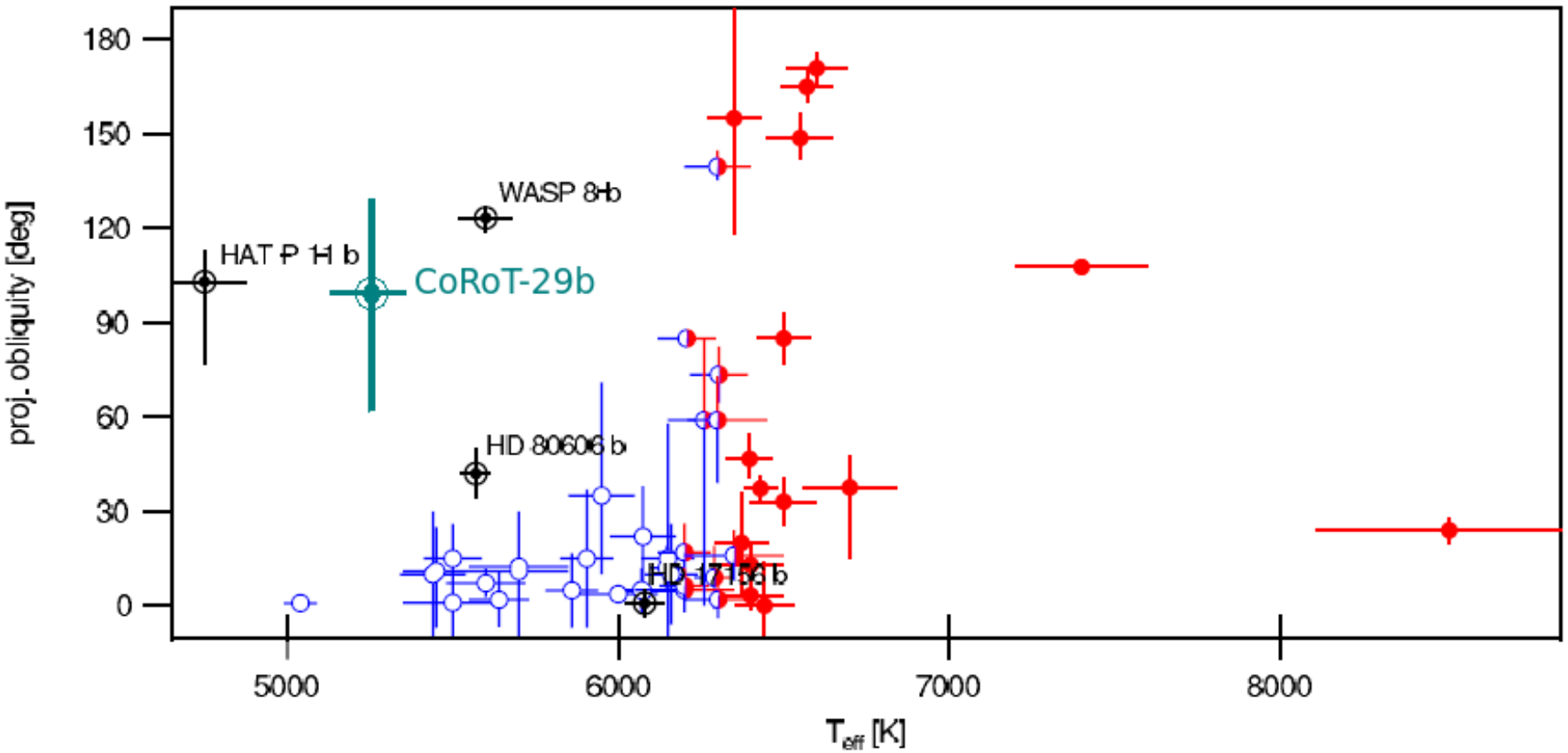


Albrecht et al. (2012) ApJ, 7757 (adapted)

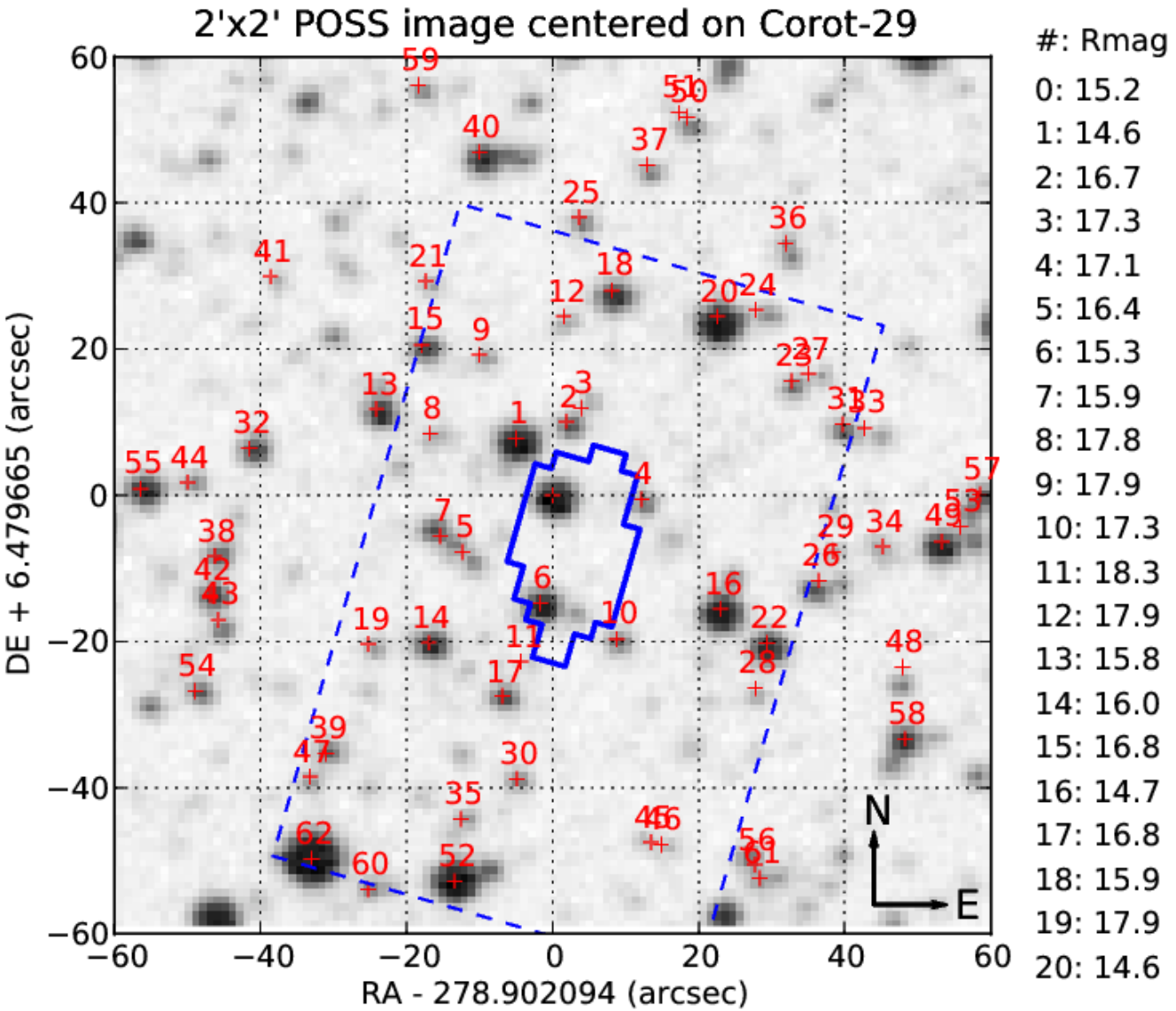
by way of conclusion

open questions

- what is the origin of the stellar asymmetry?
  - how to conciliate J_2 and k_2 theory and observations?
- what is the age of the star?
  - fundamental to study the tidal evolution
- have we missed something?

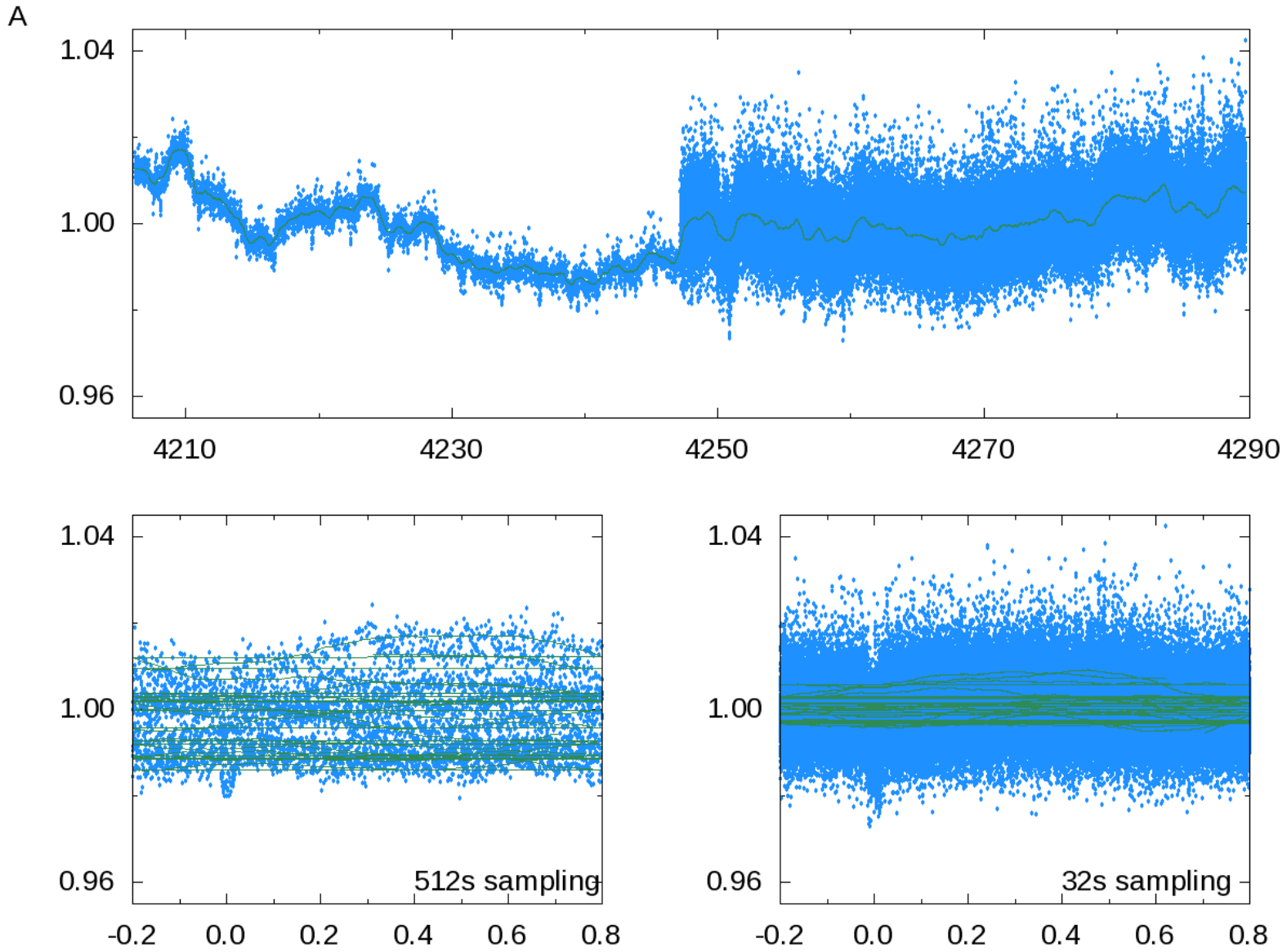
CoRoT-29b

contamination



CoRoT-29b

raw light curve



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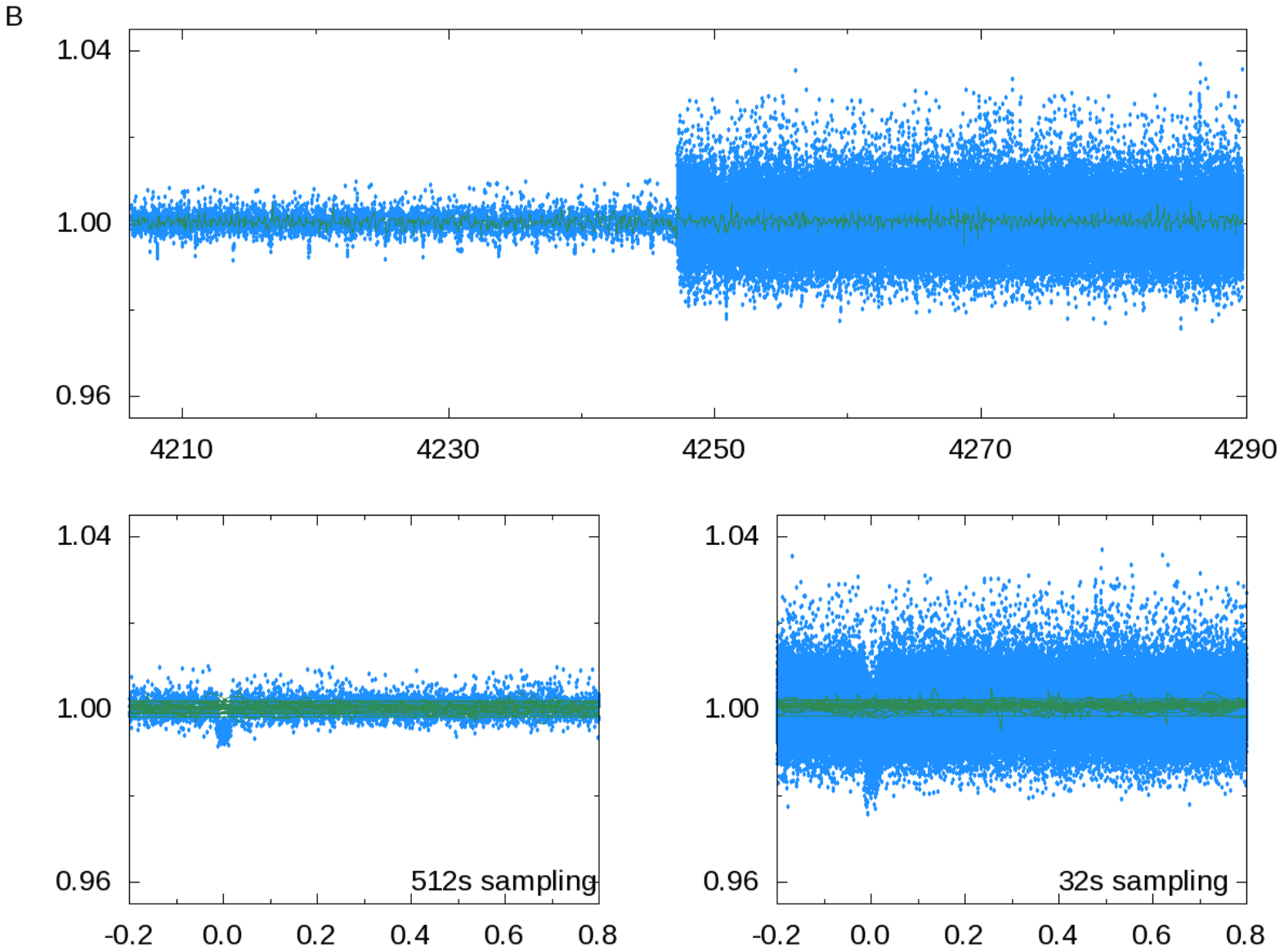

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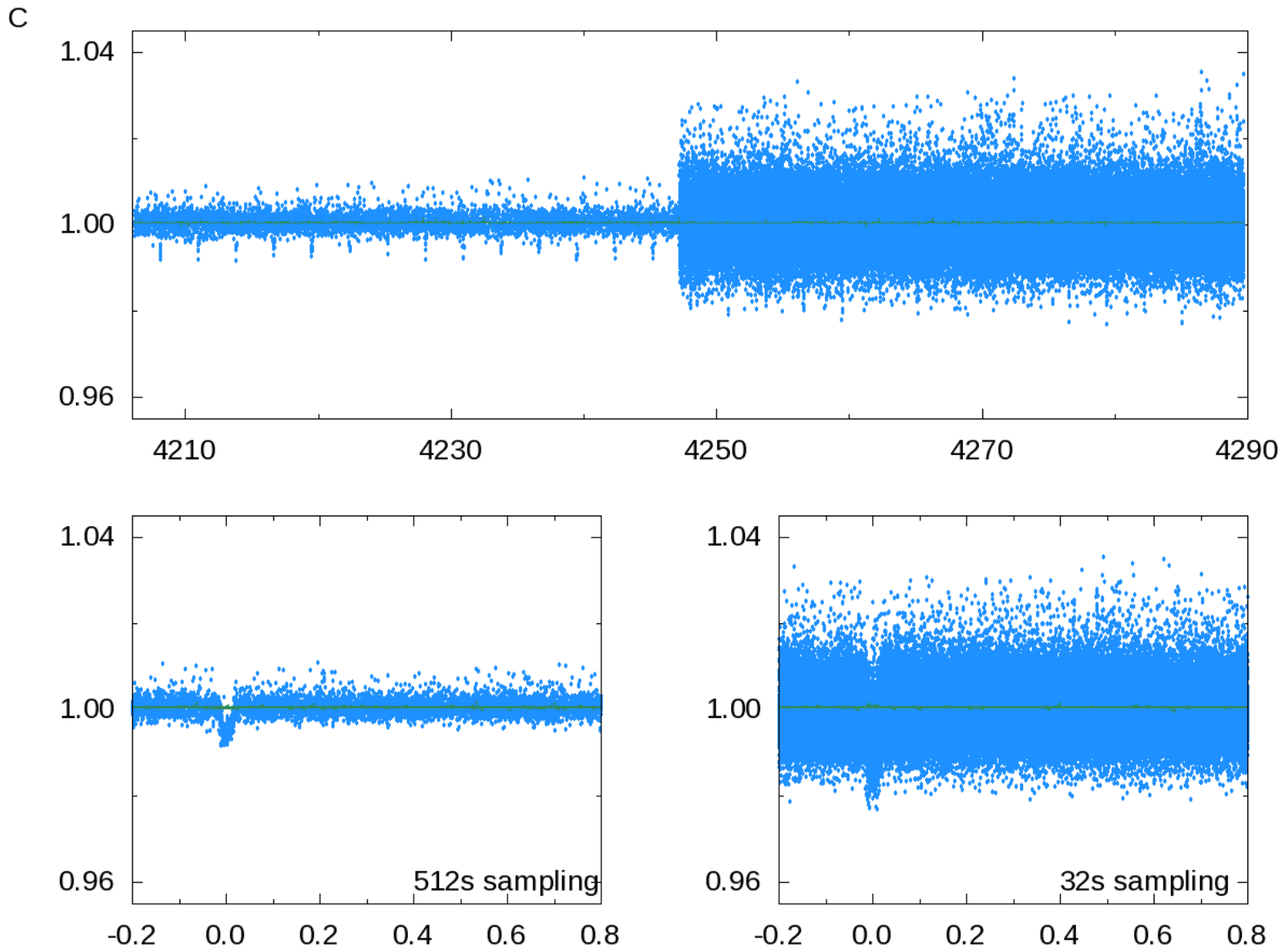

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fact sheet

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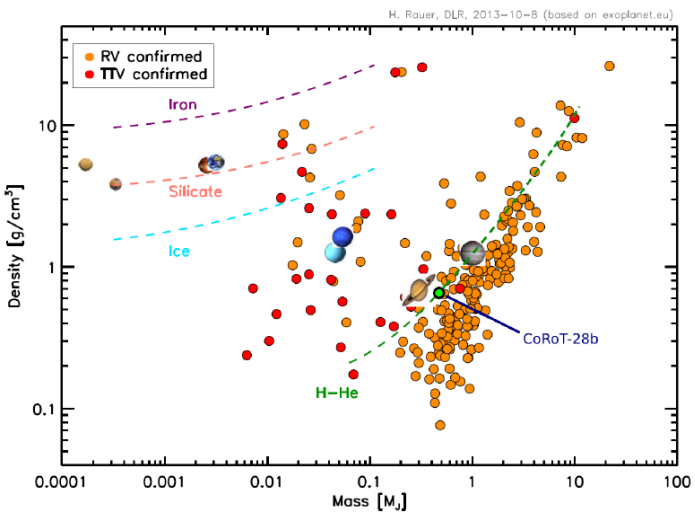
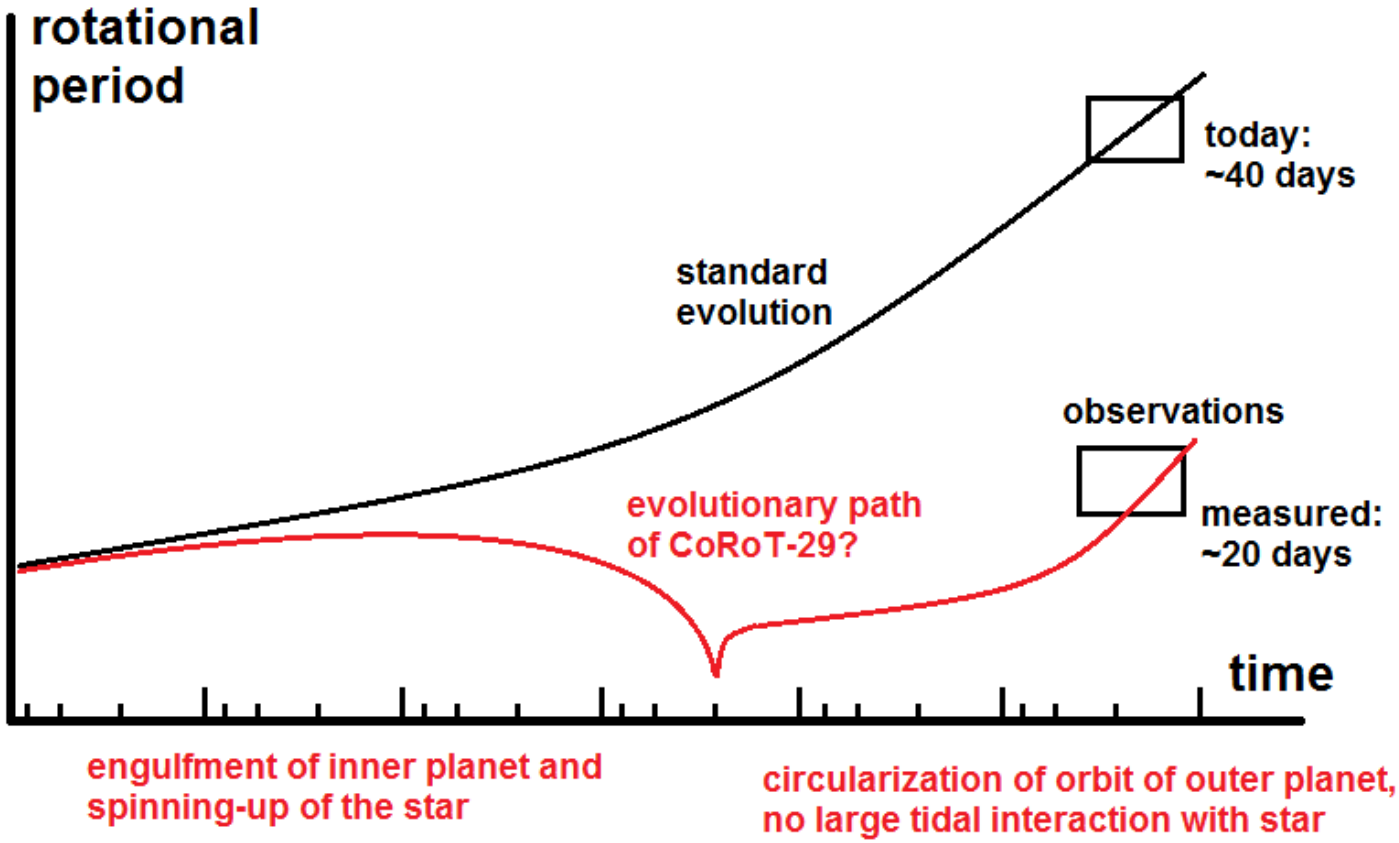
  - mass: $0.484 \pm 0.087\ M_{Jupiter}$
  - radius: $0.955 \pm 0.066\ R_{Jupiter}$
  - density: $0.60 \pm 0.27\ g\,cm^{-3}$
  - $\log g$: 3.12 ± 0.14 (cgs)
- stellar parameters
  - mass: $1.01 \pm 0.14\ M_{Sun}$
  - radius: $1.78 \pm 0.11\ R_{Sun}$
  - T_{eff}: $5\,150 \pm 100$K
  - $\log g$: 3.94 ± 0.12 (cgs)
  - age: 12.0 ± 1.5 Gyr
  - G8/9IV
- orbital parameters
  - P: $5.208\,66 \pm 0.000\,34$ d
  - a: 0.0603 ± 0.0050 AU
  - K: $56.4 \pm 4.9\ m\,s^{-1}$
  - i: $88.1 \pm 0.8°$
  - e: 0.047 ± 0.038



CoRoT-28b

tidal interactions



CoRoT-28b

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