Solar like activity of the TrES-2 host star?

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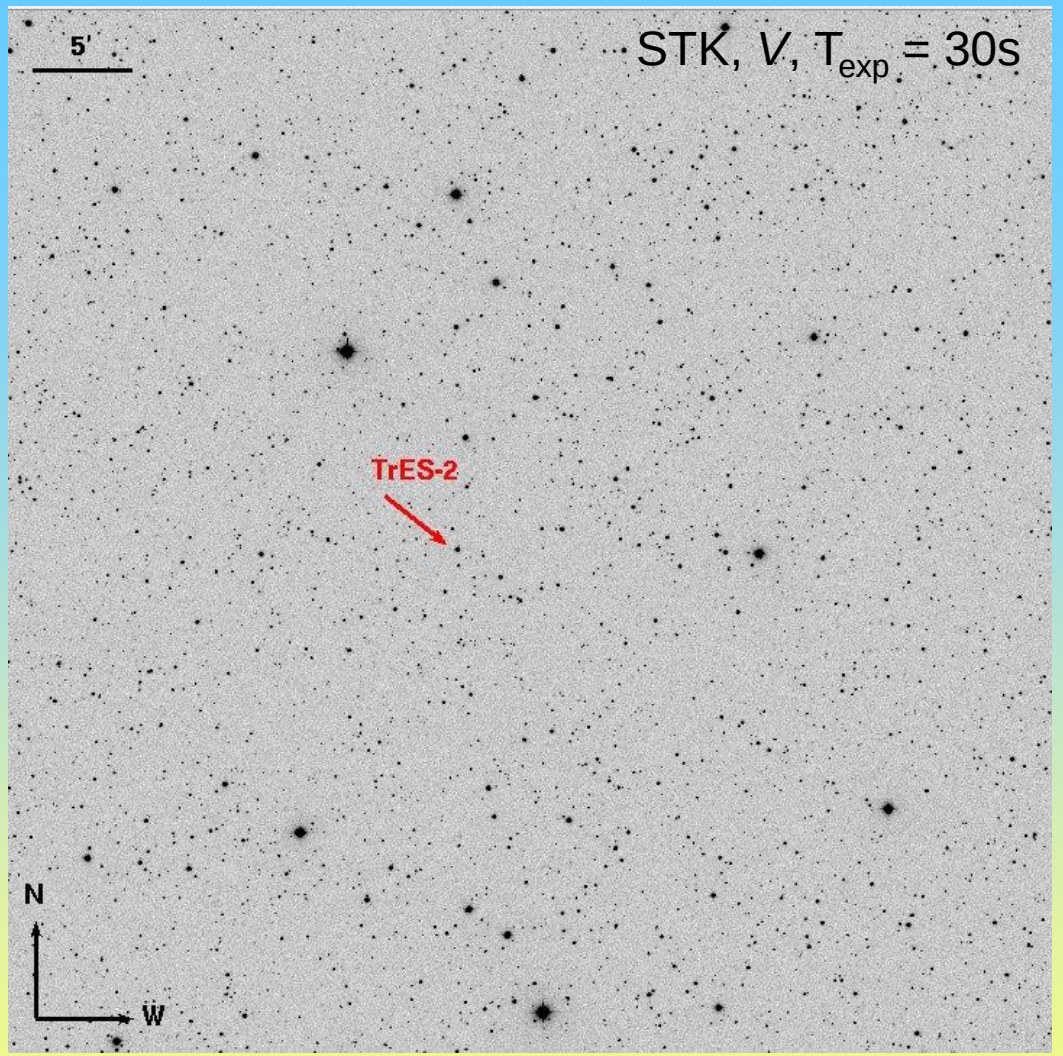
C: Christian Kranhold

Venustransit
6. Juni 2012, Steinkreuz, Jena



- University-Observatory Jena
  - 27 Nights
  - March 2007 to June 2012
  - 36 light curves
- TTV@YETI
  - Additional 8 Transits
  - Partially parallel
- 31 different Transits

- TrES-2 in the field of view of the *Kepler* space telescope

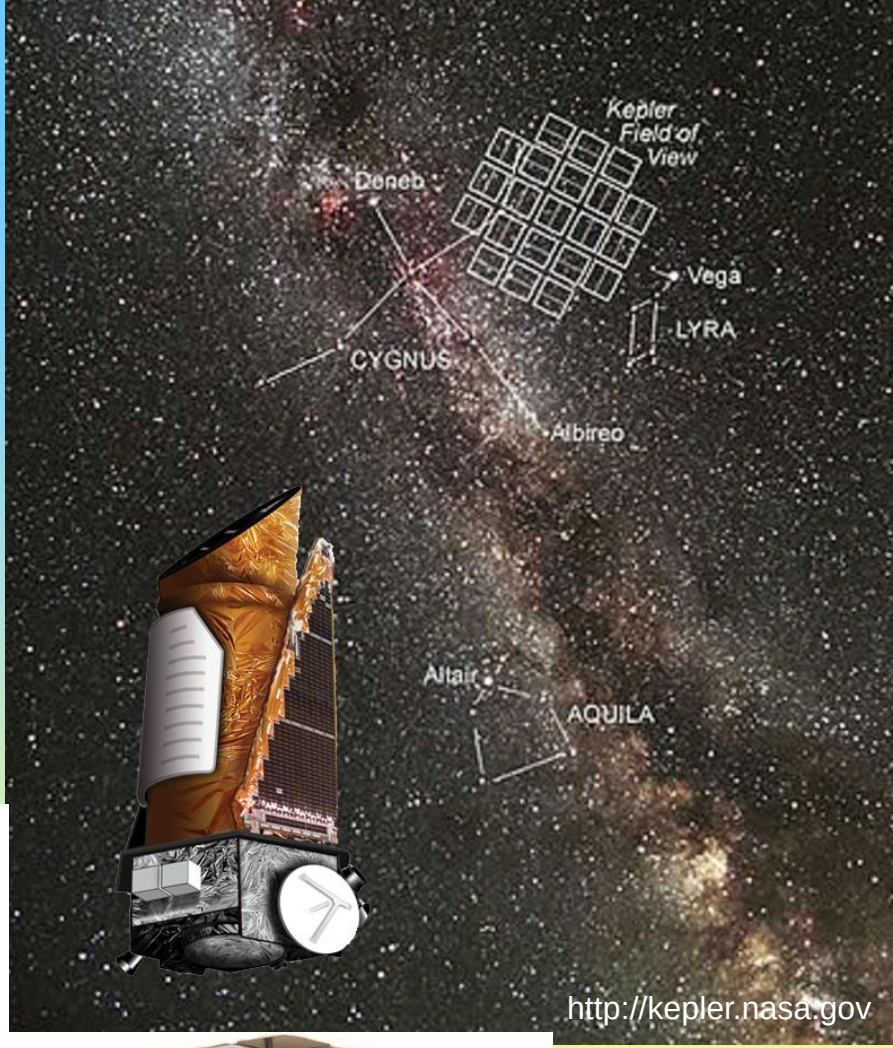
➔ unique: ground-based and space-based observations can be combined (Test of our error-bars)

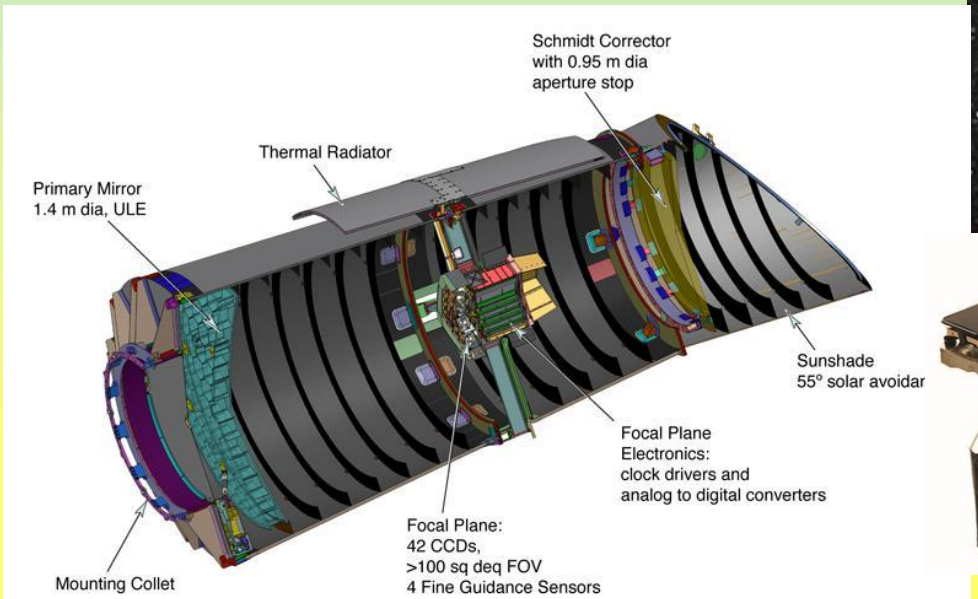
Data of the *Kepler* space telescope

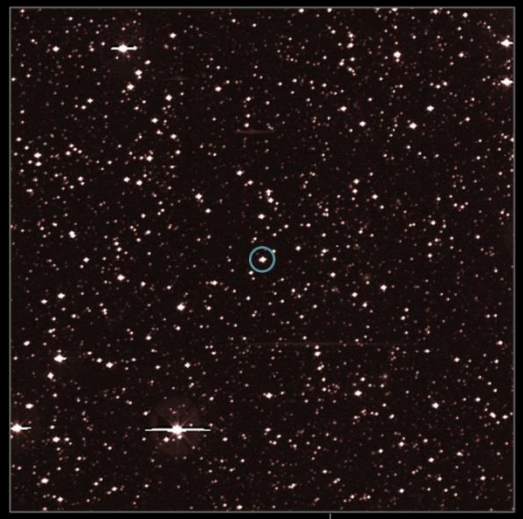
- NASA space telescope
  - launch 2009 March 6
  - Aim: detect earth-like planets in the habitable zone around sun-like Stars with the transit method

- *Kepler* is a 0,95 m Schmidt-Telescope

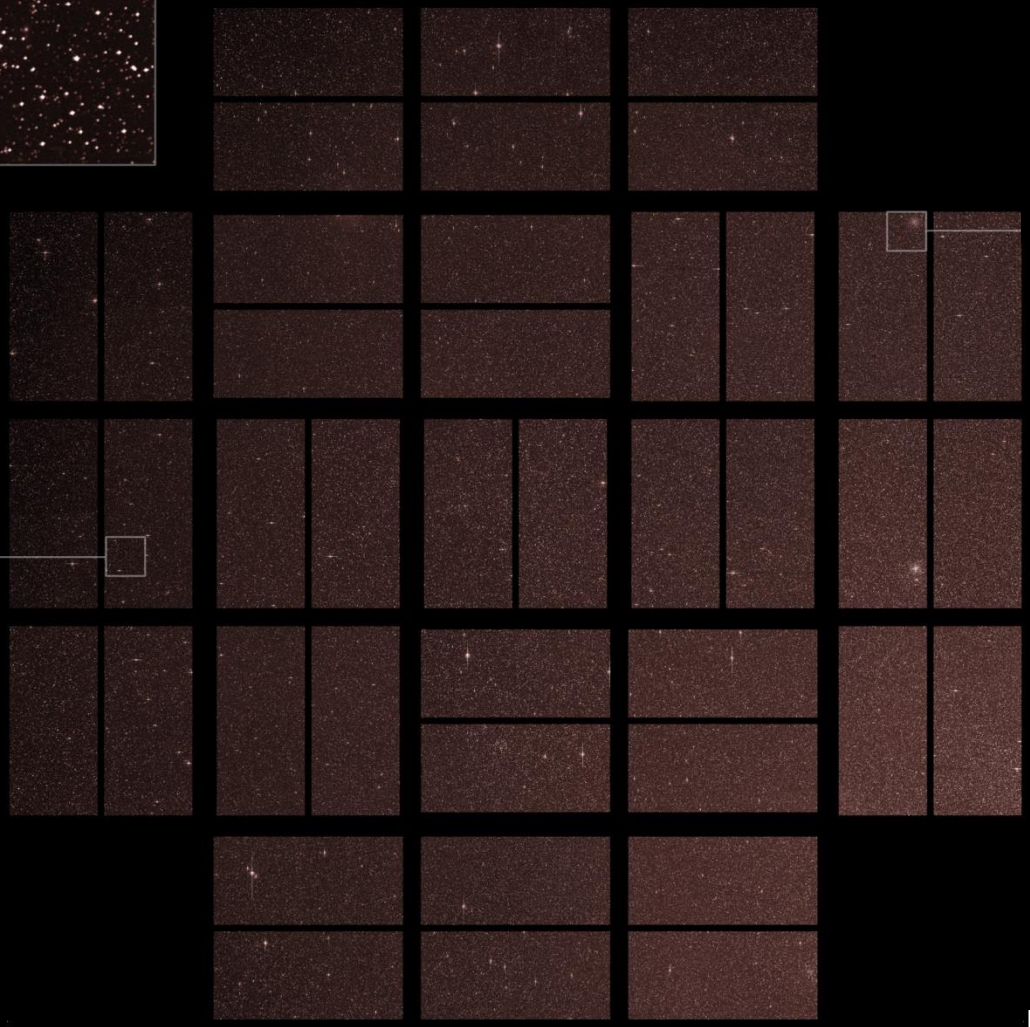
- 42 CCDs
  field of view: 105 deg^2







TrES-2



http://kepler.nasa.gov

TrES-2

- TrES-2 around the star GSC03549-02811 (Cygnus):
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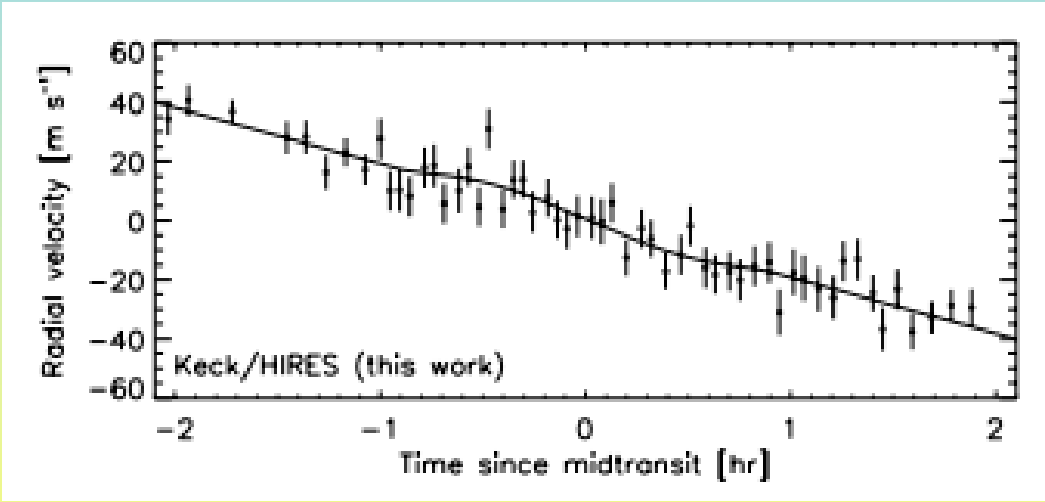

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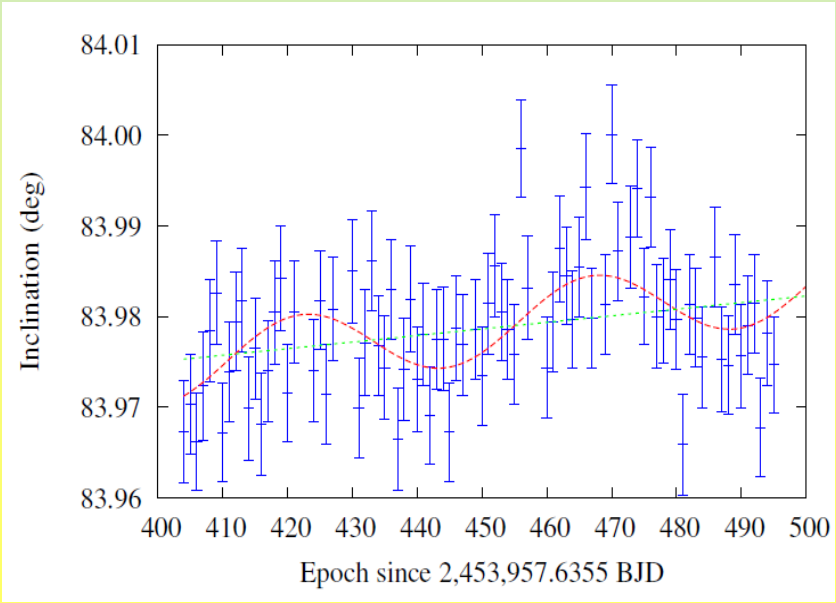

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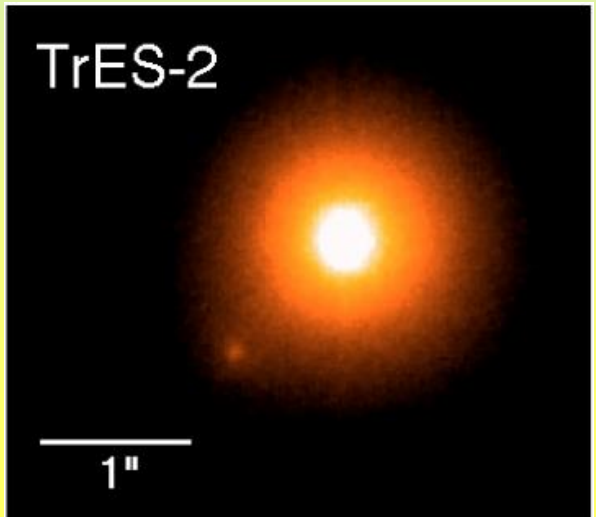

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  Spitzer (O'Donovan et al. 2010), NIR with ground-based telescopes (Croll et al. 2010), the VIS with Kepler (Kipping & Bakos 2011;Kipping & Spiegel 2011)
- Barclay et al. (2012) found in the light curve evidence for ellipsoidal variation, Doppler beaming and the reflection effect

Table 1. System parameters of TrES-2 summarized from literature.

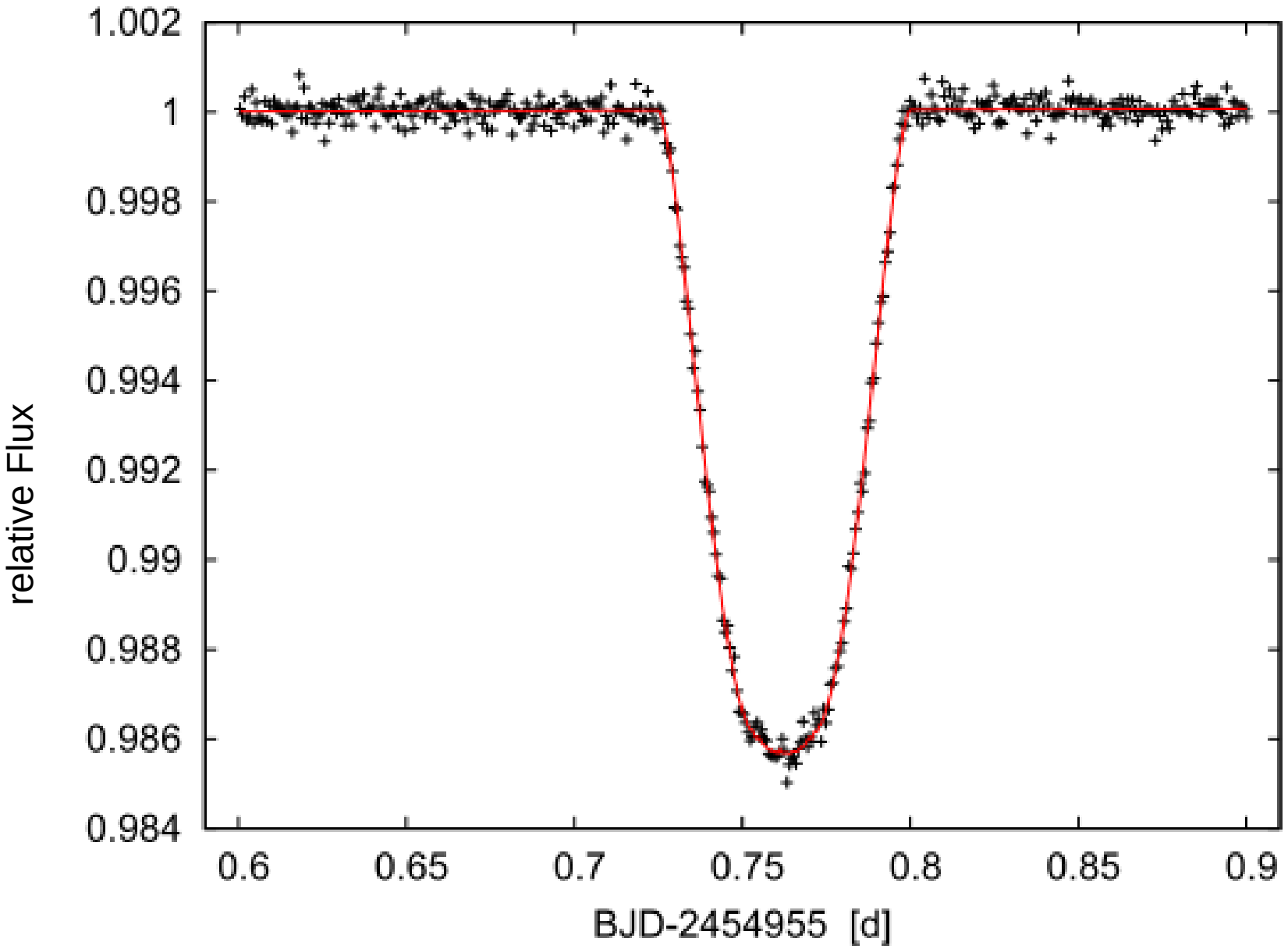
Parameter	Value	Ref
Epoch zero transit time T_0 [d]	2453957.63492	[1]
	± 0.00013	[1]
Orbital period P [d]	2.470614 ± 0.000001	[1]
Semi-major axis a [au]	0.03556 ± 0.00075	[2]
Inclination i [°]	83.62 ± 0.14	[2]
Eccentricity e	0	[3]
Mass star $M_{\rm A}$ [$M_\odot$]	0.98 ± 0.06	[4]
Radius star $R_{\rm A}$ [$R_\odot$]	1.00 ± 0.04	[4]
Effective temperature $T_{\rm eff}$ [K]	5795 ± 73	[5]
Surface gravity star $\log g_{\rm A}$	4.457 ± 0.004	[6]
Metallicity $\left[\frac{Fe}{H}\right]$	0.06 ± 0.08	[5]
Mass planet $M_{\rm b}$ [$M_{\rm Jup}$]	1.26 ± 0.05	[6]
Radius planet $R_{\rm b}$ [$R_{\rm Jup}$]	1.169 ± 0.034	[7]
Distance d [pc]	220 ± 10	[8]
spectral type	**G0V**	**[4]**

References: [1] Raetz et al. (2009), [2] Daemgen et al. (2009), [3] O'Donovan et al. (2010), [4] O'Donovan et al. (2006), [5] Ammler-von Eiff et al. (2009), [6] Southworth (2010), [7] Christiansen et al. (2011), and [8] Sozzetti et al. (2007)

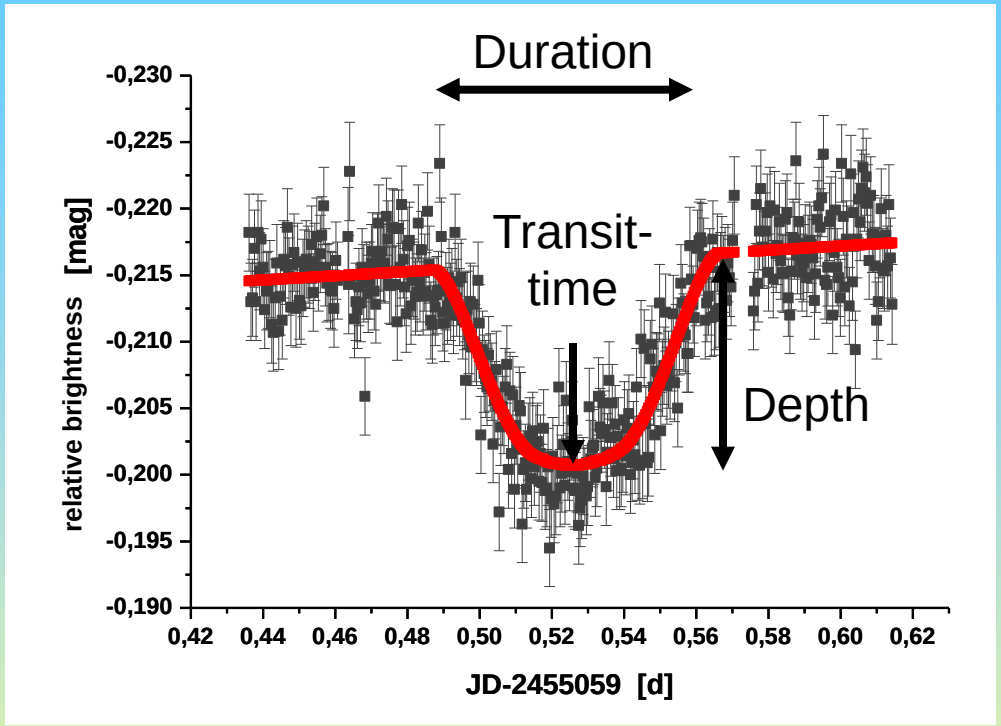
Kepler observations of TrES-2

Q	Start	End	# Transits
0	02 May 2009	11 May 2009	4
1	13 May 2009	15 Jun. 2009	14
2	20 Jun. 2009	16 Sep. 2009	33
3	18 Sep. 2009	17 Dec. 2009	33
4	19 Dec. 2009	09 Jan. 2010	9
5	20 Mar. 2010	23 Jun. 2010	38
6	24 Jun. 2010	22 Sep. 2010	37
7	23 Sep. 2010	22 Dec. 2010	35
8	06 Jan. 2011	14 Mar. 2011	
9	21 Mar. 2011	26 Jun. 2011	39
10	27 Jun. 2011	28 Sep. 2011	38
11	29 Sep. 2011	04 Jan. 2012	37
12	05 Jan. 2012	28 Mar. 2012	
13	29 Mar. 2012	27 Jun. 2012	35
14	28 Jun. 2012	03 Oct. 2012	36
15	05 Oct. 2012	11 Jan. 2013	36
16	**12 Jan. 2013**	**08 Apr 2013**	
17	**09 Apr. 2013**	**11 May 2013**	**11**
			435

Kepler observations of TrES-2



Light curve analysis



TrES-2 15.8.2009, STK, *V*, T_{exp}= 30s
397 Measurements
S/N = 5,5 σ = 2,7 mmag

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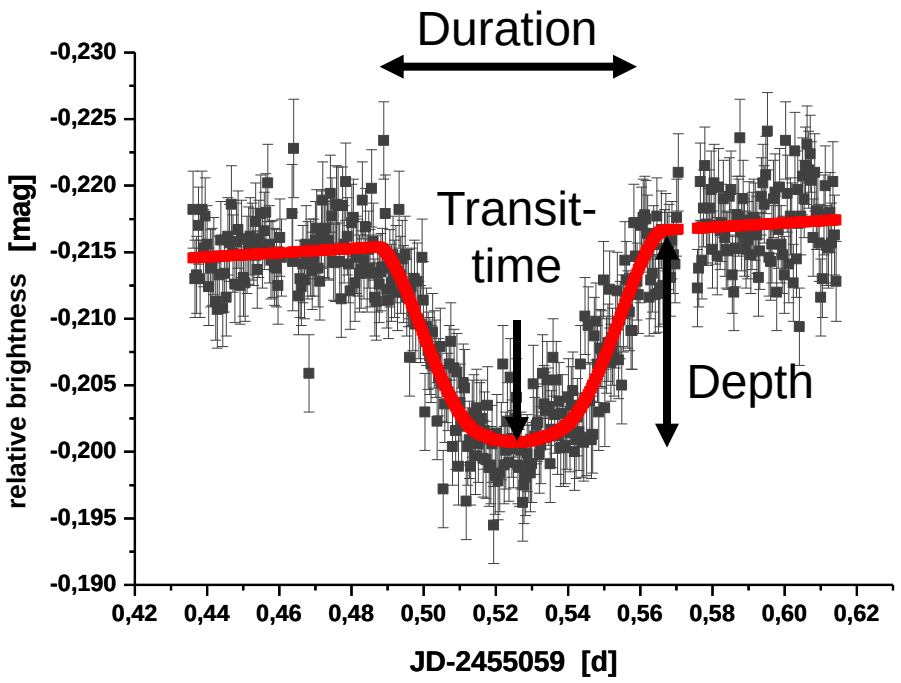

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$$\text{Duration} = \frac{P}{\pi}\sin^{-1}\left(\sqrt{(r_A + r_b)^2 - cos^2 i}\right)$$

$$\text{Depth} \sim k = \frac{r_b}{r_A}$$

$$\text{Transit time} = T_c$$

$$r_{\rm A} = \frac{R_{\rm A}}{a}, \qquad r_{\rm b} = \frac{R_{\rm b}}{a}$$

$R_{\rm A}$, $R_{\rm b}$... True radius of star and planet

- Use of ***jktEBop***: (Southworth et al. 2004a,b)
  based on „Eclipsing Binary Orbit Program - *EBop*" (Etzel 1975, 1981; Popper and Etzel 1981)
- Additional parameters: e, M_b/M_A, limb darkining coefficients, etc.
- Estiamtion of error bars:
  - Monte-Carlo Simulation
  - Residual-permutations algorithm

Variation in the system parameters

Raetz et al. 2014, submitted to MNRAS

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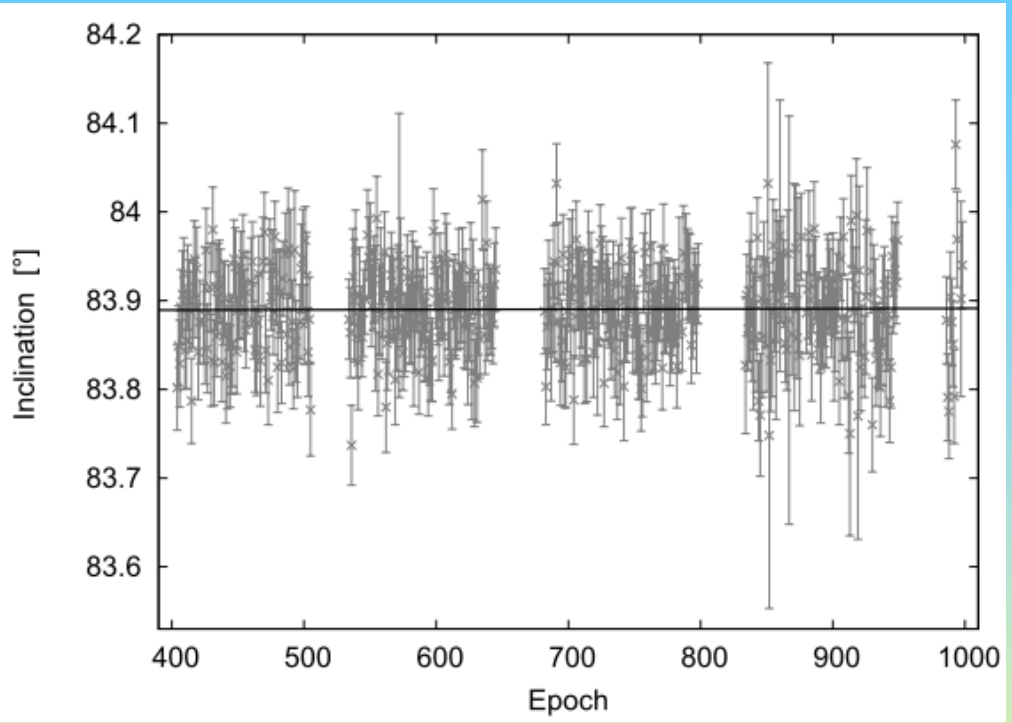

$$\Delta i = (0 \pm 1) \cdot 10^{-5}\ ^{\circ}/\mathrm{epoch}$$

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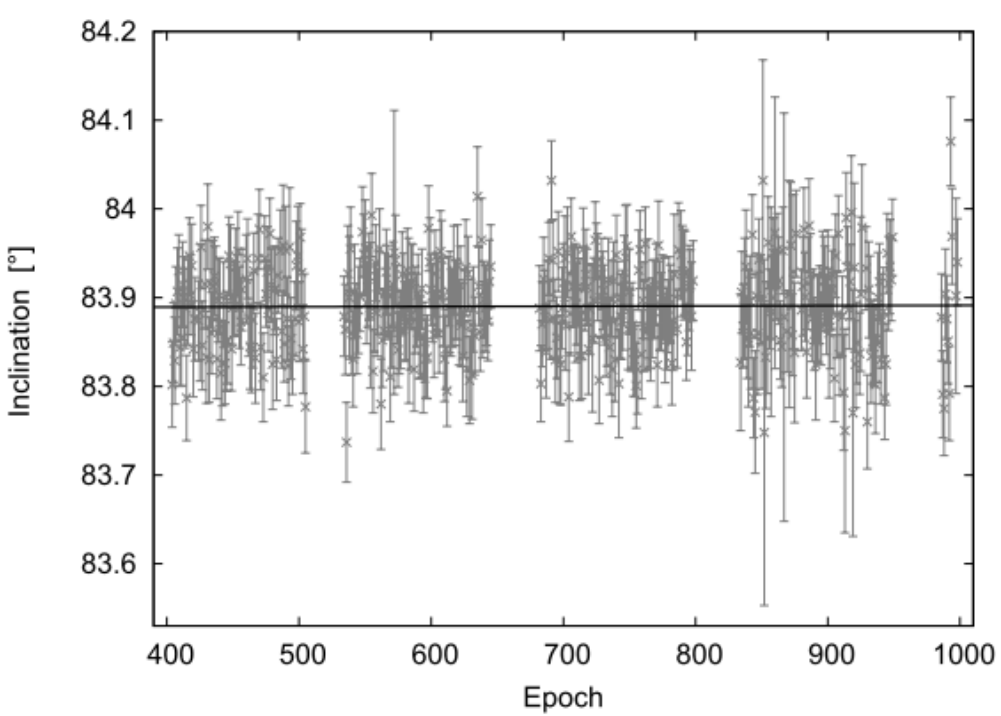
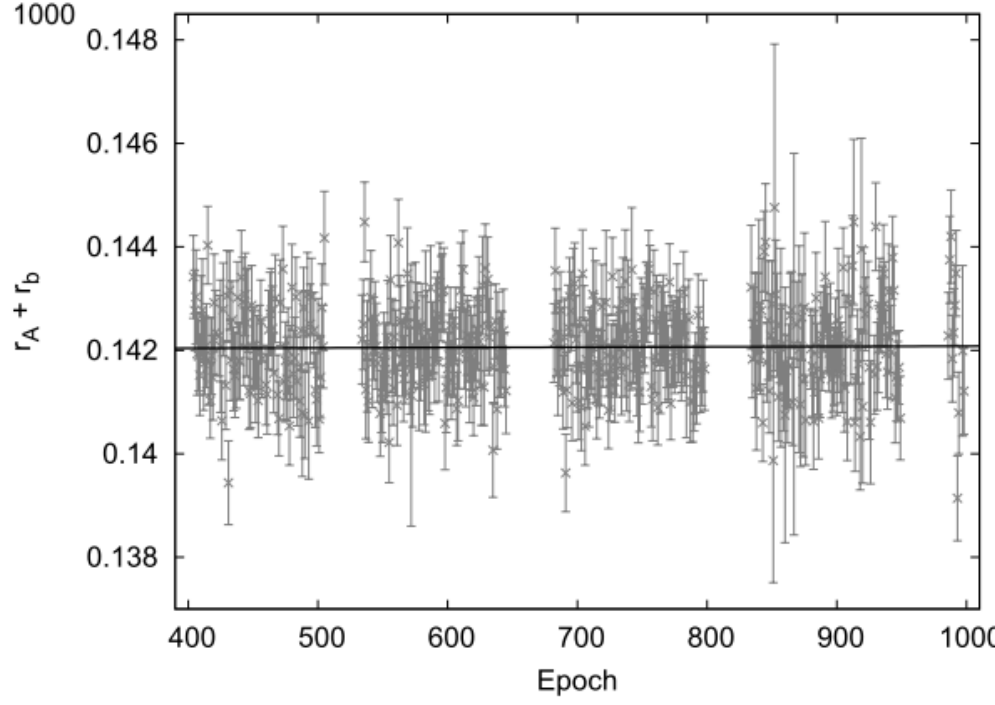


$$\Delta i = (0 \pm 1) \cdot 10^{-5}\ ^\circ/\text{epoch}$$

$$\Delta(r_\mathrm{A} + r_\mathrm{b}) = (1 \pm 2) \cdot 10^{-7}\ \text{epoch}^{-1}$$



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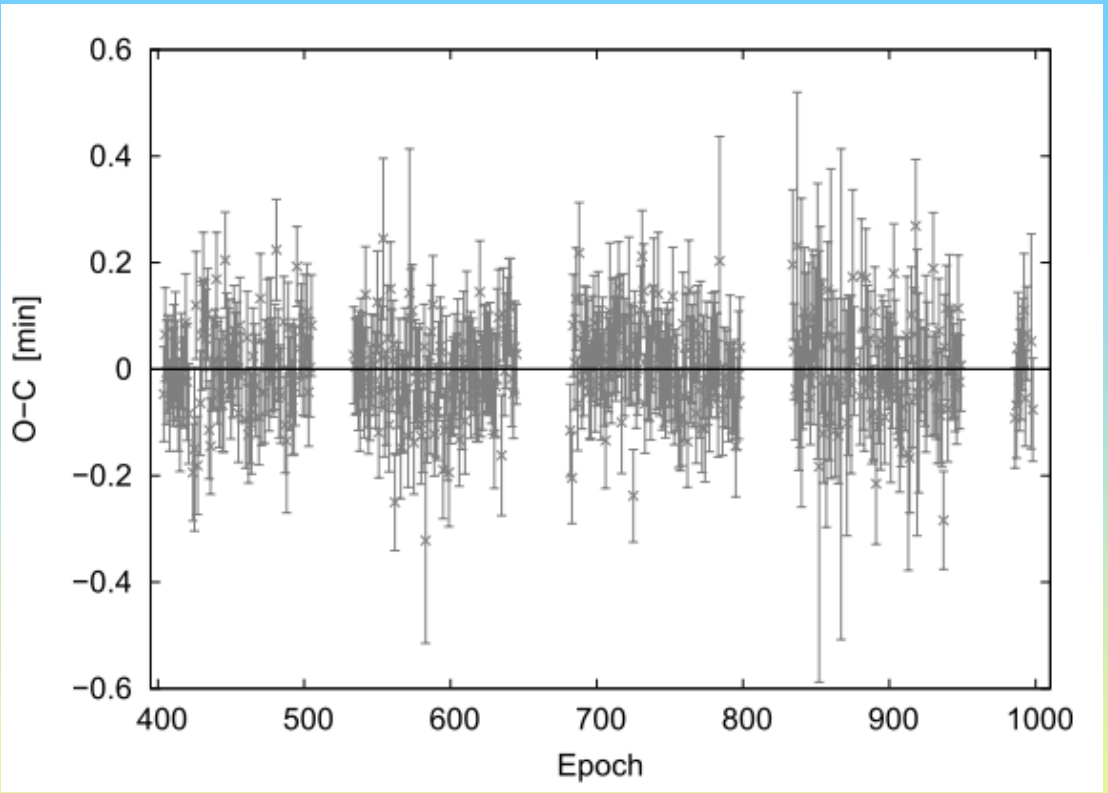
Transit Timing



O-C-diagram only for the 435 *Kepler* transits

Raetz et al. 2014, submitted to MNRAS

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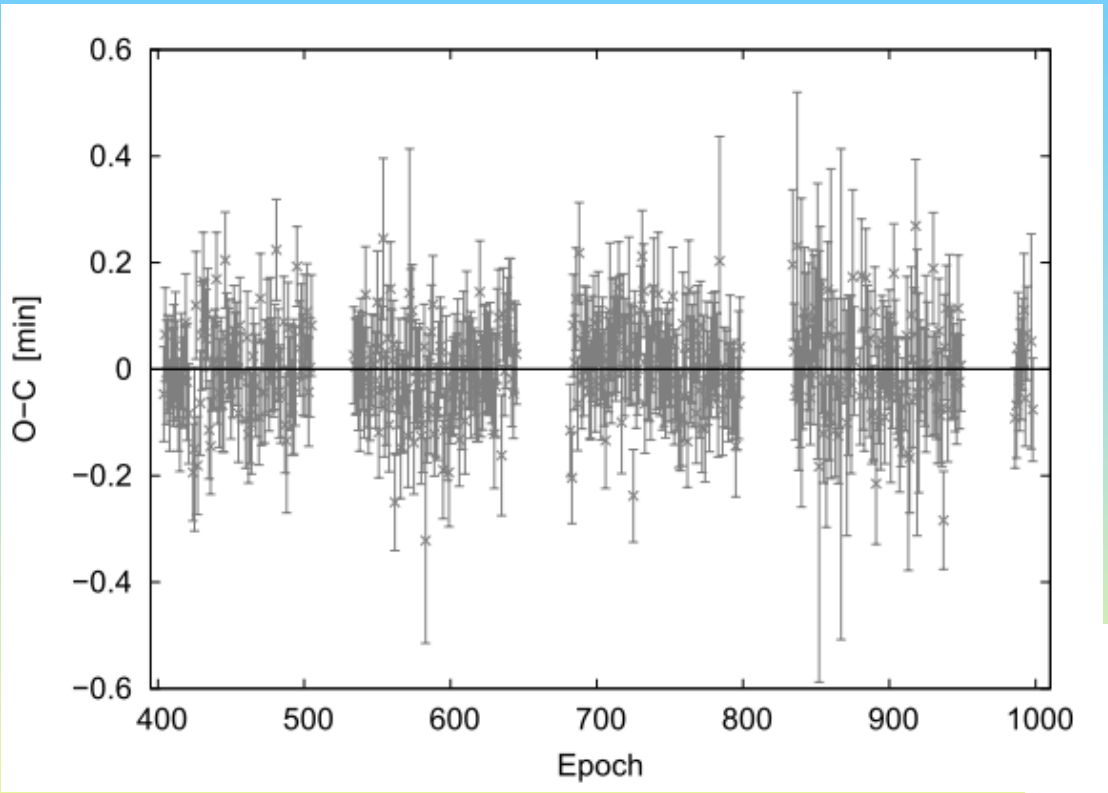

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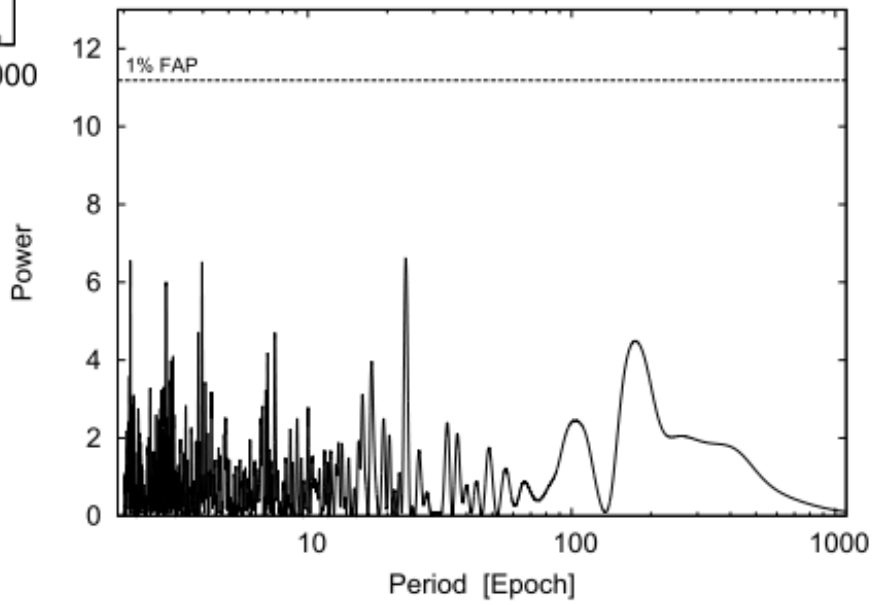
no significant periodicity
highest peak shows a FAP of 62.8%



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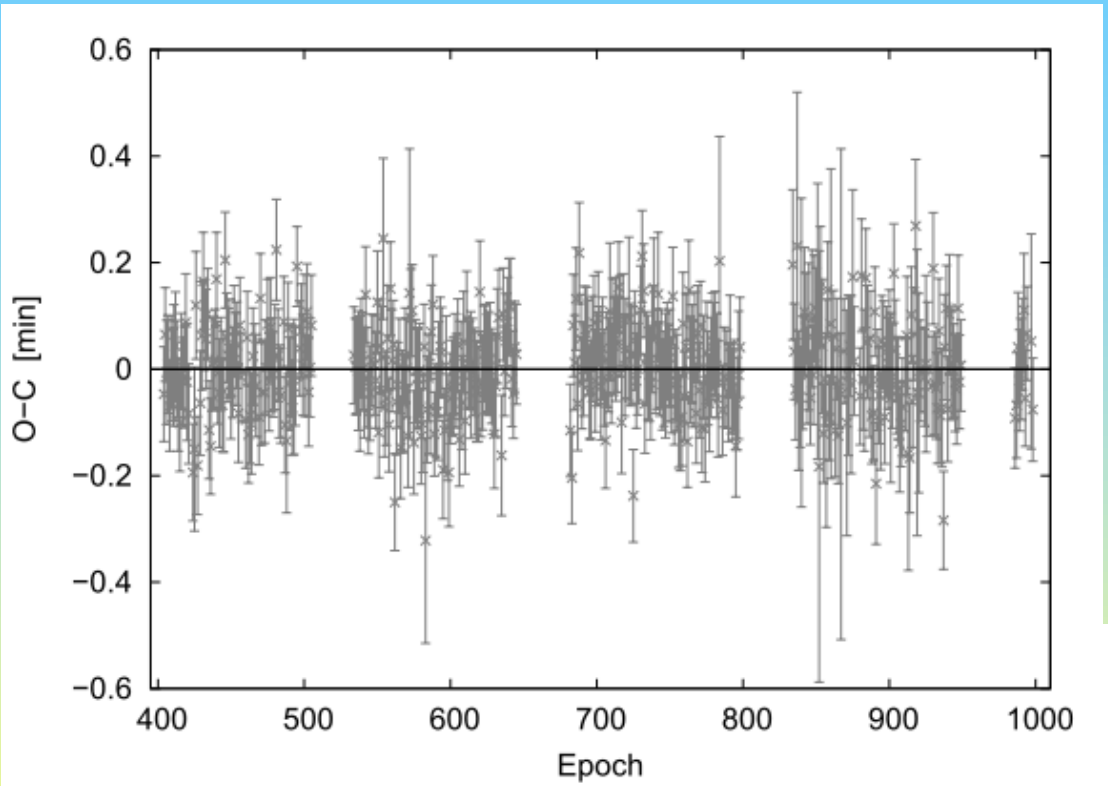

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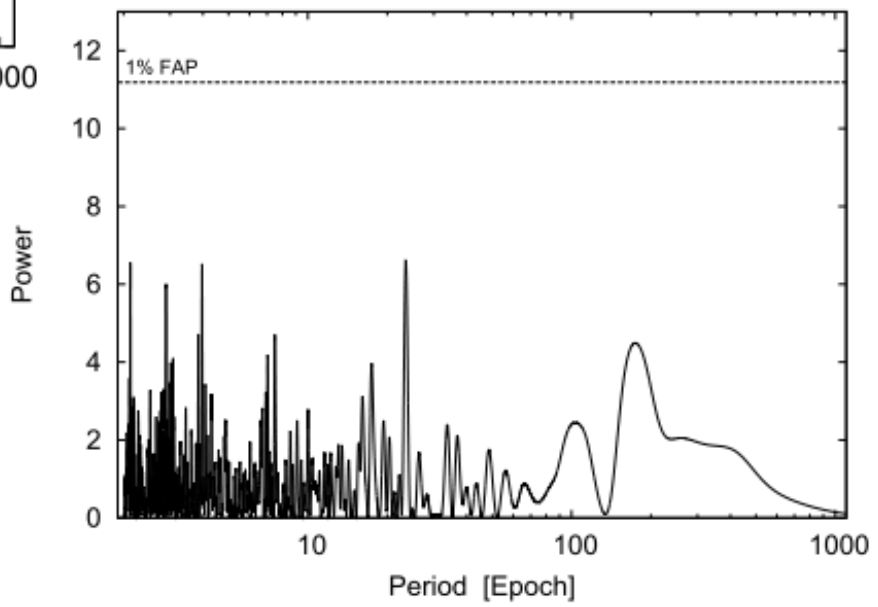
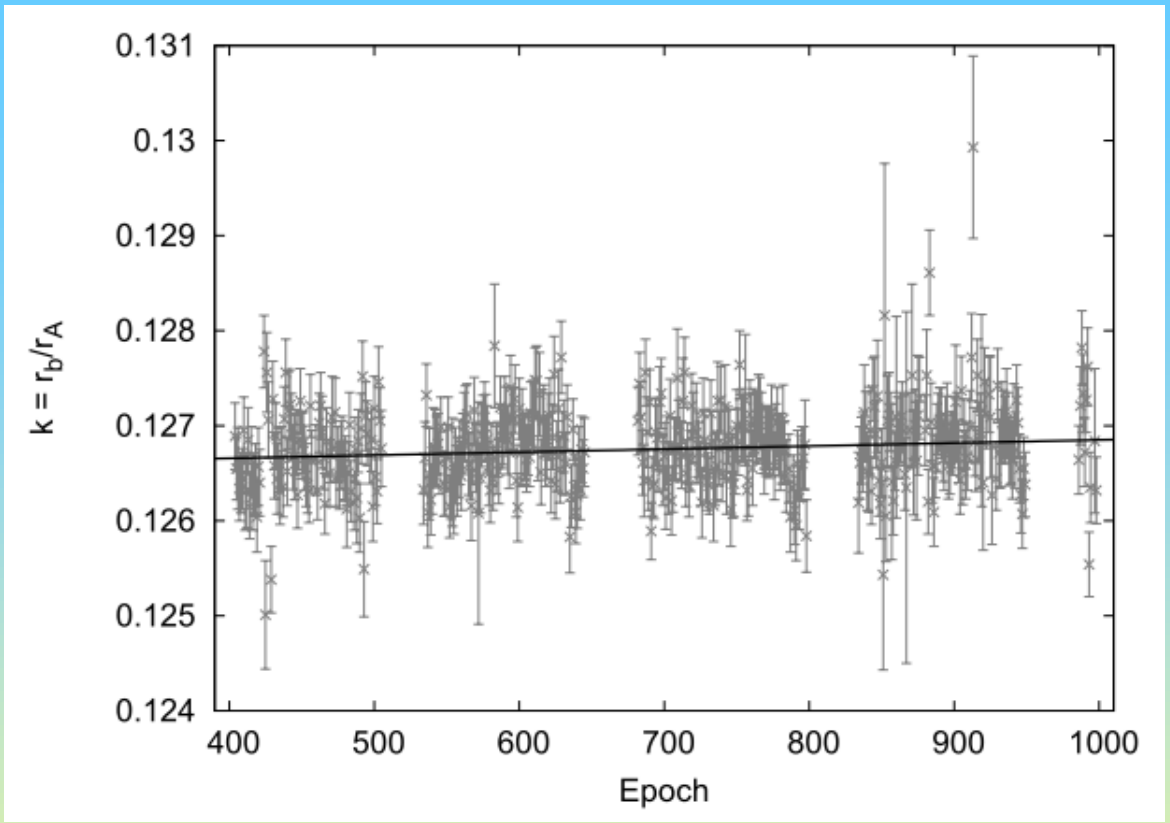
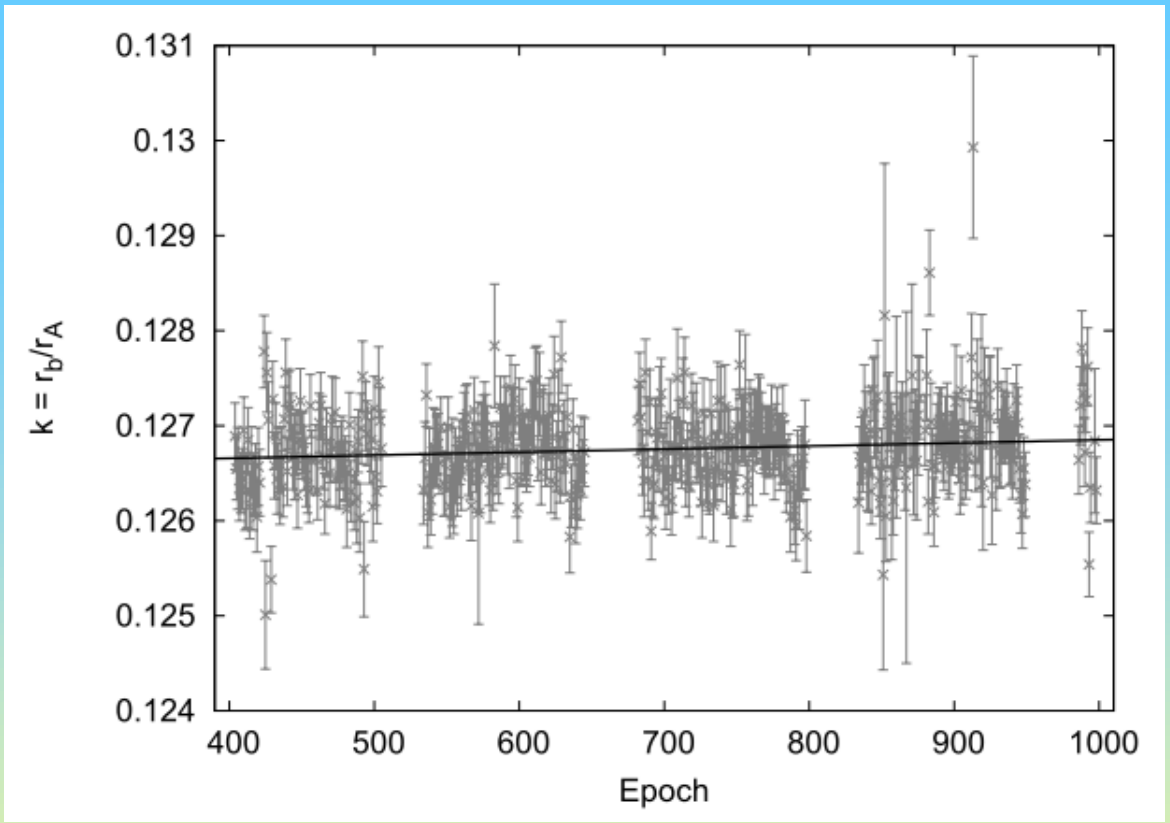


Within the *Kepler* data no evidence for TTVs could be detected

Raetz et al. 2014, submitted to MNRAS



Raetz et al. 2014, submitted to MNRAS



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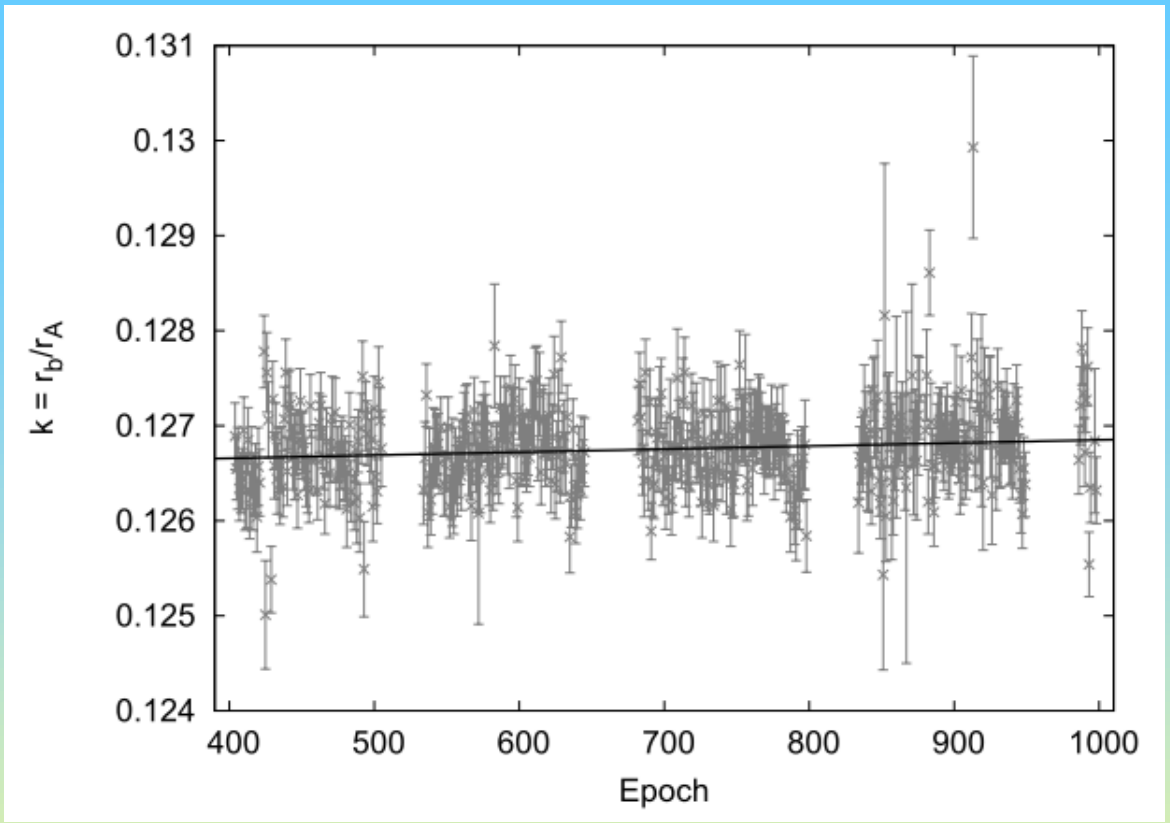
3.2σ

Raetz et al. 2014, submitted to MNRAS



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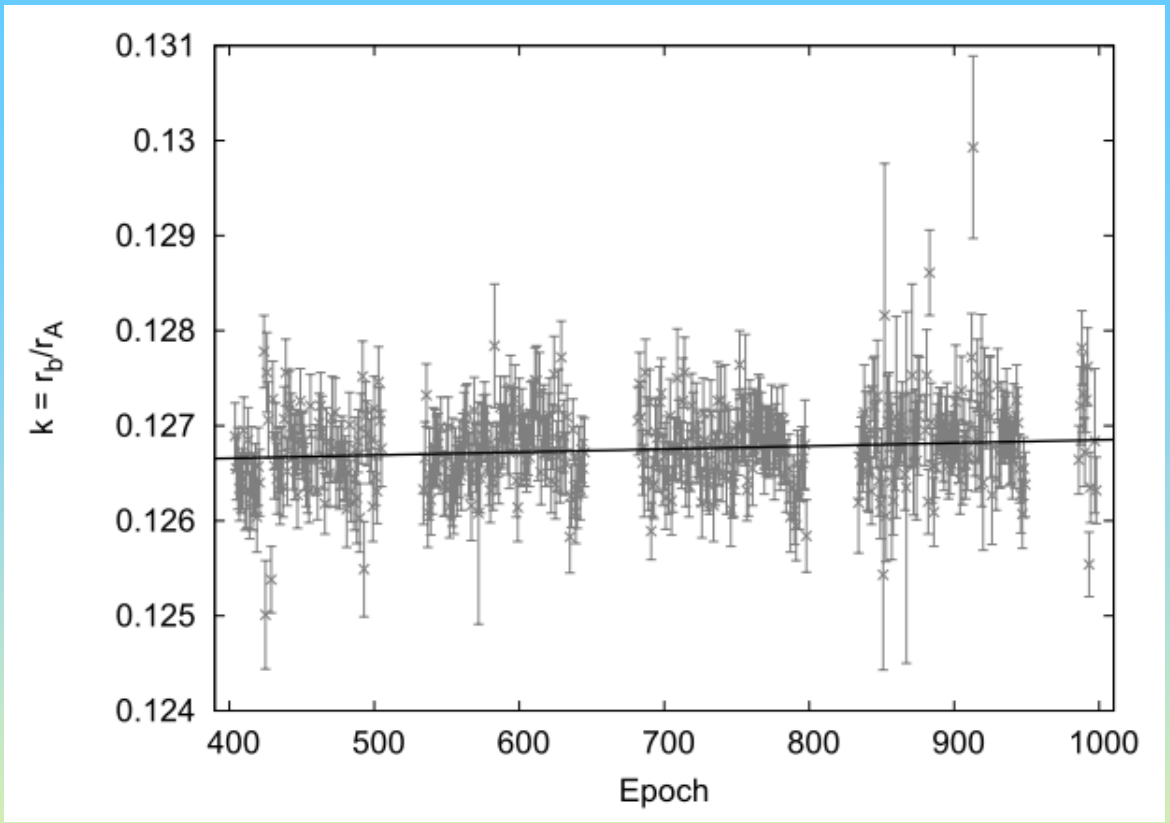
Raetz et al. 2014, submitted to MNRAS



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Several tests:

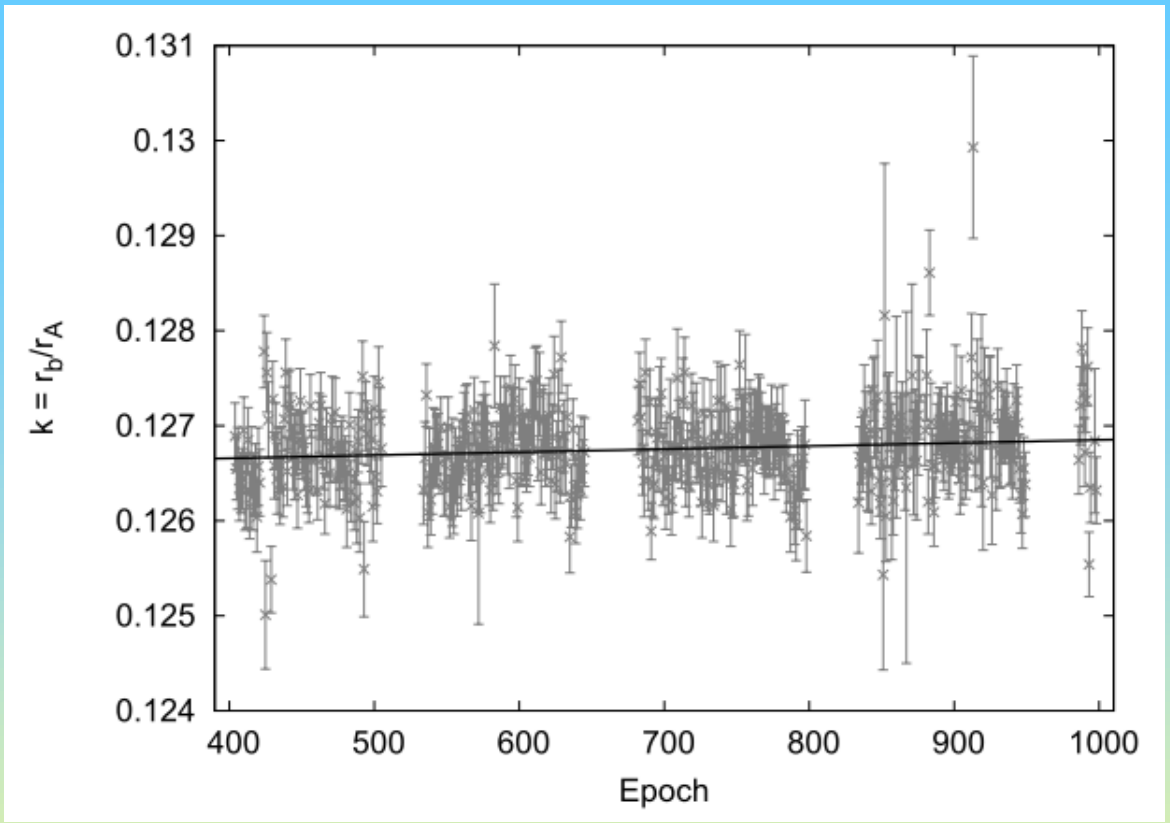
After rescaling the error bars with β = 1.08

(β-factor see e.g. Winn et al. 2008)

$\Delta k = (3.1 \pm 1.1) \cdot 10^{-7}$ 1/epoch

3.0σ

Raetz et al. 2014, submitted to MNRAS



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After 2σ-clipping (from the average of the k-values): **2.5σ**

$\Delta k = (2.7 \pm 1.1) \cdot 10^{-7}$ 1/epoch

Raetz et al. 2014, submitted to MNRAS

increase of *k* means: an increase of r_b or a decrease of r_A

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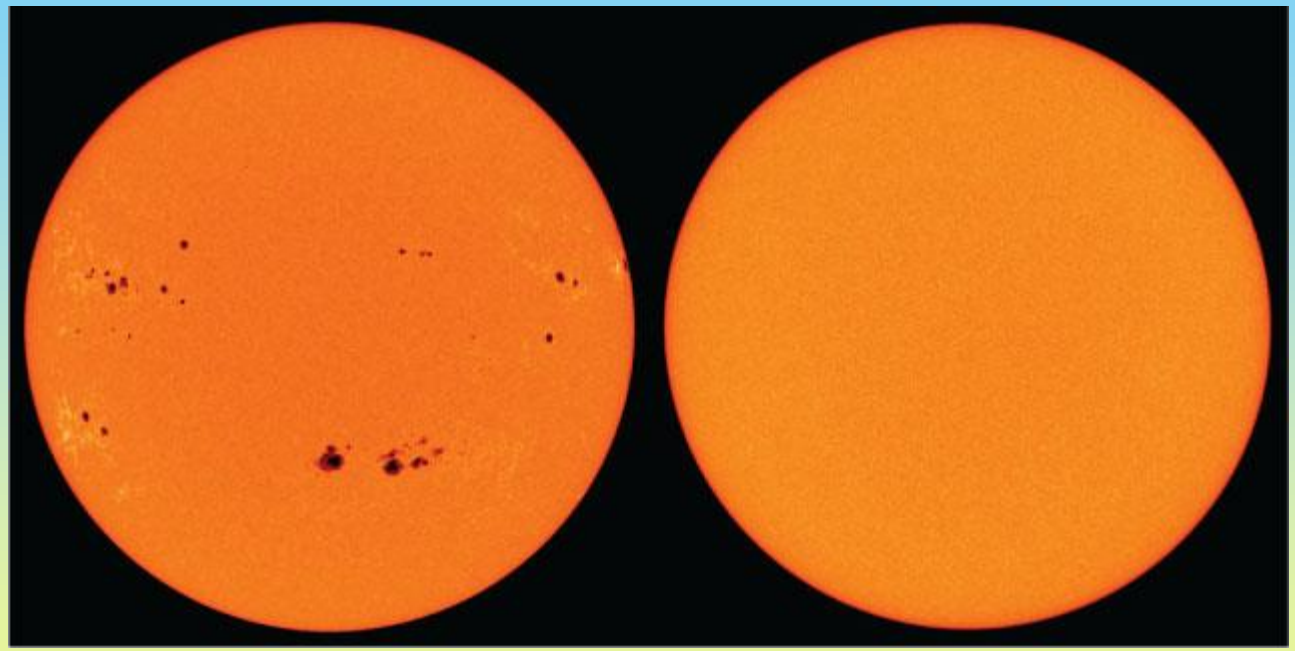


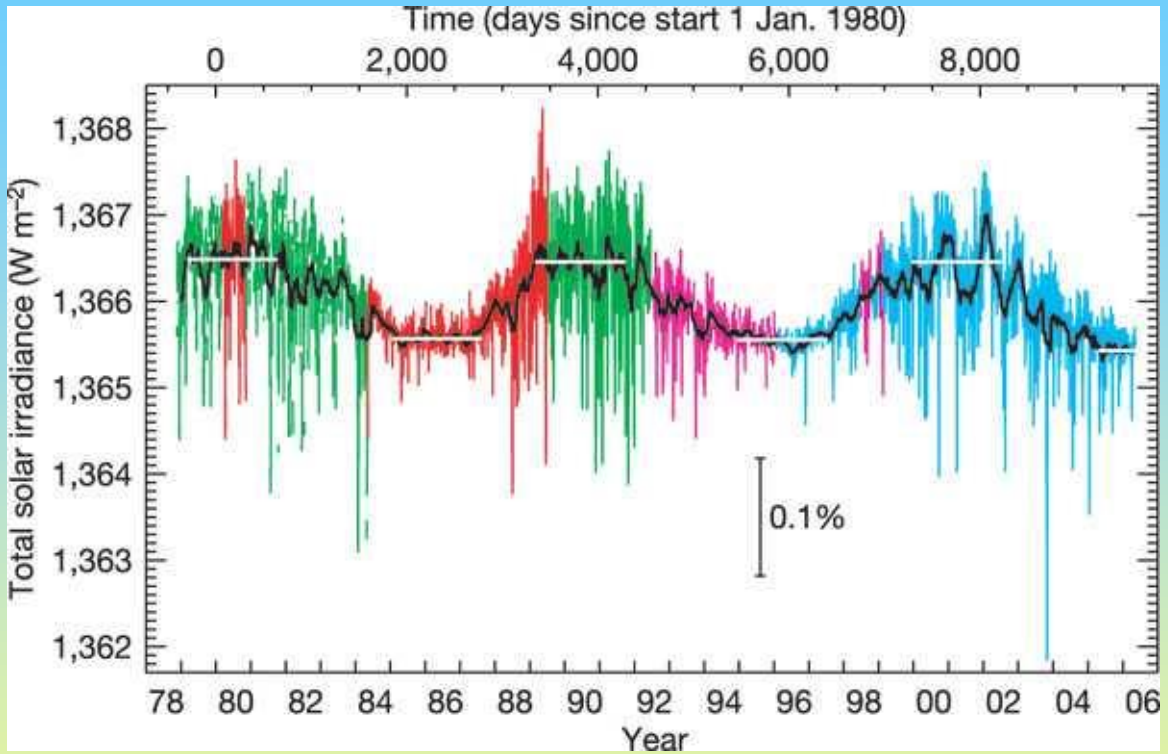
stellar spots → changes of the average temperature, hence the effective stellar radius

positive trend in k

→ a decrease in luminosity of 0.28%

→ a change of spot coverage of 0.44%.

Comparison with the solar cycle



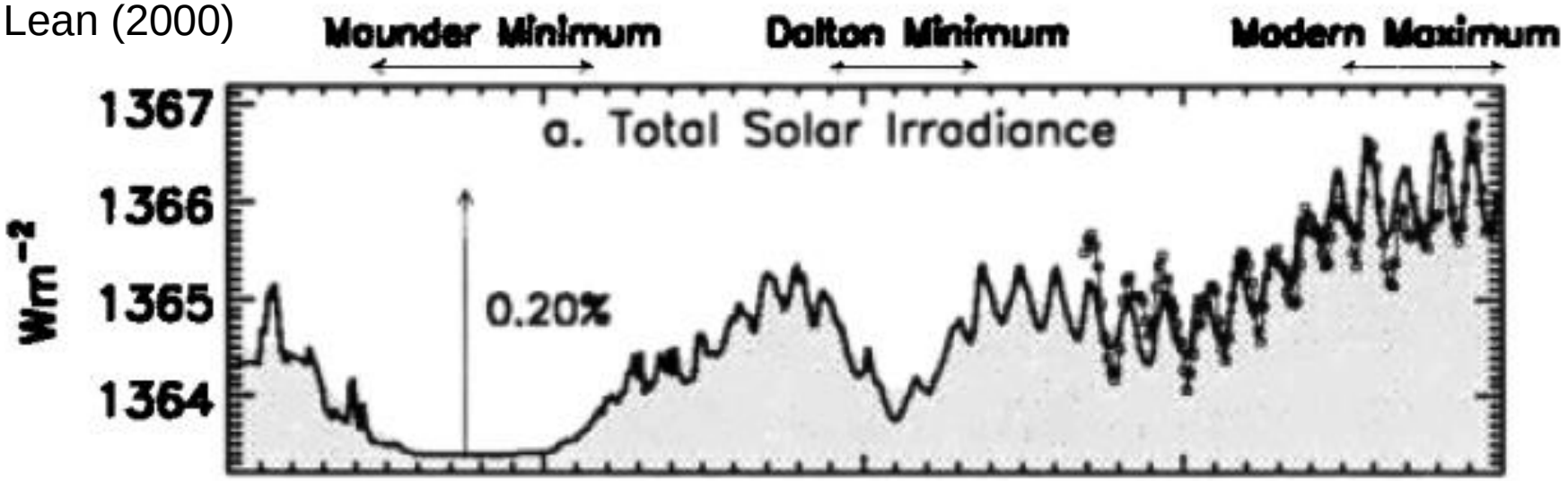
Foukal et al (2006):

variation amplitude of the solar constant within the last three solar cycles
~ 0.90 W m^{-2}

→ If translated to luminosity this yields a variation of 0.066%.
→ change in spot covered area of 0.1%

Including the Maunder Minimum:

Lean (2000)



luminosity variation can be as high as 0.2%

→ change in spot covered area of 0.34%

The Sun is known to be not a very active star (e.g. Radick et al. 1998)

→ the TrES-2 host star could have a higher spot covered area

Activity vs. Age of the TrES-2 host star

Sozzetti et al. (2007):

determined chromospheric activity from the Ca II H and K lines:

$$\langle \log R'_{HK} \rangle = -5.16 \pm 0.15$$

→ implies a very low activity of the TrES-2 host star
→ corresponds to a very high age of $\sim$ 8 Gyr.

unusual high Li abundance as it is expected from a star at the age of 1-2 Gyr.

From comparison with evolutionary models: final age of 5.1+2.7−2.3 Gyr

→ the TrES-2 host star is slightly older than the Sun and should be less active

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→Conclusion

To test the hypothesis of a changing activity it is necessary to spectroscopically and photometrically monitor TrES-2 and its host star for the next years to decades


Thank you for your attention !!!