
- New observations with CoRoT-7b with CoRoT (LRa06)
- Difference from previous CoRoT observations (LRa01)
- Our tests suggest it could be due to stellar activity.
CoRoT-7 System

• CoRoT-7b was discovered during LRa01 run, October 2007 to March 2008 (Leger et al 2009).
• Period of 0.85 days and depth 0.03%, \( r \sim 1.6X_{\text{Earth}} \). First transiting superEarth.
• Host star is young G9 showing high stellar activity - 2% variation in the flux and 40m/s RVs.
• Values planetary mass ranging from 2.3-8 Mearth.
• Possible 2\textsuperscript{nd} or 3\textsuperscript{rd} planet in the system from RV analysis (Queloz et al. 2009, Hatzes et al. 2010).
New observations

- New simultaneous HARPS and CoRoT observations during 26 consecutive nights in a lower activity level.
- The second planet was confirmed but not the third. \( M_b = 4.88 \pm 0.94 \)Me and \( M_c = 14.20 \pm 1.09 \)Me. (Haywood, R. et al.)
Lower activity level

Fig. 1 CoRoT-7 observations taken during LRa01 (left) and LRa06 (right).

- In LRa06 the light curve shows half of the amplitude variability than LRa01.
- Spectroscopic activity index $\log R'_{HK} = -4.60 +/- 0.03$ decreased to $-4.73 +/- 0.03$.
- Activity signature in RVs decreased from 40m/s to 15m/s.
Stellar density problem

Phase folded 152 transits of CoRoT-7b for LRa01

Transit derived stellar density $= 0.2 \rho_\odot$

Spectroscopic derived $= 1.6 \rho_\odot$

Suggested stellar activity or TTVs

In transit surveys the two density comparison is used to test consistency and false positive detection.

Prior in stellar radius

Leger et al. 2009
Parameter posterior distributions

Why?
→ Low signal to noise of the transit
→ Instrumental noise
→ Stellar activity

Fig. 1 Parameter correlation plots for the transit parameters of CoRoT-7b for the runs analyzed separately.
White noise test

• Using time stamps of CoRoT observations we simulated transits with the final transit shape and included white noise corresponding to each run.

• Conclude that the parameter posterior distributions observed for LRa06 are characteristic of low signal-to-noise transit where the ingress/egress time are not resolved and we cannot constraint the inclination.

• Conclude that white noise cannot explain the shape of the distribution of LRa01.
**Test LRA01 instrumental noise**

- Injected transits in a close by star in LRA01 to test instrumental noise.
- Obtained a posterior distribution shape similar to the one of white noise tests.

Could the higher stellar activity of LRA01 be the cause of the difference in the distributions?
Out-of-transit stellar variability

The 2% out of transit variability of CoRoT-7 affects transit depth:
• 0.6% affect of the derived stellar density
• 1% affect the derived planetary radius if not accounted for.

Affects shape of the light curve.
• Injected transit at different phases in the LRa01 light curve.
Simulations cannot reproduce LRa01.

In transit variability? Spot crossing events?
Effects of spot occultation events

WASP-10b (Barros et al, MNRAS 2013)


CoRoT-2 (Silva-Valio et al. 2010 A&A)

Effect of spot occultation events in the derived transit parameters as a function of spot phase.
TTVs

- When spot crossing events affect the shape of the light curves, a periodicity related to the rotation period of the star has been seen (CoRoT-8, Borde et al 2010, Kepler-17b Desert et al 2011, WASP-10, Barros et al 2013).

- Periodicity of TTVs suggested that some transit affected by spot occultation events that would produce a steeper ingress/egress of the mean transit shape.

- TTVs due to the other planets (CoRoT-7c and CoRoT-7d are less than 5 seconds below our sensitivity.)
Selection on out-of-transit flux

- The posterior probability distribution is different for the out-of-transit selection of higher flux and lower flux. This supports the difference between LRa01 and LRa06 being due to activity.
- We use this selection to obtain final results that will include RVs and stellar models.
PASTIS transit modelling
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- Transits LRa01sel + LRa06
- RVs
- Stellar evolution tracks
- Self-Consistent model

Spectroscopy (Bruntt 2010)
- $T_{\text{eff}} = 5250 \pm 60$ K
- $\text{Fe/H} = 0.12 \pm 0.06$
- $\log g = 4.47 \pm 0.05$
- Age limit 3 Gyr as Bruntt 2010
Density

- Using our new estimation of radius and the mass estimation from Haywood et al. 2014 we derive a planetary density of 1.04 +/- 0.20, so CoRoT-7b compatible with an earth composition.
- According to the composition models of Zeng et al. 2013, CoRoT-7b can be composed of silicates, compatible with a Rocky composition.
- Atmosphere would introduce degeneracy.
- Age of the system is close to the lifetime of water vapour (Valencia 2011 and Selsis 2007).

Summary

• We find different posterior parameter distributions for transit parameters in the two CoRoT observations of CoRoT-7b.

• In low signal-to-noise transits where the transit shape is not well constrained, the stellar density from spectroscopy or asteroseismology can help constrain the transit parameters.

• LRa01 appears to have an extra noise component that could be due to out-of-transit stellar variability or spot-occultation events which we favour.

• A selection using the out-of-transit flux allowed to remove transits that are more affected by the noise.

• In this case the activity does not significantly bias the transit radius which could be due to the strong external constrain on the density.
THANK YOU
Using time stamps of CoRoT observations we simulated transits with the final transit shape and included white noise with rms of 970 ppm per point.
Imposing density prior

**Photo-eccentric (PE) effect**

\[
\frac{\rho_{\text{obs}}}{\rho_{\text{true}}} \approx \left(1 + \varepsilon \sin \omega \right)^3 \\
\text{valid for: } \frac{P}{\text{days}} > 0.101 \left(\frac{\rho_{\text{true}}}{\text{g cm}^{-3}}\right)^{-2/3} \left(\frac{1 + e}{1 - e}\right)^5 \approx 10^2
\]

**Photo-blend (PB) effect**

\[
\frac{\rho_{\text{obs}}}{\rho_{\text{true}}} \approx \left(1 + \sqrt{\frac{2}{\rho_{\text{obs}}} - \frac{2}{\rho_{\text{true}}}}\right)^{3/2} \leq 10
\]

valid for: \[\frac{P}{\text{days}}^{4/3} > 0.206 \left(\frac{\rho_{\text{true}}}{\text{g cm}^{-3}}\right)^{-2/3}\]

**Photo-spot (PS) effect**

\[
\frac{\rho_{\text{obs}}}{\rho_{\text{true}}} \approx \frac{d}{\sqrt{d^2 - P_{\text{obs}}^2}} \frac{\rho_{\text{obs}}}{\rho_{\text{true}}} \approx 10^{-1}
\]

valid for: \[\frac{P}{\text{days}}^{4/3} > 0.289 \left(\frac{\rho_{\text{true}}}{\text{g cm}^{-3}}\right)^{-2/3}\]

**Photo-timing (PT) effect**

\[
\frac{\rho_{\text{obs}}}{\rho_{\text{true}}} \approx \frac{P}{P + 2.4 \text{M}_\text{J}} \leq 10^0
\]

valid for: \[\frac{P}{\text{days}}^{4/3} > 0.231 \left(\frac{\rho_{\text{true}}}{\text{g cm}^{-3}}\right)^{-2/3} A_{\text{PV}} < 1\]

**Photo-duration (PD) effect**

\[
\frac{\rho_{\text{obs}}}{\rho_{\text{true}}} \approx \frac{\left(\frac{d}{h} \rho_{\text{obs}}^2 + 4A_{\text{PV}}^2 \rho_{\text{obs}}^2 + 2A_{\text{PV}}^2 (1 - p^2)^2 - b(1 + p^2)\right)^{3/2}}{\left(\frac{d}{h} \rho_{\text{true}}^2 + 4A_{\text{PV}}^2 \rho_{\text{true}}^2 + 2A_{\text{PV}}^2 (1 + p^2 - b^2)\right)^{3/2}} \leq 10^0
\]

valid for: \[\frac{P}{\text{days}}^{4/3} > 0.231 \left(\frac{\rho_{\text{true}}}{\text{g cm}^{-3}}\right)^{-2/3} A_{\text{PV}} < 1\]

**Photo-mass (PM) effect**

\[
\frac{\rho_{\text{obs}}}{\rho_{\text{true}}} \approx 1 + \frac{M_{\text{transit}}}{M}\leq 10^0
\]

always valid

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**Figure 5. The Photo-eccentric Effect:** The minimum orbital eccentricity function, defined in Equation [32] plotted with respect to its only dependent variable, \(\rho_{\text{obs}}(P_{\text{obs}}, P_{\text{true}})\). The arrows correspond to real KOs with known astrometric or photometric measurements available, where blue are singles and red are multi's. We also mark the directions in which the other astrometric profiling effects act.

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Optimisation of the mask

LRa06
Imagette allows optimisation of mask. Minimise the noise for timescales less than 2 hours. The smaller mask in LRa06 means that the contaminations due to other stars is lower = 0.022 +- 0.002%

10% less flux due to ageing of the CCD.
Out-of-transit stellar variability

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