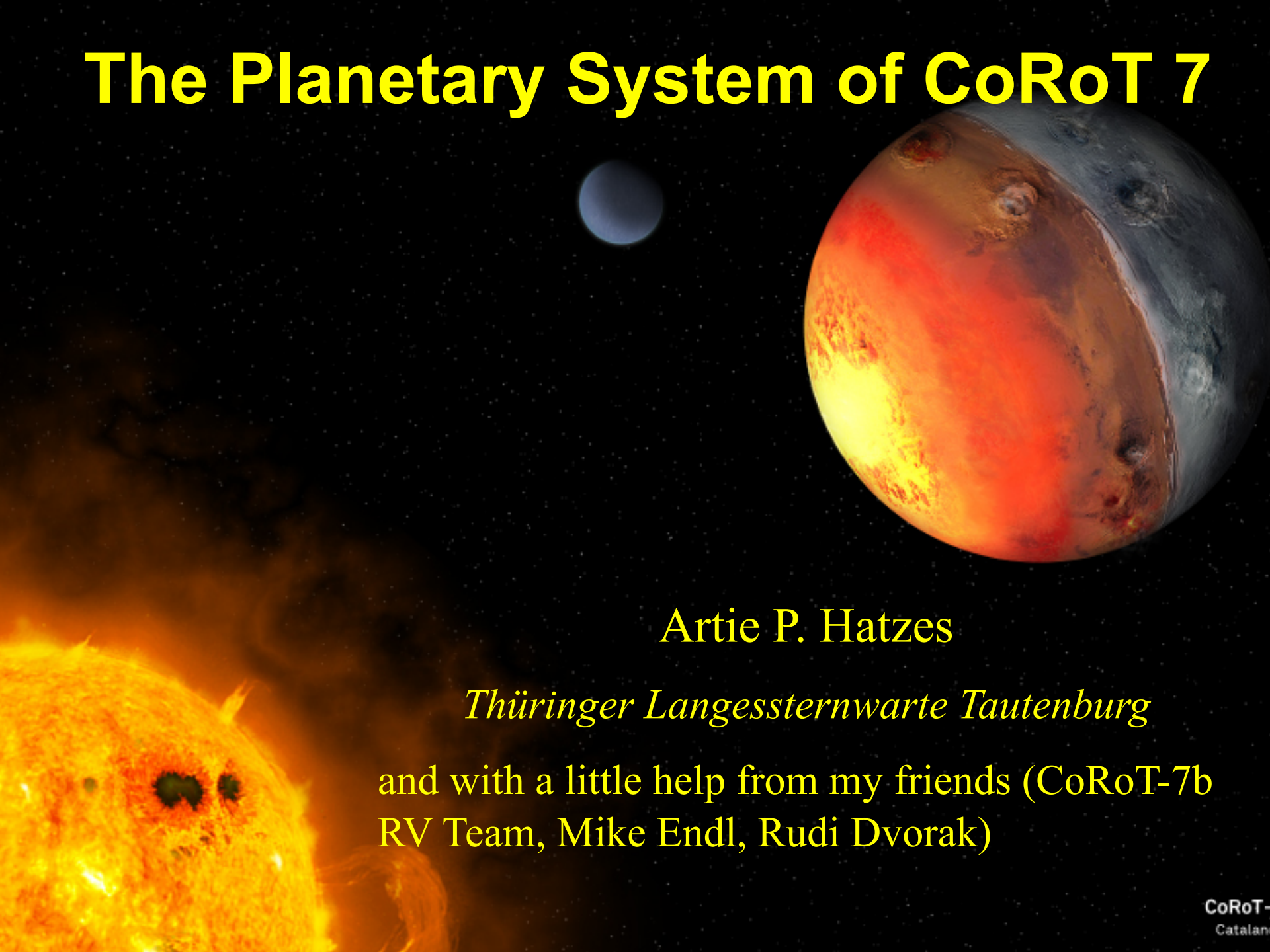
The Planetary System of CoRoT 7



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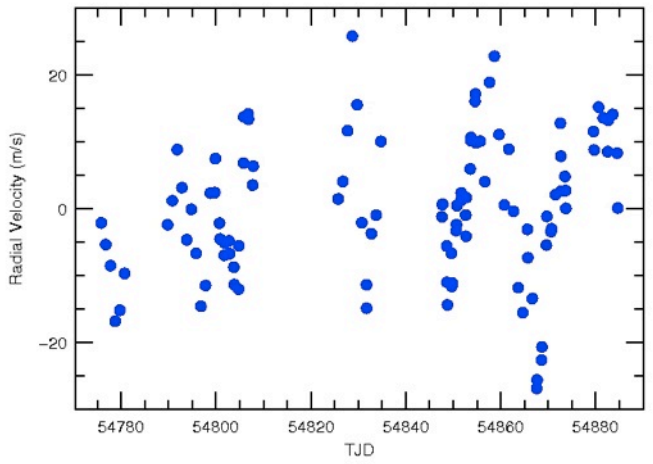
Thüringer Langessternwarte Tautenburg

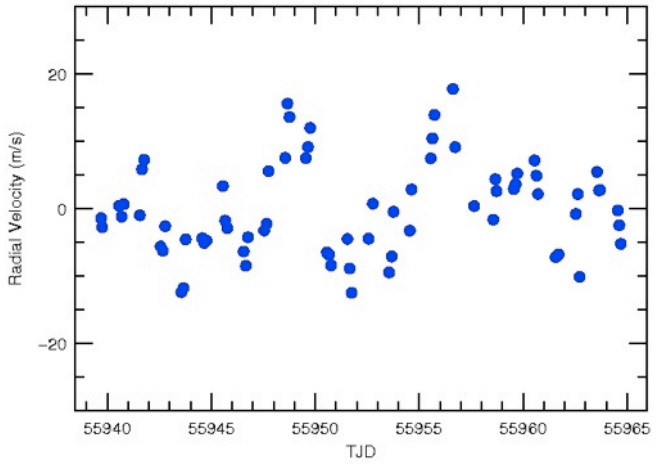
and with a little help from my friends (CoRoT-7b RV Team, Mike Endl, Rudi Dvorak)

The Radial Velocity Data

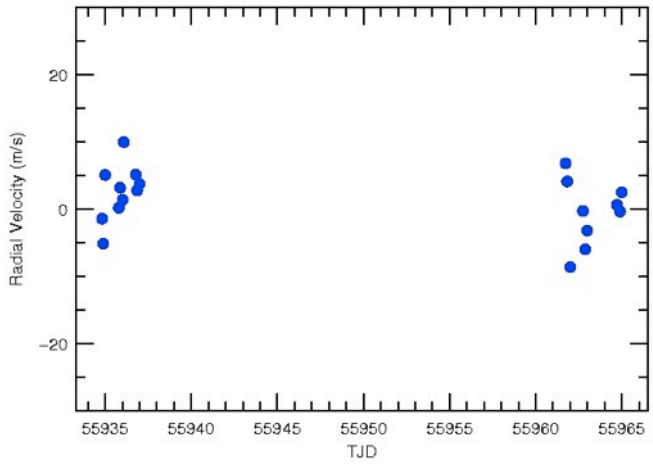
HARPS I



HARPS II



Keck



HARPS I:

- o 106 Measurements
- o Nov 2008 – Feb 2009
- o 7 nights ≥ 3 measurements

HARPS II:

- o 71 Measurements
- o Jan – Feb 2012
- o 18 nights ≥ 3 measurements

Keck:

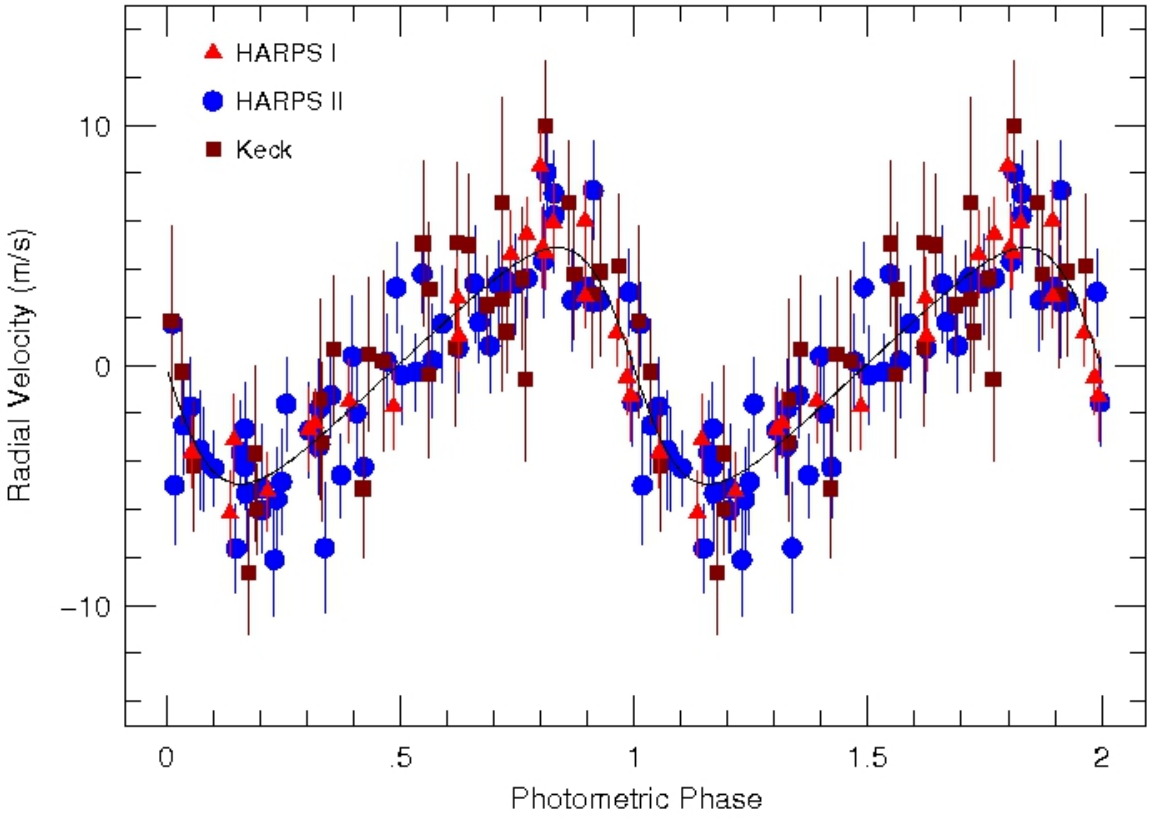
- o 30 Measurements
- o Jan – Feb 2012
- o 6 nights ≥ 3 measurements

CoRoT-7b

- Use only nights with at least 3 Measurements
- Treat each night as an independent data set
- Find best orbital solution keeping period fixed, but allowing K-amplitude, Ω, e, and zero-point offset to vary

The trick: in one night most of the observed RV variations are due to the orbital motion (0.85-d) of C7b.
Any RV contribution due to activity (24-d rotation period) or other planets is a constant value for the night.

CoRoT-7b

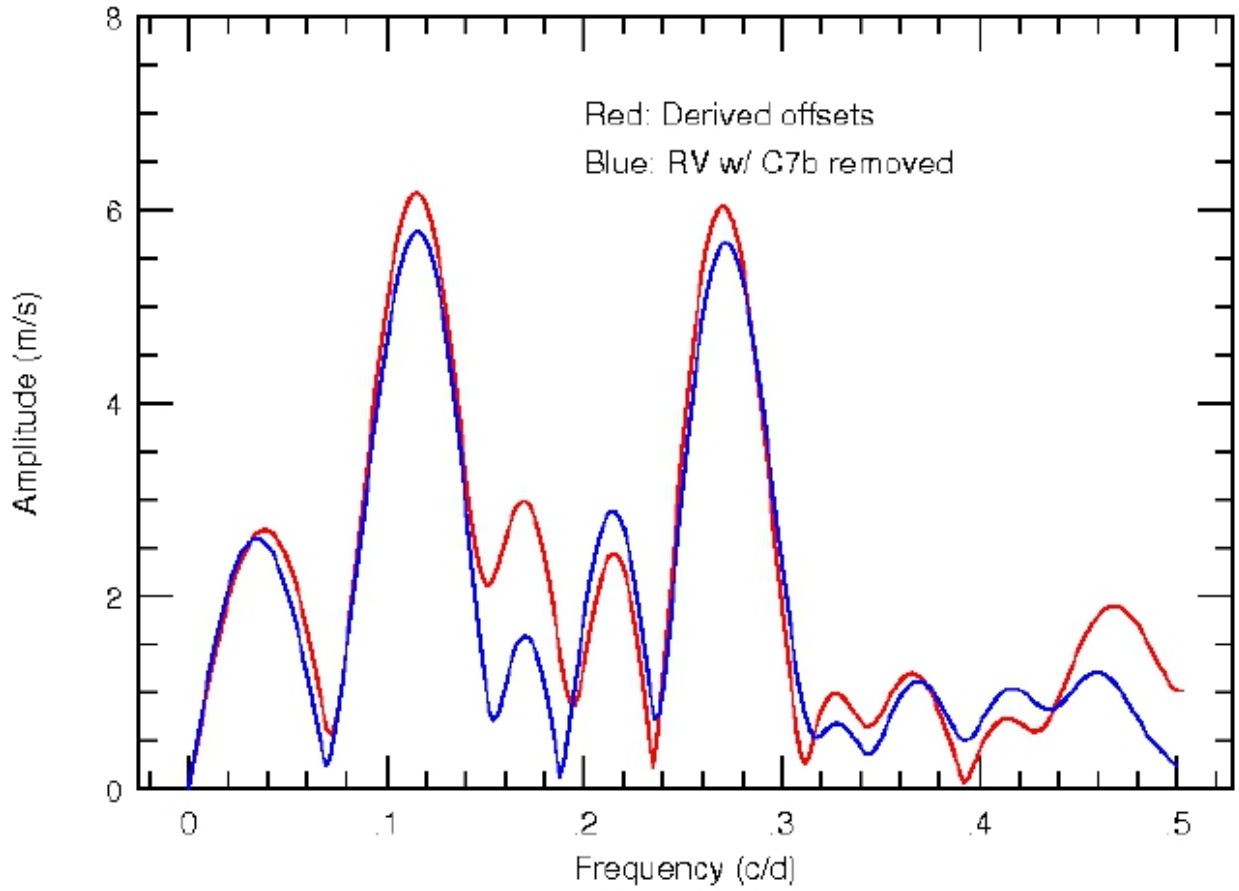


$\sigma_{HARPS\ I} = 1.27$ m/s

$\sigma_{Keck} = 2.39$ m/s

$\sigma_{HARPS\ II} = 1.87$ m/s

Sanity check:



Calculated offsets consisitent with RV variations minus C7b

CoRoT-7b

HARPS I

K : 5.49 ± 0.94 m/s
e: 0.34 ± 0.12
Ω: 112.9 ± 10.5 deg.

HARPS II

K : 4.75 ± 0.82 m/s
e: 0.32 ± 0.11
Ω: 82.0 ± 9.6 deg.

Keck

K : 5.36 ± 1.18 m/s
e: 0.34 ± 0.15
Ω: 79.0 ± 15.4 deg.

Combined

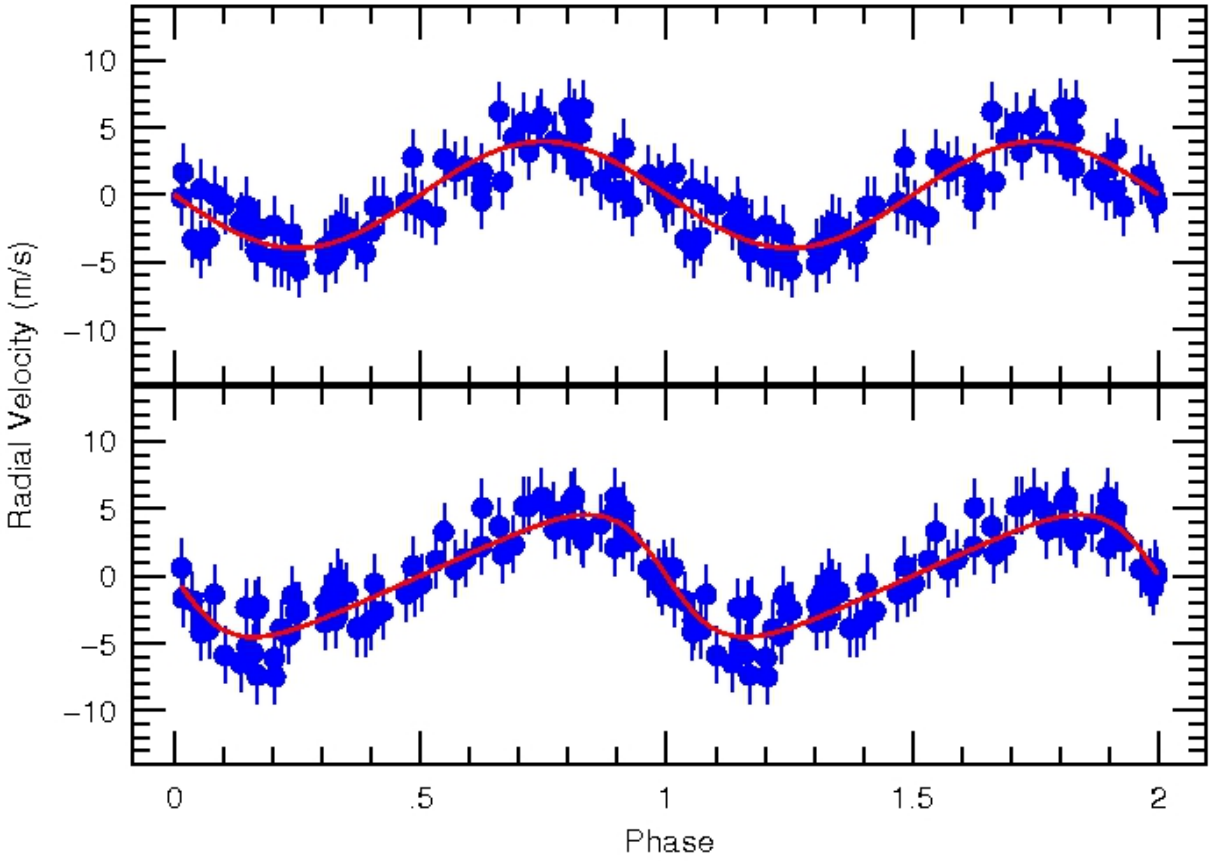
K : 4.95 ± 0.66 m/s
e: 0.28 ± 0.08
Ω: 92.27 ± 6.8 deg.
M: 6.75 ± 0.86 M_{Earth}
ρ: 9.4 ± 2.1 gm cm^{-3}

All HARPS I (2 + 3 measurements):
e = 0.08 ± 0.14

All HARPS (2+3): e = 0.10 ± 0.04

➔ Adding data with only 2 nights lowers eccentricity

An Eccentric Orbit for CoRoT-7b?



$ecc_{in} = 0.0$

$ecc_{out} = -0.01 \pm 0.09$

$ecc_{in} = 0.29$

$ecc_{out} = 0.29 \pm 0.08$

Procedure seems to recover input circular/ eccentric orbits

How many planets does CoRoT-7 have?

Queloz et al. 2009, 2 planets: C7b, C7c (3.7 d)
Hatzes et al. 2010, 3 planets: C7b, C7c, C7d (9 d)

Method of choice: Fourier Component Analysis (pre-whitening) after subtracting orbit of C7b:

- find the dominant peak in the DFT
- subtract sine component
- find the next peak
- subtract that
- stop when you have found all your signals

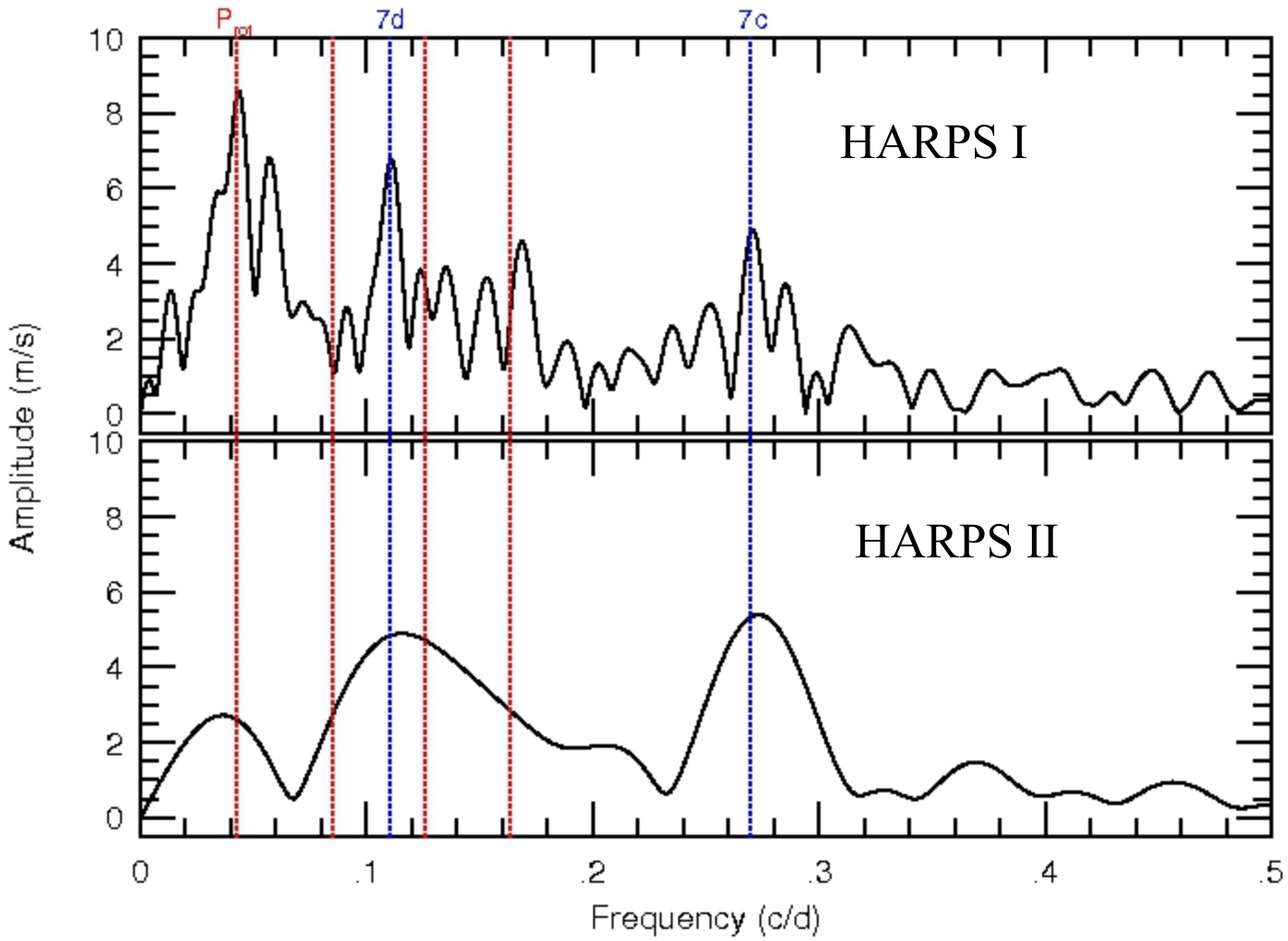
Comparison of Filtering Techniques

	K-Amp (m/s) Offset fitting	K-Amp (m/s) Fourier
HARPS I	5.49 ± 0.94	4.86 ± 0.62
HARPS II	4.75 ± 0.82	4.45 ± 0.44

Note:
If possible results should be tested with an independent method

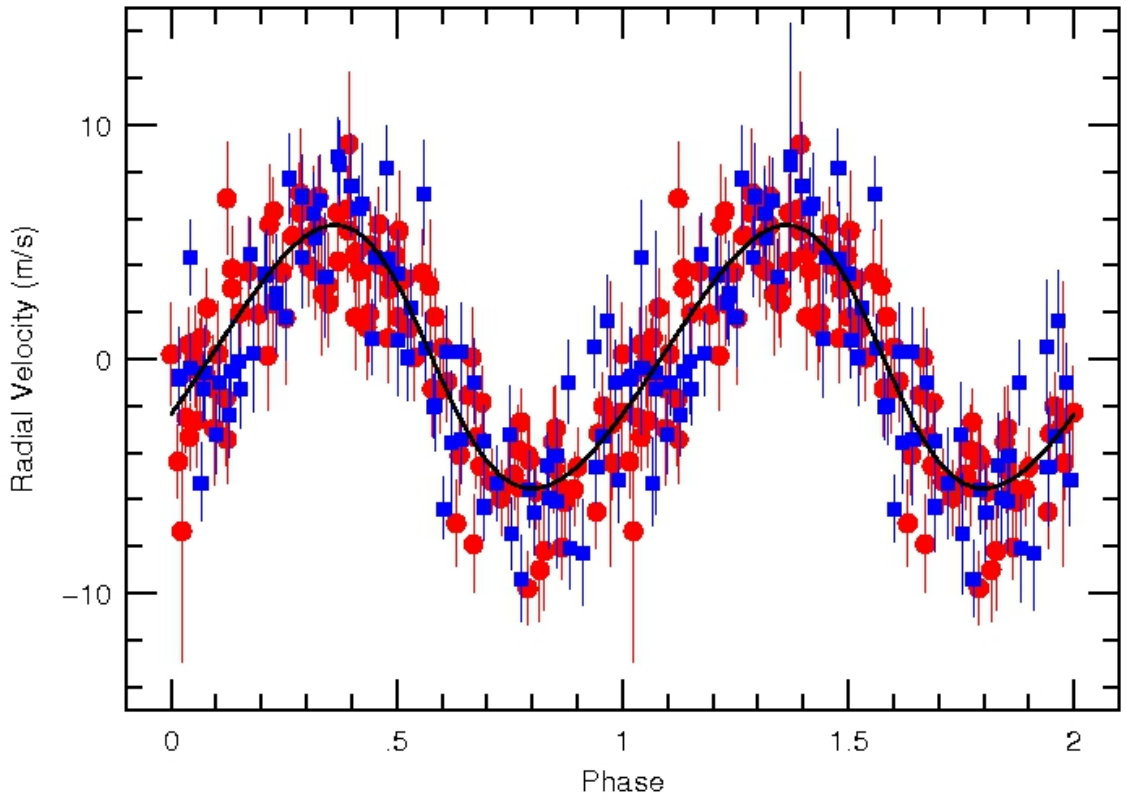
pre-whitened eccentricity, $e = 0.05 \pm 0.06$

Fourier Amplitude Spectrum of HARPS RV



The Fourier structure of the activity signal changed from 2009 to 2012

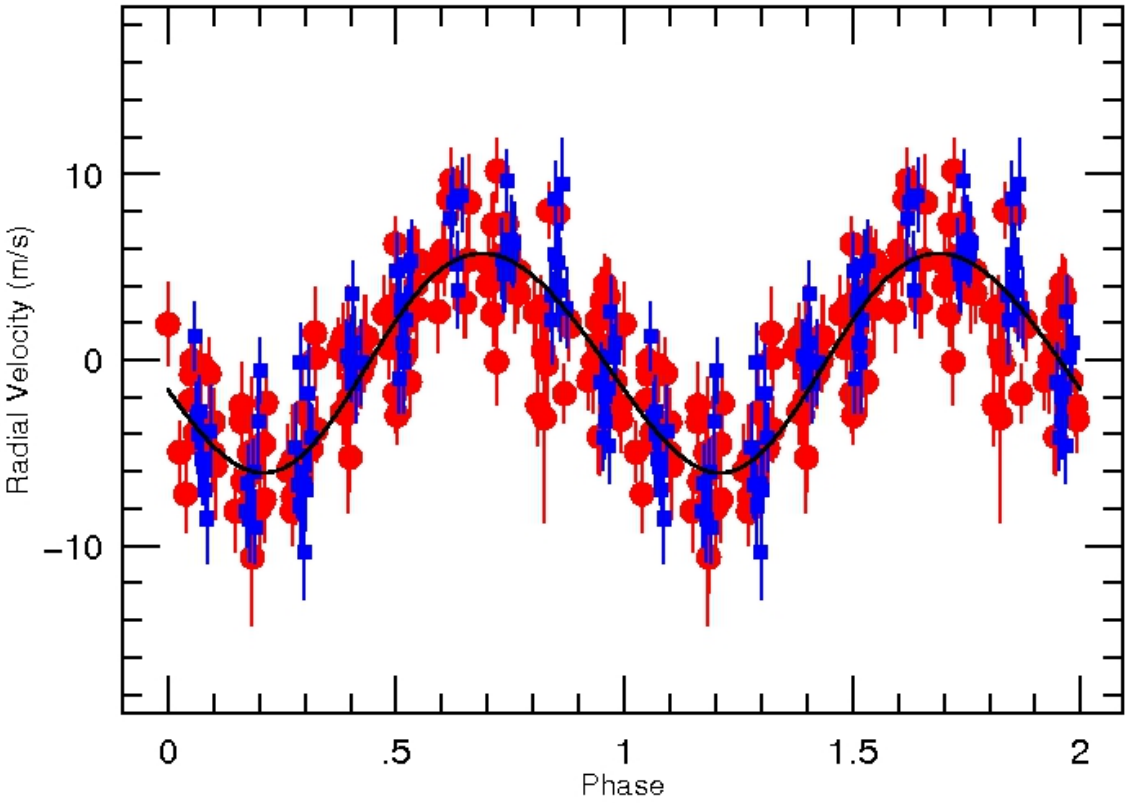
CoRoT-7c



Red dots: HARPS I
Blue squares: HARPS II

P: 3.6968 ± 0.00016 d
K : 5.63 ± 0.23 m/s
e: 0.10 ± 0.04
Ω: 80.5 ± 22.4 deg.
m sin i: 12.81 ± 0.59 M_{Earth}

CoRoT-7d



Red dots: HARPS I
Blue squares: HARPS II

P: 9.038 ±0.0113 d

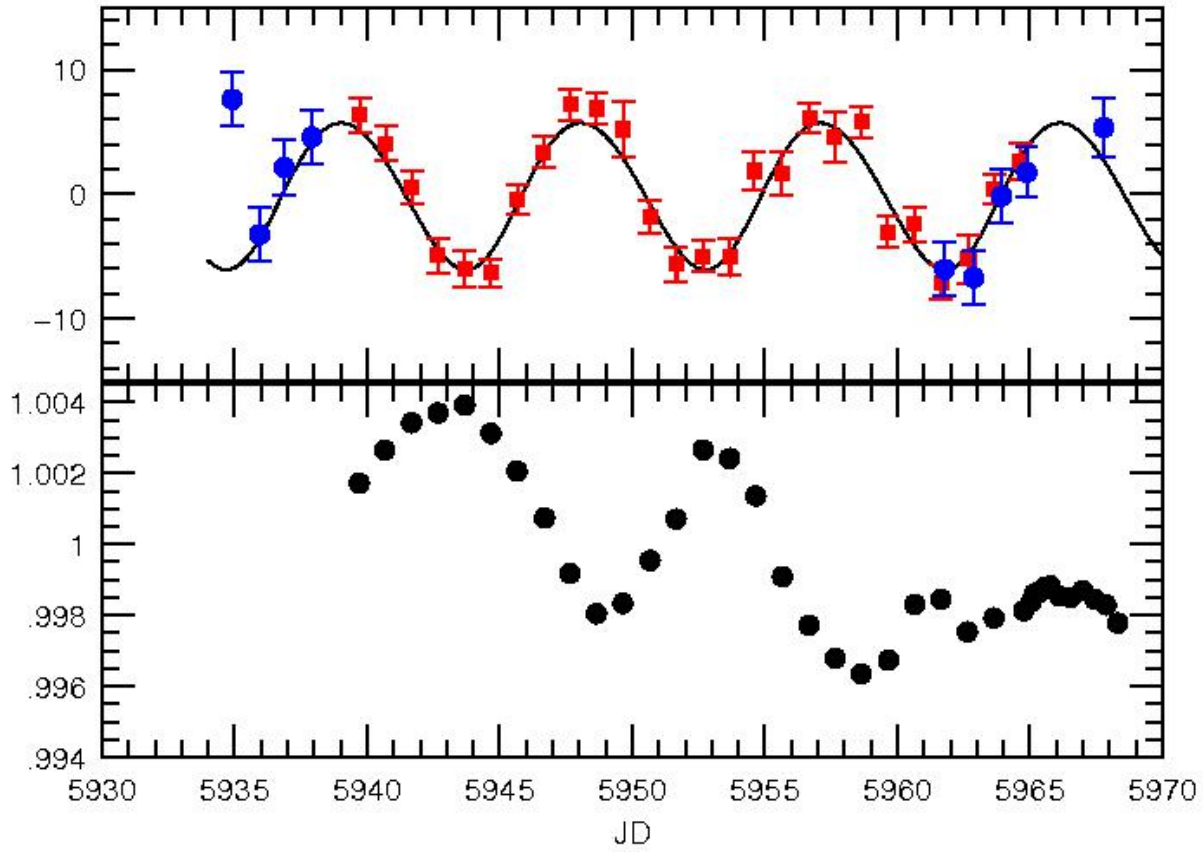
K : 5.90 ± 0.30 m/s

e: 0.044 ± 0.047

Ω: 228 ± 65 deg.

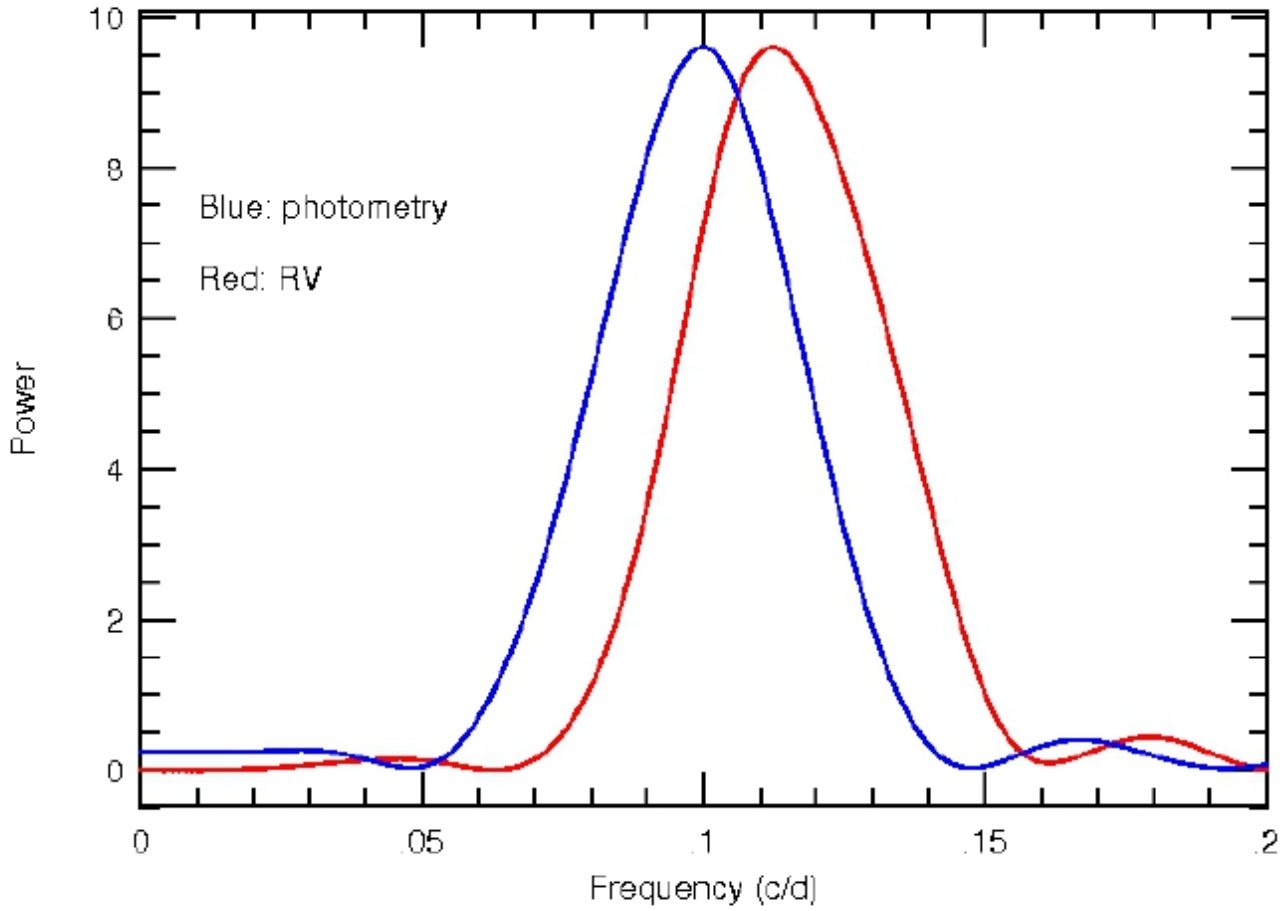
m sin i: 18.2 ± 1.10 M_{Earth}

CoRoT 7 light curve shows possible 9-d variations:



- RV signal is coherent, photometry is not
- Photometric variations from spots cannot account for the RV amplitude of C7d

Plus Photometry and RV have different periods:
10 d versus 9 d



What about the eccentricity of CoRoT-7b?

From Rudi Dvorak:

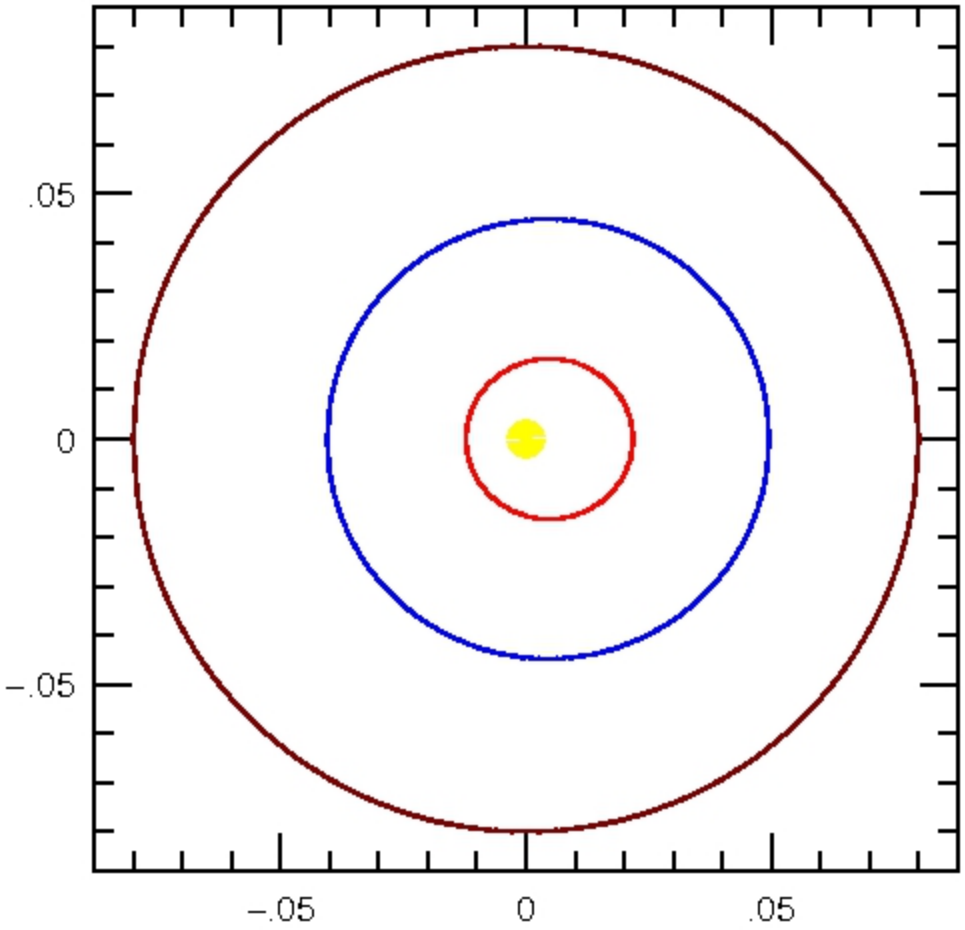
After first checks it looks stable but chaotic; I am afraid that because of the large eccentricity of CoRoT-b the planet comes too close to its star and this will -beside tides - cause other perturbations!!

I have two long runs for 1 million years:

- with planet c (i=10 deg) and d (i=20deg) within 200.000 nothing is visible in the semimajor axes but the eccentricity of planet b reaches values up to 0.35!, the inclination of planet b goes up to 35 deg!

- with planet c (i=15 deg) and d (i=30deg) within 200.000 nothing is visible in the semimajor axes but the eccentricity of planet b reaches values up to 0.4!, the inclination of planet b goes up to 50 deg! But there seems to be a trend in eccentricity to reach even higher values - I will see!

The CoRoT-7 Planetary System



The CoRoT-7 Planetary System

- Mass of CoRoT-7b is $6.75 \pm 0.86\ M_{Earth}$
- CoRoT-7b has significant eccentricity (e = 0.28) that does not seem to be part of the filtering process. The system is stable, but more work is needed.
- CoRoT-7c is confirmed with P = 3.7 d and m sin i = $12.8\ M_{Earth}$. Nearly circular orbit.
- CoRoT-7d is confirmed with P = 9.0 d and m sin i = $18.2\ M_{Earth}$. This does not seem to be due to activity.
- The CoRoT-7 is a densely packed planetary system. Kepler has shown these to be common.