CoRoT's exoplanet harvest
The giants!

Heike Rauer, Malcolm Fridlund and the CEST Team
Known extrasolar planets

Detection space for CoRoT
Today, of the known planets only transiting planets can be characterized further.

→ Basic planet parameters (mass, radius, density) when combined with radial velocity follow-up

→ albedo, spectral signatures of atmospheres when combined with IR photometry and with spectroscopy
Transiting extrasolar planets

„Discovery space“ for CoRoT

→ A large parameter space of transiting planets is still unexplored!
How CoRoT planet detection works…

1. **Observations**
2. **Data Reduction**
3. **Transit Candidate List**
4. **Follow-up Observations**
5. **Confirmed Planets**

**Transit Alarm!**
→ Preliminary candidate list
(large planets!)

**Basic Data Reduction**

**Follow-up Observations**

**Confirmed Planets**

Giant planets can be detected already in „alarm mode“!
Close-in giant objects can be discovered in „alarm mode“

- Very high S/N of data
- transit events visible at N1 level

For example:

CoRoT-Exo-4b

- Observations made during the „initial run“ of 58 days duration, starting Feb. 6, 2007
- ~72319 flux measurements
- 33 days with 512 s sampling, then switched to 32 s sampling
Transiting planets around variable stars e.g.: CoRoT-Exo-2b

- Observations made during the first „long run“ of CoRoT of 152 days duration
- ~369000 flux measurements with 512 s (1. week) and then 32 s sampling
- The star shows periodic variation over several days due to surface spots
- The transit signal is clearly identified; secondary transit tentative (2.5 σ)

Alonso et al. 2008
The „first 4“!

CoRoT-Exo-1b:
- P: 1.5089557 d
- r: 1.49 R_J
- m: 1.03 M_J
The star:
- G0V
- V = 13.6 mag
- R: 1.11 Rs
- M: 0.95 Ms

Barge et al. 2008

CoRoT-Exo-2b:
- P: 9.20205 d
- r: 1.19 R_J
- m: 0.72 M_J
The star:
- F0V
- V = 12.6 mag
- R: 1.15 Rs
- M: 0.97 Ms

Alonso et al. 2008

CoRoT-Exo-3b:
- P: 4.2568 d
- r: 1.01 R_J
- m: 21.66 M_J
The star:
- G0V
- V = 13.3 mag
- R: 1.56 Rs
- M: 1.37 Ms

Deleuil et al. 2008

CoRoT-Exo-4b:
- P: 9.20205 d
- r: 1.19 R_J
- m: 0.72 M_J
The star:
- F0V
- V = 13.7 mag
- R: 1.15 Rs
- M: 1.1 Ms

Agrain et al. and Moutou et al. 2008
The „next two“ I

CoRoT-Exo-5b

CoRoT-Exo-5b:
period: 4.0384 d
radius: 1.28 R_J
mass: 0.459 M_J

The star:
F9V
V = 14.0 mag
radius: 1.16 R_{sun}
mass: 1.01 M_{sun}

See poster Rauer et al.
The „next two“ II

CoRoT-Exo-6b

CoRoT-Exo-6b:
- period: 8.88 d
- radius: 1.15 $R_J$
- mass: 3.3 $M_J$

The star:
- $V$: 13.9 mag
- period: ~6.35 d
- radius: 1.02 $R_{\odot}$
- mass: 1.1 $M_{\odot}$

See poster Fridlund et al.
What is special about the CoRoT giants?
„Discovery space“ for CoRoT

Planetary systems of different ages

Transiting planets

![Graph showing planetary systems of different ages](image-url)
Planets around metal-poor stars

CoRoT-Exo-1b orbits one of the most metal-poor stars.

The star (Barge et al. 2008):
Type: G0V
Mass: 0.95 (± 0.15) Msun
Radius: 1.11 (± 0.05) Rsun
Fe/H: -0.3 (± 0.25)
Teff: 5950 (± 150) K
V: 13.6 mag
Stars with planets show higher metallicity:

- rv-planet searches early established a correlation of high stellar metallicity with planetary systems
- transiting surveys show less pronounced preference for high metallicity

$\Rightarrow$ Importance of „bias free“ planet searches

Planets discovered by radial velocity

CoRoT-Exo-1b

Transiting planets
Searching for additional planets by O-C analysis

Background: additional, gravitational perturbing planets in the system cause variations of the mid-transit times (TTVs).

Some illustrative examples:

Trojan planet to CoRoT-Exo-1b

Eccentric planet

S. Renner
Searching for additional planets by O-C analysis

CoRoT-Exo-4b

CoRoT-Exo-2b

• No transit timing variations have been found in the planets studied

But:

• CoRoT provides very high constraints on transit timing variations!

See poster Csizmadia et al. 2008
"Discovery space" for CoRoT

Populating the Desert

Table 6: CoRoT-Exo-3b parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass ($M_{Jup}$)</td>
<td>$21.66 \pm 1.0$</td>
</tr>
<tr>
<td>Radius ($R_{Jup}$)</td>
<td>$1.01 \pm 0.07$</td>
</tr>
<tr>
<td>Density (g cm$^{-3}$)</td>
<td>$26.4 \pm 5.6$</td>
</tr>
<tr>
<td>log $g$</td>
<td>$4.72 \pm 0.07$</td>
</tr>
</tbody>
</table>

Deleuil et al. 2008
Is CoRoT-Exo-3b exceptional?

- CoRoT-Exo-3b orbits a fast rotating star
- mid-sensitivity rv-surveys may be unable to detect planets around fast rotators
- in general, rv-surveys easily eliminated fast rotators from their surveys (focus on slow rotators)
Is CoRoT-Exo-3b exceptional?

- CoRoT-Exo-3b orbits a fast rotating star
- mid-sensitivity rv-surveys may be unable to detect planets around fast rotators
- in general surveys easily eliminated fast rotators from their surveys (focus on slow rotators)

→ Close-in, high-mass planets may escape detection around fast rotators due to a selection bias

→ High-accuracy transit surveys less biased towards slow rotators
Is CoRoT-Exo-3b exceptional?

high-mass planets detected around „high-mass“ stars

No „brown dwarf desert“ for „large“ stars?
Planets detected by radial velocity

"Planet Mass" vs "Star Mass" (299)

detection limit

High mass planets around high mass stars
Planets detected by transits

"Planet radius" vs "Star Radius" (49)

Small transit signal

large planets around large stars

large transiting planets?

exoplanet.eu (13/01/09)
Fill the parameter space with transiting planets with $P > 5$ days

"Discovery space" for CoRoT

"Planet Period" vs "Planet Mass" (54)

CoRoT planets

exoplanet.eu (13/01/09)
Possible correlation of planet mass and period

Mazeh et al. 2005

exoplanet.eu (01/02/09)
Possible correlation of planet mass and period

Close-in transiting planets show mass-period-correlation
Long-period transiting planets do not correlate.

Lack of low-mass planets on short-period orbits
But: following talk
CoRoT-Exo-4b:
P: 9.20205 +/- 0.00037 d
a: 0.09 +/- 0.001 AU
r: 1.19 R_J
m: 0.72 M_J

The star:
F0V
V=13.7 mag
P*=8.87 +/- 1.12 d

Aigrain et al. 2008

• out-of-transit photometric variability indicates a spotted, rotating stellar photosphere
• analysis of the photospheric variability, assuming activity regions remain for 2-3 rotation periods
• the rotation period P*=8.87 days derived photometrically is consistent with spectroscopic $v \sin i = 6.4 +/- 1.0$ km s$^{-1}$

→ planet and star are in a 1:1 resonance
CoRoT exciting targets I

- Monotransit found in IR01
- Transits found again in LRa01
- $P \sim 50$ days
- Depth = 5.6%
- Planet candidate if star is small $\rightarrow$ follow-up ongoing
CoRoT exciting targets II

CoRoT finds exciting objects

e.g.: possible very eccentric binary?
circumbinary objects?

…?
- Stellar activity with 13.6 days period
- After filtering our the activity, a planet candidate was found (0.11% depths around 16 mag star)
- after follow-up, it was identified as binary star…
Summary: CoRoT contributions to transit searches

- 6 giant objects with very accurate parameter determinations
- Planet around low-metallicity star
- Filling the "brown dwarf desert" → closing the gap between planet and brown dwarfs
- Filling the parameter space of transiting planets with large orbital periods
- Small transiting planets
More material…
"Planet Mass" vs "Star Mass" (50)

Star Mass (M\textsubscript{Sun})

Planet Mass (M\textsubscript{j})

exoplanet.eu (01/02/09)
Measurement of the Rossiter effect in CoRoT-Exo-2b

- the planet has a prograde orbit with respect to stellar rotation
- the sky-projected angle between the stellar spin and the planetary orbital axis is close to zero $\lambda = 7.2 \pm 4.5$ deg

**Fig. 1.** Phase-folded radial velocity measurements of CoRoT-Exo-2 during the transit of the planet with SOPHIE (dark circle) and HARPS (open circle). The solid line corresponds to the Rossiter-McLaughlin model adjusted to these data assuming the semi-amplitude $K = 563$ m s$^{-1}$ from Alonso et al. (2008). The dotted line corresponds to the Rossiter-McLaughlin model with $K$ as free parameters.

Bouchy et al. 2008
Planets and metallicity of their central stars

Rv + astrometry

Transiting planets
Table 1. Description of CoRoT runs in 2007-2008.

<table>
<thead>
<tr>
<th>Run</th>
<th>Date start-end</th>
<th>duration [d]</th>
<th>RA</th>
<th>DEC</th>
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<td>45</td>
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<tr>
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<td>18:41</td>
<td>07:10</td>
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<td>05-09/2007</td>
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<tr>
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<td>-03:20</td>
</tr>
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</table>

Optionally to be removed
Transiting extrasolar planets

„Discovery space“ for CoRoT

Transiting planets can be characterized!

- Basic planet parameters (mass, radius, density) only measured for transiting planets
- transiting planets can be characterized further in follow-up investigations (e.g. albedo, spectra)

⇒ A large parameter space of transiting planets is still unexplored!