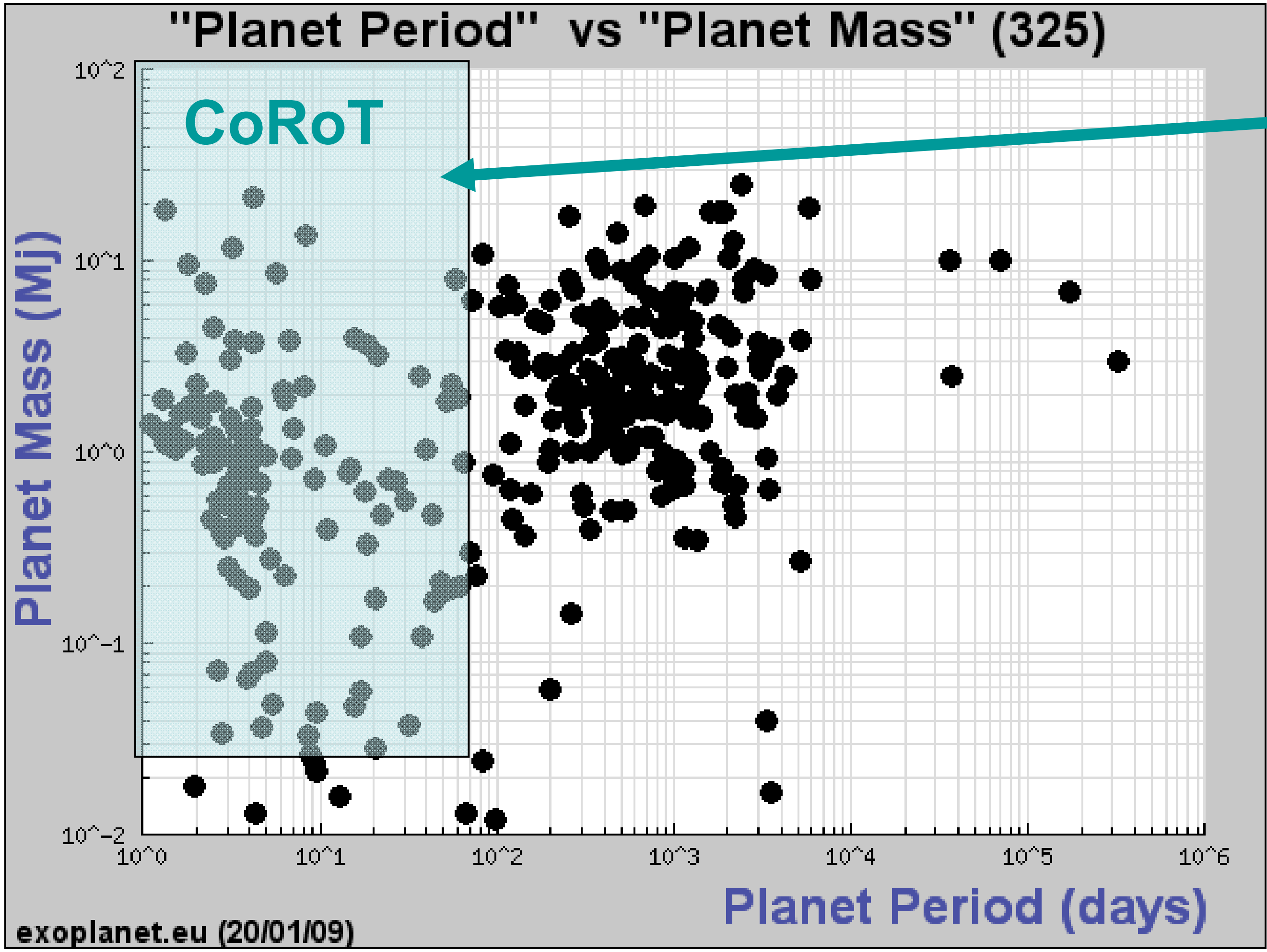
CoRoT's exoplanet harvest

The giants!

Heike Rauer, Malcolm Fridlund and the CEST Team

Known extrasolar planets



Detection space for CoRoT

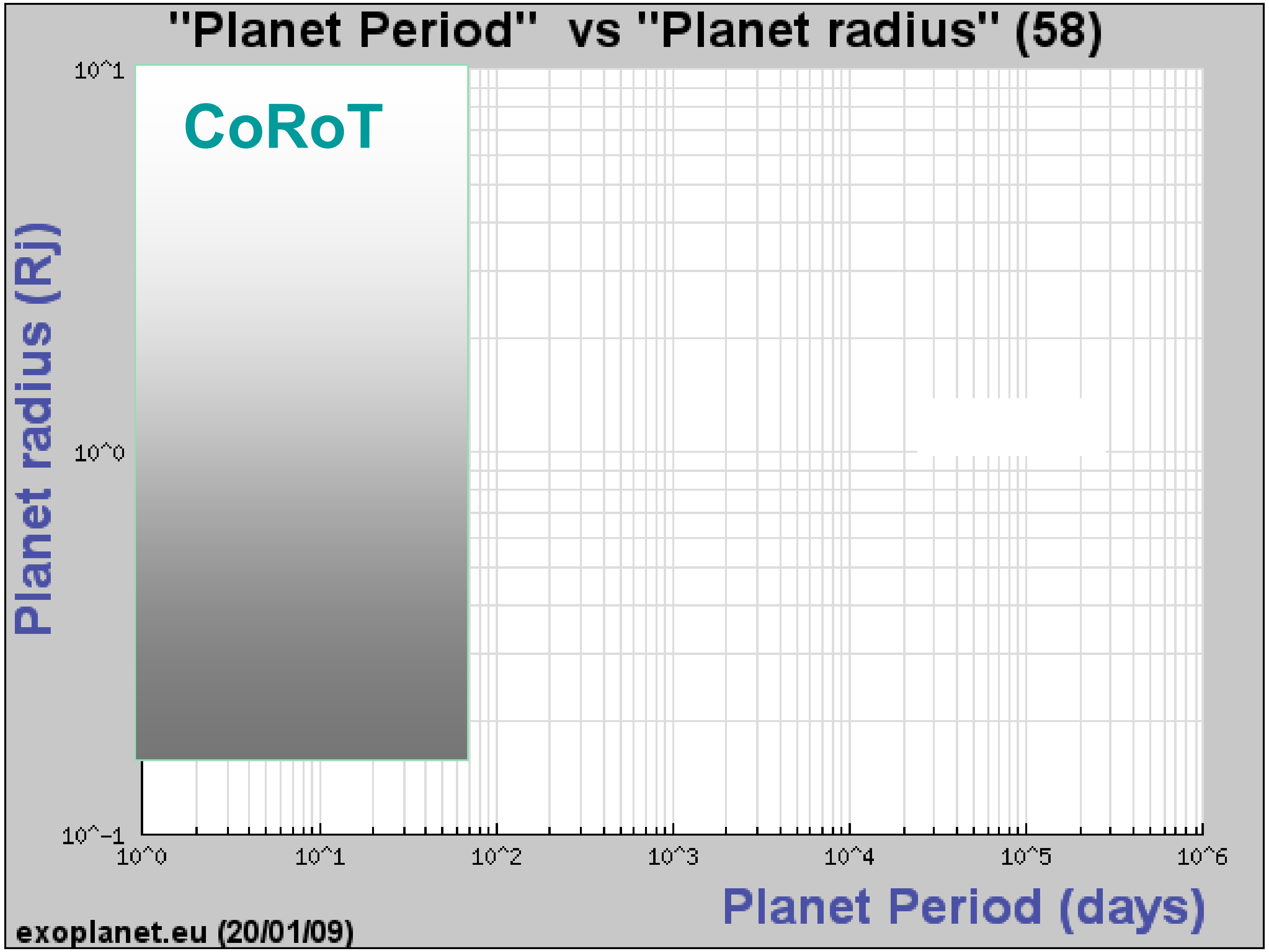
Today, of the known planets only transiting planets can be characterized further.

→ **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**

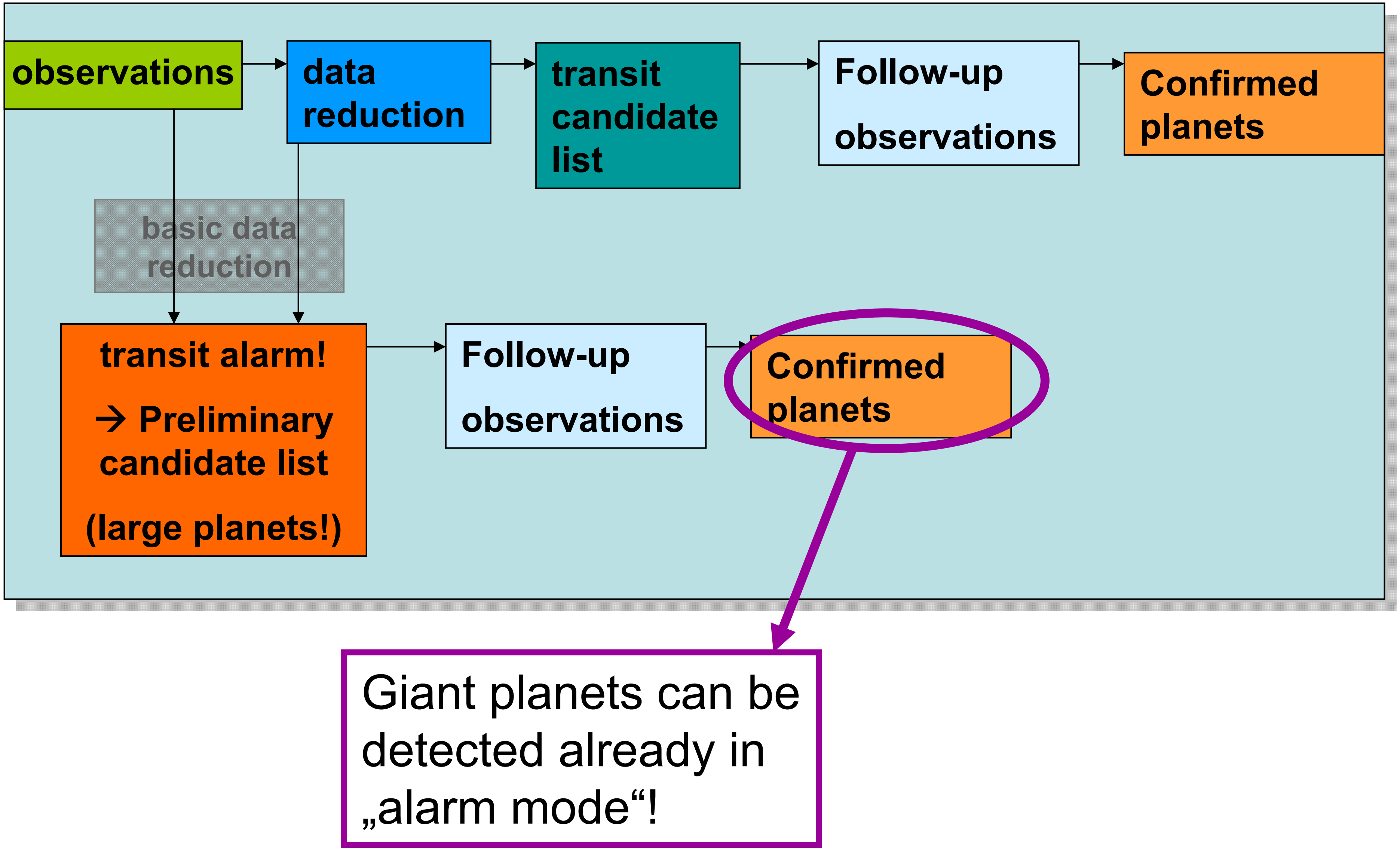
Transiting extrasolar planets

„Discovery space“ for CoRoT



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

How CoRoT planet detection works…



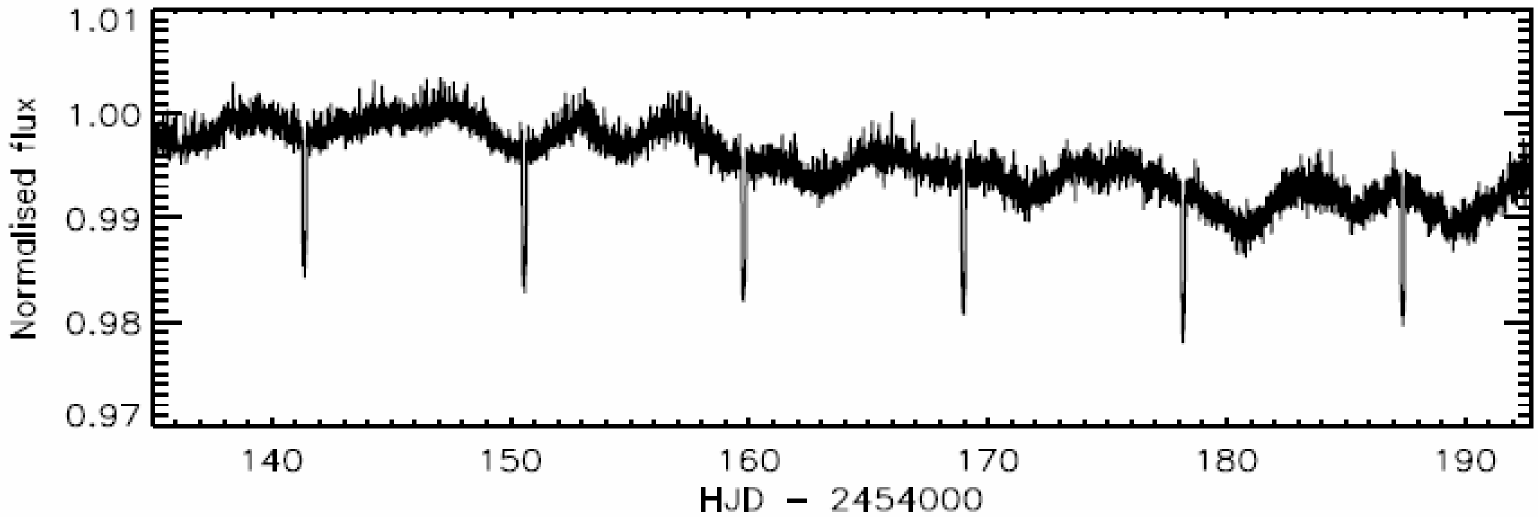
Close-in giant objects can be discovered in „alarm mode“

• Very high S/N of data

• transit events visible at N1 level

For example:

CoRoT-Exo-4b

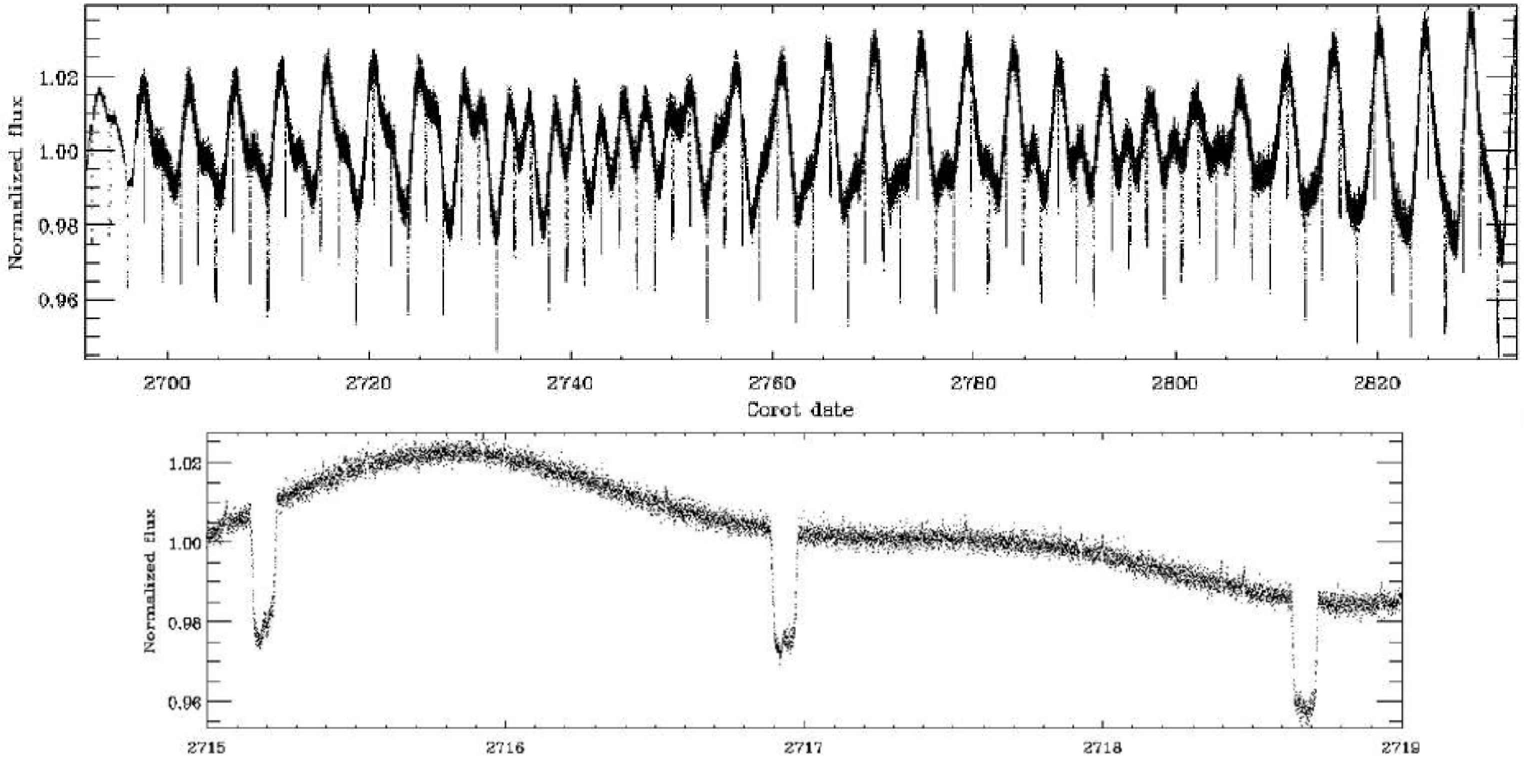


• Observations made during the „initial run“ of 58 days duration, starting Feb. 6, 2007

• ~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



Alonso et al. 2008

- 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

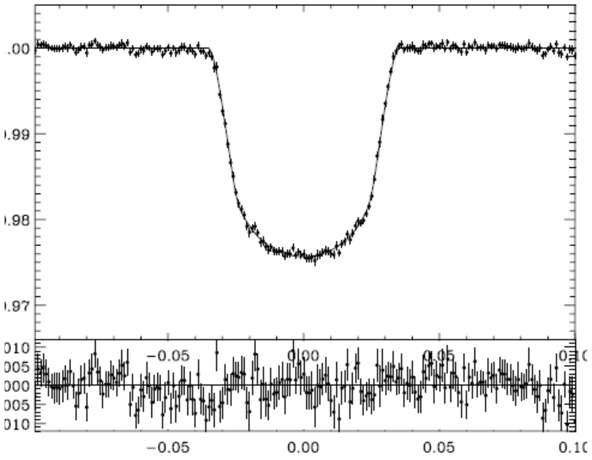
→The star shows periodic variation over several days due to surface spots

→The transit signal is clearly identified; secondary transit tentative (2.5 σ)

The „first 4“!

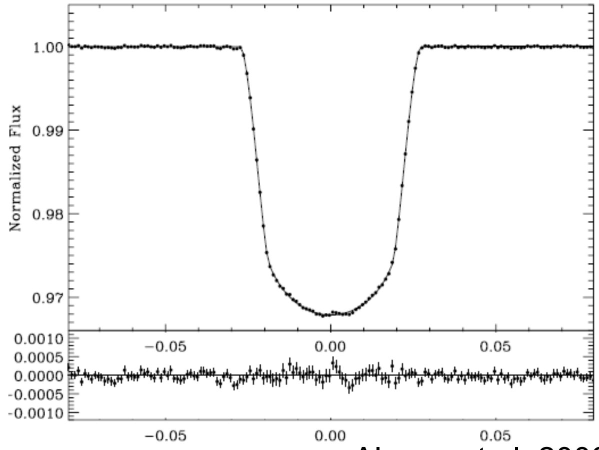
CoRoT-Exo-1b

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

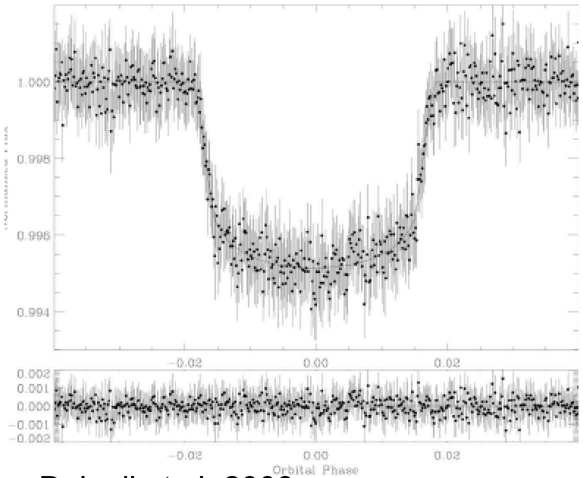


Alonso et al. 2008

CoRoT-Exo-2b:
P: 1.742996 d
r: 1.465 R_J
m: 3.31 M_J
The star:
K0V
V=12.6 mag
R: 0.902 Rs
M: 0.97 Ms

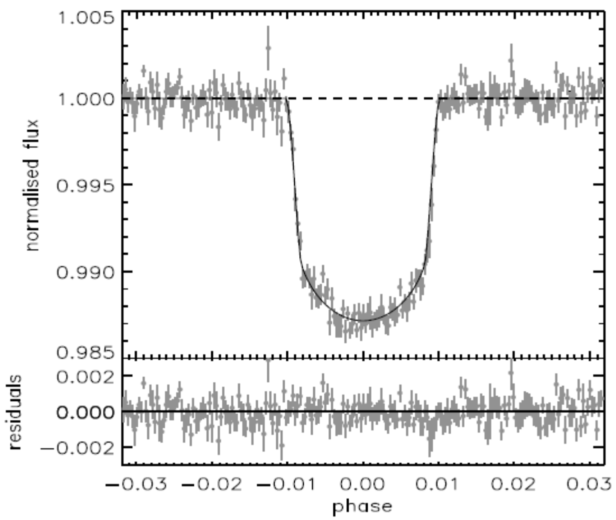
CoRoT-Exo-3b

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

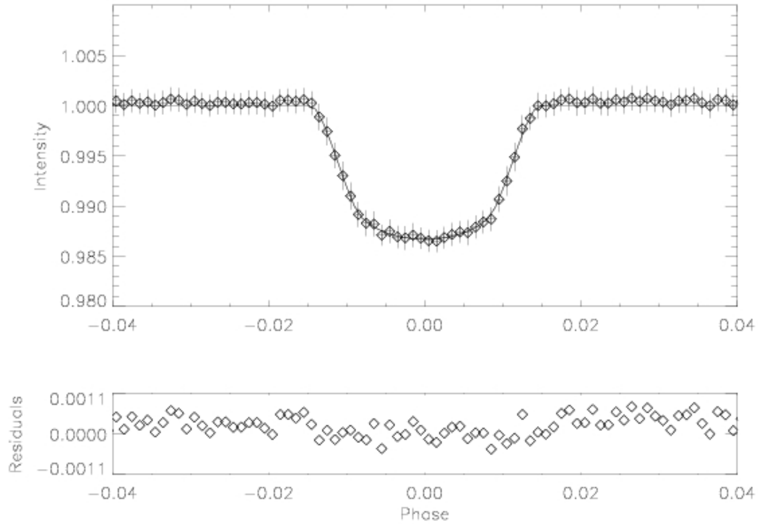


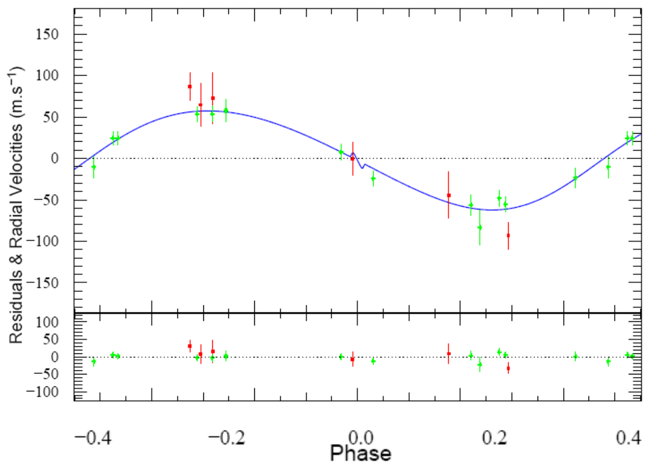
Agrain et al. and Moutou et al. 2008

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

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

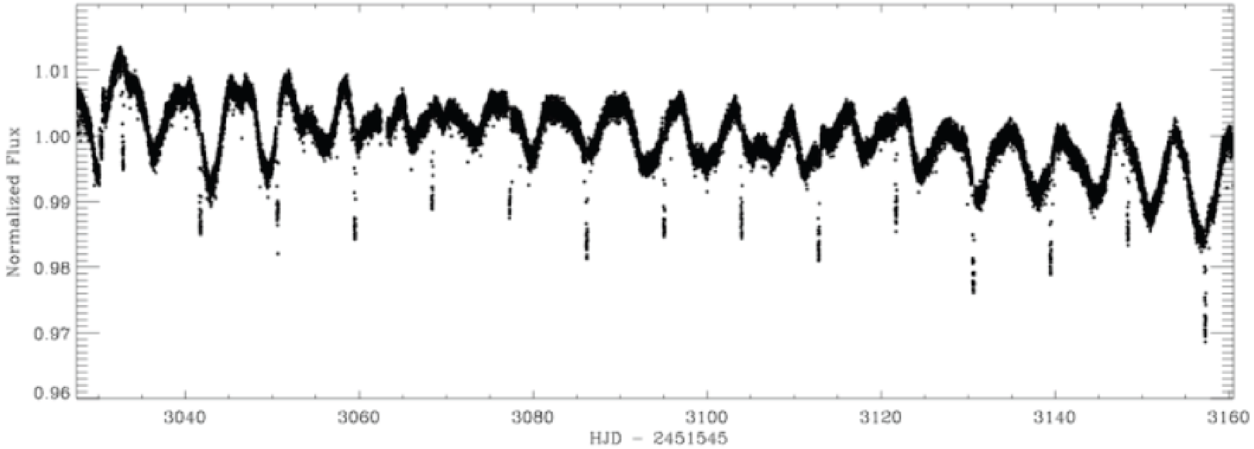
radius: 1.16 R_{sun}

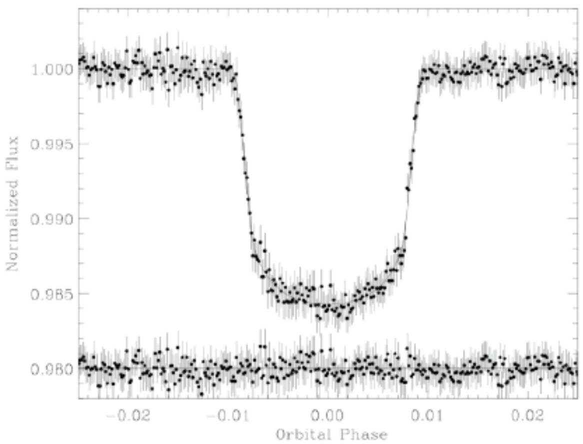
mass: 1.01 M_{sun}

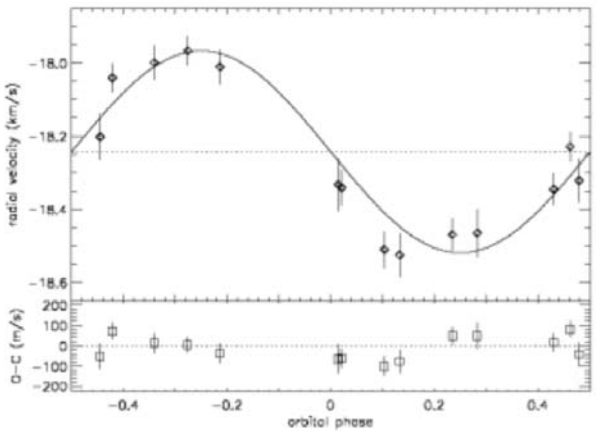
See poster Rauer et al.

The „next two“ II

CoRoT-Exo-6b







See poster Fridlund et al.

CoRoT-Exo-6b:

period: 8.88 d

radius: 1.15 R_J

mass: 3.3 M_J

The star:

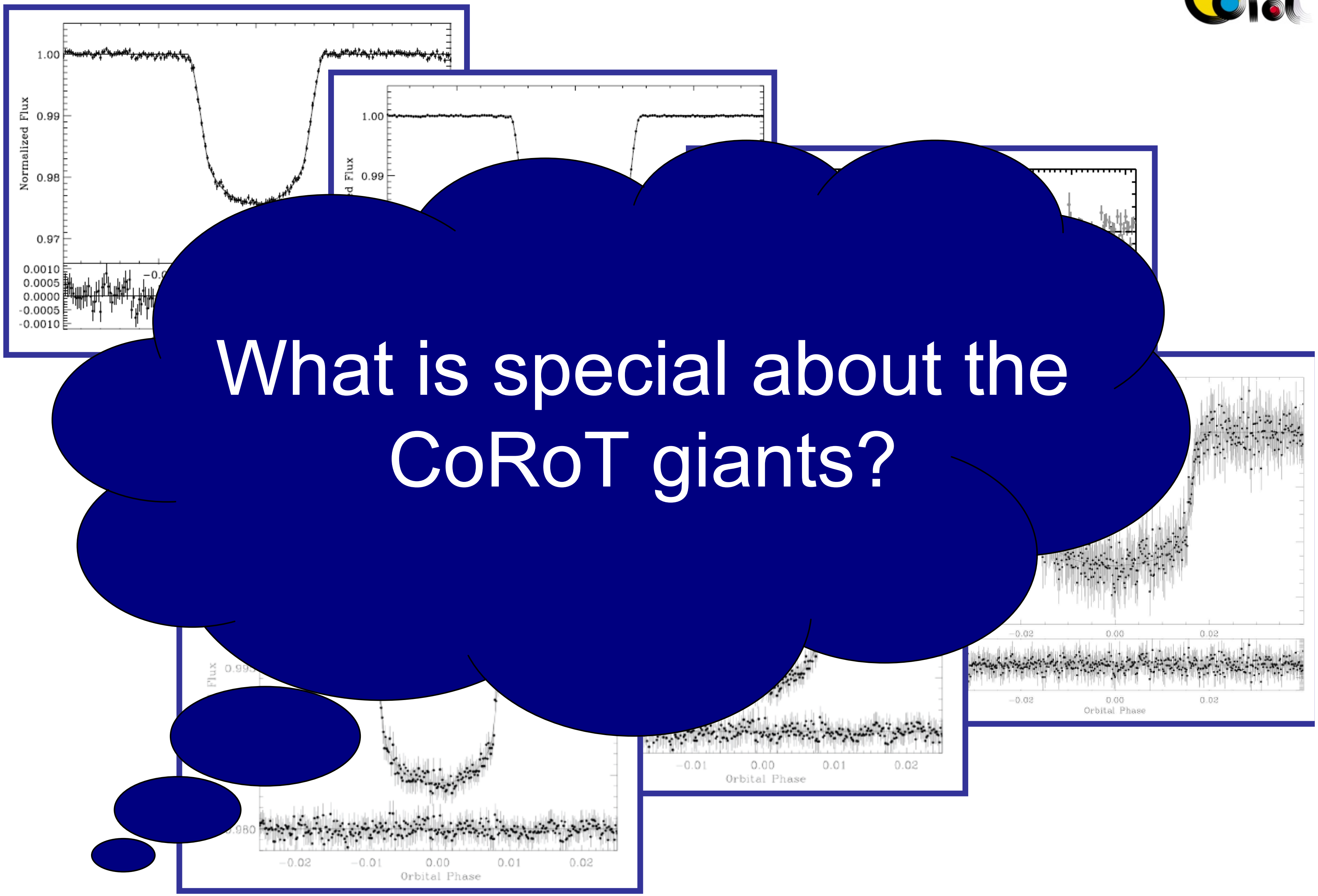
V: 13.9 mag

period: ~6.35 d

radius: 1.02 R_{sun}

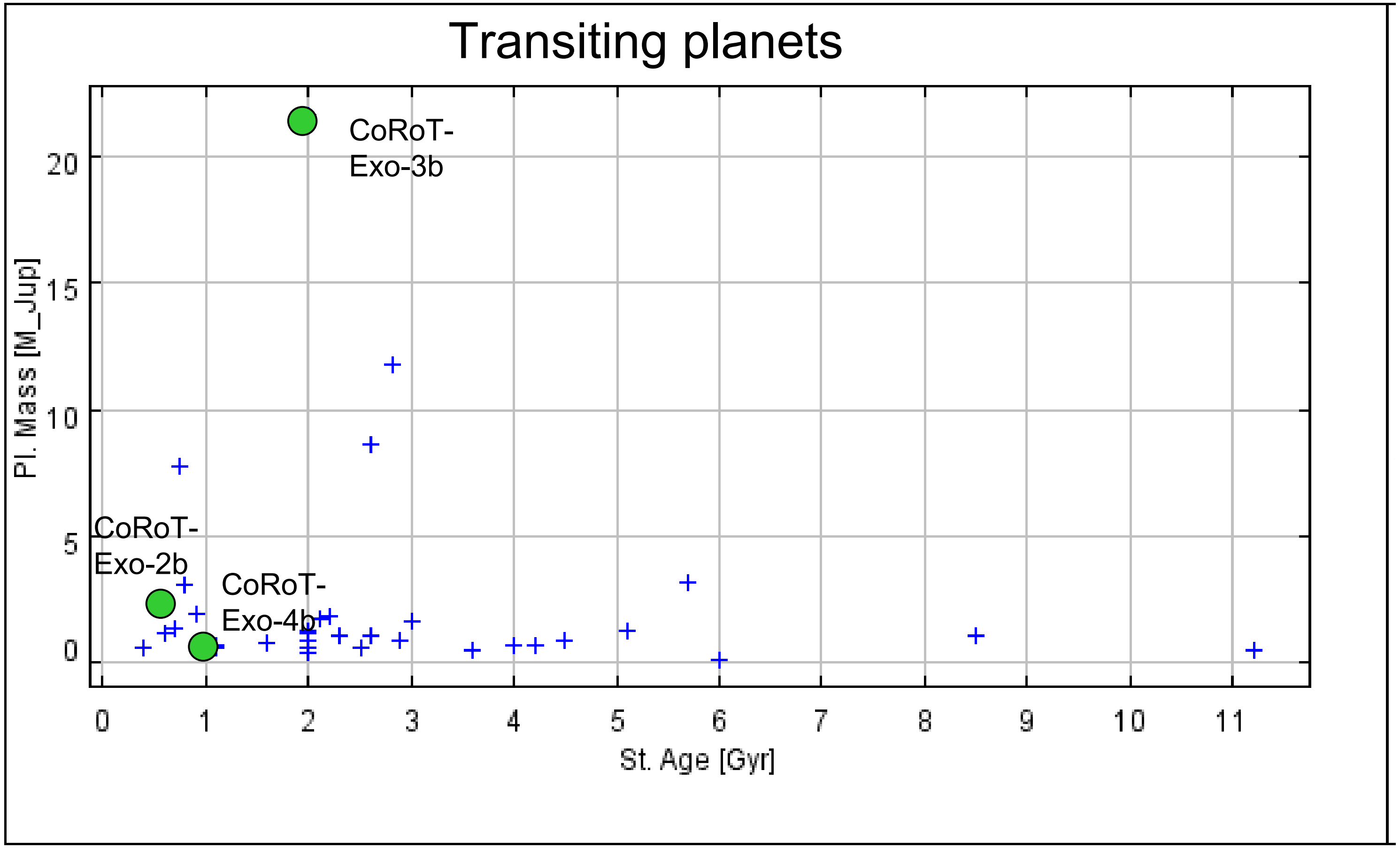
mass: 1.1 M_{sun}

„Discovery space“ for CoRoT



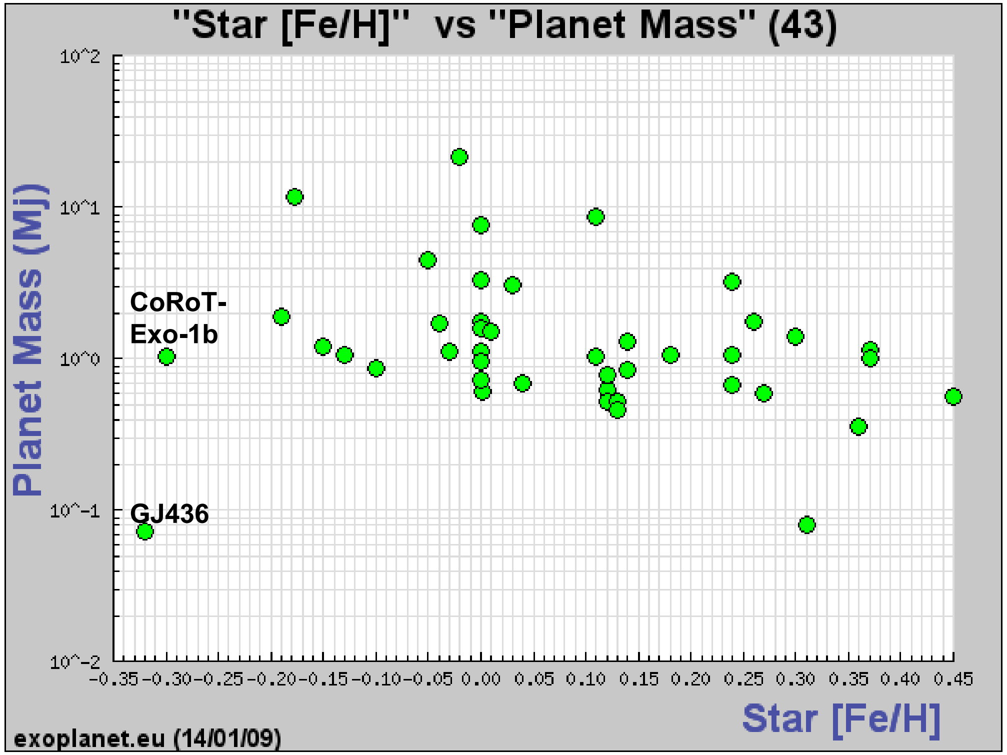
„Discovery space“ for CoRoT

Planetary systems of different ages



„Discovery space“ for CoRoT

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

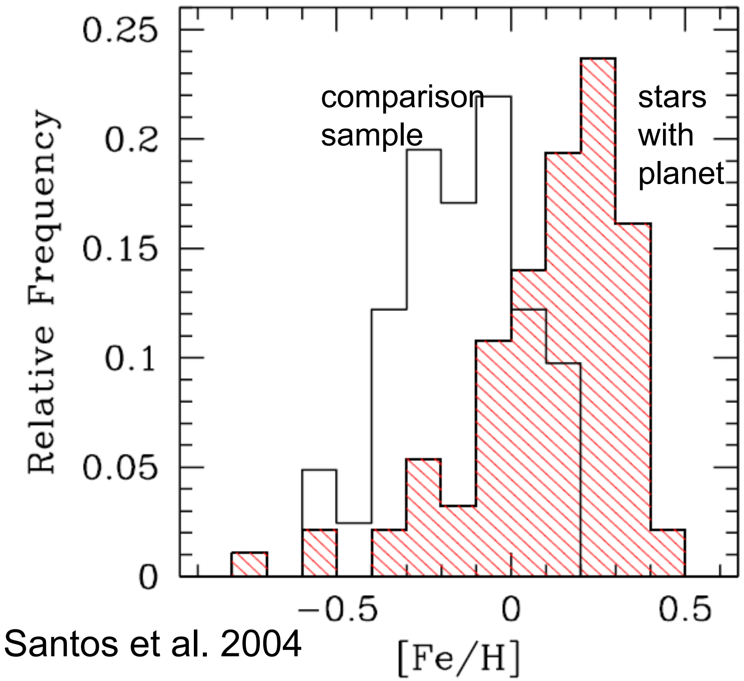
Fe/H: -0.3 (± 0.25)

Teff: 5950 (± 150) K

V: 13.6 mag

Planets and stellar metallicity

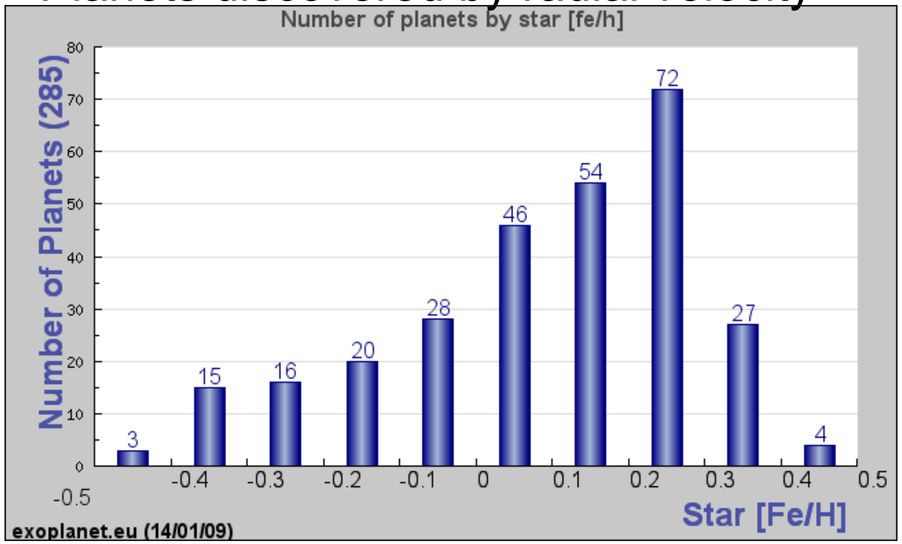
Stars with planets show higher metallicity:



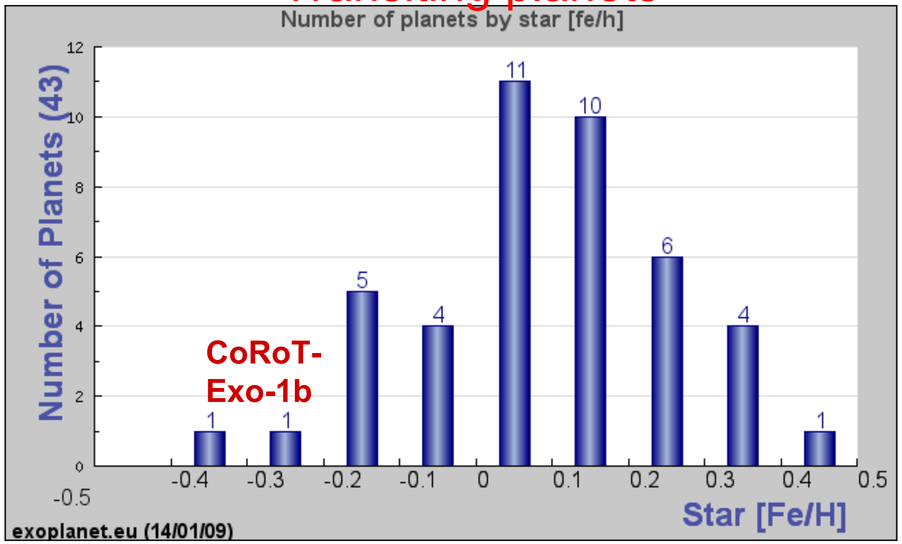
Santos et al. 2004

also e.g.: Valenti & Fischer 2008

Planets discovered by radial velocity



Transiting planets



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

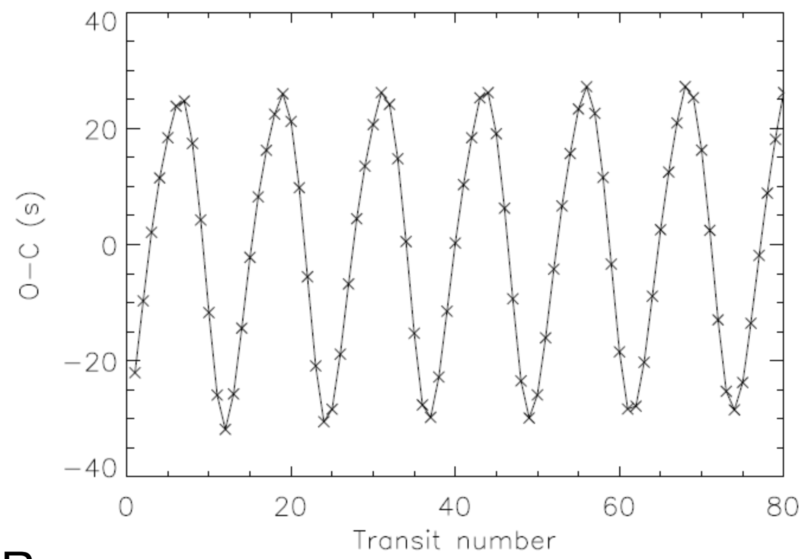
→ Importance of „bias free“ planet searches

Searching for additional planets by O-C analysis

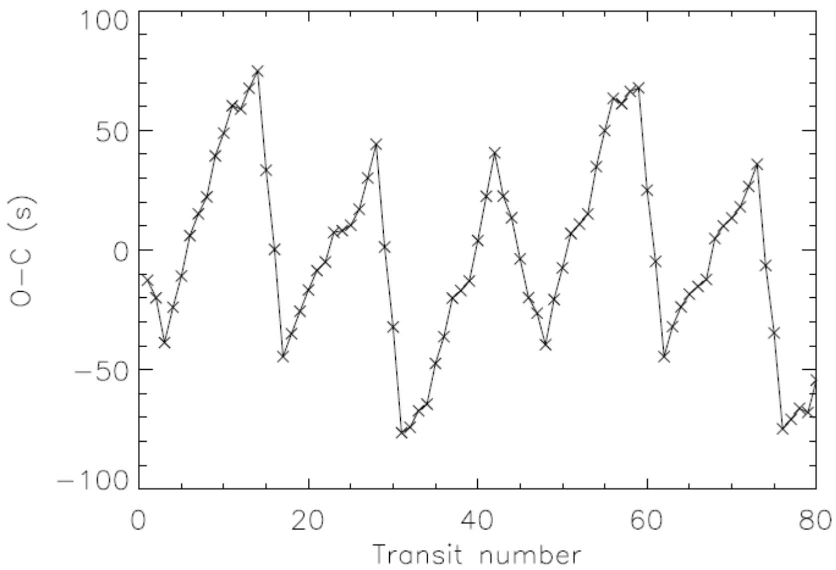
Background: additional, gravitational perturbing planets in the system cause variations of the mid-transit times (TTVs).

Some illustrative examples:

Trojan planet to CoRoT-Exo-1b



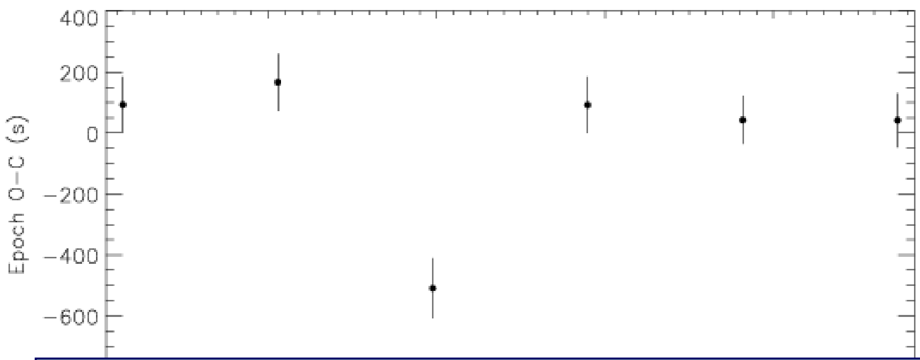
Eccentric planet



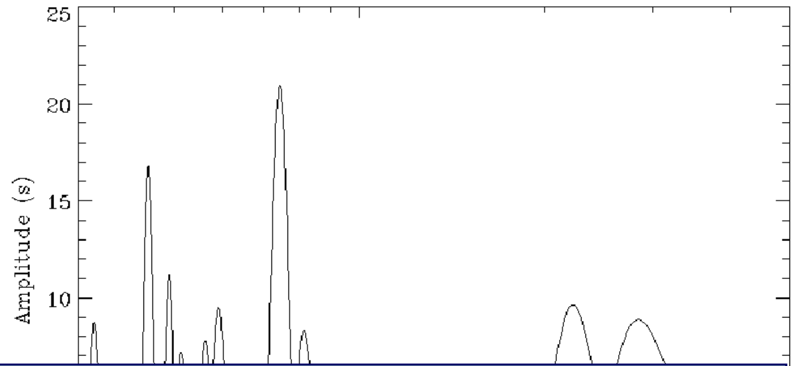
S. Renner

Searching for additional planets by O-C analysis

CoRoT-Exo-4b



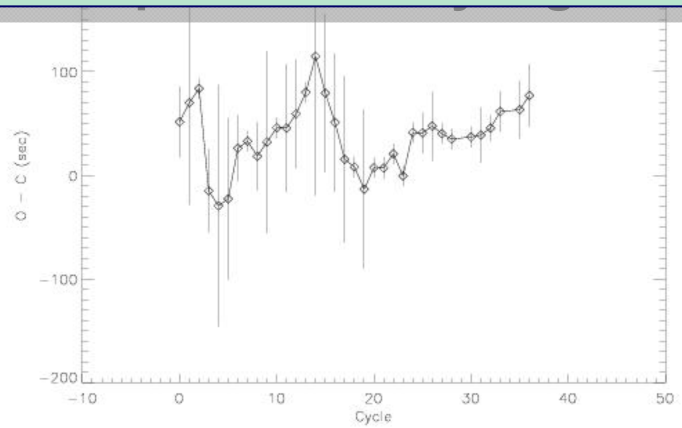
CoRoT-Exo-2b

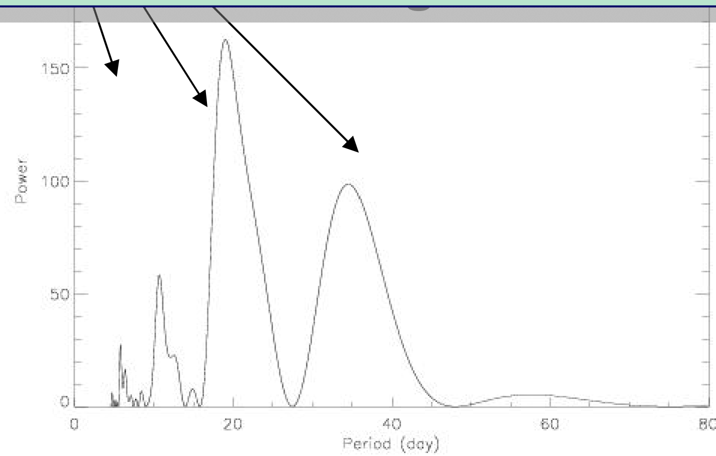


- **No transit timing variations have been found in the planets studied**

But:

- **CoRoT provides very high constraints on transit timing variations!**





See poster Csizmadia et al. 2008

„Discovery space“ for CoRoT

Populating the Desert

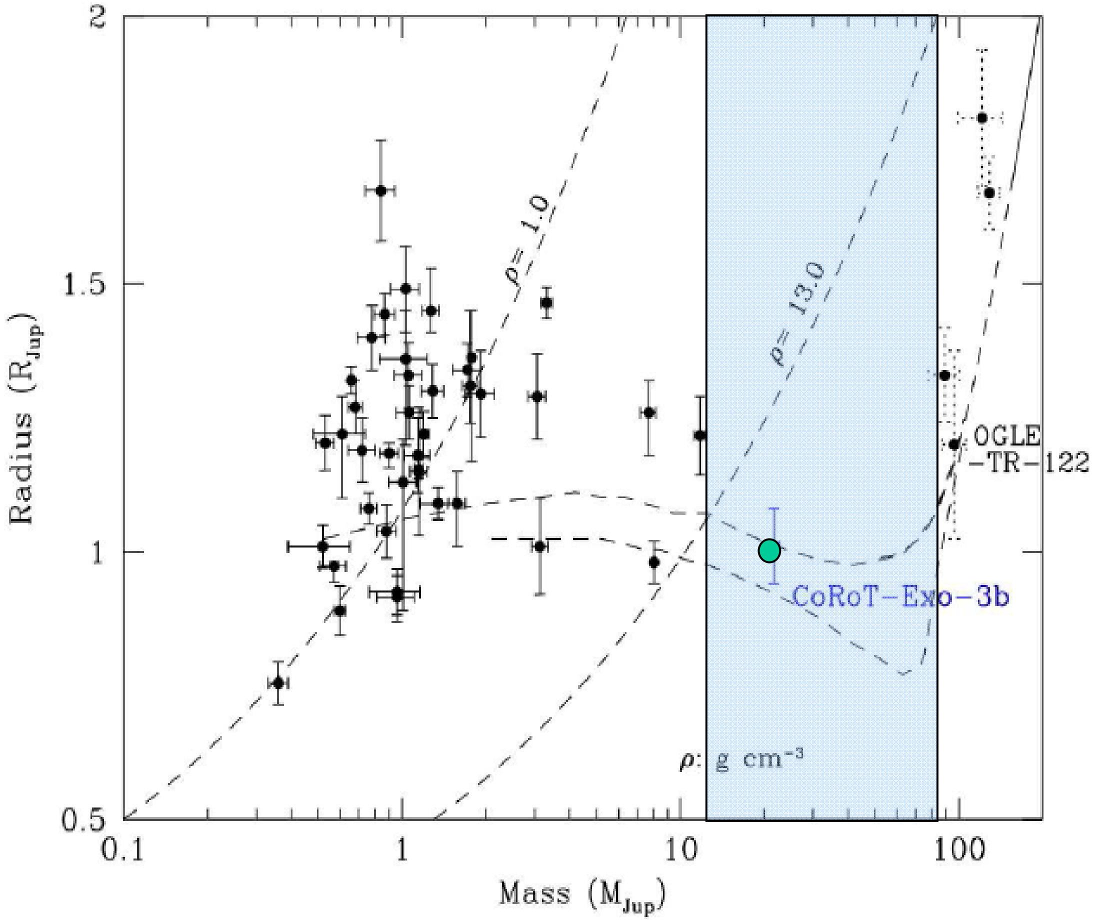
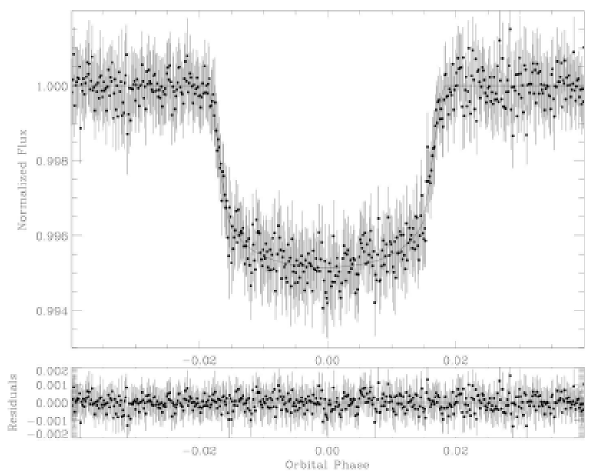


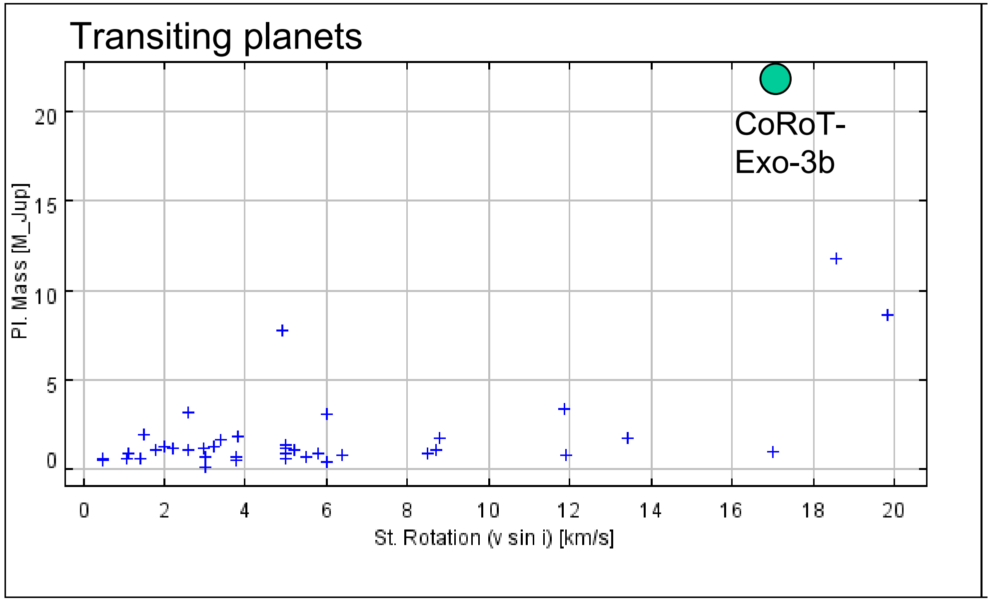
Table 6: CoRoT-Exo-3b parameters.

Mass (M_{Jup})	21.66 ± 1.0
Radius (R_{Jup})	1.01 ± 0.07
density ($g\,cm^{-3}$)	26.4 ±5.6
log g	4.72 ± 0.07

Deleuil et al. 2008

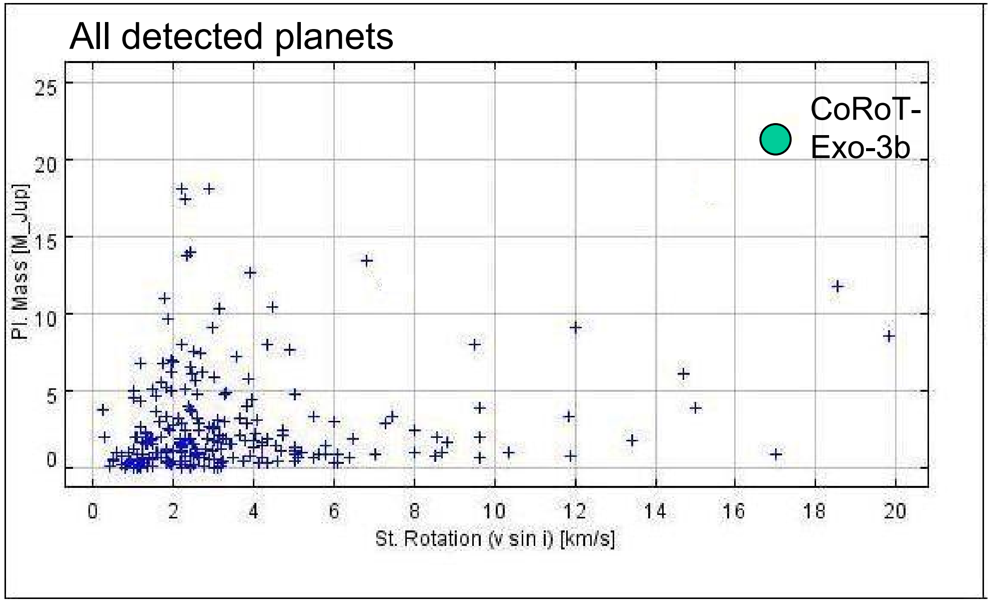


Is CoRoT-Exo-3b exceptional?



- 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

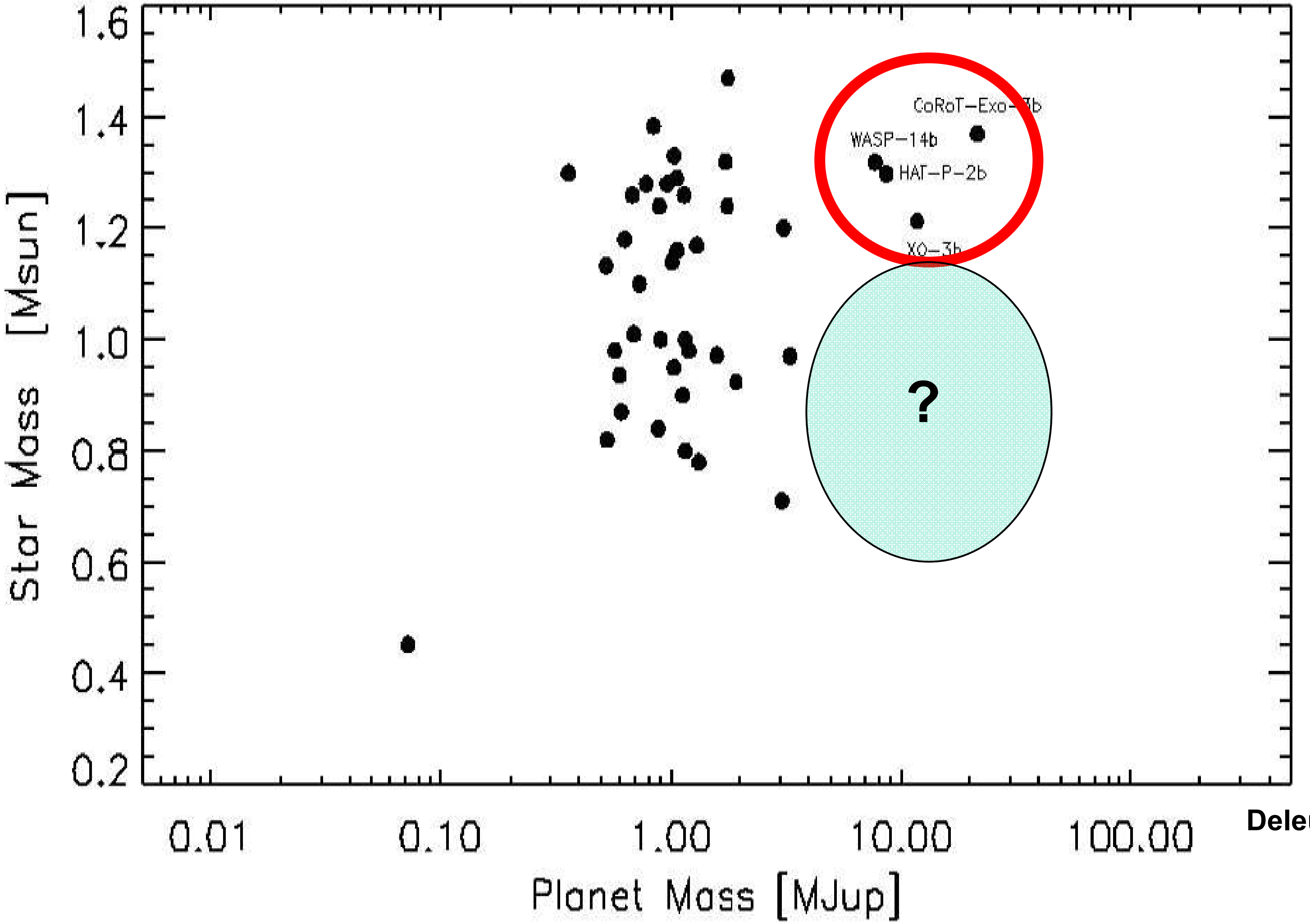
- in general surveys easily eliminated fast rotators from their surveys (focus on slow rotators)

→ 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?

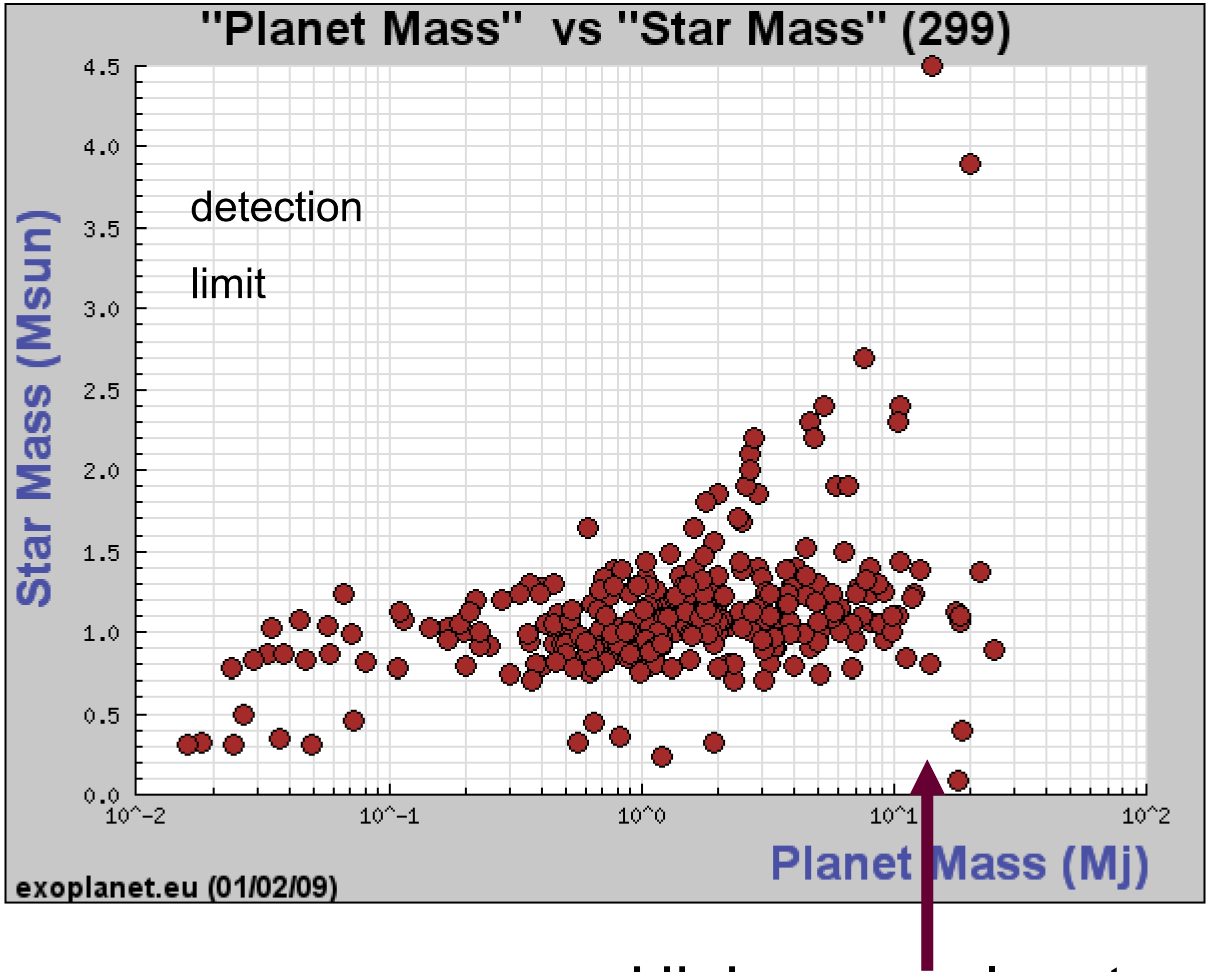
high-mass planets detected around „high-mass“ stars



Deleuil et al. 2008

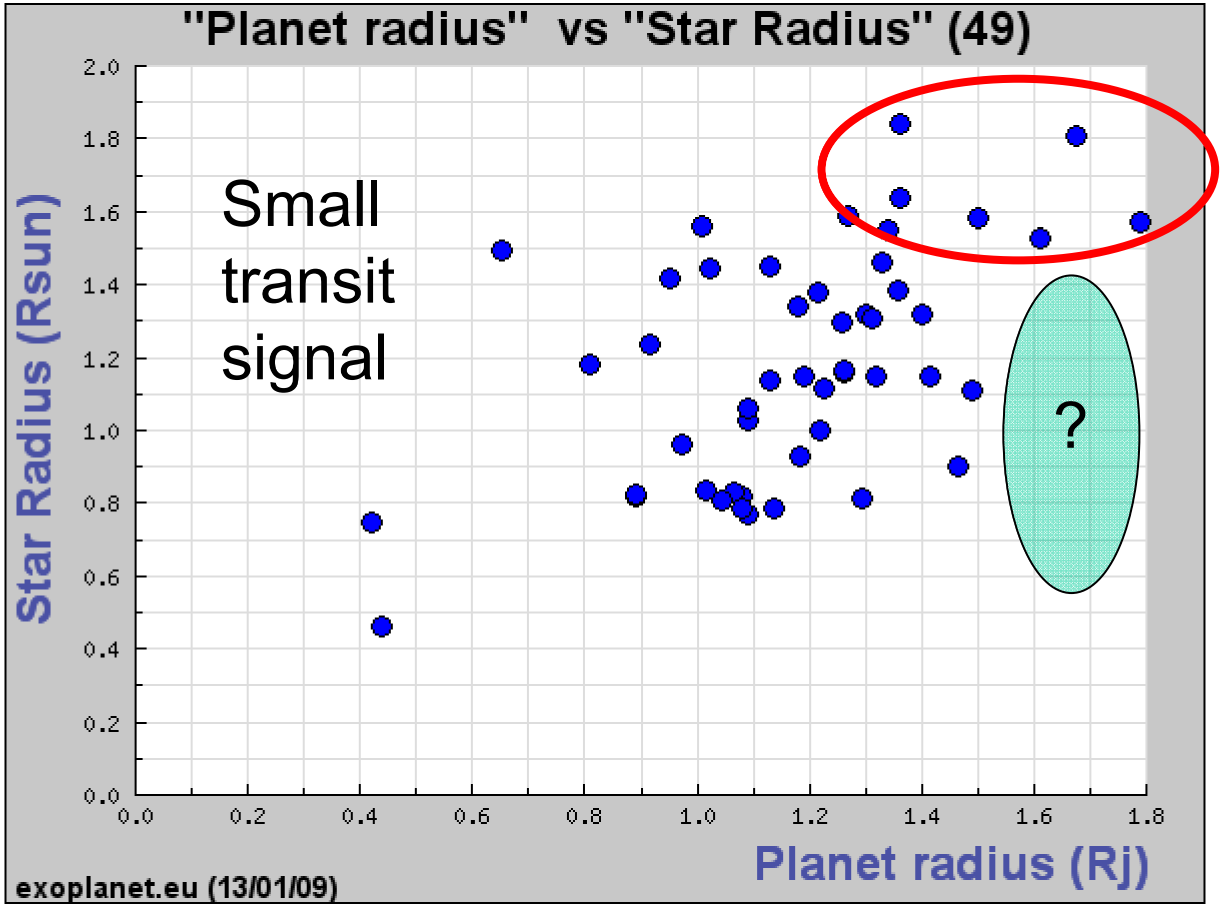
No „brown dwarf desert“ for „large“ stars?

Planets detected by radial velocity



High mass planets around high mass stars

Planets detected by transits

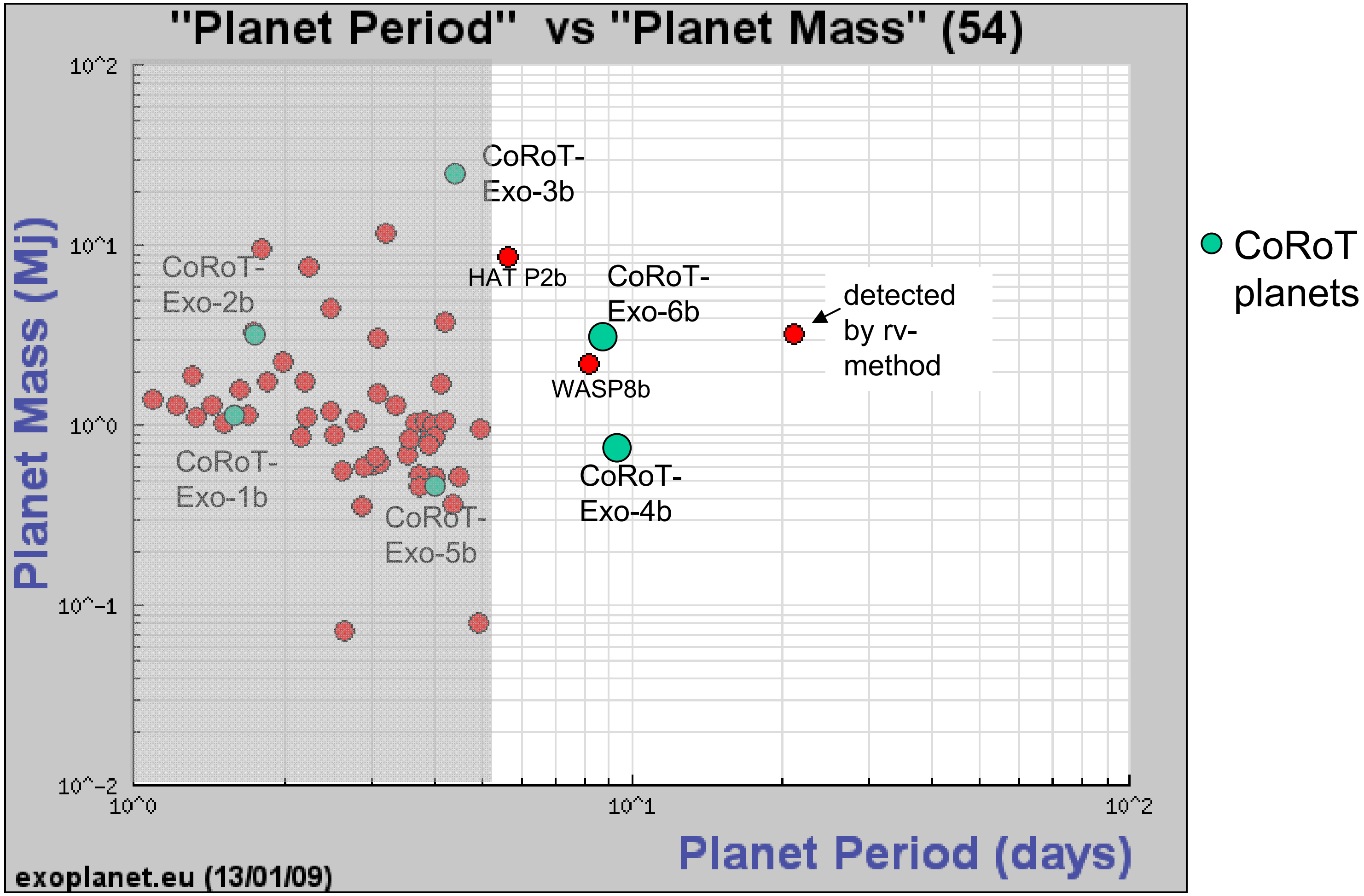


large planets around large stars

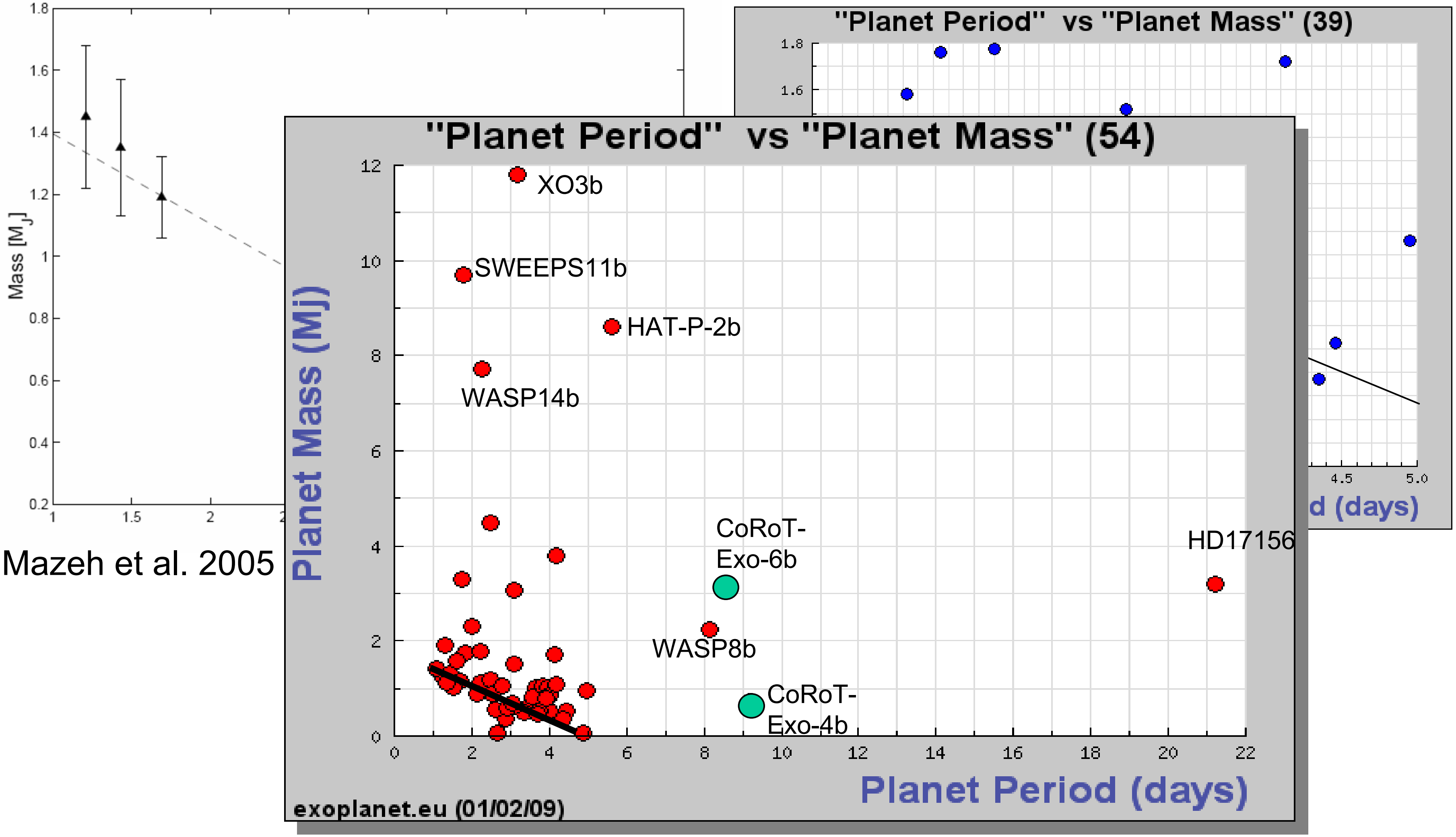
large transiting planets?

„Discovery space“ for CoRoT

Fill the parameter space with transiting planets with P > 5 days



Possible correlation of planet mass and period



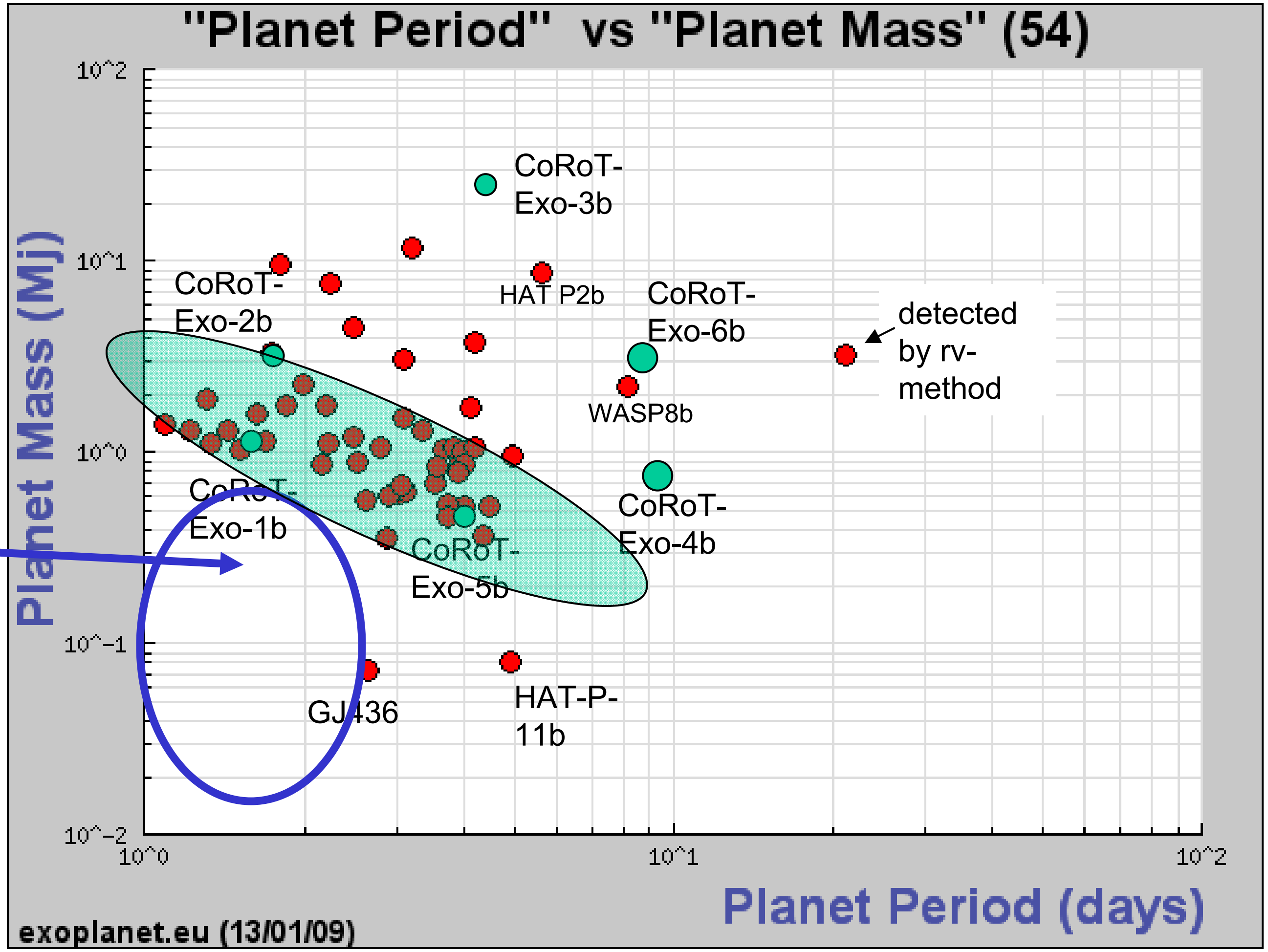
Mazeh et al. 2005

„Discovery space“ for CoRoT

Possible correlation of planet mass and period

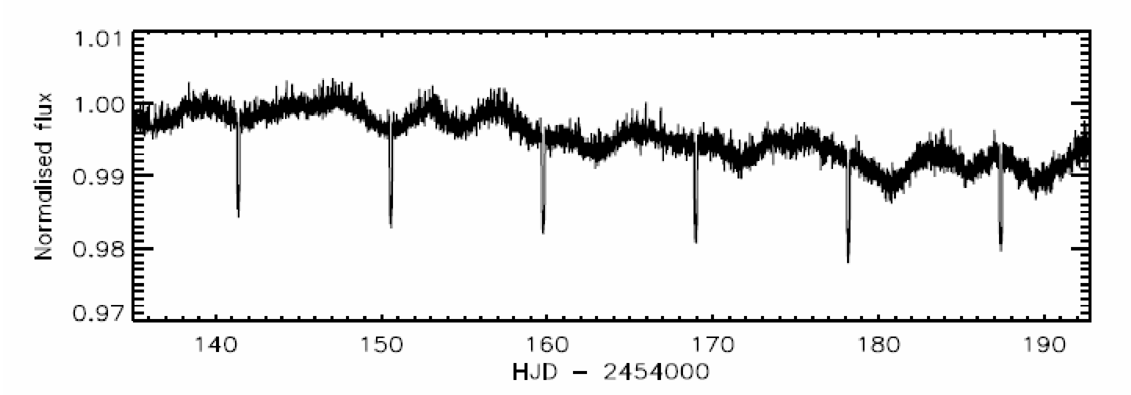
Lack of low-mass planets on short-period orbits

But: following talk



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

CoRoT4b is in synchronos orbit



Aigrain et al. 2008

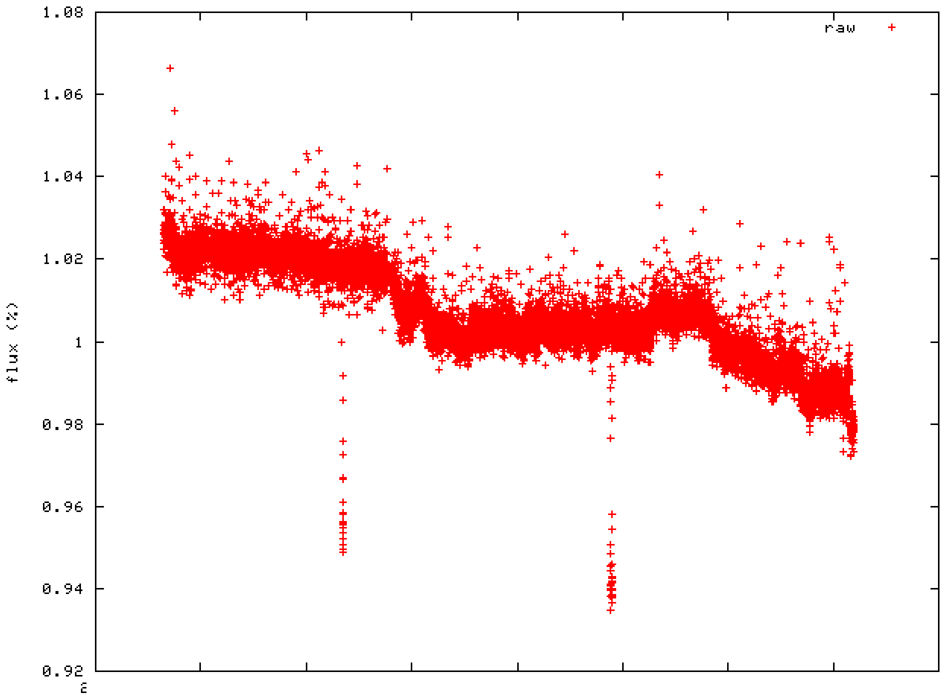
CoRoT-Exo-4b:
P: 9.20205 +/- 0.00037 d
a: 0.09 +/- 0.001 AU
r: 1.19 R_J
m: 0.72 M_J

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

- **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

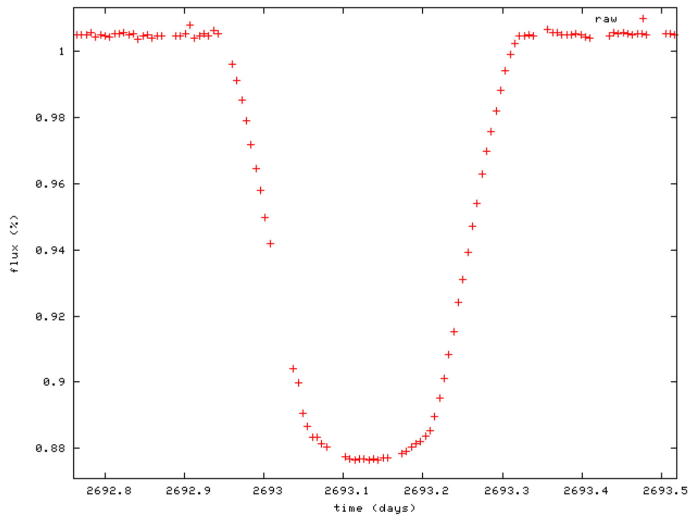
CoRoT exciting targets I



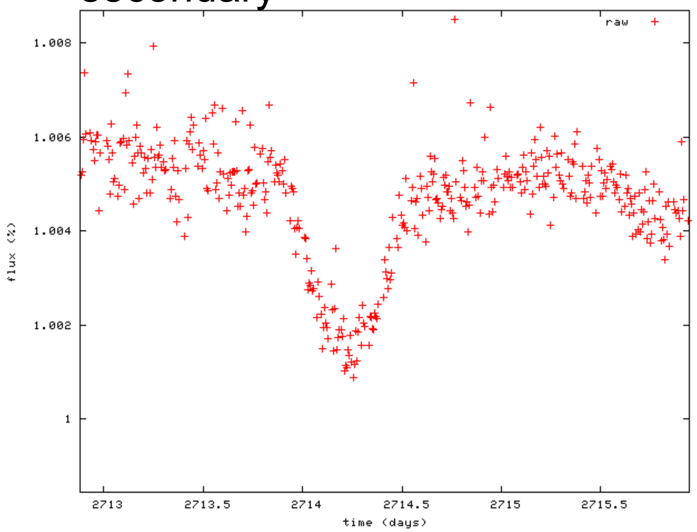
- Monotransit found in IR01
- transits found again in LRa01
- **P~ 50 days**
- depth = 5.6%
- planet candidate if star is small → follow-up ongoing

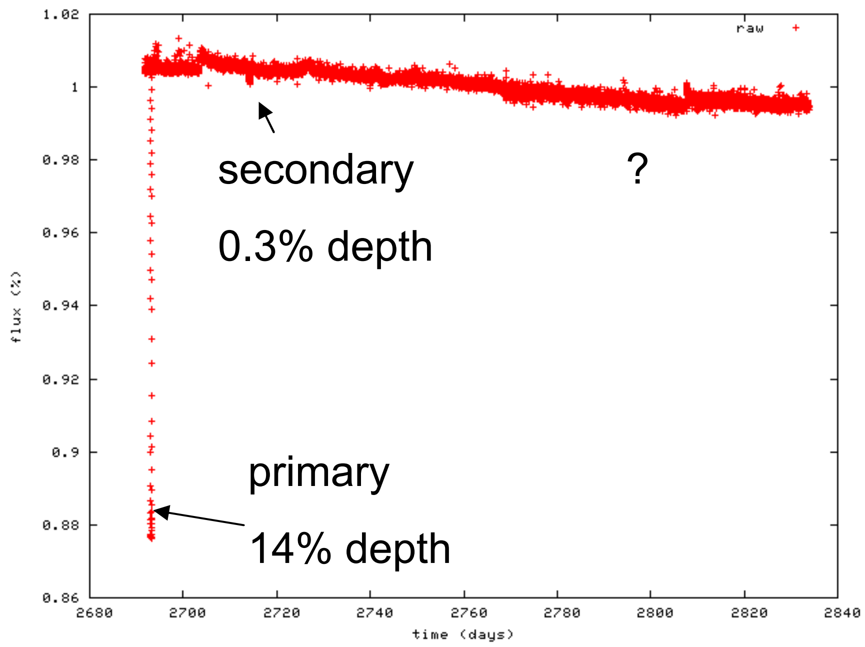
CoRoT exciting targets II

primary



secondary





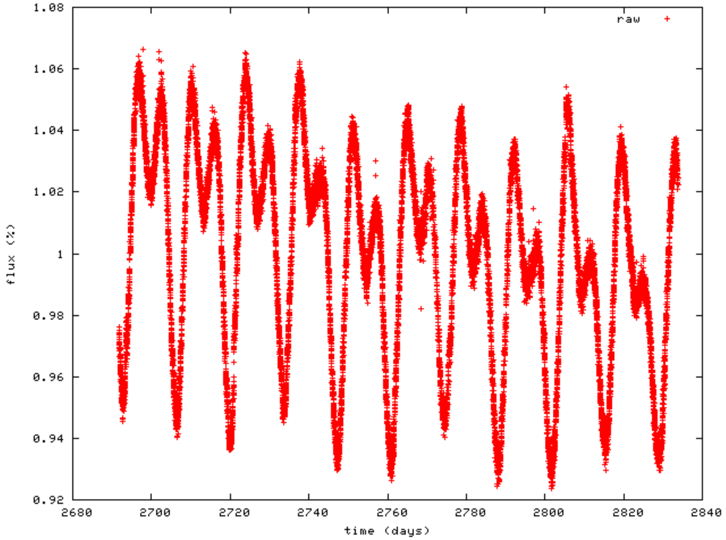
CoRoT finds exciting objects

e.g.: possible very excentric binary?

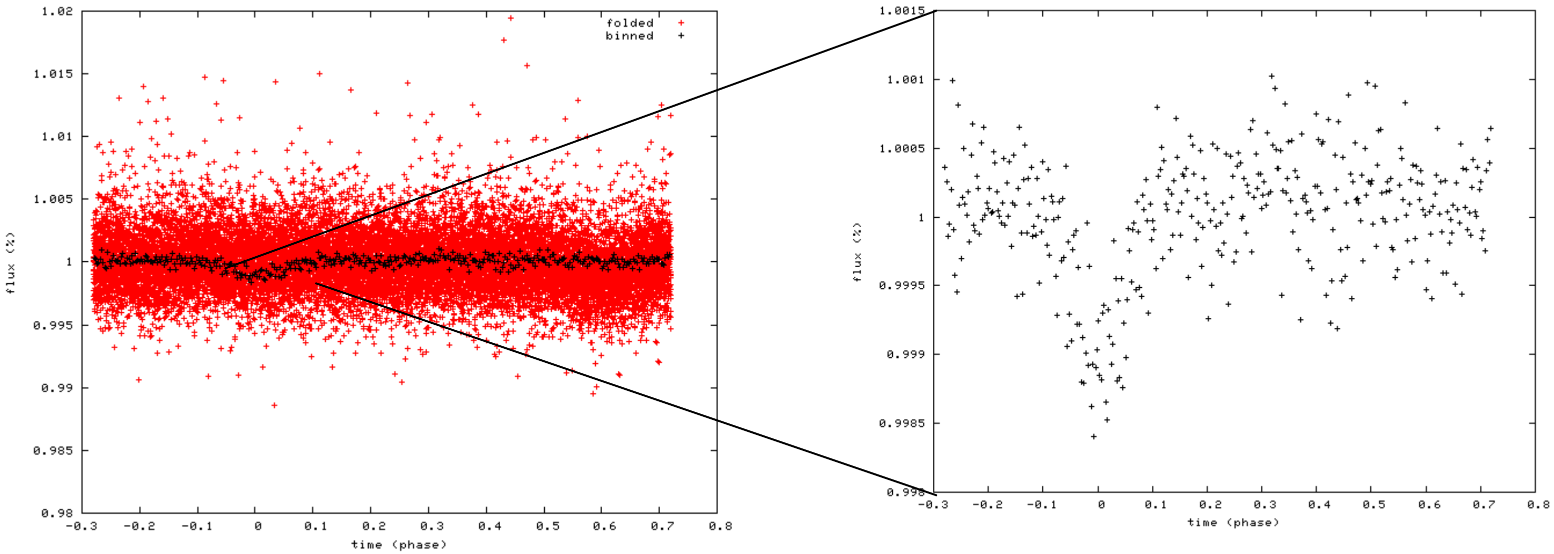
circumbinary objects?

…?

CoRoT exciting targets III



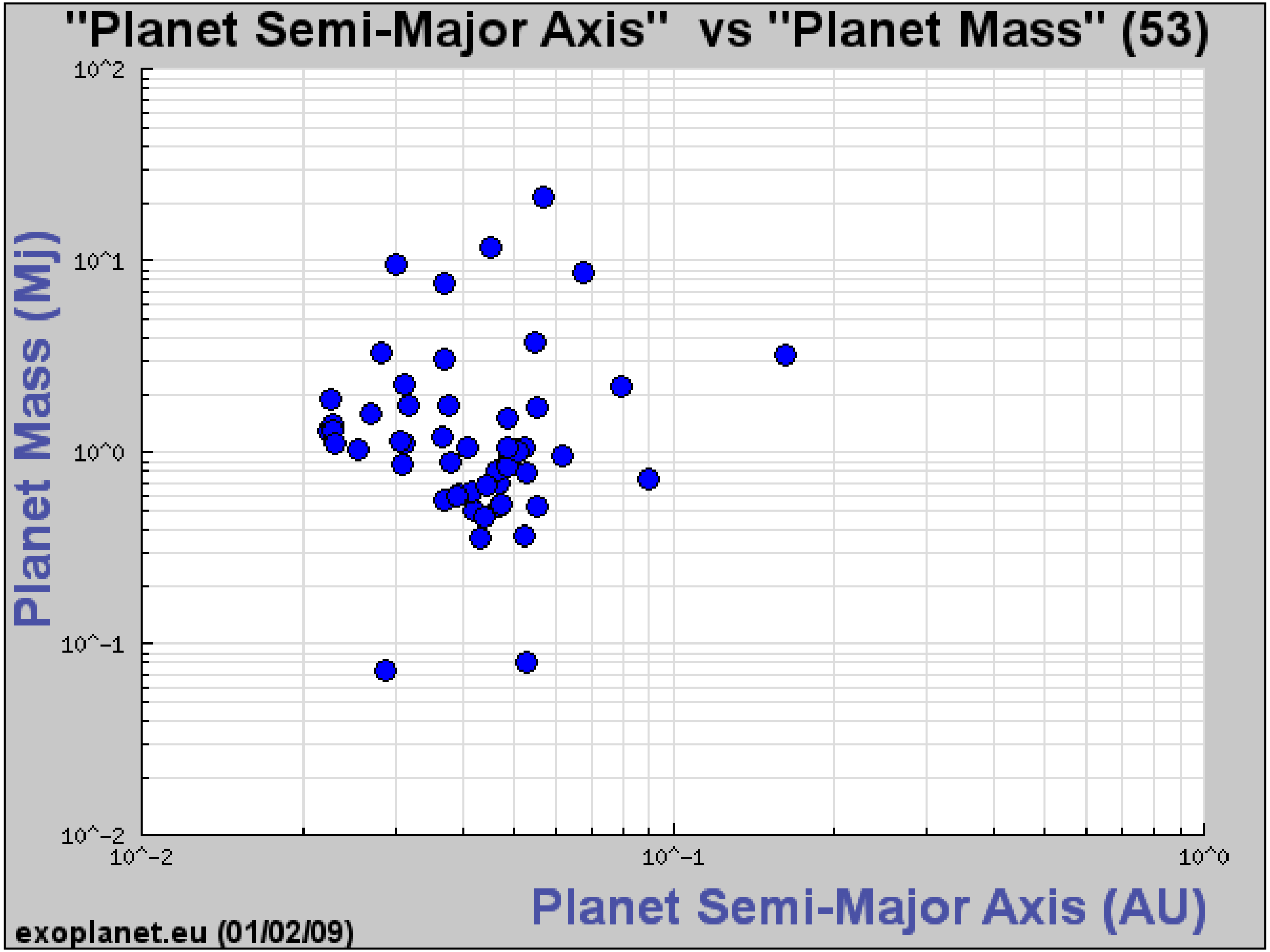
- Stellar activity with 13.6 days period
- After filtering our the activity, a planet candidate was found (0.11% depths around 16 mag star)
- after follow-up, it was identified as binary star…

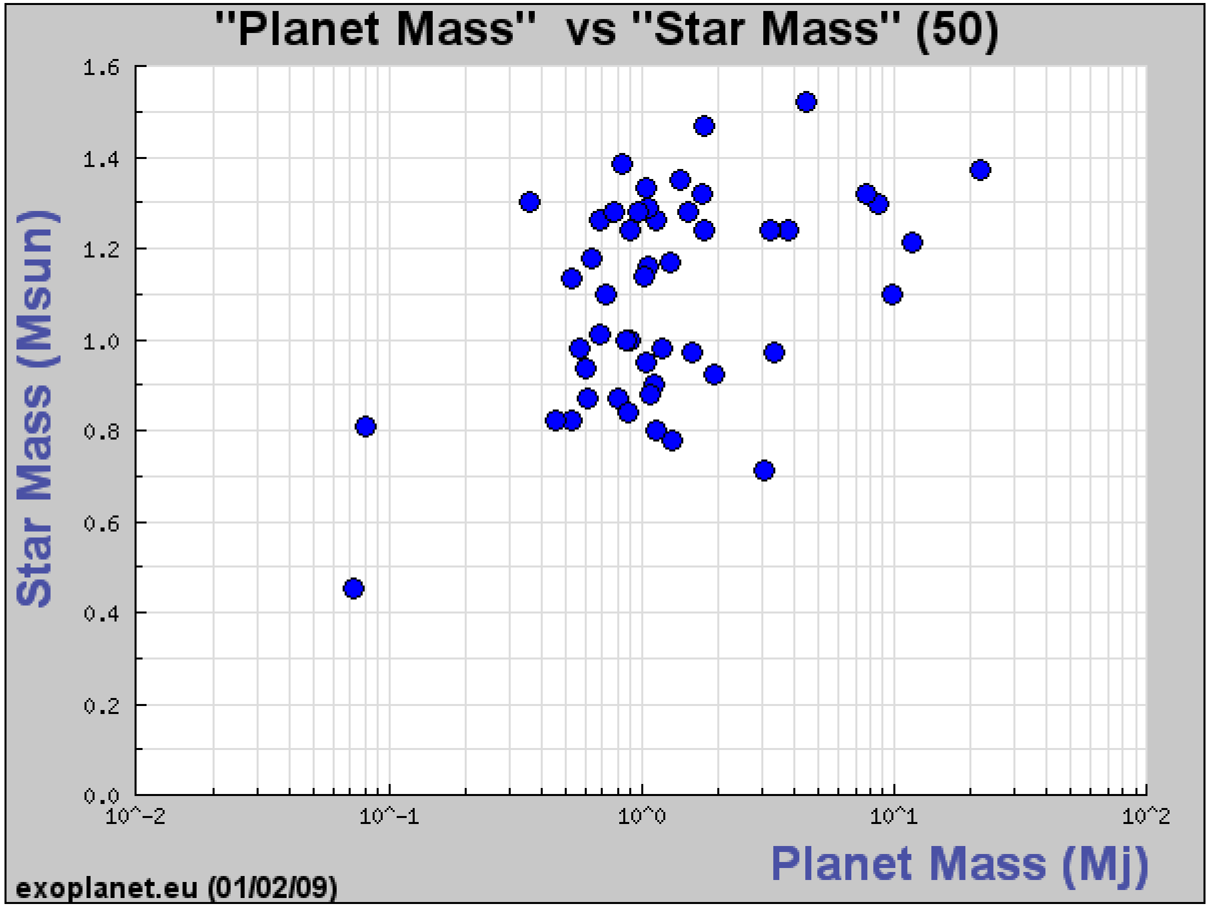


Summary: CoRoT contributions to transit searches

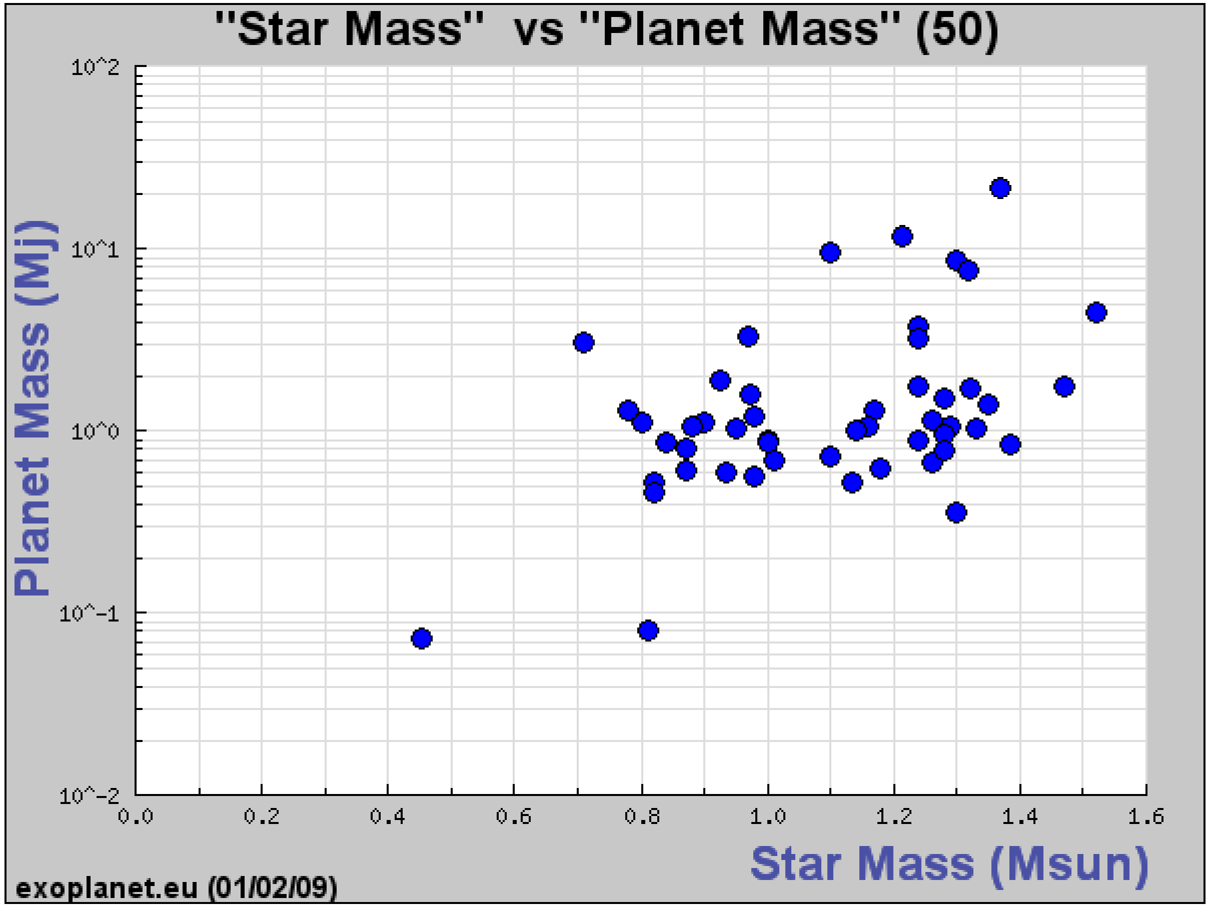
- 6 giant objects with very accurate parameter determinations
- Planet around low-metallicity star
- Filling the „brown dwarf desert“ → closing the gap between planet and brown dwarfs
- Filling the parameter space of transiting planets with large orbital periods
- Small transiting planets

More material…


"Planet Semi-Major Axis" vs "Planet Mass" (53)
10^2
10^1
10^0
10^-1
10^-2
Planet Mass (Mj)
10^-2
10^-1
10^0
Planet Semi-Major Axis (AU)
exoplanet.eu (01/02/09)



"Planet Mass" vs "Star Mass" (50)
Star Mass (Msun)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10^-2
10^-1
10^0
10^1
10^2
Planet Mass (Mj)
exoplanet.eu (01/02/09)


"Star Mass" vs "Planet Mass" (50)
10^2
10^1
10^0
10^-1
10^-2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Planet Mass (Mj)
Star Mass (Msun)
exoplanet.eu (01/02/09)

Measurement of the Rossiter effect in CoRoT-Exo-2b

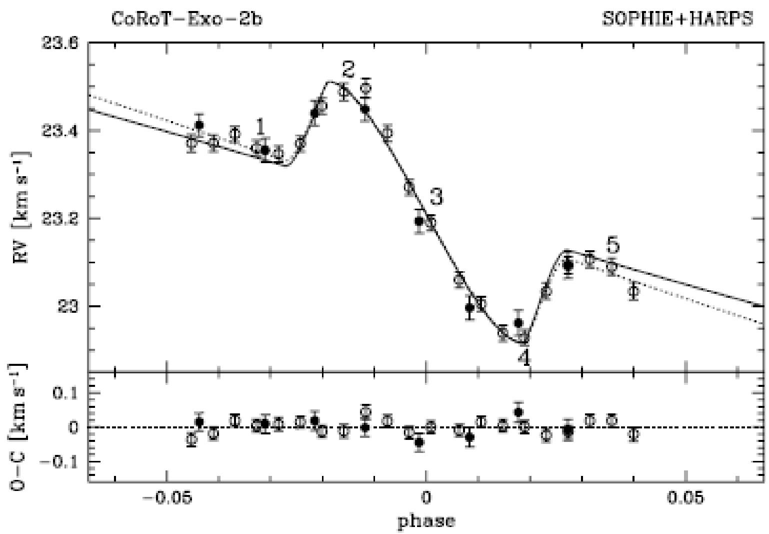


Fig. 1. Phase-folded radial velocity measurements of CoRoT-Exo-2 during the transit of the planet with SOPHIE (dark circle) and HARPS (open circle). The solid line corresponds to the Rossiter-McLaughlin model ajusted to these data assuming the semi-amplitude $K = 563$ m s^{-1} from Alonso et al. (2008).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

- the planet has a prograde orbit with respect to stellar rotation

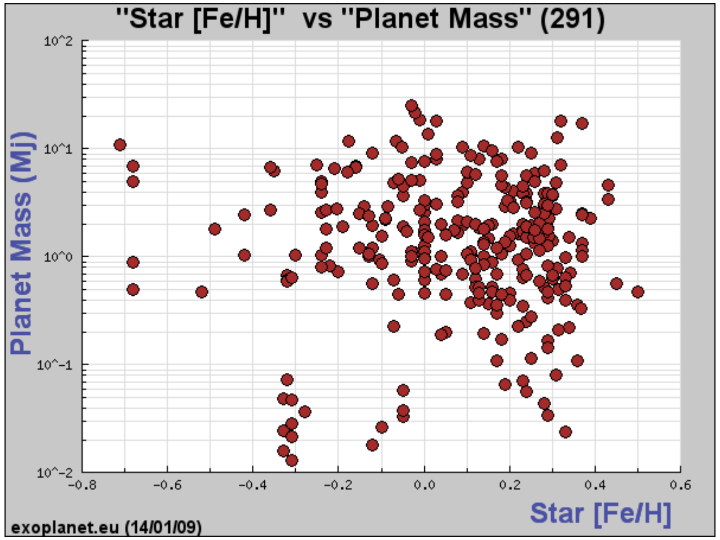
- the sky-projected angle between the stellar spin and the planetary orbital axis is close to zero $\lambda = 7.2 \pm 4.5$ deg

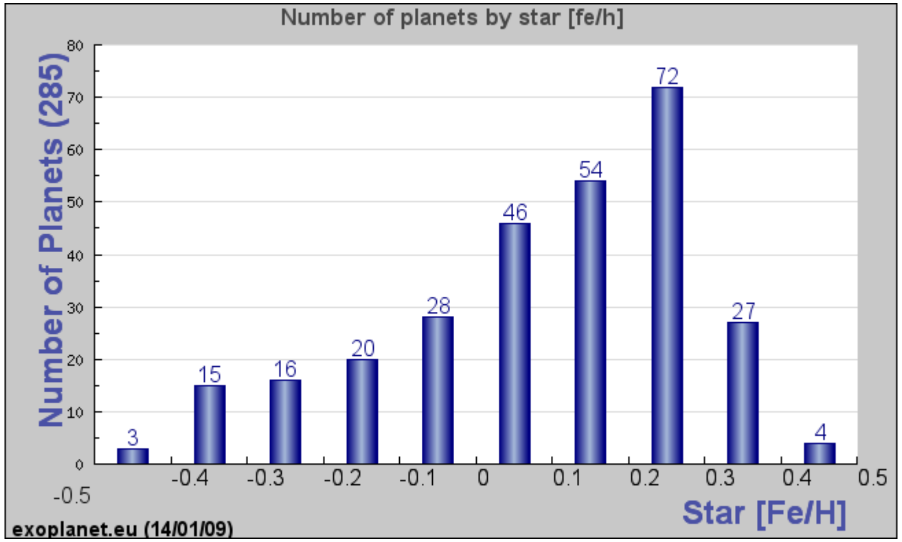
Show also?

Bouchy et al. 2008

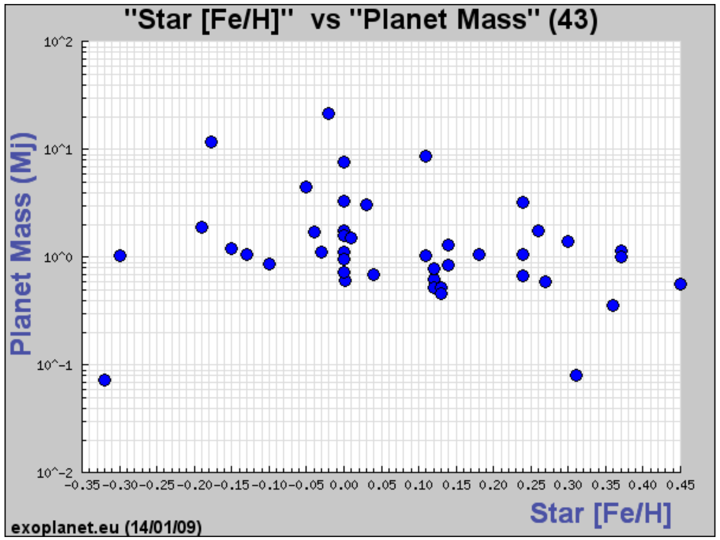
Planets and metallicity of their central stars

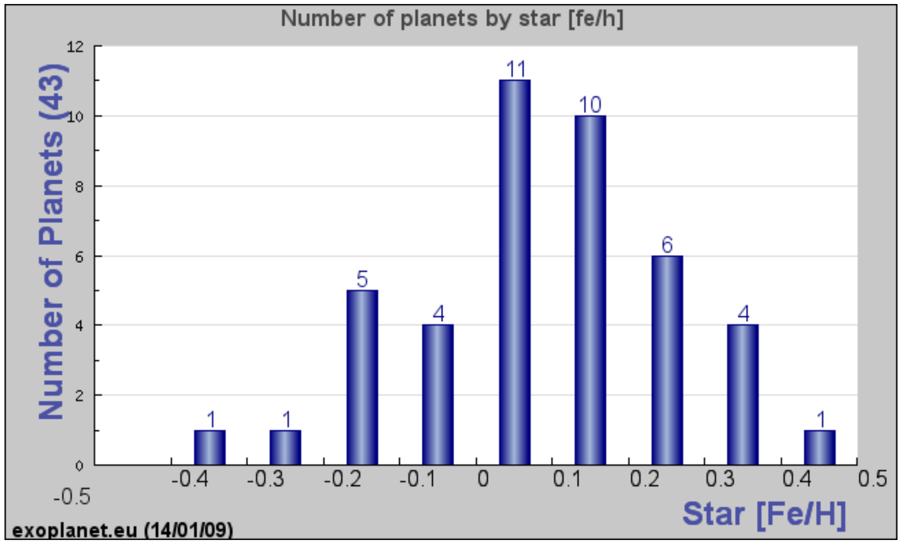
Rv + astrometry





Transiting planets



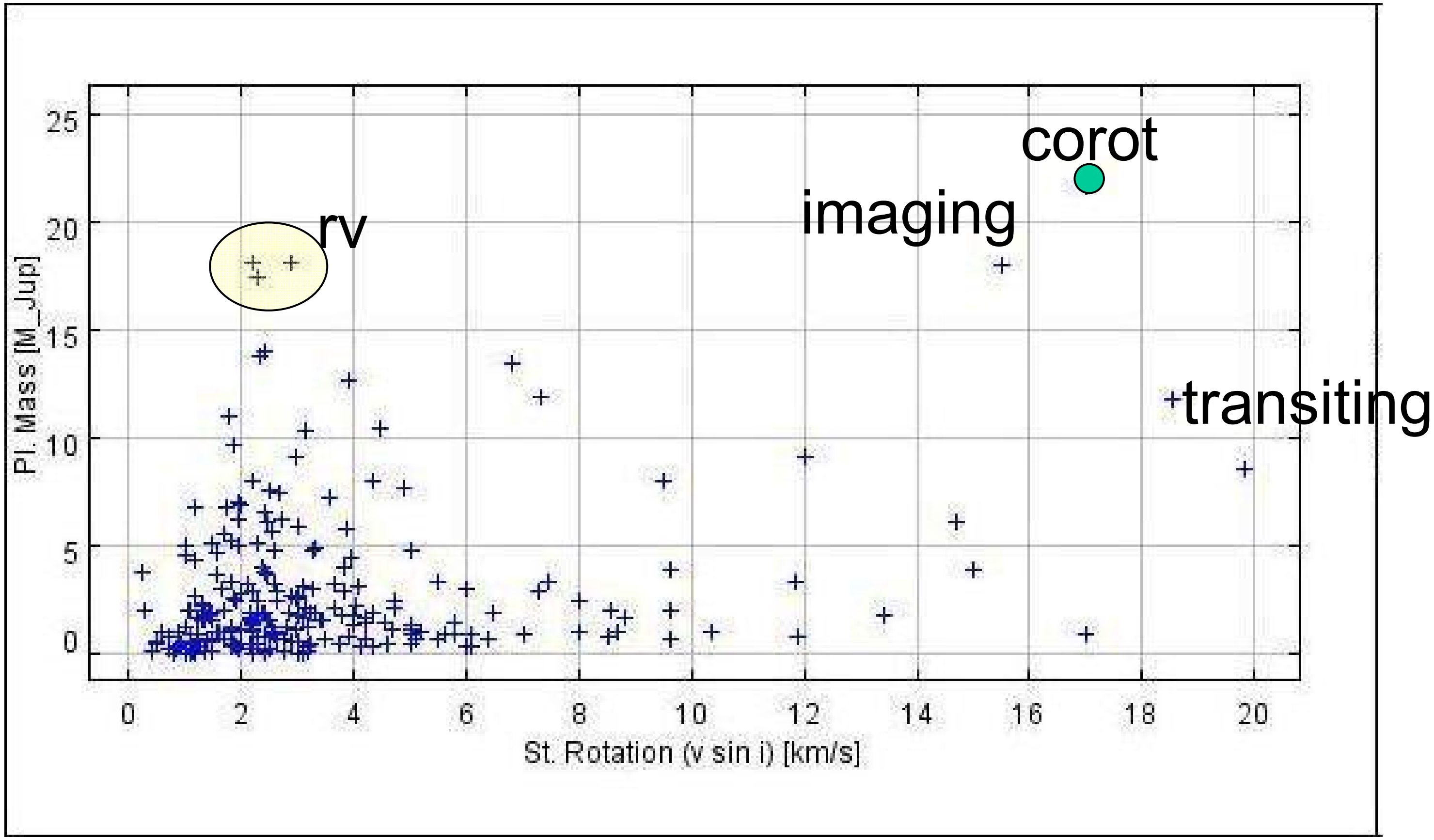


- CoRoT-Exo-1b
- CoRoT-Exo-4b
- CoRoT-Exo-2b
- CoRoT-Exo-3b
- CoRoT-Exo-5b
- CoRoT-Exo-6b

Table 1. Description of *CoRoT* runs in 2007-2008.

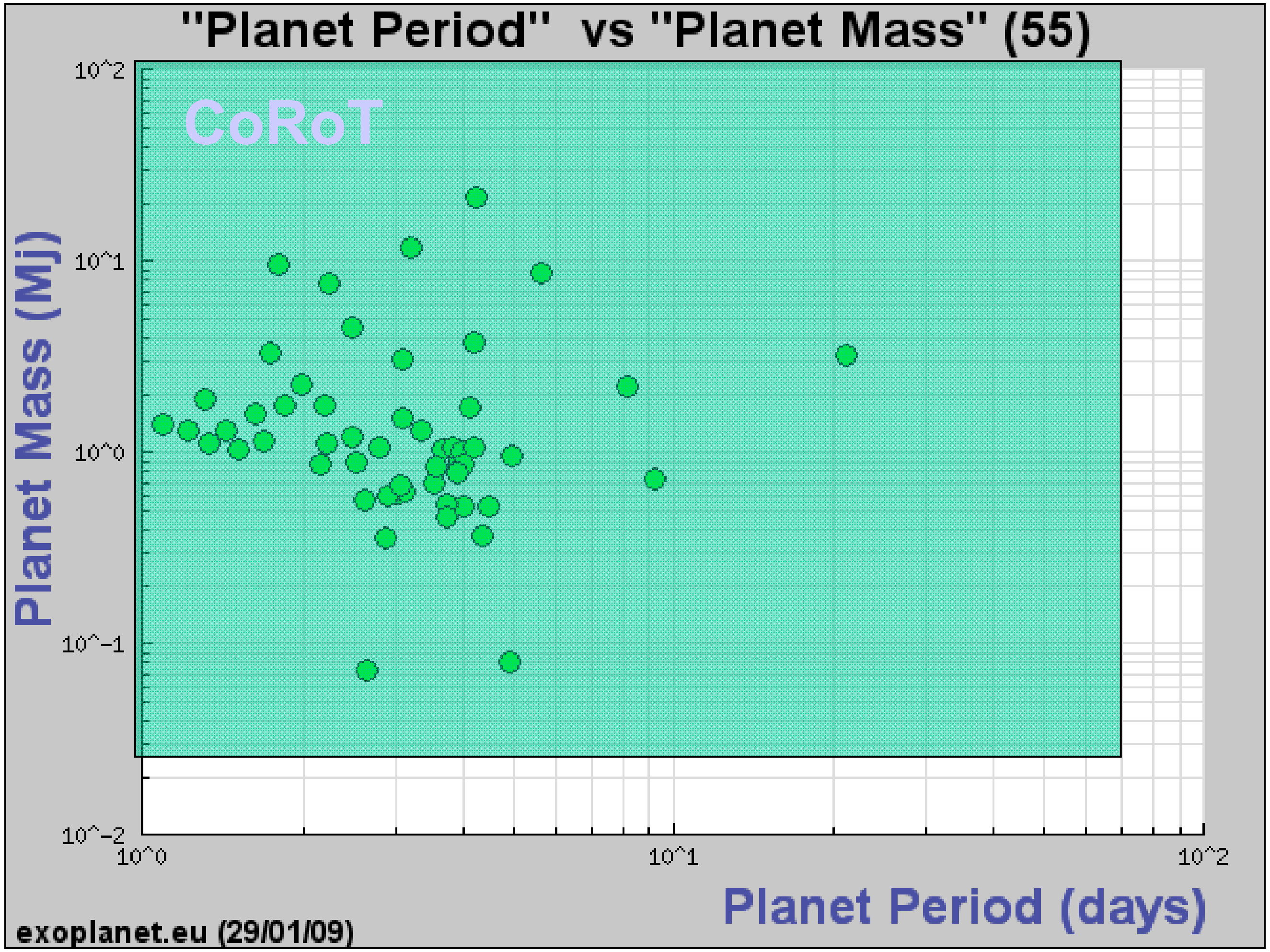
Run	Date start-end	duration [d]	RA	DEC
*IRa*01	02-03/2007	45	06:44	-01:12
*SRc*01	04/2007	26	18:41	07:10
*LRc*01	05-09/2007	152	19:23	00:27
*LRa*01	10/2007-02/2008	150	06:47	-00:12
*SRa*01	03/2008	25	06:40	+9:10
*LRc*02	04-09/2008	150	19:00	-03:20

Optionally to be removed


corot
imaging
rv
transiting
25
20
15
10
5
0
Pl. Mass [M_Jup]
0
2
4
6
8
10
12
14
16
18
20
St. Rotation (v sin i) [km/s]

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!