The background of the slide is a dark blue-grey color. At the top, there is a single, large, prominent light curve showing a regular, periodic oscillation with a sawtooth-like shape. Below this, the background is filled with a grid of many smaller, fainter light curves, some of which also show periodic patterns. The main title is centered in the middle of the slide in a large, yellow, italicized serif font.

*From CoRoT light curves  
to candidates  
& planets*

*M. Deleuil  
Laboratoire d'Astrophysique de Marseille*

# CoRoT - in brief

A French/European/Brazilian mission  
(France : 80%)

Operations started on Jan 2007

*March 2010 : end of the nominal mission*

*March 2013 : end of the first extended mission*

*March 2016 : end of the second extended mission*

*March 2009 : DPU1 stopped*

*November 2012 : DPU2 stopped*

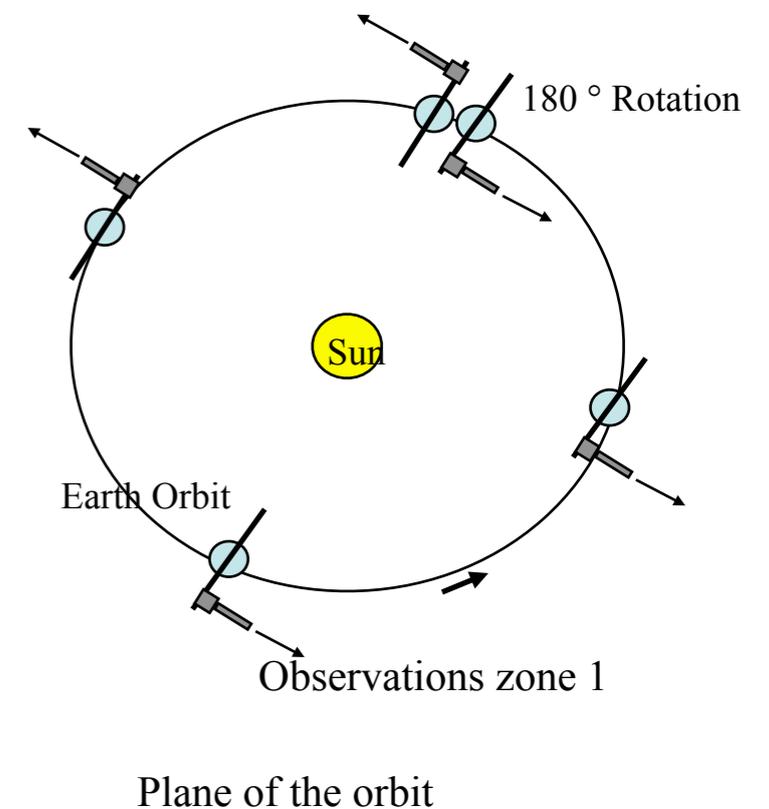
*Reconfiguration of the spacecraft on going*

*Core Program :*

- *stellar structure - asteroseismology*
- *planet search - transit method*
- *stellar physics*



Observations zone 2 start



# CoRoT *exo-workers*

## FRANCE :

IAS : P. BORDÉ, A. LÉGER, M. OLLIVIER, C. CAVARROC

LAM : C. MOUTOU, M. DELEUIL, A. BONOMO, J.C. GAZZANO, A. SANTERNE, P. GUTERMAN,  
L. JORDA, P. BARGE, J.M. ALMENARA, C. DAMIANI

OHP : F. BOUCHY, G. HÉBRARD, R. DIAZ

LESIA : D. ROUAN, B. SAMUEL, A. BAGLIN, M. AUVERGNE

LUTH : J. SCHNEIDER

OBS NICE : T. GUILLOT

CNES PROJECT AND OPERATION TEAM

## GERMANY :

A. ERIKSON, E. GUENTHER, A. HATZES, M. PAETZOLD, H. RAUER, J. CABRERA, T.  
PASTERNAKI, G. WUCHTERL, S. CSIZMADIA, L. CARONE, S. GRIZWA

## SPAIN :

H. DEEG, B. TINGLEY, H. PARVIAINEN

## ENGLAND :

S. AIGRAIN, N. GIBSON

## ESA :

M. FRIDLUND, D. GANDOLFI, S. CARPANO

## BELGIUM :

M. GILLON

## GENEVA :

D. QUELOZ, R. ALONSO

## USA :

M. ENDL, D. CIARDI, W. COCHRAN, A. SHPORER

## TEL AVIV :

T. MAZEH, A. OFIR, L. TAL-OR

## BRASIL :

S. FERRAZ-MELLO



Exoplanet Team

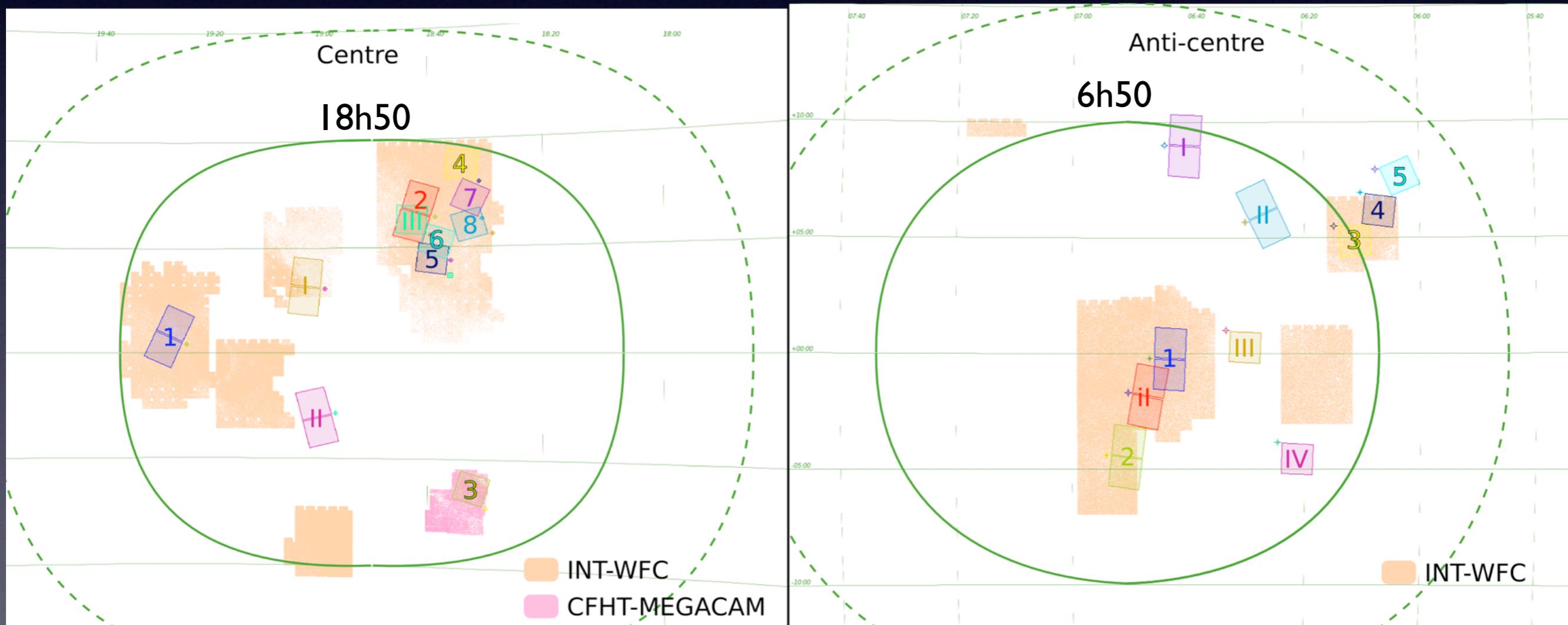
# Observations

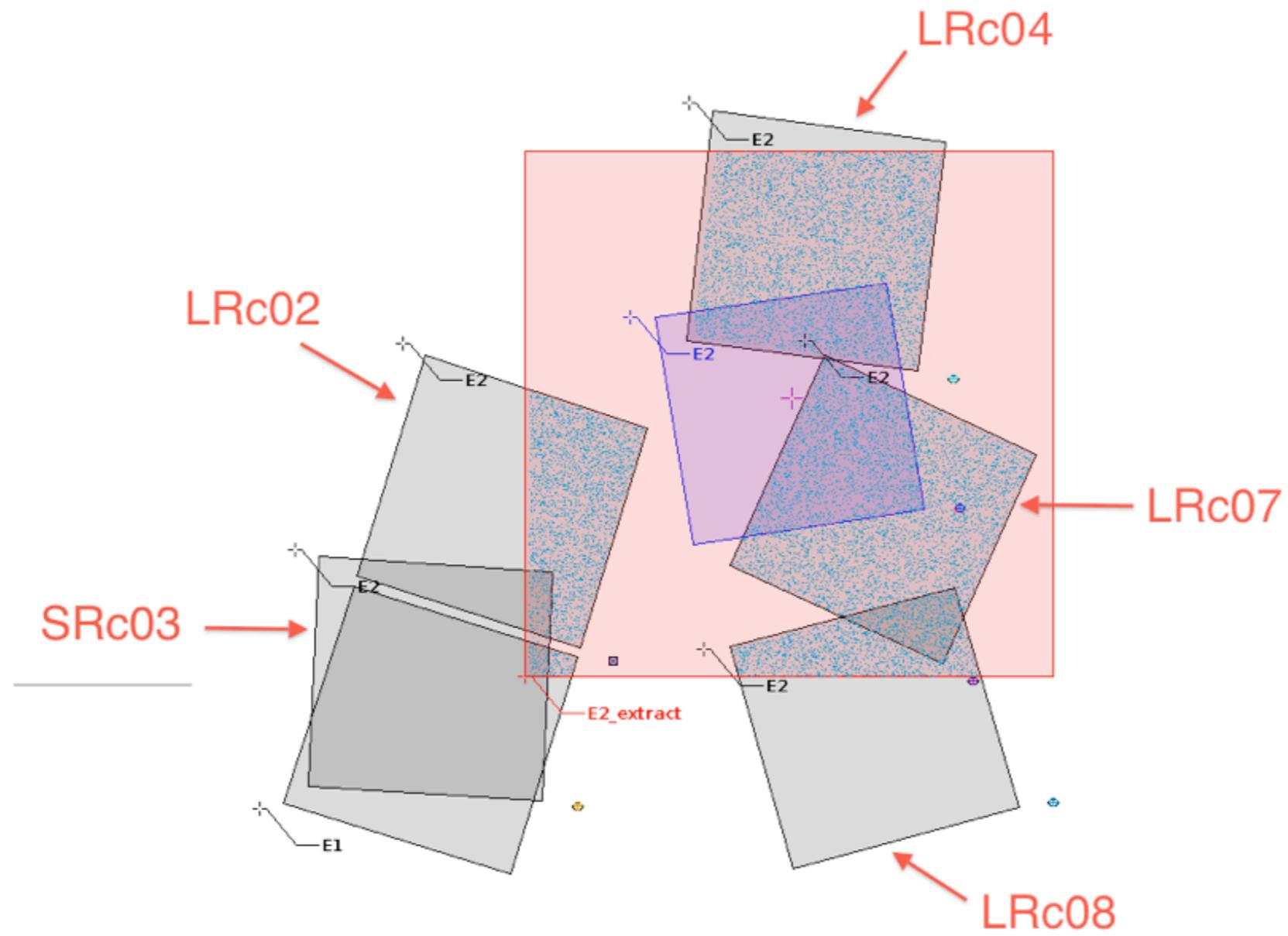
26 exoplanet fields located in two continuous viewing zones

Run duration : flexible - 21 days to 152 days

Duty cycle  $\approx 91\%$

Possibility to re-observe the same field : CoRoT-7 & CoRoT-9



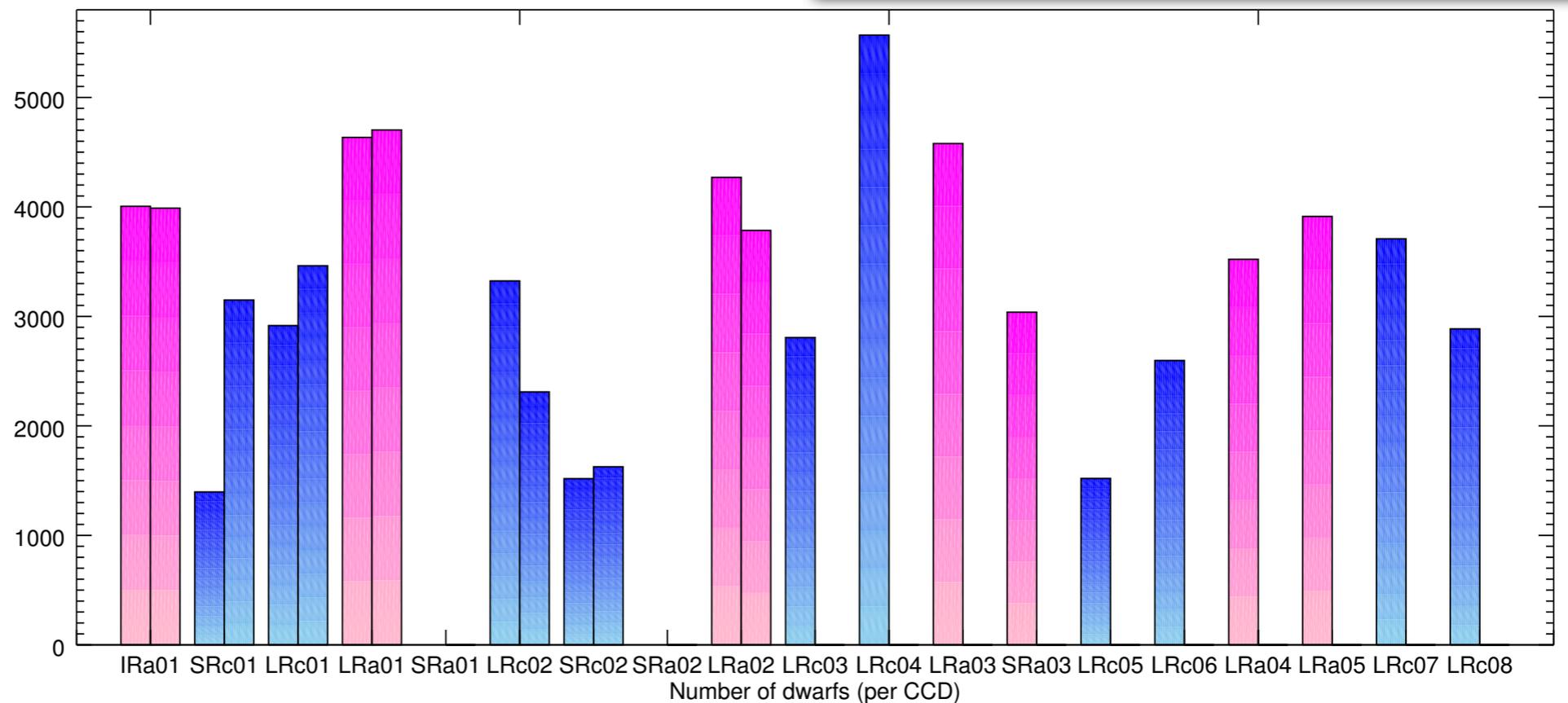
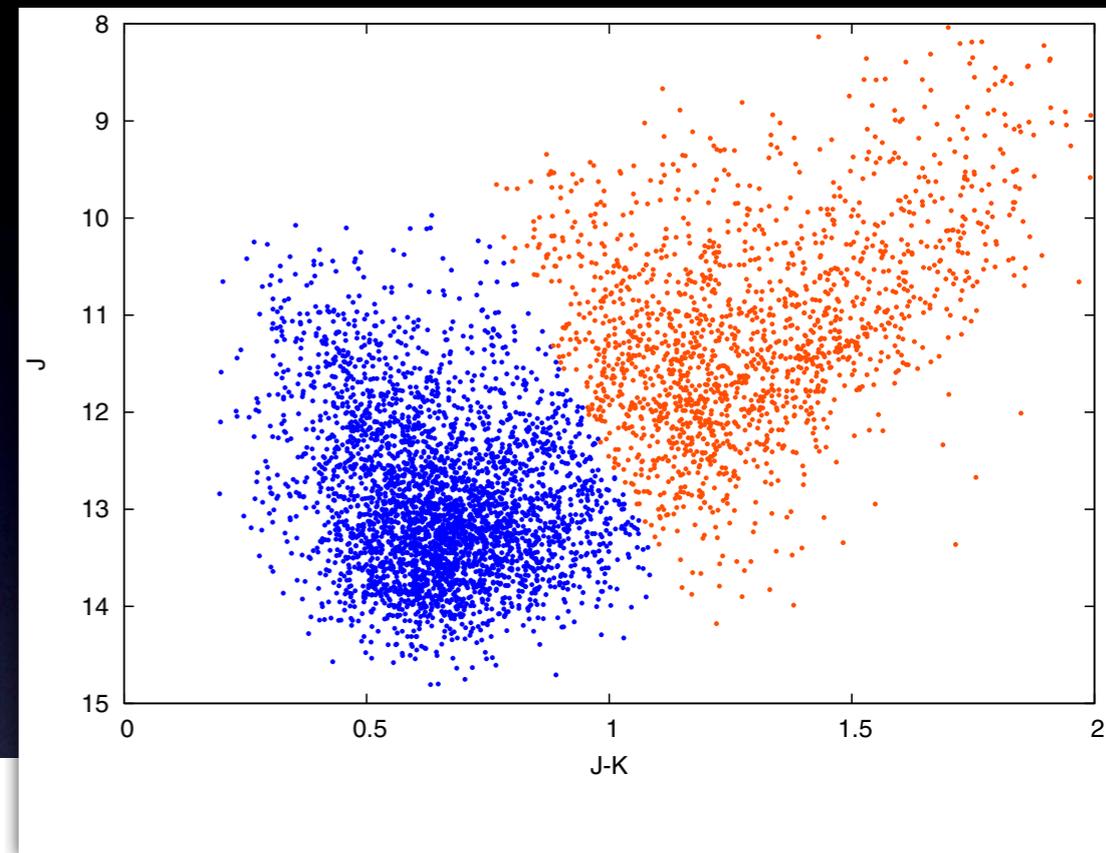


# Stellar population

163 664 light curves (oct 2012)

$11.5 \leq r\text{-mag} \leq 16$ .

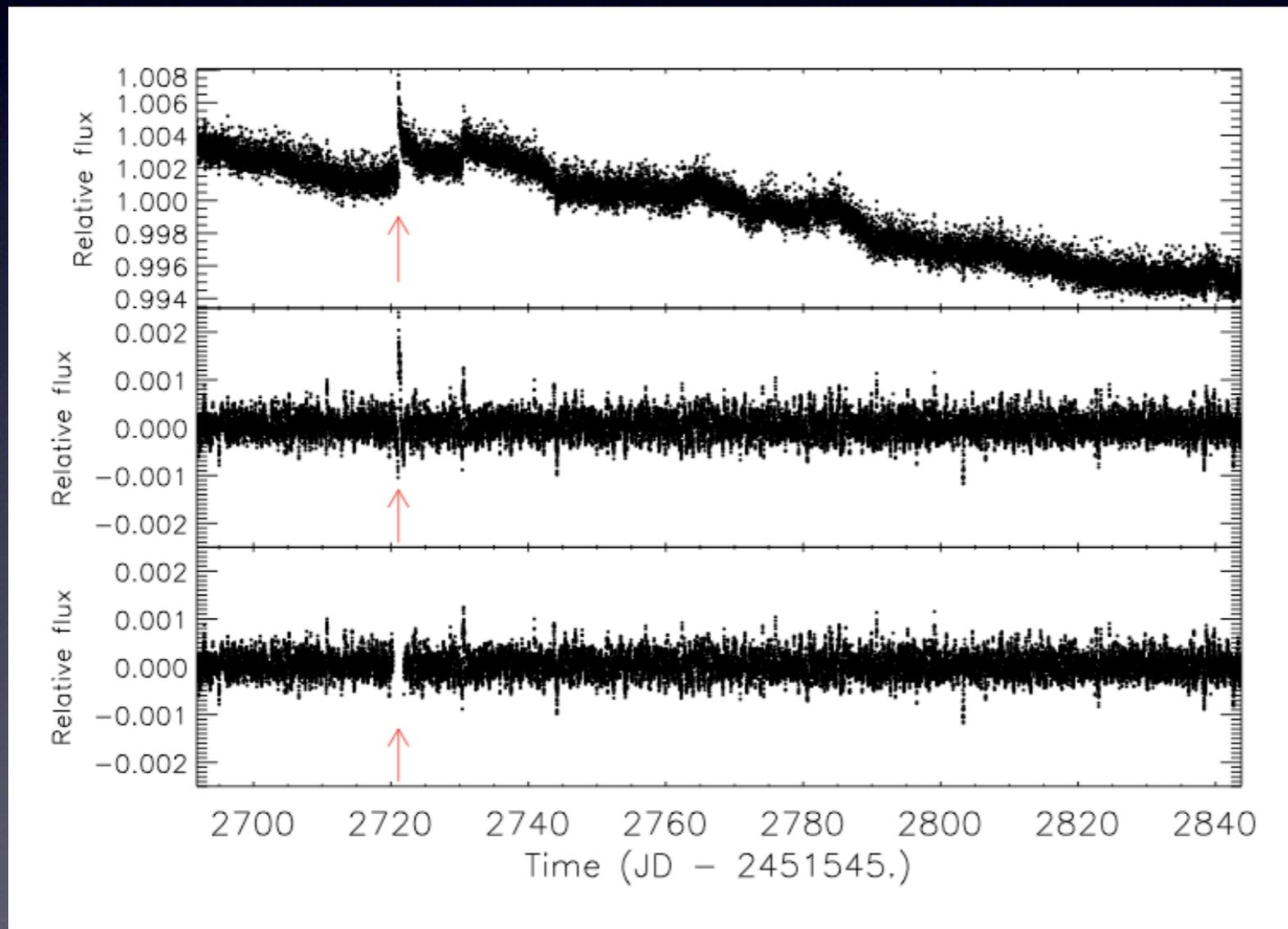
42 500 targets are classified as FGKM dwarf (class V) based on color separation



# Transit detection

No official CoRoT pipeline in charge of the transit detection but different teams in labs

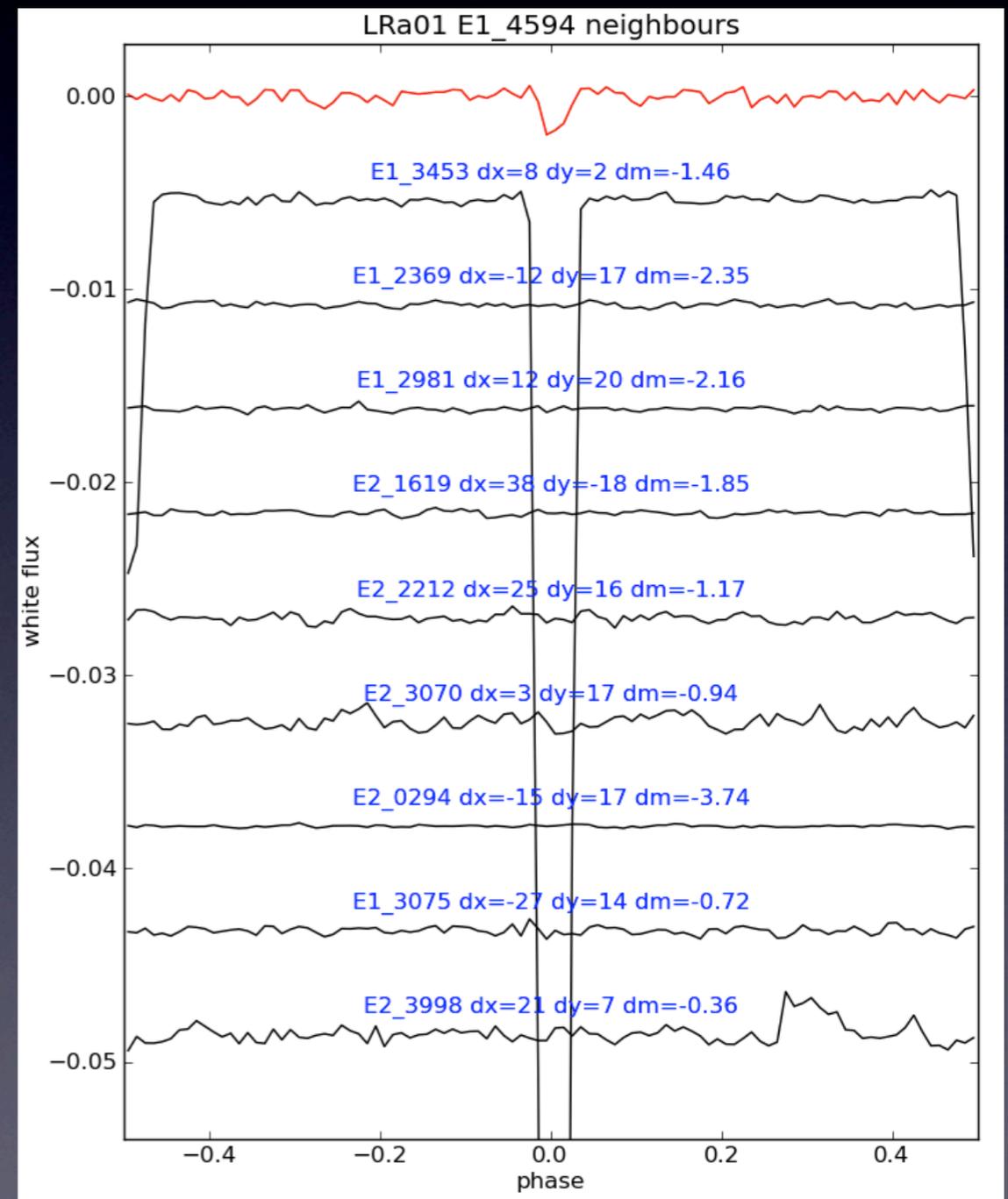
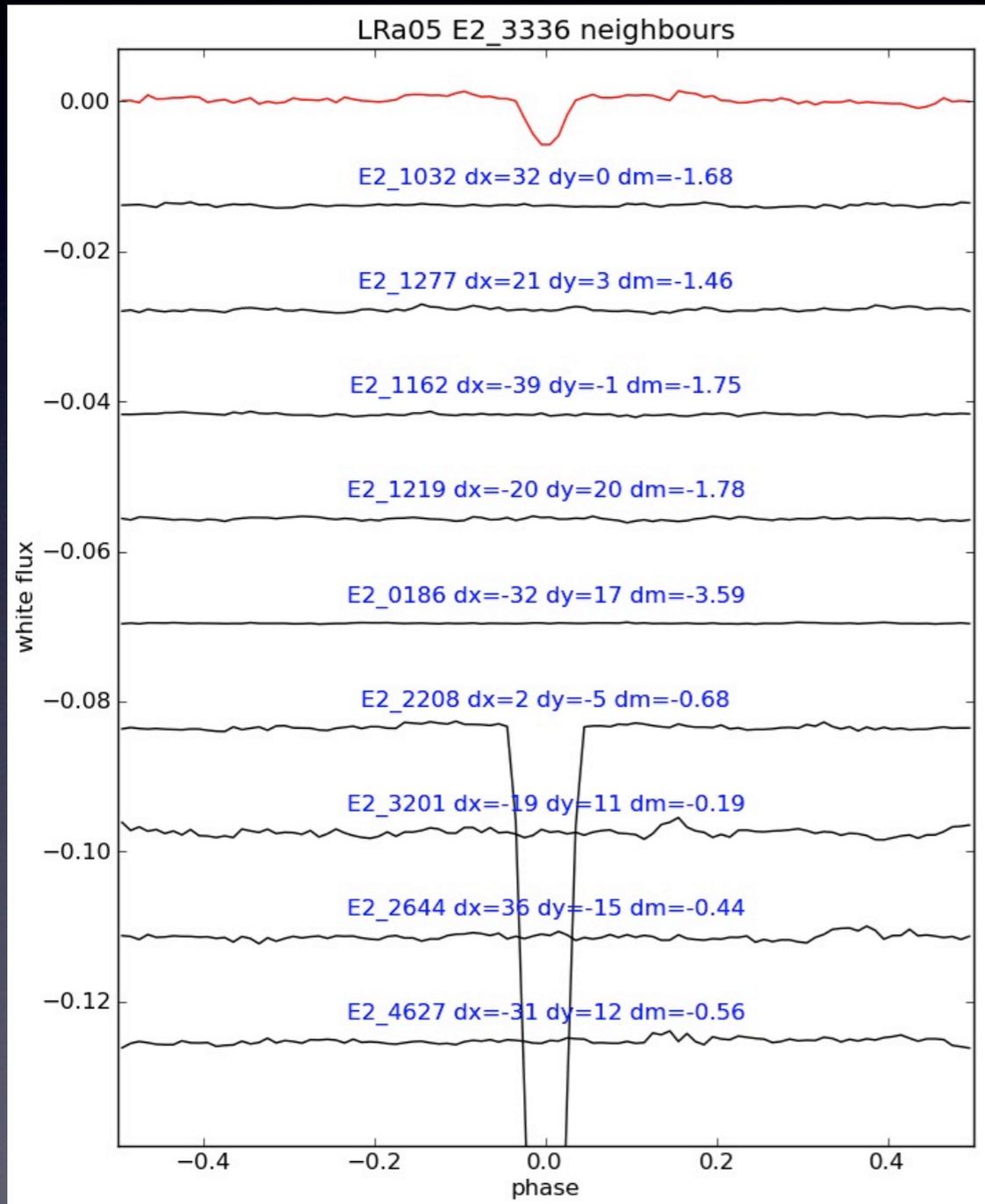
Different detrending techniques and detection algorithms



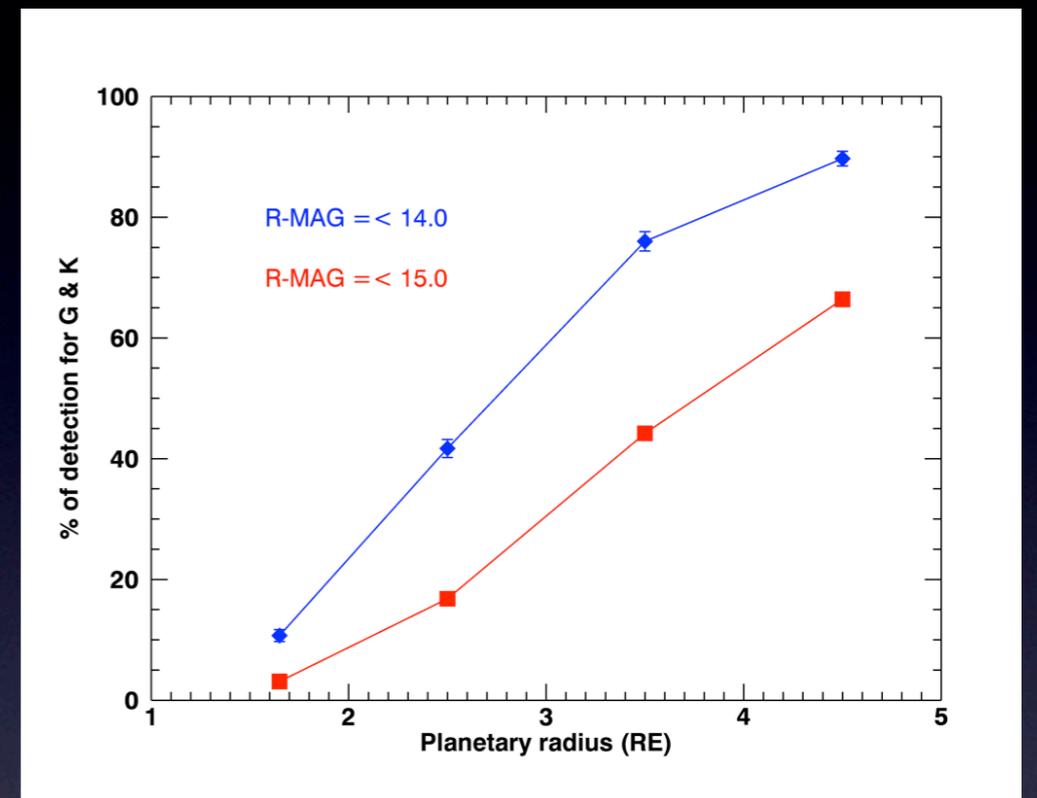
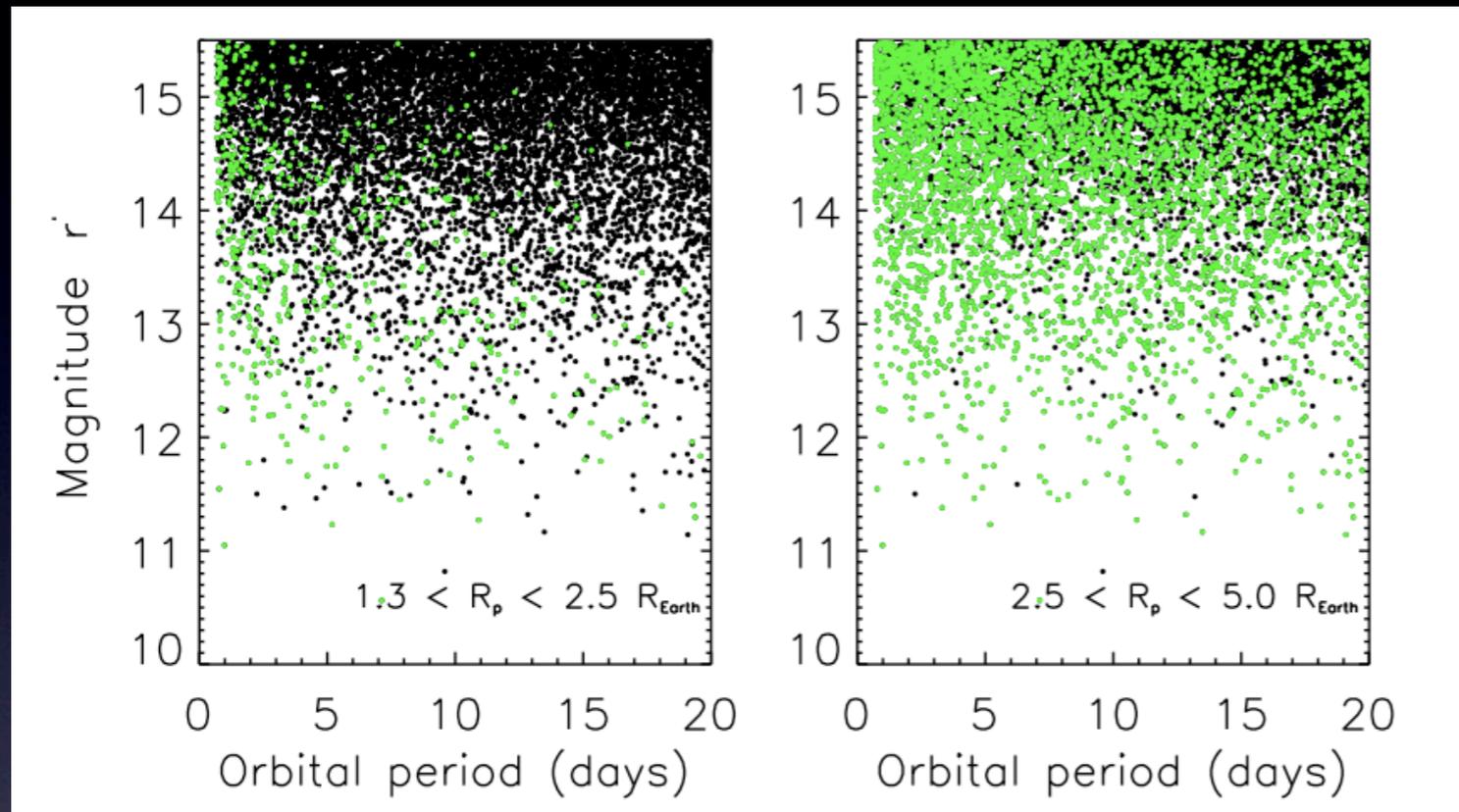
Bonomo et al., 2012

# Transit ghost signals

25 candidates excluded



# Assessing the detection capability



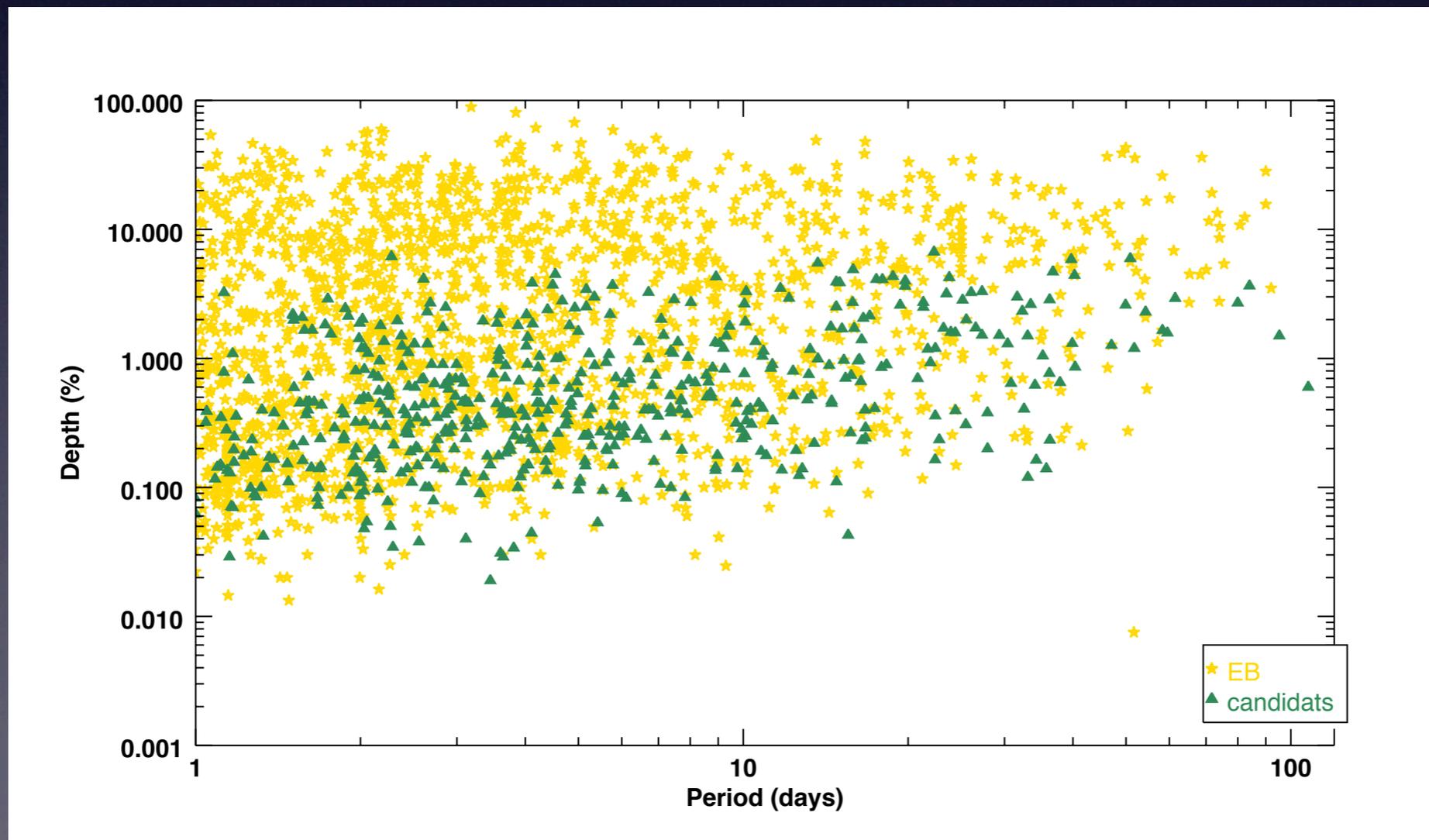
Bonomo et al., 2012

Simulations based on real 130-days LC of G & K dwarfs in 6 long runs with simulated transits  
60 % of 2 - 4  $R_{\oplus}$  planets in short periods are detected  
10 % of 1.3 - 2  $R_{\oplus}$  planets  
under-detection of Neptunes compared to Kepler:  $12 \pm 2$  expected, 1-6 detected

# *Transit signals in real light curves*

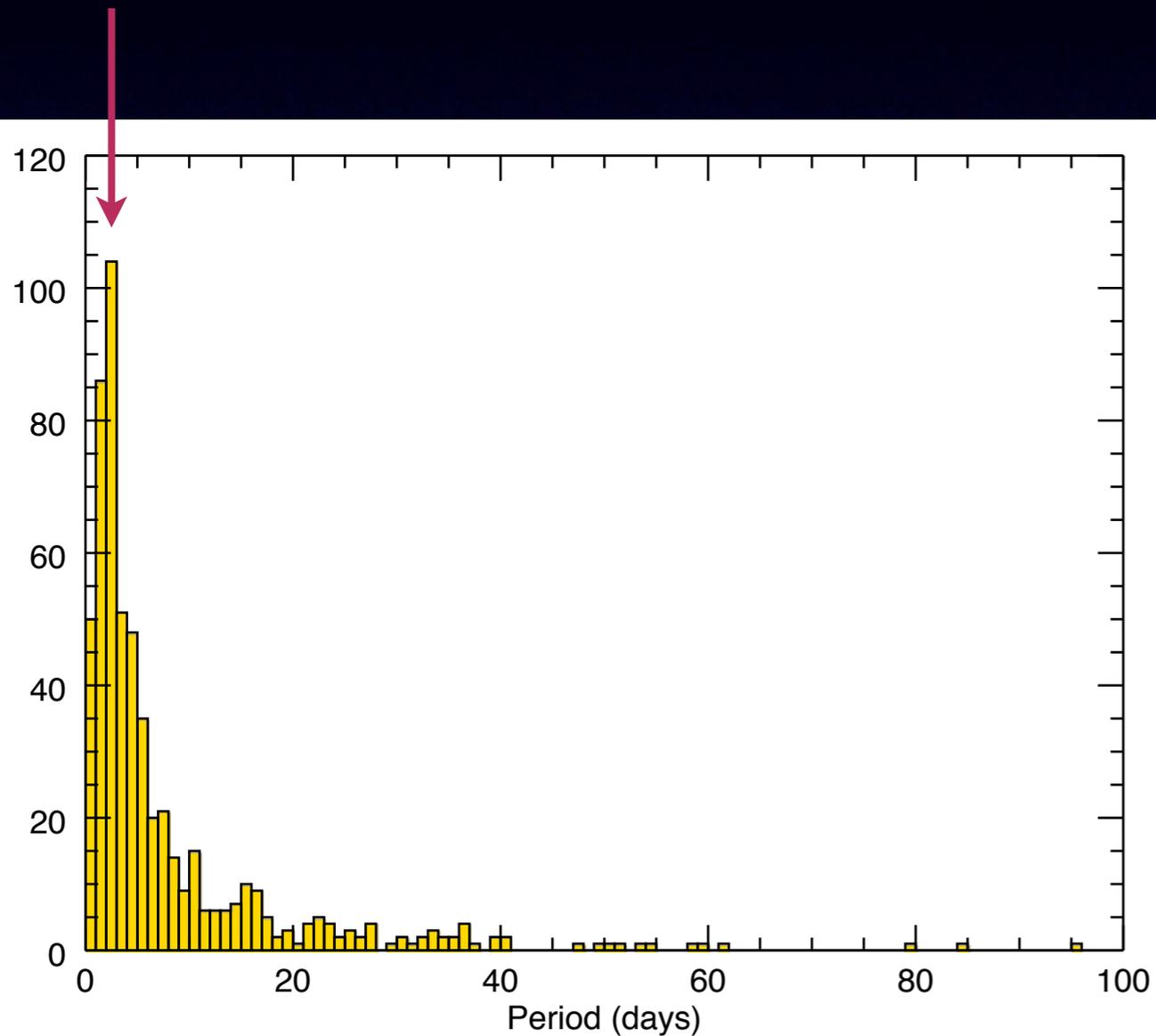
3472 transit-like signals in the 19th first runs:

- 2886 eclipsing binaries - 83%
- 567 candidates flagged for follow-up observations
- 27 single transit events - 5%

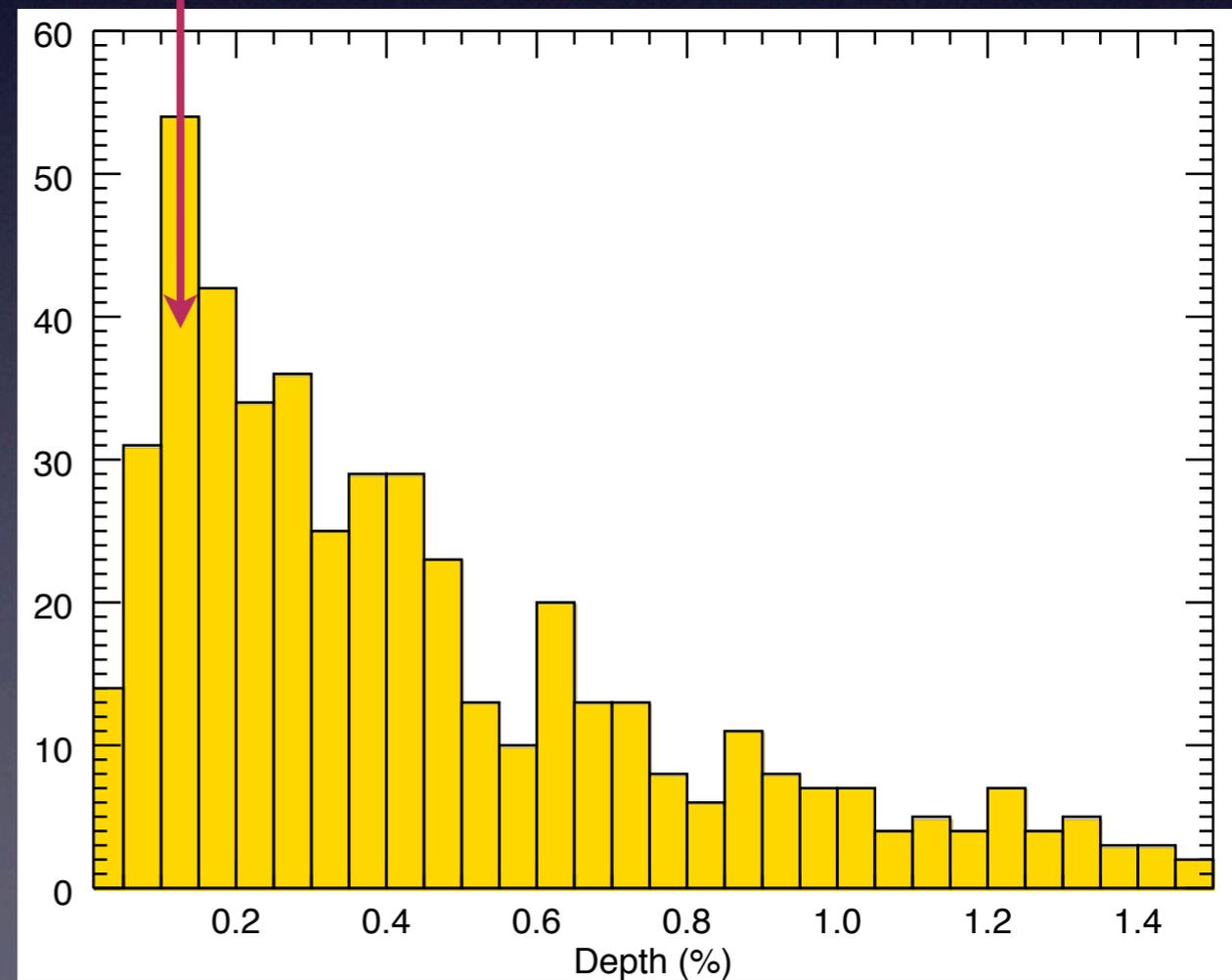


# Candidates properties

2.2 days

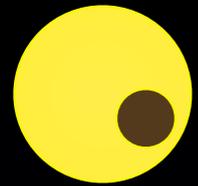


0.125 %

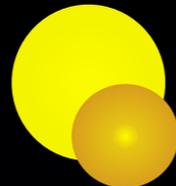




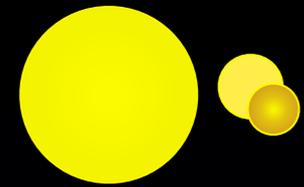
# Filtering out the candidates



Planet

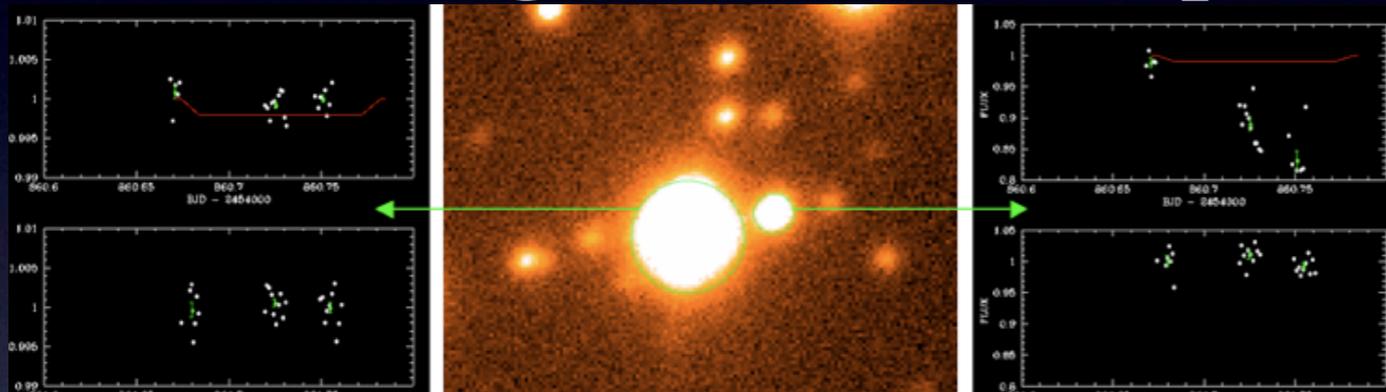


Eclipsing Binary

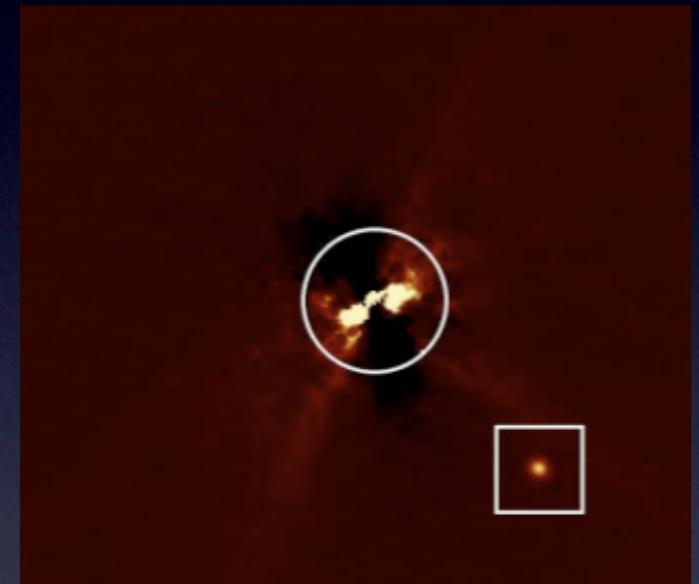


Diluted binary star

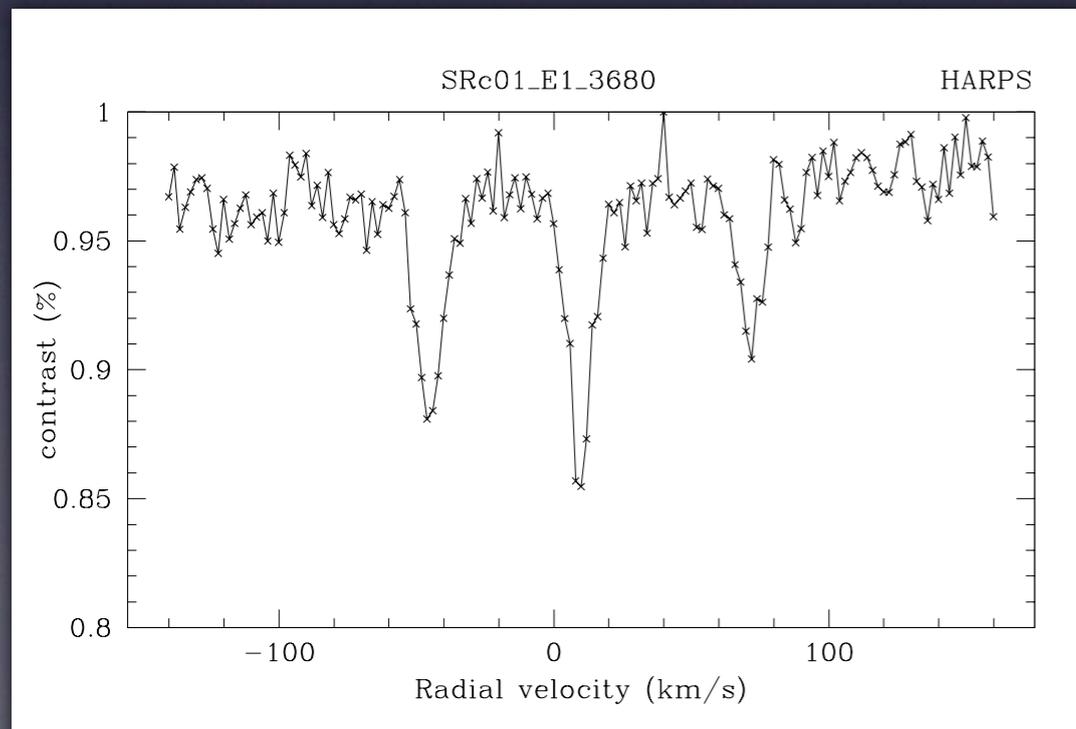
- photometric observations : more than 200 nights of 1-m telescope



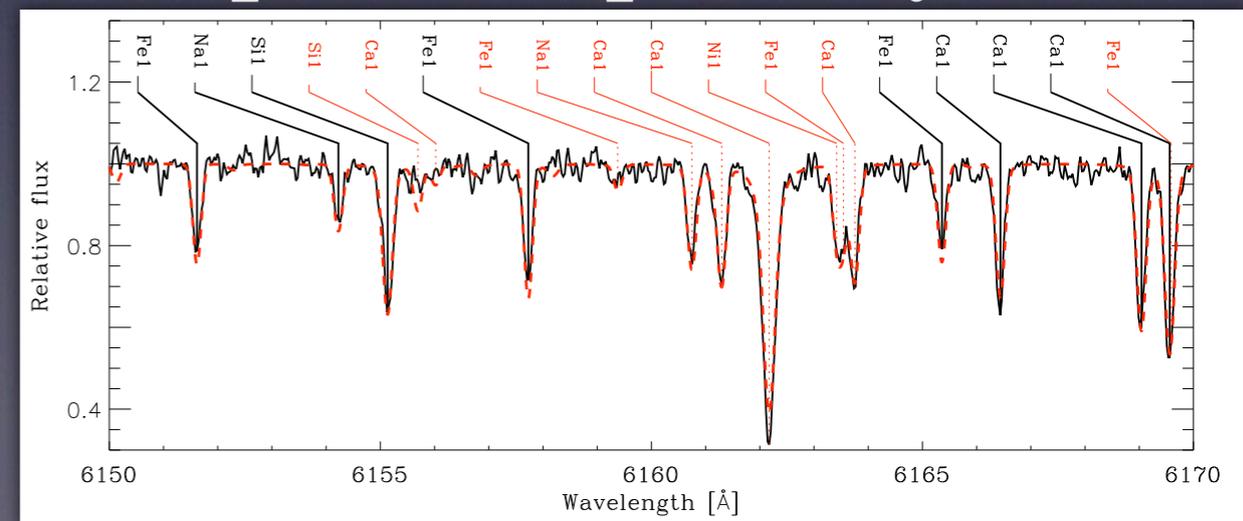
- high contrast imaging : a few nights of 8-m telescope



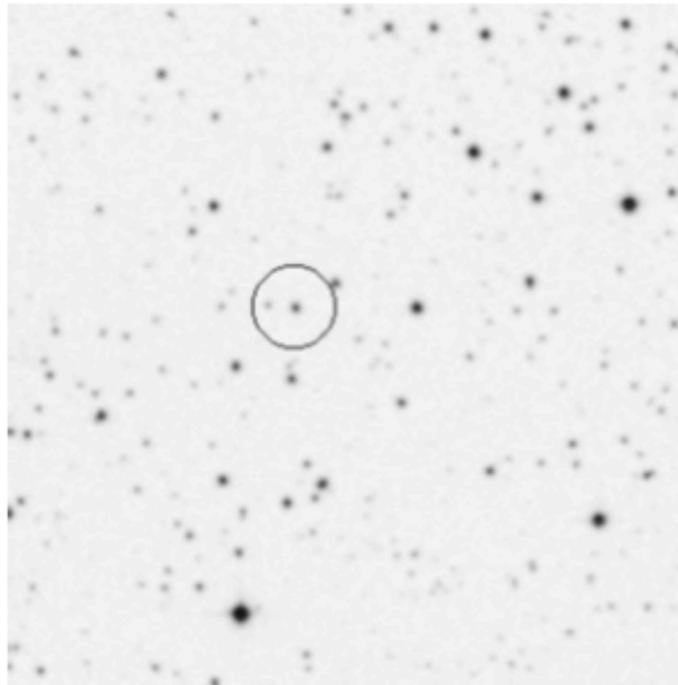
- radial velocity (RV) measurements



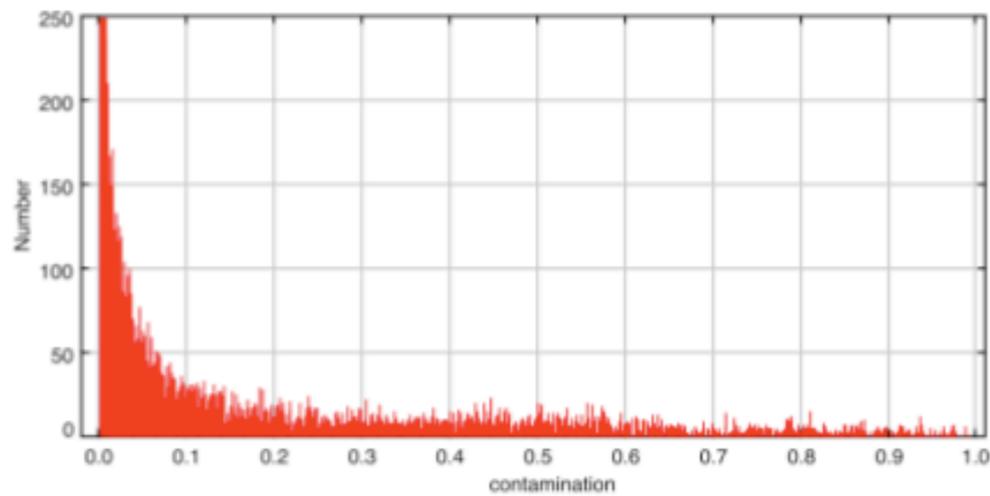
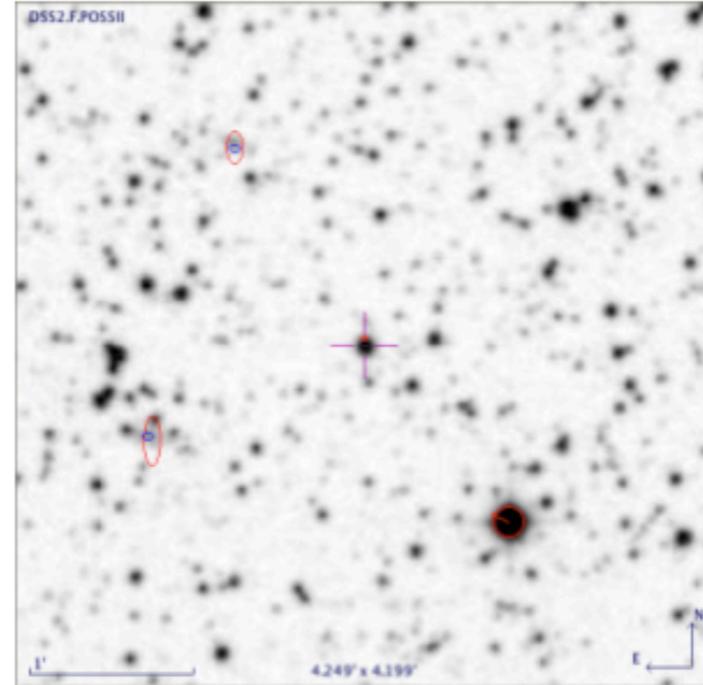
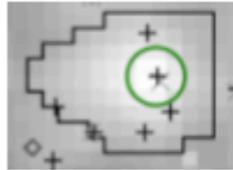
- spectroscopic analysis



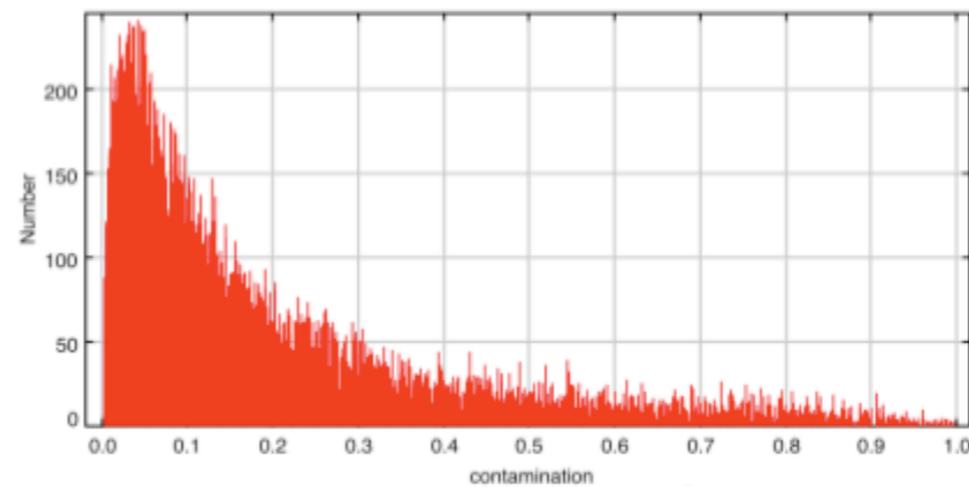
# Crowding of the field : an issue



PSF

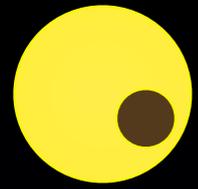


typical anticenter field

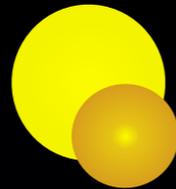


crowded center field

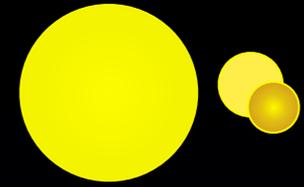
# Filtering out the candidates



Planet



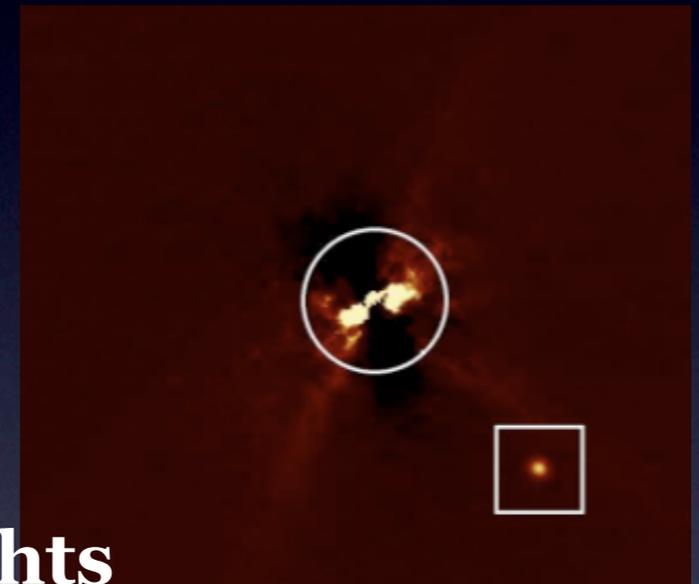
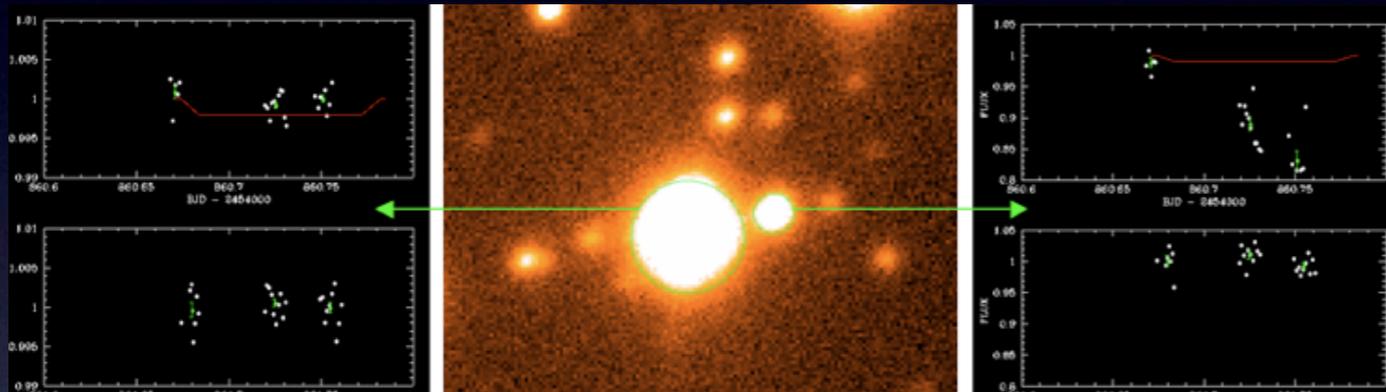
Eclipsing Binary



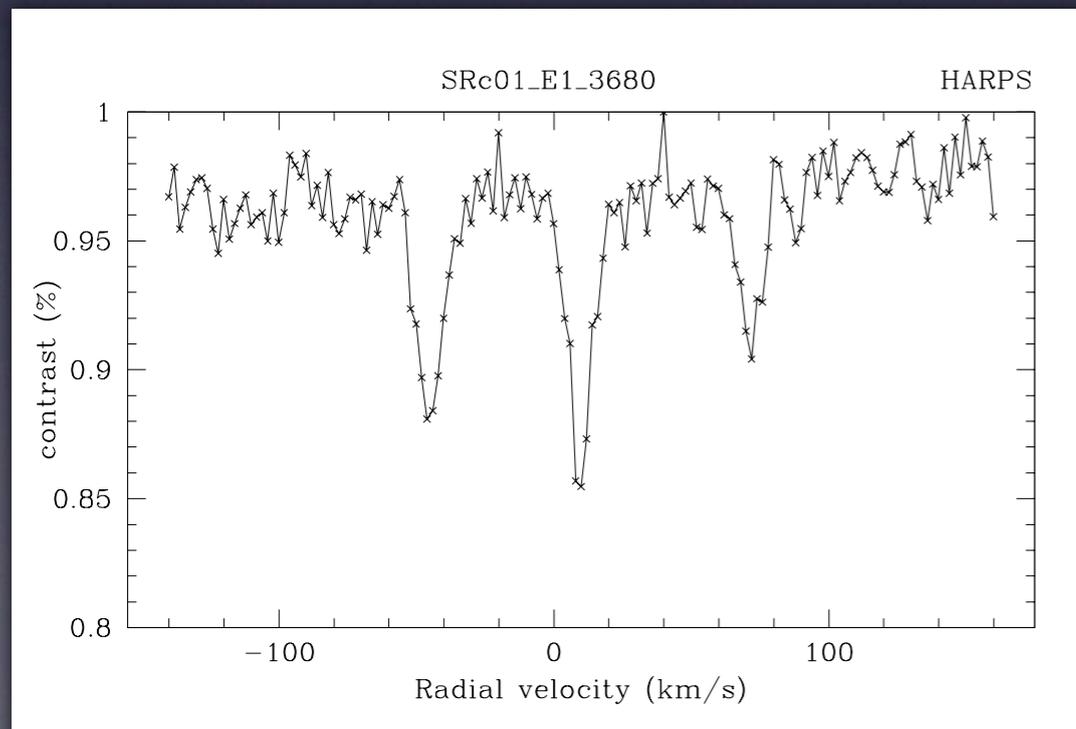
Diluted binary star

• photometric observations

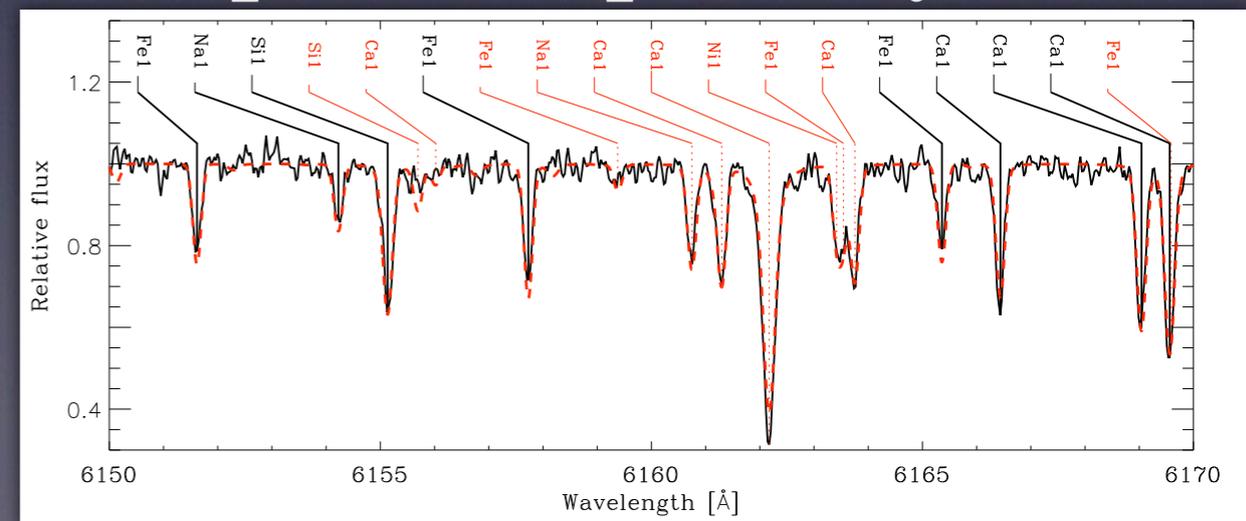
• high contrast imaging



• radial velocity (RV) measurements : ~ 350 nights

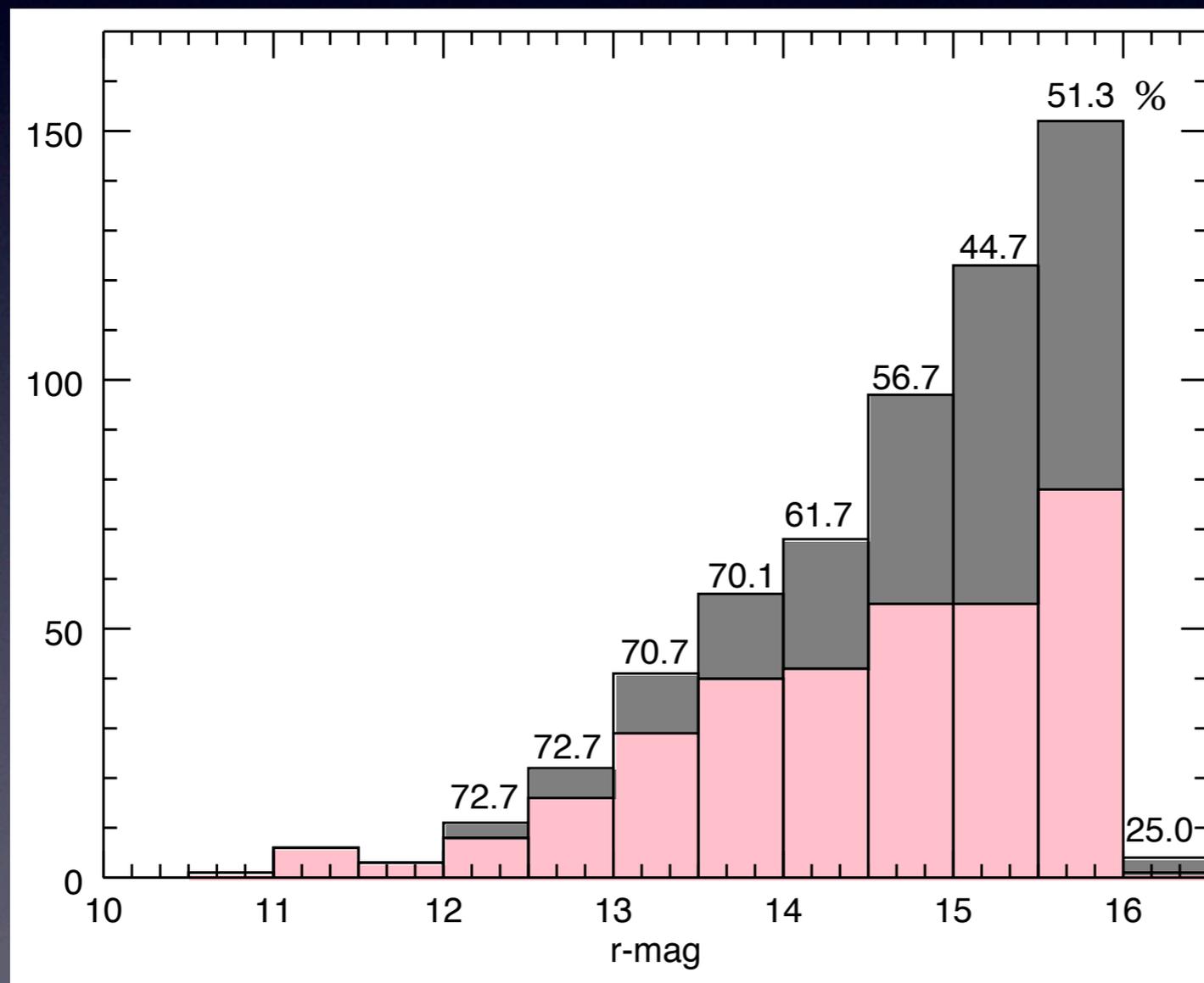


• spectroscopic analysis

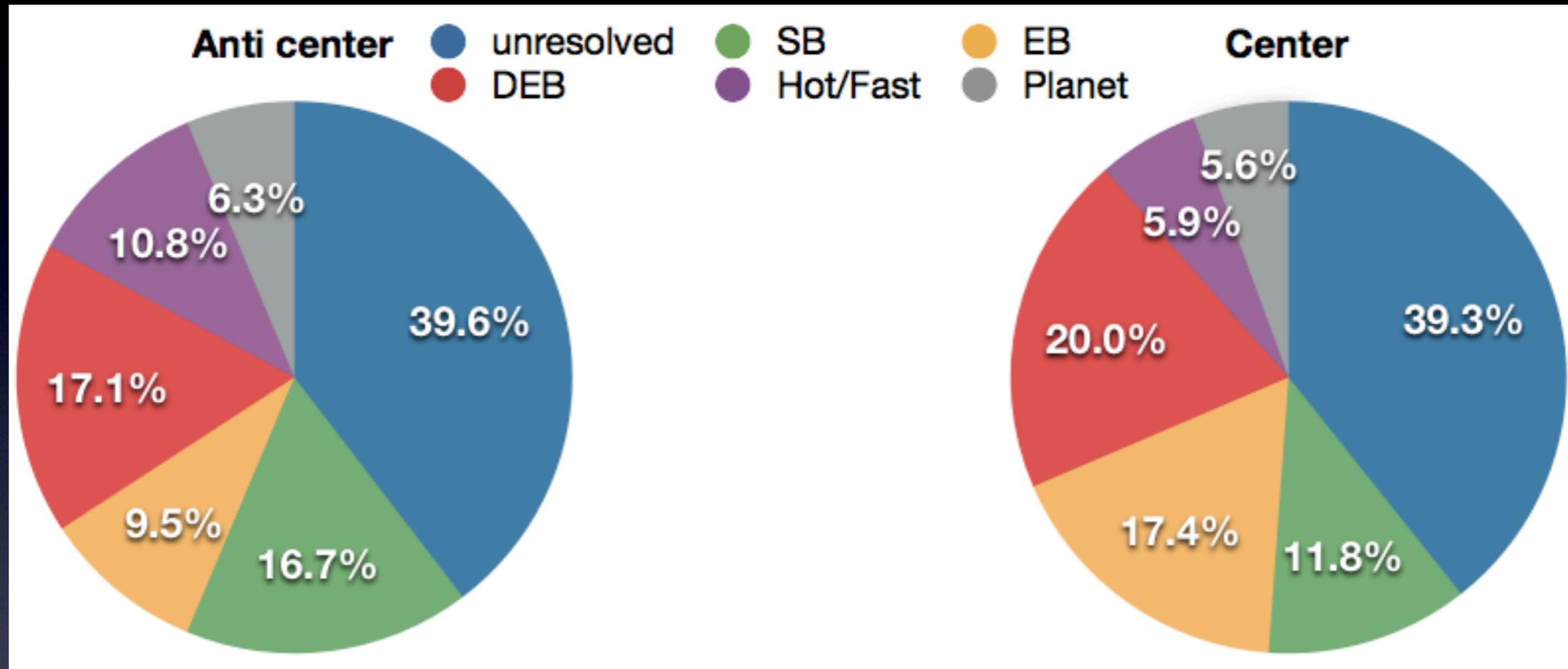


# Follow-up observations

64 % of the candidates observed by ground-based facilities (327)  
72% in the anti-center and 58 % in the center fields  
LRc06 : 25% of the candidates followed up, 95% in the LRa02



# Outcomes of follow-up observations



unresolved : no follow-up observations or inconclusive observations

Planets : ~ 6%

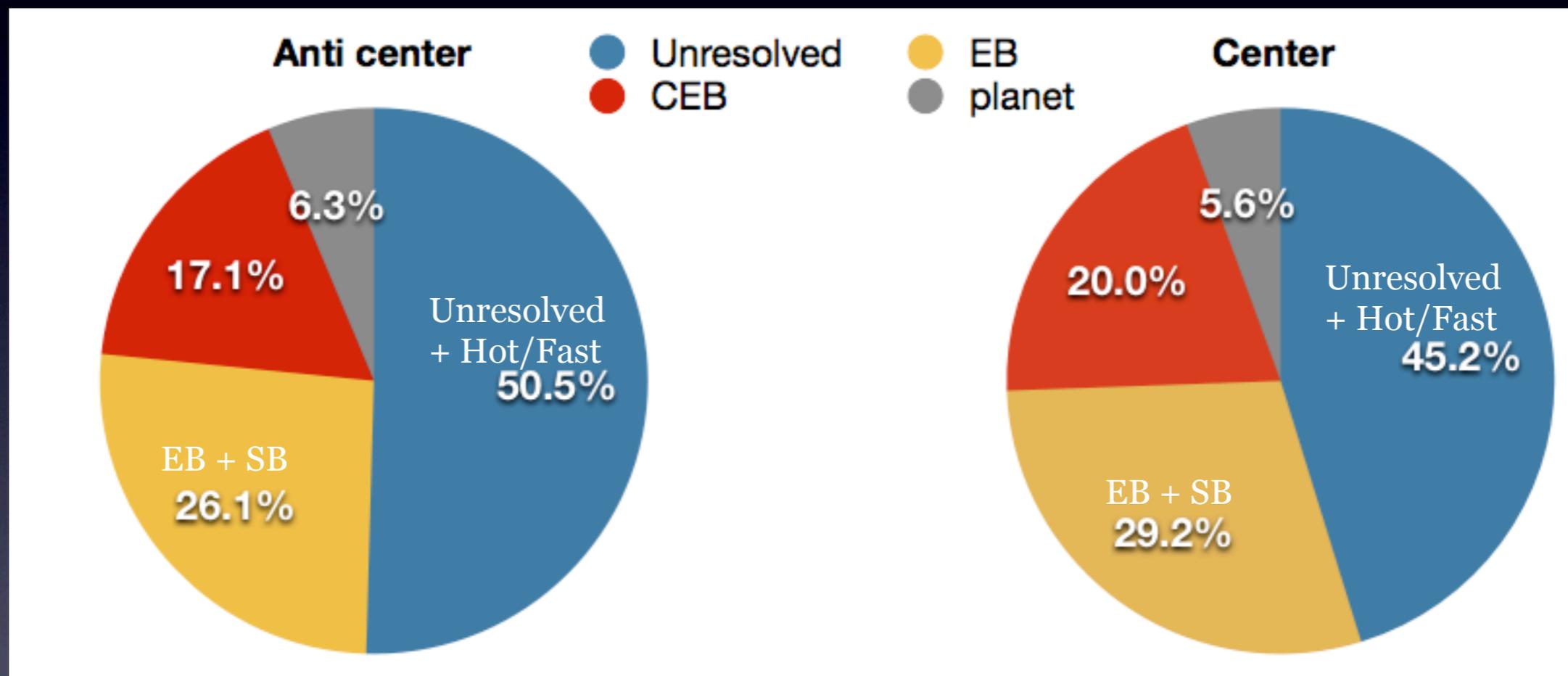
86 % of resolved configurations are FP

No major difference between the center and the anti center

# False positive

SB = eclipsing binary

Hot/Fast : transits could be those of a small star, a planet or due to a contaminating EB = unresolved cases



Assuming unresolved distributed as planets and CEB, false positives would be 77 % of the total number of candidates

→ not all the planets have been identified as such.

# Candidates flagging

Automated software developed by Suzanne Aigrain

Need a first screening of the candidates with period,  $T_0$ , depth & duration pre estimates

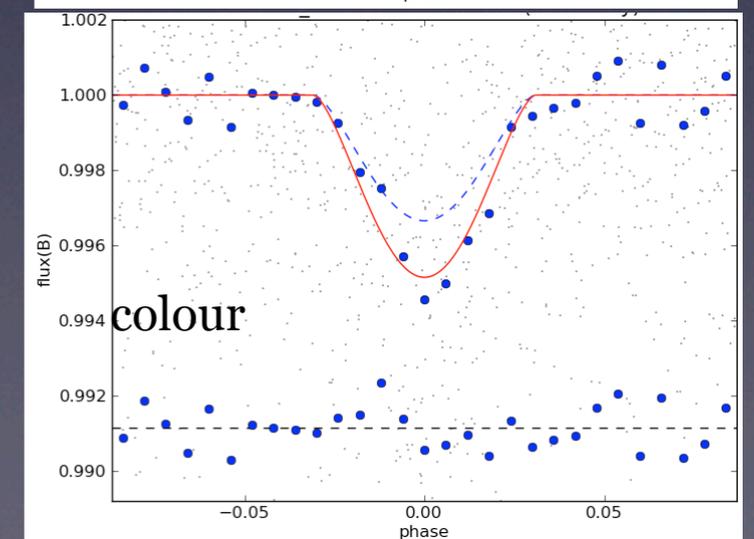
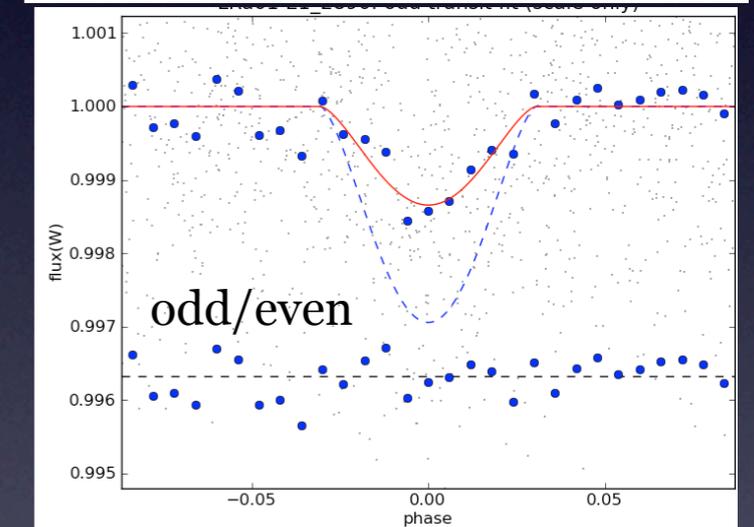
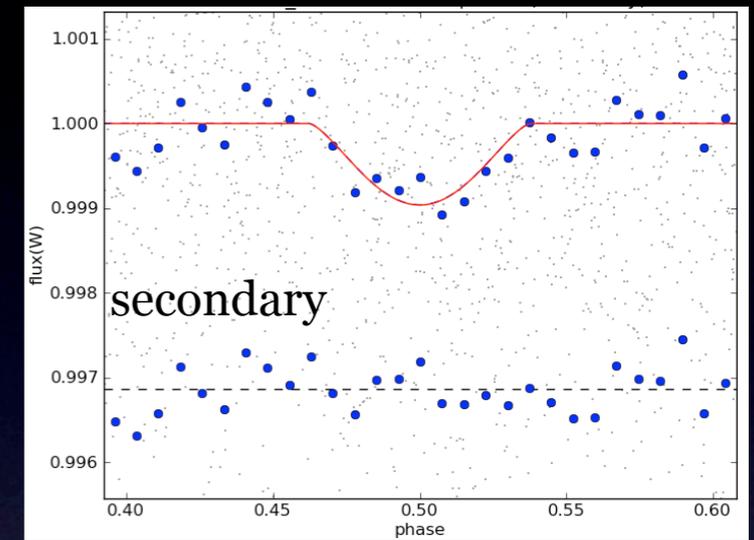
Transit model : Mandel & Algol formalism with limb darkening coefficients fixed at the values for a Sun-like star (Sing 2010)

+ additional physical parameters (Seager & Mallen-Ornelas, 2003)

6 binary flags :

- low confidence detection
- secondary detection
- odd/even depth differences
- colour depth differences
- long transit
- v-shaped

re-analysis of all the candidates done



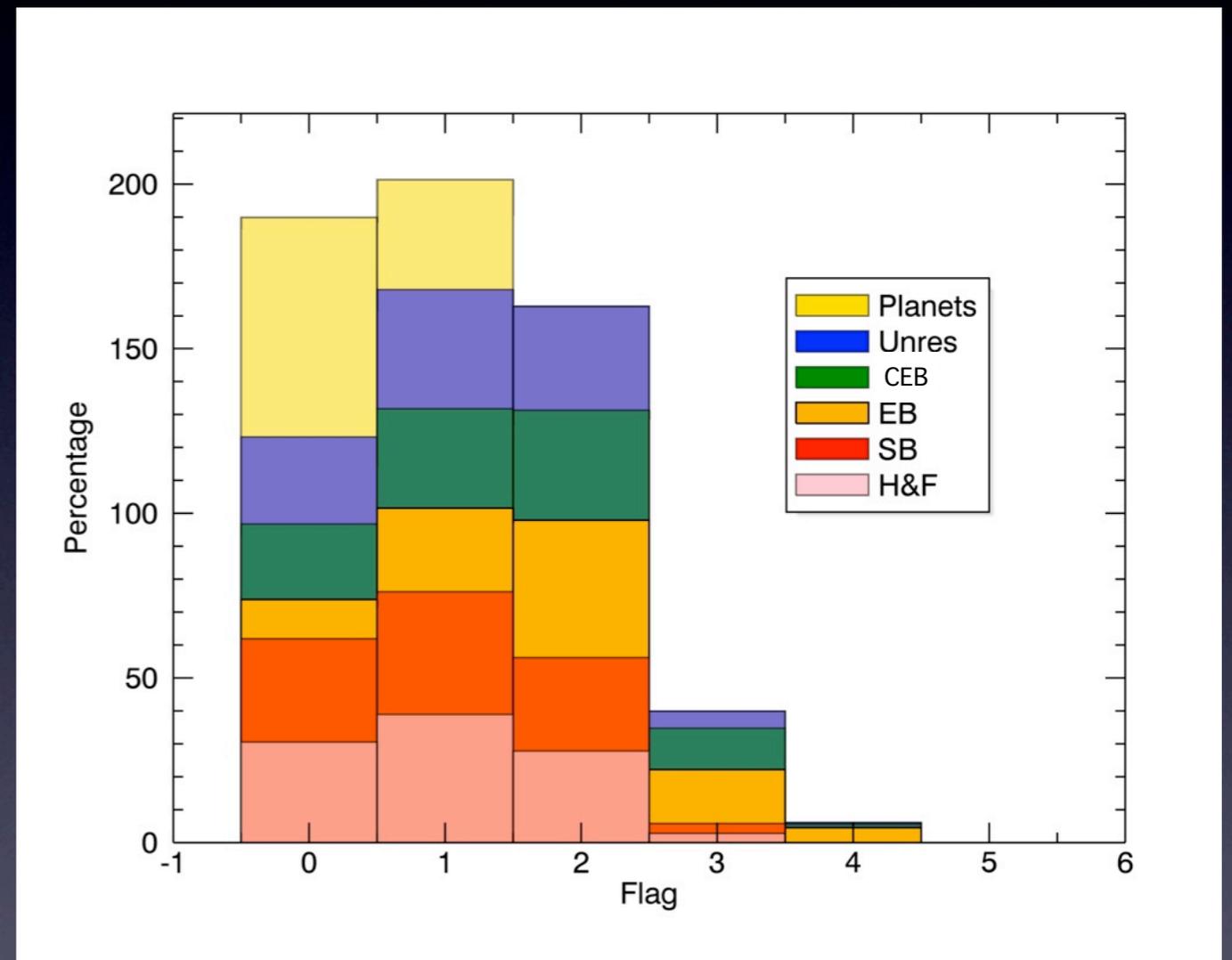
# Comparison with results from follow-up observations

→ promising for FUp observation strategy

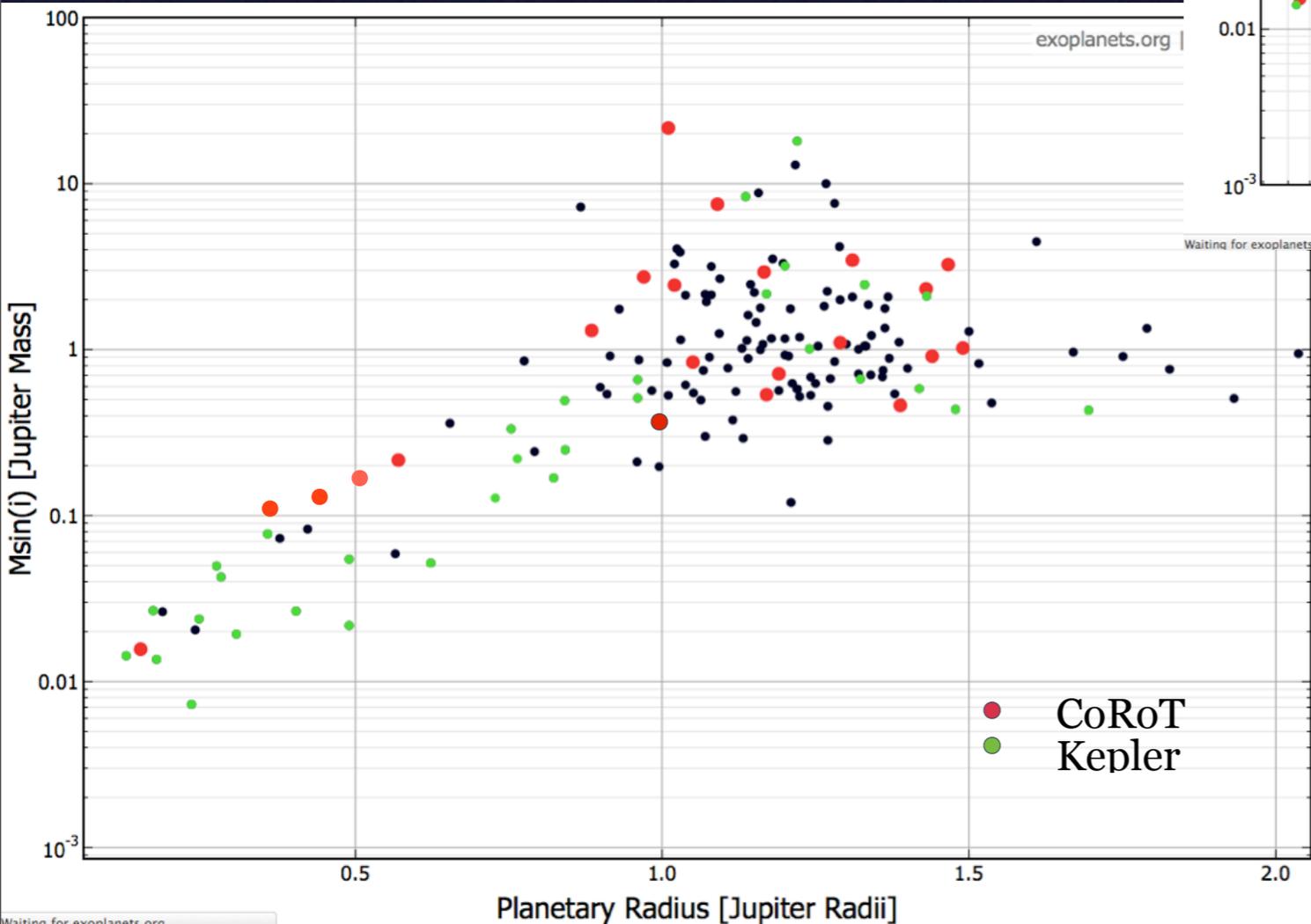
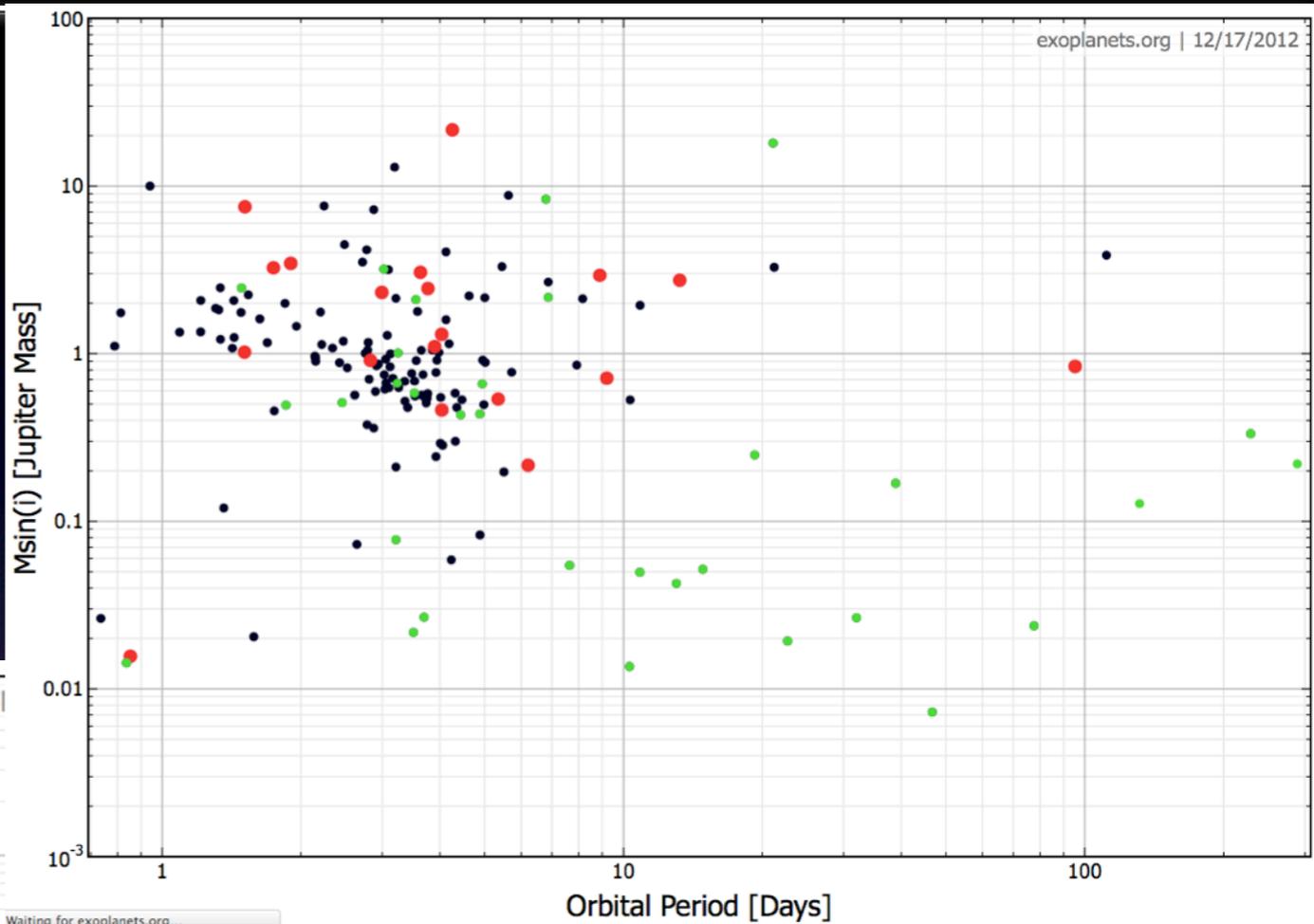
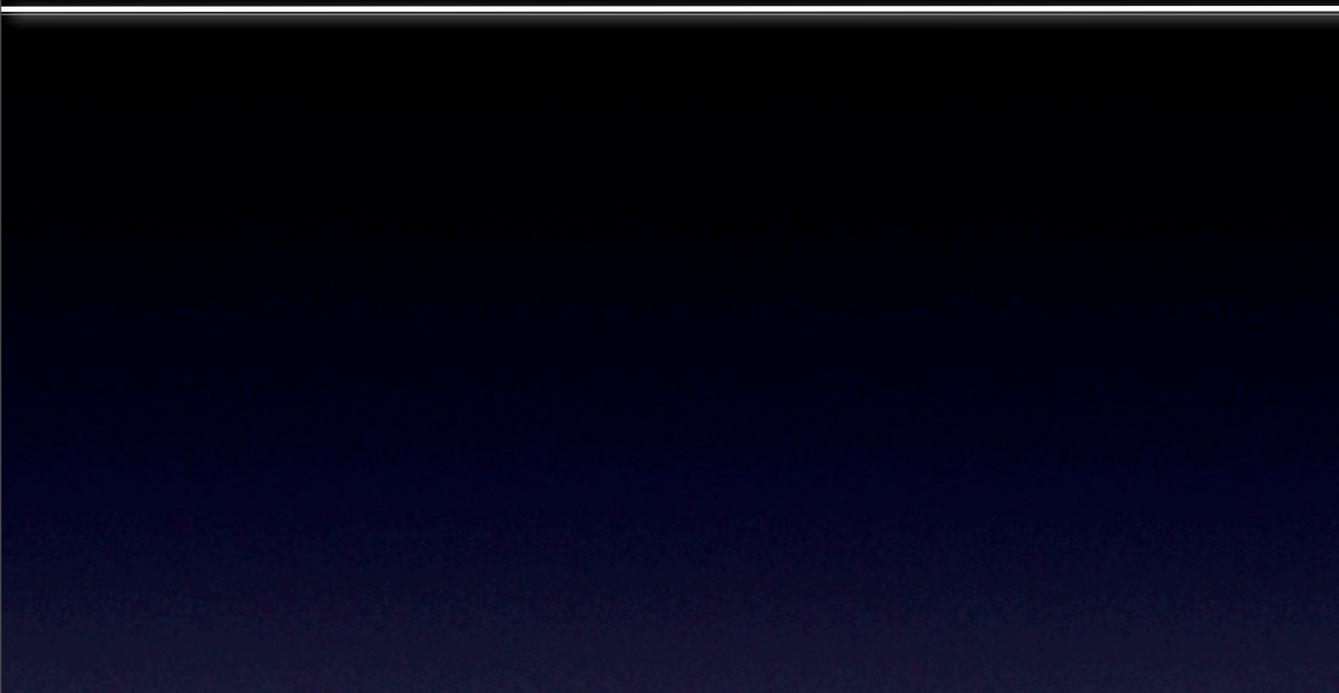
→ conservative approach : candidates with number of flag  $\leq 1$

FP : 86 %

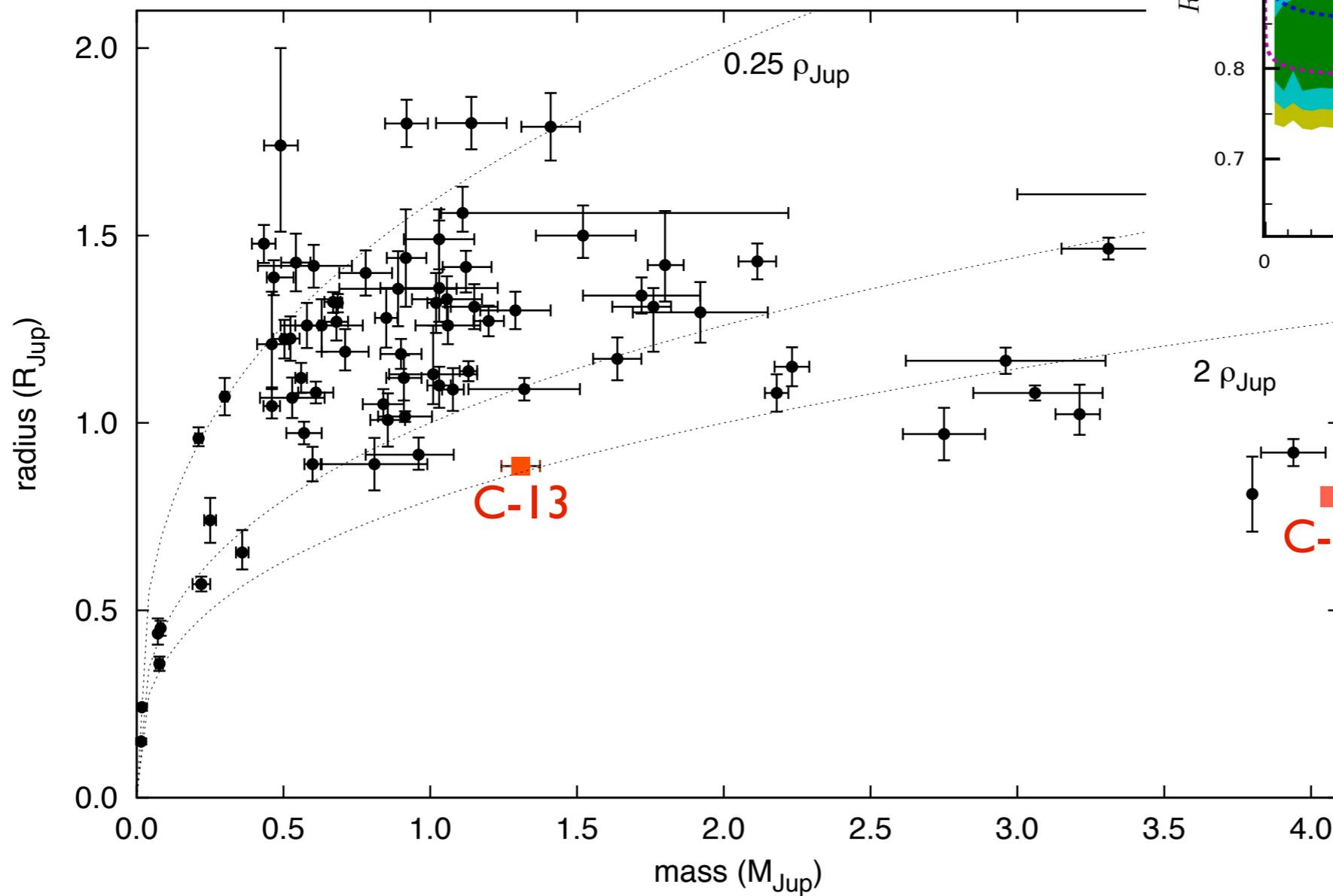
10 to 15 planets expected among unresolved



# CoRoT exoplanets highlights

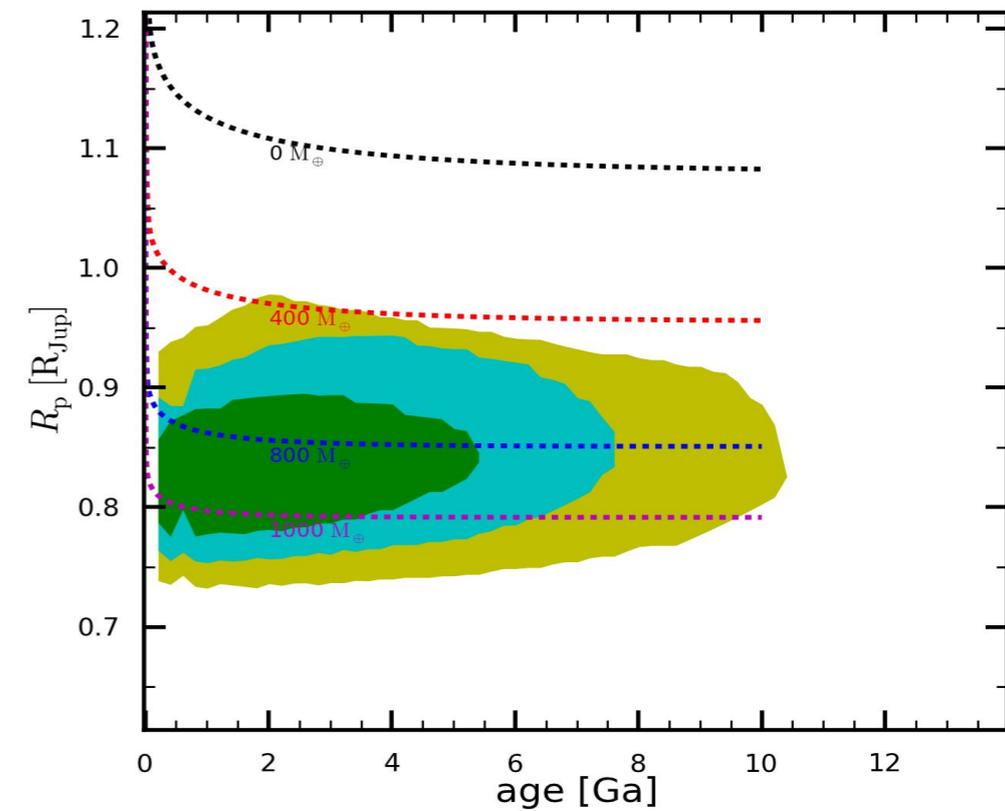


# Synergy with ground-based observations

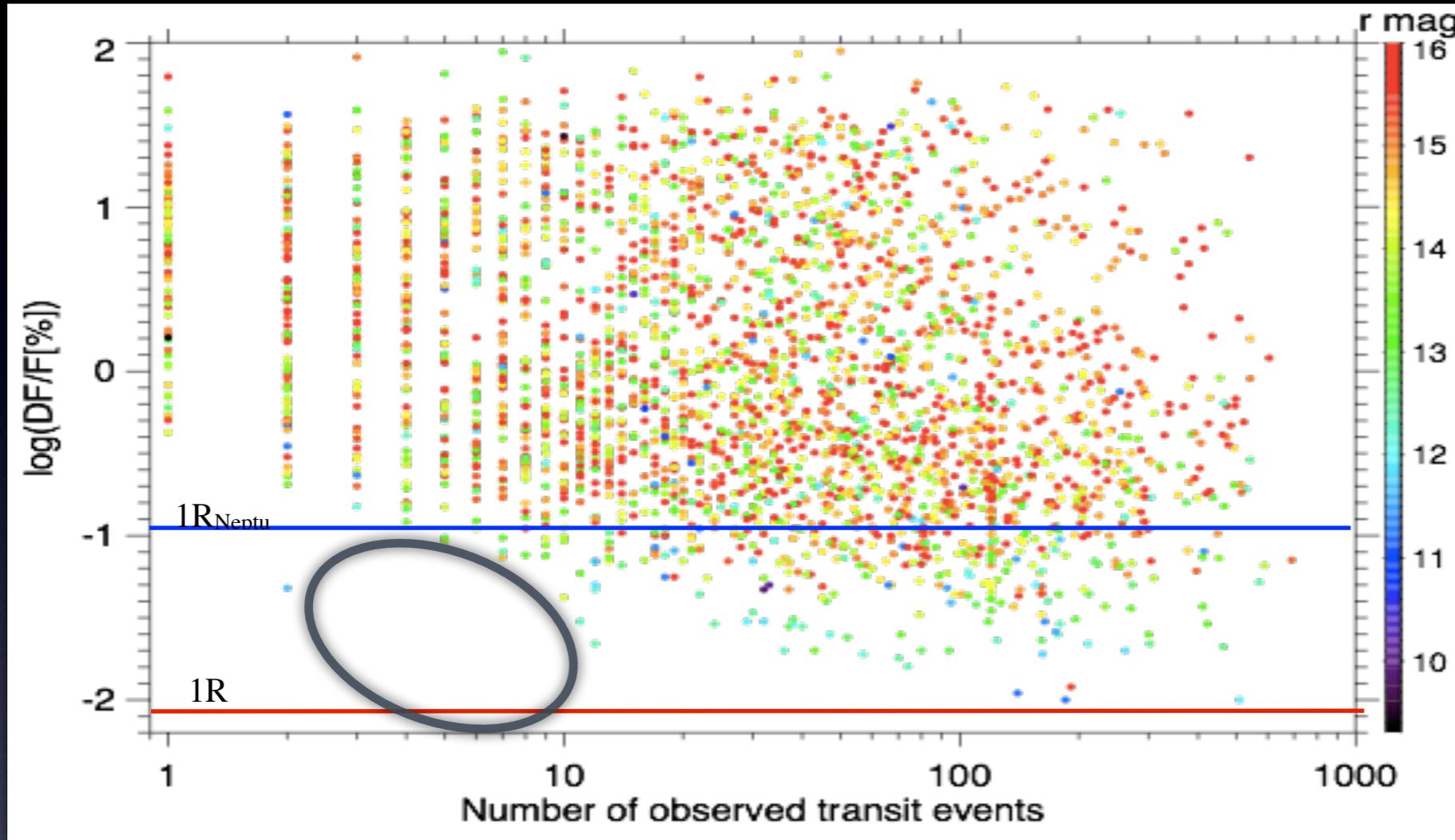


Cabrera et al., 2011

Deleuil et al., 2012



# Multi-planet systems with CoRoT



CoRoT-7 b & non-transiting c (Queloz et al 09)

CoRoT-24 b & c (Alonso et al subm)

$R_1 = 3.7R_{\oplus}$   $P = 5.1d$   
 $R_2 = 5.0R_{\oplus}$   $P = 11.8d$   
masses of  $\sim 40M_{\oplus}$

Numerous in the low mass, long period ranges

# 6 years of CoRoT

- in operation Jan 2007 to Nov 2012. Extended to 2013 and again (June 2012) to 2015. Good photometric performances still after 6 years. Operations to restore communication with the instrument on going
- 163 664 light curves collected; 3469 transit-like signals detected, 567 candidates
- Huge effort in follow-up observations
  - 2 third of the candidates were followed up
  - 40 % remains unresolved, others have their nature pinpointed. Among these unresolved cases, planets are still to be identified as such
  - confirmation & characterization of planets - difficulty for small planets around faint stars. Limited by complementary observations performances
  - 24 planets and 2 brown dwarfs that provide key M-R- constraints in an extended space parameters of planet diversity (and a few others to come soon)