CoRoT Eclipsing Binaries

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INAF - OAR
and the CoRoT Binary Team

11th CoRoT Week, Tenerife
March 21, 2013

The activity of the BTT

In CoRoT Additional programs: Binary Thematic Team
Coordinators: I. Ribas (CoI) + C. Maceroni
(>50 initial members, actually just a ``happy few'' active ones)

- Wiki pages (minimal use)
- web pages: inspect plots of EB-LC -> download N2 data (minimal use)
- GB follow-up: spectroscopy + Strömgren photometry (uvby,Hβ) of Exo-planet fields
- Update of codes for CoRoT data analysis

Core BTT main topics:
Pulsating & eclipsing binaries (PEBs)
EBs with low mass companions

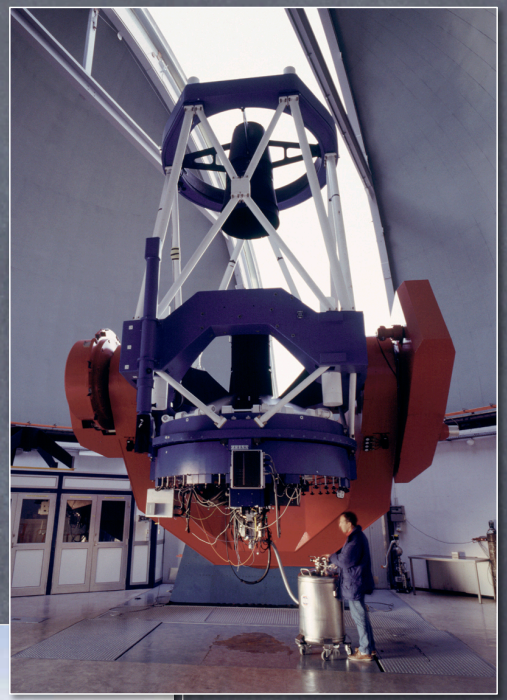
Spectroscopy of CoRoT EBs

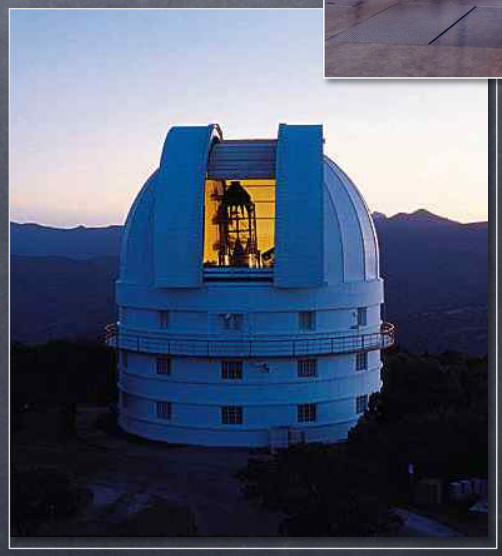
12 nights at ESO 2.2 + FEROS in two semesters (C & AC directions)

Additional observations at McDonald 2.1 + Sandiford spectrograph, SOPHIE (OHP), HERMES @ Mercator

Targets:
- EBs with pulsating components
- Binary with low mass components

Aim:
- Phase resolved spectra for RV
- atmospheric parameters after spectra disentangling





Binaries in the Seismo-field

non-eclipsing, long period binaries (study of pulsations)

HD 50230	B-type puls	suspected binary	hybrid pulsator	Degroote+2012
HD 50870	δ Sct	wide SP bin	complex puls. spectrum	Mantegazza+2012
HD 46149	O-type puls	SB1, P=829^d	solar-like oscillations	Degroote+2010
HD 51106	Am	ellipsoidal-SB2	non pulsating	Dolez+2009
HD 50747		SB2 -triple	γ Dor	Dolez+2009

Eclipsing + pulsating (eclipses additional problem but as well an opportunity)

HD 174884	late B	SB2	tidally induced pulsations	Maceroni+2009
AU Mon	B+G	SB2	accretion disc + 'hidden' pulsations	Desmet+2010 Djurăsevíc+2010

CoRoT 7758 = HD 174884

(Maceroni, Montalban, Michel, Harmanec, Prsa et al. 2009)

Secondary target in IRa1

B8V, V=7.98

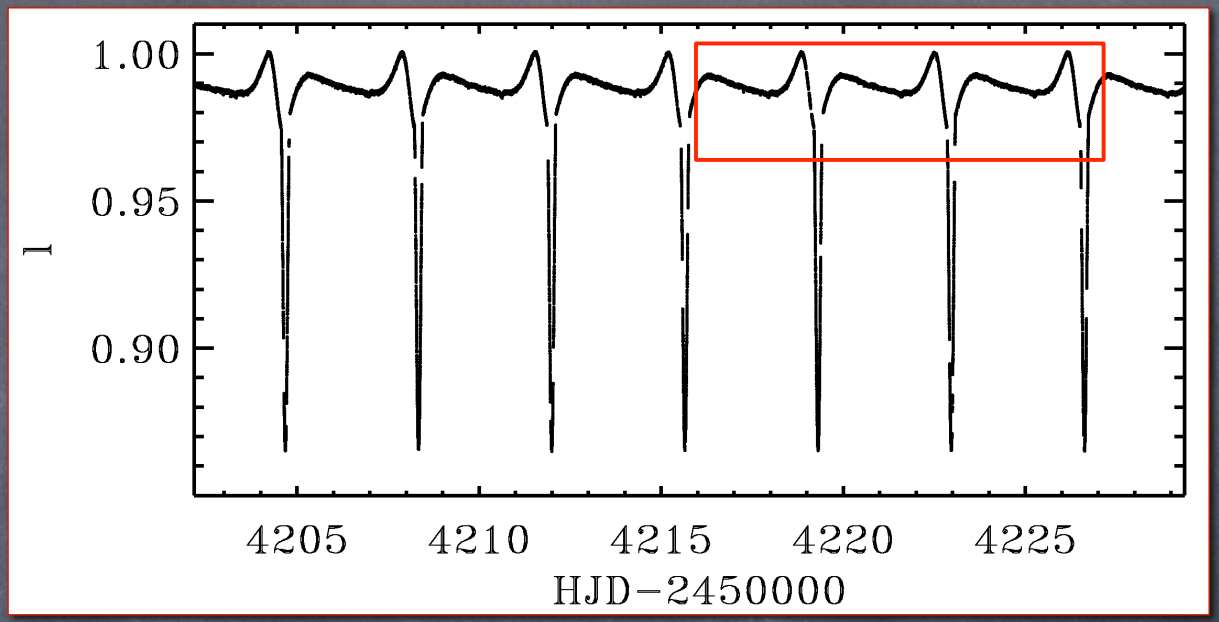
Period 3.66^d

M_1=4.04 M_2=2.72 $M_\odot$

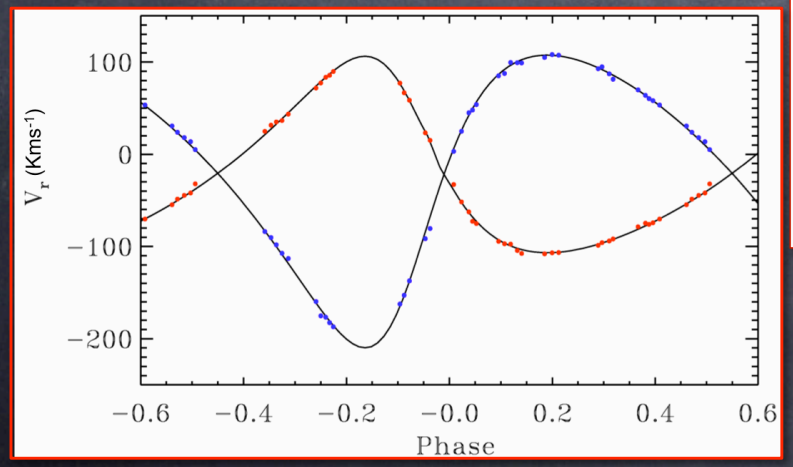
R_1=3.77 R_2=2.04 $R_\odot$

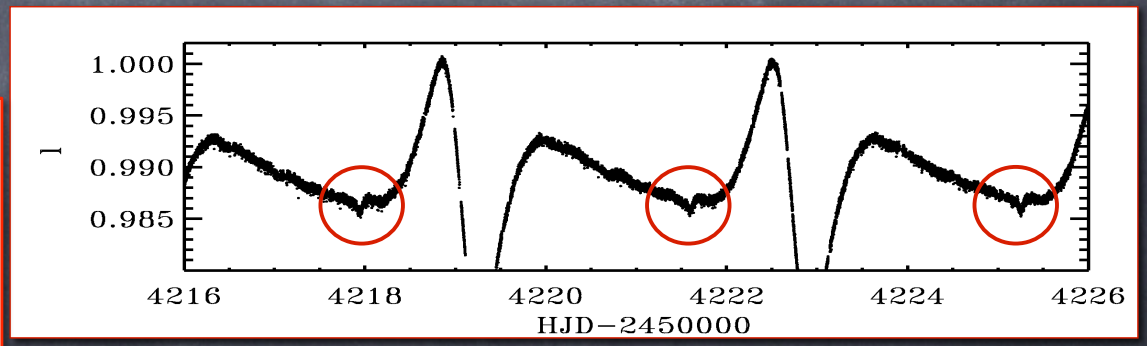
$T_{eff,1}$=13140 T_{eff2}=12044 K

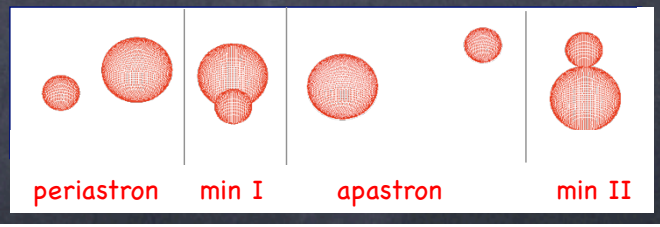
e= 0.29, ω=51.3°, i=75.3°



HERMES spectroscopy

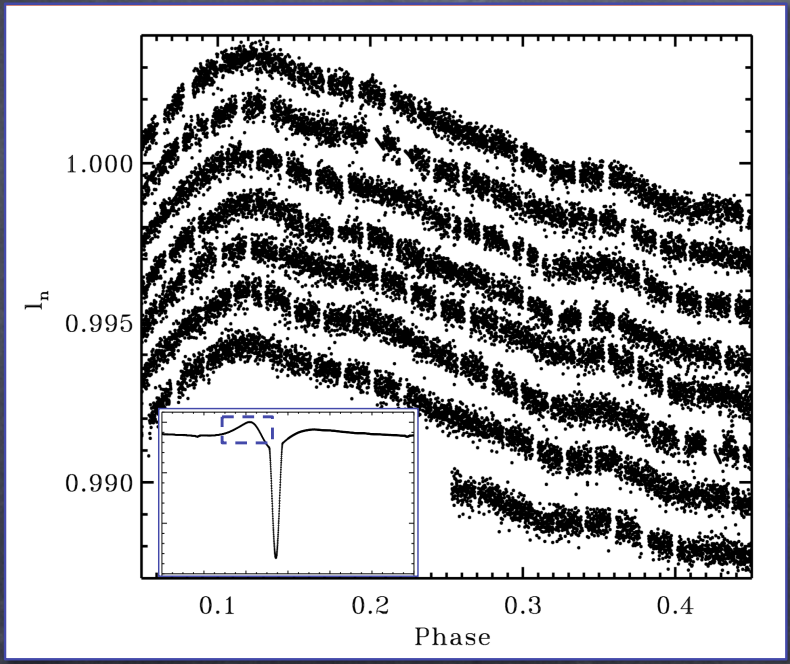




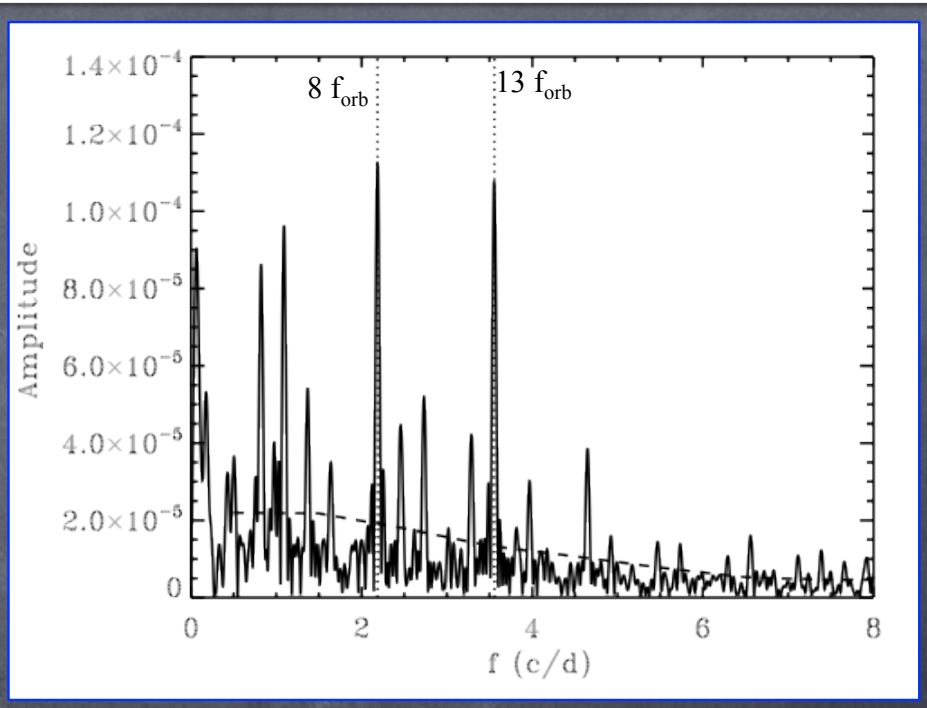


HD 174884, II

Blow-up of the phased light curve each cycle vertically shifted



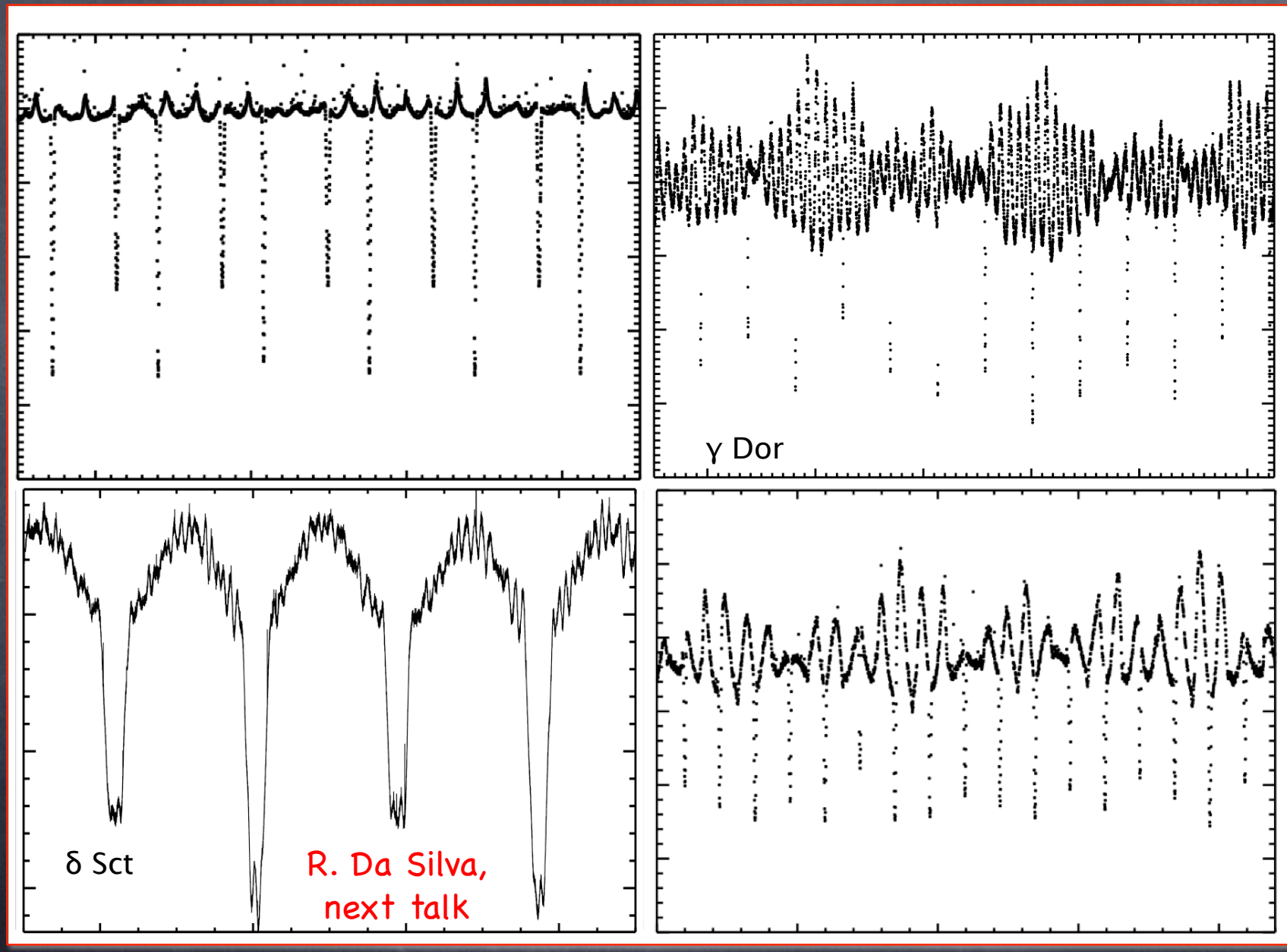
Fourier spectrum of the lc residuals pre-withened with f_{orb}= 0.27345 c/d and 2 f_{orb}

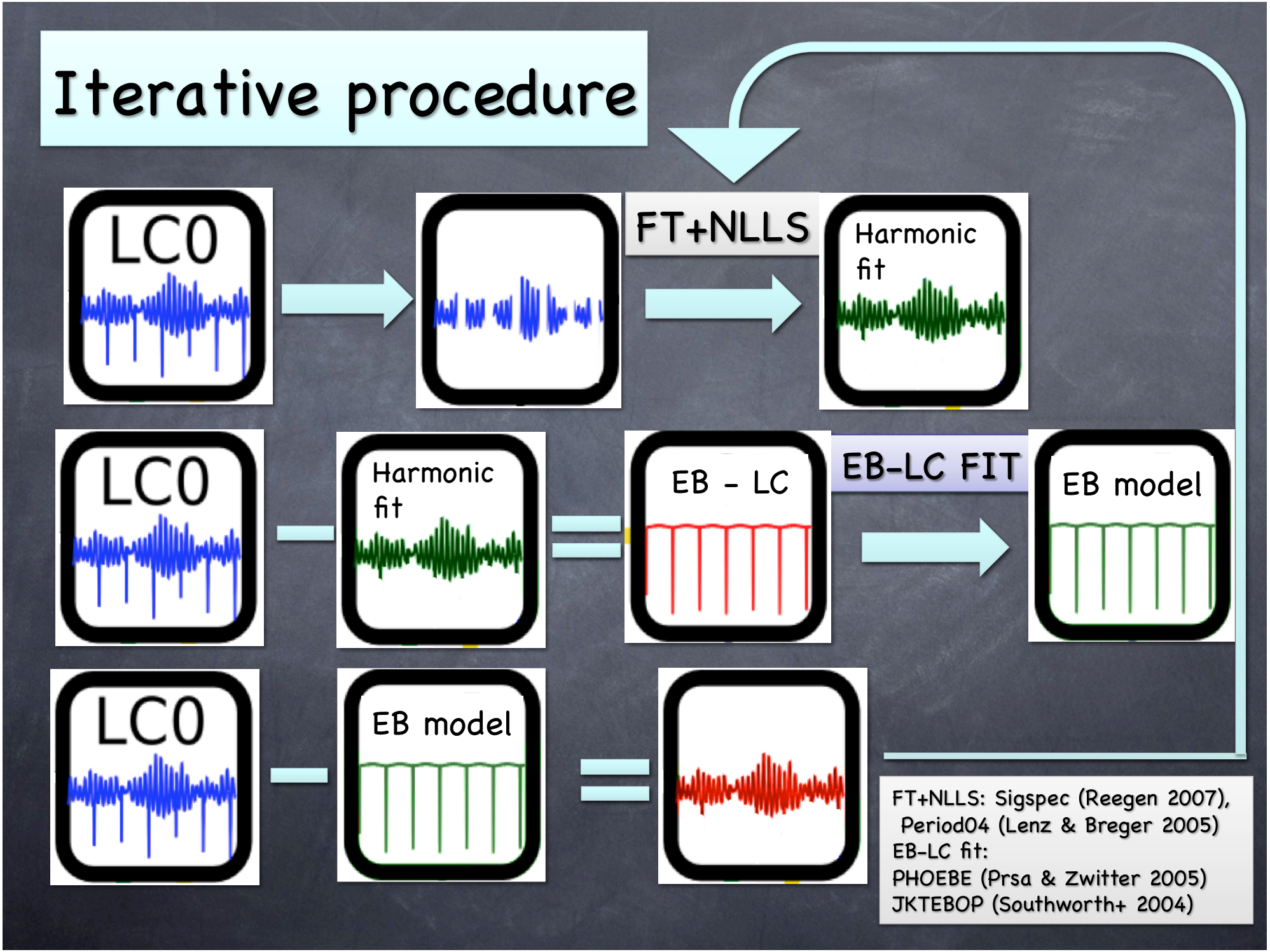


RESULTS

- Tidally induced pulsations (second case after Handler et al. 2002)

The zoo of pulsating exo-EBs




Iterative procedure
LC0
FT+NLLS
Harmonic fit
LC0
Harmonic fit
EB - LC
EB-LC FIT
EB model
LC0
EB model
FT+NLLS: Sigspec (Reegen 2007), Period04 (Lenz & Breger 2005)
EB-LC fit:
PHOEBE (Prsa & Zwitter 2005)
JKTEBOP (Southworth+ 2004)

CoRoT 102918586: γ Dor + EB

(Maceroni, Montalban, Gandolfi, Pavlovski, Rainer 2013, A&A in press)

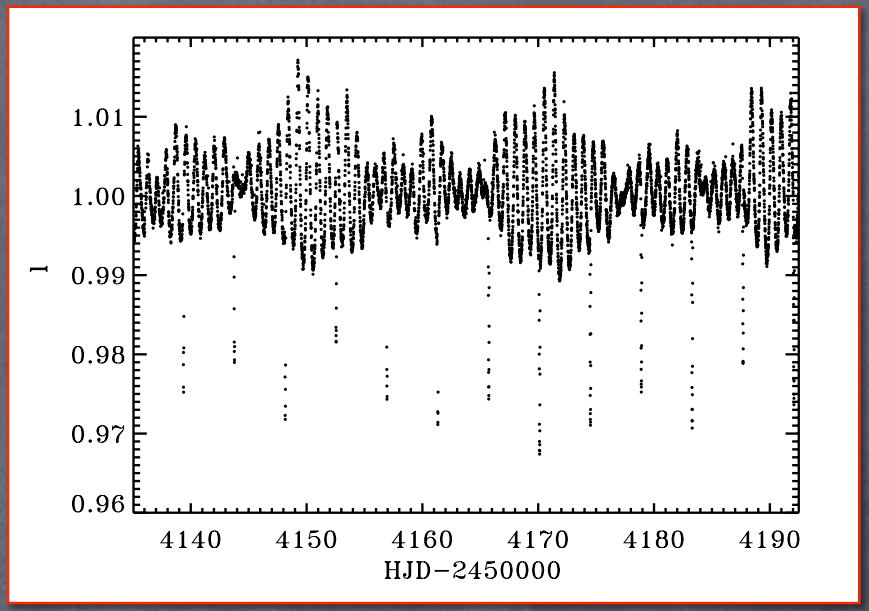
V=12.4, F0V, observed in IRa1 (57d)

Hi-res spectra (R~50000):

- Atmosphere parameters (Teff, log g, metallicity) & vsini from disentangled spectra
- RV curves (masses, radii)

Comparison with stellar models R (t, M, Z..) ⟶ age

- Pulsational analysis



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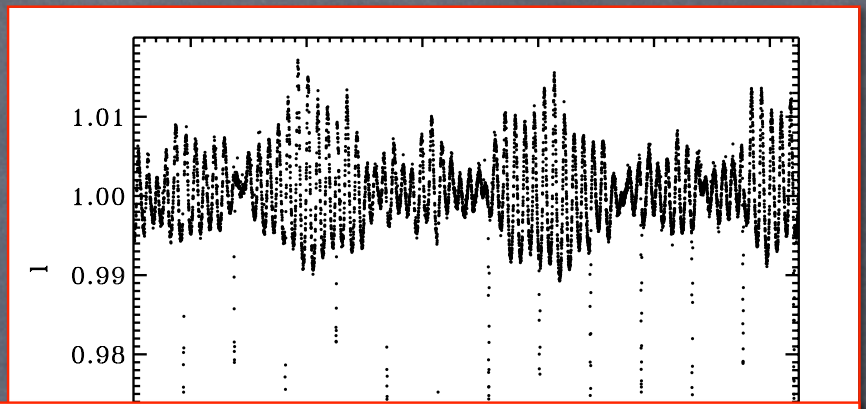
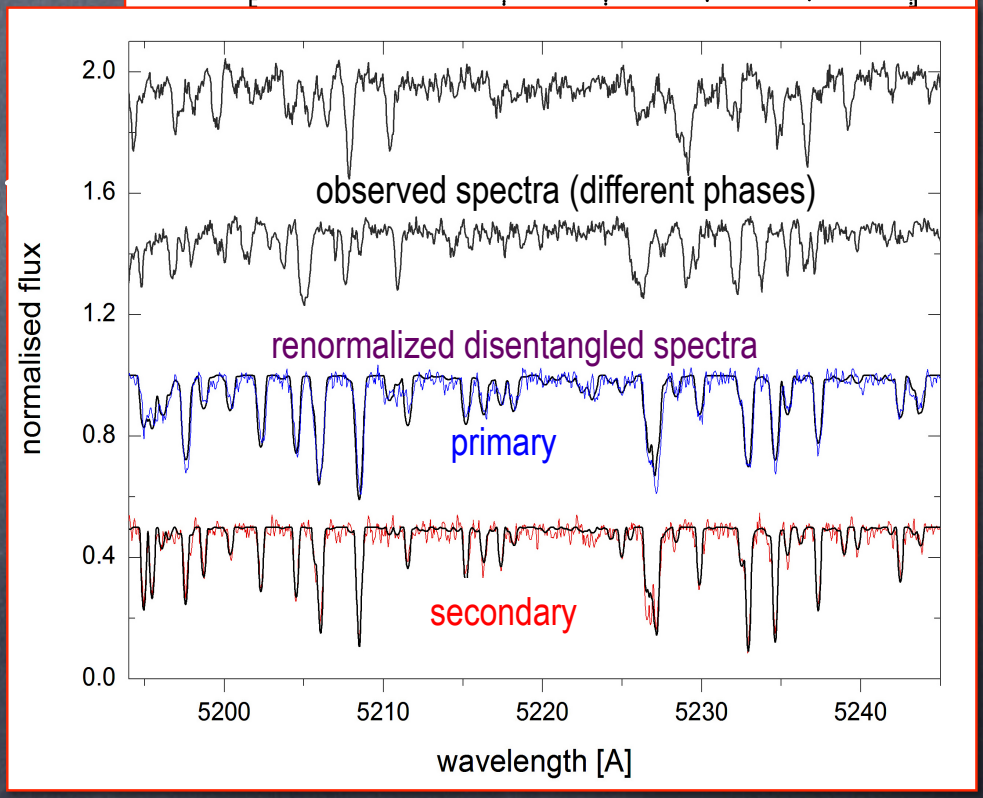
Spectra Disentangling with FDBINARY (Ilijic et al. 2004)





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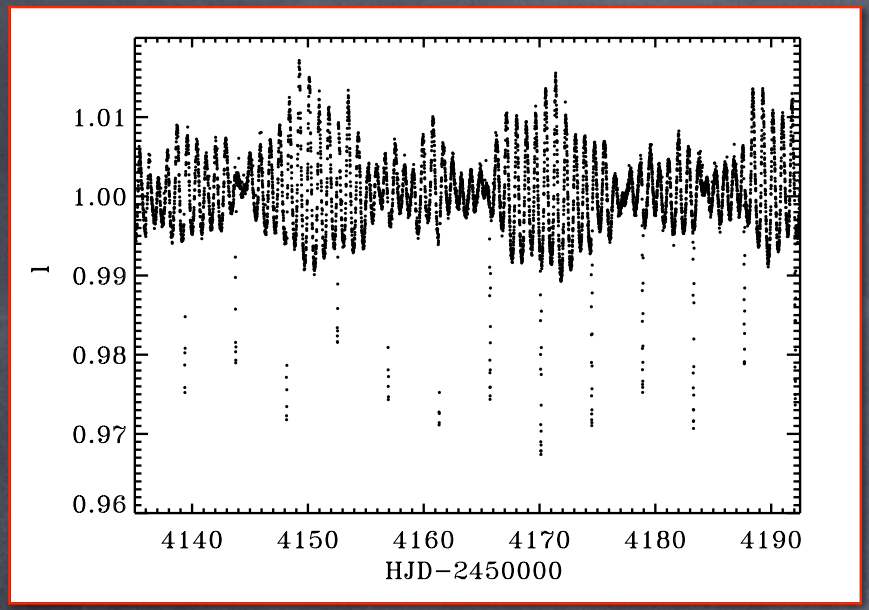

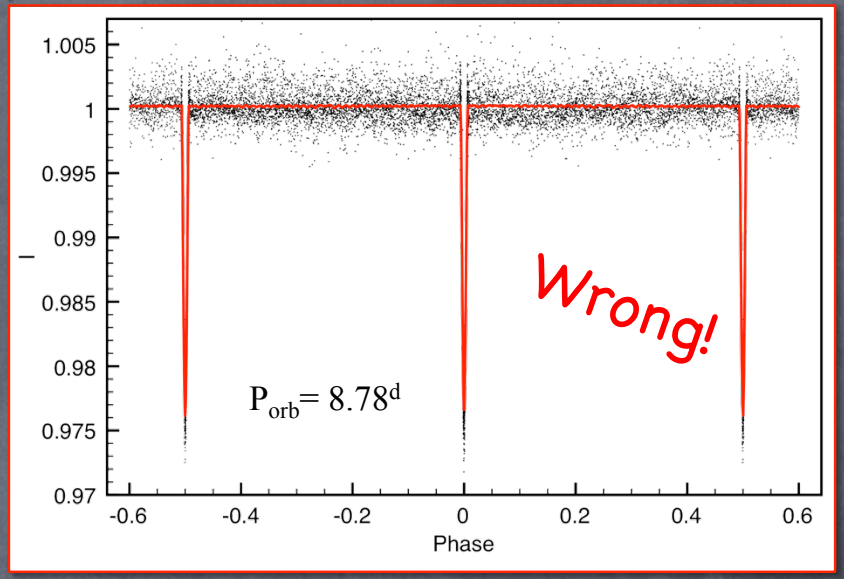

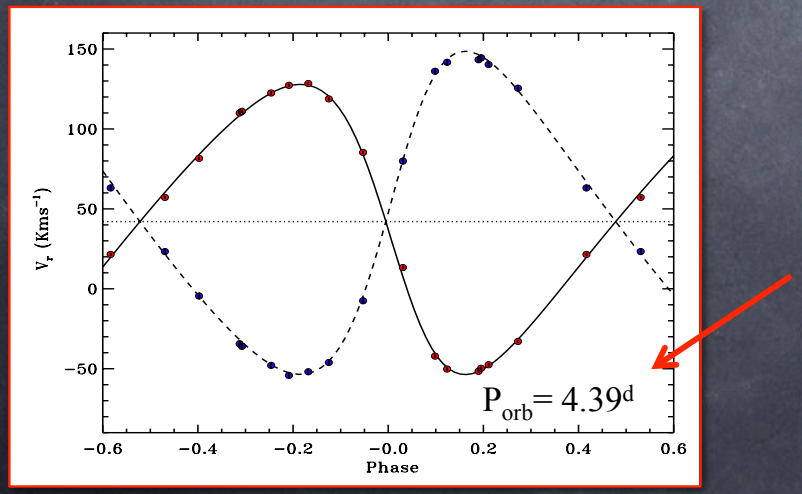

Physical parameters of CoRoT 102918586

	System		
		Primary	Secondary
i (°)	77.66 ± 0.07		
e	0.249 ± 0.005		
ω	$102.6° \pm 1.4$		
q	0.898 ± 0.007		
a ($R_\odot$)	16.53 ± 0.07		
γ (km s^{-1})	42.0 ± 0.4		
$(L_2/L_1)_{\rm CoRoT}$	0.673 ± 0.015		
$T_{\rm eff}$ (K)		$7400^a \pm 90$	7144 ± 150
$M(M_\odot)$		1.66 ± 0.02	1.49 ± 0.03
$R(R_\odot)$		1.64 ± 0.01	1.48 ± 0.01
$\log g$		4.23 ± 0.01	4.27 ± 0.01

a) Fixed value

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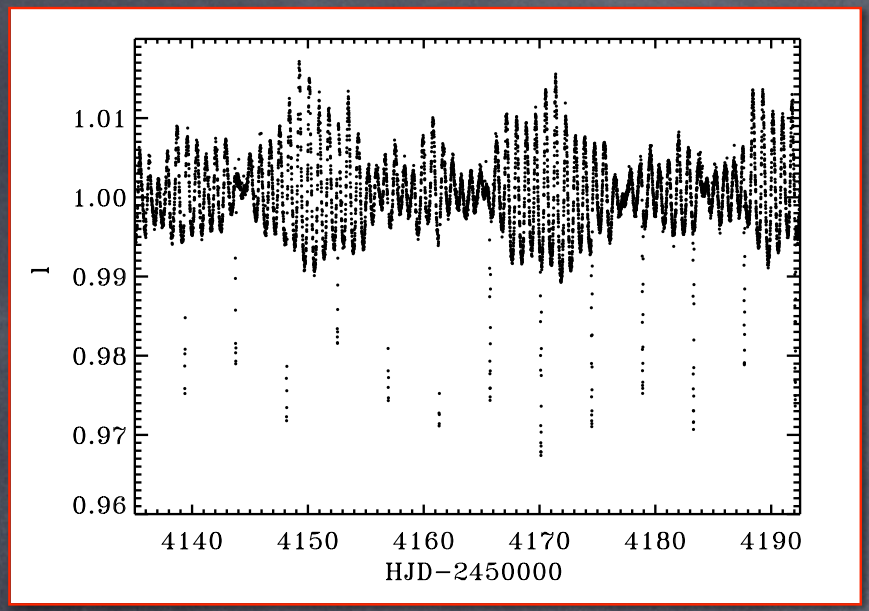
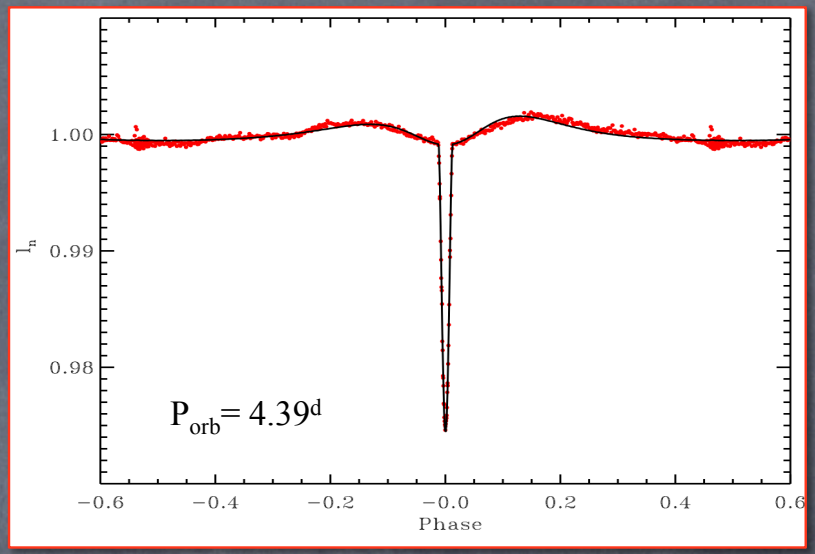
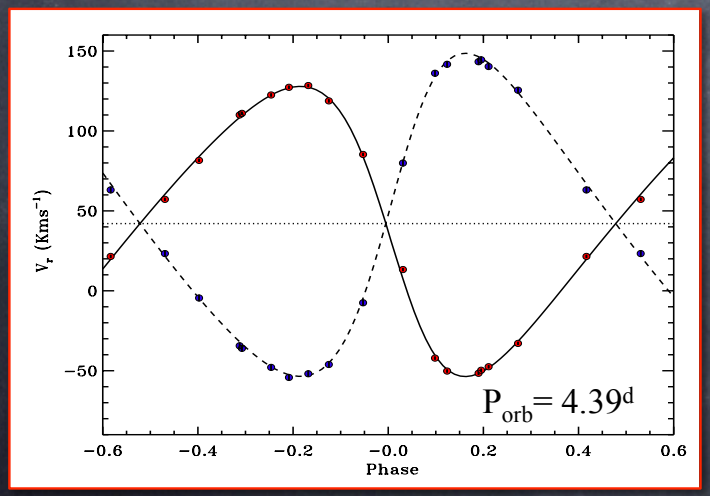
(Maceroni+2013, in press on A&A)







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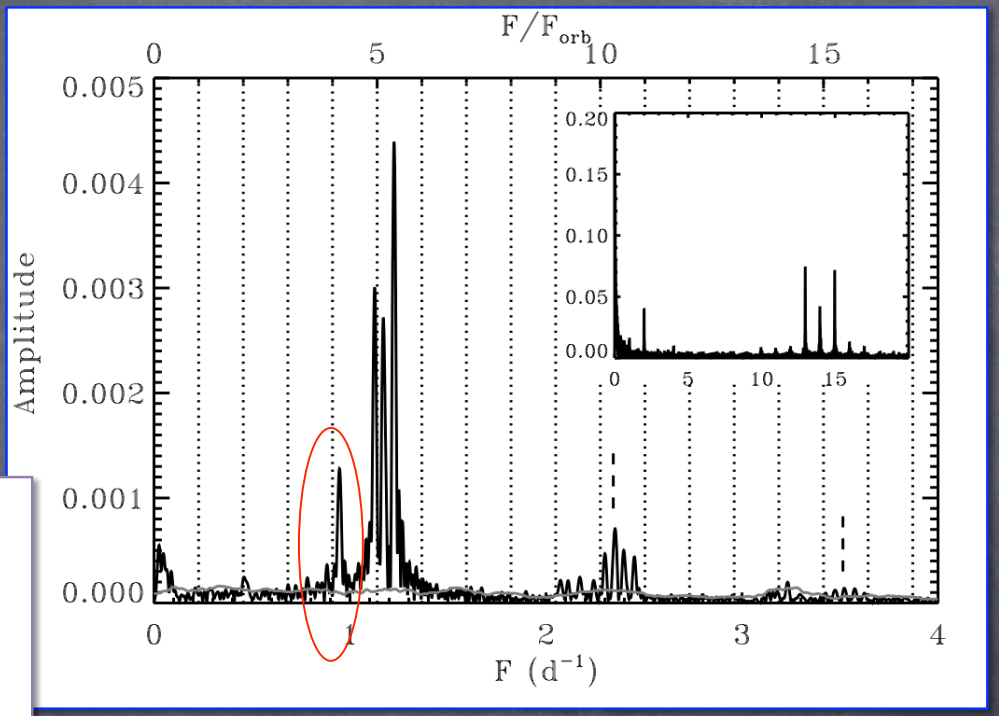
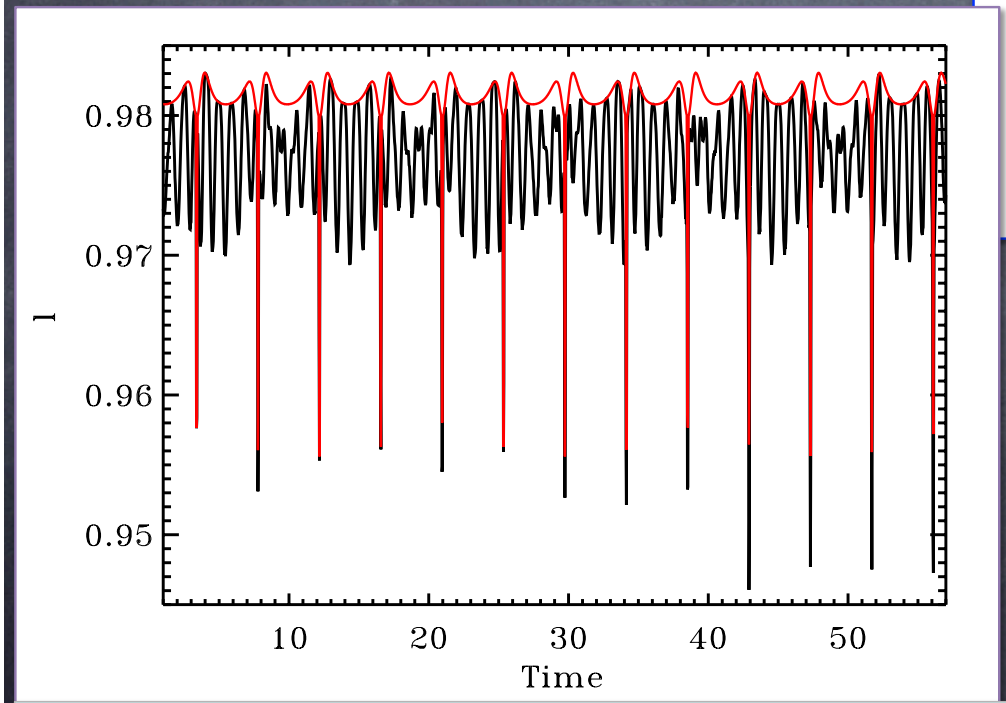
CoRoT 102918586: pulsations?

f1=1.225 d^{-1}
f2=1.125
f3=1.172
f4=0.946 (= f3-f_{orb}; f_{orb}=0.2277)

$f_{rot1} \cong f_{rot2} \cong f_{orb}$





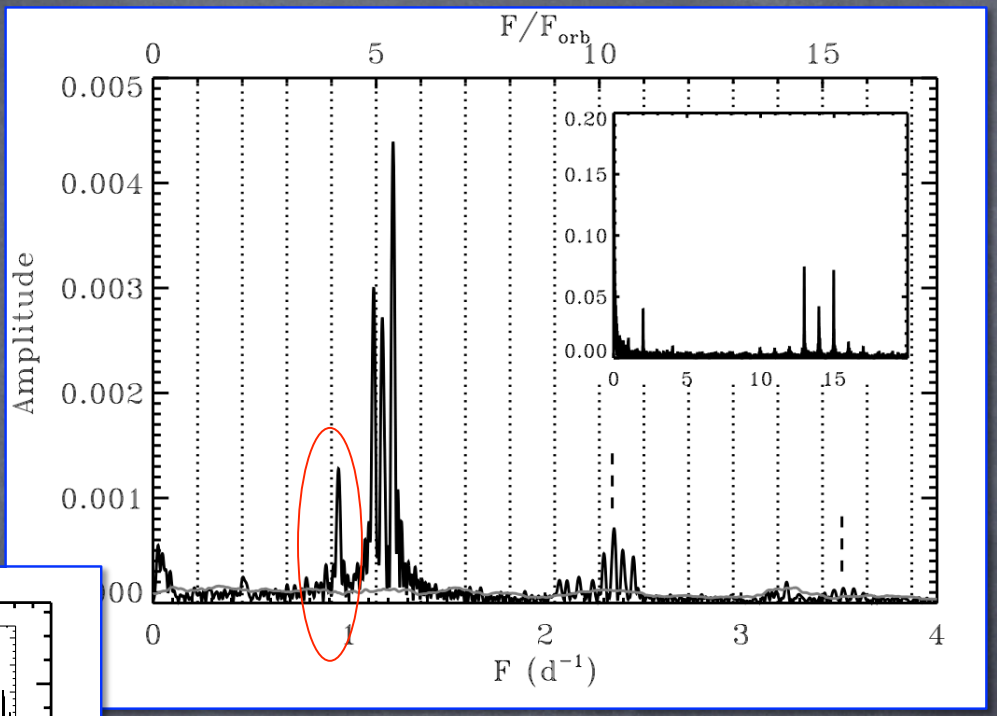
The synthetic lc of an EB with non-synchronous components and a small dark spot on each surface.

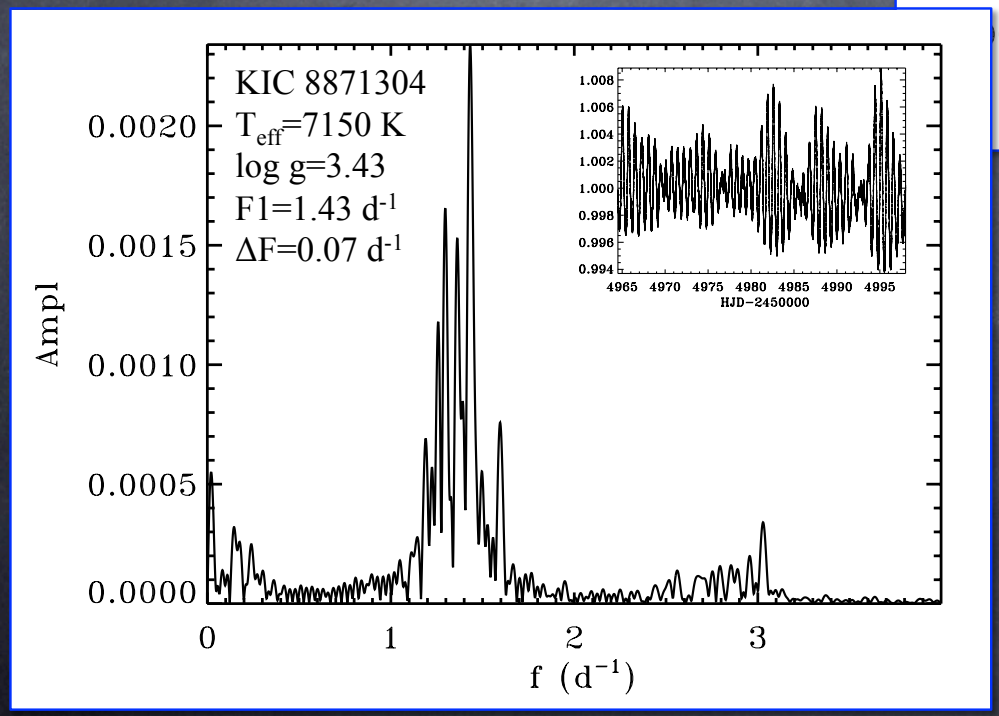
Balona (2011): in *Kepler* γ Dor sample lcs with symmetric variability (SYM) can be due to rotation + surface inhomegeneities (spots +differential rotation).

CoRoT 102918586: pulsations

f1=1.225 d^{-1}
f2=1.125
f3=1.172
f4=0.946 (= f3-f_{orb}; f_{orb}=0.2277)

g-modes:
Observed spacing in period
$\Delta P = 0.036 \pm 0.001^{d} = 3110^{s} \pm 90^{s}$





Asymptotic ΔP for ℓ =1 modes:

	PRIMARY	SECONDARY
No OV	3070-3200s	2800-3030s
α_{OV}=0.2	3300-3390s	3160-3300s

CoRoT 102918586: conclusions

- Successful disentangling of pulsations from orbital effect in a difficult and ambiguous case (thanks to spectroscopic follow-up)
- Physical parameters determined with 1-2% accuracy with a grazing, single eclipse
- Binarity does not affect pulsation (no orbital overtones, agreement of the period split with l=1 and not l=2 modes) Possible explanation: smaller fractional radii with respect to tidally excited systems as HD 174884 or HD 209295 (Handler+2002).

A low-mass binary in LRa03

D. Gandolfi, C. Maceroni, G. Sokol, J. Montalban, H. Bruntt, R. Da Silva, M. Fridlund, A. Hatzes, T. Mazeh & the SOPHIE team (work in progress)

P=7.927d, V=12.8 SpT(prim)=F9 IV

SOPHIE spectra:

T_{eff1} = 6030 ± 80 K; log g = 3.50 ± 0.10

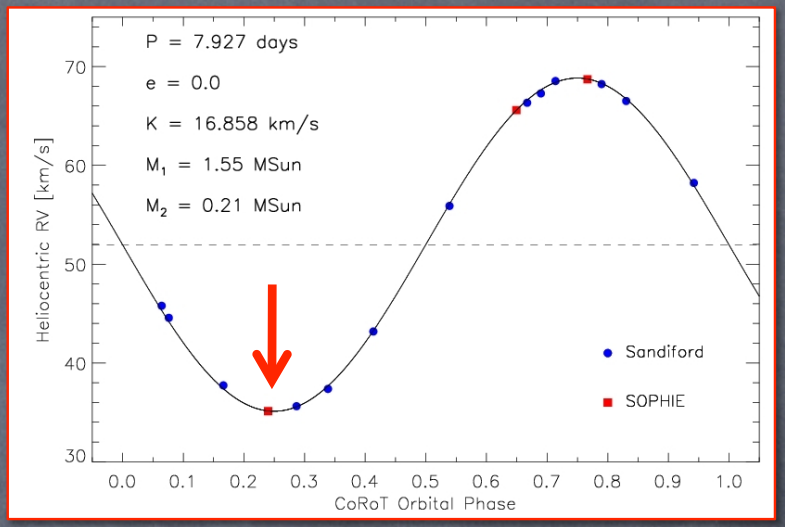
[m/H] = -0.36 ± 0.10 vsini=11 ± 1 kms^{-1}

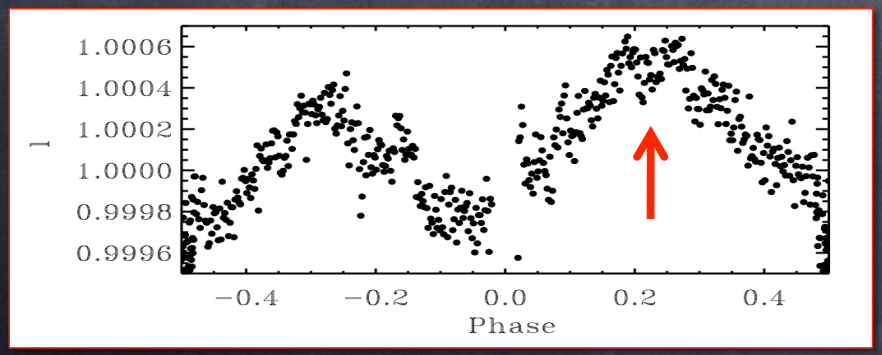
Light + RV modeling (PHOEBE):

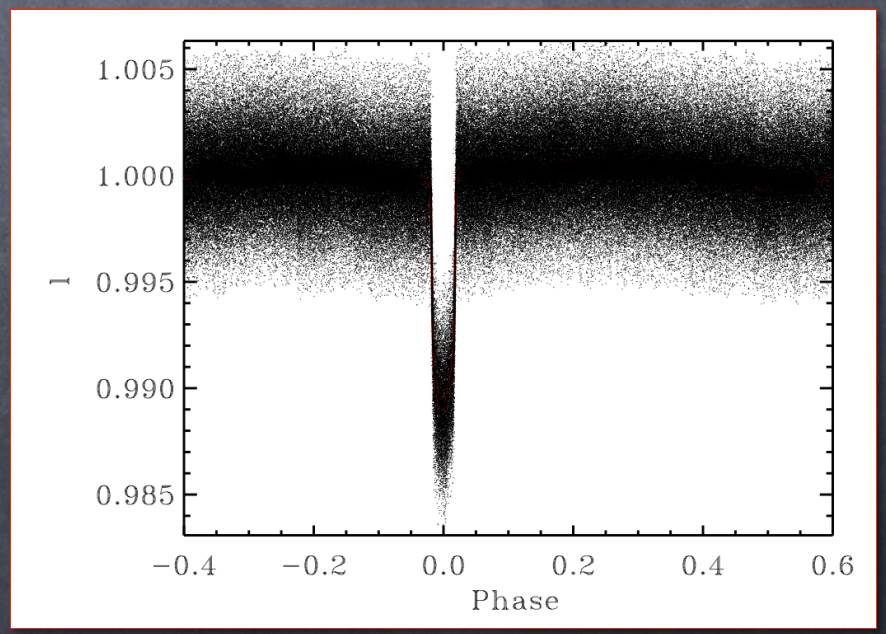
M_1=1.5 $M_\odot$ T_{e1}=6030 K R_1=2.6 $R_\odot$

M_2=0.23 $M_\odot$ T_{e2}=3000 K R_2=0.25 $R_\odot$

low mass companion (late M)







Beaming effect?

Out of eclipse variations were modeled with the BEER (BEaming Ellipsoidal Reflection) algorithm (Faigler+2012) by the Tel Aviv Univ. group.

Peak to peak amplitude in BB radiation approximation (Zucker+ 2007)

$$\frac{\Delta F_\nu}{F_\nu} = \frac{1}{c}\frac{K_1[3-\alpha_1(\nu)]F_{\nu,1} - K_2[3-\alpha_2(\nu)]F_{\nu,2}}{F_{\nu,1}+F_{\nu,2}}$$

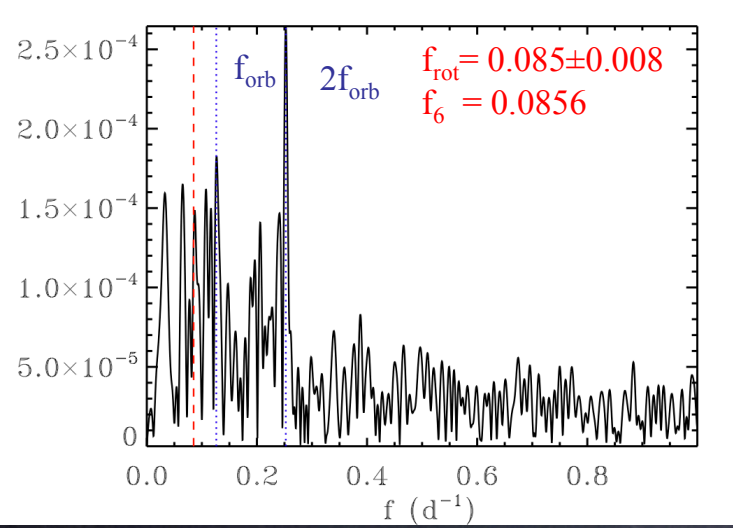
α : mean spectral index

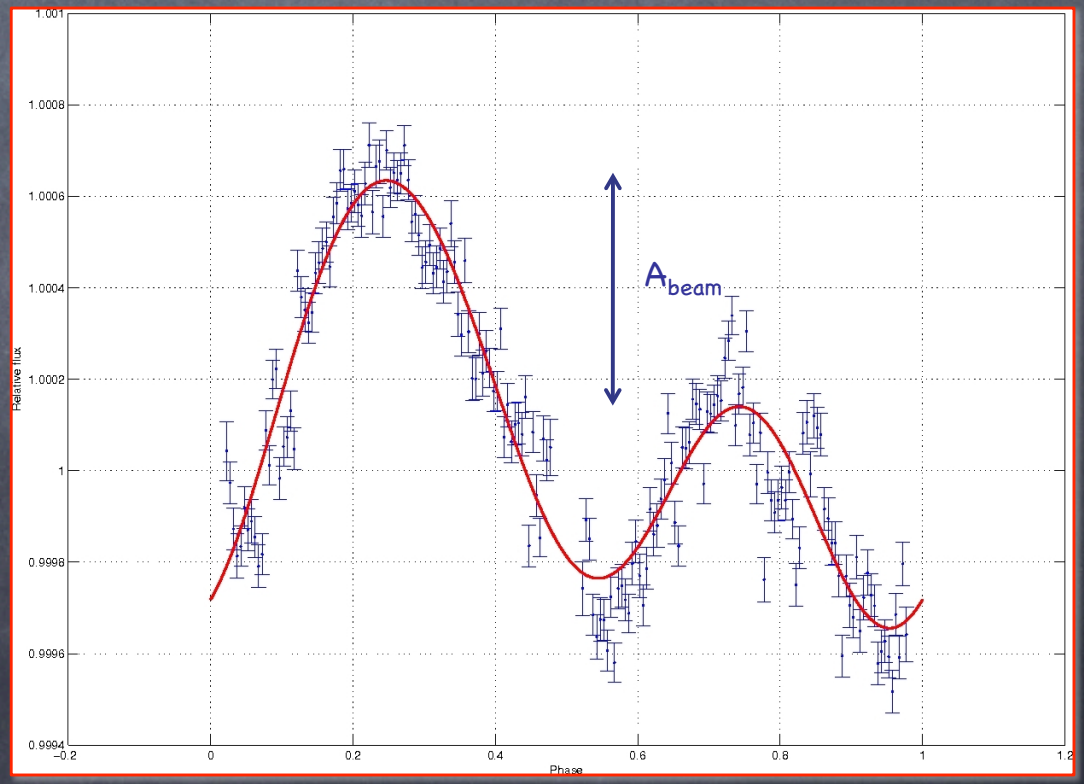
$$F_\lambda = F_{\lambda,0}\left(1 - B\frac{V_r}{c}\right)$$

A_{beam} = 281.2 ± 0.5 ppm

K_B = 21±2 Kms^{-1}

K_{RV}= 17±0.1 Kms^{-1}





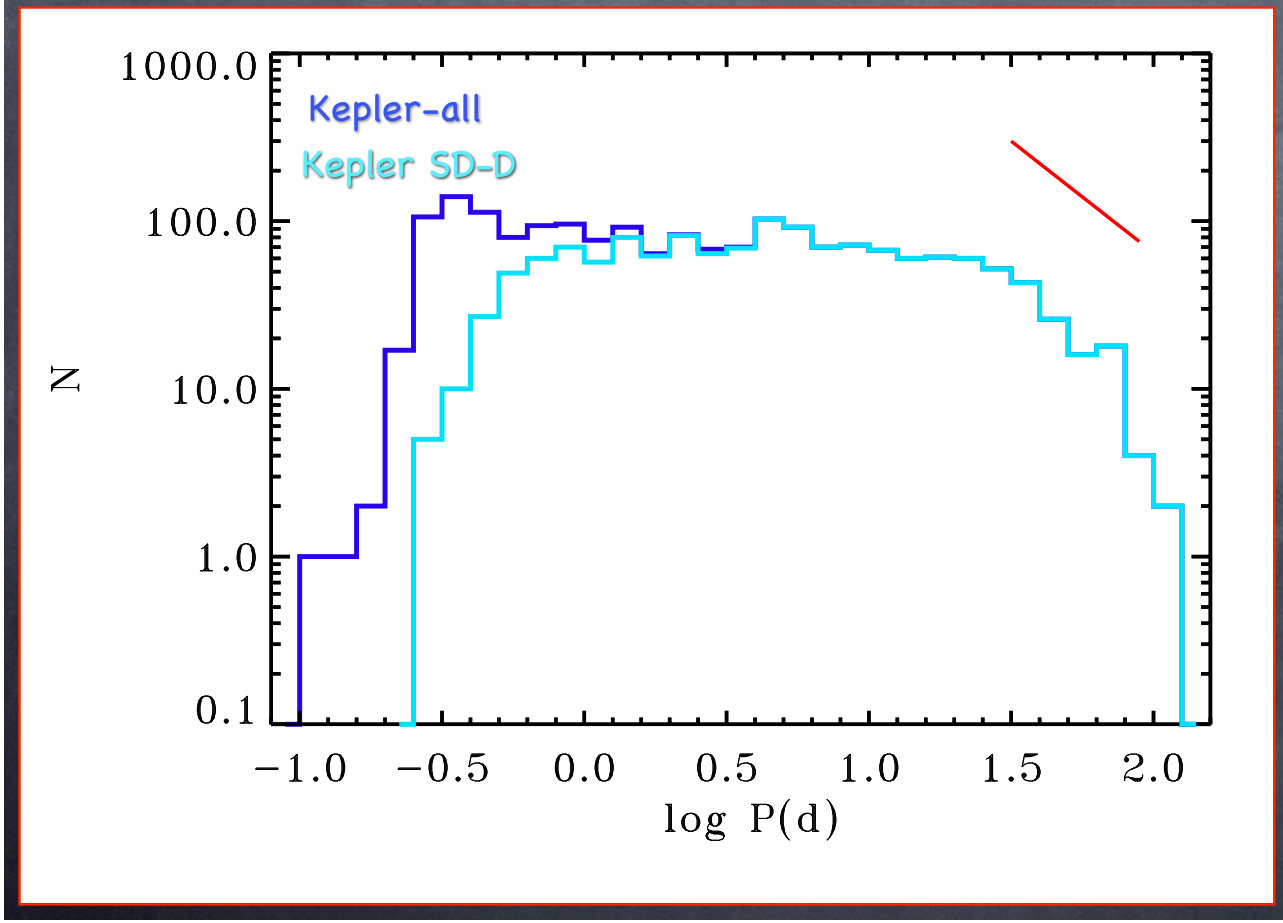
What next?

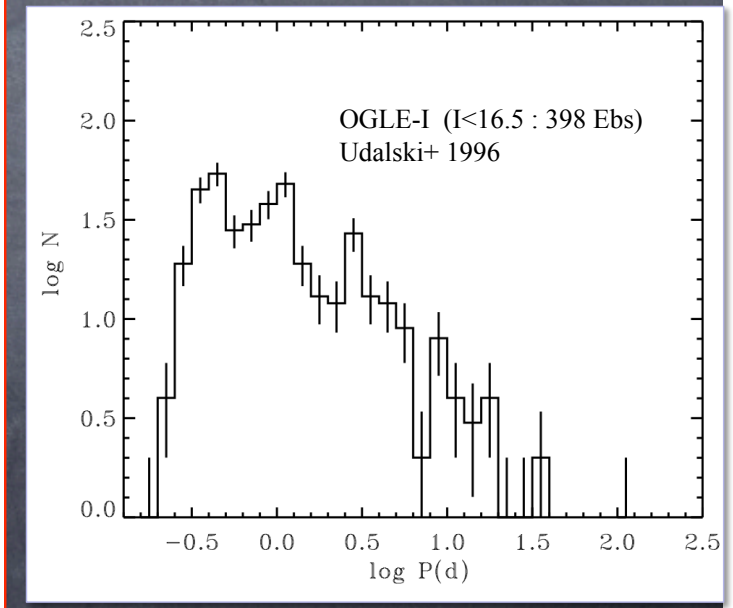
- Case studies: a seismo bright EB – SB2 of ζ Aur type (Bstar + giant) important for evolutionary model tests.
- Further studies of PEBs (role of tidal forces)
- EBs with giant components (independent test of scaling relations)
- CoRoT legacy EB catalog?
  Kepler EB catalog

Period distribution

Kepler: Q0, Q1, Q2 quarters, baseline 125^{d}: 2187 EBs (Slawson+2011)

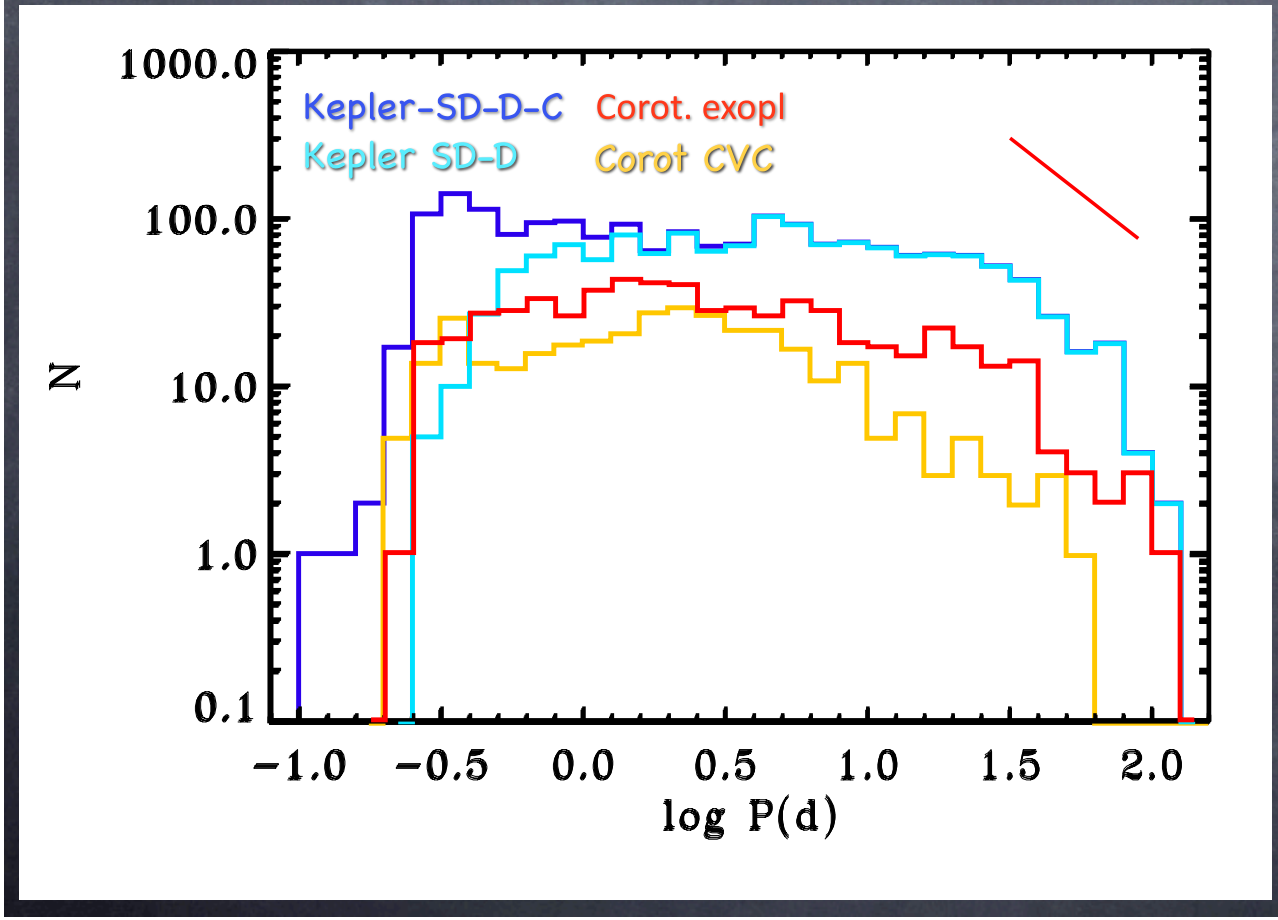
- with periods: 2133 (D, SD, OC, ELV)
- D + SD + OC: 1850
- D + SD: 1381





Period distribution

CoRoT samples: IRa1, LRc1, LRa1, baseline (57 – 130 d)
CoRoT exoplanet sample: 585 (Cabrera+2009,Carpano+2009, Carone+2012..)
CoRoT – CVC sample 349 EBs (Sarro+2009, Debosscher)



Resulting distribution depend on the algorithm; CVC tends to miss long period Ebs (narrow eclipses), Exo-lists close (contact binaries)

Matching and critical comparison of different sources is needed to establish the legacy catalog.

Thank you for your attention!