

Physical link between simultaneous photometry and radial-velocity observations

Application to CoRoT-7 system

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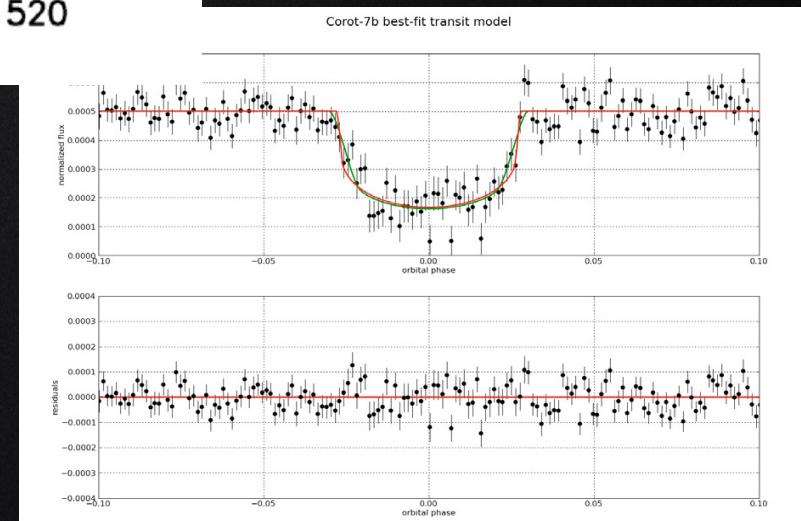
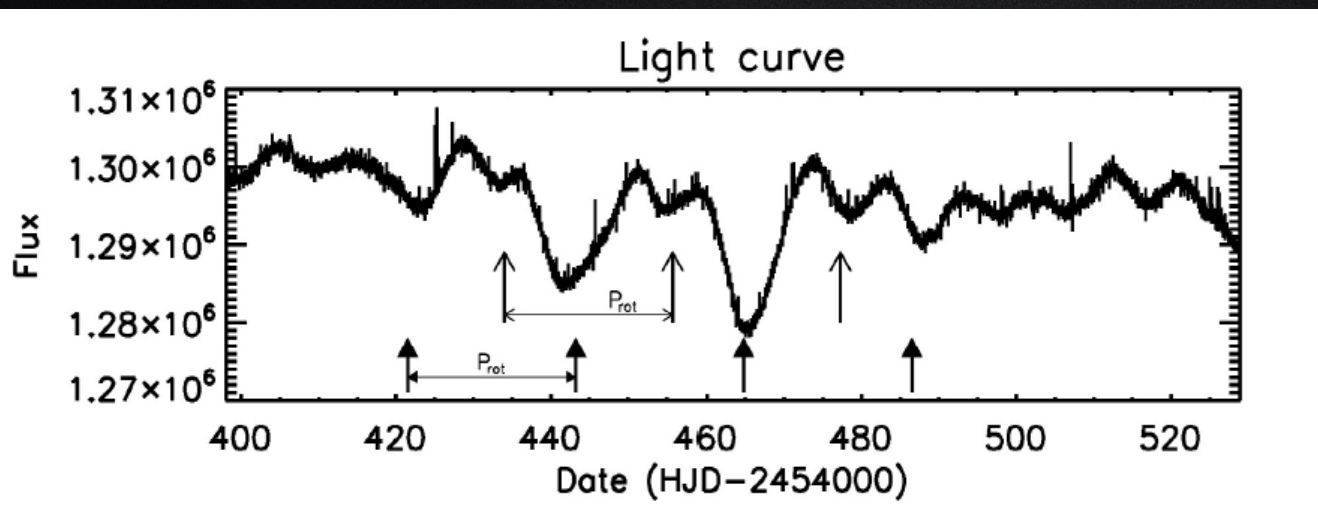
Collaborators: S. Barros, I. Boisse, G. Bruno, M. Deleuil, X. Dumusque,
J. Faria, A. Santerne, N. Santos

Outline

- CoRoT-7 history
- Simultaneous high precision RV and photometry
- Our methodology
- Applying it on CoRoT-7
- Conclusions

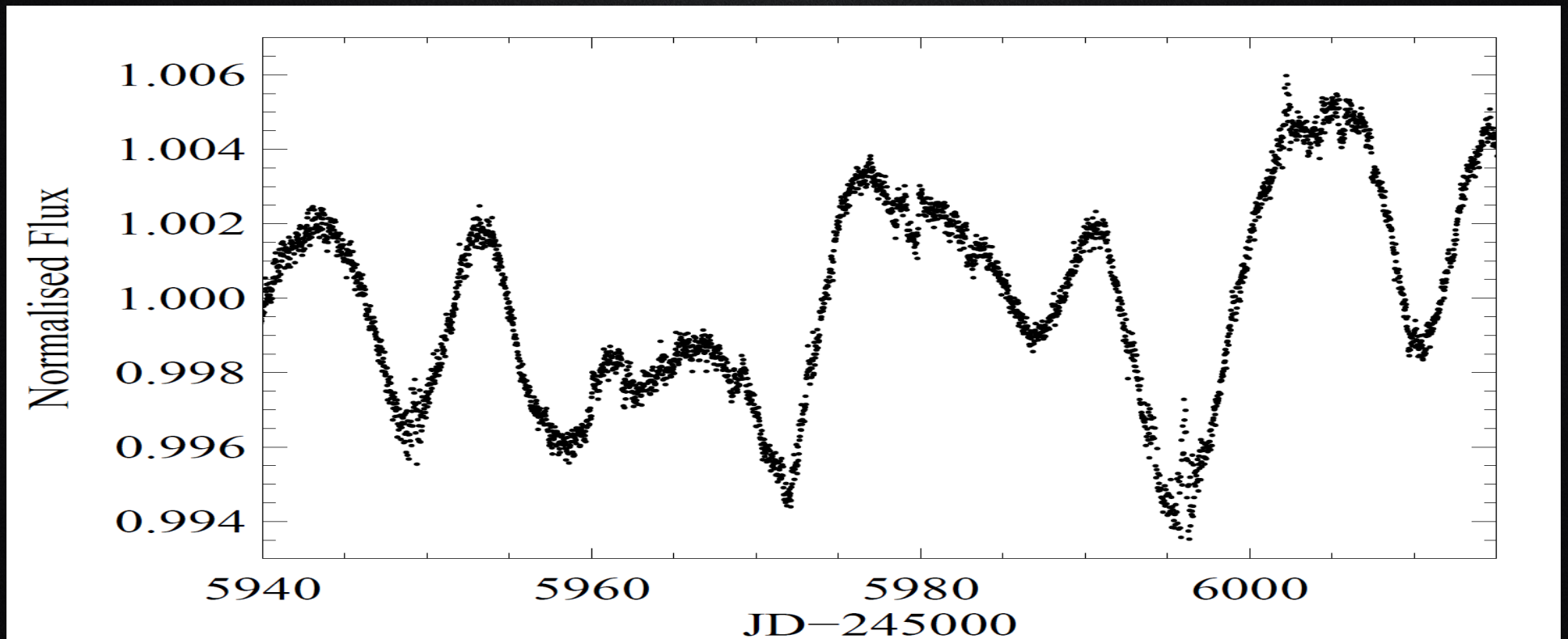
CoRoT-7 history

Transiting planet CoRoT-7b, was discovered with CoRoT telescope, with an orbital period of 0.85 days and radius of 1.68 R_e (Leger+09)



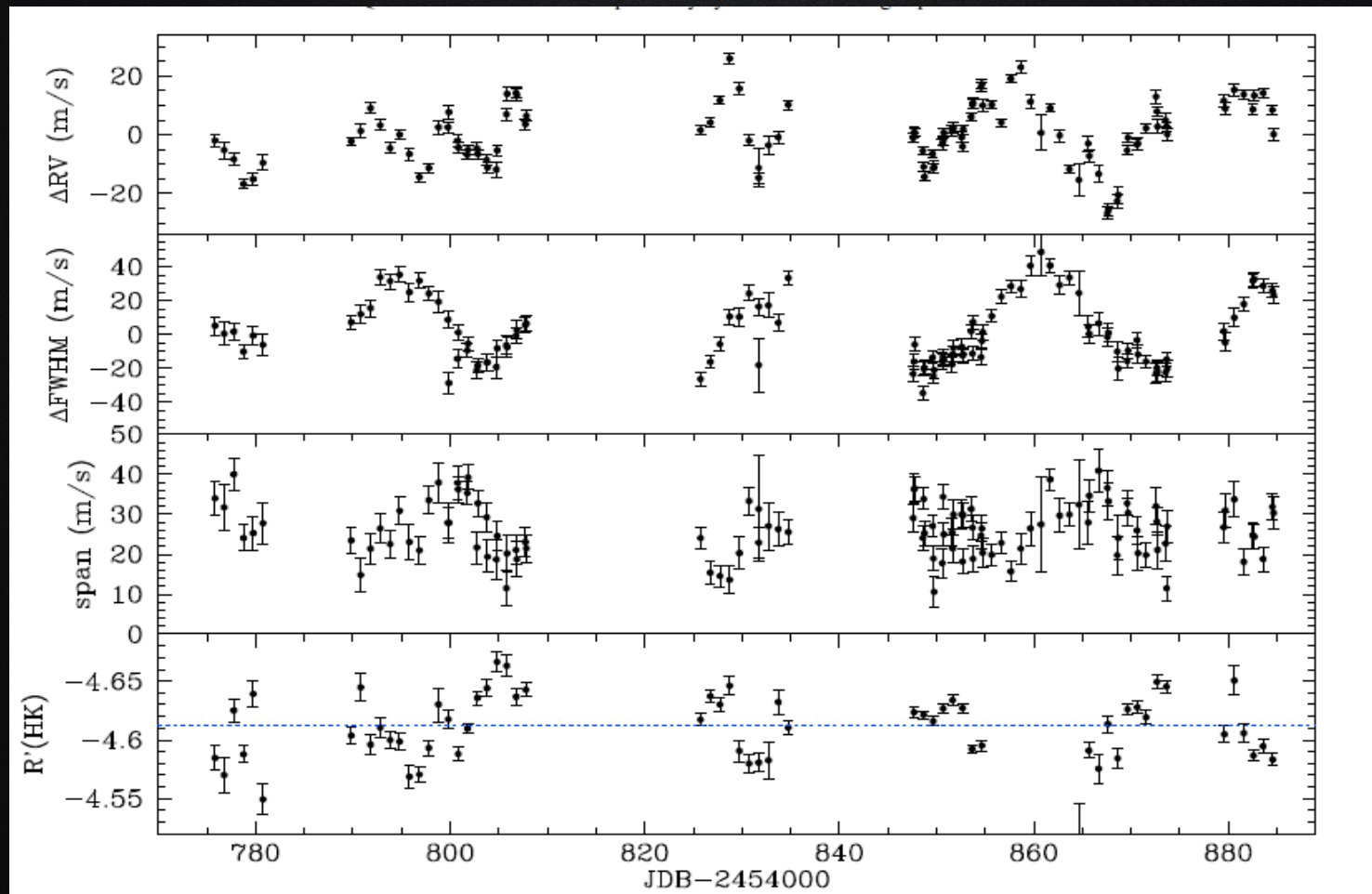
CoRoT-7 history

CoRoT-7 is an active star, which shows 2% flux modulation (e.g., Barros+14). Thus, analyzing its RV signal to confirm and characterize CoRoT-7b has never been an easy task.



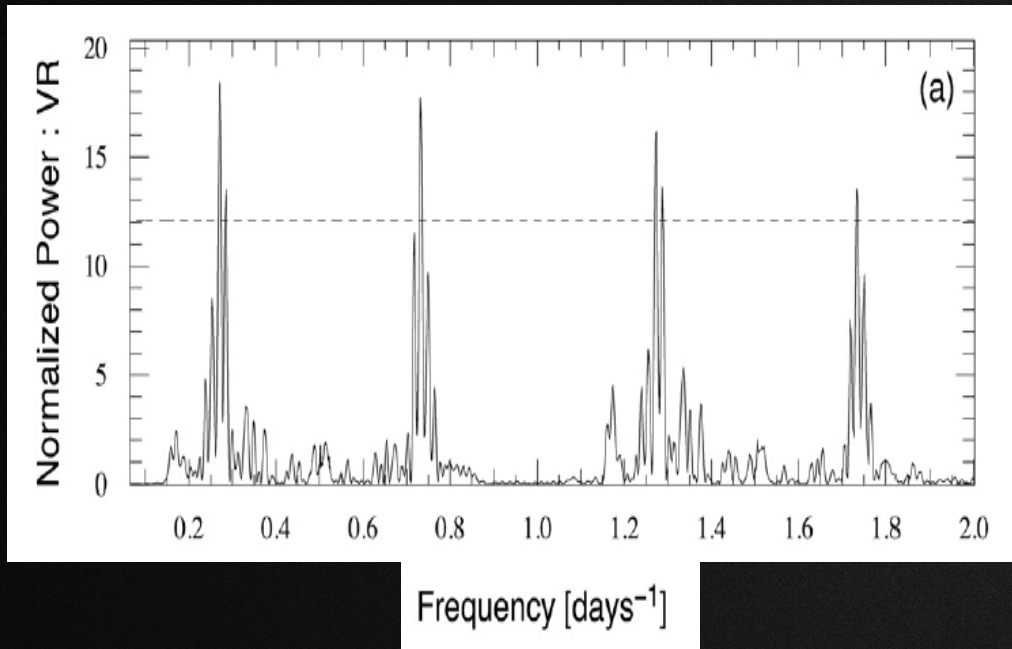
CoRoT-7 history

A 4-month intensive HARPS campaign was performed to measure the mass of CoRoT-7b (Queloz+09). In order to remove the activity induced RV signal most studies have applied different type of filtering mechanism to remove it properly.

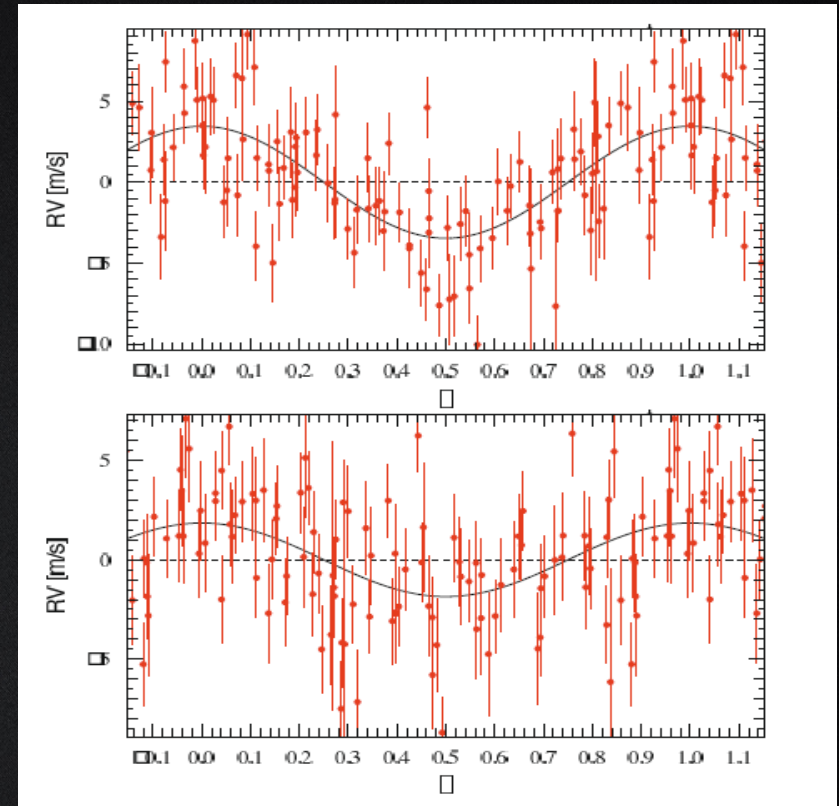


Queloz+09

CoRoT-7b and c

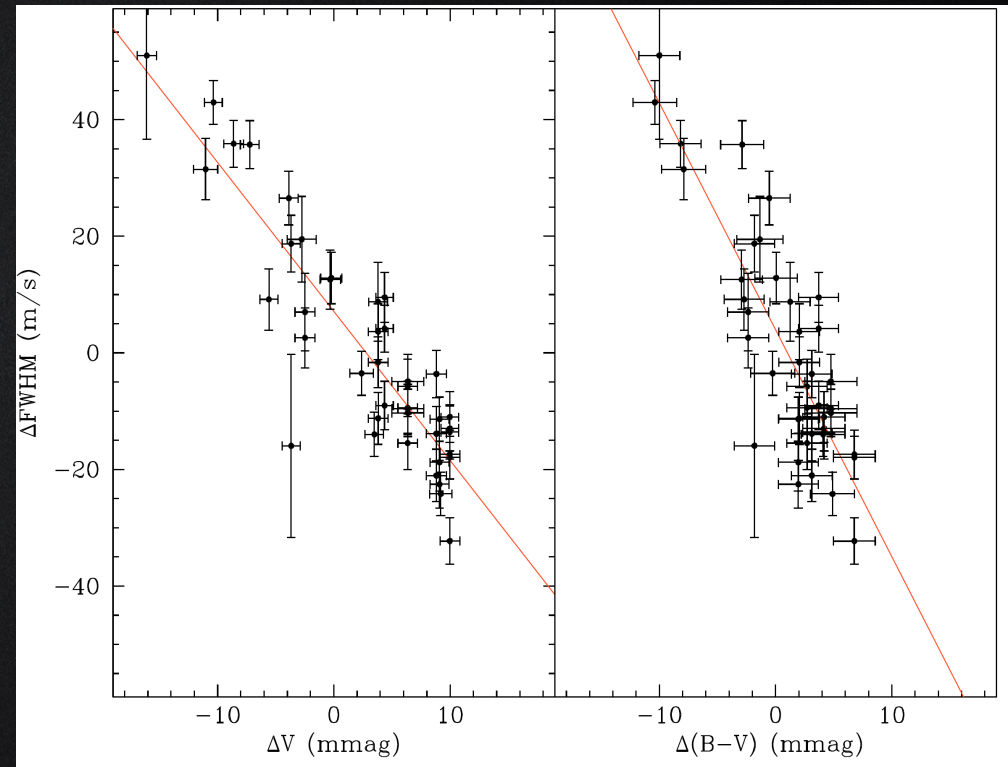
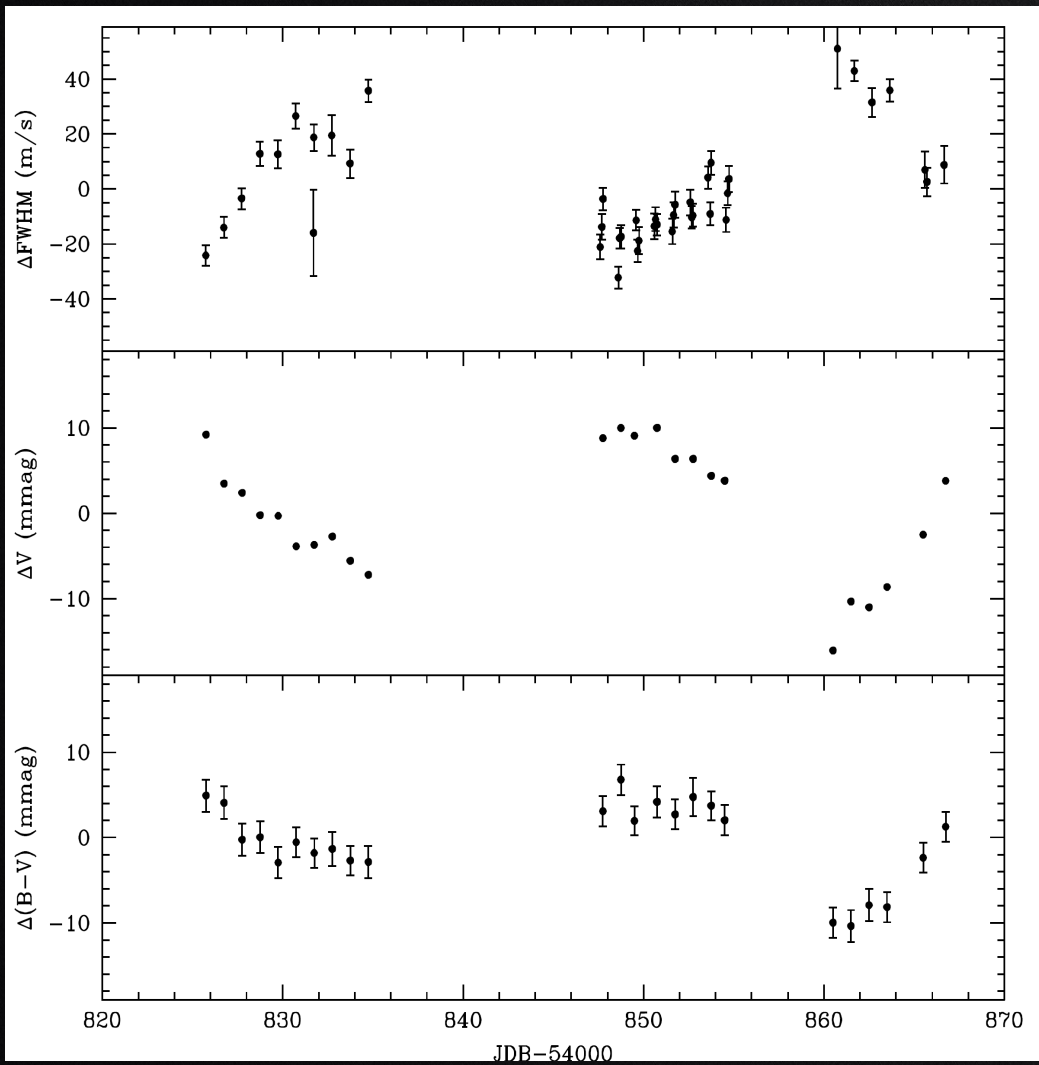


Queloz+09



CoRoT-7b	CoRoT-7c	Reference
$4.8 \pm 0.8 M_{\oplus}$	$8.4 \pm 0.9 M_{\oplus}$	Queloz et al. (2009)
$6.9 \pm 1.4 M_{\oplus}$	$12.4 \pm 0.42 M_{\oplus}$	Hatzes et al. (2010)
$7.42 \pm 1.21 M_{\oplus}$	-	Hatzes et al. (2011)
$2.3 \pm 1.8 M_{\oplus}$	-	Pont et al. (2011)
$5.7 \pm 2.5 M_{\oplus}$	$13.2 \pm 4.1 M_{\oplus}$	Boisse et al. (2011)
$8.0 \pm 1.2 M_{\oplus}$	$13.6 \pm 1.4 M_{\oplus}$	Ferraz-Mello et al. (2011)
$4.8 \pm 2.4 M_{\oplus}$	$11.8 \pm 3.4 M_{\oplus}$	Tuomi et al. (2014)
$4.73 \pm 0.95 M_{\oplus}$	$13.56 \pm 1.08 M_{\oplus}$	Haywood et al. (2014)
$5.52 \pm 0.78 M_{\oplus}$	-	Barros et al. (2014)

FWHM as flux



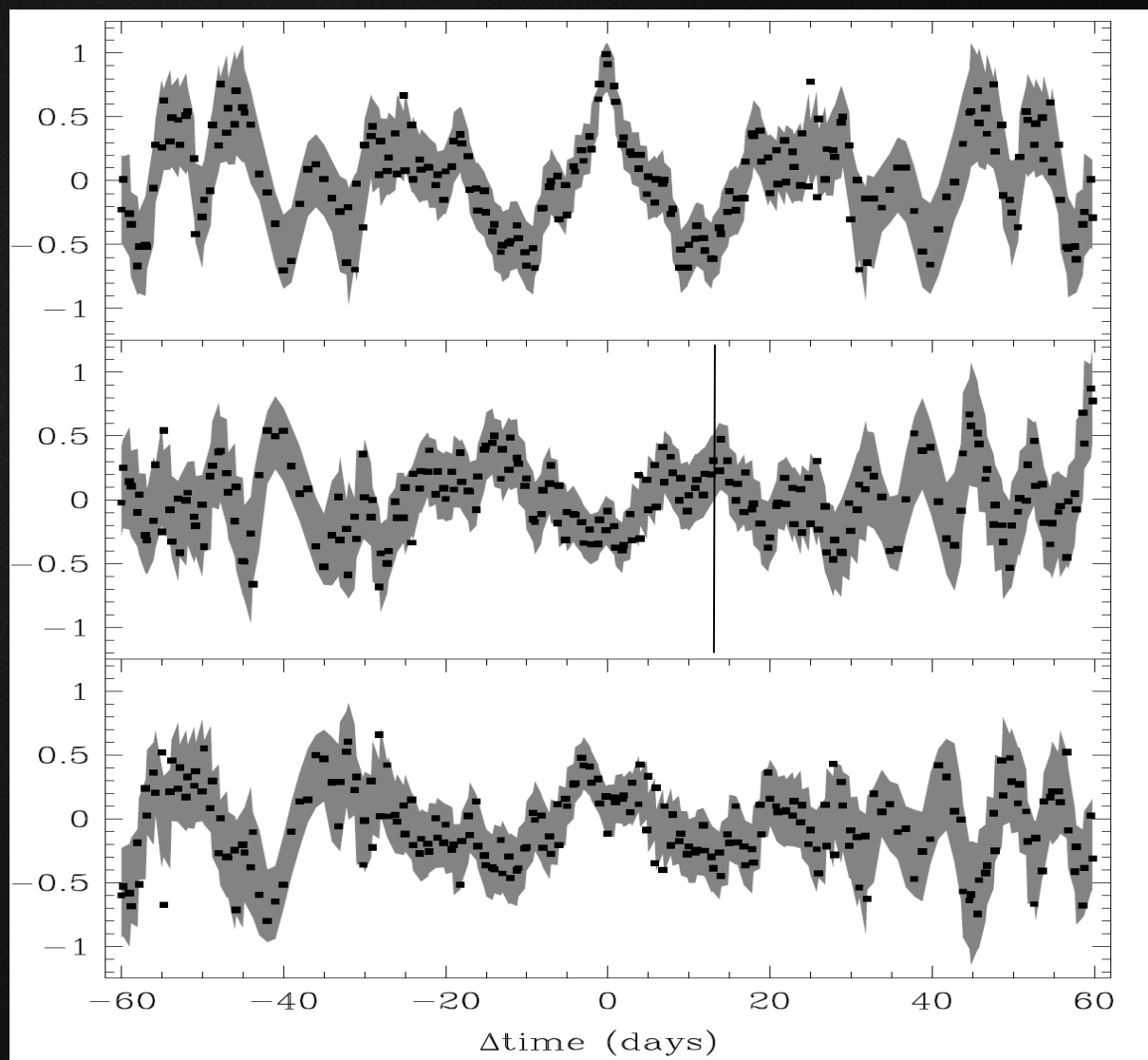
Queloz+09

FWHM and BIS showed a time shift with RV

Autocorrelation of RV

Correlation between RV and FWHM

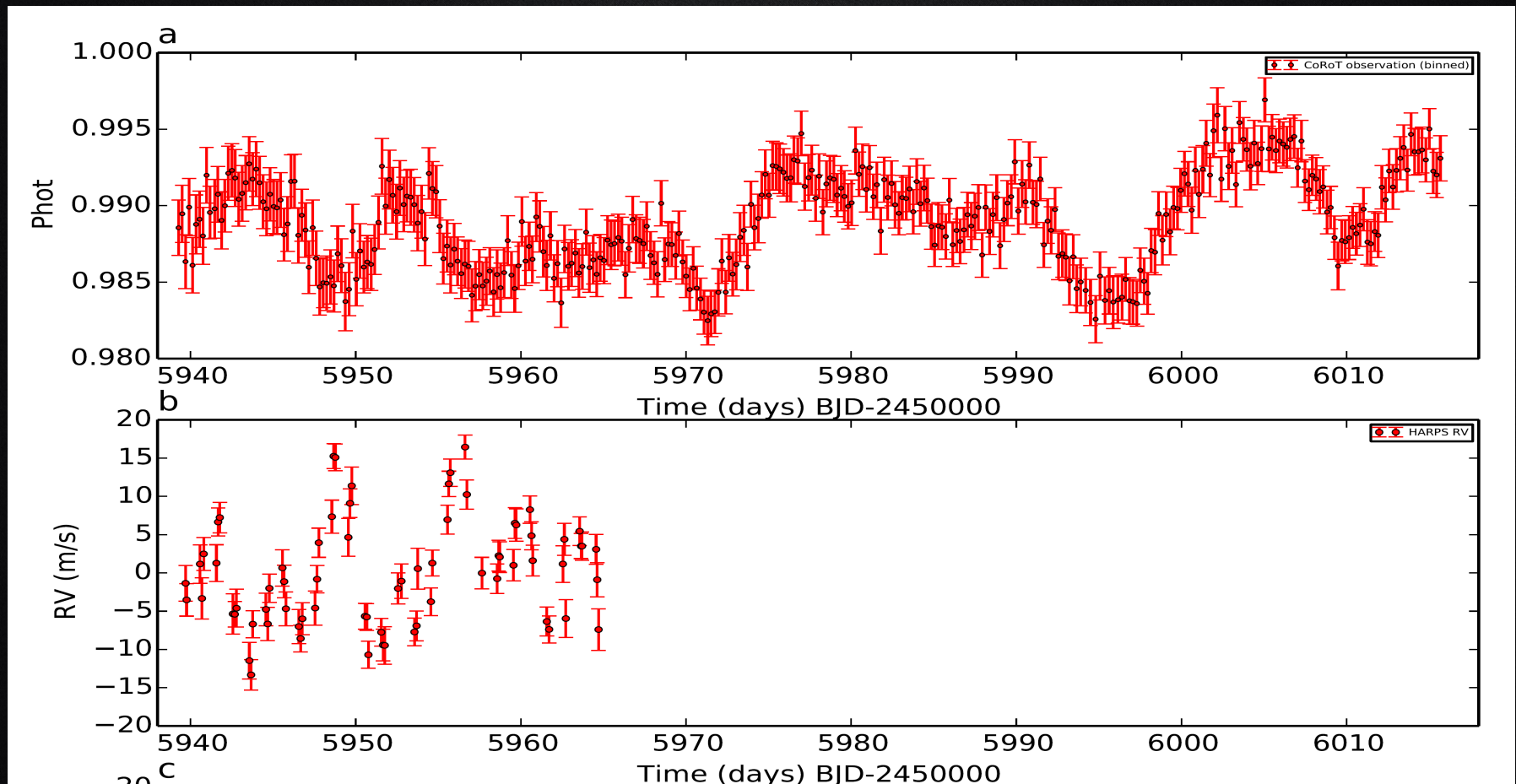
Correlation between RV and BIS



Queloz+09

Simultaneous RV and photometry

The photometric observations of CoRoT-7 were obtained by the CoRoT satellite during the run LRa06 from 10th of January to 29th of March 2012 (Barros+2014). Simultaneous RV observations were done using the HARPS from 12th of January to 6th of February 2012 (Haywood+2014).

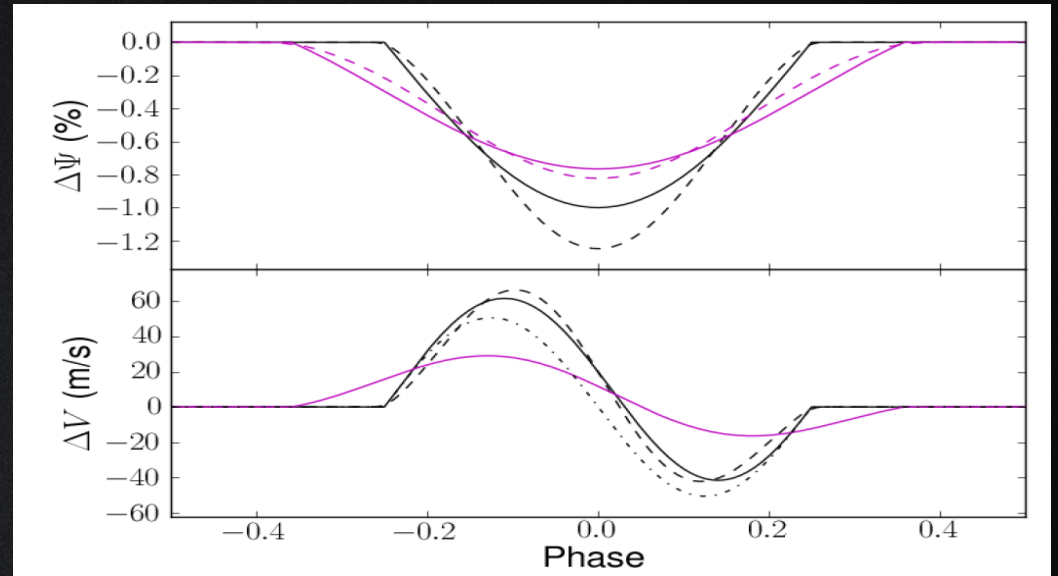


FF' method

$$\Delta RV_{\text{rot}}(t) = -\frac{\dot{\Psi}(t)}{\Psi_0} \left[1 - \frac{\Psi(t)}{\Psi_0} \right] \frac{R_{\star}}{f},$$

$$\Delta RV_{\text{conv}}(t) = \left[1 - \frac{\Psi(t)}{\Psi_0} \right]^2 \frac{\delta V_c \kappa}{f},$$

$$\Delta RV_{\text{activity}} = A\Delta RV_{\text{rot}} + B\Delta RV_{\text{conv}}$$



Aigrain+12

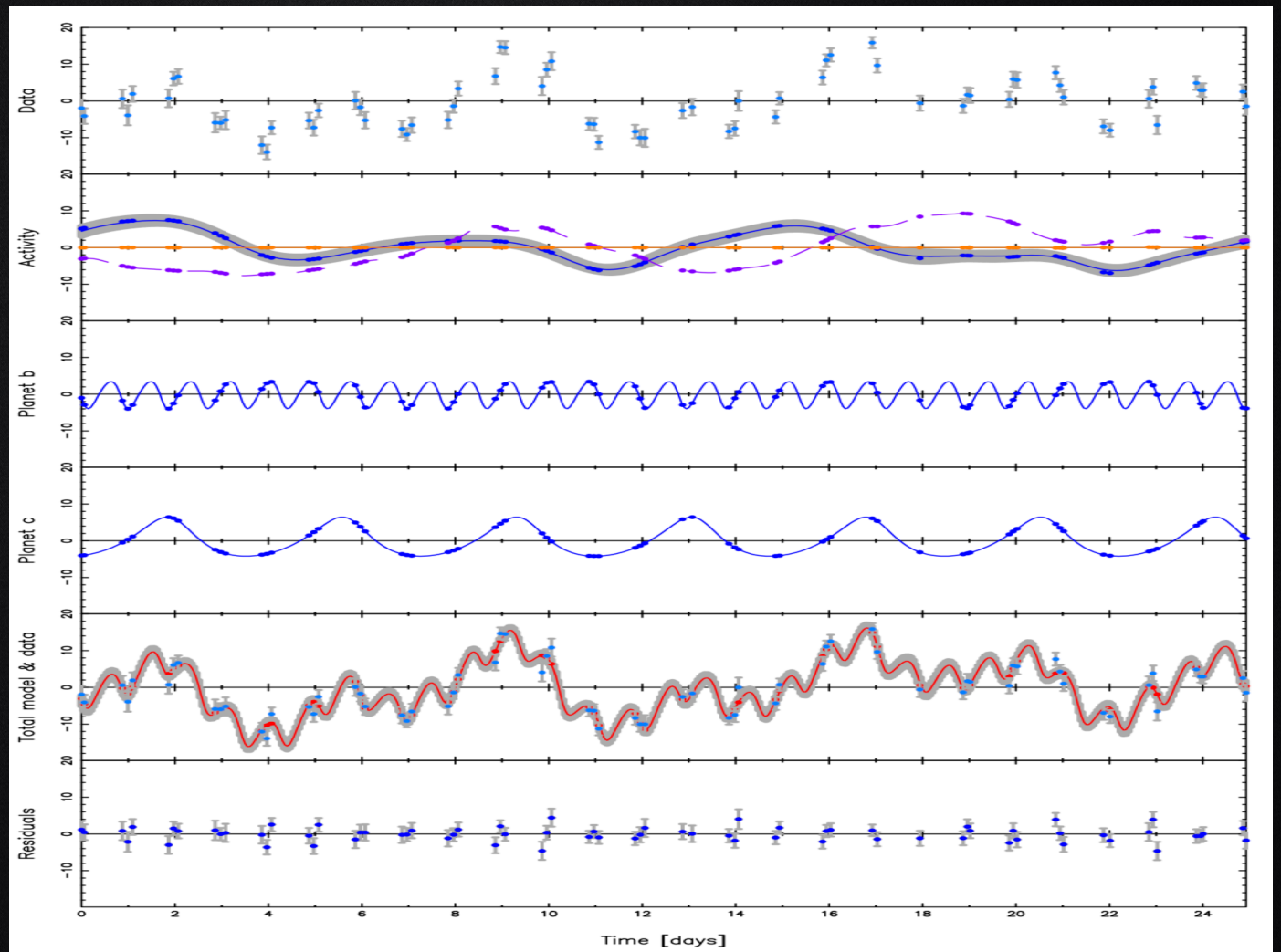
Limitations:

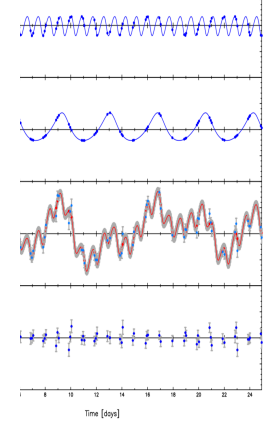
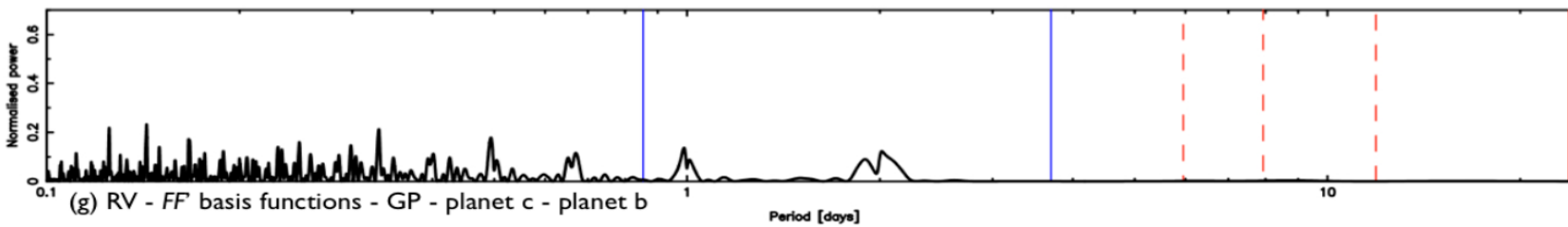
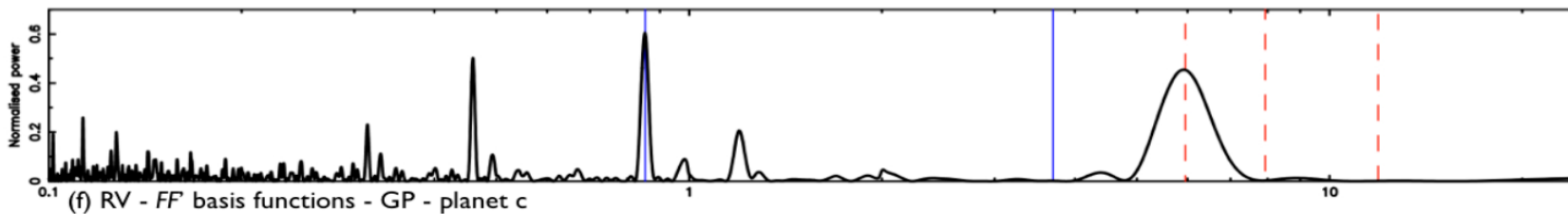
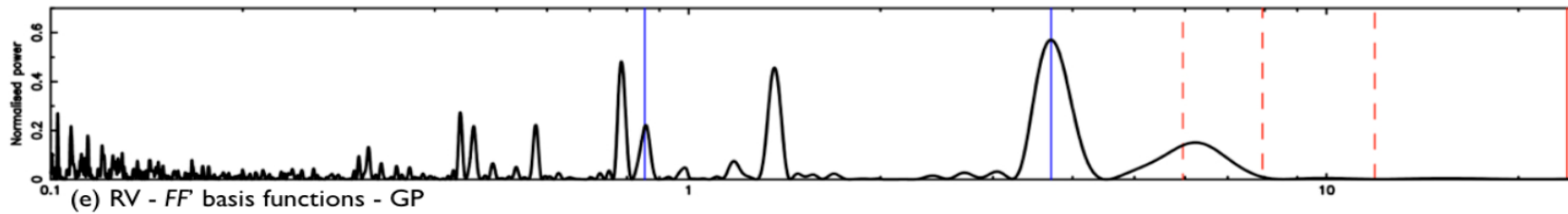
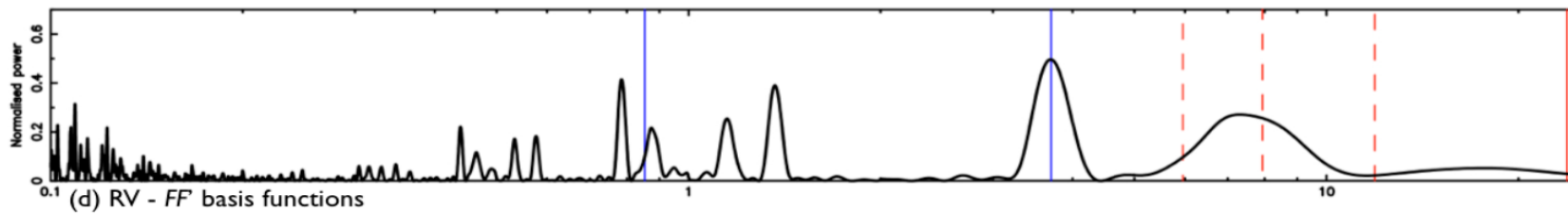
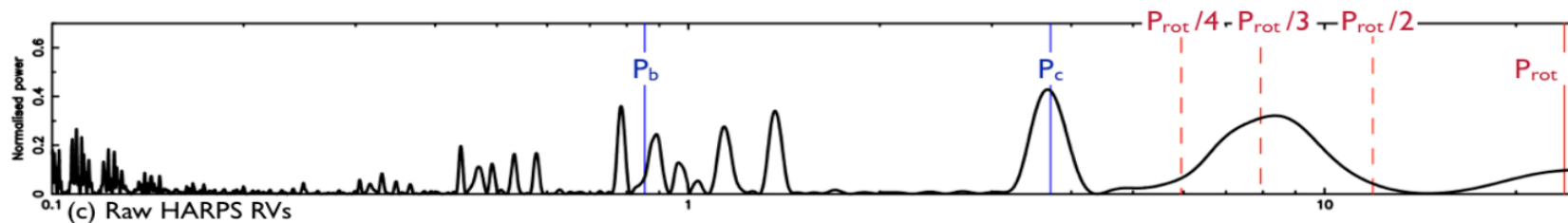
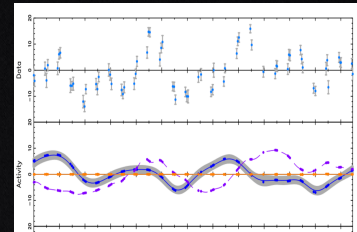
It is assumed that the spots are small and limb-darkening is ignored.

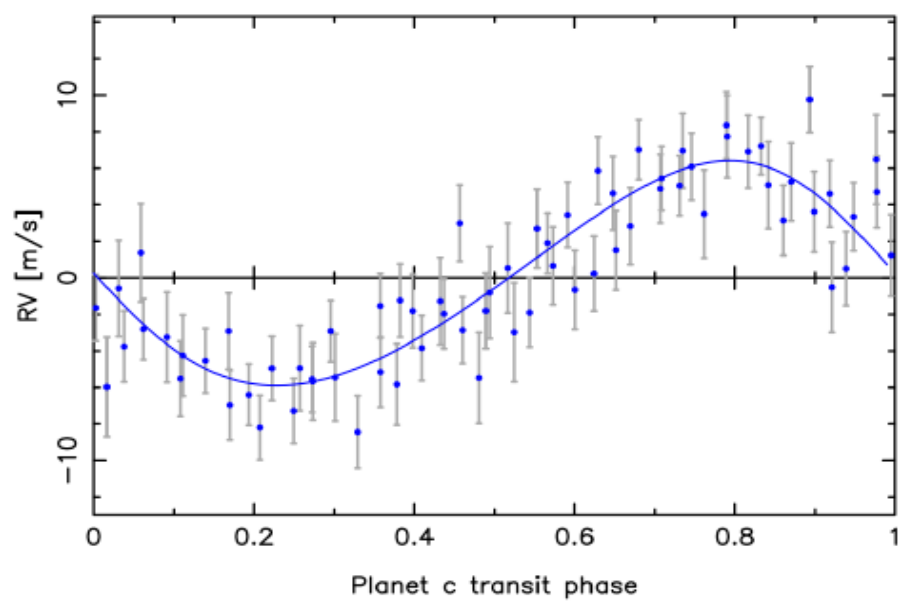
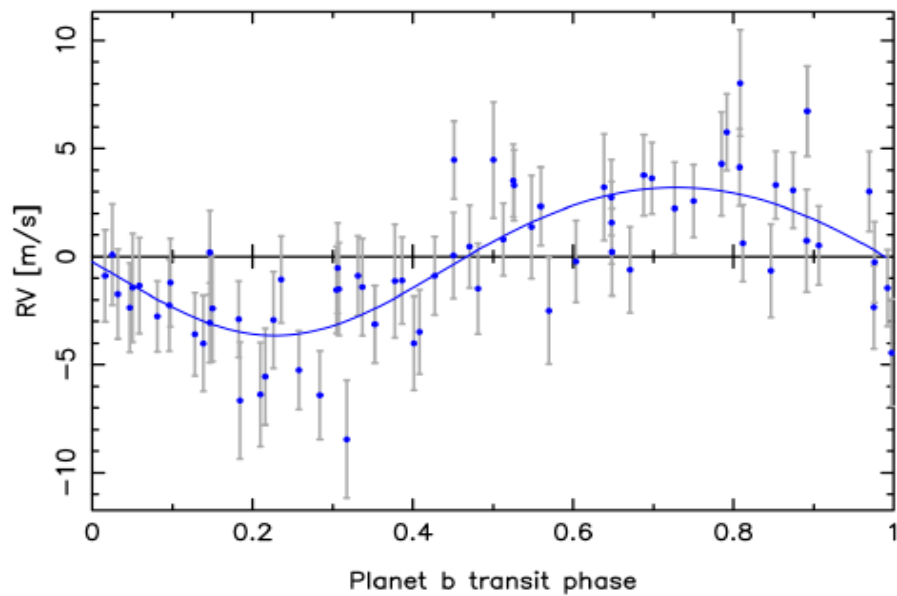
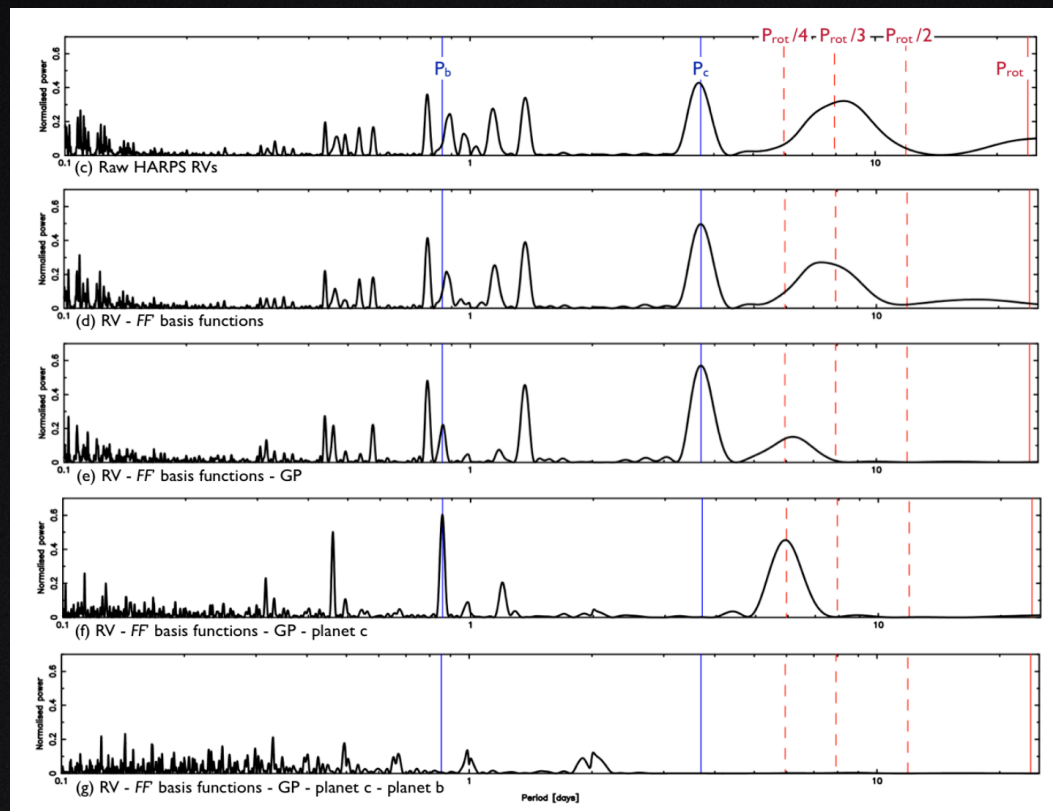
It does not consider the broad-band photometric effect of faculae that are not physically associated with starspots.

FF' and Gaussian process

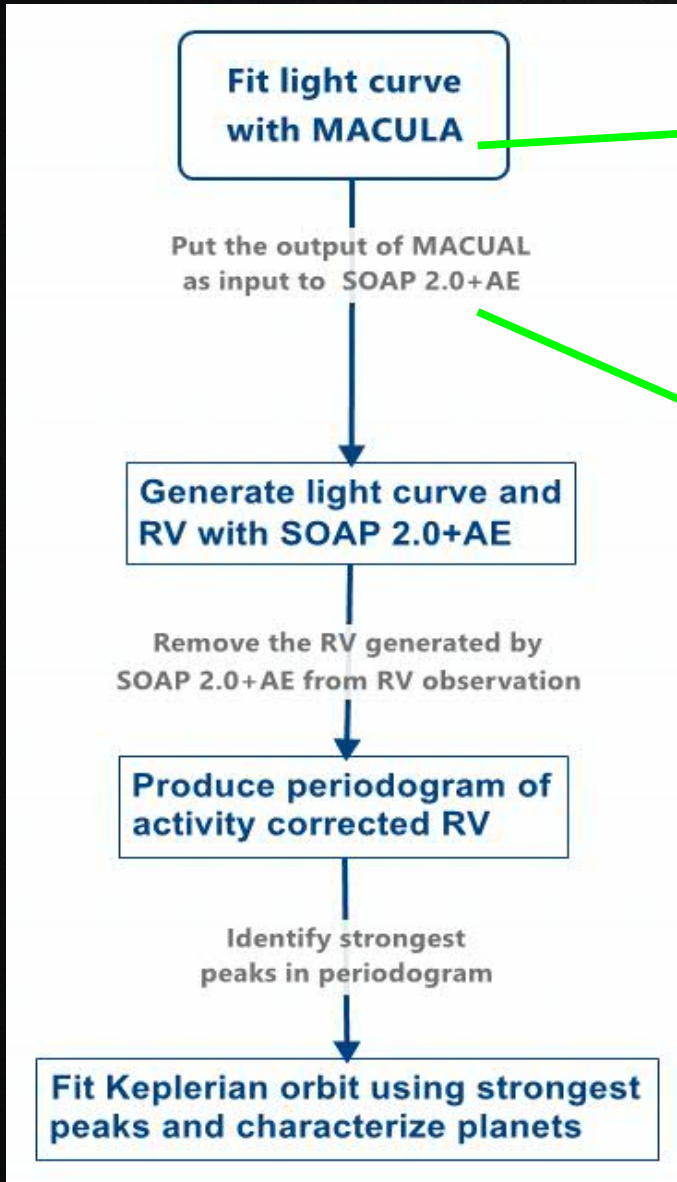
$$\Delta RV_{\text{activity}} = A\Delta RV_{\text{rot}} + B\Delta RV_{\text{conv}} + \Delta RV_{\text{additional}},$$







Our methodology

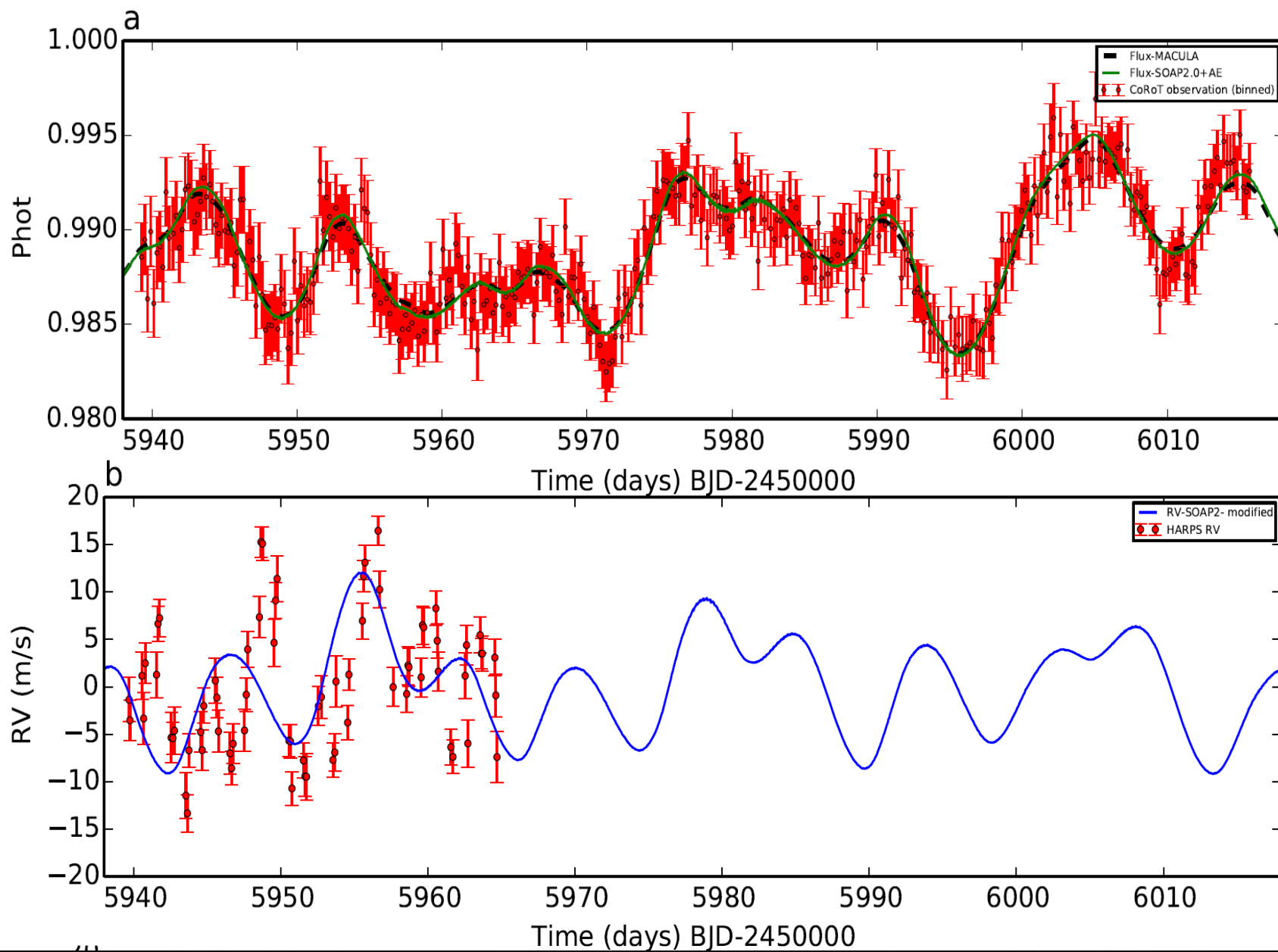


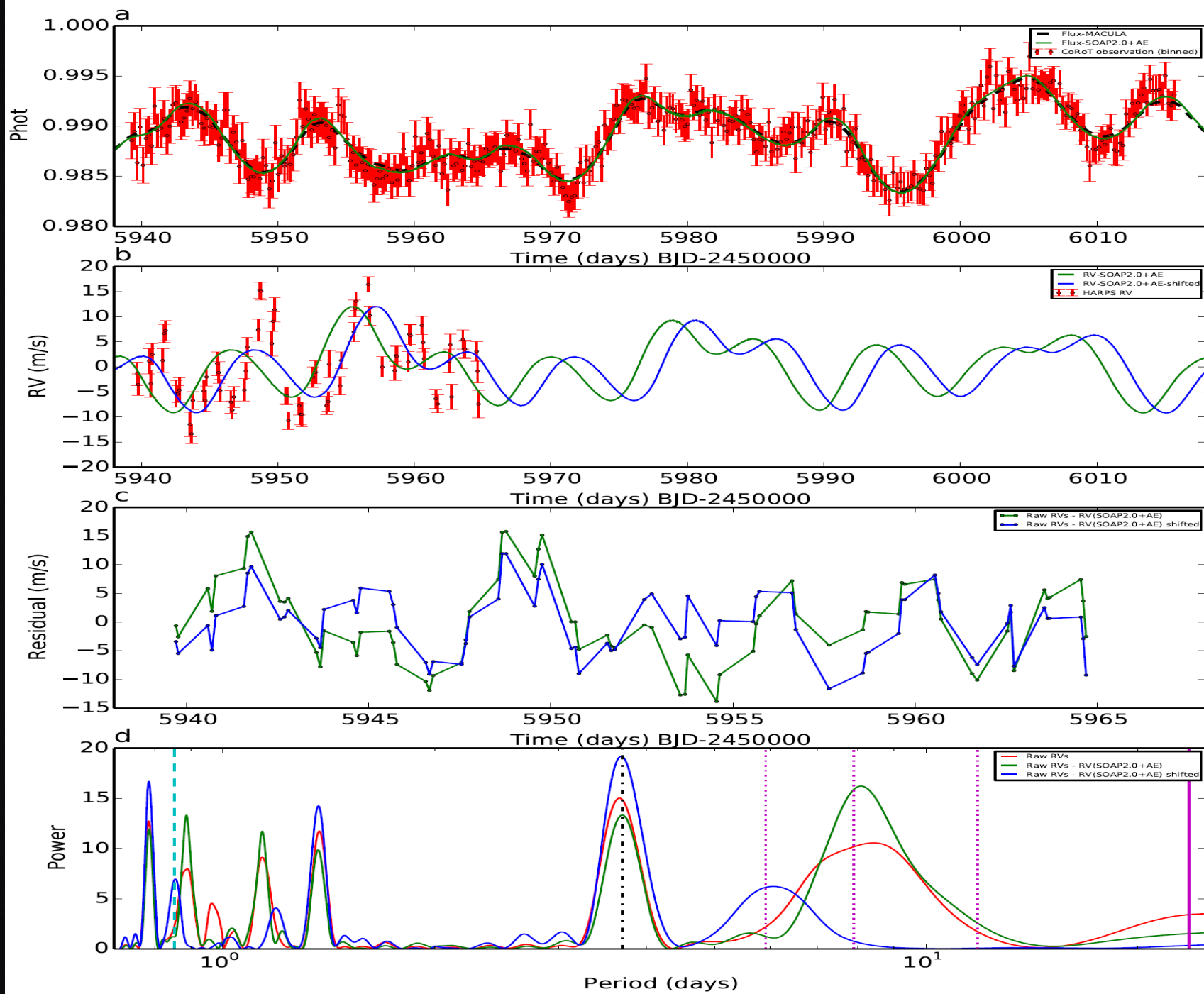
MACULA: Modeling rotational modulations in the photometry of spotted/plaged stars with considering spot/plage's size evolution (Kipping-12)

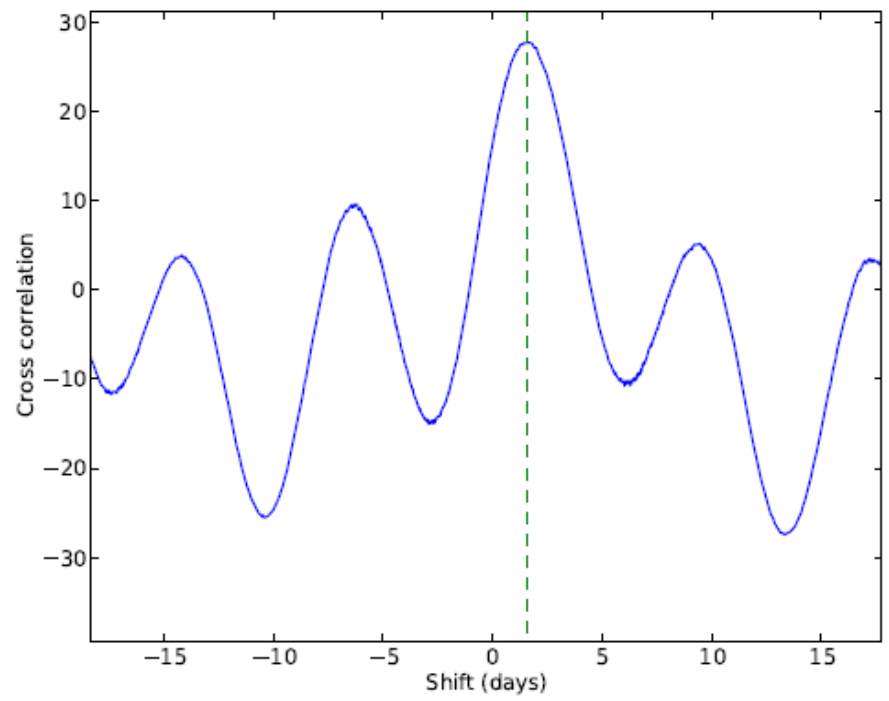
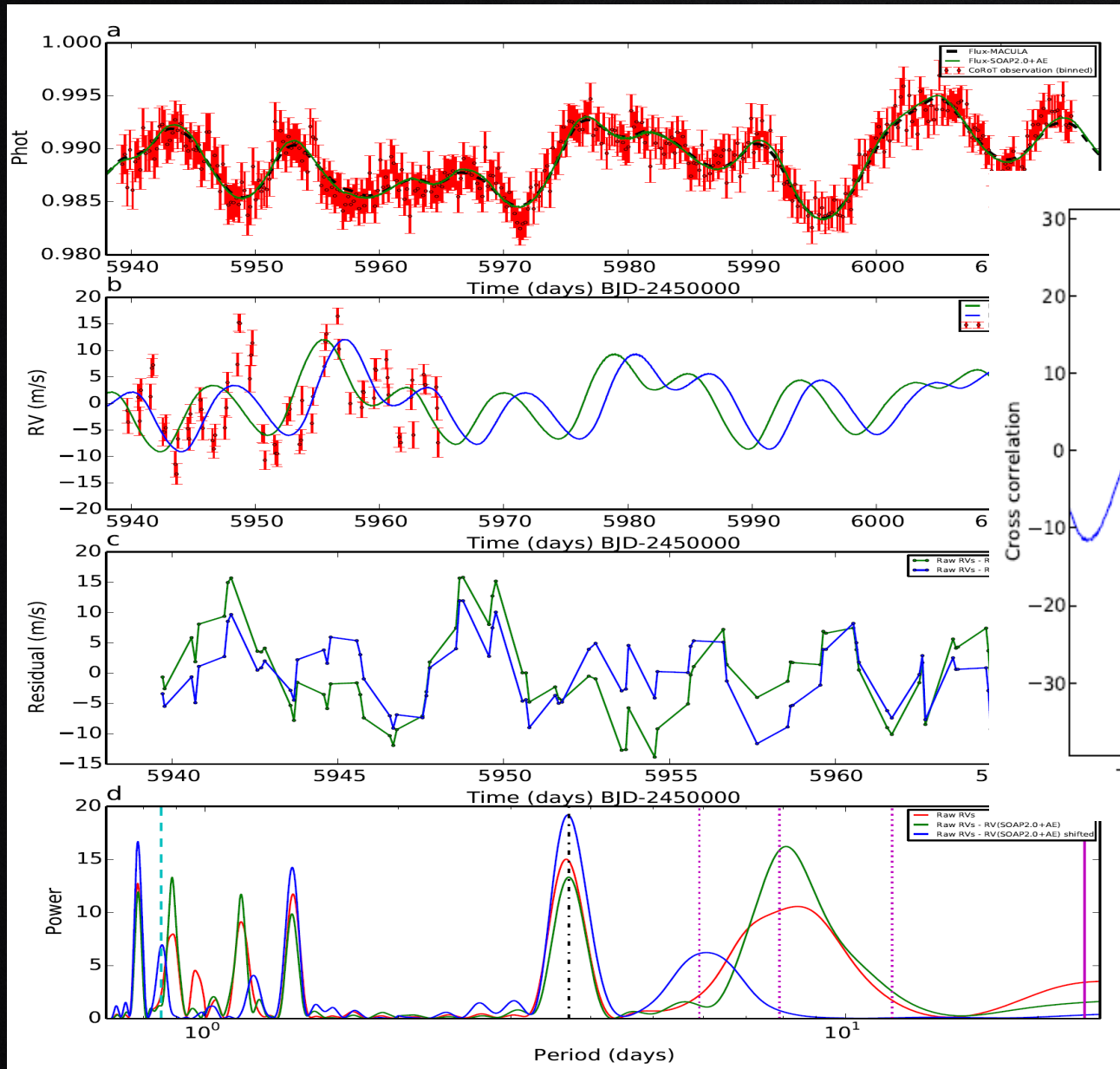
SOAP2.0: A tool to simulate the photometric and radial velocity variations induced by stellar spots and plages (Dumusque+ 2014).

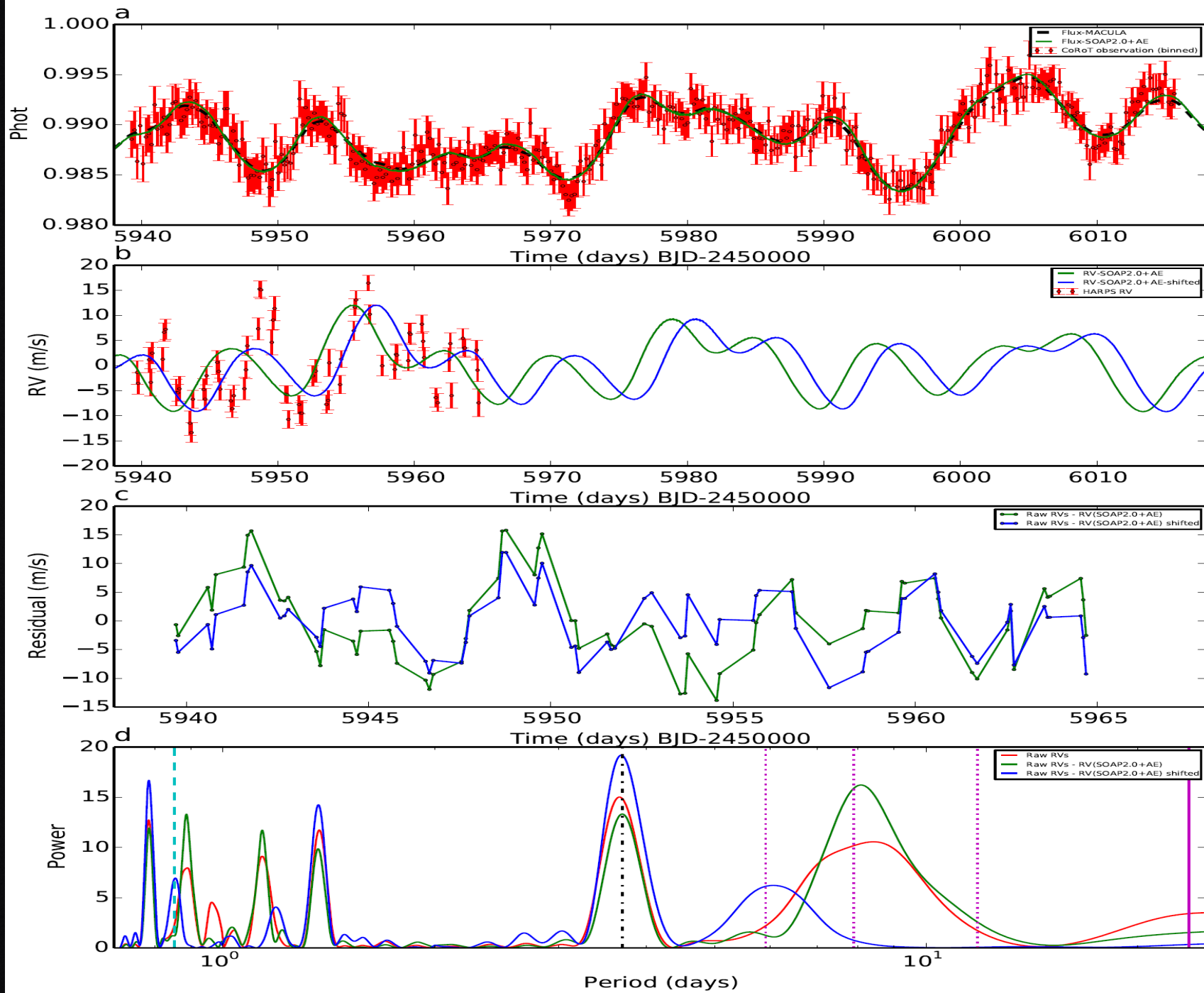
SOAP2.0+AE: Modified SOAP2.0 to take into account spot/plage's size evolution.

Applying on CoRoT-7

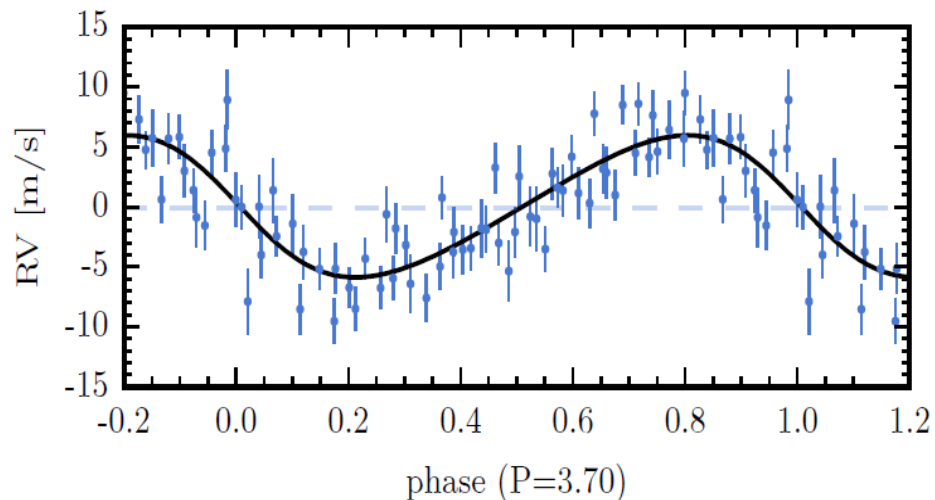
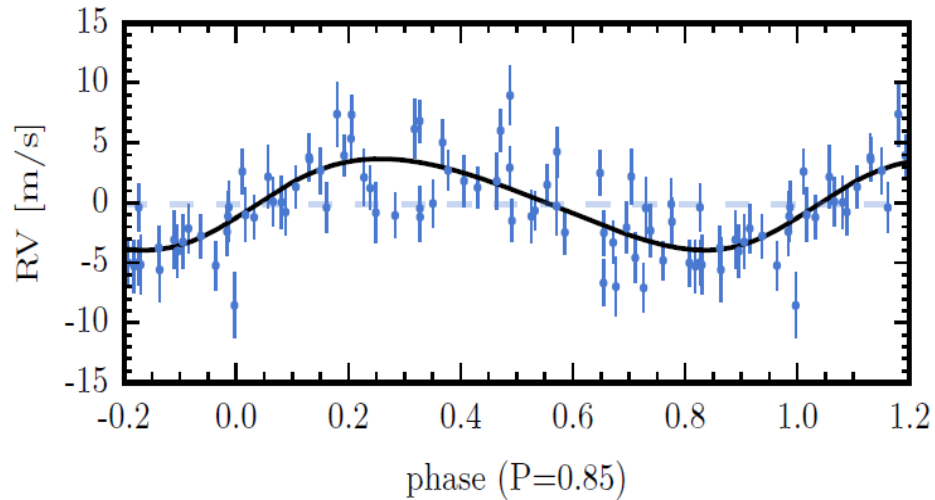






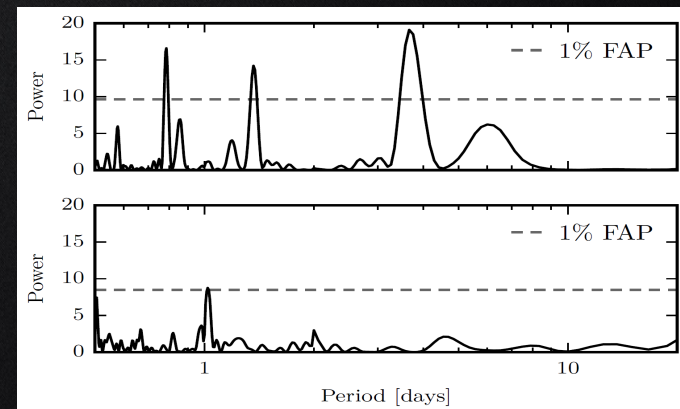


Characterizing CoRoT-7b and c



	Value	Error
CoRoT-7b		
Period(days)	0.854	$< 10^{-6}$
K(m/s)	3.812	0.256
eccentricity	0.129	0.059
$m \sin i$ (Earth mass)	5.2768	0.3620
a(AU)	0.0168	0.0001
T_0	5950.44	6.04
ω	4.417	0.865

CoRoT-7c		
Period(days)	3.703	0.014
K(m/s)	5.924	0.266
eccentricity	0.144	0.039
$m \sin i$ (Earth mass)	13.3449	0.6271
a(AU)	0.0448	0.0003
T_0	5946.11	6.42
ω	1.517	0.720



Conclusion

We detected a **time–shift** between simultaneous photometry and RV, that can indicate some physical phenomena which are missing in our modelings. Some phenomena can be the reason for the time shift of RV and FWHM (Queloz+09).

The best approach could be obtained by fitting simultaneously the photometry, RV, FWHM, and BIS

OR

to have more complete model which consider all the physical phenomena on the star.

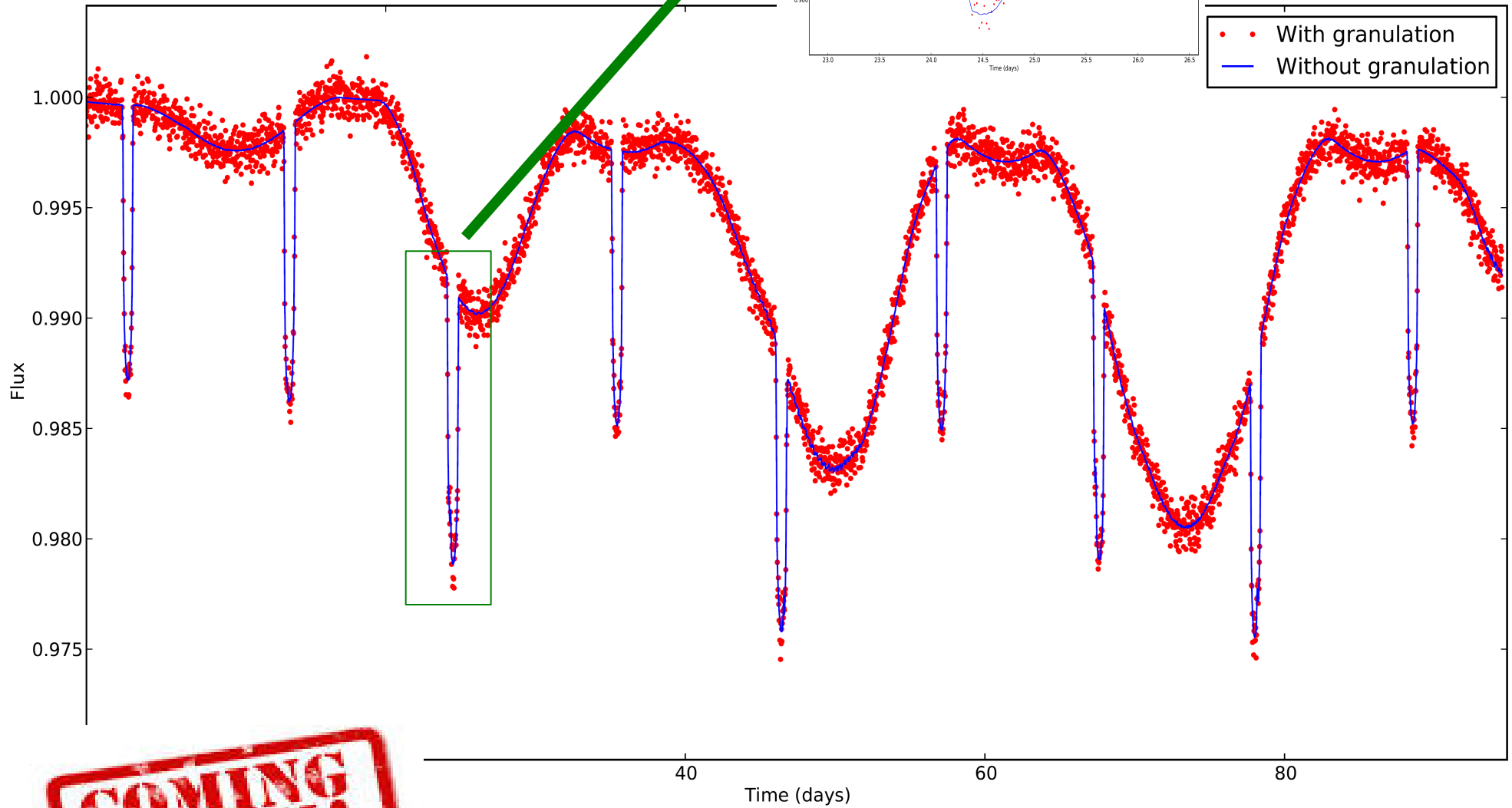
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Hopefully we will release the **LAST version of SOAP** tool for public soon, which simulates

1. A spotted/plaged rotating star
2. Taking into consideration the spot/plage's **size evolution, and latitude migration**
3. Taking into account **convective blue shift inhibition** in the active regions
4. A transiting planet **with or without ring**, with consideration of occultation with spots
5. The red noise due to **granulation phenomena**

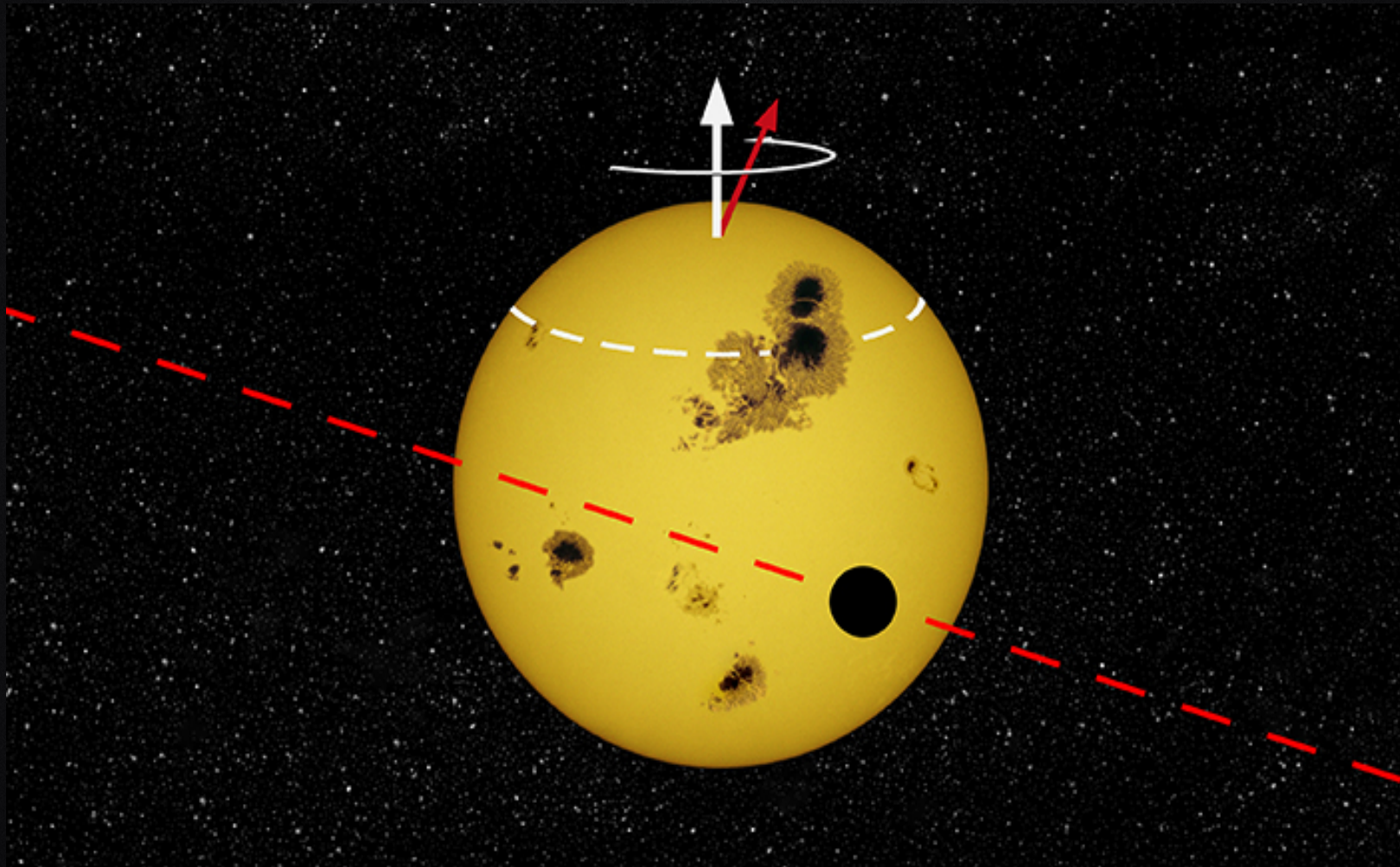
and delivers flux, RV, BIS, Vspan, Vasy, FWHM.

Advertisement

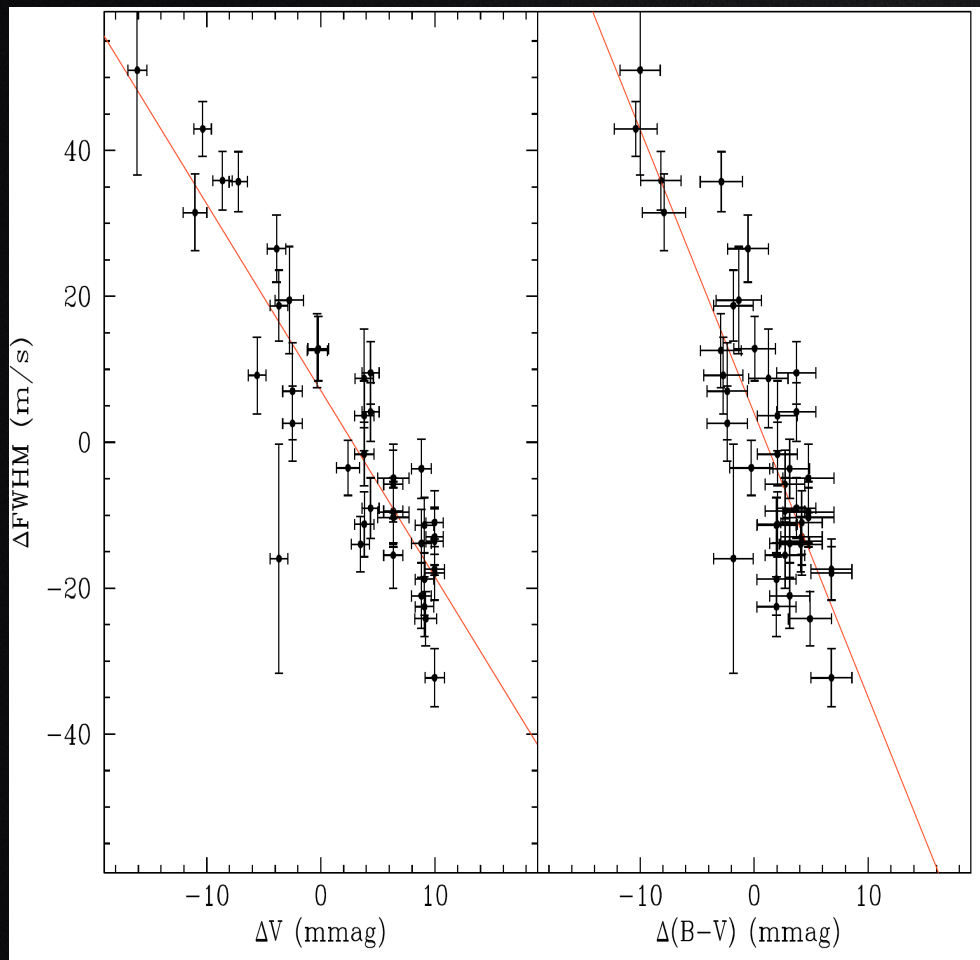


**COMING
SOON!**

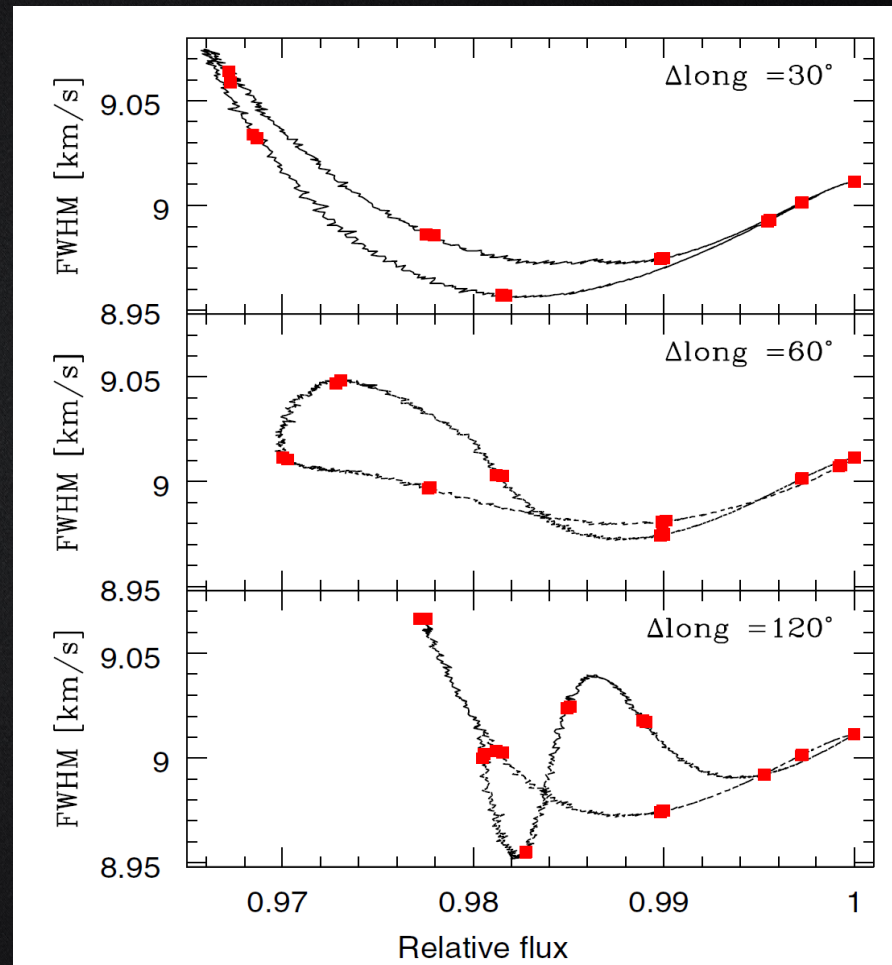
Thanks for your attention!



FWHM as flux



Queloz+09



Simulations with SOAP (Boisse+11)

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