C
ROTATION
R
O
ACTIVITY

F. Baudin

Measurement of rotation and activity

Spots and plages transiting at the surface of stars

+

long duration and stable measurements

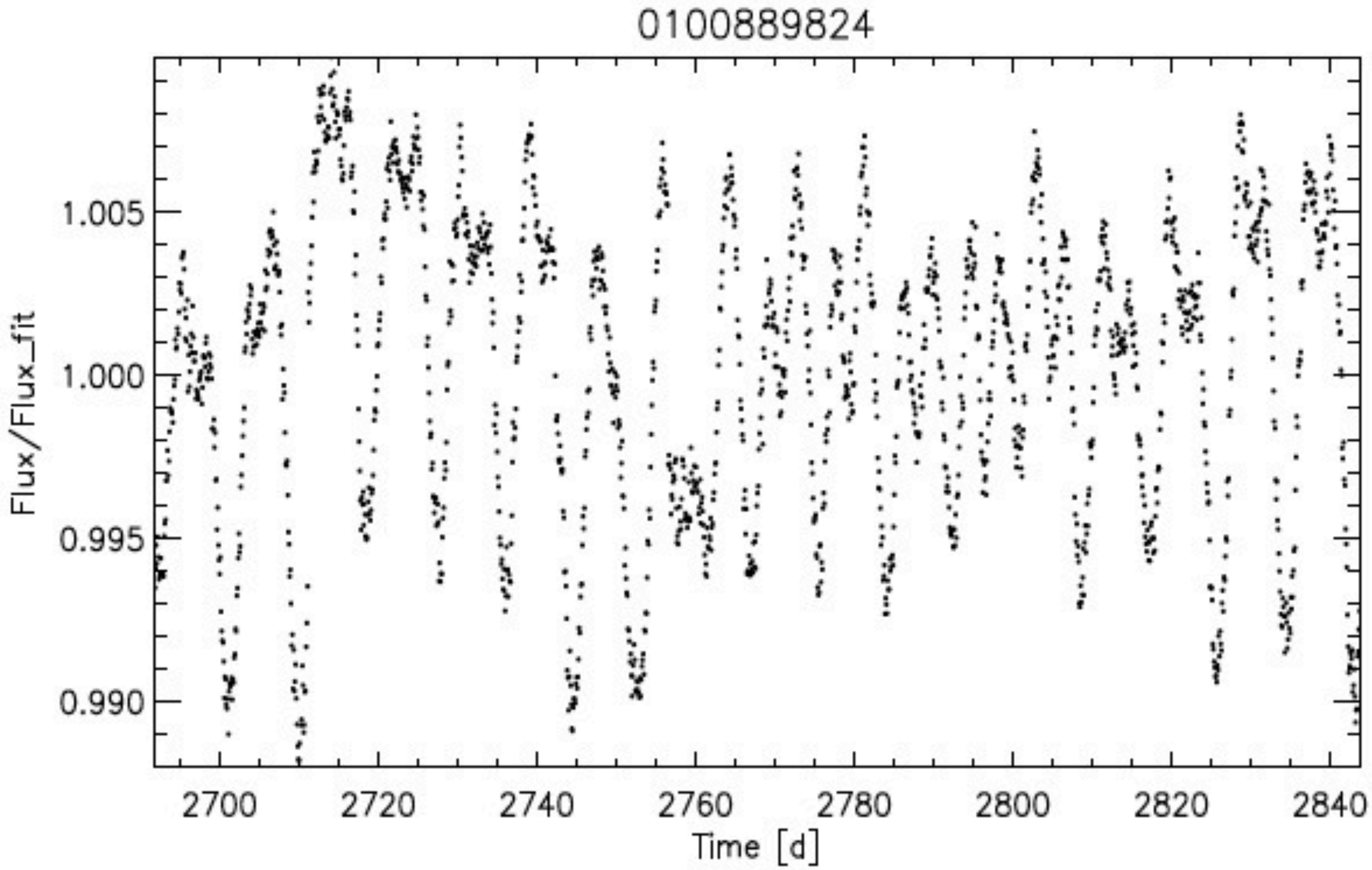
=

intensity modulation

=> rotation determination

=> one (visible) description of activity

Measurement of rotation and activity



Measurement of rotation and activity

Corot precision:
down to **0.1** mmag per hour (magnitude between 11 and 16).

Intensity variations of the Sun:
from **0.07** to **0.3** mmag at minimum and maximum activity.

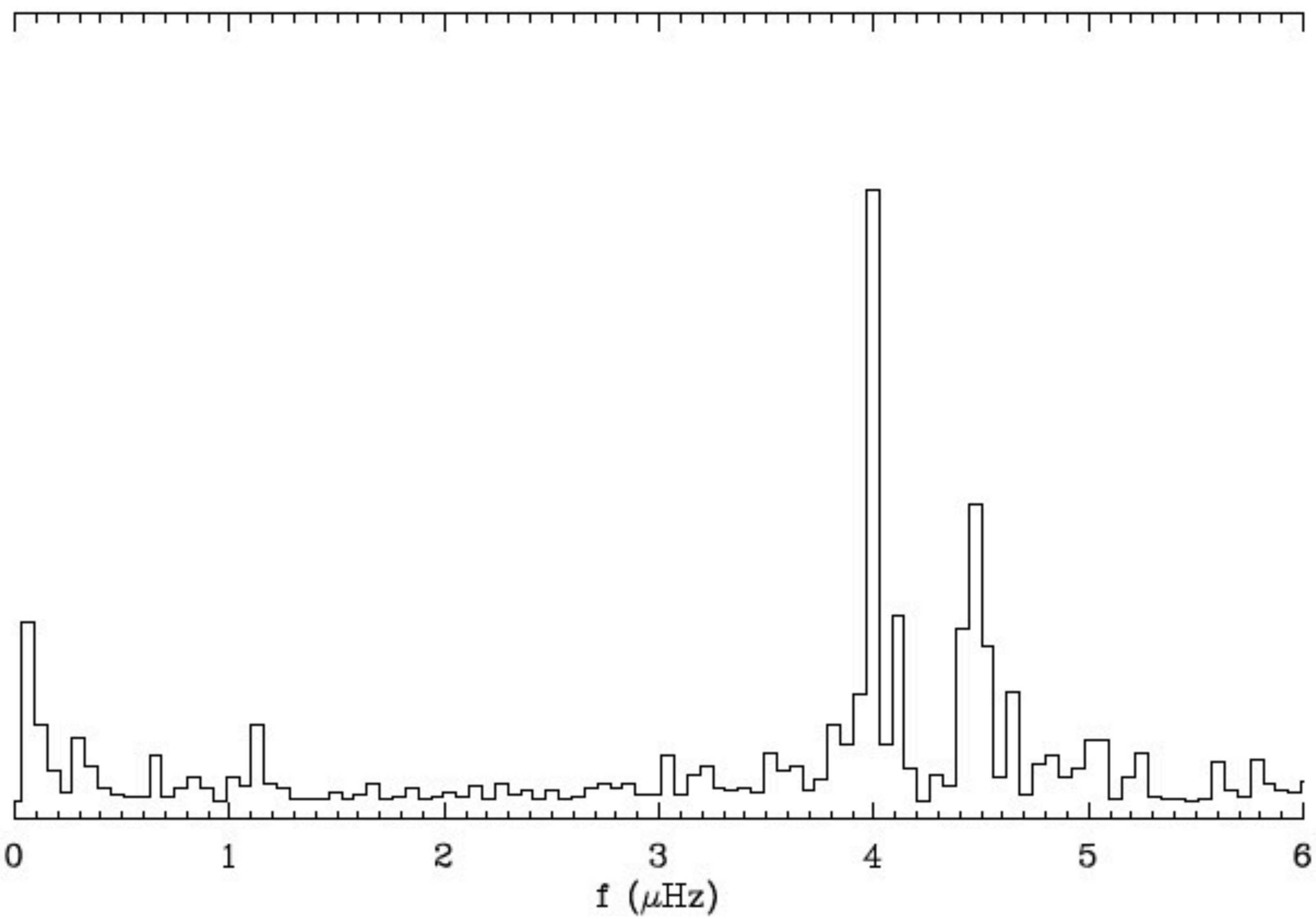
Interest of rotation and activity

- Spot activity = important manifestation of magnetism, role in star-planet interaction (mass loss, habitability...)

- Rotation = major ingredient of dynamo
- Rotation = role in transport in stars (evolution)
- Rotation = age estimation through «gyrochronology »

Rotation / Seismo side

HD181906

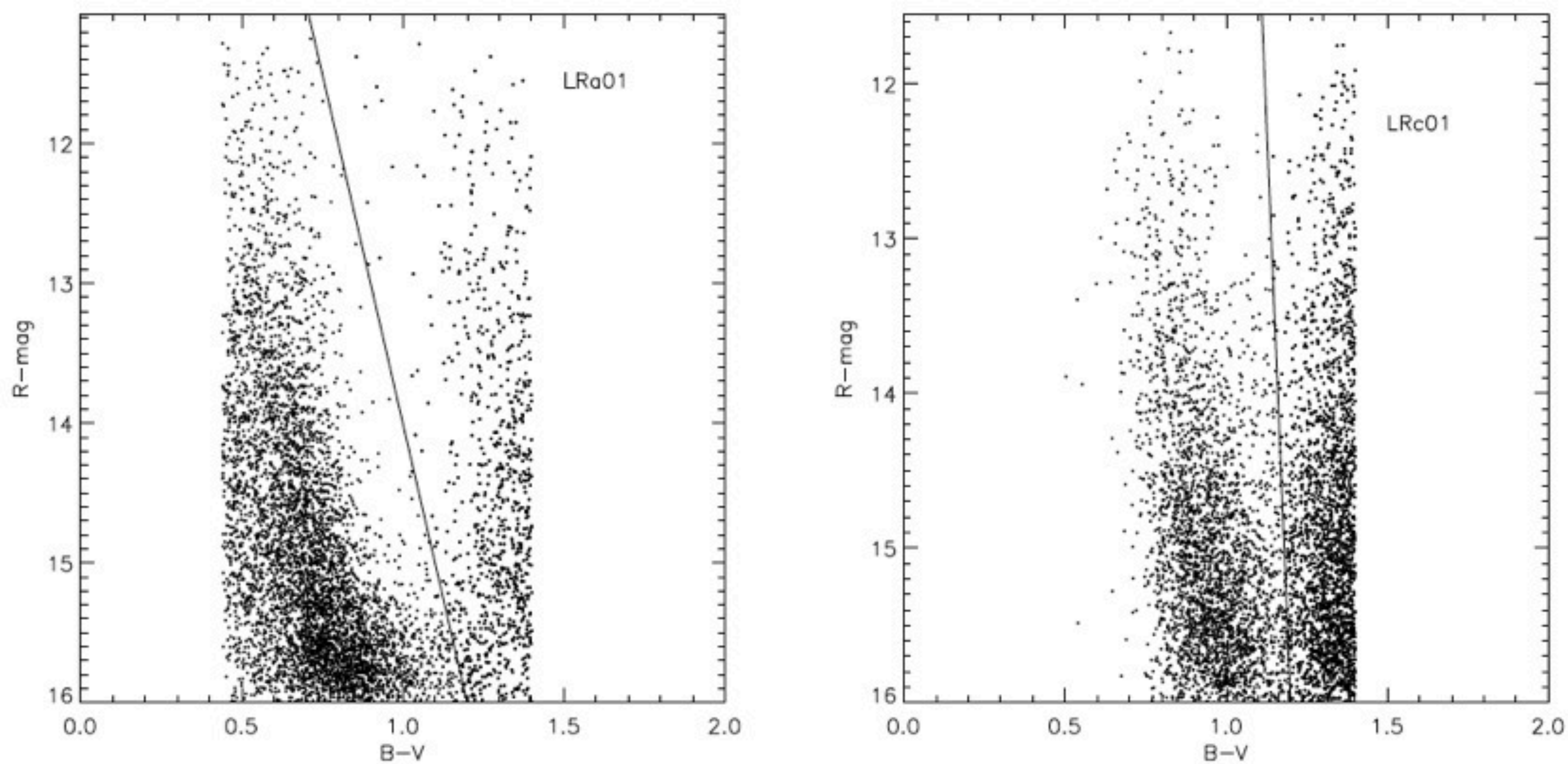


Differential rotation?

Rotation / Exo side

Affer et al (2012)

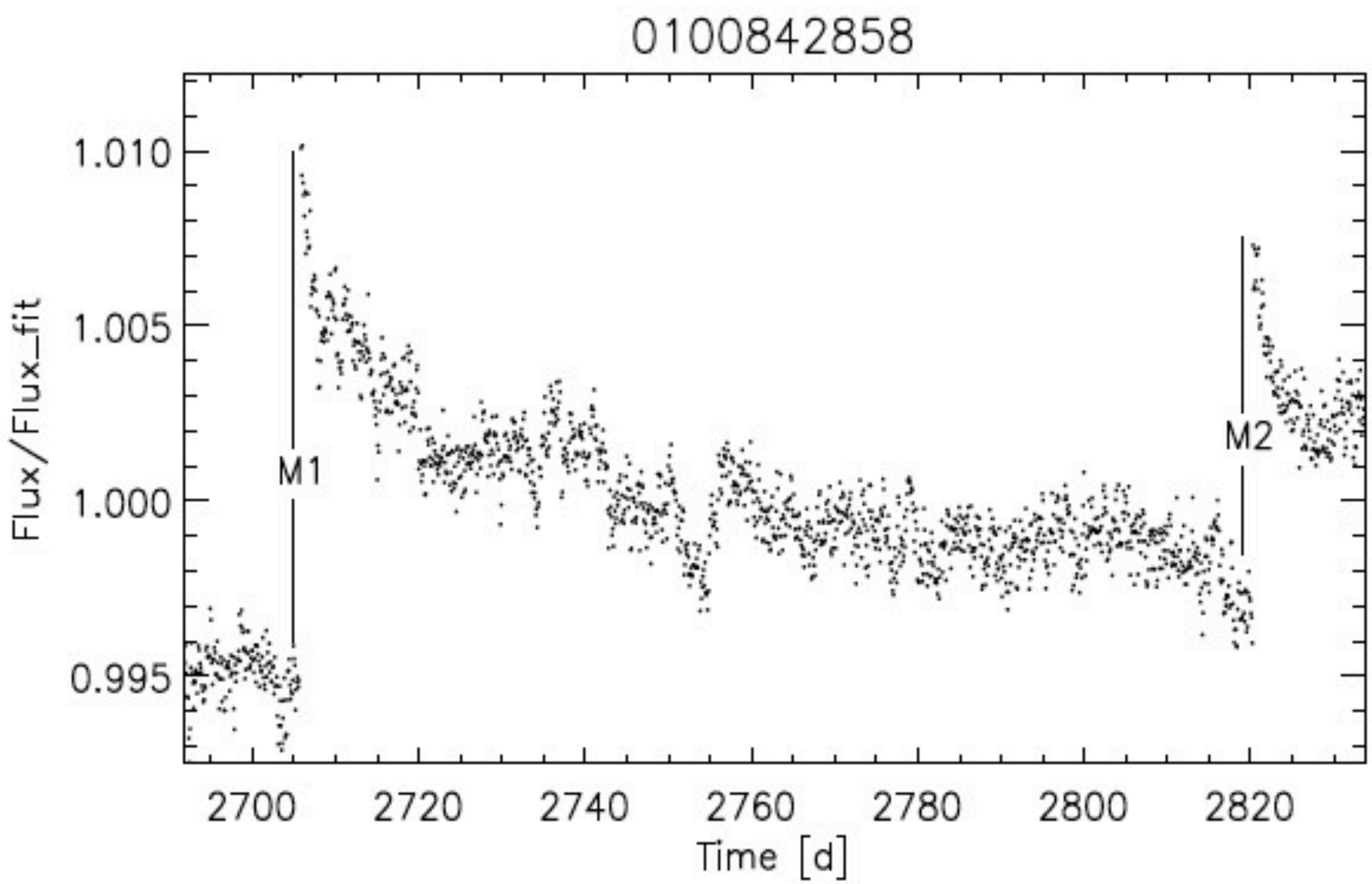
8341 dwarves selected (LRc01 + LRa01)



Rotation / Exo side

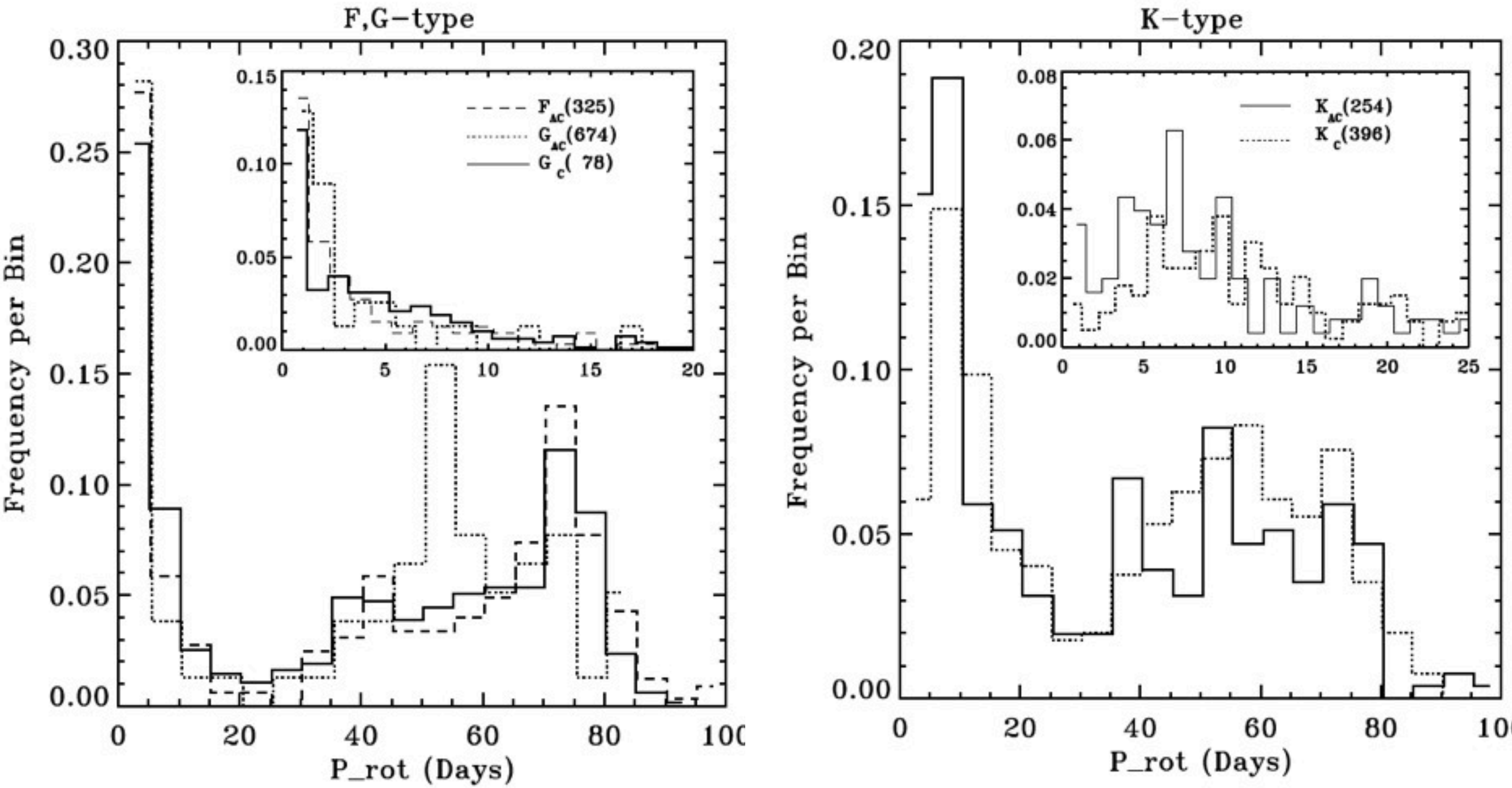
Affer et al (2012)

6241 remaining after selection based on instrumental problems (28% of LC with 2 jumps > 10 σ)

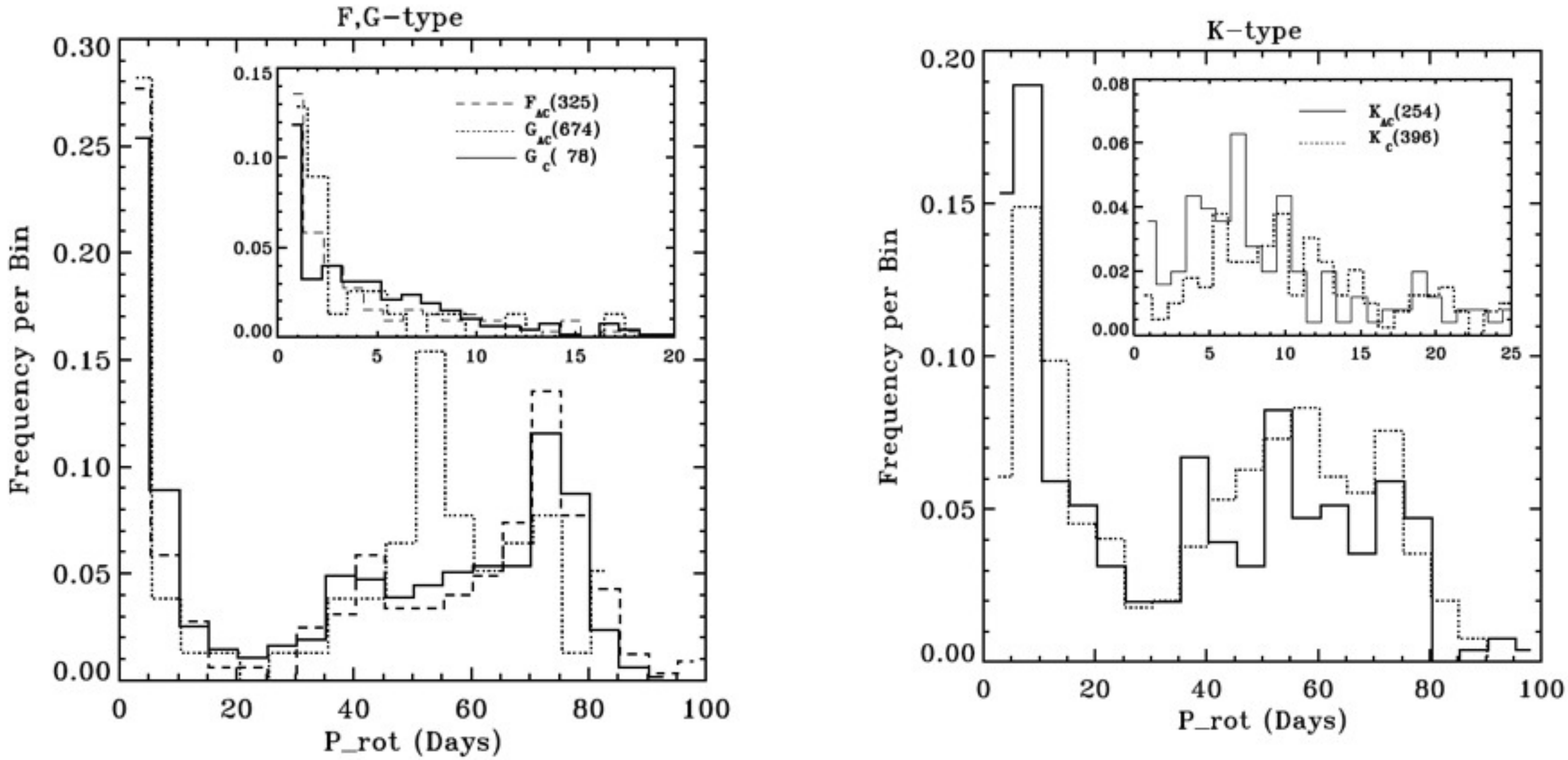


Rotation / Exo side

Rotation measured in periodogram with time series auto-correlation: **1727** rotation periods measured and confirmed from both methods, from **0.25 to 100 days**.

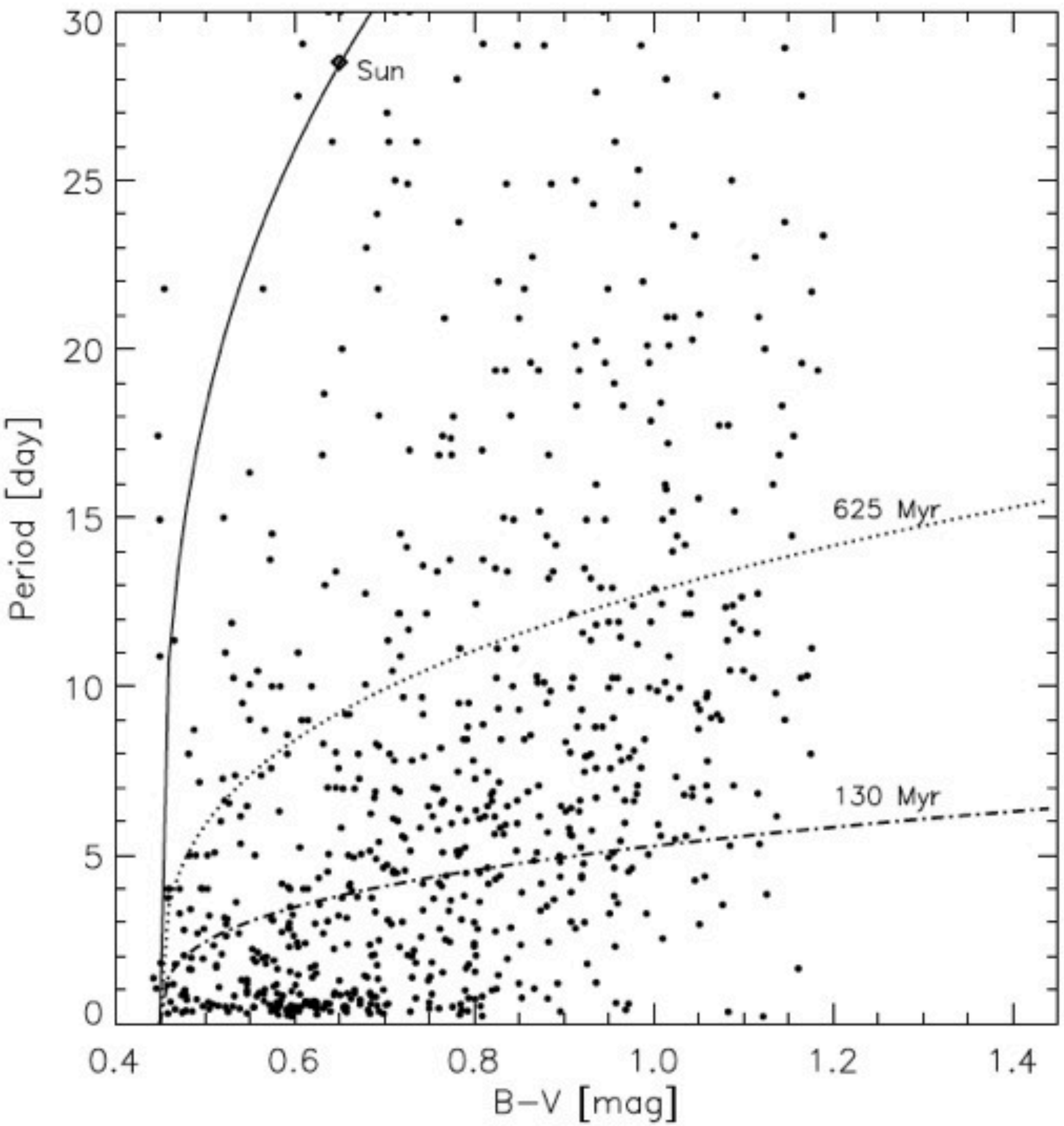


Rotation / Exo side



- Bimodal distributions: young and old populations?
- Gap between about 15 and 35 days.
- Large number of stars with short rotational periods is fully compatible with the presence in the solar neighborhood of a sample of young stars

Rotation / Exo side



- Comparison with gyrochronology (Mamajek & Hillenbrand 2008)
- Sample dominated by young stars, biased towards these stars (since they are more active)

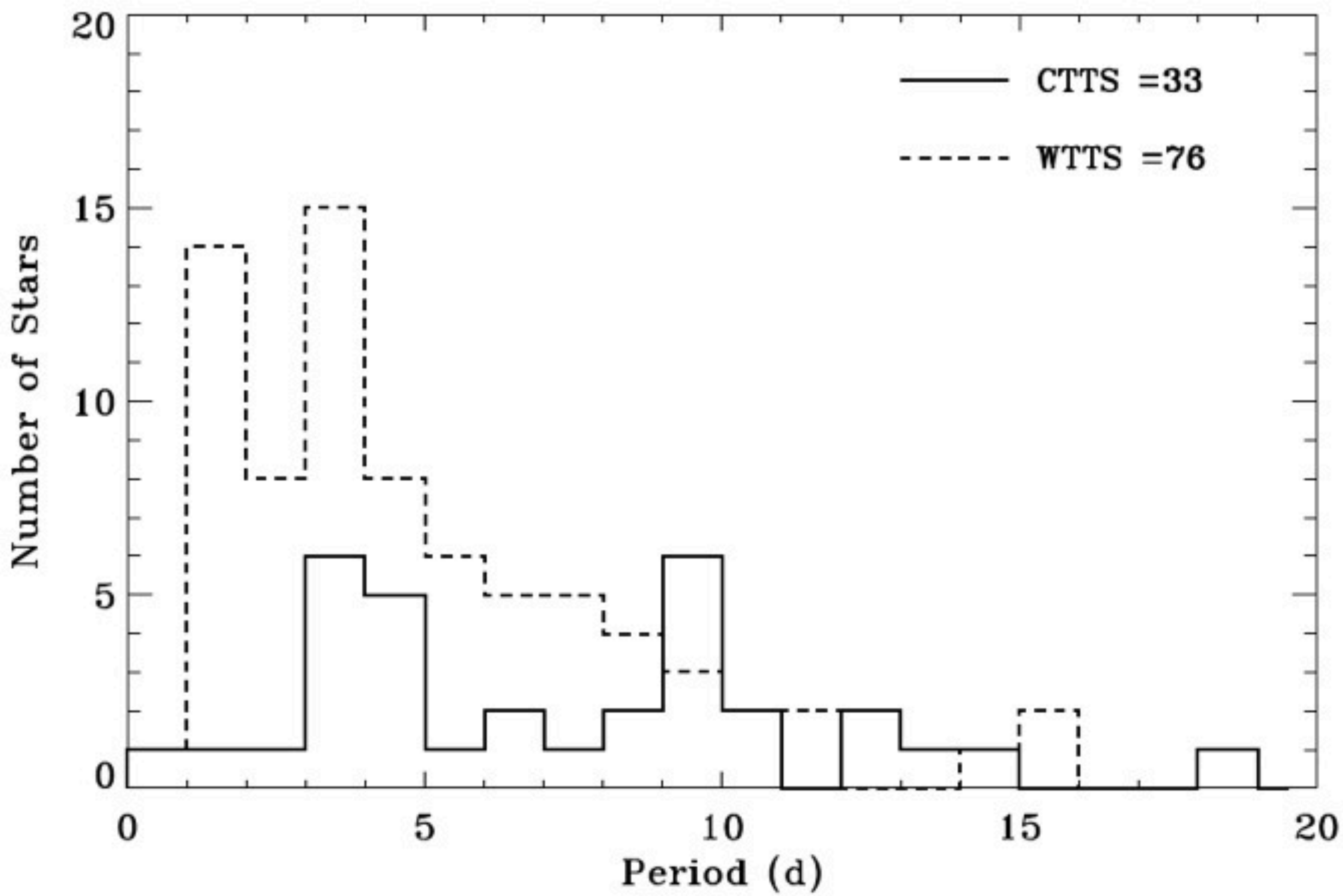
Rotation / Exo side

Affer et al. 2013

- A special target: NGC2264, star forming region in the solar neighbourhood, estimated age of 3 Myr, recent simultaneous multiband campaign (see Flacommio et al's, Zwintz et al's presentation)

-based on SRa01 data, light curves for 301 known cluster members, **189 rotation periods** measured, distributed between **2 types of T Tauri** stars (CTTS and WTTS, based on Hα measurements)

Rotation / Exo side



Possible explanation: disc locking => slower rotation

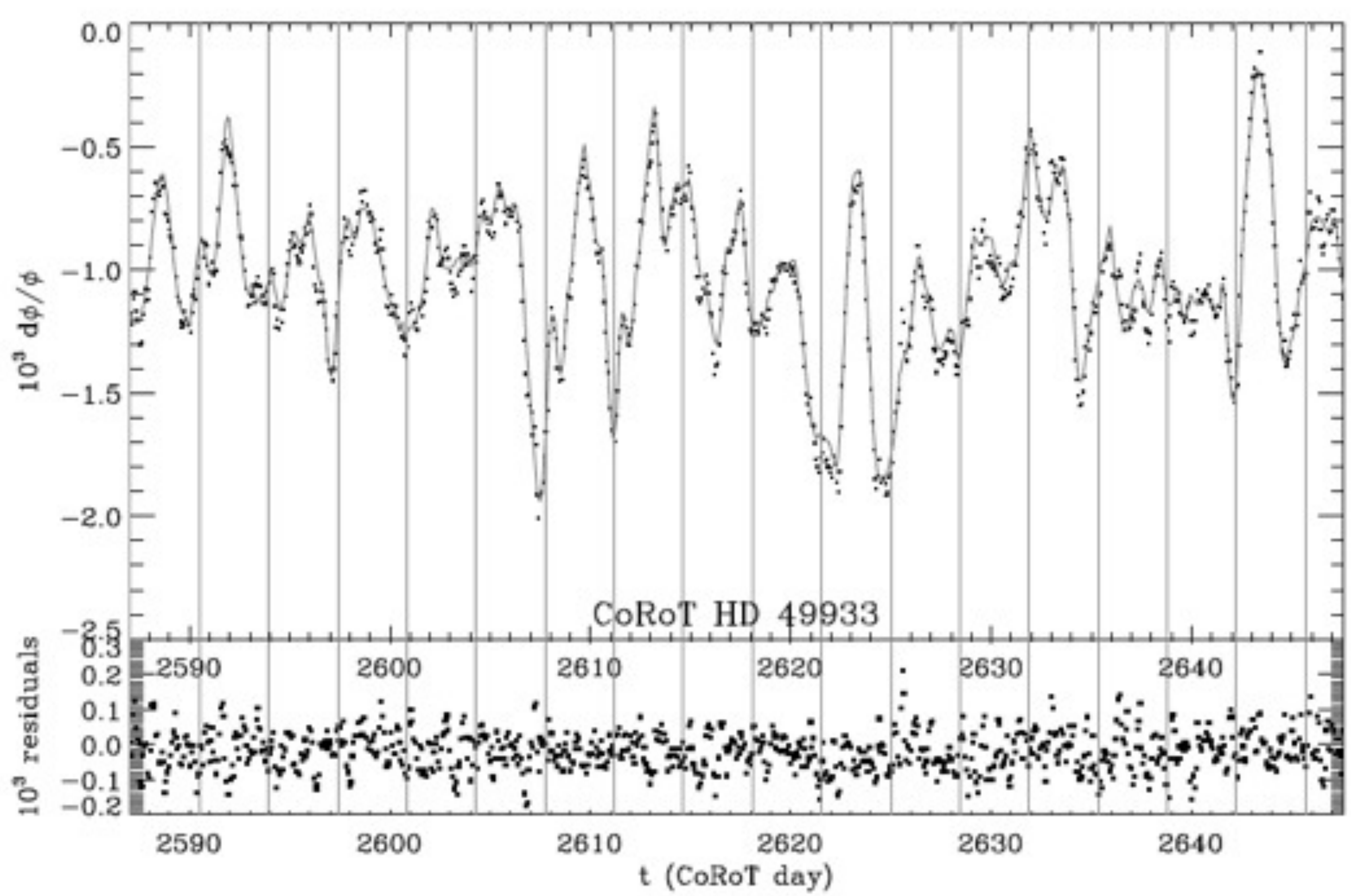
Activity / Seismo side

Spot modelling with various methods:

- 3-spot model (see Lanza et al, Gondoin et al)
- few spot model (see Mosser et al)
- 200px model + regularization (see Lanza et al)

=> distribution and characteristics of the spots

=> degenerated solutions

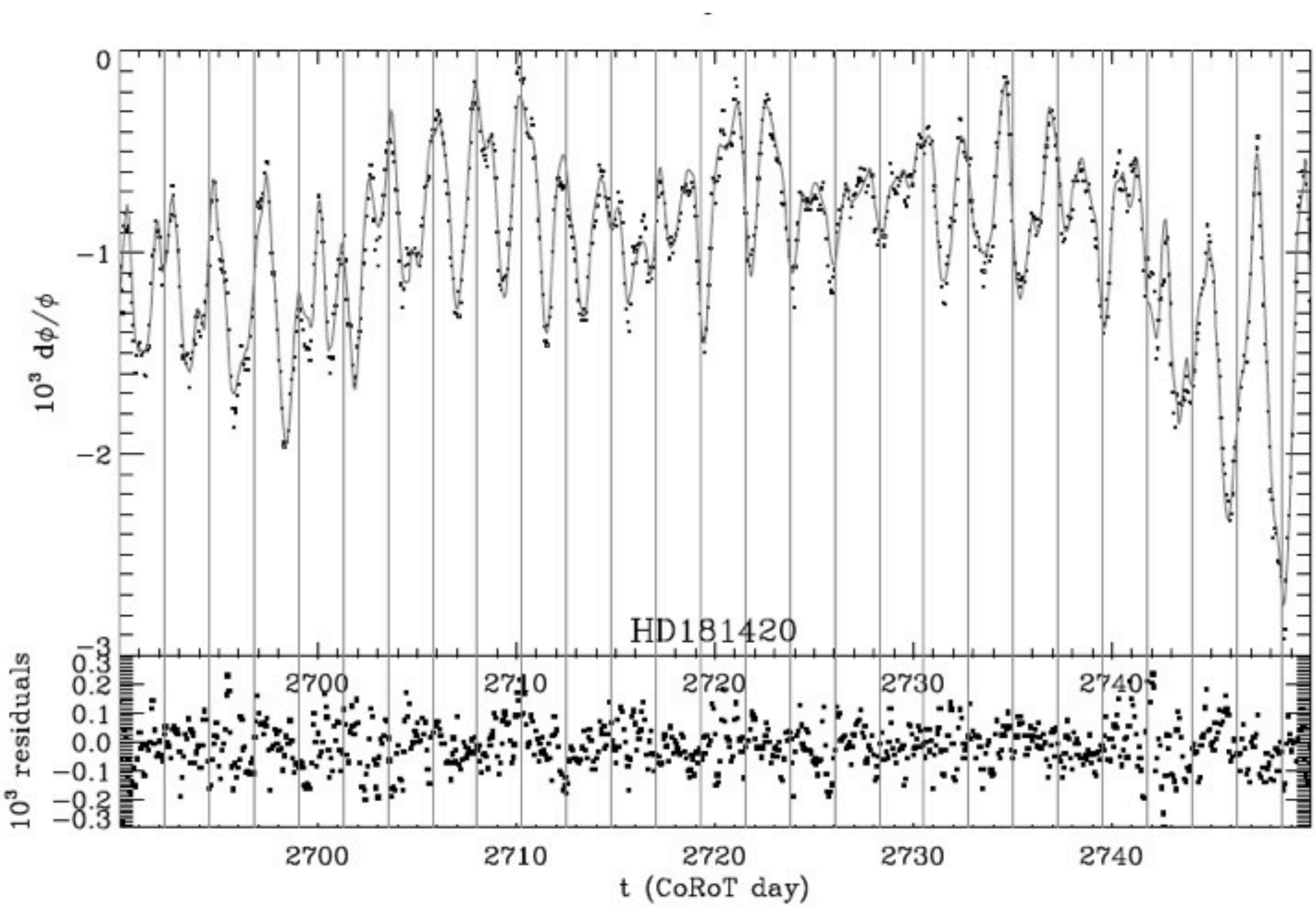


$$\Phi(t) = \Phi_0 \left[1 - \sum_{i=1}^{N_s} C_i(t) \right]$$

Activity / Seismo side

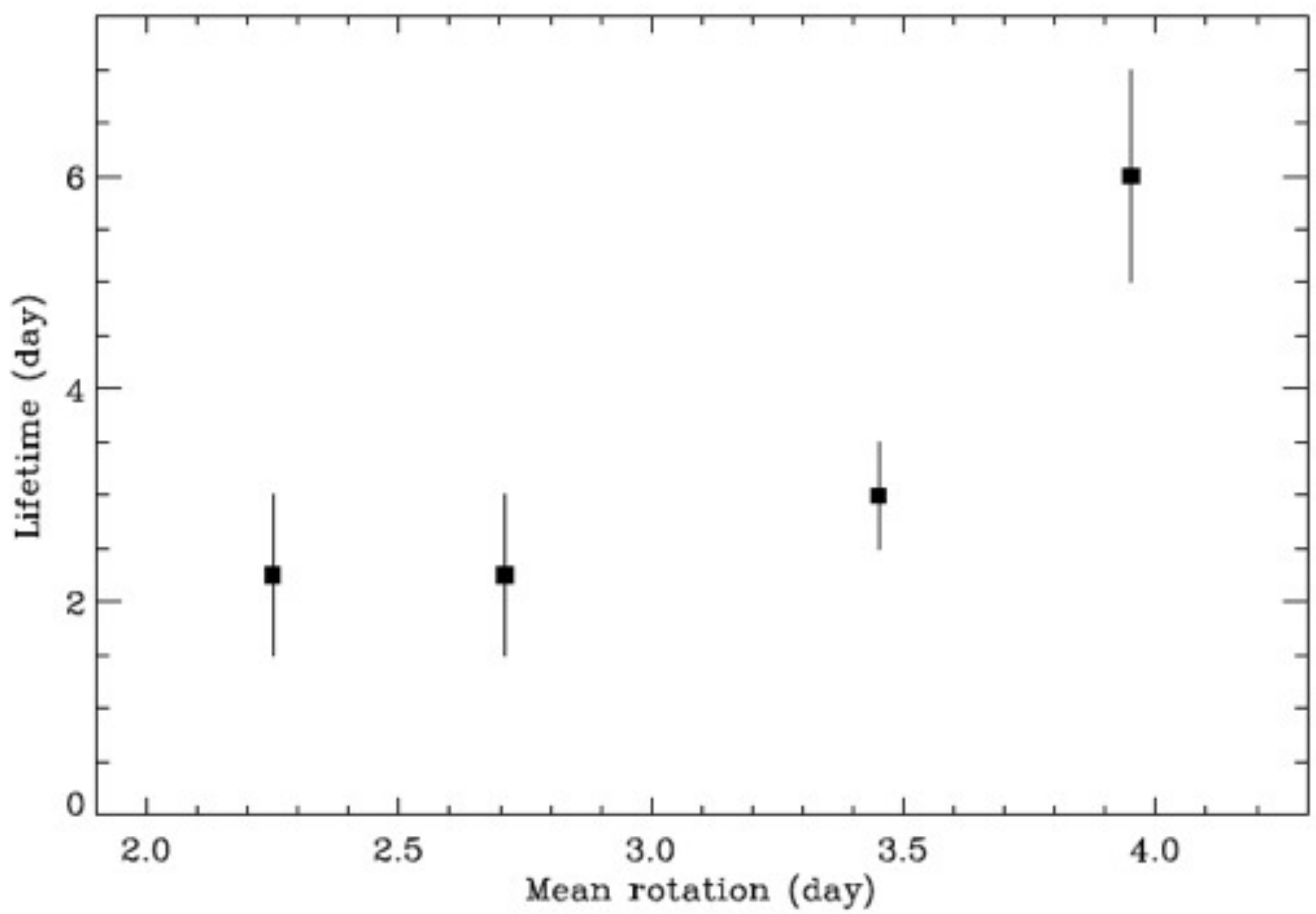
Mosser et al. 2009:

4 stars analysed F2, F5, F8, and G0, all V.



Activity / Seismo side

Star	Inclination		Spot contrast	Spot angular radius		Lifetime	Mean rotation
	i_{spot}	i_{seismo}	$\langle C_{max} \rangle$	median	range	τ	$\overline{T}$
	.... (deg)		($^0/_{00}$)	...... (deg)		.... (day)	
HD 49933	50 ± 25°	55 ± 10° (a)	1	1.8	1 → 2.5°	2.5 → 3.5	$3.45^{+0.05}_{-0.05}$
HD 175726	55 ± 25°	–	8	4.7	3 → 7°	5 → 7	$3.95^{+0.1}_{-0.1}$
HD 181420	60 ± 25°	45 ± 4° (b)	0.8	1.6	0.8 → 2°	1.5 → 3	$2.25^{+0.03}_{-0.01}$
HD 181906	45 ± 25°	24 ± 3° (c)	1	1.8	1.0 → 2.5°	1.5 → 3	$2.71^{+0.03}_{-0.01}$



Activity / Seismo side

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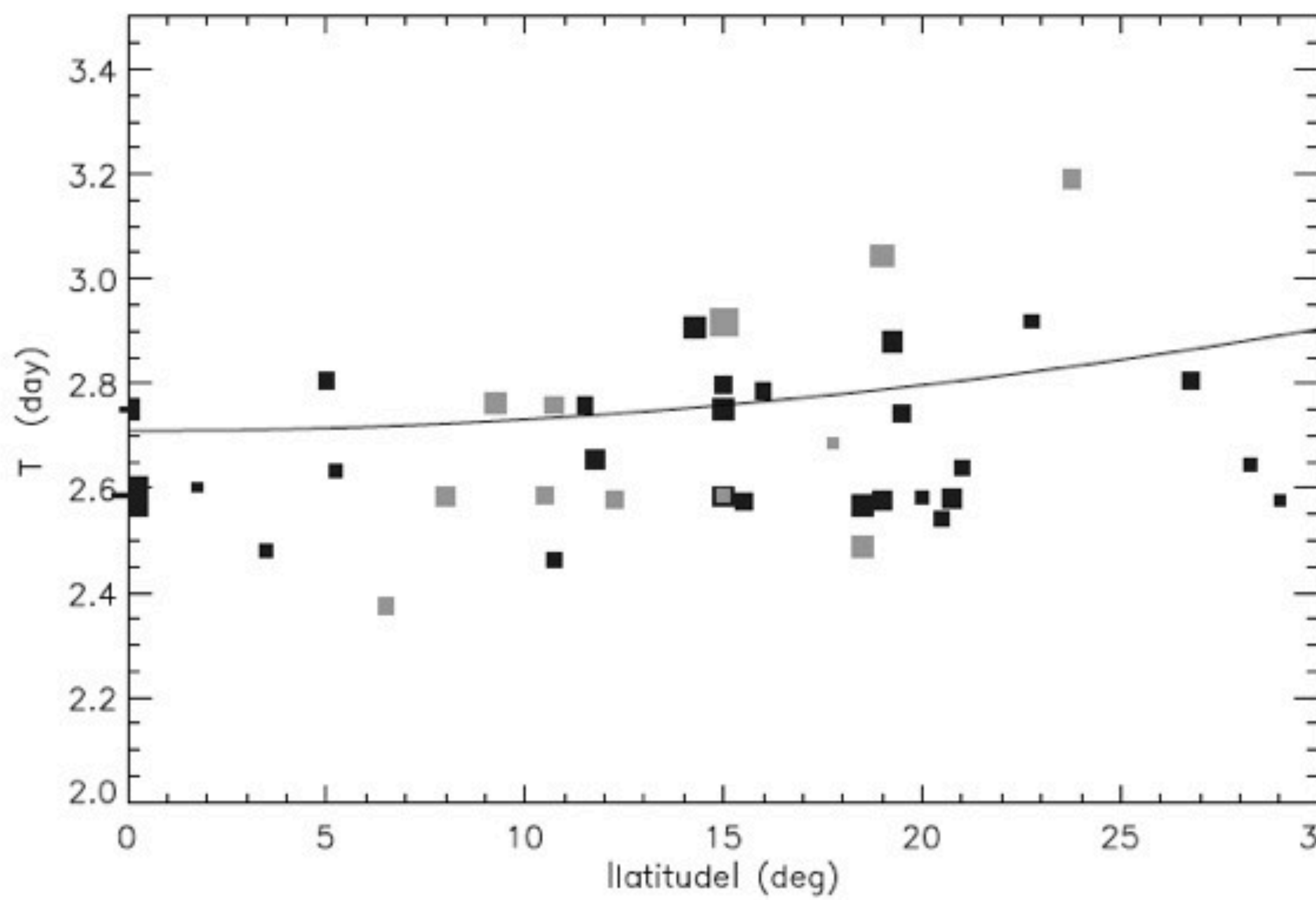
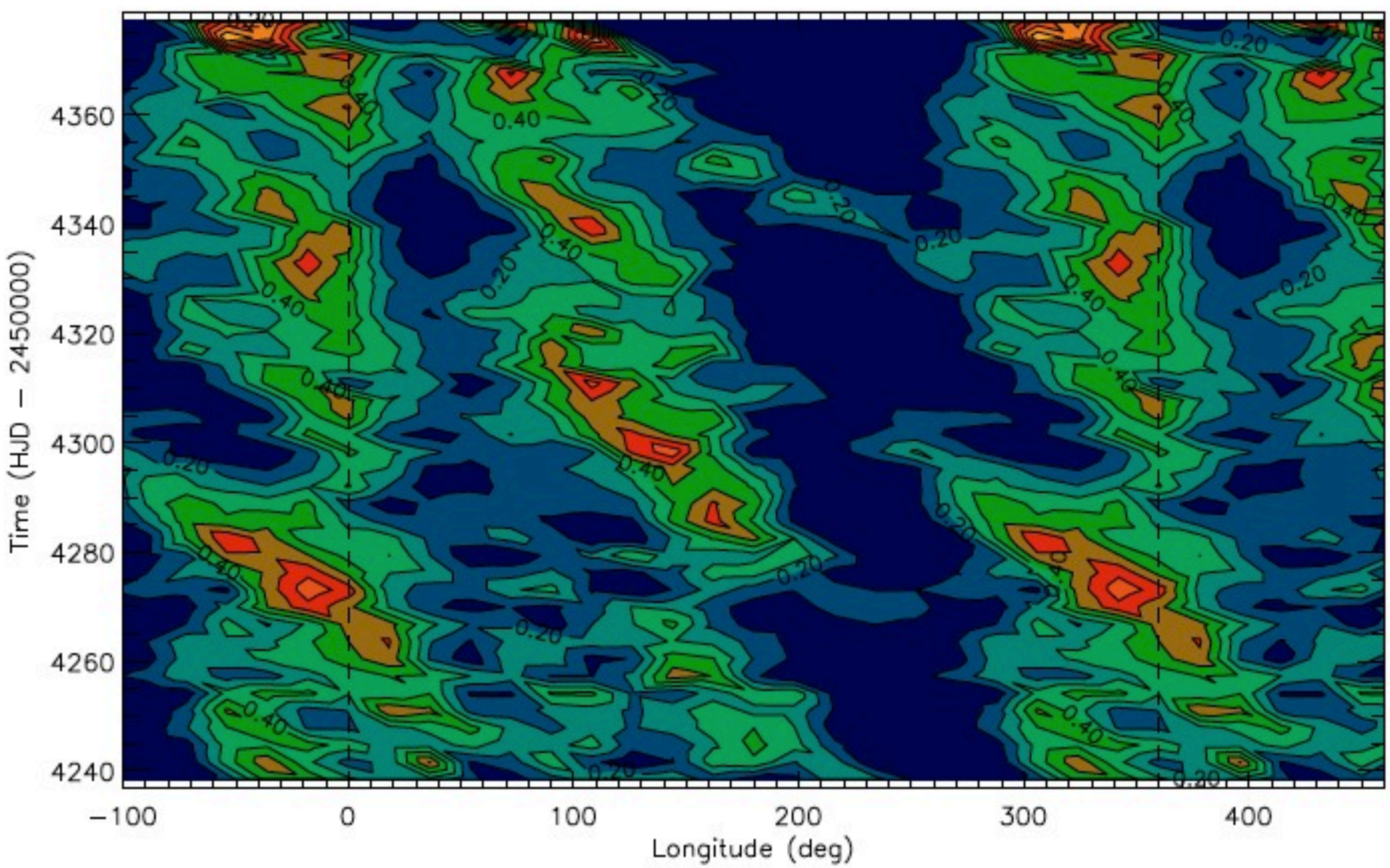
Signature of differential rotation



Activity / Exo side

Series of works of Lanza et al (2009, 2010) on stars with exoplanets: Corot-2, 4, 6 and 7a. Model including faculae.

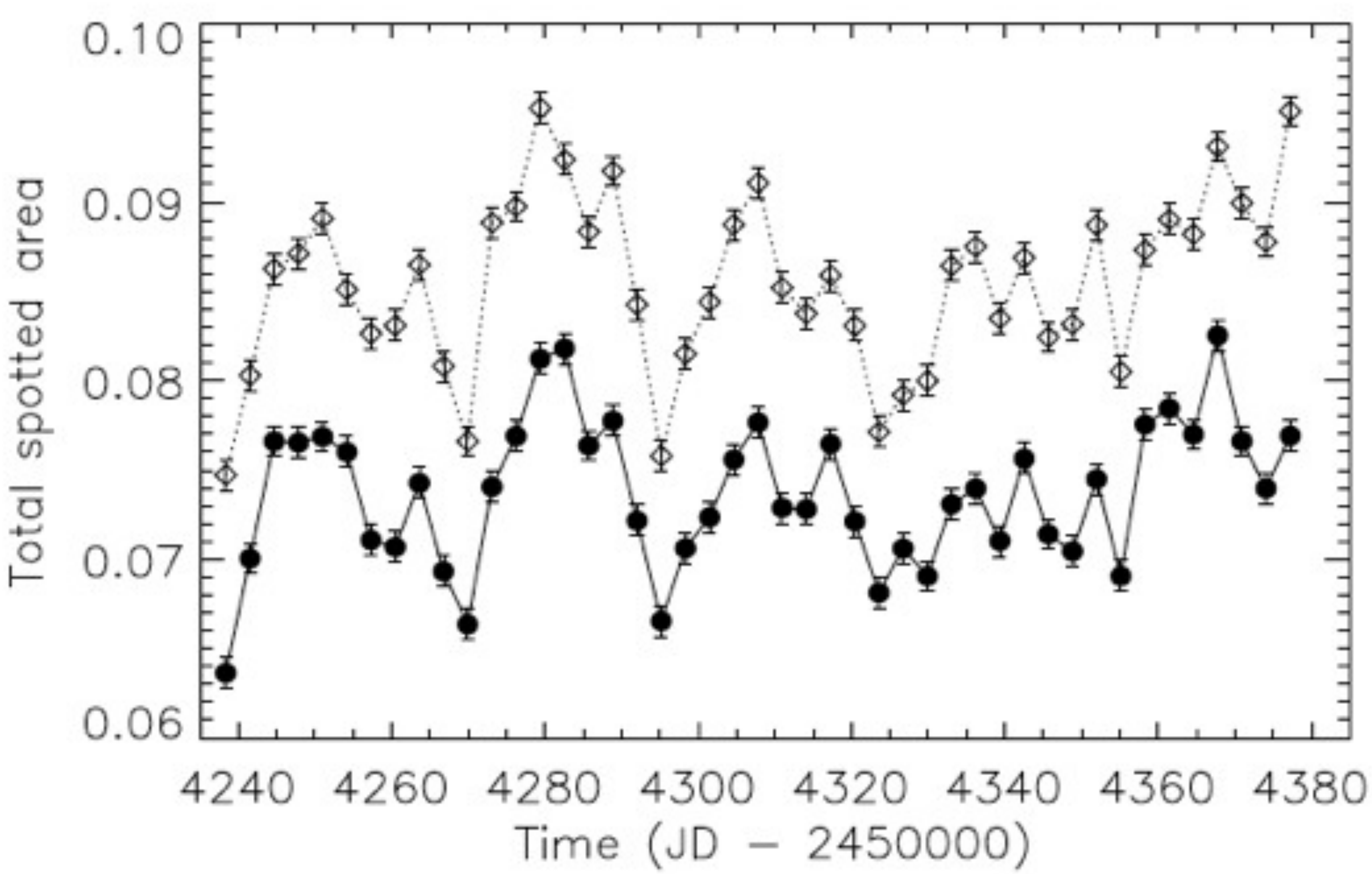


Corot-2a: two active regions, 180° apart, spots slower once formed

Activity / Exo side

Corot-2a:

- weak differential rotation (0.7%)
- best fit model without faculae
- slower spots once formed interpreted as changing «rooting» of the spots and shear layer



- total spotted area varying periodically (P~ 29days)

Activity / Exo side

Corot-2a:

- weak differential rotation (0.7%)
- best fit model without faculae

Corot-4a:

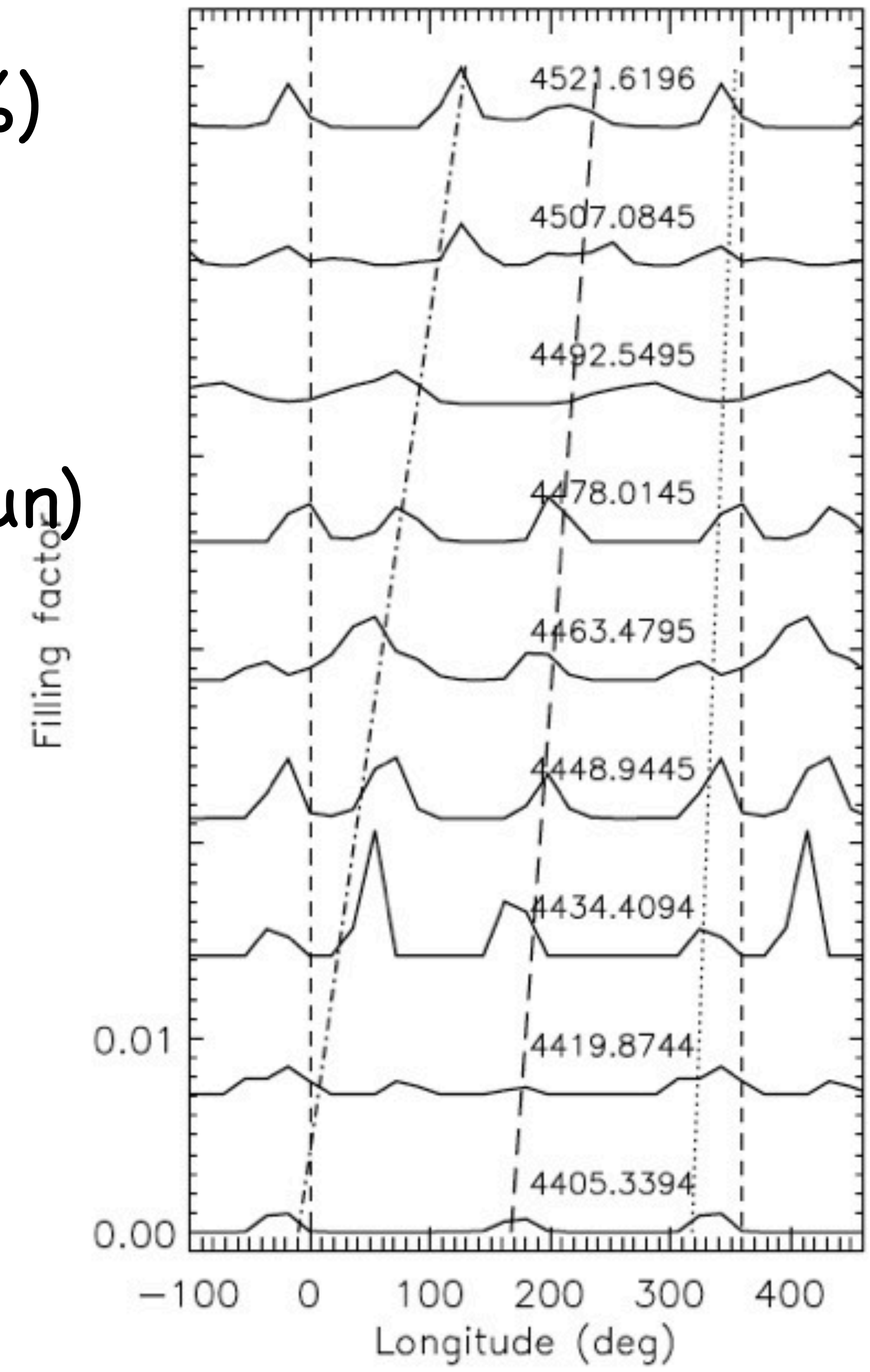
- differential rotation (6-8%; ~Sun)

Corot-6a:

- differential rotation (12%)
- faculae in best fit

Corot-7a:

- differential rotation (6%)
- faculae in best fit



Activity / Exo side

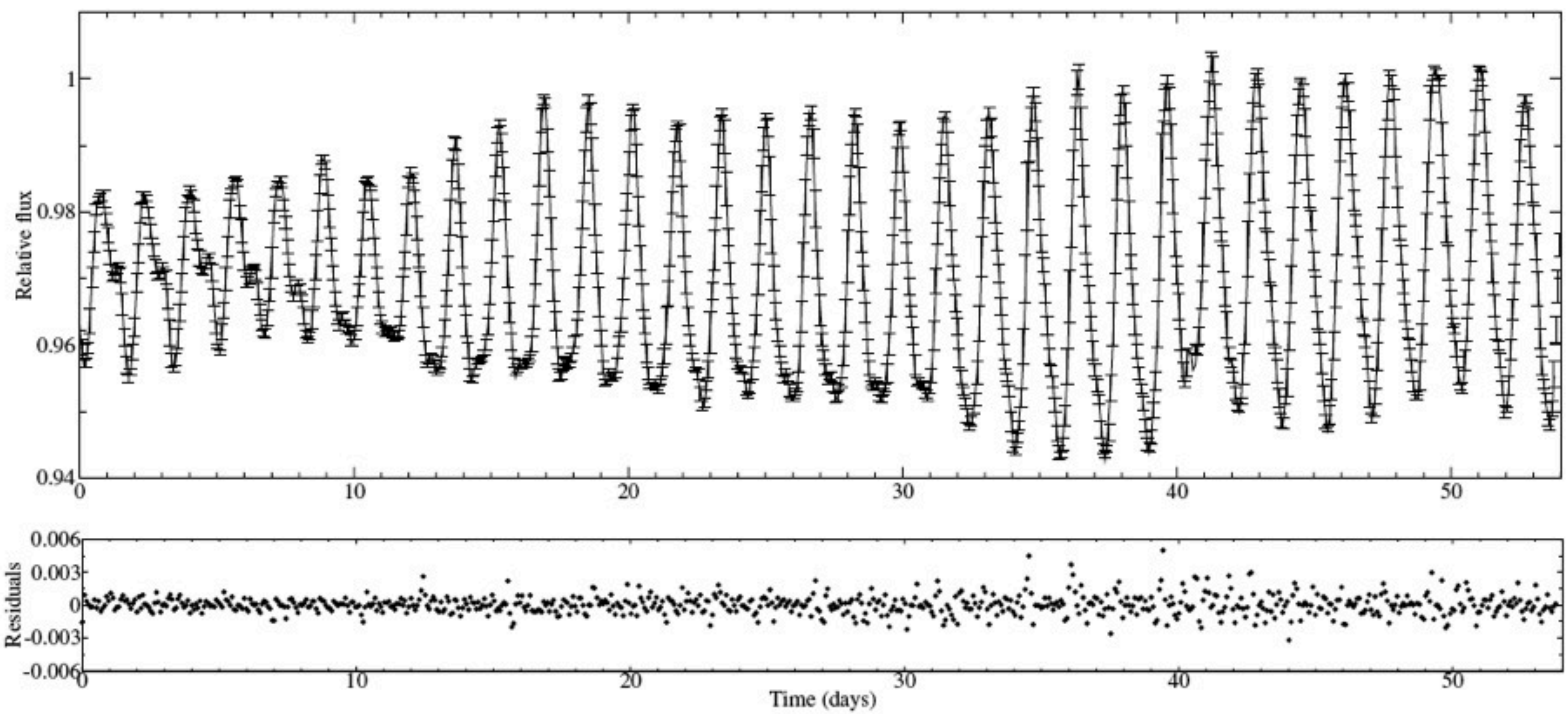
- Frohlich et al 2009: re-analysis of Corot-2a => higher (than Lanza et al) differential rotation detected (assuming longer lived active regions)

- Attempt to reconstruct RV measurements from the photometric light-curve with Corot-7a case (Lanza et al 2010)

- Possible link between the planet and an active region (which could be the footprint of a magnetic structure perturbed by the planet).

Activity / Exo side

Gondoin et al. 2012 :
Curve (3-spot) modelling of a young sun analog (P_{rot}=1.6 day) from the exo-side



Activity / Exo side

- Stellar evolution tracks => PMS star
  age=23 Myr, $\mathbf{0.96R_o < R < 1.36R_o}$,
  $M \sim 1.1M_o$

- Spot modelling => $\mathbf{P_{rot}=1.6}$ **day**; $\mathbf{74° < i < 88°}$

  => expected vsin i = 35±7 km/s

- Spectroscopic obs. => vsin i = 36±1 km/s

Activity / Exo side

- Stellar evolution tracks => PMS star
  age=23 Myr, $0.96R_{o} < R < 1.36R_{o}$, $M \sim 1.1M_{o}$

- Gyrochronology:
  2 laws, I («slower» rotators) and C (ultra-fast ones)
  70 Myr < age(C) < 180 Myr
  8Myr < **age(I)** < 25 Myr

  Suggests a stronger (magnetic) braking

Practical conclusions

- Mainly the few first runs analysed: articles appearing from 2011 on dealing with IRa01 and LRc01.

- Data glitches can be a problem (e.g. Affer et al 2012).

(short) Conclusions

=> Rotation measured for thousands of stars

=> Differential rotation measured in several stars (still more work needed)

=> Spots modelled in several stars from the seismo AND exo side

=> Star activity-planet link? Lanza et al:

«A major difficulty with the allegedly cases of magnetic star-planet interactions comes from the remarkably different behaviours observed in different stars that makes it impossible to define a common and simple phenomenology.»