



2000-04-26 16:29

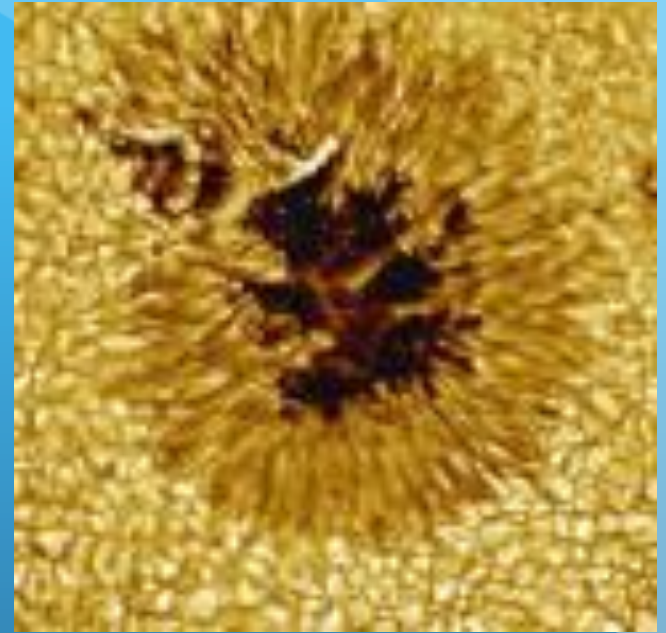
E N
S W

Spot evolution on CoRoT-2

Yuri Simplicio & Adriana Válio
CRAAM/Mackenzie - Brazil

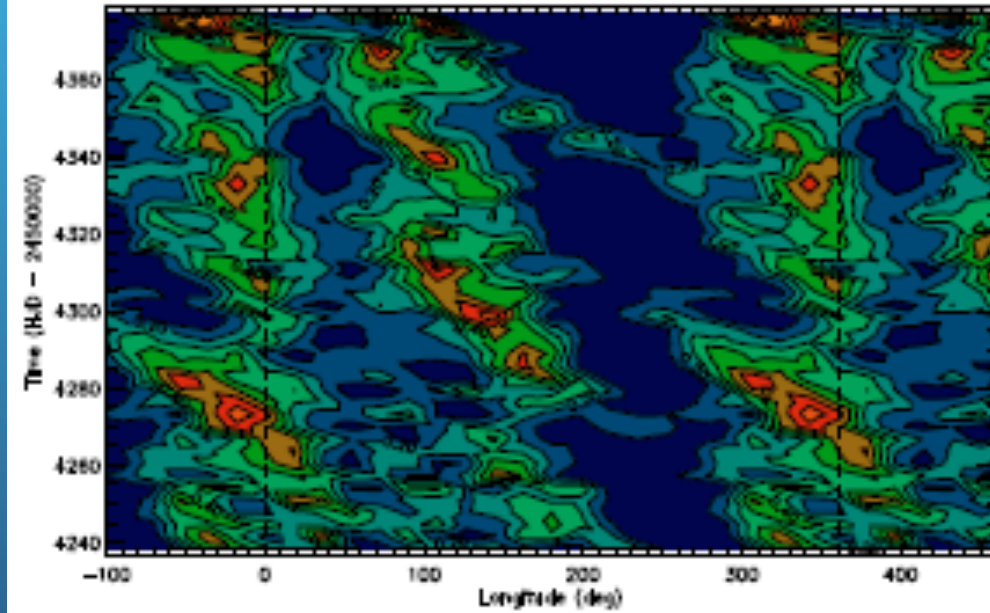
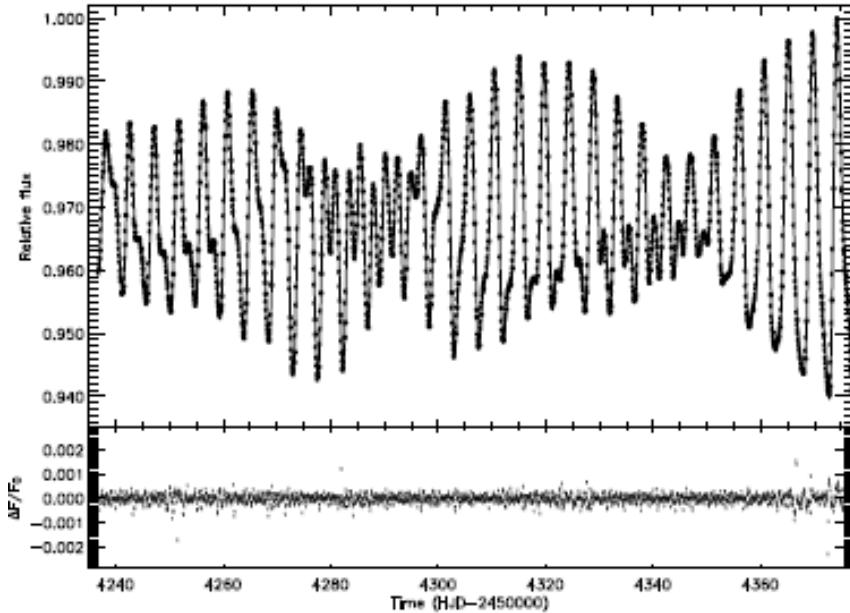
Sunspots & Starspots

- Cooler than the surrounding photosphere and therefore appear as dark regions.
- Regions of strong magnetic fields on the surface of the Sun (100s - 1000s Gauss);
- Dark spots cross the stellar disk due to rotation and thus modulate the total brightness with the rotational period of the star.
- Starspots are observable tracers of the internal dynamo activity, and their study provides a glimpse into the complex internal stellar magnetic field.



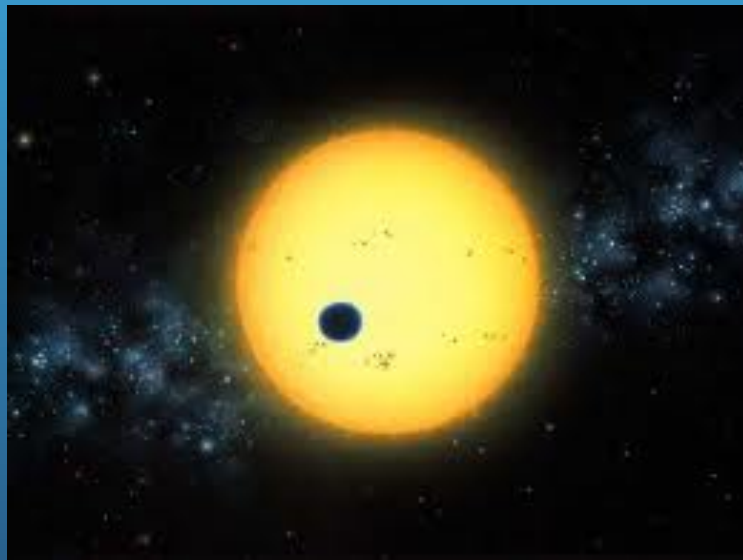
CoRoT-2

- Lanza and collaborators applied this model to many stars, among them CoRoT-2, 4, 6, 7.

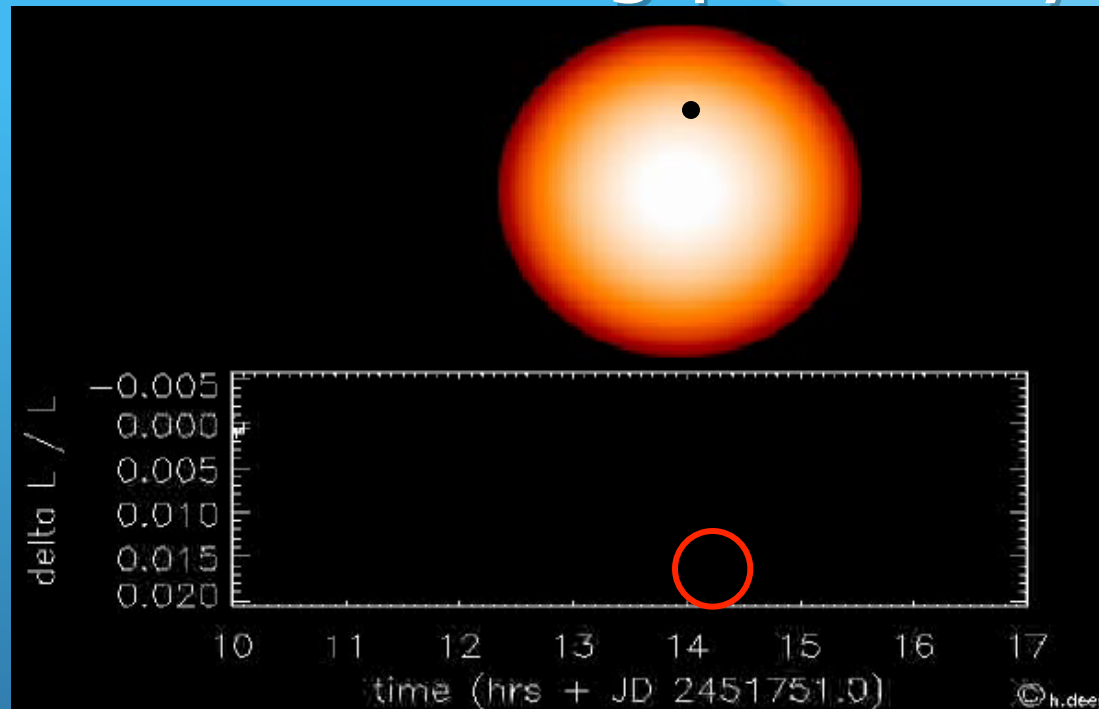


(CoRoT-2, Lanza et al. 2009)

Planetary Transit Model



Spots detection during planetary transits



- Total of 861 planets discovered orbiting other stars (13-Mar-2013);
- 294 (34%) of them transit their host star;
- During one of these transits, the planet may pass in front of a spot group and cause a detectable signal in the light curve of the star;

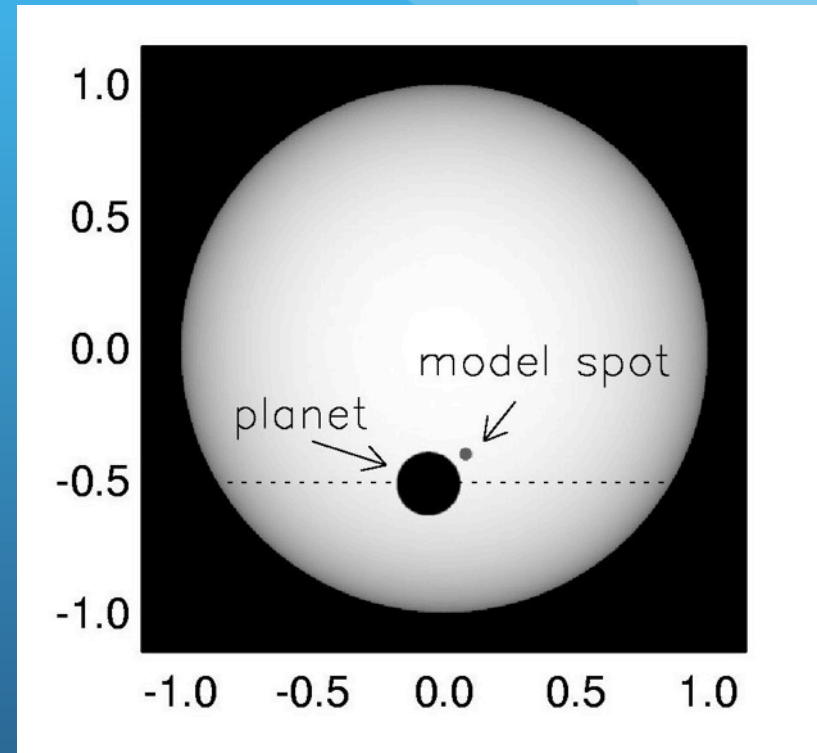
Starspots

- Method that simulates planetary transits: uses the planet as a probe to study starspots (Silva, ApJ Letters, 585, L147-L150, 2003)
- Stellar activity - infer spots physical characteristics:
 - Size (area coverage)
 - Intensity – temperature
 - Location (long & lat)
 - **Lifetime**
- Stellar properties (multiple transits):
 - Rotation period
 - Differential rotation
 - Activity cycle



Spot model

- **Spot:** characterized by 3 parameters:
 - **Intensity:** measured with respect to stellar maximum intensity (center);
 - **Size:** measured in units of planetary radius;
 - **Position:** Latitude (restricted to the transit band) and Longitude.
- Foreshortening taken into account



Modeling of observations: CoRoT-2

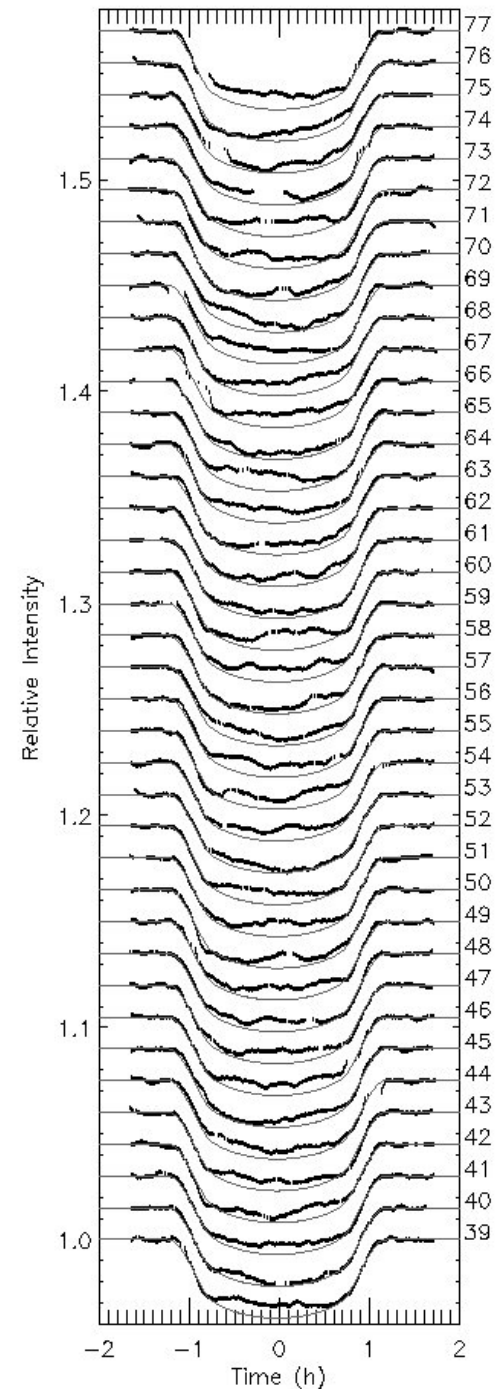
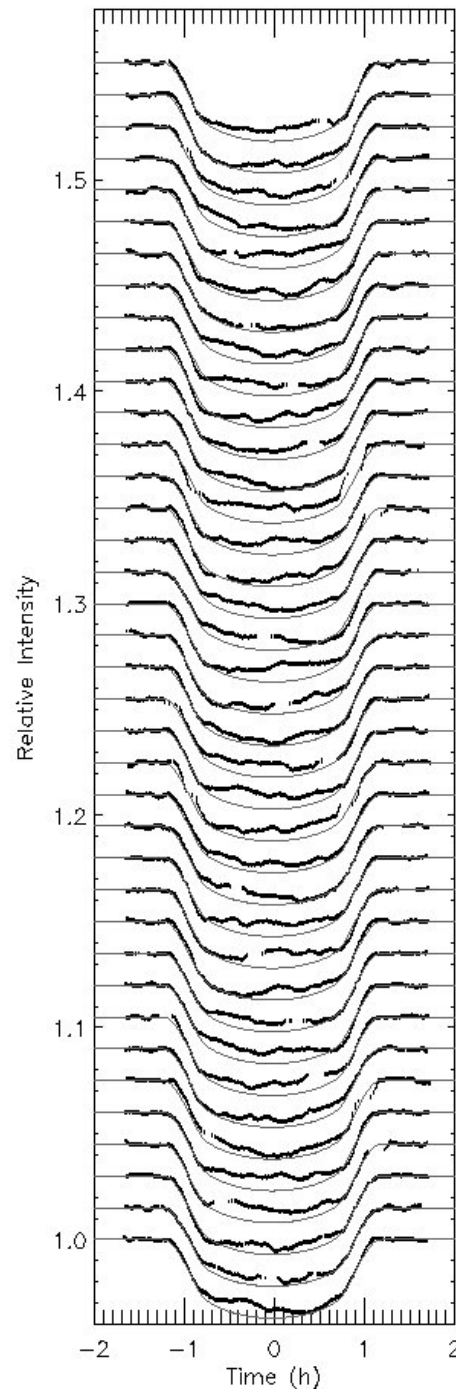
Silva-Valio et al. 2010, A&A, 510, 25

Silva-Valio & Lanza 2011, A&A, 529, 36

Transits

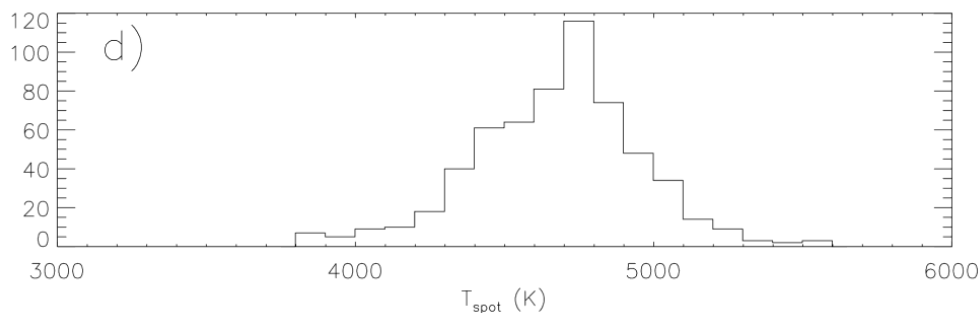
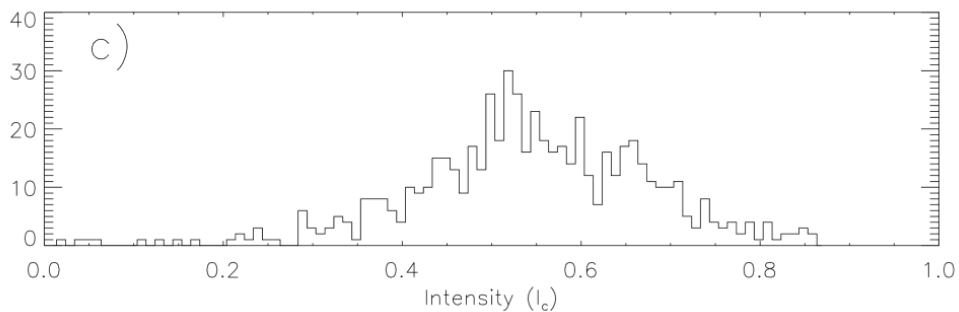
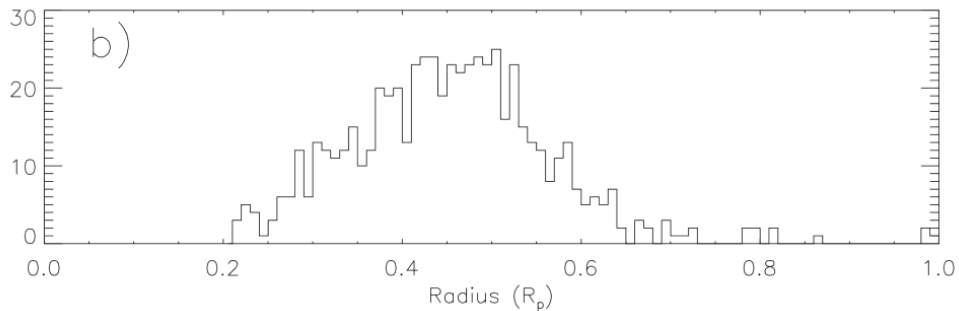
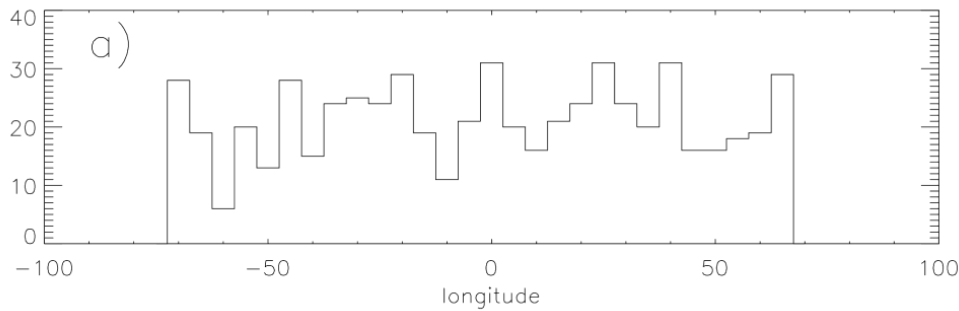
- 77 transits
- (134 days)
- $P = 1.743$ days

- Silva-Valio et al. 2010, A&A, 510, A25



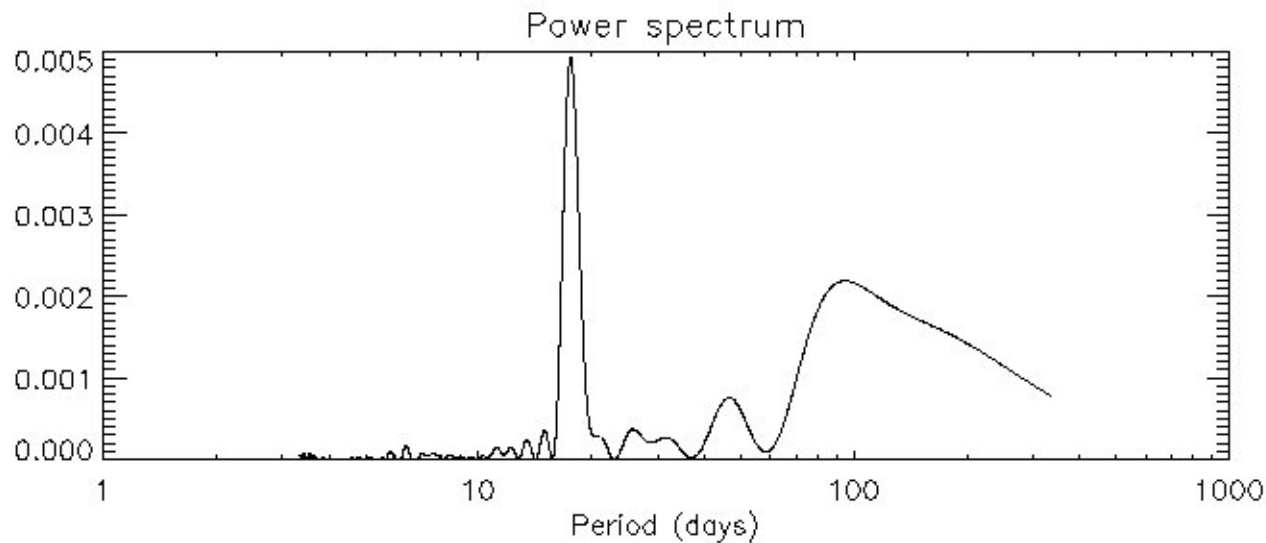
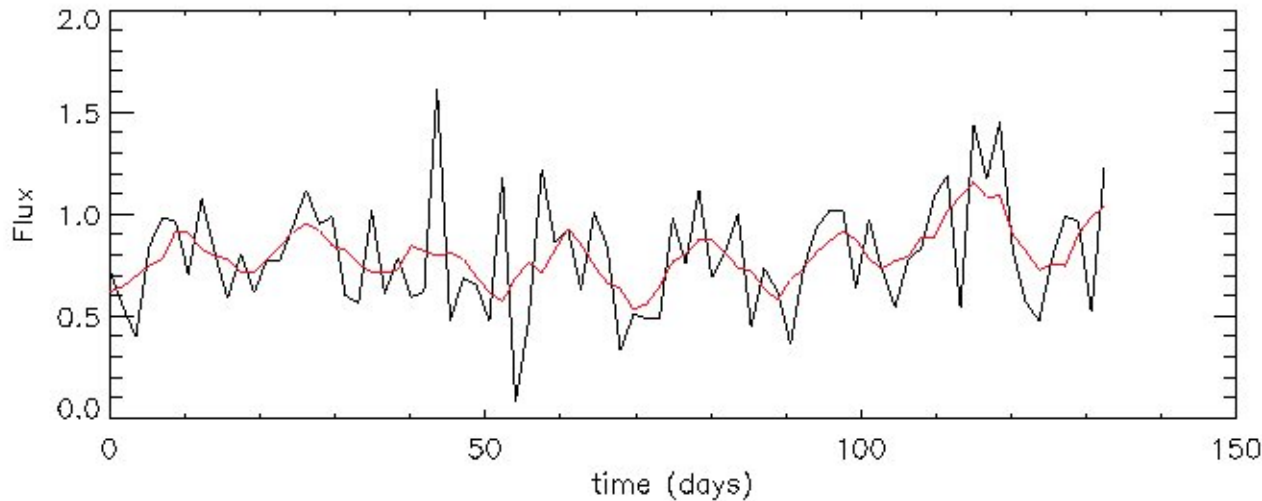
Results

- Average for 392 spots:
 - Radius = $0,46 \pm 0,11 R_p$
 - Int = $0,55 \pm 0,13 I_c$
 - $T = 4600 \pm 700$ K
- (Black body: $T_{\text{eff}} = 5625$ K)



$$\frac{I_o}{I_e} = \frac{\exp\left(\frac{h\nu}{KT_e}\right) - 1}{\exp\left(\frac{h\nu}{KT_o}\right) - 1}$$

Temporal evolution



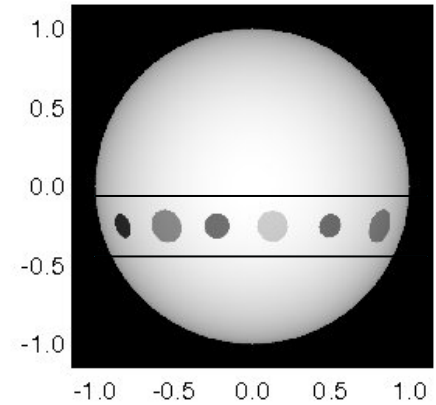
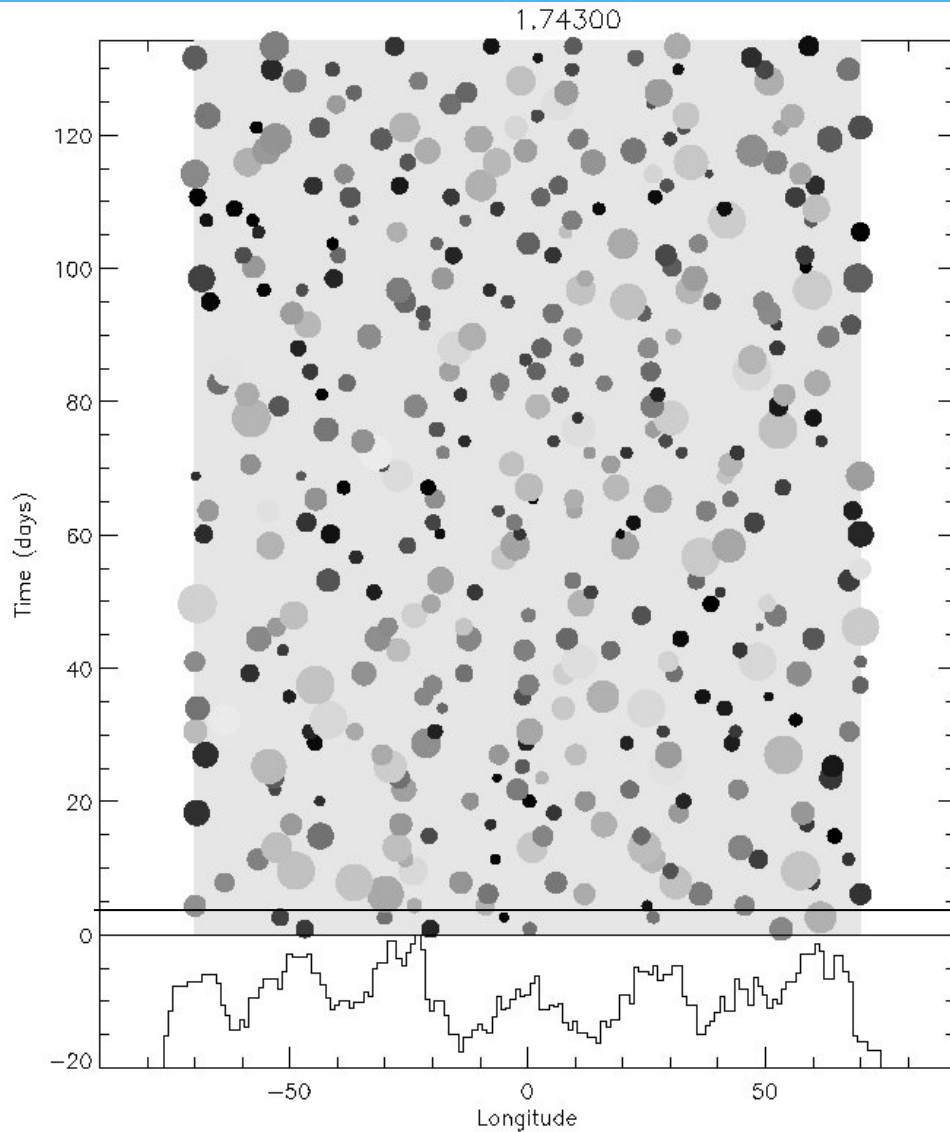
- Integrated flux deficit in longitude for each transit:

$$Flux = \left(1 - \frac{I_{spot}}{I_c}\right) \left(\frac{R_{spot}}{R_{plan}}\right)^2$$

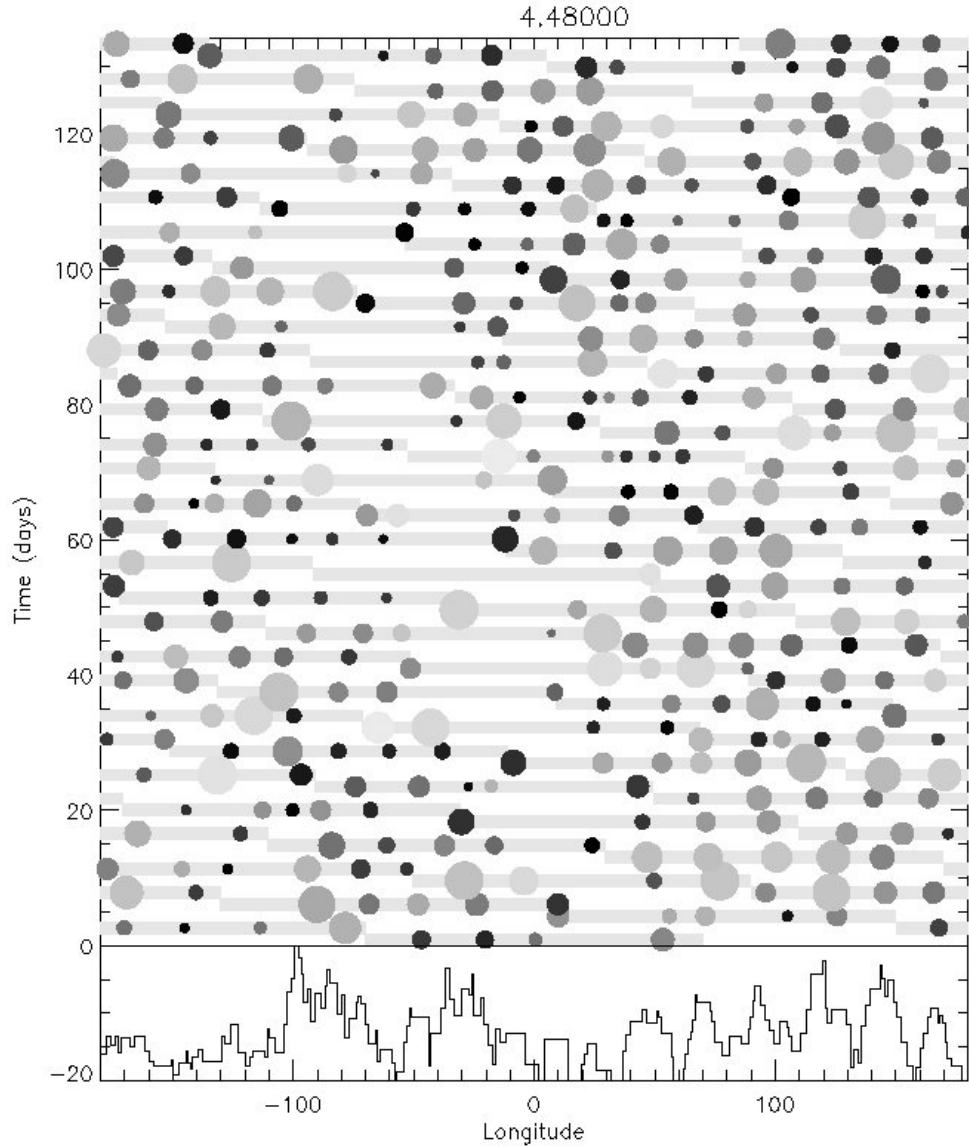
- Periodicity of 17.5 days (aprox. 10 times $P_{orb} = 1.743$ days)

Surface mapping

CoRoT-2

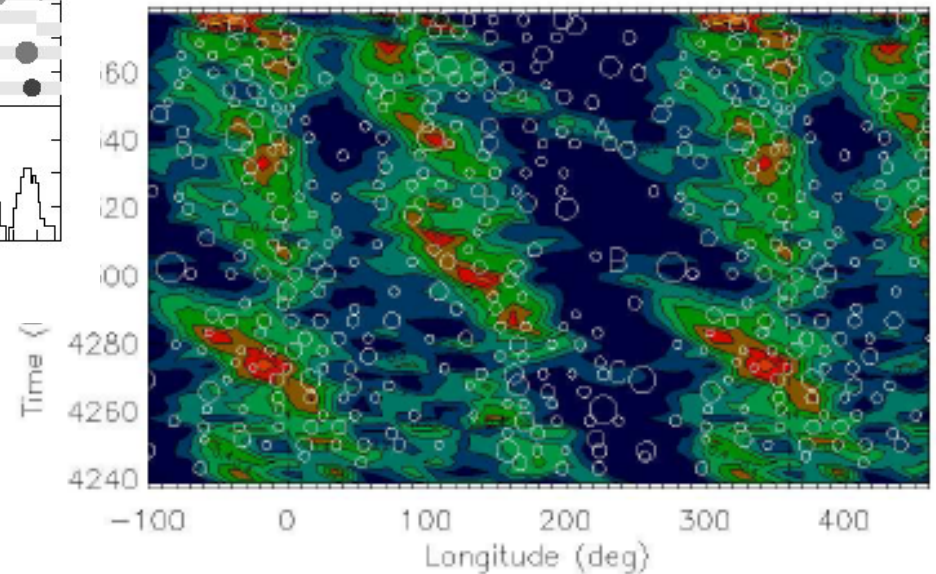


- Surface map of the star for each transit;
- Topocentric longitude (origin = l.o.s. at mid transit)



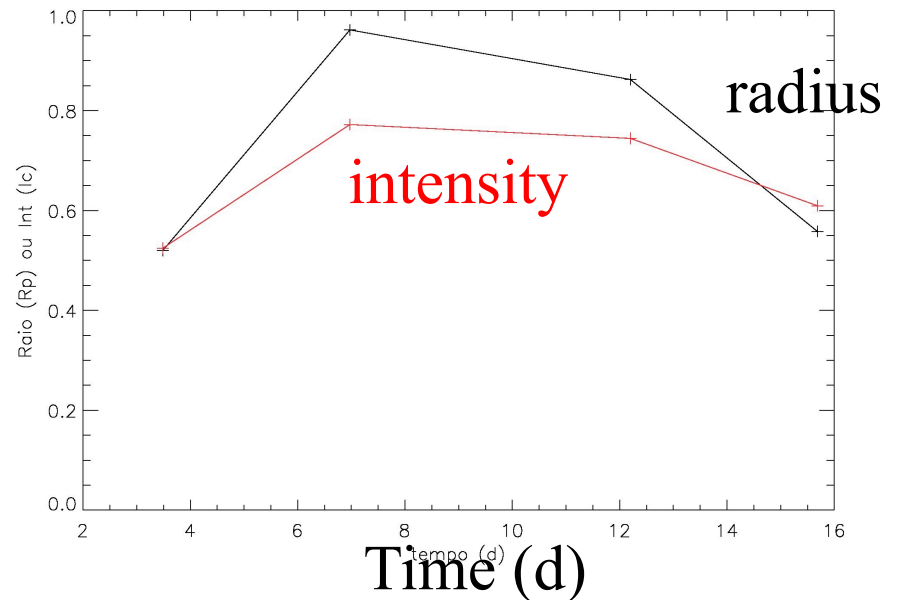
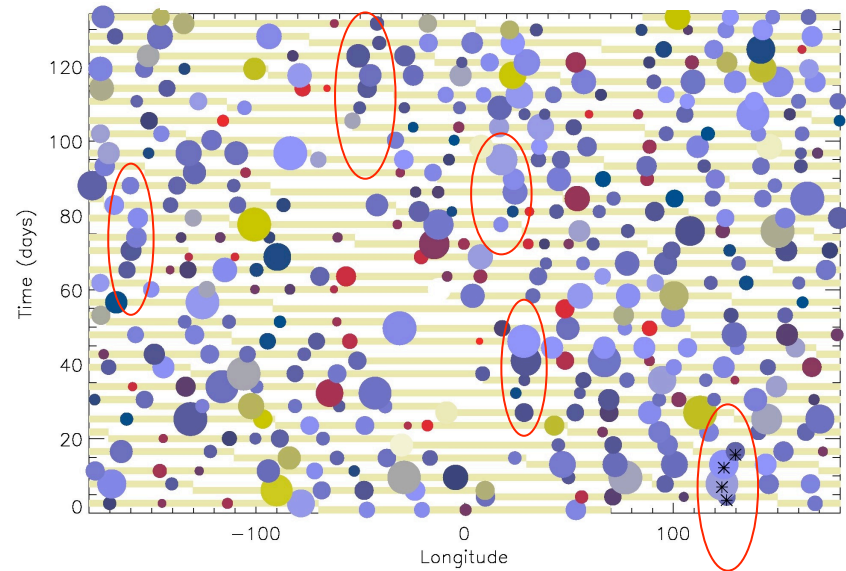
➤ Surface map that rotates with the star with $P_{\text{rot}} = 4.48 \text{ d}$

Lanza et al. (2009)



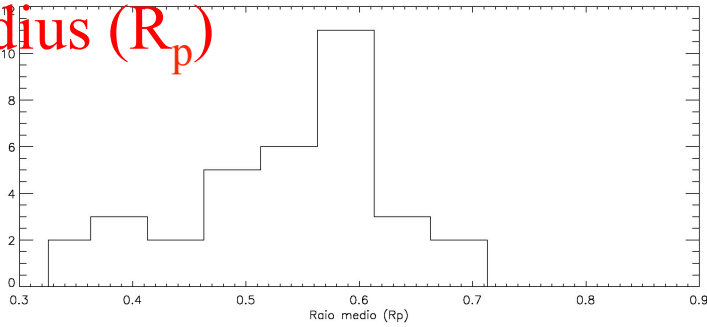
- Analysis of **34** individual spots
- Detected on multiple transits of stellar surface map with: $P_{\text{rot}} = 4.48 \text{ d}$

Long = $+126^\circ$; $\Delta\text{Long} = 4^\circ$

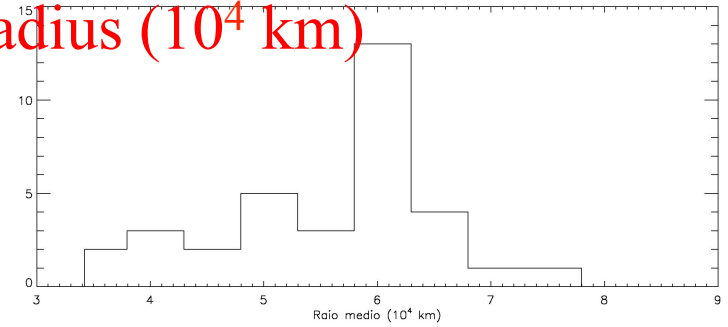


Results

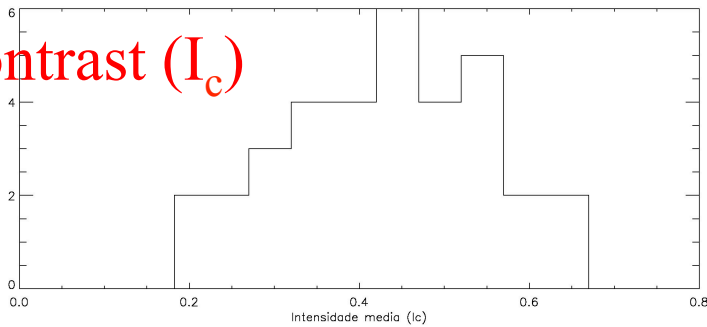
Radius (R_p)



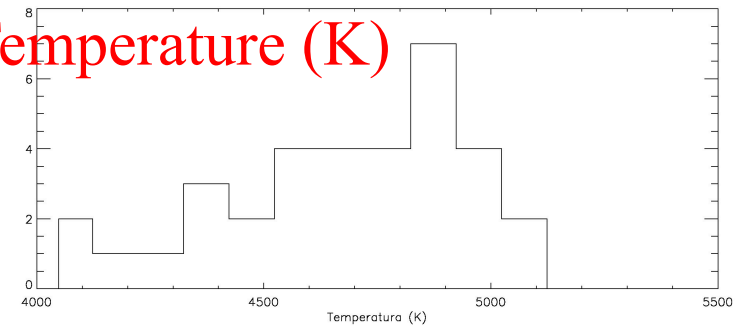
Radius (10^4 km)



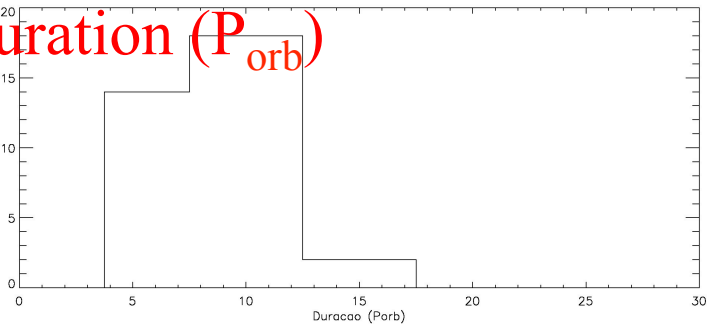
Contrast (I_c)



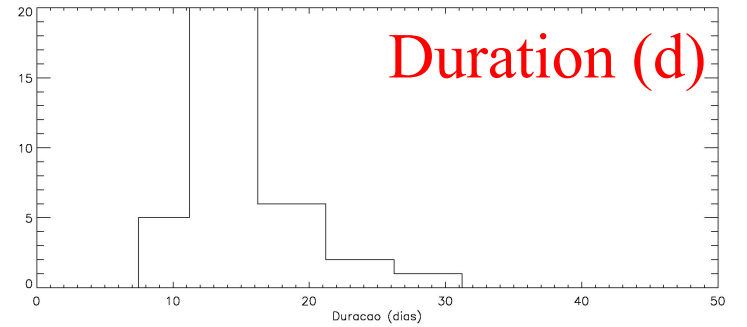
Temperature (K)



Duration (P_{orb})



Duration (d)



Averages

CoRoT-2	Model fit	Absolute values
Individual spots		
Radius	$0.56 \pm 0.09 R_p$	$5.8 \pm 1.0 (10^4) \text{ km}$
Contrast/Temperature	$0.45 \pm 0.12 I_c$	$4700 \pm 300 \text{ K}$
Duration/Lifetime	$9.9 \pm 2.9 P_{\text{orb}}$	$17 \pm 5 \text{ days}$
All 392 spots		
Radius	$0.53 \pm 0.18 R_p$	$5.5 \pm 1.9 (10^4) \text{ km}$
Contrast/Temperature	$0.45 \pm 0.25 I_c$	$4600 \pm 700 \text{ K}$

Previous result: the periodicity in spot flux for each transit summed over all longitudes is 17.5 days.

Summary

- Analysis of 34 individual spots detected on multiple transits of the star CoRoT-2;
- Average values of spot radius and temperature agree with previous results from all 392 spots;
- Individual spots on the surface of CoRoT-2 have lifetimes lasting from 10 to 30 d, with an average of 17 days;
- Longer lifetime than sunspots;
- This is 10 times P_{orb} and approx. 4 times P_{rot} ;
- Star-planet interaction.

Conclusions

- The modelling of small variations observed in the transit light curves yields:
 - Spots physical characteristics (size, temperature, location - active longitudes, **evolution/lifetime**, surface area coverage)
 - (*Silva 2003, ApJL, 585, L147, Silva-Valio et al. 2010, A&A, 510, 25*)
- Multiple transits:
 - Stellar rotation (*Silva-Valio 2008, ApJL, 683, L179*)
 - Stellar differential rotation (*Silva-Valio & Lanza 2011, A&A, 529, 36*)
- For longer observing period:
 - Stellar activity cycles

Gracias!

Spots periodicity

- Periodicity of 20° longitude bins: 33 ± 7 days
- Out-of-transit: ~ 29 days (Lanza et al. 2008)

