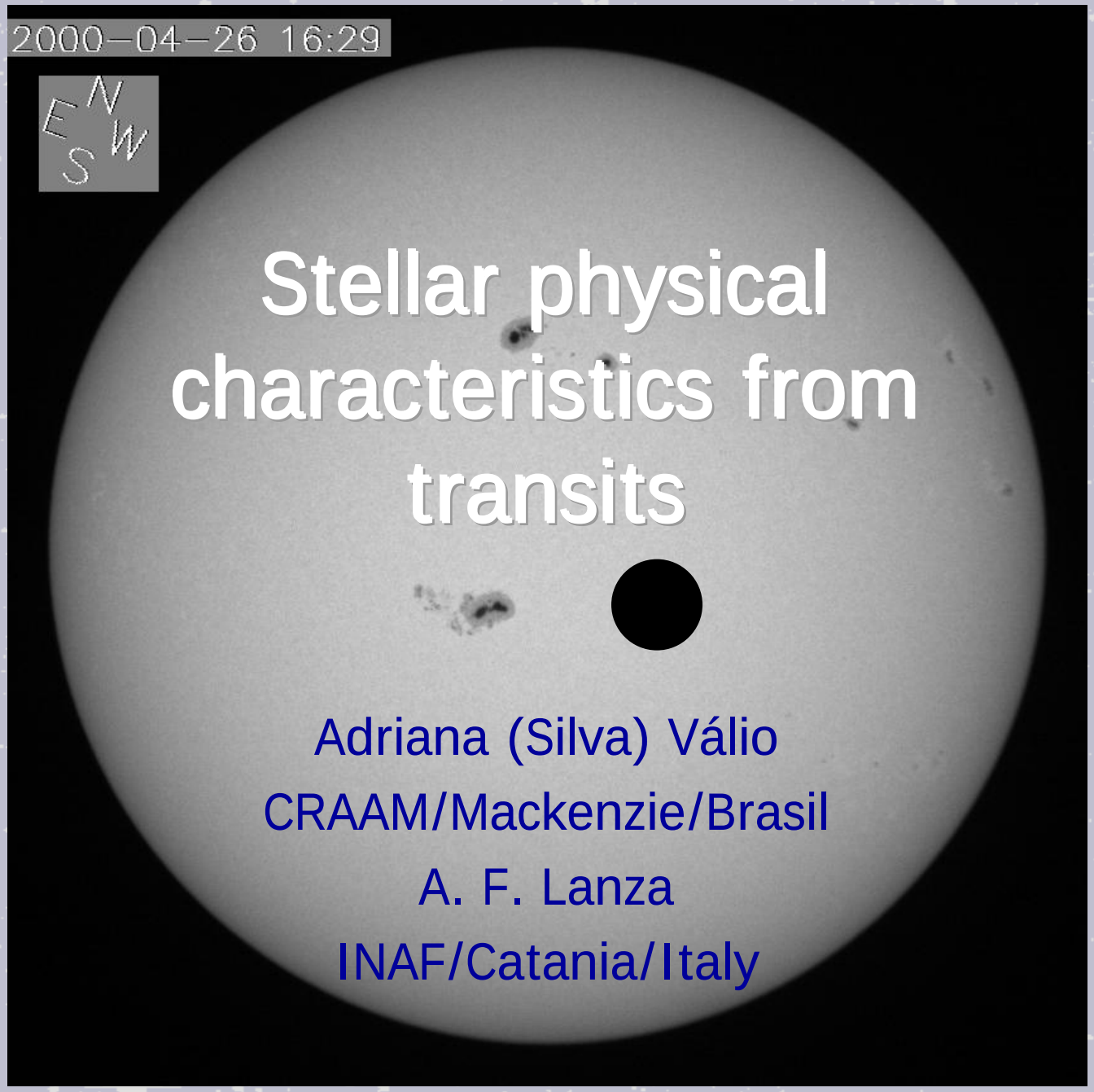


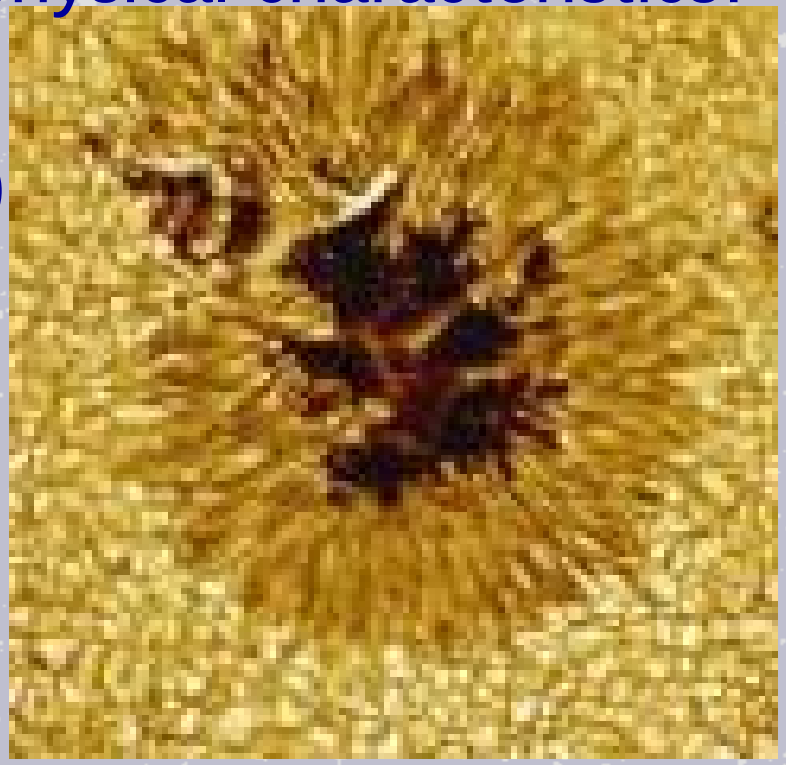

# Stellar physical characteristics from transits

Adriana (Silva) Válio
CRAAM/Mackenzie/Brasil
A. F. Lanza
INAF/Catania/Italy

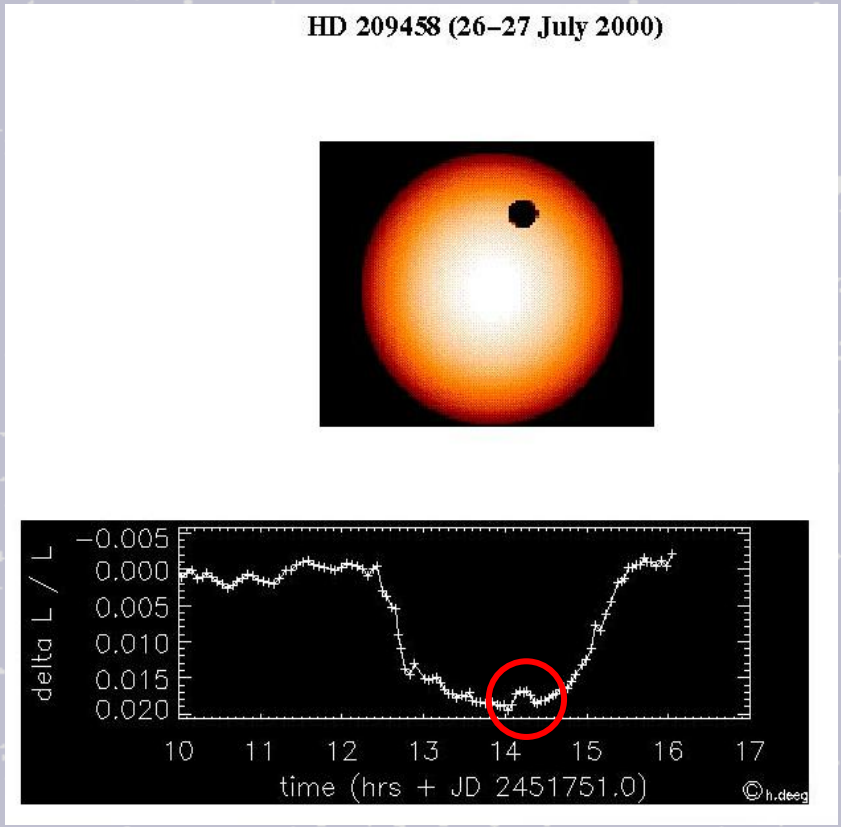
PLATO Science Conference 24-25/02/2011

# WP 123600
# Stellar Rotation from Transits

- Method that simulates planetary transits:
  - planet as a probe to study starspots
- Stellar activity - infer spots physical characteristics:
  - ✓ Size
  - ✓ Intensity (temperature)
  - ✓ Location (long & lat)
  - ✓ Temporal evolution
- Stellar properties:
  - ✓ Rotation period
  - ✓ Differential rotation

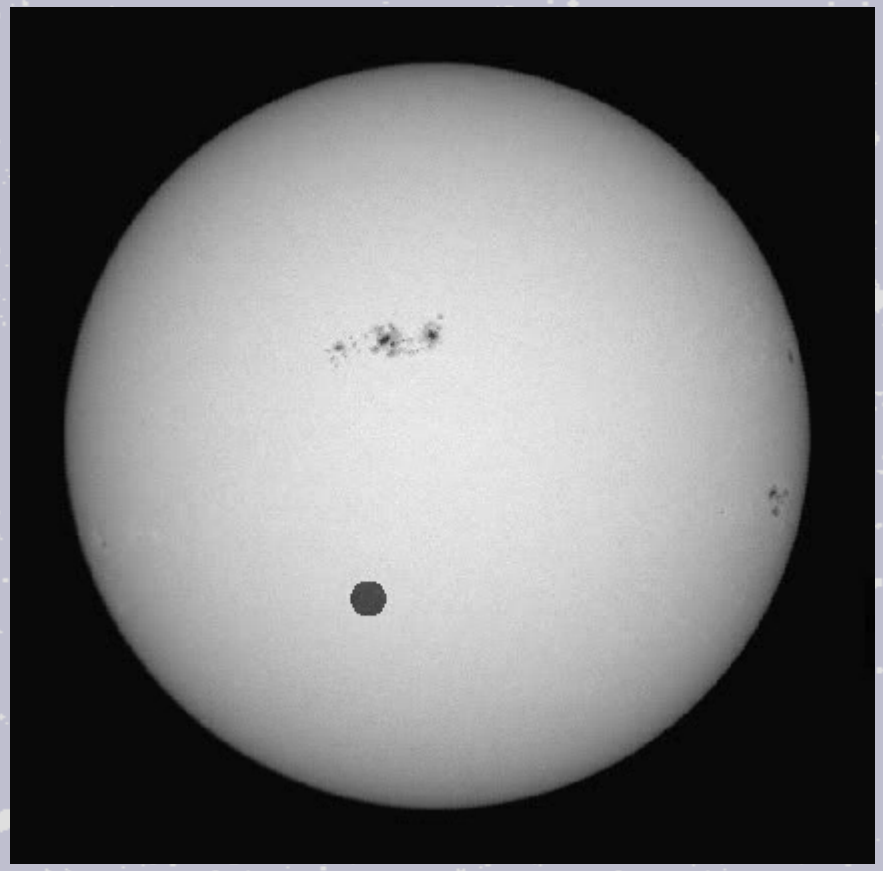


# Spot detection




- ~20% of extrasolar planets transit in front of host star.
- During one of the eclipses, the planet may pass in front of a stellar group of spots.
- Model the physical characteristics of starspots (Silva, ApJ Letters, 585, L147-L150, 2003)

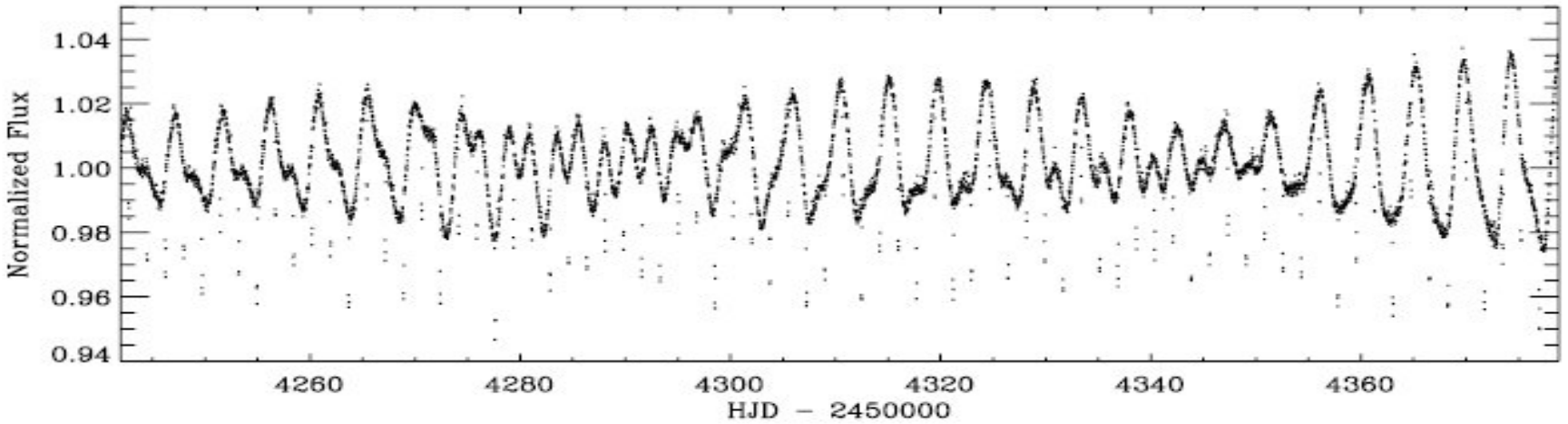
# Model: Transit Simulation

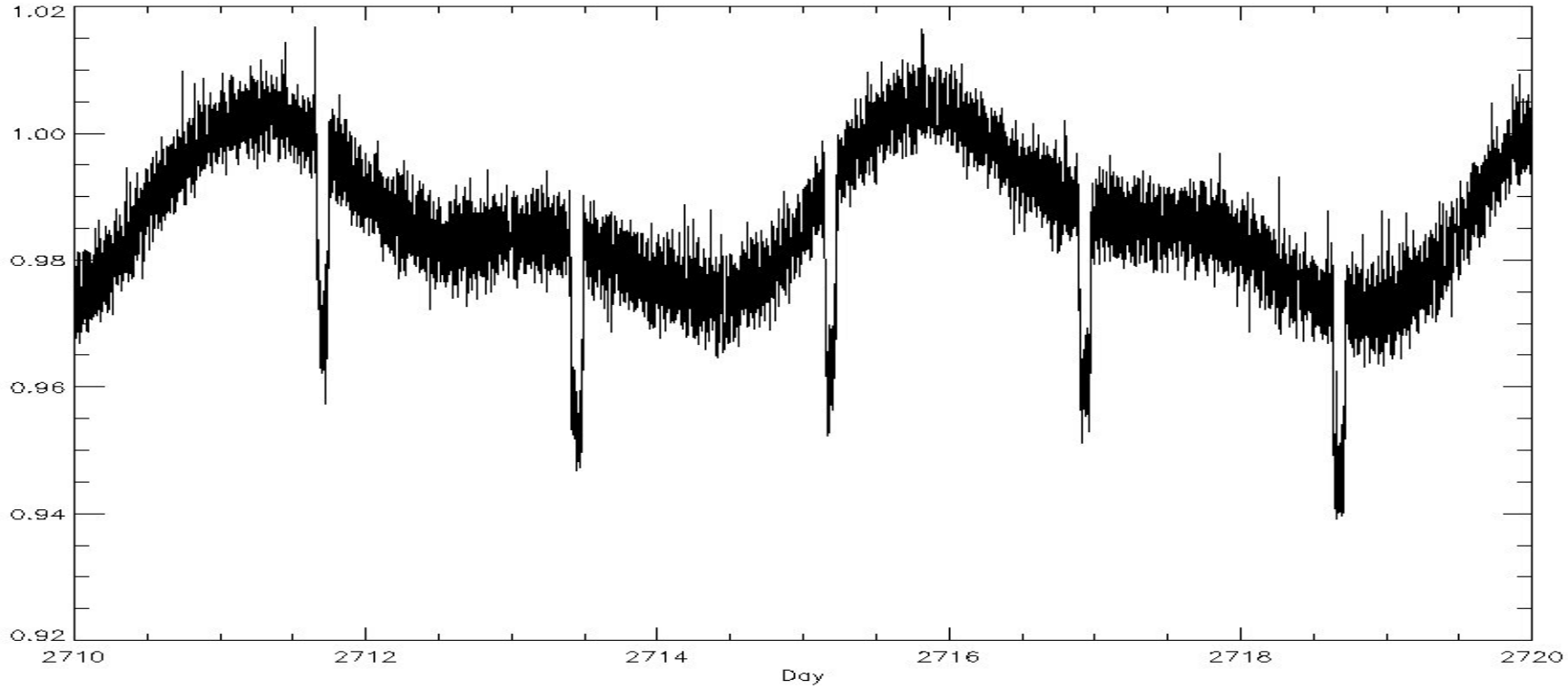


- Star: limb darkened disk
- Planet: opaque disk of radius $r/R_s$
- Transit: every two minutes, the planet is centered at a given position in a circular orbit ($a_{orb}/R_s$ and $i$)
- Light curve: integrated flux from the sum of all the pixels values in the image.

- Fit parameters: $r/R_s$, $a_{orb}/R_s$ and $i$ (Silva & Cruz, 2006 ApJ, 642, 488)

# Spot modeling (CoRoT-2)

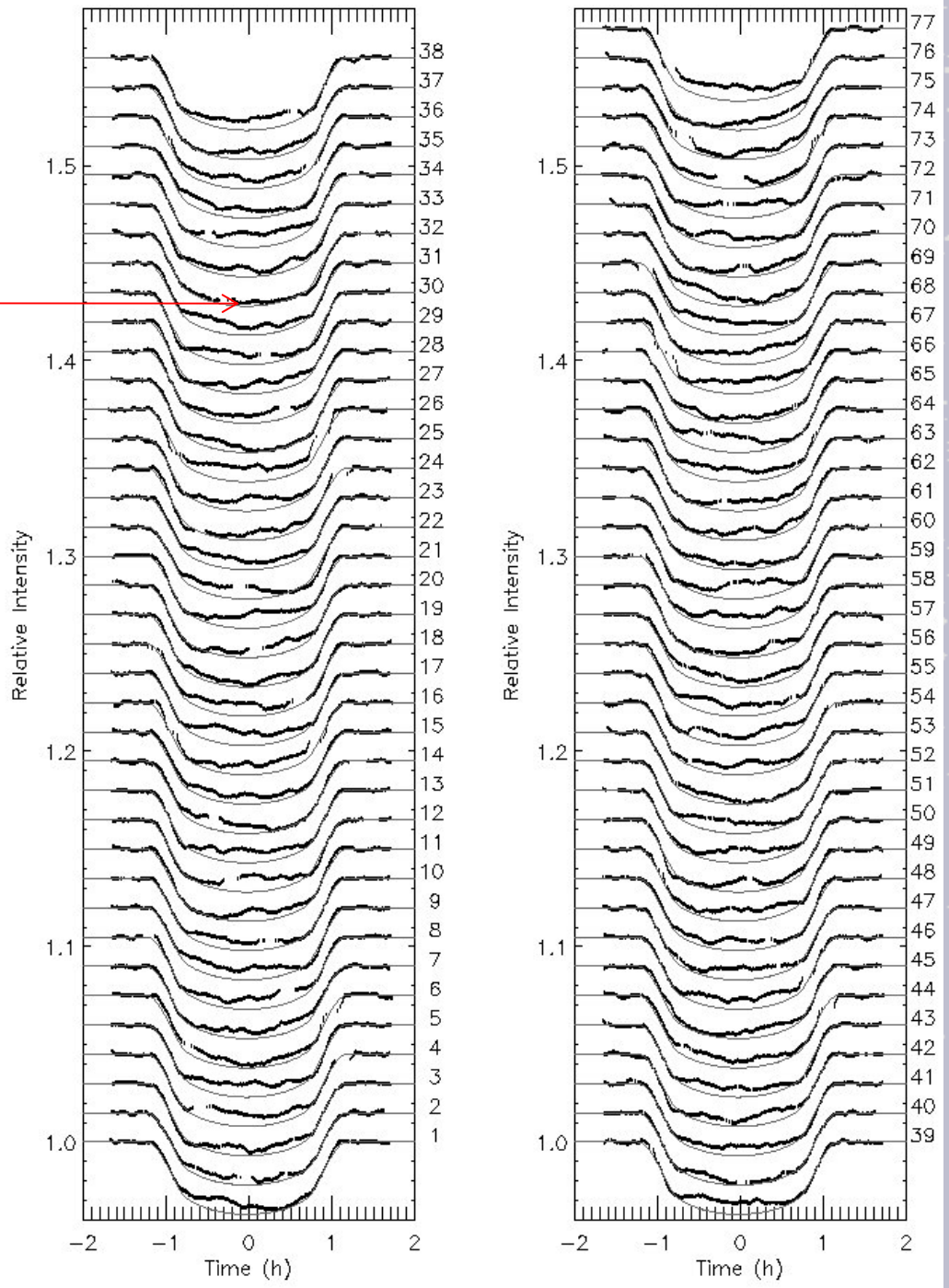

Normalized Flux
1.04
1.02
1.00
0.98
0.96
0.94
4260
4280
4300
4320
4340
4360
HJD − 2450000


1.02
1.00
0.98
0.96
0.94
0.92
2710
2712
2714
2716
2718
2720
Day

# Planet radius

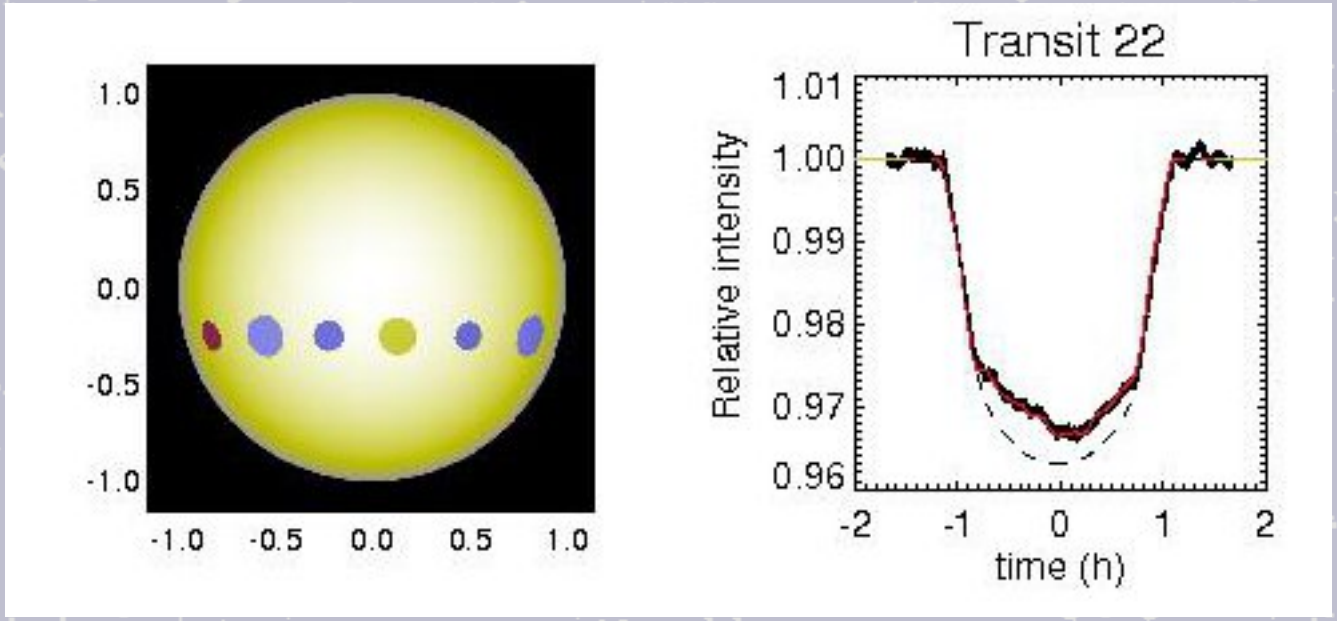
- 77 transits
- (134 days)
- P = 1.743 days
- Deepest transit (less activity)
- Planet radius = 1.544 $R_{jup}$ (1.465 $R_{jup}$) (5% larger)

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



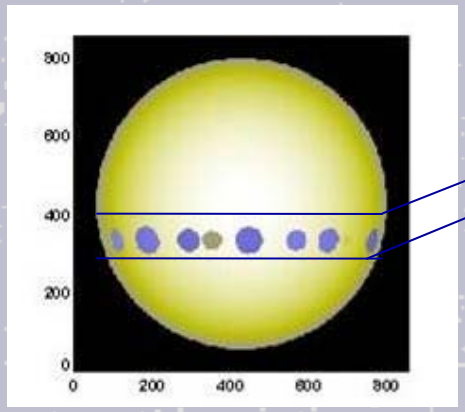
# Spot model

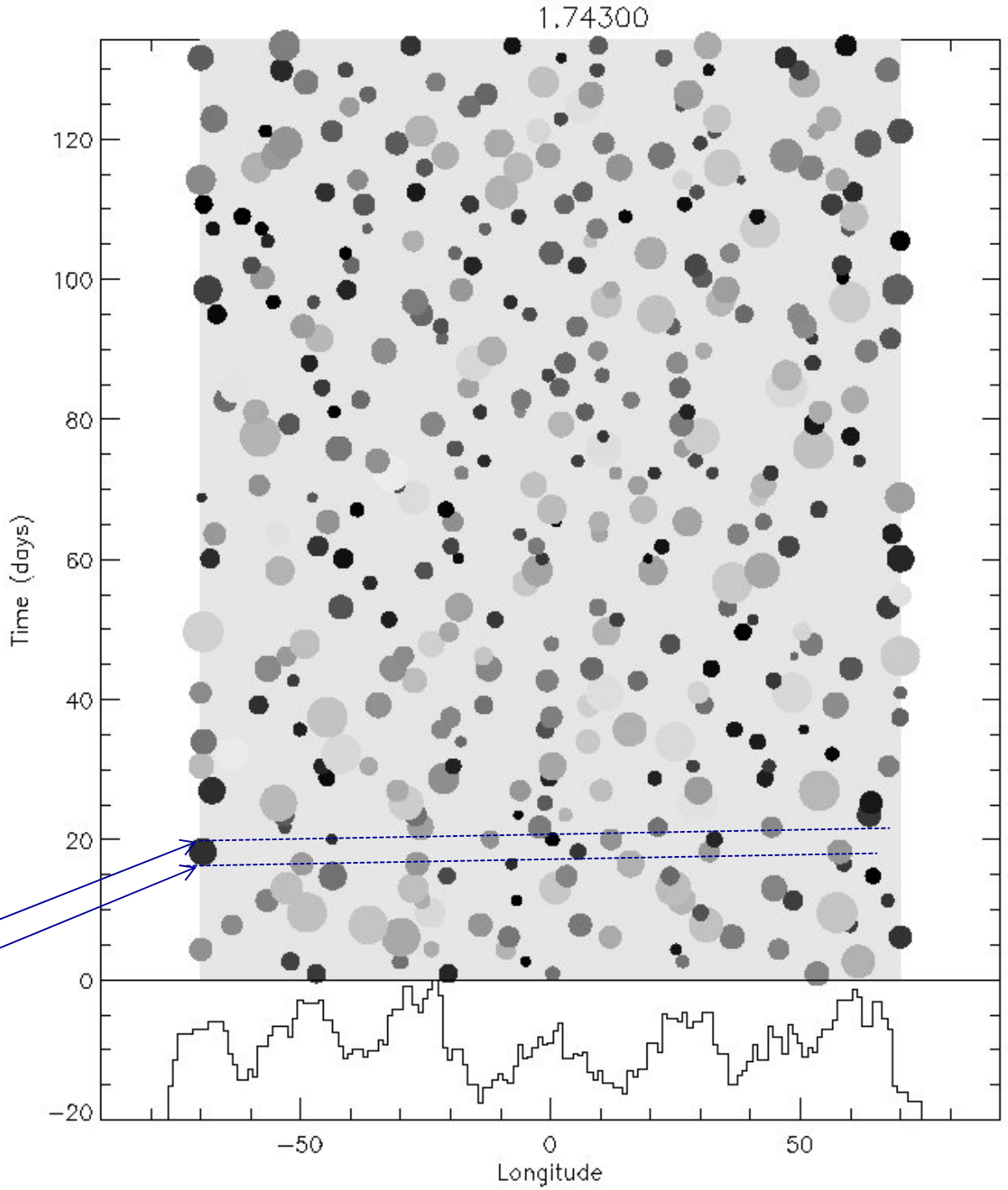
- N spots per transit, with fixed Latitude at -14.6º
- Fit parameters:
  - Longitude: between -70º and +70º
  - Intensity: 0 – 1 $I_c$
  - Radius: 0 – 1 $R_p$

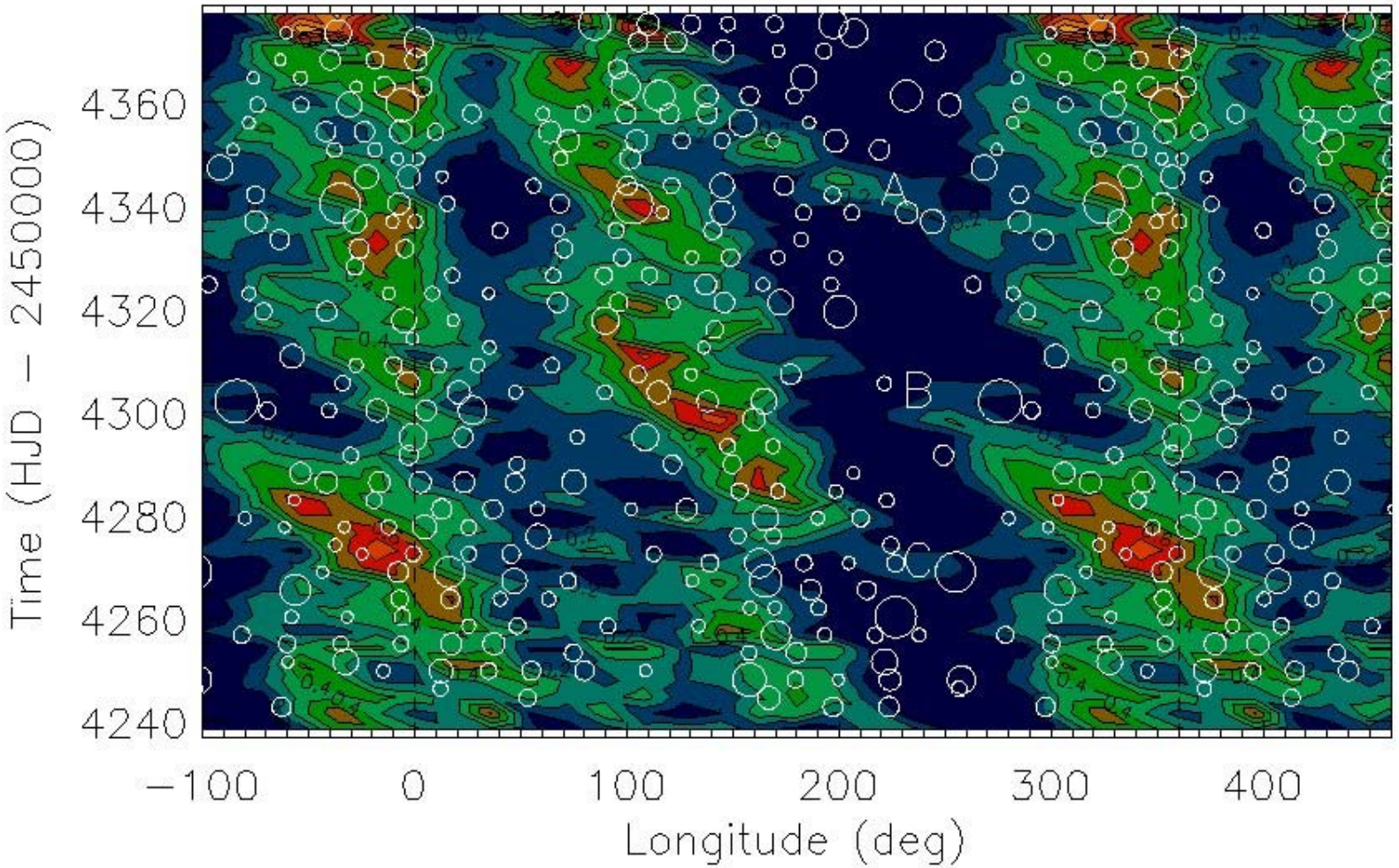


# Surface map

- Topocentric longitude (origin = l.o.s. at mid transit)






Comparison with out-of-transit modelling for $P_{rot}$=4.552 d

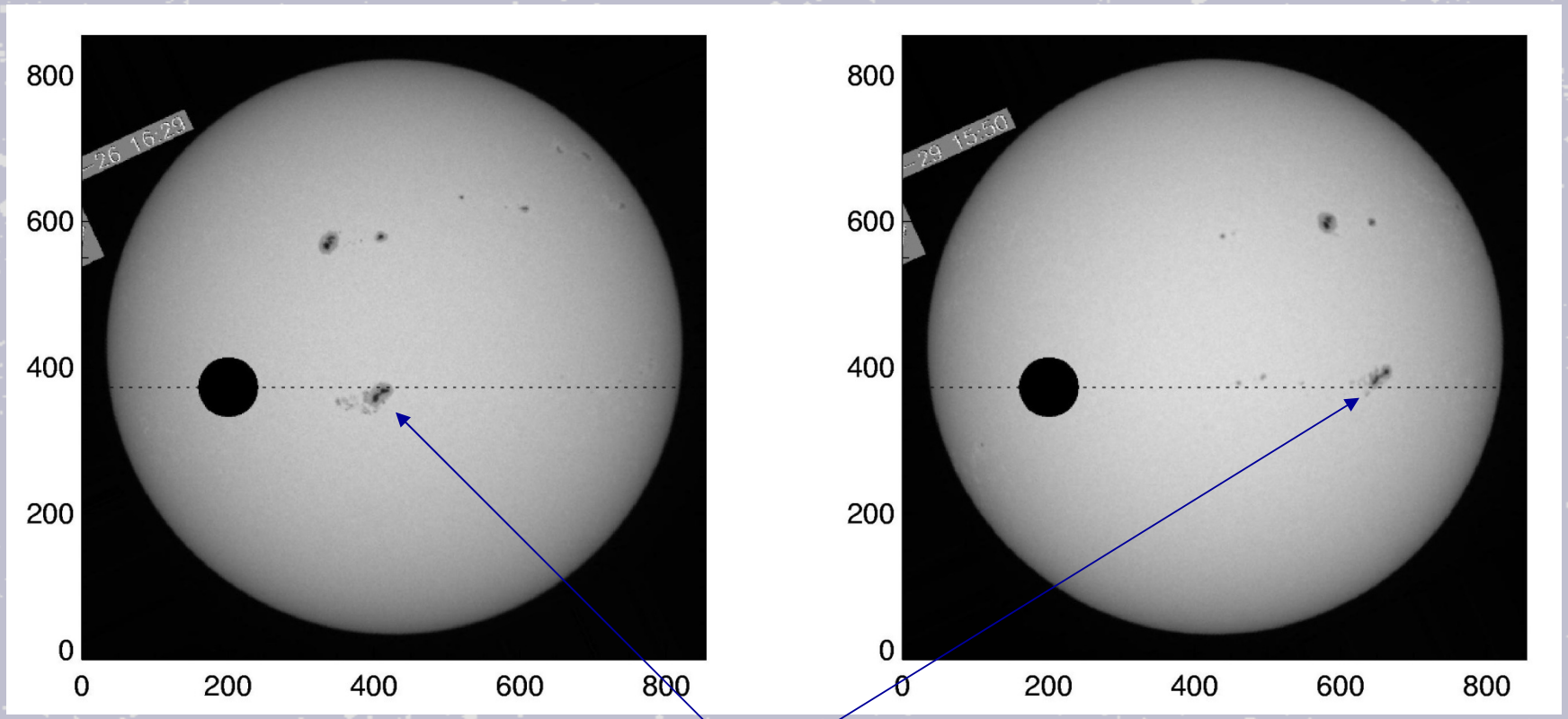
(Lanza et al. 2009)

# Rotation
# (Sun & HD 209458)

# Sun rotation

26 April 2000

29 April 2000

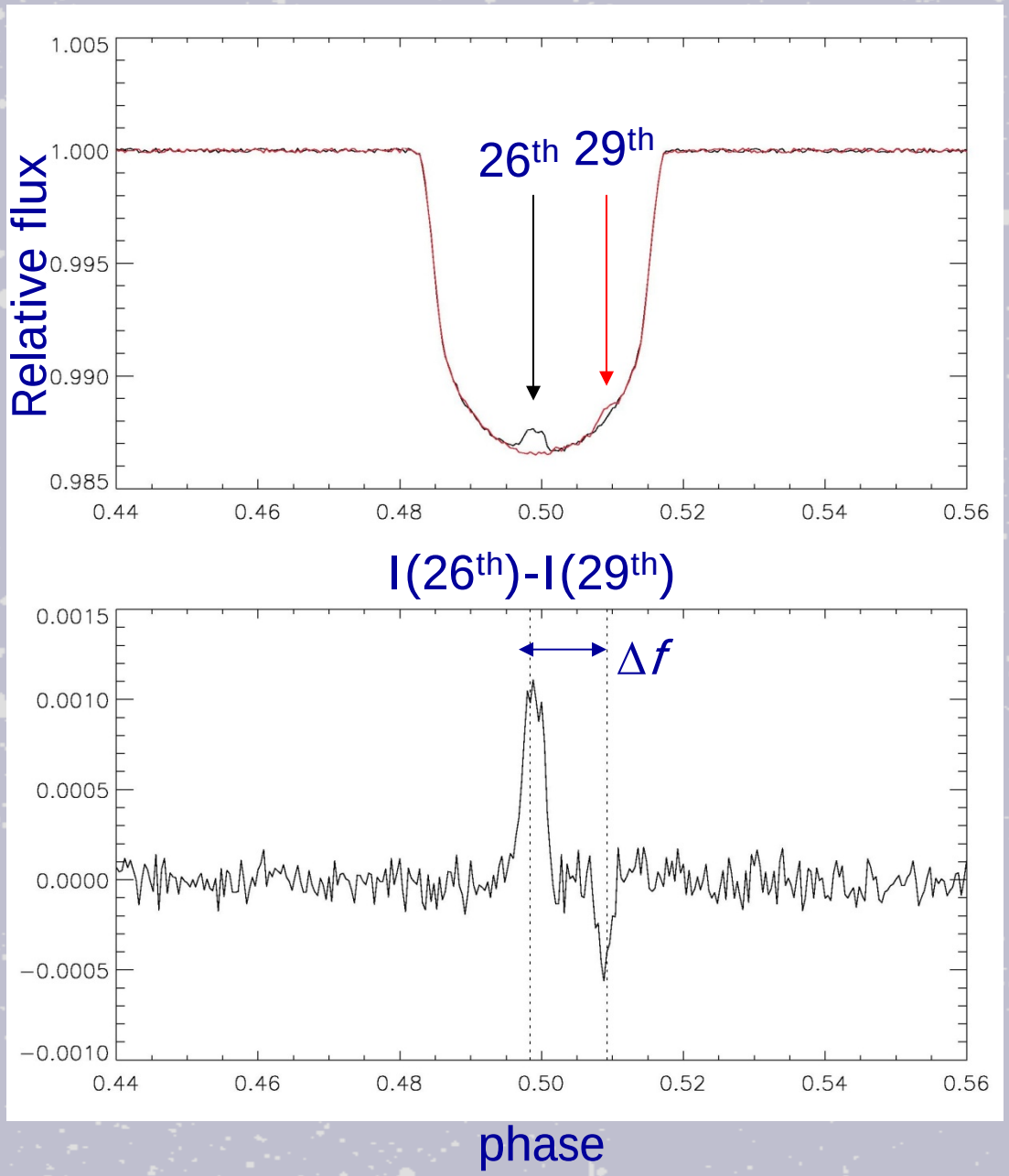


# Rotation period

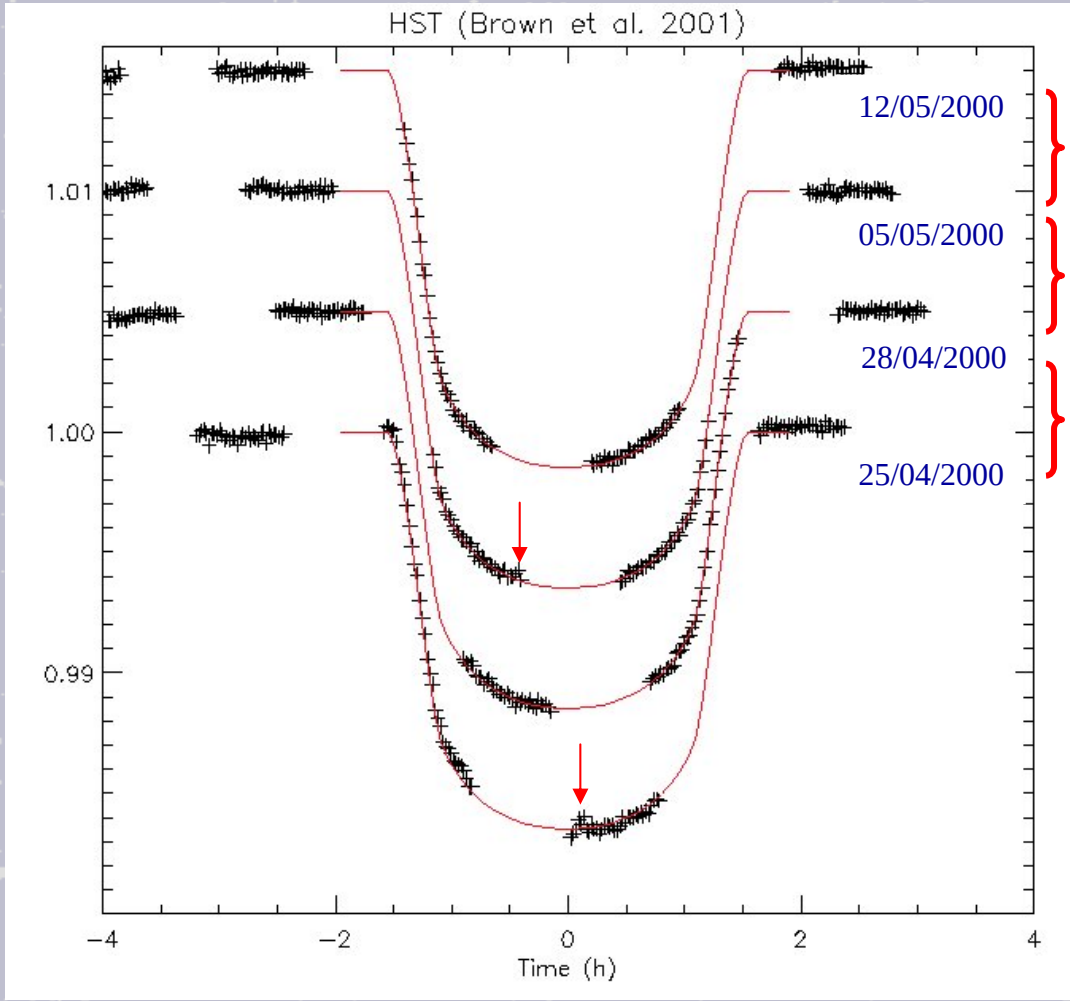
- Subtracting the lightcurve taken 3 days later, measure the $\Delta f$ between the starspot position.
- Rotation period of the star:

$$P_s = \frac{\Delta t}{\Delta f \left( \frac{a}{R_s} \right)}$$

- $P_s$=27.6 days



# HD209458 - Hubble Data




2 orbital periods

2 orbital periods

1 orbital period

(Silva-Válio 2008, ApJ Let, 683, L179)

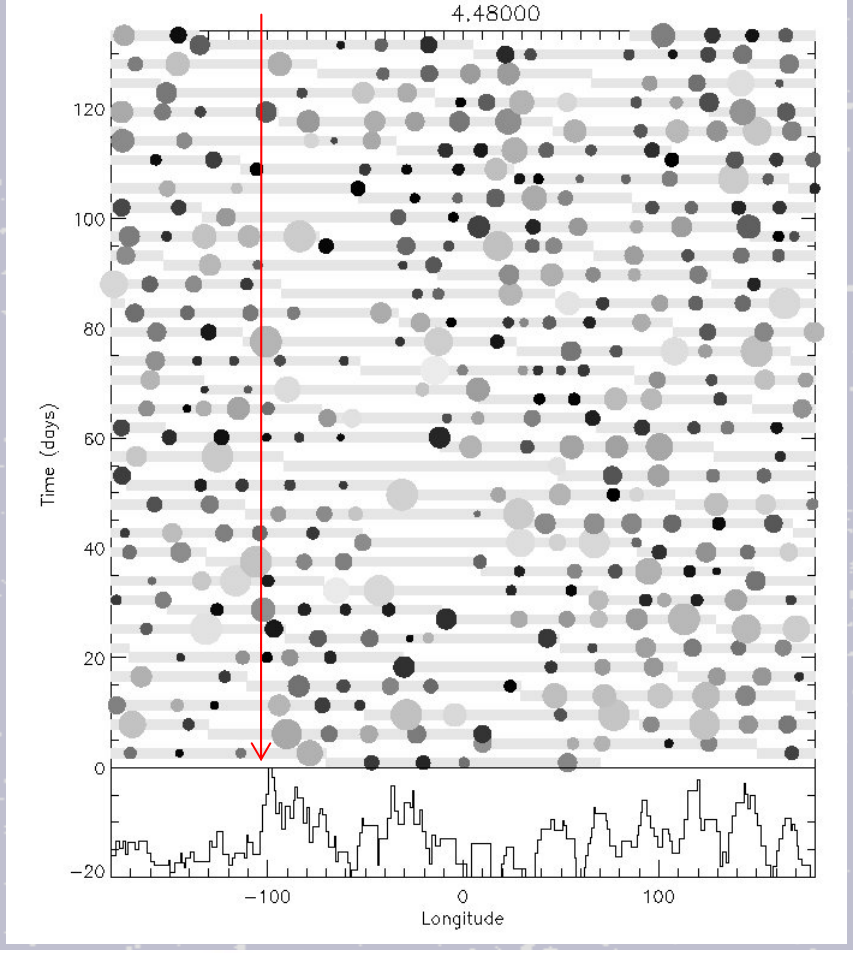
# HD 209458 - Results

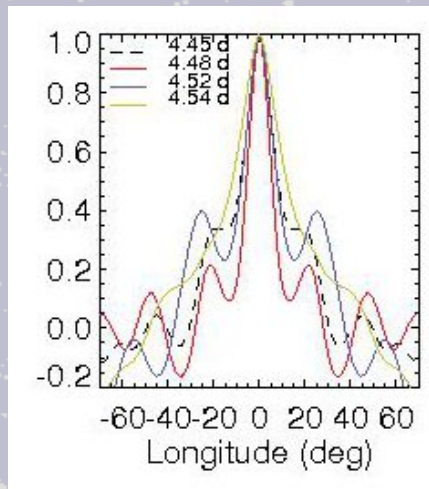
- $P_* = 11.5$ days
- Period from line velocities obs.:
  - 12.3 $\pm$ 0.5 days (Winn et al. 2005)
  - 12 days (Fisher & Valenti 2005)
  - 14.4 $\pm$ 2.1 days (Mazeh et al 2000)
  - 15 $\pm$ 6 days (Queloz et al. 2000)
- Shorter period may indicate that the star rotates differentially.

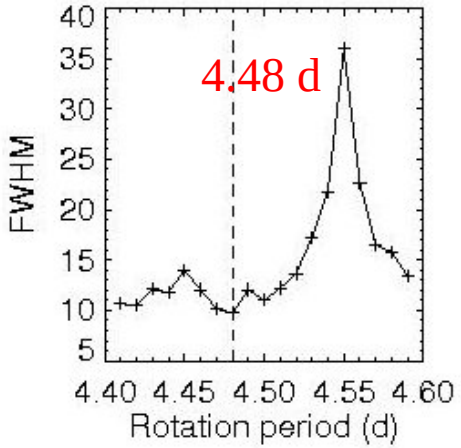
# Differential rotation (CoRoT-2)

# Auto correlation

- Vary the rotation period from 4 to 6 days every 0.01 d
- Auto-correlation of time integrated flux deficit vs longitude;
- Chose the narrowest auto-correlation function:
- $P_{rot}$ = 4.48 d @ lat = 14.6±10°



# Differential rotation

- Assume 4.54 d as the mean stellar rotation period (from out-of-transit data, Alonso et al. 2008);
- Surface rotation period within the transit band (-14.6 ± 10º) of 4.48 days.
- Solar-like differential rotation:

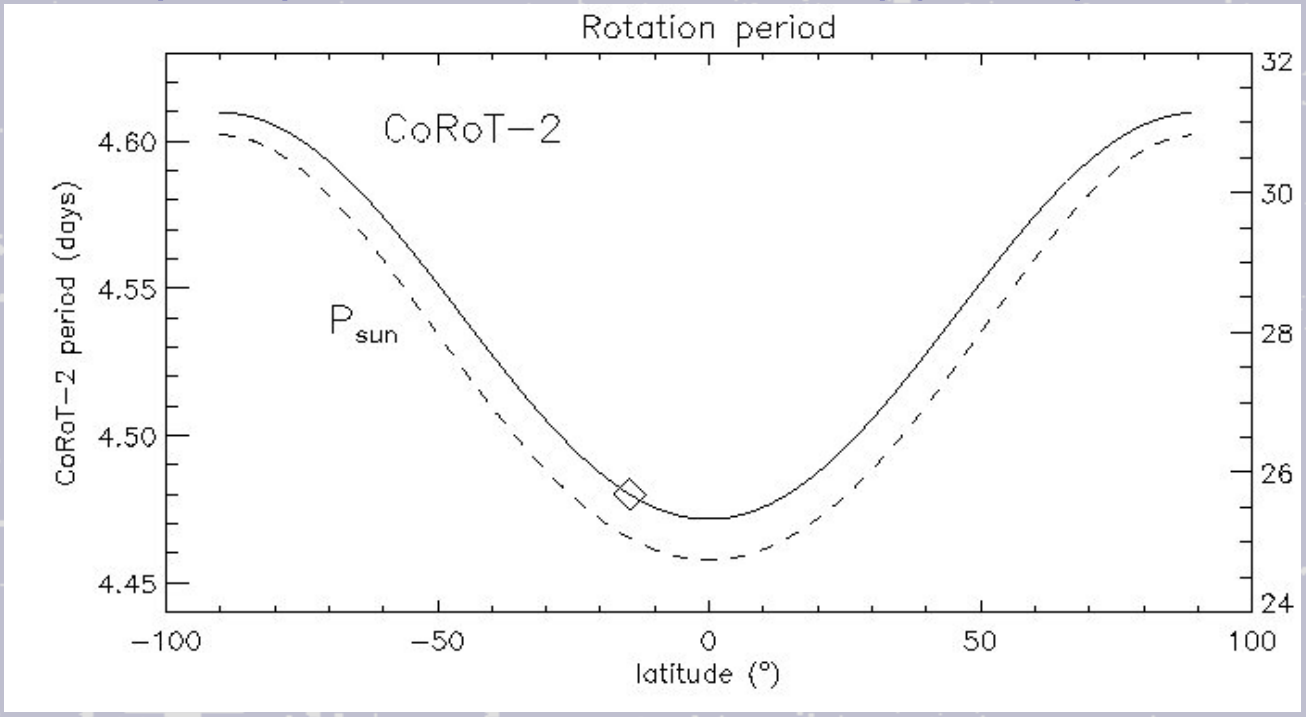
$$\Omega = A - B\cos^2\theta$$

$$P_{CoRoT-2} = \frac{360^o}{80.5 - 2.4\sin^2(\alpha)}$$

# Differential rotation

| Star | $\Delta\Omega$ (rad/d) | % |
|---|---|---|
| CoRoT-2 | 0.042 | 3 |
| Sun | 0.05 | 22 |

Fröhlich et al. (2009): theoretical calculation (dynamo) obtain 0.13 rad/d




Silva-Valio & Lanza, 2011, A&A (in press)

# Sumary– CoRoT-2

| Parameter | | |
|---|---|---|
| Radius | $0.53 \pm 0.18\ R_p$ | 100,000 km |
| Intensity/Temperature | $0.45 \pm 0.25\ I_c$ | $4600 \pm 700$ K |
| Rotation period | 4.48 d<br>4.54 d | Transit ($-14.6 \pm 10^o$)<br>mean |
| Flux Periodicity | 17.7 d | $10\ P_{orb} \approx 4\ P_{rot}$ |
| Rieger cycle (?) | $31 \pm 15$ d | |
| Differential rotation | 0.042 | 3% |

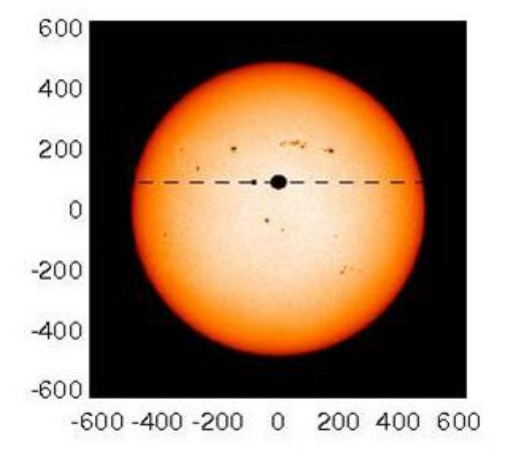
- Spot temperature, $T_0$, estimated from black body emission, where the effective temperature of the photosphere is 5625 K;
- Planet radius = 1.544 $R_{jup}$ (1.465 $R_{jup}$)

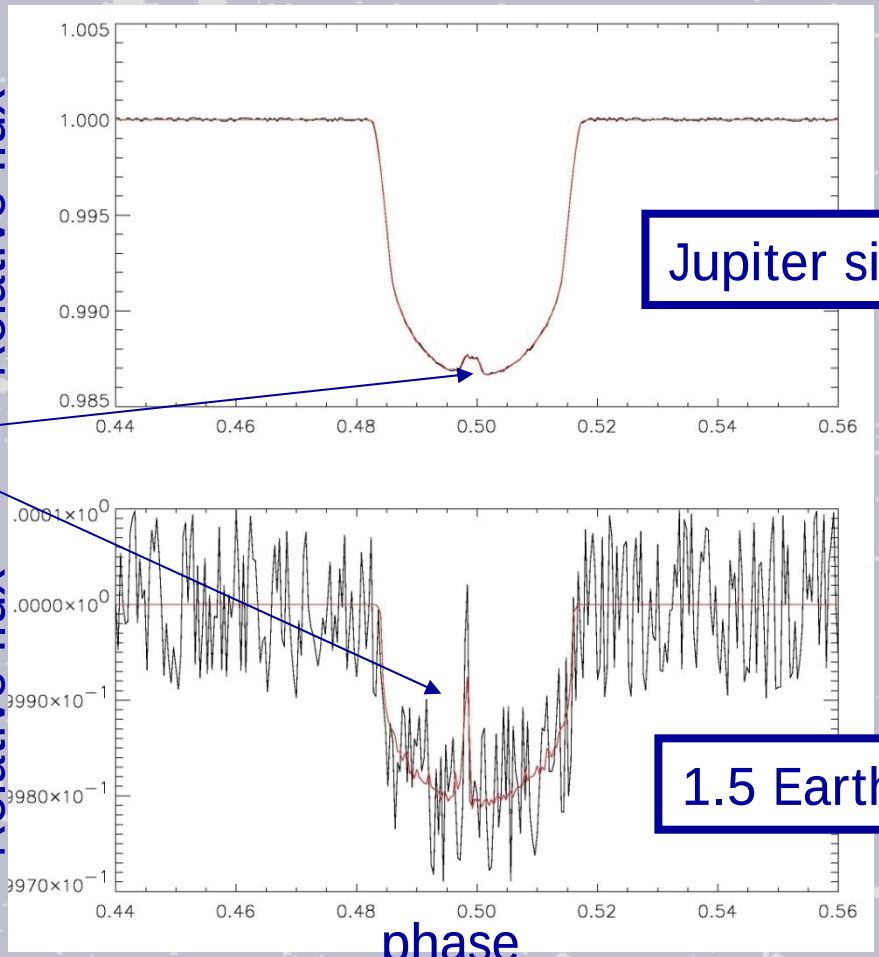
  (5% larger than that calculated from a spotless star

# Conclusions

- Modelling of small variations in transit light curves:
- Stellar activity
  - ✓Spots physical characteristics (size, temperature, location, evolution/lifetime, etc)
- Multiple transits:
  - ✓Stellar rotation
  - ✓Stellar differential rotation
- Future improvements:
  - ✓Obliquity
  - ✓Inclusion of umbra/penumbra and faculae
  - ✓ Stellar cycles

# PLATO




sunspot eclipse

Jupiter size Planet

1.5 Earth size Planet

# Dankeschön!