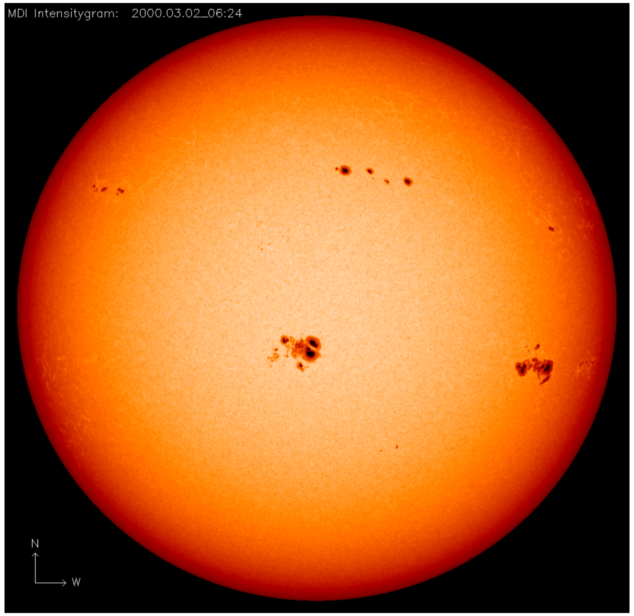
Report of Splinter Session WG3

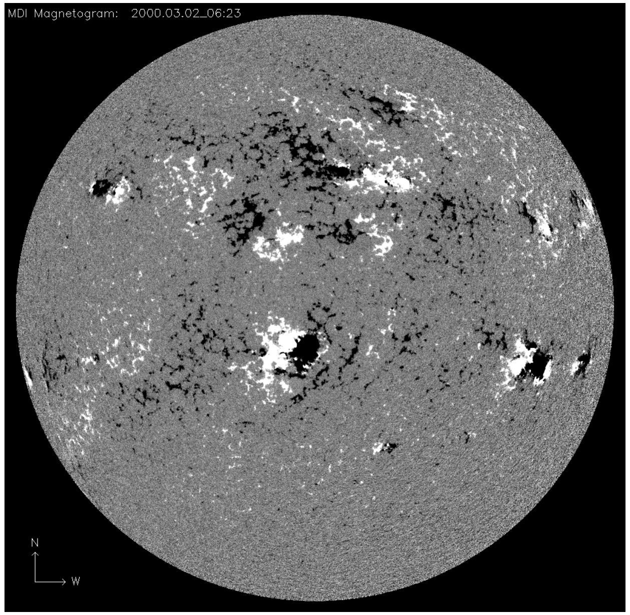
Stellar activity and rotation

A. F. Lanza on behalf of the partecipants

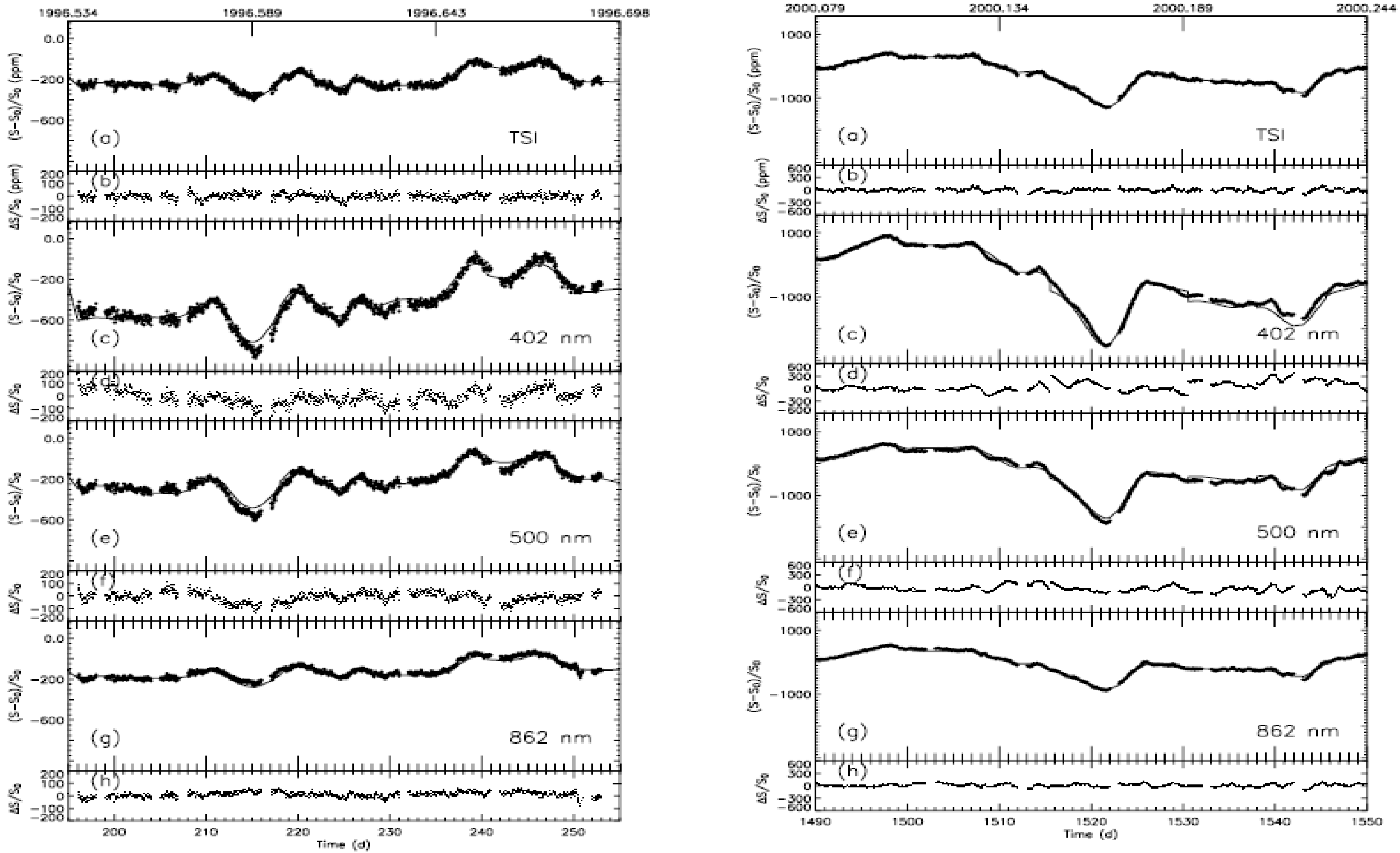
Solar activity

- In the Sun we can study stellar activity in detail, thanks to the spatial and time resolution (down to 50-100 km and a fraction of a second, respectively);
- In the photosphere, the features associated with magnetic fields are sunspots, faculae, and the network.



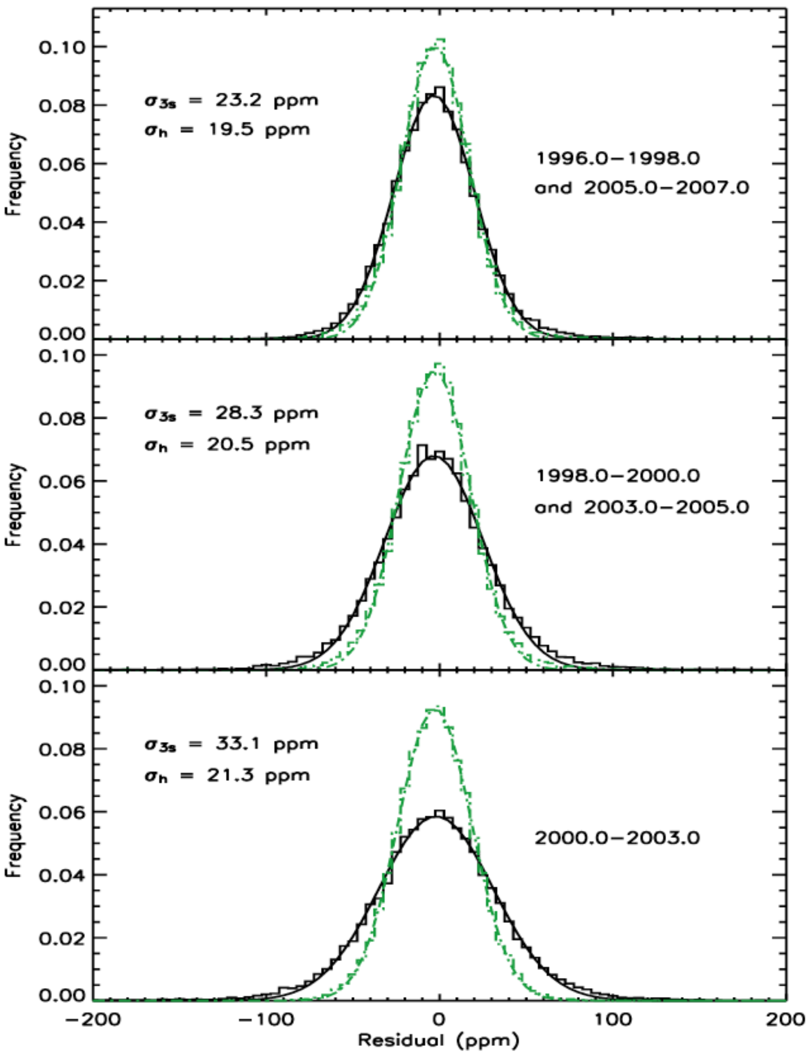


Best fits of Solar Irradiance



Best fits with a simple 3-spot model along individual intervals of 14 days (Lanza et al. 2004).

Residual distributions for the Sun



Distributions of the residuals of the best fits to the Total Solar Irradiance (TSI) during different phases of the solar 11-yr cycle. The Gaussian best fits to these distributions with the respective standard deviations are also show. Different colours refers to different fitting methods, i.e.:

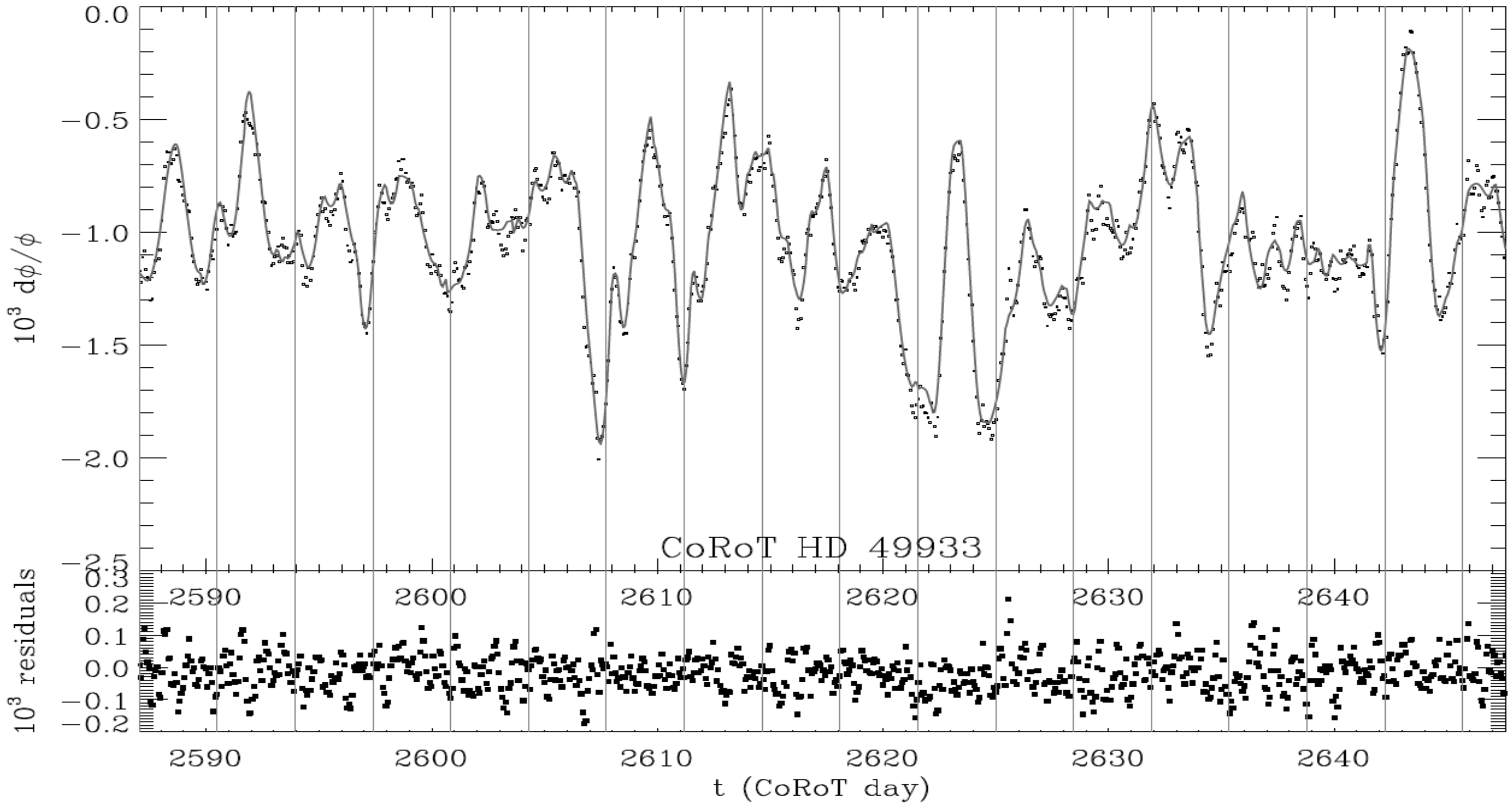
• Black: 3-spot model;

• Green: 200-harmonic best fit.

Note how spot models can fit most of the Sun variations, given that the precision of the TSI measurement is 20 parts per million (ppm).

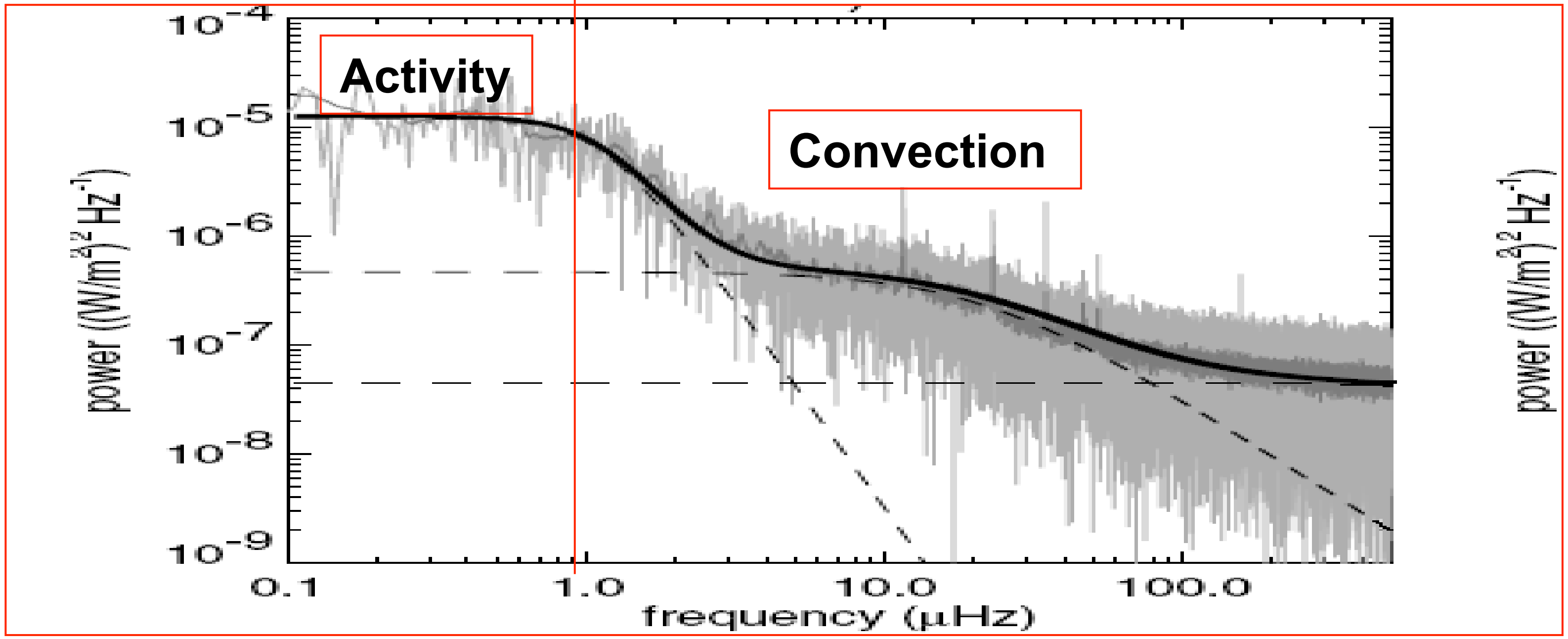
(after Bonomo & Lanza 2008)

More sophisticated spot models



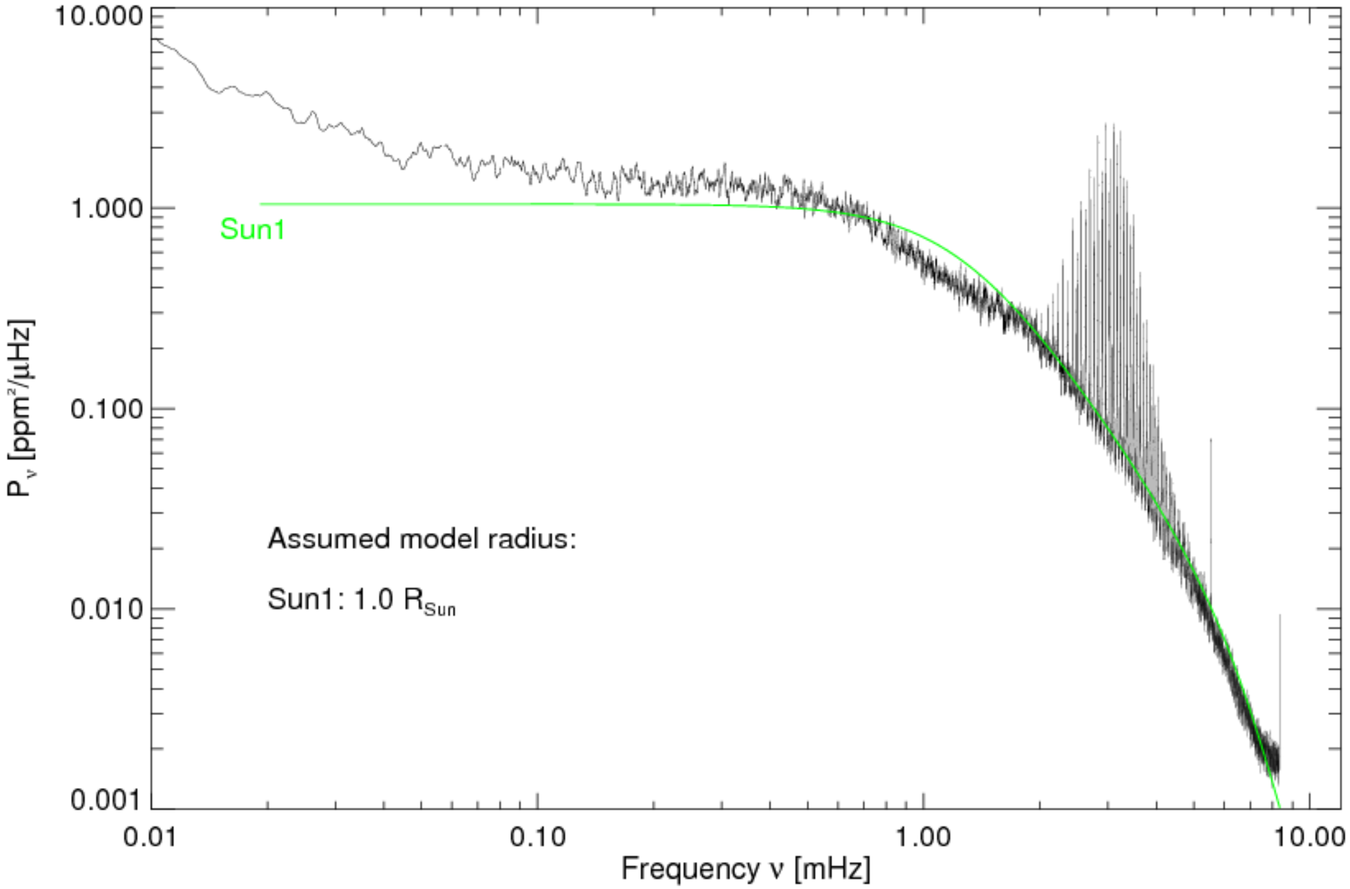
More sophisticated models include spot evolution and differential rotation (e.g., Mosser et al. 2009)

Fitting the power spectrum of the light variations



- Spot modelling will be used to model light variations at lower frequencies ($\leq \Omega_{ROT}$);
- Harvey-type parametric fits (power laws combinations) will be used for the convective part at higher frequencies.

Beyond simple parametric models: numerical models of convective irradiance fluctuations



Ludwig et al. (2009); Samadi et al. (2013)

Input needed

- L1 light curves from PLATO;
- Stellar parameters: mass, radius, limb-darkening, inclination of the spin axis, spectroscopic v sin i, chromospheric activity indexes;
- A preliminary estimate of the mean rotation period will come from Lomb-Scargle or AC techniques or wavelets (WP 123 500);

Data products (Level 0)

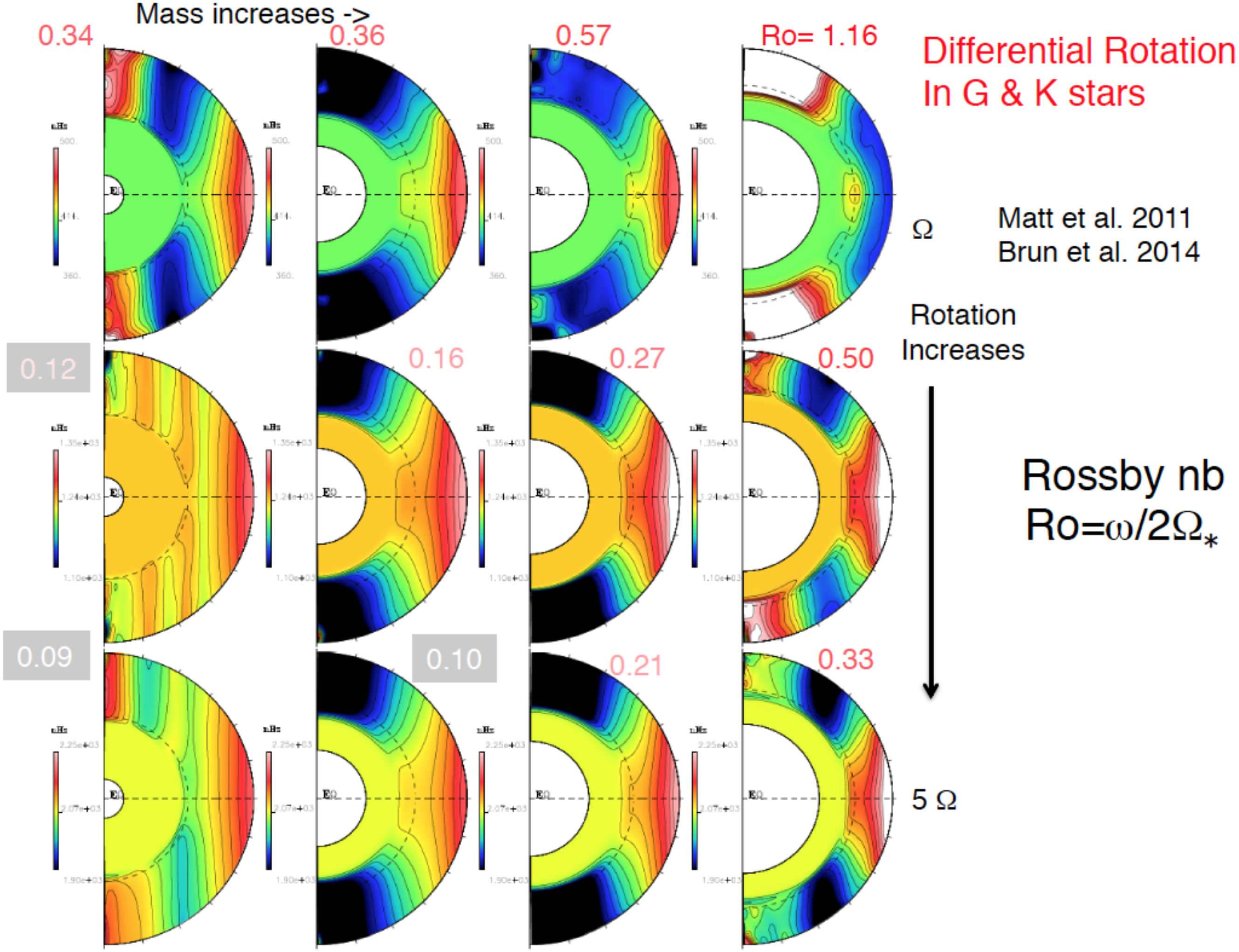
- From spot modelling (WP 123 100):
  - Mean rotation period of the spots and its uncertainty;
  - Surface differential rotation from the rotation periods of individual spots and its uncertainty;
  - Variation of the total spotted area vs. the time (an activity index);
  - Typical spot lifetime (useful to specify the uncertainty on the mean rotation period);

- From simple Harvey-type fits (WP 123 200):
  - Number of components needed to fit the power spectrum and their parameters with uncertainties.

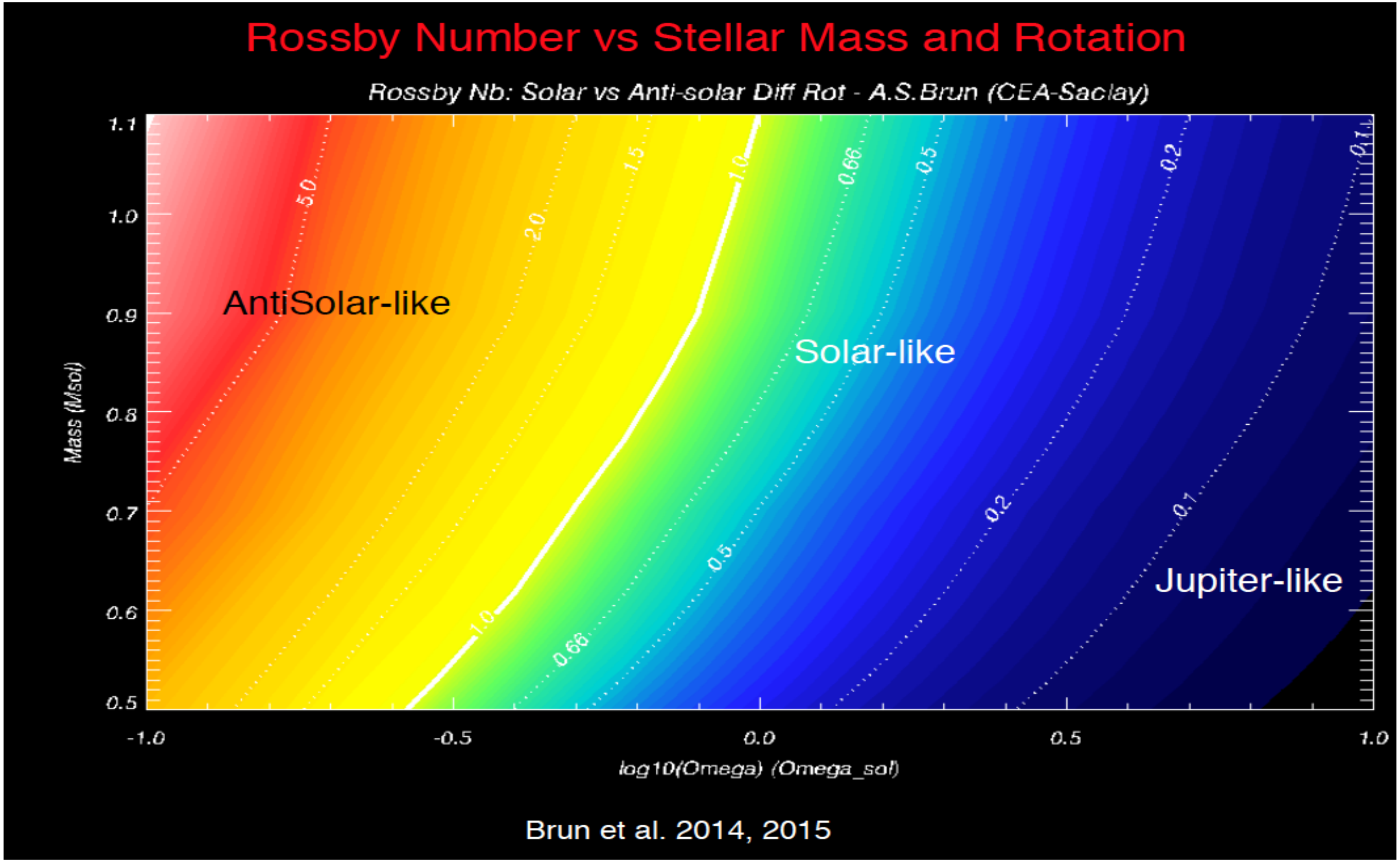
Data products (Level 1)

- From stellar parameters and the mean rotation period derived from spot modeling, compute models of differential rotation and hydromagnetic stellar dynamo (WP 123 400);
- Put priors on the distributions of the spot model parameters by using the information provided by those models (WP 123 100).

Numerical models of DR



DR regimes from theory



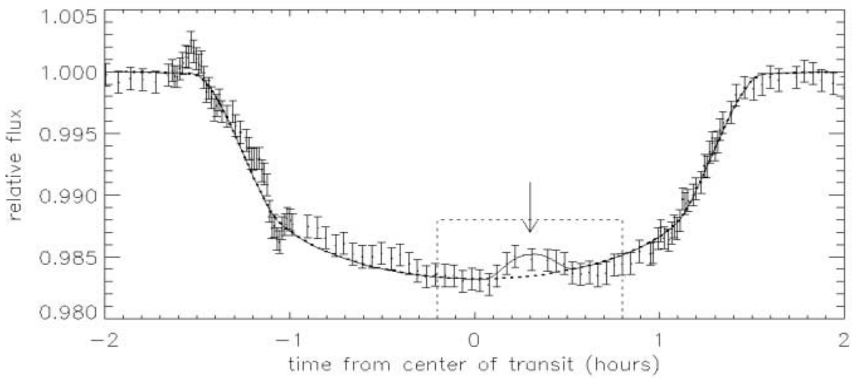
Data products (Level 1)

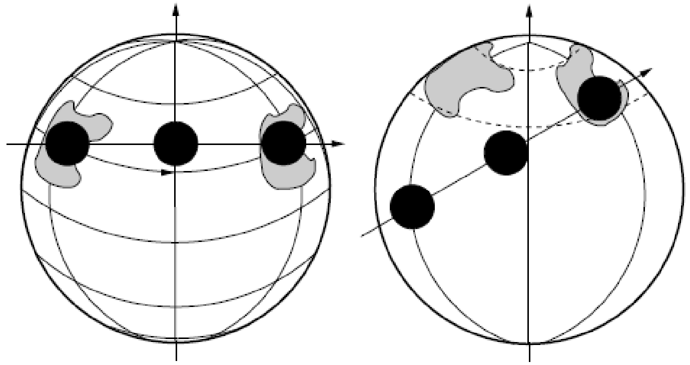
- Use numerical models of stellar convection to go beyond simple Harvey-type fits of the convection-dominated part of the power spectrum (WP 123 100 – 123 400);

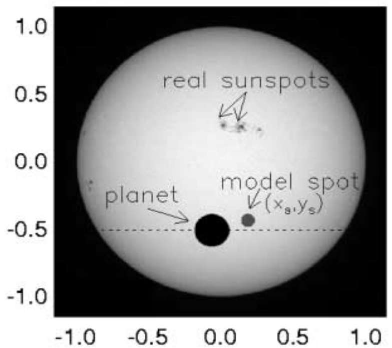
- An estimate of the surface gravity of the star comes from the amplitude of the variability on a timescale of about 8 hours (cf. Bastien et al. 2013).

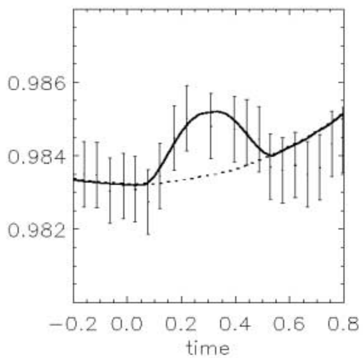
Additional data products

- Inclination of the stellar spin axis from the best fitting of planetary transits (WP 123 600)









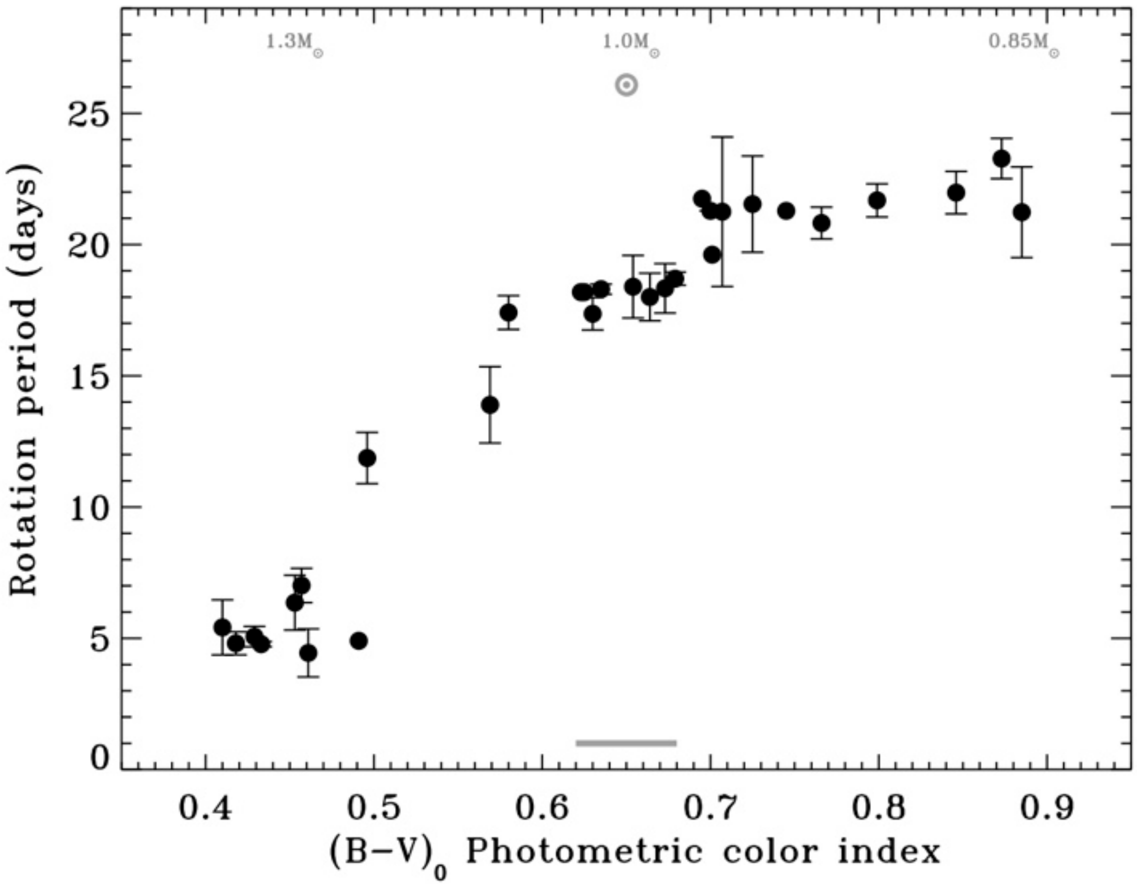
Silva (2003) and Nutzman et al. (2011): estimation of the projection of the obliquity on the plane of the sky

Ages from gyrochronology

- For stars younger than ~ 0.5 Gyr, initial conditions are important and detailed models of angular momentum evolution are needed to reach an accuracy better than 15-20 percent;

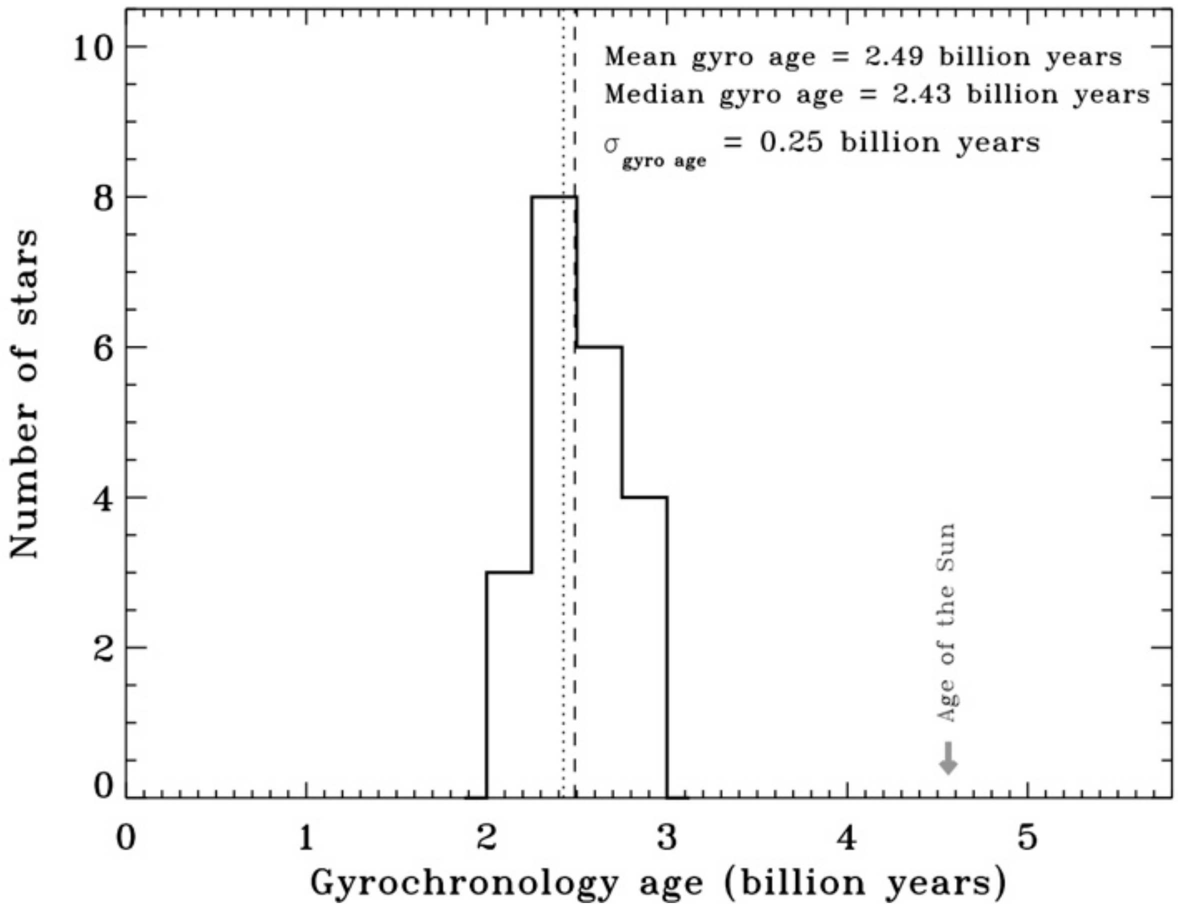
- For older stars (1.0-4.5 Gyr), the dependence on initial conditions is much less critical and an accuracy of 10-15 percent is generally possible in the colour range $0.55 < B-V < 1.0$ on the main sequence.

NGC 6819 (age 2.5 Gyr)



(after Meibom, Barnes et al. 2015). Note the uncertainty on P_{ROT} as derived from the analysis of different time intervals – spot modelling can reduce this uncertainty.

Gyro age distribution for individual members of NGC 6819



Our wishes and open questions

- Implement 25 second cadence especially for stars with transiting planets;
- Golded samples (for rotation evolution studies; convective evolution studies; and so on); require target selection and interaction with PIC;
- Metallicity of the core sample stars (convectives models are significantly affected);
- Select FoV with open clusters of different ages;
- Interaction with people working on the impact of stellar rotation on internal structure and evolution (effects on mode eigenfrequencies);
- A better understanding of stellar physics is needed to fully exploit the information we can derive from our modelling (e.g., in the case of age estimates through gyrochronology).

Q&A

- Q (M. Goupil): How can you determine the error on the rotation period ?

- A (A. F. Lanza): A preliminary estimate comes from, e.g., periodogram techniques (cf. Horne & Baliunas 1986). However, we can do much better by considering the effect of the finite spot lifetimes and surface differential rotation (SDR) that are provided by our spot modelling together with the mean spot rotation period. Spot evolution and SDR introduce an intrinsic limitation and a systematic error in the estimate of the rotation frequency. In the end, we shall combine the statistical error on the rotation period found with our modelling with the additional uncertainties coming from spot evolution and SDR to obtain a more accurate estimate of the total error.