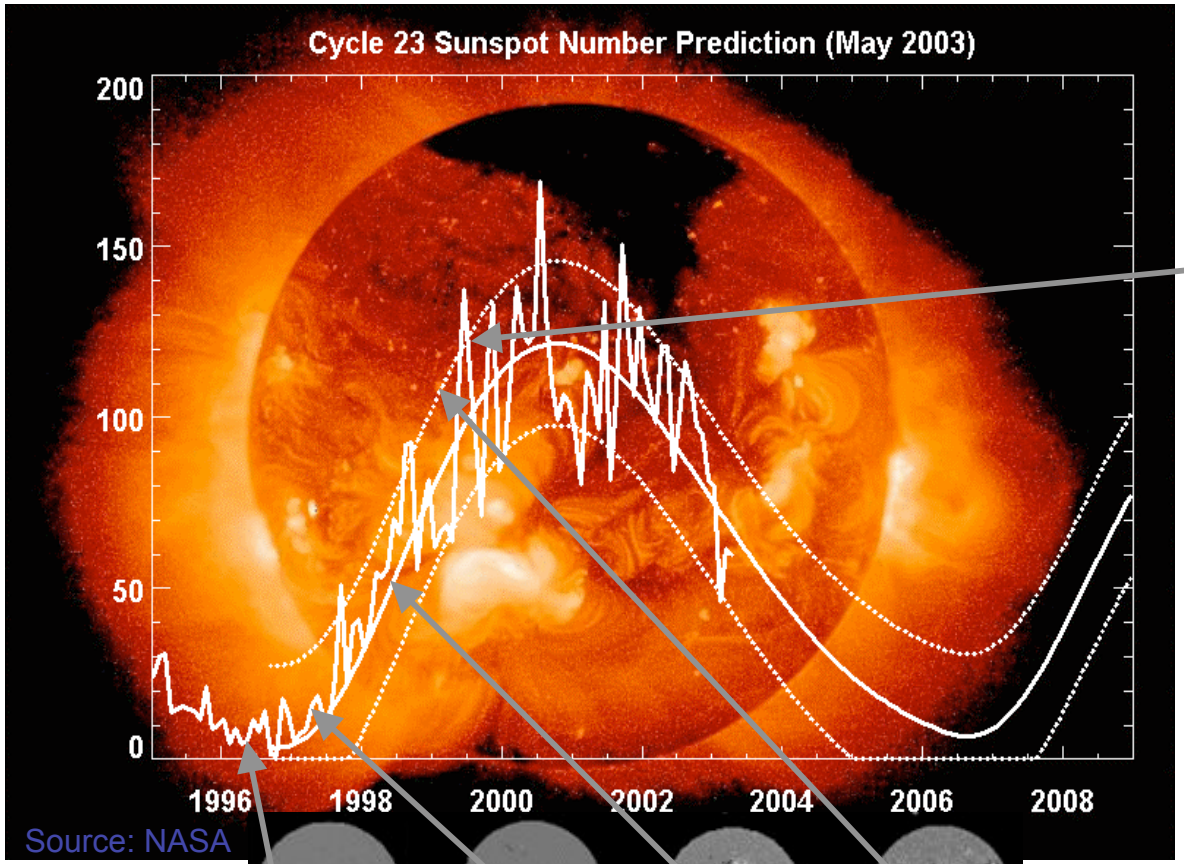
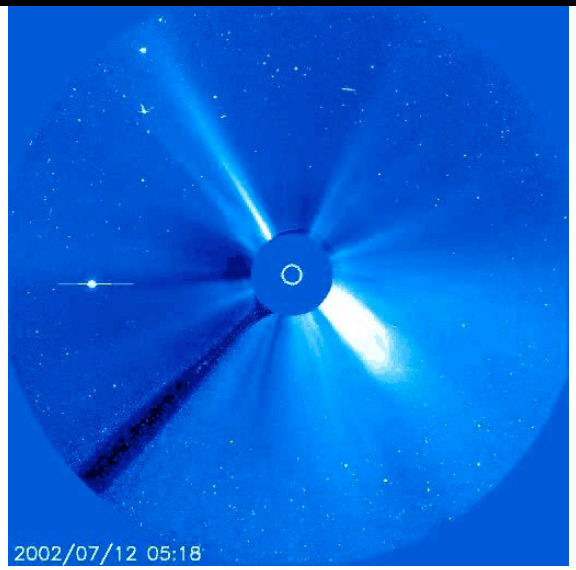
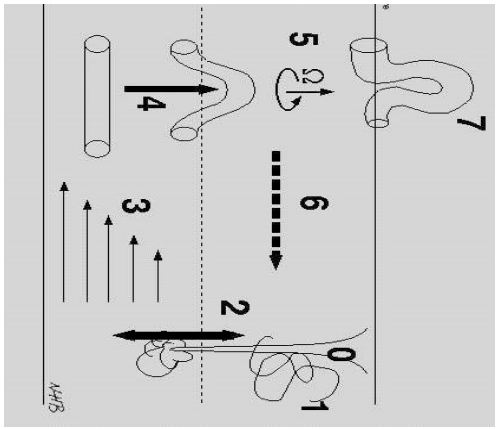
The Sun is a magnetic star: why looking deep inside the Sun ?



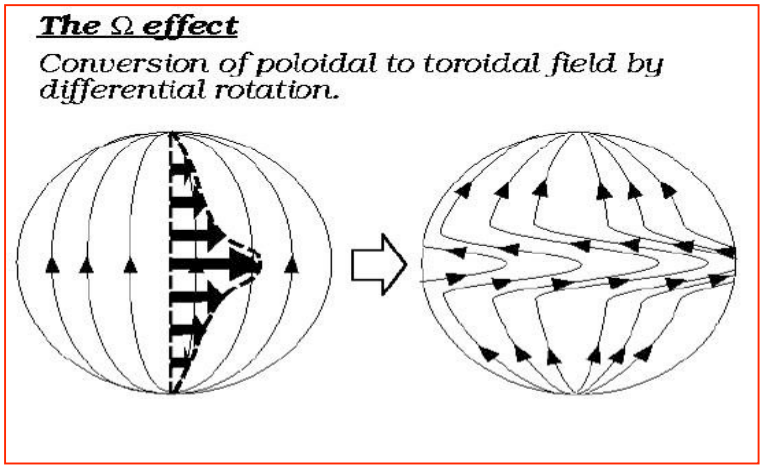


Internal rotation and Magnetic field

Tachocline
4-5% mass

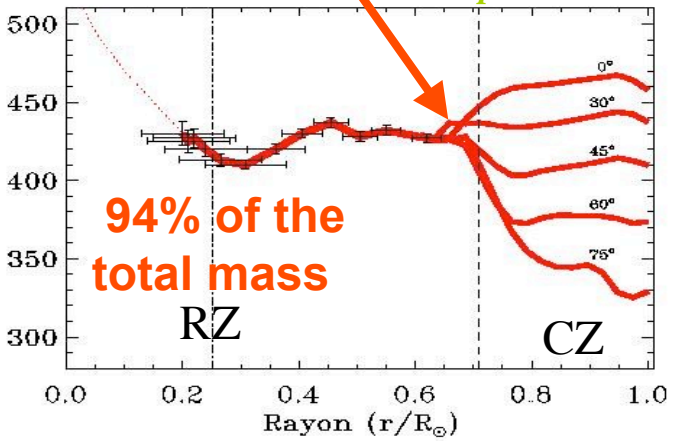


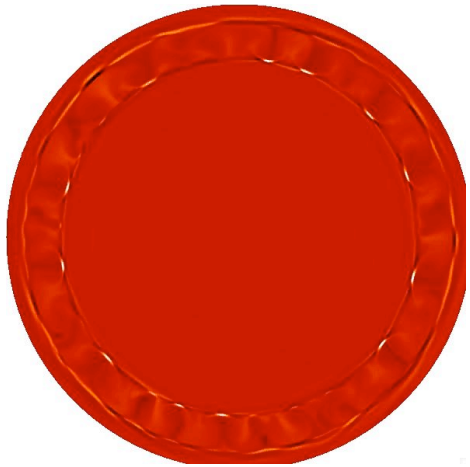
ZC: 2% $M_\odot$



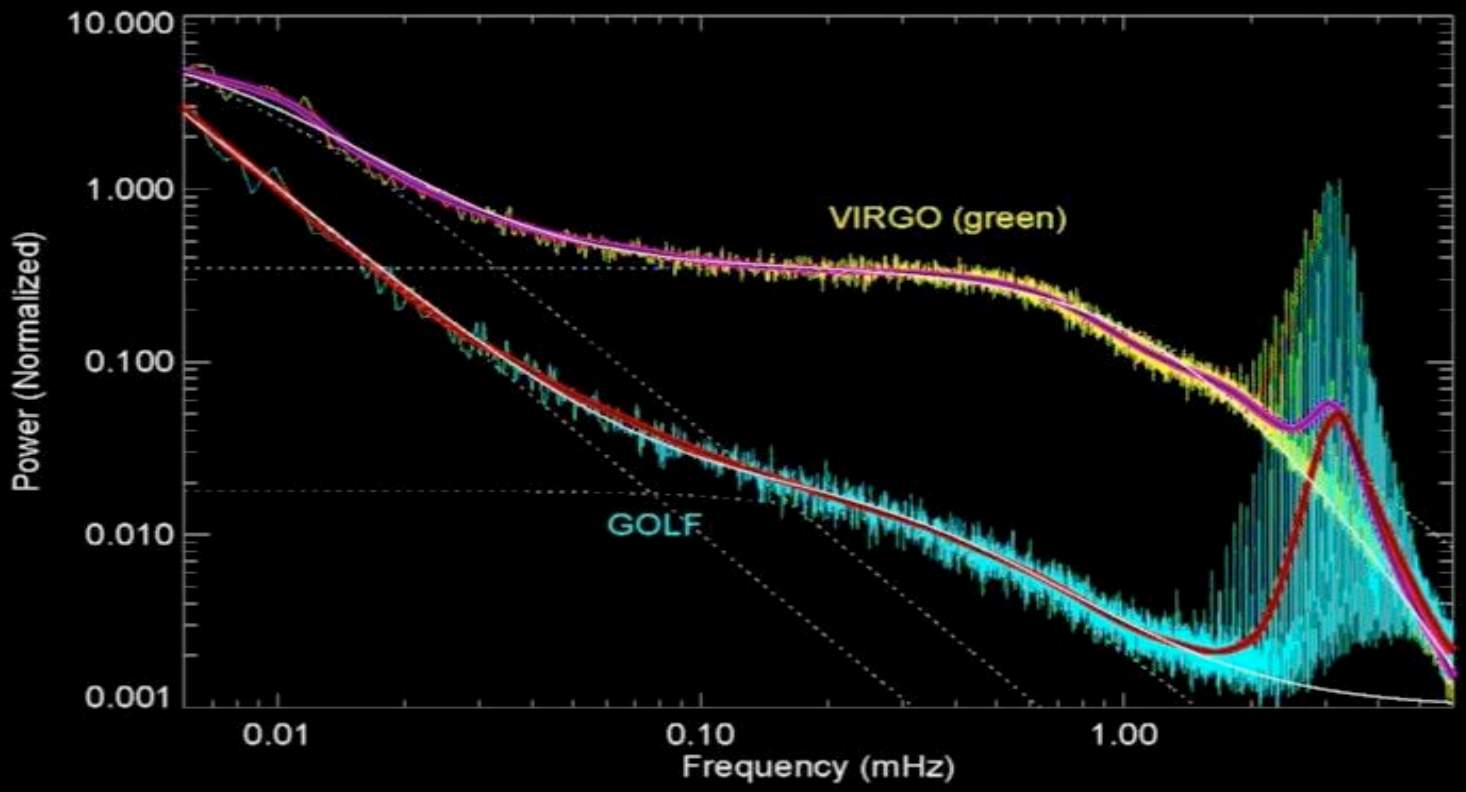
The **tachocline** plays an important role in the **stockage and amplification of the toroidal magnetic field** for the **Schwabe cycle** 22 ans, one would like to know what phenomena can justify the possible existence of the **Gleissberg** cycle (90 year ?) or greater cycles ??

Couvidat et al. 2003 *Thompson et al. 1996, Kosovichev 1997*





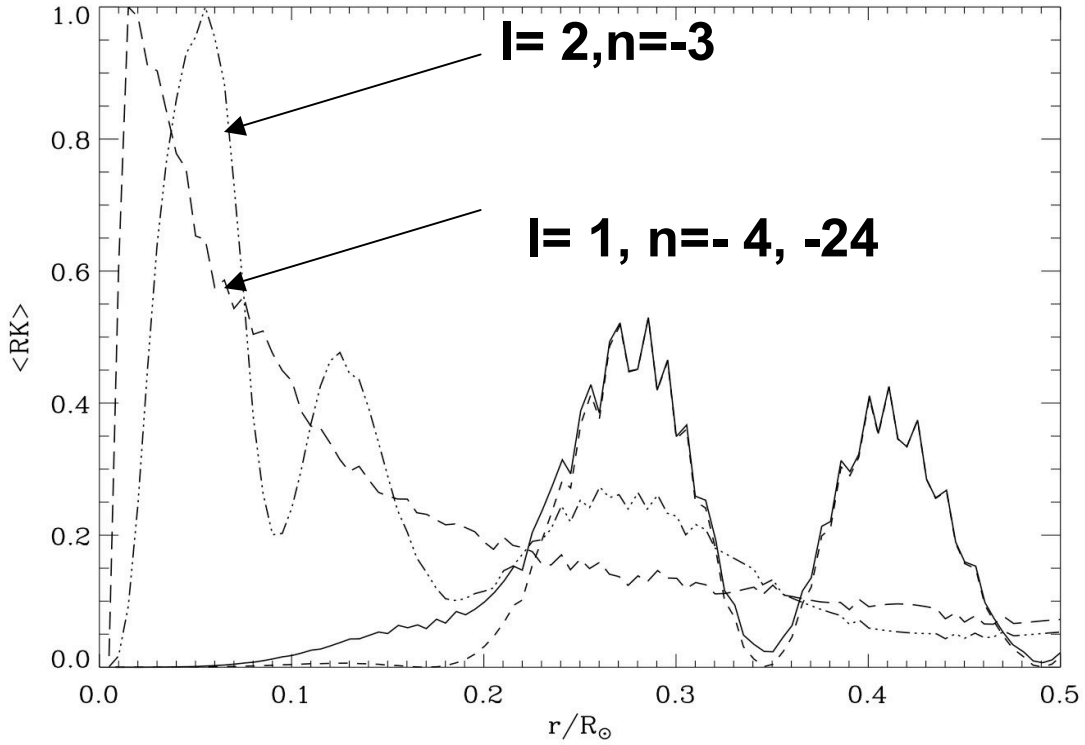
Three instruments aboard SoHO for the search of gravity modes



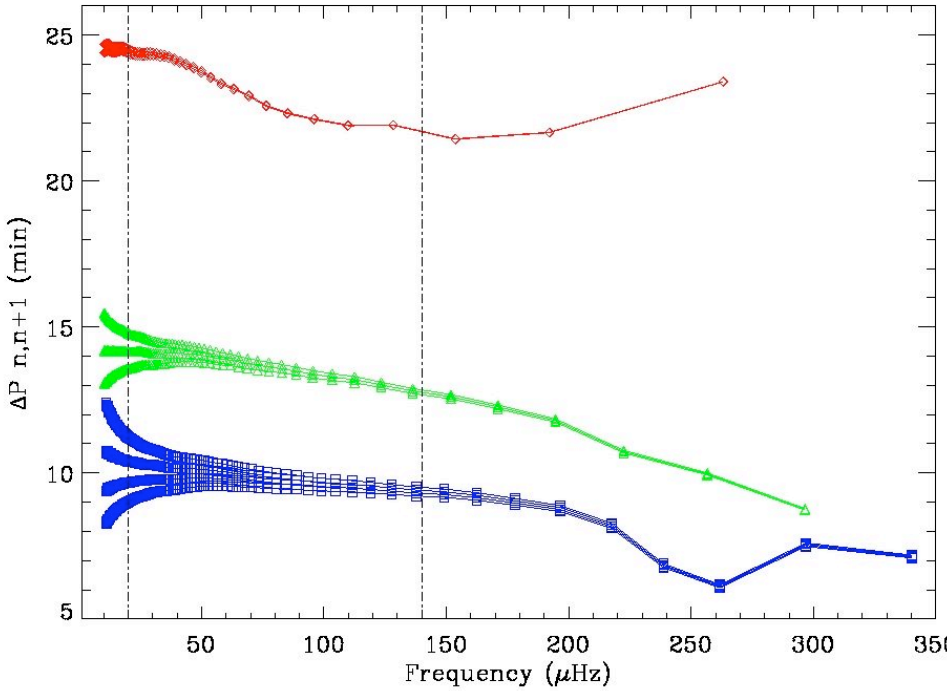
Velocity <1 mm/s

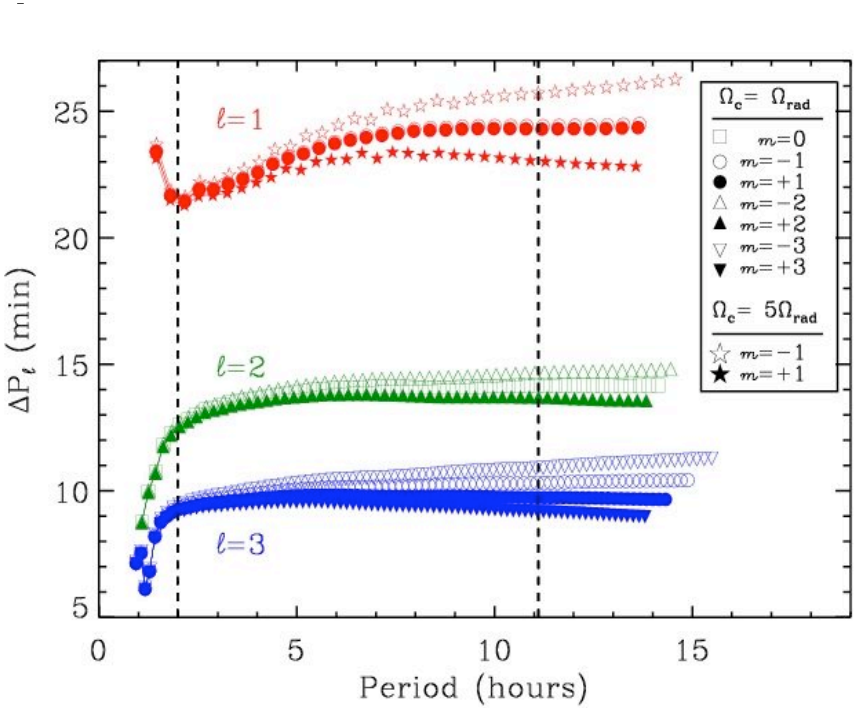
GOLF has been built to get such low velocity in looking to the variability of the Doppler velocity, largely above the turbulent photosphere

Sensibility of the kernels to the solar rotation



2nd study: below 150 μHz using G-mode

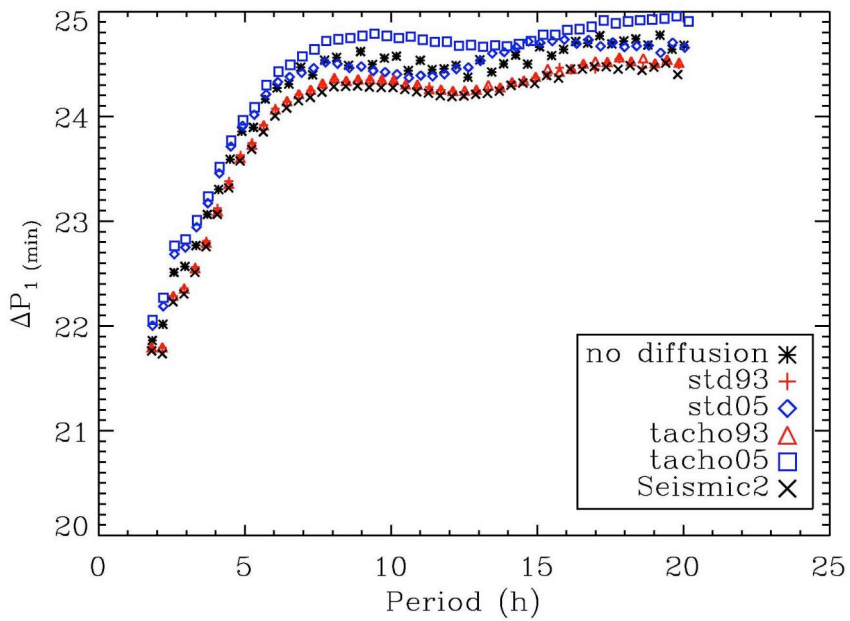


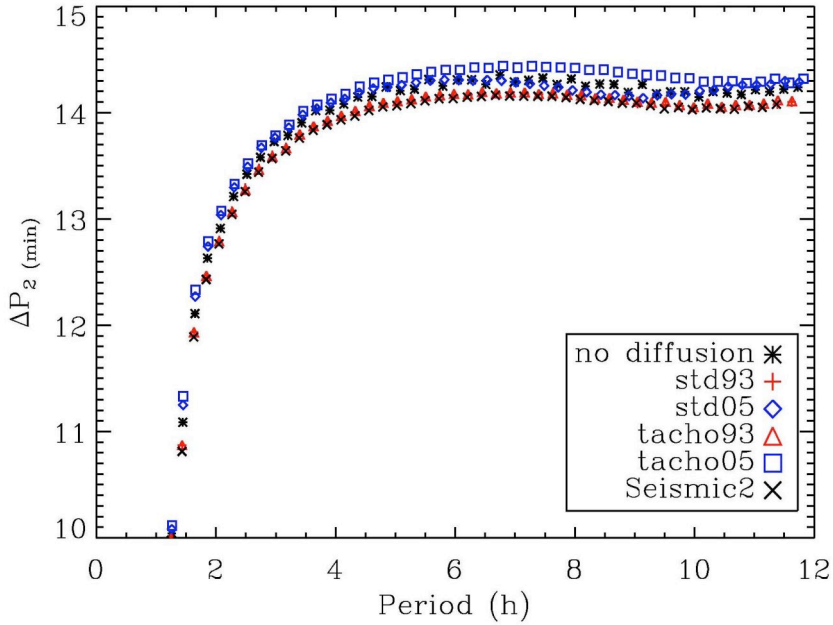


- Low order g modes are equidistant in period.
- region analyzed: 25-140 μHz: about 20-25 order modes in this range
- Depending on the rotation, the projection is more or less broad

Asymptotic behaviour of the gravity modes

All the models lead to ΔP_1 between 24.3 ands 24.8 mn including Nice model and JCD model instead between 28 mn to 60 mn (Hill 2001)

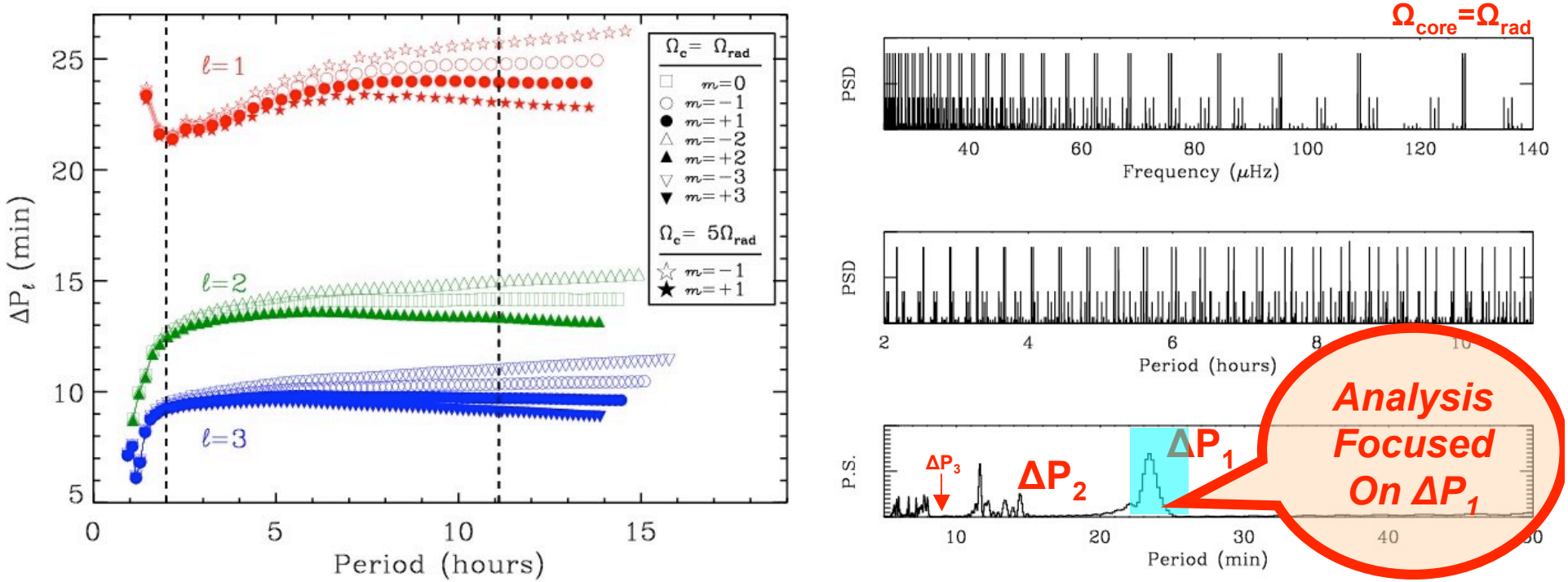




$$\Delta P_{\ell} = P_{n+1,\ell} - P_{n,\ell} = P_0 / \sqrt{l(l+1)}$$

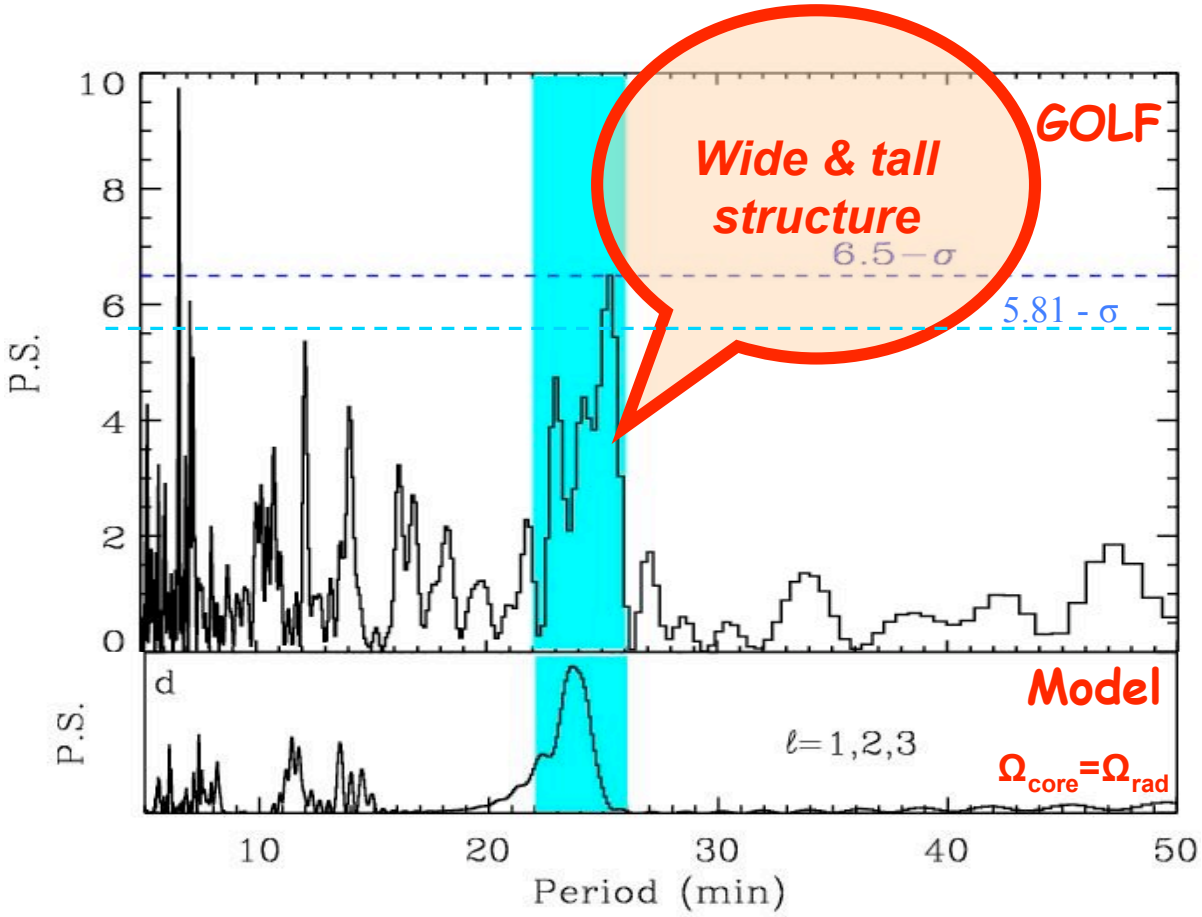
Periodicities in the PSD:

peaks in the PS of the PSD



- A peak structure appears in the PS: a main structure + harmonics
  - The peaks are not symmetric
- Shape depending on the Core properties:
  - Rotation rate, rotation axis inclination, deep magnetic field …
- Exact position depending on the internal structure

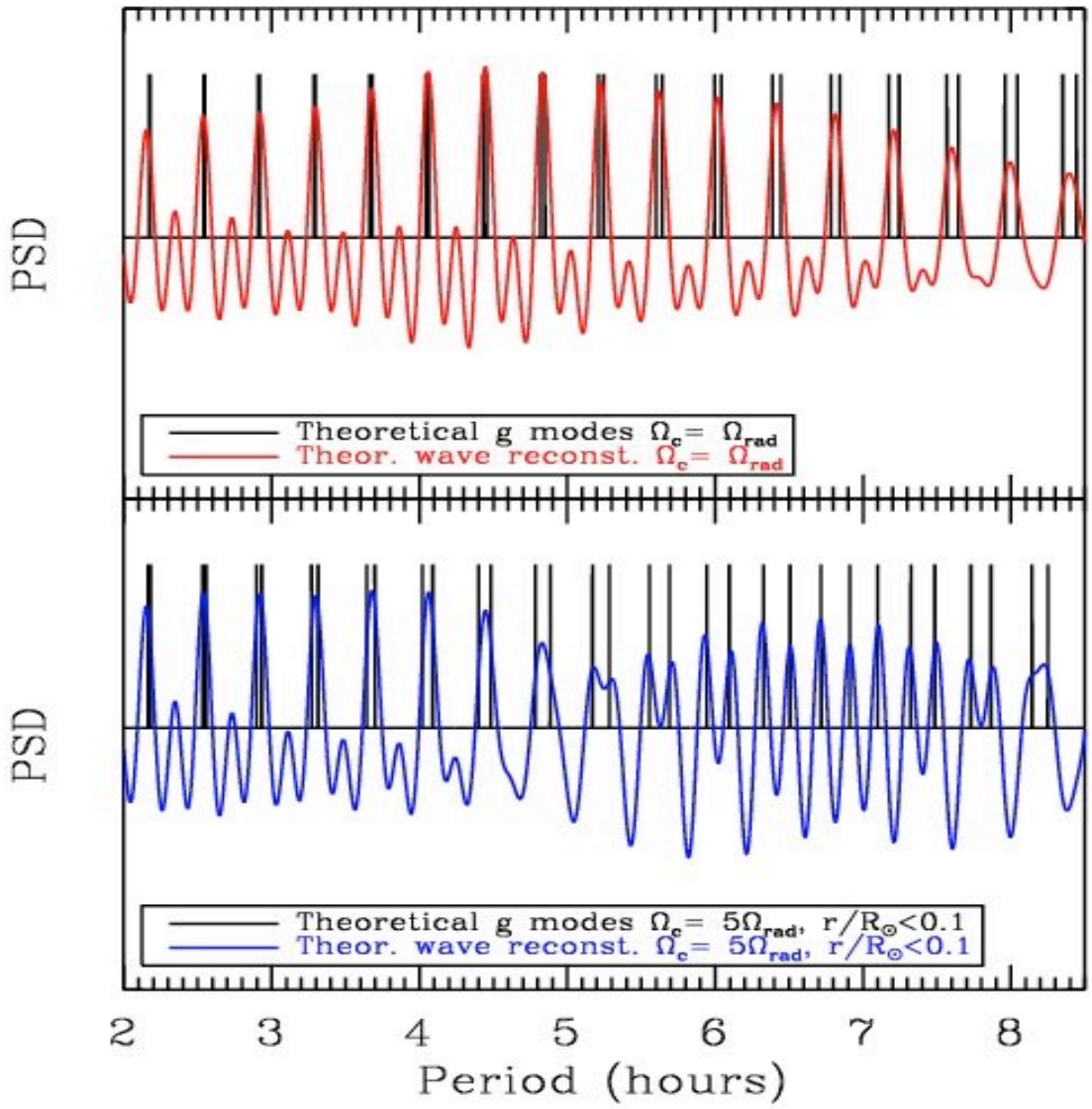
GOLF PS Periodogram



- To compute the PS:
  - Points in the FFT(P) are not equidistant
  - Sine wave fitting or Lomb-Scargle Periodogram
- PS statistics:
  - X^2 with 2 d.o.f.
  - Pb: Points are correlated
  - *Monte Carlo* simulations.

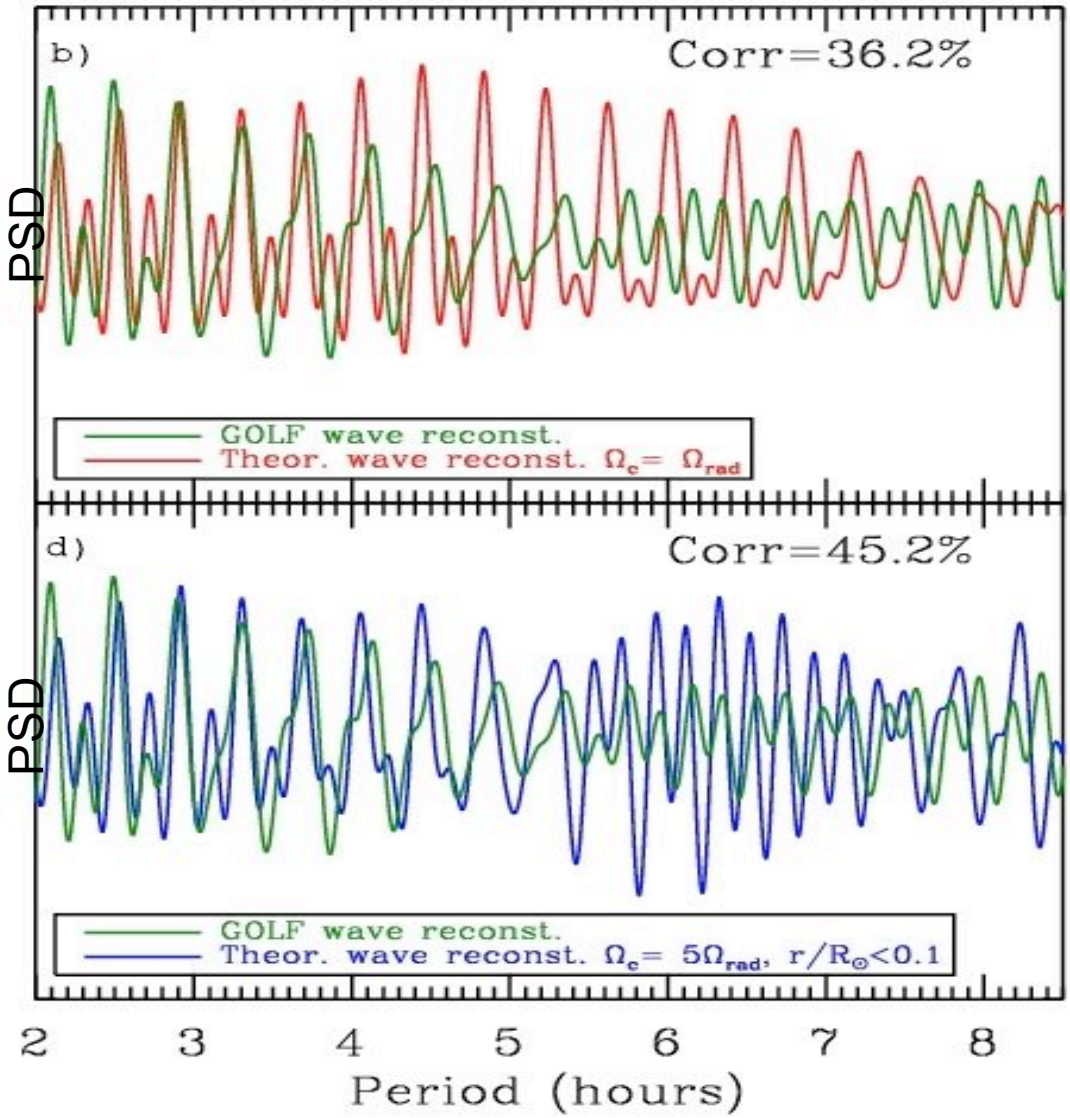
- Structure with a Peak at 6.5-σ & Integrated power > 3 average power.
- Structure also appears using different PSD regions.
- *Monte Carlo* simulations reproducing statistical GOLF noise properties.

Reconstructing waves in the PSD (model)



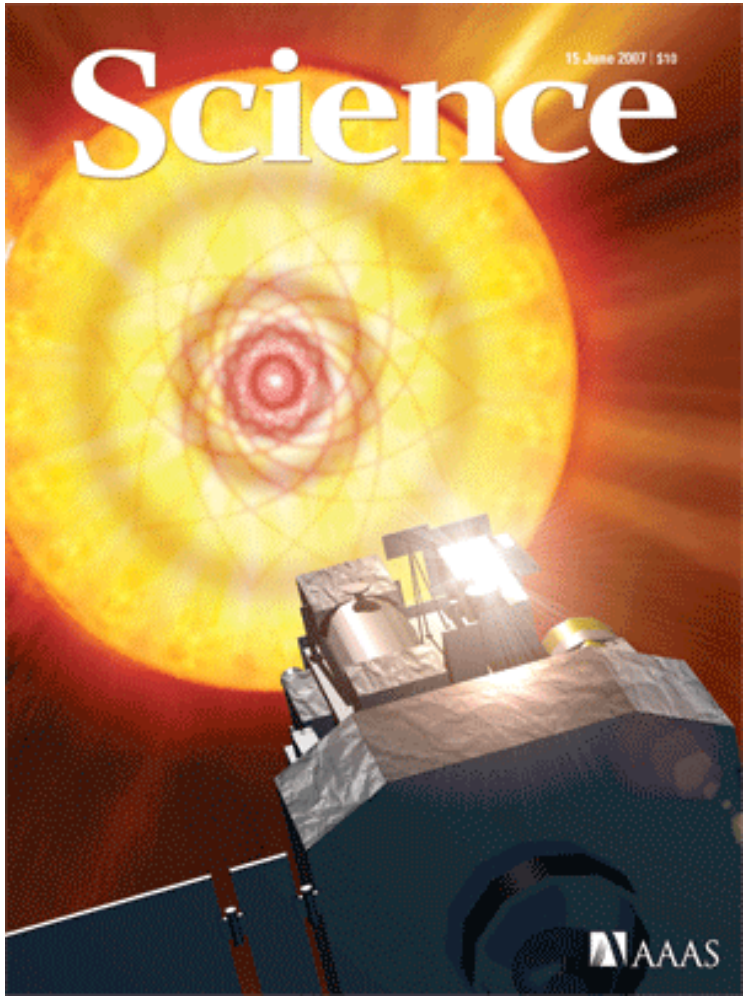
- Role of the Phase
- Using ΔP_1 & the first harmonic in the PS:
  - $\sum_i A_i \sin(2\pi t/P_i + \Phi_i)$
- Sensitivity to positions (structure) and *Splittings (dynamics)* of the g modes

Reconstructing waves in the PSD (GOLF)



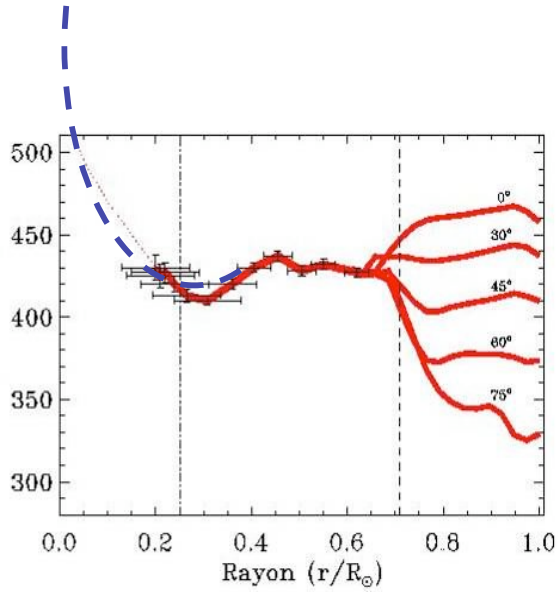
- Correlation between GOLF and models (always >20%):
  - 3 different solar models:
    - Seismic, S & OCA
  - $\Omega_{core} = N\ \Omega_{rad}$
    - N=[1,2,3,5,10]
    - different profiles
  - $R_{core} = M\ R_{\odot}$
    - M=[0.1,0.15,0.2]
  - Rotation axis inclination:
    - i=[90,60,50,20]

SoHO/GOLF have detected the first signature of gravity modes

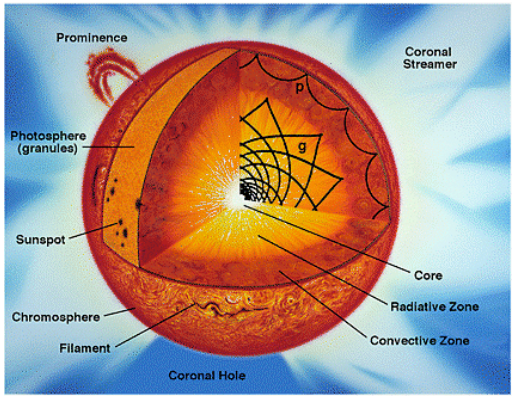


Science 15 June 2007

Garcia, Turck-Chièze, Jimenez, Ballot, Palle, Eff-Darwich, Mathur and Provost



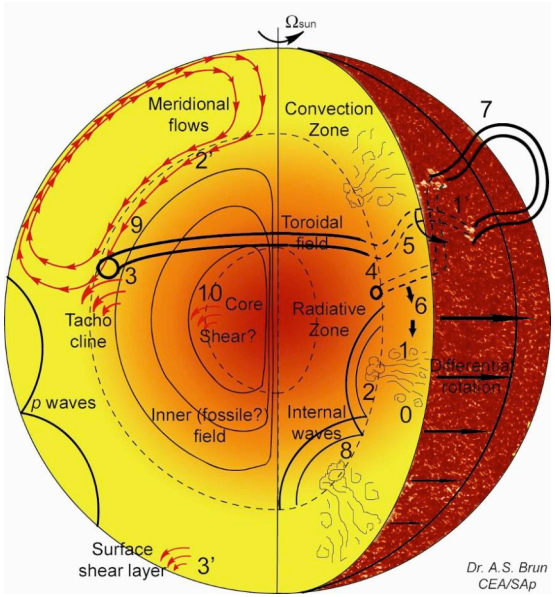
Evolution of the modelling



- Standard Model SSM

- Seismic model SeSM

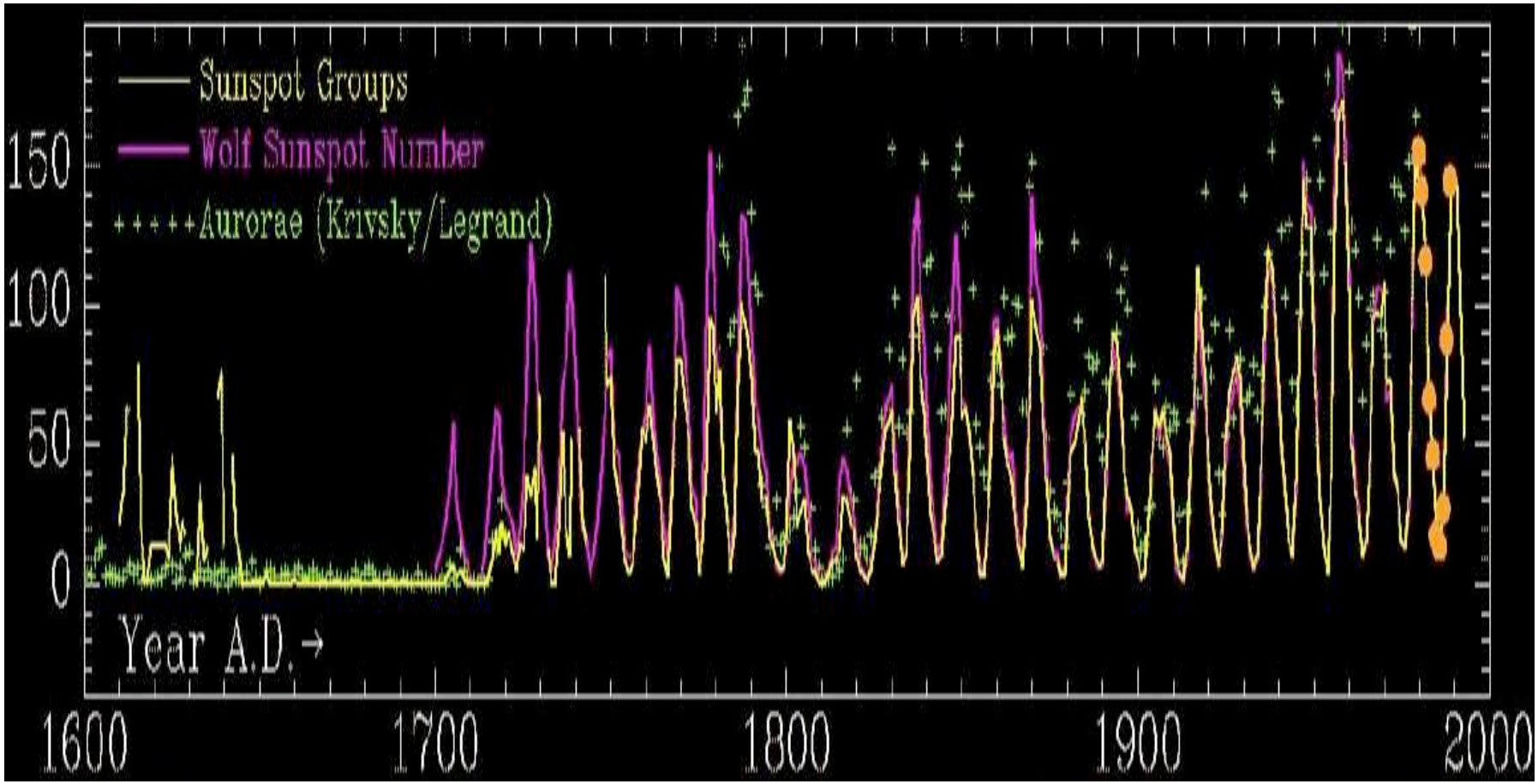
Model which reproduces the sound speed profile for the prediction of the observables



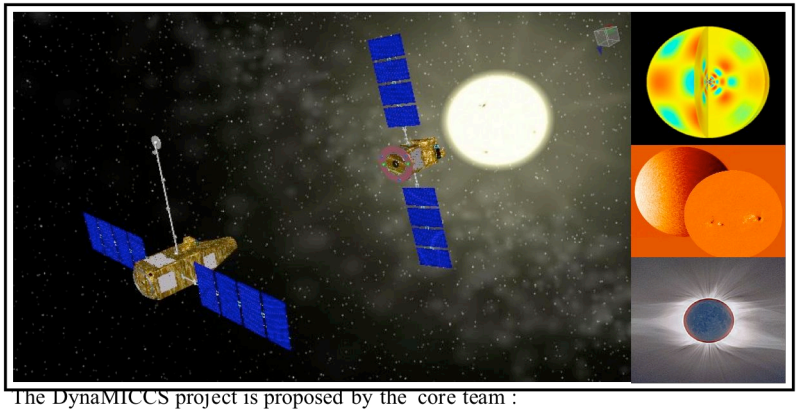
- Dynamical Model SDM

Physical model which reproduces all the observables: 1.5 D, 2D, 3D

We look for an improved understanding of the solar activity cycles, including large minima and maxima with predictions for the next century and a better description of the Sun's potential impact on earth's climate change.



DynaMICCS * : A mission for a complete and continuous view of the Sun dedicated to magnetism, space weather and space climate



The DynaMICCS project is proposed by the core team :
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and the participation of Thales Alenia Space

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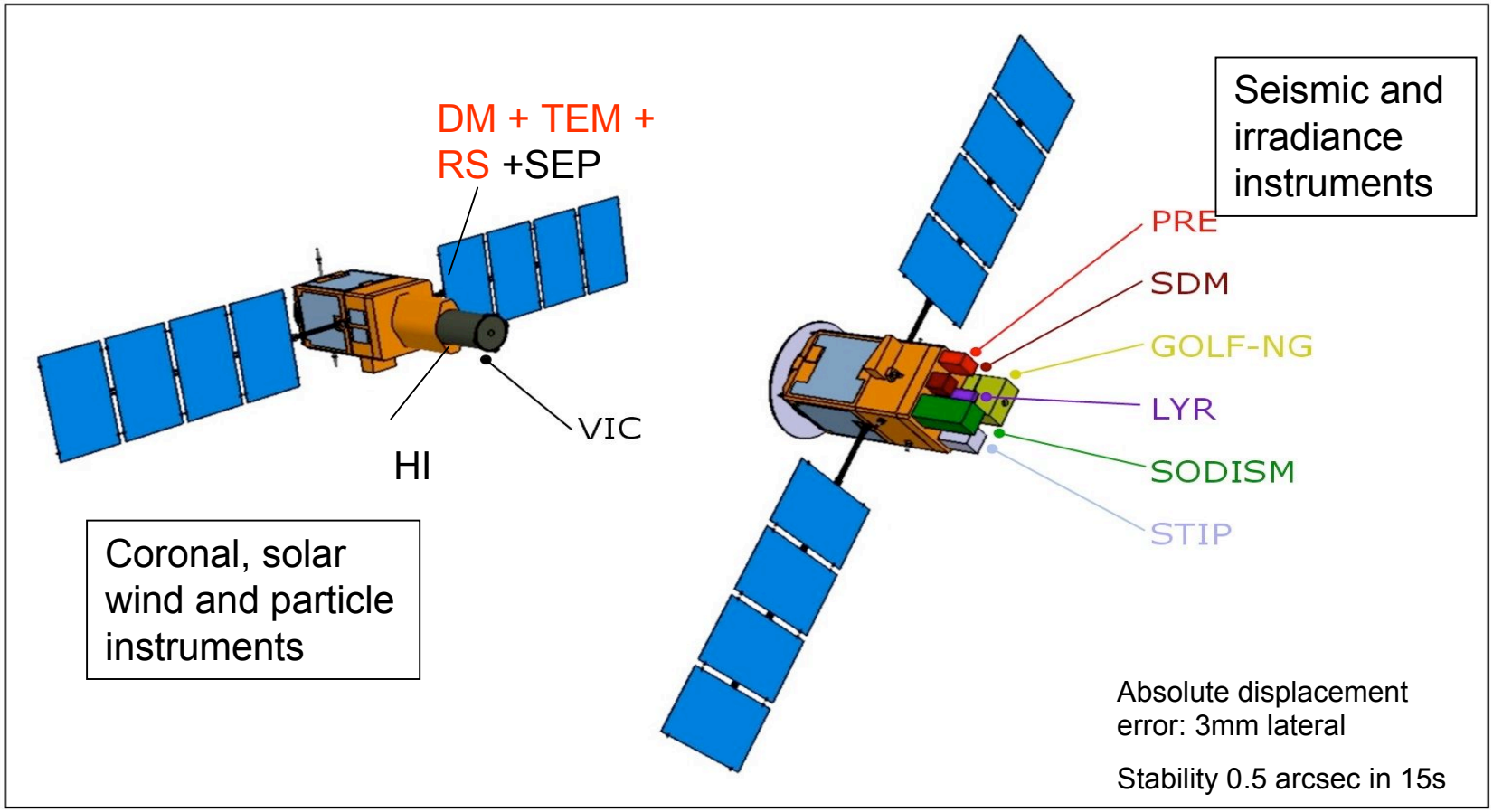
* Dynamics and Magnetism from the Inner Core to the Corona of the Sun

Illustration caption *: Left.Formation flying DynaMICCS spacecraft. Right. Illustration of the main objectives of the mission: (1) detection of gravity modes; (2) m easurements of magnetic, Doppler, and irradiance fields at photosphere-chromosphere interface; (3) imaging of low solar corona. These objectives are complemented with measurement of the characteristics of the solar wind and coronal mass ejections.*

Formation Flying Mission

2 S/C separated by 150 m realize a giant coronagraph
and will achieve conditions close to a total solar eclipse



SoHO has allowed real discoveries and solved a lot of problems on the origin of magnetism

It is just the beginning of a renew of solar and stellar physics

It is important to organise the future for solving fundamental and societal questions on our star

With the complementarity between DynaMICCS and HIRISE,we must strongly progress