WP4: Helioseismology

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WP4 Helioseismology: WP4.1 Global helioseismology & WP4.2 Local helioseismology

The main goal of SPACEIN Work Package (WP) 4 is to develop advanced methods and tools for the analysis of helioseismology data from ground-based observatories and in space, as well as to make available and use numerical simulations to interpret the observations. Current topics of investigation include meridional circulation, medium- and large-scale convection, magnetic flux emergence, and active region dynamics.
Here we introduce what we have achieved in WP4.
All the links for the data and tools are available at http://www.spaceinn.eu/data-access/wp4/ .

Photospheric solar activity proxies

The photospheric solar activity proxy, S_{ph} (Mathur et al. 2014), is calculated from the photometric observations collected by the Variability of Solar Irradiance and Gravity Oscillations (VIRGO, Fröhlich et al. 1995) instrument onboard the *Solar and Heliospheric Observatory* (SoHO) spacecraft launched on December 2, 1995 (Domingo et al. 1995). A similar activity index, S_{vel}, can be obtained from the radial velocity observations collected by the Global Oscillations at Low Frequency instrument (GOLF, Gabriel et al. 1995) onboard SoHO.

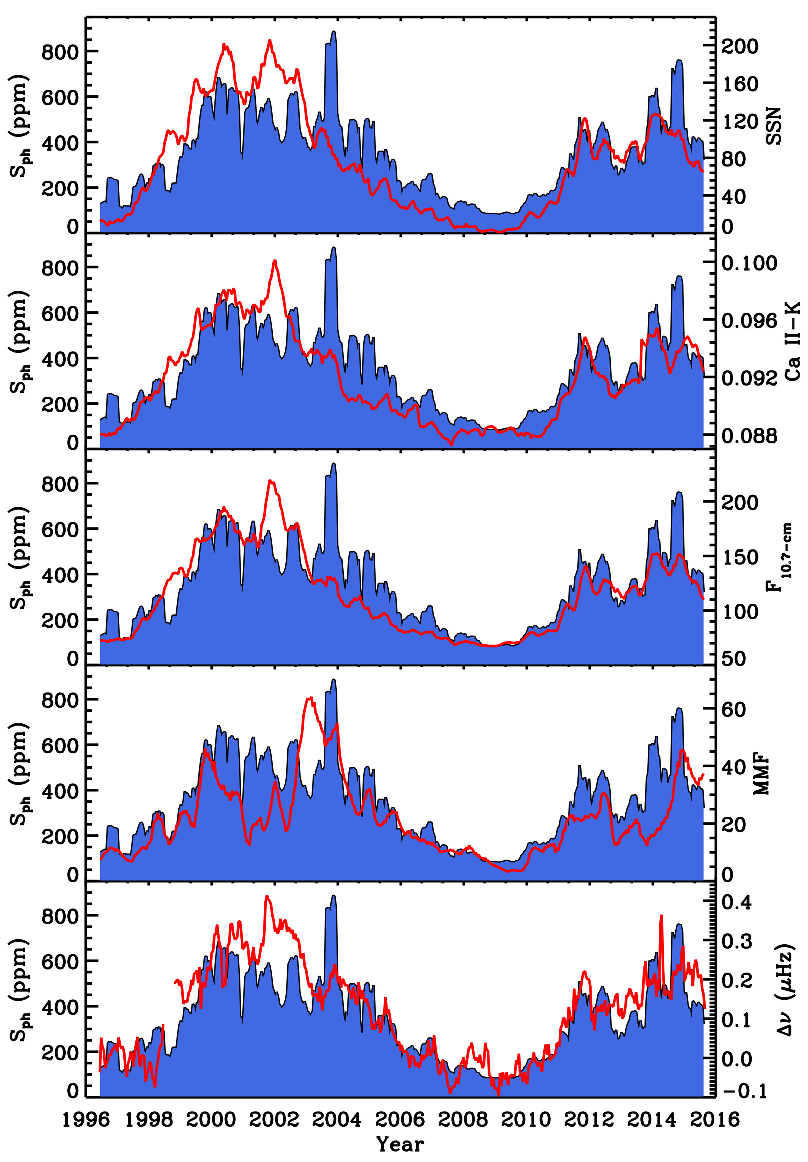

Figure 1: Magnetic activity proxy S_{ph} (in ppm) measured from the VIRGO/SPM (blue channel) observations as a function of time compared to some commonly used solar proxies (red lines). From top to bottom: the sunspot number (SSN); the Ca II-K line emission index in Å; the 10.7-cm radio flux ($F_{10.7\text{-cm}}$); the absolute mean magnetic field (MMF) in T; and the frequency shifts of the l = 0 acoustic oscillations.

Reference: S. Mathur, D. Salabert, R. A. García, and T.I Ceillier 2014, Journal of Space Weather Space Climate, 4, A15

Collecting simulation data and observation systematics

We have made available numerical simulations of seismic waves and their interactions with internal heterogeneities and magnetic regions. The dataset list is available on the SPACEINN website for the three categories below:

1. Spherical-shell simulations of magnetoconvection
2. Numerical Simulations of linear waves/modes in complex media
3. Box simulations of compressible magnetoconvection

http://www.spaceinn.eu/data-access/wp4/simul/

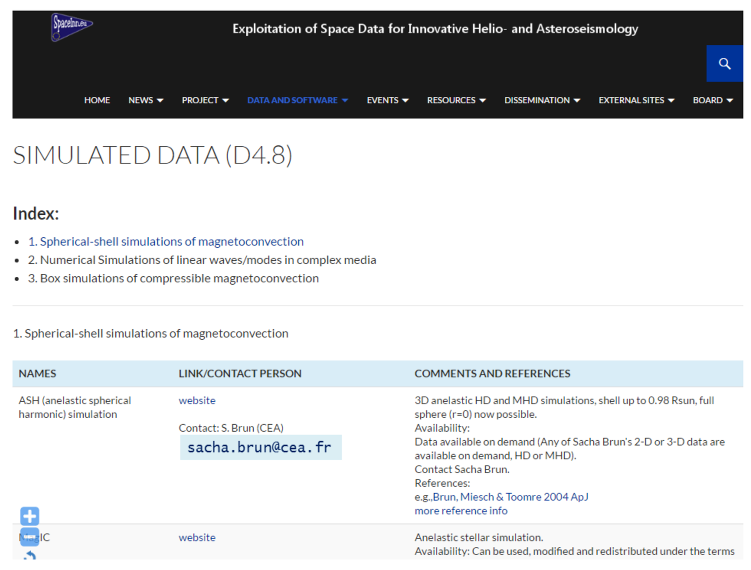

Figure 3: Screen shot of the simulation dataset website

We also have explored and collected information on systematic effects present in the analysis of space observations, e.g., geometrical distortions, instrumental errors and changes, foreshortening, and line-of-sight effects. Formerly such information was known to a few instrument scientists but not accessible to the broader community. We have, therefore, collected the information to make it available to the public. The systematics information list is available on SPACEINN website:
http://www.spaceinn.eu/data-access/wp4/systematics/

Fourier-Hankel/Legendre analysis pipeline

Fourier-Hankel/Legendre analysis is the most natural technique to study cylindrically-symmetric structures like sunspots (Braun et al. 1987, Braun & Duvall 1990), and it is also useful for the meridional flow study (Braun & Fan, 1998). Although the analysis method had been applied very successfully to data from the South Pole in the 1990s, it has rarely been applied to recent space observations. In this work, we have implemented a Fourier-Hankel/Legendre module on the SDO/HMI JSOC data-analysis pipeline for processing large sets of HMI data, based on an existing code developed by Doerr et al. (2010). Details are found at: http://www.spaceinn.eu/data-access/wp4/fhc/.

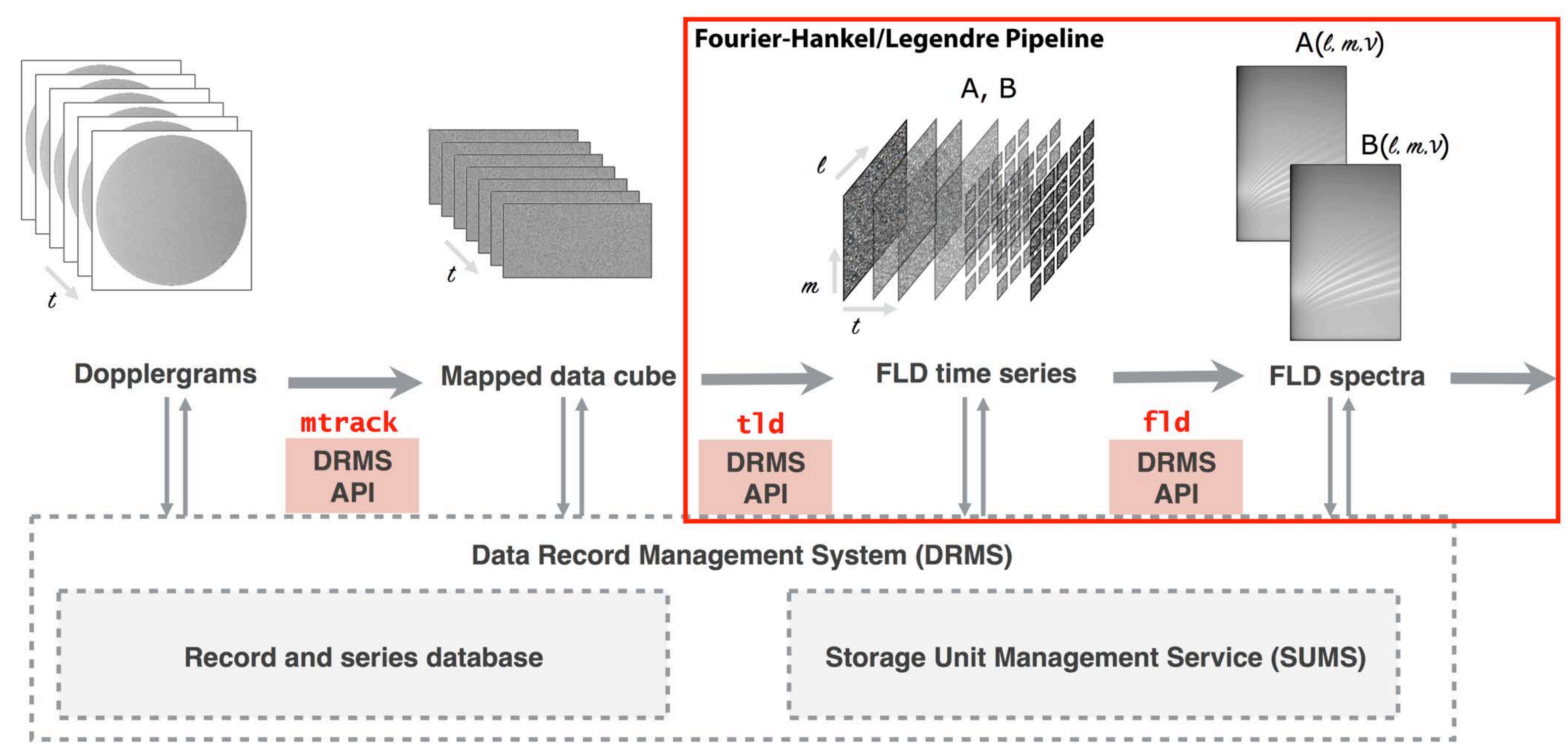

Figure 4: Flow chart of the Fourier-Hankel/Legendre module implemented on the SDO/HMI data analysis pipeline. The mapped and tracked Level 1 Dopplergram are read from the DRMS by the FLD module to provide the Fourier-Hankel/Legendre coefficients for helioseismic studies.

Fitting solar acoustic modes with DIAMONDS

We have developed a Bayesian tool based on DIAMONDS (Corsaro & De Ridder 2014) to fit the acoustic oscillations observed in the Sun from GOLF and VIRGO/SPM data. The fit uses an input background level, which accounts for the granulation signal and rotation. The comb-like pattern of oscillation peaks is then modeled using a Lorentzian mixture that incorporates the rotational ($2\ell+1$) components for each angular degree ℓ considered.

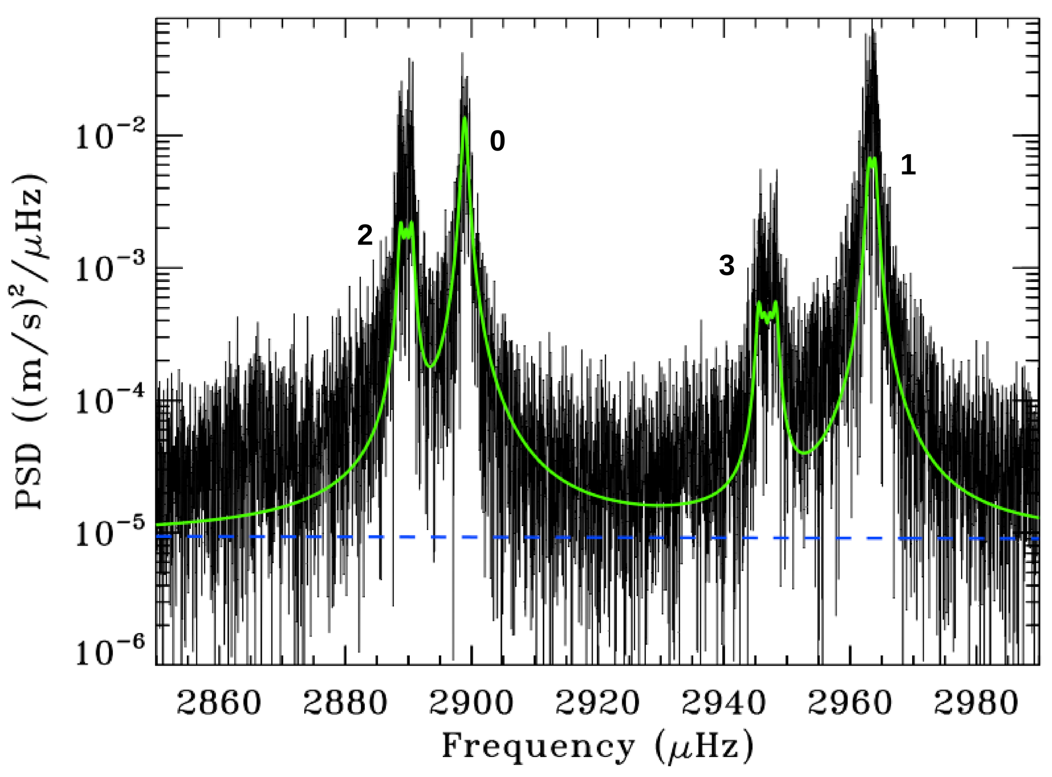

Figure 2: A Bayesian fit to four oscillation modes using GOLF data.

Reference: E. Corsaro & J. De Ridder 2014, A&A, 571, A71
D. Salabert, R.A. García, S. Turck-Chièze 2015, A&A, 578, A137

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