Report of the Phoebus Group on the activities performed at ISSI on November 2005

Background

The objectives of the Phoebus group is to detect solar gravity modes in order to study the internal structure and dynamics of the core of the Sun.

Meeting

The group met at ISSI, Bern, CH from 31 October, 2005 to 4 November 2005

Attendance

T.Appourchaux	Institut d'Astrophysique Spatiale, F
B.Andersen	Norwegian Space Center, N
A.-M.Barlow	University of Birmingham, UK
W.Chaplin	University of Birmingham, UK
T.Corbard	Observatoire de Nice, F
Y.Elsworth	University of Birmingham, UK
W.Finsterle	World Radiation Center, CH
C.Fröhlich	World Radiation Center, CH
A.Gabriel	Institut d'Astrophysique Spatiale, F
R.Garcia	Commissariat à l'Energie Atomique, F
A.Jiménez	Instituto de Astrofisica de Canarias
A.Kosovichev	Stanford University, USA
J.Provost	Observatoire de Nice, F
T.Sekii	National Astronomical Observatory
T.Toutain	University of Birmingham, UK
S.Turck-Chièze	Commissariat à l'Energie Atomique, F

Splinter Groups

The team is subdidvided in three Splinter Groups: Theory (Corbard, Gabriel, Kosovichev, Provost, Turck-Chièze), Detection Techniques (Andersen, Barlow, Chaplin, Elsworth, Finsterle, Fröhlich, Garcia, Jiménez, Toutain), Probability (Appourchaux, Corbard, Elsworth, Garcia, Toutain).

Theory Splinter Group (TSG)

The TSG presented the status of the knowledge regarding the prediction of g-mode frequencies and their amplitudes. It was agreed that the range of mixed modes is 200-400 μHz. Mixed modes are interesting because they probe the Sun close to its core while having large amplitudes in the convective zone and photosphere; they should be easier to detect. The uncertainties on the theoretical g-mode frequencies is typically less than a percent. These uncertainties are related to the uncertainties in our current state of knowledge of the Sun. The search based on generating model grid was not considered as a viable alternative for g-mode detection given the signal-to-noise ratio. This technique is found more appropriate when the signal-to-noise ratio is higher and when modes have already been detected (e.g. p modes in solar-like stars).

Detection Technique and Probability Splinter Groups (DTSG and PSG)
The DTSG and PSG reported on several older and newer detection techniques for which a detection level is available (or not):

- Power spectrum, collapsogram and smoothed collapsogram (See Appourchaux et al, 2000; Appourchaux; 2004)
- Multivariate analysis (Finsterle and Fröhlich, 2001)
- Multiplet search (See Turck-Chièze et al, 2004; Chaplin et al, 2002)
- Optimal masks (Wachter el al, 2003)
- Exact Fraction Technique
- Coincidence search
- Cavity modulation

Here after we will discuss the techniques for which there is no article available.

The Exact Fraction Technique was developped by R.Garcia after an idea from van der Raay (1989) base on the asymptotic properties of the g-mode frequencies. The technique consists in searching for periodicities in the power spectrum when it is displayed as a function of periods. Due to the asymptotic properties of the g-mode periods, regularly spaced peaks should appear in the modified power spectrum. A statistical test was yet to be derived.

The coincidence search is being developped by A-M.Barlow after an idea advocated by the late G.Isaak. The idea is to have a statistical test that would permit to give the probability of having peak coinciding due to noise. Monte-Carlo simulations provided the hint of an answer that was not yet confirmed by analytical calculations. Such an analytical calculation was derived in the course of the workshop.

The last idea is more provocative. It is commonly assumed that g modes have long lifetimes with well known frequencies. But what if the cavity providing the frequency were to be subject to variabilities due to solar activity for instance? In that latter case the frequency could be modulated by more than one bin, thereby destroying the so much hoped coherence. The idea followed by A.Gabriel was then to reinterpolate the time bin on a grid for which the frequency would fell in the same bin. Varying amount of modulation were tried that did not yet provide any positive results. The statistical test is the same as for a regular power spectrum.

Detection
Hereafter we put what 10 years of data can provide us in terms of detectability. Figure 1 shows the detection power of the collapsogram for detecting long-lived modes. Here the frequency dependence on the azimthal order *m* has been assumed linear with the mean rotation Ω_o, no dependence upon differential rotation is included. This approximation is clearly visible in Figure 1 because there are peaks on the left hand side of the main peak that are likely to be due to the quadratic dependence of the mode frequency upon *m*. Several others modes at a lower signal-to-noise ratio were detected. It must be noted that

time is playing a large factor in the detection of the modes below 1000 μHz. The modes of Figure 1 were not even detected 5 years ago. With a longer time series, lower frequency p modes will be detected if not g modes…

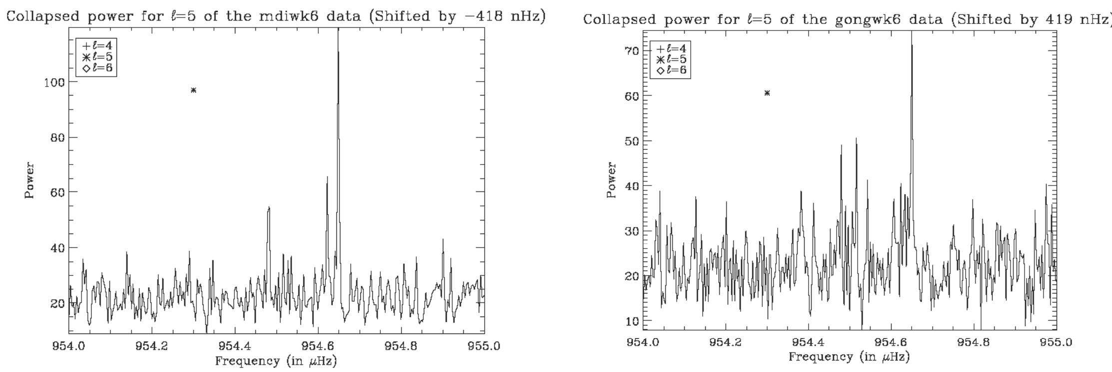

Figure 1: Detection of an *l*=5 p modes below 1000 μHz in both the GONG (ground based) and the MDI data (SOHO based). The star indicates the predicted location of this low frequency p mode.

Time tagging agreement

Given the various data sets, we had to agree on how the data are sampled and tagged. The agreement is as follows:

- Reference is midnight of Temps Atomique International
- MDI is sampled at 60 s (tag on the middle of the sample at midnight)
- SPM/LOI is sampled at 60 s (tag at the middle of the sample 32 s after midnight)
- PMO6 is sampled at 60 s (tag at the middle of the sample 52 s after midnight)
- BiSON is sampled at 40 s sampling (tag at the begin of the sample 32 s after midnight, +4.8 sec for the L1-Earth distance)
- GOLF is sampled at 20 s (tag at the begin of the sample 10 s before midnight)

Detection limit agreement

The group felt that an agreement on how the detection limit should be set. The agreement is as follows:

- Detection limit set a priori (without looking at the data)
- Range of the detection: 50-1000 μHz
- Window for setting the detection limit: 100 μHz wide
- Probability in the window: 10% or 1%

With the range provided,it means that with a 10% probability limit we will detect on average 1 mode ± 1 in the range; and with a 1% probability limit there is a probability of 10% of detecting a mode in the range.

Conference paper agreement

The group agreed on presenting one paper at SOHO-17 (10 years of SOHO, paper submitted to the SOC), and one paper at SOHO-18.

Meeting agreement

In order to prepare the paper of SOHO-17, a workshop will be held in Fréjus on 27-31 March 2006 financed partly by IAS.

The second ISSI meeting will be held on 4-8 September 2006. The purpose of the second meeting is to prepare the review paper. It is anticipated that the meeting will be held in the form of review talks (about 3 in total) each covering the subject covered by the Splinter groups.

An editorial meeting of a few members of the group is anticipated for the first half of 2007.

Acknowledgments

We are thankful to the ISSI staff for having provided us a very pleasant environment that we are eager to find and reproduce the next time we will come. Special thanks to Brigitte, Saliba, Vittorio, Roger and Silvia for the organization details. Please keep the greatly appreciated espresso machine!