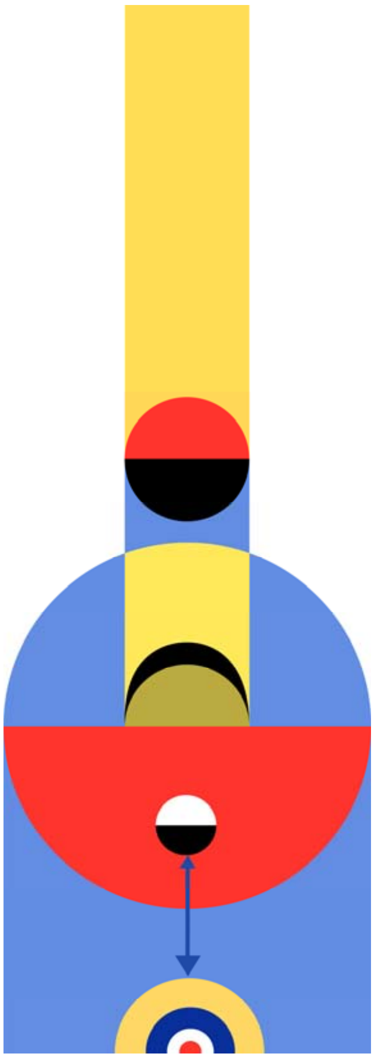
IV HELAS International Conference: Seismological Challenges for Stellar Structure

1-5 February, 2010
Arrecife, Lanzarote (Canary Islands)



PROGRAMME & ABSTRACTS

Organized by the Instituto de Astrofísica de Canarias (IAC)

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- Irene González
- Saskia Hekker
- Günther Houdek
- Steve Kawaler
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- David Salabert

SOCIAL EVENTS

Sunday, 31st January

18:00-20:00 Registration
20:00 - Welcome cocktail at *Castillo de San José*

Monday, 1st February

08:00-09:00 Registration.
09:00-09:15 Conference Opening.

10:25-11:10 "Lanzarote : What to know, what to see, what to do"
Conference Room (during Coffee Break)
Juan Antonio Belmonte

Tuesday, 2nd February

10:00-12:00 Visit to *Arrecife* for accompanying persons..

Wednesday, 3rd February

12:15-20:00 Excursion to *Timanfaya National Park* and visit to *Geria*. This will include lunch at *Bodegas (Cellar) Stratvs*

Thursday, 4th February

20:00-23:00 Closing Dinner at *Jameos del Agua*.

SCIENTIFIC PROGRAMME

Sunday, 31st January	
17:30 – 20:00	Registration
20:00 -	*Welcome cocktail*
Monday, 1st February	
08:00 – 08:45	**Registration**
	Welcome
08:45 - 09:25	**OPENING TALK**: *Seismological Challenges For Stellar Structure*. J. Christensen-Dalsgaard
Session I: Global Helioseismology Chair: Y. Elsworth	
09:25 - 10:05	The acoustic and magnetic solar cycles (Invited Talk) R. Komm
10:05 - 10:25	Internal magnetic fields inferred from helioseismic data C.S. Baldner
10:25 - 11:10	***Coffee-break & poster viewing***
11:10 - 11:50	The interior of the Sun in 3D: how to go beyond the spherical Sun picture using seismology (Invited Talk) S. Mathis
11:50 - 12:10	Theoretical amplitudes of asymptotic solar gravity modes K. Belkacem
12:10 - 12:30	What does the Sun suggest about global oscillation amplitudes in solar-like stars? G. Severino
12:30 – 14:30	Lunch break & poster viewing
Session IIa: Local Helioseismology and atmospheric waves Chair: L. Gizon	
14:30 – 14:50	*Reports on HELAS Network Activities (NA) #3 and #4: Global and Local Helioseismology* *M. Thompson & L. Gizon*
14:50 - 15:30	Theoretical tools in local helioseismology (Invited Talk) H. Schunker
15:30 – 15:50	Travel-time sensitivity kernels for density, pressure, and sound-speed perturbations R. Burston
15:50 – 16:10	Solar oscillations and Meridional circulation M. Roth
16:10 – 16:55	***Coffee-break & poster viewing***
16:55 – 17:15	The meridional flow as estimated by Fourier-Hankel decomposition H.P. Doerr
17:15 – 17:35	Sunspot seismic halos generated by fast MHD wave refraction M. Collados
17:35 – 17:55	A wave scattering theory of solar seismic haloes S.M. Hanasoge
17:55 - 18:15	Numerical helioseismic experiments of magneto-acoustic waves in the solar atmosphere. C. Nutto

Tuesday, 2nd February	
Session IIb: Local Helioseismology and atmospheric waves Chair: L. Gizon	
8:45 – 9:25	Techniques for active region seismology (Invited Talk) I. González
9:25 – 9:45	The stability of toroidal magnetic fields in rotating stellar tachoclines G. Rudiger
9:45 – 10:05	The current status of sunspot seismology H. Moradi
10:05 – 10:25	Observing magneto-acoustic waves in the solar photosphere S. Zharkov
10:25 – 11:10	***Coffee-break & poster viewing***
Session IIIa: Asteroseismology of solar like stars Chair: M. Monteiro	
11:10 – 11:50	The effect of input physics on asteroseismic models (Invited Talk) T. Metcalfe
11:50 – 12:10	Probing the cores of solar-like pulsators M. S. Cunha
12:10 – 12:30	Seismological inference on the core μ-gradient of solar-like stars via low degree mixed modes S. Deheuvels
12:30 – 14:30	***Lunch break & poster viewing***
Session IIIb: Asteroseismology of solar like stars Chair: M. Monteiro	
14:30 – 15:10	Interpretation and constraints of seismic parameters (Invited Talk) J. Ballot
15:10 – 15:30	Seismic signatures of stellar cores of Solar-like pulsators: dependence on mass and age I.M. Brandao
15:30 – 15:50	On detecting the large separation in the autocorrelation of stellar oscillation times series B. Mosser
15:50 – 16:10	Asteroseismic Modelling of Procyon A G. Dogan
16:10 – 16:55	***Coffee-break & poster viewing***
16:55 – 17:15	Constraints of a pulsation frequency on stellar parameters in an eclipsing binary system. O.L. Creevey
17:15 – 17:35	A complicated case: HD49933 O. Benomar
17:35 – 17:55	Seismic constraints on HD-46375 and detection of the direct light reflected by its Hot Jupiter companion in the CoRoT data P Gaulme
17:55 – 18:15	Can Asterseismology solve the solar abundance problem?. The test case of HD43587 A. Mazumdar

Wednesday, 3rd February	
Session IV: Special "Asteroseismology with Kepler" Session Chair: H. Kjeldsen	
09:00 – 10:25	Reports by Chairs and Members of KASC Working Groups • "The Kepler Asteroseismic Investigation: Scientific goals and first results from Kepler". J. Christensen-Dalsgaard • "The asteroseismic potential of Kepler: first results for solar-type stars I: Data Analysis", C. Karoff • "The asteroseismic potential of Kepler: first results for solar-type stars I: Modelling". T. Metcalfe • "The asteroseismic potential of Kepler: first results for solar-type stars I: Ground-based follow-up". J. Molenda-Zakowicz • "Solar-like oscillations in low-luminosity red giants: First results from Kepler", J. de Ridder
10:25 - 11:10	***Coffee-break & poster viewing***
11:10 - 12:30	Reports by Chairs and Members of KASC Working Groups • "Detection of solar-like oscillations from Kepler photometry of the open cluster NGC 6819". D. Stello • "Discovery of a red giant with solar-like oscillations in an eclipsing binary system from Kepler Space-based Photometry". S. Hekker • "Hybrid gamma Doradus - delta Scuti pulsators: New Insights into the physics ofthe oscillations from Kepler observations", A. Grigahcene • "Ground-based follow-up in relation to Kepler Asteroseismic Investigation". K. Uytterhoeven
12:30 - 20:00	***Excursion to Timanfaya National Park and visit to Geria. This will include lunch at Bodegas Stratvs.***
Thursday, 4th February	
Session V: Asteroseismology of red giants and hot subdwarfs Chair: A. Baglin	
8:45 – 9:25	Convection and oscillations (Invited Talk) G. Houdek
9:25 – 10:05	Seismic observations and interpretation for red giants (Invited Talk) S. Hekker
10:05 – 10:25	Solar-like oscillations disclose the internal structure of the CoRoT red giant HR 7349 A. Miglio
10:25 – 10:50	***Coffee-break & poster viewing***
10:50 – 11:10	Inference from adiabatic analysis of solar-like oscillations in red giants J. Montalban
11:10 – 11:30	Frequency spacings of p modes in Red Giants observed by CoRoT C. Barban
11:30 – 12:00	Structure and evolution of pulsating hot subdwarfs (Invited Talk) S. Kawaler
12:00 – 12:30	Observational asteroseismology of pulsating hot subdwarf stars (Invited Talk) R. Ostensen
12:30 – 12:50	The sdB+giant planet system V391Peg: an updated overview R. Silvotti
12:50 – 14:30	***Lunch break & poster viewing***

Session VI: Asteroseismology in stars at the instability strip Chair: M.P. di Mauro	
14:30 – 15:10	Interpretation of asteroseismic data (Invited Talk) E. Michel
15:10 – 15:50	Oscillations in rapidly rotating stars (Invited Talk) D. Reese
15:50 – 16:10	Magnetoacoustic waves in the atmosphere of roAp stars- A theoretical interpretation J. Sousa
16:10 – 16:55	***Coffee-break & poster viewing***
16:55 – 17:15	Theoretical study of γ Doradus pulsations in pre-main sequence stars M. P. Bouabid
17:15 – 17:35	Pulsational content and abundance analysis of COROT Delta Scuti stars E. Poretti
17:35 – 17:55	Magneto-acoustic pulsations in atmospheres of roAp stars E. Khomenko
17:55 – 18:15	Frequency statistics of rapidly rotating star p-mode spectrum F. Lignières
20:00 - 23:00	***Closing Dinner at Jameos del Agua***
Friday, 5th February	
Session VII: Asteroseismology of hot stars Chair: C. Aerts	
8:45 – 8:55	*Reports on HELAS Network Activities (NA) #5:Asteroseismology* *C. Aerts*
8:55 – 9:35	Seismic observations and tools for hot stars (Invited Talk) C. Neiner
9:35 – 9:55	Complex asteroseismology of the hybrid B-type pulsator γ Pegasi: a test of stellar opacities P. Walczak
9:55 – 10:15	Modelling Results for Two Late Be Stars observed by CoRoT C. C. Lovekin
10:15 – 10:35	Observations of B stars from CoRoT's asteroseismology programme P. Degroote
10:25 – 11:10	***Coffee-break & poster viewing***
11:10 – 11:30	Is the macroturbulent broadening present in OB Supergiants related with pulsations? S. Simón-Diaz
11:30 – 11:50	On the use of rotational splitting asymmetries to probe the internal rotation profile of stars. Application to β Cephi stars J.C. Suárez
11:50 – 12:10	Photometric study of two β Cephei pulsators in eclipsing systems D. Drobek
12:10 – 12:30	Ensemble asteroseismology of pulsators in the young open clusters NGC 884 and NGC 6910 from a three-year campaign A. Pigulski
12:30 – 14:30	***Lunch break & poster viewing***

Session VIII: Future and ongoing Projects Chair: P. Pallé	
14:30 – 15:00	Four years of HELAS (Invited Talk) O. Von der Lühe
15:00 – 15:10	Report of current status of the operational projects. P. L. Pallé
15:10 – 16:10	Short presentations on "planned" and "ongoing" projects • "Helioseismology with SDO". L. Gizon • "Helioseismology programs with Solar Orbiter and PICARD". T. Appourchaux • "GOLF-NG development and the ASPIICS mission". S. Turck-Chieze • "A Multiline Spectrometer for Seismic Mapping of the Solar Atmosphere at the VTT". J. Staiger • " The PLATO Mission Project". W. Zima • "Asteroseismology with SONG". J. Christensen-Dalsgaard • "Asteroseismology & Virtual Observatory: the new generation stellar physics is coming". J.C. Suárez • "EXOTIME Project". S. Benatti
16:10 – 16:55	***Coffee-break & poster viewing***
16:55 – 17:35	Round table on "What's next?"
17:35 – 18:15	**CLOSING TALK** W. Chaplin

OPENING TALK:

IT.0.1.- Seismological Challenges For Stellar Structure.

J. Christensen-Dalsgaard
Aarhus University (Denmark)

Helioseismology has provided very detailed information about the solar interior and extensive data on a large number of stars, although at less detail, are promised by the ongoing and upcoming asteroseismic projects. In the solar case there remain serious challenges in understanding the inferred solar structure, particularly in the light of the revised determinations of the solar surface composition. Also, a secure understanding of the origins of solar rotation as inferred from helioseismology, both in the radiative interior and in the convection zone, is still missing. In the stellar case challenges are certain to appear as the data allow more detailed inferences of the properties of stellar cores. Large remaining uncertainties in modelling concerns the properties of convective cores and other processes that may cause mixing. Also, there are remaining challenges in the understanding of the excitation of unstable modes; these can only get worse as more low-amplitude modes are detected in such stars. Thus we can look forward to a highly challenging, and hence exciting, era of stellar astrophysics.

SESSION 1:

Global Helioseismology

Chair: Y. Elsworth

IT.1.1.- The acoustic and magnetic solar cycle

Rudolf Komm
National Solar Observatory (USA)

The parameters describing global acoustic modes such as frequency, width, and amplitude clearly vary with the solar cycle sensing the local distribution of the surface magnetic activity. The frequency variation of the global modes provides information about the solar structure and the rotation rate in the solar interior. The rotation rate throughout the convection zone varies with the solar cycle.The so-called torsional oscillations consists of bands of faster- and slower-than-average zonal flows moving from mid-latitude toward the equator during the solar cycle. With local helioseismology techniques, it is possible to measure the flow component in the meridional direction in addition to the one in the zonal direction and to determine the north-south asymmetries of the flow components. The variation of the meridional flow with depth and solar cycle can provide insights into the operation of the solar dynamo.

OC.1.1.- Internal magnetic fields inferred from helioseismic data

Charles S. Baldner (*)*, H.M. Antia, Sarbani Basu, Timothy P. Larson*
(*) Yale University (USA)

Measuring the internal solar magnetic fields and how they change over the course of a solar cycle is one of the key aims of helioseismology. We present the results of attempts to model the global mode splitting coefficients over solar cycle 23, assuming that the frequency splitting is only due to rotation and a large-scale magnetic field. The first results using only the a_2 coefficients show that the data are best fit by a combination of a poloidal field and a double-peaked near-surface toroidal field. The toroidal fields are centered at $r_0 = 0.999R_\odot$ and $r_0 = 0.996R_\odot$ and are confined to the near-surface layers. The poloidal field is a dipole field. The peak strength of the poloidal field is 124 ± 17 G. The toroidal field peaks at 380 ± 30 G and 1.4 ± 0.2 kG for the shallower and deeper fields, respectively. The field strengths are highly correlated with surface activity. We also examine the differences between the minima at the beginning and the end of solar cycle 23.

IT.1.2.- The interior of the Sun in 3D: how to go beyond the spherical Sun picture using seismology

Stéphane Mathis
Laboratoire AIM - CEA/DSM/IRFU/Sap (France)

With all the results now obtained by global helioseismology, it is clear that we have to go beyond the classical spherical modelling of the Sun. In this way, it is now necessary to draw a picture that takes into account internal dynamical processes such as rotation, magnetic field, and waves from the core to the surface. This is a challenging task since such mechanisms involve length and time-scales that differ from several orders of magnitude and impact on the solar behaviour both on dynamical and secular times.
In this review, I will thus describe the present state of art in the modelling of the internal dynamics of the Sun with emphasizing the constraints which are now given by seismology.

OC.1.2.- Theoretical amplitudes of asymptotic solar gravity modes

K. Belkacem
University of Liege (Belgium)

Solar gravity modes are mainly trapped inside the radiative region and are then able to provide information on the properties of the central part of the Sun. However, because of their evanescent nature in the outer convective region, their photospheric amplitude (where seismic measurements are made) are expected to be very low. Their detection is thus quite challenging and has been attempted for more than 30 years. Since the mode surface velocity results from a balance between the efficiency of the excitation and the damping rates, we investigate the stochastic excitation of gravity modes by turbulent convection as well as their damping rates. We explore the low frequency domain ($\nu \in [20; 120]$ μHz) which, as we will explain, is more favorable to a reliable theoretical estimation of the gravity-mode amplitudes. We find that the maximum velocity is obtained for the $\ell=1$ mode with a value of few millimeters, that is order of magnitudes higher than previous works. From those results, the delectability threshold of those modes will be discussed.

OC.1.3.- What does the Sun suggest about global oscillation amplitudes in solar-like stars?

G. Severino (*), Th. Straus, M. Oliviero, M. Steffen
(*) INAF-Osservatorio Astronomico di Capodimonte (Italy)

Michel et al. (2008, Science, 322, 558) measured with CoRoT solar-like oscillations in three stars hotter than the Sun and found the amplitudes of the luminosity fluctuations to be about 25 % below the theoretical values. They attributed this discrepancy to the non-adiabaticity of the process at work in these stellar atmospheres.
Severino and co-workers analyzed the temperature and velocity fluctuations of the Sun by using numerical simulations of compressible convection and demonstrated that the effects of the atmospheric temperature gradient and opacity give important contributions to the observed intensity amplitudes of the solar 5-minute oscillations (Severino, Straus and Steffen: 2008, in Helioseismology, Asteroseismoly and MHD Connection, Gizon et al. eds., p. 547).
Motivated by the results of CoRoT and based on the solar experience, we develop a new stellar scaling law for the intensity-velocity amplitude ratio (gain) of resonant oscillations, which is a quantity independent of the excitation model. The comparison of our approach with observations gives new interesting results for the Sun as a star. Moreover, for the solar-like stars observed by CoRoT, we found that our scaling law provides an explanation of the low observed luminosity amplitudes which is an alternative to non-abiabatic effects.

POSTERS

1.1.- What is the best tool for the g-mode quest?

F. Baudin, T. Appourchaux, P. Boumier

Solar g modes have been the object of a long quest and their detection by one group (Garcia et al. 2007) still waits for confirmation (Appourchaux et al, in press). Several analysis methods have been used for this quest. We propose here to review and test these different methods (simple Fourier analysis, collective search in the "spectrum of the spectrum", correlation with expected frequencies...). The efficiency of these methods will be tested and compared using simulated data, before an application to real data (mainly from the GOLF

1.2.- On the correlation between high-frequency global oscillations and solar flares

Sudeepto Chakraborty, Taeil Bai, Richard S. Bogart, M. Cristina Rabello-Soares

Global oscillations have been observed in the high-frequency spectrum in velocity and intensity measurements, even above the acoustic cutoff frequency of the solar atmosphere. Recently it has been suggested that solar flares may be one of the mechanisms whereby these high-frequency oscillations are excited. Here we investigate the possibility of a causal relationship between high-frequency global oscillations and solar flares by correlating helioseismic data from GONG, MDI and VIRGO (SPM, LOI) with soft x-ray data from GOES SXI instruments.

1.3.- Detecting low order p-modes by reducing low-frequency noise in BiSON data

G. R. Davies, W. J. Chaplin, Y. Elsworth, B. Miller

We report on ongoing work to reduce low-frequency noise in BiSON data in order to detect low-order p modes and possibly even g modes. Here we simulate artificial data to provide a calibration that reduces the systematic low-frequency noise created by atmospheric extinction.

The BiSON network consists of 6 stations set over a range of longitudes. As a result, contemporaneous observation from as many as four stations is regularly achieved. The resonant-scattering spectrometers, used in all stations, reference the solar potassium Fraunhofer line to laboratory atomic transitions to produce calibrated velocities. A station may have up to 32 channels of raw data, each one sensing a different section of the solar line. The BiSON network may therefore be considered as a single instrument with over one hundred individual channels.

The latest incarnation of the "BiSON simulation tool" includes the effects of limb darkening, differential atmospheric extinction and Doppler imaging in an optically thick vapour cell. We create an artificial data set to explore the relationship between the data channels and investigate the calibration of individual channels using the information provided by all available channels to reduce noise in the key areas of the frequency power spectrum.

1.4.- Evaluation of the empirical correction for the near-surface effects through solar-age determination

A. Bonanno, G. Dogan, J. Christensen-Dalsgaard

The difference between the observed and model frequencies of the Sun can be approximated by a power law (Kjeldsen et al, 2008). We show that when this empirical law is employed to correct the model frequencies and the small frequency separation is used for solar age determination, the results are consistent with the meteoritic age. We present the results and compare with those obtained by using the ratio of small to large frequency separations (Roxburgh & Vorontsov, 2003; Christensen-Dalsgaard, 2009).

1.5.- Update of solar g-mode detection with GOLF & VIRGO aboard SOHO

García R.A., Ballot J., Eff-Darwich A., Garrido R., Jiménez A., Mathis S., Mathur S., Moya A., Pallé P.L., Régulo C., Salabert D., Suárez J.C. and Turck-Chieze S.

Since the detection of the asymptotic properties of the dipole gravity modes in the Sun, the quest to find the individual gravity modes has continued. A deeper analysis of the GOLF/SoHO data unveils the presence of a pattern of peaks that could be interpreted as dipole gravity modes. By collapsing the power spectrum we have obtained a quite constant splitting for those patterns in comparison to regions where no g-modes are expected. Besides, the same technique applied to VIRGO, unveils some common signals between both power spectra. Thus, we can identify and characterise the modes with their central frequency and spltting*s*. This would open the path towards new investigations to better constrain the solar core.

1.6.- On the flare induced high-frequency global waves in the Sun

Kumar B., Mathur S., Garcia R.A. and Venkatakirshnan P.

The study of low-degree high-frequency waves in the Sun is important for our understanding of the dynamics of the deeper solar layers. It has been observed a high correlation between the solar X-ray flux and the VIRGO/SOHO high-frequency signals. In this poster, we present the analysis of the velocity observations of the Sun obtained from MDI and GOLF instruments on board SOHO for some major flare events during solar cycle 23. We examine and discuss the influence of these flares on high-frequency global velocity oscillations.

1.7.- Structure inversion of the solar core with g modes

S. Mathur, A. Eff-Darwich, R.A. Garcia and S. G. Korzennik

Today, the dynamics and the structure of the solar interior are not yet well constrained. While the sound speed is well determined down to the core thanks to the acoustic modes, specially the l=0 modes, the density is not well constrained. Indeed, the acoustic modes being sensitive to pressure, we can have access to the sound speed profile in the inner core of the Sun. Concerning the density, we need the g modes as they are more sensitive to this quantity.

It has already been shown that adding a few g modes in the rotation inversions can give some information on the trend of the rotation rate in the solar core.

We will show here how these profiles are improved adding several g modes.

1.8.- Unstructured grid inversion of 2304-day-long MDI rotational frequency splittings

A. Eff-Darwich A., S.G. Korzennik

Helioseismic inferences of the internal rotation of the Sun are based on numerical inversions of rotational frequency splittings. The inversion matrix is positive and hence, it is possible to implement iterative inversion methodologies. In this work, we present an iterative inversion methodology based on an unstructured grid in both radius and latitude. The rotational splittings were calculated from 2304-day-long MDI time series, being the longest time series ever used to infer the solar internal rotation.

1.9.- Low-degree solar oscillations during the extended minimum of activity

D. Salabert, R.A. Garcia, P.L. Pallé, S.J. Jimenez-Reyes, A. Jimenez

We present an analysis of the variability of the solar oscillation spectrum over the last solar cycles. We use simultaneous observations of the low-degree solar p modes collected by several helioseismic Sun-as-a-star, ground- and space-based instruments. We investigate in particular the response of the p-mode parameters to the observed extended solar minimum of surface activity since 2007 as compared with the previous solar cycle 23. We study the different behaviours of the p-mode variability with angular degrees.

1.10.- In-painting ; new interpolation technique for helio- and astero-seismology data

K. Sato, R.A. Garcia, J. Ballot, S. Mathur, B. Mosser, S. Pires, E. Rodriguez, J.-L. Starck, K. Uytterhoeven

It is important in Helio- and astero-seismology to have continuous data. However, seismic observations can contain gaps and we need to take them into account. For instance, the time series of CoRoT data are periodically perturbed by high-energy particle hitting the satellite when it is crossing the South Atlantic Anomaly (SAA). The presence of repetitive gaps, which come from this perturbation, induces non-desirable peaks in the power spectrum.
To interpolate the repetitive gaps and reduce the presence of non-desirable peaks, we have adopted an interpolation technique which is called 'in-painting' algorithm.
First, we have tested this algorithm on the VIRGO data to which we had applied an artificial window to introduce gaps. We have optimized the algorithm to minimize the difference between the power spectrum density of the data with gaps and the complete time series.
We have also applied the algorithm to the CoRoT data. We have chosen two different runs: one of high quality and another one heavily perturbed by the SAA. We have perturbed the high-quality data with the SAA signature and compare the power spectrum of the new data to the original one.
We find that the power spectrum of the in-painted time series is almost as good as the original, unperturbed one. Seismic inferences obtained after interpolating the data are the same as in the original case.

1.11.- Testing for Non-Stationarity of Global Solar Oscillation Time Series

Ariane Schad, Markus Roth, Jens Timmer

We adopt a statistical test for non-stationarity based on the spectral properties of global solar oscillation time series.
The test is based on an a two-factor analysis of variance (ANOVA) procedure which allows to discriminate between different models of non-stationarity.
We investigate this in dependence on harmonic degree and radial order of the eigenmodes of the Sun.

1.12.- P-mode amplitude growth with height: theory versus observations

R.Simoniello, A.Moya, S.J.Jimenez-Reyes, F. Perez-Hernandez, R.Garrido

Although in the stellar interiors the p-mode oscillations are almost adiabatic, the motions becomes strongly non adiabatic in the atmosphere, because the thermal relaxation time is of the same order or even less than the pulsational periods. In addition, the modes may become non-linear at sufficient altitudes. In this work we aim to check upon the goodness of the adiabatic and non-adiabatic approximations of the solar oscillations by investigating the p-mode amplitude changes with height in the solar atmosphere. We use THÉMIS observations of NaD1 (5896 A) and K (7699 A) spectral lines; in fact, while formation heights of K spectral line is essentially located in the photospheric layer, the formation heights of the NaD1 line span from photosphere up to chromosphere. By analyzing power spectra obtained by temporal series at different points of the NaD1 and K spectral lines, we estimate the p-mode amplitude increase with height for frequencies in the range 2.5-4.5 mHz. These findings are compared with the theoretical predictions of p-mode amplitude changes obtained by adiabatic and non adiabatic models of linear stellar oscillations.

1.13.- Interpreting the frequency dependence of solar cycle changes in p-mode parameters with mode conversion theory

R.Simoniello, W.Finsterle, R.A.Garcia, D.Salabert, H.Schunker, A.Jimenez,Y.Elsworth, W. Chaplin

Doppler velocity or intensity observations of the unresolved Sun allow the investigation of the global properties of the low angular degree p-modes. Long high-quality helioseismic data covering the complete full solar cycle 23 are provided by the ground-based network such as BiSON and by the space-based experiments such as GOLF and VIRGO/SPM on board the ESA/SOHO spacecraft. Therefore, it has been possible to investigate the changes induced by the solar cycle on the p-mode frequencies, amplitudes and linewidths. Although the dependence of the variations in the p-mode parameters with solar magnetic activity is very well known in literature, it is still an open debate over what the mechanism behind it is. Recently, mode conversion has become the preferred mechanism to explain acoustic-power absorption in and/or around sunspots. We explore the possibility, that the solar cycle changes in p-mode parameters between $2.5<n<5.2$ mHz, observed in integrated sunlight observations, can also be explained in terms of mode conversion. Towards this aim, we compare the frequency dependence of the variations in p-mode velocity amplitude and frequency over the solar cycle with theoretical predictions of mode conversion. The results of this investigation may confirm the suggestion that the near surface magnetic field is interacting with the solar oscillations, as suggested by mode conversion theory, which is important to consider when using helioseismology to infer the interior structure of the Sun.

SESSION 2:

Local Helioseismology and atmospheric waves

Chair: L. Gizon

IT.2.1.- Theoretical tools in local helioseismology

H. Schunker
Max Planck Institute for Solar System Research (Germany)

The goal of local helioseismology is to elicit three-dimensional information about the subsurface (or far-side) structure and dynamics of the Sun from observations of the helioseismic wave field at the surface. The physical quantities of interest include flows, sound-speed deviations, magnetic fields, etc. This is an inverse problem, for which we need to first understand, and be able to solve, the forward problem. Most of the effort towards solving both the forward and inverse problems has assumed weak perturbations where different linear approximations can be applied. In this talk we discuss ways in which progress could be made to amend such limitations.

OC.2.1.- Travel-Time Sensitivity Kernels for Density, Pressure, and Sound-Speed Perturbations

R. Burston (*), L. Gizon, A.C. Birch
(*) Max Planck Institute for Solar System Research (Germany)

An important aspect of time-distance helioseismology is the calculation of travel-time sensitivity kernels for thermodynamic variables, velocity flows, and magnetic fields. We use the first-order Born approximation to derive and compute a set of 3D kernel functions, which give the sensitivity of travel-time measurements to the presence of density, pressure, and sound-speed perturbations with respect to a horizontally-invariant background solar model. Kernels for sound-speed perturbations have been studied previously and here we compare them to the kernels for density and pressure. In combination with inversions of the travel-times, this work will be useful to probe subsurface structure.

OC.2.2.- Solar Oscillations and Meridional Circulation

M. Roth
Kiepenheuer-Institut für Sonnenphysik (Germany)

One of the future challenges for helioseismology is the measurement of the solar meridional circulation, as this flow is needed in flux-transport dynamo models to explain, e.g., the length of the solar cycle. However a doubt free seismic measurement of this flow throughout the full convection zone does not exist so far.
Here, I present estimates obtained from global and local seismic techniques how the meridional flow affects solar oscillations and to which extent in depth the meridional flow can be measured.

OC.2.3.- The meridional flow as estimated by Fourier-Hankel decomposition

H.P. Doerr (*), M. Roth, L. Krieger, M. Thompson, A. Zaatri
(*) Kiepenheuer-Institut für Sonnenphysik (Germany)

We use Fourier-Hankel decomposition as suggested earlier by Braun & Fan (1998) to estimate the frequency difference caused by the horizontal meridional flow between waves that propagate polewards and equatorwards.
These frequency shifts are used to determine the meridional flow profile as a function of depth and latitude by a SOLA inversion method.
Decomposing the seismic wave field in a large patch we are able to probe a large fraction of the solar convection zone for the meridional flow.
Analysing smaller patches We are able to compare our findings to results obtained from Ring-Diagram analysis.

OC.2.4.- Sunspot seismic halos generated by fast MHD wave refraction

E. Khomenko, M. Collados
Instituto de Astrofísica de Canarias (Spain)

In this contribution, we suggest an explanation for the high-frequency power excess surrounding active regions known as seismic halos. The idea is based on numerical simulations of magneto-acoustic waves propagation in sunspots. We propose that such an excess can be caused by the additional energy injected by fast mode waves refracted in the higher atmosphere due to the rapid increase of the Alfven speed. Our model qualitatively explains the magnitude of the halo and allows to make some predictions of its behaviour that can be checked in future observations.

OC.2.5.- A wave scattering theory of solar seismic haloes

S. M. Hanasoge
Max Planck Institute for Solar System Research (Germany)

Spatial maps of the high-pass frequency filtered time-averaged root-mean-squared (RMS) Doppler velocities tend to show substantial decrements within regions of strong field and curiously, randomly distributed patches of enhancement in the vicinity. We propose that these haloes or enhancements are a consequence of magnetic-field-induced mode mixing (scattering), resulting in the preferential powering of waves that possess strong surface velocity signatures (i.e. scattering from low to high wavenumbers). With increasing frequency and consequently, decreasing wavelength, a growing number of modes are scattered by the field, thereby rendering the enhancements most visible around the high-frequency parts of the spectrum. We present compelling observational evidence in support of this theory. The implications of this thesis are (1) it is unlikely that wave power enhancements are due to field-induced locally anomalous turbulent wave excitation (a previous hypothesis) and (2) we may utilize the scattering properties to constrain properties of the field (i.e. the S matrix approach).

OC.2.6.- Numerical helioseismic experiments of magneto-acoustic waves in the solar atmosphere

C. Nutto, O. Steiner, M. Roth
Kiepenheuer-Institut für Sonnenphysik (Germany)

Classical tools of helioseismology usually rely on waves with frequencies below the acoustic cut-off frequency and which are trapped inside the acoustic cavity of the Sun. High frequency waves above the acoustic cut-off frequency, however, travel freely into the solar atmosphere. On their path through the atmosphere, these waves interact with the magnetic field. This interaction includes mode conversion, transmission, and refraction. Observations of these waves at different heights can be used to probe the magnetically structured atmosphere as for example present in active regions. However, the tools to explore these magneto-acoustic waves at different heights are still very basic.
We use numerical simulations of the propagation of high frequency magneto-acousitc waves in a realistic solar atmosphere including granular velocity fields. We present two-dimensional and three-dimensional simulations carried out with the CO5BOLD code. In the simulations we use waves that are excited by acoustic events immediately below the photosphere. The results demonstrate that mode conversion occurs and that the waves are partially refracted back into the solar atmosphere and are partially transmitted into the chromosphere. Furthermore, these simulations can now be used to test present analysis tools and develop new techniques for the interpretation of observations of high frequency waves. We are interested in deriving new observational quantities for the helioseismic exploration of the chromosphere.

IT.2.2.- Techniques for active region seismology

I. González Hernández
National Solar Observatory (USA)

Active regions are one of the most observed features in the solar surface. High resolution solar telescopes on the ground and space have revealed the fine configuration of umbra and penumbra of sunspots with amazing detail. However, the subsurface structure of active regions remains highly unknown. Thanks to the development of local helioseismology methods, the properties of active regions under the solar surface are starting to become unravelled.
In this presentation, I will review the main techniques used to infer the dynamic and magnetic properties of active regions in the subphotospheric layers as well as some recent results.

OC.2.7.- The stability of toroidal magnetic fields in rotating stellar tachoclines

G. Ruediger (*), L.L. Kitchatinov
(*) Astrophysikalisches Institut Potsdam (Germany)

The stability of toroidal magnetic fields in rotating stellar tachoclines is studied for realistic values of the Prandtl numbers. The resulting complex eigenfrequencies including growth rate and drift velocity are calculated in Boussinesq approximation for a given radial wavenumber of a nonaxisymmetric perturbation. The ratio of the Alfvén frequency to the rate of the stellar rotation controls the solutions. For strong fields they do not feel the thermal diffusion and the growth rates are very high. For weaker fields the growth rate depends on the thermal conductivity. For fields with dipolar parity and for typical values of the heat conductivity the resulting very long growth times (many years) are almost identical with those for vanishing gravity. The rotation law in the tachoclines is shown as basically stabilizing the instability independent of the sign of the shear. Already very small shear values lead to an increase of the critical magnetic field by one order of magnitude. For the solar tachocline we find a maximum magnetic field amplitude of about 1 kGauss as stable.

OC.2.8.- The Current Status of Sunspot Seismology

H. Moradi (*) , H. Schunker, L. Gizon and the HELAS Local Helioseismology collaboration
(*) Max Planck Institute for Solar System Research (Germany)

While sunspots are easily observed at the surface, determining their sub-surface structure is not at all trivial. There are two main hypotheses for the structure of the sub-surface magnetic configuration of the spot: the monolithic model and the cluster model. However, current linear inversion techniques do not yet allow helioseismology to probe the internal structure of the sunspot with sufficient confidence to distinguish between monolith and cluster models. Furthermore, interpretations of data have been somewhat ambiguous and inconsistent for applications of local helioseismic methods in solar active regions.
But thanks largely to two recent HELAS Local Helioseismology Workshops on this topic, significant progress has been made in addressing some of the outstanding issues in sunspot seismology. Extensive analyses of the sunspot in NOAA 9787 were undertaken at these workshops, using a variety of different helioseismic diagnostic methods and numerical simulations, revealing some very interesting (and sometimes controversial) results, leading to a new paradigm in sunspot seismology. We shall summarize these findings here. In particular, we find that the sunspot introduces a shallow positive wave-speed perturbation (unlike the traditional two-layer model), while both f- and p-mode travel times are now found to be consistent with a horizontal outflow in the sunspot's moat.

OC.2.9.- Observing magneto-acoustic waves in the solar photosphere

S.Zharkov (*), S.Shelyag, R.Erdelyi and M.J.Thompson
(*) MSSL UCL, University of Sheffield (UK)

We present direct evidence of magneto-acoustic waves observed at photospheric level, identified using forward MHD modelling of the wave propagation through a localised non-uniform magnetic field region. Comparing the results of these numerical simulations with observational data, we classify the observed oscillations and consider potential applications of the method as a new diagnostic tool for magneto-helioseismology.

POSTERS

2.1.- HELAS Local Helioseismology Activities

L. Gizon, H. Schunker, Y. Saidi

The HELAS Local Helioseismology Network Activity was established to promote and develop this field of research in Europe, to enhance exchange of knowledge through the organization of workshops, and to make observational data sets and software tools available to the scientific community. Here we summarize the achievements of this network activity, most of which can be consulted online at http://www.mps.mpg.de/projects/seismo/NA4/ .

2.2.- Sources of MHD oscillations of fine scale loop structures in quiet Sun regions

S. Anfinogentov, R. Sych, D. Prosovetsky

Many phenomena seen in solar atmosphere are connected with underphotospheric processes. These phenomena are, for example, longitude MHD oscillation observed in loop structures. Observations of the EUV (171 A and 304 A) emission oscillations in loop structures inside coronal hole with 20-40 min periods are presented in the report. These oscillations are shown to appear in several places of coronal hole directly after dynamical changes in coronal bright points on the border of the hole. But the background coronal hole emission oscillations and magnetic field changes are not detected. This fact allows us to assume that disturbances caused these oscillations propagate in underphotospheric layers. The comparison of the time of the oscillations beginning and bright point activity time allows us to estimate the disturbance propagating speed.

2.3.- Oscillation characteristics of active regions

Charles S. Baldner, Richard S. Bogart, Sarbani Basu, Rachel K.D. MacDonald

In this work, we present the analysis of more than three hundred active regions using MDI Dynamics campaign data to study their oscillation characteristics. We use ring-diagram analyses and apply statistical techniques to study the dependence of mode parameters, such as frequency, power, etc., as a function of the magnetic field strength of the regions. In particular, we try to determine if the changes in mode properties saturate at high magnetic fields, as has been suggested by previous studies.

2.4.- Inversions for solar structure across the solar disc

Charles S. Baldner, Richard S. Bogart, Sarbani Basu

Inversions of frequencies of solar high-degree modes obtained from ring-diagram analyses have been used successfully to study the near-surface structure of solar active regions. This technique, although useful, has so far been restricted to the study of specific regions, not applied to large quantities of data covering the full Sun. As part of the preparation for the large quantities of high resolution helioseismic data expected from the upcoming HMI instrument on the SDO spacecraft, we are perform structure inversions with frequencies obtained from the so-called ``densepacks'' of ring spectra for tracked regions of data the MDI instrument on board the SOHO. Each ``densepack'' is a set of 195 regions covering most of the solar disc and ranging between latitudes of ±60º and Stonyhurst longitudes of ±52.5º. New sets are produced 24 times per Carrington rotation. Structure inversions of these data will allow us to make synoptic maps of the structure of the near-surface regions across the solar disc.

2.5.- Sunspot seismology: forward modelling of subsurface structure

R. Cameron, H. Schunker, L. Gizon

In order to correctly interpret the observed cross-covariance of the helioseismic wavefield in the vicinity of a sunspot, it is necessary to accurately model the effect of the sunspot structure and magnetic field on the waves. Using a combination of quiet-Sun and semi-empirical models of the umbra and penumbra, we have constructed sunspot models which have helioseismic signatures that are similar to the SOHO/MDI observations, as demonstrated by 3D MHD numerical simulations of wave propagation. We also compare the helioseismic signature of two sunspot models which have identical surface properties but have different subsurface structures.

2.6.- Mode transformation and frequency change with height in 3D numerical simulations of magneto-acoustic wave propagation in sunspots

T. Felipe, E. Khomenko, M. Collados

Three-dimensional numerical simulations of magnetoacoustic wave propagation are performed in a sunspot atmosphere with a computational domain covering the photosphere to the chromosphere. The wave source, which resembles the solar spectrum, is located at different distances from the axis of the sunspot for each simulation. These results are compared with the theory of mode transformation and also with observational features. They explain the change in frequency of the oscillations in the umbra from ν =3.33 mHz at the photosphere to ν =5.7 mHz at the chromosphere in terms of linear propagation of waves with ν =5.7 mHz power which come directly from the photosphere and dominate over the evanescent long period waves at higher layers.

2.7.- A new method to compute sensitivity kernels for local helioseismology

L. Gizon and A.C. Birch

We present a new method to compute the spatial sensitivity of helioseismic travel times to weak perturbations to a background solar model. This method uses numerical simulations of solar oscillations as input. Its advantages include simplicity, a wider range of applications (e.g., perturbations with respect to a 3D background model), and the possibility of modeling subtle observational effects (e.g., line-of-sight projection, foreshortening, known systematic errors). While we present example calculations for time-distance helioseismology, this method could be generalized to any other method of local helioseismology.

2.8.- Wave trapping in supergranules

Walter W. Allen, Frank Hill

We model the trapping of waves in a supergranule by solving the wave equation within a cylinder with a regular polygonal cross-section. We will first start with an unstratifed atmosphere as a function of depth, and later extend the model to a stratified solar model. To start, the boundary conditions are fully reflective at the walls of the cylinder. We will determine the characteristics of the trapped waves as functions of the cylinder dimensions, number of sides, and temperature. These will eventually be compared to HMI observations in order to estimate the effective depth and geometry of supergranulation, and to investigate the internal structure of supergranulation. This presentation will report on the status of this study.

2.9.- Inhomogeneous Power Distribution in Magnetic Oscillations

Kiran Jain, S. C. Tripathy, S. Kholikov and F. Hill

Recently GONG has started recording high-cadence line-of-sight magnetograms. The observed signature of five-minute oscillations in these magnetograms is believed to arise due the cross talk between Doppler velocity and Zeeman splitting. We apply ring-diagram analysis and spherical harmonic decomposition methods to compute 3-dimensional power spectra of these images. This will allow us to study the power distribution in acoustic waves propagating in quiet and active regions separately. Our preliminary analysis suggests a non-homogeneous distribution of acoustic power in quiet regions while different patterns are present when there is an active region. In this paper, we present our results on the asymmetry in magnetic oscillations and its behaviour as a function of location, frequency, time and magnetic field strength.

2.10.- Subsurface Flows Beneath Rotating Sunspots

Kiran Jain, I. Gonzalez Hernandez, R. Komm and F. Hill

Sunspots that rotate around their vertical axis are classified as rotating sunspots. It is suggested that the origin of rotational motion is mainly due to the shear and twist in magnetic field lines or vice versa. It is also proposed that the magnetic twist may result from large-scale flows in the solar convection zone and the photosphere or in subphotospheric layers. We apply the technique of ring-diagrams to study the flows beneath these rotating sunspots and investigate how flow fields change with depth. We also study divergence and vorticity of horizontal flows and compare these with those for non-rotating sunspots.

2.11.- Kinetic and Magnetic Helicities of Flare Productive and Dormant Active Regions

R. A. Maurya and A. Ambastha

Solar transient activities, viz., flares and CMEs, are caused by changes in the magnetic field topology in solar atmosphere. These changes are brought about by the magnetic field lines that are rooted beneath the photosphere, where they interact with sub-surface flows. We have found that sub-surface flows in flare-productive active regions possess larger gradients in meridional component of velocity. We have also found that the flows patterns in these active regions are twisted around the depth of 2-5Mm below the surface as compared to quiet regions. We expect that this twist in the sub-surface flows may be correlated with the twist of magnetic fields. We derive kinetic helicity of sub-surface flows and helicity of magnetic fields using ring diagram analysis and photospheric vector magnetic fields, respectively. We have attempted to understand the relationship between sub-surface flow parameters (helicity, vorticity, gradients, etc.) and magnetic field parameters (helicity, alpha-best, energy, etc.). This has been applied to a large sample of flare productive and dormant active regions in order to obtain statistically significant conclusions, which may advance our understanding of the relationship between sub-surface flows and magnetic fields, and the mechanism of the solar transients.

2.12.- The subsurface structure of sunspots

H. Moradi, H. Schunker, L. Gizon and the HELAS Local Helioseismology collaboration

While sunspots are easily observed at the surface, determining their sub-surface structure is not at all trivial. There are two main hypotheses for the structure of the sub-surface magnetic configuration of the spot: the monolithic model and the cluster model. However, current linear inversion techniques do not yet allow helioseismology to probe the internal structure of the sunspot with sufficient confidence to distinguish between monolith and cluster models. Furthermore, interpretations of data have been somewhat ambiguous and inconsistent for applications of local helioseismic methods in solar active regions. But thanks largely to two recent HELAS Local Helioseismology Workshops on this topic, significant progress has been made in addressing some of the outstanding issues in sunspot seismology. Extensive analyses of the sunspot in NOAA 9787 were undertaken at these workshops, using a variety of different helioseismic diagnostic methods and numerical simulations, revealing some very interesting (and sometimes controversial) results, leading to a new paradigm in sunspot seismology. We shall summarize these findings here. In particular, we find that the sunspot introduces a shallow positive wave-speed perturbation (unlike the traditional two-layer model), while both f- and p-mode travel times are now found to be consistent with a horizontal outflow in the sunspot's moat.

2.13.- Interaction of solar waves with frozen turbulence

Rashba T.I., Gizon L., Cameron R.

On the Sun and solar-like stars near-surface turbulent magnetoconvection is associated with velocities, which are reasonably close to the local sound speed. This both excites waves as well as affects their propagation.

As a first step towards understanding the effects of the turbulence on the wave propagation we have simulated the propagation of wave packets through snapshots taken from realistic photospheric magnetoconvection simulations. The snapshots were produced with the MURaM code, and the wave propagation was studied with the SLiM code. This approach allows us to estimate the magnitude of the wave scattering depending on the statistical properties of turbulent media. It is a step towards future studies which will look at time-dependent magnetoconvection.

2.14.- Modelling Solar Oscillations

H. Schunker, R. Cameron, H. Moradi, L. Gizon

In local helioseismology numerical simulations of wave propagation are useful to model the interaction of acoustic waves with perturbations to a background solar model. However, the solution to the equations of motions include convective modes that can swamp the waves we are interested in. Thus, we choose to first stabilise the background solar model against convection. Consequently, this changes the acoustic properties (eigenmodes) of the model. Here we demonstrate the solar-likeness of our convectively stabilised model.

2.15.- New Insights into Surface Acoustic Power

H. Schunker, D.C. Braun

Spatial variations in surface acoustic power are most evident in the presence of surface magnetic fields. In addition to this, the power varies with frequency. The reason for this is not, as yet, clear. Here we show newly discovered properties of the enhanced acoustic power observed near disk center from 21 to 27 January 2002, including AR 9787. We find (i) a strong correlation of the enhanced high frequency power with horizontal magnetic-fields, (ii) the frequency of the maximum enhancement increases with magnetic field strength, and (iii) the oscillations contributing to the halos show modal ridges which are shifted to higher wavenumber at constant frequency in comparison to the ridges of waves in the quiet-Sun. These observations will help to discern the physical cause of the acoustic power variations.

2.16.- Validation of linear OLA inversions for flows

M. Svanda, L. Gizon, S.M. Hanasoge, S.D. Ustyugov

Plasma motions in the Sun cover a wide range of scales in time and space, from granulation to rotation. One of the main goals of helioseismology is to map internal motions in order to learn about convection, the global internal dynamics and the mechanism of the solar dynamo. We focus on inference of supergranular-scale flows on time scales of a day and more in upper 5 Mm of the convection zone. We demonstrate the performance and validation of linear OLA-type inversions for flows in time-distance helioseismology by considering solar-like artificial data. We show that the method is able to recover the given flow field within the predicted accuracy. Furthermore, we show that the leakage of the signal from horizontal components of the flow field into the vertical one causes serious difficulties when inverting for the vertical velocity component. To solve this issue, we have developed and tested the procedure of minimising this cross-talk effect. We demonstrate that reliable inversions of v_z down to 4 Mm below the surface are possible with travel-time maps averaged over at least 24 hours.

2.17.- Radial gradient of horizontal sub-photospheric flows as derived from ring diagram analysis

Amel Zaatri, Thierry Corbard

We invert radial gradients of the horizontal sub-subphotospheric flows using ring diagram analysis of 6 years of GONG data. This inversion requires a prior knowledge of the flows at the surface and the used kernels are the integral of the common rotational kernels. In this poster, we show our inversion results and discuss the long term variation of these gradients.

2.18.- Helioseismology and Space Weather

Frank Hill, Irene Gonzalez Hernandez, Rudi Komm

Space weather seeks to understand and forecast the magnetic phenomena on the sun and in the heliosphere that affect the earth. Since the origin of the solar and heliospheric magnetic field lies inside the sun, helioseismology can play a significant role in space weather. However, the use of helioseismic observations for space weather is just now starting. In this presentation, we summarize the current research that is being done in this area. The main areas under development are the use of far-side mapping to detect and characterize active regions before they rotate onto the earth-facing side; the measurement of subsurface vorticity and surface magnetic field to identify active regions that could potentially produce significant flares; and the monitoring of temporal variations of subsurface vorticity to forecast the occurrence of large flares.

SESSION 3:

Asteroseismology of solar like stars

Chair: M. Monteiro

IT.3.1.- The effect of input physics on asteroseismic models

Travis S. Metcalfe
High Altitude Observatory, NCAR (USA)

There are many ingredients in stellar models that could in principle be insufficient descriptions of the actual conditions inside of real stars. These deficiencies could easily lead to systematic errors in determinations of the optimal model parameters for a given set of oscillation data. For example, models that employ the relatively simple EFF equation of state lead to estimates of the stellar mass about 10% too high for the Sun, and unacceptably large systematic errors on many of the other stellar properties. Even attempting to ignore the effects of helium settling may be too coarse an approximation, since it leads to 5% errors on the mass. This is not to say that simpler stellar models cannot be used in the analysis of asteroseismic data, but some of the more sophisticated ingredients may be required to obtain accurate results from a global search of the parameter space. I will review these issues with a series of examples using Sun-as-a-star data from the BiSON experiment.

OC. 3.1.- Probing the cores of solar-like pulsators

Margarida S. Cunha and Isa Brandao
Centro de Astrofisica da Universidade do Porto (Portugal)

Stars slightly more massive than the sun develop small convective cores during their Main Sequence phase of evolution. The edges of these convective cores are associated with rapid variations in the sound speed which influence the frequencies of acoustic oscillations.
In this work we use an asymptotic analysis that is valid near the turning points of the oscillations, to derive the signature that tiny convective cores, such as those expected in main-sequence solar-like pulsators, produce in the oscillation frequencies. Moreover, we present a seismic diagnostic tool that is capable of isolating that signature, making a direct connection between the data and the physics and dynamics that characterize the convective core, and, hence, also to stellar age.
Given the well known difficulty in detecting modes of degree l=3 in space-based data, and the need of using these modes to construct the diagnostic tool referred above, we further analyse the impact that the derived frequency perturbations have on seismic diagnostic tools that involve only modes of degrees smaller or equal to 2. With recourse to artificial data, we show that these signatures are sufficiently strong to be detectable in space-based data for solar-like pulsators.

OC.3.2.- Seismological inference on the core μ-gradient of solar-like stars via low degree mixed modes

S. Deheuvels et al.
LESIA (France)

In late Main Sequence solar-like pulsators, the coupling between the p-mode cavity and the g-mode cavity is strong for modes of low degree ℓ. In a previous work (Deheuvels and Michel 2009), we have shown that in this case, an avoided crossing affects more than two modes, and induces a characteristic and easily identifiable distortion of the ridge of degree ℓ in the échelle diagram. This distortion is linked to the size of the evanescent zone between the two cavities.
It is well known that the frequency at which the avoided crossing occurs is sensitive to the amount of overshooting at the boundary of the core (Dziembowski and Pamyatnykh 1991). The distortion in the ridge provides information on the profile of the Väisälä frequency, and therefore on the gradient of chemical composition in the central regions. We here investigate on the possibility of complementarily using these two features to obtain a quantitative diagnostic on the internal μ-gradient and on the processes responsible for the extension of the mixed zone associated to the convective core. Our results are applied to the case of solar-like CoRoT target HD 49385, for which a distortion of the ℓ=1 ridge, due to the presence of an avoided crossing, has been detected.

IT.3.2.- How asteroseismology is renewing our knowledge on solar-like stars

J. Ballot
Laboratoire d'Astrophysique de Toulouse (France)

The discovery of the 5-min oscillations in the Sun almost 50 years ago has opened a wonderful window on its interior that has deeply renewed the view we had on our star. Helioseismology has provided very accurate constraints on solar structure and dynamics, with consequences for the whole stellar evolution. These highly exciting results have naturally stimulated the research of such acoustic pulsations in other solar-like stars. The low amplitudes of these stochastically-excited oscillations make their detections very challenging. The first doubtless detection and identification of p modes in α Cen A in 2001, that have been possible thanks to the development of high-performance spectrographs, marked the birth of a new investigation field. The launch of CoRoT 2 years ago has produced a quantitative leap for solar-like-star seismology by delivering 5-month-long uninterrupted time-series of high-precision photometric data. Now, several F and G main-sequence stars have been analyzed. During this review, we discussed the current status of these observations, what we are learned from them about solar-like star properties (mass, radius, rotation, inclination, convection properties...) before concluding on perspectives offered by the very long Kepler observations.

OC.3.3.- Seismic signatures of stellar cores of Solar-like pulsators: dependence on mass and age

I.M. Brandao (*), J. Christensen - Dalsgaard, O.L. Creevey, M.S. Cunha
Centro de Astrofisica da Universidade do Porto (Portugal)

With the recent launch of the Kepler satellite thousands of stars will be continuously monitored for stellar oscillations to a very high degree of precision. This will bring an unprecedented opportunity to perform asteroseismic studies. To make an optimal use of the excellent new data a strong effort has been put into the development of adequate tools to interpret the data and consequently make inferences about the internal structure of the observed stars.
The frequencies within a star are determined by the internal sound-speed and density profiles. A rapid variation in these profiles, e.g. at the borders of convective regions or regions of element ionization, will leave particular signatures in the oscillation frequencies.
With the stellar evolutionary code ASTEC we computed evolutionary series of main-sequence models with masses between 1.0 and 1.6 M_{o} and different physics, and computed their oscillation frequencies using the oscillation code ADIPLS. With these we constructed different seismic tools described in the literature and we will show how the latter encompass information about the deepest layers of these stars, including the properties of small convective cores and strong density gradients.

OC.3.4.- On detecting the large separation in the autocorrelation of stellar oscillation times series

B. Mosser (*), T. Appourchaux
(*) Paris Observatory, LESIA (France)

Autocorrelation has been presented as a powerful tool for a rapid analysis of asteroseismic time series, capable of providing measurements of the large and small frequency separations. The performance of this method needed to be assessed and quantified.
We demonstrate that the method makes it possible to measure the mean large separation, the variation of the large separation with frequency and the small separation. Furthermore, we can quantify the precision of the performance of these different measurements and we can provide a reliable degree identification.
We have used the method for analysing solar-like oscillations CoRoT and Kepler targets and will present results obtained in different cases: red giants, stars hosting an exoplanet, time series with very low signal-to-noise ratio. We have also analyzed the Fourier spectrum of Procyon, observed in 2007 with a ground-based network.

OC.3. 5.- Asteroseismic Modelling of Procyon A

G. Dogan (*), A. Bonanno, T. R. Bedding, T. Campante, J. Christensen-Dalsgaard, H. Kjeldsen
(*) Aarhus University (Denmark)

We present our preliminary results of modelling the F5 star Procyon A, including the comparison between the two different evolutionary codes that have been employed: ASTEC (Aarhus Stellar Evolution Code) (Christensen-Dalsgaard, 2008b) and GARSTEC (Garching Stellar Evolution Code) (Weiss & Schlattl, 2008). Aarhus adiabatic pulsation package (ADIPLS) (Christensen-Dalsgaard, 2008a) has been used to calculate the frequencies of the models. Our modelling is compared to the preliminary frequency analysis of ground based observations which suggests two different mode identification scenarios.

OC.3.6.- Constraints of a pulsation frequency on stellar parameters in an eclipsing binary system.

O.L. Creevey (*), F. Pinheiro , S. Sousa , J.A. Belmonte , J. Telting , G. Handler , T. M. Brown , D. Terrell, A. Zhou.
(*) Instituto de Astrofísica de Canarias (Spain)

We present an analysis of the binary system V577Oph, observed during the summer of 2007 on the 2.5m NOT telescope on La Palma. We have obtained time series spectroscopic observations, which show clear binary motion as well as radial velocity variations due to pulsation in the primary star. The binary orbital solution coupled with a photometric measurement of inclination enables a mass determination of both components. Knowing the mass of the primary star allows us to use the pulsation period to constrain other physical parameters of the star. We discuss our initial inference on these parameters, such as metallicity, effective temperature and mode identification — these emphasize the power that a single pulsation frequency can have for constraining stellar parameters.

OC.3.7.- A complicated case: HD49933

O. Benomar (*), J. Marques, M.J. Goupil, F. Baudin
(*) Institute d'Astrophysique Spatiale (France)

Solar-like stars show pulsations which are used to seismically characterize the star. Using unresolved astrophotometry, we can in theory, reliably extract valuable information from the low l degree modes of pulsations. Unfortunately, the case of HD49933 has proven to be complicated: the mode identification in terms of degree was problematic (see for example Appourchaux 2008 A&A 488, Benomar 2009 A&A 506, Gruberbauer 2009 A&A 506, Benomar 2009 A&A 507). We propose to briefly review the difficulties of the mode identification and once it is established, we propose a seismic interpretation of HD49933 using a Levenberg-Marquardt algorithm to find the best fitted physical value (Mass, Age, overshoot, mixing length, initial abundances) and discuss them.

OC.3.8.- Seismic constraints on HD 46375 and detection of the direct light reflected by its Hot Jupiter companion in the CoRoT data

P. Gaulme [(*)]*, T. Guillot, M. Vannier, S. Deheuvels, B. Mosser, C. Moutou, D. Mary, F. X. Schmider, T. Appourchaux, H. Bruntt, C. Rojas, H. Deeg., S. Aigrain*
(*) Institute d'Astrophysique Spatiale (France)

We present the first observation run which constrains a whole exo-planetary system, both with asteroseismology and detection of direct light coming from the planet. On January 2009, the CoRoT satellite has observed the solar-like star HD 46375 for 34 days, known to host a *not-transiting* Saturn like planet (M sin i = 0.22 M_{jup}). Despite of a very low excess of power, the large separation of the p-modes was identified. Moreover, the direct light due to the changing phases of the planet was evidenced, which allowed us to constrain the planetary albedo. In parallel to these observations, a Zeeman Doppler imaging campaign was led with the Narval spectro-polarimeter, which constrained the star inclination. We present the modelling of the star obtained with the seismic input and the global vision of the HD 46375 system after CoRoT. Such a work is the first example of Plato-like observations.

OC.3.9.- Can asteroseismology solve the solar abundance problem? The test case of HD43587

Anwesh Mazumdar (*), Lovy Singhal, Siddharth Prabhu
(*) Homi Bhabha Centre for Science Education-TIFR. (India)

We examine the effect of the new solar abundances on stellar evolutionary tracks due to each of three separate causes. These are the change in opacities due to difference in the relative abundances of elements in the stellar mixture, the change in nuclear yield due to the difference in abundance ratios of C, N, and O, and the revised estimate of metallicity for a given [Fe/H] because of the lower solar metallicity. We focus on a test star, HD43587, a CoRoT primary solar-type target and obtain evolutionary models adopting both old and new solar abundances. The theoretical frequencies of these models are compared. We find that if the [Fe/H] value of the star has an uncertainty of the order of +/-0.02, it is possible to make models at the same position on the HR diagram with identical mass but different chemical compositions corresponding to the two different solar abundances adopted. Such models do not exhibit significant difference in their frequencies despite the difference in surface chemical composition. However, if the [Fe/H] value is known more precisely, the models at the same position of the HR diagram must differ in mass for the two abundances, and the frequency characteristics of these models would be quite different. Therefore, the asteroseismic information can, in principle, allow us to test the solar abundance values, provided the [Fe/H] of the target star is known to a high precision.

POSTERS

3.1.- CoRoT observations of solar-like oscillations in the overmetallic cool dwarf HD52265

J. Ballot, L. Gizon, R. Samadi, G. Vauclair, T. Appourchaux, M. Auvergne, A. Baglin, F. Baudin, O. Benomar, H. Bruntt, T.L. Campante, C. Catala, W.J. Chaplin, S. Deheuvels, N. Dolez, R.A. García, P. Gaulme, S. Mathur, E. Michel, B. Mosser, C. Régulo, I.W. Roxburgh, D. Salabert, T. Stahn, G.A. Verner, and the rest of CoRoT data analysis team

The G0V star HD52265 is one of the coolest main-sequence star observed by CoRoT. We present the analysis of its light curve measured by CoRoT for 117 days from 11/13/2008 to 3/11/2009. The power spectrum exhibits a very clear comb pattern that we doubtlessly identify as p modes of degrees l=0,1 and 2 for around ten consecutive radial orders. We also find a signature of the surface rotation at very low frequencies. We discuss in this poster the p-mode characteristics (frequency, power, lifetime, rotational splitting...) we have extracted using different fitting techniques.

3.2.- Asteroseismology of the solar twin 18 Sco: first results

Michaël Bazot, Torben Arentoft, Martin Asplund, Tim Bedding, Tiago Campante, Hervé Carfantan, Matthieu Castro, Bill Chaplin, Jørgen Christensen-Dalsgaard, Jose Dias do Nascimento, Boris Dintrans, Yvonne Elsworth, Michael Ireland, Hans Kjeldsen, Jorge Meléndez, Travis Metcalfe, Mario Monteiro, Pascal Petit, Nuno Santos, Sergio Sousa, Sylvie Théado, Sylvie Vauclair

Solar twins are generating a growing interest. It is possible when studying them to address particular questions concerning the very nature of the Sun. This has culminated with the interrogation: "Is the Sun a Sun-Like Star?" (Gustafsson 1998,2008). So far these statistical studies used the atmospheric parameters of solar twins to look for any particular behaviour of the Sun. Nowadays, asteroseismology offers first opportunities for glimpses at their internal structure. A first multi-site campaign on the high-resolution spectrographs HARPS and SOPHIE has been carried on. We present here the results from this first run.

3.3.- The combined CORALIE+UVES+UCLES time series of Alpha Cen A

P. de Meulenaer, F. Carrier, A. Miglio, T. Bedding, F. Bouchy, P. Eggenberger, H. Kjeldsen, J. Montalban

In this work we combine and analyse the radial velocity time series of the solar-like star alpha Cen A obtained in 2001 in Chile and Australia with three spectrographs: CORALIE, UVES and UCLES. The resulting time series is as long as the CORALIE one (12.45 days) but contains almost 5 times more data points and its spectral window presents daily aliases reduced by a factor 2.6. A new set of frequencies has been detected along with some rotational splittings.
A comparison with stellar models indicates that the seismic constraints determined in this study (namely the small separations d_{10} and $\Delta\nu_{13}$) allow us to put an upper limit to the amount of convective-core overshooting needed to model stars of mass and metallicity similar to those of alpha Cen A.

3.4.- Asteroseismology of exoplanet host stars : new results

M. E. Escobar, M. Soriano, S. Theado, S. Vauclair, N. Dolez, G. Vauclair

Up to now, five exoplanet host stars have been observed in details for asteroseismology: mu Arae, iota Hor, 94 Ceti (with HARPS) , 51 Peg (with SOPHIE) and HD52265 (COROT). We have computed models for these stars taking into account the observed frequencies and the observed spectroscopic parameters. Here we will present new results concerning the parameters (mass, radius, Teff, age, chemical composition, etc.) and internal structure of the first four stars.

3.5.- Signature of magnetic activity cycle in HD49933 observed by CoRoT

Garcia, R.A., Ballot, J., Regulo, C. and Mathur, S.

Solar-like stars with an external convective envelope can develop dynamo under the interaction of convection, rotation and magnetic fields. Even in the Sun, these dynamo effects are not yet well understood and it would be extremely important to extend this study to different stars with different characteristics. HD49933 is a F5V, 1.2 solar Mass star that has been observed by CoRoT for 60 days during the initial Run and 137 more days delayed about 6 months. Thus, we cover a total of 400 days. Assuming that the activity cycle is proportional to the rotation of the star (which spins several times faster than our star), this time span should be enough to study the existence of such a cycle. Our analysis, which has already been tested on sun-as-a-star observations done by SPM/VIRGO, has been applied to this star. In this poster we will discuss the results we found.

3.6.- Enhancing the signal-to-noise ratio of solar-like targets observed by CoRoT

García R.A., Ballot J., Mathur S. and Régulo C.

The analysis of the first solar-like targets done by CoRoT have shown that the oscillation amplitudes are about 25% below the theoretical amplitudes while the convective background is up to three times higher than in the solar case. In such conditions the Comb-like structure of the acoustic modes has smaller signal-to-noise ratios than initially expected complicating the characterization of individual modes. In the present work we apply the curvelet filtering plus a partial reconstruction of the signal from the obtaining spacing of the comb-like structure of the acoustic modes, to the solar-like targets already observed by CoRoT to enhance the signal-to-noise ratio of the ridges in the echelle diagrams and we study how the analysis of the p modes can be improved.

3.7.- Asteroseismic constraint on the mass of the planet orbiting the CoRoT Sun-like star HD 52265

L. Gizon, J. Ballot, C. Catala, T. Stahn, G. Vauclair, T. Appourchaux, M. Auvergne, A. Baglin, F. Baudin, O. Benomar, H. Bruntt, T.L. Campante, W.J. Chaplin, S. Deheuvels, N. Dolez, R.A. García, P. Gaulme, S. Mathur, E. Michel, B. Mosser, C. Régulo, I.W. Roxburgh, D. Salabert, R. Samadi, G.A. Verner, and the other members of the CoRoT Data Analysis Team

The star HD52265 was chosen as a CoRoT prime target for asteroseismology because this Sun-like star hosts a planet, discovered in 2000 using radial velocity measurements (with a mass of 1.13 Jupiter mass divided by the sine of the angle between the line of sight and the normal to the orbital plane). Thanks to four months of CoRoT photometry, HD 52265 provides the best example of solar-like oscillations. The quality of the data is such that the angular velocity of the star and the inclination of the rotation axis can both be inferred from the rotationally-split modes of oscillation and their relative amplitudes. Assuming that the planet's orbital plane is normal to the stellar rotation axis, we find that the mass of the companion can be constrained with precision and that it is indeed a planet, not a brown dwarf.

3.8.- What can we lean from Kappa Ceti about the evolution of life?

Karoff C.

Kappa Ceti is to many known as the young solar twin because its global stellar parameters mimic those we would expect for the Sun at the time life started to evolve on the Earth. Kappa Ceti therefore represent a unique laboratory for understanding the activity of the Sun when life evolved on the Earth. One interesting aspect here is the hypothesis put forward by Svensmark that the changing solar activity results in a changing flux of cosmic rays at the Earth, which result in a changing low-attitude cloud coverage and thus a changing climate. Was this also the case four billion years ago and what effect did it have on the evolution of life?
Based on the X-ray and UV activity that is measured in Kappa Ceti today we here try to estimate what effect the Sun had on the climate on the young Earth and thus on the evolution of life - given that Svensmark's hypothesis is correct.

3.9.- Modelling auto covariance spectra of bright solar-like stars

Karoff C.

Analysis of acoustic spectra of solar-like stars normally suffers from some degree of subjectivity due to the lack of a consistent way of selecting and tacking the oscillation modes. By modelling the auto covariance spectra of the stellar acoustic spectra instead of just the acoustic spectra these problems are overcome by not having to model the individual oscillation modes themselves, but their auto covariance spectra.
We have modelled the auto covariance spectra of a large catalogue of high-precision ground-based radial-velocity observations ofbright solar-like stars in order to obtain reliable and consistent measurements of the large and small frequency separations in these stars. We use these measurements to provide estimates of the radii, masses and ages of these stars with consistent uncertainties.

3.10.- An automatic pipeline analysing solar-like oscillating targets tested on CoRoT and simulated data

S. Mathur, R.A. Garcia, C. Regulo, O.L. Creevey, J. Ballot and D. Salabert

The launch of the Kepler mission on 7th March 2009 opened a new bright future for the search of extra-solar planets while a huge amounts of stars will be observed leading to the opportunity to better understand the stellar evolution. This will allow us to probe different regions in the HR diagram and put more constraints on the stellar models.
Up to now the asteroseismic missions such as MOST and CoRoT were providing some solar-like stars at a very slow cadence.
But to study the several hundreds of solar-like oscillating stars that will be observed during the Kepler survey phase, an analysis devoted to one star is impossible if we want to have as much information as we can in a small period of time. Thus, we have developed a pipeline to analyse the acoustic oscillations as part of the several pipelines of the asteroFLAG team. Our pipeline is divided into several packages: the search for the frequency-range of the p-mode bump by looking for the large spacing, the fitting of the background, the estimation of the maximum amplitude per radial mode as well as the central maximum frequency. At this point, we can try to infer the radius and the mass of the stars from all this information. Then, if the signal-to-noise ratio is low enough we can obtain the characteristics of the p modes through a global fitting on the power spectrum. For the first package, we also have several methods that enables us to cross-check the results and to attribute a confidence level.
After describing the methodology used in the pipeline, we will apply it to the Sun and to some CoRoT targets.

3.11.- Sensitivity of the g-mode frequencies to pulsation codes and their parameters

A. Moya, S. Mathur and R.A. Garcia

From the recent work of the Evolution and Seismic Tools Activity (ESTA, Monterior et al. 2006; Lebreton et al. 2008), whose Task 2 is devoted to compare pulsational frequencies computed using most of the pulsational codes available in the asteroseismic community, the dependence of the theoretical frequencies with non-physical choices is now quite well fixed. To ensure that the accuracy of the computed frequencies is of the same order of magnitude or better than the observational errors, some requirements in the equilibrium models and the numerical resolutions of the pulsational equations must be followed. In particular, we have verified the numerical accuracy obtained with the Saclay seismic model, which is used to study the solar g-mode region (60 to 140 μHz). We have compared the results coming from the Aarhus adiabatic pulsation code (ADIPLS), with the frequencies computed with the Granada Code (GraCo) taking into account several possible choices. We have concluded that the present equilibrium models and the use of the Richardson extrapolation ensure an accuracy of the order of 0.01 μHz in the determination of the frequencies, which is quite enough for our purposes.

3.12.- Narrow frequency windowed autocorrelation as a diagnostic of solar-like stars

Ian Roxburgh

Narrow-windowed autocorrelation of a time series can reveal the variation with frequency of the large separations Δ(ν) and the half large separations Δ_{01} , Δ_{10} , thus helping with mode identification. This technique is applied to the CoRoT p-mode oscillators HD49933, HD49385, HD181420, and HD181906. Theoretical analysis and modelling are presented to illustrate the technique.

3.13.- On the likelihood ratio test applied in asteroseismology for mode identification

D. Salabert, R.A. Garcia, S. Mathur

The identification of the solar-like oscillation modes, as measured by asteroseismology, is a necessary requirement in order to infer the physical properties of the interior of the stars. Difficulties occur when a large number of modes of oscillations with a low signal-to-noise ratio are observed. In those cases, it is of common use to apply a likelihood ratio test to discriminate between the possible scenarios. We present here a statistical analysis of the likelihood ratio test and discuss its accuracy to identify the correct modes. We use the AsteroFLAG artificial stars, simulated over a range of magnitude, inclination angle, and rotation rate. We show that the likelihood ratio test is appropriate up to a certain magnitude (signal-to-noise ratio). We also discuss its limitation for the CoRoT and KEPLER observations.

3.14.- Grids of Stellar Models and Frequencies with CESAM2k + LNAWENR/ROMOSC

Marian Doru Suran, Dumitru Pricopi

In this paper we present a grid of stellar models (for $0.8M_\odot$ - $6M_\odot$, Z=0.01-0.04) obtained with CESAM2k stellar evolutionary code. We determined also the corresponding seismic properties using the LNAWENR/ROMOSC linear, non-adiabatic, non-radial stellar pulsation code.

3.15.- A power-spectrum autocorrelation technique to detect global asteroseismic parameters

G. A. Verner

Regions of p-mode power can be characterised by the self-repeating comb-like structure in a Fourier power spectrum. Using a moving-windowed autocorrelation technique applied to the acoustic power spectrum it is possible to automatically detect regions of maximum p-mode power, large and small separations and mean p-mode linewidths. With a sufficient signal-to-noise ratio, it is also possible to determine the variation in large and small separations with frequency, and the rotational splitting and inclination angle. This technique has been applied to high and low signal-to-noise data from the CoRoT spacecraft and tested successfully with artificial data to show that it provides a powerful method to detect p-mode parameters, particularly in low signal-to-noise data.

3.16.- Modelling stars using Bayesian methods

Michaël Bazot

The large incoming flux of asteroseismic data (but also data from spectroscopy, interferometry,...) shall lead to a better understanding of stellar interiors, their structure and their evolution. It provides us with strong constraints on the already existing stellar models. I focus in this presentation on the interface between data analysis and stellar modelling, and address the problem of parameter estimation. I describe briefly existing methods in Bayesian analysis, and more specifically the Markov Chain Monte Carlo numerical method(s). In a second part I present results for star with available seismic data (obtained from space or ground). An emphasis is put on the necessity to adapt the methodology (tempered MCMC, model selection method, inclusion of interpolation schemes) to the specific problem of stellar physics that is addressed.

SESSION 4:

Special Session: "Asteroseismology with Kepler"

Chair: H. Kjeldsen

OC.4.1.- The Kepler Asteroseismic Investigation: Scientific goals and first results from Kepler

Joergen Christensen-Dalsgaard
Aarhus University (Denmark)

The Kepler data provide a unique resource for asteroseismic investigation of a broad range of stars. Through an agreement with the Kepler project we have been able to make the data available to a broad community, organized in the Kepler Asteroseismic Consortium (KASC). Here I provide an overview of the KASC organization and the procedures established for data access, as a background for the presentation of the early Kepler results in the following talks. In addition, I briefly discuss the significance of Kepler asteroseismology for the study of extra-solar planetary systems.

OC.4.2.- The asteroseismic potential of Kepler: first results for solar-type stars I: Data Analysis

Christoffer Karoff
University of Birmingham (UK)

We present an asteroseismic data analysis of three G-type stars observed by Kepler. The observations, made at one-minute cadence during the first 33.5d of science operations, reveal high signal-to-noise solar-like oscillation spectra in all three stars: About 20 modes of oscillation can clearly be distinguished in each star. We discuss the appearance of the oscillation spectra, including the presence of a possible signature of facular, the presence of mixed modes and oscillation mode life-times.

OC.4.3.- The asteroseismic potential of Kepler: first results for solar-type stars II: Modelling

Travis Metcalfe
High Altitude Observatory, NCAR (USA)

We present stellar modeling results for three G-type stars observed by Kepler. The observations, made at one-minute cadence during the first 33.5d of science operations, reveal high signal-to-noise solar-like oscillation spectra in all three stars: about 20 modes of oscillation can be clearly distinguished in each star. We discuss inferences on the stellar properties obtained by comparing the characteristic spacings, individual frequencies and spectroscopic constraints with grids of stellar evolution models.

OC.4.4.- The asteroseismic potential of Kepler: first results for solar-type stars III: Ground-based follow-up

Joanna Molenda-Zakowicz
Instytut Astronomiczny Uniwersytetu Wroclawskiego (Poland)

We report on the ground-based follow-up program of spectroscopic and photometric observations of stars selected for solar-like asteroseismic targets for Kepler. These stars constitute a large group of several thousand objects which are a subject of an intensive study of the KASC Working Group number 1 (WG-1).
We present results of a literature search for atmospheric parameters of these stars performed by the members of the WG-1, and we show that only a small fraction of the total number of our targets has ever been mentioned in the literature.
Then, we compare the information on the stars' atmospheric parameters collected from the literature, with the values of Teff, log g and [Fe/H] available from the Kepler Input Catalogue (KIC). We show that since the precision of the atmospheric parameters in the KIC is not sufficient for the asteroseismic purposes, we need a coordinated, long-term observing program that would allow to derive atmospheric parameters for all stars listed as 'Solar-Like Oscillators' by the KASC.
Finally, we discuss the internal and external precision of the atmospheric parameters derived by means of different methods for same star and from the same data, and then, discrepancies that occur in Teff and log g when these parameters are derived for the same star from spectroscopic and photometric observations. Since in some particular cases these discrepancies can be significant and their origin is not always clear, we emphasise the need of explaining the reason of that phenomenon.

OC.4.5.- Solar-like oscillations in low-luminosity red giants: First results from Kepler

Joris De Ridder
Instituut voor Sterrenkunde, K.U. Leuven (Belgium)

OC.4.6.- Detection of solar-like oscillations from Kepler photometry of the open cluster NGC 6819

Dennis Stello
University of Sidney (Australia)

A prime goal of asteroseismic investigation has since its dawn been the detection of solar-like oscillations in cluster stars. The assumption of a common age, distance, and chemical composition provides stringent constraints on each cluster member, which holds promise of significant improvements in the asteroseismic output. With the unprecedented photometric quality of the Kepler data our quest for this long standing holy grail has never been closer. In this talk we will present new unambiguous detection of solar-like oscillations in a large sample of open cluster stars observed by the Kepler space mission.

OC.4.7.- Discovery of a red giant with solar-like oscillations in an eclipsing binary system from Kepler Space-based Photometry

Saskia Hekker
University of Birmingham (UK)

Oscillating stars in binary systems are among the most interesting stellar laboratories, as these can provide information on the stellar parameters and stellar internal structures. Here we present a red giant with solar-like oscillations in an eclipsing binary observed with the NASA Kepler satellite. We compute stellar parameters of the red giant from spectra and the asteroseismic mass and radius from the oscillations. Although only one eclipse has been observed so far, we can already determine that the secondary is a main-sequence F star in an eccentric orbit with a semi-major axis larger than 0.5 AU and orbital period longer than 75 days.

OC.4.8.- Hybrid gamma Doradus - delta Scuti pulsators: New Insights into the physics of the oscillations from Kepler observations

Ahmed Grigahcene
Centro de Astrofisica, Universidade do Porto (Portugal)

We present stellar modeling results for three G-type stars observed by Kepler. The observations, made at one-minute cadence during the first 33.5d of science operations, reveal high signal-to-noise solar-like oscillation spectra in all three stars: about 20 modes of oscillation can be clearly distinguished in each star. We discuss inferences on the stellar properties obtained by comparing the characteristic spacings, individual frequencies and spectroscopic constraints with grids of stellar evolution models.

OC.4.9.- Ground-based follow-up in relation to Kepler Asteroseismic Investigation

Katrien Uytterhoeven
Service d'Astrophysique, IRFU/DSM/CEA Saclay (France)

The Kepler space mission, successfully launched in March 2009, is providing continuous, high-precision photometry of thousands of stars simultaneously. The uninterrupted time-series of stars of all known pulsation types are a precious source for asteroseismic studies. The Kepler data does not provide information on the physical parameters, such as T_{eff}, log g, metallicity, and v sin(i), which are crucial for successful asteroseismic modelling. Therefore, ground- based multi-colour photometry and mid/high-spectroscopy are needed to complement the space data. We will present ground-based activities on selected Kepler/KASC targets of several pulsation types, such as delta Sct, gamma Dor, beta Cep, solar-like, Be, and Slowly Pulsating B stars, Cepheids, and pulsating stars in clusters.

POSTERS

4.1.- Characteristics of 100+ Kepler Asteroseismic Targets from Ground-based Observations

J. Molenda-Zakowicz, M. Jerzykiewicz, A. Frasca, G. Catanzaro, G. Kopacki, D.W. Latham

We present results of our 5-years-long program of ground-based spectroscopic and photometric observations of Kepler asteroseismic targets.
For more than 100 stars for which we acquired high-resolution spectra, we determined the Teff, logg, [Fe/H], the projected velocity of rotation, and the radial velocity. We put these stars in the log Teff - log g diagram and discuss the derived atmospheric parameters by comparing them with the information available from the Kepler Input Catalogue.
For 19 stars from the Kepler field of view which lie in the distance ranging from 15 to 240 pc, we measured the interstellar reddening that we found to be negligible.
Then, we show the results of our time-series multicolour photometric observations of NGC 6866 which is one of the four open clusters in the Kepler field of view. In this cluster, we discovered three δSct and two γDor pulsators that are on the list of Kepler asteroseismic targets, as well as 14 other variables of different type.
Finally, we discuss the occurrence of γDor stars in the medium-age and old open clusters of different metallicity.

4.2.- Exploring the space of stellar parameters for KEPLER targets using CESAM2k+ LNAWENR/ROMOSC codes

Dumitru Pricopi, Marian Doru Suran

In order to extract the basic stellar parameters we use the asteroseismic inversion method where the observed oscillation frequencies are used to estimate the stellar parameters. The inversion shall be understood such that the best estimated parameters for a given star correspond to the model input parameters for the model that shows frequencies most similar to the observed ones. We have computed a wide grid of stellar models and their associated oscillation frequencies and we have designed a tool to evaluate the value of χ^2 on that grid for different possible sets of observational data. Preliminary results were been obtained for some observerd KEPLER targets.

4.3.- A pipeline for Solar like oscillation with Kepler

Pierre-Olivier Quirion, Jørgen Christensen-Dalsgaard

Many pipelines interested in transforming Kepler's light curves into information about large, small separation and the maximum power frequency have been developed. Parallel to these "data analysis pipelines" (DA pipeline), a series of "modeling pipelines" (M pipeline) have been crafted to make uses of the DA pipeline outputs to pin down stellar parameters.
We have developed SEEK, a M pipeline which is especially potent at expressing realistic error on stellar parameters of Solar like oscillators. SEEK is based and a fixed stellar grid and makes use of Bayesian statistics to to handle error analysis. Its quasi instantaneous output speed makes it a perfect tool to process large database. It can also be use to constrain an area of the stellar parameter space prior to the extended computation of a mode by mode asteroseismology analysis. SEEK also comes has a ready to use IDL GUI (Widget) which can be made available on demand.
I present here the main characteristic of SEEK and finally validate the approach by comparing its output with a list of solar like oscillator having known radius from interferometric measurements and/or known mass from binarity measurements.

4.4.- Constraining Convective Cores Using KEPLER Asteroseismic Data

Silva Aguirre, V., Ballot, J., Serenelli, A., Weiss, A.

The recently launched KEPLER mission offers an unprecedented opportunity to obtain frequency observations of main sequence stars in open clusters. Taking advantage of the common properties of these stars (same age and chemical composition), we can further constrain the physics involved in stellar modeling and gain new insight into mixing processes, such as the treatment of convection, overshooting and rotational mixing.
As it is long known, convective cores create discontinuities in the chemical profile of stars, which in turn translate into sharp variations in the adiabatic sound speed. These variations produce an oscillatory behaviour of the frequencies, to which low degree p-modes are sensitive. We investigate the possibility of detecting this signature of convective cores in the frequency spectrum of low mass stars by means of suitable frequency combinations (such as differences and ratios), and study the effects of applying different convective boundary determinations and mixing prescriptions in the core. With this purpose, we have constructed different sets of evolutionary models using a stellar evolution code (GARSTEC), coupled with an oscillation package (ADIPLS) for the computation of mode frequencies.

4.5.- Asteroseismology in open clusters observed by the Kepler space mission

D. Stello &KASC Working Group 2 (details to be determined)

A holy grail of asteroseismic investigation has since its dawn been the detection of solar-like oscillations in cluster stars. The assumption of a common age, distance, and chemical composition provides stringent constraints on each cluster member, which holds promise of significant improvements in the asteroseismic output. With the unprecedented photometric quality of the Kepler data our quest for this long standing holy grail has never been closer.
In this talk we will review previous attempts towards reaching this promising goal, and present new unambiguous detection of solar-like oscillations in a large sample of open cluster stars observed by the Kepler space mission.

4.6.- Ground-based observations of Kepler asteroseismic targets

K. Uytterhoeven, J. Molenda-Zakowicz, P. De Cat, H. Bruntt, M. Marconi, R. Szabo, J. Gutierrez-Soto, M. Briquet, et al.

The Kepler space mission, successfully launched in March 2009, is providing continuous, high-precision photometry of thousands of stars simultaneously. The uninterrupted time-series of stars of all known pulsation types are a precious source for asteroseismic studies. The Kepler data does not provide information on the physical parameters, such as T_{eff}, log g, metallicity, and v sin i, which are crucial for successful asteroseismic modeling. Therefore, ground-based multi-colour photometry and mid/high-spectroscopy are needed to complement the space data. In this poster we present ground-based activities on selected Kepler targets of several pulsation types, such as δSct, γ Dor, β Cep, solar-like, Be, and Slowly Pulsating B stars, Cepheids, and pulsating stars in clusters.

4.7.- KASC Working Group #1: first results for solar-type stars

W. Chaplin and the WG#1 Kepler Team.

In this poster, we present the first asteroseismic results from KASC Working Group #1, on three G-type stars. The observations, made at one-minute cadence during the first 33.5d of science operations, reveal high signal-to-noise solar-like oscillation spectra in all three stars: About 20 modes of oscillation may be clearly distinguished in each star. We discuss the appearance of the oscillations spectra, use the frequencies and frequency separations to provide first results on the radii, masses and ages of the stars.

SESSION 5:

Asteroseismology of red giants and hot subdwarfs

Chair: A. Baglin

IT.5.1.- Convection and Oscillations

G. Houdek
University of Vienna. (Austria)

I shall present an overview of the current state of mode physics in stars with solar-like oscillations and in classical pulsators. Particular emphasis will be on the properties of various time-dependent convection formulations and their effects on mode stability. Also, the role of the small-scale turbulence spectrum in modelling low-amplitude oscillation amplitudes will be addressed.

IT.5.2.- Seismic observations and interpretation for red-giant stars

S. Hekker (*), J. De Ridder, C. Barban, F. Baudin, F. Carrier, A.P. Hatzes, T. Kallinger, B. Mosser, W. W. Weiss.
University of Birmingham (UK)

Red-giant asteroseismology has benefited largely from the development of high-resolution spectrographs with long-term stability, e.g. HARPS spectrograph, and dedicated space missions, such as MOST, CoRoT and Kepler. Observations with these state-of-the-art instruments increased the number of red giants in which solar-like oscillations are observed, and the quality of these observations drastically and will continue to do so.

Initially the interpretation of the observed solar-like oscillations in red giants led to discussions about the nature and lifetimes of the observed modes, i.e., whether non-radial modes would be observable, and whether the oscillations would have a mode lifetime of the order of a few days or tens of days. Recent results from CoRoT observations have shown that non-radial modes are observable and that the mode lifetime can be of the order of tens of days.

The rapid development of red-giant asteroseismology over the last decade has provided some answers, but many open questions remain. These will be addressed with ongoing seismic observations and development of red-giant models.

OC.5.1.- Solar-like oscillations disclose the internal structure of the CoRoT red giant HR 7349

A. Miglio (*), F. Carrier, J. Montalban, T. Morel, P. Eggenberger, A. Noels, R. Scuflaire, F. D'Antona, P. Ventura et al.
(*) Universite de Liege (Belgium)

HR 7349 is a bright [V=5.8] red giant observed by CoRoT in the sismo field of the first long run. The analysis of the CoRoT lightcurve allowed us to detect nineteen solar-like oscillation modes (both radial and non-radial), revealing a regular echelle diagramme characterized by large and small frequency spacings.
We address the modelling of this most promising target taking into account all available observational constraints, and considering models in different evolutionary stages. In the observed oscillation frequencies we find clear evidence for the signature of a sharp feature in the envelope of the star, related to the second Helium ionization zone. HR 7349 represents the first star, other than the Sun, for which we have at our disposal a local probe of the physical conditions of the envelope: prospects of this detection will be discussed in detail.

OC.5.2.- Inference from adiabatic analysis of solar-like oscillations in red giants

J. Montalban et al.
Universite de Liege (Belgium)

The clear detection with CoRoT of radial and non-radial solar-like oscillations in many red giants paves the way to seismic inferences on the structure of such stars.
We present an overview of the properties of the adiabatic frequencies and frequency separations of radial and non-radial oscillation modes, highlighting how their detection allows a deeper insight into the properties of the internal structure of red giants. In our study we consider models of red giants in different evolutionary stages, as well as of different masses and chemical composition; the effects of other physical processes and uncertainties (such as rotation, treatment of convection) are also addressed. We describe how the large and small separations computed with radial modes, and with non-radial modes mostly trapped in the envelope, are related to the properties of the acoustic cavity and we investigate the diagnostic potential of the observed modes.

OC.5.3.- Frequency spacings of p modes in Red Giants observed by CoRoT.

C. Barban (*), F. Baudin, B. Mosser, K. Belkacem, M.J. Goupil, R. Samadi, S. Hekker, J. De Ridder, F. Carrier, A.P. Hatzes, T. Kallinger, W.W. Weiss, and the CoRoT Team.
(*) Observatoire de Paris, LESIA (France)

P modes observed in Red Giants are acoustic resonances similar to those observed in the Sun, stochastically excited by turbulent convection.
The high-quality and quasi-uninterrupted space data obtained by CoRoT allow us to make a big step forward in the study of such oscillations in Red Giants by increasing significantly the number of stars for which such oscillations can be detected.
We present here the data analysis of a sample of Red Giants observed during the first long Run of CoRoT (142 days). Detailed p-modes properties are estimated with a particular emphasis on the frequency spacings.

IT.5.3.- Structure and evolution of pulsating hot subdwarfs

Steven D. Kawaler
Iowa State University (USA)

Hot subdwarfs are stars that have survived the core helium flash and are now in (or recently finished with) the core helium burning stage. At the hot end of the Horizontal Branch, many of these stars are multiperiodic pulsators. These pulsations have revealed details of their global and internal structure. While many features of their structure deduced from seismic fits have confirmed what we expected from evolutionary considerations, there have been some surprises as well. In this talk, I'll review past progress, current issues, and speculate on what the future holds for the asteroseismic study of these stars.

IT.5.4.- Observational asteroseismology of pulsating hot subdwarf stars

R. Østensen
Katholieke Universiteit Leuven. (Belgium)

Hot subdwarf stars are particularly challenging for asteroseismology due to their rapid pulsation period, intrinsic low brightness and relative rareness. These features have ensured that the preferred method of observation up to now has been white light photometry, and all asteroseismological solutions to date have been made by model fitting of the frequency spectrum. Several attempts have been made to perform asteroseismology using time-resolved spectroscopy on the brightest of these stars, but with modest results. A few attempts at simultaneous multi-color photometry have also been made, in order to identify modes with the amplitude ratio method.
We will review the most recent observational results and progress in improving the observational methods for ground-based asteroseismology of these compact pulsators.

OC.5.4.- The sdB+giant planet system V391Peg: an updated overview

R. Silvotti (*), S. Schuh
(*) INAF-Osservatorio Astronomico di Torino. (Italy)

The number of planets orbiting post-RGB stars is rapidly increasing: after V391 Peg b, the first post-RGB planet detected from asteroseismic data using the timing method, new (circumbinary) planets have been detected around the (sdB+red dwarf) system HW Vir and the cataclysmic variable QS Vir.
The presence of planets around two sdB stars suggest that sdB planets could be a common phenomenon and substellar objects could play a role near the RGB tip, when a huge mass loss occurs to form an sdB star.
In this contribution we present the status of our knowledge on V391 Peg and discuss the potential of Corot and Kepler to search for planets with the timing method and to measure the secular variation of the pulsation periods.

POSTERS

5.1.- Evolution and internal structure of extended horizontal branch stars

Lisa Each, Pierre Demarque, Sarbani Basu

Extended Horizontal Branch (EHB) stars are observed in many globular clusters and as field stars in the Galactic halo. Their evolutionary status is unclear, and a subject of debate. Current interest in these stars arise from their association with the discoveries of helium abundance inhomogeneities in the globular clusters ω Cen and NGC 2808. The origin of the inhomogeneities is not yet understood.
In order to shed light on the internal structure and evolutionary status of EHB stars, we explore the evolution of standard blue HB models using up-to-date physics. We present a grid of post-ZAHB evolutionary tracks that cover the EHB. We follow the stars to the termination of the nuclear burning phases of helium and hydrogen shell burning and associated shell flashes. The detailed properties of the sequence of helium shell flashes are described. We compare our models to observations of EHB stars by the FUSE mission.

5.2.- Solar-like oscillations of bright red giants with the HERMES spectrograph

Paul Beck, Fabien Carrier, Conny Aerts

An extensive spectroscopic multi-site campaign on solar-like oscillations in bright red giant stars is planned for 2010. The main instrument for this campaign will be HERMES, the new high-resolution spectrograph at the 1.2m Mercator telescope on La Palma.
To test if we can achieve the desired precision of m/s for the velocity time series with this instrument, we will observe a solar-like oscillator in our observing run in October 2009. The poster will report on the observations, calibration as well as the results. This work represents the first asteroseismic observations of solar-like oscillations done with the HERMES spectrograph.
The poster will end with a call to the international community to participate in the campaign, outlining its goals and planning.

5.3.- A framework for facilitating the comparison between theory and observation of sub-giant

Yvonne Elsworth, William Chaplin, Saskia Hekker and Andrea Miglio

In this paper we explore the physical characteristics of stars that have evolved off the main sequence and consider what seismic signatures might be found in the observational data. One important consideration here is to ensure that theorists and observers speak the same language.

5.4.- Stellar oscillations in giant stars hosting planets

Marie Hrudkova, Artie Hatzes, Michaela Doellinger, Michael Hartmann

Recent radial velocity surveys have discovered more than 30 extrasolar planets orbiting giant stars. These discoveries are important because the host stars have masses that are larger than the Sun. However, the determination of the stellar mass of giant stars is difficult because the evolutionary tracks of main sequence stars covering a wide range of masses all converge to a small region of the HR diagram. Here we present new results from the analysis of observed stellar oscillations of planet hosting giant stars. The investigation of stellar oscillations for these objects offers us the possibility to derive an independent determination of the stellar mass which is important for extrasolar planet studies.

5.5.- Differential rotation of Arcturus: predictions from theory

Manfred Kueker, Guenther Ruediger

Arcturus is a giant star of spectral type K2 with a rotation period of two years. This type of star is fully convective save a core with three percent of the total stellar radius. We model the internal rotation and meridional flow of the star using the mean-field theory of hydrodynamics and find strong radial shear at the lower boundary of the convective region. This would not only be a very strong generator of toroidal magnetic fields but also subject to hydrodynamic instability, which in turn would cause non-axisymmetric flows.

5.6.- Model-independent determination of sharp features inside a star from its oscillation frequencies

Anwesh Mazumdar, Eric Michel

It has been established earlier that sharp features like the base of the convective zone or the second helium ionisation zone inside a star give rise to sinusoidal oscillations in the frequencies of pulsation. The acoustic depth of such features can be estimated from this oscillatory signal in the frequencies. We apply this technique for the CoRoT frequencies of the solar-type star HD49933. This is the first time that such analysis has been done of seismic data for any star other than the Sun. We are able to determine the acoustic depth of the base of the convective zone of HD49933 within 10% error from the second differences of the frequencies. The acoustic depth of the HeII ionisation zone can also be determined, but with a larger error. The locations of these layers using this technique is in agreement with the current seismic models of HD49933.

5.7.- Population study of red-clump giants in the CoRoT exo-field

Miglio, A., Morel, T., Carrier, F., Montalban, J., Eggenberger, P., Valentini, M., Noels, A. et al.

The detection of solar-like oscillations in populations of red giants with CoRoT allows us to access the properties of so far poorly-constrained distant stars in the galactic disk.
The asteroseismic identification of a large number of red-clump stars in the disk, when combined with additional photometric constraints, allows us to estimate for the first time the distance of hundreds of stars in the population, provided that metallicity/age effects on the absolute red-clump magnitude are taken into account.
In this work we present the distance distribution of red-clump stars identified in the first CoRoT long run, and describe the relevance of CoRoT observations in the wider context of studies on the galactic structure and evolution.

5.8.- Red Supergiant Stars in the LMC: Variability and Period-Luminosity Relation

Ming Yang and B.W. Jiang

We study the varibility and period-luminosity relation for red supergiant stars from published papers by using the latest optical and infrared survey data. The typical time span of optical data is larger than 3000 days from the All Sky Automated Survey and the MAssive Compact Halo Objects project. Infrared data are come from the Two Micron All Sky Survey and *Spitzer*/SAGE Legacy Program. We use the color-magnitude diagram and two-color diagram to identify all the candidates and determine periods by using the phase dispersion minimization method, Fourier analysis and Wavelet analysis. About half of our available targets are in irregular phase of variability which indicate the dominated effect by the convection in this evolutionary phase. About one fifth of available targets are semi-regulars and the reset is long secondary variable stars. We derived a slightly loose relation from the semi-regulars in K-band and more strict tendency is obvious in longer wavelengths which suggest that the large number of RSGs is needed for deriving the relation and the best wavelength apply for it is larger than 3 μm and less than 5 μm. The long secondary variable stars do not have any linear relations by themselves or combine with semi-regulars.

5.9.- Red giant populations analyzed with CoRoT

B. Mosser, C. Barban, F. Baudin, K. Belkacem, M.-J. Goupil, S. Hekker, A. Miglio, T. Morel, R. Samadi, J. De Ridder

We have performed a massive analysis of about 2000 red giants observed with CoRoT in the direction of the Galactic center and in the opposite direction. With the Envelope AutoCorrelation Function, we have determined the parameters describing the solar-like oscillation spectra of these giants. This allows us to examine in detail the scaling laws between the frequencies characterizing the spectra (large separation, maximum amplitude frequency, mode envelope) in an unbiased data set with large separations as low as 0.7 μHz. We also measure the fundamental parameters of the stars in the red clump, test the influence of metallicity and compare the results with synthetic populations.

5.10.- 210 day CoRoT observations of red giants

S. Hekker, J. De Ridder, C. Barban, F. Baudin, F. Carrier, A.P. Hatzes, T. Kallinger, B. Mosser, W. W. Weiss

We investigate red-giant candidates which are observed during the initial run (60 days) and the first long run in the anti-centre direction (150 days) of CoRoT. We combine these data sets to compute Fourier spectra with higher frequency resolution compared to data from single runs. This increased frequency resolution will allow us to resolve solar-like oscillation modes with longer lifetimes (> 50 days).

We show results of the analysis of the Fourier spectra and an interpretation of the frequency patterns and mode life times with respect to their position in a colour-magnitude diagram. These results are then compared with theoretical predictions.

SESSION 6:

Asteroseismology in stars at the instability strip

Chairs: M. P. di Mauro

IT.6.1.- Interpretation of asteroseismic data in stars at the low classical instability strip

E. Michel
Observatoire de Paris – LESIA. (France)

The low classical instability strip crosses the Main Sequence in the domain of A and F stars. This domain is known for the large variety of stars showing specific characteristics in terms of chemical surface compositions, pulsational behaviours, magnetic fields, rotation rates. Stellar seismology has long been seen as a very appropriate tool for improving our understanding of stars in this domain and disentangle the respective role on their structure and evolution of physical processes like fast rotation, chemical diffusion, magnetic field. The recent advent of space observations, with MOST, CoRoT and now Kepler, is shedding a new light on this problem. We will try here to illustrate this new vision with a selection of such new data and interpretation works.

I.T. 6.2.- Oscillations in rapidly rotating stars

Daniel Reese
LESIA. (France)

Spurred by the observations of rapidly rotating stars, theoreticians have spent many years developing models for these stars and studying their pulsation modes. This has led to the discovery of new classes of pulsation modes and new phenomena. The space-based observations by CoRoT and Kepler are yielding data with unprecedented accuracy, which present both a challenge to the theory and a unique opportunity to further develop it. In this talk, I will review the different types of pulsation modes in rapidly rotating stars and the historical development of various methods used to study them.

OC.6.1.- Magnetoacoustic waves in the atmosphere of roAp stars – A theoretical interpretation

Joana Sousa (*); Margarida Cunha; Oleg Kochukhov
Centro de Astrofisica da Universidade do Porto (Portugal)

Studies based on high-resolution spectroscopic observations of rapidly oscillating Ap (roAp) stars show a surprising diversity in the pulsation behaviour derived from different lines in there spectra. In general, this studies show that roAp stars exhibit, in there atmospheric layers, a combination of running and standing waves. Here we present the results of theoretical model with the purpose of understanding the general trends seen in the atmospheric pulsation data acquired with high-resolution spectroscopy. We concentrate in the region of the star where the magnetic pressure is much larger than the gas pressure, the outer atmospheric region, and take the velocity field at the base of this region from the code Magnetic perturbations to pulsations in Ap stars (MAPPA-Cunha(2006)). Starting from the equations for the displacement parallel and perpendicular to the direction of the magnetic field and using the analytical solutions for the velocity components appropriate to the outermost layer, where the atmosphere can be considered isothermal, we determine the expression for the velocity component parallel to the line of sight averaged over the visible stellar disk, for a general position of the observer. Then we derive the wave amplitude and phase as function of height in the atmosphere and compare to the general trends of the phase and amplitude derived from the spectroscopic data. Such comparison allows as to link the observed behaviour to the physical and geometric quantities that are involved in the problem.

OC.6.2.- Theoretical study of gamma Doradus pulsations in pre-main sequence stars

M.-P. Bouabid (*), J. Montalbán, A. Miglio, M.-A. Dupret, A. Grigahcène, A. *Noels.*
(*) Université de Liège (Belgium)

γDoradus (gamma Dor) are F-type stars pulsating with high order g-modes. The question of the existence of pre-main sequence (PMS) γ Dor has recently been raised by COROT and MOST observations of the young cluster NGC 2264 hosting potential γDor members, and by the observation of the planets host star HR 8799 showing γ Dor pulsations and a dust disk.
We have explored the possibility of g-modes pulsations in a grid of PMS models covering the mass range 1.2 $M_o < M_* < 2.5$ M_o.
We obtain a clear instability strip for the PMS γ Dor stars. We compare the properties of γ Dor pulsations in PMS and main sequence evolutionary phases. We analyse their internal structures, their excited frequency ranges and the behaviour of their period-spacings.

OC.6.3.- Pulsational content and abundance analysis of COROT Delta Scuti stars

E. Poretti (*), L. Mantegazza, E. Michel, E. Niemczura et al.
(*) INAF-OA Brera. (Italy)

The CoRoT mission is giving a strong acceleration in the number of the frequencies detected in the light curves of Delta Sct stars. For instance, the analysis of the data obtained on HD 50844 (V=9.1, observed during 58 d) shows us that we need several hundreds of excited modes to explain the very dense power spectrum. This result has been followed by others on Delta Sct stars observed continuously for 150 d. We will emphasize the cases of very fast rotators (v sin i > 150 km s^{-1}) and of Delta Sct stars in binary systems. For the bright targets (V<9) of the CoRoT asteroseismic programme we will also compare the photometric results with the spectroscopic ones (observations performed with FEROS and HARPS instruments). This comparison greatly helps in the mode identification and in the verification of the effectiveness of the cancellation effects in the high ℓ-degree modes. On the basis of the spectroscopic observations we obtained the atmospheric parameters, chemical abundances of elements, and rotation velocities of about 20 Delta Scuti stars. The atmospheric parameters (effective temperature, surface gravity, microturbulence velocity) were determined by using both spectroscopic methods (including metal lines and Balmer profiles) and Stromgren photometric indices.

OC.6.4.- Magneto-acoustic pulsations in atmospheres of roAp stars:

E. Khomenko (*), O. Kochukhov
(*) Instituto de Astrofísica de Canarias (Spain)

Rapidly oscillating Ap stars exhibit an astrophysical interesting combination of strong, dipolar-like magnetic fields and high-overtone p-mode pulsations similar to the Sun. To understand the pulsations of these magnetic stars, we have carried out 2-D time-dependent, non-linear magneto-hydrodynamical simulations of waves for a realistic atmospheric stratification of a cool Ap star. We explore a grid of simulations in a wide parameter space, treating oscillations of the velocity, magnetic field and thermodynamic quantities in a self-consistent manner. In this contribution, we report a detailed study of the influence of the atmosphere and the magnetic field on the propagation and reflection properties of different magneto-acoustic modes, formation of node surfaces, and relative variation of different quantities. We show how these properties depend on the relative location of three important layers: cut-off layer, mode transformation layer and the density inversion layer at the photospheric base. Our simulations reproduce all main features of the observed pulsational behaviour of roAp stars.

OC.6.5.- Frequency statistics of rapidly rotating star p-mode spectrum

Lignières, F. [(*)]*, Georgeot, B.*
(*) Observatoire Midi-Pyrénées. (France)

A possible way to analyze the rich spectra of δScuti stars observed by Corot is to consider their statistical properties. These properties can then be compared with model predictions. Here, we model the distribution of consecutive frequency spacings (scaled by the mean frequency spacing) in the framework of a p-modes asymptotic theory for rapidly rotating stars (F. Lignières & B. Georgeot 2009). According to this theory based on ray dynamics, the acoustic spectrum of rapidly rotating stars is a superposition of frequency subsets associated with dynamically independent regions of the ray dynamics phase space. The consecutive frequency distribution thus results from the superposition of statistically independent frequency distributions and is close to Poisson. This is in stark contrast with the consecutive frequency distribution of non-rotating or slowly rotating stars (as confirmed by solar data). Implications for the seismology of rapildy rotating stars will be discussed.

POSTERS

6.1.- Is Vega a pulsating star?

Torsten Böhm & Francois Lignières

We obtained continous sequences of very high S/N echelle spectra of Vega in order to detect for the first time stellar pulsations in this star. Such a detection would lead to the discovery of a new type of pulsating stars as Vega, according to its position in the HR diagram, does not belong to any known class of pulsating stars. Adding seismology constraints to the many observational constraints available for this star would convert Vega as a prototype to study the effects of fast rotation on stellar structure theory. In this talk we present the progress of our ongoing work.

6.2.- Influence of rotation on the pulsations of Gamma Doradus stars

M.-P. Bouabid, M.-A. Dupret, A. Grigahcène

γDoradus (γDor) are F-type stars pulsating with high order g-modes. Their rotation and pulsation frequencies are often of the same order. Hence, rotation is expected to affect significantly the characteristics of pulsations.

Adopting the so-called traditional approximation of rotation to treat the Coriolis force, we explore the influence of rotation over the stability of γ Dor stellar models covering the mass range 1.2 M_o < M < 2.5 M_o.

We investigate the effects of rotation on the pulsation parameters of γ Dor stars : period spacings, range of excited modes, theoretical instability strips.

6.3.- STEPHI: Pulsating stars and binary systems in the cluster NGC1817

O.L.Creevey, L. Fox Machado, J.A.Belmonte, J. Fu, E. Michel, M. Alvarez

We present preliminary observational results of the multi-site STEPHI campaign on the cluster NGC 1817. The three observatories involved are San Pedro Mártir (Mexico), Xing Long (China) and the Observatorio del Teide (Spain) — giving an ideal combination to maximise the duty cycle. The cluster has 12 known delta Scuti stars and at least two detached eclipsing binary systems. This combination of characteristics is ideal for extracting information about global parameters of the targets, which will in turn impose strict constraints on the stellar models. This then allows us to use the observed pulsation frequencies to learn about the physical interior of the pulsating stars.

6.4.- HD 207331 a new Delta Scuti star in the Cygnus field: discovery and follow up observations

L. Fox Machado, W.J. Schuster, C. Zurita, J.S. Silva

While testing a Strömgren spectrophotometer attached to the 1.5-m telescope at the San Pedro Mártir observatory, Mexico, a number of A-type stars were observed, one of which, HD 207331, presented clear indications of photometric variability. CCD photometric data acquired soon after, confirmed its variability. uvby differential photoelectric photometry was carried out for three nights in 2008 November. As a result of the period analysis of the light curves we have found a dominant pulsation mode at 21.1 cd^{-1} with an amplitude of 6 mmag. In order to determine its pulsation behaviour more accurately, follow up CCD observations were carried out from 2009 August 26 to 2009 September 1 from two observatories distributed in longitude: Observatorio del Teide (0.80-m telescope IAC80) and Observatorio San Pedro Mártir (0.84-m telescope). A summary of these observations, which suggest that HD 207331 is a new multi-periodic Delta Scuti-type pulsating star, will be given in the present contribution.

6.5.- The Taiwan Automated Telescope Network Project and the Preliminary Result of HD 163032

Javier Fernández Fernández, Dean-Yi Chou, Ming-Tung Sun, Li-Han Wang, Antonio Jiménez, Alexander Serebryanskiy, Shuhrat Ehgamberdiev

The Taiwan Automated Telescope (TAT) Network is a global network of small robotic telescopes dedicated to photometric measurements of stellar pulsations. Several telescopes will be deployed in appropriate longitudes to continuously observe selected objects. Two telescopes have been installed in the Teide Observatory, Tenerife, Spain and in Maidanak Observatory, Uzbekistan. The third telescope will be installed at Mauna Loa Observatory, Hawaii, USA. Each system uses a 9-cm Maksutov-type telescope with a 16-bit 1024 x 1024 CCD camera. The field of view is 0.62 degree square. Each telescope is fully automated. The system can either run fully automatically with preset parameters or be remotely controlled from the headquarter, located at National Tsing Hua University, Taiwan. Here we report the preliminary result of a new variable star, HD 163032. The frequencies and amplitudes of pulsations together with its position on the HR diagram suggest that HD 163032 is a δScuti.

6.6.- Asteroseismic study of gamma Doradus members of the cluster NGC 2506

A. Grigahcène, A. Moya and J. -C. Suarez

Observation of NGC 2506 imposes strong external constraints on the models of its stellar population. The existence of stellar pulsators, in particular γ Doradus (Dor) oscillators among its members makes it an excellent laboratory for asteroseismic studies.

We use the latest developed theoretical and computational tools: Frequency Ratio Method (FRM) and Time Dependent Convection (TDC). These are specially adapted to analyse this type of pulsating stars. In particular the use of both techniques gives us the opportunity to construct a self-consistent interpretation procedure, allowing modes identification and improved modelling of the γ Dor members of the cluster.

6.7.- Are the observed intermediate g modes in the CoRoT hybrid Gamma Doradus Delta Scuti HD49434 star stochastically excited ?

A. Grigahcène, T. L. Campante, J. C. Suarez and M. J. Monteiro

Time Dependent Convection models predict a range in frequency that is stable to pulsations, between the simultaneously excited high-order g modes (γ Doradus) and low-order p and g modes (δ Scuti).

On the other hand theoretical studies (Samadi et al. 2002) find that in those models, stochastically excited modes are likely to be observed.

The primary target in the seismo-field of CoRoT, HD49434, shows excited intermediate order modes. Are those modes stochastically excited confirming some theoretical studies and contradicting others?

Using the statistical method described in Pereira et al. (2007), which searches for signatures of stochastic excitation in stellar pulsations, we investigate the nature of those modes with possible implications on the identification of their excitation mechanism.

6.8.- Rapidly oscillating Ap stars in the H-R diagram

O. Kochukhov

Investigation of the evolutionary state of rapidly oscillating Ap (roAp) stars and comparison of their properties with non-oscillating Ap (noAp) stars provides an ultimate test of the theories of excitation of magneto-acoustic oscillations. We undertake a comprehensive study of nearly 200 roAp and noAp stars, comparing predictions of stellar structure models with the fundamental stellar parameters established with the help of new photometric temperature calibrations and improved Hipparcos parallaxes. We define precise boundaries of the observational roAp instability strip and characterize the difference in the physical properties of pulsating and constant Ap stars. This information allows us to critically evaluate predictions of different theoretical stability calculations and identify directions where theory requires improvement.

6.9.- Towards pulsation mode identification in 3-D: theoretical simulations of line profile variations in roAp stars

O. Kochukhov, E. Khomenko

Time-resolved spectroscopic observations of rapidly oscillating Ap (roAp) stars show a complex picture of propagating magneto-acoustic pulsation waves, with amplitude and phase strongly changing as a function of atmospheric height. We have recently conducted numerical, non-linear MHD simulations to get an insight into the complex atmospheric dynamics of magnetic pulsators. Here we use the resulting time-dependent atmospheric structure and velocity field to predict line profile variations for roAp stars. These calculations use realistic atmospheric structure, account for vertical chemical stratification and treat line formation in pulsating stellar atmosphere without relying on the simplistic single-layer approximation universally adopted for non-radial pulsators. The new theoretical calculations promise to provide necessary tool to interpret the puzzling complexity of the spectroscopic pulsations in roAp stars.

6.10.- Reconstruction of nonradial pulsation patterns in eclipsing binaries

Barna Imre Bíró, Olivera Latković

Eclipsing binaries containing non-radially pulsating stars are doubly advantageous targets for astroseismologic studies: not only can we determine the absolute stellar parameters of the pair with high precision – we can also use the phenomenon of the eclipse to gain more information about the pulsation modes.

Eclipse Mapping (EM), a tomographic method, can be used to reconstruct the surface intensity patterns of the pulsations even for modes that are rotationally distorted, provided that the direction of the rotation axis is known a priori. Another approach, the direct fitting of spherical harmonics (DF), can simultaneously identify undistorted pulsation modes and the direction of the rotation axis.

Since most pulsators found in binaries are of delta Scuti type and many of their single counterparts rotate rapidly, and since in detached systems, the rotation axis may not be perpendicular to the orbit, a mixed scenario with both an inclined axis and distorted pulsations can be expected in many binaries. Neither EM, nor DF can cope with such cases independently, but using a combination of both methods leads to successful reconstruction and identification of the pulsation modes. We demonstrate the capabilities and limitations of this combined mode identification method.

6.11.- Modelling Delta Scuti stars using asteroseismic space data

A. Moya, A. García-Hernandez, C. Rodríguez-López, J.C. Suárez, R. Garrido

In the last years, space missions such as COROT, Kepler or MOST have been providing us with very accurate photometric observational data. In the particular case of δScuti stars, the observed frequency spectra have hundreds (if not thousands) of modes and a clear amplitude distribution. In this work we present new techniques for modelling these observations and the results obtained.
We first answer if a δ Scuti star is stable despite all of the observed frequencies are simultaneously excited. Then, a search for regular patterns in the observational data yields something resembling the large separation. This allows us to reduce the possible positions of the star in the HR diagram, which yields a value of the mean density with an accuracy never reached before for isolated stars of this type.

6.12.- The planetary system host HR 8799: On its Lambda Bootis nature and age

A. Moya

HR 8799 is a λ Bootis, γ Doradus star hosting a planetary system and a debris disk with two rings. This makes this system a very interesting target for asteroseismic studies. In particular, this work is devoted to the determination of the internal metallicity of this star, linked with its λ Bootis nature, and its age, taking the advantage of its γ Doradus pulsations. This is the most accurate way we have to obtain this information, and this is the first time such a study is done for such a system. To do so we have used the equilibrium code CESAM and the non-adiabatic pulsational code GraCo. We have applied the Frequency Ratio Method and the Time Dependent Convection theory to estimate the mode identification, the Brunt-Vaïsälä frequency integral and the mode instability, making the selection of the possible models. When the non-seismological constraints are used, the solar metallicity models are discarded. This result contradicts one of the main assumptions of the best hypothesis for explaining the λ Bootis nature, the accretion/diffusion of gas from a star with solar metallicity. Therefore, in sight of these new results, a revision of this hypothesis is needed, if not the proposition of a completely new one. The inclusion of accurate internal chemical mixing is necessary. The use of the asteroseismological constraints provides a very accurate determination of the physical characteristics of HR 8799, depending on the visual angle i. The determination of this angle and more accurate multicolor photometric observations can definitively fix the mass, metallicity and age of this star. In particular, an accurate age estimation is needed for a correct understanding of the planetary system. In our study we have found that the age used for modelling the system is unlike.

6.13.- Effect of stellar rotation on oscillation frequencies on massive and main sequence stars

R-M. Ouazzani, M-J. Goupil, M-A. Dupret

We present and discuss results of a recently developped two dimensional non-perturbative method to compute accurate oscillation modes of rapidly rotating stars.
The 2D calculations fully take into account the centrifugal distorsion of the star while the non perturbative method includes the full influence of the Coriolis acceleration. These characteristics give access to the computation of oscillation modes of rapid rotators - from high order p-modes in main sequence stars, to low order p- and g-modes in βCephei stars.
We compare the oscillation spectra obtained for centrifugally distorted polytropes with those of Reese et al. (2006), and give the first results for realistic models of stars such as the well studied βCephei θ Ophiuci and some main sequence stars observed by the CoRoT mission.

6.14.- The OGLE-III Catalog of Variable Stars. Delta Scuti stars in LMC

Radoslaw Poleski

The third phase of the Optical Gravitational Lensing Experiment (OGLE-III) collected data spanning 8 years with the 1.3 m Warsaw telescope at Las Campanas Observatory, Chile. The final OGLE-III data base of over 10^{11} photometric measurements gives opportunity to find hundreds of thousands of variable stars. This contribution presents results of our search for delta Scuti stars in the Large Magellanic Cloud. Almost 3000 new variables of this type were discovered. Around 70 stars pulsating simultaneously in the fundamental mode and the first overtone were found as well as 20 other double- or multimode pulsators.

6.15.- Spectroscopic monitoring of roAp star 33 Lib

M.Sachkov, T.Ryabchikova, O.Kochukhov

We present results of the analysis of spectroscopic time-series observations of the roAp star 33 Lib. Observations were carried out with the ESPADONS and FIES high resolution echelle spectrographs, which were carried out simultaneously with the MOST photometry. All these data were analysed for radial velocity (RV). This star differs in a pulsation behaviour from other roAp stars. Frequency analysis of the spectroscopic data shows that the highest amplitude frequency is the same in photometry and spectroscopy, while others can be seen only in the frequency spectra of RV of some REE lines. Photometric and spectroscopic pulsation curves are shifted in phase, and the phase shift depends on the atomic species. This clear difference in photometric and RV pulsational behaviour suggests the change in the pulsation characteristics with the height in the atmosphere of 33 Lib.

6.16.- The diversity of light curve variations of Blazhko stars

Adam Sodor

Within the framework of the Konkoly Blazhko survey, during the past 6 years, more than one dozen Blazhko stars have been extensively observed. This relatively great number of the uniquely extended multicolour data sets allow detailed study of the light curve variations during the Blazhko cycle. Our studies show that the Blazhko effect manifests itself in many different ways. The diversity of light curve variations of Blazhko stars, the appearance of the modulation in the Fourier parameters of the pulsation light curve is presented.

6.17.- The pulsational variability of the CoRoT gamma Doradus candidate HD171834

K. Uytterhoeven, P. Mathias, M. Rainer, E. Poretti, P. Amado, L. Mantegazza, K. Pollard, J.C. Suarez, P.M. Kilmartin

Gamma Doradus stars are very interesting from an asteroseismic point of view. Since they show g-mode pulsations, it allows us to probe the deep stellar interior. Since the g-modes are associated to periods of the order of a day (0.4--3 days), it is observationally a challenging task to obtain a good phase coverage. Consequently, uninterrupted time-series from space are providing new opportunities and promise a revolution in the study of gamma Dor stars. The star HD171834 is one of the two candidate gamma Dor stars in the asteroseismic core program of the CoRoT satellite mission, and has been observed for 149 days in 2008. We present preliminary results on the analysis of the CoRoT lightcurve and spectroscopic ground-based time-series, consisting of more than 1300 spectra, obtained in the framework of a multi-site campaign. From the ground, periods of 2 hours to 1 day are detected for this fast rotator (vsini ~ 70 km/s).

6.18.- γDor and γDor - δScuti Hybrid Stars In The CoRoT LRa01

M. Hareter, A. Miglio, J. Montalban, P.Reegen, A.Kaiser, I. Dekany, E. Poretti & The GammaDor Thematic Team

A systematic search for gDor and gDor - dSct hybrid pulsators was conducted on the CoRoT LRa01 Exo-archive leading a total of 419 ggDor and 274 gDor - dSct hybrid candidates. 194 and 165 respectively, of these candidates show no severe residual artifacts after our data reduction pipeline and were investigated in more detail. For about 25% of these candidates AAO classification spectra are available.
A detailed analysis of the lightcurves, including a check for combination frequencies, together with spectroscopic stellar classification allowed us to identify:
I) 34 gDor stars, which show very different pulsation spectra where mostly two modes dominate. Furthermore, a search for regularity in their oscillation spectra allowed to derive a period spacing for 5 of these gdoradus;
II) 25 clear hybrid pulsators showing frequencies in the gDor and dSct domain and A-F spectral type.

6.19.- Gravity modes in rapid rotating stars

J. Ballot, F. Ligniéres, D. Reese & M. Rieutord

Using the Two-dimensional Oscillation Program (TOP), we have explored the effects of rapid rotation on gravity modes in polytropic stars. Coriolis force, centrifugal distortion as well as compressible effects have been taken into account. Thanks to our complete calculation, we have first studied the validity domain of perturbative methods and started to explore properties of these modes.

SESSION 7:

Asteroseismology of hot stars

Chair: C. Aerts

IT.7.1.- Seismic observations and tools for hot stars

Coralie Neiner
GEPI, Observatoire de Paris-Meudon. (France)

Thanks to the advent of very successful asteroseismic space missions such as MOST, CoRoT or Kepler, important observational results have been obtained regarding the pulsations and periodic variations of hot stars. Using modelling and semi-analytical calculations, these observations allow to infer information about the internal structure of hot stars, their mixing processes, the excitation of pulsations, and even the mechanism of outbursts in the case of Be stars.
In this talk I will review the main results obtained with the asteroseismic space missions and associated ground-based observations on hot stars, as well as the tools used to extract pulsational information from the data and infer structure information.

OC.7.1.- Complex asteroseismology of the hybrid B-type pulsator Gamma Pegasi: a test of stellar opacities

Jadwiga Daszynska-Daszkiewicz, Przemyslaw Walczak(*)
(*) Instytut Astronomiczny Uniwersytetu Wroclawskiego (Poland)

γPegasi is one of a few early B-type pulsators exhibiting simultaneously low order pressure/mixed modes, typical for β Cep variables, and high order gravity modes, typical for SPB stars. The analysis of MOST observations, supported by ground based photometry and spectroscopy, revealed 8 frequencies typical for the β Cep stars and 6 peaks in the SPB frequency domain (Handler et al. 2009, ApJ 698, L56, Handler, 2009, MNRAS 398, 1339).
Such stars, called hybrid pulsators, are of special interest for asteroseismic studies because of a wide frequency range and very different character of p and g modes.
In this talk, we present mode identification for all 14 frequencies and results of complex seismic modelling of γPegasi. This modelling consists in parallel fitting of pulsational frequencies and corresponding values of the complex, nonadiabatic parameter f, defined by the radiative flux variation at the photosphere level (Daszynska-Daszkiewicz & Walczak 2009, MNRAS 398, 1961).
The concordance of the empirical and theoretical values of f obtained both for low order p and high order g modes is of special importance because a dependence of the f-parameter on the mode frequency and degree, ℓ, is very different for these two types of modes.
Complex asteroseismology of B-type hybrid pulsators provides a more plausible test of stellar parameters, atmospheres and opacities.

OC.7.2.- Modelling Results for Two Late Be Stars Observed by CoRoT

C.C. Lovekin (*), C. Neiner, H. Saio, S. Mathis & J. Gutierrez-Soto
(*) Observatoire de Paris, LESIA (France)

The Be stars HD181231(B5IVe) and HD175869 (B8IIIe) have recently been observed using the CoRoT satellite for ~ 5 months and ~ 27 days respectively. This continuous, space-based observation has allowed the detection of many low amplitude modes in these stars. In the case of HD181231, the combination of the CoRoT data and ground based spectroscopic follow-up data have placed tight constraints on the fundamental and pulsational properties of this star, allowing for detailed seismic modelling.

For HD175869, the variability has been proposed to be the result of inhomogeneities produced by stellar activity, located in or just above the photosphere. However, the CoRoT data does not allow non-radial pulsations to be excluded as the origin of the variability. Seismic modelling of this star will clarify this issue.

We have compared the observed frequencies to those calculated using 2D stellar evolution and a 2D linear adiabatic pulsation code. We will also discuss compare our results to frequencies calculated using a 1D non-adiabatic pulsation code. Using a combination of frequencies, we have been able to constrain the rotation and extra mixing for stars of a known mass and age. Here we extend this method to determine the best fitting mass, age, rotation rate and amount of extra mixing for these Be stars.

OC.7.3.- Observations of B stars from CoRoT's asteroseismology programme

P. Degroote et al.
Instituut voor Sterrenkunde (Belgium)

The CoRoT satellite is revolutionizing photometric observations of B stars. During its long runs, CoRoT observed the entire main sequence B star regime, from typical hot Beta Cephei stars, via cooler hybrid p- and g-mode pulsators to the SPB stars near the edge of the instability strip. Past the main sequence, also a B supergiant has been intensively measured. CoRoT lowers the sensitivity barrier from the typical mmag-precision reached from the ground, to the μmag-level reached from space. Within the wealth of detected and identified pulsation modes, relations have been found in the form of multiplets, combination frequencies, and frequency- and period spacings. This will allow to put strong constraints on stellar evolution models. Aside from the expected opacity driven modes with infinite lifetime, other unexpected types of variability are detected in B stars, such as modes of stochastic nature. The simultaneous observation of all these light-curve characteristics imply a challenge for both observational asteroseismology and stellar modelling.

OC.7.4.- Is the macroturbulent broadening present in OB Supergiants related with pulsations?

S. Simón-Díaz (*), A. Herrero, K. Uyterhoeven, N. Castro, C. Aerts, & J. Puls
(*) Instituto de Astrofísica de Canarias. (Spain)

Several works have recently shown that there is an important extra line-broadening (usually called macroturbulence) affecting the spectra of O and B Supergiants that adds to stellar rotation. So far, the only (very recent) physical explanation for the appearance of this extra line-broadening relates to oscillations. This is a plausible explanation, but no direct evidence confirming its validity has been presented yet. We recently started an observational project to obtain constraints on the time-scales of variability associated to this extra line-broadening and its possible origin. Our observational strategy consists of the study of a well selected group of O and B stars, for which we obtain time series of high-quality spectra. In this talk, we will present some results from our first observational campaigns.

OC.7.5.- On the use of rototational splitting asymmetries to probe the internal rotation profile of stars. Application to Beta Cephi stars.

J.C. Suárez [(*)]*, M.J. Goupil, L. Andrade*
(*) Instituto de Astrofísica de Andalucia. (Spain)

The knowledge of the internal rotation profile of stars is one of the key, yet unsolved, problems of the Stellar Physics. Thanks to Helioseismology, it is possible to invert the rotation profile of about 70% deep into the Sun. This provides a significant amount of information about both the seismic behaviour and the structure of the star. We present here the basis of a new method, currently under development, based on the use of the asymmetries of rotationally-split modes, as a constraint to the rotation profile, and thus, to the representative models of the studied star. As a practical case, we present the results of some test performed on the β Cephei star θ Ophiuchi.

OC.7.6.- Photometric study of two beta Cephei pulsators in eclipsing systems

D. Drobek (*), A. Pigulski, G. Kopacki, R. Shobbrook, A. Narwid
(*) Instytut Astronomiczny Uniwersytetu Wroclawskiego. (Poland)

We present the results of UBV photometric study of the young southern open cluster Stock 14. This cluster is known to contain two eclipsing systems with beta Cephei components, HD 101794 and HD 101838. This gives us an opportunity to derive masses and radii of those pulsating stars. We also announce the discovery of other variable stars found in the observed field.

OC.7.7.- Ensemble asteroseismology of pulsators in the young open clusters NGC 884 and NGC 6910 from a three-year campaign

S.Saesen, A.Pigulski(*) et al.
(*) Instytut Astronomiczny Uniwersytetu Wroclawskiego. (Poland)

We present the results of an extensive multisite campaign conducted for the two young open clusters NGC 884 and NGC 6910 by an international team consisting of 61 observers who operated 15 different instruments attached to 13 telescopes. The campaign covers three seasons, 2005-2007. More than 70,000 CCD frames were collected for each of the clusters, as well as absolute photometry and some high-resolution spectroscopy. Besides the few pulsators which were already known in the clusters prior to our campaign, we report the discovery of hundreds of new variable stars. In particular, we found tens of multiperiodic pulsating B stars in each of the clusters. We present the oscillation frequencies of the pulsators and identify the modes from the amplitude ratio method. We highlight the importance of these two unique datasets covering stars of the same age and metallicity, for seismic tuning of stellar structure and evolution models of massive stars.

POSTERS

7.1.- Asteroseismology of the Herbig Ae star HD104237

A. Fumel, T. Böhm

Understanding the internal structure of pulsating Herbig Ae stars by the aim of an asteroseismological study will help to constrain the origin of the tremendous activity, winds and variability observed in this group of pre-main sequence stars.

The time analysis of the LSD profiles of HD104237 has revealed non-radial pulsations of low-degree. We present the mode identification corresponding to the detected frequencies. In addition, as we need to constrain a stellar atmosphere model in order to simulate the pulsations of HD104237, we have computed accurately its fundamental parameters (Teff, log g, abundances); we present the results of this study.

7.2.- The amplitude changes in the Be star 102719279 observed with COROT

J. Gutierrez-Soto and the COROT Be Team

Be stars are non-supergiant B-type main sequence stars whose spectrum has or had at some time one or more Balmer lines in emission. They are fast rotators which may pulsate as β Cephei and/or SPB stars. The amplitudes of the frequencies detected in Be stars vary in timescales of hundred of days or less.

Here we present the analysis of the COROT light curve of the Be star 102719279, which has been observed in the Initial Run and the First Long Run in the Anticenter direction. This allows us to perform a complete study of the changes in time of the frequencies and amplitudes. These results will be compared with other Be stars observed with MOST or COROT.

7.3.- Strange mode pulsations in massive stars

Mélanie Godart, Marc-Antoine Dupret, Arlette Noels, Conny Aerts, Karolien Lefever, Joachim Puls

Strange modes are radial or non-radial pulsations trapped into a small cavity in the superficial layers or even in the atmosphere of very high L/M ratio stars (e.g., Saio et al. 1998). The CoRoT data of O and B stars point out that strange modes may be present in some of them (e.g., Degroote et al., this conference).

We computed non-adiabatic frequency spectra of massive star models representative of these CoRoT targets and we study here the effect of adopting different atmosphere models on the strange mode propagation regions, frequencies and mode excitations. We compare our theoretical predictions with the characteristics found from the CoRoT observations.

7.4.- CoRoT eclipsing binaries with pulsating components

C. Maceroni et al.

We present the result of the analysis of a sample of eclipsing binaries of asteroseismological interest discovered by CoRoT, including the seismological target HD174884 , formed by two early type stars, and two eclipsing systems with Gamma Dor candidate components which were found in the first exoplanet fields.

A ground based spectroscopic follow up of HD 174884 allowed a sound determination of the system physical parameters and age. Besides the analysis of the light curve residuals evidenced the presence of phase locked patterns, which were interpreted in terms of tidally excited pulsations in a strongly eccentric orbit.

7.5.- Effects of rotation and overshoot on the modelling of Beta Cephei stars

J. P. Marques, M.-J. Goupil

Rotation can have important effects on stellar evolution, especially by inducing turbulent mixing in stable regions. In addition, rotation affects the pulsation characteristics themselves.
We model these effects using the formalism of Zahn (1992) to calculate the evolution of the rotation profile and the prescription of Mathis et al. (2005) for the turbulent mixing. Frequencies are calculated using a non-perturbative 2-D method of Ouazzani et al.We compare the effects of rotation and instantaneous and diffusive overshoot. Finally, we apply these techniques to study of the θ Cephei stars θOph and 12 Lac.

7.6.- CoRoT observations of variable stars in the young open cluster Dolidze 25.

V. Ripepi, S. Leccia, A. Ruoppo, S. Bernabei, K. Zwintz, F. Cusano, D. Gandolfi, H. W. Guenther, S. Alencar, M. Marconi, M.J.P.F.G. Monteiro, F. Palla, J.M. Alcala', T. Boehm, C. Catala, C. Chavero, W. S. Corradi, E. Covino, Degl'Innocenti, R. de la Reza, M. Deluil, F. Favata, M. Fernandez, J. Gregorio-Hetem, J.R.D. Lepine, F. J. G. Pinheiro, P.G. Prada Moroni, G. Quast, C.A.O. Torres, W. Weiss

We present preliminary results based on the CoRoT observations of the young distant cluster Dolidze 25. The light curve for the 28 stars observed by the satellite are analyzed and the relevant periodogram presented.
The physical parameters for a subsample of stars for which we possess AAOMEGA and FLAMES@VLT spectra are also reported. In total, we have identified 2 binary, 3 Pulsating Be, 3 SPB, 2 Spotted, 1 ellipsoidal, and 1 δ Scuti variables. The membership of these variables to Dolidze 25 is discussed.

7.7.- Determination of the fundamental parameters of faint Be stars observed in exofields of CoRoT

Semaan, T, Fremat, Y, Neiner, C, Martayan, C, Hubert, A-M

Be stars are defined as non-supergiant B stars that show or have shown at least once emission in their Balmer lines. This emission is due to the presence of a circumstellar disk built from matter ejected from the star through outbursts. We present the results on the determination of the fundamental parameters of the faint Be stars newly discovered in the exofields (IR1/LRA1) of CoRoT thanks to spectra obtained with the multi-object spectrograph FLAMES/GIRAFFE mounted at ESO-VLT/UT2. The determination of the fundamental parameters is necessary to the seismic modeling of Be stars.The fundamental parameters are determined by fitting our spectra with synthetic models taking account for non-LTE effects and fast rotational effects.

7.8.- Photometric amplitudes and phases of B-type main sequence pulsators: sources of inaccuracy

Jadwiga Daszynska-Daszkiewicz, Wojciech Szewczuk

Amplitudes and phases of the light variation in various photometric passband contain information not only about geometry of pulsation modes but also about mean stellar parameters, physics and atmospheres. Moreover, because oscillation spectra of main sequence stars lack equidistance patterns, these observables are very often the only ones from which mode identification can be derived. Therefore, it is of high importance to know what is the effect of various parameters, coming both from computation of linear nonadiabatic stellar pulsation as well as from models of stellar atmospheres, on theoretical values of photometric amplitudes and phases. Here, we discuss all possible sources of uncertainty, in particular, effects of chemical composition, opacities and NLTE atmospheres.

SESSION 8:

Future and ongoing Projects

Chair: P. L. Pallé

IT.8.1.- Four Years of HELAS

O. von der Lühe (*), M. Roth, C. Aerts, J. Christensen-Daalsgard, J. Daszynska-Daszkiewicz, M. P. di Mauro, L. Gizon, M. J. P. F. G. Monteiro, P. L. Pallé, M. J. Thompson
(*) Kiepenheuer-Institut für Sonnenphysik. (Germany)

The European Coordination Action on Helio- and Asteroseismology HELAS is about to complete its fourth and final year of initial funding by the European Commission. Set up as a network which combines solar and stellar physics communities in the important and vigorously evolving field of seismology, HELAS has been able to coordinate the efforts of European astronomers with remarkable success. Four large international conferences including the present one as well as many workshops were organised with a substantial contribution from HELAS. About a dozen workshops, addressing specialized questions in global and local helioseismology and asteroseismology were entirely organised by HELAS. Data analysis tools to prepare the European communities for the upcoming influx of data from new missions have been prepared, tested and demonstrated. Lecture notes and outreach material have been assembled and prepared for general access. As a result, HELAS has an important impact on the scientific output of the astrophysics seismology communities and significantly increased the visibility of European research in this field. This talk summarizes the activities and accomplishments of HELAS.

OC.8.1.- Report on current status of the Helio- & Asteroseismology operational Projects.

Pere L. Pallé
Instituto de Astrofisica de Canarias. (Spain)

OC.8.2.- Helioseismology with SDO

L. Gizon
Max Planck Institute for Solar System Research. (Germany)

OC.8.3.- Helioseismology programs with Solar Orbiter and PICARD

Thierry Appourchaux
Institut d'Astrophysique Spatiale. (France)

OC.8.4.- GOLF-NG development and the ASPIICS mission

S. Turck-Chieze
CEA/IRFU/SAp. (France)

OC.8. 5.- A Multiline Spectrometer for Seismic Mapping of the Solar Atmosphere at the Vacuum Tower Telescope, Tenerife

Joachim Staiger
Kiepenheuer-Institut für Sonnenphysik. (Germany)

We are currently developing a Multiline Spectrometer to be installed at the Vacuum Tower Telescope (VTT) at Izana, Tenerife. It will be used to investigate the propagation of waves throughout the solar atmosphere and to analyze how this propagation is influenced by magnetic fields and activity regions. The Double-Etalon Fabry-Perot System is used in a Collimated-Beam Configuration with a field of view of 100” by 100”. The theoretical resolution limit is 0.2”. Data are recorded with a DALSA 1M30 CCD-Camera.
We carried out a first test of the new system at the VTT in July 2009. We have observed 16 spectral lines simultaneously at a cadence of 1 min. Besides oscillatory phenomena we also hope to investigate in the future impulsive events in the upper Atmosphere at a previously unattained height resolution.

OC.8. 6.- The PLATO Mission Project

W. Zima, for the PLATO Consortium
Instituut voor Sterrenkunde, K.U. Leuven. (Belgium)

In this talk I present the PLATO (PLAnetary Transits and Oscillations of stars) mission, a next generation ESA Cosmic Vision satellite project dedicated to the detection of exo-planets and to asteroseismology of their host-stars using ultra-high precision photometry. The main goal of the PLATO mission is to provide a full statistical analysis of exo-planetary systems around stars that are bright and nearby enough for detailed follow-up studies. The mission design proposed by the PLATO Consortium will enable a continuous monitoring of stars with brightness between V(mag)=4 and 13, in two large fields (>1800 square-degrees) each for three years with 95% duty-cycle and a subsequent step-and-stare phase of one year. Asteroseismology of more than 20000 cool dwarfs that will be observed at a precision better than 27 ppm/h is expected to provide estimates of the mass, age and radius at a precision of a few percent. Key asteroseismological questions like the treatment of convection, core overshooting, internal rotation rates will be tackled in great detail. A sample of more than 300000 stars that will be measured with a precision better than 80 ppm/h will significantly enhance our knowledge about the distribution of exo-planets down to sub-earth size.
A first stage of selection of the Cosmic Vision missions will be made in February 2010.

OC.8. 7.- Asteroseismology with SONG.

J. Christensen-Dalsgaard
Aarhus University. (Denmark)

OC.8.8.- Asteroseismology & Virtual Observatory: the new generation stellar physics is coming.

J.C. Suárez (*), C. Rodrigo, E. Solano, A. García-Hernández, A. Moya
(*) Instituto de Astrofísica de Andalucia. (Spain)

In the last decades, the development of the Stellar Physics has been boosted thanks to the great improvement of its laboratory: The stellar seismology (Helioseismology for the Sun, and Asteroseismology for the rest of stars). Today, this branch of the stellar physics is enjoying a great moment. Several space missions have been designed and/or adapted for the study of the stellar interior (MOST, CoRoT, Kepler) and others are now in preparation (PLATO). In addition, many high-precision instruments are being used to do Asteroseismology (eg. CriRes, UVES, FOCES, FEROS, HARPS), and others are being designed (NAHUAl, CARMENES, GIANO,...). Furthermore, one of the great revolutions concerning the management and transmission of huge amount of information is, without any doubt, Internet and its infinite number of possibilities. Currently, new Internet-based technology is coming up almost every day (eg. Web, Web2.0, social nets, ...) are present in our personal and professional environments. Science, and in particular, Astrophysics, has the challenge of managing thousands of Terabites (ground-based and space observations, laboratory data, etc.) per year or even per day, in just one *click*. Today, this challenge is now a reality with the existence of the Internet-based general tool: Virtual Observatory.

In this work, we present origin of a promising idea: to join Asteroseismology with Virtual Observatory. We give details about the applicability, and we comment a demonstration of the current status of the VO Tool, which is being developed thanks to the collaboration between the Stellar Physics department of IAA-CSIC and the Spanish VO (LAEX, CAB).

OC.8.9.- The EXOTIME project and the synergy between Asteroseismology and Exoplanet search using the timing method

S. Benatti (*), R. Silvotti, R.U. Claudi
(*) CISAS - Padova University. (Italy)

After the discovery of V391 Peg b, the first planet detected around a post Red Giant phase star (see R. Silvotti contribution), the EXOTIME (EXOplanet search with the TIming MEthod) project is focused on the search for new planets with similar characteristics. The aim of the project is to organize a global observing network to collect data from a sample of 4 to 8 subdwarf B (sdB) stars and share them to obtain a more precise analysis. These evolved pulsators may have extremely regular oscillation periods. This feature makes these stars suitable to search for planetary companions with the timing method as in the case of Pulsars. In this contribution we present the project and some preliminary results after the first two years, with particular focus on one object of the EXOTIME sample.

POSTERS

8.1.- Is n-IR hi-res spectroscopy the new breakthrough for asteroseismology?

P.J. Amado and the CARMENES team

CARMENES is a study for a next-generation instrument for the 3.5m telescope at the Calar Alto Observatory that will be built by an international consortium. CARMENES stands for Calar Alto high-Resolution search for M dwarfs with Exo-earths with a Near-infrared Echelle Spectrograph. Since M dwarfs have low effective temperatures (Teff < 4000 K), our spectrograph is designed to operate in the optical red and the near infrared, where they emit the bulk of their radiation. High thermal and mechanical stability and a suitable wavelength calibration strategy are needed to reach radial velocity accuracies of a few meters per second, which are necessary to detect exoplanets of only a few Earth masses within the habitable zones of such cool, low-mass stars. However, our main interest in the instrument is to use asteroseismology to refine the parameters of planet host stars. The target radial velocities will be monitored with a fibre-fed cross-dispersed echelle spectrograph with two channels that will provide almost full coverage of their respective wavelength ranges in one shot. The near infrared channel will cover the Y , J and H bands, have a spectral resolution R ~ 85 000 and be calibrated with ThAr lamps. We expect to reach a signal-to-noise ratio of 100 in 10 min of exposure time on a target with J = 8 mag. The visible channel, covering the spectral range from about 5 000 to 9 000 Å, will provide simultaneous monitoring of activity indicators (e.g. Halpha, Ca ii).

8.2.- The HMI Local Helioseismology Pipeline

Richard S. Bogart, Philip H. Scherrer, Junwei Zhao

The Helioseismic and Magnetic Imager on the Solar Dynamics Observatory is the first mission for which the mission data products rely on techniques of local helioseismology. Three basic approaches are to be incorporated in the HMI data pipeline: ring-diagram analysis of localized power spectra, time-distance analysis of point-to-point travel times, and farside analysis of the same. These techniques have been developed and are being regularly applied in the analysis of data from the MDI instrument and the GONG network. HMI however will be the first instrument to combine the high spatial resolution of MDI with the full spatial coverage and continuity of GONG. The data flow will consequently place unprecedented demands on the local helioseismology processing. In this paper we present descriptions of the analysis modules to be used in the pipeline (and to be made available for additional targeted analysis), the data products to be produced, and how local helioseismology is integrated into the overall HMI data pipeline.

8.3.- First results of MISOLFA solar monitor for the ground PICARD program

T. Corbard, A. Irbah, P. Assus, J. Borgnino, C. Dufour, M. Fodil, F. Morand, C. Renaud, E. Simon

Developed at the Obervatoire de la Côte d'Azur (OCA) within the framework of the PICARD space mission and with support from the french spatial agency (CNES), MISOLFA is a new generation of daytime turbulence monitor. Its objective is to measure both the spatial and temporal turbulence parameters in order to quantify their effect on the diameter measurements that will be made from ground using the qualification model of the SODISM instrument onboard PICARD. The comparison of simultaneous images from ground and space should allow us, with the help of the solar monitor, to find the best procedure possible to measure solar diameter variations from ground on the long term. MISOLFA is now installed at the Calern facility of OCA and PICARD is scheduled to be launched in February 2010. We will present here the principles of the instrument and the first results obtained on the characteristics of the turbulence observed at Calern observatory using this monitor while waiting for the launch of the space mission.

8.4.- PLATO Data Acquisition and Analysis System

L. Gizon and the PDAAS Assessment Study Team

The PLATO Data Acquisition and Analysis System (PDAAS), a key component of PLATO, will provide ground support for the acquisition, validation, calibration, and analysis of the PLATO observations. Here we present an updated summary of the PDAAS Assessment Study, including a description of the PLATO data products. The final data product is a list of confirmed planetary systems, which will be fully characterized by combining information from the planetary transits, the seismology of the planet-host stars, and the follow-up observations. The PDAAS includes the PLATO Data Centre (PDC), which will be responsible for producing and validating the science-ready calibrated light curves and centroid curves, as well as all the high-level scientific data products and the ancillary data. The PDC is led by Germany with significant contributions from France and the UK, among others.

8.5.- Solar radius measurements with SODISM/PICARD instrument: methods and algorithm development for the PICARD mission Center (CMSP)

A. Irbah, C. Dufour

PICARD space mission is scheduled for a launch in February 2010. Its main goal is the measurement of solar diameter and shape within few mili arcseconds and their potential variations during the increasing phase of the current solar cycle. We will present here the simulations and methods developed to make these measurements from SODISM images and how these have been implemented at the PICARD mission center (CMSP) in Brussels.

8.6.- Opacity measurements in laboratory

Loisel, G., Turck-Chièze, S., Gilles, G., Piau, L., Thais, F.

High energy laser facilities allow to produce plasma in stellar conditions of temperature and density. The development of pico second laser is a promising way to study LTE conditions useful for the development of helio and asteroseismology. The association of nano and pico lasers is recently explored to solve some specific atomic transitions and some astrophysical identified problems on solar and beta cepheids cases. Indeed, the measurements of absorption spectra in different wavelengths are useful to estimate the radiative transfer of energy and the radiative acceleration, two crucial elements to properly describe the excitation of the modes by kappa mechanism and the competition between the different microscopic processes in action in radiative zones of stars. It is also useful for nuclear inertial fusion.

We present first an historical point of view of the measurements done in the past. Then we discuss the experiments performed during the last two campaigns. They are useful to qualify the calculations and to point out the experimental difficulties. We finally show our plan for the next years on the experimental and theoretical sides. Ref of recent publications on this field: Loisel et al. HEDP (2009); Turck-Chièze et al., HEDP (2009).

8.7.- SIAMOIS: a 1-site network for Doppler asteroseismic observations

B. Mosser and the SIAMOIS team

Asteroseismology benefits from superb results obtained with an unprecedented photometric precision with CoRoT and Kepler. However, addressing in details specific problems requires the precision of Doppler measurements on very bright stars. We will show how these Doppler measurements, combined with other precise ground-based interferometric and spectrometric observations, yields unique results in terms of stellar physics.

The project SIAMOIS will be presented. SIAMOIS is identified as one of the top-priority for astronomy at the Concordia station at Dome C in Antarctica.

8.8.- The PLATO End-to-End Simulator

W. Zima, T. Arentoft, J. De Ridder, H. Kjeldsen, S. Salmon, C. Aerts

PLATO (PLAnetary Transits and Oscillations) is a next generation ESA Cosmic Vision mission satellite project dedicated to the photometric detection of exo-planets and to asteroseismology of their host-stars. The PLATO End-to-End Simulator has specifically been created for the assessment phase of PLATO to verify the instrument design, optimize the observing strategy, test photometric algorithms, and to estimate the data quality PLATO will deliver. It is a software tool that allows to simulate the photometric CCD observations made by the PLATO satellite in a realistic way by including all physical and instrumental noise sources that affect a space-based observatory. We present this tool and results from simulations with emphasis on the influence on the noise properties of measured light curves due to satellite pointing variations.

8.9.- German Helioseismology Center for SDO

Y. Saidi, R. Burston, L. Gizon

A data and computation center for helioseismology has been set up at the Max Planck Institute for Solar System Research to prepare for the SDO mission. Here we present the system infrastructure and the scientific aims of this major project, which is funded through grants from the German Aerospace Center (DLR) and the European Research Council (ERC).

8.10.- The EXOTIME Project

S. Benatti , R. Silvotti, R.U. Claudi

After the discovery of V391 Peg b, the first planet detected around a post Red Giant phase star (see R. Silvotti contribution), the EXOTIME (EXOplanet search with the TIming MEthod) project is focused on the search for new planets with similar characteristics. The aim of the project is to organize a global observing network to collect data from a sample of 4 to 8 subdwarf B (sdB) stars and share them to obtain a more precise analysis. These evolved pulsators may have extremely regular oscillation periods. This feature makes these stars suitable to search for planetary companions with the timing method as in the case of Pulsars. In this contribution we present the project and some preliminary results after the first two years, with particular focus on one object of the EXOTIME sample.

8.11.- A Multiline Spectrometer for Seismic Mapping of the Solar Atmosphere at the Vacuum Tower Telescope, Tenerife

Joachim Staiger

We are currently developing a Multiline Spectrometer to be installed at the Vacuum Tower Telescope (VTT) at Izana, Tenerife. It will be used to investigate the propagation of waves throughout the solar atmosphere and to analyze how this propagation is influenced by magnetic fields and activity regions. The Double-Etalon Fabry-Perot System is used in a Collimated-Beam Configuration with a field of view of 100” by 100”. The theoretical resolution limit is 0.2”. Data are recorded with a DALSA 1M30 CCD-Camera.
We carried out a first test of the new system at the VTT in July 2009. We have observed 16 spectral lines simultaneously at a cadence of 1 min. Besides oscillatory phenomena we also hope to investigate in the future impulsive events in the upper Atmosphere at a previously unattained height resolution.

CLOSING TALK:

IT.0.2.- Seismological Challenges For Stellar Structure.

W. Chaplin
University of Birmingham (UK)

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