National
Optical
Astronomy
Observatories

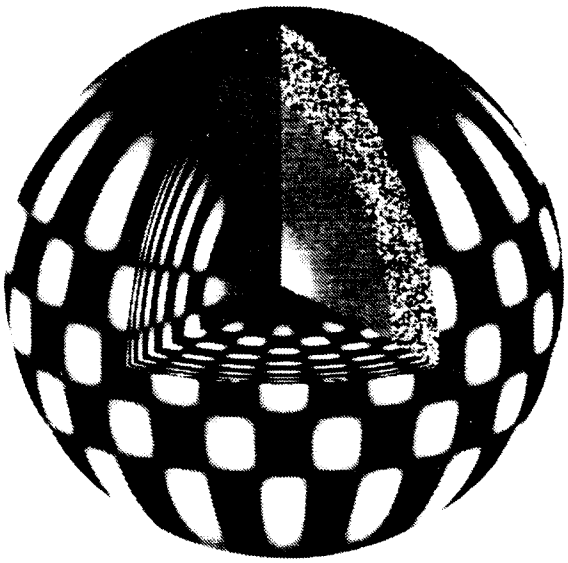
National Solar Observatory

Global Oscillation Network Group

Global Oscillation Network Group

Report Number 10

1993 Annual GONG Meeting Abstracts



GONG MEETING ABSTRACTS 1993

Table of Contents

INVERSIONS

A Preprocessing Strategy for Helioseismic Inversion

M. J. Thompson (Queen Mary & Westfield College), J. Christensen-Dalsgaard (Aarhus Universitet)

Helioseismic inversions are computationally expensive, because of the large number M of modes considered. This is particularly true of the Optimally Localized Averages (OLA) inversion methods, which require the inversion of one or more matrices of order M. However, we will show that, with a preprocessing strategy which involves taking suitable combinations of the modes before performing the expensive inversion, the original problem may be transformed into a much smaller one. This reduces considerably the cost of the OLA inversion. The important point is that our strategy is much superior to throwing away data (!), which at best degrades the error properties of the inverse solution, or naive averaging of data, which throws away information. We demonstrate for a model problem that our approach involves no significant loss of information.

Nonlinear Inversions of the Intermediate-Degree p-Mode Frequencies: Short Review of Current Results

S. V. Vorontsov (Queen Mary and Westfield College, London; Institute of Physics of the Earth, Moscow)

In theoretical description of intermediate-degree solar p-modes, an asymptotic approximation is appropriate throughout most of the solar interior, allowing the development of the composite-type descriptions, convenient for nonlinear inversion of the observational data. Regions of rapid spatial variation, where the asymptotic approximation becomes locally invalid (base of convection zone, He^+ ionization zone, and outer layers) contribute to the eigenfrequency equation with specific "acoustic phase shifts", separable from the asymptotic terms in the inverse analysis.

Some recent inversions are briefly discussed, based on the description with the second-order approximation for the asymptotic terms, and with the functional expansion for the non-asymptotic terms $\alpha_0(\omega) + (\ell + 1/2)^2/\omega^2 \cdot \alpha_2(\omega)$, which takes into account (in the leading order) the degree dependence of the acoustic phase shift (Brodsky & Vorontsov 1993, *Ap.J.*, in press). For intermediate-degree modes trapped within the convection zone, the "second" phase shift $\alpha_2(\omega)$ is produced predominantly by the He^+ ionization zone. The degree dependence of the phase shift is inferred as a distinct and prominent signal from the observational data currently available and, when taken together with the helium signal in $\alpha_0(\omega)$ used in previous studies, provides a new valuable source of information relevant to the seismic sounding of the He^+ ionization zone for the calibration of the helium abundance and of the equation of state (Gough & Vorontsov 1993, *M.N.R.A.S.*, in press). This more accurate description of the oscillation frequencies also significantly improves the precision of sound-speed inversions. The accuracy which is achieved with the observational data currently available, allows the diagnostics of the equation of state of the solar plasma deep in the convection zone, being sensitive to the effects of pressure ionization (Vorontsov, Baturin, Gough & Däppen 1993, in preparation). For modes with turning points deep in the radiative interior, a measurable contribution to the phase shifts is produced by the base of the convection zone. This signal is sensitive to the effects of penetrative convection; somewhat better accuracy of frequency measurements is needed, however, to employ its diagnostic capability (Roxburgh & Vorontsov 1993, in preparation).

D.O.G. is the Hare that Bet Us, or, We ain't nothing but Hounds, D.O.G.

C.R. Genovese, P.B. Stark (University of California, Berkeley)

We obtain preliminary rotation profiles from synthetic data provided by Hare Professor Douglas Gough (D.O.G.) through Frank Hill. We estimate the "data" error variances using iterated, weighted, regularized least-squares fits of simple 2-d models to the singlet splittings. We then estimate the rotation profile by fitting to the singlet splittings a tensor-product basis of cubic B-splines in radius and colatitude, plus a small number of radial discontinuities, using weighted, regularized least-squares. We choose the locations of the discontinuities using forward insertion followed by backwards deletion with a goodness-of-fit test. We assign uncertainties to the resulting rotation model using the modulus of continuity of the point-evaluation functional relative to the metric induced by the weighted data mapping, with an adjustment to allow for possible departures of the true model from the (finite-dimensional) space of splines plus discontinuities we consider.

Fractional differentiation technique for 2D asymptotic inversions of rotational splitting of p modes

A. G. Kosovichev[1,2] and P. Milford[3]

[1] *Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, England*
[2] *Crimean Astrophysical Observatory, 334413, Nauchny, Crimea, Ukraine*
[3] *Center for Space Science and Astrophysics, Stanford University, Stanford, CA 94305-4055*

We present a new formulation of an asymptotic JWKB solution of a full 2D inverse problem for the angular velocity. We show that the rotation law $\Omega(r,\theta)$ can be obtained explicitly by taking derivatives of order 1/2 of splitting data $\Delta\omega_{nlm}$ with respect to two asymptotic variables

$$\xi = 1 - \frac{m^2}{(l+1/2)^2} \quad \text{and} \quad \eta = \frac{(l+1/2)^2}{\omega_{nl0}^2}.$$

We suggest an inversion algorithm consisting of two steps: (i) for each (n,l) multiplet (or groups of multiplets with similar η), fit a smooth function of the continuous variable ξ (by using, for instance, piece-wise linear functions or splines) to the splitting frequencies $\Delta\omega_{nlm}$, and perform the angular inversion by halfth differentiating that function with respect to ξ; (ii) for each value of θ fit a smooth function of continuous variable η to the result of the angular inversion, and invert to obtain the radial dependence of $\Omega(r,\theta)$ by halfth differentiating with respect to η. For data sets containing f or g modes, the second step can be replaced by a standard 1D numerical inversion procedure. The technique can be applied to data with unknown systematic and random errors, and is particularly efficient for large data sets.

Progress report on structure inversions

D.O. Gough[1,2] and A. G. Kosovichev[1,3]
[1] *Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, England*
[2] *Department of Applied Mathematics and Theoretical Physics, University of Cambridge*
[3] *Crimean Astrophysical Observatory, 334413, Nauchny, Crimea, Ukraine*

A technique for direct estimates of a parameter of convective stability $A^* = \frac{1}{\gamma}\frac{d\ln p}{d\ln r} - \frac{d\ln \rho}{d\ln r}$ has been implemented. It permits us, by making use of an additional constraint: $A^* = 0$ in regions of adiabatic convection, to improve diagnoses of the base of the convection zone and of the HeII ionization zone.

We present results of direct inversions of frequency data sets, that include the new measurements of global p modes, obtained recently from integrated whole-disk measurements by BISON, the Birmingham Solar Network (Elsworth *et al.*, 1991), the IPHIR space experiment (Toutain and Fröhlich, 1992) and from observations at the Observatorio del Teide (Anguera Gubau *et al.*, 1992). We determine the radial resolution that can be achieved by the inversions for the hydrostatic parameters: density, sound speed and the parameter of convective stability. We report on current seismic evidence for deviations of solar core structure from a standard evolutionary model.

Conjugate Gradient Method for 2D Helioseismic Inverse Problems

P. N. Milford (Stanford University), A. G. Kosovichev (Cambridge Institute of Astronomy & Crimean Astrophysical Observatory)

Iterative Matrix methods present an efficient technique for solving helioseismic 2D solar rotation least squares inverse problems.

Solving least squares inverse problems directly includes the construction of a matrix $X = G^t \times G$ and computing X^{-1}. For G of size Nmodes by Nmesh this requires O(Nmodes x $Nmesh^2$) operations and up to O(Nmodes x Nmesh) storage. For large datasets, where Nmodes ~ 70,000 and Nmesh ~ 20,000, this can be impractical.

An alternative technique is to use an iterative matrix solution method. The Conjugate Gradient method iteratively finds a solution m, with observations d, such that $\| Gm - d \|^2$ (possibly with further constraints) is minimized. Each iteration requires O(Nmodes x Nmesh) operations and accesses the matrix G only a row at a time, in the form of matrix vector or transposed matrix vector products.

The Conjugate Gradient method converges for this type of least squares problem and in practice only requires a small fraction of Nmesh iterations. In addition, by recomputing part of the matrix G on each access the online memory requirement can be reduced to O(Nmodes).

A new estimate of rotational splitting of low-degree p modes from the IPHIR data

T. Toutain[1] and A. G. Kosovichev[2,3]
[1] *Space Science Department of ESA, ESTEC,2200 AG Noordwijk, The Netherlands*
[2] *Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, England*
[3] *Crimean Astrophysical Observatory, 334413, Nauchny, Crimea, Ukraine*

We show that the effect of a rigidly rotating core of radius $\simeq 0.2 - 0.3 R_\odot$ on frequency splitting is approximately the same for all the observed low-degree modes. It is suggested that in analysing poorly resolved rotationally split multiplets in oscillation power spectra, one first determines a single value for the splitting instead of estimating the splitting for individual modes separately.

We have used this property for fitting the lines of $l = 1$ and 2 in the IPHIR spectra. A mean splitting of 474 ± 23 nHz has been obtained, which is consistent with a core rotating faster than the surface.

A New Strategy for 2-D Inversion for Solar Rotation

T. Sekii (Institute of Astronomy, Unversity of Cambridge)

In the linearized integral formula for rotational splitting of solar p-mode frequencies, the dominant term in the kernel is a product of two terms, one depending on the radial coordinate alone, and the other depending solely on the colatitude. By retaining only this term in the equation, two-dimensional inverse techniques for the solar internal rotation can be formulated in such a way that the angular and radial inversions can be carried out separately (Sekii 1993). Thus the 2-D inversion is reduced to two successive 1-D inversions. This strategy leads to a dramatic reduction in computational burden when one is inverting huge data sets. In this paper the subtractive optimally localized averaging (Pijpers and Thompson 1992) and optimally localized averaging are applied to the angular inversion and the radial inversion, respectively. The quality of the inversions is illustrated by means of the resulting averaging kernels.

DATA REDUCTION

COMPARING WAVELET VERSUS FOURIER ANALYSIS OF TIME SERIES : THE SOLAR RADIUS MEASUREMENTS EXAMPLE.

Anne VIGOUROUX & Philippe DELACHE

The solar radius series provides a good example of data showing actually evidence for long term temporal variations on top of a well documented intrinsic (solar or instrumental) noise. Up to now, analysing of this data has been performed through Fourier transform. For example Gavryusev et al.(1992) have been able to assess a degree of confidence to individual frequencies by taking careful account of the actual dispersion of individual measurements.

We have compared results obtained from those techniques with models obtained along similar methods using "wavelet" instead of Fourier transform. This new analysis has capability to detect structures of different characteristic periods, appearing at different localizations in the time series; in other words, the wavelet transform is an analysis both in "time and scale" or in the "time and frequency" plane. Main results are :

- Wavelet transform analysis is very efficient in recognizing by itself that little weight is to be given to imprecise data, whereas Fourier transform is unable to do so.

- Similar quality reconstructions of the actual data variation need less parameters when processing is carried out through wavelet rather than through Fourier transform.

In conclusion, solar diameter measurements appear in a new perspective when analysed with wavelet transform : this data should thus not be considered as a superposition of stationary oscillations, but should rather be interpreted as addition of wavelets ; physical interpretation of variability would then require modeling of the phenomenon in the two dimensional "time and frequency" space.

Analysis of the GONG Prototype Data of Nov. 1-8, 1992

E.R. Anderson (GONG)

This poster presents a quick analysis of a 8-day time series generated with GONG Prototype data. Time series, power spectra and L-Nu diagrams are shown as well as PEAKFIND results for the L-Nu diagrams and selected M-Nu diagrams.

Steps Towards A GONG Merging Algorithm

C.G. Toner, W. Williams, F. Hill (NSO/NOAO)

We have begun investing several different merging algorithms to use for combining data obtained from the six GONG observing sites. Because of the computational cost of correcting each image for the observational Modulation Transfer Function (MTF), we are restricting our investigation to methods which apply the MTF correction and merge operation to the time series of Spherical Harmonic Transform coefficients. The MTF for each image is estimated using the method of Toner and Jefferies (1993, Ap.J., submitted). At this time a total of 8 different methods are being evaluated: 1) Equal weights (no MTF correction), 2) Equal weights (after MTF correction), 3) MTF weighting, 4) Sum from 3) + MTF window deconvolution, 5) "Sigma" (MTF noise) weighting after MTF correction, 6) Sum from 5) + sigma window deconvolution, 7) Pick the "best" image (no MTF correction), and 8) Pick the "best" image (after MTF correction). Preliminary tests using artificial data indicate that methods 3, 5, and 8 do the best job.

GONG Data -- The Video

R.M.Toussaint(NSO/NOAO)

A video showing recent GONG Prototype data will be presented. Calibrated velocity, calibrated modulation, average intensity and detrended calibrated velocity images from Nov. 07, 1992; as well as ten-minute averages of the above data products from Nov. 01 - 08, 1992 will be shown.

CONVECTION AND LOCAL ANALYSIS

Turbulent Compressible Convection with Rotation

J. Toomre and N.H. Brummell (University of Colorado), N.E. Hurlburt (Lockheed PARL)

Large-scale motions in the convection zone of the sun are influenced by rotation, leading to a redistribution of angular momentum which is observed as differential rotation. Simulations of global-scale convection in rotating spherical shells of fluid have so far dealt only with nearly laminar flow regimes. The disparity between the differential rotation profiles that they predict (angular velocity constant on cylinders) and those deduced from the observed frequency splitting of p modes prompts us to examine rotationally-constrained convection in more turbulent parameter regimes. We can resolve such flows on current supercomputers by restricting the geometry to a local area model. Hence we study the ensuing three-dimensional turbulent convection in a slab of perfect gas positioned at mid-latitudes on the sphere, describing the dynamics with a fully compressible hybrid finite-difference and pseudo-spectral numerical code. Cases with large Rayleigh number ($Ra = 5 \times 10^6$), fast rotation ($Ta = 10^7$), and low Prandtl number ($\sigma = 0.1$) have been studied with high spatial resolution ($192^2 \times 96$). As in a non-rotating case, a seemingly laminar surface network of downflows is established, not unlike solar granulation, although such a thermal boundary layer serves to disguise a turbulent interior punctuated by vertically-coherent structures. However, with rotation the upper network is much more mobile and curvaceous; all downflow lanes now shift and distort in time, moving, twisting and tilting the vertically-downflow sites. In such convection the Reynolds stresses and the Coriolis forces establish mean shearing flows in the zonal (east-west) and meridional (north-south) directions, and these flows possess about 5% of the total kinetic energy. The mean motions are time dependent, oscillating with the inertial frequency, and the associated fluxes indicate a general upward flux of zonal momentum and downward flux of meridional momentum.

On the Rotation Rate in the Solar Convection Zone

J. Schou (Stanford University) and T. M. Brown (High Altitude Observatory)

Recently Gough *et al.* (preprint) have argued that the rotation rate in parts of the solar convection zone may be constant on cylinders as predicted by models of the convection zone, contrary to the inferences generally made from helioseismology. In their alternative model the angular velocity is assumed to be constant on cylinders in the region where $r \sin\theta \geq r_c$, where r_c is the radius of the convection zone and θ is the colatitude. In the region of the convection zone with $r \sin\theta < r_c$ the angular velocity is given by a polynomial in $x^2 = \cos^2\theta$ with coefficients varying with radius. By choosing these coefficients properly, it is possible to get the same values of a_1 through a_5 (describing the m-dependence of the frequency variation due to the solar rotation) as in the standard model (in which the rotation rate in the convection zone is constant on radii).

Here we consider a model of the rotation rate in the solar interior similar to that suggested by Gough *et al.* and show that it is inconsistent with observations made with the Fourier Tachometer. In particular the values of the odd a-coefficients above a_5 are significantly lower than those predicted by the alternative model. We will also present evidence that it is unlikely that minor modifications to the alternative model will make it consistent with the observations.

Finally we show the result of an inversion of Fourier Tachometer observations using a high number of a-coefficients and compare it to an inversion using only a_1 through a_5.

Prospects in Helioseismic Holography

C. Lindsey (NSO), D. C. Braun (Institute for Astronomy, University of Hawaii) and S. M. Jefferies (Bartol Research Institute, Universtiy of Deleware)

The discovery by Braun, Duvall and LaBonte that surface magnetic regions strongly absorb p-modes has motivated serious consideration of the possibility of local helioseismic diagnostics. If local subsurface features, magnetic flux tubes for instance, interact appropriately with acoustic waves in the solar interior, as they do at the surface, then surface oscillations should contain considerable information on these features. Acoustic power maps made from the NSO-Bartol-NASA South Pole Observations of 1987, 1988 and 1990 strongly suggest that this is a real possibility. In this case there exists a range of techniques that could give us a window into local solar subsurface structure. The basic analog of optical diagnostics in helioseismology is accomplished by computational holography. We will present a perspective on this concept and describe our program to develop it.

RELATED PROGRAMS

Recent Progress at the Mt. Wilson 60-Foot Solar Tower

E. J. Rhodes, Jr. (USC and JPL), S. G. Korzennik (CfA), N. Johnson (USC), P. Rose (USC), and A. Cacciani (U. Rome)

Recent helioseismic progress at the Mt. Wilson 60-Foot Solar Tower has been concentrated in three main areas: 1) the continued analysis of our 1990 and 1991 observational datasets, 2) the continued development of our new PC-based image acquisition system which we plan to install shortly at the Crimean Astrophysical Observatory, and 3) the installation and initial operation of the potassium integrated-light spectrometer of the Birmingham University group, which was formerly located at the Mees Solar Observatory. Some preliminary results from the analysis of a subset of our 1990 obsrving run were presented at the GONG 92 Symposium. Since that time we have extended the number of days of data which we have processed to a total number of 124 days and we have begun computing tesseral power spectra based upon that entire time series of spherical harmonic coefficients. We have also begun to convert filtergrams from our 1991 observing campaign into Dopplergrams and into spherical harmonic coefficients. Since the time of the GONG 92 Symposium we have computed the first power spectra from our 1992 observations which were obtained with our new PC-based acquisition system. We have also interfaced a 1024x1024 pixel CCD camera to that system, and have nearly completed the integration of the complete instrument at Mount Wilson. Lastly, we completed the installation of the Birmingham spectrometer during October of 1992 and have been operating that instrument for the Birmingham group on nearly a dialy basis since that time. In this presentation we will present additional details on all three of these projects.

Solar Oscillations Investigation - Michelson Doppler Imager (SOI-MDI) Program Update

The SOI Development Team: P. Scherrer (PI), R. Bush, T. Hoeksema, P. Milford, T. Pope, W. Rosenberg, L. Springer, T. Tarbell, A. Title, J. Wolfson, and I. Zayer

MDI is a space based helioseismology instrument scheduled for launch on SOHO in July 1995. We expect to deliver the flight instrument to ESA for integration with the rest of the SOHO spacecraft in November 1993.

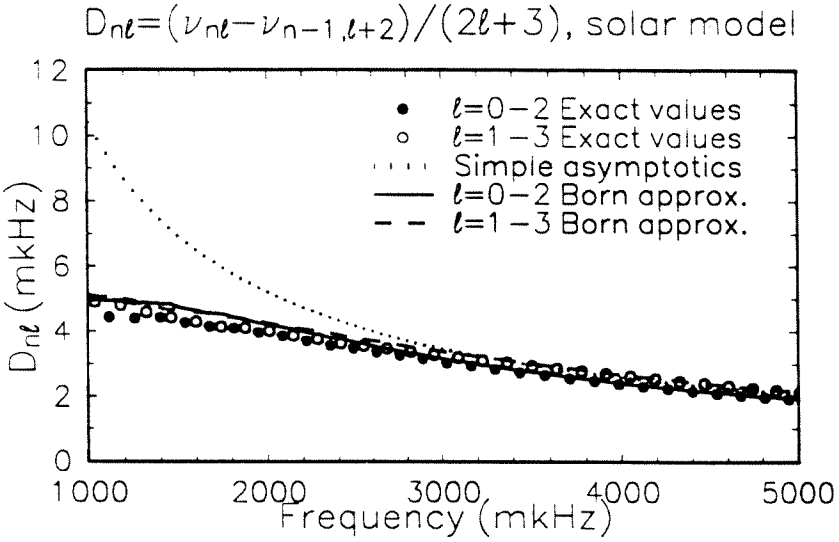
The complete set of flight optical elements have recently been assembled into the flight package and have produced filtergrams and dopplergrams. All of the flight mechanisms and most of the flight electronics (including experiment control and image processing computers as well as telemetry boards) have been used to record images. The onboard software and firmware are still being developed. We present the initial results of the flight optics tests.

MODELS

Towards the Seismology of a Stellar Core:
Simple Theoretical Description of the "Small Frequency Separations"

S. V. Vorontsov (Queen Mary and Westfield College, London; Institute of Physics of the Earth, Moscow)
I. W. Roxburgh (Queen Mary and Westfield College, London)

The "small frequency separations" of low-degree p modes are known to be sensitive predominantly to the structure of the stellar core. To employ the diagnostic capability of these measurable quantities, a convenient theoretical description capable of relating them to integral parameters of the seismic stratification is highly desirable. High-frequency asymptotic analysis is known to produce poor results, even in higher approximations, due to the inability to account for strong local effects of buoyancy forces and gravity perturbations in the core. We describe an alternative approach, which is essentially a Born approximation for the scattering by the stellar core of acoustic waves modified by the buoyancy and gravity.



Measurements of the helium abundance and the depth of the convection zone from low-degree data

A. G. Kosovichev
Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, England
Crimean Astrophysical Observatory, 334413, Nauchny, Crimea, Ukraine

I present a new approach, which involves measuring a parameter of convective stability A^*, for estimating of the helium abundance and the depth of the convection zone. The helium abundance is obtained via variations of a polytropic index γ in the HeII ionization zone by using an equation of state; and the base of the convection zone is determined as the lower boundary of a region of $A^* = 0$.

The inversion procedure has been applied to two subsets of the IPHIR data (Toutain and Fröhlich, 1992): (i) 25 frequencies of p modes of $l = 0$, 1 and 2 in the frequency range 2.5–3.5 mHz, (ii) 17 frequencies of $l = 0$ and 1 in the same range. The depth of the solar convection zone estimated from the both sets is approximately $0.32R_\odot$, which is slightly deeper than the value of $0.29R_\odot$ obtained from high-degree data. The helium abundance obtained, by making use of an MHD equation of state, from the first mode set is 0.251, and from the second - 0.256, which is smaller than the value of a typical standard solar model, 0.285. Therefore, the IPHIR data appear to give further evidence for gravitational settling of helium in the sun.

It is suggested that the technique be applied to future asteroseismic data.

MODE PHYSICS, MAGNETIC EFFECTS AND STEADY FLOWS

New Solutions for Linear Adiabatic Wave Propagation in Stratified Atmospheres

Z. Wang and R.K. Ulrich (Department of Astronomy, UCLA)

The normal dispersion analysis for linear adiabatic wave propagation in stratified atmospheres adopts a real frequency and solves for the complex vertical wave number. The imaginary part of the vertical wave number then yields the $\rho^{-1/2}$ dependence for the velocity amplitude which preserves the kinetic energy density of the wave. The dispersion analysis is a local representation of the wave behavior in both space and time. We consider the case of the near field of a boundary piston which is driven arbitrarily as a function of space and time and examine the response to this piston by an atmospheric layer which has an initially constant sound speed but which has the usual gravitational stratification. In a restricted domain of space and time near this boundary, the wavelike behavior of the medium may be described by frequencies and vertical wave numbers which are both complex. When both parameters are allowed to have imaginary components, a new range of solutions is found for which there is no cutoff frequency. We show that vertical energy propagation can take place through the solar atmosphere as a result of oscillations below the nominal cutoff frequency. Previously, the largest amplitude oscillations which generally have low frequencies were dropped from the calculation of energy flux because their frequencies are below the nominal cutoff frequency. This new family of near-field waves permits these modes to carry vertical energy and raises the possibility that the 5-minute oscillations play a larger role in the transport of acoustic energy to the chromosphere.

Time-Distance Helioseismology

T.L. Duvall Jr.(NASA/GSFC), S.M. Jefferies(Bartol), J.W. Harvey(NSO), and M.A. Pomerantz(Bartol)

The application of seismology to the study of the solar interior has advanced almost solely by the prediction and measurement of the Sun's frequencies of free oscillation. Direct measurement of the travel times and distances of individual acoustic waves-the predominant approach in terrestrial seismology-would appear to be more difficult in view of the number and stochastic nature of solar seismic sources. Here we show that it is possible to extract time-distance information from temporal cross-correlations of the intensity fluctuations on the solar surface. This approach opens the way for seismic studies of local solar phenomena, such as subsurface inhomogeneities near sunspots, and should help to refine global models of the internal velocity stratification in the Sun. We also show that acoustic waves with frequencies greater than the acoustic cutoff frequency are not significantly reflected by the solar atmosphere, with their reflection coefficient being <2%.

A Phenomenological Model for the Absorption of P-modes in Sunspots

D.-Y. Chou and C.-K. Chen (Tsing Hua University, Taiwan)

We adopt a phenomenological approach to the absorption of p-mode oscillations by sunspots. We assume that the wave dissipation in the presence of magnetic field can be described by a complex sound speed, whose imaginary part is defined as the absorption parameter. The effect of dissipation appears as a source term, which is a function of the absorption parameter and wave functions, in the wave equation. The waves scattered by a sunspot can be obtained by solving the wave equation with Green's functions and the Born approximation if the absorption parameter is small. In general, the scattered waves of mode (l, m) are related to the incident waves of all modes with the same degree l. For a special case of circular sunspot, the scattered waves of mode (l, m) are related to only the incident waves of mode (l, m). Absorption coefficients and phase shifts can be calculated from the distribution of the absorption parameter and the Green's functions.

Vertical Energy Transport by Oscillations in Active and Quiet Regions on the Solar Surface

D.G. Parker and R.K. Ulrich (Department of Astronomy, UCLA)

Observations by Braun, LaBonte and Duvall (*Astroph. J.*, **354**, 372 [1990]) have indicated that active regions absorb horizontally propagating energy from $p-$modes with an efficiency factor of up to 50%. The disposition of this energy is an important question – is it refracted into vertically propagating acoustic flux, does it go into Alfven waves or is it converted directly into local heating by a dissipative process. In order to constrain these possibilities we have examined the vertical propagation of acoustic energy by means of several time dependent measurements of the NaD_1 line profile. Each day's observation consists of a series of 256 line profiles measured with a cadence of one per 30 s. One set of seven consecutive daily series follows a point near an active region as solar rotation carried it across the apparent solar disk. Another set of daily time sequences was obtained for quiet sun conditions with a similar range of center-to-limb positions. We find that the vertical acoustic flux shows considerable variation from one day to the next independent of whether the point is for active sun or quiet sun conditions. In spite of this variation, it appears as though the peak of the vertical flux occurs nearer the photosphere for the quiet sun than for the active sun.

P-Mode Frequency Variation in Relation to Global Solar Activity

K. T. Bachmann, T. M. Brown (HAO/NCAR)

We show that p-mode frequency variations correlate remarkably well with the variations of six solar activity indicators over a six year period from October 1984 to November 1990, including both the large variation from solar minimum to solar maximum and smaller variations observed over approximately one month intervals during solar maximum. The quality of correlation as seen visually and as measured by two statistical tests differs significantly among the six activity indices, and we briefly speculate on possible reasons for this. Observations used in this study come from the HAO/NSO Fourier tachometer (FTACH) and include the spherical harmonic degree range $20 < l \leq 60$ and frequency range 2600 μHz $< \nu <$ 3200 μHz (radial orders n between 8 and 15). The data are divided into 18 separate epochs with time string duration ranging from a minimum of 18 days to a maximum of 45 days. We have particularly good coverage during the early part of solar maximum of cycle 22.