PRELIMINARY P-MODE FREQUENCIES FROM A 93-DAY MT. WILSON 60-FOOT TOWER OBSERVING RUN

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ABSTRACT By combining various supercomputer resources available in the Los Angeles metropolitan area, we have been able to reduce a full 93-day-long time series of 1024 by 1024 pixel dopplergrams, which were acquired during the summer of 1990 at the 60-Foot Solar Tower of the Mt. Wilson Observatory. The spherical harmonic decomposition was carried out for all even-\(m\), for \(0 \leq \ell \leq 600\). While the complete tesseral spectral analysis has not yet been completed, the high signal-to-noise ratio of the zonal power spectra achieved by having such a long time series allowed us to perform a preliminary determination of the p-mode frequencies at intermediate and high degree modes \((20 \leq \ell \leq 600)\). We present our latest determination of these frequencies, using power spectra computed with various frequency resolutions, each employing the full 93-day long data set.

INTRODUCTION

Since 1984 our research group has been involved in the acquisition and archival of in excess of one terabyte of solar velocity field images. During the past eight years we have obtained observations with the 60-Foot Solar Tower of the Mount Wilson Observatory on a daily basis during each summer and during several fall and winter seasons as well.

In order to maximize the scientific return from our datasets over the long term, we have consciously adopted a strategy of initially examining only a subset of those datasets in order to ensure that data of sufficiently high quality have been acquired at the telescope while at the same time developing a complete software pipeline that would ultimately allow us to extract the maximum...
possible information without decimating the spatial resolution of our images in an irreversible manner early in the pipeline. To be precise, we have chosen to retain the full 1024 x 1024 pixel resolution of our full-disk solar filtergrams and Dopplergrams throughout our data reduction pipeline.

This decision has meant that we have been limited in the speed with which we could add additional days to our existing time series of processed images. Only recently, with the availability to us of time on the Intel Touchstone Delta supercomputer at Caltech, have we been able to realize an improvement in our data reduction throughput of somewhere between 30- to 100-fold. Our use of the Touchstone Delta supercomputer is described in more detail in a companion paper by Korzennik et al. (1992a).

The massive gain in processing speed that has become available to us is due to the opportunity of employing as many as 300 computational elements simultaneously instead of the two or three which we were previously limited to at USC and at JPL. In addition the availability of 20 8mm helical scan tape drives and an excess of 48 gigabytes of temporary disk space on the Delta has meant that we have been able to load up to 20 complete days of input images onto that computer’s file system at a time instead only the few hours of data that we could access at a time at USC and at JPL.

As a consequence of the availability of the Delta to us, we have recently combined output from it together with earlier output which we had computed on the USC Alliant FX/2812 and on the JPL Cray Y/MP. By combining the output from these different computers during the past several months, we have been able to complete the conversion of 81 days of input images spanning a total of 93 days during 1990 into time series of spherical harmonic coefficients. This marks the first time ever that we have been able to analyze such a long time series from a single observing season. We have begun computing power spectra from these time series and are presenting here our first preliminary modal frequencies from an analysis of some of these spectra.

While we were able to process only 20 consecutive days of our 1988 observing run until relatively recently, the current figure of merit in helioseismology is a time series of lower spatial resolution images spanning a total of roughly 100 days in a single observing season. Hence the 93-day time series of 1990 observations which we are now analyzing will make us competitive with other groups for oscillation modes of degrees up to 140 for the first time, while greatly enhancing our ability to search for temporal shifts in the helioseismic properties of high-degree p-mode oscillations through the comparison of our 1988 and 1990 observations results.

1990 OBSERVATIONS

Our summer 1990 observing campaign at the Mt. Wilson 60-Foot Tower began on June 11 and continued through December 31. For most of that time we employed a two-cell version of the Cacciani Magneto-Optical Filter. However, due to the malfunction of an MOF cell in November of 1990, we were forced to operate with one MOF cell for the remainder of the year.
P-MODE FREQUENCIES

PROCESSING OF 1990 DATA ON THE DELTA

In the first four months of 1992 we employed the Caltech Delta supercomputer in the reduction of 30 days out of the 81 days from our July-October 1990 time series mentioned earlier.

From the total of 81 days of processed data which we have included in our analysis, we have thus far computed several different sets of power spectra. First, we computed 90601 separate tesseral power spectra for each of the 81 days in our run. Each one of these 7,338,681 one-day-long power spectra was computed from a time series of spherical harmonic coefficients for a single harmonic which had been padded with zeroes to a length of 1024 minutes, or 17.07 hours. We then averaged together the 81 1024-point zonal (i.e. m=0) power spectra to obtain a single average "low frequency resolution" zonal spectrum (i.e., a spectrum for which \( \Delta \nu = 16 \mu Hz/\text{bin} \)).

We also combined the time series of the zonal, sectoral, and tesseral harmonics into 2048-, 8192-, 32768-, and 65536-point time series by combining the data from consecutive days into longer time series and then interspersing additional zeroes wherever we had no available observations. The two sets of power spectra which resulted from the 2048- and 8192-point time series were our so-called "intermediate frequency resolution" spectra, while the sets of spectra which resulted from the 32768- and 64536-point time series became our "high frequency resolution" spectra.

CALCULATION OF HIGH-DEGREE RIDGE-FIT FREQUENCIES

There have only been three published sets of high-degree p-mode ridge frequencies (Libbrecht and Kaufman 1988 and Libbrecht, Woodard, and Kaufman, 1990, and Korzennik, 1990). The first of these datasets came from a 9.5-day long observing run at BBSO in 1986 for degrees up to 400 and a 5-day long run at BBSO in 1985 for higher degrees. However, Libbrecht, Woodard, and Kaufman (1990) themselves have recently pointed out that the Libbrecht and Kaufman frequencies contain systematic errors that are large enough to render them useless as input for careful inversion studies. Consequently, Libbrecht, Woodard, and Kaufman (1990) claim that only their newer table of high-degree frequencies should be trusted for all \( \ell > 150 \) and yet this dataset originated from only a single 9-hour long observing run in August, 1987. The high-degree ridge-fit frequencies which Korzennik (1990) published are the only set which was obtained from more than 10 days of observations. Clearly, there is an urgent need for more accurate high-degree frequencies.

Accordingly, we have begun calculations to generate just such a set of high \( \ell \) (120 < \( \ell \) < 600) frequencies from our 1990 MWO observations. The ridge-fit frequencies which we obtained by employing our Lorentzian-fitting program to our "low resolution" zonal power spectra are shown here in Figure I.

We also computed ridge-fit frequencies using the 2048-, and 8192-point zonal power spectra. At the scale of Figure I the frequencies computed from the 8192-point power spectrum were indistinguishable from those shown in that figure. As we could readily see when we compared the two sets of frequencies, there was little difference in the size of the scatter of the ridge-fit frequencies computed...
FIGURE I  p-mode frequencies computed from the average 1024-point zonal power spectrum. These frequencies were computed with a least-squares Lorentzian fitting algorithm. A set of corresponding frequencies was computed from the 8192-point average zonal power spectrum. A comparison of the plots of the frequencies computed from these two power spectra showed that there was little difference in the amount of the scatter in the two sets of frequencies. This result is what would be expected since at high degrees we are not resolving the individual p-modes but are instead only fitting the p-mode ridges at these degrees.

from the 1024- and 8192-point power spectra. This similarity in the scatter of the two sets of frequencies is due to the fact that the high-degree p-mode ridges have such shallow slopes in the \( \ell - \nu \) plane that we are not resolving them even with the 8192-point time series.

REFERENCES

Korzennik, S.G., Rhodes, E.J., Jr., and Johnson, N.M. 1992a, this volume.