SHORT PERIOD OSCILLATIONS IN ACTURUS, ALDEBARAN, AND POLLUX

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ABSTRACT. A total of 48 nights of time series data have been obtained for the K giants: Arcturus, Pollux, and Aldebaran. A careful analysis of both single and multi-night sets using the earth's motion as a velocity calibrator has yielded stellar velocity time series accurate to ± 3 m/s per observation. Periodogram analyses of these sets have revealed the existence of oscillations with periods near 2.5 hrs and amplitudes of ± 5 m/s for both Pollux and Aldebaran, but not for Arcturus. Preliminary analysis of a 5-night set for Pollux using the CLEAN algorithm suggests at least three modes separated by about 35 microHertz.

1. OBSERVATIONS

Since the discovery of 5-minute oscillations on the Sun, there has been a great deal of interest in the search for small amplitude radial velocity variations in nearby stars. Because the accurate determination of stellar radial velocity requires high spectral resolution, high signal-to-noise ratios, and short exposure times, the few measurements that have been reported in the literature have been made on bright stars. Noyes et al. (1984) found a 10-minute period in epsilon Eri with modal spacings of 172 microHertz, Fossat (1987, this Symposium) reports modal spacings in the power spectra of alpha Cen A and Procyon, and M. Smith (1983) published oscillation periods for Aldebaran and Arcturus. All these claims are unsubstantiated and so near the detection limits that it is fair to say that this work represents a brave beginning into what promises to be a new and exciting way of studying stars: asteroseismology.

We are using an instrument developed at the University of Arizona which is permanently installed at the 0.9-meter Steward Observatory telescope on Kitt Peak (McMillan et al., 1986). Serkowski et al. (1979) originated the concept of using a stabilized, carefully calibrated Fabry-Perot in transmission to provide longterm wavelength calibration during the search for planetary systems. This ensures excellent short term stability. The etalon can be accurately tilted to provide for the

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tracking of spectral features as they drift in wavelength in response to the earth's motions and to impose a known velocity shift onto the signal for use in analysis of the exposures.

By imposing a known 'velocity' signal onto several exposures and finding the fractional intensity change for each transmission order, an approximate slope (defined as the percentage intensity change in an order per km/s) can be determined for each order. The orders having small slope values, mostly continuum points, are used for normalizing the different exposures.

After normalization, the orders which fall on steeply sloped features in the spectrum ('active' orders) are used to derive velocity estimates. For each active order the relative intensity change between each observation and a reference observation chosen near the middle of the series is plotted against time. The known earth motion curve is fit to this series with only two unknowns, the slope value and a bias; these values provide accurate velocities for each active order and each observation. An average of all the active orders in a observation gives the best estimate of the velocity relative to the reference observation. Advantages of this technique are that the ensemble used in the average also gives accurate error bars for each observation and that the curve fit gives an opportunity to reject outliers caused mainly by decay events within the CCD chip. The final step in the reduction is the transform of the series by a slow Fourier technique to a normalized periodogram.

2. RESULTS AND DISCUSSION

Periodograms from single nights and sets of contiguous nights have been used to search for oscillations. It is also helpful to average the periodograms from separate nights to reduce the noise. Before concluding that an oscillation was present in the power spectrum, it was required that it be observed on several individual nights. The normalized periodogram provides a false alarm capability (Horne, and Baliunas, 1986) so that peaks which fail to exceed a minimum threshold can be safely rejected.

Arcturus has a period of 1.842±0.005 days and an amplitude of 160 m/s peak-to-peak (Smith et al., 1987). This periodic behavior is not the type of p-mode oscillation observed for the sun. When time series within a night are examined, the peaks generally fall short of the detection threshold and, when they do exceed the threshold, there does not appear to be any substantiation on subsequent nights. We conclude that for time scales between a few minutes and several hours that there are no oscillations of amplitude greater that 2-3 m/s. This result contradicts the 97±28 min period claimed by M. Smith (1983).

Although the number of data sets on Aldebaran is much smaller than for Arcturus, on several nights significant peaks appear near 2.5 hours' period. These peaks are only marginally significant in themselves, but there is strength in the multiple observations. The amplitudes are on the order of ± 5 m/s. We have obtained one set of 4 contiguous nights which has been transformed as one continuous set and also reveals the peak at 2.5±0.5 hours in agreement with M. Smith's 110±16 min period.

Unlike the previous two stars, Pollux shows a very significant peak in the periodogram which has been observed on all 14 nights currently reduced. On 1987 Jan 13, a time series greater than 10 hours in length clearly shows almost 4 cycles of oscillation. The amplitude of the oscillation can be accurately measured from the velocity plots at ± 6 m/s; however, there seems to be a different amplitude on different nights. The same sort of phenomenon occurs with the position of the peak in the periodogram: there are significant displacements between nights centered about a period near 2.5 hours. In an effort to understand these variations, a set of 5 contiguous nights has been analyzed as a single time series. The characteristic shape of the peak near 2.5 hours is a broad energy distribution about 3 times the width of the spectral window. Using the CLEAN algorithm (Roberts et al., 1987) to remove the confusing sidelobes caused by the day gaps in the time series sample, there appears to be 3 equally separated modes spaced by 35 microHertz. If these modes are real and caused by low order p modes, then the true order separation is twice this value or about 70 microHertz.

The predictions for K-giant oscillation are in a primitive state since they are extrapolations from solar models and may not include all the relevant physical processes. However, Frandsen (private communication) predicts time scales greater than 50 min for giant stars and amplitudes greater than 1 m/s per mode. He is drawing on unpublished results of the study done by Christensen-Dalsgaard and Frandsen (1983) for solar-type stars; the modal spacings they report decrease with increasing luminosity from the solar value of 136 microHertz to values less than 80 microHertz for the giant stars. The time scale is also supported by the older study of Ando (1976), who ran models specifically for K giants and stressed that the periods must be longer than the acoustic cut-off period of about 1.5 hours. It would be very helpful if more detailed models were computed for these interesting and observable stars.

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3. REFERENCES

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DISCUSSION

LINSKY Your data clearly point out the need for a network of instruments at different longitudes to study oscillations of stars without time gaps.

SMITH I agree entirely, in order to resolve the predicted mode splittings this will be essential.