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Analysis of Long-Term Single-Site Observations of the Pulsating DB White Dwarf GD 358[1]

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1. Introduction

The pulsating DB white dwarf GD 358 was observed by the Whole Earth Telescope (WET) in 1990, 1994, and 2000. While these observing runs revealed a wealth of pulsation modes, they constitute only three "snapshots" of the behavior of this star. These "snapshots" show that GD 358 has a series of $\ell = 1$ modes present in the period range of 420 to 810 seconds, with numerous Fourier Transform peaks at the sums and differences of the $\ell = 1$ mode frequencies. In addition, the amplitudes of the $\ell = 1$ modes and the sum and difference frequency peaks (which I also call "combination peaks" in this paper) are different in each WET run. These data are not sufficient to determine the time scale of the amplitude changes and whether additional $\ell = 1$ modes might be present. For this, we need more frequent data sets, although not necessarily WET data.

To this end, I and others collected single-site data on this star from 1990 to 1992 and I have archival data from 1982 to 1986. I use the WET data to determine the periods of the pulsation modes and take this information to disentangle the pulsation modes from the extensive alias pattern. I have data from April 1985, May 1986, June 1990, August 1990, April 1991, early June 1992, and late June 1992.

2. Data reduction methodology

Nather et al. (1990), Kepler (1993), and Clemens (1993) describe the general data reduction process in detail, so I will only mention the highlights here. First, I use a data reduction program called QED to eliminate bad data points. I then use QED to perform dead-time corrections, sky subtraction, extinction correction, and convert from counts to fractional amplitudes (with the mean value of the data being used as the zero point). In some cases, the extinction correction left long-term trends in individual runs, and I would subtract low-order polynomials to flatten out the individual light curves. Once I obtained the reduced data, I computed Fourier Transforms (FT) for the combined runs of a given month, along with a representative window function. For this preliminary analysis, I compared the frequencies from each month to those of the WET runs to determine their reality, and I used the window function to reject alias peaks.

[1]These data were collected at McDonald Observatory, Fort Davis, Texas

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3. Results

Space constraints prevent my showing any FT plots; please consult Winget et al. (1994) or Vuille et al. (2000) for example plots. The data show that all of the major pulsation modes (which lie between 400 and 850 s) vary in amplitude, and some modes even disappear below the noise limit for months at a time. The lowest overtone modes at 424 and 464 s ($k = 8$ and 9) are present in all but the April 1985 data, and their amplitudes vary by up to a factor of 4 when they are visible. In addition, these two modes have the most stable frequencies, varying by less than 1μHz over 9 years. I find no convincing evidence of modes at ~ 500, ~ 540, or ~ 580 s ($k = 10$, 11, and 12), even though the models of Bradley & Winget (1994) predict modes near these periods. The modes between 618 and 810 s ($k = 13$ to 18) all vary in amplitude, and all but the 700 s mode disappear from time to time. This region almost always dominates the power spectrum and the amplitudes of modes can grow to 35 mma (milli-modulation amplitude), although values of 20 to 25 mma are typical. These modes show less frequency stability; they can change by 1 to 2μHz on timescales of about a year.

Like Winget et al. (1991), Nather (1995), and Vuille et al. (2000), I find numerous peaks at the sums and differences of the pulsation modes, and these dominate the power spectrum below 1000 μHz and above 2400 μHz. As a result, these combination peaks hinder my ability to see modes with periods longer than 810 s or shorter than 420 s. However, I do see evidence of a mode at $k = 19$ in the April 1985 and May 1986 data sets. The period of this mode is about 845 s, and the period spacing is 35 s, implying that the $k = 19$ mode is trapped. At this point, I cannot rule out the low frequency alias (with a period of 854 s) being the real mode. The resultant period spacing would then be 44 s and the trapped mode would be at $k = 20$ or greater. Hopefully, with more analysis of this much larger data set, I will be able to find evidence of pulsation modes beyond the known ones between 420 and 810 s, which will be useful for refining the seismological analysis of GD 358.

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