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ASTEROSEISMOLOGY OF THE DBV WHITE DWARF GD 358 WITH THE WHOLE EARTH TELESCOPE

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ABSTRACT We report the analysis of 154 hours of nearly continuous high-speed photometric data on the pulsating DB white dwarf (DBV) GD 358 obtained during the Whole Earth Telescope (WET) run of May 1990. The Fourier transform (FT) of the light curve is dominated by power in the range from 1200 – 1700μHz, with more than 180 significant peaks in the total transform. We also see significant power at the sums and differences of the dominant frequencies, indicating the importance of nonlinear behavior. We can use this data to obtain an accurate total stellar mass, and surface He layer mass. The implied surface He layer mass, if correct, provides a significant and surprising challenge to stellar evolution theory, as well as the theory of chemical mixing.

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We observed the complex pulsator GD 358 with the Whole Earth Telescope (hereafter WET, see Nather *et al.* 1990 for a description of the WET) during May 1990. The data were reduced and analyzed using the techniques described in Nather *et al.* (1990), and Winget *et al.* (1991).

We display a portion of the FT of the light curve in Figure 1 in a multi-panel form. The top panel has been rescaled to accommodate, at least partly, the large dynamic range of the power spectrum. The data were nearly continuous during the central portion of the run; this is evidenced by the extremely low power levels in the side lobes of a single frequency sampled as the data (see Figure 1 insert). The FT is dominated by power in the range from $1000 - 2000\mu Hz$. This power consists of triplets with a typical internal uniform frequency spacing of $6.2 \pm 0.1\mu Hz$.

The triplets are consistent with $l = 1$ non-radial g-modes with radial overtones from $k = 13 - 18$, approximately equally spaced in period. We have indicated tentative radial overtone numbers (based on preliminary numerical modeling by P. A. Bradley 1992, private communication) with numerical labels in the figure. We have placed arrows over the expected locations of overtones 10,11,12,19 and 21. With the exception of three other small groups of power, essentially all of the significant power in the light curve can be accounted for in the context of this set of $l = 1$ triplets, and sums and differences of these frequencies.

The mean period spacing of the triplets is consistent with the theoretical expectations based on extensive numerical calculations by one of us (P. A. Bradley) for consecutive radial overtones of $l = 1$ nonradial g-modes, and a mean stellar mass near 0.60 solar masses. The deviations from uniform period spacing indicate compositional stratification with a surface He-layer fractional mass much less than $1.0x10^{-6}$.

The fine structure shows some variation from triplet to triplet within the large amplitude modes; preliminary theoretical calculations by C.J. Hansen (private communication) indicate that this structure is consistent with differential rotation in the surface He layer, as suggested by G. Vauclair, and W. Dziembowski. These asteroseismological results have important consequences for prior shell-burning and mass-loss evolutionary stages, as well as white dwarf spectral evolution theory and theories of convective mixing. If we use the mean frequency splitting, and assume that the observed modes are indeed $l = 1$, we have an inferred rotation period of 0.93 days.

Finally, this star presents us with a striking example of nonlinear behavior in the form of sums and differences of the dominant power. A portion of the frequencies that represent sums of the dominant frequencies are indicated in the figure. It is unclear, at present, if the sums and differences represent parametric resonances and mode coupling, or are pulse-shape artifacts, or some combination of both. Even at this preliminary stage in the analysis it is interesting to note that the sums are dominated by the mode labelled 17, even though this is *not* the mode with the highest observed amplitude in this data set. The multiplet fine-structure of the sums will provide some clues in this regard.

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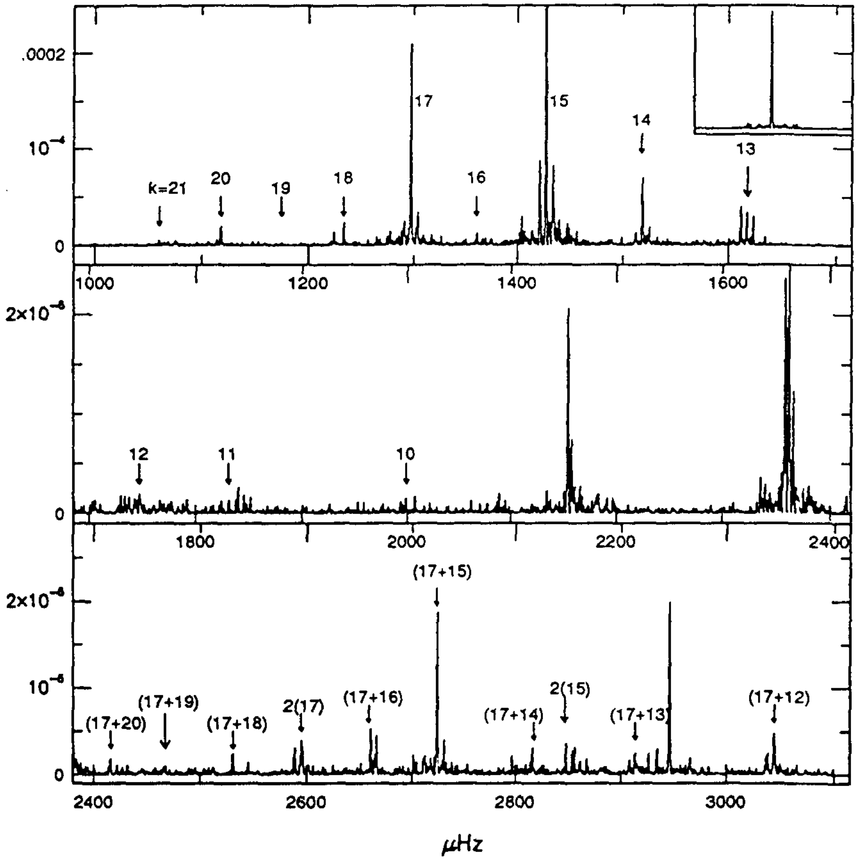

FIGURE 1: A portion of the power spectrum of GD358. Note the different vertical scales in the panels to accomodate the extreme dynamic range. The spectral window is given in the upper corner.

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