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MULTI-SITE OBSERVATIONS OF THE DAV WHITE DWARF R 548

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Abstract. The pulsating DA white dwarf R 548 was observed for 46 h in October 1993 in an eight-site campaign. New peaks near the known doublets in the Fourier transform are found.

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1. Introduction

R 548 or WD 0133-116 is one the brightest and hottest pulsating DA white dwarfs, a prototype of the ZZ Ceti stars. It was discovered to be variable by Lasker & Hesser (1971), who found two pulsation periods near 213 s and 274 s. The amplitude of the two peaks varied from night to night, and Robinson, Nather & McGraw (1976) showed that each pulsation found by Lasker & Hesser was actually an unresolved pair of pulsations, with components separated by about 0.5 s in period.

Stover et al. (1977, 1980) studied the stability of the pulsations and derived upper limits on the rate of period change for all four periods. Its study is extremely important, as in company with G 117-B15A (Kepler et al. 1995) and L 19-2 (O'Donoghue and Warner 1987), R 548 completes the set of white dwarfs for which there are measured limits on the rate of evolutionary changes. Tomaney (1987) obtained upper limits for the rates of period change for each of the 4 known pulsations in R 548, all with $|\dot{P}| < 3 \times 10^{-13}$ s/s. His results showed that different periods in this star seem to have different dP/dt values, implying that in addition to secular cooling, there are other effects involved, such as magnetic field cycles.

The DAV stars are non-radial g-mode pulsators (Kepler 1984), where the pulsation may be characterized by sets of 3 indices (ℓ, m, k). The first 2 indices specify the order of the spherical harmonic, $Y^l_m(\theta, \phi)$, which describe the angular displacements of the plasma and the temperature distribution, over the surface of the star. The k index is the number of nodes in the displacement in the radial direction.

If the star is spherically symmetric, with no rotation and no magnetic fields, the frequencies of the pulsations depend only on k and ℓ, but not on m. Therefore, the modes with the $(2\ell+1)$ possible values of m have all the same degenerate frequency. Either rotation (e.g. Brassard et. al. 1989), or magnetic fields (Jones et. al. 1989) break the spherical symmetry of the star, and therefore lift the degeneracy of pulsation modes, and the frequency of each mode depends also on m. For slow rotation, a mode with latitudinal index ℓ is split into $(2\ell+1)$ equally spaced modes. For slow rotation, as observed in most white dwarfs, all modes with same ℓ should have roughly the same splitting. If the star presents differential rotation though, even modes with same ℓ do not show the same splitting (Winget et al. 1994). If weak magnetic fields are present, the frequency correction term depends only on m^2, and $(\ell+1)$ modes arise.

The detection of only two pairs of pulsations in R 548 presents a difficulty with the theory of rotational splitting, which predicts $(2\ell+1)$ observable modes, an odd number, unless some members of a multiplet are not excited to observable amplitudes by non-linear effects (Buchler, Goupil & Serre 1995). Alternatively, inclination effects can reduce the amplitude of a component (Pesnell 1985), as observed for example in G 226-29, whose central component of the triplet is significantly smaller (Kepler et al. 1995). However, doublets are predicted for fine structure splitting of $\ell = 1$ modes by weak magnetic fields. An upper limit on the magnetic field of $B \leq 10^5$ G was derived from the splitting of the pulsations of R 548 by Jones et al. (1989). However, this value is one order of magnitude larger than the null result of $B = (-0.3 \pm 15.6) \times 10^3$ G by Schmidt & Smith (1995).

2. Observations

A total of 46 hr of usable time series optical photometry was obtained from 8 observing sites in Oct 1993. The data were obtained in un-filtered light to maximize the photon counting, as Robinson et al. (1982) demonstrated specifically for R 548 that non-radial g-mode pulsations are only temperature variations and therefore are in phase at all wavelengths. Two-star photometers were used at all sites, enabling the atmospheric extinction to be monitored. We note that this is not an official WET campaign, even though many of the sites traditionally used by WET network participated. The main difference was the elimination of coordination by a headquarters site, and the data were not reduced on-line.

The following telescopes participated in the campaign:

- 1.6 m, Observatório do Pico dos Dias, Itajubá, Brazil
- 0.90 m, McDonald Observatory, Texas, U.S.A.
- 0.60 m, Mauna Kea, Hawaii, U.S.A.
- 1.0 m, Mt. John Observatory, New Zealand
- 1.0 m, Siding Spring, Australia
- 1.0 m, Kavalur, India

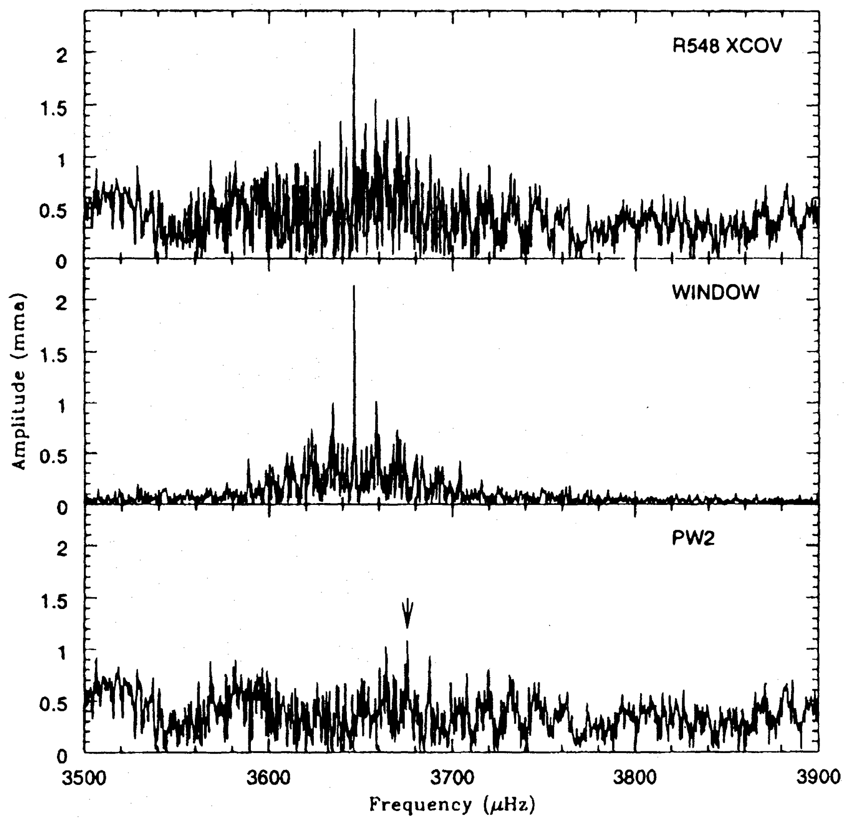

Fig. 1. The amplitude spectra of the total light curve of R 548, for the region of the 274 s doublet. The upper panel is the Fourier transform of the data. The second panel (WINDOW) is the spectral window, i.e., the transform of a noiseless sine-curve. The third panel (PW2) is the Fourier transform after removing (pre-whitening) the known doublet at $P = 274.25$ s, $Amp = 2.17$ mma and $P = 274.77$ s, $Amp = 1.32$ mma. The largest peak left is at $P = 272.04$ s, $Amp = 1.09$ mma. This peak is only at 2 $<A>$, but it has the same window structure as the other peaks.

– 1.0 m, Assy-Turgen Observatory, Kazakhstan
– 0.75 m, SAAO, South Africa.

We reduced and analyzed the data as described in Nather et al. (1990) and Kepler (1993), bringing all the data to the same fractional amplitude scale and the times to the uniform Barycentric Julian Dynamical Date (BJDD) scale. We computed the Fourier transforms of each individual light curve, always detecting the pulsations at 213 s and 274 s. We next constructed a Fourier transform of the total data set.

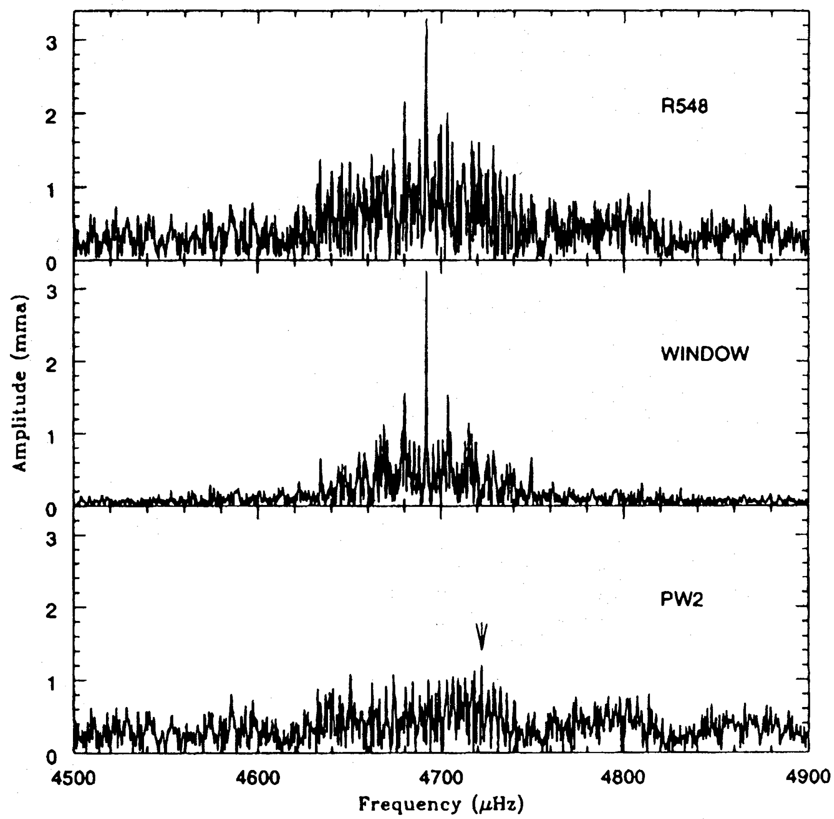

Fig. 2. The amplitude transform of the total light curve of R 548, for the region of the 213 s doublet. The upper panel is the Fourier transform of the data. The second panel (WINDOW) is the spectral window. The third panel (PW2) is the Fourier transform after removing (pre-whitening) the known doublet at $P = 213.13$ s, $Amp = 3.30$ mma and $P = 212.76$ s, $Amp = 2.06$ mma. The largest peak left is at $P = 211.76$ s, $Amp = 1.20$ mma, but this peak is less than $2 <A>$.

3. Analysis

The two known doublets are clearly seen in our data, but there is extra power left after we subtract the two doublets from our data, as seen in Figs. 1 and 2. Unfortunately these peaks are below the False Alarm Probability of 1/1000 (corresponding to 4 <A> in our plots), where <A> is the average amplitude in the Fourier transform (Kepler 1993). They might therefore be due to noise. But, at least for the peak at 272.04 s, the spectral window structure is clearly seen above the noise, raising the probability that the peak is real. As for G 117-B15A (Kepler et al. 1995), if these newly discovered peaks are real, they do not follow the theoretical predictions for rotational or magnetic splitting. In addition to the two known pairs of pulsations, the Fourier transform of the *total* data set shows indications for the existence of other small amplitude pulsations around 333 s, 320 s and 187 s. All have amplitudes around 1 mma. As the number of measurable parameters of the stellar structure is directly proportional to the number of detectable periodicities, it is crucial to measure the periods for these extra oscillation modes accurately.

Finally, we still need to measure the phases accurately for our data set, but our preliminary analysis shows that each mode has a different $\dot{P}$, and all have $|\dot{P}| < 2 \times 10^{-13}$ s/s.

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