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Letter to the Editor

A new pulsating PG 1159 white dwarf: RXJ 2117.1+3412

G. Vauclair [1], J.A. Belmonte [2], B. Pfeiffer [1], M. Chevreton [3], N. Dolez [1], C. Motch [4,5], K. Werner [6], and M.W. Pakull [5,7]

[1] Observatoire Midi-Pyrénées, Laboratoire d'Astrophysique CNRS/URA 285, 14 avenue Edouard Belin, F-31400 Toulouse, France
[2] Instituto de Astrofisica de Canarias, E-38200 La Laguna, Tenerife, Spain
[3] Observatoire de Paris-Meudon, DAEC, F-92195 Meudon, France
[4] Max-Planck-Institut für Extraterrestrische Physik, W-8046 Garching bei München, Federal Republic of Germany
[5] Observatoire de Strasbourg, 11, rue de l'Université, F-67000 Strasbourg, France
[6] Institut für Theoretische Physik und Sternwarte der Universität Kiel, Olshausenstr. 40, W-2300 Kiel, Federal Republic of Germany
[7] Landessternwarte Heidelberg, Königstuhl, W-6900 Heidelberg 1, Federal Republic of Germany

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Abstract. RXJ2117.1+3412 is a newly spectroscopically identified bright PG1159 star discovered in the ROSAT XRT sky survey. We report in this Letter the results of rapid photometry observations performed at the 2.5m Nordic Optical Telescope, on 1992 August 23-27. RXJ2117.1+3412 is a low amplitude multiperiodic pulsator. The analysis of 28 h of rapid photometry reveals that the light curve contains at least 24 frequencies. The power spectrum is dominated by a 5 mmag amplitude pulsation of 821 s period. Other modes are found in a wide range of periods: 246 s - 3150 s. A test on the period distribution indicates two mean period spacings at 20.48 s and 12.61 s which, when interpreted as the expected period spacings in the asymptotic limit for g-modes of degree $\ell = 1$ and $\ell = 2$, lead to a mass of 0.62 $M_\odot$ and 0.58 $M_\odot$ respectively.

Key Words: white dwarfs, Stars: oscillations, variables

1. Introduction

Asteroseismology of pulsating white dwarfs offers a unique opportunity to test their internal structure and check current ideas on stellar evolution. However our knowledge relies on a relatively sparse sample of variable white dwarfs: 24 DAV (ZZ Ceti), 7 DBV, 6 DOV (GW Vir) and PNNV (Planetary Nebulae Nuclei Variable). Recently, some newly discovered PNNV have been added to the only two previously known cases K1-16 (Grauer and Bond 1984) and Lo-4 (Bond and Meakes 1990) which were of PG1159 type: NGC1501, NGC2371,NGC6905 and Sanduleak 3 (Bond 1992). The DOV variable hot white dwarfs (or pre-white dwarfs) form then the rarest type of pulsating degenerate stars with only four known members: PG1159-035 (McGraw et al. 1979), PG0122+200 (Bond & Grauer 1987), PG1707+427 and PG2131+066 (Bond et al. 1984). They share with the PNNV the challenging properties that among stars of similar astrophysical parameters (effective temperature, gravity, abundances) some pulsate while some other do not. Among the PG1159 stars, the variable PG1707+427 and the non- variable PG1424+535 are undistinguishable as far as atmospheric parameters and abundances are concerned; the same is true for the pair of similar stars PG1159-035, the prototype of this class of pulsating white dwarfs, and the non-variable PG1520+525 (Werner et al. 1991a,b).

New surveys are in progress from which a large number of new white dwarfs are expected, a fraction of them hopefully of PG1159 type. Motch et al. (1992) recently reported the discovery of a new unexpectedly bright PG1159 star in the ROSAT XRT all sky survey: RXJ2117.1+3412. Its spectrum is very similar to the PNNV K1-16 spectrum. From model atmosphere and line profiles fitting, the effective temperature was found to be as high as 150000 K ± 15000 K with a surface gravity log g=5.6-6.3. The surface gravity and the detection of an old highly excited planetary nebula surrounding the X ray source put that object in the class of PNN of PG1159 type. This puts RXJ2117.1+3412 on the hot edge of the PG1159 instability strip and provides constraints on the instability mechanism.

For these reasons, this new PG1159 star was observed in August 1992 with the 2.5m Nordic Optical Telescope. We report in the present Letter our discovery that it is the third PNNV of PG1159-type: it is a low amplitude (5 mmag) multiperiodic pulsator with a dominant period of 821s. In Sect.2 we describe the observations. In Sect.3 we give the results of our analysis and a preliminary interpretation is given in Sect. 4. After a first draft of this letter was written, we learned that the pulsations of RXJ2117.1+3412 had been independently discovered by the Texas group (IAU Circular 5603).

2. Observations

RXJ2117.1+3412 was observed with the 2.5m Nordic Optical Telescope of the Roque de los Muchachos Observatory at La Palma (NOT) between August 23 and August 27, 1992. Table 1 gives the journal of observations. We obtained four runs among the five nights, totalizing almost 28 hours of rapid photometry, the middle night being lost due to thick cirrus. We use the Chevreton 3-channel photometer allowing the simultaneous record of the target star, a comparison star and

Send offprint requests to: G. Vauclair

Table 1. Journal of observations

Date (UT)	Start (UT)	Length (s)
1992 Aug. 23	22:27:00	23400
1992 Aug. 24	20:59:00	27900
1992 Aug. 26	23:17:00	19020
1992 Aug. 27	20:45:00	29400

the sky background. The photometer was used in white light (no filter) with an integration time of 1 s.

3. Data reduction and analysis

The raw data have been reduced according to a currently standard procedure. The sky background is measured at the beginning and at the end of each run in the three channels. These measurements are used to normalize the sky background level in the channels recording the programme star and the comparison star to the channel recording the sky. The sky in then subtracted from the star channels. The data are divided by second order polynomials to suppress the low frequency variations of the sky transparency during the night.

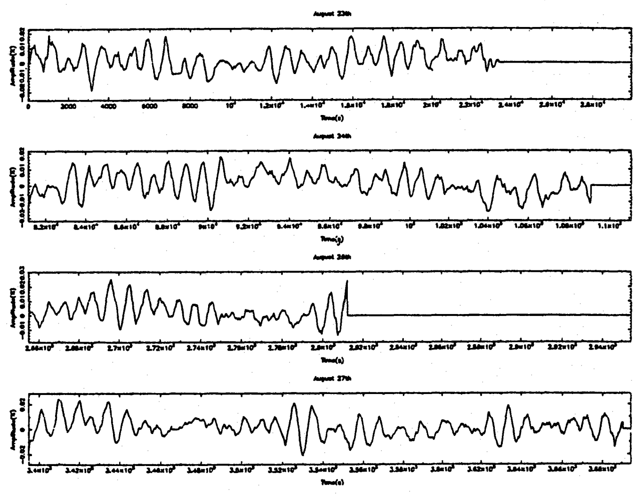

Fig. 1. Light curves of RXJ2117.1+3412 . The normalized amplitude (in percent) is shown as a function of time (in s). Each panel is identified with the date of the run.

The individual normalized light curves, shown in Fig.1, are analyzed using a Fast Fourier Transform (FFT). The FFT of each run is shown in Fig.2. A close inspection of these individual FFT first reveals changes in the amplitudes from night to night. The light curves are dominated during the four runs by a 1.2 mHz frequency of approximately constant amplitude but the amplitudes of lower frequency peaks are strongly varying. However, the frequency distribution seems to be conserved, within the resolution limit of individual runs. Accordingly, we merged the four runs to improve the frequency resolution. The resolution achieved in this way is 2.7 μHz.

The FFT of the merged data is shown in Fig.3. The figure displays the frequency range 0-5 mHz; visual inspection

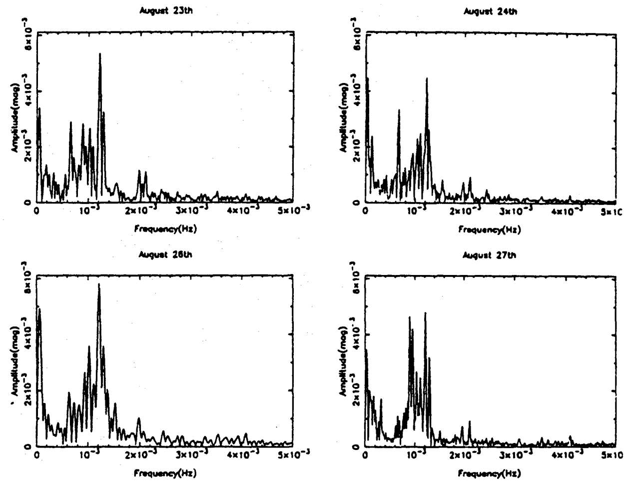

Fig. 2. Fourier spectra. The Fourier spectra of the individual light curves shown in Fig. 1 are displayed. The amplitude in millimagnitude, is shown as a function of frequency (in Hz). The date of each run is indicated at the top of the panels.

of the total FFT does not reveal any significant peak above 5mHz, within the limit of the S/N ratio achieved in these observations. We estimate the noise level to be $2\text{x}10^{-4}$ at about 1.5 mHz and $1\text{x}10^{-4}$ at 5 mHz. However, part of what we interpret as noise in the considered frequency range could well be unresolved structures in the frequency distribution of this pulsator: there seems to be regular behavior in the noise especially between 3 and 4 mHz. In the following we will only consider peaks larger than 2 σ as significant. According to this selection, 24 frequencies are present in the FFT of RXJ2117.1+3412. They are listed in Table 2 together with the amplitudes calculated after reduction of the aliases by the "CLEAN" deconvolution technics (Schwarz 1978; Roberts et al. 1987).

In addition to the "CLEAN" algorithm, the data were analyzed independently using an iterative sine wave fitting (ISWF, Ponman 1981). The results agree remarkably well: among the 19 periods found by CLEAN between 650 μHz and 5000 μHz, 18 are also found with the ISWF procedure. The frequencies agree with a r.m.s. difference of 1.4 μHz, well within the expected resolution.

The remaining five lowest frequency peaks may be uncertain detections. The lowest frequency detected in the FFT at 317 μHz falls in a frequency domain which is usually not considered to be significant because of the abrupt increase of the noise at low frequency due to the incomplete removal of the sky transparency variations. However, this frequency appears unambiguously in the Aug. 23 data and even more evidently in the Aug. 27 data (see Fig.2). Small amplitude peaks in the FFT around the higher amplitude 653 μHz one, seem also to be real. The interval of periods present in that star, from 3150s to 246s is quite large. This situation is not so different from what has been found in PG1159-035 during a WET run (Winget et al. 1991). Its power spectrum shows also some power at low frequency (around 350 μHz as well as at high frequency (around 4000 μHz). These low frequency peaks are listed in Table 2 for completness. However, the total duration of the present observations does not allow to ascertain the ex-

istence of these low frequency modes. Conservatively we will not include them in the following discussion.

4. Interpretation

In order to search for possible mean period spacing, we applied the Kolmogorov-Smirnov (KS) test (Kawaler 1988) to the period distribution listed in Table 2. In doing so, we excluded the longer periods ($P > 1531$ s) whose significance may be doubtful. Fig. 4 shows the result of the KS test as applied to the 19 periods with $P \leq 1531$ s. It is rather noisy but nevertheless, four minima appear significant. The main minimum is at 20.48 s, and the next one at 12.61 s. The two other minima are the harmonics of the 20.48 s, at 10.48 s and 40.9 s respectively. The ratio of the two identified mean period spacings is:

$20.48\ s/12.61\ s = 1.624$

Table 2. Frequencies and amplitudes in RX 2117 + 3412

f(μHz)	P(s)	±s	a (mmag)	f(μHz)	P(s)	±s	a (mmag)
317.4	3150.6	27	0.74	1107.8	902.7	2.2	2.00
402.8	2482.6	17	0.42	1191.7	839.1	1.9	1.60
508.1	1968.1	10	0.36	1217.6	821.3	1.8	4.80
558.1	1790.8	8	0.39	1289.4	775.5	1.6	2.50
605.7	1650.9	7	0.41	1315.3	760.3	1.6	1.10
653.0	1531.4	6	2.30	1362.6	733.9	1.4	0.60
764.4	1308.2	4.6	0.65	1522.8	656.7	1.1	0.63
842.3	1187.2	3.8	0.95	1968.4	508.0	0.7	0.81
889.6	1124.1	3.4	2.20	2108.7	474.2	0.6	0.85
906.4	1103.2	3.3	1.90	2447.5	408.6	0.5	0.32
950.6	1051.9	3.0	2.43	3518.7	284.2	0.2	0.32
1023.8	976.7	2.6	2.34	4066.5	245.9	0.2	0.31

This ratio is close (∼ 6%) to the expected value $\sqrt{3}$, if the minima correspond to $\ell = 1$ (for the minimum at 20.48 s) and $\ell = 2$ (for the 12.61 s minimum), with the $[\ell(\ell+1)]^{1/2}$ scaling expected in the asymptotic limit. The period ratio which is the closest to the expected value for $\ell = 1$ and $\ell = 2$, is:

$\pi_{\ell=1}/\pi_{\ell=2}$ =1.732: 821.3s/474.2s;

This strongly suggests that the largest amplitude mode with period of 821.3 s is a $\ell = 1$ mode, which is consistent with what is expected from a theoretical point of view, while the small amplitude mode at 474.2 s is a $\ell = 2$ mode.

If the mean period spacing derived from the KS test is taken at face value it is possible to derive the mass of RXJ2117.1+3412, using the Winget et al. (1991) interpolation formula. One finds $M/M_\odot$ =0.62 from the mean period spacing $\Delta\pi_{\ell=1} = 20.48$ s, or $M/M_\odot = 0.58$, from the mean period spacing $\Delta\pi_{\ell=2} = 12.61$ s. This preliminary mass determination may be compared to the value derived for PG1159-0.35 (Winget et al. 1991): 0.587 $M_\odot$ from $\ell = 1$ and 0.582 $M_\odot$ from $\ell = 2$. This mass determination is in good agreement with the spectroscopic value of $0.65^{+0.2}_{-0.1} M_\odot$ (Motch et al. 1992); the agreement is even better if one gives more weight to the mass derived from the more significant $\Delta\pi_{\ell=1} = 20.48$s period spacing.

The resolution of the data is not good enough to go further in the detailed identification of the modes or in the determination of other parameters for that star. The complete deciphering of the light curve and identification of the modes in RXJ2117.1+3412 will require data with better time resolution and longitude coverage, as provided for instance by multi-site campaigns of the WET type (Nather et al. 1990; Winget 1992).

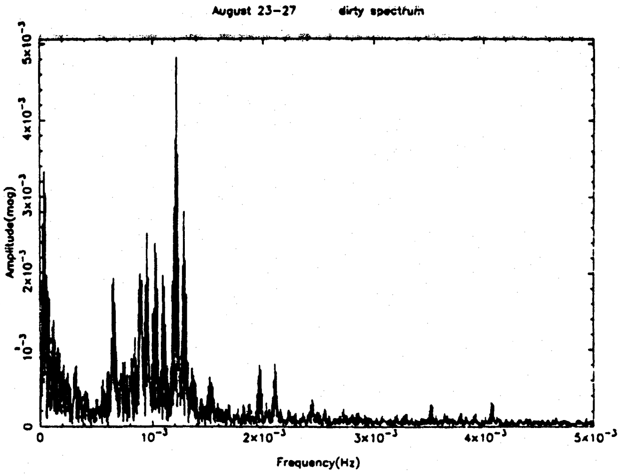

Fig. 3. Fourier spectrum of the merged Aug 23-27 light curves.

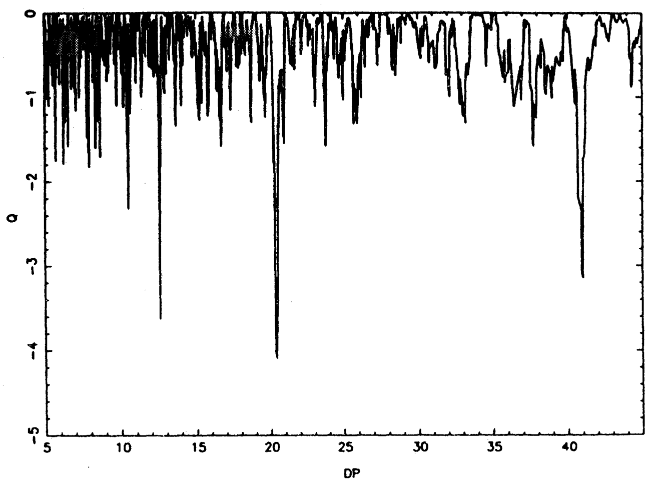

Fig. 4. Kolmogorov-Smirnov test applied to the periods identified in RXJ2117.1+3412 in the range 1531s - 246s

5. Conclusions

The newly identified PG1159 type star RXJ2117.1+3412 is pulsating. The analysis of 28h of rapid photometry obtained

with a 3-channel photometer at the 2.5m Nordic Optical Telescope reveals the star to be a low amplitude multi periodic pulsator. The 2.7 μHz resolution power spectrum of the merged light curve shows 24 frequencies between 317 μHz and 4066 μHz (periods between 3150 s and 246 s). Five low frequency peaks may be uncertain detection. The light curve is dominated by a 821 s mode of 5 mmag amplitude which remained almost constant in amplitude over the duration of the observing run (5 days), while some of the other peaks in the power spectra varied in amplitude. This suggests most probably that the light curve is not resolved. A Kolmogorov-Smirnov test applied to the 19 frequencies of high confidence level reveals two minima at 20.48 s and 12.61 s. Interpreted as mean period spacing for g modes of degree $\ell = 1$ and $\ell = 2$, respectively, this leads to a mass for RXJ2117.1+3412 of 0.62 $M_\odot$ if one uses $\Delta\pi_{\ell=1} = 20.48$ s, or 0.58 $M_\odot$ if one uses $\Delta\pi_{\ell=2} = 12.61$ s. The average mass (0.60 $M_\odot$), is very close to the 0.586 $M_\odot$ derived for PG1159-035 and is in good agreement with the spectroscopically derived value of 0.65$M_\odot$ (Motch et al. 1992).

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