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LETTER

Letter to the Editor

A pulsation episode from the sdB star PG 0856+121

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Abstract. Within the framework of a large campaign of observations of hot subdwarf stars, periodic light variations at 2.3 mHz and 3.2 mHz have been detected in the B hot subdwarf star PG 0856+121 at a $\geq 8\sigma$ confidence level. Their amplitudes are of 3.0 and 3.5 mmag, respectively.

Key words: stars: variables: general – stars: subdwarfs – stars: oscillations – stars: individual: PG0856+121 – techniques: photometric

1. Introduction

The hot subdwarf B (sdB) stars are low-mass stars ($\sim 0.5 M_{\odot}$) located near the extreme horizontal branch (Heber et al., 1984; Heber, 1986). Their helium (He) core, feeding the 3α-cycle nuclear fusion, is surrounded by a thin hydrogen (H) envelope ($M \leq 0.02$ $M_{\odot}$). Following spectroscopic and photometric studies several classification schemes can be found for the hot sds in general. According to Moehler et al. (1990b), the sdBs are He-poor stars which display optical spectra dominated by strong broad Balmer lines and weak, or absent, HeI absorption. A compilation of about 1200 hot sds can be found in Kilkenny et al. (1988). The hot subdwarfs represent in an emphasized way the classical horizontal branch problem, namely: how can a red giant of a given mass lose a substantial fraction of its H-rich envelope at or soon after the He ignition in its core? (Jeffery and Pollacco 1998). In the course of their evolution, a fraction of the hot sds is expected to form white dwarf (WD) stars with lower than average masses (Heber, 1986). Hence, a study of such stars is extremely important from an evolutionary point of view. The discovery that 13 sdB stars pulsate (O'Donoghue et al. 1999) has rapidly increased the interest of the astronomical community for these objects, since their interior can now be probed by seismological investigation. At about the same time of their discovery, investigations of the pulsational instability of the sdB stars were reported by Charpinet et al. (1996), the pulsation driving mechanism being due to an opacity bump associated with iron ionization. The observational properties of the sdB pulsating stars (called EC 14026 stars from the prototype EC 14026-2647, Kilkenny et al. 1997) are the following: periods between about 1 and 10 min, amplitudes between a few millimag to a few hundredths of mag. In addition at least 5 of them out of 13 are in binary systems (O'Donoghue et al. 1999). This percentage is not far from the 40-50$\%$ binarity rate for the hot subdwarf population (Ulla and Thejll 1998 and references therein); therefore it is unlikely, but not impossible, that binary companions play a direct role in the sdB pulsations. The oscillation properties of sdB models, now rapidly growing (Charpinet et al. 1997; Fontaine et al. 1998; O'Donoghue et al. 1998) predict that both radial and nonradial modes should have about same frequencies. It is possible, in principle, to distinguish between radial and nonradial modes: nonradial modes are affected by stellar rotation (they produce multiplets of almost equally spaced frequencies), whereas radial modes are not. The seismological investigation of the sdB stars could permit us to learn important details about their inner structure and chemical composition, as has been successfully done for several WD and pre-WD stars (Bradley 1998). Moreover, with long term measurements (months-years), we can hope to detect the variation of the pulsation period with time, which is directly related to the evolutionary changes of stellar structure.

Within the framework of our monitoring program of a hundred hot subdwarfs, in order to find eventual periodicities, in this letter we will present the results obtained for the sdB star PG 0856+121 (α_{2000} = $08^{\rm h}$ $59^{\rm m}$ $02.723^{\rm s}$; δ_{2000} = $+11^{\circ}$ $56'$ $24.73''$ by Colin et al. 1994). PG 0856+121 was classified as a typical sdB star by Moehler et al. (1990a) on the basis of its spectrum. The star does not show evidence of binarity, such as the IR CaII triplet and photometric red excess (Jeffery and Pollacco 1998). Moreover the H_{α} radial velocity is constant (Saffer et al. 1998) and the significance of the IR excess found for this object in the JHK bands by Ulla and Thejll (1998) does not reach a 2σ level

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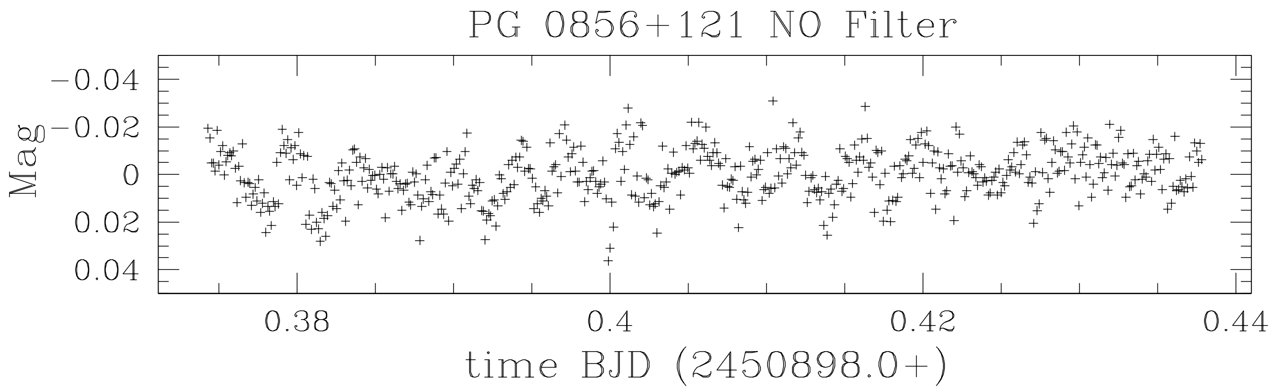

Fig. 1. Light curve of PG 0856+121 during the run of 26th March 1998.

for all the three bands. The Strömgren photometry performed by Moehler et al. (1990a) gave $y = 13.473 \pm 0.012$, $b - y = -0.095 \pm 0.04$, $m_1 = 0.094 \pm 0.005$, $c_1 = 0.035 \pm 0.007$. Wesemael et al. (1992) found photometric values in fairly good accordance with those obtained by Moehler et al. (1990a). Moehler et al. (1990b), from spectroscopy and photometry, derived $\log g = 5.1$, $T_{\rm eff} = 23\,800$K, $d = 990 \pm 370$ pc and $z = 550 \pm 210$ pc (distance from the galactic plane). Saffer et al. (1994) from optical spectrophotometry found fairly different values for temperature ($T_{\rm eff} = 26\,400$K) and surface gravity ($\log g = 5.73$). This fact renders evident the difficulty in determining the temperature of such stars using colour indices, independently of the photometric system used, since the central wavelength of the filters employed lies in the red-wing of the Planckian distribution, as also pointed out by Wesemael et al. (1992).

2. Observations

Our observational program on hot subdwarf stars, which constitutes the bulk of the Thesis of Galleti (1998), was started on November 8, 1997 at the Loiano Observatory with the G.D. Cassini 1.52 m telescope. A new version (Piccioni et al. 1999) of the two-heads fast photoelectric photometer - originally described by Piccioni et al. (1979) - has been used in the Cassegrain focus. This instrument allows simultaneous measurements of the target and a comparison star with the photon counting technique in one of the three available UBV colours or without filter. The log of observations is reported in Table 1. The measurements were performed with a sampling time of 1 s and without any filter. The sky background was measured with both photometric heads at the beginning and at the end of each run.

Table 1. Log of observations

Date	UT Start	UT End
26th March 1998	20h 53m 49s	22h 25m 24s
27th March 1998	21h 10m 01s	22h 50m 16s
14th April 1998	20h 17m 31s	21h 20m 09s
18th December 1998	00h 42m 22s	04h 53m 32s
22th December 1998	02h 10m 28s	04h 51m 33s

3. Data reduction and analysis

A first spectral analysis of the whole data set yielded no significant results at frequencies higher than 50 mHz. Then the data sets were rebinned at an effective resolution of 10 s and a definitive analysis was performed. The sky background has been removed by means of a linear interpolation between the mean values obtained at the beginning and at the end of each observational run performed around the meridian. We have calculated the magnitudes of the target and comparison stars taking into account the differential extinction. Times have been reduced to the solar system barycenter using the Stumpff (1980) algorithm. As output from the reduction process we obtain a file with the Julian date, the magnitudes of PG 0856+121 and of the comparison star, and the difference of magnitude between the two stars with their errors. Fig. 1 shows the light curve of PG 0856+121 obtained during the run of March 26, 1998, where the light variations are clearly visible.

Fourier spectral analysis was performed by using Deeming (1975) method, modified by Kurtz (1985); the results were checked performing a second analysis with Period98 (Sperl 1998). The analysed frequency range spans from 0 to 50 mHz. The noise mean power was computed in the range 1-15 mHz by using Kepler (1993) formula. This produces an overestimation of the noise mean power (MP) as in this range there are the most prominent features of the power spectrum. Our criterion for acceptance states that a feature in the Fourier power spectrum is considered *true* if greater than five times the mean power value. Taking into account the overestimation of the noise mean power, this criterion is even more restrictive.

Fig. 2 shows the power spectra of PG0856+121 (difference of magnitude) of the following runs: **a** 26th March 1998; **b** 27th March 1998; **c** sum of 26th and 27th March 1998. In the power spectra of March 26th two peaks are present at 2.3 and 3.2 mHz with a resolution of 0.2 mHz. Their values in power and the corresponding statistical significances are 3.0 mmag at 8σ and 3.5 mmag at 10.5σ, respectively. The same periodicities, but with a lower resolution because of the shorter length of the run, have been found in the night of April 14, 1998. These frequencies are not evident in the two runs of December

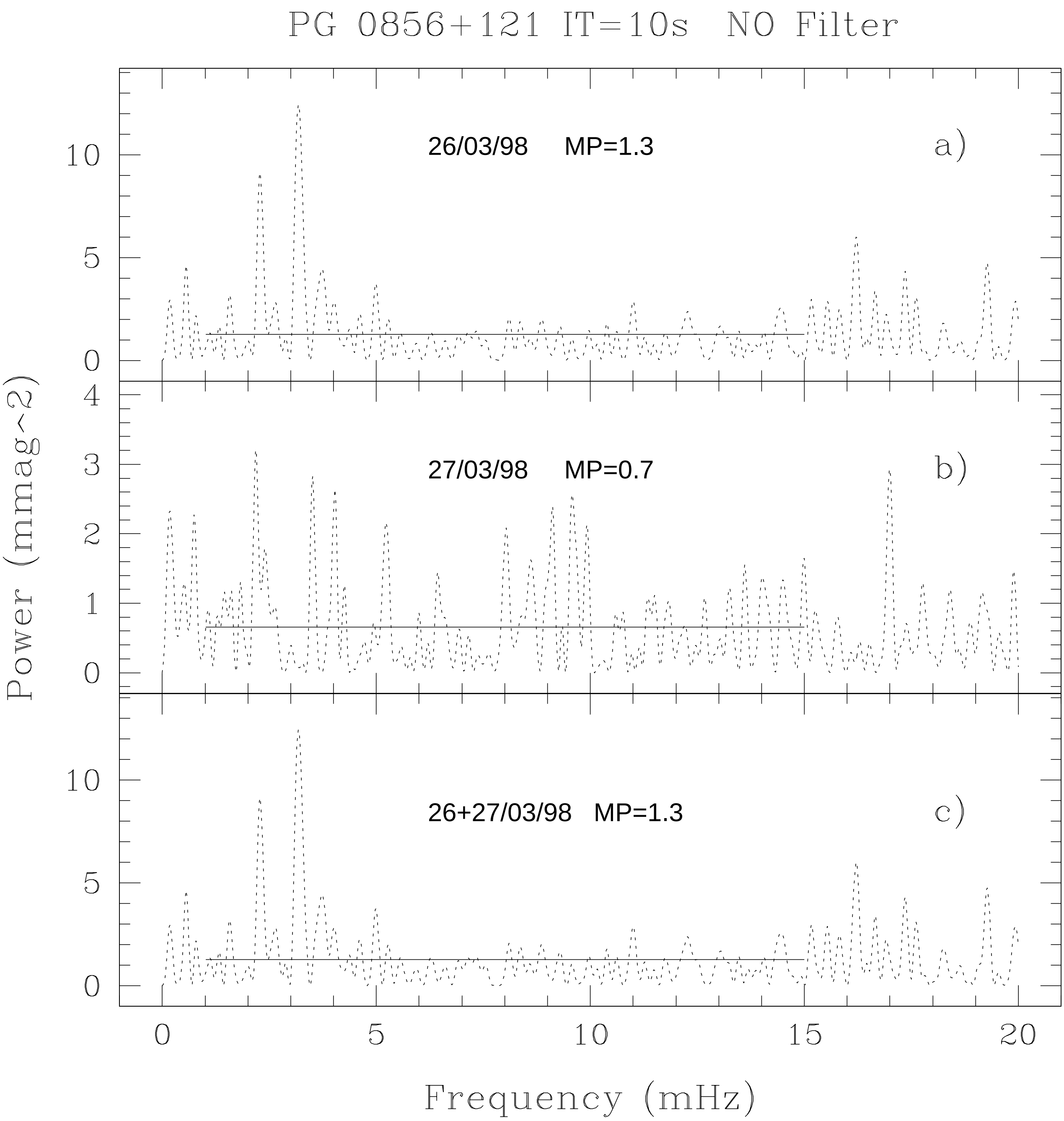

Fig. 2a – c. Power spectra of the difference of magnitude of the two stars: **a** the run of 26th March 1998; **b** the run of 27th March 1998; **c** sum of the runs of 26th and 27th March 1998.

1998. A thorough analysis of the contemporaneous observations performed on the comparison star and of all data collected in the frame of our observational campaign allows us to exclude any artifact corresponding to these pulsations; only one time we found a significant periodicity of 0.5 Hz, due both to a worn joint connecting the step motor to the right ascension gear box and to an incorrect positioning of the target star near the diaphragm border; also the CCD autoguide system, repeating the pointing corrections with a period of about 15 s, cannot introduce such a so low frequency characteristics in the power spectrum; therefore, considering these frequencies as real, foldings of rebinned data modulo 2.292 and 3.171 mHz respectively have been constructed with pre-whitening by the other period and without. The results were non significantly different, so non pre-whitened foldings have been preferred (although more noisy) because obtained directly from data without any mathematical handling. They have been reported in Fig. 3. Each dot represents the mean of all measurements included inside a 0.05 phase interval and it corresponds to about 270 original measure points performed with 1 s sampling time.

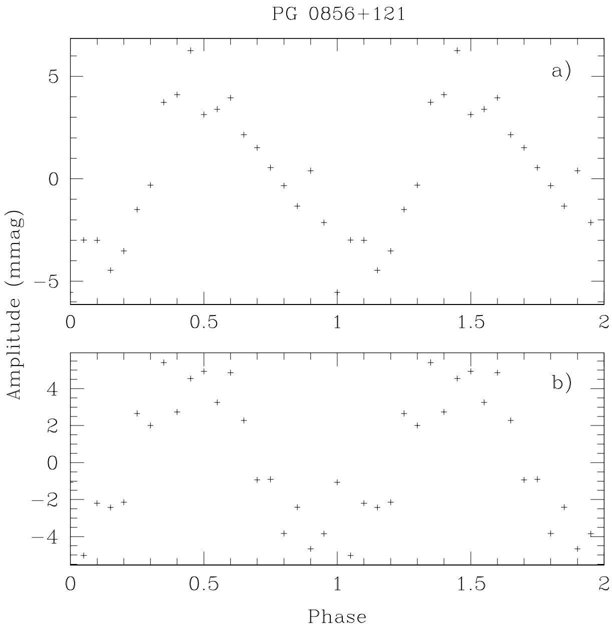

Fig. 3a and b. Foldings of PG 0856+121 data in the night 26th March 1998, performed without any pre-whitening: **a** modulo 436.30 s; **b** modulo 315.36 s. Each point of the two graphs represents the mean value obtained inside a 0.05 phase interval and is obtained from about 270 1s samples

4. Discussion and conclusions

It is apparent that we got PG 0856+121 during a pulsation phase. Pulsations in the same frequency range, although with a lower resolution, were found also during the short run of April 14, 1998, but they were absent or under the detection threshold in December 1998. At the moment we are not able to recognize the nature of these pulsations,and in particular to confirm their stability; however the values of the pulsation periods and amplitudes suggest that PG 0856+121 could be a new member of the pulsating EC14026-type stars. Further observations are needed to confirm this thesis.

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