Baltic Astronomy, vol. 15, 251–254, 2006.

TIME-SERIES SPECTROSCOPY AND PHOTOMETRY OF PG 1219+534

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Received 2005 August 1

Abstract. We present a preliminary report of time-series spectroscopic data obtained on a sdB star PG 1219+534. An analysis of three years of photometric observations is also included.

Key words: stars: hot subdwarfs – stars: oscillations – stars: individual (PG 1219+534)

1. INTRODUCTION

In order for asteroseismology to determine the structure and evolution of subdwarf B stars, we must first determine their modes of pulsation using spherical harmonics. Although time-series photometry is sufficient to detect frequencies of pulsation, time-series spectroscopy shows more promise for uniquely determining modes of pulsation (O'Toole et al. 2000; Telting & Østensen 2004). Spectroscopy is particularly sensitive to higher ℓ-modes which have lower photometric amplitudes. This is because the surface cancelation that affects photometry does not have the same affect on spectroscopy, which focuses on velocity and line-profile measurements.

The sdB star PG 1219+534 (hereafter PG 1219) is an ideal candidate for simultaneous time-series spectroscopy and photometry. Since PG 1219 was discovered to be an sdB pulsator (Koen et al. 1999), its log g and T have been constrained (Heber et al. 2000), and its pulsation spectrum has been studied (Charpinet et al. 2005). Unlike other sdB pulsators, photometry has revealed a simple pulsation spectrum of four stable frequencies with occasional low-amplitude interlopers. As long as the pulsations are not all the same mode (which is highly unlikely), PG 1219 should serve as a baseline to understand the relationship between time-series spectroscopy and models. Then other similar, but more complicated stars may be understood as well.

2. PHOTOMETRY

Photometric data of PG 1219 has been collected during 2003, 2004 and 2005 (Reed et al. 2005). Dates of observations are shown in Table 1. Although most observations were conducted at Baker Observatory, some were also done at Mc-

Table 1. List of observations of PG 1219.

Year	Inclusive dates	Hours observed
2003	May 13 – June 4	48.6
2004	March 9 – 15	21.5
2005	February 25 – March 2	23.8

Table 2. Periods, frequencies, and amplitudes of PG 1219 over three years. Formal least-squares errors in parenthesis.

Period (s)	Frequency (μHz)	Amplitudes (mma)		
		2003	2004	2005
122.4165(26)	8168.832(174)	–	1.24(22)	–
128.0775(5)	7807.754(9)	5.13(11)	7.35(22)	9.78(37)
133.5106(2)	7490.037(10)	4.36(11)	5.66(22)	6.81(37)
135.1614(54)	7398.558(298)	–	0.72(22)	–
143.6495(1)	6961.386(7)	6.48(11)	6.62(22)	7.11(37)
148.7761(3)	6721.508(14)	3.34(11)	3.93(22)	2.22(37)

Donald Observatory in 2003. Images were taken with a red cutoff filter. The list of periods, frequencies and amplitudes of each year are provided in Table 2 and the Fourier transform (FT) of each year is shown in Fig. 1.

Pulsations were detected in PG 1219 over the range of 122 to 149 seconds. There are four stable frequencies in all three years whose amplitudes vary from year to year as seen in both Table 2 and Figure 1. The frequency that has the highest amplitude varies as well. Two low-amplitude frequencies appeared in 2004 that were not detected in the 2003 or 2005 data. These frequencies were not prewhitened in Fig. 1 and they are indicated by the arrows. In the prewhitened FT of 2003 (Fig. 1), the residual signal near 7490 μHz is due to short-term amplitude variations of that pulsation frequency within that data set. The lower amplitude of this same residual peak in 2004 is due to the shorter length of the 2004 run than the 2003 run.

3. SPECTROSCOPY

Spectroscopic observations of PG 1219 were obtained at the Mayall 4 m telescope at Kitt Peak National Observatory. Although four nights were requested and granted, both weather and telescope mirror support problems led to observing only on 2005 February 24 for a duration of 1.5 hours and a total of 154 spectra. Images were taken with the F3KB blue sensitive CCD camera, RC spectrograph and KPC007 dispersion grating at a spectral resolution $\sim$2.5 Å and a wavelength range of $\sim$3400 to 5500 Å. Exposure times ranged from 15 to 20 s for a duty cycle of 28 to 34 s, respectively, providing at least four measurements per pulsation period.

The length of the run gives a pulsation resolution of 187.5 μHz, which is just barely enough to resolve the pulsations in PG 1219. Velocities were derived by cross correlating individual spectra with the mean spectra with the IRAF task *fxcor*,

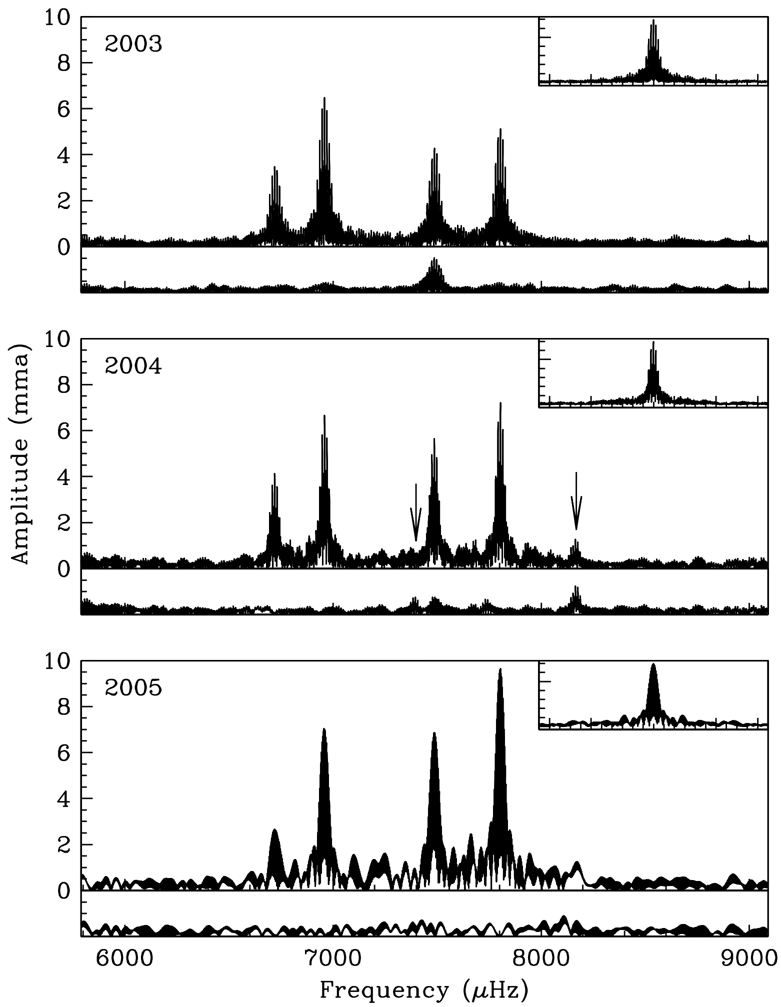

Fig. 1. The temporal pulsation spectra (FTs) for PG 1219 for three consecutive years. Each set prewhitened by four frequencies is shown below the FT. The window function for each year is shown in the inset of each panel. Arrows indicate the two low amplitude interlopers in 2004, which were not prewhitened.

then a Fourier transform was calculated for the velocities. Fourier transforms are sensitive to coherent signals while noise cancels out when many spectra are collected over a long time span. It follows that the noise level of the FT is still too high to detect any modes clearly, as there were too few measurements in this ill-fated short run. So even though the highest peak in the FT of the velocity curve (shown in Figure 2) corresponds to the highest amplitude photometric frequency, peaks of this amplitude were easily reproducible in a randomized dataset. Hence, our detection of this peak was not significant.

We still reach the conclusion that time-series spectroscopy on PG 1219 and similar stars is feasible using this instrumentation. The spectral resolution and

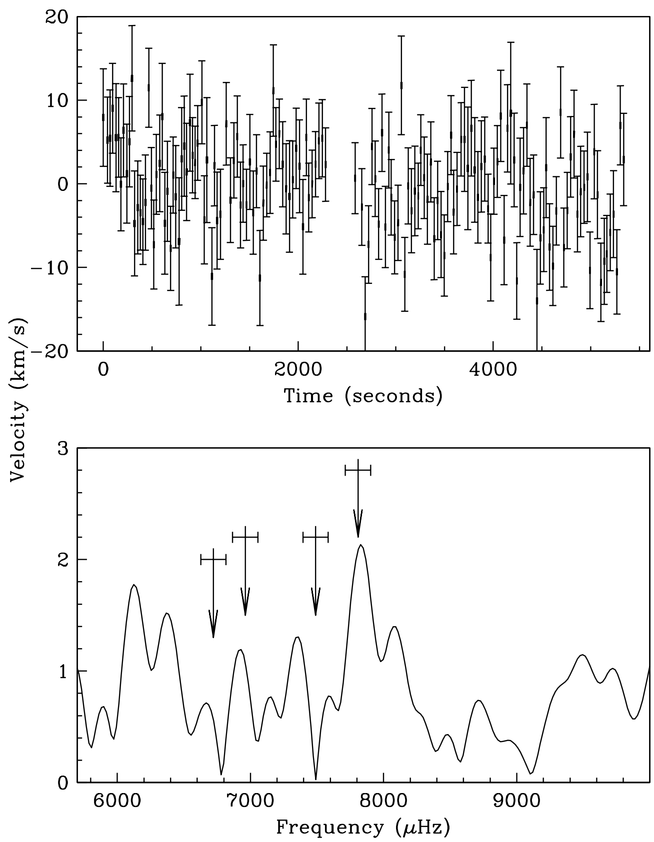

Fig. 2. Top panel: the velocity curve for PG 1219+534. Bottom panel: the Fourier transform of the velocity curve. Arrows indicate photometric frequencies with error bars from the temporal resolution of the spectroscopic data set.

integrations per period were sufficient, so had the run been longer, pulsation velocities could have been measured.

ACKNOWLEDGMENTS. This material is based in part upon work supported by the National Science Foundation under Grant Nos. AST007480 and AST9876655. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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