The Time Dependence of the Phases of the Harmonics Relative to the 1490 sec Fundamental in PG1346+082

J. L. Provencal, J. C. Clemens, G. Henry, B. P. Hine,
R. E. Nather, D. E. Winget*, M. A. Wood
McDonald Observatory and Department of Astronomy
The University of Texas at Austin
U.S.A.

S. O. Kepler
Instituto de Fisica
Universidade Federal do Rio Grande do Sul
Brazil

G. Vauclair, M. Chevreton
Observatoire Midi-Pyrenees et Observatoire de Meudon
France

D. O'Donoghue, B. Warner
Department of Astronomy
University of Cape Town
South Africa

A. D. Grauer
University of Arkansas at Little Rock
U.S.A.

Lilia Ferrario
Australian National University
Australia

INTRODUCTION

White dwarf stars provide important boundary conditions for the understanding of stellar evolution. An adequate understanding of even these simple stars is impossible without detailed knowledge of their interiors. PG1346+082, an interacting binary white dwarf system, provides a unique opportunity to view the interior of one degenerate as it is brought to light in the accretion disk of the second star as the primary strips material from its less massive companion (see Wood *et al.* 1987).

PG1346+082 is a photometric variable with a four magnitude variation over a four to five day quasi-period. A fast Fourier transform (FFT) of the light curve shows a complex, time-dependent structure of harmonics. PG1346+082 exhibits flickering – the signature of mass transfer. The optical spectra of the system contain weak emission features during minimum and broad absorption at all other times. This could be attributed to pressure broadening in the atmosphere of a compact object, or to a combination of pressure broadening and doppler broadening in a disk surrounding the compact accretor. No hydrogen lines are observed and the spectra are dominated by neutral helium. The spectra also display variable asymmetric line profiles.

OBSERVATIONS

Extended coverage photometry (Nather, these proceedings) of the variable star PG1346+082 in March 1988 (coverage given in Table 1) reveals at least 13 distinct periodicities distributed in a narrow band around 1500 s and in a second band around 1300 s. There are two dominant peaks at 1471 s and 1493 s. The fourier transform (FT) of the entire data set demonstrates that both main frequencies are coherent over the run length. Fourier transform analysis of the individual runs shows many cases where the harmonics of both the 1493 s period and the 1471 s period are simultaneously present.

Although we have not yet constructed detailed models of the system, the presence of so many identifiable periodicities suggests that we are observing pulsations at the surface of the accreting white dwarf. This is plausible: the system remained at or near minimum for most of the eighteen days of the run, so the competition from disk

---

* Alfred P. Sloan Fellow

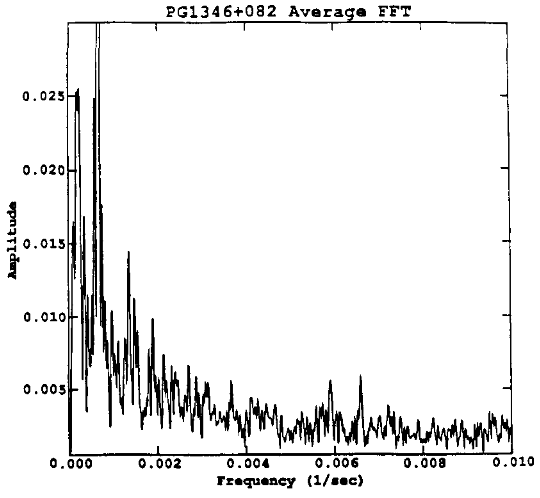

Figure 1 *Average FFT of PG1346+082. This FFT was obtained by averaging the FFTs of runs bph72, s4238 and s4246.*

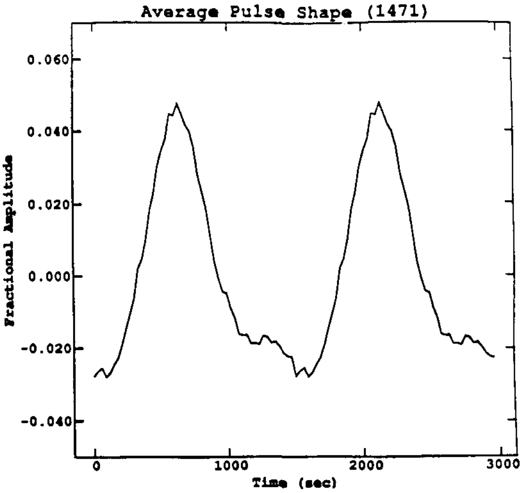

Figure 2 *Average pulse shape of the 1471 second fundamental over the entire data set.*

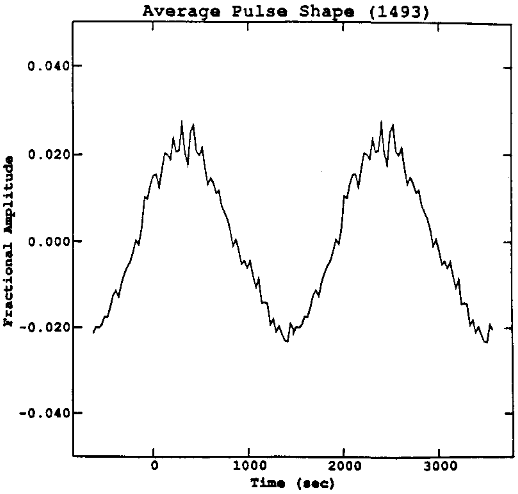

Figure 3 *Average pulse shape of the 1493 second fundamental over the entire data set.*

Table 1
Journal of Observations

Run	Location	Date	Time of Run Start (UT)	Length of Observation (hr)	Integration Time (sec)
ren18	Texas	9 March	6:28:20	1.772	10
ren19	Texas	9 March	8:39:20	1.867	10
ren20	Texas	9 March	11:24:50	0.478	10
a3	Australia	9 March	14:30:00	4.064	10
ren22	Texas	10 March	6:13:20	5.603	10
pg13a	France	10 March	22:57:06	5.173	6
ren24	Texas	11 March	5:47:00	6.067	10
pg13b	France	11 March	24:03:06	4.395	6
tol-0005	Chile	12 March	3:56:00	4.933	10
ren26	Texas	12 March	5:36:10	4.283	10
bph67	Hawaii	12 March	10:57:00	4.333	10
a10	Australia	12 March	13:41:01	4.972	10
s4227	South Africa	12 March	23:08:20	4.067	10
pg13c	France	12 March	23:20:06	5.233	6
tol-0011	Chile	13 March	3:23:00	5.625	10
ren28	Texas	13 March	5:54:08	5.931	10
bph68	Hawaii	13 March	9:18:00	5.967	10
a11	Australia	13 March	13:49:00	4.772	10
pg13d	France	13 March	23:21:06	5.052	6
tol-0017	Chile	14 March	4:10:00	2.658	10
ren29	Texas	14 March	5:24:10	5.514	10
bph69	Hawaii	14 March	8:57:00	0.639	10
a14	Australia	14 March	14:43:01	3.614	10
tol-0022	Chile	15 March	3:16:00	2.375	10
ren31	Texas	15 March	5:23:30	6.289	10
bph70	Hawaii	15 March	8:54:00	6.367	10
a19	Australia	15 March	14:46:00	3.817	10
ren33	Texas	16 March	5:23:30	6.339	10
s4238	South Africa	17 March	22:21:40	4.917	10
ren35	Texas	18 March	5:18:30	6.361	10
bph71	Hawaii	18 March	8:42:00	6.567	10
a23	Australia	18 March	13:24:00	1.211	10
ren37	Texas	19 March	5:19:00	5.502	10
bph72	Hawaii	19 March	8:45:00	6.547	10
maw3	Texas	20 March	4:29:00	7.150	10
bph73	Hawaii	20 March	8:38:00	6.677	10
a26	Australia	20 March	13:15:02	0.689	10
s4246	South Africa	20 March	22:27:20	4.800	10
maw5	Texas	21 March	4:33:52	7.086	10
bph74	Hawaii	21 March	8:41:00	6.483	10
a28	Australia	21 March	14:32:01	3.503	10
s4250	South Africa	21 March	22:54:20	4.550	10
maw7	Texas	22 March	4:17:00	6.558	10
bph75	Hawaii	22 March	8:40:00	6.425	10
maw10	Texas	23 March	4:16:00	7.333	10
bph76	Hawaii	23 March	8:28:00	2.347	10
s4253	South Africa	23 March	0:28:10	2.683	10
maw12	Texas	24 March	4:05:50	7.453	10
maw14	Texas	25 March	4:11:30	7.325	10
s4256	South Africa	25 March	23:40:50	3.367	10
maw16	Texas	26 March	7:37:20	3.892	10

luminosity was small, and the surface temperature of the accretor lies within the instability strip for DB (helium atmosphere) white dwarfs. Other explanations are possible, however, and we will explore them.

FFTs of the individual data sets, see Figure 1, show a remarkable harmonic structure associated with the two dominant frequencies. Significant power is detected out to the 13th harmonic for both of the main peaks. However, the character of the harmonic structure associated with each frequency is different. Although harmonics of both frequencies are present in the FFTs of the individual runs, only the low order harmonics of the 1471 s peak appear in the FT of the entire data set. Thus, the higher order harmonics of the 1471 s period and the entire harmonic structure of the 1493 s peak are not coherent over the 18 day run.

There are three traditional sources for these coherent modulations in a binary system. Assuming the twin degenerate, interacting binary model of Wood *et al.* (1987): the orbit of the pair, the rotation of the accreting white dwarf, and non-radial pulsations in the accreting white dwarf. Obviously, at most only one of the 13 periodiocities can be the orbital period, and its character could well be distinctly different from the others. We determined the average pulse shape of the two dominant frequencies in an attempt to identify the orbital period. The average pulse shape of the 1471s periodicity over the entire run, presented in Figure 2, is definitely not a sine wave. Taken together with the presence of coherent harmonics, this points to the nonlinearity of the pulsation. The combination of a coherent fundamental and coherent lower order harmonics mimics the structure seen in all other DB variables, strongly suggesting g-mode pulsation as its origin. The average pulse shape of the 1493 s period, presented in Figure 3, matches a sine function to within measurement error, and its harmonics are not coherent. The 1493 s period is of comparable amplitude to the 1471 s oscillation, so if the driving mechanisms are similar, the 1493 s pulsation should be nonlinear as well. It is not. In view of these differences, we identify the 1471 s period as an oscillation of the white dwarf and the 1493 s peak as either the orbital period of the system or the rotation period of the accreting white dwarf.

Evidence (discussed in detail in Wood *et al.*) indicates that PG1346+082 is an interacting binary white dwarf system of extreme mass ratio: the mass-losing object is estimated to have only $0.03M\odot$, comparable to the planetary mass assumed in simplified models of the early solar system. Steady state calculations of the tidal interactions of a planet with a disk indicate that the disk would become strongly perturbed in a multi-armed spiral pattern of shocks (Lin and Papaloizou, 1986). These shocks are most evident in the outer regions of the disk. A complex, variable structure of harmonics of the orbital period, such as is seen in PG1346+082, might be envisioned as the natural outcome of such a model. If these assumptions, similar to those proposed by O'Donoghue et al., are correct, the time-evolution of the harmonics of the orbital period could be a valuable probe of the disk structure. It may be possible to map out the density distribution and track mass transfer, as it flows through the disk, through variations in amplitude of one harmonic with respect to the others.

CONCLUSIONS

On the basis of our preliminary analysis of the harmonic structure, we suggest that the 1493 s oscillation is either the orbital period of the system or the rotation period of a magnetized, accreting white dwarf. The 1471 s is most probably a nonradial oscillation of the primary white dwarf since its character mimics that of oscillations seen in single DB variables.

We suggest that the harmonics of the 1493 s period arise in the disk of PG1346+082. Each of the harmonics arise in a different physical location where resonant density enhancements reprocess the radiation from the central object, but whose precise location can vary on the accretion flow.

If this suggestion is correct, PG1346+082 provides us with a unique opportunity to examine the time-dependent changes in the harmonics and thus probe the structure of the disk. Variations in amplitude of one harmonic relative to others could be a valuable probe of density distribution and the flow of mass in the disk. In particular we should be able to follow the large changes in brightness (from magnitude 17.2 to magnitude 13) and in this way and determine its physical origin.

This work was supported by the National Geographic Society, the Able Hanger Foundation, and the National Science Foundation through grants AST 85-52457 and AST 86-00507.

REFERENCES

Lin D. N., and Papaloizou, J. 1986, *Ap. J* **307** 395.

O'Donoghue, D., and Kilkenny, D., *High Speed Spectroscopy and Photometry of the Interaction Binary White Dwarf V803 Cen (AE-1)*, preprint, 1988

Wood, M.A., Winget, D. E., Nather, R. E., Hessman, F. V., Liebert, J., Kurtz, D. W., Wesemael, F., Wegner G., 1987,*Ap. J.* **313**, 757.