PHOTOMETRY AND SPECTROSCOPY OF GAMMA HERCULIS

G.A. Bakos
Department of Physics, University of Waterloo, N2L 3G1 Waterloo,
Ontario, Canada

J. Tremko
Astronomical Institute of the Slovak Academy of Sciences,
Skalnaté Pleso Observatory, 059 60 Tatranská Lomnica, Czecho-Slovakia

Received 2 January 1990

ABSTRACT. Photoelectric photometry of gamma Her has been conducted at both Waterloo and Skalnaté Pleso Observatories between 1982 and 1989 in the B and V spectral bands. The star is suspected to be variable and it is catalogized in New catalogue of suspected variable stars. Small and slow variations in brightness amounting to about 0.05 mag have been observed. A period of 183.6 days has been derived.

The spectroscopic data seem to satisfy a different period of 165.9 days. The discrepancy of the results has been discucced in this paper.

1. INTRODUCTION

The bright star gamma Her = BS 6095 = ADS 10022 has been used as standard star in some photometric systems (Blanco et al., 1966 and citations therein). In addition it was used as standard star for the MK spectral and luminosity classification and its spectral classification is well established (Jaschek et al., 1964 and citations therein). Zinner (1929) suspected its brightness variations and since that time it has the designation Zi 1237. In addition the star was observed sporadically usually for the purpose for including the necessary values into catalogues. The only series of observations lasting one hour was obtained by Breger (1969). The star is catalogized in the New catalogue of suspected variable stars (Kukarkin et al., 1982) under the number 07667. We started with the photoelectric observations in 1982 within the framework of binary star investi-

gations. As the brightness variations appeared already during the first observing season, we continued to observe it over a period of seven years. As a spread in the previous radial velocity data was detected it was decided to observe the star spectroscopically as well.

2. THE OBSERVATIONS

The photoelectric observations were made at the University of Waterloo Observatory with the photoelectric photometer attached to the 0.33 m Cassegrain type telescope, f/16. A cooled EMI 9849B photoelectric multiplier tube and standard colour filters which define the B and V photometric bands were used. The star HD 147647 = SAO 101994 served as a comparison star. For the second comparison star HD 145122 = BS 6013 was chosen. During the final reduction the brightness variability of HD 145122 was detected and thus the brightness constancy of HD 147647 was not proven. The observations were made close to the meridian passage of the star in order to minimize the effect of the differential extinction. As a rule the time interval of observations was less than one hour. Few observations with the same comparison star were obtained in the same photometric bands at Skalnaté Pleso Observatory. The description of the photometer of the Skalnaté Pleso Observatory and its parameters were published in preceeding papers (Horák et al., 1976; Klocok et al., 1986).

During 8 seasons together 95 photoelectric observations in the two photometric bands were obtained. They are listed in the Table 1. The mean error of one observation is $\pm$0.004 mag. Short term variations of the brightness were not detected. Therefore nightly mean values were calculated in order to save the space in the Table 1.

Table 1

Photometric observations

J.D. hel.	ΔV	ΔB	J.D. hel.	ΔV	ΔB
2445134.650	-2.336	-2.107	2445502.647	-2.361	-2.157
5140.683	-2.353	-2.129	5506.647	-2.342	-2.175
5142.653	-2.328	-2.095	5509.651	-2.358	-2.135
5144.669	-2.332	-2.109	5525.593	-2.356	-2.148
5151.614	-2.331	-2.113	5529.618	-2.352	-2.154
5152.626	-2.329	-2.114	5541.585	-2.372	-2.143
5423.837	-2.298	-2.121	5549.575	-2.370	-2.132
5425.867	-2.294	-2.108	5880.650	-2.358	-2.162
5464.765	-2.341	-2.118	5907.590	-2.355	-2.149
5466.751	-2.339	-2.128	6172.804	-2.321	-2.113
5467.728	-2.335	-2.126	6182.796	-2.333	-2.119
5487.688	-2.335	-2.096	6184.788	-2.340	-2.097
5493.678	-2.335	-2.100	6185.776	-2.332	-2.134

Table 1 - Continued

2446189.775	-2.338	-2.148	2446895.829	-2.313	-2.127
6203.735	-2.346	-2.141	6912.781	-2.335	-2.133
6207.717	-2.331	-2.127	6919.762	-2.327	-2.125
6210.710	-2.335	-2.139	6920.757	-2.325	-2.130
6214.697	-2.334	-2.122	6921.754	-2.328	-2.135
6220.681	-2.347	-2.133	6928.747	-2.332	-2.136
6223.687	-2.338	-2.142	6951.679	-2.349	-2.133
6231.654	-2.353	-2.150	6952.690	-2.345	-2.140
6237.649	-2.358	-2.150	6956.674	-2.350	-2.139
6240.636	-2.357	-2.157	6964.644	-2.362	-2.160
6241.642	-2.343	-2.140	6994.612	-2.360	-2.164
6243.650	-2.353	-2.151	6998.633	-2.376	-2.177
6244.629	-2.351	-2.145	7285.756	-2.328	-2.137
6250.607	-2.368	-2.163	7288.751	-2.328	-2.137
6256.585	-2.367	-2.139	7306.715	-2.330	-2.129
6258.592	-2.358	-2.151	7307.706	-2.327	-2.123
6259.597	-2.368	-2.151	7313.679	-2.342	-2.144
6262.589	-2.345	-2.141	7322.671	-2.330	-2.176
6263.588	-2.348	-2.131	7325.671	-2.360	-2.175
6523.889	-2.339	-2.136	7327.706	-2.355	-2.162
6533.833	-2.320	-2.114	7338.617	-2.339	-2.146
6534.826	-2.326	-2.131	7339.618	-2.340	-2.145
6543.799	-2.316	-2.122	7344.606	-2.335	-2.127
6544.803	-2.317	-2.117	7347.606	-2.339	-2.162
6558.758	-2.337	-2.137	7351.604	-2.369	-2.176
6584.689	-2.335	-2.135	7360.608	-2.364	-2.145
6591.693	-2.347	-2.173	7707.624	-2.350	-2.183
6595.664	-2.355	-2.146	7715.607	-2.354	-2.143
6598.681	-2.343	-2.144	7722.604	-2.362	-2.164
6599.658	-2.345	-2.138	7725.607	-2.365	-2.165
6606.667	-2.352	-2.151	7735.621	-2.360	-2.159
6621.632	-2.350	-2.139	7739.590	-2.346	-2.135
6626.615	-2.354	-2.146	7744.589	-2.365	-2.158
6634.588	-2.346	-2.148	7747.582	-2.365	-2.159
6894.824	-2.310	-2.120			

The available spectroscopic data have been collected from various publications. Additional observations have been made at the David Dunlap Observatory (DDO), using the 1.92 m Cassegrain type telescope with the attached spectrograph. The dispersion of these plates is 1.2 nm/mm. The spectrograms have been measured, some repeatedly 2-3 times. Only the hydrogen lines, the K line of calcium and the Mg II line at 448.1 nm were measured. The mean error of the star's velocity is rather large, about ± 7 km s^{-1}. This is partly due to the broad spectral lines, which are broadened by the high rotational velocity that amounts to 152 km s^{-1}.

Table 2

Radial velocity data

J.D.	RV	m.e.	Dispersion nm/mm	Number of measured lines	Source
2419113.00	-39		1.25		2
9150.94	-46		1.25		2
9189.86	-52 (-34)		1.25		2
9213.78	-30		1.25		2
9250	-36		1.25		2
2420708.73	-42 (-41)		5.7		2
1704.992	-29.7	±7.9	3.6		1
1854.620	-48.6		7.0		1
2181.694	-44.2	±8.7	3.6		1
3174.049	-40.2				4
3174.078	-49.3				4
3174.104	-62.0				4
3174.127	-46.2				2
3200.836	-43.5		3.0	17	3
3200.852	-46.0		3.0	17	3
3907.95	-44		3.77		2
4618.90	-49		3.77		2
4620.83	-59		3.77		2
2435281.631	-41.88	±4.10	3.2	6	This paper
5302.582	-35.70	±6.70	3.2	5	-"-
2442886.558	-29.08	±7.34	1.2	4	-"-
2891.533	-38.17	±6.23	1.2	4	-"-
2969.622	-36.80	±2.07	1.2	12	-"-
2976.569	-20.96	±7.48	1.2	4	-"-
3341.650	-10.92	±5.13	1.2	4	-"-
4041.705	-19.39	±6.27	1.2	4	-"-
4279.978	-39.11	±4.43	1.2	4	-"-

Notes: Data in parentheses were obtained by second measurer
Probable error for J.D. 2421704 and J.D. 2422181

These and the other available radial velocities have been listed in the Table 2. Our own data indicate a reasonable good velocity curve, the other velocities appear to be scattered along an imaginary line of -40 km s^{-1}. A period, satisfying the spectroscopic observations is 165.86 days.

3. DISCUSSION

The location of gamma Her in the H-R diagram and possible presence of variable stars in its neighbourhood could shed some light on the variability of

this star. Since its position in the H-R diagram can be established within a certain box errors which is important just around the Hertzsprung gap, where physical parameters of stars change substantially with insignificant change of their position in this diagram. The spectral classification A9 III - F0 III is well established. The absolute magnitude is determined with lower accuracy due to the error in the trigonometric parallax. Breger (1969) has taken $M_V = +0.3$ mag, which locates the star above giant III sequence of stars by about +0.3 mag (Corbally and Garrison, 1984), just close to the region of delta Scuti variables and close to the blue adge of the instability strip. A small percentage of stars in this region show short period and low amplitude variability, but the majority of stars in this region have constant brightness (Breger, 1969).

However this value of the absolute magnitude is lower as the recently published data by Leggett et al. (1986) indicate. According to their investigation gamma Her has a luminosity $(1.1 \pm 1.2) \times 10^2$ of that of the Sun, which transformed to magnitude is $M_V = -0.3$ mag. Thus gamma Her is 0.9 mag. above the stars of luminosity class III. According to Genier et al. (1981) this region is occupied by the group I of delta Scuti stars. There are some doubts on the existence of such bright delta Scuti stars. The absolute visual magnitude of RR Lyrae type stars is in the rande $+0.76 \pm 0.14$, independently on the Fe/H ratio (Hawley et al., 1986) or in the range of $+0.64 \pm 0.01$ (Fernley et al., 1987). Apart from the uncertainity of the absolute magnitude determination, one would expect to find in this region of H-R diagram stars of constant brightness or of short period changes lasting few hours and reaching hundreds or tenths of magnitude. The short term constancy of gamma Her found by Breger (1969) and confirmed by us is more expected as surprising, taking into account the sample of stars in this region of H-R diagram studied by him. One cannot decide whether differences in the spectral class estimates are the uncertainties in the measurements or real changes of the temperature. We have the impression that gamma Her is well above the delta Scuti type and RR Lyrae type stars sequences. This conclusion is based on the results recently obtained by Feinstein et al. (1986), Leggett et al. (1986), Hawley et al. (1986) and Fernley et al. (1987).

Our observations which lasted up to one hour have shown than gamma Her does not change its brightness during such a short interval. Comparing the mean values obtained in successive nights we came to the conclusion that there is not a periodicity in the light changes below 100 days. The precise measurements of brightness which are published in colour and magnitude catalogues cannot be used for the light changes study as the dates of observations usually are not given. The range of brightness changes is 0.05 mag. in V and 0.07 in B as derived from data published in photometric catalogues.

Nevertheless it was possible to derive a photometric period of 183.56 ± 0.01 days from our observations. The value of 122.39 days suits the observations, too. The lenght of both periods is close to harmonics of one year. The photometric and spectroscopic periods were found by a period searching computer program written by Dr. J. Zverko. The power spectrum for photometric observations is presented on Fig. 1. The scatter of the mean light curve is influenced by the variations of seasonal light curves. The spectroscopic period is 165.86 days. New

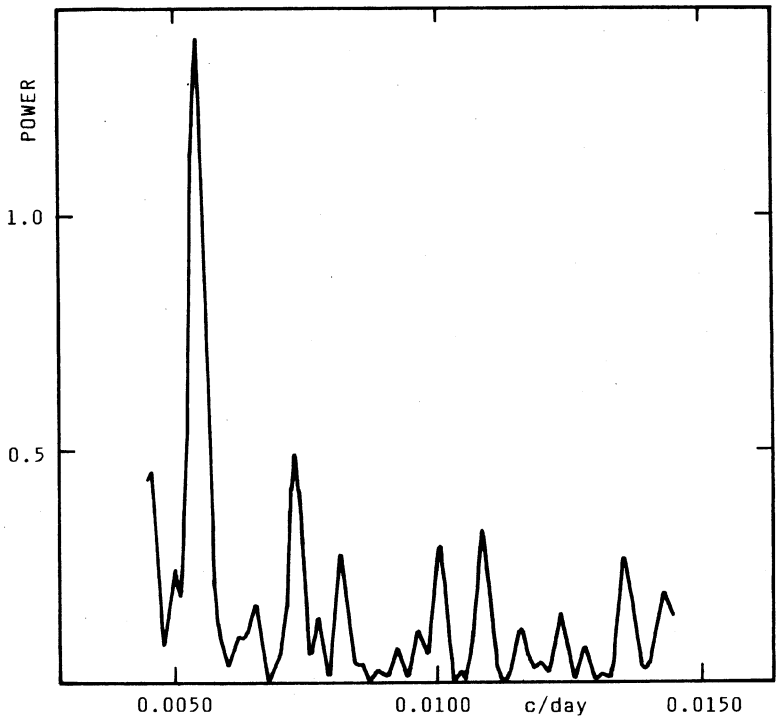

Fig. 1. Power spectrum of gamma Her. Photometric data from Tab. 1.

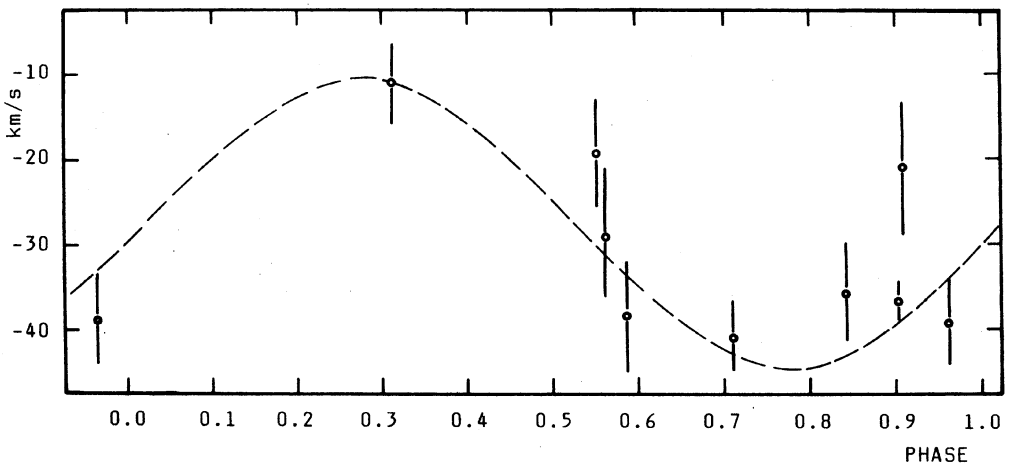

Fig. 2. Radial velocity curve from DDO spectra.

spectroscopic observations are presented on Fig. 2. The spectroscopic period was derived from the spectra obtained at DDO as the early spectroscopic observations have very low accuracy. Considering these results we conclude that the photometric changes are not related to the radial velocity changes. However, one has to keep in mind that the radial velocity curve has the amplitude exceeding approximately 5 sigma only, it is based on not too numerous observations and its maximum is determined by one value of the radial velocity. There are more radial velocity data needed for the proper determination of the radial velocity curve. The radial velocity variations parhaps could be ascribed to a spectroscopically unseen component, which causes the movement of the visible component. The light variability of stars in adjacent region of H-R diagram were studied very scarcely (not counting the studies of delta Scuti type and RR Lyrae type stars.) The study of detecting the microvariability was performed by Breger (1969) and more as two decades ago by Jackisch (1963, 1972). There is not reasonable hypothesis for an explanation of the cause of the light variations of gamma Her now. The observations published here together with some future observations could serve the purpose of solving this problem.

The authors wish to thank Dr. J. Zverko for making available his computing program. Part of this research has been performed, while one of authors (J.T.) has been as a visiting professor at the Department of Physics University of Waterloo on a Bilateral Exchange Program between Czechoslovak Academy of Sciences and National Sciences and Engineering Research Council, Canada. He would like to acknowledge the hospitality given to him at the University of Waterloo.

Sources to the Table 2.

1 Abt, H.A.: 1970, Astrophys. J. Suppl. Ser. 19, 406
2 Campbell, W.W.: 1928, Publ. Lick Obs. 16, 1
3 Harper, W.E.: 1937, Publ. Dominion Astrophys. Obs. 7, 1
4 Henroteau, F.: 1930, Publ. Dominion Obs. Ottawa Vol. VIII, 59

REFERENCES

Abt, H.A.: 1970, Astrophys. J. Suppl. Ser. 19, 406.
Blanco, V.M., Demers, S., Douglas, G.G., Fitzgerald, P.M.: 1968, Publ. US Naval Obs., Second Ser. XXI, p. 498.
Breger, M.: 1969, Astrophys. J. Suppl. Ser. 19, 99.
Burki, G., Meylan, G.: 1986, Astron. Astrophys. 159, 255.
Campbell, W.W.: 1928, Publ. Lick Obs. 16, 1.
Corbally, C.J., S.J., Garrison, R.F.: 1984, in the MK Process and Stellar Classification, Garrison, R.F., Ed., DDO Toronto, Canada, p. 277.
Feinstein, A., Vásquez, R.A., Benvenuto, O.G.: 1986, Astron. Astrophys. 159, 223.
Fernley, J.A., Longmore, A.J., Jameson, R.F., Watson, P.G., Wesselink, T.: 1987, Mon. Not. R. astr. Soc. 226, 927.
Harper, W.E.: 1937, Publ. Dominion Obs. 7, 1.
Hawley, S.L., Jefferys, W.H., Barnes III, T.G. and Wan Lai: 1986, Astrophys. J. 302, 626.

Henroteau, F.: 1930, Publ. Dominion Obs. Ottawa Vol VIII, 59.
Horák, J., Mayer, P., Tremko, J., Weidlich, M.: 1976, Contr. Astron. Obs. Skalnaté Pleso 7, 39.
Jackisch, G.: 1963, Veröff. Sternw. Sonneberg 5, 227.
Jackisch, G.: 1972, Astron. Nachr. 294, 1.
Jaschek, C., Conde, H., de Sierra, A.C.: 1964, Oss. Astron. de Univ. Nac. de la Plata, Ser. Astron. XXVIII (2), p. 84.
Klocok, Ľ., Zverko, J., Žižňovský, J.: 1986, Contr. Astron. Obs. Skalnaté Pleso 14, 97.
Kukarkin, B.V., Kholopov, P.N., Artiukhina, N.M., Fedorovich, V.P., Frolov. M.S., Goranskij, V.P., Gorynya, N.A., Karitskaya, E.A., Kireeva, N.N., Kukarkina, N. P., Kurochkin, N.E., Medvedeva, G.I., Perova, N.B., Ponomareva, G.A., Samus, N.N., Shugarov, S.Yu.: New Catalogue of Suspected Variable Stars, Nauka, Moskva, 1982, p. 107.
Leggett, S.K., Mountain, C.M., Selby, M.J., Blackwell, D.E., Booth, A.J., Haddock, D.J., Petford, A.D.: 1986, Astron. Astrophys. 159, 217.
Zinner, E.: 1929, Erg. Astron. Nachr. 8, Nr. 1.