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PHOTOMETRIC OBSERVATIONS OF AG PEGASI

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SUMARIO

Hemos obtenido fotometrías angosta y ancha en los sistemas β, δ y *UBVJHKL*, respectivamente de la estrella simbiótica AG Pegasi. Los índices β y δ de este objeto son los más intensos que hemos observado entre casi doscientas estrellas Be (que incluyen a P Cygni) y estrellas estandar. La fotometría *UBV* de AG Peg es parecida a la de una estrella de tipo temprano enrojecida. Su fotometría infrarroja corresponde muy cercanamente a la de una estrella M3 III. Esto confirma los resultados de varios estudios espectroscópicos, los cuales concluyen que esta estrella, emparentada con las novae, es una binaria con una componente caliente, WN6, y otra fría, M3 III, dentro de una nube gaseosa.

ABSTRACT

We have made *UBVJHKL* broad-band photometry, and Hβ and Hδ narrow-band photometry of the symbiotic star AG Pegasi. The β and δ-indices for this object are the strongest among nearly 200 Be stars (which include P Cygni) and standard stars. The *UBV* photometry of AG Peg is similar to a reddened early type star. Its infrared photometry corresponds very closely to an M3 III star. This confirms the results of several spectroscopic studies which conclude that this nova-like star is a binary, comprising a hot WN6 component and a cool M3 III object embedded in a gas cloud.

I. Introduction

The star AG Pegasi (HD 207757, BD + 11°4673) is a well known example of a symbiotic star. It has been the subject of many spectroscopic investigations. In recent years work has been published by Boyarchuc (1967 *a, b*) and by Hutchings and Redman (1972). The spectroscopic studies have been interpreted to correspond to a binary whose components can be described approximately by an M3 III and a WN6, with a period around 800 days. Over a hundred years ago a shell was formed; the spectrum of this shell has slowly evolved into a nebular spectrum somewhat peculiar, suggesting that mass ejection may be continuous. The present work describes photometric observations (narrow and broad-band photometries) made on this nova-like star.

II. The Observations

a) β, δ-indices

Several systems of photoelectric measurements of the strength of the Balmer lines were developed at Yerkes and McDonald observatories by Strömgren. They include methods whereby the measurement of a hydrogen line itself and the comparison in the nearby continuous spectrum could be observed simultaneously.

We have used these techniques to measure the strength of Hβ and Hδ. The observations were obtained with the apparatus described by Crawford (1958). The Hβ measurements were made with photometer I attached to the 40-inch refractor of the Yerkes Observatory, and with photometer II attached to the 36-inch reflector of the McDonald Observatory. The Hδ measurements were made only with photometer II attached to the 36-inch telescope of the McDonald Observatory. These narrow band observations were carried out in 1957 over forty different nights. They yielded the following indices:

For Hβ

$$\beta^1 = 2.5\ [\log I\,(90\text{Å filter}) - \log I\,(15\text{Å filter})] + \text{constant} \qquad (1)$$

(photometer I)

$$\beta = 2.5\ [\log I\,(150\text{Å filter}) - \log I\,(15\text{Å filter})] + \text{constant} \qquad (2)$$

From the standard stars (see Table 2) it is found that

$$\beta = \beta^1 + 1.979 \qquad (3)$$

For Hδ

$$\delta = 2.5\ [\log I\,(150\text{Å filter}) - \log I\,(44\text{Å filter})] + \text{constant} \qquad (4)$$

The mean error of a single observation is approximately ±0.005 mag. for β, and ±0.007 mag. for δ.

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b) *UBV* photometry

The *UBV* photoelectric observations were made with the same filter types as those used to define the *UBV* system an RCA IP21 photomultiplier and a standard MIT amplifier. These observations were made with the 13-inch reflector of the McDonald Observatory in 1957.

The mean error of a single observation is approximately ±0.009 mag. for the color indices *B–V* and *U–B*, and ±0.013 mag. for the *V* magnitude.

c) *JHKL* photometry

The observational data on the *JHKL* system defined by Johnson (1964, 1966 – see also Mendoza 1967) were obtained at the Observatorio Astronómico Nacional in San Pedro Mártir, Baja California in 1971 (see Mendoza, 1971). The probable error of a single observation is approximately ±0.03 mag. for *K*, *J–K*, *H–K* and *K–L*.

TABLE 1

Narrow and Broad-band Photometries

Star	*Sp*	*V*	*U–V*	*B–V*	*V–R*	*V–I*	*V–J*	*V–H*	*V–K*	*V–L*	*β*	δ
χ Peg	M2 III	4.80	3.50	1.57	1.34	2.47	3.12	3.95	4.17	4.35	—	—
φ Per	BIpe (III, V)	4.06	−0.96	−0.04	0.16	0.18	0.23	—	0.71	1.23	2.378	2.248
ρ UMa	M3 IIIb	4.76	3.41	1.53	1.47	2.73	3.43	—	4.47	4.68	—	—
72 Leo	M3 III	4.63	3.51	1.66	1.56	2.87	3.51	—	4.63	4.84	—	—
P Cyg	B pec	4.82	−0.16	0.42	0.54	0.80	1.04	—	1.51	1.95	2.231	2.230
AG Peg	WN6 + M3 III	8.37	−0.22	0.49	—	—	3.33	4.27	4.57	4.73	1.432	2.025
Intrinsic Colors	M3 III	—	3.51	1.60	1.48	2.79	3.51	(4.25)	4.58	4.77	—	—

TABLE 2

Standard Stars for β and δ-indices

BS	*Name*	*MK*	*β*	δ	*V*	*U–V*	*B–V*	*V–R*	*V–I*	*V–J*	*V–K*	*V–L*
153	ζ Cas	B2 V	2.627	2.266	3.66	−1.08	−0.19	−0.08	−0.29	−0.58	−0.74	−0.79
801	35 Ari	B3 V	2.692	2.277	4.67	−0.76	−0.13	−0.02	−0.15	—	—	—
1140	16 Tau	B7 IV	2.750	2.294	5.46	−0.37	−0.04	0.06	0.01	0.01	−0.14	−0.06
1144	18 Tau	B8 V	2.755	2.298	5.65	−0.43	−0.07	0.03	−0.04	−0.12	−0.18	−0.18
1178	27 Tau	B8 III	2.699	2.272	3.62	−0.45	−0.09	0.01	−0.04	−0.12	−0.18	−0.05
1520	μ Eri	B5 IV	2.565	2.257	4.02	−0.76	−0.16	−0.06	−0.20	—	—	—
1641	η Aur	B3 V	2.580	2.250	3.18	−0.85	−0.18	−0.05	−0.22	−0.43	−0.56	—
1749	ρ Aur	B5 V	2.717	2.270	5.22	−0.74	−0.15	—	—	—	—	—
3410	δ Hya	A0 V	2.853	2.319	4.17	0.02	0.00	0.04	0.05	—	—	—
3454	η Hya	B3 V	2.647	2.242	4.30	−0.94	−0.20	−0.07	−0.26	—	—	—
3849	κ Hya	B5 V	2.700:	2.262	5.05	−0.73	−0.15	−0.07	−0.22	—	—	—
3975	η Leo	A0 Ib	2.532	2.243	3.53	−0.25	−0.04	0.09	0.11	0.09	0.10	—
4133	ρ Leo	B1 Ib	2.542	2.225	3.85	−1.09	−0.14	−0.05	−0.21	−0.33	−0.47	—
7178	γ Lyr	B9 III	2.753	2.314	3.24	−0.13	−0.05	−0.03	−0.04	0.01	0.00	0.07
7906	α Del	B9 V	2.802	2.326	3.77	−0.27	−0.06	0.00	−0.04	—	—	—
8585	α Lac	A2 V	2.907	2.360	3.77	0.01	0.01	0.00	−0.03	—	—	—
8622	10 Lac	O9 V	2.583	2.264	4.88	−1.25	−0.20	−0.09	−0.30	−0.53	−0.67	−0.62
8965	ι And	B8 V	2.730	2.287	4.29	−0.39	−0.11	0.00	−0.09	—	—	—
8976	κ And	B8 V	2.830	2.328	4.14	−0.32	−0.08	−0.01	−0.08	—	—	—

d) Results

AG Pegasi was observed 6 times in β, 3 times in β^1, δ and *UBV*, and once in *JHKL*. On the average the standard stars for β and δ-indices, were observed 20 times each. The results are

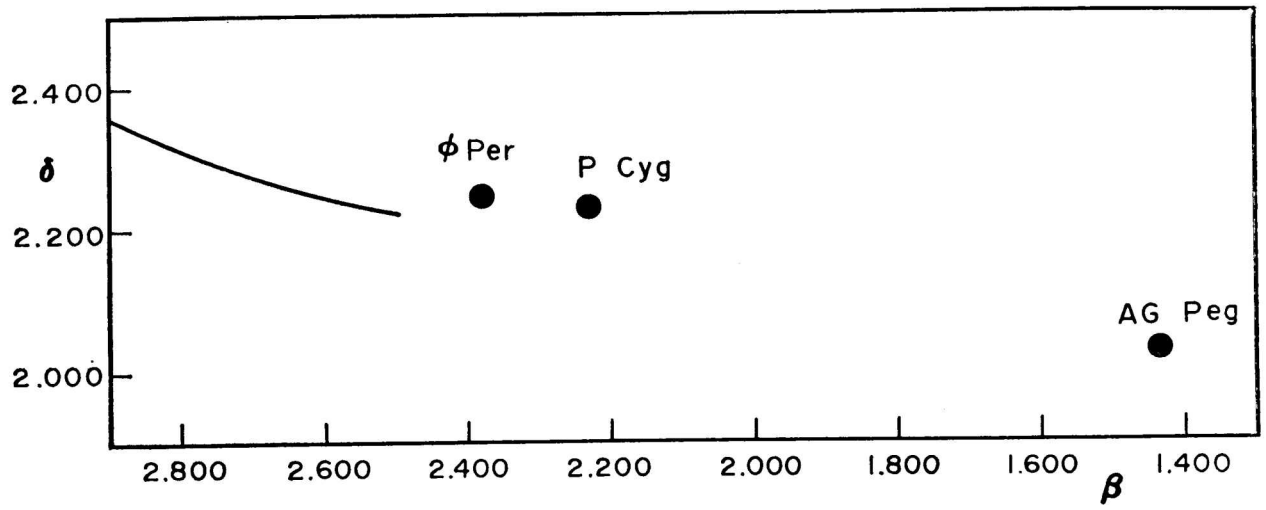

Fig. 1. *The (β, δ) diagram for stars listed in Tables 1 (filled circles) and 2 (solid line).*

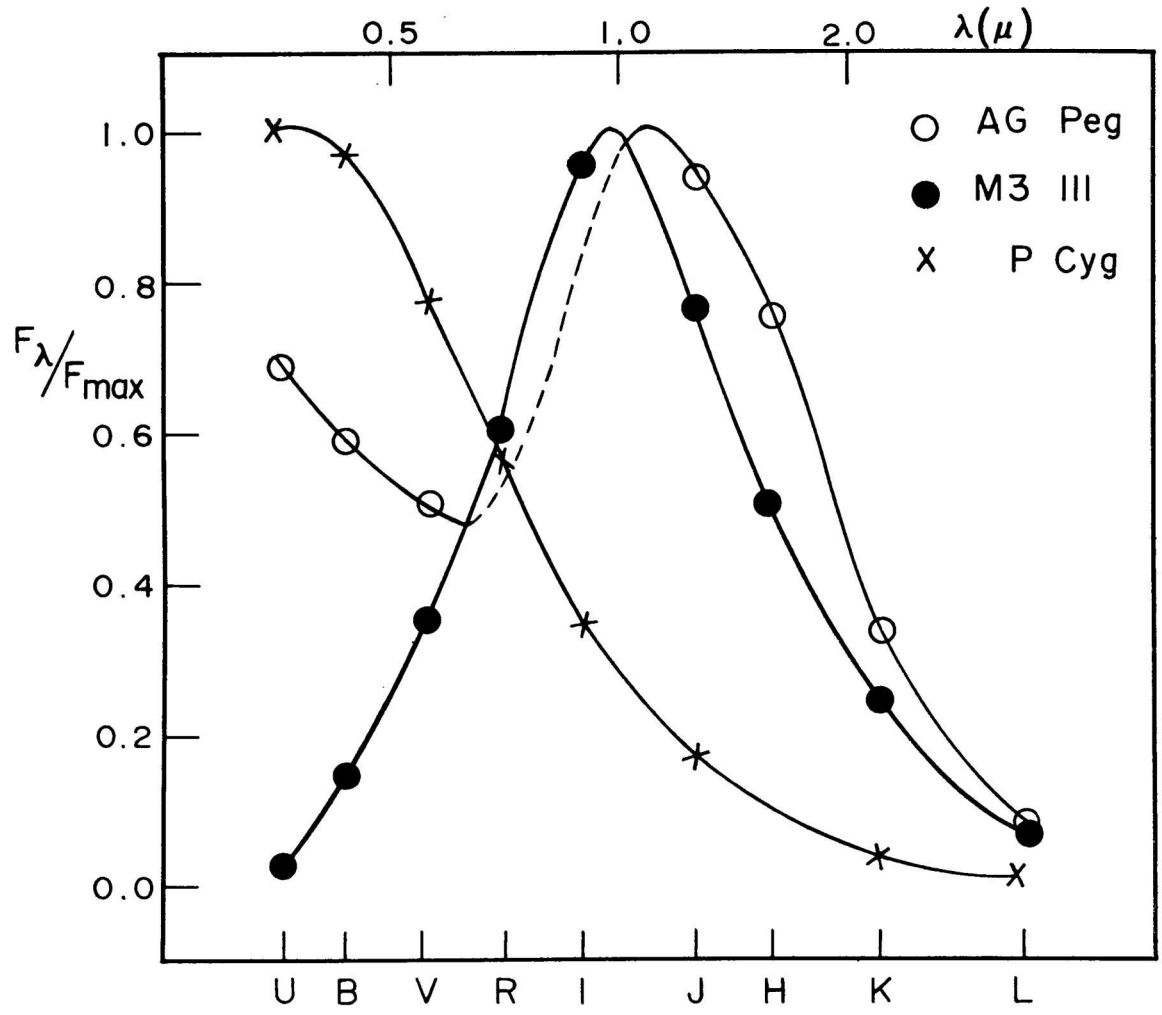

Fig. 2. *The spectral energy-curves for AG Pegasi, P Cygni, and an M3 III star (Johnson, 1966).*

given in Tables 1 and 2. The columns of Table 1 contain, first, the name of the star; second, the spectral type; third the V magnitudes; from fourth to eleventh, the $U-V$, $B-V$, $V-R$, $V-I$, $V-J$, $V-H$, $V-K$ and $V-L$ color indices; twelfth, the β-index; and last, the δ-index. In this Table stars χ Peg, φ Per, ρ UMa, 72 Leo, P Cyg are given for comparison purposes. The mean intrinsic colors of an M3 III star given also in Table 1 were taken from Johnson (1966). Table 2 lists analogous data for the standard stars which define our β, δ-system.

It should be mentioned that this β, δ-system has also been applied to nearly 200 early type stars, mostly Be (cf. Mendoza 1958*b*). However, the observations of AG Peg and P Cyg have not been reported before. The β-system is equal to that of Crawford (1958. See Table 1, fifth column).

III. Photometric Characteristics

The narrow band photometry can be used to make a two-color diagram, that of β *versus* δ. This is shown in Figure 1. In this figure the solid line represents the standard stars listed in Table 2; the filled circles represent the three emission objects listed in Table 1. They are well separated from the "standard-line". This is also true for many other Be stars. The β, δ photometry (see also Figure 1) indicates that the emission in AG Pegasi is stronger than in Be stars by a large factor.

The broad band photometry can be used to obtain spectral-energy curves. This is illustrated graphically in Figure 2. This figure shows the curves of AG Pegasi, P Cygni, and a M3 III star (see Table 2).

These energy-curves confirm the spectroscopic results, namely, that the symbiotic star AG Pegasi is a binary, comprising a hot WN6 component and a cool M3 III object embedded in a gas cloud.

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