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RECENT VARIABILITY OF THE CENTRAL STAR OF THE PLANETARY NEBULA NGC 2346

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RESUMEN

Se informa sobre las observaciones fotométricas de V651 Mon, la estrella central de la nebulosa planetaria NGC 2346, efectuadas con CCD y con un fotómetro de cuatro canales durante abril-mayo y noviembre de 1992. En ambas temporadas se registraró una ocultación cuyas amplitudes fueron 0.2 y 0.35 mag en V, en acuerdo con reportes anteriores. Estas variaciones pueden interpretarse como debidas al paso de otra(s) nube(s) de polvo frente al sistema binario que constituye la estrella central de NGC 2346, aunque probablemente haya que invocar alguna causa adicional.

ABSTRACT

We report photoelectric and CCD photometry of V651 Mon, the central star of the planetary nebula NGC 2346, made in April-May and November, 1992. During each of these two epochs an occultation was measured, of amplitude 0.20 and 0.35 in the observed V magnitude, in accordance with previous results. These variations may be interpreted in terms of other fragmented dust cloud(s) passing in front of the binary central star, but probably an additional source must be invoked.

Key words: **DUST, EXTINCTION — PLANETARY NEBULAE: INDIVIDUAL (NGC 2346) — STARS: VARIABLES**

1. INTRODUCTION

V651 Mon, the central star of the planetary nebula NGC 2346, is a well known spectroscopic binary with an A-type star and a hot companion (*cf.* Méndez & Niemela 1981), with an orbital period of nearly 16 days. The system became an intriguing object when large optical and infrared variations were detected with a modulation similar to the orbital period (Kohoutek 1982, 1983; Méndez *et al.* 1982; Roth *et al.* 1984). These first variations were interpreted as a dust cloud passing in front of the orbit of the central binary star (Costero *et al.* 1986). These occultations were periodic and developed a secondary minimum while the primary one faded.

Afterwards, V651 Mon was included in the AAVSO observing list of irregular and unusual variables. For several years it remained constant or nearly constant, until the star was reported to vary again (Kohoutek 1991; Kohoutek et al. 1992; Mattei 1992a,b,c). We report here observations made in April-May and November 1992.

2. THE OBSERVATIONS

Observations of V651 Mon were obtained with a 1024×1024 CCD attached to the 2.1m telescope at the Observatorio Astronómico Nacional at San Pedro Mártir, Baja California, México, on the nights of April 19-22 1992. The integration time was typically 1 min, with a spatial resolution of about 1″. Standard Johnson B and V filters were used. Further observations were obtained during the periods April 29–May 10 and November 13–27 with the multichannel *uvby* photometer attached to the 1.5m telescope. The typical integration time was 60 sec or more, depending on the sky brightness.

For the CCD observations the star named d by Kohoutek & Senkbeil (1973) was used as the photometric reference. The V magnitudes and $B-V$ colors for the program and the reference stars were first estimated by means of the normal reduction procedures and using several standard stars from the list by Landolt (1992). Then the magnitude and color of V651 Mon were computed by comparison with star d using the values given by Kohoutek (1982). In the reduction process a 5″ diaphragm and a ring around it for sky subtraction were used. Hence the contribution of the nebular emission to the obtained numbers must be negligible. The errors in both the magnitude and color are estimated to be less than 0.01 mag.

The Strömgren photometry is referred to the comparison stars a and b, whose V magnitudes are also given by Kohoutek & Senkbeil (1973); their $b-y$ colors (0.085 and 0.238, respectively) were adopted to be the average of those obtained with the same equipment during the five best April-May nights, when many intermediate-type standard stars were also observed for another research program; their estimated error is less than 0.01 mag. A 21″diaphragm was always used and no attempt was made to subtract the nebular contribution.

The results for V651 Mon are shown in Table 1. Estimated errors for the V and $b-y$ are smaller than 0.02 mag and 0.010 mag, respectively, except for those followed by a colon, whose values as referred to stars a and b defer by about 0.02 mag or more. The $B-V$ values shown with an asterisk have been converted from the Strömgren photometry to the Johnson system by means of the approximate expression $B-V = 1.50(b-y)+0.04$, deduced from equation 2′ of Cousins & Caldwell (1985) and assuming $m_1 = 0.22\pm0.02$ = constant for V651 Mon. This value is the average of those obtained during the April-May observing run on the 1.5m telescope. The large error is due to bright and rapidly decaying twilight sky in which most observations of the object were done during that run, turning all v filter-related measures very noisy. The error results in an uncertainty of about 0.01 on the zero point of the calculated $B-V$. Changes in m_1 originated from variable dust extinction will be $^1/_3$ those in $b-y$; since the later are small, they propagate into the calculated $B-V$ as less than 0.01 mag.

Figure 1 shows the light and color curves as function of the binary system phase according to the ephemeris given by Méndez *et al.* (1982):

$$\mathrm{JD} = 2443126.0 + 15.991\mathrm{E}$$

Table 1. Photometry of V651 Mon

Date	HJD	Phase	V	b-y	B-V
Apr 19	2448731.7	0.55	11.25		0.26
Apr 20	2448732.7	0.62	11.25		0.26
Apr 21	2448733.7	0.68	11.28		0.23
Apr 22	2448734.7	0.74	11.27		0.27
Apr 29	2448741.6	0.18	11.42	0.128	0.23*
May 01	2448743.6	0.30	11.46	0.185	0.32*
May 02	2448744.6	0.36	11.45	0.196	0.33*
May 03	2448745.6	0.42	11.45	0.194	0.33*
May 04	2448746.6	0.49		0.199	0.34*
May 10	2448752.6	0.86	11.28	0.141:	0.25*
May 11	2448753.6	0.92	11.25	0.147:	0.26*
Nov 13	2448939.9	0.57	11.55	0.192	0.33*
Nov 14	2448940.9	0.64	11.45	0.193	0.33*
Nov 17	2448944.0	0.83	11.18	0.160	0.28*
Nov 18	2448945.0	0.89	11.18	0.166	0.29*
Nov 19	2448946.0	0.95	11.20	0.155	0.27*
Nov 21	2448948.0	0.08	11.20	0.148	0.26*
Nov 22	2448949.0	0.14		0.158	0.28*
Nov 25	2448952.0	0.33	11.19	0.155	0.27*
Nov 26	2448953.0	0.39	11.18	0.157:	0.28*
Nov 27	2448954.0	0.45	11.17	0.163:	0.28*

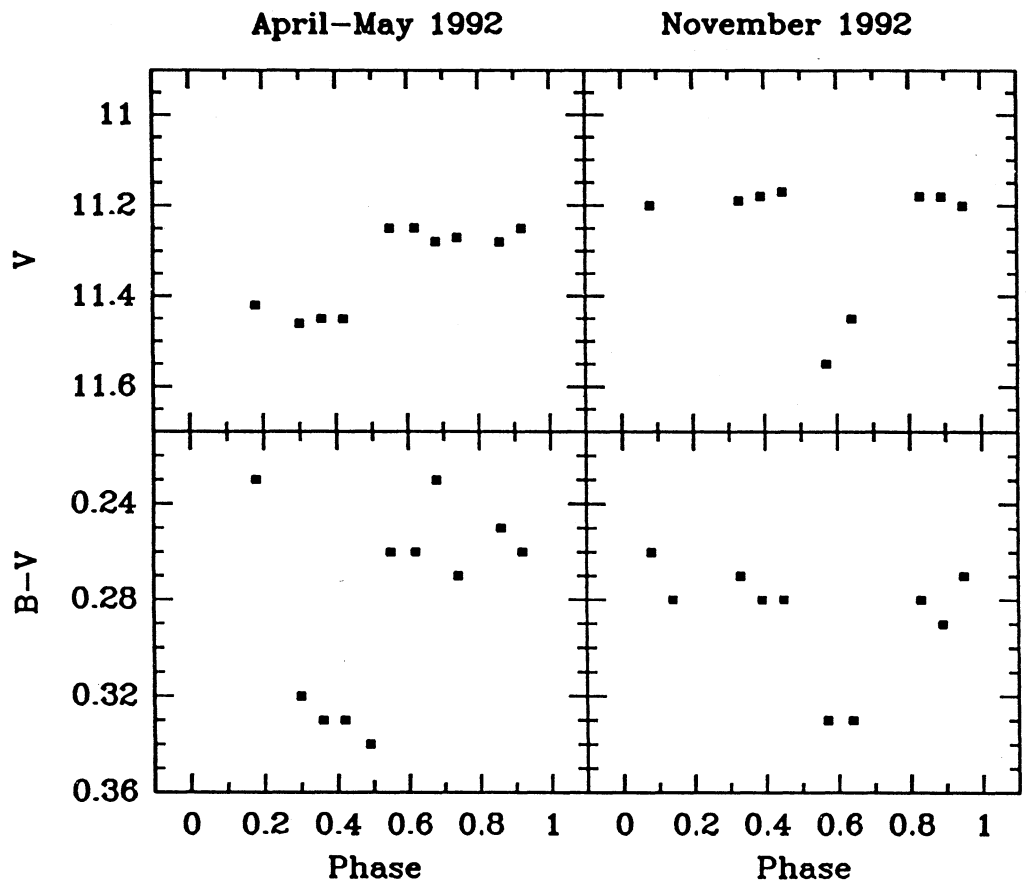

Fig. 1. — Light and color curves of the central star of NGC 2346

3. DISCUSSION

Kohoutek (1991) and Kohoutek *et al.* (1992) have published light curves showing the reappearance of possible occultations at phases between 0.42 and 0.53, computed with the orbital ephemeris given above. The reported ΔV is less than 0.2 mag, whereas our April-May observations indicate a broader and possibly deeper occultation centered between phases 0.3 and 0.4. The corresponding $B-V$ values, except for that of April 29 (phase 0.18), are compatible with another fragmented dust cloud passing in front of the bright component in the binary system, but the anomalous datum is probably correct and must be of independent origin. The observations of May 10 and 11 (phases 0.86 and 0.92) were carried out at the largest hour angles and during the brightest twilight sky. These adverse conditions affect the measures with filter b much more than those with filter y. Hence the $b-y$ values for those two nights have large errors (≈ 0.03) and should be considered with caution.

The November observations are of better quality. This time the occultation was at about phase 0.6 though only observed during the first two nights and with a nearly full moon. It was much deeper ($\Delta V \simeq 0.35$) and possibly as narrow as those reported by Kohoutek and collaborators. The observed change in color ($\Delta(b-y) \simeq 0.04$ or $\Delta(B-V) \simeq 0.06$) is about half that expected if caused by a passing dust cloud. Nevertheless the observations have not been corrected for the light contributed by the planetary nebula, whose influence is much larger in the b band (due to HeII λ 4686) than in the y band. The average $b-y$ for the eight nights when V651 Mon was observed out of occultation (November 17–27) is 0.158 with 0.005 mag dispersion. Only on two such nights—those at phases 0.08 and 0.89—was $b-y$ about 2σ away from that average. These might in fact be real variations not related to dust clouds in front of the star, because the corresponding changes in V, if any, are neither the size nor in the direction expected if caused by variable extinction.

Clearly more observations are needed to better understand the nature of the light and color variations, as well as the phase and shape changes observed. Unfortunately the required data have to be of good quality and obtained during long observing runs. The object varies too little for amateur surveying and too slowly for most professional observatories, but is probably an ideal target for automated telescopes.

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