PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC
93:630–632, October 1981

HIGH-SPEED PHOTOMETRY OF, AND SPECULATIONS ON, THE CENTRAL STAR OF M 1–2*

ALBERT D. GRAUER†
Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803-4001
and
Department of Physics and Astronomy, University of Arkansas at Little Rock, Little Rock, Arkansas 72204‡
AND
HOWARD E. BOND
Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803

Received 1981 July 2

Minkowski 1–2 is a planetary nebula whose central star spectroscopically resembles a G-type supergiant. Although the central star has recently been suggested to be an eclipsing binary with a period of four hours, we found no eclipses or other variability during nearly ten hours of high-speed photometric monitoring on two consecutive nights. If M 1-2 contains a binary system at all, our photometry indicates that its orbital period is very unlikely to be less than several days. Spectroscopic evidence suggests a period in excess of half a year.

We tentatively suggest that the central star is, in fact, a rather wide binary containing the G star and a hot companion. We speculate that the G-type "supergiant" might in actuality be a less luminous giant with heavy-element enhancements similar to those seen in marginal barium stars; this would reduce the distance of M 1–2 to a reasonable value, while explaining the resemblance of the spectrum to that of a supergiant.

Key words: binary stars—photometry—planetary nebulae—barium stars

I. Introduction

M 1–2 (= VV 8) is a 13th-magnitude stellar-appearing emission-line object that was discovered by Minkowski (1946); its 1950 position is $1^h55^m33^s$, $+52°39'.3$. O'Dell (1966) discovered that the spectrum of M 1–2 shows, in addition to strong emission lines indicative of a high-density planetary nebula, an absorption spectrum resembling that of a G2 supergiant. This leads naturally to a suspicion that the central star may be a binary, consisting of the G2 *Ib* star and a hot companion that ionizes the nebula. However, it would appear on the basis of available data that, if M 1–2 indeed contains a binary system, it cannot be a close binary. The evidence against close duplicity includes O'Dell's (1966) failure to detect any radial-velocity variations over a six-month interval, the fairly sharp absorption lines (indicating a lower rotational velocity than expected in a synchronously rotating close binary), and the finding of Arkhipova, Noskova, and Gapbarov (1974) of no photometric variations from a variety of photographic and photoelectric observations.

Nevertheless, it has recently been suggested by Drummond (1980*a*,*b*) that the central star of M 1–2 is an eclipsing binary with a period of only four hours. This would be a discovery of some importance, since only two other planetary nebulae are known to contain short-period eclipsing binaries: UU Sagittae, the central star of Abell 63 (Bond 1976; Miller, Krzeminski, and Priedhorsky 1976; Bond, Liller, and Mannery 1978) and the central star of Abell 46 (Bond, Twigg, and Grauer 1981). We therefore undertook a program of photometric monitoring of M 1–2.

II. Observations

High-speed photometry of M 1–2 with a time resolution of 5 s was obtained by A.D.G. on the nights of 1980 October 8 and 9 (UT). The No. 2 0.9-m reflector at Kitt Peak National Observatory was used with the University of Arkansas two-star photometer. A description of the photometer and reduction techniques has been published recently (Grauer and Bond 1981). A comparison star 3'.1 west and 10'.8 north of M 1–2 was measured simultaneously with M 1–2; division by these measures was used to remove effects of atmospheric extinction. The comparison-star measures show that both nights were of photometric quality (although perfectly photometric conditions are not required for two-star photometry). Standard *B* filters of the *UBV* system were used in both channels. The telescope was occasionally moved off the stars in order to measure the sky back-

Louisiana State University Observatory Contribution, No. 166.

†Visiting Astronomer, Kitt Peak National Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

‡Academic year address.

ground, which has been subtracted from the data in both channels.

Figure 1 shows the "light curve" of M 1–2 on 1980 October 8; the data have been smoothed slightly by combining the original 5-s integrations into 15-s bins. The length of this run was 4.4 hours. Although the information given by Drummond is insufficient to predict times of eclipses, our observing run was longer than his proposed period of 4.0002 hours, and at least one eclipse should have occurred. Drummond suggests an eclipse depth of 0.06 mag and an eclipse duration of 0.8 hour; such an eclipse is clearly ruled out by our data.

Figure 2 shows the data obtained on 1980 October 9. In this case, M 1–2 was observed for 6.6 hours (with a 1.2-hour interruption due to a computer failure). The data have again been combined into 15-s integrations, and again no eclipses or other variations were observed. The brightness of M 1–2 relative to the comparison star was the same (to within about ± 0.01 mag) as on the first night.

An examination of Drummond's (1980*a*) original data suggests that the "eclipse features" may actually have been statistical fluctuations in his data; M 1–2 is, in fact, rather faint for the 0.6-m telescope and low data-sampling rate he used.

Our finding of no significant variability for M 1–2 on a time scale of seconds to one day lends further support to the belief that it must be either a rather wide binary (or a nearly "pole-on" system), or a very unusual single star. In close binaries like UU Sge and Abell 46 (both of which have orbital periods near eleven hours), reflection effects produce quite conspicuous variations outside eclipse, and such variations seem absent from M 1–2.

III. Speculations

Our photometric monitoring of M 1–2 appears to

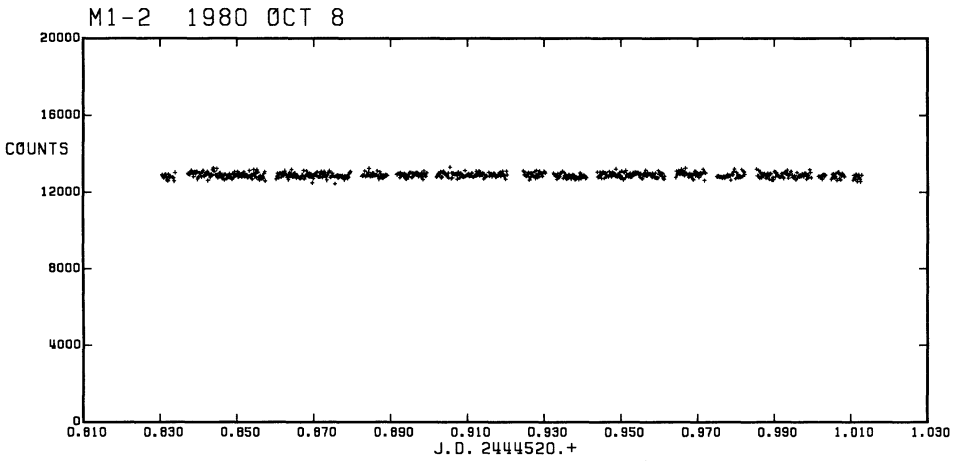


FIG. 1—Light curve of M 1–2 on 1980 October 8. Counts per 15-s integration time (corrected for atmospheric extinction and sky background) are plotted against heliocentric Julian Date. No eclipses or other variations were noted during this 4.4-hr run.

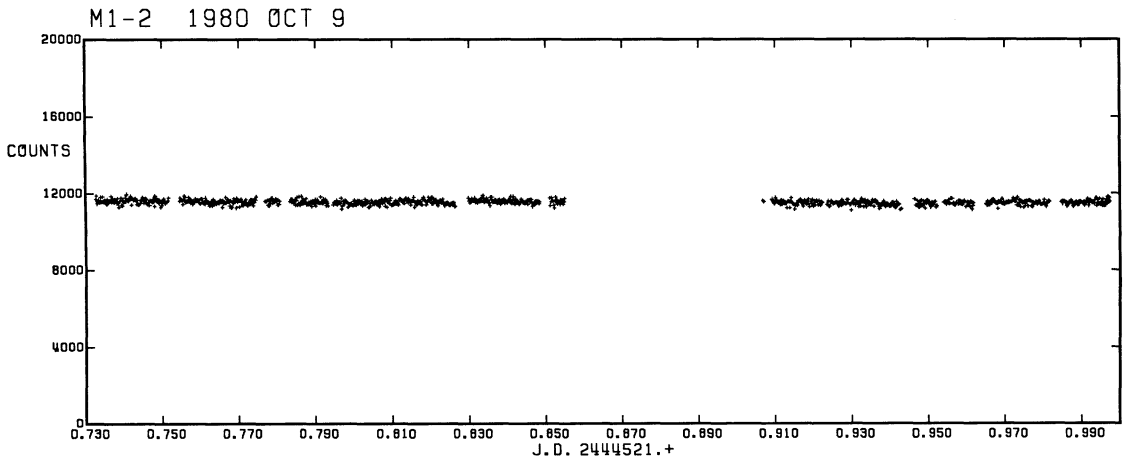


FIG. 2—Light curve of M 1–2 on 1980 October 9. This run was 6.6 hrs long, with an interruption due to computer failure. As in Figure 1, a *B* filter of the *UBV* system was used.

show that its central star is not a close binary with an orbital period of less than a few days; O'Dell's radial-velocity measurements probably rule out a period of less than about half a year. Although it is possible to construct single-star models for the M 1–2 system (e.g., Zipoy 1975), we feel that a wide-binary model might offer lesser difficulties.

The chief objection to the binary hypothesis has been the G2 I*b* classification of the absorption-line spectrum (O'Dell 1966; Lutz 1977). As several authors have pointed out, such a luminosity classification places M 1–2 at a quite improbably large distance (Adams 1975; Lutz 1977).

This difficulty could be resolved if the G star were in fact a star of lower luminosity whose spectrum mimics that of a supergiant. This might perhaps be due to low pressure in an extended envelope, but an alternative speculation is that the mimicry is the consequence of an abnormal chemical composition. There is in fact a precedent for this in the case of the Ba II stars, some of which (like ζ Capricorni) were once classified as I*b* supergiants. It is now apparent that, as a group, the barium stars have about the same luminosities as class III giants (MacConnell, Frye, and Upgren 1972; Scalo 1976). The earlier misclassification was due to strong Sr II lines and CN bands, produced by enhanced strontium and carbon abundances; in normal supergiants, the lines of these same species are enhanced by the low pressure.

In the case of the central star of M 1–2, the supergiant classification seems to be based upon the observed enhancement of Sr II in its spectrum, as discussed by O'Dell (1966). It therefore seems not impossible that, in fact, we are seeing the photosphere of a considerably less luminous giant with an enhanced strontium abundance.

Inspection of O'Dell's reproduction of the spectrum of M 1–2 indicates that the G band of CH seems to be somewhat stronger than in typical G supergiants. The Ba II line at 4554 Å does not appear to be as enhanced as it would be in a Ba II star; however, this is not a fatal objection because there is a class of "marginal" barium stars that show only enhanced strontium and CH (MacConnell et al. 1972); the lack of a barium enhancement is presumably due to a low-neutron-exposure *s*-process. A luminosity typical of the marginal barium stars (see MacConnell et al.) would place M 1–2 in the vicinity of the Perseus spiral arm, which is unobjectionable.

M 1–2 would not be the first planetary nucleus known to show *s*-process enhancements: FG Sagittae is a well-known central star showing enhanced heavy elements (Langer, Kraft, and Anderson 1974; Cohen and Phillips 1980). However, M 1–2 has no known history of rapid changes in luminosity and spectral type as does FG Sge, and M 1–2 has a far more prominent nebular emission spectrum.

It has recently been found that many Ba II stars are single-lined spectroscopic-binary systems with orbital periods of up to five years (McClure, Fletcher, and Nemec 1980; Griffin and Griffin 1980). In the case of ζ Cap, a white-dwarf companion has actually been detected in the satellite untraviolet (Böhm-Vitense 1980). These discoveries have naturally led to suggestions that Ba II stars are the result of mass transfer from a more-massive primary that has since become a white dwarf.

The infrared excess noted by Cohen and Barlow (1974) for the central star of M 1–2 could be interpreted as the result of emission by nebular debris in the system.

The binary nature of marginal barium stars has yet to be investigated. Nevertheless, it is tempting to speculate that if M 1–2 really is a wide binary composed of a hot subdwarf and a G-type giant with peculiar abundances, surrounded by nebular debris, then it might represent the stage immediately following large-scale mass transfer in the formation process of a barium star.

We thank the Director and staff of Kitt Peak National Observatory for generous observing time and assistance. A.D.G. received support from the Donaghey Foundation for travel to Kitt Peak National Observatory and summer salary from the United States Air Force Office for Scientific Research (grant No. 77-3218). H.E.B.'s portion of this work was supported in part by National Science Foundation grant AST 78-25538.

REFERENCES

Adams, T. F. 1975, *Ap. J.* 202, 114.
Arkhipova, V. P., Noskova, R. I., and Gapbarov, A. 1974, *Soviet Astr.* 18, 314.
Böhm-Vitense, E. 1980, *Ap. J. (Letters)* 239, L79.
Bond, H. E. 1976, *Pub. A.S.P.* 88, 192.
Bond, H. E., Liller, W., and Mannery, E. J. 1978, *Ap. J.* 223, 252.
Bond, H. E., Twigg, L., and Grauer, A. D. 1981 (in preparation).
Cohen, J. G., and Phillips, A. C. 1980, *Ap. J.* 237, 99.
Drummond, J. D. 1980*a*, Ph.D. Dissertation, New Mexico State University.
——— 1980*b*, *Astr. and Ap. (Letters)* 88, L11.
Grauer, A. D., and Bond, H. E. 1981, *Pub. A.S.P.* 93, 388.
Griffin, R., and Griffin, R. 1980, *M.N.R.A.S.* 193, 957.
Langer, G. E., Kraft, R. P., and Anderson, K. S. 1974, *Ap. J.* 189, 509.
Lutz, J. H. 1977, *Astr. and Ap.* 60, 93.
MacConnell, D. J., Frye, R. L., and Upgren, A. R. 1972, *A.J.* 77, 384.
McClure, R. D., Fletcher, J. M., and Nemec, J. M. 1980, *Ap. J. (Letters)* 238, L35.
Miller, J. S., Krzeminski, W., and Priedhorsky, W. 1976, *I.A.U. Circ.* No. 2974.
Minkowski, R. L. 1946, *Pub. A.S.P.* 58, 305.
O'Dell, C. R. 1966, *Ap. J.* 145, 487.
Scalo, J. M. 1976, *Ap. J.* 206, 474.
Zipoy, D. M. 1975, *Ap. J.* 201, 397.