Astron. Astrophys. 287, L31–L33 (1994)

ASTRONOMY AND ASTROPHYSICS

*Letter to the Editor*

# Spectroscopic observations of the Mt. Stromlo MACHO candidate*

**Massimo Della Valle**[1,2]

[1] Dipartimento di Astronomia, Università di Padova, Vicolo dell'Osservatorio, 5, I-35122 Padova, Italy
[2] European Southern Observatory, La Silla, Chile

Received 27 January 1994 / Accepted 10 May 1994

**Abstract.** Spectroscopic observations of the microlensing candidate recently discovered at Mount Stromlo are presented and discussed. Although the case of intrinsic variability cannot be completely ruled out, the new data give support to the microlensing event.

**Key words:** Cosmology: gravitational lensing, Stars: flare, Novae, Cataclysmic Variables

## 1. Introduction

During the search for massive compact objects in the halo of our galaxy, the MACHO team (Alcock et al. 1993) discovered a microlensing candidate event which appeared as ≈ 2 magnitudes brightening of a star of the LMC. The event peaked on about 9 March 1993 and no spectroscopic information about the amplifying of the apparent brightness of the star could be acquired during the flaring. This Letter presents spectroscopic observations of the candidate, out of the brightening episode, with the aim to check if the spectrum is that of a clump giant of the LMC, as suggested by Alcock et al. 1993, or if it belongs to some classes of known variables.

## 2. Observations

The observations were carried out on Nov. 9 1993, with the 3.6m telescope + EFOSC (ESO Faint Object Spectrograph and Camera) at La Silla Observatory. The spectroscopic camera was oriented to compensate for the atmospheric refraction. The detector was a 512 × 512 pixels Tektronix CCD having a pixel size of 27 $\mu$m, corresponding to 0″.6 on the sky. For a 1.″5 slit the resulting resolution is ≈ 15 Å . Two 40min spectrograms were flux calibrated with the spectrophotometric standard L870-2 (Oke 1974) before being stacked (Fig. 1). We also determined the magnitude of the object on 1min (see Fig. 2) and 2min CCD frames in V and B colors, respectively, by comparison with photometric standard fields (Landolt 1992). The color transformation equations derived from the Landolt's magnitudes have slopes very similar to the average values determined at La Silla, whereas the constants are ≈ 0.1 magnitudes smaller in both colors. This might indicate that the observations were probably performed under ambiguous photometric conditions. The magnitudes have been measured using the ROMAFOT (Buonanno et al. 1983) package in the MIDAS environment, after studying the point spread function of a number of field stars. The measured magnitudes, V=20.0 and B=20.6 were corrected for reddening through the H I column density value (Burstein and Heiles 1984) thus resulting in V=19.8 and B=20.3. In view of the argument above the estimated uncertainty of the brightness is ≈ ±0.1 mag.

## 3. Discussion

The lightcurve observed by Alcock et al. (1993) fulfills the requisites of a microlensing event as described by Paczynski (1986) then restricting, quite significantly, the types of intrinsic stellar variability which could originate such a lightcurve. The outburst of about 2 magnitudes, with a characteristic time scale of ≈ 30 days, observed over a period of time spanning one year rules out all kinds of pulsating variables. Among the eruptive variables only the behavior exhibited by some cataclysmic variables can partially fit the observed characteristics of the microlensing candidate. Dwarf Novae with recurrence times of ≈ 1 year can be quickly excluded due to the amplitude of their outbursts ($\langle A \rangle \geq 4-5$ mag). Remaining candidates may then be the old novae or possibly novae caught during their preoutburst stage (see Robinson 1975). Fig. 3 shows a fragment of the lightcurve of V841 Oph at minimum light illustrating an outburst of ≈ 1 magnitude which was undertaken by this nova ≈ 86 years after the maximum (Della

*Send offprint requests to*: M. Della Valle

* Based on observations made at the European Southern Observatory, La Silla, Chile.

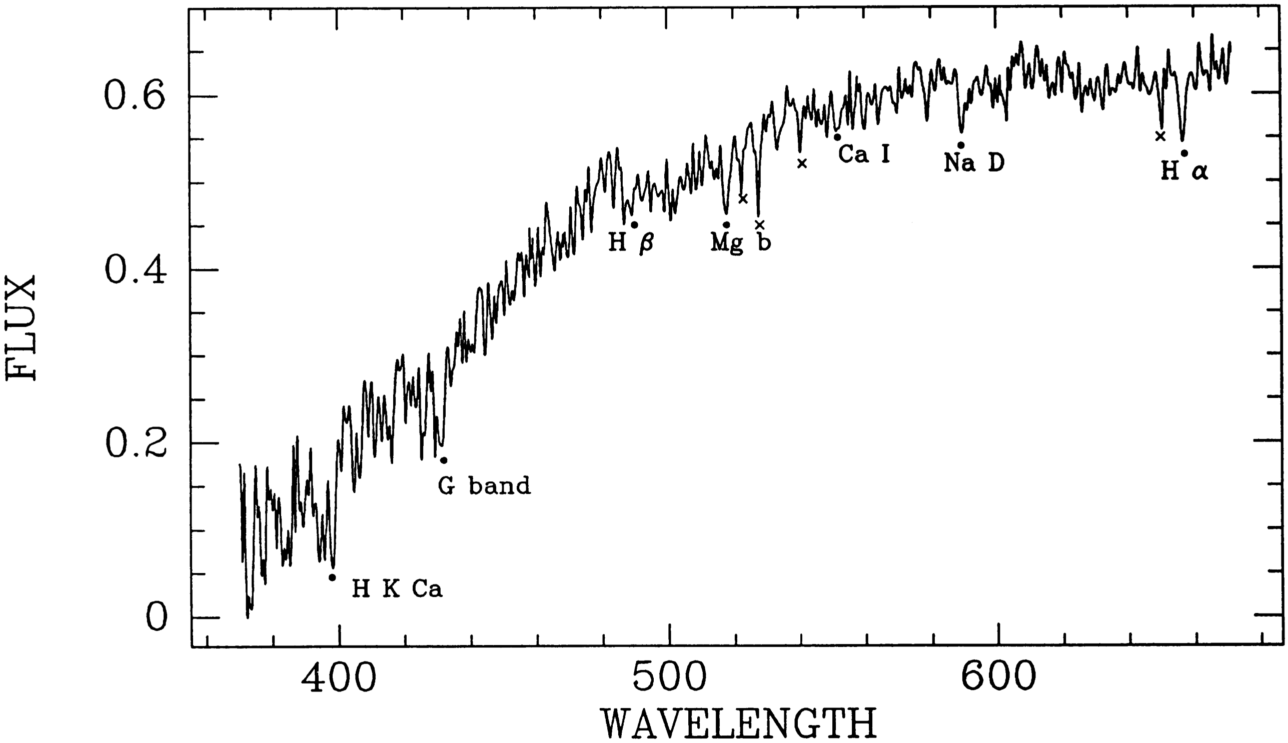


**Fig. 1.** The spectrum of the gravitational microlensing candidate. Ordinate are units of $10^{-16}$ erg $s^{-1}$ $cm^{-2}$ $nm^{-1}$. Features marked with 'x' represent cosmic rays and/or artifacts not corrected. Dots represent real features.

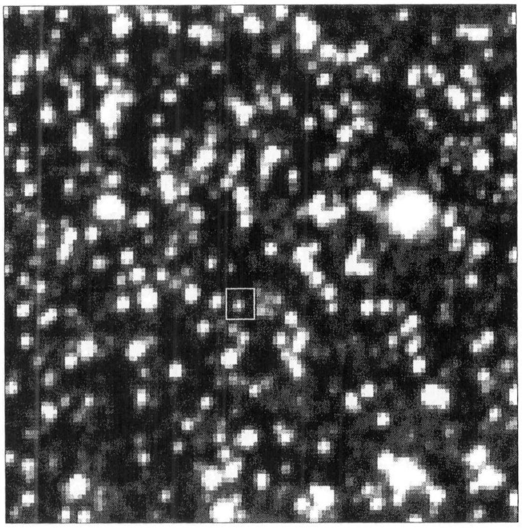

**Fig. 2.** The finding chart of the candidate. The represented area is about 1.′5 × 1.′5. The star is inside the box. North to the top, East to right.

Valle and Rosino 1987, Shara et al. 1989). The brightening reported in Fig. 3 shows a symmetric lightcurve and a time scale of ≈ 40 days. These outbursts, normally smaller than 2 magnitudes (see also Robinson 1975), may be quite common in old novae and also recurring with typical scale times of the order of ≈ 100 days (Della Valle and Calvani 1990). However, two consecutive outbursts can be separated by long quiescent stages where the star keeps its brightness constant within 0.2 magnitudes for even longer than 200 days. Therefore, from a 'pure' photometric point of view most features shown by the lightcurve of microlensing candidate can be mimicked by the photometric behavior of some old/pre-nova (see also Sabbadin and Bianchini 1983). On the other hand, old novae have a quite peculiar spectrum: normally a hot continuum with emission lines of the Balmer series, HeI and HeII, NIII-CIII blend, rarely forbidden lines, and in some case absorption lines of the late-type companion. However, there exist a few objects (like V 1017 Sgr) showing, unlike most novae, somewhat massive secondaries (Sekiguchi 1992) or nearly pure continuum with very weak emission lines which appear only in high resolution spectra (e.g. DI Lac, Kraft 1964; CI Aql, Bianchini 1994). Spectra of novae during the pre-outburst stage are available only for a very limited number of objects (V 603 Aql, V 533 Her and HR Del) and however, their energy distribution is similar to that of an O/B star (Duerbeck 1994). The spectrum of this microlensing candidate exhibits a relatively red continuum (F/G type) furrowed by the following absorbtion lines: Hα observed at 656.7 nm, Na D at 589.6 nm, Mg b (blend of Mg I lines at 516.7, 517.3 and 518.4 nm) at 517.7, Hβ at 486.6, the G band at 431.0 and H and K of Ca II (see in Fig. 1 the absorption lines marked by dots). These lines are, on the average, redshifted by 4-5 Å proving indeed that this star belongs to the LMC. Assuming a distance modulus (m−M)=18.5 for LMC (Panagia et al. 1991) an absolute magnitude of $M_v$=1.3 is derived for the candidate. This calculated absolute magnitude is consistent with a late F/G type giant. Although this magnitude is approximately 1.6 mag brighter than the average absolute magnitude of a typical slow nova at quiescence (Della Valle and Duerbeck 1993), it may still be compatible with the magnitude distribution shown by these authors.

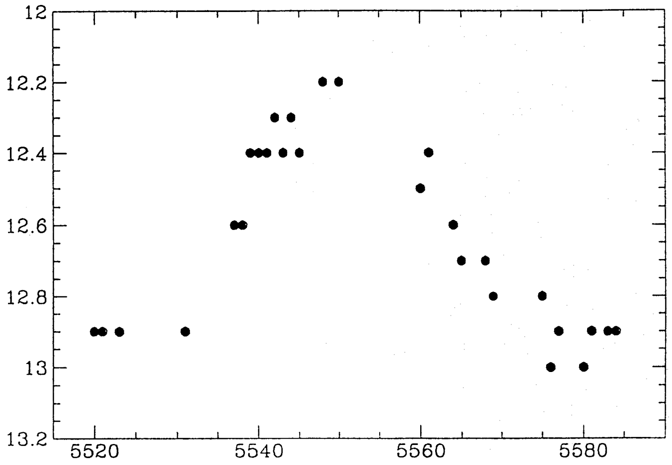


**Fig. 3.** Brightening exhibited by the old nova V841 Oph about 86 years past maximum (ordinate:magnitude, abscissa: Julian Date). The typical photometric error of each data point is $\leq$ 0.1 mag.

## 4. Conclusions

The analysis of the photometric and spectroscopic characteristics of several classes of cataclysmic variables suggests that, with the exception of some old-nova, like V1017 Sgr, none is suitable to reproduce the photometric and spectroscopic properties of the microlensing candidate. The case of the recurrent nova V 1017 Sgr is notable because of its unusual spectral type, G5–III (Kraft 1964). Moreover, spectra of this object taken in the past exhibit remarkable variations. Humason (1938) reports the lack of emission line, whereas Kraft (1964) reports the presence of emission lines found on spectra obtained by Greenstein which do not show in spectra taken by himself. The outbursts of this nova, occurred in 1901, 1973 and 1991 (McLaughlin 1946, Bianchini et al. 1994), have produced quite symmetric lightcurves (admittedly on the basis of relatively low quality photometry) with an increasing of brightness of $\approx$ 3 magnitudes in $\approx$ 100 days. Apart from this possibility, the observations show that the spectrum, the absolute magnitude, the radial velocity and the color of the candidate are, on the whole, also consistent with the signature of a late-F/early-G giant in the LMC. This would strengthen the case for gravitational lensing as reported by Alcock et al. (1993). However, it is worthwhile to mention that the microlensing candidate was discovered by monitoring close to $2\times10^6$ lightcurves of stars in the LMC. The monitoring of such a huge amount of stars leaves open the possibility that we are dealing with the properties of a yet unknown class of variable stars. Finally, we would like to point out that this issue can be clarified by future detection of other candidates and/or by obtaining the spectrum of one of them during the brightening (e.g. see Paczynski 1994).

*Acknowledgements.* I'm indebted with K. Freeman and J. Melnick for reading one of the first versions of the manuscript. I also thank the referees E. Maurice and L. Prevot for their constructive criticisms, A. Bianchini and R. Canterna for useful discussions.

## References

Alcock et al. 1993, Nature, 365, 621
Bianchini, A. 1994, private communication
Bianchini et al. 1994, in preparation
Buonanno, R. Buscema, G., Corsi, C., Ferraro, I., Iannicola, G. 1983, Astron. Astrophys., 126, 278
Burstein, D., Heiles, C., 1984, Ap.J. Supp., 54, 33
Della Valle, M., Duerbeck, H. 1993, Astron. Astrophys., 271, 175
Della Valle, M., Calvani, M. 1990, in 'Physics of Classical Novae', IAU Coll. 122, p. 48
Della Valle, M., Rosino, L. 1987, IBVS, 2995
Duerbeck, H. 1994, in *Cataclysmic Variables and Related Objects*, NASA SP–507, eds., M. Hack, C. la Dous, pag. 280
Humason, M.L.1938, Ap.J., 88, 238
Kraft, R. 1964, Ap.J. 139, 457
Landolt, A.U. 1992, A.J. 104, 340
McLaughlin, D.B. 1946, P.A.S.P., 58, 46
Oke, J.B., 1974, Ap.J. Supp., 27, 21
Paczynski, B. 1986, Ap.J. 304, 1
Paczynski, B. 1994, IAUC 5997
Panagia, N., Gilmozzi, R., Macchetto, F., Adorf, H.M., Kirshner, R.P. 1991, Ap.J. Lett., 380, L23
Robinson, E.L. 1975, A.J., 80, 515
Sabbadin, F., Bianchini, A. 1983, Astron. Astrophys. Suppl. 54, 393
Sekiguchi, K. 1992, Nature, 358, 563
Shara, M., Potter, M., Shara, D. 1989, PASP, 101, 985

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.