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FIRST OPTICAL CANDIDATE FOR A RECOVERED CLASSICAL NOVA IN A GLOBULAR CLUSTER: NOVA 1938 IN M14

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ABSTRACT

U, *B*, *V*, *R*, and Hα CCD frames of the field of the nova which appeared in the globular cluster M14 in 1938 have been compared with the nova discovery images. On the basis of positional coincidence, brightness, and blue color, we identify a candidate for the nova and determine its right ascension and declination to $\pm 1''$ each. Confirmation of the candidate and detailed study of the quiescent nova will probably require Hubble Space Telescope observations.

Subject headings: clusters: globular — stars: novae

I. INTRODUCTION

Close binaries are believed to be important sources of energy which drive the dynamical evolution of the globular clusters in which they are located (e.g., Spitzer and Mathieu 1980). The X-ray burst sources ($L_x \approx 10^{36}$–10^{38} ergs s^{-1}) near globular cluster cores are very likely $\sim 1\ M_\odot$ neutron stars accreting matter from close, nondegenerate companions (Hertz and Grindlay 1983), while it has been suggested that weak ($L_x \lesssim 10^{34.5}$ ergs s^{-1}) globular X-ray sources may be compact binaries containing white dwarfs (Hertz and Grindlay 1983).

Aside from X-ray sources, searches for binaries in globular clusters have produced mostly negative results. No giant binaries have been found in a sensitive radial velocity survey of M3 (Gunn and Griffin 1979; but see Harris and McClure 1983). No W Ursae Majoris stars have been found on deep plates of M55 (Trimble 1977). Not a single eclipsing binary of any other type is known to be a definite globular cluster member. No Hβ emission-line binaries with equivalent width > 12 Å and $M_B < 6$ exist between 4 and 30 core radii from the center of M3 (Shara, Moffat, and Hanes 1985).

Two objects suspected of being dwarf novae (and hence unquestionably, close binaries) have recently been investigated in some detail. Margon, Downes, and Gunn (1981) obtained a spectrum and photographic observations which show that the variable star V101 in a field of M5 (10 core radii $= 0.17$ tidal radii from the center) is almost certainly a dwarf nova. Margon and Downes's (1983) spectrophotometry and photographic photometry of V4 in M30 (at 50 core radii $= 0.4$ tidal radii) suggest that this is also a dwarf nova in a globular cluster.

White dwarfs accreting from nondegenerate companions that give rise to dwarf nova eruptions will eventually accrete hydrogen shells degenerate and massive enough to give rise to thermonuclear runaways (e.g., Gallagher and Starrfield 1978), i.e., classical novae. Thus, the two dwarf nova candidates in globulars suggest that classical novae should also sometimes occur in these clusters. Two good classical nova candidates have in fact been found in two other globular clusters in the last century.

Nova T Scorpii reached visual magnitude 7 in M80 in 1860 (Luther 1860; Pogson 1860) and was followed for almost 4 weeks to $m_v \approx 10.5$. Its light curve and position a few arc seconds from the globular center leave little doubt of its bona fide nova nature or cluster membership. Unfortunately the crowded field at the center of M80 makes ground-based recovery of the nova impossible with present techniques.

A star which erupted $\sim 30''$ from the nucleus of the globular cluster M14 in 1938 is also very likely a classical nova. The object was seen at $m \approx 16$ on eight plates taken during a 1 week interval of 1938 June (Hogg and Wehlau 1964), and on none of 247 other plates taken on 123 nights spread out over 1932–1963. The position of the nova (only 0.8 core radii from the cluster center) strongly supports its cluster membership. The star's absolute magnitude during the 1938 outburst ($M \approx -1.5$) (Hogg and Wehlau 1964), lack of brightness decline during the week it was observed, and nondetection at so many other epochs strongly supports the classical nova interpretation, and virtually rules out alternatives such as a dwarf nova eruption or a Mira-type variation.

Recovery and study of this object would permit an unambiguous determination of its nature. If it is an old nova, comparison between it and field old novae could show if globular cataclysmic binaries, believed to be produced by tidal capture (Fabian, Pringle, and Rees 1975), differ from those produced by

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binary stellar evolution. As the distance to M14 is independently and fairly accurately known (see § III), the luminosity and mass accretion rate in the old nova could be derived with corresponding accuracy.

As a first step in this direction, we have attempted to recover the nova. Our observations are briefly described in § II. A candidate is identified in § III. Photometry and astrometry supporting the identification are also presented. Future observations needed to confirm the candidate are suggested, along with a brief summary of conclusions in § IV.

II. OBSERVATIONS

On the nights of 1983 August 12/13 and 13/14, we imaged the field of Nova 1938 with the RCA CCD camera at the prime focus of the Cerro Tololo Inter-American Observatory 4 m telescope. Exposure times were 30 s each in broad-band R and B filters, and 30 minutes with an Hα filter (FWHM ≈ 50 Å in the f/2.67 converging beam). The raw images were trimmed, debiassed, and flat-fielded using the CTIO CCD reduction routines. Astrometric and photometric measurements described in § III were carried out with a VAX 11/780 computer, IDL software, and a de Anza image display system at the Space Telescope Science Institute (STScI).

We again imaged the nova field on 1985 May 21 with the RCA CCD camera at the prime focus of the Anglo-Australian 3.9 m telescope. Exposure times were 5 minutes each in broad-band B and V filters, and 20 minutes in a U filter. All reductions were carried out at STScI.

III. THE CANDIDATE

The position of the nova was measured relative to a dozen fairly bright, uncrowded stars appearing within 2′ of the nova on the discovery plates. The right ascensions and declinations of the dozen stars were determined relative to SAO stars on a Palomar Schmidt plate. Combining the above data sets yields, for the nova in 1938

$$\alpha(1950) = 17^{\rm h}35^{\rm m}00^{\rm s}.40;\ \delta(1950) = -03°12'54''.5\ ,$$

with an estimated error of $\pm 1''$ (from SAO positions) in each coordinate. The position of the nova, determined on the CCD frames relative to the same dozen stars, is indicated in Figures 1–5 (Plates 30–32). The brightness centroid of a faint star in the CCD frames falls within 0.5 pixel ($=0''.3$) of the position of the nova on the discovery plates. This is identical to the 1 σ error in determining a *relative* star position. We propose that this star is the nova in its quiescent state.

We have used the photometry package DAOPHOT (Stetson 1984) to measure the brightness of our candidate and several hundred other stars in the same CCD field. The zero point is set by Kogon, Wehlau, and Demers (1974) photoelectric standards B, C, and F, and checked against 26 stars in M14 with photographic photometry carried out by A. W. We find $B = 20.2 \pm 0.3$ for our candidate, with the rather large estimated error due to background and crowding. Using the Harris and Racine (1979) values for M14 of the apparent distance modulus $(m - M)_V = 16.9$ and $E_{B-V} = 0.58$, and with $(m - M)_B = (m - M)_V + E_{B-V}$, we derive $M_B = +2.7$, with an estimated uncertainty of $\pm$ 0.5 mag. Warner's (1973) Figure 1 shows that $(B-V)_0 \approx 0$ ($\sigma \approx 0.2$ mag) for old novae. Patterson (1984) finds $\langle M_V \rangle = 4.1$ (and hence $\langle M_B \rangle = 4.1$) for old novae, with a FWHM of ~ 3 mag in the distribution of M_V in quiescence. Thus, our candidate is somewhat brighter than the mean, but within the brightness range expected for a quiescent old nova at the distance of M14.

How many candidates does one expect to find along the line of sight within an error circle of diameter $\sim 3\ \sigma \approx 1''$ centered on the 1938 nova position? We have made an attempt to answer this by calculating the number of cluster stars expected in the error circle, brighter that $M_V = +6$ (the approximate faint limit for ex-novae in quiescence) and $M_V = +4$. Integration of Irwin and Trimble's (1984) J luminosity function for the less populous globular cluster M55 [assuming from their Fig. 4*a* $N = 4390$ stars per mag for $6 \leq M_J \leq 15$, $N = 0$ per mag for $M_J > 15$, and $N = 4390 \times 10^{0.25(M_J - 6)}$ for $M_J < 6$] gives $N_{\rm tot}({\rm M55}) = 5 \times 10^4$ stars, $N(M_V \leq 6)/N_{\rm tot}({\rm M55}) \approx 0.16$ and $N(M_V \leq 4)/N_{\rm tot}({\rm M55}) = 0.050$. Assuming $N_{\rm tot}$ to scale with the total absolute magnitude [M_V(tot) $= -6.85$ for M55 and -9.34 for M14; Harris and Racine 1979] yields $N_{\rm tot}$ (M14) $\approx 5 \times 10^5$ stars. On the basis of a King (1962) profile with r_c and r_t for M14 from Peterson and King (1975) we expect to find three stars with $M_V \leq 6$ and 0.9 star of $M_V \leq 4$ in the 1″ error circle of M14. This estimate is clearly compatible with the one candidate observed down to $M_V = +4$ within the error circle and cautions us that the present candidate, judged only on the basis of position and brightness, could be an ordinary cluster star masking the real (fainter) nova.

Our candidate shows the same brightness (relative to surrounding stars) in the Hα CCD frames as in the R frames. Any shell produced in the 1938 outburst is now fainter than our detection limit of $m_{\rm H\alpha} \approx 21.5$. Most old novae show Balmer emission lines with equivalent widths of only approximately 1–10 Å, and these are too weak to stand out in our 50 Å FWHM filter Hα image.

A check of the candidate star's color has been done via the cluster's color-magnitude diagram, shown in Figure 6. The CCD photometry program DAOPHOT (Stetson 1984) has been used to generate the CMD. The nova candidate is indicated with an asterisk in the figure; it is somewhat more red (by ~ 0.2 mag) than other stars of similar V.

Many, though not all old novae display negative values of $U-B$ (Warner 1973). We have again used DAOPHOT, to generate a color-color diagram for M14, shown in Figure 7. The candidate is located with an asterisk *and it is obviously much brighter in U (by ~ 0.7 mag) than stars of similar B − V*. From the candidate's position in the color-color plot (see, e.g., Cannon and Stobie 1973) we find that its dereddened colors are $(B-V)_0 \approx 0.8 \pm 0.4$, and $(U-B)_0 \approx -0.3 \pm 0.4$, with the estimated uncertainties coming from the scatter in Figure 7. The star's moderately red $(B-V)$ color is somewhat unusual for an old nova and could be due to a somewhat evolved secondary. The negative $(U-B)$ color is the strongest evidence in support of our identification.

The positional coincidence, brightness, and especially $(U-B)$ color all taken together constitute firm support, but not confirmation beyond all doubt, of our candidate for the nova in M14.

IV. FUTURE WORK AND SUMMARY

A spectrum of the candidate star would immediately confirm or reject it as the old nova. Because of the star's faintness and the crowding of its field this will be extremely difficult. Such an observation could be carried out far more easily and far better by the Hubble Space Telescope. The $\lesssim 0''.1$ resolution available with the Wide Field/Planetary Camera (WFC) would easily disentangle the nova from field stars. The Faint Object Spec-

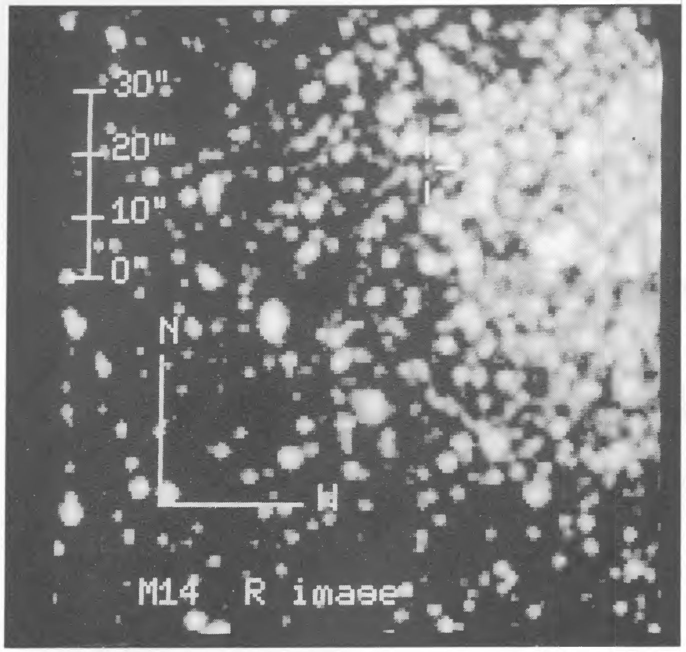

FIG. 1

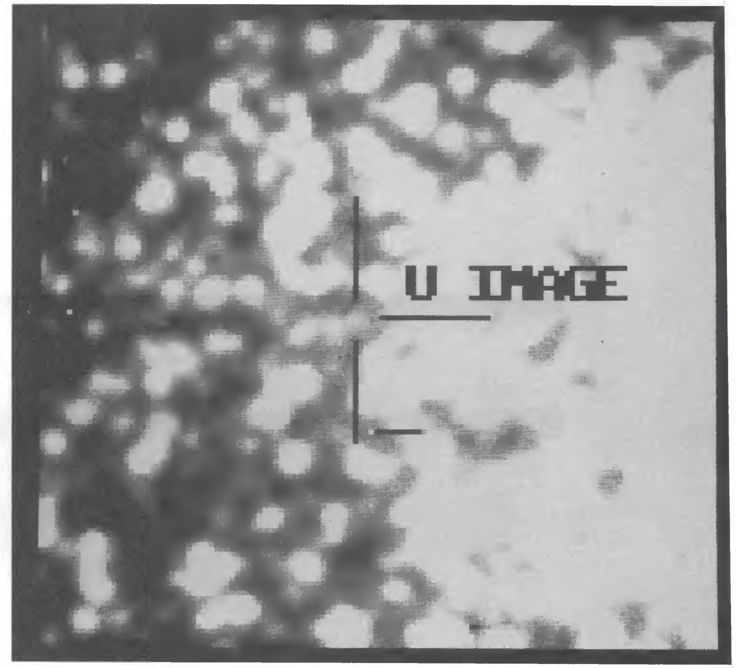

FIG. 2

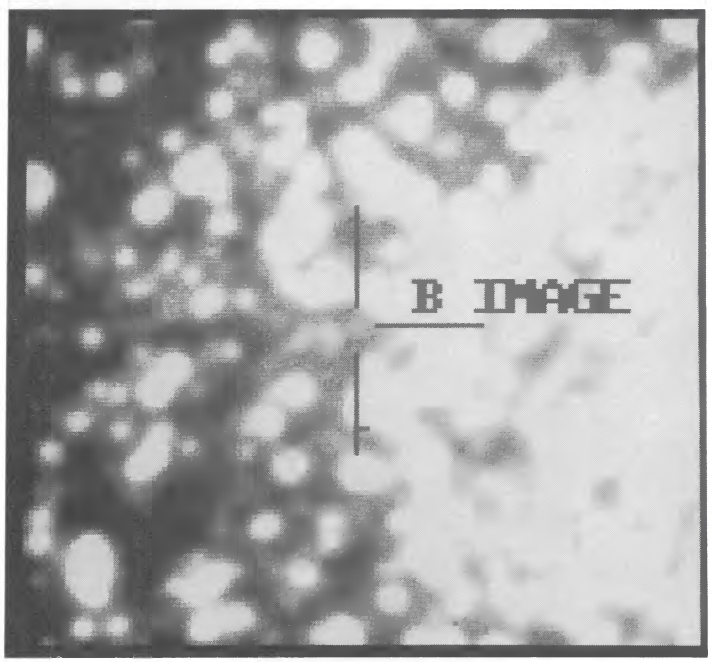

FIG. 3

FIG. 1.—A broad-band *R* image of the field of the nova of 1938 in the globular cluster M14. The 30 s exposure was taken with the RCA CCD camera at the prime focus of the CTIO 4 m telescope on 1983 August 14. Our nova candidate is indicated.

FIG. 2.—A broad-band *U* image of the field of the nova of 1938 in the globular cluster M14. The 20 minute exposure was taken on 1985 May 21 with the RCA CCD prime focus camera of the AAT 3.9 m telescope. The nova candidate is indicated with three 10″ length bars. North is up; east is left.

FIG. 3.—Same as Fig. 2, but a 5 minute broad-band *B* exposure.

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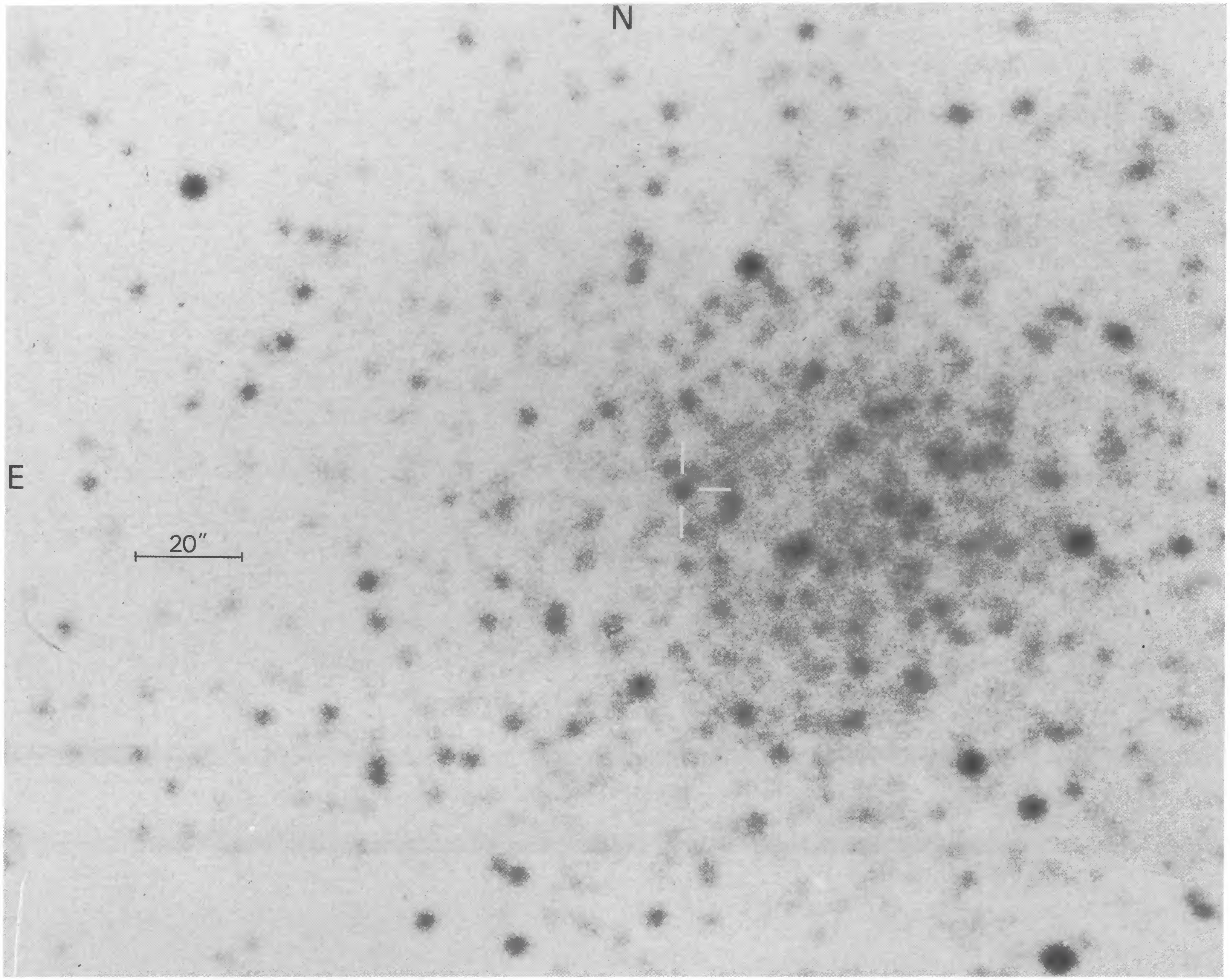

FIG. 4.—Discovery plate (DDO plate 3263) of the nova, taken 1938 June 23 on Astra II emulsion. North is up; east is left. See Hogg and Wehlau 1964 for details.

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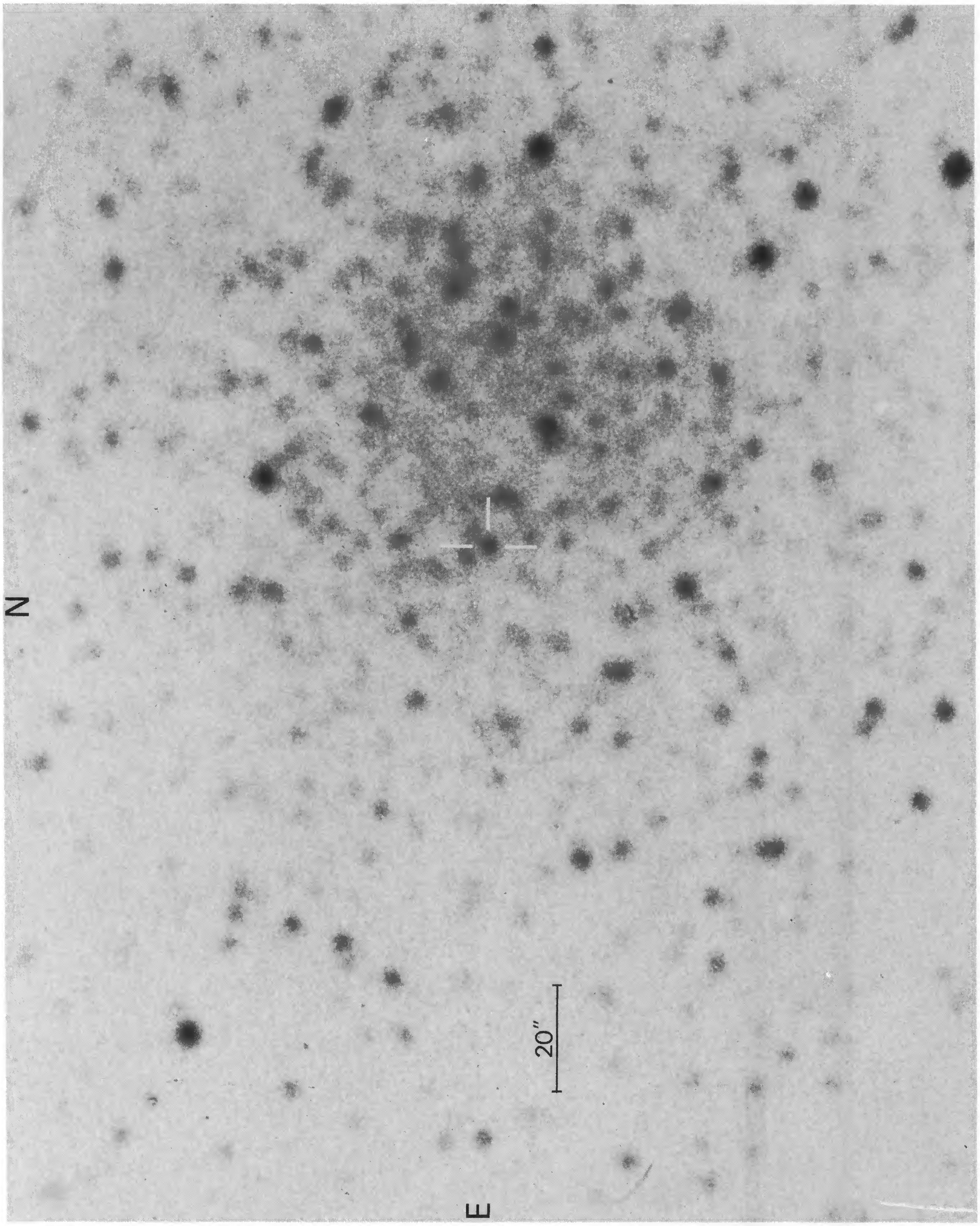

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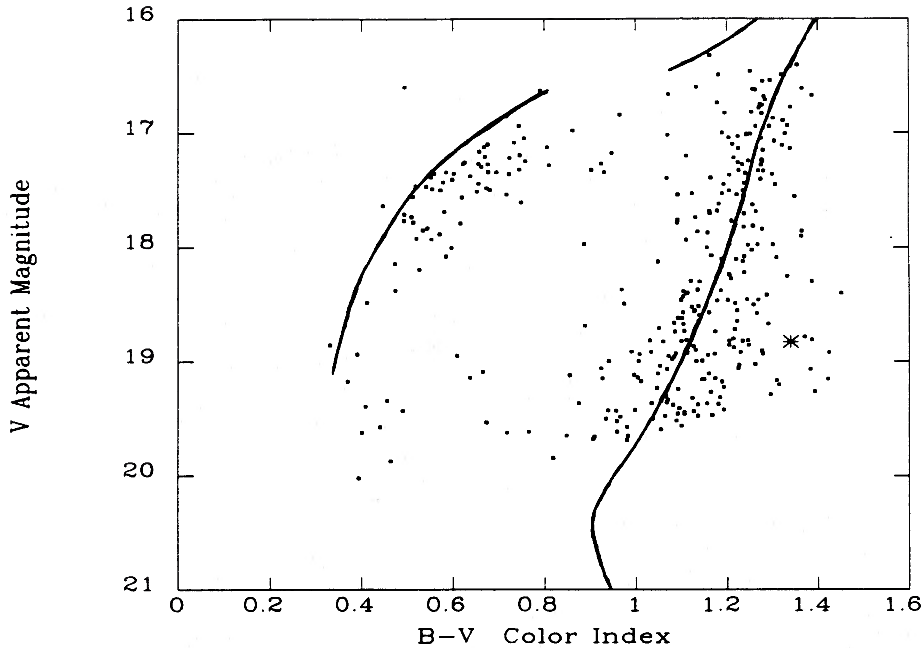

FIG. 6.—A color-magnitude diagram of the globular cluster M14, derived from AAT prime focus CCD camera images with the photometry package DAOPHOT. The nova, indicated with an asterisk, is more red than other stars of similar brightness. The solid curve is taken from Sandage's 1970 C-M diagram of the similar metallicity globular M13.

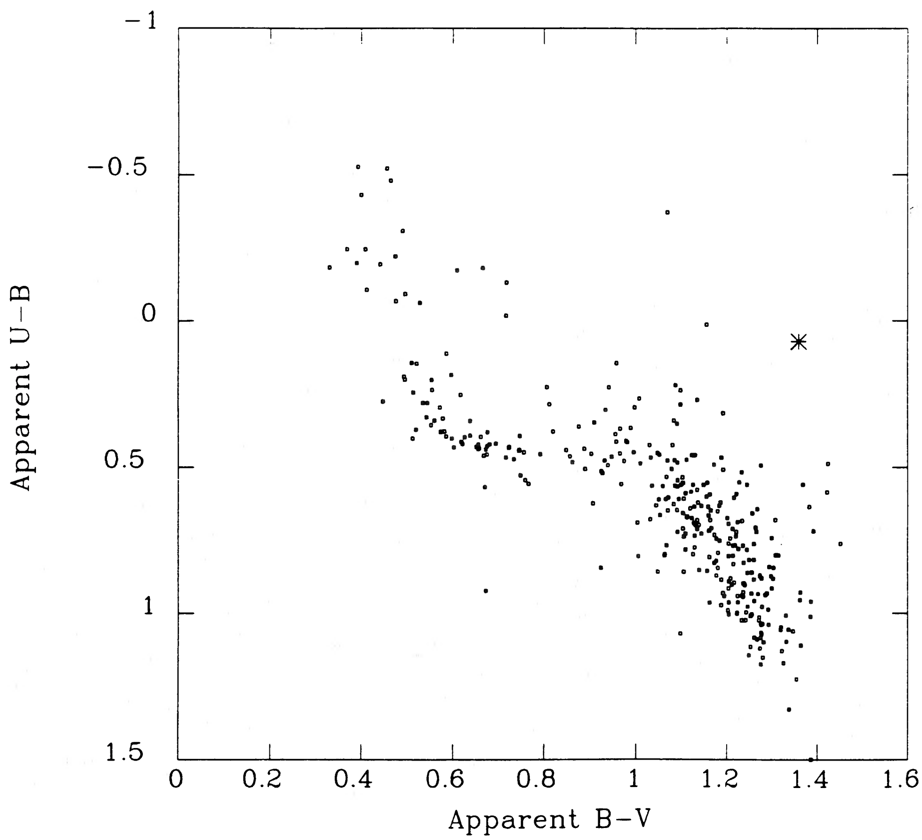

FIG. 7.—A color-color diagram of the globular cluster M14 derived from prime focus AAT CCD U, B, and V images with DAOPHOT. The nova, indicated with an asterisk, is much brighter in U than other stars of similar $B-V$.

trograph should also have no problem isolating and providing a spectrum of our candidate, or others resolved in a WFC frame. This is a Faint Object Spectrograph Instrument Definition Team project, led by Dr. Bruce Margon.

In summary, we have identified a candidate for the quiescent state of the nova which erupted in the globular cluster M14 in 1938. The absolute magnitude, position, and especially the $U-B$ color of the candidate strongly support our identification of its being the nova. Detailed study and possibly even definitive confirmation will probably require Hubble Space Telescope observations.

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REFERENCES

Cannon, R. D., and Stobie, R. S. 1973, *M.N.R.A.S.*, **162**, 227.
Fabian, A. C., Pringle, J. E., and Rees, M. J. 1975, *M.N.R.A.S.*, **172**, 15P.
Gallagher, J. S., and Starrfield, S. 1978, *Ann. Rev. Astr. Ap.*, **16**, 171.
Gunn, J. E., and Griffin, R. F. 1979, *A.J.*, **84**, 752.
Harris, H. C., and McClure, R. D. 1983, *Ap. J.* (*Letters*), **265**, L77.
Harris, W. E., and Racine, R. 1979, *Ann. Rev. Astr. Ap.*, **17**, 241.
Hertz, P., and Grindlay, J. E. 1983, *Ap. J.*, **275**, 105.
Hogg, H. S., and Wehlau, A. 1964, *J.R.A.S. Canada*, **58**, 163.
Irwin, M. J., and Trimble, V. L. 1984, *A.J.*, **89**, 83.
King, I. R. 1962, *A.J.*, **67**, 471.
Kogon, C. S., Wehlau, A. and Demers, S. 1974, *A.J.*, **79**, 387.
Luther, E. 1860, *Astr. Nach.*, **53**, 293.
Margon, B., and Downes, R. A. 1983, *Ap. J.* (*Letters*), **274**, L31.
Margon, B., Downes, R. A., and Gunn, J. E. 1981, *Ap. J.* (*Letters*), **247**, L89.
Patterson, J. 1984, *Ap. J. Suppl.*, **54**, 443.
Peterson, C. J., and King, I. R. 1975, *A.J.*, **80**, 427.
Pogson, N. 1860, *M.N.R.A.S.*, **21**, 32.
Sandage, A. 1970, *Ap. J.*, **162**, 841.
Shara, M. M., Moffat, A. F. J., and Hanes, D. A. 1985 in *IAU Symposium 113, Dynamics of Star Clusters*, ed. J. Goodman and P. Hut (Dordrecht: Reidel), p. 109.
Spitzer, L., and Mathieu, R. D. 1980, *Ap. J.*, **241**, 618.
Stetson, P. 1984, private communication.
Trimble, V. 1977, *M.N.R.A.S.*, **178**, 335.
Warner, B. 1973, in *IAU Symposium 73, Structure and Evolution of Close Binary Systems*, ed. P. Eggleton (Dordrecht: Reidel), p. 85.

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