SPECTROSCOPIC AUTHENTICATION OF VERY OLD NOVA CANDIDATES

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ABSTRACT

The evolutionary histories, and hence lifetimes and space densities of cataclysmic binaries may be controlled by long periods of "hibernation" (i.e., low mass-transfer rate $\dot{\mathscr{M}}$) between outbursts. Recovering quiescent novae, and determining their accretion luminosities and $\dot{\mathscr{M}}$ centuries after eruption is important to test the hibernation hypothesis. We have therefore obtained spectra of optical candidates for the novae of 1673, 1855, and 1860; and of a nebulosity suspected of being an old nova shell. The bluest of the Downes–Szkody candidates (their star 5) for nova T Boo (1860) shows no Balmer emission. Their star 2, prominent on all frames except the U exposure is quite red and also shows no emission lines. Their variable candidate for nova U Leo 1855 again shows no Balmer emission; but the presence of a variable so close to the position of an old nova suggests a correspondence. The Duerbeck candidate for nova Pup 1673 shows narrow Balmer absorption, as does a brighter blue star 5" to the northeast. The star closest to Richer's position is also shown not to be the nova. If the star seen (twice) in 1673 was a nova the present (quiescent) nova is in deep hibernation. The Einstein x-ray source E2000 + 223 was suggested by Takalo and Nousek as a possible old nova. However, its spectrum shows it to be a starburst galaxy at $z = 0.03$. We conclude that no remnants of the possible classical novae of 1673, 1855, and 1860 have yet been found with certainty. If the reported events were, indeed, classical nova eruptions then the underlying binaries are no longer blue, mass-transferring stars, and do not resemble the canonical picture of old novae.

I. INTRODUCTION

The hibernation scenario of cataclysmic binaries (Shara *et al.* 1986; Livio and Shara 1987) posits that the rate of mass transfer ($\dot{\mathscr{M}}$) from the red dwarf to the white dwarf in most classical nova binaries decreases sharply a few centuries after eruption. Most of the luminosity of decades-old novae is generated by accretion. Hibernation thus implies that centuries-old novae should be shining mostly by the light of the underlying binary stars, and hence be very faint. The two oldest recovered novae (CK Vul-nova 1670 and WY Sge-nova 1783) are, respectively, 100 and 10 times fainter than decades-old novae (Shara 1989).

A critical test of the hibernation scenario is to recover other very old, quiescent novae and to measure their luminosities. Decades-old novae are, on average about 12 mag fainter than novae at maximum brightness (Robinson 1975). Novae erupting before ~1800 A.D. must have reached $V \leqslant 3-4$ to have been recognized and recorded. The hibernation scenario predicts that these old novae are no longer very blue ($U-B \leqslant -0.5$) novalike variables with Balmer, He I and He II emission lines at $V \sim 16$. Such bright, novalike objects are straightforward to recover with UV surveys and to authenticate with slit spectra. Not finding such objects in the fields of well-located, ancient novae would be strong support for hibernation.

Nova Sco 1437 A.D. is one of the best located pre-telescopic novae (Clark and Stephenson 1977). A search for UV-bright objects in the two sq. degree error box around the position specified by Korean Imperial Astrologers has yielded eight cataclysmiclike stars, but none brighter than $B \sim 19$ (Shara, Moffat, and Potter 1990). The absence of a cataclysmic in the $B = 15-18$ mag range supports the hibernation scenario. The goal of this paper is to obtain spectra and thereby authenticate or discredit, other published optical candidates for very old nova. [Downes and Szkody's (1989) Table I summarizes the present state of knowledge of pre-1900 novae.] We emphasize that the discovery of very old, *luminous* novae would undermine the picture of a strongly decreasing $\dot{\mathscr{M}}$ several centuries after eruption. Conversely, the demonstration that centuries-old novae are systematically fainter than decades-old novae would strongly support the idea of hibernation.

In Sec. II we describe the spectrographic observations and reductions. Section III presents our results for the optical candidates for four old novae. The implications for the hibernation scenario are presented in Sec. IV.

II. SPECTROGRAPHIC OBSERVATIONS AND REDUCTIONS

Spectra of old nova candidates have been obtained with the South African Astronomical Observatory 1.9 m telescope, the Cerro Tololo Inter-American Observatory 4 m telescope, and the 3.6 m Canada–France–Hawaii telescope.

The CFHT spectrum (of E2000 + 223) was taken on 16 June 1988 UT with the Herzberg spectrograph and Thomp-

a) Guest Observer, Canada–France–Hawaii Telescope, operated by the National Research Council of Canada, the Centre National de la Recherche Scientifique of France, and the University of Hawaii.

b) Guest Observer, Cerro Tololo Inter-American Observatory, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

c) Guest Observer, South African Astronomical Observatory.

son CCD detector at Cassegrain focus. A 300 l/mm grating yielded a 2 pixel resolution of 8 Å. The CTIO spectra of Nova Pup candidates were taken on 6 and 8 June 1988 with the blue air Schmidt camera and GEC CCD detector of the RC spectrograph. A 300 l/mm grating resulted in spectra with 8 Å (2 pixel) resolution. The SAAO spectra of nova Boo and nova Leo candidates were obtained on 8 April 1989 with the Cass focus two-channel intensified Reticon spectrograph. A 7 Å 2-pixel resolution was obtained with a 300 l/mm grating. All data reductions were carried out with the IRAF package at ST ScI.

III. RESULTS

a) T Boo (Nova 1860)

Duerbeck lists this star as N??, and the GCVS4 classifies the object as N:. Downes and Szkody (1989) (hereafter referred to as DS) list nine stars within 142″ of the position reported by Baxendell (1861). We have obtained spectra of the two most promising DS stars, numbers 2 and 5.

Star 5 was reported by DS to be quite blue ($U-B = +0.2$) and our spectrum in Fig. 1(a) supports this claim. There is, however, no Balmer emission. This object is the "best" candidate for the old nova, but its lack of photometric variability (Downes and Szkody 1989) and emission lines argue strongly against the identification.

Star 2 was reported by DS to have been absent on their U-band frame, suggesting an eclipse for some fraction of their exposure. Our spectrum [Fig. 1(b)] of star 2 shows it to be quite red, with no flux detected blueward of ~4300 Å, and to have no emission lines. We conclude that (if it was a genuine nova) T Boo is now fainter than the DS photometric limit $V > 20.4$ (as evidenced by the faintest stars in the DS tables).

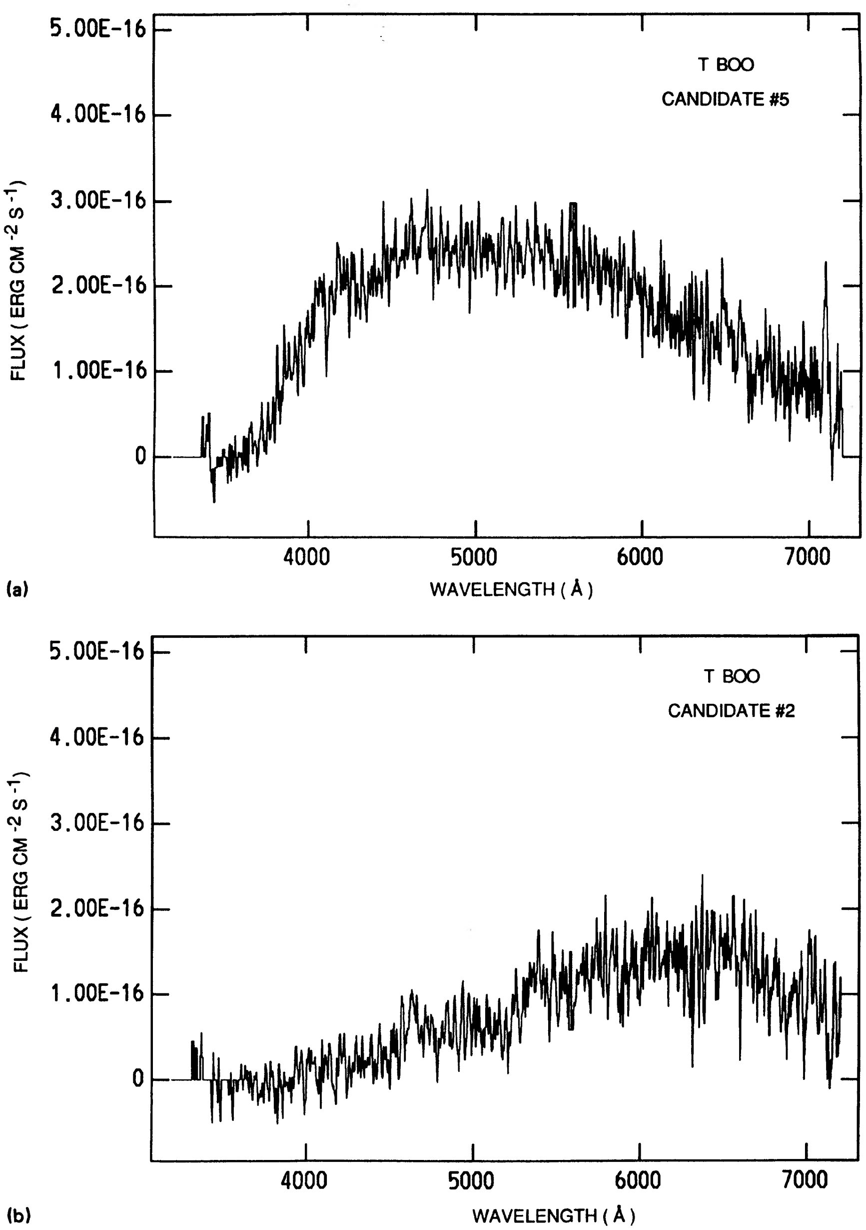


FIG. 1. (a) SAAO 1.9 m telescope spectrum of the blue candidate #5 of Downes and Szkody (1989) for the remnant of Nova Boo 1860. (b) Same as (a), but for the Downes and Szkody candidate #2.

b) U Leo (Nova 1855)

The reality of this object is also not certain, despite Kreutz's (1881) assertions. Duerbeck (1987) classifies the object as N?? and the GCVS4 lists it as N:.

Downes and Szkody (1989) discovered a star at $V = 17.3$ with sinusoidally varying brightness 9″ from the position of a missing BD star. The amplitude of the variation is 0.11 mag in the R band, and the period is either 192.5 or 385 min.

Our spectrum of the variable shown in Fig. 2 shows a G-type star; this is based on lack of strong Balmer absorption (later than F type) and wavelength of maximum intensity (earlier than K-type). This spectral type is consistent with a 385 min orbital period in a cataclysmic binary, but not with the shorter period (Patterson 1984). The lack of emission lines implies that mass transfer is not occurring in the system. If this is the remnant of U Leo, then it fits the profile of a very low mass-transfer rate (hibernating) old nova (see Sec. IV).

c) Nova Puppis 1673

The quadrant observations by G. Richer on 1673 January 12 and 21 of a 3rd magnitude star in Puppis (Zinner 1926) have given the most precise position of a potentially recoverable seventeenth-century nova.

Duerbeck (1987) identified a 20th magnitude blue star on the SRC-J Schmidt plates as the most likely candidate. Our spectrum of the object is shown in Fig. 3(a). Spectra are also shown [in Figs. 3(b) and 3(c)] of the two stars 5″ and 30″ NE, respectively, of the Duerbeck candidate. These are the brightest stars within ≈30″ of Richer's position (as reduced by Zinner).

The latter two stars, though closer to the position specified by Richer than Duerbeck's candidate, are of late spectral type and bear no resemblance to old novae. The Duerbeck candidate shows narrow Balmer absorption lines superposed on a blue continuum. While a blue color is the norm for cataclysmics, Balmer absorption lines are extremely rare, occurring in only a few very high mass-transfer rate "thick disk" systems (Ferguson, Green, and Liebert 1984). The narrow absorption lines seen in Fig. 3(a) argue against the Duerbeck candidate being such an object.

d) E2000+223

Takalo and Nousek (1985) suggested that the serendipitous Einstein x-ray source E2000 + 223 is an old nova shell. This suggestion is based on their detection of a diffuse (~20″ × 10″) object inside the IPC error circle; an emission feature close to that of the [S II] λλ 6716, 6732 lines; and weak, extended nonthermal radio emission coincident with the optical nebula and the IPC error circle.

A key assumption by Takalo and Nousek (1985) was their identification of the emission feature they detected at 6750 Å with the [S II] lines. It is immediately obvious from our much higher S/N spectrum (Fig. 4) that this assumption is incorrect. The emission feature is actually redshifted Hα! This is confirmed by the presence of Hβ, [O III] λλ 4959, 5007 and He I 5876, all of which display redshifts ranging from 0.025 to 0.033. We adopt $z = 0.029 \pm 0.004$. E2000 + 223 is therefore an active galaxy, with an x-ray flux of $\sim 7 \times 10^{41}$ ergs s^{-1} (assuming $H_0 = 75$ km/s/Mpc).

IV. DISCUSSION

Despite the intriguing variable candidate for nova U Leo 1855, no compelling evidence exists for the recoveries of any of the old novae considered in this paper. These are among the best old nova candidates yet published. None of the candidates for the novae of 1855, 1860, and 1673 display the Balmer, He I and He II emission lines seen in the spectra of decades-old novae (Williams 1982; Shara *et al.* 1986). Either the putative novae were really something else; or the nova remnants have not yet been located; or their spectra are very different from those of 10–100 year-old novae. If either of the latter two possibilities are correct then a prediction of the hibernation scenario is supported.

If the three events were really nova eruptions, and the positions of the events were accurately recorded, then the old

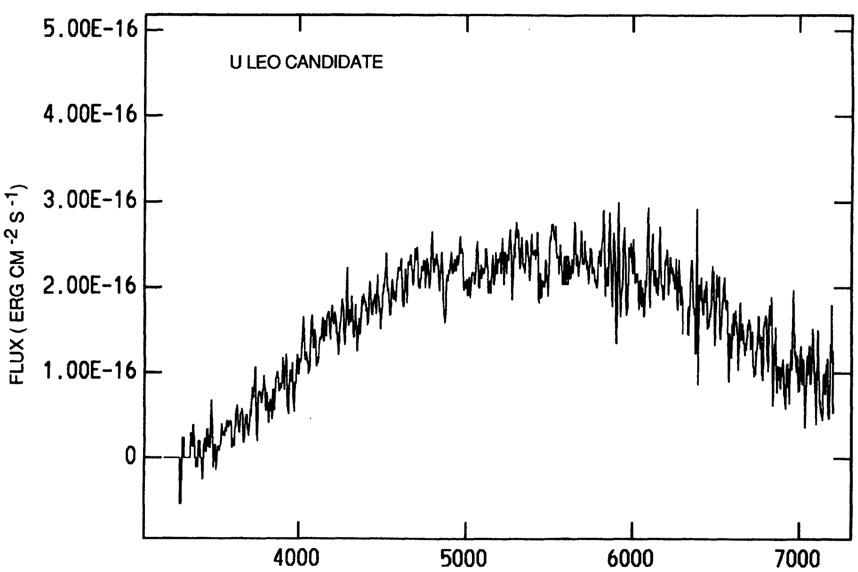
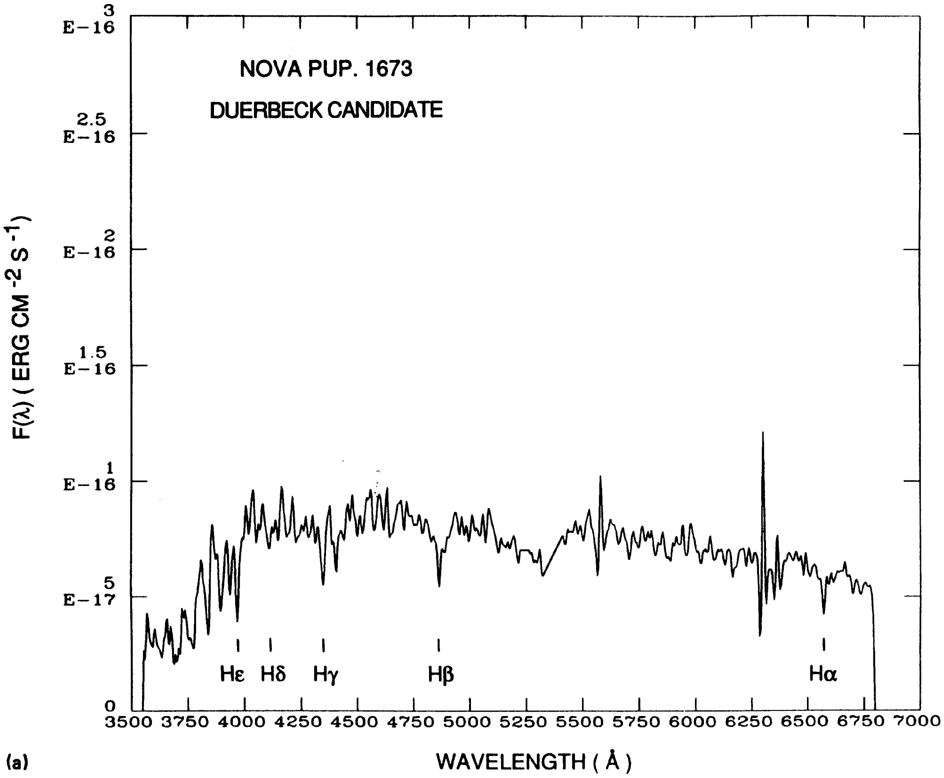
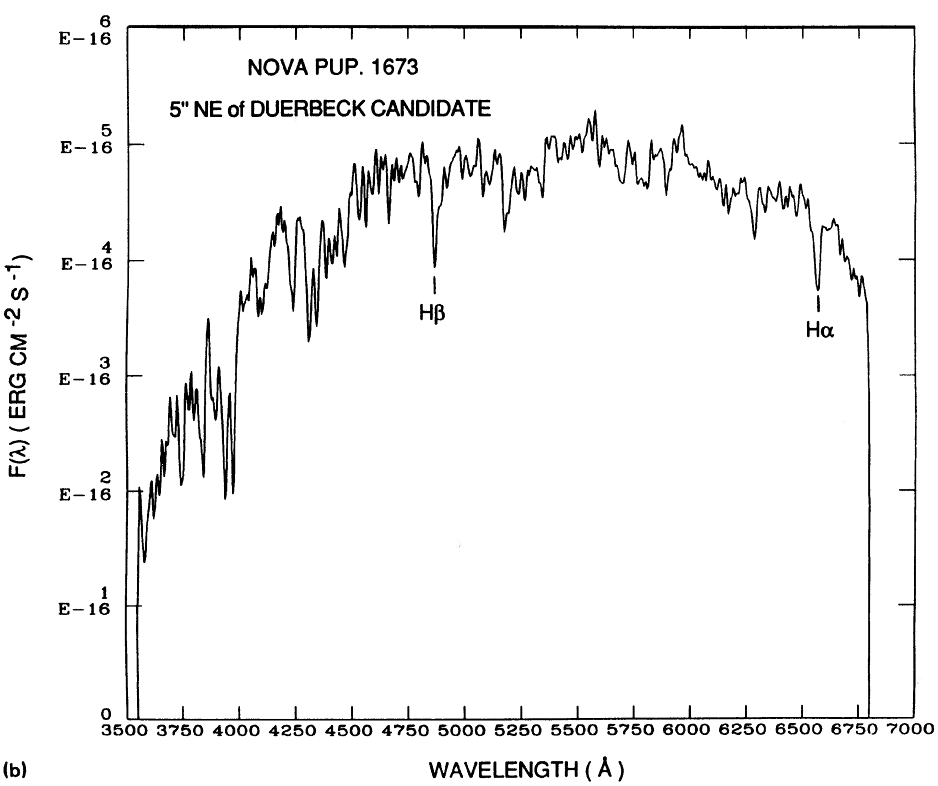


FIG. 2. Same as Fig. 1(a), but for the Downes and Szkody variable candidate for nova U Leo 1855.



(a)



(b)

FIG. 3. (a) CTIO 4 m telescope spectrum of the Duerbeck (1987) candidate for nova Puppis 1673. (b) Same as (a), but for a star 5″ NE of the Duerbeck candidate. (c) Same as (a), but for a star 30″ NE of the Duerbeck candidate.

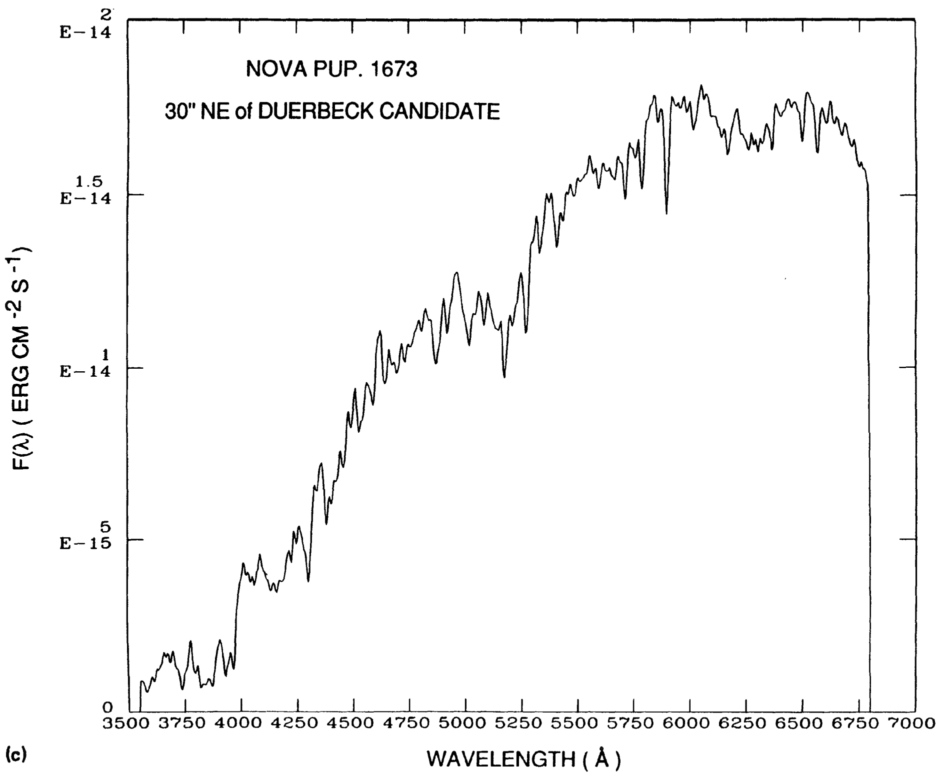


FIG. 3. (continued)

novae should have easily been recovered by Downes and Szkody (1989) (by color and variability) and by Duerbeck (1987) (on the basis of color) if *hibernation does not occur.*

The strongest limit is that on nova Pup 1673. There is no blue star (other than the Duerbeck candidate which shows no emission) at Richer's position (of an observed 3rd magnitude star) to 21st magnitude. A magnitude amplitude > 18 mag implies a present-day luminosity $\mathscr{M} \geqslant +10$, consistent with hibernation.

The results of this paper are mildly supportive of the hi-

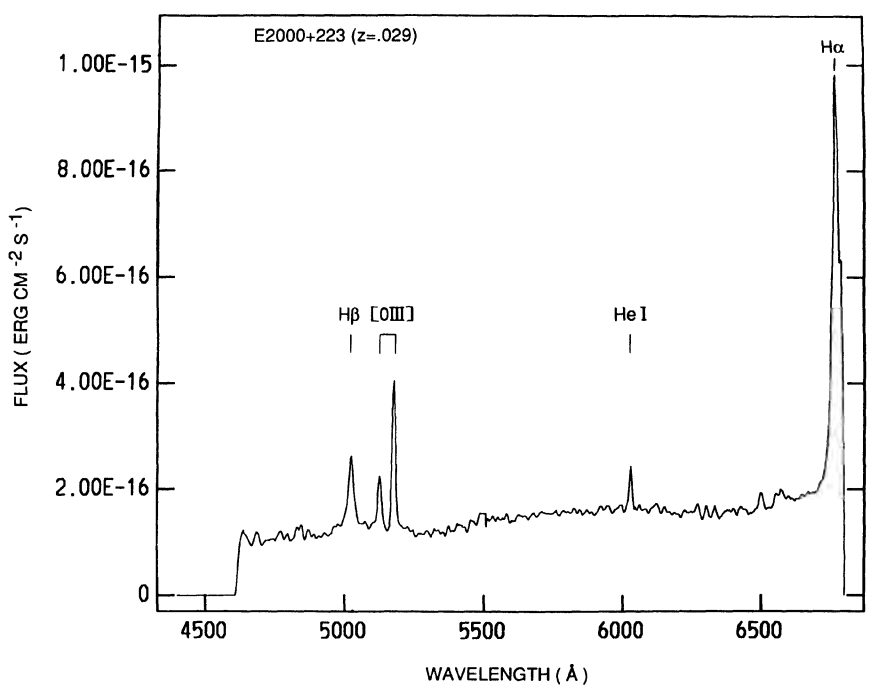


FIG. 4. CFHT 3.6 m telescope spectrum of the Takalo and Nousek (1985) candidate for an old nova shell. The spectrum demonstrates that the object is actually a starburst galaxy at $z = 0.029$.

bernation scenario if at least one of the first three objects of Sec. III was a genuine classical nova. This is because the nova remnants are too faint to have been recovered, or are not transferring mass and can thereby masquerade as "ordinary" field stars. There are, to date, no recovered old novae which contradict the hibernation scenario.

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