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THE RECOVERY OF CK VULPECULAE (NOVA 1670)—THE OLDEST "OLD NOVA"

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ABSTRACT

Comparison of narrow-band Hα with continuum plates has yielded the location of CK Vulpeculae, a slow nova which reached maximum brightness $m_B \approx 3$ in 1670 and again in 1671. CK Vul affords us the opportunity to study a nova remnant almost two centuries older than any other known. Associated with the central object are two nebulous blobs radiating mostly Hα and [N II]. These nebulae are probably ejecta of the nova sweeping up interstellar matter.

Subject headings: nebulae: general — stars: novae

I. INTRODUCTION

What becomes of a classical nova centuries after it erupts? On statistical grounds, Ford (1978) has shown that individual novae must recur hundreds or thousands of times (with successive explosions separated by $\sim 10^4$–10^5 yr). Sometime after an eruption, a nova must therefore start transforming into a configuration capable of another outburst.

A thermonuclear runaway in the hydrogen-rich envelope of a white dwarf star (accreting material from a binary companion) powers a nova outburst (Starrfield, Sparks, and Truran 1974). Envelope energy generation rates of the order of 10^{14} ergs g^{-1} s^{-1} or more rapidly bring the white dwarf close to its Eddington luminosity, and mass ejection begins.

Two numerical studies (Prialnik, Shara, and Shaviv 1978, 1979) have followed the ejection of matter during slow and moderate nova model outbursts. These simulations indicate that (1) a sizable fraction, *but not all*, of the initial envelope is ejected, and (2) novae "shut off" when their distended envelope remnants, which cannot sustain further nuclear reactions, contract back onto the white dwarf. Cooling of these low-mass envelopes and hence of old novae on a time scale of a few centuries is the prediction of the simulations, provided no further mass accretion occurs.

The white dwarf's companion star and accretion disk have of necessity been ignored in the above simulations. Yet there are strong observational indications that accretion disks and their associated mass transfer recommence within a few years of a nova eruption and continue for at least a century (e.g., Nova Oph 1848, Nova Per 1901). This hints that "nova-like" systems are the remnants of prehistoric novae (Warner 1976). However, the observed number of nova-like systems is far too low to account for the number of outbursting novae observed annually in the Galaxy (Webbink and Gallagher 1981). What, then, do novae become long after one outburst and before another?

One way to better understand the evolution of novae is to identify and study a sequence of progressively older subjects. The oldest spectroscopically confirmed nova to date is 134 year old Nova Oph (1848) (and we will report in the near future on a spectroscopic confirmation of the Weaver 1951 candidate for WY Sge, the nova of 1783).

We report here the recovery of CK Vulpeculae, a slow nova which erupted in 1670. With an age since outburst of 312 years, it is now available for study as by far the oldest nova with a known position. CK Vul is doubly interesting because (rather unexpectedly for such an old, nonrecurrent object) it is one of only a handful of novae with clearly visible ejected nebulosity.

II. OBSERVATIONS

Humason (1938) searched unsuccessfully for CK Vul —the nova is fainter than the limiting magnitude of his finder chart. An examination of the Palomar Observatory Sky Survey (POSS) also reveals no obvious blue candidate in the field specified by Humason.

The distinguishing characteristics of quiescent old nova spectra are strong Balmer and He II emission lines superposed on a blue continuum essentially free from absorption lines. To maximize our chances of finding CK Vul (with a first-quarter moon above the horizon),

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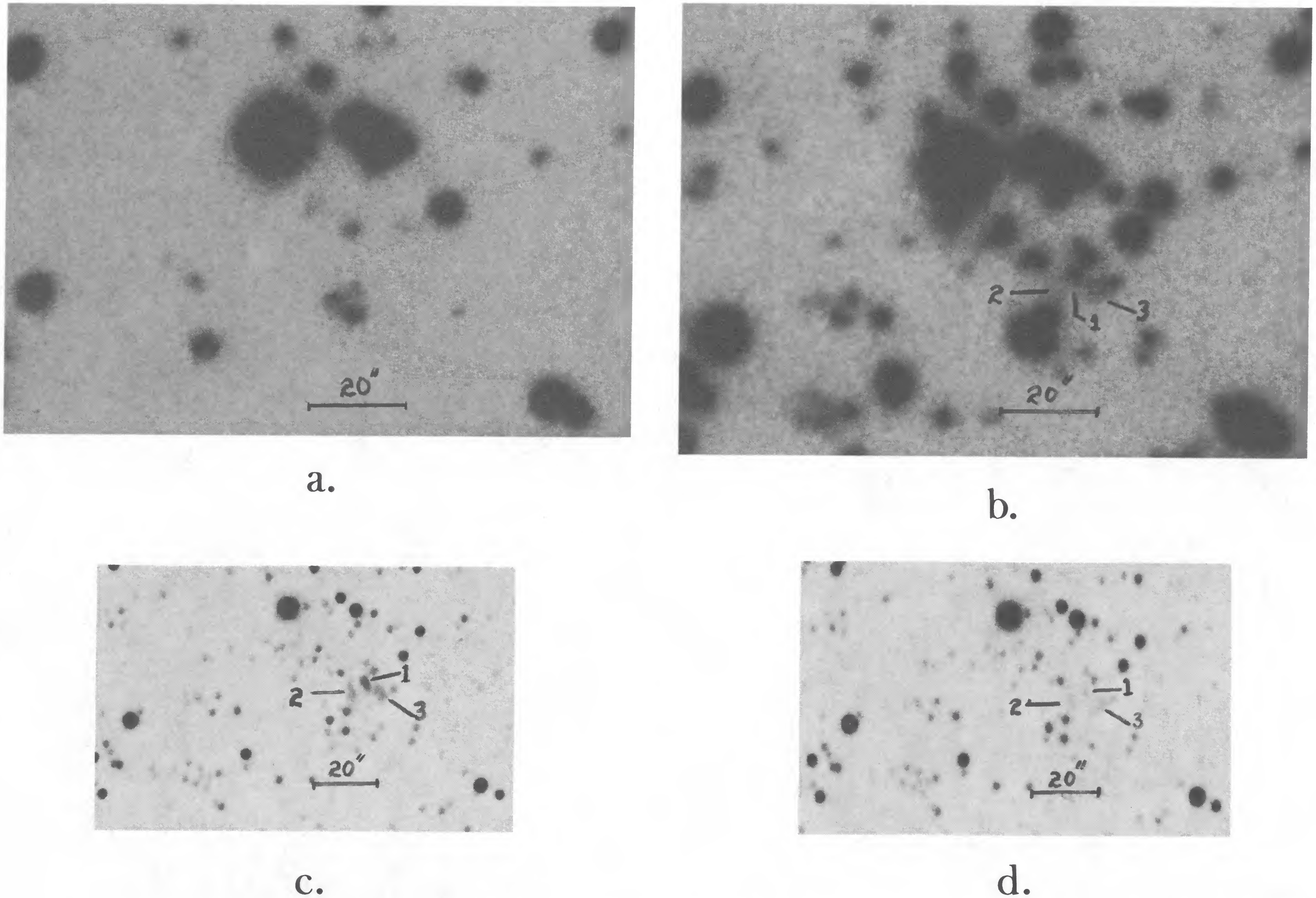

FIG. 1.—The field of CK Vul (nova 1670). North is up, east to the left. (*a*) No trace of the nova or its associated nebulosity is seen on the POSS B print. (*b*) The nova and its brighter associated nebulosities (labeled 1 and 3) are clearly visible, while nebulosity 2 is almost invisible on the POSS E print. (*c*) CFHT plus image tube plus 50 Å (FWHM) Hα plate of CK Vul. The nova candidate (labeled 1) presents an elongated image and may lie along the line of sight to ejected nebulosity. Nebulosities labeled 2 and 3 are also clearly elongated. (*d*) A 40 Å (FWHM) λ6726 plate of CK Vul. The nova and nebulosities are barely seen.

we photographed the field specified by Humason through narrow-band Hα (50 Å FWHM) and [S II] λ6726 (40 Å FWHM) filters. The baked IIIa-J plates used were taken with the 90 mm ITT image tube at the prime focus of the Canada-France-Hawaii 3.6 m telescope in 3″–4″ seeing. The [S II] plate was taken to serve as a continuum reference against which we planned to blink the Hα plate. ([S II] emission is not seen in old nova remnants.) However, the nova and its associated nebulosity are so much brighter in Hα than in continuum that we detected them by visual inspection alone.

III. DISCUSSION

Figures 1*a*–1*d* are the field of CK Vul as seen on the blue and red POSS prints, and in the light of Hα and [S II]. CK Vul lies at galactic latitude 0°, and the large resultant reddening accounts for the dearth of stars in Figure 1*a* relative to Figure 1*b*.

The nova candidate is visible as an elongated blob, composed of a stellar image (northeast part of blob) superposed on nebulosity and labeled 1 in the Hα photo, Figure 1*c*. Two associated nebulosities (labeled 2 and 3) are also clearly seen 5″–6″ southeast and southwest of the nova. All three objects are barely visible in the reference λ6726 plate, Figure 1*d*. Only the slightest hint of nebulosity 2 can be seen on the red POSS print (Fig. 1*b*), while objects 1 and 2 are clearly seen. Not surprisingly, no trace of CK Vul is seen on the POSS B print.

The positions of the brightness centers of the three Hα-bright objects have been determined to ~ 1″ accuracy with the two-axis Grant measuring machine at Kitt Peak National Observatory. These are compared with the positions (see Steavenson 1935 and Hind 1861) of Lemonnier and Hevelius in Table 1. The proper motion of CK Vul is unknown (and no repeatable differences could be measured between the POSS and present epoch plates). The good positional agreement (especially with Lemonnier, to ~ 40″ on the sky) shown in Table 1 between the reported position of the nova of 1670 and the three Hα-bright objects strongly supports our identification of CK Vul. (Lemonnier's and Hevelius's positions should be accurate to 1′–2′.)

Further support comes from spectra of the nebulous objects taken with the Multiple Mirror Telescope spectrograph plus reticon. Emission lines of Hα, Hβ, [N II] (λλ6548, 6584), and [O III] λ5007 are seen in all three of the nebulous objects we identify with CK Vul. The ~ 20 Å widths of the λλ6584, 5007 lines (which are the most easily measured) are indicative of expansion velocities of ~ 400 km s^{-1}, typical of slow novae like CK Vul. Reductions of the spectra are in progress, and a detailed analysis of the inferred chemical composition, kinematics, and distance of the nova will be presented elsewhere. We tentatively identify the stellar-like condensation in the northeast part of nebulosity 1 as the binary star responsible for the nova. Nebulae 2 and 3 are ejecta of the nova, sweeping up interstellar material.

IV. CONCLUSIONS

We have almost certainly recovered CK Vulpeculae, the nova of 1670. Detailed spectrophotometry of the candidate star, by far the oldest nova with a known position, may help us understand the structure and evolution of novae between outbursts. Two faint nebulosities 5″–6″ from the nova candidate display spectra similar to nova ejecta. This fact and the good positional agreement of the nebulae with the Lemonnier and Hevelius coordinates for the nova of 1670 strongly support our identification of CK Vulpeculae.

The main impetus to unearth the corpse of CK Vul came from Ron Webbink during his closing remarks (exhortation to the troops) at the 1981 Santa Cruz Summer School; his suggestions and continued interest in this project are much appreciated. M. M. S. is grateful to all those responsible for organizing the Santa Cruz Cataclysmic Variables School, and especially to John Faulkner for a most stimulating conference. Help and suggestions from René Racine and Rick Salmon were essential in our using efficiently the ITT image tube of the Canada-France-Hawaii 3.6 m telescope. We also thank Phil Massey for giving up an hour of CFHT time so that we could carry out this project, and Caty Pilachowski for instruction in use of the two-axis Grant

TABLE 1

POSITIONS OF CK VULPECULAE (NOVA 1670) AND ASSOCIATED NEBULOSITIES

Object Description	Observer	Year	R.A. (1950.0)	Decl. (1950.0)
Visually observed nova	Hevelius	1670	$19^h45^m26^s.8$	+27°13′24″ ±2′
Visually observed nova	Lemonnier	1670	19 45 32.6	+27 11 11 ±2′
Central star? + nebulosity 1 ...	Shara + Moffat	1981	19 45 35.08	+27 11 18.3 ±1″
Nebulosity 2	Shara + Moffat	1981	19 45 35.34	+27 11 13.9 ±1″
Nebulosity 3	Shara + Moffat	1981	19 45 34.74	+27 11 14.9 ±1″

measuring machine at Kitt Peak National Observatory. M. M. S. was supported in part by the National Science Foundation through grant AST 79-21073 to Arizona State University. A. F. J. M. was supported in part by an operating grant from the Natural Sciences and Engineering Research Council of Canada.

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