THE ASTROPHYSICAL JOURNAL, 170:547–549, 1971 December 15

V605 AQUILAE: A NOVA-LIKE VARIABLE IN AN OLD PLANETARY NEBULA

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Received 1971 June 7; revised 1971 July 29

ABSTRACT

The outburst of V605 Aql is shown to have occurred near the center of the low-surface-brightness nebula Abell 58. Hα photographs show no perceptible expansion since 1951. A spectrum of the nebula shows Hα and [N II] λ6584 in emission, with [N II] λ6584 stronger than Hα. The new observations associate the outburst of V605 Aql with the central star of the old planetary nebula A58.

The observations of the nova-like variable V605 Aql have been summarized by Bidelman (1971). In brief, V605 Aql was detected at $m_{pg} = 15.0$ on 1917 September 13 and was observed at magnitude 11.8 on 1918 August 28. V605 Aql was ~10.4 during the summer of 1919 and was near $m_{pg} \sim 12.0$ from 1921 July through November. The variable has not been seen since 1923.

Lundmark (1921) classified spectra of the variable obtained in 1921 September as R0. On the basis of the light curve and the supposition that Lundmark repeated Cannon's misidentification of a supernova spectrum with carbon-star spectra, Bidelman (1971) suggested that V605 Aql was an extragalactic supernova 120–760 kpc distant. Evidence is presented which associates V605 Aql with the central star of the old planetary nebula A58.

Comparison of Herbig's (1958) finding chart for V605 Aql with the 1951 August 24 *Palomar Sky Survey* red print shows that the position of V605 Aql is near the geometrical center of a low-surface-brightness nebula. Dr. George Herbig kindly provided prints of Lundmark's 1921 July 3 and October 20 Crossley plates of V605 Aql. The prints confirm the position of the variable within the nebula on the *Sky Survey* red print. The nebula is not on the *Sky Survey* blue print.

Interference-filter and deep-red photographs of the nebula were obtained on 1971 April 27 and April 28 with a Westinghouse WL-30677 image intensifier on the University of Oregon 24-inch f/13.5 telescope at Pine Mountain Observatory. A 95-min exposure through an Hα filter with a 50-Å full width at half-maximum (FWHM) shows the nebula with much better contrast than the broad-band *Sky Survey* red print. An 8-min exposure through a Schott RG-8 filter and a 90-min exposure through a 57-Å FWHM filter centered at λ5020 do not show the nebula. Figure 1*a* (Pl. 6) is a reproduction of the *Sky Survey* red print, and Figure 1*b* illustrates the 95-min Hα exposure.

A spectrum of the nebula from λ5800 to λ7000 with a dispersion of 200 Å mm^{-1} was obtained at Pine Mountain Observatory 1971 May 24 with the image intensifier mounted on a Boller and Chivens spectrograph (f/3.0 camera). The 105-min unguided exposure gave a moderate nightsky spectrum and shows weak emission with angular extent comparable to that of the nebula at Hα and [N II] λ6584. The nitrogen line is considerably stronger than Hα. The spectrogram is not of sufficient quality for a radial-velocity determination.

Comparison of Figures 1*a* and 1*b* shows there has been no perceptible expansion of

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PLATE 6

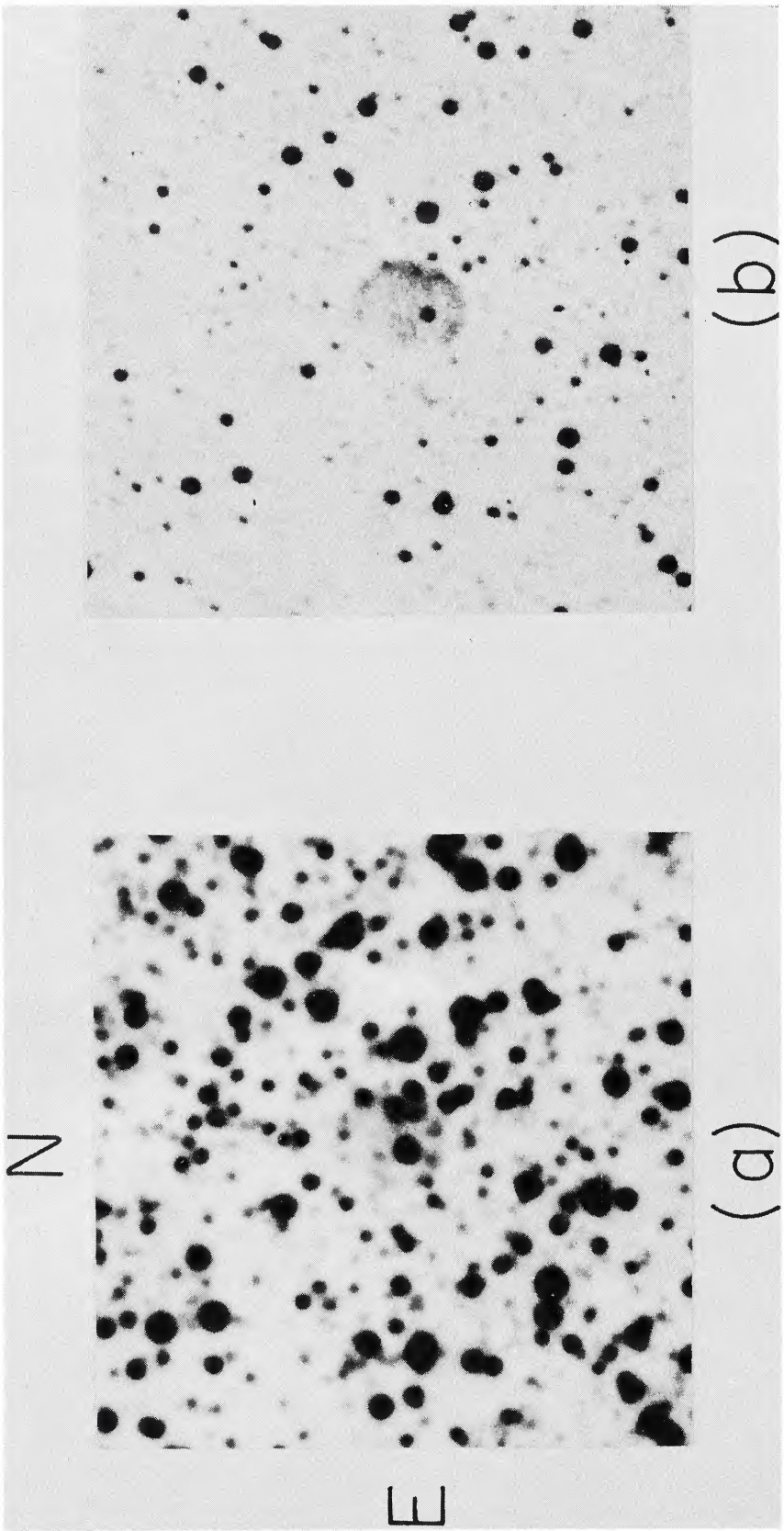

FIG. 1.—Abell 58. (*a*) Reproduction of the 1951 August *Palomar Sky Survey* red print; (*b*) 1971 April 95-min exposure through a 50-Å FWHM Hα filter taken with a Westinghouse WL-30677 image intensifier on the University of Oregon 24-inch f/13.5 telescope at Pine Mountain Observatory. Scales of (*a*) and (*b*) are 3.2″ and 3.3″ mm^{-1}. The bright rim along the south–southwestern edge of the nebula in (*b*) is due to unresolved field stars.

FORD (*see* page 547)

the nebula between 1951 and 1971. The observed lack of expansion eliminates the possibility that the nebula resulted from ejection of a shell during the 1917–1921 outburst of V605 Aql. The observed widths of Hα and [N II] λ6584 give the expansion velocity of the nebula an upper limit of $\sim$200 km s^{-1}, which is lower than typical expansion velocities of nova shells (McLaughlin 1960). The upper limit coupled with the R0 spectral type make it improbable that V605 Aql is a recurrent nova.

Two considerations make it unlikely that the nebula is a small symmetrical H II region and associated variable. The first is the observation that [N II] λ6584 is stronger than Hα, a common occurrence in planetaries but not in H II regions. In a survey of 22 planetaries, White (1952) found three with [N II] λ6584 stronger than Hα. Johnson's (1953) survey of 63 galactic emission regions and nebulae associated with O stars showed none with [N II] λ6584 stronger than Hα.

The second consideration is that an extinction of at least 5.3 photographic magnitudes would be required if the nebula is an H II region. This follows from the assumption that its distance below the plane is not more than 200 pc, the distance containing 90 percent of the B8–A5 stars (Blaauw 1965). The maximum distance modulus is then 11.7 ($l = 37\overset{\circ}{.}6, b = -5\overset{\circ}{.}2$). The brightest star "within" the nebula has $m_{pg} \sim 17$. Assuming it is the exciting star and is A0 or earlier then requires $A_v \geq 1.7$ mag kpc^{-1} if it is assumed that $A_{pg} = 1.4\ A_v$ (Whitford 1958). The argument holds for the two or three brighter stars near but outside the nebula, since they would have to be earlier than A0 to ionize the gas from their projected distances. The required extinction is inconsistent with Hiltner's (1956) value of $A_v \sim 1$ mag kpc^{-1} determined for the two early-type stars HD 177812 and HD 178129, which are in the direction of V605 Aql at a distance of approximately 2500 pc.

The nebula is number 58 in a list of 86 nebulae provisionally identified as old planetaries by Abell (1966). Abell (1966) describes the nebula as a regular and symmetrical ring of variable thickness with maximum dimensions of 44″ and 36″. Abell (1966) was unable to identify the central star of the nebula. Herbig (1958) noted that on the *Sky Survey* blue exposure there is a star with $m_{pg} = 20$ near the position of the variable. The star is visible on the *Sky Survey* blue print but cannot be seen on the red print because of its proximity to the brightest red star projected on the nebula.

Abell (1966) computed distances to the nebulae from the integrated photo-red magnitudes (Hα + [N II]) and geometries taken from the *Palomar Sky Survey* plates and with the assumptions that the nebulae have a constant mass of 0.2 $M_\odot$ and are optically thin in Hα. Abell's distance of 3472 pc to A58 becomes 3970 pc when corrected for the observed ratio [N II] λ6584/H$\alpha \sim 2$. The distance is an upper limit, since lack of identification of the central star precluded an estimate of the reddening.

With Abell's physical assumptions, the electron density N_e is given by

$$N_e = \text{const}\, f^{3/5}/V^{2/5}M^{1/5}\,, \tag{1}$$

where f is the integrated photored flux, V the angular volume, and M the mass of the nebula. Using Abell's (1966) value of V and uncorrected value of f (but assuming [N II] λ6584/Hα = 2) gives N_e a lower limit of 40 electrons cm^{-3}. Using an average extinction $A_v = 1$ mag kpc^{-1} and the upper limit to the distance 3970 pc gives a reasonable upper limit of 3.2 photo-red magnitudes correction and an upper bound of 240 electrons cm^{-3} for N_e. The bounds on the electron density are consistent with the range of densities found by Abell (1966) in the old planetary nebulae, and reflect the fact that the angular extent and surface brightness of A58 are typical of old planetary nebulae.

The observations and preceding considerations support Abell's original identification of the nebula as an old planetary nebula. The position of V605 Aql near the center of the nebula then implies that the nova-like outburst was associated with the central

star of A58. With this interpretation the variable brightened at least 9.6 mag to a photographic absolute magnitude no brighter than -8.2 (assuming $A_{pg} = 1.4$ mag kpc^{-1}). Variability is known or suspected in many planetary nuclei (Abell 1966; Kazarian 1968; Kohoutek 1964), the most notable example being FG Sge (Herbig and Boyarchuk 1968); however, none have shown variation comparable to V605 Aql.

Lundmark (1921) commented on the prominence in the spectra of V605 Aql of the CN bands with heads at λ3883 and λ4216, and the C_2 bands with heads at λ4390 and λ4754. In addition, he noted as less prominent the C_2 band head at λ4737, strong H and K absorption lines, and a very weak λ4227. The carbon-star spectrum implies a ratio of carbon to oxygen greater than 1 (Morris and Wyller 1967). It is interesting to note in this context that Greenstein and Minkowski (1964) suggested that the central stars of planetaries selected from Abell's list may belong to a carbon sequence.

It is a pleasure to thank Dr. George Herbig for providing prints of Lundmark's plates and calling FG Sge to my attention. I wish to thank Dr. Ira Nolt for advice on the spectrograph modifications and Mr. Frank Smith for his excellent work on the modifications. This work was supported by NSF grants 50-262-0102 and 50-262-0503.

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