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A NEW OPTICAL SUPERNOVA REMNANT IN CYGNUS

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ABSTRACT

During an emission line survey of the galactic plane, a new optical supernova remnant has been discovered centered at $\alpha = 19^h31^m$, $\delta = +31°10'$ (1950).

Subject heading: nebulae: supernova remnants

I. INTRODUCTION

We are conducting an emission-line survey of the Milky Way in bandpasses which isolate [S II] (6736 Å, $\Delta\lambda$ = 50 Å), Hα + [N II] (6570 Å, $\Delta\lambda$ = 75 Å), [O III] (5010 Å, $\Delta\lambda$ = 28 Å), Hβ (4864 Å, $\Delta\lambda$ = 28 Å), and the blue continuum (4225 Å, $\Delta\lambda$ = 60 Å). The survey fields are 7° in diameter, and the field centers are spaced every 5° in galactic longitude along three latitude bands (b^{II} = 0°, 5°, −5°). The survey instrument consists of 125 mm clear aperture, narrow bandpass interference filters mounted in front of a 300 mm focal length, f/2.8 Nikon lens which is mounted in front of a magnetically focused two-stage image intensifier (RCA model C33063). The survey and the instrument will be described in more detail elsewhere.

II. OBSERVATIONS

In one of our fields (l^{II} = 65.5°, b^{II} = +5°) we have discovered a new filamentary emission line structure at $\alpha = 19^h31^m$ and $\delta = +31°10'$ (1950) (l^{II} = 65.6°, b^{II} = +6°). See Figure 1 (Plates L5 and L6) and Figure 2. Based on the morphological similarity of this structure to Shajn 147, the Vela supernova remnant (SNR), CTB 1, and to a lesser degree the Cygnus Loop, we classify this structure as a supernova remnant. It is probably intermediate between van den Bergh's S147 Type and his Diffuse Shell Type (van den Bergh, Marscher, and Terzian 1973). The remnant is approximately 4° by 3.3° with its long axis at a position angle of 95° ± 5°. Two portions of the remnant are visible on both the red and blue plates of the Palomar Sky Survey and are included in the Sharpless (1959) catalog as S91 and S94. S91 is also listed by van den Bergh (1960) as one of the Bright Type III filaments in Cygnus and as possibly being associated with the γ Cygni complex. Our observations show that this particular filament is not part of the γ Cygni complex but indeed is the brightest filament in a separate, well defined SNR. Its structure as a remnant, however, is not obvious even on our narrow bandpass Hα + [N II] plate (Fig. 1*c*). On the other hand, the [O III] plates (Figs. 1*a* and 1*b*) clearly show the structure to be a highly filamentary supernova remnant.

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III. OTHER SURVEYS

The nearest X-ray source listed in the *Uhuru* (Giacconi *et al.* 1974) catalog is 3U 1953+31 located at $19^h53^m.9$, +31°59′ (1950)—approximately 5° from the center of the newly found supernova remnant and well outside the optical limits.

Felli and Churchwell (1972) in their survey of the

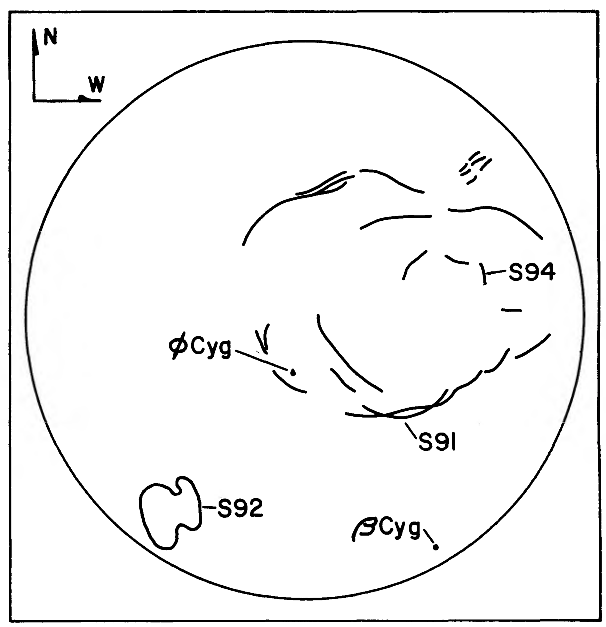

FIG. 2.—Sketch of the [O III] emission features in the field 65.5, +5 ($19^h34^m.5$, +31°01′ [1950]). Diameter of the field as drawn is approximately 7°.

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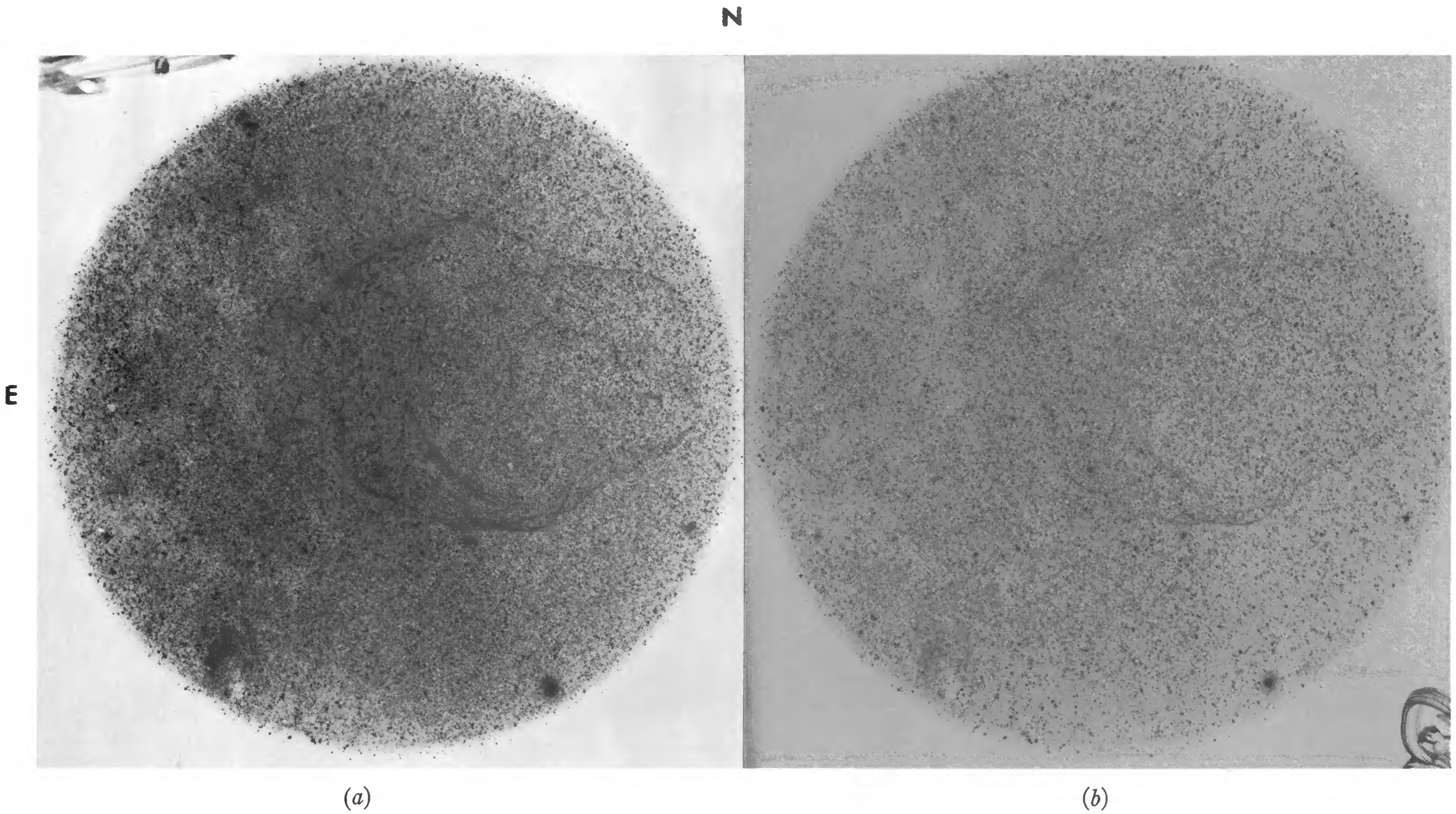

FIG. 1.—Field 65.5, +5 ($19^h34^m.5$, $+31°01'$ [1950]). The bright star at the extreme edge of the field at 5 o'clock is β Cyg; the star near the center and just above the brightest and sharpest filament is φ Cyg. The field is 7°.1 in diameter, and the original plate scale was $730''$ mm^{-1} with a resolution of about $30''$. (*a*) λ5010 [O III], 20 minute exposure. (*b*) λ5010 [O III], 15 minute exposure. (As indicated by sky background and star brightness, the emission line exposure of Fig. 1*b* is comparable with that of Fig. 1*c*, the 6570 exposure.) (*c*) λ6570 Hα + [N II], 12 minute exposure. (*d*) λ6736 [S II], 15 minute exposure.

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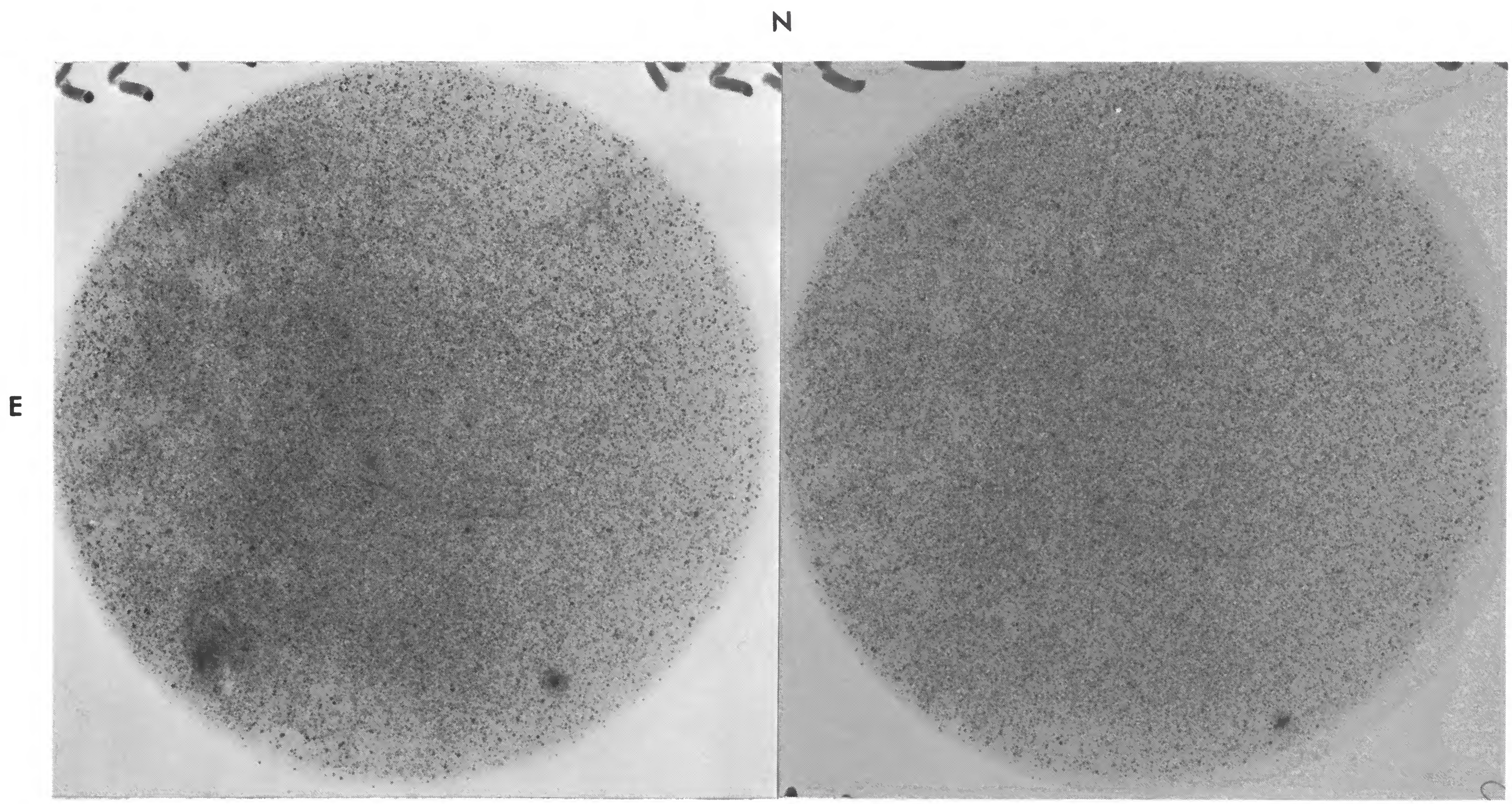

(*c*) (*d*)

Fig. 1.—*Continued*

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Galactic H II regions at 1400 MHz detected the portion of the remnant identified as S94. Apparently they did not observe S91, and in a search for continuum radiation from S96 (to the northwest of the supernova remnant) found no detectable 1400 MHz continuum radiation over a major portion of the northern part of the supernova remnant. A survey at 820 MHz by Berkhuijsen (1972) shows a faint radio feature (0.5 K above the background) in the vicinity of the supernova remnant, at $l^{II} = 64.^{\circ}5$, $b^{II} = 6^{\circ}$ and approximately 3° in angular size. Insufficient data are available to determine if the radio source is nonthermal. The supernova remnant discussed here is not included in the list of possible supernova remnants compiled by Downes (1971). With a surface brightness temperature only 0.5 K above the background (Berkhuijsen 1972) this remnant, like Shajn 147, would fall below Downes's detection limit.

We have examined several other radio surveys, including the 21 cm neutral hydrogen survey by Weaver and Williams (1973). In the general region of our SNR, two velocity components at 0 and -80 km s^{-1}, corresponding to two galactic arms, decrease smoothly in antenna temperature with increasing galactic latitude. There is noticeable substructure within both main components, but no substructure can unambiguously be interpreted as evidence of an H I shell. Such H I shells have been reported for some other SNRs—e.g., Shajn 147 (see DeNoyer 1975 and references cited therein). Expansion velocities and kinematically derived distances are thus still not known. Since these would be useful in establishing the size and age of the SNR, we are attempting to obtain such using the brightest optical emission line, [O III] λ5007.

Inspection of the pulsar lists (Terzian and Davidson 1976) reveals no pulsar within the optical boundaries of the supernova remnant. The nearest pulsar to the remnant, P1952+29 ($l^{II} = 65.^{\circ}9$, $b^{II} = 0.^{\circ}8$), is well outside the optical boundaries and has an apparent age of 4×10^9 years, much longer than any reasonable age of the supernova remnant.

IV. DISCUSSION

The axis of IC 443 (as defined by a "top" and a "bottom" indicated by reduced emission and by an apparent elongation) is approximately parallel to the plane and to the direction of the galactic magnetic field as indicated by stellar polarization (Mathewson and Ford 1970). Both our new SNR and the Cygnus Loop are located close to the direction of the longitudinal field (Mathewson and Ford 1970). In this direction, toward Cygnus, the polarization is generally random, and there seems to be only a rather general qualitative indication that the axes of the Cygnus Loop and our new SNR are parallel to the magnetic field in their vicinity.

Optical comparisons between our new SNR and the Cygnus Loop are difficult because of the Cygnus Loop's much greater brightness. Comparison with IC 443 and Shajn 147, as recorded on our survey plates, indicates that [O III] relative to Hα is stronger in the new remnant than for IC 443 or Shajn 147 and probably is comparable to the hotter optical filaments of the Cygnus Loop. Using Figures 1*b* and 1*c*, comparison with the normal H II region S92 (located near the edge of the frame at 7 o'clock) also shows the increased strength of [O III] in the remnant. Likewise, the same comparison with S92 using Figures 1*c* and 1*d* shows that [S II] is enhanced in the remnant as is expected.

With a radio surface brightness, at 820 Mc, approximately one-fifth that of the Cygnus Loop (Berkhuijsen 1972), we derive a physical diameter d between 60 pc (Ilovaisky and Lequeux 1972) and 80 pc (Downes 1971). Using a diameter of 70 pc and an angular size of $3.^{\circ}3$ we find a distance D of 1200 pc. Using the Sedov (1959) relations as modified by Chevalier (1974) and taking the initial density $n_0 = 1$ cm^{-3}, and the initial energy $E_0 = 3 \times 10^{50}$ ergs, we find an age t of 4.5×10^5 years and a shock velocity V_{sh} of 24 km s^{-1}. This velocity is too low to produce the strong [O III] that is observed which requires a shock velocity of at least 50 km s^{-1}. (A shock velocity of 100 km s^{-1} is indicated for S147 by Lozinskaya [1976] from Fabry-Perot observations.) The indicated shock velocity can be increased by reducing the diameter the diameter to about 50 pc; this moves our SNR off the (mean surface brightness, physical diameter)-relation, but probably not unacceptably so, considering that the relation is not too well defined at the old end. The shock velocity can also be increased with a 70 pc diameter by varying either E_0 or n_0. A decrease of n_0 from 1 cm^{-3} to 0.5 cm^{-3} will decrease the age to 3×10^5 years and increase the shock velocity to 50 km s^{-1}. Summing up, it seems reasonable to say that our new optical SNR has the following characteristics:

$$d \approx 70 \text{ pc}, \quad D \approx 1200 \text{ pc}, \quad V_{sh} \geq 50 \text{ km s}^{-1},$$

$$n_0 \approx 0.5 \text{ cm}^{-3}, \quad t \approx 3 \times 10^5 \text{ years}.$$

Further observations, especially in the radio region, are highly desirable in order to confirm the identification of this object as a supernova remnant.

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