THE ASTROPHYSICAL JOURNAL, 194:337–342, 1974 December 1

THE GAMMA CYGNI SUPERNOVA REMNANT AND NEBULA

HUGH M. JOHNSON*
Lockheed Missiles and Space Company
Received 1974 May 10

ABSTRACT

The object is anomalous, and the existing data appear to be rather contradictory or ambiguous. We discuss previous and new observations. The new observations are: Palomar Schmidt plates in the blue, yellow, red, and near-infrared; radiofrequency-continuum maps at 7.875 and 15.5 GHz; flux densities at 31.4 and 85 GHz; and H 94α-line data. A nebula, found only in the red, is identifiable with a small component of a supernova remnant which is altogether about 1° in diameter. The spectral index of the large, nonthermal remnant is prevalently about −0.8, but the index is probably ≥ −0.5 in the small component. The amorphous structure of the red nebula suggests that its light is nonthermal, since it is not a reflection nebula of the star γ Cygni. Optical spectroscopy and microwave recombination-line mapping in high spatial resolution are needed for further information.

Subject headings: nebulae — radio sources — supernova remnants

I. INTRODUCTION

Drake (1959) discovered a nebula about 3′ southeast of γ Cyg in a passband centered near Hα. He also found that it was absent on a well-exposed blue-sensitive plate, and suggested that it is an H II region and not a reflection nebula. This "γ Cygni nebula" is buried in the photographic halation of the star so that it is not apparent on many plates such as the Palomar *Sky Survey* plate of the region, and it is not identical with an H II region 3° in diameter, S108 (Sharpless 1959), also called the "γ Cygni nebula." Following Drake's discovery, Mathewson, Large, and Haslam (1960), found a nonthermal radio source, or a component of confused sources, near the position of the small γ Cygni nebula, and they called it the "γ Cygni source." It is the fourth-brightest supernova remnant at 400 MHz in the catalog of Downes (1971), although it has also been called a thermal source by Pike and Drake (1966) and by Terzian and Parrish (1973) among subsequent observations. Questions of the possible relationships between the radio source(s), the optical nebula, and the F8 Ib star γ Cyg have never been settled. In this paper we present new optical and radio-frequency observations of the nebula and radio source. A future paper will present ultraviolet spectral data of γ Cyg from the OAO-3 (*Copernicus*) satellite.

II. OPTICAL OBSERVATIONS

Previous photographs of the γ Cygni nebula have been published by Drake (1959), Higgs and Halperin (1968, from a plate by H. Dickle and H. Wendker), and van den Bergh, Marscher, and Terzian (1973). The Dickle-Wendker plate isophotes (Hermann 1972) show the confusion of the light of the nebula with the light of γ Cyg despite use of a narrow-band interference filter around Hα. The same technique was employed by van den Bergh *et al.* with the same filter on the same telescope, the Palomar Schmidt. An alternative technique for reducing the starlight scattered in the emulsion is the use of an occulting bar as in figures 1*a* and 1*b* (plate 8). With a glass or gelatine filter this avoids the rather strong ghost of starlight that is reflected in the layers of the interference filter or the field flattener used with this filter, but it shares with the first technique the larger, fainter ghost of starlight that is reflected in the surfaces of the Schmidt corrector plate. Table 1 lists new Palomar Schmidt plate data in four passbands utilizing the occulting bar. The γ Cygni nebula is not at all present in any passband except the red. This rules out scattering of γ Cyg light on dust in the nebula.

The area of figure 1 on the plates of table 1 has been examined in the Lick Observatory blink machine. Except for the near-infrared and the shortest red exposures the plates should reach limiting magnitudes between 20 and 21. In blinking 50-minute red versus blue, most weak images are stronger in red, but some images are equally strong, notably those circled in figure 1*a*. They may be candidates for exciting stars of the nebula. Six other images were also found by blinking to be stronger in the near-infrared than in the 5-min red, contrary to the empirical majority; none of these six is present in the blue. The oval dark cloud which extends about 1′ northeast of the strongest star image inside the γ Cygni nebula is mottled, possibly with several faint star images, but they do not behave distinctively in any of the blinking.

III. RADIOFREQUENCY-CONTINUUM OBSERVATIONS

Table 2 lists the available observations made with half-source beamwidth (HPBW) ⩽ 20′, and the flux densities are plotted in figure 2. The published data quoted in table 2 are supplemented in some cases by rms errors based on authors' comments rather than their explicit reference to the γ Cygni source in catalogs of several sources. When authors have not given full width at half-maximum (FWHM) (corrected) = [FWHM (observed)^2 − HPBW^2]$^{1/2}$, it has been listed in parentheses.

The new 7.875- and 15.5-GHz data were obtained

* Guest observer at the Hale Observatories.

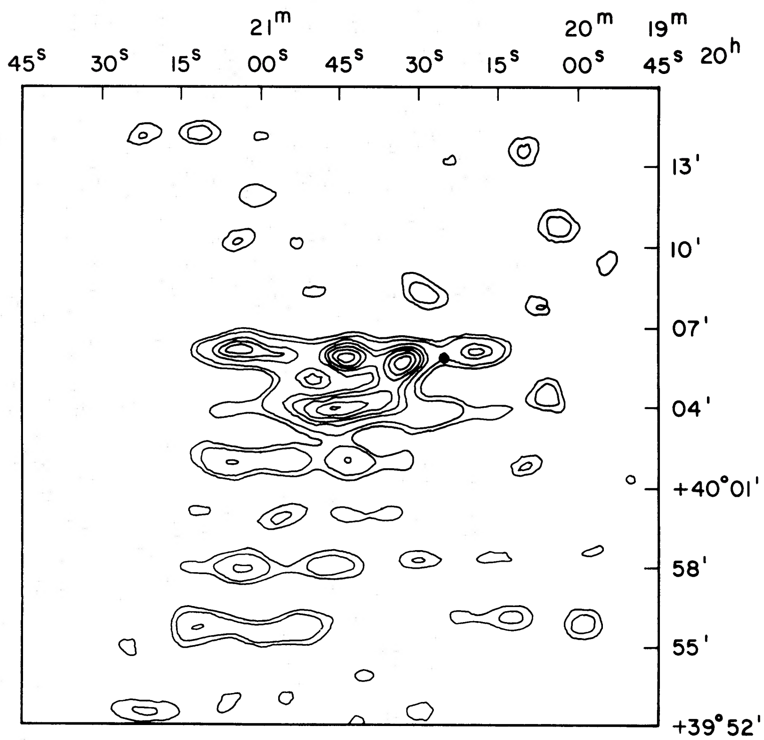

FIG. 1c.—Field of the γ Cygni source as in figs. 1a and 1b but in 15.5-GHz contour steps of 0.02° K of antenna temperature above base level between 0.05° and 0.21° K. The position of the star γ Cyg is marked with a filled circle.

with the 36.5-m telescope of the Haystack Observatory.[1] Multiple-drift-scan records were made in 2-s integrations with $\Delta\delta = 0^\circ.035$ spacings at 7.875 GHz, and in 1-s integrations with $\Delta\delta = 0^\circ.015$ spacings at 15.5 GHz. Maps of the scanned area were finally produced by a series of computer programs available at the Haystack Observatory. The mapping included atmospheric attenuations of τ(7.875 GHz) = 0.03 and τ(15.5 GHz) = 0.06. The baselines across each map are established in areas two HPBW wide outside the east and west boundaries. The computer also integrated flux densities over the mapped area, about 26′ square, in units of antenna temperature × square degrees of sky. These were reduced to jansky (Jy) units ($=10^{-26}$ W m^{-2} Hz^{-1}) by comparison with similar maps of the standard source DR 21, on the assumption that its flux density is 21.7 Jy at 7.875 GHz and 20.1 Jy at 15.5 GHz (Dent 1972). The results are given in table 2. The 7.875-GHz map is reproduced in figure 1b on the field of the blue Palomar Schmidt plate, for comparison with the optical nebula visible on the red plate in figure 1a (cf. table 1). We confirm the excellent agreement in the positions of the red nebula and the radio source, as found by Higgs and Halperin (1968), so the peak of the 7.875-GHz map agrees well with the best previous position of the source, given by them. The 15.5-GHz map, figure 1c, is noisier. This may partly account for an apparent breaking up into several peaks, of which the one at the coordinates given in table 2 appears to be principal and nearest to the peak at 7.875 GHz. This peak is confirmed by a discrete source scan (DSS) observation made at 15.5 Gz independently of the map. In this procedure the telescope offsets in δ from trial source coordinates, scans in δ, offsets in α at δ (maximum T_A), scans in α, and reports

[1] Radio astronomy at the Haystack Observatory of the Northeast Radio Astronomy Corporation is conducted with support from the National Science Foundation.

TABLE 1

NEW PALOMAR SCHMIDT PLATES OF THE γ CYGNI NEBULA

Plate No.	Exposure (minutes)	Plate + Filter	Passband (FWHM) (Å)
PS 9423......	5	103aE + RG1	6200–6600 (red)
PS 9424......	50	103aE + RG1	6200–6600
PS 9427......	60	103aE + RG1	6200–6600
PS 9425......	25	103aD + Wratten 12	5200–6300 (yellow)
PS 9426......	10	103aO + none	3500–4700 (blue)
PS 9428......	120	1N + Wratten 89B	7100–8800 (near-infrared)

TABLE 2

Radiofrequency Continuum and Coordinates of the γ Cygni Source

ν (MHz)	HPBW (′)	S (Jy)	20^h20^m(1950)	+ 40°	FWHM: ($\alpha \times \delta$) obs. (′)	FWHM: ($\alpha \times \delta$) cor. (′)	Figure 2 Identification	Reference
408......	...	< 50	00^s	10′	< 20	...	M	Mathewson *et al.* (1960)
610......	16	369 ± 55	10	11	...	33 × 24	W	Wendker (1966)
610.5....	16 × 19	695 ± 209	18 ± 3	9 30 ± 180	...	50	YW	Yang and West (1964)
1414......	10	199 ± 20	42	6	25	(23)	PD	Pike and Drake (1964)
1414......	9.7	323 ± 48	50	6	...	29 × 28	W	Wendker (1966)
2695......	20.1	243 ± 36	55	4	...	27 × 30	W	Wendker (1966)
2695......	10.6 × 11.6	134 ± 8	51 ± 5	4 ± 60	...	21 × 21	W7	Wendker (1970)
2730......	4.9 × 5.7	26 ± 7	47	3 45	25 × 30	(25 × 30)	Wi	Willis (1973)
4930......	10.9	181 ± 27	55	4	...	15 × 24	W	Wendker (1966)
5000......	10.8	75 ± 26	46 ± 2	3 42 ± 60	20 × 30	(17 × 28)	DR	Downes and Rinehart (1966)
5000......	6.5	25.6 ± 4	44	2 20	...	6.9 × 14	R	Reifenstein *et al.* (1970)
6600......	18.3	109 ± 30	55 ± 20	12 ± 240	...	43	H	Higgs (1966)
7875......	4.4	11.0	42	3 21	6.7 × 5.2	5 × 2.8	J	This paper
8000......	7	...	33 ± 1	2 54 ± 60	...	...		Hobbs (1960)
10630......	2.8	40 ± 6	38.4 ± 2	3 24 ± 20	< 3(8)	...	HH	Higgs and Halperin (1968)
15500......	2.2	7–11	40	3 58	5.3 × 2.2	...	J	This paper (map)
15500......	2.2	...	43	4 00	5.2 × 1.8	4.8(×0:)		This paper (DSS)
31400......	3.5	24 ± 5		...	12 × 7	...	TP	Terzian and Parrish (1973)
31400......	3.7	4.0 ± 0.5	35.8 ± 3	3 36 ± 6	4.6	2.7	J	This paper
85000......	1.3	3.9 ± 2.7		...	...	...	J	This paper

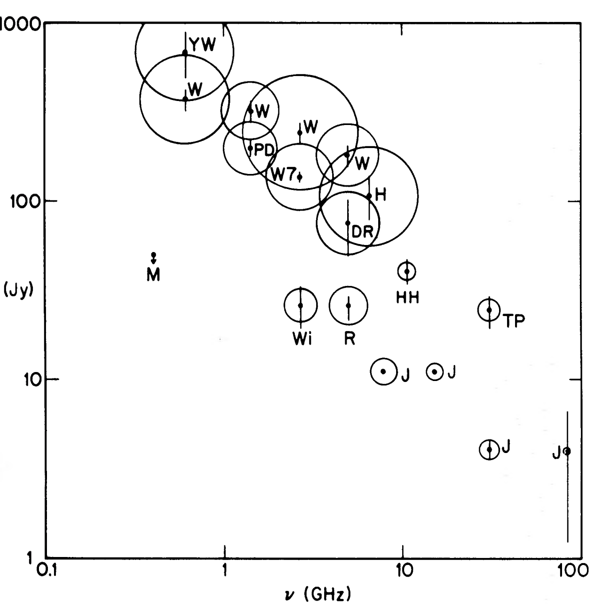

Fig. 2.—Integrated flux density S versus frequency ν in the published and in the new data of the γ Cygni source(s). The data are identified with letters as in table 2. Unit rms error bars, and circles proportional in size to HPBW of telescopes, are included around each point.

peak α, δ coordinates and Gaussian FWHM in α and δ, uncorrected for HPBW. The results are also given in table 2. At least some of the resolution of the 15.5-GHz map is real, e.g., the peak at $\alpha = 20^h20^m19^s$, $\delta = +40°06'00''$ (1950) in figure 1c can be found also in figure 1b, and it is apparently identifiable with the point source at $\alpha = 20^h20^m19^s$, $\delta = +40°06'09''$ (1950) discovered by Hermann and Dickel (1973). However, the centroid of γ Cygni-source peaks in figure 1c lies distinctly north of the peak in figure 1b, and we are not sure whether the shift is really frequency dependent.

The smaller of two flux densities reported at 15.5 GHz in table 2 reflects another mapping of about half the area of the larger map. It is not so directly comparable to the integration of the 7.875-GHz map, but it refers more specifically to the component No. 2 defined in § IV.

The 11-m telescope of the National Radio Astronomy Observatory[2] at Kitt Peak was used to obtain more new data summarized in table 2. The telescope was equipped with dual horns separated horizontally in the prime focus by 9′15″ at 31.4 GHz and by 8′45″ at 85 GHz. The beam was switched at 50 Hz between horns, and the horns were pointed alternately at a position each 30 s, i.e., with the ON-OFF technique. The horns receive orthogonal planes of polarization. Flux density has been calibrated by observations of Jupiter each night, assuming brightness temperature of 155° K at 31.4 GHz and 174° K at 85 GHz, and correcting

[2] Operated by Associated Universities, Inc., under contract with the National Science Foundation.

for disk diameter, following Ulich (1973). Ulich also gives the antenna-aperture efficiencies as 0.50 at 31.4 GHz and 0.45 at 85 GHz. These values and atmospheric optical depths of $\tau(31.4\text{ GHz}) = 0.02$ and $\tau(85\text{ GHz}) = 0.07$ are used in the reductions. The telescope was directed to the Higgs and Halperin (1968) coordinates for the γ Cygni source and, at 31.4 GHz, data were taken there and at coordinates offset $\Delta\alpha = \Delta\delta = \pm 3'$ from center. The beam is assumed to be Gaussian and then is convolved with the source, also assumed to be Gaussian but with FWHM and coordinates free to be varied by trial and error so as to match the observed ratios of flux densities in the grid. The source specified in table 2 fits the data within rms errors. The data at 85 GHz were taken only at the central coordinates, and were reduced by assuming the FWHM(31.4 GHz) and by correcting the observed flux density and rms error by the factor $1 + \langle \text{FWHM/HPBW} \rangle^2$.

IV. DISCUSSION OF THE RADIOFREQUENCY CONTINUUM OF THE SOURCES

The Haystack maps integrate in an area $\Delta\alpha \times \Delta\delta = 26' \times 26'$, exclusive of baseline borders, Higgs and Halperin (1968) define base level at the corners of an area of $53' \times 60'$, and Willis (1973) defines base level at the untied ends of drift scans in an area of $78' \times 35'$. A source of $\langle \text{FW} \rangle$ to base level $= 60'$ would probably spill over part of the base level boundaries of all of the maps at $\nu > 7$ GHz. It may be significant that all data of $S > 50$ Jy were acquired in the course of mapping many sources in the Cyg X complex, a much larger area than the regions surveyed for the γ Cygni source in the range $S < 50$ Jy.

Most of the data are consistent with a two-component source: No. 1 is the order of $\langle \text{FW} \rangle \simeq 60'$, $S(10\text{ GHz}) \simeq 50$ Jy, and power-law spectral index $\simeq -0.8$. No. 2 is a fairly sharp peak on top of No. 1 with the parameters $\langle \text{FWHM} \rangle \simeq 2'.7$, $S(10\text{ GHz}) \simeq 10$ Jy, and a spectral index which, although not well defined, can be ≥ -0.5 (relying heavily on the 408-MHz datum reported in table 2). Component No. 2 may be part of No. 1, as suggested by their concentric positions, but superficially separable by a grouping of data into those taken with large HPBW in areas $\gg$FW and those taken with smaller HPBW in areas $\leq$FW. A physically real distinction in terms of a larger-than-average spectral index in a small part of the total volume of a supernova remnant remains likely.

Discovery of polarization of 1 or 2 percent at both 3.24 and 10.63 GHz by Higgs and Halperin (1968) confirmed a nonthermal element of component No. 2. Hermann and Dickle (1973) detected component No. 2 at 2.695 GHz but illustrated only a schematic isophote of it. They also attempted to observe polarization, but the result was an upper limit of ≤ 20 percent in effective resolution elements of $8'' \times 11''$.

V. HYDROGEN RECOMBINATION LINES IN THE RADIOFREQUENCY SPECTRA

The available observational data are summarized in table 3. We are indebted to Dr. Chaisson for permission to quote his unpublished observations. They were made with the 36.5-m telescope of the Haystack Observatory, equipped much as he has described it for other observations (Chaisson 1973*a*). Except for Reifenstein *et al.* (1970), cf. table 2, the observers do not specify the α, δ coordinates to which they directed the telescopes. There may be differences of the same order as the differences in HPBW, but they do not readily explain observed differences in the width of the lines to half-power $\Delta v(\text{HP})$, velocity with respect to the local standard of rest $v(\text{LSR})$, or ratio of excess antenna temperature of the line to antenna temperature of the continuum T_L/T_C. Chaisson's observation of peak $T_L = 0.030° \pm 0.002°$ K has been combined with peak $T_C = 0.8°$ K from the present observations made at 7.875 GHz. It has not always been specified by observers that $\Delta v(\text{HP})$ has been corrected for instrumental broadening. In those cases we have assumed that an observed value $\Delta v(\text{HP})_{\text{ob}}$ should be corrected by the relation $\Delta v(\text{HP})^2 = \Delta v(\text{HP})_{\text{ob}}{}^2 - (\text{Resolution})^2$ for the values given in table 3.

Table 3 object distance cannot be derived on the basis of differential galactic rotation, even if there were no peculiar motion with respect to the circular velocity of a model of the Galaxy. In Schmidt's (1965) model $v(\text{LSR})$ at $l = 78°.2$ rises to a maximum of $+5.4$ km s^{-1} at $r = 2$ kpc, falls to zero at $r = 4$ kpc, and is negative beyond that. Most of the H-line data of the γ Cygni source permit the distance to be as small as 200 pc, the spectroscopic distance of the star γ Cyg (Morton 1973), whose $v(\text{LSR}) = +11$ km s^{-1}.

According to Mezger and Höglund (1971)

TABLE 3

RADIOFREQUENCY-LINE SPECTRA OF THE γ CYGNI SOURCE

ν_L (GHz)	HPBW (′)	Resolution (km s^{-1})	Δv (HP) (km s^{-1})	v (LSR) (km s^{-1})	T_L/T_C	Δv (HP) $\times$ $\nu_L{}^{-1.1} \times T_L/T_C$	Line	Source
1.65	34	1.8	22.5 ± 4.9	−1.8 ± 2.5	0.008 ± 0.002	0.104 ± 0.034	H 158α	1
5.01	6.5	10.2	32.7 ± 2.0	+5.1 ± 1	0.029 ± 0.009	0.162 ± 0.051	H 109α	2
5.01	6.5	3.8	21.8 ± 2.3	+1 ± 3	0.039 ± 0.003	0.145 ± 0.019	H 109α	3
5.01	6	3.1	41.3 ± 4	0.0 ± 4	0.015 ± 0.004	0.106 ± 0.029	H 109α	4
7.79	4.2	3.6	20.7 ± 1.8	+2.4 ± 0.8	0.038 ± 0.003	0.081 ± 0.010	H 94α	5

SOURCE.—(1) Dieter (1967); (2) Reifenstein *et al.* (1970); (3) Dickel and Milne (1972); (4) Terzian and Parrish (1973); (5) Chaisson (1973*b*).

$\Delta v(\mathrm{HP})\nu_L^{-1.1}T_L T_C^{-1}T_e^{1.15}$ is constant under certain simple assumptions for an H II region. The admixture of a nonthermal continuum to the H II bremsstrahlung invalidates the equation for the determination of T_e, and the left-side product should no longer be constant. In table 3 there is not even a significant progression of $\Delta v(\mathrm{HP})\nu^{-1.1}T_L T_C^{-1}$ with ν_L. To conclude, we cannot tell whether the recombination-line data of table 3 refer to the apparently Hα-bright nebula at the coordinates of the γ Cygni source in figure 1*a*. It is practically part of the definition of a supernova remnant that it shows no detectable, radiofrequency, recombination-line emission. Although several supernova remnants show Balmer lines, they are radiated by filaments rather than by an amorphous nebula such as the exceptional γ Cygni object. The most important advance in recombination-line data of the region around γ Cyg would be mapping in high spatial resolution.

VI. EMISSION MEASURES AND EXTINCTIONS

Dickel, Wendker, and Bieritz (1969) derived for the γ Cygni nebula a peak emission measure $E(\mathrm{H}\alpha) = 2610$ pc cm^{-6} $= 3.0 \times 10^{-4}$ ergs s^{-1} cm^{-2} sr^{-1}, assuming $T_e = 7500°$ K. Their photographic photometry was calibrated by photoelectric photometry. We shall derive the peak emission measure E(31.4 GHz) from our data, and attribute the difference between the two results to extinction $A(\mathrm{H}\alpha) = 2.5 \log E(31.4\ \mathrm{GHz})/E(\mathrm{H}\alpha)$. Substituting the Gaussian FWHM = 2′.7, and flux density $S(31.4\ \mathrm{GHz}) \leq 4$ Jy of component No. 2, in Schraml and Mezger's (1969) formula for emission measure, we find $E(31.4\ \mathrm{GHz}) \leq 76{,}000$ pc cm^{-6} and $A(\mathrm{H}\alpha) \leq 3.7$ mag. The inequality incorporates the conclusion in § IV that this source probably is partly nonthermal. According to standard reddening curves, $A(0.41\ \mu) = 1.8A(\mathrm{H}\alpha) \leq 6.6$ mag, and we can ask whether this is adequate to explain the complete absence of detectable emission at the center of the γ Cygni nebula in the blue passband. In the Orion Nebula line spectrum, corrected for moderate reddening (Johnson 1968), there is about 3 times as much line emission in the blue passband of table 1 as in the red. If the same ratio holds in the γ Cygni nebula, there should be about 2.6×10^{-2} ergs s^{-1} cm^{-2} sr^{-1} per blue passband before extinction, or 6×10^{-5} ergs s^{-1} cm^{-2} sr^{-1} after 6.6 mag of extinction. If the thermal part of the flux density of component No. 2 of the γ Cygni source is <4 Jy, the implied $A(0.41\ \mu)$ is lessened by an amount which leaves $>6 \times 10^{-5}$ [up to a maximum of 9×10^{-4} if thermal $S(31.4\ \mathrm{GHz}) = 0.14$ Jy] ergs s^{-1} cm^{-2} sr^{-1} of line emission in the blue passband.

For comparison we extrapolate Allen's (1963) data to estimate that the total light of the night sky in the galactic plane is about 260 stars of 10th blue magnitude per square degree, or about 600 stars of 10th red magnitude per square degree. We use the solar spectrophotometric gradient to go from 0.55 to 0.65 μ for the dominant components of the galactic light and the zodiacal light. Interpolating Johnson's (1965) calibrations these become 7.1×10^{-4} ergs s^{-1} cm^{-2} sr^{-1} per blue passband, and 1.8×10^{-4} ergs s^{-1} cm^{-2} sr^{-1} per red passband. Thus the ratio of blue (nebula + sky)/sky ≥ 1.08. This would appear to be adequate for detection of the nebula on the sky-background noise, but an equal contrast ratio of red (nebula + sky)/sky would correspond to $E(\mathrm{H}\alpha) \geq 130$, and it is not certain that the lower limit of this emission measure is a detectable nebula on a Palomar Schmidt plate (cf. Poveda 1963).

The field of the plates of table 1 is 4°.4 square, centered on γ Cyg, and the plates show many other H II regions faintly in blue and sometimes in yellow wherever they appear strongest in red. The γ Cygni nebula is as bright in the red as any of them except NGC 6888. Of 59 Hα nebulae in the catalog of Dickel *et al.* (1969) and in the above area around γ Cyg, 14 of them exceed the γ Cygni nebula in the ratio $E(2695\ \mathrm{MHz})/E(\mathrm{H}\alpha)$ in areas of 11′ diameter. This argues that they suffer greater extinction than the γ Cygni nebula, yet they are among the nebulae that are faintly visible in the blue and sometimes in the yellow, which the γ Cygni nebula is not. It is possible that bright areas transmit excess starlight along with nebular emissions because they happen to be relatively transparent gaps in the dust. It is also possible that the Hα detected at the coordinates of the 2695-MHz sources in Cyg X is mostly foreground emission, not related to obscured radio sources. This is suggested by the strength of [O II] λ3727 in Cygnus H II regions (Struve and Elvey 1938; Johnson 1953). We conclude that the γ Cygni nebula either puts relatively much power into the red passband or it is truly more obscured than other optical nebulae in Cygnus.

The structure of the larger nebulosity within ½° of γ Cyg is not sufficiently symmetrical and filametary to suggest itself as the optical counterpart of the supernova component No. 1 of 1° diameter defined in § IV. But the possibility has not yet been satisfactorily studied.

The amorphous structure of the γ Cygni nebula may hint that it is, like the light of the Crab Nebula, mostly nonthermal continuum. The power-law spectral index of component No. 2 of the γ Cygni source was found in § IV to be ≥ -0.5. If it is -0.5 and is extrapolated into the optical band, and the nonthermal radiation is spread into an area of 3′ × 3′, the surface brightness is 1.2×10^{-5} ergs s^{-1} cm^{-2} sr^{-1} per red passband, and it is 7.0×10^{-5} ergs s^{-1} cm^{-2} sr^{-1} per blue passband. The result in the red passband is smaller than the peak red brightness by a factor of 25, even without extinction. The largest spectral indices of known supernovae remnants are about -0.2, and the computations of optical surface brightness, extrapolated with this index, give 2.2×10^{-4} ergs s^{-1} cm^{-2} sr^{-1} per red passband, and 1.4×10^{-3} ergs s^{-1} cm^{-2} sr^{-1} per blue passband, without extinction. This is large enough to account for the red image but it is too large to let a blue image remain invisible on a Palomar Schmidt plate. However, the estimates are so rough that it may yet be possible to reconcile the photographic data with a nonthermal spectrum under some extinction, especially if the spectrum were to break and steepen between

0.64 and 0.41 μ. Obviously the answer to these questions calls for a spectroscopic study of the nebula at the position of the γ Cygni supernova remnant.

I thank the Directors of the Hale Observatories, Haystack Observatory, and National Radio Astronomy Observatory, for granting telescope time. The assistance of the staffs in each of these observatories was indispensable. Let me particularly thank Mr. B. G. Leslie and Dr. M. L. Meeks of Haystack. I am indebted to the Director of the Lick Observatory for permission to use the blink machine. The work was done partly under the Lockheed Independent Research Program, and partly under contracts NAS 2-7842 and NAS 5-23340 with NASA.

Note added in proof.—A Carnegie image-tube spectrogram was obtained with the 1.5-m reflector at Cerro Tololo Inter-American Observatory[3] on May 29. The center of a 2″-wide slit, fully opened to extend about 7′ east-west, was positioned 2′.6 east and 1′.5 south of γ Cyg, and a 60-minute exposure was made on nitrogen-baked IIIa-J emulsion. The spectral range included $\lambda\lambda$3727–6731 Å, and dispersion was about 117 Å mm^{-1}. Lines of [S II] $\lambda\lambda$6717–6731, [N II] $\lambda\lambda$6548–6584, Hα and Hβ, and [O III] $\lambda\lambda$4959–5007 are present. Hα and [N II] extend across the length of the slit but with knots that are strongest near center. The line of [O III] λ5007 looks somewhat knottier than Hβ, although comparably strong. No continuum is visible, and both interstellar and atmospheric extinction may account for absence of lines below Hβ.

[3] Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

REFERENCES

Allen, C. W. 1963, *Astrophysical Quantities* (2d ed.; London: University of London), p. 135.
Chaisson, E. J. 1973*a*, *Ap. J.*, **182**, 767.
———. 1973*b*, private communication.
Dent, W. A. 1972, *Ap. J.*, **177**, 93.
Dickel, H. R., Wendker, H., and Bieritz, J. H. 1969, *Astr. and Ap.*, **1**, 270.
Dickel, J. R., and Milne, D. K. 1972, *Australian J. Phys.*, **25**, 539.
Dieter, N. H. 1967, *Ap. J.*, **150**, 435.
Downes, D. 1971, *A.J.*, **76**, 305.
Downes, D., and Rinehart, R. 1966, *Ap. J.*, **144**, 937.
Drake, F. D. 1959, in *Paris Symposium on Radio Astronomy*, ed. R. N. Bracewell (Stanford: Stanford University Press), p. 339.
Hermann, B. R. 1972, Ph.D. thesis, University of Illinois.
Hermann, B. R., and Dickel, J. R. 1973, *A.J.*, **78**, 879.
Higgs, L. A. 1966, *M.N.R.A.S.*, **132**, 67.
Higgs, L. A., and Halperin, W. 1968, *M.N.R.A.S.*, **141**, 209.
Hobbs, R. W. 1960, *A.J.*, **65**, 53.
Johnson, H. L. 1965, *Comm. Lunar and Planet. Lab.*, No. 53.
Johnson, H. M. 1953, *Ap. J.*, **118**, 370.
———. 1968, in *Nebulae and Interstellar Matter*, ed. B. M. Middlehurst and L. H. Aller (Chicago: University of Chicago Press), p. 65.
Mathewson, D. S., Large, M. I., and Haslam, C. G. T. 1960, *M.N.R.A.S.*, **120**, 242.
Mezger, P. G., and Höglund, B. 1967, *Ap. J.*, **147**, 490.
Morton, D. C. 1973, in *Guide for Guest Investigators Using the Princeton Telescope on the Satellite Copernicus*, ed. T. P. Snow (Princeton University Observatory).
Pike, E. M., and Drake, F. D. 1964, *Ap. J.*, **139**, 545.
Poveda, A. 1963, *Bol. Obs. Tonantzintla y Tacubaya*, No. 23, 119.
Reifenstein, E. C., III, Wilson, T. L., Burke, B. F., Mezger, P. G., and Altenhoff, W. J. 1970, *Astr. and Ap.*, **4**, 357.
Schmidt, M. 1965, in *Galactic Structure*, ed. A. Blaauw and M. Schmidt (Chicago: University of Chicago Press), p. 513.
Schraml, J., and Mezger, P. G. 1969, *Ap. J.*, **156**, 269.
Sharpless, S. 1959, *Ap. J. Suppl.*, **4**, 257.
Struve, O., and Elvey, C. T. 1938, *Ap. J.*, **88**, 364.
Terzian, Y., and Parrish, A. 1973, *A.J.*, **78**, 894.
van den Bergh, S., Marscher, A. P., and Terzian, Y. 1973, *Ap. J. Suppl.*, **26**, 19.
Ulich, B. R. 1973, NRAO internal memorandum.
Wendker, H. 1966, *Mitt. Astr. Inst. Univ. Münster*, No. 10.
———. 1970, *Astr. and Ap.*, **4**, 378.
Willis, A. G. 1973, *Astr. and Ap.*, **26**, 237.
Yang, K. S., and West, L. A. 1964, *A.J.*, **69**, 246.

HUGH M. JOHNSON: Dept. 52-14, Bldg. 202, Lockheed Missiles and Space Co., Inc., 3251 Hanover Street, Palo Alto, CA 94304

1974ApJ...194..337J

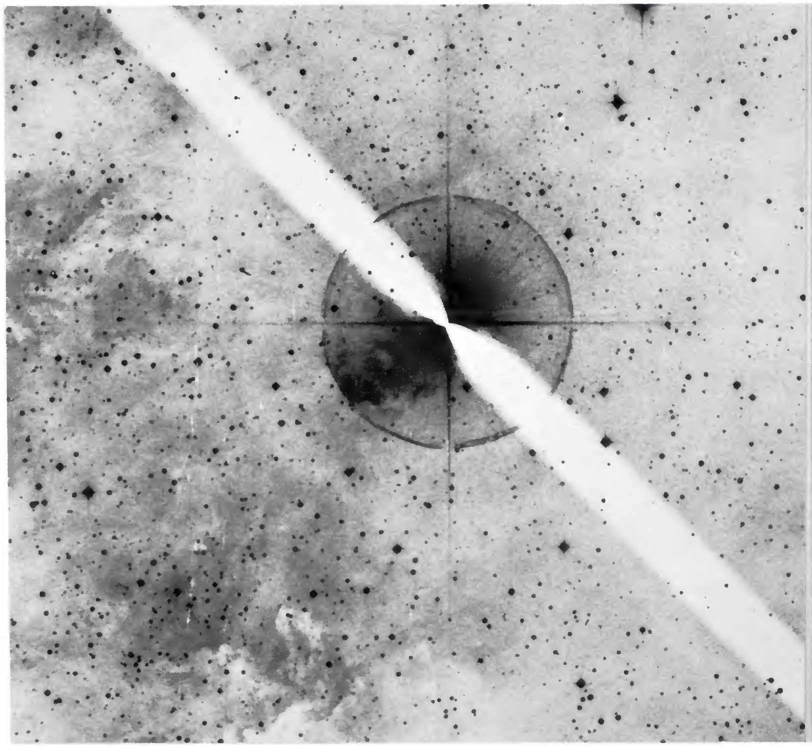

FIG. 1a

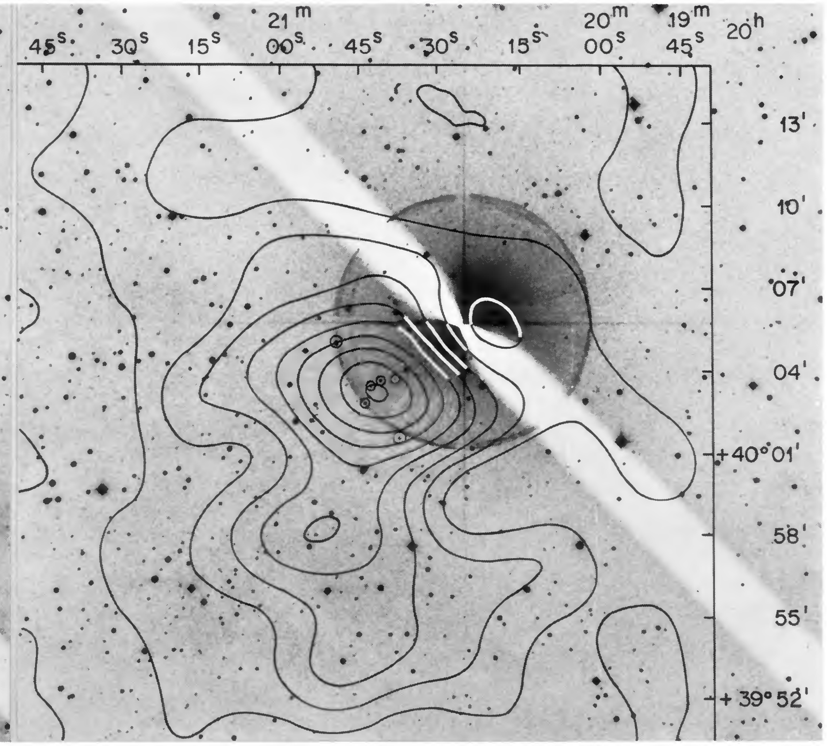

FIG. 1b

FIG. 1a.—Field of the γ Cygni nebula in a Palomar Schmidt plate with the red passband of table 1. A diagonal bar occults most of the light of γ Cyg.

FIG. 1b.—Same field as fig. 1a but in the blue passband of table 1 and with 7.875-GHz isotherms from new Haystack mapping and with a grid of epoch 1950 coordinates. The contour steps are 0.1° K of antenna temperature above base level between 0.0° and 0.8° K.

JOHNSON (*see* page 337)