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A PROBABLE SUPERNOVA REMNANT IN THE DWARF ELLIPTICAL GALAXY NGC 185

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ABSTRACT

An emission nebula has been discovered near the core of the Local Group dwarf elliptical galaxy NGC 185. On the basis of the high intensities of emission lines of [S II] and [N II] relative to Hα, we conclude that the nebula is shock heated and most likely a supernova remnant. This feature is possibly related to the existence of a Population I component in NGC 185. The ratios of [N II] to [S II] emission in the nebula suggest the interstellar medium in NGC 185 is at most moderately metal poor ($\gtrsim 1/3$ solar).

Subject headings: galaxies: general — nebulae: supernova remnants

I. INTRODUCTION

In terms of many properties, including morphology, integrated optical colors, luminosity distribution, and presence of globular clusters, NGC 185 is a typical diffuse dwarf elliptical galaxy (Baade 1944; Hodge 1963, 1971; Sandage, Binggeli, and Tarenghi 1982; Caldwell 1983; Wirth and Gallagher 1984). On the other hand, because of its proximity in the local group a variety of readily detectable peculiar features indicate that NGC 185 does not fit the normal model of elliptical galaxies as pure old Population II systems. A complex of luminous, blue stars which are probably young exists near the center of the galaxy (Baade 1951; Hodge 1963, 1972); there are several dense dark nebulae (Gallagher and Hunter 1981); and H I is present (Johnson and Gottesman 1983; Knapp 1983). Thus NGC 185 is in fact a star-forming galaxy despite its elliptical morphology (cf. van den Bergh 1968).

We have recently found another anomaly in this galaxy. Emission lines detected on a long-slit red spectrum indicate the presence of an ionized gas cloud in NGC 185 with properties similar to a supernova remnant (SNR). In this *Letter* we present a preliminary discussion of the nebula based on our discovery spectrum.

II. OBSERVATIONS

A spectrum of 1 hour exposure was obtained in 1982 October with the Cryogenic camera in conjunction with the Ritchey-Chrétien spectrograph which was mounted on the Kitt Peak National Observatory (KPNO) 4 m Mayall telescope. The slit was oriented east-west, covered approximately 4′ on the sky, and had a width of 2″.5 with a scale of 0″.84 per pixel on the CCD detector. A 300 lines mm^{-1} grism dispersing element provided approximately 15 Å resolution over a spectral range of $\lambda\lambda$6400–9700 in the first order.

Standard KPNO data reduction procedures were followed to subtract bias, remove nonuniformities in instrumental response, correct for geometric distortions, and provide a linearized wavelength solution. A rough flux calibration was obtained from observations of standard stars. Sky subtraction for extended objects presents a challenge on long slit Cryogenic camera spectra due to residual problems with distortions and focus variations. This leads to incomplete cancellation of terrestrial OH emission bands which produces a low-level "ringing" in sky-subtracted spectra. We have minimized this by smoothing the data in wavelength with a 5 pixel box filter, and we confine ourselves to the region of the spectrum blueward of 7000 Å. The resulting resolution is FWHM ~ 18 Å, so that [N II] λ6584, but not [N II] λ6548, will be just resolvable from Hα λ6563 (see Fig. 2).

Figure 1 (Plate L4) shows a gray-scale reproduction of a portion of the spectrum of NGC 185. The nebula is very faint, e.g., the peak [S II] intensity is about 6% of the combined galaxy plus sky background level (galaxy is about 0.7 of sky). The [S II] doublet and [N II] λ6584 are readily seen, but Hα emission is largely masked by the underlying stellar absorption line. In [S II] one can see that the nebula has a moderately bright core covering about 6″ with a slightly fainter feature extending an additional 11″. These correspond to linear dimensions of 20 pc and 40 pc at a distance of 0.73 Mpc (Kraan-Kortweg and Tammann 1979). The "bright core" probably appears brighter because of an increased galaxy background in that region and, in fact, the nebula itself may

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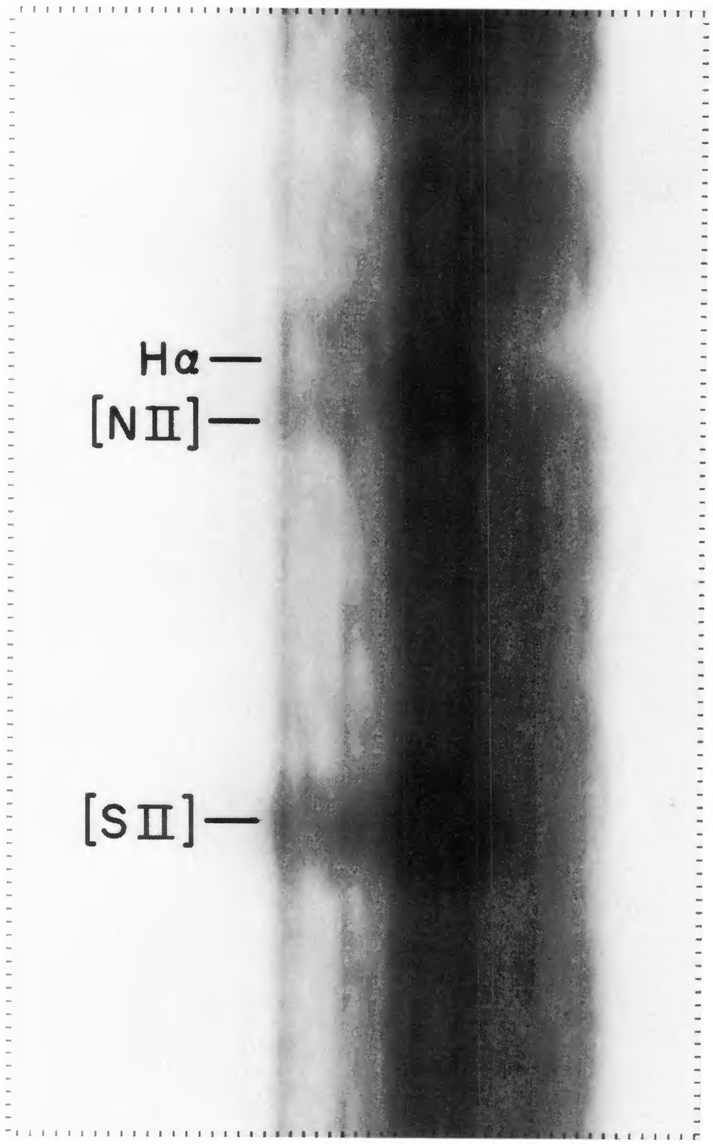

FIG. 1.—A gray-scale image of a portion of the sky-subtracted NGC 185 spectrum. The horizontal axis is wavelength, and the vertical is space along the slit with east down. One tick mark represents roughly 4 Å horizontally or 0".84 vertically, so the image covers 45" vertically and from about 6460 Å to about 6800 Å horizontally.

GALLAGHER, HUNTER, AND MOULD (*see* page L63)

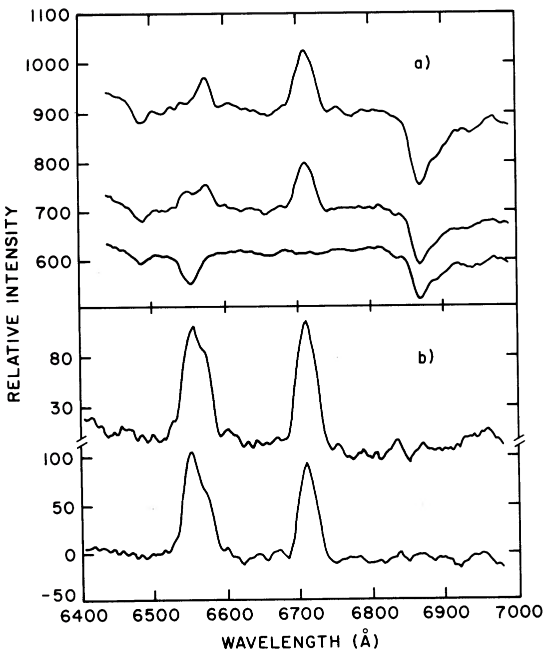

FIG. 2.—(*a*) Cuts through the NGC 185 spectrum showing Hα and [S II] have been made by averaging over all rows containing the object. From top to bottom, the spectra are from the seemingly brighter emission core, the fainter extension, and the adjacent nonemission region (in Fig. 1, above the bright blob). (*b*) Spectra of emission regions corrected for contamination by the galaxy background; appropriately normalized versions of the nonemission spectrum in (*a*) have been subtracted from the core and extensions of the nebula. The brightness of the core emission region as seen in Fig. 1 is largely due to the galaxy background. Note that [N II] λ6584 is only marginally resolved from Hα, and the [S II] doublet is unresolved.

be of nearly constant surface brightness over the 17″. The spectra presented below are consistent with this finding.

Since the slit was eyeballed on the optical center of NGC 185 (which is quite faint), the exact position and full extent of the nebula are uncertain. Most probably the nebula extends eastward from a clump of bright stars, which are themselves slightly (~ 5″) east of the center of NGC 185. This nebula thus does not coincide with the obvious dark nebulae which lie primarily west and south of the center, but it may be related to the young central stellar complex. The nebula also lies near the H I peak found by Johnson and Gottesman (1983) which is also displaced about 0′.5 east of the optical center, and a causal connection is again possible.

In Figure 2*a* we show spectra extracted for regions containing the seemingly brighter feature, the fainter extension, and the adjacent galaxy. Figure 2*b* presents spectra obtained by subtracting from the emission regions a comparison nonemission region of the galaxy which has been appropriately normalized. Although the match between the continua is quite good, the center of NGC 185 is somewhat bluer than the comparison region. The depth of the Hα absorption therefore may have been slightly underestimated. Table 1 gives a summary of emission-line data which were measured using an interactive Gaussian deconvolution and fitting program to calculate line strengths. Note that the Hα intensity is also uncertain due to blending with [N II]. The [S II] doublet is unresolved and has a centroid wavelength of approximately λ6724. This suggests the intensity ratio of [S II] λ6716 to λ6731 is $\gtrsim 1$ which implies a low electron density in the nebula ($n_e \lesssim 10^3$ cm^{-3}; Osterbrock 1974).

III. DISCUSSION

The high intensities of the [S II] and [N II] emission relative to Hα seen in Table 1 are characteristic of shock-heated gas, such as is found in SNRs and bubble nebulae formed by stellar winds (e.g., Lasker 1977). In fact, strong [S II] emission is the primary optical indicator of SNRs in external galaxies (cf. Mathewson and Clarke 1973; Blair, Kirshner, and Chevalier 1981), and Dopita (1982) suggests that nebulae with [S II] to Hα intensity ratios of $\gtrsim 0.4$ are probably SNRs (see also Lasker 1979; Chu and Lasker 1980; Chu 1982). The line ratios given in Table 1 are indeed similar to those found in SNRs in a variety of galaxies (Milky Way: D'Odorico 1974; M33: Dopita, D'Odorico, and Benvenuti 1980; M31: Blair, Kirshner, and Chevalier 1981, 1982; Magellanic Clouds: Dopita, Mathewson, and Ford 1977). Also, the very massive stars of the types associated with stellar wind bubbles do not seem to be present in NGC 185 (see below). Since only three lines have been observed, however, caution is still in order, and we consider our identification with a SNR to be tentative (cf. Blair, Kirshner, and Chevalier 1981).

Although elliptical galaxies are known to host supernovae (SNs), the rate is lower than in spiral galaxies (~ 10^{-3} yr^{-1} for 10^{10} $L_B/L_\odot$; e.g., Tammann 1982). The expected SN rate in NGC 185 which has $L_B \sim 10^8$ $L_\odot$ then is less than 10^{-4}

TABLE 1

EMISSION-LINE FLUX RATIOS FOR THE NGC 185 NEBULA

REGION	UNCORRELATED[a]			CORRECTED FOR GALAXY BACKGROUND[a]		
	[N II]/Hα	[S II]/Hα	[N II]/[S II]	[N II]/Hα	[S II]/Hα	[N II]/[S II]
"Core"	...	...	0.35	1.21:	1.68:	0.72
Extension	1.8:	3.3:	0.54	0.72	0.97	0.75
Total[b]	2.4:	4.8:	0.51	0.90	1.23	0.73

[a] I([N II]) is 4/3 × measured λ6584 [N II] intensity.

[b] Total = "core" + extension spectra, summed and then fitted. Differences in ratios provide an estimate of the internal uncertainties, and the total spectrum probably provides the most reliable line ratios.

yr^{-1}, and the mean interval between SNs should be roughly 10^5 yr. Since NGC 185 contains a trace population of young stars, its SN rate may in fact be higher than that of typical elliptical galaxies (Oemler and Tinsley 1979). Unfortunately, the ages of these stars are uncertain, but as no H II regions are seen, stars with masses of $\geq 15\ M_\odot$ are probably lacking (Hodge 1963, 1972; van den Bergh 1968; Gallagher and Hunter 1981). For purposes of discussion, NGC 185 could contain about 30 stars with masses of 10–15 $M_\odot$, in which case the mean interval between SNs produced by young stars is approximately 10^5–10^6 yr. The chance of our seeing a SNR in NGC 185 remains at only about 1 in 10, and we therefore have been lucky (cf. Blair, Kirshner, and Chevalier 1981).

SNRs in normal galaxies are optically most visible during the radiative phase which has a duration of approximately 10^4–10^5 yr, depending on conditions in the interstellar medium (McCray and Snow 1979; Kafatos *et al.* 1980). The diameter of 60 pc for the NGC 185 nebula is typical of older, optically detected SNRs in Local Group galaxies (D'Odorico 1978; Dopita, D'Odorico, and Benvenuti 1980; Blair, Kirshner, and Chevalier 1981) and could be attained by an archetypal SN with energy input of approximately 10^{51} ergs. From the mere presence of a SNR, we would estimate a mean density of about 0.1 cm^{-3} for the interstellar medium in the core of NGC 185, while the Johnson and Gottesman (1983) H I data suggest that densities as high as approximately 1 cm^{-3} are possible. Again, however, the details of the evolution of SNRs depend on the nature of the interstellar medium which is poorly known in NGC 185.

Emission spectra of gas shocked by SNRs provide useful probes of chemical abundances in interstellar matter, but accurate abundance determinations require more data than we have available here (cf. Dopita *et al.* 1984). The intensity ratio of [N II]/[S II], however, is found *roughly* to correlate with gas metallicity levels in Local Group galaxies. Our value of approximately 0.7 for this ratio in NGC 185 is somewhat higher than is found for SNRs in the LMC or M33 but is below typical galactic or M31 values (Dopita, Mathewson, and Ford 1977; Dopita, D'Odorico and Benvenuti 1980; Blair, Kirshner, and Chevalier 1981). The [N II]/Hα ratio in NGC 185 also is high for an intermediate metallicity environment. From the present data we therefore suggest the metal abundances in the NGC 185 lie between the solar and Large Magellanic Cloud (~ 1/3 solar) levels. For comparison, the metallicity of stars in the outer parts of NGC 185 is approximately 1/10 solar (Mould, Kristian, and Da Costa 1983, and unpublished research), and the abundance in the nebula could be enhanced compared with the stars. This would be consistent with the gas being recycled from stars (cf. Gallagher and Hunter 1981), and observations to confirm our preliminary abundance estimates therefore are of particular importance.

The unusual nature of NGC 185 makes its emission nebula a very worthwhile object for further study. Optical imaging and spectrophotometry are necessary to confirm the SNR identification and to obtain information on abundances and physical conditions within the nebula. Similarly, detections in the X-ray and radio spectral regions would be most interesting.

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