side of Hα; the separation between Hα and [N II] λ 6583 is 20 Å, so we assume that both lines are contributing to this very broad emission. [N II] λ 6548, for which we do not see a sharp core on L768, probably contributes relatively little to the total width and the total intensity. The velocity broadening thus must amount to about 65 Å corresponding to random motions of ± 1500 km/sec. This value is very similar to the values found in other Seyfert galaxies. The [O I] λ 6300 line is much weaker, and no extended wings can be seen.

In view of the interconnection between radio galaxies and Seyfert galaxies, and the idea that both are due to the occurrence of violent events in the nuclear regions of galaxies (Burbidge, Burbidge, and Sandage 1963), we might suppose that a violent event has occurred in the nucleus of V-V 144 and this has given rise to the great velocity broadening shown by the emission lines. No other Seyfert galaxy known as the unusual structure which is seen in V-V 144 with a relatively bright jet projecting out on one side. We note that the quasi-stellar radio source 3C 273 has a very much fainter but longer jet projecting from it (Schmidt 1963). We suggest that the jet in V-V 144 is connected with the occurrence of a violent event in it; possibly an earlier event than that which has given rise to its present-day Seyfert characteristics. As far as we are aware, no strong radio source is associated with V-V 144, but a comparatively weak radio source such as that which is associated with the Seyfert galaxy NGC 1068 would not have been detected by current radio-astronomical programs.

This work has been supported in part by a grant from the National Science Foundation.

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Received June 11, 1964
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X-RAYS AND TYPE I SUPERNOVA REMNANTS

Bowyer, Byron, Chubb, and Friedman (1964) have observed X-rays from a source that probably is to be identified with the Crab Nebula. Chiu and Salpeter (1964) have suggested that these X-rays are thermal radiation from a neutron star—which then would be the stellar remnant of the Crab Nebula supernova. We shall briefly review our knowledge of Type I supernova remnants and discuss an alternative possibility, which may be of interest since the existence of neutron stars is still somewhat in doubt.

Three Type I supernovae have been definitely recorded in our galaxy during historical times: In 1054 (Crab Nebula), in 1572 (Tycho's supernova) and in 1604 (Kepler's supernova). Some data on these supernovae and their radio and optical remnants are assembled in Table 1. Most data are self-explanatory. The interstellar absorptions were estimated from Hiltner's (1956) data on nearby O and B stars. The distances need some comment.

In the case of the Crab Nebula the distance has usually been determined on the assumption that the expansion velocity at the tips of the major axis (observed as a proper motion) is equal to that in front or behind the nebular center (observed as a radial velocity). In this case the nebula is an oblate spheroid and the distance 1000 pc. If the equally likely assumption of a prolate spheroid is made—in which case the proper motions at the tips of the minor axis should be compared with the radial velocities—the distance is 1500 pc.

In Kepler's remnant Minkowski (1959) found some filamentary emission nebulosities moving with velocities between −140 km/sec and −275 km/sec. In Tycho's object one faint filament has about zero radial velocity (Minkowski 1959). It seems unlikely that these velocities can be interpreted in terms of expanding shells.

TABLE 1

TYPE I SUPERNOVAE AND THEIR REMNANTS

Name	Crab Supernova	Tycho's Supernova	Kepler's Supernova
Year	1054	1572	1604
l^{II}	184 6	120 1	4 5
b^{II}	−5 8	+1 4	+6 8
m_v (max)	[$-5^{\text{m}}.5$]*	$-4^{\text{m}}.0$†	$-2^{\text{m}}.2$‡
Interstellar absorption	$1^{\text{m}}.6$	$3^{\text{m}}.3$	[2^{m}]
Distance (pc)	1500	2400	9900
log radio flux at 100 Mc/sec in units of 10^{-26} Wm^{-2} (c/s)$^{-1}$	3 25	2 36	1 90
Spectral index	−0 26	−0 61	−0 61
Radio diameter§	3′5 (E -W. nearly Gaussian)	6′ (ring source?)	3′0 (small-scale structure)
log absolute radio luminosity at 100 Mc/s [erg sec^{-1} (c/s)$^{-1}$]	24 68	24.20	24.97
Expansion velocity (km/sec)	1400	5900‖	12100‖

* Mayall and Oort (1942).
† Baade (1945)
‡ Baade (1943).
§ Maltby and Moffet (1962)
‖ Derived from age and diameter.

If we inspect the data for Type I supernovae in external galaxies, it appears that the visual absolute magnitudes at maximum (derived with a redshift of 100 km/sec/Mpc and corrected for $0^{\text{m}}.3$ cosec b interstellar absorption in our Galaxy) have a rather small dispersion of about a magnitude around a mean (or median) value of $M_v = -19^{\text{m}}.2$.[1] The data are probably sufficiently good to assess the dispersion correctly since many Type II supernovae have been found at absolute magnitudes that are lower than those for the fainter Type I supernovae. Because of the rather small dispersion reasonably good distances can be derived from the maximum apparent magnitudes of supernovae. If these distances are accepted, it follows that the expansion velocities are no less than those in Type II supernovae, while also the difficulties in reconciling the mean extragalactic rate of one Type I supernova per 300 years per galaxy with the number observed in our Galaxy is greatly reduced. If the same distance determination had been made for the Crab Nebula values between 2600 and 1600 pc (for m_v between $-5^{\text{m}}.5$ and $-6^{\text{m}}.5$) would have been obtained. We have adopted the 1500-pc distance derived from the kinematics for a prolate shell. It is interesting to note that Kepler's supernova is situated only 8° from the galactic center and thus may actually be not far from it. According to 21-cm observations (Rougoor and Oort 1960) part of the galactic gas in the inner parts of the Galaxy is moving outward with velocities of 50–200 km/sec and we tentatively suggest that the radial velocities observed by Minkowski may be due to the same

[1] A similar result has been obtained by van den Bergh (1960) who found $M_{\text{pg}} = -18^{\text{m}}.7 \pm 1^{\text{m}}.1$.

phenomenon, although it is also possible that the interstellar gas has been accelerated to a modest velocity by the supernova. In Tycho's object no radial velocity is expected for the interstellar gas and none is observed. Perhaps the gas is visible because it has been excited by the supernova or by the high-energy particles of its remnant. In the latter case an outward-moving excitation front could be expected and lead to the apparent proper motions that seem to have been observed. The situation may be somewhat similar to that in Cas A, where excited gas filaments are also observed that do not move bodily with the expanding shell and that probably should be interpreted as pre-existing interstellar gas cloudlets that have been ionized by the events associated with the supernova. It hardly seems possible that these non-moving filaments could represent parts of the shell that have been decelerated since the interstellar densities required are prohibitive ($10^5 - 10^6$ cm^{-3} for Cas A according to Minkowski [1959]).

In the case of the Crab Nebula the continuous radio spectrum (synchrotron radiation) extends into the optical region. No special explanation is needed as to why the other remnants do not show an optical continuum. Only in the Crab Nebula, which in this sense may be a rare case among the supernova remnants, is the radio spectrum so flat that extrapolation into the optical wavelengths leads us to expect observable optical emission. Information on the synchrotron spectrum in the far ultraviolet may perhaps be obtained from the ionization conditions in the shell.

It is not immediately obvious, in the case of the Crab Nebula, what the source of excitation and ionization is—ultraviolet radiation or collisions with the interstellar gas. In the latter case the nebular shell would probably be heated and the excitation would be purely collisional. The Balmer decrement does not provide a satisfactory criterion because of the wide range of theoretical possibilities and the rather poor quality of the observations. However, conclusions may be drawn on the basis of the intensity ratios of the [O II] and [O III] lines. If the ionization is collisional the degree of ionization depends on the temperature only. This dependence is very marked. The observed intensity ratios and their small variation from filament to filament (less than a factor 3 between extremes) would indicate a temperature of about 45000° K in the gas, with deviations from the mean for individual elements less than $\pm 2000°$ K. It seems very hard to understand why the temperature should be so constant. In the case of radiative excitation the temperature does not play a very critical part, the degree of ionization now being inversely proportional to the density. If the ionization is in fact radiative, the emission around 200 Å can be estimated (Woltjer 1958). If we correct our earlier estimate for an underestimate in the recombination cross-section, we obtain (for a distance of 1500 pc) a flux of 1.0×10^{-27} W m^{-2} (c/s)$^{-1}$. We have now reliable data on the radio emission up to several 1000 Mc/s, in the infrared and optical wavelengths (Moroz 1963; O'Dell 1962) and a plausible value in the ultraviolet. The spectral data corrected for interstellar absorption are plotted in Figure 1. The X-ray flux observed by the N.R.L. group is also indicated, and it appears a natural extension of the synchrotron spectrum.

From the usual expressions for the characteristics of synchrotron radiation, it follows that if relativistic electrons radiate at a frequency ν in a magnetic field $B_\perp$ transverse to the radius of curvature of their orbit, the time in which the electrons radiate half their energy is about $3.3 \times 10^4 \nu^{-1/2} B_\perp^{-3/2}$ years or for the X-ray electrons with $\nu = 10^{18}$ c/s and $B_\perp \approx 10^{-4}\,G$ about 33 years, or ten times shorter than the lifetime of the optical and radio electrons, which lose energy primarily by the expansion of the nebula (Woltjer 1958). If, as seems to be the case, hydromagnetic waves traverse the nebula the conditions can be even more favorable for the X-ray electrons. If the magnetic moment of the particles is conserved, in a compression wave the particle energy (transverse to $\boldsymbol{B}$) will vary as B and thus the critical frequency as B^3. Thus, even if only electrons radiating in the mean nebular field at 10^{17} c/s were present (lifetime 100 years), the hydromagnetic waves could cause emission in the X-ray region if the field is doubled in the waves. It should be emphasized that the need for accelerating particles after the initial supernova outburst exists independent of the interpretation of the X-rays, because the optical electrons cannot have survived from the time of the supernova event.

Thus in the Crab Nebula the X-rays could very well be produced without the occurrence of a neutron star. If a neutron star were responsible and if the synchrotron spectrum were cut off at about 100 Å, one would expect a dip in the spectrum between 10 and 100 Å. Unfortunately, however, such a dip can be expected in all cases because of interstellar absorption effects, which are important in this wavelength region. The angular size of the X-ray source could provide valuable information but only if it can be determined to within 1′.

If supernovae of Type I lead to the formation of neutron stars, then Tycho's remnant might provide a good chance to detect one, since its distance is not too large and since definitely no X-ray synchrotron emission can be expected. Kepler's remnant may be too distant. In the case of the Type II supernovae Cas A might provide a decisive case.

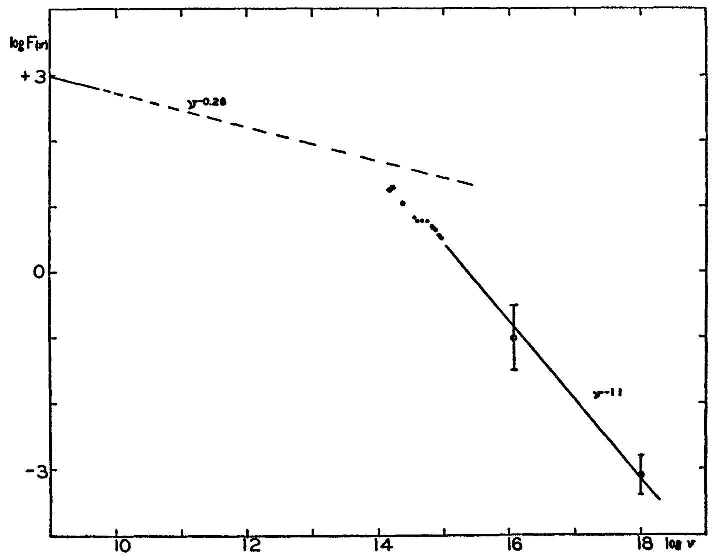

FIG. 1.—The spectrum of the Crab Nebula

Strong X-ray emission has been detected from a source in Scorpio, but no radio source or optical nebulosity is in evidence, and it is not clear that this source is related to the supernova process.

If stars condense to neutron star densities (which may well occur even for masses for which no stable static neutron stars can exist), some interesting questions can be raised with respect to the stellar magnetic field. If a star contracts in a spherically symmetrical way and *if* flux is conserved then $B \propto R^{-2} \propto \rho^{2/3}$. Thus if neutron star densities are reached, the field intensity would increase by a factor of 10^{10}, and thus stellar fields of up to 10^{14}–10^{16} G could be reached. Clearly, then, the field evolution need not be described adequately in such a simple way, and a satisfactory theory still has to be developed. But one may well speculate that such a theory could have a direct bearing on the problem of the origin and acceleration of the relativistic electrons in the Crab Nebula.

This research has been supported in part by the Air Force Office of Scientific Research under contract AF 49(638)-1358.

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June 5, 1964

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LITHIUM IN CARBON STARS

For many years it has been known that the spectra of certain carbon stars such as WZ Cas, WX Cyg, and T Ara show a strong lithium line at λ 6707 (McKellar 1940; Sanford 1944; Feast 1954). It has been difficult to make even an order-of-magnitude extimate of the lithium abundance in these stars because of the obvious difficulties presented by the blanketing by CN features as well as a lack of knowledge of the source of continuous opacity, effective temperature, etc. The contention that the great strength of the lithium line is due to a combination of low temperature and low opacity has been difficult to refute.

In this note we estimate the ratio of lithium to calcium in seven carbon stars by a comparison of the lithium line at λ 6707 with the intercombination line of calcium at λ 6572. We have measured "equivalent widths" of the two features by connecting high points in the spectrophotometric tracings to form a pseudocontinuum. The tables of CN lines by Phillips and Davis (1963) and our identification of the CN features in the stars allow us to note that the general level of CN blanketing is about the same at λ 6572 as at λ 6707. According to Phillips and Davis, three CN features blend with the lithium line and one CN line blends with the calcium line. To subtract their contribution to our measured equivalent widths we have first compared with other CN features of similar laboratory intensities. For the star V CrB it appears that the entire feature at λ 6707 is contributed by CN and so we have subtracted its equivalent width, 350 mÅ, from all the other measurements of λ 6707 except for 19 Psc, which has weaker CN and for which we assign 200 mÅ as the CN contribution. The CN feature at λ 6572 is partially resolved in the spectrum of U Hya, which has somewhat sharper lines than the other stars. Its equivalent width is 230 mÅ which we have subtracted from the equivalent widths of λ 6572 in the other stars except 19 Psc, for which we have used 150 mÅ on account of the weaker CN.

Our data are listed in Table 1 and some tracings of 8 Å/mm plates are shown in Figure 1. In Figure 1, the top spectrum has a strong lithium line, the middle spectrum has a doubtful lithium feature, and the bottom spectrum probably shows no lithium.

The conversion of equivalent widths to abundances is not entirely straightforward, except in the case in which the equivalent widths are equal. In that special case, which applies pretty well to Y CVn, W Ori, and 19 Psc, the ratio of Li/Ca is inversely proportional to the ratio of the *gf*-values of the lines, 6×10^{-5}, which is nearly ten times the Li/Ca ratio in the Sun. The Li/Ca ratio in the other stars depends upon exactly where on the curve of growth the lines lie, the velocity parameter, etc. We have no way in which to determine these necessary data accurately, but we estimate that the lines lie on the flat portion of the curve of growth. For HD 52432 and X Cnc, the equivalent width of