1.8 HIGH RESOLUTION MAPS OF THE CRAB NEBULA AT 2700 MHz AND 5000 MHz

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This paper describes some new maps of the Crab nebula made with the One Mile radio telescope. Branson (1965) used this instrument to map the nebula at 1400 MHz. It is now operating at 2700 MHz and 5000 MHz and, for the Crab nebula, the half power beamwidth is $6'' \times 16''$ at the higher frequency.

The map of total intensity at 2700 MHz shows considerable fine structure, particularly in the centre of the nebula. Features recognised at 1400 MHz reappear, together with further detail on a smaller scale. The total intensity at 5000 MHz shows still more fine structure.

In order to compare the distribution at radio wavelengths with that in the optical continuum, it is convenient to use the isophotes derived by Woltjer (1957), for which the contribution from the filaments is small. We notice the characteristic 'S' shape of the object and the bays to the west and east. The continuum emission of the central region of the nebula has been described recently by Scargle (1969a, 1969b). Apart from the thin wisp, there is relatively little continuum emission from the immediate surroundings of the pulsar. The other wisps appear to the NW of the pulsar, with less well defined activity to the SE.

Generally speaking, the radio distribution at 5000 MHz is remarkably similar to that of the optical continuum. Again there is an 'S' shaped ridge, but this is even more pronounced in the radio case. As well as this and the nearby 'bay', the valley to the east of the NW 'peak' of the 'S' and valleys to the south also appear on the radio map. Near the pulsar, we have a minimum in the radio emission. This 'valley' has a position angle of 22°. 'Ridges' of the radio emission appear both to the NW and SE of the pulsar, about 12″ from it, and in a direction approximately perpendicular to that of the valley. It may well be that these features are related to the wisp activity. The size of the radio nebula is larger than that of the optical by between $1\frac{1}{2}$ to 2, depending on the direction. The map at 2700 MHz is very similar to that at 5000 MHz but, of course, features are smoothed by the lower resolution.

In the region within a radius of about a minute of arc from the pulsar, there are a number of bright 'ridges' of radio emission which do not correlate with any optical continuum emission. Indeed, bright ridges protrude from the centre towards the 'bay' in the west and a valley in the east. If we now superpose the radio map and an optical photograph taken in a filamentary line, (kindly donated by Dr. V. Trimble) it is clear that some of these ridges are associated with bright filaments. An explanation of this enhancement may be that the magnetic field near the filaments is greater than that in the rest of the nebula. The absence of enhanced optical continuum emission could be attributed to the short half lives of the more energetic electrons. To account for

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the observations, we require an increase in the magnetic field by a factor of 1.5 or more.

The distribution of linear polarization at 2700 MHz also shows much structure. The polarized power is greatest in the central regions of the nebula; at maximum it is about 12% of the total intensity. The maximum polarization at 5000 MHz is about 25%. Bright filaments with negative radial velocities are causing depolarization, as suggested by Burn (1966). Assuming that

$$B = 5 \times 10^{-4}\ \mathrm{G}$$
$$n = 10^3\ \mathrm{cm}^{-3}$$

we find that the Faraday rotation in a filament $\simeq 29$ rad at $\lambda = 6$ cm, so that strong depolarization is to be expected.

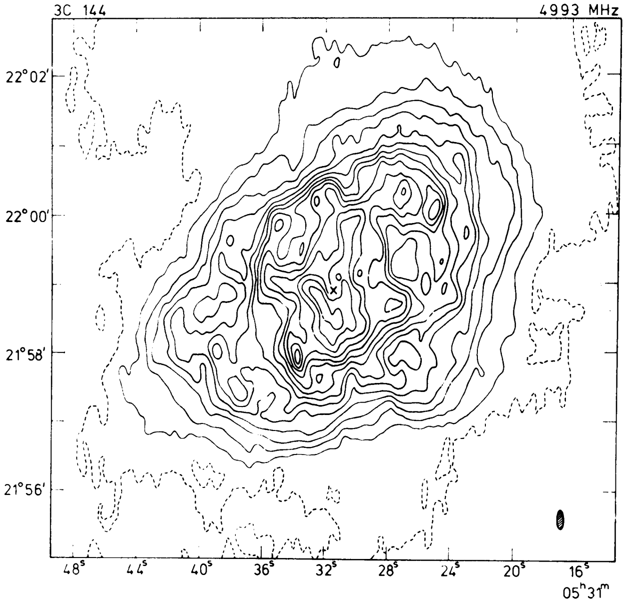

Fig. 1. The Crab Nebula at 6 cm wavelenght. The H.P.B.W. is shown in the bottom right hand corner and the cross marks the pulsar.

Apart from these features, the polarization at 5000 MHz is quite similar to the optical and there is little rotation in the centre of the map. Between 1400 MHz (Wright, 1970) and 5000 MHz the rotation in the centre is about 50°. It is hoped that a careful analysis of the distribution of rotation measure and depolarization across the nebula will define the amount of rotation in the nebula itself and in the interstellar medium and hence provide information on physical conditions in the nebula.

References

Branson, N. J. B. A.: 1965, *Observatory* **85**, 250.
Burn, B. J.: 1967, *Monthly Notices Roy. Astron. Soc.* **133**, 67.

Scargle, J. D.: 1969a, *Astrophys J.* **156**, 401.
Scargle, J. D.: 1969b, *Astrophys. Letters* **3**, 73.
Woltjer, L.: 1957, *Bull. Astron. Soc. Neth.* **13**, 302.
Wright, M.: 1970, *Monthly Notices Roy. Astron. Soc.* **150**, 271.

Discussion

J. E. Nelson: Are the correlations between 2.7 GHz intensities and the optical filament structure real? i.e. do the number of possible correlations decrease when the orientation of the 2 maps is deliberately changed by some arbitrary angle?

A. S. Wilson: I have not done this. Of course one would find correlations at some orientations. Nevertheless, I feel the correlation in the total intensity is strong enough, with sufficient bright filaments that it cannot be due to a chance coincidence. In this connection the strong correlation of the depolarised regions with negative radial velocity filaments is interesting.

C. Michel: How does your value for n_e compare with that from the pulsar observations?

A. S. Wilson: The pulsar value is < 0.5 cm^{-3}. I find 2.5×10^{-2} cm^{-3}, if the rotation is due to the nebula.

R. Minkowski: The four filaments that you consider as coincident with features of the continuum mass are neither very bright nor otherwise important. Should one not ask the inverse question: how many features of the continuum mass coincide with bright, conspicuous filaments?

A. S. Wilson: You may also find anti-correlations if you look for them.

R. G. Conway: You have compared your map with a photograph taken in one filamentary line – have you tried comparing it with photographs taken in other lines?

A. S. Wilson: The relative intensity of the filaments changes with the different lines they emit. Nevertheless the bright filaments recur whichever line you look in; it looks like the same object.

J. E. Baldwin: A comment relating to the remark concerning Drake's upper limit on the electron density in the nebula. The 21 cm observations of polarisation indicate a slow smooth variation of rotation over the nebula and that it is therefore most probably interstellar in origin.

A. S. Wilson: The question of whether the rotation is due to the nebula or the interstellar medium is not yet resolved. However Verschuur has detected a field of $3{\cdot}5\ \mu$ G in between us and the Crab by Zeeman splitting of the 21 cm neutral hydrogen line. This is in such a sense as to cause rotation in an *opposite* sense to that observed. I must emphasise that my value for n_e in the amorphous mass assumes the rotation occurs in the nebula itself.

J. E. Baldwin: Verschuur's measurement was in one cloud only and is not necessarily characteristic of the interstellar medium.

A. S. Wilson: Yes. If the rotation is in the interstellar medium alone

$$n_e B \sim 1{\cdot}3 \times 10^{-2}$$

$$n_e \text{ in cm}^{-3}, \quad B \text{ in } \mu\text{G}.$$

R. N. Manchester: For what area of the nebula have you measured the rotation measure?

A. S. Wilson: The centre only.

R. N. Manchester: What is the sense of the rotation?

R. G. Conway: The rotation measure of the Crab is -25 rad/m^2.