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OPTICAL EMISSION FROM THE CRAB NEBULA IN THE CONTINUOUS SPECTRUM

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All conclusions concerning the nature of the Crab nebula up to the present have been based upon the interpretation of its continuous spectrum given by Baade and Minkowski in their well-known studies ([1,2]; see also [3,4]), It was suggested that its continuous emission is a thermal radiation caused by the extremely hot amorphous mass of this nebula. A consequence of this interpretation is that the mass of the envelope is of the order of 10–20 solar masses and the kinetic temperature is extremely high. The filamentary part of the nebula possesses more or less ordinary characteristics.

This interpretation of the continuous optical emission meets with insurmountable difficulties. The discovery of radio emission from the Crab nebula has brought new facts, which lead to altogether new views concerning the nature of the optical emission of the Crab nebula. Several years ago a number of authors have independently proved that the radio emission from the Crab nebula cannot be considered as an extension of its continuous optical emission [3,5]. This is true for any supposition about the kinetic temperature and density of the amorphous mass of the Crab nebula. Thus the character of the radio emission from the Crab nebula must be of a non-thermal nature.

If, however, the radio emission of the Crab nebula cannot be considered as a continuation of its thermal emission, the optical emission from this nebula may be a continuation of its radio emission. Thus, both the optical and the radio emission of the Crab nebula are caused by the same non-thermal mechanism [7].

In the interval of more than six octaves (from $\lambda = 750$ cm. to $\lambda = 9\cdot4$ cm.) the spectral density of the flux of radio emission from the Crab nebula decreases only by a factor of 2·5. Radio emission from the Crab nebula at a wave-length of 3·2 cm. was recently discovered in the U.S.S.R. [6]. The value of the flux constitutes 70 % of the total flux at $\lambda = 9\cdot4$ cm. Thus in the interval of 8 octaves the spectral density of the flux decreases by a

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factor 3·5 only. It would be rather naïve to believe that the radio emission from the Crab nebula comes abruptly to an end at $\lambda = 3{\cdot}2$ cm. Beyond doubt the flux of radio emission continues towards the region of shorter wave-lengths, where it may reach optical frequencies. According to the optical observations the spectral density for $\lambda = 5{\cdot}10^{-5}$ cm. is about 1000 times less than in the metre range. If in the interval of 8 octaves the spectral density has decreased 3·5 times, in the interval of the 15 octaves that remain up to the optical range, it may decrease about 300 times. In

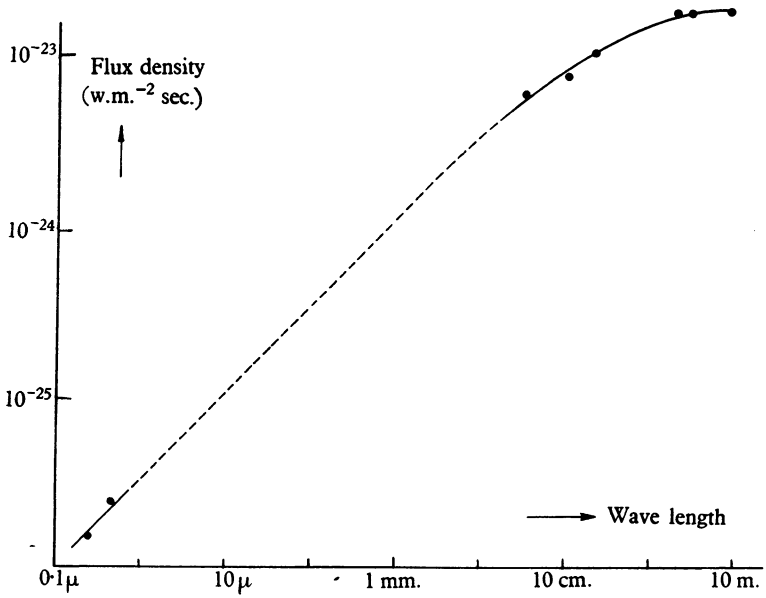

Fig. 1. Continuous spectrum of the Crab nebula.

the optical region the spectral density of the flux is approximately proportional to the frequency, the spectrum falls much steeper than in the radio region (Fig. 1).

The non-thermal mechanism of emission in radio and optical frequencies can only be emission by relativistic electrons in magnetic fields. This mechanism was discussed by the author [5, 7] some time ago in connexion with the problem of cosmic-ray generation during outbursts of supernovae and novae.

It may be shown that there must exist in the Crab nebula magnetic fields with intensities of $H \sim 10^{-4}$ gauss, the orientation of which is more or less random [8]. According to the theory of emission by relativistic electrons in

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a magnetic field the energy of the electrons responsible for radio emission from the Crab nebula ranges from $3\cdot10^7$ to $3\cdot10^9$ eV. But the energies of electrons emitting optical frequencies range from $3\cdot10^{11}$ to $3\cdot10^{12}$ eV.

From the observed flux of emission, the composition of its spectrum and the distance of the Crab nebula the concentration of relativistic electrons and their energy spectrum may be calculated. The concentration of the comparatively soft relativistic electrons causing radio emission is found to be of the order of 10^{-5} cm.$^{-3}$ and of the harder 'luminescent' relativistic electrons approximately 10^{-9} cm.$^{-3}$. The differential energy spectrum has to be

$$dN(E) \sim E^{-1\cdot5}dE(3\cdot10^7 < E < 3\cdot10^9 \text{ eV.}) \text{ and } E^{-3}(3\cdot10^{11} < E < 3\cdot10^{12} \text{ eV.}).$$

The total energy of all relativistic electrons of the Crab nebula is about 10^{48} ergs.

If the emission is caused by relativistic electrons in magnetic fields, the theory predicts that it is fully polarized. Dombrovsky [9] was the first to discover this polarization after it had been predicted theoretically. The polarization is of a fairly regular character, which is somewhat unexpected. A faint regular field is obviously superposed upon the magnetic fields of random orientation.

Thus the optical emission of the amorphous mass of the Crab nebula is caused by a comparatively small amount of relativistic particles, the total mass of which is negligibly small. This nebula may therefore be pictured as a 'soap bubble'. Only the expanding network of filaments must be considered as the 'real' nebula, the gases that were formed as a result of an outburst of the supernova of the year 1054. All the difficulties that were met when the old interpretation was accepted arise no longer in this case.

In so far as only the filamentary system constitutes the 'real' nebula the mass ejected as a result of the outburst of the supernova hardly exceeds $0\cdot1\ M_{\odot}$. Quite a number of difficulties, connected with the supernova problem can thus be avoided.

Most important is the question concerning the cause of acceleration of a comparatively small number of particles up to extremely high energies. This question was investigated in detail by some authors [10]. Obviously a considerable part of the kinetic energy of the gases, ejected during the outburst, is transferred into the energy of a comparatively small number of relativistic particles, the magnetic field playing the role of a 'driving belt' in this process.

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