RADIO EMISSION

J. G. DAVIES
(Nuffield Radio Astronomy Laboratories, England)

I understand that my task is to summarize the present state of radio observation of planetary nebulae, and to give us radio observers our marching orders for the next few years. Where, then, do we stand at the end of this Symposium? Well over 100 planetary nebulae have been looked at by one or more groups at one or more frequencies, and nearly that number have been detected. Most nebulae which have been observed at several frequencies show optically thin spectra, about eight to a wavelength of 40 cm, and three to 70 cm. The fluxes of these nebulae agree well with the values predicted from the observed Hβ radiation, after correction for interstellar extinction. Some are clearly optically thick at long wavelengths, but none have been shown to remain so at the shortest wavelengths. NGC 6853 becomes optically thin near 75 cm, and NGC 6857 may become thin near 5 cm. Eight further nebulae become thin at intermediate wavelengths.

Non-thermal spectra have been reported, but the low-frequency observations on which these are based are not free from the effects of confusion, and are open to considerable doubt.

One spectral line, the 109α recombination line, has been reported in one nebula, NGC 7027. There has been no report of any detectable polarization.

Angular detail is now available on a few nebulae, and shows general agreement with optical size; but a detailed correlation of radio features with optical data will yield valuable information.

Almost all of this information has been accumulated since the IAU met in Hamburg in 1964. What must we do between now and the next symposium on Planetary Nebulae?

It is doubtful if observations of more nebulae selected rather arbitrarily from the catalogues is of much value, although it would be worthwhile to observe at 2 or 4 cm a few which might be optically thick at short wavelengths. In view of the anomalous infrared spectra of NGC 7027, this object should be observed in the millimetre waveband.

More details of the angular distribution of radio emission at more than one wavelength, preferably concentrating on a few of the larger and brighter nebulae, are needed, since all that we can do at the moment is to assume uniform emission from the optical object.

A fairly brief interferometric survey of the reported non-thermal nebulae should

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indicate whether the radiation is really coming from the nebula or from a nearby confusing source.

The spectra of a selected list of nebulae should be studied in detail, and with the highest accuracy, since both the wavelength at which the nebula becomes optically thin and the shape of the spectrum in that region will yield information on the distribution of emission within the nebula. When sufficiently accurate spectra covering several octaves about this point are available, they can be compared with theoretical curves derived from various models of electron temperature and density distribution.

In order to do this, more accurate low-frequency observations are required, and this must be a task for the interferometers, since pencil-beam instruments do not have the resolving power required to avoid the effects of confusion.

Two final points: the report of the 109α recombination line in NGC 7027 should be followed up in other nebulae, and in other lines; and since magnetic fields are proposed in some models of planetary nebulae, a search for polarization should be made.

I am sure that the radio observers here this afternoon have taken notes of the points for which their instruments are best suited, and will catch the night train back to their telescopes, so that it need not be too long before we can meet together again in a place as delightful as Tatranská Lomnica.

DISCUSSION

Seaton: I am worried about some of the results for T_e from radio observations. The earlier work of Terzian and Menon gave results in good agreement with those from [O III], but the recent radio work of Thompson for IC 418, using isophotal contours, gives a value of T_e which seems to be surprisingly low. I hope that further careful work of this sort will be made, in order to establish whether there is any real evidence for discrepancies between temperatures from the radio surface brightness and from forbidden-line intensity ratios.

Thompson: The disagreement between the temperatures deduced from the radio spectra by myself and by Menon and Terzian results essentially from the different solid angles of the models in the two cases. Menon and Terzian assumed that only the material in a shell is optically thick, but this is not what one would expect from the Balmer line isophotes of IC 418 and NGC 6572. NGC 6572 shows a central concentration of brightness with very little evidence of shell structure.

Aller: A slitless coudé plate of NGC 6572 secured by Wilson was analyzed to obtain the spatial distribution of emitting gas. The nebula consists of a ring surrounded by an amorphous outer envelope, suggesting a very inhomogeneous structure.

Minkowski: The appearance of NGC 6572 on direct photographs matches that found on the slitless spectrograms by Wilson. NGC 6572 is definitely not a nebula without structure.

Menon: The electron temperatures computed in the paper by Menon and Terzian are based on the fluxes in the black-body region and an assumed solid angle based on optical appearance. In the case of IC 418 the new interferometer results support the angular size used in that paper. Hence, I feel that the electron temperatures computed in our paper are not overestimates, but, if anything, underestimates.