RADIO EMISSION FROM NEARBY GALAXIES AT HIGH FREQUENCIES

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High resolution observations of the radio continuum emission from nearby galaxies at several frequencies provide information about the cosmic ray electrons. Optimum results are expected by combining low-frequency synthesis observations with high-frequency single dish data, e.g. Westerbork 610 MHz / Effelsberg 10.7 GHz (1' resolution) or Cambridge 150 MHz / Effelsberg 2.7 GHz (4' resolution). Maps of 15 nearby spiral galaxies at 10.7 GHz have been made with the Effelsberg 100-m telescope (Klein and Emerson, 1980). Maps of M31 and M33 are available at 2.7 and 4.8 GHz (Beck, 1979; Berkhuijsen, 1978).

1. The spectra of the integrated emission from 15 nearby spiral galaxies between 10.7 GHz and 408 MHz (or lower) have a mean slope of -0.70 with a standard deviation of only 0.08. None of the spectra shows a positive curvature at high frequencies as would be expected in the case of substantial thermal emission; even at 10.7 GHz the non-thermal emission dominates. The thermal fraction appears to be always lower than 40%, corresponding to 14% at 1.4 GHz. For all galaxies observed, the spectral index α_n of the non-thermal emission lies in the range 0.7 to 0.85, corresponding to an electron energy spectral index of $\Gamma = 2.4$ to 2.7. This result suggests that the sources of cosmic ray electrons are similar in these spiral galaxies.

2. The radial variation of the thermal and non-thermal radio emission in the galaxies M31, M51 and NGC 6946 was determined by the variation of the spectral index, assuming $\alpha_n = 0.8$ constant across the galaxy. The thermal radio emission was compared with the thermal Hα emission from HII regions. The two curves are proportional in the disc of each galaxy, indicating that the thermal emission is indeed responsible for the spectral index variation within the disc. Furthermore, any diffuse thermal emission must be similarly distributed as the HII regions.

The radial distribution of the non-thermal radio emission in M31 is neither proportional to the thermal radio emission nor to the blue light, but seems to be a curve in between these distributions. The scale length of the non-thermal emission beyond 10 kpc is 3.8±0.4 kpc, compared with 2.0±0.5 kpc for the thermal emission and 5.5±0.2 kpc for the blue light. It may therefore be concluded that the objects responsible for electron acceleration cannot solely belong to the old

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disc stellar population. However, these data do not exclude the possibility that the sources of cosmic ray electrons are to be found among the young stellar population. The distribution of the non-thermal emission in M51 and NGC 6946 is intermediate between the thermal emission and the blue light in both galaxies. For M33, Berkhuijsen (1978) obtained a similar result.

3. The variation of the spectral index in M31 with distance from the centre was published by Beck et al. (1980). The spectral index α_n was determined in rings of 1 kpc width after subtraction of the thermal emission. The range 0 - 4 kpc is dominated by the nuclear source with $\alpha_n \cong 0.75$. Between 5 and 12 kpc (where HII regions, OB stars, open star clusters, HI gas and X-ray sources are most frequent) α_n is nearly constant (0.88±0.01); beyond 12 kpc, α_n rises to 1.1. M51 and NGC 6946 show a similar steepening of α_n beyond the optical disc. The same behaviour was also found in the edge-on galaxies N891 (Allen et al., 1978), N253 (Beck et al., 1979), N3556 (de Bruyn and Hummel, 1979) and N4631 (Klein and Beck, in preparation). The present data are not accurate enough to distinguish between diffusion and convection models of electron propagation (e.g. Strong, 1978).

4. The possibility of a halo around M31 has been investigated at 408 and 842 MHz using data from the Effelsberg and Cambridge telescopes (Gräve et al., 1980). There is serious confusion from foreground radiation, but a small amount of excess radiation is found around M31. An upper limit of a possible halo emissivity can be set which is half of that deduced for our own Galaxy. Flattened 'halos' have been detected around NGC 4631 (Ekers and Sancisi, 1977) and NGC 891 (Allen et al., 1978). A weak radio 'halo' seems to be a common phenomenon among spiral galaxies and may be due to the diffusion of electrons out of the disc (e.g. Ginzburg and Ptuskin, 1976). Whereas the halos of NGC 891 and NGC 4631 could not be detected at 10.7 GHz, the NGC 253 halo is still visible at that frequency (Beck et al., 1979).

References

Allen, R.J., Baldwin, J.E., Sancisi, R.: 1978, Astron. Astrophys. 62, 397

Beck, R.: 1979, Ph.D. Thesis, University of Bonn

Beck, R., Biermann, P., Emerson, D.T., Wielebinski, R.: 1979, Astron. Astrophys. 77, 25

Beck, R., Berkhuijsen, E.M., Wielebinski, R.: 1980, Nature 283, 272

Berkhuijsen, E.M.: 1977, Astron. Astrophys. 57, 9

Berkhuijsen, E.M.: 1978, Structure and Properties of Nearby Galaxies (IAU Symposium No. 77), 149

Bruyn, A.G. de, Hummel, E.: 1979, Astron. Astrophys. 73, 196

Ekers, R.D., Sancisi, R.: 1977, Astron. Astrophys. 54, 973

Ginzburg, V.L., Ptuskin, V.S.: 1976, Rev. Mod. Phys. 48, 161

Gräve, R., Emerson, D.T., Wielebinski, R.: 1980, submitted to Astron. Astrophys.

Klein, U., Emerson, D.T.: 1980, submitted to Astron. Astrophys.

Pellet, A. et al.: 1978, Astron. Astrophys. Suppl. 31, 439

Strong, W.: 1978, Astron. Astrophys. 66, 205