PROPERTIES OF SYNCHROTRON EMISSION AND MAGNETIC FIELDS IN THE CENTRAL REGION OF M31

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Abstract. At the centre of M31 the nonthermal spectral index between λ20 cm and λ6 cm is -0.2. It slowly decreases along the southern arm and the northern filaments visible in Hα, but perpendicular to these features it increases much faster. The magnetic field runs along the arm and the filaments. These phenomena suggest the existence of a mono-energetic source of relativistic electrons in the nucleus.

1. Observations

The proximity of the Andromeda Galaxy (M31) enables to study its central region with high linear resolution. With the VLA we observed the central 20′ at λ6 cm in the D configuration and at λ20 cm in the C and D configuration. The angular resolutions are 13″, 22″ and 45″, respectively, corresponding to 45 pc, 75 pc and 150 pc in the plane of M31. The D-array data at λ20 cm came from the new M31 survey of Beck *et al.* (1998).

We corrected for missing spacings by combining the VLA data with the new Effelsberg maps at λ6 cm (Beck, Berkhuijsen, Hoernes, in preparation) and λ20 cm (Beck *et al.* 1998). A comparison of the integrated flux densities contained within 5′ (= 1 kpc) from the centre showed that at both wavelengths the VLA missed about 50% of the total and polarized emission.

2. Spectral Index Distribution

The distribution of the total power emission at λ6 cm is very similar to that of the Hα emission (Ciardullo *et al.* 1988, Devereux *et al.* 1994) smoothed to 13″: the southern arm and the brightest filaments in the northern part are clearly visible at λ6 cm.

Y. Sofue (ed.), The Central Regions of the Galaxy and Galaxies, 351-352.

After smoothing the $\lambda 6$ cm map to $22''$, we obtained the distribution of the total spectral index $\alpha\,(S \propto \nu^{\alpha})$, which has a filamentary and patchy appearance. At the very centre the spectrum is flat with $\alpha \simeq -0.2$, and it steepens outwards. This flat spectrum cannot be due to a predominance of thermal emission, because after correction for extinction the Hα data of Devereux *et al.* (1994) account for less than 20% of the flux density at $\lambda 6$ cm. Hence, the nonthermal spectral index $\alpha_{\rm n}$ must be close to -0.2.

We calculated thermal maps at $\lambda 6$ cm and $\lambda 20$ cm from the Hα emission, subtracted them from the total power maps and determined $\alpha_{\rm n}$ between the residual nonthermal maps. At the centre $\alpha_{\rm n} = -0.2$ and decreases along the southern arm and the filamentary features reaching about -0.5 on the filaments in the inner 400 pc. At larger radii and perpendicular to the arm and the filaments $\alpha_{\rm n}$ quickly decreases to values ≤ -1.0. This behaviour is similar to that observed in the centres of the Milky Way (Pohl *et al.* 1992, Sofue, this volume) and M81 (Reuter & Lesch 1996); it suggests the existence of a black hole associated with a mono-energetic source of relativistic electrons in the nucleus.

3. Magnetic Field Properties

The polarized emission at $\lambda 6$ cm and $\lambda 20$ cm is concentrated on and around the southern arm with the highest degree of polarization along the inside of the arm. At $\lambda 6$ cm also the northern filaments show polarized emission, but this area is nearly unpolarized at $\lambda 20$ cm which is probably due to depolarization across the beam caused by the fine filamentary structure. After correction for Faraday rotation the regular magnetic field component appears to be oriented along the southern arm and the northern filaments.

Assuming energy equipartition between cosmic-ray particles and magnetic fields, the strength of the total magnetic field $B_{\rm t}$ and the regular field $B_{\rm reg}$ can be calculated. The average value of $B_{\rm t}$ in rings around the centre increases slightly from $15 \pm 3\,\mu$G at $R = 0.2$–0.4 kpc to $19 \pm 3\,\mu$G at $R = 0.8$–1.0 kpc. These values are a factor of 3 to 4 higher than the total field strength in the bright emission ring at $R \simeq 10$ kpc. $B_{\rm reg}$ increases from $4 \pm 1.5\,\mu$G at $R = 0.2$–0.4 kpc to $9 \pm 2\,\mu$G at $R = 0.8$–1.0 kpc. Hence, random magnetic fields are dominating at $R < 1$ kpc.

References

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