LINEARLY POLARISED RADIO EMISSION FROM M83 (NGC 5236) AND NGC 891

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ABSTRACT. Recent VLA 20 cm radio continuum observations of the southern face-on barred spiral M83 reveal that the magnetic field is very highly aligned at the outer regions (~12 kpc radius) and totally disrupted in the inner regions (<6 kpc) of the galaxy. The RM variation suggests an axisymmetric morphology for the magnetic field. VLA 6 cm continuum polarization observations of the edge-on spiral NGC 891 reveal ordered magnetic fields at large Z-distances (~3 kpc) from the galactic plane, probably emanating from the disk through instabilities.

1. Introduction

The large scale magnetic field alignment in the outer regions of M83 was first observed at 6.3 cm (resolution ~6.5 kpc) by Sukumar et al. (1987). We have recently reported 20 cm observations (resolution ~2 kpc) with the Very Large Array (VLA) and concluded that the low observed degree of polarization in the inner parts of M83 is a consequence of turbulence in the interstellar medium (Sukumar and Allen (1989)). Further VLA 20 cm continuum observations have resolved structures of size ~1.3 kpc (at an assumed distance of 8.9 Mpc) enabling us to study the spatial correlation of the spiral arm structure and the magnetic field alignment.

The edge-on spiral galaxy NGC 891 has been observed with the VLA (D) at 6 cm. These observations, with a linear resolution of ~ 800 pc (at an assumed distance of 7.9 Mpc), show faint polarized radio emission up to 3 kpc in the Z-direction perpendicular to the galactic plane.

2. M83 (NGC 5236)

The low inclination (24°) of this southern galaxy makes it well suited to study the azimuthal component of the magnetic field in the galactic plane as the effects of Faraday rotation along the line of sight are expected to be minimal. The VLA C and D array data from observations stretching over 2 x 6.5 hours at two 25 MHz frequency bands centered around 1452 and 1502 MHz have been combined to produce maps with resolution of 30" (circular), sensitive to structures as large as 30'. The total and linearly polarised radio emission maps having rms sensitivities of 90 and 25 μJy beam^{-1} are shown in Fig 1a and 1b respectively. The total intensity map shows a prominent nuclear source and a smooth disk component. In contrast, the polarised emission is mostly seen at the outer edges of the galaxy as two giant arcs symmetrically located at

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a radial distance of 12 kpc each stretching over 30 kpc. Very little polarisation is seen in the interior of the galaxy suggesting disruption of the magnetic field alignment.

Although the field direction shows an overall spiral morphology, even on scale sizes of ~1 kpc the polarised regions are not coincident with any prominent optical spiral arm tracers, but rather coincide with diffuse outer regions where the star formation acitvity is low. As the polarisation structure does not differ much with increasing resolution, "beam depolarisation" (see Sukumar et al. (1987)) could be ruled out. Comparing the 20 and 6.3 cm maps, the rotation measure (RM) at the outer regions of the galaxy has been computed and the RM variation suggests an axisymmetric morphology for the magnetic field (Sukumar et al. (1990)). The RM is estimated to be -15 ± 3 rad m^{-2} which is very low. It would have to increase suddenly to values > 3000 in the inner regions of the galaxy to account for the low polarised emission as a result of Faraday depolarization effects. A more likely explanation is the disruption of magnetic field alignment due to turbulent nature of the interstellar medium resulting from active star formation.

3. NGC 891

Its high inclination (>88°) is well suited to study the Z-component of the magnetic field in the thick disk of the galactic radio emission. The 6 cm VLA (D) observations at two 50 MHz frequency bands centered around 4885 and 4835 MHz were combined to produce total and linearly polarised intensity maps with rms sensitivities of 40 and 15 μJy $beam^{-1}$ respectively. The observations were sensitive to structures as large as ~9′. The total intensity map (resolution ~20") is shown in Fig 2 superimposed with vectors representing the polarised intensity and directions (not corrected for Faraday rotation) of the **E** field.

The total intensity map shows the thick disk component with faint radio emission extending up to 3 kpc from the galactic plane. The prominent point source seen about 1′ to the southwest of the nucleus is the supernova 1986J. The polarisation vectors indicating the presence of magnetic fields at high Z-distances have different directions in different regions of the galactic halo.

4. Conclusions

The VLA 20 cm observations of M83 suggest that the magnetic fields are very well aligned in the faint outer regions of the galaxy and are randomly oriented in the inner regions, possibly as a result of enhanced star formation activities. The 6 cm VLA observations of NGC 891 reveal a Z-component of the magnetic field which apparently originates in the galactic disk and rises to high Z, possibly due to instabilities.

References

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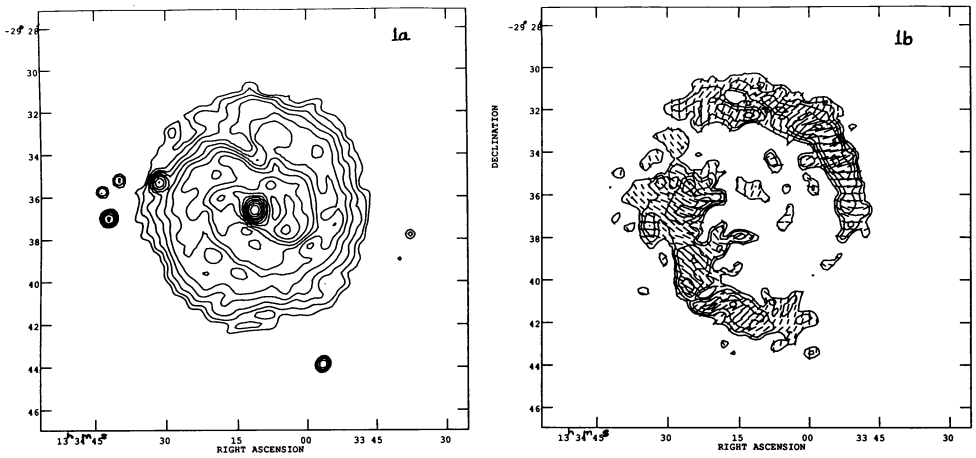

Figure 1a (1b). M83 - Total and (polarised) intensity contours with vectors indicating the orientation of the E field in 1b. The contours start at 1 (0.2) mJy beam^{-1} and increase by $\sqrt{2}$ to a peak flux of 253 (1.2) mJy beam^{-1}. The restoring beam size is 30" circular. The E vectors have not been corrected for Faraday rotation but are almost in their true directions since the RM is very low.

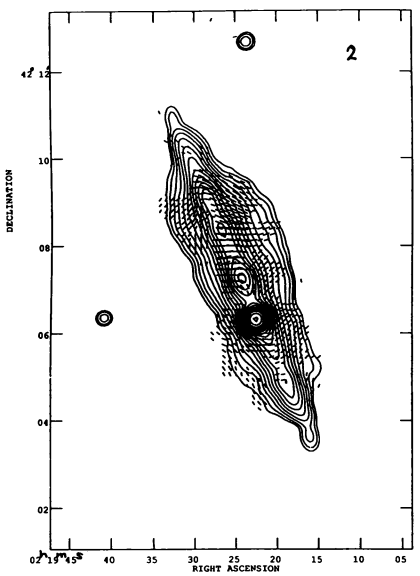

Figure 2. NGC 891 - Total intensity contours with polarisation vectors superimposed on them. The contours start at 0.2 mJy beam^{-1} and increase by $\sqrt{2}$ to a peak flux of 77 mJy beam^{-1}. The restoring beam size is 20" circular. The E field directions have not been corrected for Faraday rotation.

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VERSCHUUR: What fraction of the total flux of M83 shows the high polarization in the outer regions of the galaxy?

SUKUMAR: At 20 cm, the radio emission (total intensity) at the outer regions contributes ~20% to the integrated flux of M83.

DURIC: One would expect greatest depolarization toward the center of the galaxy where all the ionized gas is. The anti-correlation of the polarized emission with the optical disk is consistent with this. Why do you disregard this possibility?

SUKUMAR: Any effect of Faraday or beam depolarization will also have detectable variation in the polarization structure at different frequencies for which we see no evidence from observations done at various resolutions ranging from 2.45 arcmin to 10 arcsec. The rotation measure intrinsic to M83 is estimated to be -5 ± 3 rad/m^2 which is rather low. Towards the interior of the galaxy it might vary slightly but not very much since the interstellar medium is continuous. Such low RM cannot account for any great amount of depolarization and even in galaxies like NGC 6946, where higher RM is encountered, there is a substantial amount of polarized flux detected at 20 cm. However, we detect only $\leq$ 0.3 percent in the interior of M83 which cannot be obtained by Faraday or beam depolarization alone.

SPANGLER: The polarization structure of M83 shows low fractional polarization in the center and high on the periphery. A similar effect is often seen in the lobes of extragalactic radio sources, and Robert Laing has interpreted this in terms of a magnetic field structure which is completely random, but anisotropic. Have you considered the possibility that something similar could be happening in this galaxy?

SUKUMAR: There is not yet observational evidence to suggest that mechanisms responsible for generating ordered magnetic fields in radio galaxies and normal galaxies are similar.

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