MAGNETIC FIELDS AND SPIRAL STRUCTURE

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Interstellar magnetic fields are known to be a constraint for star formation, but their influence on the formation of spiral structures and the evolution of galaxies is generally neglected. Structure, strength and degree of uniformity of interstellar magnetic fields can be determined by measuring the linearly polarised radio continuum emission at several frequencies (e.g. Beck, 1982). Results for 7 galaxies observed until now with the Effelsberg and Westerbork radio telescopes are given in the table. The Milky Way is also included for comparison.

Galaxy	Type	λ (cm)	Distance (Mpc)	Linear resolution element (kpc²)	$\langle p_n \rangle$ (%)	$\langle B_u/B_r \rangle$	$\langle B_t \rangle$ (μG)	M_B	Observers
Milky Way	Sbc II	21.2-73.5	—	—	—	$\sim$0.5	$\sim$4	-20.1	Spoelstra & Brouw (in prep.)
NGC 224 (M31)	Sb I-II	11.1	0.7	0.9 x 4.2	20 ± 3	0.9 ± 0.1	4 ± 1	-21.61	Beck et al. (1980)
NGC 253	Sc(p)	2.8	2.5	1.0 x 4.9	$\sim$10	$\sim$0.4	$\sim$10	-20.72	Klein et al. (in prep.)
NGC 598 (M33)	Scd II-III	11.1	0.7	0.9 x 1.6	13 ± 4	0.4 ± 0.1	3 ± 1	-19.07	Beck, Berkhuijsen, Wielebinski (unpubl.)
NGC 3031 (M81)	Sab I-II	6.3	3.2	2.3 x 4.5	17 ± 3	0.5 ± 0.1	8 ± 3	-20.75	Beck, Klein (in prep.)
NGC 5194 (M51)	Sbc I	6.0	9	3.2 x 3.6	$\sim$20	$\sim$0.6	$\sim$10	-21.60	Segalovitz et al. (1976)
NGC 6946	Scd I	2.8	7	3.1 x 3.6	10 ± 3	0.3 ± 0.1	12 ± 4	-20.30	Klein et al. (1982)
IC 342	Scd I-II	6.3	4.5	3.2 x 3.5	20 ± 4	0.5 ± 0.1	7 ± 2	-21.4	Gräve, Beck (in prep.)

Galaxy types and absolute magnitudes are mostly taken from the Second Reference and Shapley-Ames catalogues. The linear resolution at the distance of each galaxy is given along the major and minor axis. The thermal contribution to the total flux density was estimated with help of the spectra (Klein and Emerson, 1981) and optical data if available (Beck and Gräve, 1982; Klein et al., 1982). The mean ratio of the uniform to random field strengths $\langle B_u/B_r \rangle$ follows from the mean degree of polarisation of the total nonthermal flux density $\langle p_n \rangle$ using the formulae given by Segalovitz et al. (1976) and Beck (1982), with the inclination and the nonthermal spectral index as input parameters. $\langle B_u/B_r \rangle$ refers to the linear resolution element. The mean strength of the total field $\langle B_t \rangle$ was computed from the total nonthermal flux density assuming equipartition between cosmic ray and magnetic field energy densities. As the total flux density varies with almost the fourth power of the field strength, $\langle B_t \rangle$ is believed to be accurate to $\sim$ 30% despite the large uncertainties of the input parameters.

A dependence of some property of the magnetic field on galaxy type would be of great importance for the theories of field origin. The limited sample of the present observations does not allow statistically founded conclusions, but two tendencies appear in the data:

E. Athanassoula (ed.), Internal Kinematics and Dynamics of Galaxies, 159–160.

1. The strength of the total magnetic field $\langle B_t \rangle$ seems to vary with luminosity class: Galaxies of class I contain a field of ∿ 10 μG strength, galaxies of class I-II only ∿ 6 μG. M33 representing class II-III has the weakest field.
2. For linear resolution elements of the same size, the mean ratio of the uniform to random field strengths $\langle B_u/B_r \rangle^*$ (a measure of the degree of uniformity of the magnetic field) increases with increasing luminosity. $\langle B_u/B_r \rangle^*$ is smallest in M33 and highest in M51. On a scale of 3×3 kpc^2, the ratio between the strengths of the uniform and random fields $\langle B_u/B_r \rangle$ is typically 0.5, but can reach values around 2 locally.

The distribution of the polarisation vectors in galaxies, corrected for Faraday rotation, reveals the direction of the magnetic field lines. The present data allow the following conclusions:

3. Magnetic field lines generally follow the spiral arms.
4. Large-scale magnetic field lines seem to be closed within the plane of the galaxy. No field reversals are observed.

Closed magnetic field lines suggest the action of a dynamo mechanism. Maximum deviations from circular field lines are ±10° in IC 342 and ±20° in M31 and NGC 6946. A coupling of the field lines to the streaming lines of the gas in a density wave potential is indicated. Shock fronts are able to align the field (Beck, 1982); strong shocks are expected in galaxies of high luminosity. In density wave theory, magnetic fields may also play an active rôle because they could control the growth rate of the waves.

Magnetic fields may also directly influence the star formation rate: Galaxies with bright, massive spiral arms contain the strongest fields. This can be understood in the framework of the stochastic theory of star formation (SSPSF; see Seiden and Gerola, 1982) where field lines give a preferential direction to the propagation of star formation. Hence it becomes inevitable to consider magnetic fields for theories of the spiral structure and evolution of galaxies.

LITERATURE

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