Highlights of Astronomy, Vol. 12
International Astronomical Union, 2002
H. Rickman, ed.

Magnetic Fields in Irregular Galaxies

Krzysztof T. Chyży

Astronomical Observatory, ul Orla 171, PL30-244 Kraków, Poland

Abstract. Radio data of large irregular galaxies reveal some extended synchrotron emission with a substantial degree of polarization. In the case of NGC 4449 strong galaxy-scale regular magnetic fields were found, in spite of the lack of ordered rotation required for the conventional dynamo action. The rigidly rotating large irregular NGC 55 shows vertical polarized spurs connected with a network of ionized gas filaments. Small dwarf irregulars show only isolated polarized spots.

1. Magellanic-Type Galaxies

Rapidly rotating disk galaxies are known to possess large-scale, strong magnetic fields probably generated by the conventional α–Ω turbulent dynamo, driven by Coriolis forces (Ruzmaikin et al. 1988). However, strong magnetic fields are not expected in slowly rotating irregular galaxies. Their slow rotation leads to Coriolis forces much weaker than in normal spirals. Besides, the generation time scale for magnetic fields is uncomfortably long ($\simeq$ 1 Gyr for V_{rot} = 24 km/s/kpc). Moreover, these galaxies rotate rigidly with the angular speed of $\simeq 20 - 25$ km/s/kpc, implying a Reynolds number R_α (Ruzmaikin et al. 1988) at most comparable (or smaller) to its critical value of 1, making the α^2 dynamo unlikely. Fast dynamo concepts like those in Moss, Shukurov & Sokoloff (1999) and Hanasz & Lesch (1998) based on the Parker instability may explain the magnetic fields in those galaxies.

Some signatures of a global magnetic field, resembling some parts of a spiral pattern, were detected in the Large Magellanic Cloud in the pioneering work by Klein et al. (1993). However, because this irregular galaxy still shows a significant degree of differential rotation, the conventional dynamo process could still be at work here, similarly to normal spirals (see Beck, these Proceedings).

Strong, global magnetic fields were found in a dwarf irregular galaxy NGC 4449 (Chyży et al. 2000). The radio polarization study shows two distinct kinds of magnetic vectors: near the galaxy centre, they go radially outwards from star-forming regions; in the galaxy outskirts they run along a polarized ridge, encircling the galaxy. A detailed analysis of the B-vector orientation shows a well-organized coherent spiral pattern resembling the dynamo field in spirals. The strength of the regular and total field reaches 8 μG and 14 μG, respectively. These values are comparable to that found in radio-bright spirals and are unexpected taking into account the very slow and almost chaotic rotation of this galaxy. Faraday rotation measures of NGC 4449 between 6 cm and 3 cm wavelengths show that more than 50% of the galaxy area with detectable polarization has absolute values of RM greater than 50 rad/m^2. The RM differs coherently from zero in domains having a size much greater than the telescope beam. Thus, NGC 4449 contains genuine unidirectional fields. A rapid rotation as in normal spirals is then not necessary to produce galaxy-scale magnetic fields.

Some recent results concerning radio polarization of the edge-on rigidly rotating irregular galaxy NGC 55 are available. Hα emission of this object reveals vertical ionized gas structures: elongated filaments and loops. VLA data at 20 cm analyzed by Soida et al. (in prep.) show polarized spots with apparently vertical magnetic fields associated with these vertical ionized gas filaments. The polarized spots are also accompanied by total power spurs. This detection of regular magnetic fields associated with a network of Hα filaments suggests that magnetic processes can be involved in structuring of the ionized gas. The question whether the vertical, magnetized filaments are related to the global magnetic field structure can be answered only when much more sensitive polarization observations are available.

2. Small Dwarfs

NGC 4449 with its size of 8 kpc is sometimes called a giant dwarf irregular. How do the magnetic fields appear in small dwarf irregulars like IC 10 with a diameter of only 1.5 kpc? The efficiency of production of global magnetic fields is at least proportional to the vertical scale of ionized gas – several times smaller for IC 10 than for NGC 4449. Moreover, the magnetic field escape by diffusion in such a small object is several times faster than in large irregulars. So even to the most modern concepts small irregulars should lack global magnetic fields, being governed by purely gravitation-driven gas dynamics and star-forming processes.

In fact, IC 10 lacks clear signs of large-scale regular fields (Knapik et al., in prep). However, a polarized blob was detected, coincident with HI and CO peaks. Magnetic fields are parallel to a thick dust filament and a Hα feature. They may constitute random fields compressed by infalling gas or by multiple supernova events. Alternatively, they may constitute a Parker-type large-scale instability composed of unidirectional fields. Faraday rotation data, and thus multifrequency observations, are necessary to resolve this problem. About 50% of the galaxy diffuse radio flux at 2.8 cm is still nonthermal, signifying the existence of widespread, mostly random magnetic fields.

Acknowledgments. This work was partly supported by the grant no. PB 4264/P03/99/17 from Polish Committee for Scientific Research (KBN).

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