Magnetic fields and star formation in Magellanic type galaxies

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Why Magellanic galaxies?

Galactic magnetism, while known for over 30 years and observed for various galaxy types (e.g. Beck 2005, Lect. Notes. Phys. 664, 41), is still far from being fully understood. We do not know exact conditions and drivers required for the efficient amplification of large-scale magnetic fields. Especially, low-mass objects and low surface brightness galaxies are the least known. Magellanic type galaxies, are objects intermediate in size and mass between spirals and small dwarf galaxies. Since their global rotation is slower than in typical spirals, their generation of large-scale magnetic fields seems to be problematic. However, this effect could have been compensated by a shorter timescale for complete ordering of the regular field expected for smaller galaxies (Arshakian et al. 2009, A&A 494, 667).

Here we present radio and magnetic properties of Magellanic type galaxies recently observed at 4.85 and 8.35 GHz with the Effelsberg 100-m telescope.

Our radio data

We selected six Magellanic type galaxies from the northern-sky galaxies to manifest large-scale ($> 2'$) radio emission visible in the NVSS radio survey. Our objects (Fig. 1) are in different stages of gravitational interaction: from disturbed (NGC 3239, NGC 4027), through weakly interacting or belonging to groups of galaxies (NGC 4618 and NGC 2976, respectively), to galaxies without any apparent morphological distortions (NGC 5204, UGC 11861). Within each pair, galaxies differ by at least two times in linear size and span a wide range of mass and rotational velocity.

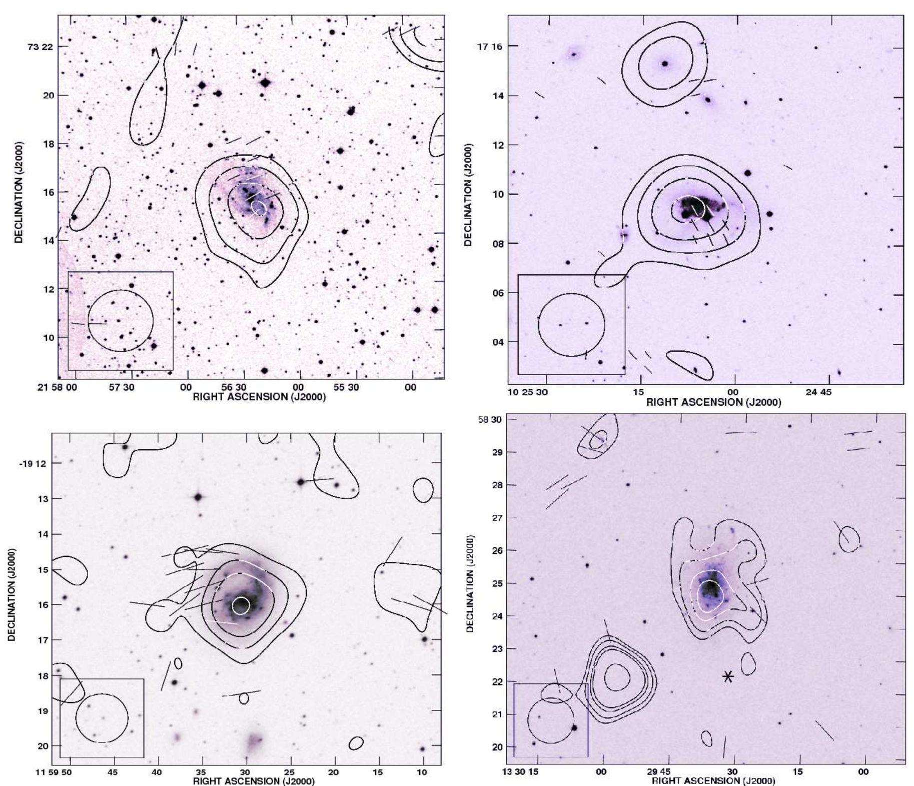


Fig. 1. The maps of radio intensity of four out of six our galaxies with apparent magnetic field B-vectors of polarized emission overlaid onto optical (DSS) images.

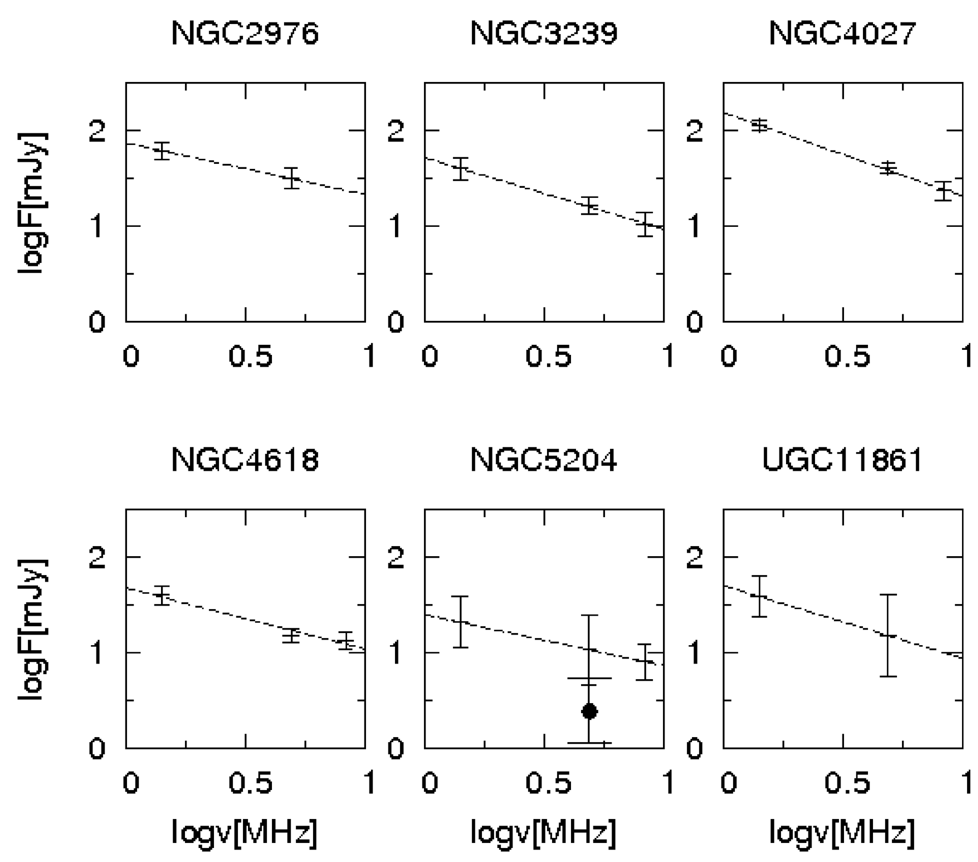


Fig. 2. Radio spectral indexes from our measurements at 4.85 and 8.35 GHz and from NVSS at 1.4 GHz.

A crude estimation of the global radio spectra of our galaxies gives values of the spectral index in the range of 0.53-0.85. These values are **closer to grand-design spirals than to low-mass dwarfs** and suggest the dominance of the synchrotron component in their radio emission. Different methods of estimation of the galactic star formation rate give separation of thermal and nonthermal emission and indeed show small galactic thermal fractions of about 0.2 at 4.85 GHz. (whereas e.g. for dwarfs IC 10 and NGC 6822 thermal fractions are about 0.5; Chyży et al. 2003, A&A 405, 513).

Global trends

Separation of nonthermal component allowed us to determine equipartition magnetic fields strengths for our Magellanic type galaxies. The galactic total field strength is within $6 - 10\,\mu$G and the ordered field within $1 - 2\,\mu$G. They are both smaller than in typical spiral galaxies and larger than in dwarfs (Chyży et al. 2011, A&A 529, 94). Faraday rotation data are still needed to reveal regular (unidirectional) fields in this objects.

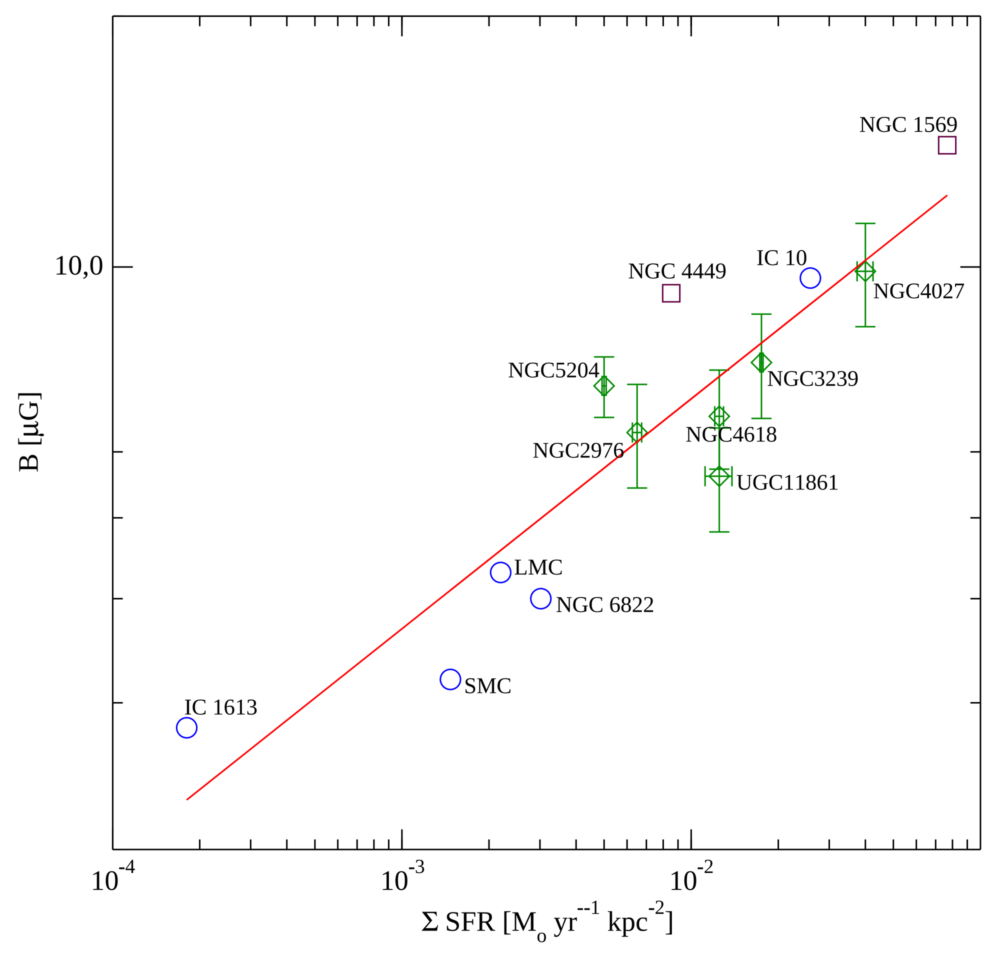
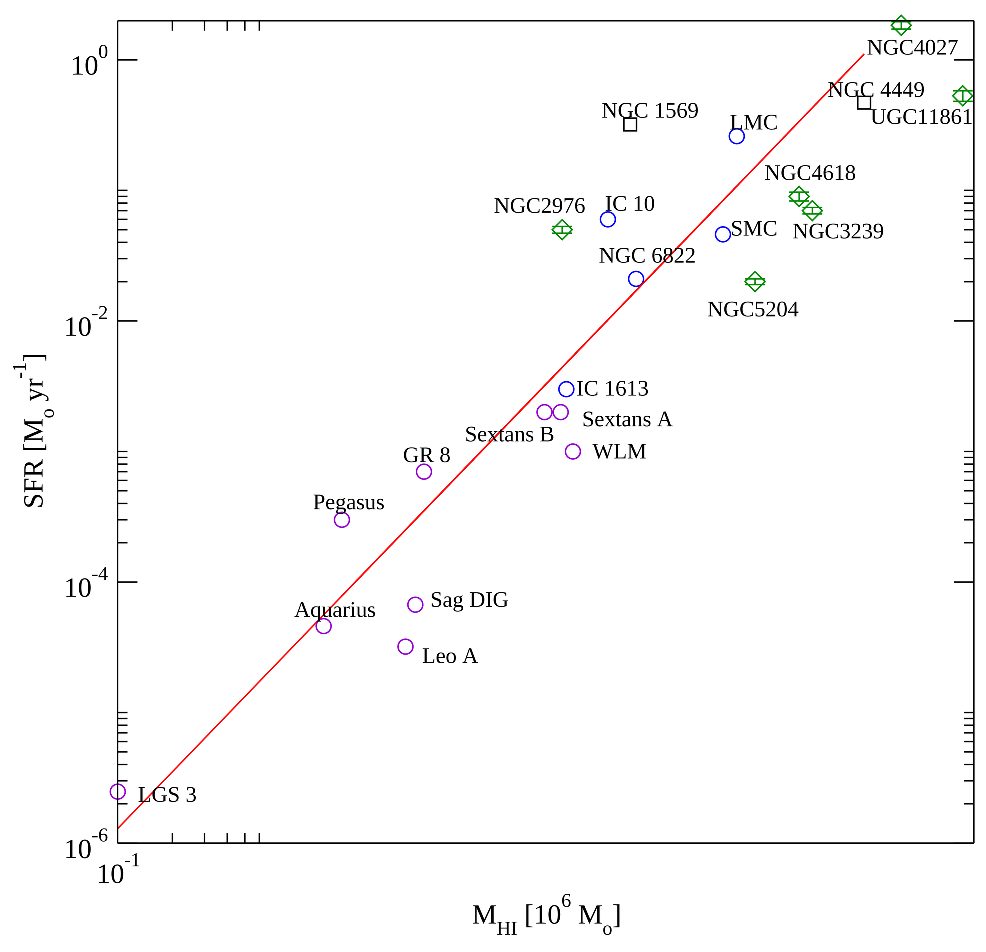


Fig. 3. The total field strength against the surface density of the star formation rate ΣSFR. The solid line presents the power-law fit.

Our Magellanic type galaxies have the total field strength and the surface density of the star formation rate ΣSFR in between the radio weakest dwarf galaxies and the starburst dwarf NGC 1569 observed before (Fig. 3, Chyży et al. 2011). For all these 13 objects **the strength of the total (mostly turbulent) field is well regulated by the density of the star formation rate** and shows a power-law relation with the exponent of 0.28 ± 0.04. This relation is statistically highly significant with correlation coefficient of 92%. It confirms a similar trend found for smaller sample of Local Group dwarfs with the power-law exponent of 0.30 ± 0.04 (Chyży et al. 2011).



Fog. 4. Correlation of the global star formation rate and HI mass of dwarf and Magellanic type galaxies.

There is also a weak hint that the magnetic field strength is correlated with the stage of galaxy interaction. This confirms the findings of a larger sample of interacting galaxies (Drzazga et al. 2011, A&A in press).

The HI mass and *global* SFR of our Magellanic type galaxies are strongly nonlinearly related with a power-law slope of 1.32 (Fig. 4). However, we do not observe a statistically significant influence of the galactic HI mass on the mean magnetic field strength.

We also constructed a radio-far infrared (FIR) correlation diagram for our galaxies (Fig. 5) and compared them with bright spirals (Gioia at al. 1982, A&A 116, 164), dwarfs (Chyży et al. 2011), and interacting objects (Drzazga et al. 2011). We used the surface brightness radio emission at 4.85 GHz and the infrared surface brightness emission at 60 μm (Moshir at al. 1990, IRAS catalogue).

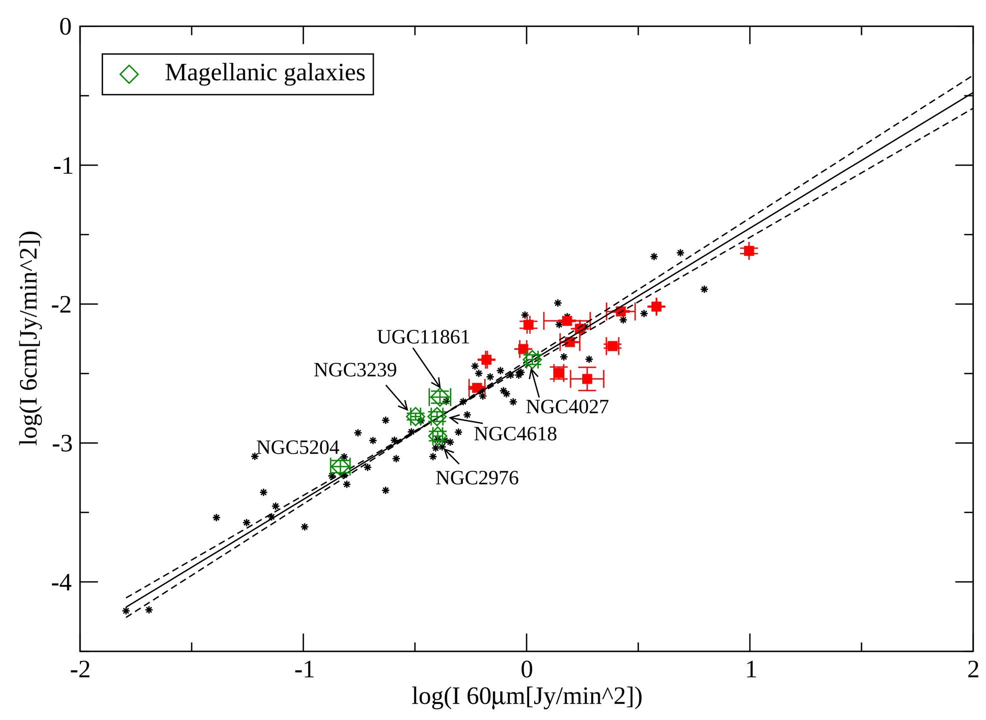


Fig. 5. The radio-FIR correlation diagram for our Magellanic type galaxies, interacting objects (red squares), and bright spiral galaxies (asterisks). The surface brightness at 4.85 GHz and at 60μm (Jy/□′) are used. The solid line is an orthogonal fit to normal galaxies, and dashed lines represent simple X vs. Y and Y vs. X regressions. Error bars for interacting galaxies are marked.

Magellanic type galaxies fit very well the radio-FIR relation constructed for bright spiral galaxies and interacting objects (represented by the power-law with a slope of 0.91 ± 0.08 and a correlation of +0.91, Drzazga et al. 2011). We do not observe any deficiency in radio emission or less efficient CR confinement due to weak magnetic fields in Magellanic type objects. Hence, low-mass stellar systems in our local neighbourhood reveal similar physical conditions for star formation, magnetic field, and cosmic-ray generation processes as for the massive spirals. A similar radio-FIR relation was also found for young, high-redshift galaxies (Seymour et al. 2008, MNRAS 386, 1695).

Conclusions

For Magellanic type galaxies radio thermal fractions are typically at least 20% at 4.85 GHz and correspond rather to large spiral galaxies than to the dwarf galaxies. Total and ordered magnetic fields are weaker than in large spirals. With new radio instrumentation e.g. the EVLA and LOFAR the Faraday rotation data could be obtained and determine if the ordered fields are of the large-scale dynamo origin or if they are anisotropic random fields from stretching of compression processes.

Magellanic type galaxies fit well the trends determined for dwarf and irregular galaxies (Chyży et al. 2011) and shows that the production of the turbulent magnetic field is well regulated by the surface density of the SFR. Surprisingly, similar trends of field production are also determined locally, within single galaxies (Chyży et al. 2008, A&A 482, 755, Krause et al. 2009, RMxAC 36, 25).

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