STATISTICS ON THE SYMMETRIC MAGNETIC FIELDS IN SPIRAL GALAXIES

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Abstract. There is an ongoing search for the agent(s) capable of triggering, catalysing, or indicating the shape of the global magnetism in a spiral galaxy, e.g., the azimuthal magnetic modes \( m_{\text{azim}} = 0 \) (axisymmetric) or \( m_{\text{azim}} = 1 \) (bisymmetric). The recent availability of newer, updated, higher quality data on galactic magnetism in the last two years makes it possible to consider anew the earlier, preliminary correlations or results on agents (triggers, catalysts, or indicators) of the magnetic field shapes.

This study confirms two possible correlations: between magnetic field shape \( m_{\text{azim}} \) (0, or 1) versus neutral HI gas mass \( (\text{high } 7 \times 10^9 M_\odot \text{, or low } 1 \times 10^9 M_\odot) \), and between \( m_{\text{azim}} \) (0, or 1) versus neutral HI gas distortion or archness VA (low 1 to 2, or high 3 to 4).

These confirmations are all the more astounding, because the best theories to date are based on turbulent dynamos which ignore the HI gas completely (current dynamo models rely on ionised HI gas).

1. Introduction

All turbulent-dynamo theories to date predict the dominance of an axisymmetric \( (m_{\text{azim}} = 0) \) magnetic field shape in spiral galaxies. Yet Faraday-rotated linear-polarization observations at radio wavelengths show that some spiral galaxies have the \( m_{\text{azim}} = 0 \) field shape, while some others show the \( m_{\text{azim}} = 1 \) (bisymmetric) field shape. It is thus of interest to find more about this apparent discrepancy between theory and observations. In this respect, it is important to find which of the observed physical parameter(s) of a spiral galaxy can be used to predict with greatest success the magnetic field shape \( m_{\text{azim}} = 0 \) or 1.

Statistical studies made earlier have encompassed over 21 observational parameters of spiral galaxies (e.g., Vallée, 1986), and many other parameters of interest to theories of galactic dynamos (e.g., Vallée, 1990).

The aims of the present study are to update the statistical search for the agents (triggers, catalysts, or indicators) of global magnetic modes or shapes in spiral galaxies, and to use the best correlations found in order to make a prediction of the global magnetism.

Section 2 assembles the recent published data on global magnetism in spiral galaxies, and Section 3 presents the result of the updated statistical study making use of these recent magnetic data. Section 4 draws together some interesting conclusions and shows a prediction for the Large Magellanic Cloud. All distances are from Tully (1988), with a Hubble constant of \( 75 \text{ km s}^{-1} \text{ Mpc}^{-1} \) and with the necessary velocity corrections.
2. Recent Published Magnetic Data

In the last statistical study (e.g., Vallée, 1990), the magnetic data collated from the published literature as of March 1990 showed that 6 spiral galaxies were known to have a definite magnetism (3 had $m_{azim} = 0$ and 3 had $m_{azim} = 1$) while 6 other spiral galaxies had a probable best estimate for their magnetism (0 had $m_{azim} = 0$ and 6 had $m_{azim} = 1$).

The more recent magnetic data collated as of July 1992 show that substantial corrections have been made in the literature, now showing that 9 spiral galaxies have a definite magnetism (5 have $m_{azim} = 0$ and 4 have $m_{azim} = 1$) while 3 other spiral galaxies have a probable best estimate for their magnetism (3 have $m_{azim} = 0$ and 0 has $m_{azim} = 1$).

Table I summarizes the details of the spiral galaxies with a known or probable magnetism, along with their references. The newer data on $m_{azim}$ are identified with the superscripted letter ($a$). Qualifying statements on the quality of the $m_{azim}$ data are given as footnotes.

3. Statistical Results

New figures and statistical results have been obtained below for various known physical parameters in spiral galaxies, which are potential triggers, catalysts or indicators of the different magnetic field modes or shapes.

A possible correlation between the $\text{H I}$ gas mass and the magnetic field shape has first been proposed by Vallée (1986, 1990, 1992a). Figure 1 shows the possibility of using the $\text{H I}$ gas mass as a trigger or catalyst or indicator of the global magnetic field configuration. A clear separation is seen near $3.5 \times 10^9 M_\odot$ of $\text{H I}$ gas in a spiral galaxy, with more $\text{H I}$ gas being associated with $m_{azim} = 0$ galaxies, and with less $\text{H I}$ gas associated with $m_{azim} = 1$ galaxies.

For $m_{azim} = 0$ galaxies the average $\text{H I}$ gas mass in units of $10^9 M_\odot$ is $a = 7.3$ with $\sigma_a = 1.1$ (s.d. of mean), while for $m_{azim} = 1$ galaxies the average is $b = 1.8$ with $\sigma_b = 0.5$ (s.d. of mean). The difference $c = a - b$ is 5.5 with $\sigma_c = (\sigma_a^2 + \sigma_b^2)^{0.5}$ is 1.2, giving a ratio $c/\sigma_c = 4.5$. This ratio is very statistically significant ($<0.1\%$) in a Student's distribution around $c = 0$ for 10 deg of freedom, and there is no overlap of the two groups of galaxies in Figure 1.

A possible correlation between the distortion or archness of the $\text{H I}$ gas disk and the magnetic field shape was proposed by Vallée (1992b). Figure 2 shows the possibility of using the distortion of the $\text{H I}$ gas disk as a trigger or indicator of the global magnetic field configuration.

The $\text{H I}$ gas distortion parameter $VA$ (‘visual archness’) has been defined elsewhere as follows:

$VA = 1$ when the $\text{H I}$ gas is spread roughly circularly in the disk plane with very little or no $\text{H I}$ gas twisting;

$VA = 2$ when some moderate $\text{H I}$ gas twisting is apparent as evidenced by some minor tidal $\text{H I}$-gas bumps or bridges or rings;