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ORIGINAL ARTICLE

Some aspects of rotational and magnetic energies for a hierarchy of celestial objects

C. Sivaram · Kenath Arun

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Abstract Celestial objects, from earth like planets to clusters of galaxies, possess angular momentum and magnetic fields. Here we compare the rotational and magnetic energies of a whole range of these celestial objects together with their gravitational self energies and find a number of interesting relationships. The celestial objects, due to their magnetic fields, also posses magnetic moments. The ratio of magnetic moments of these objects with the nuclear magnetic moments also exhibits interesting trends. We also compare their gyromagnetic ratio which appears to fall in a very narrow range for the entire hierarchy of objects. Here we try to understand the physical aspects implied by these observations and the origin of these properties in such a wide range of celestial objects, spanning some twenty orders in mass, magnetic field and other parameters.

Keywords Magnetic field · Rotation · Gyromagnetic ratio

Celestial objects over the entire range of mass and size scales possess intrinsic properties such as rotation (through their angular momentum) and magnetic fields. In case of many of these objects, such as galaxies, the origin of neither is well understood (Trimble 1984). By comparing the rotational and magnetic energies of a whole range of these celestial objects together with their gravitational self energies we find a number of interesting relationships (Sivaram 1984; de Sabbata and Sivaram 1988).

C. Sivaram
Indian Institute of Astrophysics, Bangalore, 560 034, India
e-mail: sivaram@iiap.res.in

K. Arun (✉)
Christ Junior College, Bangalore, 560 029, India
e-mail: kenath.arun@cjc.christcollege.edu

The gravitational self energy associated with an object of mass M and radius R is given by:

$$E_{grav} = \frac{GM^2}{R} \tag{1}$$

The magnetic field energy is given by:

$$E_{mag} = B^2 R^3 \tag{2}$$

where B is the average magnetic field.

The rotational energy is given by:

$$E_{rot} = \frac{1}{2} M \Omega^2 R^2 \tag{3}$$

where $\Omega = \frac{2\pi}{P}$; P being the period of rotation.

For example, in the case of earth, with $M = 6 \times 10^{27}$ g, $R = 6 \times 10^8$ cm, $P \approx 24$ h and $B \sim 0.1$ G, we have the following:

$$E_{grav} = 4 \times 10^{39}\ \text{ergs},\ \ E_{mag} = 2 \times 10^{24}\ \text{ergs}, \\ E_{rot} = 6 \times 10^{36}\ \text{ergs} \tag{4}$$

The ratio of the rotational and magnetic energies to the gravitational energy is therefore given as:

$$\frac{E_{mag}}{E_{grav}} \approx 3 \times 10^{-13} \quad \text{and} \quad \frac{E_{rot}}{E_{grav}} \approx 10^{-3} \tag{5}$$

These ratios for a hierarchy of celestial objects are tabulated below (for typical value of the parameter) (Table 1).

Some comments are in order: We see that these ratios are comparable for magnetars and galaxies, even though the rotation and magnetic fields associated with pulsars are much higher than those associated with galaxies (Brosche 1980; de Sabbata and Gasperini 1983).