THE GALAXY MAGNETIC FIELD

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The origin and dynamics of magnetic fields depend crucially on the dynamics of a gas in the Galaxy. In turn the magnetic field is needed to isotropize the cosmic rays (the influence on chemistry) and is of importance for the formation of stars (local dynamics). Thus the appearance of this topic at the Colloquium is justified.

1. The observational background

The galactic magnetic field is rather tangled. However the recent investigations (see Verschuur 1974, Heilis 1976, Spoelstra 1976 for review) convincingly proved the existence of the largescale (a few kpc) component. Its strength and direction can be obtained simply due to rotation measures of pulsars (Manchester 1974, Ruzmaikin and Sokoloff 1977)

$$B = 2.1 \pm 0.5\ \mu G$$
$$b \simeq 0^{o}\ ,\ \ell = 99^{o} \pm 12^{o} \qquad (1)$$

The comparison of results obtained with a help of RM of pulsars ($n_e B$) and RM of extragalactic sources ($n_e Bh$) enable us to obtain $h \doteq 400$ pc - the half-width of the galactic electronic disc where $n_e = 0.03$ sm^{-3} is the electron density.

The observations show that side by side with the largescale galactic magnetic field more stronger irregular fields are presented. From the analysis of the polarisation of continuous radio radiation it follows (Spoelstra and Brouw 1976) that $1 < \delta B/B < 3$. Using the simplest form (exp) of a correlation function for the irregular value of $n_e B$ which is known to us from the observations of RM of pulsars, we obtained (Ruzmaikin and Sokoloff 1977) the characteristic scale of this field.

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$$L \simeq 100 \text{ pc} \tag{2}$$

There are two main factors disturbing the magnetic field : 1) spurs (loops), now we know 7, almost all of them are situated in the Northern hemisphere and 2) the galaxy turbulence. It is also noted that the field is more regular in the Southern hemisphere.

2. The galaxy dynamo

The main component of the largescale magnetic field is the azimuth one. It can be generated from the initial field by stretching with the differential rotation. The maximal efficiency (amplification factor) is

$$\begin{gathered} B_\phi / B_o \simeq (\omega t)\max = 250 \\ \omega = \omega_\odot = 25 \text{ km/s kpc}, \; t = 10^{10} \text{ y}. \end{gathered} \tag{3}$$

It follows that only stretching is not able to generate the observed field from an admissible seed field. We know one possibility to obtain large seed fields by their rejection from stars (Bisnovatyi et al. 1971) but nobody knows how a regular field can be formed in this case. It is clear that we need a rapid (exponential) amplification. Such amplification can be achieved by a dynamo action. The galaxy dynamo developed by Parker (1971), Vainstein and Ruzmaikin (1971) and Stix (1975) contains two simultaneously acting mechanisms : 1) the stretching of azimuth field from the meridian one with the help of the differential rotation $\omega(r)$ (Elsaser, 1950) ; 2) the generation of meridian components from an azimuth one by a turbulence having a definite helicity (Steenbeck et al. 1966). The field grows exponential. The crude estimation gives

$$\begin{gathered} B = B_o \, e^{\gamma t} \\ \gamma^{-1} \simeq \omega^{-1} \cdot h/L \simeq 10^8 \text{ y}. \end{gathered} \tag{4}$$

3. The role of dynamics and evolution

In conclusion I would like to call your attention to those problems of the galaxy dynamics which are essential for the magnetic fields :
a) How many revolutions had the Galaxy made? In other words, what is the time dependence of the galaxy angular velocity? Now in the Sun vicinity $\omega = 25$ km/s kpc. At the initial stage Einasto (1970) gives $\omega = 1.5$ km/s kpc. Such small value is not sufficient for the effective action of the galaxy dynamo.
b) We have no good representation of the galaxy turbulence and can only use averaged parameters.

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$$v = 10 \text{ km/s} \quad \text{mean square velocity}$$
$$\tau = L/v = 10^7 \text{ y. correlation time} \tag{5}$$

In addition, if the galaxy turbulence generating the magnetic field is supported by supernova, expanding HII zones around stars and (or) cosmic rays we must understand how stars were formed and cosmic rays were retained without general galactic magnetic field. One suggestion comes from the paper of Bisnovatyi et al. (1972) where star formation and a local protostar magnetic dynamo take place simultaneously. Possibly a protogalactic turbulence was a good source for the generation of magnetic fields (α^2 dynamo).

c) The simplest dynamo is homogenous. The real Galaxy has spiral arms. We know that the spiral shocks result in the field lines alignment along the arms and some amplification of the field (Roberts 1969, Ruzmaikin 1976). However nobody knows which was first : spiral arms or the large-scale magnetic field?

d)Seed fields. The Harrison's (1970) suggestion refers to the earliest prerecombination stage of the Universe evolution. A good mechanism of generation of seed magnetic fields can be found at the time of galaxy formation (Mishustin and Ruzmaikin, 1971) and possibly a part of seed fields came from star's ejections (Bisnovatyi et al. 1972).

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