The Global Structure of Magnetic Fields in Our Galaxy

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Abstract The global structure of magnetic fields in our Galaxy is hard to know completely. However, we have obtained some knowledge from rotation measures of pulsars and extragalactic radio sources. Pulsars provide unique probes for the *large-scale* interstellar magnetic field in the Galactic disk. The magnetic field in the nearby half of the Galactic disk are found to be *coherent in directions* over a linear scale of $\sim$ 10 kpc between the Carina-Sagittarius and Crux-Scutum arms from $l \sim 45°$ to $l \sim 305°$. The coherent spiral structures and field direction reversals, including the newly determined counterclockwise field near the Norma arm, are consistent with the bi-symmetric spiral model for the disk field. In the Galactic halo and Galactic center, the antisymmetric rotation measure sky indicates the dipole field in the Galactic center and the azimuthal field with reversed field directions below and above the Galactic plane, which suggests that the A0 dynamo is operating in our Galaxy.

The Faraday rotation of pulsars and extragalactic radio sources are in fact the best probes of the Galactic magnetic field on the large scale!

The rotation measure (RM) of a source is proportional to the integration along its line of sight of the product of the radial magnetic field and electron density, $RM = \int_{\rm obs}^{\rm obj} B_{||} n_e dl$. Marvellously our Galaxy is the visually largest edge-on Galaxy covering all the sky. There are so many sources, either the extragalactic polarized radio sources or pulsars in our Galaxy, in all directions that contain information of the field $B_{||}$ in all parts of the Galaxy. This gives us a unique chance to study the detailed structure of the magnetic field in the Galactic halo and disk, with a principle similar to the CT technology used medically. I emphasize that this is not possible for any other galaxies.

The antisymmetric RM distribution of extragalactic radio sources as well as pulsars, covering all the inner Galaxy, reflects the azimuthal field with reversed directions above and below the Galactic plane (Fig.1), entirely consistent with the field configuration of an A0 dynamo, so that the field origin probably lies in a dynamo in the halo (Han et al. 1997).

The polar field in the Galactic center strongly supports this conclusion.

Han et al. (1997) first noticed that the RM distribution of high latitude pulsars is dominated by the halo azimuthal field (Fig.1). Afterwards, any analysis of pulsar RMs for the disk field was confined to the pulsars at lower Galactic latitudes. Han et al. (1999) then observed a good number of pulsar RMs and divided all known pulsar RMs into those lying within higher and lower latitude ranges for studies of the halo and disk field, respectively. Up to now, among about 1385 known pulsars, 523 pulsars have measured values of RM and 365 of them lie at lower latitudes ($|b| < 8°$).

At lower latitudes, the pulsar RMs can be used to diagnosis the large-scale field structure in Galactic disk. What we measured is the integration of B-fields along the line of sight. One normally assumes that the azimuthal field component B_ϕ is greater than vertical and radial components B_z or B_r. This is reasonable and has been justified (Han & Qiao 1994, Han et al. 1999). In most lines of sights, this integration reflects the major components B_ϕ of the large-scale fields. For distant region, one can use the gradient of the average or general

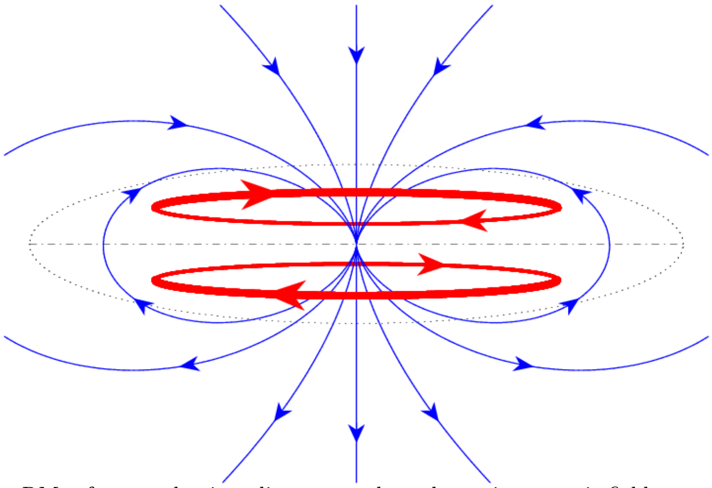

Fig. 1 The RMs of extragalactic radio sources show the antisymmetric field structure of the Galactic halo, which is the same as that of an A0 dynamo (see Han et al. 1997 for details). Filled symbols denote positive RMs and open symbols negative RMs. The distribution of pulsar RMs is very similar but with generally smaller RM values.

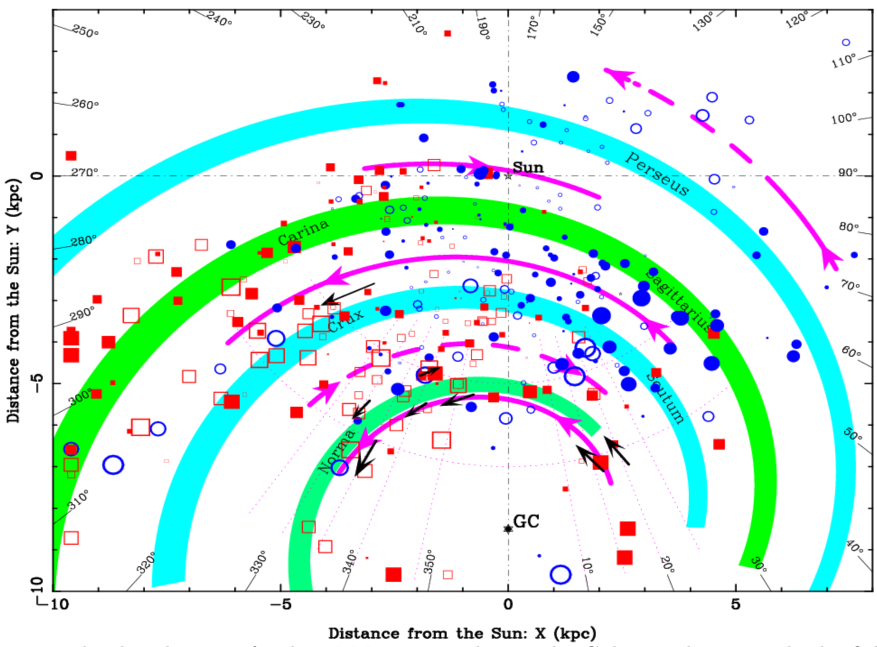

Fig. 2 The distribution of pulsar RMs projected onto the Galactic plane reveals the field structure in the Galactic disk, which has direction reversals from arm to arm (after Han et al. 2002). The square symbols are newly determined RMs from Parkes observations, and filled symbols indicate positive RMs. The well-determined field structure is illustrated by thick lines and arrows. The thick dashed lines indicate the controversial field structure which needs further data for confirmation. The newly determined field directions near the Norma arm and the Crux arm are indicated by thin arrows.

tendency of RM variations versus pulsar DMs to trace the large-scale field. The scatter of the data about this general tendency is probably mostly due to the effect of smaller scale interstellar structure, such as the HII regions.

Using all available pulsar RM data, together with our more than 200 new measurements of pulsars discovered in Parkes multibeam pulsar survey (Manchester et al. 2001), we recently report the detection of counterclockwise magnetic fields near the Norma arm, which are *coherent in field direction* over more than 5 kpc along the arm (Han et al. 2002). Our present understanding of the structure of the *large-scale* magnetic field in the Galactic disk is summarised in Fig.2, which is almost all revealed by pulsar RMs.

We conclude that based on all available information, the global field structure is best described by two distinct components: a bi-symmetric spiral field in the disk with reversed direction from arm to arm, and an azimuthal field in the halo with reversed directions below and above the Galactic plane. The latter, together with a probably dipole field in the Galactic center, corresponds to an A0 dynamo field configuration. Pulsars are the most important probes for detection of the *large-scale* interstellar fields.

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