Interstellar magnetic fields: from Galactic scales to the edge of the heliosphere

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Abstract.
I review the observational properties of interstellar magnetic fields in our Galaxy, starting from the large Galactic scales and gradually zooming in toward the heliosphere. It emerges that the large-scale magnetic field is predominantly azimuthal in the Galactic disk, but that this global field orientation is severely perturbed in the small-scale surroundings of the heliosphere.

1. Introduction
It was Alfvén (1937) who opened the era of interstellar magnetic fields (ISMFs) when he correctly pointed out that a magnetic field threading interstellar space could naturally explain the confinement of cosmic rays in our Galaxy. Pushing this notion one step further, Fermi (1949) wrote in a seminal paper on the origin of cosmic radiation [1] that “cosmic rays are originated and accelerated primarily in the interstellar space of the Galaxy by collisions against moving magnetic fields.” He went on to add, with surprising accuracy for the time, that “the magnetic field in the dilute matter is of the order of magnitude of $5 \times 10^{-6}$ Gauss, while its intensity is probably greater in the heavier clouds.”

At about the same time, two major advances occurred in observational astronomy. First, Hall (1949) and Hiltner (1949a,b) independently discovered that the optical light from nearby stars is linearly polarized [2–4] – a phenomenon that Davis & Greenstein (1951) attributed to dichroic extinction by elongated dust grains which are aligned by a coherent ISMF [5]. Second, Kiepenheuer (1950) realized that the general radio continuum emission from our Galaxy is synchrotron emission [6] – a process that implies the presence of relativistic electrons spiraling about magnetic field lines.

Thus, more than 60 years ago, two pioneering theoretical ideas as well as two ground-breaking observational discoveries pointed to the existence of ISMFs in our Galaxy. Since then, a multitude of observations have provided convincing evidence that strong ISMFs do indeed pervade our Galaxy. It has also become clear, from a theoretical point of view, that these magnetic fields play a crucial role in the interstellar medium (ISM): not only are they responsible for the acceleration and confinement of cosmic rays, but they also have a profound impact on the spatial distribution, dynamics, and energetics of the interstellar matter, and they influence – possibly even regulate – the vital process of star formation.

In this paper, I review the main observational methods employed to detect and measure ISMFs, and I summarize what each of these methods has taught us about their typical strength and direction, their overall configuration, and their spatial distribution. In Section 2, I consider
the large-scale ISM, and in Section 3, I focus on an increasingly close vicinity of the heliosphere. Throughout this paper, \( \vec{B} \) denotes the magnetic field vector, \( \vec{B}_\perp \) the projection of \( \vec{B} \) onto the plane of the sky, and \( B_{\parallel} \) the component of \( \vec{B} \) along the line of sight.

2. Large-scale interstellar medium

2.1. Polarization of starlight and dust thermal emission

Interstellar dust grains generally have irregular, elongated shapes, which, in a directional stellar radiation field, cause them to feel radiative torques. These torques have two important effects [see 7–9]. First, they spin up the grains to suprathermal rotation about their short axes. Second, they gradually bring the grain spin axes into alignment with the local ISMF. As a result, dust grains tend to line up with their long axes perpendicular to the local ISMF.

The magnetically aligned dust grains collectively act like a polarizing filter for starlight. Since they preferentially block the starlight component with polarization vector parallel to their long axes in the sky, the starlight that passes through is linearly polarized in the direction parallel to the sky-projected ISMF, \( \vec{B}_\perp \). In consequence, measuring the direction of starlight polarization directly reveals the orientation of \( \vec{B}_\perp \). This technique applied to a large number of stars indicates that the ISMF in the Galactic disk within a few kpc of the Sun is horizontal, i.e., parallel to the Galactic plane, and nearly azimuthal [10], making a small angle \( \simeq -7^\circ \) to the azimuthal direction [11]. See Figure 1.

![Figure 1](image)

**Figure 1.** All-sky map in Galactic coordinates (with the Galactic center in the middle, longitude increasing to the left, and latitude increasing upward) of the polarization vectors of 8662 stars from the compilation by [12]. The polarization vectors trace out magnetic field lines in the plane of the sky.

In addition to polarizing starlight, the magnetically aligned dust grains also emit infrared/submm thermal radiation in a dichroic manner. Since the emissivity is strongest for the radiation component with polarization vector parallel to the grains’ long axes in the sky [13], dust thermal emission is linearly polarized in the direction perpendicular to \( \vec{B}_\perp \). The 353 GHz observations of the *Archeops* balloon experiment [14] and, much more recently, the 353 GHz all-sky map from the *Planck* satellite [15] nicely bear out the ISMF orientation inferred from starlight polarimetry. See Figure 2.
2.2. Synchrotron emission

A global method to map out the ISMF in the general ISM rests on the observed Galactic synchrotron emission.

Synchrotron emission is produced by relativistic electrons gyrating about magnetic field lines. The synchrotron emissivity at frequency $\nu$ due to a power-law energy spectrum of relativistic electrons, $f(E) = K e E^{-\gamma}$, is given by

$$E_{\nu} = \mathcal{F}(\gamma) K e B_{\perp}^{\frac{\gamma+1}{2}} \nu^{-\frac{\gamma+1}{2}}$$

(1)

where $\mathcal{F}(\gamma)$ is a known function of the electron spectral index and $B_{\perp}$ is the strength of the sky-projected magnetic field.

The spatial distribution of the Galactic synchrotron emissivity was modeled by [16], based on the all-sky 408 MHz radio continuum map of [17]. Several authors then used this synchrotron distribution model to derive the ISMF distribution in our Galaxy. To do so, the vast majority of them resorted to the standard double assumption that (1) relativistic electrons represent a fixed fraction (generally taken to be 1/100) of the cosmic-ray population and (2) cosmic rays and magnetic fields are in (energy or pressure) equipartition.\footnote{The argument usually put forward to justify the equipartition assumption is that energy equipartition corresponds almost exactly to the condition that the total (cosmic-ray + magnetic) energy is minimum [18].} Relying on the cosmic-ray ion and electron spectra directly measured by the Voyager spacecraft, [19] verified that, near the Sun, cosmic rays and magnetic fields are indeed close to (pressure) equipartition, with a total magnetic field strength $B \simeq 5 \mu$G. She also found that the total field strength has a radial scale length $\simeq 12$ kpc and a vertical scale height near the horizontal position of the Sun $\simeq 4.5$ kpc. This scale height is significantly greater than that of the Warm Ionized Medium ($H_{\text{WIM}} \simeq 1.8$ kpc [20]), which in turn is significantly greater than the scale heights of the neutral phases [19], such that the plasma $\beta$ changes from $\beta \sim 1$ in the Galactic disk to $\beta \ll 1$ in the Galactic halo.

Because synchrotron emission is linearly polarized perpendicular to $\vec{B}_{\perp}$, information can also be gained on the orientation of $\vec{B}_{\perp}$. Evidently, if the observing frequency is too low to avoid Faraday rotation (see Section 2.3), the received polarized signal must somehow be “de-rotated” in order to recover the true field orientation. In addition, if the ISMF has a randomly fluctuating component, the contributions from isotropic magnetic fluctuations to the polarized
emission cancel out, leaving only the contribution from the ordered (i.e., regular + anisotropic random) ISMF, $\vec{B}_{\text{ord}}$. Thus, while the total synchrotron intensity yields the strength of the total sky-projected ISMF, the polarized synchrotron intensity yields the strength and the orientation of the ordered sky-projected ISMF. For illustration, all-sky maps of the total and polarized synchrotron intensities are displayed in Figure 3.

In the large-scale vicinity of the Sun, the ratio of ordered to total ISMF strengths turns out to be $\approx 0.6$ [21]. Together with $B \approx 5 \mu G$, this ratio implies an ordered ISMF strength $B_{\text{ord}} \approx 3 \mu G$. Besides, the radio polarization vectors rotated by $90^\circ$ (plotted in the right panel of Figure 3) are fully consistent with their optical and submm counterparts (plotted in Figures 1 and 2, respectively), thereby confirming that the large-scale ordered ISMF in the Galactic disk is horizontal.

2.3. Faraday rotation

In ionized regions of the ISM, the ISMF can be probed with Faraday rotation measures of Galactic pulsars and extragalactic sources of linearly polarized radio waves.

Faraday rotation of a linearly polarized radio wave occurs when the wave propagates along the magnetic field of an ionized region, as a result of its interaction with the free electrons gyrating about magnetic field lines. The angle by which the direction of polarization rotates is equal to the observing wavelength squared times the so-called rotation measure,

$$RM = C \int_0^L n_e B_\parallel ds,$$

where $C$ is a numerical constant, $n_e$ the free-electron density, $B_\parallel$ the line-of-sight component of the magnetic field, and $L$ the path length from the source to the observer. In practice, the rotation measure of a given radio source can be determined by measuring the direction of polarization of the incoming radiation at at least two different wavelengths.

Rotation measures have now been obtained for about 1 200 Galactic pulsars and 42 000 extragalactic radio point sources (see Figure 4). Used in conjunction either with a model for the spatial distribution of free electrons or, in the case of Galactic pulsars, with their distances and dispersion measures, these numerous rotation measures have made it possible to gather a wealth of information on the strength, direction, and spatial configuration of the ISMF in ionized regions. Here are the key points that have emerged from Faraday rotation studies.
Figure 4. All-sky map in Galactic coordinates (with the Galactic center in the middle) of the rotation measures of \(\approx 42\,000\) extragalactic radio point sources from the NVSS \((\delta > -40^\circ)\) and S-PASS \((\delta < 0^\circ)\) surveys. Positive (negative) rotation measures, which correspond to a magnetic field pointing on average toward (away from) the observer, are plotted in blue (red). Figure credit: Dominic Schnitzeler.

1) The ISMF has a regular component, \(\vec{B}_{\text{reg}}\), and a randomly fluctuating component, \(\vec{B}_{\text{fluct}}\). In the large-scale vicinity of the Sun, \(B_{\text{reg}} \approx 1.5\, \mu G\) and \(B_{\text{fluct}} \approx 5\, \mu G\) [22]. \(B_{\text{reg}}\) increases toward the Galactic center, to \(\approx 3\, \mu G\) at Galactocentric radius \(R = 3\, \text{kpc}\) [23], i.e., with an exponential scale length \(\lesssim 7.2\, \text{kpc}\). Moreover, \(B_{\text{reg}}\) decreases away from the Galactic plane, albeit at a very uncertain rate. For reference, from the rotation measures of extragalactic radio point sources, [24] derived an exponential scale height \(\approx 1.4\, \text{kpc}\); however, repeating their derivation with the WIM parameter values updated by [20] raises this scale height to \(\approx 3.8\, \text{kpc}\), much closer to the scale height deduced from synchrotron data (see Section 2.2).

2) In the Galactic disk, \(\vec{B}_{\text{reg}}\) is nearly horizontal and generally dominated by its azimuthal component. In the large-scale vicinity of the Sun, \(\vec{B}_{\text{reg}}\) runs clockwise at an angle \(\approx -8^\circ\) to the azimuthal direction [25], which is very close to the pitch angle \(\approx -7^\circ\) inferred from starlight polarization (see Section 2.1). \(\vec{B}_{\text{reg}}\) reverses direction at least a couple of times with decreasing Galactocentric radius, but the exact number and radial locations of the field reversals are still highly controversial [23; 25–29]. These field reversals have often been interpreted as evidence that \(\vec{B}_{\text{reg}}\) is bisymmetric (azimuthal wavenumber \(m = 1\)), while an axisymmetric \((m = 0)\) field would be expected from dynamo theory. In reality, [30] showed that neither the axisymmetric nor the bisymmetric picture is consistent with the existing pulsar rotation measures, and they concluded that \(\vec{B}_{\text{reg}}\) must have a more complex pattern.

3) In the Galactic halo, \(\vec{B}_{\text{reg}}\) could have a significant vertical component. Near the horizontal position of the Sun, [31] obtained \((B_{\text{reg}})_z \approx -0.14\, \mu G\) above the Galactic midplane \((z > 0)\) and \((B_{\text{reg}})_z \approx +0.30\, \mu G\) below the midplane \((z < 0)\), whereas [32] obtained \((B_{\text{reg}})_z \approx 0.00\, \mu G\) toward the north Galactic pole and \((B_{\text{reg}})_z \approx +0.31\, \mu G\) toward the south Galactic pole. In contrast to the situation prevailing in the Galactic disk, the horizontal component of \(\vec{B}_{\text{reg}}\) shows no sign of reversal with decreasing Galactocentric radius.

4) \(\vec{B}_{\text{reg}}\) exhibits some symmetry properties with respect to the Galactic midplane. At low latitudes (basically, in the disk), \(\vec{B}_{\text{reg}}\) appears to be roughly symmetric in \(z\) [26; 33], while at high latitudes (in the halo), the rotation-measure sky features a rather striking antisymmetry/symmetry in \(z\) in the inner/outer Galactic quadrants [25; 34; 35], which suggests...
that $\vec{B}_{\text{reg}}$ is roughly antisymmetric in $z$ inside the solar circle [25; 35, but see also [33]]. Finding $\vec{B}_{\text{reg}}$ to be symmetric in the disk and antisymmetric in the inner halo is consistent with the predictions of dynamo theory and with the results of galactic dynamo calculations [e.g., 36–38].

2.4. Zeeman splitting

In neutral (atomic or molecular) regions of the ISM that are sufficiently cold and dense, ISMF strengths can be inferred from Zeeman splitting measurements.

Zeeman splitting of a given atomic or molecular spectral line results from the interaction between the magnetic moment of the valence electrons and an external magnetic field. The amount of Zeeman splitting, $\Delta \nu$, is directly proportional to the magnetic field strength, $B$, so that, in principle, it suffices to measure $\Delta \nu$ in order to obtain $B$ in the region of interest. In practice, however, $\Delta \nu$ is usually too small compared to the line width to be measurable. Under these conditions, one measures instead the Stokes parameter $V$, which is directly proportional to the line-of-sight component of the magnetic field, $B_\parallel$.

A vast body of Zeeman splitting data has now built up, both for the 21 cm line of H\textsubscript{i} (in atomic clouds) and for several centimeter lines of OH and other molecules (in molecular clouds). [39], who conducted a series of Zeeman measurements of the H\textsubscript{i} 21 cm absorption line, found that in atomic clouds $B$ is typically a few $\mu$G, with a median value $\approx 6 \mu$G, and they confirmed earlier findings that $B$ shows no tendency to increase with increasing gas density, $n$ [e.g., 40; 41]. More recently, [42] performed a Bayesian analysis of Zeeman data from H\textsubscript{i}, OH, and CN surveys, on the basis of which they identified two regimes of $B$ as a function of $n$: for $n < 300 \text{ cm}^{-3}$ (atomic clouds), $B$ appears to be independent of $n$, while for $n > 300 \text{ cm}^{-3}$ (molecular clouds), $B$ is randomly distributed between very small values and a maximum value $\propto n^{0.65}$. These results suggest that the ISMF in the diffuse ISM is generally strong enough (compared to turbulence) to inhibit the formation of atomic clouds other than through gas flows along field lines, whereas the ISMF in molecular clouds is often too weak (compared to self-gravity) to cause large departures from isotropic contraction.

3. Zooming in toward the Sun

One of the important conclusions of Section 2 is that the large-scale ISMF in the Galactic disk is nearly horizontal, with a dominating azimuthal component. However, in the presence of small-scale magnetic fluctuations, we do not expect the large-scale ISMF orientation to persist all the way in to the surface of the heliosphere. So the question that naturally comes to mind is how the ISMF orientation changes as one gradually approaches the Sun.

The two tools that can be used to probe the ISMF closer and closer to the Sun are the rotation measures of nearby pulsars and the polarization vectors of nearby stars. Dust thermal emission and synchrotron emission are of little help here, because their measurement in any given direction only provides the total emission produced along the entire line of sight through the Galaxy, with no possibility of separating out the contribution from the local ISM.

3.1. Faraday rotation of nearby pulsars

[43] collected all the available rotation measures, dispersion measures, and distances of pulsars within 2 kpc of the Sun, and he binned the pulsars into three distance ranges. For each distance range, he assumed a uniform ISMF and calculated the magnetic field vector, $\vec{B}$, that yielded the best fit to the pulsar data. The strength and the direction of each best-fit $B$ are listed in Table 1, and the corresponding normalized $\vec{B}$ vector is plotted in Figure 5.

Because of the small number of pulsars, especially in the two closest distance ranges, the results of [43] are actually subject to very large uncertainties. The author did not attempt to compute error bars, but from his Table 2, the uncertainties in the ISMF strength and direction can be roughly estimated at $\sim 1 \mu$G and $\sim 20^\circ$, respectively.
Despite the very large uncertainties, the work of [43] provides clear evidence that the ISMF fluctuates widely as one approaches the Sun and completely loses the nearly azimuthal direction that prevails in the large-scale ISM in to $\sim 500$ pc of the Sun. These wide magnetic fluctuations can most likely be attributed to the presence of nearby discrete structures, such as the Local Bubble and the Loop I superbubble.

Table 1. Strength, $B$, Galactic longitude, $\ell_B$, and Galactic latitude, $b_B$, of the ISMF vector that best fits the pulsar data in three different distance ranges, with the number of pulsars used for the fitting procedure indicated in the second column [43]. The uncertainties in the ISMF strength and direction are estimated at $\sim 1 \mu G$ and $\sim 20^\circ$, respectively (see main text). The last column shows the red arrow used in Figure 5 to represent the best-fit ISMF direction.

| Distance range of pulsars | Number of pulsars | Best-fit ISMF $B \ell_B b_B$ | Arrow in Figure 5 |
|---------------------------|-------------------|-----------------------------|------------------|
| $(0 - 300)$ pc            | 7                 | $1.9 \mu G \ 16^\circ \ 45^\circ$ | $\rightarrow$    |
| $(0 - 500)$ pc            | 18                | $2.7 \mu G \ 6^\circ \ 28^\circ$ | $\rightarrow$    |
| $(0.5 - 2)$ kpc           | 103               | $2.5 \mu G \ 80^\circ \ -10^\circ$ | $\ldots \ldots \ldots$ |

Figure 5. Oblique view of the Galactic disk showing the position of the Sun (yellow dot), the shape of the heliosphere (green comet-like structure), the direction of the interstellar wind against the heliosphere (blue arrow), and the directions of the ISMF vectors that best fit the pulsar data in the three distance ranges listed in Table 1 (red arrows taken from the last column of the table). Figure credit: Philippe Terral.

3.2. Polarization of nearby stars

[44] analyzed the polarization vectors of a group of stars within 40 pc of the Sun and $90^\circ$ of the nose of the heliosphere, and they derived the ISMF orientation that best matched the polarization data. The result is shown in Table 2 and in Figure 6, where it can be compared to the ISMF orientation inferred from the polarization vectors of stars more distant than 500 pc [11]. Let me emphasize that, in contrast to rotation measures, polarization vectors provide no information on the magnetic field strength (except, very indirectly, with the Chandrasekhar-Fermi method). Moreover, since they are actually headless vectors, they only lead to the field orientation (axis without an arrow), not to the field direction (axis with an arrow).
The conclusions here are similar to those reached in Section 3.1, namely, the ISMF orientation in the close vicinity of the Sun departs significantly from that observed in the large-scale ISM beyond ~ 500 pc of the Sun. The former must be associated with discrete features within the Local Bubble – possibly with the G-cloud that lies just outside the Local Cloud in the general direction of the Galactic center [44]. [44] interpreted their derived ISMF orientation, together with the direction of the interstellar flow past the heliosphere, as evidence that the local ISM is an expanding fragment of the S1 shell of the Loop I superbubble.

### Table 2

| Distance range | Best-fit ISMF | Bar in Figure 6 |
|----------------|---------------|-----------------|
| < 40 pc        | $47^\circ \pm 20^\circ$ | $25^\circ \pm 20^\circ$ |   |
| > 500 pc       | $83^\circ \pm 4^\circ$ | $0.4^\circ \pm 0.5^\circ$ |   |

**Figure 6.** Oblique view of the Galactic disk showing the same basic features as in Figure 5, with the orientations of the ISMF axes that best fit the polarization vectors of the two groups of stars defined in Table 2 (red bars taken from the last column of the table). Figure credit: Philippe Terral.

#### 3.3. Just outside the heliosphere

[45] measured the direction of the interstellar neutral hydrogen flow that penetrates the inner heliosphere and found it to be deflected by $\simeq 4^\circ$ relative to the interstellar helium flow. They interpreted this deflection as resulting from a distortion of the heliosphere caused by the surrounding ISMF and used it to constrain the ISMF orientation. They argued that the ISMF must lie in the plane defined by the H and He velocities, i.e., the plane normal to ecliptic coordinates $(\lambda, \beta) = (167^\circ, -30^\circ)$, on the same side of the He velocity as the secondary H velocity but farther away. They also restricted the range of the ISMF ecliptic coordinates to $\lambda_B = 210^\circ - 240^\circ$ and $\beta_B = 30^\circ - 60^\circ$, assuming an angle of $30^\circ - 60^\circ$ between the ISMF and the interstellar bulk velocity. Finally, they noted that the ISMF projected onto the Galactic plane is roughly tangent to the boundary of the Local Cloud in the direction of the G-cloud, as expected if field lines are compressed between both clouds.
A very different approach relies on the Interstellar Boundary Explorer (IBEX), which discovered a circular ribbon of enhanced energetic neutral atom (ENA) emission from the outer heliosphere [46]. The center of the ribbon, toward ecliptic longitude $\lambda = 219.2^\circ \pm 1.3^\circ$ and latitude $\beta = 39.9^\circ \pm 2.3^\circ$ [47], was argued to trace the orientation of the ISMF that shapes the heliosphere [48]. [44] suggested that this field orientation could be representative of the ISMF orientation in the Local Cloud, whose boundary in the considered direction lies only $\sim 0.1$ pc away from the Sun. It is noteworthy that the ISMF orientation from the IBEX ribbon center falls well within the range estimated from the deflection of the interstellar H flow and lies nearly (within $5^\circ$) in the plane defined by the interstellar H and He velocities (see previous paragraph).

The only in-situ measurements of ISMFs were made by Voyager 1, which is now believed to have crossed the heliopause into the very local ISM [49]. Ever since August 25, 2012, when the spacecraft was at 122 AU of the Sun, it has been measuring ISMFs [50]. For the first month after August 25, 2012, the average magnetic field strength was $B = (4.4 \pm 0.1) \mu$G and the average magnetic field direction had azimuthal angle $\lambda_B = 287^\circ \pm 1^\circ$ and elevation angle $\delta_B = 14^\circ \pm 2^\circ$ in RTN coordinates [51]. This field direction is close to the Parker spiral direction, $\lambda_p = 270^\circ$ and $\delta_p = 0^\circ$. Since then, the field strength has been smoothly varying in the range $(3.8 - 5.9) \mu$G, and the field direction has been increasingly deviating from the Parker spiral [50]. The Voyager 1 measurements are consistent with the very local ISMF draping around the heliosphere and being twisted toward the Parker spiral [52].

**Table 3.** Galactic longitude, $\ell_B$, and latitude, $b_B$, of the ISMF axis inferred from the center of the IBEX ribbon [47], and complete Galactic coordinates, $B$, $\ell_B$, $b_B$, of the full ISMF vector measured by Voyager 1 [51]. The last column makes the link with the corresponding red bar or arrow in Figure 7.

| Mission     | Distance | Inferred/measured ISMF | Bar/arrow in Figure 7 |
|-------------|----------|------------------------|-----------------------|
| IBEX        | $\lesssim 0.1$ pc | 35° ± 4° 57° ± 1° | — |
may appear surprisingly high, but it should be kept in mind that the corresponding angular uncertainties along a great circle are reduced by a factor $\cos b$.

4. Summary
Various methods, primarily based on dust polarization, synchrotron emission, Faraday rotation, and Zeeman splitting, converge to show that the ISMF in the Galactic disk has a typical strength of a few $\mu$G (except in molecular clouds, where much stronger fields are observed) and a mean direction that is nearly parallel to the Galactic plane and generally close to azimuthal. In the large-scale surroundings of the Sun, the regular, ordered (regular + anisotropic random), and total field strengths are approximately $B_{\text{reg}} \approx 1.5 \mu$G, $B_{\text{ord}} \approx 3 \mu$G, and $B \approx 5 \mu$G, and the regular field runs clockwise at an angle $\approx -7^\circ$ or $-8^\circ$ to the azimuthal direction. The substantial difference between $B_{\text{reg}}$ and $B$ reflects the presence of important magnetic fluctuations, while the difference between $B_{\text{reg}}$ and $B_{\text{ord}}$ indicates that part of these fluctuations are anisotropic.

We are now starting to gain a better understanding of magnetic fluctuations in the small-scale vicinity of the heliosphere, both with standard probes (rotation measures of nearby pulsars and polarization vectors of nearby stars) and with more indirect observations (deflection of the interstellar H flow entering the heliosphere and IBEX ribbon of enhanced ENA emission). These independent methods appear to yield compatible results, showing that the local ISMF around the heliosphere points in the first octant of the sky in Galactic coordinates and completely deviates from the nearly azimuthal direction of the large-scale regular ISMF. These severe deviations most likely arise from the pushing, lifting, and twisting of field lines that accompany the expansion of the Local Bubble and the Loop I superbubble and, closer to us, the motions of the Local Cloud and the G-cloud inside the Local Bubble.

Acknowledgments
I would like to express my gratitude to my student, Philippe Terral, who kindly accepted to prepare the plots needed for Figures 5–7, and to the referee, Steven Spangler, who provided me with very valuable and constructive comments.

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