The Relation Between Polarization and Extinction in Diffuse Interstellar Medium Fields

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Abstract

The degree of linear polarization as a function of the extinction, P/A_V, also known as polarization efficiency, measures the fraction of dust-grains that are polarizing and the slope of its envelope differs for different grain/magnetic field properties. *Planck Collaboration* found a maximum upper envelopes of 13 $\%/mag$, however, different observations also have showed that the upper limit is not very well constrained yet. We use new polarimetry data of diffuse interstellar medium from the *IPS survey* (see Versteeg et al. Poster) to constrain this upper limit and to study its variation along the sky. Preliminary results show that higher values of the upper envelope are possible in some regions of the sky, especially at high latitudes ($b \geq 10°$) and where the Galactic magnetic field lines are approximately perpendicular to the line-of-sights.

Introduction

One of the first empirical estimates of the polarization efficiency upper envelope was proposed by *Serkowski*[9] as **P/E(B-V)** $\leq$ **9** $\%/mag$. Where $\mathbf{A_v/E(B\text{-}V) = 3.1}$. Recently, the *Planck Collaboration*[8] found high polarized regions in the Near-Infrared (NIR) and a new limit was suggested, **P/E(B-V) = 13** $\%/mag$. However, some polarimetric observations in the optical[6,7] have presented higher values than the aforementioned limits, suggesting that this quantity is not very well constrained yet and that it may vary across the sky.

Observations

We use brand new photometric and polarimetric information in the ***V*-band** observed in the *Interstellar Polarization Survey* (IPS)[4]. **34 fields of $\sim 0.3° \times 0.3°$** in size were carefully chosen in different locations near and within the galactic plane in the **Southern sky** (see data reduction details in Versteeg et al, Poster). We count with approximately **9000 stars**, after applying some quality filters, that have ***V*-band extinction and distances** – calculated using *Gaia* parallaxes – among other parameters from Anders et al. catalogue[1].

Results

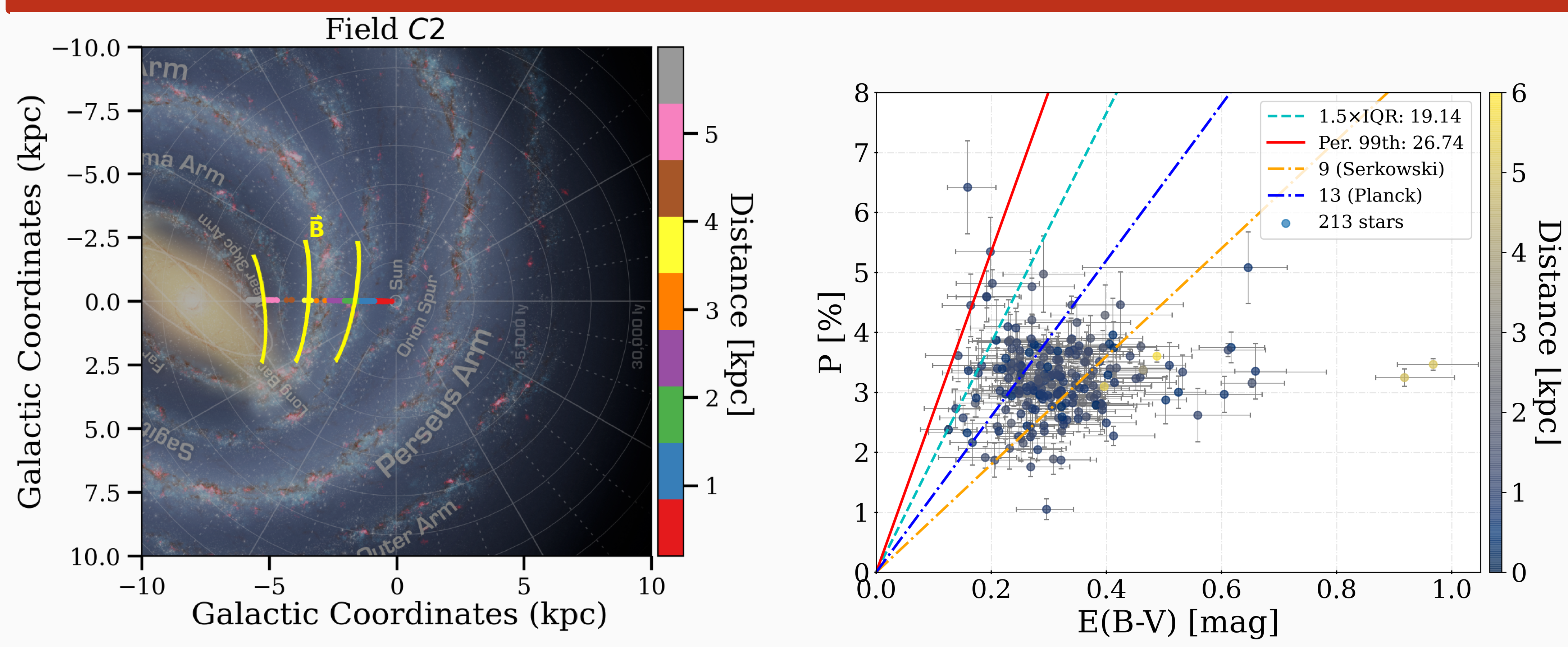

Figure 1: *Left:* Schematic of the LOS in field *C2* plotted in the XY Galactic plane. Yellow lines indicate the large-scale GMF lines. The color bar indicates the distance of the stars, d_{50}[1]. *Right:* Degree of Polarization with reddening in field *C2*. Stars are colored by distance. Upper envelopes from *Serkowski*[9] (orange dot-dashed line) and *Planck Collaboration*[8] (blue dot-dashed line) are include together with the 99th percentile (red solid line) and, in addition, we present for comparison the upper limit computed as $Q_3 + 1.5 \times$ IQR (cyan dashed line), where Q_3 is the 75th percentile and IQR is the Inter-Quartile Range of the distribution.

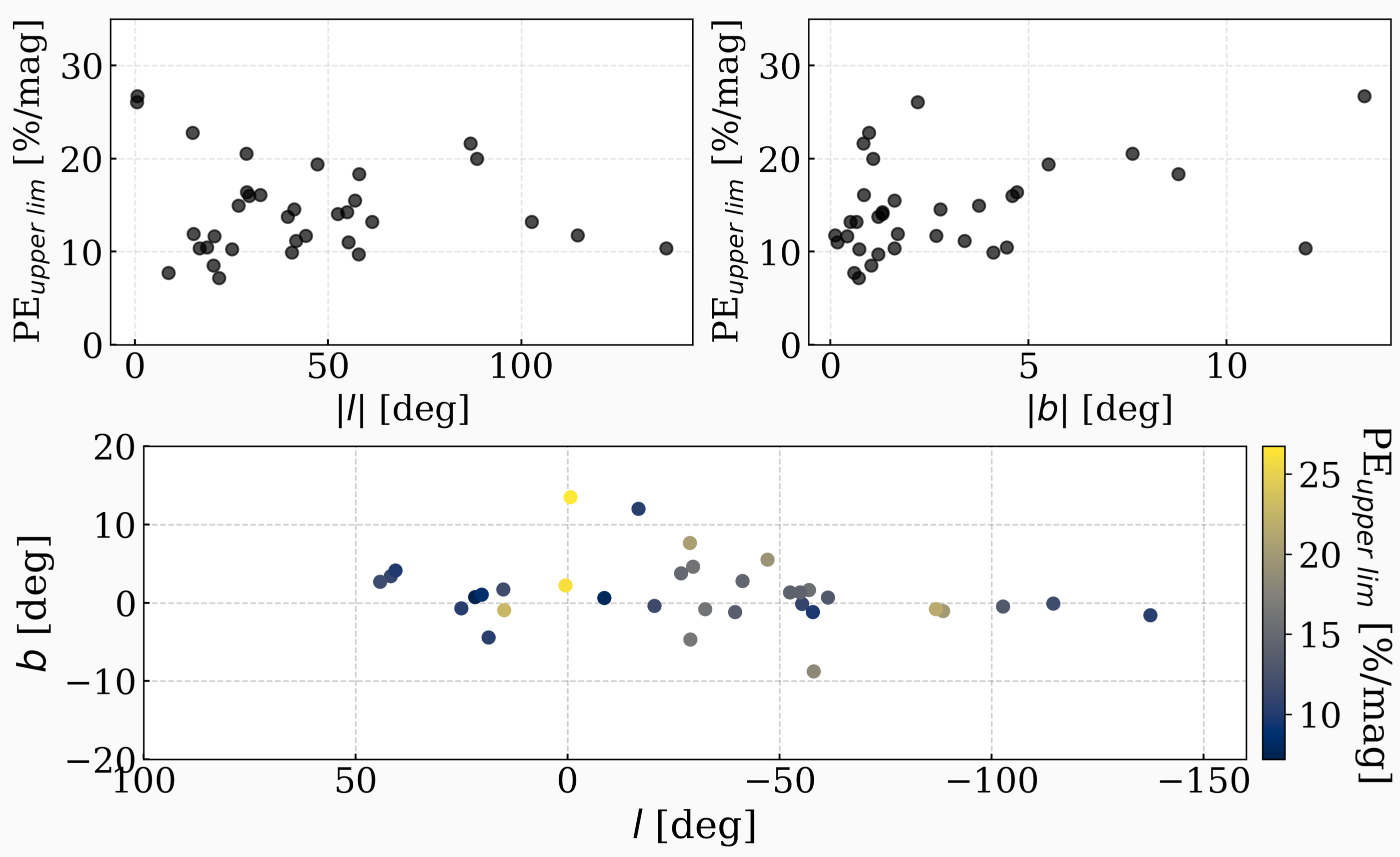

Figure 2: *Top:* Polarization efficiency as a function of the absolute value of the Galactic longitude (*left*) and Galactic latitude (*right*). *Bottom:* Sky plot of the polarization efficiency upper envelope of each IPS-GI field.

The upper envelope of P/E(B-V) is calculated on each field as the **99th percentile** of the distribution (Figure 3). The LOS on field *C2* are pointing near the Galactic Center at a high latitude ($l, b \approx (359.3°, 13.5°)$; see also Figure 1, *left*); **it avoids high extincted regions and extends perpendicular to the Galactic arms** and, thus, to the large-scale GMF lines. Hence, we defined the maximum polarization efficiency within the sample, $\mathbf{[P/E(B\text{-}V)]_{max}}$, as the upper limit in field *C2* (Figure 1, *right*).

Polarization Efficiency

The polarization efficiency depends on the alignment of polarizing dust grains with the Galactic magnetic field (GMF), and on the orientation of the magnetic field along the line-of-sight (LOS). In the diffuse interstellar medium (ISM), high polarization efficiency[6,8,10], the wavelength dependence of polarization[5] and complex dust population models[3] are all best explained with high dust-grain alignment efficiency; therefore, **we assume in our fields that grains are $\sim$ 100% aligned**. A low polarization efficiency, on the other hand, can be due to *i)* low degree of polarization caused by the GMF lines lying close to the LOS and/or *ii)* depolarization due to multiple orientations of the magnetic field along the LOS, either caused by the presence of a significant random component in the large-scale GMF[2] or by the morphology of the ISM along the LOS.

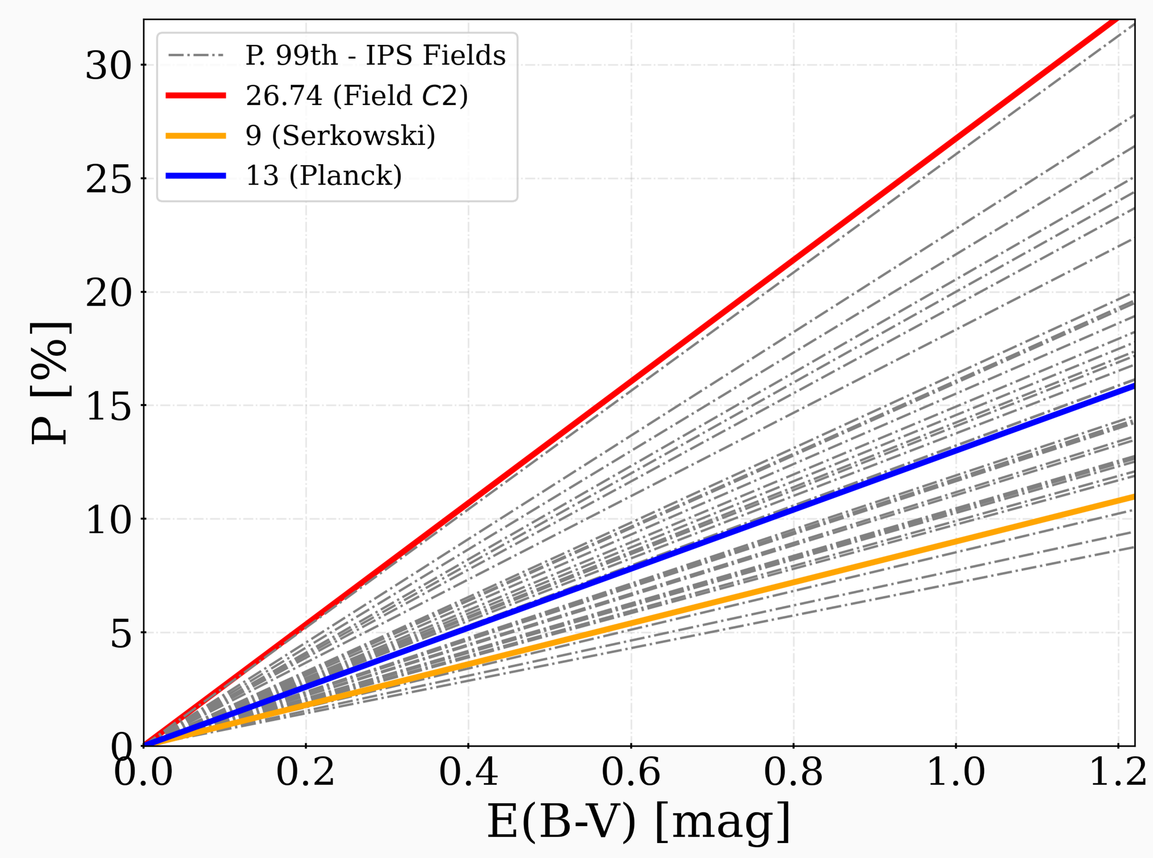

Figure 3: *Left:* Polarization efficiency upper envelopes calculated as the 99th percentiles of each IPS-GI field.

Discussion

As we approach high-latitude regions, **we expect P/E(B-V) to increase** due to low dust extinction and the lack of dense structures (Figure 2, *top-right*). However, across the Galactic longitudes (Figure 2, *top-left*), **P/E(B-V) varies a lot**, which is reasonable if we consider that the LOS can cross multiple ISM structures and the depolarization strongly depends on the magnetic field morphology. Furthermore, the **P/E(B-V) upper limits exceed** the limit from *Serkowski*[9] (orange solid line, Figure 3), and even *Planck*'s, in many IPS fields, demonstrating that the P/E(B-V) upper envelope is not well constrained yet. The high polarization efficiency, the small dispersion of polarization angle, and the LOS perpendicular to the Galactic arms, suggest that **the polarization vectors on field C2 are very close to the plane-of-sky component**, therefore, they are representative of the large-scale GMF and its direction in this region is close to the average polarization angle within the field.

Forthcoming Work

The next step in our research is to study the variation of the polarization efficiency along the LOS of each field using bins of distance up to 6 kpc. Similarly it will be done with other parameters such as the degree of polarization, the polarization angle and the dust extinction. We will also explore a possible relation between the polarization efficiency and the dispersion of the polarization angle on each field. This study may give us a clue about the mechanisms responsible for the low polarization efficiency and the high dispersion of polarization angles.

References

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