

Determination of the polarization of the Dark Cloud DCId 256.1–09.3

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Abstract. The precise determination of the distance to dark clouds allows us to understand the 3D structure of the interstellar medium. Along the line of sight toward the interstellar cloud DCLD 256.1–9.3, several interesting structures are found. Understanding the morphology of the region requires the spatial separation of these superposed components and provides insight into the role of spiral-arm structures in star formation and in shaping the interstellar magnetic field. Interstellar polarimetry, combined with distance data and color excess $E(b-y)$, allows the 3D mapping of the magnetic field orientation and the evaluation of dust-grain alignment efficiency. Polarimetric data collected with the 1.6m telescope at the Pico dos Dias Observatory (OPD/LNA) between September/2023 and February/2024, in the V and I filters, were used to investigate the interstellar components through Diagrams of linear polarization (P), polarization angle (Θ_p) and alignment efficiency $P/E(b-y)$ as a function of distance. The color-excess data are obtained from the Starhorse Catalog (Anders et al. 2022). The polarimetric analysis revealed transitions in the values of P , Θ_p and alignment efficiency ($P/E(b-y)$) in four regions. The first, before 400 pc, corresponds to the Gum Nebula with $P_{max} = 0.5\%$. The second corresponds to the Vela Molecular Ridge, at (700 ± 50) pc, with $E(b-y) = 0.08-0.35$ mag and $P = 3-10\%$. The third, between (900 ± 100) pc, shows $P = 1\% - 3\%$, an abrupt increase in $P/E(b-y)$, which allows us to conclude that DCLD 256.1-9.3 is at (950 ± 50) pc from the Sun, and may be a condensation in the VMR. The fourth, at (1400 ± 50) pc, covers the entire investigated area with $P = 3\% - 10\%$, evidence of grain alignment that may be due to the spiral arm.

Resumo. A determinação precisa da distância de nuvens escuras permite entender a estrutura 3D do meio interestelar. Na linha de visada da nuvem interestelar DCLD 256.1-9.3 encontram-se diversas estruturas interessantes. A compreensão da morfologia da região exige a separação espacial dessas componentes sobrepostas e fornece subsídios para compreender o papel de estruturas espirais na formação estelar e na configuração do campo magnético interestelar. A polarimetria interestelar, combinada com dados de distância e excesso de cor $E(b-y)$, permite o mapeamento 3D da orientação do campo magnético e avaliar a eficiência do alinhamento dos grãos de poeira. Dados polarimétricos coletados com o telescópio de 1.6m do Observatório Pico dos Dias (OPD/LNA) entre setembro/2023 e fevereiro/2024, nos filtros V e I , foram usados para investigar as componentes interestelares por meio de Diagramas da polarização linear (P), do ângulo de polarização (Θ_p) e da eficiência do alinhamento $P/E(b-y)$ em função da distância. Os dados de excesso de cor são obtidos do Catálogo Starhorse (Anders et al. 2022). A análise polarimétrica revelou transições nos valores de P , Θ_p e eficiência do alinhamento ($P/E(b-y)$) em quatro regiões. A primeira, antes de 400 pc, corresponde à Nebula de Gum com $P_{max} = 0.5\%$. A segunda, corresponde a Vela Molecular Ridge, a (700 ± 50) pc, com $E(b-y) = 0.08-0.35$ mag e $P = 3-10\%$. A terceira entre (900 ± 100) pc tem $P = 1\%-3\%$, um aumento abrupto em $P/E(b-y)$, o que permite concluir que DCLD 256.1-9.3 está a (950 ± 50) pc do Sol, e pode ser uma condensação na VMR. A quarta, entre (1400 ± 50) pc, cobre toda a área investigada com $P=3\% - 10\%$, evidência de alinhamento dos grãos que pode ser devido ao braço espiral.

Keywords. (ISM:) dust, extinction – ISM: clouds – Polarization

1. Introduction

The dark cloud DCId 256.1-09.3 was first cataloged by Hartley et al. (1986) and is located at ICRS coordinates (07:42:49.0, -42:25:48). With an angular size of approximately 2×1.5 arcmin², the cloud is situated in the constellation Puppis.

2. Methodology

Following the methodology described by Corradi et al. (1997), Reis & Corradi (2008) and Santos et al. (2011), we employed Spatial Polarization and Reddening Distribution Maps, as well as Polarization and Color Excess $E(b-y)$ versus distance diagrams, to identify the distinct components of the interstellar medium (ISM) along the line of sight. Interstellar dust absorbs and scatters starlight, producing measurable reddening. To trace this effect, we constructed Color Excess $E(b-y)$ versus Distance Diagrams for the region surrounding the target cloud. Transitions in these diagrams are identified by steep increases in $E(b-y)$, followed by a minimum or stabilization in the dispersion of color-excess

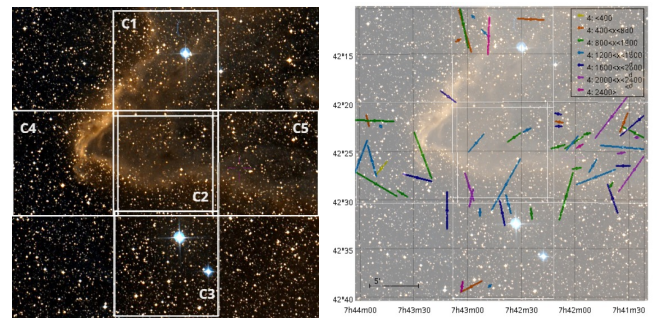


FIGURE 1. (a) Dark cloud DCId 256.1-09.3 in DSS2, showing the division of the studied area into regions (C1) to (C5); (b) Polarization map.

values. Such features indicate the presence of discrete dust layers or clouds along the line of sight.

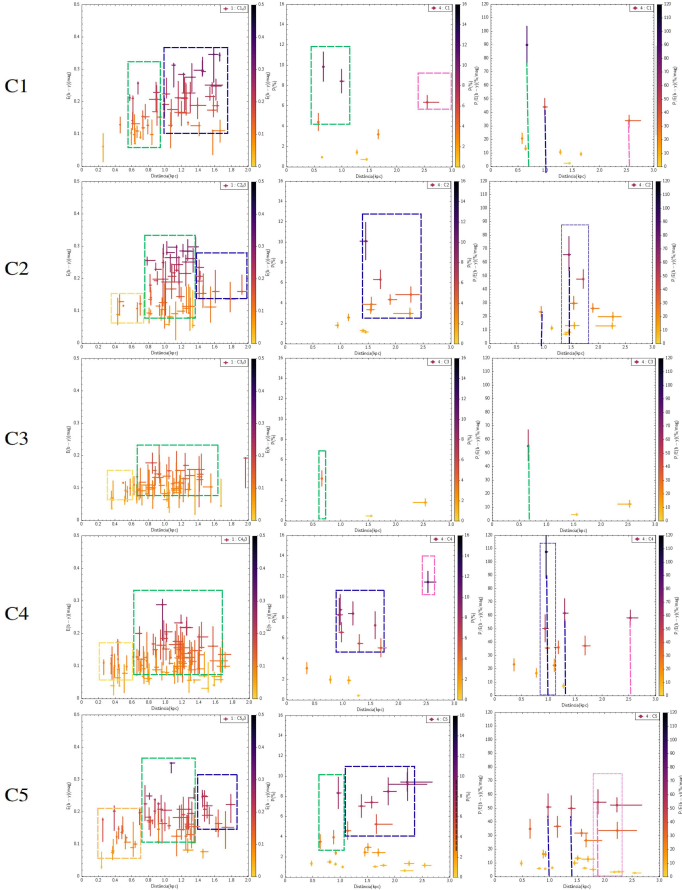


FIGURE 2. Diagrams of $E(b-y)$, P , and $P/(A_V/4.3)$ as a function of distance (kpc) for regions (C1) to (C5).

Interstellar dust also polarizes starlight through dichroic extinction. To explore this effect, we constructed Polarization versus Distance Diagrams for the same region. We searched for abrupt transitions in the polarization signal, which appear as sudden increases in the mean polarization level and are typically followed by a plateau or a minimum value beyond the transition distance. These behaviors are interpreted as signatures of distinct interstellar structures.

To isolate the transition associated with the dark cloud DCld 256.1–09.3, we analyzed both a region centered on the object (C2) and multiple comparison regions surrounding it (C1, C3, C4, and C5), as shown in Fig. ???. This strategy allows us to distinguish the reddening and polarization signatures intrinsic to the cloud from those produced by the ambient ISM.

Polarimetric data were obtained using the EgPol instrument mounted on the 1.6 m Perkin-Elmer telescope at OPD/LNA. Photometric and astrometric data were retrieved from the StarHorse2 catalog (Anders et al. 2022), which incorporates Gaia EDR3 observations. Interstellar reddening was derived using the conversion $E(b-y) = A_V/4.3$, as proposed by Strömberg et al. (2011).

3. Results

Figure 2 shows the Color Excess $E(b-y)$, Polarization and Polarization Effectiveness vs. Distance (kpc) Diagrams for the regions C1 to C5. The area surrounding the dark cloud is surveyed by region (C2). The transitions in Table 1 have been identified.

TABLE 1. Data of $E(b-y)$, P , and $P/E(b-y)$ as a function of distance.

	(200±100) pc	(700±100) pc
(E(b-y)±0.05) mag	SD	0.08–0.25
C1 (P±5)%	SD	4–10
(P/E(b-y)±10)%/mag	SD	90
(E(b-y)±0.05) mag	0.08–0.13	0.09–0.3
C2 (P±5)%	SD	SD
(P/E(b-y)±10)%/mag	SD	SD
(E(b-y)±0.05) mag	0.06–0.14	0.08–2.4
C3 (P±5)%	SD	4
(P/E(b-y)±10)%/mag	SD	55
(E(b-y)±0.05) mag	0.06–1.6	0.08–2.8
C4 (P±5)%	SD	SD
(P/E(b-y)±10)%/mag	SD	SD
(E(b-y)±0.05) mag	0.05–0.2	0.1–0.35
C5 (P±5)%	SD	3–9
(P/E(b-y)±10)%/mag	Sd	35
	(1000±100) pc	(1400±100) pc
(E(b-y)±0.05) mag	0.1–0.35	–
C1 (P±5)%	8	–
(P/E(b-y)±10)%/mag	45	SD
(E(b-y)±0.05) mag	–	1.15–0.25
C2 (P±5)%	–	13–10
(P/E(b-y)±10)%/mag	–	65
(E(b-y)±0.05) mag	–	–
C3 (P±5)%	SD	SD
(P/E(b-y)±10)%/mag	SD	SD
(E(b-y)±0.05) mag	0.08	–
C4 (P±5)%	5–10	–
(P/E(b-y)±10)%/mag	35–110	–
(E(b-y)±0.05) mag	–	0.15–0.3
C5 (P±5)%	–	5–10
(P/E(b-y)±10)%/mag	–	50

4. Conclusions

The polarimetric analysis revealed peaks in the alignment efficiency $P/E(b-y)$ in four regions:

1st - (Gum Nebula): (200 ± 50) pc, with $E(b-y) = 0.06-0.2$ mag;

2nd - (Vela Molecular Ridge): (700 ± 50) pc, with $E(b-y) = 0.08-0.35$ mag, $P = 3-10\%$, and $P/E(b-y) = 55-90\%/mag$;

3rd - (DCLD 256.1–9.3): around (900 ± 100) pc, with $P = 1-3\%$, indicating that the cloud condenses at (950 ± 50) pc from the Sun;

4th - (Spiral Arm): (1400 ± 50) pc, with $P = 3-10\%$, suggesting grain alignment in the spiral arm;

5th - (possible): (2500 ± 50) pc, with $P = 6-10\%$ and $P/E(b-y) = 35-60\%/mag$.

The polarimetric data show good agreement with the StarHorse catalog and complement the results from Franco (2012), who place the Vela Molecular Ridge between 600 and 900 pc.

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References

- Anders F. et al, 2022, A&A, 658, A91
Corradi W.J.B. et al., 1997, A&A, 326, 1215
Franco, G. A. P. A&A, v. 537, A129, 2012
Hartley, M. et al., 1986 A&A, 63, 27
Reis, W., Corradi, W.J.B., 2008, A&A, 486, 471
Santos F.P.S., Corradi W.J.B., Reis W. 2011, ApJ, 728, 104
Strömberg B. 1966, ARA&A, 4, 433