Boletim da Sociedade Astronômica Brasileira, **36**, no. 1, 221-222

Distance determination of the dark cloud DCld 294.3 -00.1

R. Silva[1], W. Corradi[1,2], N. Sasaki[3], & W. Reis[1,4]

[1] Universidade Federal de Minas Gerais e-mail: rafaelfas2001@gmail.com, wilsonr@fisica.ufmg.br
[2] Laboratório Nacional de Astrofísica e-mail: wbcorradi@lna.br
[3] Universidade do Estado do Amazonas e-mail: nsasaki@uea.br
[4] IBMEC

Abstract. In this study we explore the relationship between the color excess and distance in the direction of the dark interstellar cloud DCld 294.3-00.1. Through Color excess vs. Distance Diagrams and maps of the spatial distribution of the reddening, it has been identifed three components of the ISM along the line of sight. A first transition at least at 100pc is due to the Local Buuble. A second major transition in reddening occurs at (350 ± 30)pc, where $E(b-y)$ values jumps to 0.18mag, resembling the back of the Loop I bubble. From (850 ± 50)pc onwards, a third abrupt jump is identified with values ranging from 0.1mag to 0.3mag, suggesting this valuee as the distance to DCld 294.3-00.1. Polarimetric data has been used to further investigate the interstellar dust and the magnetic field towards the cloud. The analysis revealed that the stars exclusively in the direction of DCld 294.3-00.1 have a polarization angle of 175° and are consistent with the stars surrounding the cloud. The polarization degree follows the same pattern as the reddening. Beyond (850 ± 50) pc there is an increase from 0.4% to 2%, reaching up to 5% in specific directions, what confirms the distance to the cloud.

Resumo. Neste trabalho investigamos a relação entre o Excesso de Cor e a distância na direção da nuvem interestelar escura DCld 294.3-00.1. Por meio de diagramas de excesso de cor por distância e mapas da distribuição espacial do avermelhamento, identificamos três componentes do meio interestelar ao longo da linha de visada. Uma primeira transição pelo menos em 100pc indica a presença da Bolha Local. Uma segunda transição no avermelhamento ocorre em (350 ± 30)pc, em que os valores de $E(b-y)$ saltam para 0.18mag, que pode ser o fundo da Bolha Loop I. A partir de (850 ± 50)pc um terceiro salto abrupto é identificado, os valores de excesso de cor tem um valor mínimo de 0.1mag e chegam até 0.3mag, sugerido que esta é a distância da nuvem. Dados de polarimetria foram usados para investigar a poeira interestelar e o campo magnético na região. A análise revelou que as estrelas exclusivamente na direção da nuvem tem ângulo de polarização de 175°, consistente com as estrelas circundando a nuvem. O grau de polarização exibe o mesmo padrão do avermelhamento. Além de (850 ± 50) pc, surge um aumento abrupto no grau de polarização de 0.4% to 2%, atingindo até 5% em algumas direções, o que confirma a distância da nuvem.

Keywords. ISM: structure – ISM: dark clouds – Methods: color excess per distance diagrams – Polarimetric observations

1. Introduction

To gain a deeper understanding of the interstellar medium (ISM) and its components, continuum radio observations are essential. Such observations have led to the discovery of a structure called the Local Bubble (LB), an irregularly, low-density region of the ISM surrounding the Sun (Reis et al. 2011; Santos et al. 2011). This cavity is encircled by several other interstellar bubbles, some of which are linked to intense star-forming activity (Reis & Corradi 2008).

DCld 294.3-00.1 is a dark cloud listed in the catalog of southern dark clouds (Hartley et al. 1986). Dark clouds are important due to the close relationship between interstellar dust and gas densities, linking interstellar dust and molecules with the star formation. Additionally, they serve as tracers of the interstellar magnetic field through observations of starlight polarization (Axon & Ellis 1976). In this paper the main goal is to determine the distance to the dark cloud DCld 294.3-00.1, depicted in Figure 1. Additionally, we aim to create a polarization map by analyzing the polarization degree and polarization angle as a function of the distance.

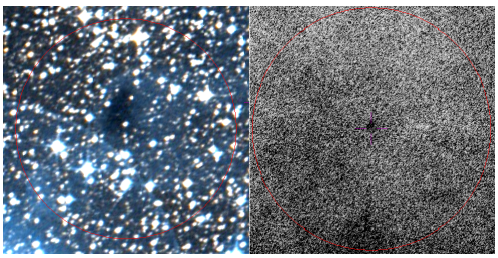

Figure 1. The dark cloud DCld 294.3 -00.1 in two distinct filters: Visible DSS2 color (left); Gaia DM I/355 (right); The circle in red in the right image has a radius of 20 arcmin centered in the coordinates of the cloud $\alpha = 11h37m33.0s, \delta = -61°44'36''$.

2. Methodology

The method involves analyzing color excess versus distance diagrams and interstellar reddening maps to identify the components of the ISM along the line of sight. This approach, previously applied by (Reis & Corradi 2008; Corradi et al. 1997), aims to detect abrupt increases in color excess toward the cloud when compared to the surrounding regions without it. These transitions help pinpoint the cloud's distance (Corradi et al. 2004). We have used visible absorption ($A_V = 4.3 \cdot E(b-y)$) and distance data obtained from the Starhorse2 catalog (Anders et al. 2022; Queiroz et al. 2018), which employs an isochrone-fitting technique to estimate various stellar parameters using Gaia EDR3 data.

Our selection criteria included using the P50 percentile for distance and $E(b-y)$ while excluding stars with a relative error greater than 10% up to 2kpc. This process yielded a final sample of 769 stars, with a confidence interval of 0–2% for distance and 0.009 mag for color excess, referring to how well the StarHorse

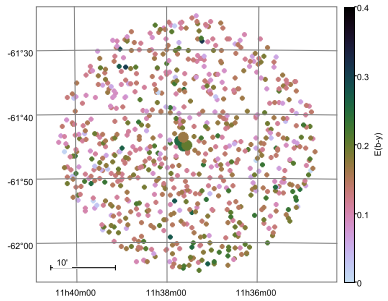

Figure 2. Interstellar reddening map. It demonstrates through the color scheme, that the color excess increases in the direction of the spatial distribution of the cloud and its surrounds (compare with figure 1.

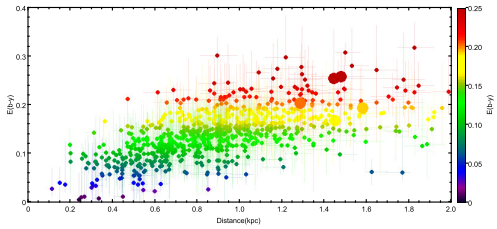

Figure 3. Strömgren $E(b-y)$ Colour Excess vs. Distance Diagram of the final sample. We identify three sudden increases in $E(b-y)$, the first at least at 100pc, the second at (350 ± 30)pc, the third at (850 ± 50)pc.

data recover the collected real data. A further set of selection criteria included applying the flags Fidelity > 0.5 and FlagOut < 1. Figure 2 displays the spatial distribution of reddening. The five stars located precisely in the direction of the cloud, represented by larger circles, had their $E(b-y)$ errors tolerated up to 50%.

For polarimetric analysis we cross-matched data from Starhorse2 catalog with polarimetric data collected in 2023 at OPD/LNA, using the B&C telescope, equipped with the IAGPOL. The images in Johson I filter were reduced using the SOLVEPOL pipeline (Ramírez et al. 2017). The observed sky area covers a field of 5.7x5.7 arcmin and polarization errors were tolerated up to 2.5%, reducing our sample to 54 stars.

3. Discussion and Results

First, we have plotted our final sample on a Color Excess versus Distance Diagram, shown in Figure 3. The $E(b-y)$ values have a median of 0.075 mag, around 100pc indicating that the LB has been crossed, in the direction of the DCld 294.3-00.1 cloud. A sudden increase of 0.05 mag to 0.18 mag around 350 pc resembles the back of the Loop I bubble.

A distinct jump in the color excess axis is observed at a distance of (850 ± 50) pc, with values rising from 0.1 to as high as 0.3 mag. This indicates that is distance of the dense cloud DCld 294.3-00.1. Figure 4 shows that beyond (850 ± 50)pc stars has an increase in polarization.

In Fig. 5 the stars exclusively in the direction to DCld 294.3-00.1 have a polarization angle of 175° and are consistent with the stars surrounding the cloud. We observe two groups of stars with completely opposite polarization angles. By displaying the polarization vectors in the plane of sky we have built a polarization map. A group of stars is observed whose polarization vectors appear to align predominantly in a vertical downward direction, corresponding to the preferential orientation of the magnetic field in the region.

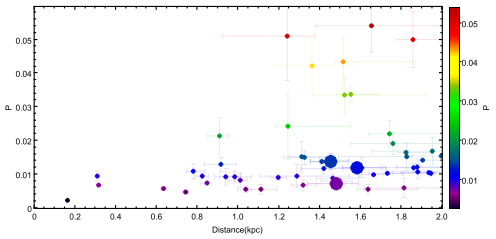

Figure 4. Degree of polarization as a function of distance. The polarization follows the same pattern as the reddening. Beyond (850 ± 50) pc, there is an increase from 0.4% to 2%, reaching up to 5% in specific directions. This confirms the distance determination of DCld 294.3-00.1

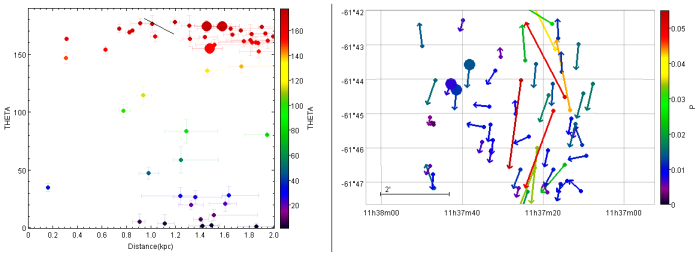

Figure 5. Left: Polarization angle as a function of distance. Right: Polarization map.

The main goal of this work has been to determine the distance to DCld 294.3-00.1. The $E(b-y)$ values have a median of 0.075 mag, around 100pc indicating that the LB has been crossed. A second sudden increase of 0.05 mag to 0.18 mag around 350 pc resembles the back of the Loop I bubble. The dark cloud distance is determined as (850 ± 50) pc, due to the third $E(b-y)$ jump from 0.1 to as high as 0.3 mag.

4. Conclusion

We have also analyzed the polarization in the region surrounding the cloud, the polarization vectors are predominantly aligned, suggesting an interaction between the interstellar dust grains and the magnetic field present within the ISM. The analysis revealed that the stars exclusively in the direction of DCld 294.3-00.1 have a polarization angle of 175° and are consistent with the stars surrounding the cloud. The polarization degree follows the same pattern as the reddening. Beyond (850 ± 50) pc, there is an increase from 0.4% to 2%, reaching up to 5% in specific directions, confirming that this is the distance to the cloud.

Acknowledgements. The authors acknowledge the support from UFMG and LNA. W.Corradi acknowledges the support from CNPq - BRICS 440142/2022-9, FAPEMIG APQ 02493-22 and FNDCT/FINEP/REF 0180/22.

References

W. Reis, W. J. B. Corradi, M. A. Avillez, and F. P. Santos, 2011, ApJ, 734, 8
F. P. Santos, W. J. B. Corradi and W. Reis, 2011, ApJ, 728, 104.
Hartley M. et al., 1986, A&AS, 63, 27.
Axon D. J., Ellis R. S., 1976, 177, 499.
W. Reis, Corradi W.J.B., 2008, A&A, 486, 471.
W. J. B. Corradi et al., 1997, A&A, 326, 1215.
W. J. B. Corradi et al., 2004, A&A, 347, 4.
Anders F. et al., 2022, A&A, 658, A91.
Queiroz A. B. A. et al., 2018, A&A, 476, 2556.
Ramírez E. A. et al., 2017, PASP, 129, 055001.