

Polarimetric investigation of the dark cloud [DB2002b] G297.33+2.22

L. H. S. De Paula¹, W. J. B. Corradi², D. A. Brissi³, N. Sasaki⁴ & W. Reis⁵

¹ IAG-USP e-mail: h.paula@usp.br

² LNA e-mail: wbcorradi@lna.br

³ IFSP Birigui e-mail: deidimar@ifsp.edu.br

⁴ UEA e-mail: nsasaki@uea.edu.br

⁵ IBMEC e-mail: wilsonr@fisica.ufmg.br

Abstract. In a previous investigation of the interstellar reddening towards the dark cloud [DB2002b] G297.33 + 2.22 its distance has been estimated, for the first time, as (925 ± 40) pc. To refine such results, polarimetric data has been collected in 2023 with the P&E 1.60 m and B&C 60cm telescopes at the Pico dos Dias Observatory (OPD/LNA/Brazil), equipped with the IAGPOL. The analysis revealed two steps in the polarization degree ($P(\%)$) vs. distance $d(\text{pc})$ diagram. The first one at (925 ± 40) pc, with $P(\%)$ from 0.5% to 1.5% and polarization angle $\theta_p = 90^\circ$; and a second one at (2275 ± 75) pc, with $P(\%)$ from 2.0% to 3% and $\theta_p = 140^\circ$. A closer look in the $E(b-y)$ vs. d diagram shows similar transitions, with color excess $E(b-y)$ going from 0.05 to 0.15 mag and $E(b-y)$ from 0.5 to 1.0 mag, respectively. These findings reassure that the photometric result that [DB2002b] G297.33 + 2.22 is located at (925 ± 40) pc and that another more distant and dense component is present. Although our data cannot give the precise distance, the minimum polarization $P \approx 0.5\%$ and $E(b-y) = 0.050$ mag indicates the crossing of Local and Loop I bubbles' interface.

Resumo. Em uma investigação prévia do avermelhamento interestelar na direção da nuvem escura [DB2002b] G297.33+2.22, sua distância foi estimada, pela primeira vez, como (925 ± 40) pc. Para refinar tais resultados, dados polarimétricos foram coletados em 2023 com os telescópios P&E 1,60 m e B&C 60 cm do Observatório do Pico dos Dias (OPD/LNA/Brasil), equipados com o IAGPOL. A análise revelou dois degraus no Diagrama de Polarização ($P(\%)$) vs. Distância $d(\text{pc})$. A primeira transição em (925 ± 40) pc apresenta $P(\%)$ indo de 0,5% a 1,5% e ângulo de polarização $\theta_p = 90^\circ$; e a segunda em (2275 ± 75) pc apresentando $P(\%)$ de 2,0% a 3% e $\theta_p = 140^\circ$. Revendo o diagrama de excesso de cor $E(b-y)$ vs. d nota-se que transições semelhantes ocorre nas mesmas distâncias, com $E(b-y)$ de 0,05 a 0,15 mag e $E(b-y)$ de 0,5 a 1,0 mag, respectivamente. Isso reafirma o resultado obtido com a fotometria de que a nuvem escura [DB2002b] G297,33 + 2,22 está localizada em (925 ± 40) pc, e existe uma outra componente mais distante e densa. Apesar dos dados não permitirem uma determinação precisa da distância, a polarização mínima $P \approx 0.5\%$ and $E(b-y) = 0.050$ indicam que a interface entre as Bolhas Local e Loop I foi atravessada.

Keywords. clouds – dust – polarization – distance

1. Introduction

The studied dark cloud has been firstly catalogued by Hartley et al. (1986) as DCld 297.3+02.2, with an estimated diameter of 3 arcmin. Dutra & Bica (2002) revised its coordinates to RA = $12^h06^m16^s$ and DEC = $-60^\circ09'12''$, and dubbed the dark cloud as [DB2002b] G297.33+2.22. An image of the cloud can be seen in Fig. 1.

De Paula et al. (2023) investigated the behavior of the interstellar extinction in the direction to the cloud as a function of the distance d . In that work, the distance to the [DB2002b] G297.33+2.22 has been estimated, for the first time, as 925 ± 40 pc.

In the same work, two other components have been identified using color excess $E(b-y)$ vs. d diagrams. Although our data cannot give the precise distance, the minimum polarization $P \approx 0.5\%$ and $E(b-y) = 0.050$ mag indicates the crossing of Local and Loop I bubbles' interface.

Then, the color excess $E(b-y)$ jumps from 0.05 to 0.15 mag at (925 ± 40) pc, identified as the distance to [DB2002b] G297.33+2.22. After that, $E(b-y)$ suffers another jump from 0.5 to 1.0 mag at (2275 ± 75) pc, revealing a more dense and large scale structure.

The goal of this project is to investigate the components of the interstellar medium in the direction of [DB2002b] G297.33+2.22 using polarimetric data, aiming to refine these findings.

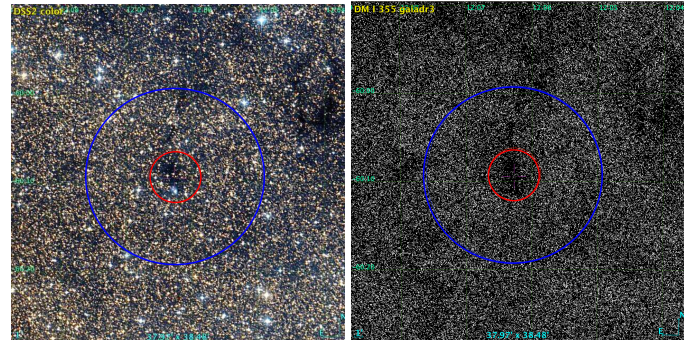


FIGURE 1. [DB2002b] G297.33+2.22 in the (left) DSS2 and (right) Gaia DR3 images. The red circle corresponds to the clouds size, 3 arcmin, and the blue circle the 10arcmin surveyed area

2. Methodology

The method involves analyzing polarization $P(\%)$ and color excess $E(b-y)$ vs. distance diagrams to identify the components of the ISM along the line of sight. The recipes of Santos et al. (2011), Corradi et al. (1997) and Reis & Corradi (2008) have been followed.

The polarimetric approach aims to detect abrupt increases in the polarization degree $P(\%)$ as well as in the polarization angle (θ_p) orientation towards the cloud when compared to the direc-

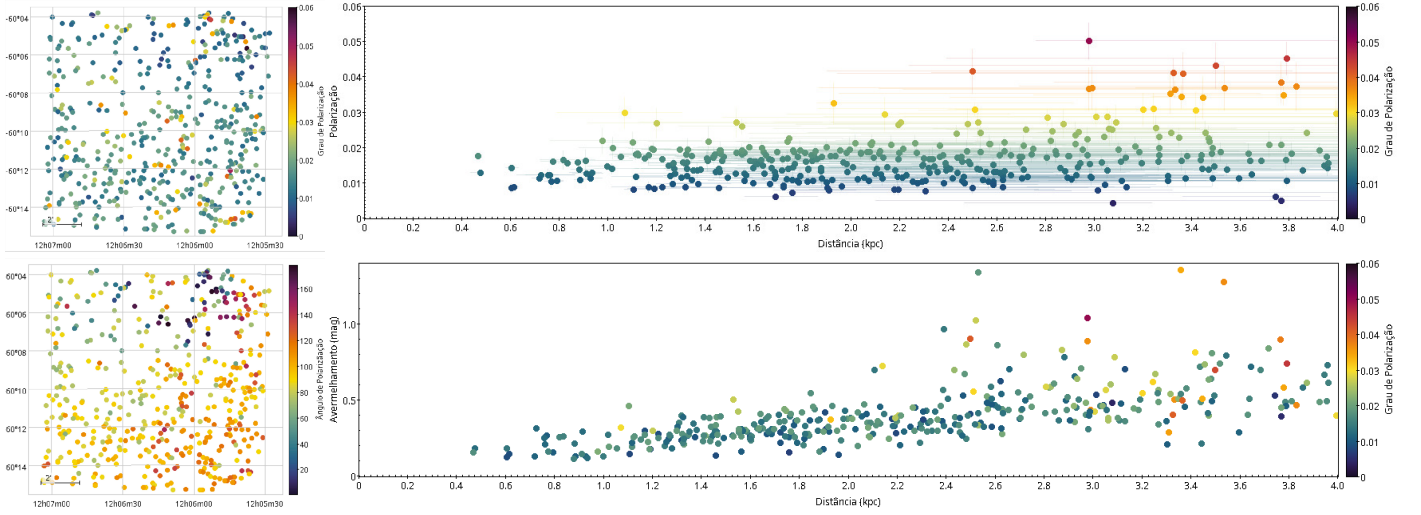


FIGURE 2. [DB2002b] G297.33+2.22. (top left) Spatial distribution map, encoded by P . (bottom left) Spatial distribution map, encoded by θ_P . (top right) Polarization $P(\%)$ vs. distance diagram. (bottom right) Colour excess $E(b-y)$ vs. distance diagram. An auxiliary colour scale, based on the P , has been used to compare with $E(b-y)$.

tions without it. In the same way, the photometric approach seeks for similar transitions in the color excess. Support from spatial reddening maps are taken to help identifying these transitions and infer the cloud's distance (Reis et al. 2011).

Polarimetric data has been collected at the Pico dos Dias Observatory - OPD/LNA with the P&E 1.60 m and B&C 60cm telescopes, equipped with the IAGPOL configured with the Johnson V and I filters, Ixon 1024x1024 CCD, a focal reducer and the guider. The images were reduced using the SOLVEPOL pipeline (Ramírez et al. 2017) to obtain $P(\%)$ and $\theta_P(\text{degree})$, as well their uncertainties σ_P and σ_{θ_P} .

3. Results

The surveyed area covers a FOV of 5.7×5.7 arcmin and polarization errors were tolerated up to 2.5%, reducing our sample to 871 stars (Fig. 2). Standard stars were observed every night, being HD110984 and HD298383 polarized and HD94851 unpolarized. They account for the polarization angle correction and intrinsic instrumental polarization, respectively.

In De Paula et al. (2023) the distances and absorptions were taken from Starhorse2 (Anders et al. 2022). To obtain the Strömgren $E(b-y)$ Colour Excess, the relation of Crawford & Mandewala (1976) and Strömgren (1966) $E(b-y) = A_V/4.3$ has been used. The data covered a radius of 10 arcmin with the following exclusion criteria applied: Distance ≤ 4 kpc, the flags Fidelity > 0.5 and FlagOut < 1 . The final sample contains 500 stars.

To determine the distances to the stars with the polarimetric data, a cross-match has been performed with the GAIA EDR3 catalog using TOPCAT (Taylor 2005) to manipulate the tables. The initial sample consisted of 871 stars, with a matching radius of 3 arcseconds. The final sample contains 667 stars.

The analysis revealed two steps in the polarization degree ($P(\%)$) vs. distance $d(\text{pc})$ diagram. The first one at (925 ± 40) pc, with $P(\%)$ from 0.5% to 1.5% and polarization angle $\theta_P = 90^\circ$; and a second one at (2275 ± 75) pc, with $P(\%)$ from 2.0% to 3% and $\theta_P = 140^\circ$.

A closer look in the $E(b-y)$ vs. d diagram shows similar transitions, with color excess $E(b-y)$ going from 0.05 to 0.15 mag and $E(b-y)$ from 0.5 to 1.0 mag, respectively. Although our data cannot give the precise distance, the minimum polarization

$P \approx 0.5\%$ and $E(b-y) = 0.050$ mag corresponds to the values obtained by Santos et al. (2011) and Reis & Corradi (2008); Reis et al. (2011) for the Local and Loop I bubbles' interface.

These findings reassure that the photometric result that [DB2002b] G297.33 + 2.22 is located at (925 ± 40) pc and that another more distant and dense component is present.

4. Conclusions

The transition of the polarization from $P = 0.5\%$ to 1.5% and the colour excess from $E(b-y) = 0.05$ to 0.15 mag) at the same distance towards [DB2002b] G297.33 + 2.22 reassures that the dark cloud is located at (925 ± 40) pc from the Sun. The stars exclusively in the direction of [DB2002b] G297.33 + 2.22 have $\theta_P = 90^\circ$.

The data reveals another structure at 2275 ± 75 pc, with $P(\%)$ increasing from 2.0% up to 3.0%, exhibiting $\theta_P = 140^\circ$. Although our data cannot give the precise distance, the minimum $P \approx 0.5\%$ and $E(b-y) = 0.050$ mag indicate that the interface of the Local and Loop I bubbles have been crossed.

Acknowledgements. The authors thank the support of IAG-USP, UFMG, LNA, IFSP Birigui, IBMEC and UEA. This work has used Aladin Sky Atlas (CDS, France) and Gaia mission (ESA) data. W. Corradi acknowledges CNPq - BRICS 440142/2022-9, FAPEMIG APQ 02493-22 and FNDCT/FINEP/REF 0180/22. L. H. De Paula was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code N° 88887.954092/2024-00

References

- Anders F. et al., 2022 A&A 658, A91.
- Axon D. J., Ellis R. S. 1976 MNRAS 177, 499.
- Crawford D. L. & Mandewala N. 1976 PASP 80, 917.
- Corradi W. J. B. et al. 1997 A&A 326, 1215.
- Corradi W. J. B. et al. 2004 A&A 347, 4.
- De Paula, L.H., Corradi, W.J.B., D.A Brissi, N. Sasaki, Reis, W., 2023, Boletim da SAB 35, 174.
- Dutra, C.M. & Bica, E., 2002, A&A, 383, 631.
- Hartley M. et al., 1986 A&AS 63, 27.
- Ramírez E. A. et al. 2017, PASP 129, 055001.
- Reis W., Corradi, W. J. B. 2008 A&A 486, 471.
- Reis W., Corradi, W.J.B., Avillez M.A., Santos F.P. 2011 ApJ 734, 8.
- Santos F.P., Corradi and W.J.B., Reis W. 2011 ApJ, 728, 104.
- Strömgren, B. 1966 ARA&A 4, 433.
- Taylor M. B. 2005 ADASS XIV 347, 29.