Boletim da Sociedade Astronômica Brasileira, **35**, no. 1, 238-239

Distance determination of the dark cloud PGCC G004.67-46.69

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Abstract. In this study, we investigated the interstellar medium components in the direction to the dark cloud PGCC G004.67-46.69. Visual absorption and distances from the Starhorse2 catalog by Anders et al.(2022), derived from Gaia EDR3 data have been used. Through color excess vs. distance diagrams and spatial reddeing distribution maps, it has been identified two components of the ISM along the line of sight. Major transitions in reddening occur at $(320 \pm 20)pc$, where $E(b-y)$ values rise to 0.075mag. From $(520 \pm 30)pc$ onward, a second jump in the color excess has been identified, with values ranging from 0.11mag to 0.14mag. The first component resembles the Local Bubble interface, while the second component is believed to be the distance to PGCC G004.67-46.69.

Resumo. Neste trabalho foram investigadas as componentes do meio interestelar na direção da nuvem escura PGCC G004.67-46.69. Valores de absorção no visível e de distânciam fornecida do catálogo Starhorse de Anders et al.(2022), foram utilizadas. Por meio de diagramas de excesso de cor por distância e mapas da distribuição espacial do avermelhamento, foram identificadas duas componentes do meio interestelar ao longo da linha de visada. Transições maiores no avermelhamento ocorrem em $(320 \pm 20)pc$, em que os valores de $E(b-y)$ saltam para 0.075mag. A partir de $(520 \pm 30)pc$ um segundo salto no excesso de cor é identificado, onde os valores de excesso de cor tem um valor mínimo de 0.11mag e chegam até 0.14mag. A primeira componente assemelha-se com a interface da Bolha Local, já a segunda componente indica a distância da nuvem escura PGCC G004.67-46.69.

Keywords. ISM: structure – ISM: dark clouds – Methods: color excess per distance diagrams – Data analysis

1. Introduction

Continuum radio observations are one of the tools used to understand the interstellar medium(ISM) and its components. By mapping the ISM it has been revealed the existence of a structure known as the Local Bubble(LB), that consists of a very irregular, low density volume of the ISM surrounding the Sun(Reis et al. 2011; Santos et al. 2011). This bubble(or cavity) is surrounded by several other interstellar bubbles that are sometimes associated with strong star-forming activity (Corradi et al. 1997).

PGCC G004.67-46.69 is a dark cloud on The Planck Cold Galactic Clumps(PGCC) catalog(XXVIII Planck Collaboration 2016), which consists exclusively of galactic cold sources detected using a dedicated method(Montier et al. 2010). The three highest Planck bands (857, 454, and 353 GHz) have been combined with IRAS data at 3THz to perform a multi-frequency detection of sources colder than their local environment.

In this paper the main goal is to determine the distance of the dark cloud PGCC G004.67-46.69, shown in Figure 1.

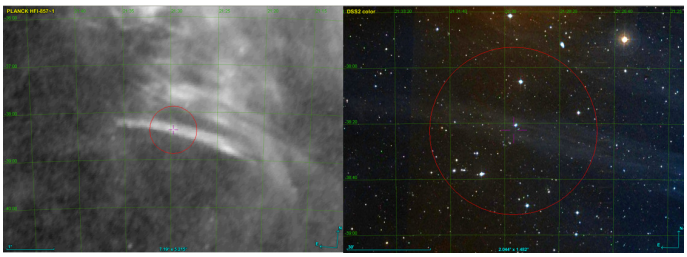

Figure 1. The dark cloud PGCC G004.67-46.69 in two distinct filters: Planck HFI-857Mhz(left); Visible DSS2 color(right); The circle in red has a radius of 30 arcmin centered in the coordinates $\alpha = 21h29m44.52s, \delta = -38°22'42.06''$, and it contemplates our initial sample of 1705 stars.

2. Methodology

The method relies on the analysis of color excess vs. distance diagrams and reddeing spatial distribution maps to determine the components of the ISM along the line of sight, a method used before by (Reis, W. Corradi, W.J.B. 2008; Corradi W. J. B. et al. 1997). The idea is to identify transitions where occur a sudden increase in the color excess, towards the cloud, when compared to regions without the cloud. The distance where the jumps occurs is the distance of the cloud (Corradi W. J. B. et al. 2004).

Visual absortion A_V has been used to derive the Strömgren $E(b-y)$ colour excess from $A_V = 4.3E(b-y)$. The A_V and distances have been extracted from the Starhorse (Anders et al. 2022; Queiroz et al. 2018) catalogue, which is an isochrone-fitting code tailored to derive lots of parameters for field stars using Gaia EDR3 data.

The selection criteria eliminate stars with an relative error greater than 20% for color excess resulting in a final sample with only 194 stars. The confidence interval was 0-2% for distance and 0,009mag for color excess.

In Figure 2 one can see the reddening spatial distribution map of the final sampe. The stars marked with X are stars that, despite the cleaning of the sample, still exhibited significant uncertainty in the color excess values. Stars represented by squares are excellent contributors for the distance estimate, with an relative error smaller than 0,09%.

3. Discussion and Results

The final data sample, with restrictions for good and bad data, have been used to build Color Excess vs Distance Diagram, shown in 3. It has been observed that $E(b-y)$ has a medium value of 0.075mag, suggesting that the Local Bubble has been crossed. Given the high Galactic latitude of the PGCC G004.67-

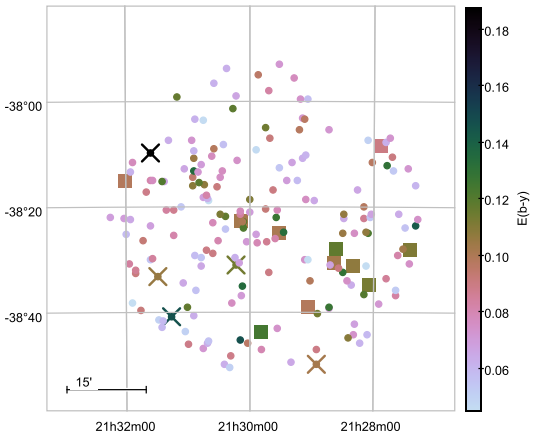

Figure 2. Reddening spatial distributio map for the total sample. It clearly demonstrates through the color scheme, that the color excess increases in the direction of the cloud (compare with Figure 1).

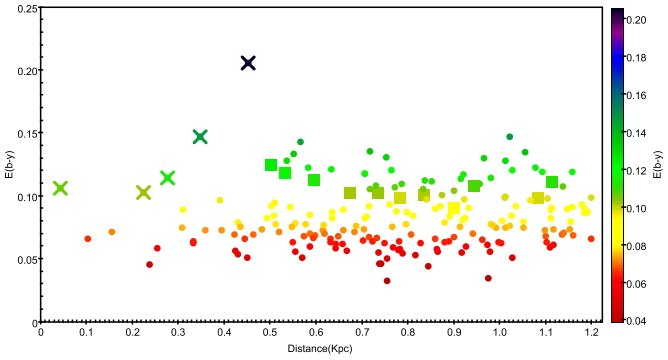

Figure 3. $E(b-y)$ vs. distance diagram for the final sample. Two sudden inscreases in $E(b-y)$, the first at $(320\pm20)pc$, the second at $(520 \pm 30)pc$ have been identified.

46.69 cloud, it is not expected to cross the interface of the Local and Loop I bubbles'.

Upon reaching $300pc$, there seems to be a sudden jump, but in reality, in the direction of the studied cloud, no other bubble is clearly mapped. Maybe Loop IV.

In $(520 \pm 30)pc$ it has been clearly observed another sudden jump in the color excess, with the values reaching 0.11 and going up to 0.14 magnitudes. The distance of the cloud is well-defined through the data represented by squares, as in the Strömgren system values above 0.1 mag are considered very high.

In figure 4 one can see a division made in the area of 30 arcminutes that encompasses the cloud. There are two regions outside the line of sight of the cloud and one region exactly towards the cloud.

Figure 5 shows that the stars towards the cloud effectively can determine its distance. The majority of the stars contributing to the abrupt jump after the distance of $520pc$ are in the direction of the cloud, represented by the color blue.

4. Conclusions

The main goal of this work was to determine the distance for PGCC G004.67-46.69. The investigation in the direction of this dark cloud suggests two transitions in $E(b-y)$ in the line of sight. The first one in $320\pm20pc$ represents the interaction with the LB, since the high Galactic latitude of the cloud is not expected to

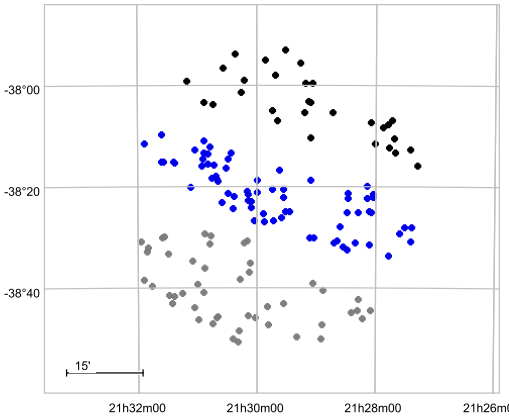

Figure 4. The final sample separeted in three parts: stars towards the cloud (blue); stars outside the direction of the cloud (black and gray);

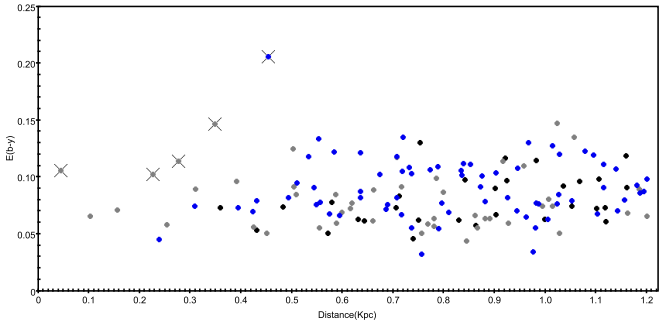

Figure 5. $E(b-y)$ vs. Distance Diagram of the final sample. The stars towards the cloud are shown in blue; the stars outside the direction of the cloud are shown in black and gray.

cross the interface of the Local and Loop I Bubbles. The second one, in an unprecedented manner, indicates that PGCC G004.67-46.69 is located at $520 \pm 30pc$ from the Sun.

In the future, polarimetric data collected at OPD/LNA will be used to refine these results.

Acknowledgements. The authors wish to thank the support from UFMG, LNA, IBMEC and UEA, the Gaia Collaboration as well as the Topcat developers.

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