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Determination of the distance to the Bok Globule [CB88] 68

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Abstract. In this work, we have analysed the components of the interstellar medium in the direction to the Bok globule [CB88] 68. The absorption and distance values are from StarHORSE2 Catalog. Colour Excess $E(b-y)$ vs. distance Diagrams and reddening spatial distribution maps have been used to determine the distance to the [CB88] 68 globule and investigate its possible connection with the nearby dark clouds. [CB88] 68 and PGCC G004.51+16.36 occupy the same area in the sky, have similar colour excess $E(b-y)$ from 0.3 up to 0.9 mag. It is suggested that they identify the same object, only seen from different wavelength ranges. The dark clouds Dobashi 0221 and PGCC G004.74+16.55 present similar behaviour, but reaching much higher $E(b-y)$, from 0.3 up to 1.2 mag. To investigate a possible connection of these objects a region dubbed "Bridge" has been select and shows results similar to the nearby clouds. For comparison, regions without a clear trace of dark clouds does not show $E(b-y) \geq$ from 0.4 mag up to 1.6kpc. The dense cores [LM99] CB 68-1 and [LM99] CB 68-2 seem just a condensation superimposed on larger scale cloud covering the area. The data cannot rule out [CB88] 68 being closer than (200 ± 30) pc, but clear signs of a denser cloud connecting the whole area at about (300 ± 50) pc is presented.

Resumo. Neste trabalho, investigamos as componentes do meio interestelar na direção do glóbulo de Bok [CB88] 68. Os valores de absorção e a distância foram obtidos do Catálogo StarHORSE2. Diagramas de Excesso de Cor $E(b-y)$ vs. distância e de mapas de distribuição espacial do avermelhamento foram usados para determinar a distância até o [CB88] 68 glóbulo e investigar sua possível conexão com as nuvens escuras próximas. [CB88] 68 e PGCC G004.51+16.36 ocupam a mesma área no céu, têm excesso de cor semelhante, $E(b-y)$ de 0,3 a 0,9 mag. Sugere-se que sejam o mesmo objeto, visto apenas em diferentes faixas de comprimento de onda. As nuvens escuras Dobashi 0221 e PGCC G004.74+16.55 apresentam comportamento semelhante, mas atingindo $E(b-y)$ muito mais elevados, de 0,3 até 1,2 mag. Para investigar uma possível conexão entre esses objetos uma região chamada "Ponte" foi selecionada e mostrou resultados semelhantes aos das nuvens próximas. Para efeito de comparação, regiões sem um traço claro de nuvens escuras não mostram $E(b-y) \geq$ de 0,4 mag até 1,6kpc. Os núcleos densos [LM99] CB 68-1 e [LM99] CB 68-2 parecem apenas uma condensação sobreposta à nuvem de maior escala que cobre a área. Os dados não permitem descartar que [CB88] 68 esteja mais próximo do que (200 ± 30) pc, mas demonstram que uma nuvem densa conecta toda a área, em (300 ± 50) pc.

Keywords. ISM: Bok globule – distance – extinction

1. Introduction

Small dark clouds are dense regions with an angular size of less than 10′ that are reasonably isolated and centrally opaque. The target of this research has been firstly classified as the dark cloud LDN 146 by Lynds (1962). Clemens (1988) reviewed its classification as a small molecular cloud, now identified as [CB88] 68. They have stated that [CB88] 68 is closer to being a smaller version of a Bok globule or a Barnard object. Dobashi (2005) estimated the area of [CB88] 68, also know as DOBASHI 0222, as approximately 6 arcmin x 10.2 arcmin (see Figure 1).

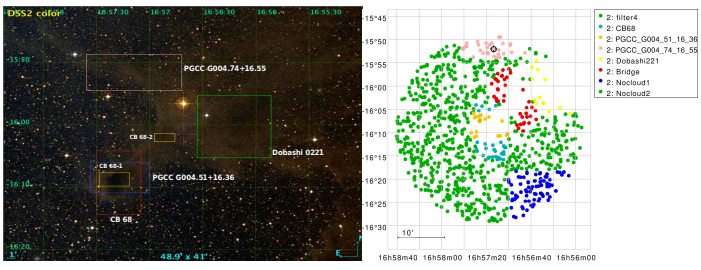

Figure 1. (left) [CB88] 68 region as seen in DSS2. Adapted from Aladin. (right) Skyplot of the [CB88] 68 globule region. The approximate location of the clouds are shown and color coded

Spatially close to the [CB88] 68 globule, within a 20arcmin radius, one can also find PGCC G004.51+16.36. A molecular cloud whose area is 7.9 x 4.8 arcmin^2 (Planck Collaboration 2016). Another four objects are seen, namely: a) PGCC G004.74+16.55, a molecular cloud whose area is 12.9 x 5.8 arcmin^2 according to Planck Collaboration (2016) ; b) Dobashi 0221, a Dark Cloud Nebula whose area is 170.52 arcmin^2 (Dobashi 2011) ; c) [LM99] CB 68-1, a Dense Core whose area is 4.1 x 2.1 arcmin^2 (Lee 1999) and d) [LM99] CB 68-2, a Dense Core whose area is 2.8 x 1.3 arcmin^2 (Lee 1999) . Figure 1 shows the aproximate size and location of the clouds, respectively. The two regions without clouds will be used for comparison.

The goal is to refine the distance to [CB88] 68, that is located in the vicinity of the Ophiuchus molecular cloud complex (Nozawa 1991; Lemme 1996; Launhardt 1997, 1998). According to Imai (2022), the history of the distance to [CB88] 68 begins when Chini (1981), using photometry, estimated it as 160 pc. This same value has been obtained by Launhardt (1998, 2010) by associating it to molecular clouds in the region. They have used two structures [LM99] CB 68-1 and [LM99] CB 68-2, also identified in Figure 1. However, Lombardi (2008) using 2MASS data obtained a much closer distance of (119 ± 6) pc. Then, Ortiz-Leon (2017) presented an estimate for the distance as (137.3 ± 1.2) pc. However, in the case of [CB88] 68, the authors recommended the distance of (120 - 140) pc. Recently,

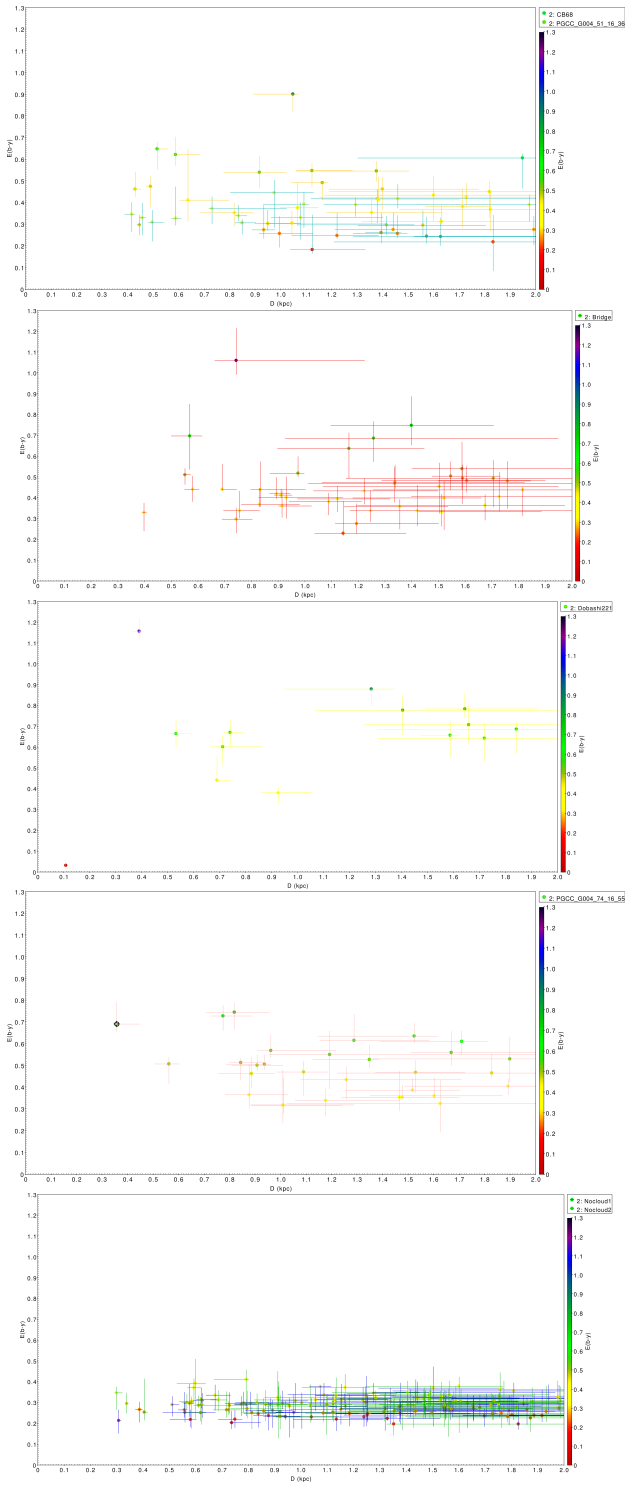

Figure 2. Colour Excess $E(b-y)$ vs. Distance Diagram. From top to bottom: [CB88] 68/PGCC G004.51+16.36; Bridge ; Dobashi 0221, PGCC G004.74+16.55 and two regions without cloud.

Zucker (2019) derived a distance of (144 ± 7) pc, using Gaia data. However, a closer look at the other objects may be also important to shed some light on the objects location.

2. Methodology

The investigation of interstellar medium components along the line of sight to [CB88] 68 and the other surrounding clouds have been carried out following the methodology described in Corradi (1997). As indicated in Reis (2008) we look for abrupt changes in the absorption of the starlight at a certain distance, indicated by a transition in the colour excess, that would represent the distance to the interstellar component. The distance and A_V were obtained from the StarHORSE2 Catalog (Anders 2022).

To obtain the Strömgren $E(b-y)$ Colour Excess, the relation of Crawford & Mandewewala (1976) $E(b-y) = \frac{A_V}{4.3}$ has been used. The data, centred in the coordinates $(RA, DEC) = (16^h\,57^m\,17.5^s; -16d\,09'\,18'')$, covered a 20 arcmin radius. Applied exclusion criteria: Distance ≤ 2 kpc, $A_V < 1.0$, the flags Fidelity > 0.5 and FlagOut < 1. The sample has 928 stars.

3. Results

The Colour Excess $E(b-y)$ vs. Distance Diagram towards the [CB88] 68 direction are shown in Figures 2. A colour scheme based on the E(b-y) has been used. Together with reddening spatial distribution maps they have been used to determine the distance to the [CB88] 68 globule and investigate its possible connection with the nearby dark clouds. [CB88] 68 and PGCC G004.51+16.36 occupy the same area in the sky, have similar colour excess $E(b-y)$ from 0.3 up to 0.9 mag. It is suggested that they identify the same object, only seen from different wavelength ranges.

The dark clouds Dobashi 0221 and PGCC G004.74+16.55 present similar behaviour, but reaching much higher $E(b-y)$, from 0.3 up to 1.2 mag. To investigate a possible connection of these objects a region dubbed "Bridge" has been select and shows results similar to the nearby clouds. For comparison, regions without a clear trace of dark clouds does not show $E(b-y)$ ≥ from 0.4 mag up to 1.6kpc. The dense cores [LM99] CB 68-1 and [LM99] CB 68-2 seem just a condensation superimposed on larger scale cloud covering the area. The data cannot rule out [CB88] 68 being closer than (200 ± 30) pc, but clear signs of a denser cloud connecting the whole area at about (300 ± 50) pc is presented.

4. Conclusion

It is suggested that the [CB88] 68, PGCC G004.51+16.36, PGCC G004.74+16.5, Dobashi 0221 and the Brigde are part of a same larger structure, at (300 ± 50) pc from the Sun.

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