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Revised distances to several Bok globules

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ABSTRACT

Aims. Distances to Bok globules and small dark nebulae are important for a variety of reasons. We provide new distance estimates to several small clouds, some of them known to harbor YSO and molecular outflows, and thus being of particular interest.
Methods. We use a procedure based on extinctions determined from the $(H-K)$ vs. $(J-H)$ diagram, and stellar distances based on a *Hipparcos* calibration of the main sequence locus: $M_J[(J-K)_0]$. The cloud confinement on the sky is determined from contours of the average $(H-K)$ color formed in reseaus. Along the sight line stars affected by the clouds extinction may be extracted from the variation of the number density of atomic hydrogen $n_H \sim A_{V,\star}/D_\star$ to provide the cloud distance and its uncertainty.
Results. According to our estimates, the group of three globules CB 24, CB 25 and CB 26 is located at 407±27 pc, farther than the previous estimates. CB 245 and CB 246 are found at 272±20 pc, suggesting that the current distance to these clouds is underestimated. Toward CB 244 we detect a layer at 149±16 pc and the cloud at 352±18, in good agreement with previous studies. CB 52 and CB 54, though to be at 1500 pc, are found at 421±28 pc and slightly beyond 1000 pc, respectively. It seems that the most distant Bok globule known, CB 3, is located at about 1400 pc, also significantly closer than currently accepted.

Key words. interstellar medium: molecular cloud distances–interstellar medium: individual objects: CB 3, CB 24, CB 25, CB 26, CB 52, CB 54, CB 244, CB 245, CB 246

1. Introduction

Distances to small dark clouds are important for several reasons. First, they are necessary to obtain luminosities of the young stellar objects or protostars embedded in the clouds (e.g., Yun & Clemens 1990). In addition, distances are needed for calculating the masses and densities of the clouds (Clemens, Yun, & Heyer 1991). While volume densities for cloud cores can be obtained via millimeter-wavelength spectral line studies (e.g., Kane, Clemens, & Myers 1994), the core mass determinations require distance knowledge. Finally, accurate information about the properties of small dark clouds is needed in order to test models of these star-forming regions. For starless Bonor-Ebert spheres, e.g. Barnard 68 (Bergin, et al. 2006) the cloud distance is essential to assess its response to gravity. With the currently adopted distance of 125 pc, Barnard 68 seems to be just on the verge of instability. Given core temperature and density the distance estimate decides the stability issue. Being the most simple and regular molecular clouds in our Milky Way, Bok globules are now considered ideal laboratories for the study of the formation of low-mass stars (Vallee et al. 2000). Distances to small molecular clouds are also important in the context of studying the structure of the Milky Way star-forming fields.

All Bok globules are too small and too opaque to easily apply star counts or photometric methods as distance estimators. Since most of the known globules should not be located beyond 1 kpc (Bok & Cordwell-McCarthy 1974), their radial velocities are dominated by peculiar motions rather than by the systematic rotational velocity field of the Galaxy. Thus, the kinematic method of distance determination can not be reliably applied. Another approach is to assume their association with larger molecular cloud complexes. Such approach has been recently used by Launhardt & Henning (1997), increasing the number of globules with known distances. However, in many cases this procedure is quite uncertain. There is also a significant number of globules which could not be associated with any known large molecular cloud structure and for them simply the average distance of 500 pc has been adopted (see Launhardt & Henning 1997). Due to these difficulties, at present only very few globules have reliably determined distances.

Despite the difficulties, at present the method of photometric distance determination seems to be most reliable. Optical or infrared photometry of moderately obscured stars located at the peripheries of the globules allows us to derive individual stellar distances and thus estimate the distance to the clouds. For example Franco (1988) used *uvbyβ* photometry to obtain an accurate distance to the dark cloud L1569. Recently Piehl, Briley, & Kaltcheva (2010) obtained *uvbyβ* photometry of stars at the peripheries of CB 3, CB 52, CB 54 and CB 246 and provided new distance estimates to some of these clouds. A broadband BVI photometry of reddened M dwarfs located in front of and behind CB 24 has been used by Peterson & Clemens (1998) to establish a method bracketing the cloud's distance. Snell (1981) studied reddened background stars to obtain an upper limit to the distance of nine Bok globules. Maheswar & Bhatt (2006) obtained distances to another nine dark globules using a method based on optical and near-infrared photometry of stars projected towards the field containing the globules. Knude (2010) developed a statistical method based on the 2MASS catalog for obtaining distances to molecular clouds with a distance uncertainty of less than 10 pc, but for the small features discussed presently the uncertainty changes to a few times 10 pc. The method has been

developed to be applicable to larger clouds, but it also provides rather reliable distances for small isolated globules.

In this paper we demonstrate the application of this method to small-scale fields in direction of several Bok globules and obtain new estimates of their distances.

2. Discussion

The procedure of estimating the distance to the globules studied in this article is described in detail by Knude (2010): briefly outlined the extinctions are determined from the $(H - K)$ vs. $(J - H)$ diagram, and the stellar distances - from a *Hipparcos* calibration of the main sequence locus: $M_J[(J - K)_0]$. For a region containing a cloud of some extinction, a rather large sample of distance-extinction pairs $(D_\star, A_{V,\star})$ of included stars is available. The cloud confinement on the sky is determined from contours of the average $(H - K)$ color formed in reseaus, $(H - K)_{res}$, as seen on the following figures. Along the sight line stars affected by the clouds extinction may be extracted from the variation of the number density of atomic hydrogen $n_H \sim A_{V,\star}/D_\star$. Stars included in the determination of the cloud distance fulfill two criteria: they are located in a reseau whose $(H - K)_{res}$ exceed a minimum value and their line of sight density falls in the peak caused by the cloud. This sample allows a fit of a general function providing the cloud distance and its uncertainty.

2.1. The region l: 155°-157°, b: 4.5°-6.5°

Several globules are located in this field, as listed in Table 1. CB 24 is a small starless spherically shaped cloud that was found to have low column density suggesting insignificant core contraction (Kane, Clemens, & Myers 1994). Using their photometric method, Peterson & Clemens (1998) found a maximum distance of 360 pc to this cloud. No IRAS point source is associated with CB 24. CB 25 was studied by Sen et al. (2000) and was one of the two clouds in their sample which exhibited the best alignment of their polarization vectors in the direction of increasing galactic longitude. The isolated Bok globule CB 26 contains an edge-on T Tauri star-disk system and is so far the most promising source to study the rotation of a molecular outflow (Launhardt et al. 2009). The latter authors recently performed millimeter-interferometric observations in order to study the disk-outflow connection, thought to play a key role in extracting excess angular momentum from a forming proto-star. Adopting a distance of 140 pc (Snell 1981), they calculated a total projected length of the bipolar molecular outflow of 2000 AU. We did not find in the literature attempts to estimate the distance of the rest of the globules included in Table 1.

Fig. 1 (top) presents contours from the average of the $(H-K)$ color, formed in reseaus, that should be directly linked to the extinction, A_V proportional to $(H-K)_{res}-(H-K)_0$. The contours of the calculated extinction, A_V, are included in the second plot and the resemblance with the average $(H-K)$ contours is evident. In the upper panel of Fig. 1, according to the $(H - K)$ contours the three CB clouds are located $\sim 0.5°$ above another, apparently more extincted region comprising a collection of LDN clouds. In order to have enough stars one might assume that the three CB clouds and the LDN clouds were associated, which may or may not be the case. Combining the stellar data from all the reseaus in Fig. 1 (top) with $(H - K)_{res} > 0.175$, a distance ~ 225 pc would be estimated. Restricting sight lines to latitudes larger than 5.5° (still referring to top frame of Fig. 1) and $155.5° \leq l \leq 156.2°$ we have a region referring to the three CB clouds only. The resulting pairs in these ~ 0.5 sq.deg within ~ 1000 pc are
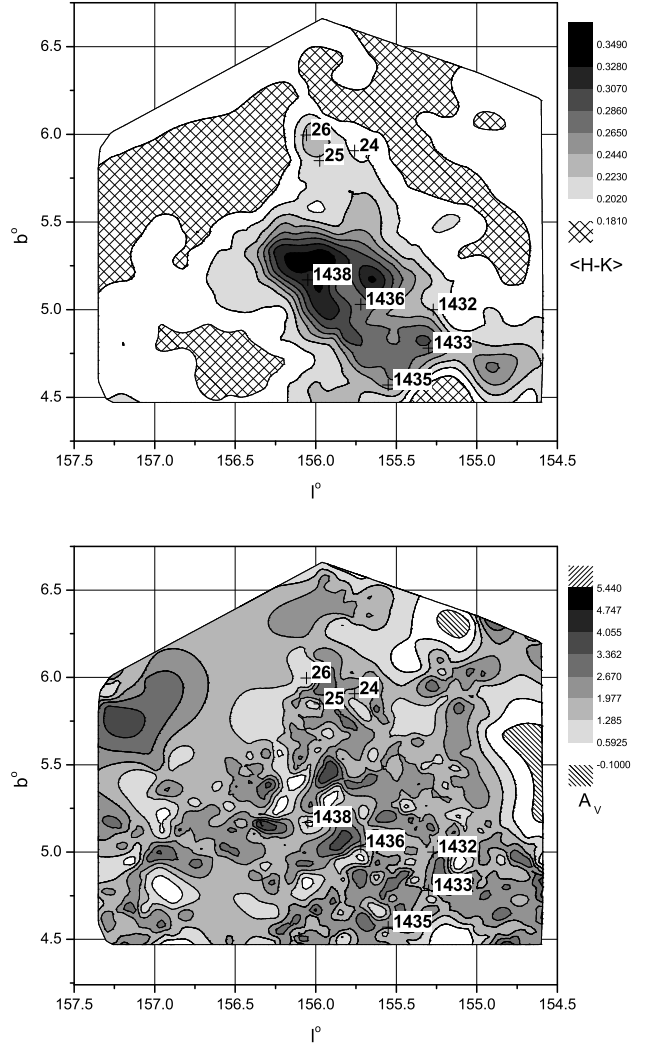

Fig. 1. The region l: 155°-157°, b: 4.5°-6.5°: distribution of the average index $(H - K)$ and the calculated extinction across the field.

Table 1. Small dark coulds in the field l=(155°-157°), b=(4.5°-6.5°). Identifications by Clemens & Barvainis (1988, CB88 hereafter) and Lynds (1962) (or alternative identification if available), followed by radial velocities included in CB88, previous estimates of distance found in the literature, and the distance calculated in this paper.

CB	LDN	V_{LSR} km s^{-1}	Distance (pc) (prev. est.)	Distance (pc) (this paper)
24	G115.76+5.9	4.6	360[1]	407±27
25	1437	5.2	-	407±27
26	1439	5.8	140[2,4], 300[3]	407±27
-	1432	-	-	225+
-	1433	-	-	225+
-	1435	-	-	225+
-	1436	-	-	225+
-	1438	-	-	225+

[1]Peterson & Clemens (1998); [2]Snell (1981), [3]Launhardt & Henning (1997), [4]Launhardt & Sargent (2001)

shown in Fig. 2 (top). The lowest curve is a scaled dn_H/dD, where n_H is the average line of sight density derived from the median A_V. The median is the upper dark curve and n_H is the
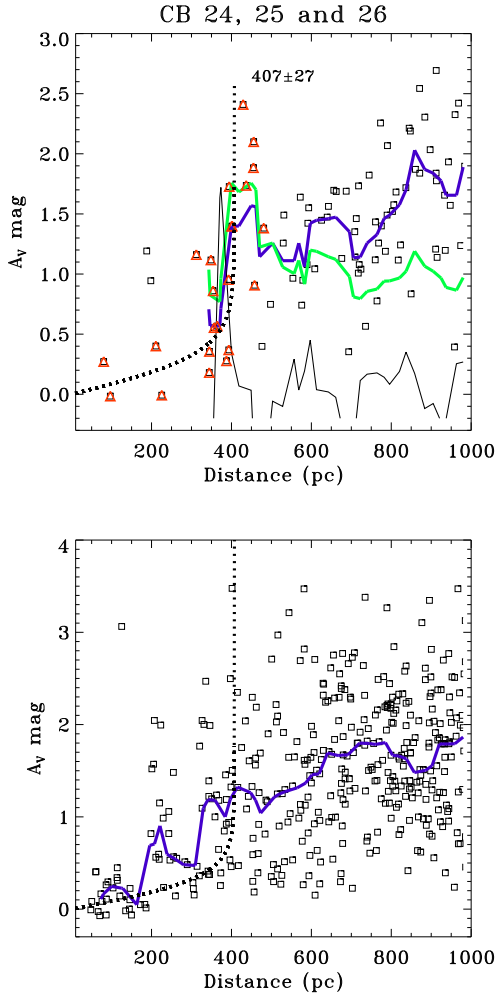
Fig. 2. Top panel. Stars confined to b≥5.5°and 155.5°≤l≤156.2° in the panels of Fig. 1. Lower curve is a scaled derivative of the average line of sight density. The light gray curve is a scaled average line of sight density. The black curve is the median extinction. Triangles compose the fitting sample and the dotted curve the fitted arctanh. The lower panel of Fig. 2 is the extraction for b≤ 5.5° and $l \leq 156.6°$ (and still within the frame of Fig. 1), and again with $(H - K)_{res} > 0.175$. The curve displays the run of the median extinction for this region.

light gray one. dn_H/dD shows a maximum at ∼ 450 pc. The squares overplotted with a triangle is the fitting sample. We note two stars at $(D_\star, A_{V,\star}) \sim (220, 1)$ which have not been included in the fit. They are left out because they may pertain to another feature at ∼ 200 pc, which is more obvious in the lower panel. Fitting *arctanh* results in 407 ± 27 pc as the suggested distance to the ensemble of three CB clouds. The lower panel of Fig. 2 is the extraction for $b \leq 5.5°$ and $l \leq 156.6°$ (and still within the frame of Fig. 1(top)), and again with $(H - K)_{res} > 0.175$. The curve displays the run of the median extinction for this region. We notice a more complicated structure than for the top panel. More than 10 stars display a rise to $A_V \sim 2$ mag in a narrow distance range centered on ∼ 225 pc, followed by a decline and another rise at ∼ 325 pc. For comparison, we also plot the curve fitted to the three CB clouds at 407 pc. We can not know whether the absence of extincted stars between 225 and 325 pc is a selection effect or is a real interstellar medium feature, caused by a patchy distribution of matter that allows low extinction lines of sight through the 225 pc structure. The LDN clouds in the lower part of Fig. 1(top) may thus have a distribution in depth.
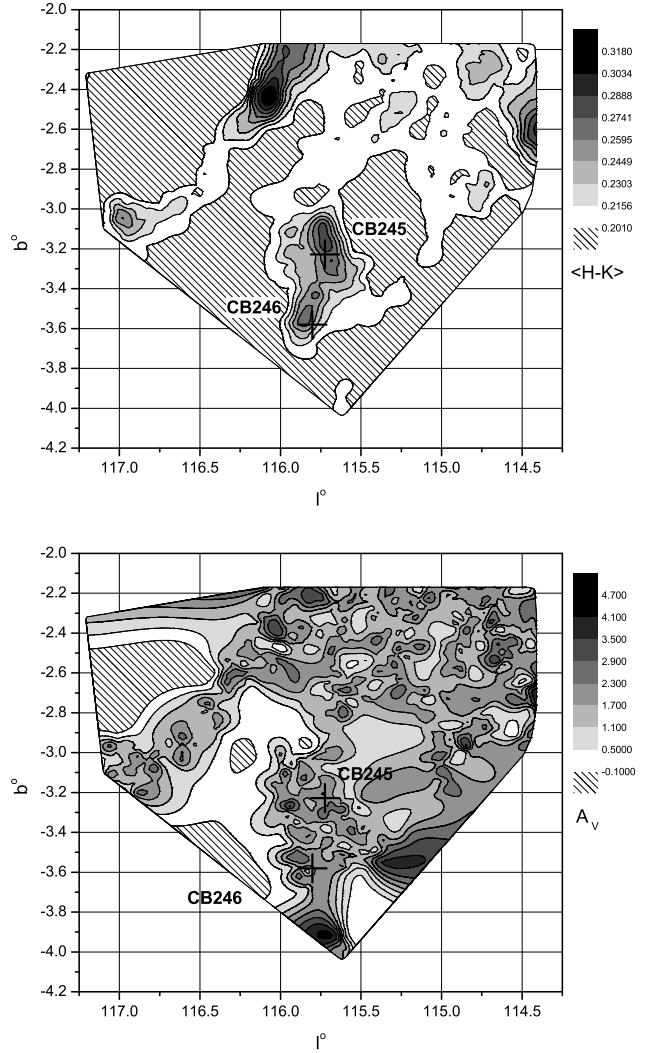

Fig. 3. The field of CB 245 and CB 246: distribution of the average index $(H - K)$ and the calculated extinction across the field.

2.2. The field of CB 245 and CB 246

The region between l=(114.5°,117°) and b=(-4.0°, -2.0°) contains two known Bok globules as listed in Table 2.

Table 2. CB 245 and CB 246. CB and LDN identifications, followed by radial velocities included in CB88, previous estimates about distance found in the literature, and the distance calculated in this paper.

CB	LDN	V_{LSR}	Distance (pc) (previous estimates)	Distance (pc) (this paper)
245	-	-0.8	-	272 ± 20
246	1437	-0.5	140[1]; 377 ± 51[2]::	272 ± 20

[1]Launhardt & Henning (1997); [2]Piehl, Briley & Kaltcheva (2010)

CB 246 does not contain any YSO, IRAS point source or CO outflows. Sen et al. (2000) found that in this cloud the polarization vectors are poorly aligned amongst themselves and also with the direction of increasing galactic longitude. Maheswar & Bhatt
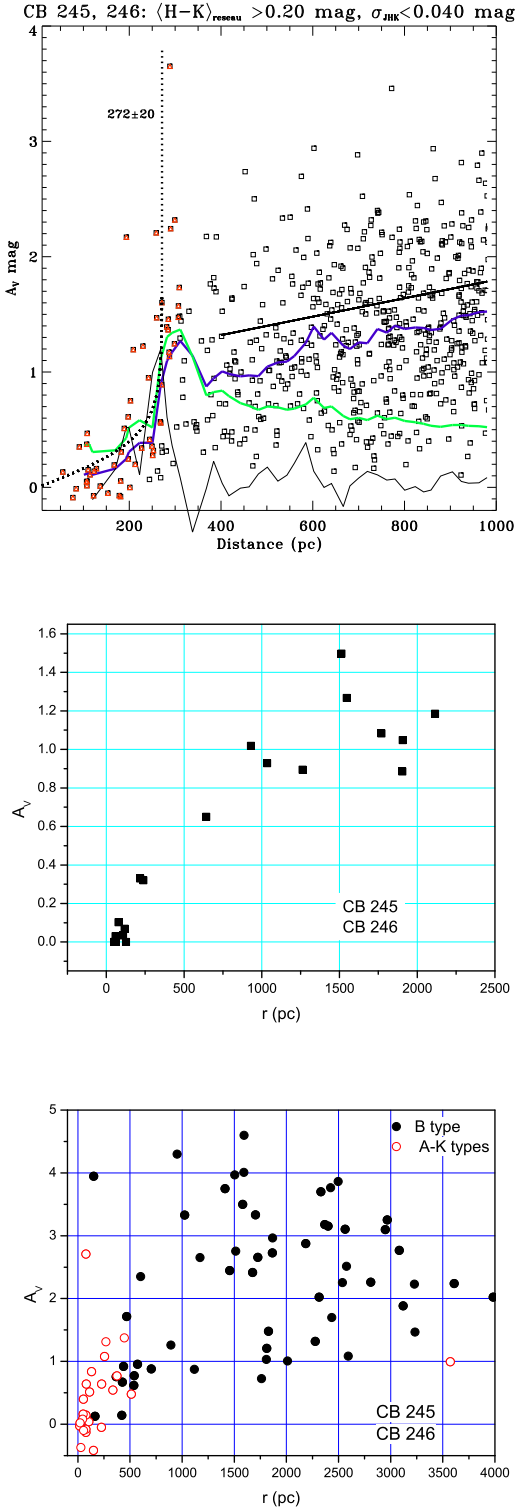
CB 245, 246: $\langle H-K \rangle_{reseau} > 0.20$ mag, $\sigma_{JHK} < 0.040$ mag

Fig. 4. Resulting distances vs. extinction diagram for the same field as in Fig. 3. The lowest solid curve indicates the derivative of line-of-sight density (arbitrary scale); the middle solid curve presents the line-of-sight density (arbitrary scale) and the upper solid curve is for median extinction (to scale). The straight line indicates the run of extinction increase from the ICM alone. Middle: extinction vs. distance for field stars with *uvbyβ* photometry in this coordinate range. Bottom: extinction vs. distance for field stars with UBV photometry and *Hipparcos* data in this coordinate range.

Table 3. CB 244: identifications, followed by radial velocities included in CB88, previous distance estimates, and the distance calculated in this paper.

CB	LDN	V_{LSR} (km s^{-1})	Distance (pc) (previous estimates)	Distance (pc) (this paper)
layer		3.9	180[1]	149±16
244	1262	3.9	370[1]	352±18

[1]Kun (1998)

(2006) obtained a distance of 400±80 pc for CB 242, which is located about 8° apart from CB 246.

Contours from the average of the $(H - K)_{res}$ color and of the calculated extinction are presented in Fig. 3. The plot of the calculated extinction vs. distance based on the 2MASS sample is shown in Fig. 4 (top). The fitting sample, presented as squares with an inscribed triangle, provides a final estimate of 272 ± 20 pc. The distance 272 ± 20 pc pc may also pertain to the two LDN clouds (1257 and 1258, not labeled on Fig. 3) located at $(l, b) = (116.0, -2.5)$. At least we can not see any different distance in our data. The field stars in this direction with available *uvbyβ* photometry (Fig. 4, middle) and available UBV photometry and *Hipparcos* data (bottom), reveal an increase of the extinction at a distance of about 250 pc. This supports the impression that the ISM structure containing CB 245 and CB 246 should be located beyond this distance. Stars at the periphery of CB 246 have been studied by Piehl, Briley & Kaltcheva (2010), but their distance estimate 377±51 pc is based on only two stars and should be considered uncertain. All of these findings support the impression that the presently adopted literature value 140 pc for CB 246 is indeed an underestimate.

2.3. The region of CB 244

CB 244 is located outside the main body of the Cepheus Flare molecular complex, and manifests a lack of background stars (Hodapp 1994). It has been suggested that it is probably part of the Lindblad ring (Lindblad et al. 1973), or of the Polaris Flare molecular cloud toward higher Galactic latitudes (Shapley & Jones 1937; Heithausen & Thaddeus 1990). Based on objective prism Schmidt survey, Kun (1998) presented a Wolf diagram for a 3°×4° field centered on the globule in order to determine its distance. She found a nearby layer around 180 to 200 pc, and another one at 370 pc. However, a distance of 180 pc has been adopted for CB 244 based on arguments connected to the properties of the T Tauri star AS 507 located along the line of sight to the globule LDN 1259 in the vicinity of CB 244 (see Kun 1998).

Contours from the average of the $(H - K)$ color and of the calculated extinction for this field are presented in Fig. 5. The area extracted from 2MASS is less than a square degree and the 0.1 sq.deg size of the densest parts of CB 244 illustrates the problem of having enough sight lines through the small globules. The bottom panel shows that we only have extinction measurements through the rim of the globule. In order to study the surroundings of CB 244 we further extracted 2MASS data for a 4°×4° region centered on (l, b) = (117°, +11°) in particular the part closer to the galactic plane. The results are presented in the top panel of Fig. 6. The squares show the distribution all over the 4°×4° field. The first discontinuity, open squares, is fitted by $D = 149 \pm 16$ pc. Leaving out these stars the next discontinuity is fitted by $D = 352 \pm 18$ pc. Confining the solid angle to $10.6° < b < 12.6°$ and $116.1° < l < 117.8°$ (see Fig. 5) the sample
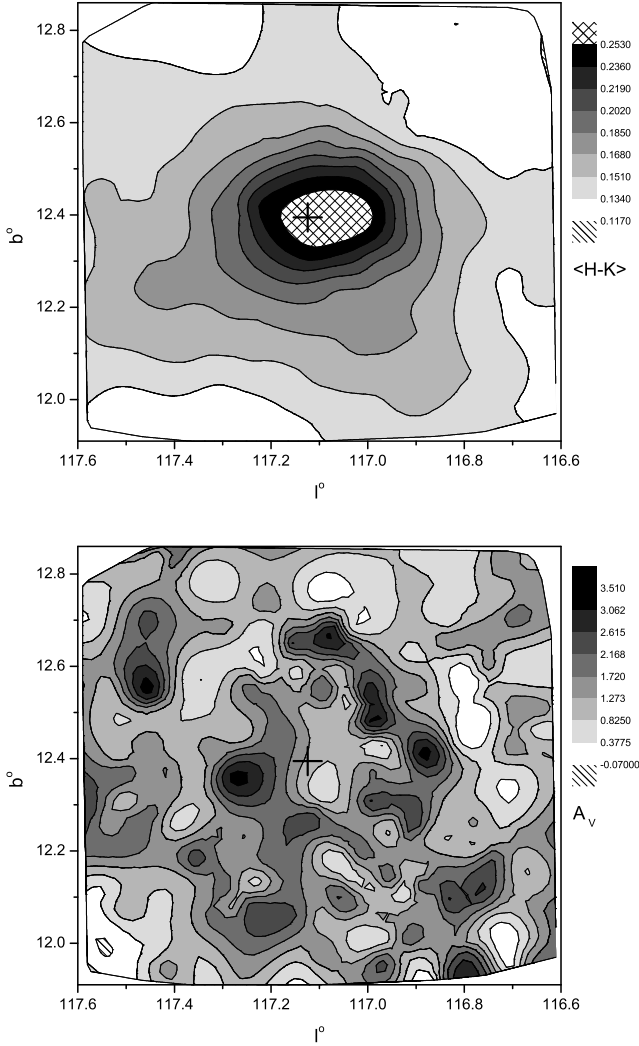
Fig. 5. The field of CB 244: distribution of the average color index ($H - K$) and of the extinction across the field. The location of CB 244 is shown with a large plus symbol.

Fig. 6. Top: resulting distances vs. extinction diagram for the field of CB 244. The lowest solid curve indicates the derivative of line-of-sight density (arbitrary scale); the middle solid curve presents the line-of-sight density (arbitrary scale) and the upper solid curve is for median extinction (to scale). Large open diamonds display the variation of extinction found for *Hipparcos* stars with Michigan classification in the $4° \times 4°$ field centered on (l, b) = (117, +11). The second panel is data for a one square degree box centered on CB 244 with σ_{JHK} relaxed to <0.10 mag comprising reseaus exceeding 0.15 mag.

is limited to the black squares. The lower panel is data from a $1° \times 1°$ area centered on CB 244 with σ_{JHK} relaxed to <0.1 mag and are shown on an expanded distance scale. The fit from the upper panel is repeated. It seems justified to claim 352 ± 18 pc as the CB 244 distance. The straight line in this panel indicates that beyond CB 244 our sample only pick up the contribution from the inter-cloud medium. The upper panel also contains information derived from *Hipparcos* parallaxes and Michigan classification from a $4° \times 4°$ area and a few stars (large diamonds) indicate that the extinction may rise to 0.5 – 1.0 mag at ∼ 150 pc and exceed 1 mag beyond ∼ 350 pc. Thus there are indications that two structures can be found in direction of CB 244, at 149 ± 16 pc and 352 ± 18 pc, respectively.

To support this findings, all stars in a $3° \times 3°$ field centered on CB 244 were extracted from the new reduction of the *Hipparcos* catalog and their distribution in terms of distance is shown in the first panel of Fig. 7. Two clumpings of stars are evident, at 100 and 265 pc, respectively, in support of the impression of two layers in this direction. The field stars with available *uvbyβ* photometry (Fig. 7, second panel) also reveal a steep increase of the extinction beyond 310 pc.
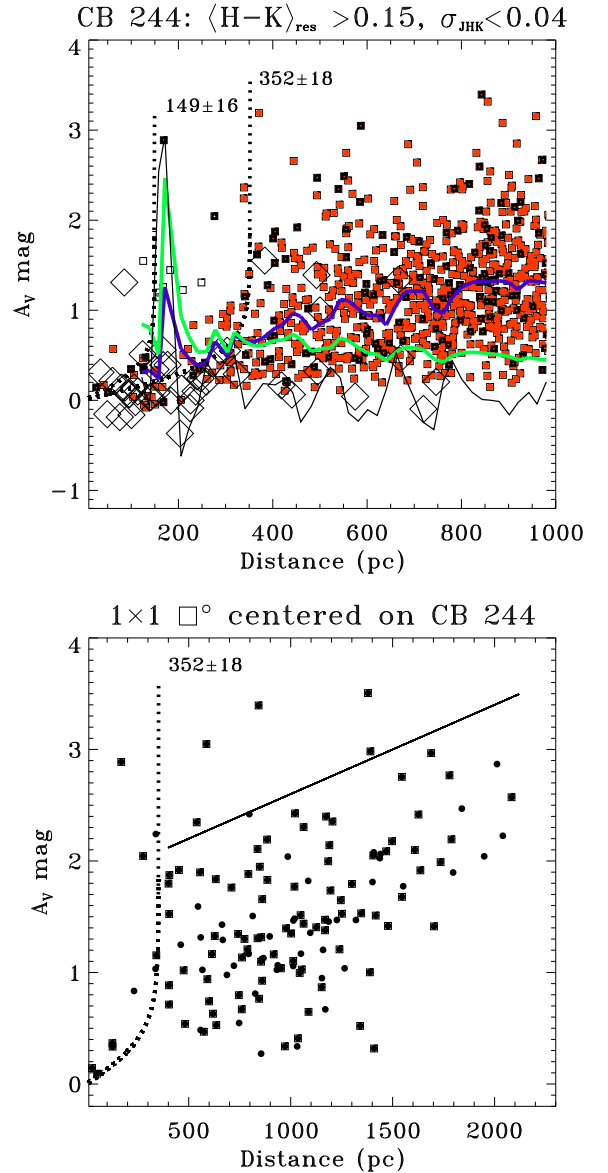
2.4. CB 52 and CB 54

Sen et al. (2000) found that the alignment of the polarization vectors appear to be disturbed and the polarization values quite dispersed for these two globules. In CB 54, the same authors suggested a presence of an emission nebulosity associated with the cloud. CB 54 contains YSO, IRAS point sources and CO outflows. Launhardt & Henning (1997) calculated kinematic distances of 1500 pc for both CB 52 and CB 54 and associated them with the Vela OB1 cloud complex. Based on *uvbyβ* photometry of stars in their peripheries, Piehl, Briley & Kaltcheva (2010) estimated a distance 579±50 pc to CB 52 (based on 4 stars only) and 918±73 pc to CB 54 (based on 14 stars). The
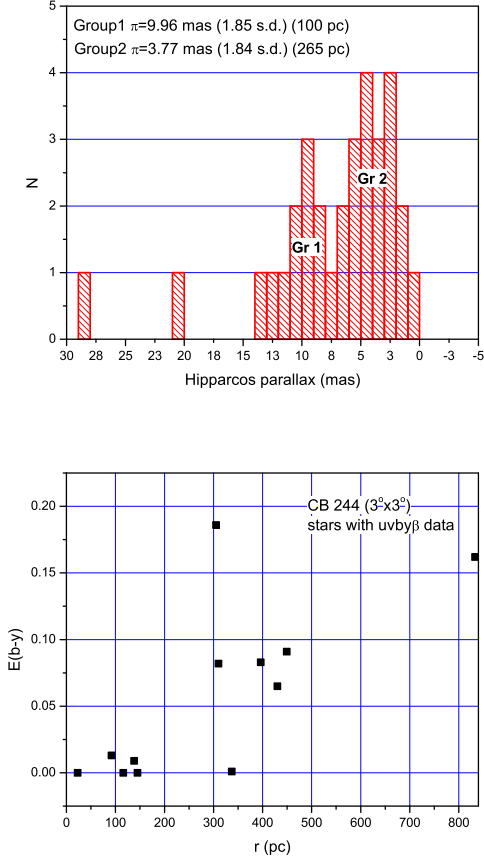
Fig. 8. The field of CB 52 and CB 54: distribution of the average index $(H - K)$ across the field.

Fig. 7. Top panel: distribution of stars in *Hipparcos* in a $3^o \times 3^o$ centered on CB 244. Second panel: extinction vs. distance for field stars with *uvbyβ* photometry in this coordinate range.

latter distances suggest that both globules are located within the CMa star-forming field.

Table 4. CB 52 and CB 54: identifications, followed by radial velocities included in CB88, previous estimates about distance found in the literature, and the distance calculated in this paper.

CB	LDN	V_{LSR} (kms^{-1})	Distance (pc) (previous estimates)	Distance (pc) (this paper)
52	-	16.6	1500^1; 579 ± 50^2	421 ± 28
54	-	19.5	1500^1; 918 ± 73^2	$> 1000::$ pc

[1]Launhardt & Henning (1997); [2]Piehl, Briley, Kaltcheva (2010)

As the $(H - K)_{res}$ contours of Fig. 8 show, CB 52 is part of the lower of two parallel filaments whereas CB 54 is isolated. The option for a distance to CB 52 is thus better than for CB 54. Restricting the sample to stars in reseaus with $(H - K)_{res} > 0.15$ and plotting the data for the upper filament as squares and the lower (with CB 52) as triangles the distribution becomes as in Fig. 9 (a). The two filaments display similar extinction - distance patterns. The median extinction and average line of sight density for the combined sample are shown. There is an apparent extinction jump at 250 pc and we may fit an uncertain distance 237 ± 50 pc to it. A second, better populated rise is noticed at ~ 400 pc to which a distance 421 ± 28 pc may be fitted. To
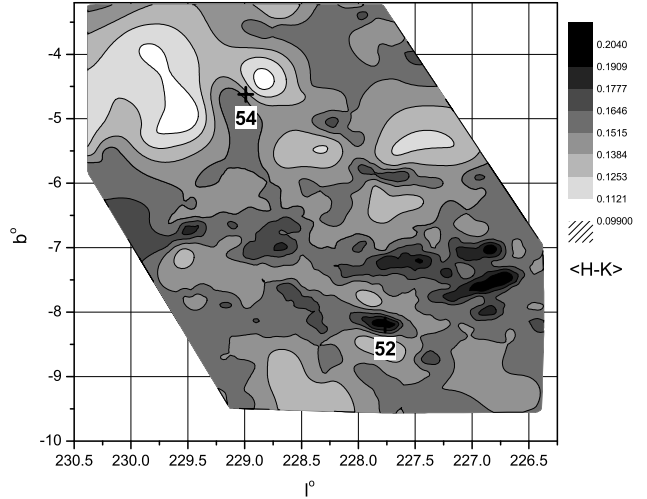
investigate the possible CB 52 distance a bit further we use another sample centered on the cloud but relaxing the photometric error to $\sigma_{JHK} < 0.1$ as compared to the data of panel (a) with $\sigma_{JHK} < 0.04$. Black dots depict stars with no $(H - K)_{res}$ restrictions. Dots in a square are the stars in reseaus exceeding 0.15. The fit 421 ± 28 pc forms a nice envelope to these data. In the $1^o \times 1^o$ box no stars measuring the feature at 237 pc are present. Our conclusion is accordingly that CB 52 is at 421 ± 26 pc. Since CB 52 is at a negative declination we may combine *Hipparcos* parallaxes and Michigan classification to have an impression of how a more precise distance determination may alter the distance – A_V diagram. Due to the much lower surface density of stars with a measured parallax we open up the solid angle to a wide $7^o \times 7^o$ centered on (l, b) = (228.3^o, -6.5^o); 7° since this is the latitude range of Fig. 8. If we compare panel (c) based on the *Hipparcos* parallaxes to panel (a), the stars within ~ 500 pc display a remarkable similarity. The 225 pc feature is also present in the *Hipparcos* sample. Surprisingly the 421 ± 26 pc fitted curve also fits the *Hipparcos* - Michigan data as well. CB 52 is a tiny structure. Its appearance may be seen in Fig. 1 of Maiolo et al. (2007). $(H - K)_{res} = 0.185$ contour displays an elongated structure measuring $\delta(l) \times \delta(b)$ of 20×10 $arcmin^2$. From this discussion we suggest the distance of CB 52 to be 421 ± 26 pc. Note that this distance is in a fair agreement with that derived by Piehl, Briley & Kaltcheva (2010), while both estimates disagree with the adopted distance of 1500 pc.

For CB 54 the situation is less favorable. We may not tie this globule to any neighboring extinction feature. Fig. 8 shows that CB 54 is almost 2° away from the filament at b~ -7°. If we relax to $\sigma_{JHK} < 0.1$ one could hope to have more stars as in panel (b) for CB 52. But this is not the case. Panel (d) are stars with $\sigma_{JHK} < 0.1$ and $(H - K)_{res} > 0.185$ that pertain to CB 54 and are separated less than 3.5 arcmin from the nominal cloud center. The curve is the expected effect from the diffuse medium outside molecular clouds assuming a density $n_H = 0.8$ cm^{-3} in the plane and a scale height $h_Z = 140$ pc. We notice that beyond 1000 pc (a most uncertain distance estimate) we see stars several magnitudes above the inter-cloud medium variation. A most tentative suggestion for CB 54 is that it probably is slightly
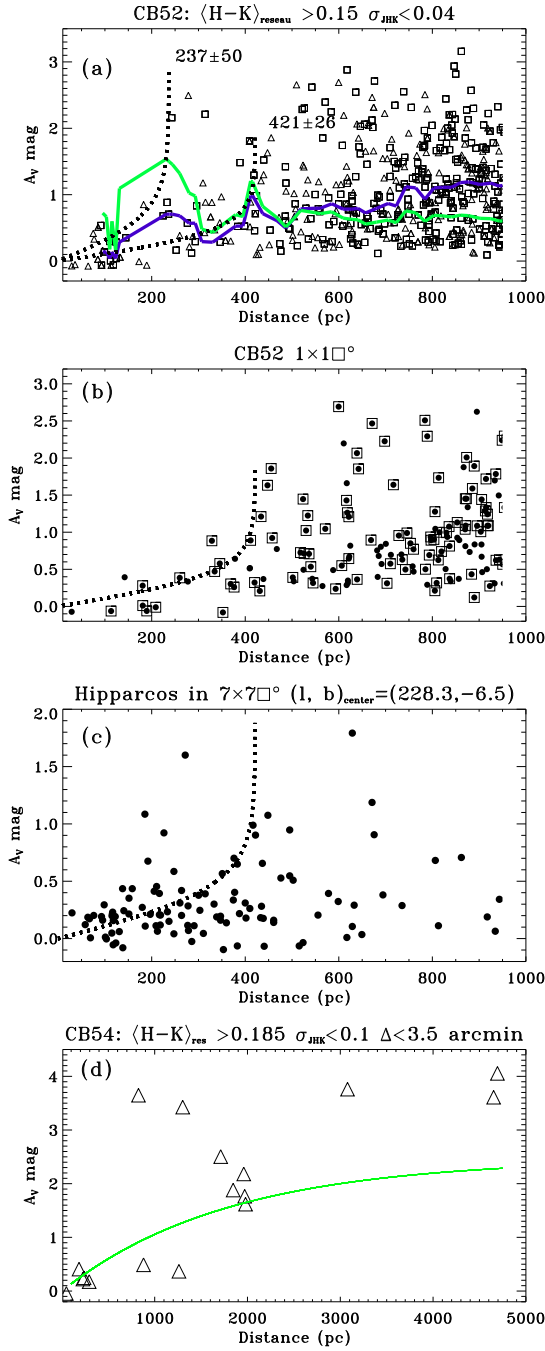
Fig. 9. (a) Resulting distances vs. extinction from the field in Fig.8. Data pertaining to the two filaments are plotted with different symbols. Triangles are for the one containing CB 52. (b) 1°×1° on CB 52 but with σ_{JHK} <0.1 mag. Dots average (H-K) > 0.15. Dots in a square (H-K) >0.16 mag. Curve is the one fitted to the data in panel (a). (c) Extinction variation from Hipparcos/Michigan in a 7°×7° area centered on (l, b) = (228.3°, -6.5°). Curve is again the one fitted to the data in panel (a). (d) Data for CB54 with σ_{JHK} < 0.1 and reseau average exceeding 0.185. Incidentally these sight lines are within ≈3.5 arcmin of the nominal center of CB 54. The curve displays the expected variation caused by the diffuse medium outside the molecular clouds assuming n_H=0.8 cm^{-3} in the plane and a scale height h_Z = 140 pc.

beyond 1 kpc, which is in agreement with the estimate based on $uvby\beta$ photometry (see Table 4).

The field stars with available $uvby\beta$ photometry (Fig. 10) reveal an increase of the extinction at ∼ 500 pc for CB 52, and an
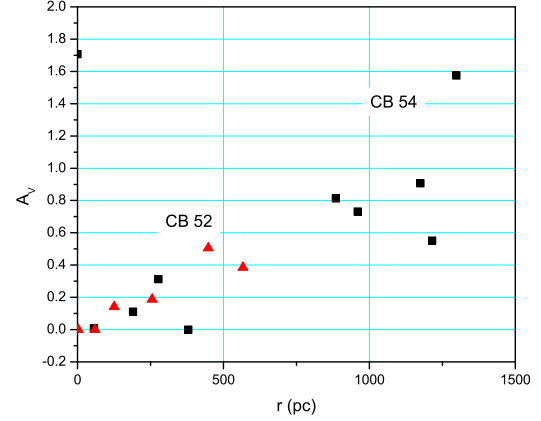

Fig. 10. Extinction vs. distance for field stars with $uvby\beta$ photometry in this coordinate range of CB 52 (triangles) and CB 54 (squares).

increase at ∼ 1000 pc in direction of CB 54, thus supporting the findings based on the 2MASS sample.

2.5. The field of CB 3

CB 3 is the most distant object among all globules in the list of Launhardt & Henning (1997), and thus the only one presently associated with the Perseus arm. Based on $uvby\beta$ photometry of 16 stars located in the periphery of this globule, Piehl, Briley & Kaltcheva (2010) obtained a distance of 969±112 pc to the cloud, but an increase in the extinction is evident at 457±18 pc. A distance of about 1 kpc would position the cloud within the Local arm.

Table 5. CB 3: identifications, followed by radial velocities included in CB88, previous estimates about distance found in the literature, and the distance calculated in this paper.

CB	LBN	V_{LSR} (kms^{-1})	Distance (pc) (previous estimates)	Distance (pc) (this paper)
3	594	-38.3	2500[1]; 969 ± 112[2]	1419 ± 46:

[1]Launhardt & Henning (1997); [2]Piehl, Briley, Kaltcheva (2010)

Contours from the average of the $(H - K)$ color and of the calculated extinction for this field are presented in Fig. 11, depicting CB 3 as an isolated cloud, not connected to any of the surrounding larger features. The plot of the calculated extinction vs. distance based on the 2MASS sample is shown as squares in Fig. 12 (top). In order to obtain a distance estimate to CB 3 only, this plot was confined to a small region: 119.66°≤ l≤120.06°; -6.19°≤ b≤ -5.808°. Stars with average $(H - K) > 0.125$ mag and $\sigma_{JHK} < 0.04$ mag are included. Lower curve scaled average density and the upper curve represents median extinction. Variation in mean density can not be used to locate any remote clouds be-
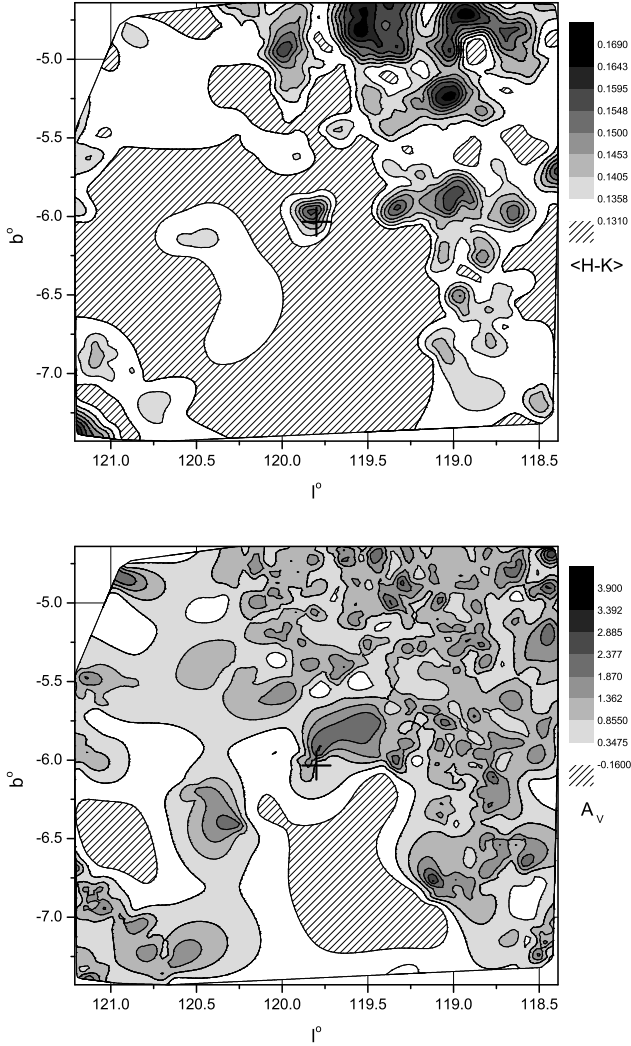
Fig. 11. The field of CB 3: distribution of the average index $(H - K)$ and extinction across the field. The location of the cloud is shown with a large plus symbol.

Fig. 12. Top: resulting distances vs. extinction diagram for a similar field as in Fig. 11. The lowest solid curve indicates the average of line of sight density (arbitrary scale); the upper solid curve presents the median extinction (to scale). Small filled symbols within 1 kpc are the extinction variation from the *Hipparcos* - Michigan combination of data. Bottom: extinction vs. distance for field stars with UBV photometry and *Hipparcos* parallaxes in this coordinate range.

cause the distances are so large that the diffuse medium itself contributes ~1.5 mag at 1.5 kpc thus smoothing the median extinction. *Hipparcos* stars with distance–A_V pairs calculated for a 3°×3° centered on (l, b)=(119.8006°,-06.0345°) are shown in the plot, but not included in the distance fit. The *Hipparcos*-Michigan combination of data indicates a local extinction increase at ~ 250 pc.

Our new estimate for the distance to CB 3 is 1419 ± 46 pc, significantly smaller than the kinematic distance of 2500 pc provided by Launhardt & Henning (1997). The field stars with available UBV photometry and *Hipparcos* parallaxes in a 3°×3° region centered on CB 3 are included in the second panel of Fig. 12. They also indicate a slight increase in the extinction at 250 pc and a more significant jump at about 1000 pc.

3. Conclusion

Utilizing the 2MASS catalog and applying a statistical method based on extinctions determined from the $(H-K)$ vs. $(J-H)$ diagrams, and stellar distances from a *Hipparcos* calibration of the main sequence, we obtain new distances to several small molec-

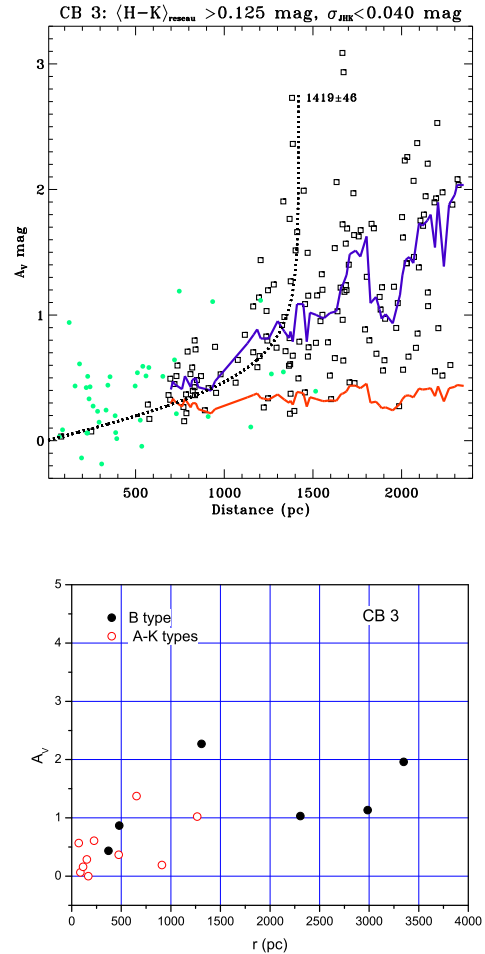ular clouds. We find that the group of three globules CB 24, CB 25 and CB 26 is located at 407±27 pc, a distance larger than the previous estimates. The collection of LDN clouds found ~ 0.5° below the three CB clouds is beyond 225 pc and possibly has a distribution in depth. CB 245 and CB 246 are both at 272±20 pc. A layer at 149±16 pc is detected in front of CB 244, which is located at 352±18 pc. CB 52 and CB 54 are found at 421±28 pc and slightly beyond 1000 pc, respectively. We estimate a distance about 1400 pc to CB 3, ruling out its connection to the Perseus Arm.

The way we estimate the distance to a globule from 2MASS-*Hipparcos* was devellloped for more extended molecular features. It is thus encouraging that this method may possibly also be of some use to much smaller interstellar clouds when they are within ~500 pc and located in dense stellar fields. The size of the formal distance error from the curve fitting has increased but is still on the ≲10% level.

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