Imaging polarimetry of the rotating Bok globule CB67

M.S. Prokopjeva\textsuperscript{a,}\textsuperscript{*}, A.K. Sen\textsuperscript{b,c}, V.B. Il’\textsuperscript{d,e}, N.V. Voshchinnikov\textsuperscript{a}, R. Gupta\textsuperscript{b}

\textsuperscript{a}St. Petersburg State University, Astronomical Institute Universitetskij pr. 28, St.Petersburg, 198504, Russia
\textsuperscript{b}Inter University Centre for Astronomy and Astrophysics, Ganeshkhind, Pune 411007, India
\textsuperscript{c}Assam University, Silchar, 788011 India
\textsuperscript{d}Main (Pulkovo) Astronomical Observatory, Pulkovskoe sh. 65/1, St.Petersburg, 196140, Russia
\textsuperscript{e}St. Petersburg State University of Aerospace Instrumentation, ul. Bolshaya Morskaya 67, St.Petersburg, 190000, Russia

Abstract

Polarimetric observations of about 50 stars located in a close vicinity of the Bok globule CB67 having significantly nonspherical shape and rapid rotation are performed. The data obtained are compared with the available observations of this globule at radio and submillimeter wavelengths as well as some theoretical calculations. It is found that the elongation and the rotation moment of CB67 are oriented rather perpendicular to the magnetic fields, which is unusual for Bok globules and is difficult to be explained from the theoretical point of view.

Keywords: Bok globules, polarimetry, interstellar magnetic fields

1. Introduction

The Bok globules are known to be small molecular clouds where low mass stars are formed. Despite a long interest in these rather simple objects, details of the star formation process in them are not well known (see, for example, \cite{1,2,3}). Undoubtedly, the magnetic fields and to some extent rotation should play an important role in the evolution of the globules \cite{4}. However, detailed observational data are still required for more adequate understanding of the low mass star formation.

Observations of polarization of background stars is the basic way to study the magnetic fields in the vicinity and outer layers of such clouds \cite{5}. Though the first polarization maps of Bok globules were obtained in the mid-eighties, only in a few cases the data were sufficiently detailed (the number of stars was about 30 or more). Like for more massive clouds the polarization maps of globules have shown different behavior of the magnetic fields (see for more details \cite{1}). The connection of the magnetic fields in the outer regions of globules with those in their cores has been investigated by using the polarization maps at submillimeter wavelengths \cite{6}.

\textsuperscript{*Corresponding author.

Email addresses: ari-76@yandex.ru (M.S. Prokopjeva),
asokesen@yahoo.com (A.K. Sen), 11in55@yandex.ru (V.B. Il’in),
voshchinnikov@mpi-hd.mpg.de (N.V. Voshchinnikov), ranjanicaa@gmail.com (R. Gupta)

Information about angular velocity and the kind of rotation has also been obtained only for a few Bok globules (see, for example, \cite{7,8}). The magnetic fields and rotation of globules were observationally considered only by Kane and Clemens \cite{9}. Using polarization maps obtained for 6 globules with known rotation (the maps were not presented in the paper), they concluded that the magnetic fields, the rotation axis and the Galactic plane direction tend to be parallel. Note that for all these globules the angle between the mean magnetic fields and the rotation axis did not exceed 50°.

In this paper a polarization map obtained by us for the rapidly rotating Bok globule CB67 is presented. In Sect. 2 and 3 the basic information about this cloud is given and the polarimetric data derived for about 50 stars in its field are described. In Sect. 4 we discuss the obtained results and point out that they are untypical of globules.

2. Object

CB67 (L31) is a small isolated globule (the center position: $l \approx 1°, b \approx +16°$) in the complex of molecular clouds in Ophiuchus which is located at the distance of about $\sim 120$ pc \cite{10}. The angular size of this globule on the POSS maps is $16′ \times 4′$, the position angle (hereafter all position angles are given in the equatorial coordinates) of the large semiaxis equals about $110°$ \cite{11}, the opacity class is 6 \cite{12}.
The globule has been observed in CO, $^{13}$CO, C$^{18}$O and OH lines. These observations have shown that the globule velocity is about 4.7 km/s with the velocity dispersions $\sigma_v$(CO) ≈ 1.3 km/s and $\sigma_v$(13CO) ≈ 0.9 km/s. CB67 has the rapid differential rotation with the velocity gradient $\nabla v \approx 2$ km/s/pc, the angular velocity $\omega = 7 \times 10^{-14}$ s$^{-1}$ and the positional angle of the rotation axis of $\theta_1 = 112 \pm 1^\circ$ [7]. The parameters of two cores which were observed in 13CO line are similar: the size is about 14' × 5', the density $n(H_2) \approx 3 \times 10^3$ cm$^{-3}$ and the mass $M \approx 7$–8 M$_\odot$ [13].

Infrared observation did not reveal protostellar sources in this globule [14]. Visser et al. have investigated CB67 at submillimeter wavelengths and shown that the emission region at 850 µm has the approximate size of 11' × 1.5' and mass of 2.2 M$_\odot$ [15]. Note that these authors observed only a part (approximately a half) of the globule, and the region of cold dust emission looks like a filament with the typical diameter of about 0.06 pc [15].

So, the shape, size, location in the sky and other characteristics of CB67 seem to be rather typical of Bok globules.

The large- and small-scale geometries of the Galactic magnetic field are not yet well known [17, 18]. According to the standard stellar polarization data set given by Heiles' catalog [19], the Galactic magnetic field component $\vec{B}_\perp$ forms a large arc including the points $(l, b) = (300^\circ, 0^\circ), (330^\circ, -15^\circ), (360^\circ, 0^\circ)$. So, in the Galactic plane below CB67 ($l = 0^\circ, b = -5^\circ$) the mean position angle of stellar polarization is about 170$^\circ$.

The globule CB67 is close to the ring-shaped interface between the Local Bubble and Loop I Bubble at the distance 70–280 pc [20]. The polarization of stars in the area of this interface was studied by Santos et al. [21]. They found that the polarization position angle in their field A2 ($l = 355 – 15^\circ, b = 20 – 35^\circ$) varied from about 50 to 150$^\circ$ with the preferable direction in a part of the interface ($l = 355 – 10^\circ, b = 17 – 20^\circ$) most close to CB67 being characterized by $\theta \sim 65^\circ$.

The stellar polarization data given by Heiles [19] for the field $l = 350 – 10^\circ, b = 7 – 27^\circ$ including the Ophiuchus cloud complex were analyzed by Li et al. [22]. They found that the mean polarization was nearly parallel to the “main filament” with the position angle being equal to 62 ± 26$^\circ$, which generally agrees with the polarization in the interface region obtained in [21]. Using the same polarization data source, we have considered the stellar polarization in a 7$^\circ$ radius circle around CB67. The position angle distribution is shown in Fig. 1. The mean value equal to 60 ± 15$^\circ$ well agrees with the results described above.

Thus, we conclude that the positional angle of the mean Galactic magnetic field component $\vec{B}_\perp$ in the Ophiuchus cloud complex and in the Local Bubble – Loop I Bubble interface close to CB67 is about 60$^\circ$, which does not strongly differ from the direction of the Galactic plane characterized by $\theta_G = 38.5^\circ$.

3. Observations

We performed polarimetric observations of stars in the vicinity of CB67 using the 2-meter telescope of Girawali observatory (IUCAA) in Pune (India) on March 12–14, 2013. The IUCAA Faint Object Spectrograph and Camera (IFOSC) and the imaging polarimeter IM-POL [23, 24] were used, the field of view had the diameter of 4', the wavelength range was 0.35–0.8 µm. Some more details and references to the description of the camera work in the polarization mode can be found in [25].

For the polarimetric standards HD94851 and HD43384, we performed observation in the B and V bands and obtained the following values of the polarization degree: $P_B = 0.065 \pm 0.05%$ for the first star and $P_V = 2.936 \pm 0.019%$ (with the position angle error of 0.2$^\circ$) for the second star. These values well agree with data from the literature: $P_B = 0.057 \pm 0.18%$ for HD94851 [26] and $P_V = 2.94 \pm 0.04%$, $\theta_V = 169.8 \pm 0.7^\circ$ for HD43384 [27]. The position angle of the latter standard was used to calibrate the position angles of polarization observed.
The instrumental polarization of the IFOSC on the 2-m Giravali telescope has been monitored for many years and is known to be less than 0.05% (see, e.g., [28]), which is also confirmed by our results for the unpolarized standard. As the instrumental polarization is such small and does not behave like a systematic error, it is not being subtracted. Note also that our conclusions below are based on data with \( P > 1\% \) when uncertainty of the position angle caused by the instrumental polarization should be below 1.5°.

Our polarimetric observations of three fields of 4’ diameter were made without the use of any filters. Data were processed in the standard way. The results are presented in Fig. 2 where the polarization vectors for 49 stars (the vector length is proportional to the polarization degree) and contours of intensity in the \(^{13}\)CO line [13] and at 850 micron [15] are shown. Table 1 contains the coordinates, polarization degree and position angle for the stars shown in Fig. 2.

Note that some of our stars are located in the region of CB67 that was considered by Kane and Clemens when they studied its rotation [24]. In Fig. 3 we present the figure from their paper after adding the vector of rotation moment, the line parallel to the Galactic plane, the polarization vectors for stars observed by us and the average direction of the magnetic fields near CB67 according to our results.

Using \( JHK \) data available for some of our stars in the Two-Micron All-Sky Survey catalog [29], we have roughly estimated the distances \( d \) and visual extinction \( A_V \) for about 20 stars observed (see Table 2) following the approach developed in [30]. For other our stars, either \( JHK \) data were absent, or \( (J-K) > 0.75 \), which makes such spectral class estimates less reliable. Two

| No. | \( \alpha \), h | \( \delta \), deg | \( P \%), \text{err} P \% | \( \theta \), deg | err\( \theta \), deg |
|-----|-------------|-------------|----------------|-------------|----------------|
| 1   | 16.840147   | -19.061911  | 0.393          | 0.041       | 201.823        |
| 2   | 16.837495   | -19.046930  | 2.111          | 0.074       | 174.043        |
| 3   | 16.837724   | -19.056358  | 1.908          | 0.096       | 181.931        |
| 4   | 16.838400   | -19.065884  | 2.039          | 0.180       | 180.529        |
| 5   | 16.839283   | -19.066020  | 1.737          | 0.254       | 174.395        |
| 6   | 16.837975   | -19.045488  | 2.844          | 0.242       | 181.629        |
| 7   | 16.837627   | -19.043412  | 2.833          | 0.458       | 168.032        |
| 8   | 16.839890   | -19.047447  | 1.065          | 0.305       | 172.202        |
| 9   | 16.840997   | -19.084549  | 0.782          | 0.246       | 160.286        |
| 10  | 16.836435   | -19.057038  | 1.330          | 0.540       | 159.830        |
| 11  | 16.839278   | -19.039856  | 0.772          | 0.373       | 158.423        |
| 12  | 16.838130   | -19.037979  | 1.726          | 0.500       | 160.545        |
| 13  | 16.837925   | -19.062799  | 2.050          | 0.254       | 167.744        |
| 14  | 16.836777   | -19.073952  | 2.054          | 0.814       | 176.928        |
| 15  | 16.839089   | -19.070290  | 1.237          | 0.550       | 144.600        |
| 16  | 16.838930   | -19.066020  | 1.737          | 0.254       | 174.395        |
| 17  | 16.838400   | -19.044588  | 2.844          | 0.242       | 181.629        |
| 18  | 16.839890   | -19.047447  | 1.065          | 0.305       | 172.202        |
| 19  | 16.840515   | -19.086444  | 3.821          | 0.395       | 159.396        |
| 20  | 16.840861   | -19.060600  | 1.067          | 0.784       | 160.231        |
| 21  | 16.839561   | -19.042167  | 3.099          | 0.972       | 138.034        |
| 22  | 16.838070   | -19.032501  | 1.330          | 0.540       | 159.830        |
| 23  | 16.838130   | -19.037979  | 1.726          | 0.500       | 160.545        |
| 24  | 16.837295   | -19.062799  | 2.050          | 0.254       | 167.744        |
| 25  | 16.836777   | -19.073952  | 2.054          | 0.814       | 176.928        |
| 26  | 16.839089   | -19.070290  | 1.237          | 0.550       | 144.600        |
| 27  | 16.838130   | -19.037979  | 1.726          | 0.500       | 160.545        |
| 28  | 16.837925   | -19.062799  | 2.050          | 0.254       | 167.744        |
| 29  | 16.836435   | -19.057038  | 1.330          | 0.540       | 159.830        |
| 30  | 16.839278   | -19.039856  | 0.772          | 0.373       | 158.423        |
| 31  | 16.838130   | -19.037979  | 1.726          | 0.500       | 160.545        |
| 32  | 16.837295   | -19.062799  | 2.050          | 0.254       | 167.744        |
| 33  | 16.836777   | -19.073952  | 2.054          | 0.814       | 176.928        |
| 34  | 16.839089   | -19.070290  | 1.237          | 0.550       | 144.600        |
| 35  | 16.838130   | -19.037979  | 1.726          | 0.500       | 160.545        |
| 36  | 16.837925   | -19.062799  | 2.050          | 0.254       | 167.744        |
| 37  | 16.836777   | -19.073952  | 2.054          | 0.814       | 176.928        |
| 38  | 16.839089   | -19.070290  | 1.237          | 0.550       | 144.600        |
| 39  | 16.838130   | -19.037979  | 1.726          | 0.500       | 160.545        |
stars (N 29 and 32) were not included in Table 1 and our figures shown above because of their large polarization errors: $P = 0.4 \pm 1.8\%$ for N 29 and $P = 0.8 \pm 1.3\%$ for N 32. The values of $A_V$ were also estimated utilizing the extinction map obtained from 2MASS data with the NICE technique in [31]. A weak correlation of two extinction estimates given in Table 2 can be seen.

Using Table 2 we produced Fig. 4 that shows the dependencies of $P$ and $P/A_V$ on $A_V$. Excluding the stars N 27 and 40 for which we probably derive too low extinction $A_V = 0.18$, our Fig. 4 demonstrates the trends typical of other globules (see, e.g., [28, 32]): 1) a growth of maximum of the polarization degree $P$ (in percent) with $A_V$ (in mag.) so that $P < 2 A_V$; 2) a decrease of maximum of the polarization efficiency $P/A_V$ with $A_V$ so that $P/A_V < -1.5 A_V + 5$. Note that as the wavelength $\lambda_{\text{max}}$ of maximum polarization $P_{\text{max}}$ for stars such close to globules usually is in the interval about 0.5–0.65 $\mu$m (e.g., [28]) and for the standard Serkowski law of the wavelength dependence of interstellar polarization in the interval $\lambda/\lambda_{\text{max}} = 0.75–1.3$ the values of $P(\lambda)$ differ from $P_{\text{max}}$ by less than 10%, we probably have $P \approx P_{\text{max}} \approx P_V$ where $P$ is the polarization degree derived by us without a filter in the instrument range 0.35–0.80 $\mu$m. Note also that according to our estimates all stars in Table 2 except for N 29 are located at distances larger than ~400 pc as expected from a statistical point of view.

### 4. Discussion

Figure 3 shows that the vectors of observed polarization are oriented rather uniformly in the field of CB67. It is better seen in Figs. 5–6 where we present some distributions over the position angle. Note that the polarization degree is mainly within the range 0.8–3% and the position angle $\theta$ in the interval 150–200°, with the average position angle being $\bar{\theta} = 176.7^\circ$ and the dispersion $\sigma_\theta = 14.8^\circ$.

The distribution of stars over $\theta$ is rather typical of globules (see, for example, a similar distribution for globule B227 in [28]). Note, however, that there are many globules where the distribution of polarization vectors is not such uniform [9].

The important question is where the polarization we observe is originated? Generally, stellar polarization can provide information about the magnetic fields in dusty media located foreground or background of a cloud complex or within the complex but not physically related to the cloud studied.

A study of stellar polarization performed in [21] has shown that for their field I2 corresponding to the Ophiuchus molecular cloud complex for all (about couple of dozens) stars at the distance $d < 100$ pc one has the po-

---

**Table 2: Estimates of distance and visual extinction from JHK photometry**

| No. | $P, \%$ | $J$   | $H$ | $K$ | $d, \text{pc}$ | $A_V, \text{mag}$ | $A_V, \text{mag}$ |
|-----|--------|-------|-----|-----|----------------|-------------------|-------------------|
| 1   | 0.39%  | 10.416 | 10.096 | 9.901 | 400 | 2.18 | 1.71 |
| 2   | 2.83%  | 14.343 | 13.827 | 13.608 | 1010 | 2.14 | 1.61 |
| 9   | 0.78%  | 13.148 | 12.805 | 12.632 | 1030 | 1.65 | 1.87 |
| 15  | 0.77%  | 13.855 | 13.285 | 13.129 | 560 | 0.41 | 1.55 |
| 23  | 2.31%  | 14.775 | 14.308 | 14.091 | 1560 | 2.25 | 1.61 |
| 27  | 4.02%  | 15.549 | 15.137 | 15.002 | 1600 | 0.69 | 1.63 |
| 29  | 0.39%  | 8.649  | 8.346  | 8.251  | 95  | 0.18 | 0.81 |
| 32  | 0.77%  | 10.680 | 10.327 | 10.152 | 360 | 1.67 | 1.46 |
| 37  | 1.51%  | 13.235 | 12.690 | 12.530 | 460 | 0.69 | 0.92 |
| 40  | 1.54%  | 14.063 | 13.597 | 13.473 | 730 | 0.18 | 0.81 |
| 41  | 2.98%  | 14.691 | 14.236 | 14.021 | 1600 | 2.24 | 0.97 |
| 43  | 1.50%  | 15.227 | 14.744 | 14.486 | 2260 | 3.01 | 1.46 |
| 48  | 2.17%  | 14.407 | 14.079 | 13.943 | 1650 | 0.94 | 0.95 |
| 49  | 2.42%  | 15.349 | 15.031 | 14.901 | 2730 | 0.89 | 1.40 |
| 50  | 1.94%  | 15.32  | 14.864 | 14.684 | 1630 | 1.55 | 1.33 |
| 51  | 1.05%  | 15.177 | 14.603 | 14.441 | 1010 | 0.54 | 1.14 |
| 53  | 3.06%  | 14.287 | 13.747 | 13.541 | 770 | 1.80 | 1.55 |
| 57  | 1.81%  | 14.328 | 13.857 | 13.681 | 930 | 1.35 | 1.79 |
larization degree $P < 0.05\%$, and for stars at $d > 120$ pc $P$ is in the interval $0$–$2\%$. As for all (except for two) stars observed we got $P > 0.8\%$ we can conclude that the contribution of the foreground material to observed polarization should be negligible in the case of CB67.

The foreground polarization can be calculated for more directions from a relation between the interstellar extinction and polarization. But both the estimates based on Strömgren photometry and Hipparcos parallaxes in [53] and those derived from interstellar lines of Na I and Ca II in [54] do not show any significant extinction in the direction of $l \approx 0^\circ$ up to about 100 pc where the Ophiuchus cloud complex appears.

The contribution of background polarization hardly can be well estimated. The line of sight to CB67 ($l \approx 1^\circ$, $b \approx 16^\circ$) is directed generally above the Galactic center. Looking in the Galactic plane we see the Carina-Sagittarius arm at $d$ about 0.7–1.4 kpc and the Crux-Scutum arm at $d$ about 3 kpc. As Table 2 predicts the stars observed should mainly belong to the interarm space and the Carina-Sagittarius arm. As the CB67 latitude is high enough we can agree with [22] that there should not be much diffuse dust outside the Ophiuchus molecular cloud complex to produce essential interstellar (extinction and) polarization. Additionally, all dark clouds with the estimated distance in the field of the Ophiuchus complex have $d \sim 150$ pc (see, e.g., [55] and references therein), and there are no signs that another more distant dense cloud is projected on the CB67 region.

Considering emission in the $^{13}$CO line studied in [13], we see that the stars observed are projected well inside the contours related with CB67 (see Fig. 4). Additionally, about 1/3 of our stars is projected on the contours of the systematic motion (rotation) of CB67 observed in [7]. Obviously, this denser gas and the dust mainly responsible for the observed polarization should spatially coincide. A weaker argument for the relation of the polarization with CB67 is that the dependences $P$ vs. $A_V$ and $P/A_V$ vs. $A_V$ presented in Fig. 4 well resemble those obtained for similar dense clouds.

Thus, we assume that the mean direction of observed polarization characterizes the magnetic field in the close vicinity of the globule (according to our results its position angle is $\theta_0 = 177 \pm 15^\circ$), the rotational angular momentum ($\theta_1 = 112 \pm 1^\circ$ [17]), the Galactic plane ($\theta_G = 38^\circ$) and the elongation of the globule image on the $^{13}$CO maps [13] ($\theta^G_{\text{CO}} = 110 \pm 7^\circ$). The directions of the largest extension in visual and at submillimeter wavelengths have similar values: $\theta^\text{vis} = 110^\circ$ and $\theta^\text{submm} = 104^\circ$, respectively. Note that according to Li et al. (2013) the direction of “the main filament” of the Ophiuchus molecular cloud complex has $\theta_{BG} = 70 \pm 12^\circ$.

For CB67, the difference $|\theta_0 - \theta_G| = 67 \pm 13^\circ$ is rather close to 90$^\circ$. For other extended molecular clouds, this difference is close to either 0 or 90$^\circ$ [1]. Li et al. [22] have considered 12 cloud complexes, entering into the Gould belt, and found that the main filament direction and the average magnetic field one differ by either less than 10$^\circ$ (4 complexes), or more than 70$^\circ$ (7 complexes, and in 5 cases this difference exceeds 85$^\circ$). On other side, Ward-Thompson et al. [6] have noted that in the cores of low mass molecular clouds (7 ones were considered) the difference of the small semiaxis direction and the magnetic field one obtained from submillimeter polarimetry data is about 30$^\circ$ with a small dispersion. If the field inside CB67 were parallel to that in its vicinity, we would have $|\theta^\text{submm} - \theta^G_{\text{CO}}| \approx 15^\circ$.

We get $|\theta_0 - \theta_G| \approx 30 \pm 1^\circ$. Note that Kane and Clemens [7] have considered 14 globules and found that this difference takes values from 0 to 90$^\circ$ with approximately equal probability, though the values in the range 40–50$^\circ$ may be a bit more probable.

The difference $|\theta_0 - \theta_G| = 65 \pm 15^\circ$ is remarkable. So far only Kane and Clemens have systematically compared polarization maps and rotation of globules [9]. They found that for 5 out of the 6 globules studied the primary magnetic field direction was aligned with the projected rotational axis, and the difference $|\theta_0 - \theta_G|$ was less than 20$^\circ$. These 5 globules included CB4 and CB17 with uniform and well aligned magnetic fields nearly parallel to the Galactic plane (all like in our case of CB67) and CB161, CB195, CB228 with a bimodal distribution of polarization position angles. Kane and Clemens further suggest that some (primary) polarization traces the field local to the globules, while other polarization traces the field at some distance away from (most likely behind) the globules. The secondary polarization usually appears to follow the Galactic plane. The notable case is CB183 where two equally strong components are observed one of which follows the Galactic plane while another does not coincide with either magnetic field component. The authors conclude that CB183 may not be a simple singly condensed globule,
Figure 4: Dependence of polarization degree $P$ on visual extinction $A_V$ (a) and dependence of polarization efficiency $P/A_V$ on $A_V$ (b) for some stars near CB67.

Figure 5: Polarization degree $P$ in dependence on the positional angle $\theta$ for all stars observed.

Figure 6: The distribution of all stars observed over $\theta$. The labels show the position angles of the largest extension in visual (X), the angular moment (J), the Galactic plane (G), and the mean magnetic field (B).
but a conglomeration of condensations.

The theoretical papers mainly included MHD calculations of collapse for rotating spherical clouds when the magnetic fields and the rotation axis are parallel and very seldom when they are not. In the latter case a disk is formed and its angular rotation moment tends to be parallel either to the magnetic fields or to the rotation axis of the cloud depending on the relative strength of the fields (see, for example, [37]).

The situation observed for CB67 when the cloud (core) is extended and rotates around an axis which is almost perpendicular to the magnetic field direction does not fit the theoretical modeling.

5. Conclusions

On the basis of polarimetric observations of about 50 stars located in the vicinity of the Bok globule CB67 the orientation of the magnetic fields near and in the outer layers of this cloud has been considered. It is found that the globule and its core are extended and rotate around the axis that makes the angle of about 70° with the magnetic field direction. This situation is unusual for globules and can be hardly explained in the framework of MHD calculations of collapse of a low mass cloud.

The authors are thankful to an anonymous referee for useful remarks which helped considerably to improve the manuscript.

The authors thank Inter University of Centre for Astronomy and Astrophysics, Pune, India for allotment of telescope time for doing this work.

This work was supported by the joint RFBR and DST (India) Grant 11-02-92695 (RUSP 1110) which supported an Russia–India scientific collaboration, the RFBR Grant 13-02-00138 and a Grant of the Ministry of Education and Science of the Russian Federation for allotment of telescope time for doing this work.

This work was supported by the joint RFBR and DST (India) Grant 11-02-92695 (RUSP 1110) which supported an Russia–India scientific collaboration, the RFBR Grant 13-02-00138 and a Grant of the Ministry of Education and Science of the Russian Federation for allotment of telescope time for doing this work.

The authors thank Inter University of Centre for Astronomy and Astrophysics, Pune, India for allotment of telescope time for doing this work.

The situation observed for CB67 when the cloud (core) is extended and rotates around an axis which is almost perpendicular to the magnetic field direction does not fit the theoretical modeling.

5. Conclusions

On the basis of polarimetric observations of about 50 stars located in the vicinity of the Bok globule CB67 the orientation of the magnetic fields near and in the outer layers of this cloud has been considered. It is found that the globule and its core are extended and rotate around the axis that makes the angle of about 70° with the magnetic field direction. This situation is unusual for globules and can be hardly explained in the framework of MHD calculations of collapse of a low mass cloud.

The authors are thankful to an anonymous referee for useful remarks which helped considerably to improve the manuscript.

The authors thank Inter University of Centre for Astronomy and Astrophysics, Pune, India for allotment of telescope time for doing this work.

This work was supported by the joint RFBR and DST (India) Grant 11-02-92695 (RUSP 1110) which supported an Russia–India scientific collaboration, the RFBR Grant 13-02-00138 and a Grant of the Ministry of Education and Science of the Russian Federation for allotment of telescope time for doing this work.

The situation observed for CB67 when the cloud (core) is extended and rotates around an axis which is almost perpendicular to the magnetic field direction does not fit the theoretical modeling.

5. Conclusions

On the basis of polarimetric observations of about 50 stars located in the vicinity of the Bok globule CB67 the orientation of the magnetic fields near and in the outer layers of this cloud has been considered. It is found that the globule and its core are extended and rotate around the axis that makes the angle of about 70° with the magnetic field direction. This situation is unusual for globules and can be hardly explained in the framework of MHD calculations of collapse of a low mass cloud.

The authors are thankful to an anonymous referee for useful remarks which helped considerably to improve the manuscript.

The authors thank Inter University of Centre for Astronomy and Astrophysics, Pune, India for allotment of telescope time for doing this work.

This work was supported by the joint RFBR and DST (India) Grant 11-02-92695 (RUSP 1110) which supported an Russia–India scientific collaboration, the RFBR Grant 13-02-00138 and a Grant of the Ministry of Education and Science of the Russian Federation for allotment of telescope time for doing this work.

The situation observed for CB67 when the cloud (core) is extended and rotates around an axis which is almost perpendicular to the magnetic field direction does not fit the theoretical modeling.

5. Conclusions

On the basis of polarimetric observations of about 50 stars located in the vicinity of the Bok globule CB67 the orientation of the magnetic fields near and in the outer layers of this cloud has been considered. It is found that the globule and its core are extended and rotate around the axis that makes the angle of about 70° with the magnetic field direction. This situation is unusual for globules and can be hardly explained in the framework of MHD calculations of collapse of a low mass cloud.

The authors are thankful to an anonymous referee for useful remarks which helped considerably to improve the manuscript.

The authors thank Inter University of Centre for Astronomy and Astrophysics, Pune, India for allotment of telescope time for doing this work.

This work was supported by the joint RFBR and DST (India) Grant 11-02-92695 (RUSP 1110) which supported an Russia–India scientific collaboration, the RFBR Grant 13-02-00138 and a Grant of the Ministry of Education and Science of the Russian Federation for allotment of telescope time for doing this work.

The situation observed for CB67 when the cloud (core) is extended and rotates around an axis which is almost perpendicular to the magnetic field direction does not fit the theoretical modeling.

5. Conclusions

On the basis of polarimetric observations of about 50 stars located in the vicinity of the Bok globule CB67 the orientation of the magnetic fields near and in the outer layers of this cloud has been considered. It is found that the globule and its core are extended and rotate around the axis that makes the angle of about 70° with the magnetic field direction. This situation is unusual for globules and can be hardly explained in the framework of MHD calculations of collapse of a low mass cloud.

The authors are thankful to an anonymous referee for useful remarks which helped considerably to improve the manuscript.

The authors thank Inter University of Centre for Astronomy and Astrophysics, Pune, India for allotment of telescope time for doing this work.

This work was supported by the joint RFBR and DST (India) Grant 11-02-92695 (RUSP 1110) which supported an Russia–India scientific collaboration, the RFBR Grant 13-02-00138 and a Grant of the Ministry of Education and Science of the Russian Federation for allotment of telescope time for doing this work.

The situation observed for CB67 when the cloud (core) is extended and rotates around an axis which is almost perpendicular to the magnetic field direction does not fit the theoretical modeling.

5. Conclusions

On the basis of polarimetric observations of about 50 stars located in the vicinity of the Bok globule CB67 the orientation of the magnetic fields near and in the outer layers of this cloud has been considered. It is found that the globule and its core are extended and rotate around the axis that makes the angle of about 70° with the magnetic field direction. This situation is unusual for globules and can be hardly explained in the framework of MHD calculations of collapse of a low mass cloud.

The authors are thankful to an anonymous referee for useful remarks which helped considerably to improve the manuscript.

The authors thank Inter University of Centre for Astronomy and Astrophysics, Pune, India for allotment of telescope time for doing this work.

This work was supported by the joint RFBR and DST (India) Grant 11-02-92695 (RUSP 1110) which supported an Russia–India scientific collaboration, the RFBR Grant 13-02-00138 and a Grant of the Ministry of Education and Science of the Russian Federation for allotment of telescope time for doing this work.

The situation observed for CB67 when the cloud (core) is extended and rotates around an axis which is almost perpendicular to the magnetic field direction does not fit the theoretical modeling.
[21] Santos F. P., Corradi W., Reis W., Optical polarization mapping toward the interface between the local cavity and loop i, The Astrophysical Journal 728 (2011) 104. doi:10.1088/0004-637X/728/2/104

[22] Li H., Fang M., Henning T., Kannuulainen J., The link between magnetic fields and filamentary clouds: bimodal cloud orientations in the gould belt, Monthly Notices of the Royal Astronomical Society 436 (2013) 3707–3719. doi:10.1093/mnras/stt1849

[23] Sen A. K., Tandon S. N., Two-channel optical imaging polarimeter, in: David L. C., Eric R. C. (Eds.), Instrumentation in Astronomy VIII, Vol. 2198 of Proc. SPIE, 1994, pp. 264–273.

[24] Ramaprakash A. N., Gupta R., Sen A. K., Tandon S. N., An imaging polarimeter (impol) for multi-wavelength observations, Astronomy and Astrophysics Supplement 128 (1998) 369–375. doi:10.1051/aas:1998150

[25] Paul D., Das H. S., Sen, A. K., Imaging polarimetry of the bok globule ch56, Bulletin of the Astronomical Society of India 40 (2012) 113–119.

[26] Turnshek D.A. et al., An atlas of hubble space telescope photometric, spectrophotometric, and polarimetric calibration objects, The Astronomical Journal 99 (1990) 1243–1261. doi:10.1086/115413

[27] Hsu J., Breger M., On standard polarized stars, The Astrophysical Journal 262 (1982) 732–738. doi:10.1086/160467

[28] Eswaraiah C., Maheswar G., Pandey A. K., Jose J., Ramaprakash A. N., Bhatt H. C., A study of the starless dark cloud ldn 1570: Distance, dust properties, and magnetic field geometry, Astronomy and Astrophysics 556 (2013) A65. doi:10.1051/0004-6361/201220603

[29] Skrutskie, M. F. et. all, The two micron all sky survey (2mass), The Astronomical Journal 131 (2006) 1163–1183. doi:10.1086/504423

[30] Maheswar G., Lee C. W., Bhatt H. C., Malik S. V., Dib S., A method to determine distances to molecular clouds using near-infrared photometry, Astronomy and Astrophysics 509 (2010) A44. doi:10.1051/0004-6361/200912694

[31] Rowles J., Froebrich D., The structure of molecular clouds - i. all-sky near-infrared extinction maps, Monthly Notices of the Royal Astronomical Society 395 (2009) 1640–1648. doi:10.1111/j.1365-2966.2009.14658.x

[32] McCutcheon W. H., Vrba F. J., Dickman R. L., Clemens D. P., The lynds 204 complex - magnetic field controlled evolution?, Astrophysical Journal 309 (1986) 619–627. doi:10.1086/164630

[33] Vergely J.-L., Valette B., Lallement R., Raimond S., Spatial distribution of interstellar dust in the sun’s vicinity. comparison with neutral sodium-bearing gas, Astronomy and Astrophysics 518 (2010) A31. doi:10.1051/0004-6361/200913962

[34] Welch B. Y., Lallement R., Vergely J.-L., Raimond S., New 3d gas density maps of nai and caii interstellar absorption within 300 pc, Astronomy and Astrophysics 510 (2010) A54. doi:10.1051/0004-6361/200912202

[35] Hilton J., Lahulla J. F., Distance measurements of lynds galactic dark nebulae., Astronomy and Astrophysics Supplement 113 (1995) 325.

[36] Joos M., Hennebelle P., Ciardi A., Protostellar disk formation and transport of angular momentum during magnetized core collapse, Astronomy & Astrophysics 543 (2012) A128. doi:10.1051/0004-6361/201118730

[37] Machida M. N., Matsumoto T., Hanawa T., Tomisaka K., Evolution of rotating molecular cloud core with oblique magnetic field, The Astrophysical Journal 645 (2006) 1227–1245. doi:10.1086/504423