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Magnetic fields in cometary globules – III. CG 12

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ABSTRACT

We present results of optical linear polarization measurements of stars in the region of the relatively isolated cometary globule CG 12 in Centaurus at a galactic latitude $b \simeq 21^\circ$. A polarization map representing the geometry of the magnetic field in the cloud is produced. In the lower-density outer parts of the cloud, the field is more or less parallel to the cometary tail and other elongated structures like the bipolar molecular outflow from near the infrared source IRAS 13547–3944 and the nebulosity around star 2 embedded in the cloud. Polaization vectors for the more highly reddened stars in the head region of the globule are found to be more or less parallel to the long axis of the elliptical, high-density $C^{18}O$ core of the cometary globule head.

Key words: polarization – ISM: globules – ISM: individual: CG 12 – ISM: magnetic fields.

1 INTRODUCTION

Cometary globules (CGs), first noted by Hawarden & Brand (1976) on SERC IIIaJ Sky Survey plates, are interstellar clouds that show a head–tail morphology similar to comets. Their heads are dusty, compact and bright-rimmed. A faintly luminous tail extending from the head generally points away from a nearby bright early-type star. Most of the CGs have been found to be associated with star-forming regions with massive OB type stars (e.g. Hawarden & Brand 1976; Sandqvist 1976; Schneps, Ho & Barrett 1980; Reipurth 1983; Zealey et al. 1983; Gyulbudagyan 1985; Sugitani, Fukui & Ogura 1991; Block 1992). The largest of such systems of CGs is associated with the Gum Nebula in Vela–Puppis with ∼30 CGs (Reipurth 1983; Zealey et al. 1983) centred around the Vela OB2 association. However, relatively isolated CGs are also known, for example CG12 (Williams et al. 1977). There is evidence for current star formation in a number of CGs. For example, Bernes 135, a pre-main-sequence star, is associated with CG 1 (Brand 1983; Reipurth 1983), CG 30 contains the Herbig–Haro object HH 120 and the infrared source CG 30-IRS 4 (Pettersson 1984) and a number of CGs in the Gum Nebula have *IRAS* point sources with spectral energy distributions characteristic of young stellar or protostellar objects, associated with their compact heads, indicating star formation at relatively enhanced rates (Bhatt 1993).

Models for the formation and evolution of CGs have been discussed by Reipurth (1983), Zealey et al. (1983), Bertoldi (1989), Bertoldi & McKee (1990), and Lefloch & Lazareff (1994, 1995). Relatively smaller dense cores distributed in a parent giant molecular cloud, exposed to the radiation and stellar winds from massive OB type stars in a newly born central OB association, can develop cometary head–tail morphology as the less dense core is shock-compressed to produce the head. The shocks can also trigger star formation in the CG head. It is generally well recognized that magnetic fields play an important role in the formation of interstellar clouds, controlling their morphology and the star-formation process. However, our observational knowledge of the magnetic field and understanding of its role in the evolution of CGs is still rather limited. Although the action of radiation and stellar wind from massive star(s) may account for the presence and the overall radial orientation of the tails, the fine structure and variety displayed by CGs is hard to explain. Does a magnetic field aligned along the CG tail help confine the gas which, for the observed velocity dispersions (Zealey et al. 1983; Sridharan 1992), would be expected to disperse perpendicular to the tail? As part of a programme to map the magnetic fields in CGs by making optical polarization measurements of stars projected in the regions of these globules, we had earlier observed CG 22 (Sridharan, Bhatt & Rajagopal 1996, Paper I) and the CG 30–31 complex (Bhatt 1999, Paper II). In CG 22, a majority of the stars seen projected within the cloud boundaries were found to be polarized (at a level ∼1 per cent) with the electric vector oriented parallel to the CG tail. If the polarization is a result of non-spherical dust grains aligned by the magnetic field (Davis–Greenstein mechanism), then the results for CG 22 imply that the magnetic field in this CG is parallel to its tail. In the CG 30–31 complex, the field was found to be nearly perpendicular to the cometary tails and is more or less parallel to the bipolar molecular outflow from the young stellar object IRS 4 embedded in the head of CG 30 (Paper II). Both CG 22 and the CG 30–31 complex are part of the system of CGs around the Vela OB2 association. In this paper we present the results of polarization measurements of stars in the region of the relatively isolated cometary globule CG 12 in Centaurus with a galactic latitude $b \sim 21^\circ$.

2 THE COMETARY GLOBULE CG 12

CG 12, with the reflection nebula NGC 5367 surrounding the double star h4636 in its head, was first identified as a ‘cometary globule’ by

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Hawarden & Brand (1976). The globule is at a considerable galactic latitude ($l = 316\overset{\circ}{.}5$, $b = 21\overset{\circ}{.}2$). Its head is ∼10 arcmin in diameter, and its nebular tail is more than 1° in length and lies roughly perpendicular to the galactic plane. Williams et al. (1977), from *UBV* observations of 11 stars and *JHKL* photometry of h4636, showed that the sparse young cluster embedded in and illuminating NGC 5367 in the head of CG 12 suffers about 1 mag of visual extinction in the cloud and estimated its distance to be ∼630 pc. CO and *IRAS* measurements for CG 12 have been reported by Van Till, Loren & Davis (1975), White (1993) and Yonekura et al. (1999). The CO and *IRAS* study of CG 12 by White (1993) revealed the presence of a bipolar molecular outflow centred close to the infrared source IRAS 13547–3944, and the double star h4636 consisting of two B-type stars. This is a low-luminosity (mechanical luminosity $\sim 4 \times 10^{-3}\ L_{\odot}$) molecular outflow that is well collimated (axial ratio $\geqslant 5$) and extends ∼5 arcmin roughly along the major axis of the cometary globule. Near-infrared *JHK* imaging of a region around IRAS 13546–3941 in CG 12 by Santos et al. (1998) has shown the presence of a couple of objects that have near-infrared colours characteristic of low-mass young stellar objects. CG 12 is thus an example of a relatively isolated low-to-intermediate-mass star-forming cometary globule, which has been suggested (Williams et al. 1977) to have been caused by a high galactic latitude supernova explosion at $l = 320°$, $b = 30°$. Optical linear polarization measurements of the brightest three stars, numbered 1, 2 and 4 in Williams et al. (1977), in the head region of CG 12 were made by Marraco & Forte (1978). They found their polarization vectors, with position angles at 161, 146 and 135° respectively for the three stars, to be more or less parallel to the cometary tail whose position angle, as given in Hawarden & Brand (1976), is 135°. Polarimetric observations of a larger sample of stars in and around CG 12, covering both the head and the tail regions of the cometary globule, would be useful for making a more detailed polarization map and study the geometry of the magnetic field in the cloud.

3 OBSERVATIONS

Polarization measurements were carried out with a fast star-and-sky chopping polarimeter (Jain & Srinivasulu 1991) coupled at the $f/13$ Cassegrain focus of the 1-m telescope at the Vainu Bappu Observatory, Kavalur, of the Indian Institute of Astrophysics. A dry-ice cooled R943-02 Hamamatsu photomultiplier tube was used as the detector. Thirteen stars brighter than ∼13 mag were observed with integration times of 5–10 min. Two of the stars observed were in common with those observed earlier by Marraco & Forte (1978). All the measurements were made in the *V* band and an aperture of 15 arcsec was used. Observations were made on the nights of 2000 March 1–3. The instrumental polarization was determined by observing unpolarized standard stars from Serkwoski (1974). It was found to be ∼0.1 per cent, and has been subtracted vectorially from the observed polarization of the programme stars. The zero of the polarization position angle was determined by observing the polarized standards from Hsu & Breger (1982). A Digitized Sky Survey (DSS) image of the region of CG 12 observed is shown in Fig. 1.

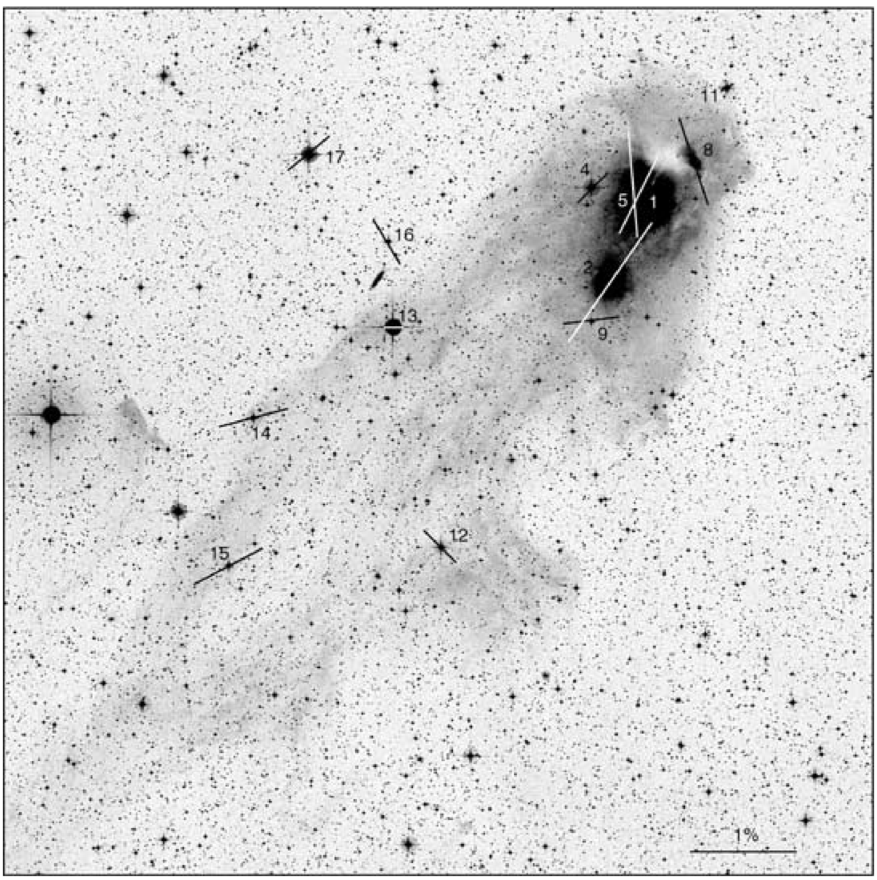

Figure 1. Polarization map for the region of CG 12. The polarization vectors have been drawn centred on the stars observed. The 1° × 1° optical image [centred at α (2000) = $13^{h}58^{m}59^{s}$, δ (2000) = $-40°15'22''$] has been reproduced from the Digitized Sky Survey. North is at the top, east to the left.

4 RESULTS

The results of our polarimetric observations are presented in Table 1. Column 1 of Table 1 gives the identification number for the stars observed. We have followed the numbering system of Williams et al. (1977) as some of the stars observed here for polarization are identical to those studied photometrically by Williams et al. (1977). The measured values of polarization *P* (in per cent) and the probable error in polarization ϵ_P (in per cent) are given in columns 3 and 4 respectively. The polarization position angle (of the ***E*** vector) θ (in degrees) and the probable error in position angle ϵ_θ (in degrees) are given in columns 5 and 6. The position angles, in the equatorial coordinate system, are measured from the north, increasing eastward. As a rough guide to the brightness of the stars measured, column 2 of Table 1 gives the magnitudes of the stars obtained from the mean intensity measured in our polarimetric observations. The probable errors in these magnitudes are ~0.1 mag. We have included the polarization measurements for stars 1, 2 and 4 by Marraco & Forte (1978) in Table 1. For stars 1 and 2, our results agree with the observations of Marraco & Forte (1978) to within the probable errors of the measurements. In Fig. 1, superposed on the optical image, we show a polarization map for CG 12. The polarization vectors have been drawn centred on the stars observed. The length of the polarization vector is proportional to the percentage polarization *P* and it is oriented parallel to the direction corresponding to the observed polarization position angle θ. For star 4, measurements by Marraco & Forte (1978) have been used.

Table 1. Polarimetric measurements for stars in the region of CG 12.

Star identification	Mag	P (per cent)	ϵ_p (per cent)	θ (°)	ϵ_θ (°)
1 (h4636)	9.8	0.78	0.12	156	6
	9.8†	0.83†	0.02†	161†	7†
2 (CD−39 8583)	10.1	1.43	0.13	150	3
	10.1†	1.25†	0.12†	146†	3†
4 (CD−39 8586)	9.2†	0.46†	0.09†	135†	6†
5	12.8	1.03	0.40	7	13
8	12.9	0.82	0.39	15	17
9	11.9	0.57	0.30	95	11
11 (CD−39 8577)	9.6	0.13	0.11	120	11
12 (CD−39 8597)	10.1	0.49	0.19	46	7
13 (HD 121912)	7.9	0.19	0.08	93	6
14	11.0	0.61	0.21	109	9
15	10.4	0.81	0.19	117	7
16	11.0	0.51	0.22	29	14
17 (HD 121972)	8.0	0.48	0.09	130	7

†measurements by Marraco & Forte (1978).

5 DISCUSSION

The observed polarization of stars in the region of CG 12 ranges from ~0.1 to ~1.4 per cent. We notice, from Table 1, that fainter stars tend to show larger values of polarization. Although the distances to individual stars are, in general, not known, it is likely that most of the fainter stars are in the background of the cloud and suffer larger extinction due to dust in the cloud, while most of the brighter stars are less extinguished stars outside the cloud boundaries or nearby stars in the foreground of the cloud. For stars showing relatively larger values of polarization ($P \gtrsim 0.5$ per cent), the observed polarization is likely to be caused by the globule. CG 12 is an isolated cloud at a considerable galactic latitude ($l = 316\overset{\circ}{.}5$, $b = 21\overset{\circ}{.}2$), and interstellar polarization in this direction is expected to be relatively small. We have plotted in Fig. 2, the polarization position angle against the percentage polarization for stars in the region of CG 12 as given in Table 1. Also plotted in Fig. 2 are field stars in this direction, within ~5° of the CG 12 head at $l = 316\overset{\circ}{.}5$, $b = 21\overset{\circ}{.}2$, for which polarization measurements are available in the stellar polarization catalogues (Heiles 2000). There are 11 such field stars, at angular distances from the CG head ranging from $2\overset{\circ}{.}01$ to $5\overset{\circ}{.}20$, plotted in Fig. 2. Their polarizations range from ~0.02 to ~0.2 per cent, while

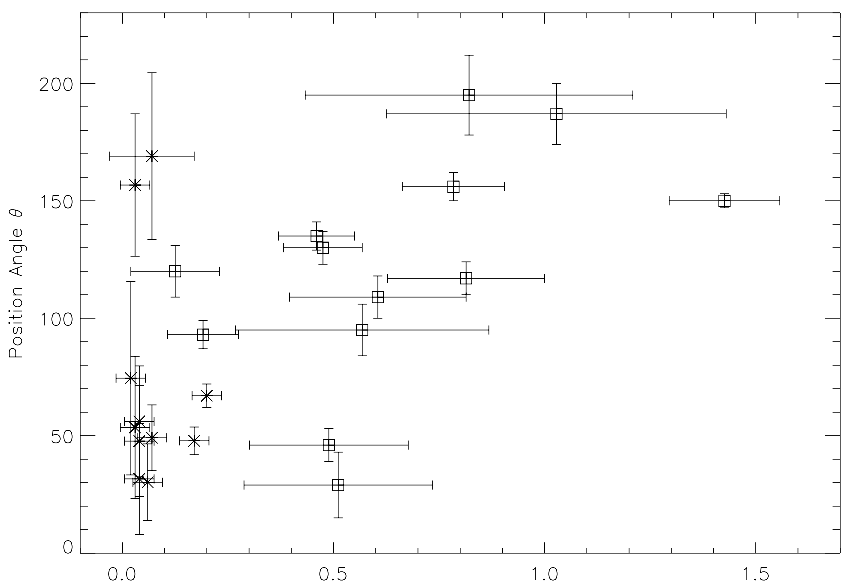

Figure 2. Polarization position angle (°) plotted against degree of polarization (per cent) for stars in the region of CG 12 (squares) and for stars within ~5° of CG 12 from the stellar polarization catalogues (Heiles 2000) (asterisks).

their distances (from the Sun) range from ∼60 to ∼400 pc as given in the *Hipparcos* catalogue.

The polarization position angles for a majority of the field stars (except two stars with position angles near 160° having large error bars) cluster around 50°. Stars in the region of CG 12 occupy a part of the P–θ diagram shown in Fig. 2 that is distinct from that occupied by the field stars. Only two stars, numbered 12 and 16, have polarization position angles similar to the majority of the field stars. Distances to these stars are not known. Both show relatively lower values of polarization (0.49 ± 0.19 and 0.51 ± 0.22 per cent respectively). Star 16 is seen projected outside the cloud boundary. The observed polarization for this star is likely to be due to the general interstellar medium in this direction. Star 12, seen projected within the cloud boundary, may be a foreground star, although its distance is not known. Accurate distance measurement is available for only one star, i.e. star 13, for which the *Hipparcos* catalogue gives a parallax of $\pi = 7.84 \pm 0.92$ mas. Therefore, star 13, with a distance of 128 ± 15 pc is clearly in the foreground of CG 12 which is at a distance of ∼630 pc. The relatively low value of the observed polarization ($P = 0.19 \pm 0.08$ per cent) for star 13 is consistent with its being a nearby star. The rest of the stars have polarization position angles that are quite different from the average value of 50° shown by the field stars. They are likely to be either stars involved in the cloud (e.g. star 1 ≡ h4636), or background stars whose light is being polarized by aligned dust grains in CG 12. For these stars θ ranges from ∼95° to ∼195° with the average $\langle\theta\rangle = 139°$. The position angle shows a large dispersion in values, but it appears to vary somewhat systematically from an average $\langle\theta\rangle = 118°$ for stars (numbered 4, 9, 11, 14, 17) with $P \lesssim 0.75$ per cent, most of which are in the tail region of CG 12, to an average $\langle\theta\rangle = 161°$ for stars (numbered 1, 2, 5, 8, 15) with $P \gtrsim 0.75$ per cent which are all, except star 15, seen projected on the head of the cometary globule.

Two other stars projected outside the cloud boundary are star 11 and star 17. Both show lower values of polarization, but the position angles are dissimilar from those for the field stars. Star 11 is just outside the CG head, as seen in the optical image in Fig. 1. It is possible that it suffers a relatively low extinction and polarization due to a lower-opacity envelope around the globule head as is commonly observed in molecular clouds. In fact, as discussed below (Section 5.1 and Fig. 3), star 11 is seen projected within the cloud boundary as represented by *IRAS* 100-μm emission. Star 17 is well outside the cloud boundary. Its position angle is difficult to explain. In the following we consider the polarization of stars 12, 13, 16 and 17 to be due to the general interstellar medium, while for the rest of the stars it is suggested to be due to the dust in the cometary globule.

5.1 Correction for the interstellar polarization

The polarization vectors for stars 1, 2, 4, 5, 8, 9, 11, 14 and 15 seem to follow, more or less, the elongated morphology of the cometary globule. For these stars, the average value of the polarization position angle is $\langle\theta\rangle = 140°$ with a dispersion $\sigma_\theta = 35°$. The position angle of the cometary tail of CG 12, as given in Hawarden & Brand (1976), is 135°. Although the polarization for the stars in or behind the globule may be dominated by the dust in the cloud, the observed polarization will be a superposition of an interstellar component due to interstellar dust in the foreground of the cloud, and another component due to the dust in the cloud. To evaluate the polarization caused only by the dust in the cloud, we need to subtract the foreground interstellar component from the observed polarization of the stars. As mentioned earlier, nearby field stars (with distances

Table 2. Percentage polarization and position angle for stars in the region of CG 12 after correcting for interstellar contributions.

Star identification	P (per cent)	ϵ_p (per cent)	θ (°)	ϵ_θ (°)
1	0.96	0.12	153	6
2	1.62	0.13	149	3
4	0.66	0.09	137	6
5	1.03	0.40	1	13
8	0.78	0.39	8	17
9	0.60	0.30	105	11
11	0.31	0.11	132	11
14	0.72	0.21	116	9
15	0.96	0.19	121	7

in the range from ∼60 to ∼400 pc) within ∼5° of CG 12 have polarizations in the range from ∼0.02 to ∼0.2 per cent with position angles clustered around 50°. An inspection of the Heiles (2000) and the *Hipparcos* catalogues shows that in the direction of CG 12, stars with $b \geqslant 15°$ and within ∼10° of the globule do not exceed $P \sim 0.2$ per cent even for distances larger than ∼500 pc. We therefore take the component of polarization caused by the general interstellar dust in the foreground of CG 12 to be represented by $P_i = 0.20$ per cent, $\theta_i = 50°$. We then correct for the interstellar component by subtracting the corresponding Stokes parameters $U_i = P_i \sin 2\theta_i$ and $Q_i = P_i \cos 2\theta_i$ from those observed for the stars. The resulting P and θ, for stars 1, 2, 4, 5, 8, 9, 11, 14 and 15, representing the polarization caused by the dust in CG 12 are listed in Table 2 and shown pictorially in Fig. 3. In the polarization map in Fig. 3 we have superposed the $C^{18}O$ contours, representing the high-density head of CG 12, from Yonekura et al. (1999), and the *IRAS* 100-μm contours representing the lower-density outer parts of CG 12 obtained from the Infrared Processing and Analysis Centre (IPAC). The *IRAS* 100-μm contours (in MJy sr^{-1}) are at 2.6 (the outermost contour), 3.6, 4.6, 6.6, 8.6 and 12.6 (innermost contour). Contours with 100-μm flux density larger than 12.6 MJy sr^{-1} are not shown in Fig. 3 to avoid overlap with $C^{18}O$ contours in the CG head. Star 11 is seen projected within the cloud boundary as represented by *IRAS* 100-μm emission.

5.2 Effects of nebulosity

The polarization map of Fig. 3 can be considered to represent the geometry of the projected magnetic field in CG 12 if the polarization is caused by dust grains in the cloud aligned by the magnetic field (Davis–Greenstein mechanism), similar to the mechanism for interstellar polarization. It can be seen from Table 2 that the dust in the cloud causes polarization of $P \sim 1$ per cent. Photometry for some of the stars, observed here polarimetrically, near the CG 12 head by Williams et al. (1977) indicate that they suffer extinction $A_V \sim 1$ mag. Thus for these stars the ratio P/A_V is ∼1 per cent mag^{-1}, similar to that for the general interstellar medium. However, it must be noted that CG 12 has an associated reflection nebulosity, that is brightest near star 1 (h4636) in the head region of the globule. The nebulosity may contribute polarized light over the aperture (15 arcsec in diameter) used for the polarimetric observations. In a separate study to look for $H\alpha$ emission-line objects by CCD imaging, we have obtained $H\alpha$ and V-band images (10 × 10 arcmin^2 field centred at a point ∼2 arcmin south of h4636) in the head region of CG 12 that includes stars 1, 2, 4, 5 and 8. We have estimated the V-band surface brightness of the nebulosity in this region. Over most of the CG head the nebulosity is fainter than ∼24 mag arcsec^{-2}

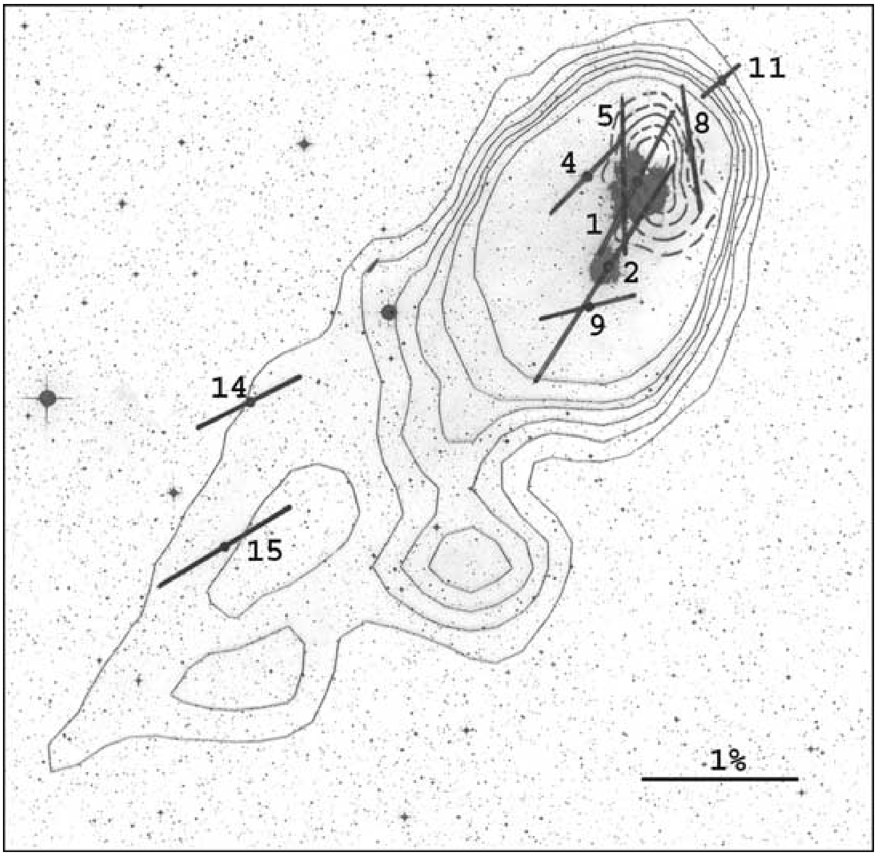

Figure 3. Polarization map for CG 12 after correcting for interstellar contributions. $C^{18}O$ contours (broken line) from Yonekura et al. (1999) representing the high-density CG head, and *IRAS* 100-μm contours representing the lower-density parts of the cloud, are overlaid on the DSS image. The image field is the same as in Fig. 1.

except close to stars 1, 2, 5 and 8. In the tail region of the cloud, not covered in our CCD images, it is likely to be similar or fainter. Except for stars 1, 2, 5 and 8, over the aperture of 15 arcsec used for the polarimetric measurements, the nebulosity can contribute light equivalent to ~18.4 mag. Even if this light is 100 per cent polarized, it can result in $\lesssim$0.1 per cent polarization for stars of 11 mag, assuming no chopping. The star/sky chopping will remove much of the light due to the nebulosity; only surface brightness gradients over 2-arcmin angular scale (used for chopping in the polarimeter) will contribute. Thus the contribution of the nebulosity to the observed polarization will be negligible for the relatively bright stars 4, 11, 12, 13, 14, 15, 16 and 17. For star 9 ($V \sim 12$), a 24 mag arcsec^{-2} nebulosity can contribute up to 0.25 per cent polarization, whereas the observed polarization is 0.57 per cent. Close to the stars, within a few seeing-disc (~3 arcsec in our observations) radii, it is difficult to measure the nebular brightness at a level below ~1 per cent of the stellar brightness. At an angular distance of 10 arcsec from stars 1, 2, 5 and 8, we estimate the nebular surface brightness to be about 18.6, 19.6, 21.0 and 21.6 mag arcsec^{-2}, respectively. In an aperture of 15 arcsec the nebulosity can contribute about 6, 3, 9, 6 per cent or more (since the nebular surface brightness is generally increasing towards the stars) light to the stellar brightness for these stars. If the nebular light is strongly polarized, this can result in large polarization values for the stars. However, since the nebulosities around the stars are more or less symmetric, the net polarization contributed by the nebular light can be much less. Calculations of the polarization and reddening produced by ellipsoidal circumstellar scattering envelopes by Shawl (1975) have shown that the maximum linear polarization, even for a circumstellar dust optical depth $\tau \sim 0.2$, is about 1.1 per cent. Stars 1, 2, 5 and 8 show polarizations of ~1 per cent, somewhat larger, but not greatly different from other stars polarized by the cloud dust. However, they show polarization position angles that are systematically larger (rotated eastward) than the other stars. This may be due to the nebular contributions to the observed polarization for stars associated with bright nebulosities in the CG head.

5.3 Magnetic field and cloud morphology

From the above discussion we conclude that the polarization in the light of stars 4, 9, 11, 14 and 15 seen projected within the boundaries of CG 12 is caused due to selective extinction by dust grains aligned by the magnetic field in the cloud. The polarization vectors for these stars, as shown in Fig. 3, can be considered to represent the geometry of the projected magnetic field in CG 12. The field is more or less parallel to the cometary tail of the globule. Two other features in CG 12, the bipolar molecular outflow centred close to the infrared source IRAS 13547–3944 discovered by White (1993) and the elongated structure in the nebulosity around star 2 noted by Marraco & Forte (1978), are also oriented nearly parallel to the CG tail. If circumstellar discs around the young stars 1 and 2 are the cause of these structures, then the discs must be perpendicular to the cloud magnetic field. This is consistent with current theories of star formation that suggest cloud collapse parallel to the magnetic field, leading to the formation of a flattened disc perpendicular to the field and a bipolar flow channelled parallel to the field.

As noted earlier, stars 1, 2, 5, 8 show polarization position angles that are systematically larger (rotated eastward) than the other stars, and this may be due to the nebular contributions to the observed polarization for these stars associated with relatively brighter nebulosities in the CG head. Alternatively, if the nebular contribution is negligible, polarization vectors for these stars also represent the direction of the projected magnetic field. Then, the position angles for these stars, in particular those for stars 5 and 8, suggest rotation of the field in the denser parts of the CG head. We notice from the CO maps for CG 12 by Van Till et al. (1975) and Yonekura et al. (1999) that the CG head is elliptical with the long axis oriented more nearly in the north–south direction than the CG tail. In fact the highest density region of the CG head, which includes stars 5 and 8 in projection, most clearly seen in the $C^{18}O$ map by Yonekura et al. (1999), which has been superposed on the DSS image in Fig. 3, is elongated and the position angle of its long axis is at $\sim 7°$, similar to the polarization position angle for stars 5 and 8.

The cometary shape of CG 12 and its orientation has been suggested by Williams et al. (1977) to have been caused by a high galactic latitude supernova explosion at $l = 320°$, $b = 30°$. The expanding supernova remnant that blew the lower-density outer parts of the globule into a cometary tail is likely to have dragged the ambient magnetic field lines in the same direction. In the higher-density inner parts of the globule head the original magnetic field may remain unperturbed. If the nebular contribution to the polarization of stars in the CG head is negligible, then the observed polarization position angles for stars 5 and 8 suggest that the original magnetic field in the cloud was parallel to the long axis of the elliptical core of the globule.

6 CONCLUSIONS

In this paper we have presented the results of optical linear polarization measurements of stars in the region of the relatively isolated cometary globule CG 12. The dust in the cloud causes ∼1 per cent polarization in the light of the stars seen projected within the cloud boundaries. A polarization map representing the geometry of the magnetic field in the cloud is produced. Our results can be summarized as follows.

In the lower-density outer parts of the cloud, the field is more or less parallel to the cometary tail, with position angle $\theta \sim 130°$. Other elongated structures, like the bipolar molecular outflow from near the infrared source IRAS 13547–3944 and the nebulosity around star 2 embedded in the cloud, are also oriented in the same direction.

Polarization vectors for the more highly reddened stars in the head region of the globule are found to be more or less parallel to the long axis of the elliptical, high-density $C^{18}O$ core of the CG head, with position angle $\theta \sim 7°$. If the nebular contribution to the polarization of stars can be neglected, then a magnetic field in the high-density core oriented parallel to its long axis is indicated.

It is suggested that the expanding supernova remnant that blew the lower-density outer parts of the globule into a cometary tail is likely to have dragged the ambient magnetic field lines in the same direction. In the higher-density inner parts of the globule head the original magnetic field remained unperturbed.

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