Polarimetry in the outskirts of NGC 6611 ⋆

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ABSTRACT

We present new polarimetric UBVRI observations of 25 stars in direction to the halo of NGC 6611, the rich stellar open cluster embedded in an ionized hydrogen complex (M 16). Our plan is to characterize the interstellar material (ISM) associated to halo stars, so as to make a comparison with the ISM dusty core characteristics which resulted from a previous investigation from the same authors.

A 47 % of the halo stars (8 out of 17) show indications of intrinsic polarization in their light, similar to the one found for core stars (50 %).

We have identified the presence of nearby dust clouds located on the Local arm, which produce a mean polarization of about 1%, a $\overline{\lambda_{max}} = 0.61 \pm 0.07\mu$m which is slightly larger than that of the average ISM and a mean direction of the polarization vectors of $\overline{\theta_V} = 81^\circ\!.9 \pm 1^\circ\!.8$. The ISM associated to the halo region has a $\overline{\lambda_{max}}$ similar to the general interstellar medium (0.55 $\pm$0.07μm). The observed

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polarizations show a gradual increase from halo ($\overline{P_{max}} = 1.93 \pm 0.3$ %) to core ($\overline{P_{max}} = 3.19 \pm 0.63\%$).

Position angles of the e-vector for both groups are similar in general but there exists a slight difference in mean direction between them, which is within the errors. We have also found that the halo stars are possibly represented by Whittet & van Breda's (1978) relationship, while in the cluster's core the dust does not fulfill the above mentioned relationship.

As a conclusion, we cannot find any clear difference between core and halo dust characteristics, with exception of $\overline{\lambda_{max}}$ which may suggest a change in dust size.

Subject headings: ISM: dust, extinction – open clusters and associations: individual: NGC 6611 – technique: polarimetry

1. Introduction

NGC 6611 (C1816-138) is a stellar rich open cluster located in the Sagittarius spiral arm, in the plane of the Galaxy (l = 17°.0, b = 0°.8). It is embedded in an ionized hydrogen complex (M 16), a large nebulosity connected with dense dust clouds. The central portion of the cluster is part of the North-West of M 16, but nowadays it is assumed that it comprises the whole complex (e.g. de Winter et al. 1997).

This object and the surrounding dark and bright nebulosities have been the subject of a great number of studies, centered particularly on two main issues: the existence of an age spread (proposed by Hillenbrand et al. (1993), and confirmed by de Winter et al. (1997)) and also the determination of which extinction law is valid for the cluster.

Several years ago, Orsatti, Vega & Marraco (2000) (hereinafter OVM) conducted an investigation to test independently the existence of larger than average grains in the dusty central part of NGC 6611. Through UBVRI polarimetric observations, they found that the Whittet & van Breda (1978)'s relation between E_{V-K}/E_{B-V} and λ_{max} (the wavelength of maximum interstellar polarization) is not valid for stars belonging to the M 16 core. This situation may arise mainly from the presence of silicate grains of slightly larger size than the standard ISM and also from a considerable increase in mean graphite grain size, according to previous results from Chini & Wargau (1990).

It was also found by OVM that a high percentage of the observed stars (about 50%) displayed indications of intrinsic polarization in their measurements, a percentage similar to the one found in IC 2944 (Vega et al. 1994), another young open cluster closely related to an H II region.

Since in the OVM investigation only stars in the core of NGC 6611 were observed, we propose here to extend the polarimetric observations to members belonging to the outskirts of the object. Our plan is to characterize the interstellar material (ISM) associated to halo stars, so as to make a comparison with the ISM dusty core characteristics. We also plan to individualize through the observations, those stars with indications of a non interstellar polarization, in order to make a comparison between both sections of the cluster.

To obtain an homogeneous set of observations, we have used the same photopolarimeter and technical reduction as in the past investigation.

2. Observations

Observations in the $UBV(RI)_{\rm KC}$ bands (KC: Kron-Cousins, $\lambda_{U_{\rm eff}}$ = 0.36 μm, FWHM = 0.05 μm; $\lambda_{B_{\rm eff}}$ = 0.44 μm,FWHM = 0.06 μm; $\lambda_{V_{\rm eff}}$ = 0.53 μm, FWHM = 0.06 μm; $\lambda_{R_{\rm eff}}$ = 0.69 μm, FWHM = 0.18 μm; $\lambda_{I_{\rm eff}}$ = 0.83 μm, FWHM = 0.15 μm) were carried out using the five-channel photopolarimeter of the Torino Astronomical Observatory attached to the 2.15 m telescope at the Complejo Astronómico El Leoncito (San Juan, Argentina). They were performed on 3 nights (June 14-16) in 2002 and 1 night (May 29) in 2003. Standard stars for null polarization and for the zero point of the polarization position angle were observed several times each night for calibration purposes and the standards were taken from Clocchiati & Marraco (1988). For further information on the instrument, data acquisition and data reduction, see Scaltriti (1994).

Table 1 lists the 25 stars observed in direction to the halo of the open cluster, including the percentage polarization (P_λ), the position angle of the electric vector (θ_λ) in the equatorial coordinate system and their respective mean errors for each filter. We also indicate the number of 60 sec independent integrations with each filter. Star identifications are taken from Walker (1961) and we indicate possible non members, according to de Winter et al. (1997), with an asterisk in this Table as well as in Table 2 below. The distribution of the observed stars in the field of NGC 6611 is shown in Figure 1, where the rectangular area indicates the region studied by OVM.

3. Results

By observing the amount of interstellar polarization in several bandpasses, the wavelength at which maximum polarization ($P_{\rm max}$) occurs can be computed. This wavelength

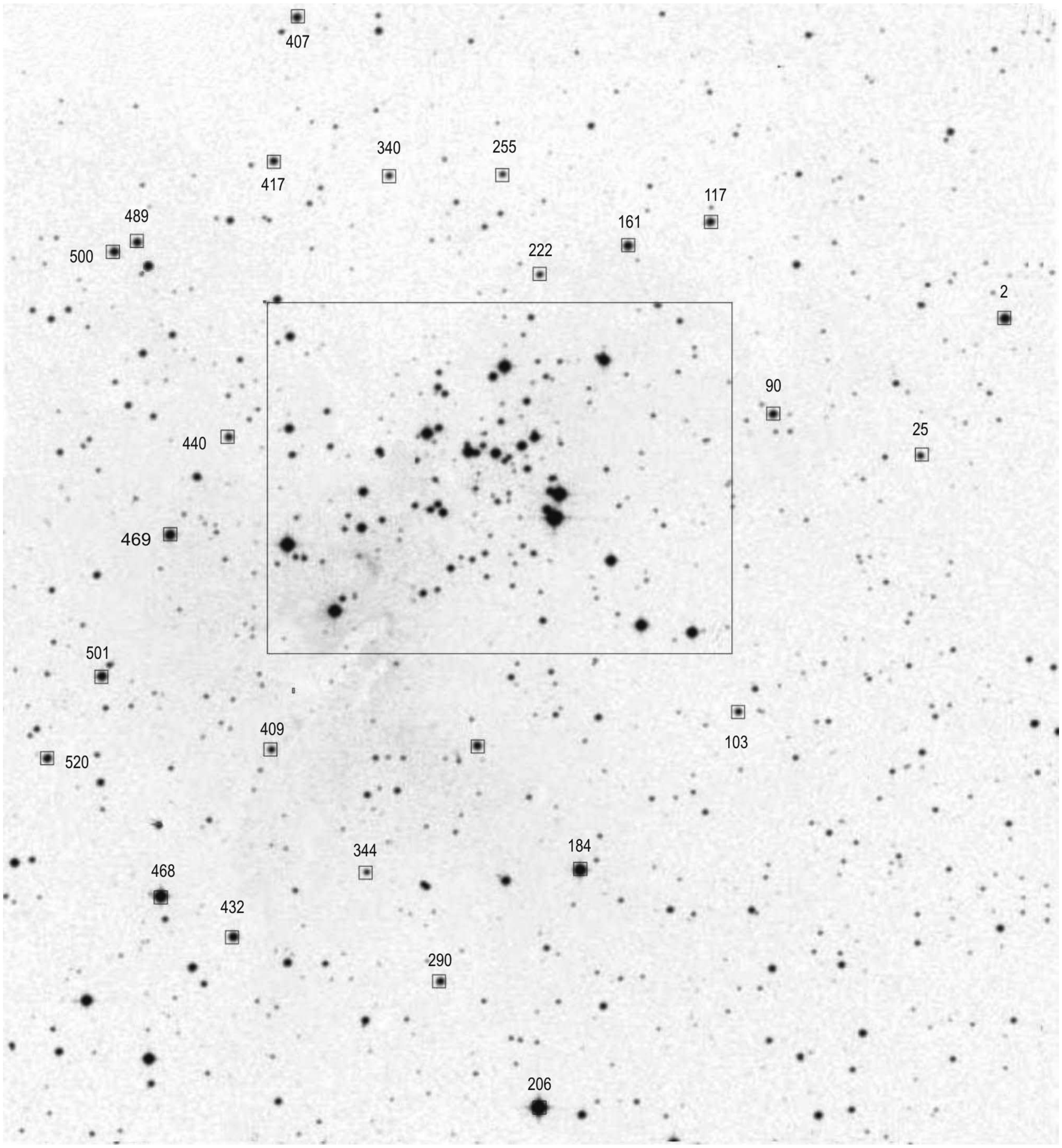

Fig. 1.— The stars observed in the field NGC 6611. The rectangular area indicates the region studied by OVM

$\lambda_{\max}$ is a function of the optical properties and characteristic particle size distribution of the aligned grains (McMillan 1978; Wilking et al. 1980). The maximum polarization $P_{\max}$ has been calculated by fitting the observed polarization in the $UBVRI$ bandpasses to the standard Serkowski's polarization law (Serkowski 1973)

$$P_{\lambda}/P_{\max} = \exp[-K \;\; ln^2 \; (\lambda_{\max}/\lambda)] \qquad (1)$$

and adopting the relationship

$$K = -0.01 + 1.66\lambda_{\max}$$

with $\lambda_{\max}$ in microns, from Whittet et al. (1992).

If the polarization is well represented by this relation (meaning that the measured polarization is of interstellar origin), σ_1 (the unit weight error of the fit) should not be higher than 1.5 because of the weighting scheme; a higher value could indicate the presence of intrinsic polarization in the light from the star, that is, a polarization not originated in the interstellar material between star and Sun. The dominant source of intrinsic polarization is asymmetric circumstellar dust (e.g. in binary systems) and, for classical Be stars, electron scattering.

Table 2 lists the $P_{\max}$, $\lambda_{\max}$ and σ_1 values for the observed stars. In the last column we also list spectral types from the WEBDA database (http://obswww.unige.ch/webda, developed and maintained by Jean Claude Mermilliod). The mathematical expression used to obtain the individual σ_1 values will be found in this Table as a footnote.

4. Analysis and Discussion

¿From their measurements, 10 objects have values for the unit weight error of the fit (σ_1) above 1.5. They are: two non members (nos. 25 and 440), and eight members (nos. 290, 340, 409, 468, 469, 489, 501 and 520). As stated previously, these stars may be suspected of having intrinsic polarization. There is another criterion to detect this presence: a fitted $\lambda_{\max}$ which is much shorter than the average general value for the interstellar medium (0.55 μm; Serkowski et al. 1975); this is the case for no. 161, another non member star, with a $\lambda_{\max}$ which amounts to 0.28 μm.

The most remarkable P_{λ} and θ_{λ} vs. λ plots for stars with indications of intrinsic polarization are shown in Figure 2, where the solid curve denotes the standard Serkowski's curve (1), the valid law for an interstellar origin in the measured polarization. The presence of intrinsic polarization in the light from a star causes a mismatch between observations and

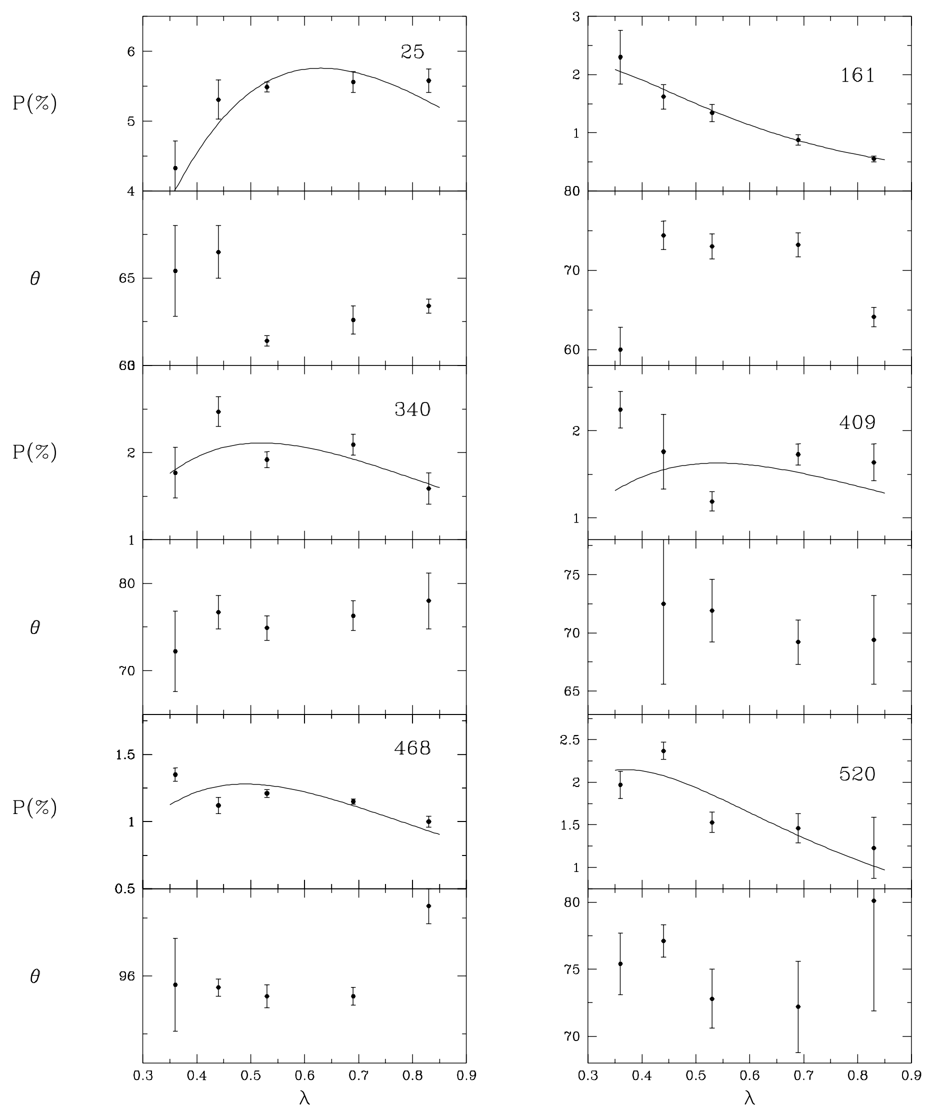

Fig. 2.— Polarization and position angle dependence on wavelength for stars with indications of intrinsic polarization (mismatch between observations and Serkowski's curve fit and/or variable position angle)

the Serkowski's curve fit, and/or a rotation in position angle of the polarization vector. The above-mentioned mismatch is clearly seen in every plot, except for star 161, but the rotation in position angle with λ is a common characteristic of the whole group of stars with σ_1 higher than 1.5, including that star.

We have searched the literature looking for clues about possible origins of the intrinsic polarization detected in this group of eleven stars. We have found, for example, that Hillenbrand et al. (1993) suggest that no. 25 (B0.5 V) has circumstellar material based on IR excesses, while Dûchene et al. (2001) have found it is member of a binary system, with a separation of 1.43 arc seconds. The light from this star shows a very high polarization (5.75 %). According to the same authors, no. 290 (B1 V; σ_1 = 1.64) is part of another binary system, with a separation of 1.37 arcsec between members but this fact cannot be associated with intrinsic polarization. No. 409 is an Orion type variable, with spectral type B4 Ve and a very high σ_1 value: 3.46. About nos. 468 (B1 Vp) and 161, Kumar et al. (2004) have found that they show mid-infrared (7-100 μm) (MIR) excesses, which indicate that cool circumstellar dust is present. This identifies them as Vega-like stars or precursors to such phenomenon. Star 469 (B1.5 Vp) has Hβ partially filled in with emission. We could not find any particular clue for the rest: they are probably undetected close binary systems or perhaps rapid rotators. The spectroscopic information used in this section comes from the WEBDA database.

It is known that for the interstellar medium the polarization efficiency (ratio of the maximum amount of polarization to visual extinction) rarely exceeds the empirical upper limit

$$P_{\max} \leq \; 3 \; A_V \; \simeq \; 3 \; (R_V \; E_{B-V} \qquad (2)$$

obtained for interstellar dust particles (Hiltner 1956). The ratio $P_{max}/(R_V.E_{B-V})$ depends mainly on the alignment efficiency and the magnetic field strength, as well as on the fact that sometimes radiation traverses more than one cloud with different field directions.

Figure 3 depicts the relation that exists between reddening and polarization originated in dust along the line of sight to NGC 6611. Open circles represent halo member stars observed in this work, while filled circles are used for stars in the core (OVM). Triangles represent the position of the "frontside" stars, used to subtract the effects of foreground extinction from the light coming from any other star observed in the central region.

The empirical upper limit (2), known as the line of maximum efficiency, has been drawn adopting $R_V = 3.1$. Excesses E_{B-V} were obtained from the literature or from the relationship between spectral type and color indices following Schmidt-Kaler (1982). It can be seen that the points lie to the right of the interstellar maximum line; this situation indicates that the observed polarization is mostly due to interstellar material.

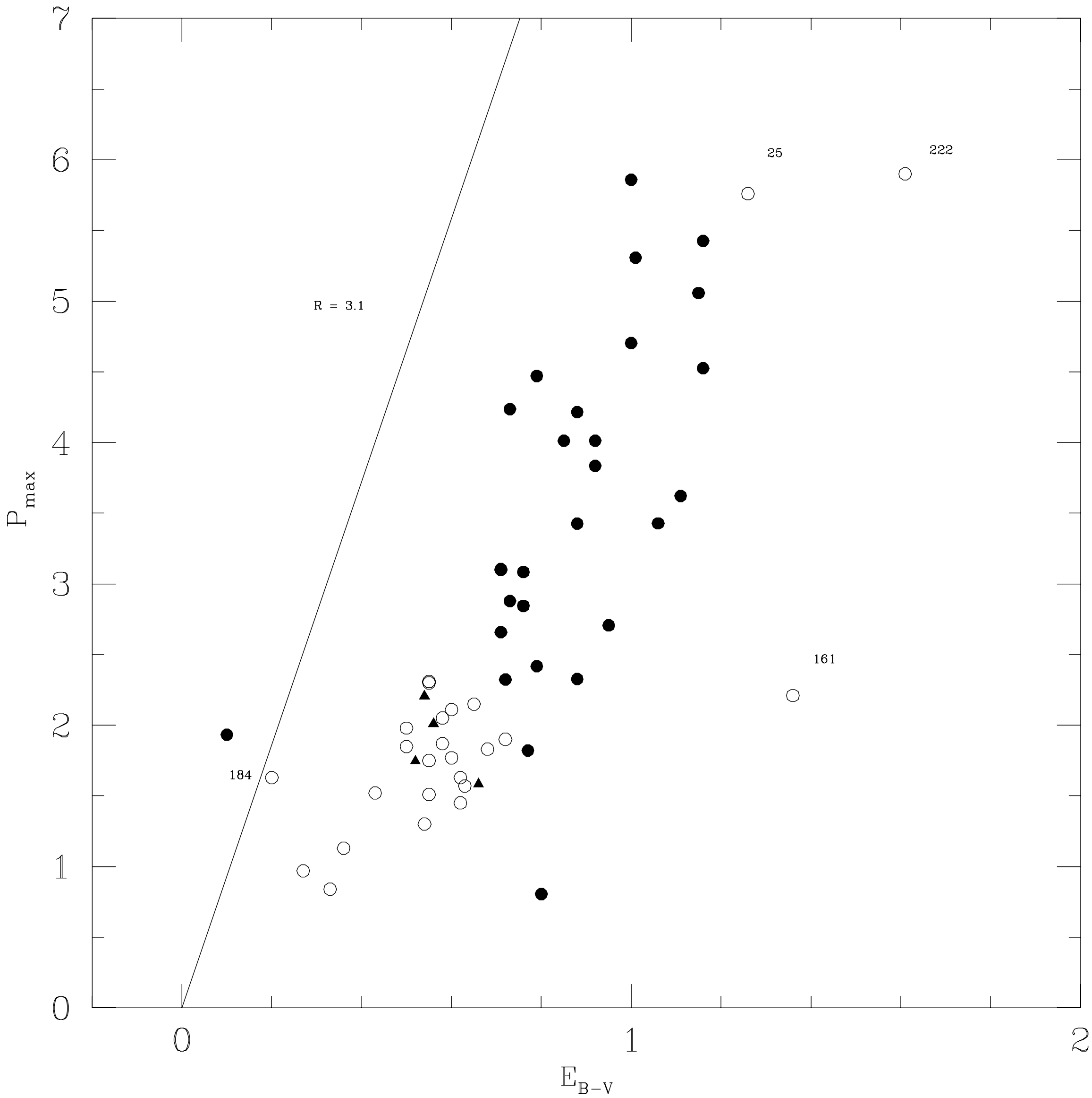

Fig. 3.— Polarization efficiency diagram. Filled symbols correspond to OVM's observations while open symbols are for stars observed in direction to the halo. Triangles indicate the four stars adopted as "frontside" in the core investigation. The line of maximum efficiency is drawn adopting $R_V = 3.1$

Star 184 is located very close to the interstellar maximum line. It has been classified as K2 III (Walker 1961), and its excess is low: $E_{B-V} = 0.20$ mag. Tucholke et al. (1986) have proposed for this star a 0 % membership probability in NGC 6611. Its polarization amounts to $P_{max} = 1.70$ %, which is too high for its distance from the Sun (534 pc). Even when the σ_1 value (0.73) does not indicate the presence of intrinsic polarization, we think that due to evolution the star is ejecting material to space, which originates the high polarization. Stars 25 and 222 are background stars according to the literature.

Figure 4 shows the run of the polarization vector P through its components in the equatorial system, the Stokes parameters Q and U. This plot supplies useful information on variations in interstellar environments: if the light from individual members of an open cluster has gone through a common sheet of dust, their representative points will concentrate on a given region of the plot, indicating similar optical characteristics of the interstellar material. If the plot shows more than one concentration, this means that the light from a certain group of stars has traveled through dust with somewhat different characteristics. In this Fig. we identify at least 2 different groupings. One of them consists of the frontside stars 206, 344 and 432 (squares), which belong to the Local arm. Based on the spectral type of star 206 we conclude that the light from this group is affected by nearby clouds, located at less than 750 pc from the Sun, which originate a mean polarization of about 1%. Its $\overline{\lambda_{max}} = 0.61 \pm 0.07\mu$m (mean of 3 stars) is slightly larger than that of the average ISM and it has a mean direction of the polarization vectors of $\overline{\theta_V} = 81.^\circ9 \pm 1.^\circ8$. The square plotted in the upper part of Fig. 4 represents star 222, previously mentioned as a background star.

The second group consists of halo member stars (open symbols) and core members (filled symbols). Halo and core stars do not overlap each other in the plot; the only exceptions are stars 349, 367, 374 and 455 , which were selected in the past investigation as "frontside" in order to subtract the dust in front of core stars. According to this plot, it seems that these four stars are halo members, projected against the core. The light from the halo stars shows a mean vectorial polarization of 1.93 ± 0.3 %. Their $\overline{\lambda_{max}}$ has a value similar to the ISM (0.55 $\pm 0.07\mu$m) and the low dispersion indicates homogeneity in the distribution of the polarizing dust. The polarization vectors have a mean direction given by $\overline{\theta_V} = 77.^\circ1 \pm 5.^\circ5$. Stars with intrinsic polarization have not been included in the calculations.

Star 103 (E_{B-V}= 0.44 mag), plotted in Fig. 4 as a square near the halo stars group, is considered as a probable non member by de Winter et al. 1997, according to its excess. The star has a polarization of 1.78 %, and the orientation of its e-vector is $\theta_V = 82.^\circ1$. Both polarimetric magnitudes are compatible with an halo membership and for that we propose the star is a probable member of NGC 6611 but located near the cluster limits.

Finally, the filled symbols distribution seems to reveal the presence of another group.

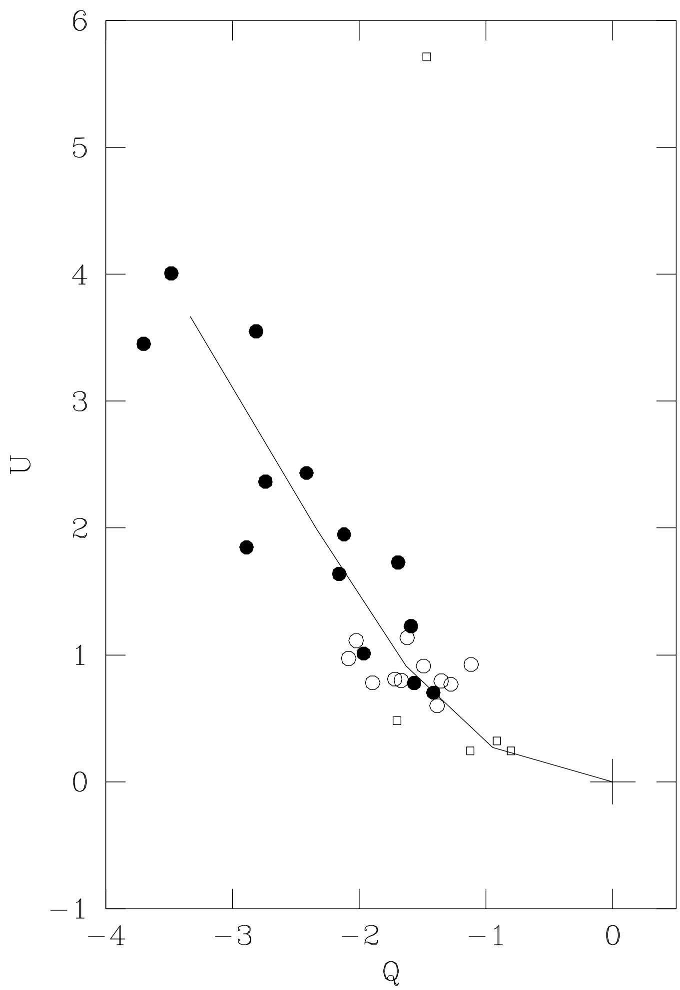

Fig. 4.— Q and U parameters for the observed stars in NGC 6611. Filled symbols are for observations in the direction to the core (OVM), open symbols are for halo stars (this investigation) and squares are for non-members from both works. Stars with intrinsic polarization are not included in this plot

We think they are only stars more deeply immersed in the dust core, or perhaps on the far side of it. The line represents the changing direction of the projected e-vector while the line of sight travels from the Sun to the cluster. As can be seen, there is practically no deviation in the line direction between halo and core stars.

Figure 5 plots the polarization vectors and their orientations for the observed stars in direction to the cluster. It reproduces OVM's Fig. 6 (upper plot) for core stars, with the addition of halo stars (filled and open circles, respectively). Position angles for both groups are similar in general, with a slight difference in mean direction of the e-vector between both groups, which is under the errors: $70.^\circ0 \pm 2.^\circ5$ (core) vs. $73.^\circ7 \pm 2.^\circ5$ (halo).

Figure 6 shows the E_{V-K}/E_{B-V} vs. λ_{max} plot for stars observed in the core of NGC 6611 (filled symbols) and in the halo (open symbols), following the procedure outlined in Hillenbrand et al. (1993) and Belikov et al. (1999). Here we find that the halo stars are possibly represented by Whittet & van Breda (1978)'s ($R_V = 5.6\lambda_{max}$) relationship, but the somewhat larger errors involved prevent us from drawing definite conclusions.

5. Conclusions

We were not able to find any significant difference between the core and halo dust characteristics. A 47 % (8 out 17) of the halo stars has indications of intrinsic polarization in their light, a percentage which is similar to the one found for core stars (50 %). A possible explanation for these high values comes from the work of Dûchene et al. (2001) on the total binary frequency of high-mass stars in NGC 6611. ¿From observations of stars in direction to the cluster (OVM and this paper) we have concluded that the light from member stars is affected by several dust clouds. Such dust clouds are located: a) in the Local arm, contributing to the final measured polarization with some 1.0%; b) in the Sagittarius arm, in front of the cluster outskirts (that is, intra-arm dust, contributing with another 0.8 %); c) variable intracluster dust contribution, as found in OVM' s core investigation and this paper.

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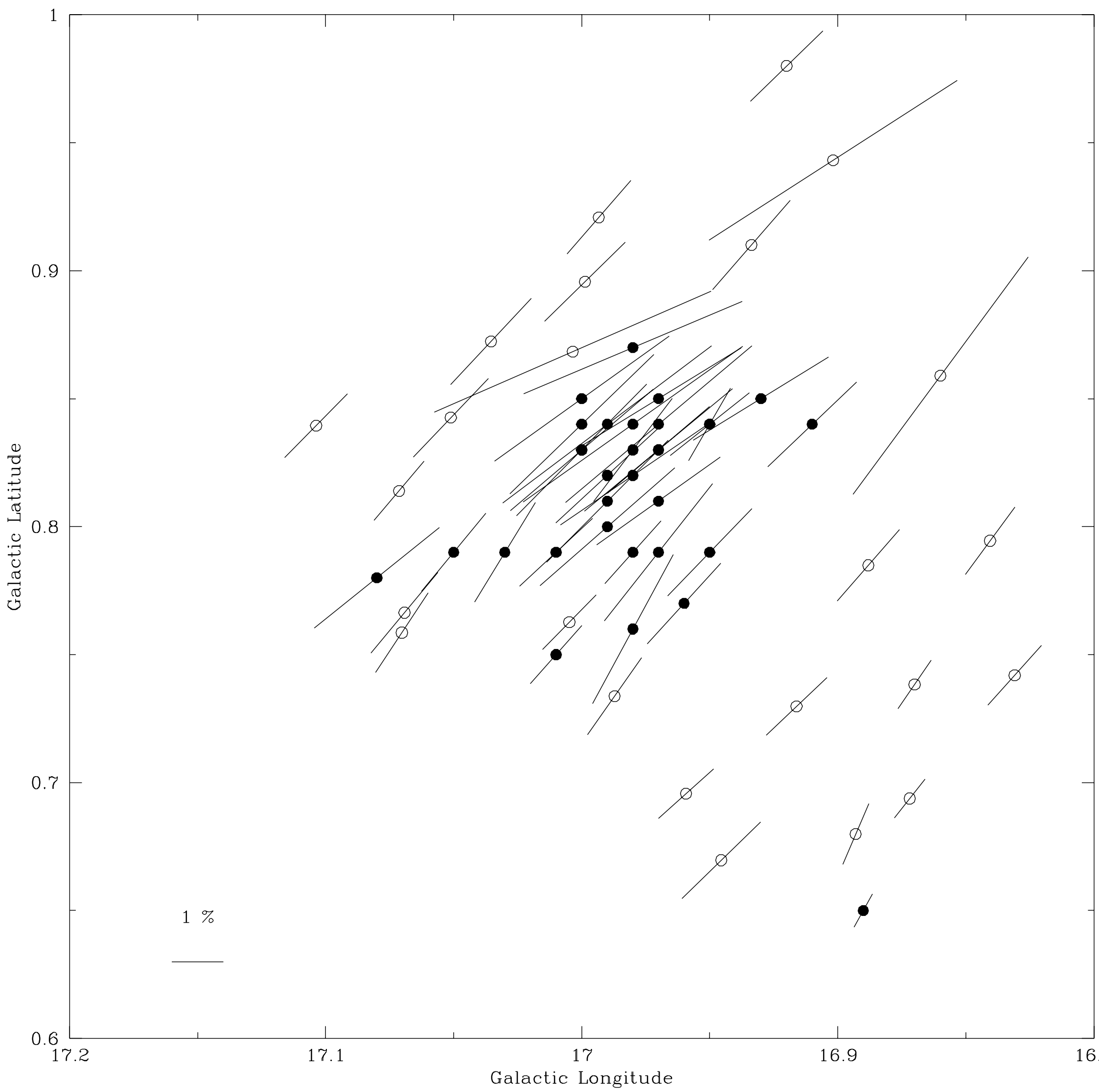

Fig. 5.— Polarization vectors and their orientations for the observed stars in direction to NGC 6611. Same symbols as in previous Figures. The length of each vector is proportional to the percentage polarization.

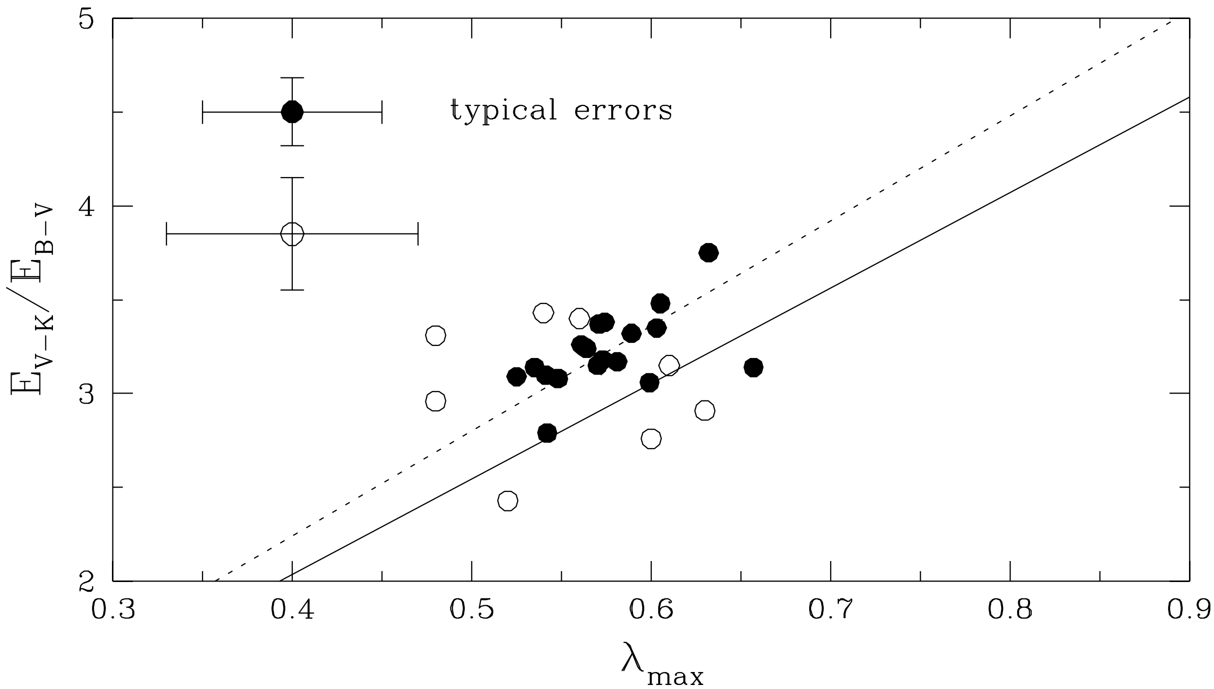

Fig. 6.— E_{V-K}/E_{B-V} vs. λ_{max} plot for stars observed in the core of NGC 6611 (filled symbols) and its surroundings (open symbols). The lines drawn are: Whittet & van Breda (1978)'s relationship (continuous line) and the relationship found in OVM for the core stars (dotted line).

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Table 1. Polarimetric observations in NGC 6611

Star [a]	*HD/BD/H* [b]	filter	P_λ %	ϵ_p %	θ_λ °	ϵ_θ °	*n* [c]
2	BD −13° 4914	U	1.70	0.25	63.9	2.1	2
		B	2.18	0.21	65.0	1.4	
		V	1.99	0.13	72.5	0.9	
		R	1.55	0.12	72.6	1.1	
		I	1.59	0.19	71.1	1.7	
25*		U	4.33	0.39	65.4	2.6	3
		B	5.31	0.28	66.5	1.5	
		V	5.49	0.07	61.4	0.3	
		R	5.56	0.15	62.6	0.8	
		I	5.58	0.17	63.4	0.4	
90		U	2.14	0.65	70.5	4.3	2
		B	2.10	0.25	73.2	1.7	
		V	2.13	0.15	77.5	1.0	
		R	2.22	0.12	74.7	0.7	
		I	2.25	0.17	75.5	1.1	
103		U	–	–	–	–	2
		B	1.30	0.32	88.0	3.5	
		V	1.68	0.24	82.1	2.1	
		R	1.98	0.16	78.4	1.2	
		I	1.40	0.24	86.1	2.5	
117		U	1.80	0.17	70.0	1.3	2
		B	1.86	0.36	78.2	2.8	
		V	1.55	0.16	77.4	1.4	
		R	1.72	0.09	77.0	0.8	
		I	1.61	0.08	75.1	0.7	

Table 1—Continued

Star [a]	*HD/BD/H* [b]	filter	P_λ %	ϵ_p %	θ_λ °	ϵ_θ °	*n* [c]
161*	H 14	U	2.30	0.46	60.0	2.8	2
		B	1.62	0.21	74.4	1.8	
		V	1.34	0.15	73.0	1.6	
		R	0.88	0.09	73.2	1.5	
		I	0.55	0.05	64.1	1.2	
184*	BD −13° 4924	U	2.09	0.39	82.5	8.1	2
		B	1.71	0.30	82.0	2.5	
		V	1.44	0.16	82.6	1.6	
		R	1.30	0.08	85.3	0.9	
		I	1.14	0.16	79.4	2.0	
206*	HD 168097	U	–	–	–	–	3
		B	0.71	0.16	89.5	3.1	
		V	0.79	0.12	76.7	1.2	
		R	0.81	0.08	81.6	1.4	
		I	0.81	0.06	86.0	1.2	
222*		U	2.90	0.45	52.5	4.4	2
		B	4.75	0.35	65.1	2.1	
		V	5.49	0.43	52.2	2.3	
		R	5.81	0.17	57.1	0.9	
		I	5.80	0.45	55.0	2.2	
255		U	–	–	–	–	2
		B	2.25	0.31	77.1	3.9	
		V	2.23	0.23	75.6	3.0	
		R	1.87	0.12	74.7	1.8	
		I	1.48	0.12	80.9	2.4	

Table 1—Continued

Star [a]	*HD/BD/H* [b]	filter	P_λ %	ϵ_p %	θ_λ $\circ$	ϵ_θ $\circ$	*n* [c]
265		U	1.87	0.19	70.0	2.9	2
		B	1.75	0.15	76.1	1.2	
		V	1.78	0.18	77.2	1.4	
		R	1.48	0.13	79.8	1.2	
		I	1.37	0.12	82.4	2.3	
290		U	1.32	0.26	71.1	5.5	2
		B	1.53	0.04	77.5	0.8	
		V	1.53	0.03	76.5	0.5	
		R	1.58	0.06	74.8	1.1	
		I	1.23	0.09	72.5	2.1	
340		U	1.77	0.29	72.2	4.6	2
		B	2.47	0.17	76.7	1.9	
		V	1.92	0.09	74.9	1.4	
		R	2.09	0.12	76.3	1.7	
		I	1.59	0.18	78.0	3.2	
344*		U	0.98	0.52	22.5	13.9	2
		B	0.79	0.32	101.1	11.2	
		V	1.15	0.15	83.9	3.6	
		R	1.17	0.15	83.4	3.7	
		I	0.93	0.34	97.8	10.1	
407		U	1.51	0.14	79.4	2.7	2
		B	1.49	0.09	80.2	1.8	
		V	1.65	0.05	74.3	0.9	
		R	1.75	0.05	77.2	0.8	
		I	1.62	0.10	79.4	1.7	

Table 1—Continued

Star [a]	*HD/BD/H* [b]	filter	P_λ %	ϵ_p %	θ_λ $^\circ$	ϵ_θ $^\circ$	n [c]
409		U	2.24	0.21	83.6	2.7	2
		B	1.76	0.43	72.5	6.9	
		V	1.19	0.11	71.9	2.7	
		R	1.73	0.12	69.2	1.9	
		I	1.64	0.21	69.4	3.8	
417		U	1.13	0.41	74.4	5.1	2
		B	1.57	0.11	75.9	2.0	
		V	1.46	0.05	78.3	1.8	
		R	1.44	0.03	75.6	1.2	
		I	1.25	0.03	79.9	0.9	
432*		U	0.95	0.12	85.0	3.7	2
		B	0.89	0.08	88.6	2.7	
		V	0.95	0.05	80.3	1.6	
		R	0.89	0.04	86.4	1.5	
		I	0.75	0.09	93.9	3.4	
440*		U	1.99	0.92	56.5	12.5	2
		B	1.15	0.30	68.9	7.3	
		V	1.46	0.06	74.5	1.2	
		R	1.49	0.06	76.1	1.1	
		I	1.07	0.09	72.3	2.4	
468	BD -13° 4934	U	1.35	0.05	95.7	1.6	2
	H 6	B	1.12	0.06	95.6	0.3	
		V	1.21	0.03	95.3	0.4	
		R	1.15	0.02	95.3	0.3	
		I	1.00	0.04	98.4	0.6	

Table 1—Continued

$Star$ [a]	$HD/BD/H$ [b]	filter	P_λ %	ϵ_p %	θ_λ °	ϵ_θ °	n [c]
469	BD -13° 4933	U	1.45	0.11	80.1	1.8	2
	H 13	B	1.56	0.06	81.1	1.0	
		V	1.68	0.07	83.3	0.6	
		R	1.69	0.06	83.5	0.6	
		I	1.68	0.01	81.9	0.3	
489		U	2.41	0.31	72.0	1.8	2
		B	2.05	0.21	77.4	1.5	
		V	1.95	0.09	78.8	0.6	
		R	2.01	0.06	80.1	0.5	
		I	1.85	0.10	80.2	0.8	
500		U	1.74	0.34	82.3	2.8	2
		B	1.73	0.14	80.8	1.2	
		V	1.83	0.09	85.1	0.7	
		R	1.79	0.07	85.4	0.5	
		I	1.63	0.11	84.7	0.9	
501		U	0.24	0.48	149.6	31.7	2
		B	1.13	0.13	74.1	3.5	
		V	1.44	0.04	70.2	0.9	
		R	1.44	0.04	70.6	0.7	
		I	1.15	0.09	74.0	2.3	
520		U	1.97	0.16	75.4	2.3	2
		B	2.37	0.10	77.1	1.2	
		V	1.53	0.12	72.8	2.2	
		R	1.46	0.17	72.2	3.4	
		I	1.23	0.36	80.1	8.2	

Note. —

a : Identifications from Walker (1961)

* Stands for nonmember

b : Identifications from Hoag et al. (1961) (H), Henry Draper (HD) or Bonner Durchmusterung (BD)

c : number of integrations

Table 2. Polarization results

Star [a]	$P_{\max}$ %	ϵ_p %	σ_1 [b]	$\lambda_{\max}$ μm	ϵ_λ μm	*Sp. T.* [c]
2	1.96	0.14	1.14	0.44	0.06	B8 V
25*	5.75	0.10	1.52	0.64	0.03	BO.5 V
90	2.29	0.07	0.79	0.64	0.04	B3 V
103*	1.78	0.15	1.27	0.63	0.12	AO V
117	1.85	0.10	1.34	0.54	0.05	–
161*	3.21	0.58	0.49	0.28	0.01	O8.5 V
184*	1.70	0.16	0.73	0.36	0.04	K2 III
206*	0.84	0.02	0.31	0.67	0.02	G6 II
222*	5.91	0.21	0.89	0.72	0.04	O7 III ((f))
255	2.62	0.28	1.16	0.31	0.04	–
265	1.81	0.06	0.53	0.43	0.02	–
290	1.56	0.04	1.64	0.53	0.04	B1 V
340	2.09	0.14	1.99	0.50	0.07	A0 V
344*	1.15	0.06	0.51	0.63	0.07	–
407	1.71	0.05	1.20	0.61	0.04	–
409	1.61	0.26	3.46	0.54	0.20	B4 Ve
417	1.51	0.04	0.96	0.53	0.02	–
432*	0.96	0.03	0.58	0.50	0.02	–
440*	1.49	0.23	2.46	0.49	0.04	G1 III/K1 III
468	1.25	0.06	1.60	0.49	0.03	B1 Vp
469	1.81	0.03	1.56	0.63	0.02	B1.5 Vpe
489	2.09	0.09	1.55	0.56	0.05	B8.5 V
500	1.86	0.02	0.40	0.57	0.02	B2 V (e?)
501	1.45	0.08	1.70	0.61	0.10	–
520	2.36	0.05	2.50	0.27	0.09	B7: V

Note. —

a : Identifications from Walker (1961)

* Stands for nonmember

b : ${\sigma_1}^2 = \sum (r_\lambda/\epsilon_{p_\lambda})^2/(m-2)$; where

m is the number of colors and

$r_\lambda = P_\lambda - P_{\max}\ \exp(-K\ ln^2(\lambda_{\max}/\lambda))$

c : Spectral type from the WEBDA database