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Linear Polarization of the Galactic Centre in the near Infrared

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Summary. The linear polarization of the Galactic Centre has been measured in the H and K wavelength bands as (11.6 ± 1.5) and (5.2 ± 0.14) percent respectively. The results represent a significant improvement in accuracy over hitherto published data and thus allows a more stringent test of the mechanism responsible for polarizing the radiation. The results are discussed in terms of aligned interstellar grains and found to be consistent with the standard interstellar law for linearly polarized radiation.

Key words: galactic centre — polarization — infrared

Introduction

Previous polarization measurements in the near infrared of the Galactic Centre have been interpreted as arising from two contributions. At the longer wavelengths, between 8 and 13 microns, Capps and Knacke (1976), Knacke and Capps (1977) have shown that the polarization may be attributed to absorbing silicate grains local to the individual infrared sources shown in the high resolution map of Becklin and Neugebauer (1975). In particular they found evidence for variation of the position angle of the polarization between these individual sources.

On the other hand, polarization measurements at 2.2 microns by Adams and Hough (1977), Knacke and Capps (1977) and Maihara et al. (1977), were discussed in terms of selective absorption by the intervening interstellar dust grains in the Sagittarius Galactic Arm. As noted by Maihara et al. (1977), a more stringent test of this latter interpretation is to measure the polarization in the 1.6 micron band since, for dust grains of typical interstellar size, the polarization would be expected to increase significantly at the shorter wavelength. The position angle, however, should be unchanged provided there is no significant twisting of the aligned grains along the line of sight. Furthermore, if the interstellar medium is the only source of polarization at 1.6 and 2.2 microns and provided the degree and direction of grain alignment does not vary within small ($\sim 30''$) angular regions of the sky then the level of polarization and position angles should be the same for the individual infrared sources at the Galactic Centre. Such measurements have recently been reported by Knacke and Capps (1977) at 2.2 microns. Unfortunately our signal to noise ratio was sufficient only to measure the polarization of the brightest of these sources.

The Observations

The measurements were made using a recently updated version of the Hatfield Polarimeter (Cox, 1975), mounted on the 1.5 m Infrared Flux Collector at the Cabezon Observatory, Tenerife.

The instrumental polarization in the H and K bands was measured to be 0.10 and 0.06% respectively and was subtracted from all the data presented below (in fact the corrections are essentially negligible when dealing with polarization as high as those recorded for the Galactic Centre). The centre wavelengths of the pass band filters were 1.68 and 2.18 microns. On all occasions the polarimeter was centred on source 7 of the infrared map of the Galactic Centre (Becklin and Neugebauer, 1975) using an offset guider built into the polarimeter. No sky chopping is employed in the Hatfield Polarimeter, modulation being achieved by a rapidly rotating Polaroid Corporation "HR" polarizer whose principal transmittances were measured over the band pass of each filter using the technique described by Rupprecht et al. (1962). The absence of sky chopping is of course advantageous for sources as extended as the Galactic Centre. Background measurements, taken every 25 s, were made at a point 10′ to the East of the Galactic Centre. The resulting data showed that any possible systematic errors due to variations in the sky background were negligible

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Table 1. Summary of observations of polarization (P) and position angle (θ)

Beam (arcsec)	Wavelength (microns)	No. of independent observations	P (percent)	θ (deg)
55	2.18	4	5.2 ± 0.14	13 ± 1
33	2.18	3	4.8 ± 0.5	10 ± 4
11	2.18	3	5.7 ± 1.3	9 ± 18
55	1.68	4	11.6 ± 1.5	11 ± 3

compared to limitations imposed by detector noise. The zero point of the polarization position angles was determined by inserting into the optical beam a calibration polaroid whose transmission axis was aligned along the meridian to an accuracy of 1 degree.

The data obtained between July 2–3, 1977, are presented in Table 1.

Discussion

The degree of polarization and position angle at 2.18 microns, obtained with the widest beam, is in excellent agreement with the result of (5.2 ± 0.3)% and (16 ± 3) degrees obtained by Maihara et al. (1977) with an almost identical beam width. (We note that the level of polarization is somewhat lower than the value reported previously by Adams and Hough (1977) using a sky chopping instrument although the difference is less than 2 standard errors of the earlier result.) The level of polarization measured at 1.6 microns appears consistent with the substantially less accurate value of (16.7 ± 5.7)% reported by Maihara et al. (1977). The increased precision at the shorter wavelength is important in distinguishing the production mechanism or mechanisms for the polarized radiation. We find no evidence for a change in polarization at 2.18 microns as the aperture is decreased although the result using an 11″ beam has a relatively large uncertainty.

Knacke and Capps (1977), however, find that the level of polarization at 2.2 microns varies from source to source and obtain a somewhat lower value of (3.0 ± 0.3)% for the polarization of the brightest source (source number seven) measured with a 7″ beam. The position angles of the measured sources are essentially the same and in good agreement with those reported here. Taking account of the 2.2 micron flux from each of the sources (Becklin and Neugebauer, 1975) we calculate from the results of Knacke and Capps (1977) a weighted polarization of (3.4 ± 0.5)% which again is somewhat lower than the value reported here using a wide beam covering all sources.

Any variations in the level of polarization from source to source could indicate that they are intrinsically polarized. The case against this, however, appears to be strong. Firstly all the sources have position angles of polarization aligned within 20 degrees of the Galactic plane, which is a feature also shared by the foreground stars studied by Mathewson and Ford (1970) out to a distance of ~4 kpc. Secondly, if the polarization is intrinsic then it might be expected that decreasing the beam width would increase the level of polarization whereas the experimental evidence suggests the level remains constant or even decreases. It would thus seem that the variations in polarization reported by Knacke and Capps (1977), if confirmed, must be attributed to variations in magnetic field and or changes in mean particle size along the line of sight to each source.

Further evidence that the polarization results from interstellar absorption is given by comparing the polarization at 1.68 and 2.18 microns, particularly noting that the position angles at the two wavelengths are in excellent agreement.

It has been demonstrated by many authors that the interstellar polarization $P(\lambda)$ follows an empirical law

$$\frac{P(\lambda)}{P(\lambda_{\max})} = \exp\left[-1.15 \ln^2 (\lambda_{\max}/\lambda)\right]$$

where $\lambda_{\max}$ is the wavelength at which the maximum interstellar polarization $P(\lambda_{\max})$ occurs (Serkowski, 1973). Taking $\lambda_{\max} = 0.56$ microns, as given by the sky map of Serkowski (1973), then the ratio of polarization at 1.68 and 2.18 microns should be 2.1. This value is very close to the measured ratio of 2.2 ± 0.3. Extending the same argument to the longer wavelength measured by Knacke and Capps (1977), we calculate the polarization produced by interstellar absorption to be 0.91% at 3.5 microns. At this wavelength the observed polarizations of the individual sources (Knacke and Capps, 1977) are about 3 to 4 times larger than calculated above. Hence, although the position angles at 3.5 microns are still largely aligned with those at 2.2 microns, it would seem difficult to entirely account for the polarization in terms of interstellar absorption.

From the present results we are also able to investigate the alignment efficiency of the interstellar grains on line of sight to the Galactic Centre. This may be estimated from the ratio of $P(\lambda_{\max})/E_{B-V}$ where E_{B-V} is the colour excess (Serkowski, 1973).

Now the ratio R of total to selective interstellar extinction (A_V/E_{B-V}) may also be calculated from the general relationship $R = 5.5\lambda_{\max}$ (Serkowski et al., 1975). Taking a value of 0.56 microns for $\lambda_{\max}$ and a value for A_V of 27 magnitudes (Becklin and Neugebauer, 1968) we calculate the colour excess E_{B-V} to be 8.8 magnitudes. Hence, using the measured polarization at 2.18 microns and the empirical interstellar law we calculate a value for $P(\lambda_{\max})/E_{B-V}$ of 4.94 ± 0.13. This is less than the maximum observed value for the interstellar medium of 9.0 but is in very good agreement with the average value of 4.96 calculated from the sample of 204 stars measured by Serkowski et al. (1975). Similar average values of 5.03 and 4.4 have been found by Berger (1977) for 21 stars near the Orion Nebula and by Carrasco et al. (1973), respectively, for a somewhat smaller sample in the ρ Oph Dark Cloud.

We conclude that in general the polarization in the H and K bands appears to fit well the standard interstellar law and the efficiency of grain alignment would appear to be that typically found in other regions of the galaxy. The possible variation of polarization among individual infrared sources reported by Knacke and Capps (1977) would, if confirmed, lead to knowledge of the microstructure of the magnetic field along line of sight to the central regions of the galaxy.

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