NO. 89 WAVELENGTH DEPENDENCE OF POLARIZATION. VII. INTERSTELLAR POLARIZATION*

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ABSTRACT

Observations were made of the interstellar polarization on eight selected stars with the Kitt Peak 36-in. reflector. The telescope was found, in 1961, to be free of instrumental polarization thanks to careful aluminization procedures.

THIS paper is one in a continuing series in this Journal. Eight stars were especially selected to be as far away and as faint as possible with the available equipment, and also to have uniform color characteristics. The observations of these eight stars are presented here. A detailed discussion of the results, and of those obtained on brighter stars, will be made in a following paper.

1. *Filter Tracings*

The filters used in this program were traced anew, with the Cary 14 spectrophotometer of the Kitt Peak National Observatory. We thank the Observatory for the use of this fine instrument and we thank Mr. S. F. Pellicori who made all tracings.

Table I describes the tubes and filters and the resulting wavelengths. Table I of Gehrels and Teska (1960) is hereby superseded. The principal changes are the addition of a filter near 1.19 μ^{-1}, especially important for the interstellar polarization, and the use for shorter wavelengths of an EMI 6255*S* phototube which has a quartz window. The R_1 filter of Table I is temporary and will be replaced by an interference filter that does not have a "tail" of transmission out to 1 μ.

The values of the effective wave numbers are defined by

$$\left(\frac{1}{\lambda}\right)_{\text{eff}} = \frac{\int I(1/\lambda)1/\lambda d(1/\lambda)}{\int I(1/\lambda)d(1/\lambda)}.$$

The average color of the stars of the present paper was taken into account for sec$z$ = 1.0 at 7000 ft altitude, and the sensitivity curves of the phototubes (as provided by the manufacturer) were used, as well as the tracings of our filter transmissions. The values of $(1/\lambda)_{\text{eff}}$ have an estimated probable error of ± 0.03.

2. *Instrumental Polarization*

About 10 stars were observed with the Kitt Peak 36-in. reflector in order to determine the instrumental polarization. As usual in this program, the stars were chosen from the Behr (1959) catalogue with the polarization, $p < 0.0008$ mag. Even if these small polarizations are real, the average observed polarization should be zero because the 10 selected stars show a nearly uniform distribution of position angles.

The average of the observed polarizations with the

TABLE I. Filters and phototubes.

Filter	$(1/\lambda)_{\text{eff}}$	Eff. wavel.[a] in μ	Multiplier[b] phototubes	Description of the filters[b]
N	3.04	0.33	EMI 6255*S*	st. th. C.S. 7–54; plus 8.7 mm thickness of a solution: 98% $NiSO_4 \cdot 6 H_2O$, 420 g/liter, and 2% $CuSO_4 \cdot 5 H_2O$, 260 g/liter; plus $\frac{1}{16}$-in. thickness of fused silica.
U	2.79	0.36	EMI 6255*S*	2 mm UG 2, plus 2 mm $CuSO_4 \cdot 5 H_2O$, 260 g/liter, plus $\frac{1}{16}$-in. of fused silica.
B	2.33	0.43	EMI 6255*S*	st. th. C.S. 5–57, plus st. th. GG 13.
G_1	1.95	0.51	EMI 6255*S*	2 mm C.S. 3–71, plus 2 mm BG 18.
G_2	1.85	0.54	RCA 7102	2 mm C.S. 3–71, plus 2 mm BG 18.
R_1	1.39	0.72	RCA 7102	$\frac{1}{2}$ st. th. C.S. 2–64, plus $\frac{1}{2}$ st. th. C.S. 1–58.
R_2	1.19	0.84	RCA 7102	$\frac{1}{2}$ st. th. C.S. 2–64, plus st. th. C.S. 5–57.
I	1.05	0.95	RCA 7102	st. th. C.S. 7–56.

[a] The reciprocal of $(1/\lambda)_{\text{eff}}$.
[b] EMI = Electra Megadyne Inc.; RCA = Radio Corporation of America; C.S. = Corning Specification; UG, etc., are Jena glass filters; st. th. = stock thickness.

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Kitt Peak 36-in., in 1961, is less than 0.002 mag. for all filters. The residual effect, if real, is probably intrinsic to the polarimeter or to the observing method. The instrumental polarization of this telescope in 1961, therefore, is negligible. This near-zero result, over the full range of wavelengths 0.3–1.0 μ, is compared with that of other telescopes in Fig. 1 of Gehrels and Teska (1963).

The aluminization of the mirrors of the Kitt Peak 36-in. had been done carefully with: (1) the glow discharge used sparingly; (2) the use of liquid-nitrogen baffling to eliminate backstreaming of oil vapors; and (3) having the glow discharge as well as the aluminum deposition normal and symmetrical to the surface of the mirrors. Pellicori recently made an additional suggestion, that is to aluminize the secondary while mounted in the hole of the primary, and to mount the secondary on the telescope after rotation of 90° with respect to the primary.

3. *Star Selection*

Eight stars were chosen from the Hiltner (1956) catalogue, with four selection rules as follows:

(1) $+0.29<(B-V)<+0.42$, and $-0.65<(U-B)<-0.53$.
(2) The amount of polarization $p>0.033$ mag.
(3) $V<8.0$ mag. This still is rather faint for high precision with the present equipment, especially for the N and the I filters. In order to improve the precision, a special effort was made to observe the amount of polarization rather than the position angle. For example, if the position angle for a star in the catalogue was 133°, the analyzer orientations would be as follows: 135° and 225°, 120° and 210°, 150° and 240°, and 133° as a seventh angle. Finally, each star was observed several times (on the average, three times with each filter).
(4) An attempt was made to include a wide range of values of the polarization–extinction ratio $p/3E_{B-V}$. To a first approximation, this ratio can serve as an indicator of orientation of the grains responsible for the polarization. If the ratio is small this may be due either to p itself being small or to E_{B-V} being large (or both). Small $p/3E_{B-V}$ indicates, if the same grains are responsible for both extinction and polarization, that they are poor polarizers. This would be the case, for example, if the grains were poorly aligned. On the other hand a large value of $p/3E_{B-V}$ indicates a high degree of alignment of the particles.

Table II lists the stars in order of galactic longitude; the Henry Draper catalogue number is used for identification. The spectral type, V, $B-V$, $U-B$, and $p/3E_{B-V}$ are all taken from the Hiltner (1956) catalogue.

TABLE II. Selected stars.

HD	Sp.	V	$B-V$	$U-B$	$p/3E_{B-V}$
193443	O9 III	7ᵐ24	+0ᵐ41	−0ᵐ54	0.016
207538	B0 V	7.31	.33	.64	24
218342	B0 IV	7.38	.41	.55	19
6675	B0.5 III	6.90	.31	.64	20
18326	O8	7.82	.38	.63	34
22253	B0.5 III	6.53	.33	.56	22
24431	O9 IV–V	6.72	.38	.61	20
43753	B0.5 III	7.90	+0.30	−0.64	0.034

4. *Observations*

The observations were made mostly with the 36-in. reflector of the Kitt Peak National Observatory during the fall of 1961. Additional observations were made with the McDonald 36-in. reflector, January 1962, and with the McDonald 82-in. in November 1963. The polarimeter is the same as used before in this series of papers. It has been described by Gehrels and Teska (1960; 1963). All reductions were made by Ann Silvester, to whom we are indebted for her careful work.

Table III gives the weighted mean of the observed percentage polarization. From internal agreement it appears that the probable error, of the results without a colon in Table III, is ±0.08% (nearly independent of wavelength). Colons are given when the precision appears of the order of ±0.4% or worse. A depolarization correction-factor of 1.01 was applied before entry in the table.

TABLE III. Observed interstellar polarization.

	Percentage polarization observed at $1/\lambda=$						
HD	1.05	1.19	1.39	1.95	2.33	2.79	3.04
193443	1.54:	1.03:	2.00:	1.70	1.84:	1.71:	1.30:
207538	1.51:	1.58	1.92	2.12	2.23	2.12:	1.72:
218342	1.85:	1.75	2.07	2.14	1.88	2.04	2.09:
6675	1.48	1.46	1.69	1.66	1.44	1.44	1.73
18326	2.51	2.51	3.88:	3.03	3.15	2.89	3.09
22253[a]	1.36	1.35	1.48	1.63	1.58	1.76	1.67
24431	1.57	1.60	1.34	2.14	1.87	2.12:	1.90
43753	2.18:	2.65	2.84:	2.80	2.59	2.28	2.51

[a] HD 22253 was also observed at $1/\lambda=1.85$; $P=1.94\%$, $\theta=113$:°.

Table IV gives the weighted mean of the position-angle observations. The probable error, of the results without a colon, is ±4°. (Section III describes the reason for poor precision of the position angle.)

TABLE IV. Observed position angles of interstellar polarization.

	Position angle observed at $1/\lambda=$						
HD	1.05	1.19	1.39	1.95	2.33	2.79	3.04
193443	34:°	58:°	71°	52°	43°	74°	64:°
207538	49	55	57:	59	59	56	63
218342	61:	56	53	54	54	50	67:
6675	110	125	127	130	121	116	130
18326	118	109	120:	115	119	116	119
22253	128	129	128	125	122	113	112
24431	125	121	120	113	119	117	110
43753	176:	164	150:	166	168	166	161

5. *Wavelength Dependence*

Table V shows the wavelength dependence of the percentage polarization; the normalization method of Treanor (1963) is followed. For each star, the straight average of the polarizations at $1/\lambda = 1.95$ and 2.33 is set equal to 100.0, and the resulting normalized percentage for each filter is listed in Table V.

The limited precision of the numbers in Table V should be kept in mind. Without colons, the probable error is about ±4%, and with colons it is ±20% or worse. Only two conclusions, therefore, appear established: all stars show a drop in the infrared, and in the ultraviolet there may or may not occur a decline in the amount of polarization.

TABLE V. Normalized interstellar polarizations.

	Normalized percentage polarization at $1/\lambda =$						
HD	1.05	1.19	1.39	1.95	2.33	2.79	3.04
193443	87:	58:	113:	96	104:	97:	73:
207538	69:	73	88	97	103	97:	79:
218342	92:	87	103	106	94	101	104:
6675	95	94	109	107	93	93	112
18326	81	81	126:	98	102	94	100
22253	85	84	92	102	98	110	104
24431	78	80	67	107	93	106:	95
43753	81:	98	105:	104	96	85	93

It is noted that HD 6675 has hardly any dispersion in the percentage polarization. HD 22253 clearly shows dispersion in the position angle of interstellar polarization. No correlation is apparent between any of the observed features and the ratio of polarization to extinction (last column of Table II).

In a following paper (Coyne and Gehrels 1966), an analysis will be made of all stars observed in this program to date.

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