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INFRARED POLARIMETRY OF VERY YOUNG OBJECTS INCLUDING THE BECKLIN-NEUGEBAUER SOURCE

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ABSTRACT

The Becklin-Neugebauer source in Orion shows 25 ± 3 percent linear polarization at 1.6 microns. An upper limit of 3 times the average interstellar value is derived for the size of the aligned dust particles likely to be responsible for the polarization.

NU Orionis is polarized in the infrared and visible regions with a significant rotation of position angles. The positon angle and wavelength dependence of polarization suggest that the optical polarization arises from aligned intracluster dust particles in front of the object while the infrared polarization may be due to a circumstellar shell.

Subject headings: infrared sources — interstellar matter — Orion Nebula — polarization

This letter reports the results of infrared polarization measurements of several infrared sources in regions of star formation. The bright point source in Orion (Becklin and Neugebauer 1967, hereafter called BN) is invisible in the optical region and shows a high circular polarization of 0.86 percent at 3.4 μ (Serowski and Rieke 1973). High linear polarization longward of 2 μ has also been reported (Loer, Allen, and Dyck 1973; Dyck *et al.* 1973). In particular, the amount of polarization increases with decreasing wavelength (excluding the 10-μ absorption feature), and unusually high values near 14 percent were reported at 2.2 μ.

For our measurements, the infrared polarimeter at Kitt Peak National Observatory attached to the 50-inch (127-cm) telescope was used on 1972 December 30 and 31 and 1973 January 1 (UT). The instrumental polarization was determined by observing several bright stars (assumed to be unpolarized) and found to be less than 0.1 percent in all filters. We adjusted our position angles to the values of VI Cygni No. 12 (Dyck 1973) and BN at 2.2 μ. Table 1 lists our results for the three objects investigated. The 14 percent polarization for BN at 2.2 μ has been confirmed. The optical polarization of NU Ori also presented here is an average of the measurements taken during 1971–1973 in a survey of the Orion region by one of us (M. B.).

The 25 percent polarization at 1.6 μ of the BN object is the largest yet measured in that wavelength region for any stellar object. Our measurements most likely are not contaminated by another, also optically invisible, infrared source found by Hilgeman (1970) about 10 $''$ north of BN. It is twice as bright as BN at 1.6 μ but only one-forth as bright at 2.2 μ. Since we centered on BN at 2.2 μ with a $12''$ beam size and then offset and guided carefully, the other source should have had no chance to enter either the source beam or the comparison beam. Furthermore, our data also allow us to calculate rough infrared fluxes for BN, and these were found to be very similar to those measured by Becklin and Neugebauer (1967).

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TABLE 1

LINEAR POLARIZATION MEASURED FOR YOUNG OBJECTS

Object	λ (microns)	Polarization (percent)	Position Angle (degrees)
Orion BN	1.6	25.5 ± 3.1	117
	2.2	14.2 ± 1.3	115
NGC 2264 Allen	2.2	2.7 ± 0.6	106
	3.4	3.3 ± 0.4	114
NU Ori	0.35	1.09 ± 0.04	71
	0.44	1.27 ± 0.04	67
	0.55	1.59 ± 0.05	66
	0.65	1.90 ± 0.06	64
	0.75	1.66 ± 0.06	59
	1.25	1.34 ± 0.12	0
	1.6	0.68 ± 0.26	161
	2.2	1.89 ± 0.81	161

The polarization of BN increases sharply toward shorter wavelengths. Arguments have been given by Dyck *et al.* (1973) that the polarization mechanism is likely to be a cloud of cool, absorbing, elongated, aligned dust particles around or in front of BN. This explanation is consistent with the new data. We can also derive a limit on the size of the dust particles. The wavelength of maximum linear polarization is expected to be proportional to the mean value of the parameter $(m - 1)a$, where m is the refractive index of dust grains and a their radius (Serkowski 1972). The high linear polarization at 1.6 μ places this wavelength at 1.6 μ or less. Consequently, the *upper* limit of the dust-grain particle size is 3 times the median size of interstellar grains.

Another, probably similar, object is situated slightly north of the Cone Nebula in NGC 2264 (Allen 1972; Schmidt 1972). Our measurements show that significant infrared polarization exists. However, since it is much smaller than that of BN, no further conclusions can be drawn at this time.

NU Orionis (HD 37061, Brun 747) is a B1 V star near the Orion Nebula surrounded by a large 25″ infrared dust shell (Ney, Strecker, and Gehrz 1973). The polarization measured for NU Ori is presented in table 1. The shape of the optical polarization curve is in excellent agreement with previous measurements by Coyne and Gehrels (1967) who observed different wave lengths. Several conclusions can be drawn:

i) The *optical* polarization is caused by aligned interstellar/intracluster dust rather than by reflection nebulae or scattering in asymmetric circumstellar shells. Support for this hypothesis comes from the fact that the wavelength dependence of polarization shortward of 1.2 μ fits the "standard" interstellar dust curve (Serkowski 1972) if the latter is scaled such that $P_{\max}$ occurs near 0.65 μ. The size of the aligned dust grains is therefore only slightly larger than that of the "average" interstellar medium and resembles that in the Scorpius region. Furthermore, several other stars situated near NU Ori show the same (optical) position angle of polarization, ruling out purely local origins of polarization. We notice that the polarization of NU Ori shows a significant rotation of position angle even in the optical region. No variation with beam size was found. This means that the measured fluxes were not contaminated by the large 25″ shell.

ii) The *infrared* polarization is significant to better than 2.5 times the internal error at all wavelengths, and the 1.6- and 2.2-μ position angles agree. The simplest

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explanation seems to be that the infrared flux and consequently the infrared polarization arises in the shell around NU Ori rather than in the star.

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