POLARIZATION IN THE LAGOON NEBULA

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Summary

A V-band polarimetric survey of stars associated with the Lagoon nebula has been conducted. The data have been combined with existing photometric and spectroscopic observations in order to investigate the alignment of magnetic field lines with identifiable symmetry axes and to evaluate the nature of dust in the immediate vicinity. Although stars are not in general highly polarized, electric vectors align with the minor axis of the Lagoon nebula, perpendicular to the major axis of the spatial distribution of massive stars. The observations indicate that the collapse of the molecular cloud progenitor was inhibited along directions perpendicular to magnetic field lines. Considering the low polarization efficiency and the high ratio of total to selective extinction, smaller grains of intranebular dust appear to have been destroyed.

Background

Theoretical efforts to interpret the spectra of photo-ionized gases are hampered by uncertainty about the quantity and nature of embedded dust. Internal dust affects the transfer of radiation through the nebula, thereby modifying the ionization and thermal balance everywhere. Studies of the polarization of stars in local HII regions help to determine the nature of surviving dust grains. For example, multi-colour polarimetric observations of stars embedded in the Orion nebula show that the wavelengths of peak polarization are systematically shifted redward with respect to stars outside the nebula. (McCall, M. L. 1981, M.N.R.A.S., **194**, 485). Considering the constraints imposed by gas-phase metal abundances, the shift of the mean grain size may arise from preferential evaporation of the smaller grains embedded in the gas (McCall 1981).

Besides information about grains, polarimetry of stars associated with HII regions may provide some insights into the route to massive star formation. It has long been suspected that the collapse of molecular clouds is inhibited perpendicular to magnetic field lines due to the effects of magnetic pressure. Whether or not this is true might be gleaned from the degree of alignment of polarization vectors with observable symmetry axes.

For both problems, a good candidate for study is the Lagoon Nebula (M8). The nebula is especially well suited for a polarimetric study because of its association with a cluster of bright stars (NGC 6530). At least six O stars contribute to the ionization of the region. The flattened appearance of both the nebula and the zone of massive star formation suggests that the collapse of the molecular cloud progenitor was not symmetrical.

The authors have undertaken a study of the polarization of stars in the Lagoon nebula in order to study the orientation of the magnetic field lines with respect to the axis of massive star formation and to assess the effects of the environment on embedded dust. In this paper, the results of the initial V-band survey are presented.

Observations

Polarimetry of stars brighter than $V \sim 12$ in the vicinity of the Lagoon nebula was carried out over four nights using a two-channel polarimeter attached to the Australian National University 0.6 m telescope at Siding Spring Observatory. With this device it was possible to observe a source and a nearby background field simultaneously, and thereby accurately correct measurements for polarized background emission. Each night, four unpolarized standards were measured to correct for instrumental polarization, and several highly polarized standards were measured to determine the zero-point of position angles and to assess the degree of depolarization.

Observations of two K giants just in the foreground of the nebula were used to estimate the level of the foreground extinction and polarization. Both were found to be non-negligible, with $E(B-V) = 0.19$ and $P = 0.8\%$ at position angle $\theta = 79°$.

Results

The polarization introduced by foreground dust is nearly perpendicular to the preferred plane of polarization for the most highly polarized stars. Once the correction is applied, the polarizations of stars in the Lagoon nebula are systematically shifted to higher values and electric vectors show a high degree of alignment (see Figure 1). Of those stars which are polarized at the three-sigma level, the electric vectors are oriented close to the minor axis of the nebular boundary (as delineated by [S II] emission) and essentially perpendicular to the major axis of the distribution of massive stars. The alignment appears to be related to local phenomena, because the the position angle of the galactic plane differs from the preferred direction by 40°. The observations suggest that the collapse of the molecular cloud progenitor was inhibited along directions perpendicular to magnetic field lines.

Applying the cluster method to classified stars in the survey sample, the ratio of total to selective extinction for dust in the immediate environment of the Lagoon nebula is 4.5. The large value confirms that the grains are on average larger in the Lagoon nebula than in the general interstellar medium. Considering that stars are not efficiently polarized even though electric vectors are highly organized, the shift in the grain size distribution may arise from preferential evaporation of the smallest particles.

The sample stars cluster around two distance moduli separated by 0.79 mag, suggesting that many stars are multiple. Neither the distance moduli nor the polarizations of Be stars differ systematically from the values for normal B stars, indicating that many of the Be classifications are in error, perhaps due to contamination by nebular emission.

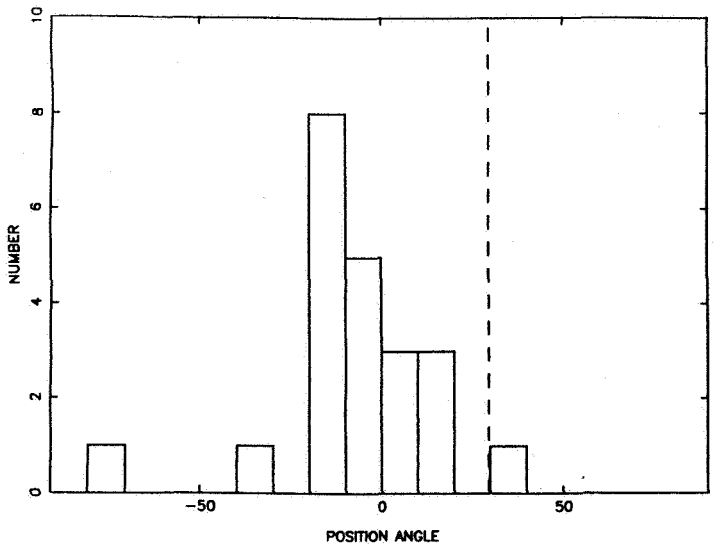

Figure 1. Histogram of position angles (in degrees east of north) for stars in the Lagoon nebula with $P/\delta P \geq 3.0$. All observations have been corrected for foreground dust. The dashed line shows the position angle of the galactic plane. The position angle of the minor axis of singly ionized sulphur emission is about 0°.