MAPPING DUST EXTINCTION IN MOLECULAR CLOUDS

JOÃO ALVES AND CHARLES J. LADA

Smithsonian Astrophysical Observatory
60 Garden Street
Cambridge, MA 02138

Abstract. Infrared array cameras have enabled the measurement and mapping of dust extinction within molecular clouds to significantly greater optical depths and at significantly higher angular resolution than previously possible. In this paper we present a map of the dust extinction in the dark cloud L978 in Cygnus derived from a large-scale multi-wavelength infrared survey. Analysis of our observations reveals significant variations in cloud structure on scales smaller than our $1'.5$ resolution, thus confirming trends previously observed in IC5146 dark cloud.

1. Introduction

Although molecular clouds are composed almost entirely of molecular hydrogen their most basic physical properties (e.g., size, mass, density and temperature) have been derived almost exclusively from observations of rare, trace molecules such as CO, CS and NH_3. However, the most direct way to trace the hydrogen content of a molecular cloud is to measure the distribution of dust through it since the gas-to-dust ratio in interstellar clouds appears to be constant (e.g., Lilley 1955; Bohlin, Savage, & Drake 1978).

Recently, Lada et al. (1994) demonstrated that large scale imaging surveys of dark clouds can be used to directly trace the distribution of dust extinction and column density through a molecular cloud at considerably higher angular resolution and greater optical depth than previously possible from star counts (Bok 1937).

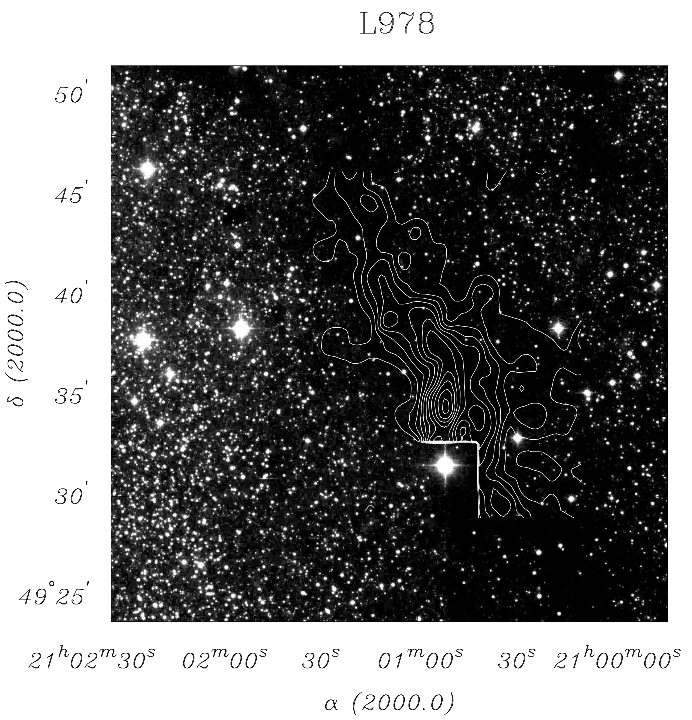

Figure 1. Map of the dust extinction in L978. Contours start at 5 magnitudes of visual extinction and increase by steps of 2 magnitudes. The map is overlayed on the Palomar red plate.

2. The Color Excess Method

Briefly, the dust column density is measured from the H-K colors of thousands of background stars observed through a cloud using the color excess: $E(H-K) \equiv (H-K)_{\rm observed} - (H-K)_{\rm intrinsic}$ where the intrinsic color is determined from the observation of unextincted background field stars. The color excess is directly related to the extinction at any wavelength via the reddening law (e.g., $A_v = 15.9 \times E(H-K)$; Rieke & Lebofsky 1985). The measured color excesses or extinctions then can be spatially binned to produce uniform sampled maps at angular resolutions comparable to mm wave observations for direct comparison with molecular line data. Observations of the IC5146 molecular cloud done by Lada et al. (1994) enabled very precise mass determinations of this dark cloud as well as direct abundances measurements of $C^{13}O$, $C^{18}O$, and CS, and permitted a quantitative description of the cloud structure at small angular scales.

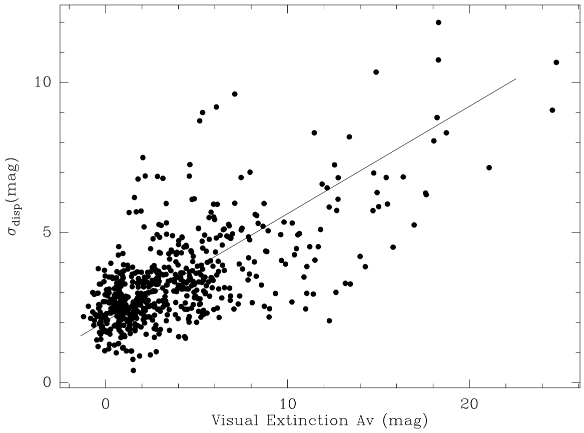

Figure 2. The variation of $\sigma_{\rm disp}$, the dispersion in the extinction measurements, with A_v the derived mean extinction for L978. Also plotted is the least-squares linear fit to the data.

3. Application to L978 and Concluding Remarks

Figure 1 displays the extinction map we derived for the L978 molecular cloud using this method (Alves et al. 1996). Almost 2000 stars were observed in the J, H, and K near-infrared bands to derive the dust extinction with a dynamic range of $5<A_v<25$ mags. The distribution of extinction agrees well with the shape of the cloud from the optical plate. Presented in Figure 2 is the relation between the dispersion in each (binned) pixel of the map versus the mean visual extinction in the same pixel. This behaviour, $\sigma_{\rm disp}$ increasing in a systematic fashion with increasing A_v, first discovered by Lada et al. in IC5146, demonstrates the existence of significant variations in cloud structure on scales smaller than our $1.5'$ binned resolution. Our observations appear to confirm the trends found in IC5146 suggesting that analogous distributions of dust characterize both clouds on small spatial scales.

References

Alves, J., Kenyon, S., Phelps, R., Lada, E. A., Lada, C. J. 1996, in preparation
Bohlin, R. C., Savage, B. D. and Drake, J. F. 1978, ApJ, **224**, 132
Bok, B. J. 1937 The Distribution of Stars in Space, (Chicago, Univ. of Chicago Press)
Lada, C. J., Lada, E. A., Clemens, D. P., Bally, J. 1994, ApJ, **429**, 694
Lilley, A. E. 1955, ApJ, **121**, 559
Rieke, G. H., & Lebofsky, M. J. 1985, ApJ, **288**, 618