Surveying Giant Molecular Clouds for Low Mass Stars: NIR Imaging of the DR22 and S184 Regions

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Abstract: Due to recent advances in infrared detector array technology, near-infrared imaging is emerging as a powerful technique for surveying the embedded stellar population of giant molecular clouds. We discuss the strengths and limitations of this technique through the analysis of two regions, DR22 and S184. Near-infrared images of these regions show dense clusters of low-intermediate mass stars. We analyze the properties of the stars and the initial mass functions of the regions using photometry in the near-infrared bands.

1 Introduction

Most of this meeting has been devoted to the gas and dust which comprise giant molecular clouds (GMCs), but little has been said on the stars which form in and eventually determine the evolution of molecular clouds. The lack of discussion on this topic is the result of a lack of data on the stellar content of GMCs. The huge extinction through molecular clouds ($A_V > 10$) obscures stars from optical UBVRI band imaging with CCD cameras. Radio continuum observations with telescope arrays can map the gas ionized by massive stars with subarcsecond resolution, but these observations trace only the most massive component of the stellar population. Far-infrared data, especially IRAS data, is invaluable in measuring the total luminosity of stars in a molecular cloud core, but the luminosity is again dominated by the most massive stars. In the past few years, this situation has been radically altered by the development of large format near-infrared (NIR) arrays. With these arrays and 2 meter class telescopes, surveys of the stellar content can be made which can detect stars with masses close to the substellar limit ($0.08 \, M_\odot$) at distances of 2 kpc.

The first infrared surveys with arrays concentrated on the Orion region. Surveys of the Trapezium region and the Orion B cloud showed clusters of low mass stars surrounding sites of high mass star formation (Lada et al. 1991 and Zinnecker et al. 1993). The result from the Orion B cloud survey was that 58% to 96% of the embedded sources were found in dense clusters; this suggests that most stars form in clusters and not in isolated dense cores (Lada et al. 1991).
Fig. 1. Optimal Bands for Molecular Cloud Surveys

This figure displays the optimal wavelength band for detecting an embedded star as a function of reddening and photospheric temperature. The curves trace the region of parameter space where the signal to noise ratio for the two adjacent bands are equal. In the regions between the curves, the signal to noise ratio is dominated by the designated band. Note that the optimal $H$-band region lies in a narrow strip, between the $J$ and $K$-band regions, which is not resolved in our plot.

Following the Orion surveys, a growing list of regions have been surveyed in the 1-2.5 $\mu$m regime. Given the sensitivity of the NIR arrays, regions out to 3 kpc can be efficiently surveyed for young ($10^6$ years), low-mass stars ($< 1 M_\odot$). In almost all surveys of regions showing the signposts of high mass star formation, dense clusters of low mass stars are detected. For a recent review of these regions, see Zinnecker et al. 1993.

In the following contribution, we discuss why the 2.2 $\mu$m regime is important for surveying the stellar content, and we present the detection and analysis of two young clusters associated with regions which have recently formed massive stars. The analysis illustrates the methods used to interpet NIR photometry of young stars and clusters. We will discuss the ambiguities inherent in such an approach, and some possible observations which may circumvent these problems.

2 Why a 2.2 $\mu$m Survey?

The rapid pace of infrared detector array development has revolutionized infrared astronomy. In the past few years, relatively large format infrared arrays have