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Spitzer-MIPS survey of the young stellar content in the Vela Molecular Cloud-D

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Abstract. A new, unbiased Spitzer-MIPS imaging survey (~ 1.8 square degrees) of the young stellar content of the Vela Molecular Cloud-D is presented. A total of 849 sources are detected at 24 μm and 52 of them also have a 70 μm counterpart. About 400 of the 24 μm sources have a 2MASS counterpart, that have been used to construct a K_s vs. K_s-[24] diagram and to identify the protostellar population inside the cloud. We find an excess of Class I sources in VMR-D in comparison with other star forming regions. This result is reasonably biased by the sensitivity limits at 2.2 and 24 μm, or, alternatively, may reflect a very short lifetime ($\lesssim 10^6$ yr) of the protostellar content in this molecular cloud.

Key words. Stars: formation, surveys –ISM: individual (VMR) – ISM: clouds

1. Introduction

Infrared maps of star forming Giant Molecular Clouds (GMCs) are an essential tool in the modern study of star formation. The sensitivity of infrared techniques means that even shallow surveys can in principle reveal the processes of both low and high mass star formation in clouds that are not too far away. Among the available targets, one is the Vela Molecular Ridge (VMR), a complex of four adjoining GMCs, located in the galactic plane (b=±3°; l ~ 260° - 275°); most of the gas (clouds named A, C and D) at a distance of about 700 pc.

The advent of the Spitzer Space Telescope and the imaging photometric facilities on board, i.e. the Multiband Imaging Photometer for Spitzer (MIPS, 24, 70, 160 μm) and the InfraRed Array Camera (IRAC, 3.6, 4.5, 5.8, 8.0 μm) have enabled us to obtain maps of the VMR-D from 3.6 to 70 μm. The primary goal of this survey is to obtain a census of the embedded young stellar population of VMR-D and to correlate it with its gas and dust cores. Here we describe our MIPS observations of the VMR-D, that cover ~ 1.15 (in R.A.) × 1.6 (in dec.) degrees. Aperture photometry of the field leaded to the detection of 849 and 61 point sources at 24 μm and 70 μm, respectively.

2. Source classification

About half of the 24 μm detections have identifiable 2MASS counterparts at K_s (limiting magnitude of 15.3) within a radius of 5″. These 2MASS fluxes have been used to construct

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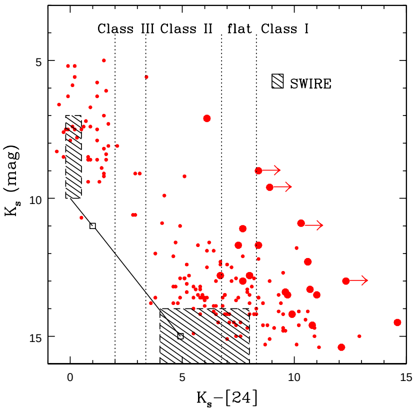

Fig. 1. Color-magnitude diagram for the 2MASS K_s-band and the MIPS 24 μm sources. Large dots denote sources with 70 μm detections, while arrows refer to sources saturated at 24 μm. The thick line indicates different values of A_V (open squares refer to A_V=10 and 50 mag).

the K_s vs. K_s-[24] color-magnitude diagram given in Fig.1. Also reported are the *loci* of the extragalactic sources in the SWIRE survey (Lonsdale, et al. 2003). As expected for a molecular cloud in the galactic plane, there are very few extragalactic sources seen. A remarkable number of objects fall at K_s<8.5 mag and K_s-[24]~0, which delimits the region of normal photospheres in VMR-D (these points could also be foreground/background stars). From an evolutionary point of view, protostars can be characterized on the basis of the spectral classification between 2 - 24 μm (e.g. Rebull et al. 2007, R07), according to which different evolutionary stages, from the accretion phase (Class I) to the beginning of the main-sequence (Class III), are manifested. The relative percentages of sources attributed to different classes can be compared with those of other star forming regions. For example, the percentage of Class I vs. Class II objects is 6% vs. 63% in Serpens and 6% vs. 85% in IC348 (Harvey et al. 2007) and 7% vs. 67% in NGC1333 (R07) In contrast, we find percentages in VMR-D of 23% of Class I and 28% of Class II. Two alternatives could explain such a difference: *i)* VMR-D is younger than either Perseus or Serpens. Such an hypothesis is supported by the age estimates of 1-2 Myr derived in Perseus (R07) and of 2 Myr derived in Serpens (Djupvik et al. 2006) as compared with an age of 10^5-10^6 yr towards the clusters of VMR-D (Massi, et al. 2000); *ii)* our K_s vs. K_s-[24] diagram suffers from missing two categories of sources. One is represented by the ~ 450 objects detected at 24μm, but without a K_s-2MASS counterpart. This implies that these 450 sources are objects whose SED is rising with wavelength and thus they could be young objects that tend even to increase the already anomalous percentage of Class I sources. The second category, however, is represented by the about 5 10^4 2MASS objects not having a MIPS 24μm counterpart. Their SEDs are allowed to decrease with increasing wavelength. Hence, although many of them could be foreground/background objects unrelated with the VMR population, they represent a potential reservoir of Class II and III objects. It should be sufficient that ~ 1-2% of them were genuine Class II/III sources to reduce significantly the relative excess of Class I in VMR, and then to increase the apparent age of the region. In this view the disagreement with other star forming regions could be reconciled, by considering that, being they located outside the galactic plane, the lower background has permitted to reach detection limits at 24μm up to an order of magnitude fainter than in Vela, therefore allowing to trace the SED also for faint K_s sources declining from the near- to the far-infrared. We expect to provide a more certain answer to this issue by means of forthcoming IRAC images covering the relevant spectral bands at more adequate sensitivity.

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