IDENTIFYING PRIMORDIAL SUBSTRUCTURE IN NGC 2264 WITH THE SPITZER SPACE TELESCOPE. P. S. Teixeira
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The Spitzer Space Telescope has ushered in an era that is proving to be rich in observational evidence of the very earliest phases of star formation. We are now begining to probe aspects of star formation problem that have been previously “kept in the dark”. One of these aspects is the fragmentation of the cloud into active star-forming cores. We report in this poster paper unique observations of this type of primordial substructure, found in massive young cluster NGC 2264. NGC 2264 is a massive hierarchically structured cluster (Lada & Lada, 2003) associated with a GMC in the Monoceros (Mon) OB1 complex and located at a distance of 800 pc (Dahm & Simon, 2005). MIPS (Multiband Imaging Photometer for Spitzer) has enabled us to identify in one particular region of NGC 2264 bright 24 µm sources aligned in curious linear structures converging on the central IRAS source, IRAS06382+0439 (IRAS 12). We refer to this region henceforth as the “Spokes” due to this special geometric configuration of the 24 µm sources. Comparison of this distribution with sub-millimeter data from Wolf-Chase et al. (2003) shows a remarkable correlation between the dust filaments and the spatial location of the 24 µm sources. Various submillimeter cores are identified within these dusty filaments and Spitzer shows that these cores are actively forming stars.

Figure 1 shows a color composite image of the Spokes region in NGC 2264, where the color coding corresponds to MIPS 24 µm (red), IRAC 8.0 µm (green), and 3.6 µm (blue) observations. The bright saturated source corresponds to IRAS 12, while the more extended nebulosity in the image corresponds to polycyclic aromatic hydrocarbon (PAH) emission of the molecular cloud in 7.7-7.9 µm and subsequently detected in IRAC band 4. The 24 µm sources form several linear structures that cannot be discerned from the IRAC (Infrared Array Camera) data alone. There is a particularly dense agglomeration of sources 2.3' southeast of IRAS 12. We are able to resolve the sources within this sub-clustering in bands 1 and 2 of IRAC. Counting 10 sources detected at 4.5 µm within a radius of 12.5" (0.05 pc), we find the stellar number density of this sub-cluster to be 2.2 x 10³ pc⁻³. We refer to this sub-clustering henceforth as the “micro cluster”. Unfortunately the MIPS resolution is low, hindering us in the attempt to attribute the 24 µm flux to any particular source in the micro cluster.

Comparison of the spatial distribution of the 24 µm sources with sub-millimeter data yields a strong correlation, as seen in Figure 2. The contours refer to 850 µm fluxes that begin at 3 and are in steps of 0.1 Jy/beam (Wolf-Chase et al., 2003). The star symbols mark the positions of emission at 24 µm and their sizes are proportional to the magnitudes of the sources. It is remarkable how the bright 24 µm sources are so well aligned with the dusty filaments. The same result is obtained when using the 450 µm data, also from Wolf-Chase et al. (2003).

The micro cluster coincides with a dense 450 µm and 850 µm sub-millimeter peak. Williams & Garland (2002) report HCO⁺ observations of the sub-millimeter peaks shown in Figure 2, in particular, they detect a deep, redshifted absorption dip in the spectra of the core associated with the micro cluster, interpreted as an infall signature. They calculate an envelope mass of 100 M☉ within a radius of 0.17 pc. Gaussian fits to the H13CO⁺ spectra show that the non-thermal velocity dispersion is typically in the range 0.7 - 1.0 km s⁻¹ (Williams & Garland, 2002). If the sources within the micro cluster would have a velocity dispersion of this value, then they would have already traveled 0.5 pc from their birthplace within 0.5 Myrs. The proximity of these sources (<0.05 pc) imply that they are very young, in the very initial stages of star formation.

The summarized conclusions we have reached are as follows:

1. Spitzer traces out the youngest population in NGC 2264 with MIPS 24 µm data
2. these protostars have spatial distributions that are coincident with dense and dusty filaments
3. within the Spokes region we can identify a dense sub-cluster with IRAC data. This micro cluster is coincident with strong sub-millimeter peaks at 450 and 850 µm and with bright 24 µm emission.
4. Evidence of infall from HCO⁺ observations (Williams & Garland, 2002) indicate that the micro cluster is indeed very young and in an early stage of star formation.

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REFERENCES
Figure 1: False color images of the Spokes region. The color coding corresponds to red of 24 µm, green of 8.0 µm, and blue of 3.6 µm. The image shows usual linear structures of bright sources, while the image built from IRAC data alone does not show this feature.

Figure 2: Comparison of the spatial locations of 24 µm MIPS sources with dust emission at 850 µm (SCUBA data courtesy from Wolf-Chase et al. (2003)). The greyscale and contours represent the submillimeter dust emission (contours range from 0 to 2 in steps of 0.1 Jy/beam), while the stars mark the position of the sources detected at 24 µm with MIPS. The sizes of the stars are proportional to their magnitude, having the brightest 2.0 magnitudes and the faintest 12.0 magnitudes.