A Spitzer Study of the Serpens Young Stellar Cluster

Elaine Winston(1), Tom Megeath(1), Lori Allen(1), Scott Wolf(1), Robert Gutemuth(1), Phil Myers(1), Jesus Hernandez(2)

(1) Harvard-Smithsonian Centre for Astrophysics, Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge MA 02138.
(2) Experimental Physics Department, University College Dublin, Belfield, Dublin 4, Ireland.
(3) University of Rochester, Rochester, NY.
(4) CIDA, Merida, Venezuela.

Abstract:

The Serpens young stellar cluster is one of the nearest regions of ongoing star formation in a clustered environment. Here we present the first stage of a collaborative study of the region at multiple wavelengths to observe the characteristics of the young, pre-main sequence stars comprising the cluster, and of the development of the cluster as a whole. The paper presents observations from the Spitzer Space Telescope, utilizing the IRAC and MIPS instruments to view the region at infrared wavelengths from 3 to 24 microns. These data allow us to detect thermal emission from circumstellar disks and protostellar envelopes, and to classify stars with disks and protostars using both colour–colour diagrams and spectral energy distributions (SEDs). These data will be combined with optical (far-red) spectra and Chandra X-ray data to understand the evolution of the disks and envelopes and the X-ray properties of the young stars.

Images

Right: Two IRAC Images of the Serpens Cluster, covering a ~100 x 30 arc min field. The images are composites of mosaics in three of the four IRAC bands: 3.6 microns (blue), 4.5 microns (green), and 8.0 microns (red). The positions of IRAC excess sources marked.

Top Right: The positions of those sources classified using Spectral Energy Distributions. The large circles indicate those objects classified as Class I. The squares are the positions of the Class II sources. Overlap occurs where sources that have been classified as Class I prior to dereddening of the data have been reclassified as Class II. The dereddened slopes of these new sources are close to 0, akin to those of the ‘flat-spectrum’ sources — these may be protostars.

Bottom Right: The bottom image shows the positions of sources classified as having an excess from the IRAC four band and MIPS/PACS colour–colour diagrams. The large circles indicate those sources having an excess at 24 microns. The smaller squares indicate those that have an excess in the 8.0 micron band.

Spectrophotometric Measurements:

Spectra of the Serpens Cluster were taken using the Houston Spectrometer on the AMI in IR, Hopkins, in the L-band, IRAC excess targets were chosen based on their J and H magnitudes, J_16 mag < J_H < 2. Of forty-three spectra, 23 were usable and could be fitted.

Above Right: The IRAC colour–colour diagram marks those infrared-excess sources chosen for the Spectrometer run (asterisks), and those that were spectroscopically classified (circles). The spectroscopy sample included a majority of Class II objects, with some examples of the less extreme Class I objects. Increased reddening causes many of the Class I objects to be faint (< 20 mag in the L-band).

Above Left: Hertzsprung–Russell Diagram for the Serpens Cluster. The solid line indicates isochrones for the young pre-main sequence objects at 1 Myr, 3 Myr, and 10 Myr (Baraffe, 1995). The points lie about the 1 Myr isochrone. Scattering is likely to be caused by uncertain distances, which are stars with data observed 'edge-on,' thus most of the light seen is scattered light from the disk. Serpens is therefore a ~1 Myr old cluster.

Spectral Energy Distributions

Below: Class II SEDs; (top) raw, (bottom) dereddened. Below: Class I SEDs; (top) raw, (bottom) dereddened. Notice the flattened spectrum post dereddening.

Below:

Spectral Energy Distributions (SEDs) are plotted for the six selected Class I and II objects detected in the 2MASS H and K, IRAC 3.6, 4.5, 5.8 and 8.0 micron and MIPS 24 micron bands using uncertainties less than 1 mag. The Spectrometer photometry were dereddened by deconvoluting the extinction from the J and K photometry and adjusting accordingly. This was carried out to better distinguish between genuine Class I objects, with increasing slopes due to extinction and thermal emission in an infalling envelope, and Class II objects which have been reddened by dust in the molecular cloud surrounding the cluster. Both the raw and dereddened SEDs are shown.

The plots also show a 400 K blackbody scaled to the observed flux in the H-band, and a line showing the flux of a power law to the SED. Only the IRAC and MIPS data are used in this figure. The applied extinction and the slope (i.e. power law index) of the fit are also displayed. The fit of the slope is made using the IRAC and MIPS data. Both the raw slopes and the dereddened magnitudes can be compared with values given in the literature for similar objects and possibly derived through 24 micron bands. Objects with slopes between 0 and -2 were identified as Class II objects, objects with slopes greater than 0 were identified as Class I objects.

The four class objects displayed have a rising slope before dereddening— but a roughly flat spectrum after dereddening. It is not clear whether dereddening using the near-IR colors is appropriate for these objects. Since these appear to be flat spectrum sources in the dereddened SEDs, these may not appear to be typical Class II objects, and are probably either Class I protostars or Class I protostars transitioning into Class II objects.

Colour-Colour Diagrams

Above: Colour– Colour diagrams using the IRAC photometry (Left) and combined (IRAC and MIPS photometry) (Right). Pure photophores, including pre-main sequence Serpens members without disks and field stars in the line of sight, are clustered around (0,0). The direction of the reddening vector is shown for the IRAC 4-band diagram. The sources classified using the IRAC only data are marked, the large circles are Class I, the small squares are Class II, and the objects with both are the four transitional objects (see discussion on SEDs). The sources marked with an ‘x’ in the IRAC 4-band diagram are selected in the MIPS 24 micron image, two such sources with very red colours are not classified by their SEDs due to the lack of 2MASS H and K detections. The classification of objects by their SEDs is consistent with the classification schemes using mid-IR colours as described in Allen et al. 2004, Megeath et al. 2004 and Muzerolle et al. 2004. However, highly reddened Class II objects may be misclassified as Class I objects in the colour–colour diagrams, and we are exploring schemes of incorporating the near-IR colours to separate reddened Class II from Class I objects.

References:
