A Spitzer Study of the Serpens Young Stellar Cluster

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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 composing the cluster, and of the development of the cluster as a whole. The poster presents observations from the *Spitzer* Space Telescope, utilising 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.

Serpens Cluster:

The Serpens Cluster lies at a distance of 310 pc. The cloud contains a mass of 500-1500 solar masses in a diameter of ~ 0.6 pc. It is an example of a very young, deeply embedded cluster, with 61 previously known young stellar objects (Kaas 2003). As part of a survey of young stellar clusters within 1 kpc of our sun, we imaged a 25'x25' field centred on the Serpens cluster, with the IRAC [3.6,4.5,5.8,8.0 micron bands] and MIPS [24 micron band] instruments onboard Spitzer.

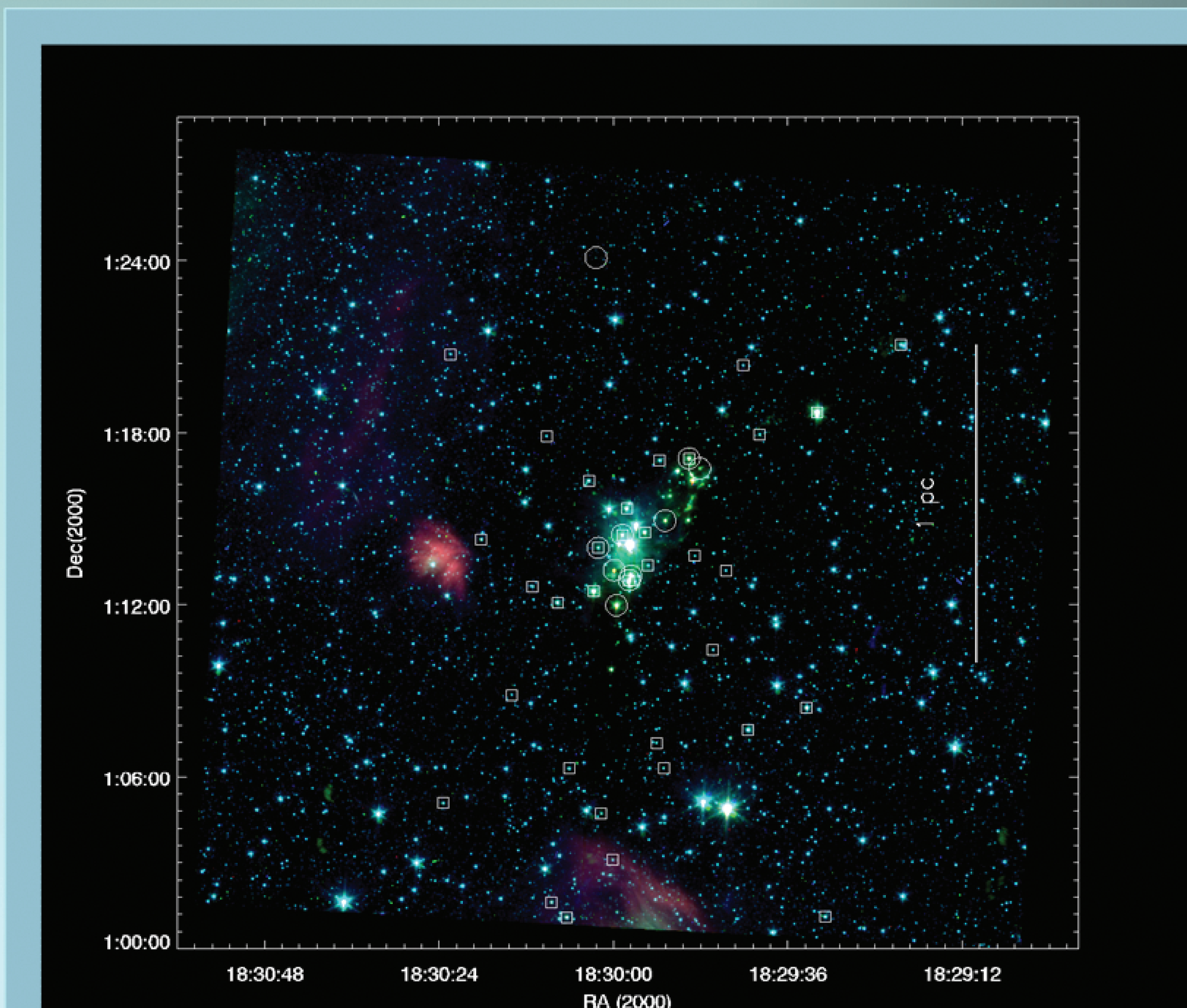
This study finds: 80 sources with 8 micron excesses in the region, and 75 with 24 microns excesses (not all sources detected at 8 microns are detected in the 24 micron band). A preliminary Spectral Energy Distributions analysis using combined 2MASS, IRAC and MIPS photometry yielded 34 Class II objects and 10 Class I objects.

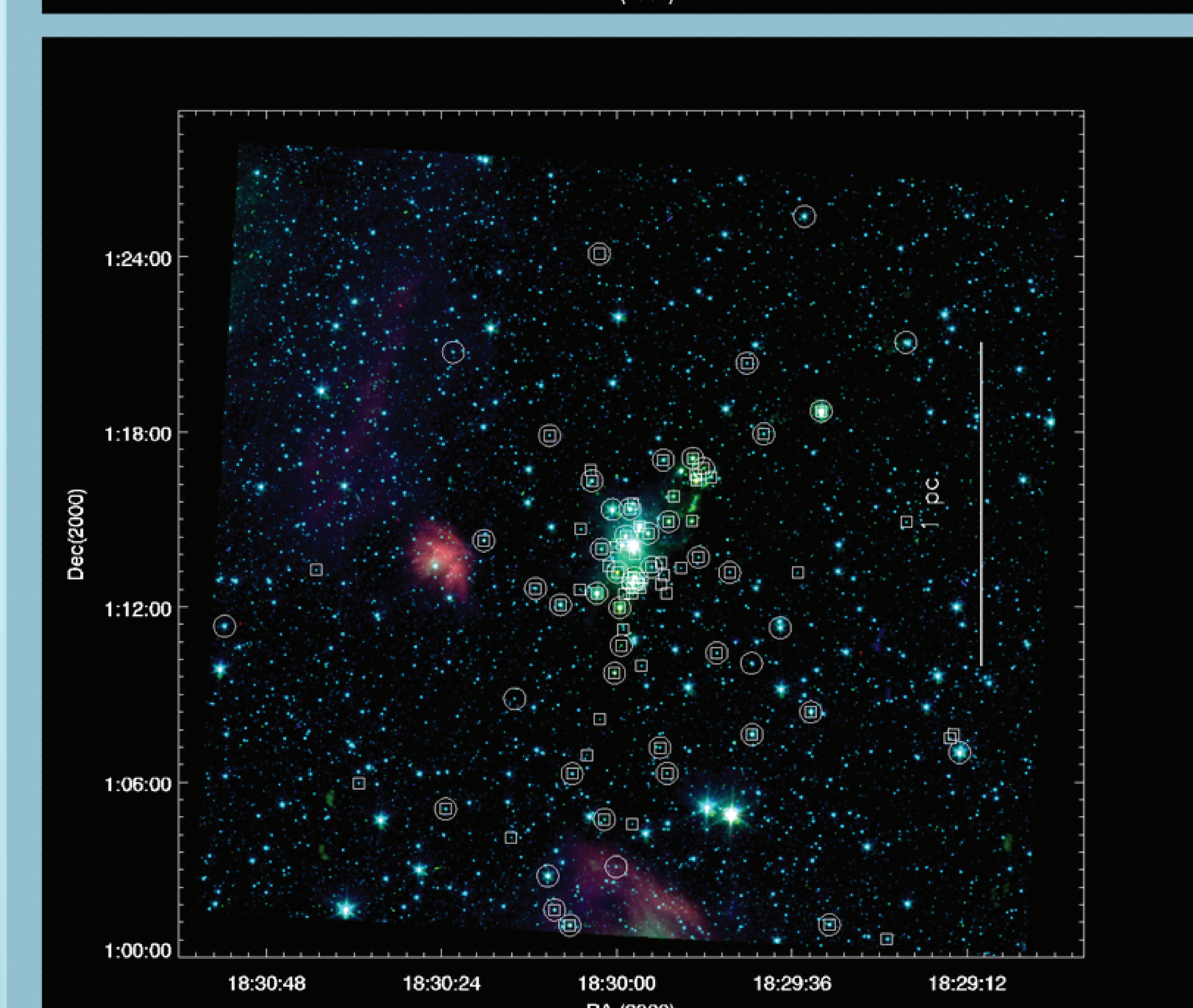
Images

Right: Two IRAC images of the Serpens Cluster, covering a ~30x30 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 microns (red). The positions of IR-excess sources marked.

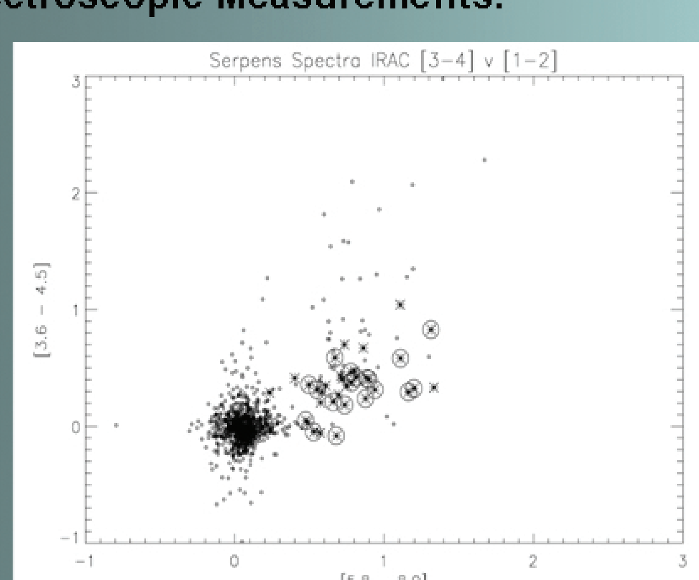
Top Right: the positions of those sources classified using Spectral Energy Distributions. The large circles indicate those objects classified as Class I. The smaller squares are the positions of the Class II sources. Overlap occurs where sources that have been classified as Class I prior to dereddening 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 - and these may be protostellar sources.

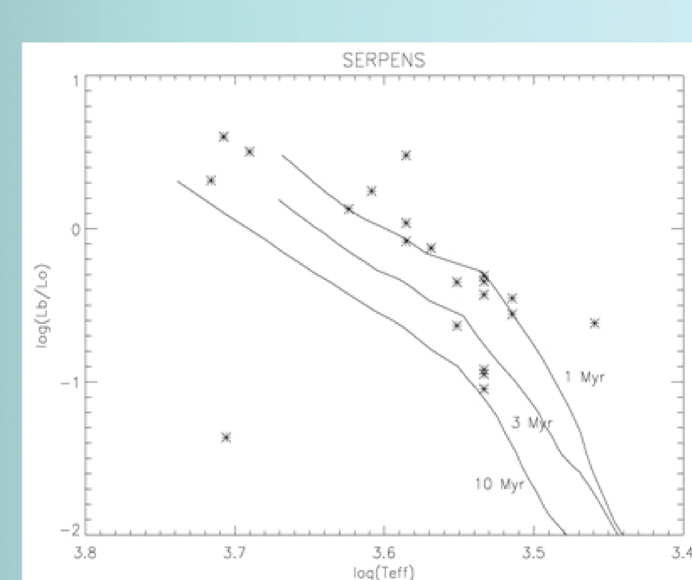
Bottom Right: The bottom image shows the positions of sources classified as having an excess from the IRAC four band and MIPS/IRAC colour-colour diagrams. The large circles indicate those sources having an excess at 24 microns. The smaller squares indicate those sources that have an excess in the 8.0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





Spectroscopic Measurements:





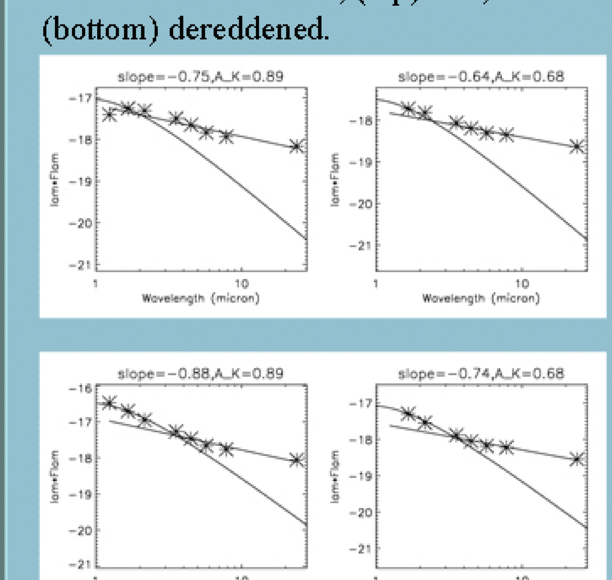
Spectra of the Serpens Cluster were taken using the Hectospec instrument on the MMT on Mt. Hopkins, in the I-band. IRAC excess targets were chosen based on their J & H-band magnitudes, J > 16 mag & [J - H] < 2. Of forty-three spectra, 22 were viable and could be typed.

Above Right: The IRAC colour-colour diagram marks those infrared-excess sources chosen for the Hectospec run (asterisks), and those that were spectral typed (circles). As can be seen, the spectroscopy sample included a majority of Class II objects, with some examples of the less extreme Class I objects. Increrased reddening causes many of the Class I objects to be too faint (< 20 mag) in the I-band.

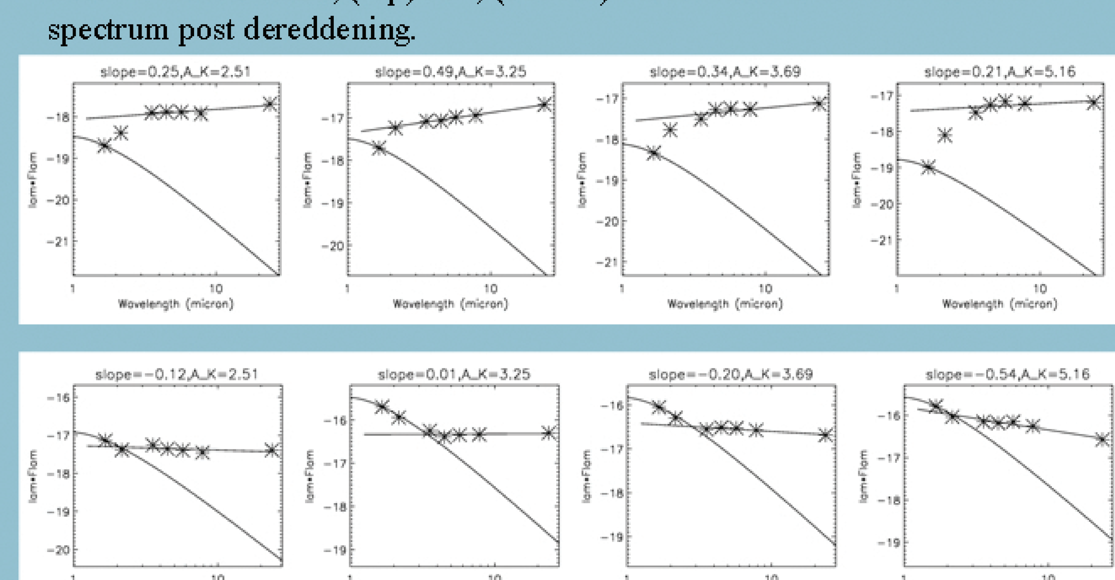
Above Left: Hertzprung-Russell Diagram for the Serpens Cluster. The three tracks indicate isochrones for young pre-main sequence objects at 1 Myr, 3 Myr, and 10 Myr (Baraffe,1998). The points lie about the 1 Myr isochrone: Scattering is likely to be caused by underluminous sources, which are stars with disks 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.



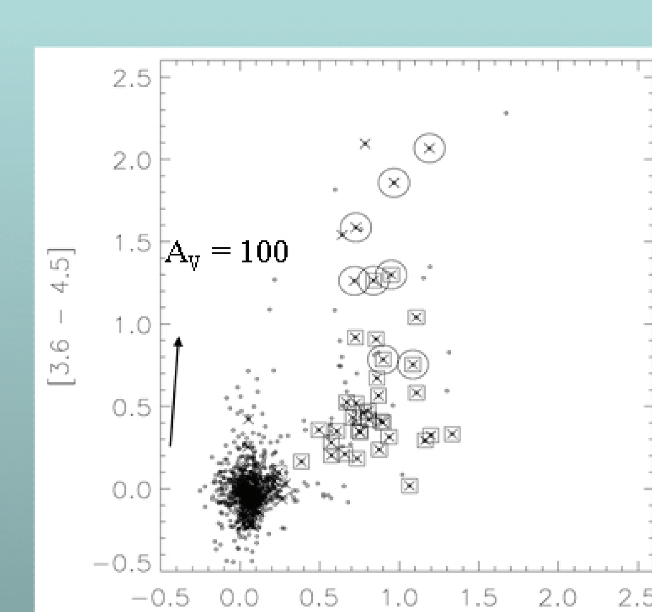
Below: Class I SEDs; (top) raw, (bottom) dereddened. Notice the flattened spectrum post dereddening.

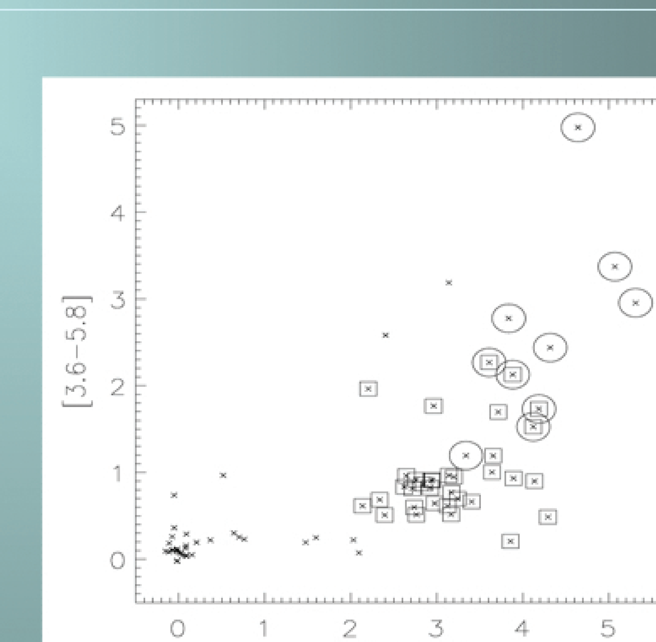


Spectral Energy Distributions (SEDs) are plotted for six selected Class I and II objects detected in the 2MASS H and K, IRAC 3.6, 4.5, 5.8 and 8.0 micron and MIPS 24 micron bands with uncertainties less than 0.1 mag. The *Spitzer* photometry were dereddened by determining the extinction from the J,H and K photometry and adjusting accordingly (Gutermuth, in prep). This was carried out to better distingush 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 4000 K blackbody scaled to the observed flux in the H-band, and a line showing the fit of a power law to the SED. Only the IRAC and MIPS data are used in the fit. 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 slopes are shown for comparison. This analysis was appled to all stars with detections in at least the H 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 I objects displayed have a rising slope before dereddening - but a roughly flat spectrum afer 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 do 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 photospheres, including pre-main sequence Serpens members without disks and field stars in the line of site, are clustered around (0,0). The direction of the reddening vector is shown for the IRAC 4-band diagram. The sources classified using the SEDs are marked, the larger 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 only with an x in the IRAC 4-band diagram are detected in the MIPS 24 micron image; two such sources with very red colours are not classifed 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 misidentified as Class I objects in the colour-colour diagrams, and we are exploring schemes of incorporating the near-IR colors to separate reddened Class II from Class I objects.

References:

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