X-RAY SPECTRAL CLASSIFICATION: A NEW METHOD FOR INVESTIGATING STAR-DISK-JET INTERACTIONS.

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We are developing objective techniques for spectral and temporal classification of X-ray sources to sort and analyze the wealth of new medium-resolution (CCD) X-ray spectra and light curves of young star clusters being obtained by the Chandra X-ray Observatory (*Chandra*) and XMM-Newton. Our X-ray spectral classification technique positions the sources in a multidimensional spectral sequence and then groups the ordered sources into clusters based on their spectra. These clusters appear more distinct for sources with harder observed spectra. The apparent diversity of source spectra is reduced to a three-dimensional locus in principal component (PC) space.

Initial application of our technique (Hojnacki et al. 2007) to a sample of 444 strong sources from the ~ 838 ks Chandra Orion Ultradeep Project dataset has revealed two spectrally distinct classes of X-ray sources that are of particular interest to studies of star-disk-jet interactions in young stars: hard X-ray sources which exhibit strong, impulsive flares and evidence for iron fluorescence from 'cold' disk material; and the Beehive Proplyd, which has an unusual, double-peaked X-ray spectral energy distribution indicative of a combination of strong shocks in the jet collimation region and a variable, magnetically-active X-ray source (Kastner et al. 2005, see Fig. 1). These classes can be seen in the resulting plot of the first two principal components (Fig. 2). In this horseshoe-shaped curve, the spectral hardness of the classes decreases moving clockwise. Sources in spectral class 1 are easily identified as a distinct X-ray spectral group by our classification technique. All of the class 1 sources lack optical and near-infrared (ONIR) counterparts, display strong Fe K$-\alpha$ line emission and — although the classification algorithm is based solely on spectral information with no input from the temporal domain — all display high-amplitude, fast-rise implusive X-ray flares versus more low-level activity (Getman et al. 2005). Therefore, the objects in our class 1 are most likely very young protostars deeply embedded in the Orion Molecular Core.

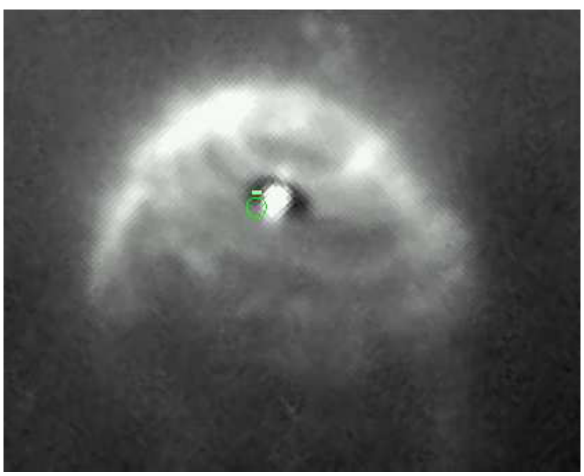

Figure 1: Hubble Space Telescope image of the Beehive Proplyd (Kastner et al. 2005). The position of the associated X-ray source is shown by the green circle.

COUP 948 is the only source in spectral class 17. Its position in the horseshoe plot is significantly offset from the locus of sources in all three dimensions (Hojnacki et al. 2007). This extraordinary X-ray source is associated with the unusual optical jet source called the Beehive Proplyd (Bally et al. 2005). The X-ray spectrum of COUP 948 has distinct hard and soft components with the soft component peaking at around 0.85 keV and the hard component at about 3.5 keV. This unique source has been readily isolated by our technique, holding promise for the discovery of additional examples of such hybrid X-ray spectra buried among the thousands of pre-MS stars detected thus far by *Chandra* and XMM-Newton.

We present the results of X-ray spectral simulations, to aid in the interpretation of the principal component plot (Fig. 2). The model input to the XSPEC simulations consisted of thermal plasma emission plus intervening absorption. The simulated spectra were run through the same spectral classification algorithm applied to the 444-source COUP subsample. The resulting 2-D principal component plot is shown in Fig. 3, with the simulations superimposed on the distribution of COUP sources. The simulated sources are represented as solid diamonds and are labeled with their log N_H values; simulated sources of equal kT are connected by lines. Moving clockwise around the horseshoe, the simulations form a sequence of monotonically decreasing $\log N_H$, from 23.5 in the extreme lower left of the plot to 20.5 in the lower right. We show that the distribution of simulated X-ray sources in PC-space reproduces the fundamental shape of the horseshoe-like distribution formed by the COUP subsample.

Finally, we briefly discuss how sources in class 2, which show very large N_H, may consist of an *intrinsically* soft population, comparable to the X-ray sources in classes 15 and 16. The principal difference between sources in these classes appears to be N_H, suggesting that class 2 objects are similar to objects in classes 15 and 16 — that is, fairly evolved K- and M-type PMS stars — but that class 2 stars are located on the far side of the Orion Molecular Cloud. A similar interpretation may hold for sources in classes 3-7.

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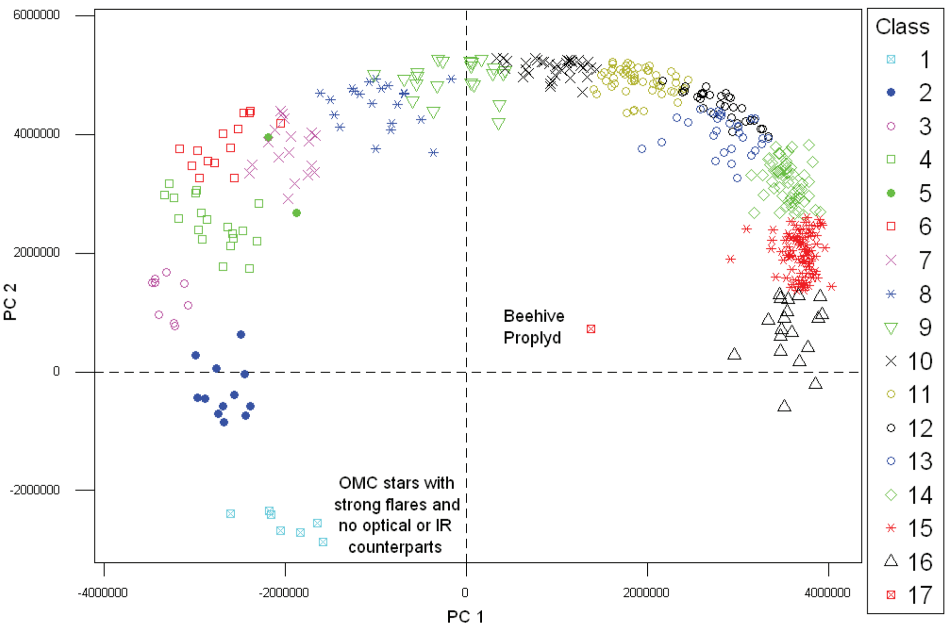

Figure 2: Plot of the first 2 principal components with the source classes shown. The class numbers increase clockwise around the horseshoe-shaped curve. Nearly all of the X-ray sources in the input sample lie in a single spectral sequence. Class 17 consists of one outlier.

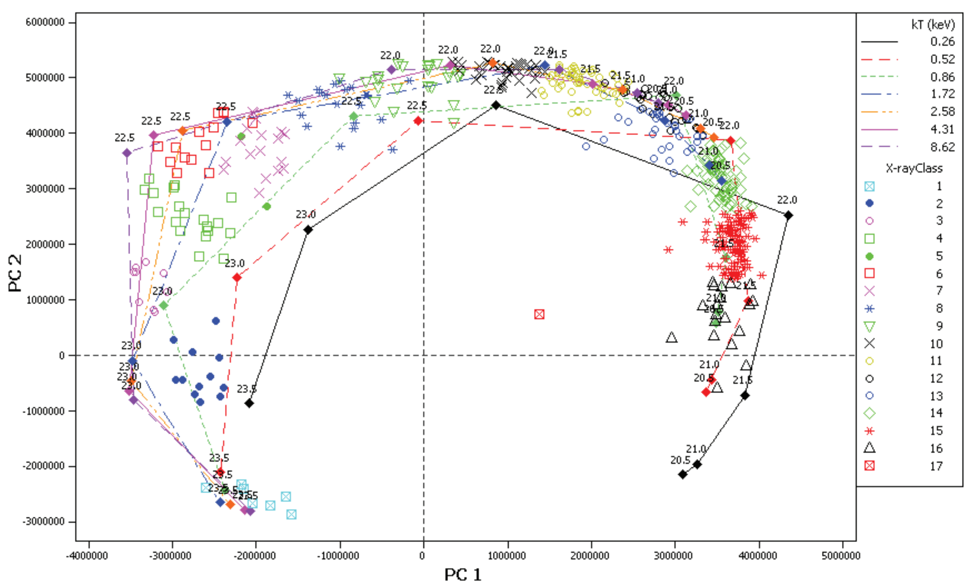

Figure 3: Simulated spectra with varying kT and N_H are overlaid on the principal component plot for the 444 COUP sources. Lines connect simulations calculated for a given value of kT; the points on the lines represent the locations in PC-space of the simulated spectra. Each point is labeled with the value of log N_H used in the simulation. The basic horseshoe-shaped curve is also produced by the simulated spectra.