LARGE SCALE FLARING LOOP STUCTURES IN T TAURI STARS OF THE ORION NEBULA CLUSTER.

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The Orion Nebula Cluster is an active site of star formation which provides observers with a glimpse into the earliest stages of stellar evolution. The cluster is home to thousands of objects a few million years of age or younger; for a subset of these young stars, highly energetic activity has been observed using the Chandra X-ray Observatory.

Using a uniform cooling loop (UCL) model effective in characterizing solar magnetic field loops, Favata et al. (2005) derive loop arc lengths of tens of stellar radii or larger in some cases. We present the results of work aimed at exploring the stellar environs of these sources to ascertain whether star-disk interaction is taking place via the stellar magnetosphere. To do so, we construct Spectral Energy Distributions (SEDs) using photometry from the Hubble Advanced Camera for Surveys, 2MASS, and Spitzer IRAC and MIPS near to mid infrared data. Additional photometric data (V and I magnitudes) as well as stellar parameters necessary for SED fitting were taken from Hillenbrand (1997). We utilized the online model SED fitter by Robitaille et al. (2007).

Somewhat surprisingly, we find that the majority of the sample stars show SEDs consistent with bare photospheres. These enormous flaring loops appear to be originating from naked T Tauri stars. Some examples are shown below; Fig. 1 is the SED of a source which exhibits a more or less black body, stellar photosphere energy distribution. Excess disk flux shown in this plot is merely a model of what a disk could look like were one indeed present. In Fig. 2, we show a source which exhibits some near infrared excess consistent with a disk lacking a central cavity, as there is an abundance of flux in the near-IR. Most sources have SEDs like Fig. 1.

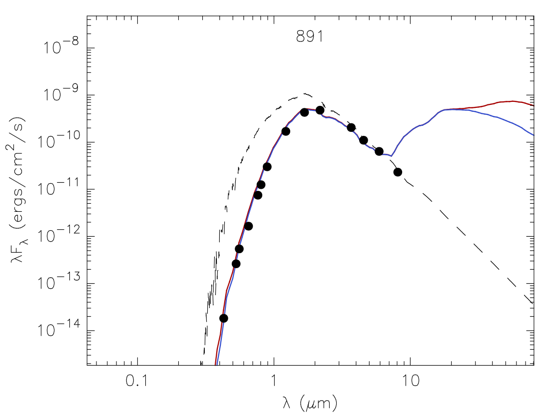

Figure 1: Spectral energy distribution for source COUP 891. Fluxes shown were derived from HST ACS optical, 2MASS JHK, and Spitzer IRAC photometry. Blue and red indicate aperture sizes of 10" and 5", respectively. The blue and red models show what a disk might look like, were a disk present; as constrained by the IRAC 8 μm data, there appears to be no disk.

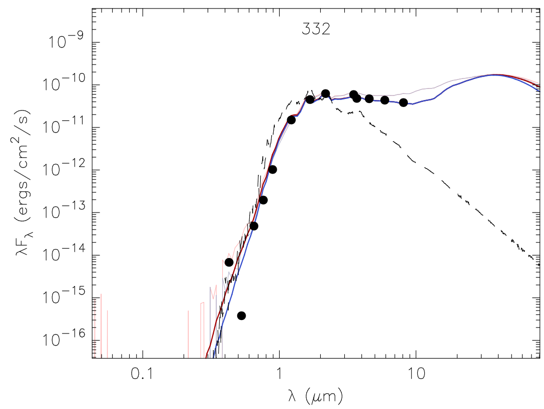

Figure 2: In the SED of COUP 332, IRAC fluxes (with L band photometry) imply the presence of a disk.

Putting together the flaring loop information and our SEDs, we compare the radii of the magnetic field structures with the modeled disk truncation radii. Figs. 3 and 4 are histograms depicting the range of possible truncation radii from the best fit SEDs (hatched) while the red filled bin(s) indicate the range of flaring loop radii. Gray filled bins represent the distribution of truncation radii of the entire model grid searched by the SED fitter. Consistent with our disk findings, a small fraction of the sample show overlap in these radii which would possibly indicate some kind of interaction between stellar fields and circumstellar disks.

The implications of this work extend into various aspects of the current stellar evolution picture. Would these kinds of flaring events have a significant impact on disk dissipation? In the context of stellar angular momentum loss in the pre-main sequence phase, could "scaled-up" solar-type coronal mass ejections shed a significant amount of the young star's angular momentum?

Future work on this project will include searching for additional near-mid IR data to better constrain the SED fitting in that region of the distribution. Presently, MIPS 24 μm data are only available for four of the 32 sources, the majority of the sample is effectively saturated out by nebulosity in the region. We have taken preliminary steps to address the angular momentum loss question posed above. Our future work includes making this calculation more robust as well as including more of the flaring loop sources in the analysis; presently, rotation period data are only available for 8 of the 32 sample stars, and rotation period is necessary for calculating the stellar angular momentum. Our initial results indicate that an average spin-down timescale, the time needed to completely shed all of the stars' angular momentum, is $\sim 10^{10} - 10^{11}$yr if an event rate of 10 flares per year is assumed.

References

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[2] Hillenbrand, L. A. 1997 , 113, 1733

[3] Robitaille, T. P., Whitney, B. A., Indebetouw, R., & Wood, K. 2007 , 169, 328

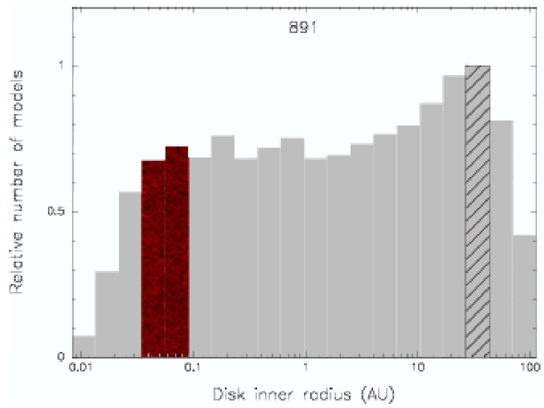

Figure 3: Here, we compare the truncation radii associated with the ten best fit SEDs for source COUP 891 to the range of possible flaring loop radii, assuming spherical loop structure. The former are pictured as cross-hatched bins, while the latter are red shaded bins. The shaded background bins are representative of the entire model SED grid coverage in truncation radius space. The red bin height was chosen to preserve the grid truncation radius distribution information. We see here that the flaring loop would occur well within a disk truncation radius, were a disk indeed present.

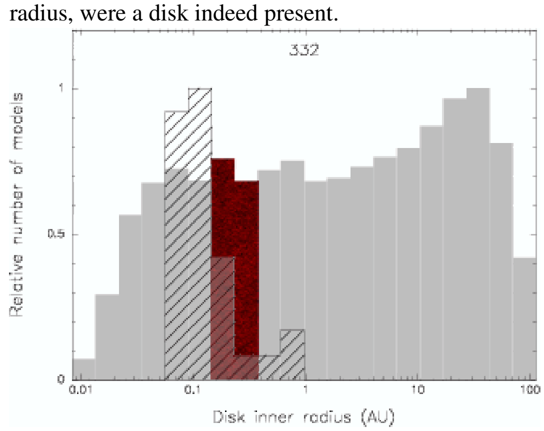

Figure 4: In this plot, we apply a similar analysis to source COUP 332 as performed in Figure 3. In this case, the near-mid IR excess corresponds with a truncation radius that is coincident with the flaring loop length. This was an uncommon instance in our sample; the length coincidence could be indicative of interaction taking place between the stellar magnetosphere and circumstellar disk material.