PRE-MAIN SEQUENCE ACCRETION AND X-RAY EMISSION: NEW (RE)CONNECTIONS.

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The Chandra and XMM-Newton X-ray observatories have established direct connections between the X-ray emission from low-mass, pre-main sequence (pre-MS) stars and disk/wind processes in these objects. These X-ray observations provide a unique means to probe the innermost regions of pre-MS star-disk-wind systems. Recent results in this regard include anomalous X-ray line ratios (Figs. 1, 2) and soft X-ray excesses — indicative of accretion and/or wind shocks — observed in a number of classical T Tauri stars, and contemporaneous optical/IR and X-ray monitoring of erupting pre-MS stars (most notably, V1647 Ori; Fig. 3).

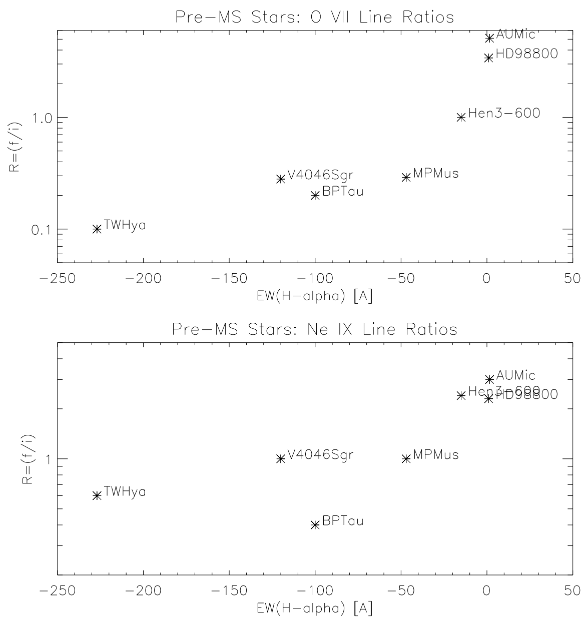

Figure 1: Equivalent width of Hα vs. the forbidden to intercombination line ratio f/i within triplet lines of the He-like ions O VII (top panel) and Ne IX (bottom panel) for the low-mass, pre-main sequence systems measured to date with gratings spectrometers aboard *Chandra* and *XMM* (Kastner et al. 2007 and references therein).

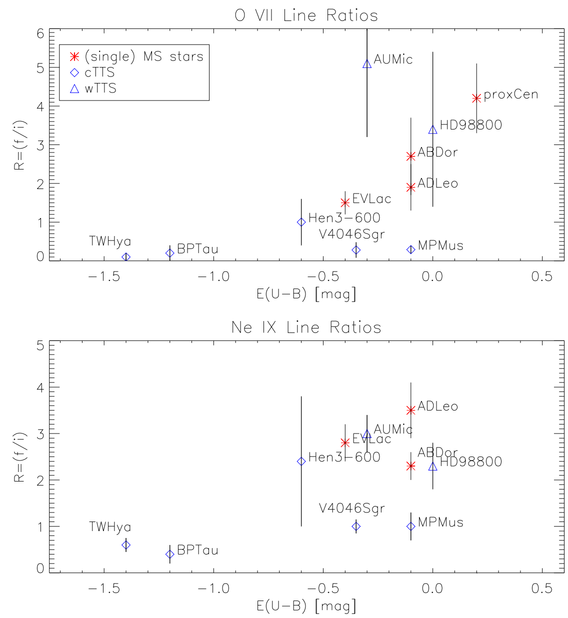

Figure 2: Ultraviolet excess $E(U-B)$ vs. f/i within triplet lines of the He-like ions O VII (top panel) and Ne IX (bottom panel) as measured for chromospherically active, single main sequence stars (asterisks) and low-mass, pre-main sequence stars (diamonds, cTTS; triangles, wTTS). The values of $E(U-B)$ were obtained from published U, V magnitudes and estimates of intrinsic $(U-B)$ colors appropriate for each star's spectral type.

X-ray line ratios as diagnostic of pre-main sequence accretion. Figures 1 and 2 (from Kastner, Huenemoerder, Testa, Schulz, & Weintraub 2007, in prep.) compare equivalent width of Hα and ultraviolet excess $E(U-B)$, respectively, with the density-sensitive forbidden to intercombination (f/i) line ratios of triplet lines of He-like ions, as measured for chromospherically active main sequence stars and low-mass, pre-main sequence (T Tauri) stars. It is apparent that:

1. For T Tauri stars, Hα equivalent width and the X-ray f/i line ratios are well correlated.
2. Actively accreting stars (i.e., the classical T Tauri stars TW Hya, BP Tau, V4046 Sgr, and MP Mus) have anomalously small values of f/i, with no apparent correlation between f/i and ultraviolet excess.
3. The properties of the apparently nonaccreting (weak-lined T Tauri star) systems AU Mic and HD 98800 more closely resemble those of coronally active main sequence stars than actively accreting pre-main sequence stars.
4. The weakly accreting pre-MS system Hen 3-600 appears as an intermediate case, lying between the classical T Tauri stars on the one hand, and weak-lined T Tauri stars and coronally active main sequence stars on the other.

(These results are described in more detail in Kastner et al. 2007, in the context of analysis of *Chandra* gratings spectroscopy of Hen 3-600, a transitional T Tauri star system in the TW Hya Association.)

Taken together, these results suggest that small f/i values in the X-ray spectra of accreting, low-mass pre-MS stars

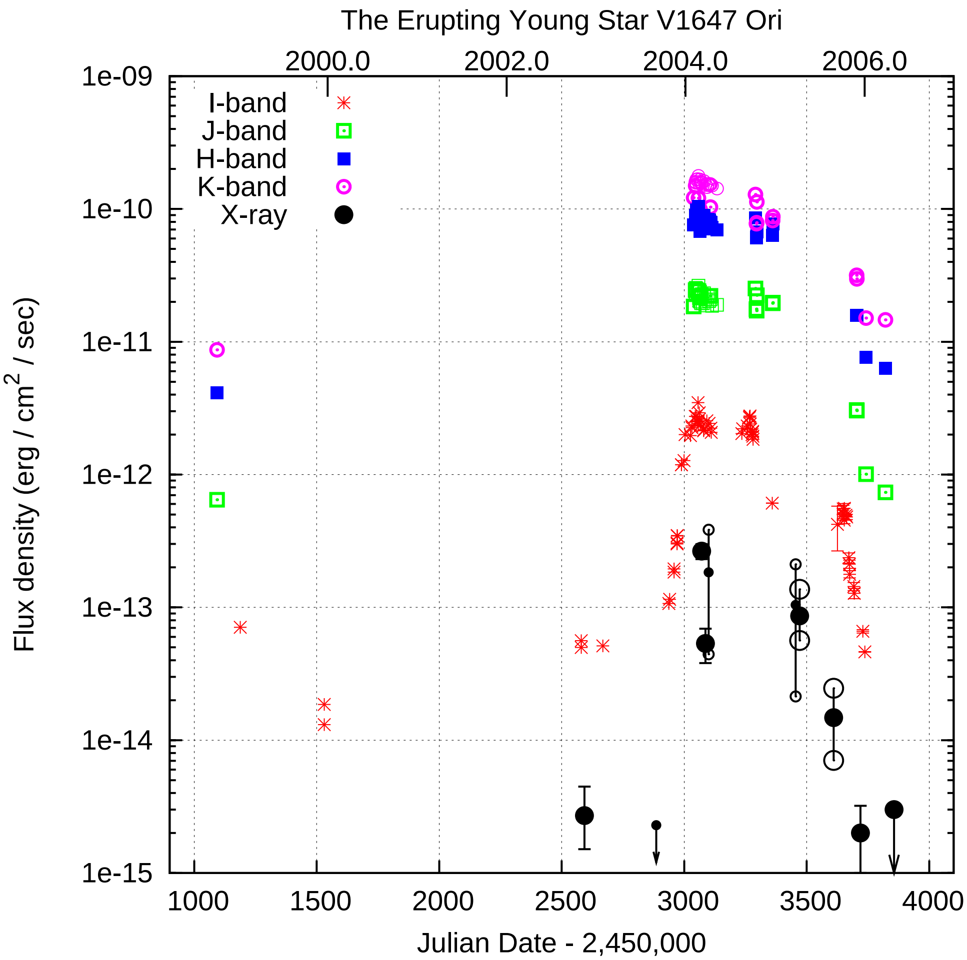

Figure 3: The near-IR and X-ray light curves of V1647 Ori covering the period from 1998 to May 2006 (from Kastner et al. 2006). The X-ray flux measurements were obtained by *Chandra* (larger circles) and *XMM* (smaller circles). The open circles indicate the range in X-ray flux during a single exposure, while the filled circles indicate the mean flux averaged over the exposure. Note the close correspondence between X-ray and infrared light curves over the course of the 2003–2005 eruption.

are indicative of high density, shocked plasma at the feet of magnetospheric accretion columns or (perhaps) at the bases of star-disk wind acceleration regions. Alternatively, it is possible that the X-ray-emitting plasmas in some or all of these accreting systems reside in coronal structures that lie in very close proximity to accretion shocks, such that the accretion-spawned UV irradiation drives the f/i ratios away from the low-density limits (~ 3.9 and ~ 3.1 for O VII and Ne IX, respectively) characteristic of coronal sources. The lack of correlation between f/i and $E(U-B)$ for classical T Tauri stars (Fig. 2) appears to cast doubt on the latter interpretation. Regardless, it appears high-resolution X-ray spectra are diagnostic of accretion processes in low-mass, pre-MS stars.

Accretion-generated X-ray emission from erupting pre-MS stars. The correspondence between the X-ray and infrared light curves of V1647 Ori during its recent eruption (Fig. 3) makes clear that its increase in X-ray flux during the eruption was generated by a sudden increase and subsequent decline in its accretion rate. On this basis, Kastner, Richmond, Grosso et al. (2006, ApJ, 648, L43) proposed that the flux of hard X-ray emission from erupting low-mass, pre-MS stars, and the duration and intensity of such eruptions, reflect the degree to which star-disk magnetic fields are reorganized before and during major accretion events. *Chandra* and *XMM* "target of opportunity" observations of future, spectacular (V1647 Ori-like) pre-MS eruptions are required to test this assertion.