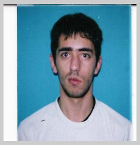

Accretion and Corona: HETG Chandra observations of TW Hya

Gerardo Luna (SAO/CFA), N. S. Brickhouse (SAO/CFA) and A. K. Dupree (SAO/CfA)

We present results from an ongoing analysis of a 500 ks Chandra/HETG observation of the young accreting, possibly planet hosting star, TW Hya (Setiawan et al. 2008). From line ratio measurements we determine temperature and density in 3 different intensity stages, low flux state, high flux state and very high flux state or flaring episode.

TW Hya is one of the oldest known stars (~10 Myr) still in the CTTS (accreting) phase. Its optically thin, inner disk is truncated on the inner edge at ~10 R_* (Eisner et al. 2006). TW Hya is uniquely poised in an interesting state of evolution when it will soon stop accreting, lose its disk, and probably form planets (e.g. Calvet et al. 2002). At a distance of only 57 pc, it is also one of the brightest T Tauri stars in X-rays.

ASCA and ROSAT data are modeled with a two-temperature plasma with T_1 ~ 2 MK and T_2 ~ 10 MK (Kastner et al. 1999). Based on a 50 ks *Chandra*/HETG observation, Kastner et al. (2002) suggest that the lower temperature emission originates in the shock of the accretion flow at the stellar surface, while presumably the higher temperature component arises from coronal emission.

Beginning on 02-15-2007 we obtained a 500 ks *Chandra*-ACIS/HETG observation of TW Hya (divided in 4 segments). During the second segment (ObsId 7437) a “flare” occurred lasting for ~20 ks. Previous data show that “flares” are common in the system (see Kastner et al. 2002). Kastner et al. (2002) analyzed the flaring period (of ~18 ks) and concluded from line-based light curves that NeX lines participate in the flaring episode, but OVIII lines do not.

-Timing analysis:

We extracted zeroth order light curves which show that a broad modulation is present (Fig. 1). In order to investigate its origin, we divided the light curve in three different intensity levels (Fig. 1): “low”, with 0.0 < count rate < 0.055 c/s; “high”, with 0.055 < count rate < 0.08 c/s and “flaring” with count rate > 0.08 c/s.

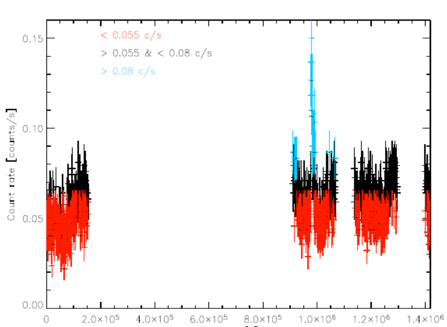

Fig. 1: Zeroth order light-curve of TW Hya. Three different intensity levels are highlighted: > 0.08 c/s also identified as a “flare”; between 0.055 and 0.08 c/s for a “high” quiescent level and less than 0.055 c/s for a “low” quiescent level.

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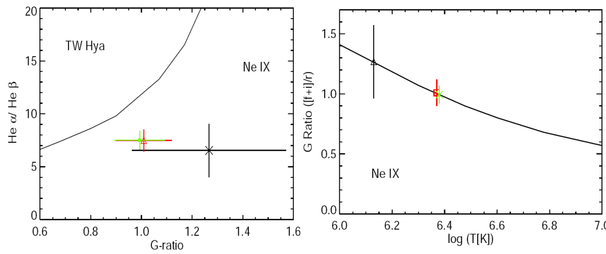

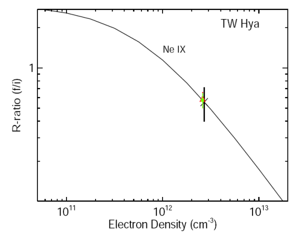

Fig. 2: *Top left panel*: *G*-ratio vs Heα /Heβ for Ne IX. *Top right panel*: *G*-ratio vs log T_e. *Bottom panel*: *R*-ratio vs n_e . “Low” (red), “high” (green) and “flare” (black) intensity levels with 90% confidence error bars are overplotted. For each panel solid line is calculated from the APED database (Smith et al. 2001).

- Line ratio diagnostics:

For each intensity level we measured the flux of Ne IX (*r*[a.k.a He α] ,*f*,*i* and He β) lines using MEG and HEG ± 1 orders. Other diagnostic lines from OVII and Mg XI were too weak for a reliable measurement. For Ne IX we obtained *R*- and *G*-ratios which are density and temperature indicators (assuming that the EUV continuum is not driving the He-like *f/i* ratio to a high density value). In figure 2 we show the *G*- and *R*-ratio as a function of log T_e and n_e respectively, and Heα/Heβ vs *G*-ratio. Using the *R*-ratio we derived a log n_e[cm^{-3}]~ $12.40^{-0.08}_{+0.11}$ and log n_e[cm^{-3}]~ $12.41^{-0.12}_{+0.20}$ during high and low levels respectively. From the G-ratio we derived a log T_e [K] ~ $6.37^{-0.16}_{+0.11}$ for the low and high intensity levels and log T_e[K] ~ $6.13^{+0.29}$ during the flare.

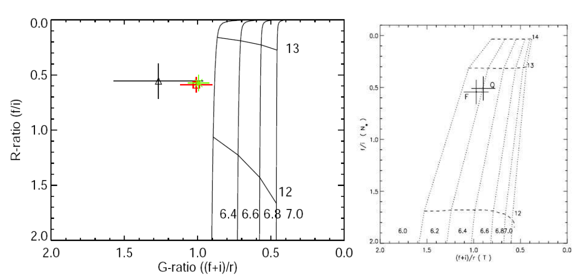

Fig. 3: R- vs G-ratio of Ne IX during high, low and flare level (left panel) and for quiescent and flare level (right panel, from Kastner et al. 2002). Full lines in left panel indicate contours of constant log n_e and log T_e from APED (Smith et al. 2001). Dashed and dotted lines in fig. 4 from Kastner et al (2002) indicate contours of constant log n_e and log T_e respectively calculated from Raymond & Smith (1985) thermal emission models. In both cases, no measurable change in n_e or T_e were found.

- Line-based light curves:

We extracted line-based light curves (2000 s bin) of ions which are formed at the lower temperature (fig. 4). If the “flare” is related to accretion, these light curves should also show the flare as seen in broadband light curves. In Table 1, we show the measured RMS and Poisson noise calculated in the segment which contains the flare. Significant differences between RMS and Poisson noise indicate intrinsic variability as in the case of “Free”, which refers to line-free regions from 1 to 17 Å. The flare strongly manifests itself in the high-T continuum and weakly in the lines. Moreover, as shown in fig. 4 and table 1, Ne X and OVIII lines do not participate in the flare.

Table 1. RMS and Poisson noise for line-based and continuum light curves with 2000 s bin. Light curves were extracted for the full ObsId 7437 and also from a 50 ks interval including the flare.

Ion	RMS	Poisson	RMS[1]	Poisson[1]
NVII	1.73	1.52	3.09	2.81
OVII	1.19	1.18	2.37	1.89
NeIX	0.27	0.25	1.10	0.42
NeX	0.36	0.35	1.16	0.57
FeXVII	0.54	0.48	1.38	0.80
MgXI	0.97	0.81	1.86	1.20
MgXII	0.65	0.57	1.47	0.85
SiXIII	0.88	0.58	1.80	0.86
SiXIV	0.95	0.67	1.79	0.97
OVIII	0.66	0.58	1.41	1.01
Free	0.94	0.31	2.00	0.44

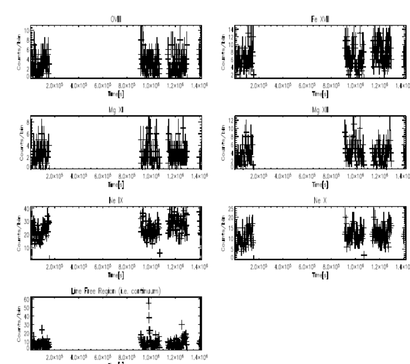

Fig. 4: Line and line-free regions light curves for the 4 segments of the observation. Bin size is 2000s and error bars correspond to Poisson noise statistic.

-Conclusions:

- •No significant changes in NeIX density and temperature can be measured in the three different intensity levels. The broadband modulation in the light curve may be related to rotation.
- •The flare does not show evidence of being related with accretion and apparently is originated in the corona.
- •From top-left panel in fig. 2, we can see that absorption is present in the system, though its distribution is uncertain.

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