X-ray Emission from Young Stars in the TW Hya Association

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Abstract. The 9 Myr old TW Hya Association (TWA) is the nearest group (typical distances of ∼50 pc) of pre-main-sequence (PMS) stars with ages less than 10 Myr and contains stars with both actively accreting disks and debris disks. We have studied the coronal X-ray emission from a group of low mass TWA common proper motion binaries using the *Chandra* and *Swift* satellites. Our aim is to understand better their coronal properties and how high energy photons affect the conditions around young stars and their role in photo-exciting atoms, molecules and dust grains in circumstellar disks and lower density circumstellar gas. Once planet formation is underway, this emission influences protoplanetary evolution and the atmospheric conditions of the newly-formed planets. The X-ray properties for 7 individual stars (TWA 13A, TWA 13B, TWA 9A, TWA 9B, TWA 8A, TWA 8B, and TWA 7) and 2 combined binary systems (TWA 3AB and TWA 2AB) have been measured. All the stars with sufficient signal require two-component fits to their CCD-resolution X-ray spectra, typically with a dominant hot (2 kev (25 MK)) component and a cooler component at 0.4 keV (4 MK). The brighter sources all show significant X-ray variability (at a level of 50-100% of quiescence) over the course of 5-15 ksec observations due to flares. We present the X-ray properties for each of the stars and find that the coronal emission is in the super-saturated rotational domain.

1. Introduction

Young stars are bright X-ray and ultraviolet (UV) emitters due to strong stellar magnetic activity fostered by rapid rotation. These high energy photons can greatly influence protoplanetary evolution and the atmospheric conditions of newly formed planets. Stellar X-ray/EUV photons are the major ionization source over most of a protoplanetary system (Alexander, Clarke, & Pringle 2006). Observation and modeling of representative samples of young stars can provide important insights into protoplanet evolution, because such data provides direct, unambiguous constraints for models. The evolutionary trend is from gas-dominated circumstellar physics to a solid-dominated structure where the gas component exists as icy surfaces on planetesimals and larger bodies or in the atmospheres of protoplanets.

Table .1: Observed TW Hya Association Members and X-ray Properties

Star	Spectral Type	V (mag)	Binary Sep. (")	Distance (pc)	P_{rot} (days)	Exposure (ksec)	f_x (10^{-12} erg cm^{-2} s^{-1})	log L_x (erg s^{-1})
TWA 13A [NW]	M1V	11.5	5.1	$55.6^{+2.3}_{-2.1}$	5.56	14.57	2.19 ± 0.03	29.91 ± 0.02
TWA 13B [SE]	M1V	12.0	···	$59.7^{+2.8}_{-2.5}$	5.35	···	2.80 ± 0.03	30.02 ± 0.03
TWA 8A [N]	M3V	12.2	13	$46.9^{+3.3}_{-2.9}$	4.65	4.56	3.30 ± 0.06	29.94 ± 0.04
TWA 8B [S]	M5V	15.3	···	$47.1^{+3.4}_{-3.0}$	0.76	···	0.16 ± 0.01	28.64 ± 0.06
TWA 9A [SE]	K6V	11.3	5.8	$46.7^{+6.1}_{-4.9}$	5.10	4.56	2.13 ± 0.04	29.74 ± 0.07
TWA 9B [NW]	M3V	14.0	···	$50.3^{+6.9}_{-5.4}$	3.98	···	0.19 ± 0.01	28.75 ± 0.07
TWA 7	M3V	11.7	···	$34.4^{+2.8}_{-2.2}$	5.05	4.69	3.33 ± 0.13	29.67 ± 0.05
TWA 3AB	M4V+ M4V	12.6; 13.1	1.5	$35.3^{+2.2}_{-1.9}$	···	6.42	1.07 ± 0.07	29.20 ± 0.04
TWA 2AB	M2V+ M3V	11.1	0.6	$46.6^{+3.0}_{-2.7}$	4.86	4.86	0.82 ± 0.07	29.33 ± 0.05

The TW Hya association (TWA) is a nearby (distances $\sim$ 50 pc) group of 9 Myr old pre-main-sequence stars that samples a crucial phase of protoplanetary evolution. We have studied the high energy emission from a group of low mass, TWA common proper motion binaries, several of which can be spatially resolved by *Chandra* and thus permit measurement of the coronal properties for the individual stars. These stars possess extremely strong photospheric magnetic fields with typical field strengths of 3 kG (Yang, Johns-Krull, & Valenti 2008) and starspots large enough to show significant optical rotational modulation (Lawson & Crause 2005). These strong magnetic fields produce a high level of coronal heating and X-ray emission and most TWA members have been recognized initially as anomalously strong X-ray sources (Webb et al. 1999). The physical properties of the stars are listed in Table .1.

Considerable effort has been devoted recently to obtaining better astrometry for TWA members and this has provided vastly improved knowledge of their distances, proper motions, and space motions. For our sample, astrometry is provided for TWA 13 and TWA 2 by Weinberger, Anglada-Escudé, & Boss (2013), for TWA 8 by Riedel et al. (2014), and for TWA 3 and TWA 7 by Ducourant et al. (2014). The best astrometry source for TWA 9 is still the Hipparcos Catalogue. The distances that we have used are listed in Table .1.

2. Observations and Data Analysis

We measured the X-ray emission from nine members of the TW Hya association using the *Chandra* ACIS-S3 detector (Obsids: 8569, 8570 – PI: Herczeg; 12389 – PI: Brown) and the *Swift* XRT (Obsids: 31981001, 90207001, 90410001 – PI:Brown), with the goal of a better detailed understanding of the coronal properties of the young, low-mass (K-M) dwarf stars in

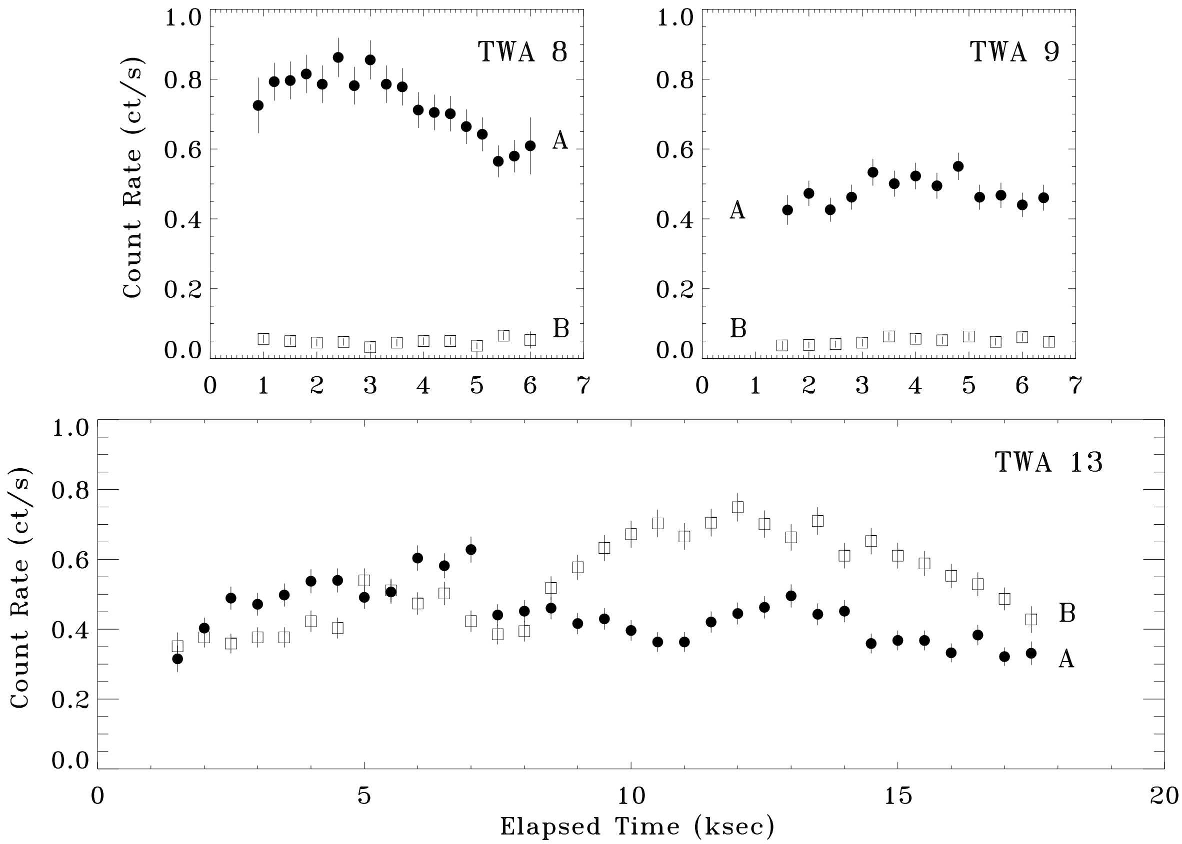

Figure .1: Chandra ACIS-S3 source variability for the three common-proper-motion binaries TWA 8AB, TWA 9AB, and TWA 13AB sampled in 500 second time-bins. TWA 8A, TWA 13A, and TWA 13B are clearly variable.

the TW Hya Association. CCD-resolution X-ray spectra with exposure times of $\sim$ 5-15 ksec were obtained The *Chandra* data were processed using CIAO Version 4.3 reduction recipes, while the *Swift* data were processed using the XTOOLS data commands outlined in the *Swift XRT Data Reduction Guide*. The X-ray fluxes and luminosities over the energy range 0.3-10 keV were measures (see Table .1). The source variability was investigated when sufficient counts were available (see Fig. .1). All the resulting spectra were fitted using XSPEC Version 12.5.0 (Arnaud 1996; Dorman, Arnaud, & Gordon 2003) and typically required use of a two-temperature VAPEC model. At CCD-resolution the spectra are only sensitive to changes in a few elements, particularly Fe and Ne and with a weaker sensitivity to O.

3. Chandra/Swift Results

Our basic results can be summarized as follows:

- The TWA stars were all readily detected as strong X-ray sources. Sufficient counts are collected to determine the X-ray sources positions accurately and these all agree with the expected proper-motion-corrected optical positions.
- Our *Chandra* observations resolved the TWA 13, TWA 8 and TWA 9 common proper motion binaries and show that the lower mass but more rapidly rotating secondaries TWA 8B and TWA 9B are far less luminous.
- Stars in the TW Hya association have super-saturated coronae where increasing rotational velocity leads to a decrease in the X-ray luminosity (see Jeffries et al. (2011) for a general discussion). This has significant implications for how the X-ray radiation fields evolves as the stars contract and spin-up.
- The coronal emission is continuously varying (see Fig. .1) due to magnetic flaring, with time-resolved spectral fitting showing higher temperatures corresponding to higher count rates. Similar time-scale FUV variations are seen in our contemporaneous *HST* COS spectra (Loyd & France 2014).
- The higher luminosity (log L_X = 29.5-30.1 ergs s^{-1}) stars have very hot (2 keV) coronal plasma, but the less active stars only show a cooler (0.5 keV) coronal component, based on 2-temperature XSPEC VAPEC spectral fitting (see Fig. .2). This cooler component is present in the spectra of all the stars.

Acknowledgements. This work was supported by Chandra grant GO1-12031X and NASA Swift grants NNX09AL59G and NNX10AK88G to the University of Colorado.

References

Alexander, R. D., Clarke, C. J., & Pringle, J. E. 2006, MNRAS, 369, 229

Arnaud, K. A. 1996, Astronomical Data Analysis Software and Systems V, eds. G. Jacoby and J. Barnes, ASP Conf. Series Vol. 101, p.17

Dorman, B., Arnaud, K. A., & Gordon, C. A. 2003, BAAS, 35, 641

Ducourant, C., Teixeira, R., Galli, P. A. B., et al. 2014, A&A, 563, 121

Jeffries, R. D., Jackson, R. L., Briggs, K. R., Evans, P. A., & Pye, J. P. 2011, MNRAS, 411, 2099

Lawson, W. A. & Crause, L. A. 2005, MNRAS, 357, 1399

Loyd, R. O. Parke & France, K. 2014, ApJS, 211, 9

Riedel, A. R., Finch, C. T., Henry, T. J., et al, 2014, AJ, 147, 85

Webb, R. A., Zuckerman, B., Platais, I., et al. 1999, ApJ, 512, L63

Weinberger, A. J., Anglada-Escudé, G., & Boss, A. P. 2013, ApJ, 762, 118

Yang, H., Johns-Krull, C. M., & Valenti, J. A. 2008, AJ, 136, 2286

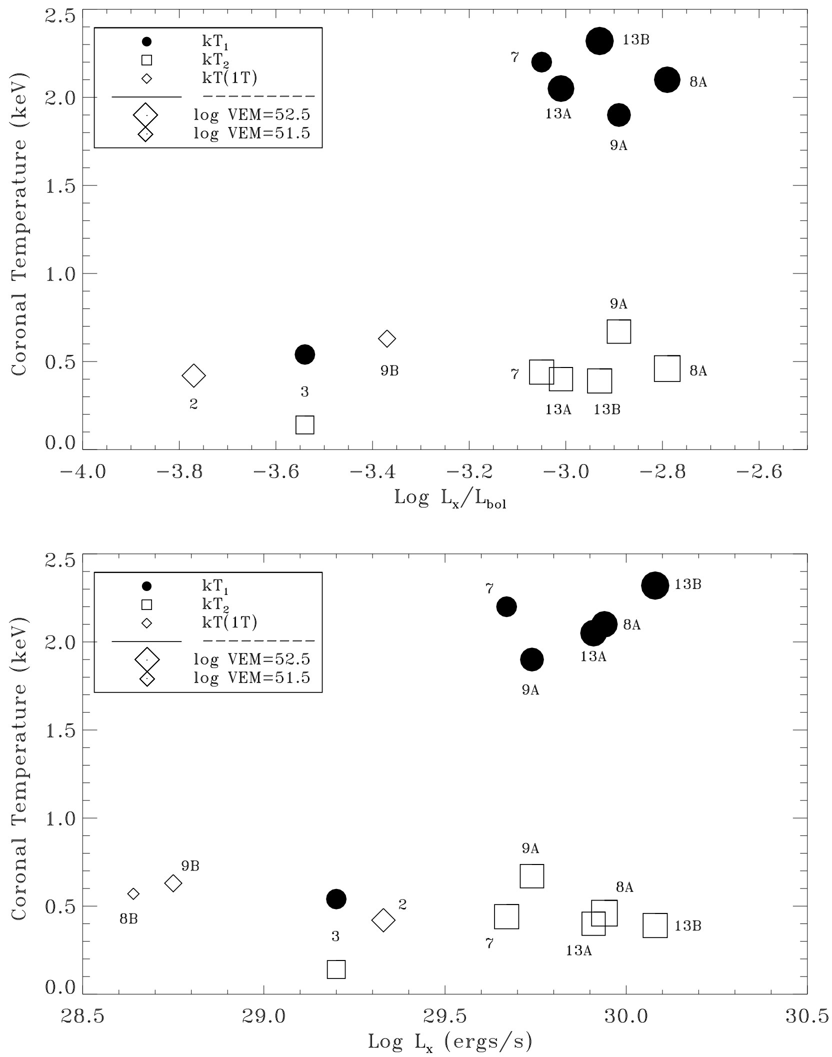

Figure .2: Coronal X-ray temperature distributions as a function of X-ray luminosity and the ratio of X-ray to bolometric luminosity. Temperature components from 2-T parameterizations are shown as filled circles and open squares, with the size of the symbol scaled to the volume emission measure. A factor of 10 increase in VEM is shown by a doubling of the symbol size. Single temperature parameterizations are shown by open triangles.