A comprehensive view of young stars with Chandra/HETG

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Abstract

We present results from the archival analysis of all high resolution spectra of cool stars observed with Chandra/HETG. Thanks to the spectral resolution of HETG, we can study the individual emission lines from these stars and now have hundreds of observations to make a comprehensive study between the Classical T Tauri (CTTS) versus the Main Sequence (MS) stars possible. These emission lines reveal the physical conditions of the outer layers, which are expected to be different between active coronae and accreting young stars. Our preliminary results show that (i) in the R versus G plot, the prototypical CTTS TW Hydrae exhibit smaller density for longer wavelength lines (like Ne and O). (ii) We also perform temperature diagnostics by plotting the soft excess (i.e., H/He lines of Si, Mg, Ne and O) versus their respective line luminosities. We find a positive correlation between these two quantities. Interestingly, we find that irrespective of whether the stars have undergone flaring during the Chandra observation or not, the trend remains the same. (iii) Finally we report that the CTTS TW Hydrae can be distinguished as separate in the Ne X/ Ne IX versus the O VIII/O VII plot when compared against other MS stars. We discuss our findings in the light of the influence of accretion on these line formations.

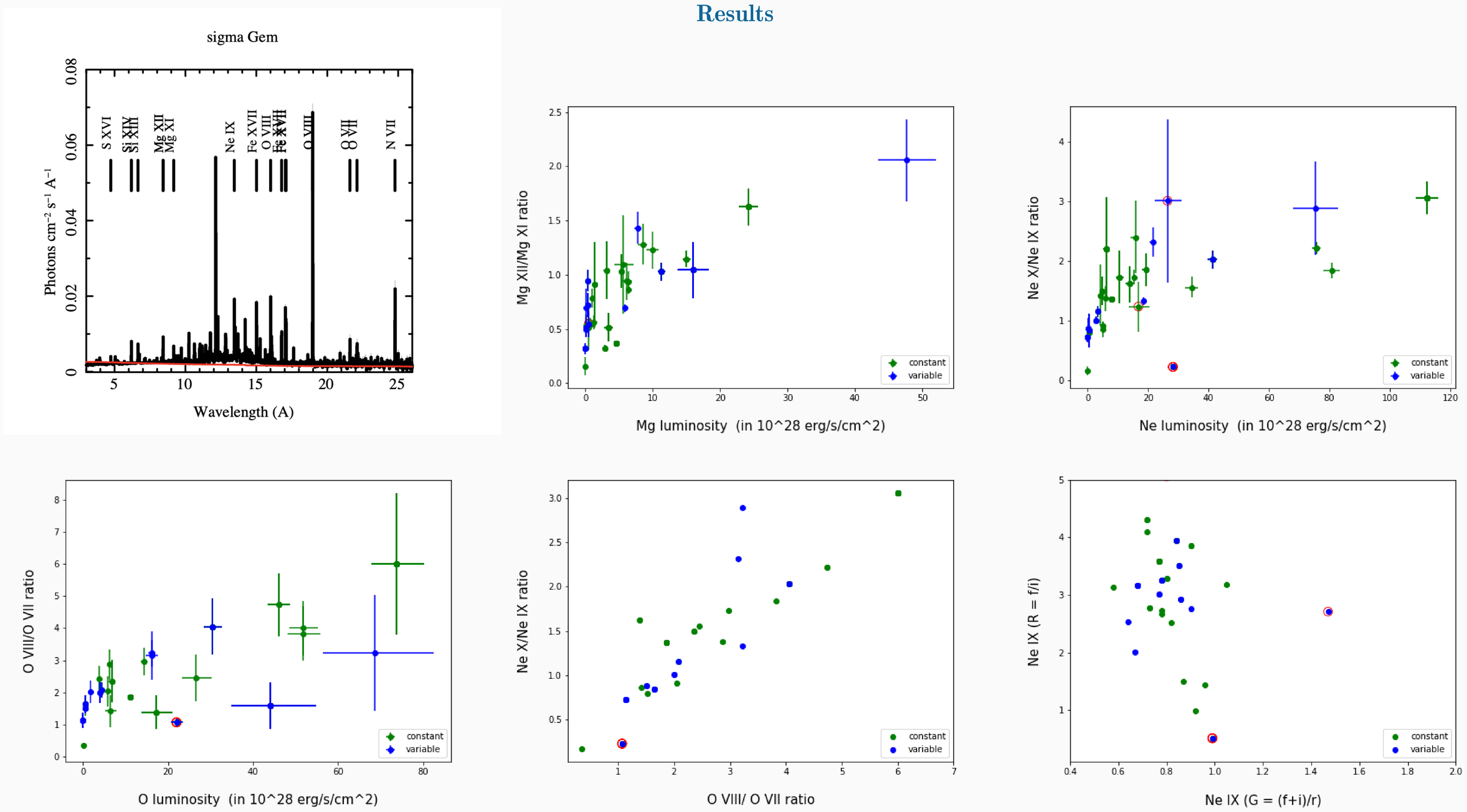
Introduction

Cool stars broadly fall either in the Main Sequence (MS) or the Classical T-Tauri stars (CTTS) category (see., Gudel & Naze 2009, A&A Rev., 17, 309 for review). The late MS sequence stars have convective envelopes where a solar-like dynamo creates a magnetic field. The magnetic activity in the corona lead to X-ray emission. On the other hand, the most massive MS stars have supersonic, radiatively-driven winds and instabilities in the winds shock-heat the gas to a few MK. In addition to the stellar corona, the observed X-ray emission of young late-type stars i.e., the CTTS are attributed to the presence of accretion disks in such systems. The inner disk rim is ionized and accreting matter channel along the magnetic field lines until it impacts the star near free-fall speed forming a strong accretion shock. This shock heats the accreted matter up to a few MK and as the plasma cools an increase in O VII emission lead to a reduced O VIII/O VII ratio compared to MS stars. The differences between the accreting CTTS and the coronal MS stars should be manifested in the plasma and temperature diagnostics afforded by the study of He-like lines, H/He lines respectively and is the motivation behind our current study.

Data reduction and analysis

We made a list of all cool stars seen with Chandra and extracted the X-ray spectrum. We then fit the continuum of these stars with a 3T plasma model. Individual lines were fit parametrically by assuming a Gaussian shape to each line. For those regions with strong Fe blends (e.g., Ne IX), we let our analysis be guided by the expected theoretical ratios.

Results



Top left: Chandra/HETG spectrum of sigma Gem where the emission lines have been marked. Top center: Ratio of Mg XII H-like line to Mg XI He-like line versus the sum of the luminosity of Mg lines. Top right: Ratio of Ne X H-like line to Ne IX He-like line versus the sum of the luminosity of Ne lines. Bottom left: Ratio of O VIII H-like line to O VII He-like line versus the sum of the luminosity of O lines. Bottom center: Ratio of Ne X/Ne IX to O VIII/O VII in our cool star sample. The errors have not been plotted to assist visual clarity. Bottom right: : Ratio of R (f/i) to G ((f+i)/r) for Ne IX. The errors have not been plotted to assist visual clarity. In the figures, the green points indicate those stars that did not show significant flaring during the Chandra observation while the blue points are variable. The known accreting stars have been circled with red.

Summary

From a detailed systematic study of the high resolution spectrum of cool stars with Chandra/HETG, we find that the difference between the MS and CTTS is reflected in the lines of longer wavelength (Ne and O). Our findings support the fact that the X-ray emission in these two systems can be ascribed to two different X-ray emission mechanisms (coronal versus accreting). A reduced O VIII/O VII ratio in CTTS has been known to exist in literature (e.g., Gudel & Telleschi 2007, A&A, 474, L25), here we also report similar behaviour in the Ne X/Ne IX ratio. We find that the behaviour in H/He of emission lines versus its luminosity is similar whether the star was persistent or flaring during the observation. This indicates that although flares are expected to increase the overall temperature (measured by H/He) in the star, the subsequent increase in luminosity cause the two states of the stars to be indistinguishable. We are currently also studying the Chandra/LETG and XMM/RGS spectrum in order to expand our sample space to more stars at longer wavelengths.