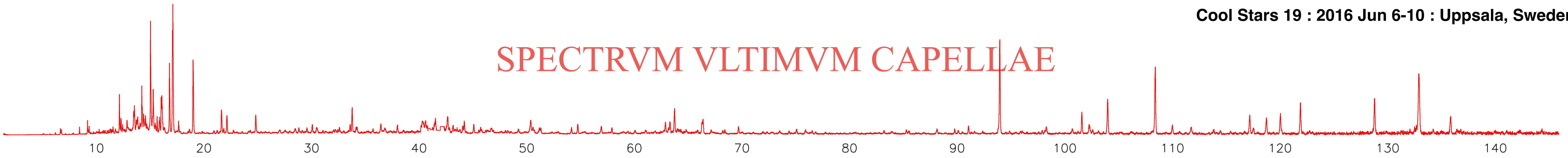
Cool Stars 19 : 2016 Jun 6-10 : Uppsala, Sweden

SPECTRVM VLTIMVM CAPELLAE



Emission Lines from the Coronae of Capella

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*Over the course of its mission, Chandra has observed the active binary Capella with high-resolution gratings (HETGS+ACIS-S, LETGS+ACIS-S, LETGS+HRC-S) for over 1.3 Msec (see **Figure 1**). Combining the data, we find >1000 emission lines, and evidence for variability at high temperatures.*

Line Detection

- We use a Haar-wavelet based line detection method, which detects lines by searching for fluctuations in the wavelet coefficients that are large compared to both that expected from the background and from nearby wavelength regions.
- The detection is run separately for each grating arm for each observation (e.g., separately for the +1 and -1 orders of HRC-S/LETG) and for the combined co-added orders (but separately for 1st, 2nd, and 3rd orders where applicable).
- Wavelength shift corrections are carried out between HRC-S/LETG +1 and -1 orders to account for degap differences between the aimpoint region and the dispersion region of the detector. The correction is computed by matching the profiles of strong lines observed in both orders, with background effects and statistical errors computed via Monte Carlo bootstrap. On average, the shift is $\delta\lambda=0.0262\pm0.0005$ Å
- The resulting lists of lines are merged by proximity based on the expected FWHM of the LRF. This means that line blends are merged into a single detection, and require manual follow-up if deblending is required.
- We detect **1081** lines over the wavelength range $\lambda\in(1.203,173.03)$Å. The detected line locations are shown for the combined HRC-S/LETG spectrum in **Figure 2**.
- We have carried out preliminary identifications using the Chianti v7.1.3 database. The number of lines from each element, and the corresponding peak formation temperatures, are shown in **Figure 3.** In the case of blends, the line is allocated to the largest contributor at the nominal peak emissivity. 31 lines remain unidentified.

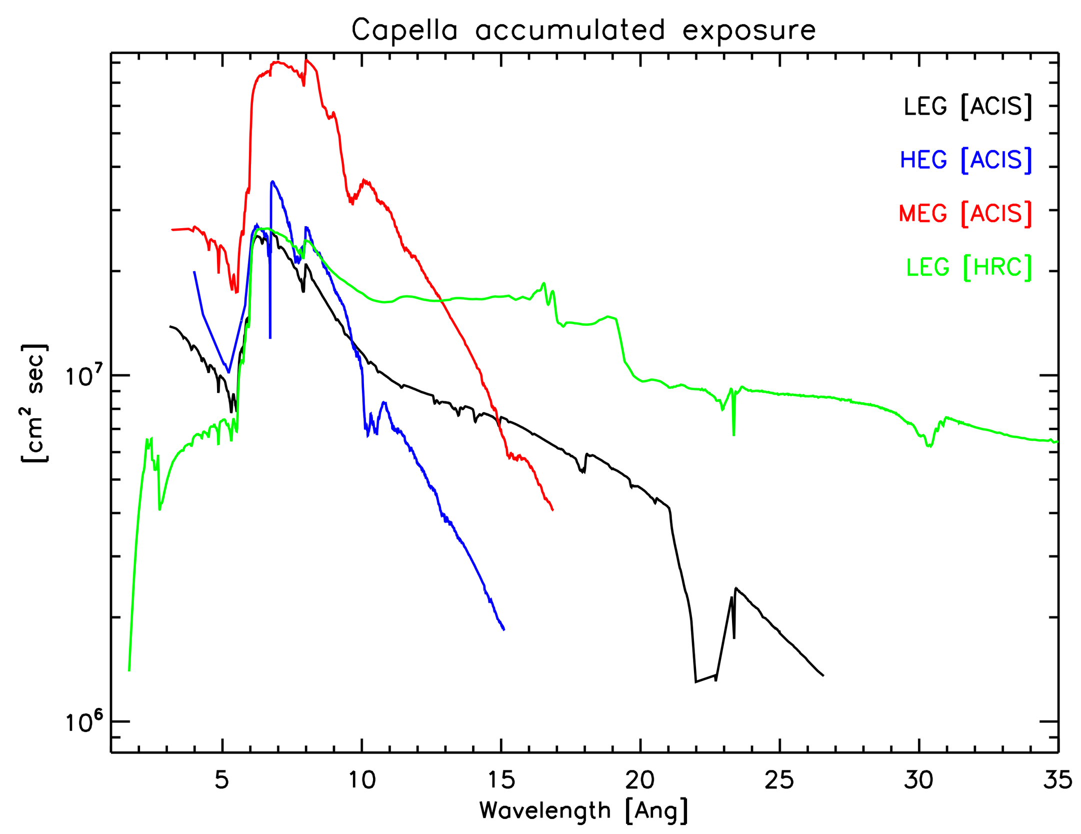
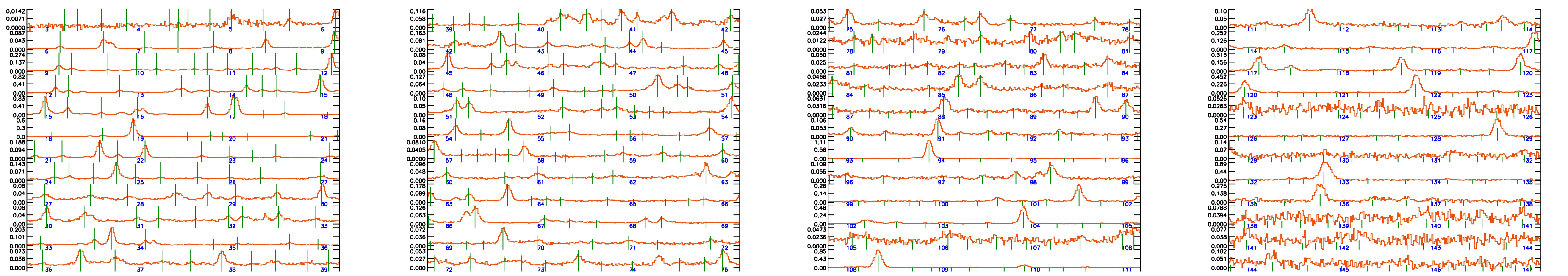


Figure 1: Combined sensitivity of Capella with *Chandra*. The products of the exposure time and the co-added first order effective areas are shown for ACIS-S/LETG (black), ACIS-S/HEG (blue), ACIS-S/MEG (blue), and HRC-S/LEG (green).



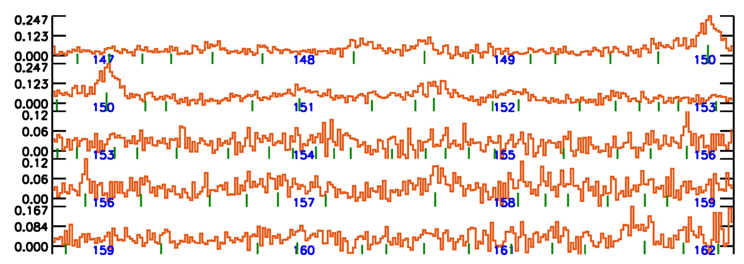


Figure 2: Lines detected in HRC-S/LETG (vertical green lines) superposed on co-added HRC-S/LETG spectrum (red curve).

Variability

Capella is a very steady source, but the long baseline of the Chandra mission lets us explore variability at different temperatures. We have computed χ^2 and fractional variance σ/μ as measures of variability. Variability is ubiquitous at the lines level in Capella, but most of it is concentrated at temperatures of logT ~6.5-7.5 (**Figure 4**). This is consistent with expectations of how the Capella DEM behaves. However, the variability is not always in sync, as can be seen in some example light curves in **Figure 5**.

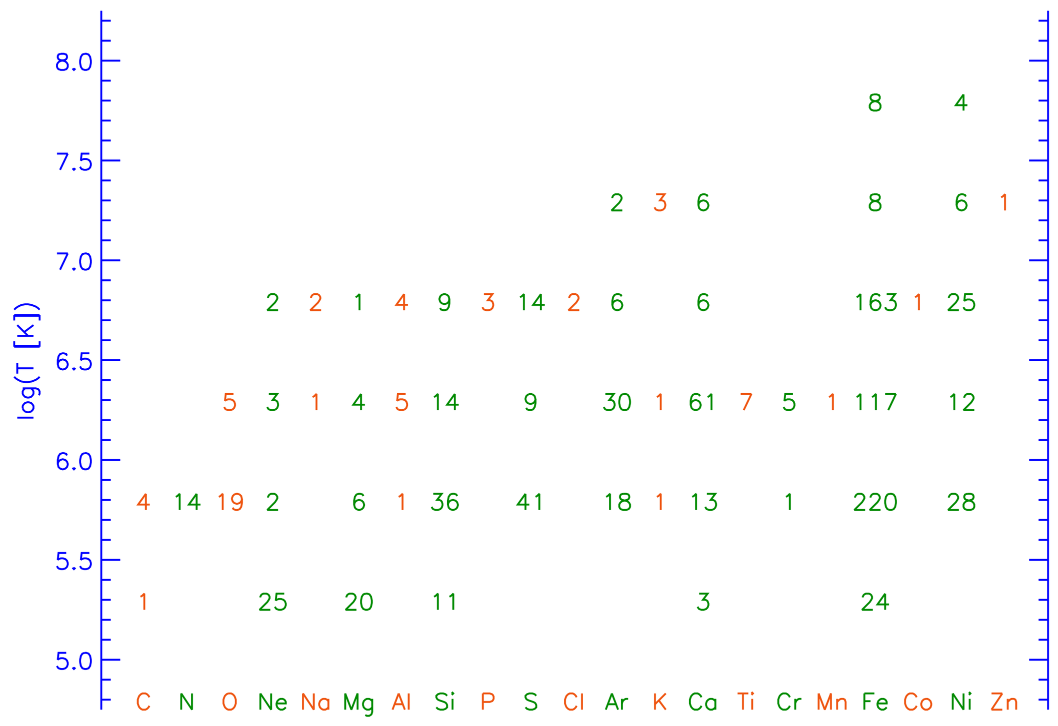


Figure 3: Lines and line blends identified with specific elements plotted against temperature of peak emissivity. 1050 of 1081 lines are identified using Chianti v7.1.3

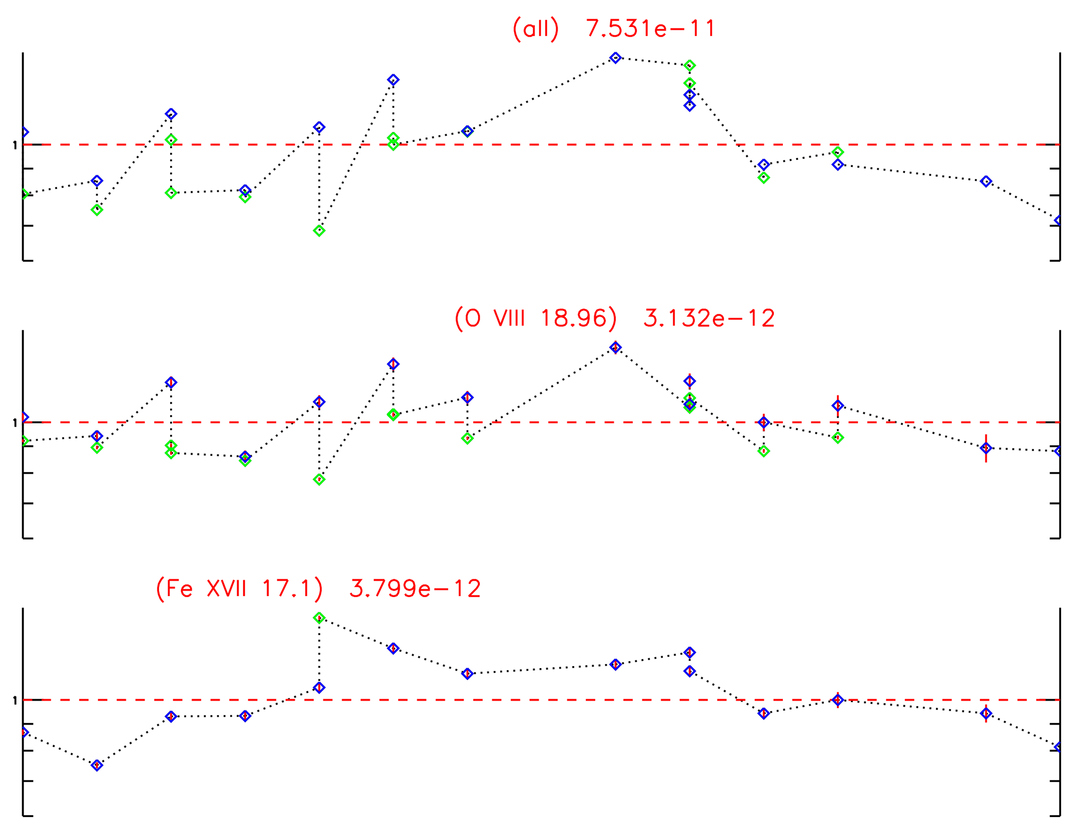


Figure 5: Example light-curves in selected wavelengths. The estimated fluxes are shown normalized by their median flux (in [ergs s^{-1} cm^{-2}]) at each epoch, from the summed fluxes from all detections (top), O VIII 18.96 (middle), and Fe XVII 17.09 (bottom). HRC-S/LETG points are marked in green and ACIS-S/HETG points in blue. Statistical errors are shown as vertical red bars. O VIII tracks the overall luminosity to within 10%.

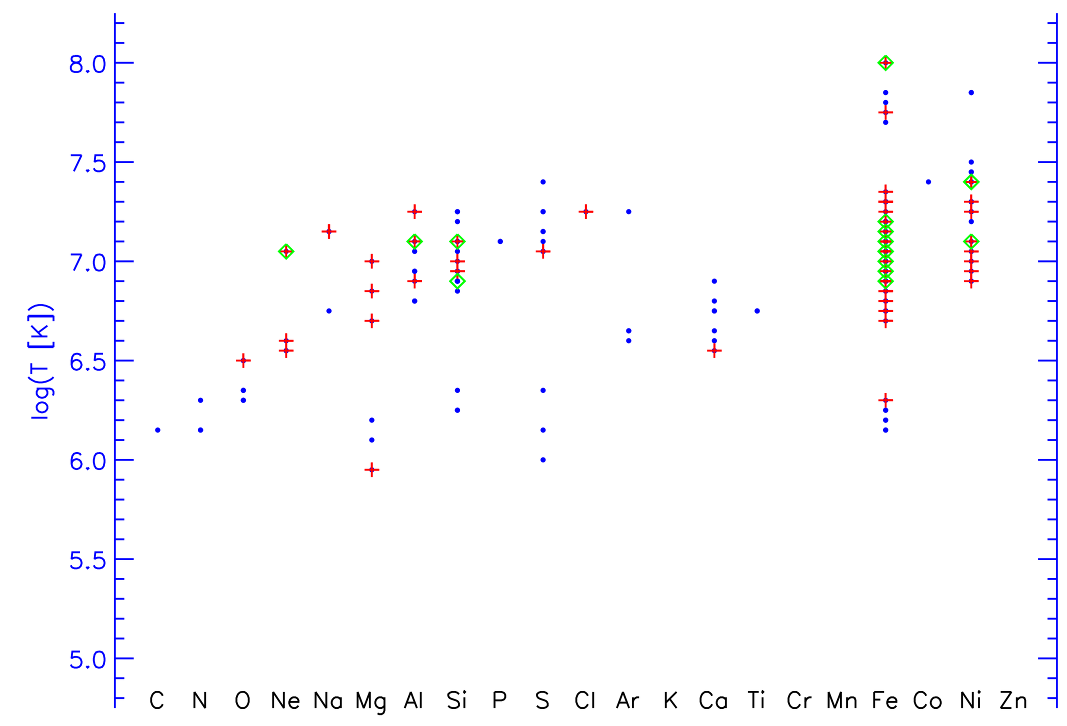


Figure 4: Variability in Capella lines. Lines that show reduced $\chi^2>10$ (red pluses) and $\sigma/\mu>1$ (green diamonds) over sample sizes of at least 10 observations are shown. Blue dots are for all lines and blends, as in **Figure 3**.