VARIABILITY OF THE X-RAY SPECTRUM OF CALIBRATION SOURCE CAPELLA

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The X-ray calibration source Capella has been extensively observed by *Chandra* and *XMM-Newton* since 1999, the year of the launches of the two satellites. We have investigated eleven X-ray spectra obtained by LETGS aboard *Chandra* over the last 5 years. Variability of the zeroth order count rate (lightcurve) as well as variability of the line fluxes of highly ionized iron features (Fe XVIII-XXI) is established. The fluxes have been compared with measured line fluxes from EUVE observations between 1992 and 1995. A strong resemblance between variations in the period 1992-1995 and the period 2000-2005 is noticed.

1. Introduction

Capella (G8III + G1III) is a luminiscent stable X-ray source with an overwhelming amount of narrow line features in the energy range from 0.07 up to 12 keV, i.e., from 1 to 180 Å (see Fig. 1). Therefore Capella is one of the most frequently used calibration sources for X-ray satellites. For both the most advanced X-ray space observatories nowadays (*Chandra* and *XMM-Newton*) Capella was subject of the first light paper ([1], [2]). The publications were followed by more extensive papers on line fluxes, emission measures and temperatures ([3]) and on electron densities ([4]). Over these years Capella has proved to be a remarkably stable X-ray source without any flaring.

Before the *Chandra* and *XMM-Newton* era Linsky et al. ([5]) and Johnson et al. ([6]) investigated the Fe XXI line at 1354 Å using the Hubble Space Telescope/Space Telescope Imaging Spectrograph in 1995 and 1999. They noticed some variation in the flux of that line. Based on a comparison of the two observations and thanks to the high dispersion at that wavelength the variability could be assigned to the G8III component of the binary system. In this presentation we study a number of eleven observations of Capella by means of *LETGS* aboard *Chandra* over the period September 1999 to October 2005. We discuss the variation in 0^{th} order count rate over this period in section 2. A relation between line flux ratios of different ions (different formation temperatures) for two of the observations (OBSID=1248 and OSBID=5956) is given in section 3. A comparison of line fluxes of three selected Fe-lines over the years 1992-2006, based on observations with *EUVE* by Linsky et al. ([5]) and this work is given in section 4. Section 5 will give the conclusions.

2. Lightcurves

For all spectra of Capella observed by *LETGS* the observation identification numbers (OBSID), the dates of observation, the Julian Day-values, the count rates, and their statistical 1σ values have been collected in Table 1. The count rates

Table 1
Average count rates of Capella, based on the *LETGS* observations over a period of years from the launch of *Chandra* in 1999 to now, ordered by time.

OBSID	Date of Obs.	JD	Counts/s
62435	1999-09-06T05	2451427.7	1.961(.013)
1420	1999-10-30T00	2451481.5	2.074(.014)
1248	1999-11-10T01	2451492.5	2.112(.008)
0058	2000-03-08T12	2451612.0	2.067(.013)
1009	2001-02-14T15	2451955.1	1.976(.014)
2582	2002-10-05T04	2452552.7	2.103(.014)
3479	2002-10-06T15	2452554.1	2.015(.015)
3675	2003-09-28T08	2452910.8	1.888(.014)
5041	2004-09-11T11	2453260.0	2.184(.014)
5956	2005-03-31T12	2453461.0	2.756(.015)
6165	2005-10-02T08	2453645.7	3.040(.018)

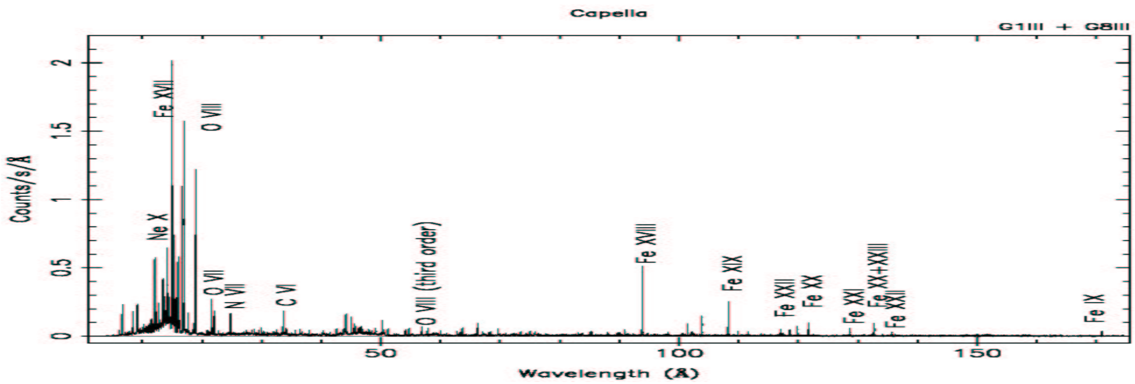

Figure 1. The spectrum of Capella (OBSID=1248) obtained with *LETGS* aboard *Chandra*.

were obtained by fitting a constant through the data of the lightcurves. From this table we notice that for nine out of eleven observations the count rate is close to 2 counts/sec, while for two recent observations (OBSID=5956 and 6165) the count rate is about 2.9 counts/sec, i.e. 50% higher.

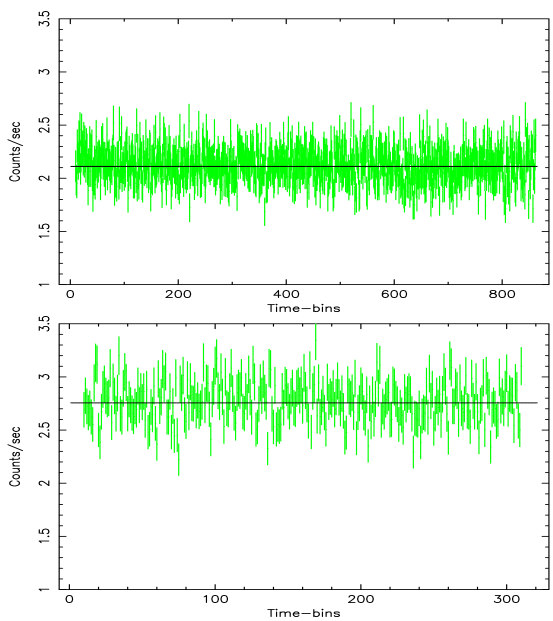

Figure 2. **Top panel**: The lightcurve of the X-ray spectrum of Capella of OBSID=1248; observation date 1999-11-10. **Bottom panel**: The same for OBSID=5956; observation date 2005-03-31. For both lightcurves the time bin is 100 sec.

For all observations a lightcurve has been subtracted from the 0^{th} order spectrum. For two of them (OBSID=1248 and 5956) the lightcurves and the fitted count rate levels are shown in Fig. 2. Both lightcurves are flat and constant (but at different level), without any flaring. The time is binned to 100 sec. The observation with OBSID=1248 was exposed during 85 ks, and that with OBSID=5956 during 30 ks.

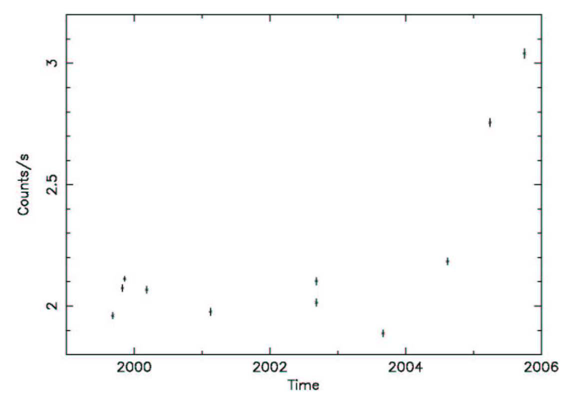

Figure 3. The count rate versus the time over the years 1999 to 2006, as observed by *LETGS*.

The behaviour of the count rates from Table 1 versus the time is shown in Fig. 3. It concerns only *LETGS* observations from 1999 (launch) until now. During the first years of observations the curve in this figure is flat, evoluating to an increase from September 2004 until the last observation in October 2005. No reliable comparisons with earlier lightcurves from former satellites could be made.

3. Line fluxes versus temperature

Apart from the lightcurves the fluxes of the individual lines have been measured. This was done by folding a Gaussian shape through the instrumental response matrix and by fitting the resultant to the data. We have made a comparison between the line fluxes of lines from different ions for different observations. We have focussed on two observations OBSID=1248 ("low state") and OBSID=5956 ("excited state"). The line flux ratio for the two observations as a function of the optimal formation temperature of the ion is shown in Fig. 4. From this figure we notice that all line fluxes in OBSID=5956 are higher than in OBSID=1248. However, compared to the optimal formation temperature the increase of line flux is not constant, but goes from 1.2 at low temperatures to about 2 at higher temperatures. From Fig. 4 it is clear that especially the hotter plasma varies.

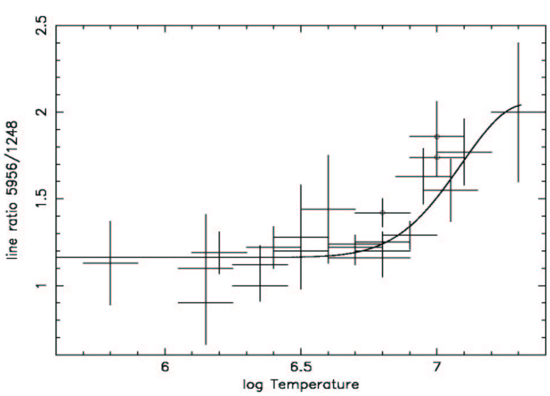

Figure 4. The line flux ratio between OBSID=1248 and OBSID=5956 versus the optimal formation temperature. Notice the strong enhancement for the hotter plasma. The data points with diamonds are from [5].

4. Line fluxes versus time

For three selected lines, Fe XVIII (93.92 Å), Fe XIX (108.37 Å), and Fe XXI (128.73 Å), that were formerly observed by Linsky et al. ([5]) in EUVE spectra the line fluxes were measured for all observed *LETGS* spectra. Our measured line fluxes are very well comparable with those measured by Linsky et al. ([5]) over the period 1992 - 1995. The line fluxes show an increase during both periods of observation (1992-1995 [5] and 1999-2006 [this work]). To obtain a better S/N ratio the measured flux values of the three lines were summed. The summed flux values in units 10^{-13} $ergs\ cm^{-2}\ s^{-1}$ versus the time are shown in Fig. 5. From this figure we notice that the two increases in 1995 (2449800JD) and end 2005 (2453700JD) can be very well described by the same shape. From the graph drawn through the data points a time difference of 10.8(.3) years is obtained between the two maxima. Whether we deal with a real periodicity of 10.8 years or with two independent increases has to be proven by means of observations in 2016.

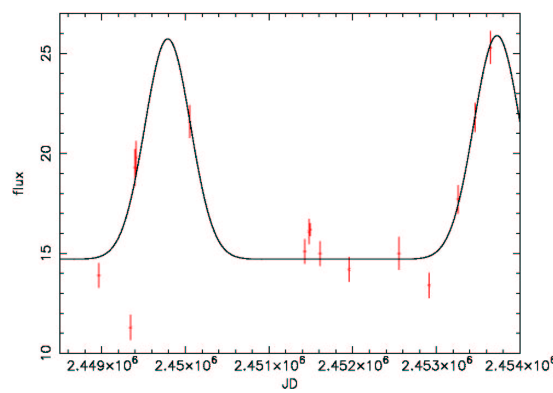

Figure 5. The summed fluxes of the Fe XVIII (93.92 Å), Fe XIX (108.37 Å), and Fe XXI (128.73 Å) line features. The fluxes are in units 10^{-13} $ergs\ cm^{-2}\ s^{-1}$. The data before JD=2451000 are from Linsky et al. ([5]); after JD=2451000 are from this work. The drawn graph shows the resemblance of the two events.

5. Conclusions

The X-ray calibration source Capella shows clear variability over the years 1999 - 2006, the era of *Chandra* and *XMM-Newton*.

The observed variabilities are especially related to the hotter plasma.

Line flux variations over the *Chandra* era show a remarkable resemblance with line flux variations noticed by Linsky et al. in EUVE observations ([5]).

A time interval between the two increases ([5] and this work) of 10.8(.3) years is established. Whether we deal with a real periodicity or occasional events can not be decided from these first results and needs further investigations in the period 2010-2016.

The lightcurves are flat and constant (but at different level depending on the time of observation). No individual (short time) flares are detected. Between different observations a count rate difference up to about 50% is noticed.

REFERENCES

1. Brinkman, A.C., Gunsing, C.J.T., Kaastra, J.S. *et al.* 2000, ApJ 530, L111
2. Audard, M., Behar, E., Güdel, M. *et al.* 2001, A&A 365, L329
3. Mewe, R., Raassen, A.J.J., Drake, J.J. *et al.* 2001, A&A 368, 888
4. Ness, J.-U., Mewe, R., Schmitt, J.H.M.M. *et al.* 2001, A&A 367, 282
5. Linsky, J.L., Wood, B.E., Brown, A., Osten, R.A. 1998 ApJ 492, 767
6. Johnson, O., Drake, J.J., Kashyap, V. *et al.* 2002, ApJ 565, L97