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Detection of H- and He-like resonance lines of chlorine in solar flare spectra

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Abstract. Preliminary analysis of spectra collected with the RESIK Bragg bent crystal X-ray spectrometer aboard CORONAS-F indicates the presence of many spectral features which until recently were unidentified. We present RESIK spectra in which the H-like Cl XVII Lyα line at 4.182 Å and He-like Cl XVI triplet components in the range 4.43 Å - 4.45 Å are identified.

1. Introduction

Brief description of RESIK spectrometer and its initial observations is given by Sylwester *et al.* (2002). The wavelength coverage of RESIK is 3.35 Å - 6.1 Å. We have recently done calibration calculations, establishing an absolute wavelength scale and absolute photon fluxes for RESIK spectra. This has allowed us to identify spectral features, some of which are observed for the first time from astrophysical plasmas. In particular we have detected lines due to highly ionized sulphur, silicon, argon, potassium and chlorine. According to standard sources of solar element abundances, chlorine has a very low abundance ($A_{\rm Cl}$ less than 10^{-6} relative to hydrogen) but is very interesting because it is one of the few elements observed in both photosphere and corona having a high (larger than 10 eV) first ionization potential (FIP). No previous spectral analysis has allowed the absolute coronal abundance of chlorine to be determined, and even its relative abundance has only been determined with large uncertainties (Phillips and Keenan, 1990).

2. Analysis and Results

We analyzed RESIK spectra for 80 selected time intervals in several flares observed in January – March 2003. In the left panel of Figure 1 we present a part of average RESIK spectrum. According to theoretical calculations we expect to see the H-like spin doublet Lyα line and He-like triplet lines of chlorine at the positions marked by vertical dotted lines. Indeed, we can see spectral features at these positions. In order to deduce the temperature behavior of these features we inspected the total set of about 1200 spectra now reduced. We grouped them according to the temperature as obtained using the flux ratio in the shortest and longest wavelength regions (channels No. 1 and No. 4 respectively). It turned out that the feature at 4.18 Å is the most prominent in **cooler** plasma. This is in the contrary to what was expected for the Cl XVII Lyα line behavior which is expected to be more brilliant in the higher temperature plasma. Our conclusion is that the spectral feature seen around 4.18 Å must contain substantial contribution from satellites line(s) formed in a cooler plasma. There are many S XIV lines (satellites to S XV) in this region. The most intense is expected to be at 4.1919 Å, in addition, there

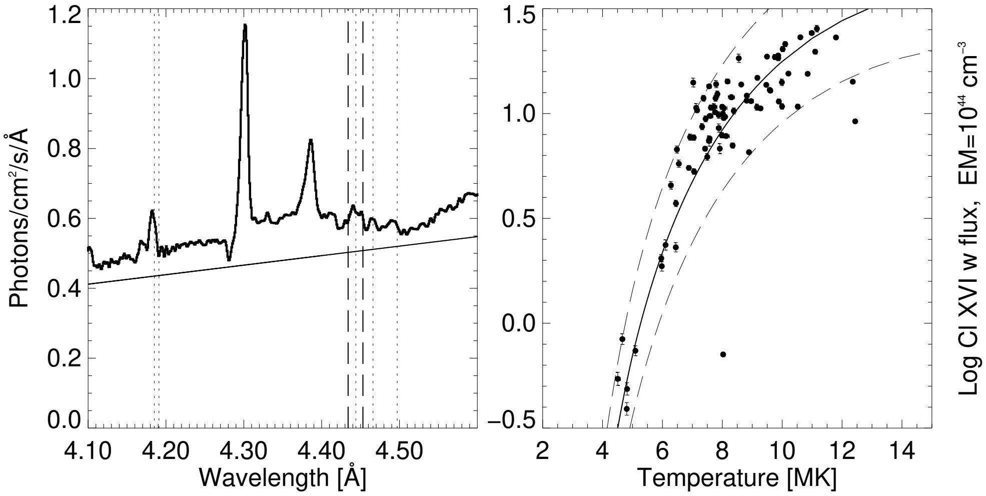

Figure 1. *Left*: Displayed is a part of RESIK spectrum covering the range of expected resonance Cl lines. *Right*: Theoretical dependencies of Cl resonance line flux on temperature plotted over the observations.

are other satellites between 4.1773 Å and 4.1959 Å. As a result we can not (at present) estimate the contribution of chlorine Lyα line to this complex in a simple way. Much easier appears the interpretation of the spectral region around 4.44 Å where the He-like chlorine triplet is expected to show up. Undoubtedly in the average spectra grouped according to their temperature, these lines are more prominent at higher temperatures (as expected). We have therefore identified the individual components of the triplet at λ=4.444 Å, 4.468 Å and 4.497 Å as corresponding to $1s^2$ - 1s2p transitions.

In Figure 1, the vertical dashed lines bound the region of the Cl resonance line at λ=4.444 Å taken here for the flux determination. The thin line at the bottom of the spectrum represents the continuum level as calculated based on the temperature and emission measure estimated from the ratio of total fluxes measured in 1st and 4th channels. Using these total fluxes we have calculated the temperature and emission measure (in the isothermal approximation) and the Cl resonance line fluxes for example set of 80 spectra. The results are plotted in the right panel of Figure 1. Theoretical dependencies of Cl line flux on temperature are presented also (lines). The shapes and positions of these lines are calculated for assumed unit emission measure (10^{44} cm^{-3}) and three different chlorine abundances: $3.98\,10^{-7}$, $\mathbf{7.76\,10^{-7}}$ and $1.58\,10^{-6}$. The middle (continuous) line position corresponds to our new determination of A_{Cl} for the corona.

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