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X-ray and extreme-ultraviolet spectroscopy in astrophysical and laboratory plasmas

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A large amount of high quality spectra with high-resolution and imaging have post deep insights for our understanding to universe objects, including their emission measure, physical environment, morphology, heating mechanism and so on [1]. New-generation X-ray missions in planned will further open up a vast discovery space and for the hot and energetic universe. However, there are still large gaps between extensively used models (e.g. Chianti, AtomDB, Cloudy, Xstar etc) and observations, for example, the X-ray emissions at the boundary of supernova remnants, the X-ray formation in protostellar jets, as well as possible 'dark matter' messenger, e.g. 3.5 keV emission in galaxy cluster — Perseus.

Electron beam ion trap (EBIT) was usually used to benchmark various spectral models or help line identification for coronal-like plasmas due to its characteristics of consistent plasma condition to astrophysical cases [2], as well as measurements of critical parameters for electron/neutral-ions collisions in plasmas [3]. The Livermore and Heidelberg EBIT groups used such platform further to simulate charge-exchange X-ray emissions in comets and galaxy [4,5]. Recently, other laboratory platforms were used to modelling the condition of black-hole objects, e.g. intense laser [6]. On Shengguang-II facility, we also investigate the X-ray formation in protostellar jet [7].

As reported by Savin et al [8], theoretical models are the foundations for the understanding of observations, and will remain so into foreseeable future, that is also necessary for the connection between the astrophysical observation and the laboratory miniature. So we setup a visualized analysis package [9] – Spectral Analysis System for Astrophysical and Laboratory plasmas (SASAL) - for the spectroscopic measurements in laboratory and their application to astrophysical observations. By using this analysis tool, we successfully diagnose the averaged velocity of solar wind by spectral fitting of charge-exchange, as well as the estimation of vacuum condition in the trap center of EBIT.

Chandra ACIS observation for Linear C and CX fitting

References:

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Table 2
Available Observation Data Sets for LINEAR 1999 S4 before Breakup (2000 July 14), with the ACIS-S Instrument from *Chandra* Public Data Archive

Obs_ID	Exposure Times (ks)	Average Count Rate	Event Count	Start Time
584	0.95	3.00	2839	04:29:19
1748	1.18	2.83	3331	05:06:19
1749	1.18	2.98	3501	05:31:29
1750	1.19	2.85	3384	05:56:39
1751	1.18	7.13	8383	06:21:49
1752	1.19	6.81	8093	06:46:59
1753	1.18	7.46	8812	07:12:09
1754	1.36	4.06	5516	07:37:19

3.3.1. Observation Data for LINEAR

The available data set for LINEAR 1999 S4 in the *Chandra* public archive are listed in Table 2 before its breakup. The data reduction is performed by using the *Chandra* Interactive Analysis of Observations (CIAO) software (ver 4.5)[10] and by following the science threads for imaging spectroscopy of solar system objects. In the data reduction, the source region covers the S3 chip with a circle region with a radius of 4′.56, while the background is extracted from S1 chip with a circle region (radius of 3′.78). The data set with Obs_ID of 1748 was not included in the our analysis due to its low S/N. The other seven spectra were combined by using the *combine_spepctra* tool to get a high S/N spectra. Correspondingly, associate auxiliary response files and energy dependent sensitivity matrices were obtained by this tool simultaneously. The resultant observational spectra is presented by symbols with error bars in Figure 11. We also notice the difference of the comet LINEAR observations between the present extraction and Lisse et al. (2001)'s data before its breakup as well as the data adopted by Otranto et al. (2007). This is due to different source regions adopted in the spectral extraction as illustrated by Torney (2007). In the work of Lisse et al. (2001), they adopted EUVE spatial profiles and the full extent of the comet to correct the *Chandra* X-ray flux because the comet overfills the S3 chip and falls outside its field of view. However, the relative emission line fluxes have small differences between the present observation and previous ones and are within uncertainties. This means the comparison of relative solar wind abundance with published values that will be discussed in the following subsection, is still feasible.

3.3.2. Fitting in Sherpa with the SASAL Model

The fitting procedure is done in the *sherpa* package of CIAO version 4.5.[10]. A multi-Gaussian model is constructed based on the spectral lines calculated by our SASAL package, as the following formula,

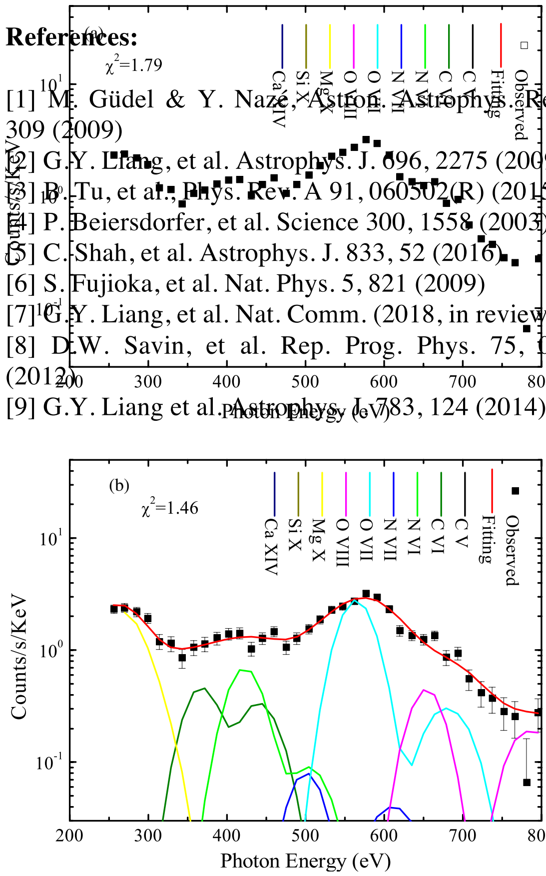

Figure 11. Co-added *Chandra* ACIS observation of Linear C/1999 S4 before its breakup on 2000 July 14 and its total fitting performed in *Sherpa* with line-width of 50 eV at different solar wind velocity of 300 km s^{-1} (a) and 600 km s^{-1} (b), respectively. Specie's contributions are overlapped by multiplying their CXE model spectra by their fitted fractions.

(A color version of this figure is available in the online journal.)

here is consistent with the ACE-SWEPAM and SOHO-CELIAS online data archive (592 km s^{-1}). The line width is set to be 50 eV, being consistent with that adopted by Bodewits et al. (2007) and Lisse et al. (2001). It is narrower than the intrinsic line-width of 110 eV FWHM of the ACIS-S back-illuminated CCD (Garmire et al. 2003).[11] As stated by Lisse et al. (2001), it is not significant statistically. In this model, we include contributions from Mg X, Si X, and Ca XIV CX emissions. But no Ca^{14+} species