PREDICTION OF COMETARY SOLAR WIND CHARGE EXCHANGE SPECTRA IN EXTREME-ULTRAVIOLET WAVEBAND FOR SATELLITE DESIGN.

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Introduction: Cometary solar wind charge exchange process happens when ions in solar wind capture electrons from neutral particles in coma, and excited state – ground state transitions of the elections can emit photons in extreme ultraviolet (EUV) and soft X-ray waveband. The study of this process plays an important role in understanding the process itself, the stellar wind represented by the solar wind, the nature and structure of comets, and so on. In view of the low frequency and occasional nature of near-Earth comets that create challenges for observations, the University of Hong Kong is planning to launch a space detector in EUV band in the near future. Observing solar wind charge exchange process in comets will be one of its scientific goals. Thus this study is intended to select an appropriate bandpass for the detector. The charge exchange (CX) model in the SPEX software package [1] was used to iteratively fit the spectra of five comets observed by by ACIS-S3 of Chandra X-ray observatory (CXO ACIS-S3). Taking into account the coronal mass ejection (CME), another three free parameters, abundance of magnesium, silicon, and iron, were introduced into the comet 153P/2002 to re-fit. Finally, the fitting results of five comets were obtained, which helped to predict the spectral lines of comets in EUV band. Then by comparing with the data in AtomDB, we identified some strong EUV emission lines, and gave a proposal for the design of the detector by statistics: Select different energy band according to the possible resolution, and at the same time pay attention to the detector's effective area.

Data Selection: Only around 30 comets have been observed in X-ray waveband since the first cometary X-ray radiation was discovered, which limited the selection of our data sample. Observation data of five typical comets detected by CXO ACIS-S3 were used in this study to represent most kinds of space conditions, whose two aspects are respectively cometary conditions and solar-wind conditions. The five comets are C/1999 T1, C/2001 Q4, 153P/2002, 73P/2006 and C/2011 L4. The two aspects of their space conditions are shown in Fig.1 and Fig.2.

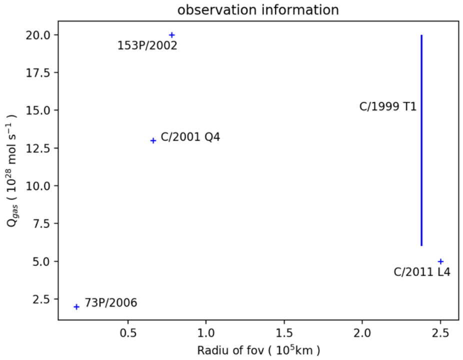

Fig.1 Gas production rate versus field of view for the sample of comets. Comets which have greater slope are more possible to be in the collisional thick conditions.

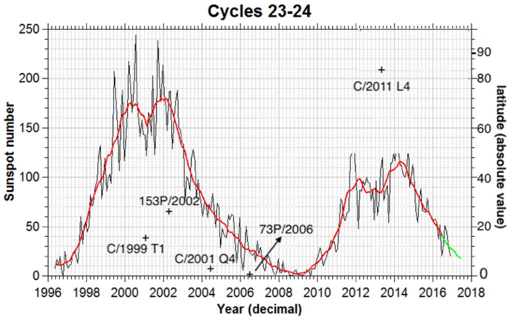

Fig.2 Latitude distribution and observation time of the comets. The solar period data are from www.solen.info.

Spectra Fitting: Charge Exchange (CX) model in SPEX software package was used to fit the cometary X-ray spectra, and the given parameters would be used to predict cometary spectra in EUV waveband. Considering the small effective area of CXO ACIS-S3 below 0.4keV and the low flux produced by charge exchange process above 1.0keV [2], the waveband from 0.4keV to 1.0keV was chosen to be fitted. Seven fitting parameters were listed as follow: Collision velocities between ions in solar wind and neutral particles in coma, which can reflect values of cross sections; Electron temperature which decide charge state distribution of solar wind; The normalization coefficient which represent molecular and atomic densities of coma; Abundance of the elements C, N, O and Ne in solar wind.

The initial fitting results are shown in Table.1, which indicates more details should be considered for

153P/2002. The emission line at 9.3Å produced by Magnesium ions in the X-ray spectra of 153P/2002 indicates CME perhaps happened during the observation, when the ejection could introduce more heavy ions. Therefore the abundances of silicon, magnesium and iron were introduced to re-fit.

Comet	C/1999 T1	C/2001 Q4	153P/2002	73P/2006	C/2011 L4
Normalization(10^{64}m^{-3})	3.39	2.09	22.23	2.38	5.19
Electron temperature (keV)	0.18	0.12	0.22	0.15	0.19
Collision velocities (km s^{-1})	628.34	630.67	199.83	599.82	199.09
Abundance of C	16.91	4.55	94.46	13.32	44.96
Abundance of N	12.86	27.17	35.41	7.38	0.0
Abundance of O	3.96	4.46	10.63	2.51	3.00
Abundance of Ne	7.63	34.34	14.29	3.03	6.85
Reduced chi-square	0.99	0.51	6.38	0.75	2.15

Table.1 Initial fitting results

Results: According to the fitting results, spectra of the five comets in EUV waveband could be predicted, and that of C/1999 T1 is shown in Fig.3 as an example.

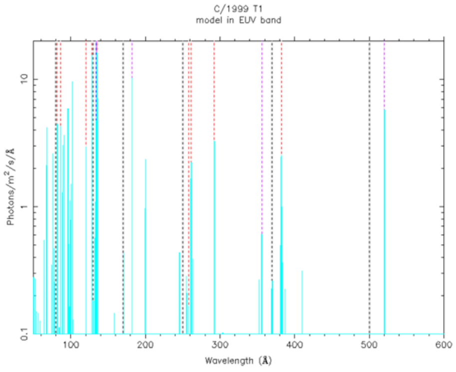

Fig.3 Predicted EUV spectrum of C/1999 T1. The Cyan solid lines are predicted emission lines. The red, pink and blue dashed lines respectively mark strong lines of O, C and N ions. The grey dashed lines separate wavebands suggested by the laboratory.

In order to give more suggestions to the design of the detector, a focused waveband should be ensured by finding strong emission lines in most comets, i.e. most space conditions, which can be decided by the statistical result of the predicted EUV spectra. The relative intensities of different emission lines in different comets are shown in the statistical (Fig.4).

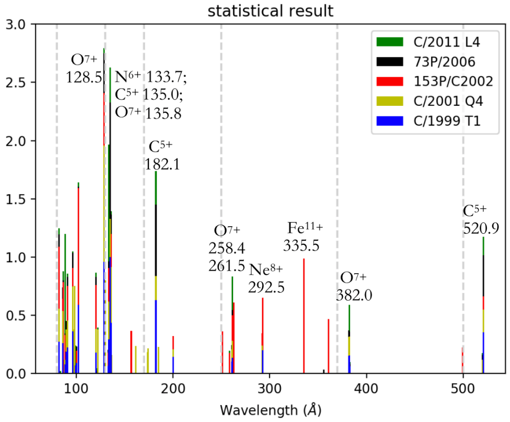

Fig.4 Statistical result of the predicted emission lines of comets in EUV waveband.

Conclusion: According to the statistical result of the predicted EUV spectra of the five comets, the decision of a focused waveband should depend on possible energy resolution. If the possible resolution is larger than 200, the waveband from 80Å to 140Å can be chosen as the focused waveband because there are a number of strong emission lines, and all of C, N and O have strong lines. If the possible resolution is less than 200 but larger than 10, the waveband from 250Å to 370Å can be chosen because it not only contains lines emitted by O^{7+} and Ne^{8+}, which can be observed in most space conditions, but also perhaps contains lines emitted by Fe^{11+}, which can serve as a probe for magnetohydrodynamics activities. If the possible resolution is less than 10, the waveband from 170Å to 250Å should be chosen due to the strong emission line of C^{5+}. Besides, because most typical emission lines occur around the edges of suggested wavebands given by the laboratory, focused waveband or effective waveband of the detector should be adjusted flexibly to avoid negative edge effects.

References: [1] Gu L., Kaastra J. & Raassen A. J. J. (2016) A&A, 588, A52-11. [2]Bodewits D. et al. (2007) A&A, 469(3), 1183-1195.