Challenge to reveal solar-wind charge exchange mechanism with TES X-ray microcalorimeter

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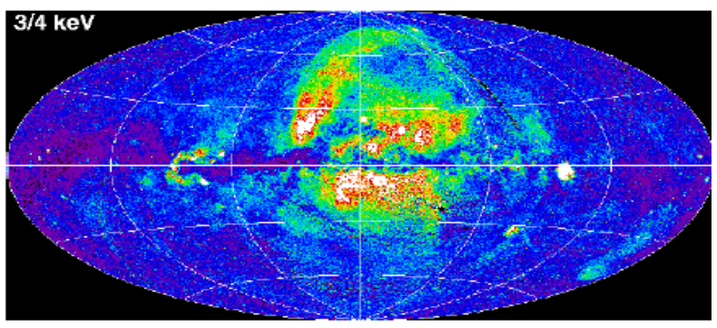
Abstract

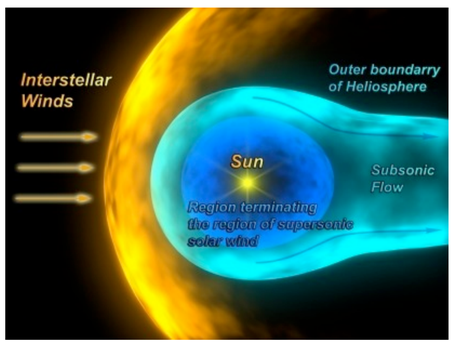
In X-ray astronomy, it is open question that existence of the soft X-ray emission that changed in a short term (few days order). From the research in recent years, this radiation generated by charge exchange process that occurred between the solar wind and the interstellar matter. But, it was difficult to identify that this emission was generated by charge exchange reaction from the problem of spectral resolution of ongoing X-ray astrophysics Satellites.Our group advance the experiment that aim to reveal mechanism of Solar-Wind Charge eXchange(SWCX) occurred in space using high resolution X-ray spectrometer TES X-ray micro-calorimeters and 14.25 GHz ECR(TMU-ECR) Ion source . Here, I present brief explanation of project overview and TES micro X-ray calorimeter , and I reports on the progress of experiments.

Our Purpose:
To reveal charge exchange mechanism between solar-wind ion and neutral matter of earth atmosphere using high energy resolution spectrometer TES micro-calorimeter.

1. Introduction ~Soft X-ray background~



RASS (ROSAT ALL SKY SARVY) 3/4 keV image[1].
Some structure at high latitude region except Galactic center is contribution of charge exchange mechanism.



Schematic view of Heliosphere from
http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=42898

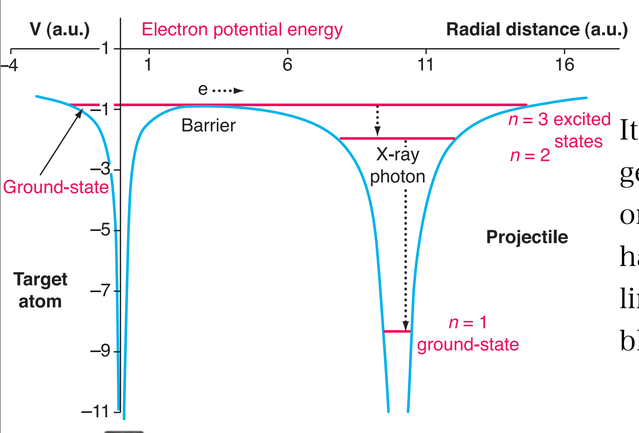
Large scale structure and mysterious time-variation of Soft X-ray emission
↓
Correlation of solar-wind flux
Discovery of X-ray emission from comet[3]
→ charge exchange process
Evidence of charge exchange reaction earth atmosphere[2]

Possibility of origin of this emission is charge exchange reaction occurred between the solar wind and the interstellar matter.

Charge exchange process

~unique tool for diagnosis thin atmosphere~

Interaction between highly Ionized Ion (A^{q+}) and neutral atomic (B). The Ion rob electron from atoms, and electron capture excited state of Ion. When electron transition from excited state to ground state, electron emit emission that has a same energy of gap .



$$A^{q+}+B \rightarrow A^{(q-1)+}+B^{+}+h\nu$$

It is clearly that charge exchange process generate line emission. But, X-ray spectrometers onboard current satellite such as CCD, grating has not enogh performance to separate between line from charge exchange reaction and thermal blems from high temperature plasma.

Research issue left for charge exchange process
How large cross section(intensity)?
How distribute several lines (line fine structure)?
How depend collisional velocity in universe (Solar wind, SNR)?

To solves above issue, it is essential to observe charge exchange process with high energy resolution spectrometer, and reproduce situation in space.

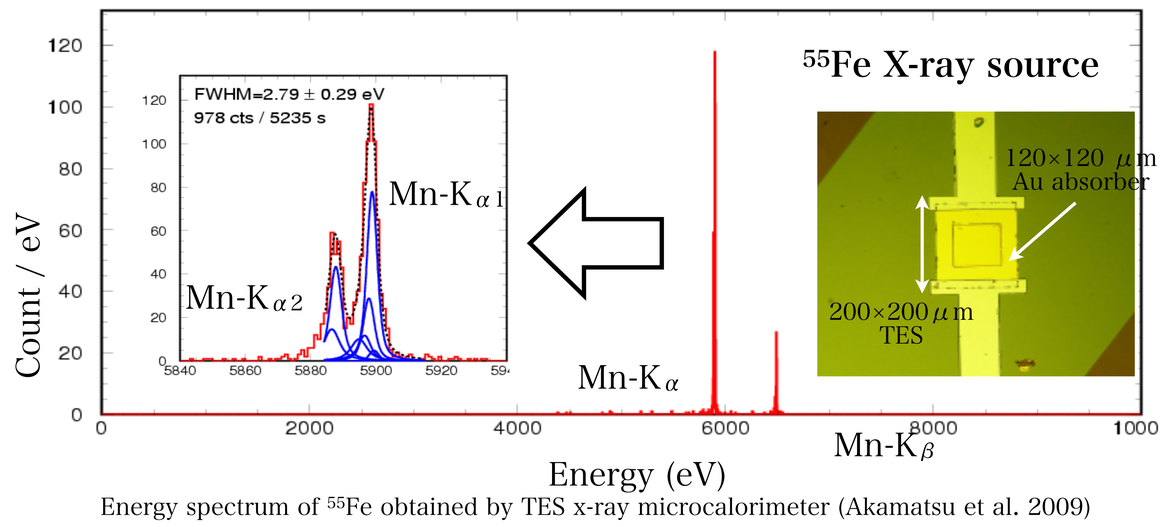
2. Transition Edge Sensor X-ray microcalorimeter

~ state of art High resolution X-ray spectrometer~

Microcalorimeter is an X-ray detector that absorbs the energy of the X-ray photon with the absorber, and produces signals by the temperature rise. The energy resolution of microcalorimeter depends on temperature T, thermal capacity C and the temperature sensitivity α of the thermometer as shown above. Microcalorimeter can achieve excellent performance at an extremely low temperature below 100 mK. Using TES for the thermometer, it is possible to achieve the energy resolution of 1 eV at 5.9 keV.
We produced TES calorimeters by in-house process. Our TES consists of Ti/Au thin film to control transition temperature through proximity effect. The device is shown here, which consists of TES with size of 200 ×200 × 0.135 μm³.
Our TES calorimeter shows good energy resolution as ΔE = 2.8 eV @ 5.9 keV.

$$\Delta E_{\mathrm{FWHM}} = 2\sqrt{2\ln 2}\cdot\sqrt{k T^2 C / \alpha_{eff}} \qquad \alpha_{eff} = \alpha/(1+\beta)$$

$$\alpha = \frac{\partial \ln R}{\partial \ln T} \qquad \beta = \frac{\partial \ln R}{\partial \ln I}$$

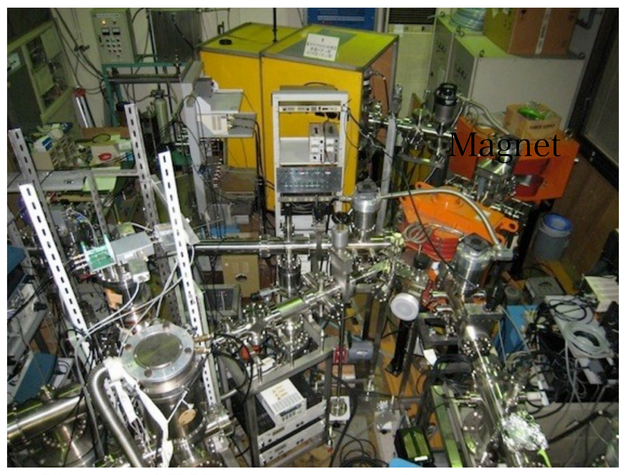


Energy spectrum of ^{55}Fe obtained by TES x-ray microcalorimeter (Akamatsu et al. 2009)

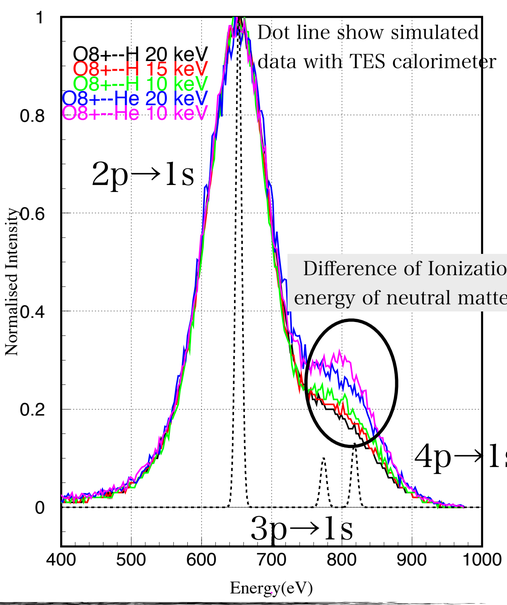
4. TMU-ECR+TES calorimeter ~Expected scientific result~

We plan to measure charge exchange process, which occurred between neutral hydrogen in the earth atmosphere and highly ionized oxygens in the solar wind, on the ground. The charge exchange reaction is achieved by the ECR(Electron Synchrotron Resonance) ion source with a multivalent heavy ion collision device. The picture of collision device (include ion source) and the spectrum obtained semiconductor X-ray detector (~ ΔE=110 eV) .

ECR Ion source



Picture of ECR ion source and



Summary of Highlights

Charge exchange process is a very important for X-ray astrophysics and key to solve soft x-ray background.
TES calorimeter is a state of art x-ray spectrometer which offer good energy resolution(2.8 eV @ 5.9 keV)
TMU-ECR+Heavy Ion collision device can generate charge exchange process same condition in space.

Combining TMU-ECR+TES calorimeter, we can reveal charge exchange mechanism between solar-wind ion and neutral matter of earth atmosphere.

Reference

[1] Snowden et al., 1998, Apj, 610, 1182
[2] R. Fujimoto et al., 2007, PASJ, 59, S133
[3] Cravens et al., 2002, Science, 296, 1042
[4]Akamatsu et al., 2009, AIP,
[5]Shinozaki et al., 2009, SPIE,