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

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I would like to discuss about the current status of laboratory astrophysics and future X-ray missions such as Astro-H, IXO etc...

My whole dream is to make X-ray laboratory astrophysics system in Japan. So, I would like to study about what is demanded from future missions.

Abstract

In X-ray astronomy, it is still a question that the soft X-ray diffuse emission shows variations in short time scales (a few days order). Recent research indicated that this radiation is generated by charge exchange process caused by the solar wind interacting with the interplanetary matter (SWCX: Solar-Wind Charge eXchange). However, firm identification of this emission requires high spectral resolution which can separate resonance and forbidden lines from ionized oxygen.

Our group is developing an experimental system to reveal the SWCX mechanism using TES X-ray microcalorimeters with high spectral resolution combined with a 14.25 GHz ECR Ion Source (TMU-ECRIS). Here, I present brief description of this experiment and its current status.

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Our Purpose:

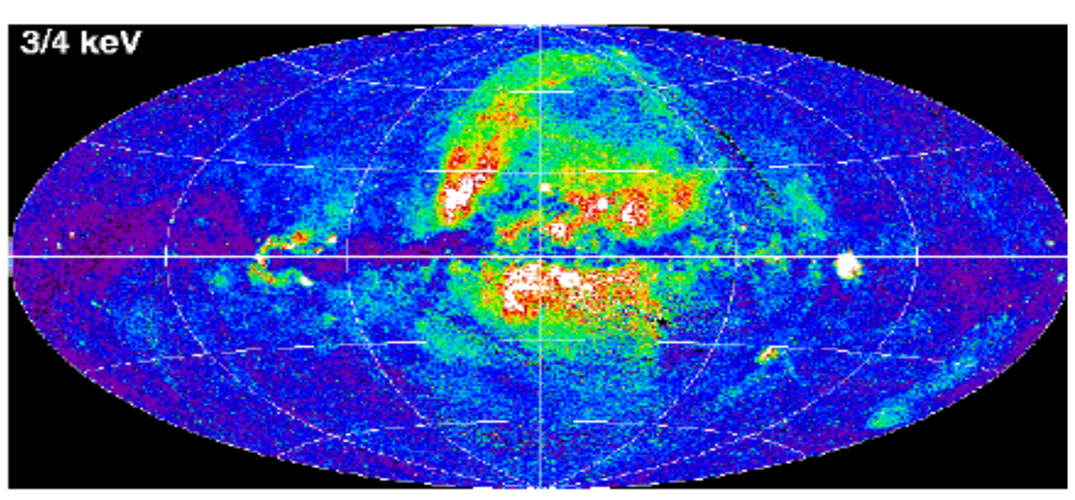
To understand and model the Solar Wind Charge eXchange process, we will measure line distribution and cross section of the SWCX process with TES X-ray microcalorimeter and TMU-ECRIS.

1. Introduction

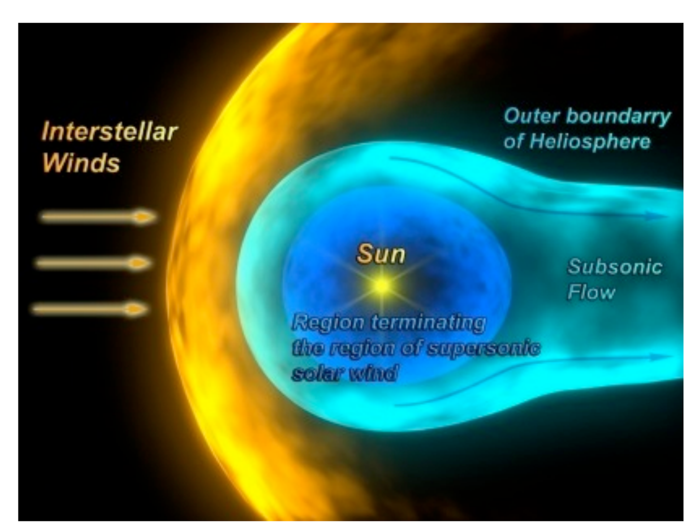
~Soft X-ray background and Solar Wind Charge eXchange(SWCX)~

The diffuse soft X-ray background shows time variations in a few days and also in years[1]. ROSAT observation of Hyakutake comet detected significant X-ray emission[2].

In the Chandra era, many comets show X-ray emission. The mechanism for the comet and the diffuse X-ray emission is considered the charge exchange (CX) process between the highly ionized solar wind and the neutral atoms (molecules) in the earth neighborhood and around comets.



RASS (ROSAT ALL SKY SARVY) 3/4 keV image[1]. Some structure at high latitude region considered due to charge exchange process.



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

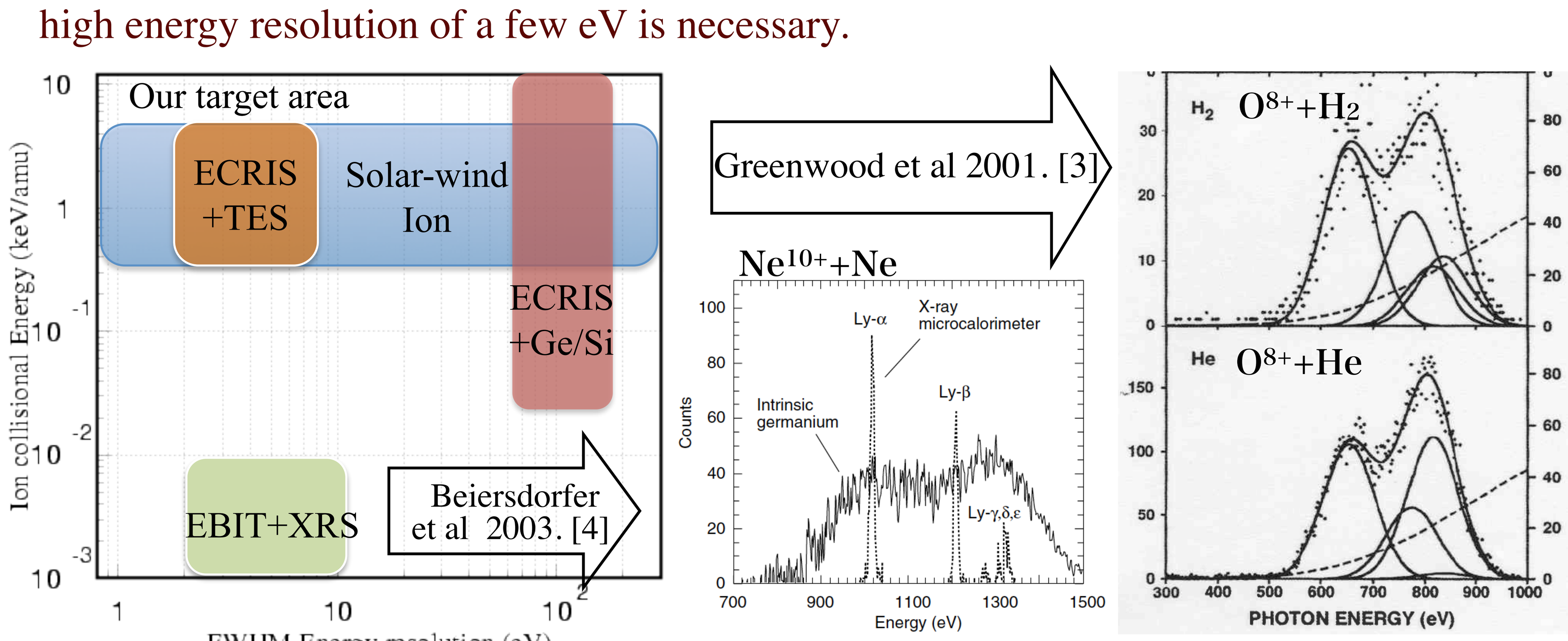
Charge exchange process: $A^{q+} + B \rightarrow A^{(q-1)+} + B^{+} + h\nu$

Interaction between highly ionized ion (A^{q+}) and neutral atom (B). An electron is transferred from atom to ion, and goes into a highly excited level. When the electron make transition to lower levels, the ion emits X-ray lines with the energy corresponding to the level difference.

2. Previous works and our purpose

~Necessity of new data for the CX process ~

To understand and model the SWCX mechanism, we need reliable data about the line distribution and the cross section of this process. In the figures below, there is no data with a good energy resolution for the same collision energy as the solar wind. The collision energy of the solar wind is around 1 keV. To separate individual lines from different states, high energy resolution of a few eV is necessary.



Conditions of current laboratory measurements and some results related with the SWCX.

Issues about the charge exchange process

How much is the cross section?

How do lines from different levels distribute?

How does the line emission depends on collision energy?

3. Our experimental system

~High resolution spectrometer + ECRIS (Electron Cyclotron Resonance Ion Source)~

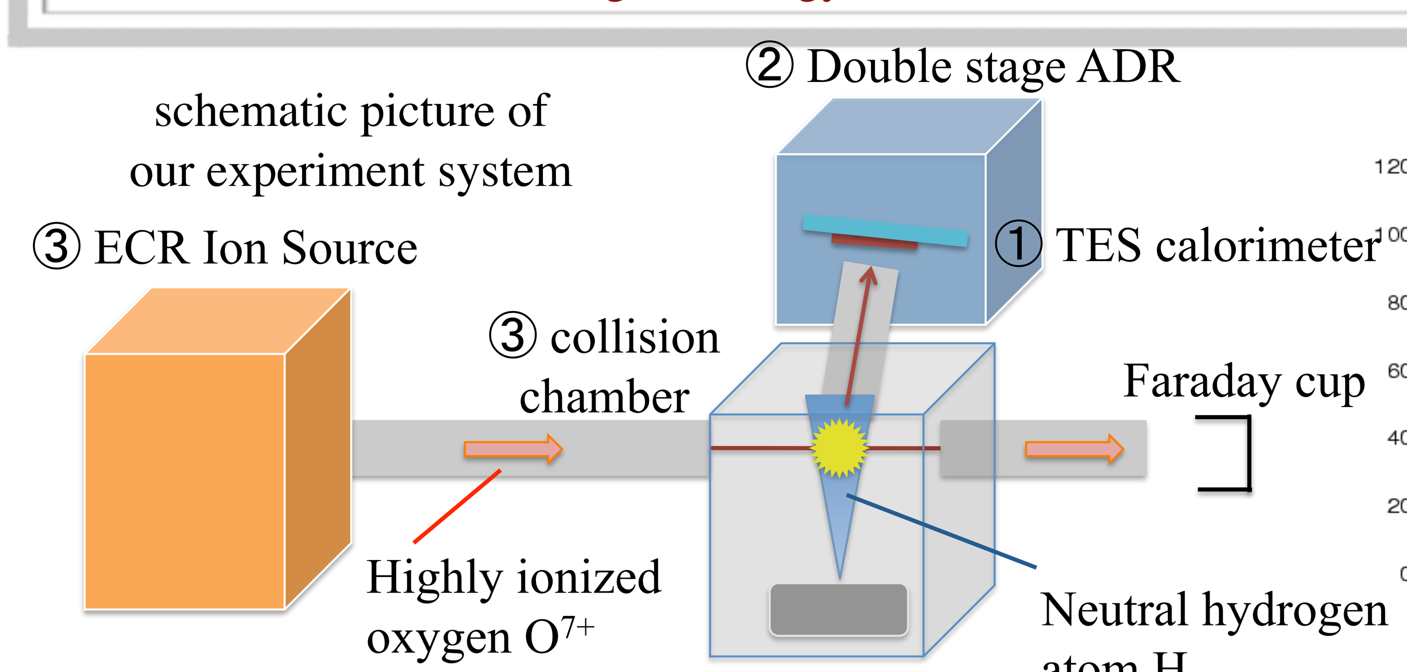
We plan to simulate the CX process between the neutral hydrogen in the earth atmosphere and the highly ionized oxygen in the solar wind, and measure the X-ray emission using a high resolution TES X-ray microcalorimeter.

The CX process is generated by ECRIS with a multiply heavy ion collision system.

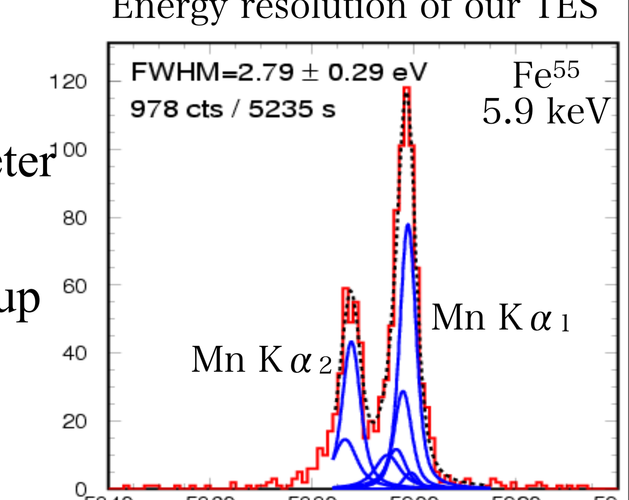
TES (Transition Edge Sensor) X-ray microcalorimeter

Microcalorimeter is an X-ray detector that absorbs X-ray energy with the absorber, and produces signals by the temperature rise. Microcalorimeter shows excellent performance at an extremely low temperature below 100 mK. TES calorimeters achieve the energy resolution of 1 eV. We produced TES calorimeters through in-house processes.

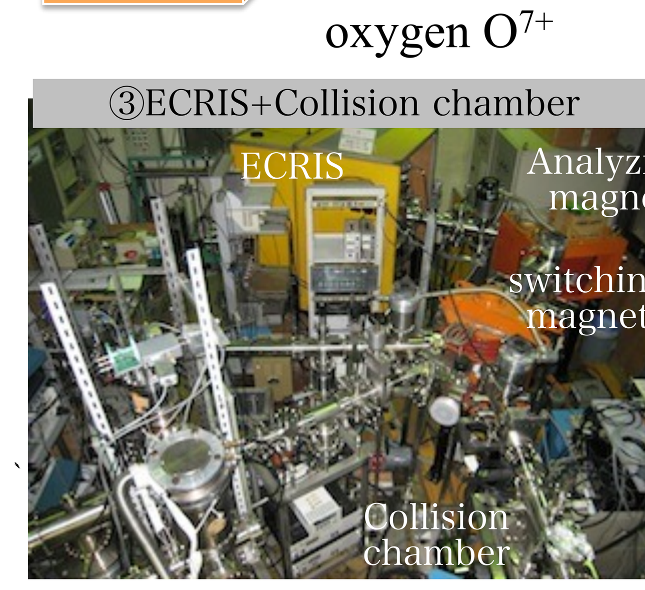
Our TES calorimeter shows good energy resolution of ΔE = 2.8 eV @ 5.9 keV [5].



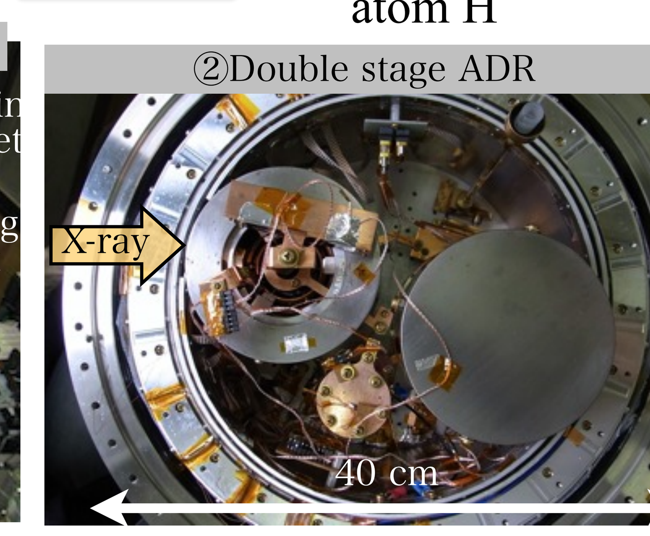
Energy resolution of our TES



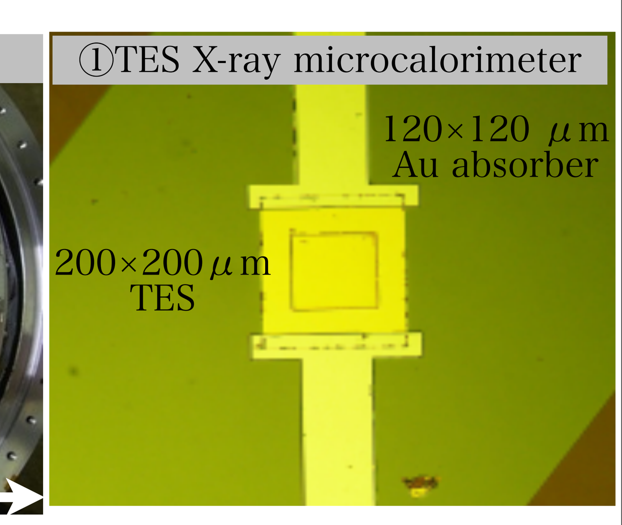
③ECRIS+Collision chamber



②Double stage ADR



①TES X-ray microcalorimeter



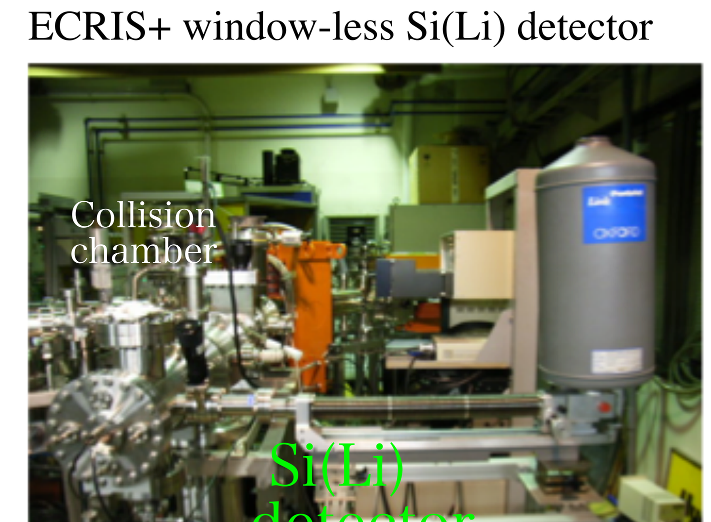
4. Preliminary measurement

~ECRIS + Si(Li) and future TES calorimeter~

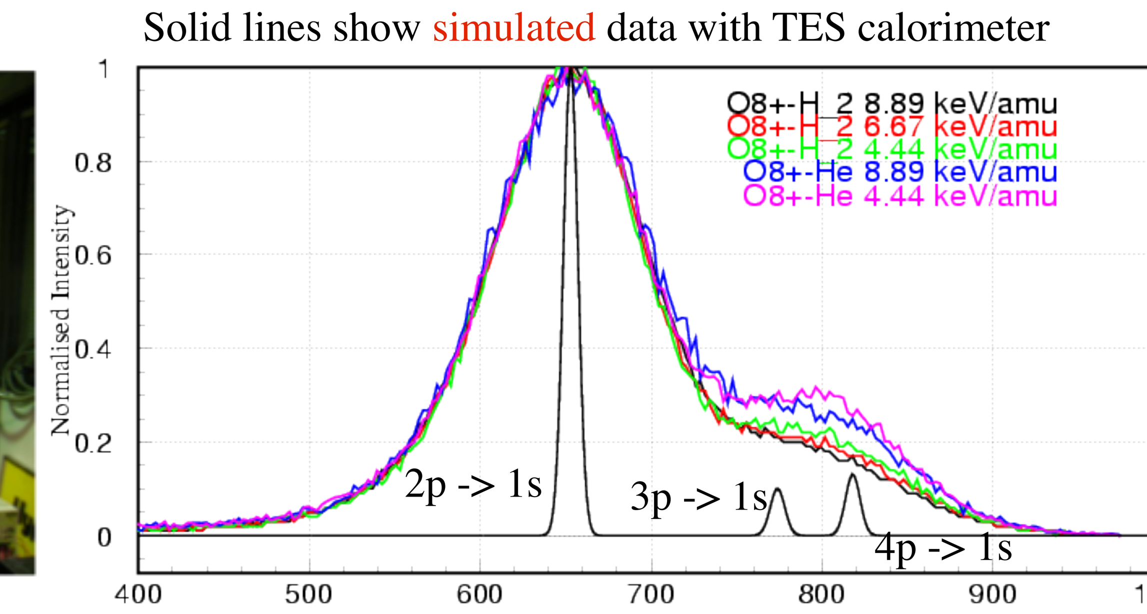
We measured X-rays from the collision of O^{7+} and O^{8+} ions with neutral He or Hydrogen molecule using a window-less Si(Li) detector. The detector shows an energy resolution of 107 eV @ 1 keV. As shown in the figure below, we confirmed emission lines from 2p, 3p, and 4p to 1s transitions of O^{7+}. We analyzed the spectrum by fixing the peak energy of each line using the NIST database and the energy resolution to be 107 eV. The results indicate some difference from the previous work (Greenwood et al. 2001), regarding the intensity ratio of the lines. This might be caused by the correction of X-ray window transmission (Tanuma et al. in prep).

To examine this difference, a new high-resolution measurement will be important.

ECRIS+ window-less Si(Li) detector



Solid lines show simulated data with TES calorimeter



Reference

[1] Snowden et al., 1998, ApJ, 610, 1182
[2] Glanz, 1996, Science, 272,196
[3] Greenwood et al. 2001, PhysRevA,63,062707
[4] Beiersdorfer et al, 2003, Science, 300,5625
[5] Akamatsu et al. 2009, AIPC, 1185, 195

Summary and prospects

CX process is important and key mechanism to solve the nature of the soft X-ray diffuse background.

TES calorimeter is a state-of-the-art X-ray spectrometer with good energy resolution (2.8 eV @ 5.9 keV).

TMU-ECRIS+Heavy Ion collision system generates CX process with the same condition in space.

Combining TMU-ECRIS with TES calorimeter, we can examine CX mechanism between solar-wind ions and neutral matter of earth atmosphere with high spectral resolution.