Solar Wind Charge eXchange in Laboratory

宇宙物理 + 原子物理
共同研究

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Practical formulae :

$$v = \sqrt{\frac{2E}{m}} = 1.389 \times 10^{4} \cdot \sqrt{\frac{E/\text{eV}}{m/\text{u}}} \quad \text{m/s}$$

v : ion velocity in m/s
E : ion kinetic energy in eV
m : ion mass in amu

$$n = \frac{P}{kT} = 7.243 \times 10^{16} \cdot \frac{P/\text{Pa}}{T/\text{K}} \quad \text{cm}^{-3}$$

n : gas number density in cm^{-3}
P : gas pressure in Pa
T : gas temperature in K

Initial velocity of the solar wind :

$v = 400 - 1000$ km/s

Corresponding ion energy :

H^+ (m = 1) : E = 0.83 – 5.18 keV

C^{q+} (m = 12) : E = 9.95 – 62.2 keV

O^{q+} (m = 16) : E = 13.3 – 82.9 keV

$q = 7$: V = 1.90 - 11.8 kV

Fe^{q+} (m = 56) : E = 46.4 – 290 keV

Attenuation of the incident ion beam intensity

$$I = I_0 \exp(-\sigma n l)$$

I : ion intensity/current
σ : cross section
n : number density of target gas
l : intersection length

$\sigma n l << 1$: single collision condition

$$I \approx I_0 (1 - \sigma n l)$$

$$\sigma \approx \frac{1}{nl}\left(1 - \frac{I}{I_0}\right)$$: cross section measurement

Growth rate of the product ion/electron/photon

$$i \approx I_0 \cdot \sigma n l$$

i : intensity of the collision product
σ : cross section
n : number density of target gas
l : intersection length

$\sigma n l << 1$: single collision condition

$$\sigma \approx \frac{i}{I_0 n l}$$: cross section measurement

$\sigma nl << 1$: single collision condition

σ : cross section
n : number density of target gas
l : intersection length

$$\sigma = 10^{-15} - 10^{-14}\ \mathrm{cm}^2$$

$$l \approx 1\ \mathrm{cm}$$

$$n << \frac{1}{\sigma l} = 10^{14} - 10^{15}\ \mathrm{cm}^{-3}$$

$n \sim 10^{13}\ \mathrm{cm}^{-3}$ は少し高すぎる ($P \sim 0.1$ Pa)

$n \sim 10^{12}\ \mathrm{cm}^{-3}$ が理想的 ($P \sim 10^{-2}$ Pa)

・水素原子源については継続検討中

熱解離型で 10^{10} cm^{-3} ？

・現状の装置によるテスト実験候補

O^{7+}/Ne^{9+} - CO_2

Ne^{10+}-Ne   Ne X : 1s-*n*p

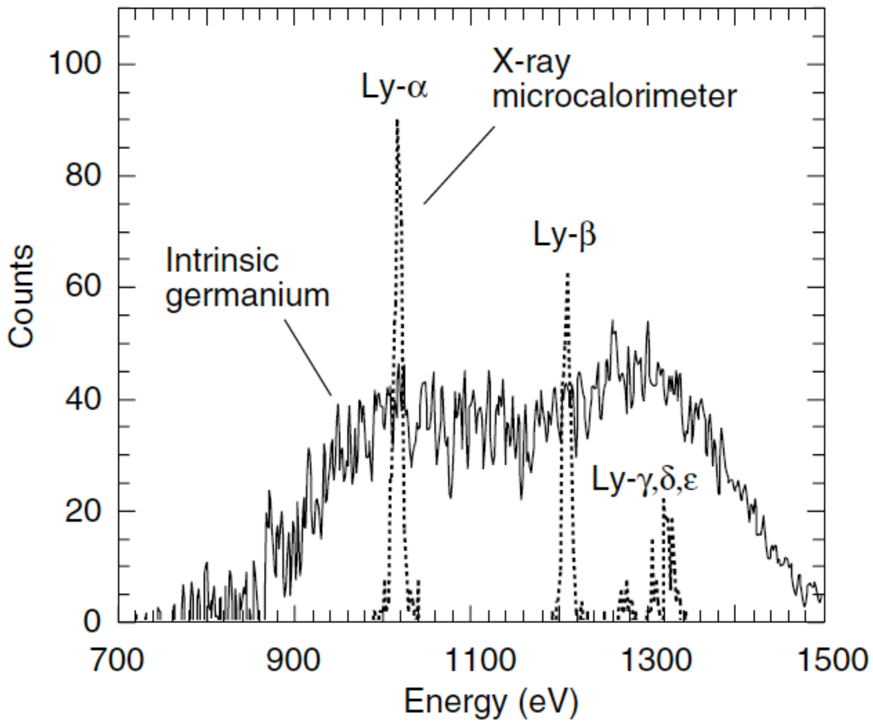


Fig. 1. X-ray emission of Ne^{9+} measured with high-purity Ge detector (solid trace) and with the X-ray microcalorimeter (dashed trace). The emission is produced in the interaction of Ne^{10+} ions with atomic neon. The collision energy is a few eV/amu.

EBIT : *E* = a few eV/u

LLNL

O VIII : 1s-*n*p

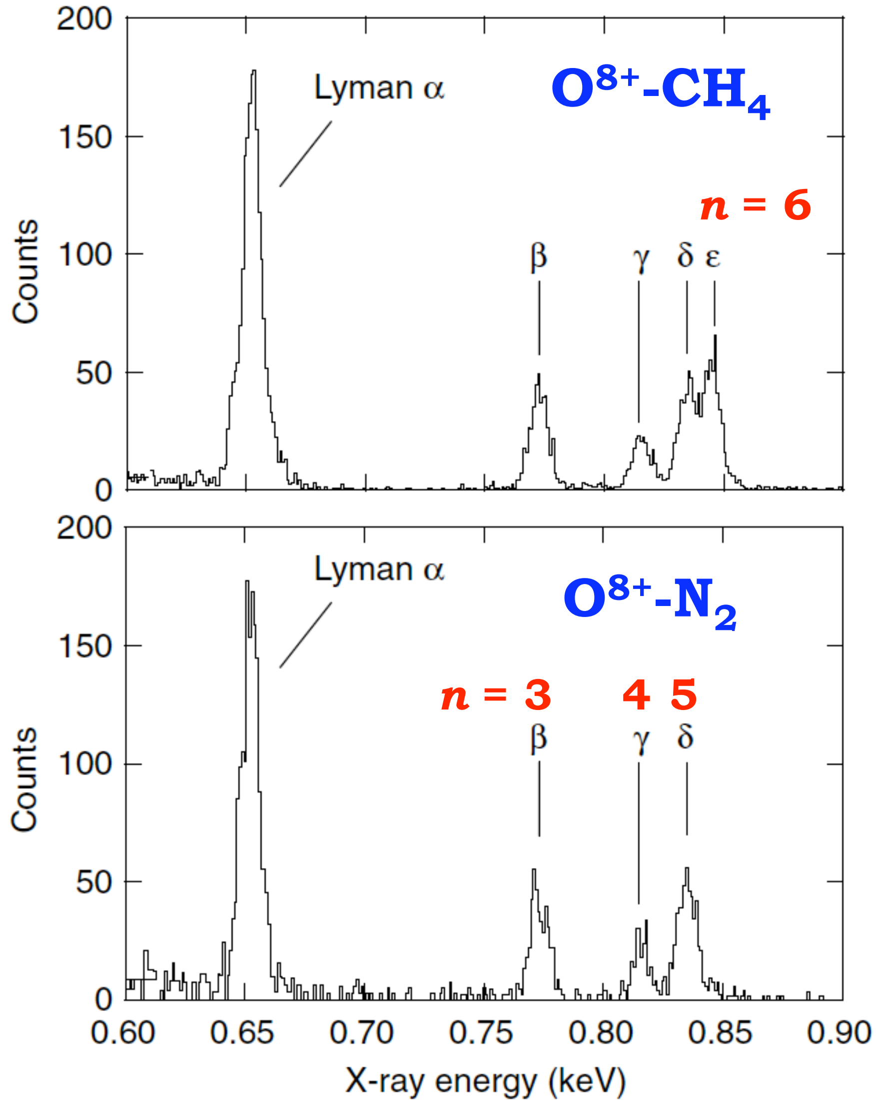
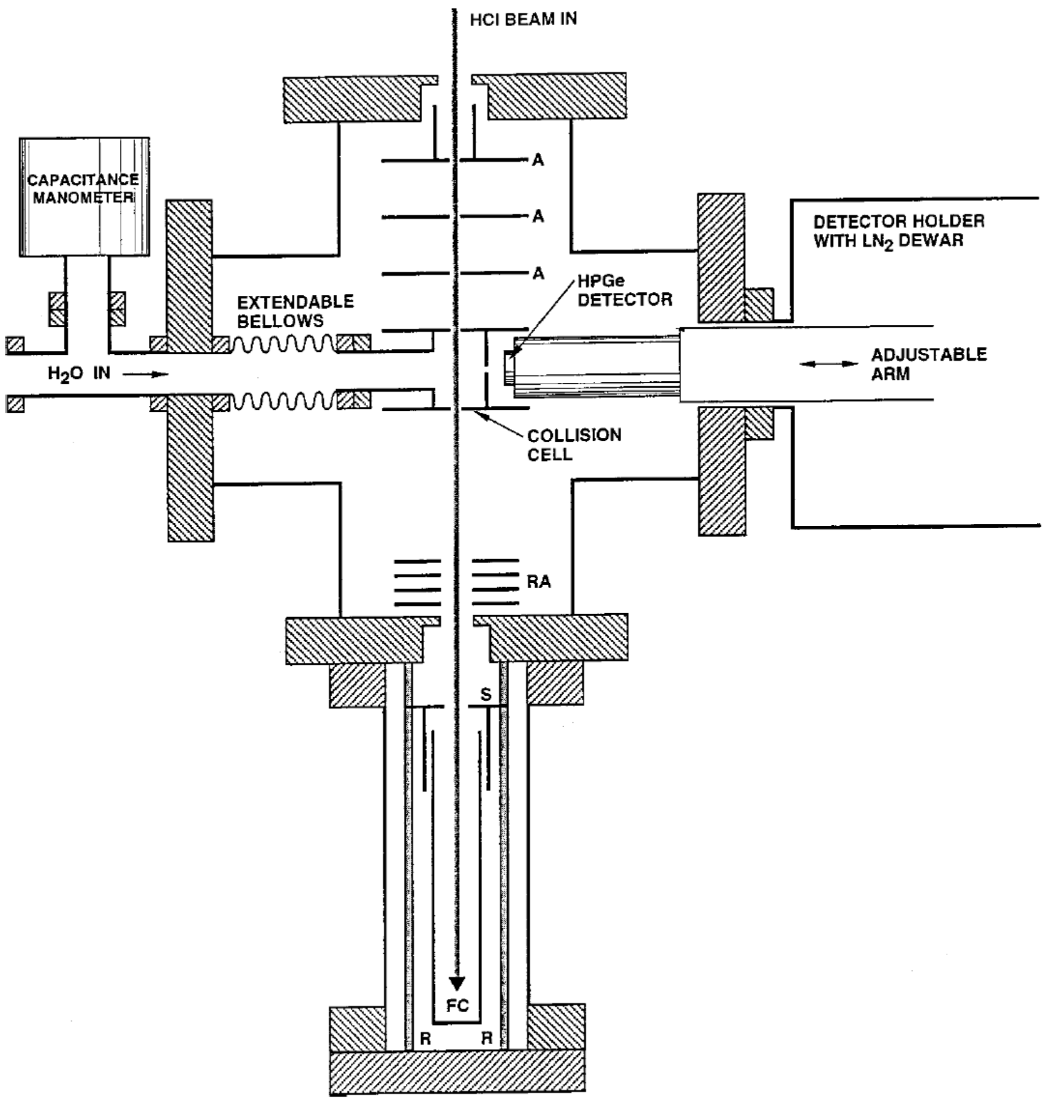
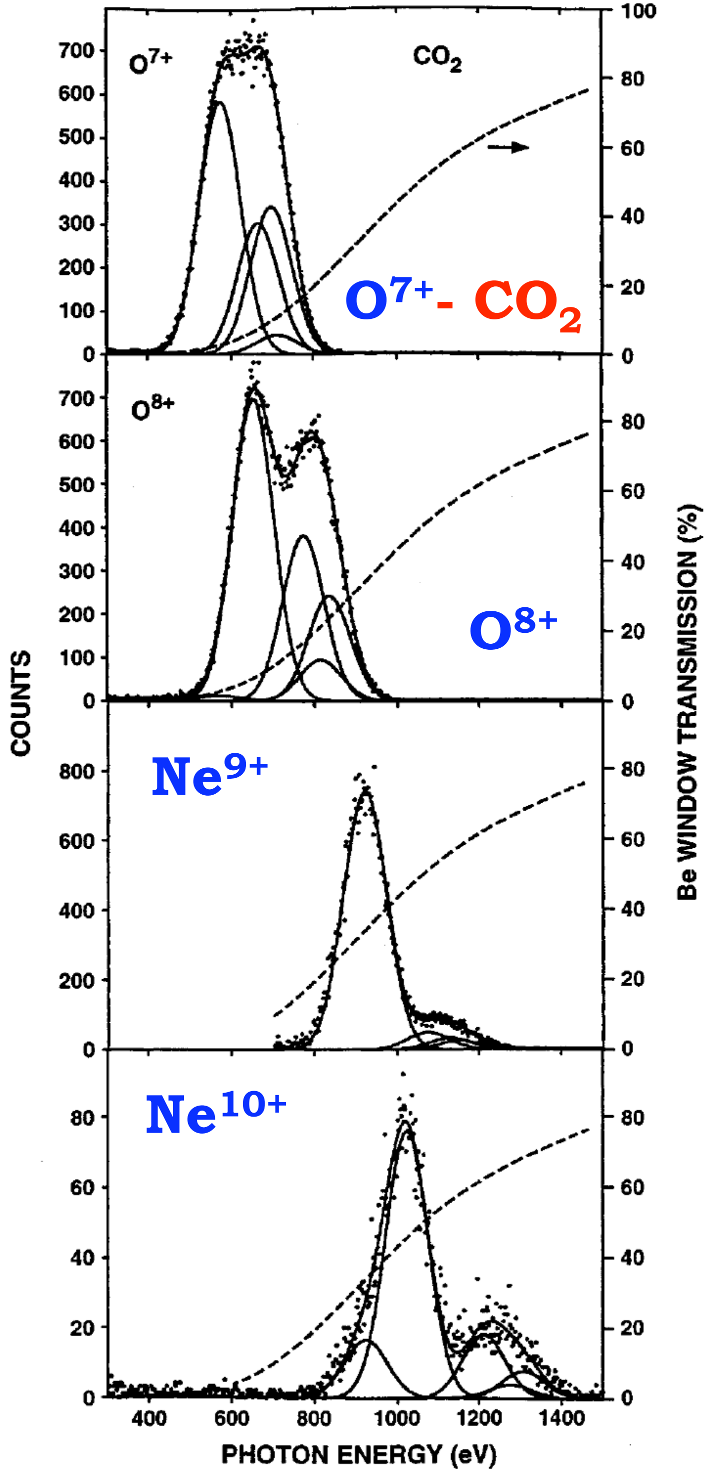


Fig. 2. K-shell emission of H-like O^{7+} produced by charge exchange with CH_4 (top) and N_2 (bottom). Note changes in the ratio of Lyman-δ emanating from $n = 5$ and Lyman-ϵ from $n = 6$.





(J. Greenwood *et al*., 2001)

JPL

LLNL　: EBIT + TES

→　衝突エネルギーが低すぎる

JPL　: ECRIS + Ge

→　エネルギー分解能が低い

TMU　: ECRIS + TES

→　最適な組み合わせ

= 実際の衝突エネルギー + 高分解能

∴　測定する価値あり