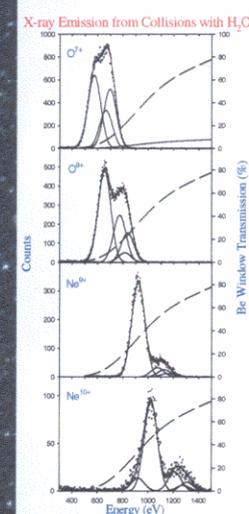
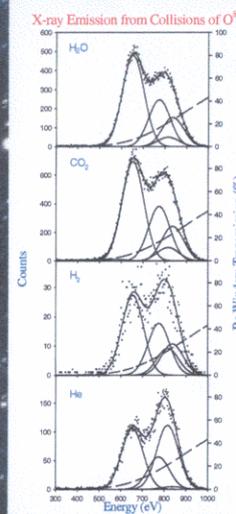
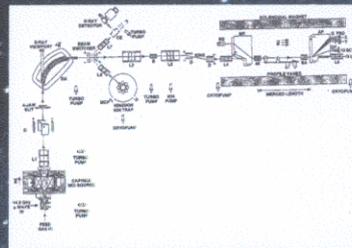
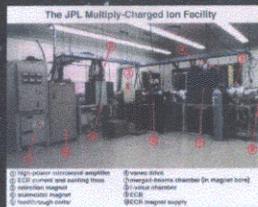
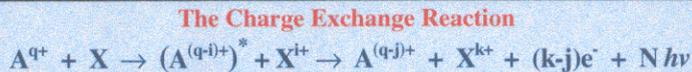


# X-ray Emission from Charge Exchange of HCIs in Atoms and Molecules

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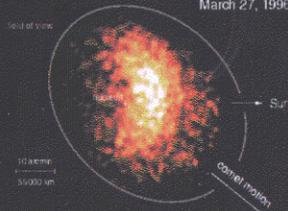
## X-ray Emission from Comets

First discovered from comet Hyakutake in 1996 by ROSAT X-ray satellite.  
All comets were subsequently found to be X-ray emitters!!

### FIRST X-RAY IMAGE OF A COMET

Comet Hyakutake · C/1996 B2 ROSAT HRI

March 27, 1996



C. Lisse, M. Mumma, NASA GSFC  
K. Dennerl, J. Schmitt, J. Englhauser, MPE

## Hale-Bopp



## Experiment

- Highly charged ions produced in an ECR ion source
- Mass to charge (m/q) selection by a 90° bending magnet
- Beam highly collimated by 0.5mm apertures
- Gas pressure in collision cell measured directly by a Baratron
- Ions scattered by less than 2° collected by a Faraday cup
- Product and primary ions separated by electrostatic reflection
- Pure Ge solid state X-ray detector with 7.5µm Be window
  - views collisions at 90°
  - has high collection and detection efficiency
  - has good resolution for a solid state device (~100eV)

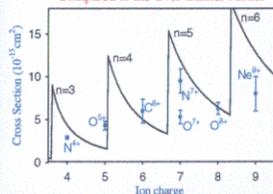
## The New High Resolution X-ray telescopes

XMM

Chandra



### Single Exchange Cross Sections in H<sub>2</sub>O Compared to the Over-Barrier Model



## Results

### Total Cross Sections

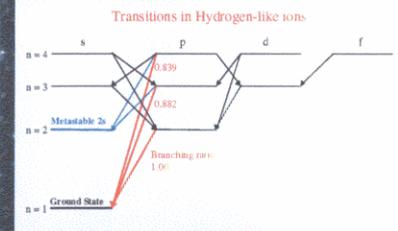
- Absolute results measured at collision energies of 7q keV
- Classical over-barrier model not reliable as capture occurs into more than one n-level
- Double exchange cross sections can be large
- Large contributions to exchange cross sections from autoionizing multiple capture

### X-ray Spectra

- H and He-like Lyman X-ray transitions (np → 1s) are observed
- Metastable 2s level weakly populated (< 5%)
- Intensities show initial population of l-levels is not statistical - s, p and d orbitals preferred
- Radiative stabilisation following double capture observed in Ne<sup>10+</sup> + X → Ne<sup>8+</sup> (2p → 1s)

### Publications

- Greenwood et al., Ap. J., 529, 605 (2000)
- Greenwood et al., Ap. J., 533, L175 (2000)



## Interaction of the Solar Wind with Solar System Gases

- Solar Wind
  - Consists of small amounts (~0.1%) of C, N, O, Ne, Si, Mg, Fe in highly charged states
  - Velocities of < 200 to 800 km s<sup>-1</sup> (100 - 3000 eV/amu)
- Interacts with gases in the solar system
  - Planetary atmospheres, cometary atmospheres (H<sub>2</sub>O, CO<sub>2</sub>, CO, etc.), interstellar gas at the heliopause (H, He)
- Charge exchange cross sections are large (10<sup>-15</sup> - 10<sup>-14</sup> cm<sup>2</sup>) → dominant atomic process
- Charge exchange believed to contribute to X-rays from
  - Comets, Lisse et al., Science, 274, 205 (1996), Lisse et al., Icarus 141, 316 (1999)
  - Background radiation, Cravens Ap. J., 532, L153 (2000)
  - Jovian Aurora, Cravens et al., J. Geophys. Res., 100, 17153 (1995)

## Acknowledgements

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Hyakutake