Probing the Dependence of Charge Exchange on Solar Wind Velocity with Laboratory Experiments

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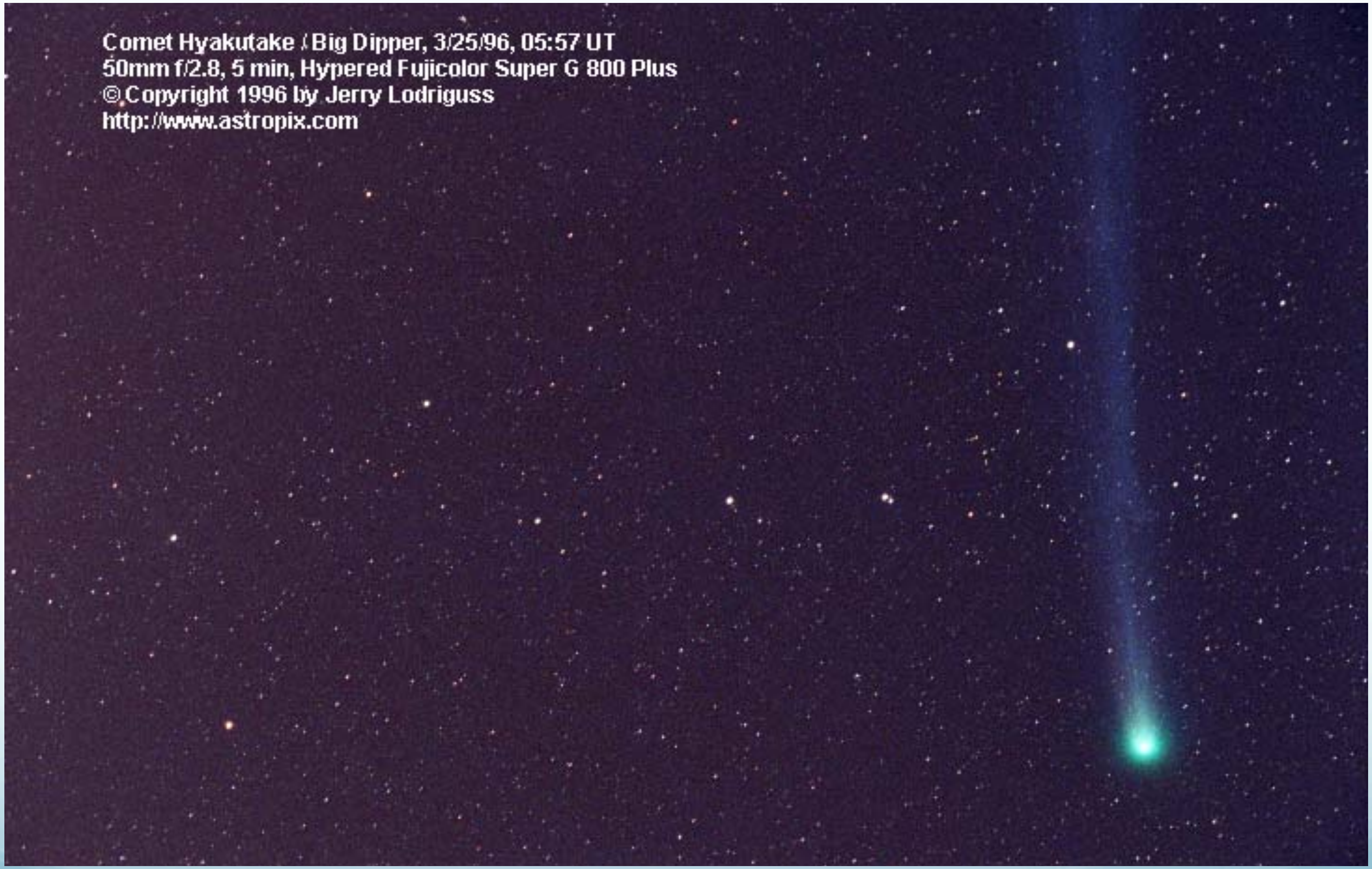
TERPS conference 2012

The Story of Hyakutake: How We Know That Comets Produce X-rays



Comet Hyakutake (with the Big Dipper) as seen from Chatsworth, New Jersey

The Story of Hyakutake: How We Know That Comets Produce X-rays

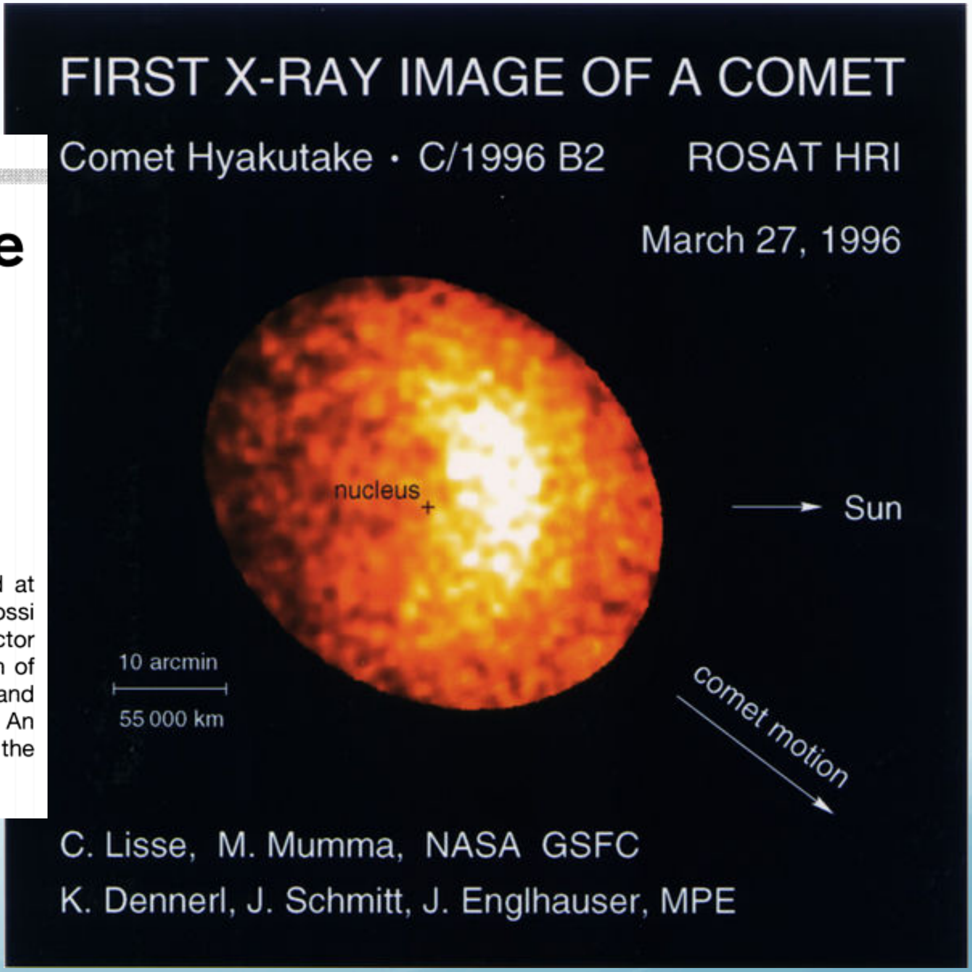
RESEARCH ARTICLES

Discovery of X-ray and Extreme Ultraviolet Emission from Comet C/Hyakutake 1996 B2

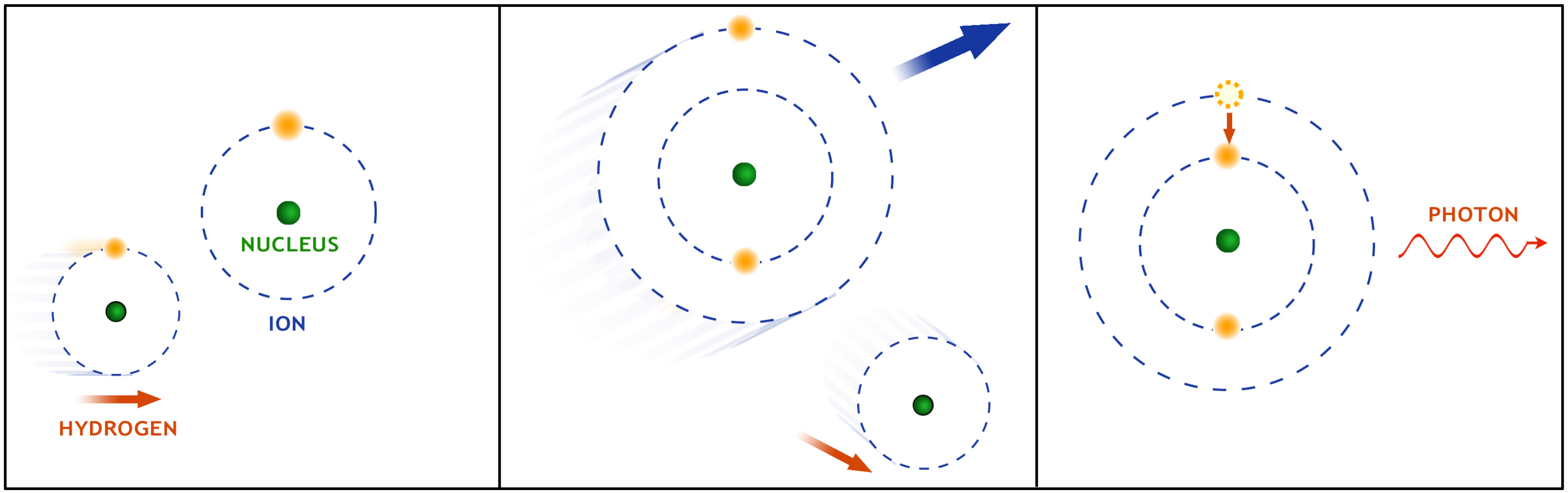
C. M. Lisse, K. Dennerl, J. Englhauser, M. Harden, F. E. Marshall, M. J. Mumma, R. Petre, J. P. Pye, M. J. Ricketts, J. Schmitt, J. Trümper, R. G. West

During its close approach to Earth, comet C/Hyakutake 1996 B2 was observed at extreme ultraviolet and x-ray wavelengths with the Röntgen X-ray Satellite and Rossi X-ray Timing Explorer. The emission morphology was symmetric with respect to a vector from the comet's nucleus toward the sun, but not symmetric around the direction of motion of the comet with respect to interplanetary dust. A slowly varying emission and a large impulsive event that varied on time scales of 1 to 2 hours were observed. An interaction between the comet and the solar wind/solar magnetic field seems to be the most likely mechanism for the observed emission.

Science, 11 October 1996



Final Consensus on Emission Mechanism: Charge Exchange



1. Ion approaches neutral target
2. Ion captures electron(s) from neutral atom into excited state(s)
3. Electron decays down, emits X-ray(s)

Final Consensus on Emission Mechanism: Charge Exchange

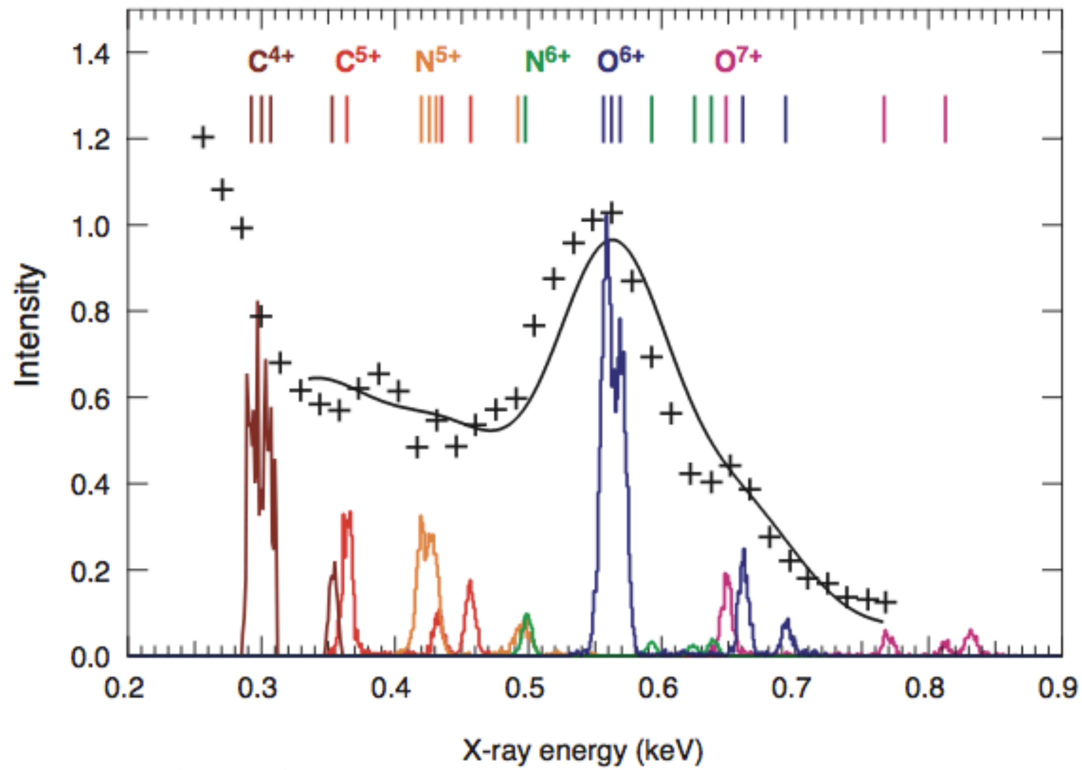
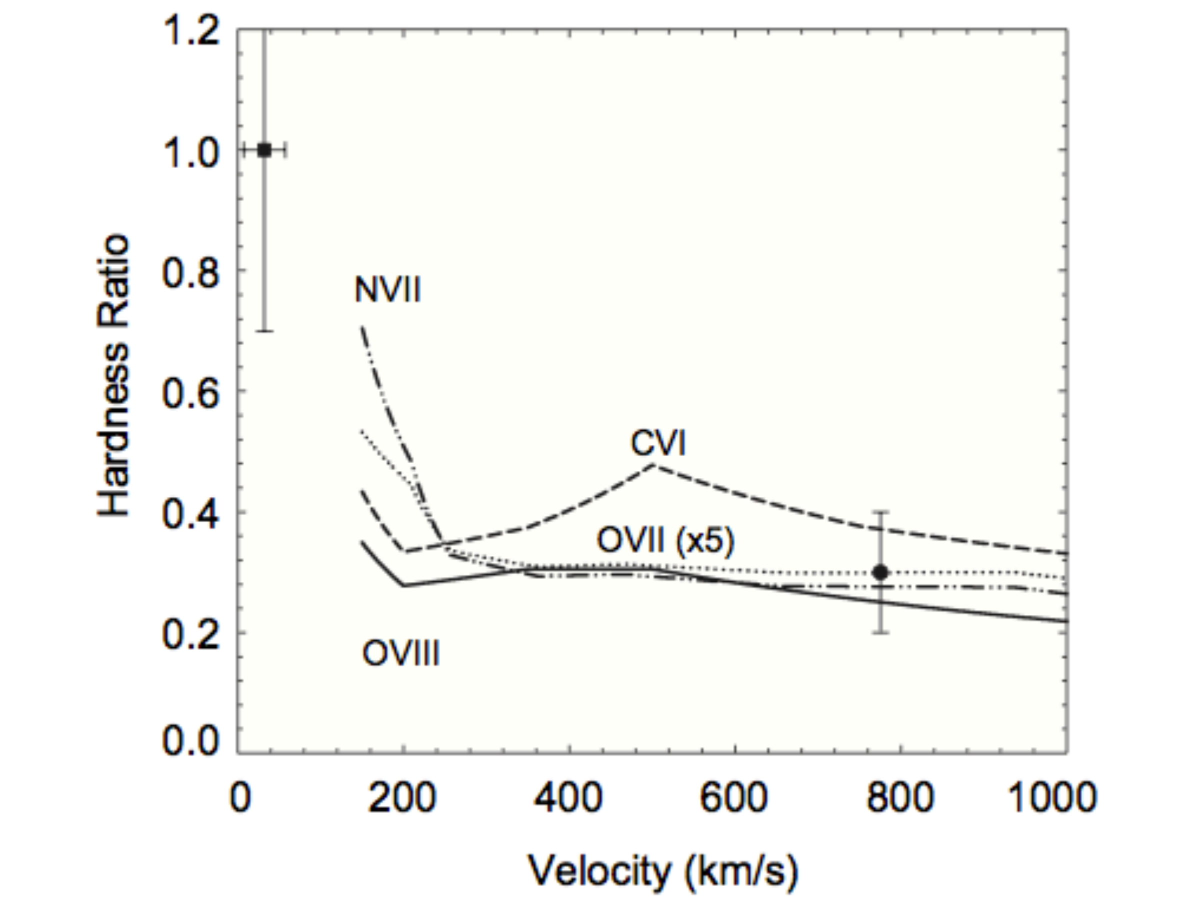


Fig. 3. X-ray intensity versus photon energy. Crosses denote the measurement of the soft x-ray spectrum of comet Linear C/1999 S4 obtained on 14 July 2000 by the Chandra X-ray Observatory ACIS-S instrument. The solid line indicates the best fit using the charge exchange–induced x-ray emission from hydrogen-like C^{5+}, N^{6+}, and O^{7+} and helium-like C^{4+}, N^{5+}, and O^{6+} after the interaction with CO_2 (color traces) recorded with the ASTRO-E microcalorimeter on the Livermore EBIT-I electron beam ion trap.

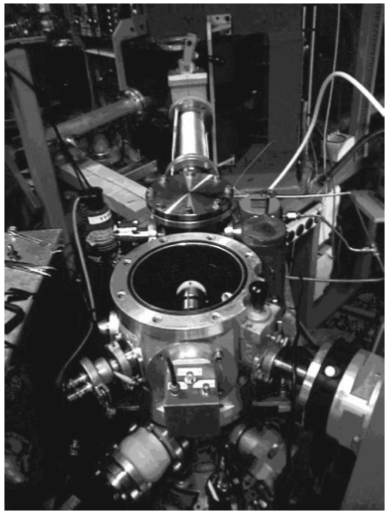
Experimental charge exchange data convolved with the instrumental function produces an excellent fit to Chandra observations.

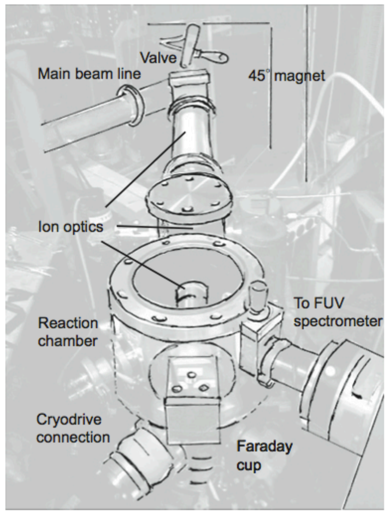
Charge Exchange Depends on Solar Wind Velocity – but how?



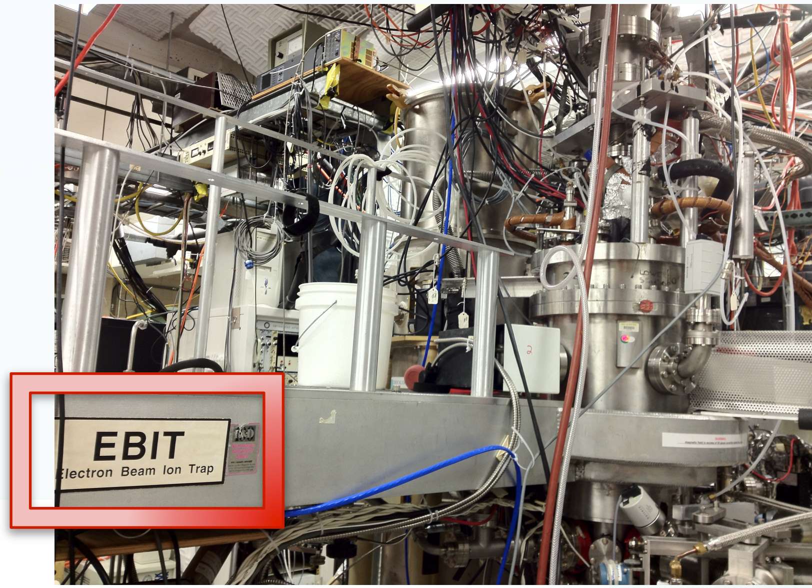
Model of velocity dependence of hardness ratio, with two experimental data points

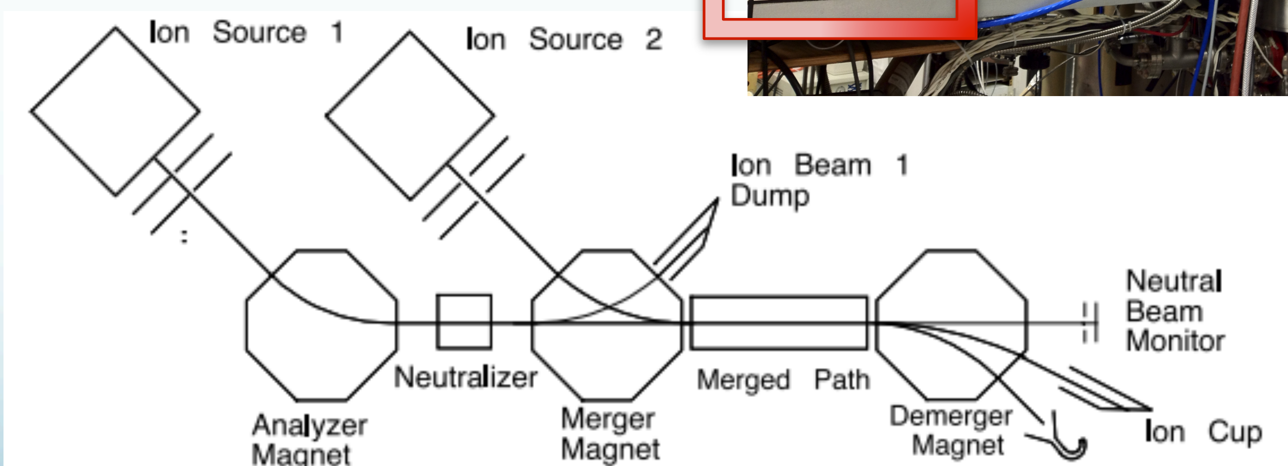
Laboratory data can help





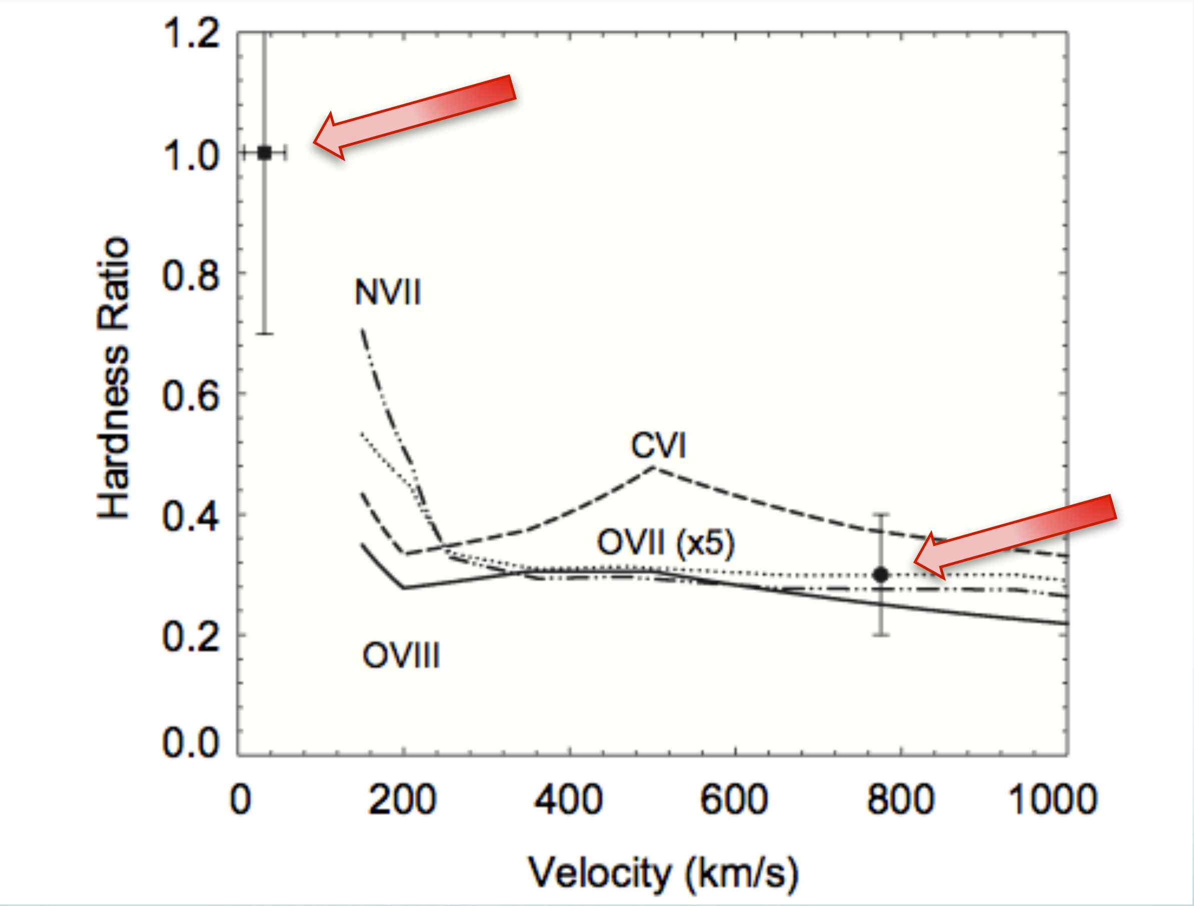
Crossed Beam





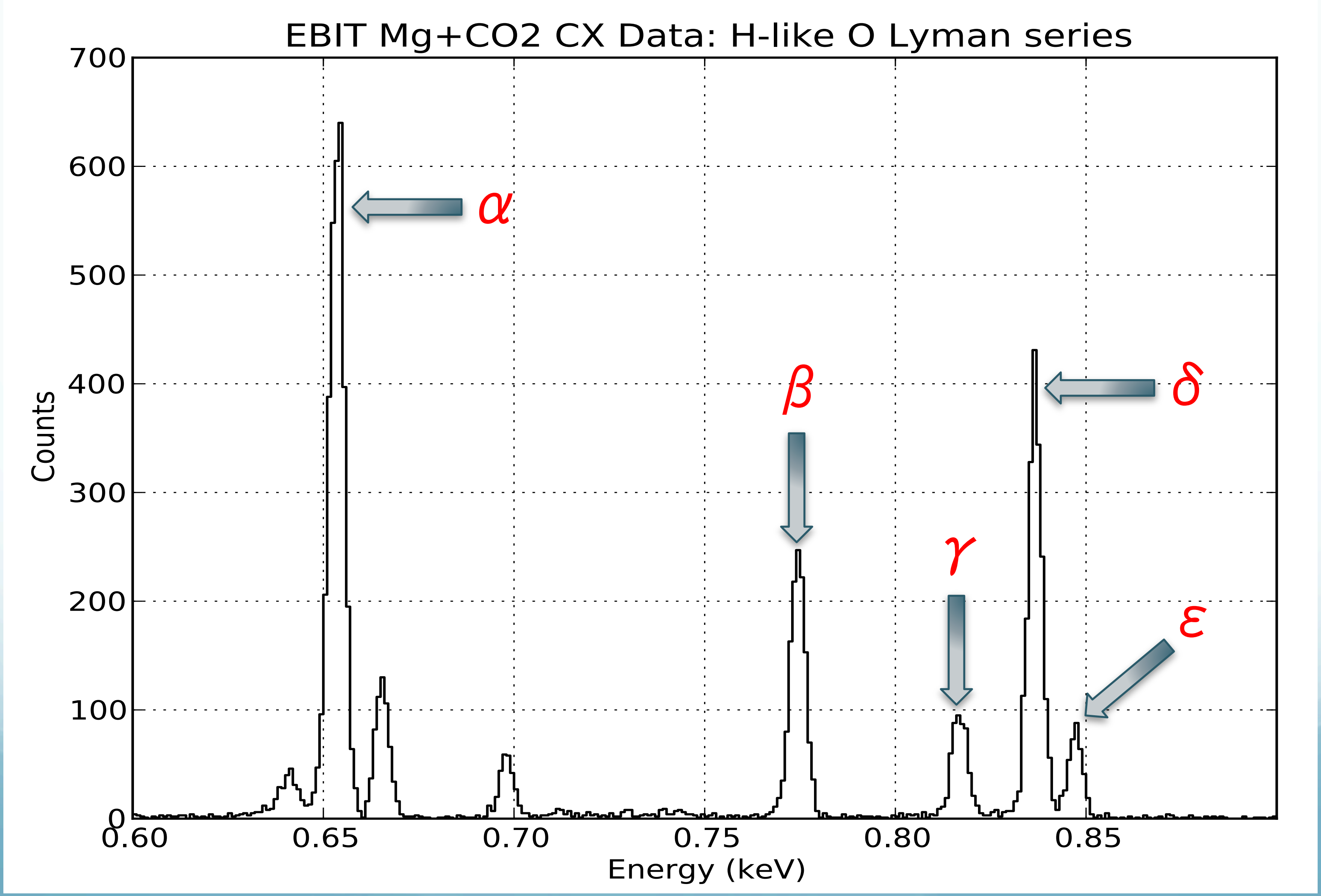
(a) **Merged Ion and Atom Beams**

EBIT data can help

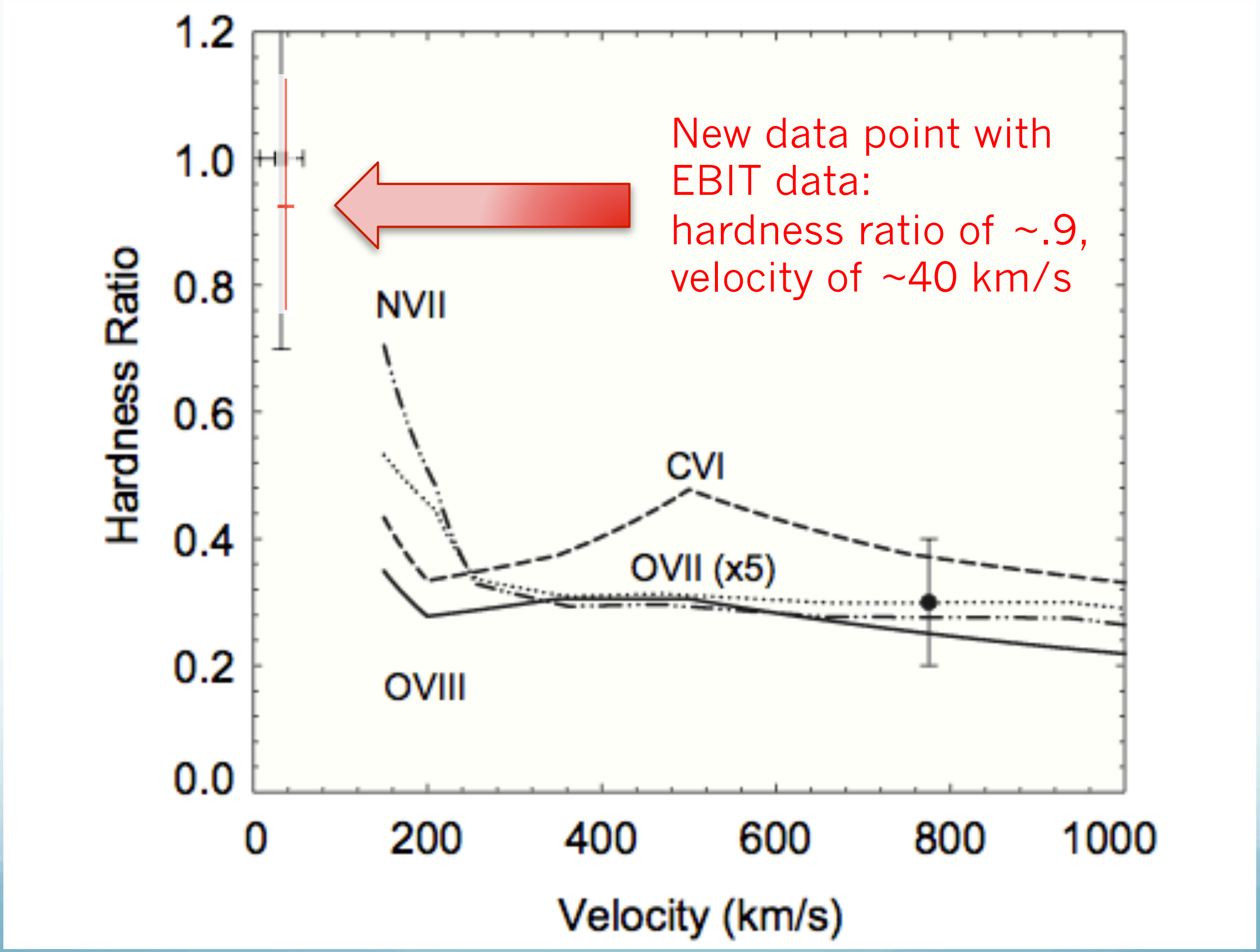


I will add another data point to this graph using EBIT charge exchange data.

EBIT data can help



EBIT data can help



Conclusions

- Comets produce X-rays!
- Charge exchange is the main emission mechanism
- Charge exchange cross sections depend heavily on collision velocity
- We can recreate charge exchange reactions between various species at different velocities using accelerators already in place across the globe
- In this way, we can better understand the charge exchange dependence on velocity in all relevant regimes

Questions?