# Atomic data needs for high resolution X-ray astronomy

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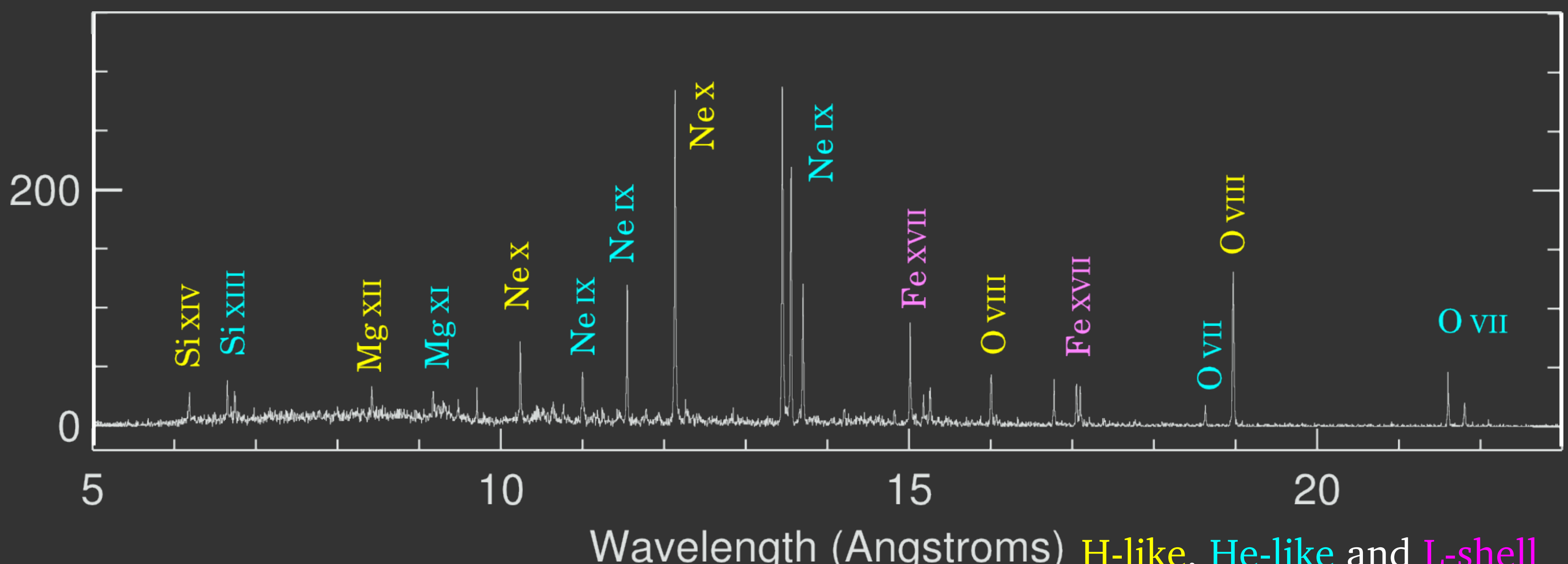
# Definitions

| **"High Resolution"** | **X-ray** |
|---|---|
| $\Delta E = 5\text{eV}$ | $0.3 < E < 50$ (keV) |
| $E/\Delta E \sim 1000.0$ | (no molecules) |




H-like, He-like and L-shell

# Upcoming Missions: Astro-H (2016)

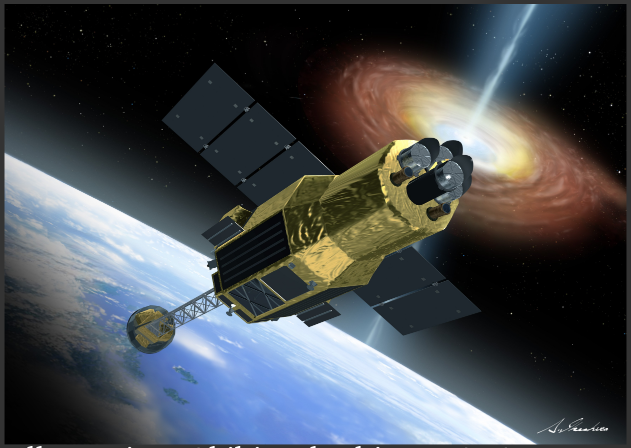
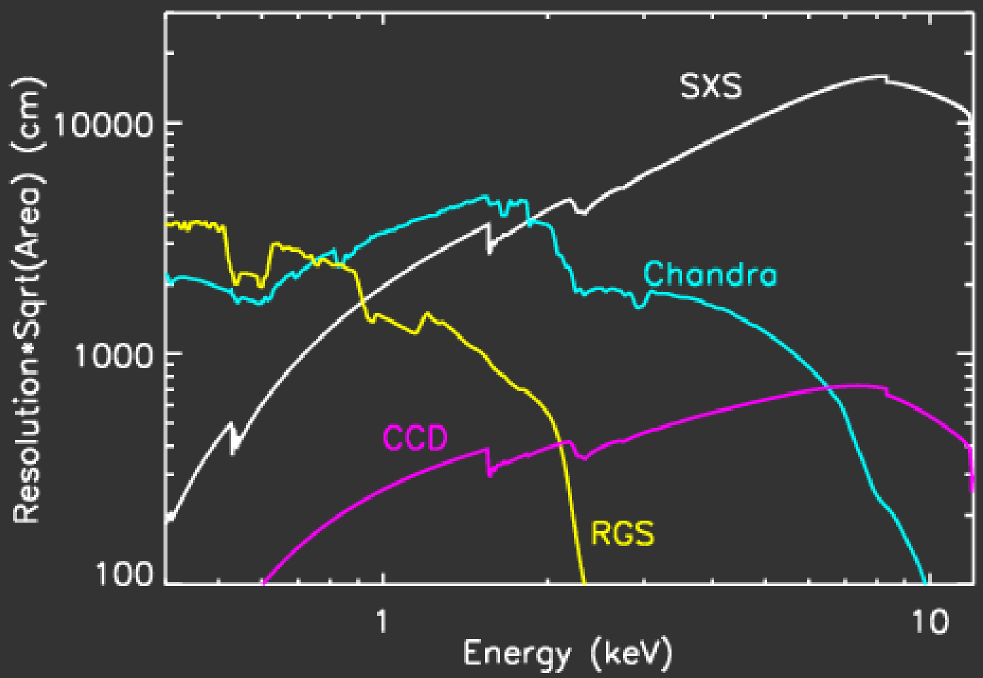
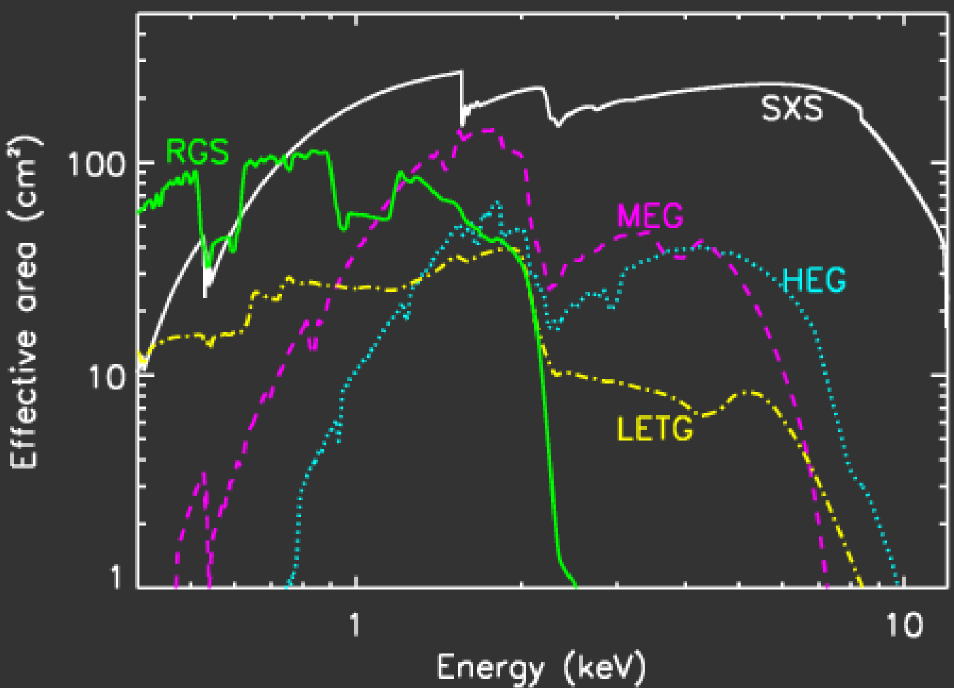


Illustration: Akihiro Ikeshita / JAXA

- Hard X-ray Imaging System (HXI)
- Soft X-ray Spectroscopy System (SXS)
- Soft X-ray Imaging System (SXI)
- Soft Gamma-ray Detector (SGD)

Observe energies from 0.3-300keV



# Athena - launch 2028

European Space Agency “L2” mission

2.5eV energy resolution

High spatial resolution (~5 arcsec)

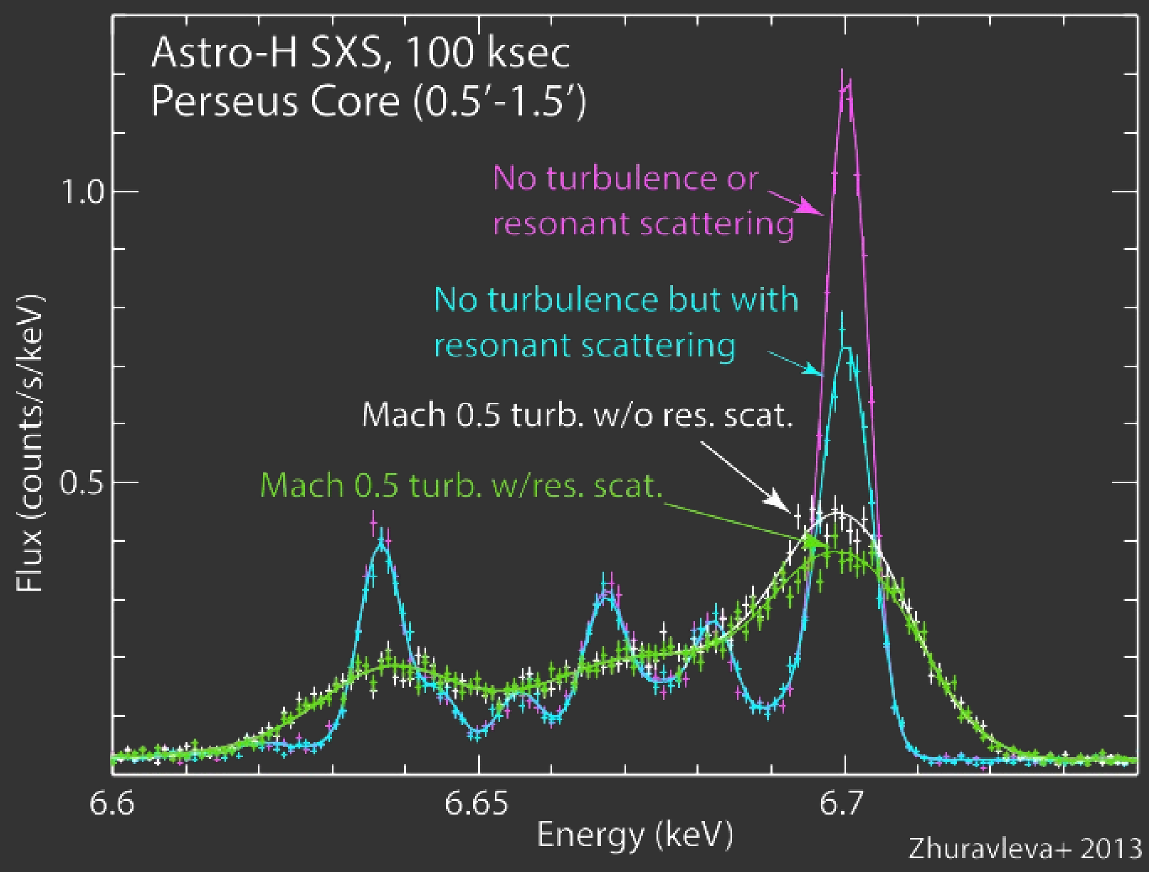
Exploring “The Hot and Energetic Universe”

- the formation and evolution of groups and clusters of galaxies
- the chemical evolution of hot baryons
- feedback effects of active galactic nuclei in clusters
- missing baryons thought to populate the intergalactic medium
- formation and early growth of black holes
- accretion by supermassive black holes through cosmic time
- galaxy-scale feedback involving active galactic nuclei and star formation
- physics of accretion onto supermassive black holes as a driver of active galactic nuclei

Not going to say more as we have 13+ years to wait...

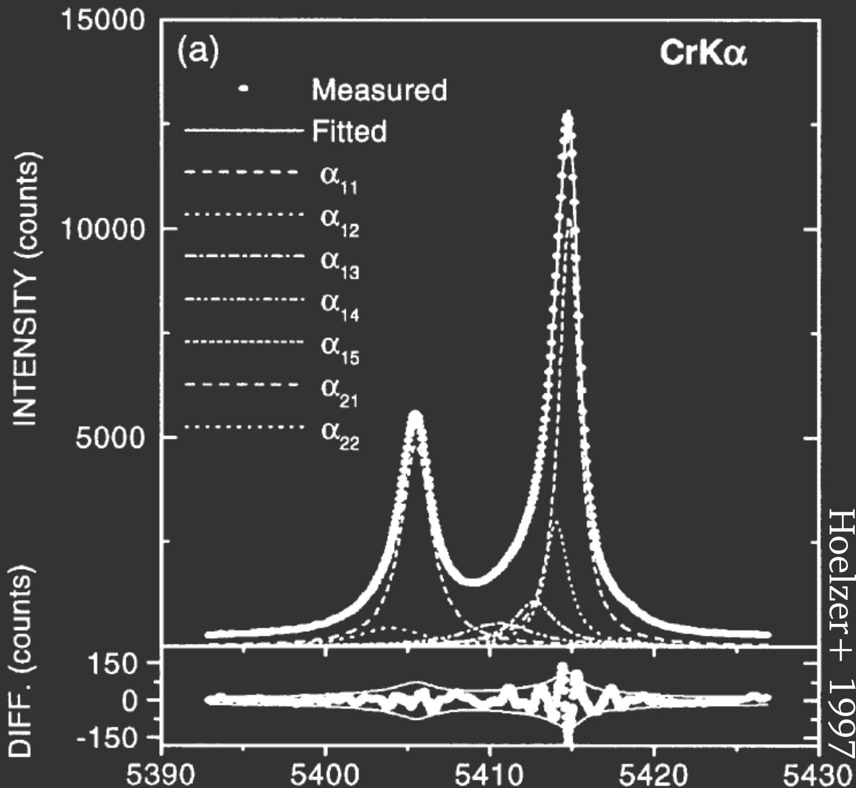
# Lineshapes

- SXS: 5eV resolution, non-dispersive spectrometer
- Allows study of extended objects with high resolution for the first time
- Astro-H goal: “Revealing the large-scale structure of the Universe and its evolution”
- Galaxy clusters are of particular interest

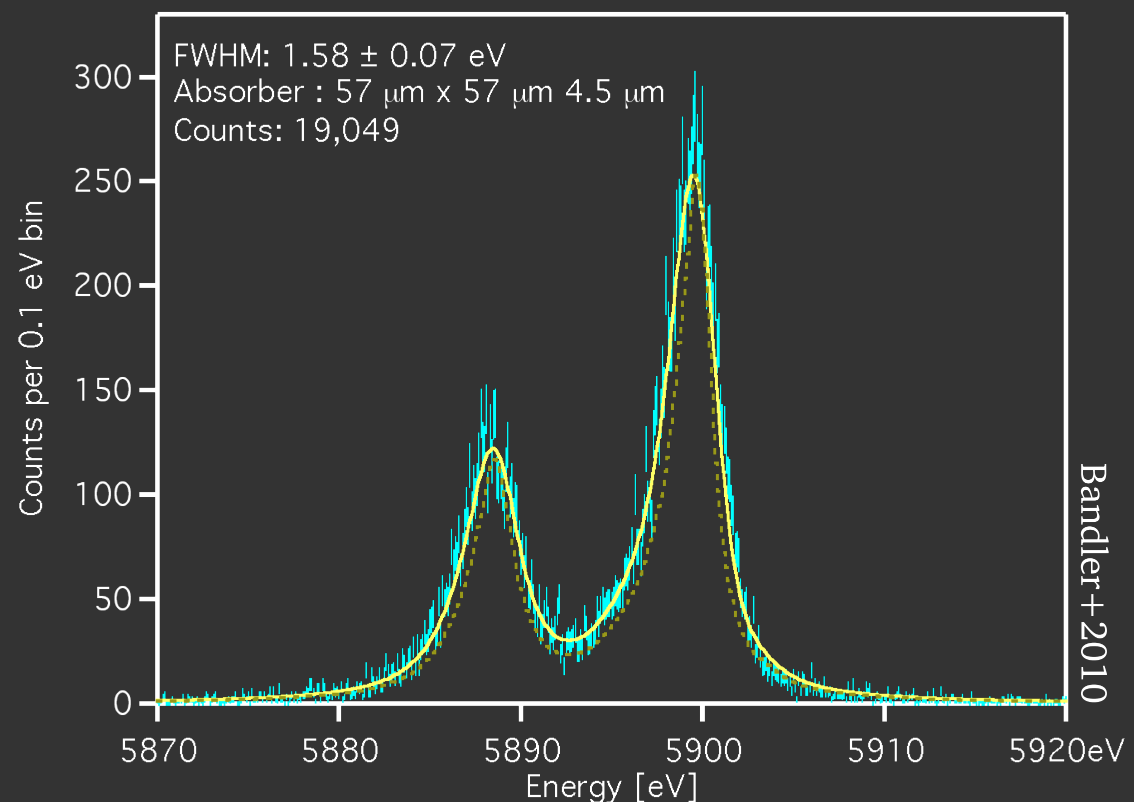



Need accurate line shapes for modeling these features

# Calibration Standard



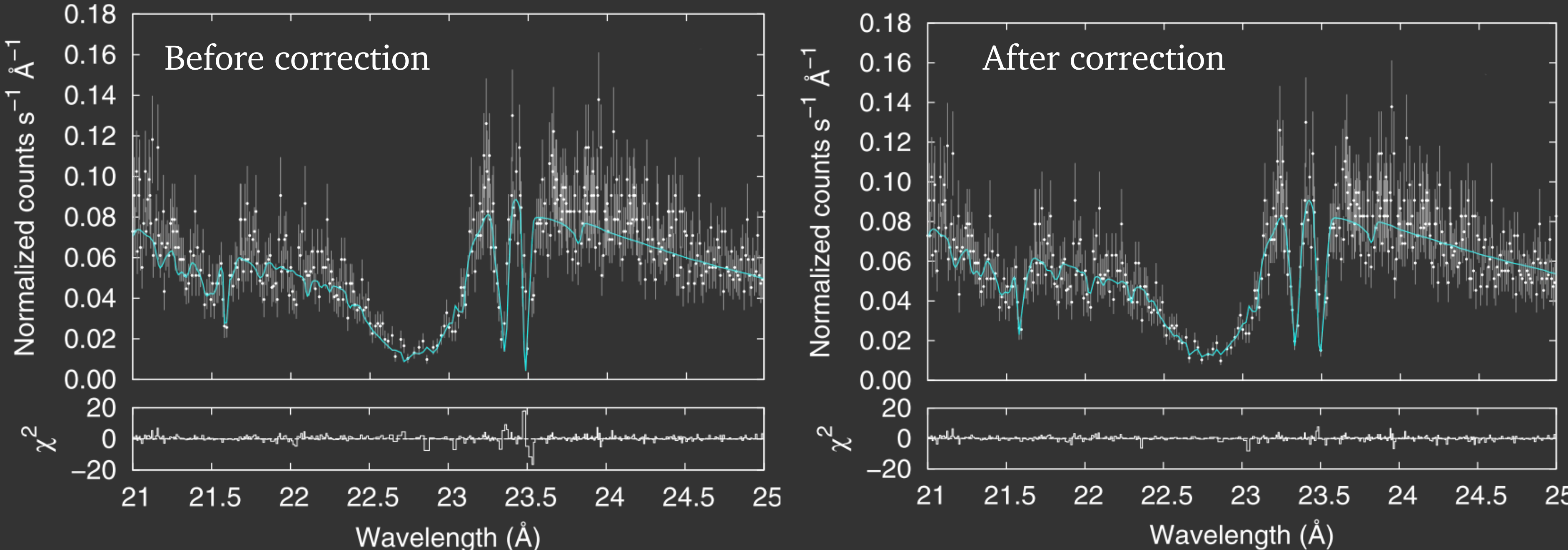

Hoelzer+ 1997




Bandler+2010

Line widths measured by current calorimeters are dominated by the natural line widths – which are not known for many useful elements!

# Absorption Cross Sections




Gatuzz et al 2013

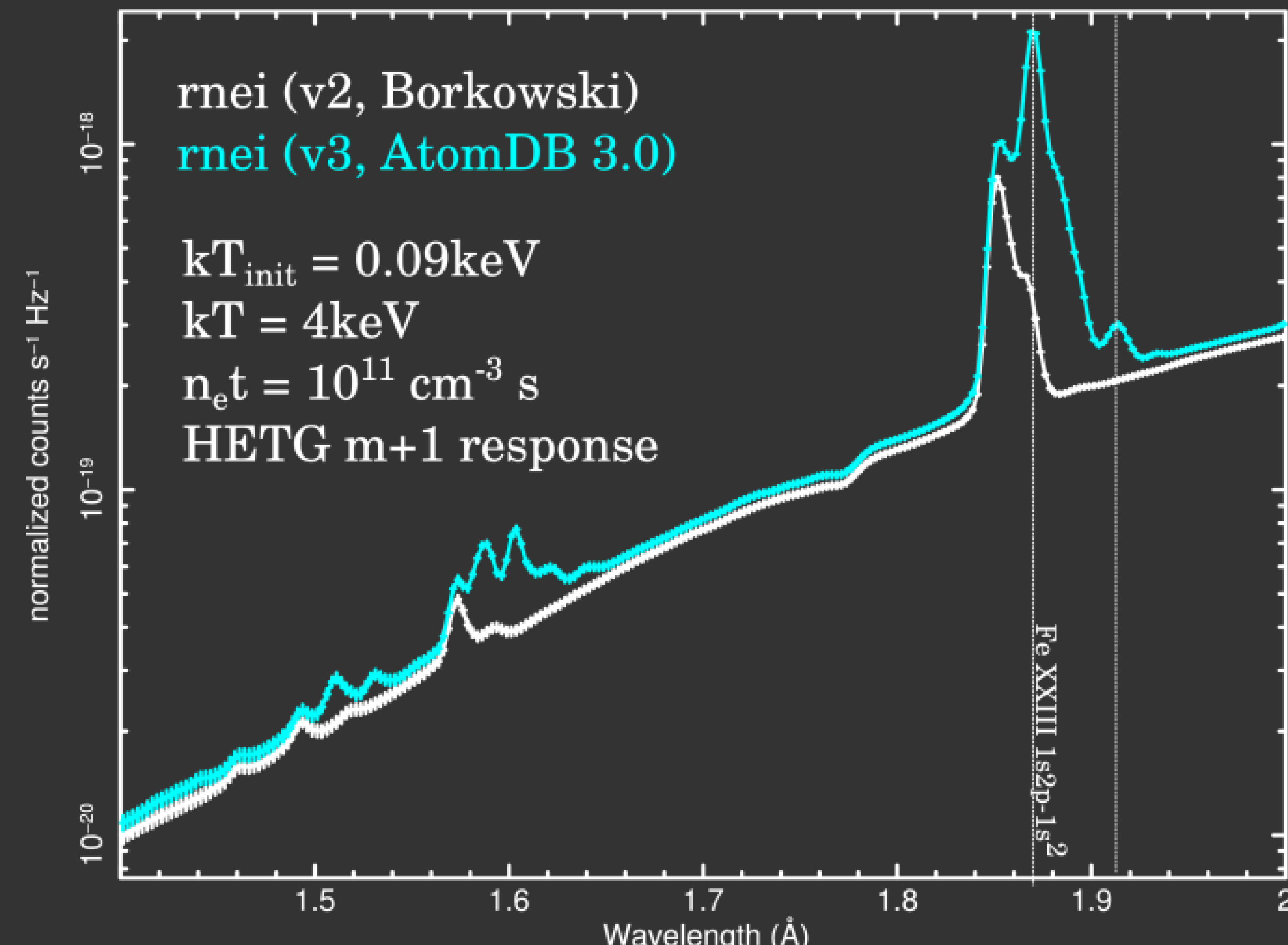
Chandra HETG observations of interstellar medium absorption.

Initally find poor fit, low ionization parameter

Shift wavelengths of O I and O II cross sections, get better fit

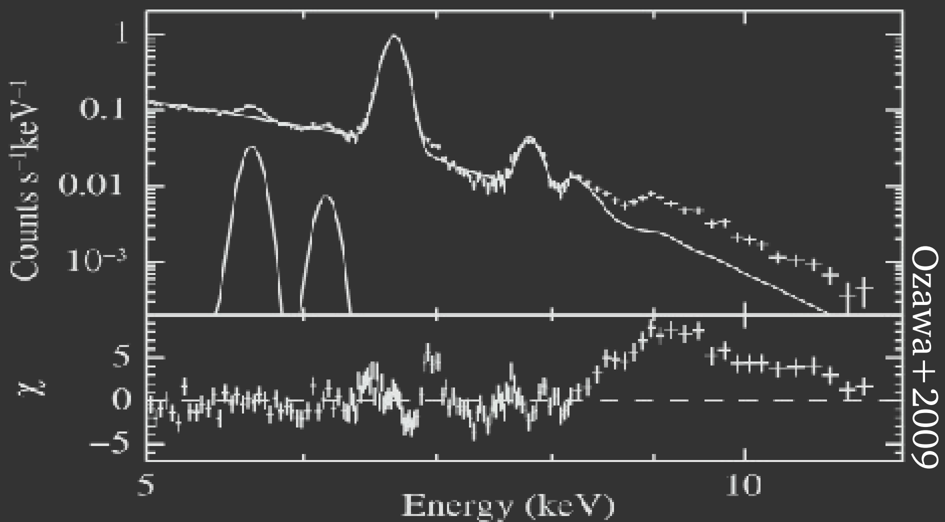
> Absorption cross section wavengths  known to ~50mA accuracy.
> Current detectors can already get to ~23mA.

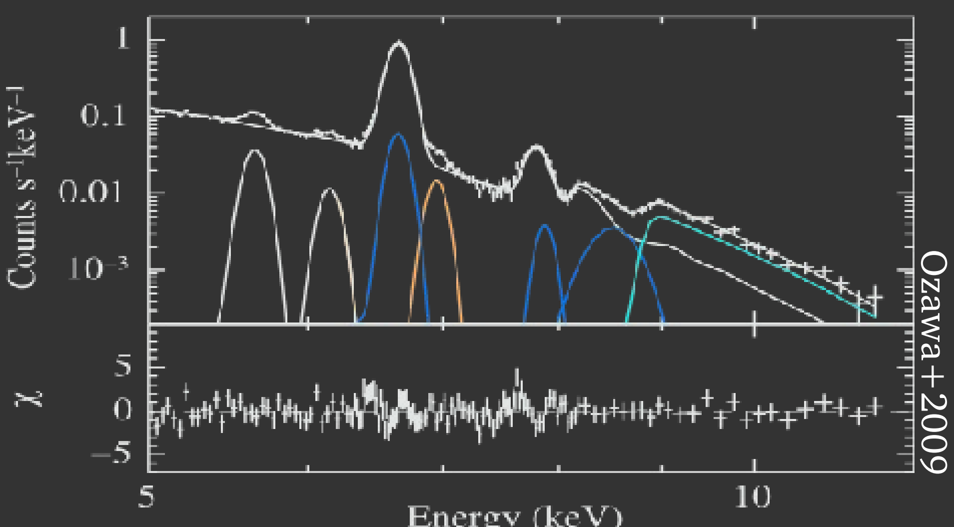
# Non-equilibrium

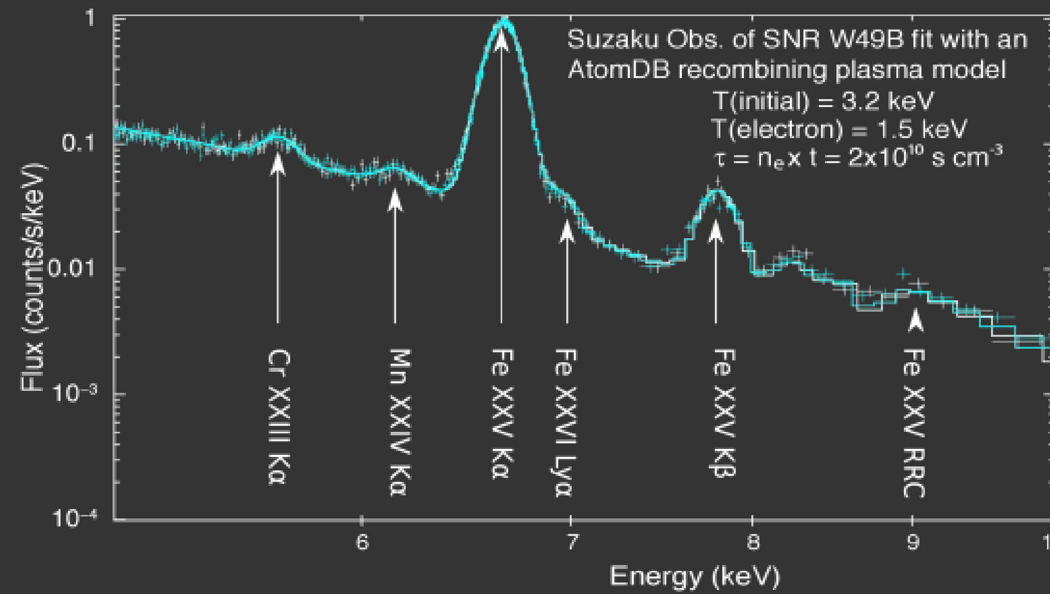



Have "complete" data for all ions of all elements. Very few calculations/measurements to compare with, especially for inner shell ionization. Doubly so for Kβ

# Non-equilibrium

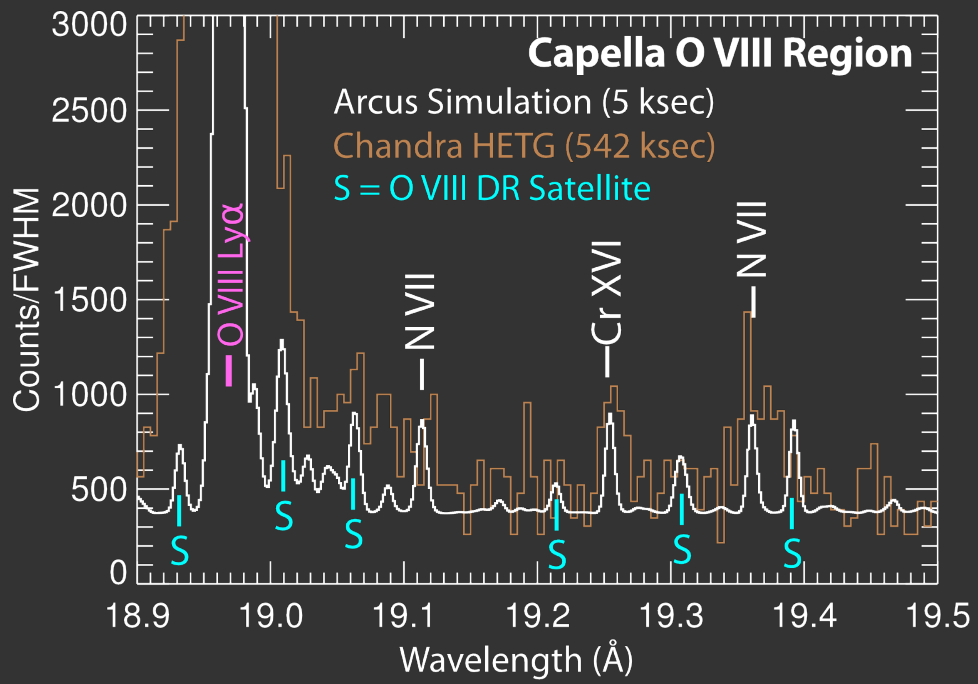


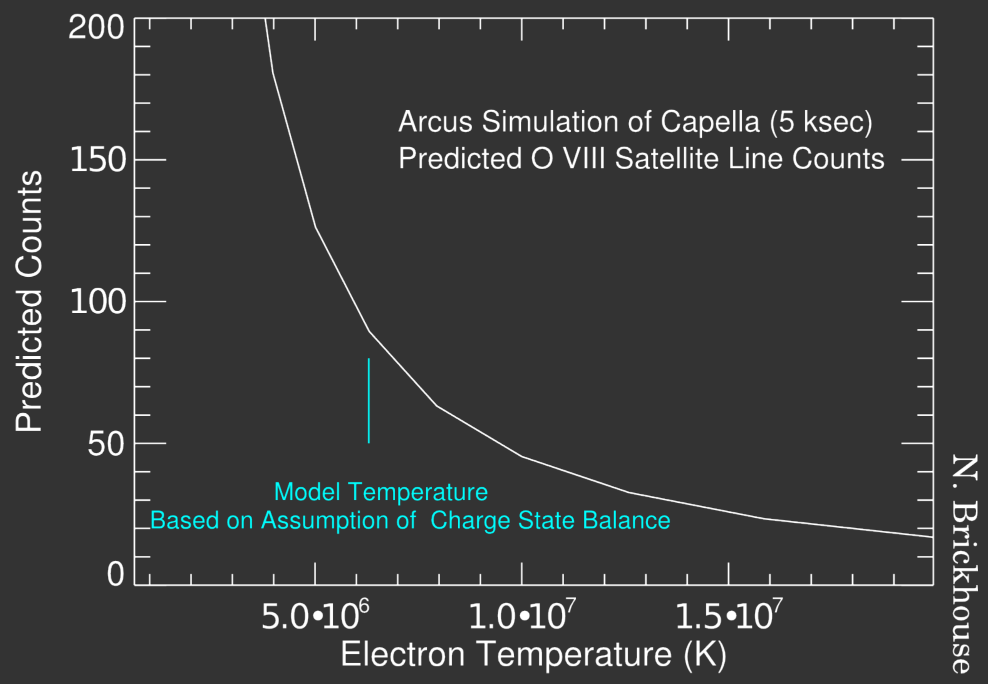




| Quantity | Ozawa | AtomDB 3.0 |
|---|---|---|
| kTe | 1.5keV | 1.5keV |
| $Fe_{abund}$ | 4.44 | 2.43 |
| $Ni_{abund}$ | 10.9 | 3.63 |
| norm | 0.16 | 0.16 |

# DR-Lines

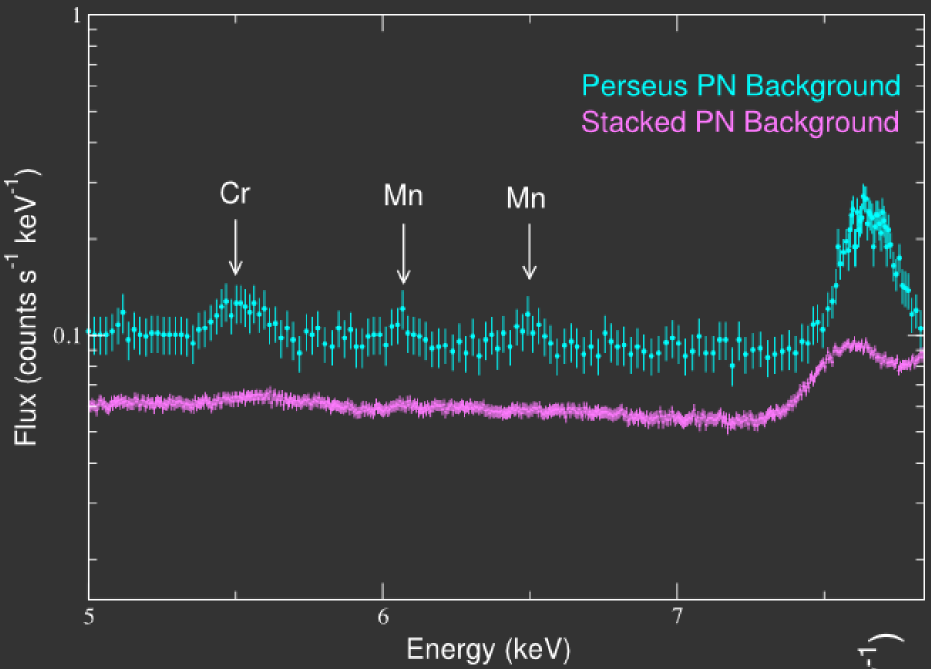



DR satellite lines are a strong potential temperature diagnostic

Satellite line emissivities need to be updated and expanded

# 3.55keV “sterile neutrino” Line



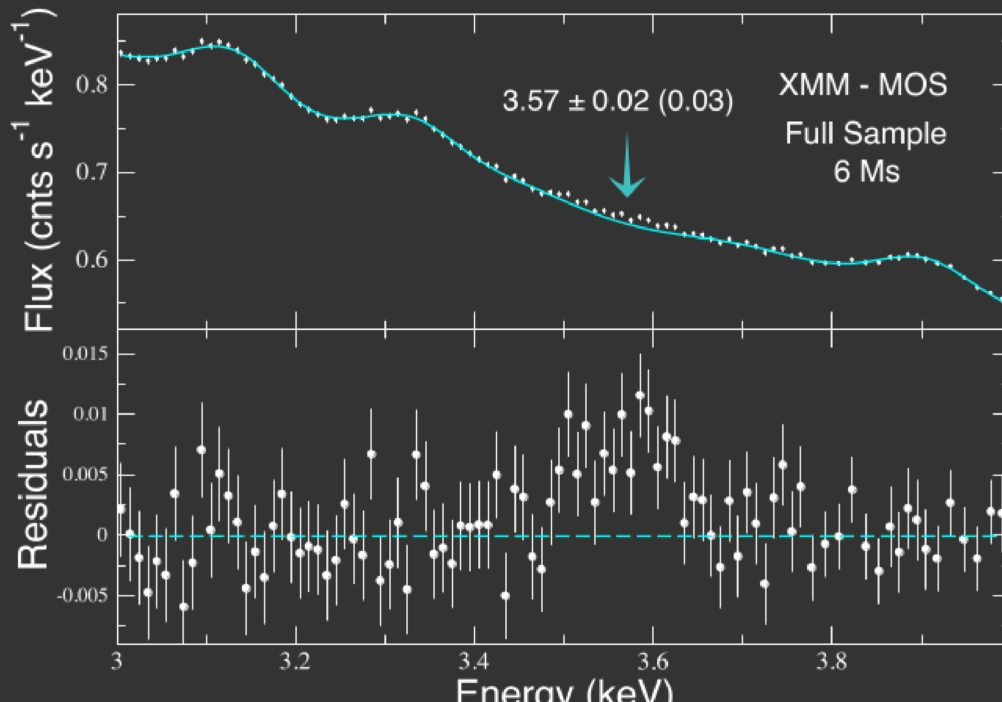

Stacked 73 galaxy clusters at their rest frame.

“Smears out” instrumental effects

Find residual line at 3.57keV in a range of cluster samples.

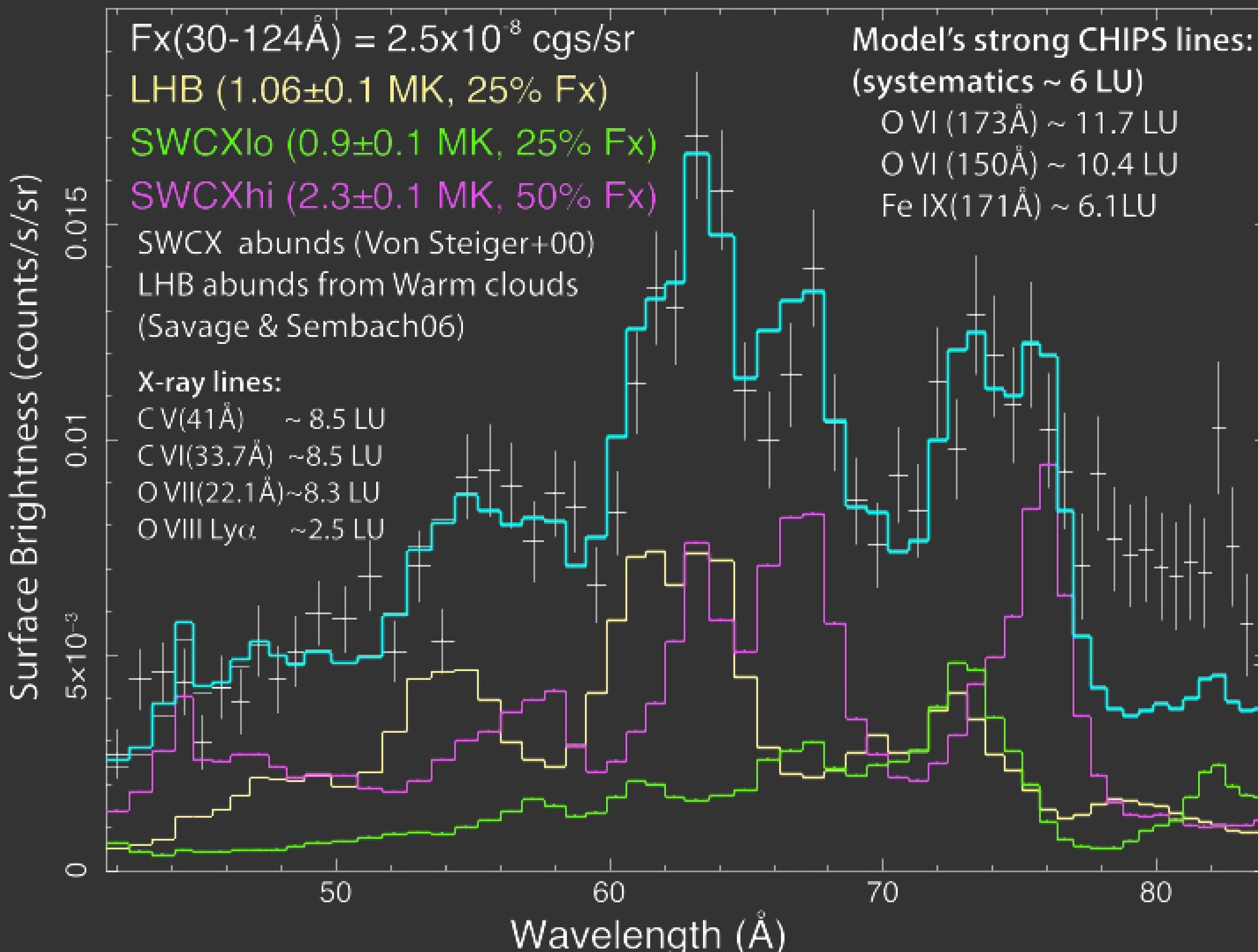
Found in all instrum

Nearby atomic lines:
K XVIII 2p-1s @ 3.515keV
Ar XVII DR @ 3.62keV




Bulbul+2014

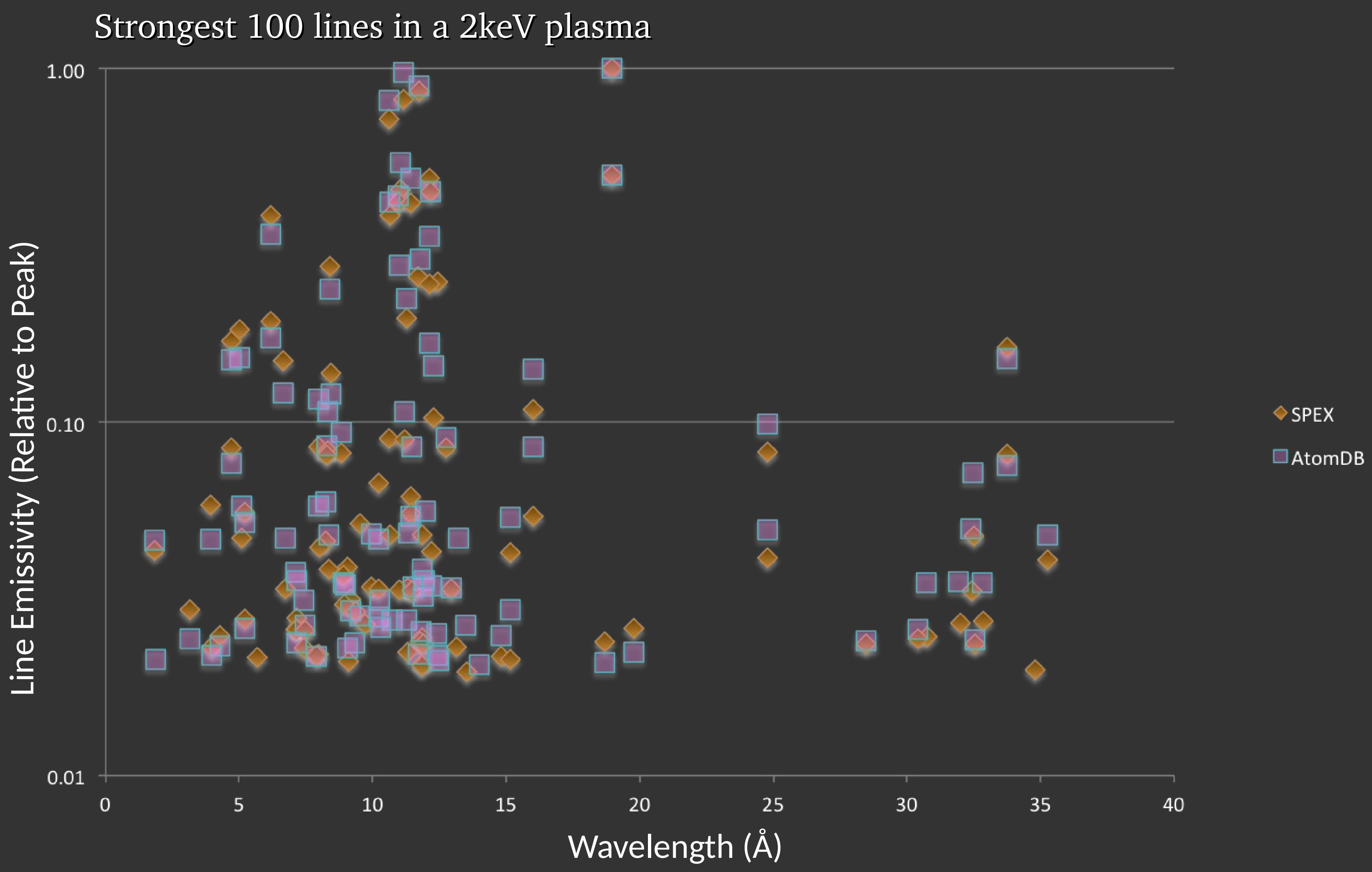
# (Low Energy!) Charge Exchange




Smith+2013

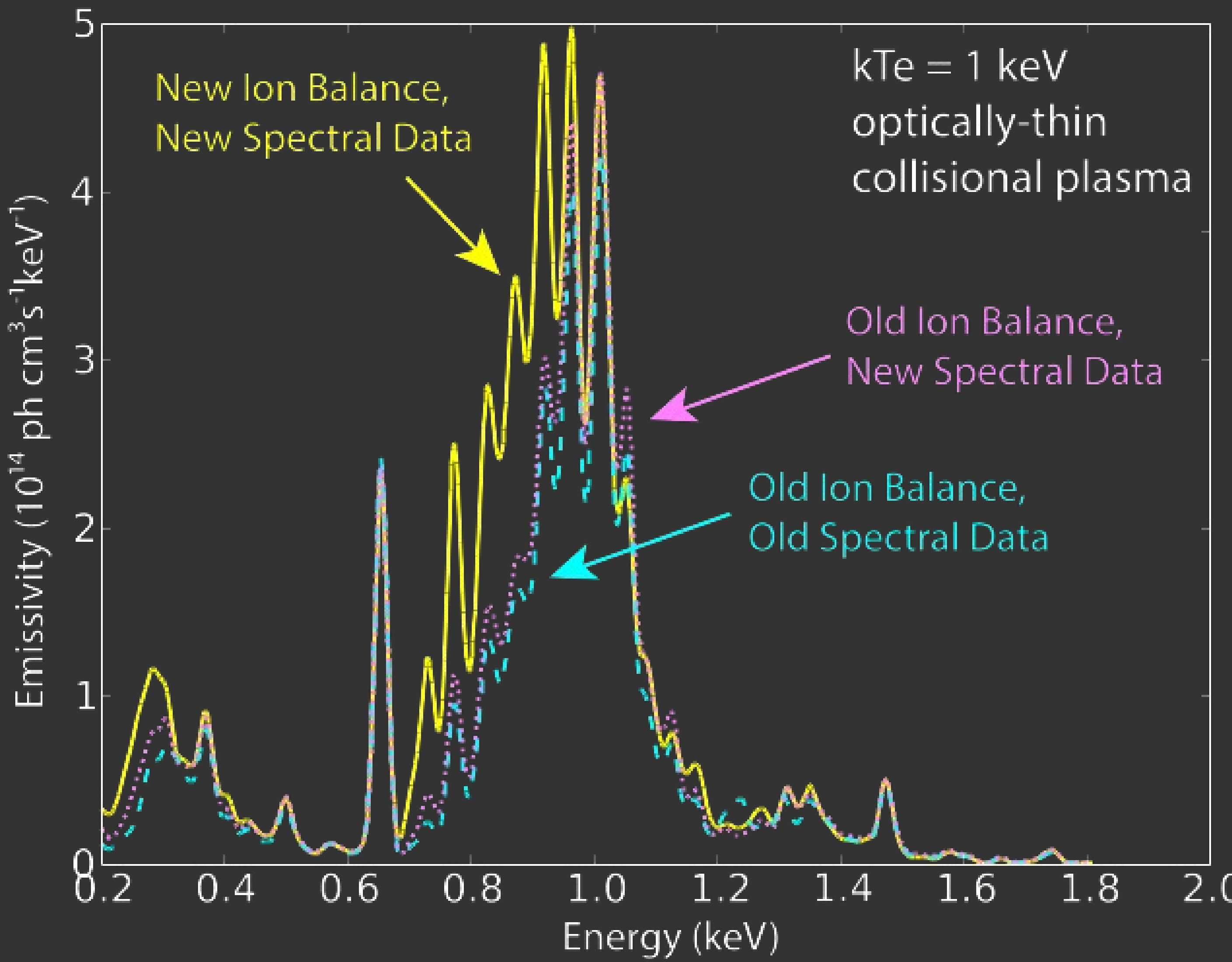
Simplified CX model created to model SWCX. Improved model (REAL cross sections!) needed to model comets/planetary atmospheres.
Ongoing project with University of Georgia to obtain theoretical cross sections

# Comparison of Models




Need to identify how and why these models differ!

# Uncertainties!




Foster+2012

Need to identify how and why these models differ!

# Summary

- We are about to have much improved spatial and spectral resolution, but not all requirements are driven by this. Identified needs are:
  - Line widths & shapes
  - Absorption Cross Sections (energy level accuracy)
  - Inner shell ionization collision strengths
  - Dielectronic Recombination Satellite Lines
  - Charge Exchange cross sections
  - Model Comparison
  - Uncertainties