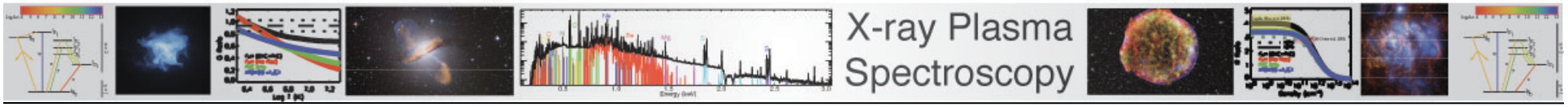


The Challenges of Plasma Modeling: Current Status and Future Plans

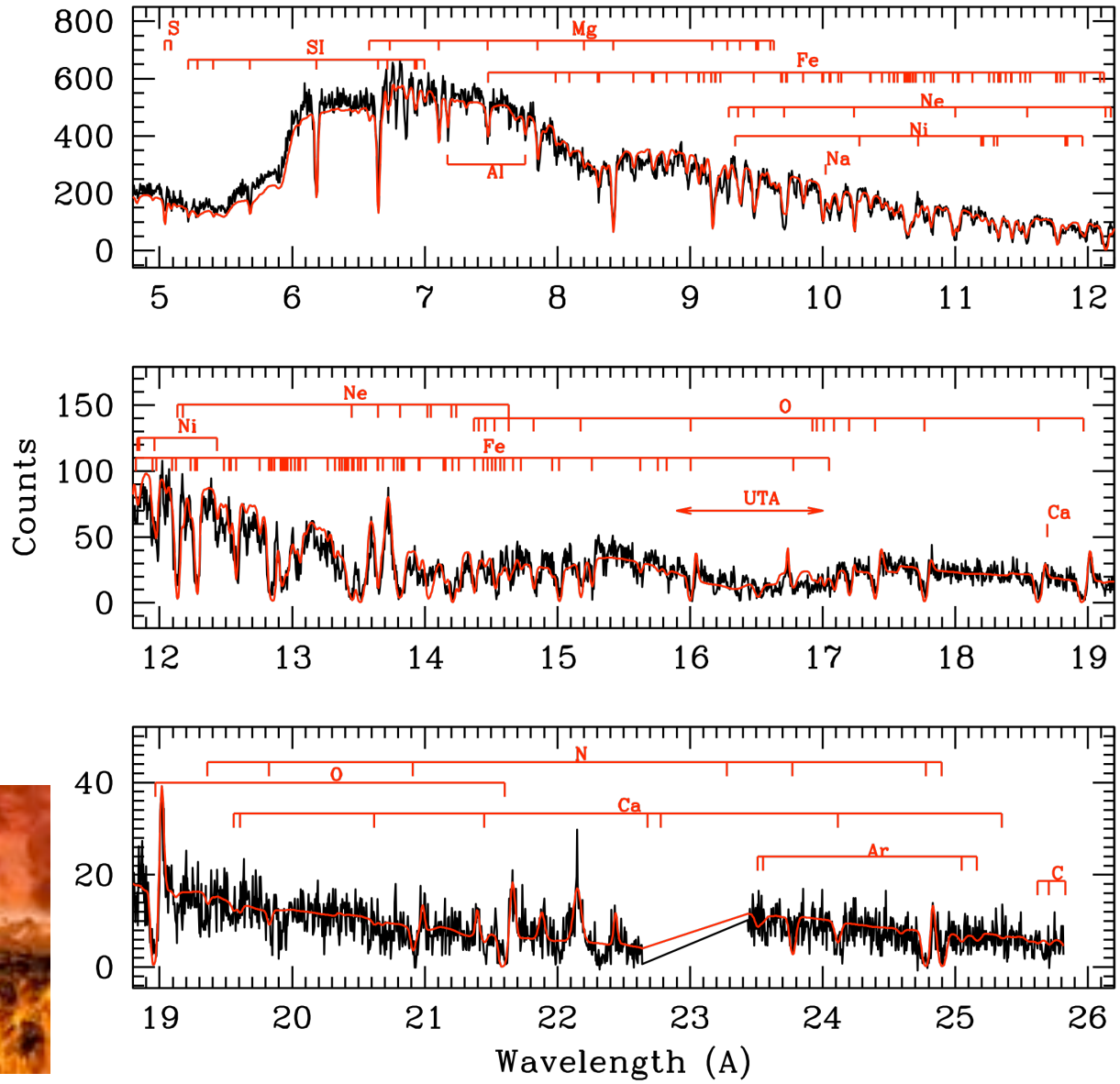
Randall K. Smith

Smithsonian Astrophysical Observatory

NGC 3783:

Imagine a world filled with spectra like this…would it be

or

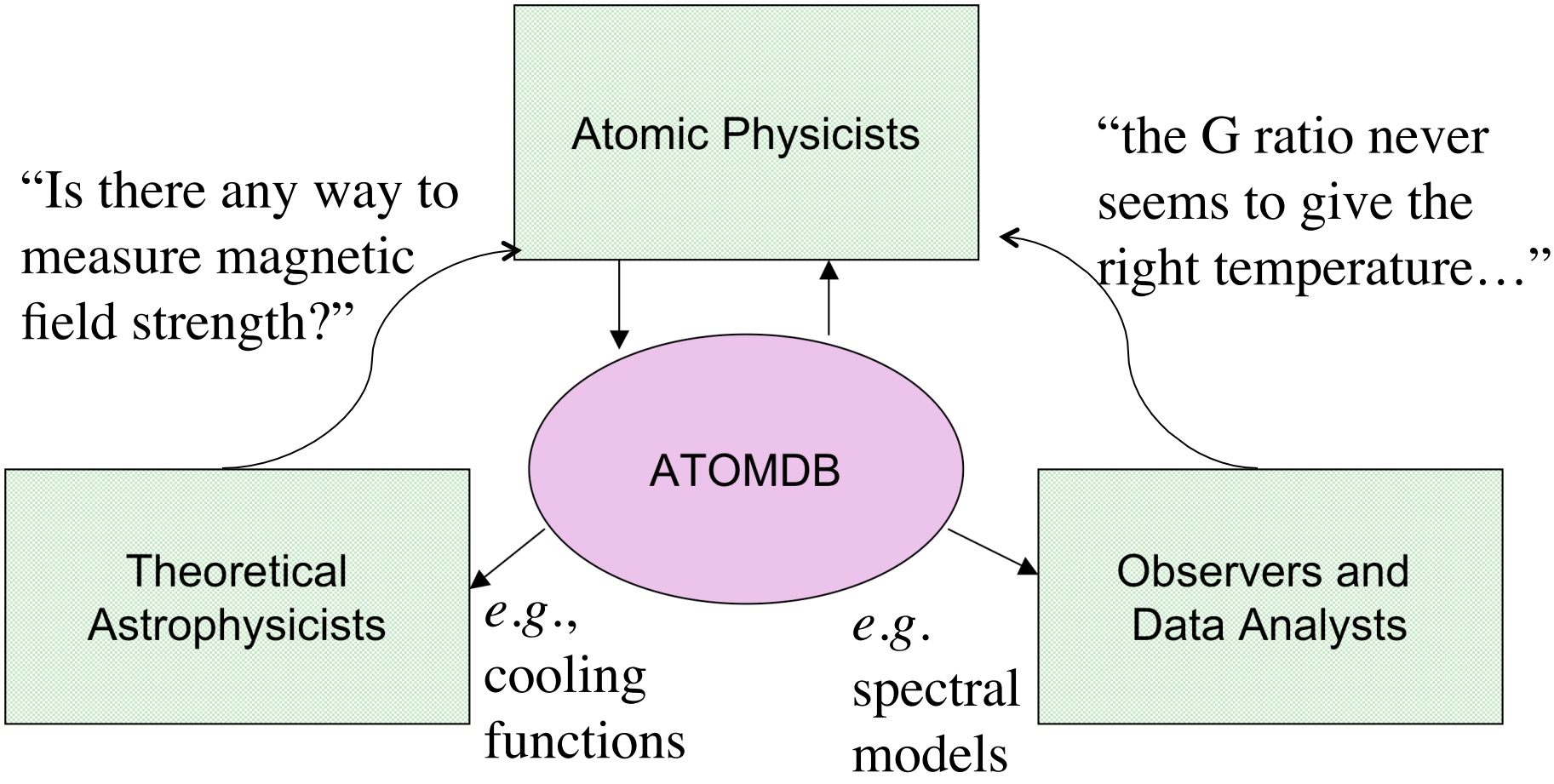


Starting with the Conclusion

As more high-resolution X-ray spectra become available, the X-ray astrophysics community, **including**

laboratory astrophysicists,
observers, and
modellers,

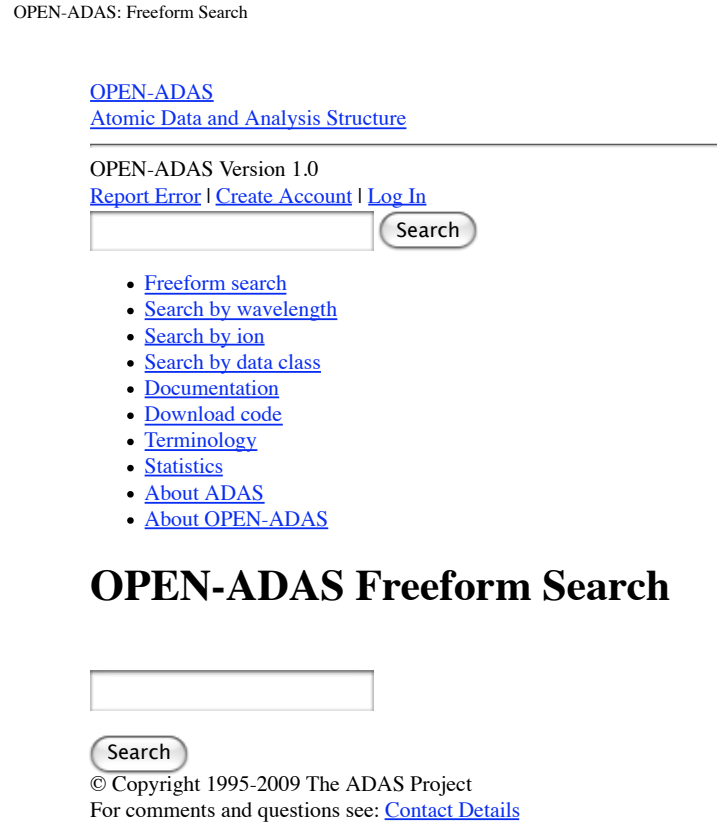
needs a common storehouse of accurate and complete atomic data that can be easily accessed in order to analyze this data.


Atomic Physicists
"Is there any way to measure magnetic field strength?"
"the G ratio never seems to give the right temperature…"
ATOMDB
Theoretical Astrophysicists
Observers and Data Analysts
e.g., cooling functions
e.g. spectral models

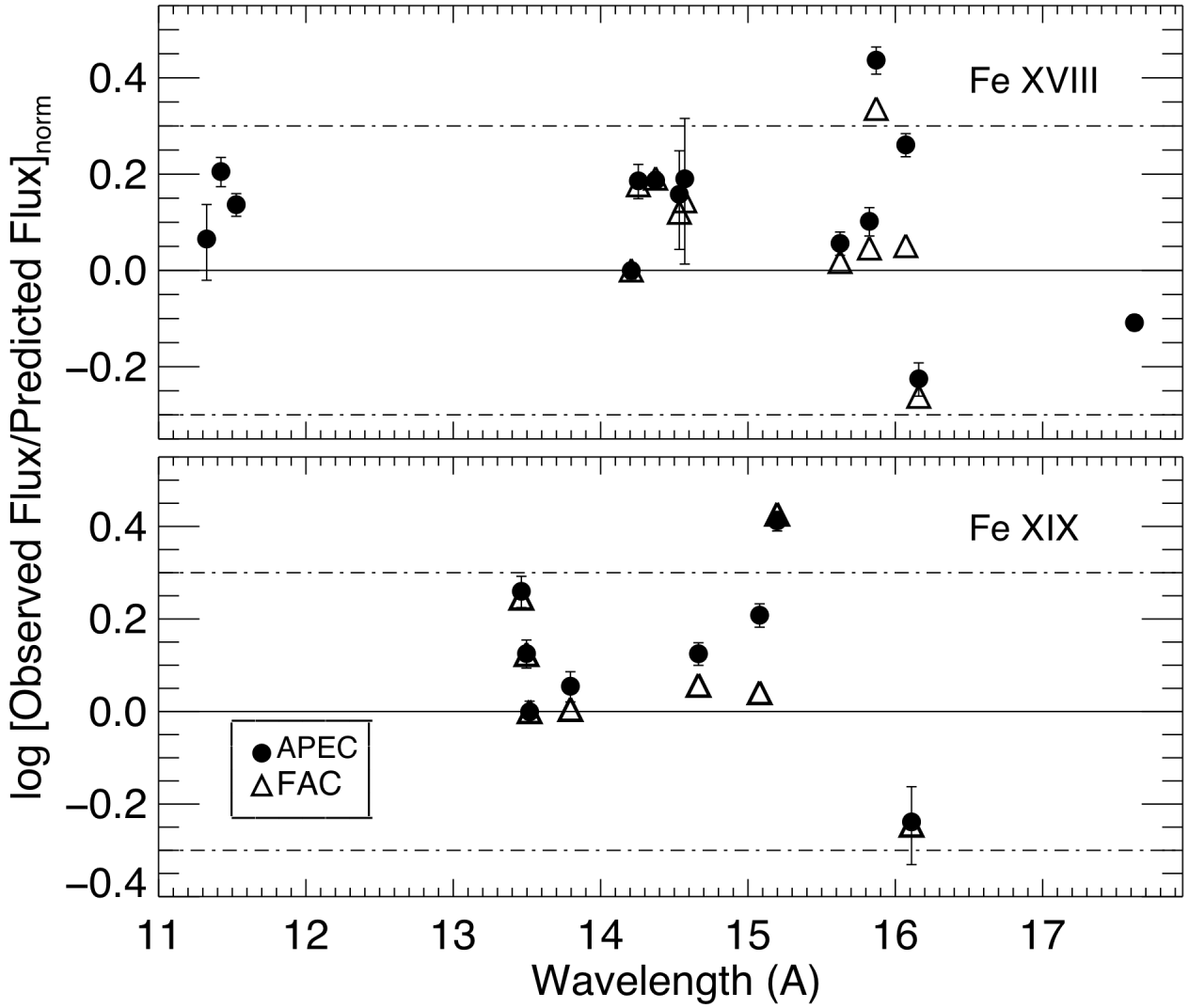
A few words about ADAS

http://open.adas.ac.uk/

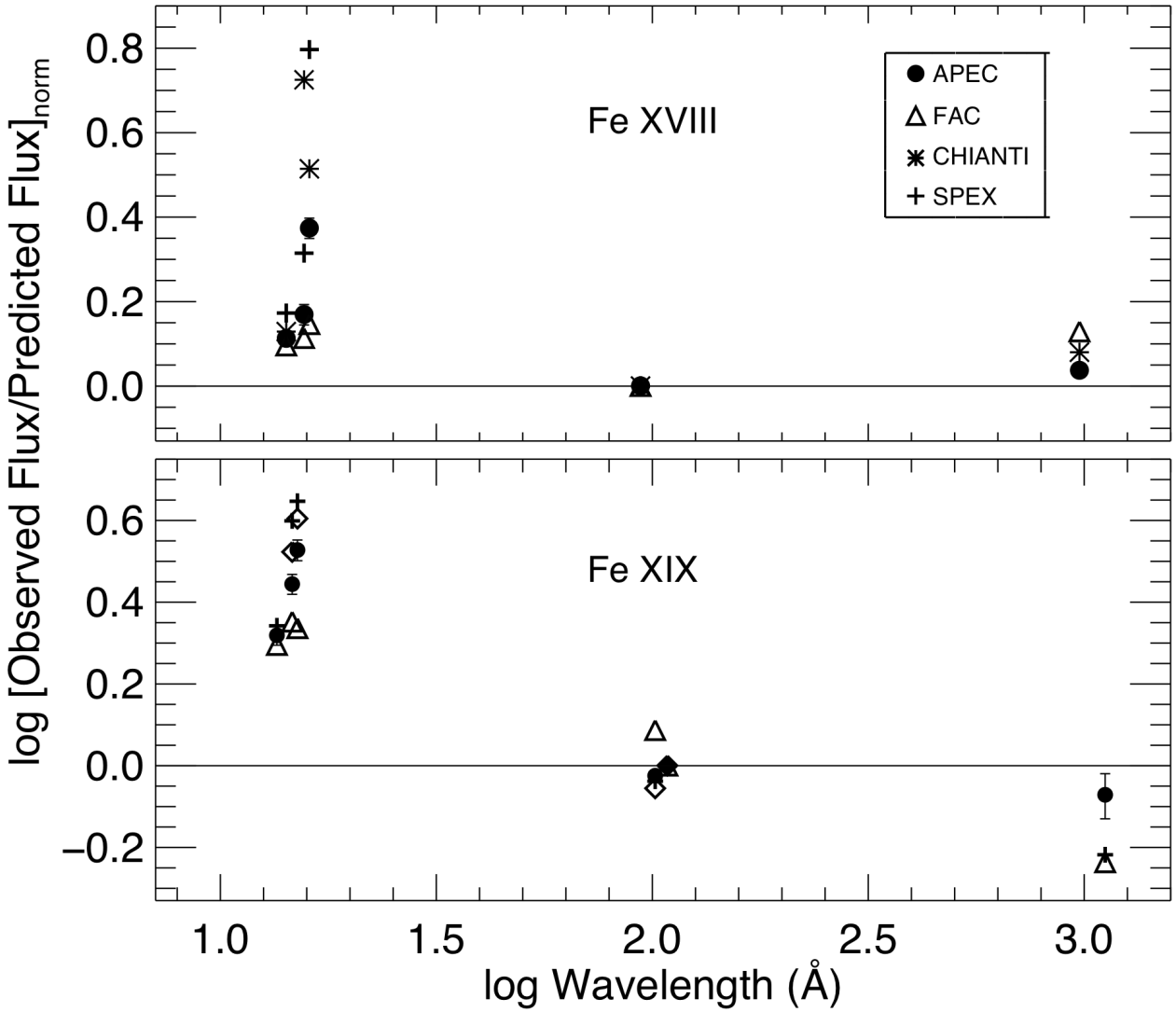
- The fusion community is, in a number of ways, ahead of us.
- ADAS (Atomic Data and Analysis Structure) is a suite of atomic codes, analysis tools, and atomic data
- Much of this is now available at OPEN-ADAS
- Be careful of the fire-hose…



Accuracy of APEC, FAC



Adding CHIANTI, SPEX…



Note the issues when comparing UV and X-ray lines…

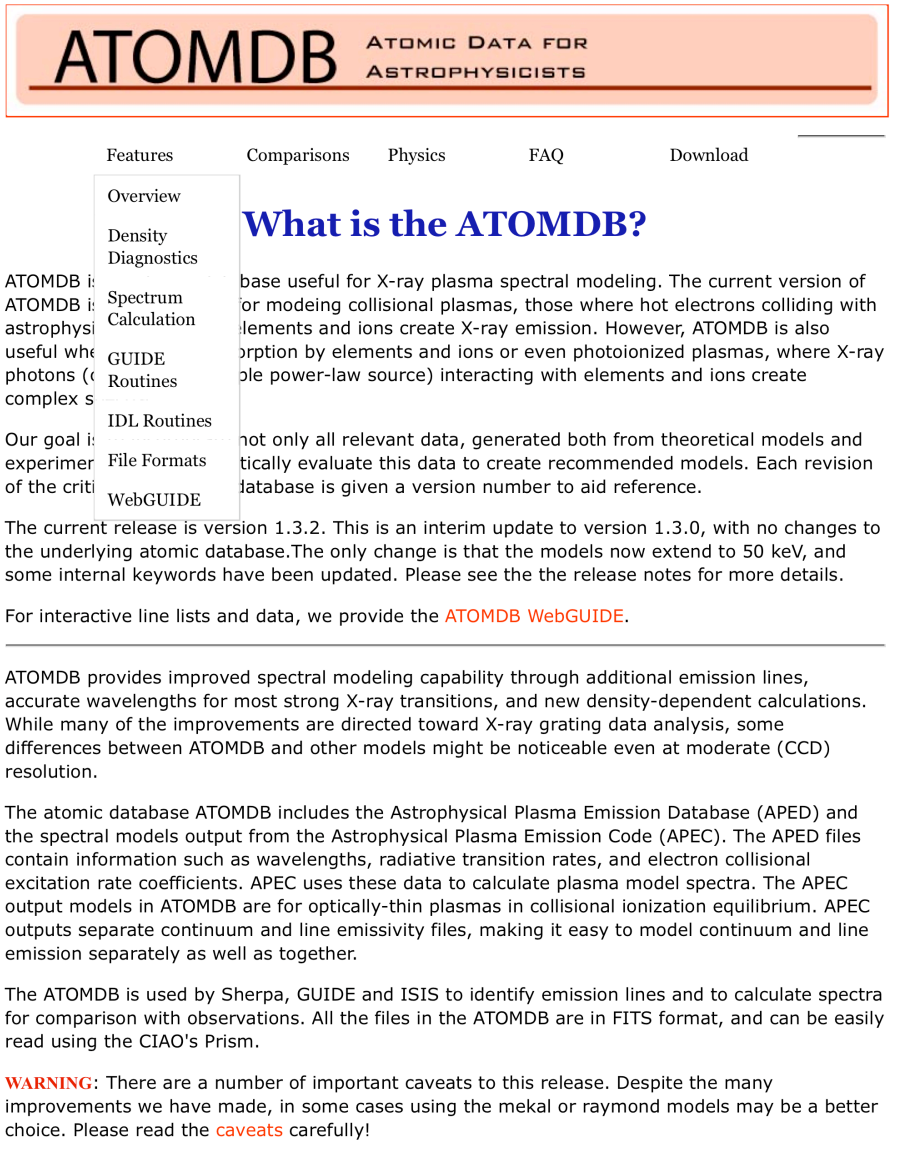
ATOMDB

- New web site:

http://www.atomdb.org/

(/beta at the moment)

- Describes code, physics, answers basic questions
- Will have new tools to simplify data analysis



ATOMDB Atomic Data for Astrophysicists

Features | Comparisons | Physics | FAQ | Download

- Overview
- Density Diagnostics
- Spectrum Calculation
- GUIDE Routines
- IDL Routines
- File Formats
- WebGUIDE

What is the ATOMDB?

ATOMDB i…base useful for X-ray plasma spectral modeling. The current version of ATOMDB i…or modeing collisional plasmas, those where hot electrons colliding with astrophysi…lements and ions create X-ray emission. However, ATOMDB is also useful whe…orption by elements and ions or even photoionized plasmas, where X-ray photons (…ple power-law source) interacting with elements and ions create complex s…

Our goal i…not only all relevant data, generated both from theoretical models and experimer…tically evaluate this data to create recommended models. Each revision of the criti…database is given a version number to aid reference.

The current release is version 1.3.2. This is an interim update to version 1.3.0, with no changes to the underlying atomic database.The only change is that the models now extend to 50 keV, and some internal keywords have been updated. Please see the the release notes for more details.

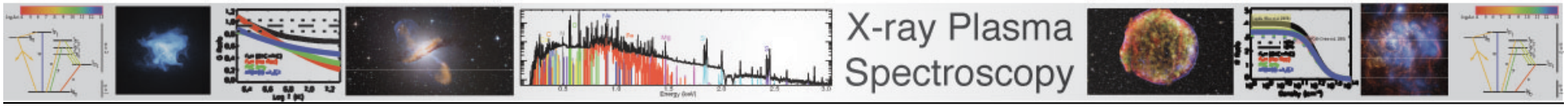
For interactive line lists and data, we provide the ATOMDB WebGUIDE.

ATOMDB provides improved spectral modeling capability through additional emission lines, accurate wavelengths for most strong X-ray transitions, and new density-dependent calculations. While many of the improvements are directed toward X-ray grating data analysis, some differences between ATOMDB and other models might be noticeable even at moderate (CCD) resolution.

The atomic database ATOMDB includes the Astrophysical Plasma Emission Database (APED) and the spectral models output from the Astrophysical Plasma Emission Code (APEC). The APED files contain information such as wavelengths, radiative transition rates, and electron collisional excitation rate coefficients. APEC uses these data to calculate plasma model spectra. The APEC output models in ATOMDB are for optically-thin plasmas in collisional ionization equilibrium. APEC outputs separate continuum and line emissivity files, making it easy to model continuum and line emission separately as well as together.

The ATOMDB is used by Sherpa, GUIDE and ISIS to identify emission lines and to calculate spectra for comparison with observations. All the files in the ATOMDB are in FITS format, and can be easily read using the CIAO's Prism.

WARNING: There are a number of important caveats to this release. Despite the many improvements we have made, in some cases using the mekal or raymond models may be a better choice. Please read the caveats carefully!



http://cxc.harvard.edu/atomdb/WebGUIDE/

Webguide will see some major advances – please let me know what you'd like to see in the 'new' Webguide

Interactive GUIDE for ATOMDB version 1.3

Identify | Describe | Strong

Wavelength (•) Angstrom ( ) keV

Temperature (•) Kelvin ( ) keV

Note: After choosing Wavelength and Temperature units please "refresh" the page for all of the values to fill in

Note: Currently, the sort and select features do not work in Netscape 4.7X and other earlier browsers.

► Identify

The "Identify" command selects all emission lines within a selected wavelength range that have peak emissivities (assuming solar abundances) greater than a set value. The green boxes are required and the blue boxes are optional.

Wavelength		Angstrom (0.1 - 10^6)
Width	0.01	Angstrom (0.0 - 1.0)
Mininum Emissivity	1.e-18	photons cm3/s (default=1.e-18, min=1.e-20, max=1.0)

Go Reset

► Describe

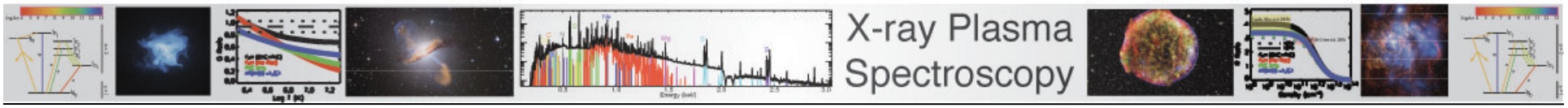
The "describe" command lists all available data about a given atomic transition, including the upper and lower levels, the observed and theoretical wavelengths, and the radiative transition rates. ADS Bibcodes are also listed for the original sources of the data.

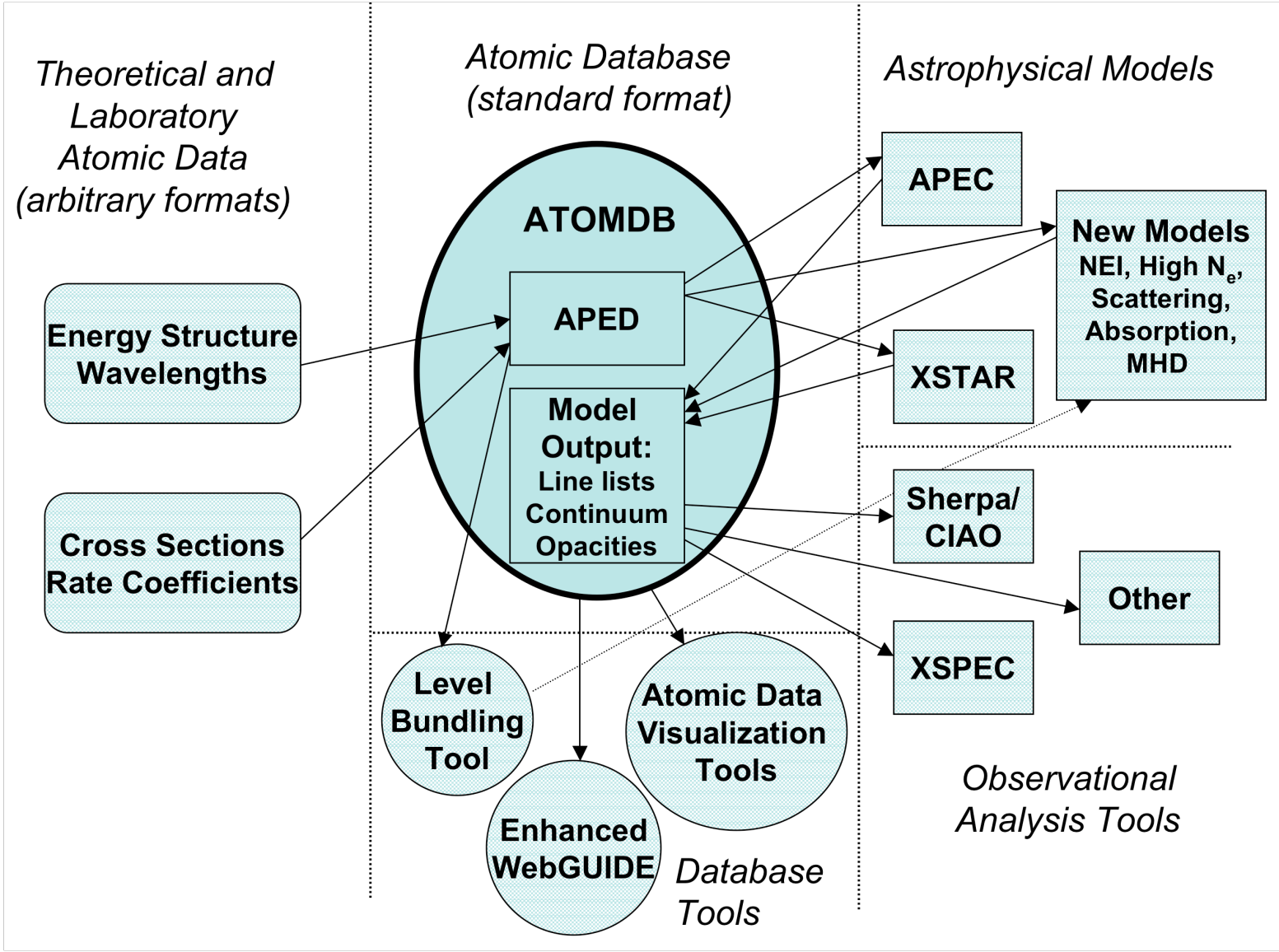
Element Z		(1 - 28)
Ion (neutral=1)		(1 - Element Z above)
Lower Energy Level		(1 - 30000)
Upper Energy Level		(1 - 30000)

Go Reset

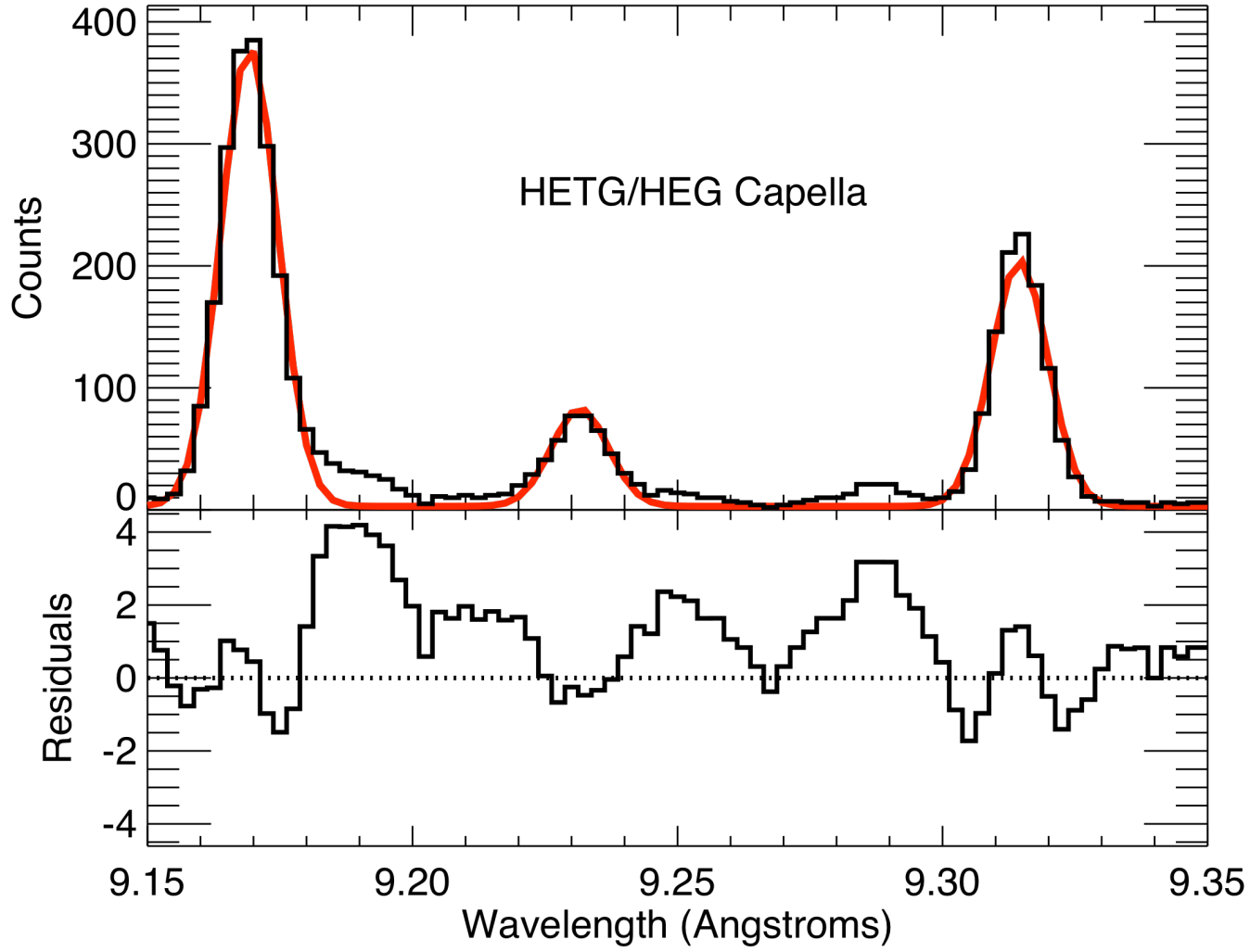
► Strong

The "strong" command selects all emission lines within a selected wavelength range that have emissivities (assuming solar abundances) greater than a set value at the given temperature. The output emissivity value is approximate, and should not be used except as an estimate. The green boxes are required and the blue boxes are optional.


X-ray Plasma
Spectroscopy

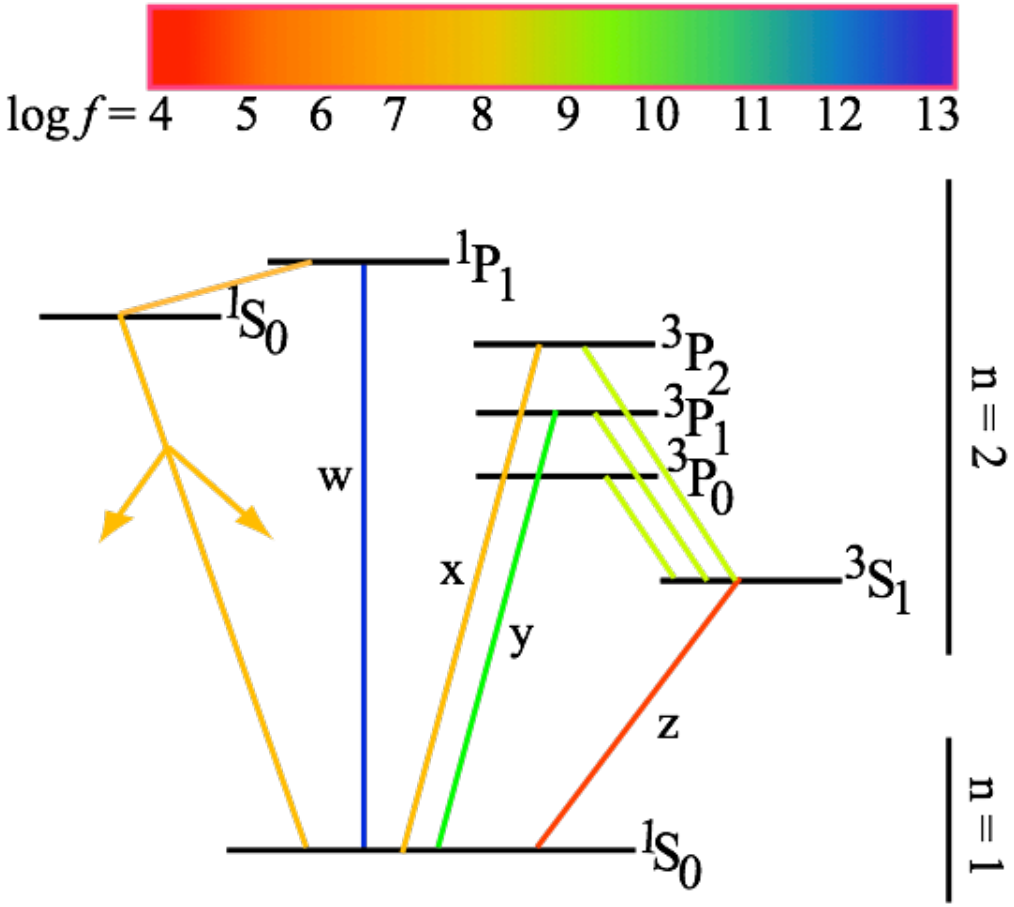

Theoretical and
Laboratory
Atomic Data
(arbitrary formats)
Atomic Database
(standard format)
Astrophysical Models
ATOMDB
APED
Model
Output:
Line lists
Continuum
Opacities
Energy Structure
Wavelengths
Cross Sections
Rate Coefficients
APEC
New Models
NEI, High N_e,
Scattering,
Absorption,
MHD
XSTAR
Sherpa/
CIAO
Other
XSPEC
Level
Bundling
Tool
Atomic Data
Visualization
Tools
Enhanced
WebGUIDE
Database
Tools
Observational
Analysis Tools

Mg XI Region: Still missing lines…

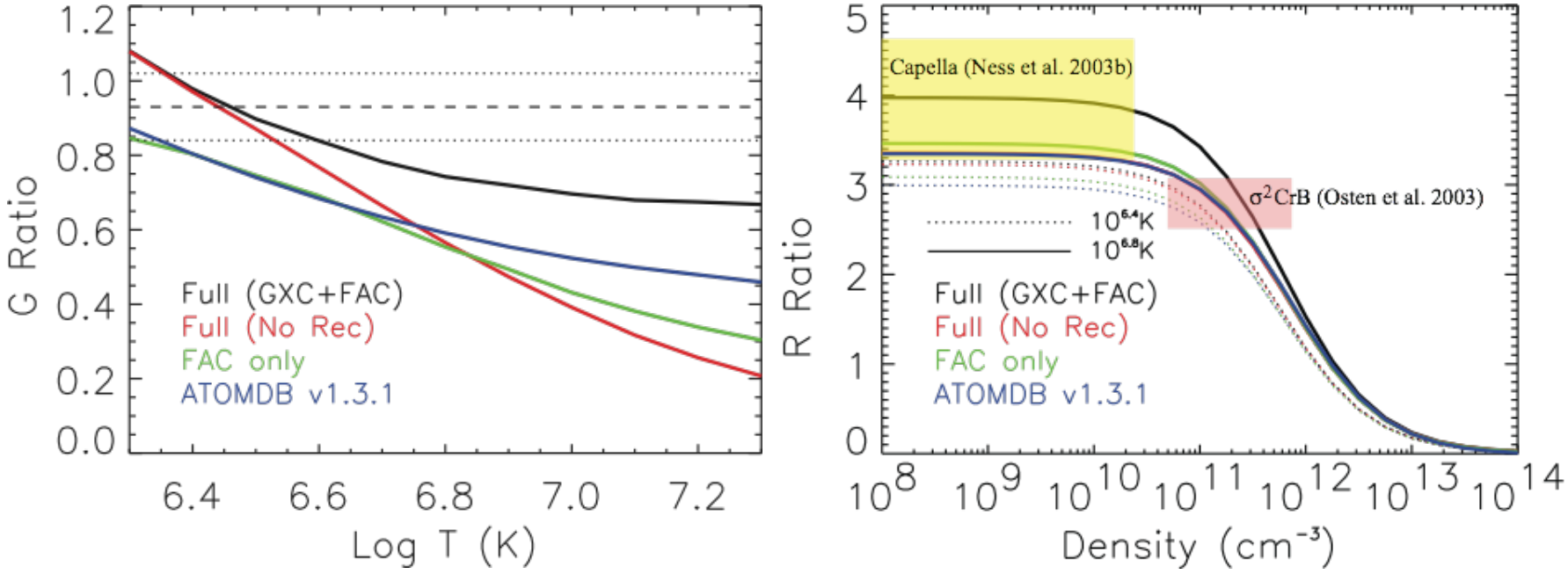


He-like Systems

- All strong transitions
- Different f (A) values lead to line diagnostics



Line Ratio Uses



[Left] Temperature diagnostic (triplets/singlet)
[Right] Density diagnostic (forbidden/intercomb)

Dealing With Model Error

"The model rates are error free. We define an approximation and calculate the rates within that framework. There is **no error** in these rates…"

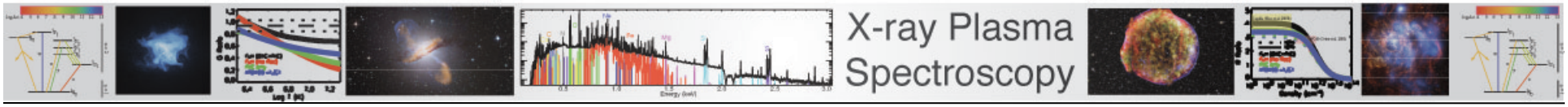
Dealing With Model Error

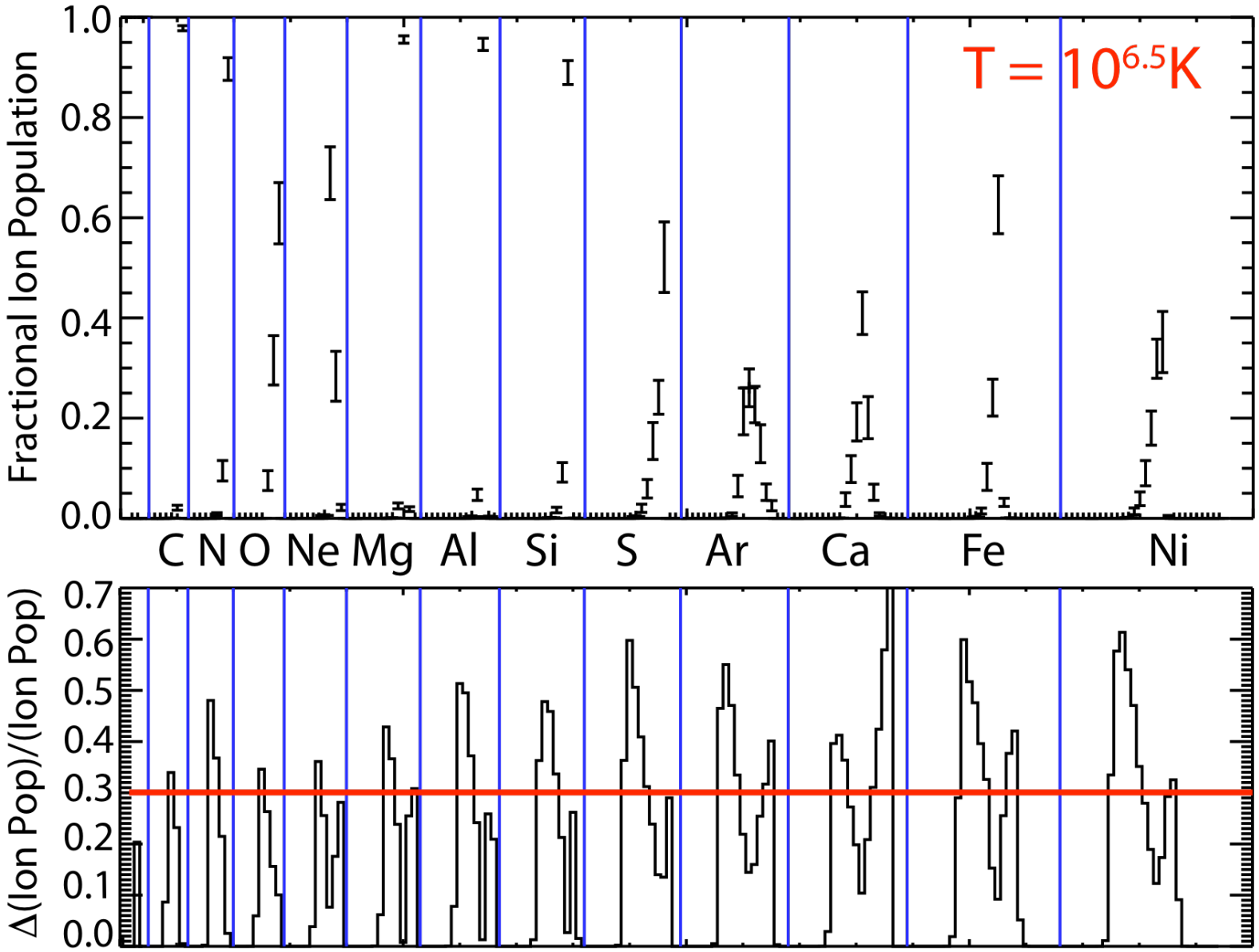
"The model rates are error free. We define an approximation and calculate the rates within that framework. To our knowledge, there is no error in these rates…"

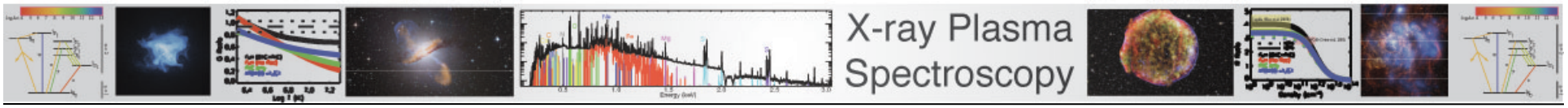
But errors in the approximation method, of course, are beyond the scope of this statement. It is hard to know the accuracy of your atomic model in any detail.

Dealing with Model Errors

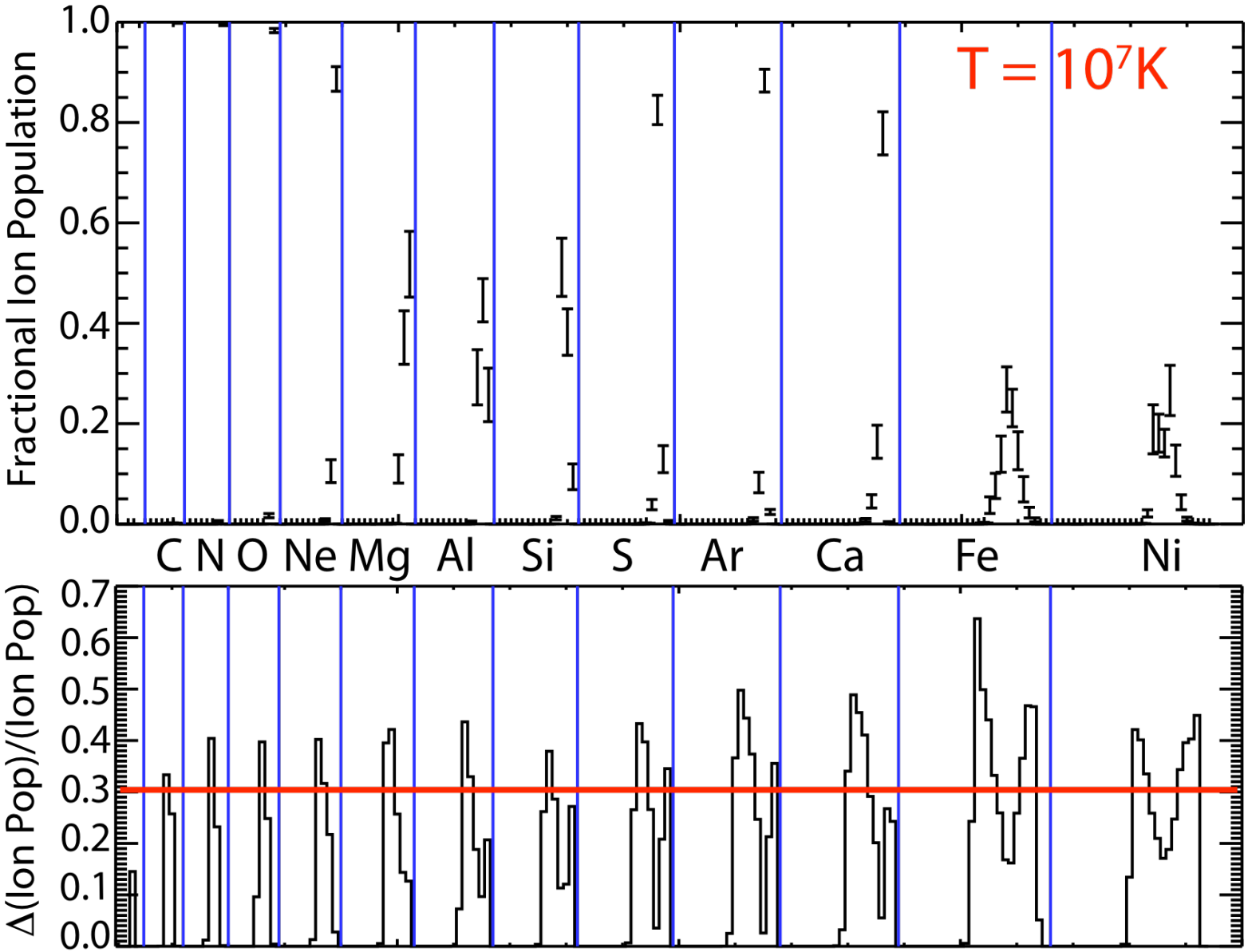
- Theoretical cross section errors tend to be correlated, not random
- Typical quoted values range from 5-30% for rates & cross sections.
- Wavelengths are often 1%, or with great effort, 0.1%. (Remember that at 10Å, 0.1% is 0.01Å, or 300 km/s)
- I propose running a range of test cases to check sensitivity of results to input errors and to give users some advice…

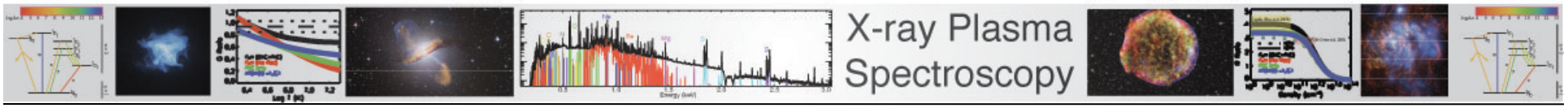

X-ray Plasma
Spectroscopy

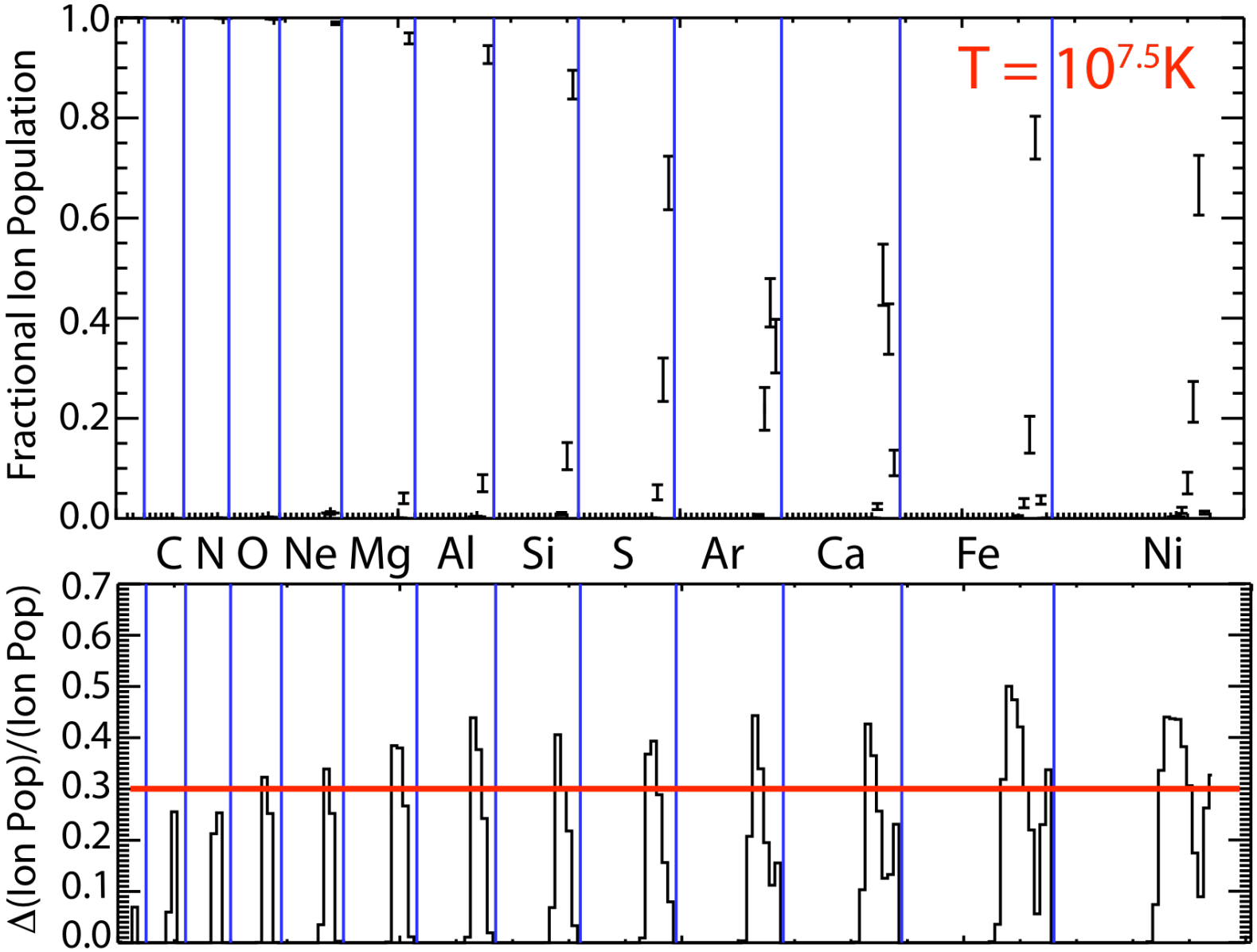

T = 10^6.5K
Fractional Ion Population
1.0
0.8
0.6
0.4
0.2
0.0
C N O Ne Mg Al Si S Ar Ca Fe Ni
Δ(Ion Pop)/(Ion Pop)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0



X-ray Plasma Spectroscopy




X-ray Plasma
Spectroscopy


T = 10^7.5K
Fractional Ion Population
1.0
0.8
0.6
0.4
0.2
0.0
C N O Ne Mg Al Si S Ar Ca Fe Ni
Δ(Ion Pop)/(Ion Pop)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

Conclusion

As more high-resolution X-ray spectra become available, the X-ray astrophysics community, **including**

laboratory astrophysicists,
observers, and
modellers,

needs a common storehouse of accurate and complete atomic data that can be easily accessed in order to analyze this data.