Status of Atomic Plasma Models

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...with assistance from many plasma modelers...
Codes Used for High-Energy Spectroscopy

• Collisional
  • AtomDB
  • Chianti
  • SASAL
  • SPEX
  • ADAS (Fusion)

• Photoionized
  • Cloudy
  • SPEX
  • XSTAR
  • Mocassin, others
Codes Used for High-Energy Spectroscopy

• Collisional
  • AtomDB  (From Raymond-Smith 1977)
  • Chianti  (From Landini & Monsignori-Fossi, 1970)
  • SASAL  (2010’s Blend of Chianti, ADAS)
  • SPEX   (From Meka code; Mewe 1972)
  • ADAS (Fusion)  (Begun with JET experiment in ~1982...)

• Photoionized
  • Cloudy  Ferland, 1980s or before
  • SPEX    (From Meka code; Mewe 1972)
  • XSTAR   (Kallman & McCray 1982)
  • Mocassin, others
The ‘Lorentz Meeting’

At this meeting, we developed recommendations for a baseline set of model calculations that could be performed by all or most plasma models, with clearly specified temperatures, densities, plasma compositions and output formats.

Lorentz Tests (Equilibrium)

- **CIE-CSD** Charge State Distribution in equilibrium with electron density $10^6$ m$^{-3}$ and three temperatures: $10^6$K, $6 \times 10^6$K, and $4.642 \times 10^7$K (=4 keV). These temperatures correspond to typical values for the Sun, Capella, and Perseus cluster.

- **Power** Total radiative power in ergs/s from a 1 m$^3$ plasma with $n_e = 10^6$ m$^{-3}$ for proto-Solar gas over the range 13.6 eV to 13.6 keV. Done per element, over $T=10^4$-$10^9$K in 51 log steps.

- **StrongLines** The 100 strongest lines with $\lambda<1000$Å, in photons/s, from a 1 m$^3$ plasma in the same state as CIE-CSD

- **PI-CSD** The CSD and electron temperature at $\log(\xi) = 1, 2, 3$ for an optically thin $10^8$ cm$^{-3}$ proto-Solar plasma excited by a single power law ionizing continuum with $\Gamma=2$ and low and high energy cutoffs are 0.1 eV and 1 MeV, with a central source with $L_{bol} = 2.76 \times 10^{43}$ erg/s.

- **PI-Lines** The lines with the largest optical depth from each ion at $\log(\xi) = 1, 2, 3$ for the same case as PI-CSD

- **PI-HeatCool** The heating and cooling rates (both total and broken down by contributing process) at $\log(\xi) = 1, 2, 3$ for the same case as PI-CSD.

- **PI-Abs** The absorption spectra at $\log(\xi) = 1, 2, 3$ for the same case as PI-CSD.
Lorentz Tests (Non-Equilibrium)

• **NEI-CSD** Charge State Distribution of proto-Solar gas from a non-equilibrium plasma at constant volume and $n_e=10^6\text{m}^{-3}$ at $10^4\text{K}$, raised to $2.32\times10^7\text{K}$ (=2 keV) and allowed to evolve for a fluence $n_e \times t = 10^{10}\text{cm}^{-3}\text{s}$. This corresponds, roughly, to a Cas A-type supernova remnant.

• **NEI-Lines** The 100 strongest lines with $\lambda < 1000\text{Å}$ from a 1 m$^3$ plasma with $n_e=10^6\text{m}^{-3}$ for proto-Solar gas and allowed to evolve as per NEI-CSD.

• **NEI-Cont** The spectrum from 10 eV to 10 keV of a 1 m$^3$ plasma $n_e=10^6\text{m}^{-3}$ for proto-Solar gas that starts in equilibrium at $T_e = 3.5\text{ keV}$, then jumps to $T_e = 1.5\text{ keV}$ and the plasma evolves to a fluence $n_e \times t = 10^{10}\text{cm}^{-3}\text{s}$. This model corresponds, roughly, to the recombinating SNR W49B.

• **LevelPop** For 17 ‘key’ X-ray lines, the line flux and formation method in photons/s, from a 1 m$^3$ proto-Solar gas plasma with densities $10^6\text{m}^{-3}$ and $10^{18}\text{m}^{-3}$ (=10$^{12}\text{cm}^{-3}$) at $10^6$, $6\times10^6\text{K}$, and $4.642\times10^7\text{K}$ (=4keV). Formation methods include electron [de-]excitation, proton [de-]excitation, radiative decay into/out of the level, radiative recombination into the level, dielectronic recombination into the level, and inner shell ionization/excitation into the level.
CIE-CSD

ALL RESULTS ARE PRELIMINARY

- AtomDB
- SPEX
- Chianti
- ADAS
CIE-CSD

ALL RESULTS ARE PRELIMINARY
NEI-CSD

ALL RESULTS ARE PRELIMINARY
POWER
(Oxygen)

ALL RESULTS ARE PRELIMINARY

ADAS+2.5 at $n_e=5\times10^7$ cm$^{-3}$

Log Emissivity (erg cm$^2$ s$^{-1}$)

Log $T(K)$

AtomDB  SPEX  Chianti  ADAS+2.5  SASAL
POWER (Iron)

ALL RESULTS ARE PRELIMINARY
Strong Lines

Comparing SPEX to AtomDB

ALL RESULTS ARE PRELIMINARY
Strong Lines

Comparing SASAL to AtomDB

ALL RESULTS ARE PRELIMINARY
Strong Lines

Comparing Chianti to AtomDB

ALL RESULTS ARE PRELIMINARY