Throwdown:
A Comparison of N-level Atom Codes

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Introduction

A modest number of 5-level atom codes have been developed over the past few decades, more or less independently, that compute level populations & volume emissivities for low-lying levels of common ions. This permits the derivation of T_e, N_e, and ionic abundances for collisionally excited species. Lately the developers of **nebular** and **ELSA** have begun a detailed comparison:

- To verify correct functionality
- To compare feature sets
- To develop regression test suites
- To identify issues with the input atomic data

Nebular vs. ELSA

Nebular* is a package within IRAF/STSDAS

- Heritage is FIVEL program of De Robertis, Dufour & Hunt (1987)
- Is an N-level atom "toolbox" for analyzing CELs in ~3 dozen ions
- Computes T_e, N_e for a variety of ground-state electron configurations, using default or user-defined transitions
  - Can compute diagnostics, abundances separately for up to 3 zones of ionization
- Completely data driven
  - FITS tables for atomic data, which are stored ~as they appear in literature
  - ASCII configuration files
- Includes plotting/data visualization
- Can be scripted; fairly robust error trapping
- CGI version offered on Web

*Shaw & Dufour (1995, PASP, 107, 896)

Nebular vs. ELSA

ELSA is a stand-alone C program

- 5-Level atom code developed by R. Henry, which was augmented by K. Kwitter, with technical development by M. Johnson & J. Levitt.
- Automates workflow from IRAF-based log of spectral line measurements to LaTeX tables of intensities, diagnostics, ICFs, & abundances
- Computes extinction, physical diagnostics & abundances from a selected set of transitions
- Also computes He abundance from recombination lines
- Adding/updating atomic data possible, but requires new code and/or recompilation

Initial Experiments

Given identical input, do we derive the same ionic abundances?

- Compute T_e, N_e and abundances, given particular emission line intensities from 2 planetary nebulae
  - We rapidly found that the codes arrive at diagnostics differently
  - Disagreement at the 5—50% level, mostly because of different T_e
- Compute abundances, given fixed T_e, N_e
  - Results mostly agree at the 2—10% level
  - Some discrepancies (e.g., [Cl III], [S III]) identified, may be related to choice of atomic data

Where to Go from Here…

The initial comparisons did not explore a large range in nebular properties (T_e+N_e); and did not include a very wide range of ions, transitions, or diagnostics. Also, the comparison was somewhat labor intensive.

What I would like to see going forward:

- Generation of multiple reference data sets
  - Could come from observations, Cloudy model, or be entirely fictitious
- Include more N-level atom codes
  - R. Wesson & G. Ferland have signed on
- Cover a more complete set of transitions for all available ions
- Automate the regression testing of the N-level atom codes
- Generate visual & tabular reports of the tests

Final Objectives

The comparison of these codes is in an early phase, but we intend to publicize our results and make the effort reproducible and, perhaps, routine

- Present results at the IAU PN Symposium
  - July 2011, at IAC
- Make public the reference atomic dataset
- Re-run results whenever code or supporting atomic data change
- Perhaps set up a web-based interest group