CHIANTI

An Astrophysical Database for Emission Line Spectroscopy

CHIANTI TECHNICAL REPORT No. 24

The CHIANTI level-resolved recombination files (rrlvl)

Ver 1.0, 22 February 2019, Peter Young

For CHIANTI version 9 a new file type with the suffix ".rrlvl" was added. This contains level-resolved radiative recombination data, but there is crucial difference with the existing ".reclvl" files.

1 The difference between rrlvl and reclvl files

The rrlvl files contain rate coefficients for direct radiative recombinations from the recombining ion to the recombined ion. The reclvl files contain effective radiative recombination rate coefficients.

Consider the case of a CHIANTI model that has 10 levels. There is direct recombination from the ground state of the recombining ion to level 10. This rate coefficient (α_{10}) goes in the rrlvl file.

Now, suppose that the calculation that produced the recombination rate coefficients also had additional levels 11 through 100 that are not part of the CHIANTI model. Further suppose that, after recombining into level 100, there is a radiative decay to level 10. This is an additional population mechanism for level 10 that can not be directly included in the CHIANTI model. However, we can write the radiative recombination rate coefficient for level 10 as $\alpha^*_{10}= \alpha_{10}+\alpha_{100}A_{100,10}$ (where is A is the radiative decay rate). This *effective* rate coefficient goes into the reclvl file.

A CHIANTI ion should have *either* a rrlvl file, *or* a reclvl, but not both. Many ions do not have either file.

The reclvl files were introduced in CHIANTI 5 (Landi et al., 2006, ApJS, 162, 261). There is a plan to replace these data-sets with the direct recombination data, which began with CHIANTI 9.

2 File format

The rrlvl file has a *free format*, so will be successfully read as long as there is white space separating the columns.

For each transition there are two lines of data. The first gives the temperatures at which the rates are tabulated, and the second line gives the rates.

2.1 Line 1 format

Column 1 – atomic number

The atomic number of the ion. Not read by the software.

Column 2 – spectroscopic number

The spectroscopic number of the ion. For example, 22 corresponds to XXII. Not read by the software.

Column 3 – index of the initial state

This is the level index of the recombining ion and thus should match the correct level index of the recombining ion model.

Column 4 – index of the final state

The index of the final level of the transition in the recombined ion.

Columns 5 onwards – temperatures

The temperatures at which the rates are tabulated. Note that, although each transition has its own temperature array, in practice the software assumes all transitions have the same temperature array.

2.2 Line 2 format

Column 1 – atomic number

The atomic number of the ion. Not read by the software.

Column 2 – spectroscopic number

The spectroscopic number of the ion. For example, 22 corresponds to XXII. Not read by the software.

Column 3 – index of the initial state

This is the level index of the recombining ion and thus should match the correct level index of the recombining ion model.

Column 4 – index of the final state

The index of the final level of the transition in the recombined ion.

Columns 5 onwards – rate coefficients

Direct radiative recombination rate coefficients in units of $cm^3\ s^{-1}$, defined for the temperatures given on line 1.

Comments section

The comments section begins with a '-1' on a single line. The comments are in free format. The comments section is then closed with a '-1' on a single line.

3 Reading the rrlvl files

The rrlvl files are read with read_rrlvl.pro. As an example, the calling sequence for O VI is:

```
IDL> zion2filename,8,6,fname
IDL> rrdata = read_rrlvl( fname, status )
```

The output *rrdata* is a structure and the tags are given in Table 1. The optional output *status* is an integer with value 1 if the file was successfully found and read and 0 otherwise.

Although a temperature array is provided for each transition, the output temperature array is only 1D. Therefore there is an implicit assumption that *the temperature array is the same for all transitions.* The temperature array returned by read_rrlvl actually corresponds to the first transition of the reclvl file.

Table 1. Structure tags of the output from the read_rrlvl.pro routine.

Output	Data	Type
RATE	Recombination rates	Double [ntrans, ntemp]
TEMP	Ionization rates	Float [ntemp]
FINAL_LEVEL	Level index in the recombined ion	Integer [ntrans]
INITIAL_LEVEL	Level index in the recombining ion	Integer [ntrans]
REF	File comments	String array

Appendix

1 Update history

Ver. 1.0, 22-Feb-2019: document created.