Background to ADAS

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Atomic physics and fusion plasmas

Atomic physics plays a significant role
in many aspects of fusion plasma analysis.

- Atomic physics is key to understanding spectra and hence determination of important parameters.
- Atomic physics supplies the source terms for impurity/trace transport modelling.
- Cooling curves, arising from atomic physics, show the limits of allowable impurity concentrations.
- eg Pink, D_α, n=3–2 emission in JET.

JET #75689 @ t=63.25s

Quantitative measurement demands accurate atomic data.

Atomic physics and fusion plasmas

- Consider a 'typical' atom/ion in a 'typical' fusion plasma.
- The atom/ion could be:
  - in the core plasma behaving itself?
  - interacting with a surface?
  - in a beam?
  - being hit by a beam?

No such thing as a 'typical' atom

- Whatever its behaviour, it will be emitting light/radiation in some form or another:
  - Quenching the plasma?
  - Giving key diagnostic information?
  - Radiatively cooling a divertor?

Important to understand the emission

- Let's first look at how light from ions in a plasma comes about...

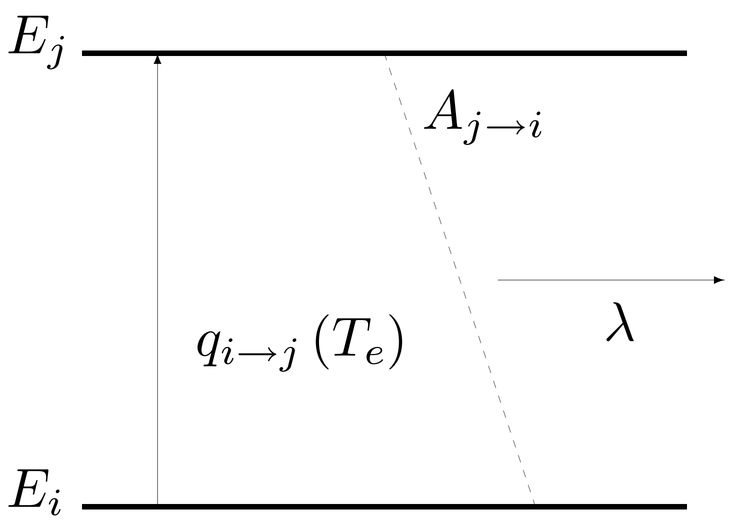
Coronal Model

Fairly simple model: an atom or ion is excited by an electron collision to an upper state and then radiatively decays giving off a photon.

- Emission can be written as:

$$\epsilon_{i\to j} = N_e q_{i\to j}\left(T_e\right) A_{j\to i} / \sum_l A_{j\to l}$$

- Linear density dependence.
- Widely used in astrophysics (e.g. in the solar *corona*) where it's **usually appropriate**.
- Sometimes used in fusion where it's **often inappropriate**.



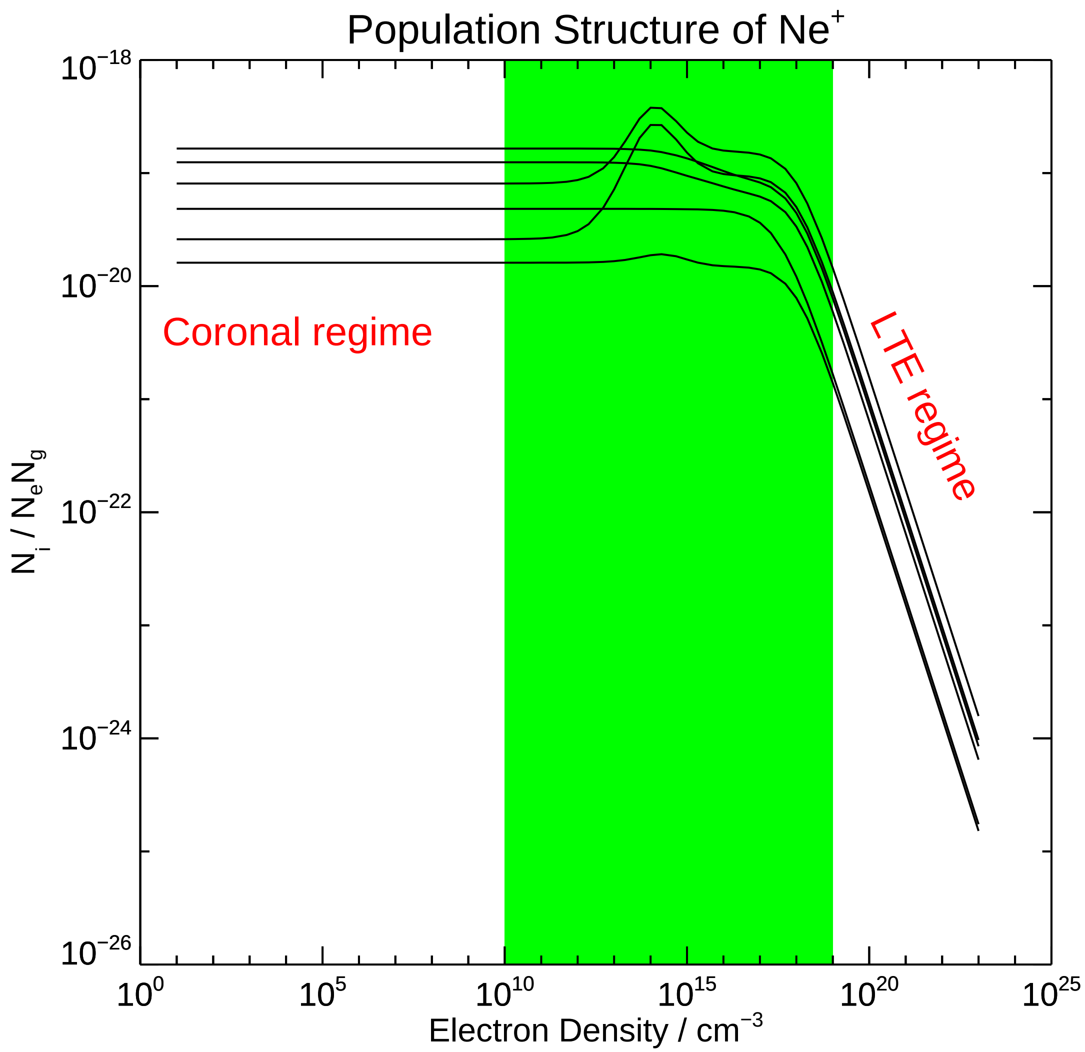
Local Thermodynamic Equilibrium — LTE

The other extreme: statistical populations.

$$N_j \propto e^{-\frac{E_j}{kTe}}$$

- The emission can be written as: $\epsilon = A_{j\to i} e^{-\frac{E_j}{kTe}}$
- Not really applicable in fusion plasmas (although sometimes used).
- Applies in high density plasmas (laser produced, centre of sun etc.).
- No dependence on density.

Magnetically Confined Plasmas



Between the two extremes (Coronal and LTE) there exists a more complicated regime. For many ions this is right at fusion plasma densities.

This is called the collisional–radiative regime.

Atomic Data Provision

ADAS — Atomic Data and Analysis Structure — addresses the atomic requirements for plasma modelling.

What is ADAS?

- ADAS, as a database delivers:
  - extensive fundamental and derived data tuned for plasma modelling and spectroscopic analysis,
  - provides ‘baseline’ level data for any element and ion stage.
  - makes data available on http://open.adas.ac.uk (with IAEA).
- ADAS, as a computer system, is designed to:
  - provide codes which are easy to use,
  - provide subroutine libraries for inclusion in other codes,
  - allow direct access to diagnostically relevant data.
- ADAS, as an organisation:
  - provides guidance (training courses, visits etc.) on running codes,
  - gives recommendation on the best data to use,
  - assists in analysis and development of analysis tools and models.

The ADAS Project

- The ADAS Project is a self-funding (i.e. funded by participants) project consisting of most major fusion laboratories along with other astrophysical and university groups. In its present incarnation it is over fifteen years old but the roots in JET go back almost twenty-five years.
- As an implementation, it is an interconnected set of computer codes and data collections for modelling the radiating properties of ions and atoms in plasmas.
- Historical roots are in fusion (JET) and so are the bulk of the users/members. Has also been extensively applied to astrophysics.
- Is governed by a steering committee coming from its members. Day to day running and implementation is done by the University of Strathclyde.

The ADAS members

Site	Country	Contact Person
Armagh Observatory	UK	Gerry Doyle
Central Electronics Engineering Research Institute	India	Ram Prakash
Centre de Recherches en Physique des Plasmas	Switzerland	Basil Duval
Commissariat à l'énergie atomique Caderache	France	Rémy Guirlet
Consorzio RFX	Italy	Marco Valisa
FOM — Instituut voor Plasmafysica Rijnhuizen	Netherlands	Gerard van Rooij
Forschungszentrum Jülich	Germany	Phillipe Mertens
General Atomics	USA	Todd Evans
INAF — Osservatorio Astrofisico di Catania	Italy	Alessandro Lanzafame
Institute for Plasma Research	India	Parameswaran Vasu
ITER	-	Richard Pitts
Japan Atomic Energy Agency	Japan	Tomohide Nakano
JET	EU	Martin O'Mullane
Kungliga Tekniska Högskolan	Sweden	Elisabeth Rachlew
Max-Planck-Institut für Plasmaphysik	Germany	Thomas Pütterich
National Fusion Research Institute	Korea	Mi-Young Song
National Institute for Fusion Science	Japan	Takako Kato
Nat. Inst. for Laser, Plasma & Radiation Physics	Romania	Viorica Stancalie
Oak Ridge National Laboratory	USA	Dave Schultz
Princeton Plasma Physics Laboratory	USA	Doug McCune
RRC Kurchatov (ITER Domestic Agency)	Russian Federation	Sergei Tugarinov
Southwestern Institute of Physics	China	Xuru Duan
STFC Rutherford Appleton Laboratory	UK	Andrzej Fludra
CCFE	UK	Martin O'Mullane
University of Auburn	USA	Mitch Pindzola
University of Strathclyde	UK	Hugh Summers
University of Toronto	Canada	Peter Stangeby
University of Texas	USA	Bill Rowan
University of Wisconsin	USA	Daniel Den Hartog

Size and Scope of use

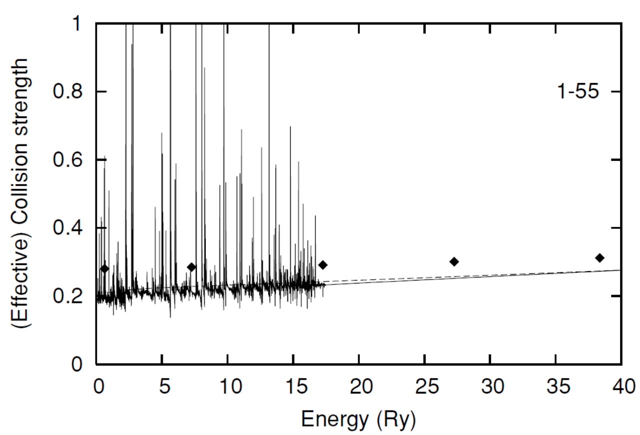
Rough idea of the computational ‘size’ of ADAS:

- 5.8GB of data in 26,774 distinct files,
- 422,967 lines of Fortran and 400,776 lines of IDL,
- also contains C, Perl, csh, Matlab and C++ code,
- tentative plans to expand to support Python.
- Integrated into key fusion transport codes (Strahl, JETTO, EDGE2D, SOLPS, CHEAP etc.).

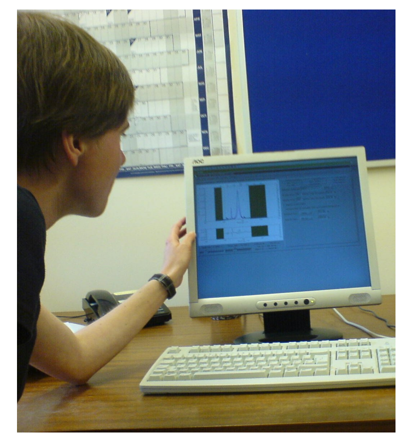
The recent work on heavy species, in particular tungsten, increases the size of the database considerably.

Two worlds

Fundamental data



Derived data



Some ADAS data classes

11 of the 40 ADAS data classes

Class	Description	Files	S ize
ADF01	Charge exchange cross sections	118	3.0 MB
ADF04	Resolved specific ion data collections	2102	3.1 GB
ADF07	Electron impact ionisation coefficients	67	1.8 MB
ADF08	Radiative recombination coefficients	100	2.6 MB
ADF09	Dielectronic recombination coefficients	1787	1.2 GB
ADF11	Iso-nuclear master files	343	50 MB
ADF12	Charge exchange emission coefficients	45	2.0 MB
ADF13	Ionisation per photon coefficients	153	38 MB
ADF14	Thermal charge exchange	12	308 kB
ADF15	Photon emissivity coefficients	173	77 MB
ADF21	Effective beam stopping coefficients	218	4.4 MB
ADF22	Effective beam emission coefficients	402	7.6 MB

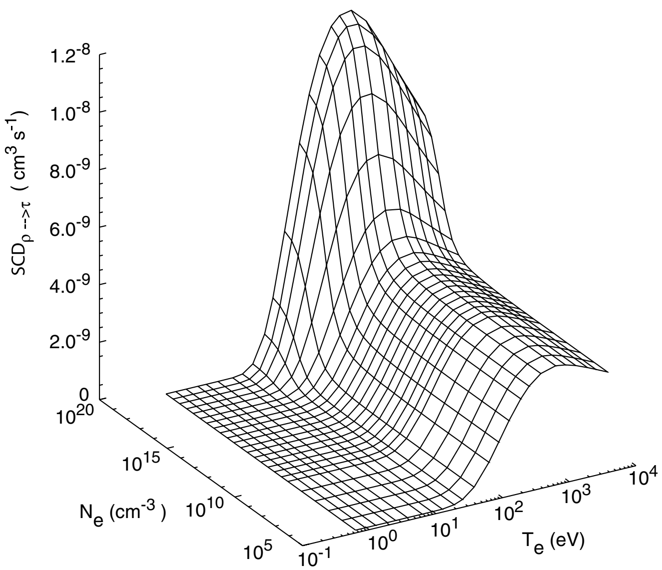
Some ADAS data class examples

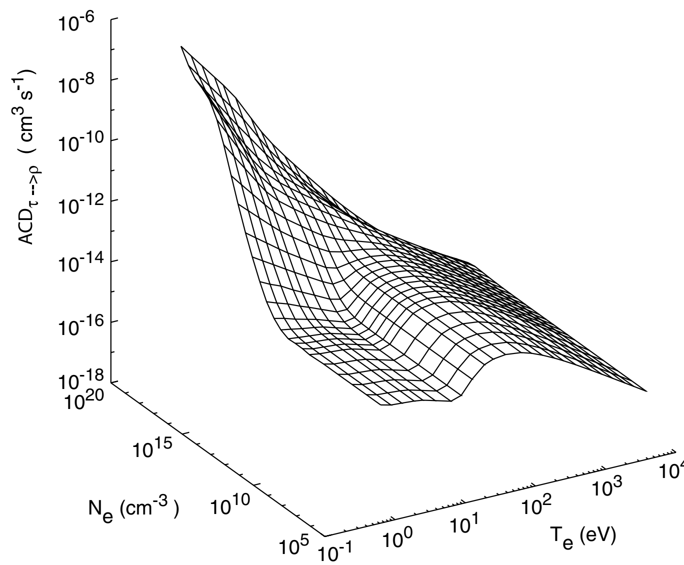
SCD

$O^{3+}2s^22p\ ^2P$

$\downarrow$

$O^{4+}2s^2\ ^1S$





ACD

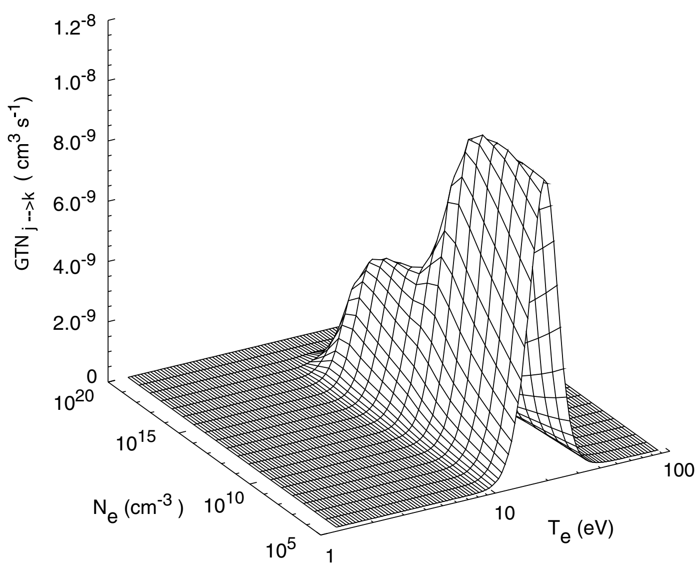
$O^{4+}2s^2\ ^1S$

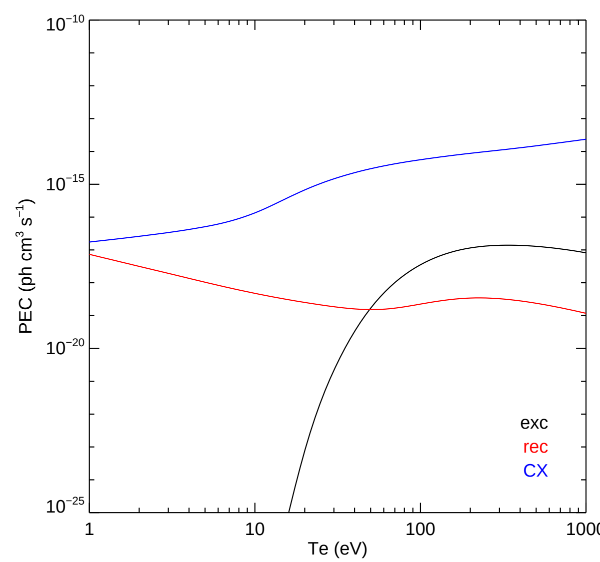
$\downarrow$

$O^{3+}2s2p^2\ ^4P$

GTN

O^{1+} 629.7Å





PEC

C^{4+} 35.0Å