R-matrix electron-impact excitation data for the C-like ions

Junjie Mao

N. R. Badnell, G. Del Zanna

junjie.mao@strath.ac.uk
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Plasma diagnostics
- Abundance
- Density
- Temperature
- Velocity

Plasma codes
- AtomDB
- CHIANTI
- Cloudy
- SPEX
- XSTAR

... ...
Electron-impact excitation

Plasma codes are built on a large and ever-increasing amount of atomic data

- **(de-)Excitation**
  - Electron
  - Proton
- **Ionization**
  - Photon
  - Electron
- **Recombination**
  - Radiative + dielectron
  - Charge exchange

... ...

Adapted from Hitomi atomic paper, 2018, PASJ, 70, 12
Atomic database

- **Ion resolved (SPEX)**
  - H-like ions (interpolation)
  - C-like and Ne-like (patchy)
  - N-like to F-like only Fe & Ni

- **Level resolved (CHIANTI)**
  - Low-lying levels (more RM data)
  - High-lying levels (more DW data)
  - Temperature range (extrapolation)

Complete and accurate (not yet)
UK APAP network (PI: NRB)

- Li-like (Liang & Badnell 2011)
- Be-like (Fernandez-Menchero et al. 2014a)
- B-like (Liang et al. 2012)
- C-like (Mao et al. 2020)
- N-like (Mao et al. to be subm.)
- O-like (Mao et al. in prep.)
- F-like (Witthoeft et al. 2009)
- Ne-like (Liang & Badnell 2010)
- Na-like (Liang et al. 2009)
- Mg-like (Fernandez-Menchero et al. 2014b)

- 590/725/640 levels (~ $10^5$ transitions) for each C/N/O-like ion
- Rates over 6 decades in kT
- Ions up to Zn for each sequence
AS + ICFT

Structure
- AS: AUTOSTRUCTURE (Badnell 2011)
- MCHF, GRASP, FAC, CIV3, SS, ...

Scattering
- ICFT: Intermediate coupling frame transfer (Griffin et al. 1998)
- BSR, DARC, BPRM, ...

Other good RM data for low-charge ions are recommended to use

N-like O II
- M20: Mao et al. 2020 (AS + ICFT, 725 levels)
- K09: Kisielius et al. 2009 (SS + BPRM, 5* levels)
- T07: Tayal 2007 (MCHF + BSR, 47 levels)
Diagnostics lines (solar)

Key diagnostic lines

- Mohan et al. 2003
- Del Zanna & Mason (2018)

N-like Si VIII

- M20: Mao et al. 2020 (AS + ICFT, 725 levels)
- W19: Wang et al. 2018 (AS + ICFT, 272* levels)
- T12: Tayal 2012 (MCHF + BSR, 68 levels)
- C-901: Bell et al. 2001 (CIV3 + BPRM, 22 levels)
Solar corona (NIR)

10149 Å
forbidden

236.27 Å
allowed

Ar XIII 10149/236.27 Å, 2.8 MK

R–matrix
DW

Credit: G. Del Zanna
AGN wind (X-ray)

Mao et al. 2017 (see also Kaastra et al. 2004, Miller et al. 2008)
An X-ray bright future

Electron-impact excitation RM data
- C-like ions (pub.)
- N-like ions (to be subm.)
- O-like ions (in prep.)

Other calculations & lab measurements
- Many other talks and posters in this workshop
Supplementary materials
Resonance

C-like S XI (AS + ICFT)
- X-axis: Mao et al. 2020 (590 levels)
- Y-axis: Liang et al. 2011 (254 levels)

C-like Fe XXI (AS + ICFT)
- X-axis: Badnell & Griffin 2001 (200 levels)
- Y-axis: Fernández-Menchero et al. 2020 (564 levels)
Hitomi → XRISM

Plasma codes
- AtomDB/APEC v3.08
- SPEX v3.03.00
- CHIANTI v8.0

Uncertainty
- Fe abundance: 16%
- Statistical: ~1%

Hitomi Atomic Paper, 2018, PASJ, 70, 12
**HUBS (homepage)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Expectation</th>
<th>Goal</th>
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<tbody>
<tr>
<td>Detector array</td>
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<tr>
<td>Regular grid</td>
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<tr>
<td>Central grid</td>
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<tr>
<td>Energy resolution (eV) at 0.6 keV</td>
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<tr>
<td>Regular pixels</td>
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<tr>
<td>Central pixels</td>
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<td>Effective area(^a) (cm(^2)) at 0.6 keV</td>
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<td>600</td>
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<td>FoV (deg(^2))</td>
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<td>Grasp (cm(^2) deg(^2)) at 0.6 keV</td>
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<tr>
<td>Angular resolution (HPD) (arcmin)</td>
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<td>0.7</td>
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</tbody>
</table>

\(^a\)The effective area has factored in the solid-angle-averaged throughput of the optical system, filter transmission, and detector efficiency

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NGC 5548

Kaastra et al. 2017

Mao et al. 2017

Kaasstra et al. 2017
AGN winds