AtomDB workshop 2020 (online)

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

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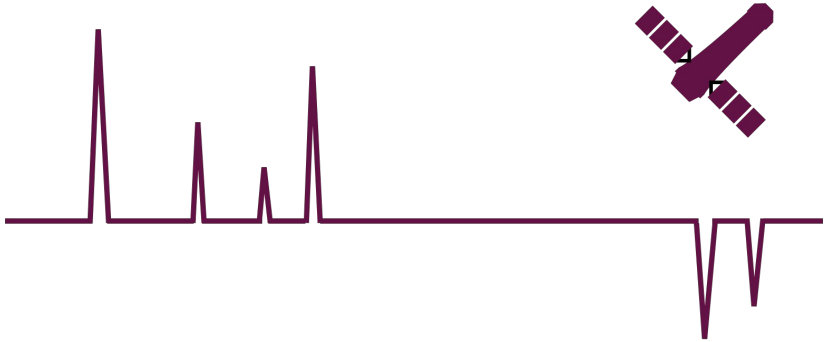
1999 2020 2030+



Plasma diagnostics

- Abundance
- Density
- Temperature
- Velocity

… …

Plasma codes

- AtomDB
- CHIANTI
- Cloudy
- SPEX
- XSTAR

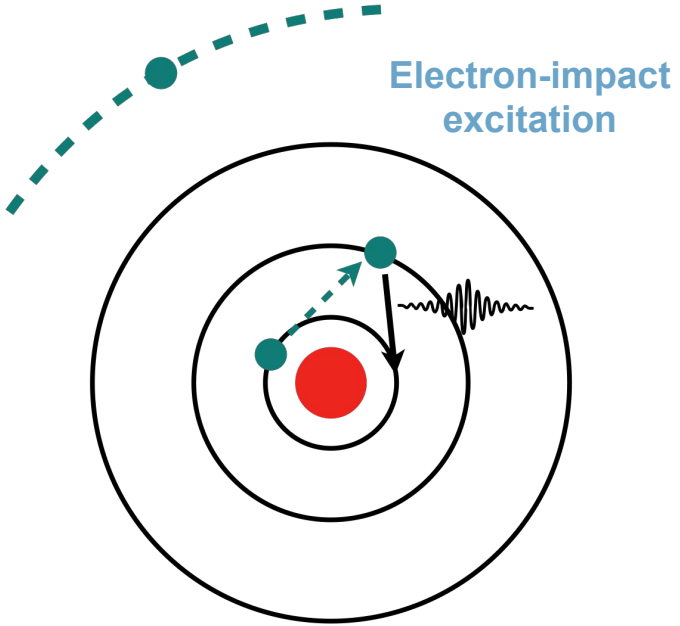
… …

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

… …

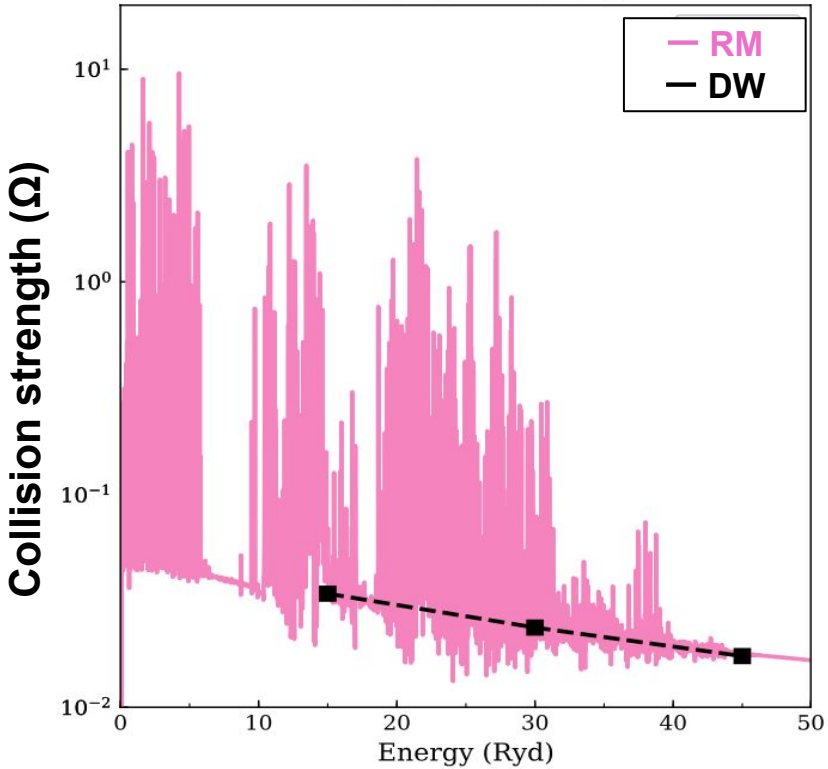


Adapted from Hitomi atomic paper, 2018, PASJ, 70, 12

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)

Index	Conf.	Index	Conf.	Index	Conf.
1	$2s^2 2p^2$	2	$2s2p^3$	3	$2p^4$
4	$2s^2 2p3s$	5	$2s^2 2p3p$	6	$2s^2 2p3d$
7	$2s2p^2 3s$	8	$2s2p^2 3p$	9	$2s2p^2 3d$
10	$2p^3 3s$	11	$2p^3 3p$	12	$2p^3 3d$
13	$2s^2 2p4s$	14	$2s^2 2p4p$	15	$2s^2 2p4d$
16	$2s^2 2p4f$	17	$2s2p^2 4s$	18	$2s2p^2 4p$
19	$2s2p^2 4d$	20	$2s2p^2 4f$	21	$2p^3 4s$
22	$2p^3 4p$	23	$2p^3 4d$	24	$2p^3 4f$
25	$2s^2 2p5s$	26	$2s^2 2p5p$	27	$2s^2 2p5d$

- **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

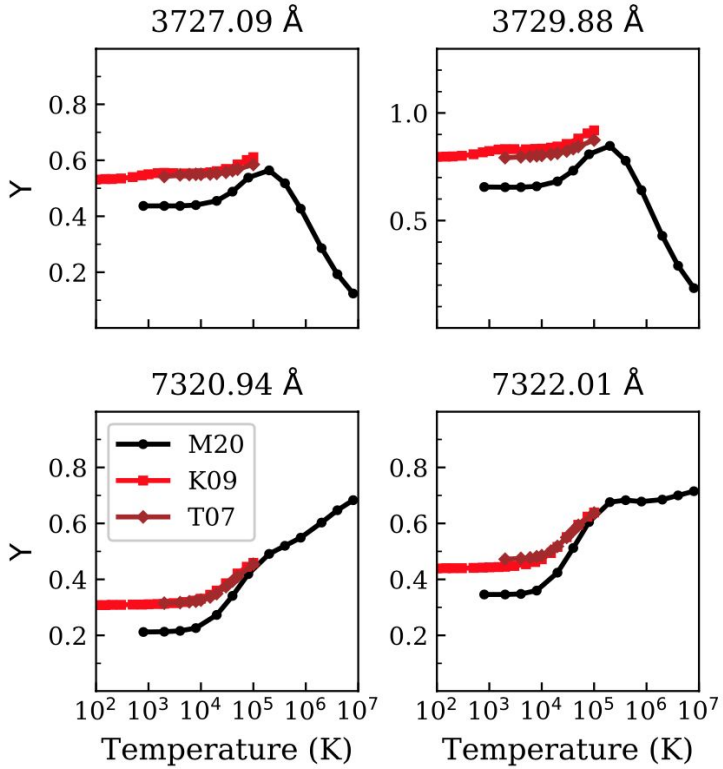
Structure

- 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)

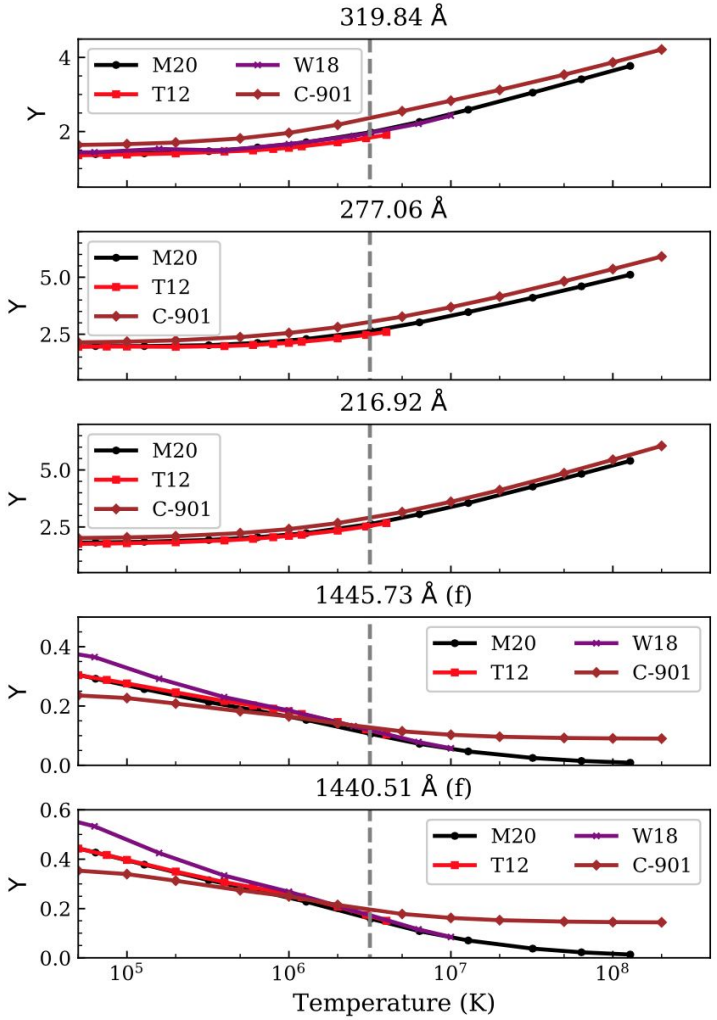
Diagnostics lines (solar)

Key diagnostic lines

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

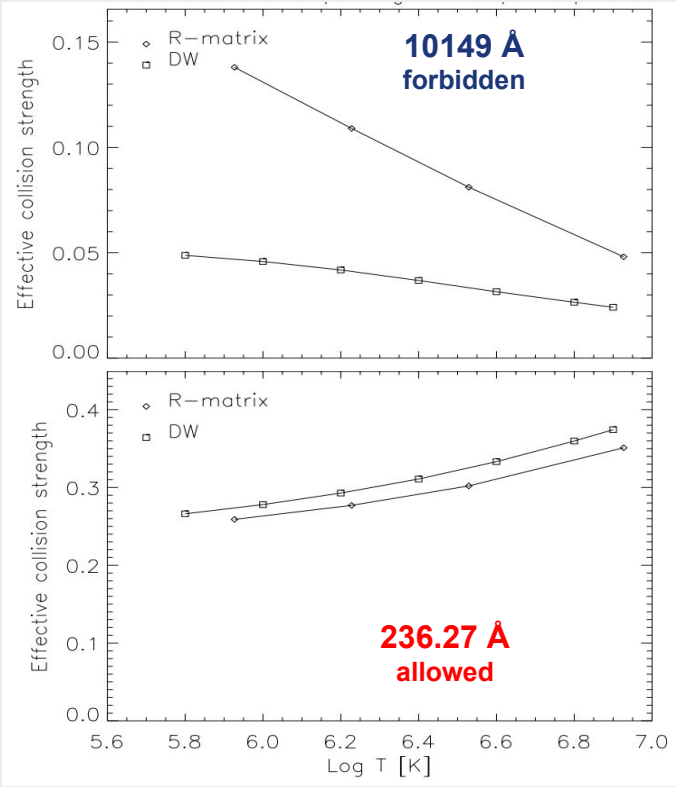
N-like Si VIII

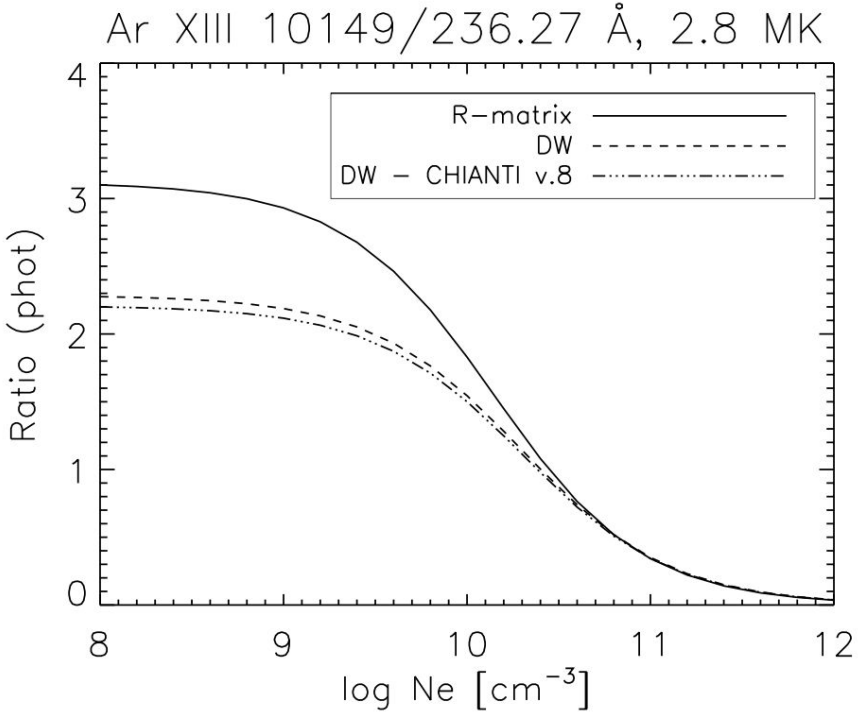
- M20: Mao et al. 2020 (AS + ICFT, 725 levels)
- W19: Wang et al. 2018 (AS + ICFT, 272* levels)
- T12: Tayal 2012 (MCHF + BSR, 68 levels)
- C-901: Bell et al. 2001 (CIV3 + BPRM, 22 levels)



Solar corona (NIR)

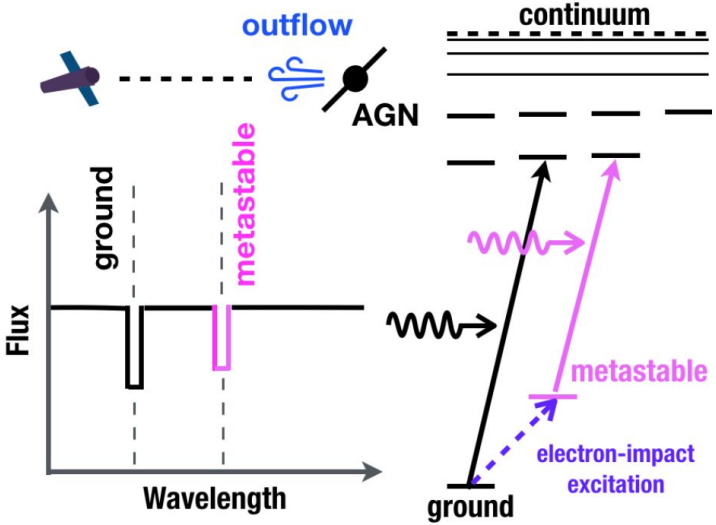
RM: Mao et al. 2020; DW: Dere et al. 1979

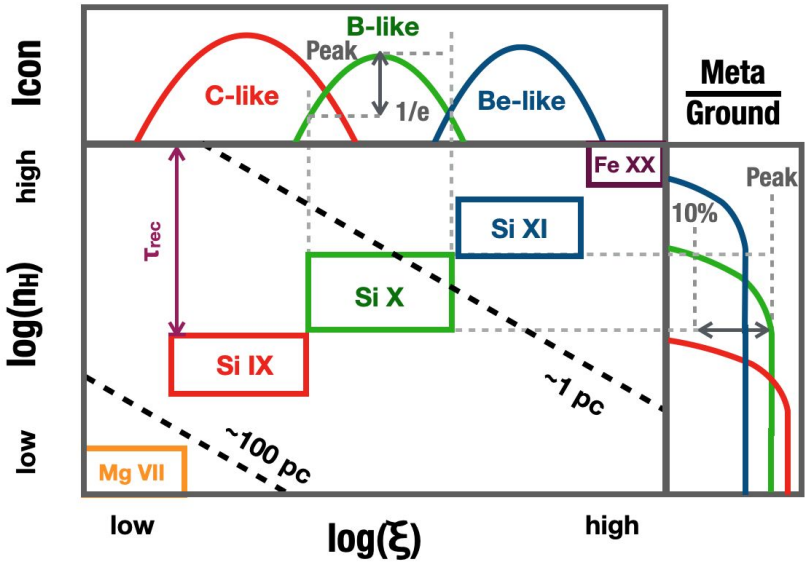




Credit: G. Del Zanna

AGN wind (X-ray)





Mao et al. 2017 (see also Kaastra et al. 2004, Miller et al. 2008)

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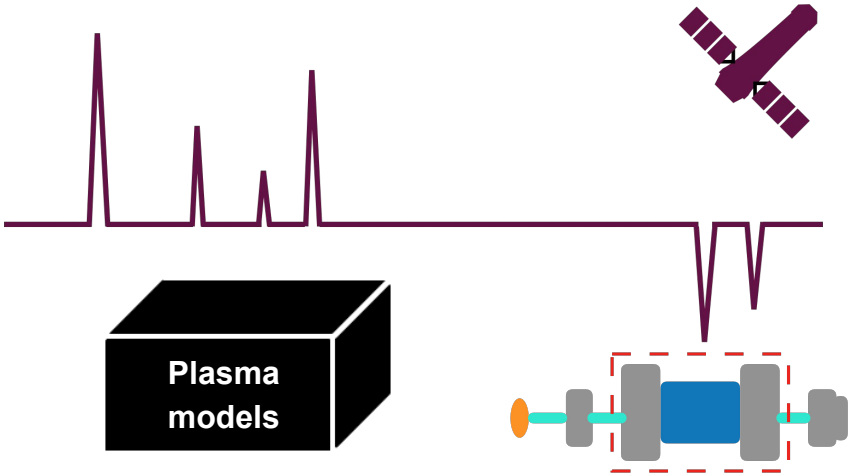
An X-ray bright future



Electron-impact excitation RM data

- C-like ions (pub.)
- N-like ions (to be subm.)
- O-like ions (in prep.)

Other calculations & lab measurements

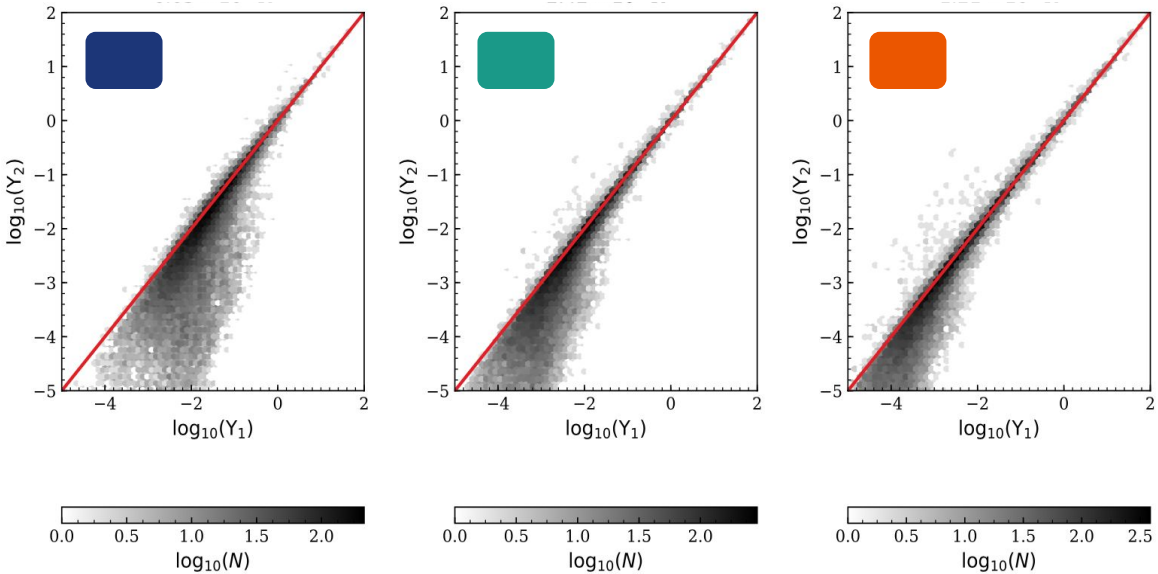
- Many other talks and posters in this workshop

Supplementary materials

Resonance

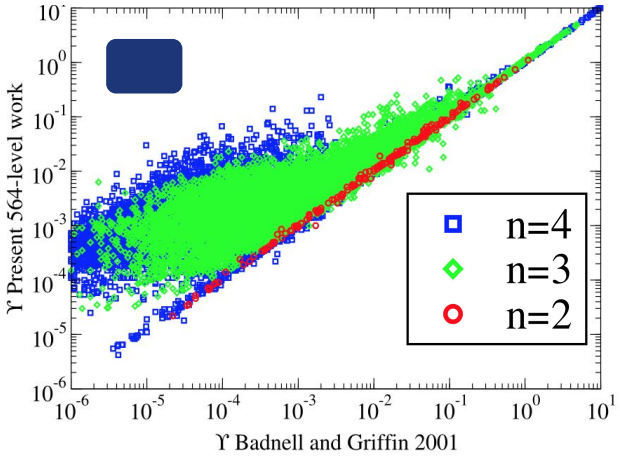
C-like S XI (AS + ICFT)

- 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)



Low T Mid T High T

Hitomi → XRISM

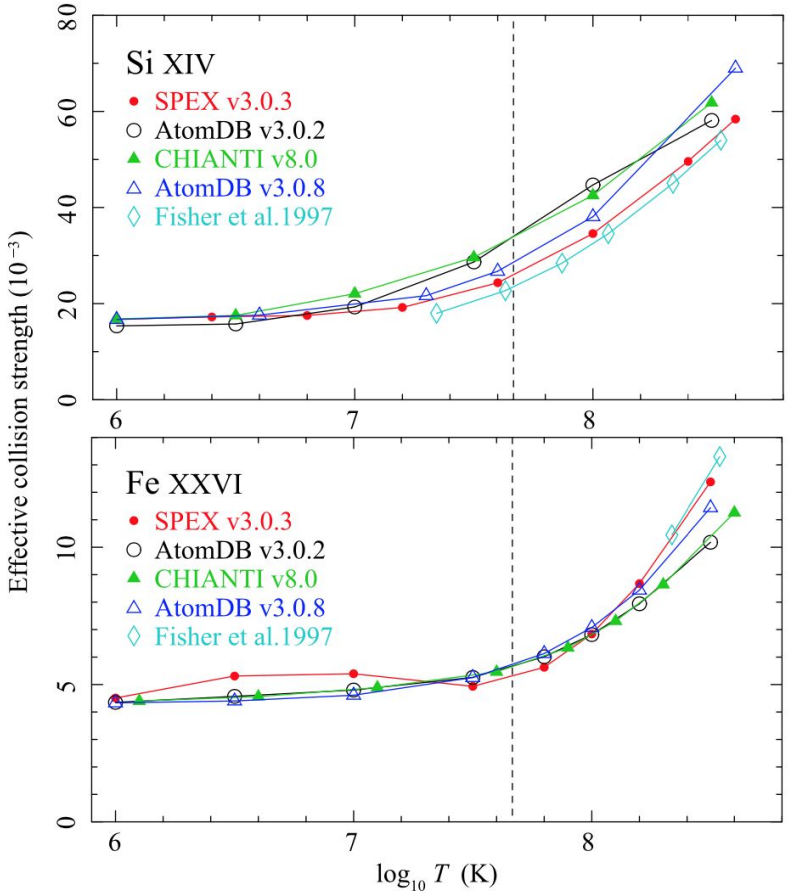
Plasma codes

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

Uncertainty

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

Hitomi Atomic Paper, 2018, PASJ, 70, 12

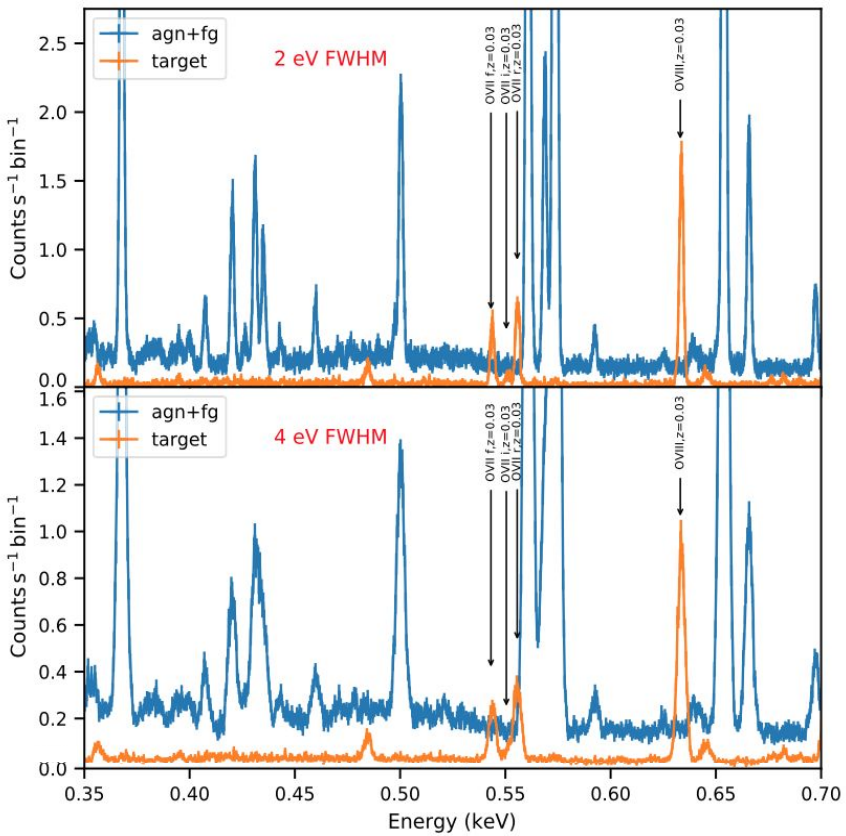


HUBS [(homepage)]

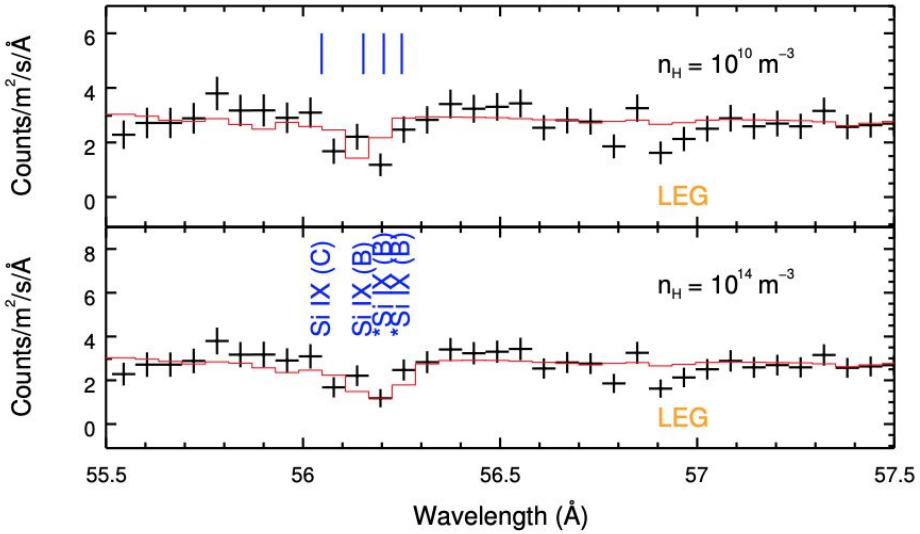
Parameter	Minimum	Expectation	Goal
Detector array			
Regular grid		60×60	
Central grid		12×12	
Energy resolution (eV) at 0.6 keV			
Regular pixels	2.5	2.0	1.5
Central pixels	1.0	0.8	0.6
Lower energy (keV)	0.2	0.2	0.1
Higher energy (keV)	1.0	2.0	2.0
Effective area[a] (cm^2) at 0.6 keV	400	500	600
FoV (deg^2)	0.8	1.0	1.2
Grasp (cm^2 deg^2) at 0.6 keV	320	500	720
Angular resolution (HPD) (arcmin)	1.3	1.0	0.7

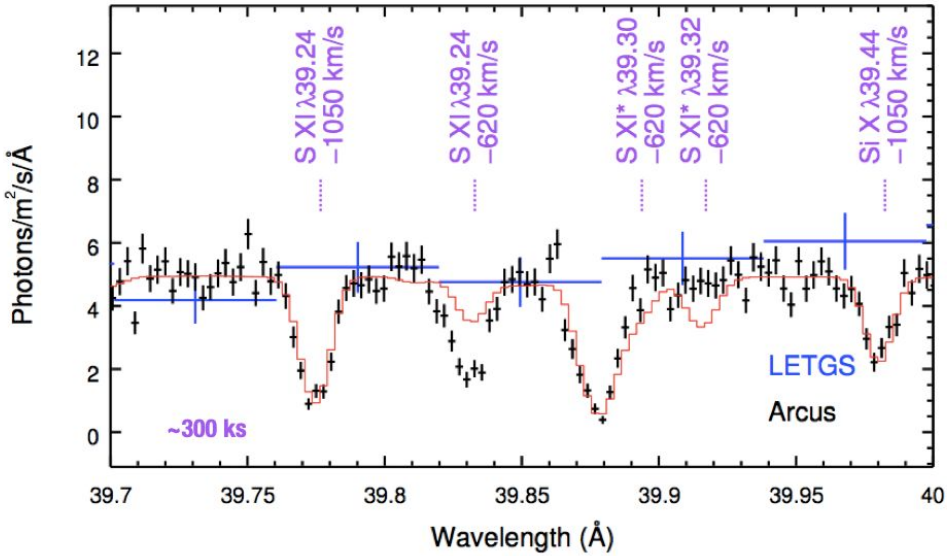
[a]The effective area has factored in the solid-angle-averaged throughput of the optical system, filter transmission, and detector efficiency

Cui et al., Journal of Low Temperature Physics (2020) 199:502–509



NGC 5548

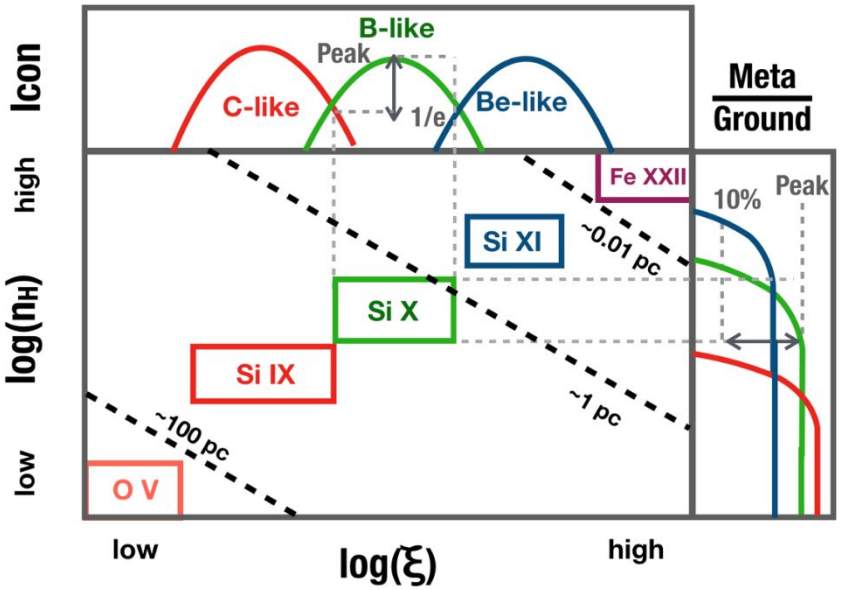


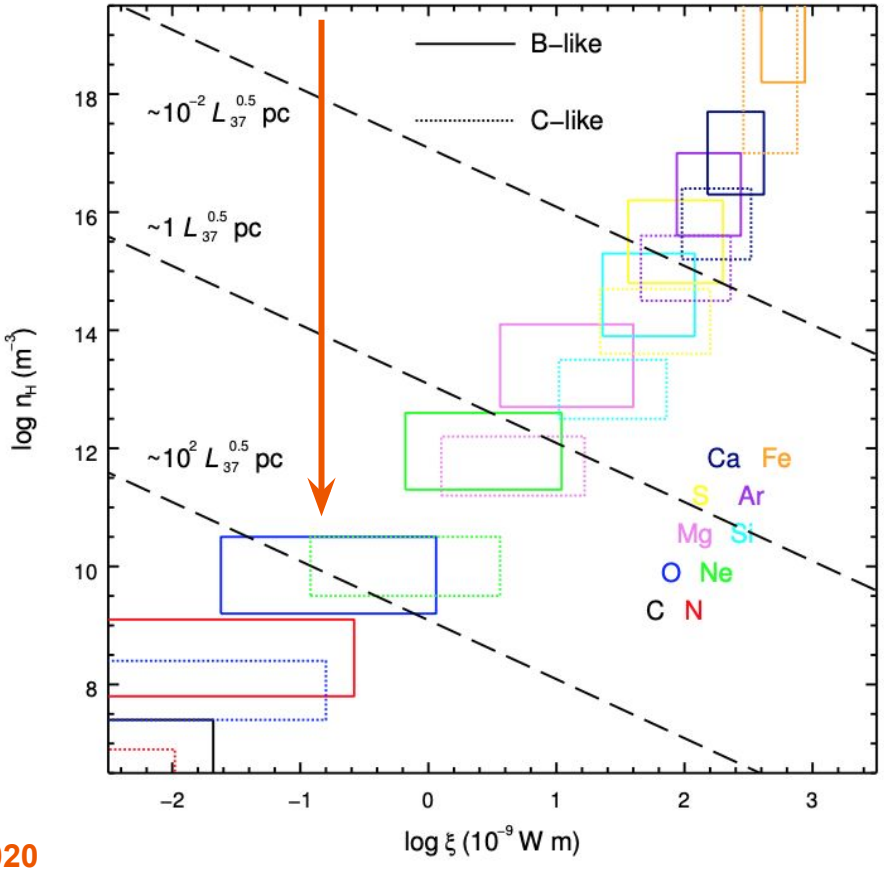


Mao et al. 2017

Kaastra et al. 2017

AGN winds





Meta: Kaastra et al. 2004, Miller et al. 2008, Mao et al. 2017
Timing: Kaastra et al. 2012, Silva e al. 2016, de Marco et al. 2020