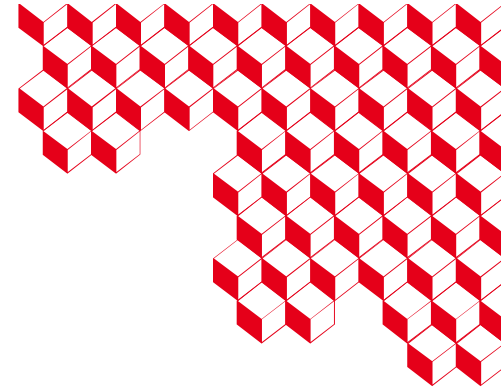


The logo for CEA (Commissariat à l'énergie atomique et aux énergies alternatives) consists of the lowercase letters 'cea' in a white, sans-serif font, positioned above a horizontal white line. This logo is set against a solid red square background.The logo for IRFM (Institut de Recherches sur les Fusions Magnétiques) consists of the lowercase letters 'irfm' in a red, sans-serif font. The logo is positioned to the right of the CEA logo, with a red L-shaped line extending from the bottom of the 'irfm' text.

Tungsten EUV lines and quasi-continua: identification and interpretation

R. Guirlet

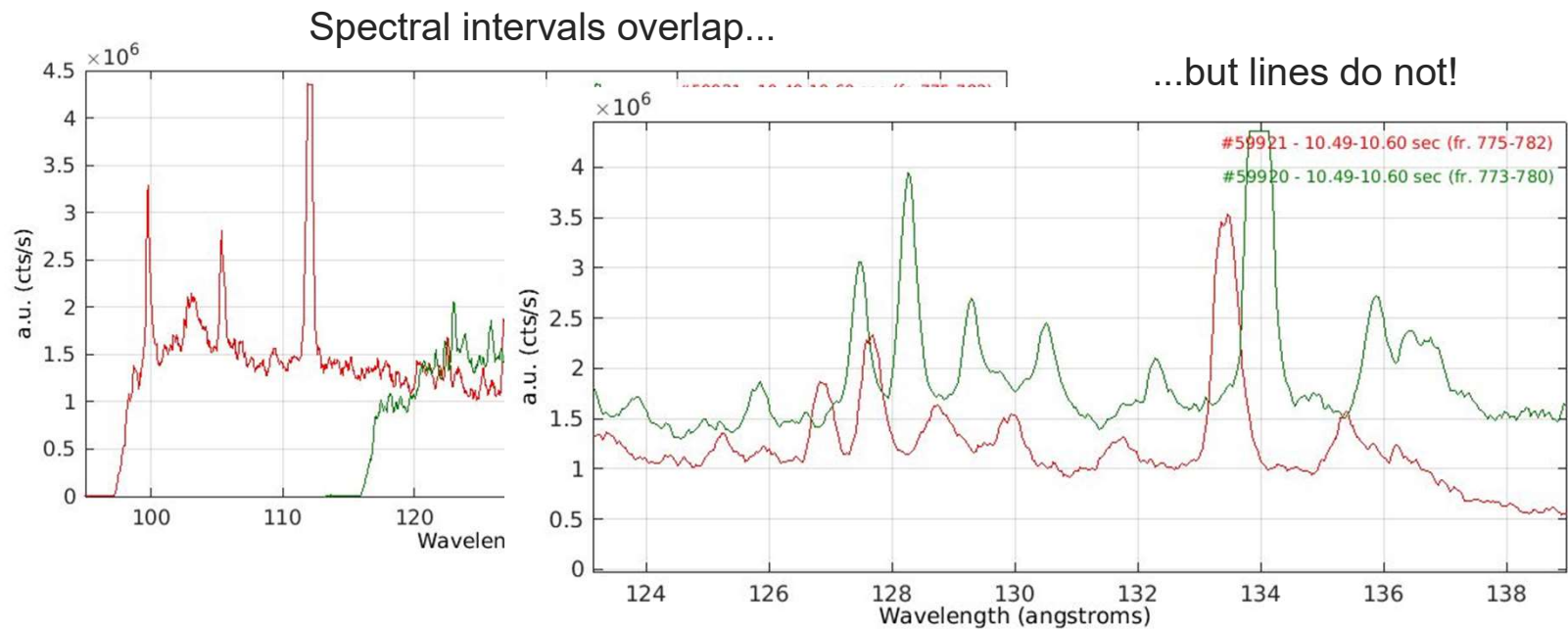
IAEA Consultancy meeting – Aug. 29-30, 2024



Line identification

- Wavelength calibration with 0.1 Å error necessary

Ex: WEST grazing incidence spectrometer with mobile detector, two identical plasmas

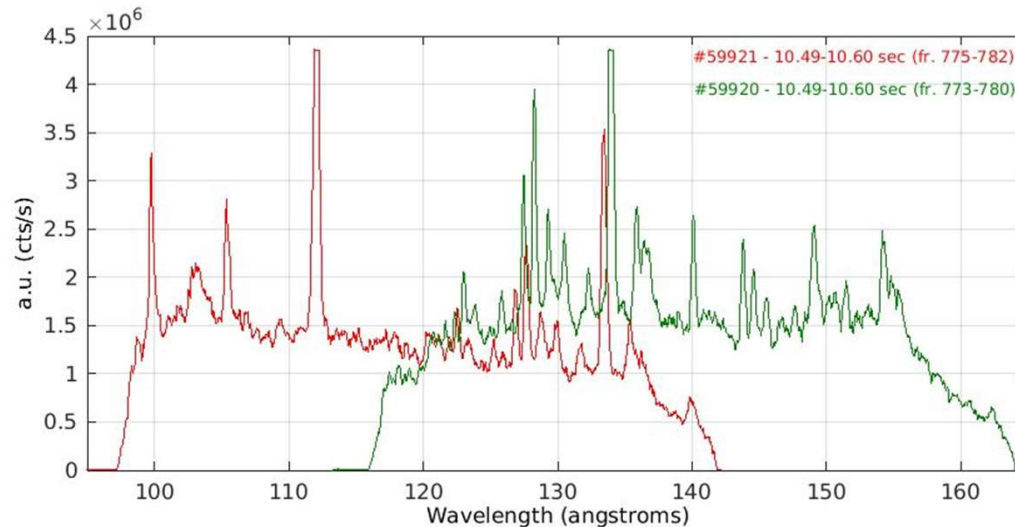




Line identification

- Wavelength calibration with 0.1 Å error necessary
- Relative calibration (i.e. pixel-to-pixel calibration) is very helpful in multiplet identification.

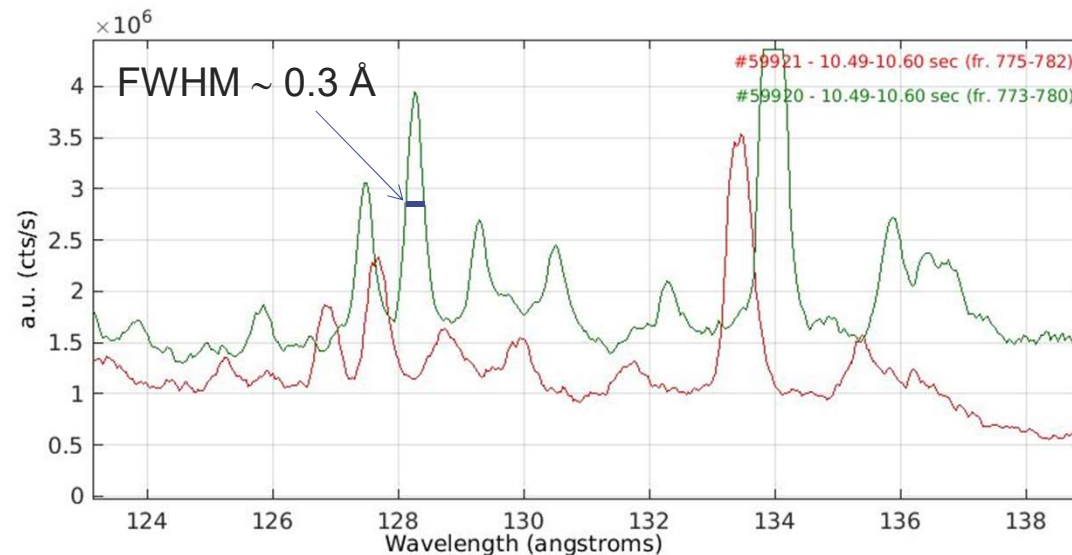
No calibration → Line 'intensities' (cts/s) and ratios depend on position on detector.





Line identification

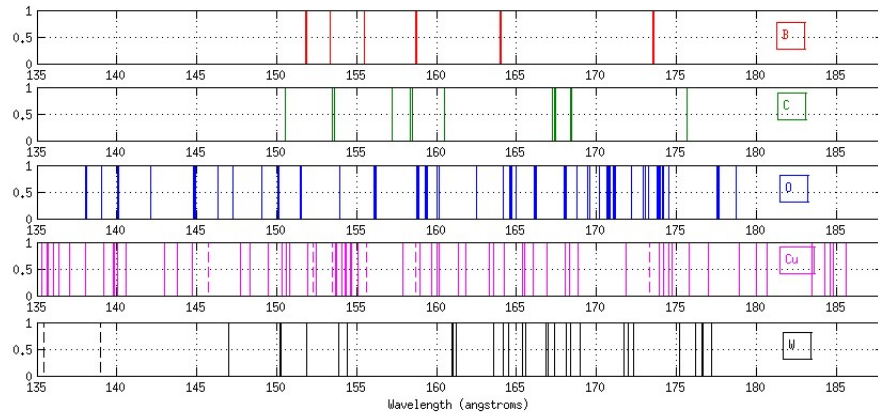
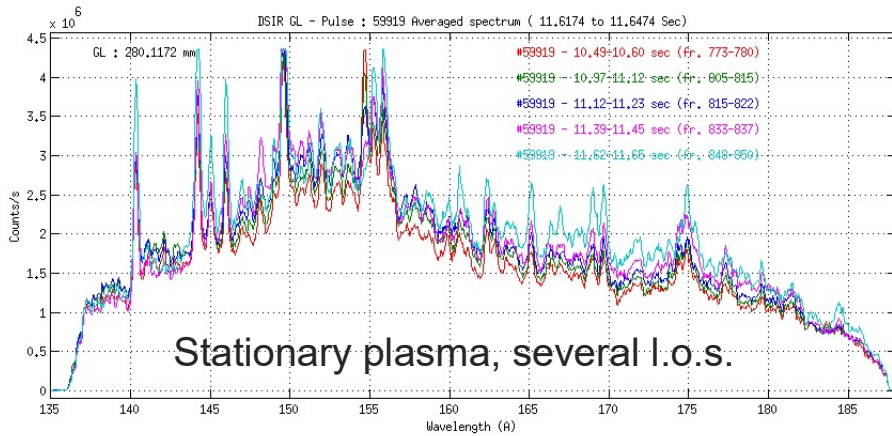
- Wavelength calibration with 0.1 Å error necessary
- Relative calibration (i.e. pixel-to-pixel calibration) is very helpful (e.g. multiplet identification).
- Spectral resolution: FWHM should be $< 0.2 \text{ \AA}$



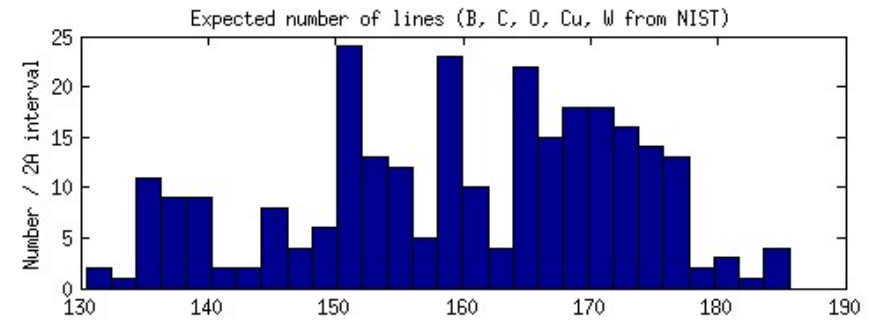


Line identification

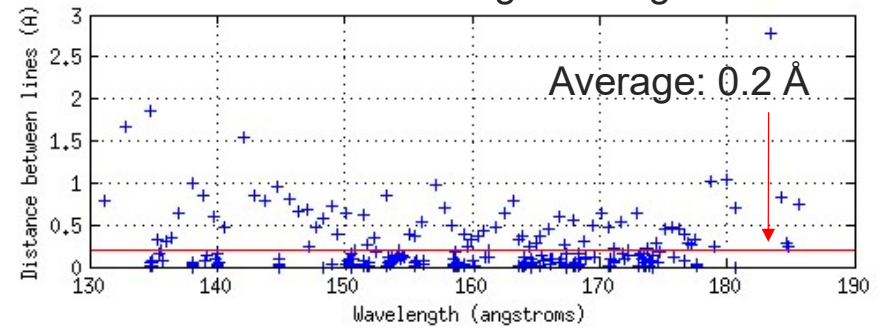
- Spectral resolution: FWHM should be $< 0.2 \text{ \AA}$ → Example: WEST 135-188 \AA



- Expected lines (NIST)
- Nb of lines per 2 \AA interval



- $\Delta\lambda$ between neighbouring lines





Line identification – low charge states in tokamaks?

• Observations

W I: 4008.75 Å, ...

W II: van Rooij 2013

W IV: 895-935 Å (Lawson 2022)

W V: 400-480 Å, 775-875 Å (id.)

W VII, VIII: 150-350 Å, 480-720 Å (id.)

No/rare observation of W III-IV (Coenen 2015)

No/rare observation of IX-XX (IX: Ryabtsev 2015, XV-XVII: McCarthy 2016)

• Expected (NIST)

20-300 Å:

W VII → 14 lines

W VIII → 188 lines

W XIV → 4 lines

300-1000 Å:

W III → 2 lines

W IV → 171 lines

W V → 153 lines

W VI → 11 lines

W VII → 543 lines

W XIV → 1 line

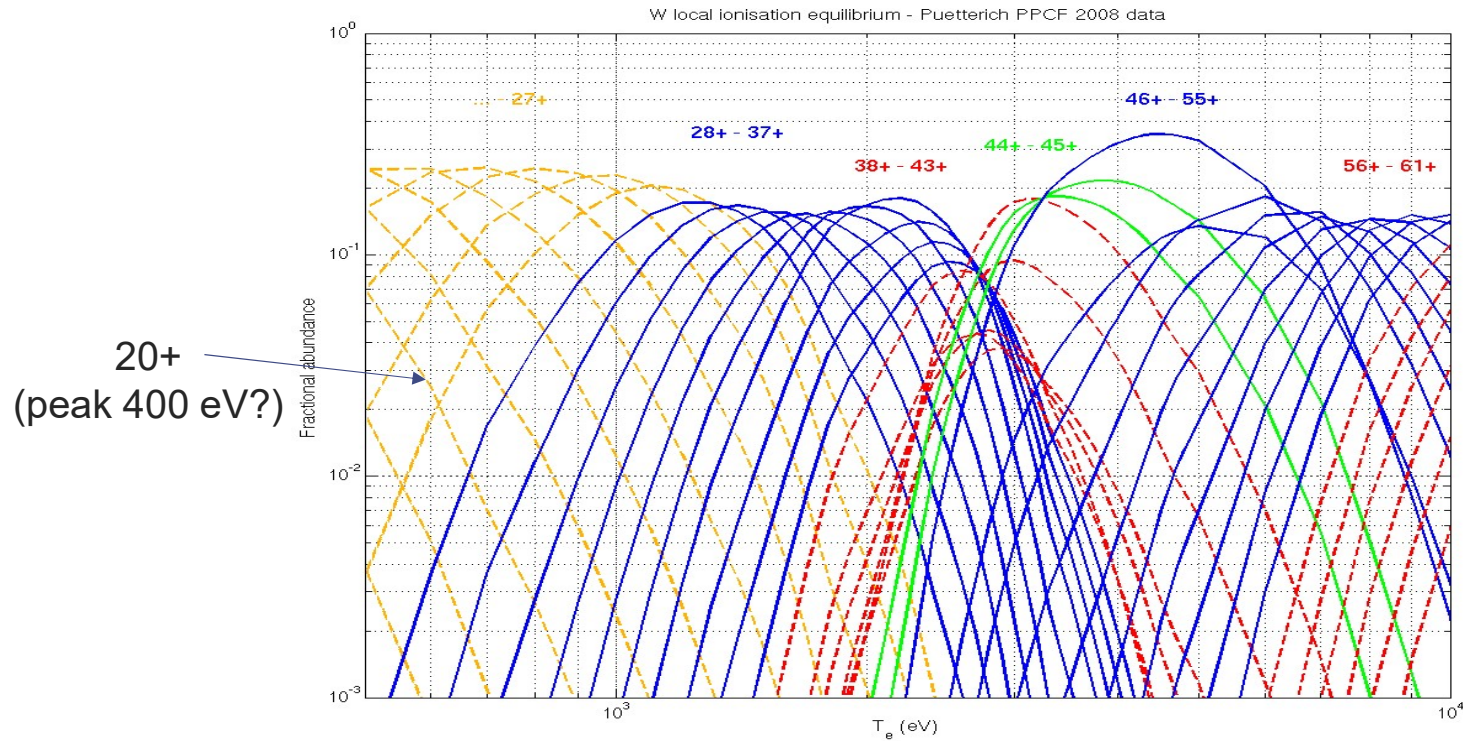
1000-3000 Å:

W I-VII → > 7500 lines

No line for IX-XIII, XV-XX below 3000 Å



Line identification – low charge states in tokamaks?





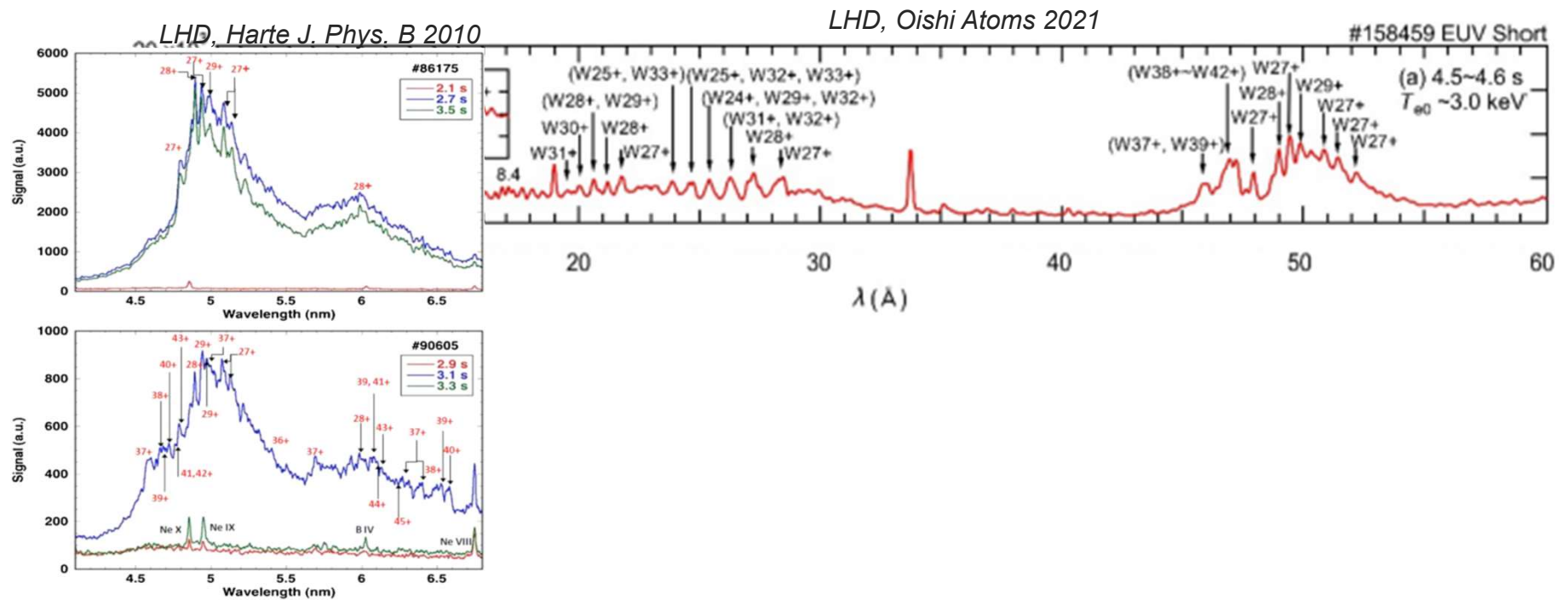
Interpretation of spectra

- Line \rightarrow W^{z+} densities
- Line ratios \rightarrow Te \rightarrow localisation



Interpretation of spectra

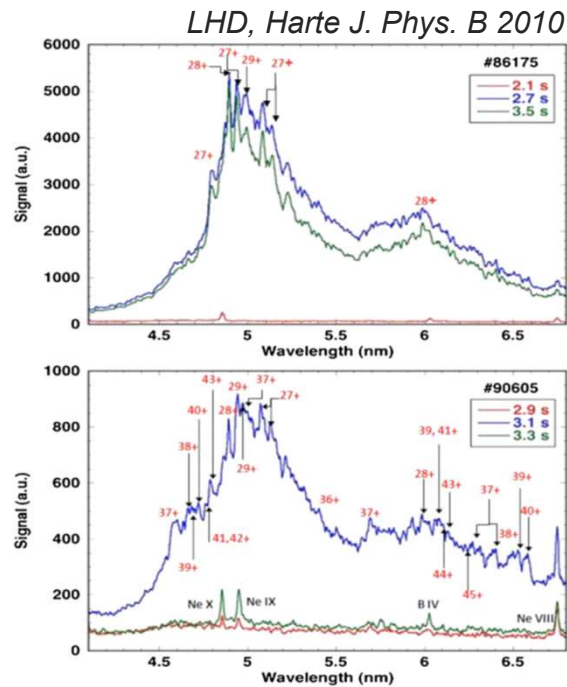
- Line $\rightarrow W^{z+}$ densities
- Line ratios $\rightarrow T_e \rightarrow$ localisation
- Quasi-continua: a lot of line identification – Ex: 45-65 Å



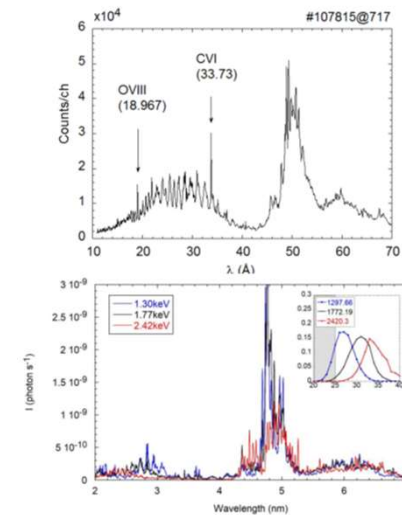
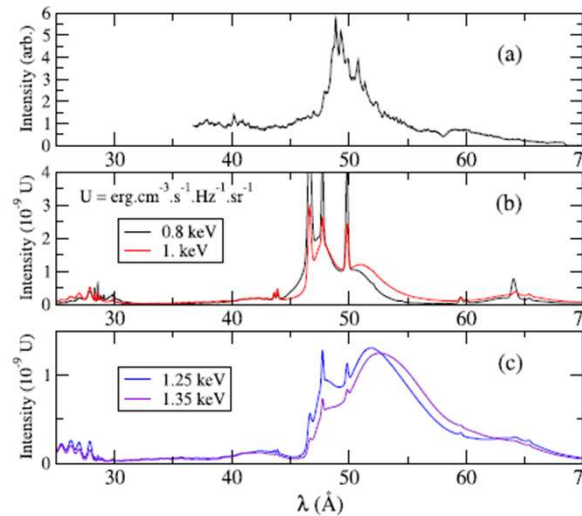


Interpretation of spectra

- Line $\rightarrow W^{z+}$ densities
- Line ratios $\rightarrow Te \rightarrow$ localisation
- Quasi-continua: a lot of line identification – Ex: 45-65 Å



And also attempts at modelling the QC itself (getting better!)



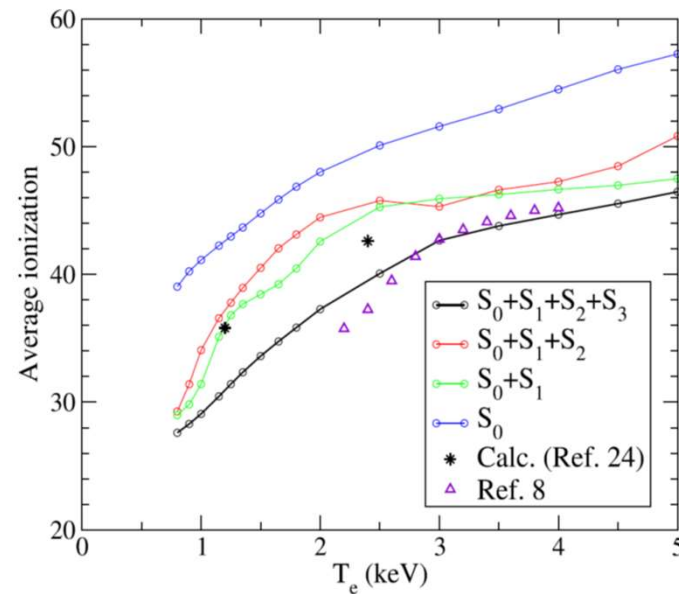
Spectrometer line of sight integrates through inhomogeneous plasma
 \rightarrow ionisation equil. must be accurate



Interpretation of spectra

- Ionisation equilibrium: no consensus, despite many different models

One of the latest attempts (Boumendjel & Peyrusse 2023) shows the importance of the configuration choice





Summary

- **Many observations in VUV but line identification complex, time consuming and not always rewarding/successful**
- **Low ionisation stages: few observations on W III-IV, limited nb on W V-VI, almost none on W IX-XX → lack of experimental information on plasma < 400 eV**
- **Quasi-continua: 45-65 Å being studied in detail but QC not well described – promising but interpretation difficult**
- **Ionisation equilibrium: use ad hoc modified equil. from Puetterich 2008 - various calculations but no consensus (?)**



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