Investigation of the Extreme-UV background emission in WEST tokamak

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Background & Motivations

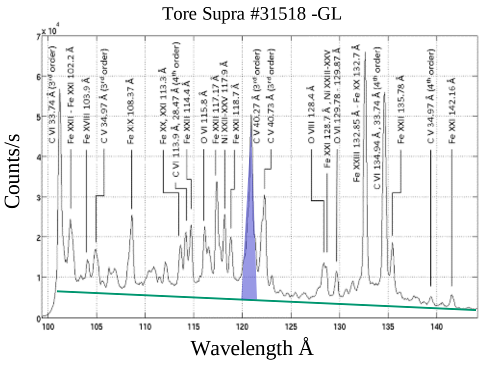
- Tungsten (W) density can be determined experimentally from its spectral line brightness [1]: $B_{ij} = \int n_e N_W f_z C_{ij} \, dl$

- Errors in line brightness determination due to background estimation.

- Low Z spectra (Tore Supra):

- Small background compared to lines.

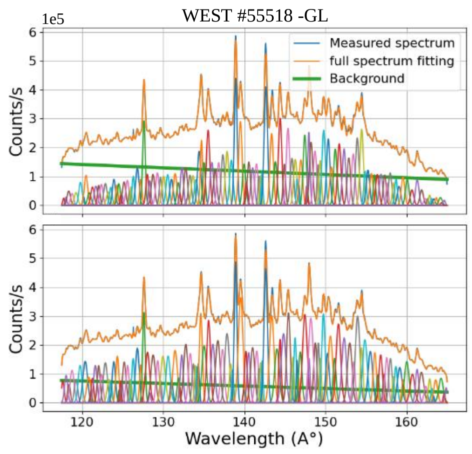
→ Minor role on brightness values. Uncertainties are small.



- High Z spectra (WEST):

- Apparent background is not small.
- Fitting procedure results depend strongly on the initial guesses.

→ What is the background real value ?



We attempt to answer this question by assuming that the measured spectrum B_{tot} (in the wavelength region 115-165 Å) is composed of:

$$B_{tot} = B_{line} + B_{ff} + B_{fb} + B^{m>1}$$

Bremsstrahlung (B_{ff}), Recombination radiation (B_{fb}), Higher diffraction orders emission ($B^{m>1}$)

Higher diffraction orders emission

- Light propagation Inside the spectrometer:

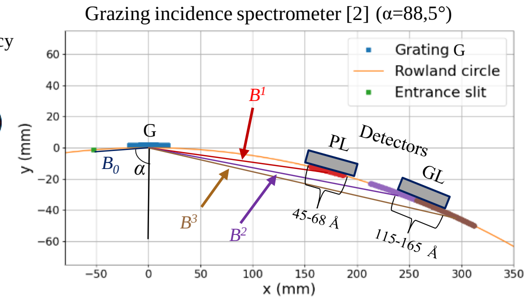
$$B^m(m\lambda) = B_0 E_G^m(\lambda) E_D(\lambda)$$

Measured brightness, Grating efficiency, Detector efficiency

$$\frac{B^{m>1}(m\lambda)}{B^1(\lambda)} = \frac{E_G^{m>1}(\lambda)}{E_G^1(\lambda)} \frac{E_D^{GL}(\lambda)}{E_D^{PL}(\lambda)} = K^{m>1}(\lambda)$$

→ $$B^{m>1}(m\lambda) = B^1(\lambda) K^{m>1}(\lambda)$$

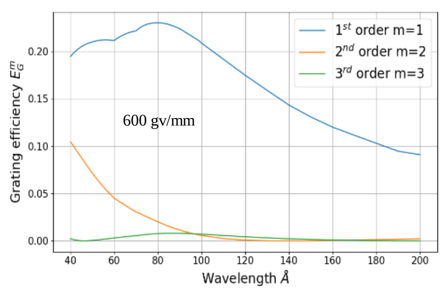
Higher orders ($B^{m>1}$), First order (B^1)



Grating efficiency simulation

- Differential method [3]
- Wavelength region : λ = 40 – 200 Å
- Grating parameters:

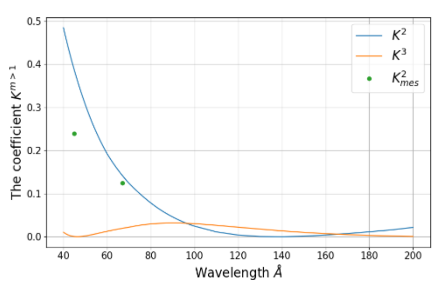
Grating length	Grating radius	Incidence angle α	Blaze angle	Coating
35 mm	1999.5mm	88.50°	1.5°	Gold



- $K^{m>1}(\lambda)$ coefficient :

relates the spectrum brightness of a particular order m $B^{m>1}$ to the first order spectrum B^1.

- Identical detectors (their efficiency ratio ~1)
- Good agreement: 2nd order K^2 calculations and measurements.
- Errors : concave grating aberrations (5-15 %).



Bremsstrahlung & recombination radiation

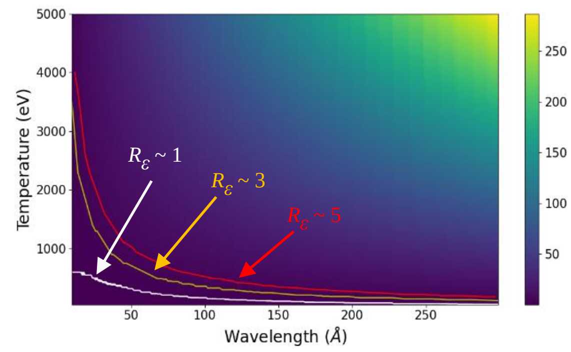
Continuum emission calculations (ff, fb)

- Maxwellian emission coefficients (C_{ff}, C_{fb}) [4].
- Impurity : tungsten (Z=74).
- Wavelength range : λ = 10 – 300 Å.
- Temperature range : T_e = 50 – 5000 eV.

→ Reasonable and fast estimation of the two processes

- The comparison of Bremsstrahlung (ff) and radiative recombination (fb) is done by calculating the local emissivity ratio R_ε of the two processes:

$$R_\varepsilon = \frac{\varepsilon_{ff}}{\varepsilon_{fb}} = \frac{\sum_z f_z C_{ff}^z}{\sum_z f_z C_{fb}^z}$$



- λ < 50 Å: fb is not negligible and can be dominant below 500 eV.
- λ > 50 Å: fb is negligible with respect to ff for almost all temperatures (λ=115-165 Å in particular).

- Total Bremsstrahlung [5] : $\varepsilon_{ff}(\lambda) = 9.584.10^{-14} \frac{n_e^2}{\lambda \sqrt{T_e}} Z_{eff} \overline{G_{ff}} \exp(-\frac{hc}{\lambda T_e})$

Analysis of a low temperature spectrum (T_e ~ 1 keV)

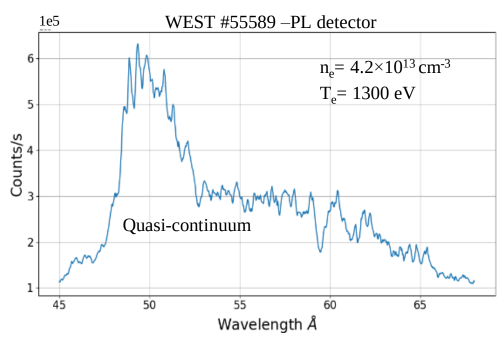
- Application to spectrum measured by GL (115-165 Å) during the discharge #55647:

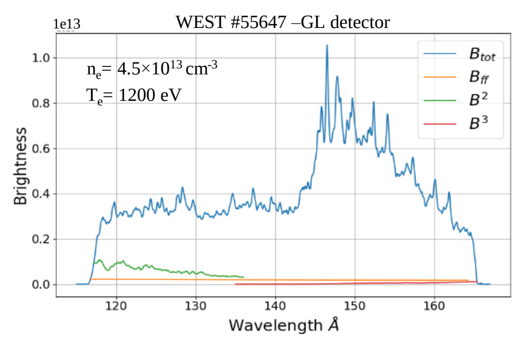
Higher diffraction orders B^2 and B^3

- Estimated using a spectrum measured by PL (45-68 Å) during the discharge #55589.

Bremsstrahlung B_{ff}

- Evaluated using #55647 plasma parameters and Z_{eff}=2.5.





- Bremsstrahlung (B_{ff}) is negligible.
- 2nd order B^2 may contribute to the spectrum.
- spectral lines dominate the emission (merge into an apparent background ?).
- Individual lines wavelengths above 145 Å correspond very well with those of 47-53 Å quasi-continuum, which casts some doubt on the 3rd order calculation.

→ Uncertainties in line brightness (therefore W density) determination may not be small.

Conclusion & Perspectives

- In the wavelength region 115-165 Å at low temperatures (Te ≈ 1 keV) :
- Continuum emission (Bremsstrahlung and recombination) is very weak.
- Higher diffraction order emission may contribute to the spectra.
- Spectral lines dominate the emission.

$$B_{tot} = B_{line} + \cancel{B_{ff}} + \cancel{B_{fb}} + B^2 + \cancel{B^3}$$

- What about spectra measured in different wavelength and temperature ?

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