



HAL
open science

Investigation of the Extreme-UV background emission in WEST tokamak

M. B. Boumendjel, R. Guirlet, C. Desgranges, J. L. Schwob, P. Mandelbaum,
E. Popov, O. Peyrusse

► **To cite this version:**

M. B. Boumendjel, R. Guirlet, C. Desgranges, J. L. Schwob, P. Mandelbaum, et al.. Investigation of the Extreme-UV background emission in WEST tokamak. 48th EPS Conference on Plasma Physics, Jun 2022, E-Conference, Netherlands. cea-03780554

HAL Id: cea-03780554

<https://cea.hal.science/cea-03780554>

Submitted on 19 Sep 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

M.B. Boumendjel¹, R. Guirlet¹, C. Desgranges¹, J.L. Schwob², P. Mandelbaum³, E. Popov⁴, O. Peyrusse⁵ and the WEST team¹

¹ CEA, IRFM, F-13108 St Paul-lez-Durance, France.

² Racah Institute of Physics, Jerusalem, Israel

³ Jerusalem College of Engineering, Ramat Beth Hakerem, Jerusalem, Israel

⁴ Aix-Marseille Université, Institut Fresnel UMR 7249, Marseille, France.

⁵ Aix-Marseille Université, LP3, Marseille, France



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.

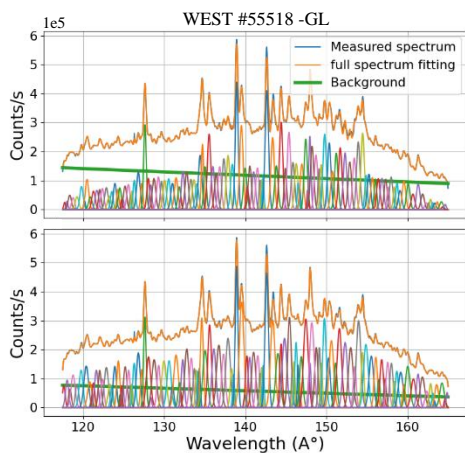
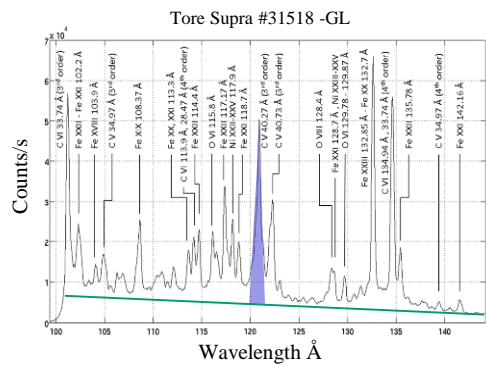
Uncertainties are small.

• 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:

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

Higher diffraction orders emission

Higher diffraction orders emission

➤ Light propagation inside the spectrometer:

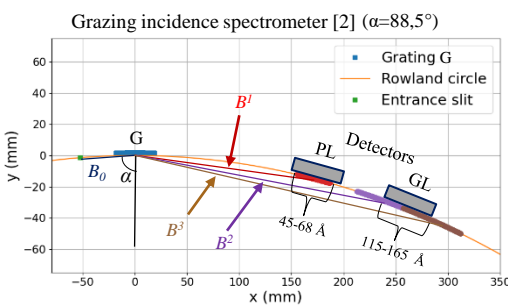
$$B^m(m\lambda) = B_0 E_G^m(\lambda) E_D(\lambda)$$

Measured brightness Grating efficiency Detector efficiency

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

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

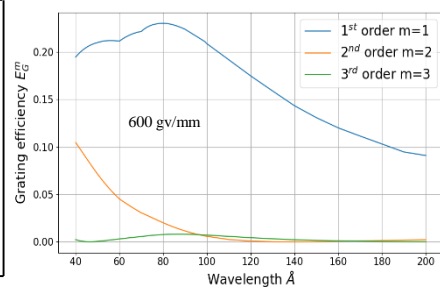
Higher orders First order



Grating efficiency simulation

- Differential method [3]
- Wavelength region : $\lambda = 40 - 200 \text{ \AA}$
- Grating parameters:

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



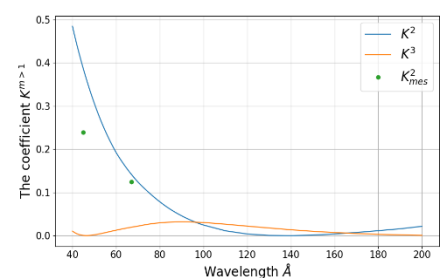
➤ $K^{m>1}(\lambda)$ coefficient :

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

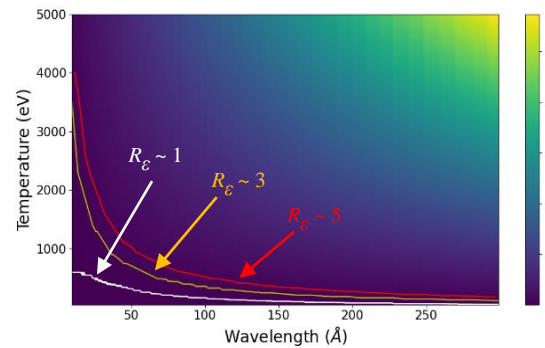
Continuum emission calculations (ff, fb)

- Maxwellian emission coefficients (C_{ff} , C_{fb}) [4].
- Impurity : tungsten ($Z=74$).
- Wavelength range : $\lambda = 10 - 300 \text{ \AA}$.
- Temperature range : $T_e = 50 - 5000 \text{ eV}$.

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_e of the two processes:

$$R_e = \frac{\epsilon_{ff}}{\epsilon_{fb}} = \frac{\sum_z f_z C_{ff}^z}{\sum_z f_z C_{fb}^z}$$



- $\lambda < 50 \text{ \AA}$: fb is not negligible and can be dominant below 500 eV.
- $\lambda > 50 \text{ \AA}$: fb is negligible with respect to ff for almost all temperatures ($\lambda=115-165 \text{ \AA}$ in particular).

➤ Total Bremsstrahlung [5] : $\epsilon_{ff}(\lambda) = 9.584 \cdot 10^{-14} \frac{n_e^2}{\lambda \sqrt{T_e}} Z_{eff}^2 \bar{G}_{ff} \exp(-\frac{hc}{\lambda T_e})$

Analysis of a low temperature spectrum ($T_e \sim 1 \text{ keV}$)

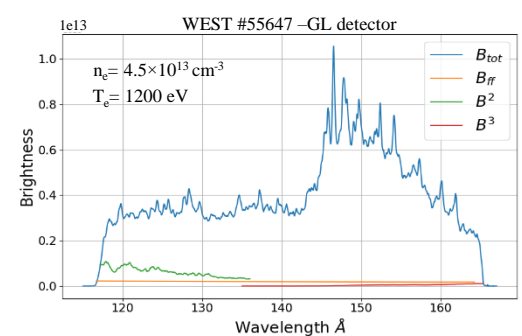
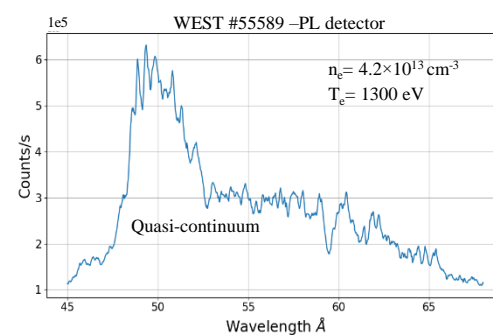
➤ Application to spectrum measured by GL (115-165 Å) during the discharge #55647:

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 ($T_e \approx 1 \text{ keV}$) :
 - Continuum emission (Bremsstrahlung and recombination) is very weak.
 - Higher diffraction order emission may contribute to the spectra.
 - Spectral lines dominate the emission.

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

➤ What about spectra measured in different wavelength and temperature ?

References:

- [1] R. Guirlet, et al. Plasma Physics and Controlled Fusion, 2022.
- [2] J.L. Schwob, et al. Review of scientific instruments 58.9: 1601-1615, 1987.
- [3] E. Popov, M. Nevier. J. Opt. Soc. Am. A, 18, 2886-2894, 2001.
- [4] A. Burgess, H.P. Summers, Monthly Notices of the Royal Astronomical Society, 226(2):257-272, 1987.
- [5] M.E. Foord, et al, Review of Scientific Instruments, 53(9), 1407-1409, 1982.



This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.