D spectral line modelling for the diagnostic of ITER

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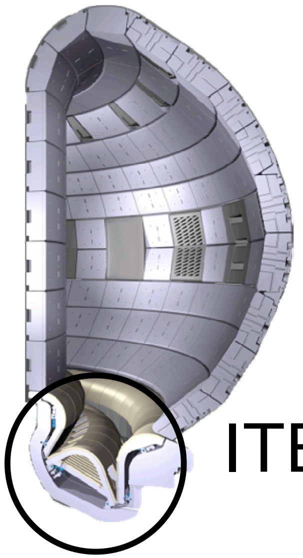
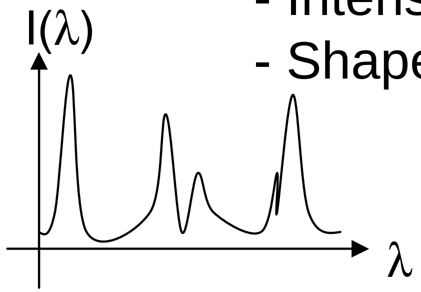
Introduction

Passive spectroscopy is used for the diagnostic of tokamak edge plasmas





- Intensity of the lines
- Shape

N, T…

ITER divertor:

How accurate information can be extracted from line shapes?

Outline

1) Line broadening: theory and models
2) Simulations of D spectra for ITER

Why D spectra?

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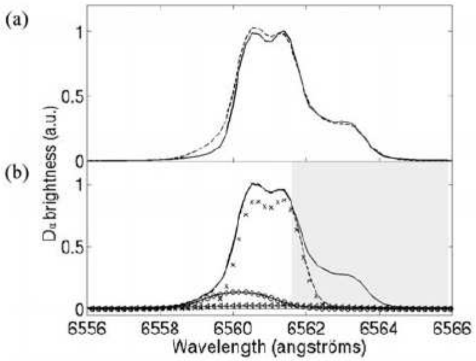
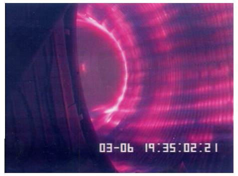
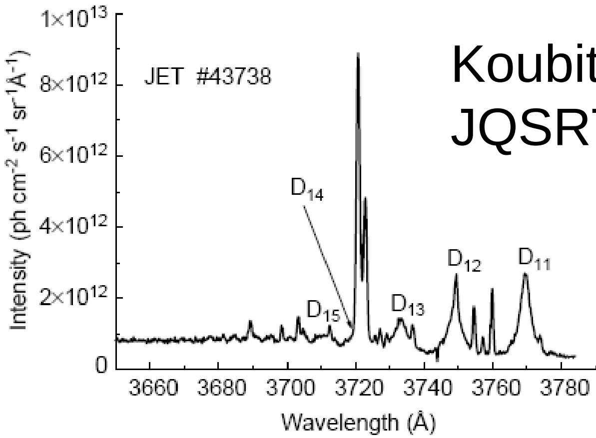


Tore Supra

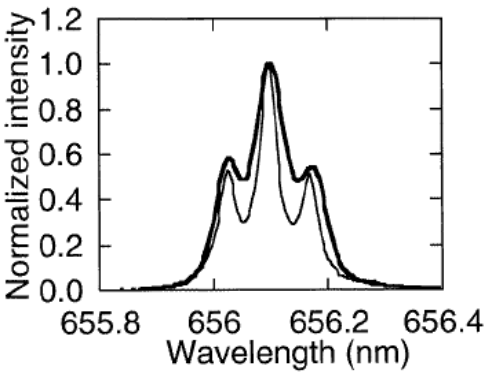


JET



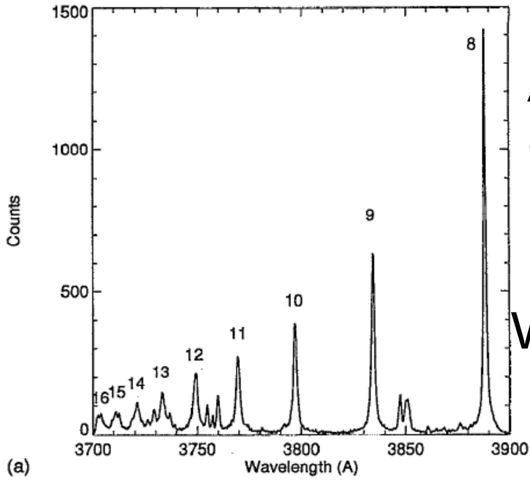
Koubiti et al., JQSRT (2003)

Guirlet et al., PPCF (2001)

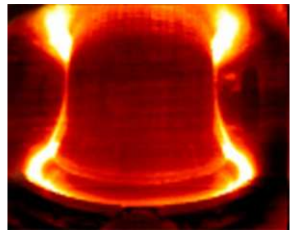


JT-60U

Kubo et al., PPCF (1998)

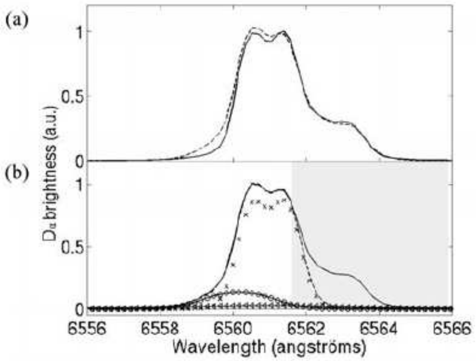


Alcator C-Mod



Welch et al., PoP (1995)

Why D spectra?



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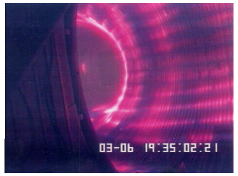

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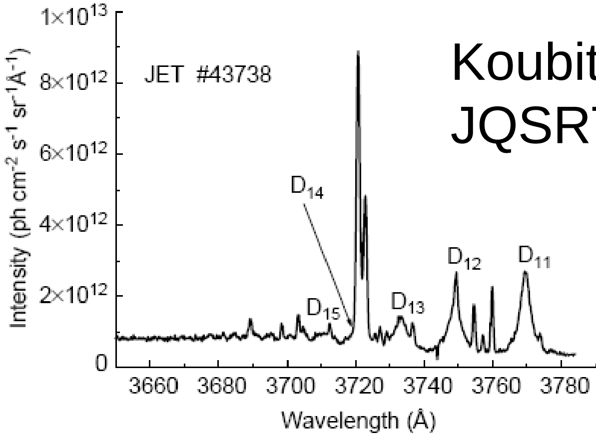

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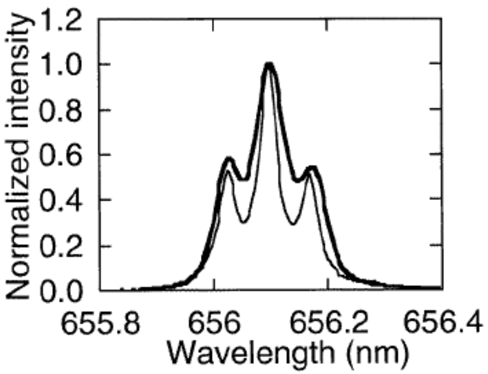

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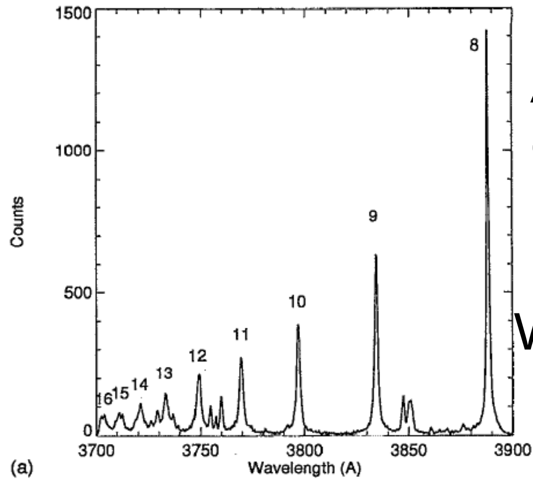
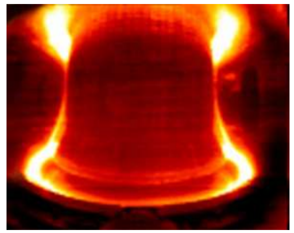


Alcator C-Mod



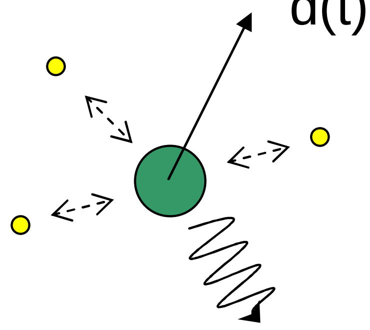
Welch et al., PoP (1995)

Kubo et al., PPCF (1998)

Low-n lines: Zeeman-Doppler profiles => information on f(v), B; modelling = OK
High-n lines: Stark effect => information on N; need for sophisticated models

Stark broadening formalism

Fourier transform of the dipole autocorrelation function



$$I(\omega)=\frac{1}{\pi}\mathrm{Re}\int_0^\infty C_{dd}(t)e^{i\omega t}dt$$

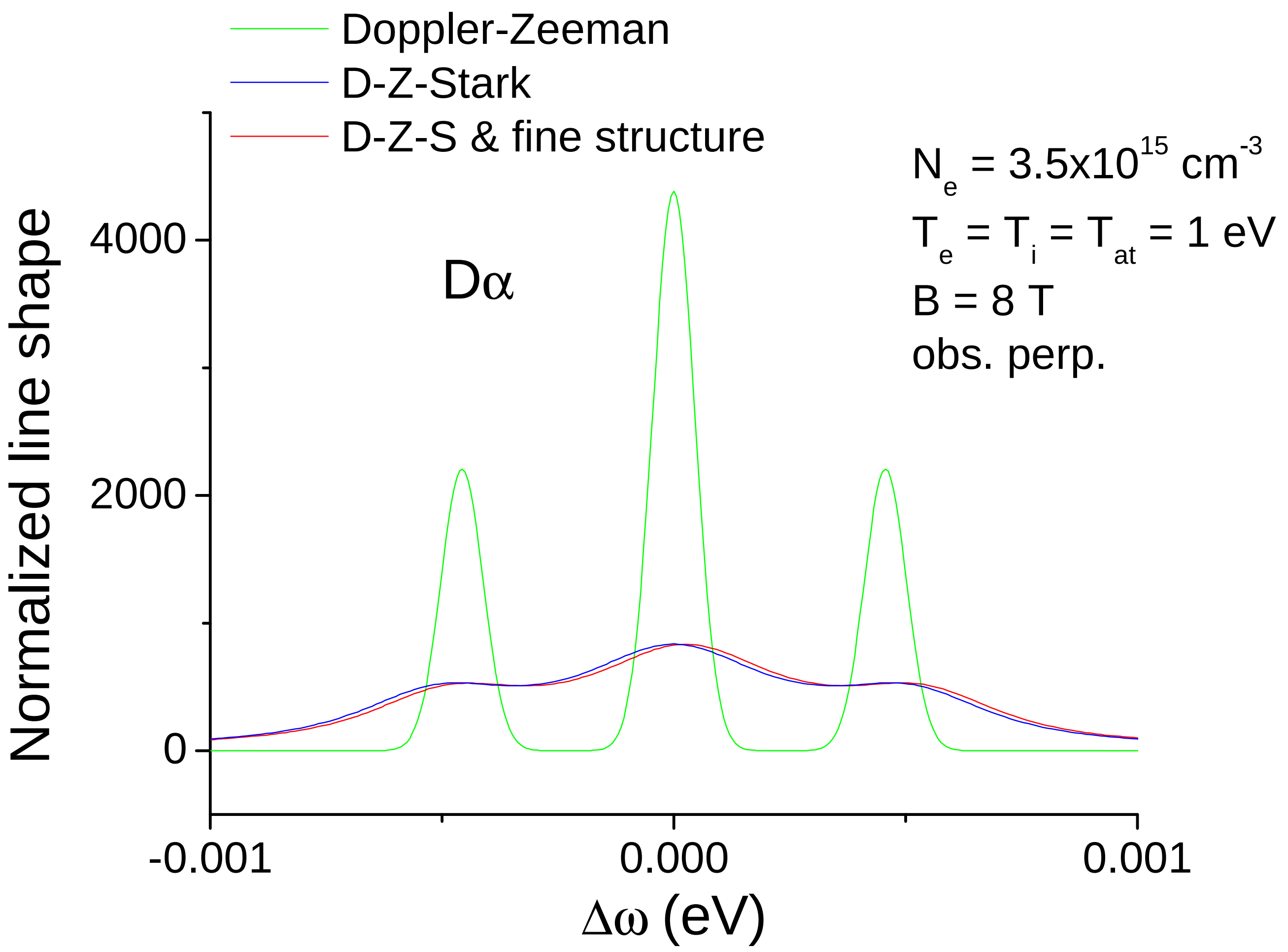
$$C_{dd}(t)=\{\mathrm{Tr}(\rho d(0)d(t))\}$$

$$\vec{d}(t)=U^+(t)\vec{d}(0)U(t)$$

- ρ: atomic density matrix
- d: dipole matrix elements
- U(t): time dependent Schrödinger equation

$$i\hbar\frac{dU}{dt}(t)=(H_0-\vec{\mu}.\vec{B}-\vec{d}.\vec{E}(t))U(t)$$

Dα in ITER: Stark vs Doppler



Stark and Doppler broadenings are of the same order

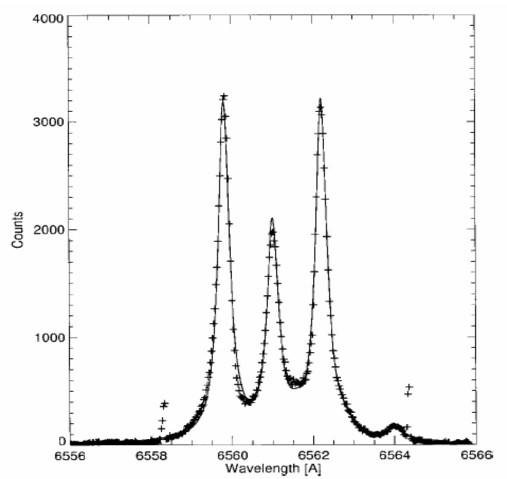
Fine structure: slight shift of the line shape

Problematic issues for ITER

The divertor will be of large size
Can one obtain local information on the plasma parameters?

The density will be sufficiently high so that low-n lines will be affected by both Doppler and Stark effects
Can one extract reliable information on the neutrals' VDF from Doppler analysis?

Already problematic in Alcator C-Mod



Dα Zeeman-Lorentz triplet: both Doppler & Stark effects contribute to the broadening

Welch et al., PoP (2001)

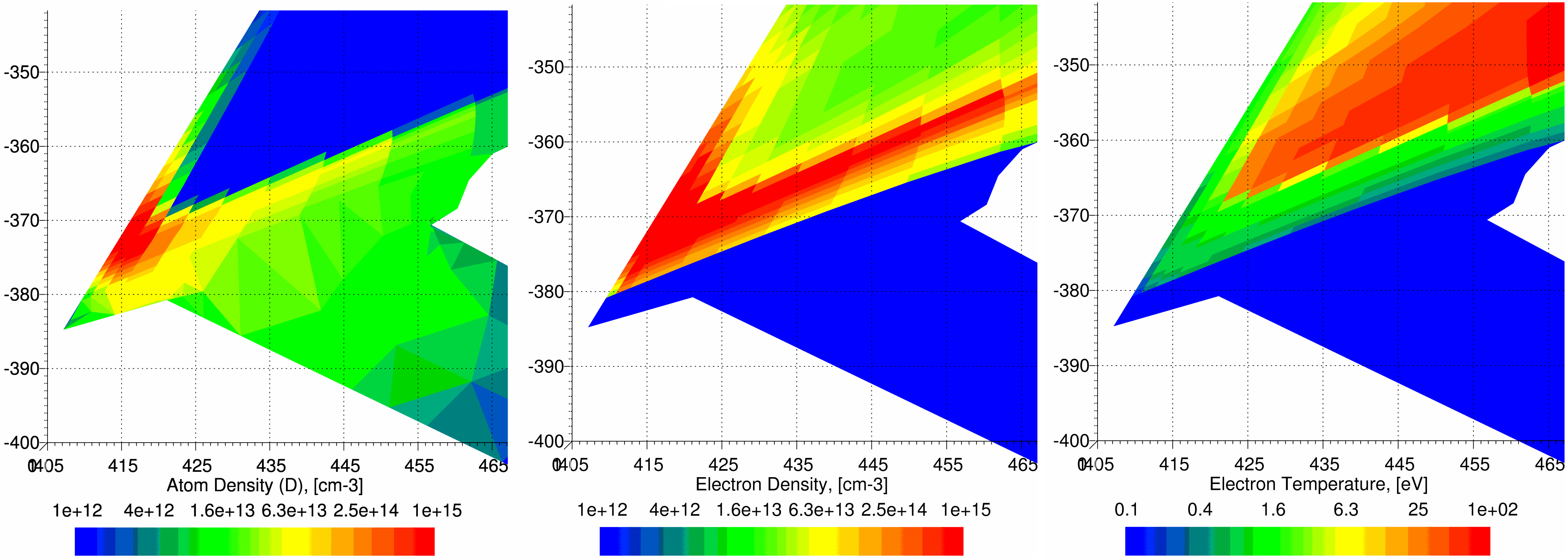
Simulations of ITER with B2-EIRENE (www.eirene.de)

Self-consistent description of the plasma dynamics

- Ions, electrons: stationary fluid model, finite volume method (B2)
- Neutrals: kinetic transport model, Monte-Carlo method (EIRENE)

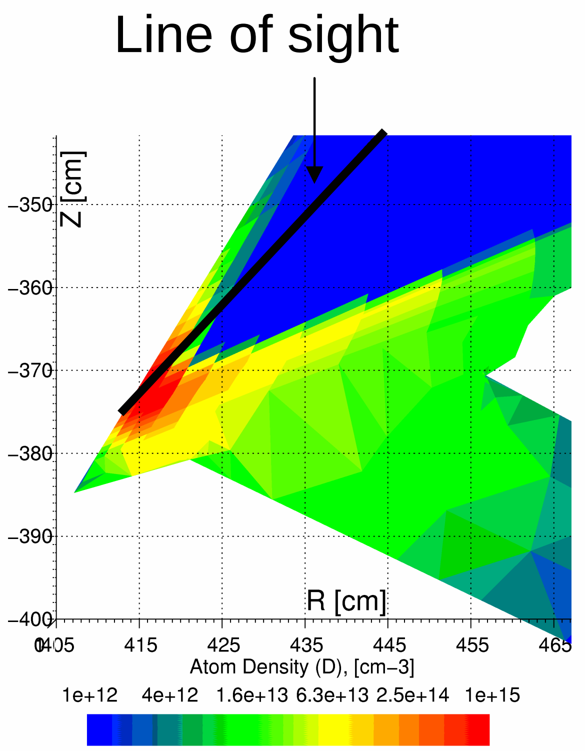
Atomic levels are resolved through a collisional-radiative model, incl. Ly-opacity

V. Kotov et al., CPP (2006)

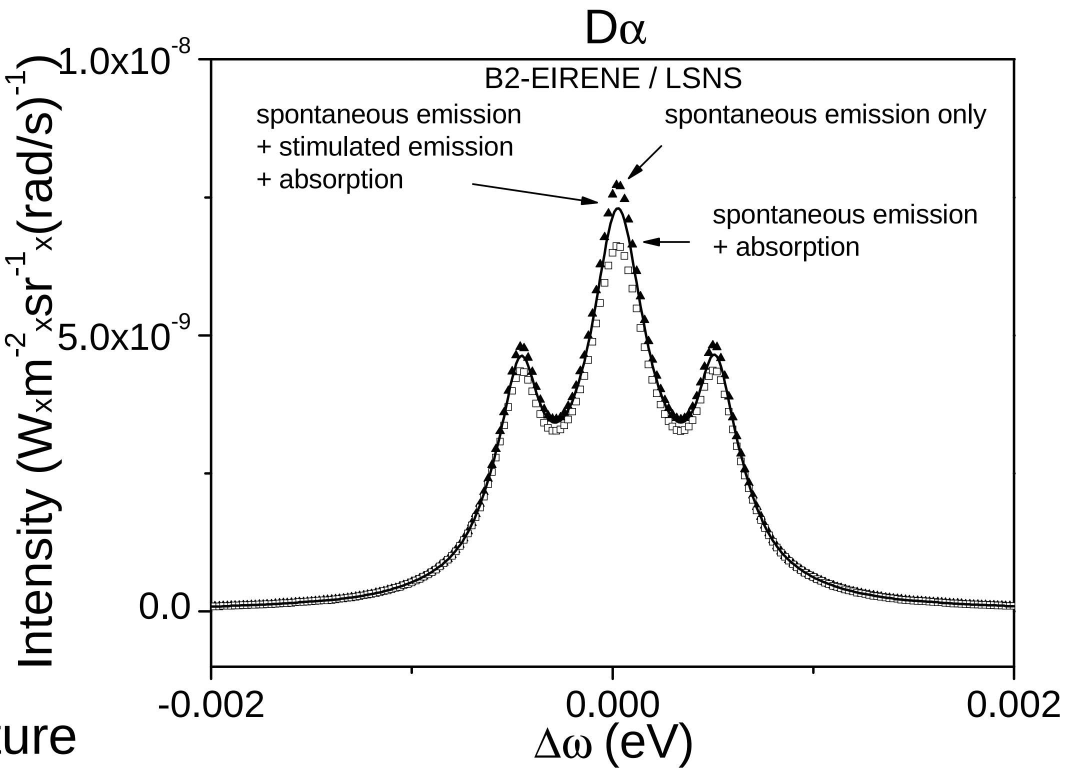


High N & low T close to the wall

Setting up the simulation of an observed spectrum



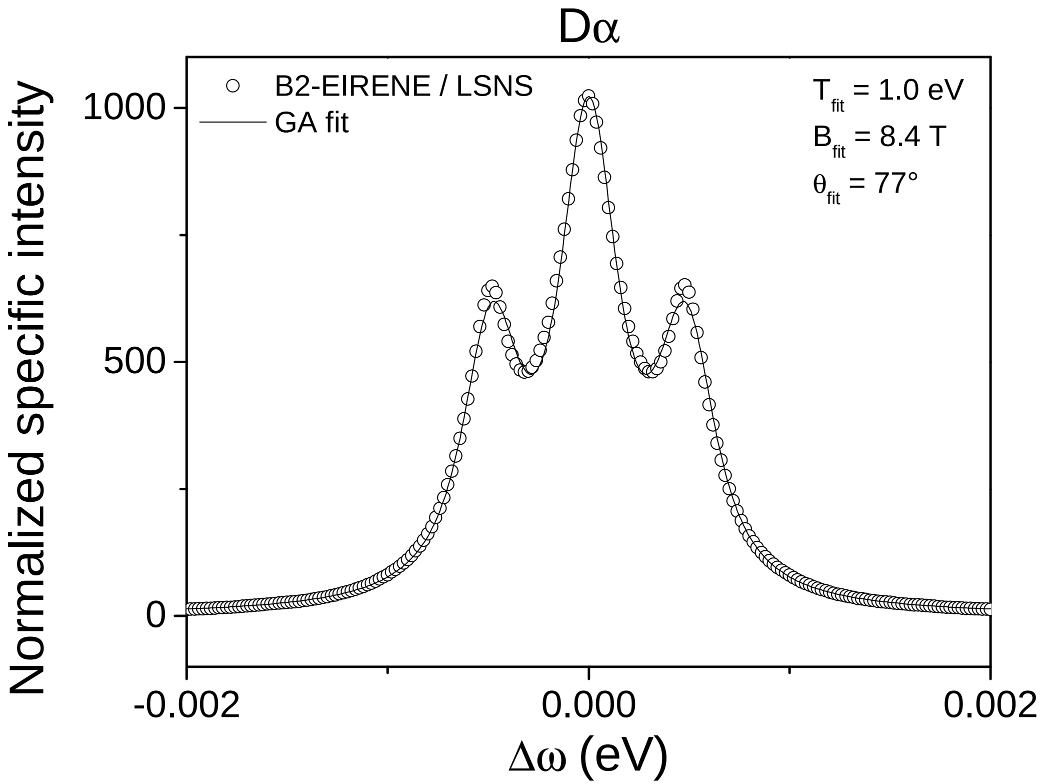
The B2-EIRENE result serves as a plasma background



At each point:
integration of the time-dependent Schrödinger equation
=> Doppler, Zeeman, Stark, fine structure

Analysis of Balmer α

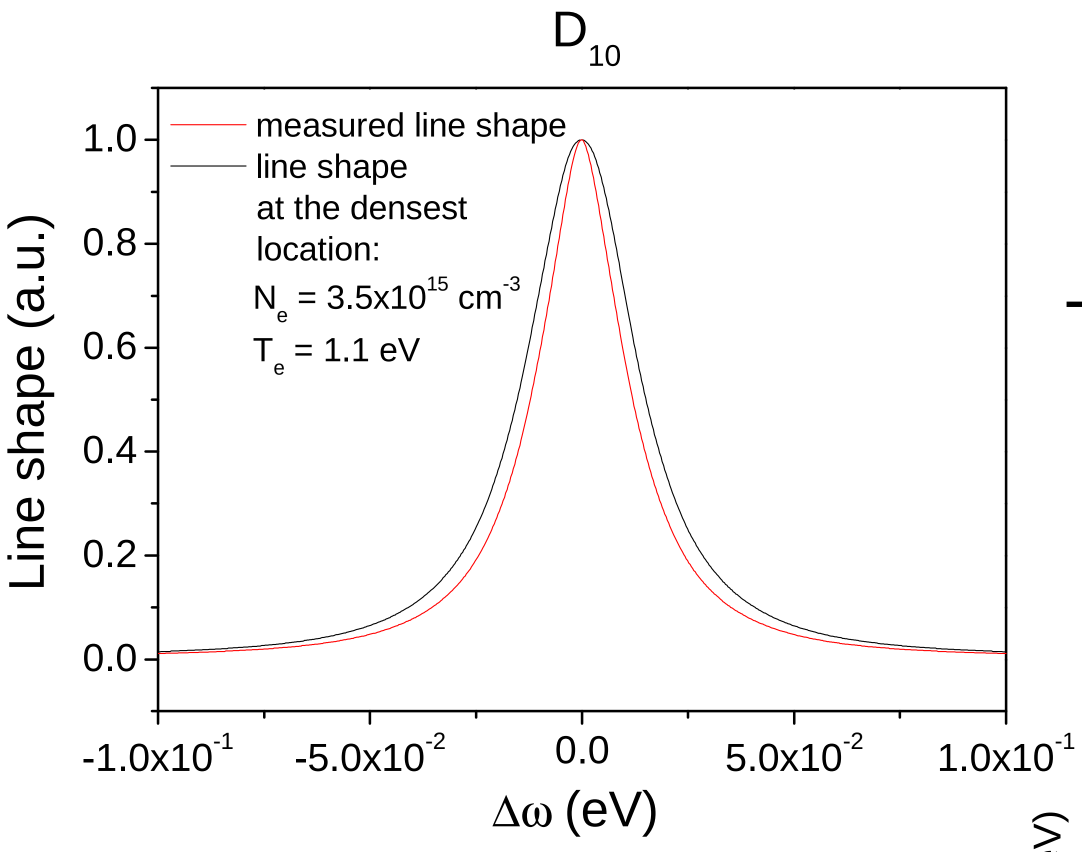
A fitting has been done with a genetic algorithm: 3-Voigt function model



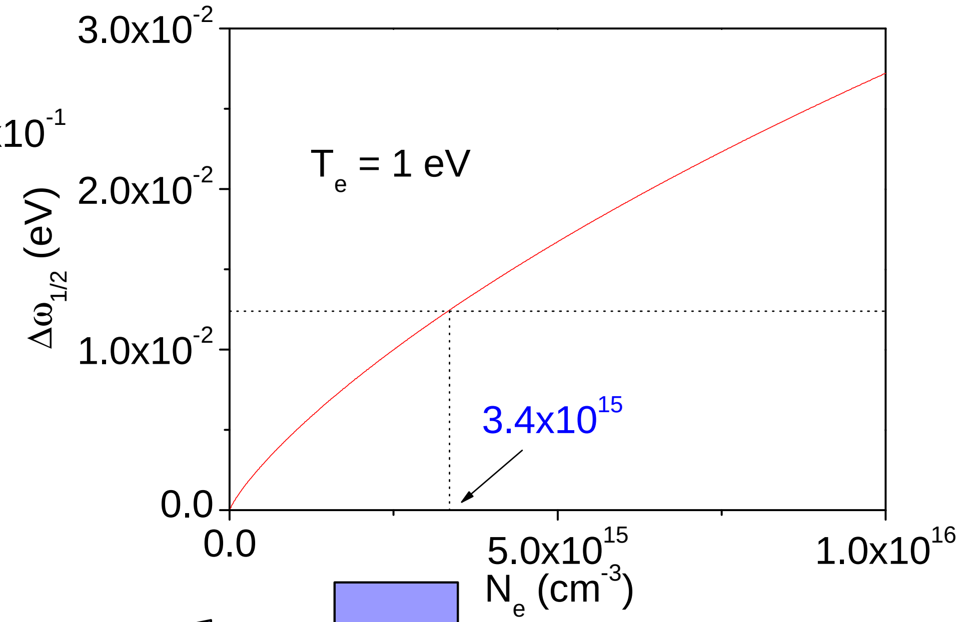
The fitting model agrees well with the simulation

The extracted T, B, θ correspond to the densest location on the line-of-sight

Analysis of D10-2



The Stark effect is dominant



Estimate of N_e:

$$\Delta\omega_{1/2} = C_1 N_e + C_2 N_e^{2/3}$$

The density is extracted with a good accuracy

Summary

Passive spectroscopy provides information on the parameters of divertor plasmas: present tokamaks & ITER

At high density regime, all lines of the Balmer series are affected by Stark broadening

Coupled plasma-lineshape codes => local information can be obtained for ITER:
- neutrals’ temperature from low-n lines
- density from high-n lines

Turbulence?