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Résumé - Les raies Ly-α de l'Argon hydrogenoïde et les raies satellites dielectroniques associées ont été observées dans le Tokamak de Frascati (FT) en suivant l'injection d'impuretés d'Argon dans un plasma de Deutérium. Les données atomiques relatives ont été calculées pour les satellites n = 2 - 5 en utilisant le code AUTOLSJ. Les raies non résolues (n = 5 - 15) ont été également introduites. La comparaison avec les spectres observés fournit un bon diagnostic en température.

Abstract - The hydrogen-like Argon Ly-α doublet and associated dielectronic satellites have been observed in the Frascati Tokamak (FT) after injection of Ar impurities in a deuterium plasma. The atomic data of the lines have been computed for n = 2 - 5 with AUTOLSJ. The unresolved satellites n = 5 - 15 have also been included. Comparison with experimental spectra provide good temperature diagnostics.

Introduction and experimental conditions

The hydrogen-like Argon resonance Ly-α doublet and associated dielectronic satellites lines arising from transitions 1snl - 2pnl ($n \geq 2$) have been observed in the Frascati Tokamak (FT) using a curved crystal polychromator of high resolution ($R \backsim 20000$) and high throughput (1). The spectra were recorded from Deuterium discharges (total duration $\backsim$ 1.2S) following injection of Argon impurities 200 to 300 ms after the beginning of the discharges. During this phase the plasma conditions were almost constant with $T_e \backsim 1.4\ 10^7$K and $N_e \backsim 10^{14}$cm^{-3}. The complete wavelength range between Ly-α and the strong n = 2 satellite structure was recorded in four parts. In the present study, the analysis has been restricted to spectra including the long wavelength component (Ly-α_2) of the resonance doublet and the related satellites n = 2 - 15 up to the strong line T ($1s2s\,^1S_0$ - $2s2p\,^1P_1$). Figure 1 shows an example of this spectral range. In the present analysis, we have considered a temporal sequence of eight such spectra recorded during the stable phase of the discharge with a resolution of 50 ms. All the atomic parameters of the relevant spectral lines have been computed. These have been used to build synthetic spectra which were fitted to the observations to provide temperature diagnostics of the plasma.

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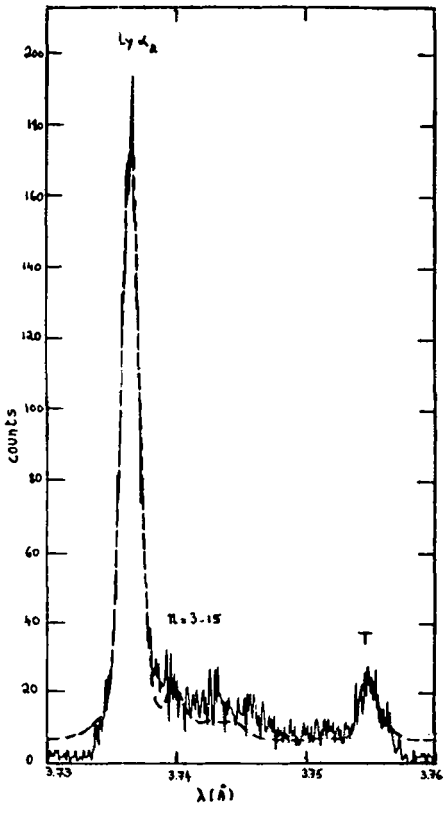

Fig. 1 - Observed (full line) and synthetic (dashed line) spectra of Lyα_2 and dielectronic satellites.

Line intensities and atomic data

The spectral line intensities can be written in the form

$$I = N_e\ N\ C(T_e)\ \text{photon}\ S^{-1}$$

where N_e is the electron density, N the population density of the Ar XVIII ground state. C (T_e) is the electron collision rate of the Ly-α components calculated following the method of paper (2). For the satellites, $C(T_e)$ is the dielectronic recombination rate coefficient which can be formally expressed as

$$C(T_e) = F_1(T_e).\ F_2\ (S)$$

where $F_1(T_e)$ is a function of the electron temperature alone and $F_2(S)$ depends only on the radiative and autoionisation probabilities. Up to n = 5 these atomic parameters have been computed using the three coherent codes : SUPERSTRUCTURE(SS)(3), DISTORTED, WAVES(DW)(4) and AUTOLSJ(5). The wave functions, energy levels and radiative probabilities are computed with SS. In a first step the wave functions are determined by

diagonalisation of the non relativistic hamiltonian, using orbitals derived in Thomas-Fermi potentials $V(\lambda_1,n)$. The scaling parameters λ_1 have been obtained after energy minimization of the lowest terms (triplets) arising from the configurations 2snl, 2pnl, for each value of n = 2 - 5. In the second step, the basis is used to diagonalize the Breit-Pauli hamiltonian. The multiconfiguration wavefunctions thus obtained include the relativistic effects in the configuration mixing coefficients. To calculate the autoionisation probabilities the term coupling coefficients for the N and N+1 electron systems and the bound-free transition matrix elements are required. The coupling coefficients are obtained with SS whereas the transition matrix elements are derived in DW. The autoionisation probabilities are then computed with AUTOLSJ.

For $n \geqslant 5$ the atomic parameters of the higher lines have been derived with a new method developed for the calculation of the Ca XX unresolved satellites and described in detail in reference (6). This method uses hydrogenic wavefunctions and makes it possible to determine analytically the energies and radiative probabilities of all the lines arising from high n transitions. The autoionisation probabilities are obtained from Quantum Defect Theory by extrapolation below threshold of the reactance matrix elements related to the parent resonance transitions. The method was tested for the Ar XVIII satellites by comparison of the n = 3 - 4 satellite lines with the results of the detailed calculations. Agreement was found to be within 15 %.

Temperature diagnostics

The complete set of atomic data was used to build a synthetic spectrum which was then compared with the observation. The comparison is based on a fitting procedure in which the intensity and the shape of the lines in the synthetic spectrum are determined respectively by the values of the electron and doppler temperatures (T_e, T_d). In this procedure T_e and T_d are varied so as to minimize the fitting function

$$FIT = \sum_i \frac{(O_i - T_i)^2}{\sigma_i}$$

where O_i is the observed photon rate at wavelength λ_i, σ_i the related statistical error and T_i the corresponding computed intensity. Figure 1 includes an example of the best fitting spectrum which shows good agreement with the observation and provides the "best" values for T_e and T_d. The results for the temporal sequence considered in the analysis are summarized in table 1.

Table 1

$T_e(10^7K)$	1.40	1.27	1.45	1.45	1.45	1.45	1.42	1.42
$T_d(10^7K)$	1.43	1.14	1.29	1.41	1.26	1.31	1.33	1.35

Temperature diagnostics derived from the best fitting spectra

The above results are consistent with the observation of the stable phase of the discharge. As to the electron temperature, they agree to within better than 5 % with independent measurements based on Thomson scattering. It should be pointed out that the importance of including the unresolved satellites ($n \geqslant 5$) is borne out by the fact that when their contribution is neglected, the derived electron temperatures are 25 % larger than those shown in table 1.

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