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Plasma Molecule Interactions and Their Influence on Detachment in Magnetically Confined Fusion Devices.

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Plasma detachment is considered essential for the successful operation of future fusion devices such as ITER and DEMO, as it can reduce the target heat flux by orders of magnitude. The reason for its necessity is the avoidance of unsustainable heat loads at the divertor. During detachment, atomic and molecular reactions induce simultaneous power, momentum, and particle losses, leading to a reduction in particle flux to the divertor plates in a tokamak [1].

Divertor spectroscopy is essential in diagnosing detachment. Plasma-atom and molecule interactions result in *excited hydrogen atoms*. Analysing the Balmer line series emitted by those atoms, yields important information about the conditions of hydrogen plasmas. Excited atoms from molecular break-up involving reactions with molecular ions play a significant role in Balmer line emission through chain processes and cannot be ignored in the diagnosis of detachment [1, 2, 3]. Molecules may play a very important role in the detachment process itself. Particle and power loss may occur through plasma-molecule reactions; and momentum and power transfer through collisions [1, 2]. Collisions between the plasma and the molecules can result in *excited molecules*, leading to emission of the Fulcher band from electronically excited molecules [4].

The aim of this PhD project is to perform a deep analysis of high-resolution Fulcher band data obtained by divertor spectroscopy in the MAST-U tokamak, in order to gain a better understanding of the role of molecules in detachment. Plans include Fulcher and Balmer line analysis and comparison of measurements with simulation data generated by synthetic diagnostics employed on SOLPS-ITER simulations. This approach requires modelling the Fulcher emission band, which would be useful tool for the community.

Such analysis is intended to provide input on the populations of the excited levels of the molecules. Monitoring those distributions is important as they have large model uncertainties whilst they have a strong impact on the various reaction rates between the plasma and the molecules. For example, it is known that the distribution of vibrational states in molecules has a significant effect on the formation of D_2^+ and D^-.

Ultimately, determining the utility of Fulcher emission measurements during plasma detachment is an important goal. It is explored whether the Fulcher emission brightness may be used as a temperature diagnostic; as there is a minimum electron energy required to excite molecules electronically.

[1] Verhaegh, K et al, Nuclear Fusion **59**. 126038 (2019); [2] Verhaegh, K et al, Nuclear Materials and Energy **26**. 100922 (2021); [3] Kukushkin, A. S et al, Nuclear Materials and Energy **12**. 984-988 (2017); [4] Fantz, U et al, Nucl. Fusion **46** S297 (2006).