

Observation of metastable 3S_1 He-like oxygen decay in an electron beam ion trap

F. Grilo¹, C. Shah^{2,3}, J. Marques⁴, J. P. Santos¹, J. R. Crespo López-Urrutia³, P. Amaro¹

¹Laboratory of Instrumentation, Biomedical Engineering and Radiation Physics (LIBPhys-UNL), Department of Physics, NOVA School of Science and Technology, NOVA University Lisbon, 2829-516 Caparica, Portugal

² NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 20771, USA

³ Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany.

⁴LIP — Laboratory of Instrumentation and Particle Physics and Faculdade de Ciências, Universidade de Lisboa, Portugal

Motivation

Oxygen ions appear in a wide range of temperatures, particularly in the He-like charge state due to the closed-shell nature. This makes the understanding of this ion of high importance for astrophysical modeling [1, 2].

In astrophysics, the KL transitions of he-like ions are used as plasma diagnostic tools. The $1s2s\ ^3S_1$ metastable state population is highly sensitive to the electron temperature and density conditions.

Ratios between the so-called w, x, y and z lines are used to determine these conditions.

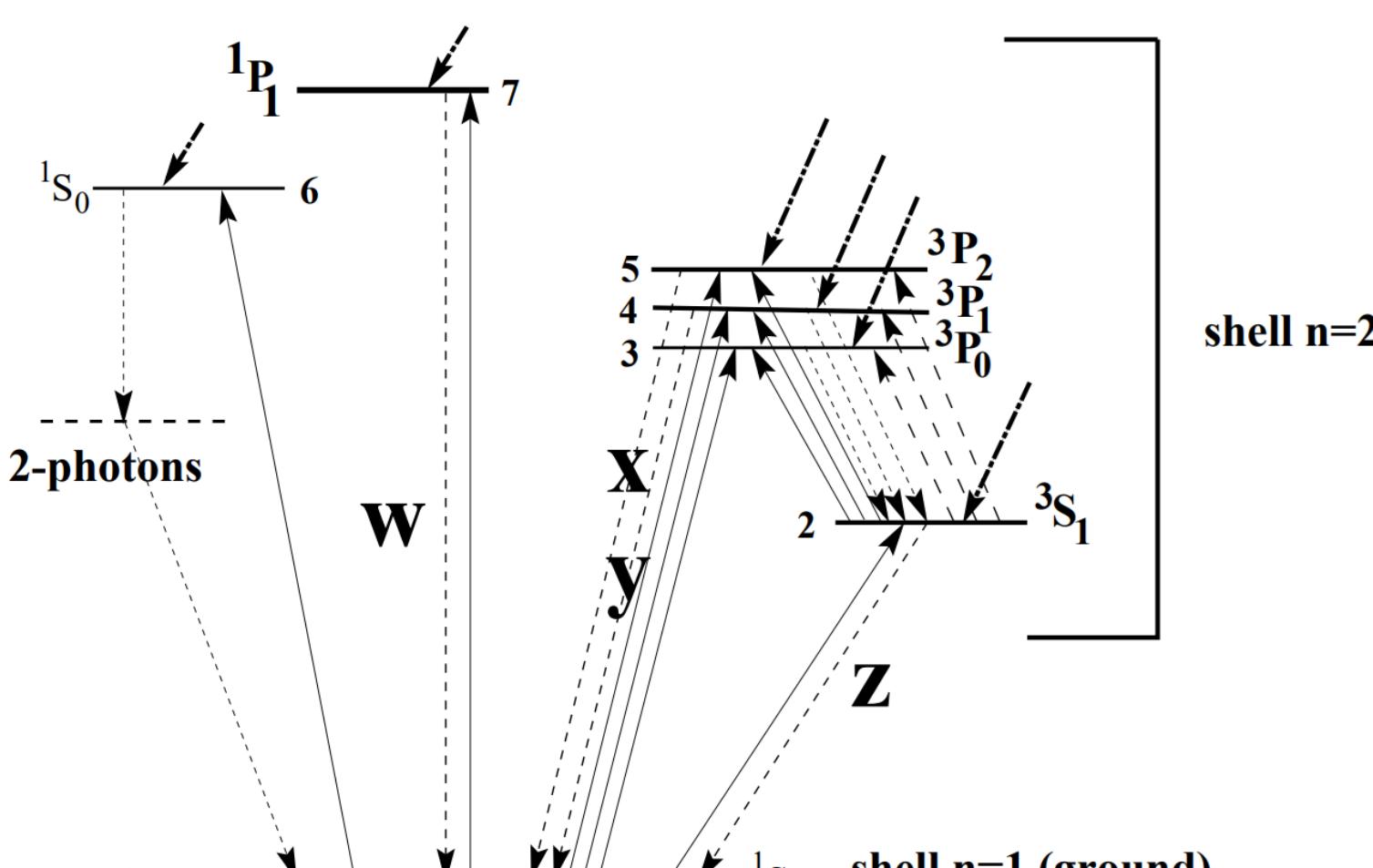


Fig 1. Generic level diagram of a He-like ion. Adapted from [1].

Electron Beam Ion Trap

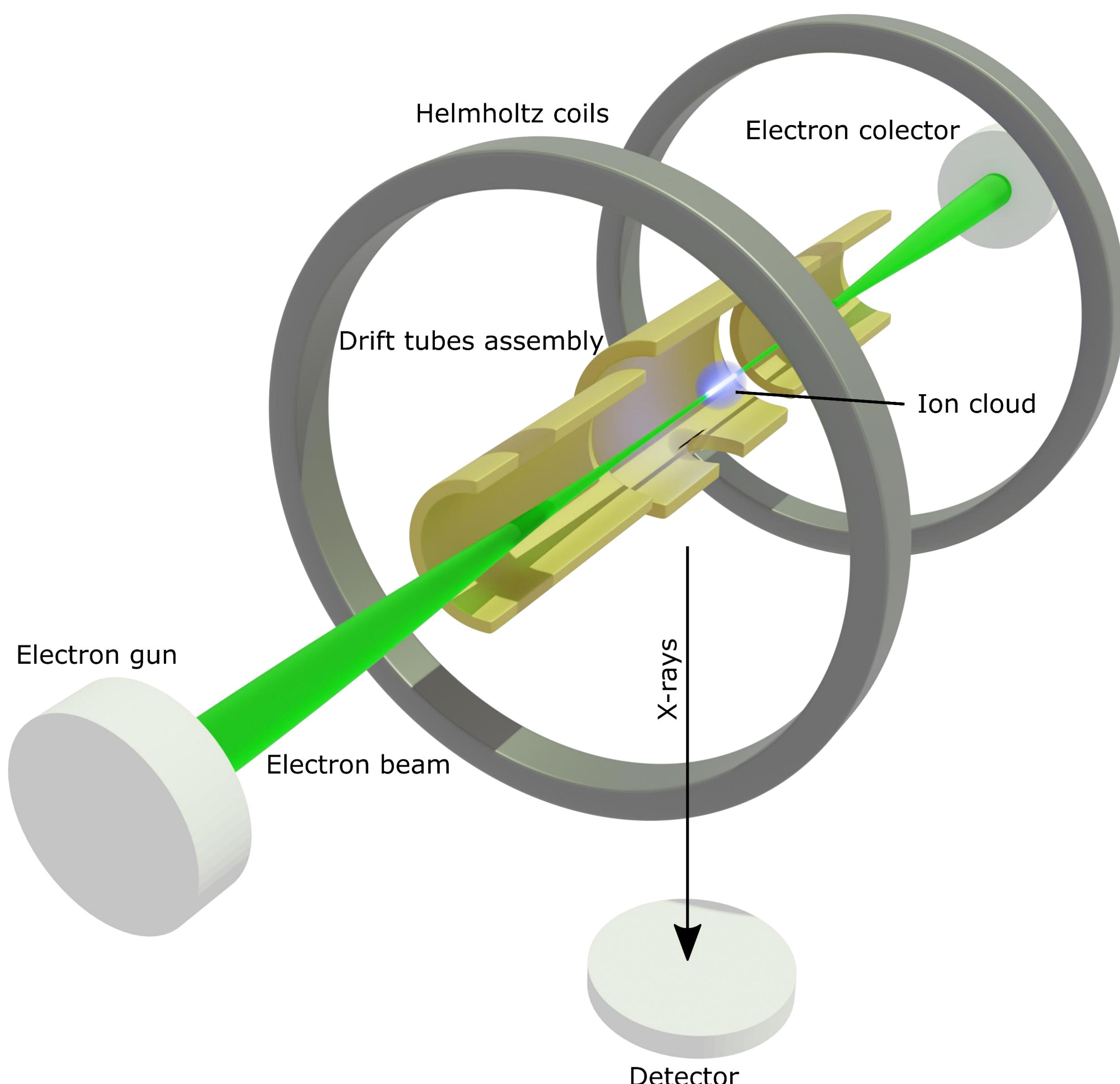


Fig 2. Schematic representation of an EBIT.

An Electron Beam Ion Trap (EBIT) is a device where an injected gas is simultaneously ionized and trapped by an electron beam. To increase the ionization rate and the radial trapping potential, the electron beam is compressed by a strong magnetic field, thereby increasing the current density.

Metastable Decay

During the experimental probing, when the electron beam has an energy above the excitation (CE) of the metastable 3S_1 [3], there is a steady production of metastable ions. Below the threshold, the production of such ions ceases.

In the Fig 3, the downward scan is subtracted by the upward scan for the 20 ms period cycle. As the beam energy goes below the threshold, the metastable population starts to decay exponentially. It was possible to observe a population decay with an experimental lifetime of around 0.955 ms that starts around the excitation threshold (~ 560 eV), thereby confirming the emission of this metastable state.

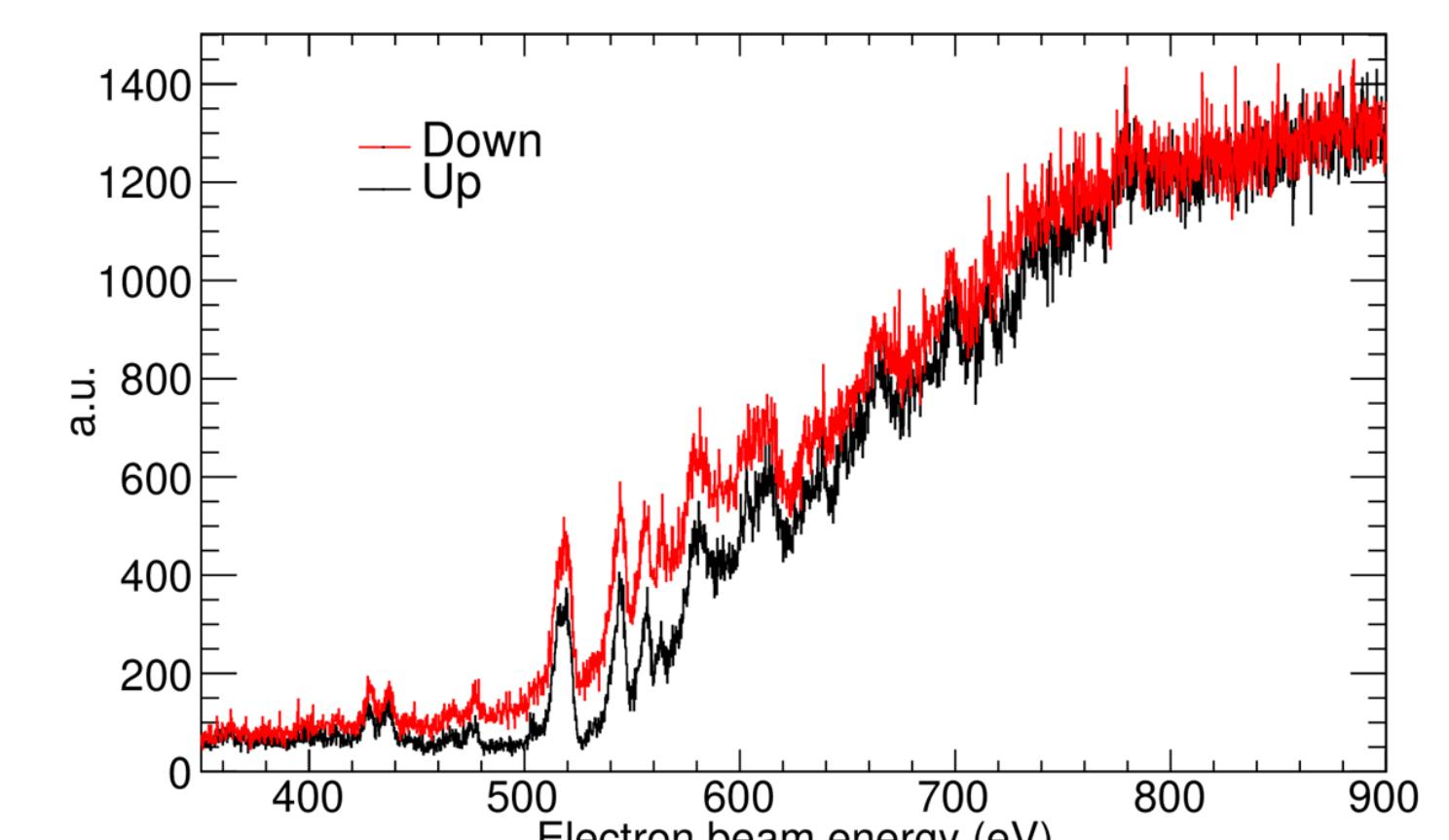


Fig 3. Top: Upwards and downwards scan with a 20 ms period. Bottom: Exponential fit of the subtraction of the down scan by the up scan. The dashed line indicates the 560 eV excitation energy threshold.

3S_1 Direct Impact Excitation

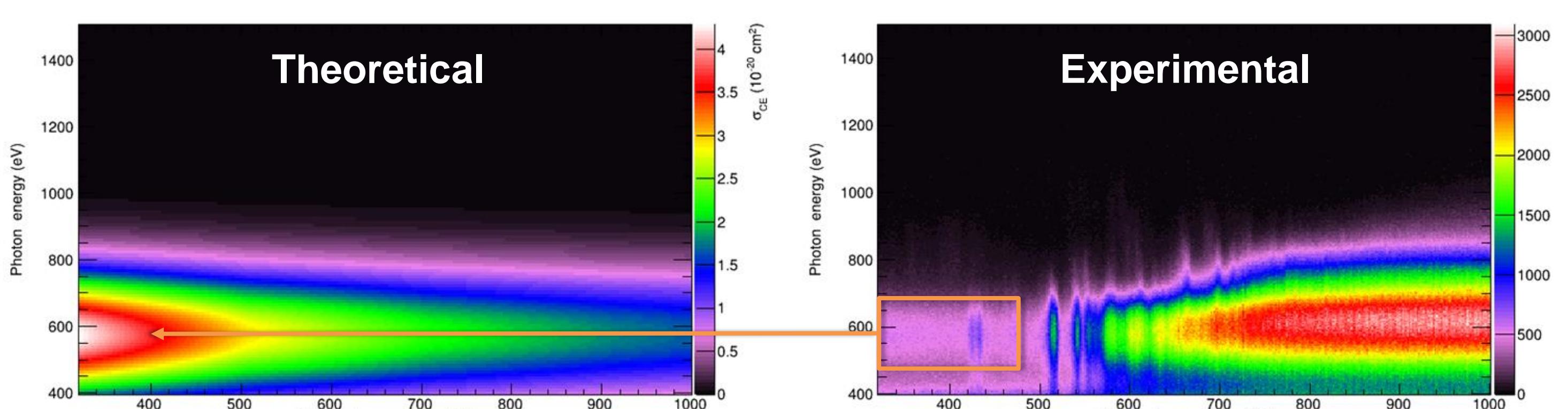


Fig 4. Left: Theoretical Direct-Impact excitation cross section of the metastable state. Right: Experimental intensity as a function of electron beam energy and photon energy.

The direct impact excitation process $1s2s + e^- \rightarrow 1snl + e^-$ has an extremely high cross section. This process appears to be present in the experimental data, as shown in the Figure 3. Currently, there are no measured cross-sections of this process, which is a key process in astrophysics diagnostics. Efforts are undergoing in data analysis, as well as in evaluation of theoretical cross-sections based on Flexible Atomic Code (FAC) [4] and Multiconfiguration Dirac-Fock (MCDF) [5]. Moreover, we will provide theoretical line ratios of He-like oxygen, benchmarked by laboratory measurements, which are extensively used in astrophysics.

References

- [1] Porquet, et al. 2010, Space Sci Rev 157
- [2] M. Togawa, et al. 2020, PRA, 102, 052831
- [3] J. R. Crespo López-Urrutia, et al. 1998, PRA, 58, 238.
- [4] <https://github.com/flexible-atomic-code/fac>
- [5] Desclaux, J. P., 1975, Computer Physics Communications, 9, 31