Characterization and Optical Diagnostics of Air – Breathing Electric Thrusters by 4CDGM

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Abstract

♣ **4CDGM**, a four initial components (**O, O_2 , N, N_2**) is a volume averaged **detailed global model** meant to **analyze** the functioning of **Electric Thrusters (ET)** of **Air-Breathing Electric Thrusters (ABET)** type, to **foresee** the plasma constitution and to **diagnose** it by **Optical Emission Spectroscopy (OES)**

♣ Towards this aim, 4CDGM provides **Plasma Component Composition (PCC)**, **Functioning Diagrams (FD)** and theoretical **atomic line intensities** with the adequate model allowing for **Optical Emission Spectroscopy (OES)** diagnostics

Summary of Presentation

Following **1. Introduction, results of 4CDGM are presented** consisting of :

2. Density of species, containing **PCC** and concomitant diagrams

3. A pressure depending **FD**

4. Typical **oxygen** & **nitrogen theoretical emission spectra**, leading to Optical Emission Spectroscopy (**OES**) diagnostics

5. Conclusions

1. Introduction (1/3)

♣ **Disruptive ET propulsion technology** based on ***In Situ* Resources Utilization** (**ISRU**) for propellant to be used by **ET**, developed for Low Earth Orbit (**LEO**) satellites maintenance and for orbit raising is **supported by 4CDGM**. It is also of interest to Very Low Earth Orbit (**VLEO**) satellites and to propulsion of very low flying s/c of various types. Whenever the breathed propellant is conveniently stored, **ABET** technology may also serve for extended space traveling.

♣ The four components addressed here are the main atomic and molecular constituents of the Atmospheric Remnants (**AtR**) in about 180 km altitude (50.1 % O / 47.5 % N_2 / 2.16 % O_2 / 0.28 % N).

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2. Katsonis, K., Berenguer, Ch., Gonzalez del Amo, J. & Stavrinidis, C. (**2015**). Atmospheric Remnants in the Low Earth Orbit Region around 200 km Altitude. World Journal of Engineering and Technology **3**, 26

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4. Stavrinidis, C., Gonzalez del Amo, J., Berenguer, Ch. & Katsonis, K. (**2015**). Diagnostics of Air-Breathing Electric Thrusters. World Journal of Engineering and Technology **3**, 33

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6. Berenguer, Ch. & Katsonis, K. & Gonzalez del Amo J. (**2018**). Air Breathing Electric Thrusters Characterization and Diagnostics by a Four Components Detailed Global Model, 6th Space Propulsion Conference, Paper ID SP2018_**00345**, Seville, Spain; Summary presentation in Poster.

1. Introduction (2/3)

♣ **OES diagnostics** pertains here to plasma containing neutral / ionized species created in case of **ETs fed by AtR**. In order to better tackle OES diagnostics, extended sets of nitrogen and of oxygen data encompassing the main N I to III, O I to III levels, had been included in **4CDGM**.

♣ **Electron temperature T_e , pressure *p*** and **absorbed power P_{ABS}** , are the main parameters present in the **PCCs** diagrams giving the plasma composition with **FD** giving the plasma ionization percentage for the propellant feed which contains iso-thermal, iso-energetic and iso-baric curves.

1. Introduction (3/3)

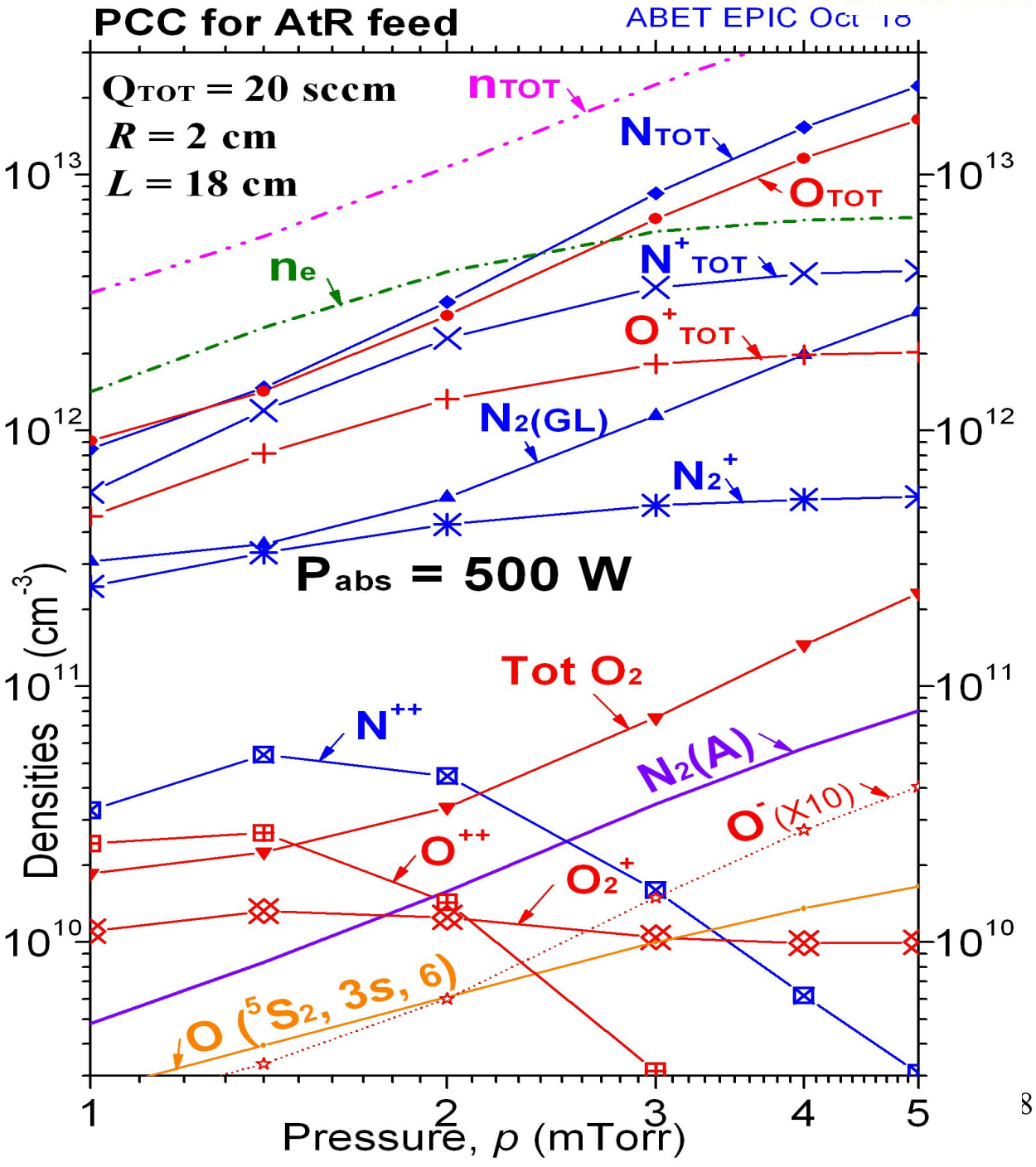
♣ We consider typical **AtR** propellant constitution encountered in about 180 km altitude. 4CDGM results corroborate our conjecture for feeding by an adequate **O_2 / N_2 mixture** instead of the cumbersome **AtR** one, without relying on cumbersome hyperthermal atomic oxygen **O** and molecular nitrogen **N_2** beams.

♣ Results pertaining to **O_2 / N_2 mixture** to be used in case of preparation, diagnostics and evaluation of on ground ABET experiments, were presented previously in **[3 - 6]**.

2. Density of Species PCC

Fig. 1.
P_{abs} = 500 W
pressure dependent **PCC**

AtR feed of 20 sccm, **form factor** of R=2 cm, L=18 cm throughout



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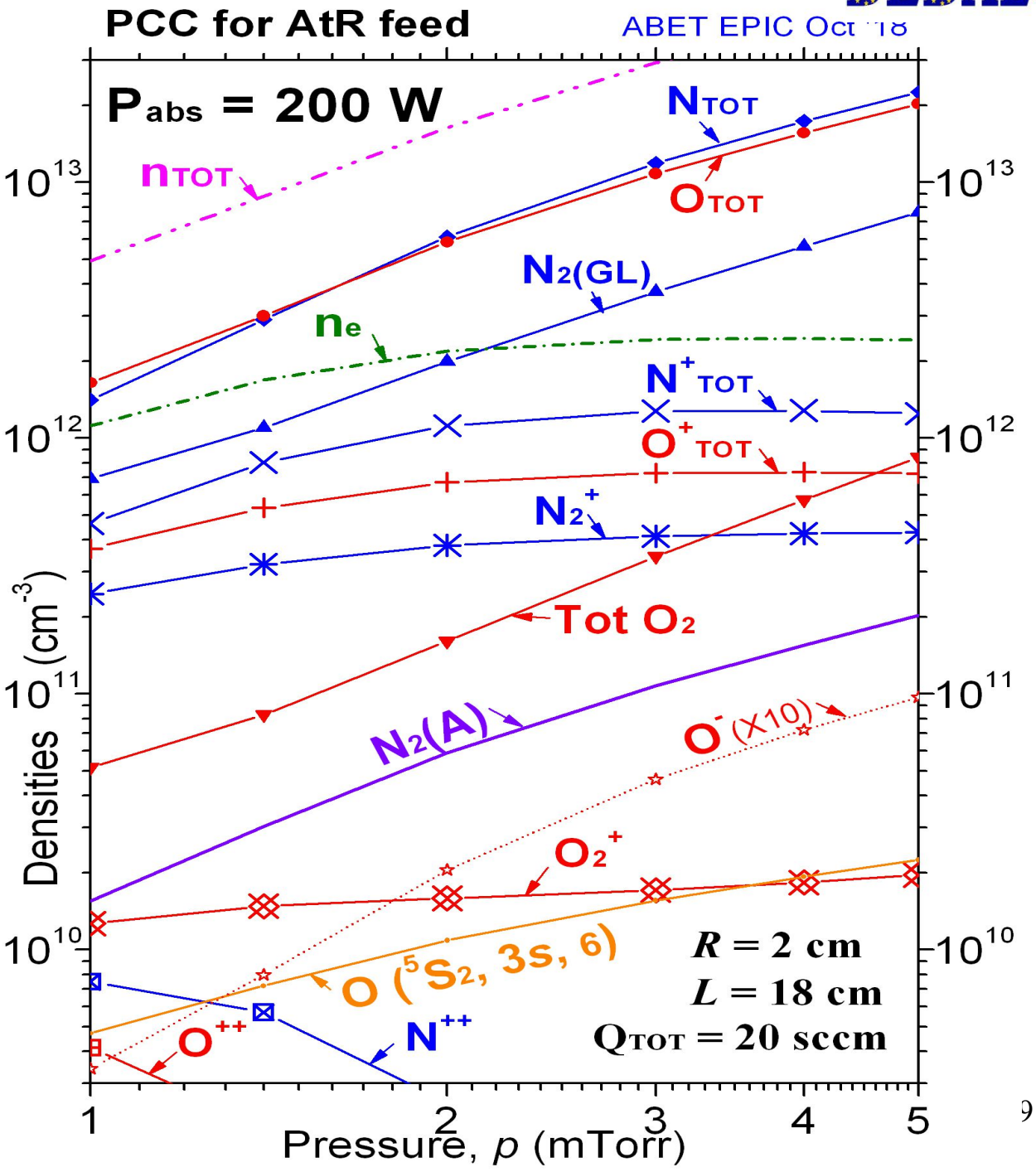
2. Density of Species PCC

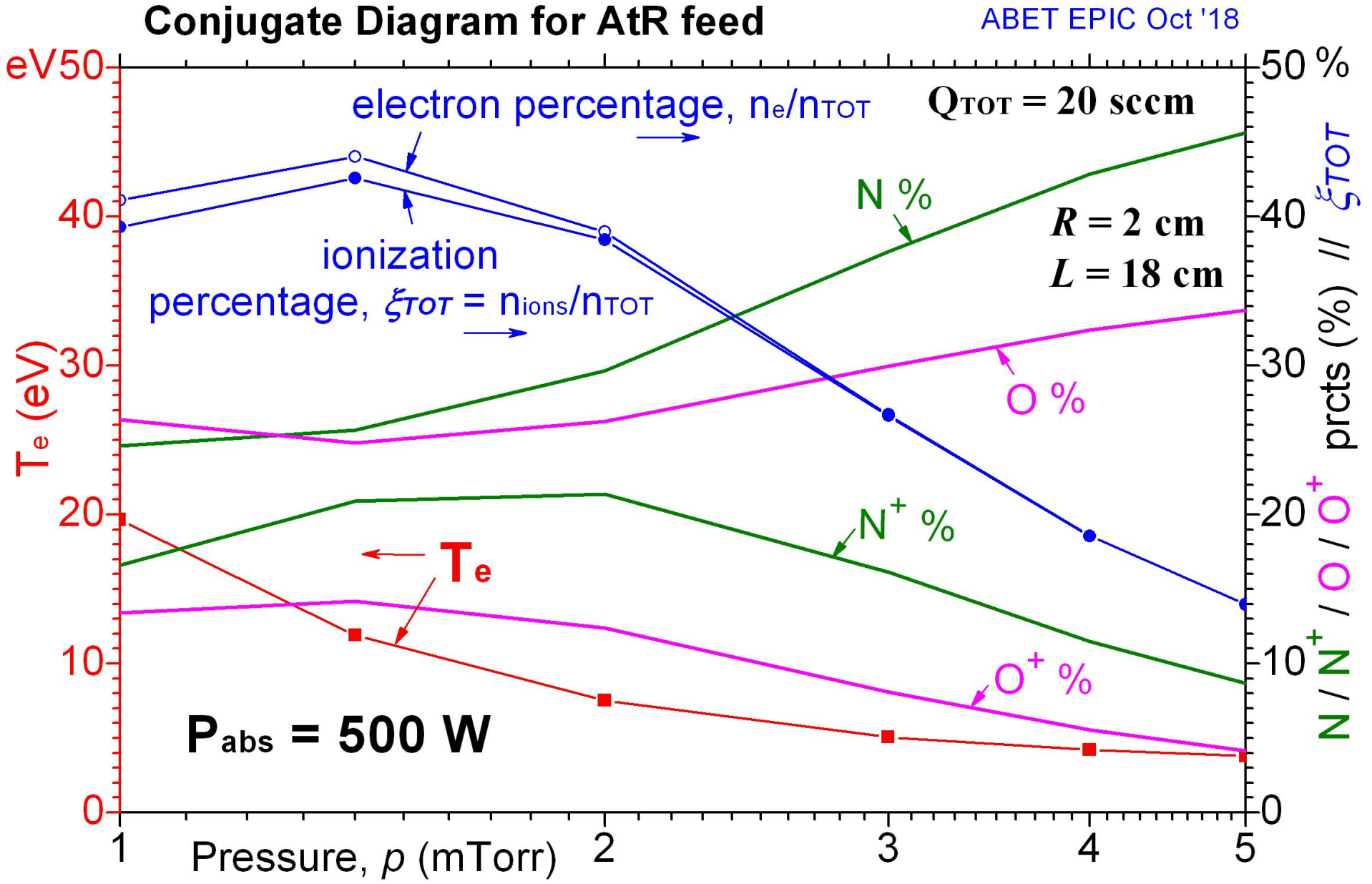
Fig. 2.
P_{abs} = 200 W
pressure dependent PCC

AtR feed of 20 sccm, form factor of R=2 cm, L=18 cm



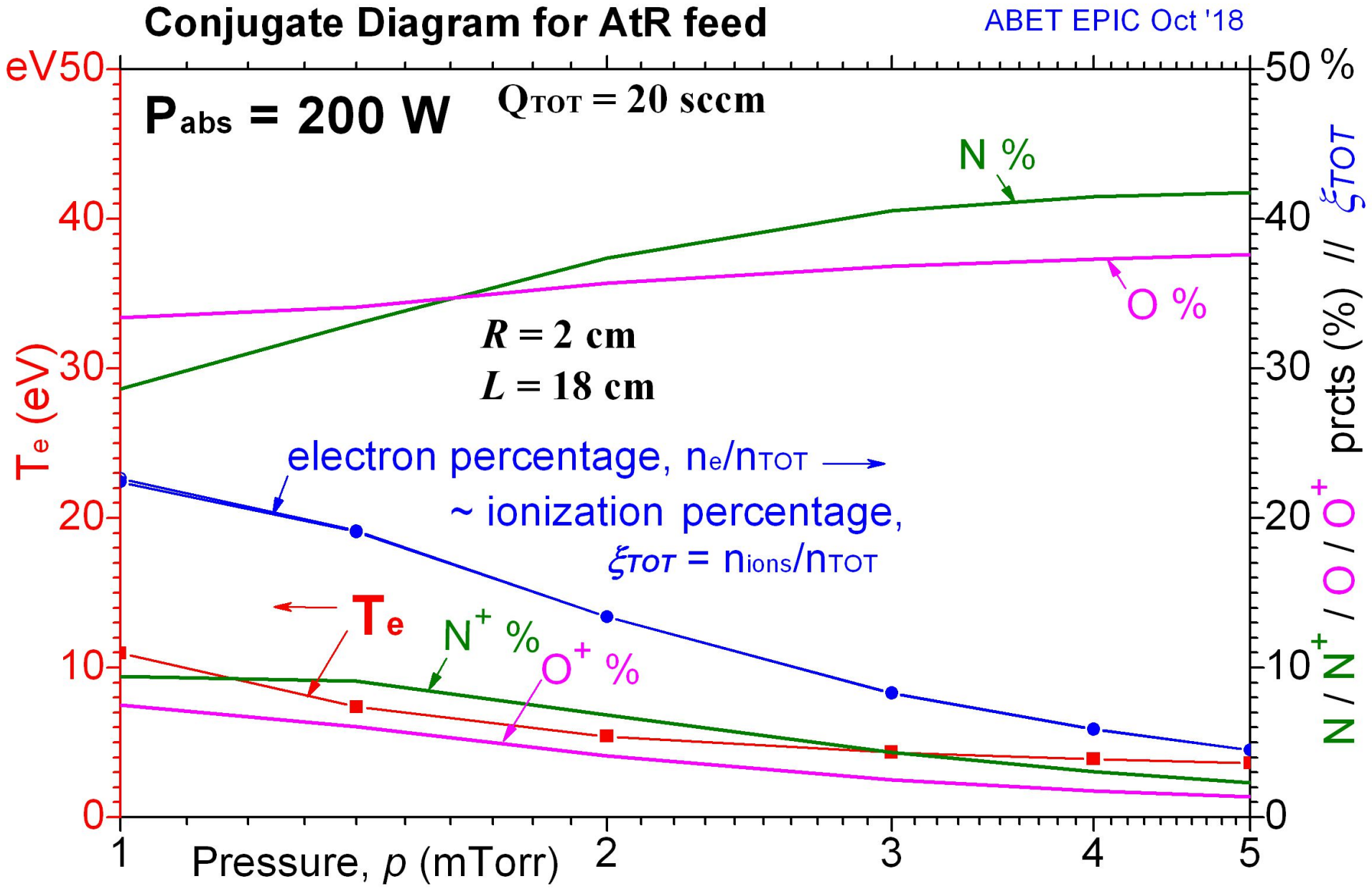
2. Density of Species PCC

Fig. 3. Concomitant of Fig. 1



2. Density of Species PCC

Fig. 4. Concomitant of Fig. 2



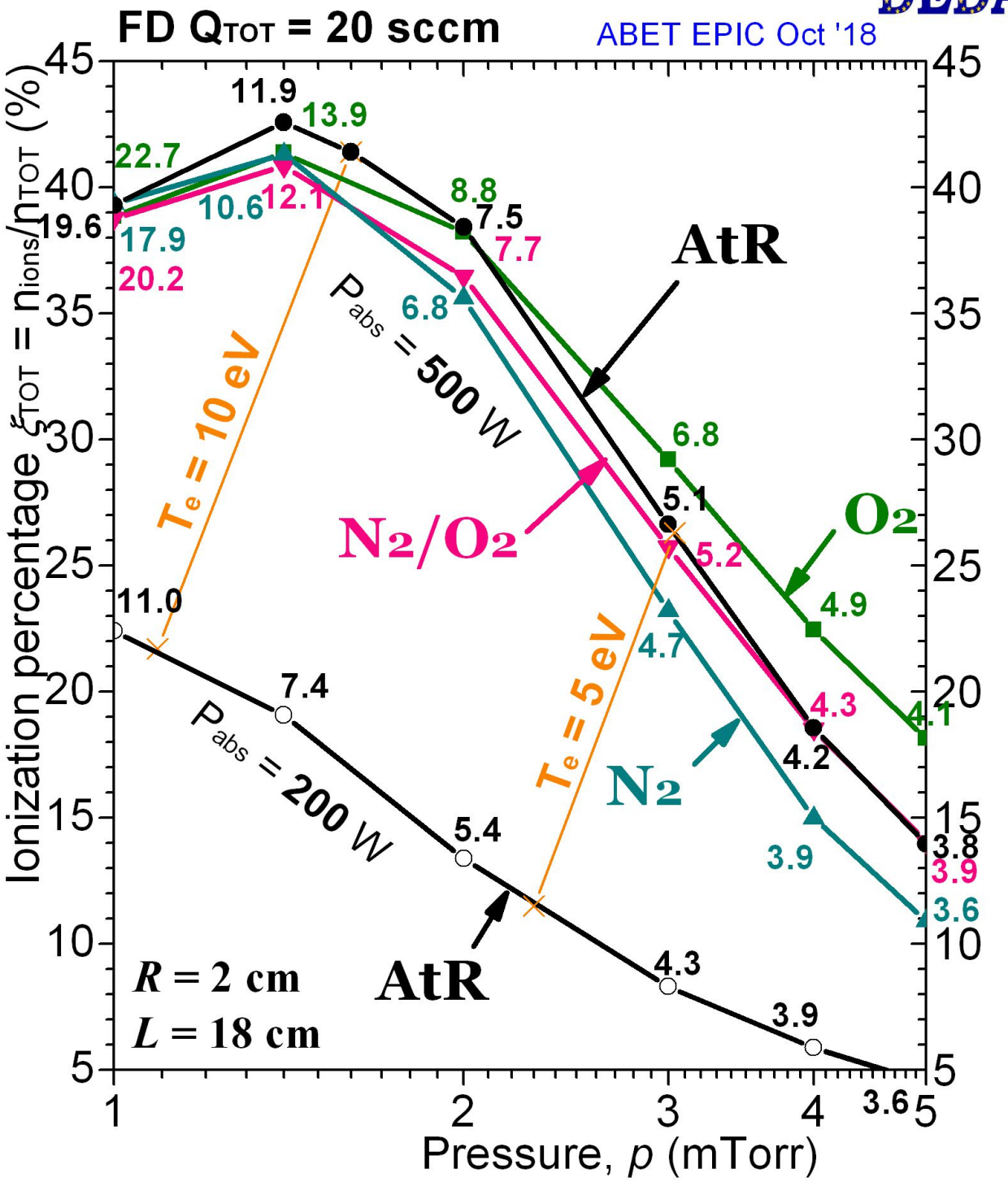
3. Functioning Diagram, FD

Fig. 5.

FD for P_{ABS}= 200 W & 400 W

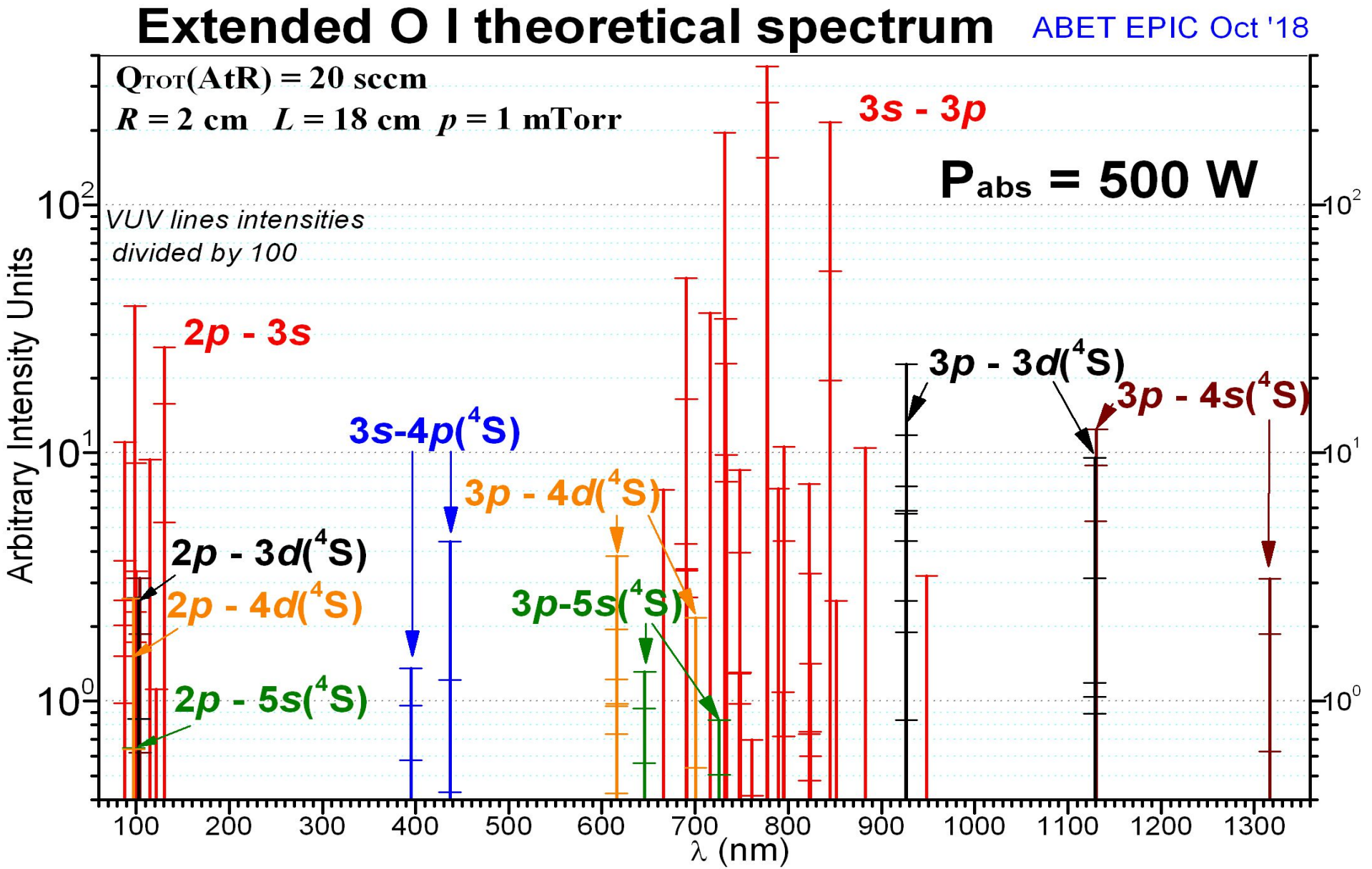
N_2, O_2, N_2/O_2, AtR, T_e = 5 eV & 10 eV,

form factor as before



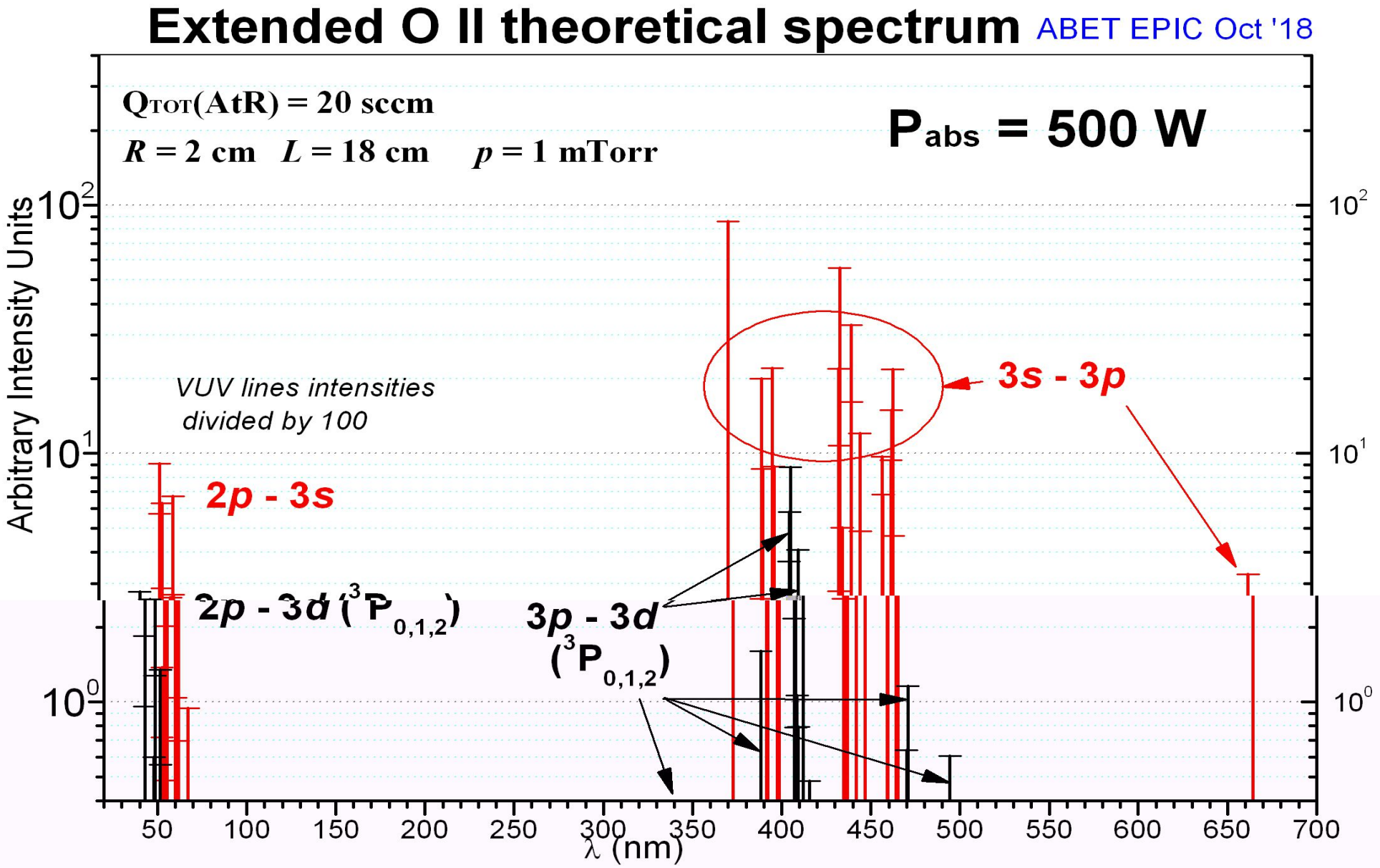
4. Theoretical spectra, OES

Fig. 6. AtR, theoretical O I spectrum for P_{ABS} = 500 W



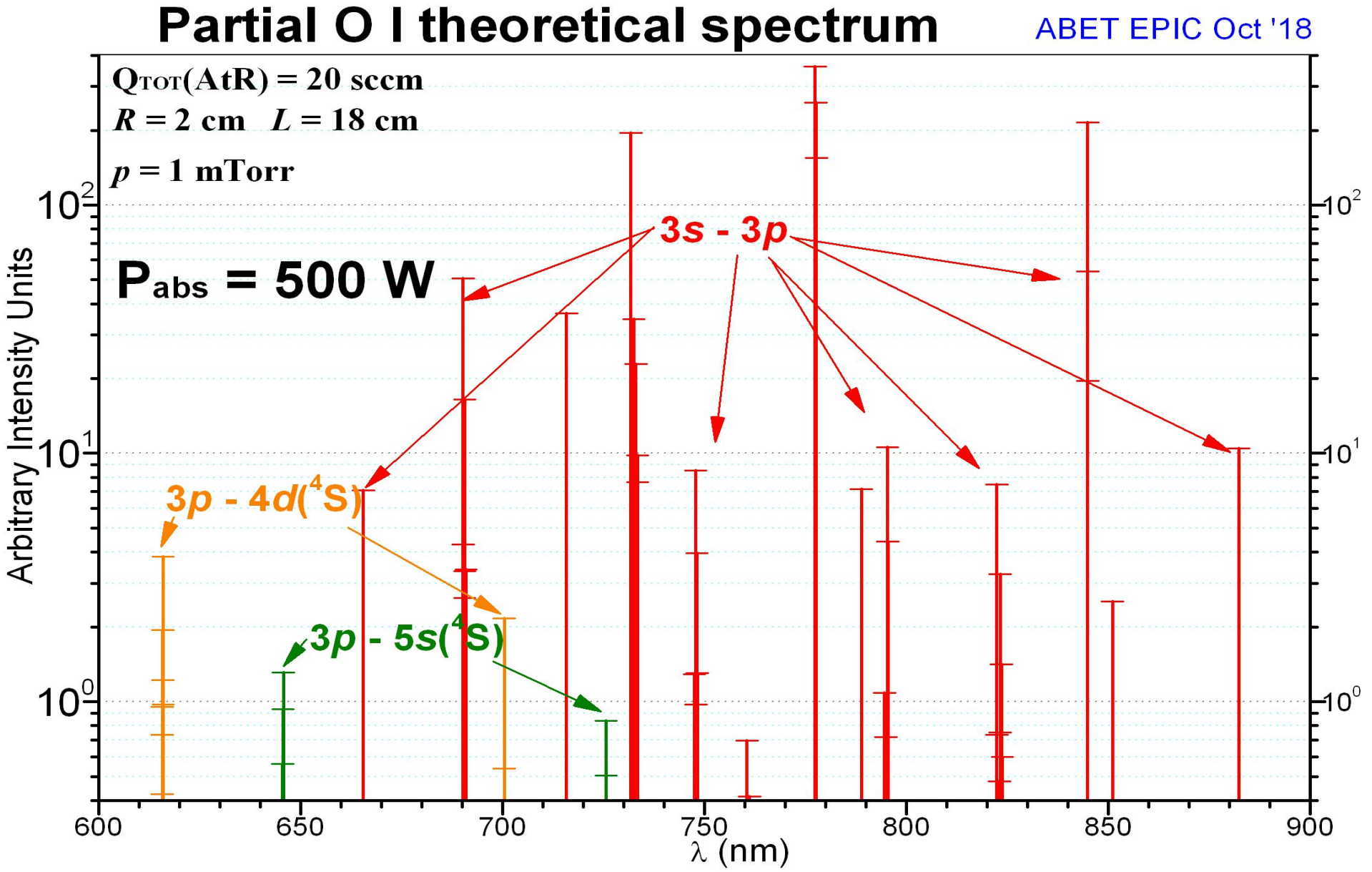
4. Theoretical spectra, OES

Fig. 7. AtR, theoretical O II spectrum for P_{ABS} = 500 W



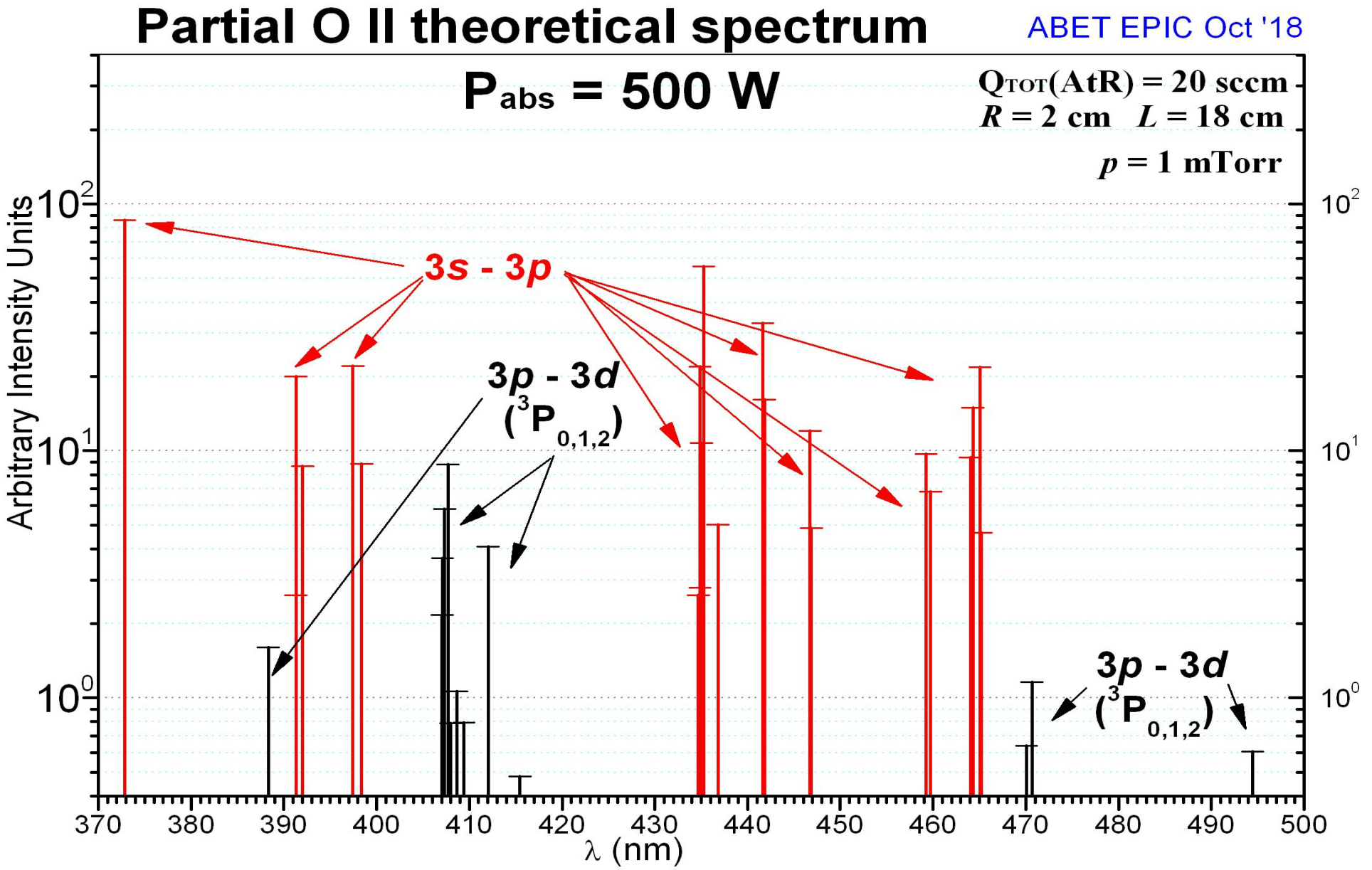
4. Theoretical spectra, OES

Fig. 8. AtR, theoretical O I spectrum for P_{ABS} = 500 W



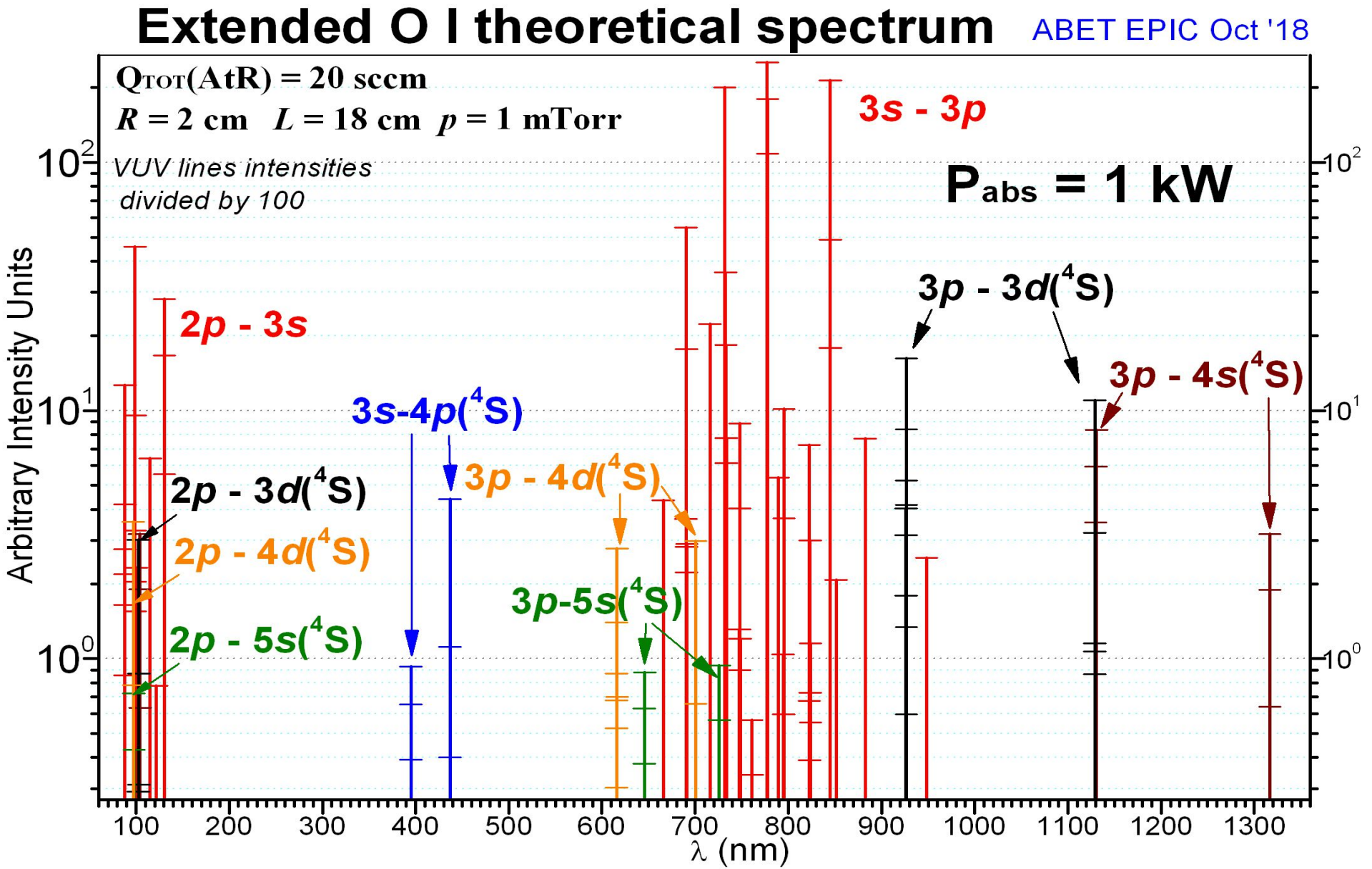
4. Theoretical spectra, OES

Fig. 9. AtR, theoretical O II spectrum for P_{ABS} = 500 W



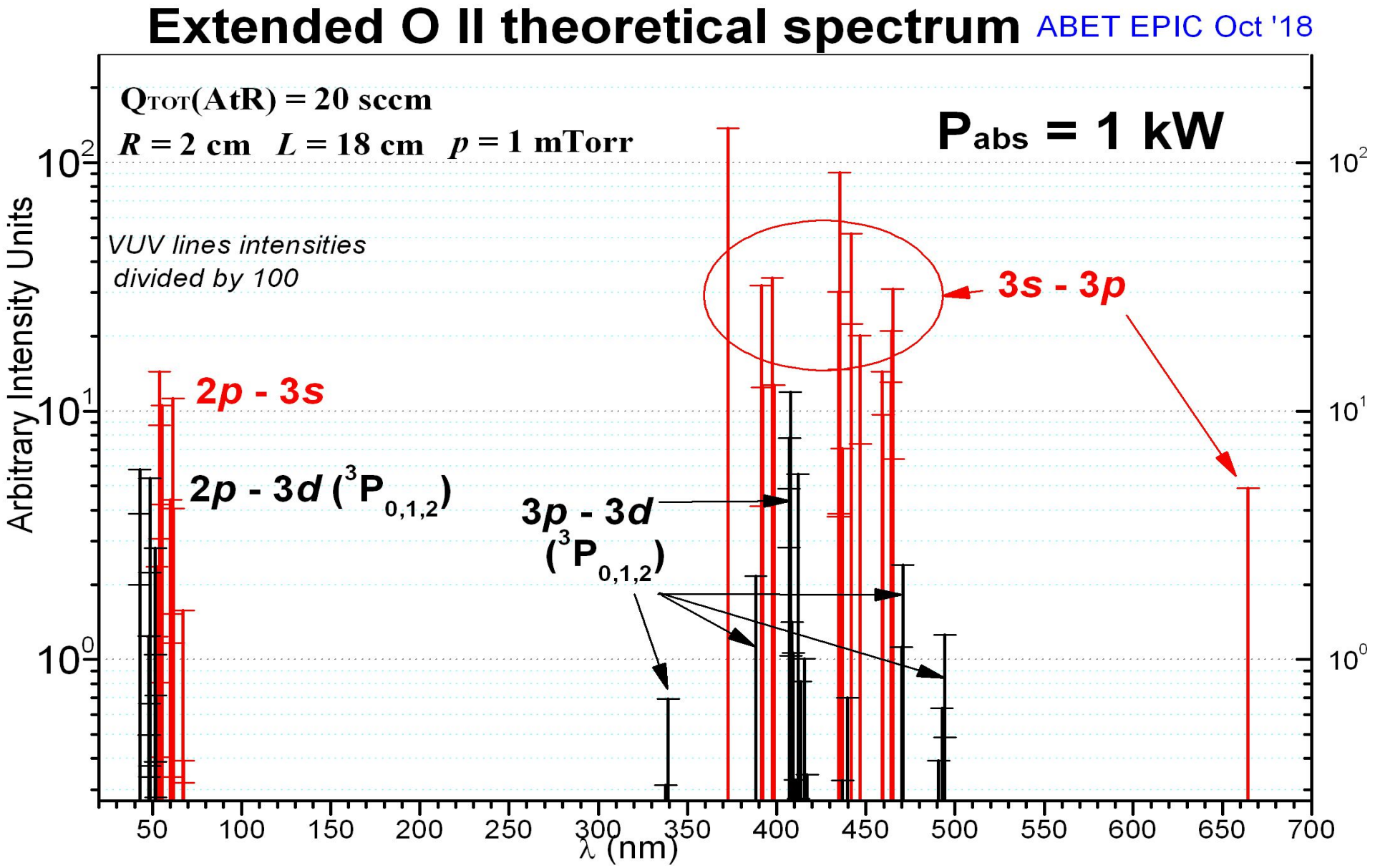
4. Theoretical spectra, OES

Fig. 10. AtR, theoretical O I spectrum for P_{ABS} = 1 kW



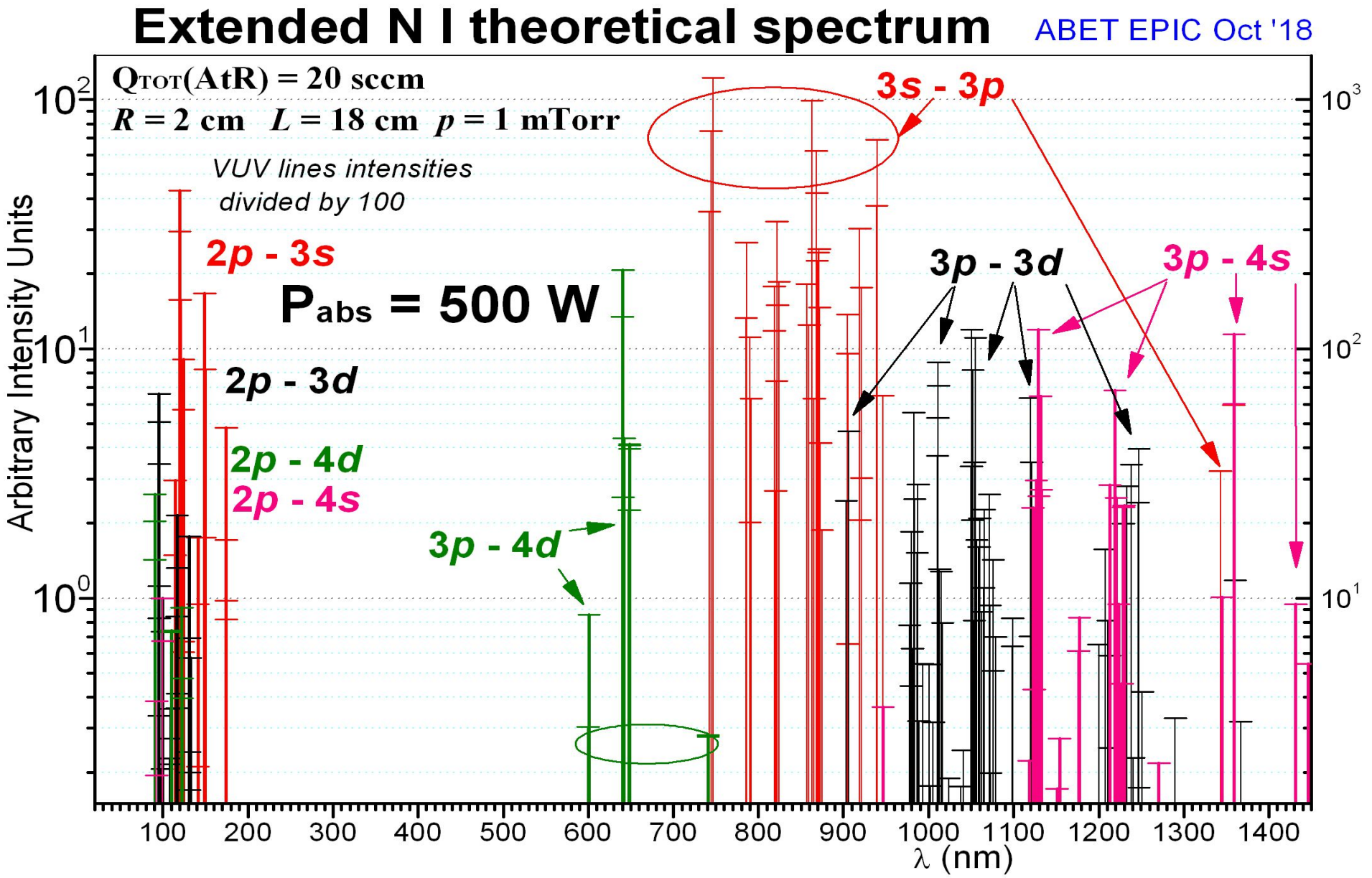
4. Theoretical spectra, OES

Fig. 11. AtR, theoretical O II spectrum for P_{ABS} = 1 kW



4. Theoretical spectra, OES

Fig. 12. AtR, theoretical N I spectrum for P_{ABS} = 500 W



5. Conclusions

♣ **4CDGM** allows for ET feeding by an adequate O_2 / N_2 mixture on ground, to replace the cumbersome AtR one. It leads to experimental results equivalent to those obtainable by AtR feeding. Such a mixture can be used for preparation and diagnostics of on ground ABET experiments.

♣ Plasma containing neutral and ionized species created in case of **ETs** fed by **AtR** allow for **OES**.

♣ After including in **4CDGM** extended sets of nitrogen and of oxygen data, encompassing the main **N** I – III and **O** I – III levels, better description of the atomic and molecular structure effects and of the chemical reactions was obtained. It allows for detailed calculation of theoretical spectra to be used in OES diagnostics.

Thank you for your attention