Diagnostics of hollow cathode low pressure air discharges as a tool for understanding Halo spectral features in the Earth mesosphere

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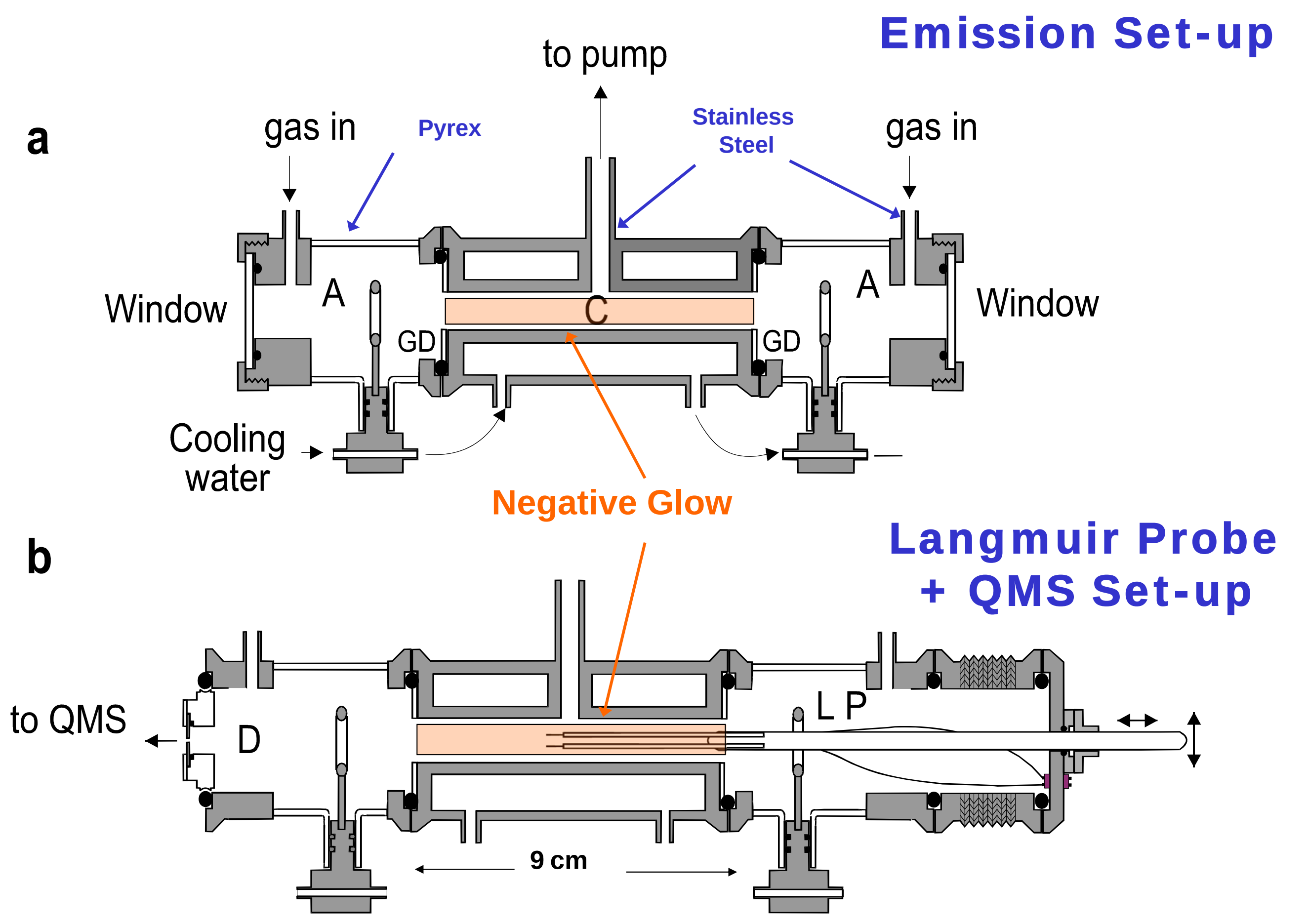
Abstract

Low pressure dc air discharges are characterized by emission spectroscopy from the near UV to the near IR spectral range, by quadrupole mass spectrometry, and with a double Langmuir probe. Several N_2 and N_2^+ emission bands are analysed to obtain the gas temperature. Mass spectrometry is employed to observe the production of nitrogen oxides, and the Langmuir probe provides charge densities and electron temperatures of the air plasma. The spectroscopic results are compared with theoretical models developed to study Halo emissions from transient luminous events (TLEs) in the upper atmosphere.

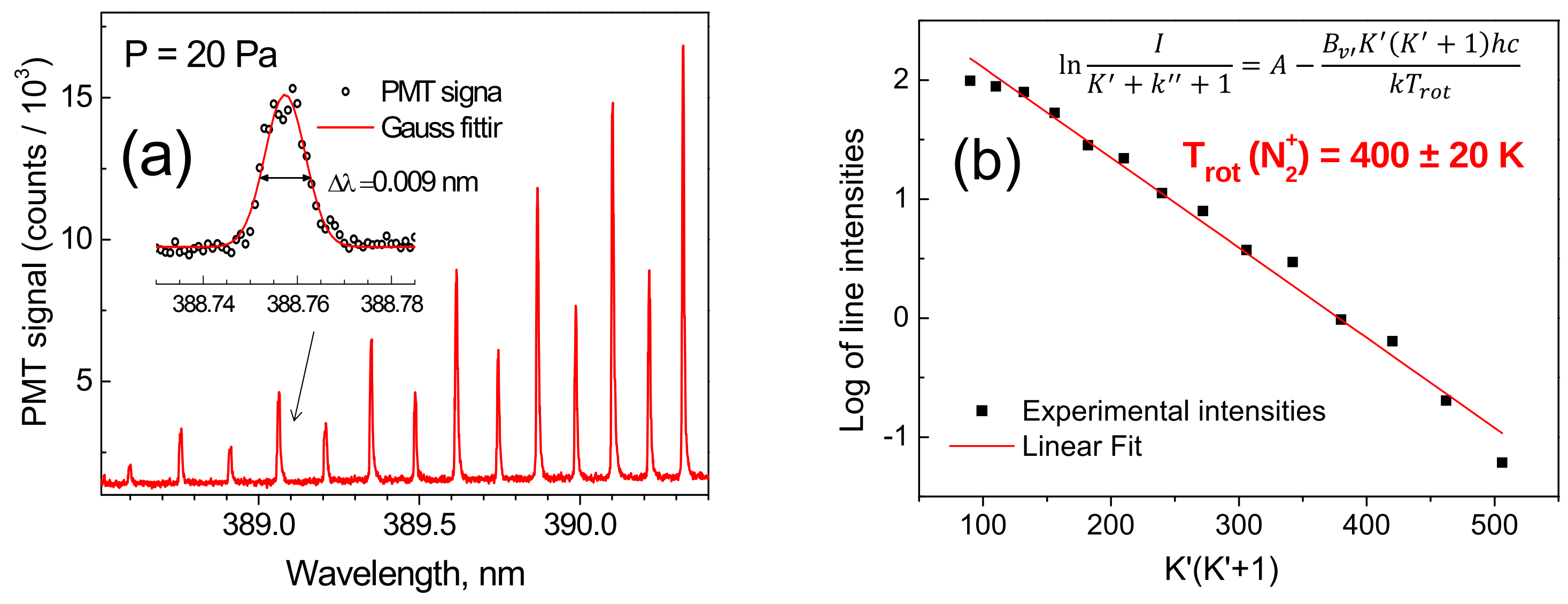
Experimental System

- The air plasmas are generated in a DC hollow cathode gas flow reactor [1,2]. I_{DC} ~ 30-70 mA, $V_{DC} \approx$ 300-500 V, Pressure ~ 2 – 20 Pa.
- Emission spectroscopy is acquired in the 300-1100 nm range with a FHR1000 Jovin-Yvon, 1 m, spectrometer, equipped with CCD and PMT. The spectral resolution can be regulated between 0.008 and 0.14 nm. Low resolution (2 nm) spectra are obtained with an Ocean Optics QE65000 spectrometer. The spectral responses are calibrated with a calibrated tungsten lamp.
- Quadrupole mass spectrometry with ionization by electron impact is performed with a Pfeiffer Prisma Plus instrument located in a differentially pumped vacuum chamber (base pressure = 10^{-5} Pa), sampling through a 100 μm diaphragm. Traces of NO and N_2O are detected in the air plasma.
- Double Langmuir probe provides $N_e=(1.0\pm0.2)10^{11}$ cm^{-3} & $T_e=2.3\pm0.5$ eV



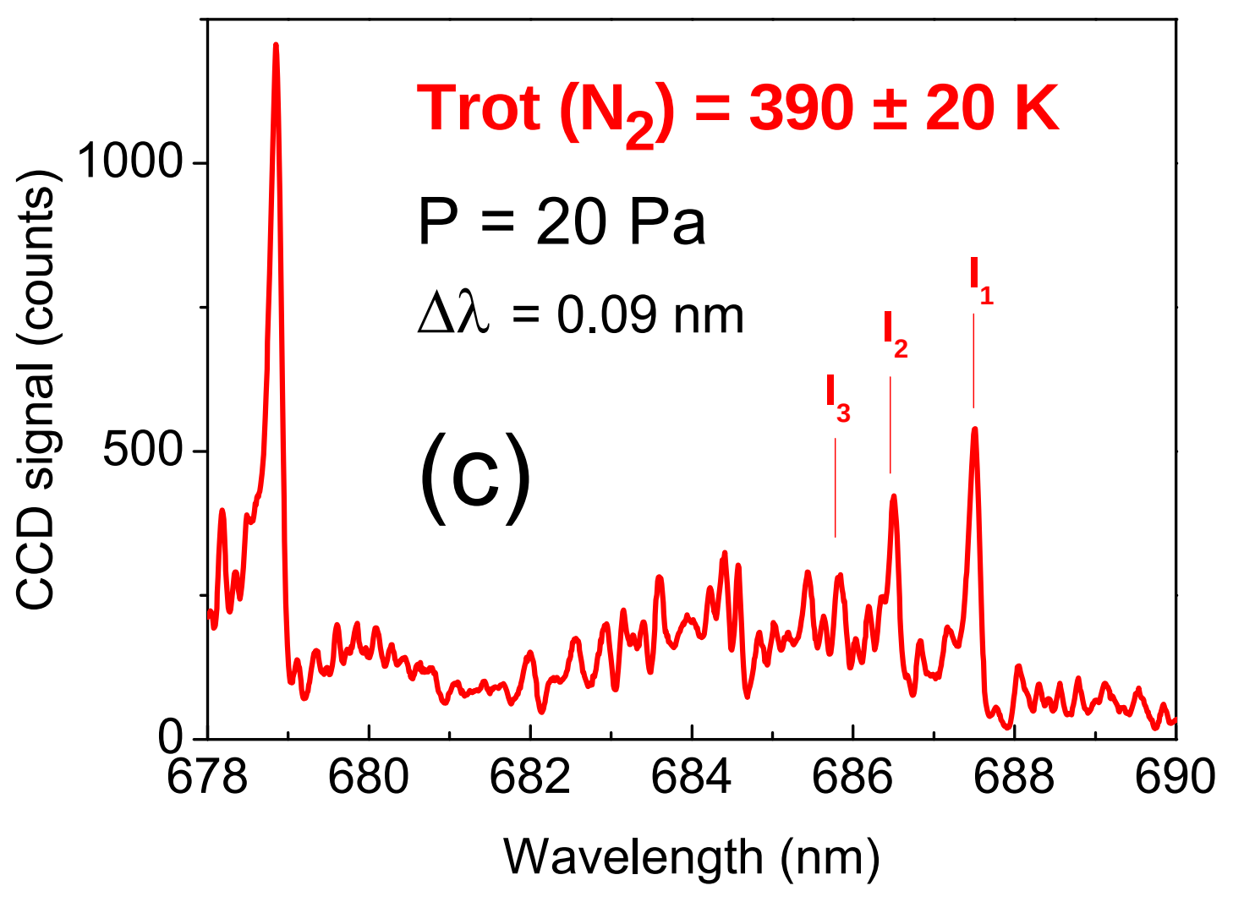
Air Glow

Emission Spectra and Gas Temperature

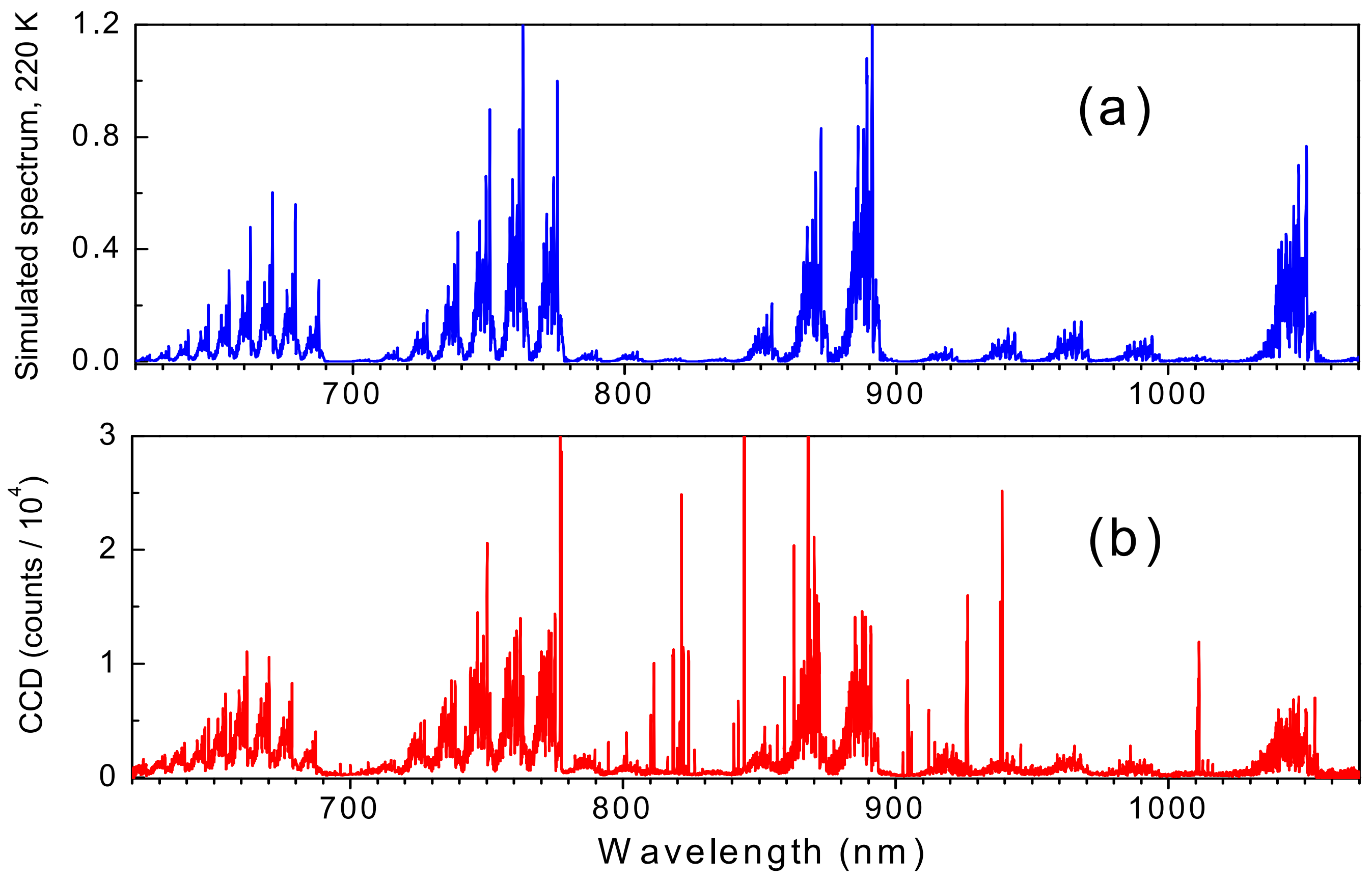


(a) High resolution spectrum of $N_2^+(B^2\Sigma^+_u, v=0) \rightarrow N_2^+(X^2\Sigma^+_g, v=0)$, R branch.
(b) Boltzmann plot and estimation of the rotational temperature T_{rot}.

(c) Low resolution spectrum of the N_2 $(B^3\Pi_g, v'=3) \rightarrow N_2$ $(A^3\Sigma^+_u, v''=0)$ band. T_{rot} is calculated following the method described in [3]. The obtained T_{rot} value agrees with that of N_2^+. T_{rot} is usually assumed to be close to T_{gas} in low temperature plasmas.



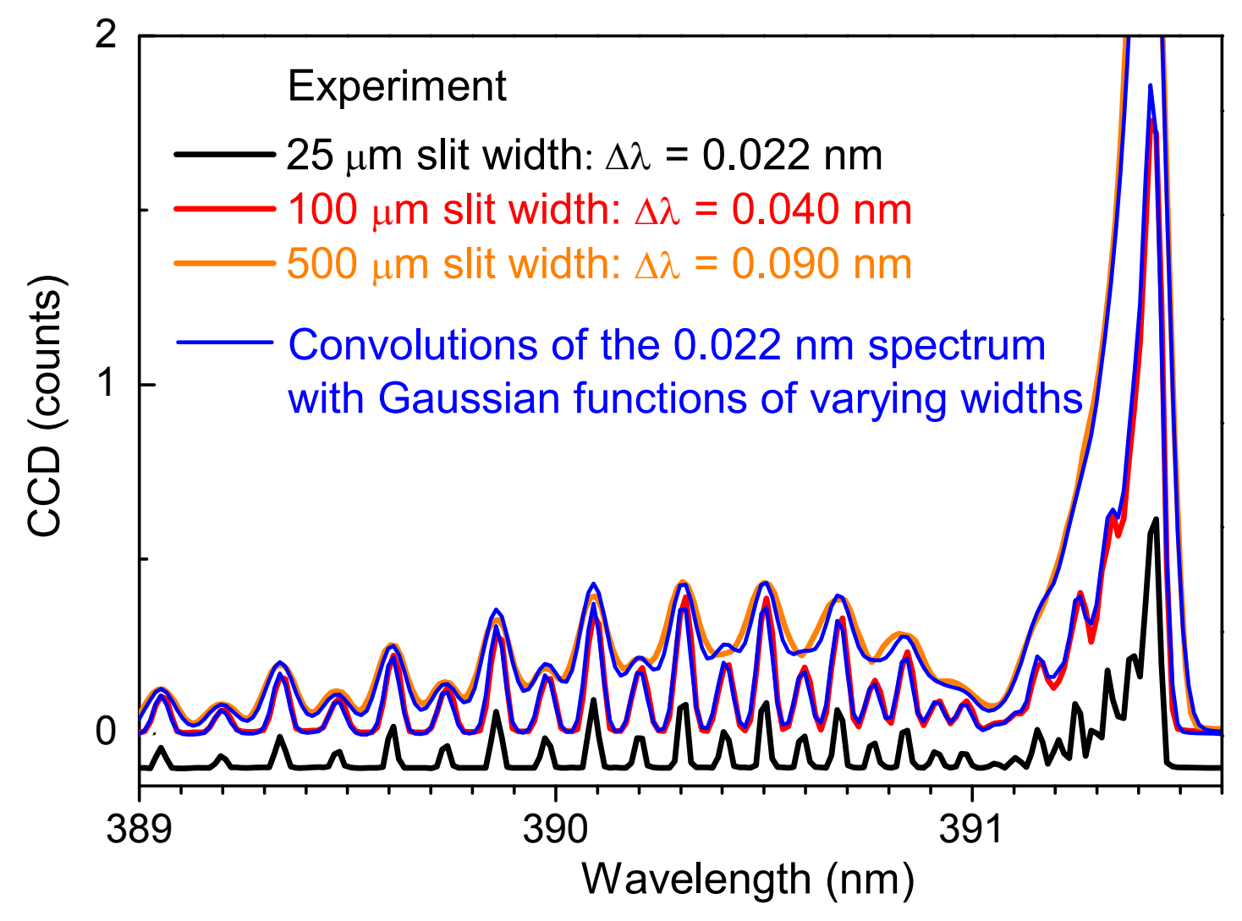
Experimental vs. simulated spectra



Comparison of a calculated spectrum (a) at the typical conditions of Halos at 74 km (P = 5 Pa, T_{gas} = 220 K) [4,5], and an experimental air discharge spectrum at 20 Pa (b), with estimated T_{gas} = 400 K. The spectral resolution is 0.14 nm in both spectra.

In the experimental spectrum, emissions proceeding from N_2^+ and O transitions are observed, together with the emissions of the first positive system of N_2 that are displayed in the calculated spectrum.

Signal Processing



High resolution spectra can be compared with those obtained with a smaller, low resolution, spectrometer by convolution of the first spectra with the instrumental line shape of the smaller spectrometer (usually a Gaussian function in the case of dispersive instruments).

The figure shows 3 spectra acquired with our FHR1000 spectrometer at 3 different resolutions. The blue lines correspond to the convolution of the highest resolved spectrum with Gaussian functions. In this way, the spectra at lower resolution are well reproduced. The first spectrum is displaced downwards for clarity.

Conclusions

- Low temperature, low pressure air plasmas have been generated in hollow cathode discharges and experimentally characterized.
- Current TLE studies can benefit much from measurements on laboratory plasmas, which are helpful in the optimization of diagnostic techniques for field investigations.
- Laboratory data are useful for the validation of model assumptions, although the differences between laboratory and TLE plasmas should be taken into account carefully.

References

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