Production and radiative transfert of the OI 130.4 and 135.6 nm emissions in the Mars aurora

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1 - INTRODUCTION

A weak **oxygen emission at 130.4 nm** was first detected in limb observations of the Martian aurora with **SPICAM/Mars Express** (Soret et al., 2016).
The *Emirates Mars Ultraviolet Spectrometer* (**EMUS**) instrument (Holsclaw et al., 2021) on board the HOPE Emirates orbiter is now able to map the optically thick **130.4 nm** auroral emission (Lillis et al,2022). The forbidden OI **135.6 nm** emission has also been observed (Jain et al., 2022).
We present here **Monte Carlo model simulations** of these oxygen emissions for different initial **electron energies,** discuss possible **seasonal variations** and validate our model with EMUS observations.

2 - PRODUCTION

The OI 1304.4 and 135.6 nm auroral emissions on the nightside are excited by **direct impact of energetic electrons** on CO_2, CO, and O atoms.
We use Monte Carlo model simulations of the production of the O ^3S and ^5S excited states for different initial electron energies. Figure 1 shows that the main production mechanisms are e + O(^3P) → e + O($^3S^0$) and e + O(^3P) → e + O($^5S^0$).

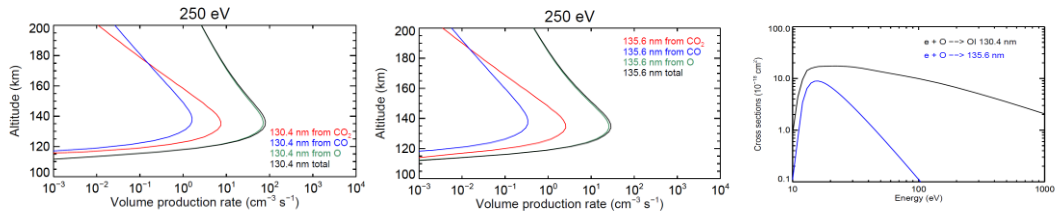

Figure 1: The OI 130.4 and 135.6 nm emissions are mainly produced by electron impact on O. Emission cross sections are shown on the right.

These volume emission rates need to be converted into nadir intensities to be compared with observations. However, a vertical integration of the columns is not sufficient since the 130.4-nm emerging intensity is enhanced by **multiple scattering and** decreased by **absorption by CO_2**(Gérard et al., 2008). We solve the radiative transfer equation for the 130.4-nm triplet and show that **the I(130.4 nm/I(135.6 nm) nadir intensity ratio is expected to widely vary with the initial electron energy** (Figure 2).

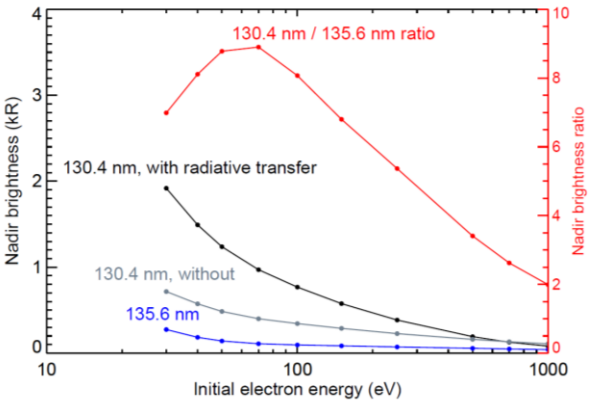

Figure 2: Ratio (red) of the 130.4 (black) and 135.6 nm (blue) nadir intensities plotted as a function of the initial electron energy. The ratio values can be read along the right y-axis (red).

3 - SEASONALITY

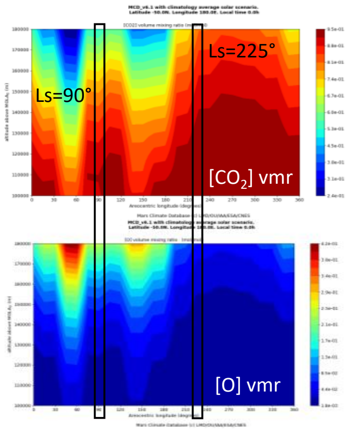

Figure 3: Atmospheric inputs of the Monte Carlo model (from LMD MCD).

Simulations shown in section 2 use Mars Climate Database values as input of the Monte Carlo model. The density profiles were taken in the strong crustal magnetic field area, where aurorae tend to be the brightest and occur more frequently (Schneider et al., 2021). We selected: latitude=50° S, longitude=180° , local time=00:00 and **solar longitude Ls=90°** . We now use the same parameters, except for **Ls=225°** (perihelion). The O and CO_2 volume mixing ratios are quite different (Figure 3) and the simulated nadir brightness are stronger near perihelion by a factor of 2 but their ratios remain almost identical (Figure 4).

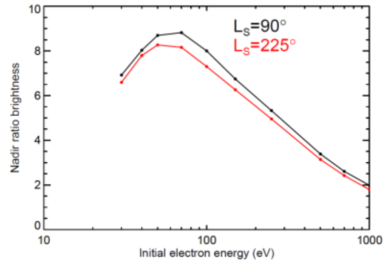

Figure 4:
The I(130.4)/I(135.6) nadir ratios calculated at Ls=90° and Ls=225° are almost identical.

Conclusions:
The I(130.4)/I(135.6) nadir ratio varies between 2 and 9 with the initial energy electron
The I(130.4)/I(135.6) nadir ratio remains almost constant over the Martian year
The ratio reflects the energy of the incoming electrons and may be used to map their spatial distribution.

4 - FUTURE WORK: HOPE/EMUS OBSERVATIONS

Since April 2021, the EMUS instrument on board the HOPE Emirates orbiter has been collecting spectral images in the 110-180 nm range. The OI 130.4 and 135.6 nm auroral emissions have both been observed. Jain et al. (2022) and Lillis et al. (2022) found an average ratio value of ~1.5-5 in the discrete aurorae and ~4-7 in the sinuous aurora. **These values are within the range of the nadir intensity ratio estimated by the Monte Carlo and radiative transfer models.** Additional studies of the EMUS detections will allow to refine the EMUS ratios and estimate the energy of the precipitated electrons generating the auroral emissions.

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