Remote sensing of plasma phenomena in the upper atmosphere of the Earth by ground-based optical emission spectroscopy

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Remote sensing of the Earth mesosphere (50 - 90 km altitude) is difficult because it is too high for atmospheric balloons and usually too low for most satellite sensing. The occurrence of Transient Luminous Events (TLEs) in the upper layers of the atmosphere connected to lightning activity in the troposphere (0 - 14 km) can be now remotely sensed with GRASSP, the *GRanada Sprite Spectrograph and Polarimeter*, which can provide middle resolution (0.24 nm) spectra of transient plasma phenomena occurring in the mesosphere of the Earth. Spectra recorded with GRASSP can provide valuable information about key features of the mesosphere through remote sensing of such transient plasmas. We present preliminary results of gas temperatures and the degree of vibrational excitation of mesospheric air plasmas.

1. Introduction

The first and simultaneous spectroscopic campaigns of TLEs were carried out in the mid 1990s [1, 2], soon after the discovery of TLEs in 1989 [3]. These initial campaigns provided preliminary results on the optical emissions of TLEs corresponding to the first positive system (FPS) of $N_2(B^3\Pi_g) \rightarrow N_2(A^3\Sigma^+_u)$ in the visible and near infrared (NIR) spectral range (540–840 nm) recorded at standard video rate (30 fps) and at low (between 9 and 6 nm) spectral resolution.

More recently, in 2007, spectroscopic observations of sprite optical emissions between 640 nm and 820 nm provided information on the relative vibrational concentrations of the emitting electronic state $N_2(B^3\Pi_g, v')$ at different altitudes using higher video rate (300 fps) and higher spectral resolution (3 nm) spectrographs [4] originally designed for aurora spectroscopy [5].

The above mentioned sporadic TLE spectroscopic campaigns identified some of the key optical emissions from sprites (a type of TLE) and were even able to quantify some of the vibrational concentrations of the emitting levels in reasonable agreement with model predictions [6]. However, the best spectral resolution achieved to date is 3 nm and it is not enough to spectrally resolve the different low-lying vibro-rotational transitions of the FPS of N_2.

This contribution focuses on (1) the latest upgrades of the GRanada Sprite Spectrograph and Polarimeter (GRASSP), a ground-based medium-high spectral resolution spectrograph aimed at characterizing from ground the spectroscopic fingerprints of all sort of TLEs occurring in the mesosphere of the Earth and (2) the GRASSP 2015, 2016 summer-autumn TLE spectroscopic campaign in Europe when we got the first ever recorded high-resolution spectra of sprite halos and columniform and carrot-like sprites.

High-resolution spectra of TLEs recorded with GRASSP are a valuable tool to remotely probe the upper atmosphere of the Earth and extract information about the gas temperature and the distribution of vibrational levels of $N_2(B^3\Pi_g)$ underlying some of the transient optical emissions of TLEs.

GRASSP works at 0.24 nm spectral resolution covering the spectral range between 700 nm and 800 nm. The last version of GRASSP is currently installed in Castellgalí, Barcelona (Spain), it is aimed and operated manually by the operator from the UPC group on-site or operated remotely from IAA-CSIC in Granada.

GRASSP is already being used for systematic TLE spectroscopic surveys in Europe as part of the ground support for the future *Atmospheric Space Interaction Monitor* (ASIM) and the *Tool for the Analysis of RAdiation from LightNIng and Sprites* (TARANIS) space missions to be launch by the end of 2017 and 2018, respectively.

2. References

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