Geophysical Research Abstracts
Vol. 21, EGU2019-1909-7, 2019
EGU General Assembly 2019

Understanding Planetary Ultraviolet Dayglow Through Laboratory Spectroscopy

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The UV response of upper atmospheres to the solar radiation fields (i.e. solar wind and solar extreme-UV) is the focus of the recent generation of Mars, Earth, Titan, and Venus UV missions. These missions are Mars Express (MEX), Mars Atmosphere and Volatile Evolution Mission (MAVEN), Global-scale Observations of the Limb and Disk (GOLD) at Earth, Cassini at Titan, and Venus Express (VEX). Each spacecraft is equipped with a UV spectrometer that senses far-ultraviolet (FUV) emissions between ∼110–190 nm. The dayglow intensities are dependent upon three quantities: 1) electron/ion particle fluxes, 2) the altitude distribution of species present in the ionosphere (CO, CO_2, O, and N2 at Venus and Mars, and N2, O, and O_2 at Titan and Earth), and 3) the emission cross section for the collision process. UV spectroscopy provides a benchmark to the present space environment and indicates pathways responsible for removing upper atmospheric gas (e.g., water escape from Mars, Venus and Earth; N, O, and H escape and surface formation at Titan) over eons. We present a UV laboratory program that utilizes an instrument that can measure excitation mechanisms by particle (i.e. electron, ion) impact that occur in a planetary atmosphere and results in allowed and/or forbidden optical transitions. The resulting accurate emission cross sections include that of the optically forbidden emissions of the Cameron bands from both CO and CO_2, the Fourth-Positive Group (4PG) band system of CO (recently found to contain a small contribution from forbidden cascade), the Lyman-Birge-Hopfield (LBH) bands of N2, and the O I (5So → 3P; 135.6 nm) multiplet from both CO and CO_2. There are presently uncertainties by a factor of two in the existing measurements of the emission cross section, affecting accurate modeling analysis of electron transport. We have recentlyperformed laboratory measurements using mono-energetic electrons to excite band systems by the same processes that occur on solar system objects. We have ascertained vibrational structure and emission cross sections for the strongest band systems and atomic features on solar system objects. The most significant result for the three solar system bodies (Earth, Titan, and Triton) containing N2 as a major species and strong LBH bands is that we have been able to show that the total LBH emission (a 1Πg → X 1Σg+) is generated by two equally important and optically forbidden processes: (i) direct excitation (X 1Σg+ → a 1Πg) resulting in optically forbidden fluorescence by magnetic dipole and electric quadrupole moments and (ii) indirect excitation of the a-state via dipole-allowed (‘slow’) radiative and collisional induced electronic transition (CIET) cascade processes (i.e. a′ 1Σu− → a 1Πg and w 1Δu → a 1Πg). This laboratory measurement represents the first experiment to isolate spectral measurements of the electron-impact-induced N2 cascade spectrum at low electron energies (∼30 eV) without direct excitation. The observed vibrational populations for low vibrational levels from v′=0–2 of the a-state are enhanced by CIET on both Earth and Titan at low thermosphere altitudes