ABSTRACT

Laboratory Aeronomy by Electron Impact of CO and CO_2 for Analysis of UV Observations of the Martian Upper Atmosphere

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We have developed a laboratory aeronomy program at the University of Colorado to study electron impact fluorescence of the Cameron Bands CO ($a\,^3\Pi \rightarrow X\,^1\Sigma^+$; 180–260nm) in the MUV (middle ultraviolet) from two species, CO and CO_2, to match and model the spectra of past, present, and future spacecraft equipped with MUV capabilities to observe the upper atmosphere of Mars (100-300km). Mars Express (MEx) and Mars Atmosphere and Volatile EvolutioN Mission (MAVEN), currently in orbit, are two such spacecraft. UV missions to Mars by NASA and ESA have been motivated by UV dayglow, which responds to solar cycle XUV (extreme ultraviolet) variation, which over eons determines the escape of gases (H and O) in Mars' volatile evolution. One of the most experimentally challenging emission spectral features observed on Mars is the optically forbidden Cameron band system resulting from direct excitation of CO and dissociative excitation of CO_2, whose spectra by electron impact have never been successfully studied in the laboratory before. The rotational levels of the CO a-state, important in Mars' ionosphere, have a lifetime of approximately 5 ms, requiring a mean free path of at least 1 m to observe in laboratory. We present a successful laboratory system, unique in the world for allowing measurement of such optically forbidden transitions, which utilizes a large vacuum chamber, an electrostatic electron gun, and the optical engineering model of the Imaging UV Spectrograph (IUVS) aboard MAVEN. The laboratory spectra compare, though different for each gas, closely with Mars data from MEx and MAVEN, indicating prevalence of a CO_2 dissociation process. Through analysis of these spectra, we have obtained preliminary results for accurate emission cross sections in the MUV of the Cameron bands at 30 and 100 eV, as well as the lifetime of the CO ($a^3\Pi$) state. Current emission cross section uncertainties make analysis of Martian MUV dayglow and determination of constituent number densities of CO and CO_2 by altitude very uncertain. Determining the cross sections will establish a set of fundamental physical constants for electron impact codes to be used in the accurate analysis of MUV spectra in current and future missions to Mars and other terrestrial bodies, such as the aforementioned, Venus Express, Cassini at Titan, and the upcoming Emirates Mars Mission.