Visible to near infrared emission spectra of electron-excited H\textsubscript{2}

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Abstract

H\textsubscript{2} is the most abundant molecule in the universe and is an active component of star formation. Inside dense molecular clouds, heating and ionization occur by cosmic rays, X-rays and shock waves, generating energetic electrons. Collisional excitation by electrons is the source of both UV and Visible-optical-IR (VOIR) H\textsubscript{2} fluorescence in the ISM, circumstellar disks and certain classes of stars [1]. The importance of collisional excitation processes has been verified with analysis of HST and IUE observations of Herbig-Haro (HH) Objects, T Tauri stars and reflection nebulae [2,3]. In particular, intense H\textsubscript{2} transitions in the VOIR from various vibrational levels have been observed in highly-collimated jets of matter from young stellar objects [4]. These observed lines trace the colder molecular part of the post-shocked gas [5].

In recent work, we have demonstrated [6] that the gerade series (EF\textsuperscript{\Sigma}\textsubscript{\textit{g}}\textsuperscript{+}, GK\textsuperscript{\Sigma}\textsubscript{\textit{g}}\textsuperscript{+}, H\textsuperscript{\Sigma}\textsubscript{\textit{g}}\textsuperscript{+}, I\textsuperscript{\Pi}\textsubscript{\textit{g}}, J\textsuperscript{\Delta}\textsubscript{\textit{g}}...) makes a significant contribution to the UV spectrum of H\textsubscript{2} via its cascade spectrum in the visible/near IR to the \( n = 2\sigma\pi\) and \( 2\rho\pi\) states, the upper states of the Lyman and Werner bands, respectively. Here, we have measured the electron-impact-induced emission spectrum of H\textsubscript{2} in the VOIR wavelength region 700 nm to 950 nm at a spectral resolution of 2 nm (FWHM). A model spectrum of H\textsubscript{2}, based on newly calculated transition probabilities and line positions including rovibrational coupling for the strongest band systems is in excellent agreement with observed intensities.

The VOIR emission spectra of H\textsubscript{2} and HD have never been studied before in optically-thin single-scattering conditions. This work will complete analytic models for use in electron transport codes of the two most fundamental sets of electronic cross sections in UV astronomy: the Lyman and Werner band systems (B\textsuperscript{\Sigma}\textsubscript{\textit{u}}\textsuperscript{+} 1\sigma2\rho\sigma – X\textsuperscript{\Sigma}\textsubscript{\textit{u}}\textsuperscript{+} and C\textsuperscript{\Pi}\textsubscript{\textit{u}}\textsuperscript{+} 1\sigma2\rho\pi – X\textsuperscript{\Sigma}\textsubscript{\textit{u}}\textsuperscript{+}) of H\textsubscript{2} and HD [7].


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