Visible to near infrared emission spectra of electron-excited H_2

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Abstract

H_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_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_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 ($EF^1\Sigma_g^+$, $GK^1\Sigma_g^+$, $H^1\Sigma_g^+$, $I^1\Pi_g$, $J^1\Delta_g$...) makes a significant contribution to the UV spectrum of H_2 via its cascade spectrum in the visible/near IR to the $n = 2p\sigma$B and $2p\pi$C states, the upper states of the Lyman and Werner bands, respectively. Here, we have measured the electron-impact-induced emission spectrum of H_2 in the VOIR wavelength region 700 nm to 950 nm at a spectral resolution of 2 nm (FWHM). A model spectrum of H_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_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 ($B^1\Sigma_u^+ 1s\sigma 2p\sigma$ – $X^1\Sigma_u^+$ and $C^1\Pi_u^+ 1s\sigma 2p\pi$ – $X^1\Sigma_u^+$) of H2 and HD [7].

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