Characterizing Precipitating Electrons in Ganymede's Auroras through Juno/UVS observations and Coupled Electron Transport and Radiative Transfer Models

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Abstract

Auroral emissions offer crucial insights into the coupling between planetary magnetic fields, atmospheres, and surrounding plasma. While Jupiter's aurorae are well studied, those of Ganymede, the only moon with an intrinsic magnetic field, remain less understood. Observations by the Hubble Space Telescope (HST) and Juno/UVS have revealed UV auroral ovals on Ganymede, shaped by its interaction with Jupiter's magnetosphere and associated with atomic oxygen emissions at 130 and 135 nm. While these emissions, originate from electron impact excitation of oxygenated species such as H_2O, O, and O_2, are clearly detected, the energy and distribution of the precipitating electrons responsible remain poorly constrained.

Building on our previous work on Jupiter's aurorae (Benmahi et al. 2024a,b), we applied a similar methodology to Ganymede, focusing on emissions in the 125–135 nm range. Using our electron transport model TransPlanet coupled with a custom non-LTE radiative transfer model, we reproduced the OI 130 and 135 nm emissions observed by Juno/UVS during the PJ34 flyby, across sunlit regions 0 to 16.

By analyzing the total brightness and intensity line ratio (I_{135}/I_{130}), and accounting for solar UV reflection by the surface, we constrained the energy flux and mean energy of the precipitating electrons. The theoretical line ratio varies with species: ~0.2 for H_2O, ~2.2 for O_2, and ~0.02 for O. The observed median ratio of 2.22 suggests a dominant contribution from O_2, consistent with sublimation-driven H_2O depletion in the analyzed regions, located far from the subsolar point.

To infer the electron energy distributions, we tested both broadband kappa and monoenergetic inputs. Kappa distributions failed to reproduce the observed brightness and ratio simultaneously. In contrast, monoenergetic distributions provided better agreement, with characteristic energies from ~20 eV in quiescent areas up to ~200 eV in the brightest spots, and corresponding energy fluxes of 0.5–5.0 mW/m². These results indicate relatively low-energy electron precipitation, yet with energy fluxes comparable to those at Jupiter. The absence of high-energy electrons is consistent with Ganymede's tenuous atmosphere, where excitation cross sections for the OI 3S and 5S states decrease sharply with energy, limiting emission production at 130 and 135 nm.

In conclusion, while monoenergetic models generally offer the best fit, some discrepancies remain. These likely reflect uncertainties in the atmospheric composition, especially the H_2O profile, or alternative, more complex electron distribution functions. Refinements in atmospheric models and in-situ constraints from future missions will be essential to fully characterize Ganymede's auroral processes.

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