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Comparative Planetary Atmospheric Responses to Auroral Precipitation

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Abstract

We will review planetary-comparative multi-wavelength auroral studies including our modeling approach. We test the UV emission rates from H_2 and fundamental line IR emission from H_3^+ as functions of exospheric temperature, auroral electron energy and flux. The differences between Jupiter and Saturn emissions can be explained by the different temperatures and the possible existence of H20 in Saturn's auroral ionosphere.

1. Introduction

Planetary aurorae are observed at various wavelengths according to the energy relaxation of atmospheric particles following impact by energetic auroral electrons. Ultraviolet (UV) and infrared (IR) observations of the outer planets show both similarities and differences; i.e., a different brightness distribution along the main oval at Jupiter [1] and similar main oval location but different lower- and higher- latitude emission profiles (e.g., [2]) including broad polar IR emission at Saturn. Auroral emission models have been developed to explain the observed UV and IR emissions, relating their spatial and temporal variations to parameters such as auroral electron energy and flux, atmospheric temperature, and H_3^+ density.

In order to understand the similarities and differences of UV and IR emissions at Saturn and Jupiter in a systematic way, we develop a model to investigate their dependence on the incident electron spectrum and atmospheric temperature. The next section introduces our modelling study [3].

2. Emission Model Study

2.1 Overview

Fig. 1 shows a flowchart of the model. Auroral electrons collide with and excite atmospheric molecules and atoms. The UV aurora is emitted from electron-excited H_2 and H when it de-excites to its ground state. Absorption of UV by hydrocarbon molecules is effective at low altitude. Auroral electrons also ionize molecular hydrogen, which can undergo various chemical reactions to produce ions including H_3^+. Following collisions with background H_2 under high thermospheric temperature, H_3^+ is excited vibrationally. Some excited H_3^+ ions de-excite by IR emission to generate the aurora. Our model estimates the population of excited H_3^+ under non-LTE (local thermal equilibrium) conditions caused by this efficient IR emission. Here we consider a Maxwellian distribution of electrons for simplicity with the mean energy of the distribution $2\varepsilon_0$ and flux f_0. The altitude profile of atmospheric temperature is assumed and varies with exospheric temperature T_{ex}. For the different planets, Jupiter and Saturn, we use the same model code with different inputs.

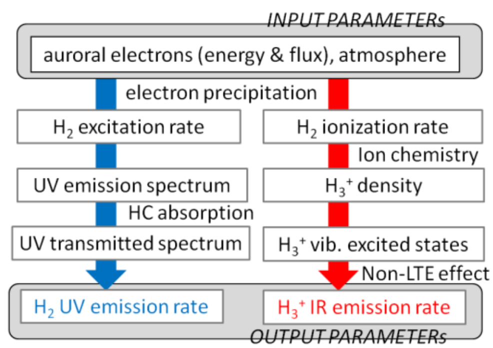

Figure 1: Flowchart of developed emission model.

2.2 Results: UV/IR dependences

The dependence of altitude-integrated values of UV and IR emissions on electron energy ε_0, flux f_0, and exospheric temperature T_{ex} for Jupiter is shown by diamonds and crosses in **Fig. 2** and for Saturn is in **Fig. 3**. The emission intensities are normalized to the conditions ε_0 = 10 keV, f_0 = 0.15 μA/m^2, and T_{ex} = 1200 K for Jupiter and the same ε_0 and f_0 with T_{ex} = 420 K for Saturn. The normalized emission intensities of UV (lines in 117–174 nm range) and IR (Q(0,1-) line) are 38.1 kR , and 33.0 μW/m^{2}str for Jupiter, and 37.3 kR and 0.530 μW/m^{2}str for Saturn.

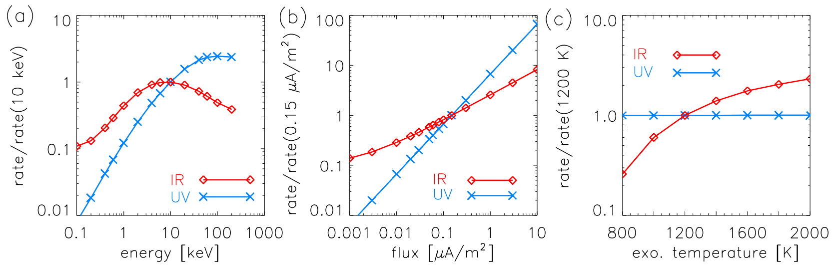

Figure 2: Jupiter UV/IR dependence on (a) electron energy, (b) flux, and (c) temperature.

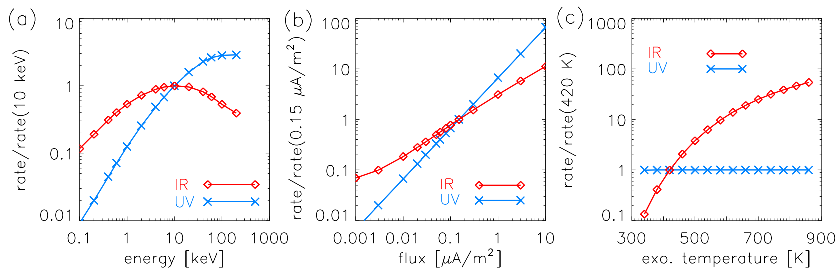

Figure 3: Saturn UV/IR dependence on (a) electron energy, (b) flux, and (c) temperature.

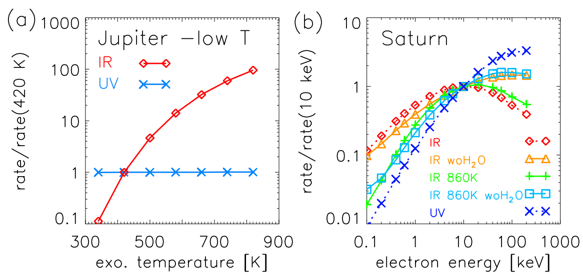

Figure 4: Test of UV/IR dependence on (a) temperature at Jupiter and (b) electron energy at Saturn under the different conditions.

The different dependence of emission rates on electron energy and temperature between the Jupiter and Saturn models is summarized as two main points: (1) the temperature-dependent variability of IR emissions for Saturn (three orders of magnitude, **Fig. 3c**) is larger than that for Jupiter (one order of magnitude, **Fig. 2c**), and (2) the electron energy dependence of IR emission for Saturn (**Fig. 3a**) has a smaller slope in the energy range of 0.5–5 keV than that for Jupiter (**Fig. 2a**).

2.3 Discussion: Jupiter-Saturn comparison

The dependence of Jovian emission intensities on temperature in the 300–820 K range (**Fig. 4a**) shows a large IR variation like Saturn (**Fig. 3c**). Therefore these differences are caused by the absolute value of exospheric temperature. **Fig. 4b** shows the dependence of Saturn's emission intensities on energy for a high temperature case and a no H_2O case. Both decrease the discrepancy between UV and IR emission rates at small energy ~1 keV, with the temperature causing the largest effect. Therefore the different energy dependence between Saturn and Jupiter is due to the temperature and existence of H_2O.

3. Summary

Auroral emissions reflect properties of the source electrons and background atmosphere environment. The UV/IR emission model is useful to constrain the cause of different UV and IR emissions at Jupiter and Saturn, which recent ground-based and spacecraft observations have revealed.

References

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