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Observing Jupiter's Aurorae using the Juno Microwave Radiometer

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Abstract

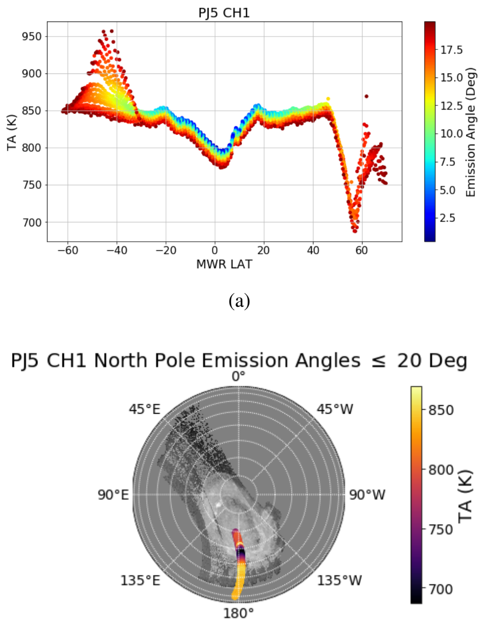
The effect of aurorae on Jupiter's microwave emission has been detected using Juno's Microwave Radiometer (MWR). These effects were characterized by cold spots detected in the northern and southern aurorae on channels 1 (0.6 GHz), 2 (1.24 GHz), and 3 (2.6 GHz). Out of Juno's first 19 orbits, cold spots in channel 1 or channels 1-3 have been detected in eight orbits. In order to understand the cause of these cold spots, a microwave radiative transfer code has been developed to derive the effects of Jupiter's aurorae using the Appleton-Hartree equation.

1. Introduction

Jupiter's magnetosphere creates aurorae in the northern and southern hemispheres that are 100 times more energetic and have 10 times higher surface brightness than Earth's aurorae. These auroral events occur in Jupiter's upper atmosphere, primarily in the ionosphere where the atmospheric pressure is less than 1 bar [2]. The Juno mission has four instruments dedicated to measurements of the features of Jupiter's aurorae: the Jovian Auroral Distributions Experiment (JADE), the Juno Energetic particle Detector Instrument (JEDI), the Jovian InfraRed Auroral Mapper (JIRAM), and the Ultra Violet Spectrograph (UVS). However, recent results from the Juno mission suggest that some auroral effects can be measured with Juno's MicroWave Radiometer (MWR). The main objective of the MWR instrument is to determine the composition and dynamics of the deep atmosphere and the global water abundance of Jupiter. The MWR instruments consists of six radiometers and accompanying antennas operating at 0.6 GHz, 1.24 GHz, 2.6 GHz, 5.2 GHz, 10 GHz , and 22 GHz with channel numbers in ascending order [4]. In the auroral regions, channels 1, 2, and 3 can be affected based on the electron density of the aurora which is indicated by a dip in antenna temperature known as a cold spot. Simulating the characteristics of the plasma in Jupiter's aurorae and incorporating them into a microwave radiative transfer algorithm can improve our understanding of how microwave frequencies interact with the jovian aurorae.

2. Juno Microwave Observations

For the preliminary observations, cold spots were determined by using the antenna temperature at the equator as a baseline. At Jupiter's equator, there is a significant amount of ammonia in the deep atmosphere that absorbs microwaves causing a significant dip in antenna temperatures. For channel 1, the antenna temperature drops to approximately 800 K at the equator. Thus, a cold spot can be assumed at the northern and southern aurorae if the antenna temperature drops below 800 K for channel 1. Cold spots for channel 2 and 3 are identified as similar dips at the same location as channel 1. In order to correlate these cold spots with aurorae, the MWR data was plotted on top of UV maps produced by Juno's UVS team [1]. Channel 1 was the best baseline for auroral cold spots because it is at the frequency least susceptible to ammonia absorption. Consistently, the cold spots have been found along the edge of the main auroral oval for the northern and southern aurorae. Out of the first 19 perijoves (excluding perijove 2), there have been auroral cold spots found in eight orbits: perijoves 1, 3, 5, 6, 7, 10, 11, and 15. Figure 1 displays an example of results from PJ 5, the strongest cold spot thus far. There was a significant cold spot for channel 1 at 45-60 degrees latitude that reaches down to about 680 K. This dip was also seen in channels 2 and 3.



(a)

(b)

Figure 1: (a) MWR data for emission angles less than 20 degrees during PJ 5 for channel 1. Significant cold spot at 45-60 degrees latitude. (b) Polar plot of MWR data from PJ 5 channel 1 mapped on top of UVS data for the northern aurora.

3. Numerical Approach

The effects of Jupiter's aurorae can be simulated using JPL's Jupiter Atmospheric Microwave Radiative Transfer (JAMRT) code [4]. JAMRT uses a microwave radiative transfer model to produce brightness temperatures that can be convolved with antenna beam patterns to produce antenna temperatures.To simulate the aurora effect, the absorption coefficient and scattering coefficient are calculated using the Appleton-Hartree equation [3]:

$$n^2 = 1 - \frac{X}{1-iZ-\frac{\frac{1}{2}Y^2\sin^2\theta}{1-X-iZ}\pm\frac{1}{1-X-iZ}\left(\frac{1}{4}Y^4\sin^4\theta+Y^2\cos^2\theta(1-X-iZ)^2\right)^{1/2}} \quad (1)$$

$$X = \frac{\omega_0^2}{\omega^2} \quad (2)$$

$$Y = \frac{\omega_h}{\omega} \quad (3)$$

$$Z = \frac{\nu}{\omega} \quad (4)$$

where ω is the radial frequency, ω_0 is the electron plasma frequency, ω_H is the electron gyro frequency, and ν is the electron collision frequency. The real part of the refractive index is used to determine the scattering coefficient and the imaginary part is used to determine the absorption coefficient.

4. Summary and Conclusions

The cold spot observations from MWR data are believed to be caused by either a significant amount of absorption or reflection based on the structure of the auroral plasma. If absorption dominates, this would suggest ion-neutral coupling and a high electron density in the ionosphere which would cause a significant amount of attenuation along the path towards the radiometer. If reflection dominates, this would suggest electron bunching where the electron density is significantly higher at certain areas of the aurora and the plasma frequency is close to or equal to the frequency of the affected channel. The series of simulations conducted can be used to determine the characteristics of the plasma that caused the observed cold spots.

Acknowledgements

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