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# Seasonal variability in the ionosphere of Uranus

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## Abstract

Ground based infrared observations of the $H_3^+$ ionosphere of Uranus, spanning 16 years, have been analysed as to identify any long-term trends in temperature and density. Between 1992 and 2008, the temperature is seen decreasing by 8 K per year, between 715 K and 534 K. With equinox occurring in 2007, the cooling of the atmosphere appears linked to seasonal geometry with respect to the Sun, even though the Sun alone cannot not provide enough energy to heat the planet to the observed temperatures. The mechanism that is responsible for heating the planet is therefore likely linked to conductivity, regulated by nightside relaxation of the ionosphere.

## 1. Introduction

Uranus is an outlier of a planet, with its rotational axis titled along the plane of the ecliptic and with its mangetic field offset 97° from that. In addition, its magnetic field has significant higher order field components, creating an environment for which auroral activity is both complex and poorly understood.

In 1986 Voyager 2 became the first and only spacecraft to encounter Uranus, and there has only been one single observation that has spatially resolved the aurora [3]. In addition, as with all the giant planets, the upper atmosphere of Uranus is too hot, based on solar input alone, such that mechanisms other than solar energy (hitherto unknown) must be responsible for the elevated temperatures.

$H_3^+$ is formed in the upper atmosphere of all giant planets via the ionisation of $H_2$, such that emission from $H_3^+$ becomes a tracer of energy inputs – generally in the form of either solar EUV or particle precipitation in the form of aurora. Since $H_3^+$ radiates thermally at the temperature of the surrounding neutral atmosphere, analysing the spectral emission of $H_3^+$ can tell us both the temperature of the upper atmosphere and the density of ionosphere. Therefore, with $H_3^+$ being observable from the ground, it can be used to characterise how the upper atmosphere of Uranus changes over time.

## 2. Data

Emission from the molecular ion $H_3^+$ was first observed from Uranus by [5] in 1992, and has subsequently been observed at relatively regular intervals up until 2008 with the NASA Infrared Telescope Facility (IRTF), the United Kingdom Infrared Telescope (UKIRT) and Keck II. These observations form a unique data-set that characterise the long-term behaviour of the ionosphere of the planet. There are 12 set of observations analyzed here.

Figure 1 shows how the geometry of Uranus, as seen from the Earth, changes between 1992 and 2008.

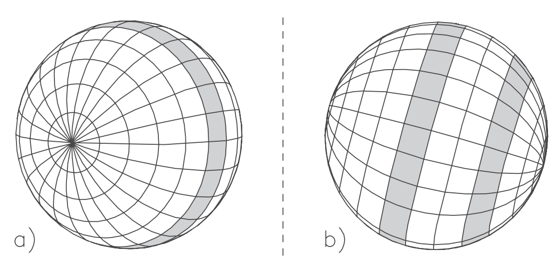


Figure 1: The geometry of Uranus as seen from the Earth in 1992 (a) and 2008 (b). The shaded regions indicate the latitudes of the magnetic poles.

## 3. Results & Discussion

The long-term behaviour of the temperature of the ionosphere of Uranus can be seen in Figure 2 (solid), with the smoothed solar cycle plotted dotted and a parameter describing the fractional illumination plotted dashed. The temperature drops about 200 K between 1992 and 2008, showing the the upper atmosphere cooling as the planet rotates towards equinox in 2007 by 8 K year$^{-1}$. Solstice occurred in 1985.

Due to the peculiar geometry of the planet, the IAU southern hemisphere is constantly illuminated during solstice. At equinox, the planet is aligned in a fashion more similar to that of the Earth, with any point on the surface being illuminated for about half a rotation each day ($P = 17.24$ h [2]). This means that at equinox the ionosphere is given time to relax as it rotates in towards the night-side, whereas at solstice, the ionosphere is never able to relax. Therefore, even though the Sun cannot inject enough energy to heat the planet to the observed temperatures, it must be directly regulating the temperature itself in the form of ionospheric conductivity.

It is noteworthy that the ionospheric variability is in no way correlated to solar cycle, such that the energy deposited by the sun can only represent a small fraction of the total energy budget. This seasonal dependence (at the same rate) has also been observed at lower altitudes [1], albeit pre-solstice. The seasonal control of temperature provides an important piece to solving the energy balance puzzle.

The results outlined here are presented in more detail in [4].

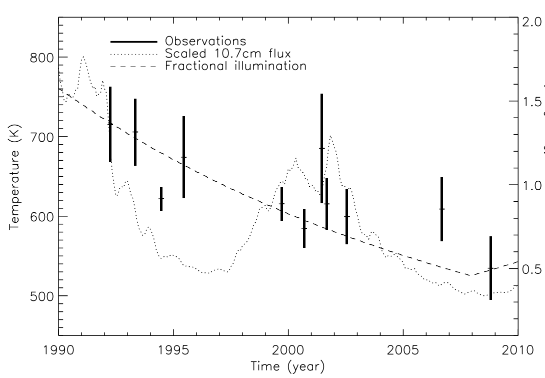


Figure 2: The long term behaviour of the ionosphere of Uranus. The dashed line is the fractional illumination.


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