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The post-equinoctal behavior of the ionosphere of Uranus

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Abstract

Observations of H_3^+ emission from the upper atmosphere of Uranus was performed in the latter half of 2011 using Gemini North, NASA Infrared Telescope Facility (IRTF) and the Very Large Telescope (VLT). These determined an average H_3^+ ionospheric temperature of 520±32 K, which is smaller than any perviously determined value. This long-term cooling, initially observed by Melin et al. (2011, ApJ), was thought to be connected to seasonal mechanisms. However, with Uranus' equinox having occurred in 2007, the planet has already rotated some 15° along its circumsolar orbit. This continued cooling may be due to the changing geometry of the magnetosphere and rotational axis with respect to the solar wind.

1. Introduction

The upper atmosphere of all the giant planets are much hotter than can be explained by solar radiative heating alone [6]. Both auroral processes and transfer of energy from the hot core of the planets are plausible sources of energy, but as of yet, we do not understand the mechanisms by which these could be re-distributed globally.

Infrared emission from H_3^+ was discovered at Uranus by [5]. This molecular ion is produced via the ionisation of molecular hydrogen, such that emission from H_3^+ maps energy that has been injected into the upper atmosphere. Generally, this energy is in the form of Extreme Ultraviolet (EUV) radiation, or in the form of auroral processes whereby charged particles are accelerated down the magnetic field lines and impact upon the planet.

[3] analysed ground-based infrared observations of H_3^+ from Uranus spanning from 1992 to 2008, and observed an 8 K/year cooling of the upper atmosphere, from ∼750 K in 1992 to ∼550 K in 2008. Since this coincided with the approach to the 2007 equinox, this variability was assumed to be seasonal in nature, such that the thermosphere would begin to warm again as the planet approached the next solstice. It appeared that the mechanism responsible for the high thermospheric temperature is regulated by solar illumination, such that at equinox there may exist larger conductivities, enabling currents to transfer more energy from the magnetosphere into the atmosphere. This work questions this conclusion.

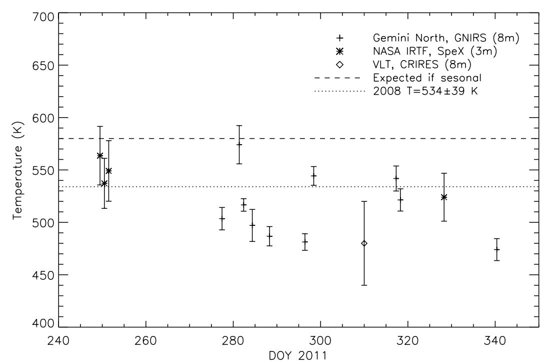

Figure 1: *The temperature of the upper atmosphere of Uranus, derived from infrared ground-based observations of H_3^+ using Gemini North (crosses), NASA IRTF (stars), and VLT (square) in late 2011. The dashed line indicates the expected temperature if the variability was purely seasonal and the dotted line indicate the temperature observed in 2008.*

2 Observations

H_3^+ emission from Uranus has been observed using Gemini North (GNIRS), NASA IRTF (SpeX), and VLT (CRIRES), between 2011 day of year (DOY) 251 and 2011 DOY 241. By observing emission from H_3^+ we can determine both the thermospheric temperature and ionospheric density.

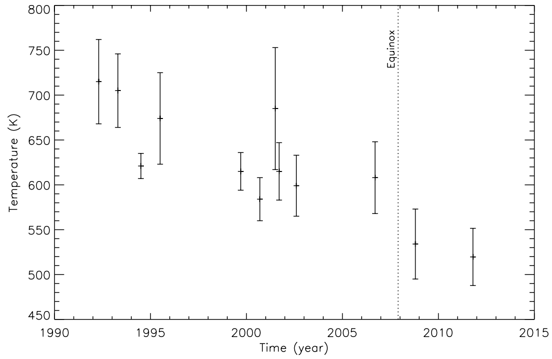

Figure 2: *The long-term behaviour of the temperature of Uranus' upper atmosphere, as derived from fitting H_3^+ spectra. The dotted line indicates the time of equinox. The temperature displays a clear decreasing trend, even well beyond equinox.*

3. Results

The temperature of the upper atmosphere during the fall 2011 period can be seen in Figure 1. All of the temperatures are lower than the temperature expected if the long-term variability was purely seasonal. In addition, the majority of the observed temperatures are lower than that measured in 2008, such that Uranus has continued to cool after its 2007 equinox.

Figure 2 shows the long-term trend of the upper atmosphere of Uranus, clearly showing a declining trend over the 20 years of observations. The mean decrease is $\sim$8 K/year.

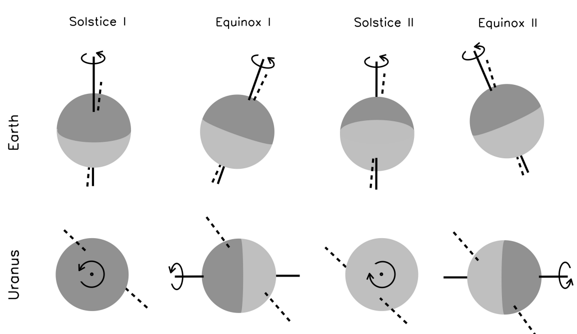

Figure 3: *The notion of magnetic season, whereby each equinox is very different in terms of the magnetic field, rotational axis and solar wind flow geometry.*

4. Discussion

The geometry of the Earth and Uranus as seen from the Sun at the two equinoxes and the two solstices are shown in Figure 3. From a magnetospheric point of view, the spring and vernal equinoxes at Earth are geometrically approximately equivalent, as the dipole field is centred at the centre of the Earth. At Uranus, the magnetic field is offset some 0.3 R_U from the centre of the planet [4], which in combination with a highly inclined rotational axis produces a geometric scenario in which the spring and vernal equinoxes are very different indeed, especially since each magnetic pole has a different field strength. The slowly changing geometry of the magnetic field, rotational axis and the solar wind may produce an annual variability driven by changes in particle precipitation that heat the upper atmosphere – we call this *magnetic season* and it has the wavelength of a uranian year.

5. Summary and Conclusions

We have measured the temperature of the upper atmosphere of Uranus in late 2011 and find that it is still decreasing, even 5 years after equinox (2007). This is suggestive of longer-term variability, which may be driven by the magnetosphere, rotation, and solar wind flow geometry.

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