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Saturn's northern auroras as observed by the Hubble Space Telescope

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Abstract

Auroral emissions are a vital tool in diagnosing the dynamics of planetary magnetospheres. While Saturn's southern UV auroras have been observed with high-sensitivity cameras onboard the Hubble Space Telescope (HST), the observatory has only ever observed the northern auroras at very oblique angles. However, Saturn has now passed equinox and is moving toward summer in the northern hemisphere, such that the northern auroras are now visible from Earth, and previous results from HST have indicated that Saturn's northern auroras are not simply mirror images of the southern. We use HST images of Saturn obtained during April 2011 to show that the northern auroras exhibit a variety of morphologies, which seem broadly similar to those previously observed in the south. During the observing interval an interplanetary compression region impinged on the magnetosphere, and the response of the northern auroras is qualitatively similar to the south, i.e the initially dim oval emission brightens and both poleward and equatorward boundaries move toward the pole. In this presentation we review the evolution of the auroral morphology in conjunction with in situ Cassini and ground-based data.

1. Introduction

Saturn's auroras were first observed using spectrographs onboard the Voyager and International Ultraviolet Explorer spacecraft in 1980, and have been imaged with increasing sensitivity and resolution since then using the Faint Object Camera, the Wide Field and Planetary Camera 2, the Space Telescope Imaging Spectrograph and the Advanced Camera for Surveys (ACS) onboard HST. The latter two instruments have revolutionised our understanding of Saturn's magnetosphere, although until 2009 these instruments had only observed the southern auroras. In 2009, the planet's equinox facilitated tantalising glimpses of the northern auroras from very oblique viewing angles [6]. These equinoctial observations showed that Saturn's northern and southern auroras often differ significantly in size, intensity and morphology at any one time, such that our knowledge of the southern auroras cannot be naïvely applied to the northern. The southern auroral emission consists of a $\sim$2° wide 'oval' of radius $\sim$10-20° co-latitude [1, 2]. The oval is generally brighter on the dawn side, and patches of emission are observed to slide along the oval at $\sim$20-70% of corotation [4]. Transient, bright features are occasionally observed both poleward and equatorward of the oval, and a separate arc of emission has been observed $\sim$3° equatorward of the main oval on the nightside [5]. This collection of features is thought to be the manifestation of many different magnetospheric phenomena, such as sub-rotation of magnetospheric plasma and plasma injections, but without similar observations of the northern auroras it is not possible to say whether these represent phenomena local to the south or to the wider magnetosphere. Many of these features cannot be resolved in the oblique views obtained in 2009. In comparison, Figure 1 shows the views of Saturn's northern auroras during April 2011, the first images of a 3-year program of observation. These observations thus represent the first high-sensitivity HST images of Saturn's northern auroras from viewpoints which allow the unambiguous determination of Saturn's northern auroral morphology.

2. Data

HST images of Saturn's auroras were obtained on days 91, 93, 95, 97, and 99 of 2011 using the ACS Solar Blind Channel (SBC). The ACS/SBC detector is a 1024 × 1024 Multi-Anode Microchannel Array, with an average resolution of $\sim$0.032 arcsec pixel^{-1}, such that the field of view is 35 × 31 arcsec^2. Images were obtained using the F115LP and F125LP long-pass filters, the former of which admits H_2 Lyman and Werner bands and H Lyman-α emission, while the latter mostly excludes the H Lyman-α band. Nineteen images were obtained during each ∼1 h observing interval (visit). The exposure times were 100 s, for which the blurring at the CML of any corotating features is ∼1°, decreasing away from the CML. The images were reduced using a bespoke pipeline which utilises the latest dark count, flat field and geometric distortion correction reference files available from the Space Science Telescope Institute.

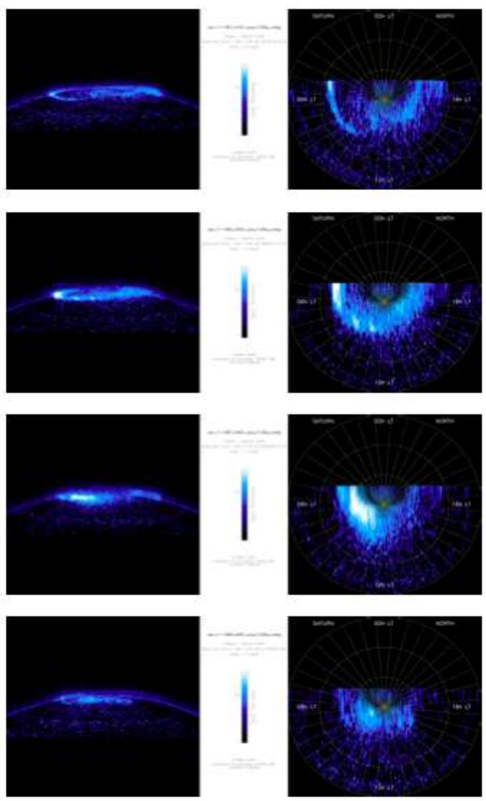

Figure 1: A selection of HST images of Saturn's northern auroras obtained during this program. Each image comprises 5 co-added exposures, such that the total exposure time is 500 s. The left panels show the auroras as observed, while the right panels show planetocentric projections of the auroras.

3. Summary of Results

We show that Saturn's northern auroras exhibit a variety of morphologies, which seem broadly similar to those previously observed in the south. At the start of the interval the auroras exhibited an oval, similar to the 'quiet time' morphology observed in the south [3] during solar wind rarefaction regions. On 3 April 93 an interplanetary forward shock impinged on the magnetosphere, observed in situ by the Cassini spacecraft, which was in the solar wind at ∼50 R_S in the dusk sector. The subsequent compression region lasted for a few days, during which time the auroras brightened and both poleward and equatorward boundaries moved toward the pole, again reminiscent of the behaviour of the southern auroral emission during similar events [2].

Acknowledgements

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