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Saturn's Visible Aurora

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Abstract

Cassini camera's movies show Saturn's aurora in both the northern and southern hemispheres. The color of the aurora changes from pink at a few hundreds of km above the cloud tops to purple at 1000-1500 km above the cloud tops. The spectrum observed in 9 filters spanning wavelengths from 250 nm to 1000 nm has a prominent H-alpha line and roughly agrees with the laboratory simulated auroras by [1]. Auroras in both hemispheres vary dramatically with longitude. Auroras form bright arcs, sometimes a spiral around the pole, and sometimes double arcs at 70-75° both north and south latitude. 10,000-km-scale longitudinal brightness structure can persist for ~3 days. This structure rotates together with Saturn. Besides the steady structure, the auroras brighten suddenly on the timescales of few minutes. 1000-km-scale disturbances may move faster or lag behind Saturn's rotation on timescales of tens of minutes. The auroral curtains can extend more than 1200 km from their base to their top. The stability of the longitudinal structure of the aurora in 2009 allowed us to estimate its period of rotation of 10.65 $\pm$ 0.05 h. This is consistent to the Saturn Kilometric Radiation (SKR) period detected by Cassini in 2009. These periods are also close to the rotation period of the lightning storms on Saturn. We discuss those periodicities and their relevance to Saturn's rotation.

In April-May 2013 a multi-instrument campaign using Cassini and Earth-based data was monitoring Saturn's aurora. We will discuss the results of this campaign.

1. Introduction

Before Cassini's arrival, Saturnian aurora was observed in UV and infrared wavelengths, where the auroral light does not interfere with the daylight. Cassini's camera was the first to observe the aurora in visible light. Such observations can only be taken at the night side of Saturn because the aurora is extremely faint: less than 10^{-4} of the dayside brightness. Movies taken by the Cassini camera show the aurora at unprecedented spatial resolution as fine as tens of km/pixel, and at time resolution as fine as one minute. We present visible auroral observations from Cassini arrival at Saturn in 2004 until now (spring 2013).

2. Summary of the visible aurora detections.

Table 1 summarizes all ISS observations that have detected Saturn's aurora up to date.

Table 1: Cassini camera's observations detecting aurora. The start time of the observation is given as follows: (year)-(day of the year)T(hour):(minute). In some observations, the sequence of images in different filters was repeated N_{fr} times. For single-filter movies N_{fr} is the total number of frames. The last column indicates northern (N) or southern (S) hemisphere. The asterisks (*) mark noisy detections.

Start time	Duration	Filters	N_{fr}	
2006-197T01:06	13:30	multi	5	N
2007-003T06:50	2:30	clear	9	N
2009-278T16:30	12:08	clear	~200	N
2009-279T14:58	13:25	clear	~200	N
2009-280T18:43	9:41	clear	~200	N
2009-281T21:29	6:55	clear	~100	N
2010-177T03:50	13:40	clear	~800	S
2010-179T04:25	5:35	9 filters	~10	S
2010-180T18:15	6:45	9 filters	~10	S
2010-331T01:14	4:57	9 filters	10	S
2012-195T07:35	~4:30	clear	266	S
2012-197T22:49	~11:30	clear	180	S
2012-199T12:33	~11:30	clear	277	S
*2012-244T06:28	~7:30	clear	120	S
2012-329T03:00	4:29	clear	289	S
*2012-342T21:46	2:40	clear	49	S
*2012-343T01:46	2:40	clear	49	S
*2013-003T16:49	2:40	clear	43	S
*2013-110T15:43	~3:00	clear	100	S
*2013-110T08:40	~6:00	clear	109	S

3. Auroral spectrum

Figure 1 shows auroral spectrum observed on 2010-331. Several multi-filter movies in Table 1 give information about visible spectrum of Saturn's aurora. The 2010-331 observation gives the best detection of aurora with all nine filters. Upper panel of Fig. 1 shows a clear-filter frame detecting particularly bright aurora in the 2010-331 image sequence. The dark night side disc of Saturn near its south pole is on the upper left. Clear sky can be seen because it is marked with star tracks produced by spacecraft motion during the long exposures. The white scale bar shows elevation above Saturn's "surface", which is defined by the stars dimming as they set below the horizon. The color of the boxes sampling auroral spectrum is the true color as derived from the measurements in RED, GRN and BL1 filters. The 9-filter spectra sampled in the boxes during the length of the movie are shown in the middle panel. Spectral shapes of the ISS filters [2] are shown in the lower panel with line styles alternating between solid and dotted to avoid confusion. In the middle panel, the brightness measured in Rayleigh/nm in each filter is normalized by the brightness in the clear filter. We also show the black curve of laboratory-simulated spectrum for the atmosphere bombarded by 20eV electrons. The lab spectra were provided by A. Aguilar (personal communications), see also [1]. The lab data for UV1 and UV3 filters are not processed at this time. At longer wavelengths the laboratory curve is broadly consistent with aurora measurements, though the H_α line in Saturn's aurora is stronger.

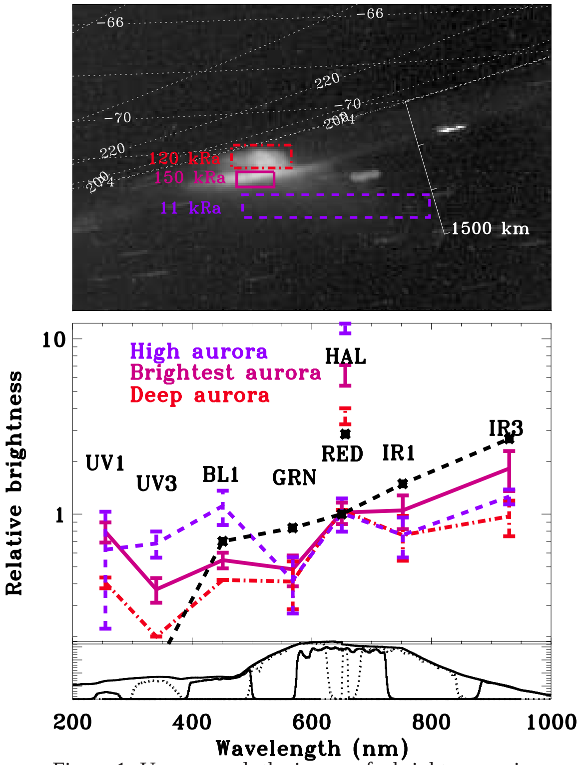

Figure 1: Upper panel: the image of a bright aurora in 2010-331 sequence. White dashed lines show the longitudes and latitudes. Colored boxes show the areas where the spectra of the aurora were sampled. Middle panel: Colored curves show the aurora spectra measured inside the upper panel's colored boxes. The vertical error bars indicate the measurement's uncertainty. Data points at broadband filters are connected with a line. Data points at narrow H_α filter (HAL) are shown as separate data points. The dashed black curve shows lab-simulated spectra convolved with ISS filter shapes, which are shown in the lower panel.

4. Discussion

The visible observations taken to date reveal location of the aurora, the motion of the stable features, sporadic brightenings, and the spectrum in visible wavelengths. Starting in 2009, the auroral observations by several instruments on Cassini were coordinated so data are taken simultaneously and can be combined. These observations are enriched by Earth-based observations during April-May 2013 Saturn auroral campaign. Collaborative studies on these simultaneous observations are in progress and promise a substantial advance in our understanding of Saturn's aurora and magnetosphere.

Acknowledgements

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References

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