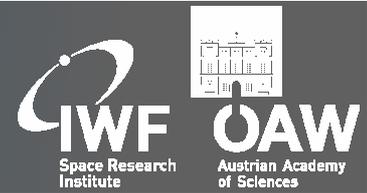


Overview of Saturn lightning observations

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Abstract

The lightning activity in Saturn's atmosphere has been monitored by Cassini for more than 6 years. The continuous observations of the radio signatures called **SEDs (Saturn Electrostatic Discharges)** combined favourably with imaging observations of related cloud features as well as direct observations of flash-illuminated cloud tops. The **Cassini RPWS (Radio and Plasma Wave Science)** instrument and **ISS (Imaging Science Subsystem)** in orbit around Saturn also got ground-based support: The intense SED radio waves were also detected by the giant UTR-2 radio telescope, and committed amateurs observed SED-related white spots with their backyard optical telescopes. Furthermore, the **Cassini VIMS (Visual and Infrared Mapping Spectrometer)** and **CIRS (Composite Infrared Spectrometer)** instruments have provided some information on chemical constituents possibly created by the lightning discharges and transported upward to Saturn's upper atmosphere by vertical convection. In this presentation we summarize the main results on Saturn lightning provided by this multi-instrumental approach and show how it correlates to the SED activity as measured by RPWS as a function of time throughout the Cassini mission.

Observations by Cassini RPWS over 6 years

Until now the Cassini RPWS instrument has recorded 10 storms of Saturn lightning (named O,A,B,C,D,E,F,G,H,I), which are displayed in Figure 1. Such SED storms can last from a few days up to several months. There was also an interval of 21 months between storms E and F with no SED activity. The last years around Saturn equinox (August 11, 2009) were characterized by strong SED activity which might be a seasonal effect.

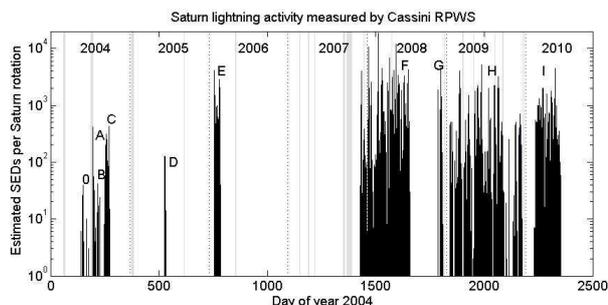


Figure 1: Numbers of SEDs per Saturn rotation as a function of time. The gray background denotes data gaps and the SED numbers from 2009 and later are first estimates.

Direct optical observations of Saturn lightning flashes

The first direct optical observation of Saturn lightning was performed by Cassini ISS on August 17, 2009 [Dyudina et al., 2010]. The reduced ring shine around equinox allowed the cameras to detect illuminated cloud tops on Saturn's night side, which are displayed on the left side of Figure 2. The size of the spots of a few hundred kilometers allowed the determination of the SED source depth which should be located 125-250 km below the cloud tops, most likely in the water cloud layer.

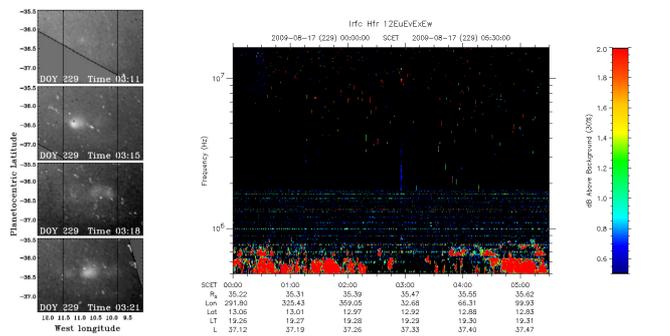


Figure 2: The left side shows images of Saturn lightning flashes observed by Cassini ISS in 2009 [from Dyudina et al., 2010]. Longitude, latitude and time of the observations are given. The right side shows the corresponding RPWS dynamic spectrum which shows the radio wave intensity as a function of time and frequency.

References

- Baines et al. [2009], Planet. Space Sci. 57, 1650-1658.
- Delcroix and Fischer [2010], EPSC 2010 Rome, Abstract 132, Session OA2 on Friday in Lecture Room 3 from 9:25 to 9:40.
- Dyudina et al. [2007], Icarus 190, 545-555.
- Dyudina et al. [2010], Geophys. Res. Lett. 37, L09205.
- Fischer et al. [2007], Icarus 190, 528-544.

Cassini ISS and ground-based optical observations

For 8 of the 10 SED storms Cassini ISS and/or ground-based observers detected an associated cloud feature in the so-called "storm alley" at a latitude of 35° south. For only two short storms (O and D) no associated storm cloud could be found. The relation between the SEDs and the storm clouds is characterized by consistent longitudes and drift rates, and the clouds are brighter when SED rates are high [Dyudina et al., 2007; Fischer et al., 2007].



Figure 3: Two Cassini ISS images on the left and right side are shown with two ground-based Saturn images from Marc Delcroix (South is up here) and Christopher Go in the center. All images were taken during SED storm F which lasted for 7.5 months.

Figure 3 shows four images of Saturn with storm clouds taken during SED storm F. This storm consisted of two phases: First, there was only one storm cloud at 35° south (left Cassini image and image by Delcroix). In a later phase of the storm a second storm developed at the same latitude (right Cassini image and image by Go). See also presentation by Delcroix and Fischer [2010].

Figure 4 shows images from ground-based observers during the SED storms G, H, and I. These images have become increasingly important since lately the coverage of Saturn's atmosphere by Cassini ISS was only sparse and sometimes the storm longitudes were missed. SED storm G lasted only for about 3 weeks, but it was followed by the longest SED storm which was ever observed. Storm H lasted for about 11 months from mid-January to mid-December 2009 (with some week-long interruptions within it). SED storm I this year started as a small white spot but gradually increased in longitude and finally showed three bright regions before it faded away.



Figure 4: Ground-based telescopic observations of Saturn with SED storm cloud by Damian Peach, Anthony Wesley, and Trevor Barry (South is up here). Observations were done on Dec. 7, 2008; March 6, 2009; and June 3, 2010; and they show the storm clouds of SED storms G, H, and I, respectively.

Cassini VIMS and CIRS observations

Spectroscopic observation with Cassini VIMS revealed soot particles attached to NH₃ and NH₃SH condensates in the dark spots. The soot might be created from CH₄ dissociated by lightning and transported to altitudes around 0.4 bar by vertical convection.

Cassini CIRS found more PH₃ around white spots brought up to higher levels by convection. It is suspected that an ammonia-ice blizzard is going on a few hundred km below the tropopause.

This was announced in a news feature on April 29, 2010, on the Cassini page <http://saturn.jpl.nasa.gov/news/cassinifeatures/feature20100429/>.

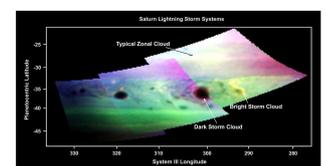


Figure 5: False color image taken by Cassini VIMS of bright storm cloud with dark spots in μm wavelength range [from Baines et al., 2009].

Summary and acknowledgement

This poster gives an overview of the SED activity measured by Cassini RPWS within the last 6 years. It shows that studying Saturn lightning has become a multi-instrumental task involving the Cassini instruments RPWS, ISS, VIMS, CIRS as well as ground-based optical observations and measurements by giant radio telescopes like UTR-2 (the latter not shown in this poster).

Acknowledgement: Georg Fischer thanks all the committed amateurs (T. Barry, M. Delcroix, C. Go, S. Kowolik, D. Peach, R. Vandebergh, A. Wesley... to name some of them) that support the study of Saturn lightning with their marvelous photos of Saturn.