LIGHTNING AND SPRITES OBSERVATIONS ON BOARD OF THE INTERNATIONAL SPACE STATION

E. Blanc [(1)] , T. Farges[(1)], R. Roche[(1)], D. Brebion[(2)], T. Hua[(3)]

(1) Commissariat à l 'Energie Atomique, Département Analyse Surveillance Environnement, BP12, 91680 Bruyères le Chatel, France,

(2) Commissariat à l 'Energie Atomique, Département Conception et Réalisation des Expériences, BP 12, 91680 Bruyères le Chatel, France,

(3) Laboratoire d 'Astronomie de Marseille, Traverse du Siphon,12ème arr. BP8, 13376 Marseille Cedex 12, France,

Abstract

The experiment LSO (Lightning and Sprite Observations) is dedicated to the study from the International Space Station of the sprites occurring in the upper atmosphere above the thunderstorms. The objective is to validate a new measurement concept for future observations of sprites and associated emissions from space at the nadir. Observations are performed by two micro-cameras, one in the visible and near infra red, the other equipped with a filter at 761 nm. This spectral line corresponds to the most intense N2 1P emission of the sprites and is close from the oxygen absorption A band of the atmosphere. The light emissions from sprites occurring in the middle and upper atmosphere are then differentiated from the emissions from lightning, occurring more deeply in the atmosphere. This paper presents the first observations of sprites from space at the nadir.

Introduction

Sprites are observed from space (Boek et al., 1995), from planes (Sentman et al., 1995) and from the ground (Winkler et al., 1996). Observations are performed at large distances at the horizon where they are spatially differentiated from the lightning flashes. Sprites could be produced by relativistic runaway electrons triggered by cosmic radiation (Roussel Dupré et al., 1998). The light emission associated with sprites could be then only a part of more complex phenomena implying a high energy electron beam injected in the ionosphere with electromagnetic radio emissions in a very large frequency range associated with X-gamma emissions. Simultaneous measurements from space of the electromagnetic and particles emissions associated with sprites needs however nadir observations, never performed until now. Measurements from the nadir are difficult because the light emissions of sprites are superimposed on the intense light emissions of the lightning diffused by clouds.

We propose a method of spectral differentiation of sprites from lightning for space observations at the nadir and we present the first observations of sprites, using this method, by the experiment LSO (Lightning and Sprite Observations) on board of the International Space Station (ISS).

Experiment

The LSO experiment was proposed in the frame of the flight of the French astronaut Claudie Haigneré (mission Andromède) on the International Space Station in October 2001. The experiment was developed by the Commissariat à l'Energie Atomique with the participation of the Centre National d'Etudes Spatiales. The measurements were realized with the collaboration of RKK Energia (Russia).

The frequency band, proposed for the selective spectral measurements of sprites, corresponds to the most intense sprite emission band the N2 1P line at 762 nm. A theoretical spectrum of sprite is presented in Figure 1 (top, Milikh et al., 1998). The interest of this spectral band is that it is very close to the absorption band of the dioxygen near 760.8 nm. For this reason, the sprite emission line N2 1P does not appear on the sprite spectra measured at the ground (Figure 1, bottom), (Hampton et al., 1996) where the dioxygen density is important. At the contrary, it will be observed from space because the sprites are produced in the altitude range 30-100 km where the dioxygen concentration is low. The other light emissions from ground and lightning produced in the lower atmosphere will be absorbed.

Observations are performed with two cameras, one with a filter in the selected band and the other in the visible and near infra red. The experiment uses digital space micro-cameras : 512x512 pixels CCD, 10 bits dynamic, field of view : 35°, aperture f/10, observation range : 400 to 1000 nm. The images of both cameras are taken simultaneously, the time exposure is 1s. The cameras are fixed on a ISS window. The measurements are automatic, they are programmed during night-time over continents were storms are mainly expected.

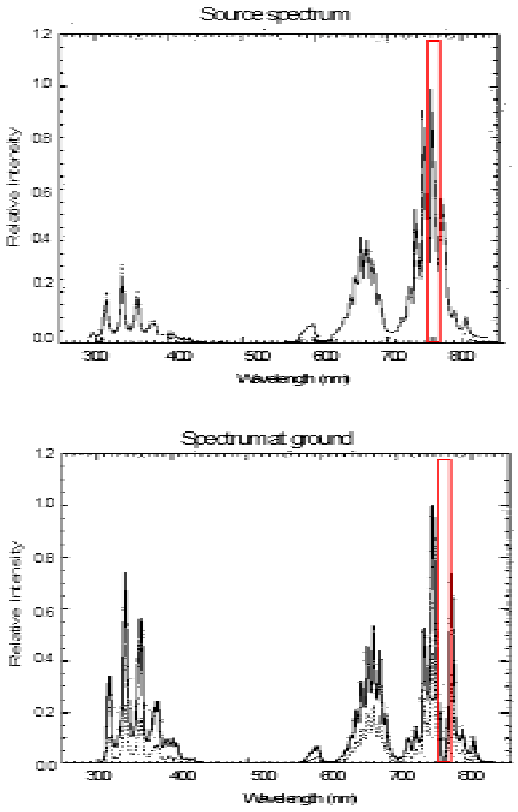

Figure 1 : Sprite spectra : at the source and measured at ground

Observations

LSO observed 60 transitory events with the camera in the visible and near infra redand 13 with both cameras. An example of transitory event, recorded by both camera on October 16th 2001 at 10:51:13 UT while ISS was moving toward Japan, is shown in Figure 2 (left). The ratio of the intensities received by both cameras is about 2 to 4 %. The event was correlated by lightning activity measured at ground by the Japan Lightning Detection Network.

This example illustrates the class of sprite events defined by a ratio of both camera intensities, higher than 2%. Ten events belonging to this class were identified. They are very intense events with radiances in the filtered camera of 0.6 to 3.5 µJ/cm^2/ster. Their brightness is estimated in the range 500 kR to 5 MR. A second class of lightning events is defined by a lower intensity ratio of both camera intensities ²of about 1%. Only three events of this class were observed. One example is shown in the right part of Figure 2. A

comparison of LSO data with the LIS data of the TRMM mission (Christian, 2001), available on the NASA Web site (2002) showed that the LSO observed the most intense lightning corresponding to about 25% of the LIS lightning flashes. A comparison with the observations reported by Turman (1977) showed that the lightning events detected by both LSO cameras belong to the class of the intense superbolts with a power from 3 10^{11} to 7 10^{12} W.

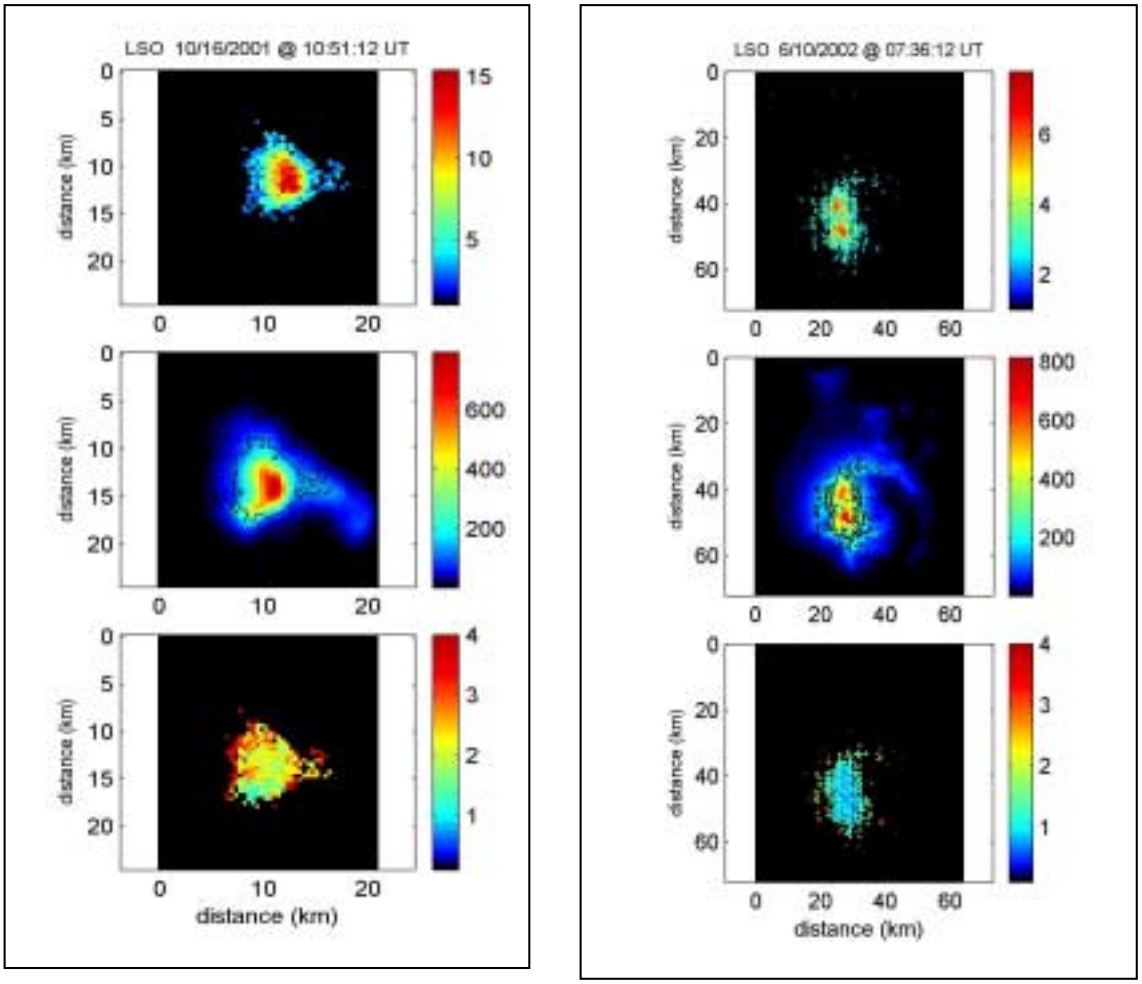

Figure 2: Examples of events observed by LSO. The color scale indicate the measured intensity in the camera digital unit. 1/ Top : filtered camera 2/ Middle : camera in the visible and near IR, 3/ Bottom : ratio of both camera intensities in percent. The event at the right is an intense lightning while the event on the left is a sprite. They are differentiated by the ratio of the intensities measured by both cameras, most intense for sprites than for lightning.

Conclusion

LSO observed 60 transitory events. Among then, ten sprites were identified, they are very intense events with radiances in the filtered camera of 0.6 to 3.5 µJ/cm^2/ster. Their extension varies from about 1 to 5 kilometers. They are often associated with sprite halos. Sprites are distinguished from the lightning by the

filter in which most of the lightning did not produce any response. Only 3 events are possibly associated with lightning, their power corresponds to the class of the superbolts.

The measurement concept described in this paper will be used by the microsatellite Taranis (Tool for the Analysis of RAdiation from lightNIng and Sprites) dedicated to the study of sprites and associated phenomena and to the global analysis of the coupling between the atmosphere, the ionosphere and the magnetosphere in relation with these phenomena.

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