OBSERVATIONS OF SPRITES FROM SPACE AT THE NADIR: THE LSO (LIGHTNING AND SPRITE OBSERVATIONS) EXPERIMENT ON BOARD OF THE INTERNATIONAL SPACE STATION

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Abstract

The experiment LSO (Lightning and Sprite Observations) on board of the International Space Station is the first experiment dedicated to sprite observations at the nadir. Such observations are difficult because the luminous emissions of sprites and lightning can be superimposed when they are observed from space at the nadir. Such observations are however needed for measuring simultaneously all possible emissions (radio, X-γ, high energy electrons) associated with sprites for a better understanding of the implied mechanisms. They are possible in specific spectral lines where sprites are differentiated from lightning. Absorption bands of the atmosphere are well adapted for this differentiation because the light emissions from sprites occurring in the middle and upper atmosphere are less absorbed in these bands than lightning emissions occurring more deeply in the atmosphere. The most intense spectral emission band of the sprites, corresponding to the N₂1P band at 761 nm, partly superimposed with the oxygen absorption A band of the atmosphere, is used by the LSO experiment. The experiment is composed of two micro-cameras, one in the visible and near infrared, the other equipped with an adapted filter. Only sprites, halos and superbolts, which correspond to a class of rare very intense lightning, are transmitted through the filter. Sprites, halos and superbolts are identified by the ratio of the intensities received through the filter and in the whole spectrum. This ratio is lower for superbolts than for sprites and halos. The response of the sprites is also more complex and variable than the response of superbolts which is very flat and comparable from an event to another. Finally, LSO observed 17 sprites, 3 halos and 9 superbolts. Several examples of differentiation of sprite and superbolts are given. The results of a first global statistical study are also presented.
7.1 Introduction

Most of the observations of sprites are performed from planes (Sentman et al., 1995) and from the ground in different parts of the world (Lyons et al., 2003; Hardman et al., 2000; Neubert et al., 2001; Su et al., 2002) at the horizon where sprites are spatially differentiated from the lightning flashes. Different types of emissions (jets, halos, elves) called TLE (Transient Luminous Events, Lyons et al., 2000) have been identified. Recent observations provide details of the space and time evolution of these phenomena (Gerken et al., 2000; Moudry et al., 2003). The first space observation of sprites was performed during thunderstorm observations (Boeck et al., 1998). Few experiments are now designed for sprite observations from space at the horizon: (i) MEIDEX onboard of the Space Shuttle performed 7 hours of sprite observations over thunderstorms (Yair et al., 2004), (ii) the ISUAL experiment is the first sprite experiment onboard a satellite (Chapter 6).

However sprites are complex phenomena and the emissions in the visible constitute only a part of the emissions related with sprites. Theoretical studies show that sprites can be produced by electrostatic electric fields above the altitude where the thunderstorm electric field exceeds the air breakdown electric field threshold (Pasko et al., 1997). This process predicts ELF electrostatic emissions which can be observed at the ground (Cummer et al., 1998; Fülekrug et al., 2001). Electromagnetic pulses are involved in the elf formation (Barrington-Leigh et al., 2001). Sprites have also been explained by relativistic runaway electrons triggered by cosmic radiation (Roussel-Dupré and A., 1996; Roussel-Dupré et al., 1998). The resulting high energy electron beam interacts with the atmosphere producing intense electromagnetic radio emissions in a large frequency range in the HF-VHF part of the spectrum and X-gamma emissions by bremsstrahlung process. Both conventional and runaway processes could occur in parallel (Roussel-Dupré et al., 2002). The runaway electron theory is supported by the observations of X and γ ray emissions from the Earth’s atmosphere (Fishman et al., 1994; Feldman et al., 1995; Lopez et al., 2004). Ground based observations of energetic radiation up to many tens of MeV, produced during rocket triggered lightning shows that this process is more frequent than expected (Dwyer et al., 2004).

For a better understanding of these mechanisms, simultaneous measurements of all these emissions from space are needed. However, these observations are difficult to realize, because the light emissions of sprites are then superimposed on the intense light emissions of the lightning diffused by clouds.

The LSO (Lightning and Sprite Observations) experiment on board of the International Space Station (ISS) has been designed to perform sprite observations at the nadir using an original method of spectral differentiation between sprites and lightning by an adapted filter. The first sprite observations obtained