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# Via-Lux Project: A Quantitative Imagery Method for Lightning Event Analysis

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**ABSTRACT**

Via-Lux Project aims to examine thoroughly the electrodynamical features of lightning flashes and some features in the atmosphere related to their occurrences. For this purpose, it will be used mainly a high speed CCD-camera and a sensitive camcorder, a specialized system for lightning tracking and/or a portable lightning tracking device, and an electronical device to detect the electric signature of lightning. Recent mathematical tools (such as, fractal technique and wavelet-fractal technique) will be used in order to provide quantitative analyses. As this project integrates distinct areas of research, it could be possible to develop an integral study of the convective processes from the imagery point of view. Also lightning features obtained from this imagery analysis will help to improve the numerical models related to atmospheric discharge path and help to understand the hidden electrical mechanisms. So this experiment contributes not only to develop an analysis methodology and to provide information about brazilian lightning but also to extend the knowledge on lightning features in a worldwide sense.

## INTRODUCTION

This work presents a project under development, hereafter Via-Lux project, to analyze more carefully the features of lightning flashes. For this purpose, it will be used mainly a high speed CCD-camera and a sensitive camcorder, a specialized system for lightning tracking and/or a portable lightning tracking device, and an electronical device (being projected) to detect the electric signature of lightning (so called sferic).

As Brazil presents a great number of lightning, it becomes an interesting scientific region. Lightning flashes consist of high current atmospheric discharges and are classified into cloud-to-ground, ground-to-cloud, intracloud, intercloud, horizontal, and upward lightning categories (Uman, 1987; Volland, 1984). The most studied category is the cloud-to-ground flash because it strikes the Earth surface and can burn forests, damage installation, affect services and injury animals and people. At present in consequence of technology advance (for instance, the sensitive microelectronic componentes used in many devices, the feasibility of higher transcontinental flights, and so on), all atmospheric electric discharges are becoming of large concern. Furthermore, from a scientific point of view a recent coupling was found between thunderstorm and the higher atmosphere (Sentman and Wescott, 1998), encouraging experiments of observation of the whole electrical activities in thunderclouds in order to understand the true active physical mechanisms concerned to atmospheric electricity.

Throughout the world many researchers have developed the most different studies on this subject (Pinto, 1996). Taking part in the state of the art in the imagery equipment, this experiment contributes not only to develop an analysis methodology and to provide information about brazilian lightning but also to extend the knowledge on lightning features in a worldwide sense. Thus, the major aim of this project is to establish an image based measurement system (Heijden, 1994) to improve information on lightning in a qualitative and quantitative way. Other important aspect is that this study considers lightning as an individually characterized event. The study methodology of this project consists of the analysis of electric activity in thunderclouds and the evolution of thunderclouds, the analysis of the path and the behaviour of ionized lightning channel, and the investigation of visual phenomena related to lightning occurrences. In a complementar way, meteorological information and magnetospheric indices will be used to investigate macroscale processes.

## EXPERIMENTAL TECHNIQUE AND METHODOLOGY

This project is based in a CCD-camera of high performance to obtain images of lightning flashes, used simultaneously with other equipments. Optimized Charged Coupled Device consists of a matrix arrangement of a lot of small detector cells, that react with great efficiency to the incident light photons. An image projected through an optical system on this matrix can be stored in a digital way to be processed later by special signal processing techniques. The high performance CCD-camera was chosen because it presents all parameters in an optimized level that allows also quantitative results.

So, in order to obtain high speed images (time interval = 2.5 ms) and a better space resolution (512 x 240 pixels), a Kodak Motioncorder Analyser (Model SR-500) will be used (shown in Figure 1). This high speed device presents the

following specifications: pixel size 7.4 x 7.4 microns, display array: 658 x 496 pixels, full video resolution for all recording and playback speeds up to 500 frames per second, and 256 gray scale levels. This gray scale will be calibrated by traditional optical techniques used in astrophysics.

In addition, a Kodak Ektapro Multichannel Data Link Acessory will allow to obtain the sinchronized time from a GPS and the sferic signature from an adequated sensor. From an internal memory the captured image sequence will be seen in a compact high resolution flat screen display and dowloaded to 8 mm video cassette recorder. Also a notebook provided with adequated softwares and midia facilities will give the necessary additional support.

Fig. 1 – A high speed CCD-camera system (Kodak Motioncorder Analyser, Model SR-500).

Other information will be collected simultaneously. A sensitive camcorder (Handycam Sony, CCD-TRV65 HI8) will be used to obtain panoramic images of atmospheric conditions. Unlike the other commercial camcorder this model presents night shot, a convenient feature for acquisition of faint luminous phenomena. A lightning Positioning and Tracking System (LPATS) will give information (latitude, longitude, polarity and estimated peak current) of the CG-flashes filmed by these cameras (Bent and Lyons, 1984). A sensor of this system is shown in Figure 2. Since this mounted analysis system is portable allowing experiments in different sites, in regions of Brazil not covered by LPATS a simpler stormtracker system (from Boltek Inc) will be used (device shown in Figure 3). It allows to establish the location and the activity evolution of the thundestorms.

This research will be developed initially in three privileged sites. They were choosen to allow the shooting of lightning flashes due to logistic conveniences and geographycal conditions. They are: (a) the observatory of Brazilian Laboratory for Astrophysics (LNA-Laboratório Nacional de Astrofísica) with azimuthal view of $360^{o}$, altitude 1872 m, at Pico dos Dias, Brasópolis, Minas Gerais; (b) a 25 m-height observation tower with azimuthal view higher than $180^{o}$ at Centro Tecnológico da Aeronáutica-CTA, São José dos Campos, São Paulo; (c) a 30 m-height place with view of $180^{o}$ at Goiânia, Goiás. Also these sites are covered by LPATS. The possibility of using three other sites is being analysed (at Rio de Janeiro, RJ; at the Pantanal, MS; and at Serra Gaúcha, RS).

A visual evaluation will be done taking into account the sampled image of the atmosphere and the formation of convective structures (Cotton and Anthes, 1989). Every stage of convection will be analysed: the earlier meteorological conditions; at the beginning, during, and at the end of the lightning activity. So, the study starts in potential situations of lightning events, i. e., in the beginning of the development of convective structure, for local events, or some hours before, of non-local forecasting meteorological convective events (such as meso-scale systems, frontal systems and so on). This kind of data set could help to understand the convective processes developed and other qualitative features related to lightning, such as hail, rain, wind, thunder, etc.

The events of lightning flashes filmed will be analysed initially in a qualitative way according to primary features: (a) the category of the discharge, the starting location, the path evolution, the channel tortuosity, and the branching; (b) for CG-flashes, the interstroke time interval and the number of consecutive discharges per flash (so called multiplicity); and (c) the tropospheric and eventual stratospheric luminous feature. This information will be classified and organized on data set of lightning features. This kind of imagery data set needs a great amount of storage, so an adequated wavelet technique is being investigated to compact these pictures in an efficient way.

In a quantitative aspect, with these CCD especifications, the cloud-to-ground lightning flashes will be resolved in their component discharges (so called strokes). Also all lightning flashes will have the path presented in successive images. The tortuosity and the branching of the ionized channel in the atmospheric discharge will be well defined. The analysis of lightning images has pointed to the existence of scales in this phenomenum(Martins and Matos, 1997). So, this path data set could be analyzed to verify if it has detectable auto-similarity properties. Basically it could be done using the recent fractal techniques (Takayasu, 1990) or wavelet-fractal techniques (Foufoula and Kumar, 1994). The importance of this analysis concerns to identify features of the atmosphere, such as electrical conductivity, what is not an easy task. These kinds of techniques also could help to analyze other spatial-temporal features of the atmosphere, e. g., time scale



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evolution of the lightning path, spatial scales of thunderclouds, and so on. Also these quantitative observations could help in the parametrization of the lightning discharge models (Mendes et al., 1998). This could help to understand the hidden physical processes and to improve lightning alarm systems.

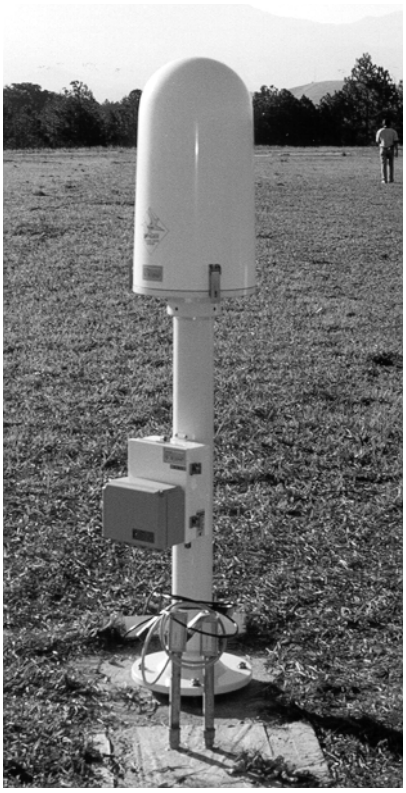

Fig. 2 – A sensor of Lightning Positioning and Tracking System installed in Cachoeira Paulista, SP, Brazil.

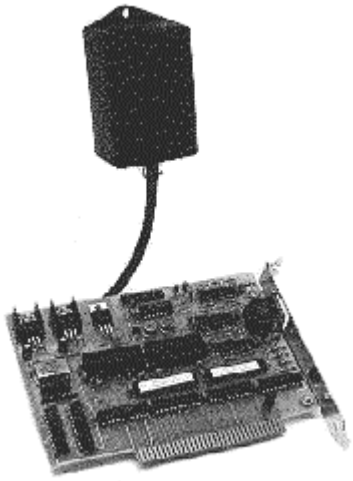

Fig. 3 – A portable stormtracker device (the sensor and the electronic card).

**CONCLUSIONS**

The aims of this project are to analyse the electrodynamical aspects of lightning flashes and some features in the atmosphere related to their occurrences. This will be the first quantitative lightning imagery measurements in Brazil and, due to the recent advanced CCD-camera technology, it has a great importance in this kind of analysis, in general. So, this work will also contribute to a new lightning imagery treatment.

As this project integrates distinct areas of research, it could be possible to develop an integral study of the convective processes from the imagery point of view. This data set will be very important in the characterization and understanding of the interactive atmospheric processes, also taking into account the coupling between lower and upper atmosphere from electrodynamical point of view.

The features obtained from this imagery analysis will improve the numerical models related to atmospheric discharge path and help to understand the electrical mechanisms, such as developed in Mendes et al. (1996) and Kawasaki et al. (1989).

Using this specialized imagery equipment, typical and unusual features of lightning flashes in brazilian region will be characterized. So this experiment contributes not only to develop an analysis methodology and to provide information about brazilian lightning but also to extend the knowledge on lightning features in a worldwide sense.

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