Research Networking Programmes

## Short Visit Grant ☒ or Exchange Visit Grant ☐

*(please tick the relevant box)*

# Scientific Report

**The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online <u>within one month of the event</u>. It will be published on the ESF website.**

***Proposal Title:*** 2.5D Coupling of fluid and particle model for streamer simulation

***Application Reference N°:*** 7045

## 1) Purpose of the visit

The generation of X- and Gamma-rays in electric discharges have been studied intensively since the discovery of Terrestrial Gamma-ray Flashes (TGFs) by the Compton Gamma-ray Observatory in 1994 [Fishman et al., 1994]. Emissions are bremsstrahlung from energetic electrons accelerated in the discharge electric field. Whereas many observations have been done, from thunderstorm clouds [Torii et al., 2009], lightning [Moore et al., 2001] and in the laboratory [Dwyer et al., 2005], the phases of the discharge where emissions are generated are still debated and several processes for electron acceleration have been put forward by theorists [Dwyer et al., 2005]. The proposed simulation effort will allow to have a reliable numerical tool to experiment with the acceleration of low energy electrons in the enhanced electric field of streamers or lightning leaders.

During this visit, it was proposed to work  the coupling of a Drift-Diffusion model developed by Anne Bourdon (LPP, Ecole Polytechnique) and Zdenek Bonaventura (Masaryk university) with the Particle in Cell model developed by DTU Space described in [Chanrion et al., 2013]. In our previous joint work, we have shown that this coupling was working efficiently for discharge in gaps in a 1.5D configuration. The purpose of this visit was to develop a 2.5D version of the code and to take into account realistic electric fields  to carry out simulations directly related with atmospheric electricity.

## 2) Description of the work carried out during the visit

## 2.1 Scientists involved.

### 2.1.1 DTU Space, Denmark

- Olivier Chanrion, Scientist, DTU Space
- Torsten Neubert, Scientist, DTU Space.

### 2.1.2 LPP, Ecole Polytechnique, France

- Anne Bourdon. Senior Scientist, LPP.

### 2.1.3. Masaryk University, Brno. Czech Republic.

- Zdenek Bonaventura, Scientist, Department of Physical Electronics, Faculty of Science, Masaryk University, Czech Republic.

## 2.2 Preparation

All the preparative work is inherited from the previous short exchange visits. The current work was to develop a 2.5D based on the existing 1.5D model developed previously.

## 2.3 Implementation

### 2.3.1 Particle model

All the particle in cell routines had been ported to 2.5D.
The particle in cell part of the code has been parallelized to speed-up calculations. Furthermore, the code has been adapted to the outputs of the 2D Poisson solver used in the fluid part of the code.

### 2.3.2 Fluid model

The Poisson solver and the drift-diffusion solver has been inherited from previous studies performed by Anne Bourdon (LPP, Ecole Polytechnique) and Zdenek Bonaventura (Masaryk university), the whole in 2.5D [Bonaventura et al. 2012]. To represent accurately the electric field produced by a leader, we have added an equipotential region in the computational domain with the shape of a rod ended by a semisphere.The Poisson solver is parallelized.

The short visit was very important to work alltogether and to make sure that the fluid and particle models are coherent and use exactly the same physics.

# 3) Description of the main results obtained

## 3.1 Model Development

Resulting from the collaboration, we have now at our disposal a 2.5D code which contains realistic decay of the field around a leader tip, and can calculate the evolution of a streamer in the atmosphere. It can therefore simulate the propagation of streamers in the streamer region of lightning leaders inside or outside clouds.

The first tests were conclusive.

3.2 Scientific results

The pre-results are yet to be confirmed but so far, we have observed some interesting findings from the work performed.

- For some cases with large electric field from a 3D leader, the 2D streamer does emit high energy electrons from the discharge.
- These results confirm that the high energy electrons must be simulated in an appropriate manner to study the production of hard radiation by streamer discharges.

The code allows now to go deeper into the undestanding of the process by allowing to test different leader field configurations and at different altitudes .

## 4) Future collaboration with host institution (if applicable)

It is planned to continue the collaboration in two ways:

- Several test cases relevant to atmospheric electricity will be run in collaboration with the host institute.
- Another exchange visit will allow to discuss and analyze the results and select key results for the writing of a joint paper.

## 5) Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

During this visit, we have also worked on the writing of a joint paper, that will be submitted to a special issue in the journal "plasma physics and controlled fusion".

The paper is entitled: "Infuence of the angular scattering of electrons on the runaway threshold in air" and the authors are O. Chanrion , Z. Bonaventura , A. Bourdon and T. Neubert

The paper will be sumitted before the submission deadline on june 28.

## 6) Other comments (if any)

Non applicable.