*Research school of Birkeland Centre for Space Science:*

Atmospheric Electricity and Hard radiation from Thunderclouds

When: May 20-24, 2019

Where: Department of Physics and Technology, University of Bergen, Allegt 55, Bergen, Norway

School hours: 25 lectures of 45 minutes

Curriculum: 144 pages descriptive

80 pages theory

110 pages from scientific journal articles

Total: 334

Project: Estimated 4 weeks of work – submitted to UB and evaluated

ETCS credits 10

The credits are given by University of Bergen and need to be approved by the home university

Registration Before February 1, 2019, link to registration form

Tuition fee None

Application for  
financial support Before February 1, 2019, link to application form

**Financial Support:**

For students who do not have their own support, limited financial support is available for travel expenses and accommodation. Applications, including a support letter from supervisor should be submitted before February 1, 2019. This aid is only given to you if you attend the school and also commit to do the project work afterwards.

**Curriculum:**

***Background material*** *(self-study, short presentations will be given by the students themselves)*

Vladimir A. Rakov and Martin A. Uman - Lightning, Physics and effects (2003)

* Chapter 1: Introduction (12 pages)
* Chapter 3: Electrical structure of lightning-producing clouds (27 pages)
* Chapter 4: Downward negative lightning discharges to ground (84 pages)
* Chapter 9: Cloud discharges (21 pages)

***Theory of lightning and its initiation*** *(lectures will be given)*

Vernon Cooray - The lightning flash (2003) *– lecture by Vernon Cooray*

* Chapter 3: Mechanism of electrical discharges. (80 pages)

***The production of Terrestrial Gamma-ray flashes*** *– lecture by Joseph Dwyer*

* Dwyer, J. R., M. A. Uman*,* The Physics of Lightning*, Physics Reports,*  
  Volume 534, Issue 4, 30 January 2014, Chapter 5 (38 pages)
* Dwyer, J. R., D. Smith and S. A. Cummer, High Energy Atmospheric Physics:

Terrestrial Gamma-ray Flashes and Related Phenomena, *Space Science Rev*,  
doi: 10.1007/s11214-012-9894-0, 2012. (58 pages)

* Celestin, S., and V. P. Pasko, Energy and fluxes of thermal runaway electrons produced by exponential growth of streamers during the stepping of lightning leaders and in transient luminous events, *J. of Geophysical Research*, 116 (A3), 1–14, doi:10.1029/2010JA016260, 2011. (14 pages)

**Description:**

The research school on *Atmospheric Electricity and Hard radiation from Thunderclouds* shall give the student an understanding of the basic mechanisms and physics involved in the production and electrification of thunderclouds. The students will also become familiar to observations of different types of lightning by electric field measurements, visible signals and radio-waves. This part of the curriculum will not be taught in class.

A more detailed description and theories for how streamers and leaders are formed and propagate will be given as lectures. This is how electric discharges initiate and how they branch through the air, both as it is observed in nature as lightning and as long sparks in the laboratory

Finally, the main theories for how hard radiation is produced in thunderclouds will be given as lectures. This part will focus on electron relativistic run-away and relativistic run-away electron avalanches in air and what electric field strengths are needed for these processes to occur. Also, where such fields can be produced in a thundercloud in order to produce tens of MeV electrons and gamma-rays. Characteristic time-scales, energy spectrum of electrons and terrestrial gamma-rays as they propagate out of the atmosphere will also be derived.

Classes will also include observations of TGFs, instruments to detect TGFs, propagation of photons through the atmosphere, what is an Energy Response Matrix, radio waves from lightning, and long sparks in the laboratory.

Finally, the course will include a project to be completed after the conclusion of the school and submitted for evaluation.

**Project:**

Determine the distribution of TGFs detected by AGILE, RHESSI and Fermi in

* Longitude
* Latitude
* Duration
* Local times
* Ocean, coast and land

And discuss how and why they are different – different instruments, different orbits etc….

Lists of TGFs from the three platforms will be given

The project requires programming by the student. A report of no less than 10 pages should include an introduction, results with relevant figures/plots and a discussion. The introduction should reflect the background material (self-study) and some of the TGF theory. The report should be submitted not later than 6 weeks after the research school. It will be evaluated and will serve as the documentation for passing the course or not.

*(See detailed schedule for the week on next page.)*

**Week plan:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Monday 20.5** | **Tuesday 21.5** | **Wednesday 22.5** | **Thursday 23.5** | **Friday** |
| **0900-0945** | Information about the course | Rakov and Uman,  Chapter 4.1-4.4.6:  Pawel Jujeczko  Chapter 4.4.7-4.6:  Marcelo Arcanjo | Rakov and Uman  Chapter 9.1-9.3: Stan Nnadih:  Chapter 9.4-9.7:  Julia Tilles | TGF-theory:  Joe Dwyer | ASIM results  (Nikolai Østgaard) |
| **1000-1045** | Rakov and Uman,  Chapter 1:  Edith Tueros, José Tacza and Edith Macotela | Mechanism of electrical discharges. Vernon Cooray | Mechanism of electrical discharges: Vernon Cooray | TGF-theory:  Joe Dwyer | TGF-theory:  Joe Dwyer |
| **1100-1145** | Mechanism of electrical discharges. Vernon Cooray | Mechanism of electrical discharges. Vernon Cooray | X- and gamma-ray observations in Florida:  Hamid Rassoul | Instrumentation for TGF detection  (Martino Marisaldi) | Radio waves from lightning  (Andrey Mezentzev) |
| **Lunch** |  |  |  |  |  |
| **1300-1345** | Mechanism of electrical discharges. Vernon Cooray | TGF-theory:  Joe Dwyer | TGF-theory:  Joe Dwyer | Propagation of photons through atmosphere  (David Sarria) | Long sparks in laboratory - aircraft in thunderclouds  (Pavlo Kochkin) |
| **1400-1445** | Presenting the project  (Martino Marisaldi) | Rakov and Uman,  Cont. Chapter 4.4.7-4.6:  Marcelo Arcanjo  Chapter 4.7-4.12 Julia Tilles | X- and gamma-ray observations in Florida:  Hamid Rassoul | Project/study |  |
| **1500-1545** | Rakov and Uman,  Chapter 3: Ekaterina Svechnikova (3.1-3.2.3)  And Thomas Produit (3.2.4-3.4) | Project/study | Project/study | Project/study |  |
| **1600-1645** | Project/study | Questions & Answers  Vernon Cooray | Project/study | Questions & Answers  Joe Dwyer |  |

Lunch will be served everyday

Monday, immediately after the school, we will have an ice-breaker in h-bar (same building, in the basement), where pizza will be served and you can buy drinks.

Wednesday after school, food and wine will be served.

Background material presented by the students

Lectures given by the UIB group

Supplementary:

* Dwyer, J. R., A fundamental limit on electric fields in air, Geophysical Research Letters, 30 (20), 1–4, doi:10.1029/2003GL017781, 2003.
* Dwyer, J. R., Source mechanisms of terrestrial gamma-ray flashes, Journal of Geophysical Research, 113 (D10), 1–12, doi:10.1029/2007JD009248, 2008.
* Moss, G. D., V. P. Pasko, N. Liu, and G. Veronis, Monte Carlo model for analysis of thermal runaway electrons in streamer tips in transient luminous events and streamer zones of lightning leaders, Journal of Geophysical Research, 111 (A2), 1–37, doi:10.1029/2005JA011350, 2006.
* Eduard M. Bazelyan and Yuri P. Raizer - Lightning physics and lightning   
  protection (2000) Chapter 2: The streamer-leader process in a long spark.