THE NORWEGIAN ACADEMY OF SCIENCE AND LETTERS

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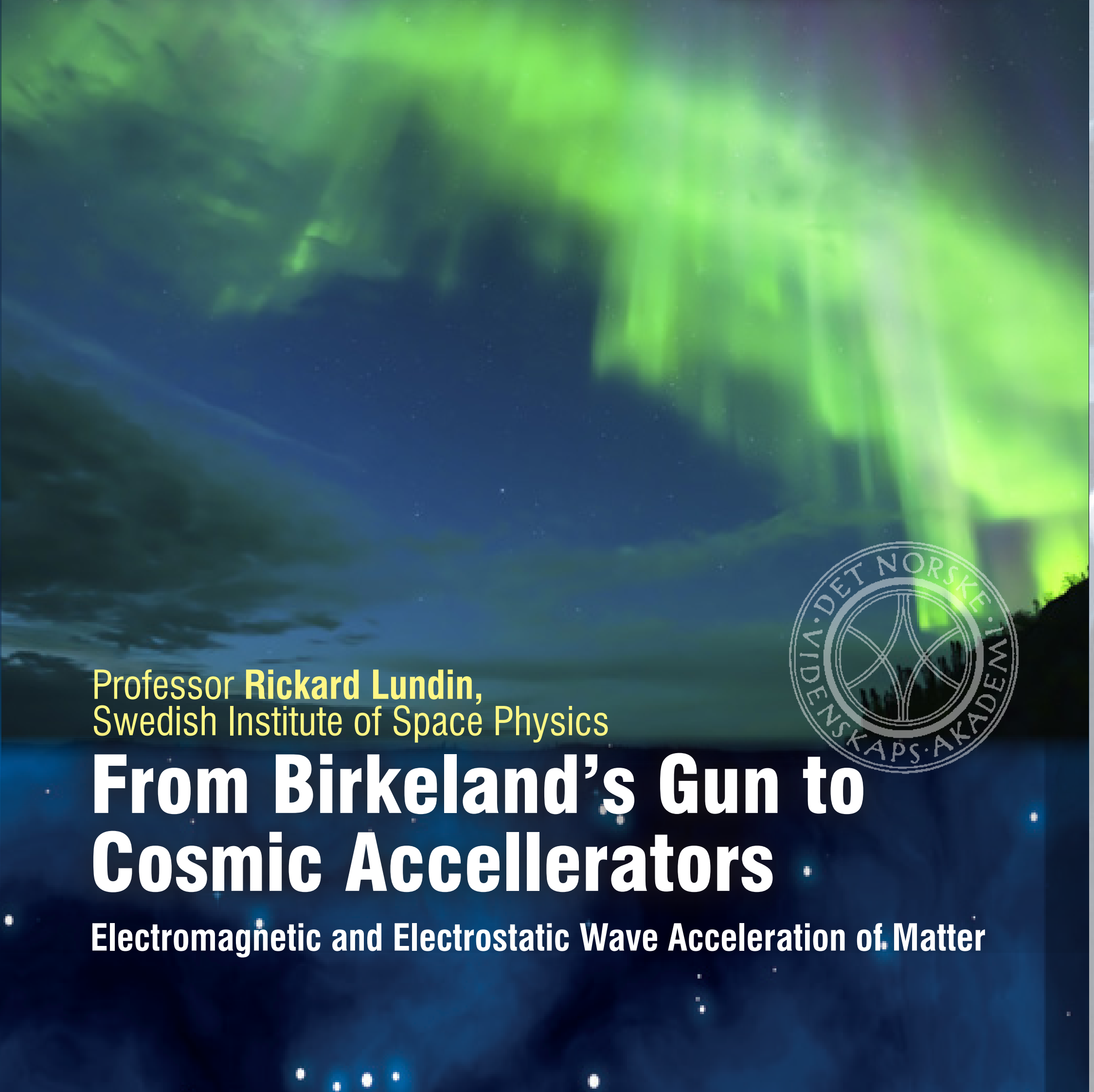
# The Birkeland Lecture 2018



Professor **Rickard Lundin,**
Swedish Institute of Space Physics

## From Birkeland's Gun to Cosmic Accellerators

**Electromagnetic and Electrostatic Wave Acceleration of Matter**

FOTO: COLOURBOX

This portrait of Professor Kristian Birkeland was painted by Asta Nørregaard in 1906.

## The Birkeland Lecture

The first Birkeland Lecture was given in Oslo in 1987 by the Nobel Laureate Hannes Alfvén. The lecture was a joint venture by the University of Oslo, the Norwegian Academy of Science and Letters and the Norwegian company Norsk Hydro. In 2004 Yara ASA took the place of Norsk Hydro and since 2005 the Norwegian Space Centre has been a partner in this cooperation. The Birkeland Lecture is above all an endeavor to honor the great Norwegian scientist and entrepreneur Kristian Birkeland. However, it has also given the organizers an opportunity to invite to Oslo many outstanding scientists within the field of geophysical and space research, areas which were central in Kristian Birkeland's own research.

Except for the year 1993, when the lecture was presented in Tokyo, and in 1998, when a mini-seminar was organized at the Norwegian Embassy in Tokyo, the lectures have been given in Norway, most of them at the Academy's premises in Oslo. Some years seminars have been arranged in connection with the lectures, e.g. in 1993 when the lecture was a part of a "Joint Japanese – Norwegian Workshop on Arctic Research", in 1995 when the lecture was a part of a seminar on Norwegian environmental research, and in 2001 when the lecture was given in connection with a workshop on Norwegian space research, with emphasis on the Cluster satellite programme.

In 2017 the Birkeland Lecture was a part of the celebration of Kristian Birkeland's 150 years anniversary, a three-day event with lectures and seminars.

## Organizing committee:

Professor Jan A. Holtet, Department of Physics, University of Oslo
Professor Alv Egeland, Department of Physics, University of Oslo
Professor Jøran Moan, Department of Physics, University of Oslo
Øyvind Sørensen, Chief Executive, the Norwegian Academy of Science and Letters
Svein Flatebø, Senior Adviser, Yara International ASA
Pål Brekke, Senior Advisor, Norwegian Space Centre

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A list of former Birkeland lecturers is found on
http://www.dnva.no/artikkel/vis.html?tid=44857

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YARA
Knowledge grows


Professor **RICKARD LUNDIN**
Swedish Institute of Space Physics


Rickard Lundin started as graduate student in 1971 at the Swedish Institute of Space physics (IRF). His PhD 1977 in space physics at the University of Umeå entitled – Auroral electron acceleration based on sounding rocket data.

After his dissertation he joined a Sweden-USSR space science collaboration, becoming Principal Investigator (PI) of the ion mass-analyzing instrument PROMICS, on the Soviet Prognoz-7 satellite. The PROMICS-1 instrument provided unique data, the first measurements demonstrating that outflowing atmospheric oxygen ions are essentially omnipresent in the Earth's magnetosphere. Besides the ion composition aspects, it also led him to work on the topic magnetospheric boundary layer physics The PROMICS success offered an opportunity to become involved the USSR planetary program, a revisit of Mars – Phobos 1/2– launched in 1988. Measurements from the mass analyzing ASPERA instrument on Phobos-1 became another "first" - hydrogen and oxygen ion escaping from the planetary atmosphere of Mars. This lead to further speculations on the history of water on Mars.

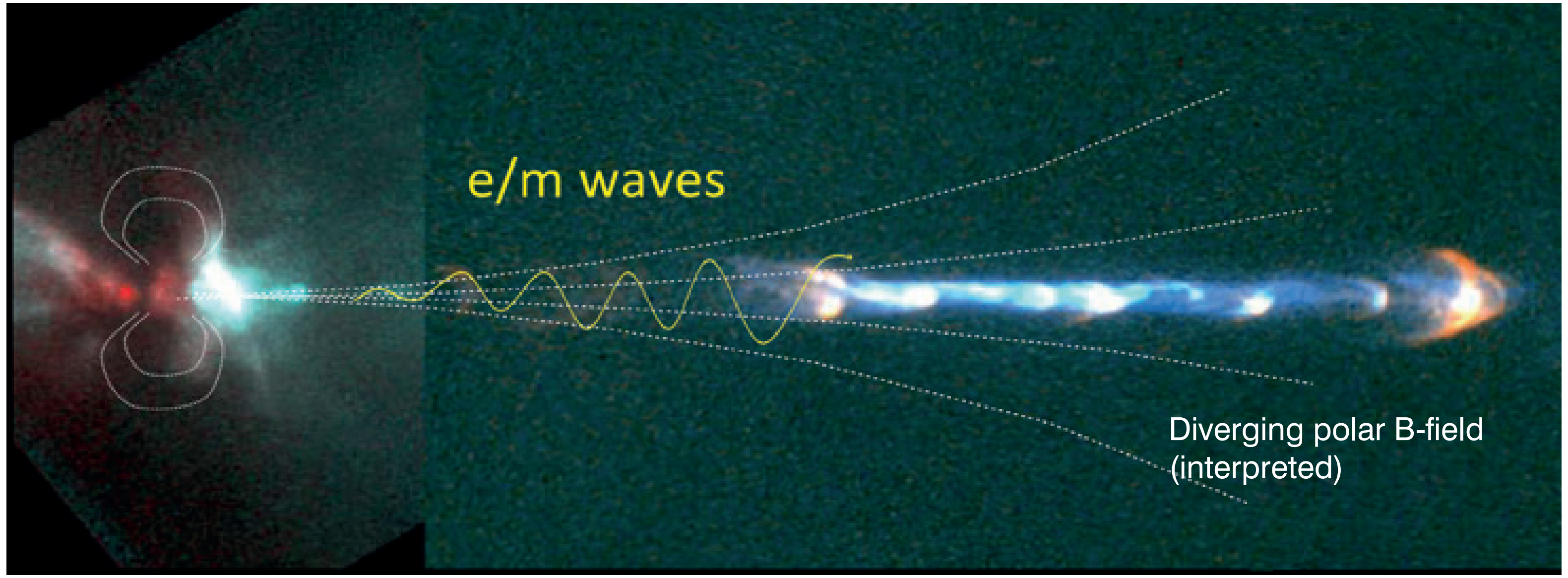
The success with Phobos-1 was probably the reason for being selected as PI with another mass-analyzing instrument, ASPERA-3 on ESA's Mars Express (MEX). The MEX mission is now celebrating 15 years in orbit around Mars. ASPERA-3 still continues to produce excellent results and high impact publications.

**A summary of his scientific interest involve the following topics:**

- Solar wind energy and momentum transfer to the Terrestrial planets.
- Ionospheric ion escape, long-term implications on the stability of a planetary atmosphere.
- Acceleration processes in magnetized plasma in general (e.g. by Ponderomotive forcing) and in particular,
- On weakly and strongly magnetized celestial objects (Earth, Mars, Venus, etc)

Lundin became full Professor in Space Physics in 1988. and from1994 to 2003 he was director of IRF. He has been Principal Investigator of experiments on 9 space missions, and co-investigator on 6 space missions.

In 2008 he received The Alfvén Medal by the European Geophysical Society, and in 2001 Ordre de Mérit, Commandeur, France.




Plasma jet from Herbig-Haro object 111, a star with strong dipole magne:c field (HH-111, WFPC•NICMOS on Hubble Space Telescope).

## RICKARD LUNDIN:

# From Birkeland's Gun to Cosmic Accellerators

### Electromagnetic and Electrostatic Wave Acceleration of Matter

Polar aurora is a consequence of high-altitude acceleration and precipitation of charged particles into the upper atmosphere. The first observational records of the "polar light" dates back some 2200 years (Archimedes). A long time passed before Celsius and Hiorter could establish a connection between aurora and magnetic disturbances in the mid 18th century. Eventually, 150 years later Størmer and Birkeland presented a theory that still applies, the aurora is related with charged particles guided by the Earths' magnetic field, subsequently precipitating into the polar upper atmosphere.

The first artificial satellite Sputnik 1, launched in 1957 marked the beginning of "Space Age", an opportunity to measure cosmic plasma in-situ. So far space missions in the inner solar system remains the only option for advanced studies of "cosmic" plasma phenomena in situ. Sixty years of space plasma measurements have markedly increased our understanding of cosmic plasma acceleration processes.

A particular aspect of the latter is electromagnetic and electrostatic acceleration of charged particles by "ponderomotive" wave forcing - energy and momentum transfer by waves. Kristian Birkeland was probably first to test this principle in laboratory, an electromagnetic "coil-gun" intended for practical (military) purposes. Hannes Alfvén a more "peaceful" minded admirer of Birkeland's work and the inventor of magneto-hydrodynamics (MHD) suggested an alternative version, a plasma gun responsible for the high-velocity (300-1000 km/s) solar wind.

Dipole magnetic fields, like the Earth's field, play a major role for the efficiency of auroral and cosmic acceleration processes, especially when waves are involved. Theoretically the maximum energy of accelerated charged particles scales with the magnitude of the magnetic field and wave electric field. Another implication of a diverging magnetic field (e.g. dipole field) is that plasma beams tend to focus in the direction of a weakening magnetic field. A number of magnetized objects in Cosmos, let alone in the solar system comply with the above picture. Now, adding wave (ponderomotive) forcing to a diverging magnetic field leads to further acceleration, i.e. a third version of an electromagnetic "gun" powered by waves.

Besides being applicable for cosmic plasma acceleration processes, the "third" version offers interesting and useful applications.

# Yara Birkeland – Representing the next generation of ships


***Bjørn Tore Orvik,***
Project Hub Manager Scandinavia, Yara


The motivation behind Yara Birkeland is to move the transport of finished product from our Porsgrunn plant to the shipping hubs in Brevik and Larvik from road to sea. After exploring different energy options for the autonomous container vessel, the conclusion was to use batteries. The two pillars autonomous and zero emission were established as a vision for Yara in this project, aiming to create the world's first fully digital supply chain operation for containers.

Early in the project we approached Kongsberg who had several ongoing projects to develop autonomous ships and a reputed history within ship automation, in addition to ongoing tests on small vessels in cooperation with FFI. The core of the technology is deep learning, sensor fusion, and an integrated IT solution for the ship itself. Together with Kongsberg we realized that we could develop a game changer within short-sea shipping.

Yara Birkeland will be part of a supply chain, and thus the project includes establishing a quayside solution for container handling. This involves autonomous car technology to handle cars, trucks and pedestrians within a restricted mixed traffic environment in the industrial area. The two pillars in the project - autonomous and zero emission - was used to identify Kalmar as the partner to develop the fully autonomous solution for land logistics.

Yara will integrate systems from Kongsberg and Kalmar in order to realize the world's first fully digital supply chain operation for containers.