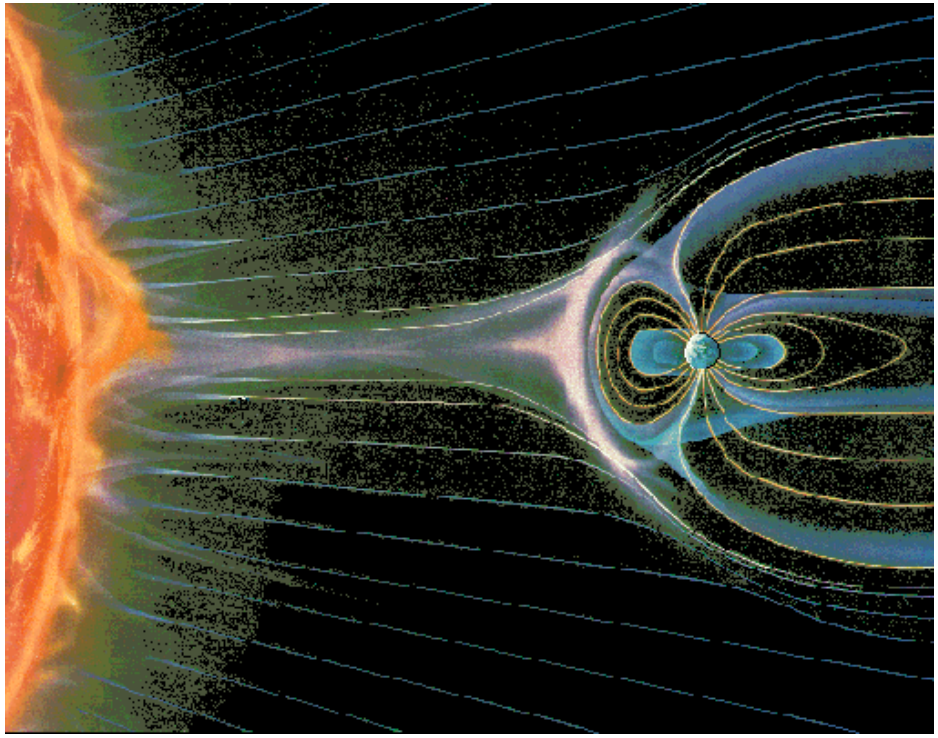
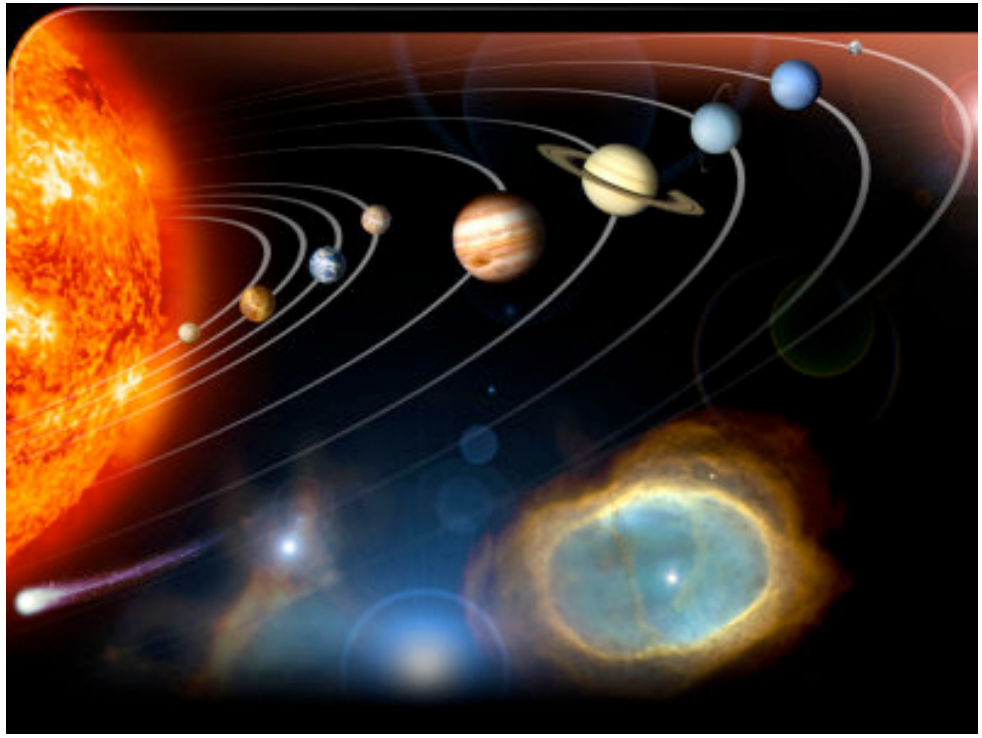

BOSTON
UNIVERSITY
C · S · P
BOSTON UNIVERSITY CENTER FOR SPACE PHYSICS
Boston University
Center for Space Physics

Space Physics

Space Physics: the study of the outer atmospheres and plasma environments of solar system objects, including the sun.

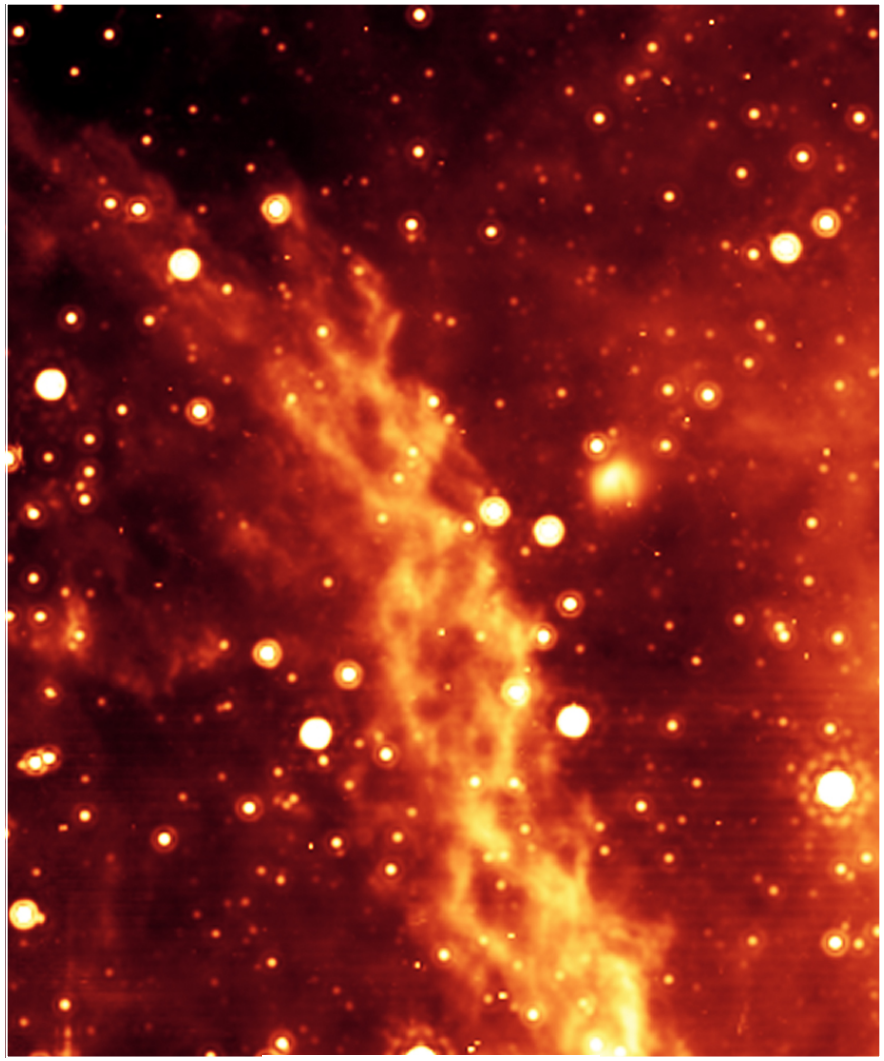
The Center for Space Physics (CSP) was founded in 1988 to promote research and education in space science and space-related technologies.



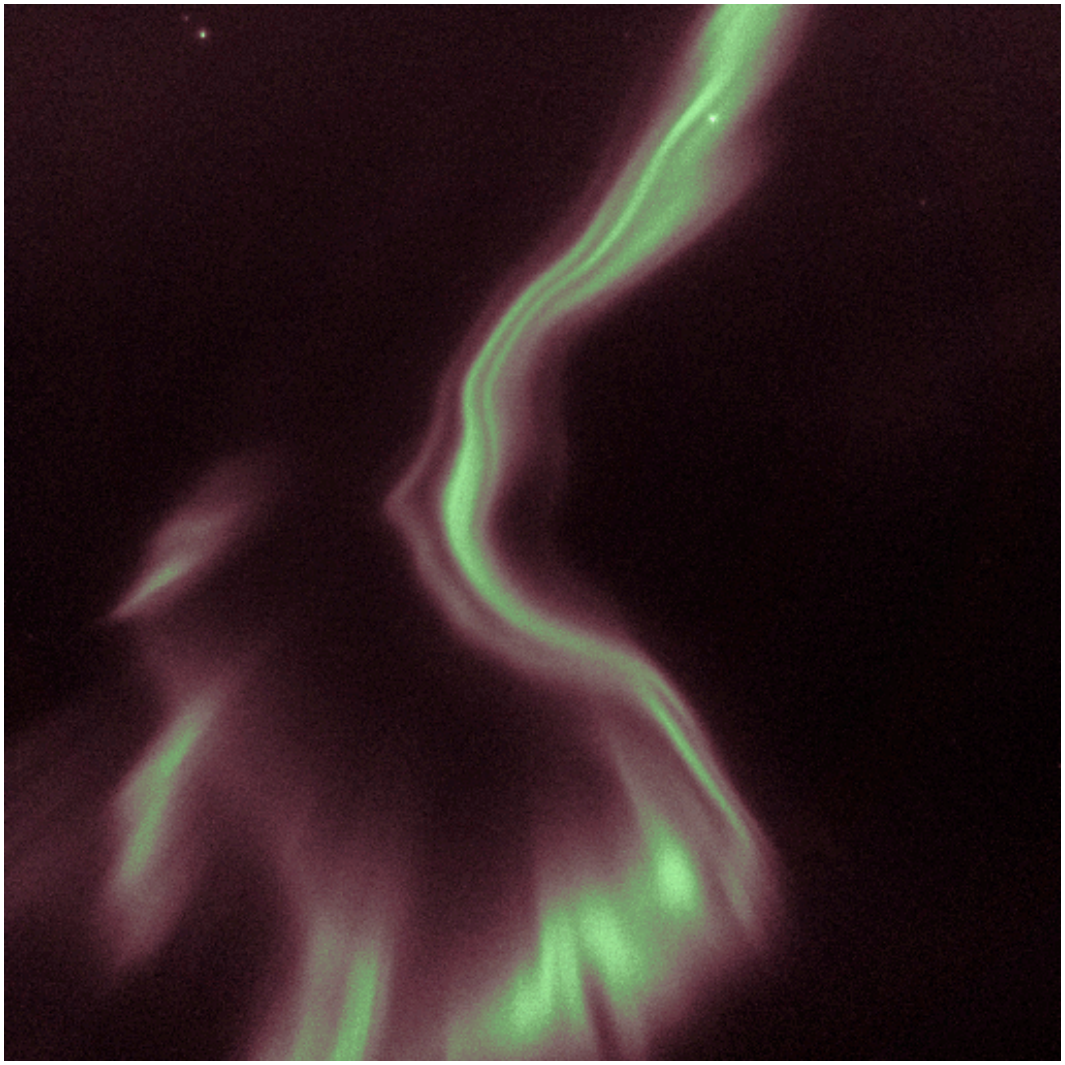


Universal Themes

- Plasma luminescence reveals magnetic field structure.



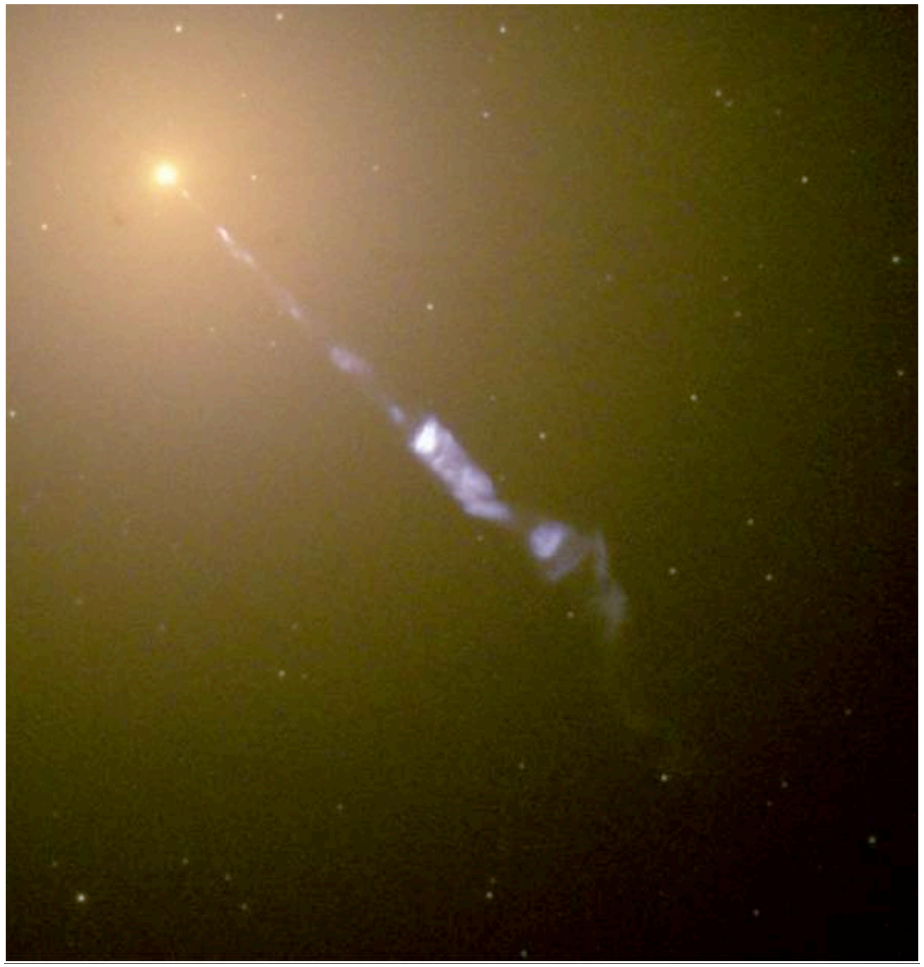
80 light years

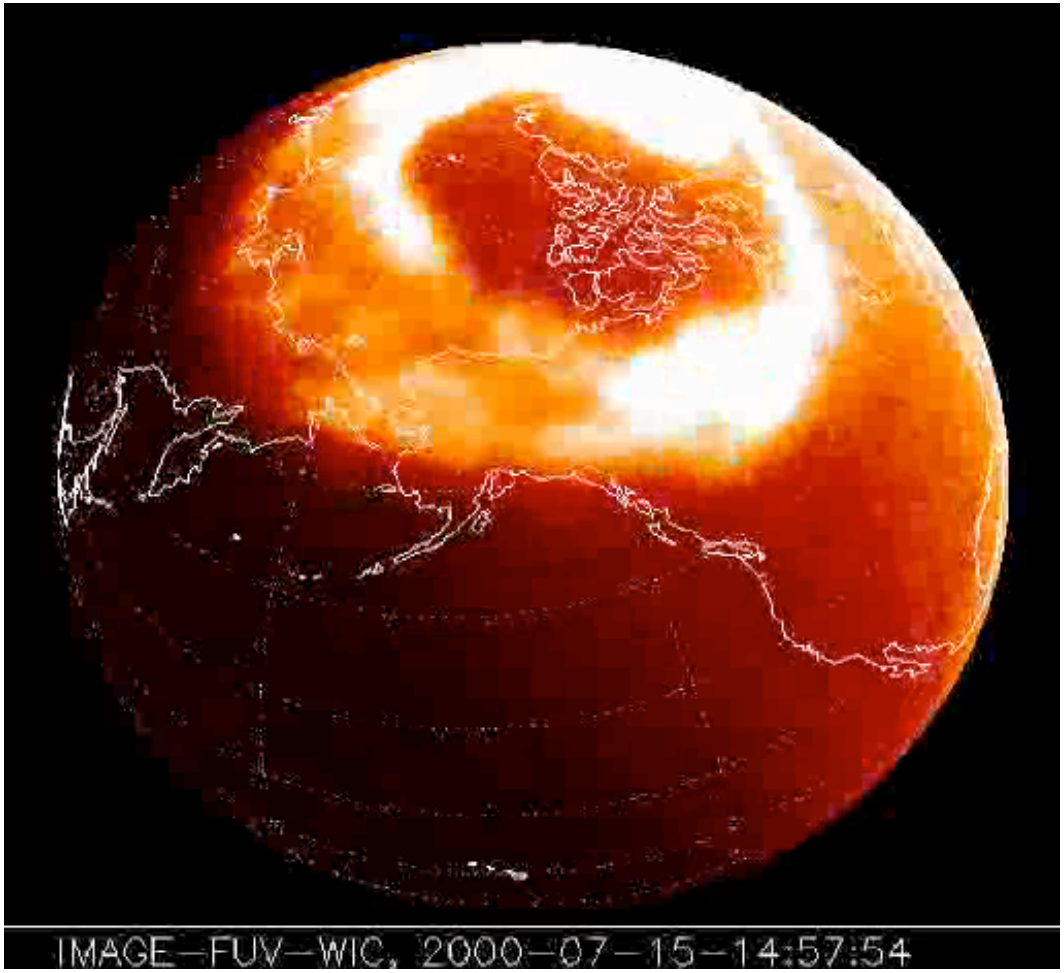


15 km

Universal Themes

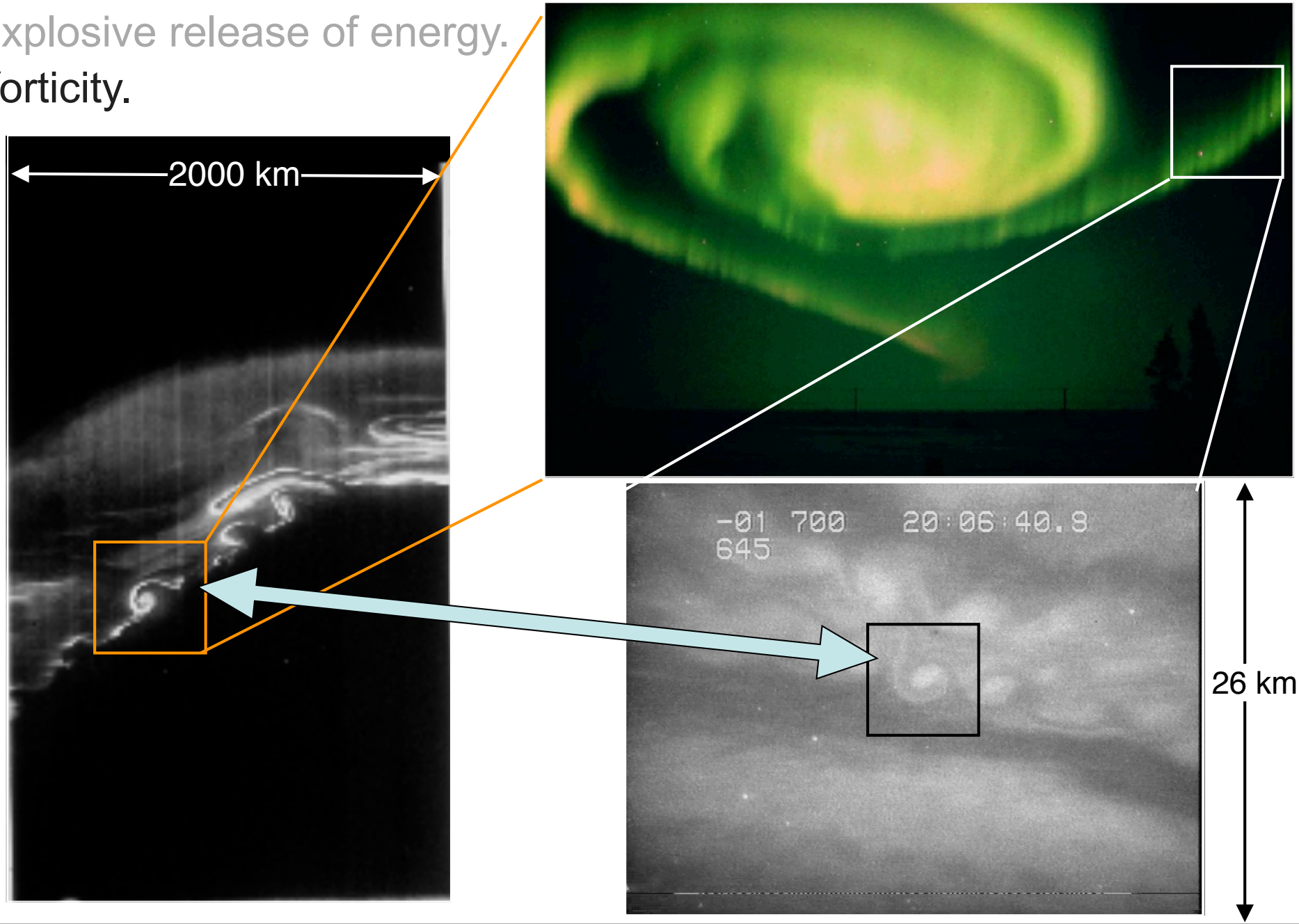
- Plasma luminescence reveals magnetic field structure.
- Explosive release of energy.





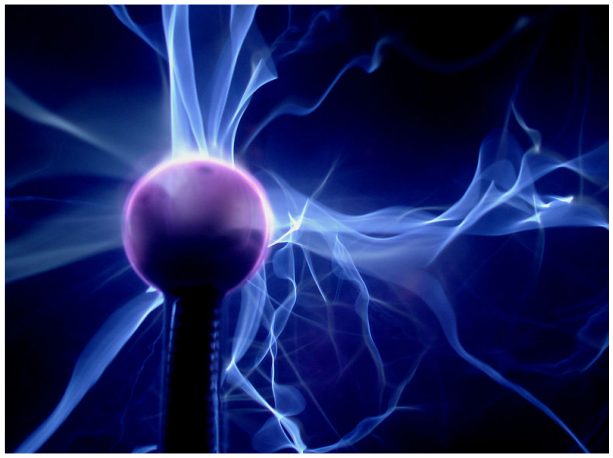
Universal Themes

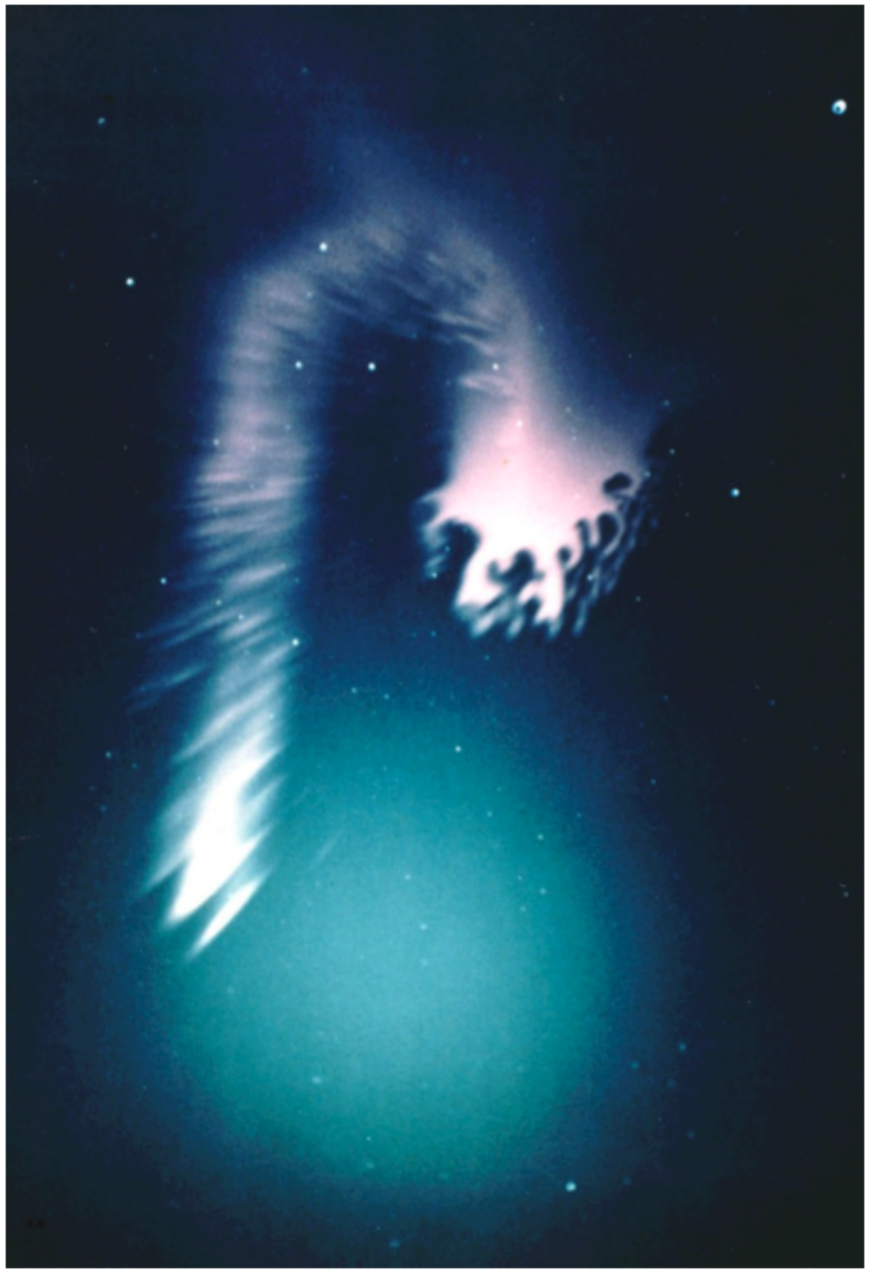
- Plasma luminescence reveals magnetic field structure.
- Explosive release of energy.
- Vorticity.



Universal Themes

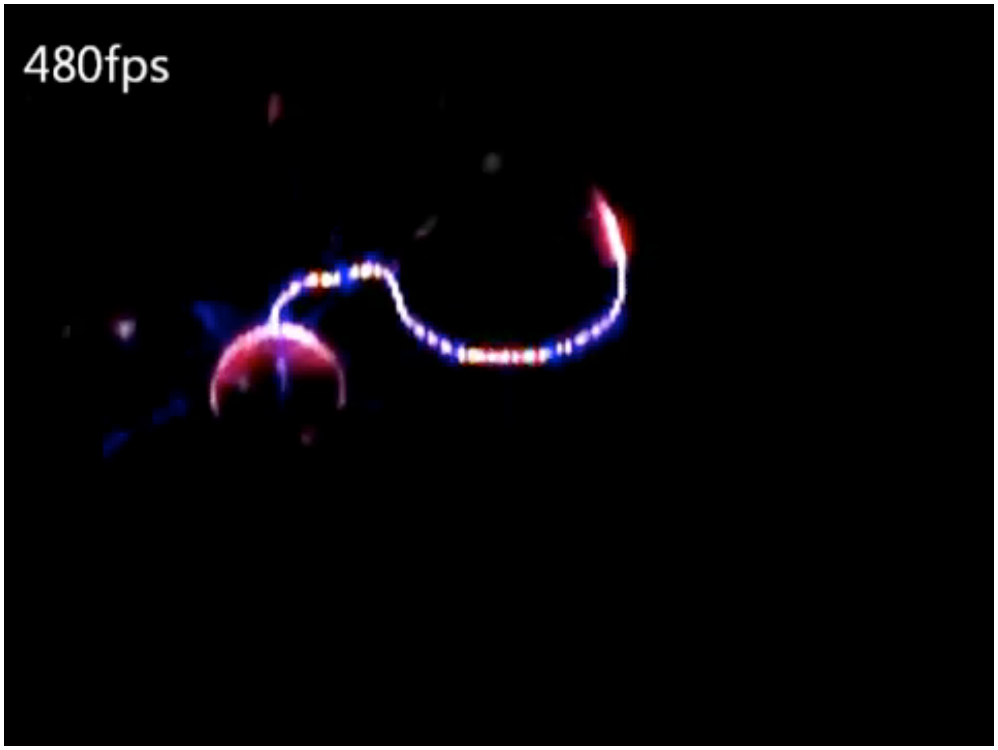
- Plasma luminescence reveals magnetic field structure.
- Explosive release of energy.
- Vorticity.
- Filamentation.



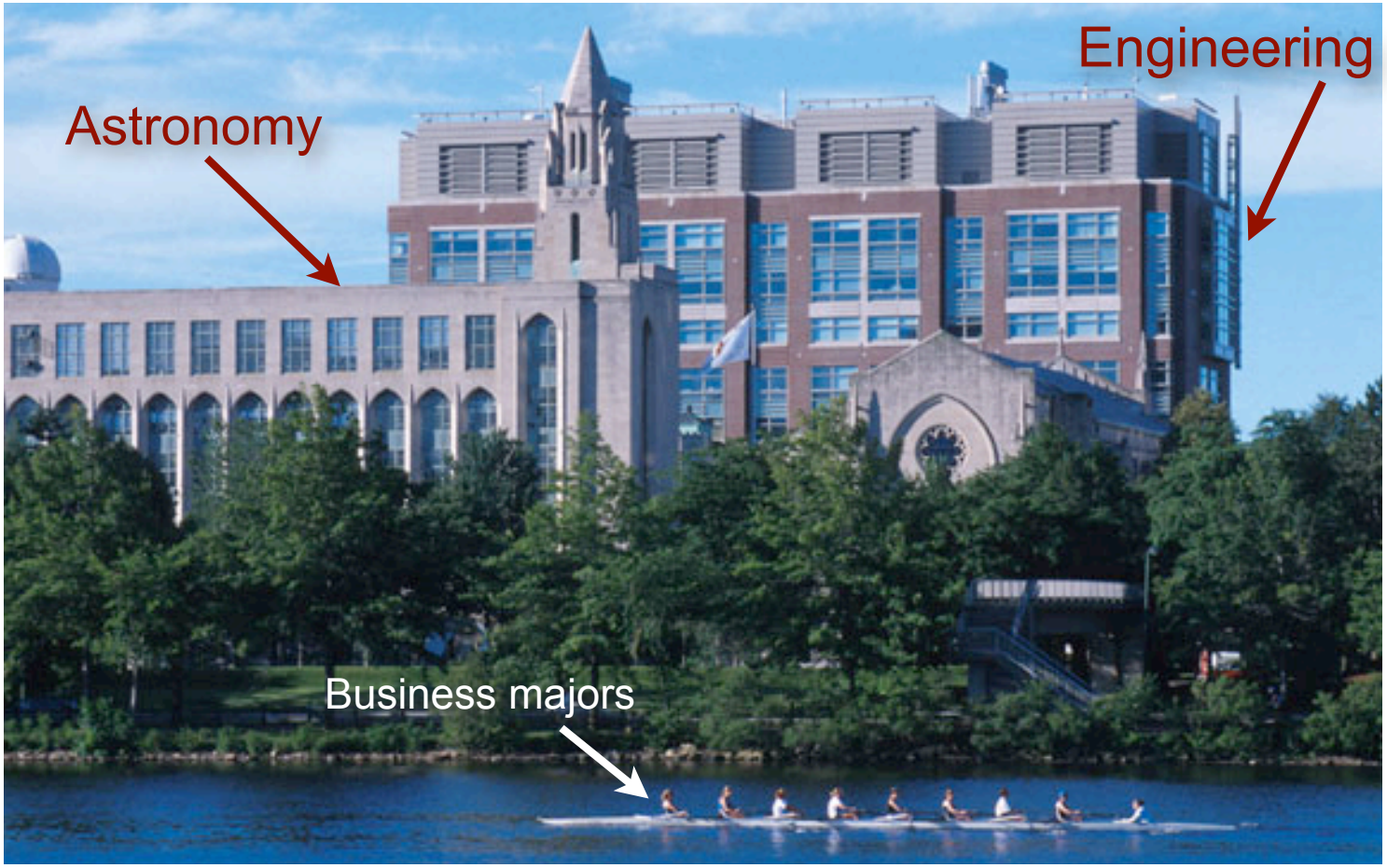


Universal Themes

- Plasma luminescence reveals magnetic field structure.
- Explosive release of energy.
- Vorticity.
- Filamentation.
- Sensor Resolution (space, time wavelength).



CSP: An Astronomy - Engineering Collaboratory



Whos is the CSP?

Faculty (13):
John Clarke (CSP Director / Prof. AS)
Joshua Semeter (Assoc. Director / Assoc. Prof. ECE / Affil. AS)
Supriya Chakrabarti (Prof. AS / Affil. Prof. ECE)
Theodore Fritz (Prof. AS / Affil. Prof. ECE / Affil. Prof. ME)
Michael Mendillo (Prof. AS / Affil. Prof. ECE)
Merav Opher(Assoc. Prof. AS)
Andrew West (Asst. Prof. AS)
Paul Withers (Asst. Prof. AS)
William Oliver (Prof. ECE)
Michael Ruane (Prof. ECE)
W. Clem Karl (Prof. ECE)
Meers Oppenheim (Prof. AS)
Tom Bifano (Prof. ME, Director of Photonics Center)
George Siscoe (Res. Prof. AS)
Nancy Crooker (Res. Prof. AS)

Administrative Staff (3):
Despina Bokios, Asst. Director
Amanda Rochette, Proposal Development Administrator.
Alysson Savoie, Administrative Assistant

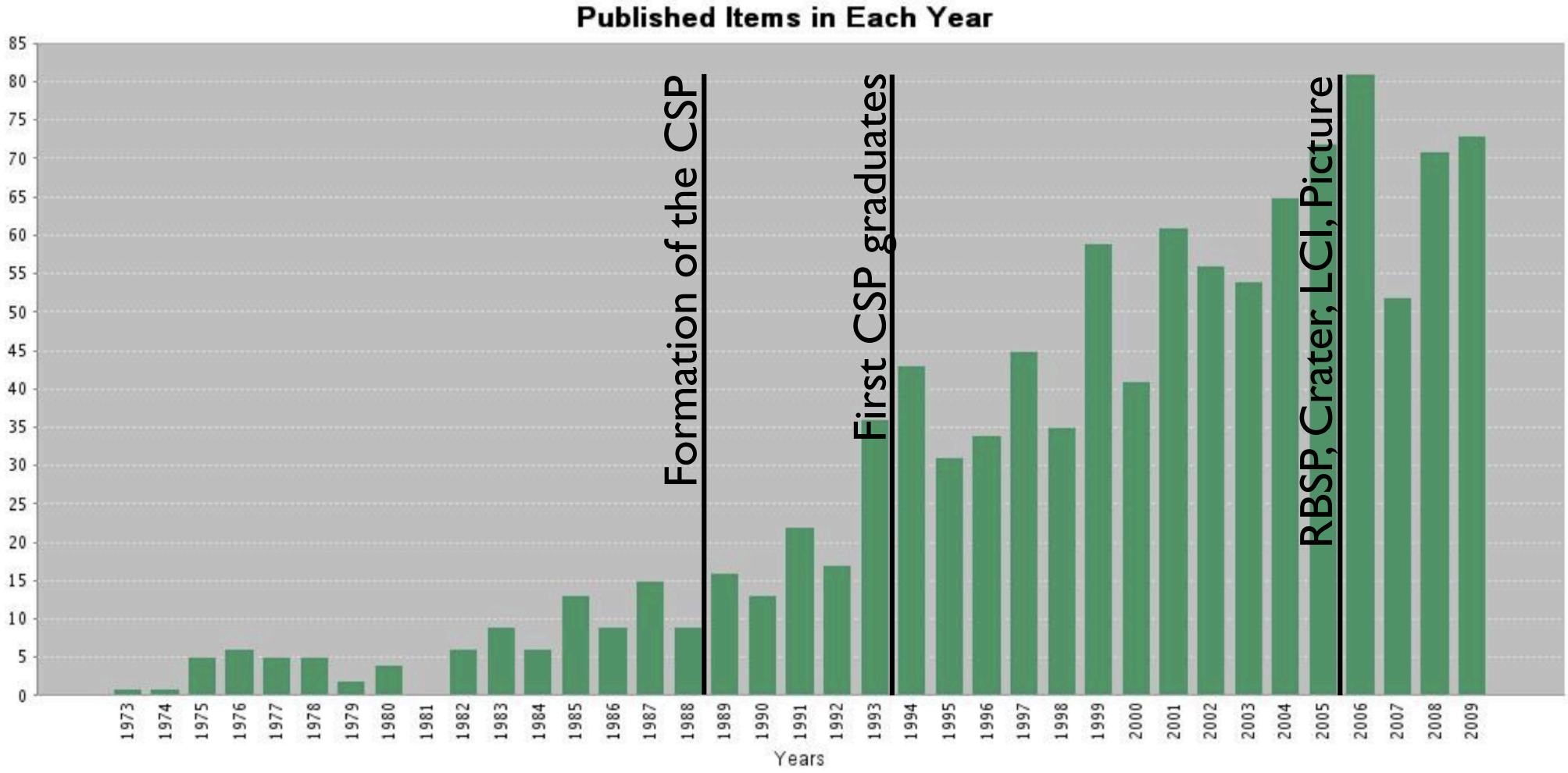
Research Associates (9):
Jeffrey Baumgardner (Senior Research Associate)
Yakov Dimant (Senior Research Associate)
Carlos Martinis (Research Associate)
Luke Moore (Research Associate)
Steven Smith (Senior Research Associate)
Hanna Dahlgren (Research Associate)
Torbjorn Sundberg (Research Associate)

Technical Staff (9):
Erik Beiser (Project Manager, LCI)
Anton Mavretic (Project Engineer, LCI)
Joei Wroten, (Senior Staff Researcher)
Clara Narvaez (Staff Researcher)

Plus ~30 graduate students (and ~20 undergraduates)

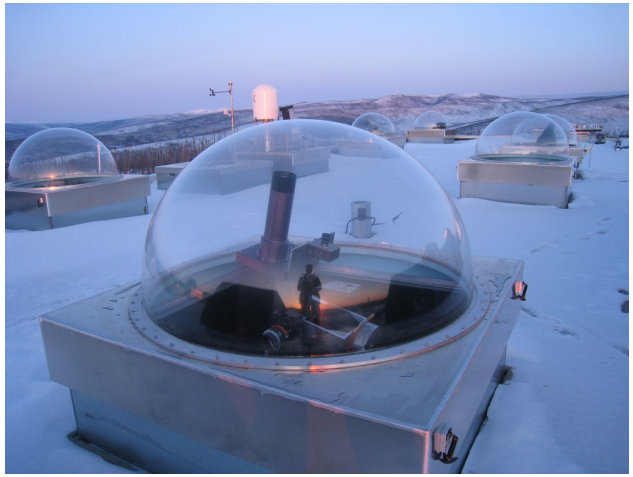
About 60 people at BU are affiliated with the CSP at any given time

CSP Through Time

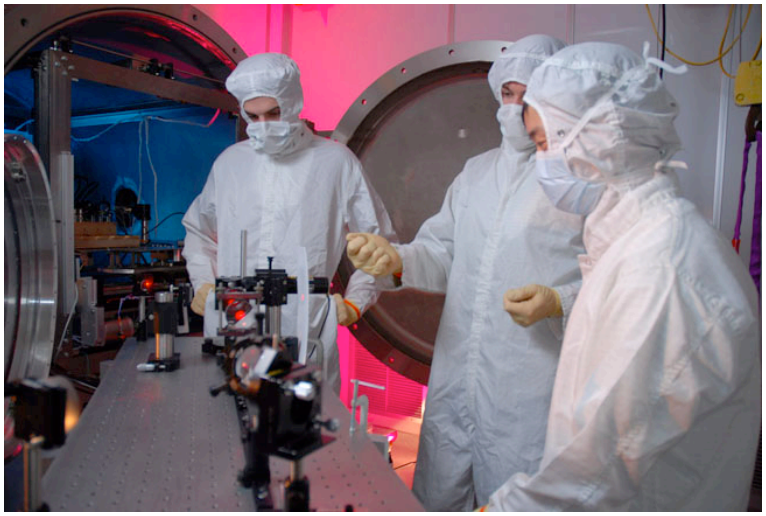


Source: Journal Citation Index. Complete list of 1042 CSP publications: http://heaviside.bu.edu/shared/csp_publications.pdf

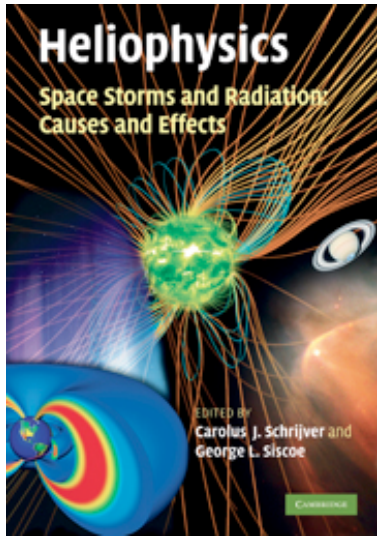
Current CSP Activities



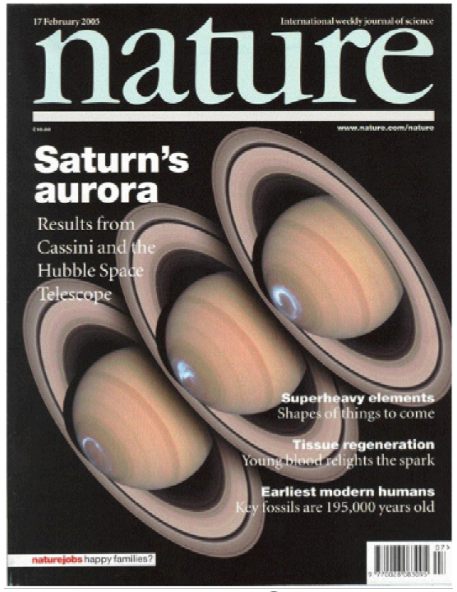
Optical aeronomy



Space hardware

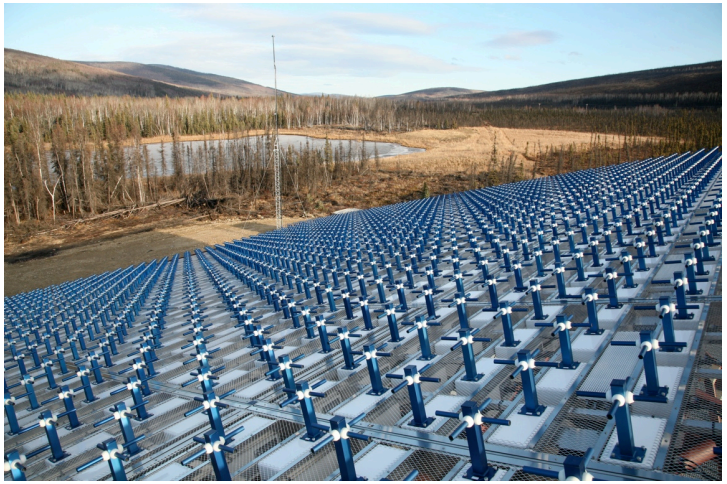


Heliophysics



Planetary Science

Plasma simulation

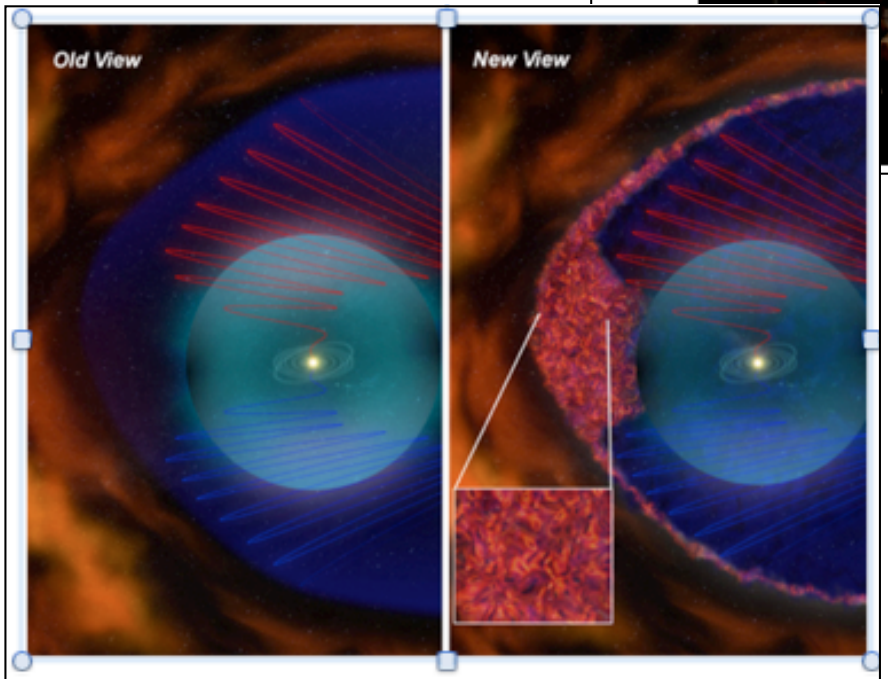


Radio Science

Heliophysics

New discoveries from the edge of the solar system

NASA's Voyager probes are truly going where no one has gone before. Gliding silently toward the stars, 9 billion miles from Earth, they are beaming back news from the most distant, unexplored reaches of the solar system. These probes have recently revealed exciting new information about the edge of our solar system. The results were discussed by AS Associate Professor Merav Opher and three other luminaries at a NASA sponsored press conference on Jun 9, 2011.



Old and new views of the heliosheath. Red and blue spirals are the gracefully curving magnetic field lines of orthodox models. New data from Voyager add a magnetic froth (inset) to the mix. (Credit: NASA).

Space Hardware

The search for extra-solar planets

PICTURE is a sounding rocket experiment which will perform the first test in space of a coronagraph designed to image planets orbiting nearby stars. It will image the debris disk around epsilon Eridani in order to both determine the background of scattered light that we will need to find the planet Epsilon Eridani-b in and study the material from which the planet formed. It will mark the first flight of a deformable mirror developed by Boston Micromachines Corporation (BMC), the first flight of a nulling interferometer, and the first flight test of an ultra-lightweight (5 KG) telescope primary mirror.

The 5th floor hallway of CAS became a rocket lab as graduate students Chris Mendillo (AS) and Brian Hicksi (ECE) prepared the PICTURE payload for delivery.

Hicks and Mendillo pose confidently in front of their competed project at the NASA Wallops Island flight facility.

Debris disks are remnants of the process of planet formation. While gas and solid material in some parts of a young protoplanetary disk may grow into gas giants and terrestrial planets, the process is never completely efficient. The Solar System, for example, has two bands of leftover material - the asteroid belt lying between Mars and Jupiter and the Kuiper Belt lying just outside Neptune's orbit. These belts contain large Pluto-

Planetary Astronomy

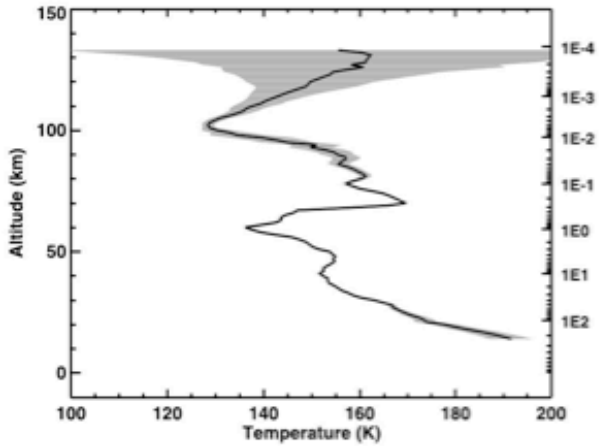
ssini at Jupiter.

Io leaves a magnetic footprint on Jupiter's upper atmosphere that appears as a spot of ultraviolet emission that remains fixed underneath Io as Jupiter rotates. The spot seems to arise because of an electromagnetic interaction between Jupiter's magnetic field and the plasma surrounding Io, driving currents of around 1 million amperes down through Jupiter's ionosphere. Here we report persistent, faint, far-ultraviolet emission from the jovian footprints of Ganymede and Europa. We also sh... that Io's magnetic footprint extends well beyond the imp... icinity of Io's flux-tube interaction with Jupiter, a... er than predicted theoretically; the emission ... hours downstream. We infer from these ... opa have persistent interactions ... ite their thin atmospheres ... featured in the ... http://www.p...

s of Saturn Aurora.

have in ways different from how scientists e for the last 25 years, according to new astronomers led by John Clarke, a professor Space Physics. The team's findings have about how Saturn's magnetosphere behaves s are generated. Their results were featured on ebruary 17, 2005, issue of *Nature* (impact factor ormation, see BU press release: du/phpbin/news/releases/display.php?id=863

Professor Withers is using the flight of spacecraft through the atmosphere of Mars to measure atmospheric properties, such as its temperature profile. He used onboard accelerometer measurements from the 2008 descent of the Phoenix lander to the Martian arctic to obtain the first such profile from the polar atmosphere. These measurements revealed signatures of a mixture of thermal tides in the Martian atmosphere.



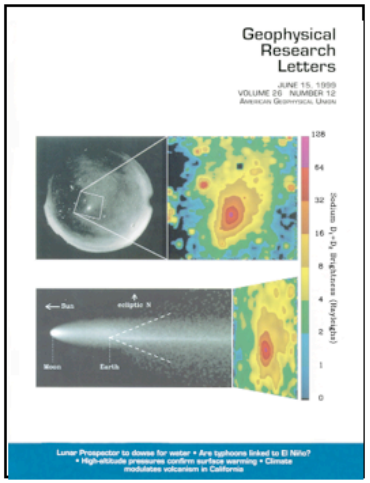
Temperature profile measured during Phoenix entry into the

Withers also demonstrated and published a technique to

Terrestrial Aeronomy

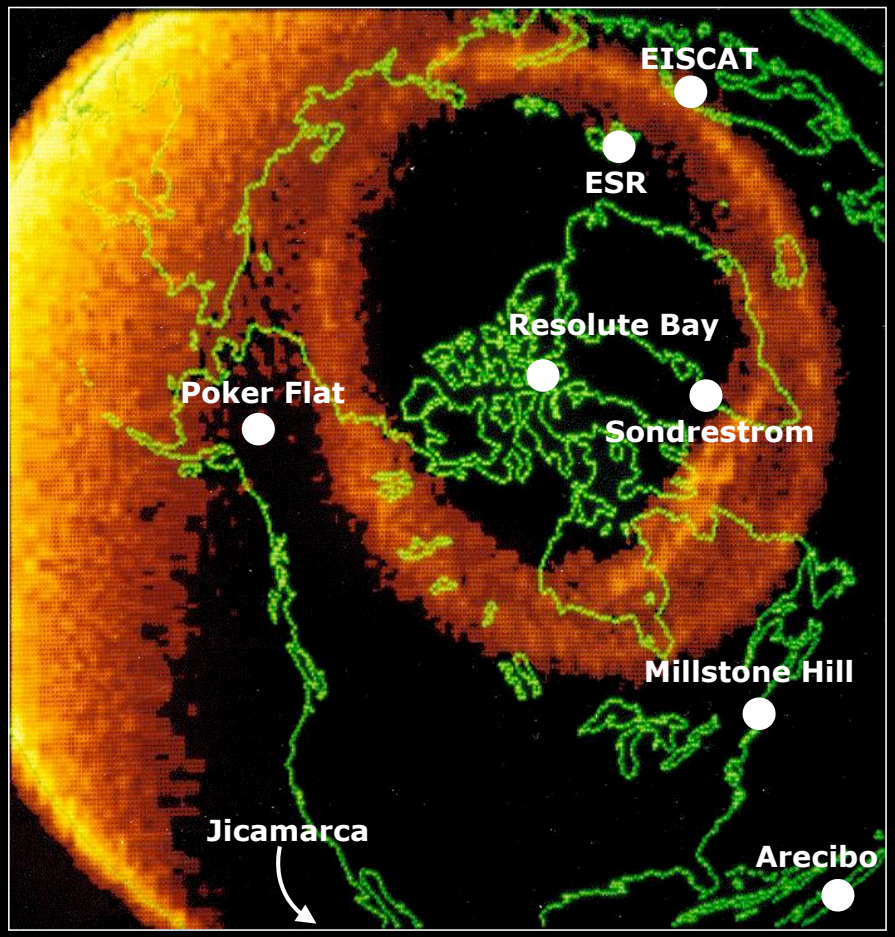
The Moon's Sodium Tail.

Boston University astronomers have announced the discovery of an enormous tail of sodium gas stretching to great distances from the moon. The observations were made at the McDonald Observatory in Fort Davis, Texas, on nights following the Leonid meteor shower of November 1998. The tail of sodium gas was seen to distances of at least 500,000 miles from the moon, changing its appearances over three consecutive nights. The discovery of this new solar system phenomenon by Dr. Steven Smith of the BU Center for Space Physics was featured on the June 15, 1999, issue of *Geophysical Research Letters*. For more information see BU press release:
http://www.bu.edu/phpbin/news/releases/display.php?id=43

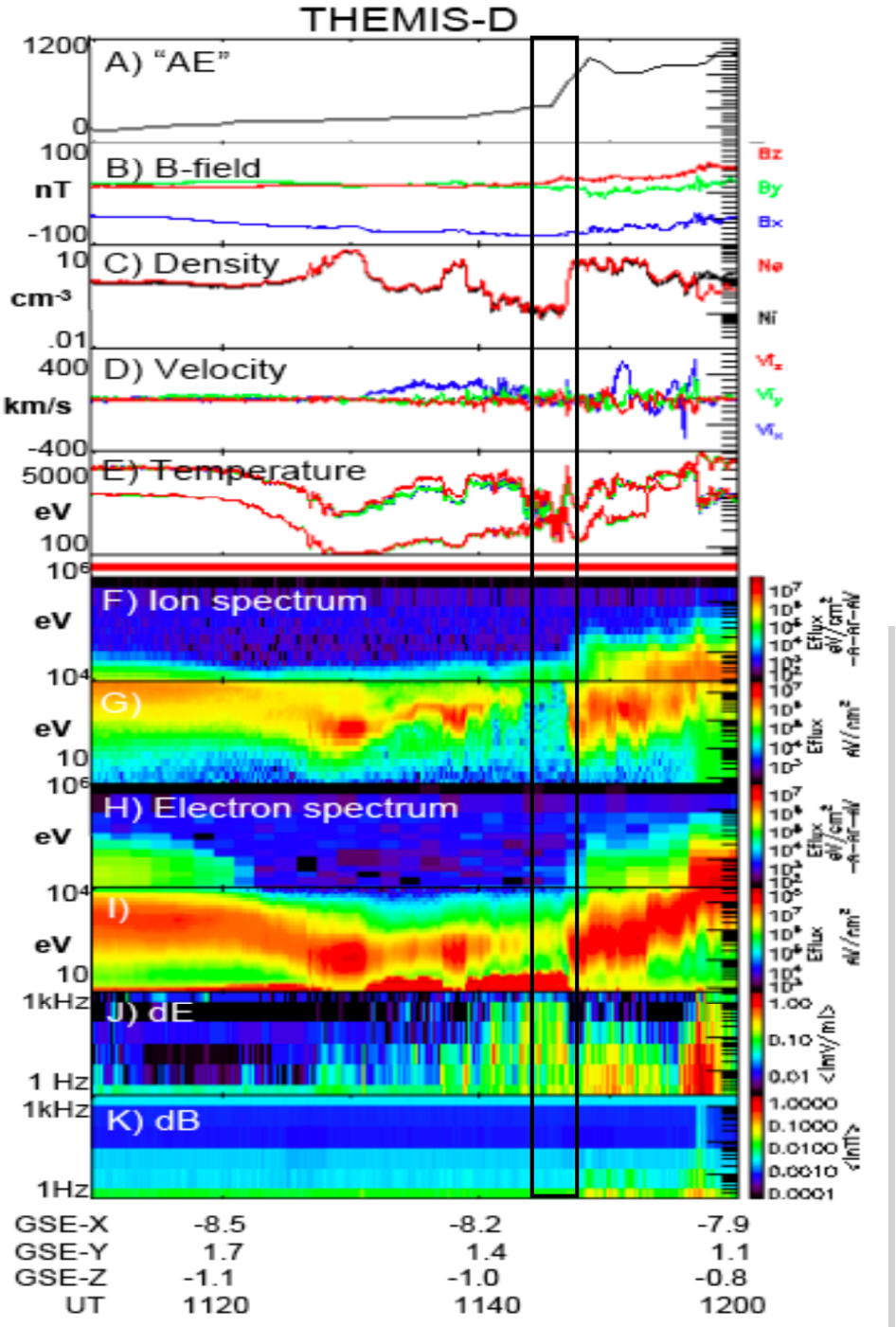


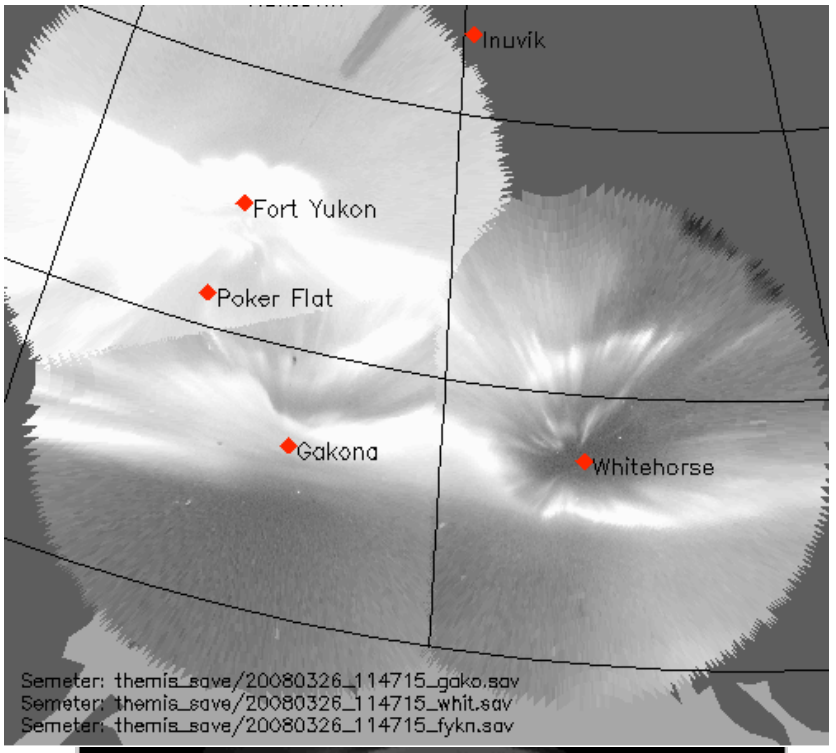
Radio Science

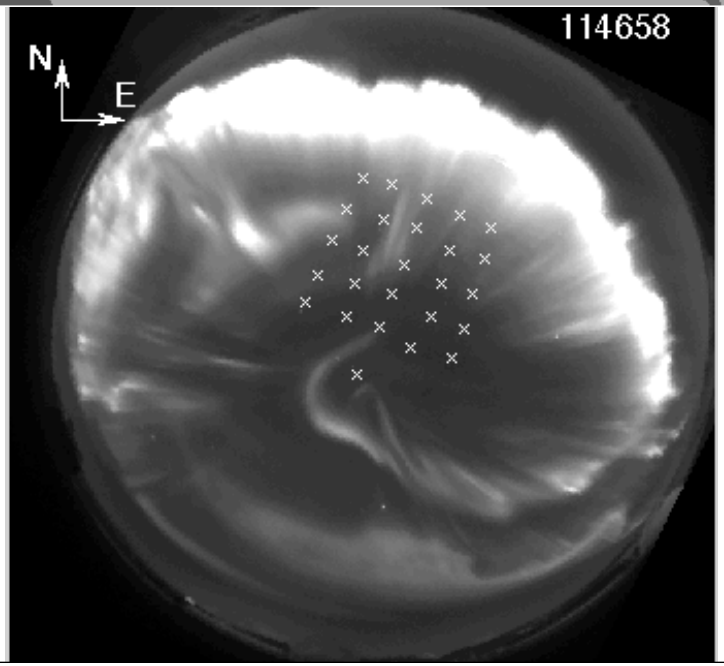
Advanced Modular Incoherent Scatter Radar



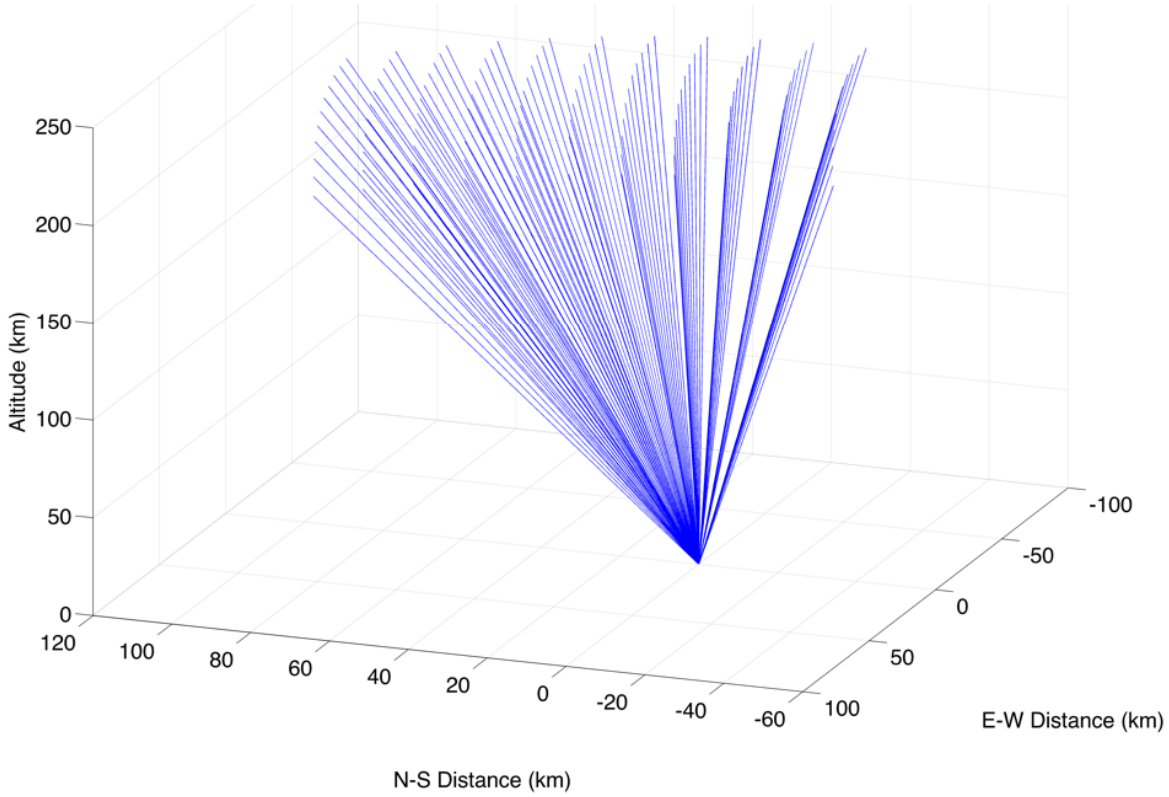
Standard view of substorm onset

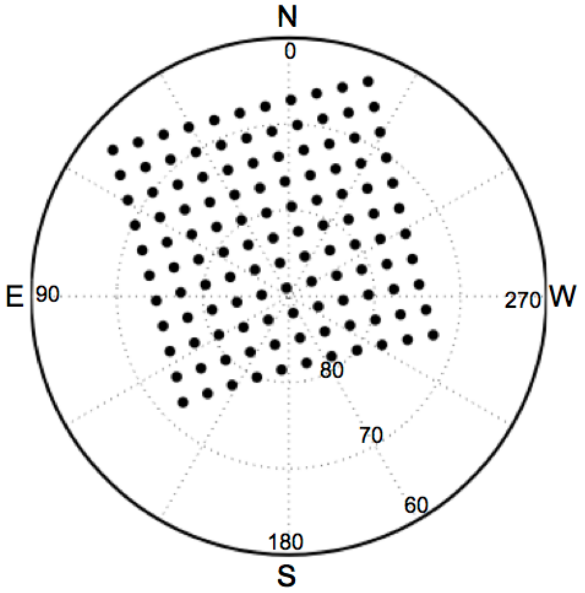






Volumetric imaging of substorm onsets





11x11 grid of beams

3 deg separation

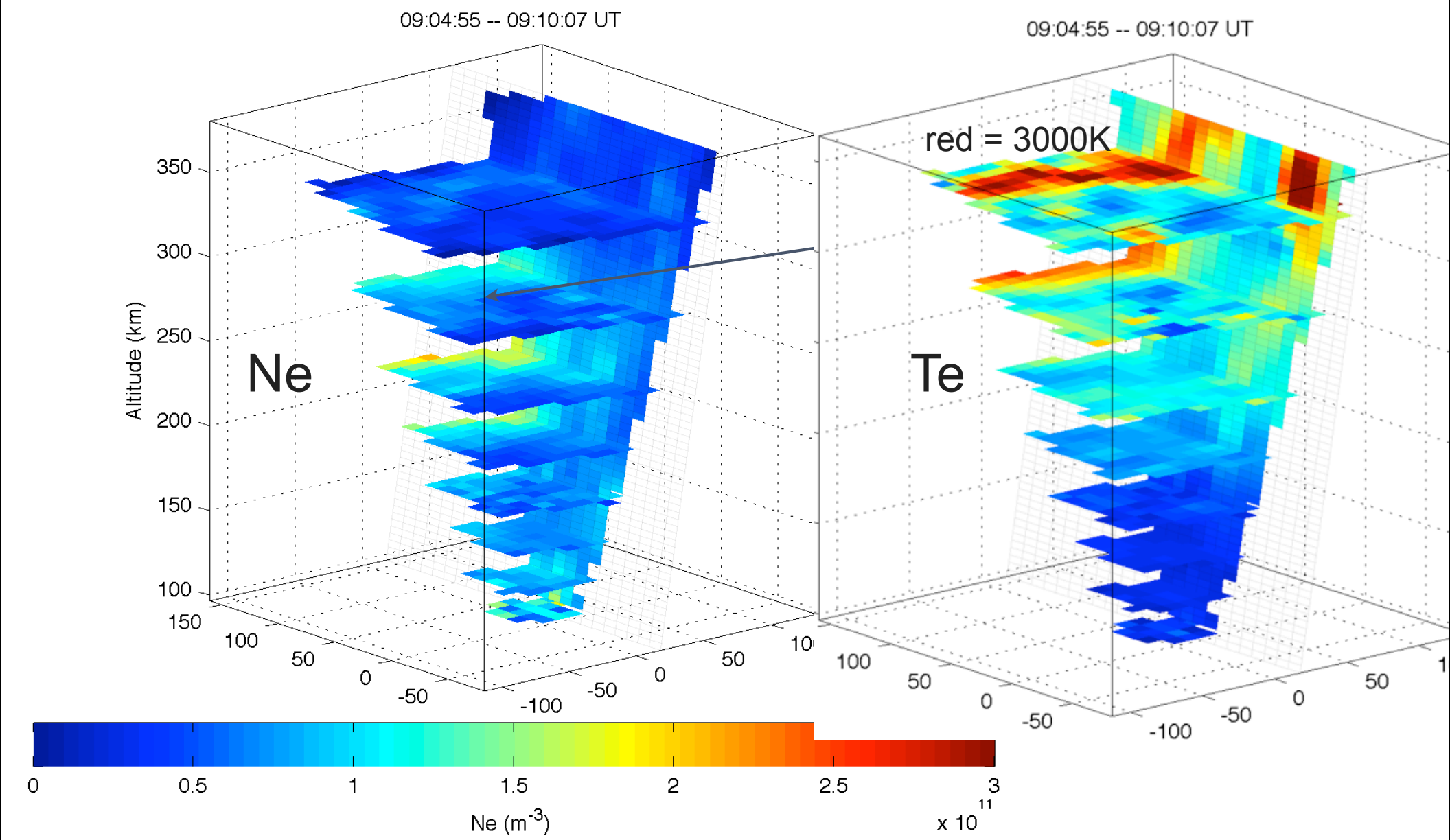
Two pulse patterns:

13 Baud Barker code

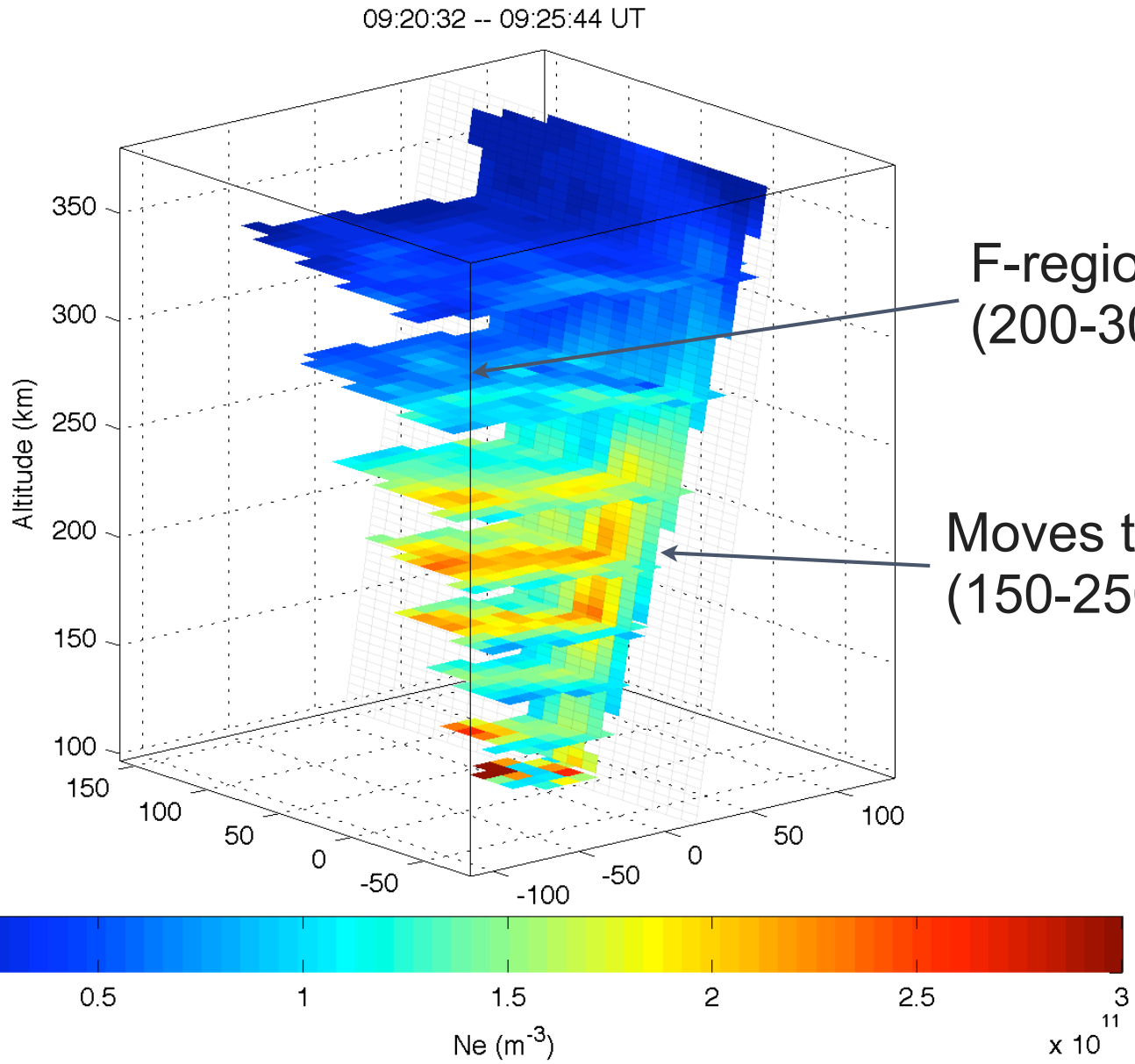
480us uncoded pulse

14.6 s integration = 48 pulses/beam

Volumetric view



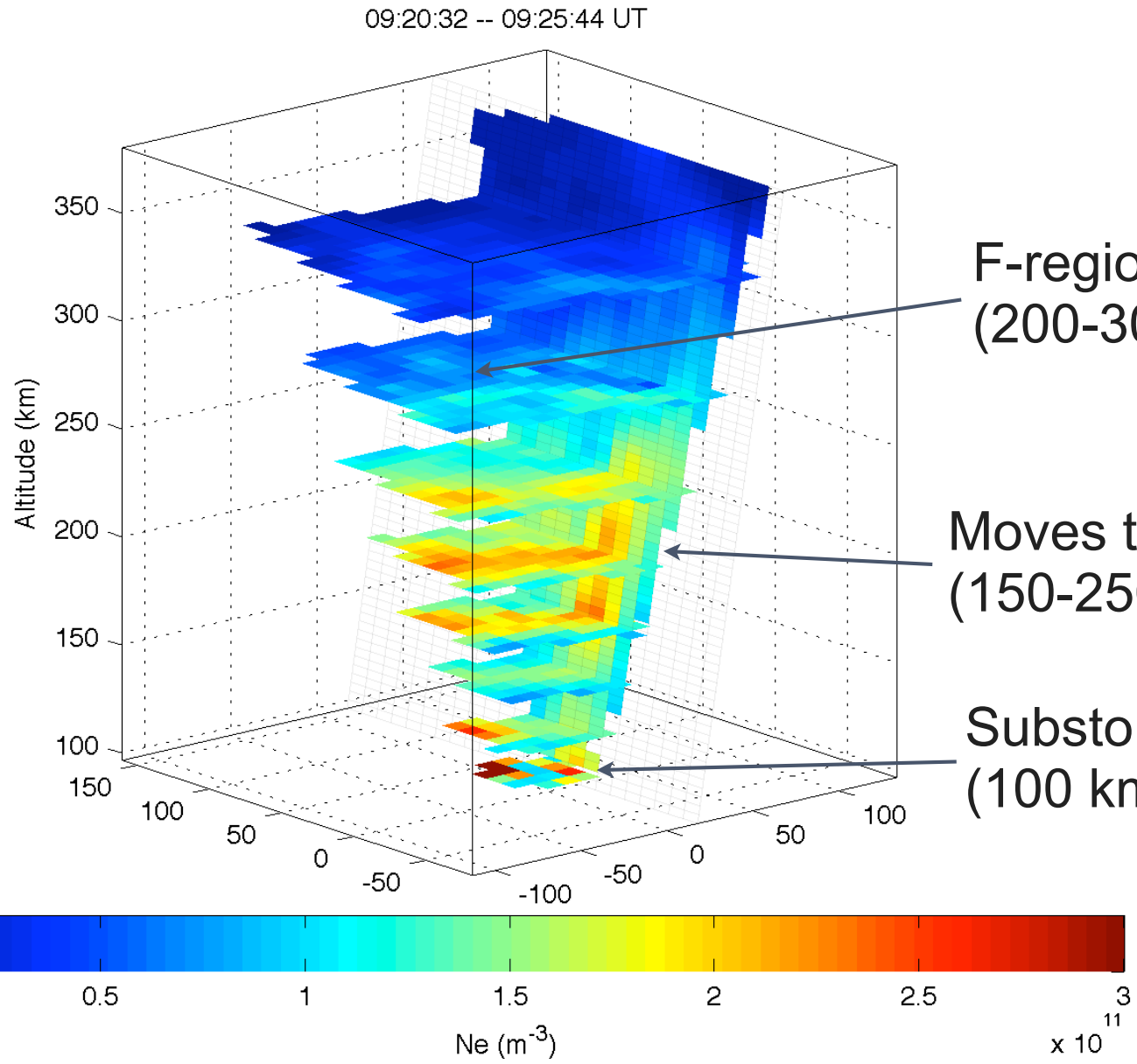
Volumetric view



F-region production
(200-300 km, t-20min)

Moves to lower altitude
(150-250km, t-5min)

Volumetric view

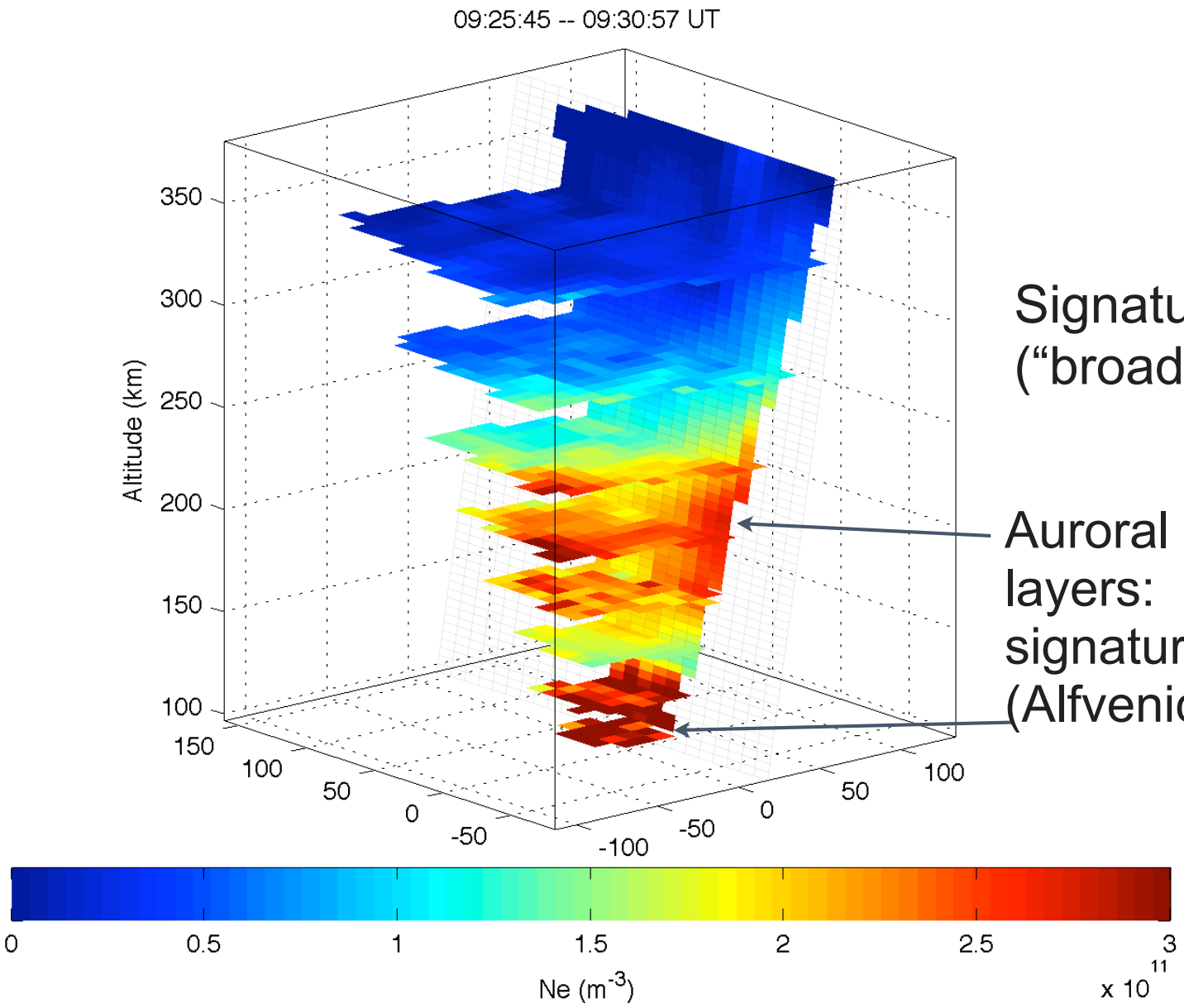


F-region production
(200-300 km, t-20min)

Moves to lower altitude
(150-250km, t-5min)

Substorm onset
(100 km)

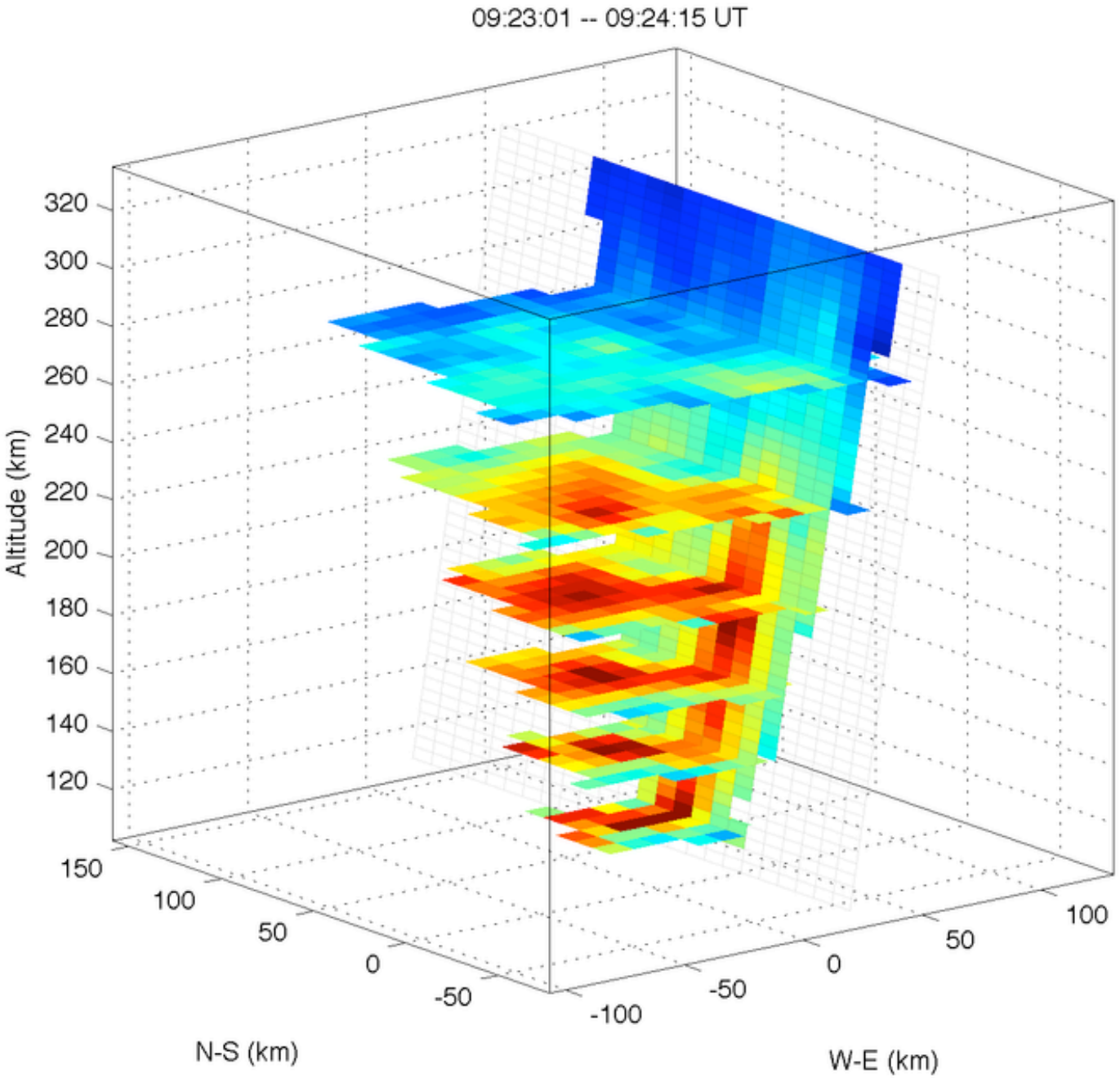
Volumetric view



Signature of Alfvenic ("broad band") precipitation

Auroral ionization in two layers:
signature of broad (Alfvenic) energy distribution

“Growth phase” arcs



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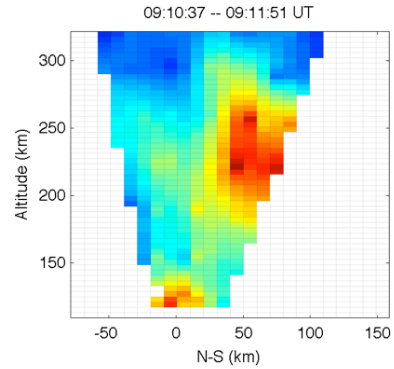
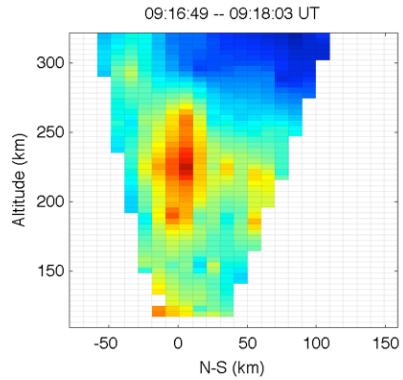


09:16:49



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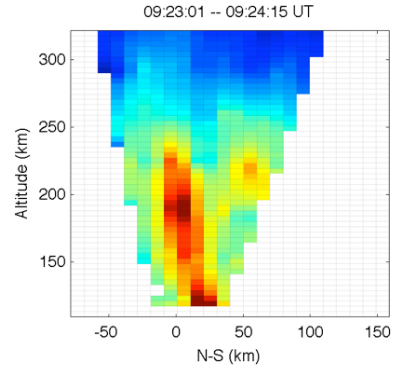
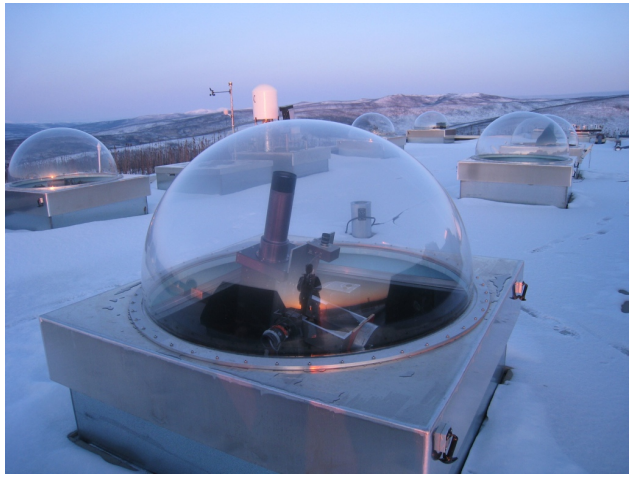
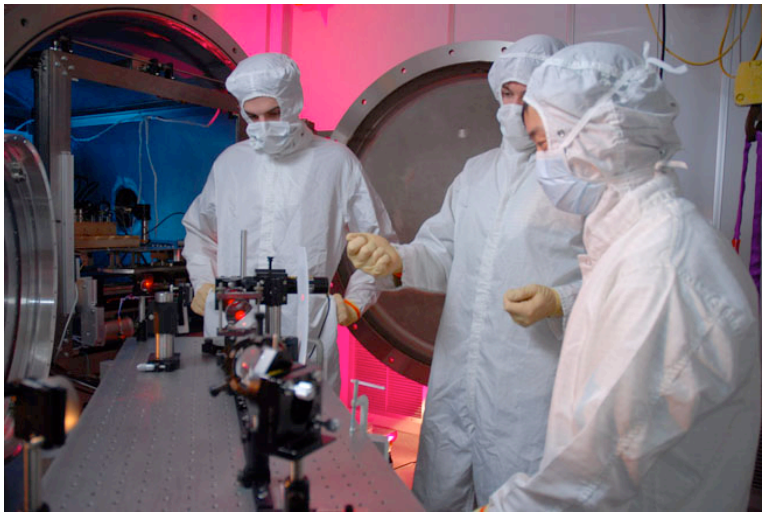


Semeter et al., JGR 2012, in review

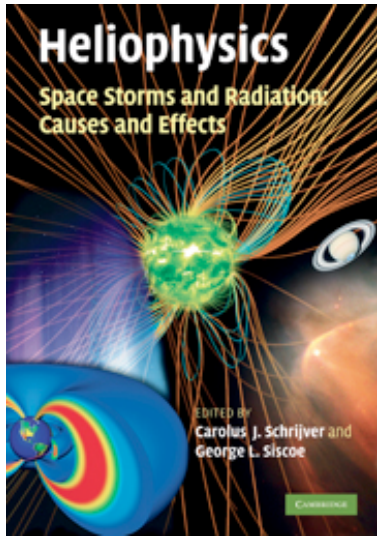
Current CSP Activities



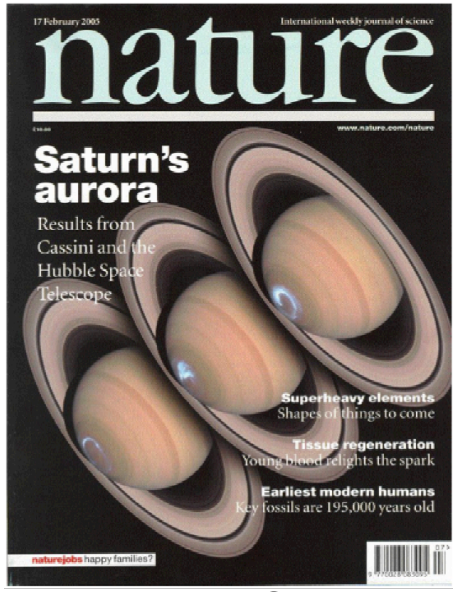
Optical aeronomy



Space hardware

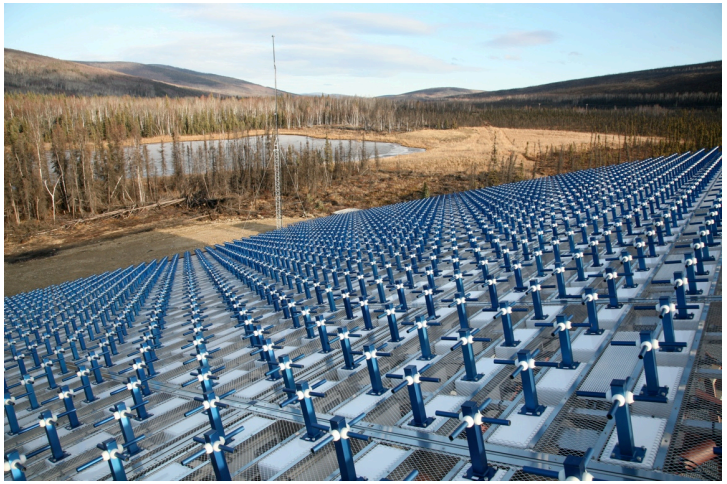


Heliophysics



Planetary Science

Plasma simulation



Radio Science

Plasma Simulation

Particle-in-cell (PIC):

$$\frac{d\,\mathbf{v}_i}{d\,t} = \frac{q_i}{m_i}(\mathbf{E}(\mathbf{x}_i) + \mathbf{v}_i \times \mathbf{B}(\mathbf{x}_i))$$

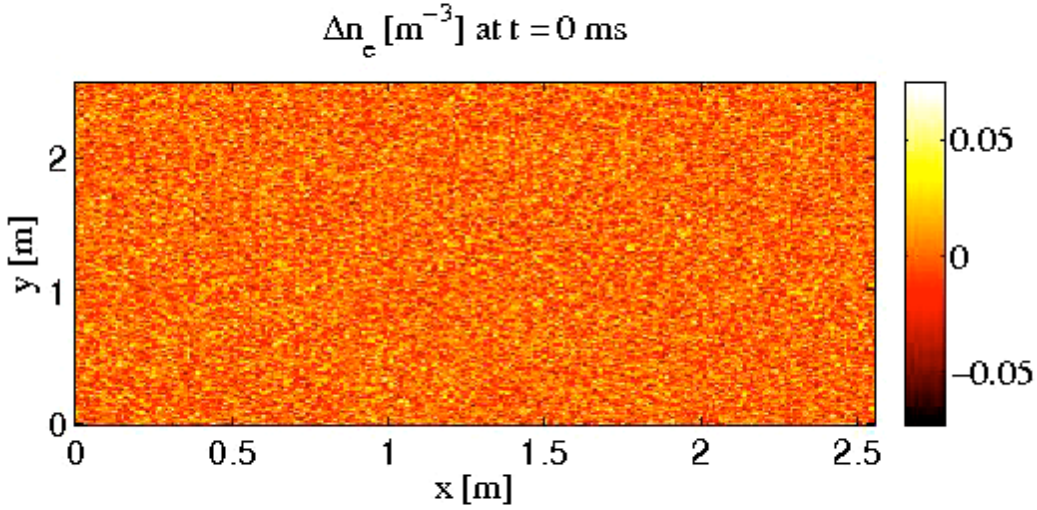
$$\nabla \times \mathbf{E} = \frac{-\partial \mathbf{B}}{\partial t}$$

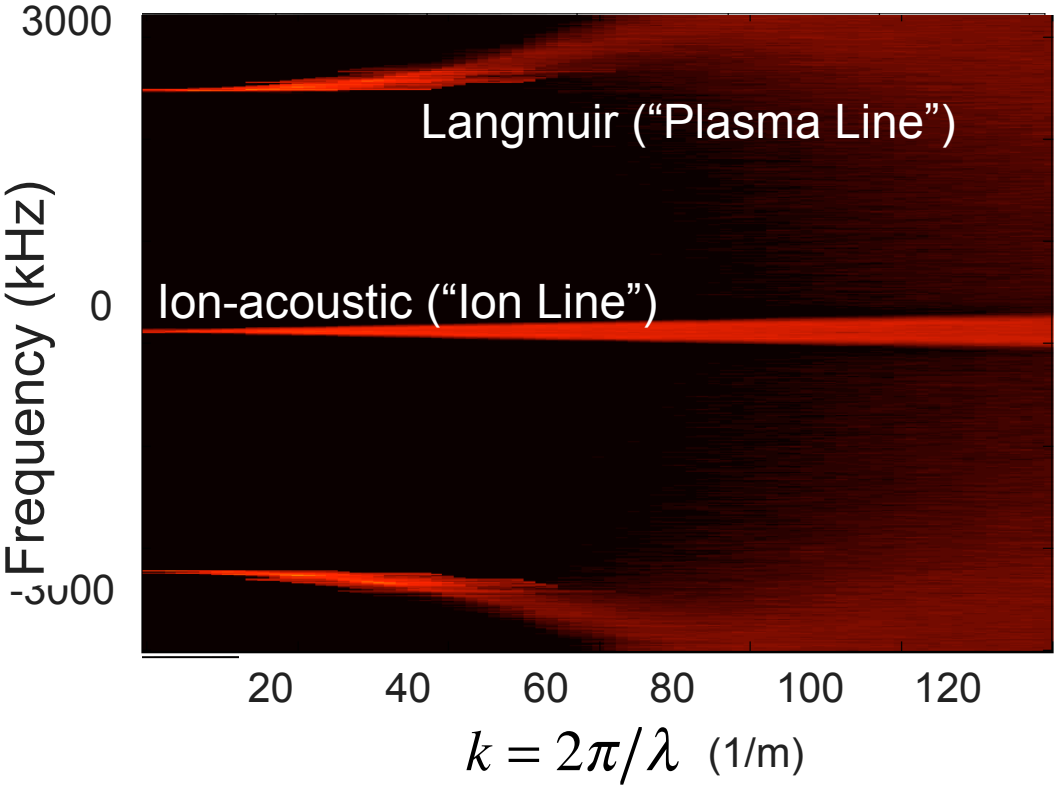
$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

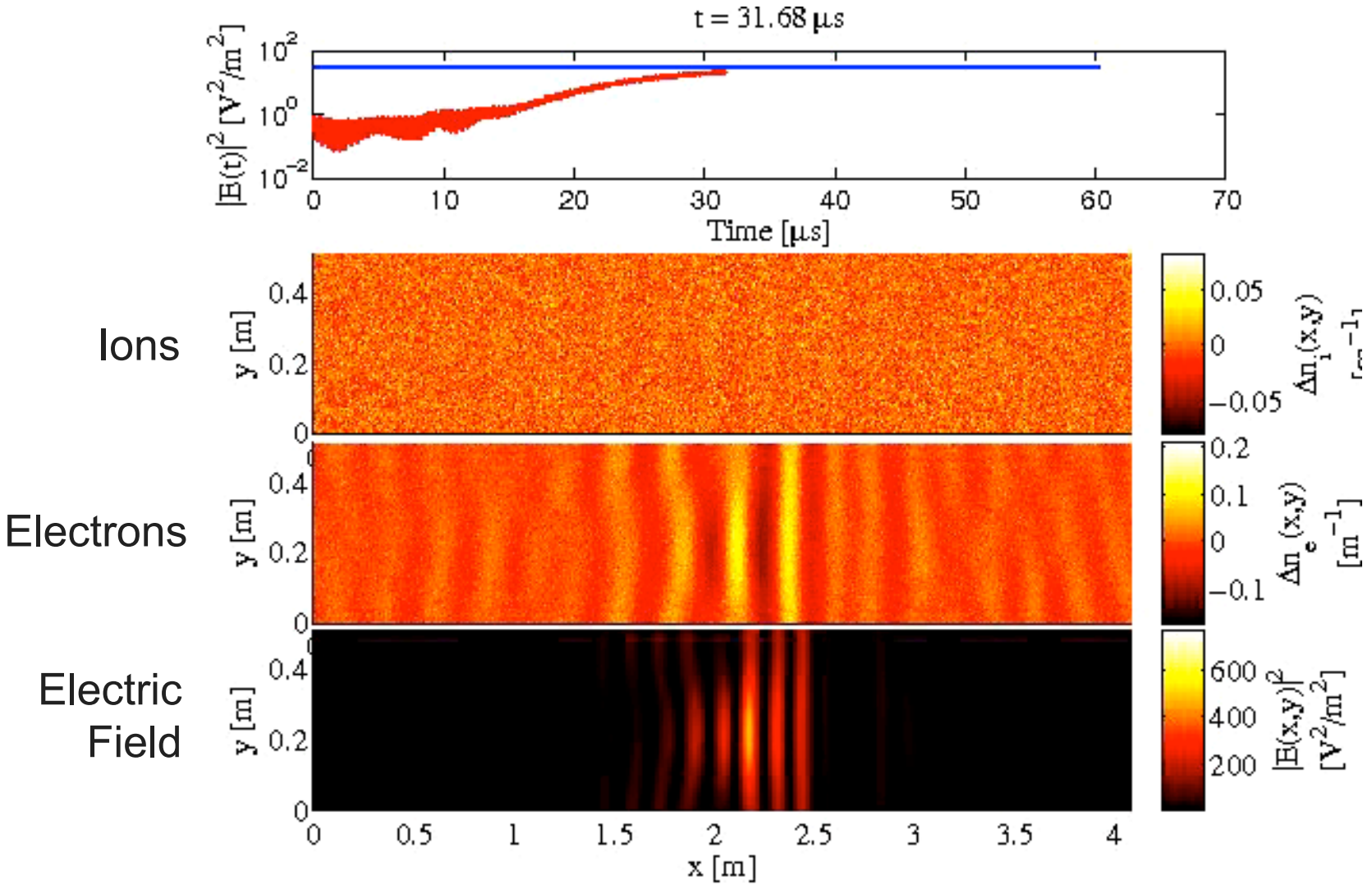
$$\nabla \cdot \mathbf{B} = 0$$

Simple rules yield complex behavior





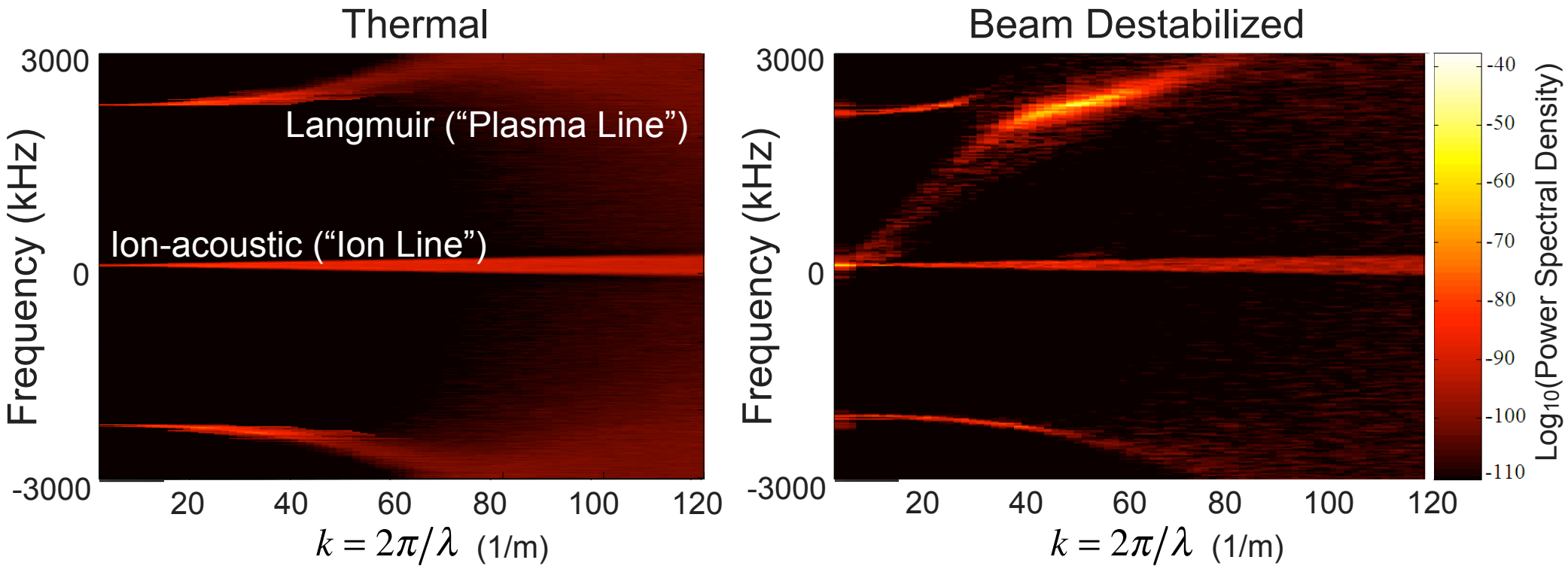
Plasma Simulation



Once threshold electric field is achieved (blued line in top panel), parametric decay to ion acoustic mode occurs

Diaz et al., Ann. Geophys. 2011

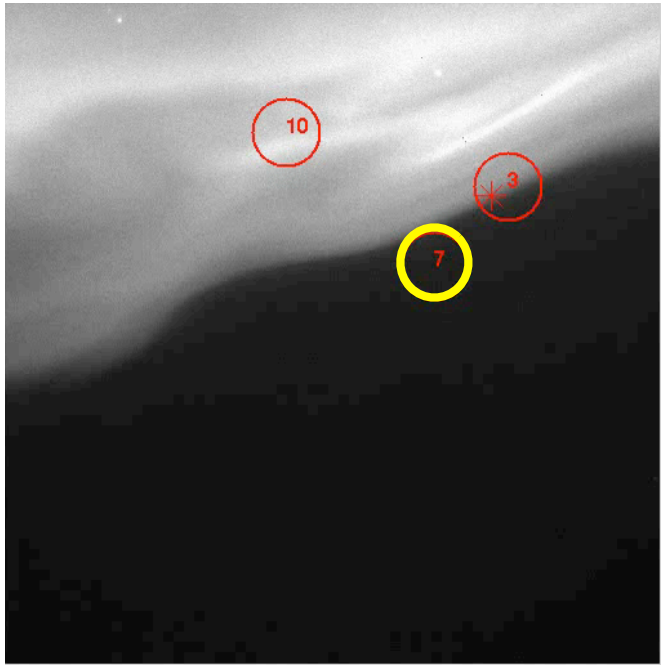
Beam destabilized plasma



Parametric decay of Langmuir waves produces enhancement in ion-acoustic waves

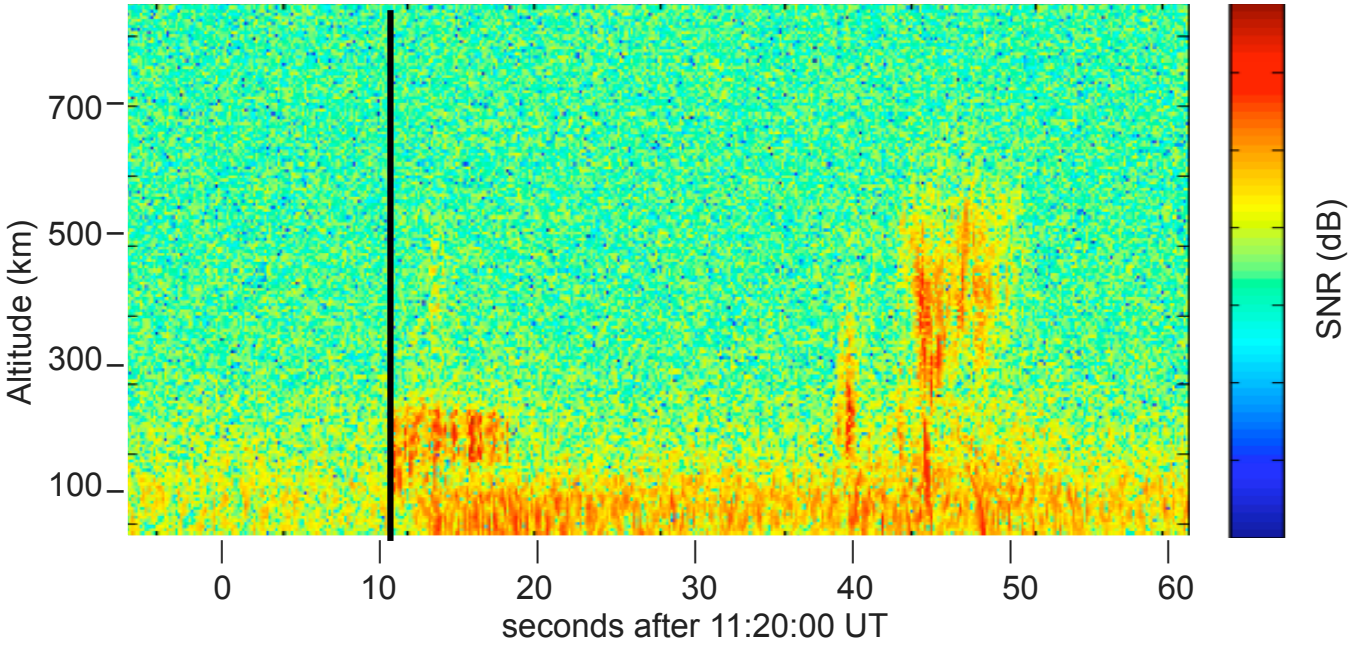
Diaz et al., JGRA 2011

PFISR non-thermal echoes at onset



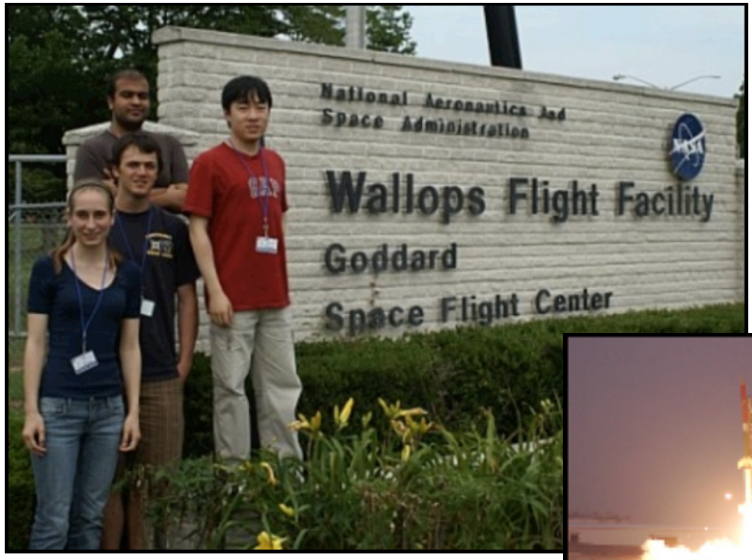
11° x 11°
field-of view

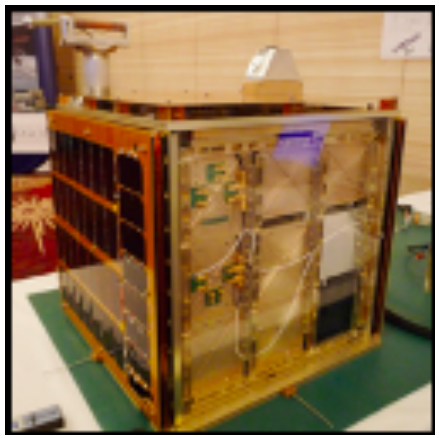
21 x 21 km



Semeter et al., JGR 2009, Akbari et al., GRL 2012

Undergraduate Education





Over 70 undergraduates in ECE, ME, and AS have been involved in the small satellite project BUSAT led by Professor Ted Fritz.

Several undergraduates have also worked on the RockSat sounding rocket project.

The interest from undergraduates in space science and space technology has led to the introduction of a new junior ECE elective on "Sensors in Space" which will be offered by Fritz for the first time in Spring 2011.