Magnetosphere-Ionosphere Observatory

(MIO)... *Discerning What Drives Auroral Arcs*

✓ **Get inside the aurora in the magnetosphere**
✓ **Know you're inside the aurora**
✓ **Measure critical gradients**

Fundamental Question Addressed

How is energy tapped from the magnetosphere to power auroral arcs in the ionosphere?

Importance of the Question

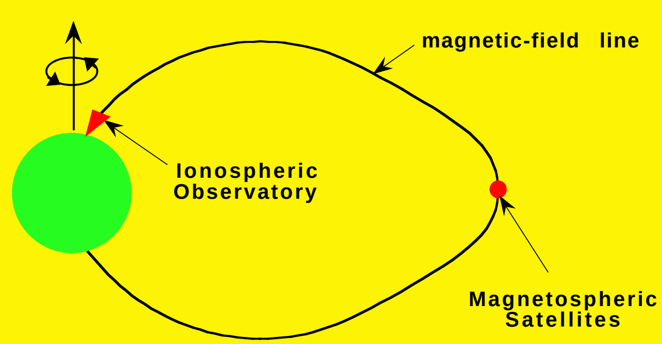
The magnetosphere loses a substantial amount of energy to the ionosphere via small-scale auroral structures. This energy loss feeds back on magnetospheric dynamics. There are many theories for the generator mechanism of auroral arcs, but none are confirmed owing to a lack of observations in the magnetosphere.

Auroral arcs are the site of important processes:

- energy extraction from the magnetosphere
- enhanced ionization in the ionosphere
- enhanced electrical current
- field-aligned electric fields
- particle acceleration
- kinetic Alfven-wave propagation
- magnetosphere-ionosphere flow decoupling

No comprehensive model of the auroral arc can be built without first knowing how the generator mechanism operates.

Geosynchronous Satellites Remain Magnetically Connected to the Ground-Based Observatory



4-satellite swarm
1 satellite carries electron gun to mark footpoint

Science Objectives

Fundamental objective:

♥ **What drives auroral arcs?**

Other objectives:

♥ Magnetosphere-ionosphere coupling
♥ The causes of other types of aurora
♥ Feedback of aurora on the magnetosphere
♥ Dynamics of magnetic-field-line mapping

Mission Description

- 4 satellites in geosynchronous-orbit equator
- Measure critical gradients in the magnetosphere
- 1 ground-based observatory to monitor aurora
- Electron gun to certify satellite-auroral conjugacy
- Geosynch to lock satellites to the observatory

Measurement Strategy

Geosynchronous satellites:

- Multi-point electric fields
- Multi-point ion distributions
- Multi-point electron distribution s
- Multi-point magnetic fields
- Single electron-beam generator
- Single plasma contactor
- Time resolution of 1 second

Ground Observatory:

- All-sky cameras
- Optical beam-spot locator
- Ionospheric radar

Technology Requirements

Utilize the technology developed by NASA's active-experiments program in which energetic electron beams were successfully generated in space.

EPO Themes

"Seeing the invisible", "magnetic fields", "coupled system", "orbits"

Web Site

http://www.lanl.gov/csse/MIO.html

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Magnetosphere-Ionosphere Observatory (MIO)

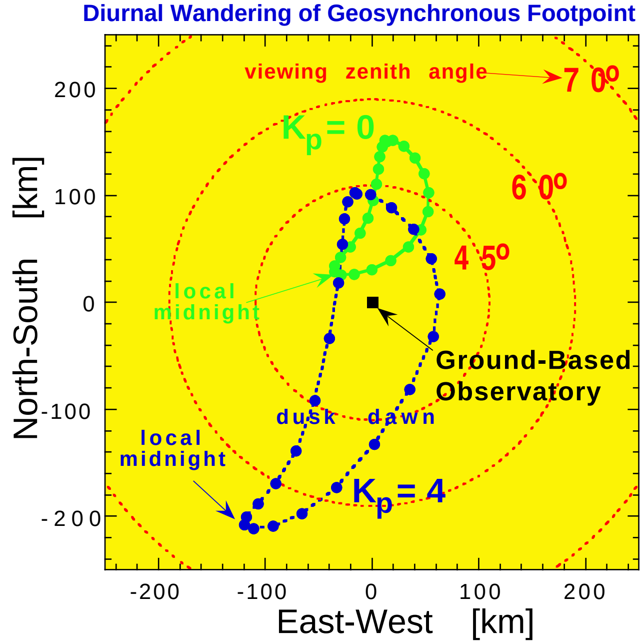
Auroral arcs are important links in the SEC chain of influence from the sun, to the magnetosphere, to the thermosphere. Energy of some form or another is tapped from the magnetosphere by means of auroral arcs. This significant energy loss undoubtedly has feedback consequences for magnetospheric evolution and dynamics, but without knowing how the energy is tapped, we cannot know the consequences. **Auroral arcs are there for a reason, but we don't know why.** There are many theories for the mechanism that taps energy from the magnetosphere to generate auroral arcs, but owing to a lack of observations of the generator region in the magnetosphere, none are confirmed.

Satellites undoubtedly have flown through the magnetospheric end of the aurora, but owing to uncertainties in the magnetic-field-line connectivity between the magnetosphere and ionosphere, one cannot discern when this has occurred. To be able to use satellite measurements to study how the aurora is driven by the magnetosphere, a way must be developed to determine whether or not a satellite is on magnetic-field lines that connect to the aurora in the atmosphere. The only feasible way to determine this is to mount an electron gun on one magnetospheric satellite and fire the gun into the loss cone to illuminate the magnetic footpoint of the satellite in the upper atmosphere and then locate the illumination either optically or via radar and check the location relative to images of the aurora. Both optical and radar spotting of such electron-beam footpoints have been confirmed experimentally.

For times when conjugacy with an auroral arc is established, the multi-satellite data will be examined to obtain measurements of critical gradients across the arc. For some of the theoretical mechanisms for auroral-arc generation that appear in the literature, the critical gradients to measure are given in the table below. Each mechanism also has a unique feedback consequence for the magnetosphere. Satellite separations of about 100 km are needed, with time resolutions of about 1 second.

Generator Mechanism	*Unique Observable*
Velocity Shear	Abrupt velocity shift across arc
Ion Pressure Gradient	Ion-temperature jump across arc
Electron Pressure Gradient	Electron-temperature jump across arc
Resonance Absorption	AC Poynting flux changes across arc
Particle Anisotropies	Pitch-angle distributions change across arc
Ionospheric- Feedback	Distinct flow directions relative to arc drift
Ion Streams	Field-aligned ions within arc
Electrostatic Turbulence	Fluctuating E-fields and flows around arc
Conductivity Channel Flow	Deflection of radial flow across arc

Diurnal Wandering of Geosynchronous Footpoint



Using MIO, the magnetospheric causes of other types of aurora will also be straightforward to ascertain. These include diffuse, pulsating, proton, and black aurora, and auroral patches.

As the figure above indicates, the satellite footpoints always will be in view of a single ground observatory. Geosynchronous orbit has the strong advantage that the satellites and the ground observatory will stay linked together 24 hours a day. This simplifies locating the beam spot and will result in full-time magnetosphere-ionosphere conjunction data. Geosynchronous footpoints in the Fairbanks or the Northern-Scandinavia regions would be advantageous because these locations are already well instrumented. Also, geosynchronous satellites reside in the auroral structures for long periods of time.

MIO is a mission high on quantitative magnetospheric and ionospheric science that will bring to closure the important question: **What drives auroral arcs?**

—Joe Borovsky, Dave McComas, Steve Mende, Tom Moore, Craig Pollock, Michelle Thomsen