

# The Aurora



# OUTLINE

- HISTORY
- CAUSES
- AURORA SPECTRUM
- AURORAL OVAL
- AURORA OCCURRENCE
- AURORAL SUBSTORM
- PROTON AURORA
- EXPERIMENTS
- AURORA ON  
OTHER PLANETS
- References



# HISTORY

- China ~ “Flying Dragons” (2000 aC)
- Bible  
(Antico Testamento, Ezechiele “Ed ecco un vento tempestoso avanzarsi dal Settentrione, una grande nube che splendeva tutt'intorno, un fuoco in cui guizzavano bagliori, e nel centro come lo splendore dell'eletto in mezzo al fuoco”)
- Ancient Greece (Senofane “Cumuli di nubi ardenti”)
- Halley ~ “Orientation of Auroral Curtains aligned with Earth’s Magnetic Field” (1716, Marzo)
- Loomise ~ “Auroral Ovals” (1859)

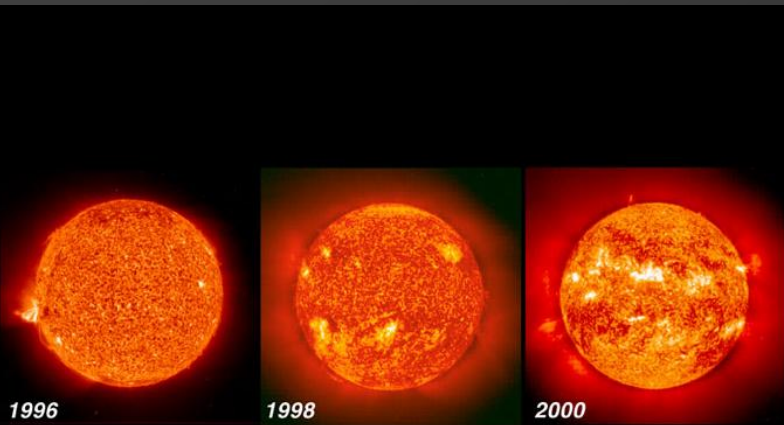
# HISTORY

- Becquerel ~ “Solar Particles” (1878)
- Birkeland ~ “Field Aligned Currents” (1902-3)
- Störmer ~ “Motion of Charged Particles in Earth’s Magnetic Field, Height of the Aurora” (1907)
- Vegard ~ “Proton Aurora” (1939)
- Anger ~ “First Global Space-Based Auroral Image (ISIS-2)” (inizio anni ‘70)

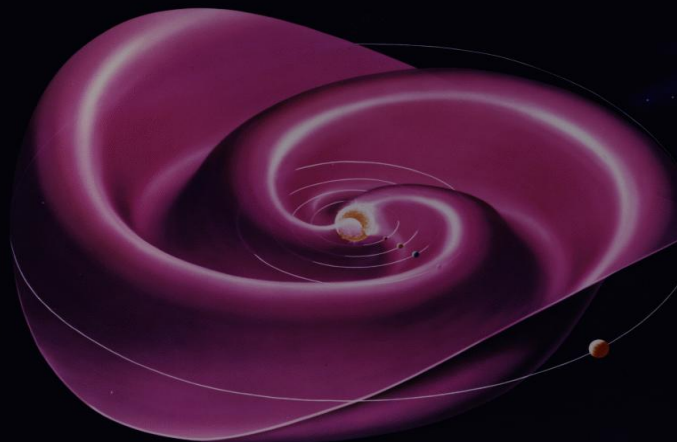
The launch of more advanced spacecraft (**Dynamics Explorer, Viking, Polar e Image**) made it possible to obtain the **global auroral distribution**

# SOLAR WIND

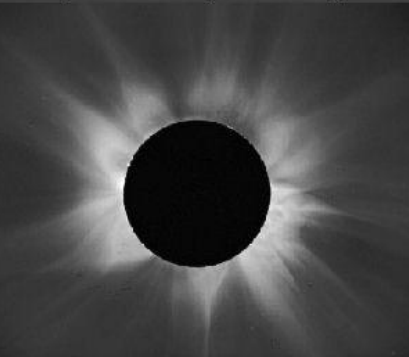
Flow of charged particles - *plasma* - streaming from the Sun's *corona* in *all directions*



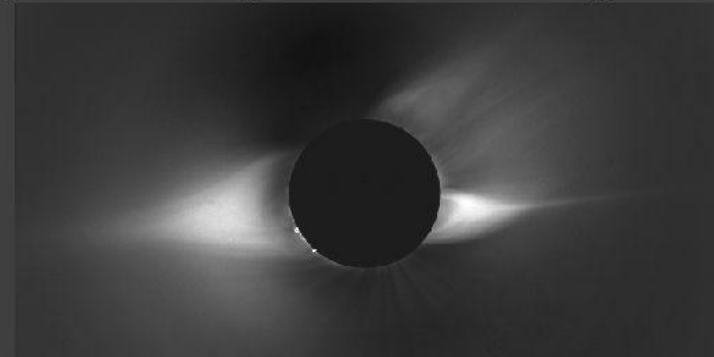
Parameter	Min	Av	Max
Flux ( $\text{cm}^{-2}\text{s}^{-1}$ )	1	3	100
Vel (km/s)	200	400	900
Density ( $\text{cm}^{-3}$ )	0.4	6.5	100
Helium %	0	5	25
B (nT)	0.2	6	80



Comparison of the Solar Corona at Solar Maximum and Minimum  
(White Light Eclipse Images from the High Altitude Observatory)



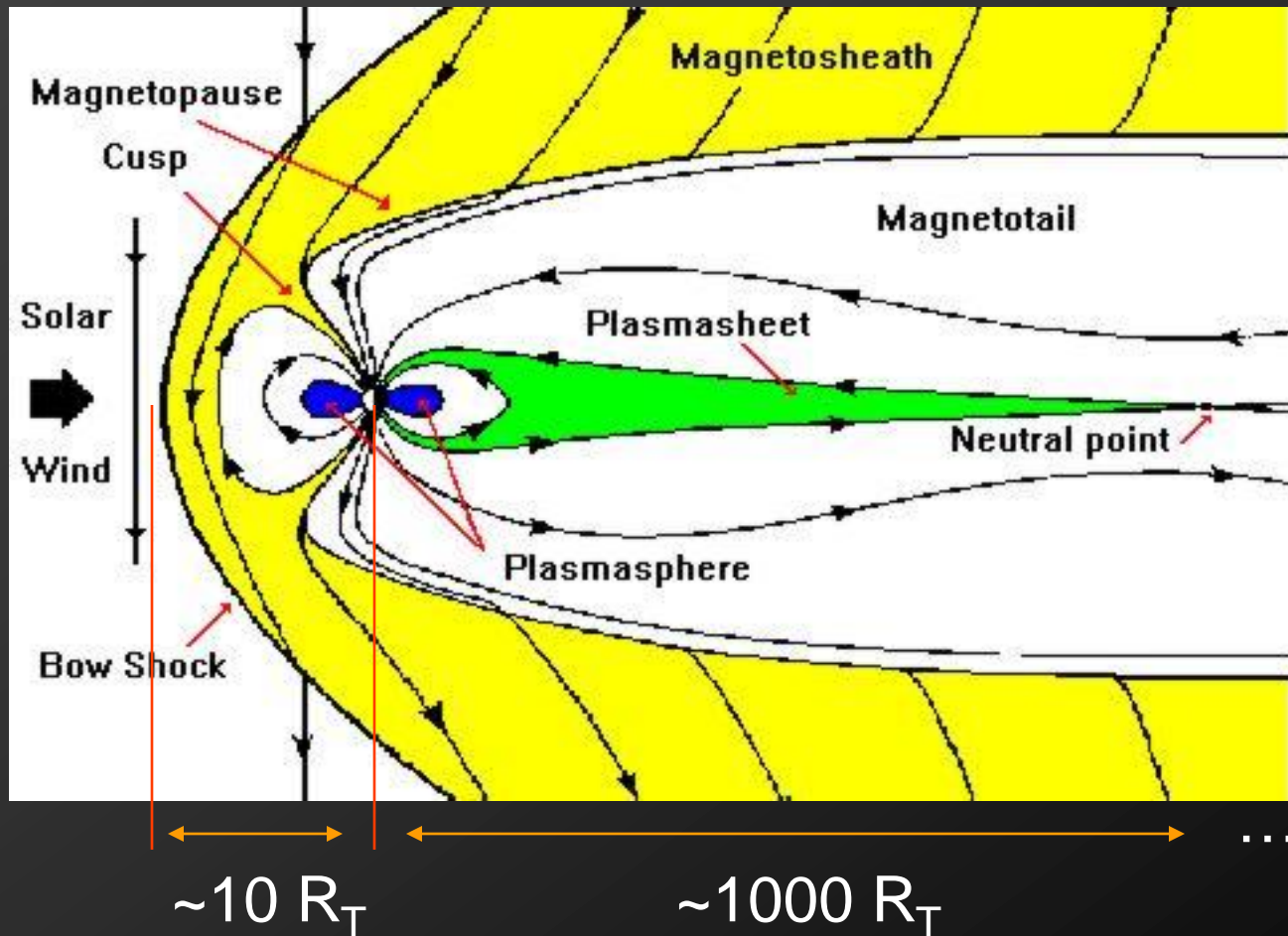
February 16, 1980 Solar Eclipse  
(Near Solar Maximum)



November 3, 1994 Solar Eclipse  
(Near Solar Minimum)

# MAGNETOSPHERE

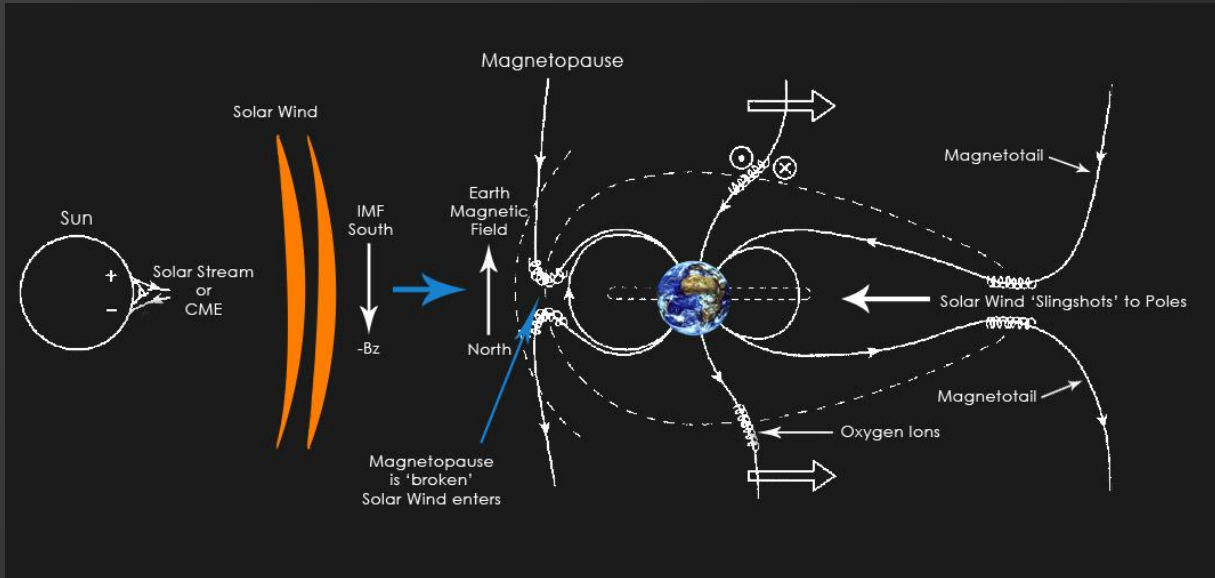
*Region surrounding a planet where the planet's magnetic field dominates*





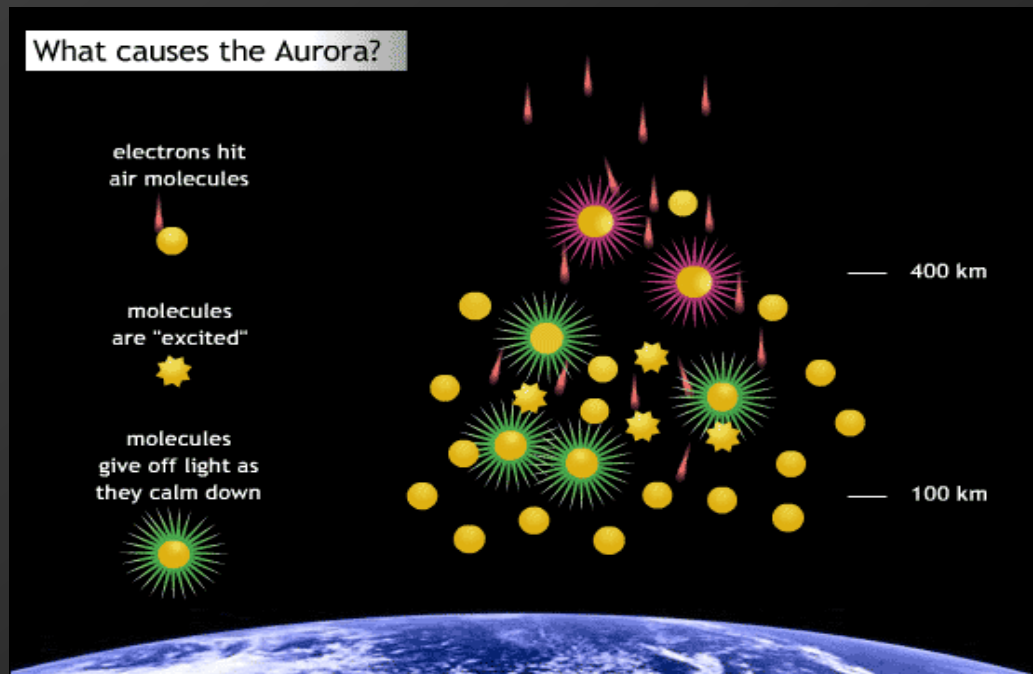
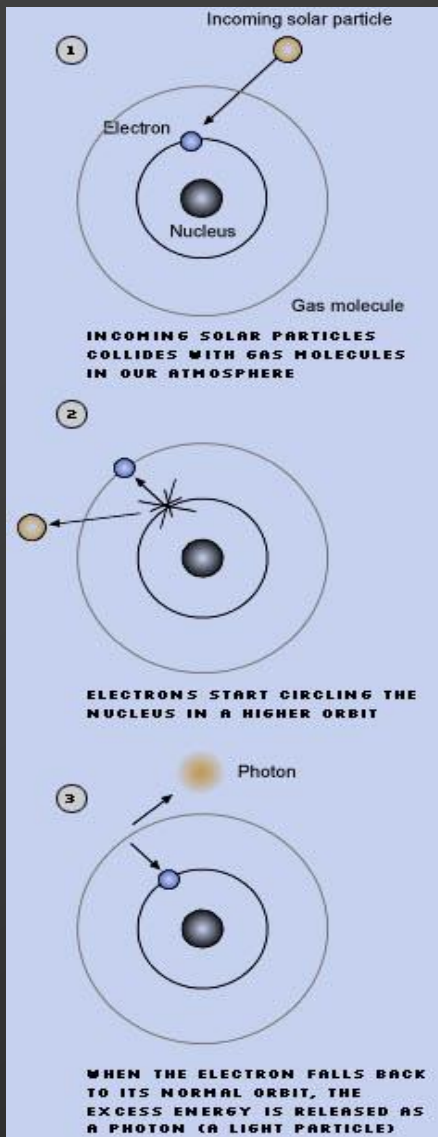
# WHAT CAUSES THE AURORA?

- The aurora is a visible manifestation of the *solar-terrestrial connection*



Solar wind particles, following the geomagnetic field lines, precipitate into the upper atmosphere where interact with atmospheric atoms

# WHAT CAUSES THE AURORA?



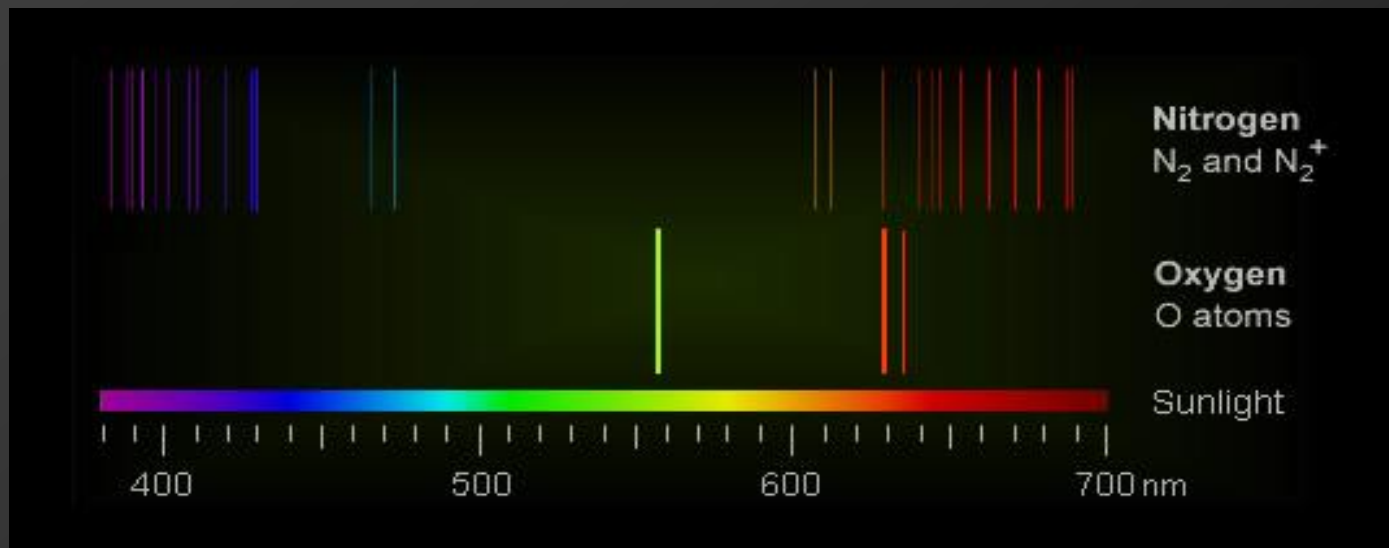
$$h\nu = \Delta E$$





# AURORA SPECTRUM

The aurora is a source of X-rays, UV, IR, radio and *optical radiation* → *electron interacts with neutral atoms or molecules which emits radiation due to disexcitation*



*Green colour* → atomic oxygen line at 557.7 nm, 100-200 Km altitude

*Red colour* → atomic oxygen spectral triplet at 630.0, 636.4, 639.1 nm, >200 Km altitude, protons

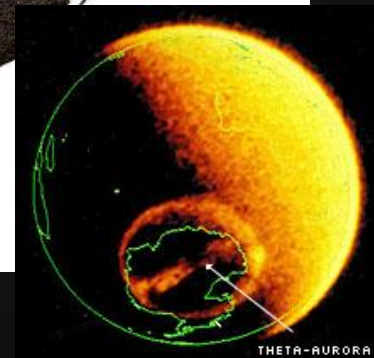
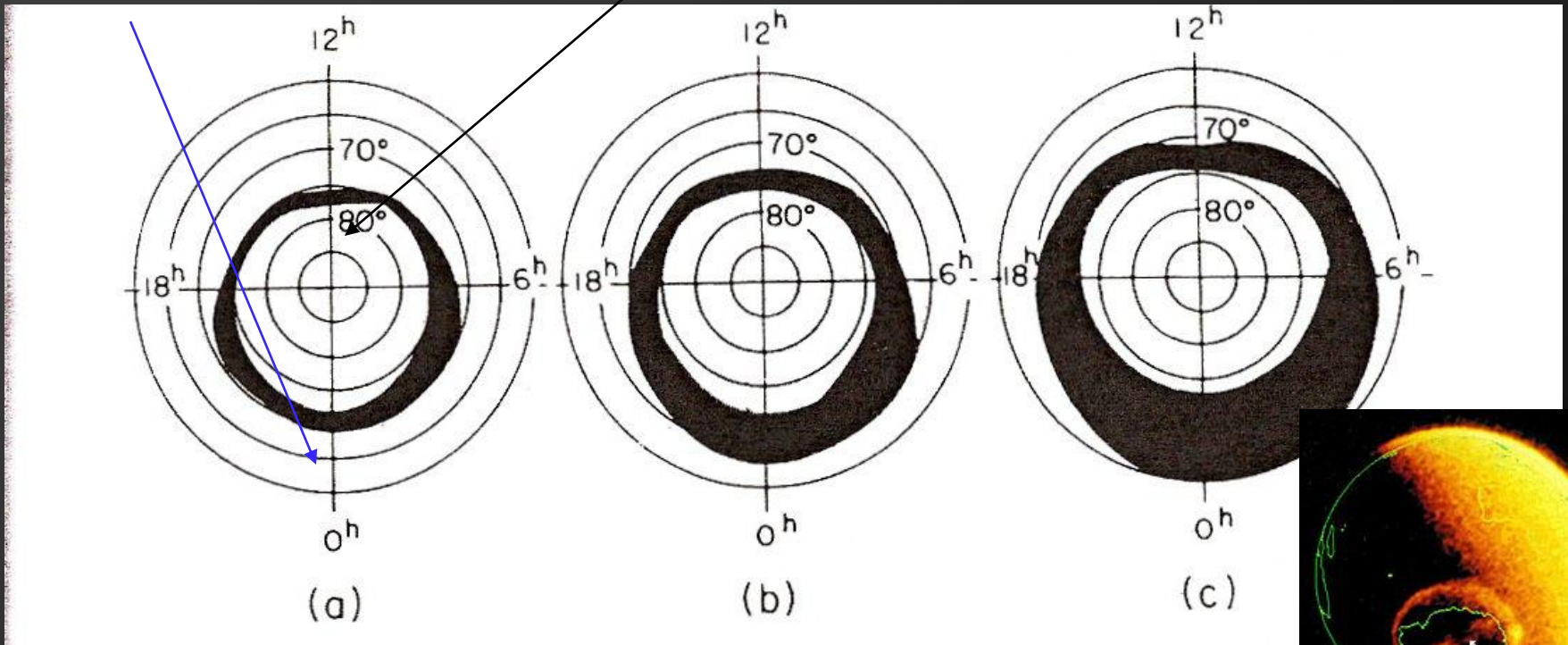
*Violet or Blue colour* → molecular nitrogen line at 391.4, 427.0, 470.0 nm, <100 km altitude

# AURORAL OVAL

Seen from space, northern and southern lights appear as oval shaped circle with the magnetic pole in the centre

Stretched out untisunward  
~67° geomagnetic latitude

Compressed sunward  
~78° geomagnetic latitude

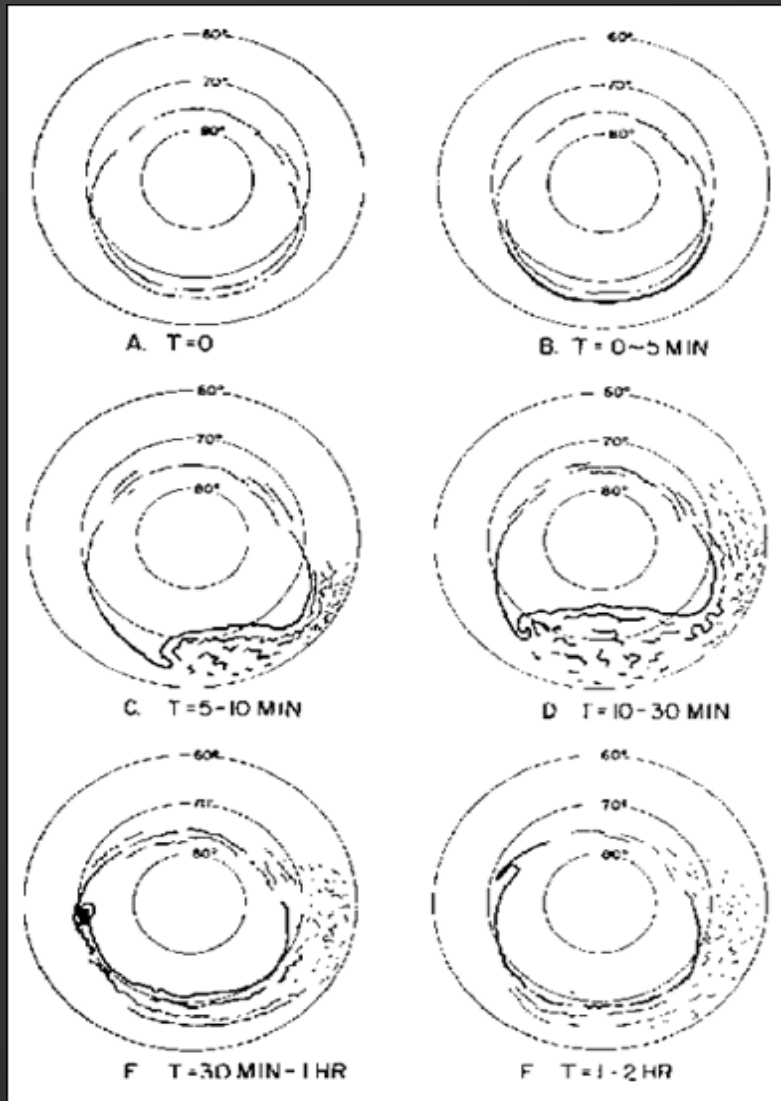


# AURORA OCCURRENCE

Within the auroral zone, the aurora can be seen every clear winter night

- 27-day intervals
- more frequent in late autumn and early spring
- Northern lights activity corresponds closely to sunspot activity, which follows an 11-year cycle → *BUT* 1 year delay
- 20-30% less during solar minimum than at solar maximum

# THE AURORAL SUBSTORM

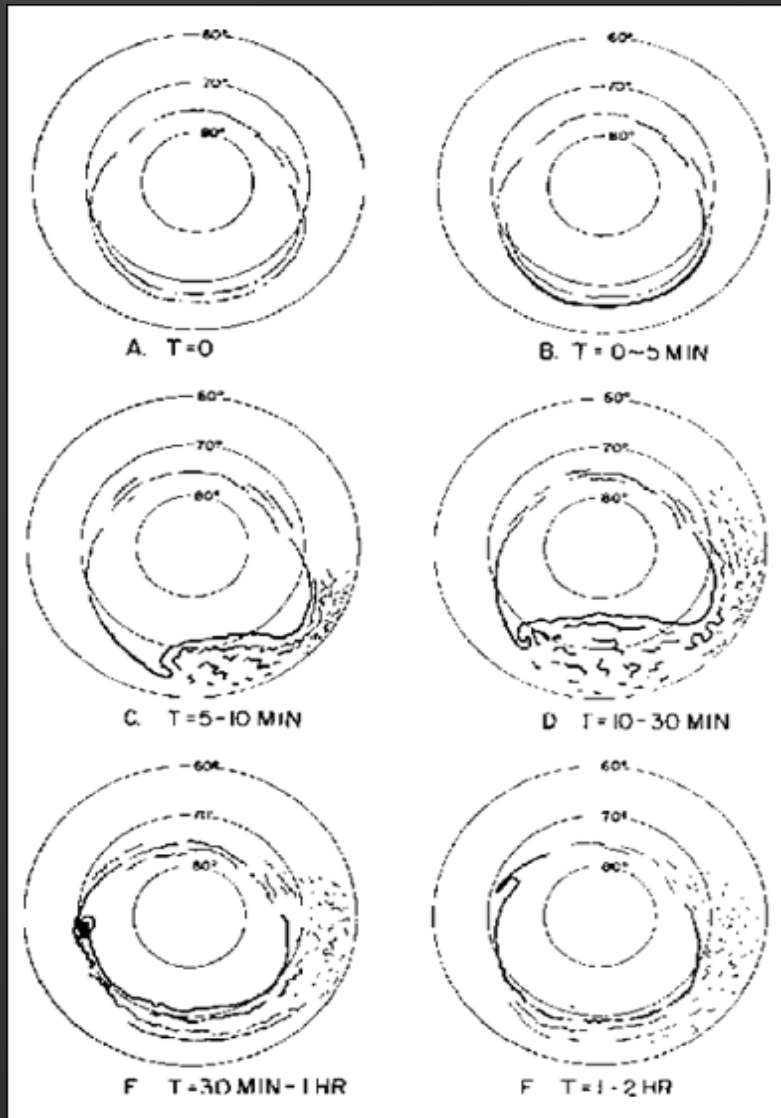


$T = 0 \text{ min} \rightarrow$  **Quiet phase:**  
weak arcs in the midnight  
regions at high geomagnetic  
latitude ( $\sim 75^\circ$ )

$T = 0\sim 5 \text{ min} \rightarrow$  **Onset phase:**  
southernmost arc brightens  
and moves southward

$T = 5\sim 10 \text{ min} \rightarrow$  **Expansion  
phase:** the bright arc forms a  
bulge which expands northward  
and moves westward at high  
speed

# THE AURORAL SUBSTORM



**T = 10-30 min → Expansion phase maximum:**  
the bulge expands westward and northward, irregular pulsating aurora on the morning side

**T = 30~60 min → Recovery phase:** weak arcs start to contract toward the north. Pulsating aurora at lower latitudes in the morning side

**T = 1~2 hrs → Recovery phase:** the situation retreats to the pre-onset condition



# AURORAL STRUCTURE

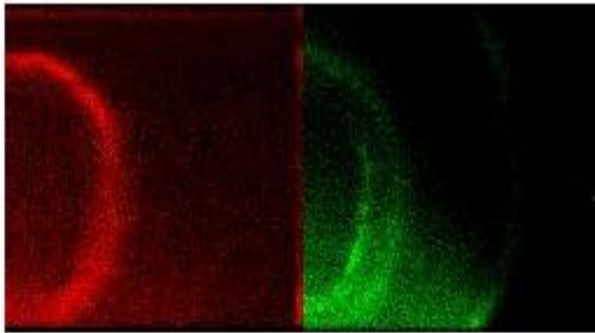


- *Arcs*: green, sometimes with red above and purple below, quiet phase
- *Bands or Arcs with Structure*: green, sometimes with red above and purple below, expansion phase
- *Corona*: Geometric perspective effect, expansion phase
- *Diffuse Glows*: greenish at high latitudes, red at lower latitudes, recovery phase, faint



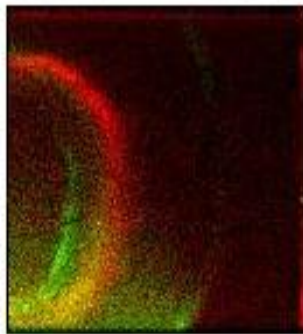
# PROTON AURORA

*Electron and proton auroras are different and **develop differently** over time*



proton aurora

electron aurora



proton + electron  
aurora

- equally bright but *less structured*
- Protons quickly become *neutralized* as they combine with electrons
- very important at the *start* of the substorm

# EXPERIMENTS - IMAGE

## *Imager for Magnetopause-to-Aurora Global Exploration*

Launch: 25 March 2000

Mission end: Dec 2005

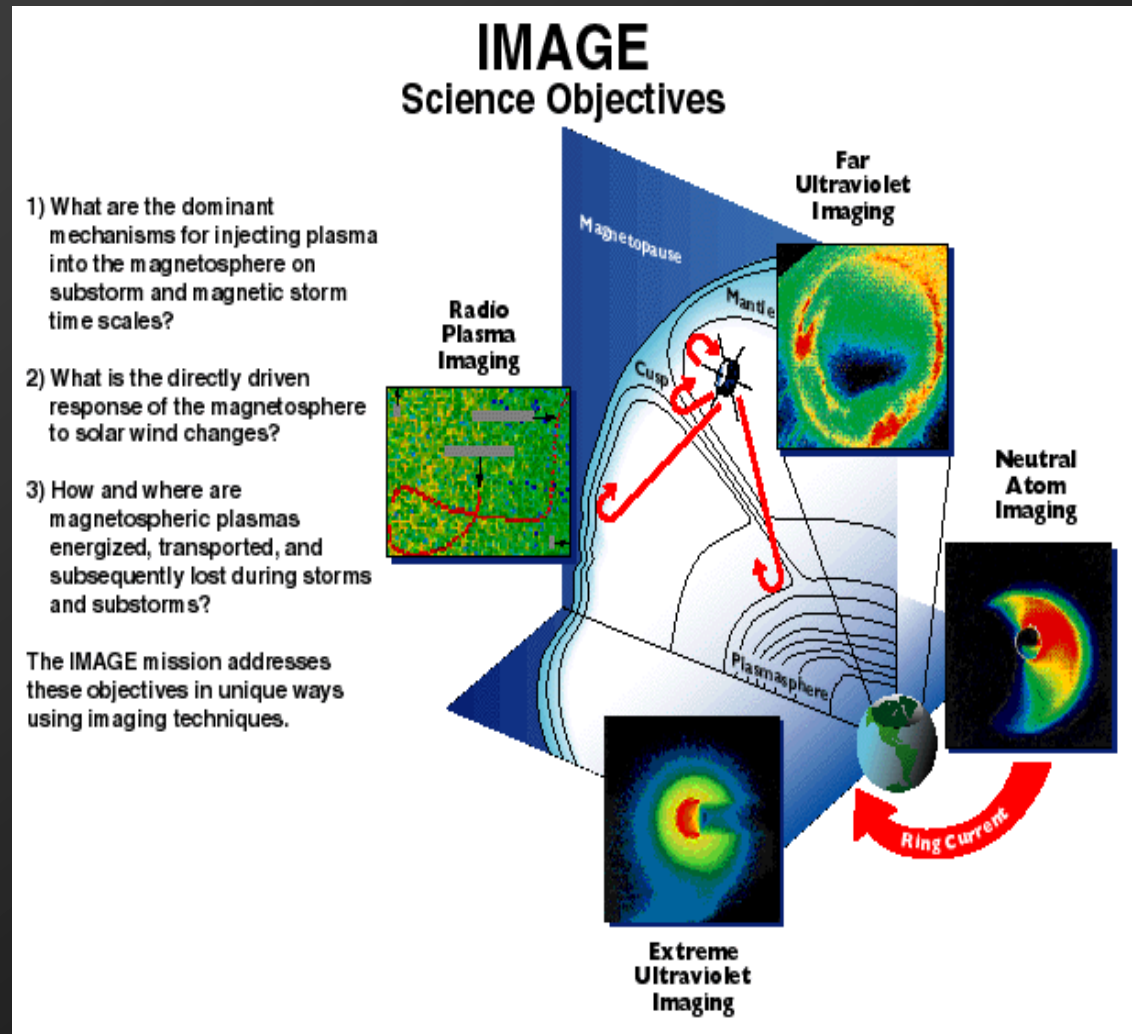
Elliptical polar orbit:

Apogee =  $7.2 R_T$

Perigee = 1000 Km

$i = 90^\circ$

*IMAGE was the first satellite mission dedicated to imaging the Earth's magnetosphere*



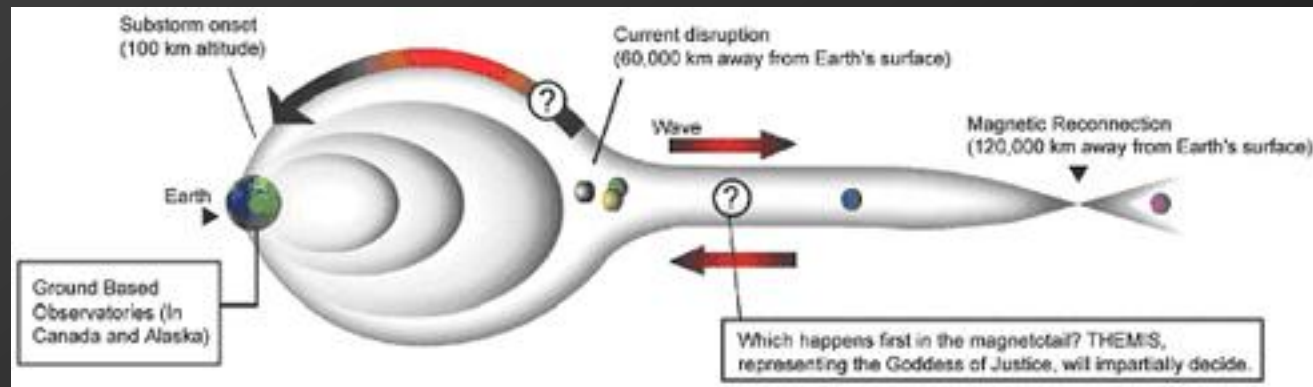
# EXPERIMENTS - THEMIS

*Time History of Events and Macroscale Interactions during Substorms*

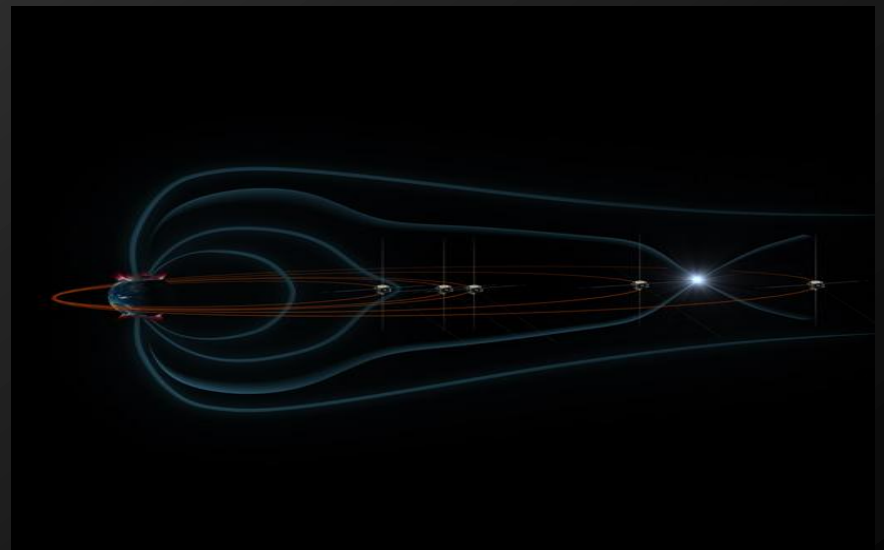
Launch Date: Feb. 17, 2007

2-year mission

5 identical probes



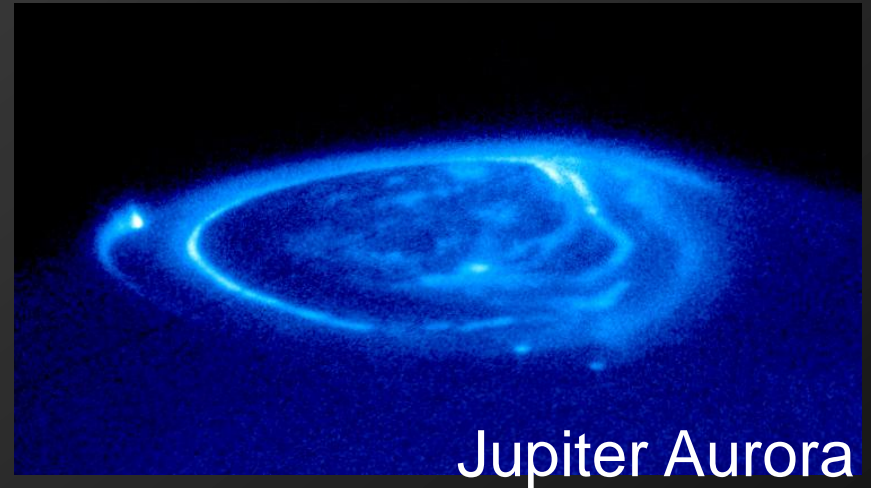
*Determine what physical process in near-Earth space initiates the violent eruptions of the aurora that occur during substorms*



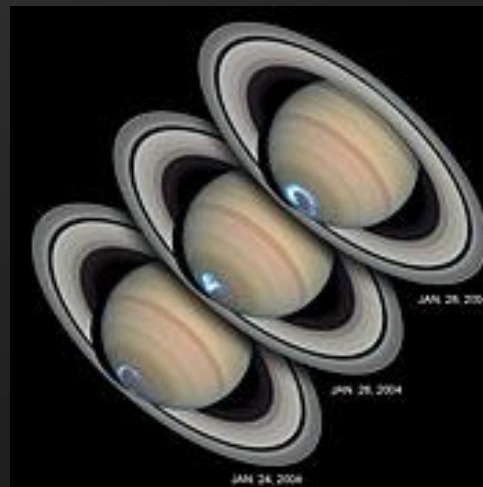
# AURORA ON OTHER PLANETS

Aurora can occur on every planet or moon with a *magnetic field* and an *atmosphere*

The *process* of generating auroras is the *same* throughout the whole solar system even if the *configuration*, the *colours* and particularly the *rapidly-varying* displays, are *different* from what we see on earth



Jupiter Aurora



Saturn Aurora



Aurora on Saturn  
Credits: Hubble Space Telescope

# REFERENCES

- **BOOKS**

*Handbook of the Solar-Terrestrial Environment*, Y. Kamide & A.Chian Editors, Springer

*Physics of the Upper Polar Atmosphere*, Asgeir Brekke,  
WILEY

- **LINKS**

[http://www.esa-spaceweather.net/spweather/BACKGROUND/PHYS\\_PROC/physics.html](http://www.esa-spaceweather.net/spweather/BACKGROUND/PHYS_PROC/physics.html)

<http://128.39.102.187/english/what/cause.shtml>

<http://www.spaceweathercenter.org/>

<http://image.gsfc.nasa.gov>

[http://www.nasa.gov/mission\\_pages/themis/multimedia/index.html](http://www.nasa.gov/mission_pages/themis/multimedia/index.html)

<http://themis.ssl.berkeley.edu/overview.shtml>