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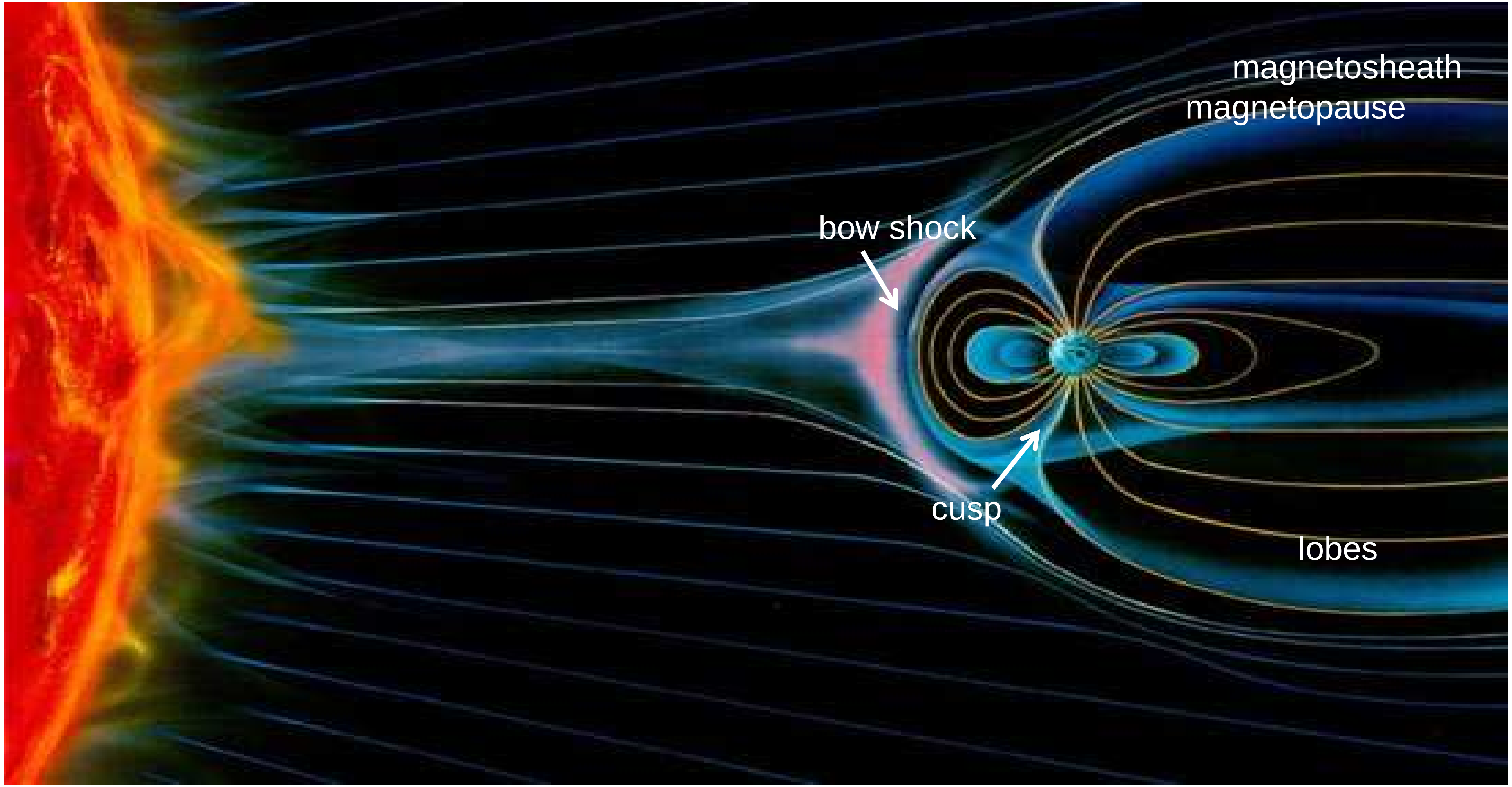
Aurora Borealis – northern light
Spectroscopy
Noctilucent clouds
Gamma bursts

Space Technology I

Vendela Paxal

Earth's protection: the magnetosphere



Picture from ESA, not to scale

Earth’s Magnethosphere

- Shape determined by:
  - Earth’s internal magnetic field
  - Solar winds (plasma)
  - Interplanetary magnetic field
  - Non spherical
- Contains free charged particles
  - From solar winds
  - From earth’s ionosphere
  - Confined by electric and magnetic forces stronger than gravity and collisions

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Magnetosphere shape

- Bounded by the Magnetopause
- Bullet shaped
- Varies with the intensity of the solar winds
- Day side: 10-12 R_E
- Night side: 15 R_E abreast, forms a ”cylinder” with radius 20-25 R_E. Tail region streches past 200 R_E

1R_E = Earth radii = 6370 km
Moon is at 60 R_E from Earth
GEO orbit is at about 7 R_E from Earth
Distances given from Earth centre

Earth magnetism

- Driven by rotation of the liquid metal (Fe) in the core of the Earth and electric currents in the Magnetosphere
- Dipole field
- Inclined by ~11° to the rotation axis
- Magnetism of about 30-60 μT at the Earth surface
- Magnetism is decreasing by $1/d^3$ at a distance *d* from the Earth
- Higher harmonics exist but diminish faster

Examples:

5 mT is the typical strength of a refrigirator magnet

3T is the strength of an MRI system.

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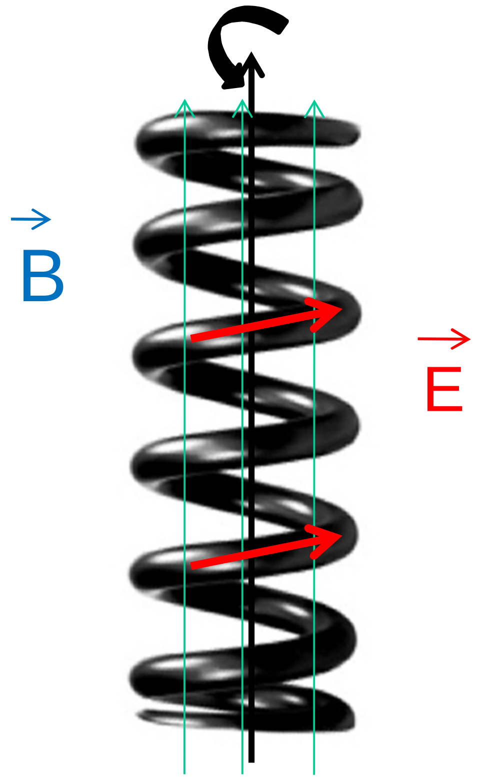
Magnetic field effect

An electrically leading material spinning in a magnetic field will induce electrical current. An electrical current in a coil, will induce a magnetic field.



Maxwell's equations:

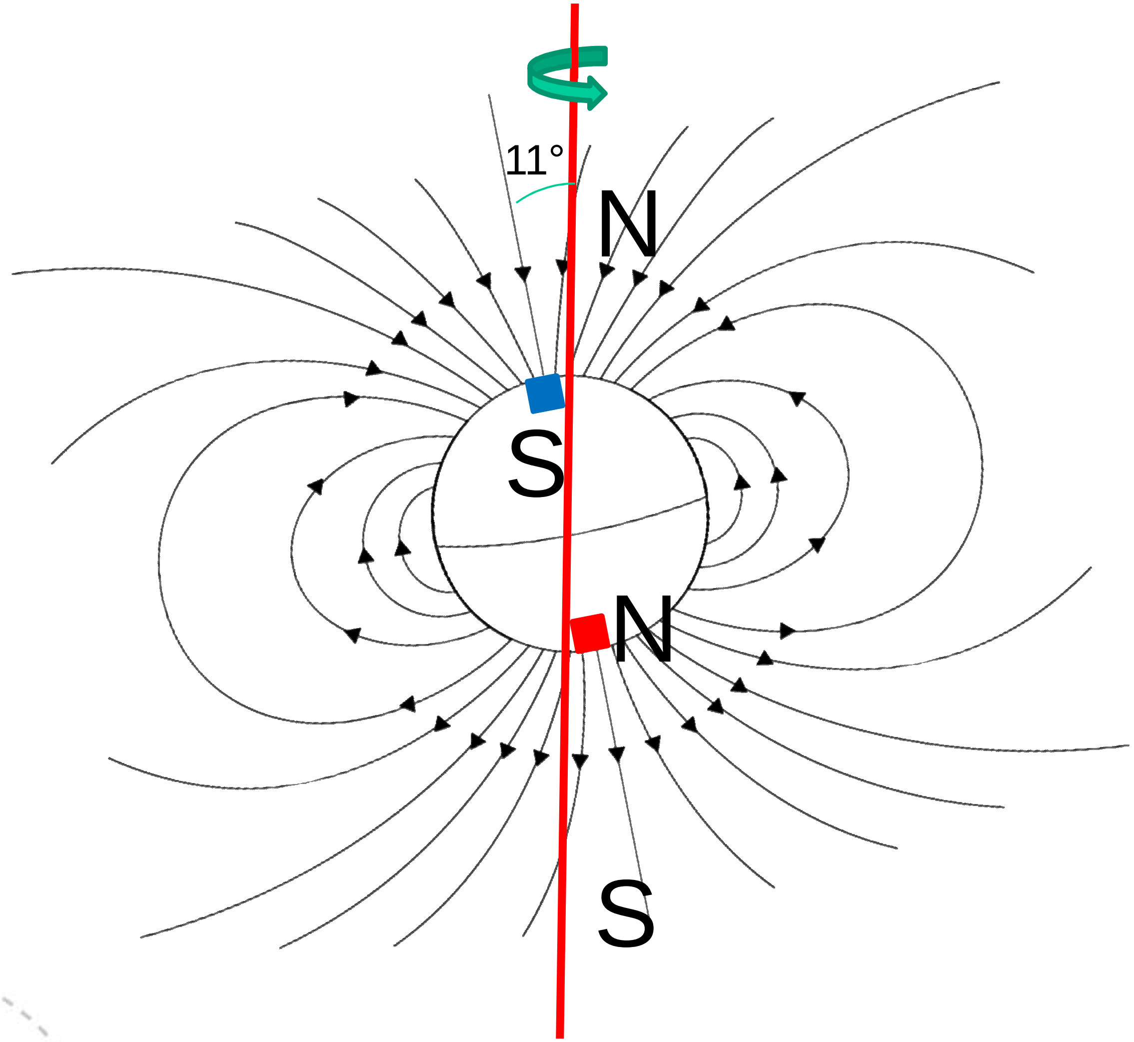
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

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

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

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

Earth = magnetic dipole



Magnetopause, Magnetotail, Magnetosheath

- Difficult for solar wind plasma to mix with terrestrial plasma, the boundary is the Magnetopause
- The magnetotail is formed by the pressure from the solar winds on the Magnetosphere
- A temporary weakening in the Magnetotail results in an injection of solar plasma into the inner Magnetosphere giving aurora and ring current
- Collision free bow shock forms in the solar wind ahead of the Earth. The region behind the shock is the Magnetosheath

Solar flares

- Several classes of solar flares depending on their peak flux.
- Occur mostly in or around sun spots
- The result of intense magnetic fields emerging from the Sun’s surface into the corona
- Can take several days to build up, but only minutes to release.

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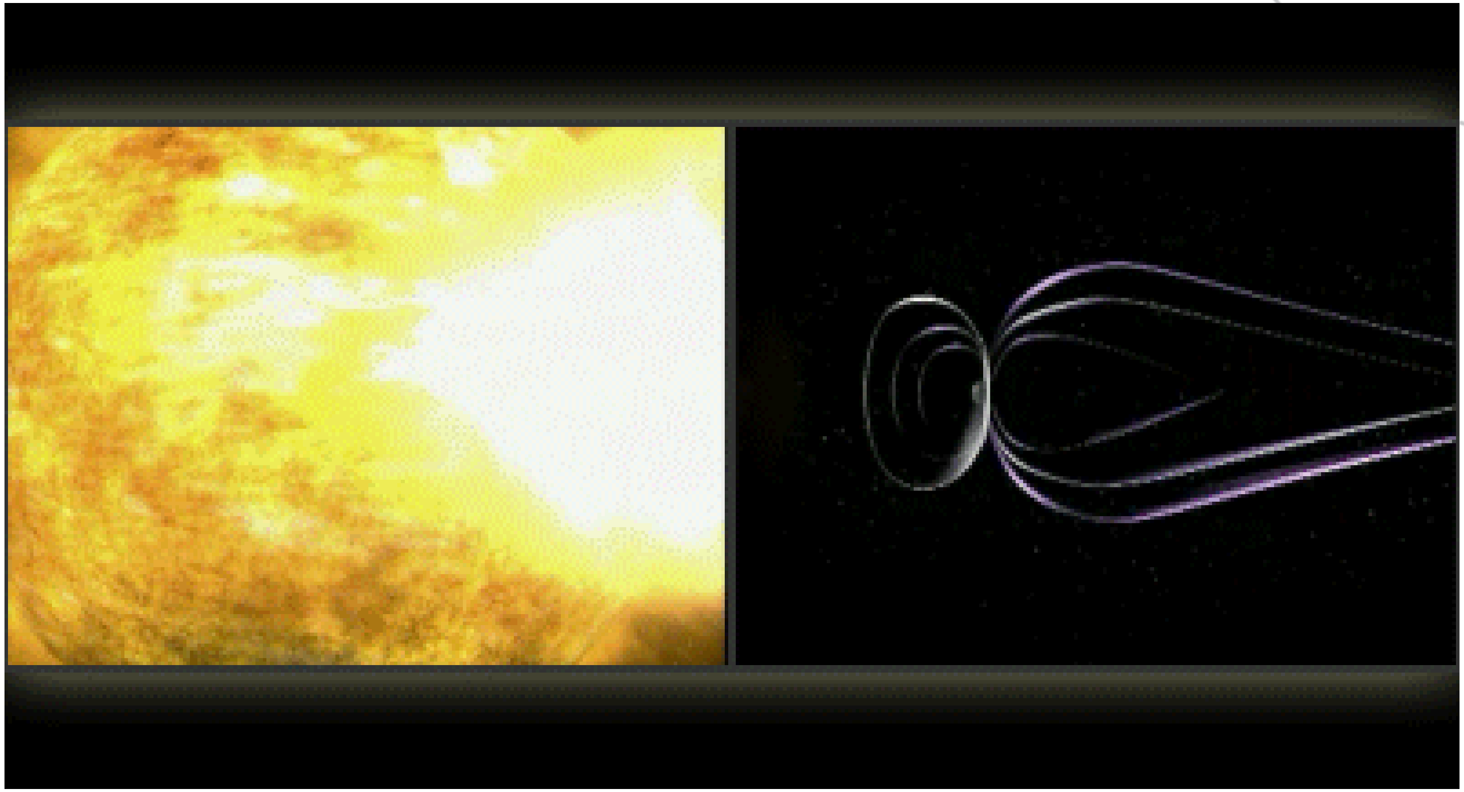
www.space.com

Solar winds meet the magnetosphere



http://www.esa.int/esaCP/SEMF75BNJTF_index_0.html

Solar flares giving auroras

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History

Polar light studies were started with a French expedition to Alta in 1839-1840.

In 1882-83, a Norwegian expedition was sent to Finnmark to study the polar light.

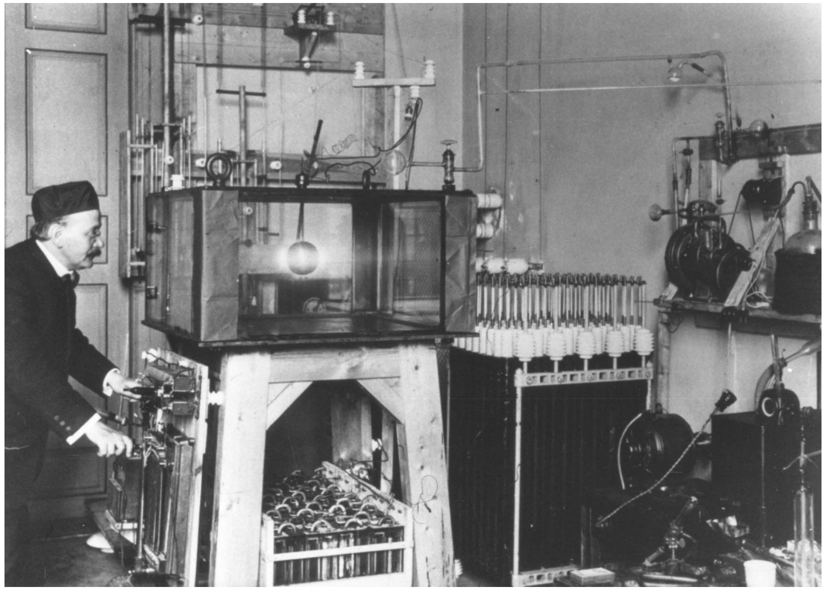
In the 1880ies, Professor Kristian Birkeland started the pioneering studies to explain the phenomenon. He published a theory of the polar light phenomenon, and he produced artificial polar light in his Terella laboratory.

In 1909 Professor Carl Størmer took the first good pictures of the polar light, and he managed to calculate the height by the triangular method.

Professor Vegar contributed with his work on the spectral properties of the polar light.

In 1899, the polar light observatory at Halddetoppen in Alta was built, and since then the polar light has been studied continously.

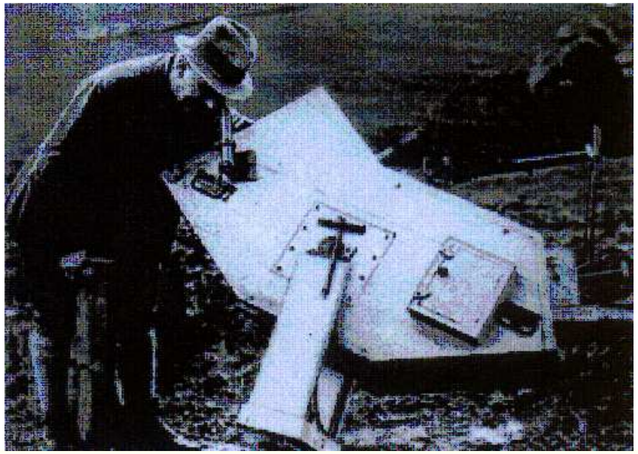
The first artificial polar light was created in 1958, when an atomic bomb was detonated in the atmosphere.



Birkeland

Størmer

Vegard



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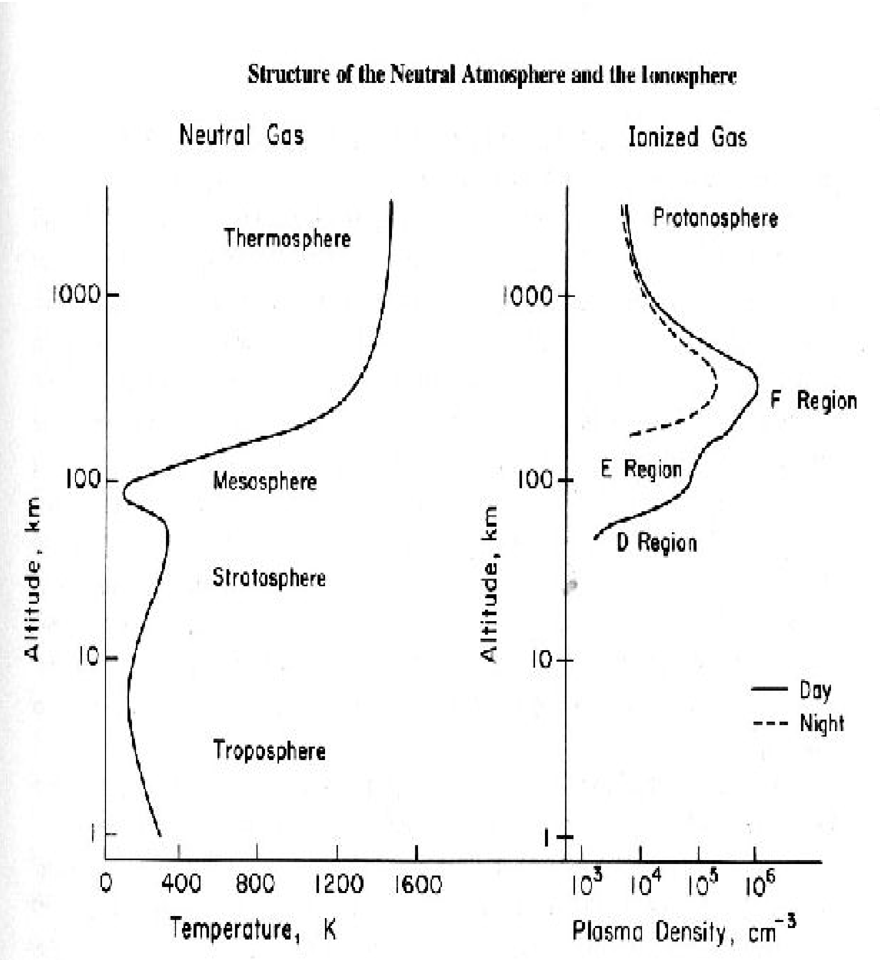
Ionosphere created by radiation



- Troposphere: up to 10 km
- Stratosphere: 10 km – 80 km, incoming UV creates the ozone layer
- Mesosphere: 80 km – 100 km
- Thermosphere above 100 km
- Ionosphere: 50 km – more than 1000 km, a shell of electrons and ions since the atmosphere is so thin that free electrons can exist for short periods of time before they are captured by a nearby positive ion

- The ionization depends on:
  - sun activity
  - diurnal effect
  - seasonal effect
  - geographical location

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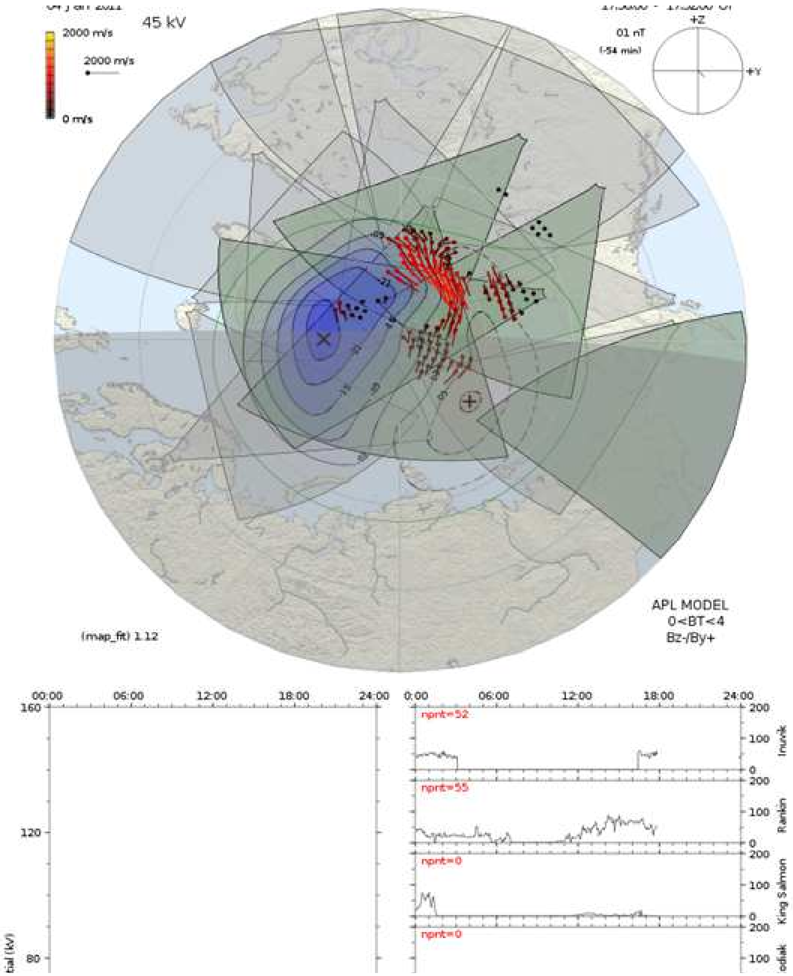
Ionosphere movements



Johns Hopkins Applied Physics Laboratory 2010

Creation of the ionosphere

Between equator and about 60º north the creation of the ionosphere is mostly due to UV radiation from the sun.

Photonic quantic energy: E=hf, h is Planck's constant,

f the radiative frequency of the photon.

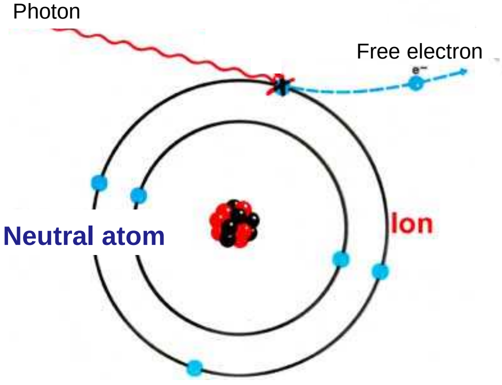
$hf + X \rightarrow X^{+} + e$

$hf + XY \rightarrow XY^{+} + e$

Recombination:

$X^{+} + e \rightarrow hf + X$

$XY^{+} + e \rightarrow X + Y$ (dissosiative recombination)



http://xphysics.co.uk/

Northern regions

In northern regions, energetic electrons, protons and α-particles from the sun and the magnetosphere will penetrate the atmosphere and produce an extraordinary amount of ions, in particular in the E and D layers.

This is the origin of northern lights, but can also provoke radio black-out, disturbance in power supply and corrosion of oil pipes.

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D, E and F layers

F-layer:

Above 150 km extreme UV radioation (10nm<λ<90nm) will provoke:

$O + hf \rightarrow O^+ + e$ and $N_2 + hf \rightarrow N_2^+ + e$. These ions will soon react with neutral atoms and molecules: $O^+ + N_2 \rightarrow NO^+ + N$ and $N_2^+ + O \rightarrow NO^+ + N$.

Therefore, the most dominant ions in the F-layer are O^+ and NO^+ , O^+ above 200 km.

E-layer:

From about 95 km to 150 km. X-rays (1nm<λ<10nm) and UV-rays (100nm<λ<150nm) ionise O_2 and N_2. However, N_2^+ will soon disappear either as:

$N_2^+ + O_2 \rightarrow O_2^+ + N_2$ or as $N_2^+ + O \rightarrow NO^+ + N$. Hence O_2^+ and NO^+ are the dominant ions in this layer. The recombination is dissosiative: $O_2^+ + e \rightarrow O + O$ or $NO^+ + e \rightarrow N + O$.

Thin layers of Na^+ , Mg^+ and Fe^+ may appear in this layer. They are due to meteors.

D-layer:

Below 75 km, heavy ions are created mostly due to highly energetic cosmic radiation.

From about 70 km to 95 km, NO ionasation is dominant and mostly due to Lyman α-radiation (λ= 121.5nm, a very strong spectral line in the solar spectrum). Solar X-rays also contribute.

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Andøya Rocket Range

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Andøya observation location

Why Andøya?

Located in a ”civilized” part of the world, under the polar light oval

Good conditions to observe phenomena like polar light, noctilucent clouds, ozon layer, and environmental changes

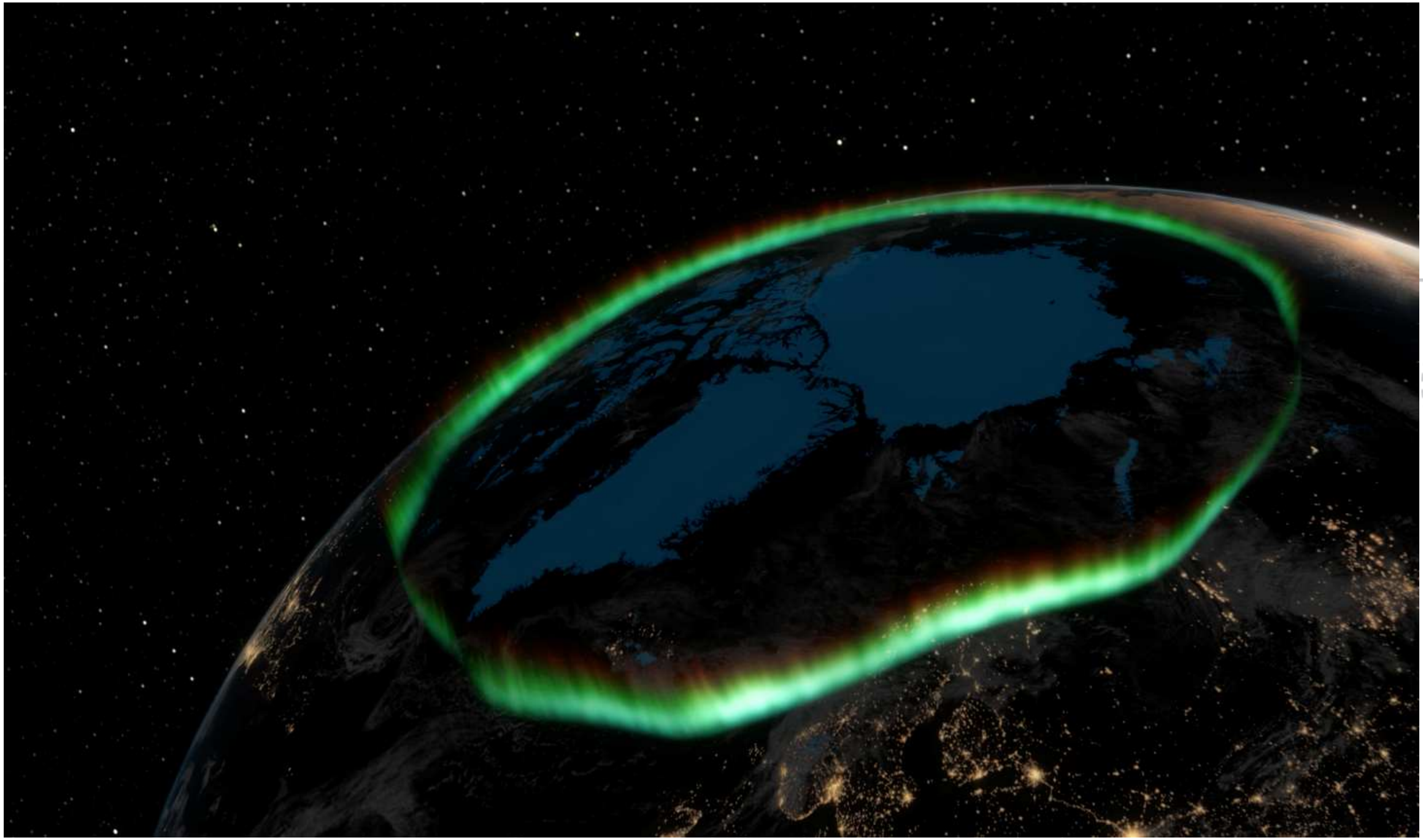
Northern light observatories in Norway:

-Tromsø (1928-)

- Alta (1899-1926)

- Svalbard (1978-)

Polar light oval location



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The aurora oval

The aurora oval is determined by the position of the sun and the magnetic pole.

The centre of the oval is displaced a few degrees to the nightside with respect to the geomagnetic pole.

The midnight portion of the oavl is, on average, at a geomagnetic latitude of 67º, the midday portion is at about 76º.

The oval is fixed with respect to the sun, the earth rotates below.

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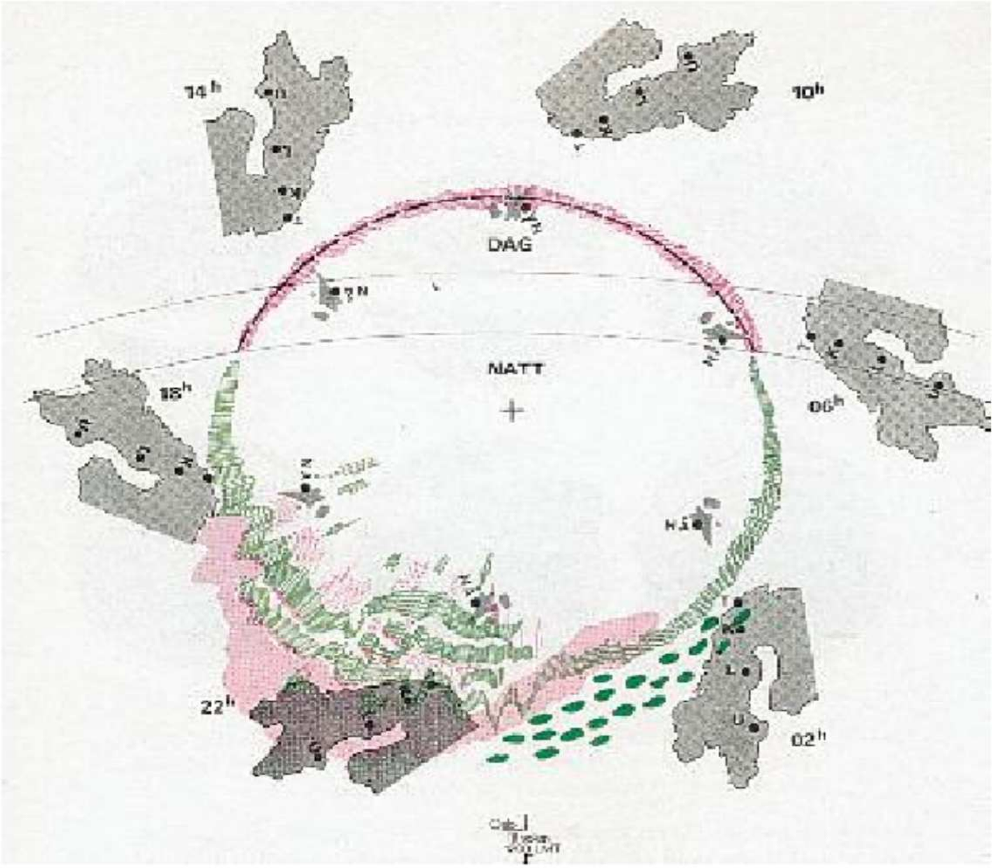

Oval position relative to Norway during 24h

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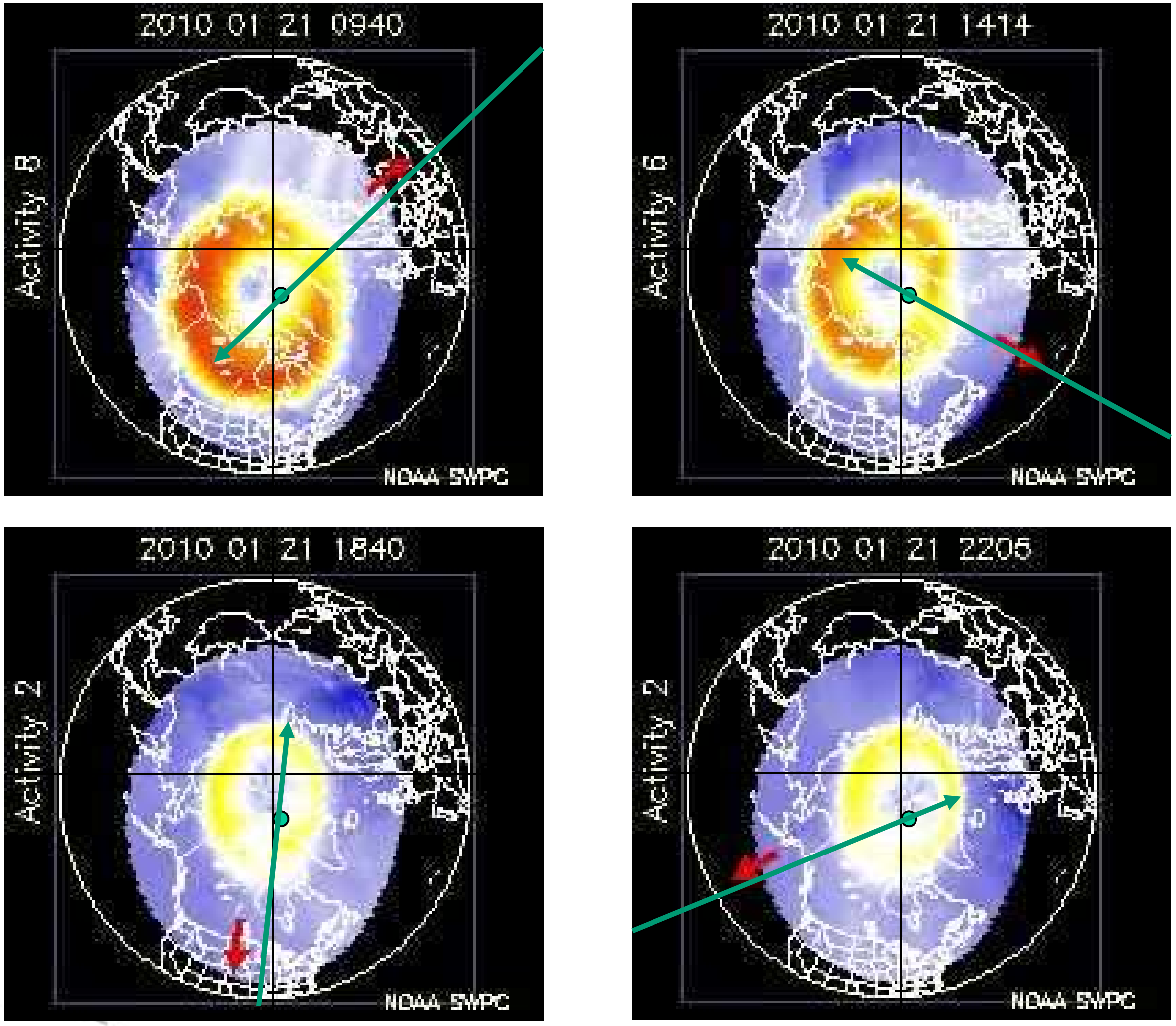
Magnetic midnight



Magnetic midnight:
When the observer,
the magnetic pole and
the sun are on a streight line.

In northern Norway,
an outbreak will usually appear
between 18h and 02h local time,
as the magnetic midnight is
at 22 hours local time.

Magnetic pole

Indicates the direction
towards the noon meridian

Indicates the direction
towards the magnetic midnight

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http://www.umanitoba.ca/science/astronomy/cbrown/aurora/aurora202.html and http://www.swpc.noaa.gov/pmap/AnimateN.html

Midnight lights

On the night side of the earth, where the ovals are lit by the magnetotail break-down and particles streaming back towards the earth.

Northern and southern light ovals (aurora borealis and australis) are symmetric around the magnetic poles, about 23º inclination from the poles. The zones are from 500-1000 km wide, and appears further to the south with increasing solar activity.

Average hight 100-150km, may dip down to 85km and reach up to 500km.

Midday lights

Weak nordic lights, often in red color tones, linked to the polar cusp (the hole in the magnetosphere).

Can be seen daytime, in the winter, e.g. at Spitzbergen.

The dayside is closer to the magnetic pole than the night side, with about 12º inclination from the magnetic poles.

Average hight 200km.

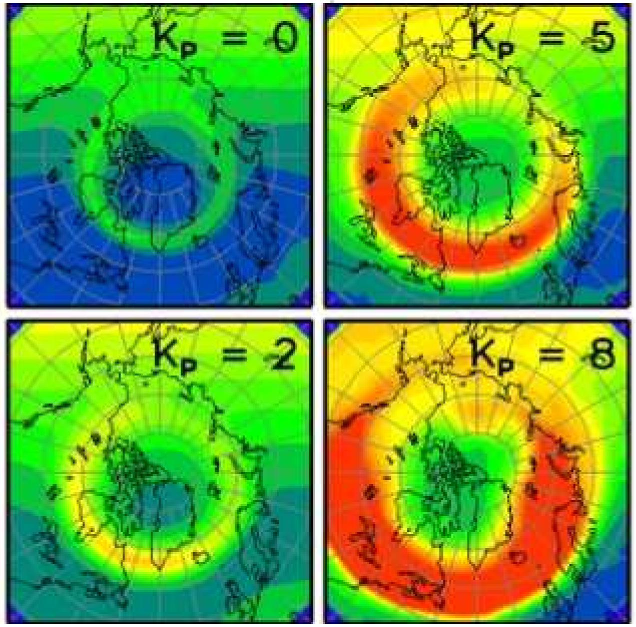
Arctic polar light

Polar light may appear inside the oval, i.e. the central arctic area.

This light is weaker than the polar light in the ovals, and the spectrum is different. It has short life time, and appears within calm magnetic periods, in contrast to the polar light of the ovals.

Many questions about this light are still not answered, even though the knowledge has increased significantly since the 1980-ies.

Kp index



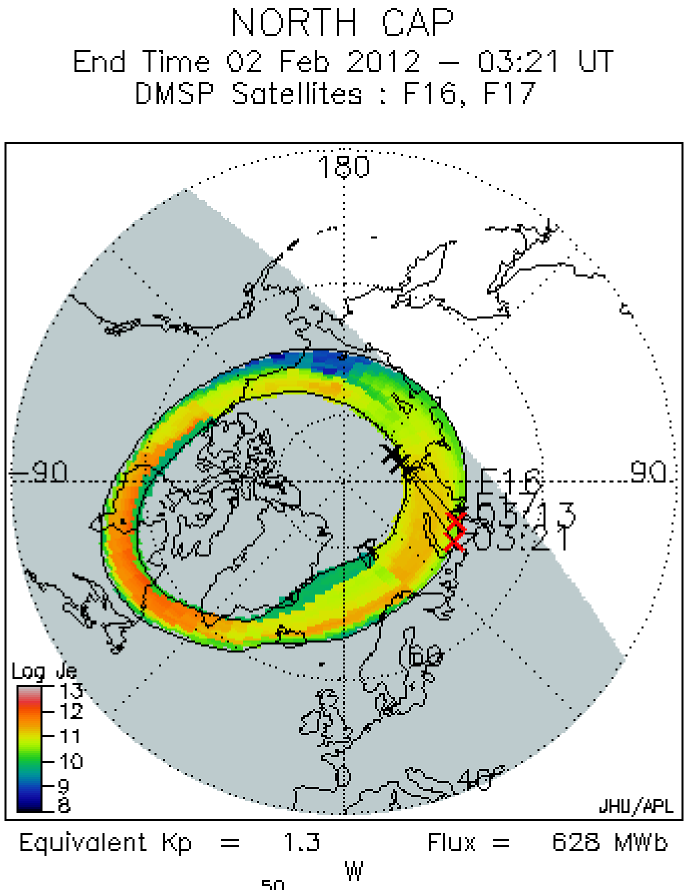
A particularly useful predictor of the aurora that scientists use is the Kp index, also called the planetary-K index, which is compiled from magnetometer measurements at 13 stations that have records going back to 1949. Every 3-hour period of each day is assigned a Kp activity level between 0 and 9, somewhat similar to the Richter scale for earthquakes or the Beaufort scale for wind and storms. A Kp level of 0 means exceptionally quiet, whereas more disturbed times are described as:

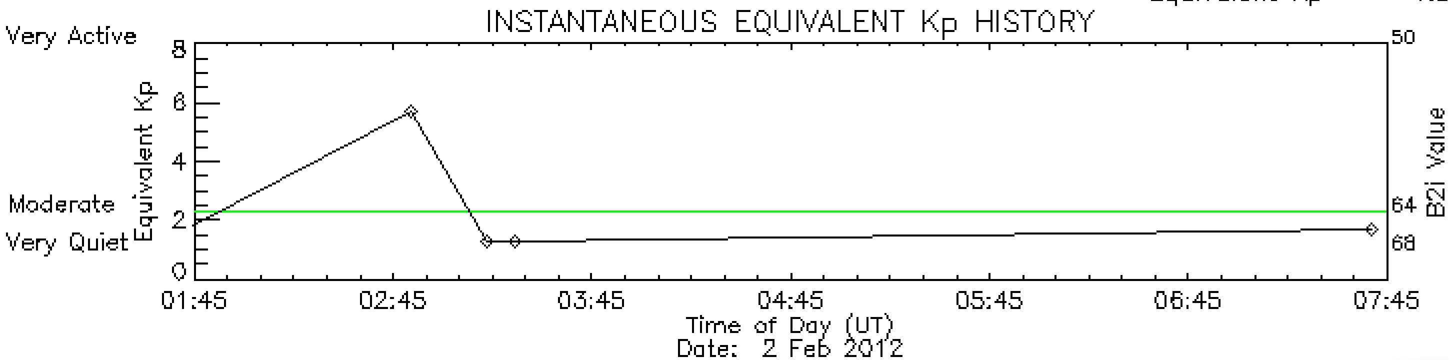
- Kp = 4: Calm Conditions
- Kp = 5: Minor storm conditions
- Kp = 6: Moderate storm conditions
- Kp = 7: Strong storm conditions
- Kp = 8: Severe storm conditions
- Kp = 9: Extreme storm conditions

http://www.sunearthplan.net/4/780/Seeing-the-northern-lights-from-Britain

Example of polar light activity

2012 February 02 03:21 UT





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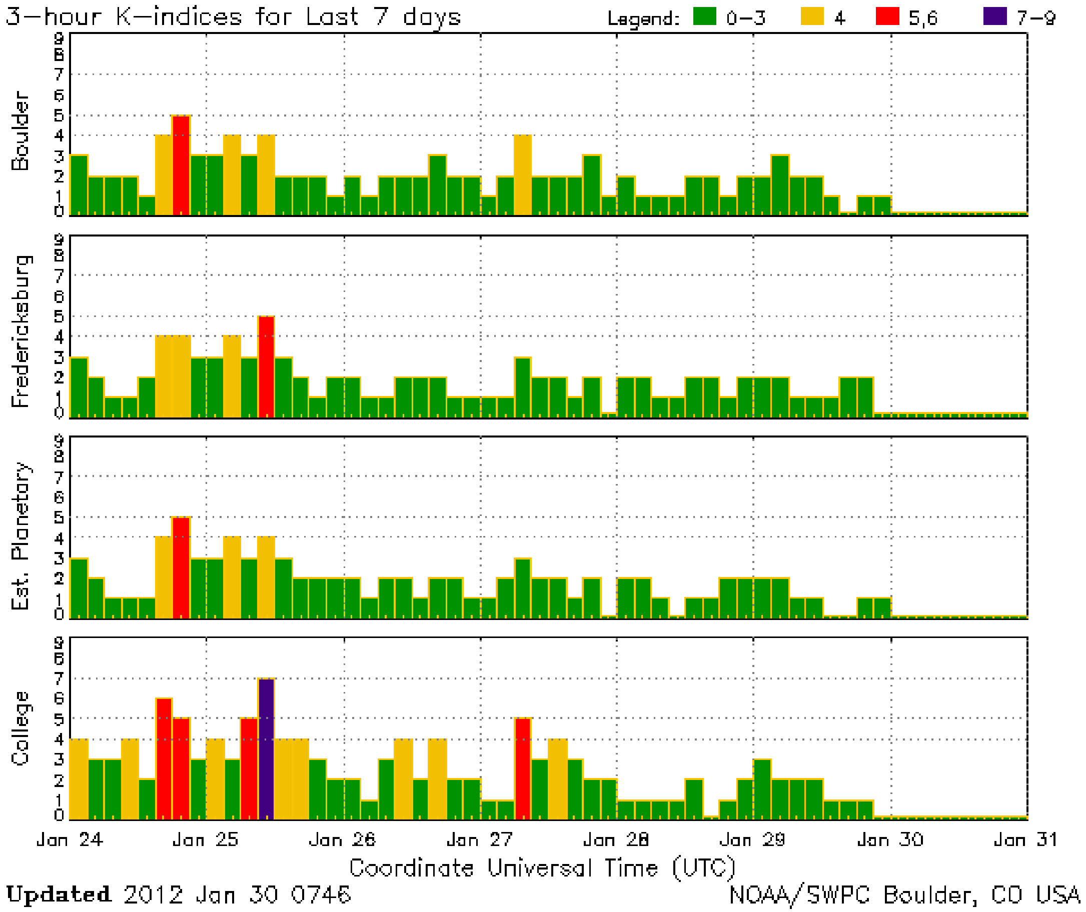
From: http://sd-www.jhuapl.edu/Aurora/ovation_live/n The Johns Hopkins University Applied Physics Laboratory

Kp indexes for the last 7 days, from 30.01.2012



Geomagnetic K-indices

- This chart is updated every 15 minutes at 1, 16, 31, and 46 minutes past the hour.
- The Estimated 3-hour Planetary Kp-index is derived at the NOAA Space Weather Prediction Center using data from the following ground-based magnetometers: Boulder, Colorado; Chambon la Foret, France; Fredericksburg, Virginia; Fresno, California; Hartland, UK; Newport, Washington; Sitka, Alaska. These data are made available thanks to the cooperative efforts between SWPC and data providers around the world, which currently includes the U.S. Geological Survey, the British Geological Survey, and the Institut de Physique du Globe de Paris

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Aurora above Tromsø 23-01-2012

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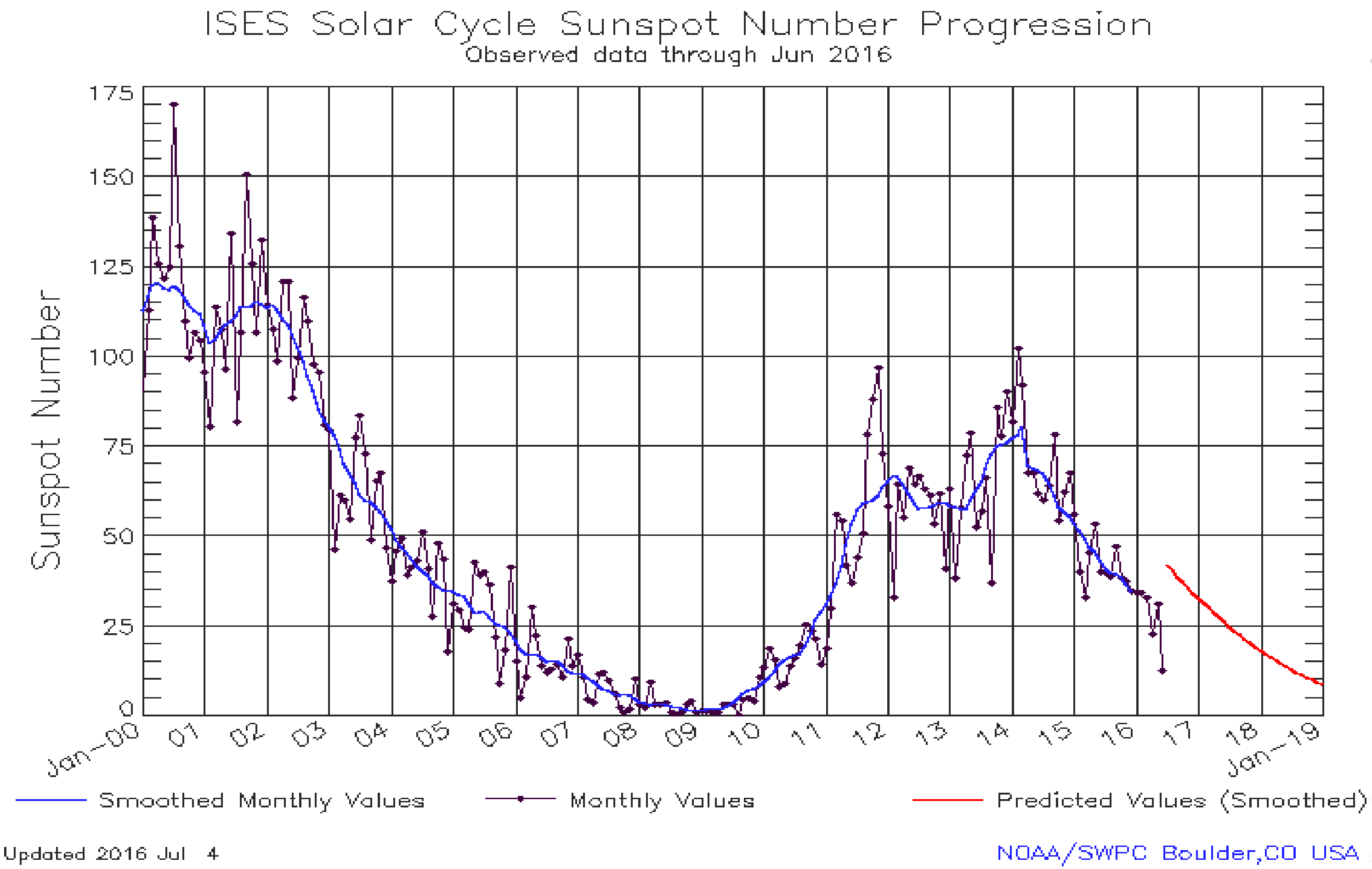
Ionosphere activity is linked to solar cycles



Solar eruptions are most likely to appear at sun spot maximum and during the decrase.

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http://www.swpc.noaa.gov/

Magnetic disturbance

Polar light is one of the effects of the physical phenomenon. However, the magnetic field is also disturbed, and the compass needle is affected. This is due to the appearance of ring currents in the E-layer.

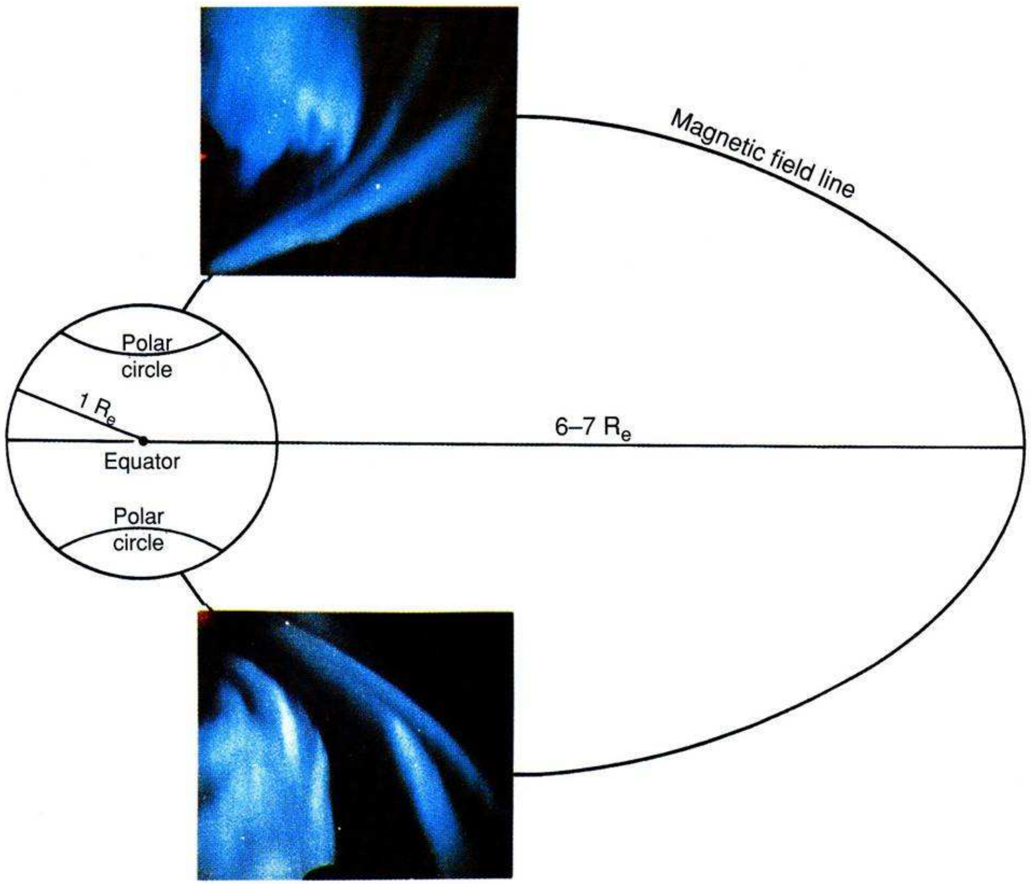
The displacement of the northern light oval, and the movement of the northern light are linked to the currents. Variations in the magnetic field is called magnetic storms.

Polar sound and ecco

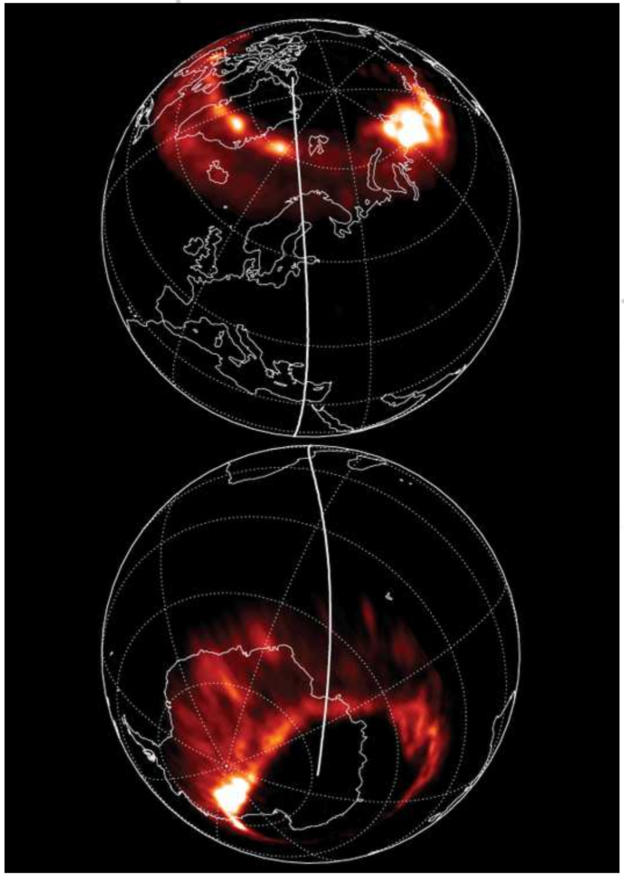
The polar light particles may produce radio waves, and may be detected by sensitive receivers. They are in the frequency range of the human ear (~100 - 10000 Hz). It has a musical character.

Radio signals may be dispersed or reflected by the polar light, called northern light ecco. The reflected waves are in the range 50-1000 MHz (FM band).

Mirror phenomenon?



Previous observations and mirror conclusion



Article in Nature in July 09

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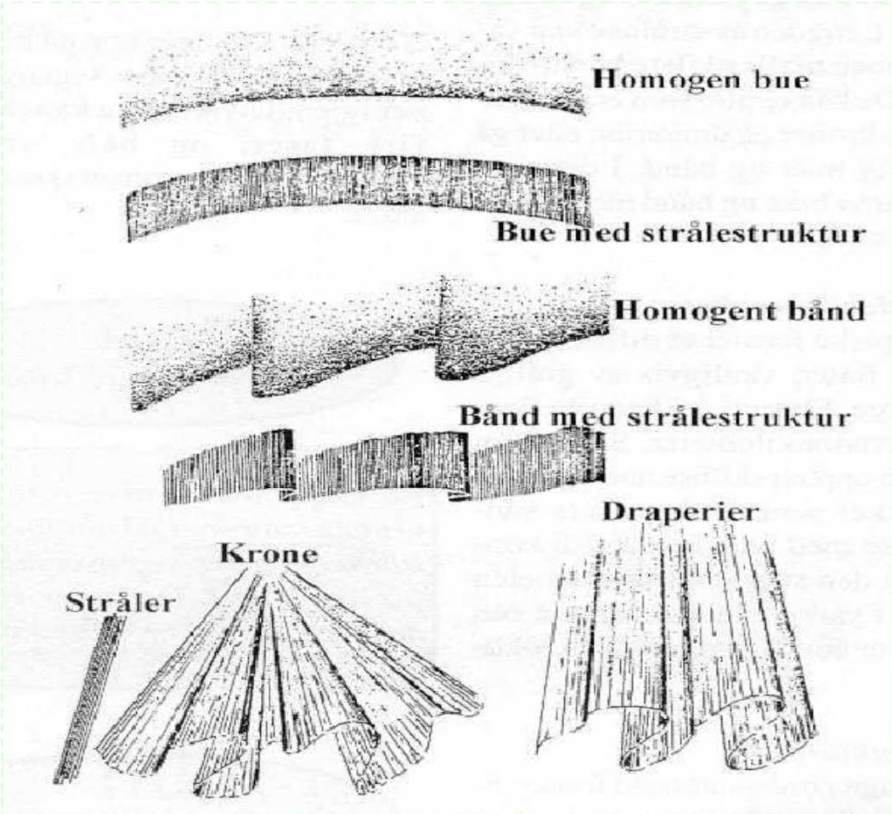
 www.fys.uio.no/plasma/nordlysinfo/nordlys/, http://www.uib.no/form/nyheter/2009/07/nordlyset-og-sorlyset-er-ikke-speilbilder-av-hverandre

Usual forms of the polar light



Homogeneous arch

Arch with beam structure

Homogeneous ribbon

Ribbon with beam structure

Beam Corona Draperies

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Ribbons

Homogeneous

Beam structure

Draperies

Homogeneous

Beam structure

Corona

Homogeneous ribbons and arches

Calm structures, diffuse

Can strech for more than 1000 km

They are orthogonal to the magnetic field lines

Beam structures

Active phenomenon

Beams will follow the magnetic field lines

The length of the beams vary from tenths to hundreds of kilometers

They appear in ribbons, arches, draperies and coronas

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Other structures

<u>Diffuse patches or sheets</u>

Resemble clouds, gray-green

May cover hundres of square kilometers

Appear on the dayside, 4-8 hours after magnetic midnight

<u>Spirals or curles</u>

Appear with strong solar activity

Geometric forms like spirals

May reach 10 to 100 km

They spin in certain directions and may spin quickly

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Polar light phases

Phase 1

Quite stable yellow-green-white arches going east-west. It can last for a couple of hours, is not intense and may drift slightly towards the equator, otherwise they remain calm.

Phase 2

The intensity is increasing, may include weak red light above the green. Beams will appear; thin vertical needles will show. The arches will often change to ribbons. The light will move quickly towards the south until it reaches senit in northern Norway. This phase (the growth phase) lasts on average about 30 minutes.

Phase 3

This is the outburst phase, where quick and dramatic changes will occur for about 10-15 minutes. The symmetry is broken and the polar light will expand into wide ribbons or draperies. It may curl or pulsate. The changes are quick, and red and violet colors may appear with the dominant green. Coronas may develop.

Phase 4

The last phase of the outbreak, lasting for about an hour. The intensity will diminish, and the light will expand over the sky as a gray-green viel.

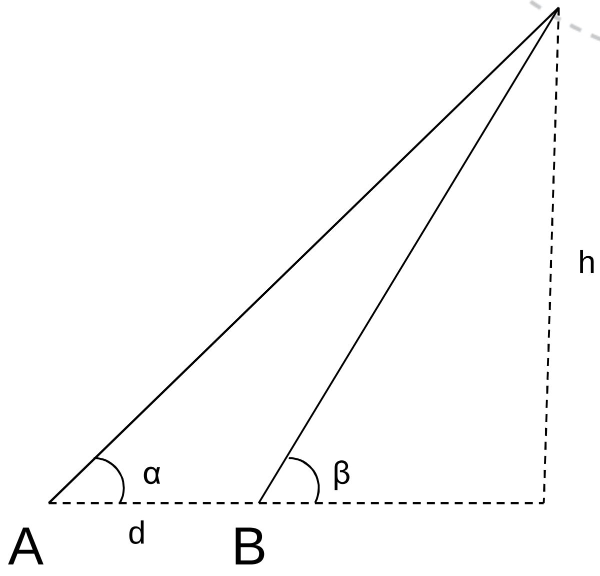
The height of the polar light

Triangular method (Størmer) based on photos taken from different locations.

Most polar lights appear within 100-150 km height.

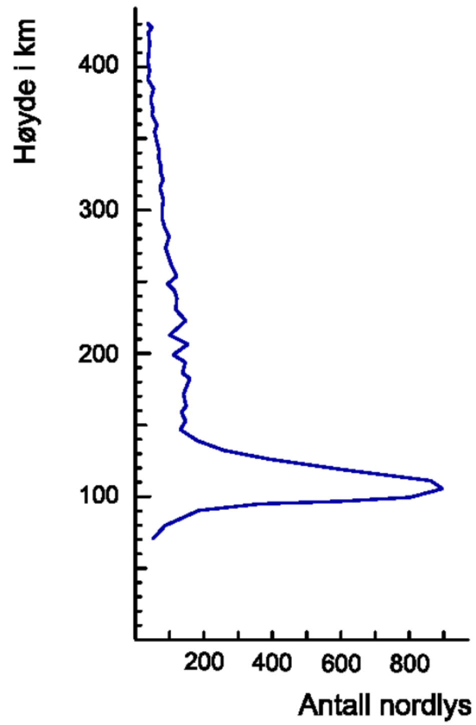
May dip to 85 km or reach beyond 500 km.

The height depends on the magnetic latitude.



Number of observations at different hights (Størmer & Co.)

Number of polar light observations by height, based on a total number of observations equal to 20000 performed from 1910 to 1940.



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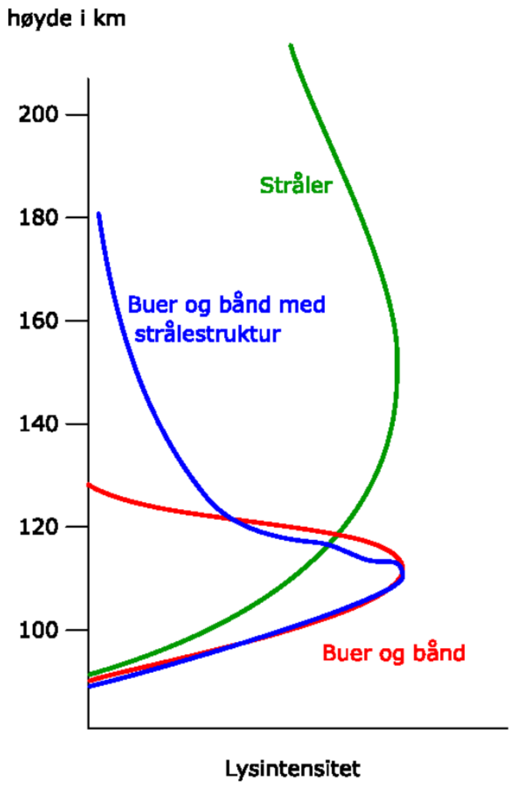
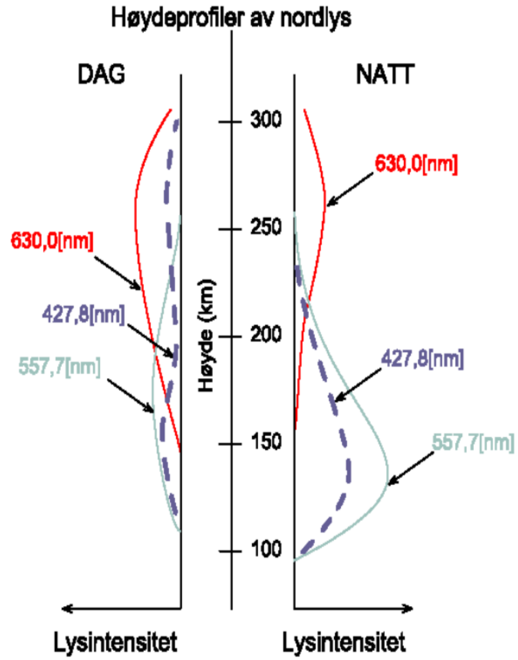
Height profiles – structures and colors





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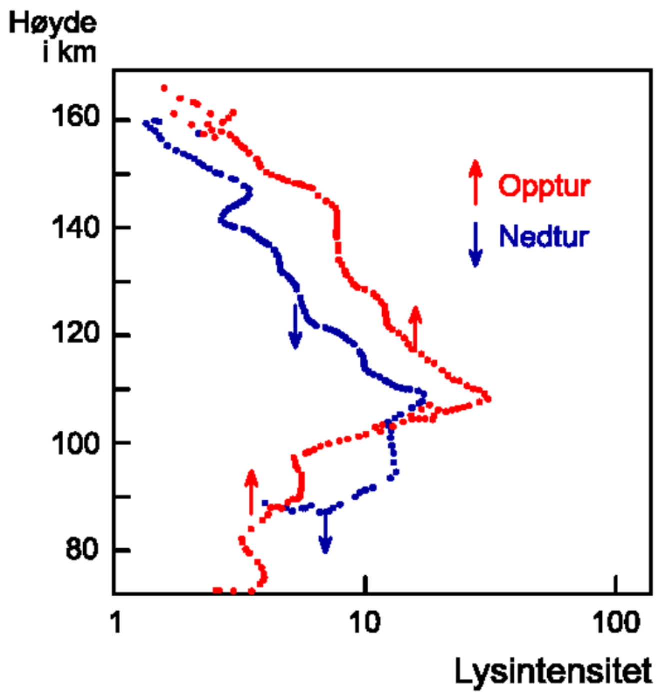
Use of rockets for polar light studies



It is only by using rockets flying through the polar light, that first hand information about height profiles can be obtained. A number of observations of the night polar light has been performed, but very few of the day polar light or the arctic polar light – diffuse glows.

The figure shows a profile of a diffuse glow with a rocket from Andøya Rocket Range.

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Polar light intensity

The northern light is not strong, at its highest intensity it can be compared to moonshine. The flux of

- strong polar light is $1 mW/m^2$, whereas the
- full moon is $3 mW/m^2$.
- Polar light of $10^{-3} mW/m^2$ can be detected by the human eye.
- By comparison the sun flux is $10^6 mW/m^2$ and
- the total flux of the stars $2 \cdot 10^{-3} mW/m^2$.

The weak polar light flux corresponds to the emission of 400 photons per cm^3 and per second.

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Polar light colors

Spectral lines are caused by electron transitions in the atom.

Spectral ribbons are caused by electron transitions in the molecule.

1 to 2% of the solar wind particles will provoke excited ions, atoms or molecules, the rest will only ionise.

$O + e \rightarrow O^* + e'$, where $e' = e - 36eV$

as O^* is unstable $O^* \rightarrow O + hf$

$N_2 + e \rightarrow (N_2^{\ +})^* + e_n + e'$

as $(N_2^{\ +})^*$ is unstable $(N_2^{\ +})^* \rightarrow N_2^{\ +} + hf$

e_n is a free electron with little energy.

Laboraty studies have shown that on average 36eV is needed for each ionisation process.

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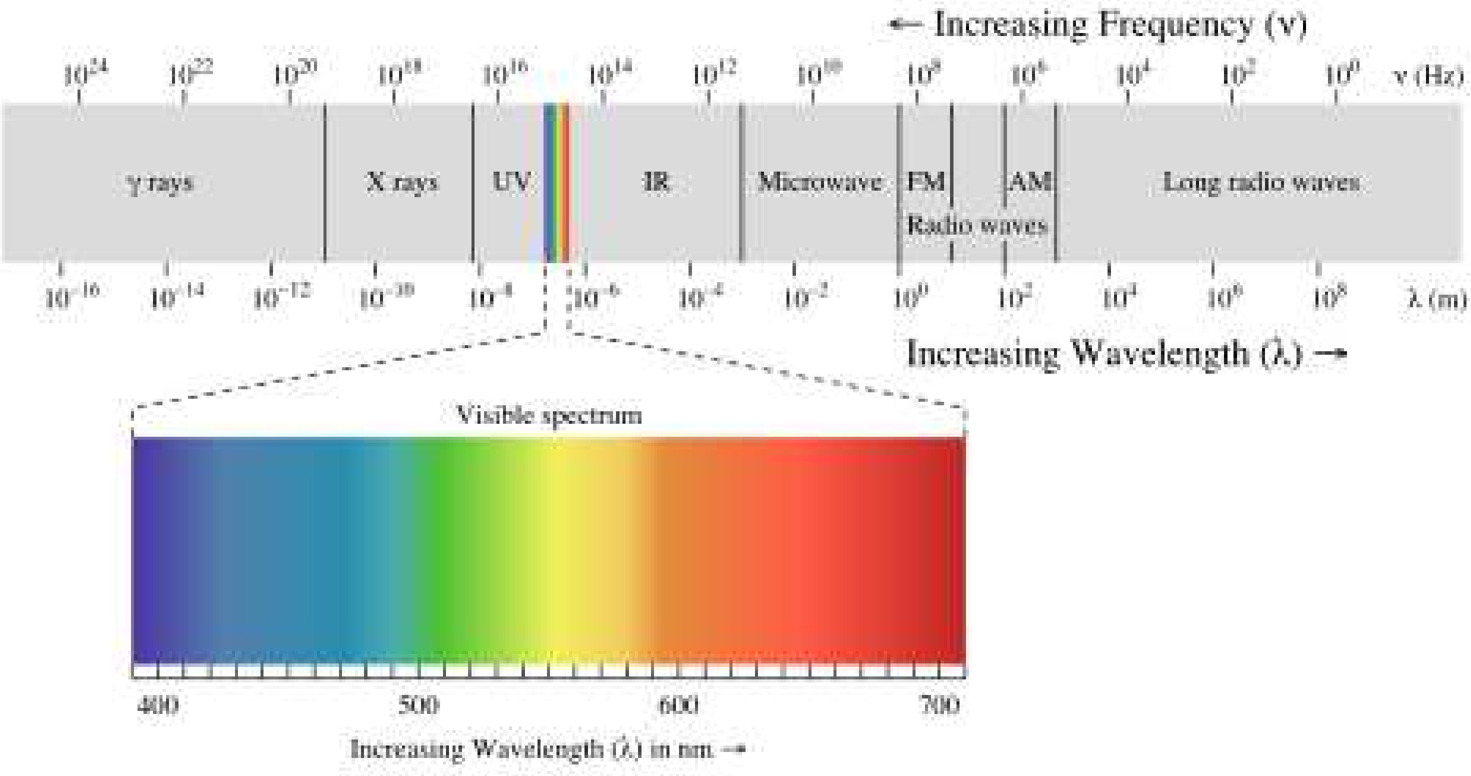
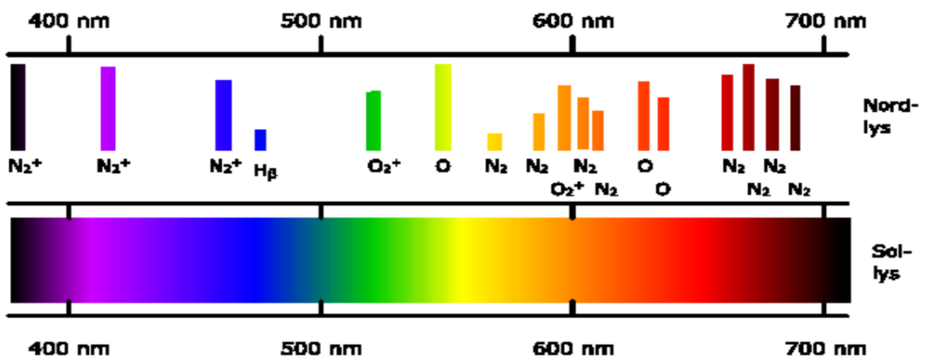
Electromagnetic spectrum



Spectral signature of the polar light

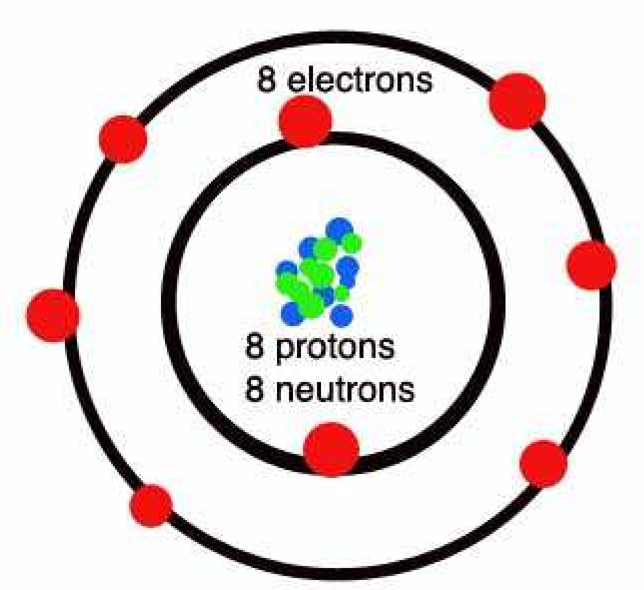


The polar light spectrum is composed of ”allowed” and ”forbidden” spectral lines. In order to understand their origin, some notions of quantum mechanics are needed. The strongest line in the polar light originates from the forbidden green-yellow spectral line at 557.7nm.

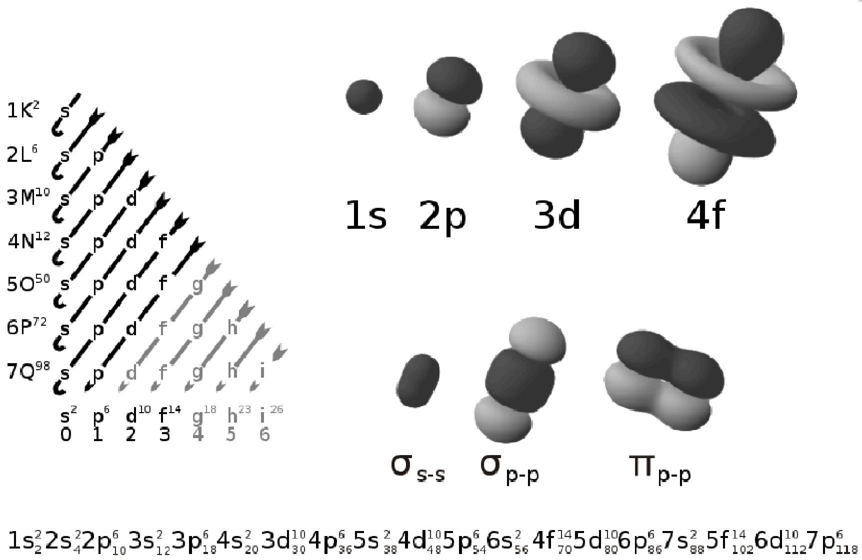
Major spectral components of the polar light:

391.4 - 427.8 - 470.9 - 557.7 - 630.0 - 636.4 nm

Molecular orbital theory



Oxygen atom



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Quantum numbers

n principal quantum number, describes the electron ”orbit” with respect to the nucleus, n=1,2,3,...

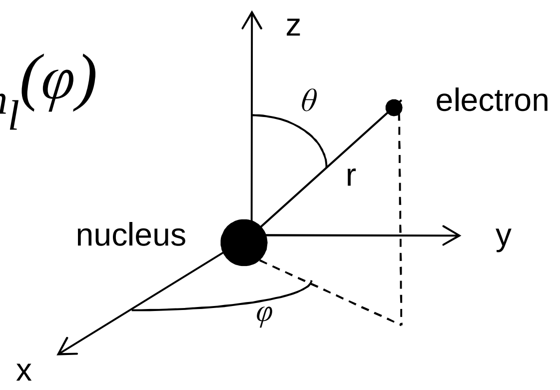
l the azimutal quantum number, l=0,..n-1

m_l the magnetic quantum number, m_l=-l, -l+1,..-1,0,1,..l-1,l

m_s the spin quantum number, m_s= -½, ½, or ↑↓

The electron ”orbit” is modelled by the electronic wave function:

$$\Psi(r,\theta,\varphi) = R_{nl}(r)\,\Theta_{lm_l}(\theta)\,\Phi_{m_l}(\varphi)$$



D.C.Harris & M.D.Bertolucci, ”Symmetry and Spectroscopy”

The wave function and the uncertainty principle

The wave function does not describe where the electron orbit is, but the probability distribution of where to find an electron.

The Bohr radius, a_0, is the most probable distance from the nucleus to find an electron with the lowest energy level, on the 1s shell (n=1). a_0= 5.292nm

Heisenbergs uncertainty principle:

$\Delta x \cdot \Delta p \geq \hbar$

$\Delta E \cdot \Delta t \geq \hbar$

where $\hbar = h/2\pi$, Δx is the distance/position, Δp the momentum, ΔE the energy and Δt the time/lifetime.

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Electron orbits of a one-electron atom

n	l	m_l	*name*
1	0	0	$\psi(1s)$
2	0	0	$\psi(2s)$
2	1	0	$\psi(2p_z)$
2	1	±1	$\psi(2p_x)$, $\psi(2p_y)$
3	0	0	$\psi(3s)$
3	1	0	$\psi(3p_z)$
3	1	±1	$\psi(3p_x)$, $\psi(3p_y)$
3	2	0	$\psi(4d_{z^2})$
3	2	±1	$\psi(3d_{xz})$, $\psi(3d_{yz})$
3	2	±2	$\psi(3d_{x^2-y^2})$, $\psi(3d_{xy})$

………..

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Atomic and molecular orbitals

Atomic orbital theory is usually introduced by explaining the wave functions and orbitals of an electron in a Hydrogen atom.

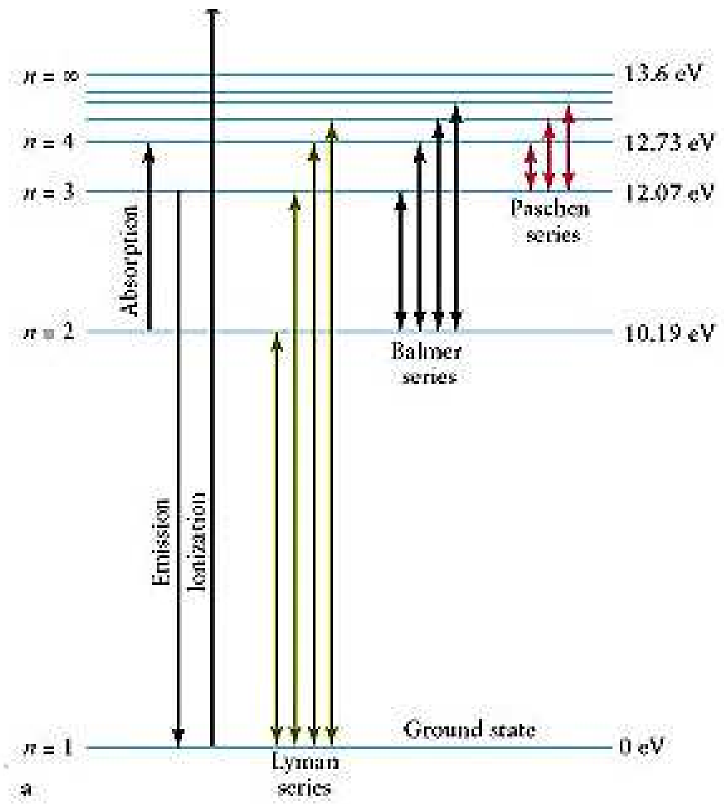
The orbitals of more complex atoms are not directly deduced.

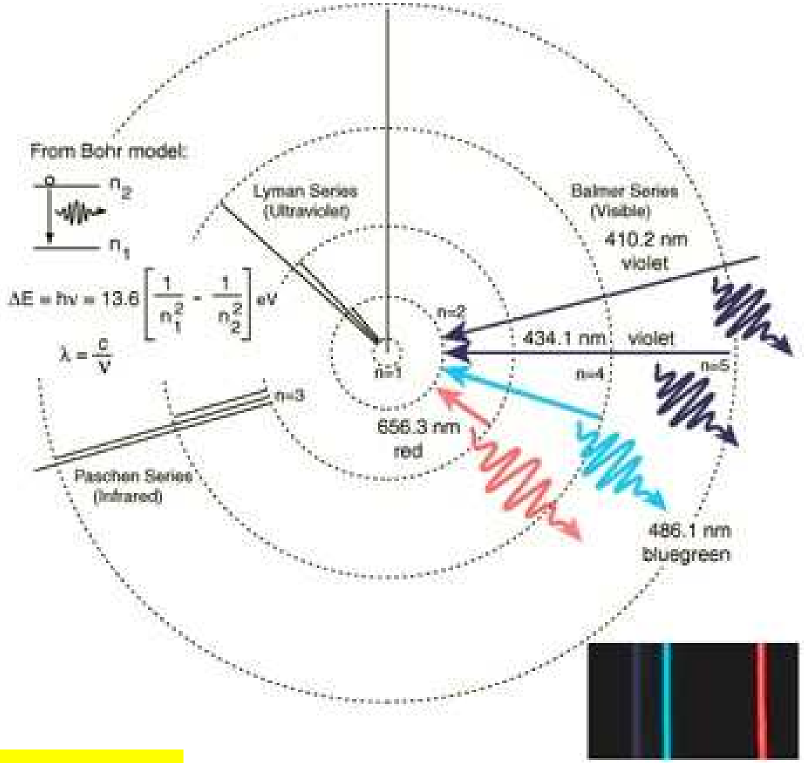
The orbitals of molecules are not directly deduced either, even though it is possible to use a simplified model where molecular electronic wave functions are linear combinations of atomic electronic wave functions.

Spectral lines of an atom or of a molecule

It is the signature.

The spectral lines of a Hydrogen atom are well known and just represent electronic transitions between shells.





$\Delta E = hf$

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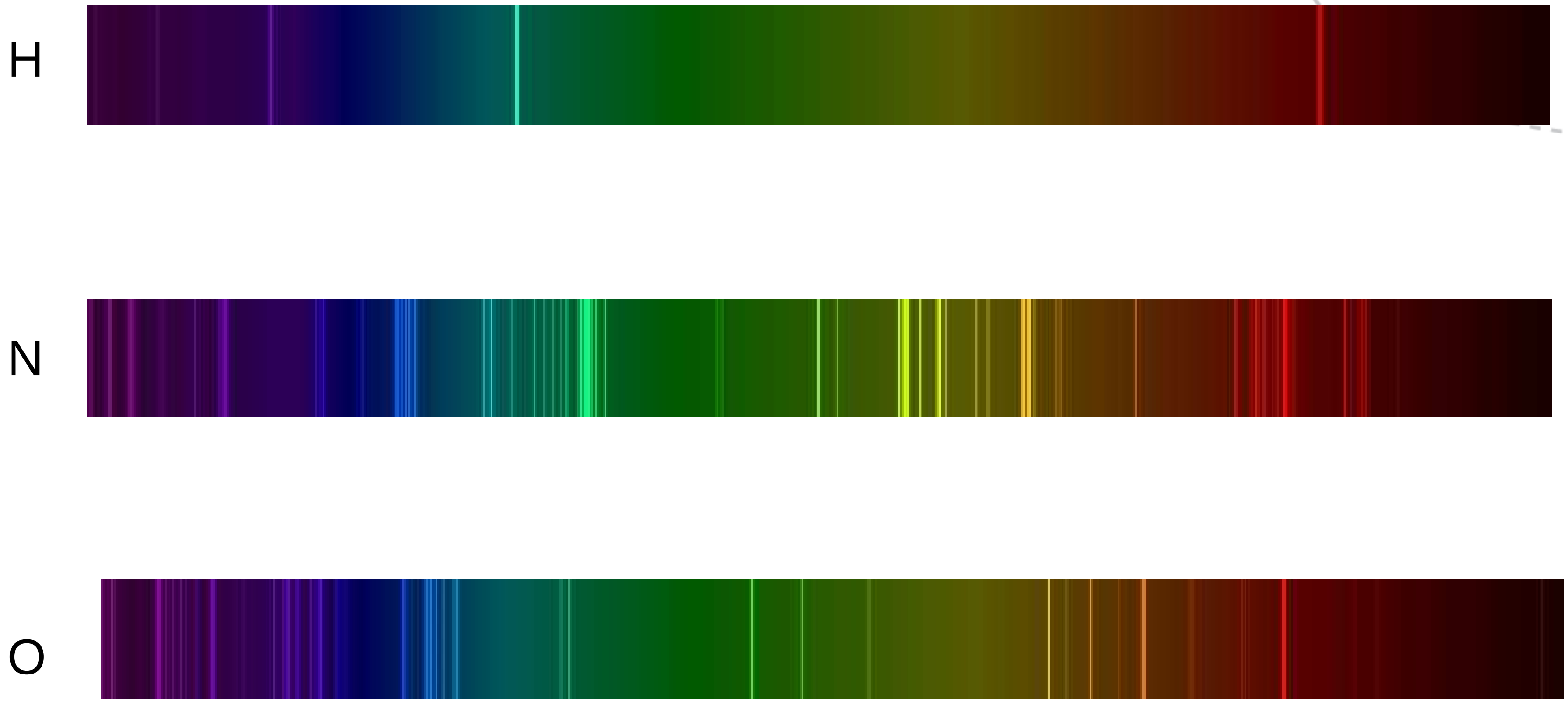
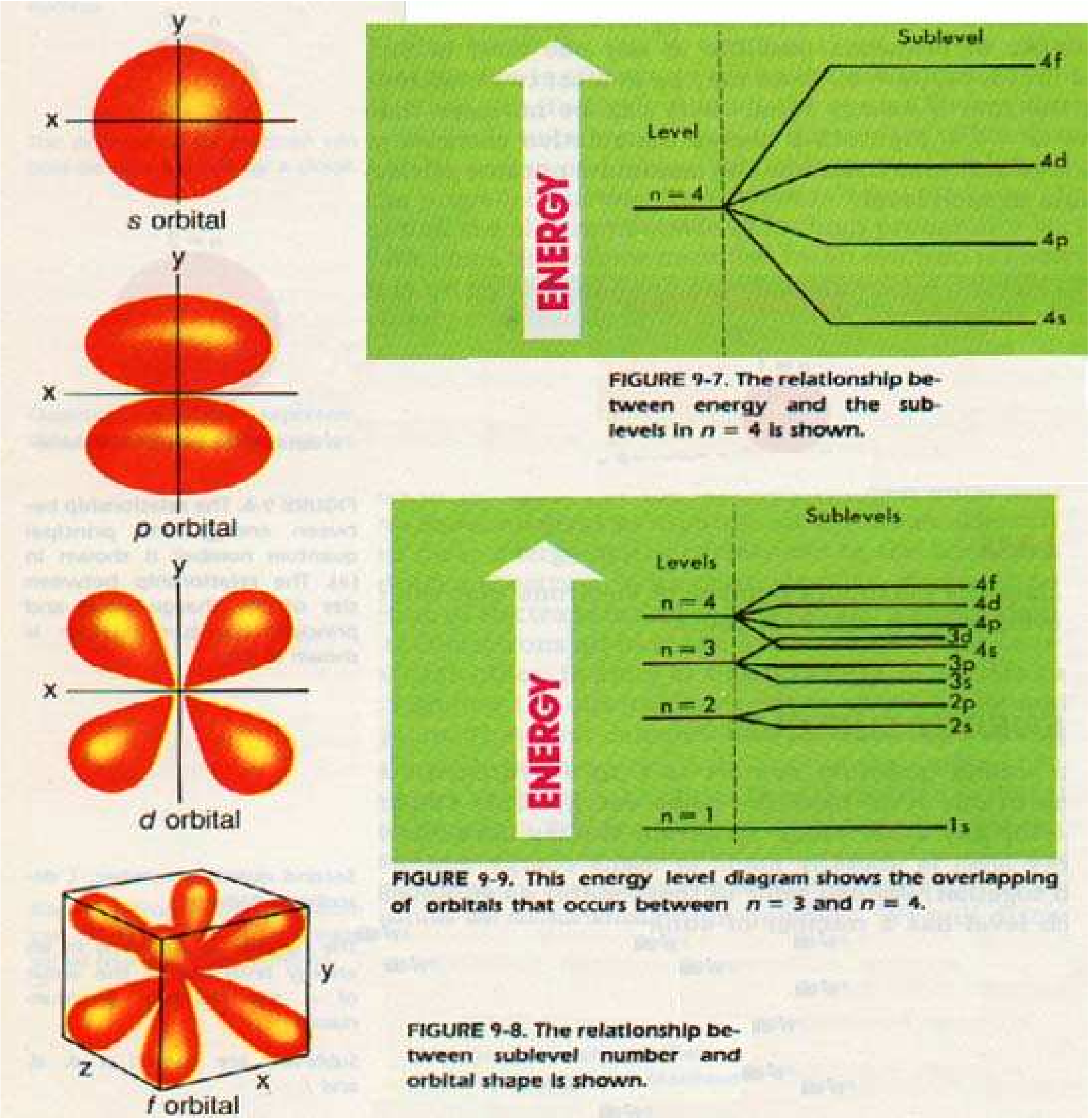
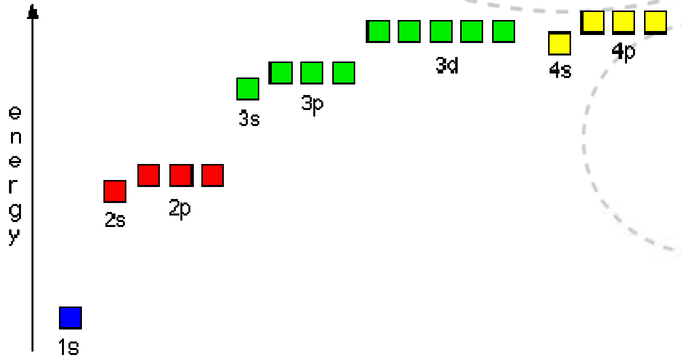
Energy transitions, spectral lines



Quantic energy levels





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Spin values – Pauli rule

Pauli exclusion rule: no two electrons in an atom can have the same set of quantum numbers

Nitrogen is in a ground state with the configuration: $1s^2\ 2s^2 2p^3$
Oxygen is in a ground state with the configuration: $1s^2\ 2s^2 2p^4$

	1s	2s	2p		
N	↓↑	↓↑	↑	↑	↑
O	↓↑	↓↑	↓↑	↑	↑

m_s the spin quantum number denoted ↑↓

But why not one of the following for Oxygen?

O	↓↑	↓↑	↓↑	↑	↓
O	↓↑	↓↑	↓↑	↓↑	

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Ground states – Hund’s first rule

Hund’s first rule: the configuration with the greatest number of unpaired spins has the lowest energy

But all three are states of the Oxygen atom. Electronic transitions of atoms or molecules represent changes in the state, and not necessarily the configuration, $1s^2\ 2s^2 2p^4$.

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Classification of states

Classification according to the total orbital angular momentum, L, and the total spin angular momentum, S. All filled subshells can be ignored as their total momenta are zero. For oxygen only the 2p shell has to be considered. n is the total number of electrons

$M_L = \Sigma_{i=1}^{n} (m_l)_i$ and M_L = -L, -L+1,...0, ... L-1,L

$M_S = \Sigma_{i=1}^{n} (m_s)_i$ and M_S = -S, -S+1,...0, ... S-1,S

Hund's second rule: for states with the same spin multiplicity, the state with the greater orbital angular momentum will usually be lower in energy

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Classification continued

Tables are set up with possible combinations of M_L and M_S values, and each combination is given a name. The names are given according to the Russel-Saunders coupling scheme, each atomic state is given the symbol ^{2S+1}L, with the name S if L=0, P if L=1, D if L=2, F if L=3 etc.

Three states arising from the oxygen ground state are, by order of increasing energy: $^3P < {}^1D < {}^1S$

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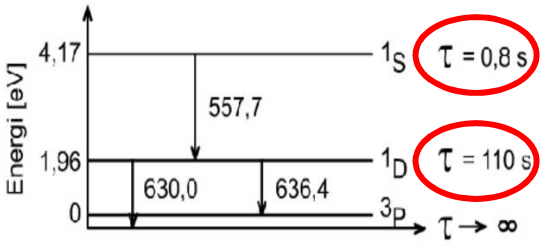
Forbidden lines



Oxygen "forbidden" spectral lines in the aurora

$\Delta E = hf$
$f = (4.17-1.96)\text{eV}/h$
Planck's constant: $h = 6.626\cdot10^{-34}\text{Js}$
$= 4.136\cdot10^{-15}\text{eVs}$

$f = (4.17-1.96)\text{eV}/\ 4.136\cdot10^{-15}\text{eVs}$
$= 5.34\cdot10^{14}\ \text{Hz}$
$\lambda = c/f = 3\cdot10^{8}\text{m/s} / 5.34\cdot10^{14}\ \text{Hz} = 557.7\text{nm}$

1 electronvolt (eV) is the amount of energy acquired by an electron accelerating through a potential difference of one volt (1V).
It is a very small amount of energy: 1 eV = 1.6 × 10^{-19} J

- A forbidden spectral line is a spectral line emitted by atoms undergoing energy transitions not normally allowed by the selection rules of quantum mechanics.
- Although the transitions are nominally "forbidden", there is a non-zero probability of their spontaneous occurrence, should an atom or molecule be raised to an excited state.

  "Forbidden" transitions are only relatively unlikely: states that can only decay in this way (so-called meta-stable states) usually have lifetimes of order milliseconds to seconds, compared to less than a microsecond for decay via permitted transitions.
- Forbidden emission lines have only been observed in extremely low-density gases and plasmas, either in outer space or in the extreme upper atmosphere.
- Because of the extremely low densities in these regions, the lifetime of forbidden transitions is shorter than the mean time between collisions. The statistical distribution of the excited states of these ions thus favours an overpopulation of the metastable states and forbidden transition dominate the spectrum. McLennan (1928) and Paschen (1930) have explained the green and red auroral lines as corresponding to forbidden transitions (1S->1D and 1D->3P, respectively) of the neutral O atom.

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http://en.wikipedia.org/wiki/Forbidden_mechanism and http://laserstars.org/spectra/Aurora.html

Dominant colors

- The strongest spectral line in the visible part of the polar light spectrum is the green-yellow oxygen line at 557.7 nm. This is the color giving the polar light its carachteristic green-yellow glow. There are also two quite strong red oxygen lines at 630 and 636.4 nm and several nitrogen lines. A red top color indicates that the northern light is reaching high up, and the 630 nm color is the dominant red color.

- The green-yellow line is due to the ^1S to ^1D energy transition. The two red oxygen lines at 630 and 636.4 nm are related to the transition from ^1D to ^3P and ground state respectively . With normal polar light conditions, the width of the green-yellow line is less than 0.01 nm. This line was first discovered in the polar light, long before it was produced in laboratory experiments.

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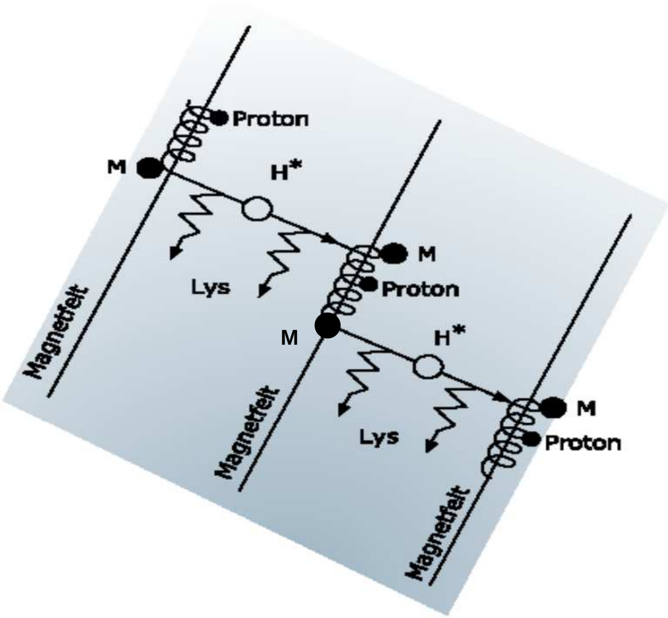
Northern light seen from ISS , filmed by austronaut Mike Fossum, published 21.09.2011: http://twitpic.com/6nkbev

Hydrogen spectral emission – the proton light



In the polar light spectrum, the two first lines of the Balmer series are also present, the H_α (656.3 nm, red) and H_β (486.1 nm, blue). This is due to the penetration of energetic protons, H^+.

$M + H^+ \rightarrow M^+ + H^*$

$H^* \rightarrow H + hf$

$M + H \rightarrow H^+ + M + e_n$

May start again as long as the energy of the protons is above 36 eV.

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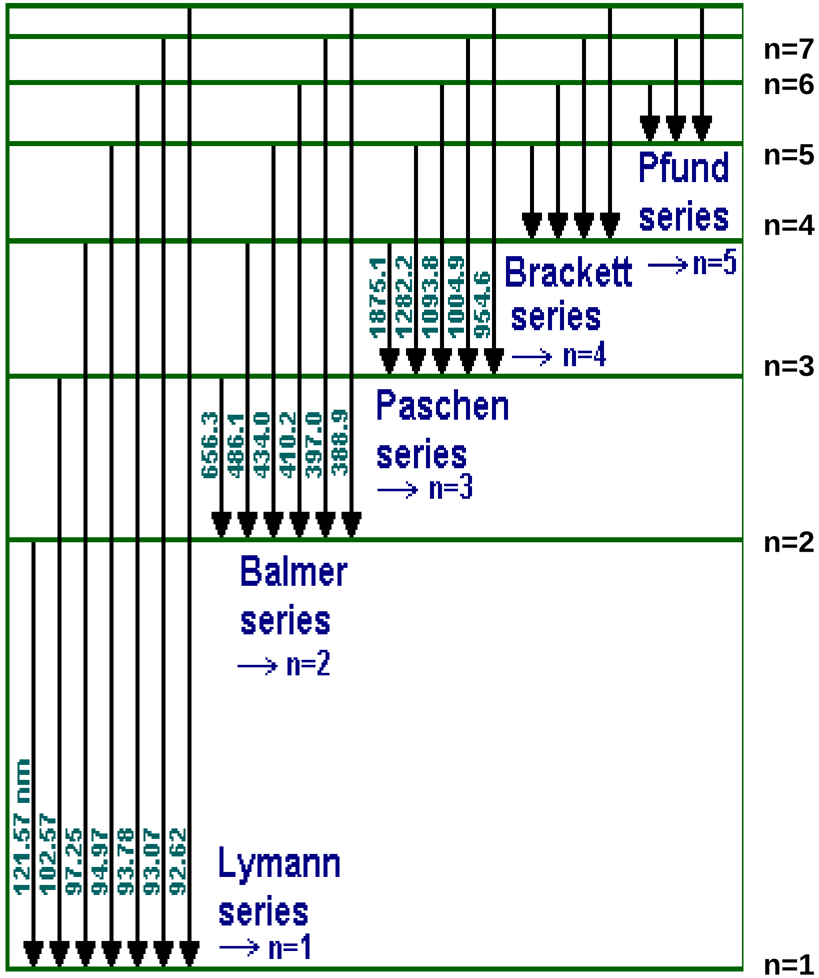

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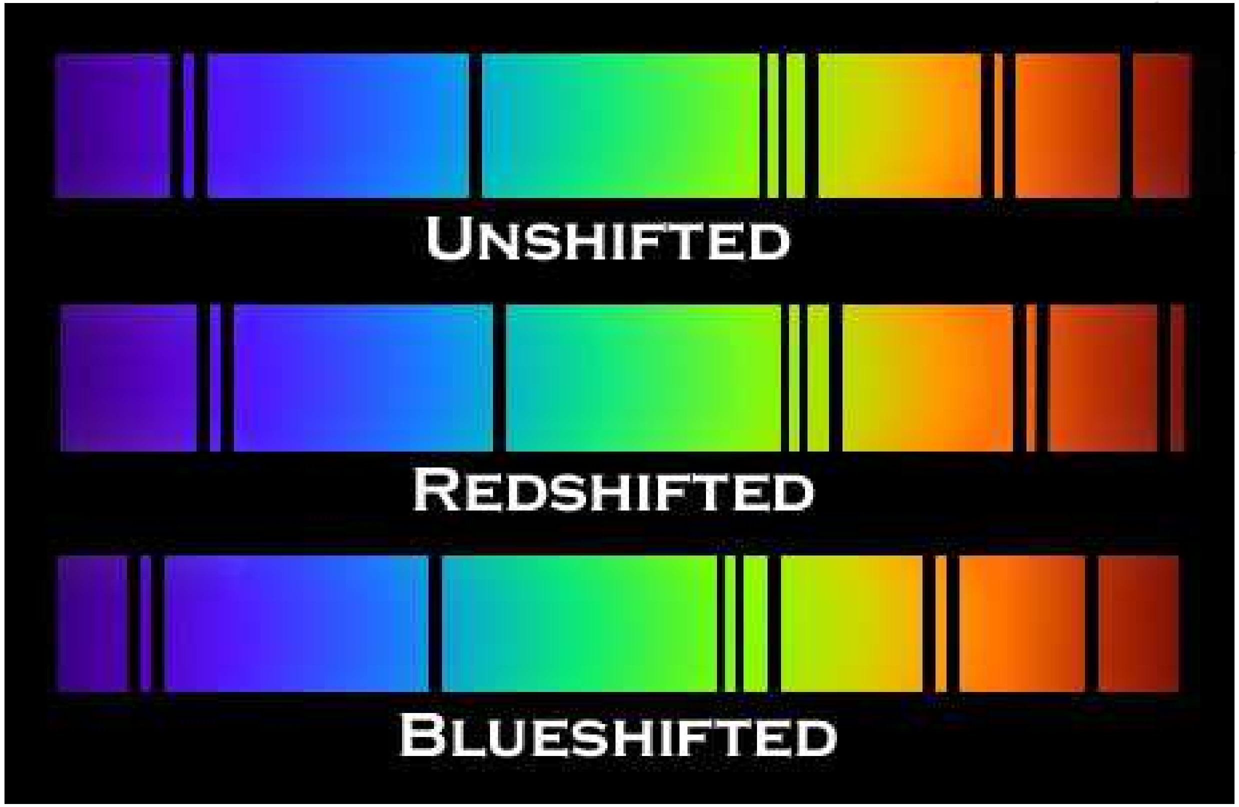
http://library.thinkquest.org/C006669/data/Chem/atomic/spectra.html

Applications – doppler shift



- measuring wind speeds in the upper atmosphere
- measuring the speed of the protons, and thereby the energy
- astronomy – speed detection in the universe

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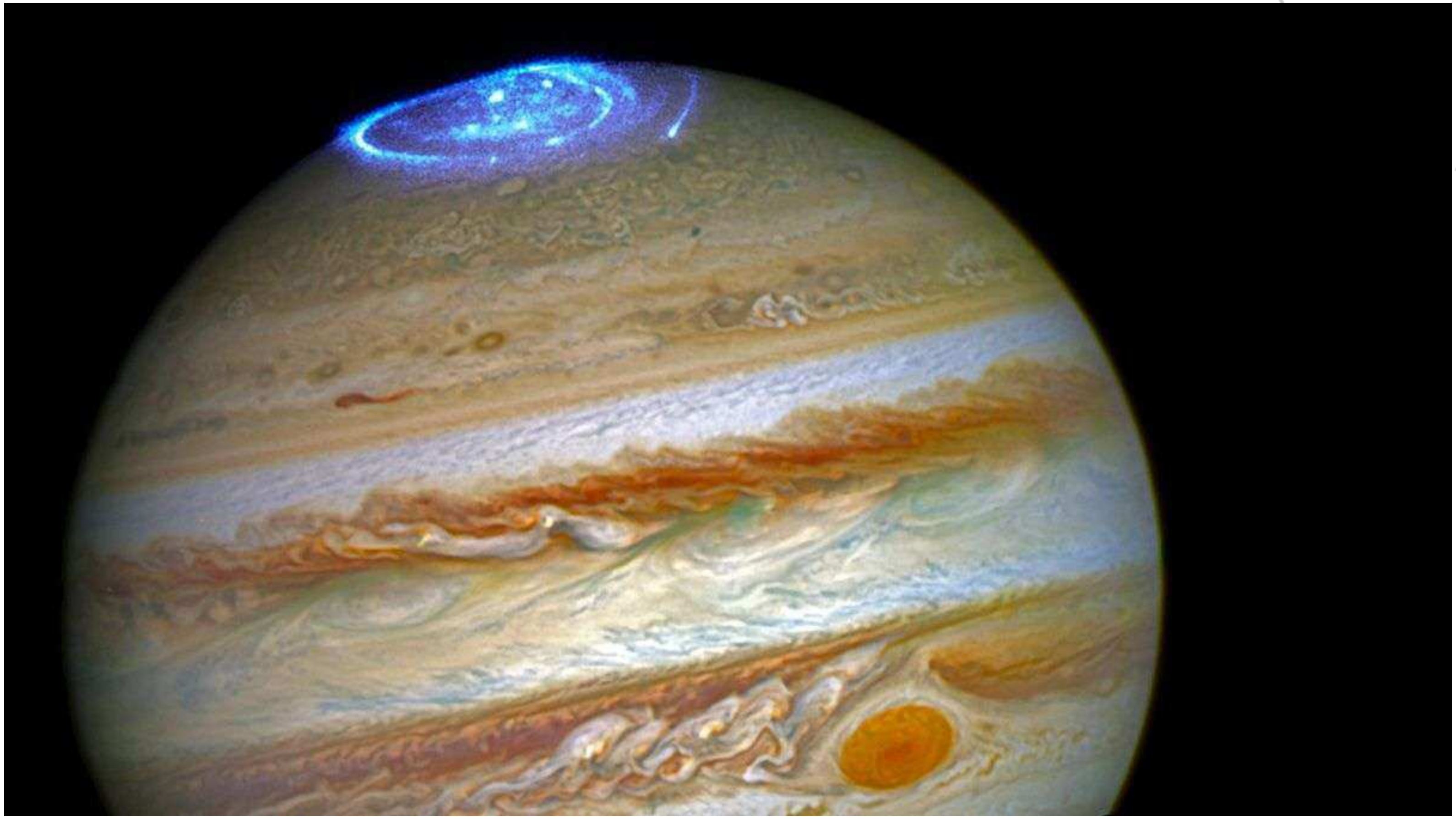
http://snews.bnl.gov/popsci/spectroscope.html

Northern lights on other planets
Jupiter



A composite image created by combining a 2014 optical image taken by the Hubble Space Telescope and ultraviolet observations of its auroras in 2016. NASA/ESA

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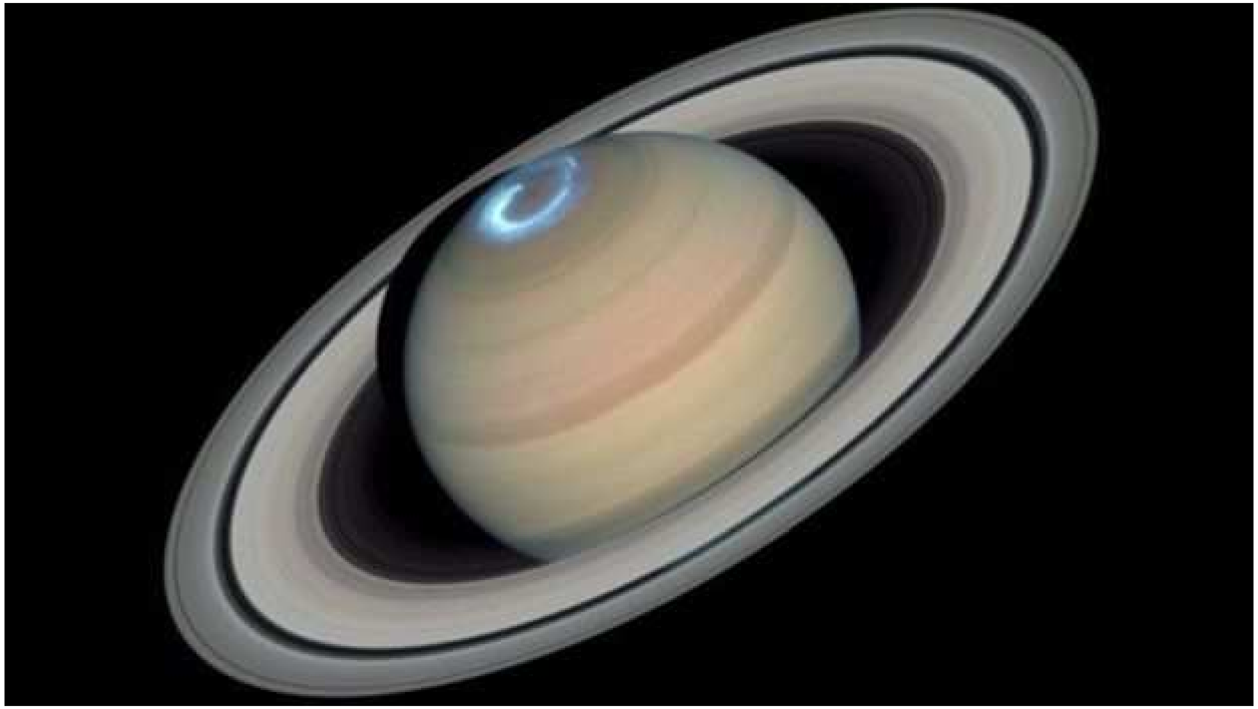
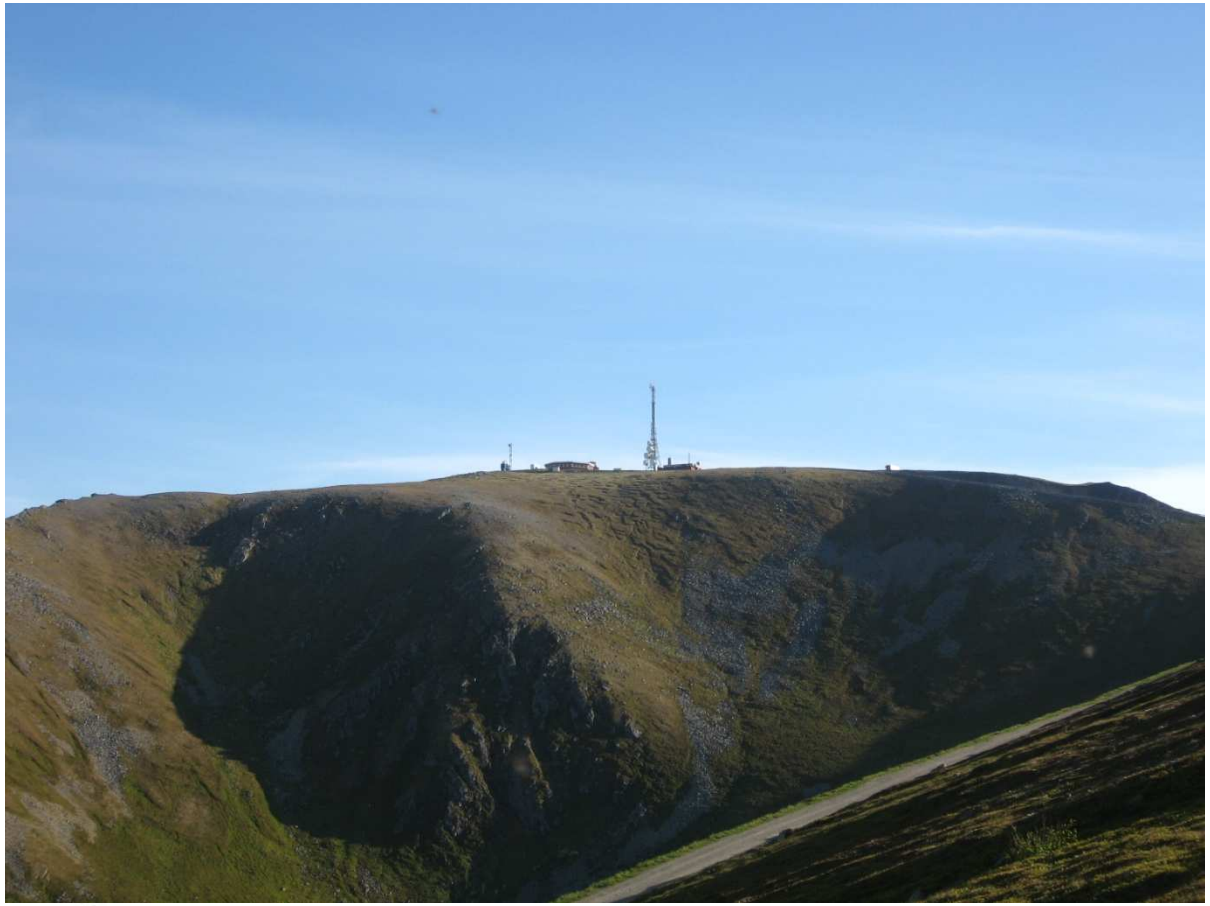
Polar light on Saturn

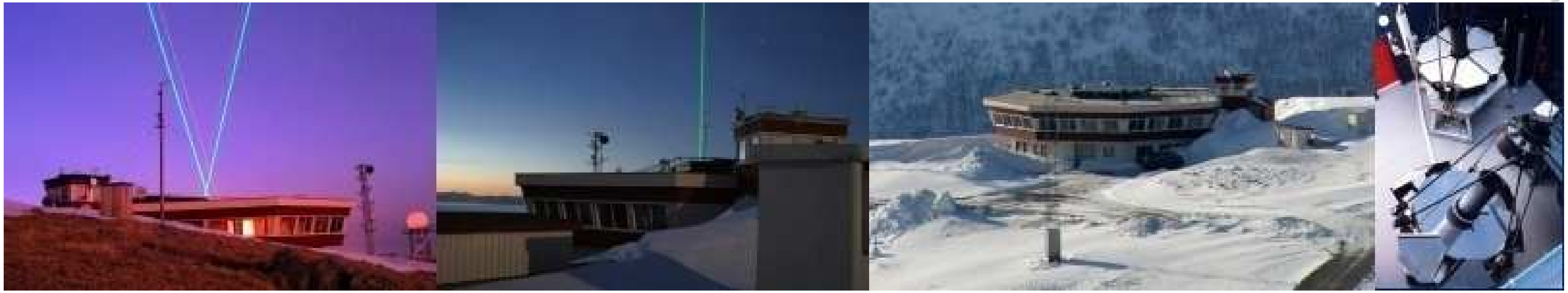


Credit: NASA

Alomar - Andøya



Alomar



Northern light over Alomar

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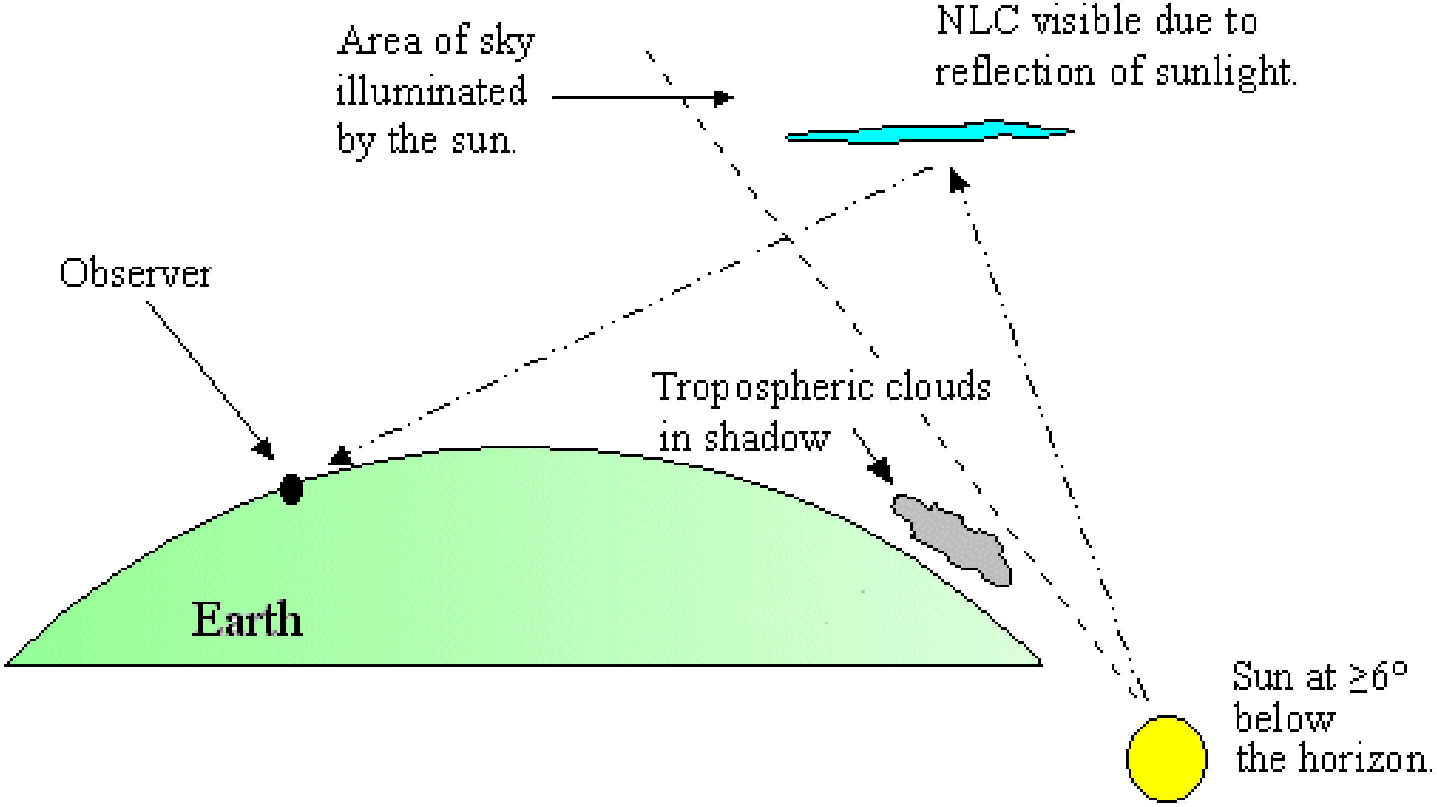
Noctilucent clouds

Geometry



http://science.nasa.gov/headlines/y2003/19feb_nlc.htm

Noctilucent clouds observed from ISS

ISS017E011632

Noctilucent clouds

- They are the highest clouds in the earth atmosphere
- Observed in the summer months from between 50º and 70º latitude south and north of the equator
- Increasing number of observations
- Composed of tiny crystals of water ice 40 to 100 nanometers in diameter
- Exist at a height of about 76 to 85 kilometers
- Formed from water condensing on the surface of dust particles
- The sources of both the dust and the water vapour in the upper atmosphere are not known with certainty
- The dust is believed to come from micrometeors, although volcanoes and dust from the troposphere are also possibilities
- The moisture could be lifted through gaps in the tropopause, as well as forming from the reaction of methane with hydroxyl radicals in the stratosphere
- The exhaust from Space Shuttles, which is almost entirely water vapour, has been found to generate individual clouds. About half of the vapor is released into the thermosphere, usually at altitudes of 103 to 114 kilometers. This exhaust can be transported to the Arctic region in little over a day, although the exact mechanism of this very high-speed transport is unknown. As the water migrates northward, it falls from the thermosphere down into the colder mesosphere.

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http://en.wikipedia.org/wiki/Noctilucent_cloud

Temperature inversion

As the mesosphere contains very little moisture, approximately one hundred millionth that of air from the Sahara desert, the ice crystals can only form at temperatures below about −120 °C. This means that noctilucent clouds form predominantly during summer when, counterintuitively, the mesosphere is coldest. Noctilucent clouds form mostly near the polar regions, because the mesosphere is coldest there. Clouds in the southern hemisphere are about 1 km higher up than those in the northern hemisphere.

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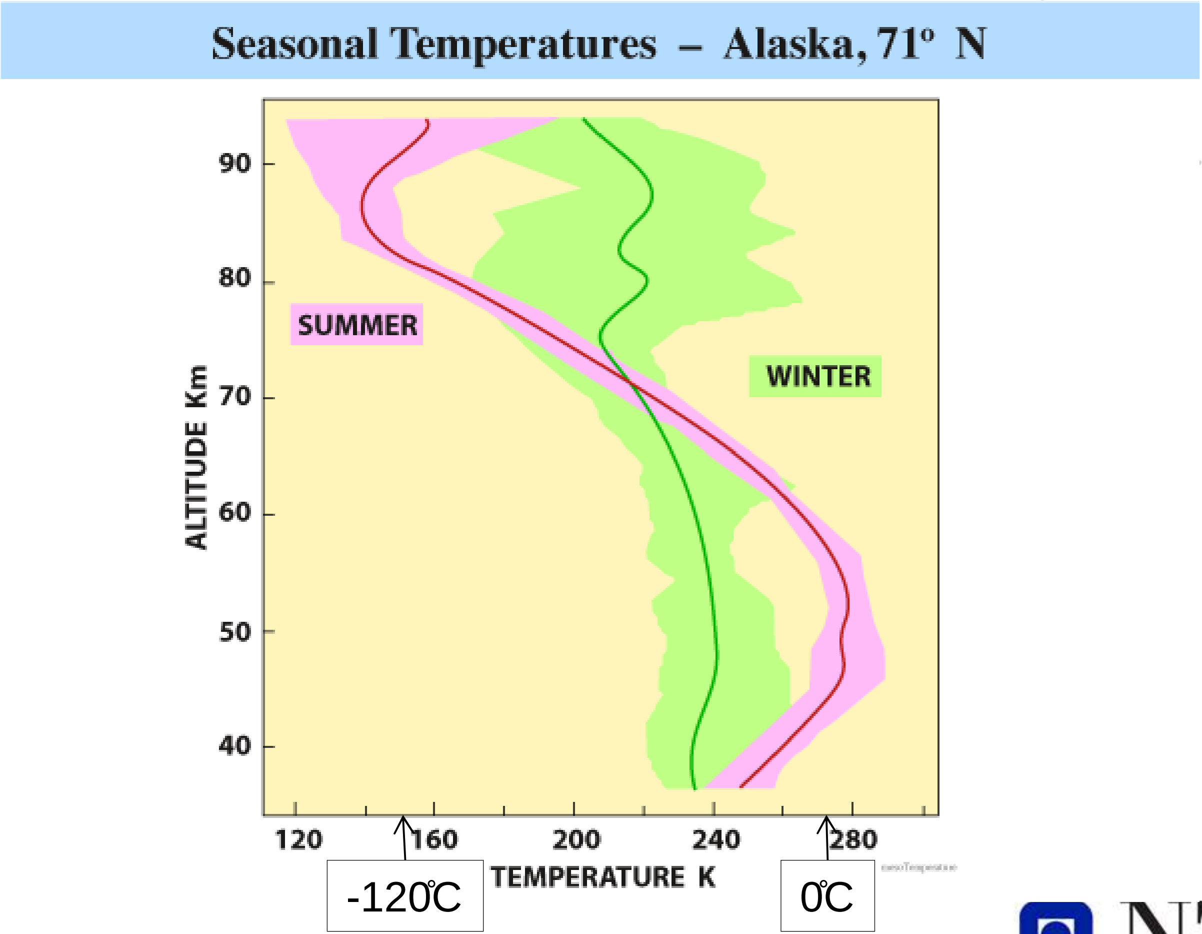
Temperature inversion



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Other mysteries

- Ultraviolet radiation from the Sun breaks water molecules apart, reducing the amount of water available to form noctilucent clouds. The radiation is known to vary cyclically with the solar cycle and satellites have been tracking the decrease in brightness of the clouds with the increase of ultraviolet radiation for the last two solar cycles. It has been found that changes in the clouds follow changes in the intensity of ultraviolet rays by about a year, but the reason for this long lag is not yet known.
- Noctilucent clouds are known to exhibit high radar reflectivity, in a frequency range of 50 MHz to 1.3 GHz. This behavior is not well understood but Caltech's Prof. Paul Bellan has proposed a possible explanation: that the ice grains become coated with a thin metal film composed of sodium and iron, which makes the cloud far more reflective to radar. Sodium and iron atoms are stripped from incoming micrometeors and settle into a layer just above the altitude of noctilucent clouds, and measurements have shown that these elements are severely depleted when the clouds are present. Other experiments have demonstrated that, at the extremely cold temperatures of a noctilucent cloud, sodium vapor can rapidly be deposited onto an ice surface.

Website presentation

The ALOMAR Observatory (69 16 42 N, 16 00 31 E, elev. 380 m) is a modern facility where scientific groups from 6 nations are investigating in atmosphere research. At the same time ALOMAR is responsible for all ground based instrumentation of the Andøya Rocket Range The ALOMAR instrumentation covers all atmospheric layers from the troposphere to the lower thermosphere. Additional instruments looking at physical parameters in the ionosphere, magnetosphere and auroral oval are making ALOMAR a full size atmospheric laboratory in the arctic.

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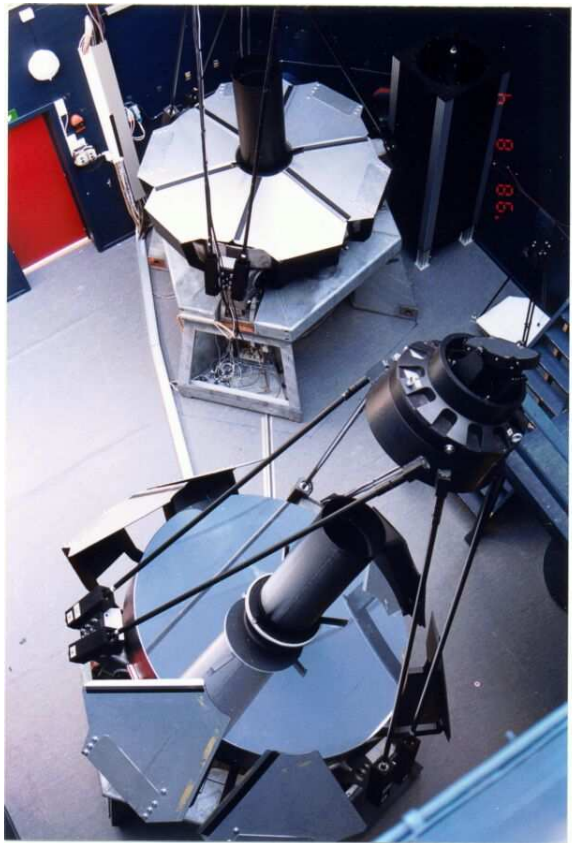
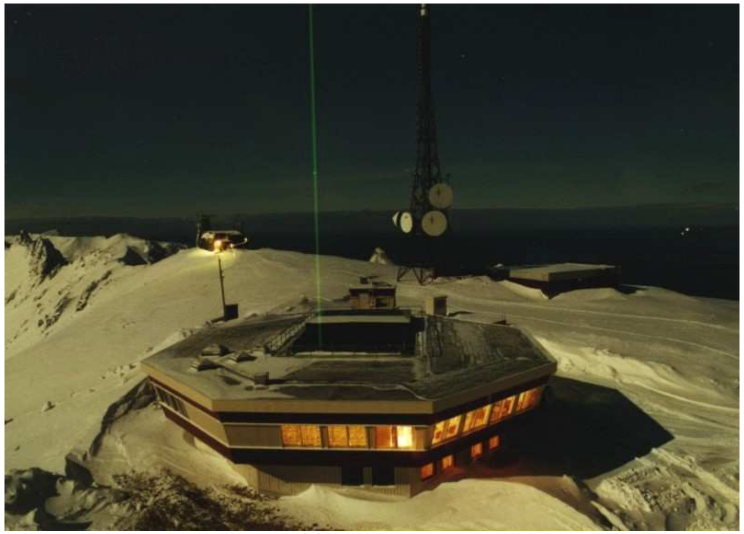
http://alomar.rocketrange.no/

LIDAR for noctilucent cloud studies



RMR LIDAR (**R**ayleigh, **M**ie, and **R**aman scattering Light Detection and Ranging)



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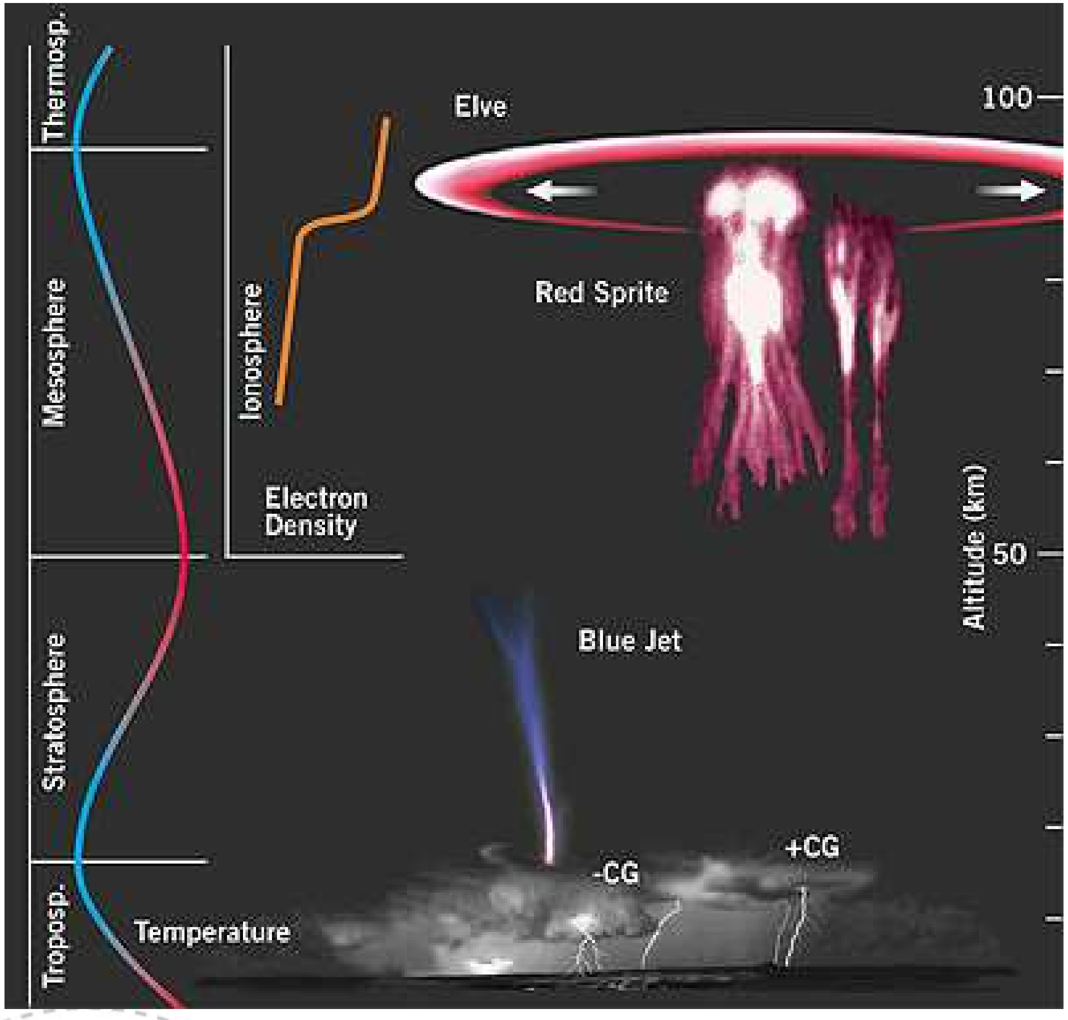
Applications

- RMR – Noctilucent clouds
- Ozone profile
- Sodium density
- Troposphere Lidar
- Radars – for Andøya rocket range
- Other equipment

Terrestrial Gamma Flashes



Sprites are large-scale electrical discharges that occur high above a thunderstorm cloud, giving rise to a range of visual shapes. They are triggered by the discharges of positive lightning between the thundercloud and the ground.
The phenomena were named after the mischievous sprite (air spirit) Puck in Shakespeare's *A Midsummer Night's Dream*.
They often occur in clusters, lying 50 to 90 kilometres above the Earth's surface.
Sprites have been mentioned as a possible cause in otherwise unexplained accidents involving high altitude vehicular operations above thunderstorms.

Blue jets differ from sprites in that they project from the top of the cumulonimbus above a thunderstorm, typically in a narrow cone, to the lowest levels of the ionosphere 40 to 80 km above the earth. They are also brighter than sprites and, as implied by their name, are blue in colour.

ELVES often appear as dim, flattened, circular in the horizontal plane, expanding glows around 400 km in diameter that last for, typically, just one millisecond.
They occur in the ionosphere about 100 km above the ground over thunderstorms. Their color was a puzzle for some time, but is now believed to be a red hue. Elves is an acronym for **E**missions of **L**ight and **V**ery Low Frequency Perturbations from **E**lectromagnetic Pulse **S**ources.
This refers to the process by which the light is generated; the excitation of nitrogen molecules due to electron collisions (the electrons possibly having been energized by the electromagnetic pulse caused by a discharge from the Ionosphere).

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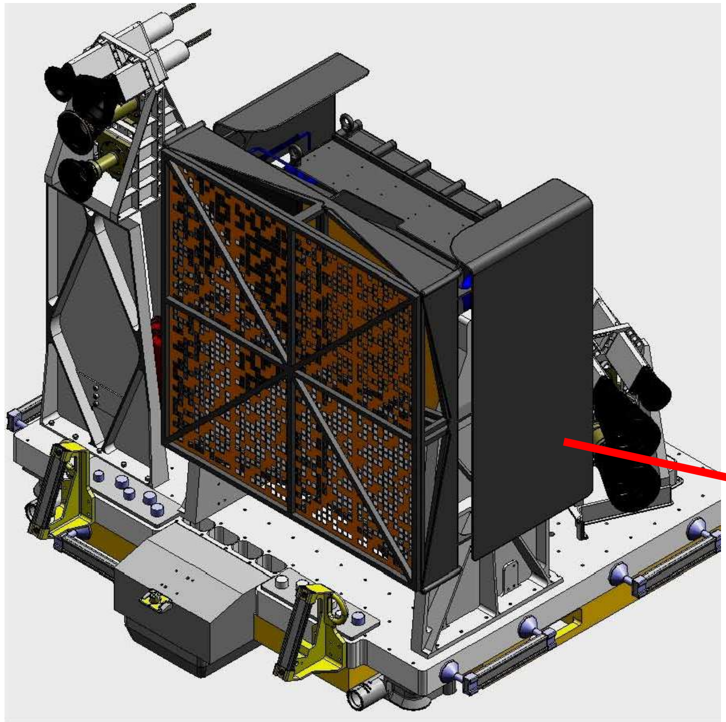
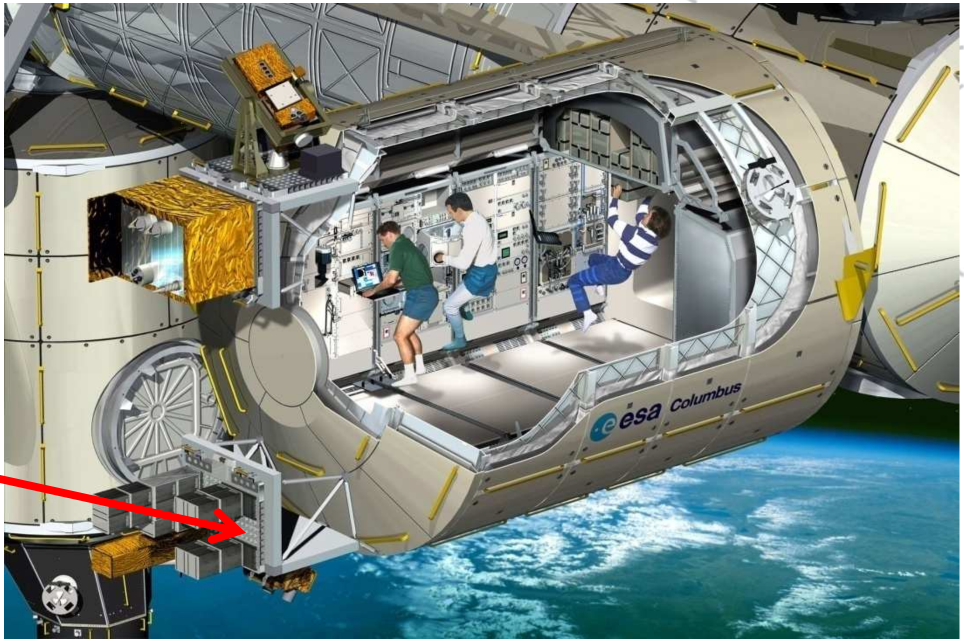
http://en.wikipedia.org/wiki/Lightning

ASIM from UiB on ISS

The goal is to understand the connection between lightening and gamma flashes. How common they are, and how important they are.





Atmosphere Space Interaction Monitor

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Courtesy of Professor Nikolai Østgaard, UiB

Positrons and relativistic electrons

- Relativistic particles are feeding the Van Allen belts
- This is a newly discovered (1992) source of particle transfer from Earth to space
- Typical duration < 1 ms
- Energic photons with energy above 40 MeV
- The gamma flashes are produced below 20 km altitude

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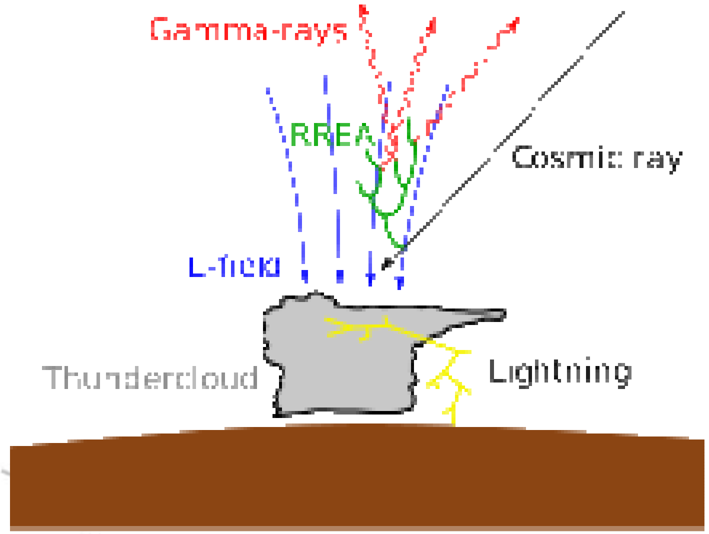
Courtesy of Professor Nikolai Østgaard, UiB

Basic hypothesis

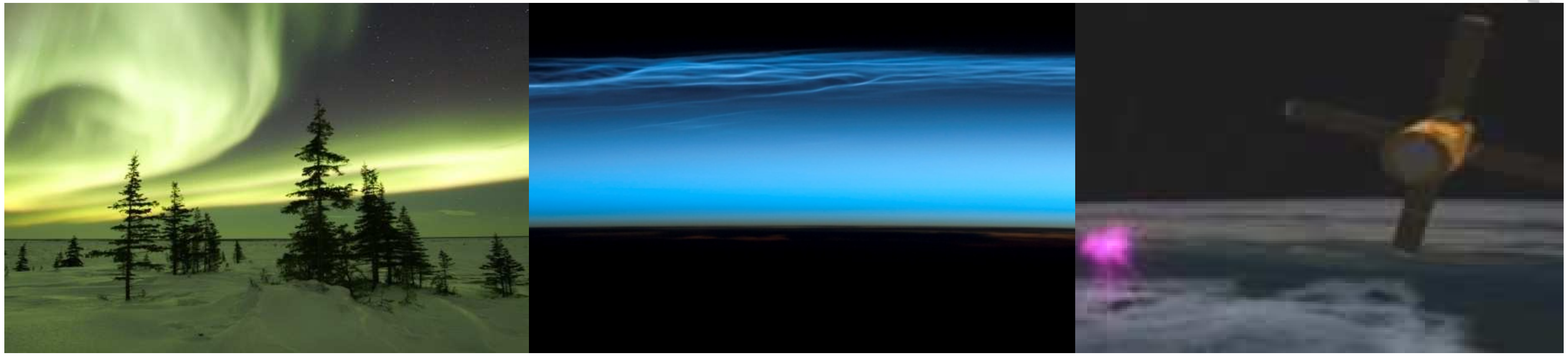
Though the details of the mechanism are uncertain, there is a consensus forming about the physical requirements. It is presumed that TGF photons are emitted by electrons traveling at speeds very close to the speed of light that collide with the nuclei of atoms in the air and release their energy in the form of gamma rays (bremsstrahlung). Large populations of energetic electrons can form by avalanche growth driven by electric fields, a phenomenon called relativistic runaway electron avalanche (RREA). The electric field is likely provided by lightning, as most TGFs have been shown to occur within a few ms of a lightning event (Inan et al. 1996). Beyond this basic picture the details are uncertain.



http://en.wikipedia.org/wiki/Terrestrial_gamma-ray_flash

Conclusion

There is more in heaven and earth……*



….. and we still discover new phenomena and/or explanations

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*Shakespeare's Hamlet to Horatio