

One of the most fascinating phenomena in the dark sky

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**What are they?**

The Northern Lights or Aurora Borealis and Aurora Australis are phenomena, which exist in the sky of the Northern and Southern hemisphere. They can be seen usually in the clear and dark nights

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 **Sun provides light and heat for human** Jyrki Manninen

- We can see the biggest sun spots by naked eyes on the "surface" of the Sun, but there are lots of things outside the visible light



ATTENTION! NEVER LOOK DIRECTLY AT THE SUN WITHOUT A REASONABLE FILTER!

©2009 NASA, ESA, JPL-Caltech, STScI, and the European Space Agency. Image courtesy of NASA, ESA, and the European Space Agency. 2009-10-05

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## Observing the Sun

- The Sun can be observed
  - directly from the ground by optical telescopes (sunspots, flares)
  - by satellites: coronal mass ejections (CME), flares, coronal holes, magnetic field of solar wind, and particle flux
- This is the way to get information in advance about the disturbances that can cause problems in:
  - communication
  - navigation
  - electric power lines
  - gas and oil tubes

**AND AURORA!**

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## Solar activity is changing

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- Sunspot number is commonly used as an activity parameter: Galileo Galilei observed sunspots already 400 years ago
- Activity is changing with 11 years periodicity, and we have just passed a deep minimum

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## We are approaching next maximum soon...

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**The Northern Lights and the solar activity** Jyky Mammien

- The Northern Lights are caused by the particle flux originating from the Sun. This flux is called as solar wind:
  - The properties of solar wind are varying all the time, most important of them are:
    - number of particles (density of the solar wind) 5-10 particles/cm<sup>3</sup>
    - magnetic field orientation in the solar wind
  - the velocity of the particles is in average 500 km/s (varying within 200-1500 km/s)

1 AU = 149 598 000 km  
 e.g. 500km/s → 3.5 days  
 light: about 8min 20s

- The Earth is continuously under the effects of solar magnetic field and particle flux → auroral process is running in the upper atmosphere all the time, and its strengthening is seen as auroral storm

*Aurora* *Sorolla*

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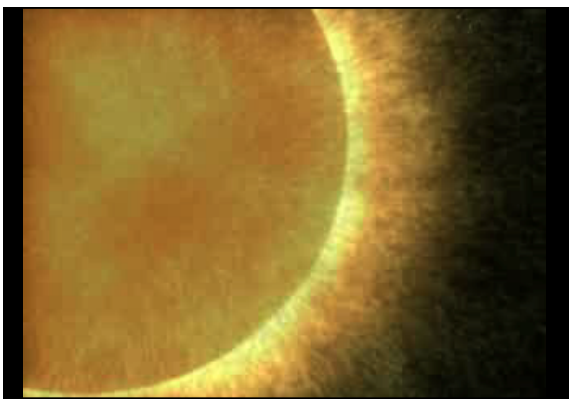
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**Magnetosphere**

Distance from Earth's surface:

- 70 000 km on dayside
- 7 000 000 km on nightside

Dipole field without solar wind

Earth's magnetic field due to solar wind

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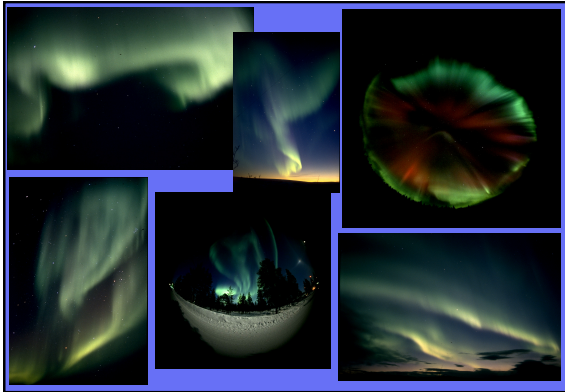
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## The Earth's magnetic field

More than 99 % the magnetic field observed on the ground is caused by electric currents in the outer core of the Earth. This magnetic field is resembling the dipole field.

The Earth's Magnetic Field

Origin of the field is explained by so called dynamo theory.

Slow variation of the field observed on the ground is called as secular variation.

Aurora    Auroras

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## The Earth's magnetic field

Less than 1 % the magnetic field observed on the ground is caused by ionospheric and magnetospheric currents. This field is varying quickly.

Part of these currents is caused by direct radiation from the Sun, another part is driven by the interaction between solar wind and Earth's magnetic field. Latter is depending on the activity of the Sun.

Quick variations (pulsations, magnetic storms): variations have large amplitude and period changes

Aurora    Auroras

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## Magnetic flux density in different parts of the world

SI unit: Tesla  
 $1 \text{ T} = 1 \text{ Vs /Am}^2$   
 Other units in use:  
 $1 \text{ Gauss} = 10^{-4} \text{ T}$   
 $1 \text{ gamma} = 10^{-5} \text{ T}$   
 $1 \text{ Örsted} = 1 \text{ Gauss}$

Nowdays the unit used for magnetic flux density is nT (  $10^{-9} \text{ T}$  ).  
 E.g. F (SOD) ~ 52 200 nT

Aurora    Aurora      

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## Theory of Northern Lights (1)

- Electrons and protons precipitate into the atmosphere. They are guided by the Earth's magnetic field.
- The atmosphere becomes thicker and thicker for the particle.
- The first collisions between particles and atmospheric atoms and molecules can occur already at the altitude of 1000 km.
- The deeper particle will penetrate the probability for collisions with atoms and molecules will increase.
- Atoms and molecules will be excited in the collisions.

Aurora    Aurora   

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## Theory of Northern Lights (2)

- Atom or molecule loose its excitation by emitting light, which is seen as Northern lights.
- Light comes from O and N atoms, N<sub>2</sub> molecules and N<sub>2</sub><sup>+</sup> ions.
- Atmosphere is already at 90 km too thick so that particles could penetrate deeper. This determines the altitude of lower edge of aurora.
- Upper edge can be even at 1000 km altitude.
- Visible thickness is usually less than 50 km.

Aurora    Aurora      

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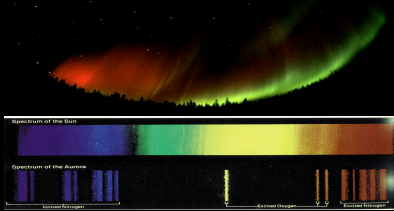
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### Main colours of aurora

- The main colour seen by naked eye is green (or yellow green) from oxygen.
- Deep red colour above green is also coming from oxygen.
- Darker red colour seen in the lower edge of aurora is coming from nitrogen.
- Blue and purple colours seen usually by special equipment are also coming from nitrogen.



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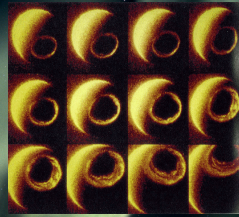
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### Auroral zone

- Auroral zone is like an angel's ring around the magnetic poles



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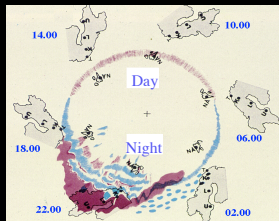
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### Occurrence of aurora

- Northern lights exist a few hundreds of kilometres wide zone about  $\sim 23^\circ$  from Earth's magnetic poles.
- Occurrence rate varies according to solar activity (11 years cycles).
- They exist in Northern Finland during 200 nights per year and in Helsinki during 20 nights per year.
- At the time of magnetic storm they can exist quite far in south: in Middle Europe once or twice per year and in North Africa once per 11 years.



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## Occurrence of aurora

- Probability of occurrence is increasing towards north. Auroral oval is located over the Arctic Ocean every night. During geomagnetic disturbances the oval is spreading southward.
- Attention! When the weather conditions are taken into account the probability will be smaller than shown in the map.

(kartta: Jouni Jussila)

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## Mirror images

Husafell, Iceland

Syowa, Antarctica

Auroras on the Northern and Southern hemispheres are similar but mirror images

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## View from above the aurora

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### Aurora seen from space



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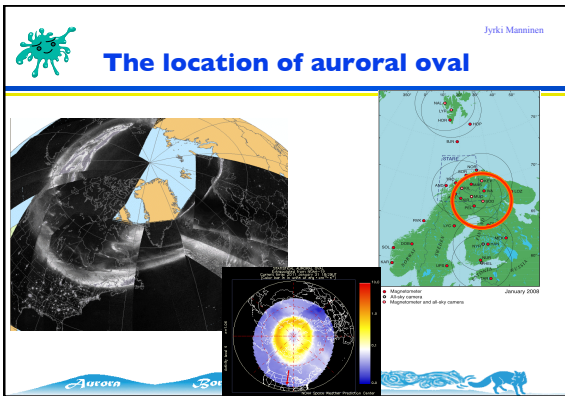
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### Effects of aurora

- Psychological effects on man
- Induced currents
- Disturbances in radio communication
- Radiation problems in space crafts

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### Psychological effects

- Beliefs and stories
- Northern lights are felt as positive experience
- Effects on man's health is negligible



Inuits believe that Aurorae are caused by a football game in the sky where the souls of deaths are playing. They are using the skull of walrus as ball.

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### Other interesting things

- Earth's magnetic field can vary even 4 %
- Strong electric currents even 100 000 – 1 000 000 A
- There are free electrical power 1 000 000 MW (= 1 000 nuclear power stations) ! ! ! !
- Northern lights can affect e.g.:
  - ☞ TV picture
  - ☞ Telecommunications
  - ☞ Power lines
  - ☞ Railways
  - ☞ Welding in gas and oil tubes
  - ☞ SW radio wave broadcasts
  - ☞ Satellites and probes
  - ☞ Finding of minerals
  - ☞ GPS



Aurora
Sarcalis


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## Ancient observations

- Some drawings in the caves made by Cro Magnon man may present aurora.
- There are five descriptions of aurora in Old Testament. The best one is in the book of Ezekiel.
- Observations in Greece about 600-400 B.C.
- In 360 B.C. Byzantium was tried to take, but dogs and additional lights prevented the plans. This 'brought' a crescent of Moon to be appeared in many flags (e.g. Turkey).
- Altogether 55 trusted observations from B.C.


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## History (1)

- In the theory of Aristotle solar radiation caused the ground to evaporate steam. The steam collided with fire element, which was caught and caused aurora.
- There were made several notes about aurora in China already more than 4000 years ago
  - ✓ Aurora did not have own name, but they were described with fire and especially dragon.
  - ✓ The oldest description is about 4600 years old: The Mother of Yellow Empire saw strong lightning rotating around a star named Su of Bei-Dou star constellation, and light illuminated whole landscape. After that she become pregnant.
- When the Roman Empire was destroyed, a silence of a millennium started also in auroral studies.

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## History (2)

- During 17th century aurora got name - Aurora Borealis
  - ✓ Galileo Galilei and his student Guiducci used this name in 1616.
- After 1621 the Northern lights were missing almost a century.
  - ✓ There were no sun spots at all
  - ✓ The weather conditions were also very strange
  - ✓ This period is known as Maunder minimum
  - ✓ Maunder minimum ended violently to strong auroral event on 17th March 1716

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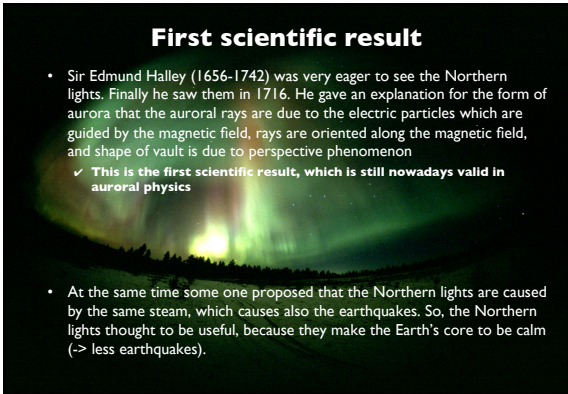
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### First scientific result

- Sir Edmund Halley (1656-1742) was very eager to see the Northern lights. Finally he saw them in 1716. He gave an explanation for the form of aurora that the auroral rays are due to the electric particles which are guided by the magnetic field, rays are oriented along the magnetic field, and shape of vault is due to perspective phenomenon

✓ This is the first scientific result, which is still nowadays valid in auroral physics

- At the same time some one proposed that the Northern lights are caused by the same steam, which causes also the earthquakes. So, the Northern lights thought to be useful, because they make the Earth's core to be calm (-> less earthquakes).



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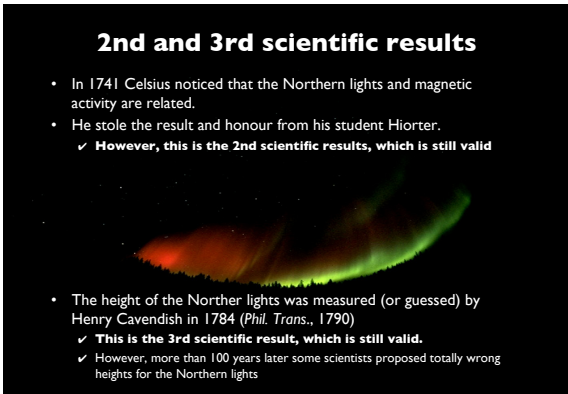
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### 2nd and 3rd scientific results

- In 1741 Celsius noticed that the Northern lights and magnetic activity are related.
- He stole the result and honour from his student Hiorter.  
✓ However, this is the 2nd scientific results, which is still valid

- The height of the Northern lights was measured (or guessed) by Henry Cavendish in 1784 (*Phil. Trans.*, 1790)  
✓ This is the 3rd scientific result, which is still valid.  
✓ However, more than 100 years later some scientists proposed totally wrong heights for the Northern lights



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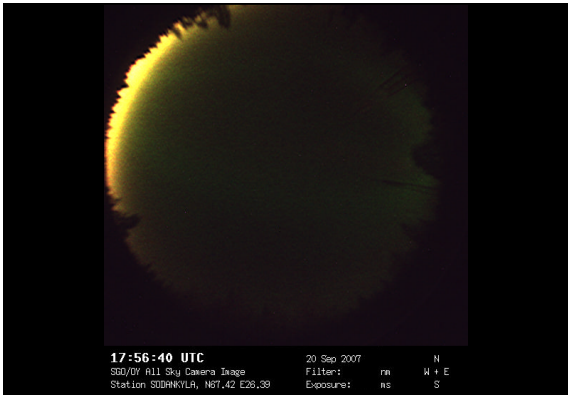
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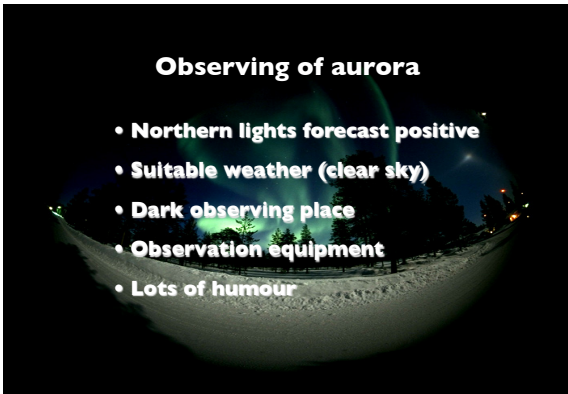
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### Forecasting

- Active events on the "surface" of the Sun are observed immediately, but solar wind bring the particles within 2-3 days on the Earth  
-> Occurrence of aurora can be forecasted
- There are lots of forecasts in the Internet (e.g.):
  - Space Environment Center ([www.swpc.noaa.gov/forecast.html](http://www.swpc.noaa.gov/forecast.html))
  - SpaceWeather.com ([spaceweather.com](http://spaceweather.com))
  - Solar Terrestrial Activity Report, Jan Alvestad ([www.dxic.com/solar/](http://www.dxic.com/solar/))
- It takes about 27.5 days for one solar rotation and the active areas stay alive about 2-5 solar rotations  
-> active periods may be repeated in 4 weeks
- REMEMBER WEATHER FORECAST !

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### Activity can repeat during several months

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THE NORTHERN LIGHTS CAN REPEAT AFTER 27 DAYS, WHICH IS THE PERIOD OF SOLAR ROTATION

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Space Environment Center  
Report of Solar and Geophysical Activity

Last 75 Daily Reports   Online Data at SEC   Today's Space Weather   Space Weather Now

Jyväskylä Mammion

VI. Geomagnetic Activity Probabilities 09 Feb-11 Nov


A. Middle Latitudes

Active	05/10/10
Minor storm	01/01/01
Major-severe storm	01/01/01

B. High Latitudes

Active	15/15/15
Minor storm	10/15/15
Major-severe storm	05/10/10

**LOOKS BAD!!  
HOWEVER, LOOK AT THE SKY**




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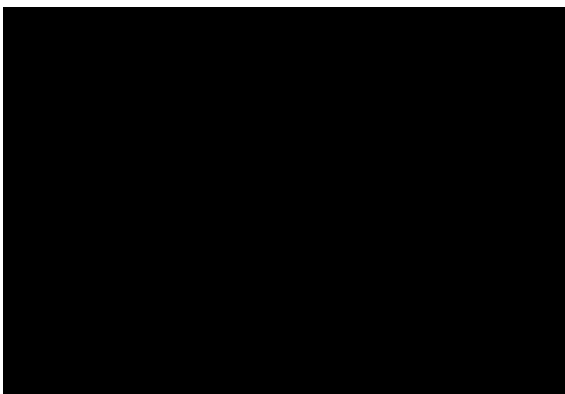
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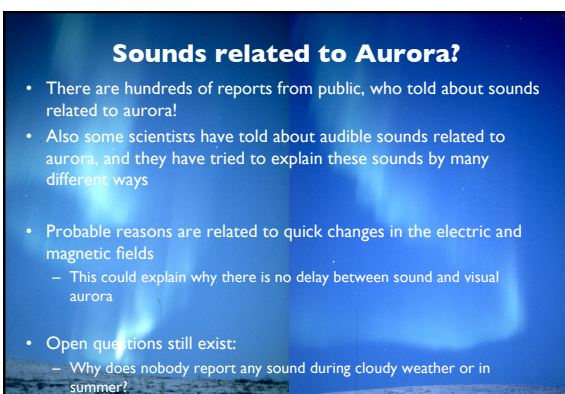
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**Sounds related to Aurora?**

- There are hundreds of reports from public, who told about sounds related to aurora!
- Also some scientists have told about audible sounds related to aurora, and they have tried to explain these sounds by many different ways
- Probable reasons are related to quick changes in the electric and magnetic fields
  - This could explain why there is no delay between sound and visual aurora
- Open questions still exist:
  - Why does nobody report any sound during cloudy weather or in summer?




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## Links

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- In the beginning you can find information about auroral situation:
  - www.sgo.fi -> RealTime
    - here are SGO's real-time magnetograms and auroral all-sky camera pictures during dark time
  - www.spaceweather.com
    - American pages giving the information about space weather and aurora. There are also real-time satellite data to see what is going on just now.
  - http://aurora.fmi.fi/
    - aurora and space weather pages made in cooperation between SGO and FMI (only in Finnish). However, other auroral all-sky cameras can be found here.




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## Some useful literature

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- Martti Rikkonen, The Northern Lights, 1998, (also French, Japanese, Spanish)
- Robert H. Eather, Majestic Lights, 1980
- Harald Falck-Ytter, Aurora, 1983
- Kristian Schlegel, Vom Regenbogen zum Polarlicht, 1995 (in German)
- M.G.J. Minnaert, Light and Color in the Outdoors, 1993
- Neil Bone, The Aurora, Sun-Earth interactions, 1991




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## Contact information

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- **[www.sgo.fi](http://www.sgo.fi)**



**NOTE!**

You can ask whenever and whatever you want,  
I will answer whenever and whatever I want.

*Aurora*

*Sorcellis*



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