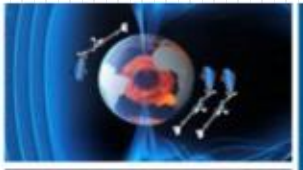
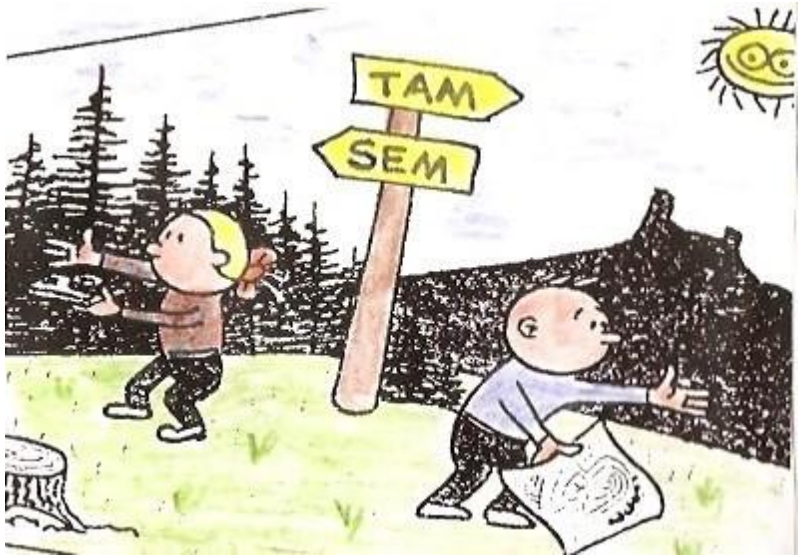




GOOD HOPE
FOR EARTH SCIENCES
27 August - 1 September 2017
Cape Town, South Africa
IAPSO-IAMAS-IAGA

Importance of geomagnetic field for the life on the Earth

Eduard Petrovsky
Inst. Geophys. CAS, Prague 4, Czech Republic

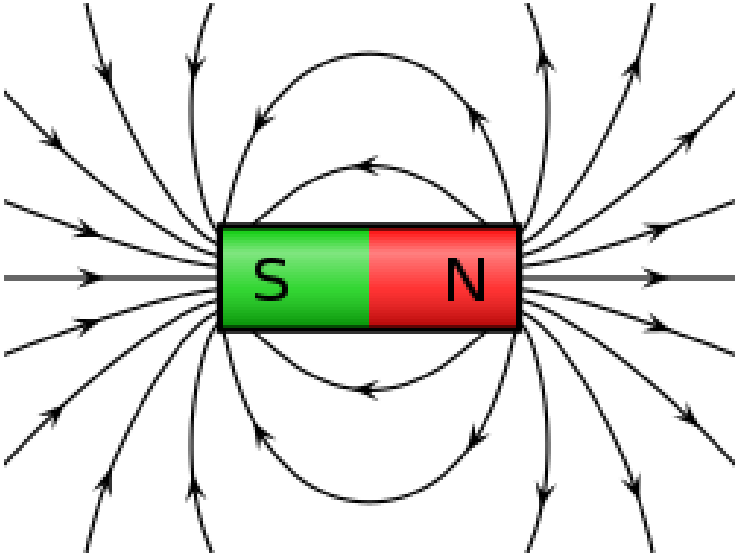
- Humans for ages use geomagnetic field for their orientation (compass needle)
- Lodestone (magnetized piece of magnetite) was known to the ancient Greek philosophers Thales of Miletus and Socrates
- The idea for using it in a compass first appeared in China. A manuscript written in 1040 refers to “an iron fish” suspended in water that pointed to the south. Another reference to a magnetic direction-finding device for land navigation is recorded in a Song Dynasty book dated to 1040-44.
- In 1088 Shen Kuo decsribed experiment with compass and postulated the idea of declination.

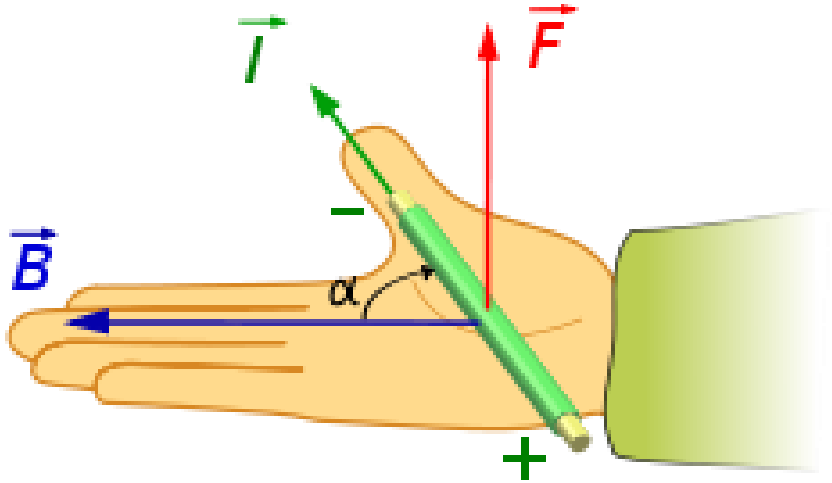


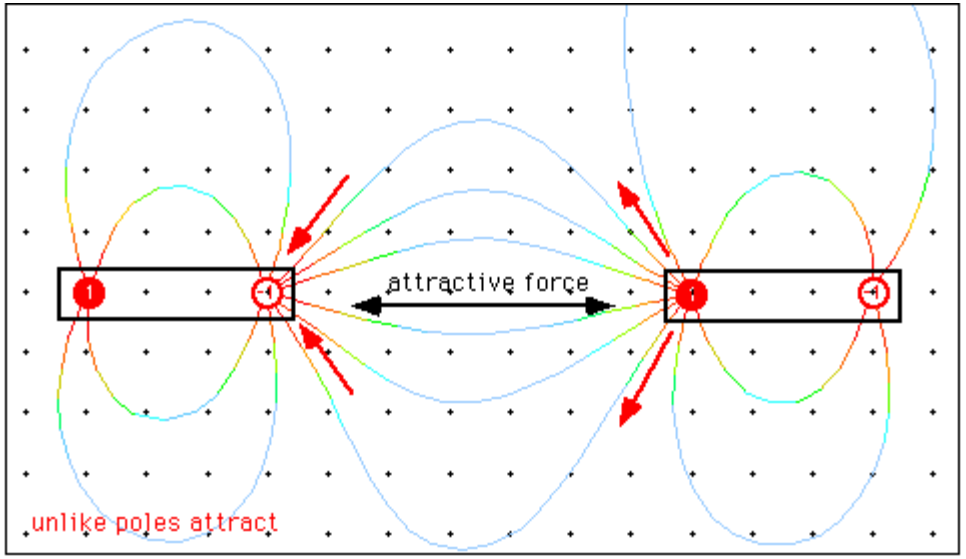

STANDBY COMPASS
RADIO RECEIVERS ON


Compass. S/N : BE1320210
Orig. : LFBO
TO FLY (HB-JHH) STEER
360 360 180 180
030 030 210 210
060 059 240 241
090 089 270 272
120 119 300 303
150 150 330 331
Date : Aug 2010
CALIBRATION WITH
RADIO RECEIVERS ON

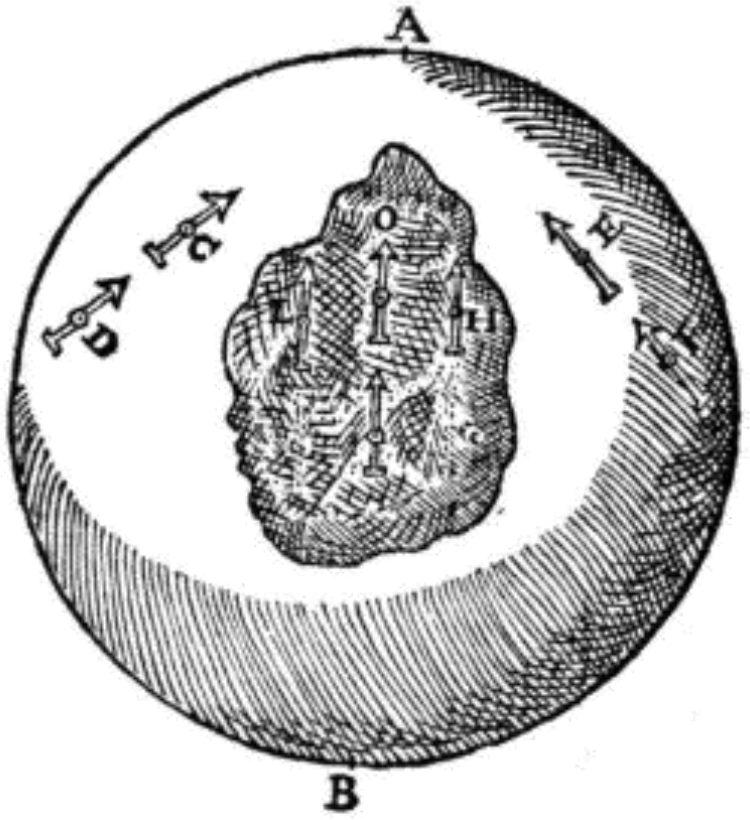
All magnetized objects create in its vicinity (invisible) lines of force, emerging from the north (+) pole, which act by a force on either moving electric charges (Lorentz, or Laplace force) or magnetic moments.

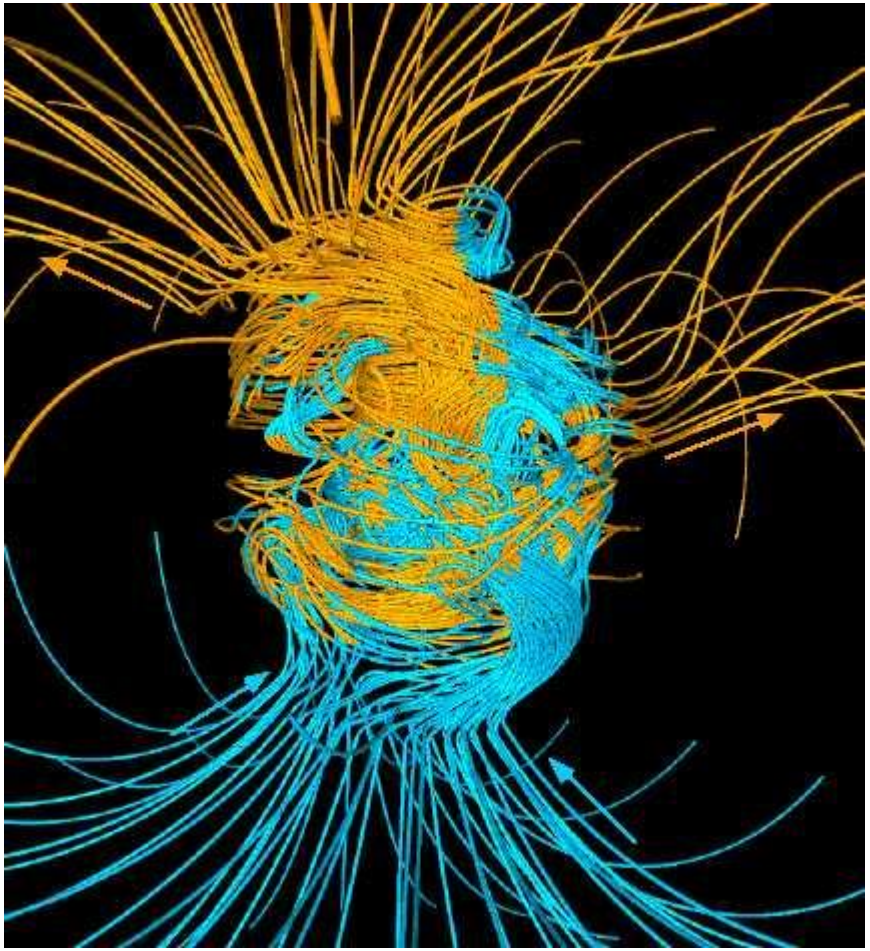


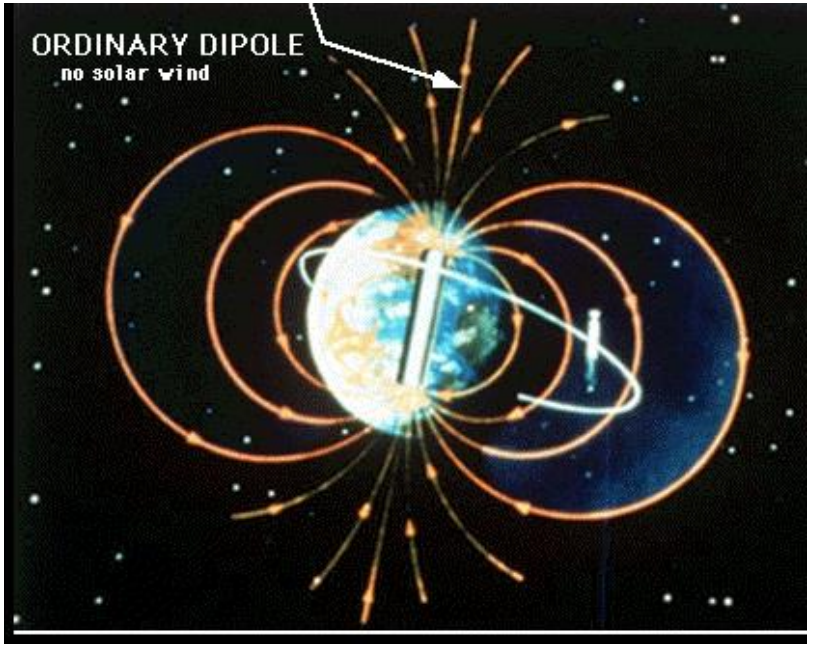


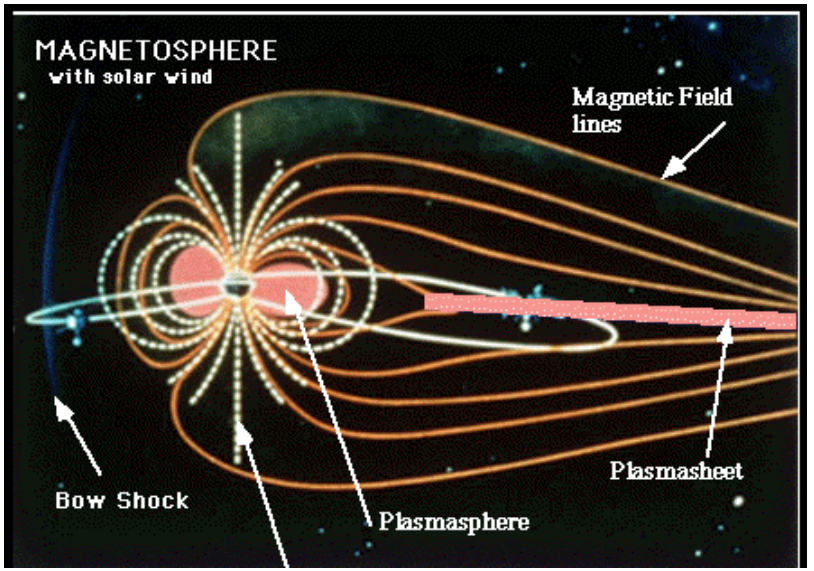


- William Gilbert (Gilberd): *De Magnete, Magneticisque Corporibus, et de Magno Magnete Tellure (On the Magnet and Magnetic Bodies, and on the Great Magnet the Earth)*, 1600
- The Earth was itself magnetic and that this was the reason compasses point north
  - previously, some believed that it was the pole star (Polaris) or a large magnetic island on the north pole that attracted the compass

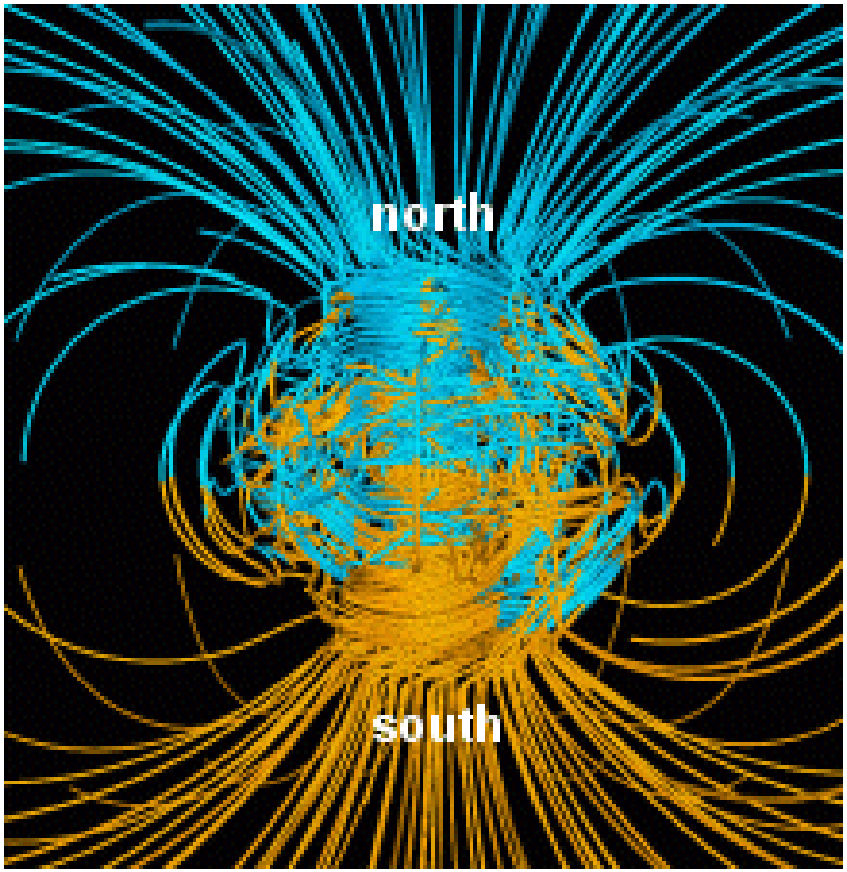


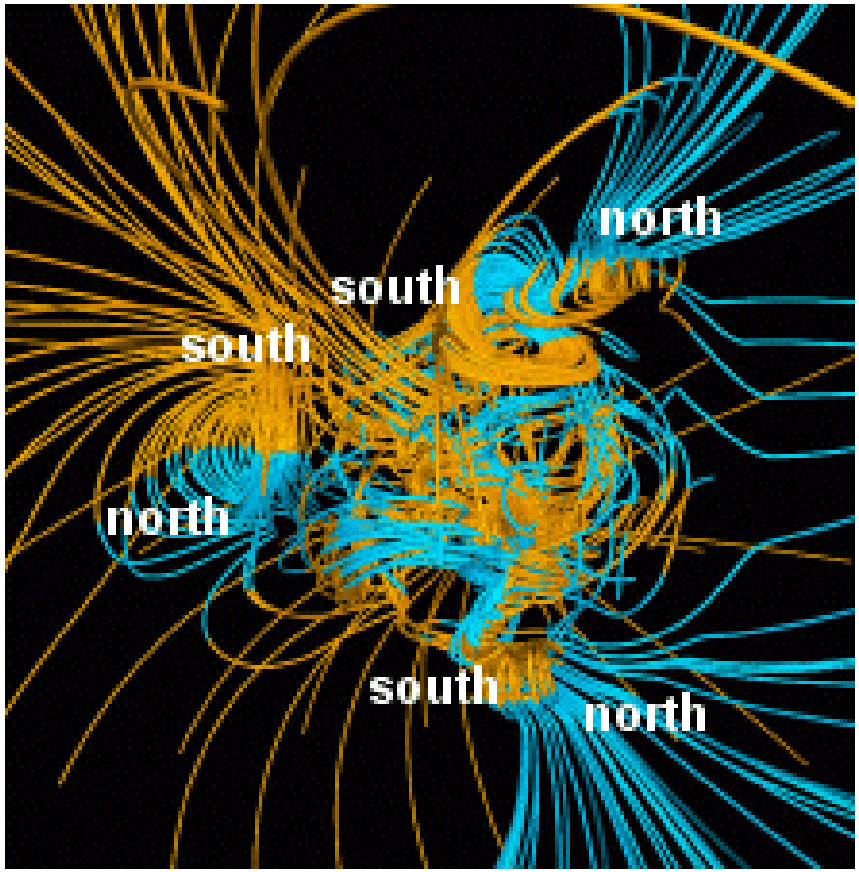



ORDINARY DIPOLE
no solar wind

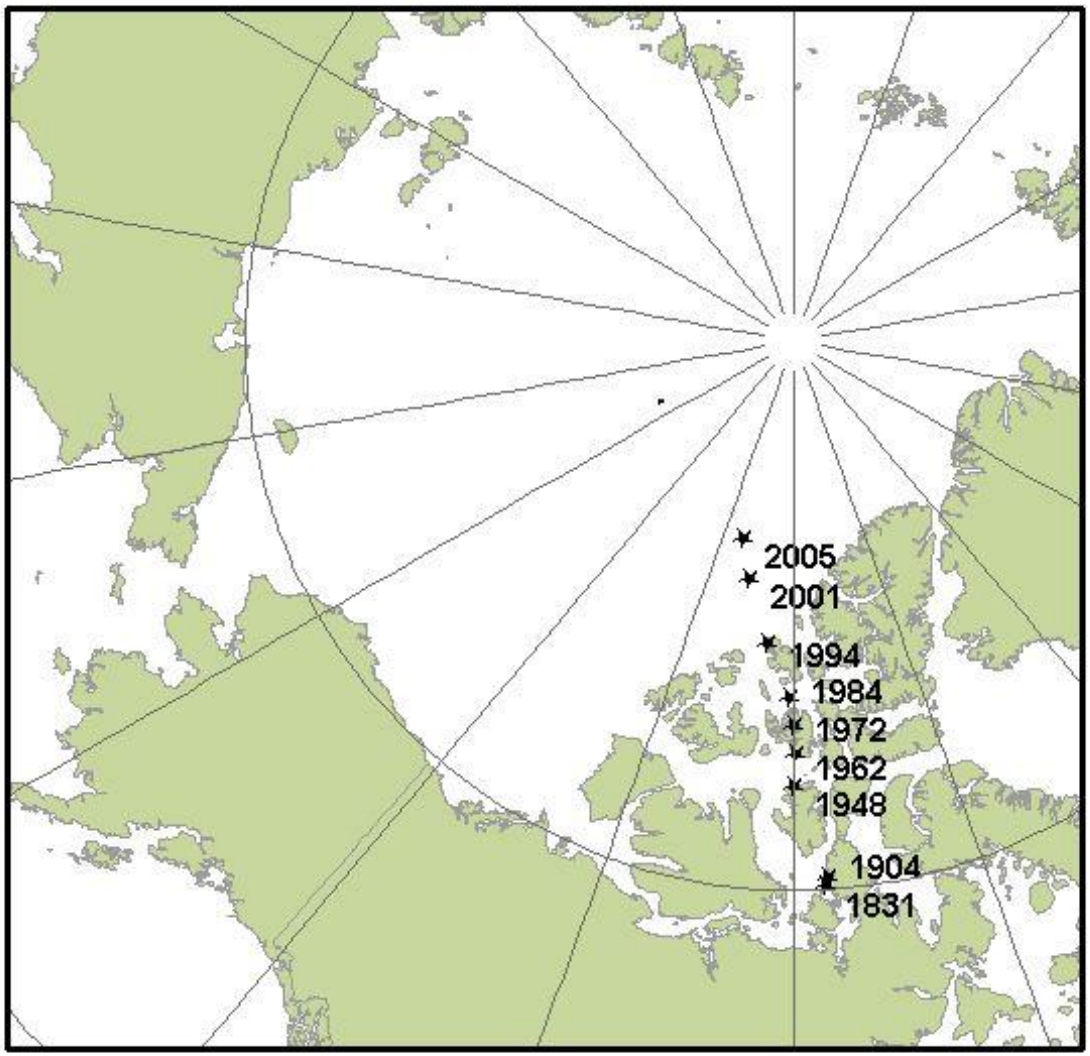

MAGNETOSPHERE
with solar wind
Magnetic Field lines
Plasmasheet
Bow Shock
Plasmasphere

Magnetic field is unstable, dynamic and complex, statistically once in 350000 years it changes its polarity. Last change was 780000 years ago (Brunhes-Matuyama)

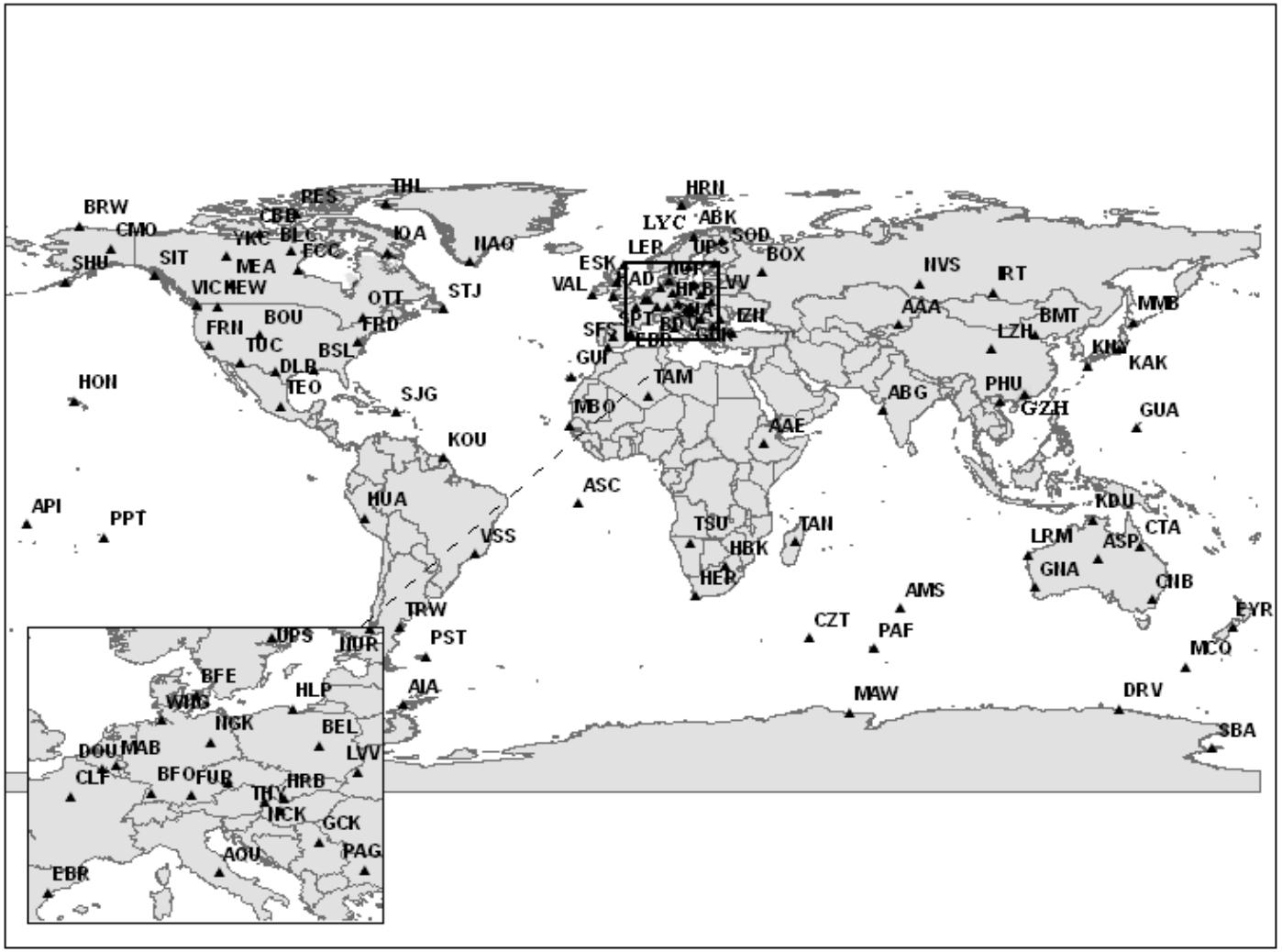


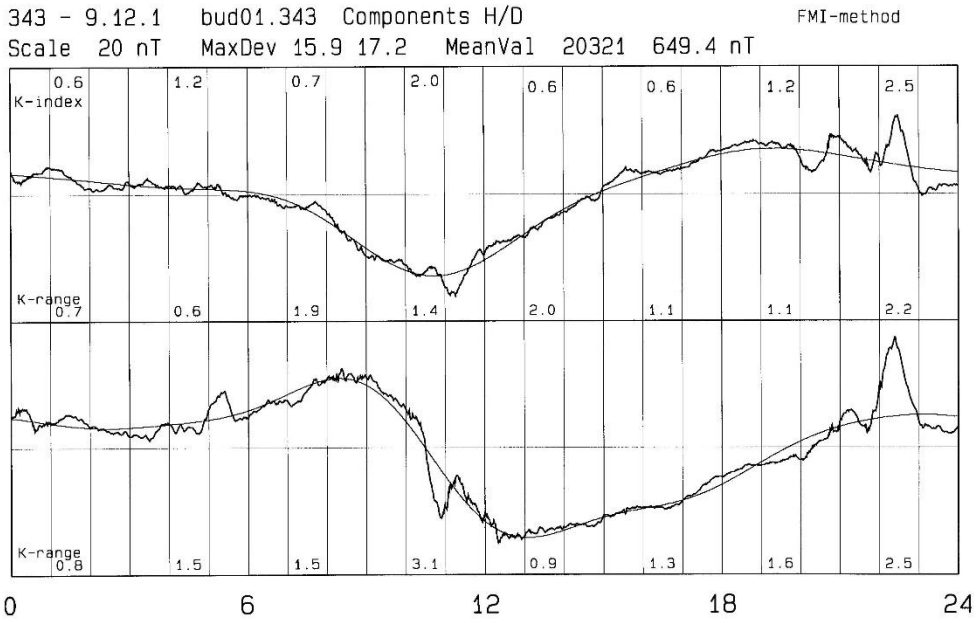


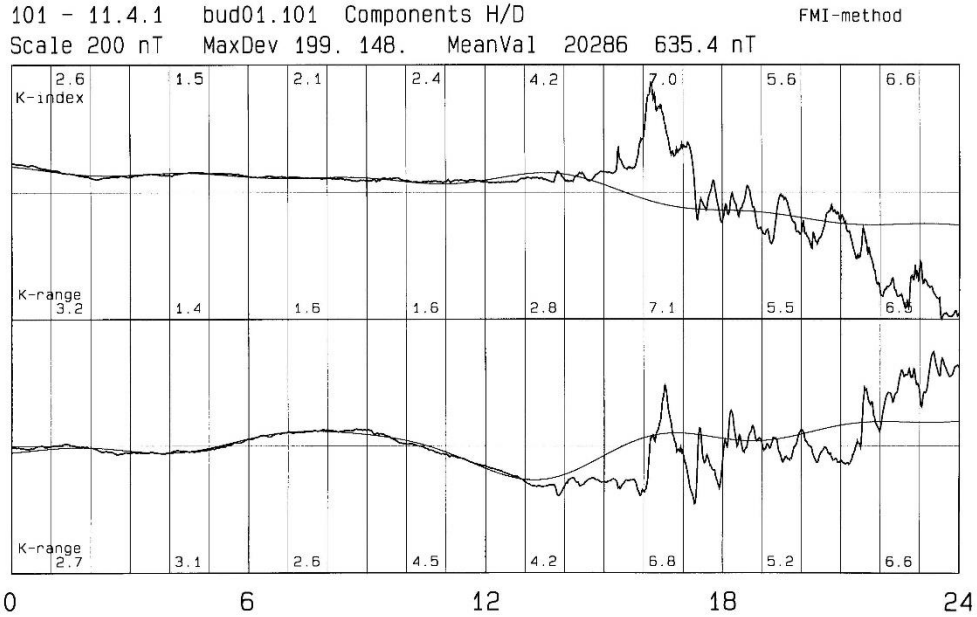
Magnetic poles "travel" also during the "stable" periods



INTERMAGNET – 141 observatoří




343 - 9.12.1 bud01.343 Components H/D
FMI-method
Scale 20 nT MaxDev 15.9 17.2 MeanVal 20321 649.4 nT
K-index
0.6 1.2 0.7 2.0 0.6 0.6 1.2 2.5
K-range 0.7
0.6 1.9 1.4 2.0 1.1 1.1 2.2
K-range 0.8
1.5 1.5 3.1 0.9 1.3 1.6 2.5
0 6 12 18 24


101 - 11.4.1 bud01.101 Components H/D
FMI-method
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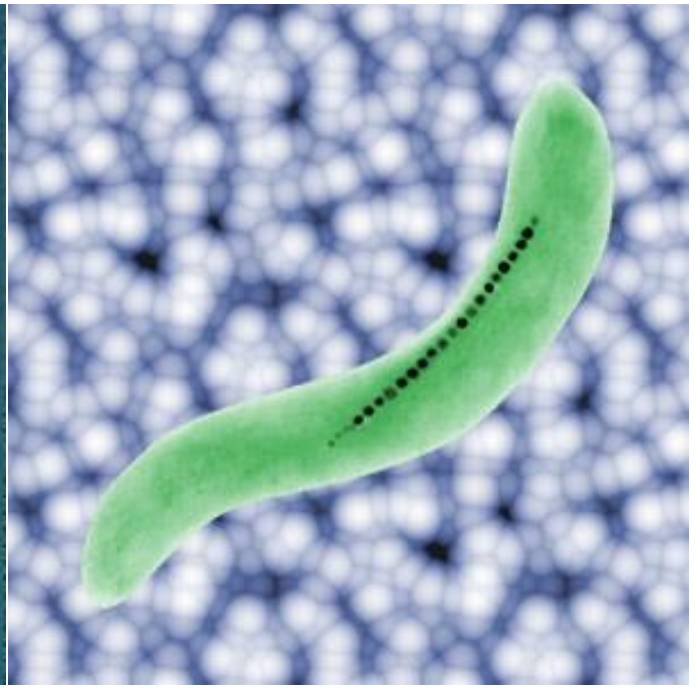
K-index
2.6 1.5 2.1 2.4 4.2 7.0 5.6 6.6
K-range 3.2
1.4 1.6 1.6 2.8 7.1 5.5 6.6
K-range 2.7
3.1 2.6 4.5 4.2 6.8 5.2 6.6
0 6 12 18 24

Why is geomagnetic field important?

- Orientation and navigation
  - Humans – compass
  - Animals – bacteria, migrating birds, vertebrates, …
- Protection of the life on the Earth's surface from harmful radiation and energetic particles from space
- Negative effects
  - Geomagnetic storms
  - Induced currents and voltage
  - Energetic systems, satellites, communication
  - Sensitive individuals
    - Cardiovascular diseases
    - Epilepsy and other CNS diseases

Orientation of livings

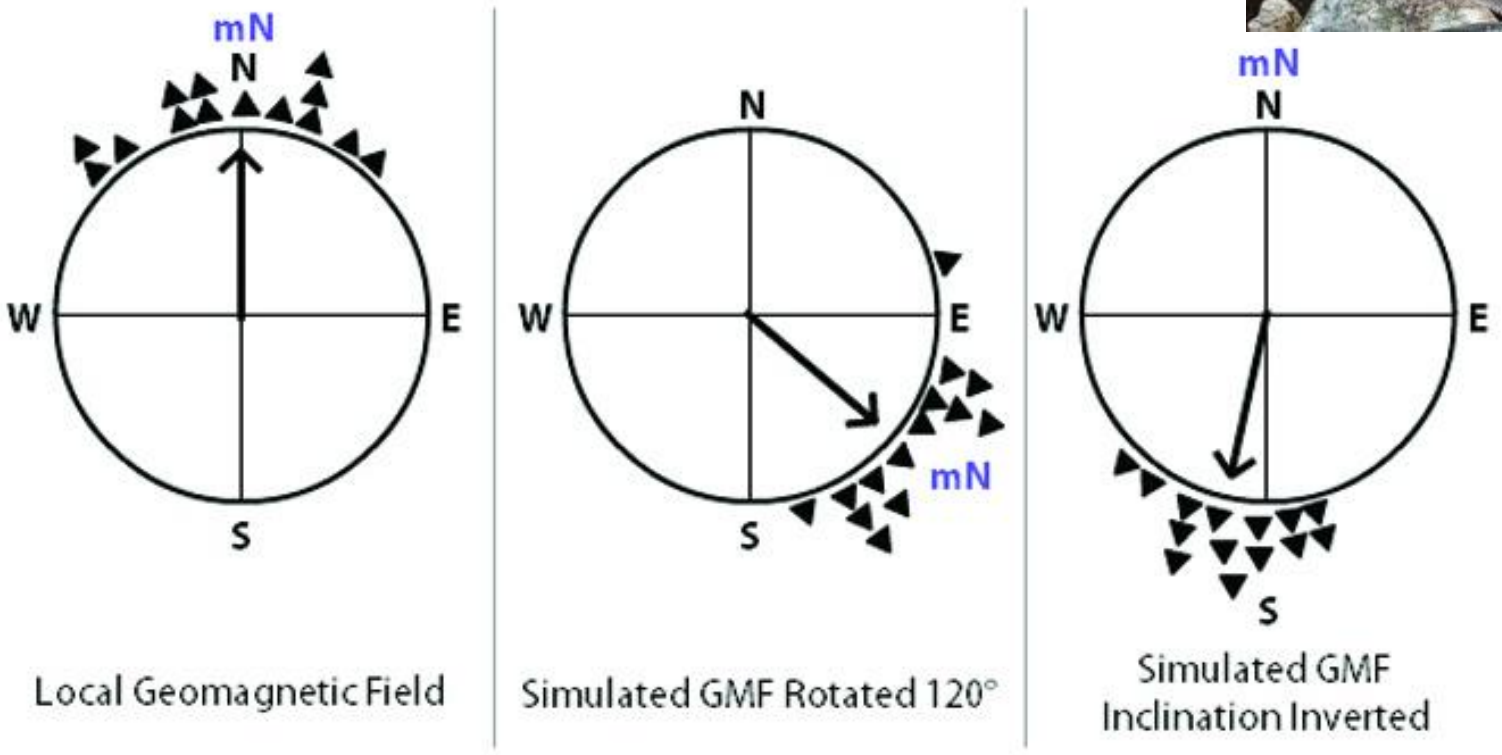
Magnetotactic bacteria – orientation due to chain of single-domain magnetite particles - magnetosomes



Video1, Video2, Video3, Video4

Orientation of animals

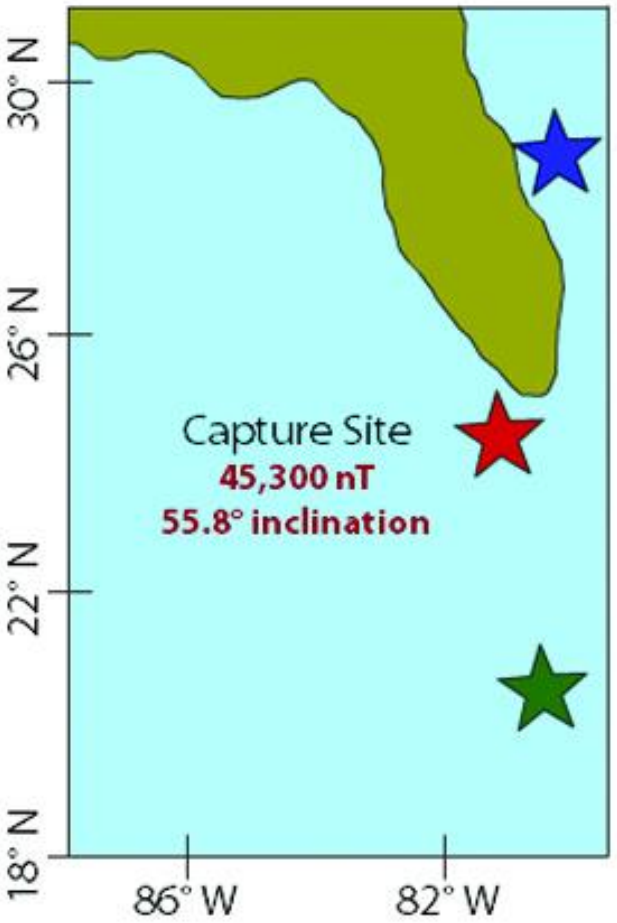
"Inclination compass" – e.g., American robin
Does not work when intensity changes by 20-30%
(Wiltschko and Wiltschko, *Journal of Comparative Physiology, A, 2005*)

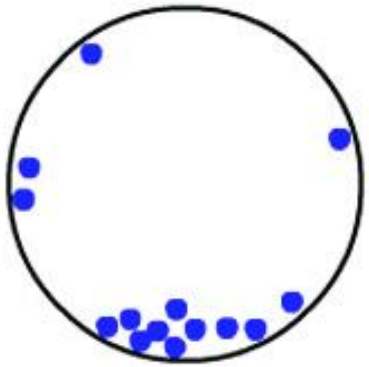


Orientation of animals

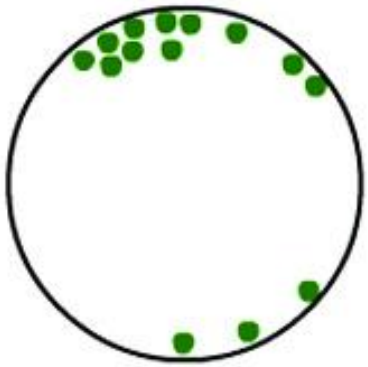
"Geographical orientation" – e.g., lobsters

(Wiltschko and Wiltschko, *Journal of Comparative Physiology, A, 2005*)





Lobster orientation in simulated northern location:
47,900 nT
59.3° inclination

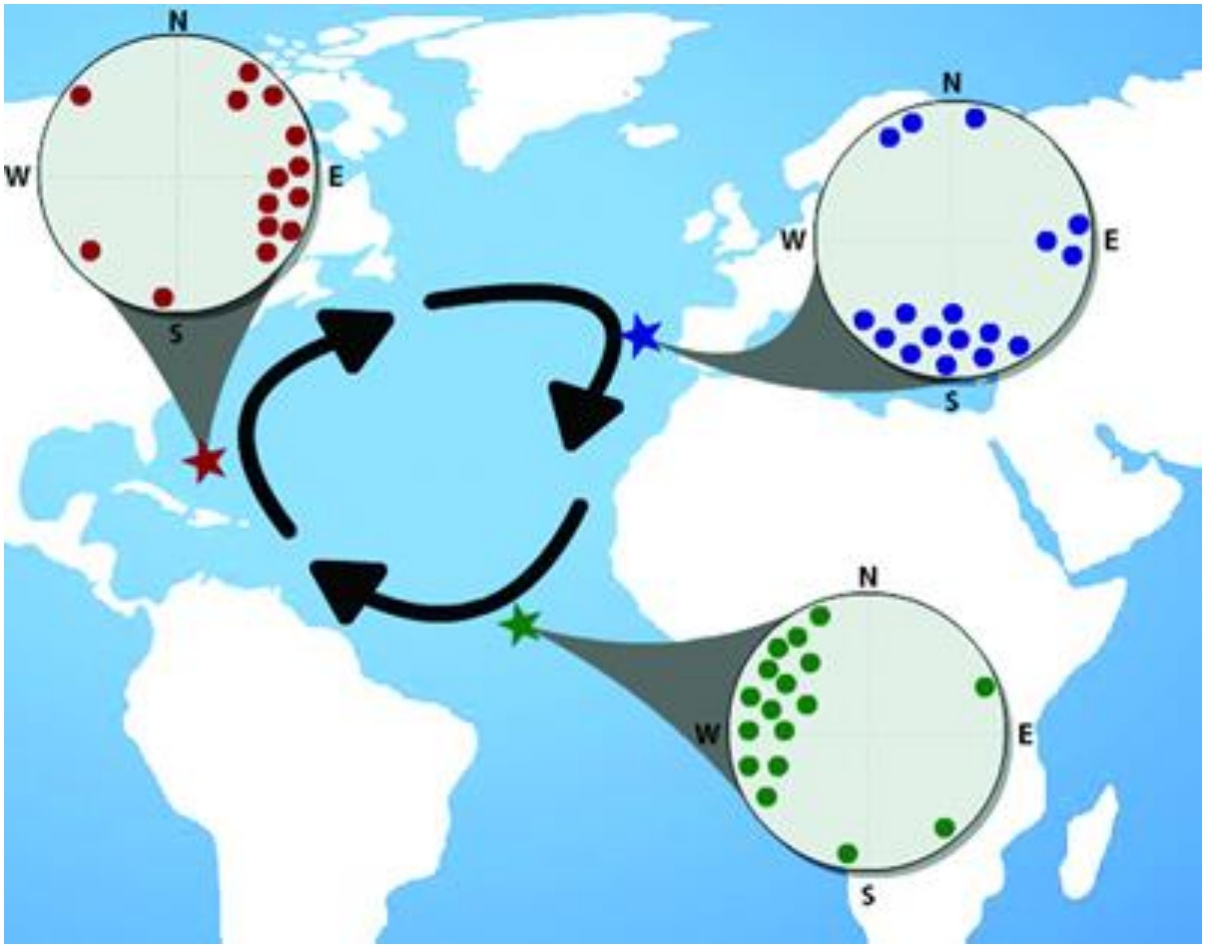


Lobster orientation in simulated southern location:
42,800 nT
51.4° inclination

Orientation of animals

Inherited information – "magnetic map" – juvenile turtles

(Wiltschko and Wiltschko, *Journal of Comparative Physiology, A, 2005*)

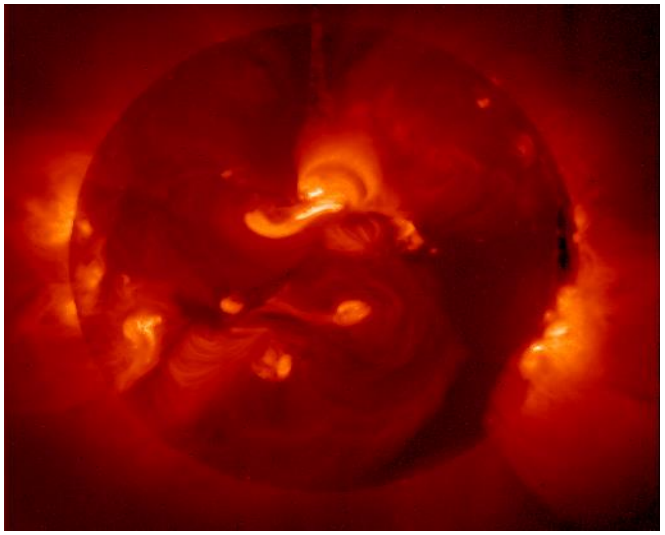


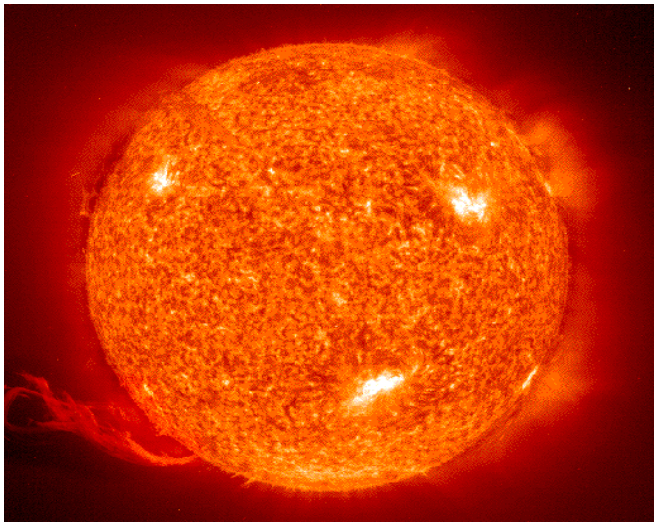
The Sun

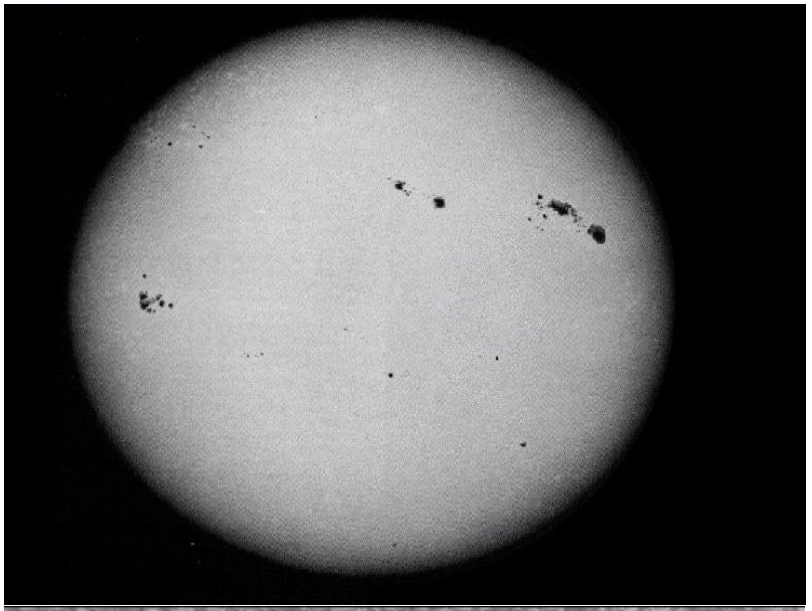
- R = 6.96×10^5 km ≈ 110 x radius of the Earth
- Radius of the core ≈ 0.25 total radius
- Volume 1.3 x 10^6 more then that of the Earth
- M = 1.99×10^{30} kg ≈ 330 000 more then Earth
- Temperature on the surface ≈ 6000°C
- Sun spots – about 4000°C
- Age about 4.5 x 10^9 (billion) years

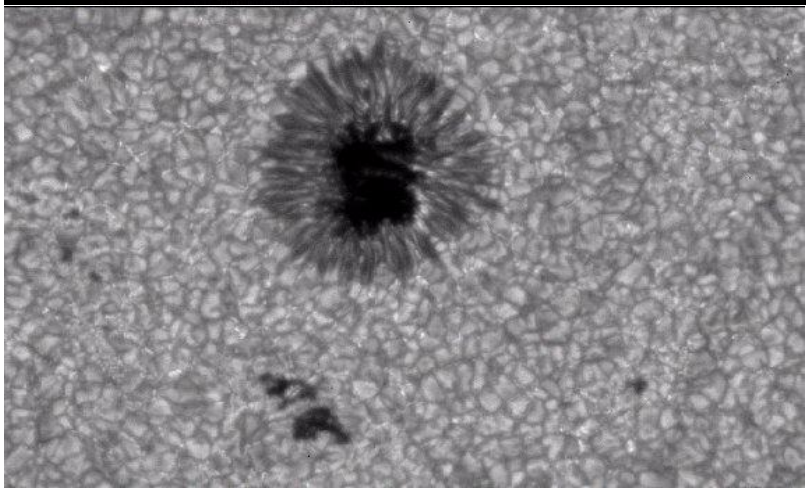
Solar eruptions

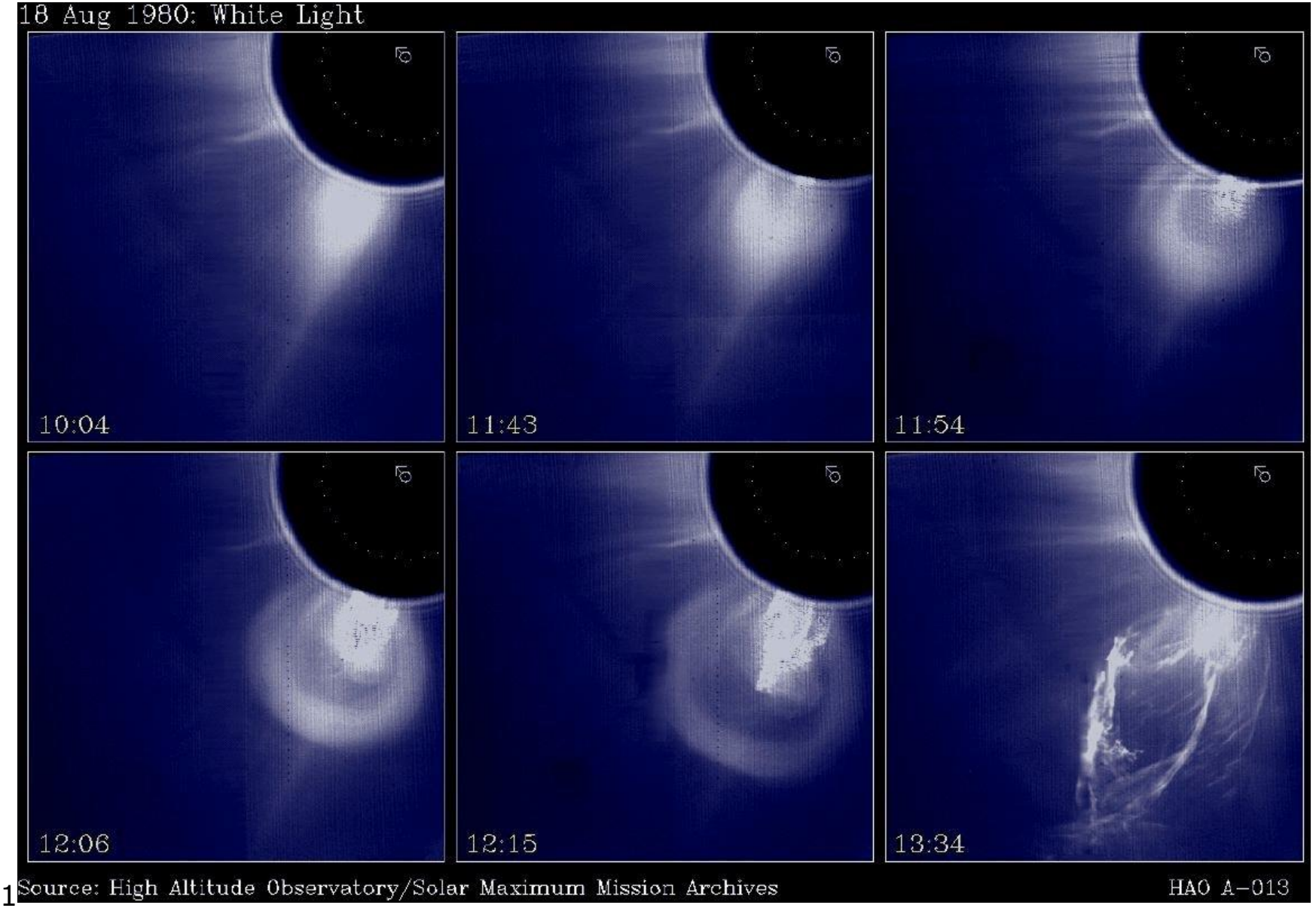
Source of energetic particles and gamma radiation

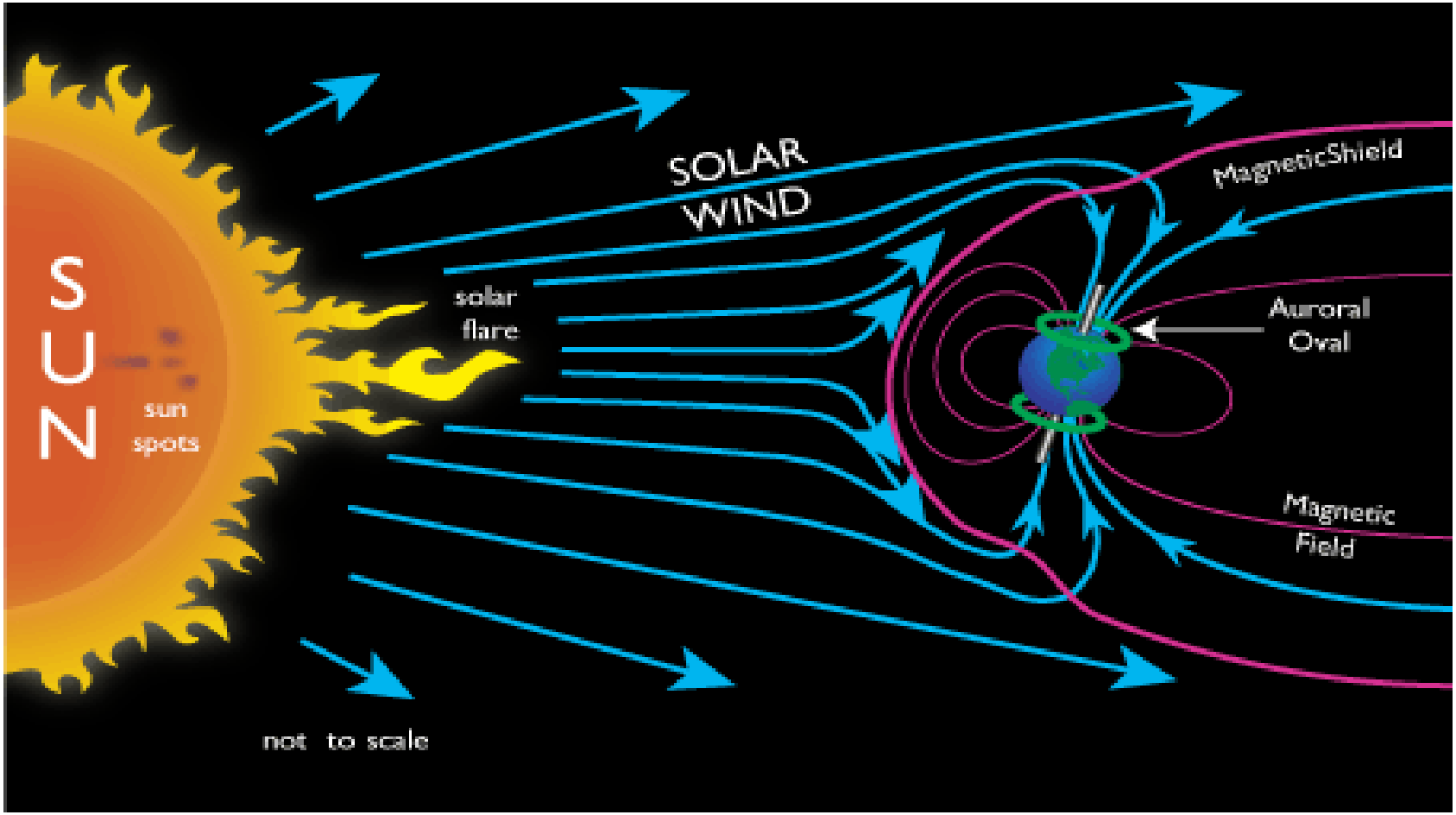






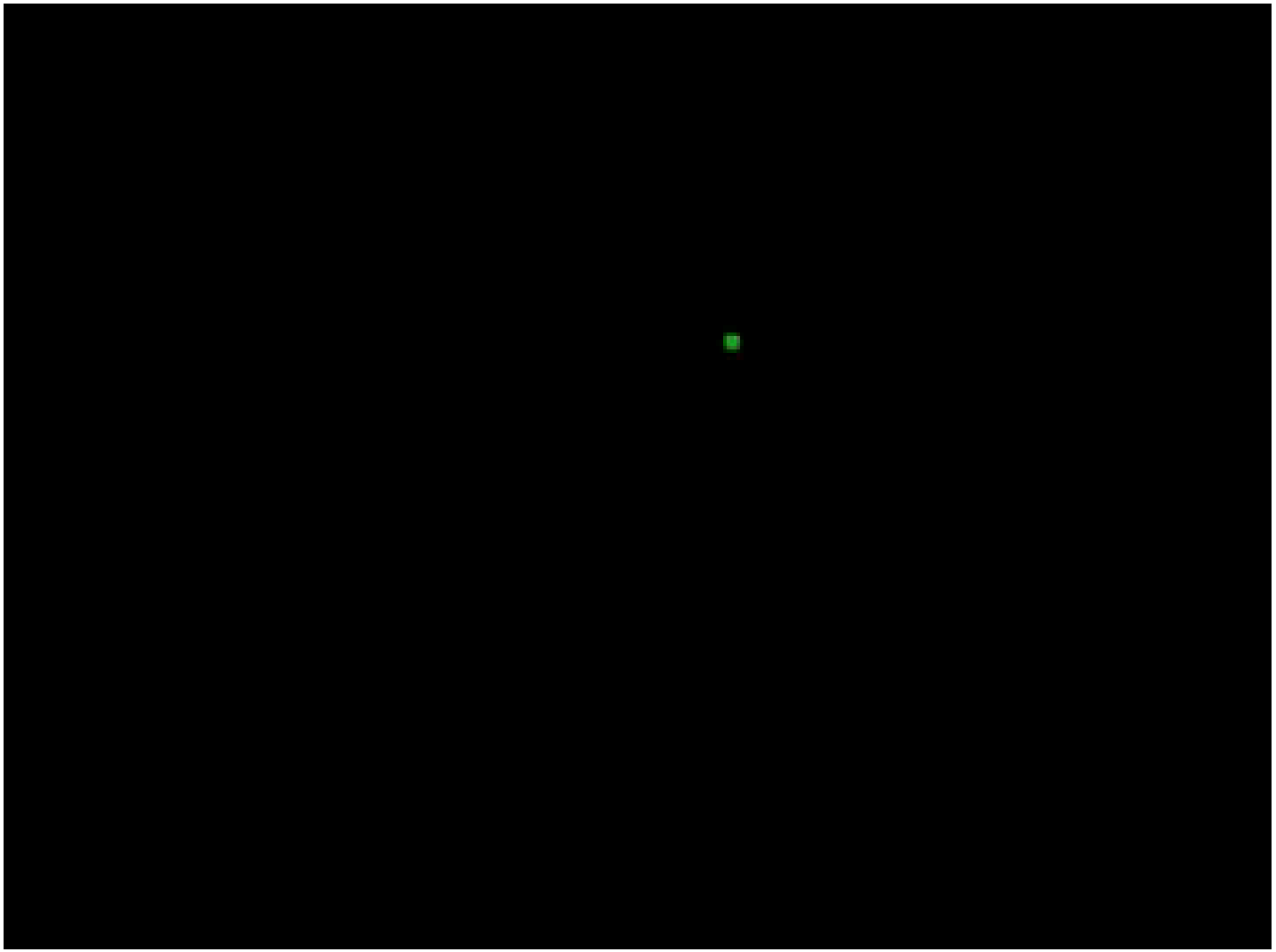



18 Aug 1980: White Light
10:04
11:43
11:54
12:06
12:15
13:34
Source: High Altitude Observatory/Solar Maximum Mission Archives
HAO A-013



Charged particles hit the lines of force of the geomagnetic field like an umbrella and follow these lines. In polar regions interact with molecules of Oxygen and Nitrogen present in the atmosphere.

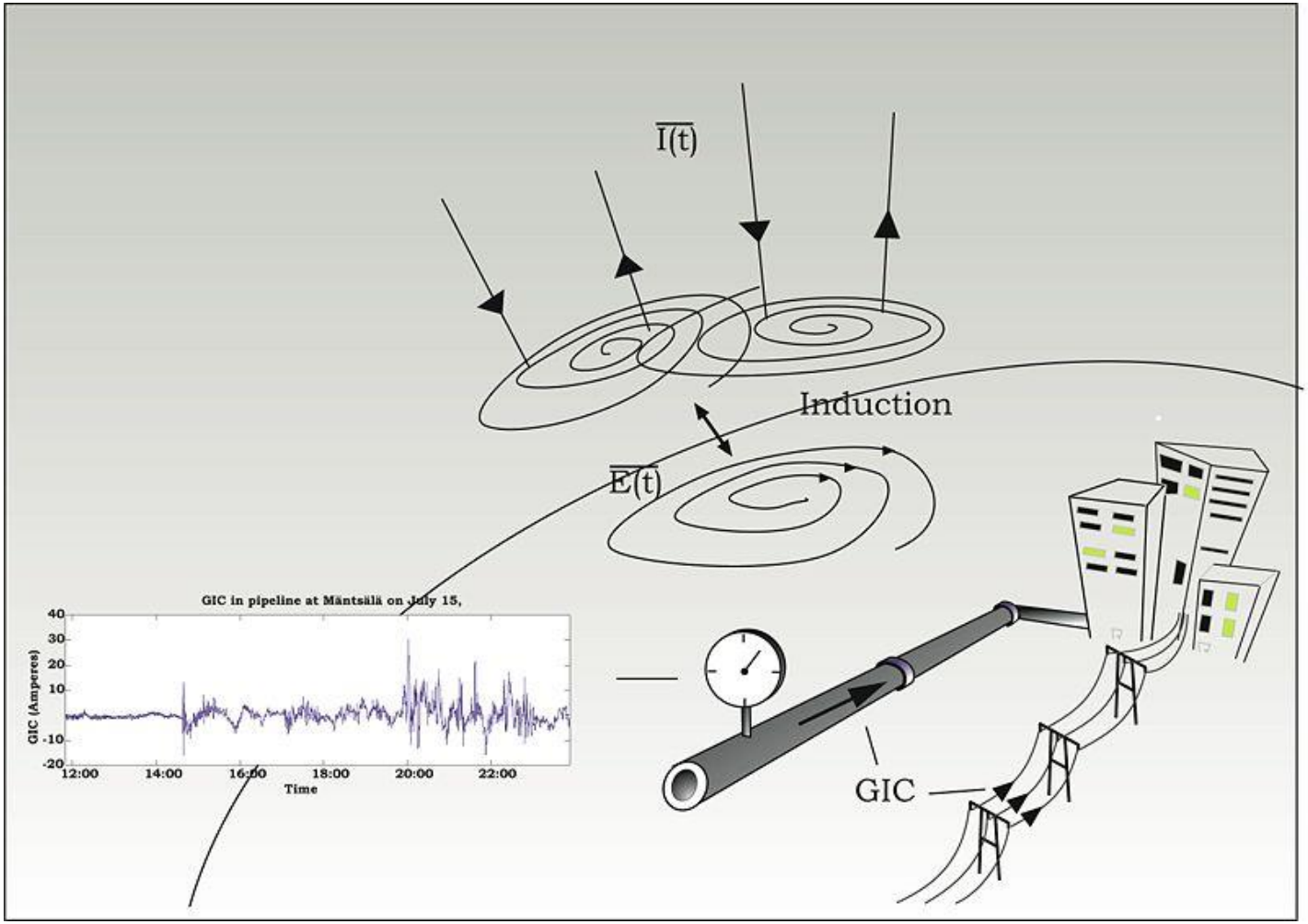
Solar eruption



Effects on the Earth

- Auroras
  - Kinetic energy given to molecules of Oxygen and Nitrogene in the atmosphere (35-350 km above the surface)
  - This excess energy is released in form of light
  - Green – Oxygene up to 240 km
  - Red – Oxygene above 240 km
  - Blue – Nitrogene up to 100 km
  - Violet – Nitrogene above 100 km

Effects on the Earth



Effects on the Earth

- In the middle of the 19th century (September 1859), one of the largest geomagnetic storm (Carrington event) recorded occurred. Auroras were observed as south s the Carribean and as north as Queensland in Australia. Due to the storm telegraphs all over Europe and North America failed, in some cases giving telegraph operators electric shocks, or worked even disconnected from power supply ("Polovina 19 století – telegrafy při geomagnetické bouři nefungovaly, nebo fungovaly i bez napájení („nebeská baterie")

Effects on the Earth

- On March 13, 1989 the entire province of Quebec, Canada suffered an electrical power blackout. Due to the storm 6 millions of people were 9 hours without electricity.
- Some of the U.S. electrical utilities had their own cliffhanger problems to deal with.
- In space, some satellites actually tumbled out of control for several hours. NASA's TDRS-1 communication satellite recorded over 250 anomalies as high-energy particles invaded the satellite's sensitive electronics. Even the Space Shuttle Discovery was having its own mysterious problems.

Risk of irradiation

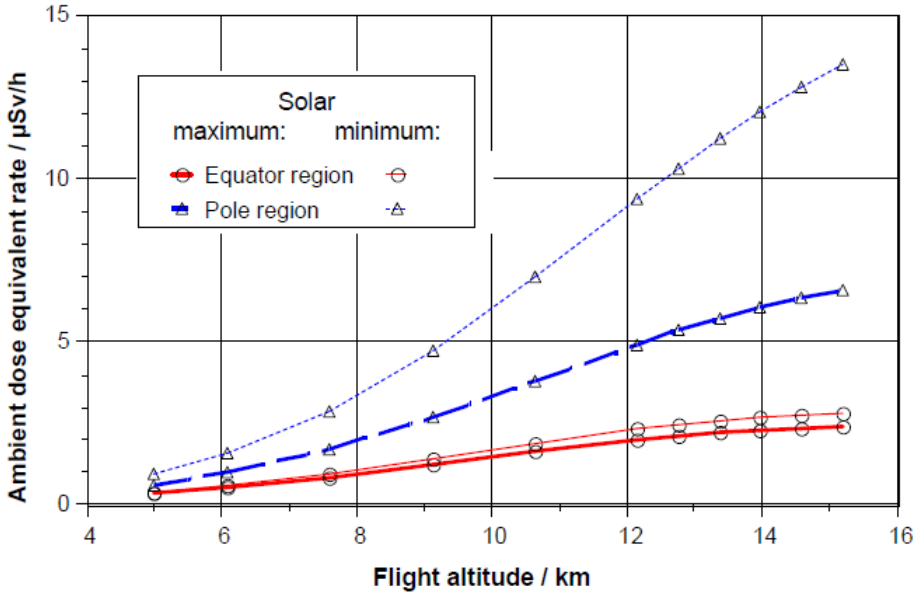
Safe doses

- 0.1 mSv – standard X-ray image of lungs
- 3 mSv – total annual dose from natural environment
- 10 mSv – standard CT of abdomen
- 50 mSv – limit for people working in radiative environment (USA)

Risk

- 100 mSv – increased risk of cancer
- 500 mSv – short-term changes in blood cells

Risk of irradiation



- Space radiation – neutrons – 95% of total irradiation, stable, well predictable
- Flight in altitude of 12 km above polar regions:
  - 5 µSv/h in January 1990 (solar maximum)
  - 9 µSv/h in January 1998 (solar minimum)

O'Sullivan et al., 2000?
http://cordis.europa.eu/documents/documentlibrary/75331981EN6.pdf

Risk of irradiation

- Solar erruptions – short-term increase of dose (20 μSv to 1 mSv)
- Typical total effective dose during a trans-atlantic flight over polar region is about 50 μSv
- Flight crew staff exposed to annual dose up to about 2 mSv
- Event of February1956 represented about 10 mSv/hour
  - During a flight the dose received could correspond to the limit allowed for people working in radiative environment

Take-home message

- Geomagnetic field is necessary for our life
- Orientation and navigation
  - Bacteria, birds, vertebrates, people, ???
- Source of currents in the Earth – study of deep interior (magnetotellurics)
- Protective role – shielding from penetration of energetic particles and electromagnetic radiation from the Sun and outer space
- Negative effects
  - People sensitive to changes in the intensity
  - Technologies vulnerable to changes in intensity
    - Power systems, pipe lines, radio communication, sattelites, …

Thank you for your attention