Physics with Scaler Mode of the Pierre Auger Observatory

Ahmed Saleh
Laboratory for Astroparticle Physics

University of Nova Gorica

May 29, 2013

Outline

- Introduction
- Scaler mode and single particle technique
- Solar physics and Forbush decreases
- Scaler mode and seismology
- Aging process of detectors
- Summary

Gamma ray bursts

- GRBs are short and intense bursts of gamma photons coming from random directions in the sky
- It is lasting from 0.01 s to $\approx$ 1000 s

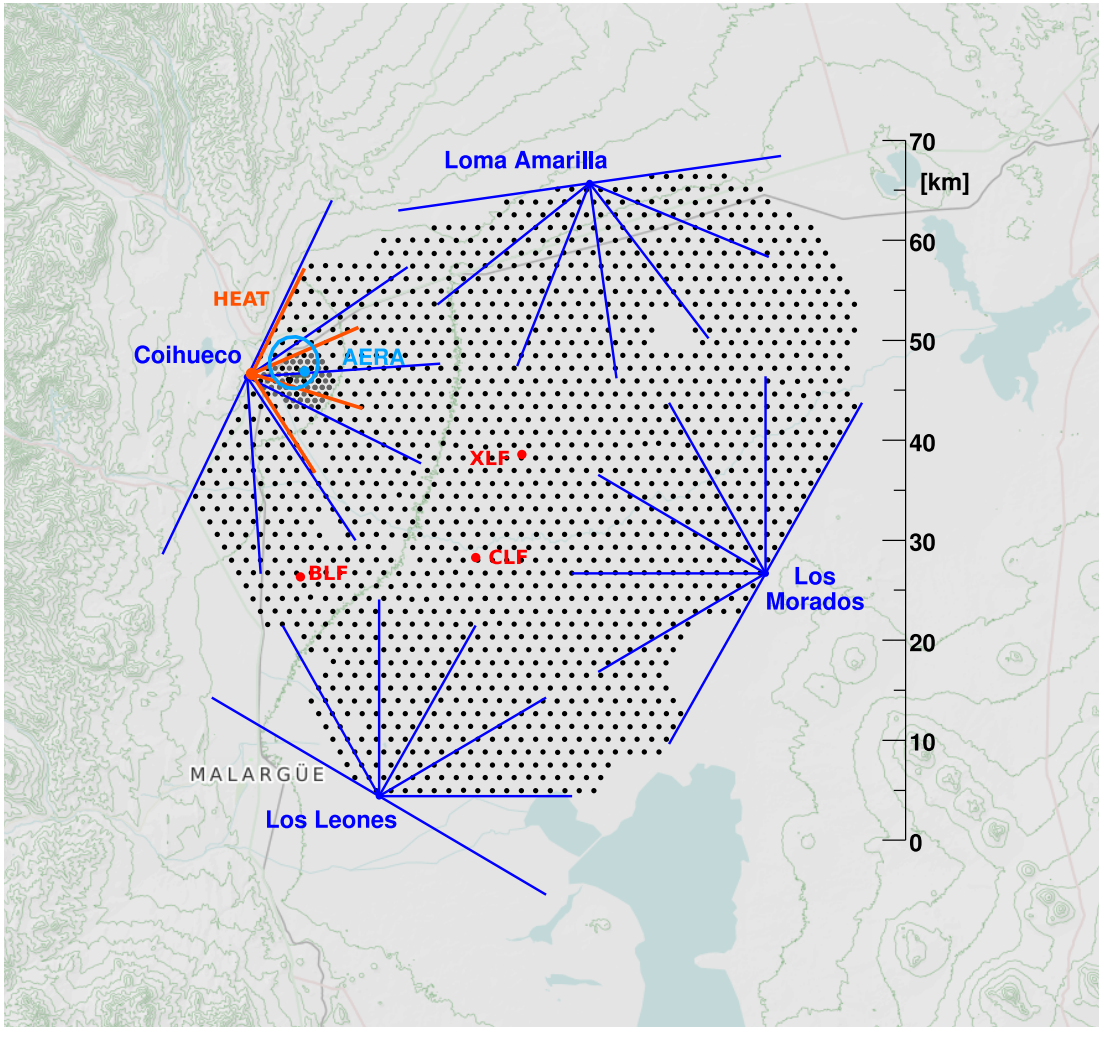
Space - based detectors

- GLAST studies the GRBs in energy range of 8 keV up to more than 300 GeV

Earth - based detectors

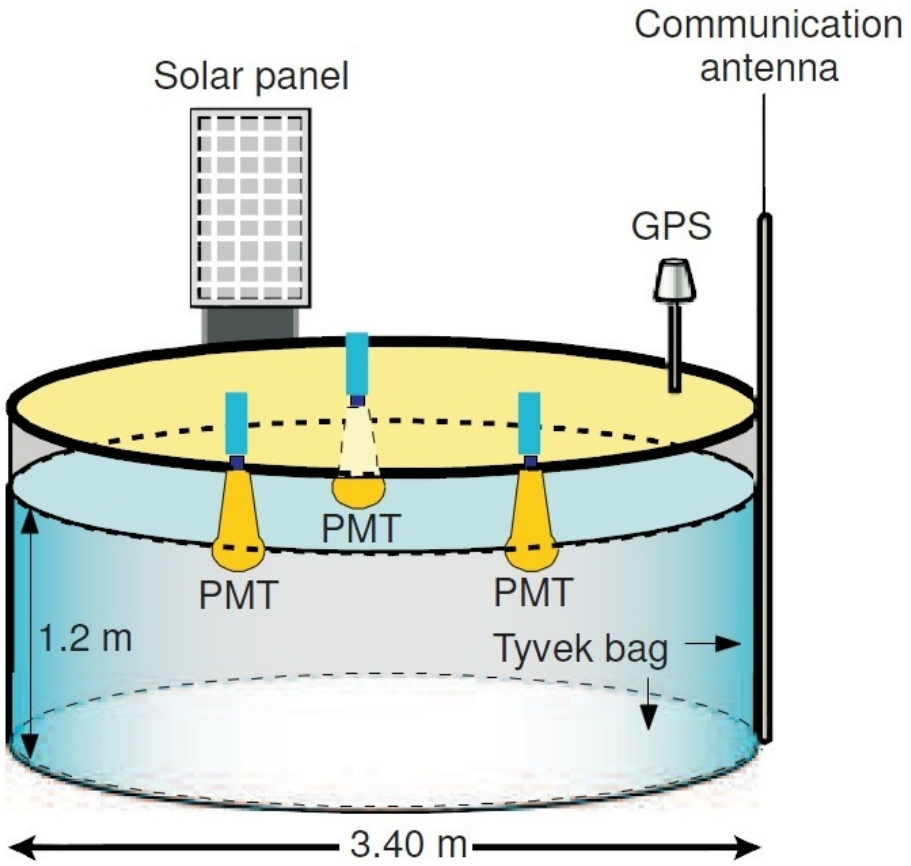
- Detecting the Cerenkov radiation is the way to see UHE Gamma-rays
- HESS in Namibia, near Gamsberg (1800 m a.s.l.) & Milagro, near Los Alamos (2630 m a.s.l.)

Pierre Auger Observatory



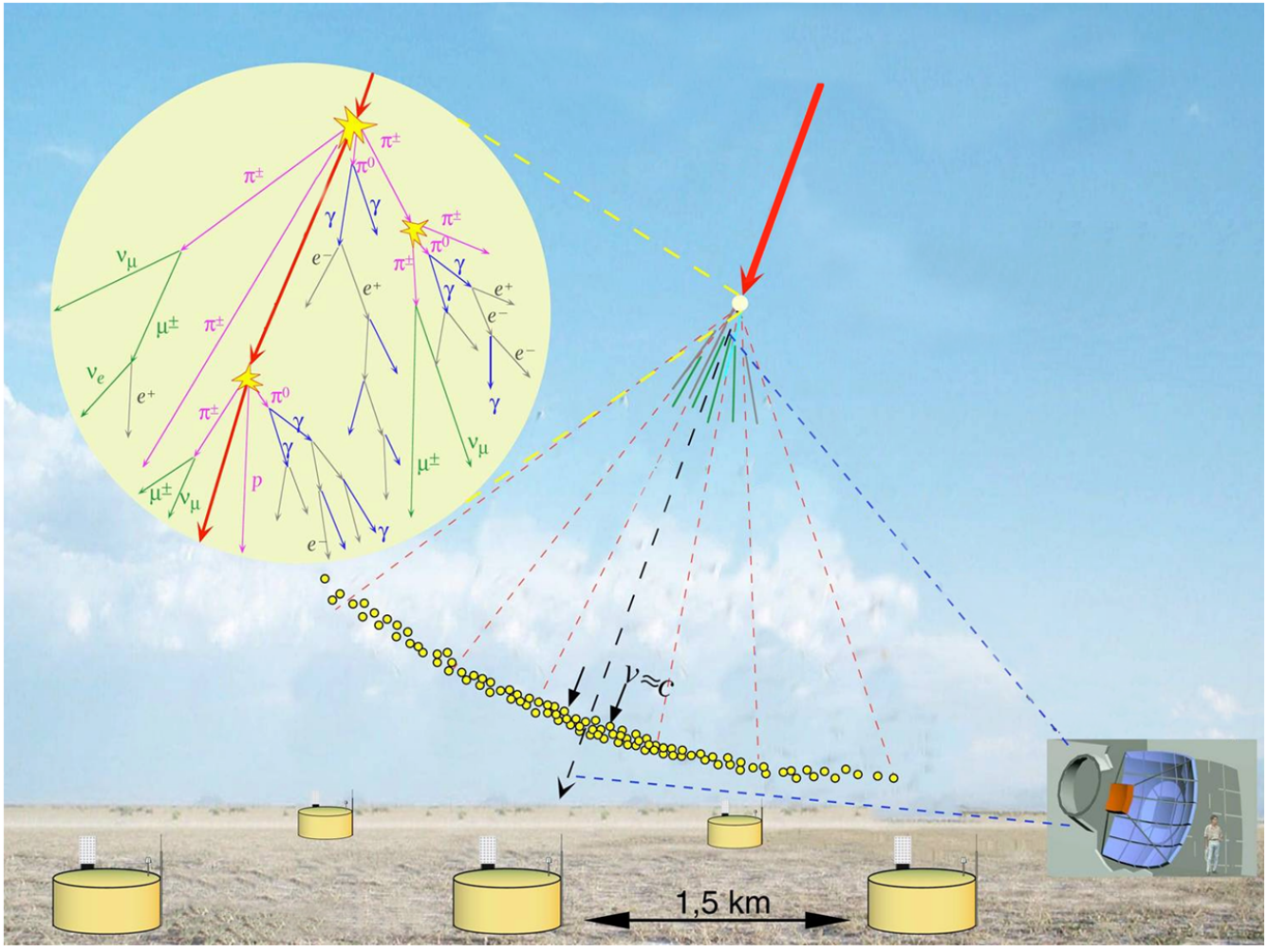
- Malargüe, Argentina, South America
- Altitude: 1400 m a.s.l.

Surface detector stations



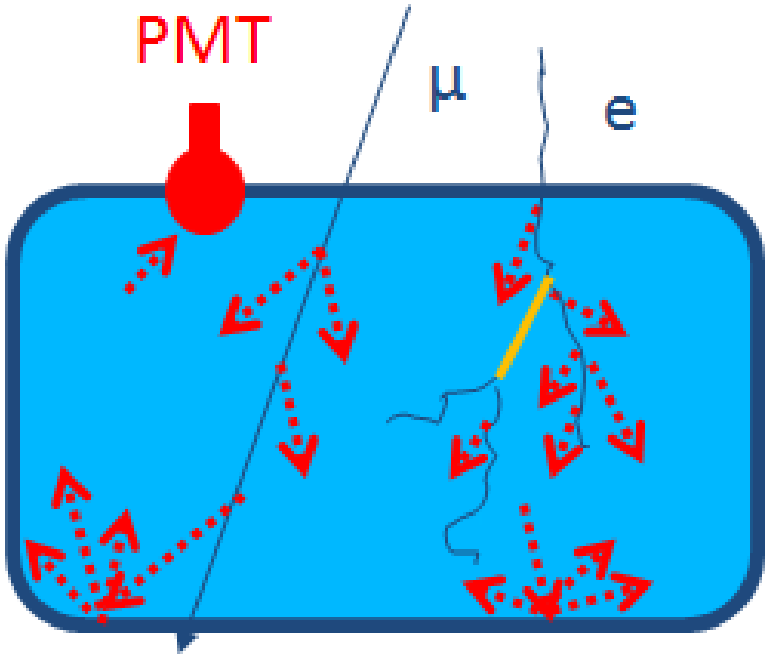
- Measure charged secondary particles at ground
- 100% duty cycle
- Cherenkov light is collected by three 9" PMTs

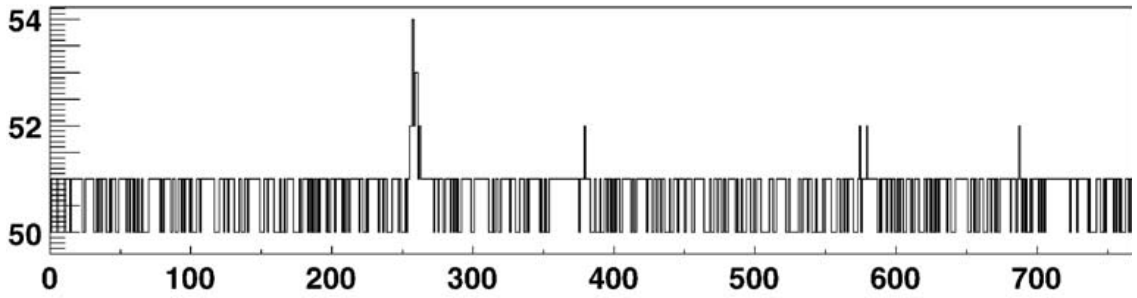
Cosmic ray air-shower



- Extensive air-showers (EAS) induced by collisions of primary cosmic particles with atoms of the Earth's atmosphere

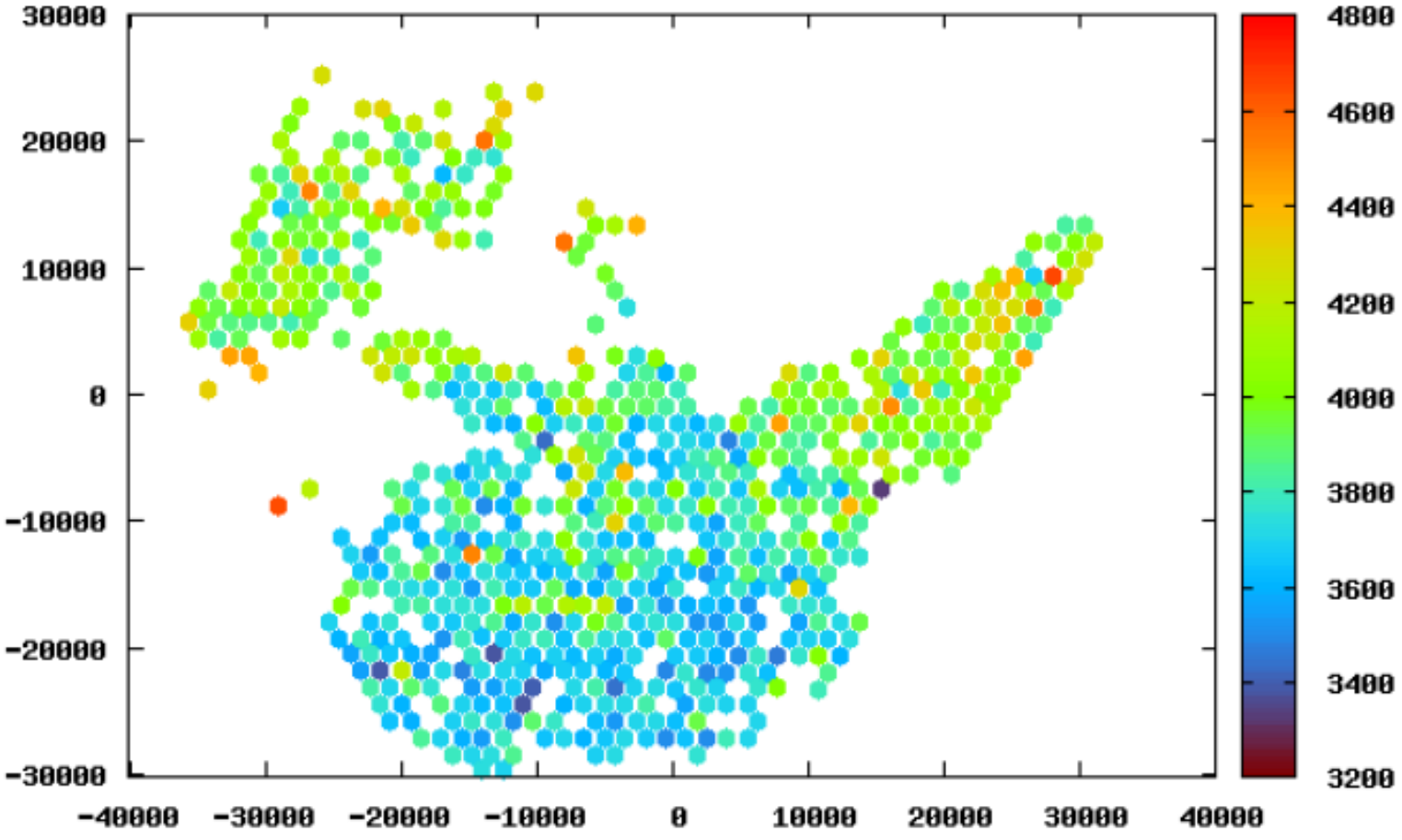
The scalers





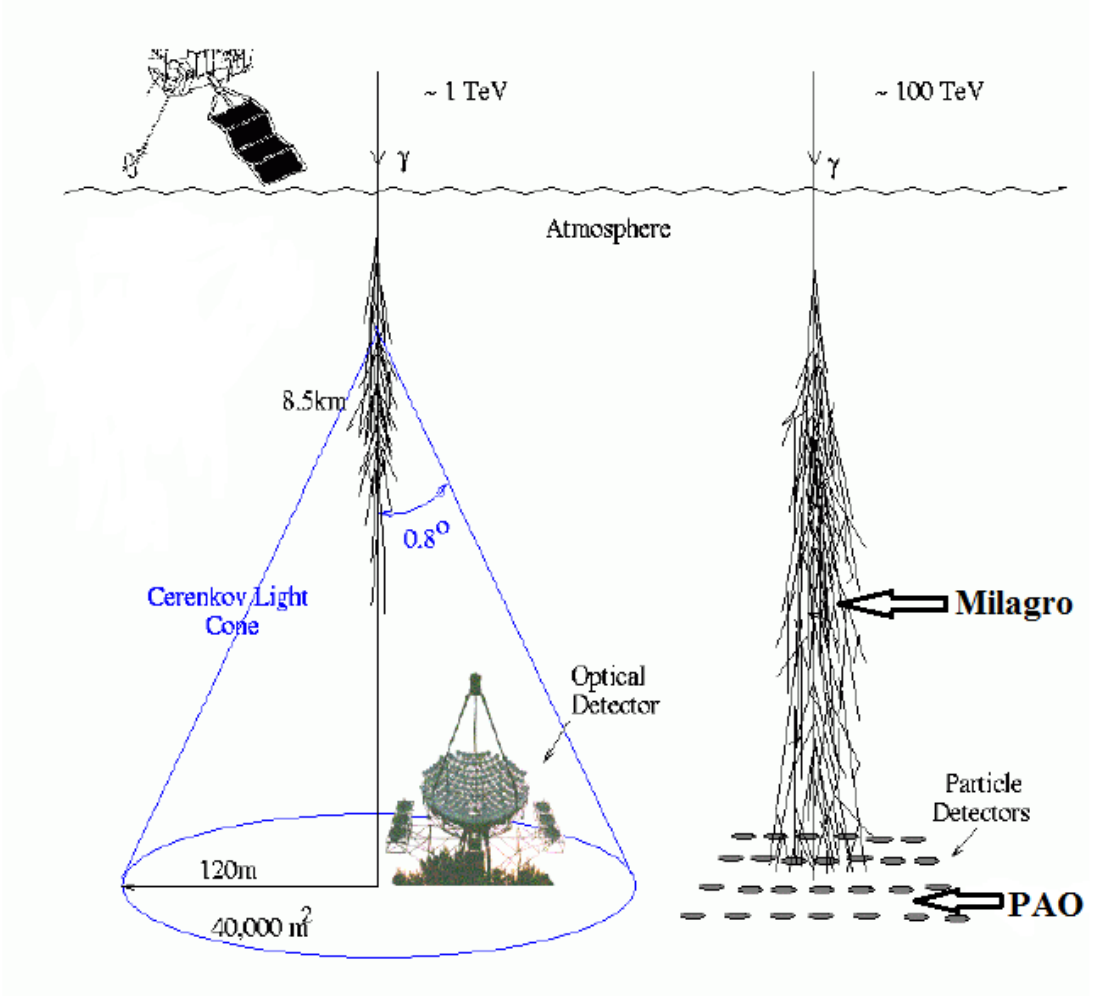
- The scalers are simple counters for low-energy particles crossing the tank of light emission
- Scalers record any signal above a threshold of $\approx 15\,\mathrm{MeV}$

The scalers



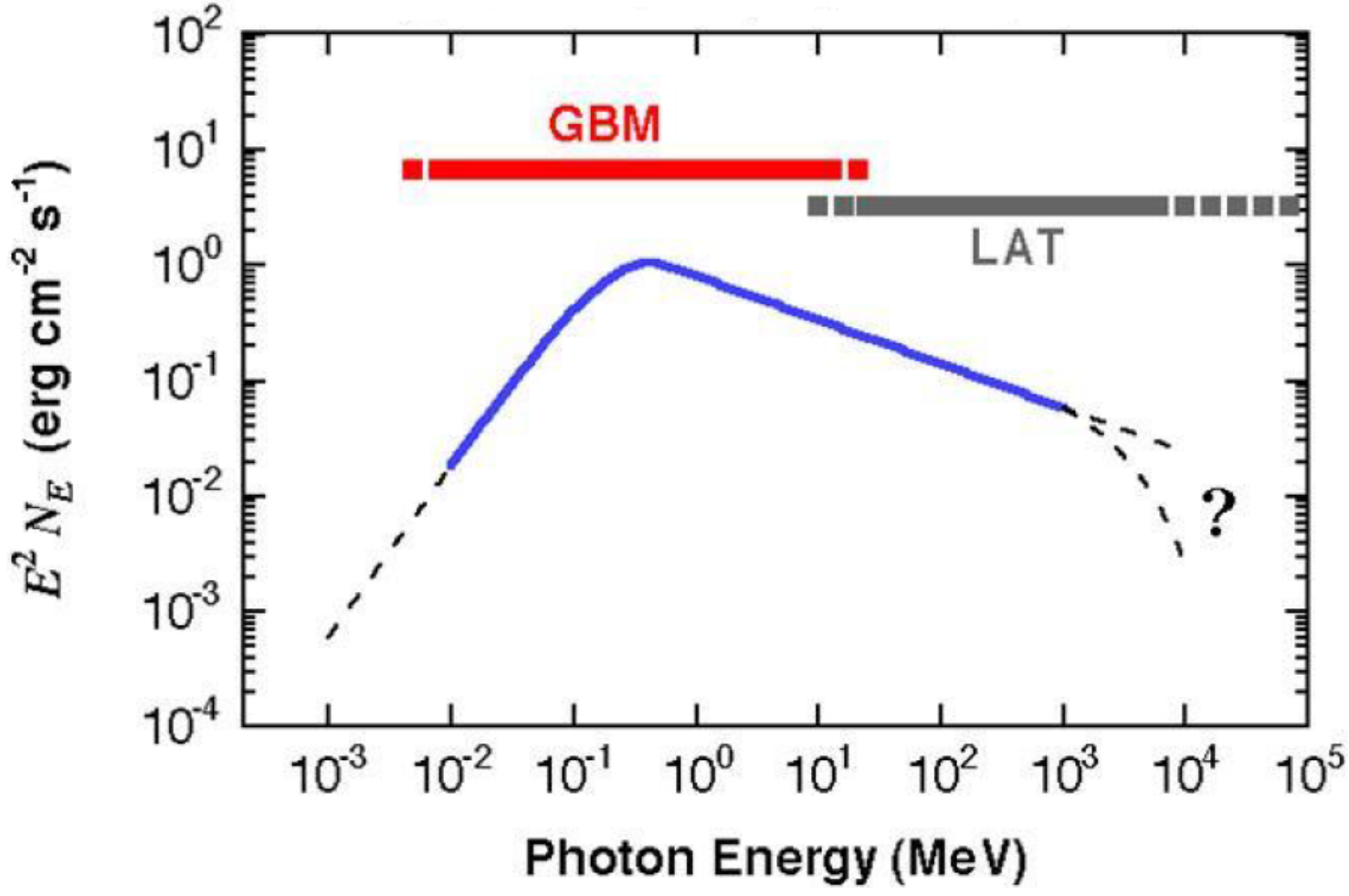
- The typical average scaler rates is around 3800 counts s^{-1} m^{-2}
- The rates at each detectors are recorded and sent to CDAS for storage and further analysis

Gamma ray air-showers



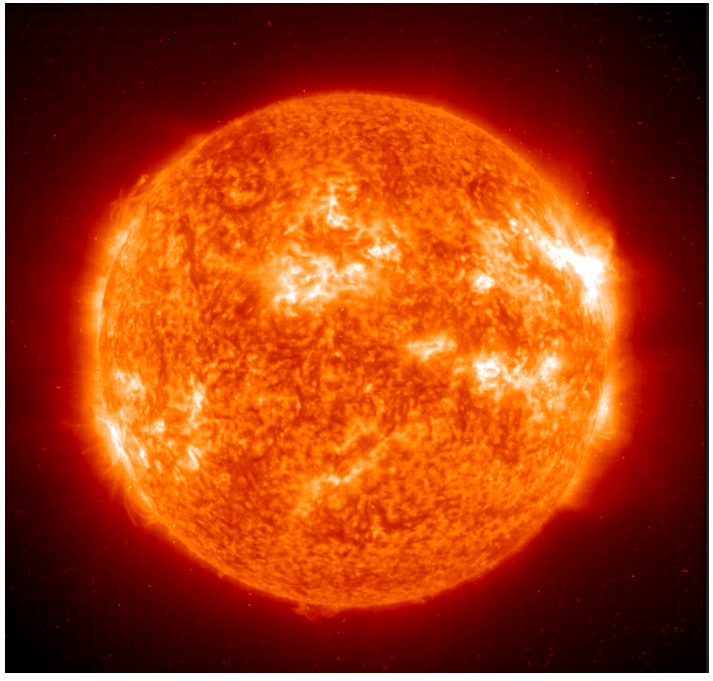
- The showers of lower-energy events are attenuated in high atmosphere
- The showers of high-energy events reach the ground-based detector

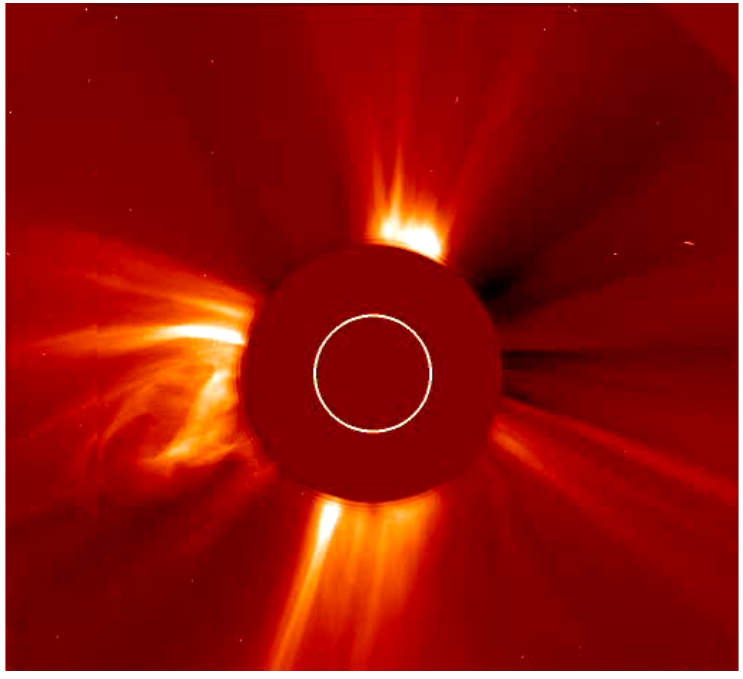
Typical GRB spectrum



- Low statistics with high-energy events
- Unfortunately, we don't see an increase of the scaler rate during the GRBs

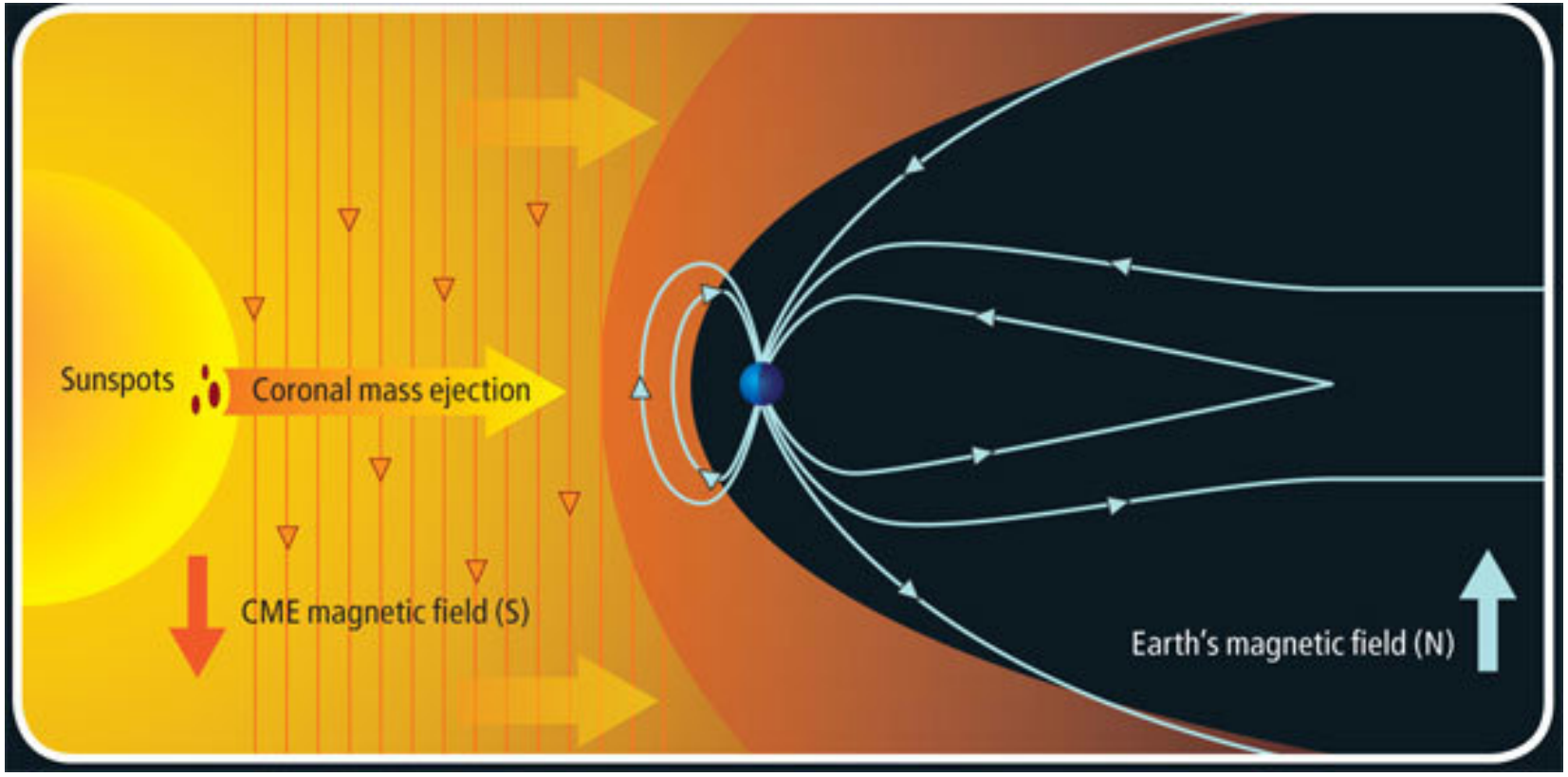
Solar energetic events





- Solar wind is a stream of charged particles released from the upper atmosphere of the Sun
- Solar flares are energetic explosions in the lower solar atmosphere
- Coronal mass ejection is a huge amount of matter and electromagnetic radiation ejected from outer layers of the Sun surface

CMEs consequences

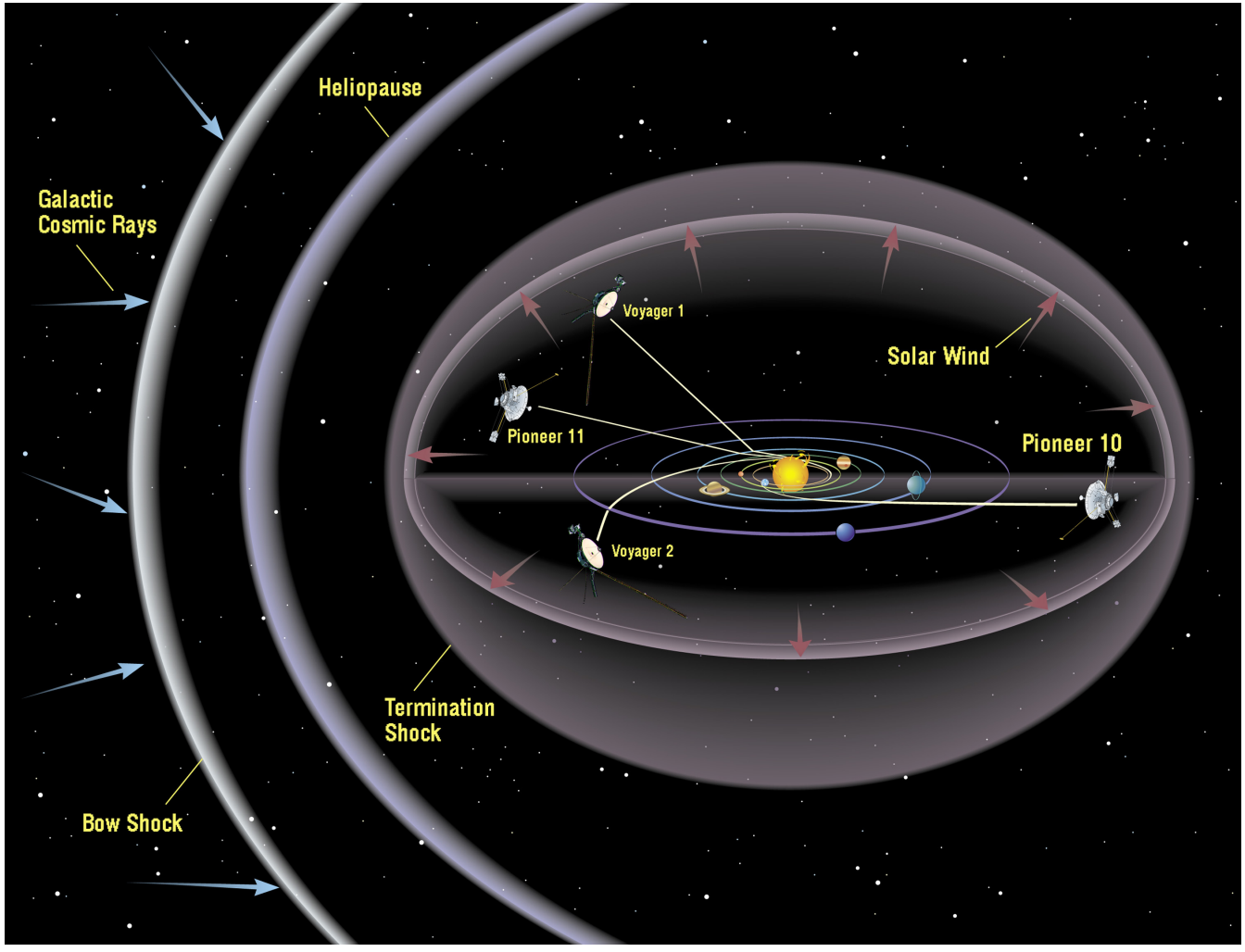


- CMEs compress the Earth's magnetosphere. They can also push the magnetopause into the Van Allen belts

CMEs consequences

- The charged particles are directed along the Earth's magnetic field lines to the Earth's poles, where they interact with the atmosphere, creating beautiful aurorae

CMEs consequences

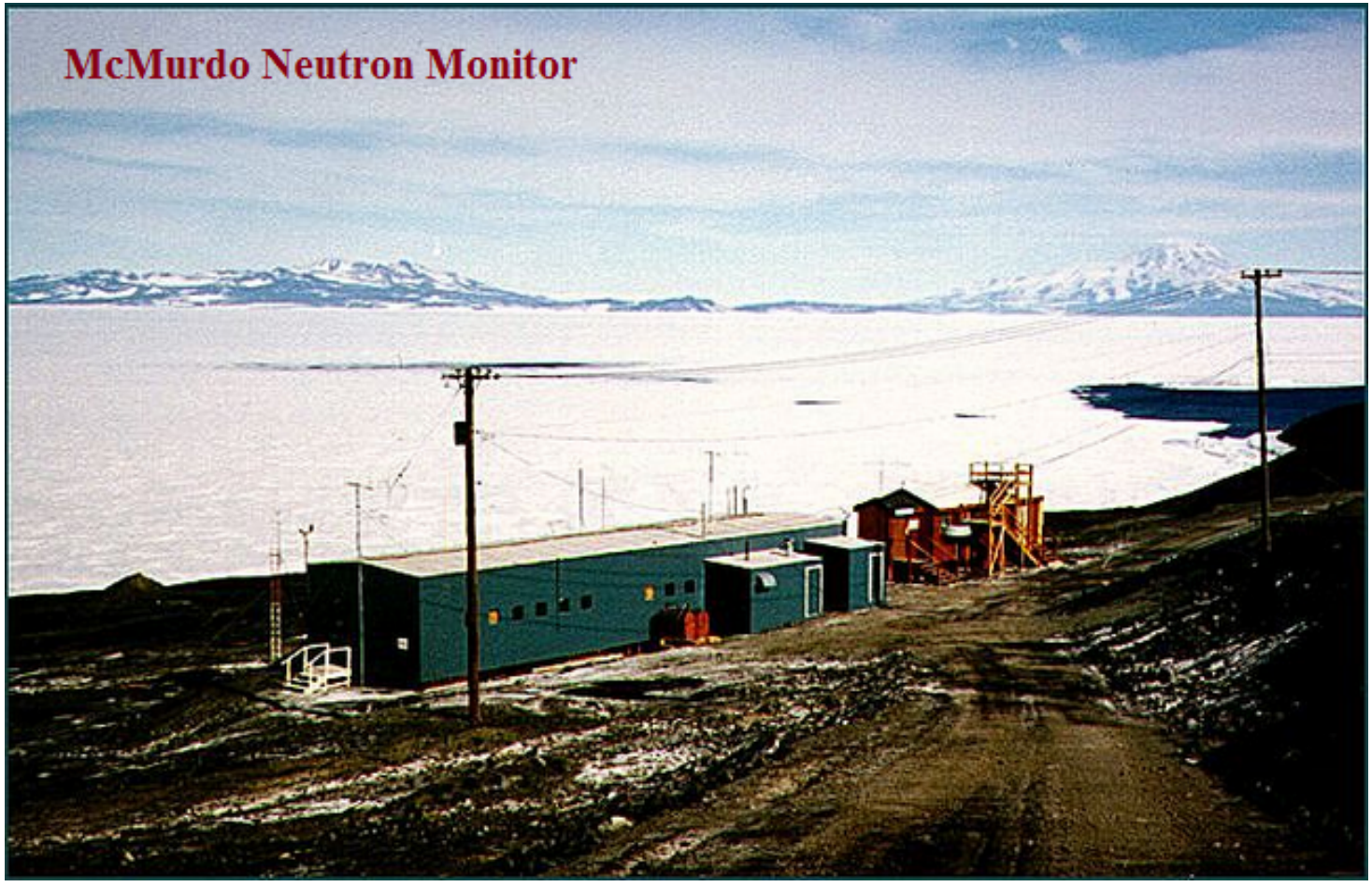


- The size of the heliosphere was estimated to about 100 AU
- CMEs reach the earth and deflect a fraction of the incoming GCR flux

Forbush decrease

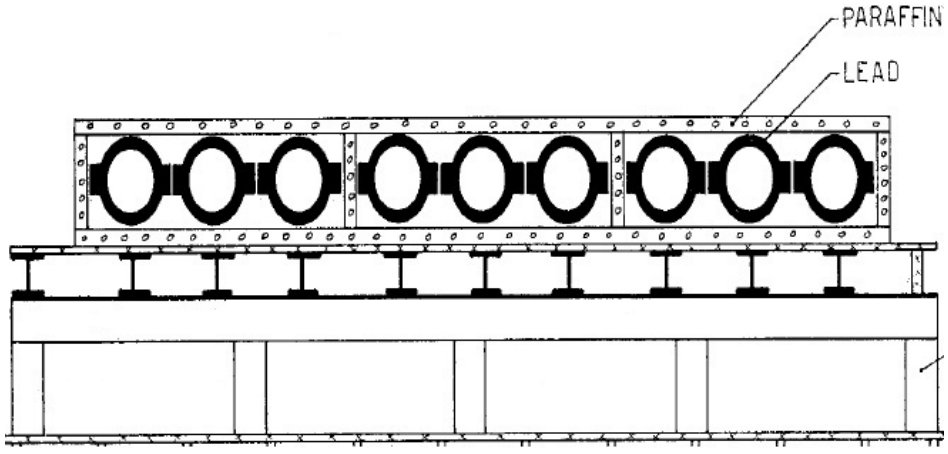
- The Forbush decrease is a rapid decrease in the observed galactic cosmic ray intensity following CMEs
- Forbush decrease is seen by ground-based observations

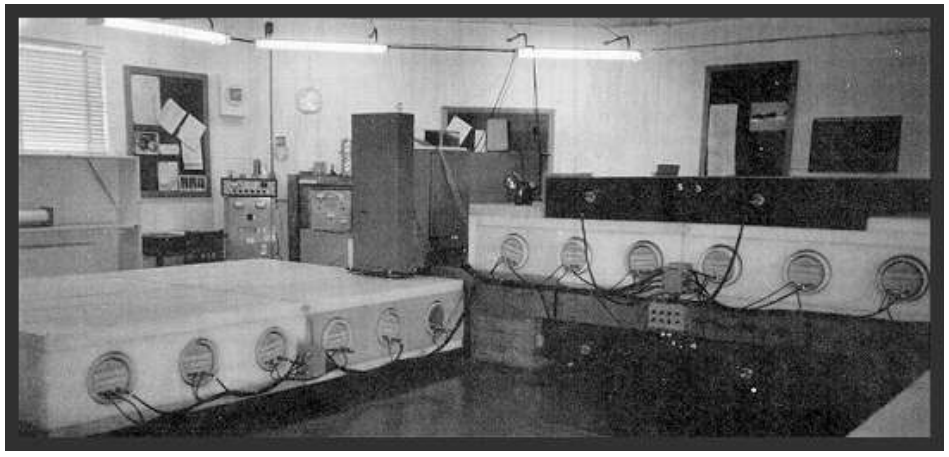
Neutron monitors



- A neutron monitor is a ground-based detector designed to measure the number of high-energy particles striking the Earth's atmosphere from outer space

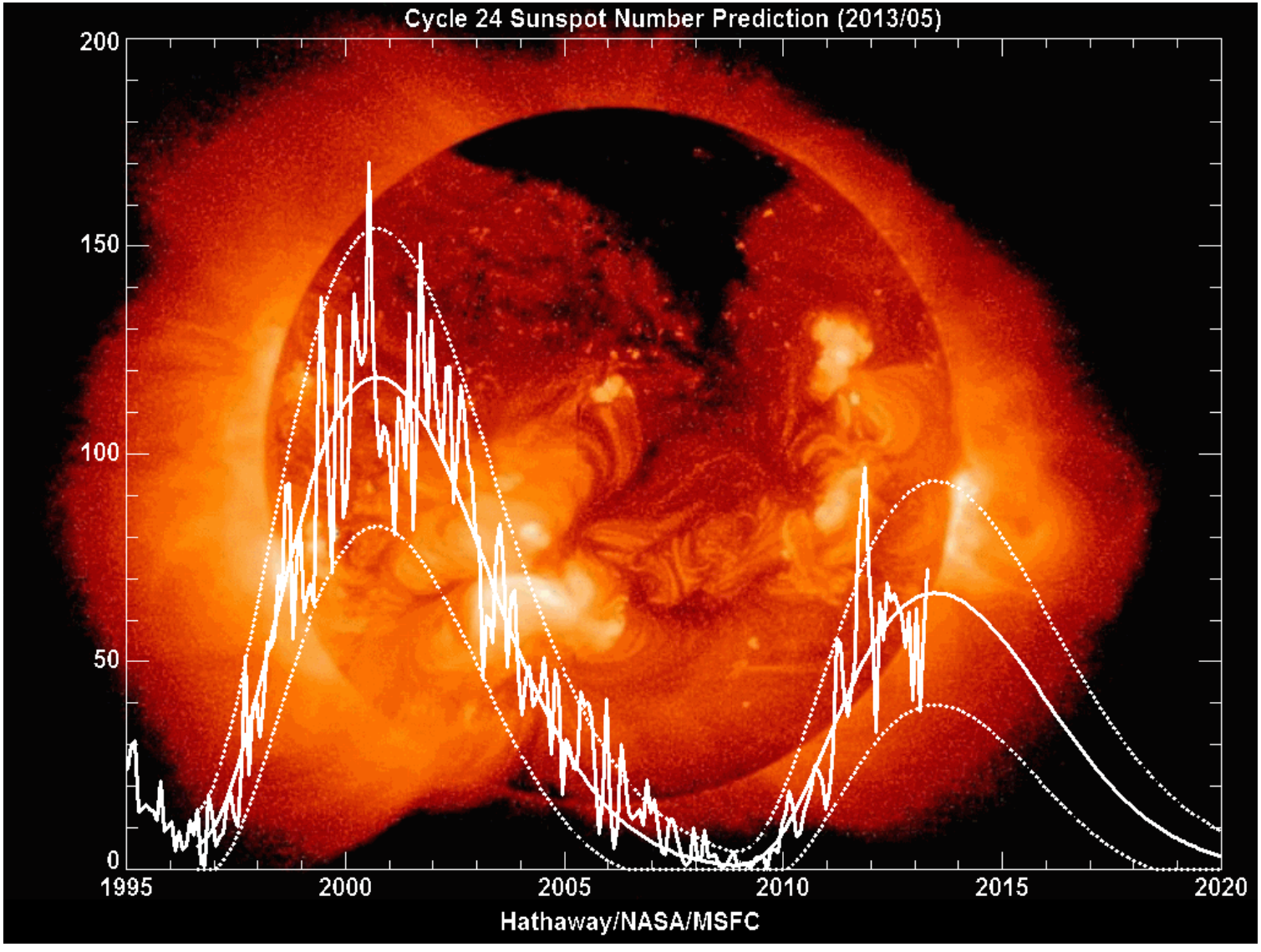
Neutron monitor





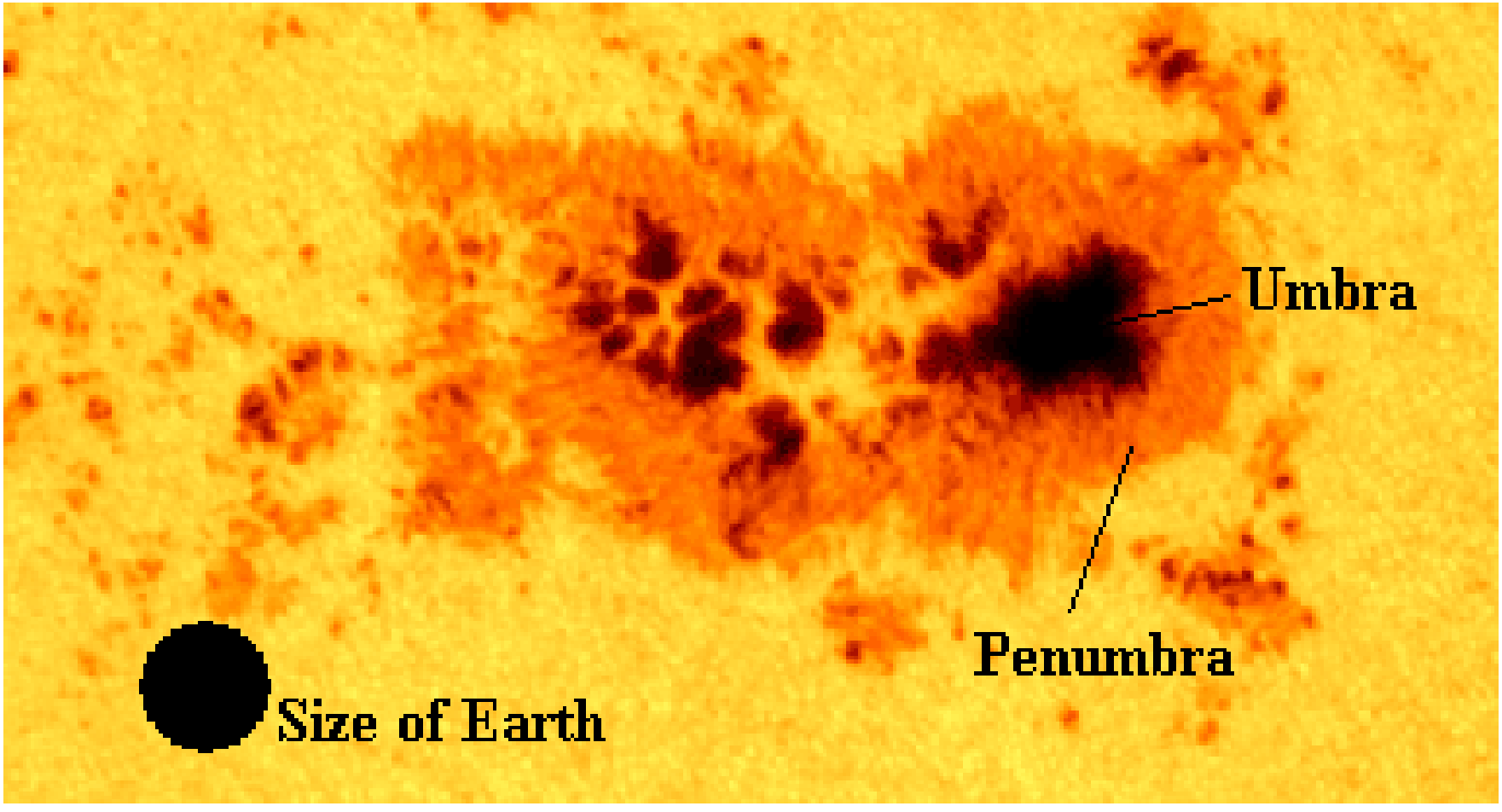
- $^{10}\mathrm{B} + \mathrm{n} \rightarrow {}^{10}\mathrm{Li} + \alpha$
- $^{3}\mathrm{He} + \mathrm{n} \rightarrow {}^{3}\mathrm{H} + \mathrm{p} + \gamma_{6.65MeV}$
- NMs record the GCR and their variation over the solar cycle

Solar maximum and minimum



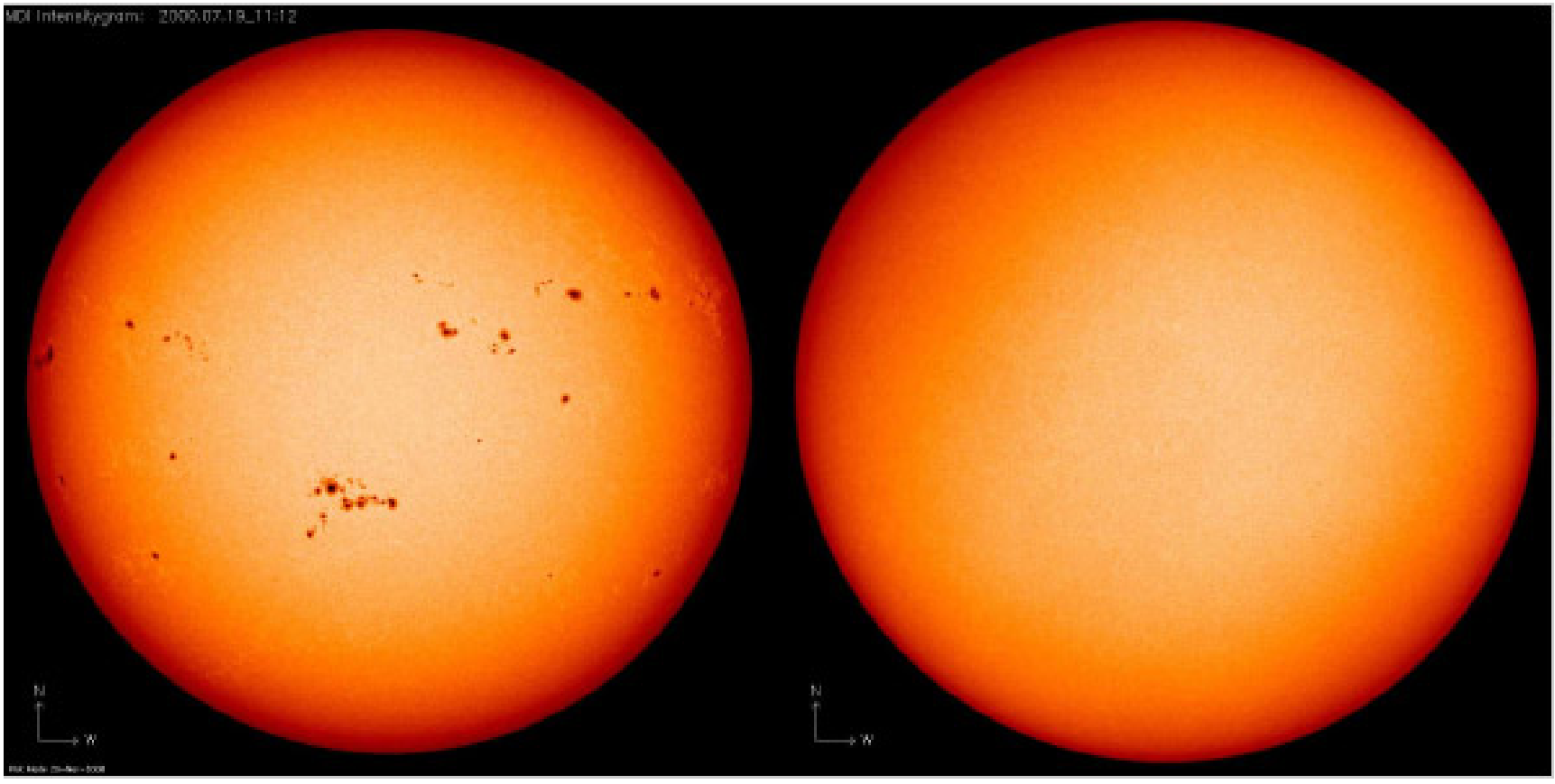
- Solar cycle lasts 11 years on average

Sunspots



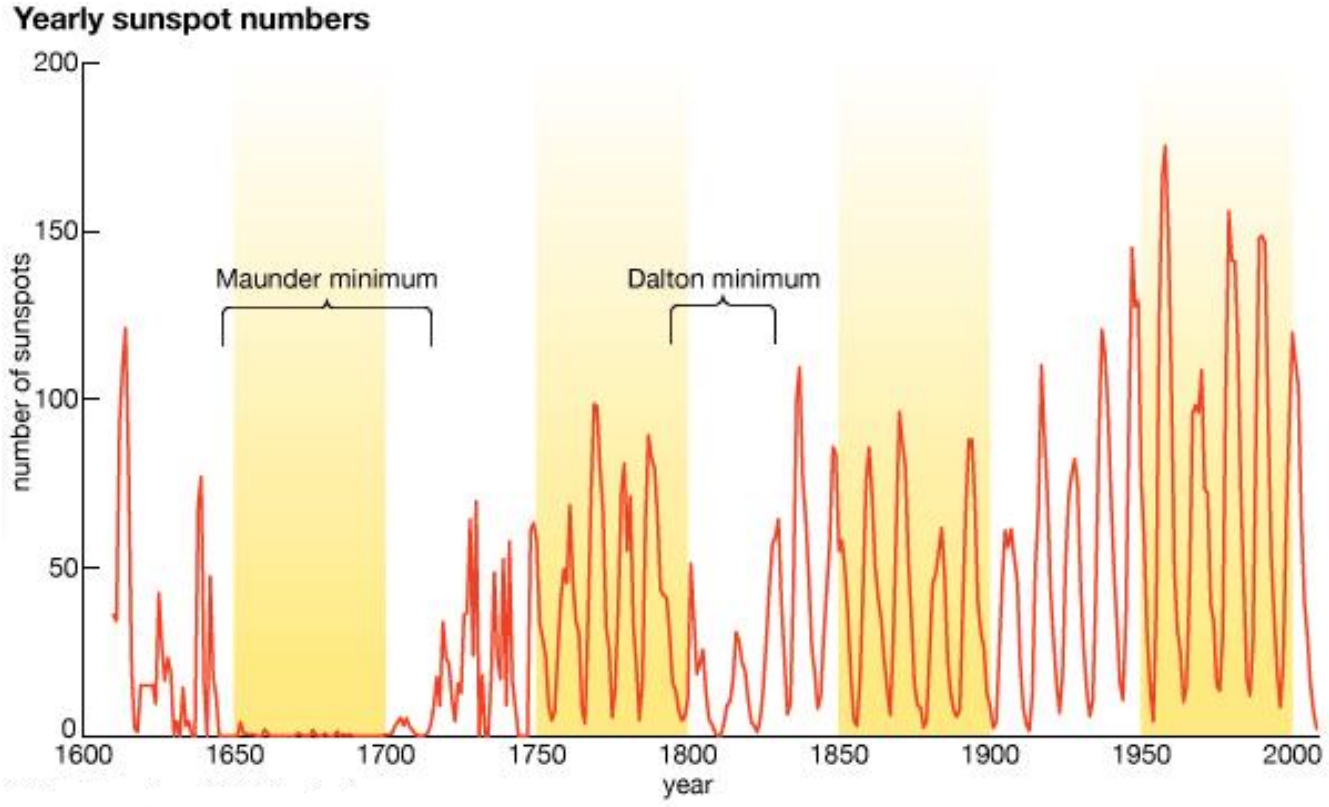
- The solar magnetic field is very strong
- Size between 2500 km and 50, 000 km
- Two distinct parts (Umbra & Penumbra)

Solar maximum and minimum



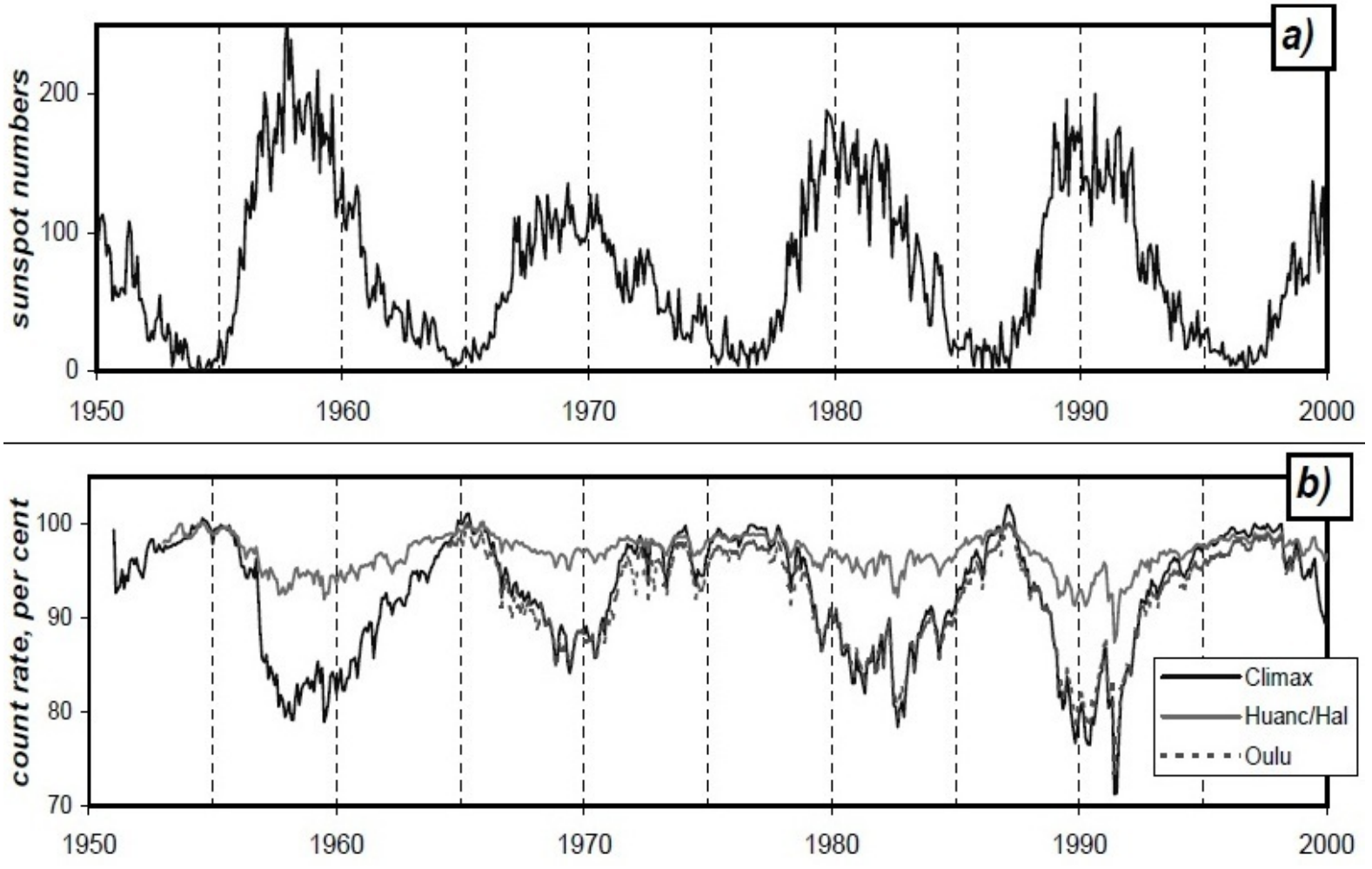
- Sunspots appear darker than their surroundings
- During solar maximum, sunspots appear
- During solar minimum, sunspots disappear

The Maunder and Dalton minima



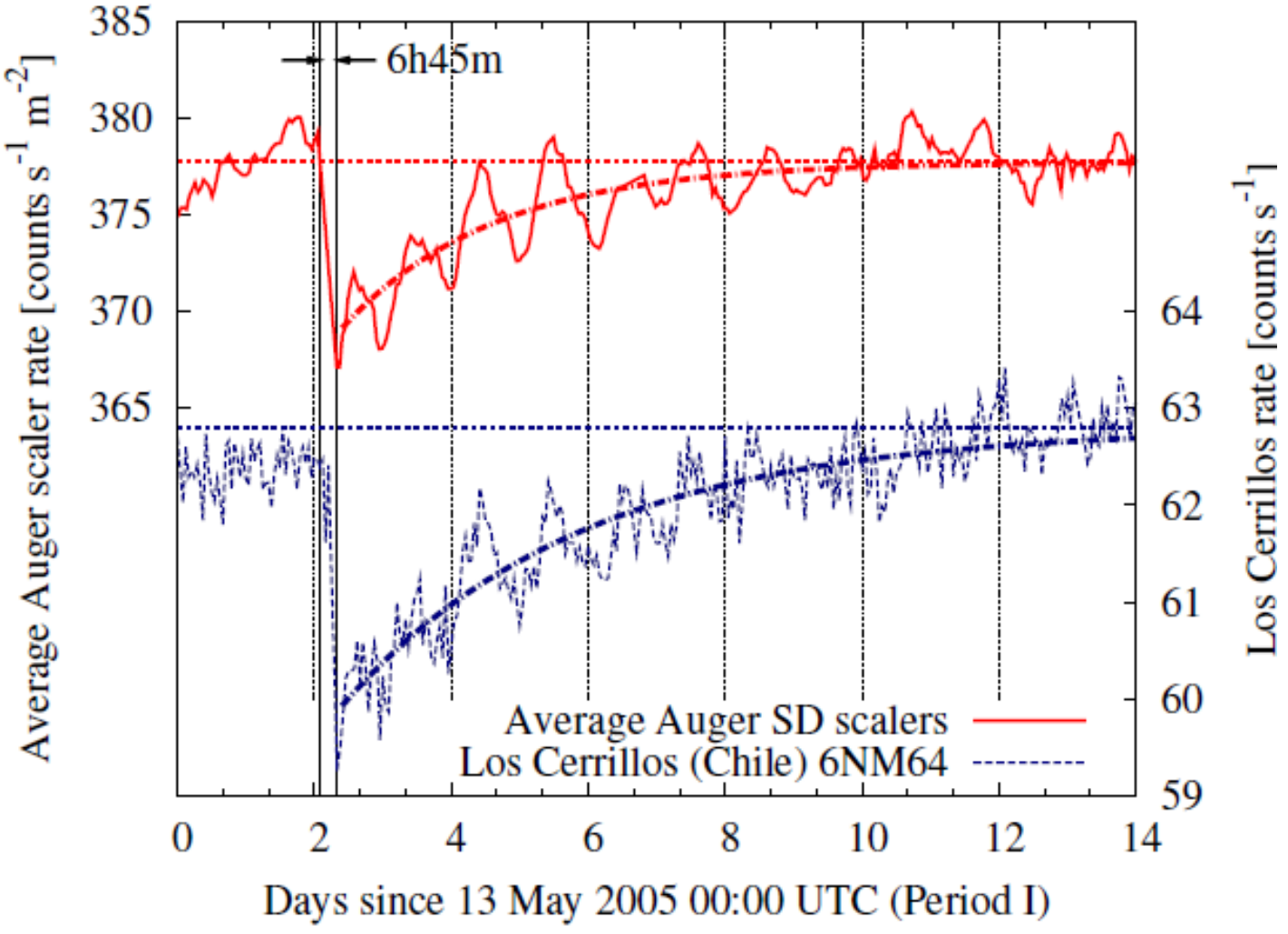
- The Maunder and Dalton minima are periods of low solar activity
- Maunder coincided with the Little Ice Age, during which Europe and North America were bitterly subjected to cold winters
- Dalton minimum coincided with a period of low temperatures

Solar modulation of galactic cosmic rays



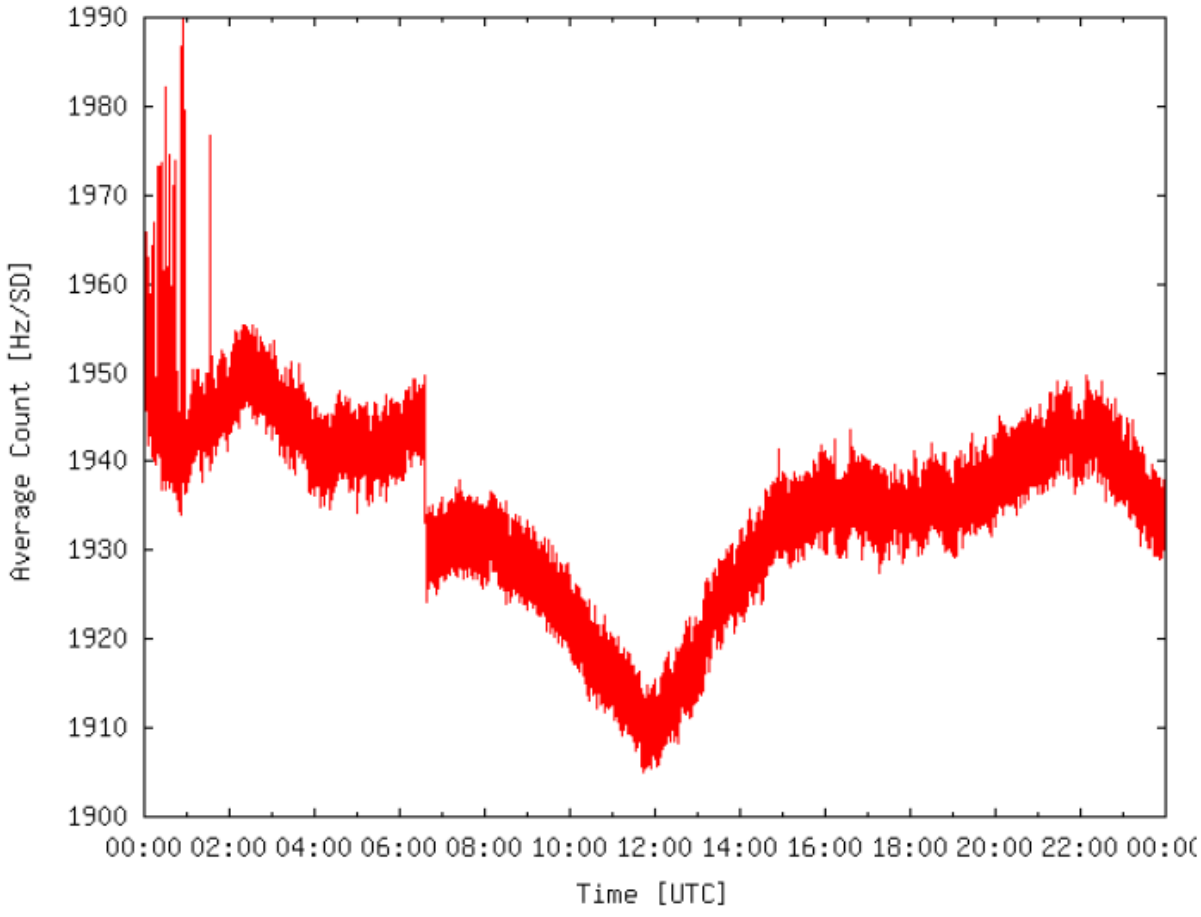
- At energies below a few GeV/nucleon, GCRs show a strong dependence on solar activity with maximum intensities during solar minimum

Scalers and solar physics



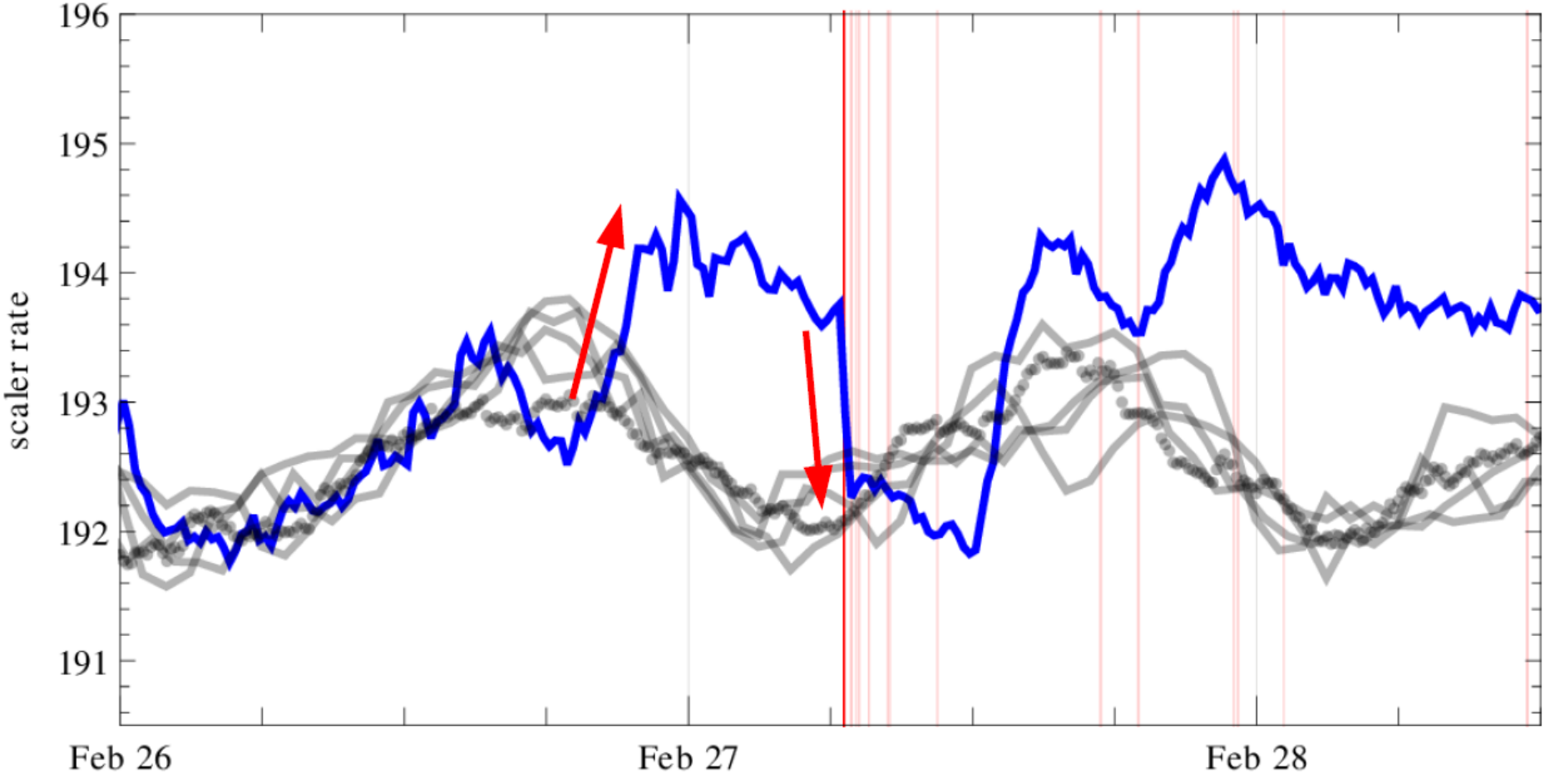
- The general pattern is very similar and Forbush decreases are clearly visible

PAO sees earthquakes



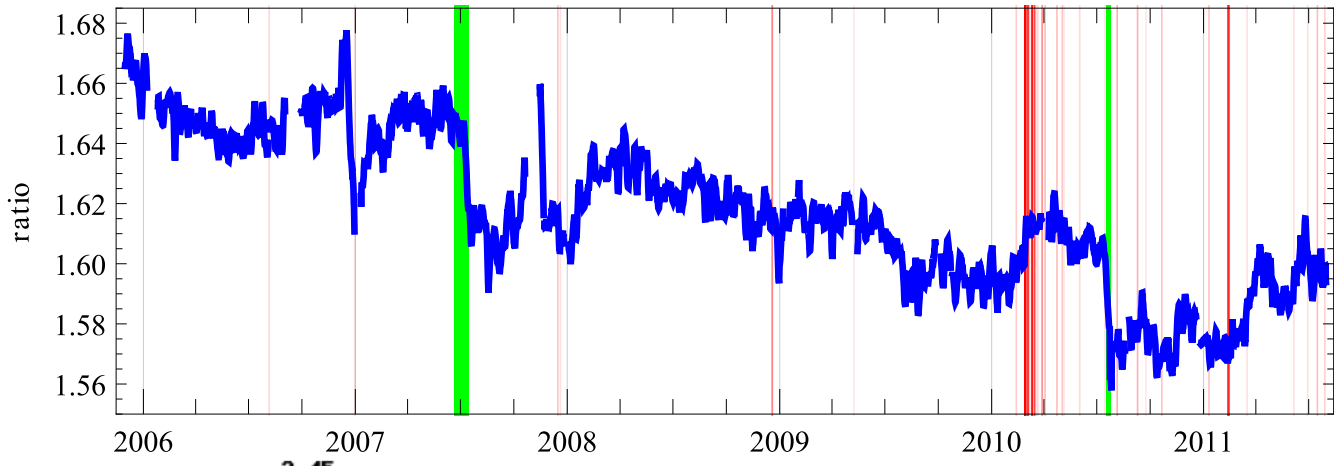
- On February 27, 2010, at 6h34:14 UTC, Chile was stuck by an 8.8 magnitude earthquake

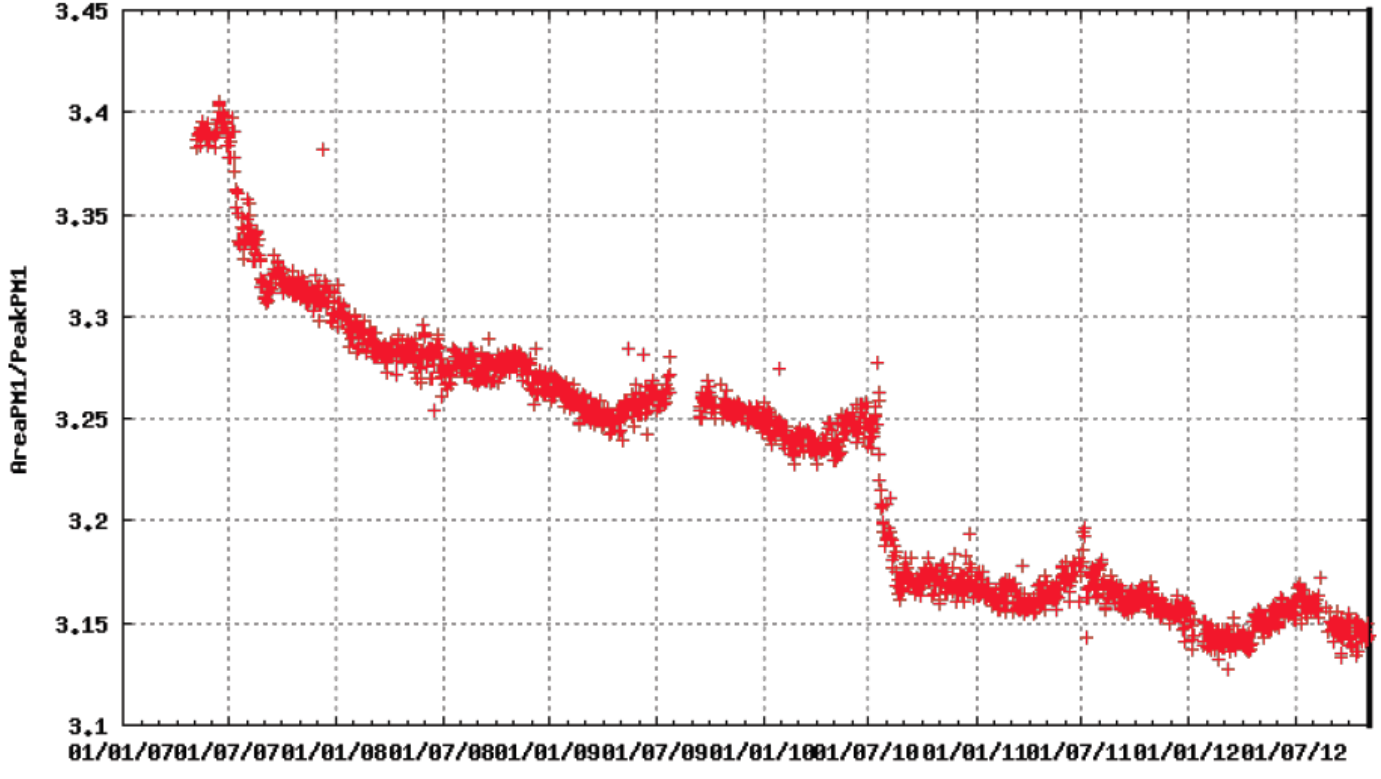
PAO sees earthquakes



- Increase of CR before the earthquake
- Strong drop during the earthquake

Aging process of detectors
Auger scaler ratio to Tsumeb NM and AoP





Summary

- Scaler is a background radiation measurement mode.
- GRBs and CMEs are expected to be seen as a significant excess above the default background.
- GRBs aren't seen by Auger scaler rate.
- Auger scaler rate sees Forbush decrease and earthquake as well.
- The AoP quantity is an indirect measure of the pulse duration associated to a single muon. It reflects a decrease of the light collection efficiency, and thus the detector aging.
- Scaler rate decreases as the detector is aging.

End


THANK YOU FOR YOUR ATTENTION
Photographed by Radomir Smida