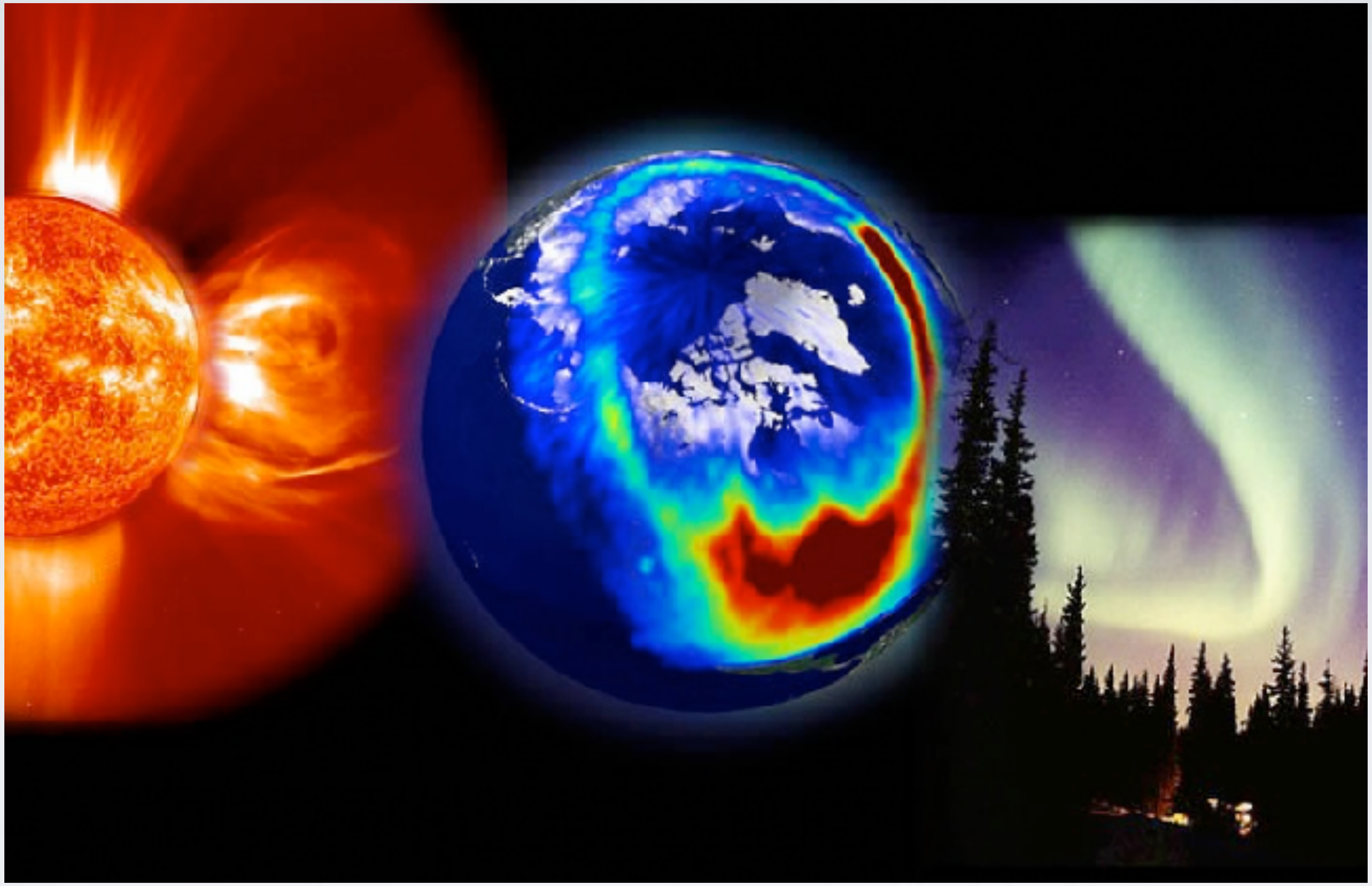
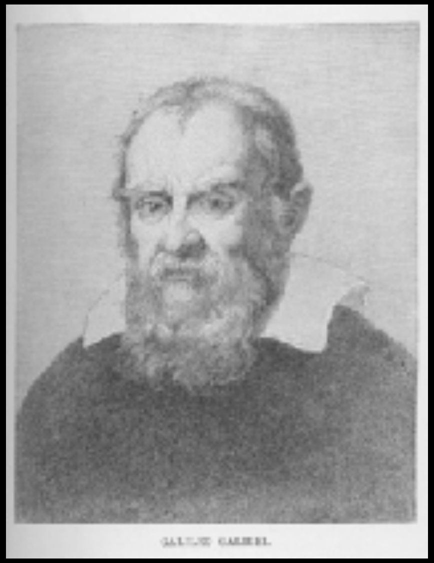
The Stormy Sun and the Northern Lights

AGF-216

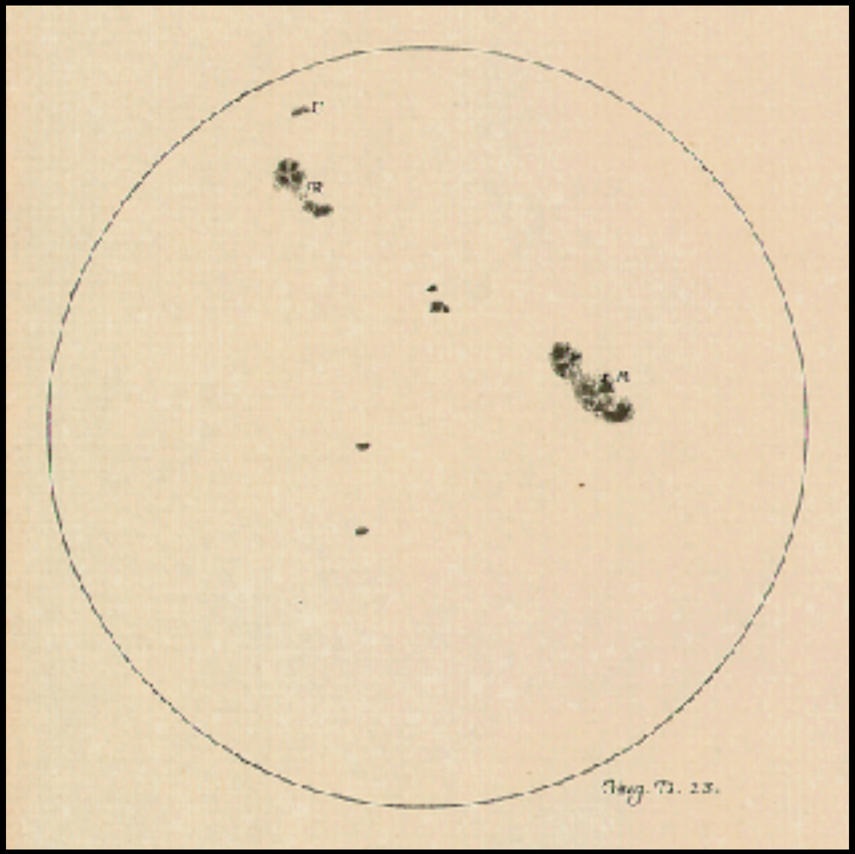


Short summary

GALILEO AND HIS TELESCOPE


Sarah. K. Botton/Justus Sustemans

Gelileoscope.org

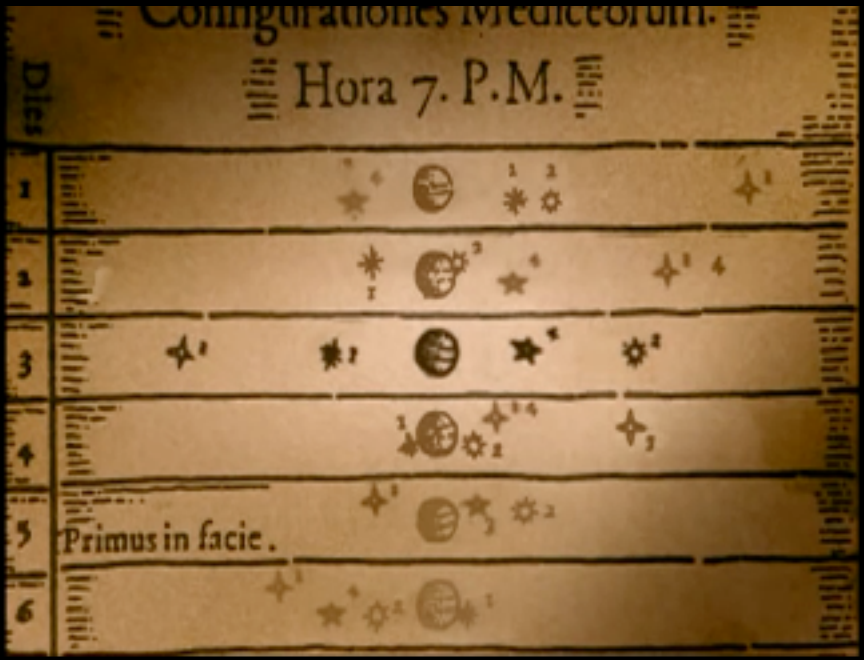

Galileo Project/Rice Univ.)

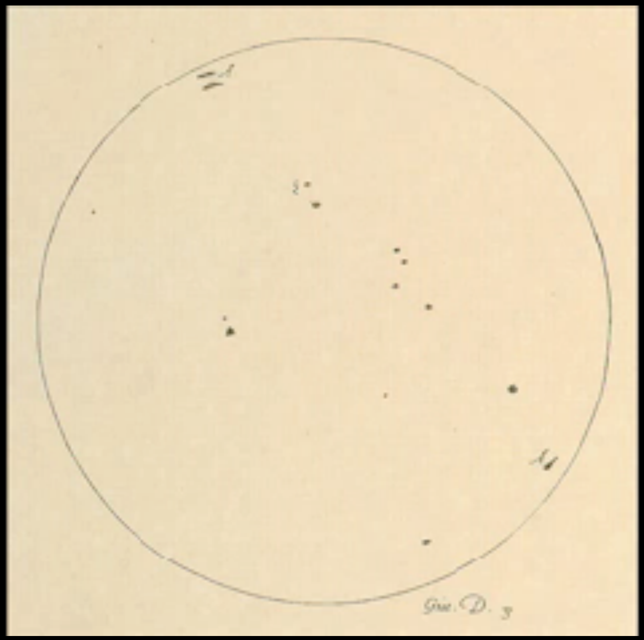
The summer of 1609 Galileo Galilei (1564 – 1642) learned about a new invention in the Netherlands that could bring far objects to appear closer. An optician had made the first telescope. Galileo bought some lenses from his local optician and build his own telescope.

When he pointed the telescope towards the Sun in 1610, he noticed dark spots on the surface. He studied the spots over months and noticed how they moved each day.

Was he the first to observe sunspots? Maybe not. The English astronomer Thomas Herriot was probably somewhat earlier and we know of his drawings of sunspots but he never published them as Galileo did. Some people argued that the spots were located between the Sun and the Earth. Galileo, however, argued that the spots were part of the Sun and that the Sun rotated around its own axis.

Galileo’s Discoveries





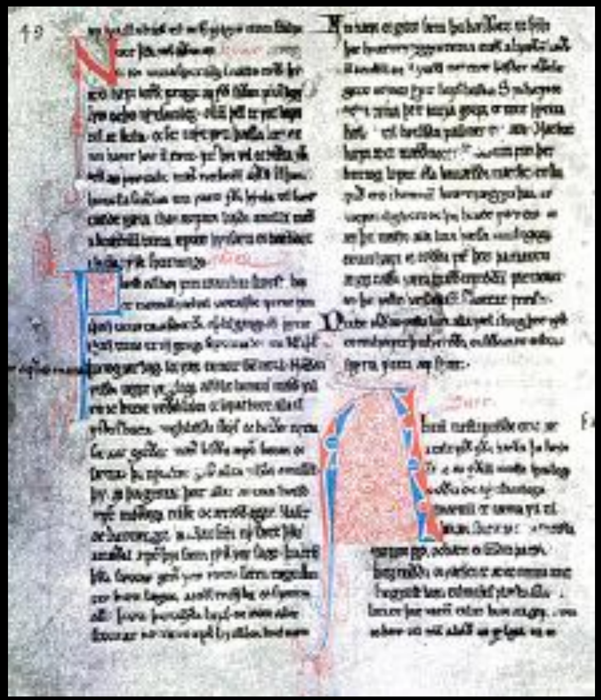
The Name - Aurora Borealis

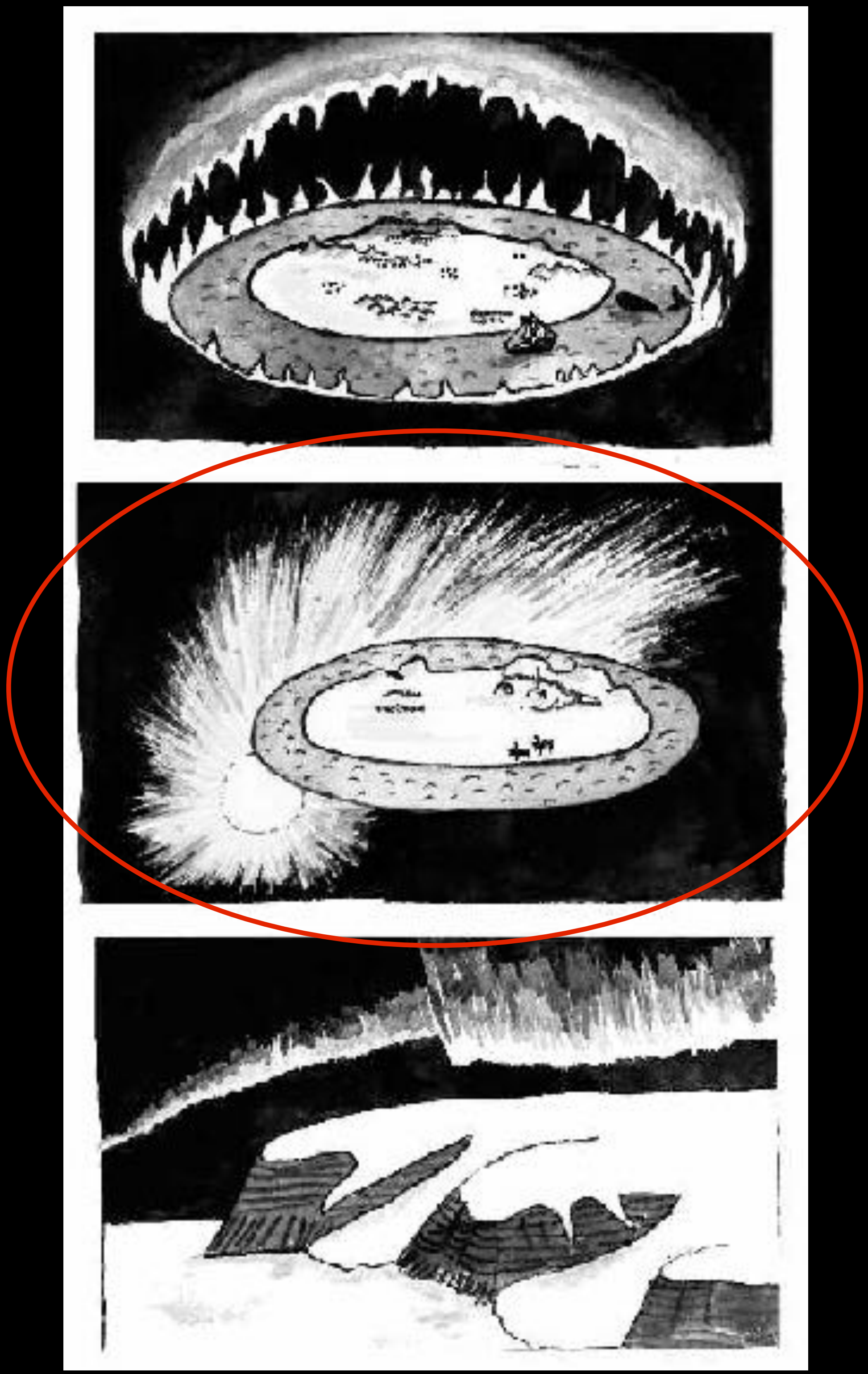
- The scientific name for the phenomena is Aurora Borealis, which is Latin and translates into "the dawn of the north".
- It was the Italian scientist Galileo Galilei (1564-1642) who first used the expression. On the latitude where Galileo was living, northern lights consist of mainly red colour.

Galileo Galilei (1564-1642), Italian mathematician, philosopher and astronomer. Among his discoveries are the four Galiliean moons around Jupiter. Although he wasn't the first to see northern lights, he gave it it's scientific name.

Aurora in Science

- The first realistic description of auroras is found in the Norwegian chronicle the King's Mirror from about 1230 AD. The book is originally written as a textbook, probably for the young King Magnus Lagabøte by his father.
- Reflected sunlight from below the horizon?, fires at Greenland?

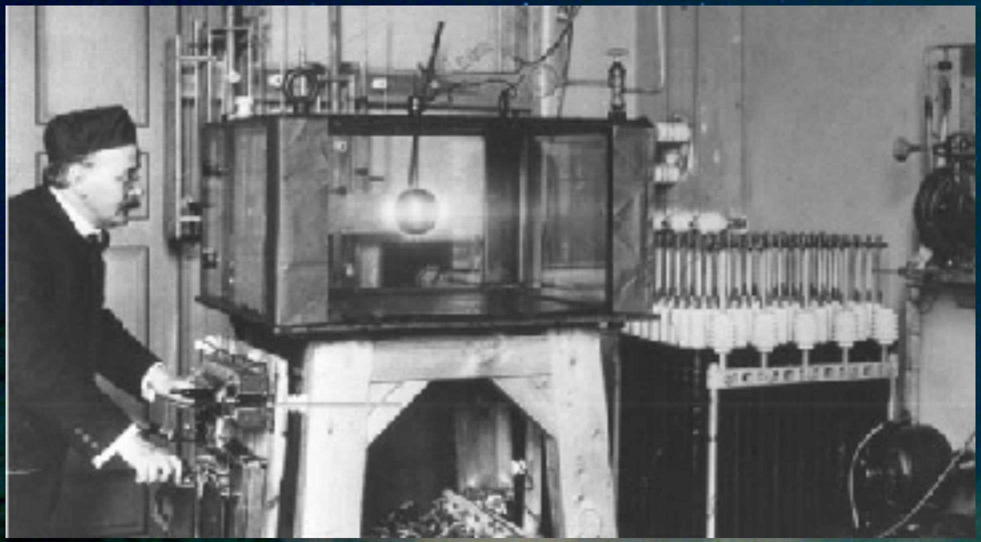




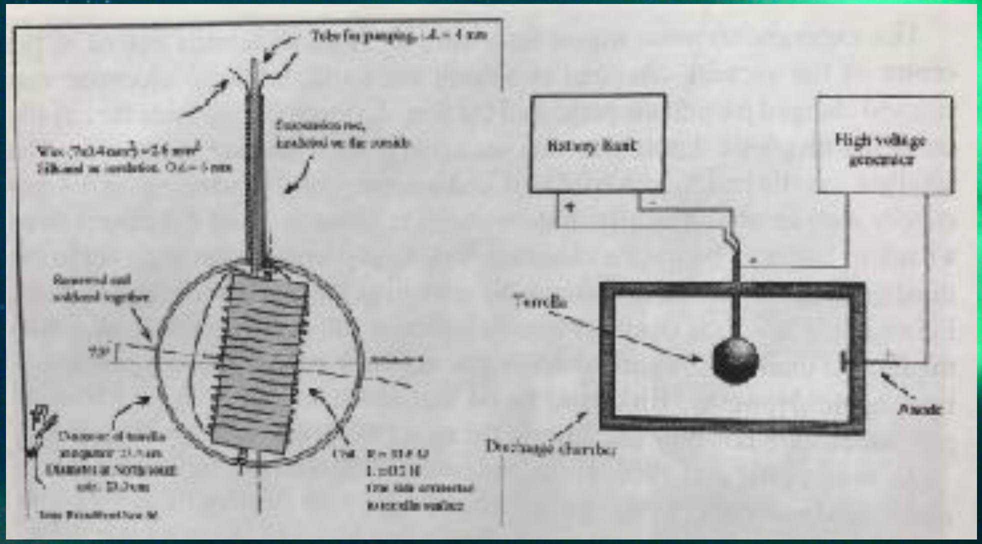
Birkelands Terrella-experiments

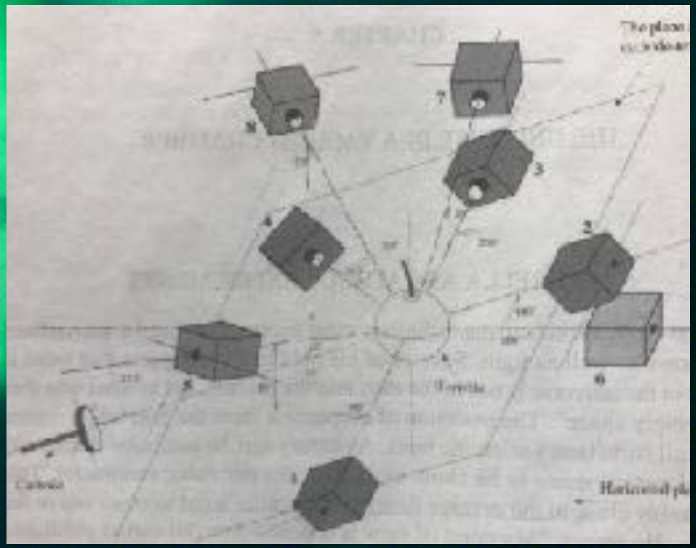
Using an electromagnet, he could create a magnetic field around the terrell mimicking Earth's magnetosphere.

The atmosphere was a layer of fluorescent paint that would give off light when it was struck by charged particles.

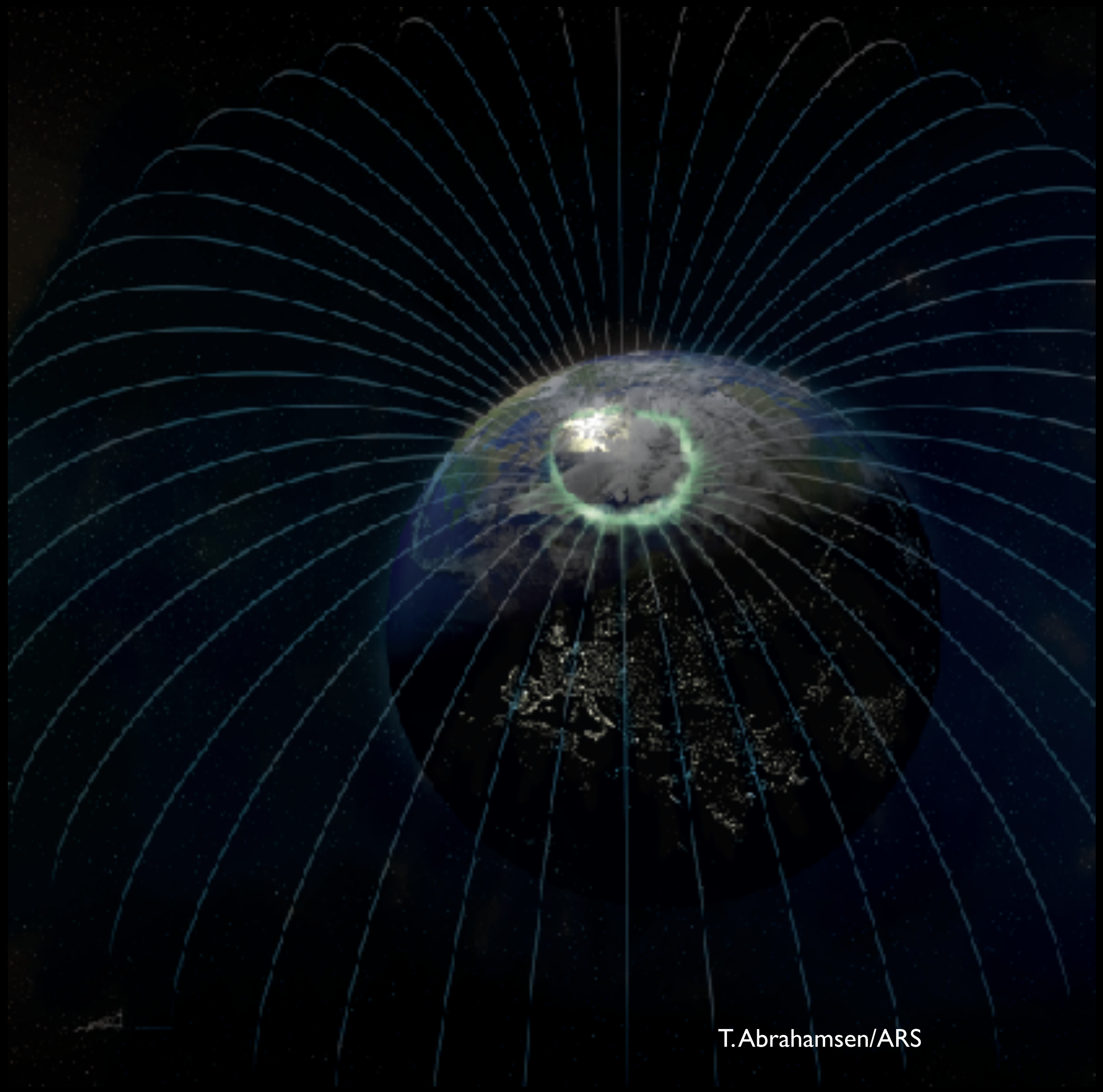


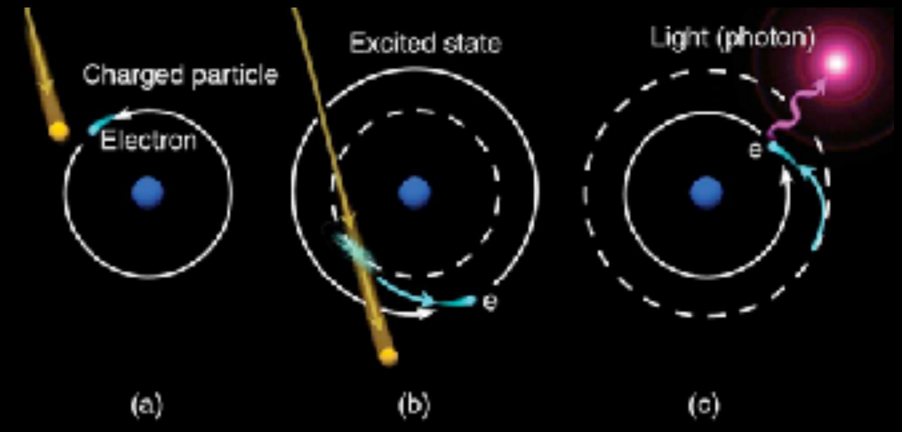
The voltage was 25.000 volt

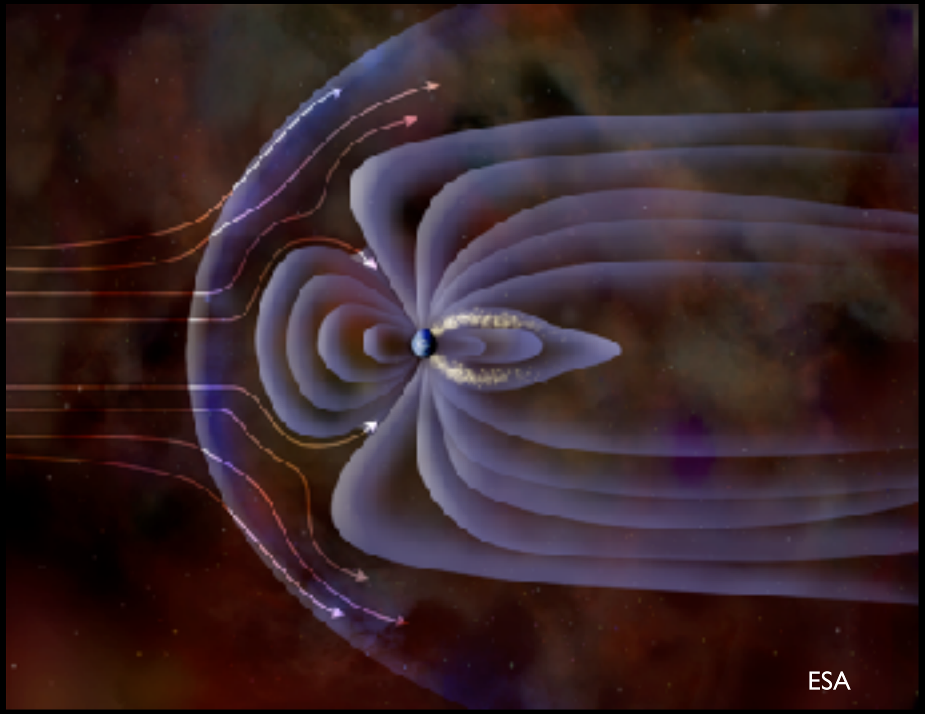




HOW ARE THE NORTHERN LIGHTS CREATED?





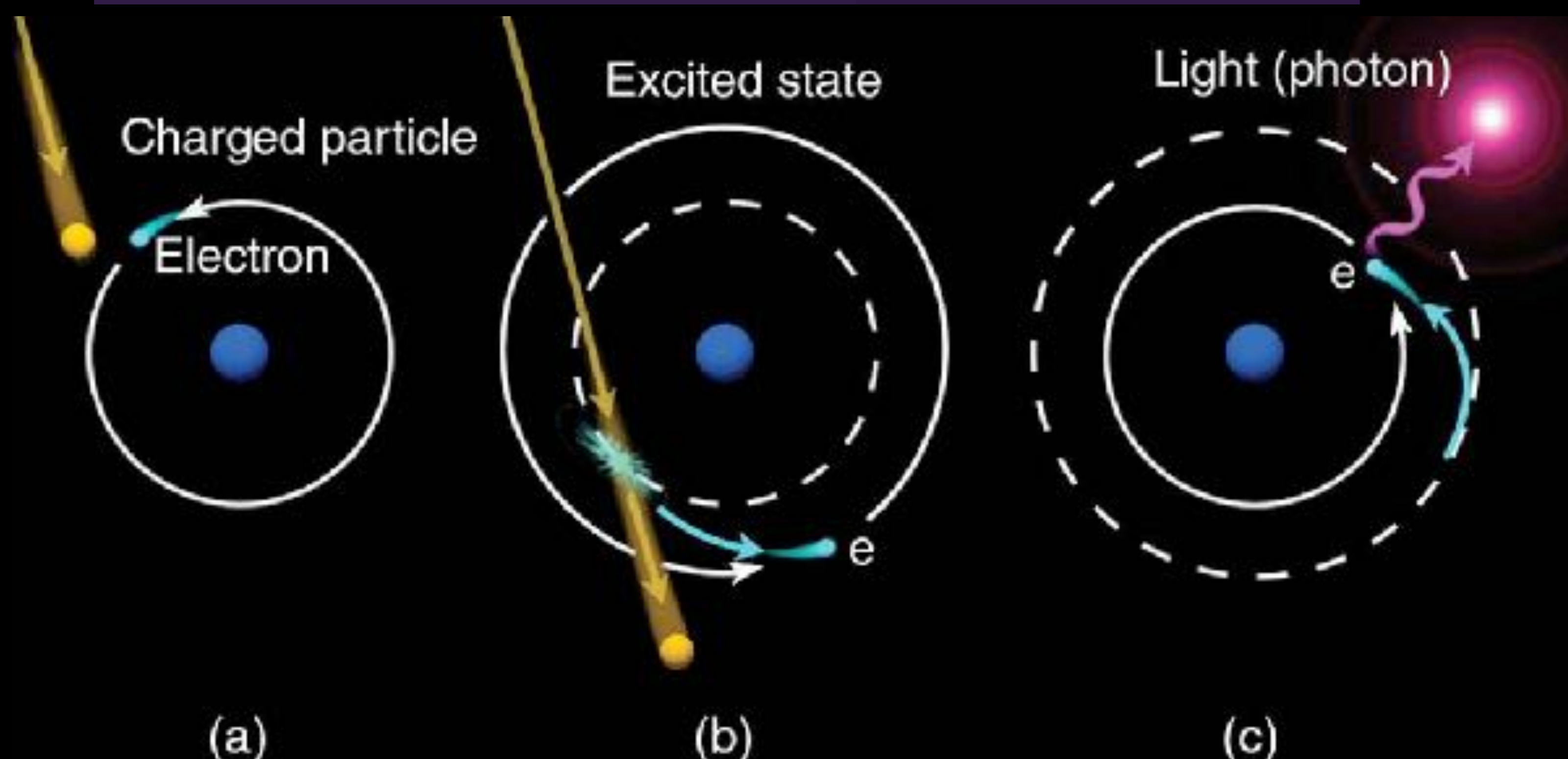


The aurora is formed when particles from the Sun interfere with our magnetosphere. Some particles manage to penetrate the magnetosphere on the night side (tail). When solar storms shakes up the magnetosphere particles inside this magnetic cocoon will be ejected back towards the Earth along the magnetic field lines. They are guided down towards the Polar Regions.

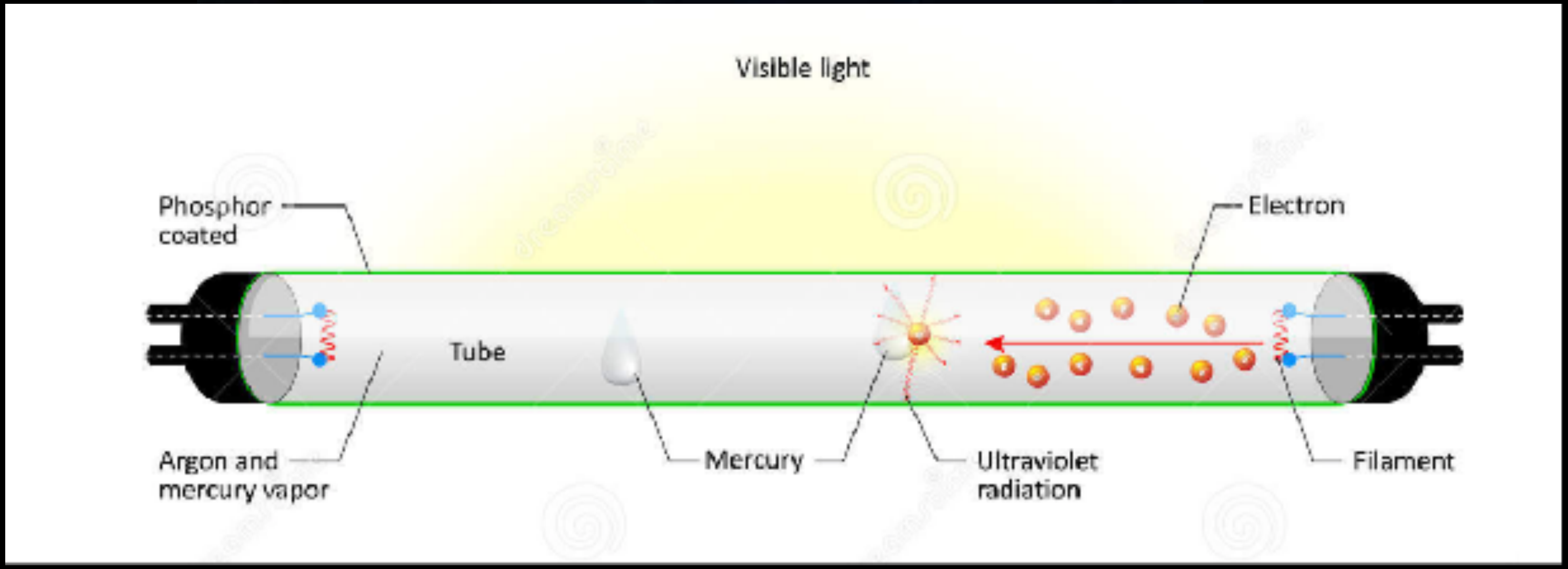
When they hit Earth's atmosphere they collide with oxygen and nitrogen. These collisions, which typically occur at altitudes between 80 to 300 km, transfer some energy to theses atoms (they get excited), and immediately send out light on a certain frequency or color.

The Colors of the Aurora

- The light from the Sun appears white but consist of all colors (e.g rainbow)
- The aurora light is composed of distinct colors that comes from certain gases in the Earths atmosphere.
- The colour composition of the aurora is the atmosphere's fingerprint.

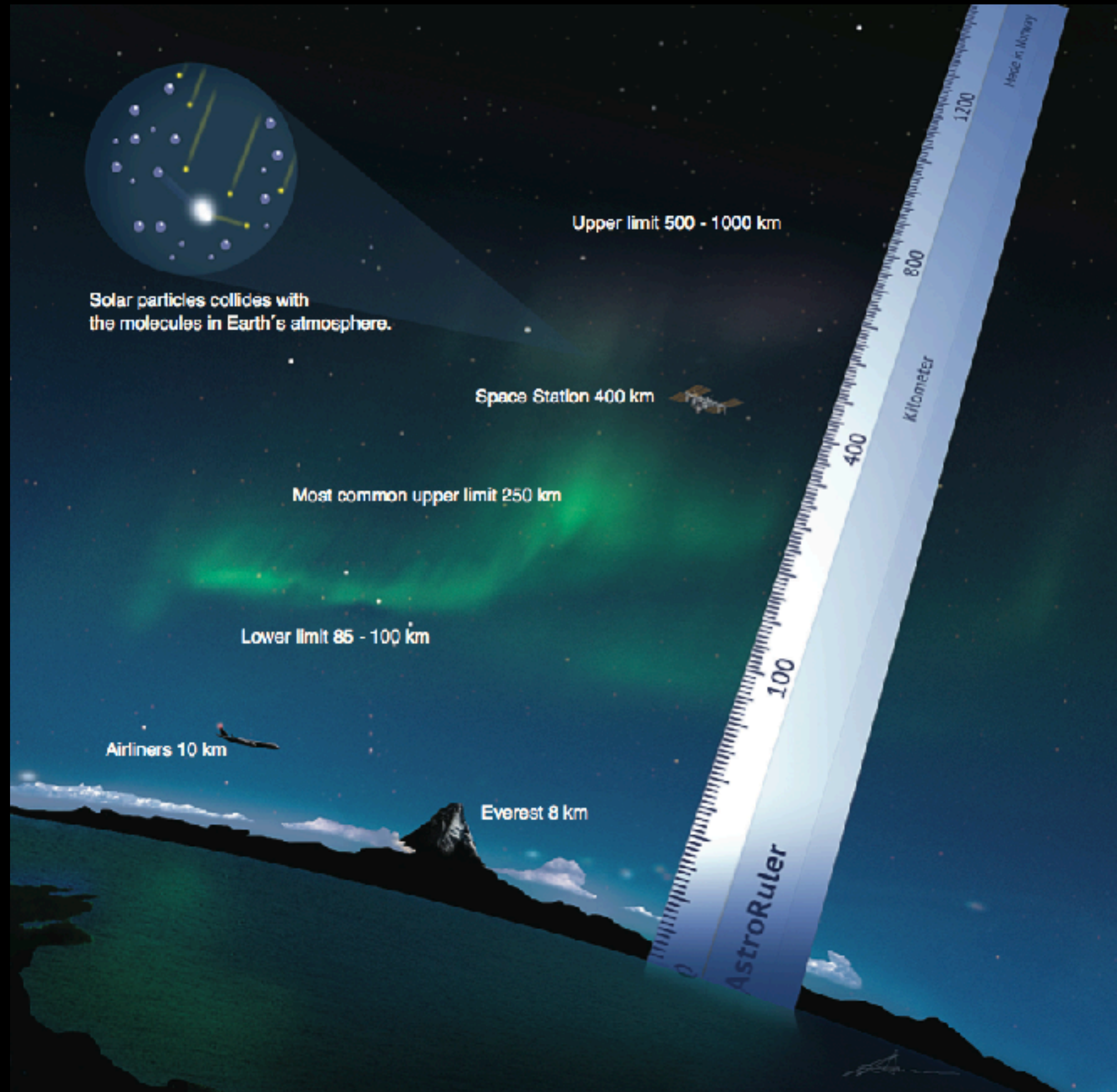


The aurora - A gigantic neon sign



The Height of the Aurora

- The Aurora extends from about 80 km to about 250 km and sometimes up to over 500
- Thus, the aurora is not a weather phenomenon



T. Abramhamsen/ARR

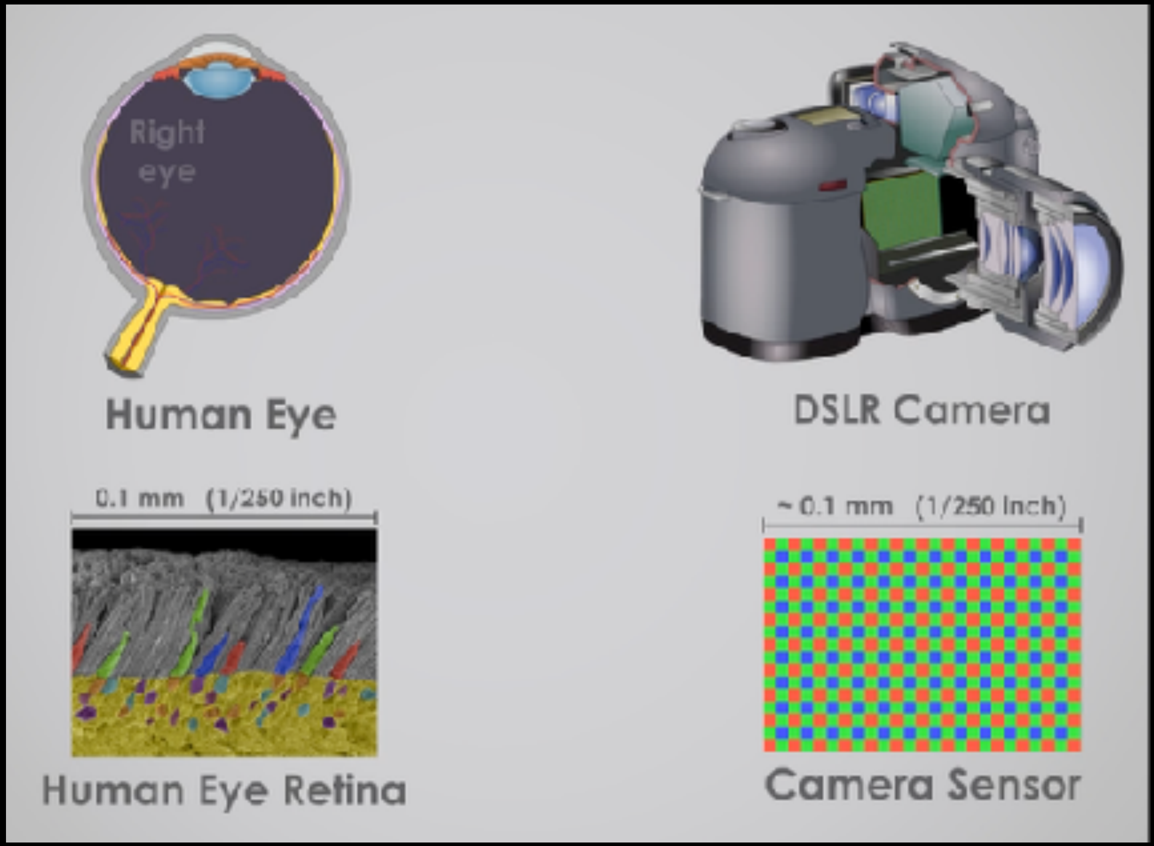
Human eyes vs cameras

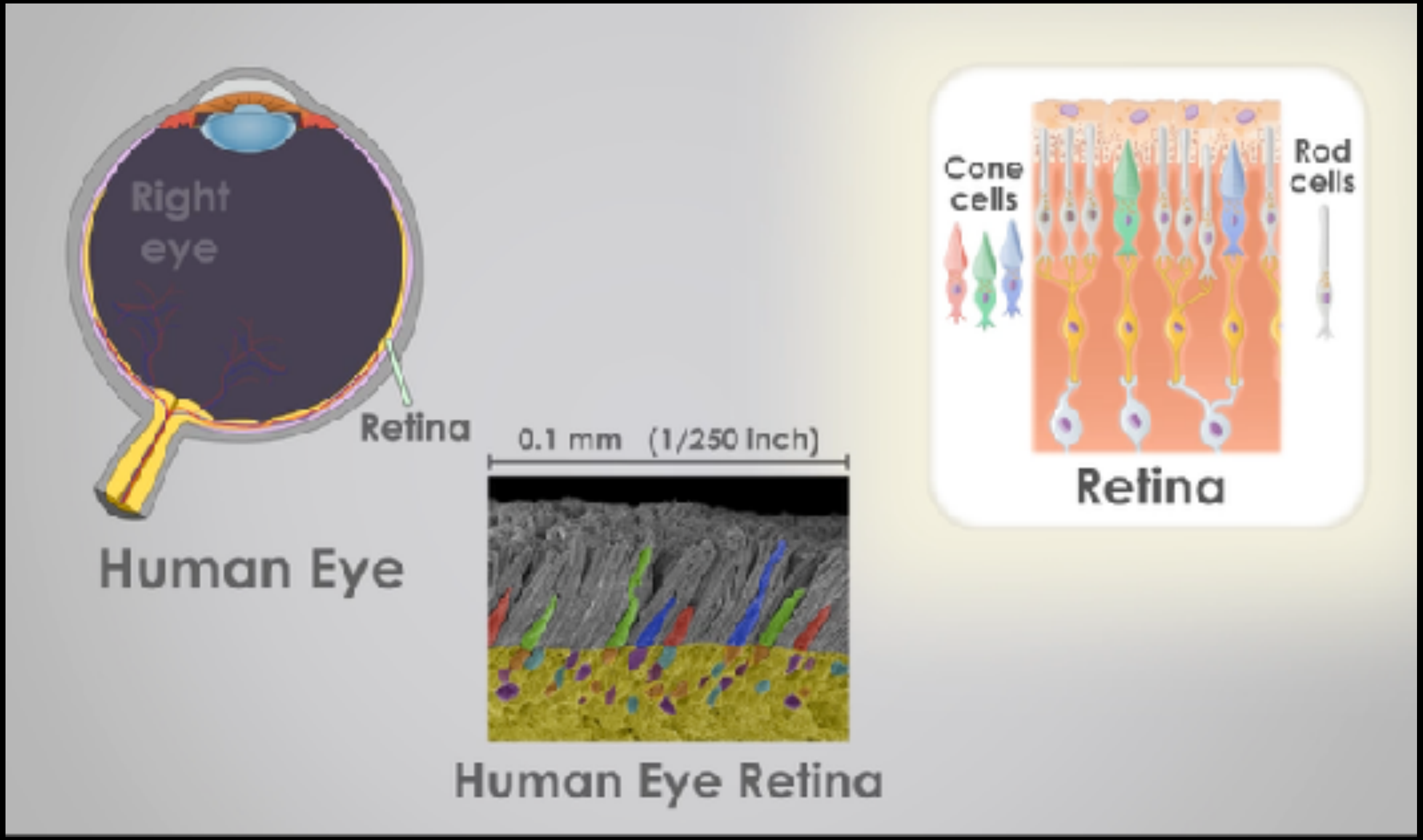
Many people will be somewhat dissapointed when they see the Northern light - with less bright green colors compared to the postcards and images online. SOme photographers tweak the coloers to much, but the main reason is that our eyes are not designed for night vission and low light conditions.

Human eyes has nmeny rod cells that gives good night vission but no colors. We have fewer of the cone cells that provide color vision. That is why we see less colors in dark condition - and why the northern lights often looks more whitish than bright green.

Cameras also have the advantage of being able to accumulate light for a long time (long exposures) in addition to being more sensitive to colors.

Some people can see more colors in dark konditions that others - but during very strong northern lights activity most people can se many coloers - like pruple, blue and red.

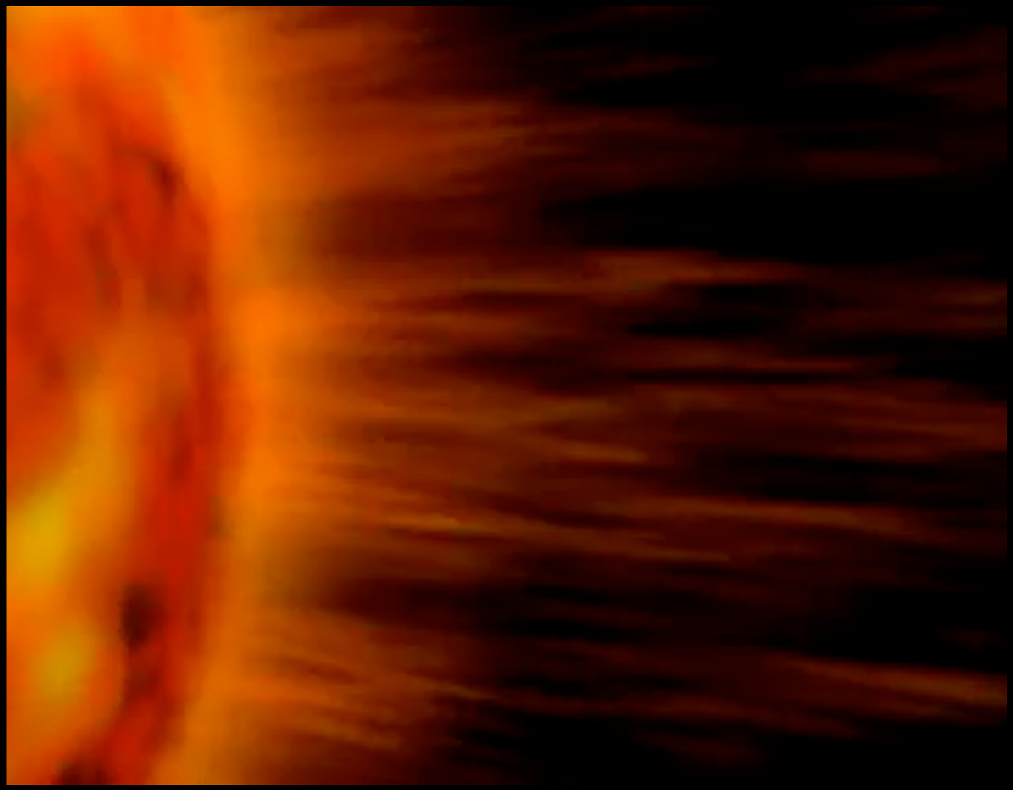


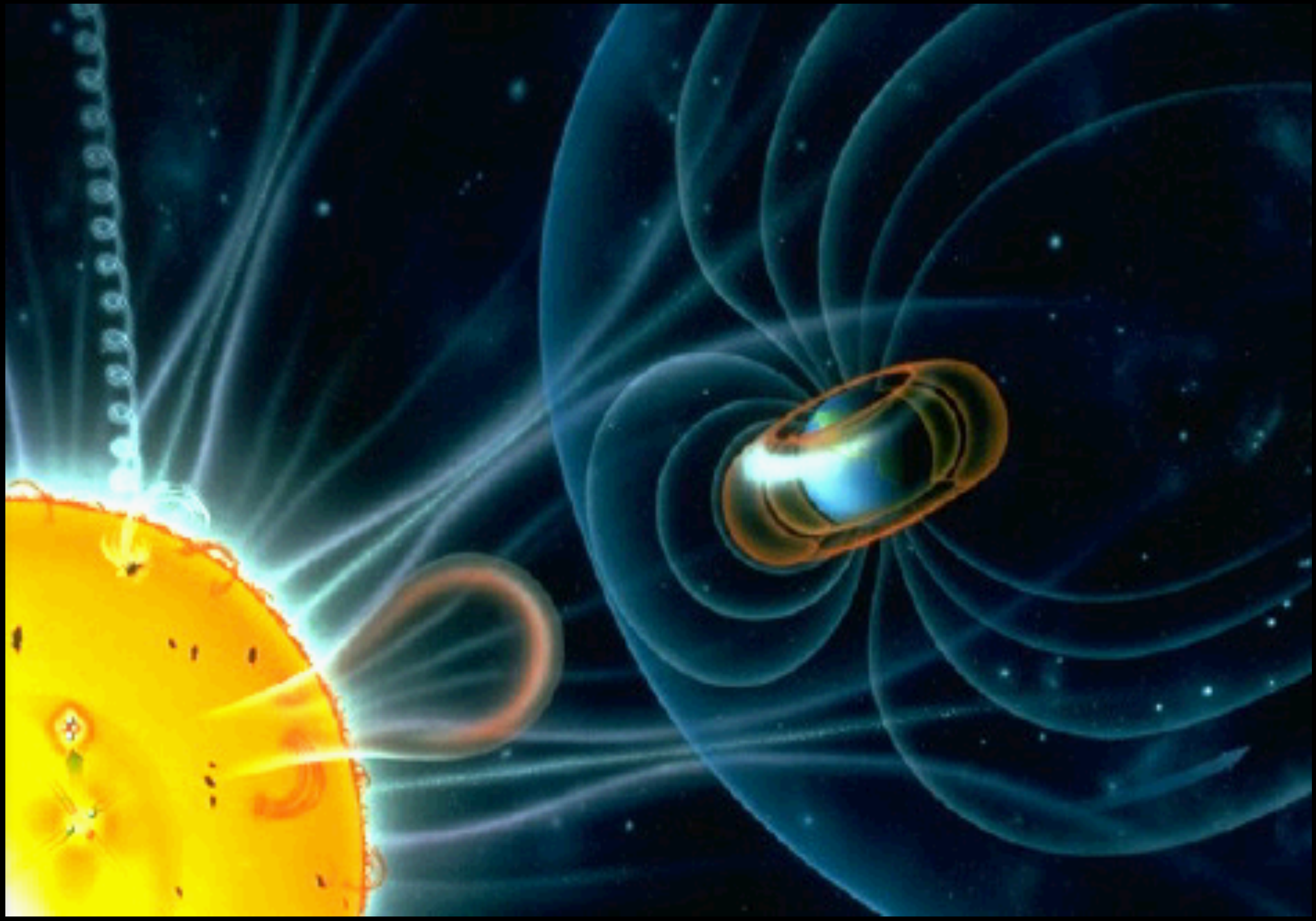


Credit: Paul Jensen

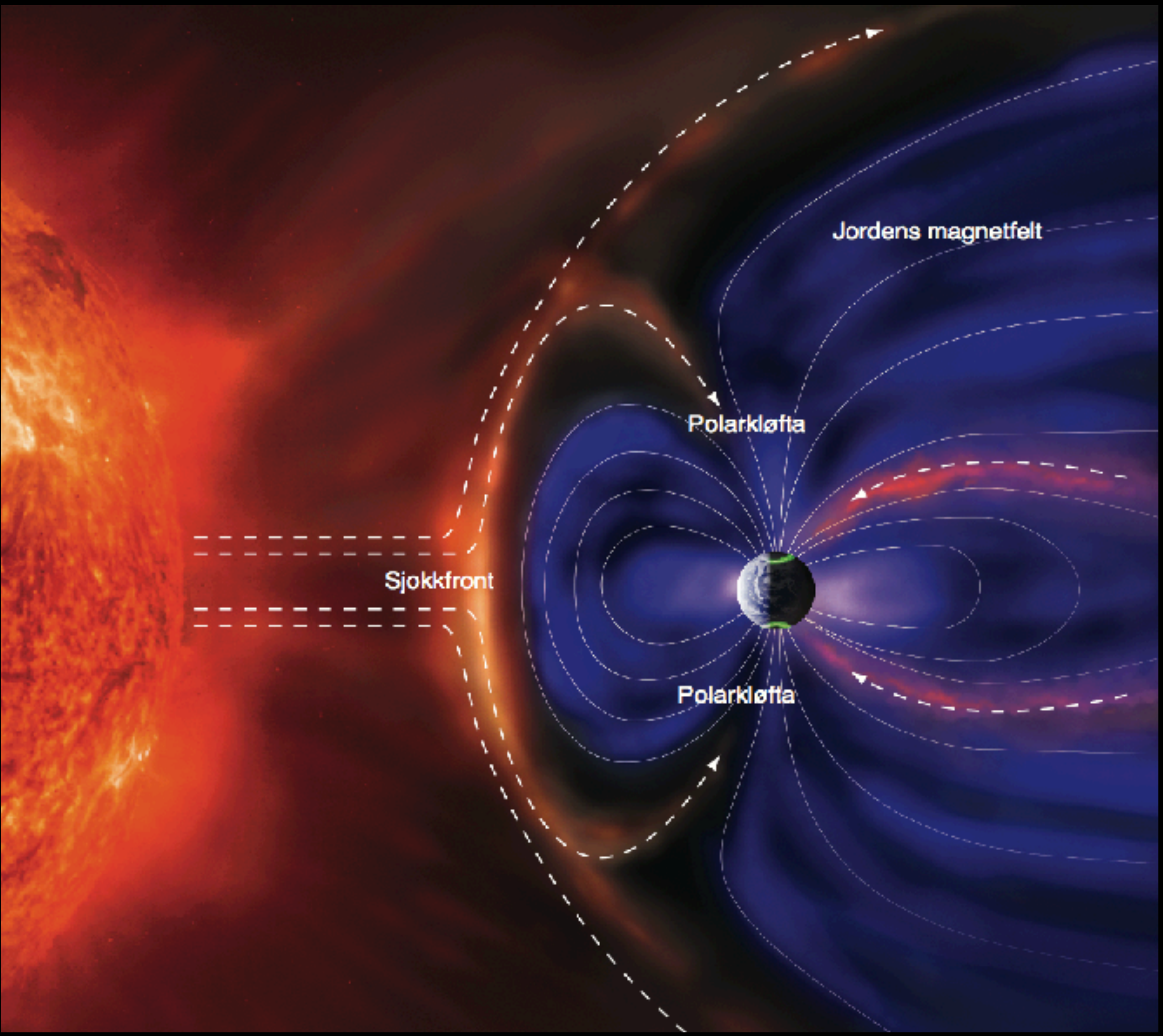
What is the Solar Wind?

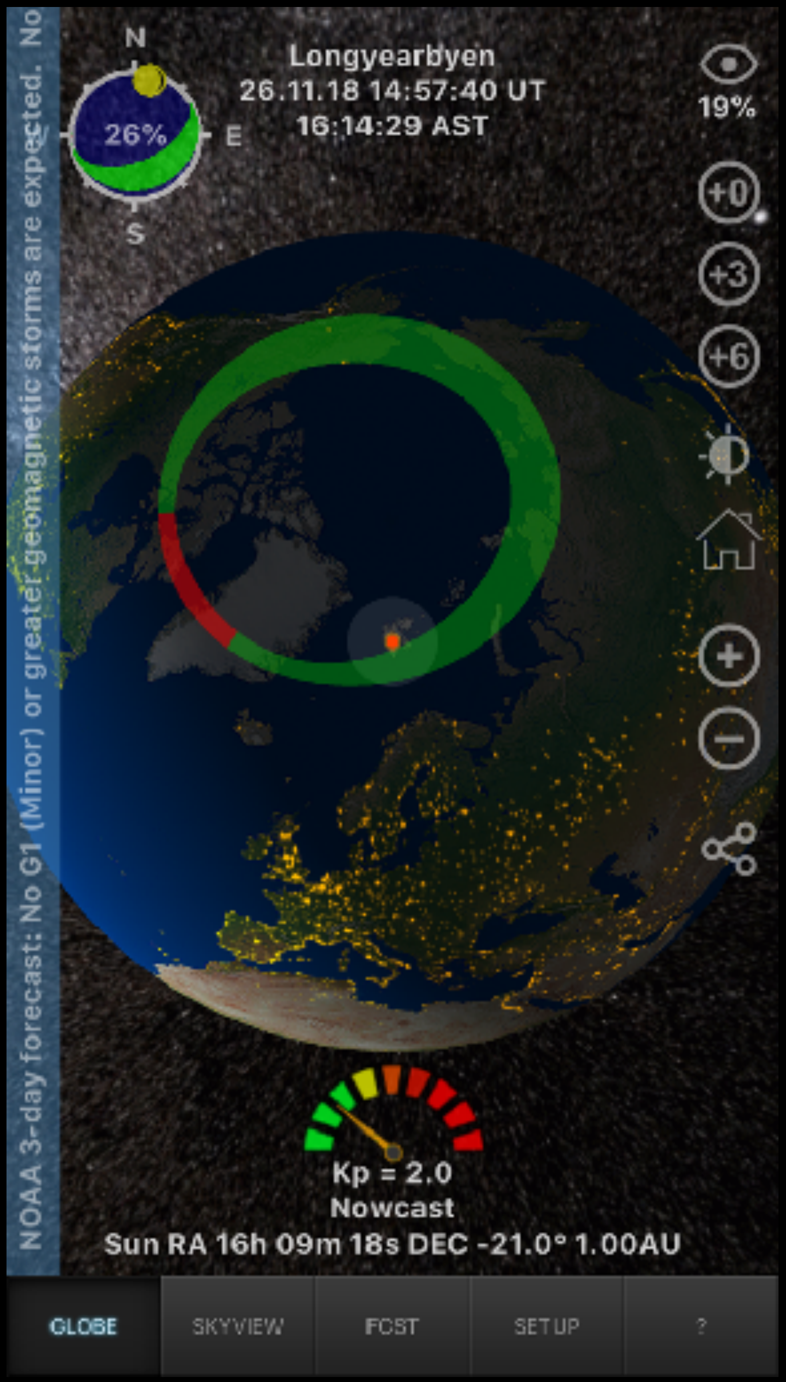
- A constant stream of particles flows from the Sun’s corona, with a temperature of about a million degrees and with a velocity of about 1.5 million km/h. The solar wind reaches out beyond Pluto's orbit (about 5900 million kilometres). The drawing shows how it pushes on and shapes the Earth’s magnetosphere.



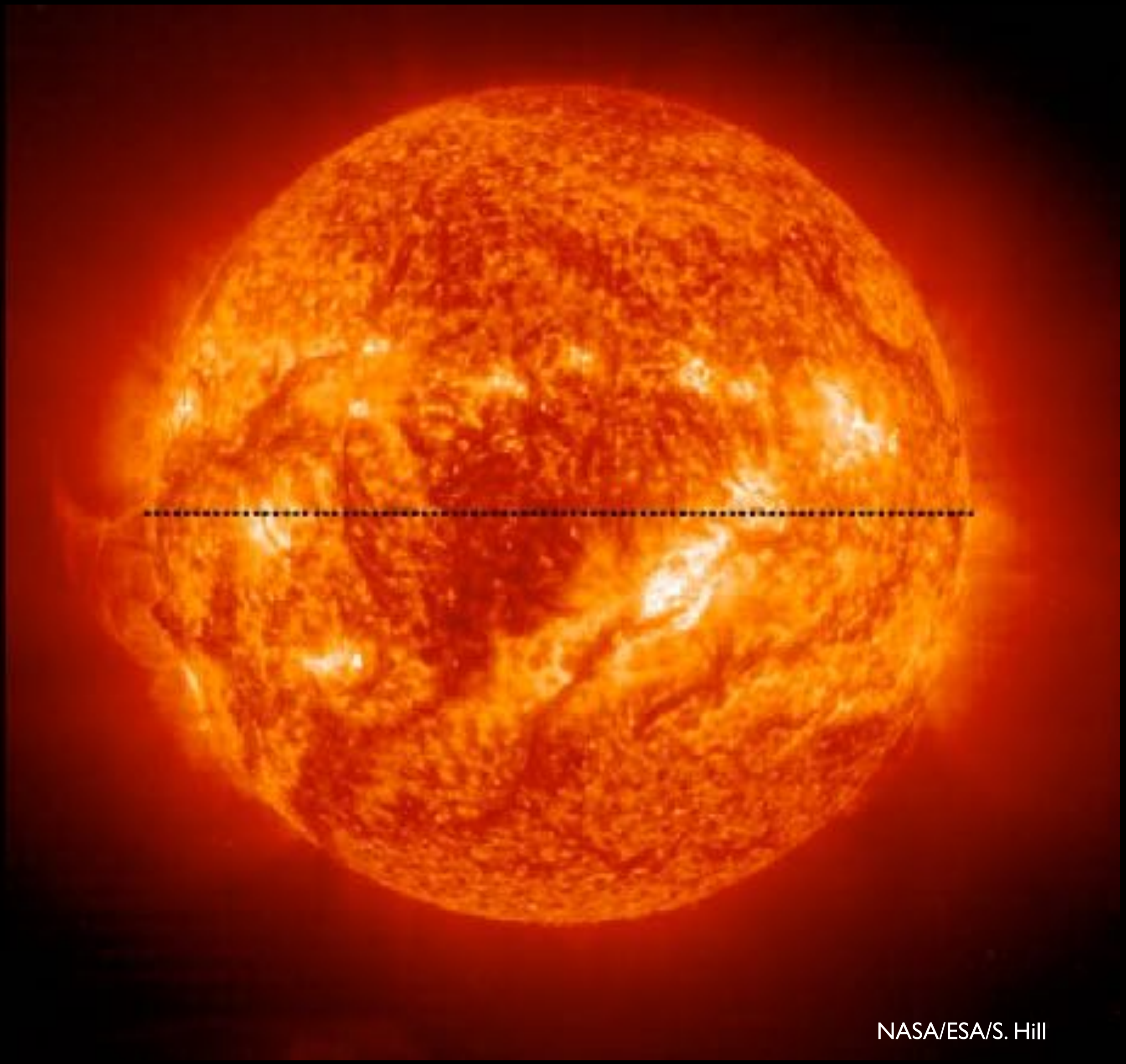


Svalbard and the Dayside-aurora



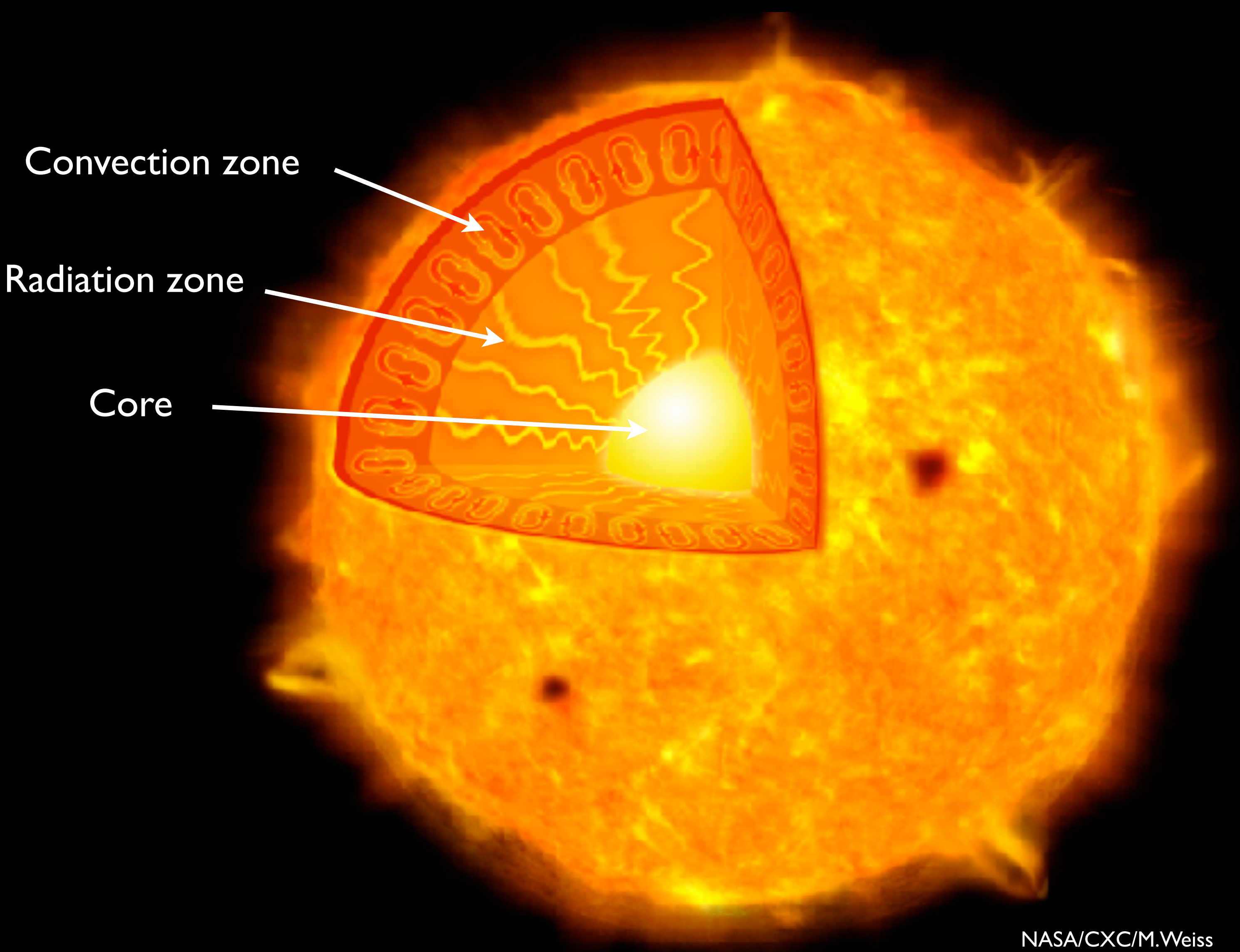


The Sun



- The Sun is 333,400 times massive than the Earth.
- The Sun contain 99.86% of the total mass in the solar system
- The diameter is 109 times the Earth – 1.3 million Earths can fit inside the Sun
- Consist of 78% Hydrogen and 20% Helium and 2% other elements.

THE STRUCTURE OF THE SUN



The hot compact core of the Sun – where the energy is created – has a radius of about 175,000 km. Outside the core is a layer where the energy is transported by electromagnetic radiation or photons. This layer is called the radiation zone.

Further out we find the convection zone where the energy is transported as a turbulent churning motion similar to a pot of boiling soup.
The visible surface, the photosphere, is only about 400 km thick. Above the photosphere we find the chromosphere, a layer of thin hot gas extending to a few thousand kilometres. Above the chromosphere is the corona, the Sun´s outermost part of the solar atmosphere.

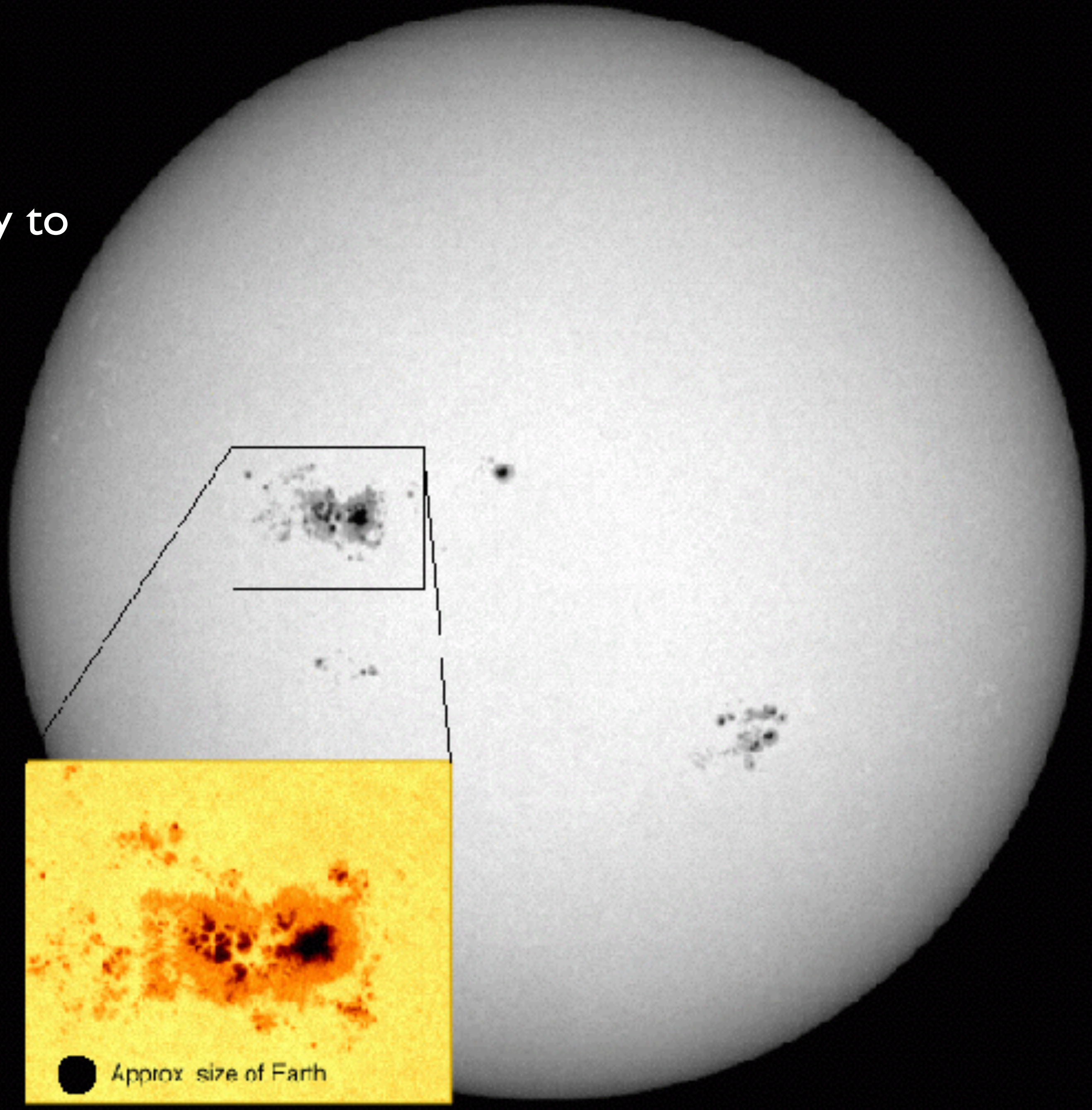
SUNSPOTS

Dark features on the solar surface

Caused by strong magnetic fields emerging from the solar interior.

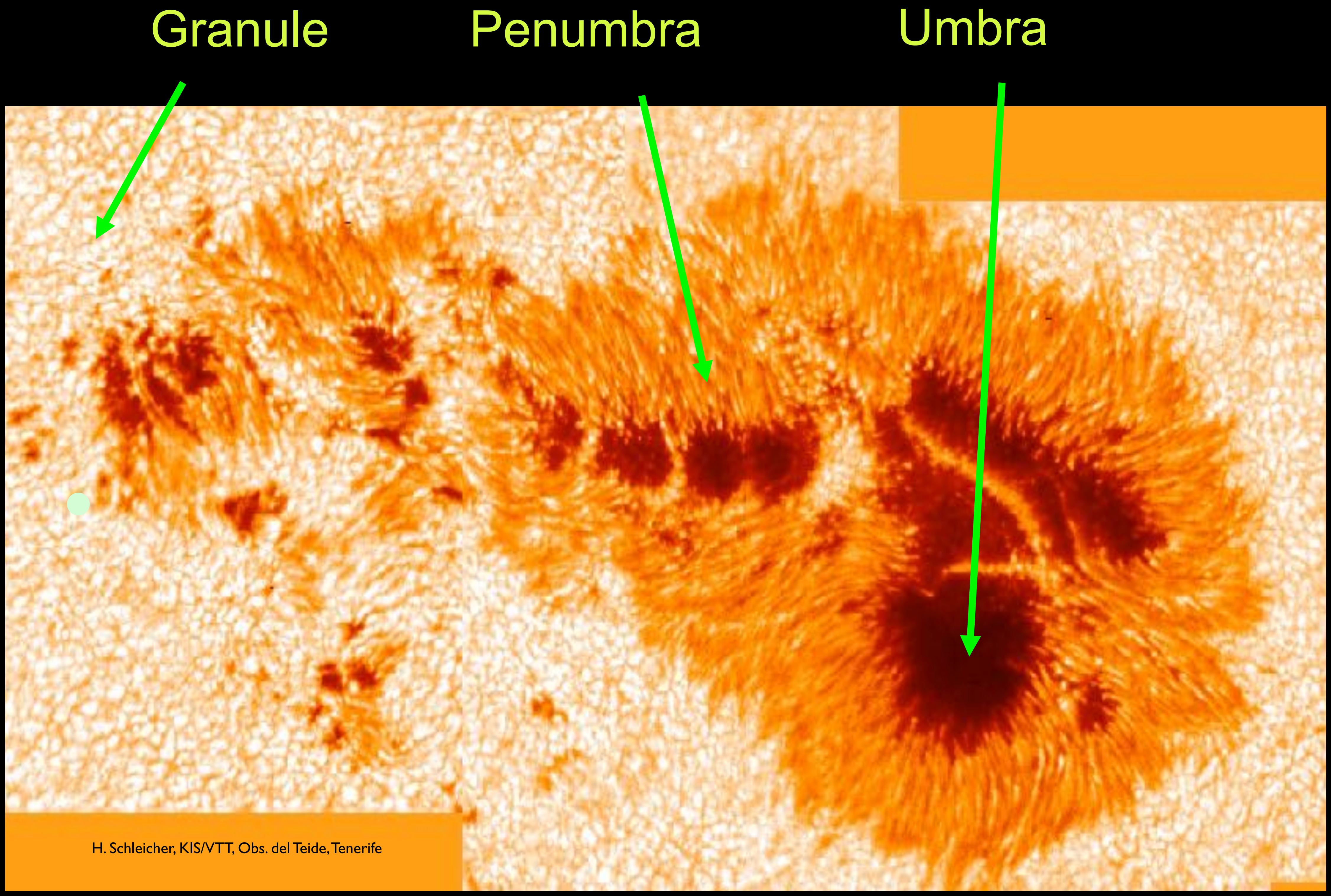
The strong magnetic fields blocks some of the energy to emerge from these regions.

NASA



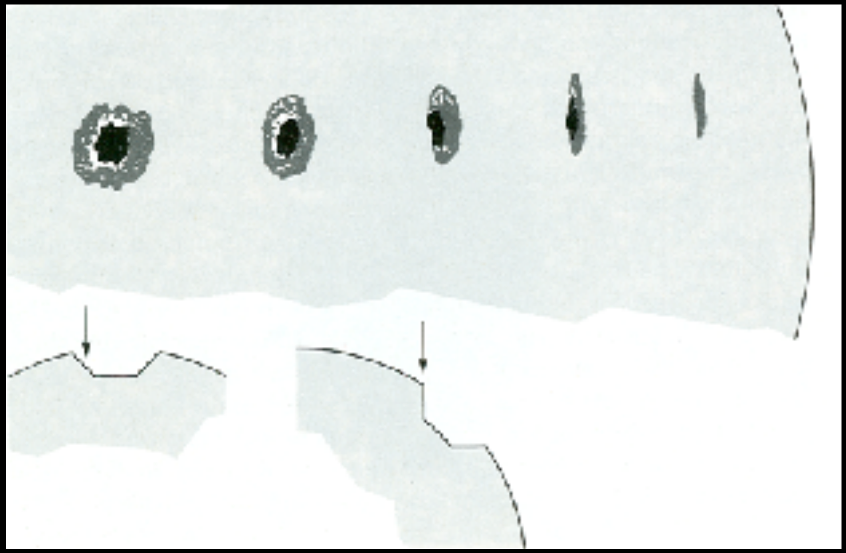
NASA/ESA/S. Hill

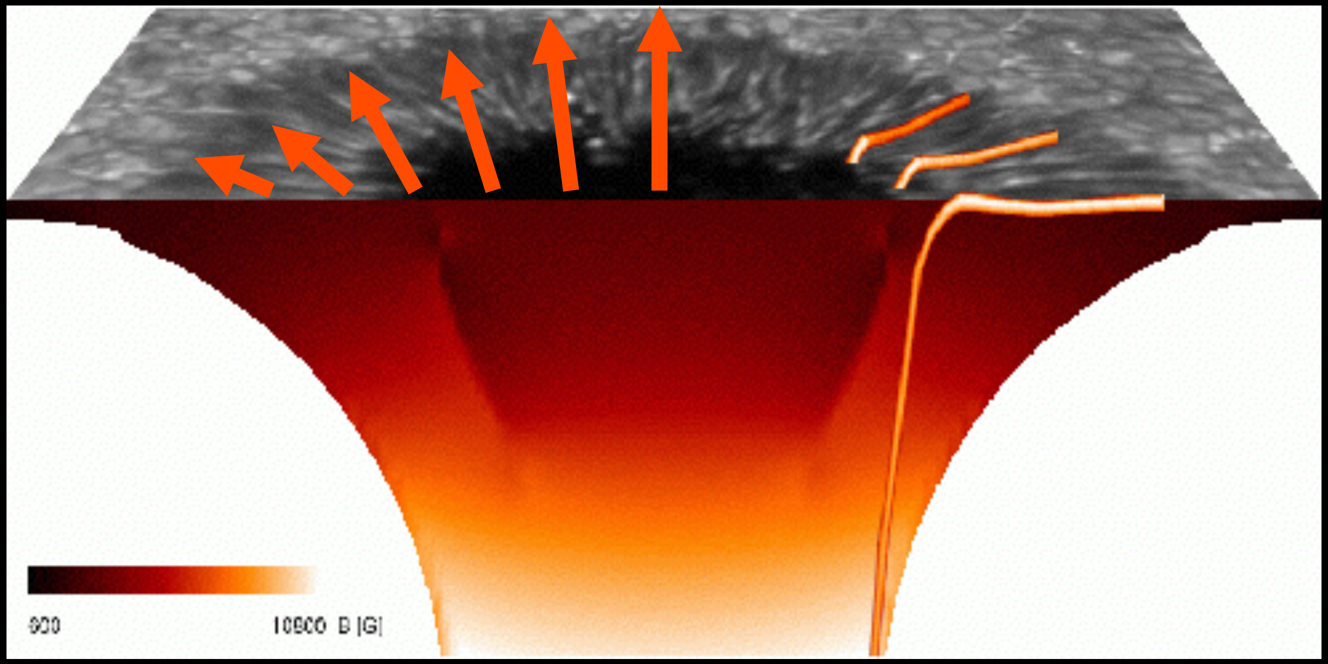
Sunspot structure

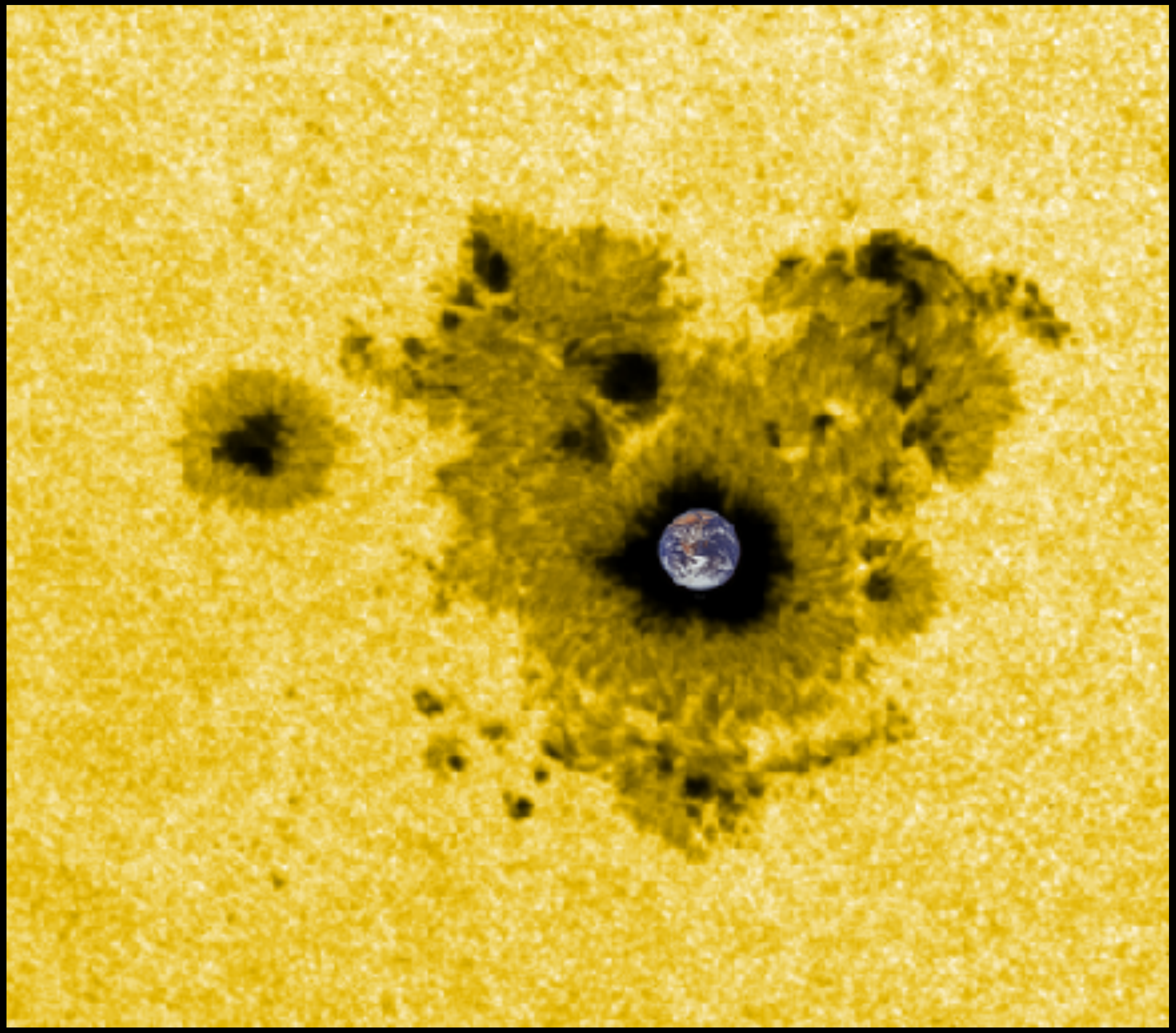


Sunspots, some properties

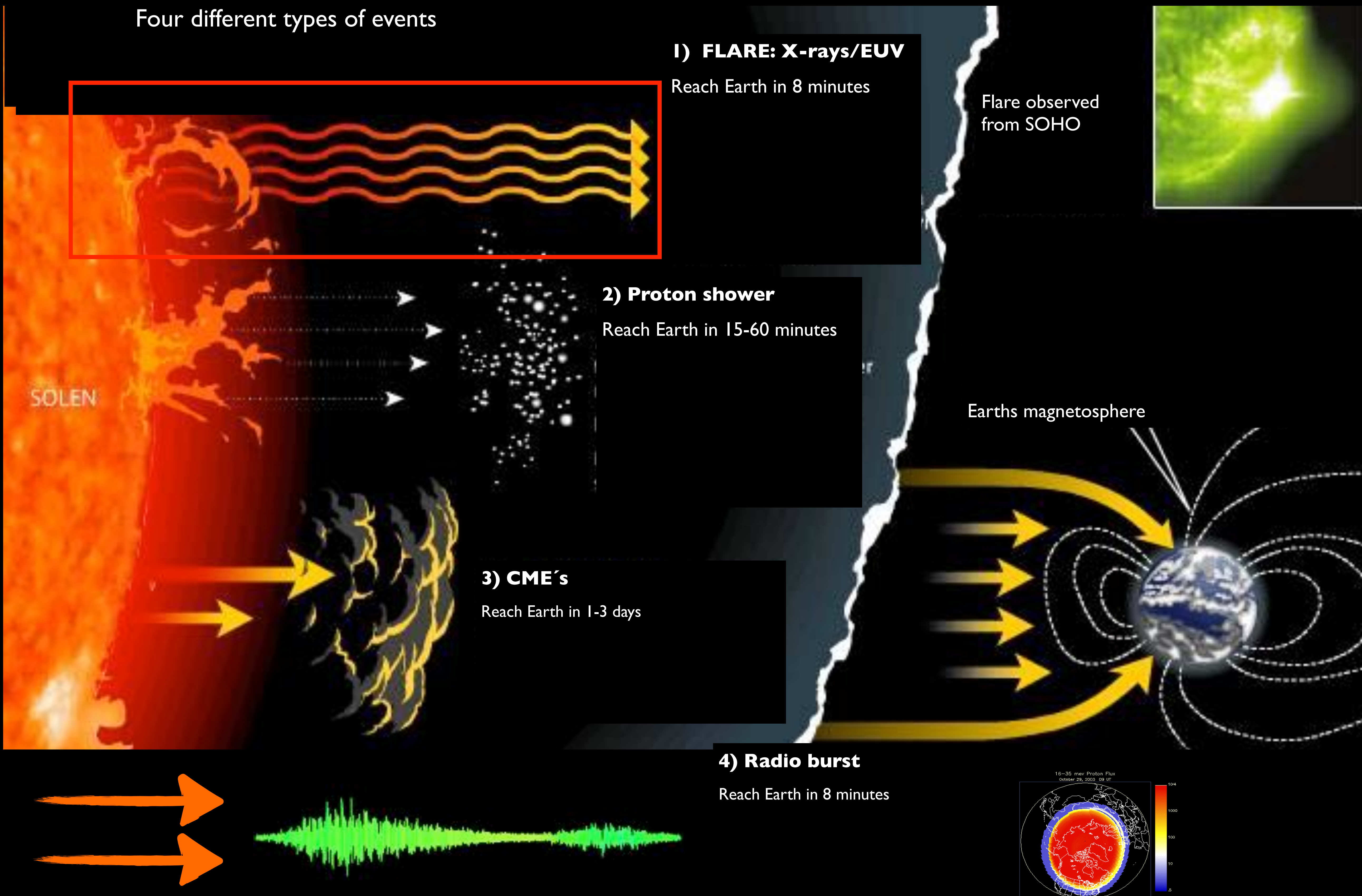
- Field strength: Peak values 2000-3500 G (Earth < 1 Gauss)
- Brightness: umbra: 20% of quiet Sun, penumbra: 75%
- Sizes: thousands of km's to 10 times the Earth
- Lifetimes: between hours & months:.



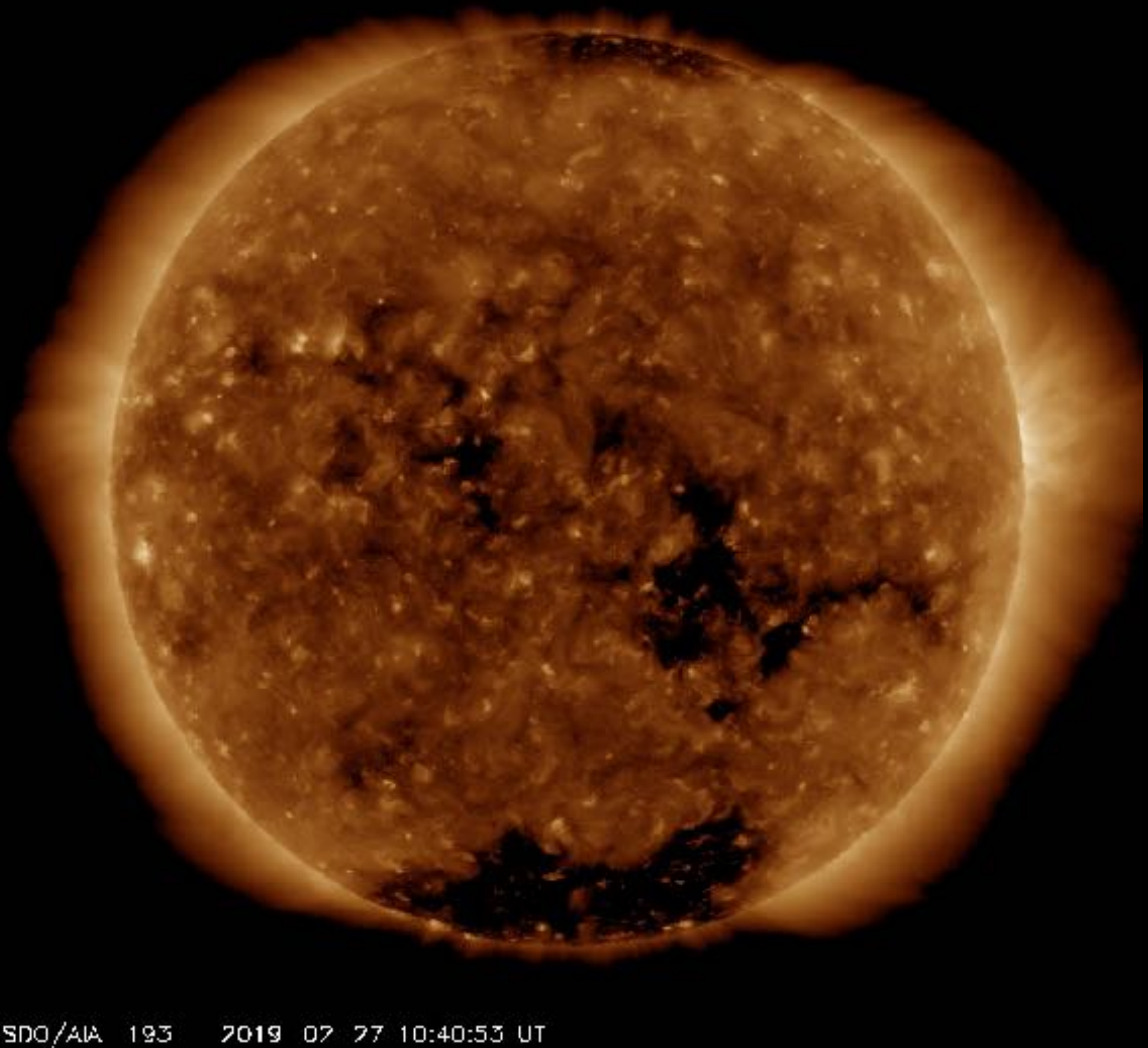


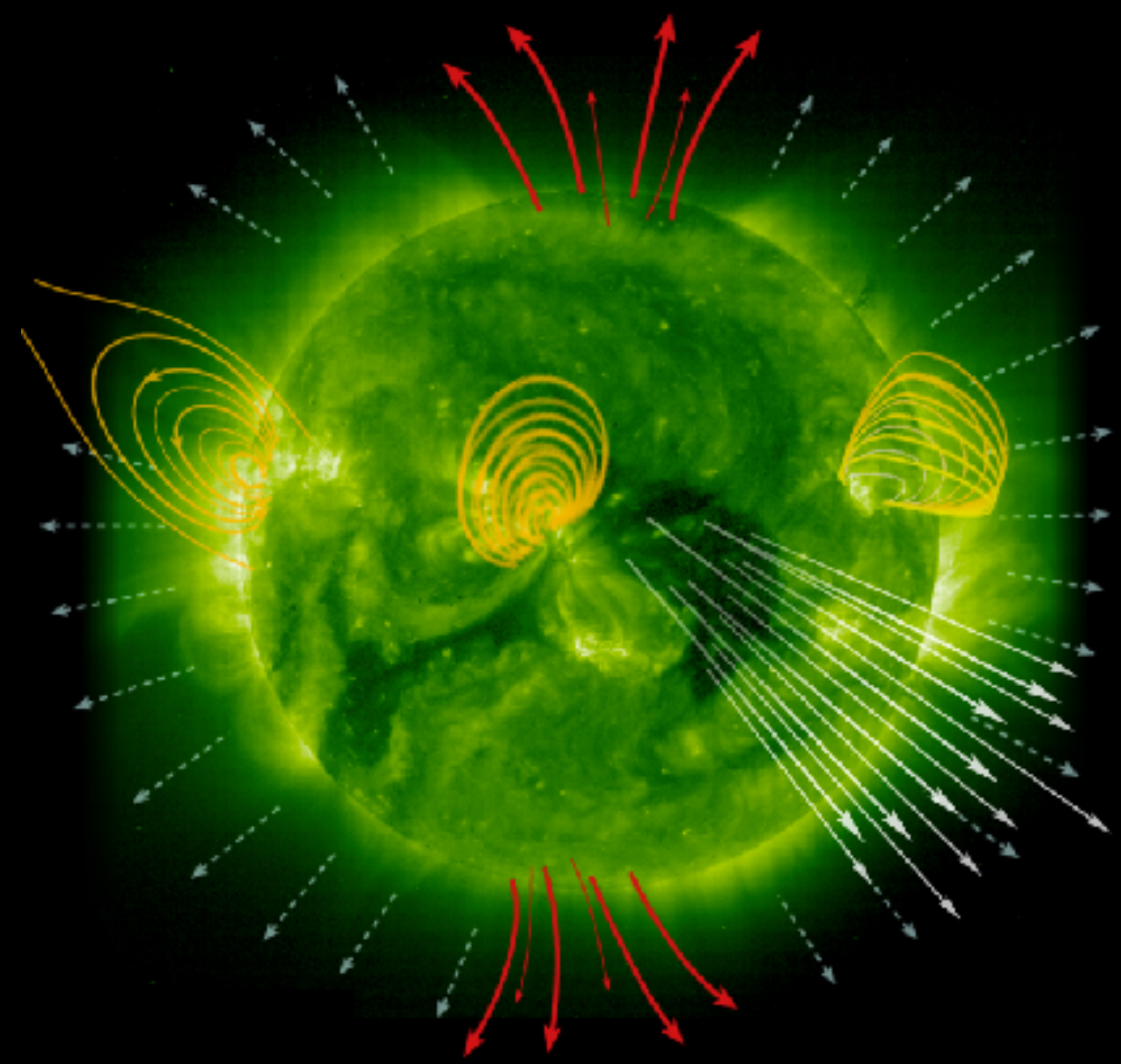


The four different types of events



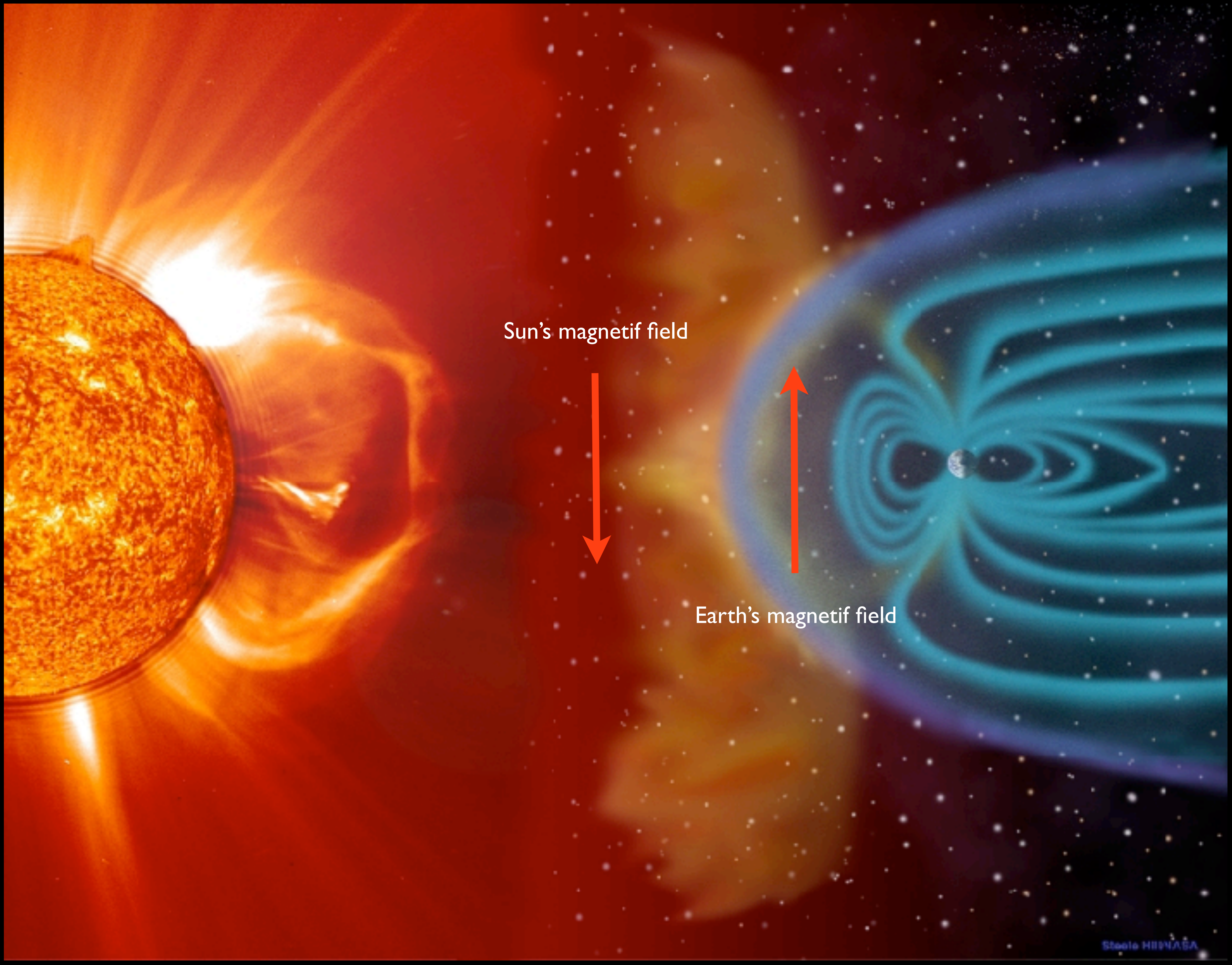
Coronal holes



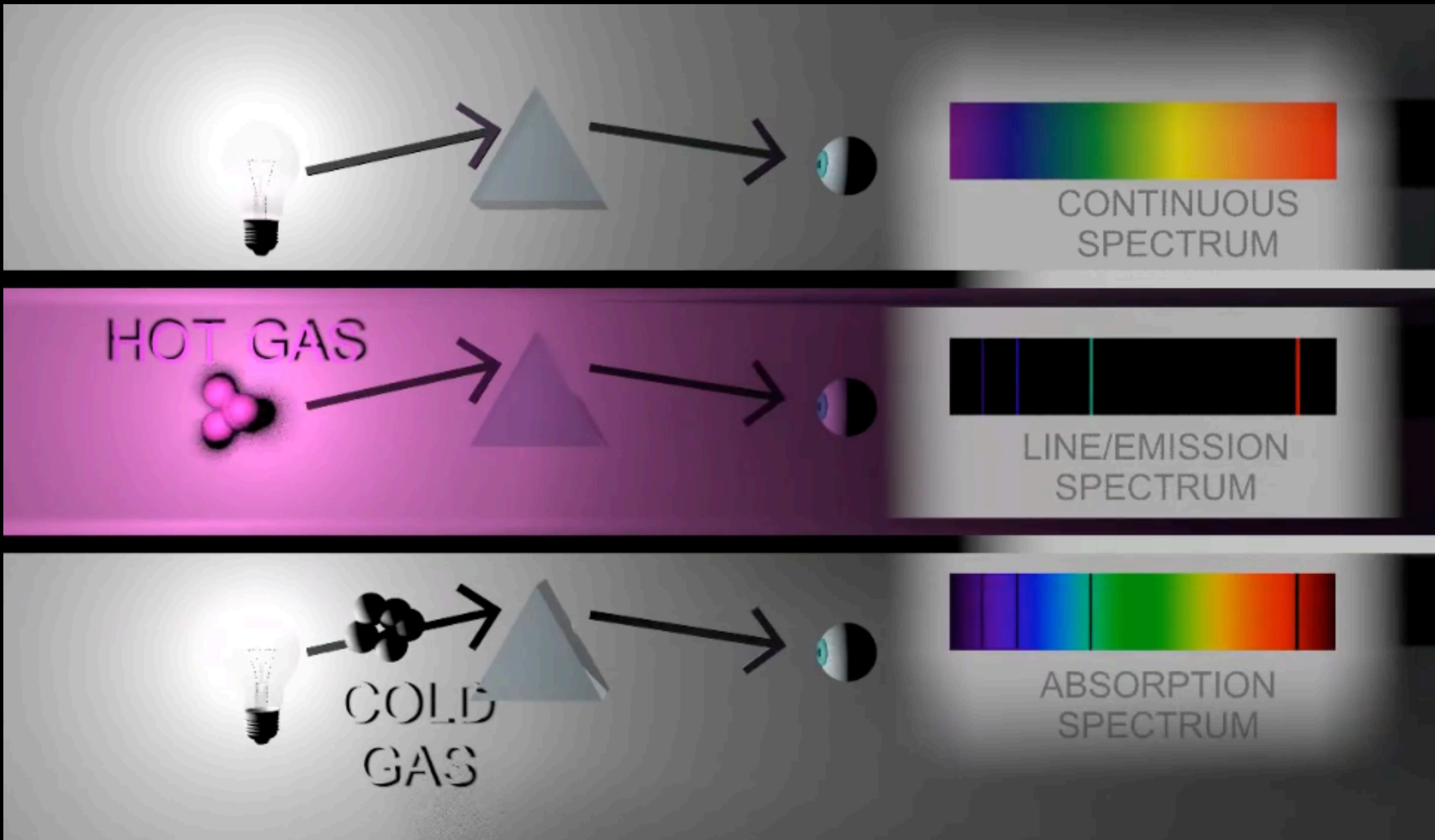


How effective wil the storm be?

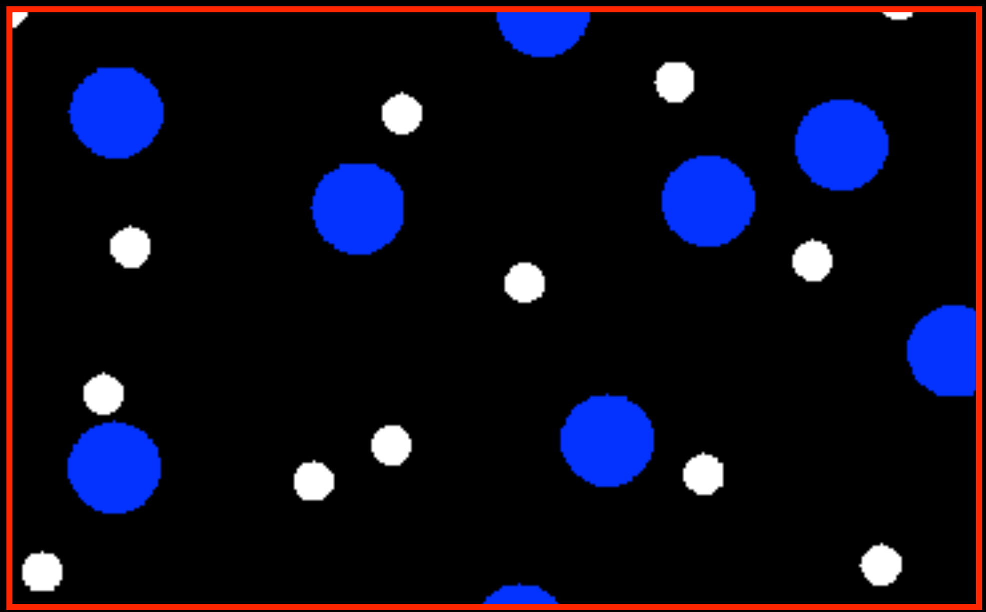
Opposite direction - strong interaction - strong geomagnetic storm

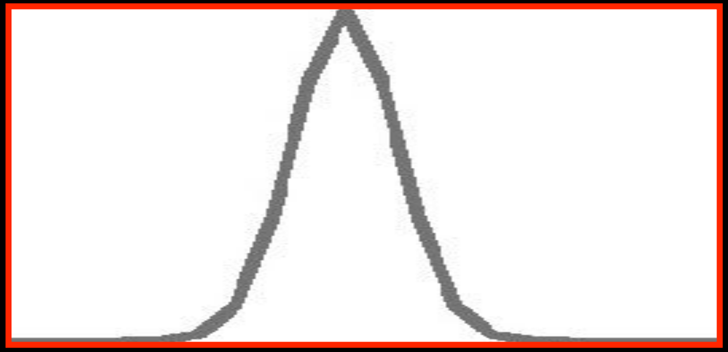


Absorption, emission and continuous spectra

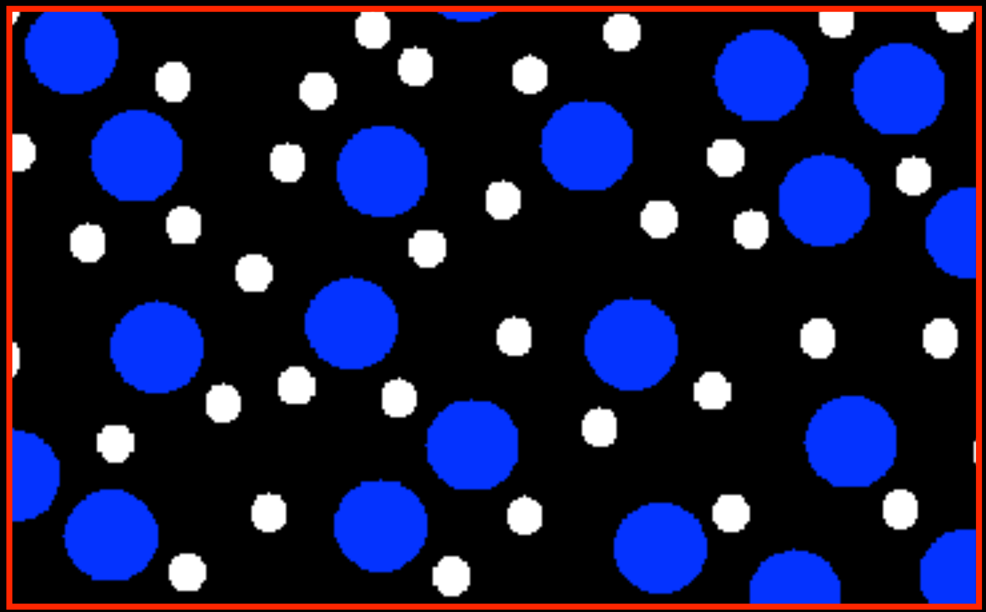


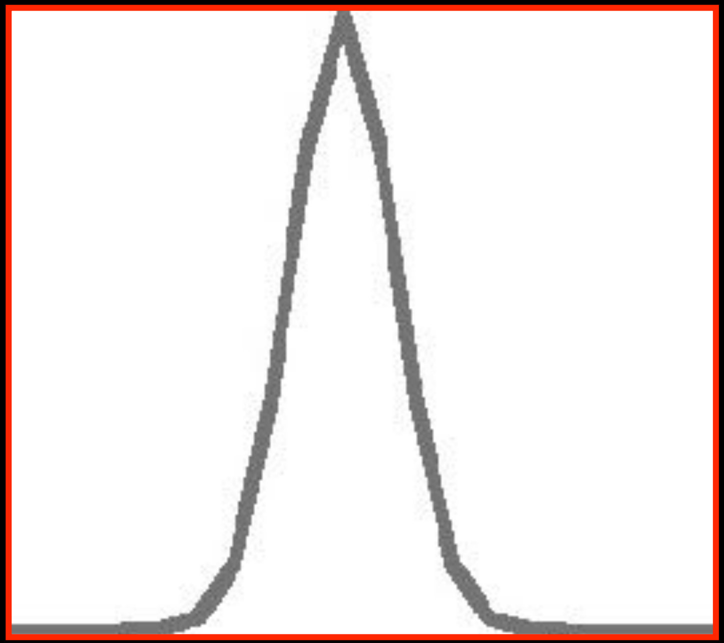
What can we learn from a spectrum
#1: Line Intensity





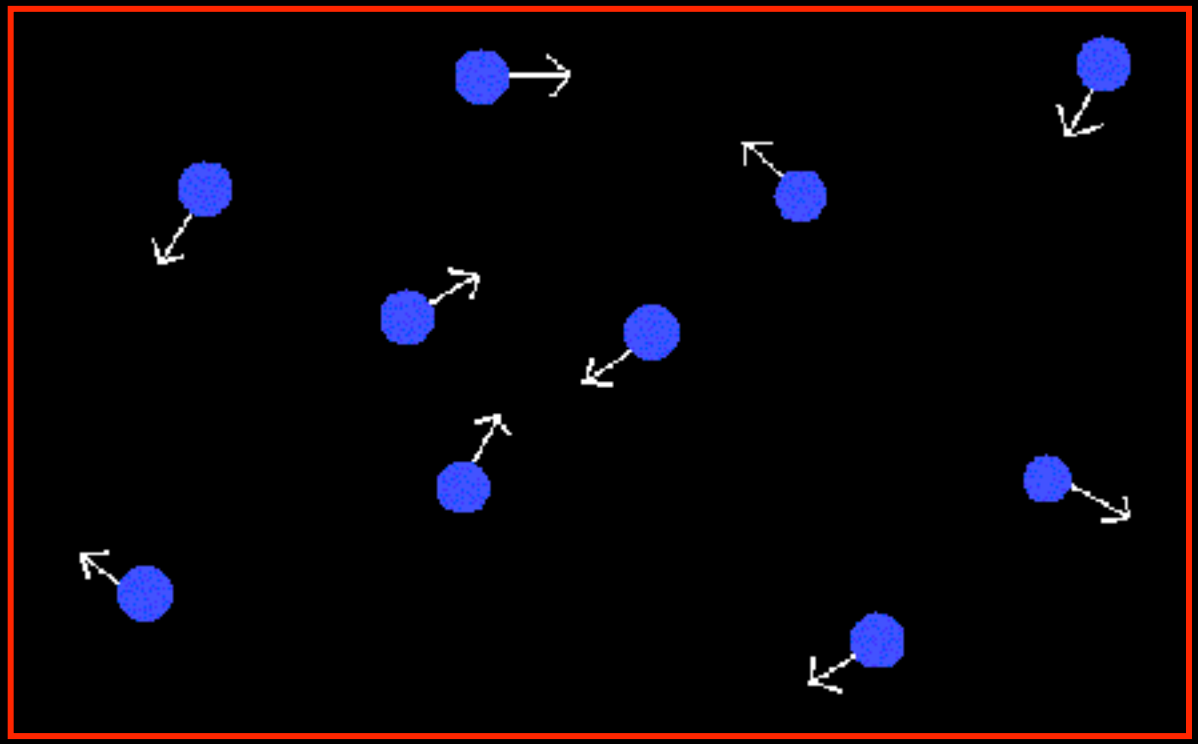
Less particles
→lower intensity
(fainter line)

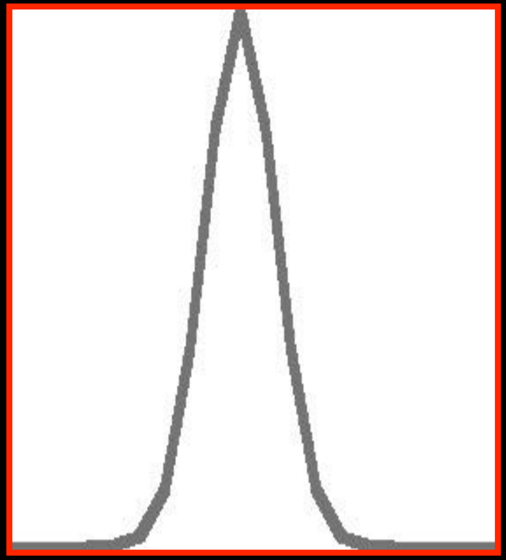




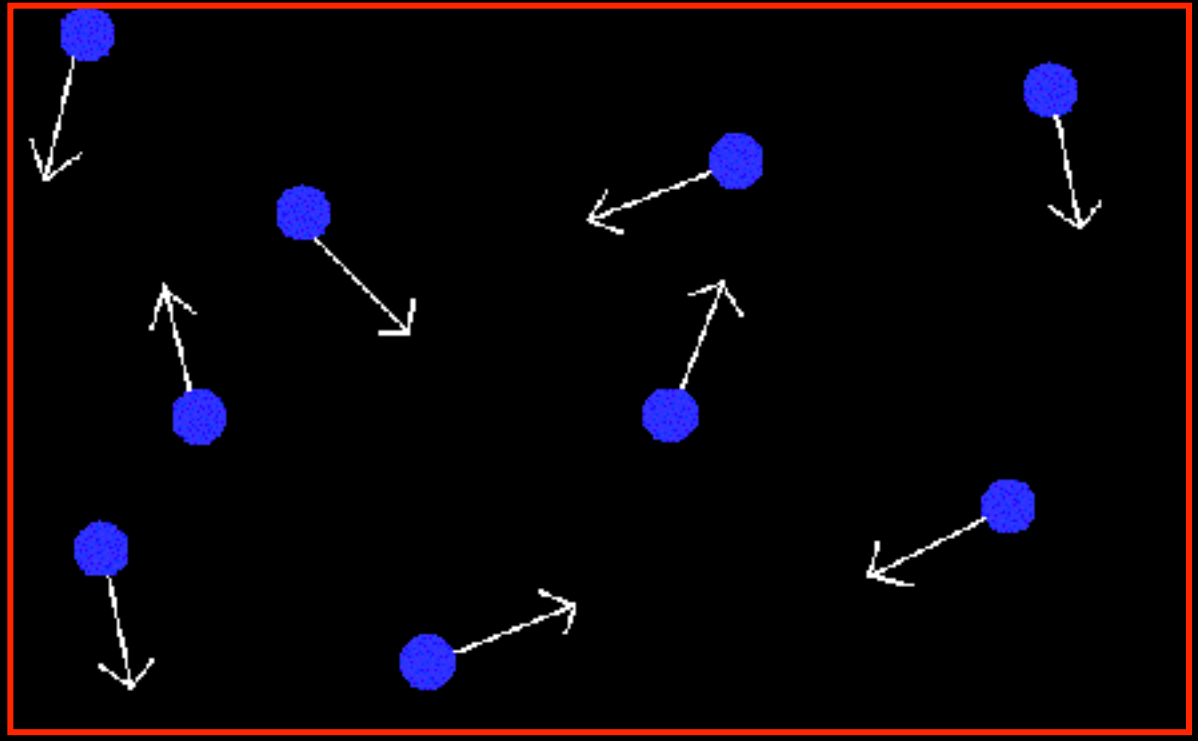
More particles
→higher intensity
(brighter line)

What can we learn from a spectrum #2: Line Profile

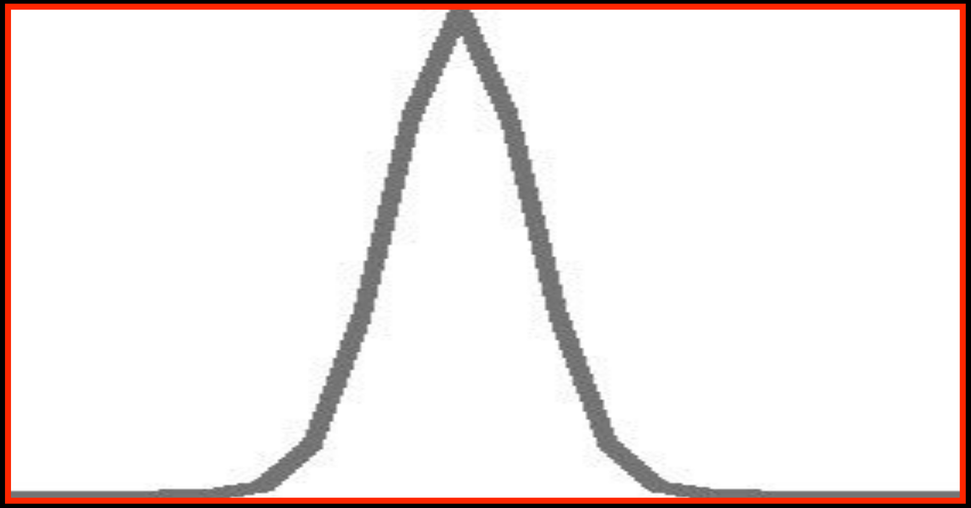




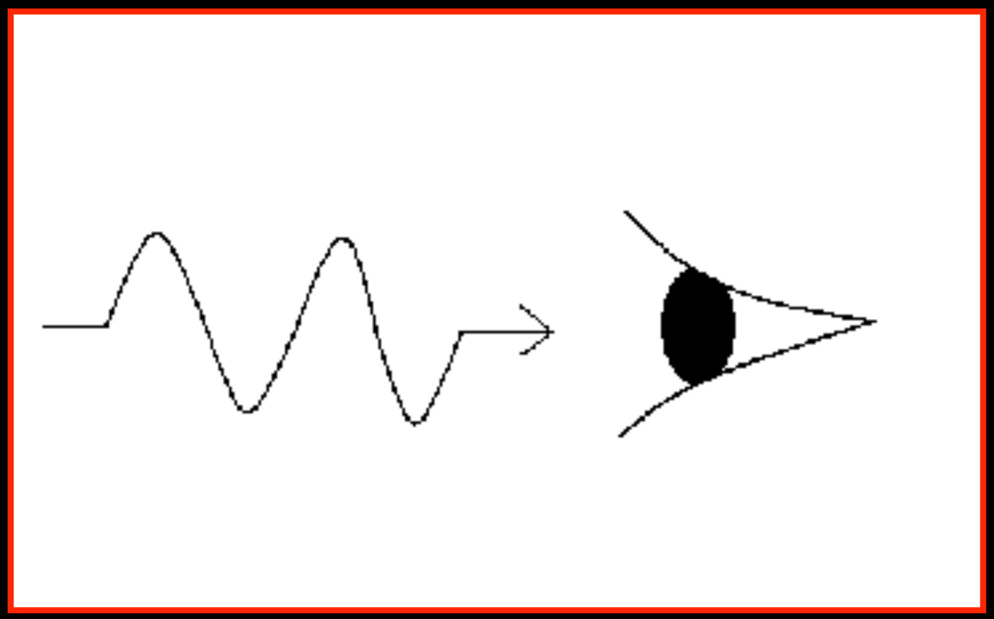
Slower random motion → narrower width

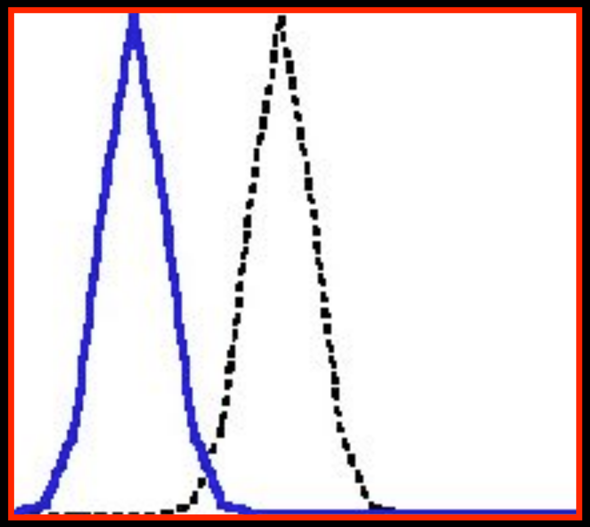


Faster random motion → wider width

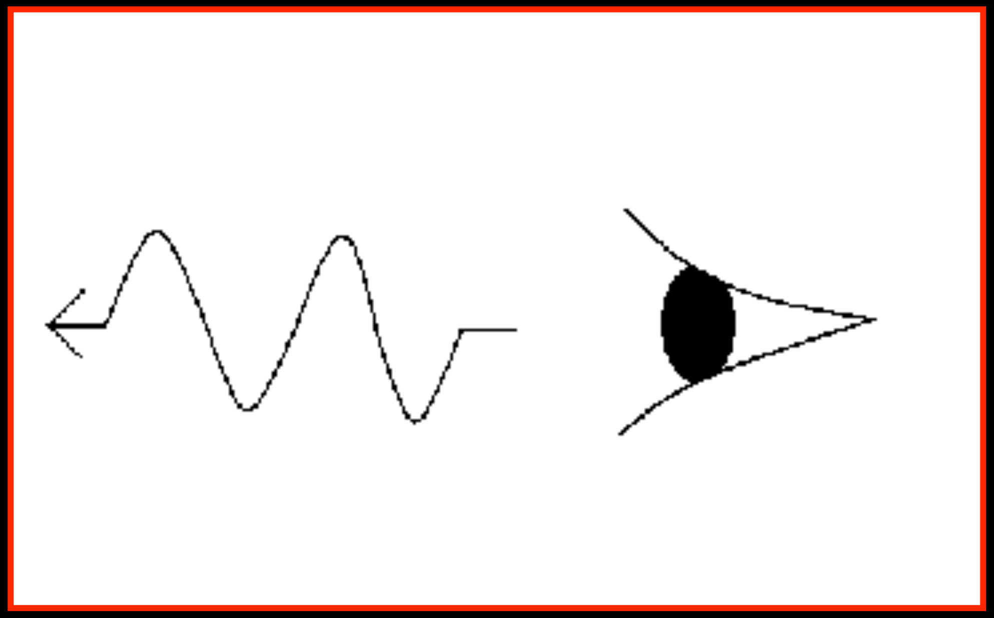


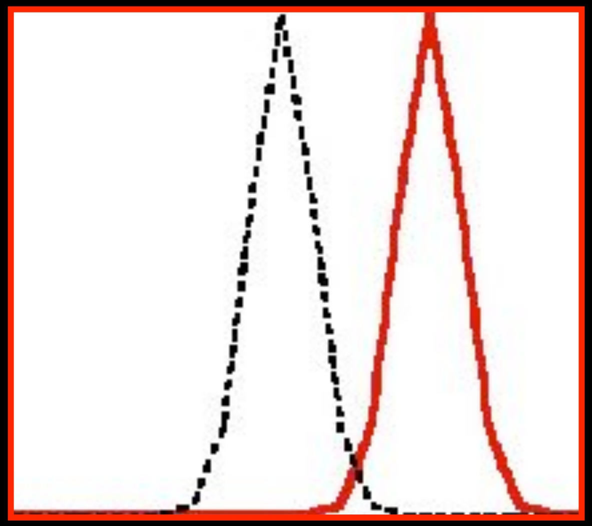
What can we learn from a spectrum
#3: Line Shift





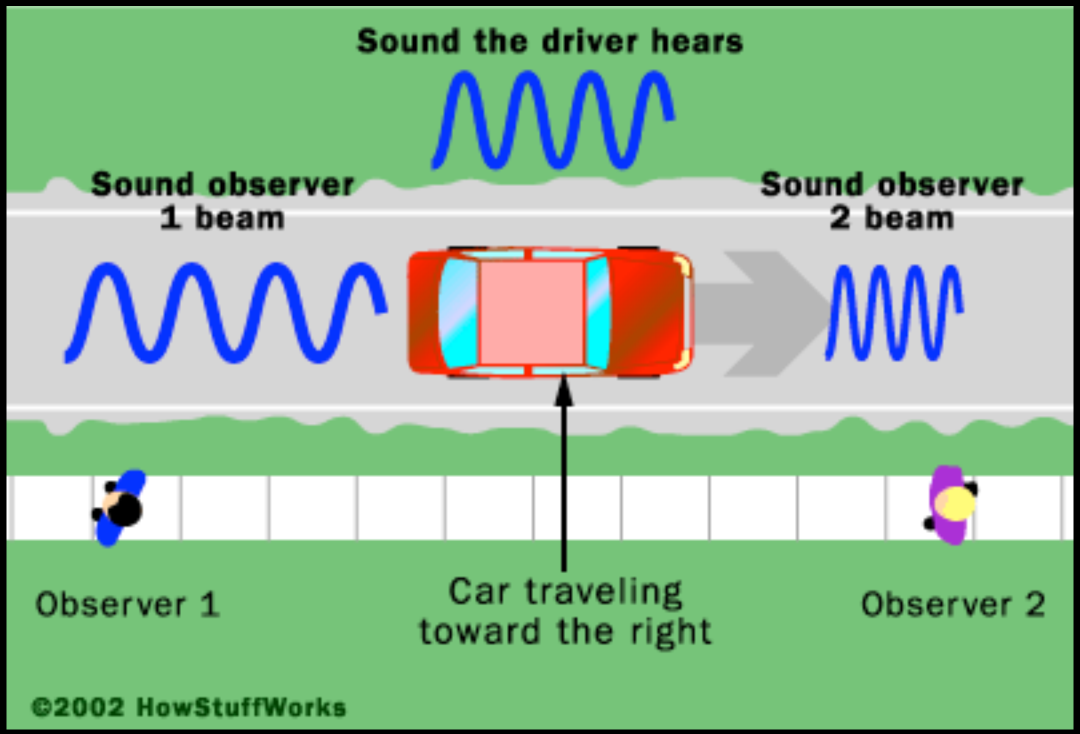
Source moving toward us
→ blue shift (shorter wavelength)

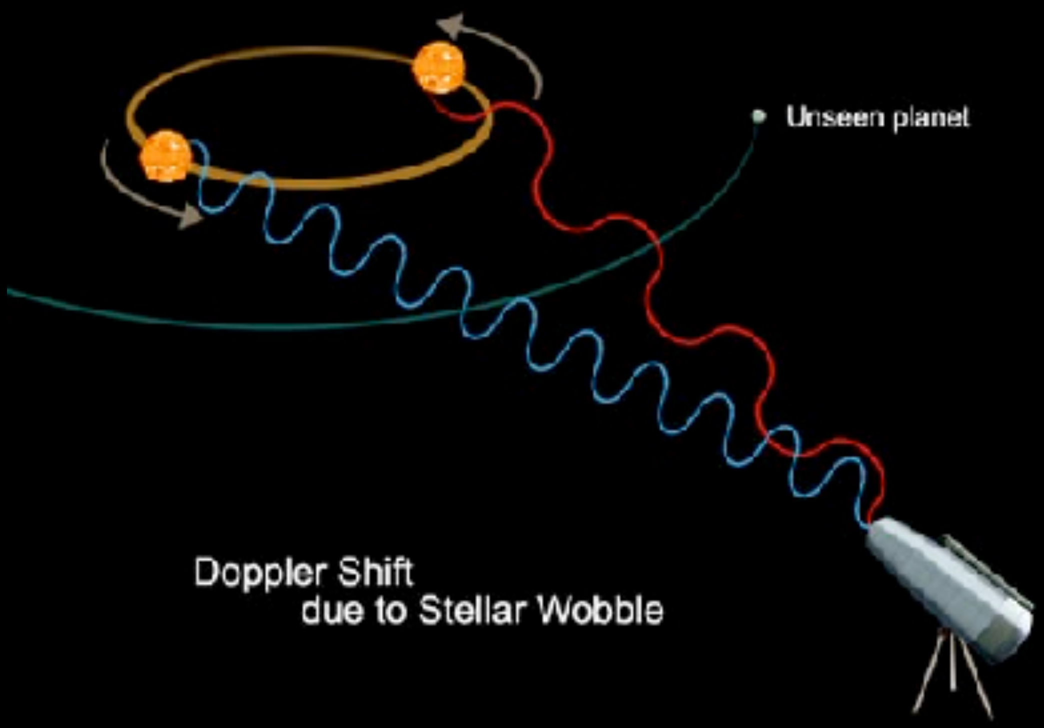




Source moving away from us
→ red shift (longer wavelength)

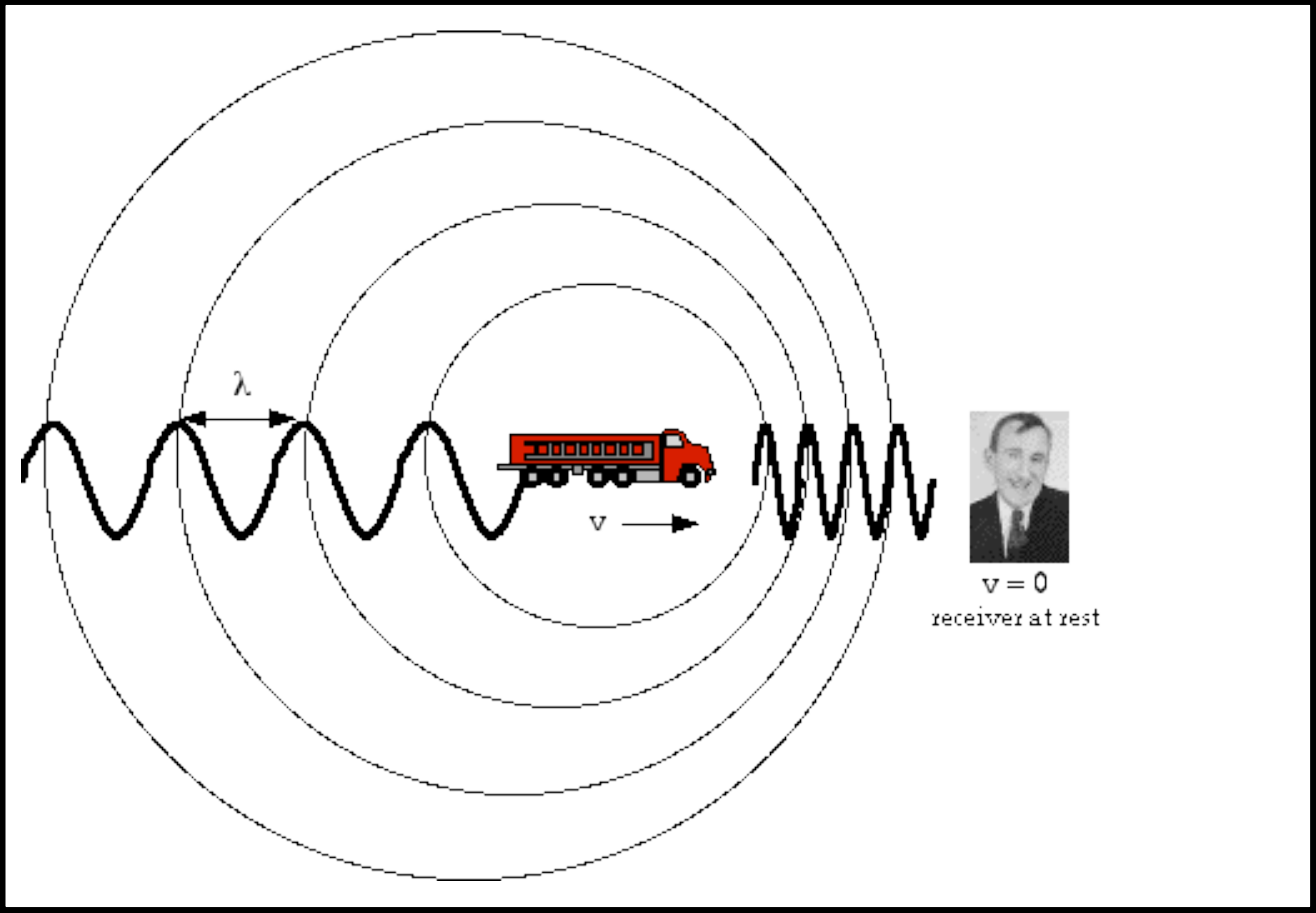
Dopplershift





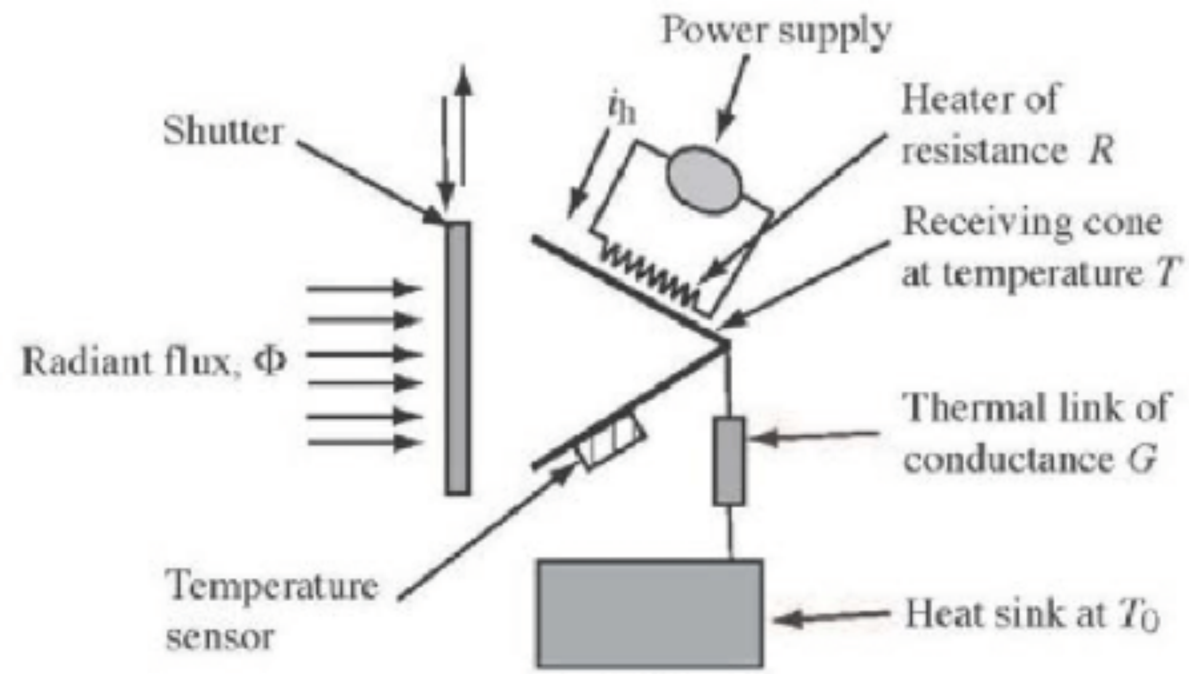
The **Doppler effect** (or the **Doppler shift**) is the change in frequency or wavelength of a wave for an observer who is moving relative to the wave source. It is named after the Austrian physicist Christian Doppler, who described the phenomenon in 1842.

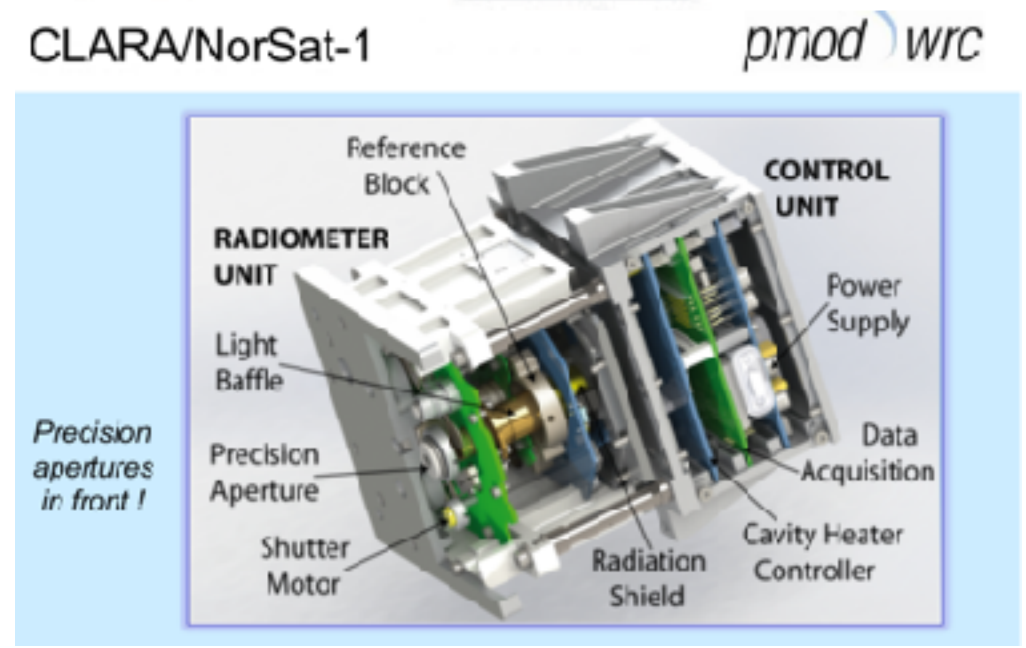
Have you noticed that when an emergency vehicle with its siren blaring passes you that the tone that you hear changes in pitch? This is an example of the Doppler shift, and it is an effect that is associated with any wave phenomena (such as sound waves or light).



How to measure TSI accurately?

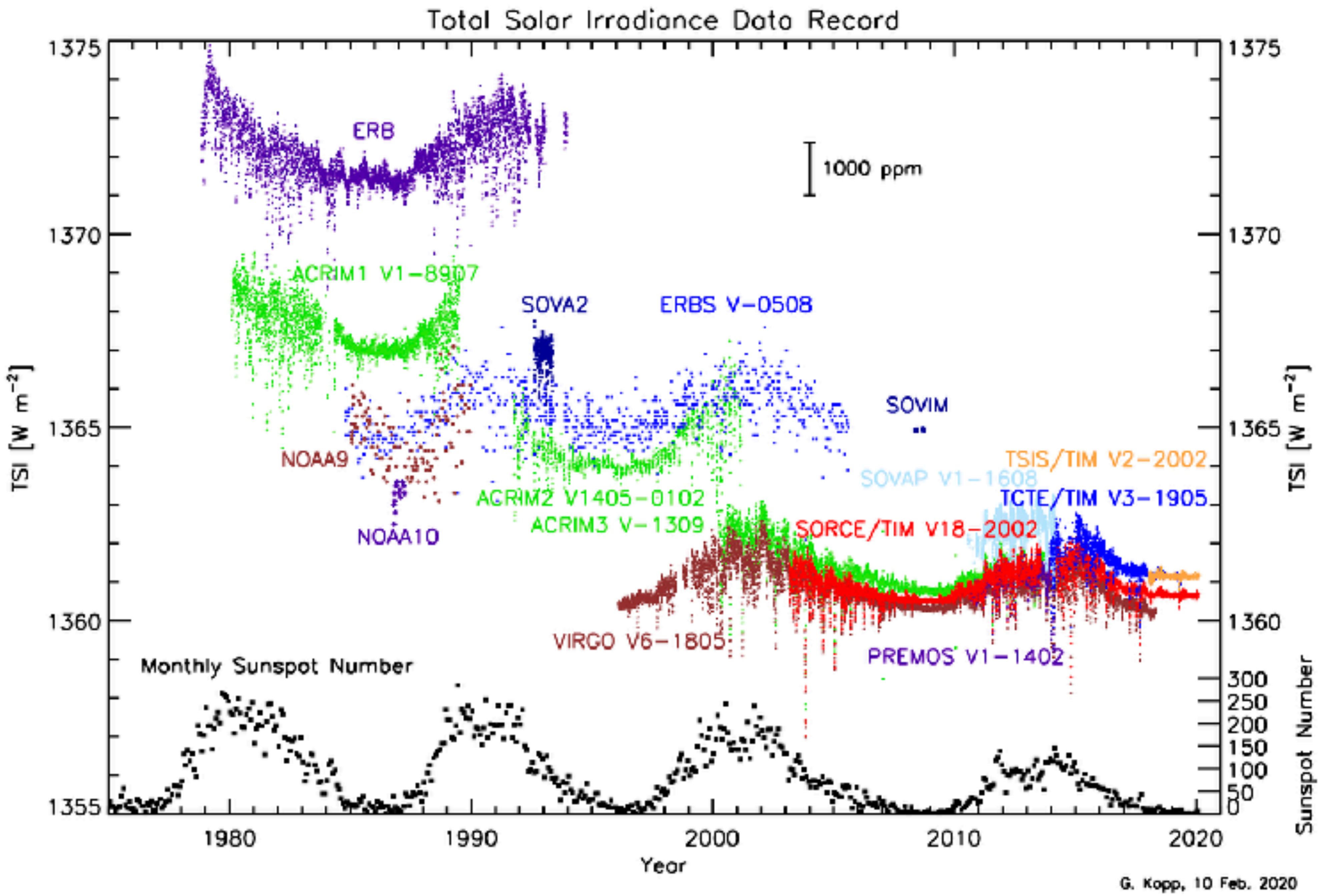
- Need knowledge of geometry
- All normal sensors degrade in space.
- Electrical substitution active cavity radiometer.
- Measure the current that is required to give the same heating of a blackbody cavity.
- Precision is 10 ppm, while accuracy is more like 400-800 ppm





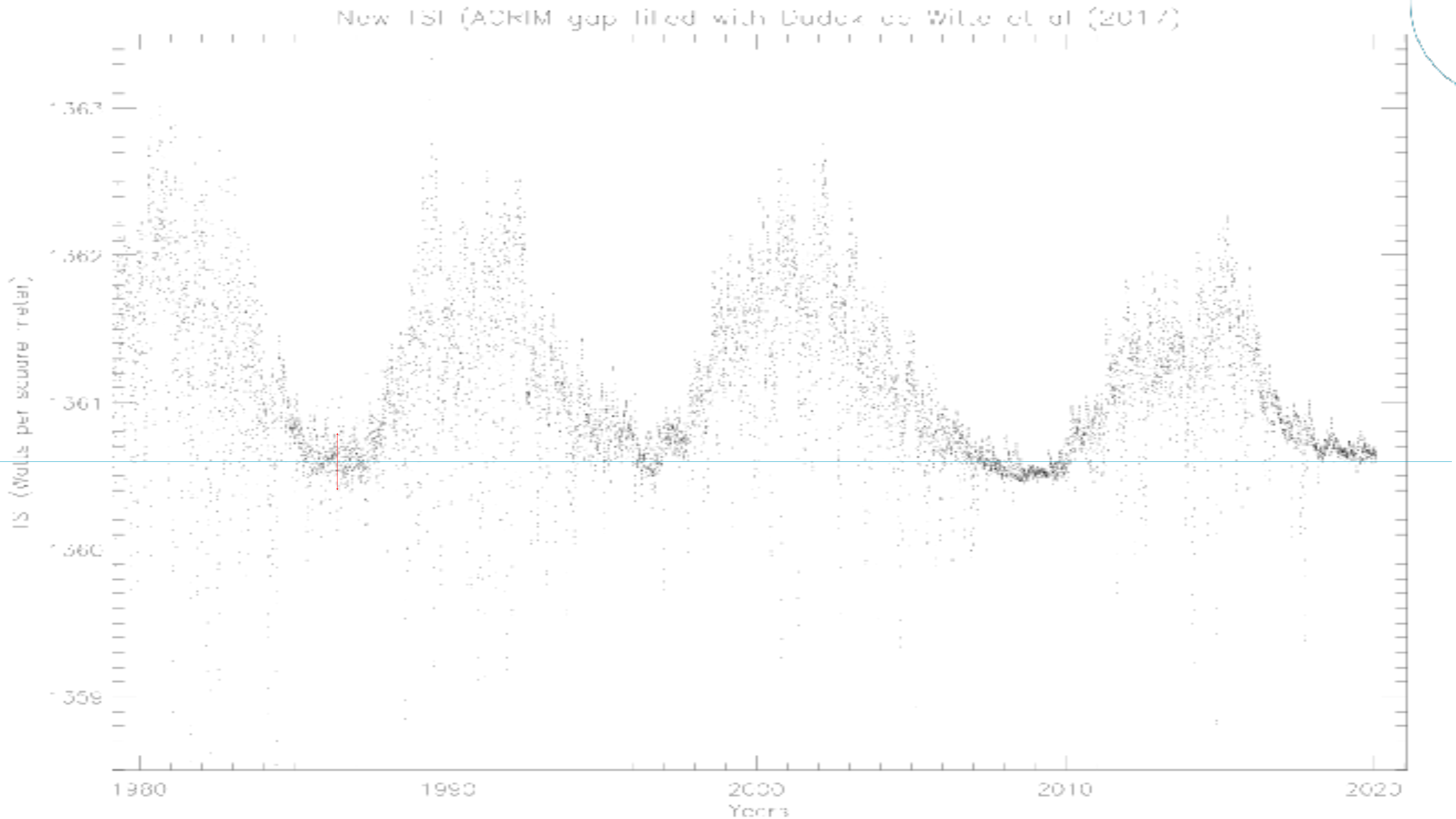
Norsk Romsenter
Norwegian Space Agency

It is not easy and what is the stability?



Norsk Romsenter
Norwegian Space Agency

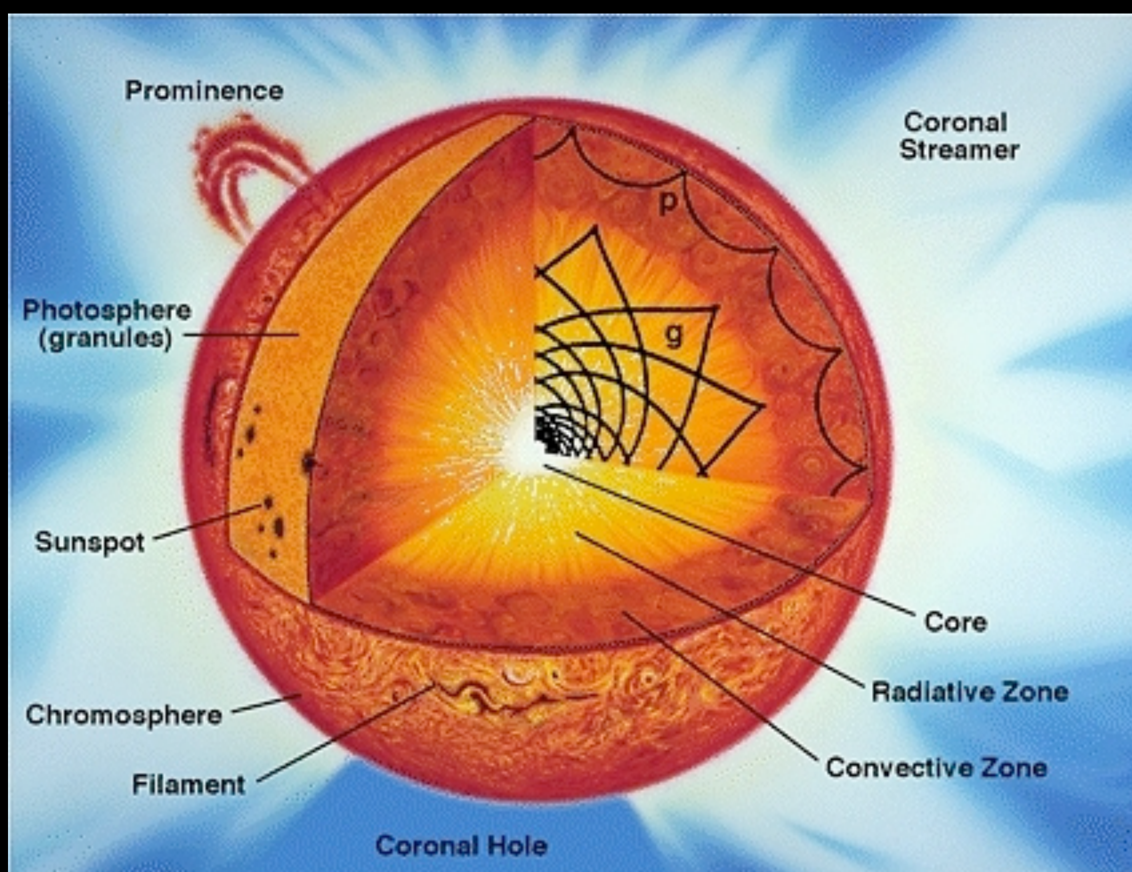
Solar energy output (TSI) as good as it gets!

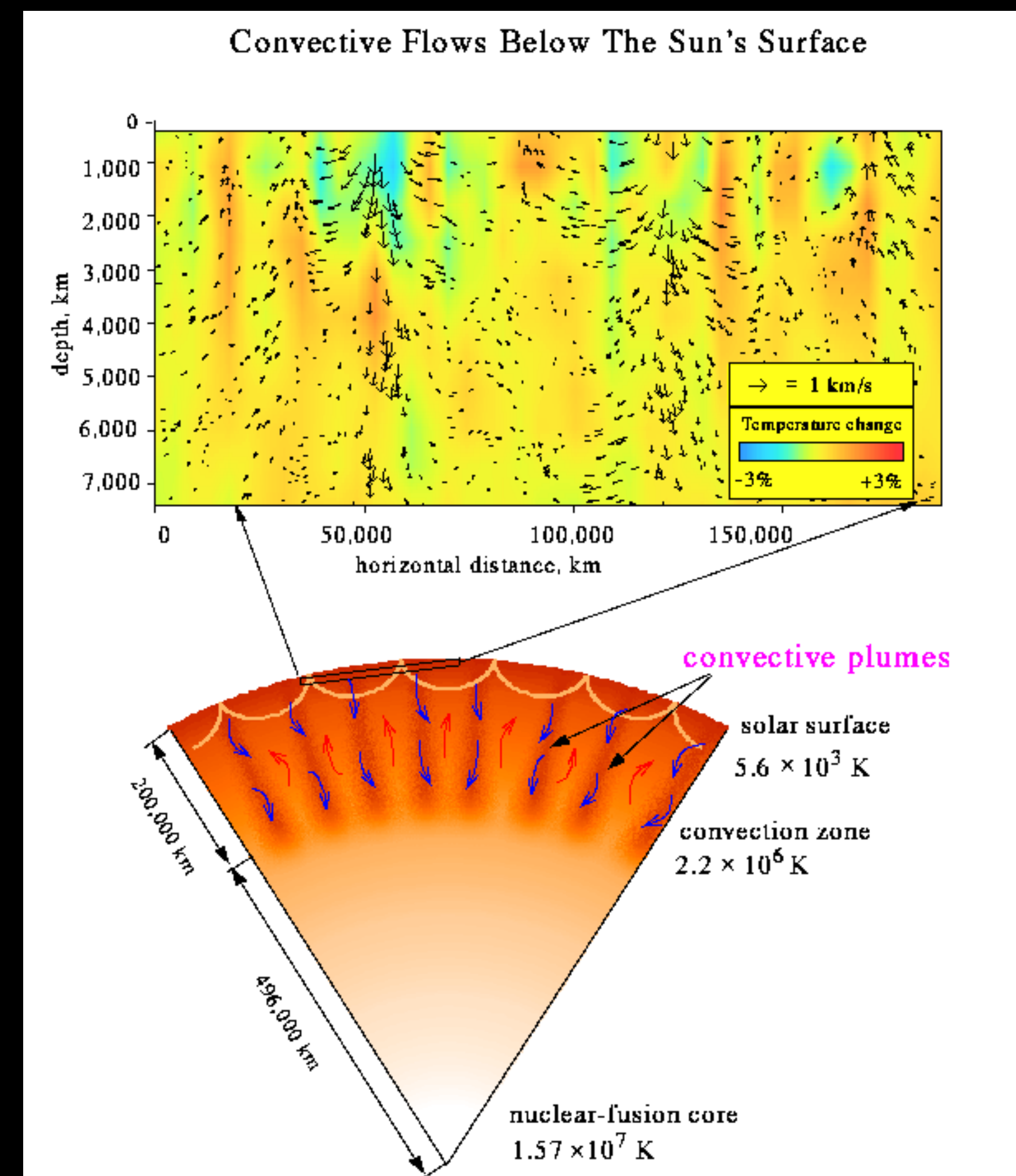


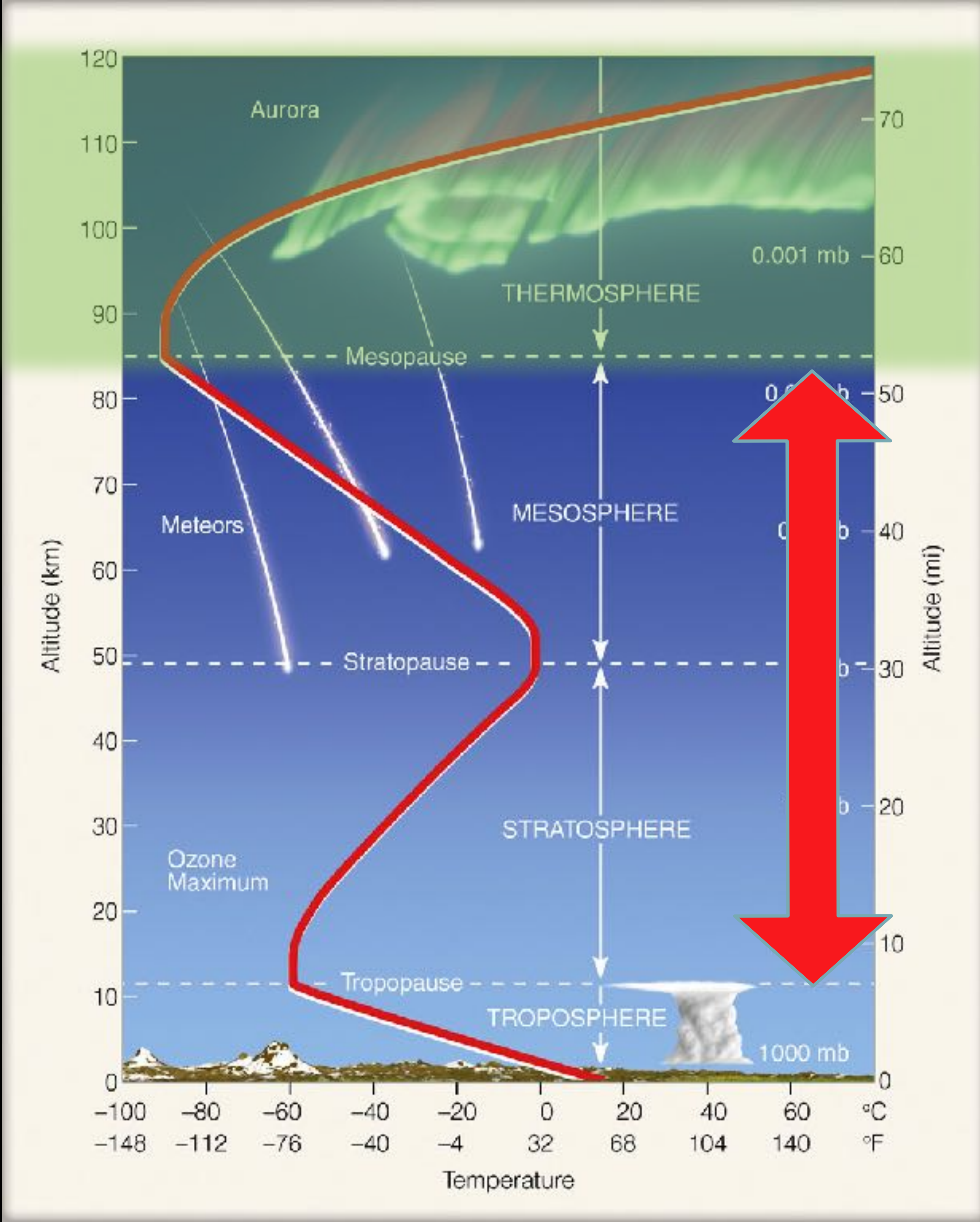
Norsk Romsenter
Norwegian Space Agency

Helioseismology

- The entire Sun is vibrating due to sound waves propagating inside.
- The sound waves are reflected off the surface - causing the surface to oscillate up and down.
- By observing the oscillations, and thus the sound waves we can obtain information about the solar interior (temperature, density and flow velocities).







Mesopausen
- COLDEST PART OF THE ATMOSPHEE

Middle Atmosphere
Mesosphere and Stratosphere

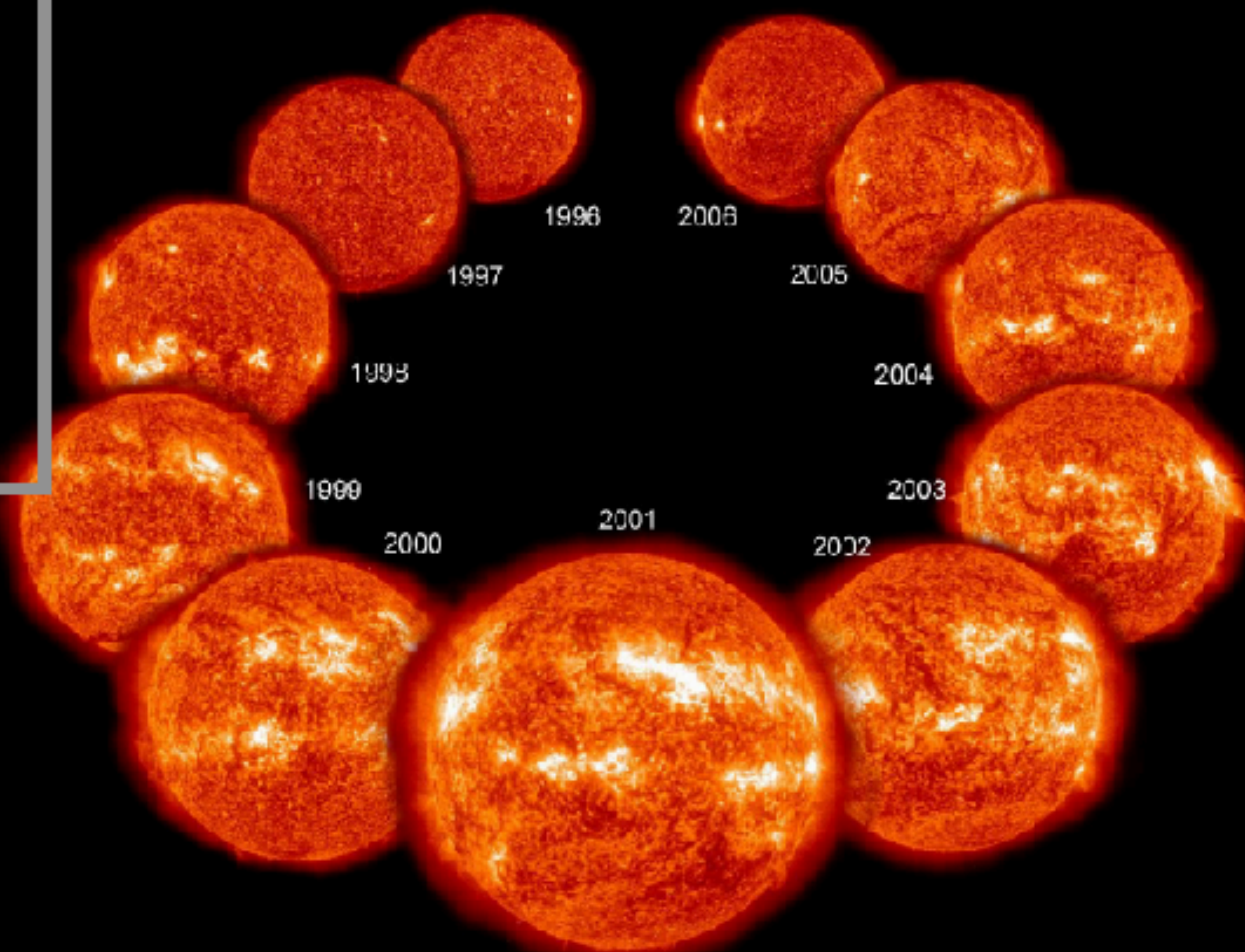
SOLAR CYCLE

Solar radiation

Total solar radiation power changes between the solar maximum and solar minimum are of the order of 0.1%

UV changes ~5-8%

Solar minima



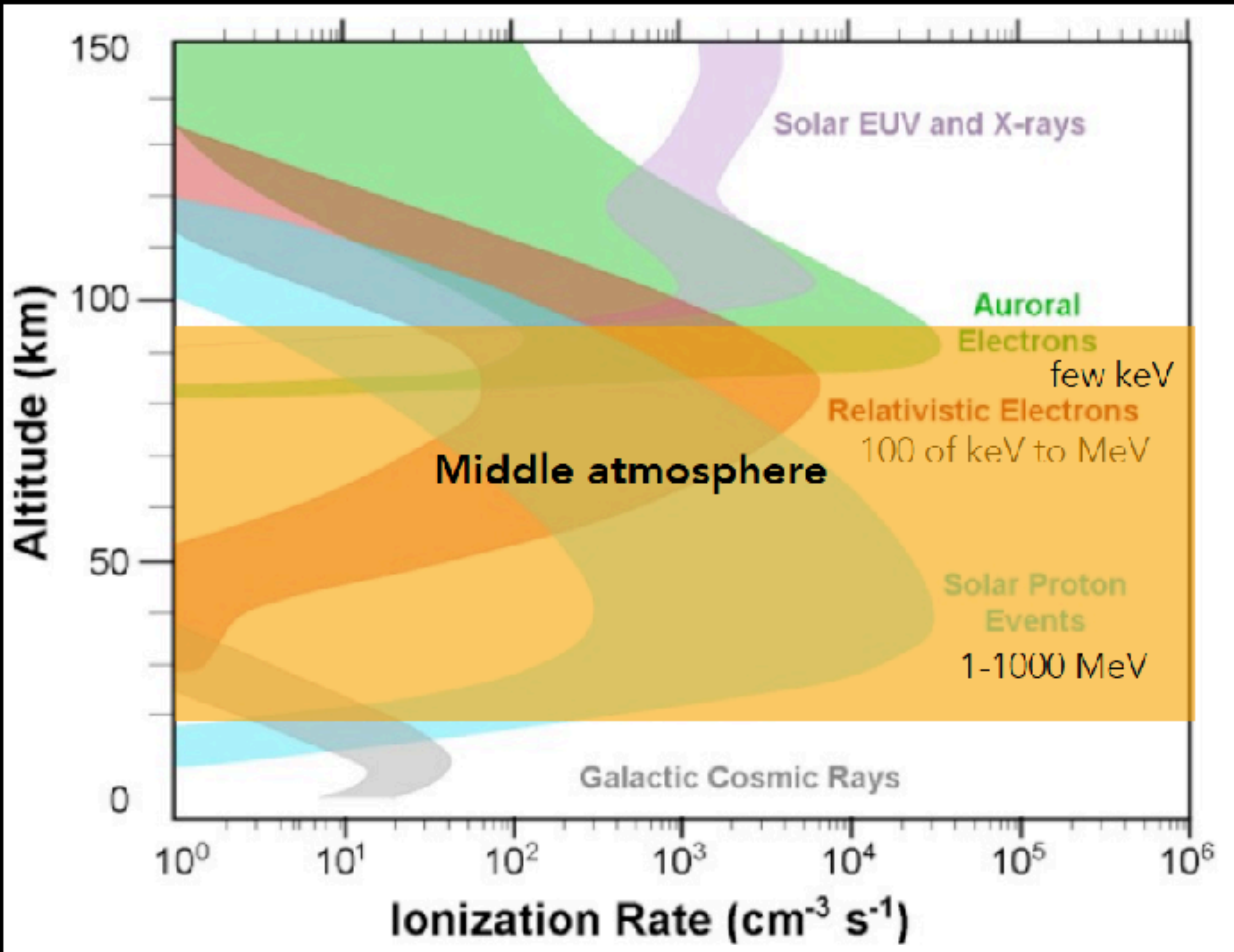
Solar maximum

Solar particles

Particle output changes between the solar maximum and solar minimum are of the order of 100%

Illustration: NASA

PARTICLE ENERGIES AND IMPACT HEIGHTS



Particle energy determines the altitude of impact.

Ionisation rate = # of ion pairs/cm3/s

Airglow (Nightglow)

Visible all around the globe!!!

Airglow

Chicago

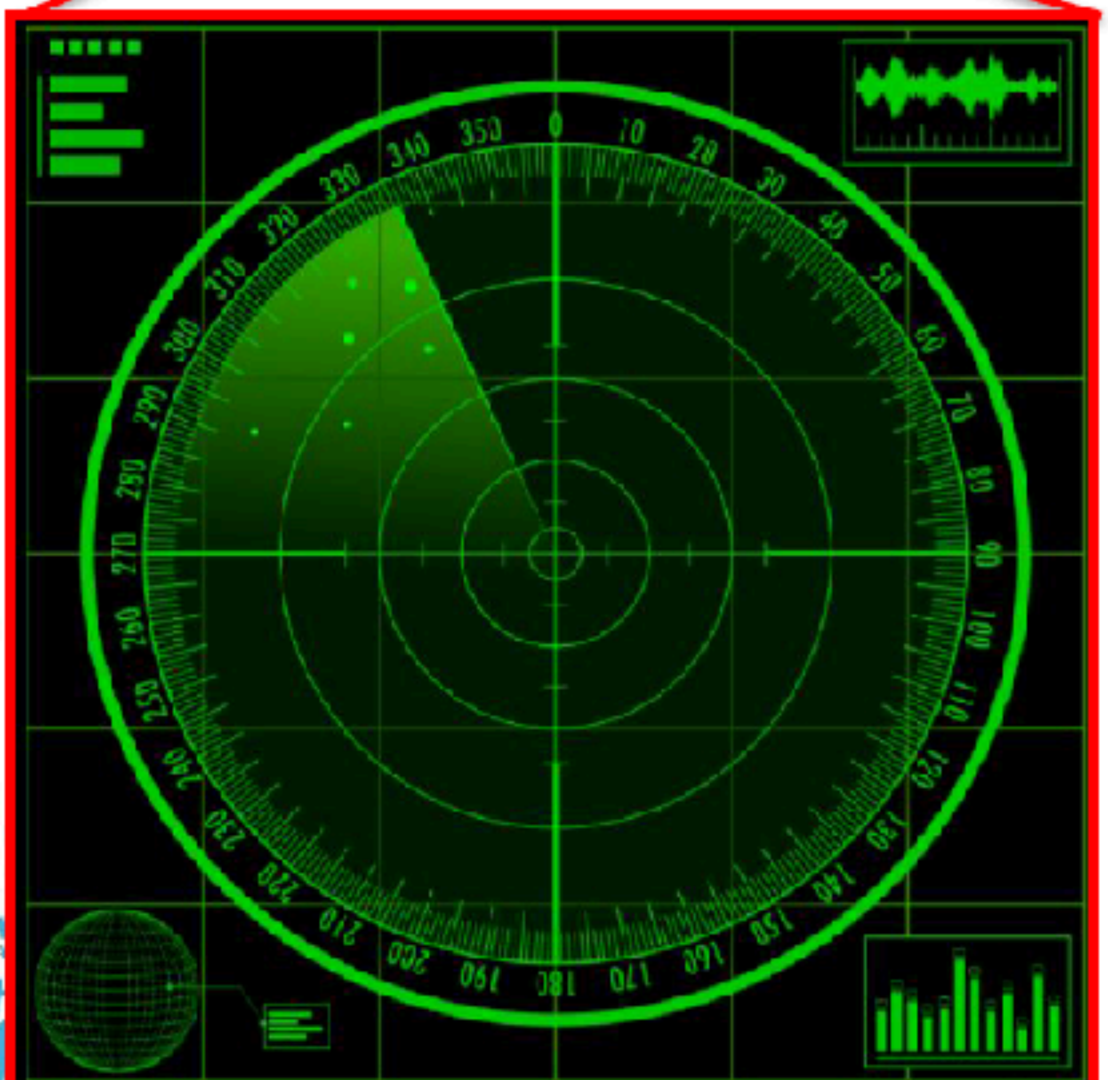
Red and green aurora

Amazing timelapse video made from photos from ISS by PhD in neuroscience(!) Alex Rivest (www.alexrivest.com):

What is a RADAR?

UNIS
The University Centre in Svalbard

- RAdio Detection And Ranging

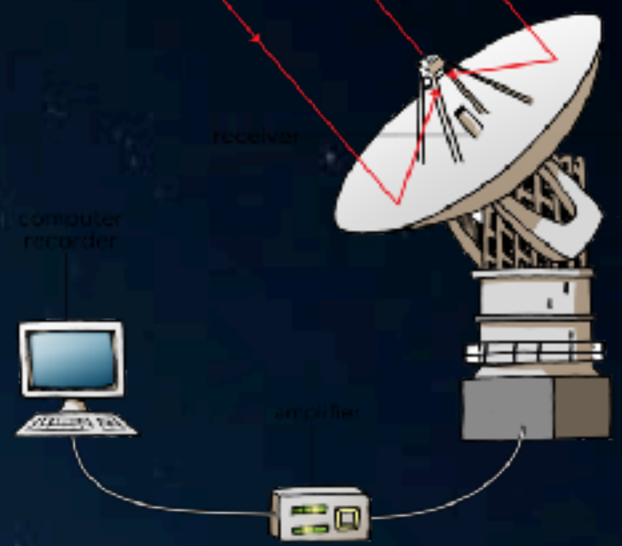


- The radio waves reflect off a target
- If we receive a signal back then there must be an obstacle in the direction that we sent the radio wave

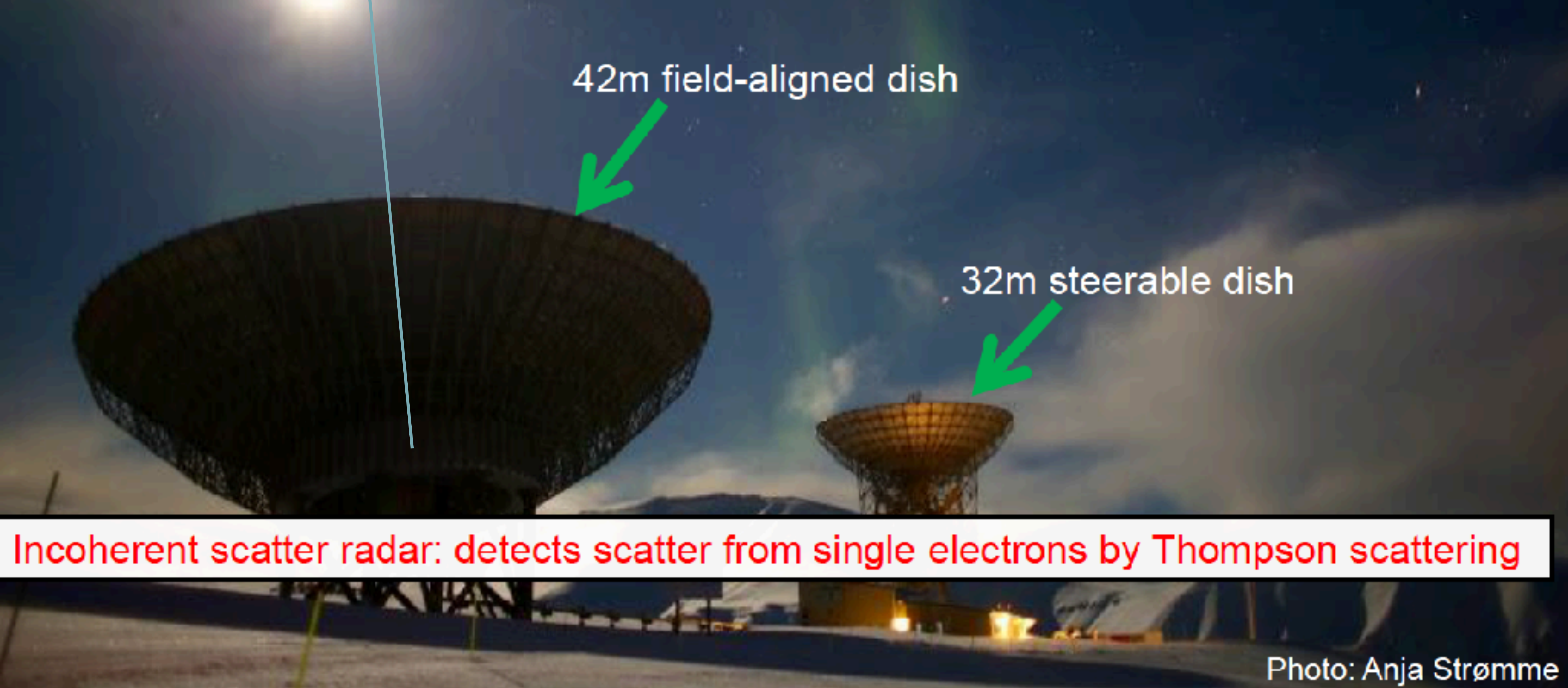
EISCAT Svalbard Radar

Can measure the effects of the aurora all year!!!

- Transmission frequency 500 MHz
- Peak transmission power of 1 MW
- 2x parabolic dish antenna: uses a curved surface to direct radio waves



This antenna is pointing along Earth's magnetic field



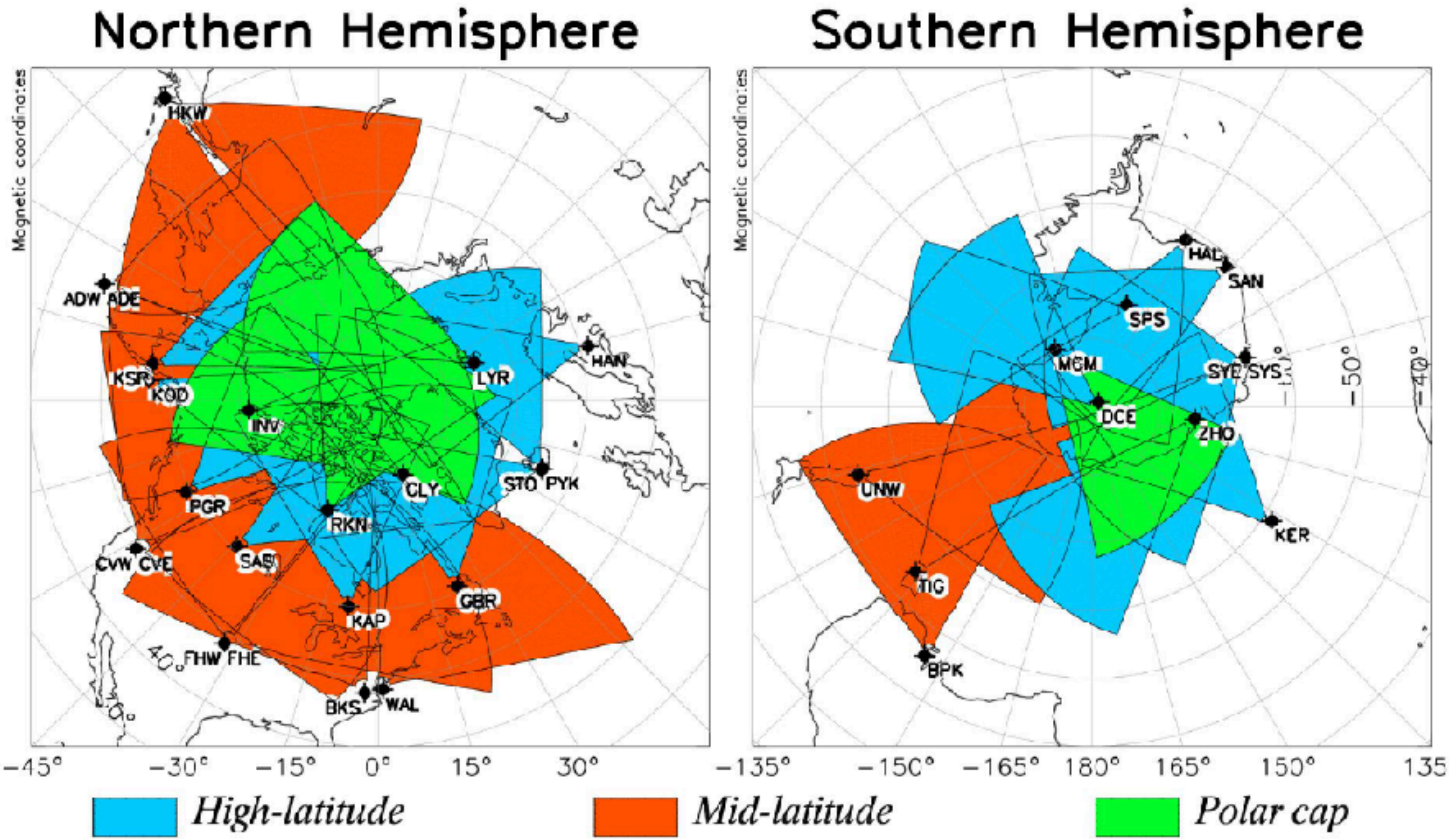
Incoherent scatter radar: detects scatter from single electrons by Thompson scattering

Photo: Anja Strømme

SuperDARN Network

24 radars

12 radars



We can combine all of these measurements to make global maps….

EISCAT vs SuperDARN

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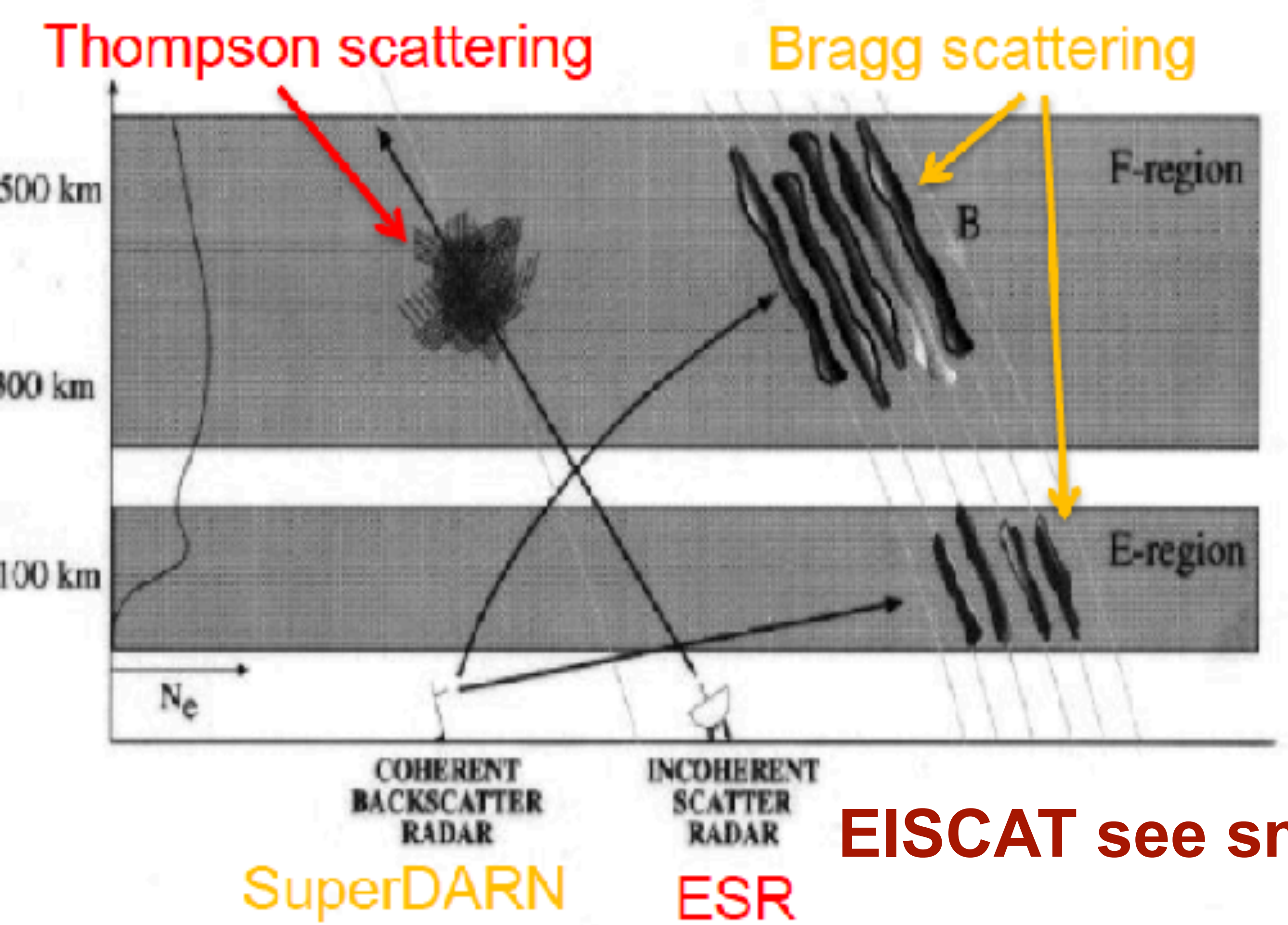

Radar	EISCAT	SuperDARN
Scatter type	Incoherent (Thompson)	Coherent (Bragg)
Frequency	Fixed (500 MHz)	Variable (9-20 MHz)
Range resolution	~100m-10km	15-45 km
Field of view	Narrow	Wide

EISCAT see smaller structures - higher range resolution

- ISRs see smaller structures in any direction using Thompson scattering
- CSRs see bigger structures aligned with the magnetic field using Bragg scattering