DE ZON

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We are all familiar with terrestrial tropospheric weather. It is what we experience all around us; our atmospheric environment. It may be fine, cloudy, stormy or sunny. It may rain or hail. We know about temperature and pressure and humidity. This is all about weather in the lowest 10 km of our atmosphere.

Wikipedia
Weather is the **state of the atmosphere**, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy.[1] Most weather phenomena occur in the lowest level of the atmosphere, the troposphere,[2][3] just below the stratosphere. Weather refers to day-to-day temperature and precipitation activity, whereas climate is the term for the averaging of atmospheric conditions over longer periods of time.[4]

Troposfeer 6-20 km
Stratosfeer 50 km
Mesosfeer 85 km
Thermosfeer 690 km oa poollicht
Exosfeer 10 000 km

Ionosphere: 60-1000 km
As we go out into space, the **atmosphere** becomes very thin, until by the time we are in space, it has **almost vanished**. Almost, but not quite. Even in space there are **some atoms** which are often moving very quickly. **Many forms of energy also move through space and it is the interaction of energy and atoms that produces what we refer to as space weather**. In particular, **space weather is the changes that occur in the space environment.**

The **sun** is the source of 'normal' terrestrial weather. It is also **the primary (but not the only) source of space weather**. Most aspects of space weather affect us to some extent. **The more our society becomes dependent on technology and the more we utilize space, the more we are affected by space weather**. Some aspects of space weather are benevolent, and allow activities not otherwise possible such as long range radio communications. Some aspects are benign but fascinating such as the Aurora, and some are malevolent. Like terrestrial weather, it depends on the situation and the event.

Definition of Space Weather
Space weather describes the conditions in space that affect Earth and its technological systems. Space weather storms originate from the Sun and occur in space near Earth or in the Earth's atmosphere. These storms generally occur due to eruptions on the Sun known as solar flares, proton storms and the solar wind.



How can we study the Sun - simply by watching it.
in different circumstances, at special events, using a telescope - from 1609 - to magnify

Visible light

A special event: a solar eclipse. In the past, people thought it was a divine event: the gods interfered and made the sun disappear. Now we know it is the moon that occults the sun.
The moon appears to be as big as the Sun.

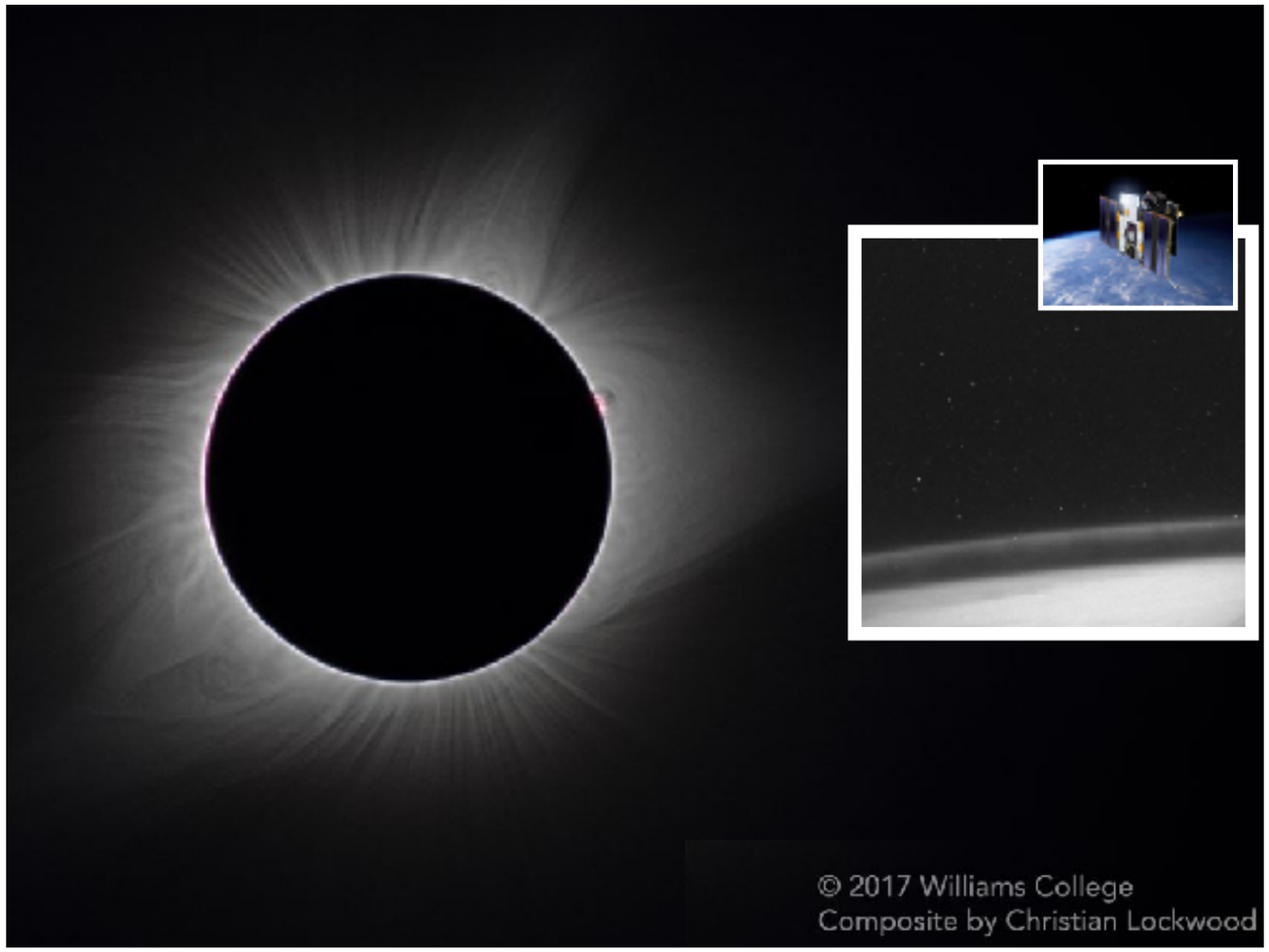
The total solar eclipse of 1 August 2008, observed from Siberia.
What happens:
-visible light from the disc bounces off from plasma in the corona in our direction (Thompson scattering) - refracted light
-the solar disc is a million times brighter than the corona, the light we see during eclipse is always there but swamped in the much brighter direct light

Seeing the corona ‘naturally’ is exceptional on astronomical scales:
- the apparent size of moon and star have to match the distance planet-star
- the moon should have no atmosphere
- the planets atmosphere should be transparant

Tijdens een eclipse wordt het rechtstreeks licht tegengehouden en zien we het weerkaatste licht. We kunnen zo de deeltjes zien die zich in de zonneatmosfeer bevinden. Wat blijkt: er zit structuur in de zonneatmosfeer.



Eclipse Northern America
It is big



corona is warm daardoor is die dik
De aardatmosfeer is een dunne schil.

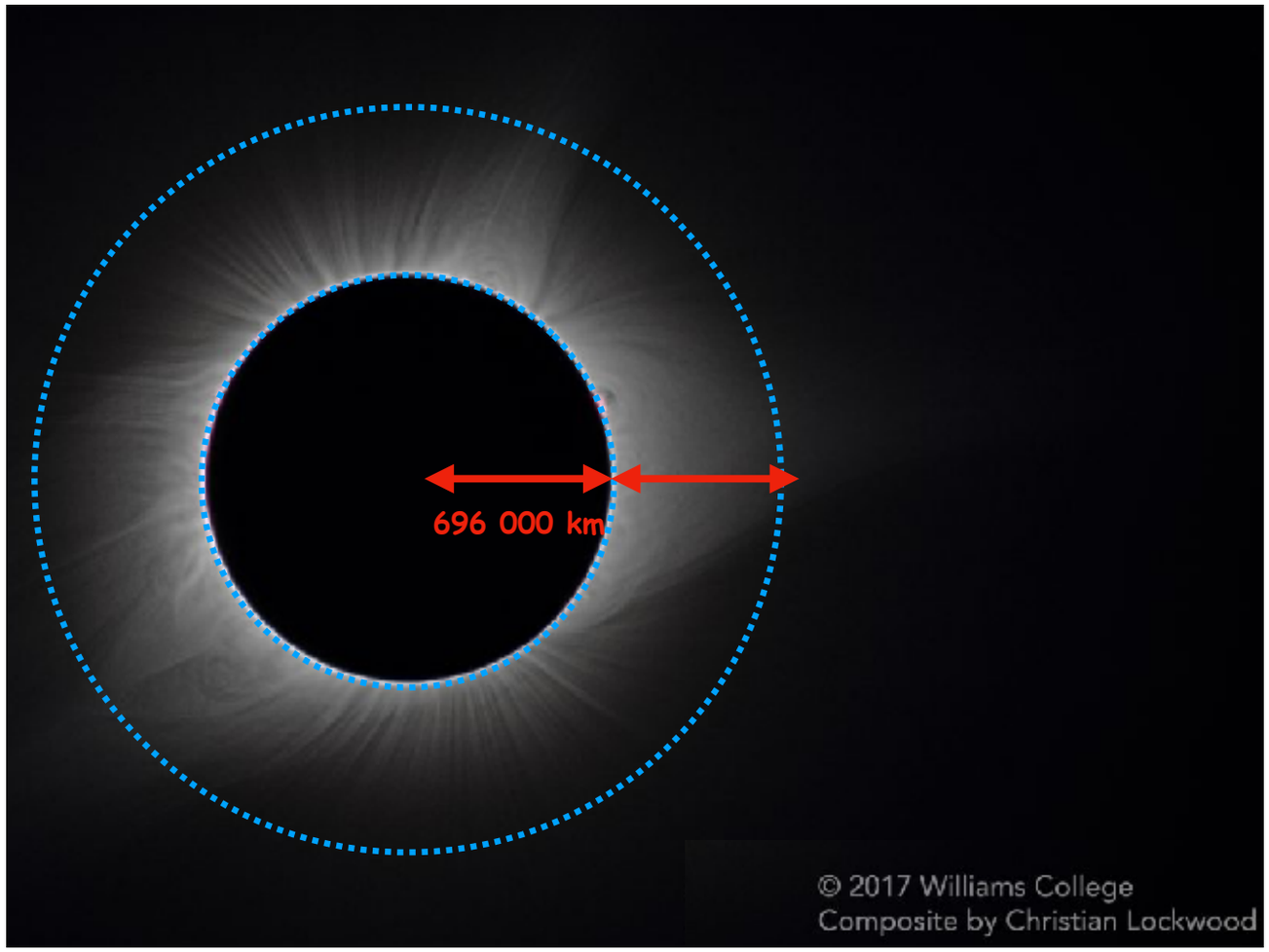
Why is the atmosphere of the Earth, relatively speaking so much smaller?

The beginning of the wind is best "seen," said Parker, in pictures of a total solar eclipse. During a total solar eclipse the moon passes between the Earth and sun, blocking sunlight from reaching Earth. In pictures of the events, bits of the sun's corona—the outer edge of the sun—can be seen extending out into space.
"Around the 1930s scientists determined the temperature [of the corona] must be a million degrees [Celsius] because of the way it stood out into space," said Parker. "**If it weren't so hot, it wouldn't be puffed out so much.** Then some very clever spectroscopic detective work confirmed this extraordinary temperature."
The total solar eclipse of 1 August 2008, observed from Siberia. Equatorial streamers and polar plumes clearly map the corona's magnetic field. Earthshine illuminates the silhouetted lunar disk. (Images in from J.M.P., W. G. Wagner and H. Druckmüllerová, image processing by H. Druckmüllerová

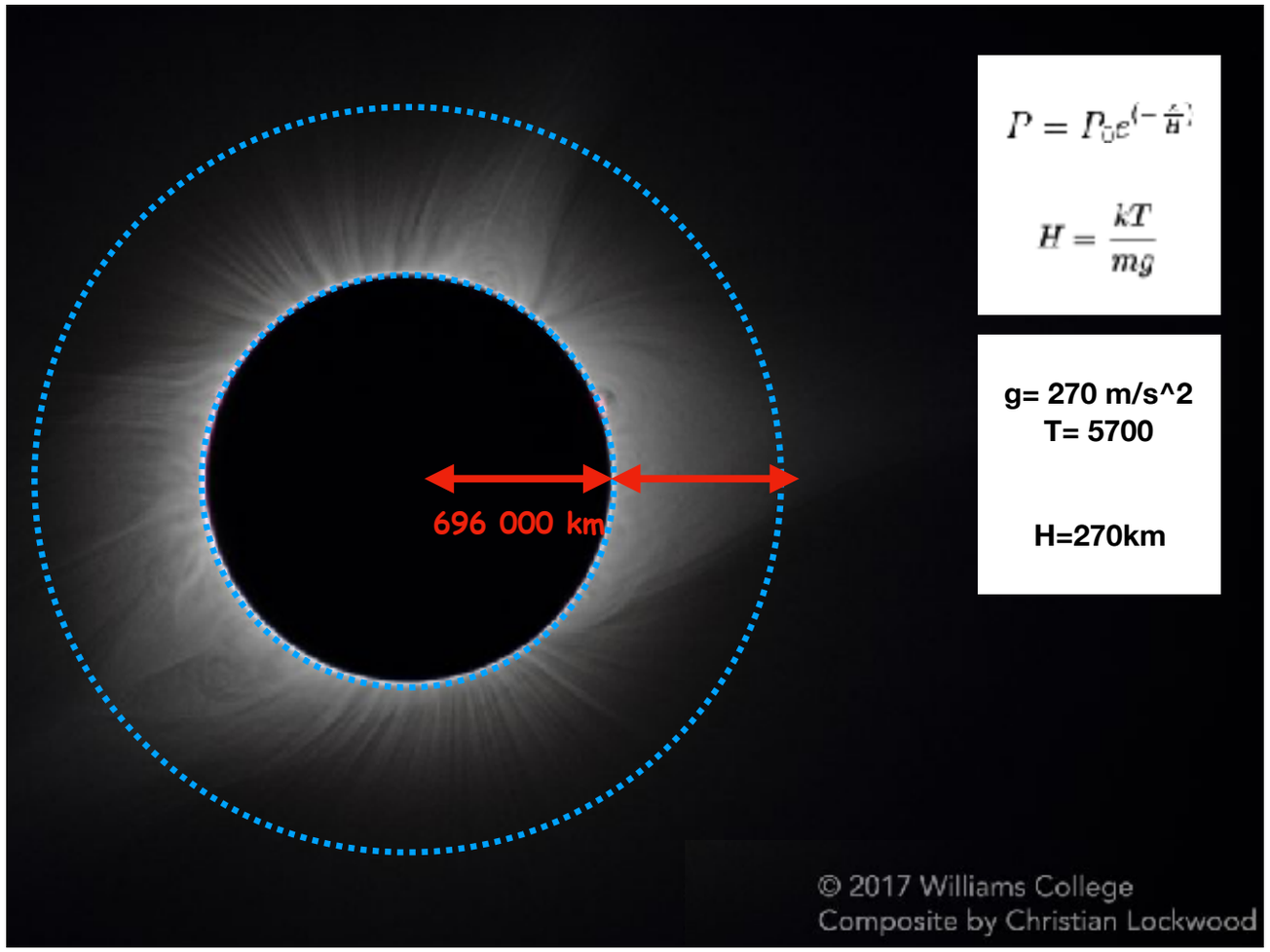
Solar eclipses as an astrophysical laboratory
Jay M. Pasachoff
Nature 459, 789-795(11 June 2009)
doi:10.1038/nature07987

steek er hogere temperaturen in en ge komt tot een dikke atmosfeer
we zouden eigenlijk dus al heel lang moeten geweten hebben dat de corona heet is

Foto genomen door de star tracker-cameras aan boord van de micro-satelliet PROBA2: hiermee kan PROBA2 zich autonoom oriënteren. Er zitten sterrenkaarten in de computer van PROBA2.
In deze foto zie je de aardatmosfeer (per toeval) en, het belangrijkste, de sterren.



Some rough science:
Corona is easily another solar radius higher



Vertically Stratified atmosphere where **gas pressure pulls** the atmosphere **up** and **gravity pulls** the atmosphere **down**.

Density or pressure is exponentially decaying as you go higher in the atmosphere
This decay comes with a characteristic length scale H. a **scale height is a distance over which a quantity decreases by a factor of e** (approximately 2.72, the base of natural logarithms). It is usually denoted by the capital letter H.

https://en.wikipedia.org/wiki/Scale_height
Scale height used in a simple atmospheric pressure model[edit]

For planetary atmospheres, scale height is the increase in altitude for which the atmospheric pressure decreases by a factor of e. The scale height remains constant for a particular temperature. It can be calculated by[1][2]

H=kT/mg
Or
H=RT/Mg

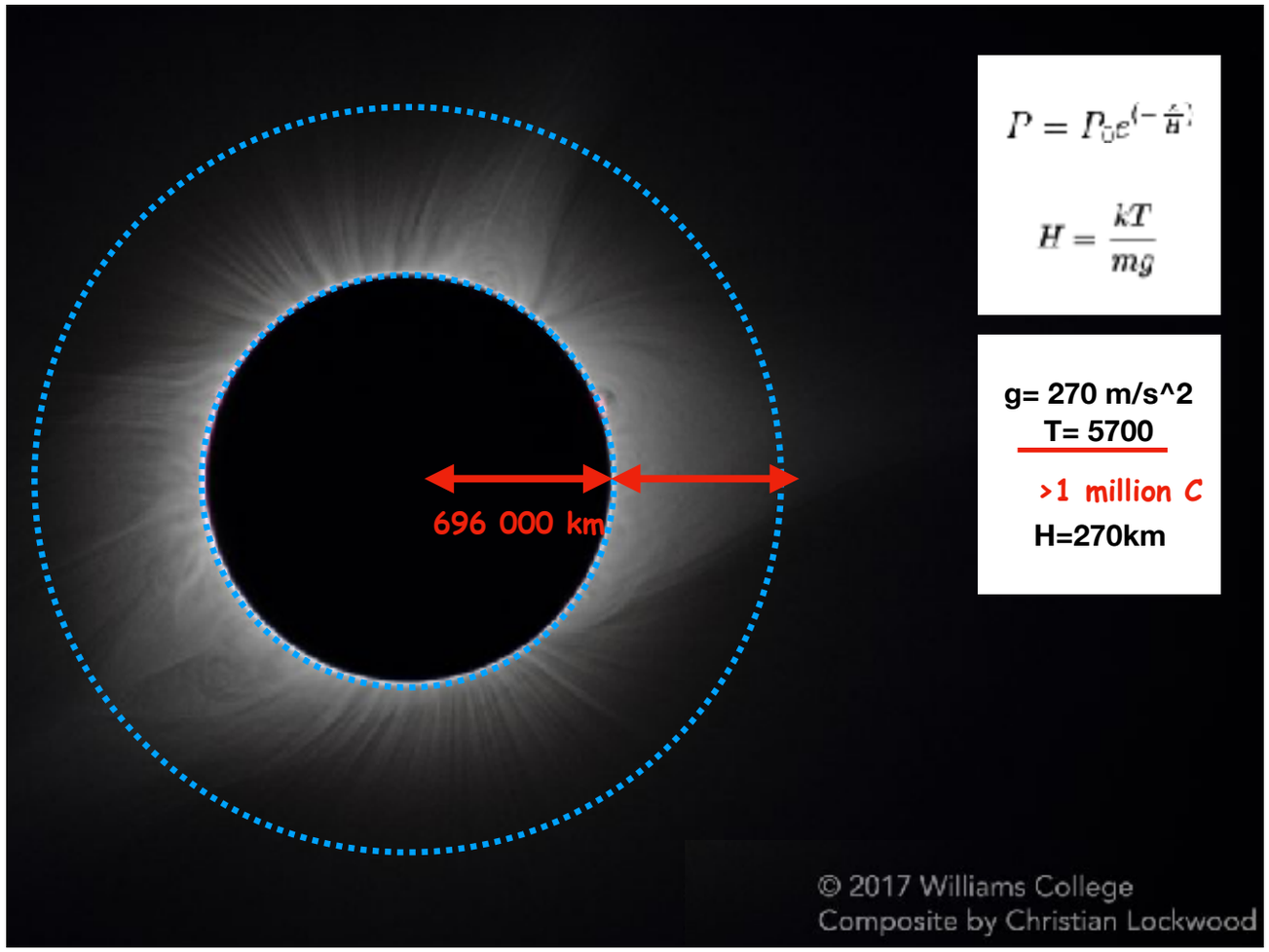
where:

k = Boltzmann constant = 1.38 x 10−23 J·K−1
R = Gas constant
T = mean atmospheric temperature in kelvins = 250 K[3] for Earth
m = mean mass of a molecule (units kg)
M = mean molecular molar mass of one atmospheric particle = 0.029 kg/mol for Earth
g = acceleration due to gravity on planetary surface (m/s^2)

If you fill in numbers for **Earth** (g=9.8 m/s2) you get **H=9km**.
On the mount Everest, the atmosphere is around a factor e less dense what it is here. The formula makes sense.

Zon:
m—-> mostly Hydrogen

Sun: **H=270 km**
Few hundred kms I can't plot here. The corona is way thicker than it is supposed to be knowing the temperature of the surface and the gravity of the sun.
The corona can not be this temperature. It must be much hotter. The corona is not at the same temperature as the photosphere.



$$P = P_0 e^{\left(-\frac{z}{H}\right)}$$

$$H = \frac{kT}{mg}$$

g= 270 m/s^2

T= 5700

>1 million C

H=270km

Spectroscopic detective work

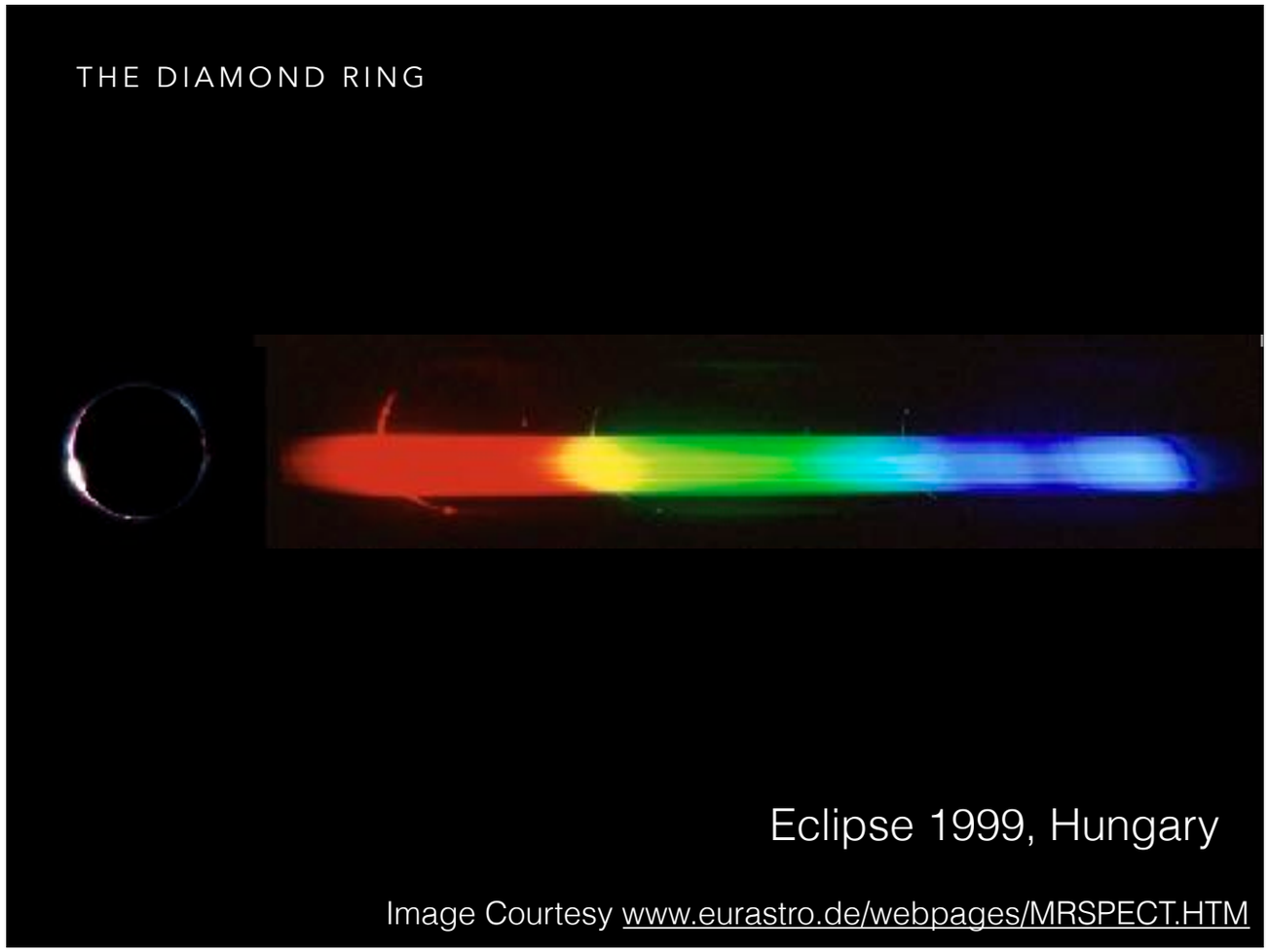
The same information can be learned in spectroscopical way.

THE DIAMOND RING - CHROMOSPHERE - CORONA



The phases observed during a total eclipse are called:[15]

First contact—when the Moon's limb (edge) is exactly tangential to the Sun's limb.
Second contact—starting with Baily's Beads (caused by light shining through valleys on the Moon's surface) and the diamond ring effect. Almost the entire disk is covered.
Totality—the Moon obscures the entire disk of the Sun and only the solar corona is visible.
Third contact—when the first bright light becomes visible and the Moon's shadow is moving away from the observer. Again a diamond ring may be observed.
Fourth contact—when the trailing edge of the Moon ceases to overlap with the solar disk and the eclipse ends.



Eclipse 1999, Hungary

Image Courtesy www.eurastro.de/webpages/MRSPECT.HTM

Het licht wordt door diffractie uit elkaar getrokken, zoals in een prisma.
Zijn allemaal cirkels, telkens in een andere golflengte.

Spectra of the sun taken at different phases of the eclipse. diamond ring, chromosphere, corona. The three spectra look quite different:
Diamond ring:
A continuum spectrum of the **photosphere**, some bright emission lines of the chromosphere are already visible. In the **continuum**, very fine dark lines are visible, particularly in the green and blue part of the spectrum (Fraunhofer absorption lines).

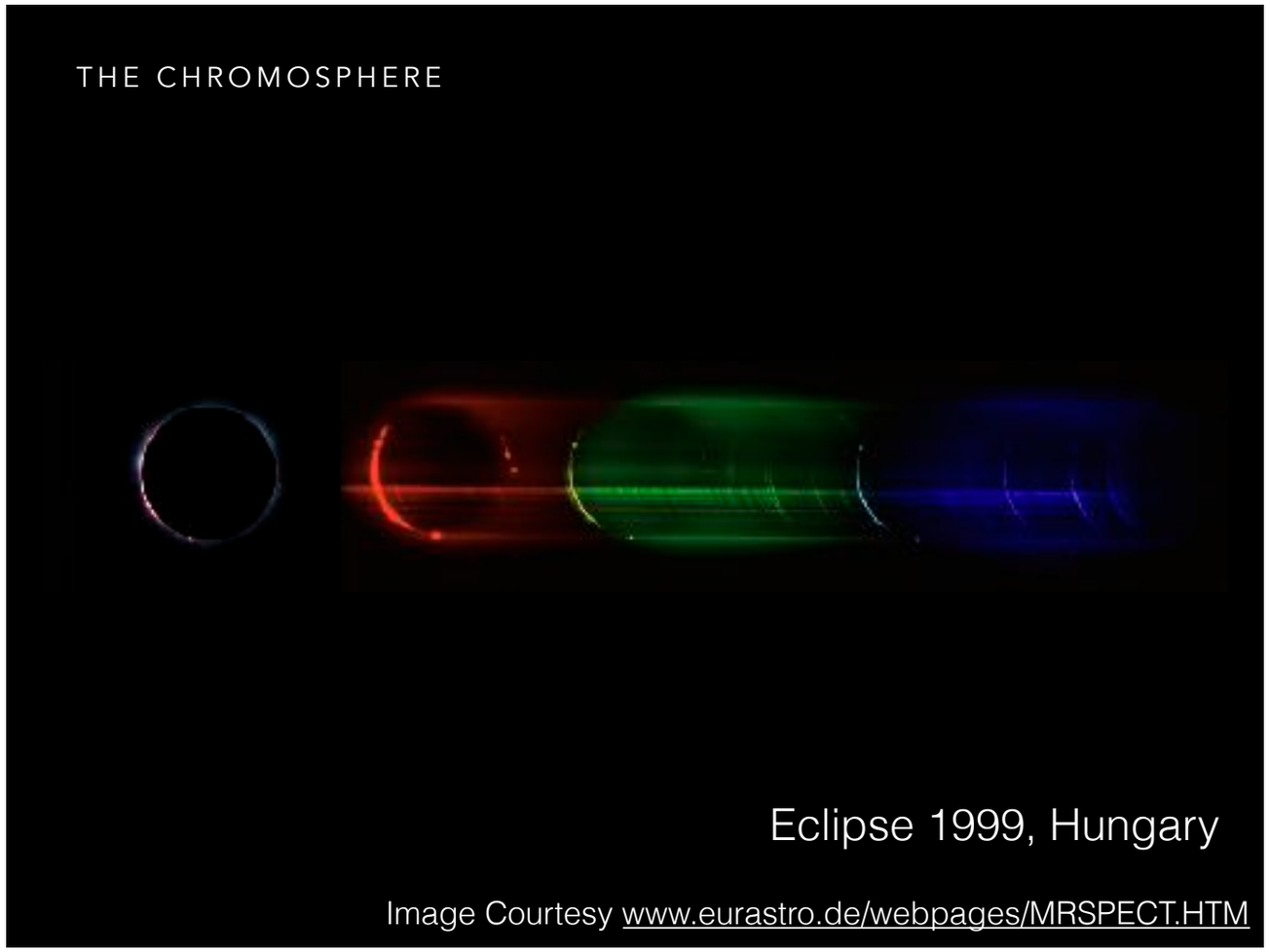
H-alpha 656.28 nm - rood - 9000 °K

C II K 3933.7Å - 393.37 nm - blauw -

zichtbaar licht: 780 - 380 nm / 7800- 3800 Angstrom / ROGeGrBIV

UV: 380 - 10 nm / 3800 - 100 Angstrom

EUV: 100 - 10 nm / 1000 - 100 Angstrom

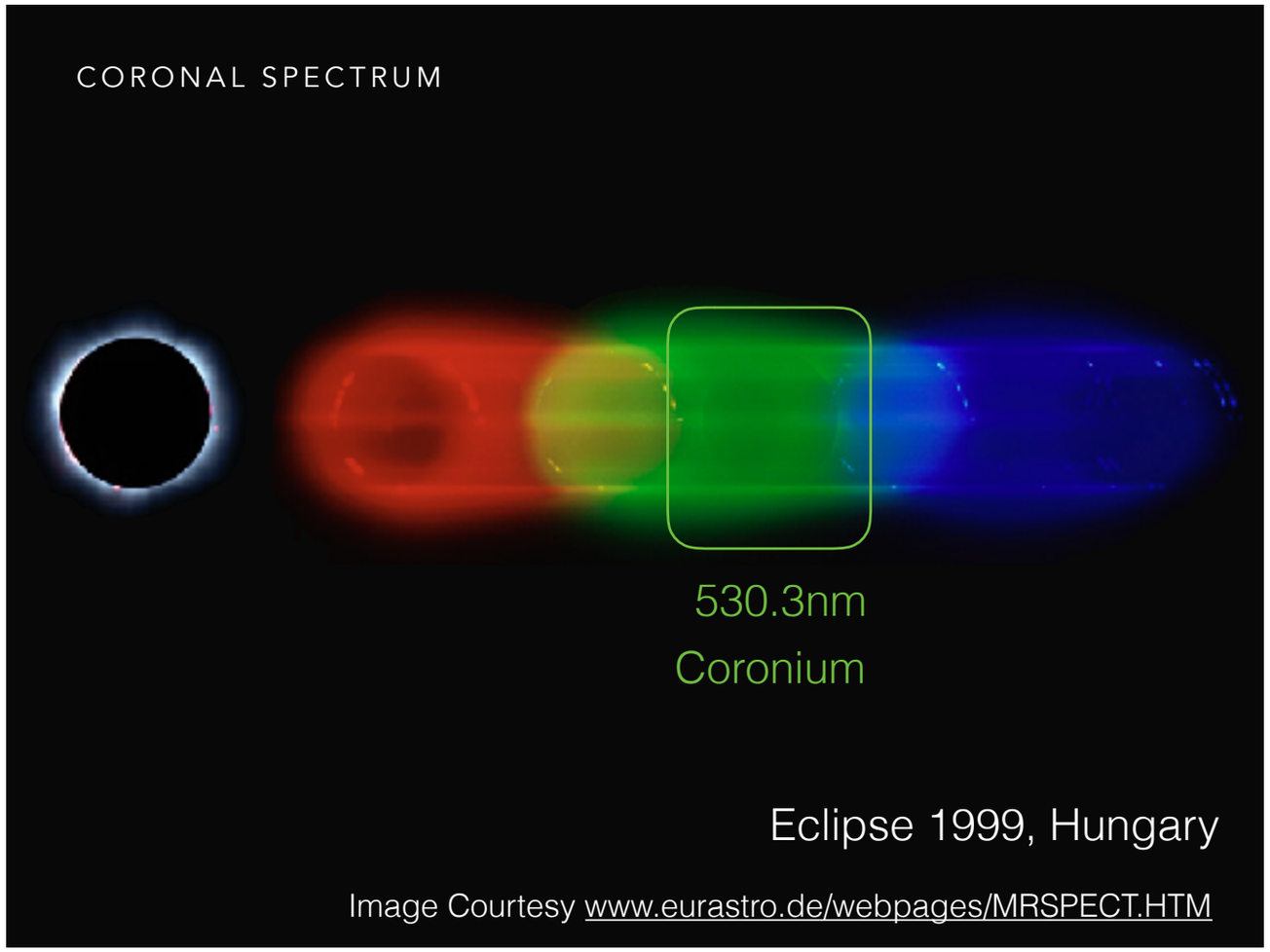


Spectrum of the **chromosphere**:
Some seconds after the second contact, and some seconds before the third contact, the chromosphere is visible. The chromosphere is a rather thin (ca. 5000 km) atmospheric layer of the Sun (The pink-coloured region on the left-hand side of the solar image). The **composition and temperature** of the chromosphere are **comparable** to that of the photosphere, however **the density** of the chromosphere is far **less** than that of the photosphere. Therefore the continuum spectrum changes to an **emission spectrum**, where the emission lines correspond to the absorption lines in the continuum spectrum, although some other lines are visible.

Since the bright emission lines of the chromosphere are visible for several seconds only, and appear rather suddenly, the chromospheric spectrum is also called "**Flash spectrum**".
The bright lines in **red and turquoise, and two of the blue lines** correspond to **hydrogen**, whereas the **yellow** line is indicative of **helium**. Helium was first discovered in 1868 by its yellow emission line in the flash spectrum recorded during a solar eclipse.

The **wavelength of the emission lines is indicative of the composition** (chemical elements) while the **intensity of the lines reflects the abundance** of the elements (ca. 70% hydrogen, 28% helium, the rest heavier elements).

See the emission lines of: Hydrogen (656, 486, 434, 410 nm; indicated by white lines), Helium (587 nm (white line), 502, 447 nm),
Sodium (589 nm, close to the yellow helium line), Magnesium (516, 517, 518 nm), Calcium (397, 393 nm). Many of the green lines are due to the presence of iron.

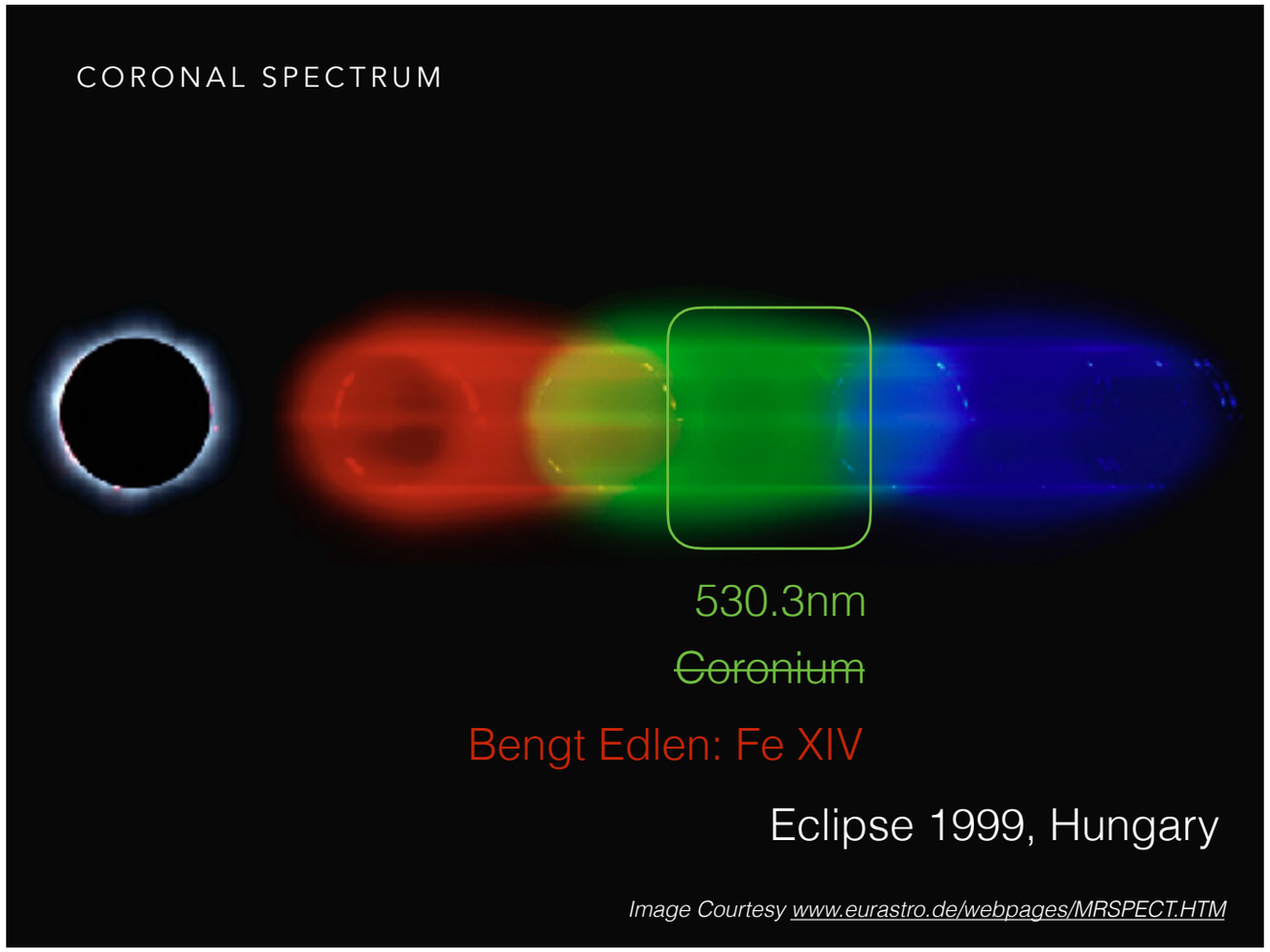


Coronal spectrum
The corona is the extremely tenuous outer part of the Sun's atmosphere which attains temperatures of up to several million kelvin and extends many million kms into the interplanetary space. A spectrum of the inner corona is shown in the picture.
In the spectrum you can distinguish a red, yellow, a faint green, turquoise, and several blue circles. Each of them represents an image of the solar corona in a different wavelength. The **red, turquoise, and some of the blue images again are due to the hydrogen emissions, and the yellow image corresponds to helium**. **The bright dots on the circumference of the solar images represent the prominences.**

The green emission at a wavelength of 530 nm was first discovered at an eclipse in 1869. An emission line at that wavelength was unknown in laboratory spectra, and a new element was suspected, named "coronium".

Coronium, also called newtonium, was the name of a suggested chemical element, hypothesised in the 19th century. The name, inspired by the solar corona, was given by A. Gruenwald in 1887.[1] A new atomic thin green line in the solar corona was then considered to be emitted a new element unlike anything else seen under laboratory conditions. Because of this it was also mis-classified as Iron Line Number 1474.[2]

During the total solar eclipse of 7 August 1869, a green emission line of wavelength 530.3 nm was independently observed by Charles Augustus Young (1834–1908) and William Harkness (1837–1903) in the coronal spectrum. Since this line did not correspond to that of any known material, it was proposed that it was due to an unknown element, provisionally named coronium.
In 1902, in an attempt at a chemical conception of the aether, the Russian chemist and chemical educator Dmitri Mendeleev hypothesized that there existed two inert chemical elements of lesser atomic weight than hydrogen. Of these two, he thought the lighter to be an all-penetrating, all-pervasive gas, and the slightly heavier one to be coronium. Later he renamed coronium as newtonium.[3]



"Around the 1930s scientists determined the temperature [of the corona] must be a million degrees [Celsius] because of the way it stood out into space," said Parker. "If it weren't so hot, it wouldn't be puffed out so much. Then some very **clever spectroscopic detective work** confirmed this extraordinary temperature."

Later it turned out that this green emission was due to iron atoms from which 13 electrons have been stripped off (FeXIV), and which can only be found under the extreme conditions of the corona at temperatures of 2,000,000 Kelvin or higher. **This also makes clear why there are no green "dots" (images of prominences) on the circumference of the green solar image. The temperature of the prominences is about 4000-6000 K only and thus far too low to allow the formation of the highly ionized FeXIV.**

It was not until the 1930s that Walter Grotrian and Bengt Edlén discovered that the spectral line at 530.3 nm was due to highly ionized iron (Fe13+); other unusual lines in the coronal spectrum were also caused by highly charged ions, such as nickel, the high ionization being due to the extreme temperature of the solar corona.[4]

The corona is big & hot

Further investigations:
(simply) watching the Sun

LOOKING AT AN OBJECT

A picture of a hand in visible light.



We study object by looking at them.

Solar visible light bounces back from the hand into our eyes.

You see the surface. Visible light can’t penetrate into the skin. The skin is not transparant for visible light.

LOOKING AT AN OBJECT

...in x-rays.



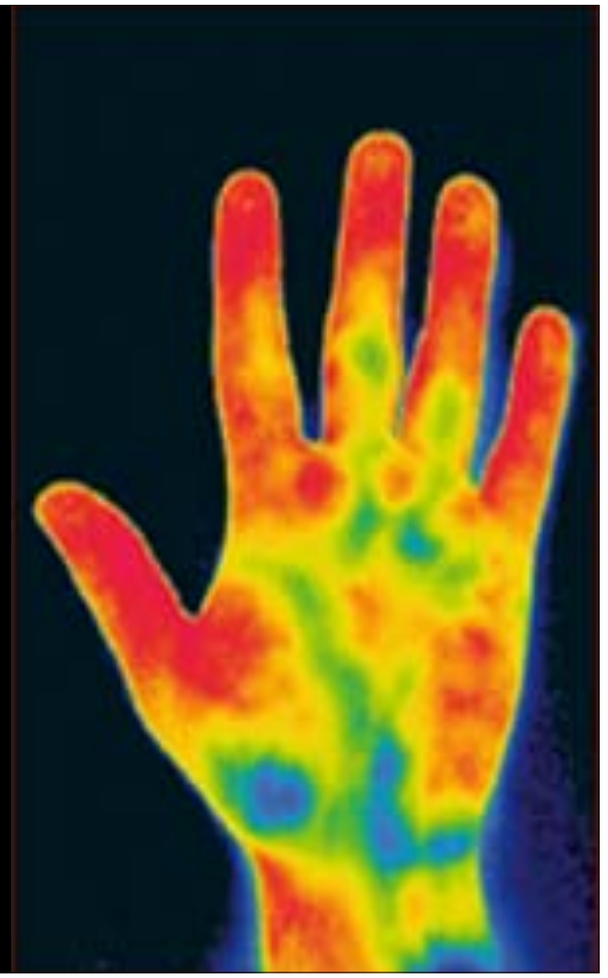
By looking at objects using another sort of light, we see different things.
X-rays are produced by a machine. The x-rays pass soft tissues, but bones for example are less opaque to x-rays.
Medical pictures: x-rays are sent through the body. It is the shadow of the x-ray light that you see in the image. Bones have more shadow than soft tissues.

Hard X-rays can traverse relatively thick objects without being much absorbed or scattered. For this reason, X-rays are widely used to image the inside of visually opaque objects. The most often seen applications are in medical radiography and airport security scanners, but similar techniques are also important in industry (e.g. industrial radiography and industrial CT scanning) and research (e.g. small animal CT). The penetration depth varies with several orders of magnitude over the X-ray spectrum. This allows the photon energy to be adjusted for the application so as to give sufficient transmission through the object and at the same time good contrast in the image.
X-rays have much shorter wavelengths than visible light, which makes it possible to probe structures much smaller than can be seen using a normal microscope. This property is used in X-ray microscopy to acquire high resolution images, and also in X-ray crystallography to determine the positions of atoms in crystals.

An X-ray generator is a device that produces X-rays. Together with an X-ray detector, it is commonly used in a variety of applications including medicine, fluorescence, electronic assembly inspection, and measurement of material thickness in manufacturing operations. In medical applications, X-ray generators are used by radiographers to acquire x-ray images of the internal structures (e.g., bones) of living organisms, and also in sterilization.

LOOKING AT AN OBJECT

…in infra-red.



Each body radiates infrared. When molecules are moving, there is heat and infrared.

Infrared can be used as a way to measure the heat radiated by an object. This is the radiation produced by the motion of atoms and molecules in an object. The higher the temperature, the more the atoms and molecules move and the more infrared they produce. Any object which has a temperature i.e. anything above absolute zero (-459.67 degrees Fahrenheit or -273.15 degrees Celsius or 0 degrees Kelvin), radiates in the infrared. Absolute zero is the temperature at which all atomic and molecular motion ceases. Even objects that we think of as being very cold, such as an ice cube, emit infrared. When an object is not quite hot enough to radiate visible light, it will emit most of its energy in the infrared. For example, hot charcoal may not give off light but it does emit infrared which we feel as heat. The warmer the object, the more infrared it emits. We experience infrared radiation every day. The heat that we feel from sunlight, a fire, a radiator or a warm sidewalk is infrared. Although our eyes cannot see it, the nerves in our skin can feel it as heat. The temperature-sensitive nerve endings in your skin can detect the difference between your inside body temperature and your outside skin temperature. We also commonly use infrared rays when we operate a television remote.
What specifically do infrared images reveal?
Infrared is a type of light that we cannot see with our eyes. Our eyes can only see what we call visible light. Infrared light brings us special information that we do not get from visible light. It shows us how much heat something has and gives us information about an object's temperature. Everything has some heat and puts out infrared light. Even things that we think of as being very cold, like an ice cube, put out some heat. Cold objects just put out less heat than warm objects. The warmer something is the more heat it puts out and the colder something is the less heat it puts out. Hot objects glow more brightly in the infrared because they put out more heat and more infrared light. Cold objects put out less heat or infrared light and appear less bright in the infrared. Anything which has a temperature puts out infrared light. In the infrared images shown in these lesson plans, different colors are used to represent different temperatures. You can find out which temperature a color represents by using the color-temperature scale show to the right of most of the images. The temperatures are in degrees Fahrenheit.
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_zoo/lessons/background.html

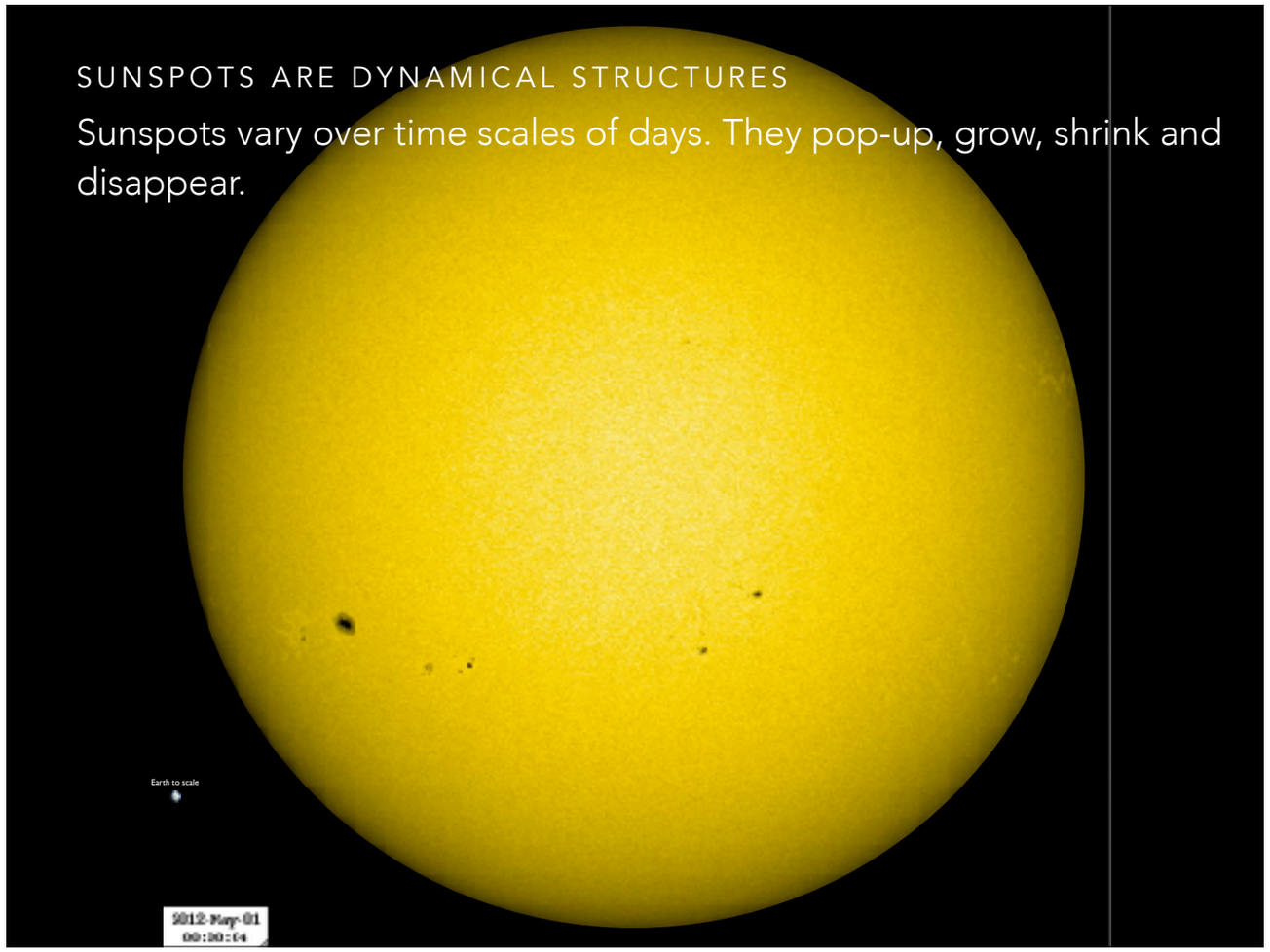
STUDYING THE SUN

By watching it with a simple telescope from Earth in visible light .

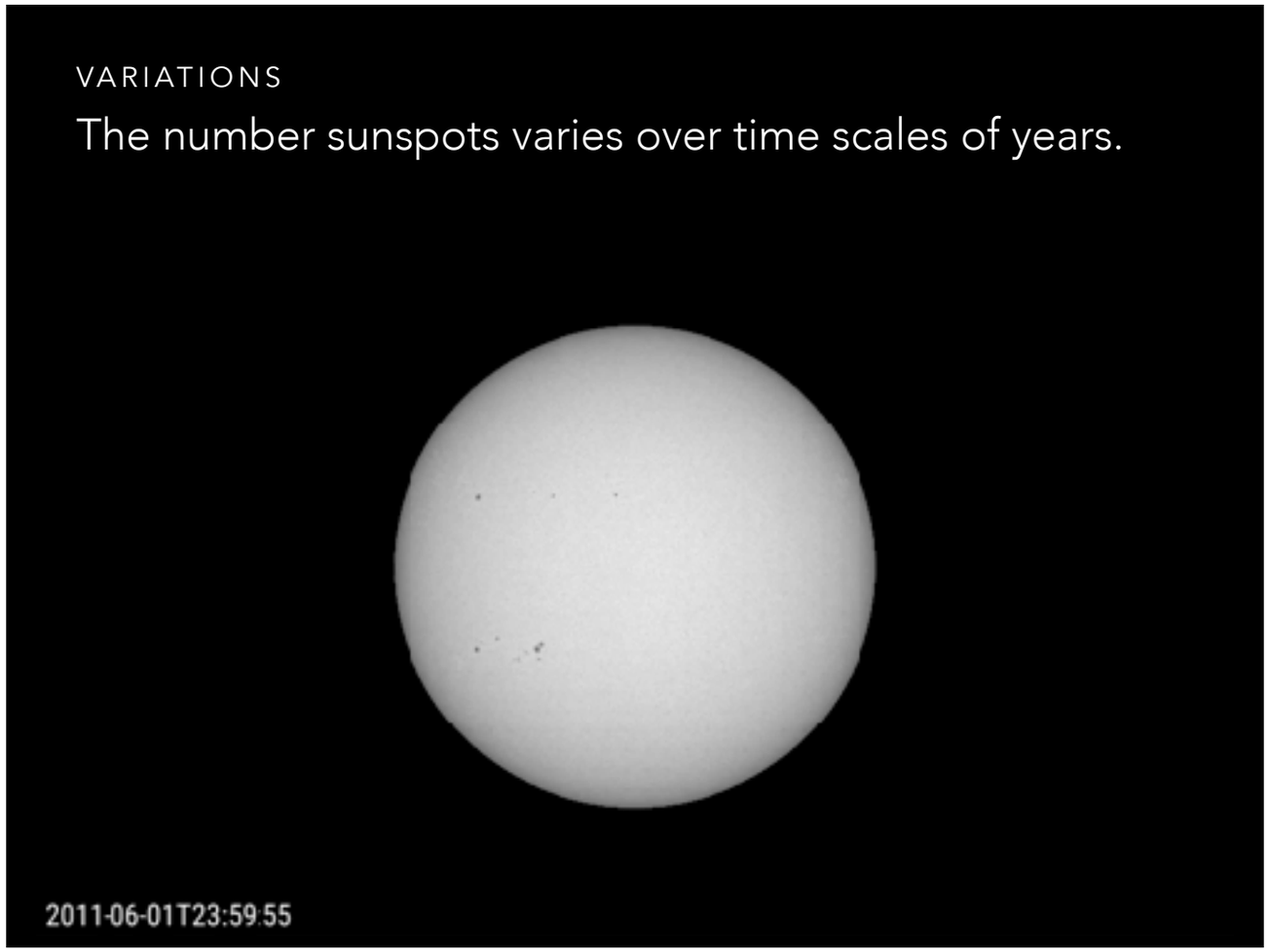


The simplest way to study the sun is to watch it through a simple telescope from earth. A telescope can enlarge the image.

Visible light and Sunspots



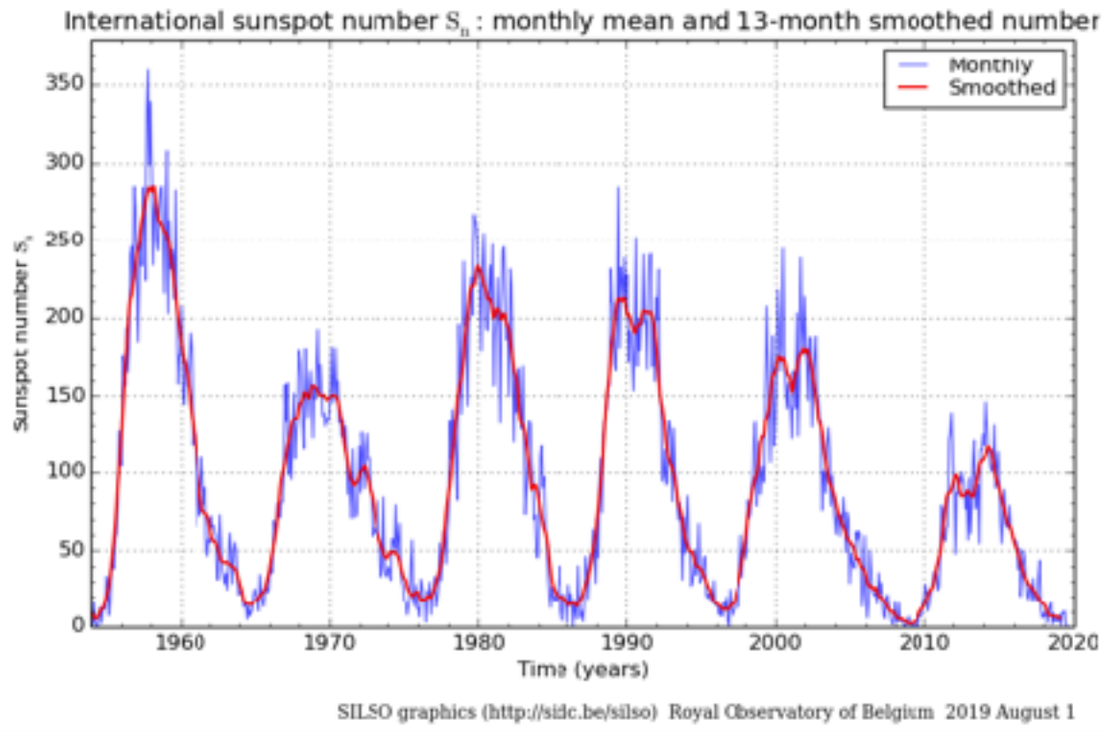
Het wordt pas interessant als er iets verandert.
Variatie over dagen - week



Variatie over jaren

COUNTING SUNSPOTS

Stations worldwide count sunspots and calculate their Wolf number: R = k (10 x Ng + Ns). The WDC calculates the daily ISN.



K - reduction coefficient, scaling factor, quality index — ingevoerd door Wolfer. Wolf, de vorige directeur heeft k = 1.

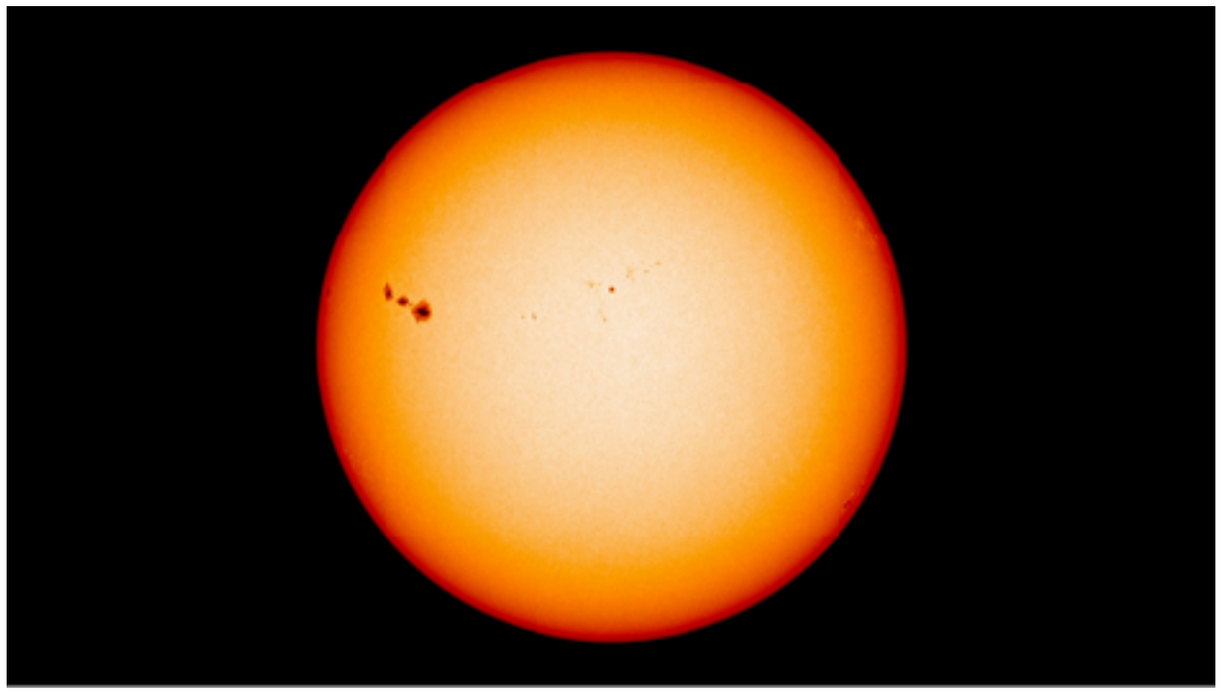
hangt af van hoe
goed een waarnemer kleine zonnevlekken kan waarnemen : persoonlijke ervaring, lokale zichtbaarheid, sterkte telescoop, zicht van de ogen, …

waarnemer groepen opsplitst

hierdoor kan het zonnevlekkengetal van 1 waarnemer verschillen van een geheel getal.

EUV and magnetic loops

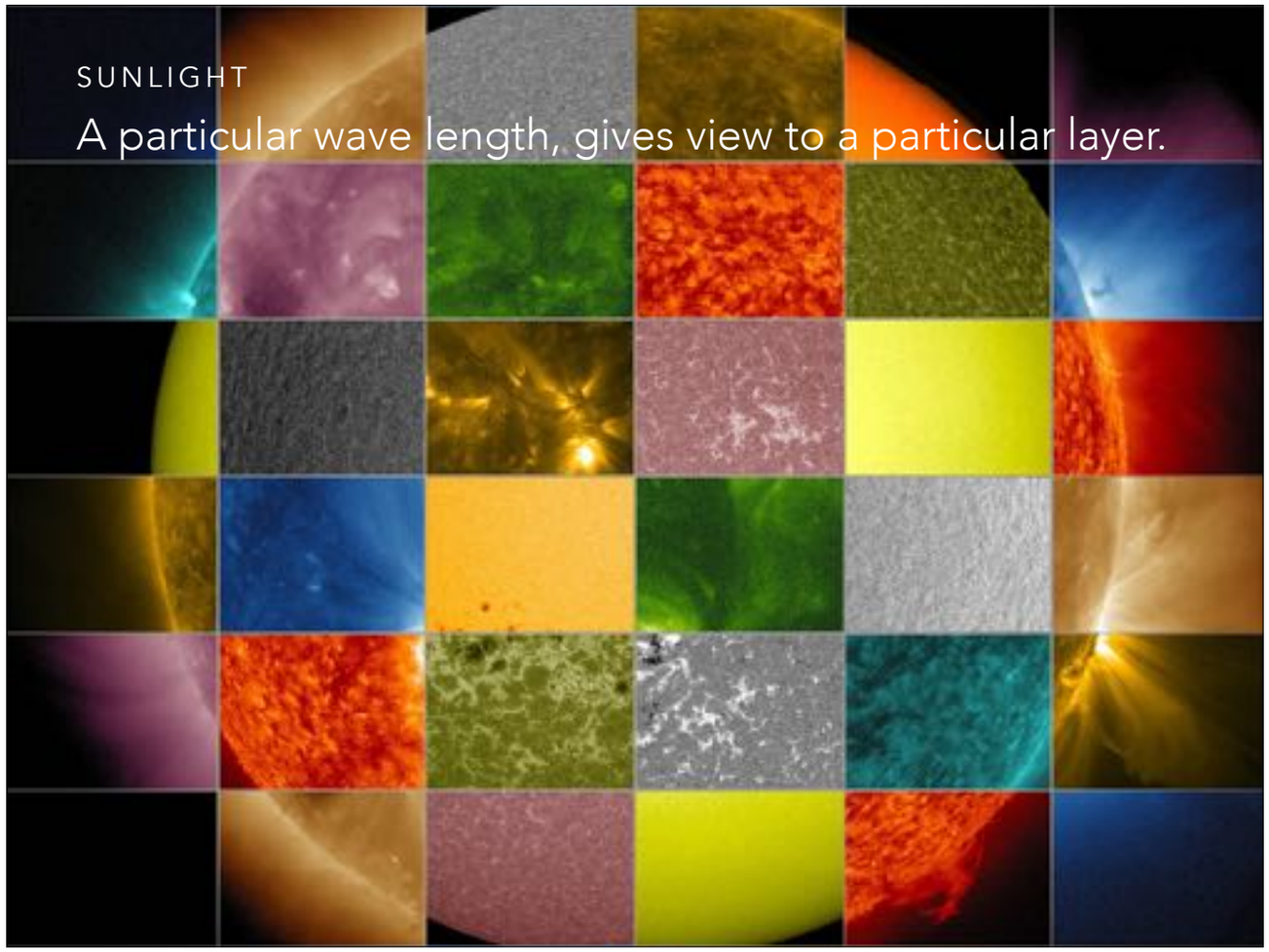
LOOKING AT AN OBJECT IN ALL SORTS OF LIGHT

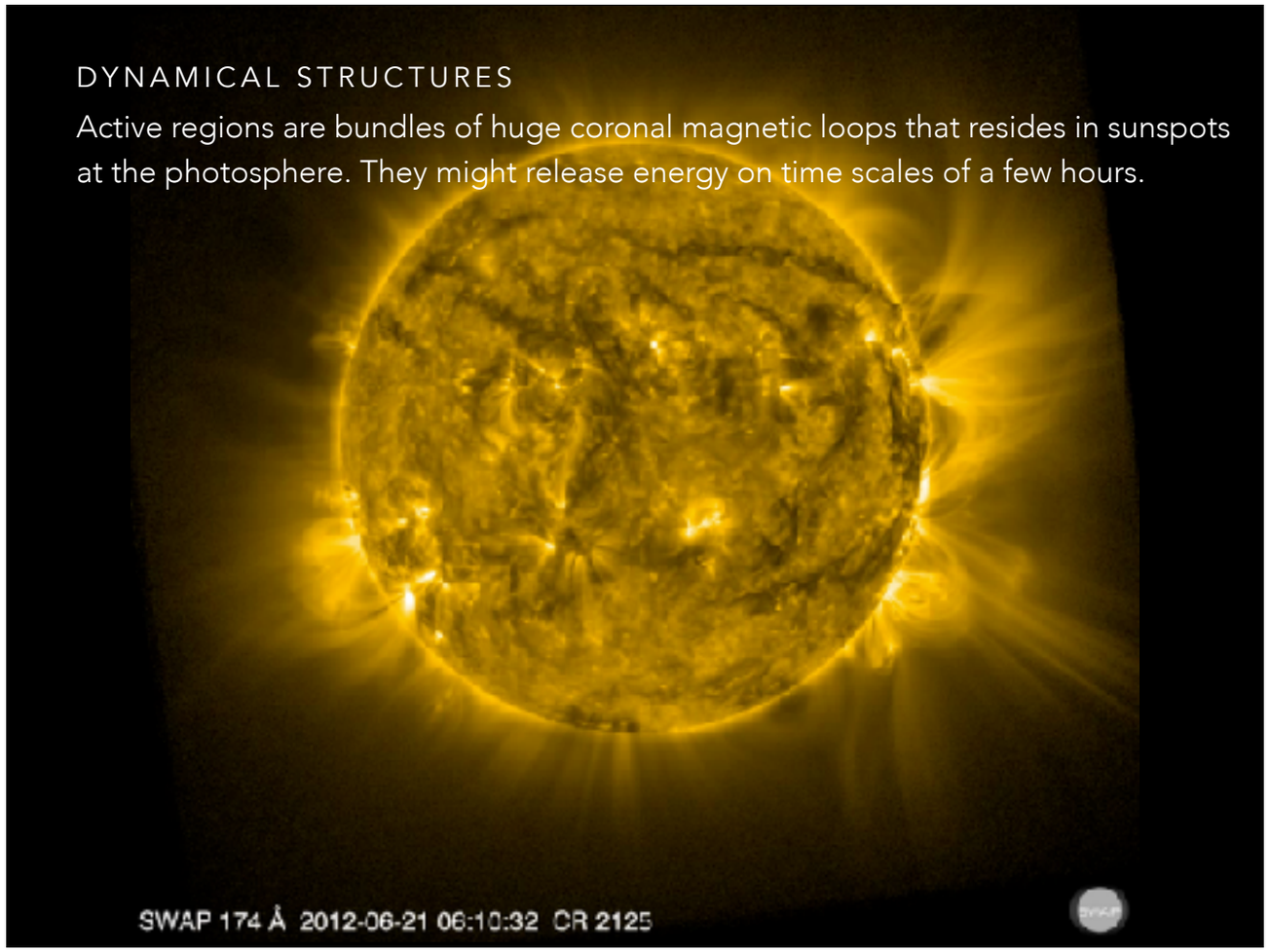


But the sun is so hot that emits even more energetic light, with much shorter wavelengths than visible light. If you catch this light, the sun looks very different.
To catch this light, we have to go to space. So, it was only since the start of the space age that we were able to make such recordings.
In een andere golflengte zien we telkens iets anders. 1 bepaalde structuur ziet er compleet anders uit in een andere golflengte. We zien dat de zon een magnetische persoonlijkheid heeft.

The Sun has a hidden part that became only visible at the start of the space age. From the moment, we could inspect the Sun in other wavelengths, the Sun showed its dynamic, explosive and magnetic personality.

We use many tricks to observe the Sun and its activity. One of them is to look at the Sun using different parts of the light spectrum, thus in different wavelengths. From Earth, with the naked eye, we see the surface of the Sun in white light like this. However, now that I start the movie, you can see how looking at the Sun in other wavelengths from space reveals very different structures and complexity. For this we mainly use extreme ultraviolet wavelengths because we are studying the hot outer region of the Sun, the corona. We see active regions, these are the bright patches, that show up in EUV wavelengths where the sunspots were first seen in white light. We also see the effects of the sun's magnetic field in the many loops above these sunspots. Each wavelength shows us different aspects and different layers of the solar atmosphere and by combining them, we try to build a complete picture of the solar activity.
Therefore, we have many instruments in space to observe the solar atmosphere. This movie was made combining different observations from the AIA telescope on board the Solar Dynamics Observatory.

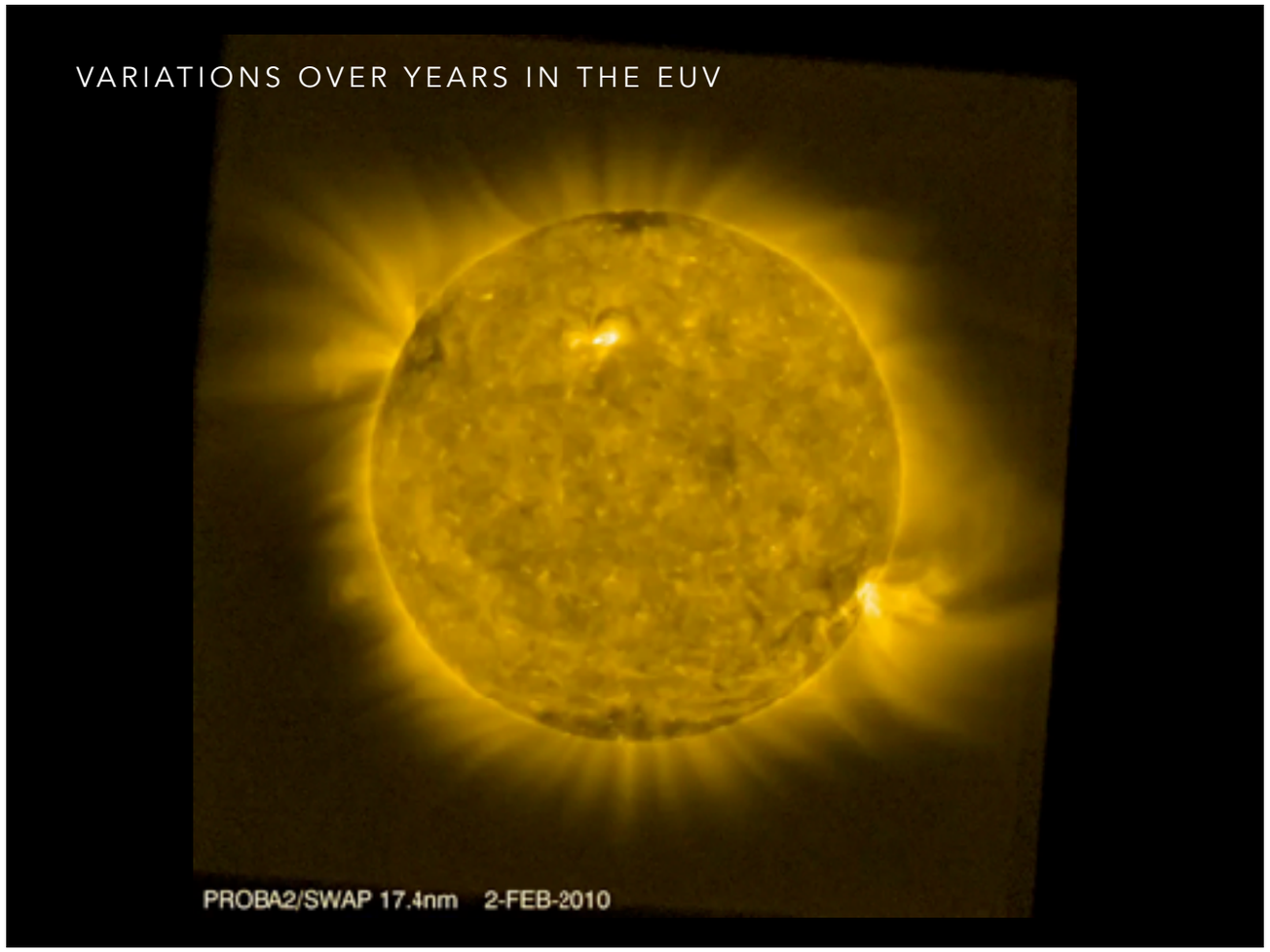

SUNLIGHT
A particular wave length, gives view to a particular layer.



In het EUV zien we dat die structuren erg dynamisch en beweeglijk zijn. Dit is een filmpje over enkele zonnerotaties.

Actieve gebieden kunnen net zoals zonnevlekken ontstaan, groeien, verdwijnen.

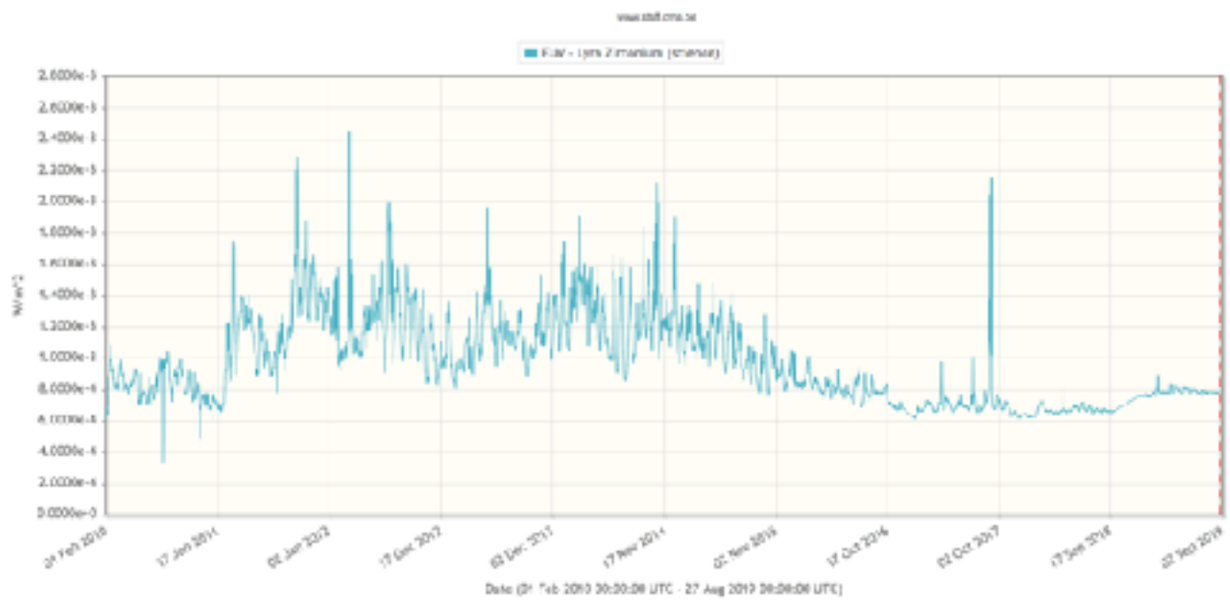
More variations



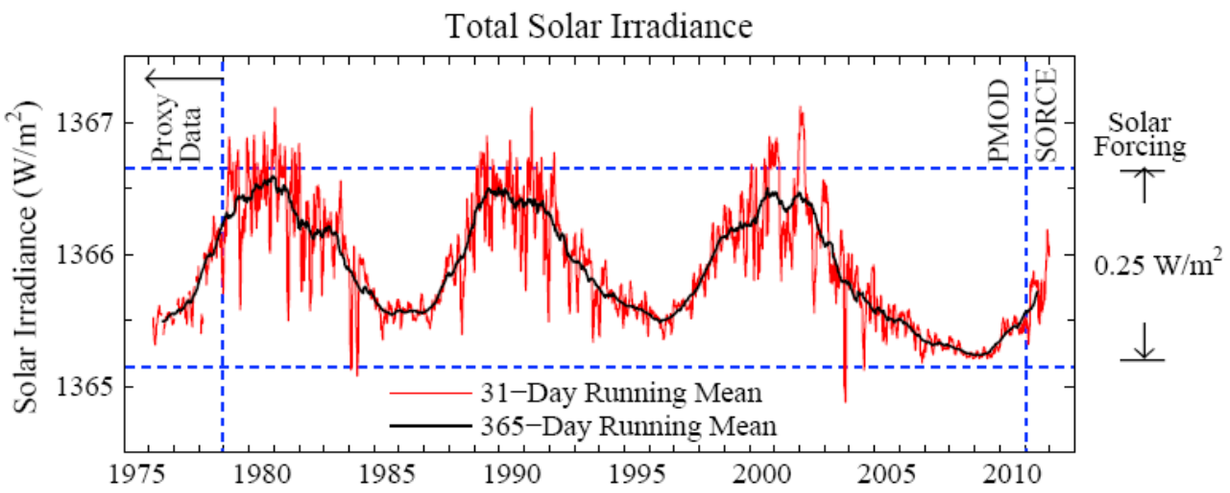
EUV variatie over 5 jaar

MEASURING 1 EUV WAVELENGTH

The radiometer LYRA onboard PROBA2 measures the EUV radiation in 4 wavelengths. The intensity varies over years.



SOLAR VARIATIONS



Verband tussen de TSI en de luminositeit/helderheid?

De stralingsenergie die de aarde bereikt per seconde, bedraagt ongeveer 1365 Watt per vierkante manier aan de top van de atmosfeer. Dit is de “total solar irradiance” (TSI) en wordt gebruikt in klimaatstudies
Vermogen is watt

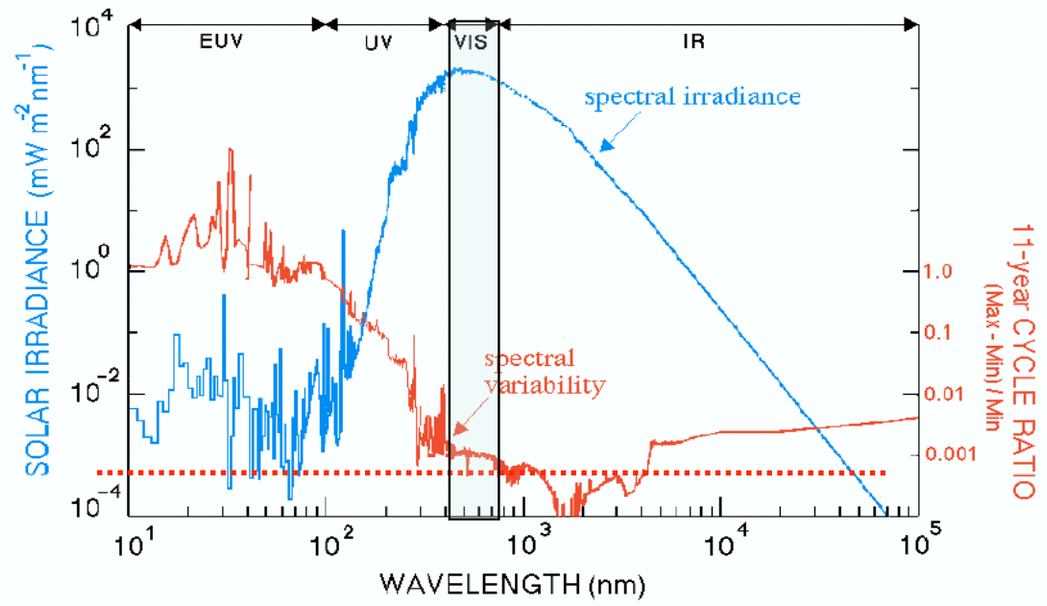
This represents a fraction of the total amount of electromagnetic radiation emanating from the Sun in all directions.

In de astronomie wordt onder de **lichtkracht** (luminositeit, helderheid) van een ster verstaan het **totaal uitgezonden vermogen (watt, energie/tijd) in de vorm van elektromagnetische straling**. De lichtkracht is afhankelijk van de effectieve temperatuur van de ster en z'n omvang.
De lichtkracht wordt uitgedrukt in Watt of in eenheden van de lichtkracht van de zon (L☉).
De lichtkracht van de zon kan direct gemeten worden door de bepaling van de zonneconstante. De lichtkracht van een ander ster bepaalt men door z'n absolute helderheid te vergelijken met die van de zon of van een andere ster met reeds bekende lichtkracht.

als je de TSI vermenigvuldigd met het oppervlak van een bol met straal 1AU,
4*Pi*R^2*1367 met R=1,496 10^8 km dan bekom je de lichtkracht van de zon, 3,839 10^26 Watt

VARIATION PER WAVELENGTH

The variation is the strongest is the short wavelengths.



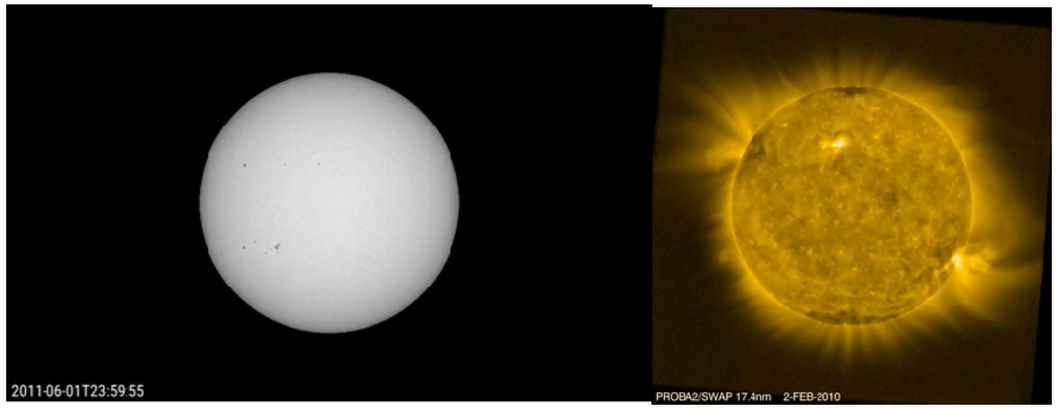
Logaritmische schaal

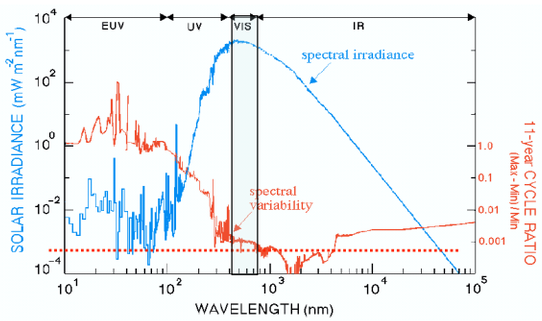
als je alles integreert onder de blauwe curve, bekom je de TSI

Het zichtbare en infrarode spectrum, voortgebracht ter hoogte van de fotosfeer, varieert bijzonder weinig (<1%).
De variaties zijn veel hoger (een factor 10 tot 1000), bij golflengtes onder de 320 nm, in het ultraviolet. **Deze straling, die echter van de andere lagen komt (chromosfeer, corona) komt slechts overeen met 2% van de totale straling**. Ze heeft niettemin een belangrijk effect op de hogere aardatmosfeer

VARIATION PER WAVELENGTH

The variation is the strongest is the short wavelengths.





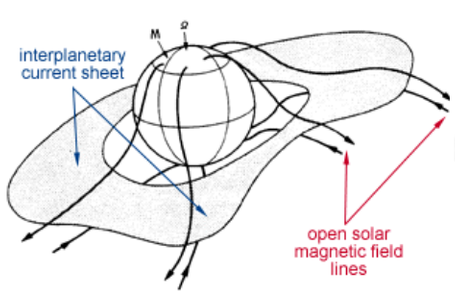
Logaritmische schaal

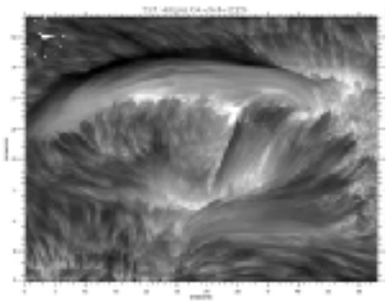
In zichtbaar licht wordt de zon of stukken van het oppervlak niet helderder - terwijl in het EUV er duidelijk een variatie is -

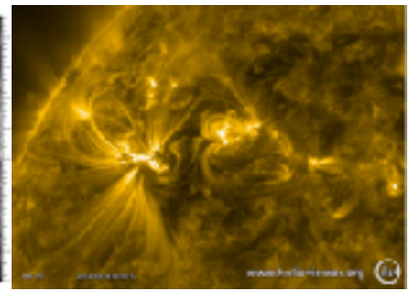
Magnetism

MAGNETISM

Magnetic fields are the driving force behind solar activity. You have different spatial and time scales.







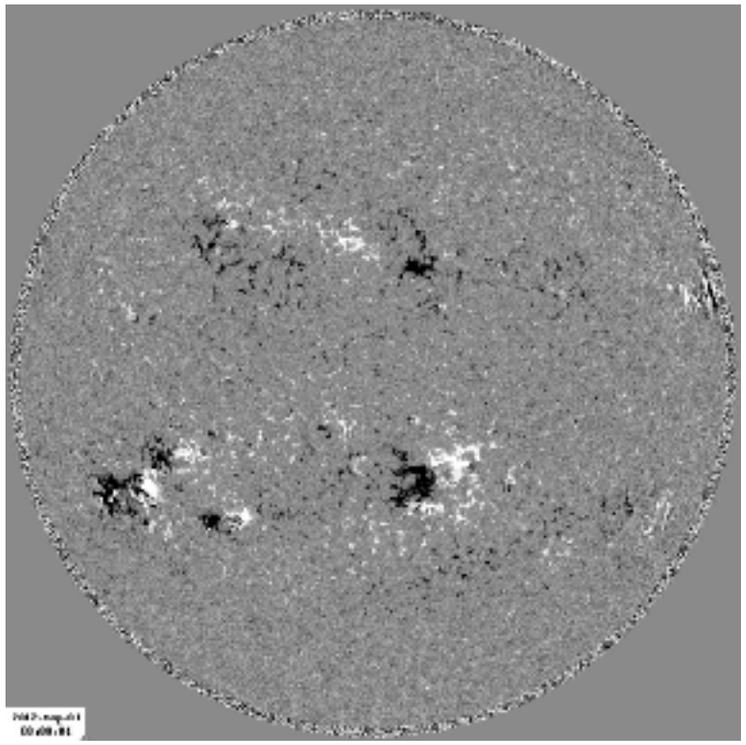
Het weer en klimaat wordt gestuurd door magnetische velden. Je hebt deze op alle mogelijke schalen.

spicules, AR, June 2004

Swedish Solar Telescope; hydrogen “alpha”

THE PHOTOSPHERIC MAGNETIC FIELD

Similar like sunspots and magnetic coronal loops, it varies over time scale of days.



variatie over een maand

THE SOLAR ATMOSPHERE CHANGES OVER TIME



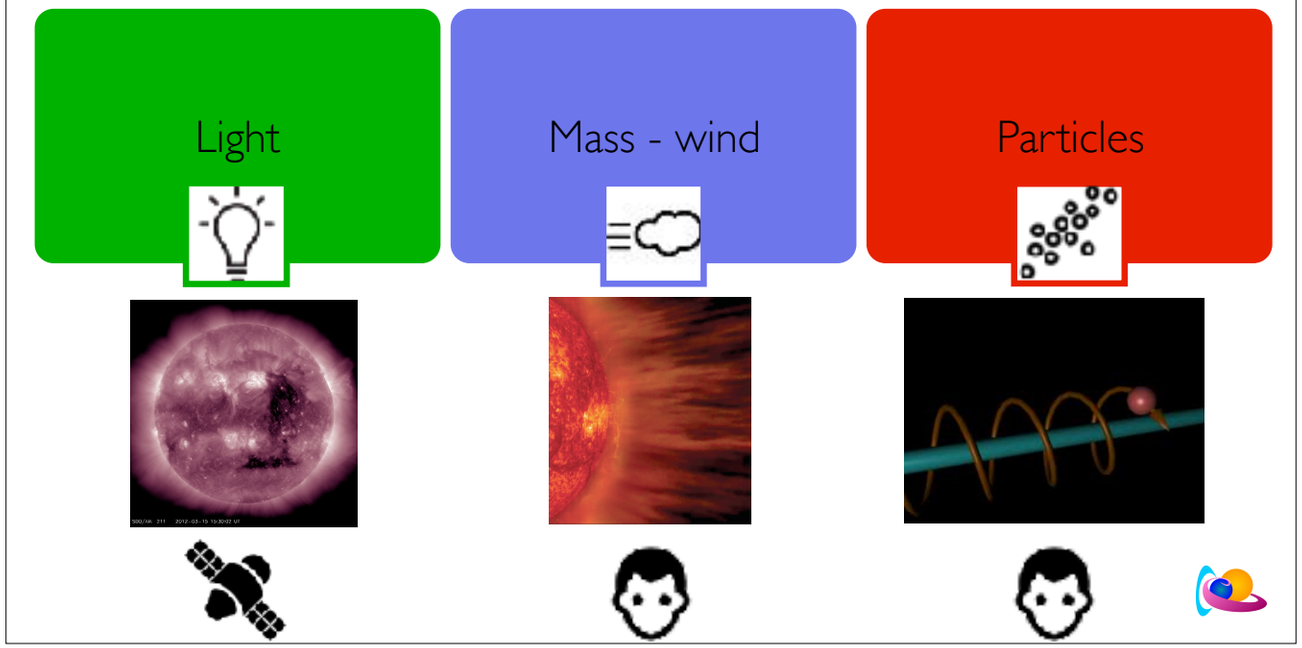
2008 2015 2017

De zonneatmosfeer verandert op hetzelfde ritme van de zonnecyclus.

The source of the solar wind is situated in the inner solar corona. This graph, with the heliocentric distance along the horizontal axis and the speed on the vertical axis, shows a typical solar wind acceleration profile. The solar surface is here, ten solar radii is here, and the Earth is here. We can see that the wind acceleration takes place very rapidly. Within the first **15 solar radii** the wind becomes **superalfvénic**, and the **sonic point** is reached even lower, within **two-three solar radii**. The inner corona, here loosely defined as the region within five solar radii, is also the place where coronal mass ejections, CMEs, accelerate.

SPACE CLIMATE

The sun emits continuously energy and creates a space climate that has 2 seasons: a more active and a less active. This seasonal variation is called the solar cycle and takes around 11 years.



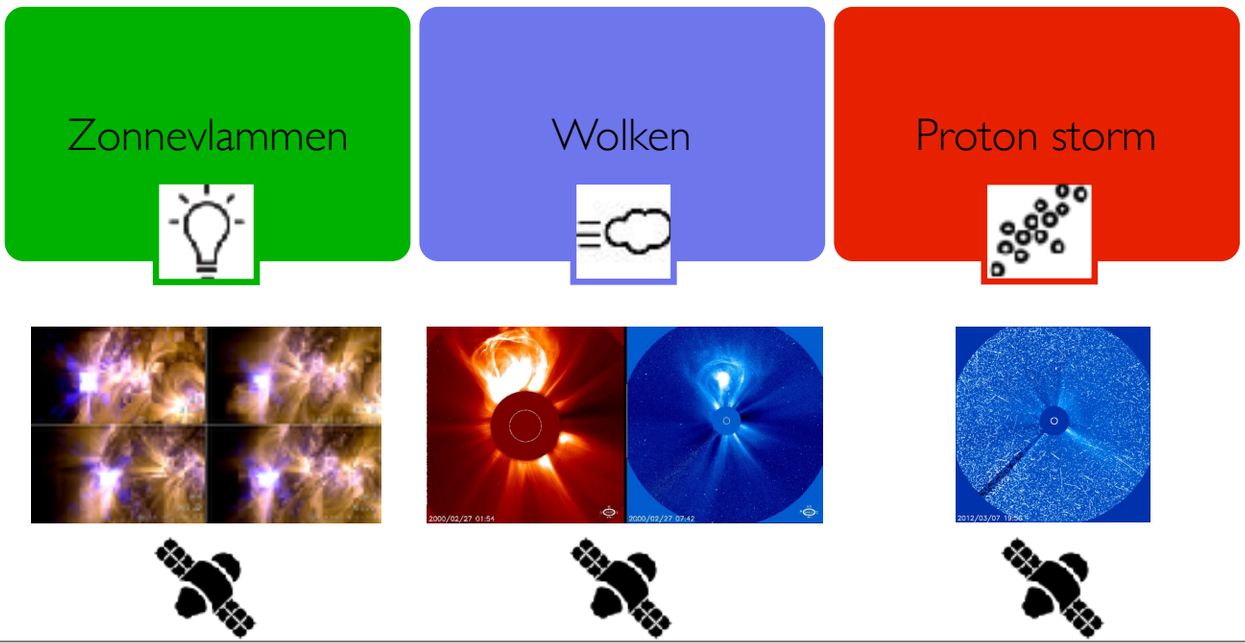
energievormen
De uitstoot varieert over een periode van 11 jaar - klimaat

Klimaat
algemene toestand in de ruimte
verschillende vormen van energie die in de ruimte ‘rond dwalen’

Rood - Beweging en gedrag wordt per deeltje beschreven.
Blauw - wordt als een geheel bekeken, MHD

SPACE WEATHER

The sun looses energy in different forms in an abrupt, impulsive and brutal way.



Plotse veranderingen van de energietoestand

De zonneactiviteit is het geheel aan fenomenen waarbij energie op een **impulsieve** manier wordt vrijgegeven in de zonneatmosfeer, en die **gegenereerd wordt door de evolutie en brutale transformatie van magneetvelden die doorheen het zonneoppervlak lopen**.

Ze veroorzaakt impulsieve variaties in de zonne-emissies:
- Intense stralingsuitbarstingen over het gehele electromagnetische spectrum, in het bijzonder in het UV, X- en gamma-stralen, en radio-stralen (met golflengten van centimeters tot decameter).
- coronale massa-uitstoten (CME's
- Productie van deeltjesjets over een breed energiegamma (tot aan het relativistisch regime)

De meest intense zonneactiviteit wordt gelinkt aan actieve gebieden, met een hoge concentratie magneetvelden die zonnevlammen genereren.

De toestand op een bepaald moment is ruimteweer. Het gebeurt regelmatig dat de zon een oprisping heeft ten gevolge van een plotse magnetische instabiliteit en een extra pakket licht, massa en/of deeltjes uitspuwt. Dit komt bovenop de gewone achtergrondstraling, zonnewind of deeltjesstroom en zijn eruptieve ruimteweerfenomenen. We hebben ook niet eruptieve fenomenen die eveneens het weer in de ruimte bepalen. Een coronaal gat is een voorbeeld een niet eruptief fenomeen. Dit is een locale magnetische coronale structuur die lange tijd aanwezig kan zijn en de zonnewind beïnvloedt.

variaties: gradueel of plots

flares: if you don't see them, they don't hurt you

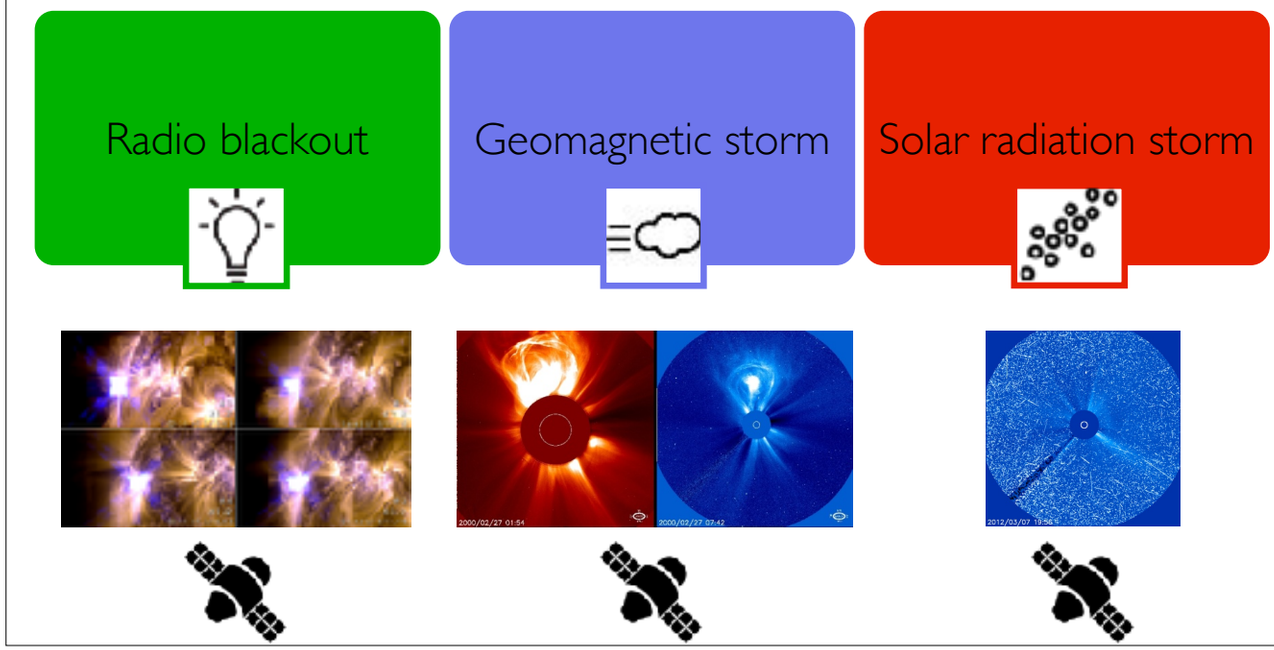
The "solar wind" from the Sun streams past the Earth and is mostly deflected by the Earth's magnetic field. But variations in the solar wind cause changes in the Earth's magnetic field.

Sometimes these changes are gradual increases in density or velocity. Sometimes they are huge clouds of atoms preceded by a shockwave (a little like an oceanic tsunami). The Aurora results from the passage of the solar wind past the Earth.

Occasionally a huge release of magnetic energy, called a solar flare, occurs on the Sun. Flares can produce large quantities of x-rays which affect the Earth's atmosphere. They can also accelerate atomic particles (mostly protons) to very high speeds (a substantial fraction of the speed of light!). These high energy particles are dangerous to man and can reach the stratosphere where jetliners fly.

SPACE WEATHER

The Earth and its environment reacts on these space weather events. The solar storms that impact earth are called 'radio blackout', 'geomagnetic storm' or 'solar radiation storm'.



Plotse veranderingen van de energietoestand

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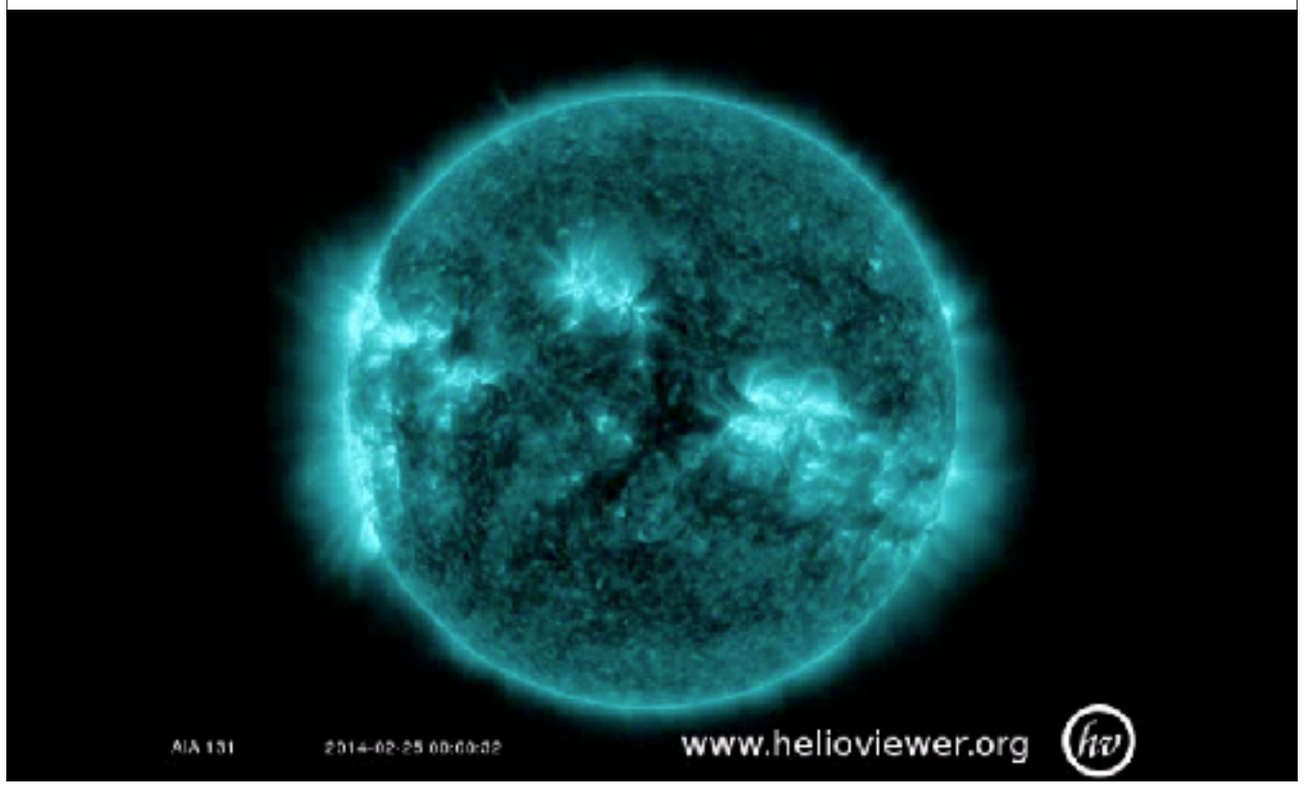
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SOLAR STORMS

From time to time, we see light flashes. These are solar flares.



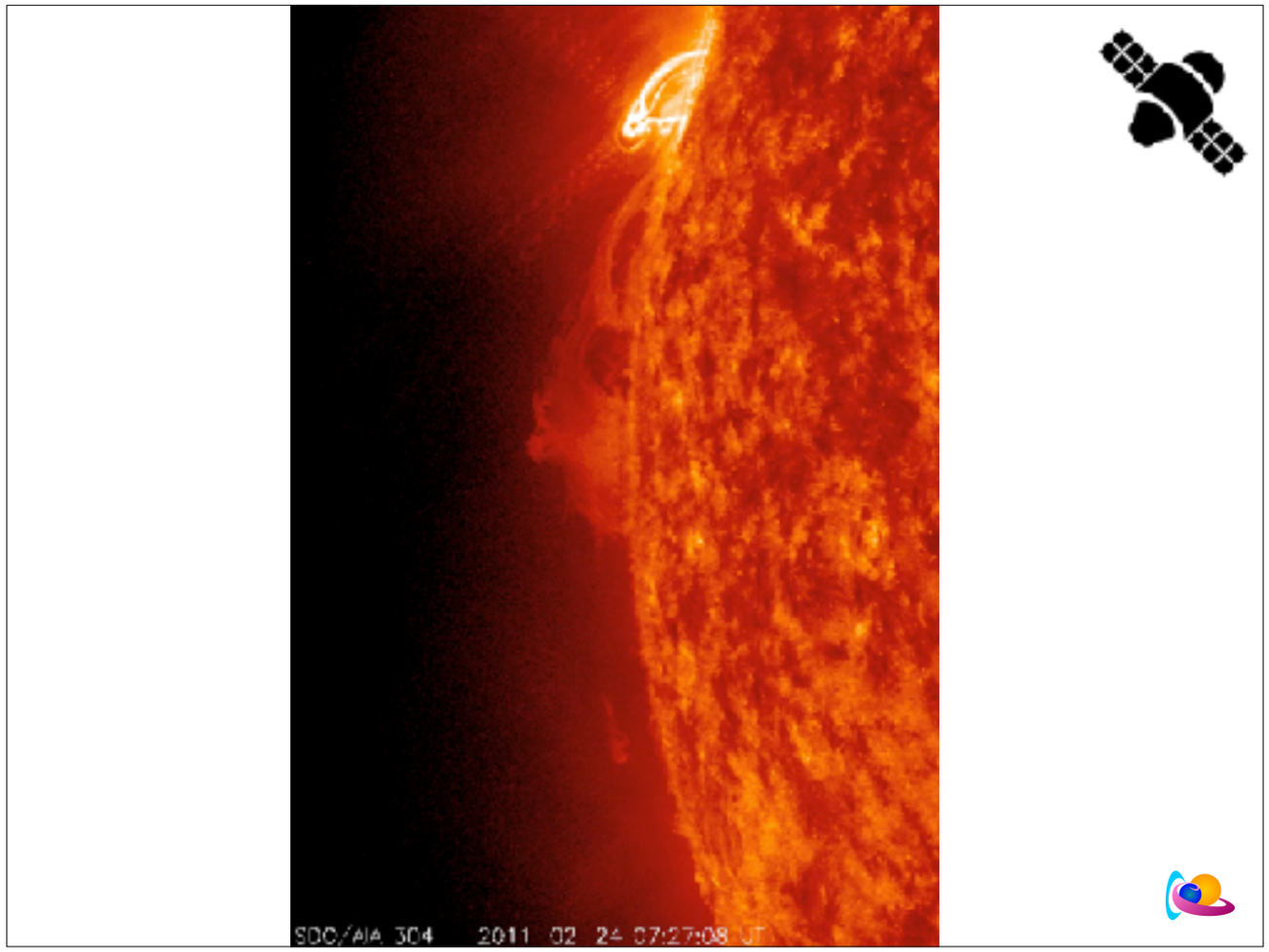
131 angstrom
of 13,1 nm

1700 Angstrom

zichtbaar licht: 780 - 380 nm / 7800- 3800 Angstrom / ROGBIV

UV: 380 - 10 nm / 3800 - 100 Angstrom

EUV: 100 - 10 nm / 1000 - 100 Angstrom



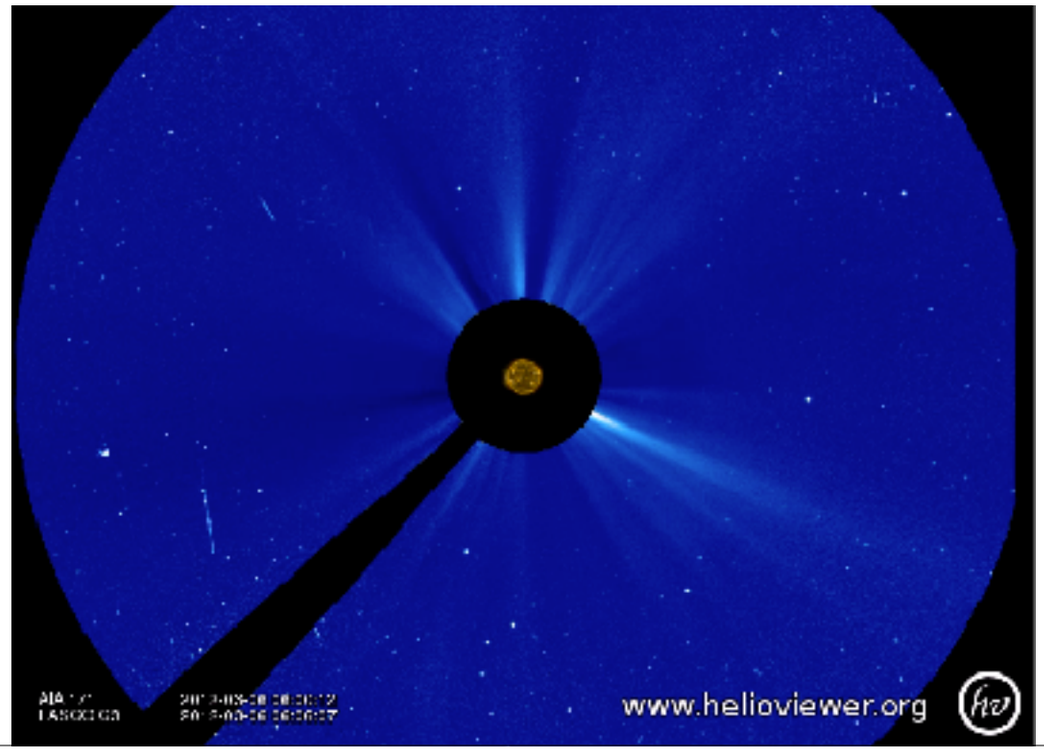
zichtbaar licht: 780 - 380 nm / 7800- 3800 Angstrom / ROGBIV

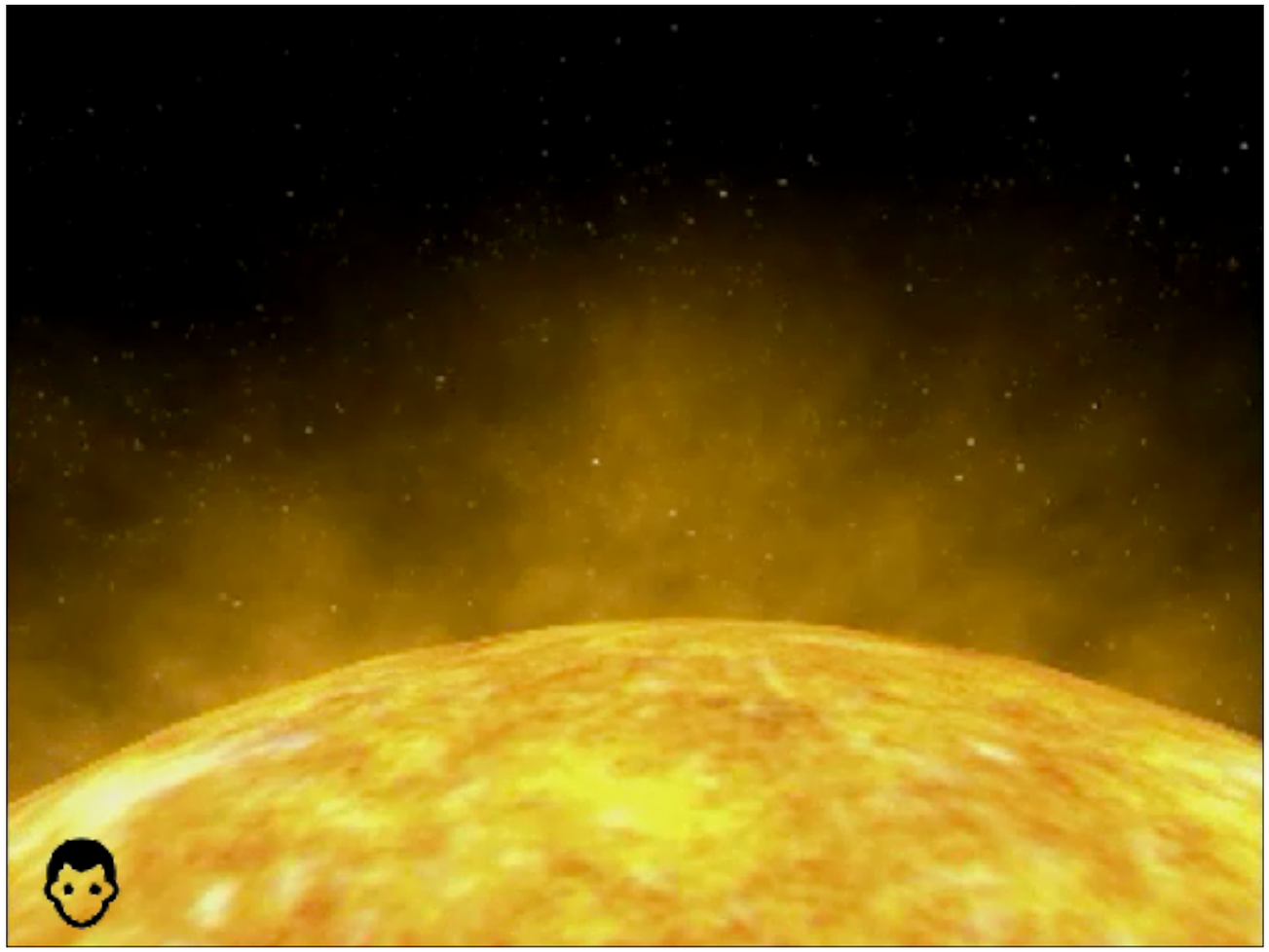
UV: 380 - 10 nm / 3800 - 100 Angstrom

EUV: 100 - 10 nm / 1000 - 100 Angstrom

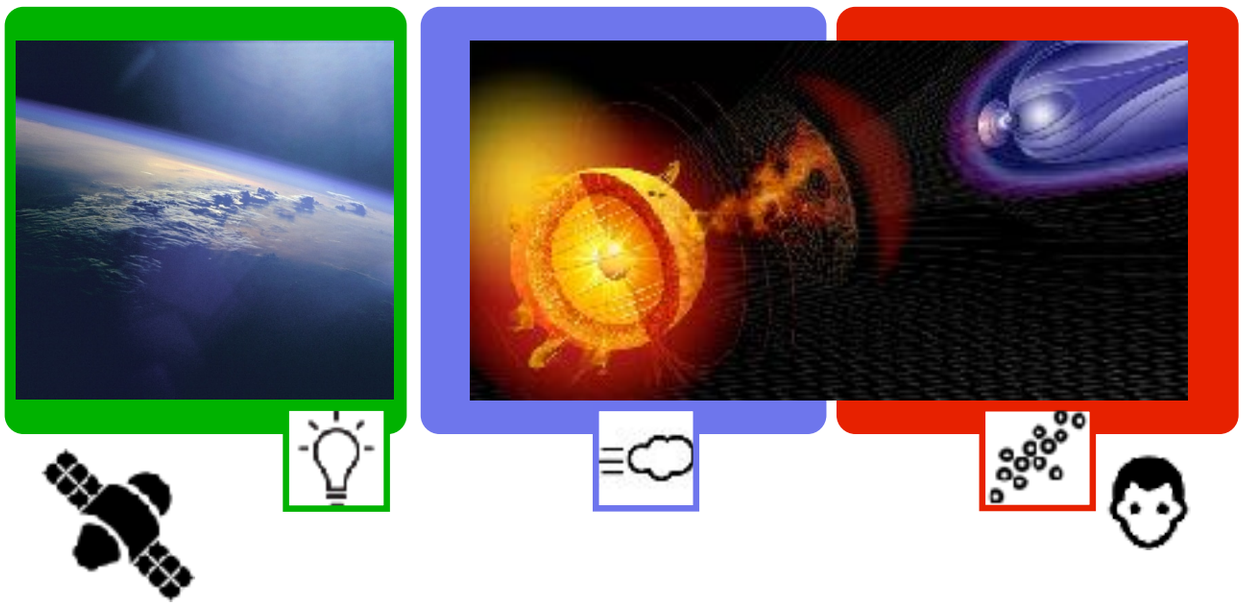
SOLAR STORMS

A solar cloud hurling through space. Solar particles hit the coronagraph.



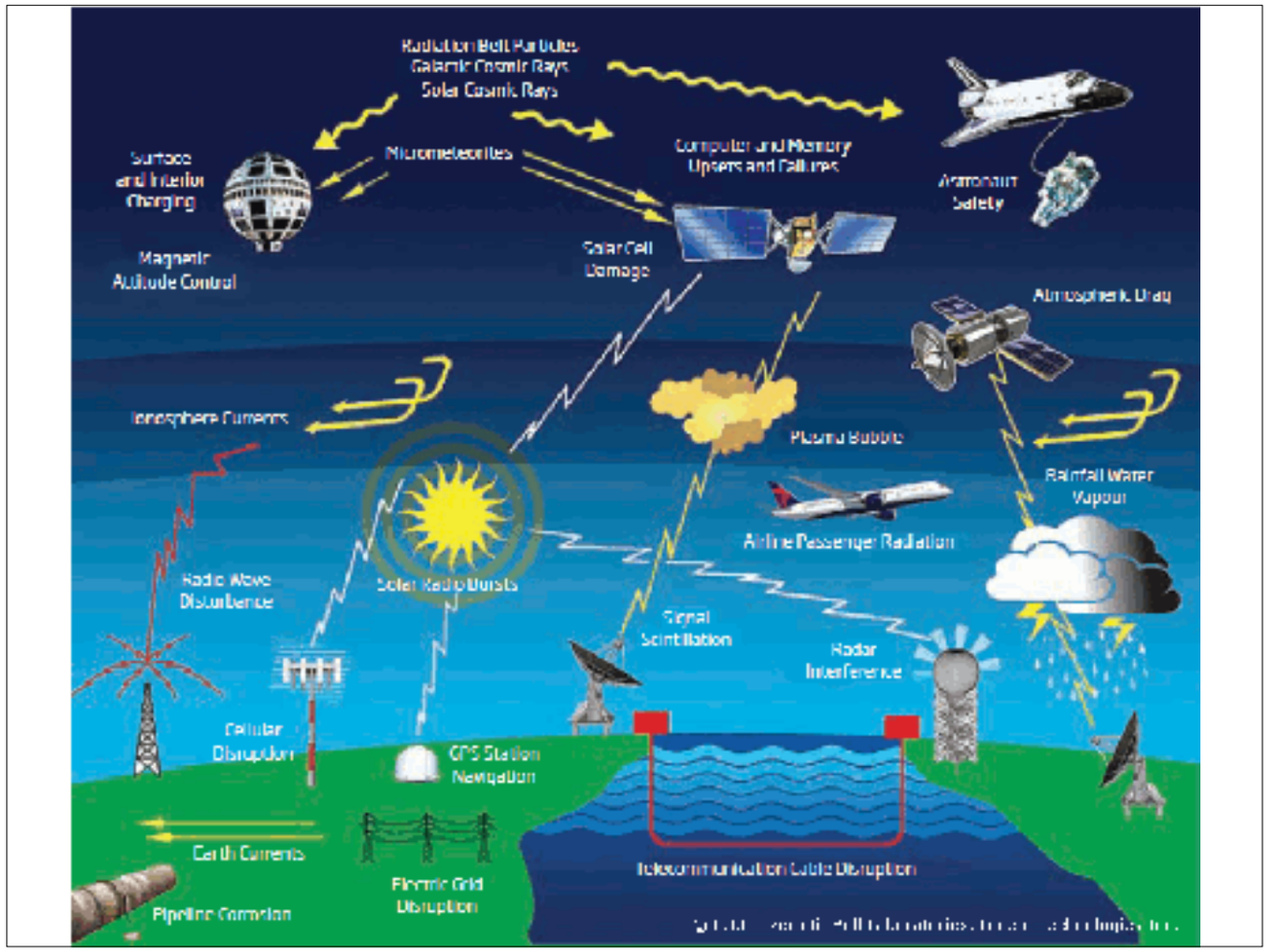


The earth's atmosphere protects us against solar flares.
The earth's magnetic shield protects us against solar clouds and particles.



De magnetosfeer en de atmosfeer **beschermen het leven op aarde** tegen de schadelijke invloed van de Zon (zonneklimaat en zonneweer): de aardatmosfeer wordt niet weggeblazen dankzij de magnetosfeer, hoogenergetische deeltjes worden gereflecteerd, X-straling wordt tegengehouden door de atmosfeer. Het biologisch leven wordt beschermd.

Maar tegelijkertijd zorgen verstoringen in de magnetosfeer en de atmosfeer/ionosfeer veroorzaakt door het ruimteweer voor de nodige technologische problemen.



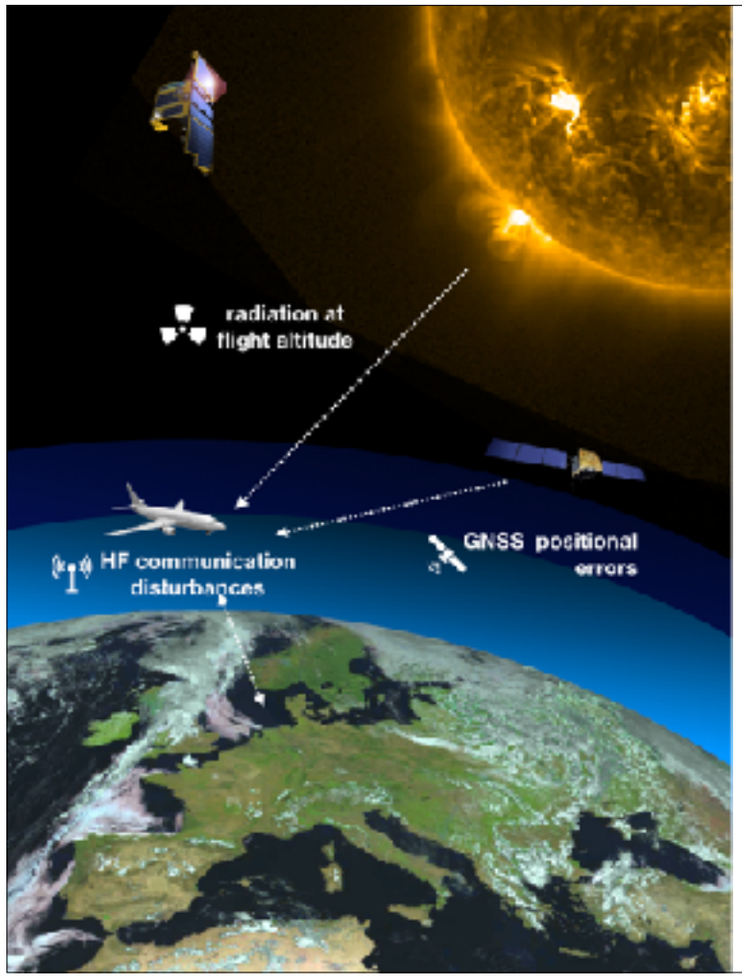
aurora - drag on satellites - GNSS, Global navigation satellite system - GIC

Polar flights - astronauten - aan boord electronica

radio-communicatie
De zon schijnt al sinds mensenheugen. Sinds we bestaan is nog geen enkele zonnestorm geweest die de mensen van de aardbol heeft geveegd. We worden beschermd door de magnetosfeer en door de atmosfeer tegen de energie die de zon continue uitstoot of tegen de plotse energiepieken (zonnestorm).

Sinds de start van het ruimtetijdperk, hebben we de zon op andere manieren kunnen bestuderen: dynamisch, energiek, geweldadig.
Samen met de start van het ruimtetijdperk, zijn onze hoogtechnologische systemen uitgebouwd: navigatie (GNSS), satellieten, radio communicatie, grote energietoevoer...

Met die hoogtechnologische systemen bestuderen we de zon maar tegelijkertijd is onze maatschappij zeer kwetsbaar geworden. Het is een kluwen van afhankelijkheid.



IMPACT ON AVIATION

Our technology is impacted. PECASUS concerns impacts on aviation operations.

Radio blackout



Geomagnetic storm



Solar radiation storm



SOLAR RADIO BURST

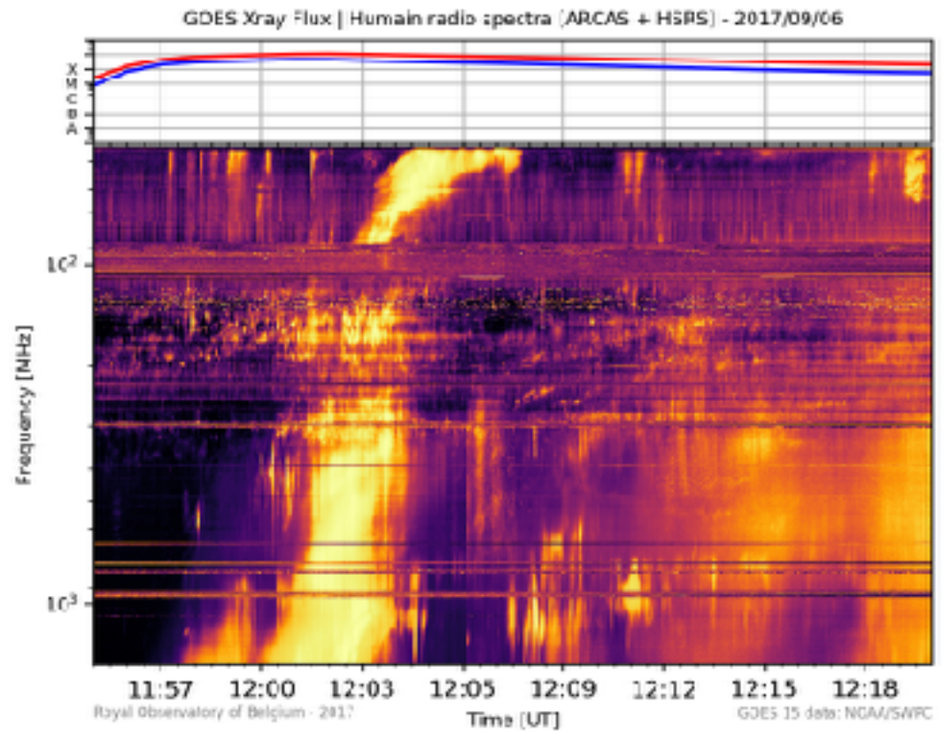


IONOSPHERIC STORMS



SOLAR RADIO BURSTS

SRB are produced by energetic electrons accelerated by solar eruptive events, like flares, filament eruptions, coronal mass ejections. Their radial signature - how it looks like in a spectrogram - tells something about the fate of these electrons.



These bursts are triggered by a solar event.
Signature of presence of a CME, flare

****

Detected by measuring e.m. waves in the radio wavelength
Type II, III and IV are important for space weather.

We can measure the **solar e.m. radio output and put it into a spectrogram**.
At low frequencies, **5 types** of radio wave bursts are seen, **each with a unique signature in frequency and time.**

Mind the orientation of the vertical axis! Other figures may have a reversed direction. As the frequency is proportional to the square root of the density, and the density decreases with increasing distance from the Sun, a decreasing frequency means locations higher up in the solar atmosphere.

The ionospheric cut-off frequency is around 15MHz (due to too low frequency and so reflected by ionosphere). In order to observe radio disturbances below this frequency, one has to use satellites (above the earth atmosphere) such as STEREO/SWAVES or WIND. Radio bursts at low frequencies (< 15 MHz) are of particular interest because they are associated with energetic CMEs that travel far into the interplanetary (IP) medium and affect Earth's space environment if Earth-directed.
Low frequency radio emission needs to be observed from space because of the ionospheric cutoff.
Example: https://stereo-ssc.nascom.nasa.gov/browse/2017/01/16/insitu.shtml

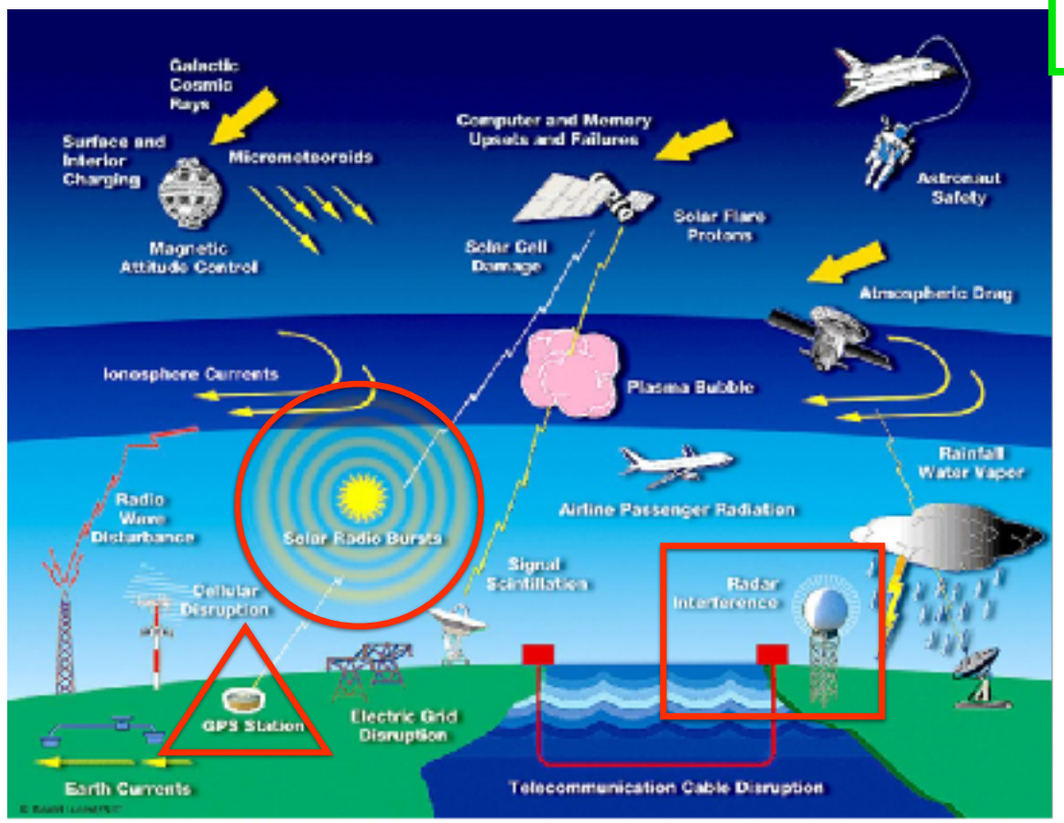
Coronal Mass Ejections and solar radio emissions, N. Gopalswamy
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.708.626&rep=rep1&type=pdf
Gopalswamy: The three most relevant to space weather radio burst types are type II, III, and IV. Three types of low-frequency non-thermal radio bursts are associated with coronal mass ejections (CMEs): Type III bursts due to accelerated electrons propagating along open magnetic field lines, type II bursts due to electrons accelerated in shocks, and type IV bursts due to electrons trapped in post-eruption arcades behind CMEs.

[Radio burst type II, III, and IV are also the only ones that ever get mentioned in the Ursigrams.]

****

A type II burst is caused by a shock that triggers the local plasma to emit radio waves. While **most of the interplanetary shocks are CME-driven, coronal shock waves can be attributed to solar flares**, CMEs, or some combination of these two phenomena. Since the acceleration phase of the CME and the flare impulsive phase are usually closely synchronized, it is **hard to distinguish between the flare energy-release effects and the CME expansion**. Due to this problem the origin of the coronal shocks, i.e. metric type II bursts, still remains unresolved.

Type II



Impact of SRB itself

GPS station

Signal/noise - signal is from the satellite. GPS receivers are designed to be sensible to the signal above them, not at the horizon.
When there is a strong **radio burst** - in the typical GPS frequencies - the **noise increases**.
GPS receiver ontvangt signalen die niet van een satelliet komen maar van de Zon. De GPS ontvanger maakt geen onderscheid tussen solar noise en satelliet signaal.

Radar interference

Radars are monitoring the planes near the horizon - descending and ascending planes.
Radar 'ziet' vliegtuigen door de reflectie van radio-signaal. Radio-signalen van de zon kunnen geïnterpreteerd worden als 'spook'-vliegtuigen: vliegtuigen die je ziet op het radar-scherm maar er in werkelijkheid niet zijn.

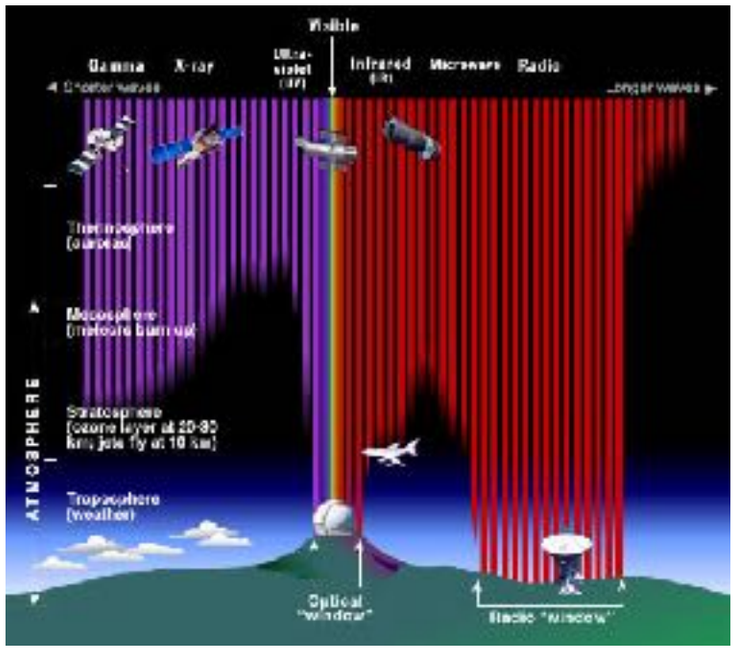
SRB can impact HF communication (no feedback from industry) and navigation

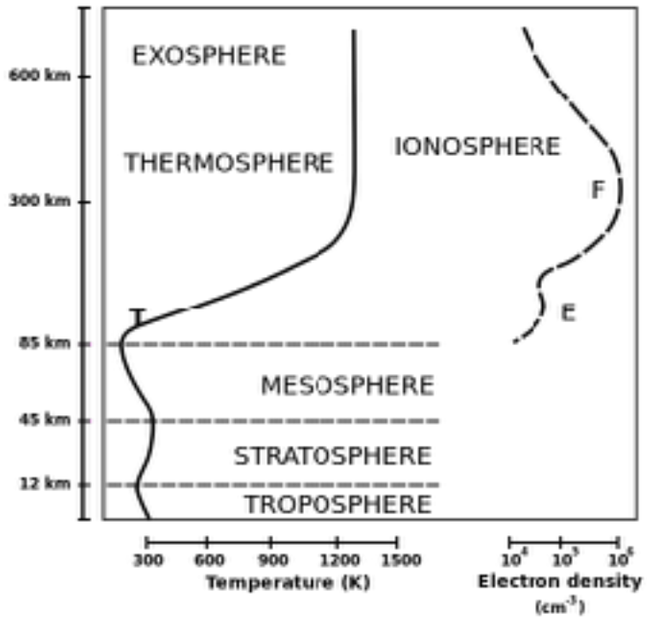
IONOSPHERE

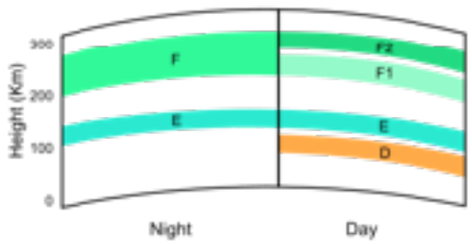
Exists because of ionising solar e.m. radiation

TRANSPARENCY OF EARTH ATMOSPHERE

Our atmosphere protects us against harmful solar light. This ionising solar light can penetrate only until a certain height.



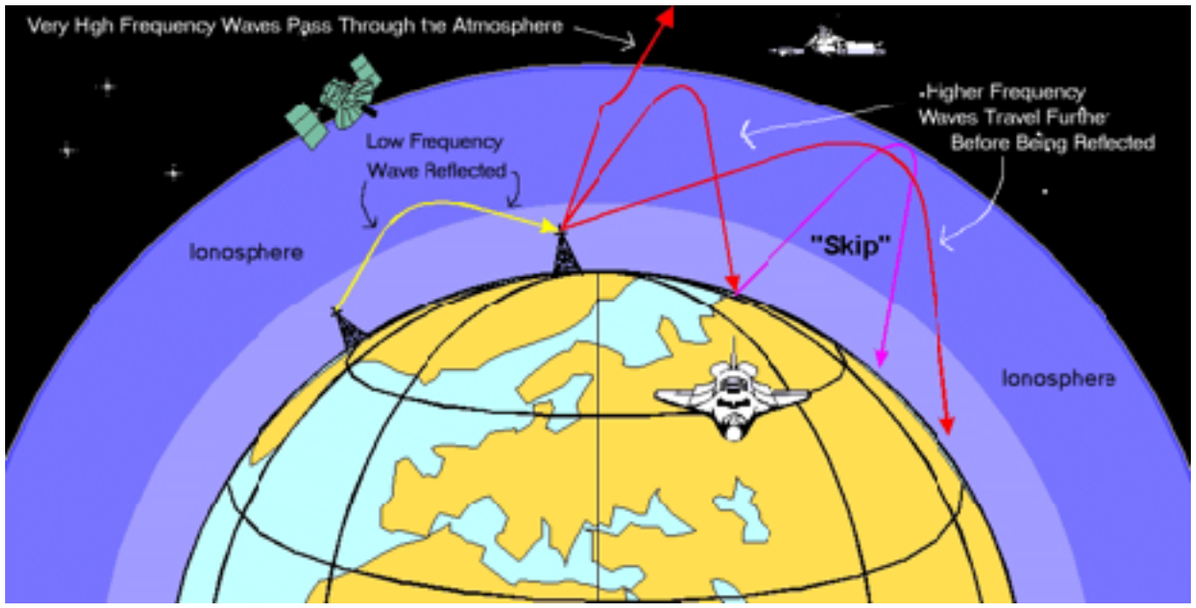




IONOSPHERE

The ionosphere (/aɪˈɒnəˌsfɪər/[1][2]) is the ionized part of Earth's upper atmosphere, from about 60 km (37 mi) to 1,000 km (620 mi) altitude, a region that includes the thermosphere and parts of the mesosphere and exosphere. The ionosphere is ionized by solar radiation. It plays an important role in atmospheric electricity and forms the inner edge of the magnetosphere. It has practical importance because, among other functions, it influences radio propagation to distant places on the Earth.[3]

The Total Electron Content (TEC) is the integrated total number of electrons present along a path between a radio transmitter and receiver.



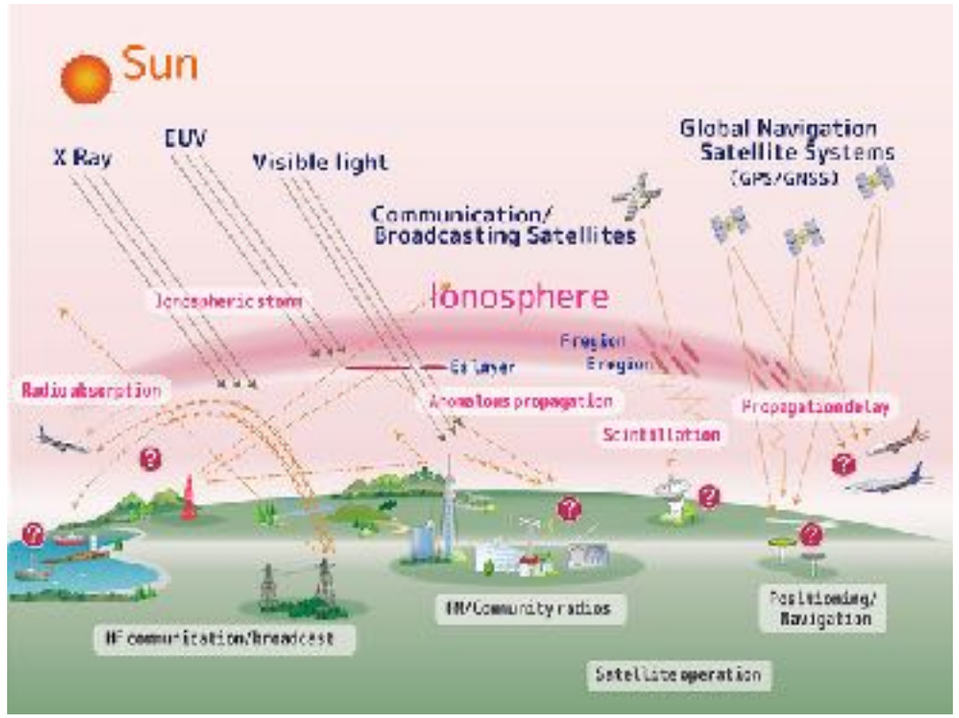
RADIO WAVES

The ionosphere has the ability to reflect radio waves. If the degree of ionisation would be zero, no radio waves would be reflected and all would pass.

Ionisation can change over time.
Ionisation is not the same everywhere.

HF goes through
LF are reflected

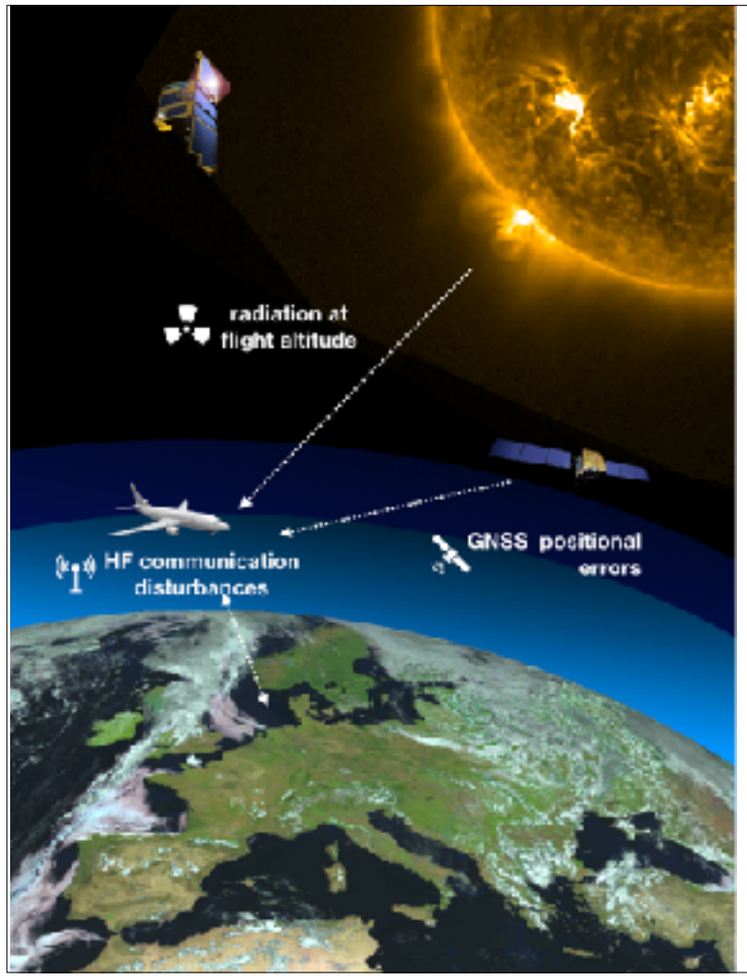
During the night, the ionisation decreases – the skill to reflect drops.
—> also LF goes through —> Maximum Usable Frequency, MUF decreases.



IONOSPHERIC STORMS

Als die ioniserende straling veranderd, introduceer je veranderingen in de ionosfeer. —> TEC
How the ionosphere behaves has an impact on HF communication and navigation

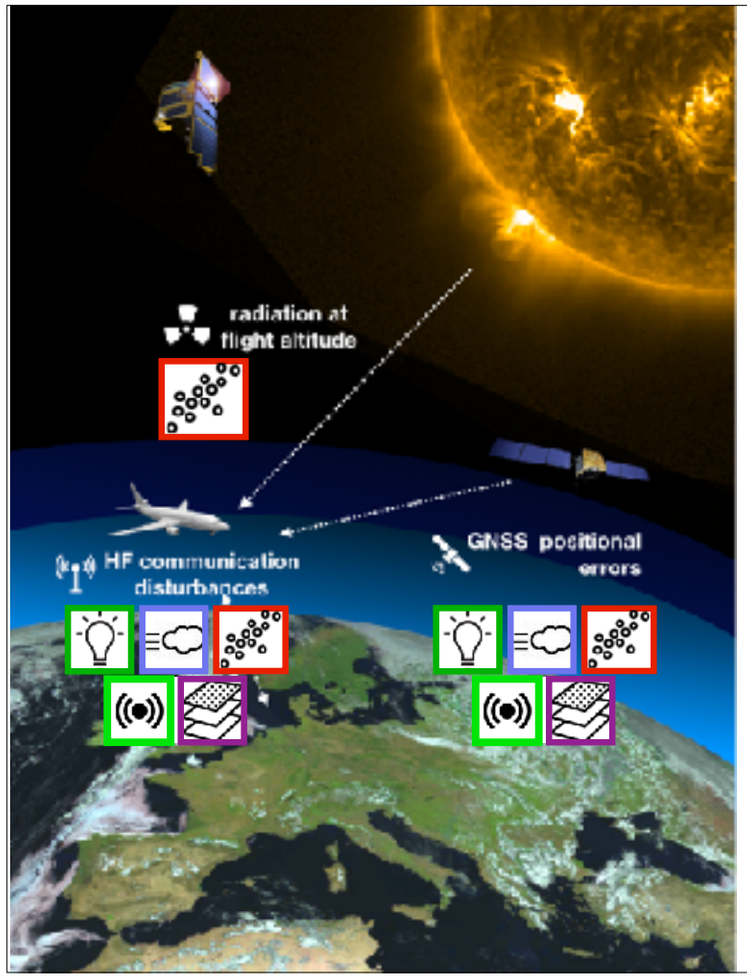
Ionospheric storms primarily affect the equatorial regions but can also extend into the middle latitudes and affect GNSS navigation.



IMPACT ON AVIATION

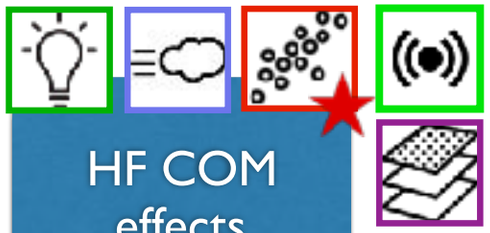
Our technology is impacted. PECASUS concerns impacts on aviation operations.





IMPACT ON AVIATION

Our technology is impacted. PECASUS concerns impacts on aviation operations.



Space Weather Centre

SEVere or MODerate

Forecasts up to 24 HR

We can use also ‘NIGHTSIDE’

(communication header)	
SWX ADVISORY	
DTG:	20161108/0100Z
SWXC:	(to be determined)
SWX EFFECT:	HF COM SEV
ADVISORY NR:	2016/1
OBS SWX:	20161108/0100Z DAYLIGHT SIDE
FCST SWX +6 HR:	20121108/0700Z DAYLIGHT SIDE
FCST SWX +12 HR:	20161108/1300Z DAYLIGHT SIDE
FCST SWX +18 HR:	20161108/1900Z DAYLIGHT SIDE
FCST SWX +24 HR:	20161109/0100Z DAYLIGHT SIDE
RMK:	PERIODIC HF COM ABSORPTION HAS BEEN OBSERVED AND IS LIKELY TO CONTINUE IN THE NEAR TERM. COMPLETE AND PERIODIC LOSS OF HF ON THE SUNLIT SIDE OF THE EARTH EXPECTED. CONTINUED HF COM DEGRADATION LIKELY OVER THE NEXT 2 DAYS. SEE WWW.SPACEWEATHERPROVIDER.WEB
NXT ADVISORY:	20161108/0700Z

OBS SWX
FCST SWC
NO SWX EXP

YYYYMMDD/UTC

Additional info on a web-site

Update provided as necessary but
at least after 6 HR



Het PECASUS team, tijdens de ICAO audit, Helsinki, Finland, 2017.