# DE ZON

Petra Vanlommel
Solar-Terrestrial Centre of Excellence


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.

# Jij als wetenschappelijk onderzoeker.


Eclipse Northern America
It is big


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

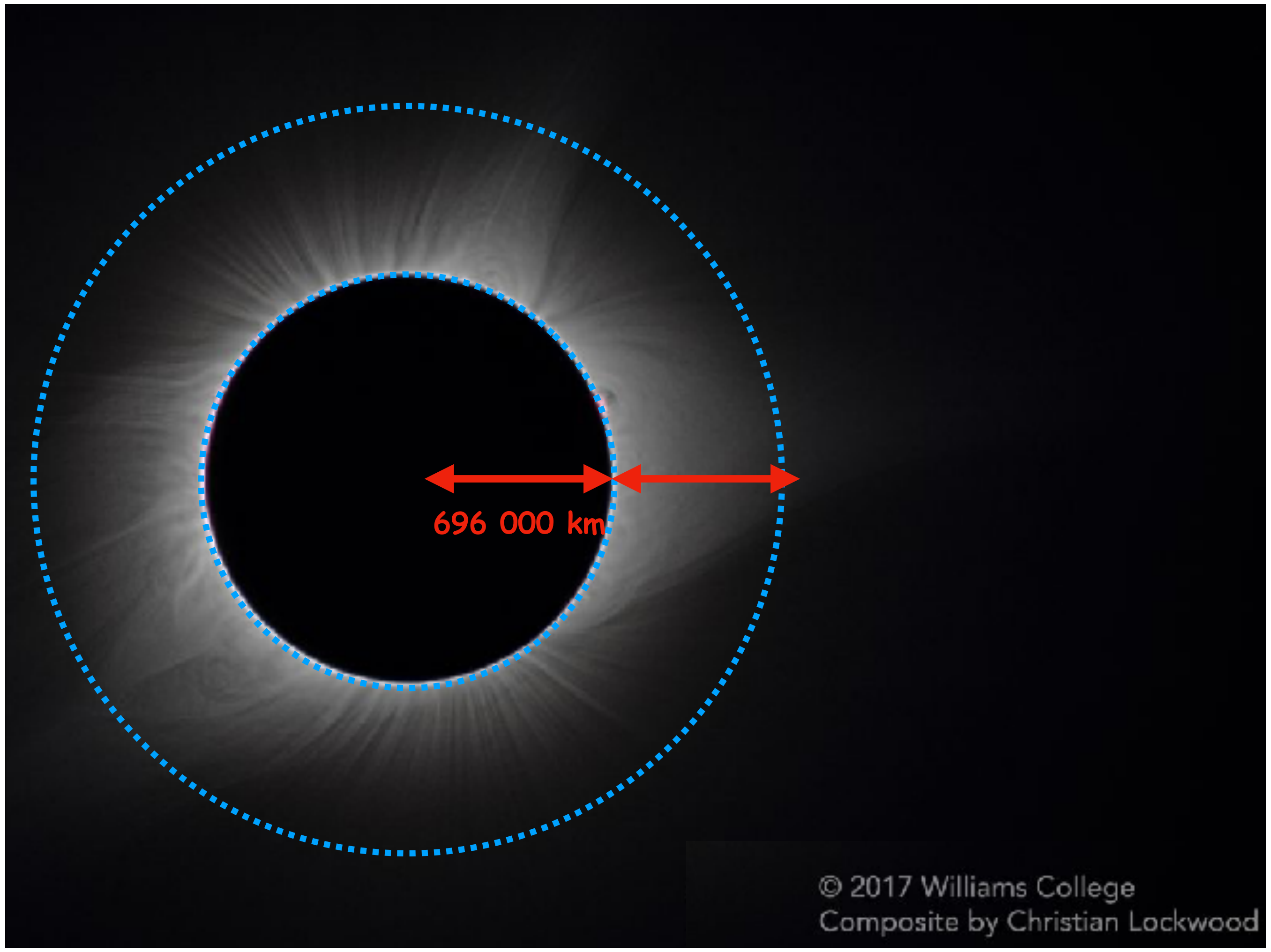
Why is the atmosphere of the Earth, relatively speaking so much smaller?

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

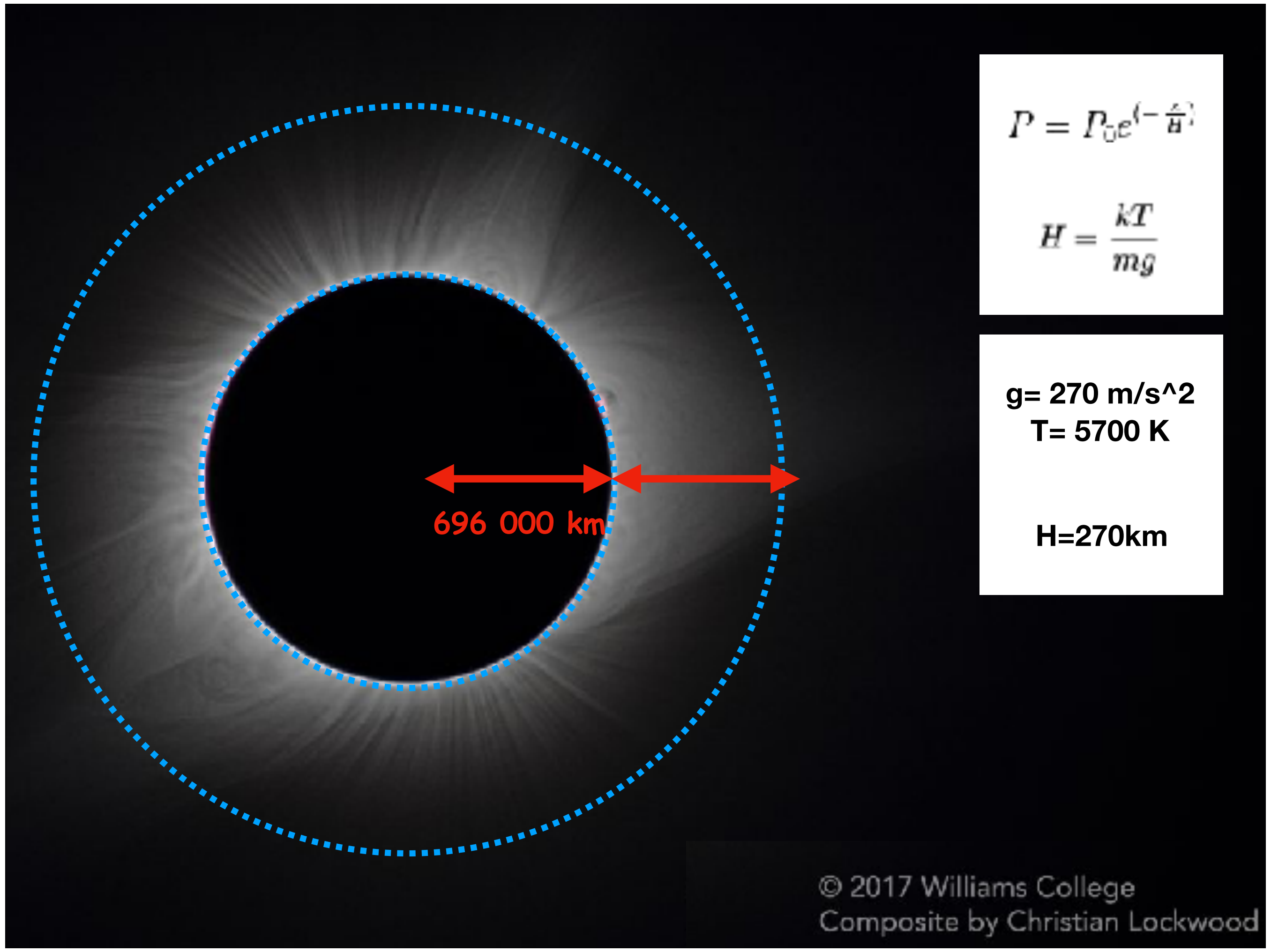
Solar eclipses as an astrophysical laboratory
Jay M. Pasachoff
Nature 459, 789–795(11 June 2009)
doi:10.1038/nature07987

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]

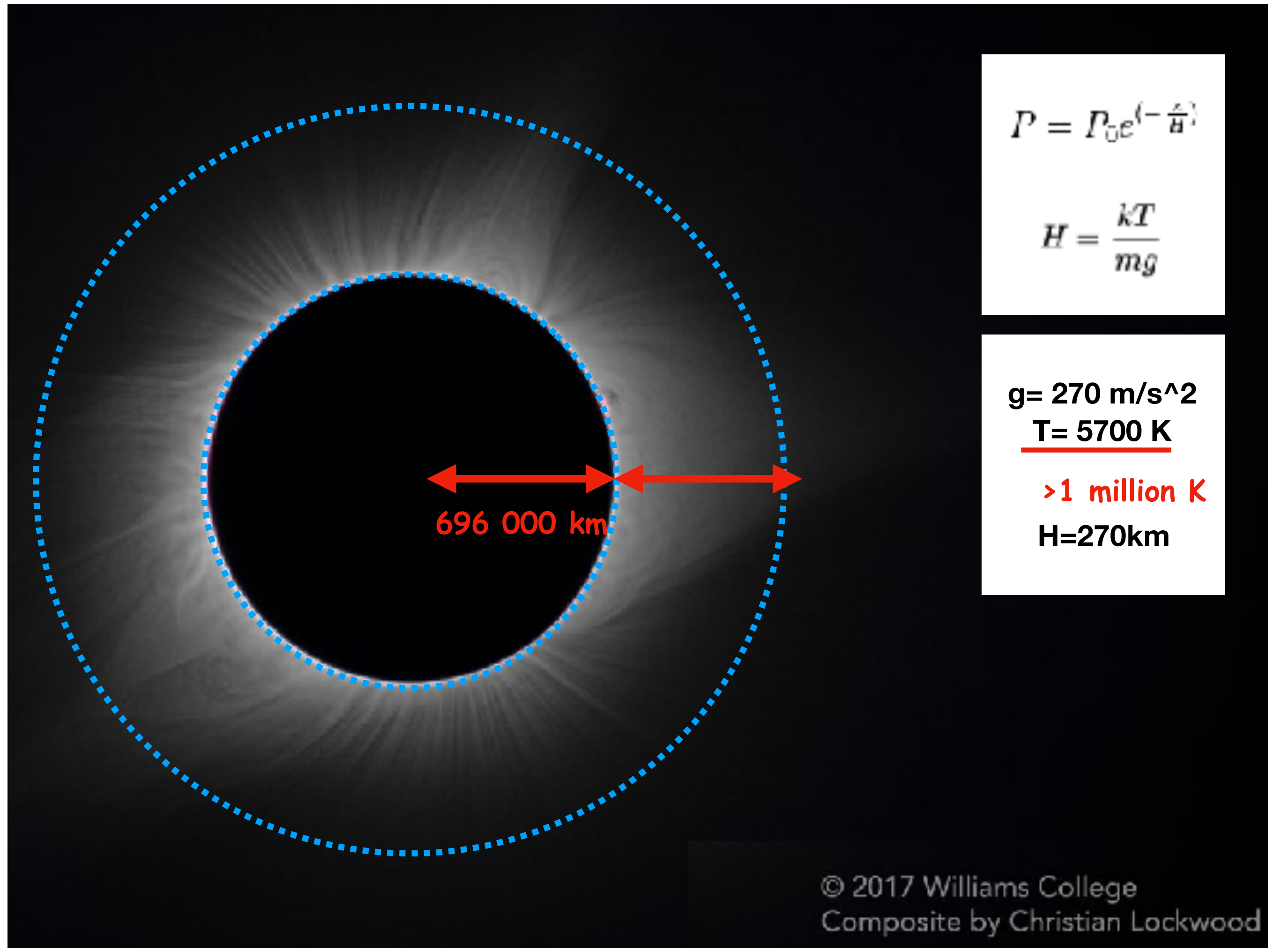
H=kT/mg
Or
H=RT/Mg

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.
aarde: 78 % stikstof (nitrogen, N2), 21% zuurstof (O2)

**Zon:**
m—-> mostly Hydrogen (waterstof)
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.


$P = P_0 e^{(-\frac{z}{H})}$
$H = \frac{kT}{mg}$
g= 270 m/s^2
T= 5700 K
>1 million K
H=270km
696 000 km
© 2017 Williams College
Composite by Christian Lockwood

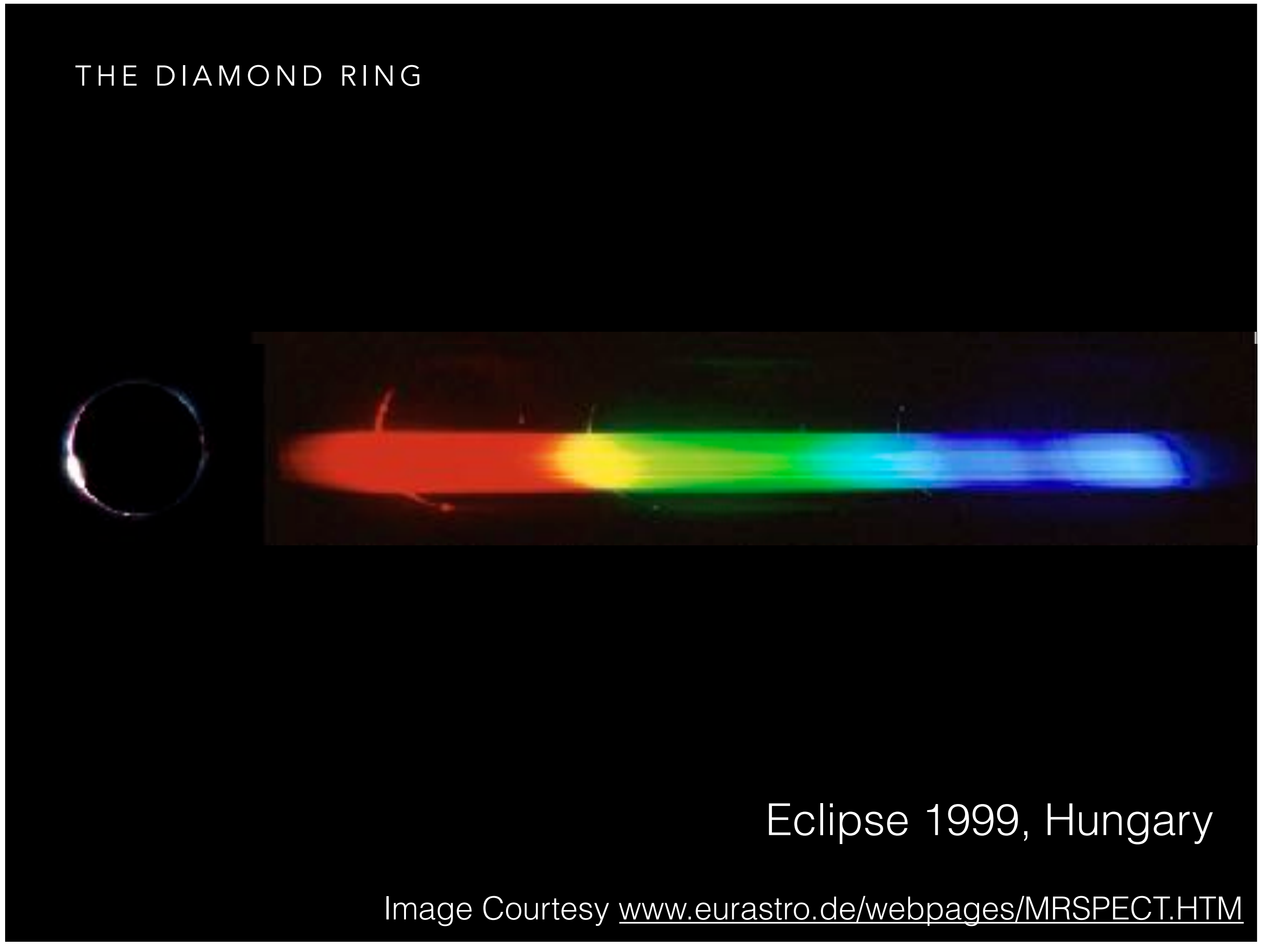
# Spectroscopic detective work

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.




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

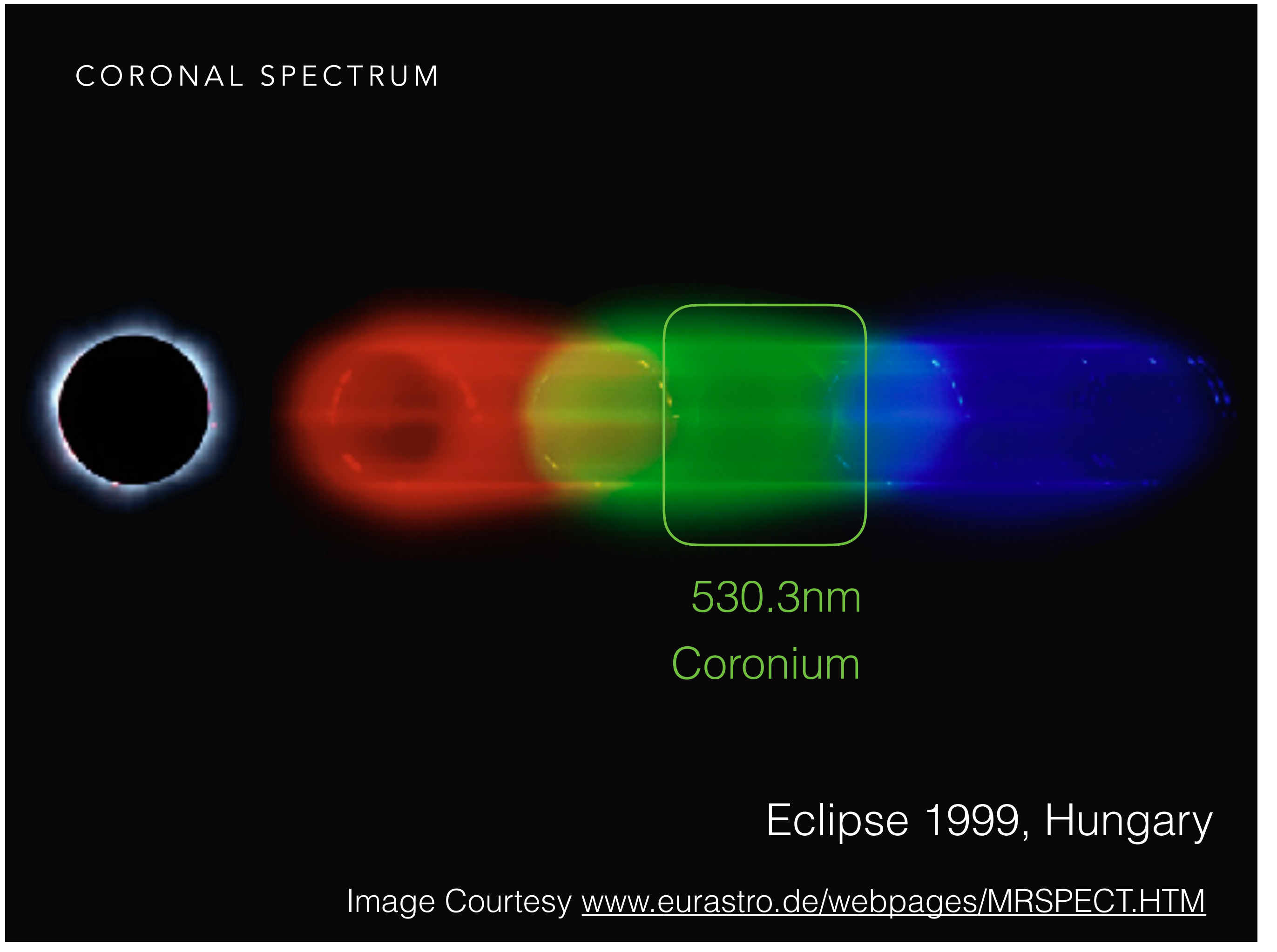
EUV: 100 - 10 nm / 1000 - 100 Angstrom


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.

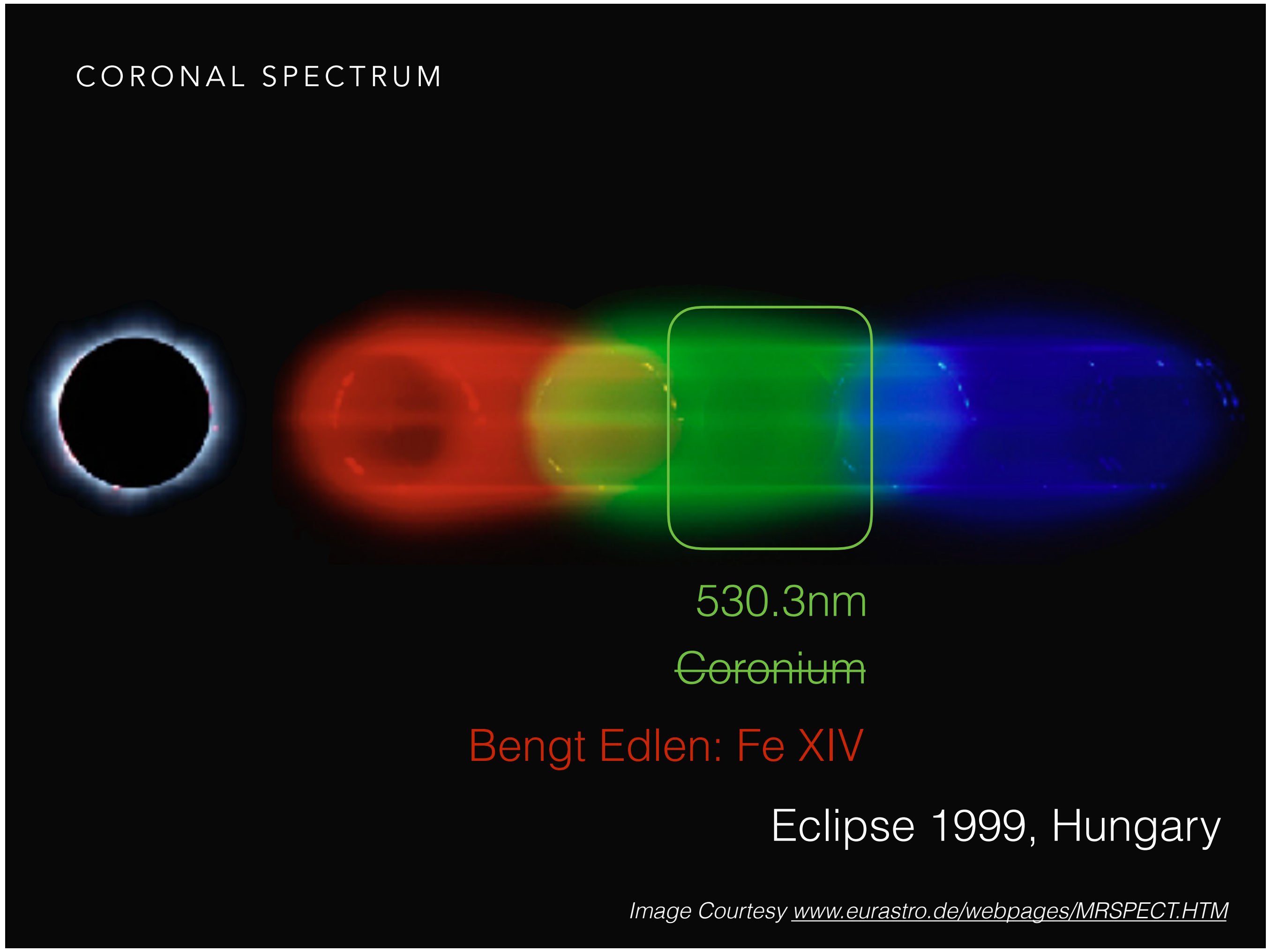



**Coronal spectrum**
The corona is the extremely tenuous outer part of the Sun's atmosphere which attains temperatures of up to several million kelvin and extends many million kms into the interplanetary space. A spectrum of the inner corona is shown in the picture.
In the spectrum you can distinguish 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

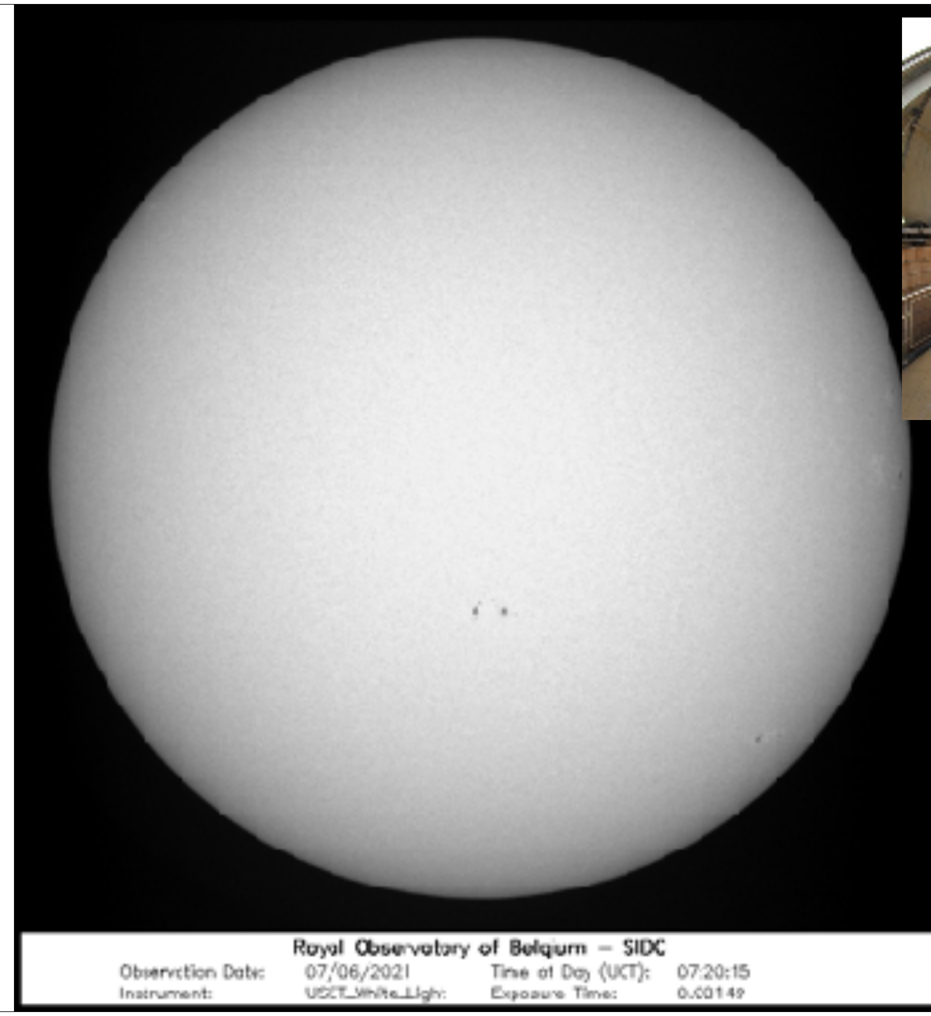
STUDYING THE SUN

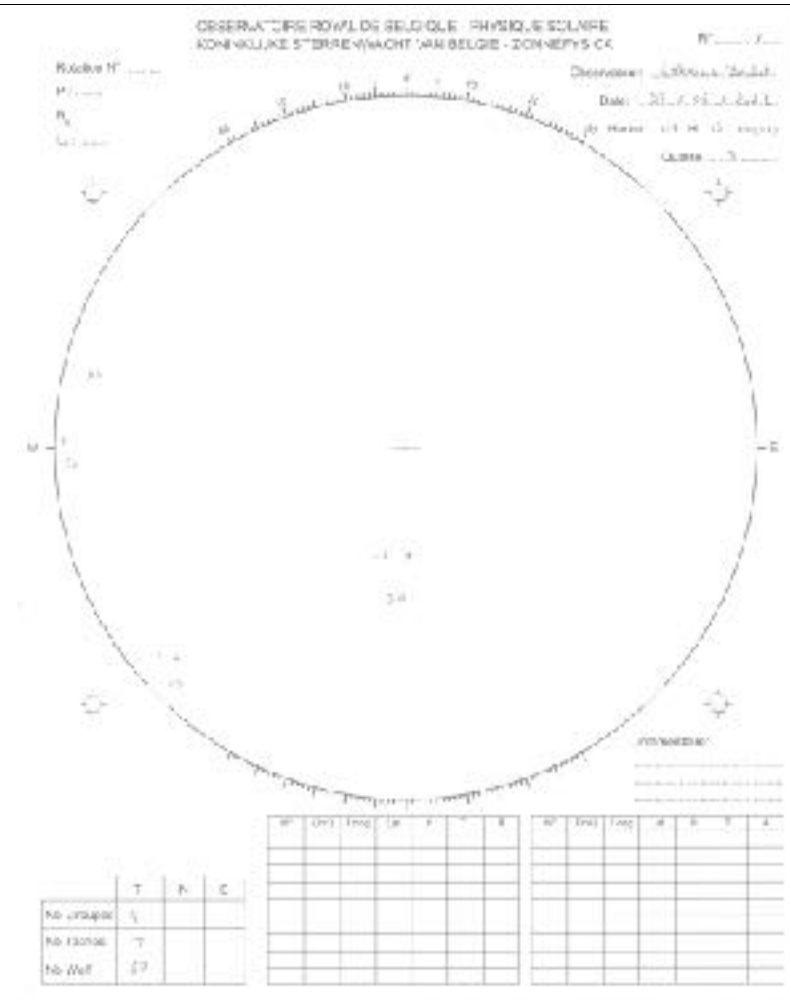
## By watching it with a simple telescope from Earth.

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

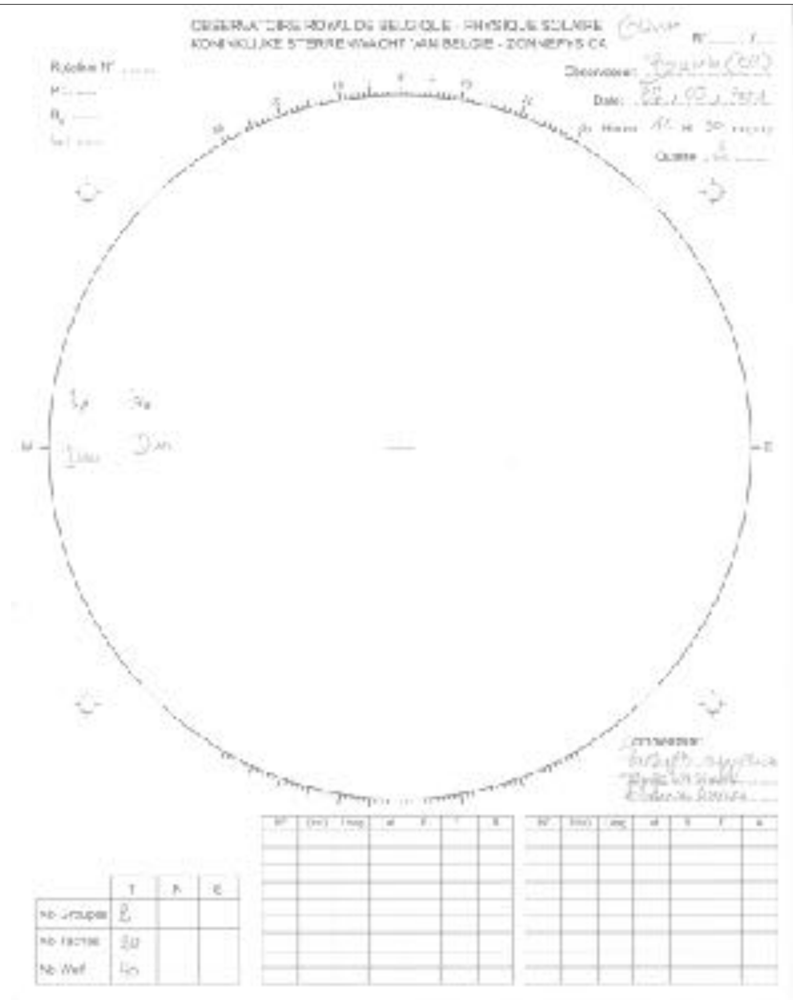
KIJKEN NAAR DE ZON

Dit is onze zonnekoepel met een equatoriale tafel waarop 3 telescopen zijn gemonteerd.


Royal Observatory of Belgium – SIDC
Observation Date: 07/06/2021
Time of Day (UCT): 07:20:15
Instrument: USET_White_Ligh:
Exposure Time: 0.00149

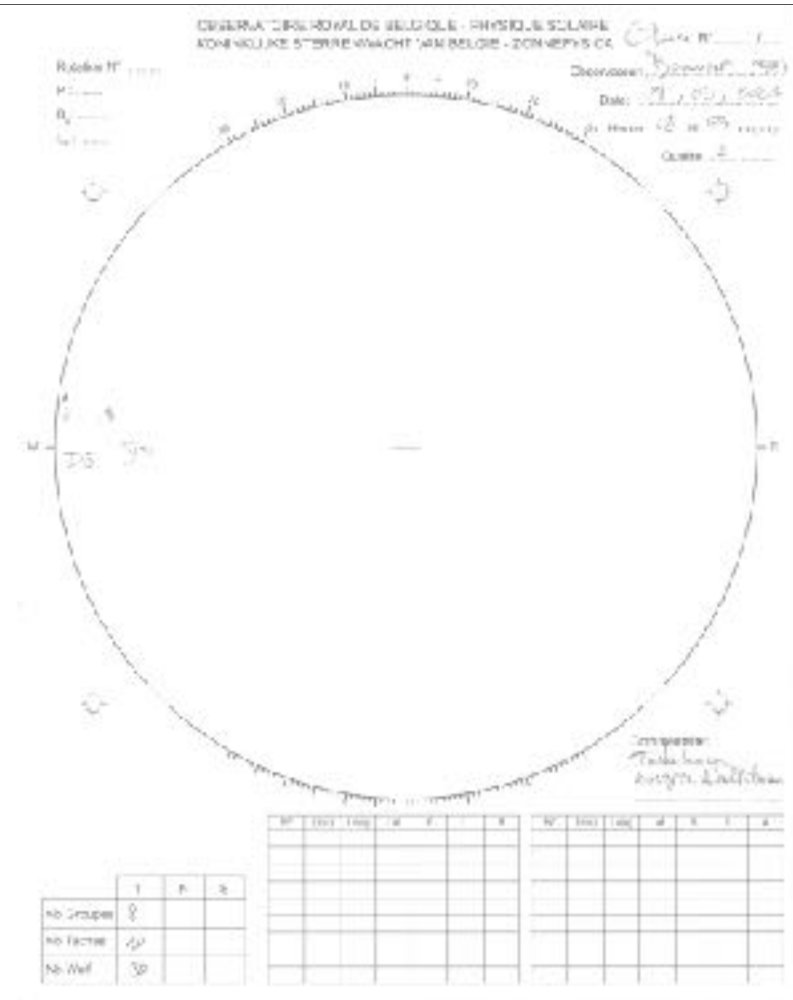


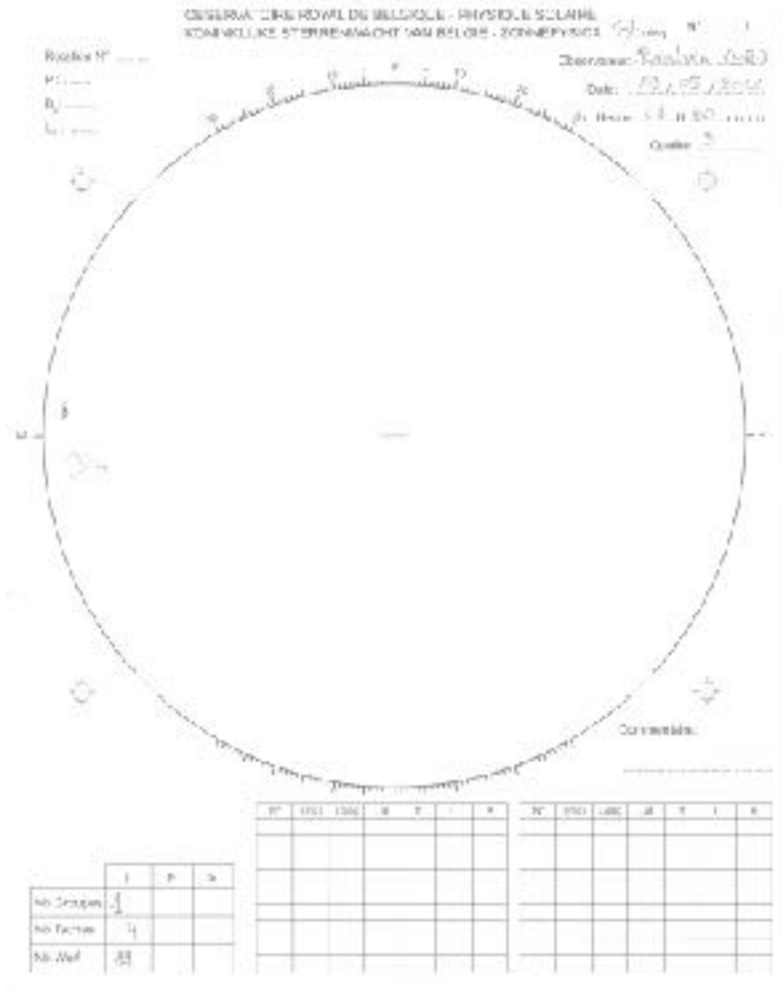
We maken ook tekeningen – hetgeen te zien is op de zon, tekenen we over.

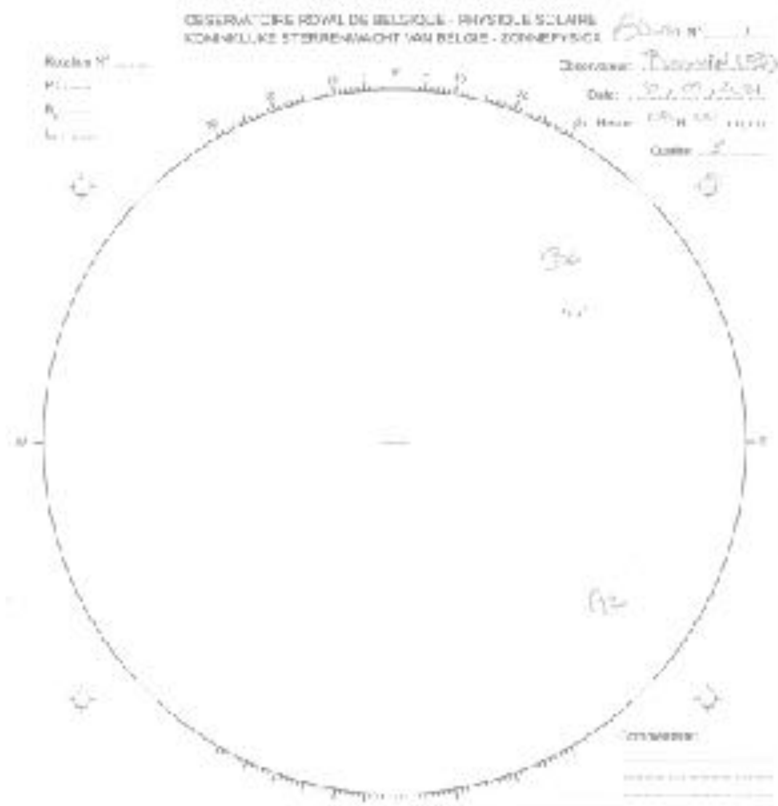

OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA

Observateur:
Date:
Heure
Qualité

| | T | P | E |
|---|---|---|---|
| Nb Groupes | 2 | | |
| Nb Taches | 20 | | |
| Nb Wolf | 40 | | |


No Groupes
No Taches
No Wolf


OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA
Observateur:
Date:
Heure
Qualité
Commentaires:
Nb Groupes
Nb Taches
Nb Wolf


OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA

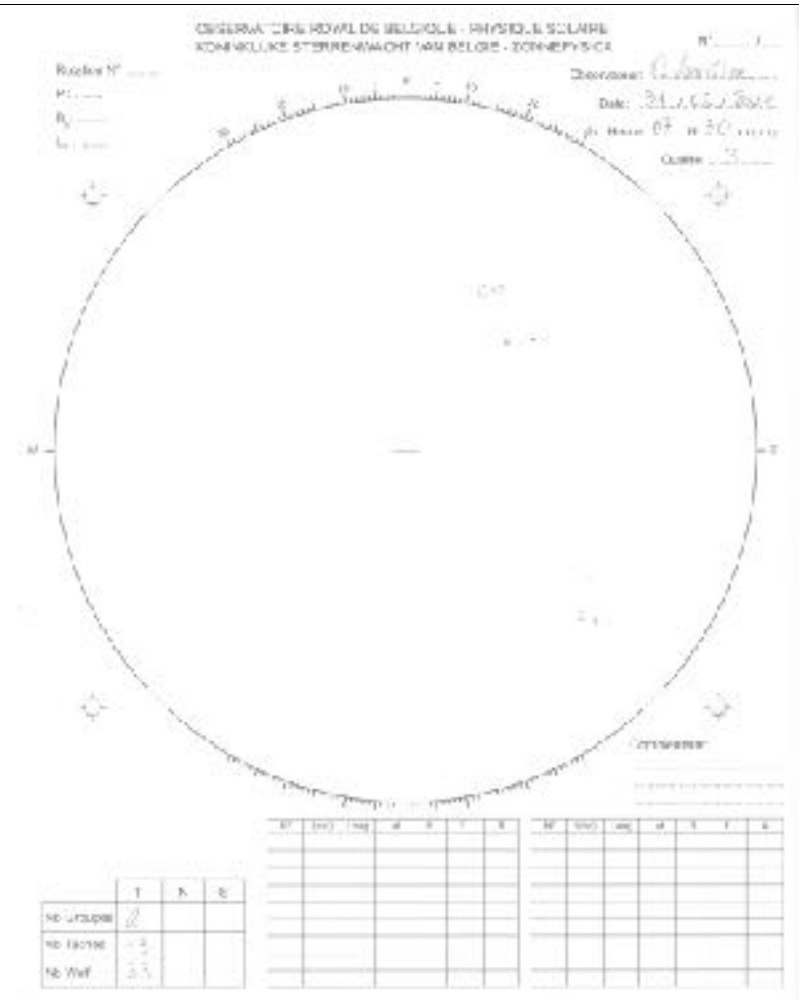
Observateur:

Date:

Heure:

Qualité:

| | T | N | S |
|---|---|---|---|
| No Groupes | 2 | | |
| No taches | 8 | | |
| No Wolf | 28 | | |


OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA

Rotation N° ......

P : ......

$B_0$ : ......

$L_0$ : ......

Observateur: ..........

Date: 24 / 05 / 2006

Heure 07 h 30 ......

Qualité ..3..

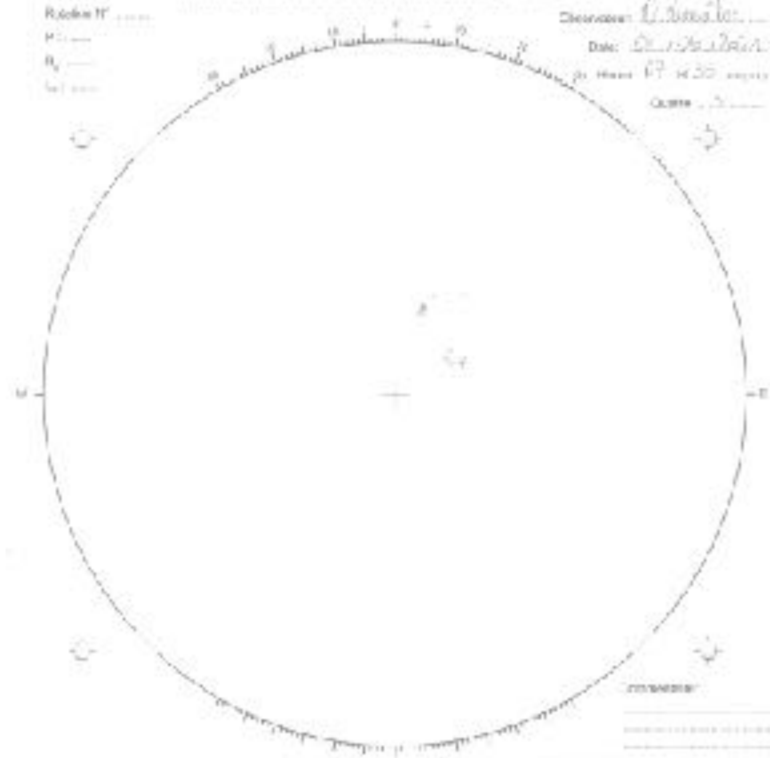
Commentaire:

| | T | A | E |
| --- | --- | --- | --- |
| Nb Groupes | 2 | | |
| Nb Taches | [illegible] | | |
| Nb Wolf | [illegible] | | |

OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA

Rotation N° ......
P : ......
$B_0$ : ......
$L_0$ : ......

N° ...... / ......
Observateur : [illegible]
Date : [illegible]
Heure : 07 h 30
Qualité : ......



Commentaire :

| | T | N | S |
|---|---|---|---|
| No Groupes | 1 | | |
| No Taches | 2 | | |
| No Wolf | 12 | | |

| N° | Cml | Long | lat | F | [illegible] | R |
|---|---|---|---|---|---|---|
| | | | | | | |

| N° | Cml | Long | lat | R | T | A |
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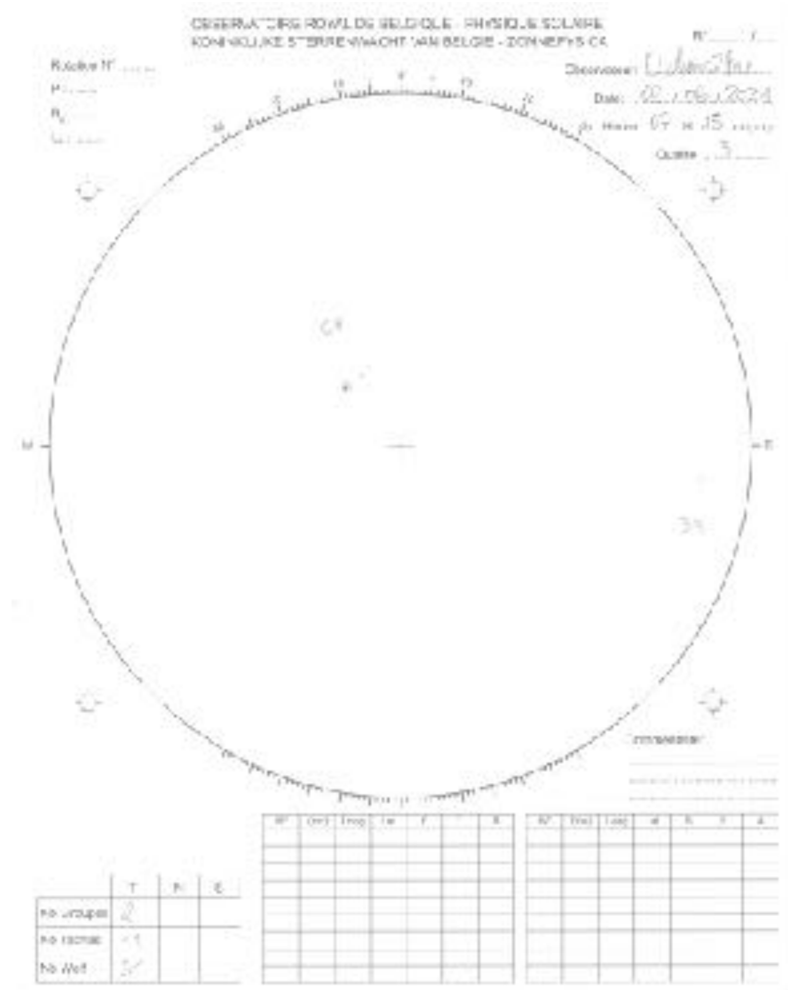
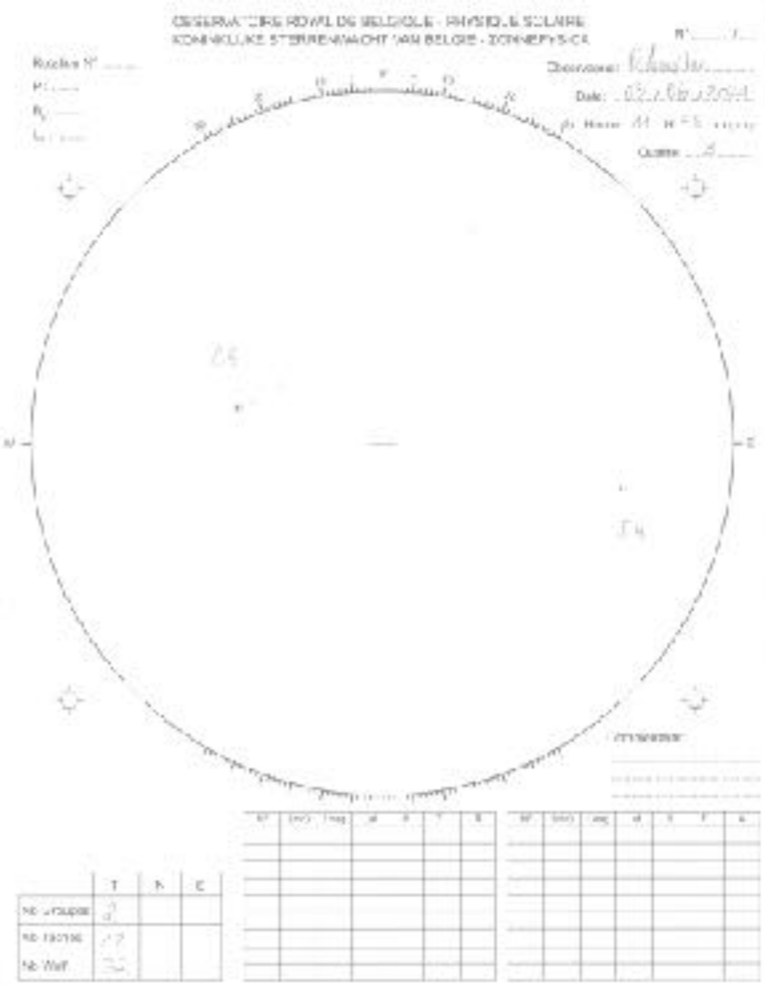

OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA
Date: 02 / 06 / 2024
Heure 07 h 15
Qualité 3
N
S
E
No Groupes 2
No Taches
No Wolf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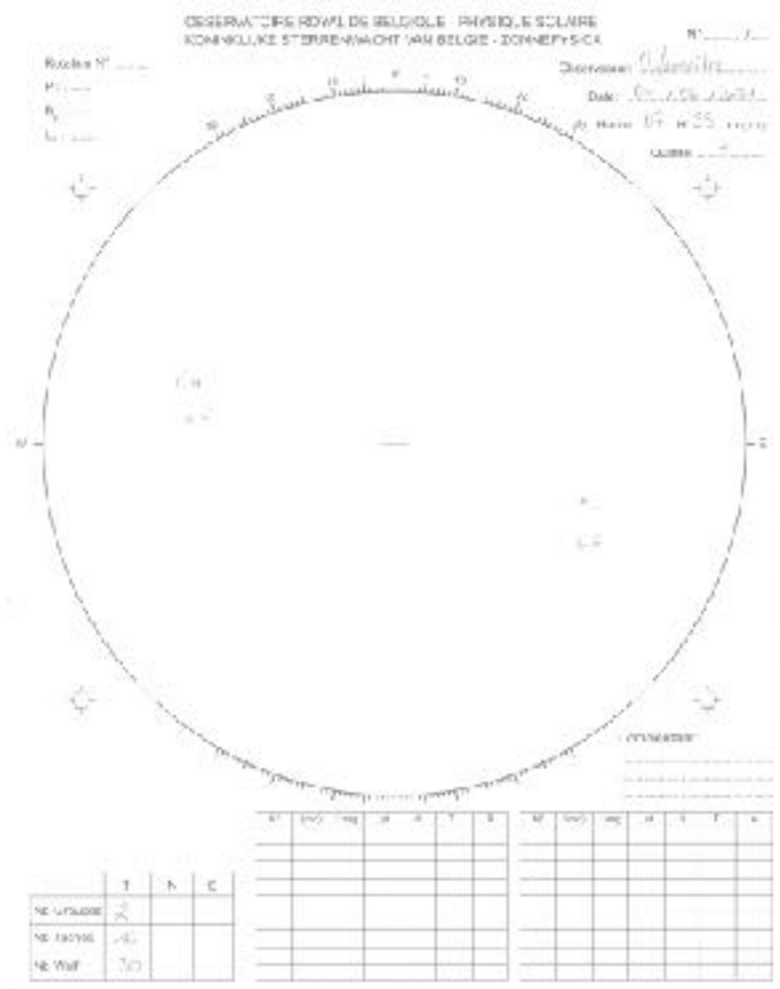
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA
Rouleau N°
Observateur:
Date:
Heure
Qualité
Commentaires
T
N
S
Nb Groupes
Nb Taches
Nb Wolf


OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA
Nb. Groupes
Nb. Taches
Nb. Wolf

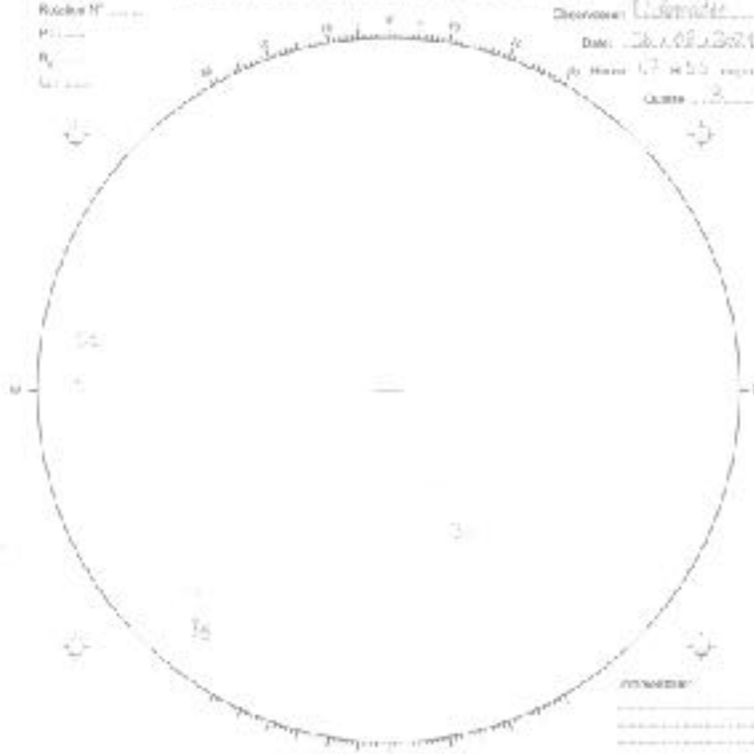
OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA

Observateur: [illegible]

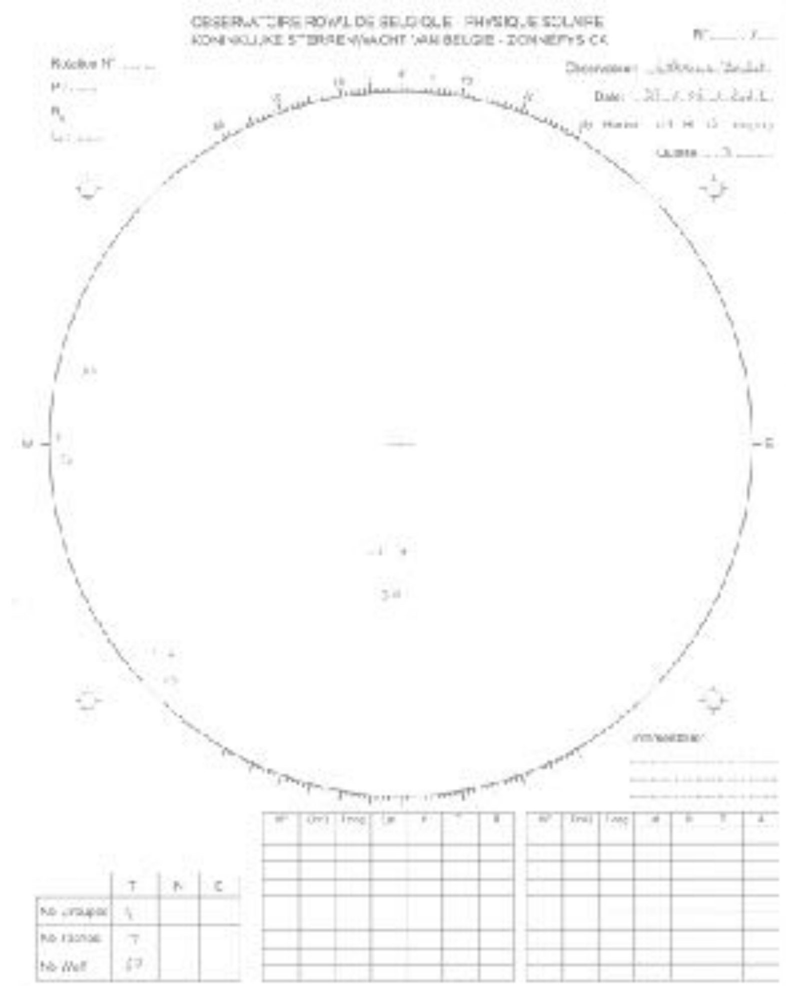
Date: 26.08.2021

Heure: 17 h 55

Qualité: 3

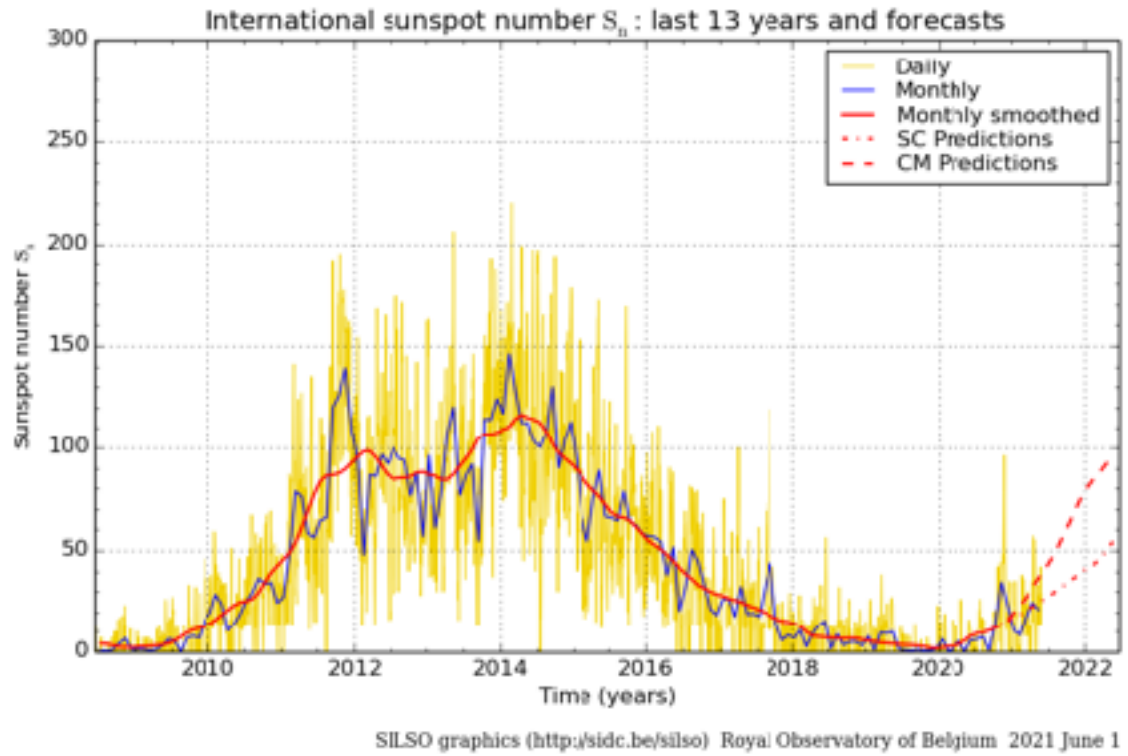


| | T | A | C |
|---|---|---|---|
| No Groupes | 3 | | |
| No Taches | [illegible] | | |
| No Wolf | [illegible] | | |

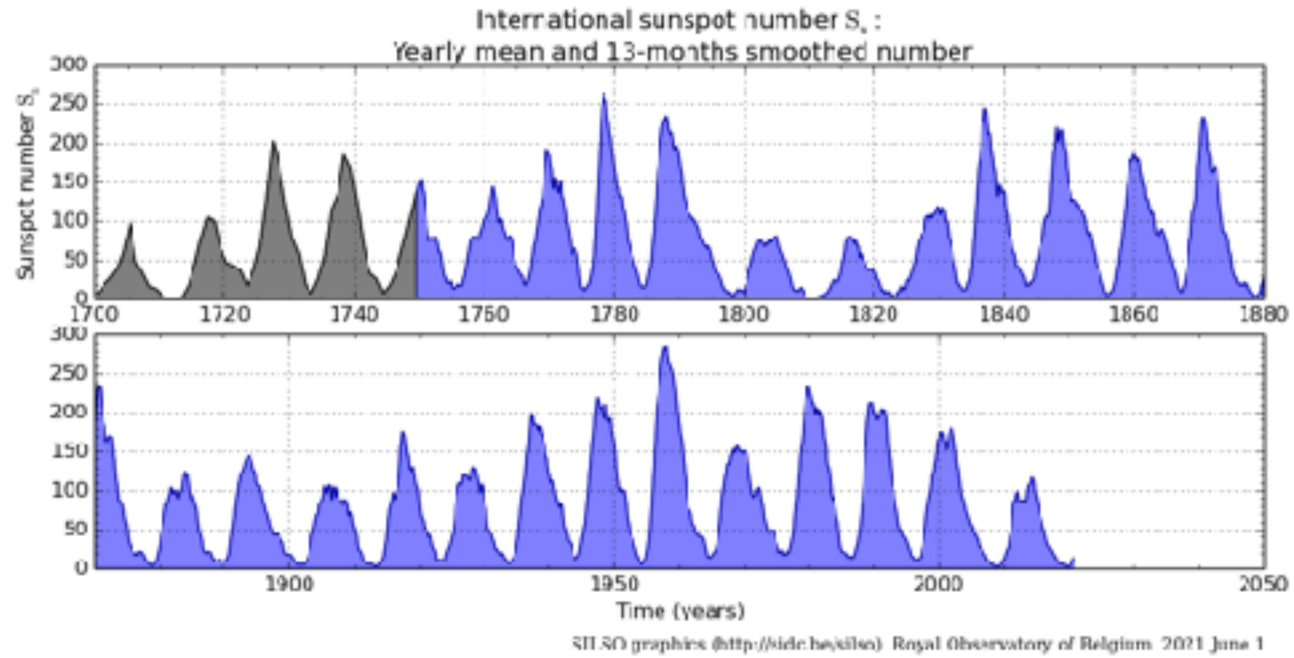

OBSERVATOIRE ROYAL DE BELGIQUE - PHYSIQUE SOLAIRE
KONINKLIJKE STERRENWACHT VAN BELGIE - ZONNEFYSICA
Observateur:
Date:
No Groupes
No Taches
No Wolf

COUNTING SUNSPOTS

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




Dit is de grafiek van de zonnecyclus waar we nu aan bezig zijn. Deze grafiek toont het zonnevlekkengetal, het resultaat van elke dag tellen. Daarbij maakt een groep van zonnevlekken het zonnevlekkengetal veel groter dan een eenzame zonnevlek, omdat veel zonnevlekken samen willen zeggen dat het magnetische veld daar heel sterk is en dat is belangrijk om te weten.




Hier zien jullie ook zo'n grafiek, maar die gaat heel ver terug in de tijd, wel tot in het jaar 1700, meer dan 3 eeuwen geleden. Je ziet hier heel duidelijk dat er zonnecyclussen zijn die lang duren en die korter zijn (sommige bultjes zijn breder of dunner) en ook sommige cycli met heel veel zonnevlekken en andere met weinig. Deze grafiek is gemaakt met behulp van al die oude tekeningen van de zonnevlekken en zo kunnen we weten hoe actief de zon was heel lang geleden.

De Zon roteert om haar eigen as en heeft een zonnevlekkencyclus.

## 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.

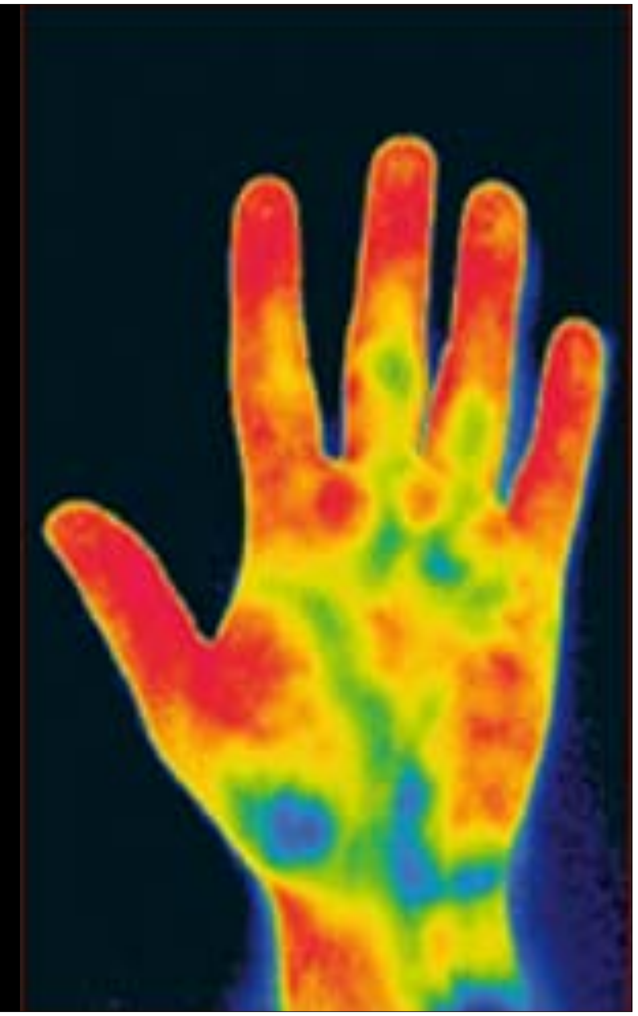

By looking at objects using another sort of light, we see different things.
X-rays are produced by a machine. The x-rays pass soft tissues, but bones for example are less opaque to x-rays.
Medical pictures: x-rays are sent through the body. It is the shadow of the x-ray light that you see in the image.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

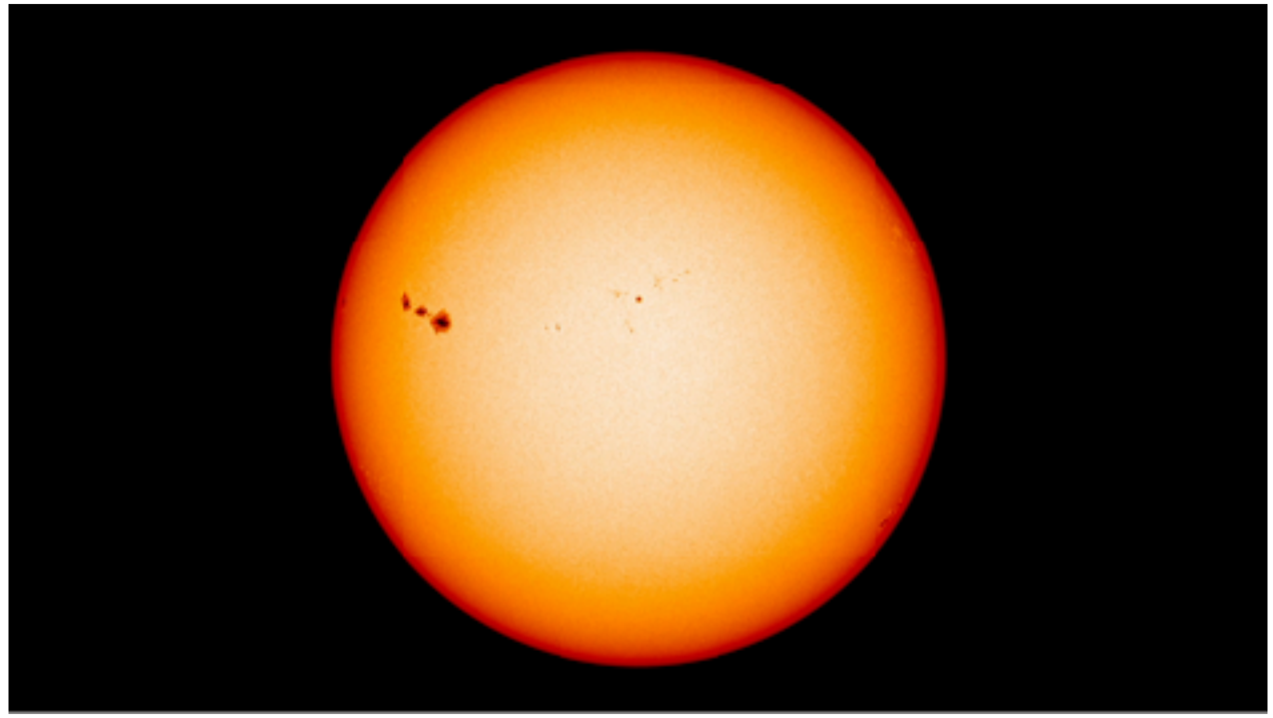


Each body radiates infrared. When molecules are moving, there is heat and infrared.

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

# EUV and magnetic loops

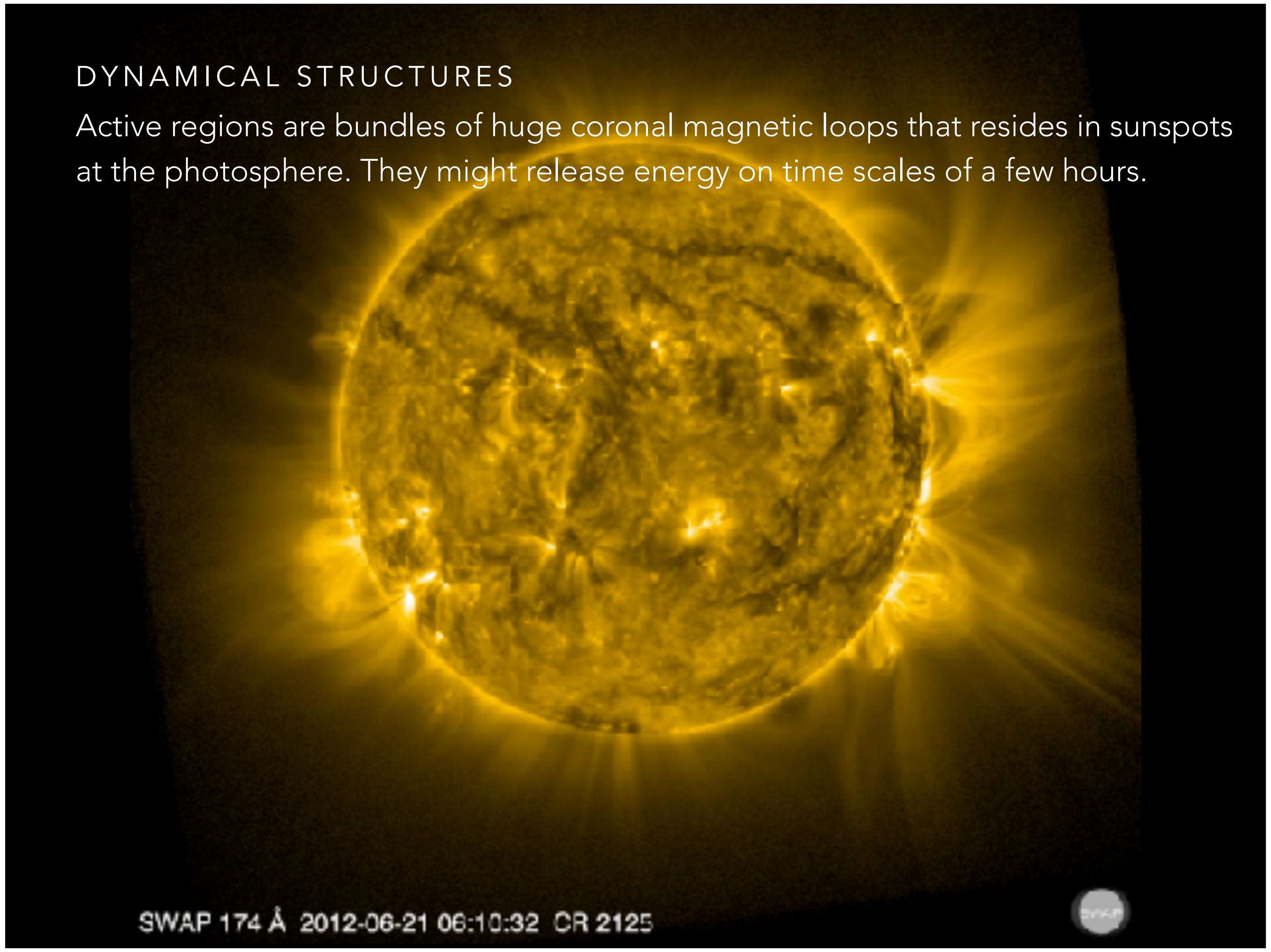
## LOOKING AT AN OBJECT IN ALL SORTS OF LIGHT



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.




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.

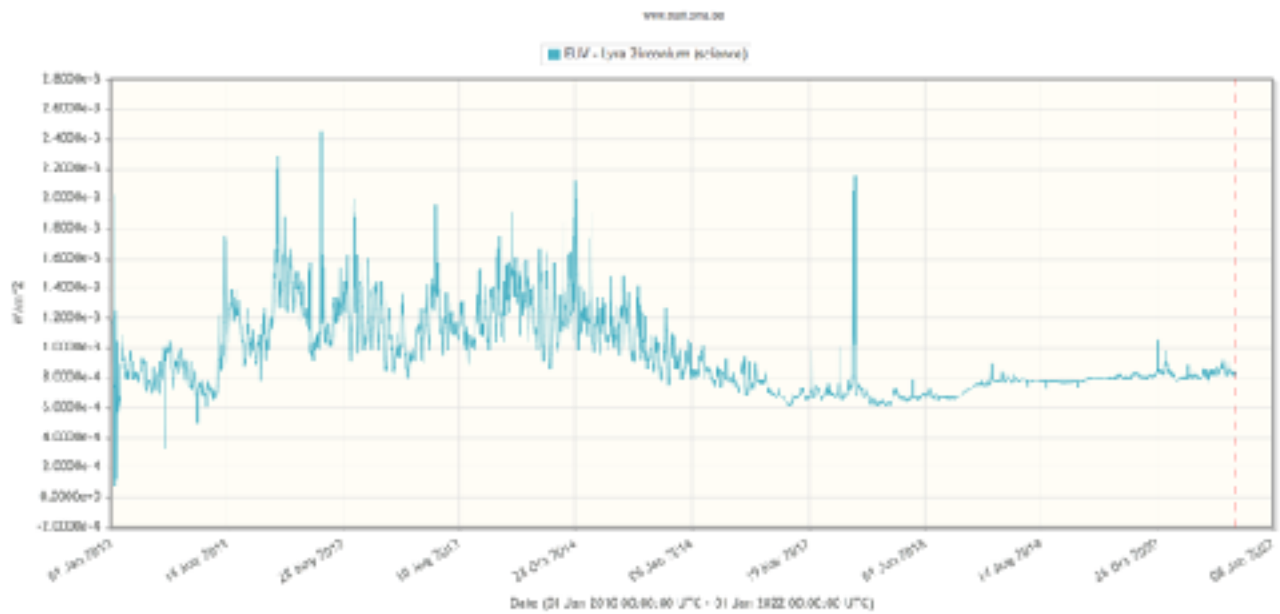
# More variations

## VARIATIONS OVER YEARS IN THE EUV

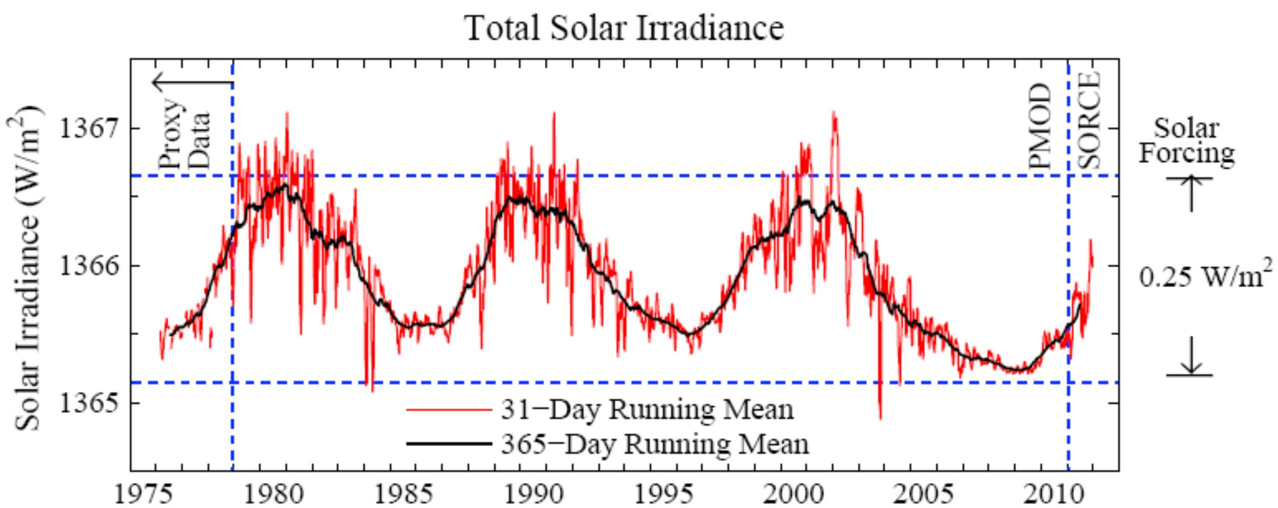

EUV variatie over 5 jaar

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

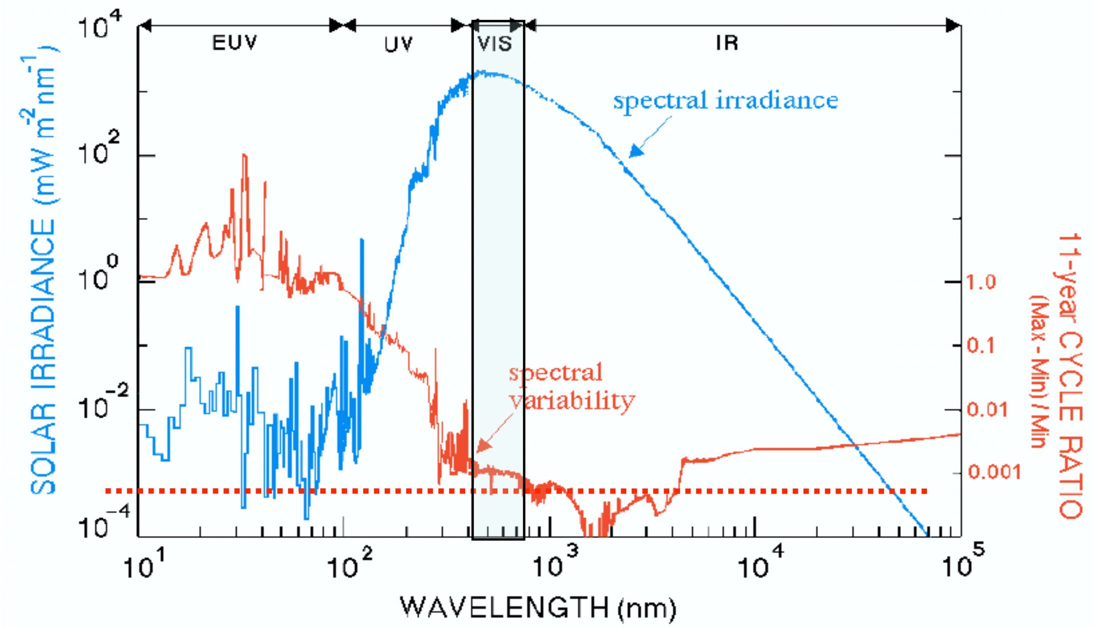
This represents a fraction of the total amount of electromagnetic radiation emanating from the Sun in all directions.

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.



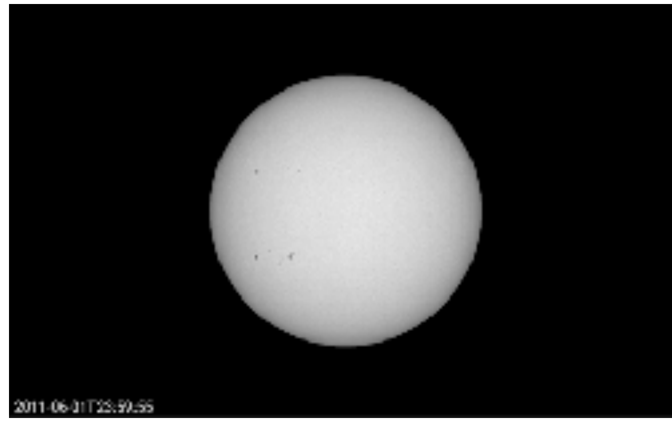

Logaritmische schaal

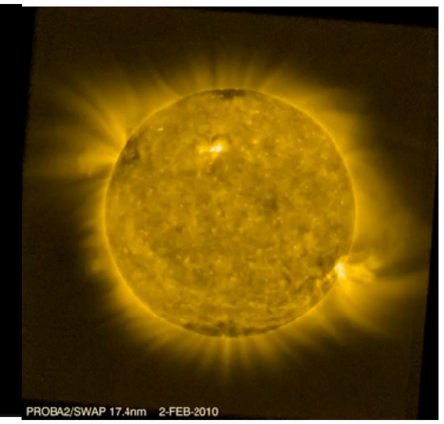
als je alles integreert onder de blauwe curve, bekom je de TSI

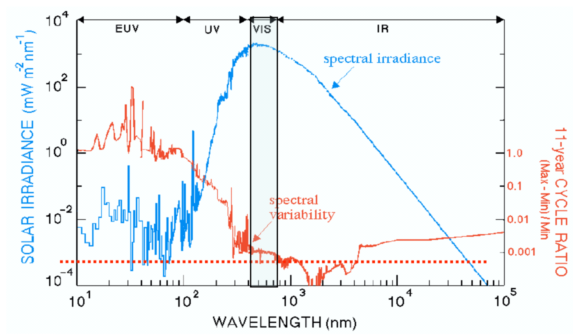
Het zichtbare en infrarode spectrum, voortgebracht ter hoogte van de fotosfeer, varieert bijzonder weinig (<1%).
De variaties zijn veel hoger (een factor 10 tot 1000), bij golflengtes onder de 320 nm, in het ultraviolet. **Deze straling, die echter van de andere lagen komt (chromosfeer, corona) komt 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

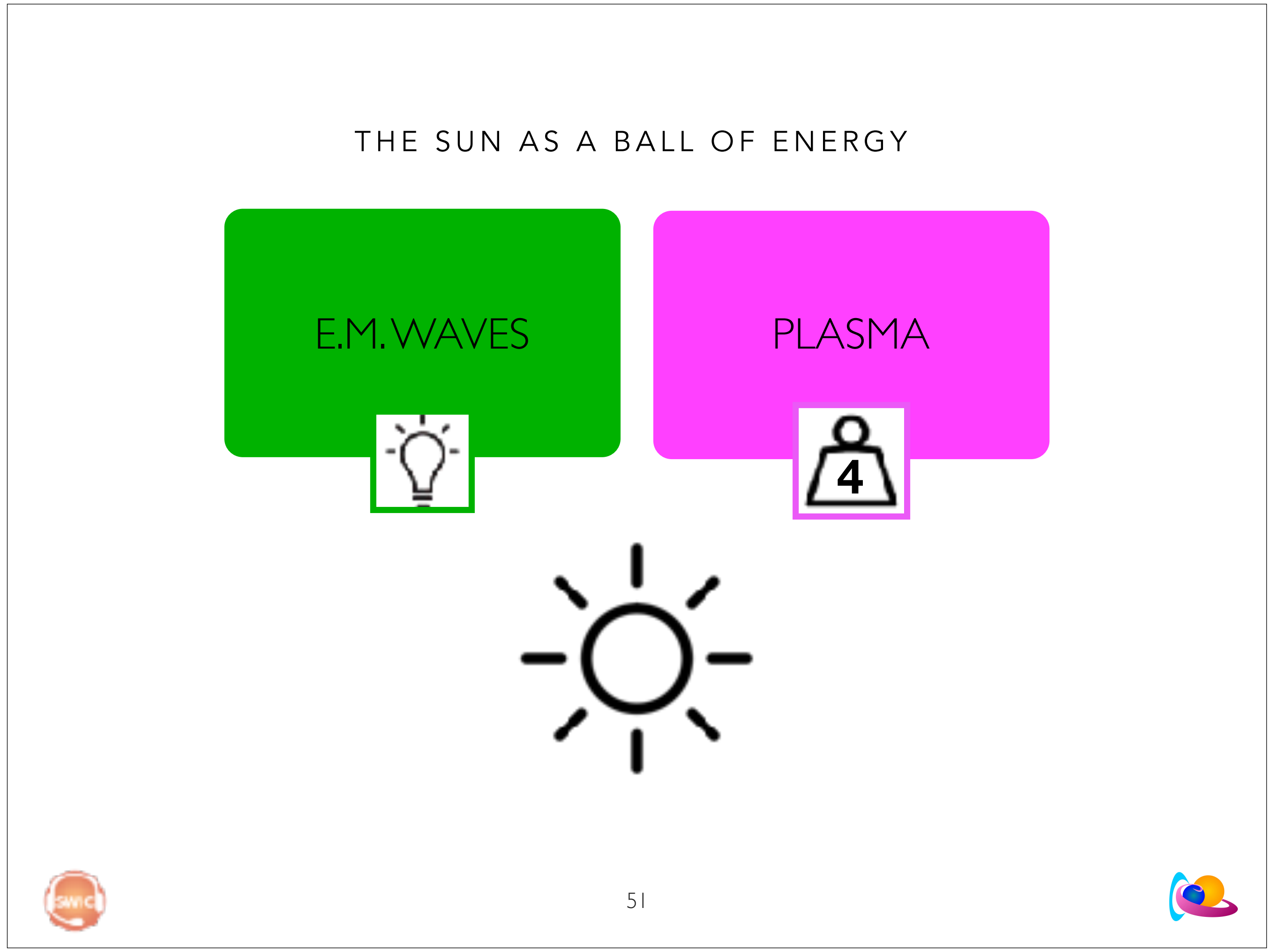
THE SOLAR ATMOSPHERE CHANGES OVER TIME

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.

# Ruimteklimaat

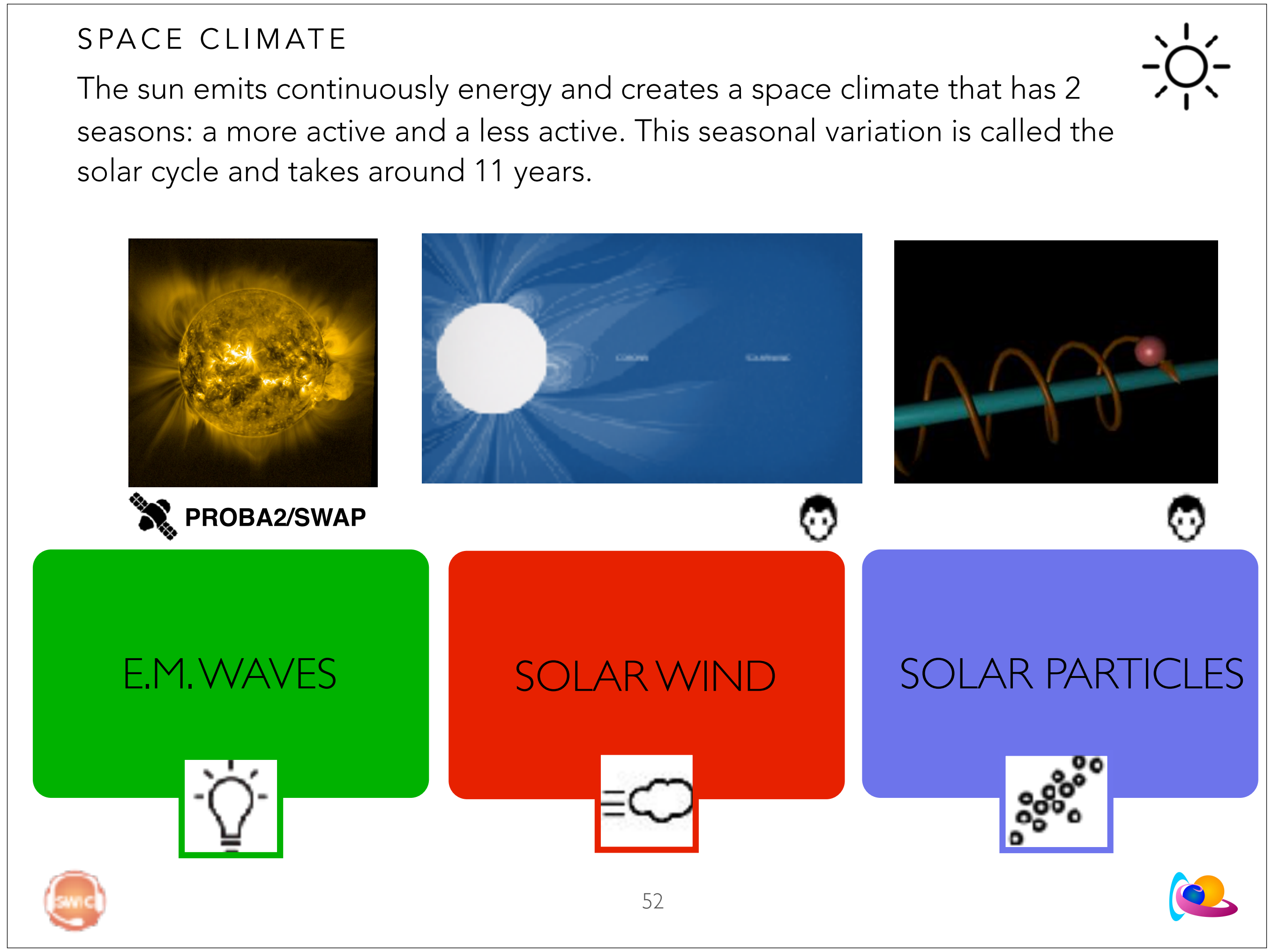



The sun is a gigantic ball of energy: magnetic energy, heat, moving plasma, …

This energy is kept inside the Sun but also on its surface and in its atmosphere in magnetic structures like sunspots and magnetic loops, filaments or prominences ready to be released.

This energy is expelled, leaves the Sun to outer space and is carried away by electromagnetic waves and plasma.

Note: the solar plasma is hot. The plasma particles bump on each other. These collisions changes their kinetic energy. This change is emitted in the form of thermal radiation, light photons. Once these photons are at the solar surface, they can escape and move freely.
Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. You have thermal motion as soon as the temperature is above absolute zero.




The outward flow of solar particles and magnetic fields from the Sun. Typically at 1 AU, solar wind velocities are near 375 km/s and proton and electron densities are near 5 cm−3. The total intensity of the interplanetary magnetic field is nominally 5 nT.

TSI, e.m. radiation is not linked to the IMF. It doesn't follow the magnetic field lines.
PROBA2/SWAP, the sun in the EUV.

However, plasma containing ions and electrons has to follow the magnetic field lines. Or you can also say that the magnetic field lines guide the plasma.
The solar wind plasma is glued to the IMF – or the IMF is glued to the plasma.
The plasma in the solar wind is considered as a gas, a group of particles behaving and moving in group. You don't speak about that particular particle in the solar wind, you speak about the solar wind, a whole bunch together.
Cartoon

Electrically charged particles have to follow the IMF. These electrically charged particles are considered as individuals and behave as individuals.
Cartoon

Near Earth, the IMF still controls the solar wind and its movement. Much much further away from the Sun, the IMF becomes very weak and doesn't control the solar wind anymore. But, this is not important for us. At 1AU, the IMF influences the plasma and the plasma the IMF.

About the animated gif:
Conceptual animation (not to scale) showing the sun's corona and solar wind.
Credits: NASA's Goddard Space Flight Center/Lisa Poje

The solar wind is a continuous radial stream of solar plasma that leaves the sun and moves away from it. It fils the space between the planets with solar mass. The solar wind reaches the boundaries of the heliosphere, a magnetic shield around the Sun. In the heliosphere, the Sun sets the rules and you have solar weather. Outside the heliosphere, you have the rest of the galaxy. Earth is in the heliosphere.

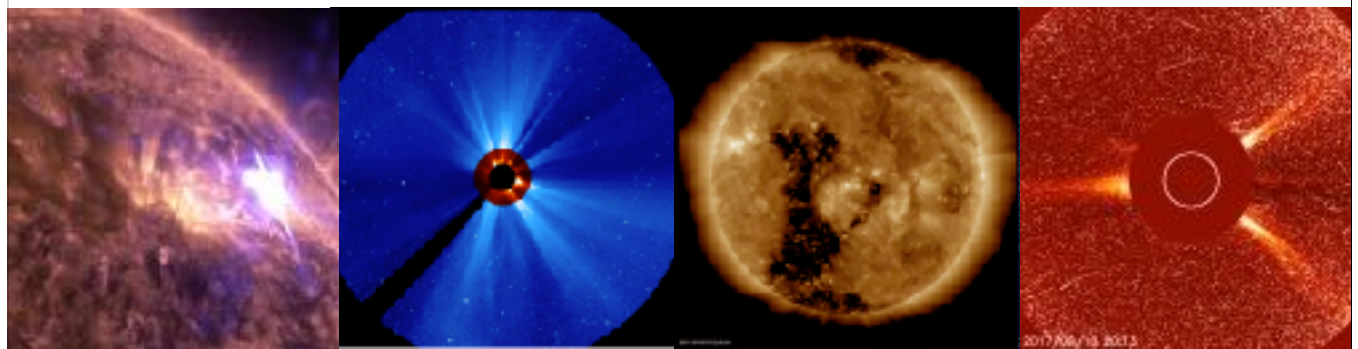
A nice movie is found on

https://www.nasa.gov/feature/goddard/2016/images-from-sun-s-edge-reveal-origins-of-solar-wind

https://youtu.be/QYM2_ytkjQo

## SOLAR STORMS

At a certain moment, energy might be released on a shorter time scale. Space weather is the change that occur on the Sun or in the space environment. This chance might be in an abrupt, impulsive and brutal way (flare, Coronal Mass Ejection or CME, proton storm) or in a non-eruptive manner (Coronal Hole - CH).



FLARE

CORONAL MASS EJECTION CORONAL HOLE

PARTICLE STORM



Remote sensing (seeing) – in situ (taste and touch the ambient space)

Space weather is the change of energy that occur in the space environment.

A Flare is a sudden strong increase of the solar e.m. radiation. The light flash is localised on the solar surface.
SDO/AIA

A Coronal Mass Ejection is a plasma cloud that is ejected into space. You consider it as a cloud and not as a bunch of individual particles. It is superimposed on the background solar wind. You can see a CME as a complex magnetic bag with different magnetic layers with plasma in it that travels as a tsunami through space. It can go faster/as fast as/slower than the background solar wind. When it is faster, you will see a shock in front of the cloud. This is exactly the same as the shock you see in front of a speed boat.
A CME is visible as a white cloud in corona graphic images like the one on the slide. A coronagraph is a telescope that creates an artificial eclipse and makes pictures in the visible light of the region around the sun.
SOHO/LASCO C2 (red) and LASCO C3 (blue)

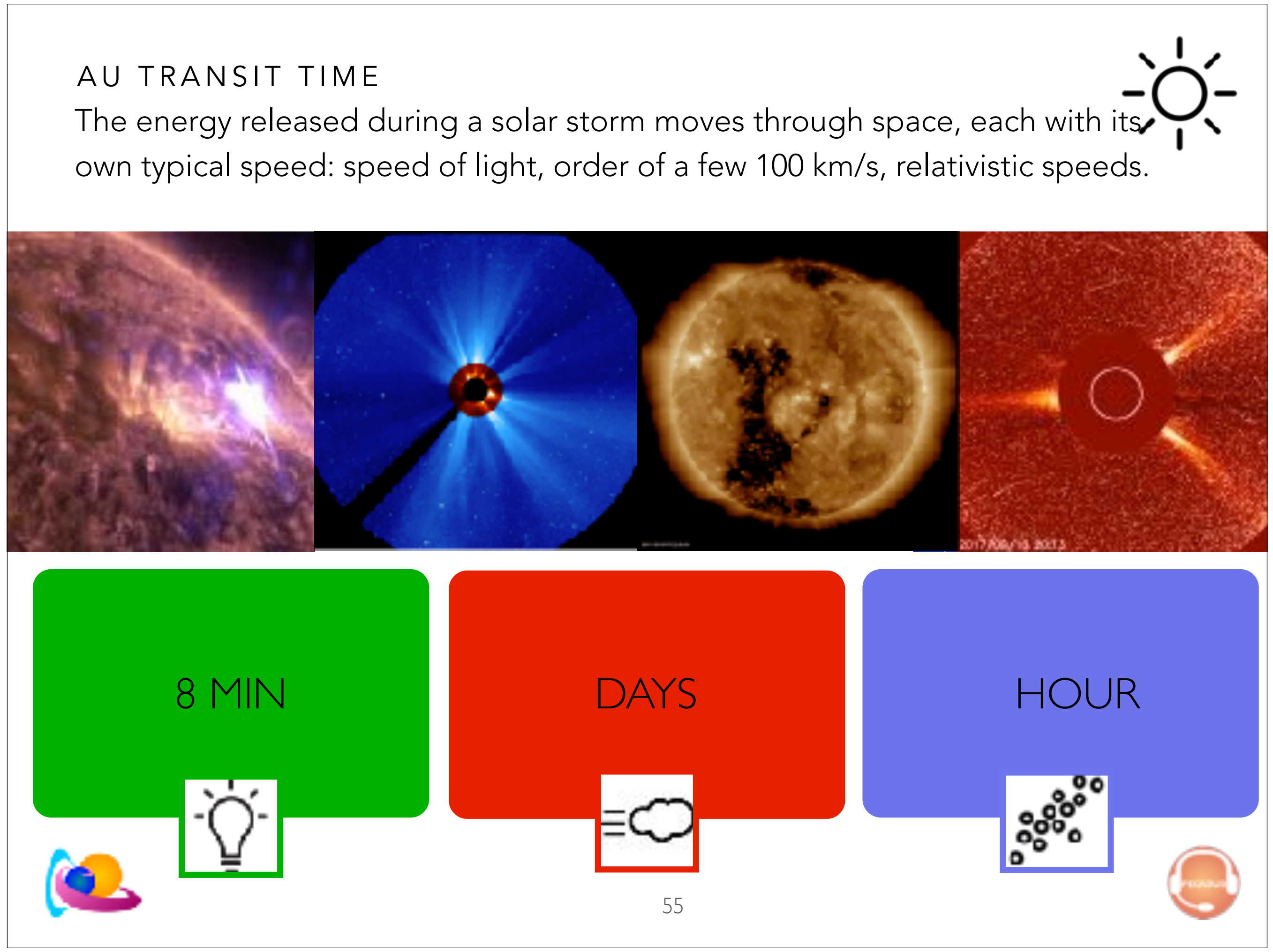
A coronal hole is a structure in the solar corona that you see as a black area in the EUV. It looks black because there is less plasma present that radiates in the EUV. The magnetic field lines are open, i.e. fan out into space. There are no magnetic loops above a coronal hole. The solar wind emanating from a CH is faster compared to the usual solar wind.
SDO/AIA

A particle storm is a bunch of electrically charged particles that are accelerated in the solar atmosphere to very high velocities by a large-scale magnetic eruption often causing a CME and/or solar flare.
They follow the IMF
They may impact telescopes. They are seen as white stripes and dots: this are particles that fall into the lens and blind the pixel(s). During that particular moment, the telescope can't see anymore through the impacted pixels. You can say that the dots and stripes represent a sort of in situ measurement.

In situ means that you measure a parameter local. Remote sensing means that you look at something from a distance.

Near Earth, the IMF still controls the solar wind and its movement. If we would go much much further, the CME magnetic bag with solar plasma would be almost empty (all the solar material is spread over an immense volume) and the magnetic bag would have evaporated. But, this doesn't matter for us. We are at 1AU and at 1AU the IMF and solar plasma make space weather in a normal way, in an extreme way.

Magnetische krachten in het plasma geven vuurwerk!
Dit zijn zonnestormen.

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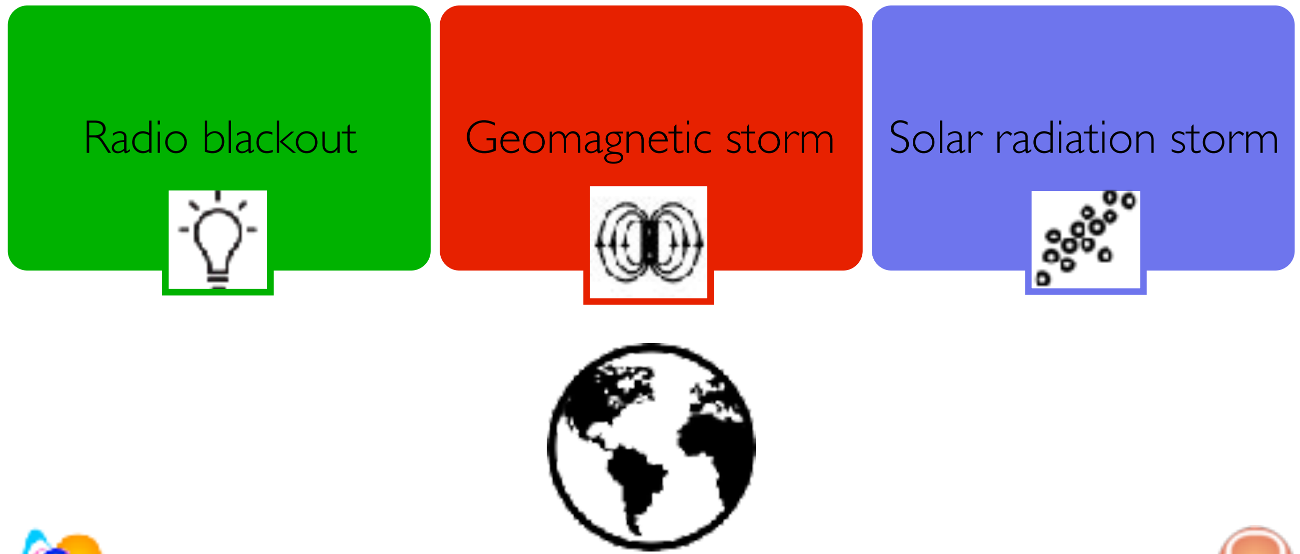
SPACE WEATHER

Our atmosphere and magnetosphere can respond in a dramatic way to solar storms. A solar storm can initiate space weather processes in our atmosphere and magnetosphere. This impact is measured near or on Earth and results in 3 sorts of space weather storms.





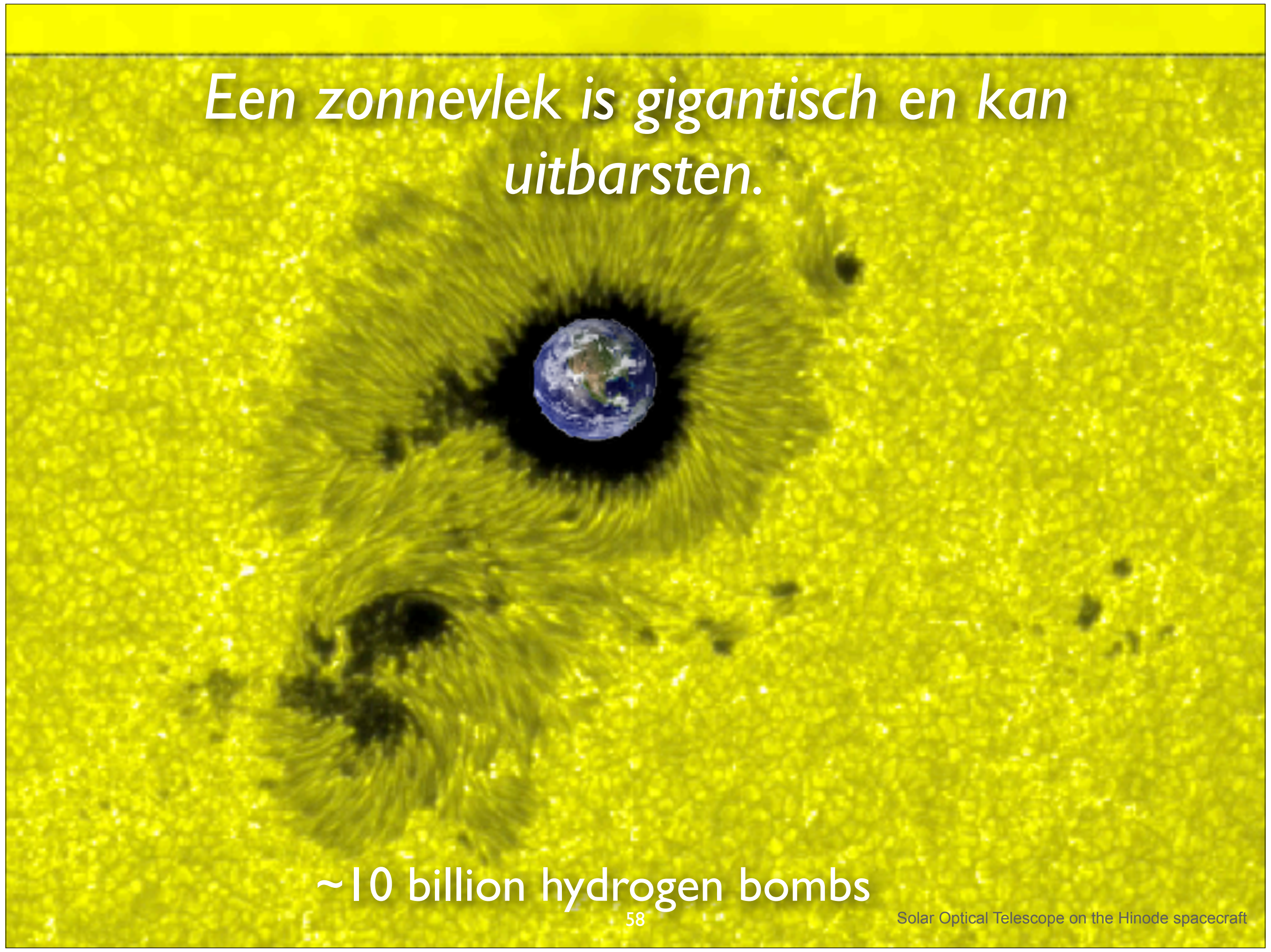

The consequence of a solar flare is a radio black out

The consequence of a troubled solar wind, is a geomagnetic storm.

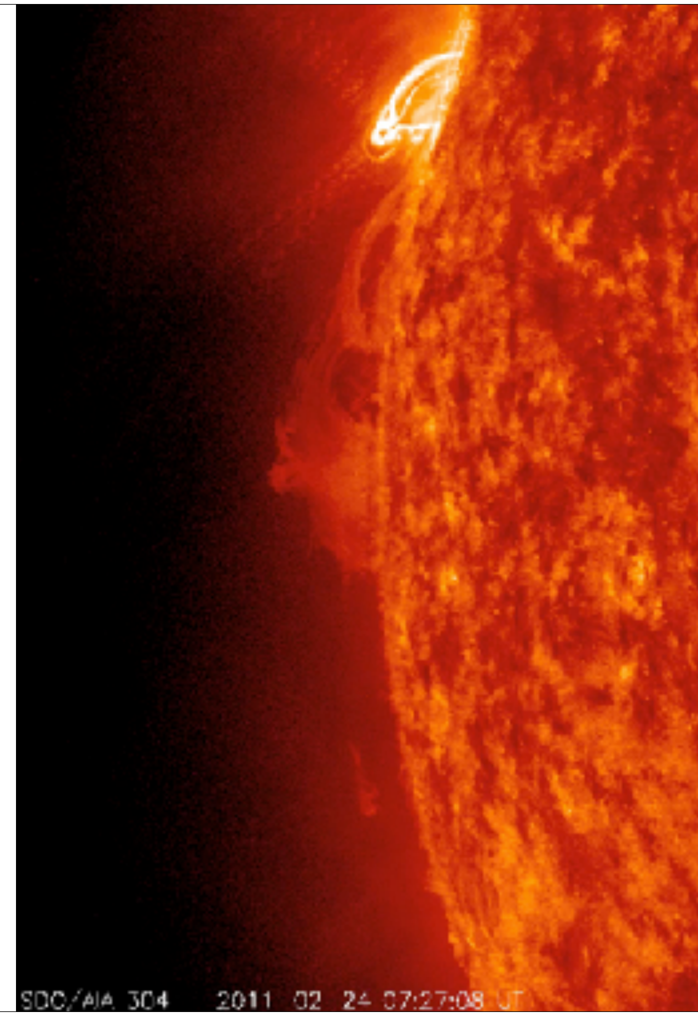
The consequence of a particle storm, is a solar radiation storm.
Not a geomagnetic storm. An individual particle doesn’t carry a magnetic field that can couple or disturb the magnetic field of Earth.

SOLAR STORMS

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

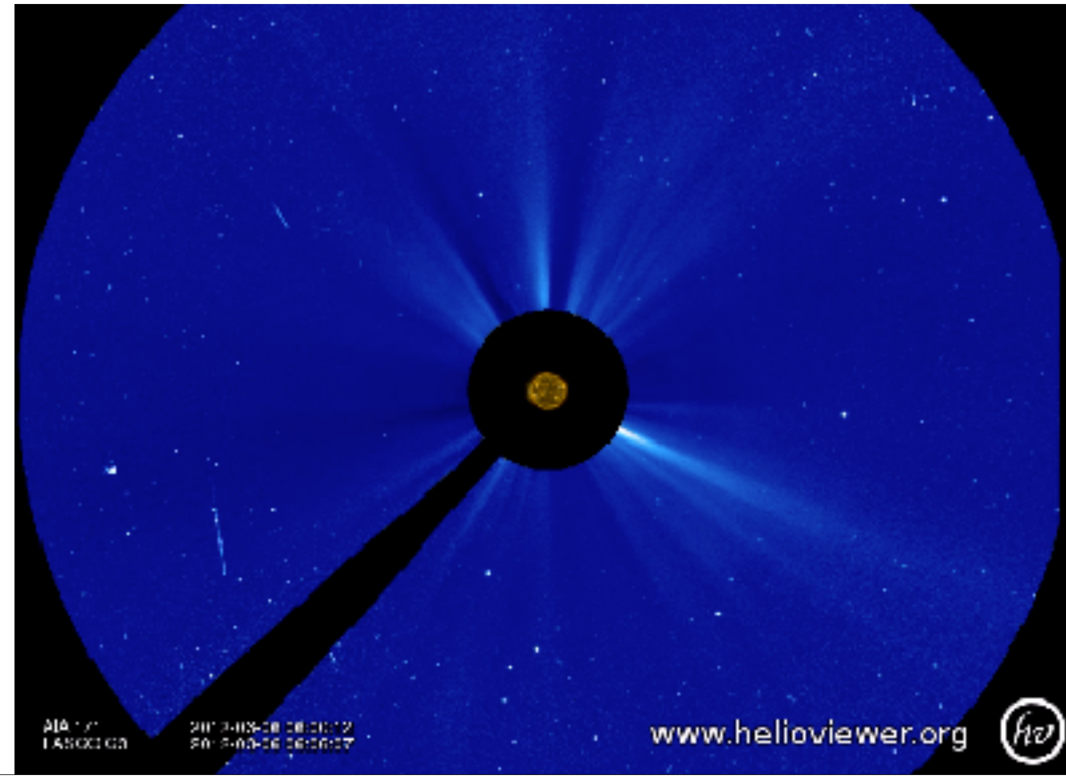



in 1859 werd door carrington de link gelegd tussen een uitbarsting een vlek en gebeurtenissen op de aarde: ruimteweer.


SDO/AIA 304 2011 02 24 07:27:08 UT

SOLAR STORMS

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

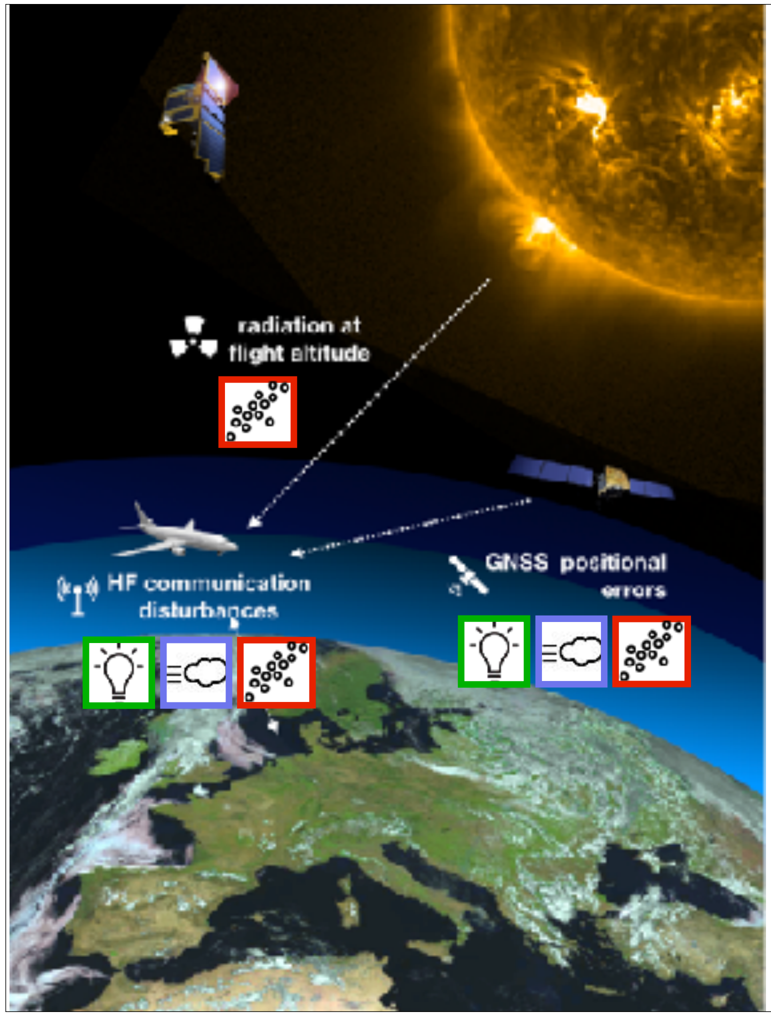


# Het weerbericht


Die ruimtestormen zijn dus best wel belangrijk en kunnen soms gevaarlijk zijn. Daarom is het belangrijk dat wij proberen te voorspellen wanneer die gaan gebeuren. Net zoals we dat doen bij het weer op Aarde.


Wij maken ook voorspellingen: van het weer in de ruimte, maar die komen niet op de TV

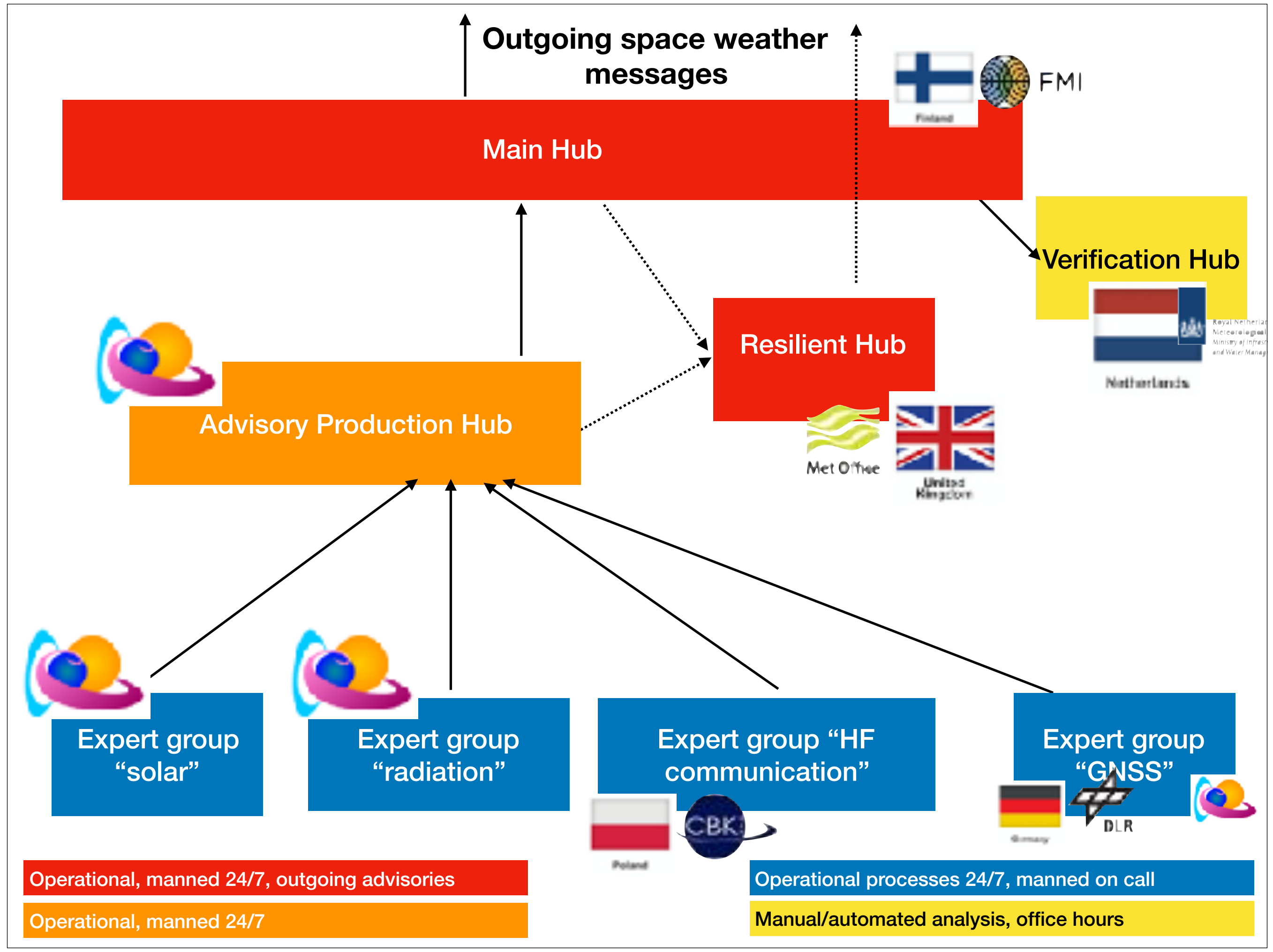
Op de sterrenwacht voorspellen wij elke dag wat het weer in de ruimte zal zijn. Zijn er nieuwe wolken van plasma gezien die over een paar dagen zullen toekomen op aarde? Is er een zonnevlam geweest? Is er een groot coronaal gat dat sterke zonnewind naar de aarde stuurt?




# IMPACT ON AVIATION

Our technology is impacted. PECASUS provides services for civil aviation.

Sinds 2019 monitoren we het ruimteweer voor de civiele luchtvaart. We kijken hoe het ruimteweer evolueert in tijd en ruimte en wat hun impact is op satelliet-navigatie, hoge frequentie radiocommunicatie en het stralingsniveau op vlieghoogte.




Het STCE België heeft een belangrijke rol in PECASUS dat geleid wordt door FMI, Finland: advisory production hub - d.i. het opstellen van de advisories op basis van de verzamelde data die we visualiseren in een 'dashboard'. Tevens hebben we een leidende rol in 2 expert-groepen: zonneweer en deeltjesstraling.

Het STCE is ook verantwoordelijk voor de opleiding van de PECASUS operatoren en gebruikers, zoals piloten.

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FNXX02 EFKL 150645

SWX ADVISORY
DTG:              20210515/0645Z
SWXC:             PECASUS
ADVISORY NR:      2021/18
NR RPLC:          2021/17
SWX EFFECT:       HF COM SEV
OBS SWX:          23/0535Z EQS W045 - E045
FCST SWX +6 HR:   23/1800Z NOT AVBL
FCST SWX +12 HR:  23/0000Z NOT AVBL
FCST SWX +18 HR:  23/0600Z NOT AVBL
FCST SWX +24 HR:  23/0600Z NOT AVBL
RMK:              SPACE WEATHER EVENT (MAXIMUM USABLE
FREQUENCY DEPRESSION) IS IN PROGRESS. IMPACT ON HIGHER HF
COM FREQUENCY BANDS EXPECTED. LOWER FREQUENCY BANDS MAY BE
LESS IMPACTED.
NXT ADVISORY:     WILL BE ISSUED BY 20210515/1222Z=
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Dit is een advisory voor een ernstige impact op HF communication ten gevolge van verstoord ruimteweer.
Wegens een geomagnetische storm kunnen minder frequenties gebruikt worden voor HF radiocommunicatie. Het venster van mogelijke frequenties werd kleiner.