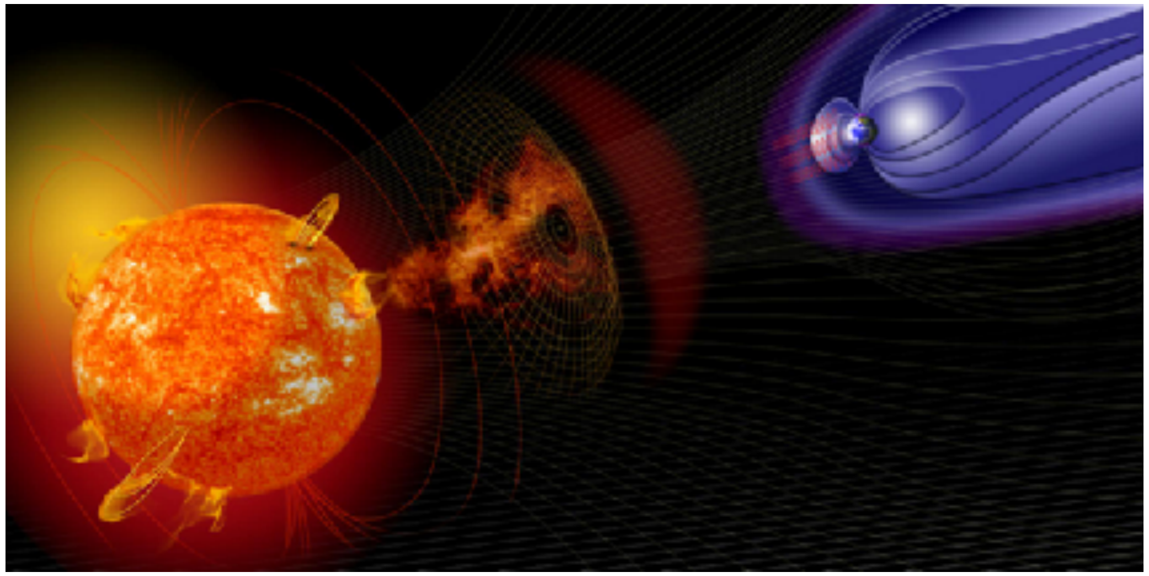


SPACE WEATHER

Solar Radio Bursts

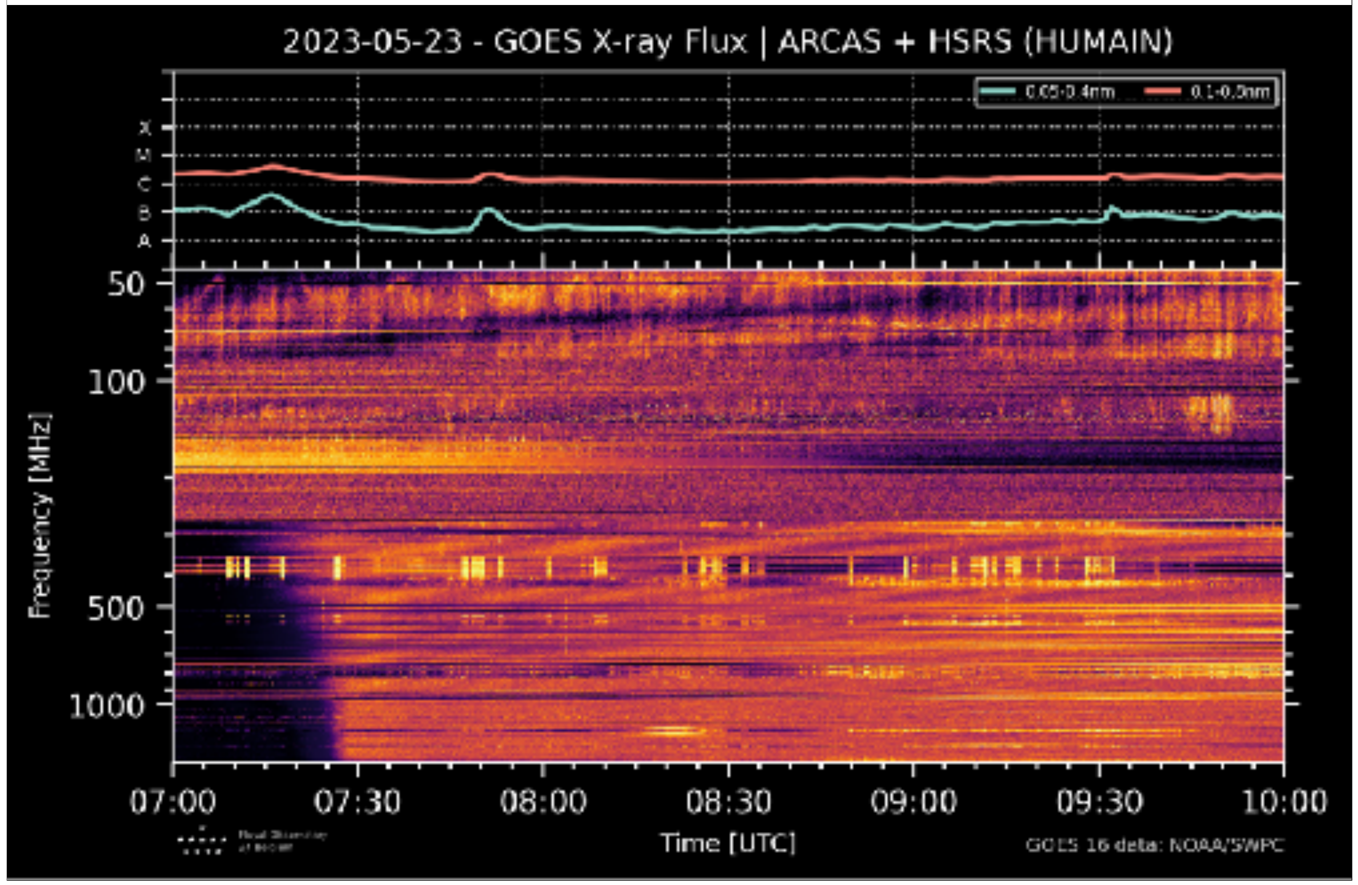
Petra Vanlommel

Observations in the e.m. spectrum

- 10 cm flux —> index for solar activity, similar like the sunspot index
- Solar Radio Bursts

One value of the 10 cm flux value per day —> index for solar activity like the sunspot number

RADIO SPECTRUM - SPECTROGRAM



Electrons start radiation because they got an energy boost from a solar event.
Signature of presence of a CME, flare.
As such, a SRB are not a consequence of magnetic reconnection.

Note: 10.7cm —> 2800 MHz: not in this spectrum

****

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

type II burst, slowly drifting, often with fundamental/2nd harmonic structure, due to plasma emission
cause is a shock wave, propagating at 500-2000 km/s outward into the corona into interplanetary space (also seen down to kilometric wavelengths).

Type III

- type III burst, rapidly drifting, often with fundamental/2nd harmonic structure, due to plasma emission. The fundamental is highly o-mode polarized, and the 2nd harmonic is weakly (15%) x-mode polarized.
  - cause is a stream, or **beam, of electrons moving at speed ~ c/3, propagating from low corona into interplanetary space** (also seen down to kilometric wavelengths).
- type III storm -- a long lasting (up to a day or more) series of type III bursts, RS (reverse slope) bursts, reverse-drift pairs, and continuum.

Type IV

- stationary type IV -- broadband continuum emission, sometimes highly polarized, due to either plasma emission (o-mode polarized) or gyrosynchrotron emission (x-mode polarized).
  - cause is a plasmoid or high, filled loops of non-thermal particles
- moving type IV -- a similar cause, but entrained in a CME or expanding arch.

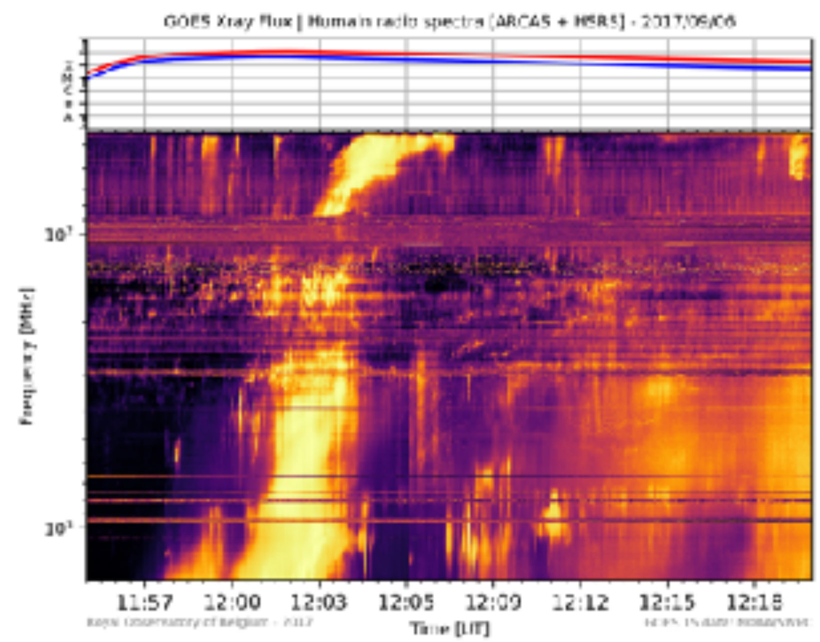
Type V

- type V burst, continuum emission following a type III burst, x-mode polarized (opposite sense to the associated type III)
  - cause is **slower type III-like electrons** in widely diverging magnetic fields, with both forward and counterstreaming langmuir waves, perhaps generated by previous passage of type III electrons.

linked with a solar event, like a flare, CME, languir waves

SOLAR RADIO BURSTS

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



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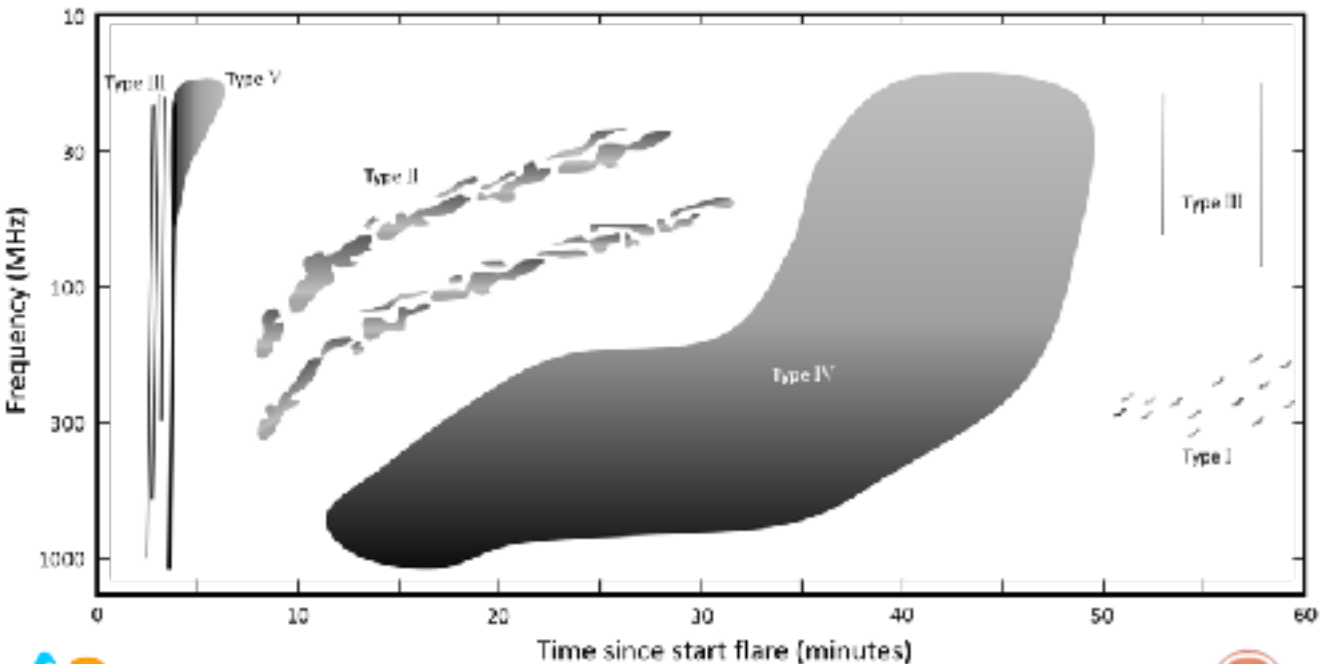

Tells us something about the fate of the electron: trapped or pushed forward

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Freq ~ density^1/2

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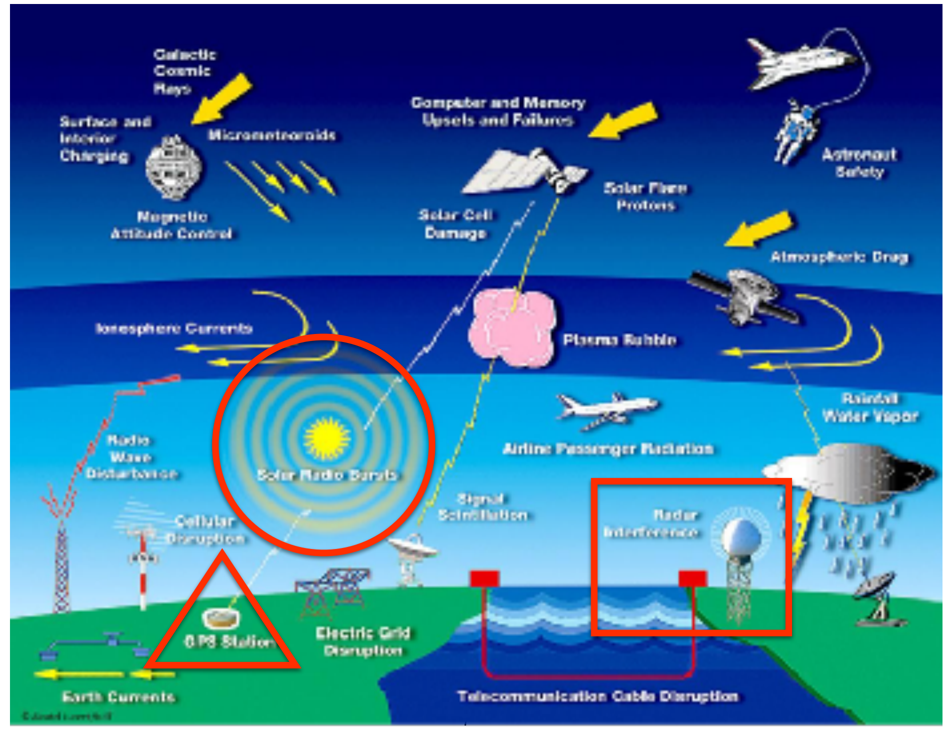
Can a Solar Radio Burst impact the ionosphere?

CONTRARY TO SOLAR RADIO BURSTS

Noise increase - the ionosphere is not impacted but the signal itself. The noise of the Sun is too loud, the GNNS receiver can't hear the satellite signal clear enough. Or the radar interprets the radio waves coming from the Sun as being a plane.



SRB can impact radar systems and GNSS but it a complete other way compared to flares. Flares, i.e. ionising radiation impact the ionosphere.
The radio waves from a SRB behave as a wave used by the GNSS and radar technology

Noise increase – the ionosphere is not impacted but the signal itself

<u>GPS station</u>
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.

<u>Radar interference</u>
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.

HF Com
f you have a strong radio burst in HF, your MUF might be full of solar noise and in practice not usable

SRB can impact HF communication (no feedback from industry) and navigation
But this is not taken into account by ICAO