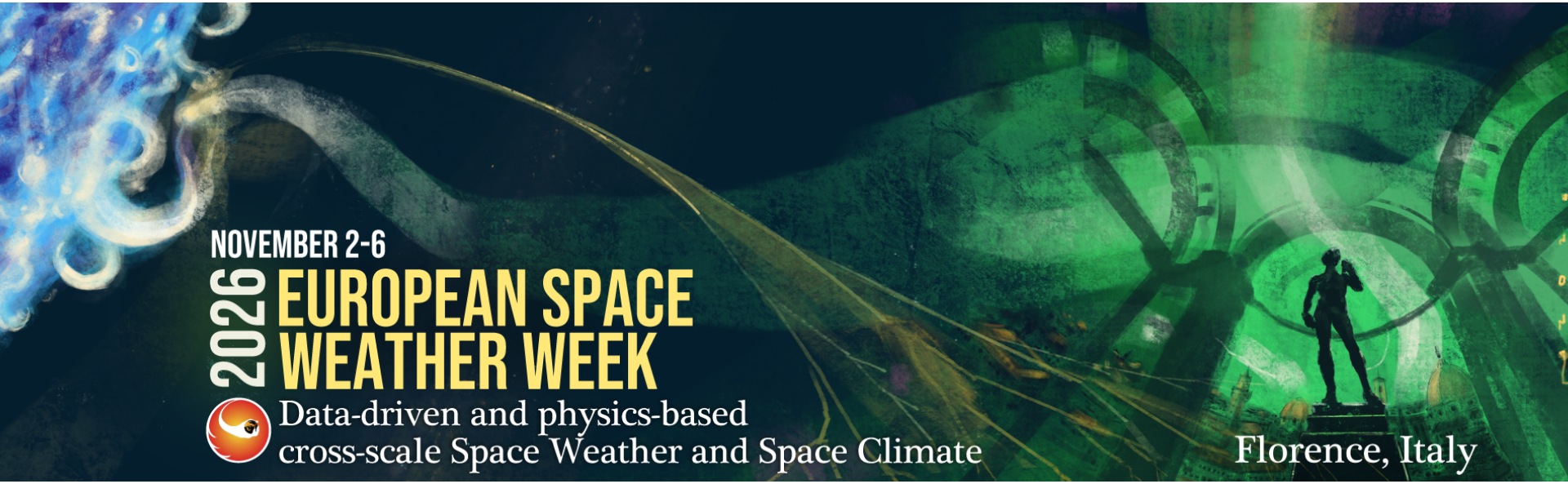
Space Weather Training Course



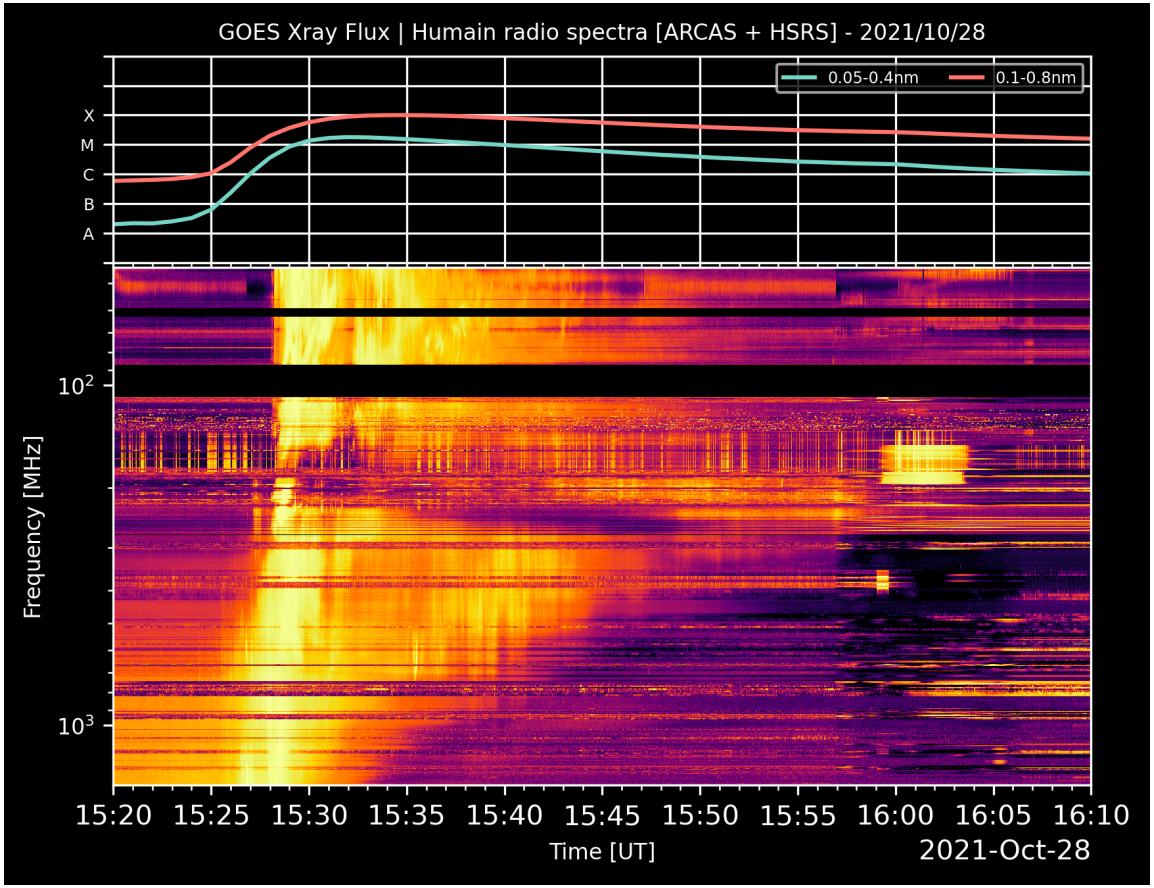
Collaboration of

e-swan

SWEC
Space Weather Education Centre

COMMUNITY COORDINATED MODELING CENTER

RADIO SUN



Humain

Quiet Sun

The Radio Sun

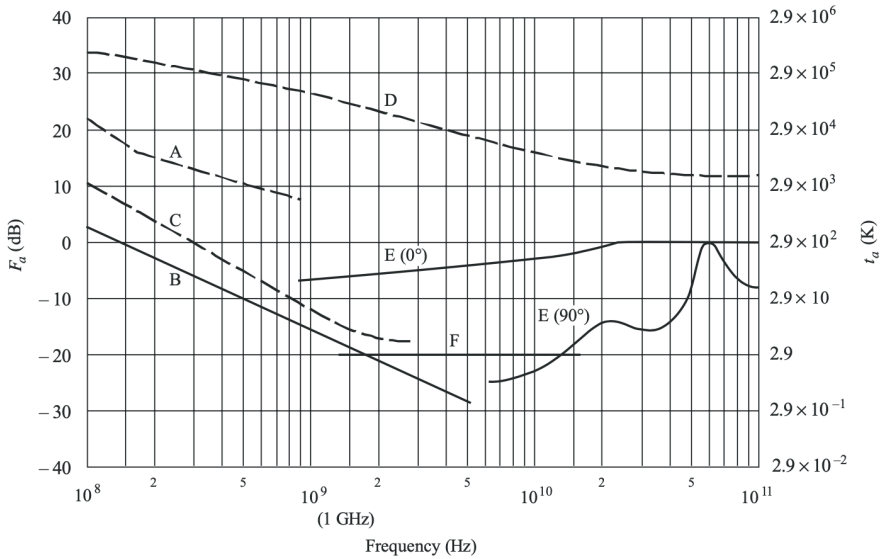
The Sun is the strongest radio source in the sky above ~100 MHz

Quiet Sun

Mostly thermal emission from hot corona

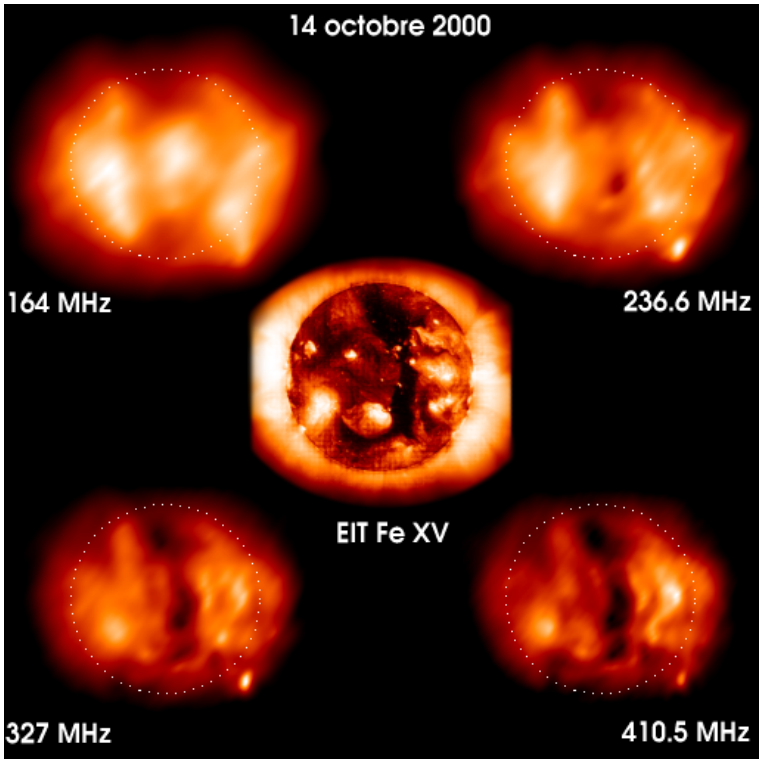
FIGURE 3

F_a versus frequency (10^8 to 10^{11} Hz)

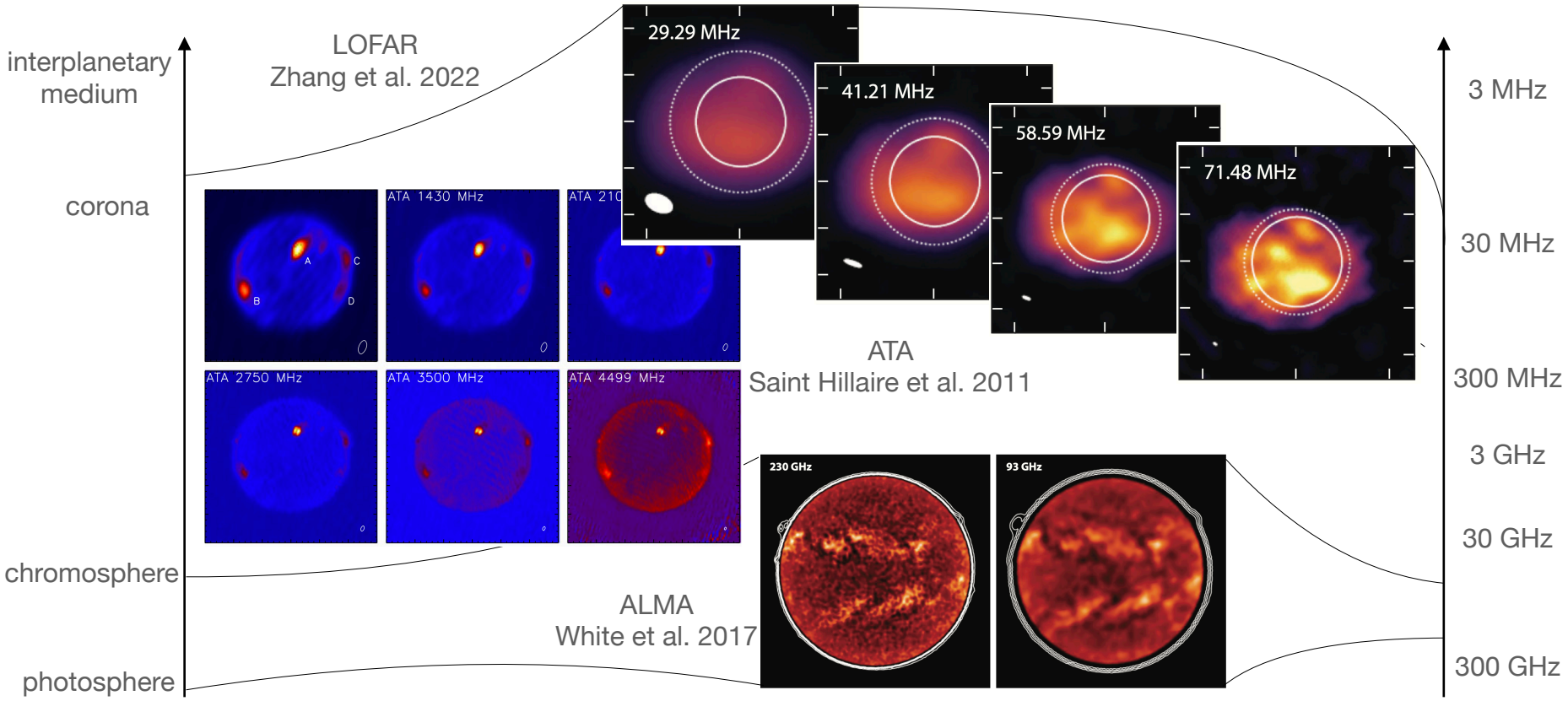


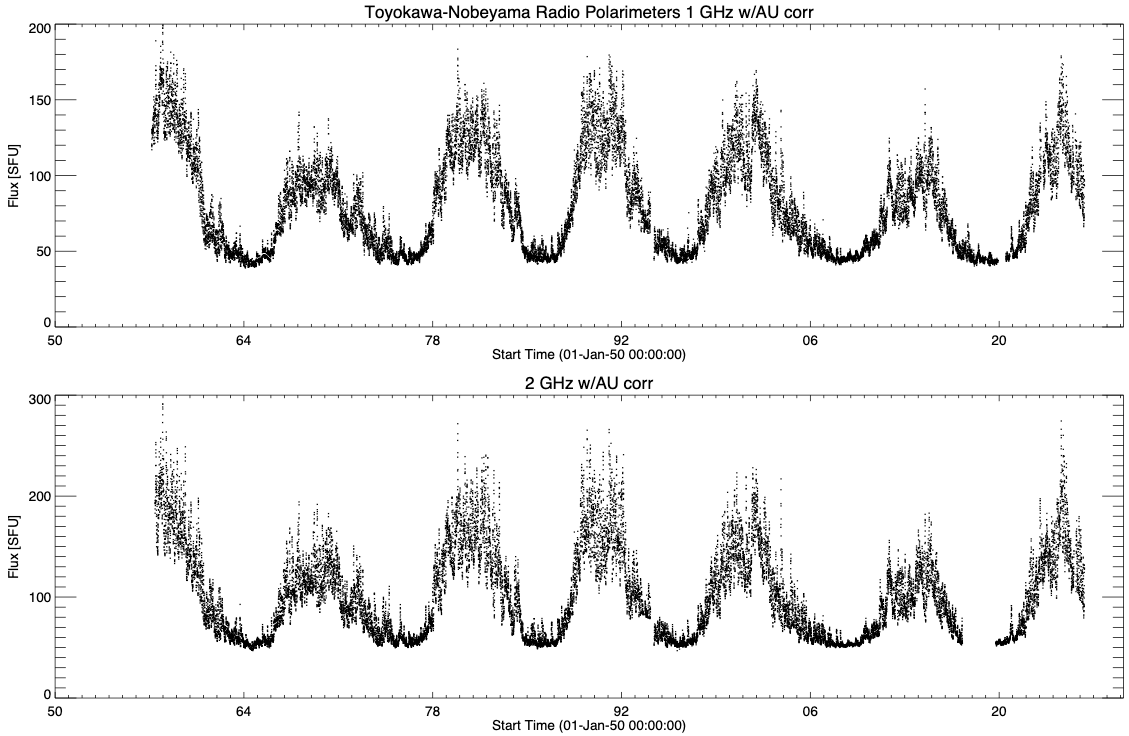
A: estimated median city area man-made noise
B: galactic noise
C: galactic noise (toward galactic centre with infinitely narrow beamwidth)
D: quiet Sun (½° beamwidth directed at Sun)
E: sky noise due to oxygen and water vapour (very narrow beam antenna); upper curve, 0° elevation angle; lower curve, 90° elevation angle
F: black body (cosmic background), 2.7 K
minimum noise level expected

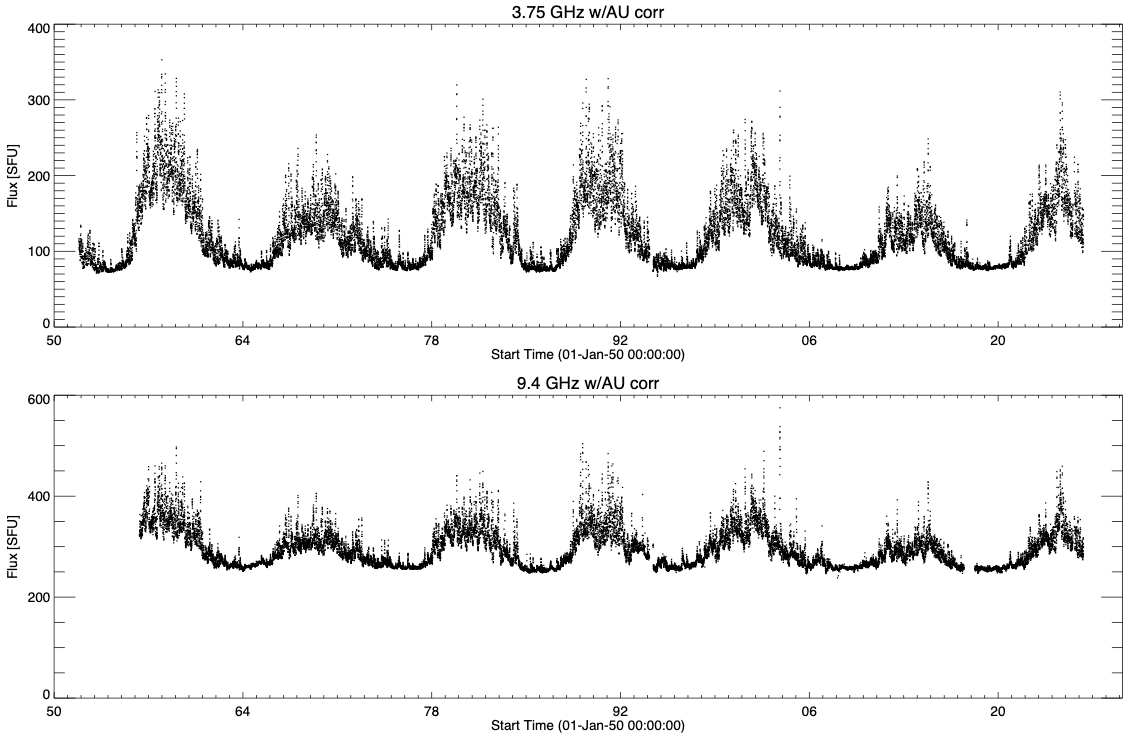
P.0372-03



All layers of the solar atmosphere are accessible to radio observations




Toyokawa-Nobeyama Radio Polarimeters 1 GHz w/AU corr
Flux [SFU]
200
150
100
50
0
50
64
78
92
06
20
Start Time (01-Jan-50 00:00:00)
2 GHz w/AU corr
Flux [SFU]
300
200
100
0
50
64
78
92
06
20
Start Time (01-Jan-50 00:00:00)


3.75 GHz w/AU corr
Flux [SFU]
400
300
200
100
0
50
64
78
92
06
20
Start Time (01-Jan-50 00:00:00)
9.4 GHz w/AU corr
Flux [SFU]
600
400
200
0
50
64
78
92
06
20
Start Time (01-Jan-50 00:00:00)

F10.7 index

$$\lambda = 10.7 \text{ cm} \equiv 2.8 \text{ GHz}$$



Figure 3. The flux monitors. Flux Monitor 1, the secondary instrument is in the foreground; Flux Monitor 2, the primary instrument is in the background, on the tower.

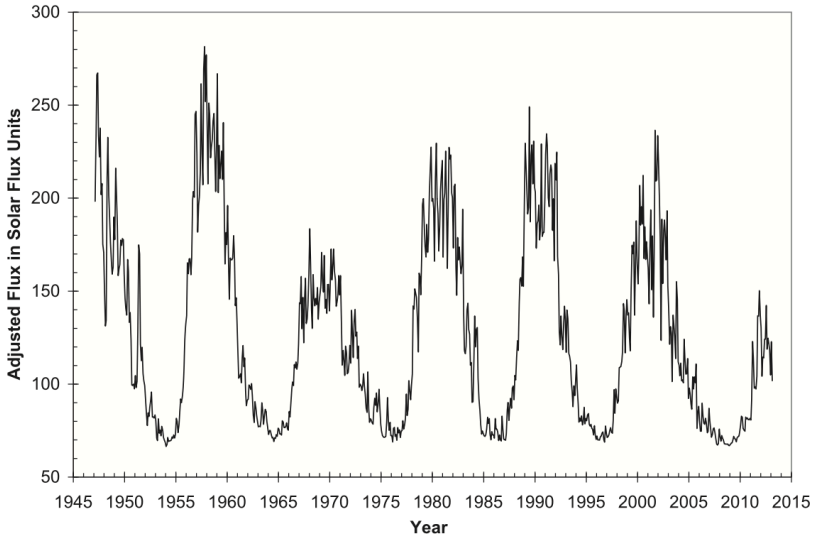


Figure 1. Monthly averages of the adjusted (scaled for an Earth-Sun distance of 1 AU) $F_{10.7}$ values since 1947.

Tapping 2013

F10.7 index





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Research Article

The operational and research DTM-2020 thermosphere models

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Received: 11 June 2021 | **Accepted:** 23 August 2021

Abstract

Aims: The semi-empirical Drag Temperature Models (DTM) predict the Earth's thermosphere's temperature, density, and composition, especially for orbit computation purposes. Two new models were developed in the framework of the H2020 Space Weather Atmosphere Models and Indices (SWAMI) project. The operational model is driven by the trusted and established F10.7 and *Kp* indices for solar and geomagnetic activity. The so-called research model is more accurate, but it uses the indices F30 and the hourly Hpo, which are not yet

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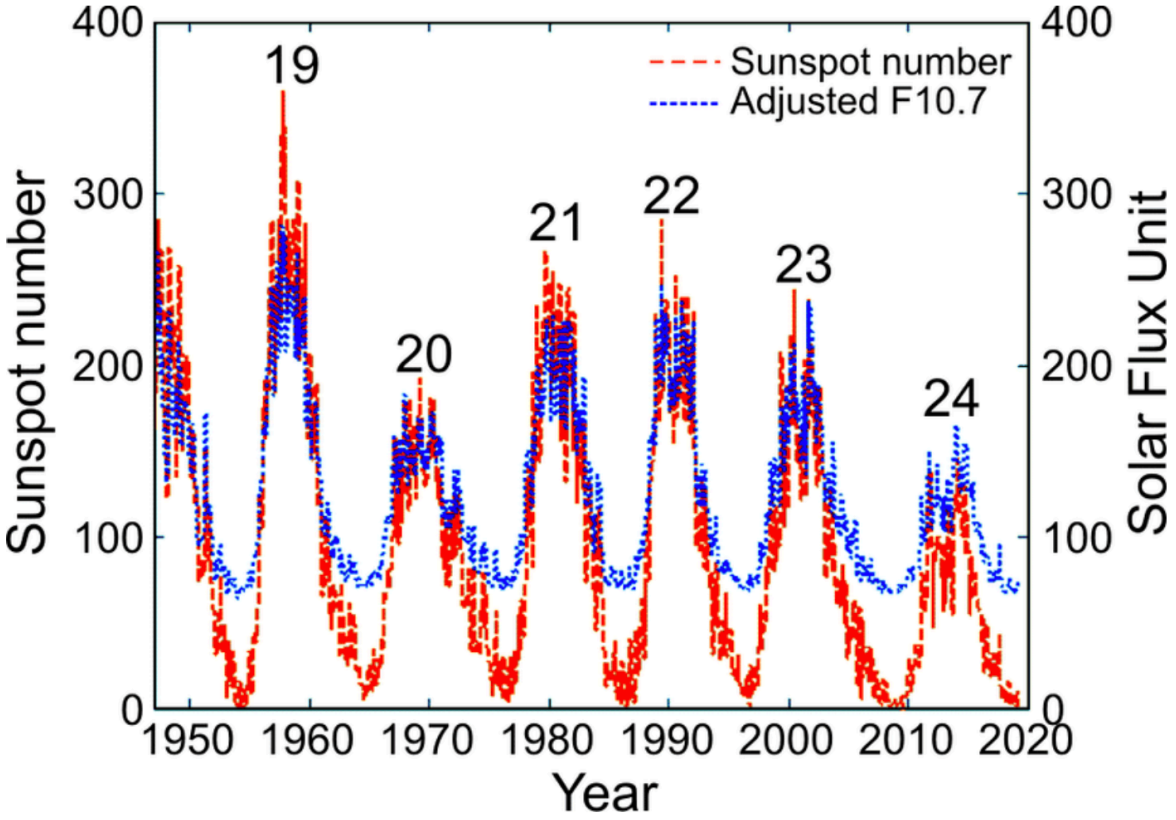
Related Articles

Semi-empirical thermosphere model evaluation at

2010 2015

Figure 3. The flux m … aled for
ondary instrument is … e 1947.
2, the primary instr…
the tower.

F10.7 index



The sunspot numbers (red curve) and the 10.7 cm solar flux (F10.7, blue curve) from the middle of the 20th century [69-71]. The F10.7 values are in solar flux units (sfu), 1 sfu is equal to 10 -22 W m -2 ·Hz -1 . The observed F10.7 is presented on the right axis.

Solar radio bursts

Radio bursts

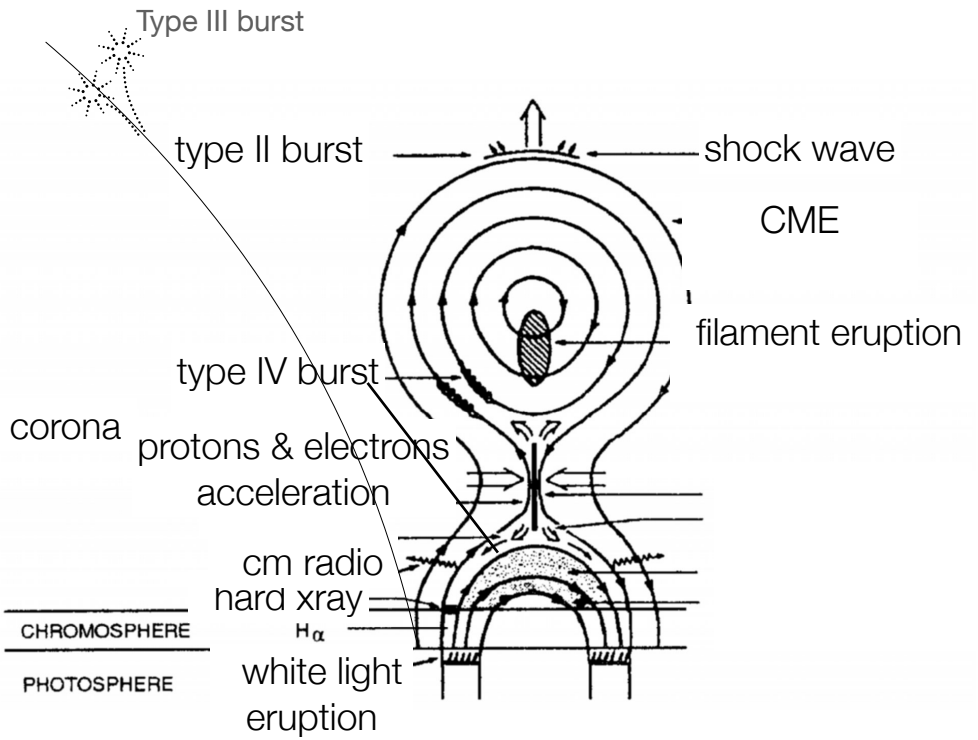
Solar radio bursts are produced by non-thermal electrons accelerated during eruptive events of all magnitudes.

For frequencies (f) below ~ 1- 2 GHz, the dominant emission is called plasma emission, where energetic electrons trigger local plasma oscillations which are then converted into E. M. radiations

$$f \propto \sqrt{n_e}$$

Spectral signatures (type I, type II, type III ...)

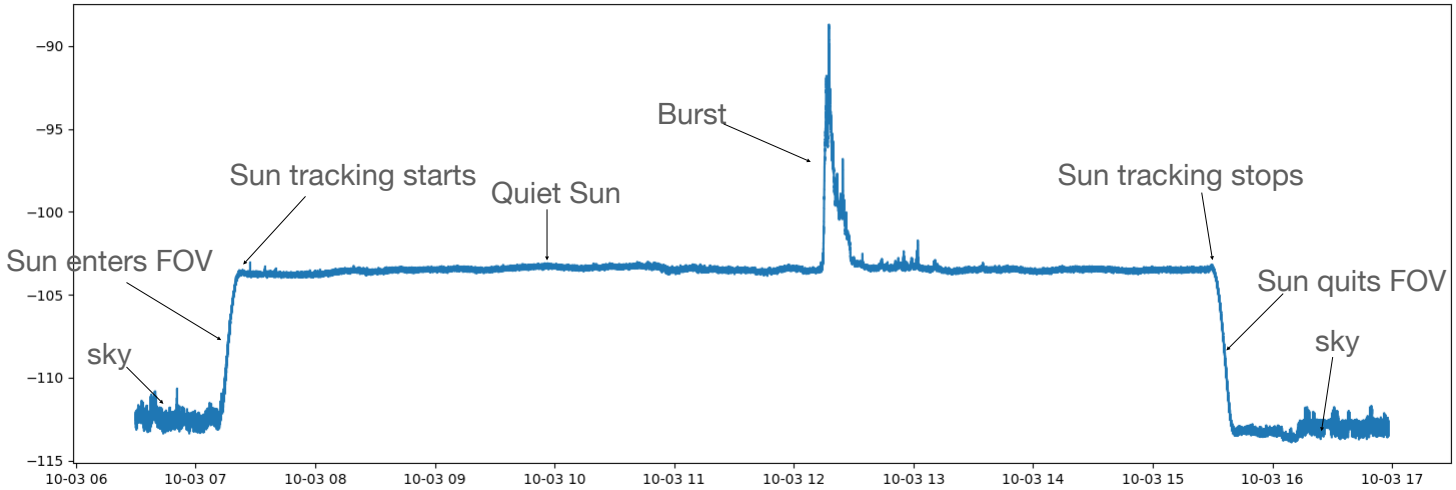
Above, gyroemissions, gyrosynchrotrons or bremstrahlung emissions dominate.



Example in L band

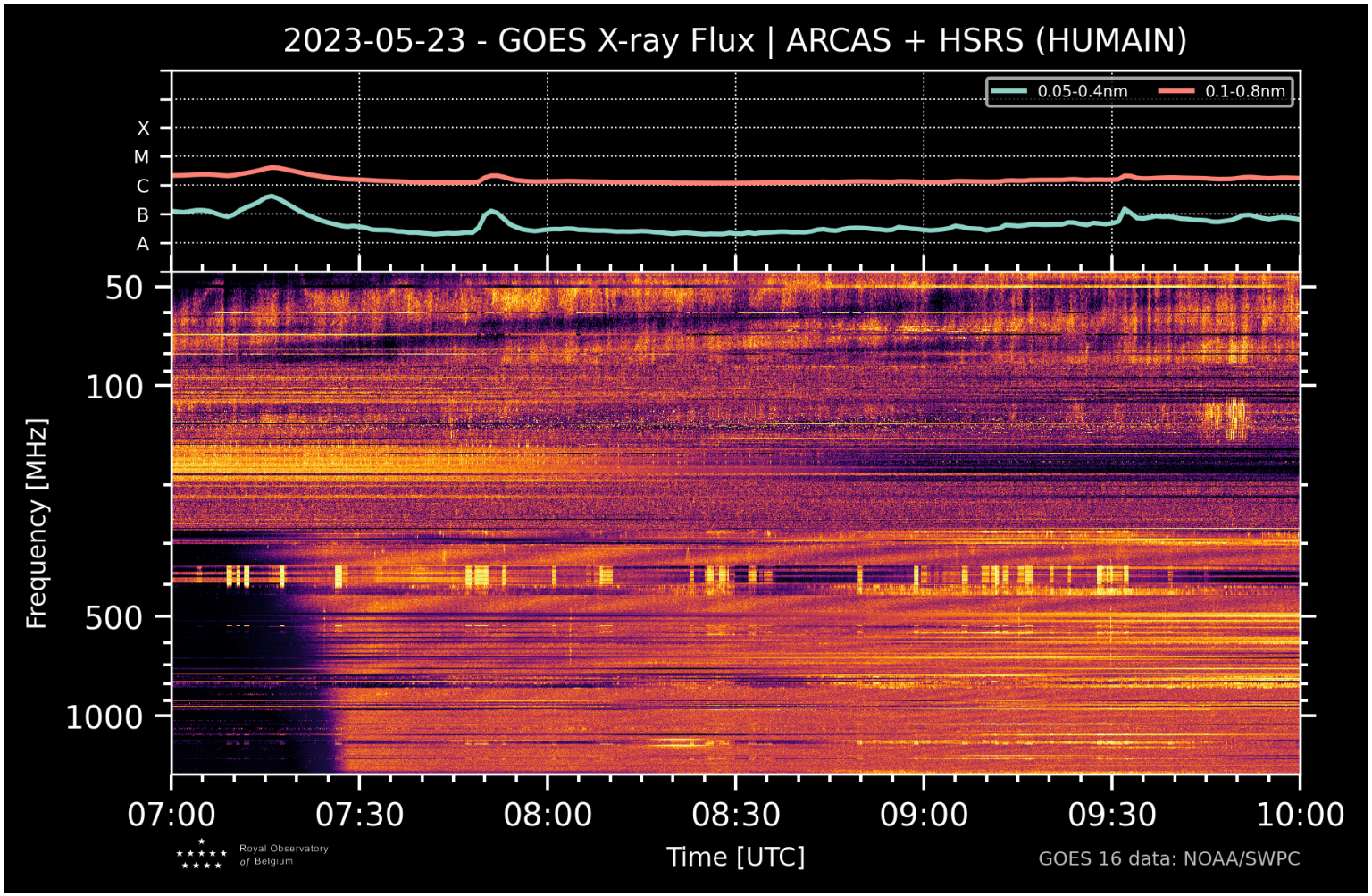


Solar Observations from Humain, Belgium

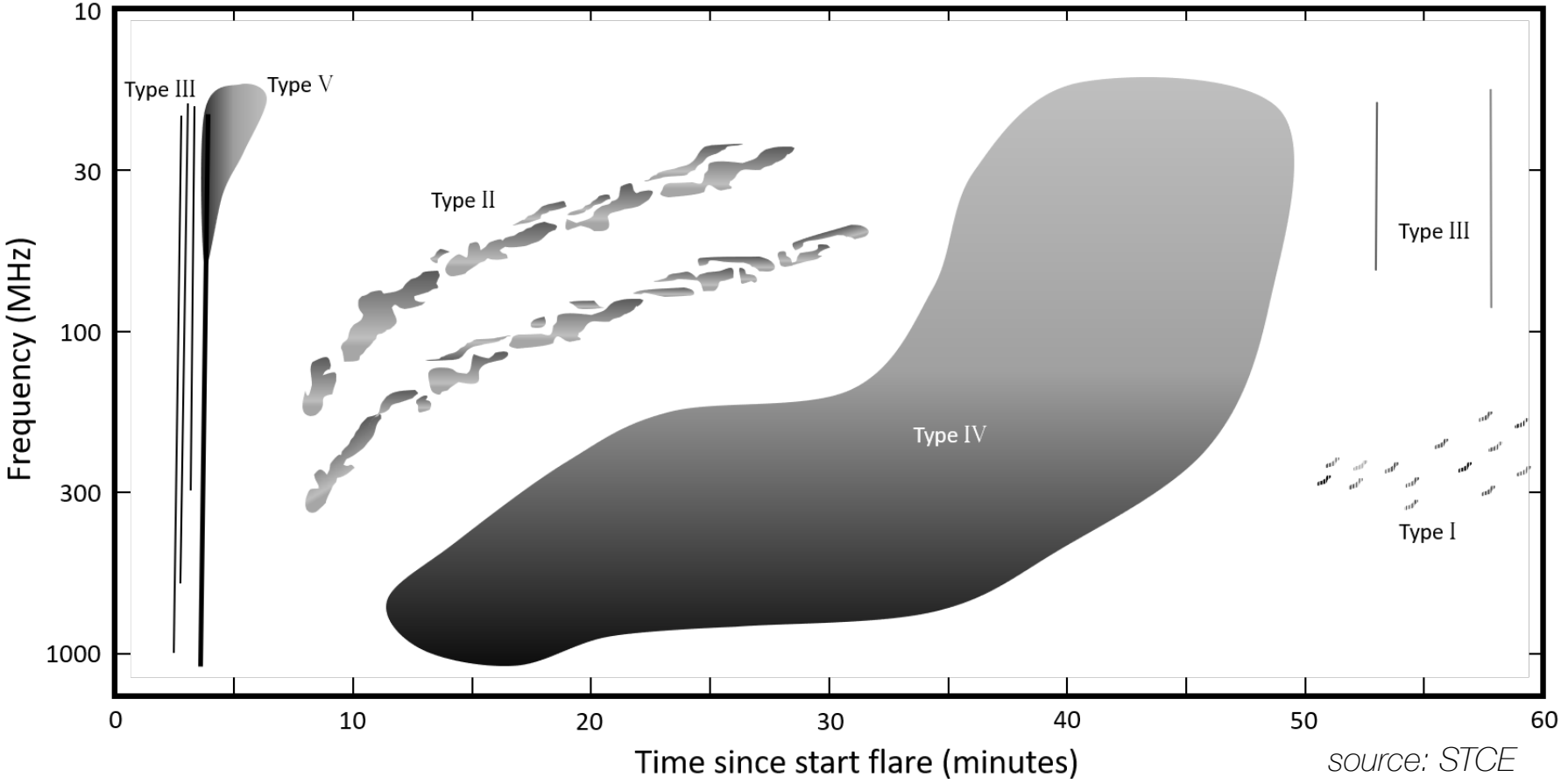


Spectrogram – Radio Spectrum

Humain

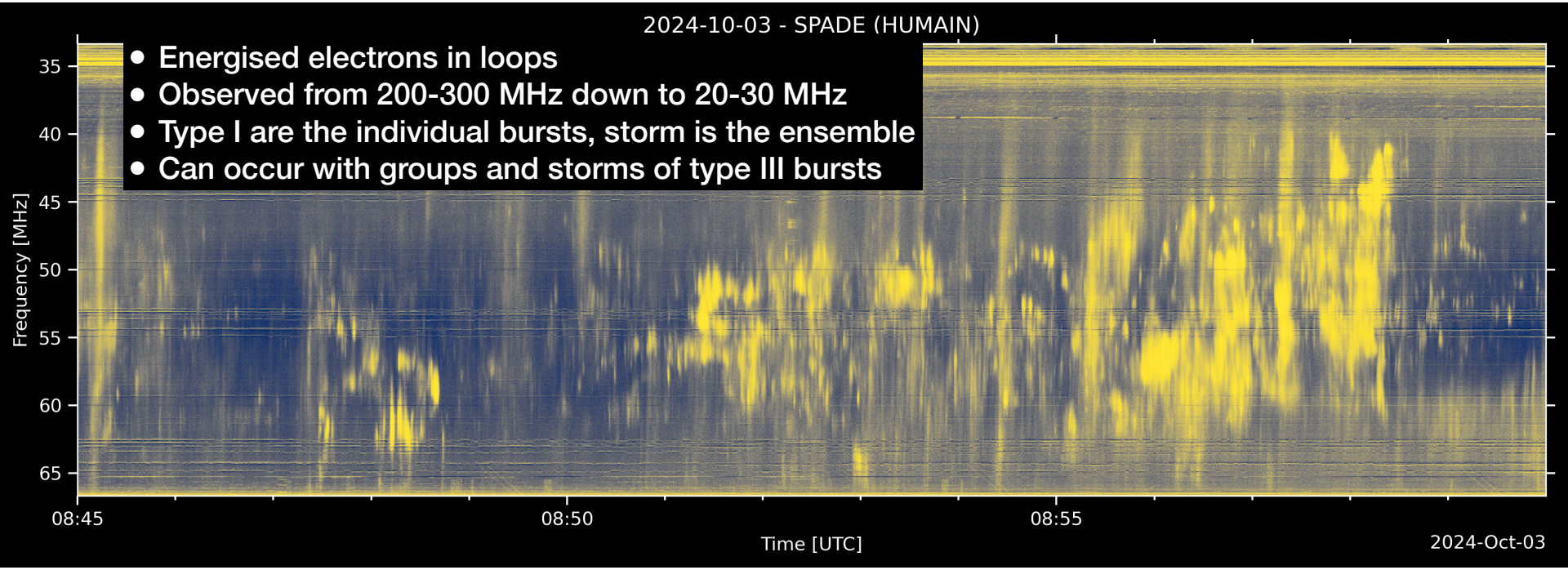


Radio bursts



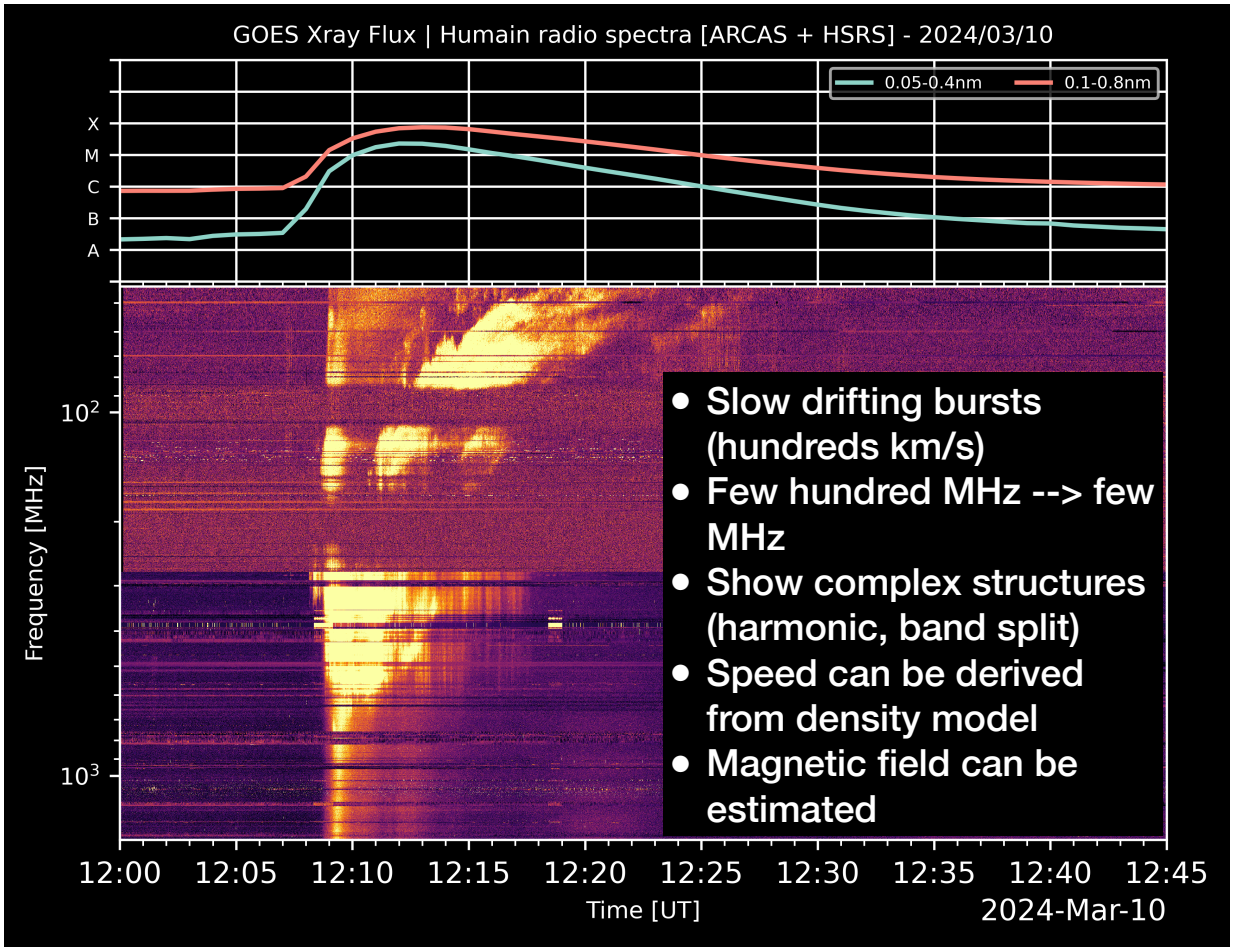
Type I & noise storms

Non flaring radio bursts linked to sunspots



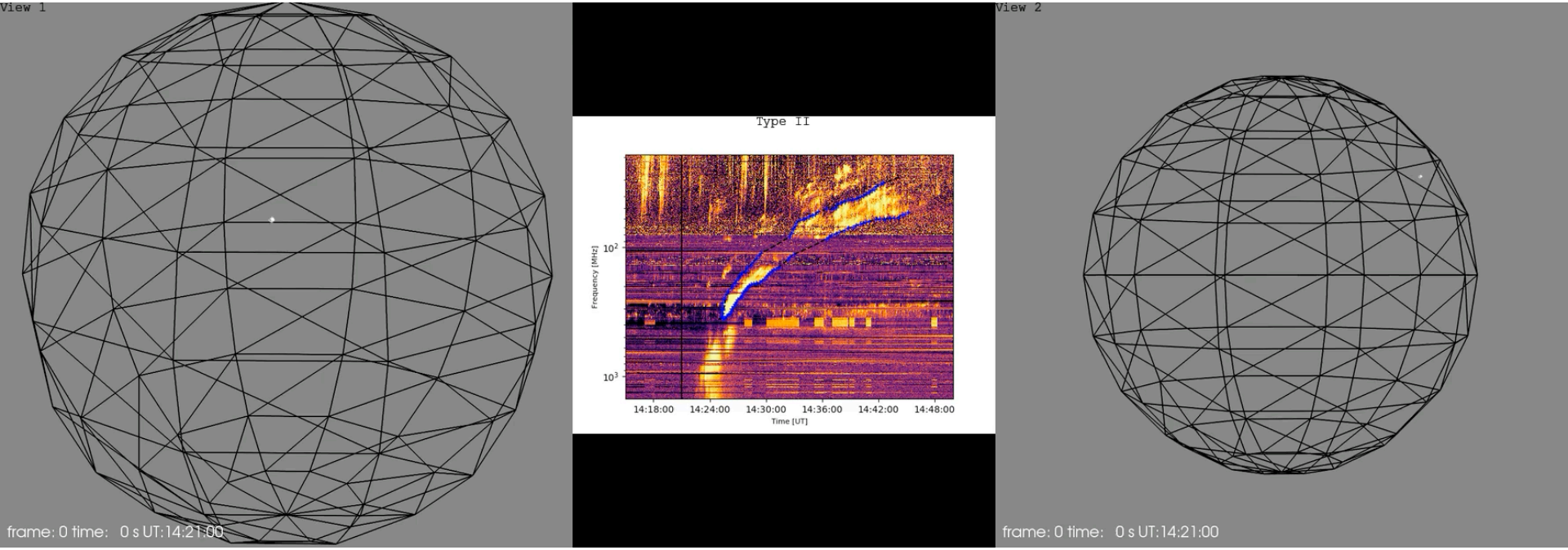
Type II bursts

Linked to shock waves propagating out in the corona



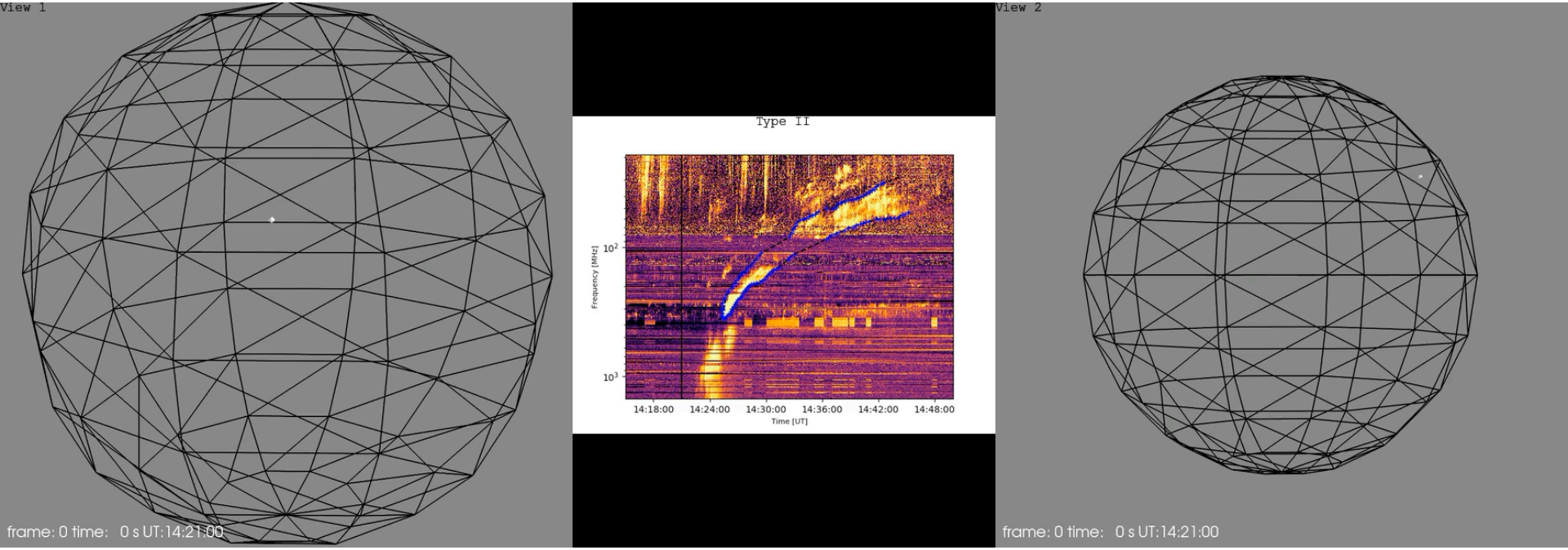
Type II bursts

Linked to shock waves propagating out in the corona



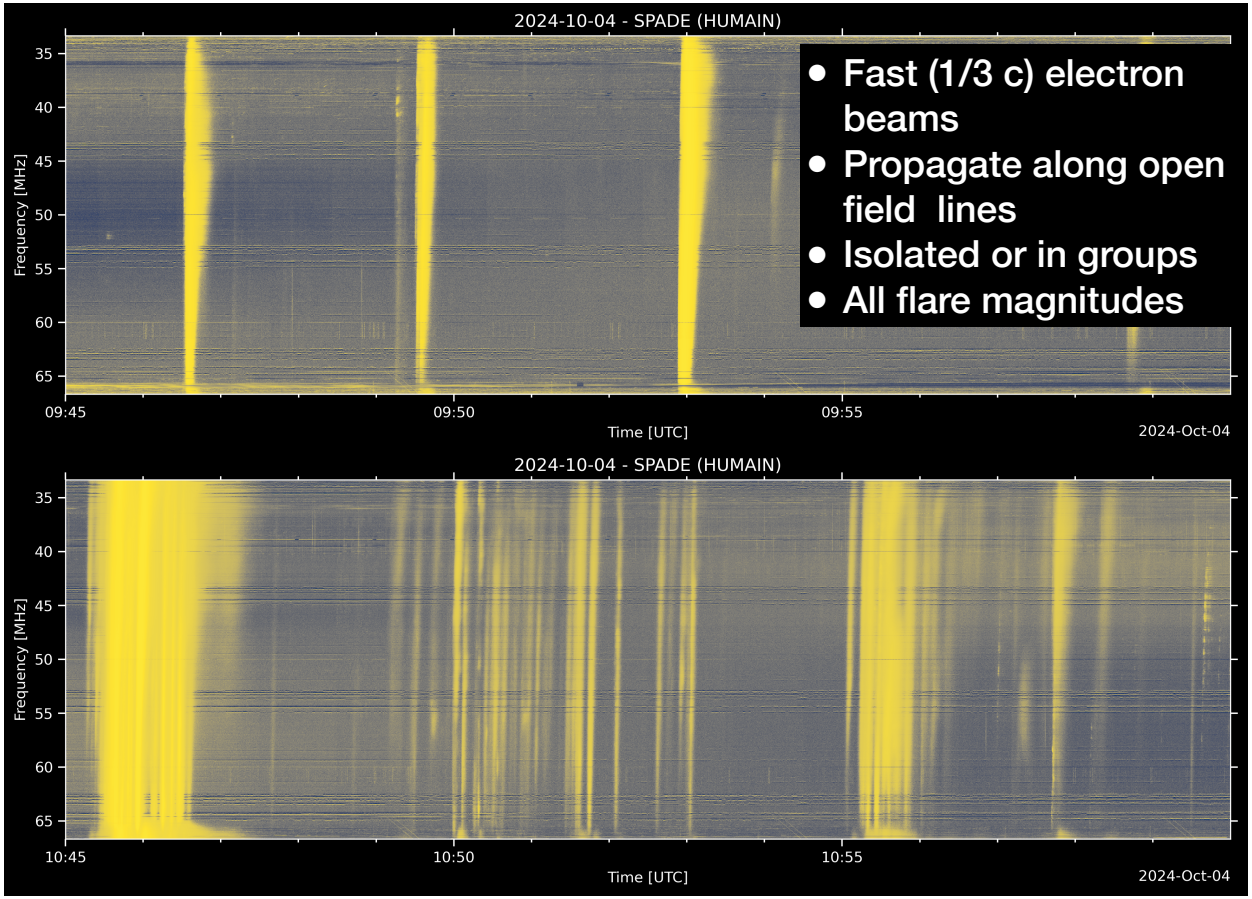
Type II bursts

Linked to shock waves propagating out in the corona



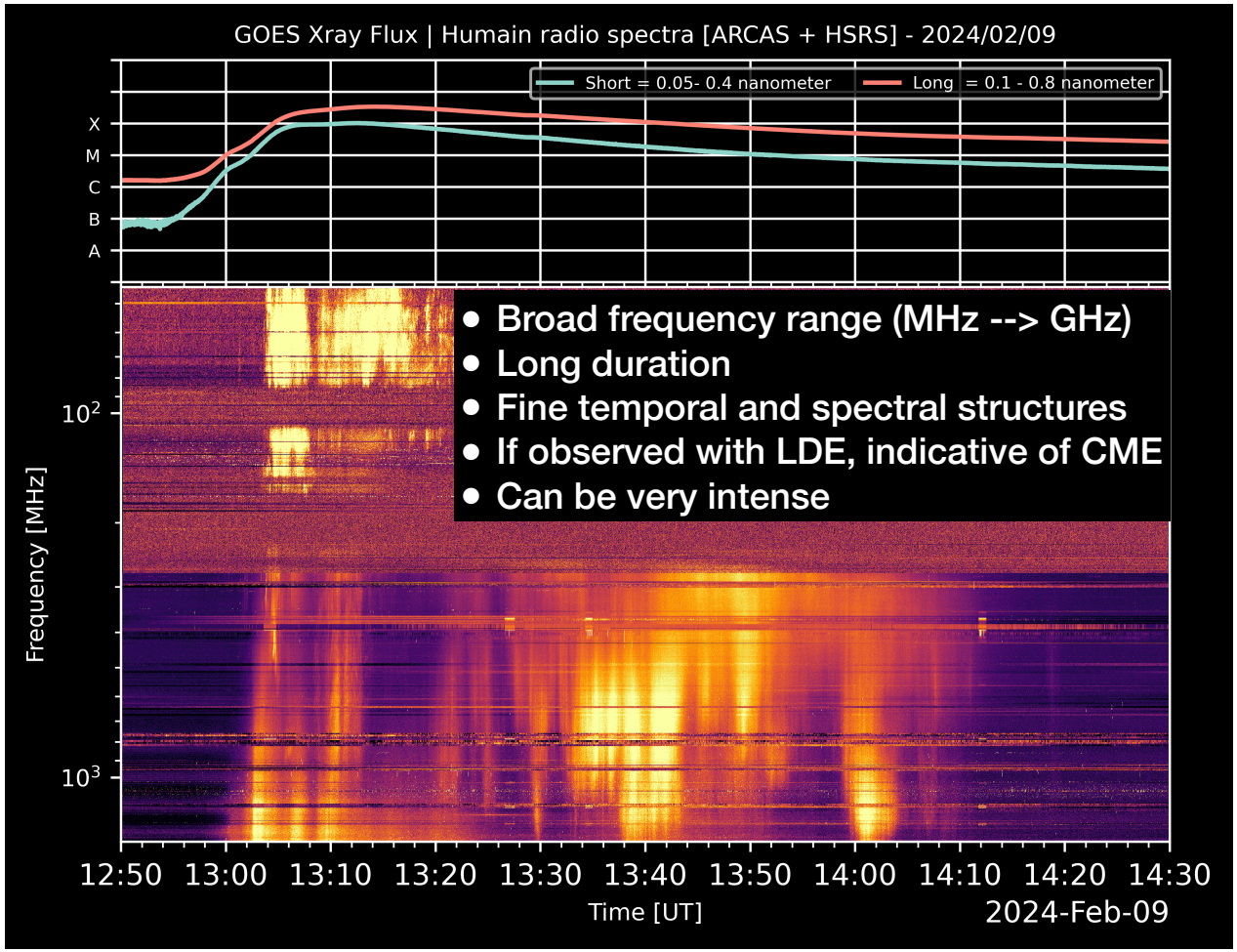
Type III bursts

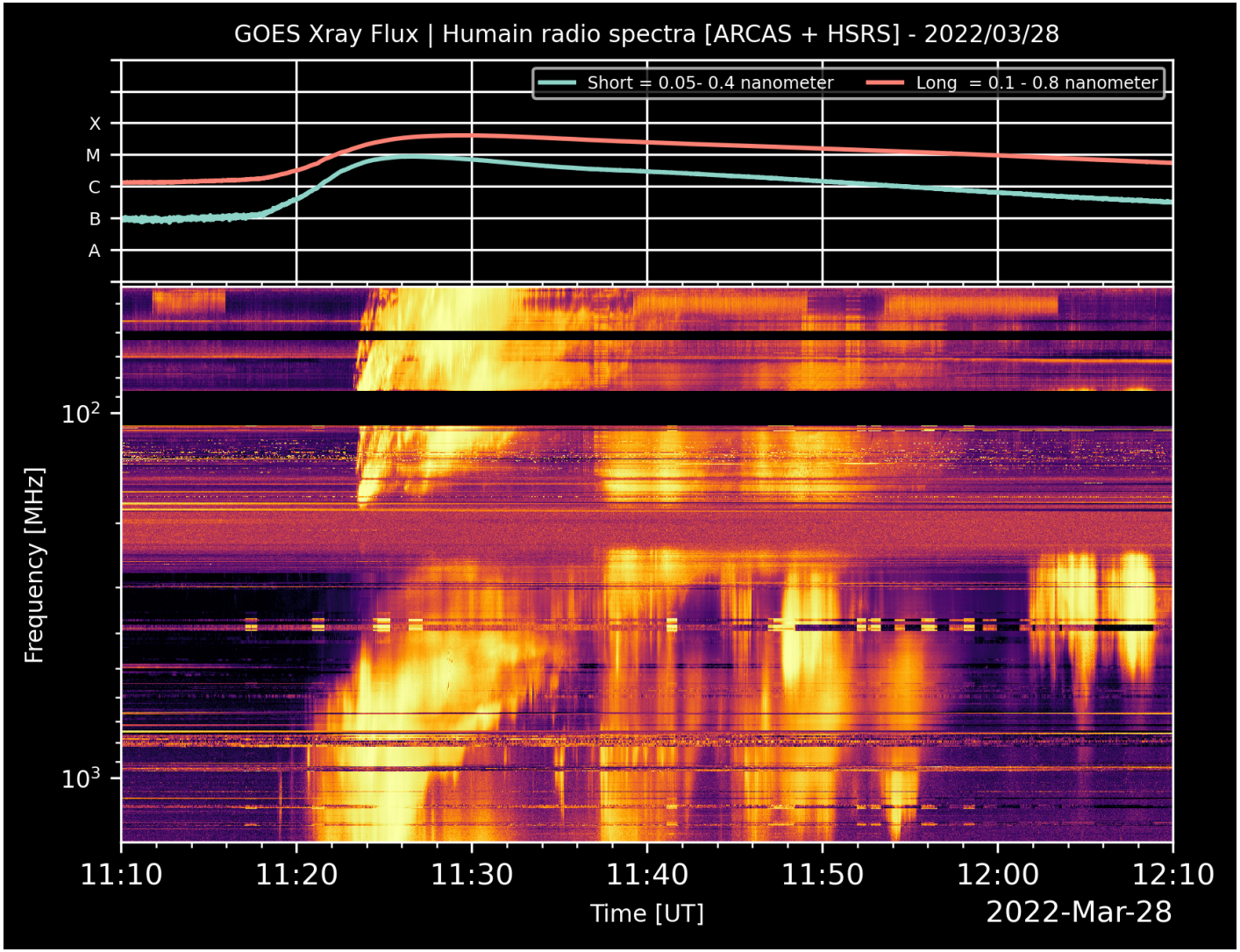
Most frequent type of bursts

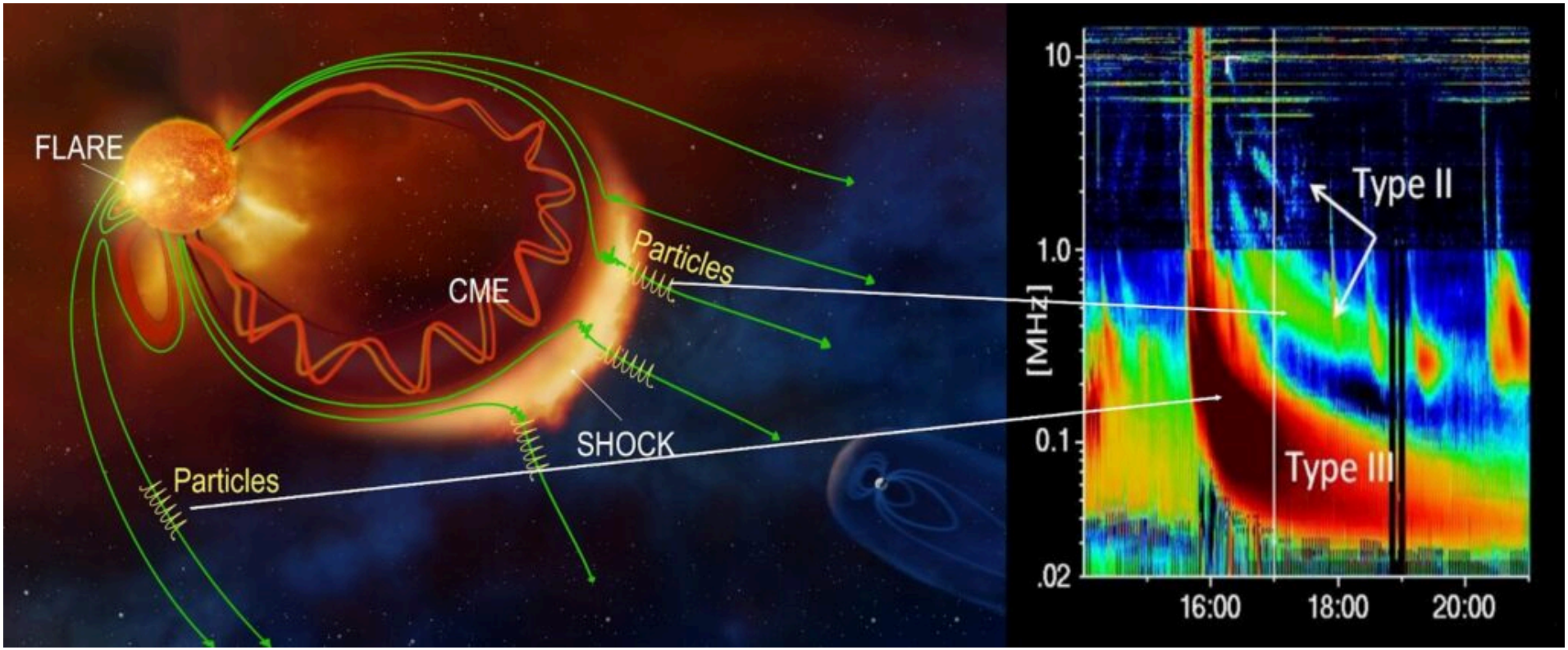


Type IV bursts

Energetic electrons trapped in post-flare loops



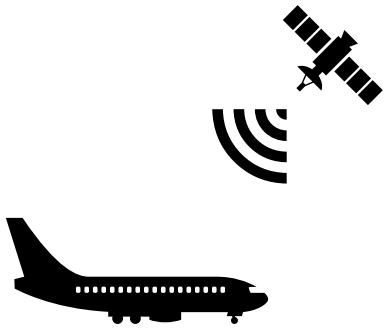

GOES Xray Flux | Humain radio spectra [ARCAS + HSRS] - 2022/03/28
Short = 0.05- 0.4 nanometer
Long = 0.1 - 0.8 nanometer
X
M
C
B
A
Frequency [MHz]
10^2
10^3
11:10
11:20
11:30
11:40
11:50
12:00
12:10
Time [UT]
2022-Mar-28


FLARE
CME
Particles
SHOCK
Particles
10
1.0
0.1
.02
[MHz]
Type II
Type III
16:00
18:00
20:00

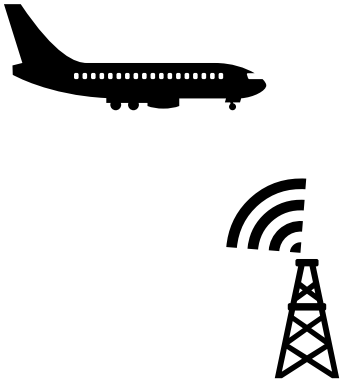
Impact of solar radio bursts



Cell phones



GNSS



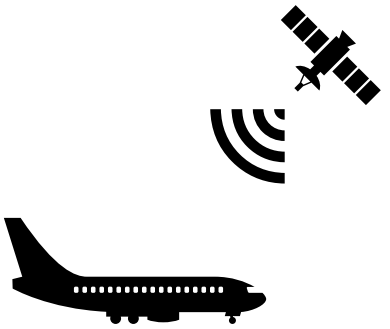
Surveillance radars



Radar altimeters



Cell phones



GNSS





Surveillance radars



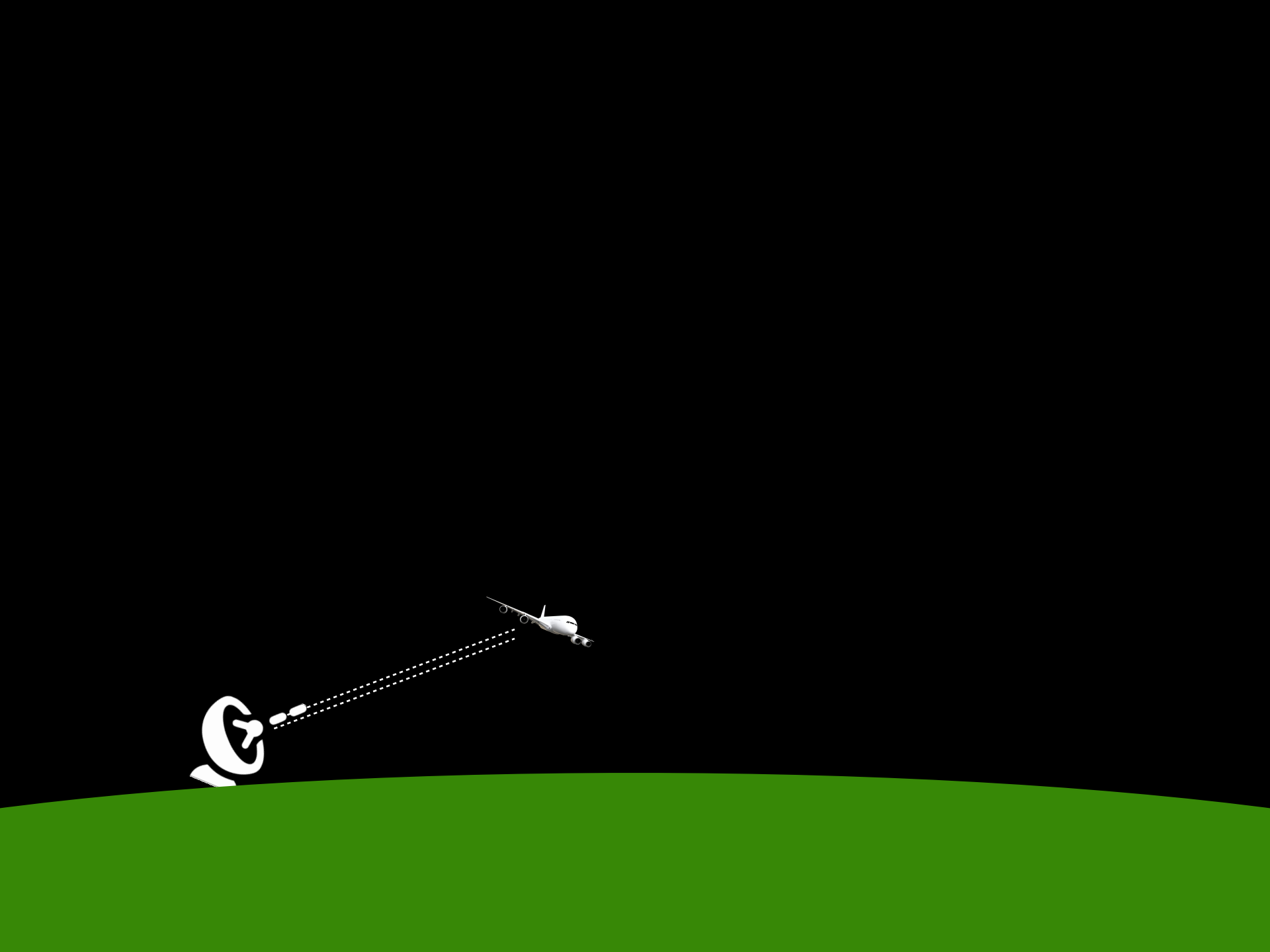
Radar altimeters

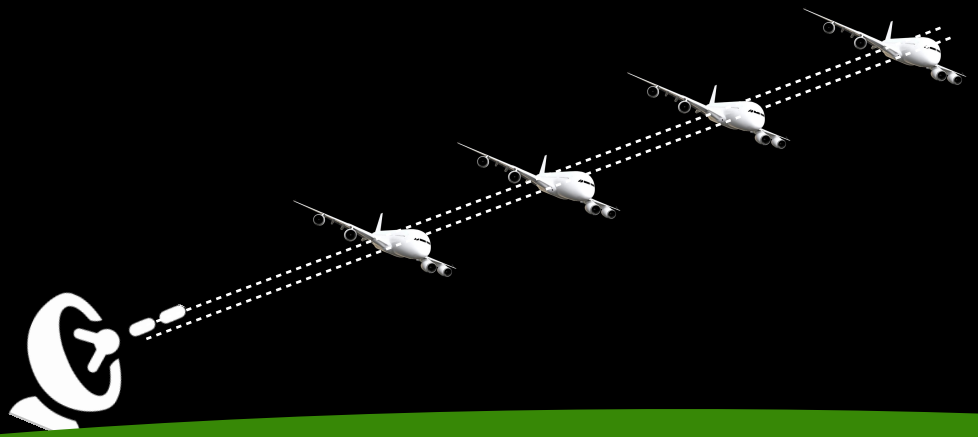
November 4, 2015 - a media storm

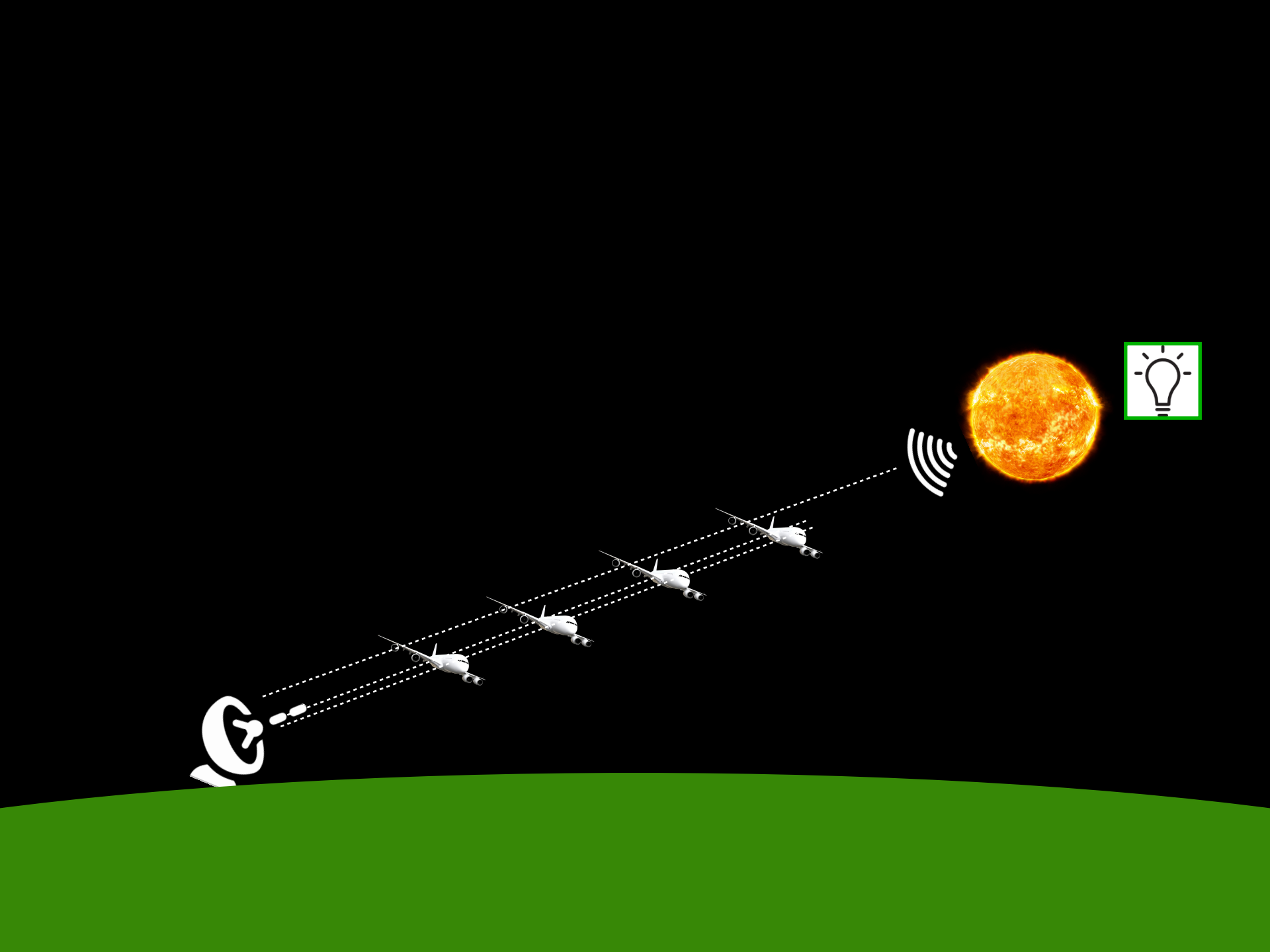
- ATC radars in Sweden suffered severe disturbances between 14:20 UT and 16:00 UT
- Sweden: Partial closure of air space for an hour (Incoming flights were deviated, no departures allowed)
- Minor disturbances in Norway, Belgium
- Geomagnetic storm was initially considered as the source of disturbances (media)



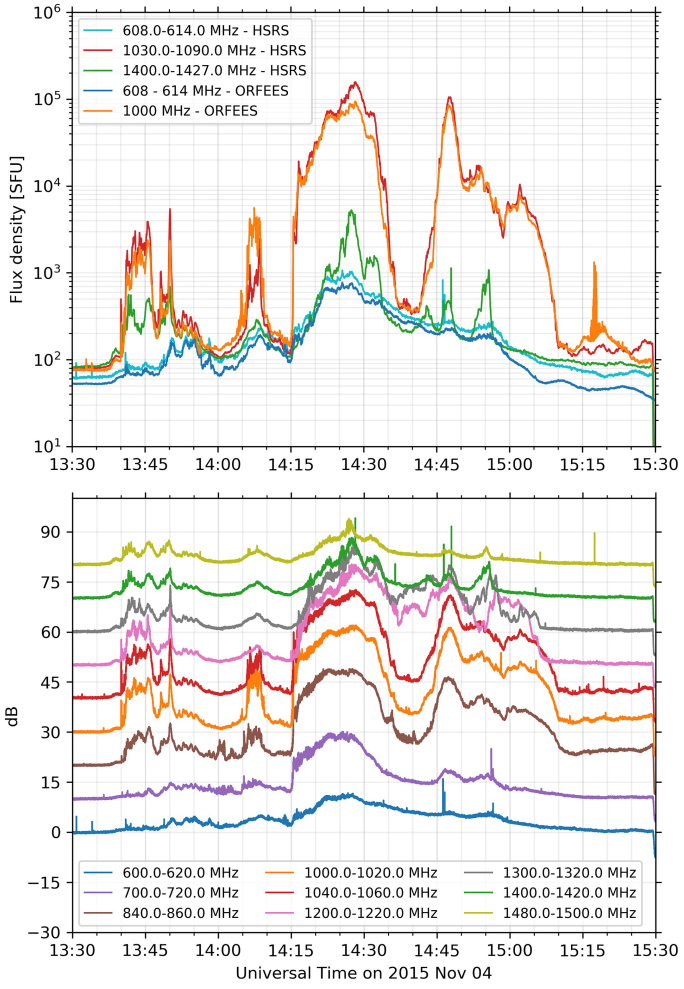




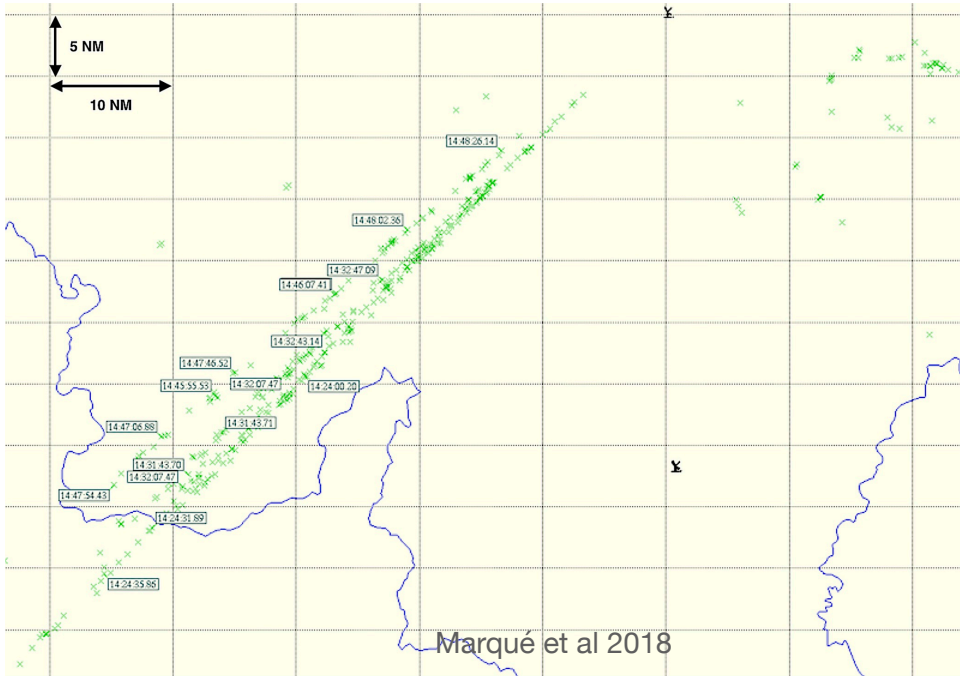


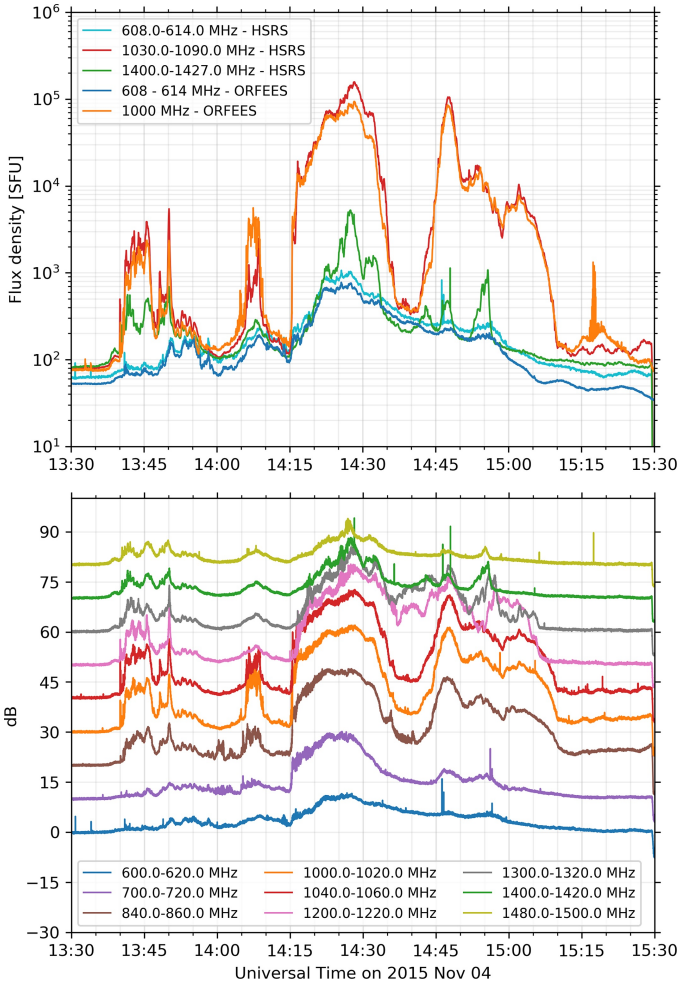


Impact on radar systems

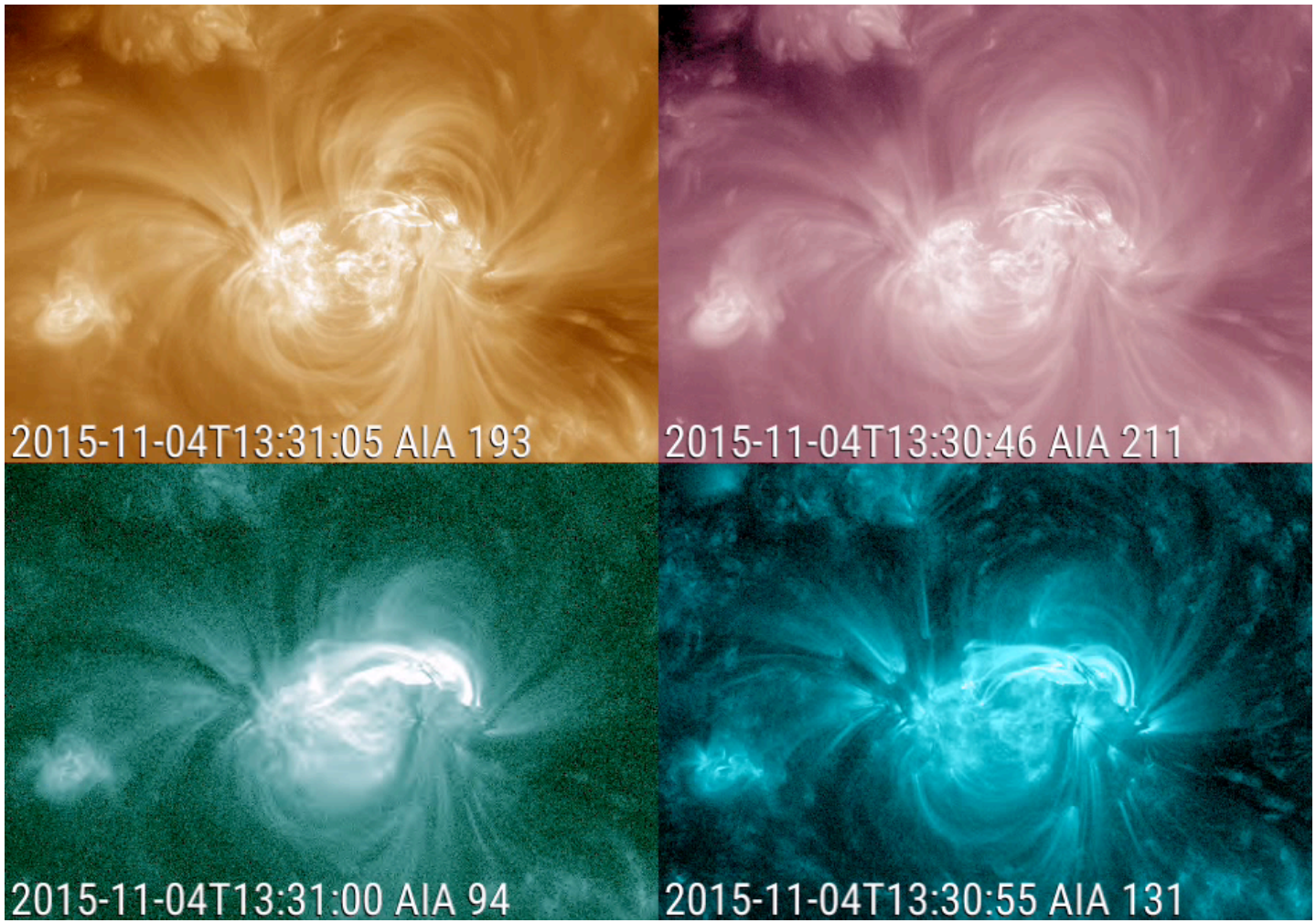


Impact on radar systems



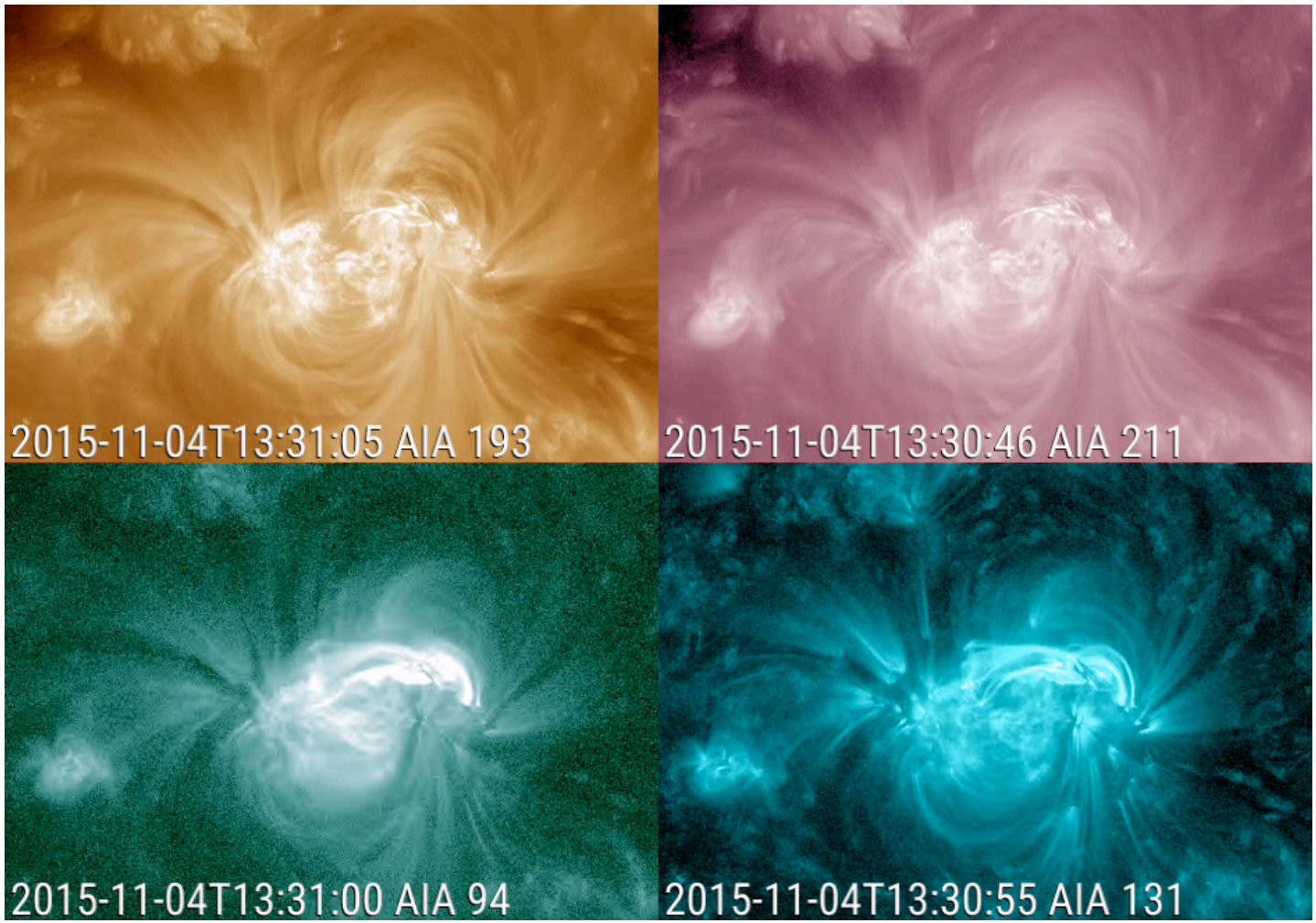


Solar event



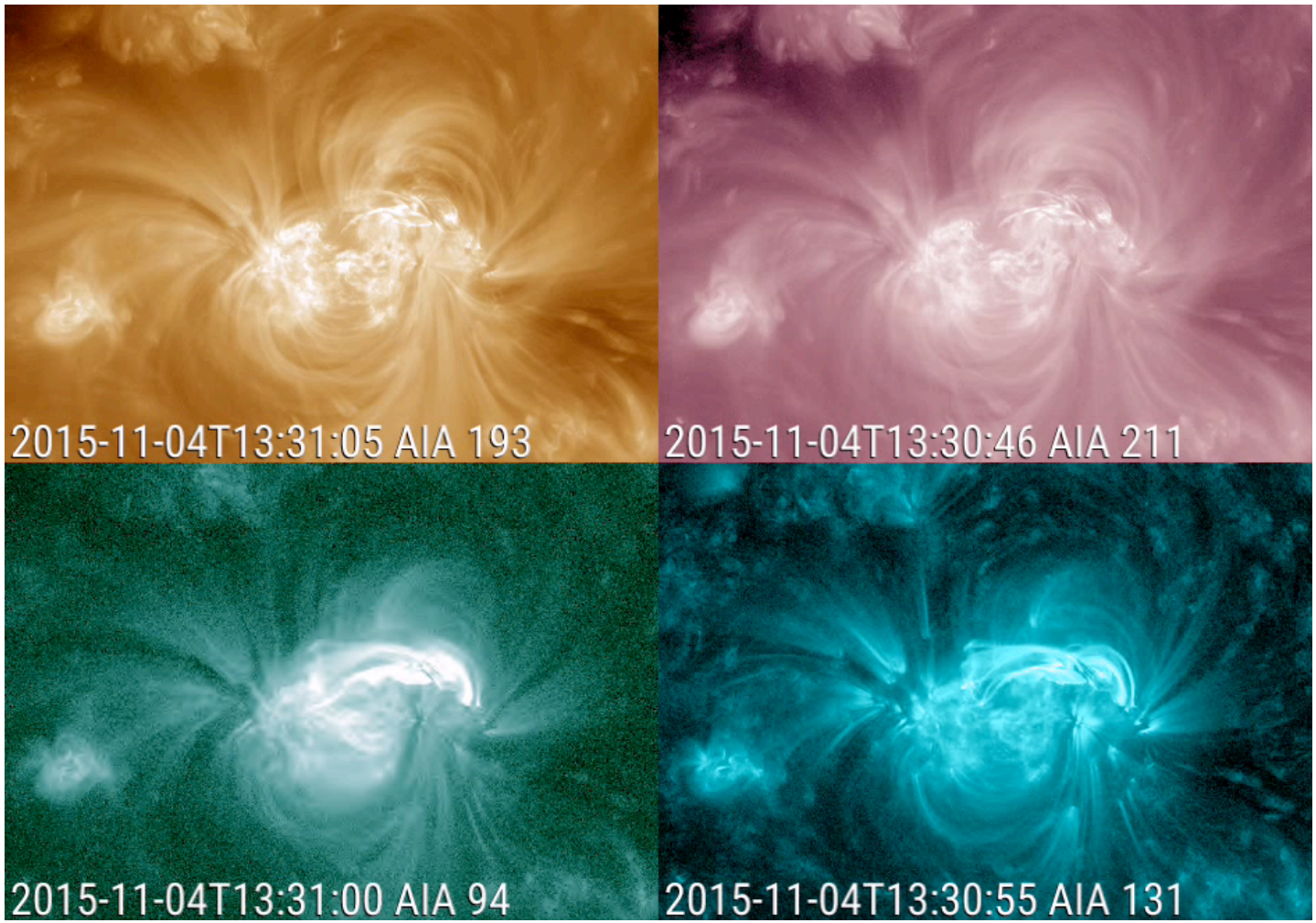
M3.7 flare - peak at 13:52 UT

Solar event



M3.7 flare - peak at 13:52 UT

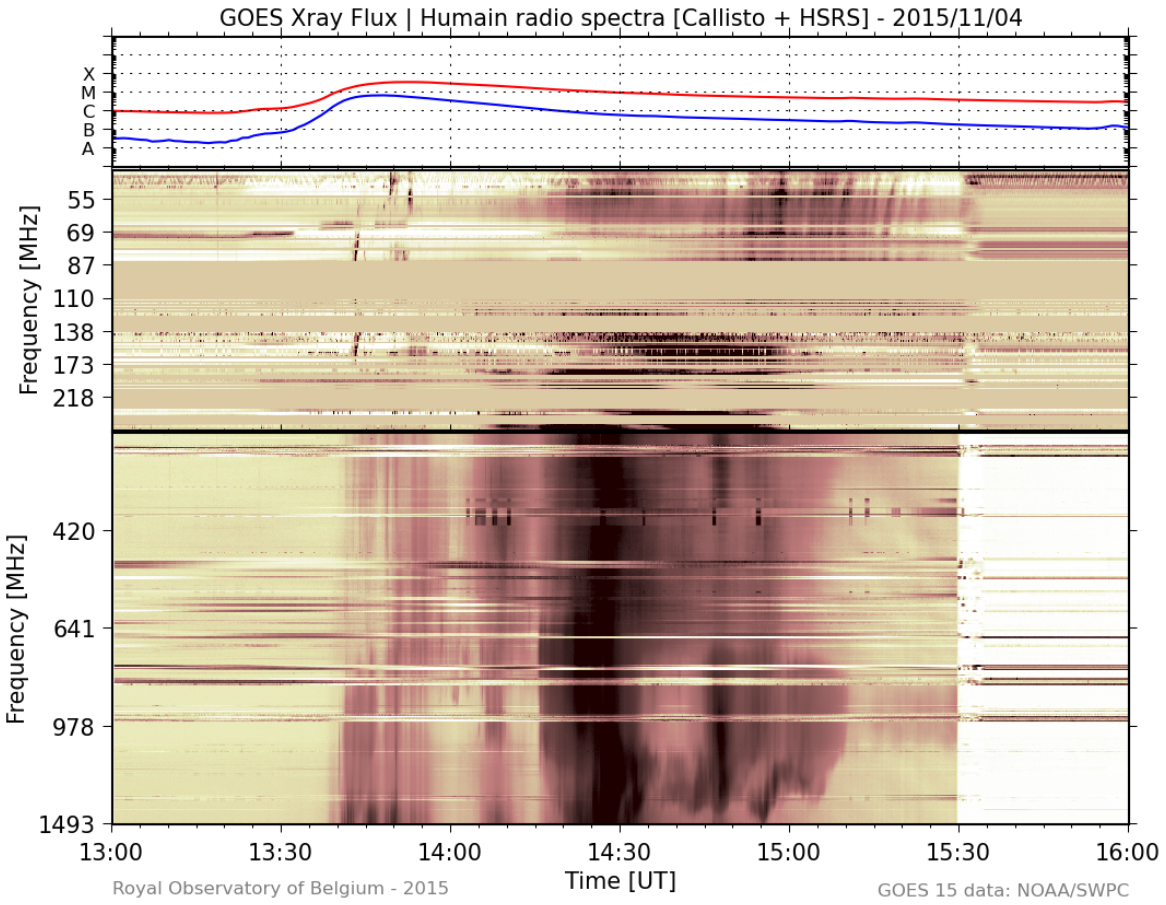
Solar event



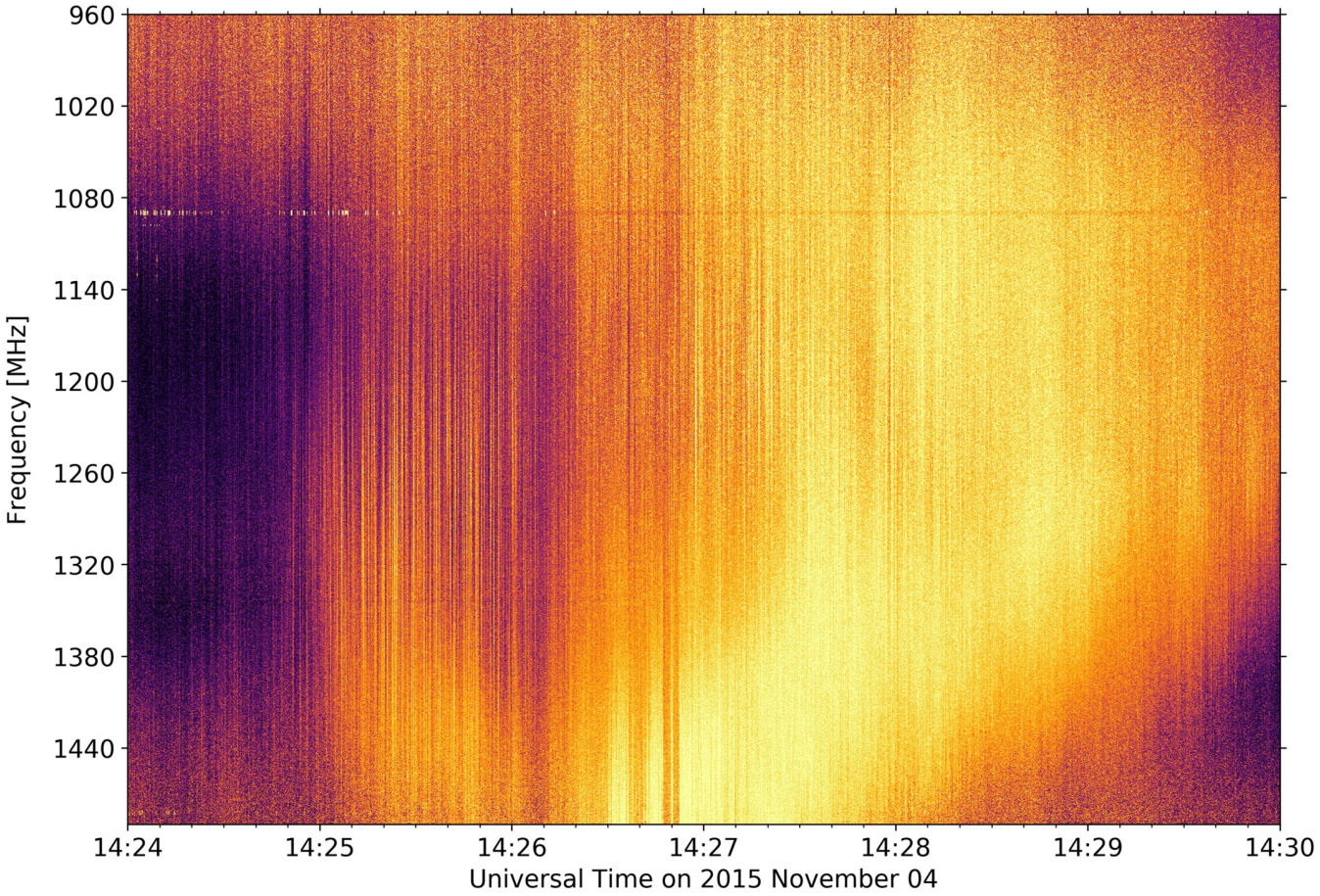
M3.7 flare - peak at 13:52 UT

In Humain

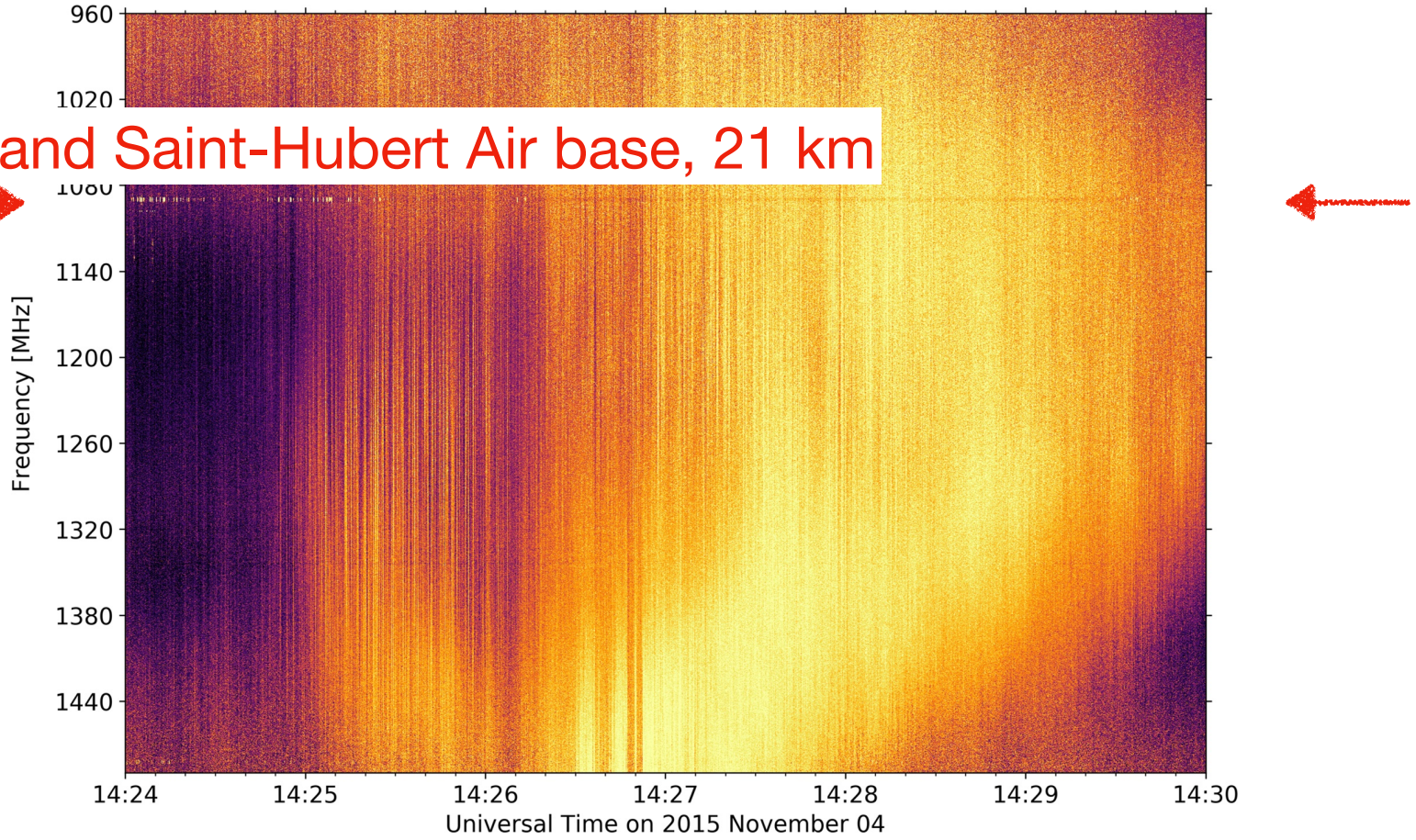




https://www.sidc.be/humain


960
1020
1080
1140
1200
1260
1320
1380
1440
Frequency [MHz]
14:24
14:25
14:26
14:27
14:28
14:29
14:30
Universal Time on 2015 November 04

Radar band Saint-Hubert Air base, 21 km



	Frequency range	Properties	Impact
Noise storms / Type I	HF, VHF	can be intense, long duration (days), frequent	**Possible**
Type II	HF, VHF	last few minutes, rare	**No**
Type III	HF, VHF	Intense, short duration, very frequent	**No**
Type IV	HF, VHF, UHF	Intense, long duration, broadband	**Yes**

Links

Where to find solar radio data?

Bursts & radio events	https://www.swpc.noaa.gov/products/solar-and-geophysical-event-reports https://www.ncei.noaa.gov/products/space-weather/partners/swpc-products-and-data
Recent radio flux	https://services.swpc.noaa.gov/text/solar_radio_flux.txt
F10.7	https://spaceweather.gc.ca/forecast-prevision/solar-solaire/solarflux/sx-5-en.php
Humain data	https://www.sidc.be/humain 🇧🇪