CALLISTO Spectrometer and SDR Replacement as a Space Weather Tool

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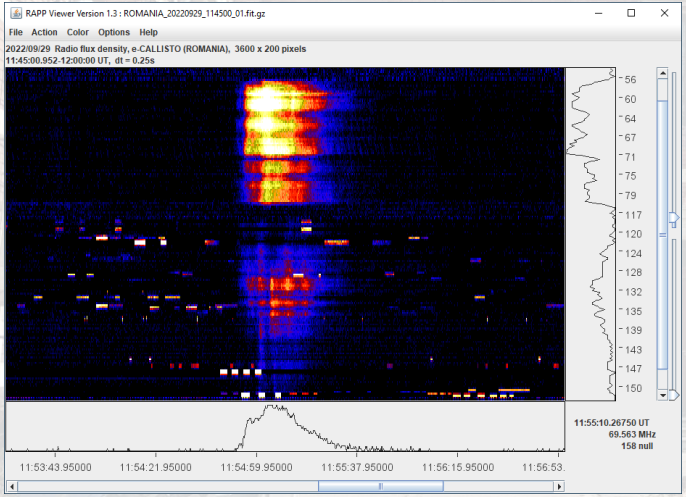
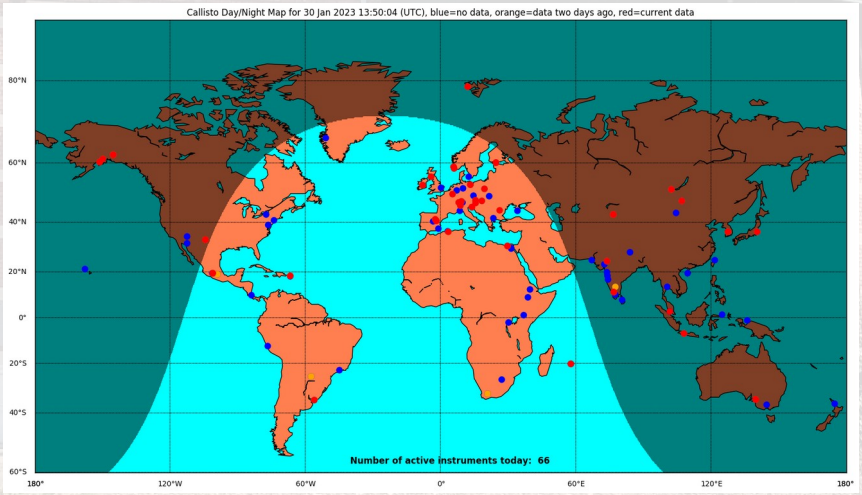
Introduction

SPACE WEATHER as a result of the solar activity include the radio quiet Sun flux and bursts
CALLISTO = frequency agile spectrometer, instrument developed by Christian Monstein for detecting and analyzing solar radio bursts
e-callisto.org = international network of CALLISTO instruments deployed around the globe, 24/7 coverage





CALLISTO

- based on Philips analog TV tuner
- high sensitivity
- 8 bit ADC
- medium frequency resolution 200-400 channels
- 0.25 s time resolution
- 45-830 MHz bandwidth
- low cost (550$)
- free complete dedicated software package
- research, Universities, students

e-callisto.org
solar.astro.ro/radiodata.html
romania_events2.html

REPLACEMENT searching

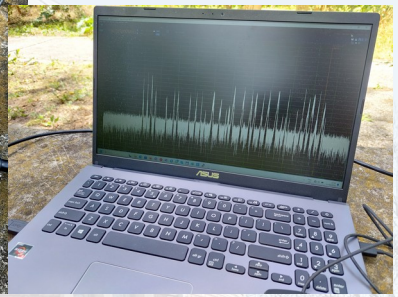
Spectrum Analyzers

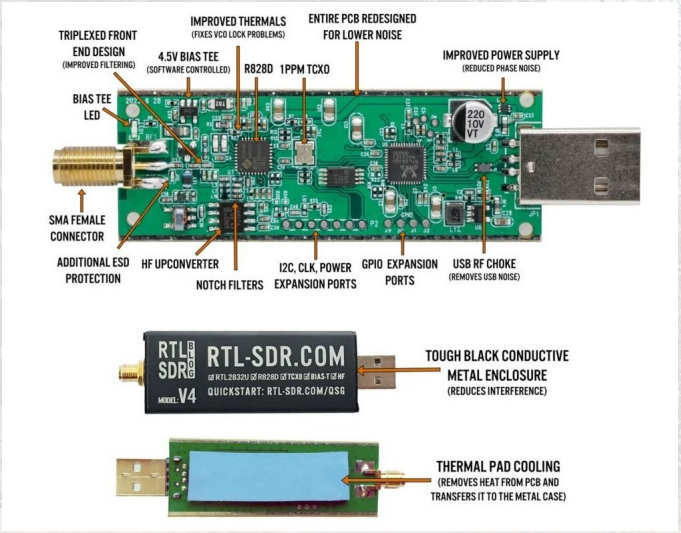
- high performance
- medium to high cost
- many characteristics and functions we don't need
- Open Source / proprietary software
- no dedicated RA software

Software Defined Radio

- wide range of characteristics
- wide range of prices: 30$ – 25.000$
- some RA software available
- Open Source / proprietary software

List of SDR - Wikipedia



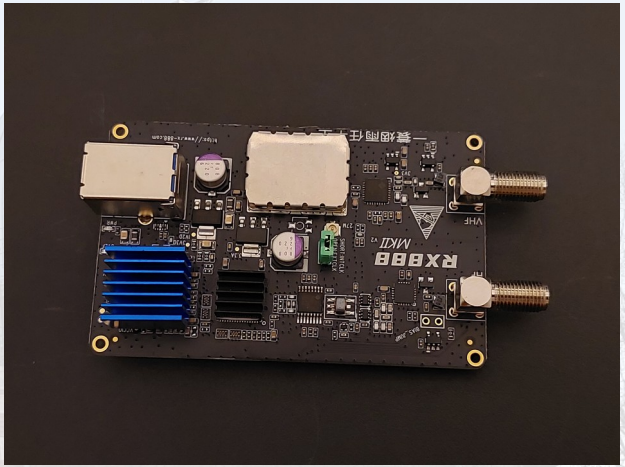


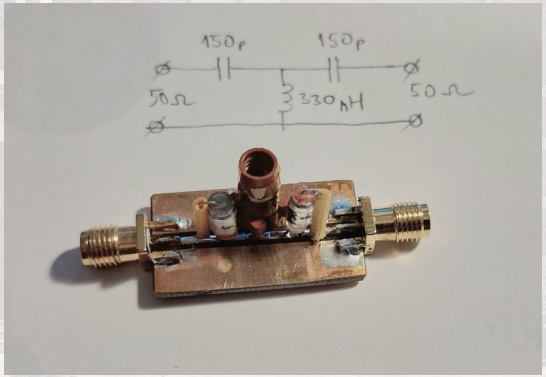
RX-888 MKII Software Defined Radio

- direct sampling, 16 bit ADC
- high sensitivity
- high dynamic range
- 65 MHz bandwidth (130 MHz, overclocking up to 140 MHz)
- internal variable RF amplifier+atenuator
- configurable time resolution
- low cost (200$)
- Open Source software
- *dedicated Linux software developed by Nathan Towne*

RX-888 MKII prerequisites

- thermal management: small radiators on main chips and an external fan
- antenna = Tri-band HF radioamateur
- HPF filter design, build and test
- installing, testing and improvements of the *Nathan Towne software suite* (from alpha to beta phases of development)

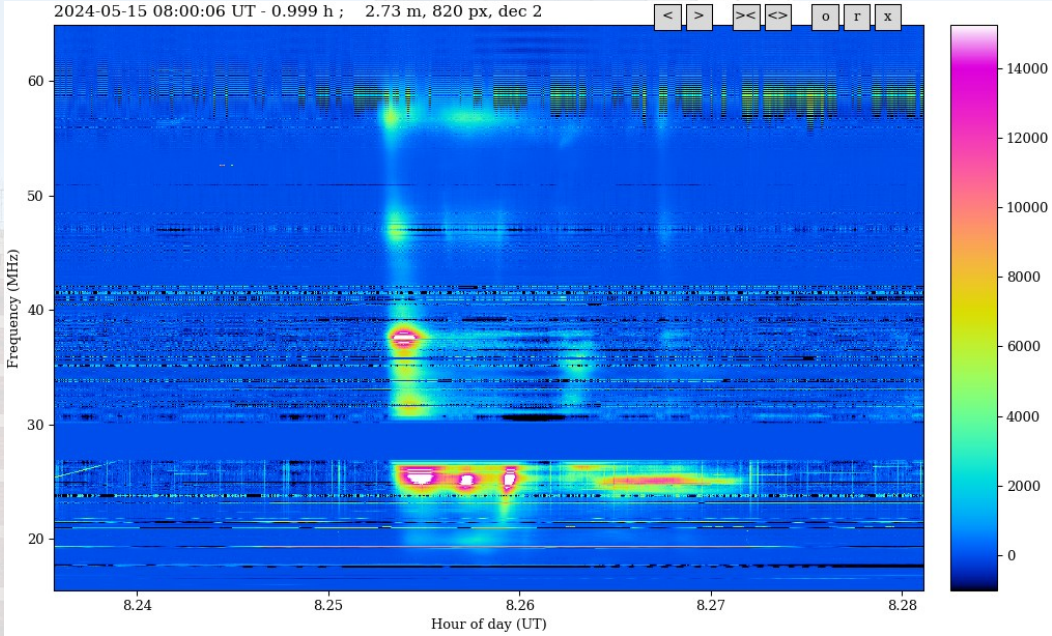




First detection of a solar radio burst

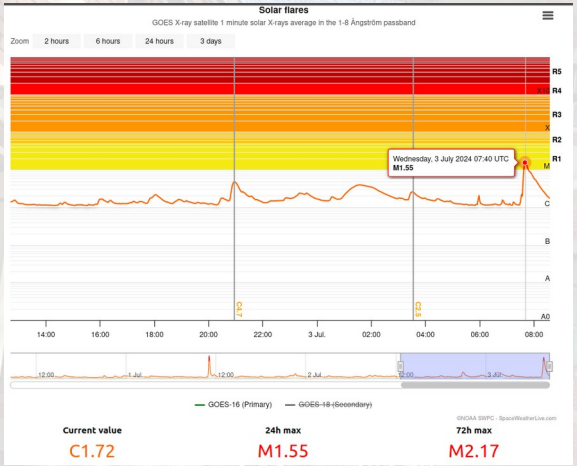
- ***rx2fits*** software generate and save FITS files according to XML config files for the observatory (location, instrument, observer s.o.) and observation (bandwidth, integration time, amplifier and attenuator levels s.o.)
- ***fitsview.py*** for view, analyze and save pictures
- functions: zoom in and background subtracted

Type III radio burst, detected in 15th of may, 2024 at Bucharest

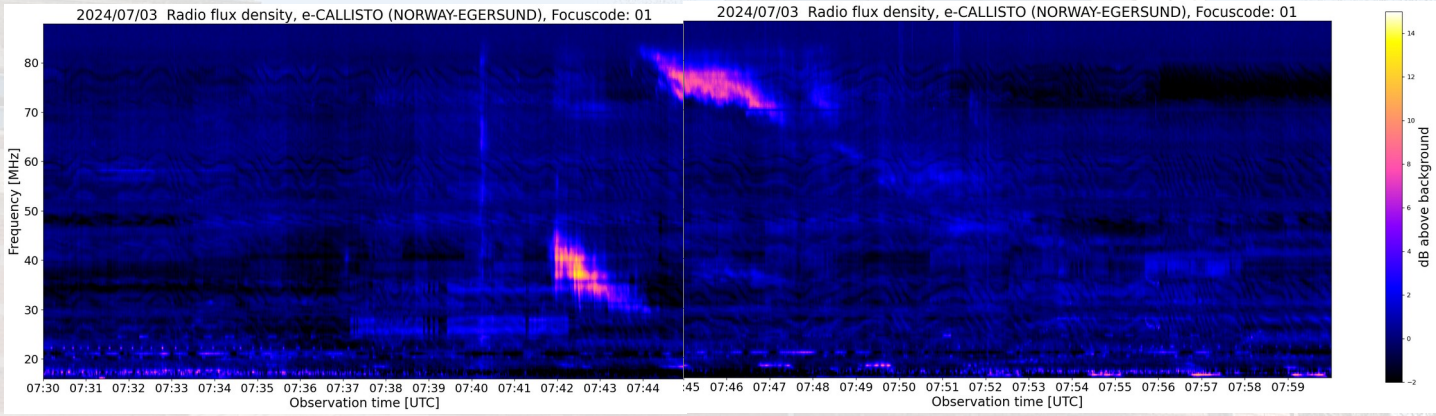


Event analysis example

3th of July 2024, 7:40 M1.55 flare + CME – > Type II radio burst

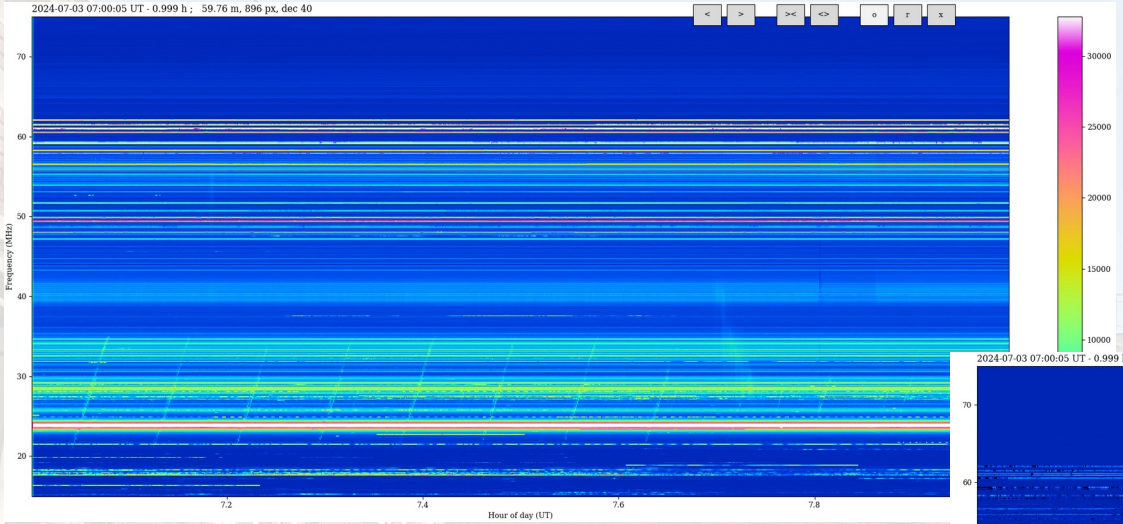


GOES X-ray flux from spaceweatherlive.com

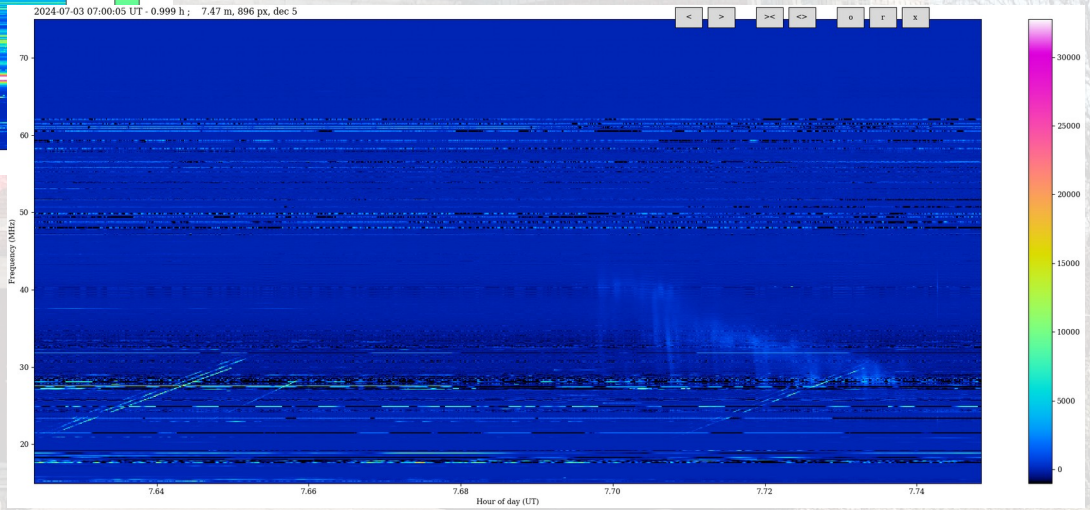


CALLISTO spectrograms from Norway Egersund (wide band dipole active antenna, 20dB, up converter)

Event analysis example

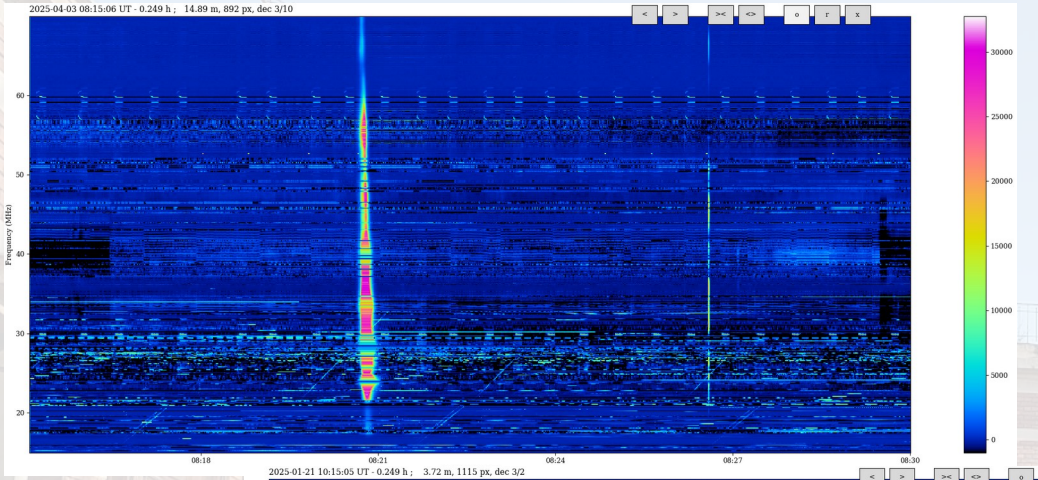


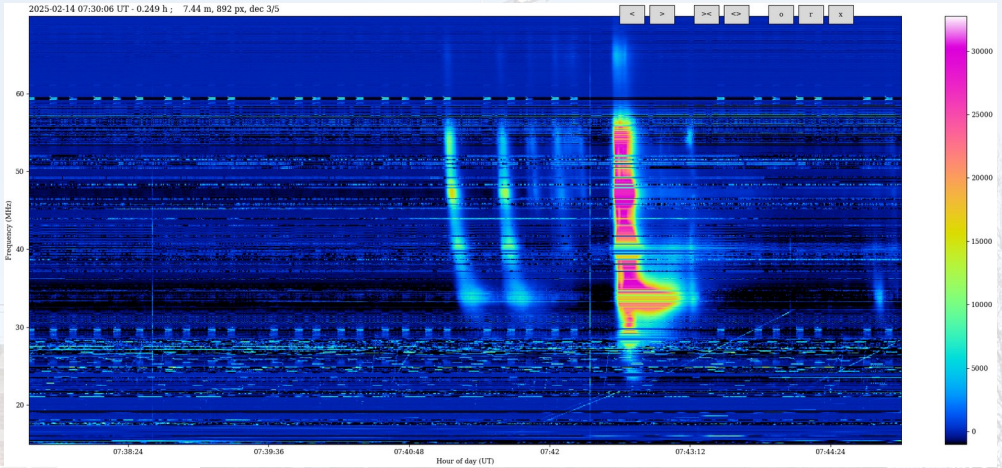
- 1 hour FITS file
- radio spectrum is crowded with communication/broadcasting
- over the horizon radar signals visible
- faint patterns at the time of the flare

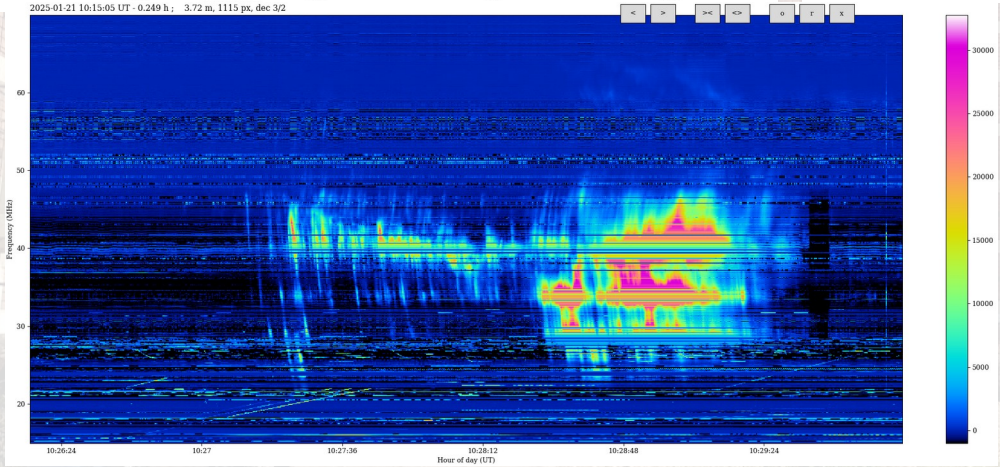


- zoom in, background subtracted
- “herring bone” pattern visible
- slow frequency drift
- 2nd harmonic is not visible
- high gain antenna is needed

Type III radio bursts examples

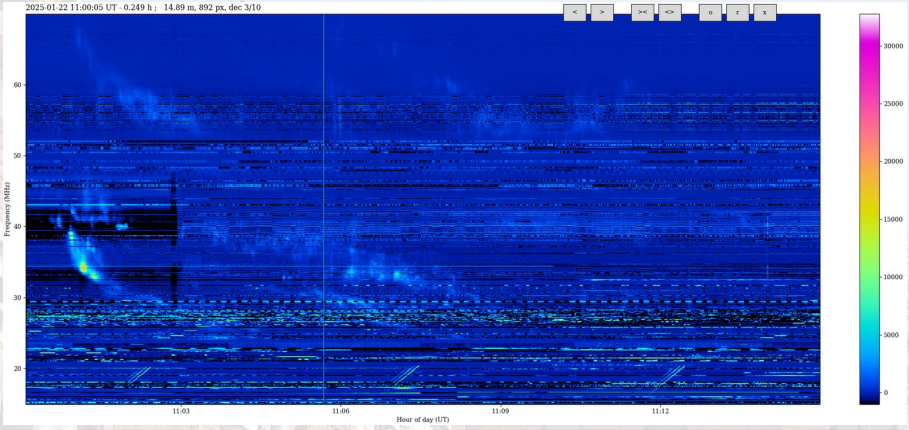


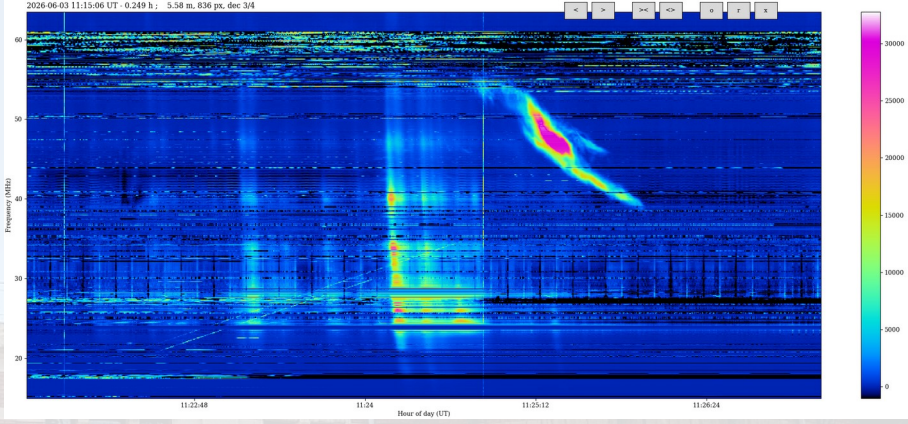




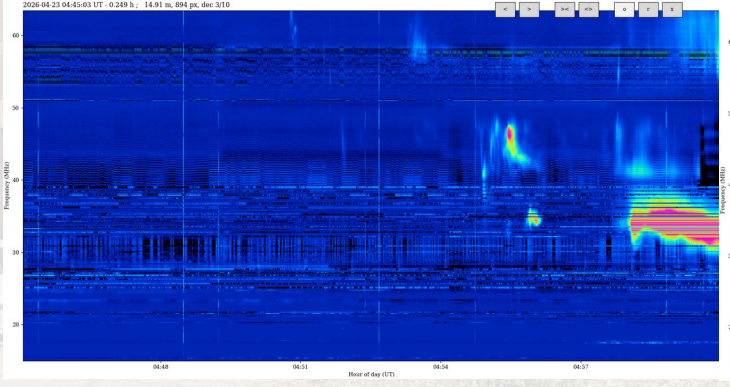
- most frequent bursts
- narrow bursts associated with flares
- fast frequency drift
- single or in groups
- herringbone structure
- followed by Type II burst if CME

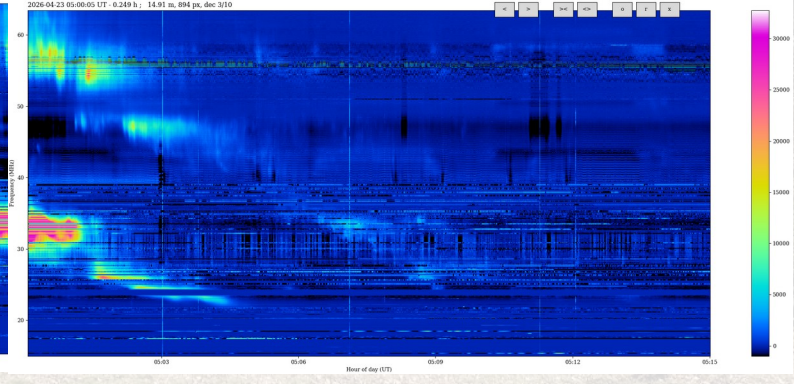
Type II radio bursts examples



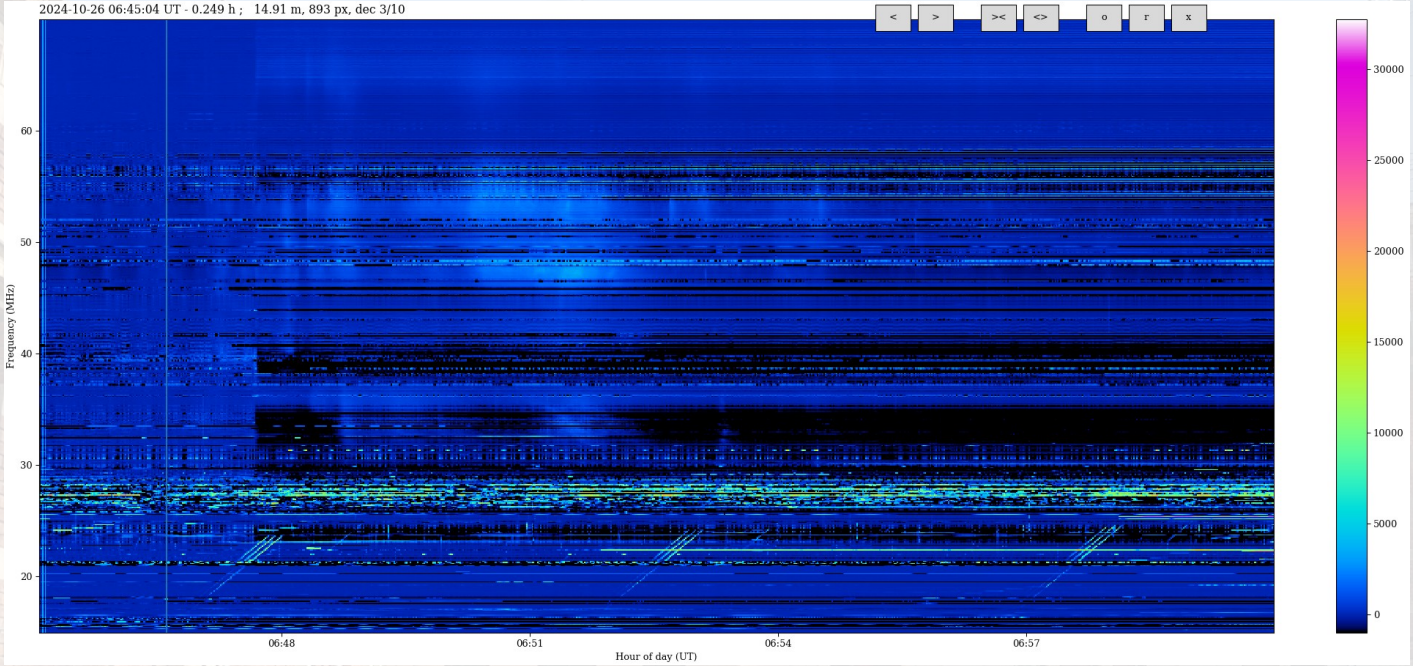


- shock wave from CME
- non-relativistic electrons
- slow frequency drift
- fundamental and second harmonic frequencies
- herringbone fine structure



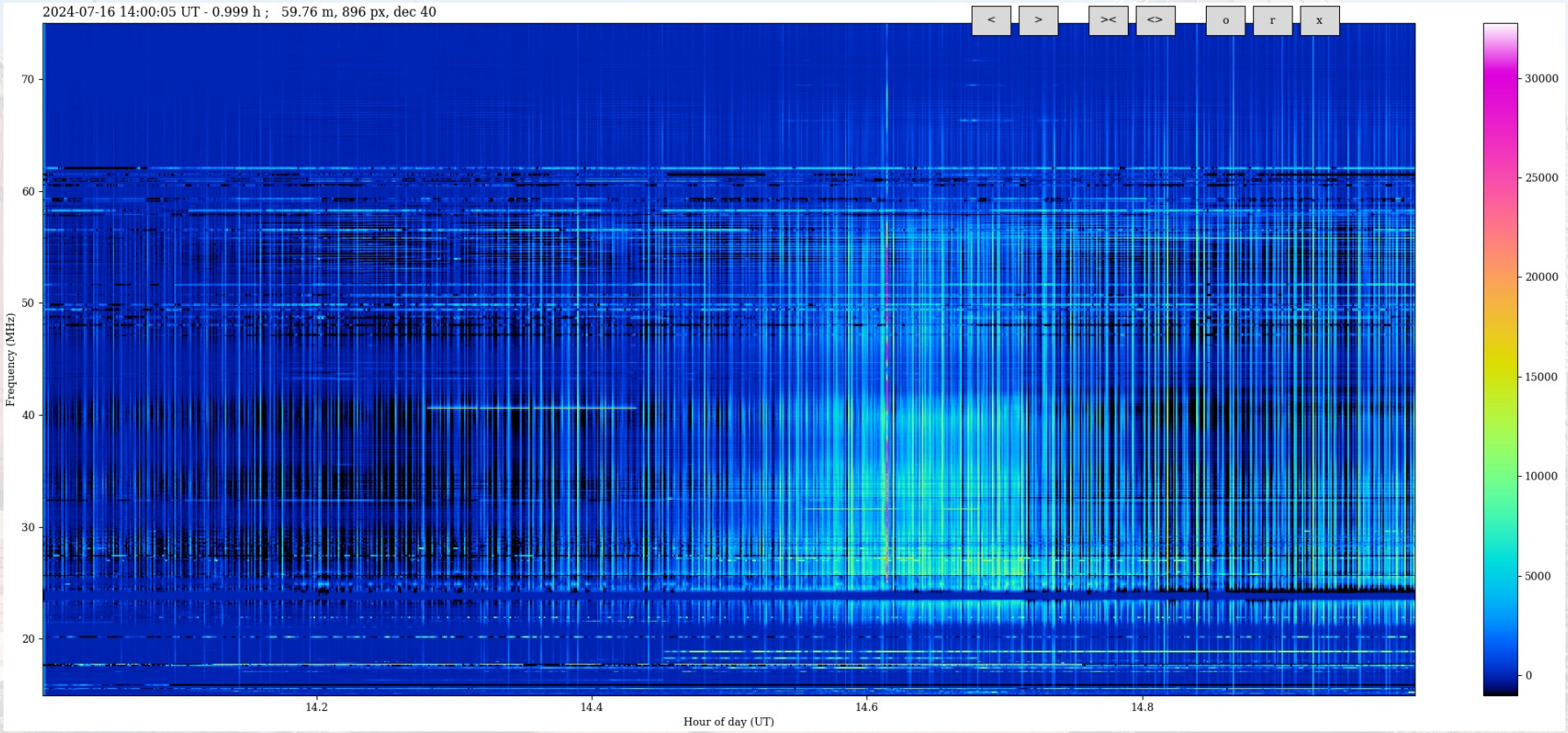


Type IV radio bursts example

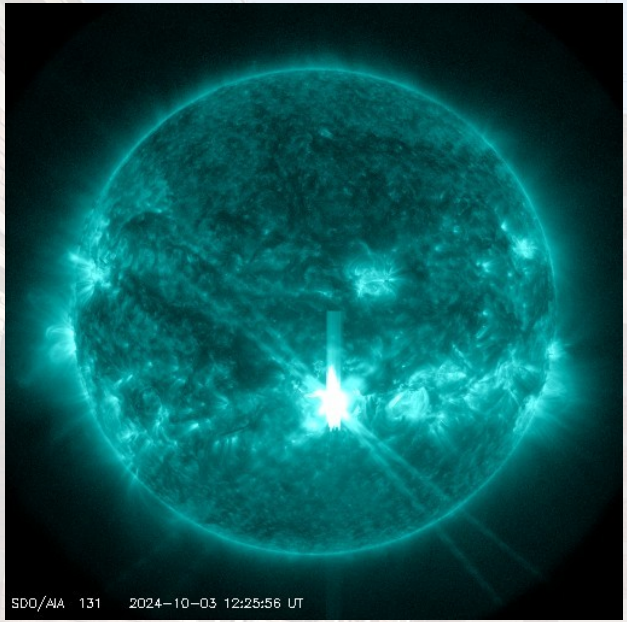


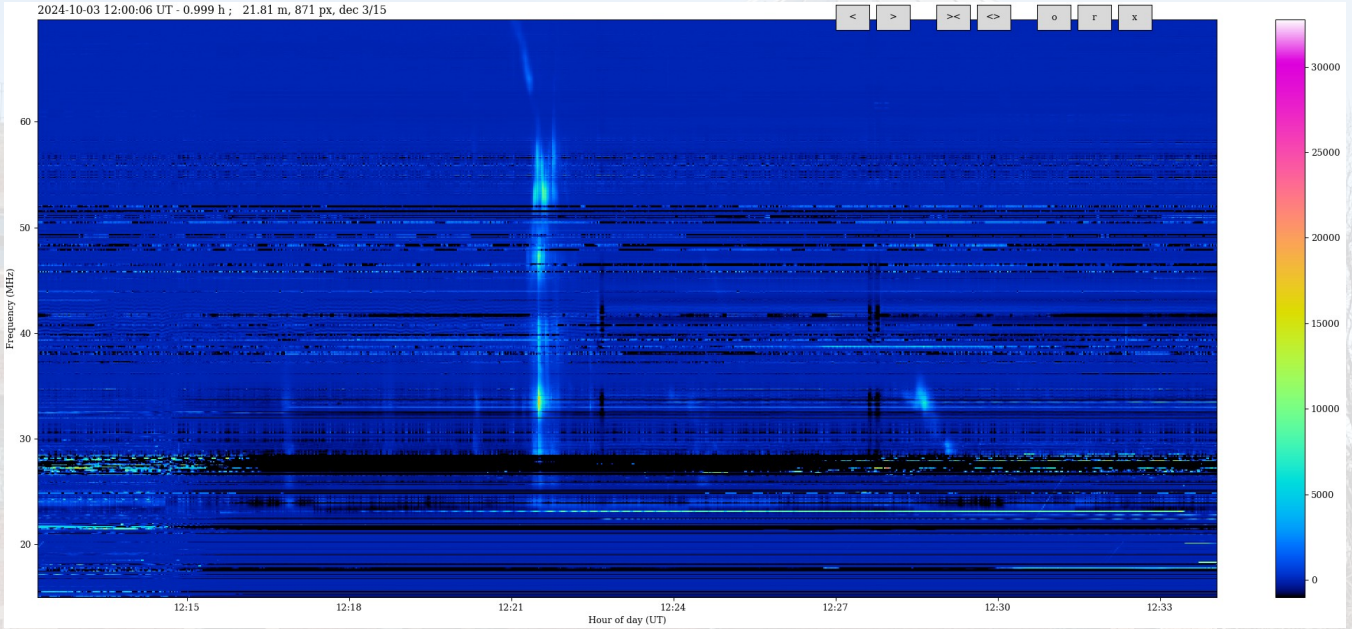
- spikes of broad-band continuum emission that include a few distinct sub-types associated with different phenomena and different emission mechanisms

Terrestrial thunderstorm



HF radio frequencies blackout after an X9.05 flare, Type III and II bursts

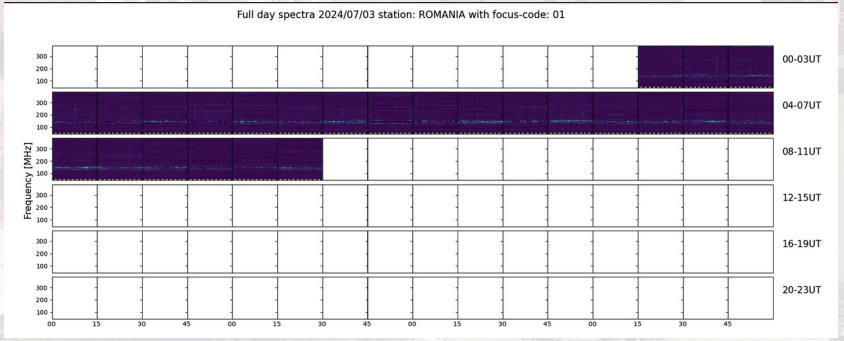




The class X 9.05 flare: 03.10.2025-12:18 UTC in AR3842, was followed by a CME → more M, X class flares → G4 geomagnetic storm 10-11 oct → aurora visible in ROMANIA

Further development

- high gain, sky noise delimited antenna (LOFAR/LBA)
- radio quiet location
- double polarization system
- software improvements
- automatic image conversion - done
- online observations database
- neural network automatic detection
- automatic alert system



THANK YOU!

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