

# Radio observations at Nançay in support of Solar Orbiter and Parker Solar Probe

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# Solar observations at the Nançay radio observatory

## Overview



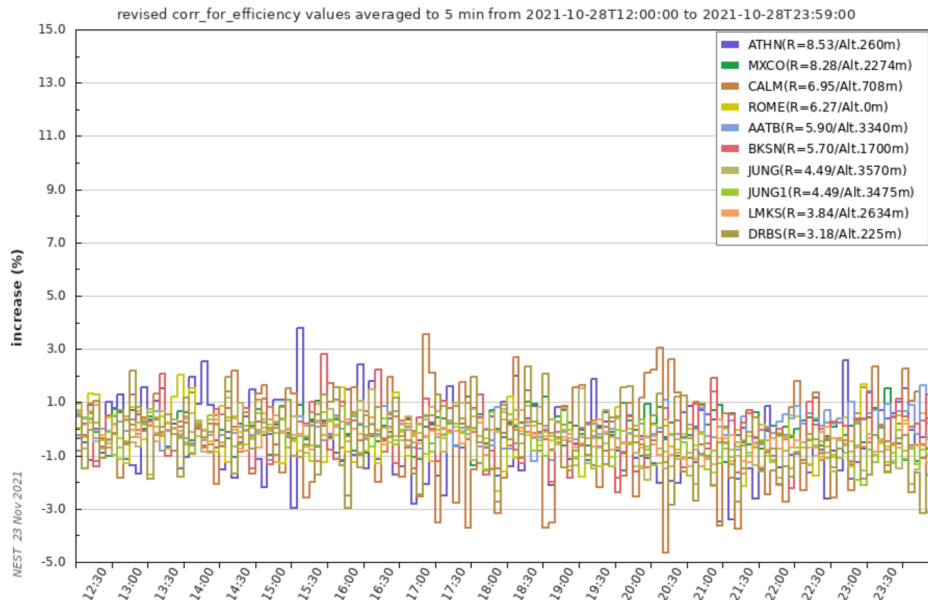
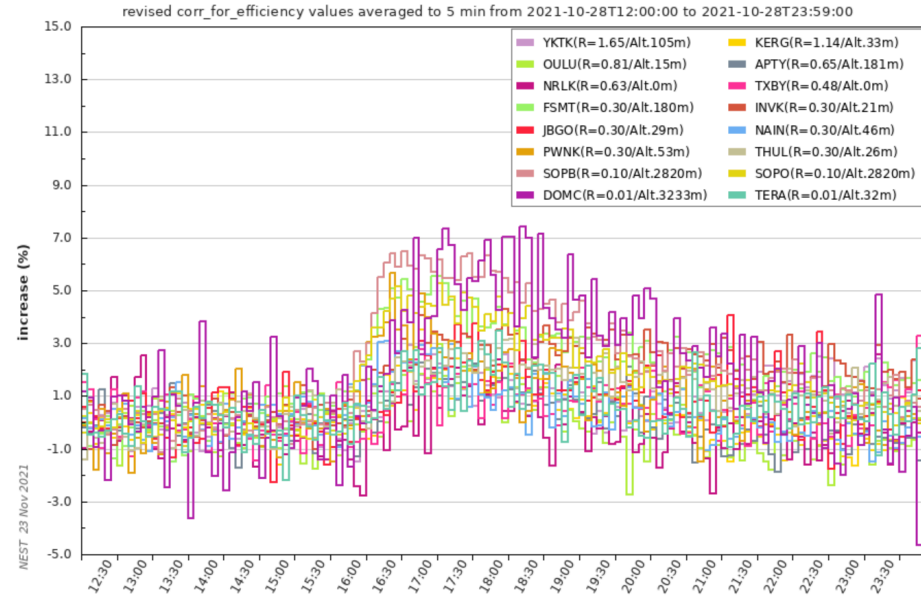
- Continuous monitoring, ~8:30-15:30 UT, 1 GHz – 10 MHz (ionosphere permitting)
- A unique combination of complementary instruments
  - Radioheliograph (NRH; imaging up to 10 frequencies, 150-450 MHz),
  - Spectrography low/middle corona (<0.5 solar radii; 1 GHz – 130 MHz; ORFEES, since 2012)
  - Spectrography high corona (5-80 MHz; Decametre Array, Jupiter or Sun)
- Data, plots, movies available at <http://secchirh.obspm.fr/>

# The relativistic solar particle event on 2021 Oct 28

Work in progress

# Relativistic solar particle event on 2021 Oct 28

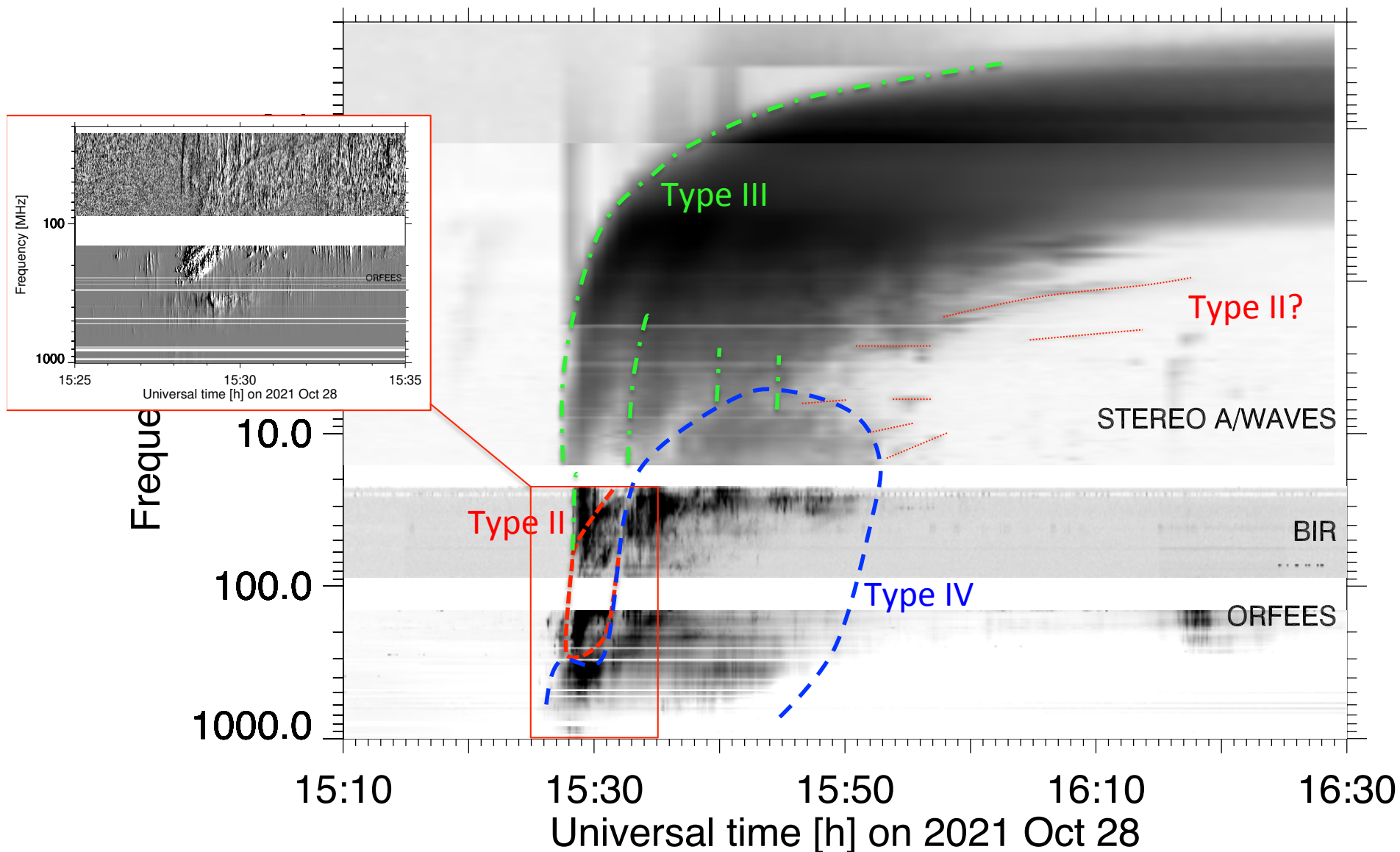
## Neutron monitor observations



- GLE 73 – [www.nmdb.eu](http://www.nmdb.eu) (5 min integration)
- Seen by NMs with  $R < 1.9$  GV ( $E < 1.2$  GeV)
- Not seen at  $R > 2$  GV
- Rather weak GOES  $> 10$  MeV

# Relativistic solar particle event on 2021 Oct 28

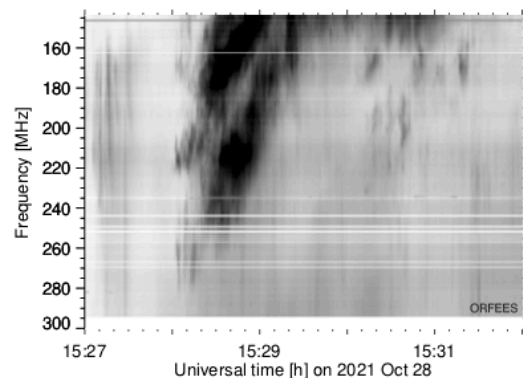
## Radio observations low corona – 1 AU



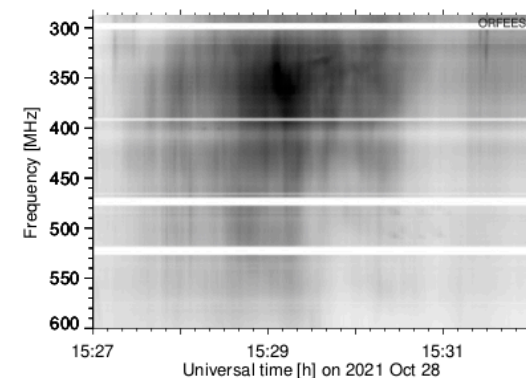
# Relativistic solar particle event on 2021 Oct 28

## Radio observations low and middle corona

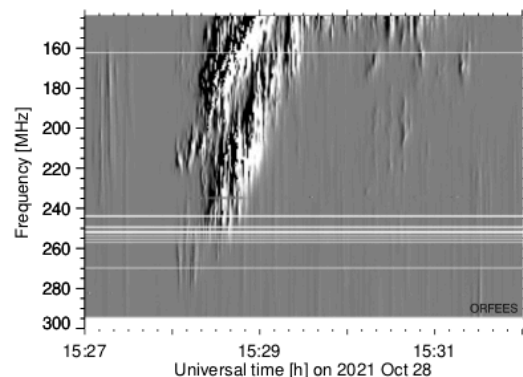
- Type II burst:
  - $\nu \leq 280$  MHz, fast drift  $\rightarrow$  exciter speed 1900 km/s
  - Split bands:  $\nu_d / \nu_u = 1.35$  ( $X=1.82$ ,  $M_f \approx 1.7$ )
  - Simultaneous with first type III group  $< 100$  MHz
- Type IV burst: starts at frequencies  $>$  type II, before type II
  - Continuum + bursts: broadband pulsations, fiber bursts
  - No signature of reverse-drift bursts (=electron beams coming from the type II shock at greater altitude)



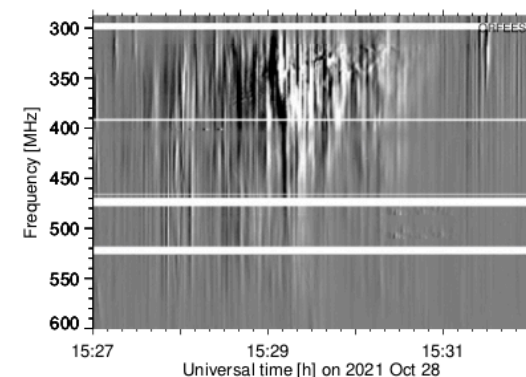
Bg-normalised spectrum, log. scaling, from 0.95 to \*\*\*\* (30% of peak value)



Bg-normalised spectrum, log. scaling, from 0.95 to 50.00 (8% of peak value)



Bg-normalised spectrum, lin. scaling, from \*\*\*\* to 10.00 (5% of peak value)

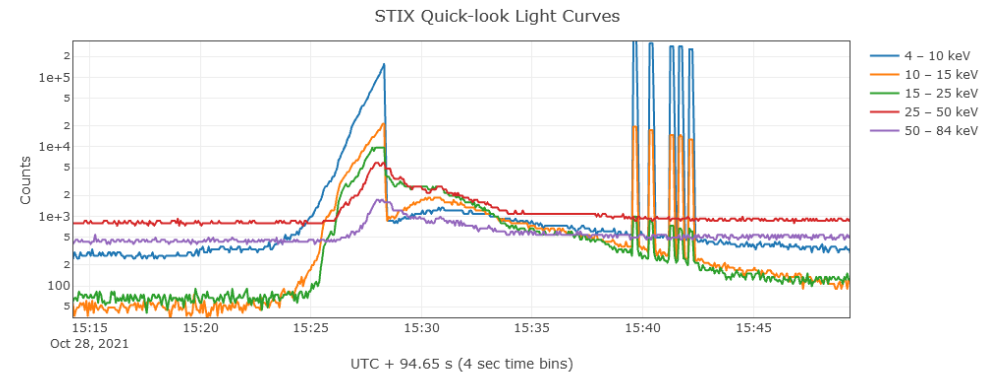
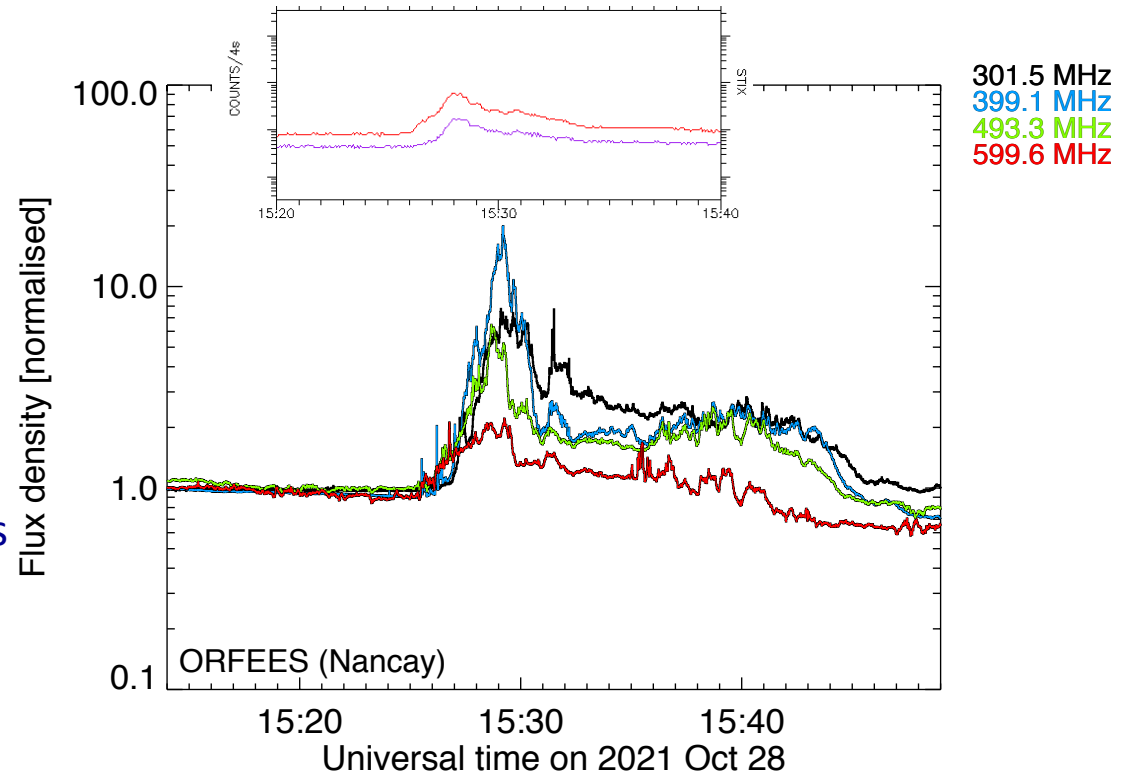


Bg-normalised spectrum, lin. scaling, from -1.00 to 1.00 (0% of peak value)

# Relativistic solar particle event on 2021 Oct 28

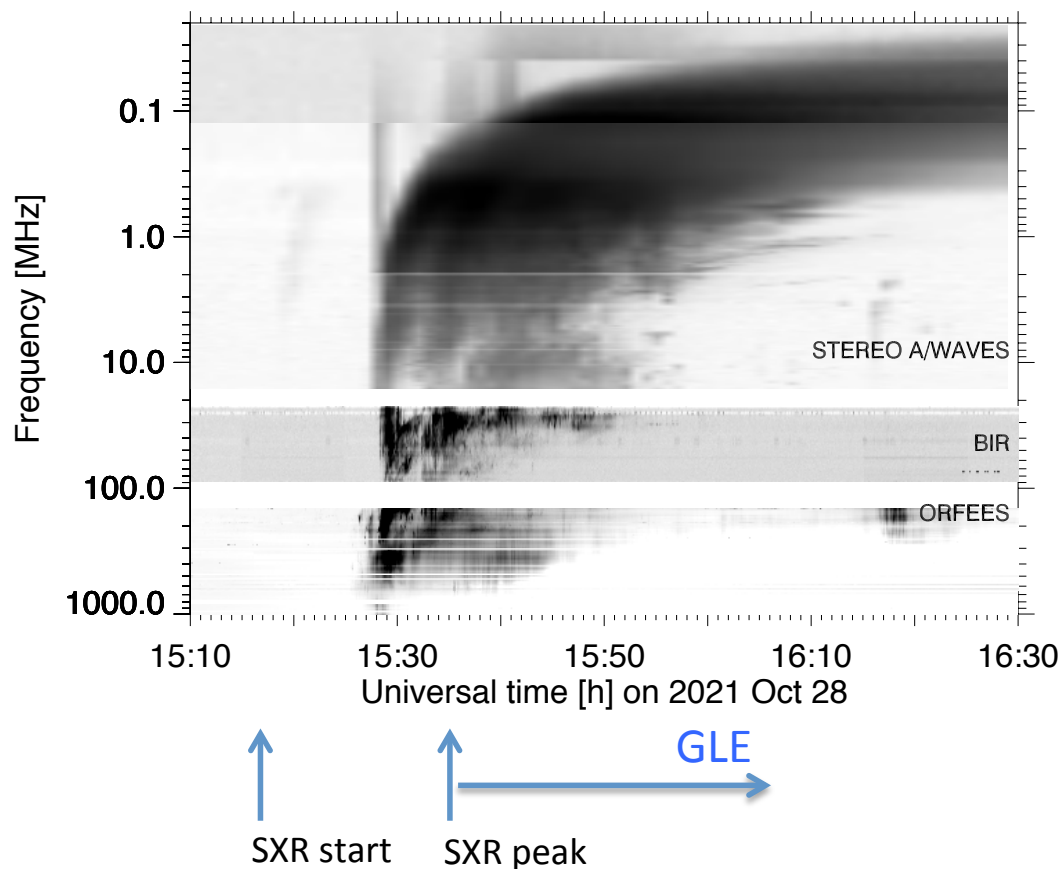
## HXR and radio observations

- Type II burst:
  - $\nu \leq 280$  MHz, fast drift  $\rightarrow$  exciter speed 1900 km/s
  - Split bands:  $\nu_d / \nu_u = 1.35$  ( $X=1.82$ ,  $M_f \approx 1.7$ )
  - Simultaneous with first type III group  $< 100$  MHz
- Type IV burst: starts at frequencies  $>$  type II, before type II
  - Continuum + bursts: broadband pulsations, fiber bursts
  - No signature of reverse-drift bursts (=electron beams coming from the type II shock at greater altitude)
  - Overall similarity with the HXR time profile
  - Electron acceleration and release into closed magnetic structures ?



# Relativistic solar particle event on 2021 Oct 28

## Electron acceleration



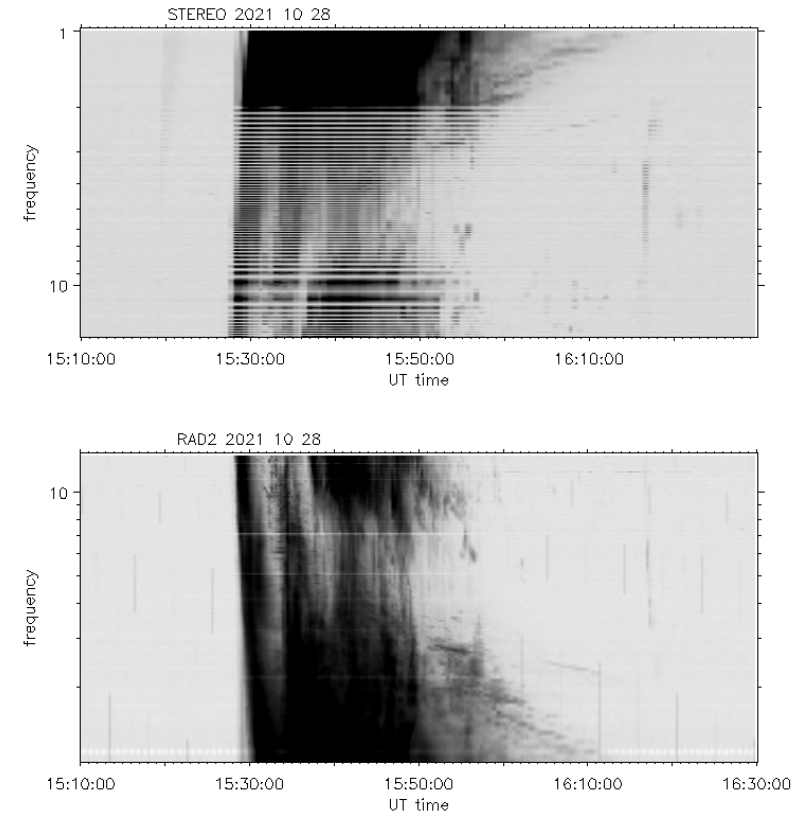
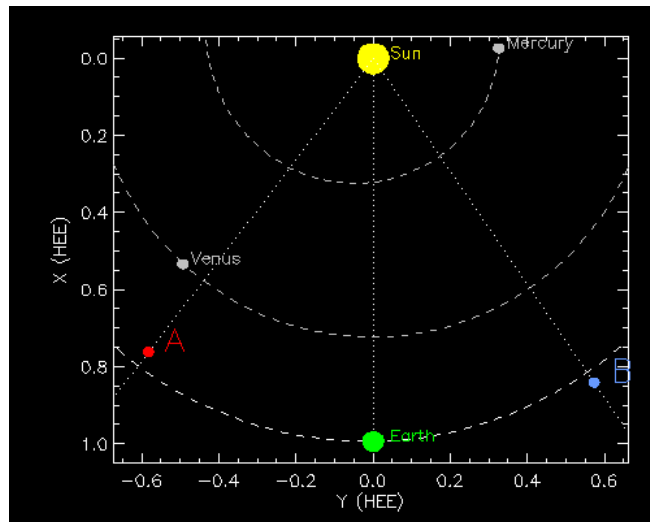
- Electron acceleration in the low/middle corona (HXR STIX, radio 1000-20 MHz – ORFEES Nancay, e-Callisto/Birrh Castle):
  - type III < 100 MHz
  - type II at  $dm-m-\lambda$ , possible traces at  $DH-\lambda$
  - type IV including slowly-drifting features extending to < 10 MHz
  - similarity with HXR profile
- Electron escape to the high corona and IP space signalled by type III bursts (Wind, STEREO A)



# Relativistic solar particle event on 2021 Oct 28

## Radio observations of electrons in the high corona and IP space

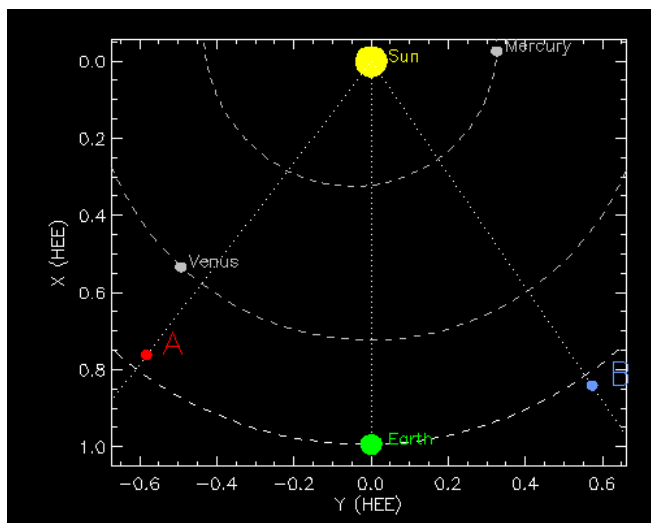
- Wind and STEREO see the same radio bursts in their HF range (14(16)-1 MHz)



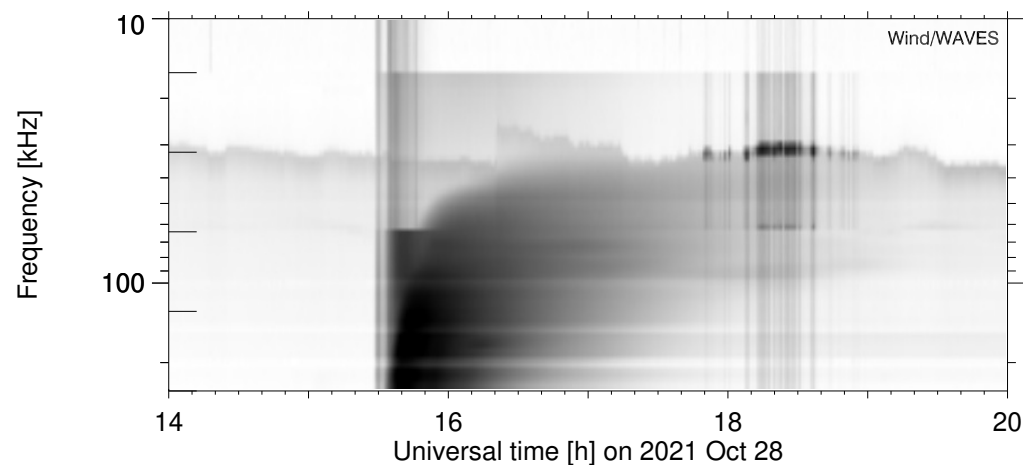
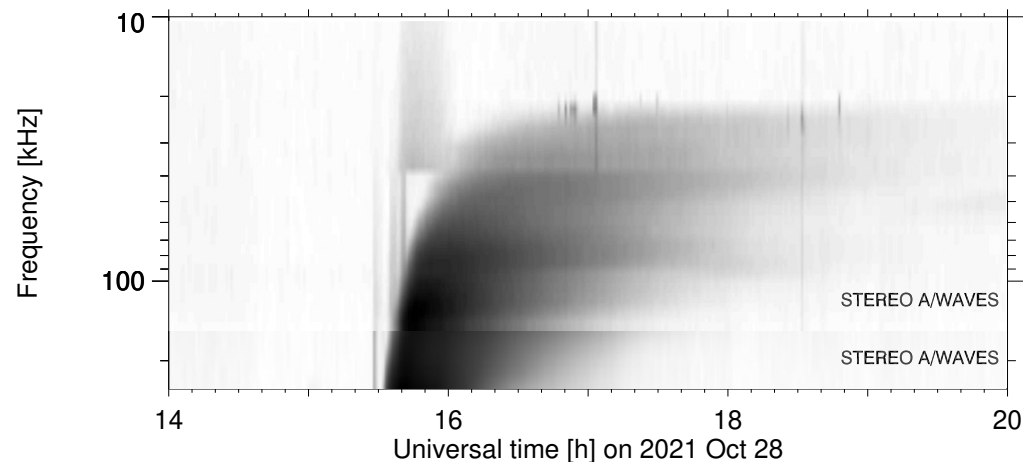
# Relativistic solar particle event on 2021 Oct 28

## Type III bursts, Langmuir waves, magnetic connections

- Wind and STEREO see the same radio bursts in their HF range (14(16)-1 MHz)



- ... and at km- $\lambda$ : LF edge of III bursts  $\rightarrow$  local plasma frequency, Langmuir waves



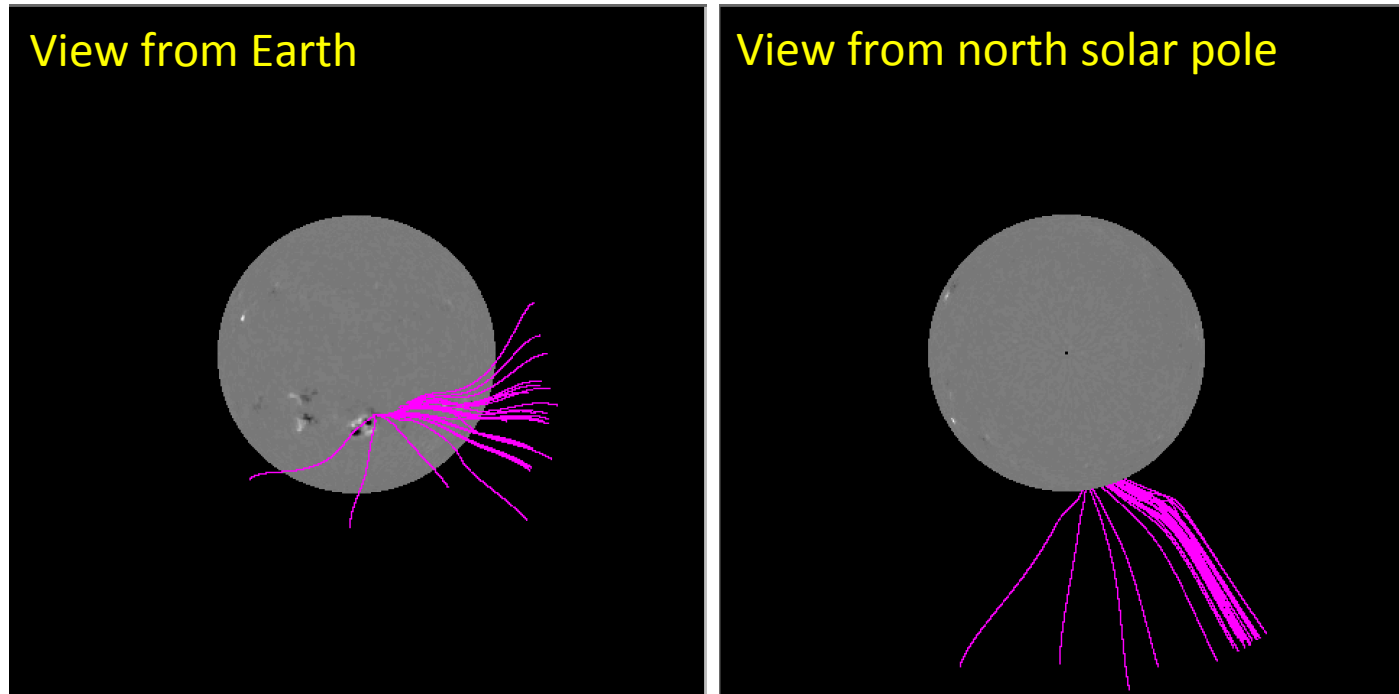
GLE



- $\Rightarrow$  Both s/c are magnetically connected to the acceleration region

# Relativistic solar particle event on 2021 Oct 28

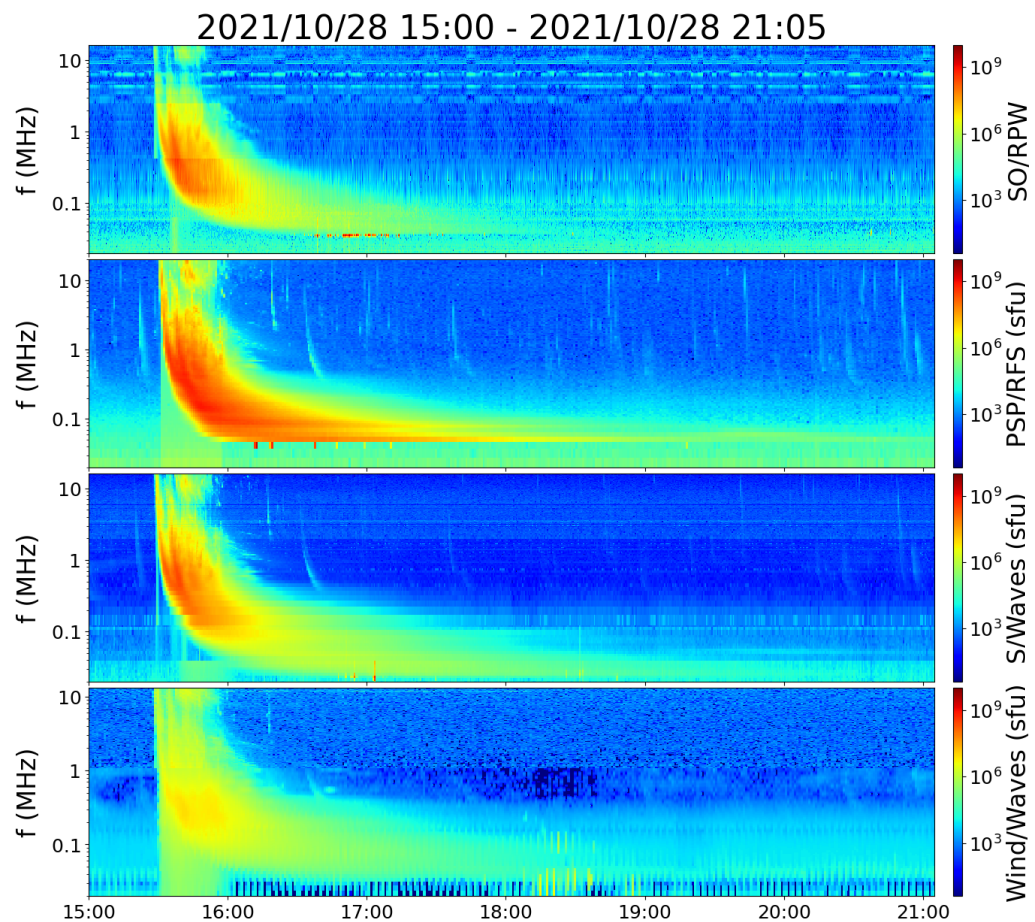
## PFSS extrapolation and magnetic connections



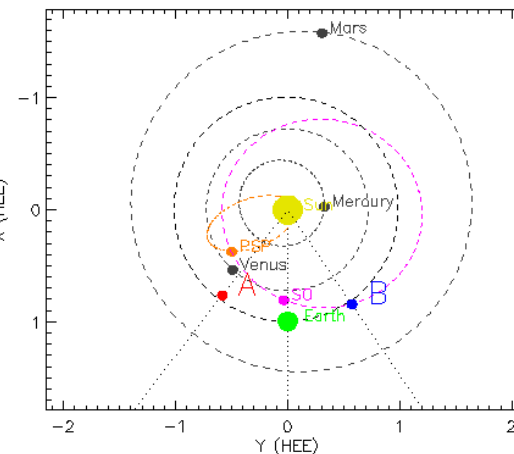
- PFSS extrapolation of the photospheric magnetogramme (MDI Oct 28, 12:04 UT)
- Broad longitudinal extent of the bundle of open field lines at the source surface ( $2.5 R_{\odot}$ ):
  - Parker spiral through STEREO A well-connected to the AR ( $\varphi_0=25^\circ$ ) ...
  - ... but not the Parker spiral through L1 ( $\varphi_0=82^\circ$ )

# Relativistic solar particle event on 2021 Oct 28

## Type III bursts, Langmuir waves, magnetic connections



Plot courtesy  
M. Maksimovic/RPW team



- => SoLo and PSP are also magnetically connected to the acceleration region
- L waves at all s/c => a group of type III bursts may come from electron beams propagating about simultaneously along different magnetic field lines

# Relativistic solar particle event on 2021 Oct 28

## A preliminary summary of neutron monitor and radio observations

- GLE 73
  - observed by NMs with nominal cutoff rigidity up to 2 GV ( $E \leq 1$  GeV)
  - weak, if any, anisotropy
- Weak at proton energies near 10 MeV
- Electron acceleration and escape:
  - common signatures in the HXR and radio range, during about 20 min
  - shock acceleration at greater altitude, first group of III bursts
  - evidence for an acceleration region that rises in altitude during this time
  - immediate escape to a range of IMF lines (spread  $40^\circ$ ) throughout the radio and HXR emission
- Onset of the GLE during the HXR/radio bursts, onset time poorly defined (weak and slow rise)
- During the bulk of the GLE the Earth (L1) is magnetically connected to the source of energetic electrons (type III bursts) => closely related sources of NT electrons and relativistic protons

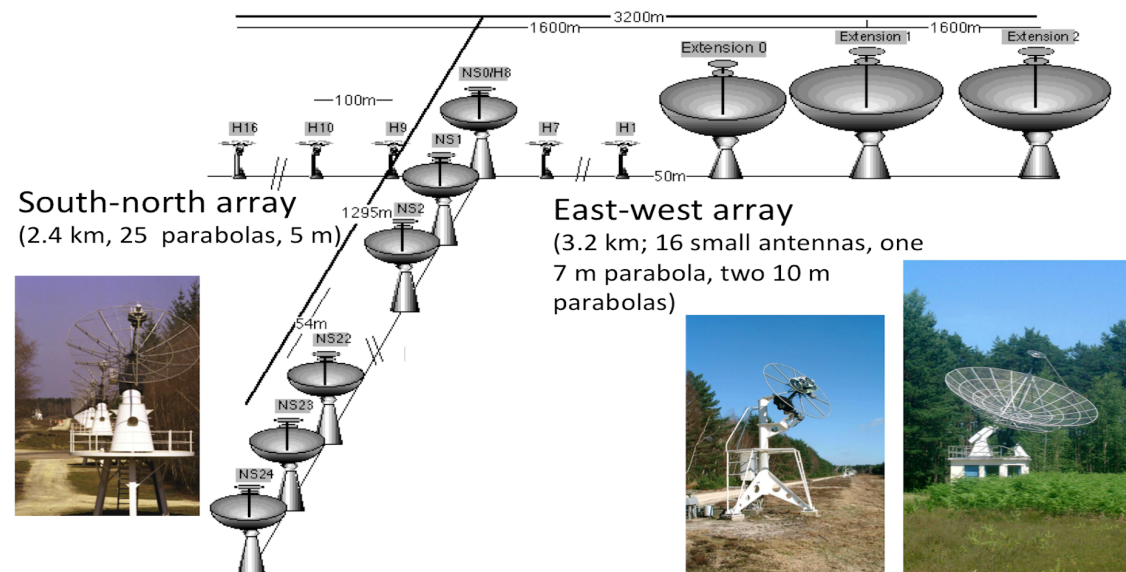
# Filament eruption and type IV burst on 2021 Aug 248

Work in progress

# The Nançay radioheliograph

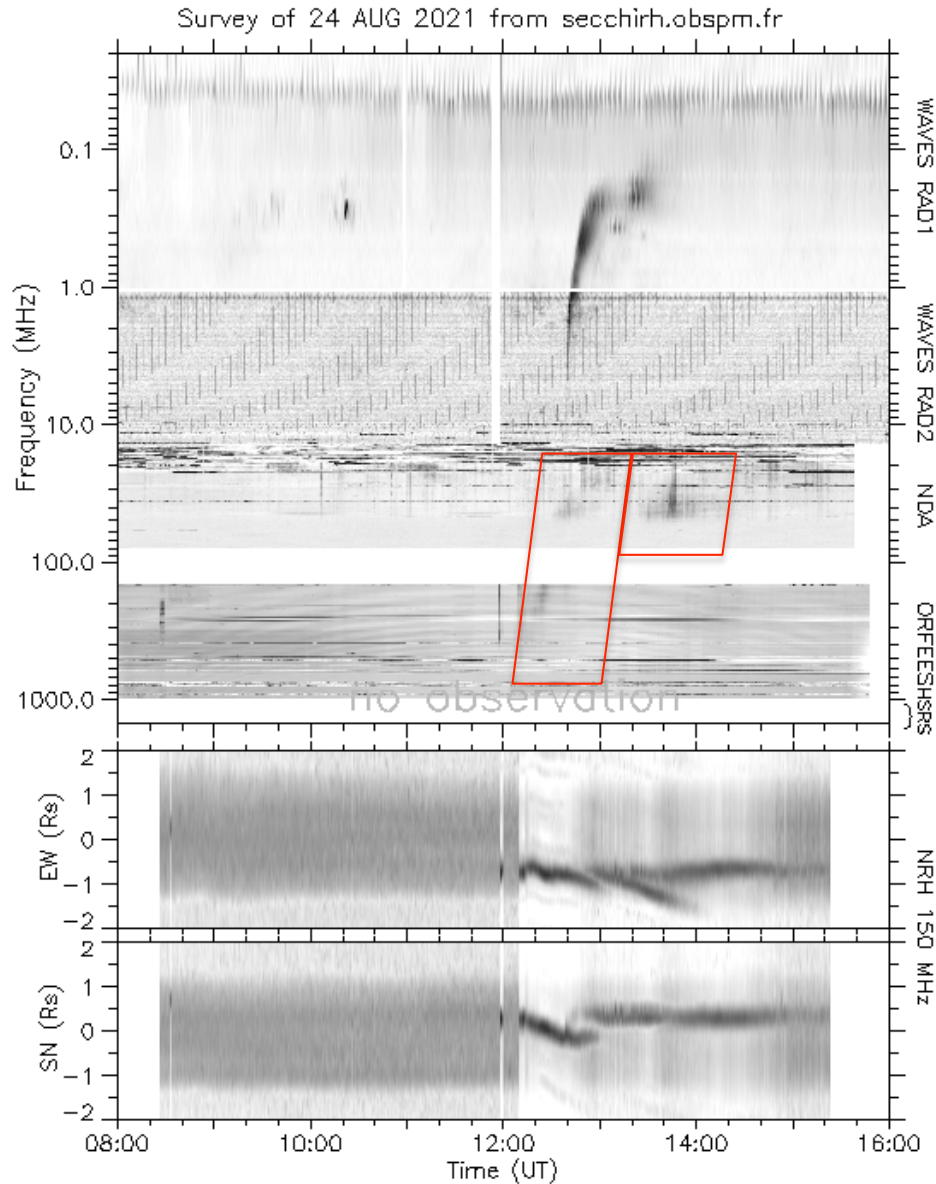
## Overview of the renovation

- Operations 2015-2020 (phase 1):
  - Replacement of the correlator (update technology, use all 1128 baselines)
  - Replacement of the data acquisition system



# Filament eruption and type IV bursts on 2021 Aug 24

## Overview of dm-km- $\lambda$ observations

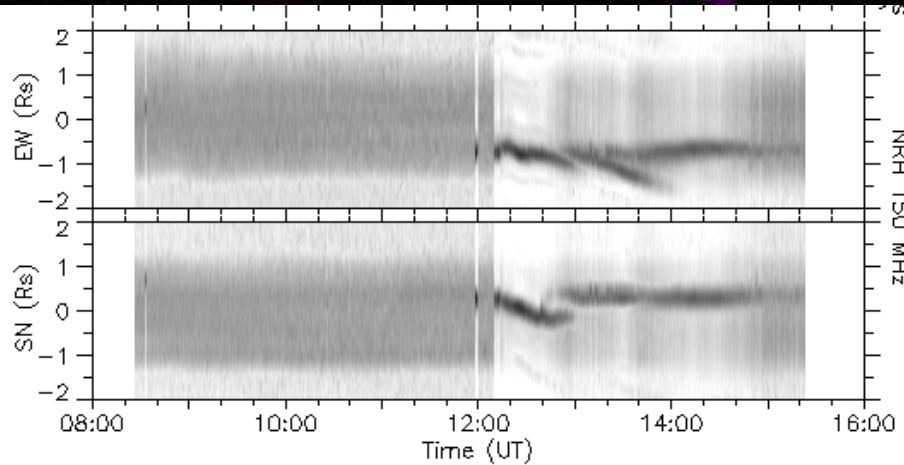
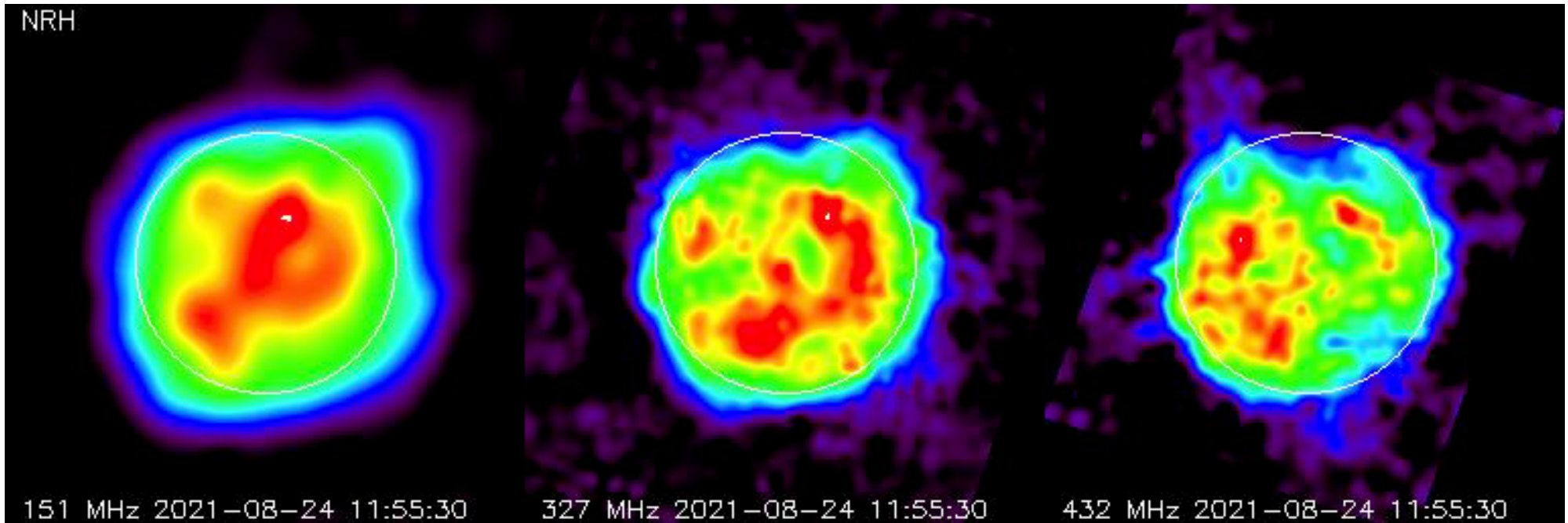


- Impulsive phase
- Two successive moving type IV: ORFEES-NDA-NRH
- The 2<sup>nd</sup> one followed by stationary type IV
- Small DH type III out of first moving type IV
- Relatively simple radio event with well-developed source motions



# Filament eruption and type IV bursts on 2021 Aug 24

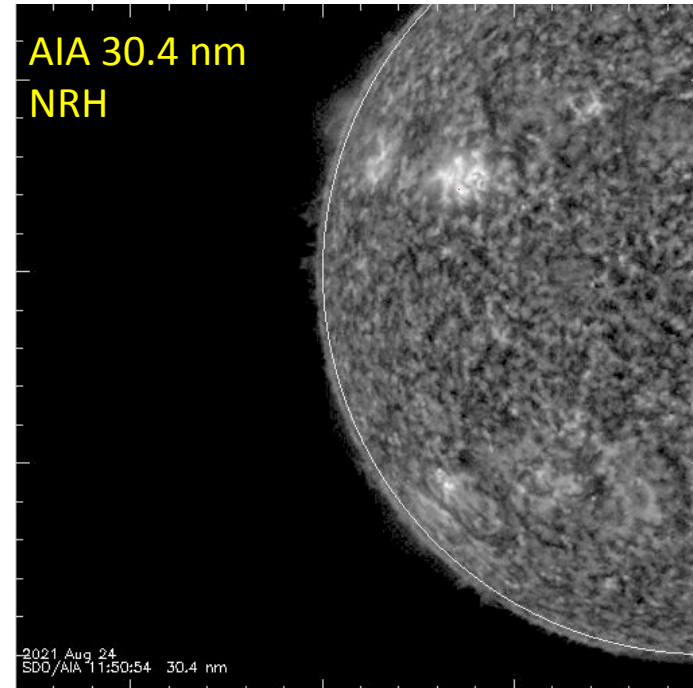
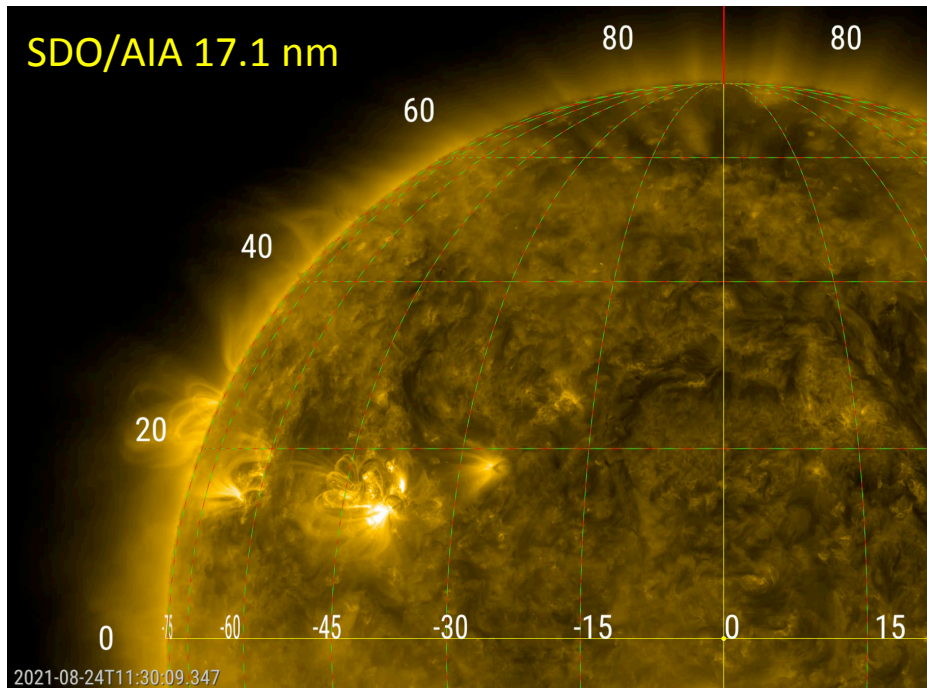
NRH observations 151, 327, 432 MHz



Integration time 1 min

# Filament eruption and type IV bursts on 2021 Aug 24

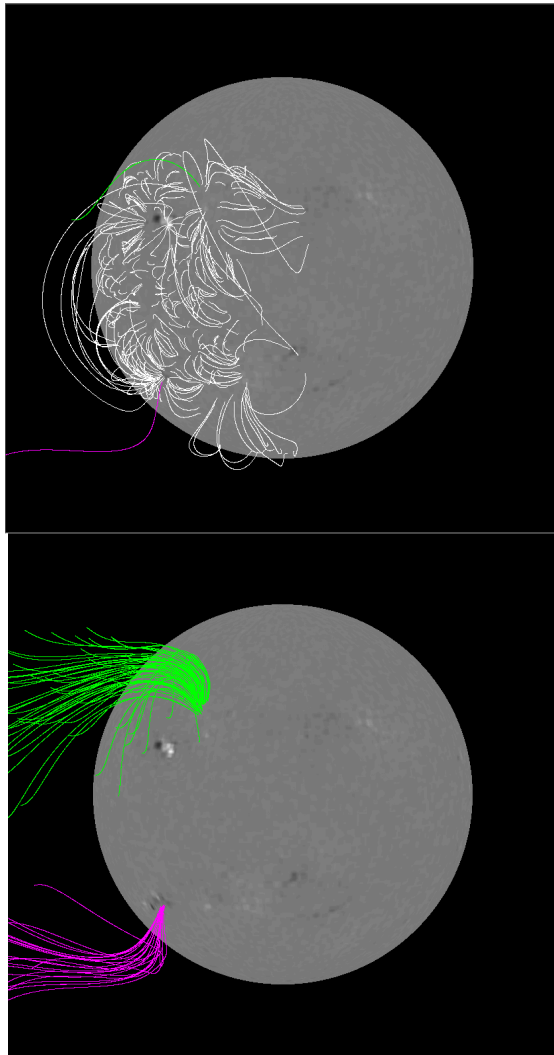
## Filament material and radio sources



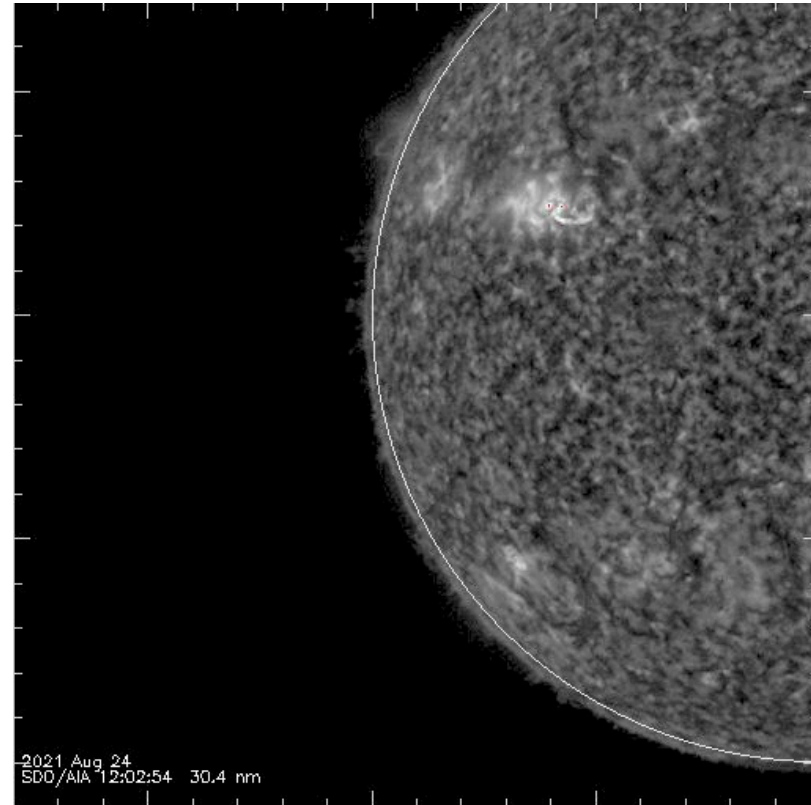
- 1<sup>st</sup> moving IV: pushed by the magnetic structure of the erupting filament
- 2<sup>nd</sup> moving IV: moving with another magnetic structure confining filament material
- Stationary IV: common origin with the 2<sup>nd</sup> moving IV

# Filament eruption and type IV bursts on 2021 Aug 24

## Filament material and radio sources



SoHO/MDI + PFSS (SolarSoft  
– M. Derosa)

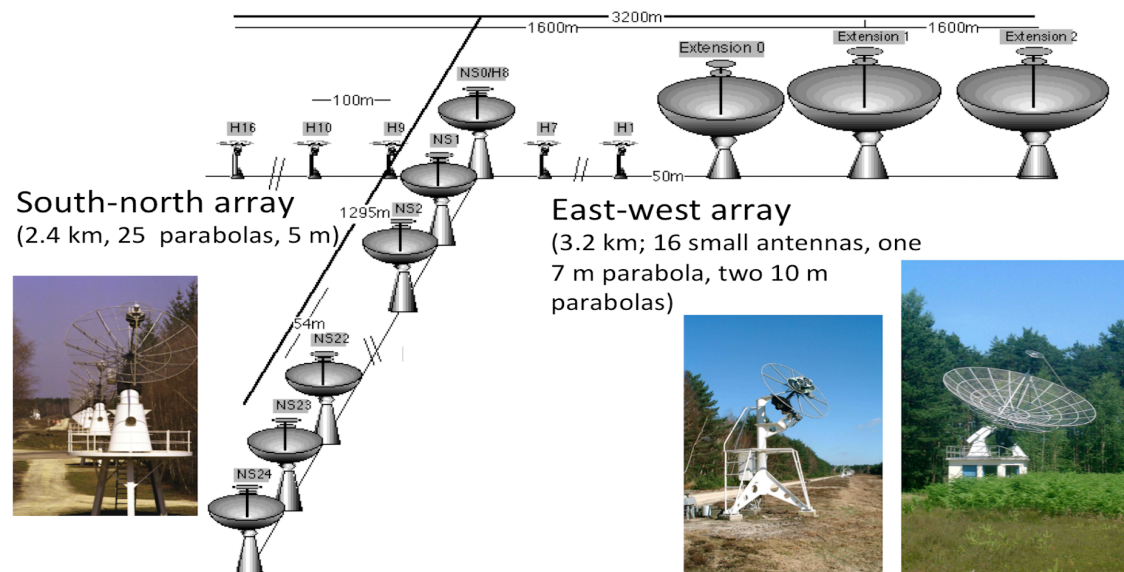


- 1<sup>st</sup> moving IV: pushed by the magnetic structure of the erupting filament
- Type III emitting electrons at the interface between the expanding structure and pre-existing open field lines ?

# The Nançay radioheliograph

## Overview of the renovation

- Operations 2015-2020 (phase 1):
  - Replacement of the correlator (update technology, use all 1128 baselines)
  - Replacement of the data acquisition system



- Operations 2021-2024 (phase 2 – partially funded):
  - Renewal of the focal systems: SN array (funded), EW array
  - Renewal of the antenna pointing system
  - Maintenance/replacement of equipment: geared motors and reducers
  - Electricity supply to the antenna arrays
  - Anti-corrosion treatment of the antennas