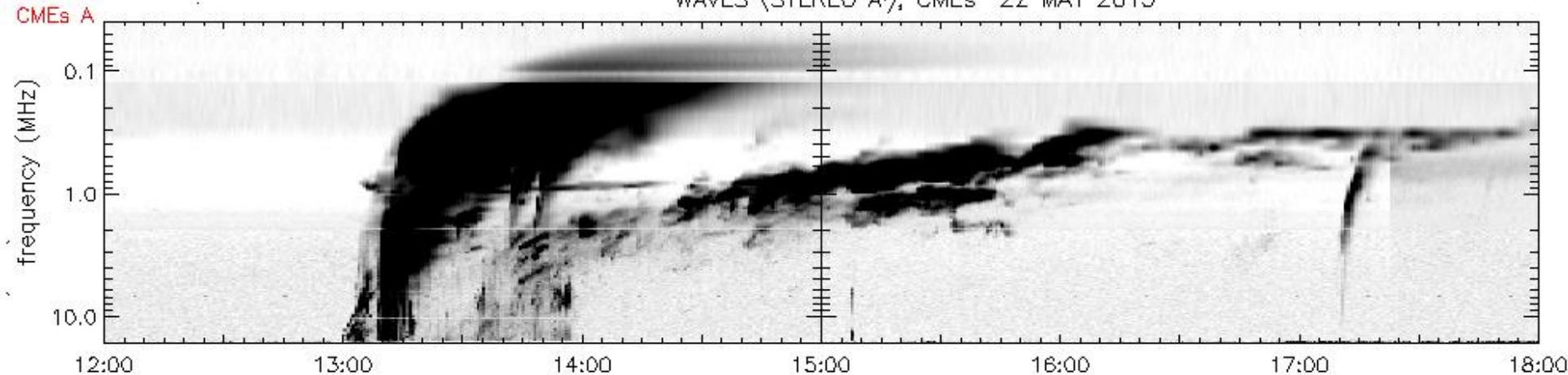




WAVES (STEREO A), CMEs 22 MAY 2013

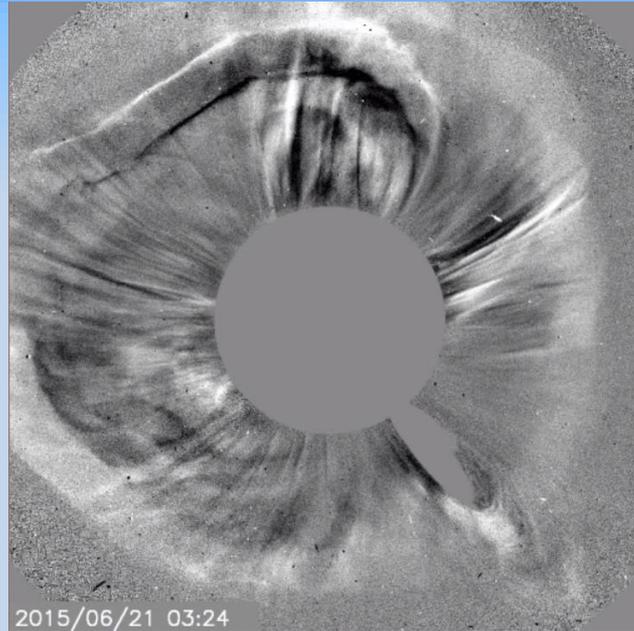
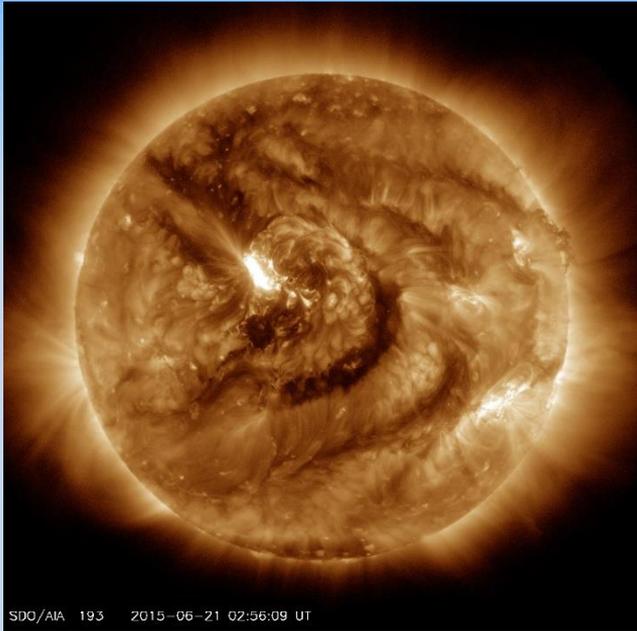


Radio Observations and Space Weather Research

Jasmina Magdalenić

Solar-Terrestrial Centre of Excellence – SIDC,
Royal Observatory of Belgium

What is space weather and why is it important?



Eruptive processes:
flare/CME events

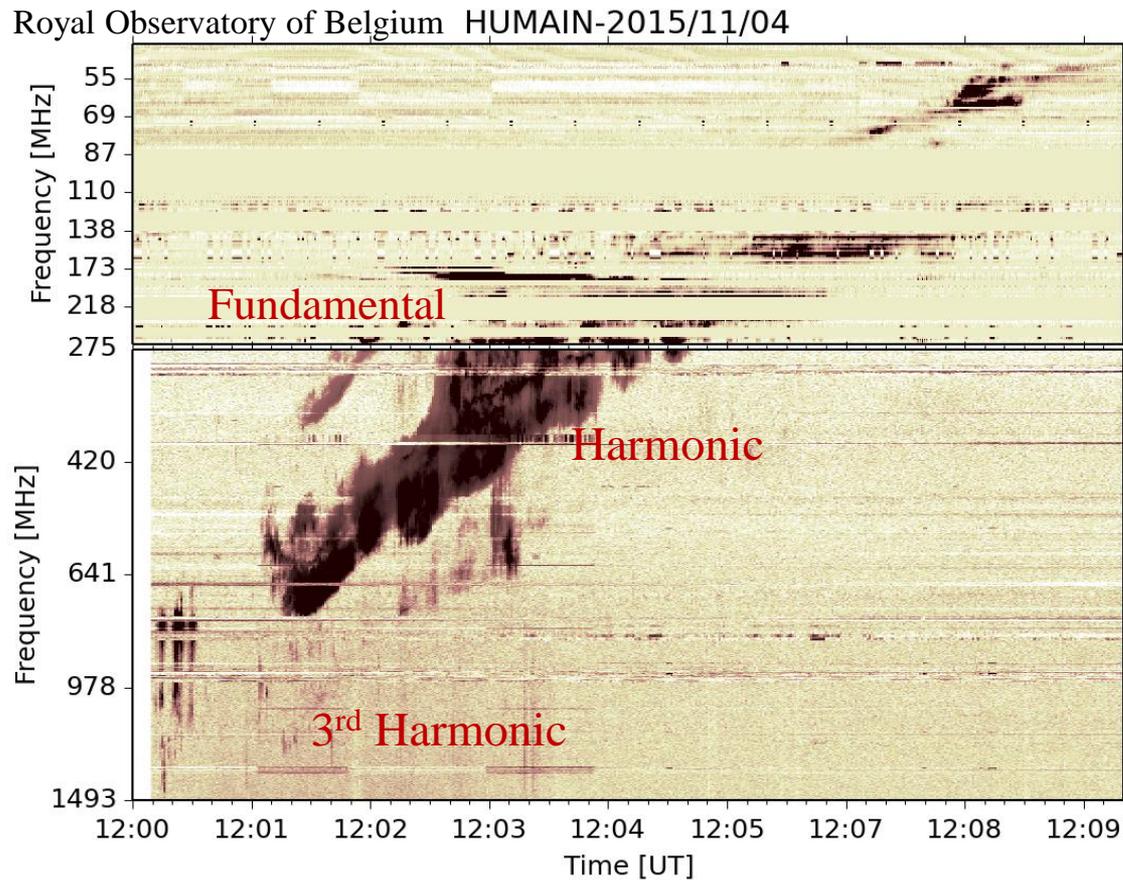


heating of corona,
plasma motion,
waves & shocks
(in white light & **radio**
and in situ).

The eruptive phenomena on the Sun and the solar wind can impact the Earth's magnetosphere and influence the performance of space-based and ground-based technology.

Space Weather research are efforts to study generation and propagation of the solar phenomena – solar storms and their impact to the Earth with the aim to understand and forecast the phenomena.

What can be deduced from the solar radio observations? Metric wavelengths (corona).



Observed:

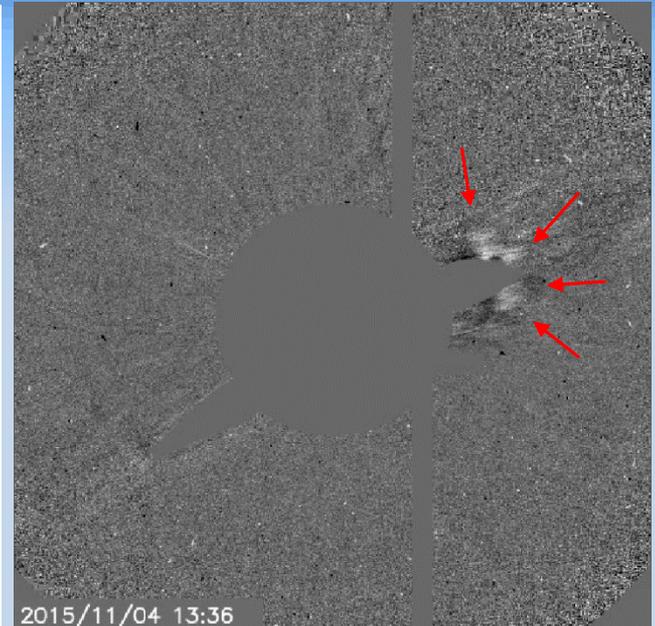
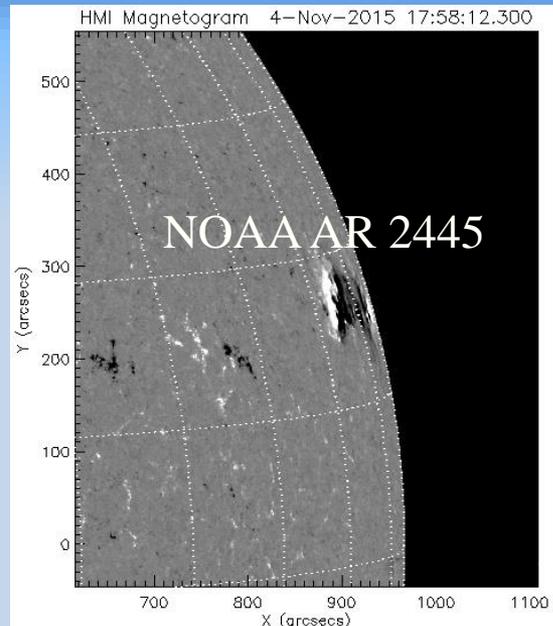
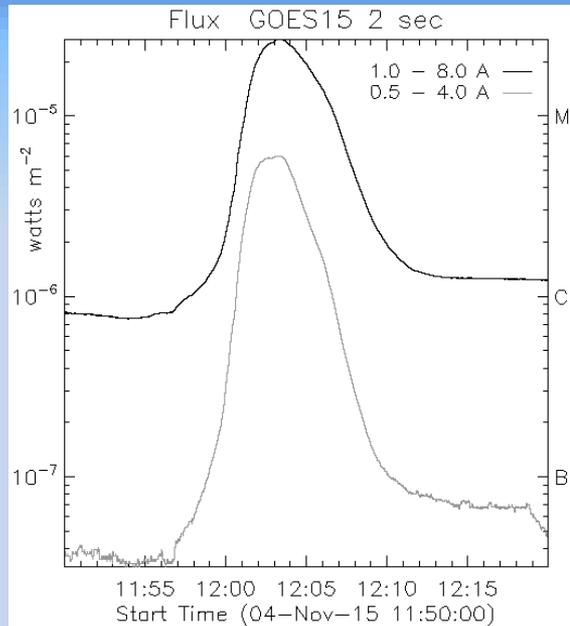
- Type II radio burst,
- Intense type II burst starting at high frequency,
- Third harmonic,
- No associated type III and/or type IV radio emission.



Deduced:

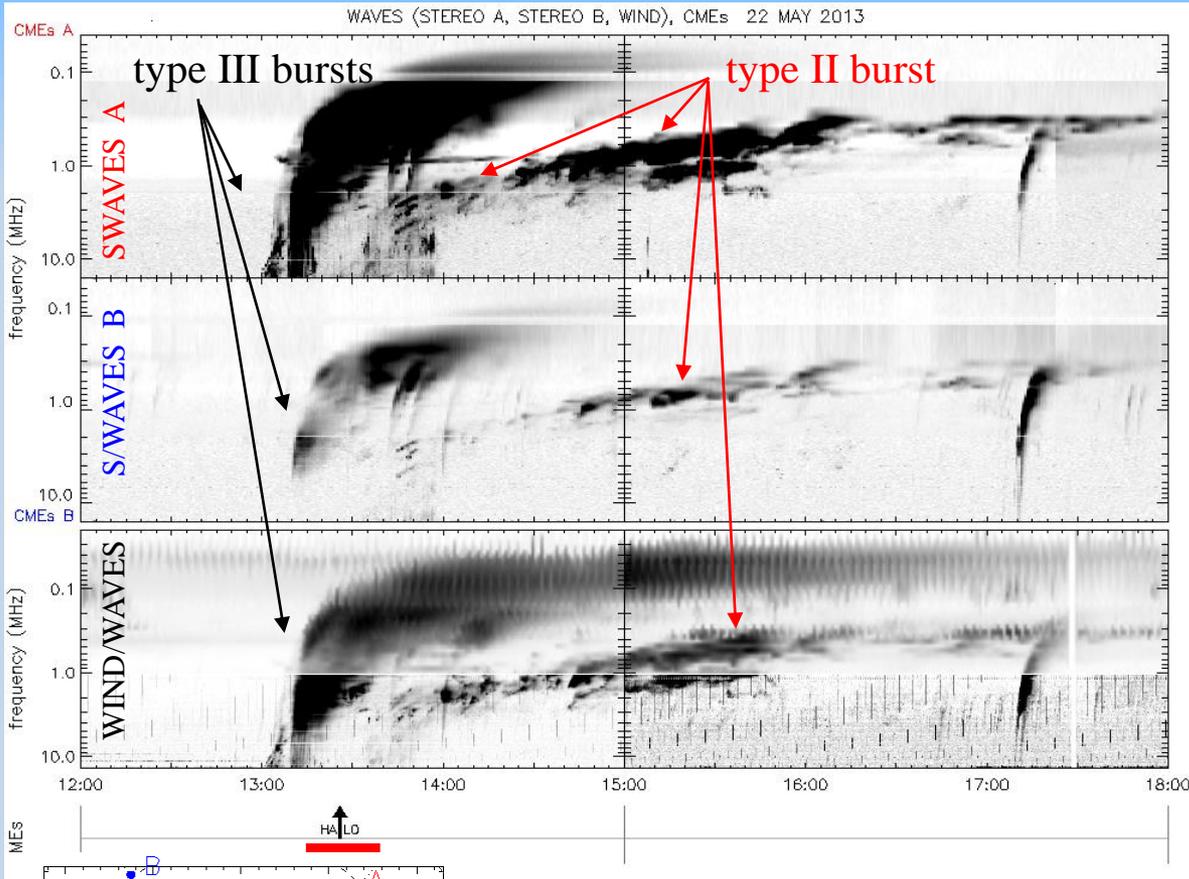
- ❖ Coronal shock wave,
- ❖ Impulsive & possibly strong flare,
- ❖ Limb event,
- ❖ Not very wide & fast CME?

Associated CME/flare event



- Impulsive M2.5 flare (rise time 8 min),
- Active region NOAA AR 2445 situated close to the solar limb,
- Narrow CME (angular width of about 30°), weak and slow in the SOHO LASCO C2 field of view (270 km/s), not observed by SOHO LASCO C3.

What can be deduced from the radio observations? Kilometric wavelengths (interplanetary space).



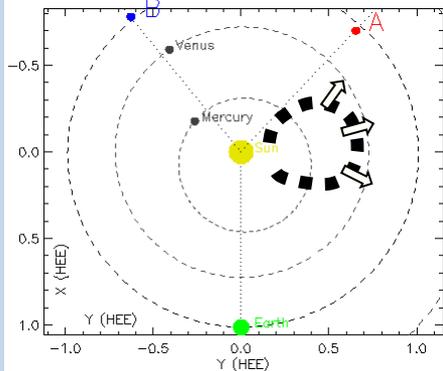
Observed:

- Strong & fast interplanetary type II burst with possible metric counterpart & strong type IIIs,
- Intensity of the radio emission different for different spacecraft,
- Occulted high-frequency part of type III bursts as seen by SWAVES B.

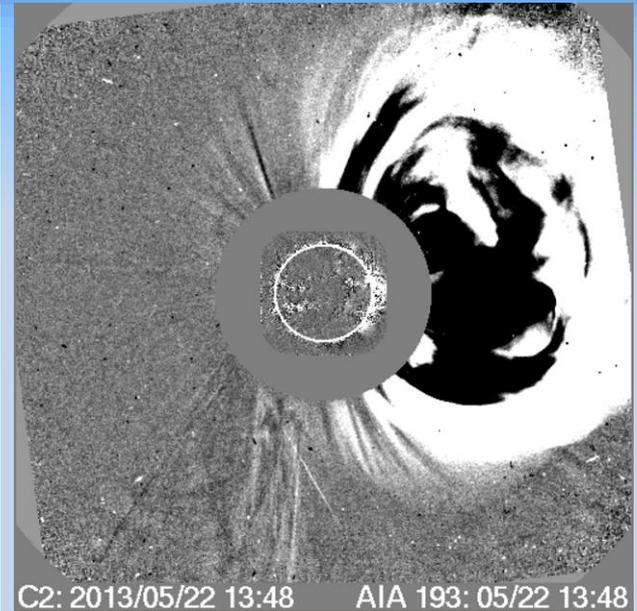
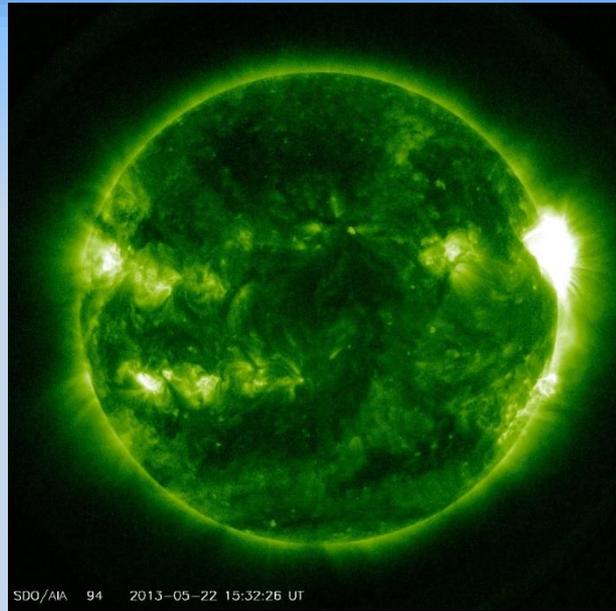
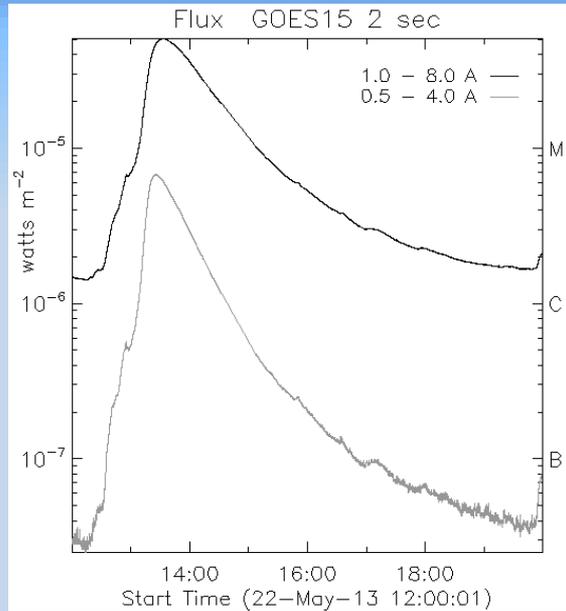


Deduced:

- ❖ Strong, long-duration flare & wide, fast CME,
- ❖ Direction of the CME propagation between SWAVES A & WIND WAVES, more towards SWAVES A,
- ❖ Source region close to the west solar limb (occulted for SWAVES B).



Associated CME/flare event



- Long-duration M5.0 flare (duration 6 hours),
- Active region NOAA AR 1745 (N15°W70°) situated close to the solar limb,
- Halo CME with projected speed of about 1500 km/s,
- Direction of the CME propagation between STEREO A & WIND.

For studies of this event see e.g. Ding et al., 2014; Cheng et al., 2014; Makela et al., 2016.

Statistical approach:

HELCCATS = Heliospheric Cataloguing, Analysis and Techniques Services



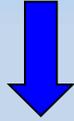
Catalogs of ICMEs and associated slowly drifting radio emission (interplanetary type II radio emission) observed by STEREO WAVES and WIND WAVES.

http://www.helcats-fp7.eu/catalogues/wp7_cat.html

- Studies of shock & CME arrival using interplanetary type II radio bursts (observed mostly by WIND WAVES)
e.g. Reiner et al., 1998; Dulk et al., 1999; Leblanc et al., 2001; Cremades et al., 2007, 2015.

Radio triangulation:

Ground-based radio imaging (e.g. Nançay radioheliograph observations) provide 2D information on the position of the radio emission in the low corona.



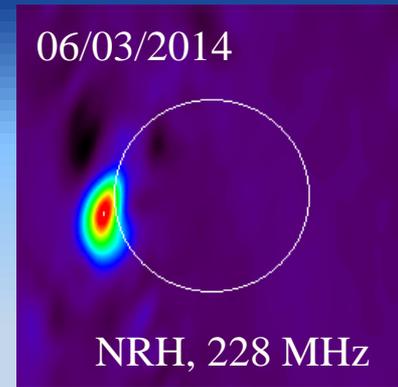
Radio triangulation is the only way to obtain the 3D information on the position of the radio emission in the interplanetary space.

WHAT is radio triangulation?

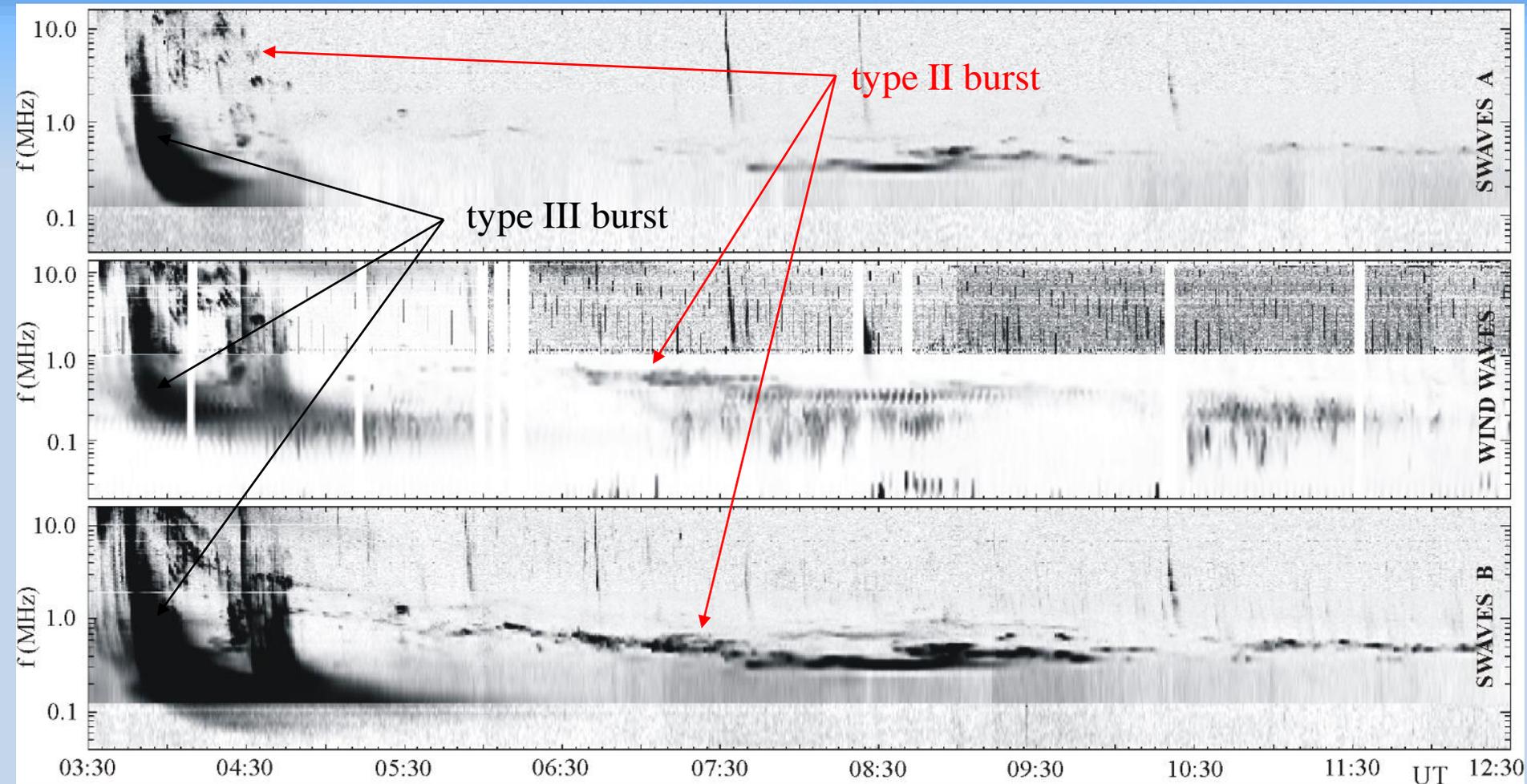
Estimation of the radio source position using goniopolarimetric observations.

WHY is radio triangulation important?

- Track the propagation of shock waves in the corona and interplanetary space and assess the possibility of their arrival to Earth.
 - Determine the relative position of the CME, the associated shock and its radio signatures.
-
- Radio triangulation studies of type II source positions and comparison with associated CMEs e.g. Oliveros et al., 2012, 2015, Magdalenić et al., 2014, Krupar et al., 2016, Makela et al., 2016.

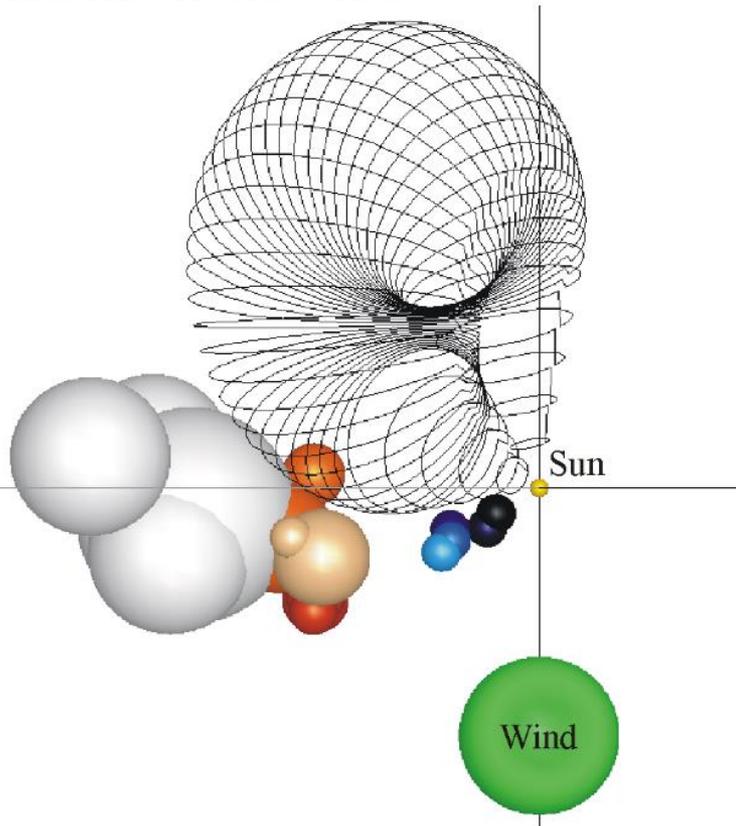


Example of radio triangulation: event on 2012, March 5

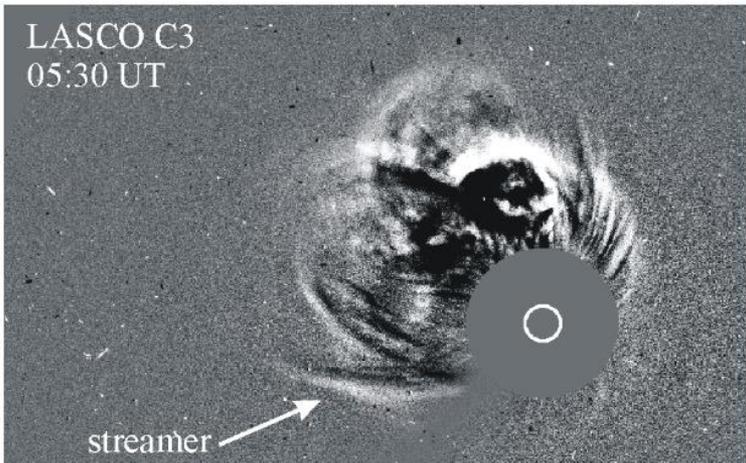


Radio triangulation of the type II and the type III radio bursts associated with the CME/flare event on 2012, March 5 (Magdalenić et al., 2014).

view from the Earth - zoom

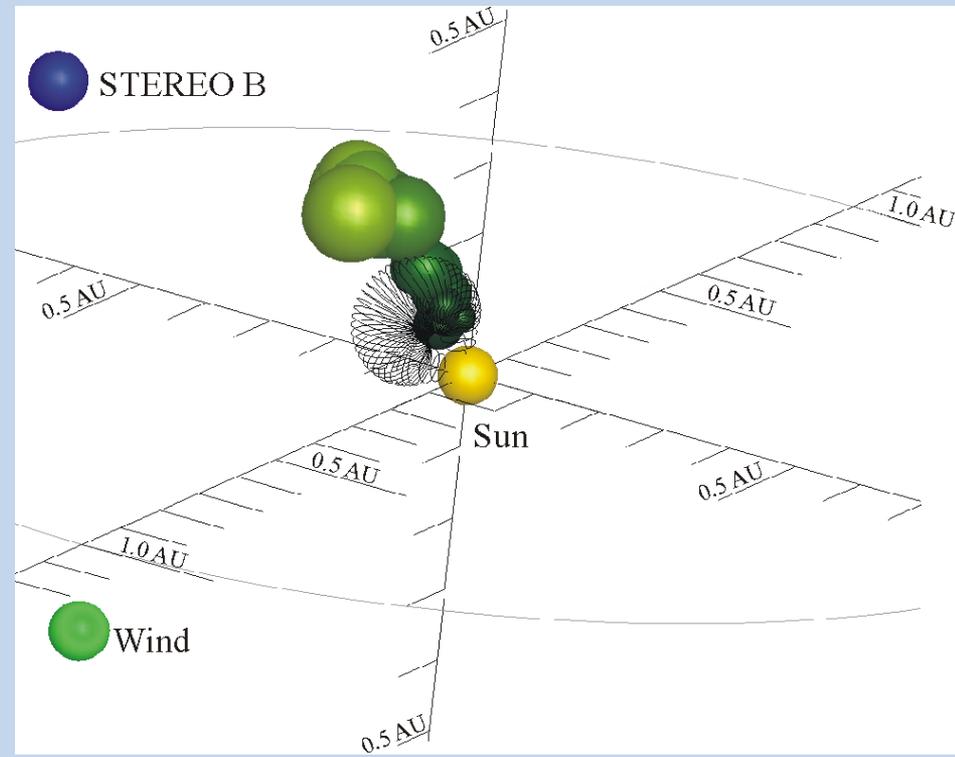


LASCO C3
05:30 UT



Results of radio triangulation

- The sources of the type II radio burst were situated close to the southern flank of the CME.
- The interaction of the shock wave and the streamer resulted in the enhanced radio emission (Magdalenić et al., 2014).

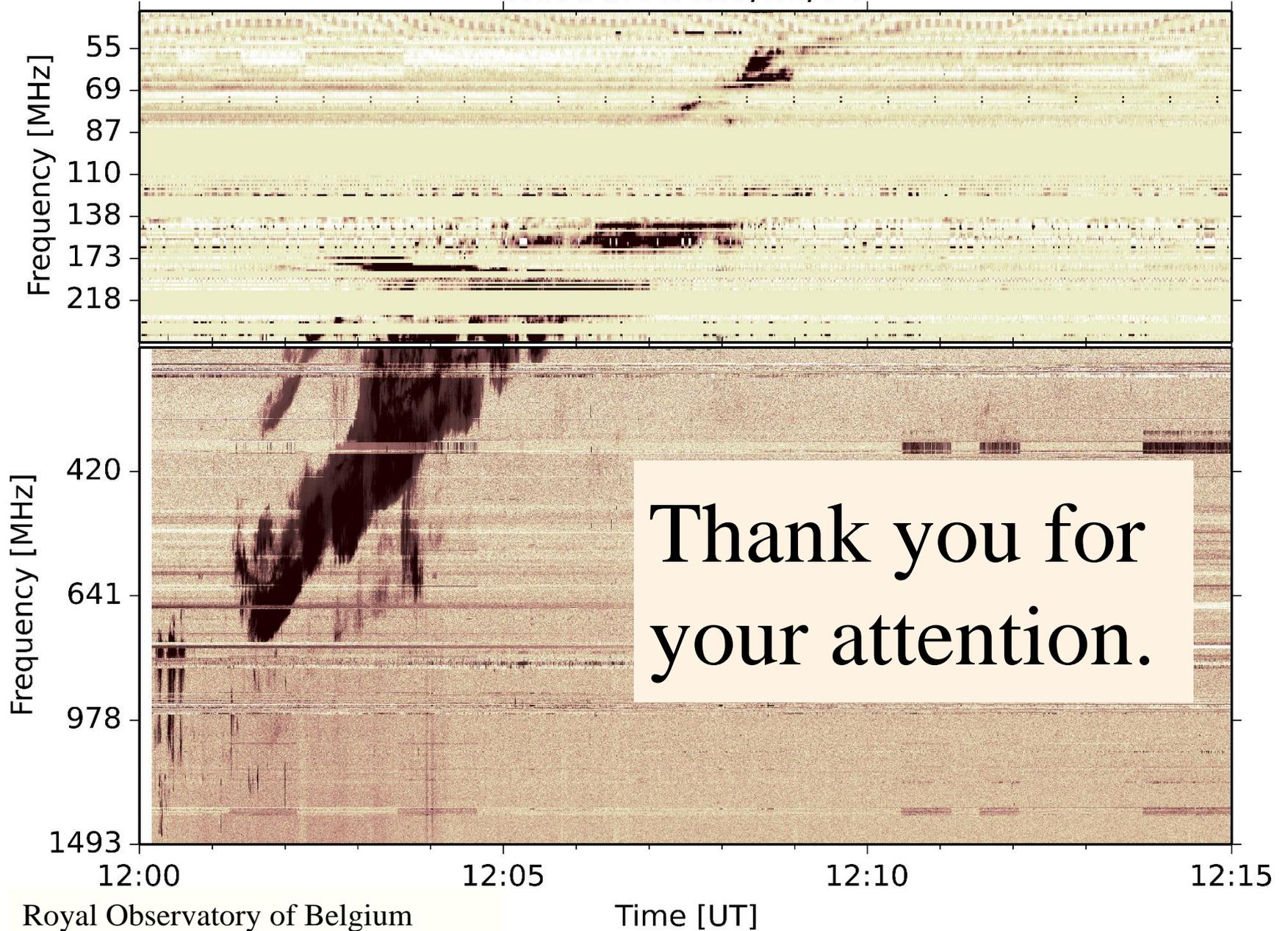


- The sources of the type III radio burst were situated northward of the northern CME flank.

Summary:

- ❖ Radio observations are very useful for the space weather forecasting purposes because they bring a number of indications on the characteristics of the associated flare/CME event.
- ❖ Understanding and quantifying the relationship between the radio emission and associated eruptive events is particularly important for the space weather forecasting services.
- ❖ Different approaches to the problem will give complementary results.
- ❖ Radio triangulation is the only way to obtain the 3D information on the position of the radio emission in the studies of CME & shock propagation.
- ❖ Studies of the radio emission associated with the shock waves provide us with information for better prediction of the shock arrival at the Earth.

HUMAIN-2015/11/04



Abstract

Coronal mass ejections and associated shock waves are the most frequent drivers of disturbed geomagnetic conditions. Therefore, tracking of CMEs and the CME-driven shock waves from the low corona through the inner heliosphere became one of the most often addressed topics of the space weather research.

Observations of solar radio emission associated with CME-driven shock waves are unique means for tracking the shocks, as the shock radio emission can be observed in a broad frequency range (from several hundred MHz down to a few kHz), which encompasses the whole solar atmosphere and the inner heliosphere. Moreover, in many instances, radio emission also brings unique information on the coronal parameters e.g. coronal magnetic field strength and coronal electron density.

In this presentation I will discuss how the radio observations (from metric to kilometric wavelength range) can be used in the space weather forecasting. The focus will be on the so-called type II bursts, radio signatures of shock waves. I will also address some of the recent results of the radio triangulation studies (of type II, type III and type IV radio bursts) which bring completely new insight into the causal relationship of the CMEs and associated solar radio emission.