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berlin

Flare-accelerated electrons and the thermal evolution of the associated active region

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LOFAR Family Meeting 2023

Outline

I. Scientific context – solar flares

II. Observations of flare-accelerated electrons

- Away from the sun – radio (LOFAR)
- Towards the sun – X-ray (STIX)

III. Thermal evolution of the active region during type-III radio bursts

Scientific Context – Solar Flare

- sudden release of energy
- stored in the non-potential magnetic field
- due to magnetic reconnection
- Consequences
  - particle acceleration
  - heating
  - radiation

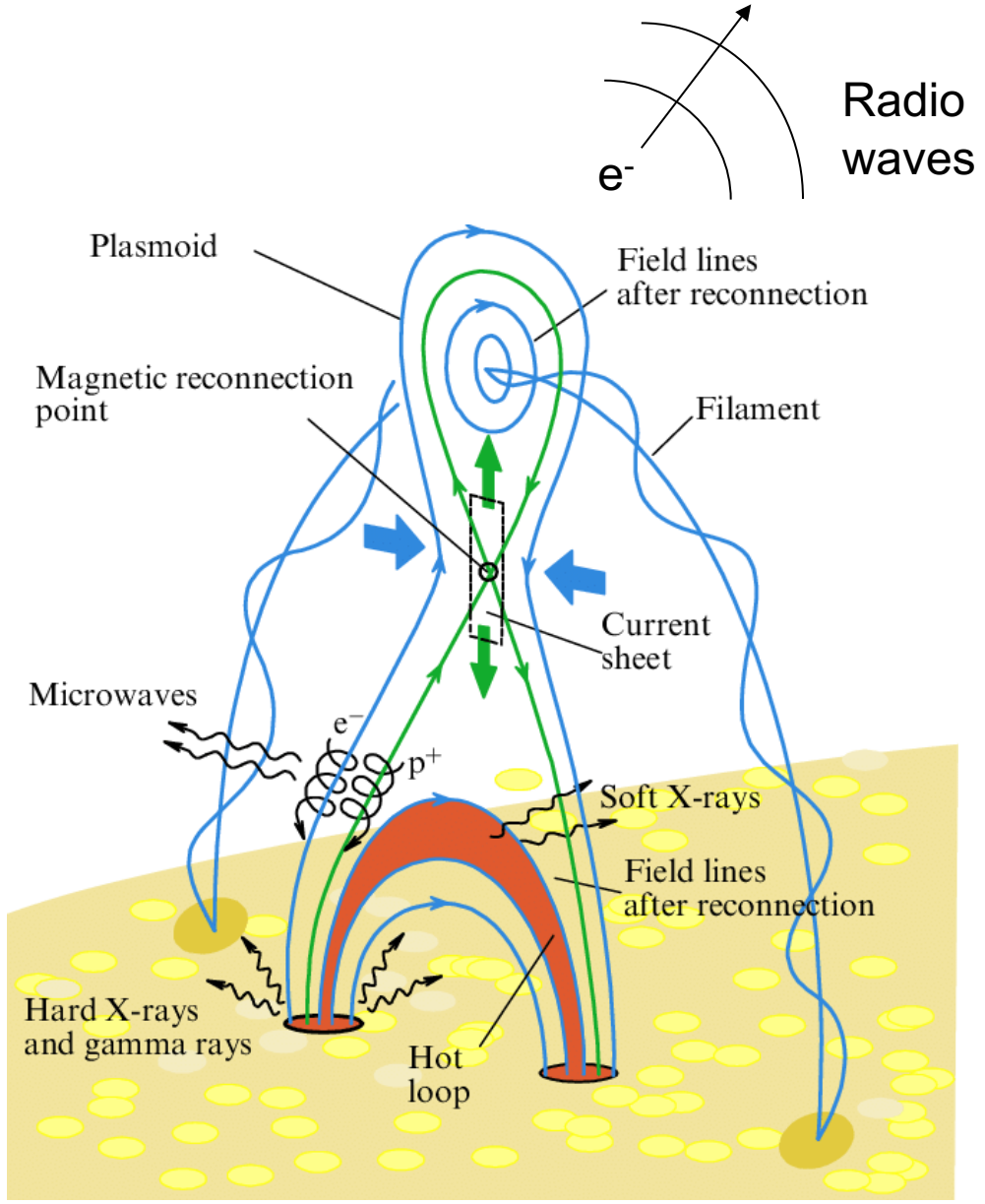


Figure is from A. L. Lysenko et al 2020 Phys.-Usp. 63 818

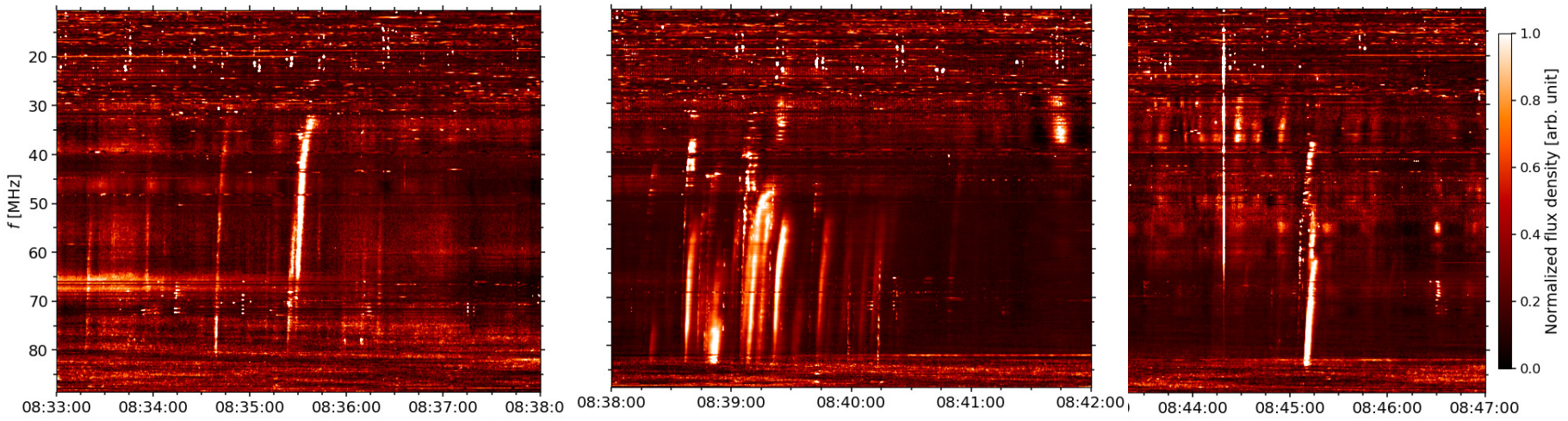
II. Observations of flare-accelerated electrons

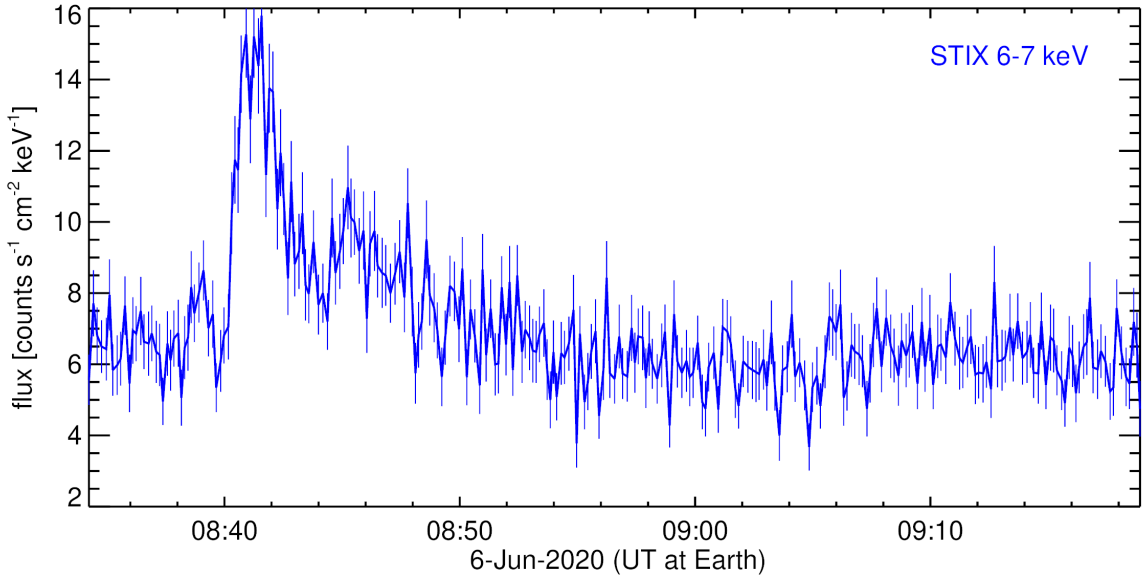
Away from the sun – radio (LOFAR)

Towards the sun – x-ray (STIX)

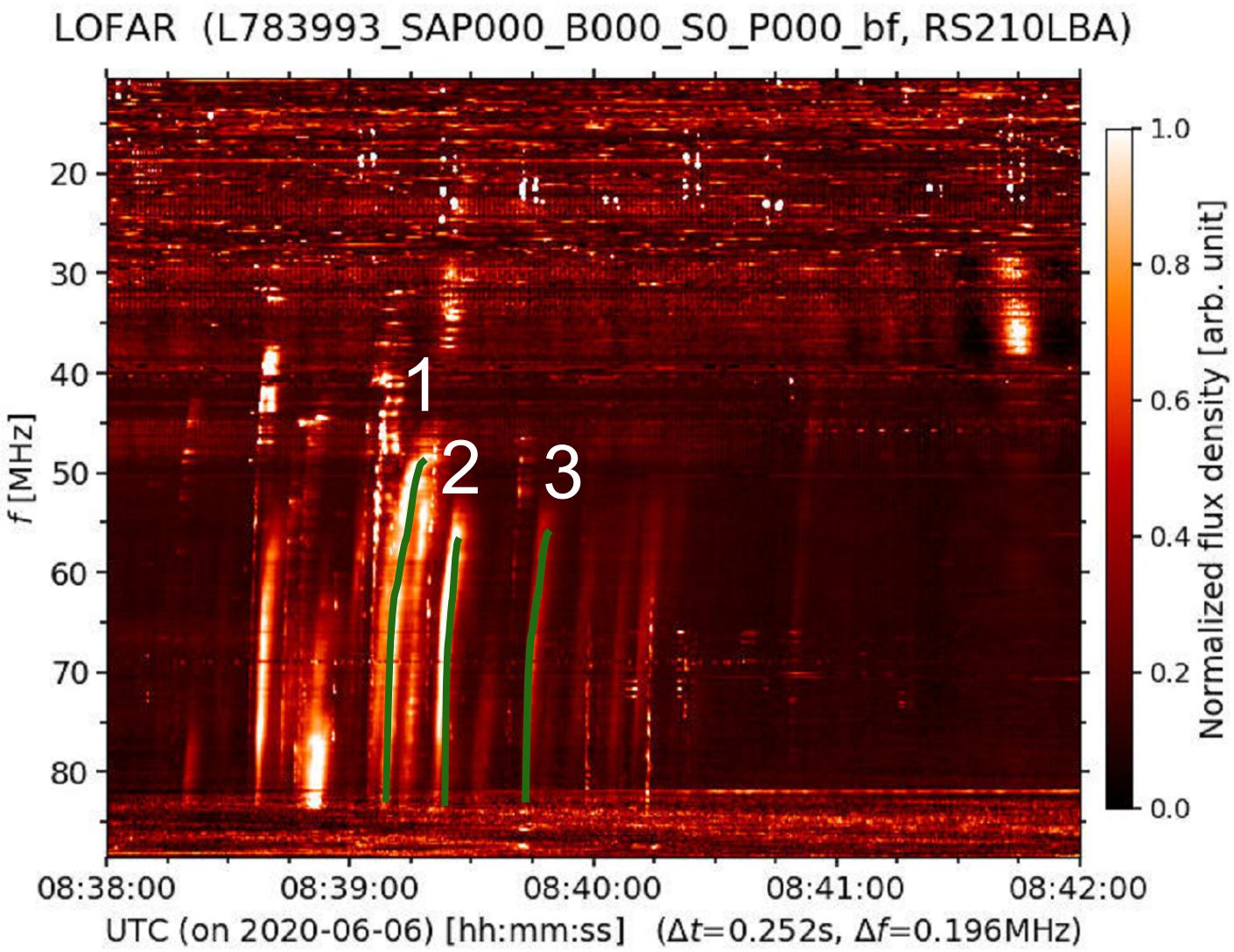
Event from joint observing campaign: 06 June 2020

Solar Type-III Radio Bursts and STIX data during solar flare on 06 June 2020



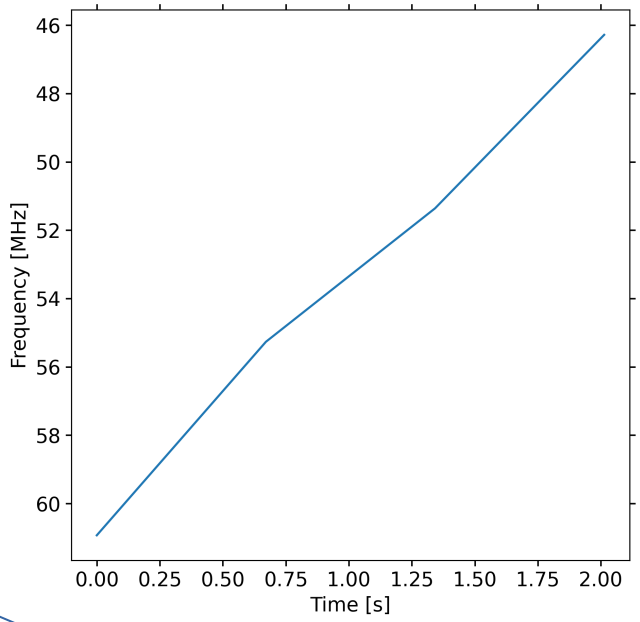


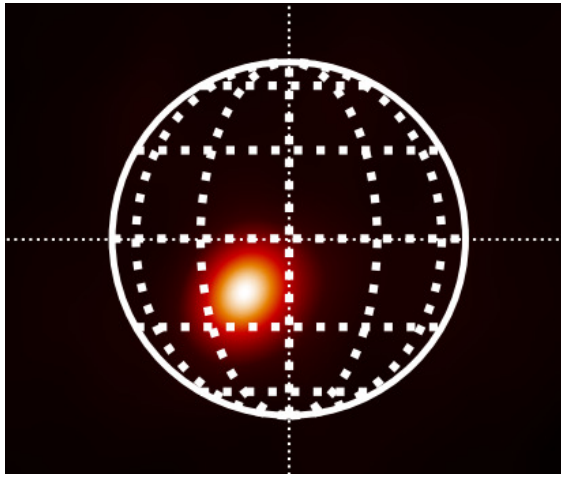
Solar Type-III Radio Bursts during solar flare on 06 June 2020

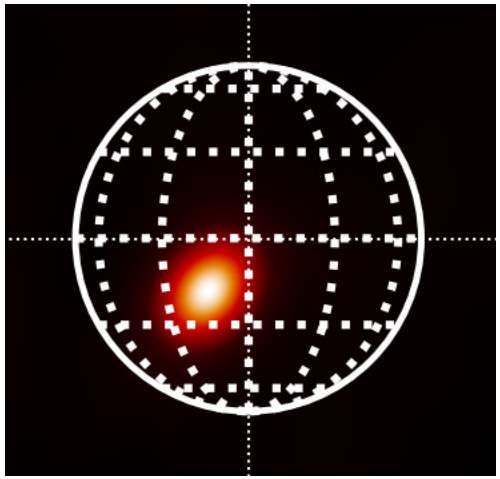


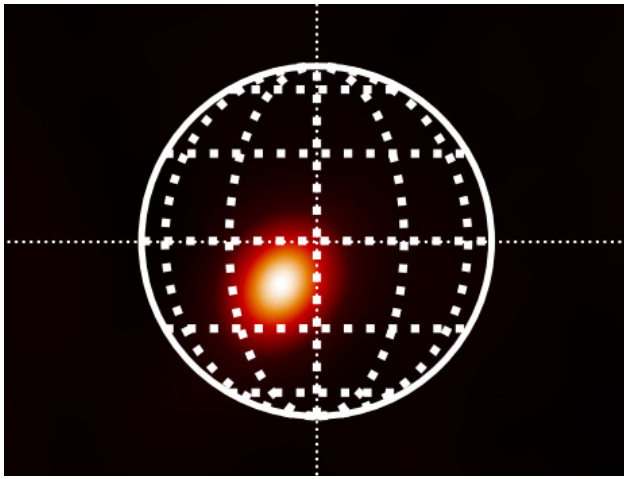
Following the electron beam through the Corona

Time [s]	0.6	1.3	2.
f [MHz]	55	51	46



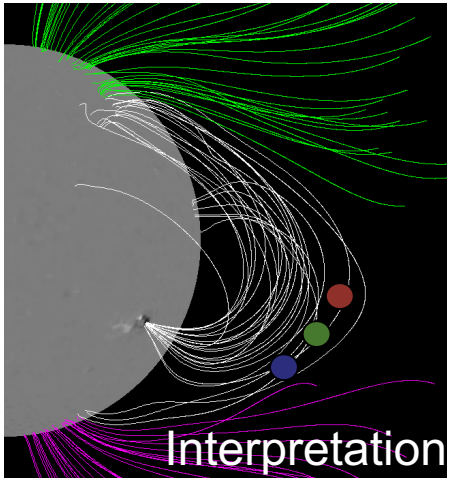


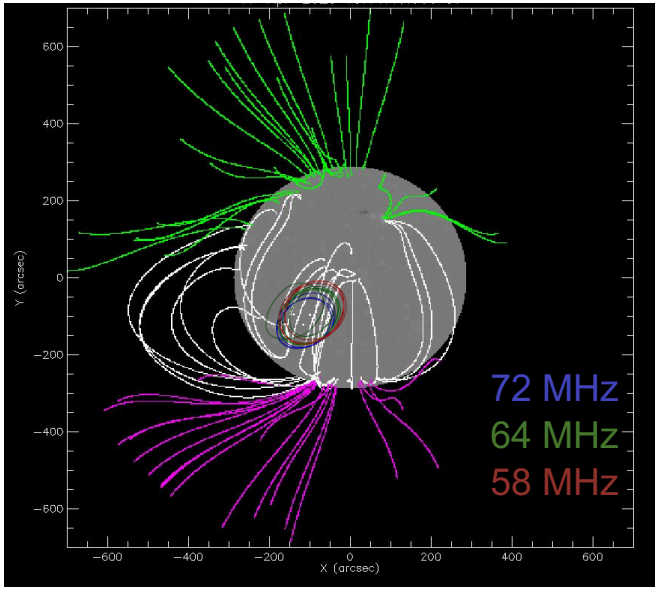




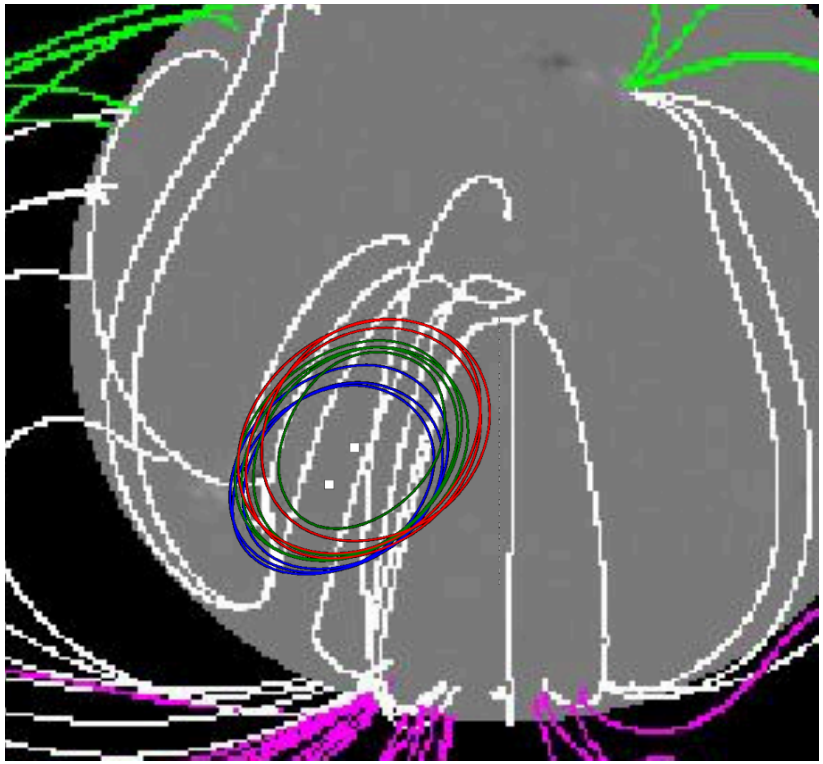
Potential field source surface (PFSS) model

- method to extrapolate the photospheric magnetic field through the corona
- Based on HMI (SDO) data





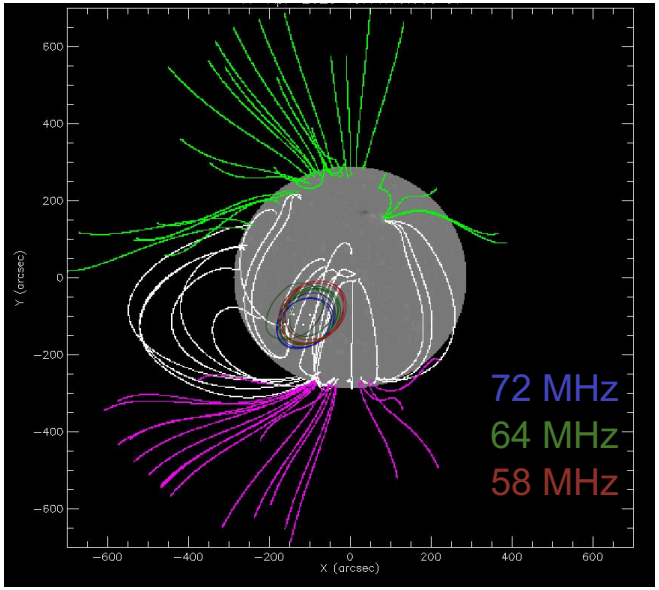
Bursts at 08:39,
08:40 and 08:45 UT



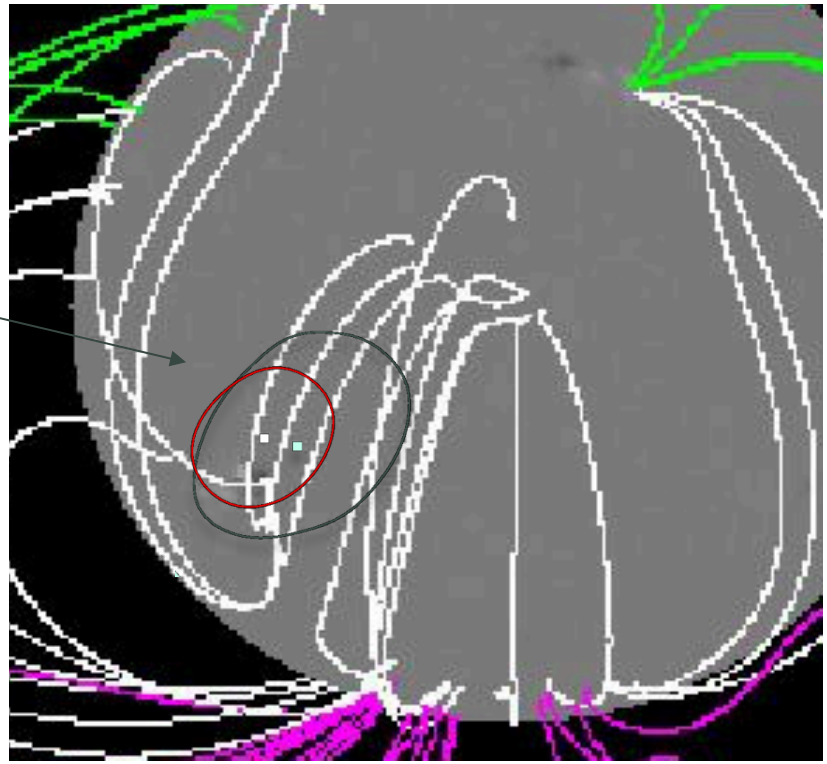
Schrijver, C.J., DeRosa, M.L. Photospheric and heliospheric magnetic fields.
Sol Phys 212, 165–200 (2003)

Potential field source surface (PFSS) model

- Radio source of burst at 08:35 UT moves to a different directions than the other bursts

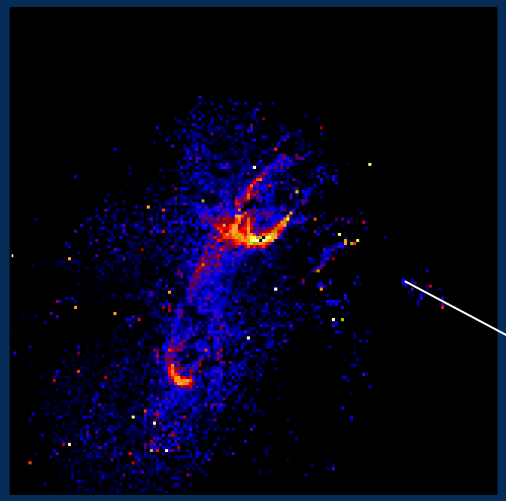


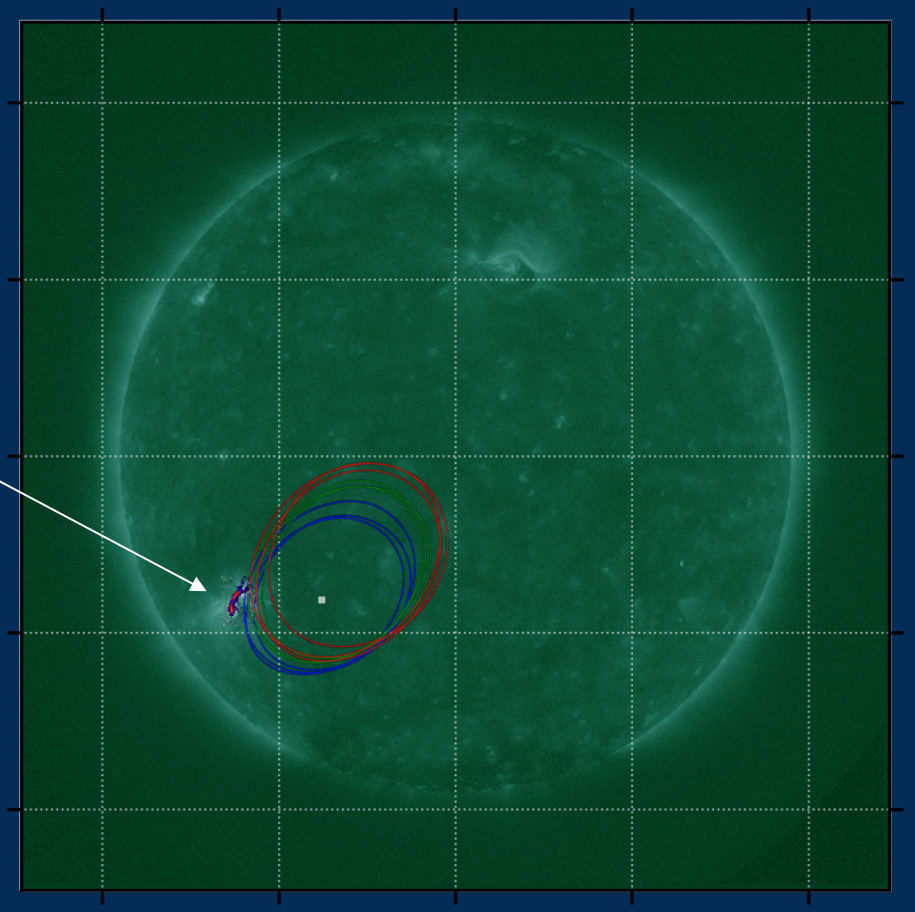
Burst at 08:35 UT



Schrijver, C.J., DeRosa, M.L. Photospheric and heliospheric magnetic fields.
Sol Phys 212, 165–200 (2003)

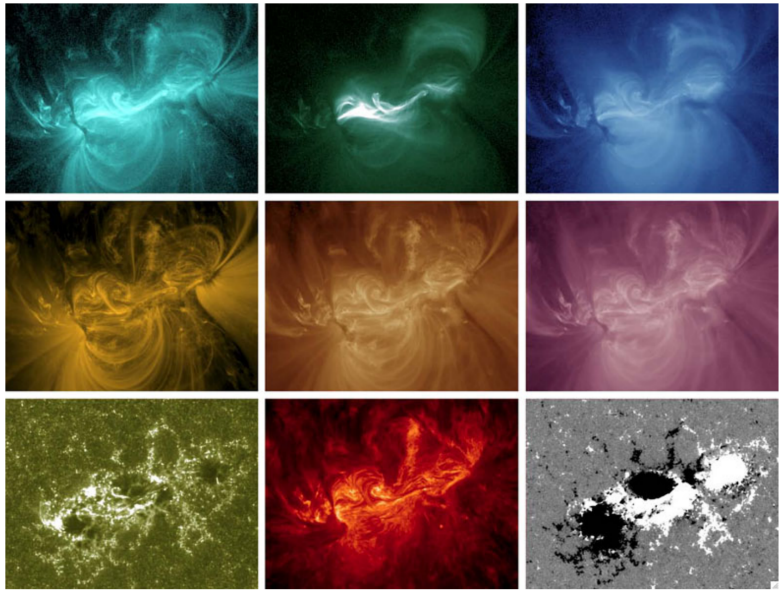
III. Thermal evolution of the active region during type-III radio bursts

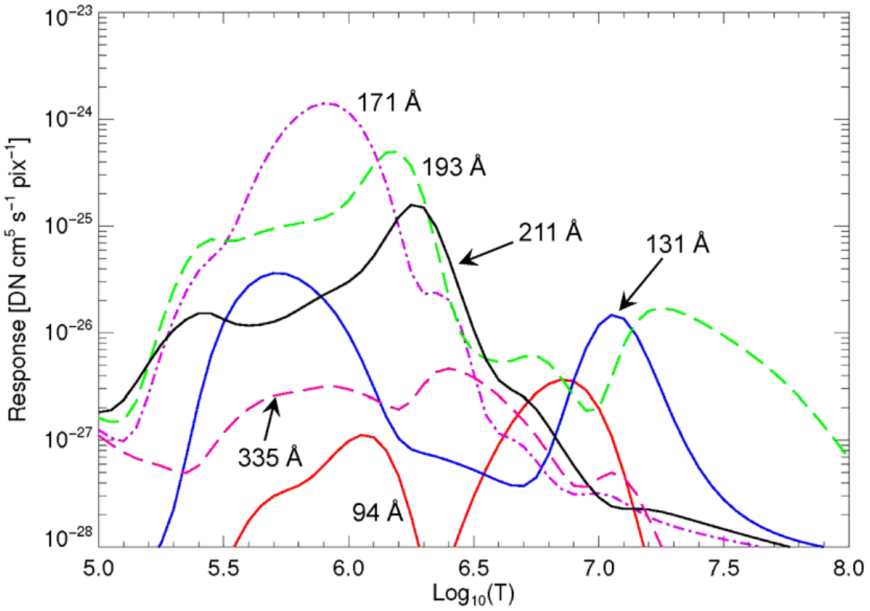




Atmospheric Imaging Assembly (AIA) Data

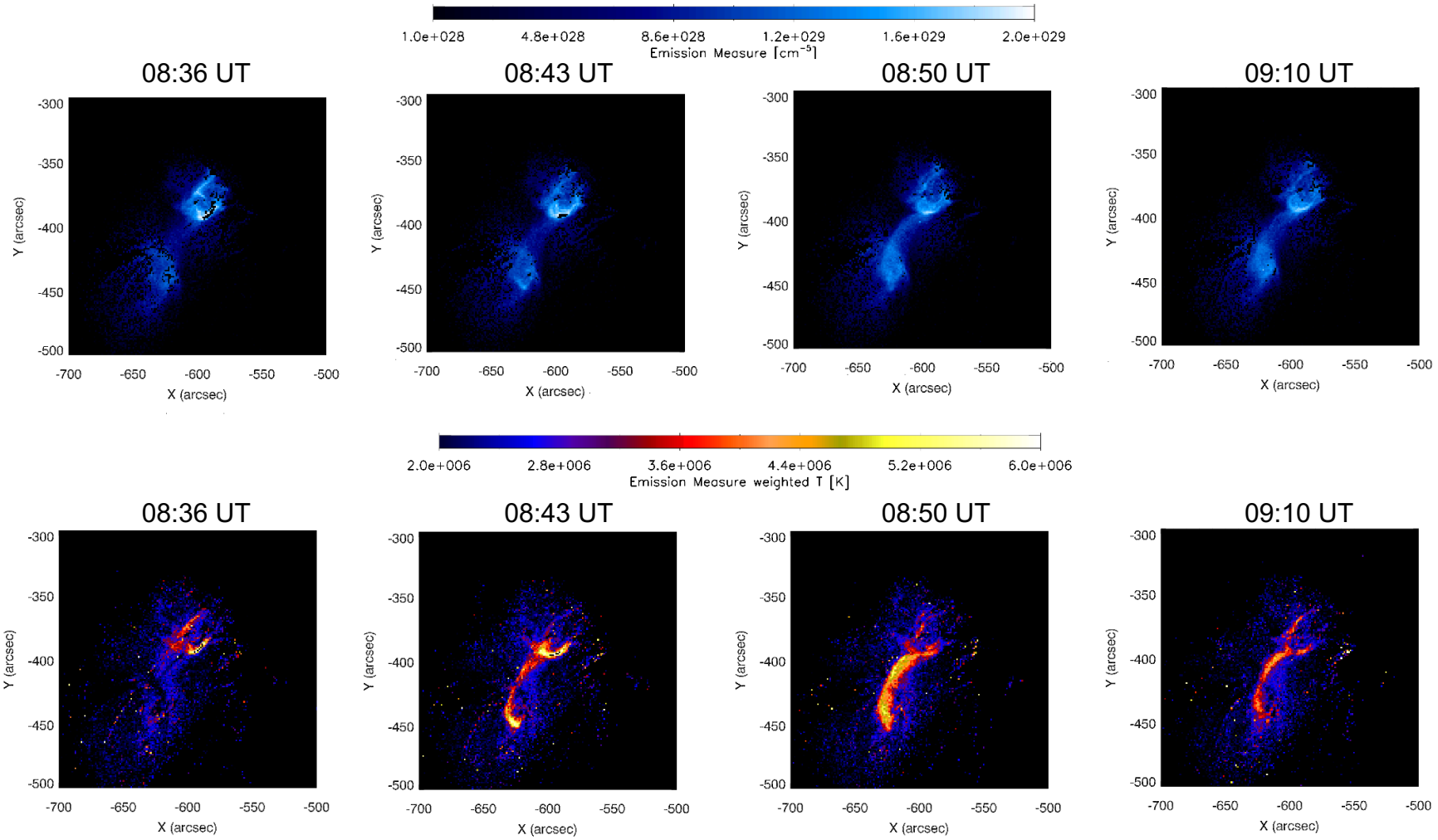
- Imager on the Solar Dynamics Observatory
- multiple simultaneous high-resolution full-disk images of the corona and transition region
- 1.5-arcsec spatial resolution and 12-second temporal resolution





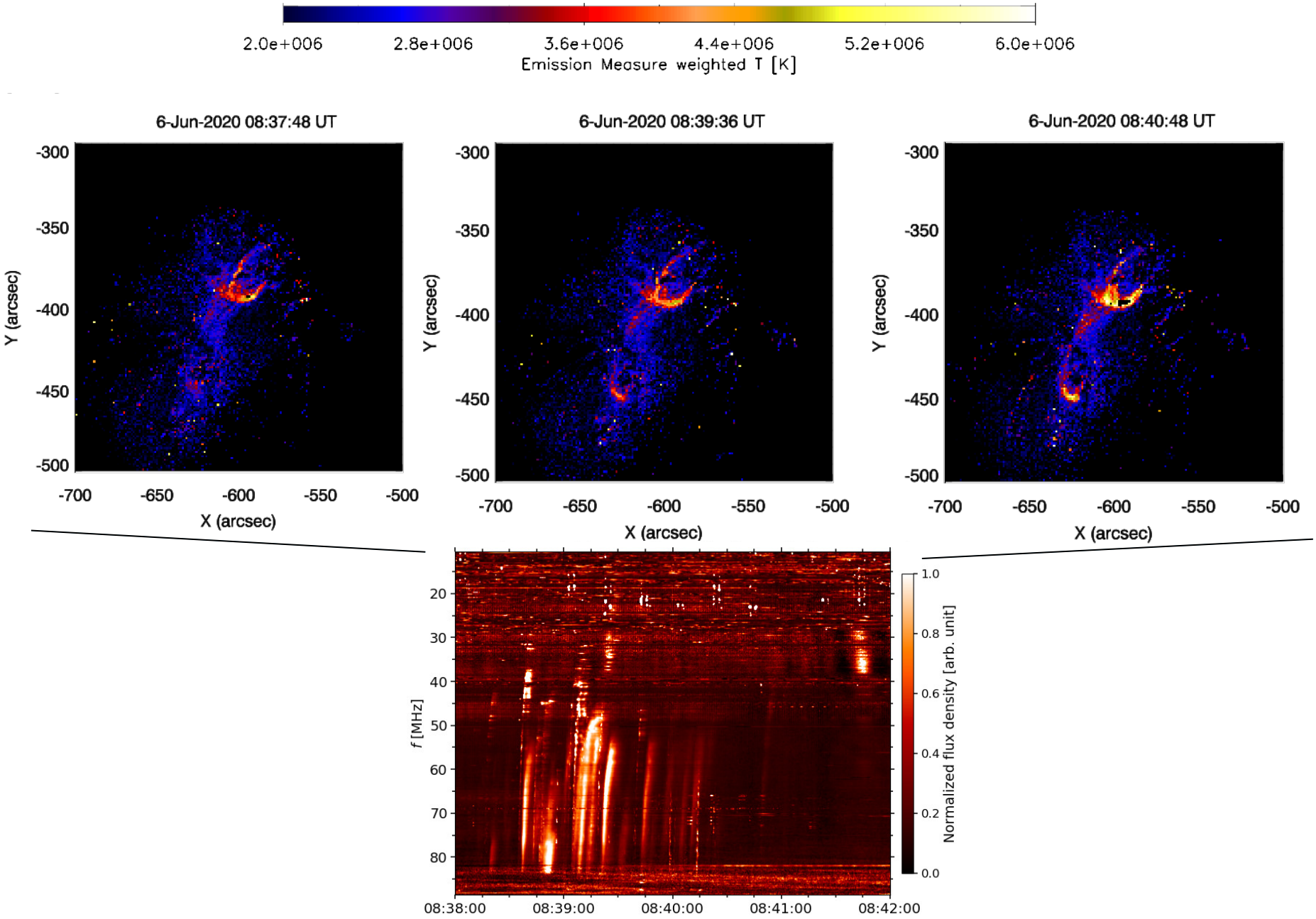
DEM Anaylsis based on EUV data

$$EM_T = DEM(T) \cdot \Delta T = \int_{T_0}^{T_1} \int n_e^2(T,z)\,dz\,dT$$

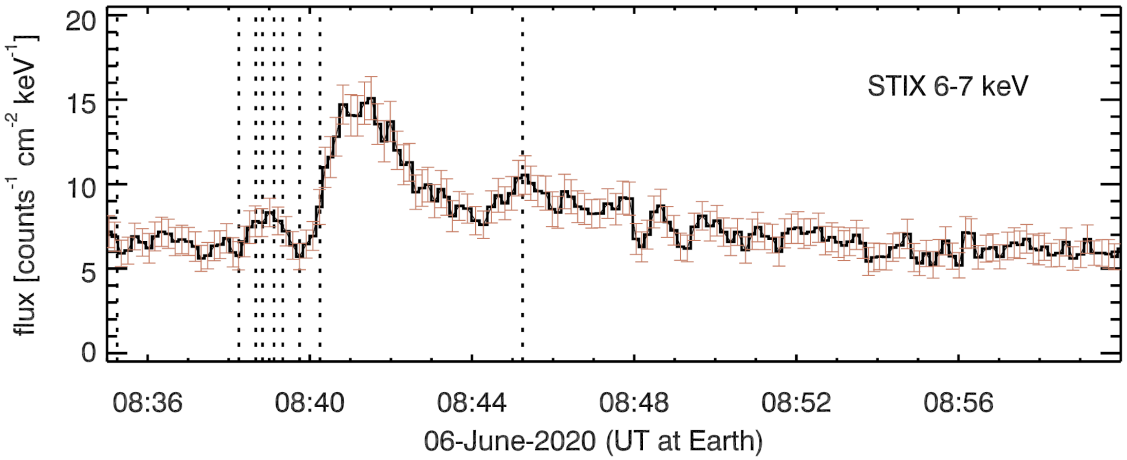


Differential Emission Measure (DEM) describes the amount of thermal plasma along the line-of-sight as a function of the temperature T.

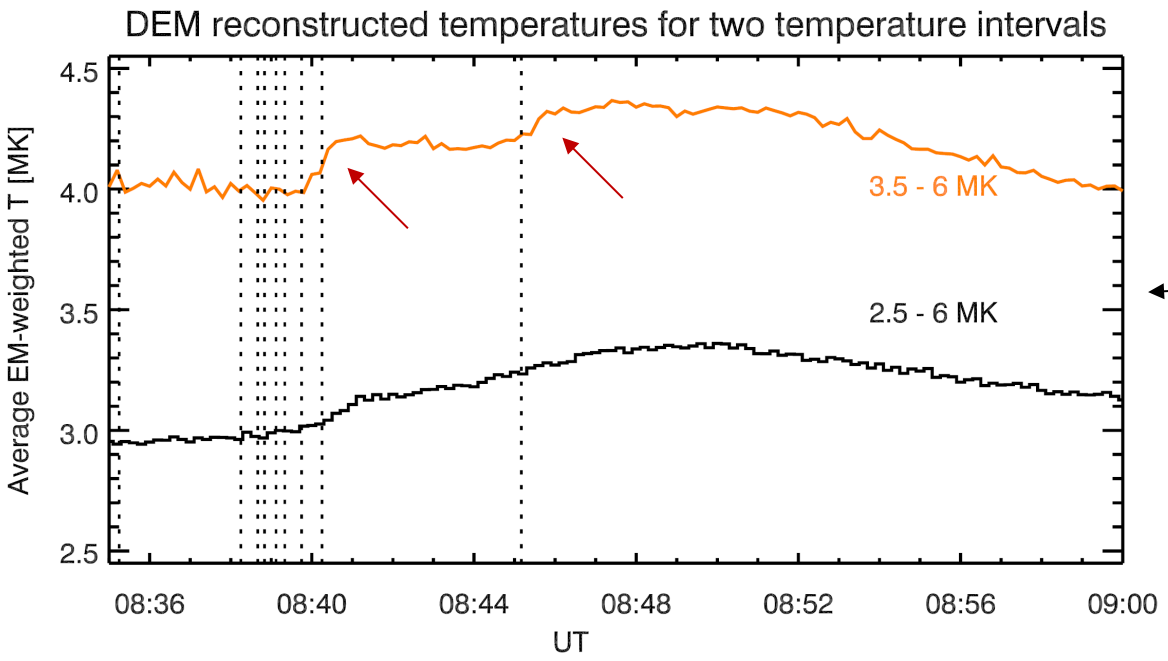
DEM Method: Yang Su et al 2018 ApJL 856 L17

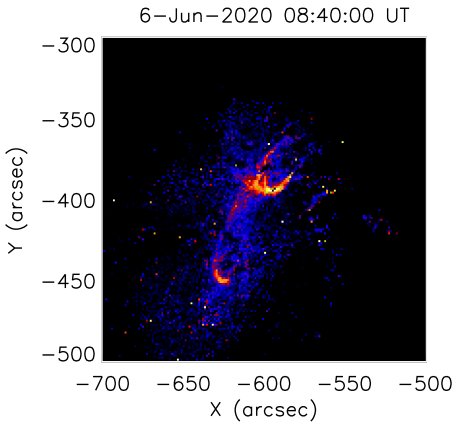

2.0e+006
2.8e+006
3.6e+006
4.4e+006
5.2e+006
6.0e+006
Emission Measure weighted T [K]
6-Jun-2020 08:37:48 UT
6-Jun-2020 08:39:36 UT
6-Jun-2020 08:40:48 UT
Y (arcsec)
X (arcsec)
-300
-350
-400
-450
-500
-700
-650
-600
-550
-500
f [MHz]
20
30
40
50
60
70
80
08:38:00
08:39:00
08:40:00
08:41:00
08:42:00
Normalized flux density [arb. unit]
0.0
0.2
0.4
0.6
0.8
1.0

Average EM-weighted temperatures of the active region

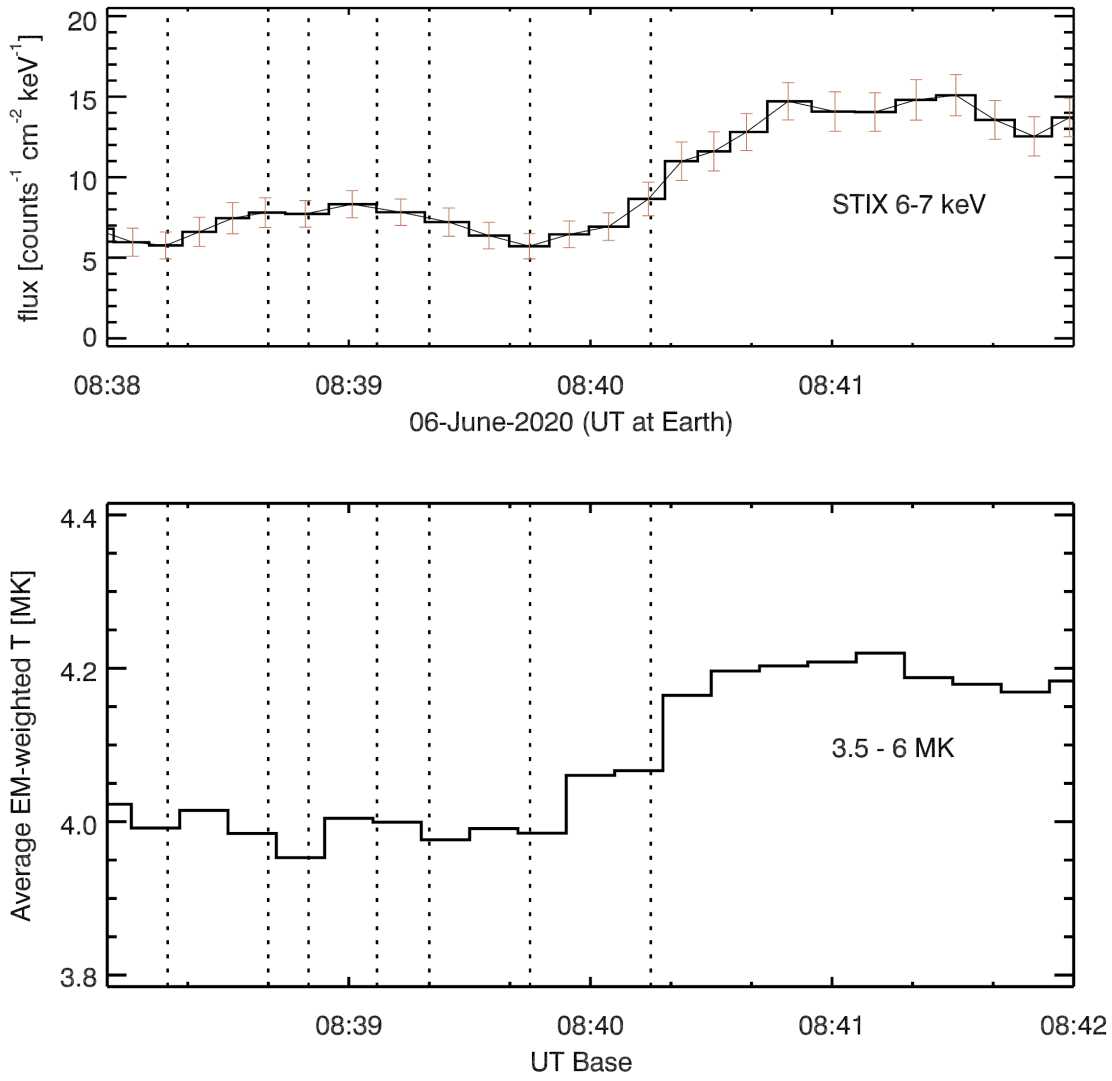


Type-III radio bursts observed by LOFAR

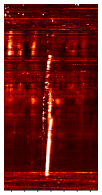


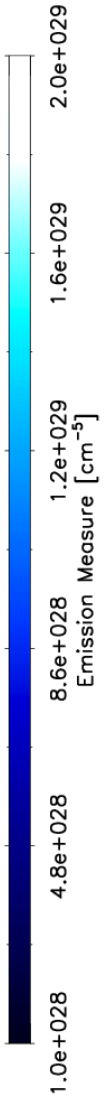


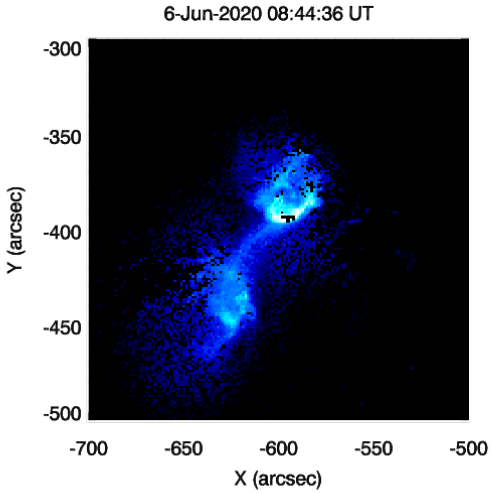
Temperature evolution and X-ray flux during the impulsive flare phase

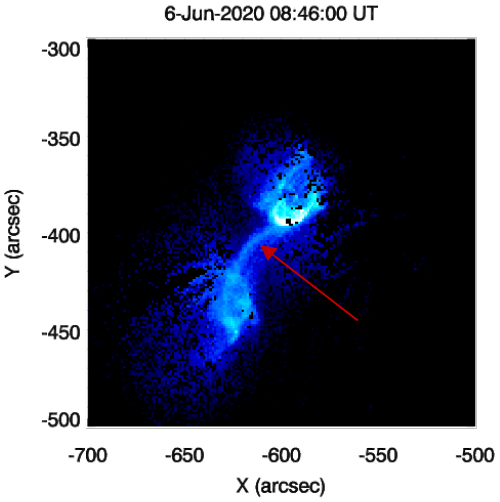


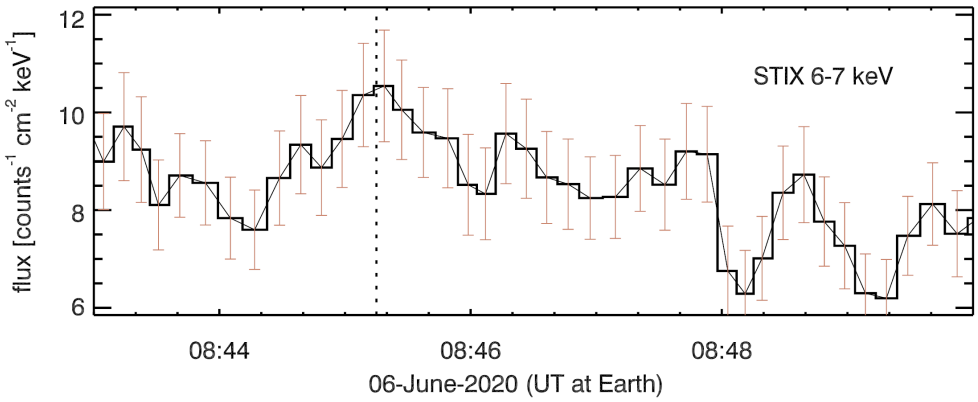
before type-III radio burst

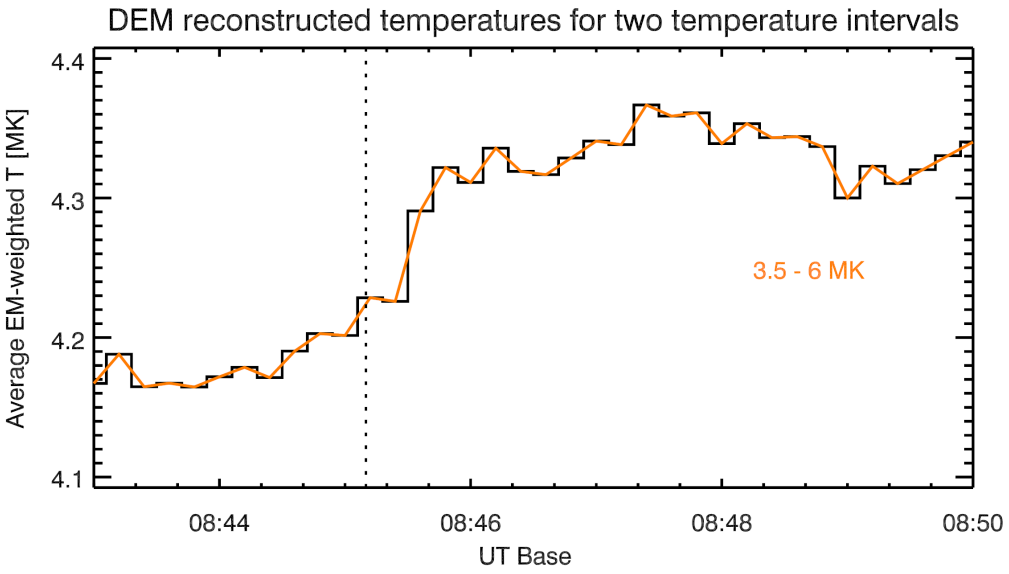












After type-III radio burst

Summary

- In this event **type-III radio bursts** mark the on-set of the heating process in the impulsive flare phase.
- There are also type-III radio bursts **before the flare**, which are not accompanied by a significant temperature change of the active region.
- There are radio quieter periods with ongoing heating occurring in parallel.
- The radio **source position** stays rather constant during the impulsive phase, but changed from previous burst around 08:35 UT.
- The **Radio flux** of radio bursts decreases right before the X-ray on-set at 08:40 UT.

Outlook

- Application of the presented analysis techniques to further events to the investigate relations between flare-accelerated electrons and the heating process of the active region.

Data Acknowledgements

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This research is based (in part) on data obtained with the International LOFAR (van Haarlem et al. 2013) Telescope (ILT) under project code LT16_ 001. Furthermore we have used data from AIA on NASA’s SDO satellite and STIX on the Solar Orbiter satellite.

Software Acknoledgment

PFSS model: Schrijver, C.J., DeRosa, M.L. Photospheric and heliospheric magnetic fields. Sol Phys 212, 165–200 (2003).

DEM Method: Yang Su et al 2018 ApJL 856 L17.

This research used version 4.0.6 of the SunPy open source software package.

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Image Sources

https://phys.org/news/2016-01-magnetic-sun.html
https://www.todaysmedicaldevelopments.com/article/medium-voltage-electron-beams/

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Thank you for your attention!