Evolution of the magnetic connectivity during solar flares as seen from type-III radio bursts

Malte Bröse
Prepared at Leibniz-Institute for Astrophysics and Technical University Berlin
PhD supervisors: Dr. Christian Vocks and Prof. Dr. Dieter Breitschwerdt
Outline

I. Context – magnetic connectivity in solar flares

II. Multi-wavelength observations of two B-class flares:
   • X-ray fluxes and thermal evolution of the active region
   • Radio observations with LOFAR

III. Summary of observations
Flare-accelerated electrons and their traces

- 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
LOw Frequency Array – Radio Interferometer

LOFAR structure:

- Central core (Exloo, NL) 24 stations
- 14 remote Stations (NL)
- 14 International Stations

Frequency range:
- Low Band: 30 – 90 MHz
- High Band: 110 – 250 MHz
Type-III bursts and magnetic connectivity

- Signs of down- and upward particle propagation are correlated, but do not always appear symmetrically (Kundu et al. (1980), Reid et al. (2011), James & Wilmer (2023)).

- Type-III bursts are very sensitive indicators for changes in the AR.

- Number of electrons producing type-III bursts is only around 0.1% of the number of electrons necessary to produce X-rays (Lin et al. (1973)).

- Large event sizes are not a requirement for type-III bursts.

- Magnetic connectivity: The incorporation of small-scale processes leading to particle acceleration into the large-scale magnetic structures (Raulin et al. (2000))
II. Multi-wavelength observations of two flare events

06-Jun-2020

22-Oct-2022

© NASA/SDO/A. Diercke
Magnetic configuration

- electrons propagate along magnetic field lines in encapsulated loop systems
B-class flare on 06 June 2020

- Small event with several X-ray peaks
Concentrated energy release in the active region
Selected bursts related to a similar energy release in the AR

80 MHz (purple), 70 MHz (blue), 60 MHz (green), 50 MHz (orange), 40 MHz (red)
Solar Type-III Radio Bursts and PFSS model

80 MHz (purple), 70 MHz (blue), 60 MHz (green), 50 MHz (orange)
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 Analysis based on EUV data

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

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

Before type-III radio burst

After type-III radio burst
Average EM-weighted temperatures of the active region

Type-III radio bursts observed by LOFAR
EUV observations of the limb event – 25 October 2022
2nd Event – 25 October 2022

STIX imaging – 6-7 keV
Dynamic radio spectra
Radio source positions for selected bursts

Burst 1: 12:16:49 UT
Burst 2: 12:18:22 UT
Burst 3: 12:22:46 UT
Burst 11: 12:30:10 UT
Burst 12: 12:34:09 UT
Burst 13: 12:34:55 UT

80 MHz (purple), 70 MHz (blue), 60 MHz (green), 50 MHz (orange)
Thermal evolution (DEM analysis)
III. Summary

- **Magnetic connectivity** can be indirectly studied with multi-wavelength observations.
- In the event on 06 June 2020 **type-III radio bursts** mark the on-set of the heating process. **Suppressed access to the higher altitudes** in the corona was accompanied by strong heating.

- The radio **source position** stays rather constant within each phase.
- The **large-scale magnetic field** is rather stable, while the ability to access certain field lines changes over time.
- It was possible to **identify single loops** affected by the energy release by conducting detailed DEM analysis of AIA/EUV data.
Data Acknowledgements

We thank the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) and the National Science Centre, Poland, and for granting “LOFAR observations of the solar corona during Parker Solar Probe perihelion passages” in the Beethoven Classic 3 funding initiative under project numbers VO 2123/1-1 and 2018/31/G/ST9/01341, respectively.

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 Acknowledgment


This research used version 4.0.6 of the SunPy open source software package.
Thank you for your attention!
Evolution of the magnetic connectivity during solar flares as seen from type-III radio bursts

Date: 2024-06-11

Author: M. Bröse

Institute: Leibniz Institut für Astrophysik Potsdam, Technische Universität Berlin


https://www.todaysmedicaldevelopments.com/article/medium-voltage-electron-beams/