Astronomical Institute of the Czech Academy of Sciences

Radio observations of spectral cleaving feature in solar type II bursts

Artem Koval[1], Marian Karlický[1], Anatolii Brazhenko[2], Aleksander Stanislavsky[3], Anatolii Frantsuzenko[2], Marek Vandas[1], Aleksander Konovalenko[3], Miroslav Bárta[1], Igor Bubnov[3], Rositsa Miteva[4], and Serge Yerin[3]

[1]Astronomical Institute of the Czech Academy of Sciences, 251 65 Ondřejov, Czech Republic
[2]Institute of Geophysics, Gravimetrical Observatory, 36014 Poltava, Ukraine
[3]Institute of Radio Astronomy of the National Academy of Sciences of Ukraine, 61002 Kharkiv, Ukraine
[4]Institute of Astronomy and National Astronomical Observatory - Bulgarian Academy of Sciences, 1784 Sofia, Bulgaria

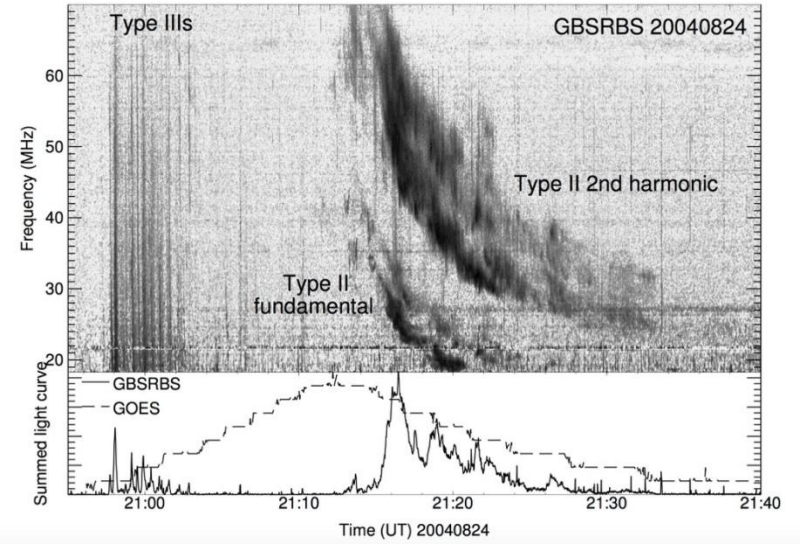
Type II solar radio bursts

• Metric-decametric type II radio bursts are known radio signatures of coronal shocks

• A type II burst is generated by energetic electrons accelerated at propagating shock waves driven by solar eruptions (i.e., flares or coronal mass ejections (CMEs)) via the plasma emission mechanism

• Emission at fundamental (f) and second-harmonic (2f) of local plasma frequency can be observed [Melrose (1986)]

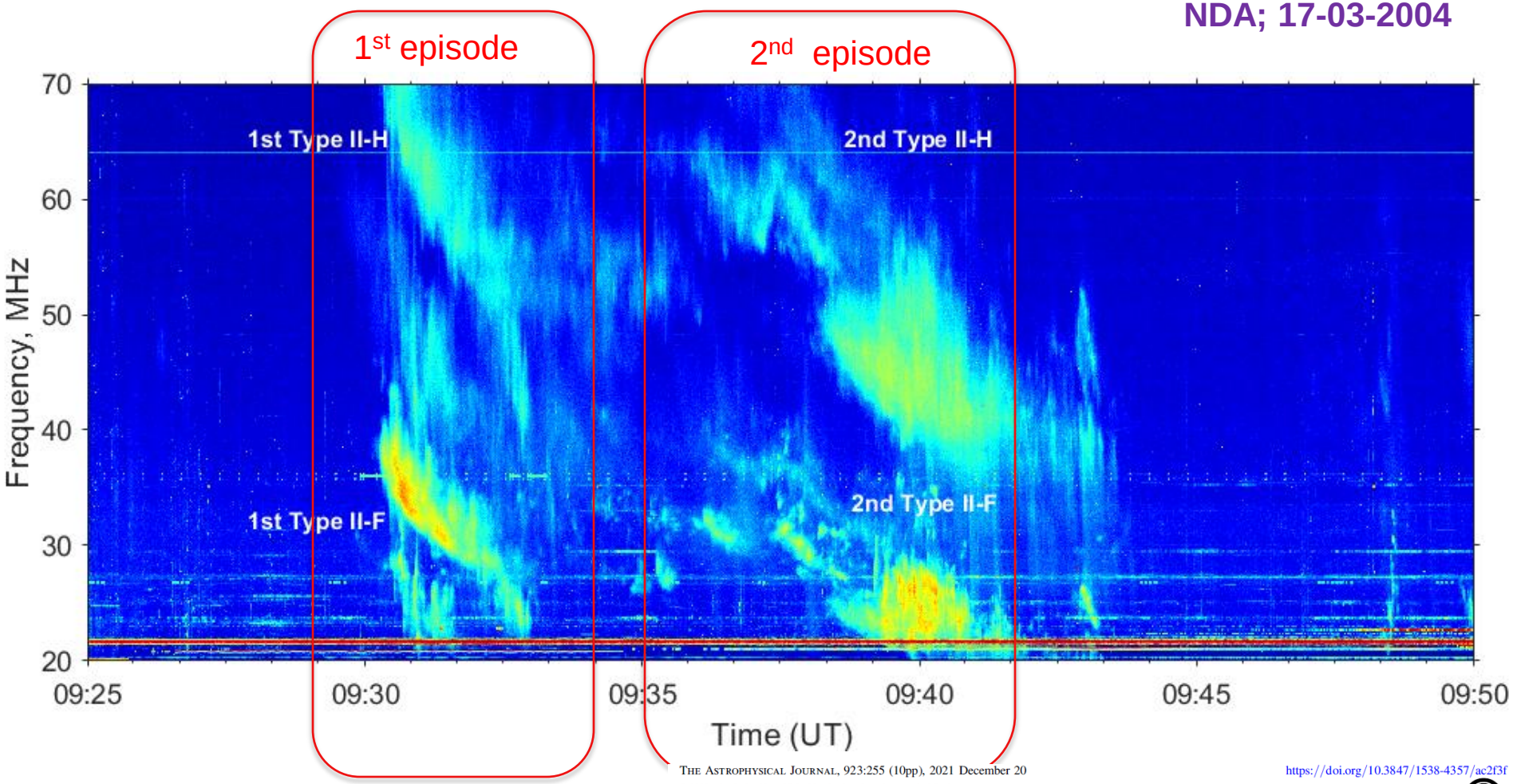
• Each of the Fundamental (F) and Harmonic (H) bands can experience splitting into two thinner bands, a phenomenon known as “band-splitting” [Smerd et al. (1975)]



• Since the ambient electron number density in the solar corona decreases with height, type II bursts appear as slow drifting lanes in the dynamic spectra from high to low frequencies.

Spectral Break and Bump in Type II solar bursts

NDA; 17-03-2004



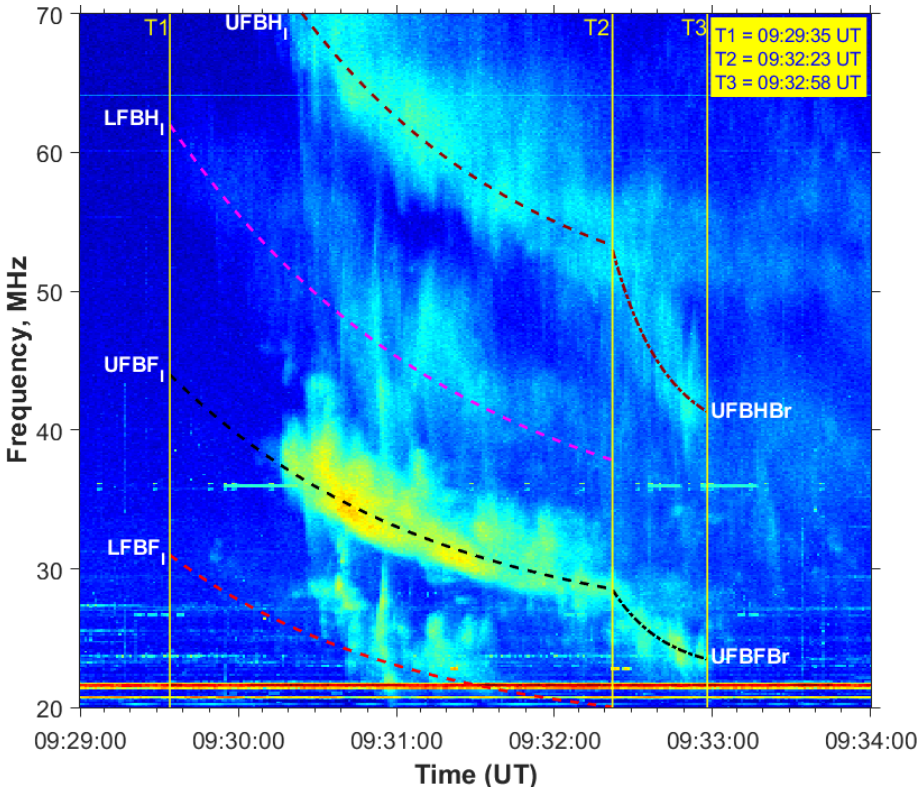
THE ASTROPHYSICAL JOURNAL, 923:255 (10pp), 2021 December 20 https://doi.org/10.3847/1538-4357/ac2f3f

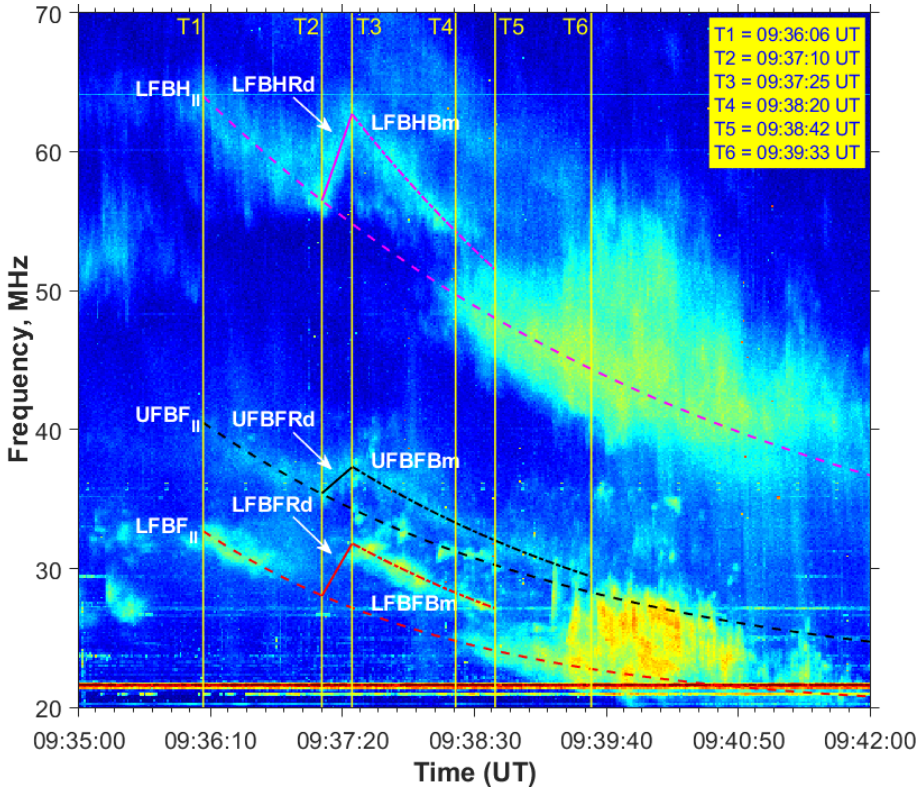
Shock-wave Radio Probing of Solar Wind Sources in Coronal Magnetic Fields

Artem Koval[1], Marian Karlický[1], Aleksander Stanislavsky[2,3], Bing Wang[4], Miroslav Bárta[1], and Roman Gorgutsa[5]
[1] Astronomical Institute of the Czech Academy of Sciences, 251 65 Ondřejov, Czech Republic; koval@asu.cas.cz
[2] Institute of Radio Astronomy, National Academy of Sciences of Ukraine, 61002 Kharkiv, Ukraine
[3] Faculty of Pure and Applied Mathematics, Hugo Steinhaus Center, Wrocław University of Science and Technology, 50-370 Wrocław, Poland
[4] Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, School of Space Science and Physics, Institute of Space Sciences, Shandong University, 264209 Weihai, People's Republic of China
[5] Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russian Academy of Sciences, 108840 Troitsk, Russia

Spectral Break and Bump in Type II solar bursts

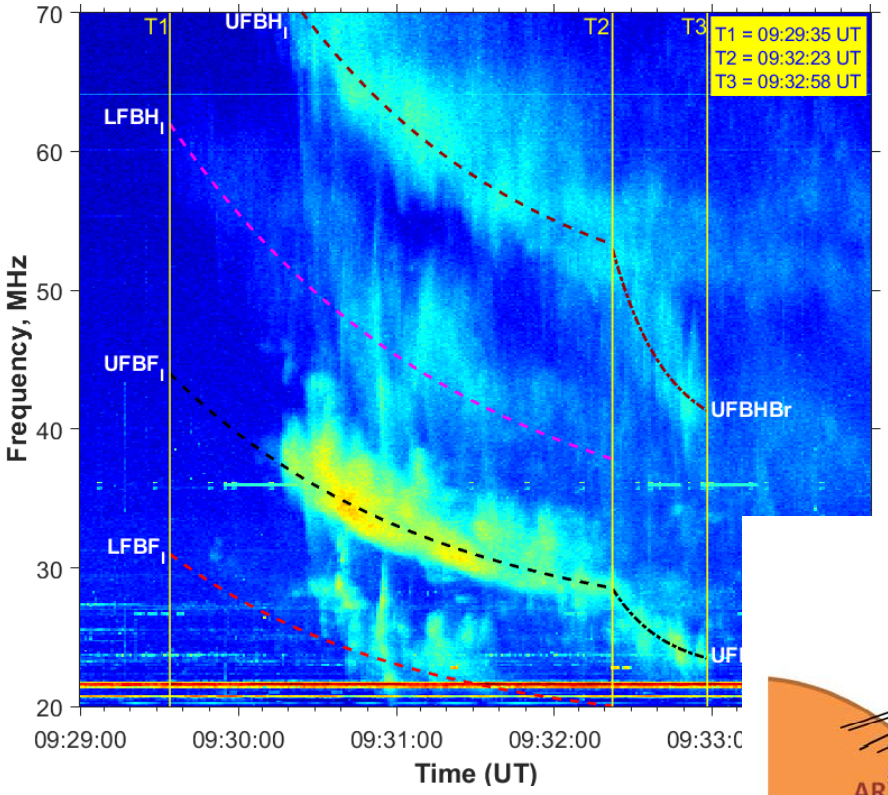
NDA; 17-03-2004

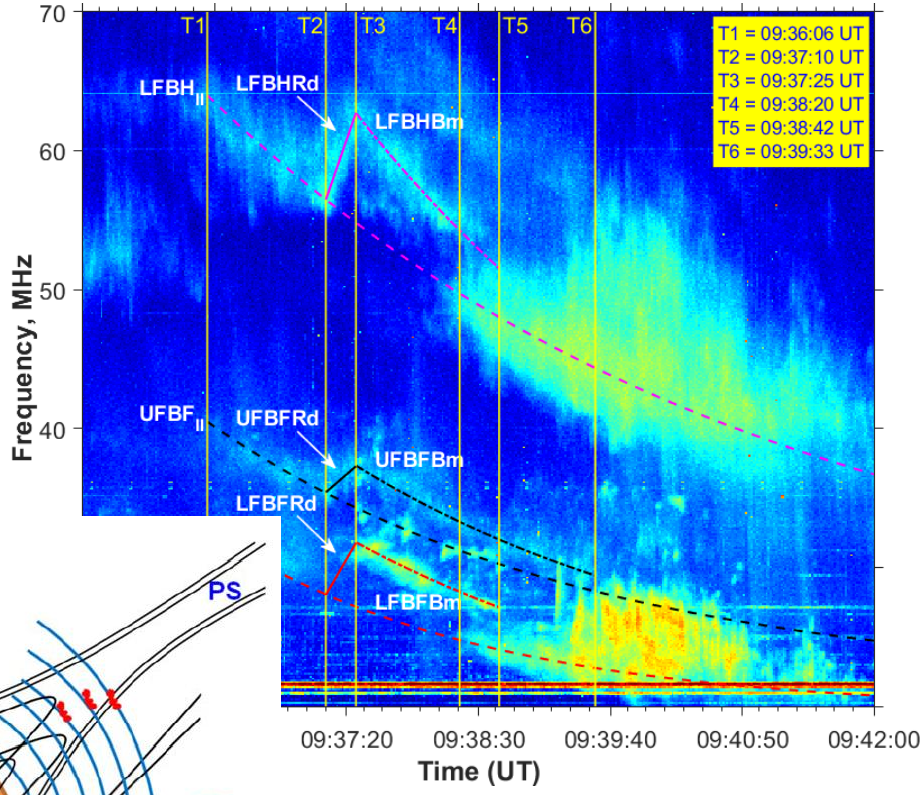


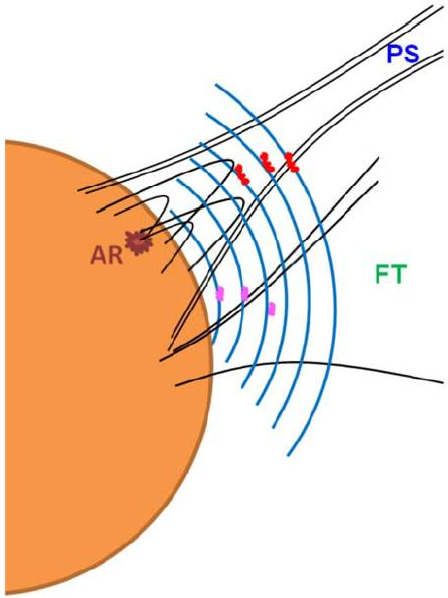


Spectral Break and Bump in Type II solar bursts

NDA; 17-03-2004



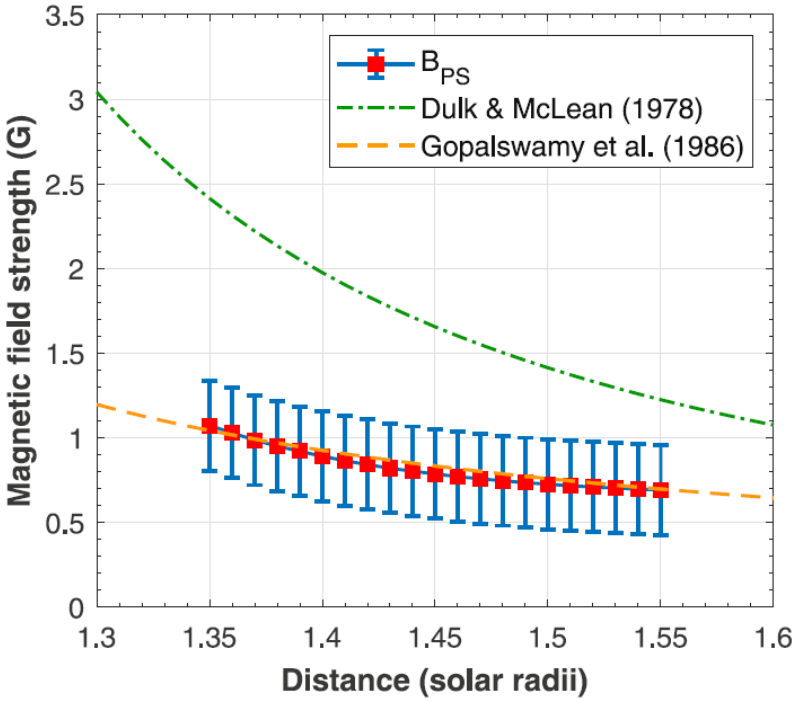


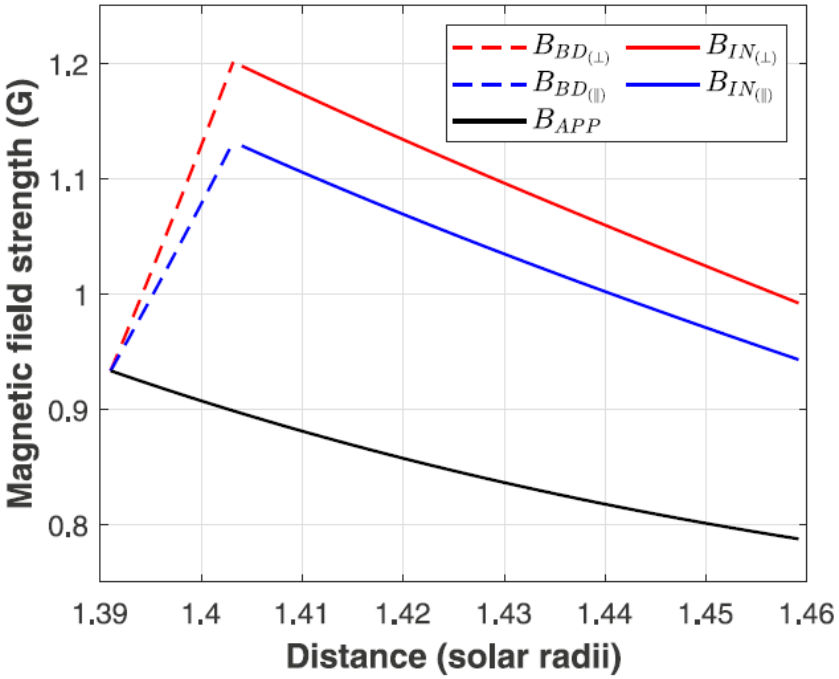


A spectral break is the result of a density decrease when a type II emission source propagates from the inside of a streamer to the outside .

A spectral bump is produced when a type II emission source propagates across a streamer or flux tube structure from one side to the other .

Calculations of Magnetic Field (1st and 2nd episodes)





[Gopalswamy et al. (1986)]

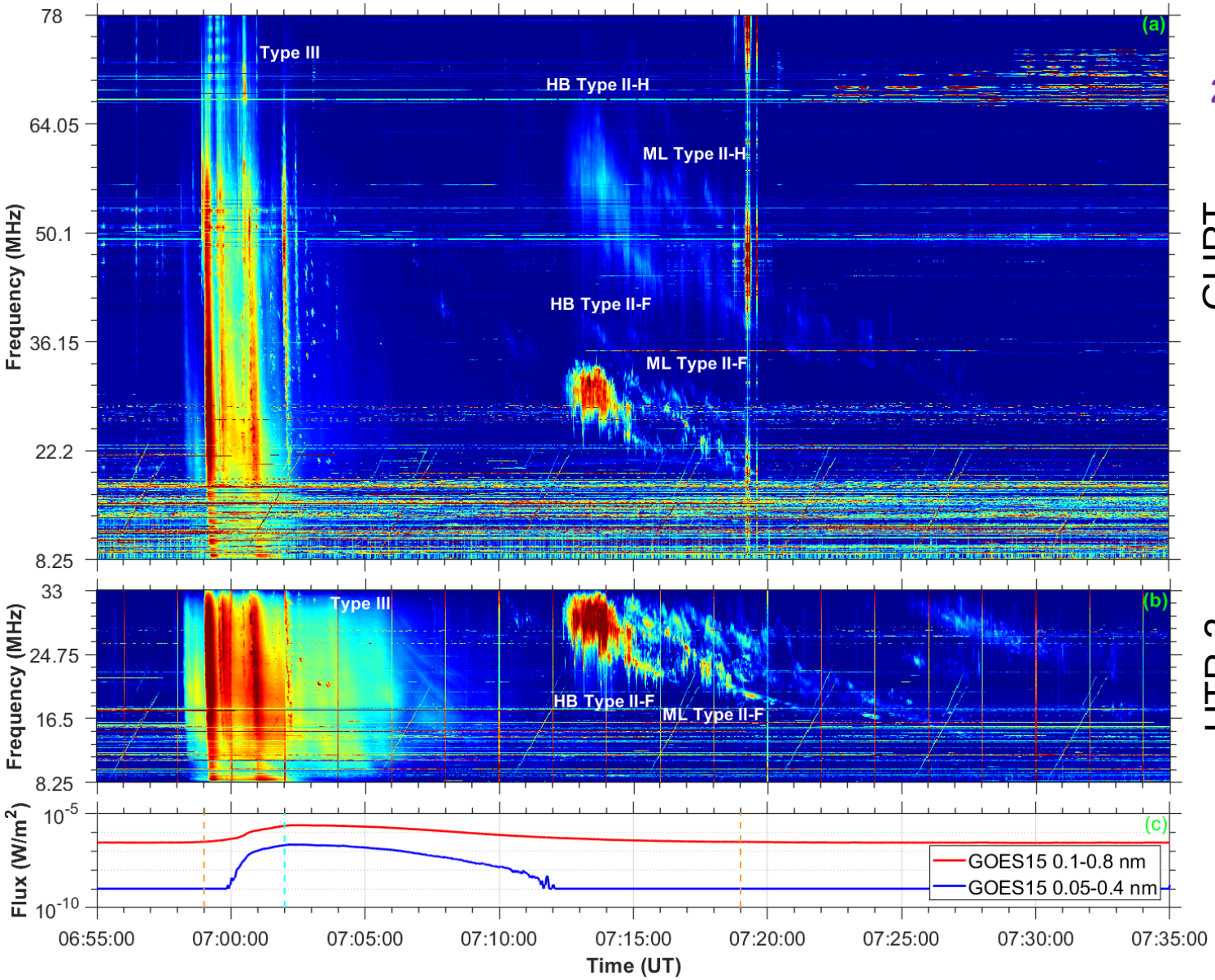
[Dulk & McLean (1978)]

The Astrophysical Journal, 923:255 (10pp), 2021 December 20
https://doi.org/10.3847/1538-4357/ac2f3f

Shock-wave Radio Probing of Solar Wind Sources in Coronal Magnetic Fields

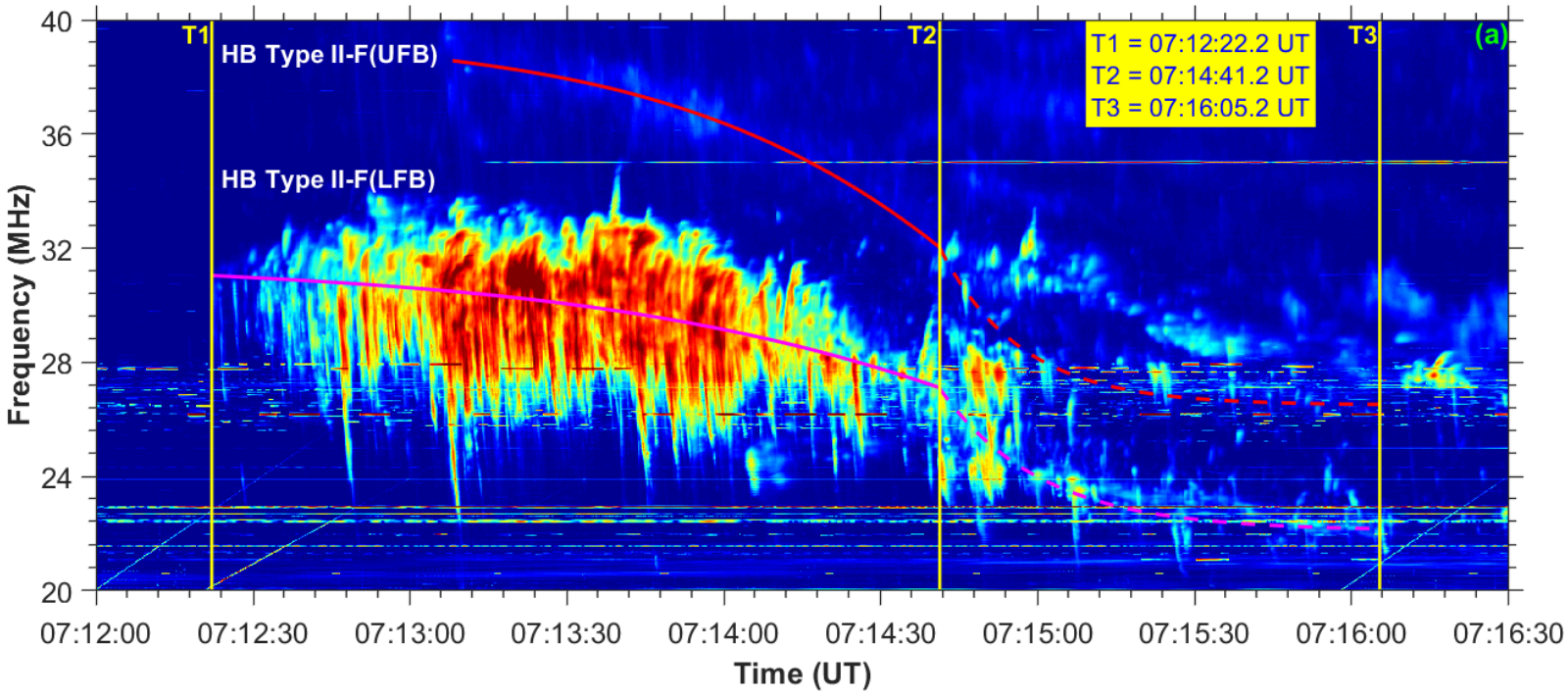
Artem Koval[1], Marian Karlický[1], Aleksander Stanislavsky[2,3], Bing Wang[4], Miroslav Bárta[1], and Roman Gorgutsa[5]
[1] Astronomical Institute of the Czech Academy of Sciences, 251 65 Ondřejov, Czech Republic; koval@asu.cas.cz
[2] Institute of Radio Astronomy, National Academy of Sciences of Ukraine, 61002 Kharkiv, Ukraine
[3] Faculty of Pure and Applied Mathematics, Hugo Steinhaus Center, Wrocław University of Science and Technology, 50-370 Wrocław, Poland
[4] Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, School of Space Science and Physics, Institute of Space Sciences, Shandong University, 264209 Weihai, People's Republic of China
[5] Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russian Academy of Sciences, 108840 Troitsk, Russia

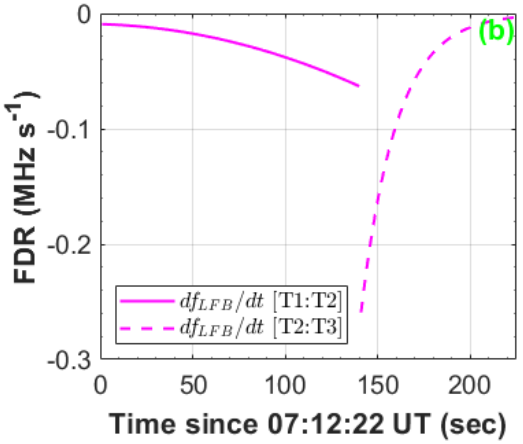
GURT/UTR-2/GOES15 observational data



25-07-2014

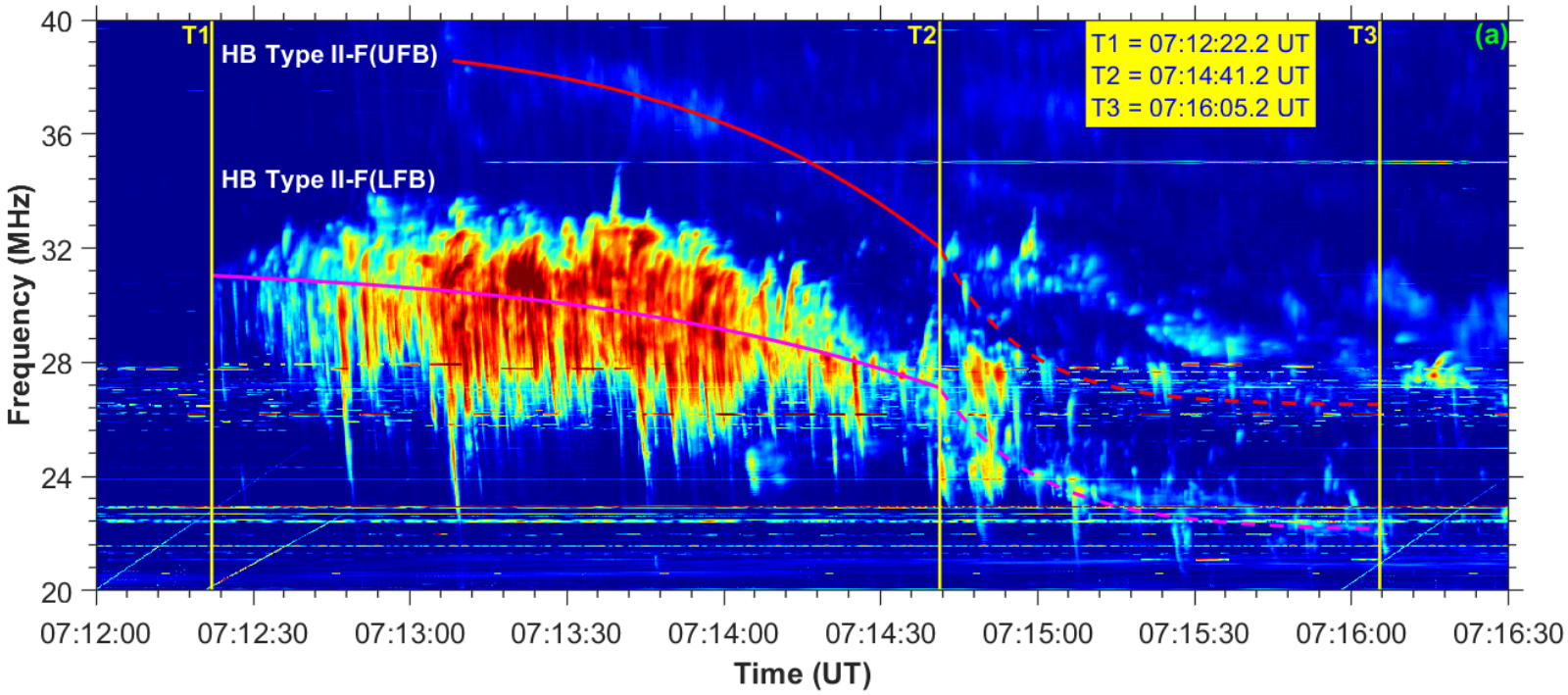
HB Type II-F: band-splitting and spectral break

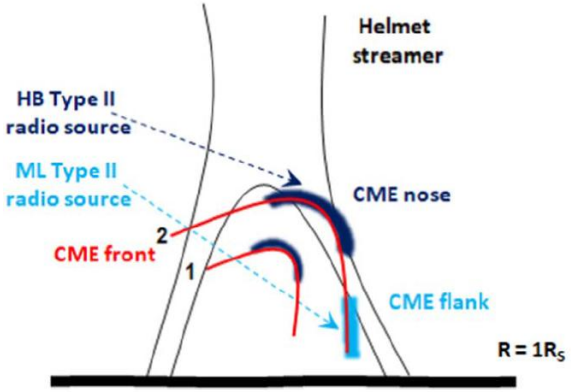




- **FDR values of both lanes gradually increase with time.**
- **At the spectral break point FDR magnitudes grow abruptly. In particular, FDR of HB Type II-F(LFB) is about |-0.26| MHz/s at T2 and falls down to |-0.1| MHz/s within 20 seconds after the spectral break point.**

HB Type II-F: band-splitting and spectral break





THE ASTROPHYSICAL JOURNAL, 952:51 (9pp), 2023 July 20
https://doi.org/10.3847/1538-4357/acdbcc

Morphology of Solar Type II Bursts Caused by Shock Propagation through Turbulent and Inhomogeneous Coronal Plasma

Artem Koval[1], Aleksander Stanislavsky[2,3], Marian Karlický[1], Bing Wang[4], Serge Yerin[2], Aleksander Konovalenko[2], and Miroslav Bárta[1]
[1] Astronomical Institute of the Czech Academy of Sciences, 251 65 Ondřejov, Czech Republic; koval@asu.cas.cz
[2] Institute of Radio Astronomy of the National Academy of Sciences of Ukraine, 61002 Kharkiv, Ukraine
[3] Faculty of Pure and Applied Mathematics, Hugo Steinhaus Center, Wrocław University of Science and Technology, 50-370 Wrocław, Poland
[4] Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, School of Space Science and Physics, Institute of Space Sciences, Shandong University, 264209 Weihai, People's Republic of China
Received 2023 March 1; revised 2023 May 20; accepted 2023 June 4; published 2023 July 18

Motivation

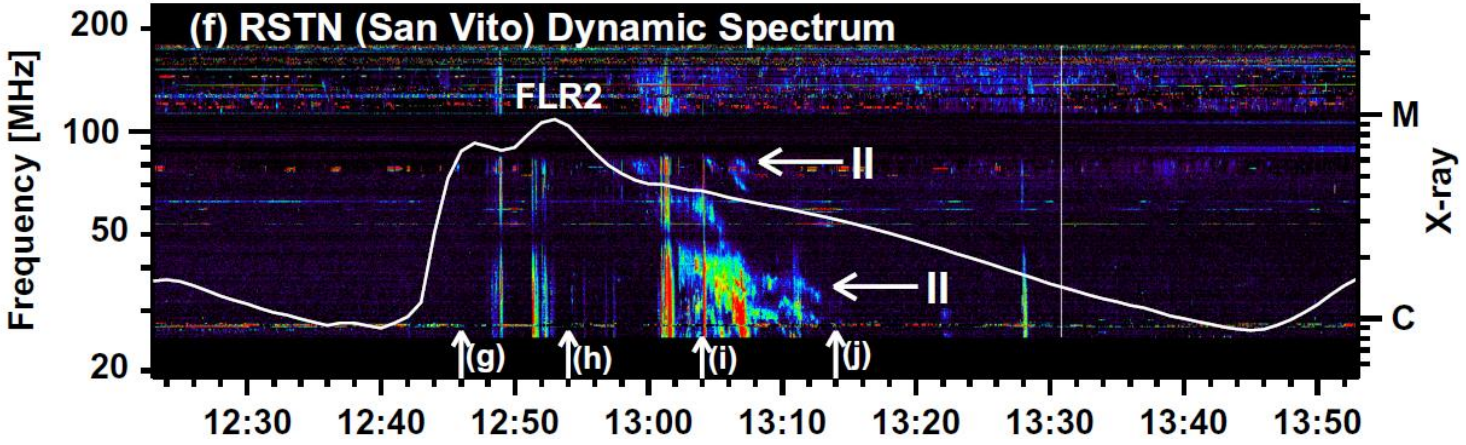
Over the past decade, advancements in modern radio telescopes have substantially enhanced our capacity to acquire high-fidelity solar data. It makes possible to reveal previously unknown/unnoticed morphological features of the type II spectrum.

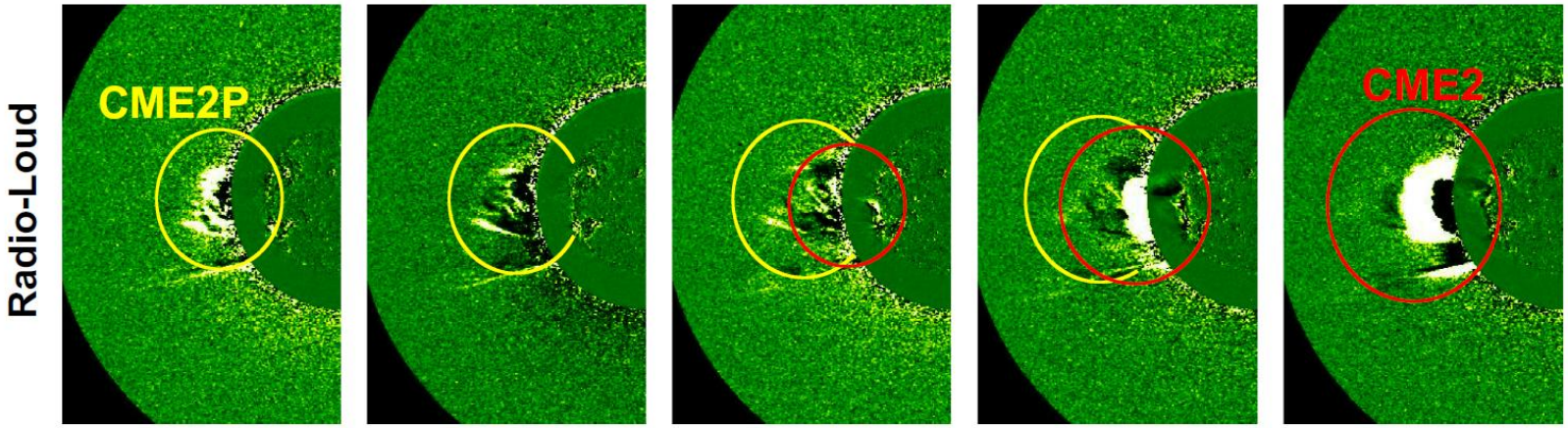
So far, there are not many type II events in which the spectral bumps and breaks were recognized and examined. Note, those studies attempted to explicate the features in qualitative terms.

We have shown that “fractured” type II radio bursts can be exploited as a novel tool to probe magnetic field strength in different coronal structures and electron density turbulence inside those structures.

Our last studies on “fractured” type II have attracted attention of colleagues in a community of solar radio astronomers.

Pre-existing analysis of the 2011-02-14 type II burst





The radio-loud CME (CME2) propagated into the aftermath of the preceding CME (CME2P) indicated by the yellow circles.

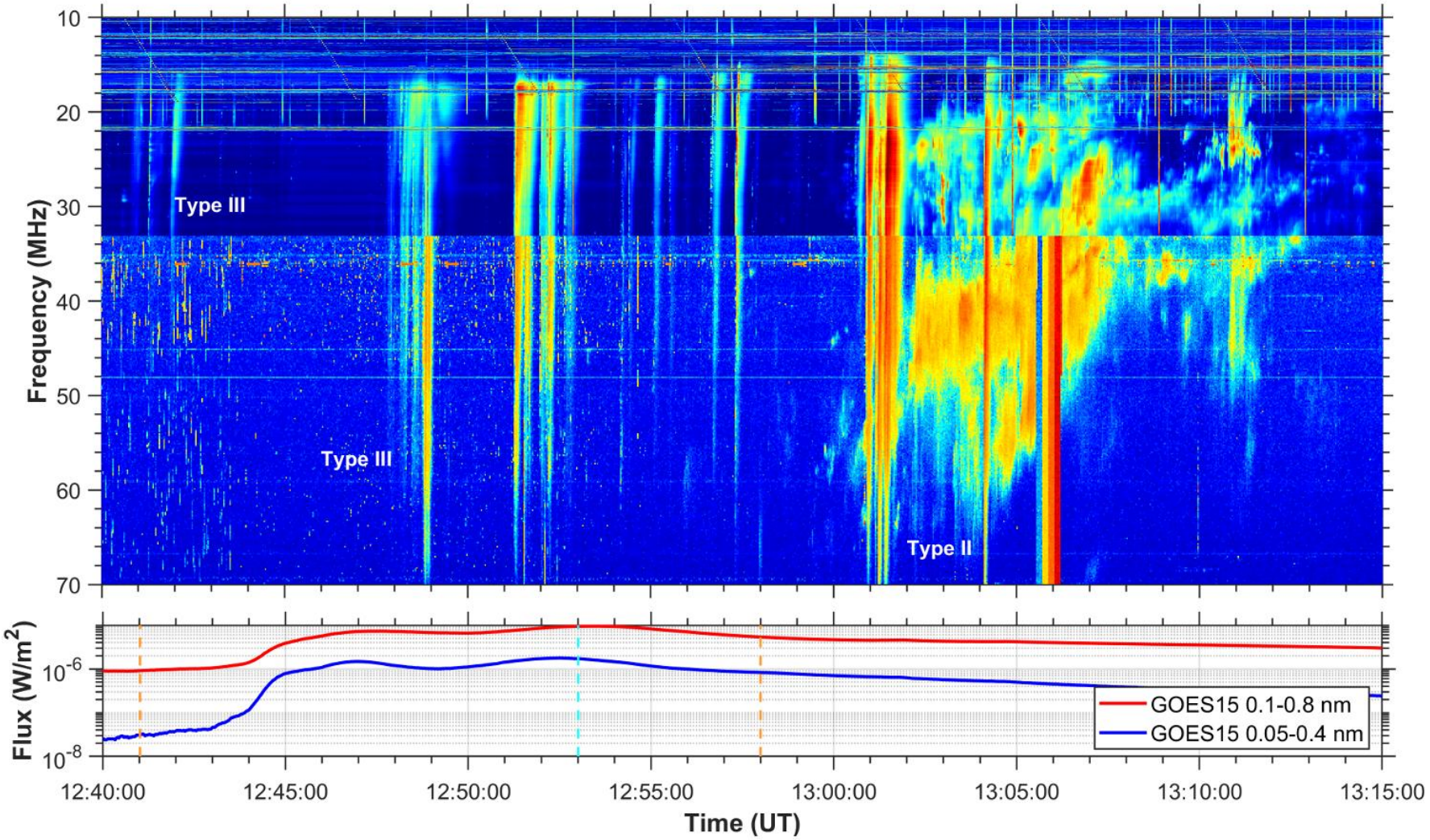
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Homologous flare–CME events and their metric type II radio burst association

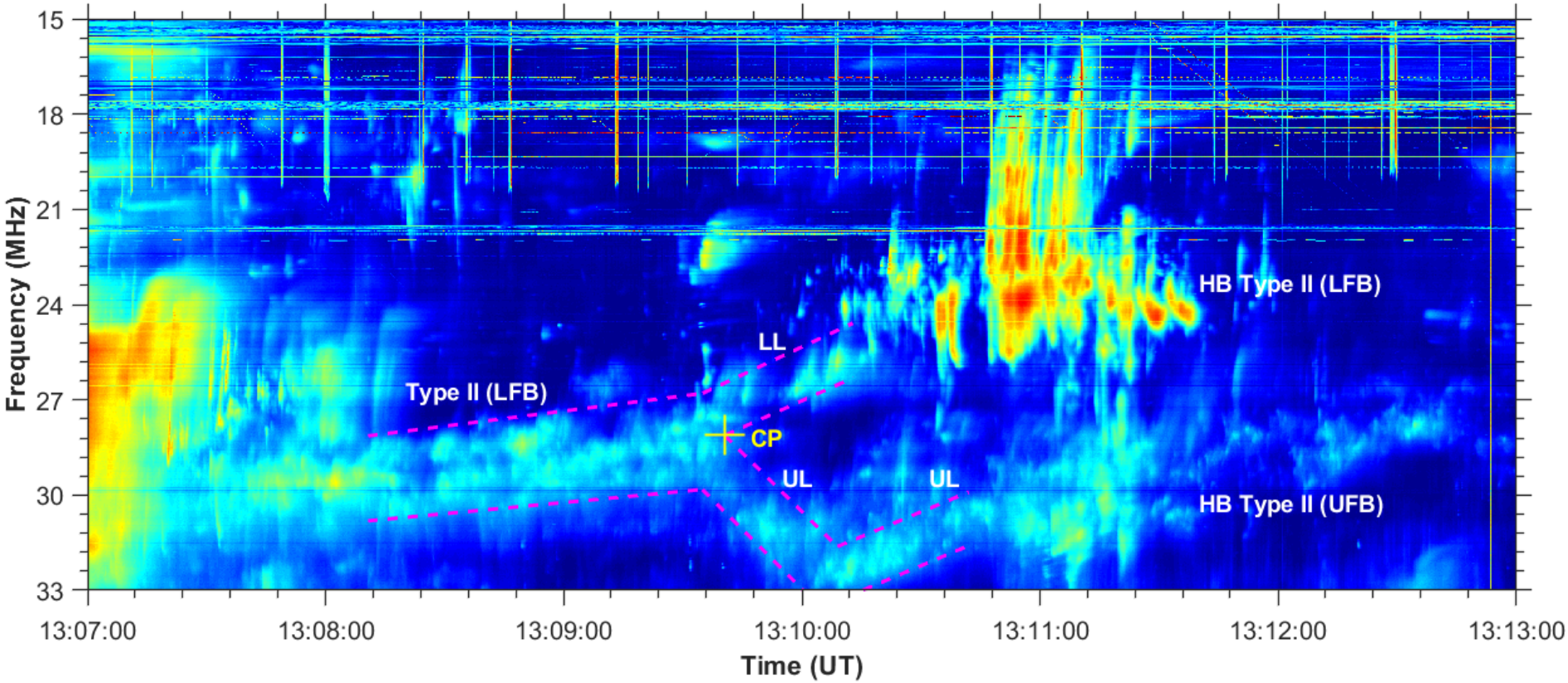
S. Yashiro [a,b,*], N. Gopalswamy [b], P. Mäkelä [a,b], S. Akiyama [a,b], W. Uddin [c], A.K. Srivastava [d], N.C. Joshi [j], R. Chandra [e], P.K. Manoharan [f], K. Mahalakshmi [f], V.C. Dwivedi [f], R. Jain [k], A.K. Awasthi [c,g], N.V. Nitta [h], M.J. Aschwanden [h], D.P. Choudhary [i]

Current analysis of the 2011-02-14 type II burst

NDA & URAN-2 observational data (2011-02-14)



URAN-2 observational data (2011-02-14)



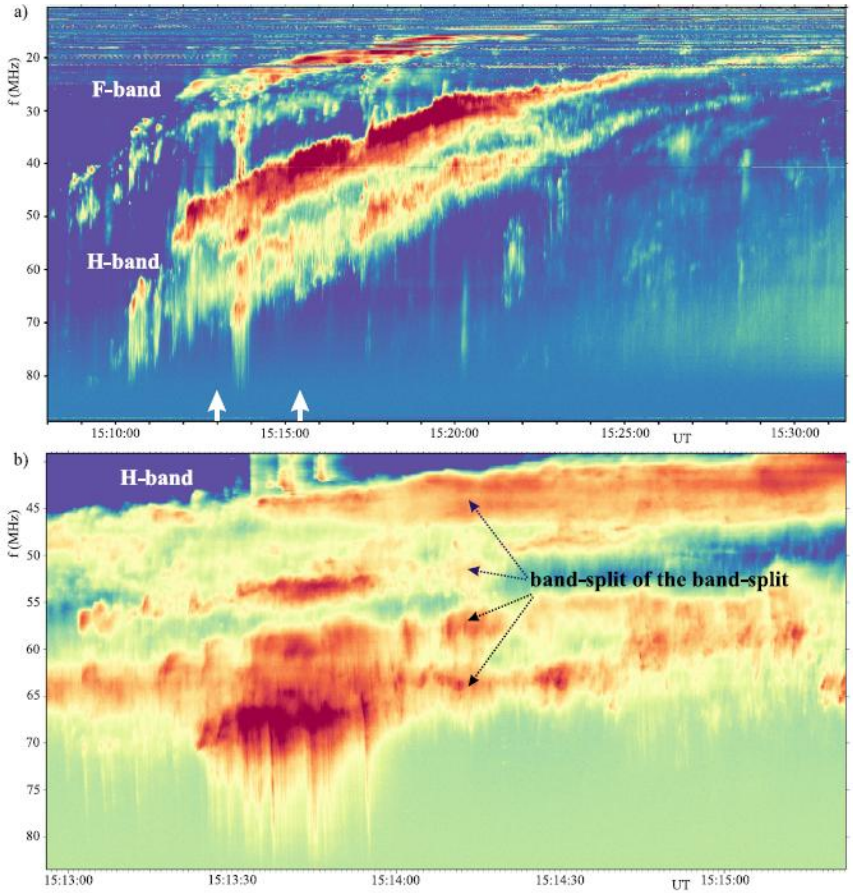
- **A new feature, which we term a spectral cleaving, has been recognized in the lower frequency band (LFB) of the Type II.**
- **The spectral cleaving looks like an actual branching of the type II emission lane into two, namely lower) and upper lanes (LL and UL).**
- **In the band-splitting, the upper and lower frequency bands (UFB and LFB) appear on a spectrogram already split, separated in frequency and nearly parallel to each other.**

Band-split of the band-split feature

The Astrophysical Journal Letters, 897:L15 (8pp), 2020 July 1 https://doi.org/10.3847/2041-8213/ab9abc

Fine Structure of a Solar Type II Radio Burst Observed by LOFAR

Jasmina Magdalenić[1], Christophe Marqué[1], Richard A. Fallows[2], Gottfried Mann[3], Christian Vocks[3], Pietro Zucca[2], Bartosz P. Dabrowski[4], Andrzej Krankowski[4], and Valentin Melnik[5]
[1] Solar-Terrestrial Centre of Excellence—SIDC, Royal Observatory of Belgium, 3 Avenue Circulaire, B-1180 Uccle, Belgium; jasmina.magdalenic@sidc.be
[2] ASTRON—The Netherlands Institute for Radio Astronomy, Oude Hoogeveensedijk 4, 7991 PD Dwingeloo, The Netherlands
[3] Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, D-14482 Potsdam, Germany
[4] Space Radio-Diagnostics Research Centre, University of Warmia and Mazury in Olsztyn, Poland
[5] Institute of Radio Astronomy, National Academy of Sciences of Ukraine, Kharkov, Ukraine
Received 2020 February 17; revised 2020 June 5; accepted 2020 June 9; published 2020 July 1



Interpretation of the spectral cleaving feature

Holman & Pesses 1983 ApJ

- Shock Drift Acceleration (SDA) mechanism of electrons is responsible for solar type II radio bursts.
- Particles energies will be increased by multiple encounters with the shock.

Ball and Melrose 2001 PASA

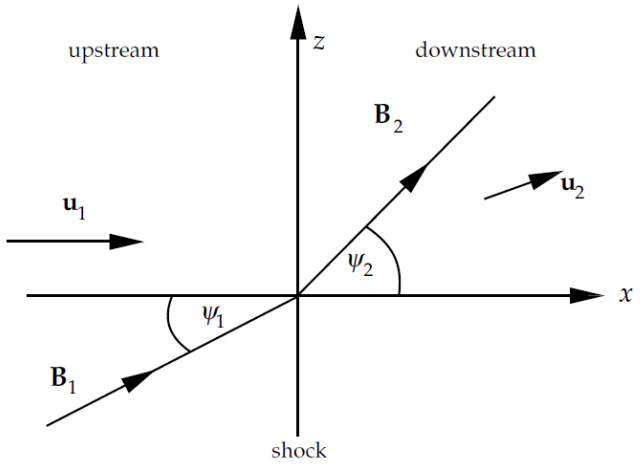


Figure 1 The normal incidence frame, in which the shock is at rest and the upstream (unshocked) fluid flows toward the shock along the shock normal.

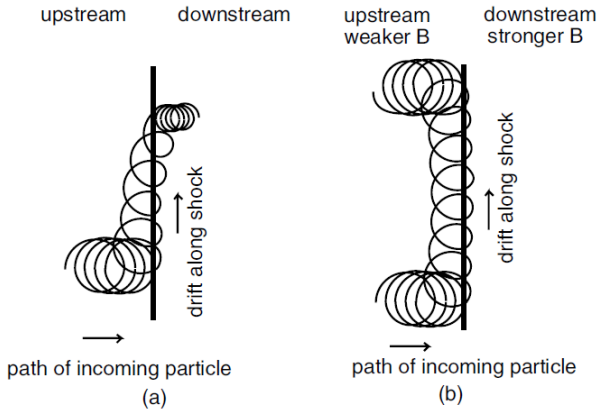
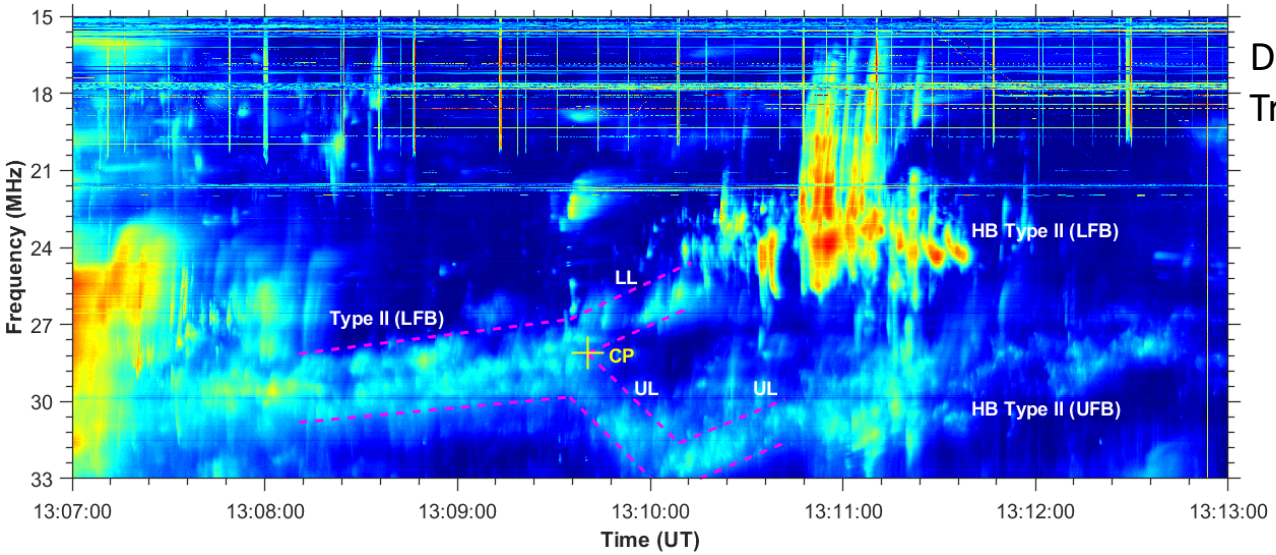


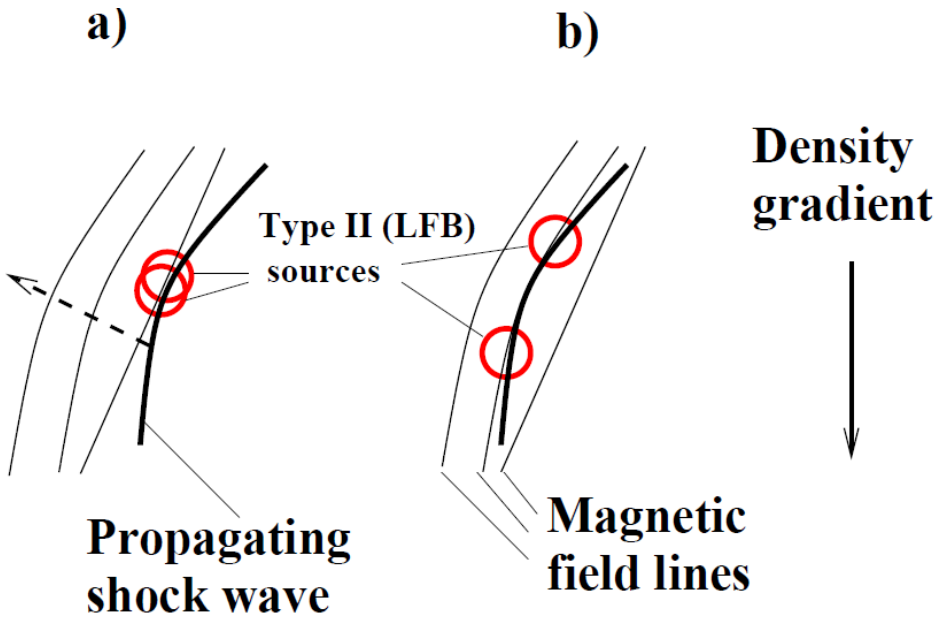
Figure 2 A schematic charged particle orbit as it (a) crosses or (b) is reflected at a shock whose thickness is much less than the particle gyroradius. The increase in magnetic field across the shock means that the gyroradius is smaller in the downstream region than on the upstream side. The result is a particle drift along the shock that is analogous to the drift caused by a gradient in magnetic field.

- Quasi-perpendicular shocks (Ψ1 ≈ 90°) are able to accelerate electrons very efficiently.
- Sources of a type II burst emission are assumed to locate close to the regions on a shock front, where the efficiency of electron acceleration is maximum. It implies that these regions are not everywhere at the shock front.

Interpretation of the spectral cleaving feature



Duration of the Type II: 13 minutes
Travelled distance: 0.5 solar radii



Sketch demonstrating a possible scenario of the occurrence of the spectral cleaving in the Type II (LFB) step by step:
a) phase before the cleaving (~ 13:09:30 UT);
b) phase after the cleaving (~ 13:10:00 UT)

A&A, 689, A345 (2024)
https://doi.org/10.1051/0004-6361/202451010

Astronomy & Astrophysics

Spectral cleaving in solar type II radio bursts: Observations and interpretation

Artem Koval[1,⋆], Marian Karlický[1], Anatolii Brazhenko[2], Aleksander Stanislavsky[3], Anatolii Frantsuzenko[2], Marek Vandas[1], Aleksander Konovalenko[3], Miroslav Bárta[1], Ihor Bubnov[3], Rositsa Miteva[4], and Serge Yerin[3]

[1] Astronomical Institute of the Czech Academy of Sciences, 251 65 Ondřejov, Czech Republic
[2] Institute of Geophysics, Gravimetrical Observatory, 36014 Poltava, Ukraine
[3] Institute of Radio Astronomy, National Academy of Sciences of Ukraine, 61002 Kharkiv, Ukraine
[4] Institute of Astronomy and National Astronomical Observatory - Bulgarian Academy of Sciences, 1784 Sofia, Bulgaria

Conclusions

• We have reported radio observations of a previously unrecognized feature, termed “spectral cleaving”, in solar type II bursts.

• We offer an initial interpretation of the spectral cleaving in type II bursts. The intricate interplay between the shock wave and magnetic field configurations plays a key role here.

• The proposed interpretation of the spectral cleaving phenomenon is novel and may concern solar type II radio bursts in a wider context.

Thank you!