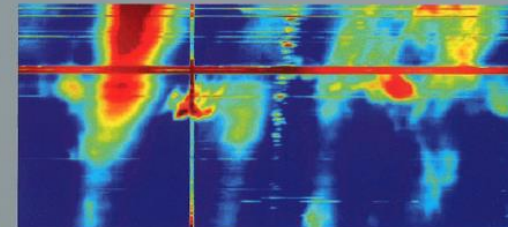


V. Melnik und H.O. Rucker:  
**Decameter Radio Emission of the Sun**  
Austrian Academy of Sciences Press  
(Erscheinungsdatum März 2024)

Helmut O. Rucker  
URSI Austria Team Meeting 2024  
3. Juni 2024

V. Melnik, H. O. Rucker

**Decameter Radio  
Emission of the Sun**



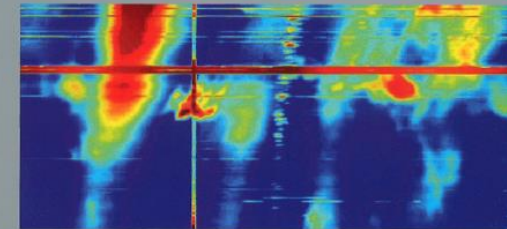
AUSTRIAN  
ACADEMY  
OF SCIENCES  
PRESS

## Contents

<b>1 Introduction</b>	<b>13</b>
<b>2 Decameter Radio Telescopes UTR-2, URAN-2 and GURT</b>	<b>17</b>
2.1 Radio telescope UTR-2 and interferometer URAN . . .	17
2.2 GURT . . . . .	22
2.3 Comparative analysis of solar observations by the single antenna and large array . . . . .	24
2.3.1 Space observations by the WIND/Waves instrument at 9 MHz – 13.8 MHz . . . . .	29
<b>3 Solar Activity</b>	<b>35</b>
3.1 History: the Sun as a goddess . . . . .	35
3.2 First observations of the Sun . . . . .	35
3.3 First scientific observations and measurements . . . . .	37
3.4 Solar phenomena at active regions . . . . .	38
3.5 Explosive events . . . . .	40
<b>4 Radio Emission of the Quiet Sun</b>	<b>43</b>
4.1 Radio emission of the quiet Sun at decameter wavelengths . . . . .	43
4.1.1 Observations of the quiet Sun by URAN-2 . . . . .	46
4.1.2 Observations of the quiet Sun by UTR-2 . . . . .	48
4.2 Sizes and brightness temperature of the quiet Sun at decameter wavelengths . . . . .	51
4.2.1 Radio emission of the quiet Sun at 20 and 25 MHz – sizes and brightness temperatures . . . . .	51
<b>5 Type III Bursts</b>	<b>61</b>
5.1 Introductory remarks . . . . .	61
5.2 Fast Type III bursts . . . . .	66
5.3 Type III bursts with fine time structure . . . . .	73
5.4 Type IIIb . . . . .	75
5.4.1 Observations . . . . .	77
5.5 Powerful Type III bursts . . . . .	80
5.6 Type III bursts with changing sign of drift rate . . . . .	85
5.7 “Dog-leg” Type III bursts at the decameter wavelengths . . . . .	90
5.7.1 Observations . . . . .	92

V. Melnik, H. O. Rucker

# Decameter Radio Emission of the Sun



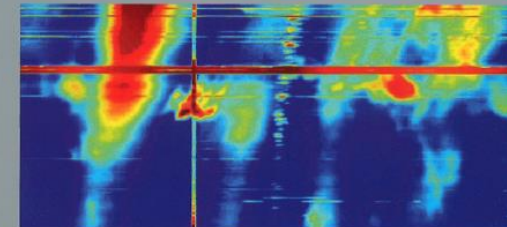
**AUSTRIAN  
ACADEMY  
OF SCIENCES  
PRESS**

## Contents

<b>1 Introduction</b>	<b>13</b>
<b>2 Decameter Radio Telescopes UTR-2, URAN-2 and GURT</b>	<b>17</b>
2.1 Radio telescope UTR-2 and interferometer URAN . . .	17
2.2 GURT . . . . .	22
2.3 Comparative analysis of solar observations by the single antenna and large array . . . . .	24
2.3.1 Space observations by the WIND/Waves instrument at 9 MHz – 13.8 MHz . . . . .	29
<b>3 Solar Activity</b>	<b>35</b>
3.1 History: the Sun as a goddess . . . . .	35
3.2 First observations of the Sun . . . . .	35
3.3 First scientific observations and measurements . . . . .	37
3.4 Solar phenomena at active regions . . . . .	38
3.5 Explosive events . . . . .	40
<b>4 Radio Emission of the Quiet Sun</b>	<b>43</b>
4.1 Radio emission of the quiet Sun at decameter wavelengths . . . . .	43
4.1.1 Observations of the quiet Sun by URAN-2 . . . . .	46
4.1.2 Observations of the quiet Sun by UTR-2 . . . . .	48
4.2 Sizes and brightness temperature of the quiet Sun at decameter wavelengths . . . . .	51
4.2.1 Radio emission of the quiet Sun at 20 and 25 MHz – sizes and brightness temperatures . . . . .	51
<b>5 Type III Bursts</b>	<b>61</b>
5.1 Introductory remarks . . . . .	61
5.2 Fast Type III bursts . . . . .	66
5.3 Type III bursts with fine time structure . . . . .	73
5.4 Type IIIb . . . . .	75
5.4.1 Observations . . . . .	77
5.5 Powerful Type III bursts . . . . .	80
5.6 Type III bursts with changing sign of drift rate . . . . .	85
5.7 “Dog-leg” Type III bursts at the decameter wavelengths . . . . .	90
5.7.1 Observations . . . . .	92

V. Melnik, H. O. Rucker

# Decameter Radio Emission of the Sun



AUSTRIAN  
ACADEMY  
OF SCIENCES  
PRESS



**The world's largest UTR-2 radio telescope (N-S arm, 1.9 km x 60 m)  
Frequency range - 8... 32 MHz; number of elements - 2040;  
effective area - 150,000 square meters.**

## Type III bursts

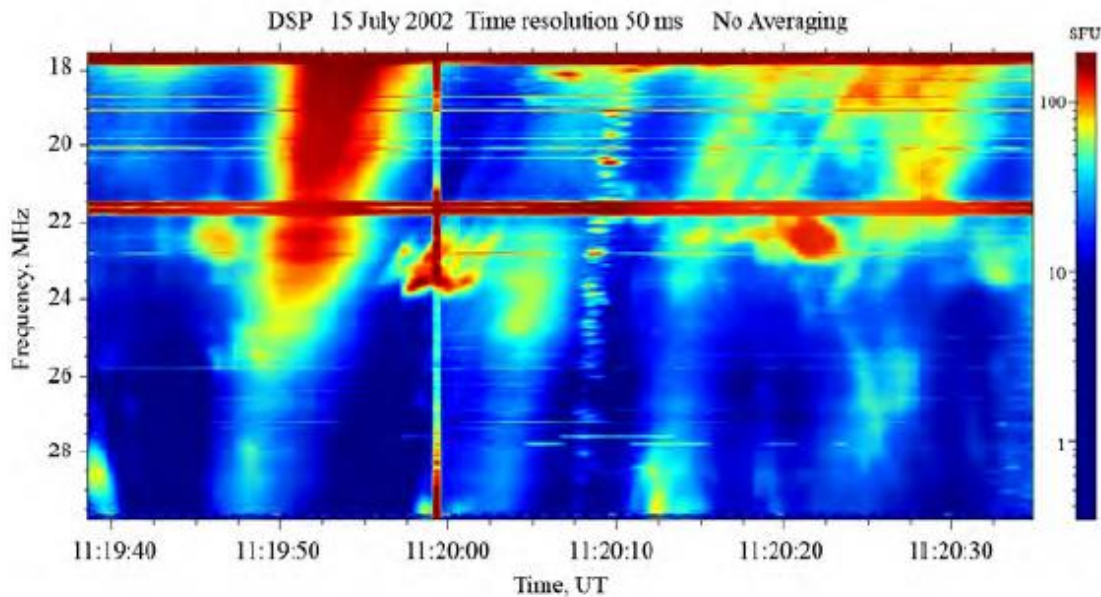


Figure 5.9: An example of Type IIIb burst (11:20:10 UT) together with Type III bursts (11:19:50 UT; 11:20:00 UT; 11:20:13 UT; 11:20:25 UT) in the frequency range from 18 to 30 MHz.

## Contents

<b>1 Introduction</b>	<b>13</b>
<b>2 Decameter Radio Telescopes UTR-2, URAN-2 and GURT</b>	<b>17</b>
2.1 Radio telescope UTR-2 and interferometer URAN . . .	17
2.2 GURT . . . . .	22
2.3 Comparative analysis of solar observations by the single antenna and large array . . . . .	24
2.3.1 Space observations by the WIND/Waves instrument at 9 MHz – 13.8 MHz . . . . .	29
<b>3 Solar Activity</b>	<b>35</b>
3.1 History: the Sun as a goddess . . . . .	35
3.2 First observations of the Sun . . . . .	35
3.3 First scientific observations and measurements . . . . .	37
3.4 Solar phenomena at active regions . . . . .	38
3.5 Explosive events . . . . .	40
<b>4 Radio Emission of the Quiet Sun</b>	<b>43</b>
4.1 Radio emission of the quiet Sun at decameter wavelengths . . . . .	43
4.1.1 Observations of the quiet Sun by URAN-2 . . . . .	46
4.1.2 Observations of the quiet Sun by UTR-2 . . . . .	48
4.2 Sizes and brightness temperature of the quiet Sun at decameter wavelengths . . . . .	51
4.2.1 Radio emission of the quiet Sun at 20 and 25 MHz – sizes and brightness temperatures . . . . .	51
<b>5 Type III Bursts</b>	<b>61</b>
5.1 Introductory remarks . . . . .	61
5.2 Fast Type III bursts . . . . .	66
5.3 Type III bursts with fine time structure . . . . .	73
5.4 Type IIIb . . . . .	75
5.4.1 Observations . . . . .	77
5.5 Powerful Type III bursts . . . . .	80
5.6 Type III bursts with changing sign of drift rate . . . . .	85
5.7 “Dog-leg” Type III bursts at the decameter wavelengths . . . . .	90
5.7.1 Observations . . . . .	92

## Type III bursts

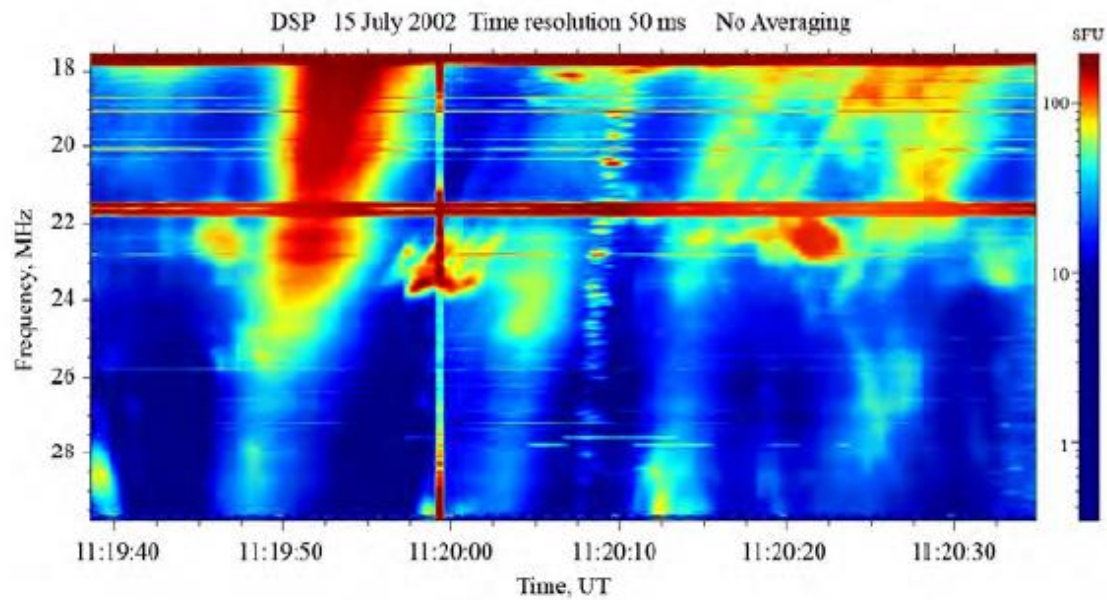


Figure 5.9: An example of Type IIIb burst (11:20:10 UT) together with Type III bursts (11:19:50 UT; 11:20:00 UT; 11:20:13 UT; 11:20:25 UT) in the frequency range from 18 to 30 MHz.

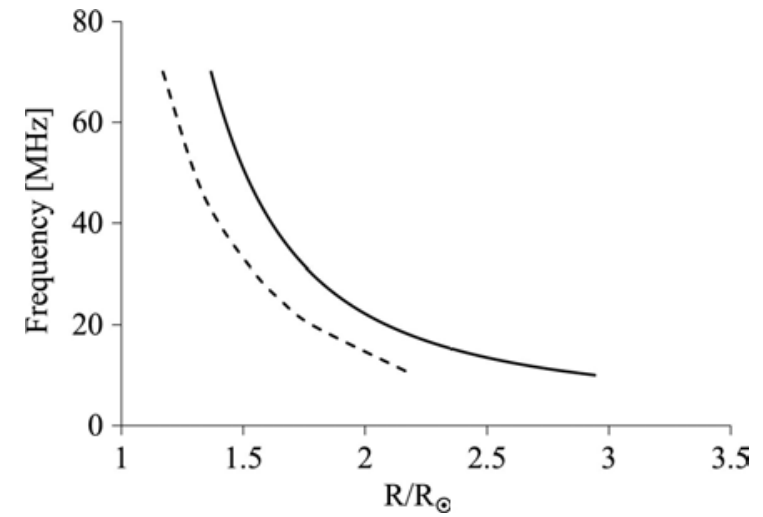


Figure 4.8: Baumbach-Allen (dashed) and Newkirk (solid) models in dependence of radii of the quiet Sun.

## Type III bursts

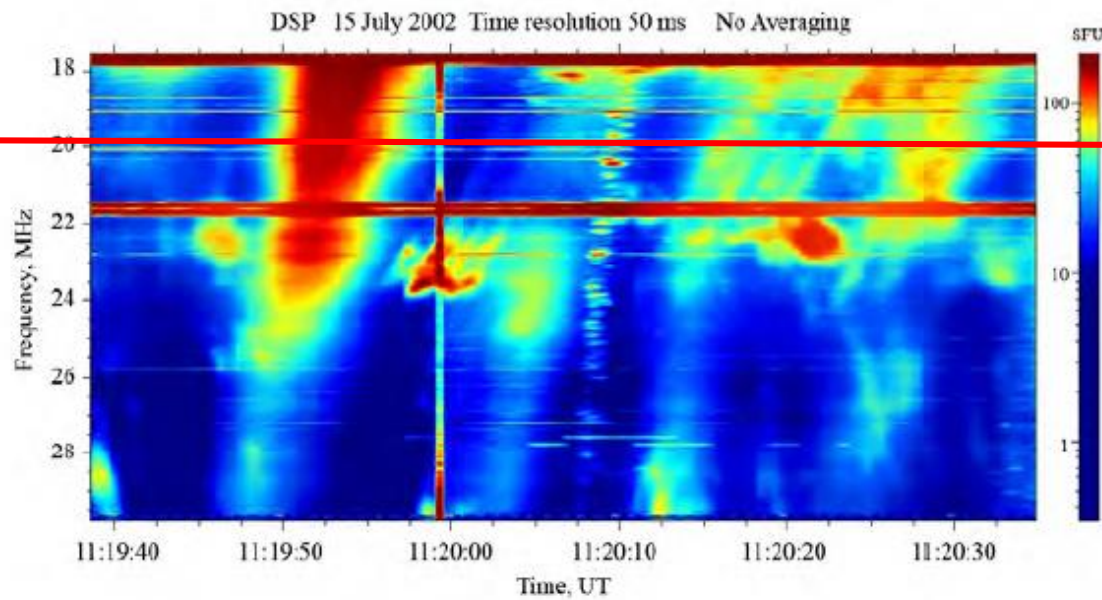


Figure 5.9: An example of Type IIIb burst (11:20:10 UT) together with Type III bursts (11:19:50 UT; 11:20:00 UT; 11:20:13 UT; 11:20:25 UT) in the frequency range from 18 to 30 MHz.

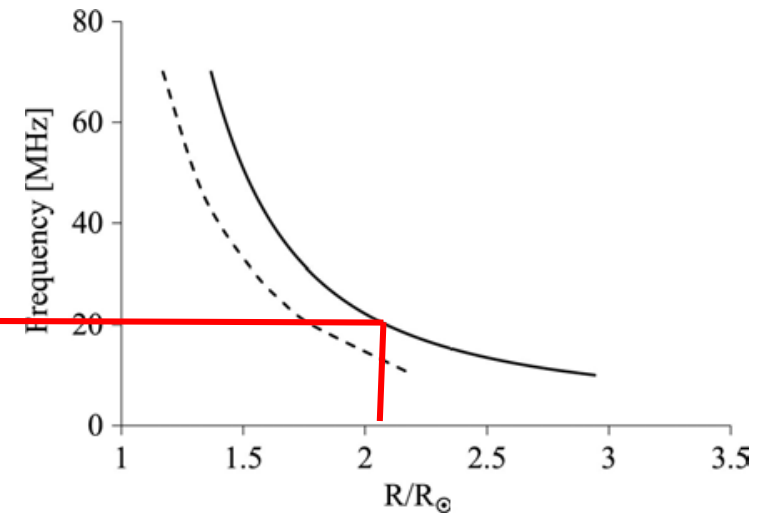
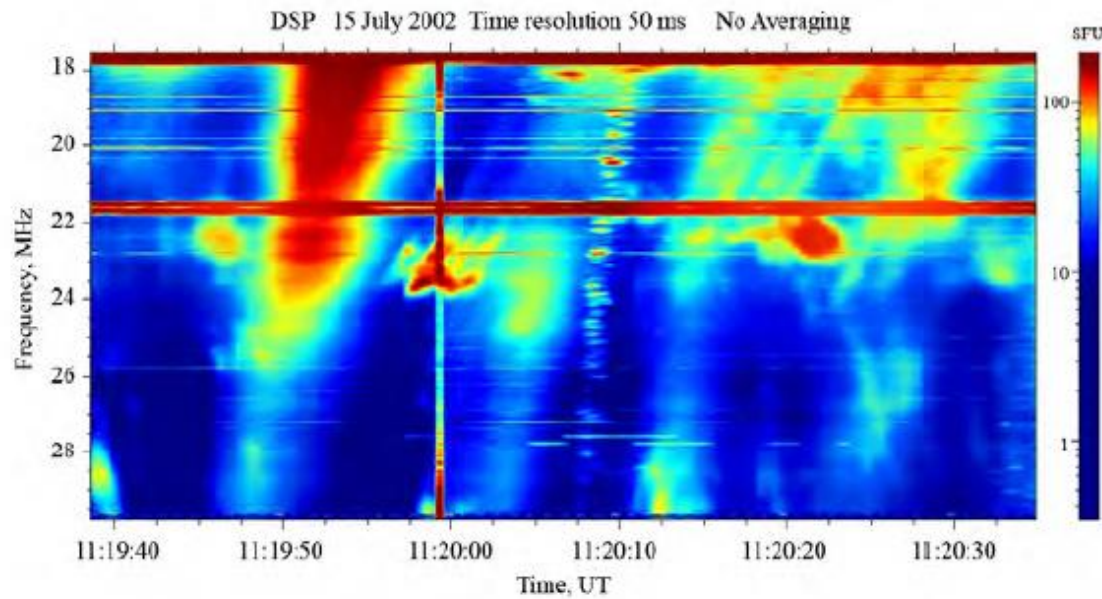


Figure 4.8: Baumbach-Allen (dashed) and Newkirk (solid) models in dependence of radii of the quiet Sun.

## Type III bursts



$$f_p = \frac{1}{2\pi} \sqrt{ne^2 / m\epsilon_0}$$

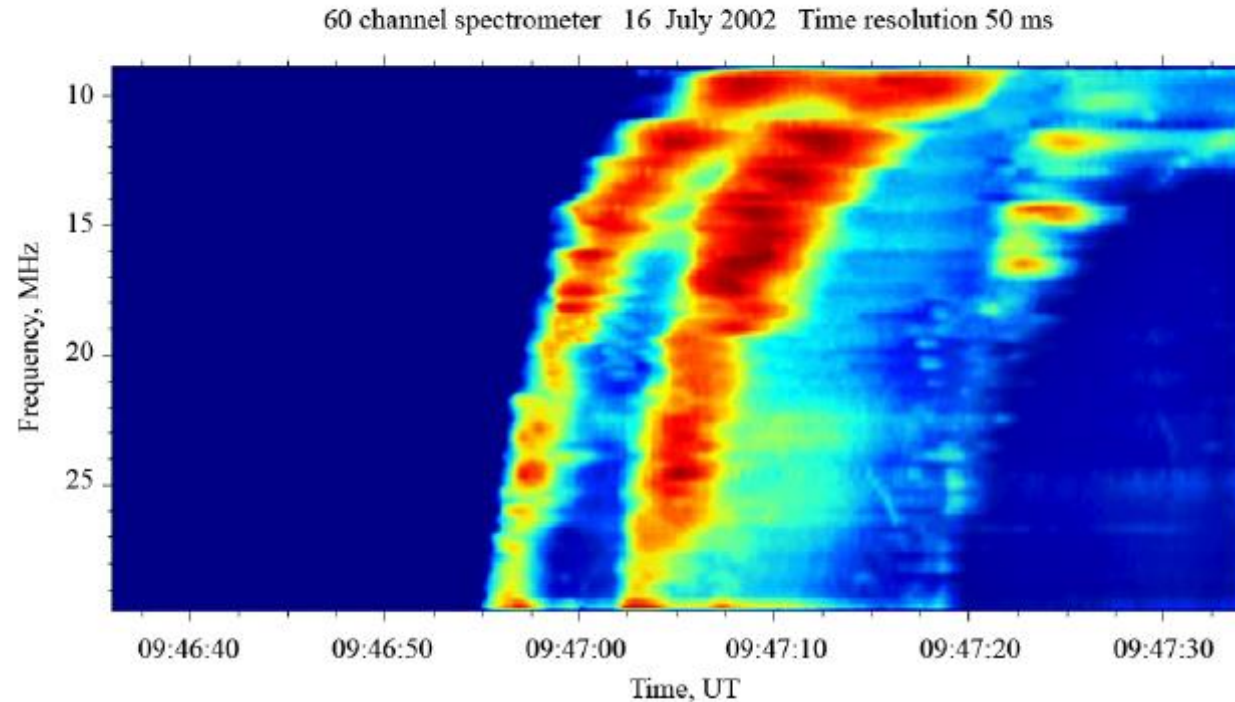
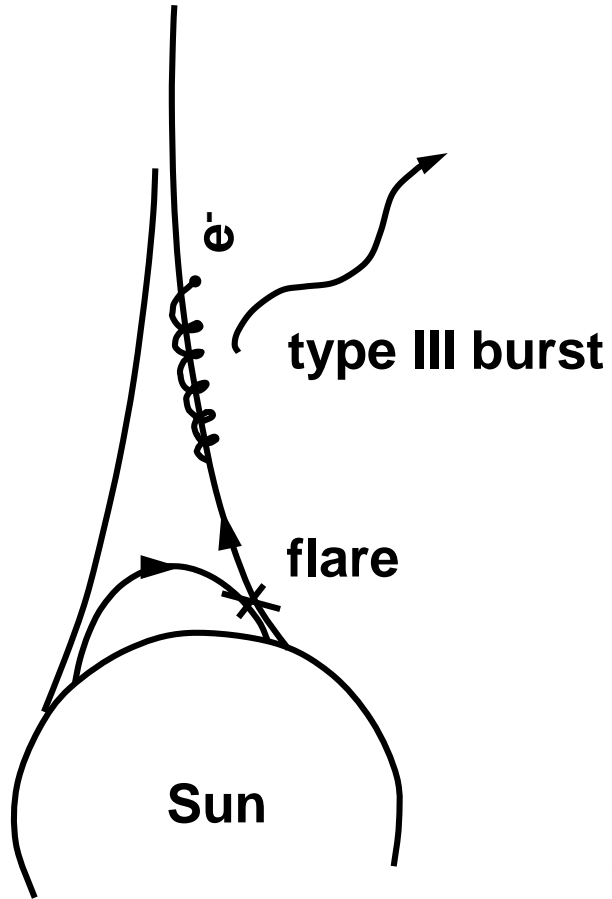
$$f_p \rightarrow f_{radio}$$

plasma density  $n$   
in solar corona

Figure 5.9: An example of Type IIIb burst (11:20:10 UT) together with Type III bursts (11:19:50 UT; 11:20:00 UT; 11:20:13 UT; 11:20:25 UT) in the frequency range from 18 to 30 MHz.



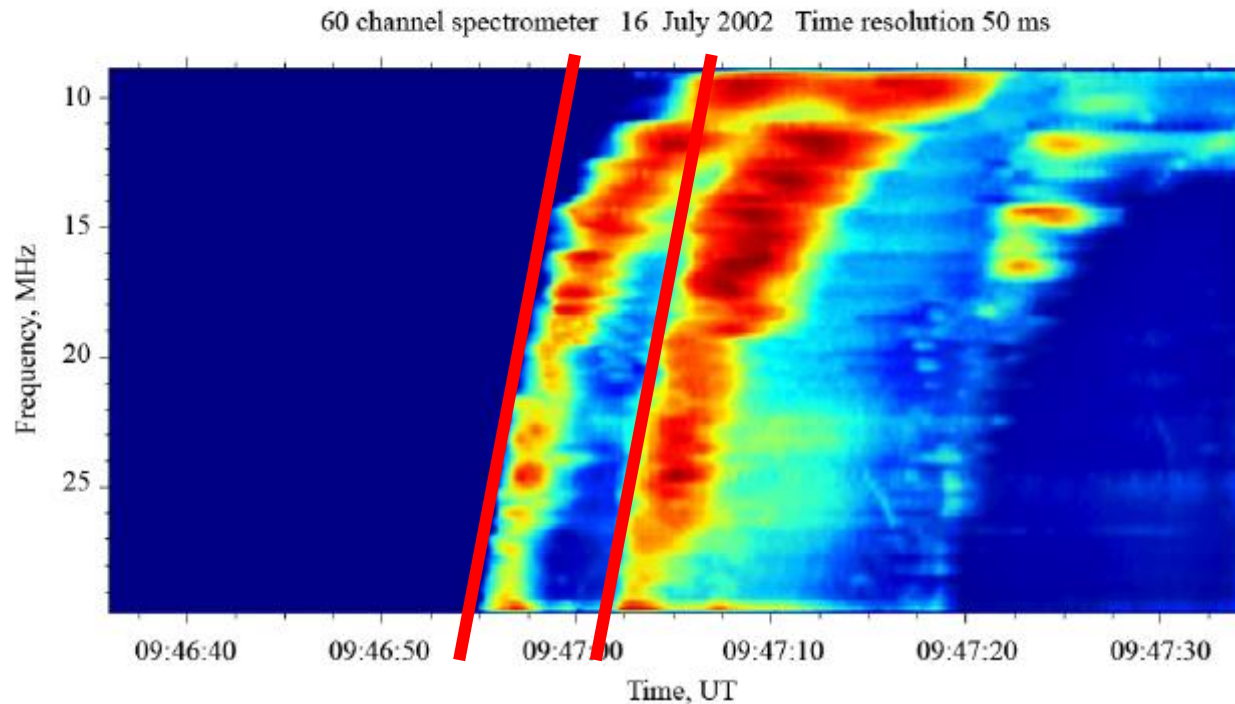
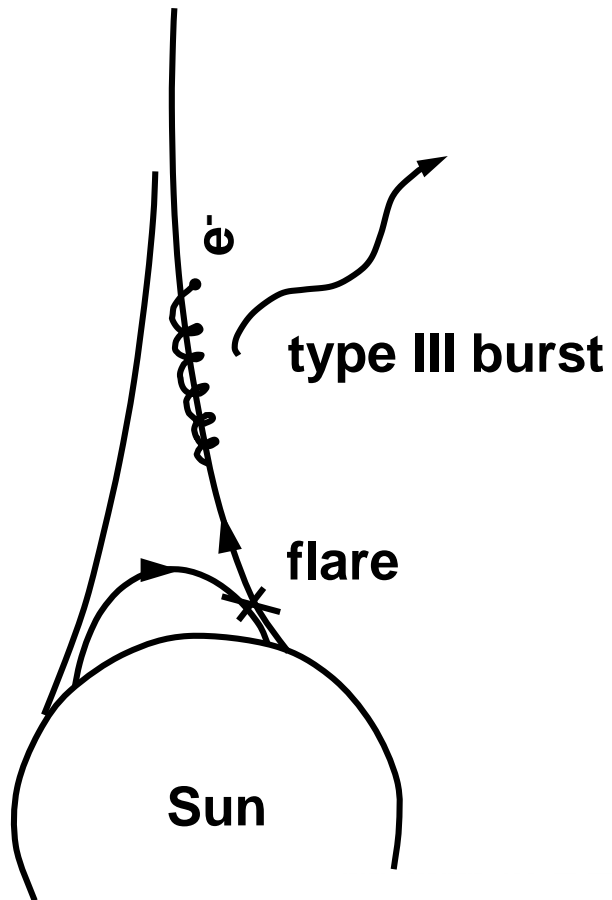
## Type III bursts



*Harmonic pair of two powerful Type III bursts observed on July 16, 2002.*

Der Type III burst ist die Radio-Signatur eines Elektronenstrahles, welcher durch einen flare erzeugt wird. Die Propagierung erfolgt entlang von Magnetfeldlinien durch die Korona, Radiowellen werden emittiert.

## Type III bursts

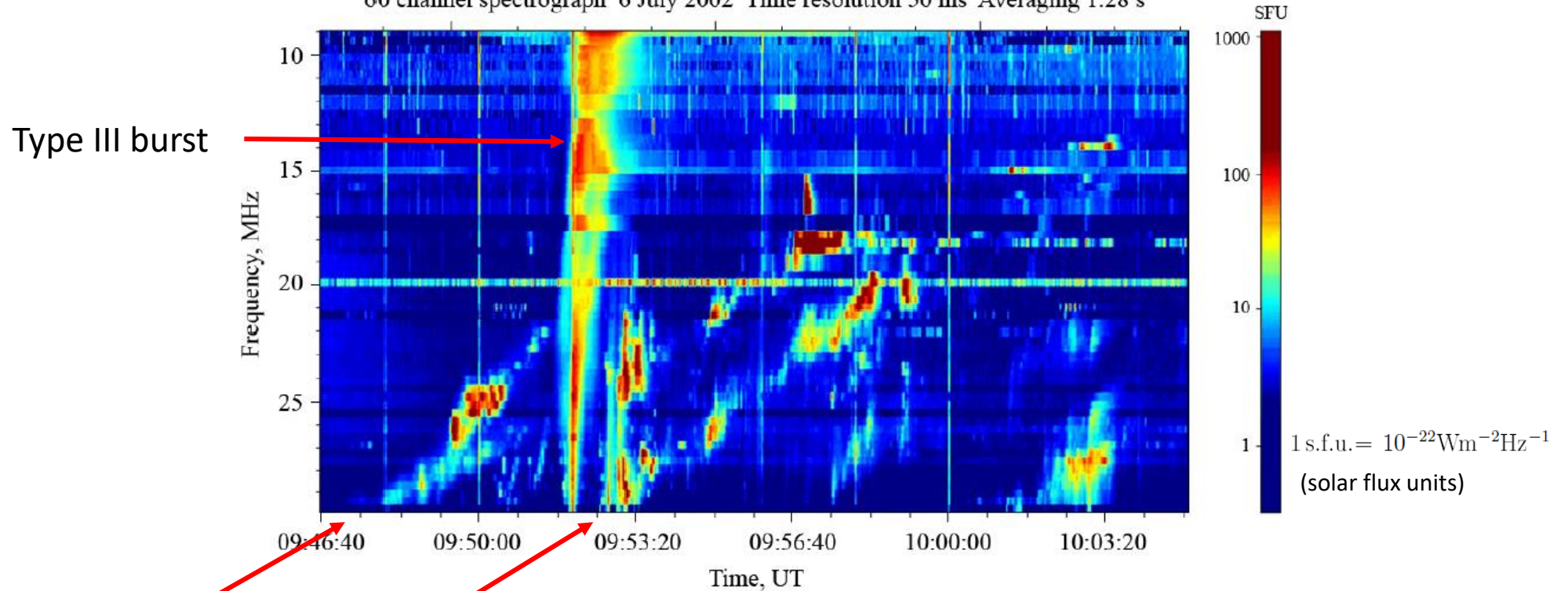


*Harmonic pair of two powerful Type III bursts observed on July 16, 2002.*

Drift rate:  $D_f = \frac{df}{dt} = \frac{f}{2} \frac{1}{n} \frac{dn}{dr} V_{\text{source}} \longrightarrow V_{\text{source}} \sim 0,25 c$

## Type II and Type III bursts

60 channel spectrograph 6 July 2002 Time resolution 50 ms Averaging 1.28 s



Type III burst

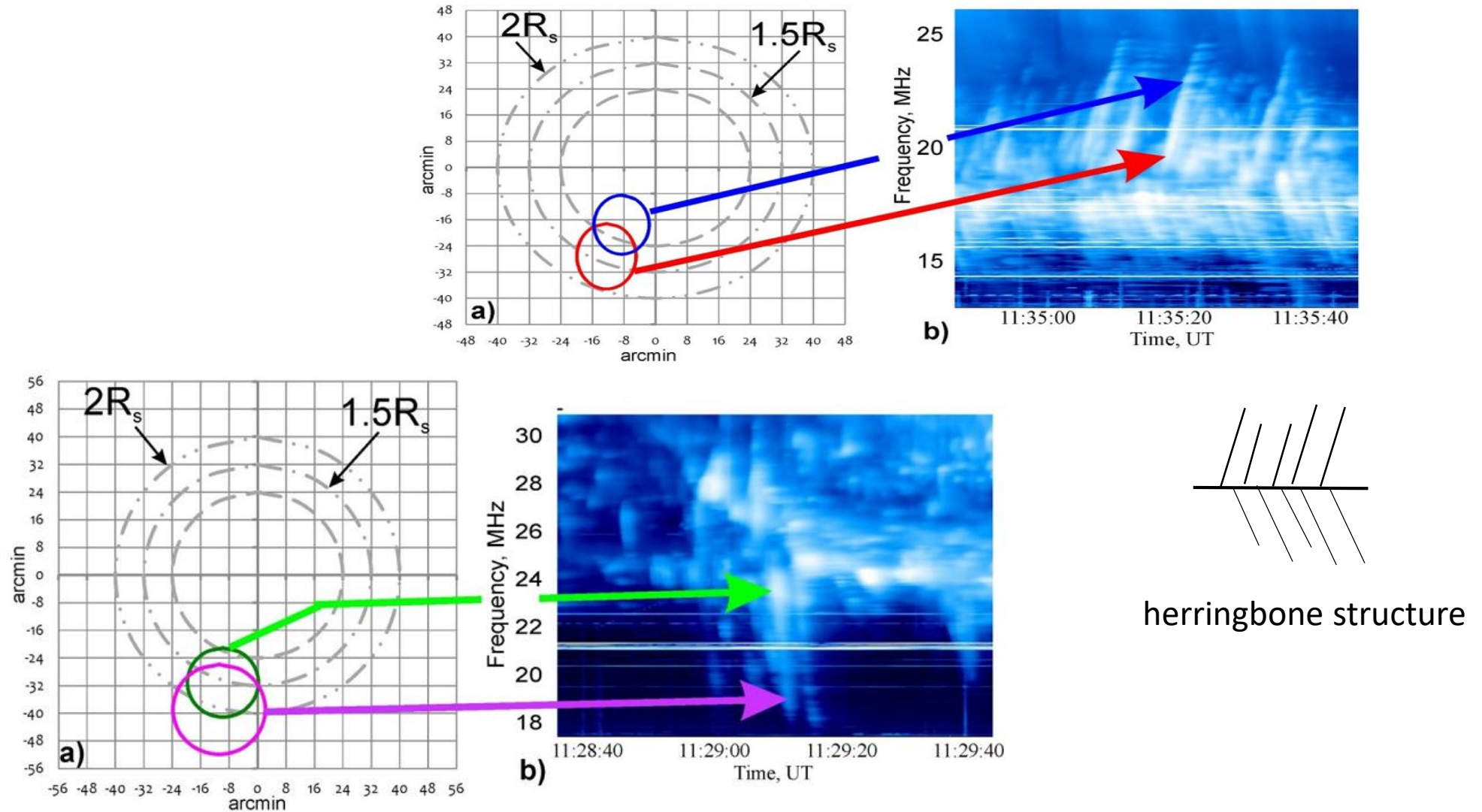
Type II fundamental

Type II harmonic

*Type II burst with band splitting of fundamental and harmonic emission observed by the 60-channel spectrometer. At 09:52:00 UT a Type III burst is visible.*

Flares und Coronal Mass Ejections (CMEs) verursachen Schockwellen in der Korona, in weiterer Folge werden Type II bursts erzeugt.

# Interferometer observation of Type II burst with herringbone structure on 31 May 2013



## Weitere Beispiele von Radio burst Phänomenen:

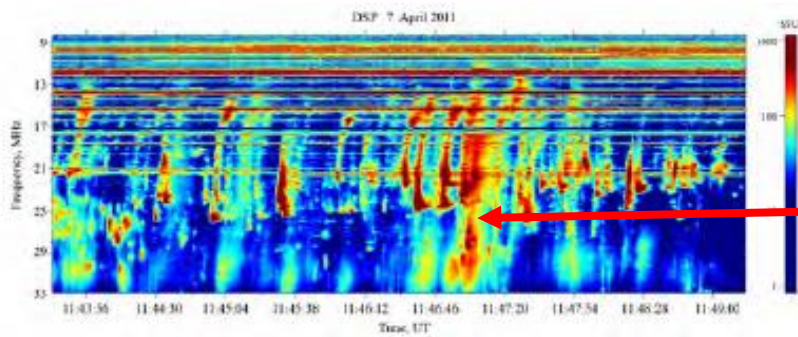


Figure 6.21: *Separate tadpoles of Type II burst with upward and downward tails.*

### Contents

5.7.2	Interpretation of the observations . . . . .	95
5.8	Decameter Type IIb-III pairs . . . . .	97
5.8.1	Observations . . . . .	99
5.8.2	Discussion . . . . .	103
5.9	Trios . . . . .	108
5.9.1	Trio of Type IIb and Type III bursts . . . . .	108
5.10	Spatial sizes and heights of Type III radio emission at the decameter wavelengths . . . . .	115
5.10.1	Sizes of Type III sources and heights of their radio emission at frequencies 20 and 25 MHz . . . . .	115
5.11	Inverted U- and J-bursts . . . . .	124
5.12	Observations of the solar U-bursts harmonic pair with new radio telescope GURT . . . . .	131
<b>6</b>	<b>Type II Bursts</b> . . . . .	<b>139</b>
6.1	Solar Type II bursts at frequencies 10 MHz - 30 MHz . . . . .	139
6.1.1	Study of the decameter Type II bursts with rich fine and superfine structures . . . . .	148
6.2	Type II burst with herringbone structures . . . . .	155
6.2.1	Analysis and discussion . . . . .	158
6.3	Tadpoles - a new type of solar radio bursts . . . . .	163
<b>7</b>	<b>Type IV Bursts</b> . . . . .	<b>171</b>
7.1	Decameter Type IV burst associated with a behind-limb CME observed on November 7, 2013 . . . . .	171
7.1.1	Observations . . . . .	172
7.1.2	Interpretation of the observations . . . . .	175
7.2	Decameter Type IV bursts observed in the years 2003-2006 . . . . .	180
7.3	Properties of decameter Type IV bursts . . . . .	188
7.4	"Fingerprint" fine structure of decameter Type IV burst . . . . .	194
7.4.1	Sub-bursts in emission and absorption . . . . .	207
7.5	Oscillations of Type IV bursts . . . . .	211
7.5.1	Quasi-periodic variations of radio emission . . . . .	215
7.6	Absorption bursts . . . . .	221
7.6.1	Observations and their analysis . . . . .	223
7.6.2	Level of absorption . . . . .	227
7.6.3	Size of absorbing region . . . . .	230
<b>8</b>	<b>Drift Pairs Bursts</b> . . . . .	<b>233</b>
8.1	Properties of decameter drift pairs . . . . .	233
8.1.1	Drift pairs in the decameter range . . . . .	233
8.2	Polarization of drift pairs . . . . .	243

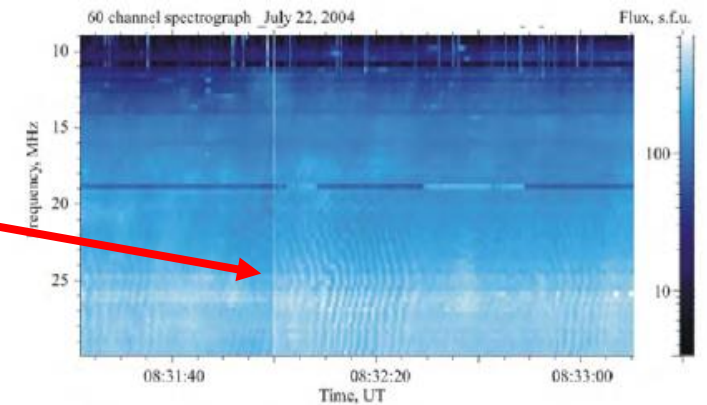


Figure 7.26: *Three groups of zebra patterns.*

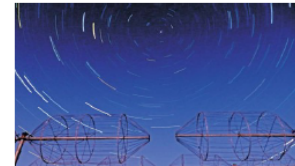
9th Annual Science at Low Frequencies (SALF) conference  
(hosted by ASTRON)  
Amsterdam/NL, 11. – 15.12.2023



# Ukrainian T-shape Radio Telescope UTR-2: 50-Years in Operation and Perspectives

A. Konovalenko<sup>1</sup>, V. Zakharenko<sup>1</sup>, O. Ulyanov<sup>1</sup>, P. Tokarsky<sup>1</sup>, M. Sidorchuk<sup>1</sup>, S. Stepkin<sup>1</sup>, Ph. Zarka<sup>2</sup>,  
J. Girard<sup>2</sup>, J.-M. Grießmeier<sup>2,3</sup>, M. Tagger<sup>4</sup>, R. Vermeulen<sup>5</sup>, L. Gurvits<sup>6</sup>, H.O. Rucker<sup>7</sup>, A. Lecacheux<sup>2</sup>, N. Kalinichenko<sup>1</sup>,  
A. Stanislavsky<sup>1</sup>, V. Melnik<sup>1</sup>, V. Dorovsky<sup>1</sup>, N. Shevchuk<sup>1</sup>, V. Shepelev<sup>1</sup>, A. Brazhenko<sup>8</sup>, V. Ryabov<sup>9</sup>, I. Bubnov<sup>1</sup>,  
A. Reznichenko<sup>1</sup>, V. Bortsov<sup>1</sup>, Y. Vasylykivskyi<sup>1</sup>, G. Litvinenko<sup>1</sup>, S. Yerin<sup>1</sup>

- 1- Institute of Radio Astronomy of NASU, Kharkiv, Ukraine
- 2- LESIA, Observatoire de Paris, CNRS, PSL, Sorbonne U., U. Paris Cité, Meudon, France
- 3- LPC2E/CNRS, l'Université d'Orléans, Observatoire Radioastronomique de Nancy, Observatoire de Paris, France
- 4- Laboratory of Astro Particles, Université d'Orléans, France
- 5- International LOFAR Telescope, ASTRON (Netherlands Institute for Radio Astronomy)
- 6- JIVE-ERIC the Netherlands
- 7- Commission for Astronomy, Austrian Academy of Sciences, Graz, Austria
- 8- Gravimetrical Observatory, Institute of Geophysics named S.I. Subbotin of NASU, Poltava, Ukraine
- 9- Future University Hakodate, Hakodate, Japan



Dec 11 – 15, 2023  
WCW, Amsterdam Science Park



9th Annual Science At Low  
Frequencies (SALF) Conference

**Ukrainian T-shape Radio Telescope UTR-2:  
50-Years in Operation and Perspectives**

A. Konovalenko<sup>1</sup>, V. Zakharenko<sup>1</sup>, O. Ulyanov<sup>1</sup>, P. Tokarsky<sup>1</sup>, M. Sidorchuk<sup>1</sup>, S. Stepkin<sup>1</sup>, Ph. Zarka<sup>2</sup>,  
J. Girard<sup>2</sup>, J.-M. Grießmeier<sup>2,3</sup>, M. Tagger<sup>4</sup>, R. Vermeulen<sup>5</sup>, L. Gurvits<sup>6</sup>, H.O. Rucker<sup>7</sup>, A. Lecacheux<sup>2</sup>, N. Kalinichenko<sup>1</sup>,  
A. Stanislavsky<sup>1</sup>, V. Melnik<sup>1</sup>, V. Dorovsky<sup>1</sup>, N. Shevchuk<sup>1</sup>, V. Shepelev<sup>1</sup>, A. Brazhenko<sup>8</sup>, V. Ryabov<sup>9</sup>, I. Bubnov<sup>1</sup>,  
A. Reznichenko<sup>1</sup>, V. Bortsov<sup>1</sup>, Y. Vasylykivskyi<sup>1</sup>, G. Litvinenko<sup>1</sup>, S. Yerin<sup>1</sup>

- 1- Institute of Radio Astronomy of NASU, Kharkiv, Ukraine
- 2- LESIA, Observatoire de Paris, CNRS, PSL, Sorbonne U., U. Paris Cité, Meudon, France
- 3- LPC2E/CNRS, l'Université d'Orléans, Observatoire Radioastronomique de Nancy, Observatoire de Paris, France
- 4- Laboratory of Astro Particles, Université d'Orléans, France
- 5- International LOFAR Telescope, ASTRON (Netherlands Institute for Radio Astronomy)
- 6- JIVE-ERIC the Netherlands
- 7- Commission for Astronomy, Austrian Academy of Sciences, Graz, Austria
- 8- Gravimetrical Observatory, Institute of Geophysics named S.I. Subbotin of NASU, Poltava, Ukraine
- 9- Future University Hakodate, Hakodate, Japan

Dec 11 – 15, 2023  
WCW, Amsterdam Science Park

9th Annual Science at Low Frequencies (SALF) conference  
(hosted by ASTRON)  
Amsterdam/NL, 11. – 15.12.2023





## Ukrainian T-shape Radio Telescope UTR-2: 50-Years in Operation and Perspectives

A. Konovalenko<sup>1</sup>, V. Zakharenko<sup>1</sup>, O. Ulyanov<sup>1</sup>, P. Tokarsky<sup>1</sup>, M. Sidorchuk<sup>1</sup>, S. Stepkin<sup>1</sup>, Ph. Zarka<sup>2</sup>, J. Girard<sup>2</sup>, J.-M. Grießmeier<sup>2,3</sup>, M. Tagger<sup>4</sup>, R. Vermeulen<sup>5</sup>, L. Gurvits<sup>5</sup>, H.O. Rucker<sup>7</sup>, A. Lecacheux<sup>2</sup>, N. Kalinichenko<sup>1</sup>, A. Stanislavsky<sup>1</sup>, V. Melnik<sup>1</sup>, V. Dorovsky<sup>1</sup>, N. Shevchuk<sup>1</sup>, V. Shepelev<sup>1</sup>, A. Brazhenko<sup>8</sup>, V.Ryabov<sup>9</sup>, I. Bubnov<sup>1</sup>, A. Reznichenko<sup>1</sup>, V. Bortsov<sup>1</sup>, Y.Vasylykivskiy<sup>1</sup>, G. Litvinenko<sup>1</sup>, S. Yerin<sup>1</sup>

- 1- Institute of Radio Astronomy of NASU, Kharkiv, Ukraine
- 2- LESIA, Observatoire de Paris, CNRS, PSL, Sorbonne U., U. Paris Cité, Meudon, France
- 3- LPC2E/CNRS, l'Université d'Orléans, Observatoire Radioastronomique de Nancy, Observatoire de Paris, France
- 4- Laboratory of Astro Particles, Université d'Orléans, France
- 5- International LOFAR Telescope, ASTRON (Netherlands Institute for Radio Astronomy)
- 6- JIVE-ERIC the Netherlands
- 7- Commission for Astronomy, Austrian Academy of Sciences, Graz, Austria
- 8- Gravimetrical Observatory, Institute of Geophysics named S.I. Subbotin of NASU, Poltava, Ukraine
- 9- Future University Hakodate, Hakodate, Japan




9th Annual Science At Low Frequencies (SALF) Conference

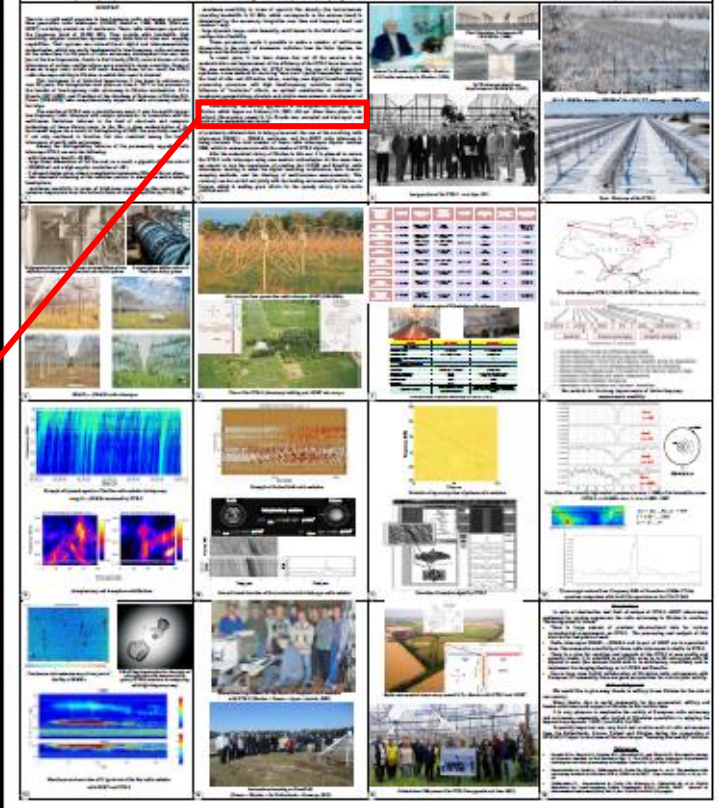


Dec 11 – 15, 2023  
WCW, Amsterdam Science Park

Unfortunately, the military aggression of the neighboring country against Ukraine, which began on February 24, 2022, did not allow these plans to be realized. Observatory named S. Ya. Braude was occupied and destroyed, and much of the equipment was looted.



Ukrainian T-shape Radio Telescope UTR-2:  
50-Years in Operation and Perspectives



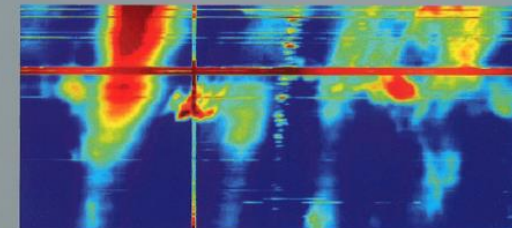
The image shows a grid of various scientific papers and photographs. A red arrow points from the text box on the left to a specific paper in the grid, which is highlighted with a red box. The papers include titles, abstracts, and images related to the UTR-2 radio telescope and its operations.

The book  
V. Melnik and H.O. Rucker:  
Decameter Radio Emission of the Sun  
is now via  
Open Access free of charge available by the  
Austrian Academy of Sciences Press:

[https://verlag.oeaw.ac.at/produkt/decameter-radio-emission-of-the-sun/99200987?name=decameter-radio-emission-of-the-sun&product\\_form=5387](https://verlag.oeaw.ac.at/produkt/decameter-radio-emission-of-the-sun/99200987?name=decameter-radio-emission-of-the-sun&product_form=5387)

V. Melnik, H. O. Rucker

## Decameter Radio Emission of the Sun



AUSTRIAN  
ACADEMY  
OF SCIENCES  
PRESS