

Sporadic radio emission of the Sun at decameter wavelengths

V.N. Melnik

Ukraine A.A.Konovalenko, L.L.Bazelyan, E.P.Abranin, V.V.Dorovsky, A.I.Brazhenko,
V.A. Shepelev, A.A.Stanislavsky, N.V.Shevchuk, B.P.Rutkevich, A.I. Boiko

Austria H.O. Rucker, M. Panchenko, M.Y. Boudjada

Belgium S. Poedts, Yu. Voitenko

Georgia T.Zaqarashvili, B. Shergelashvili

Germany G. Mann, A. Warmuth

Great Britain E. Kontar

France A. Lecacheux P. Zarka, C. Rosolen, C. Briand

Russia V.V. Zaitsev, E. Zlontik, Ya. Tsybko

Sweden B. Thide, M. Khotyaintsev

The UTR-2 (Kharkiv, Ukraine) is the world-largest decameter radio telescope

effective area about $150,000 \text{ m}^2$
sensitivity 5 Jy

operation frequency $8\text{-}33 \text{ MHz}$
beam at 25 MHz $30'$



North-South arm



West-East arm

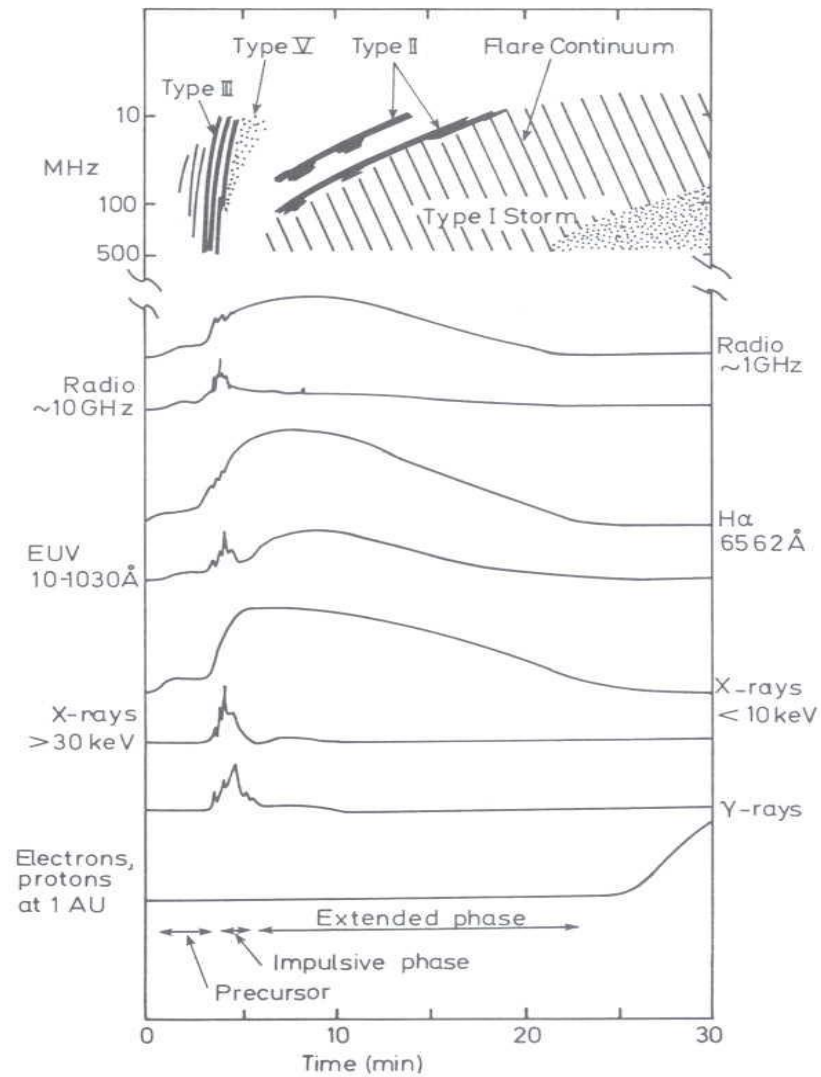


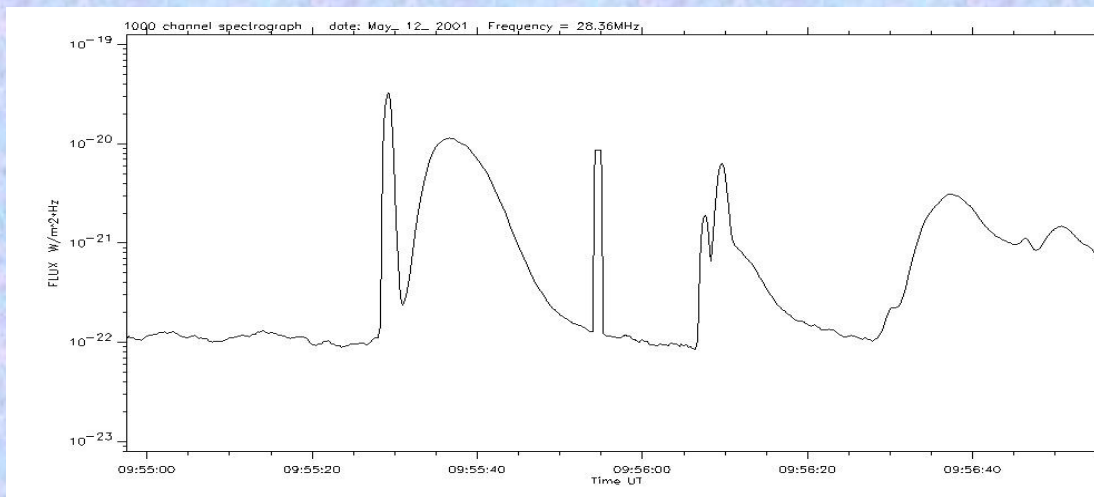
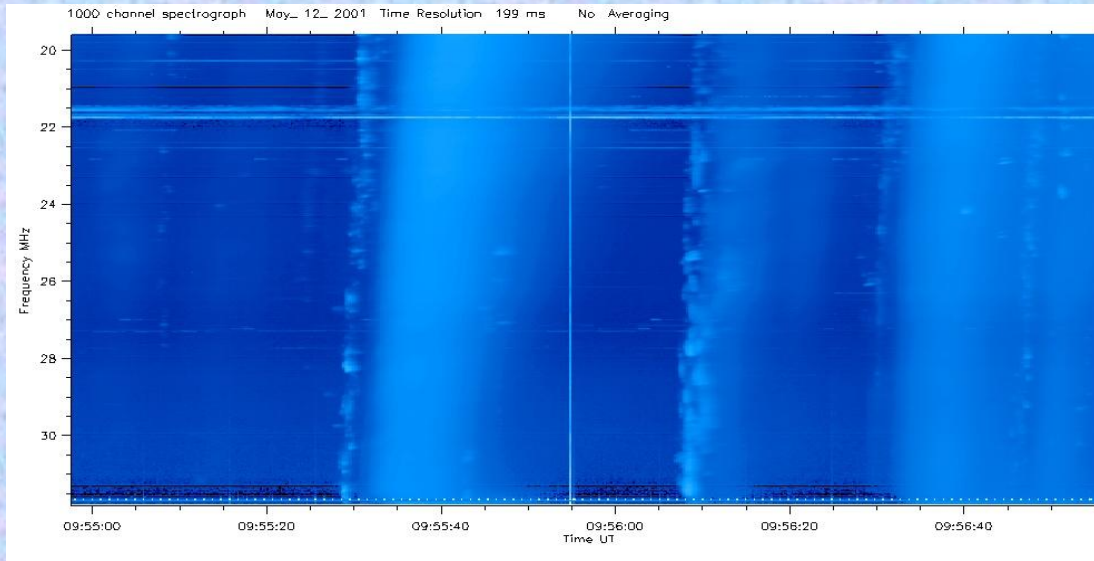
Fig. 4.1 - A schematic representation of the different phases of a typical solar flare as observed in electromagnetic and particle radiation. (Adapted from Kane 1974.)

The sporadic phenomena observed in the decameter range

- **Type III bursts**
 - **Type IIIb bursts**
 - **Type III bursts with fine time structure**
 - **Type III-like bursts**
 - **inverted U - and J - bursts**
- **Type II bursts**
 - **Type II bursts with herring-born structure**
 - **Type II bursts with second and third harmonics**
- **Type IV bursts**
 - **fiber-bursts in emission and absorption**
 - **zebra pattern**
- **S-bursts**
- **drift pairs**
- **spikes**
- **large scale bursts in absorption**
- **unusual bursts**

Type III bursts

Typical Type IIIb-III pairs



Parameters of Type III bursts

burst drift rate 3 MHz/s

duration 9 s

flux density $1 \cdot 10^{-20} \frac{W}{m^2 \cdot Hz}$

Parameters of Type IIIb bursts

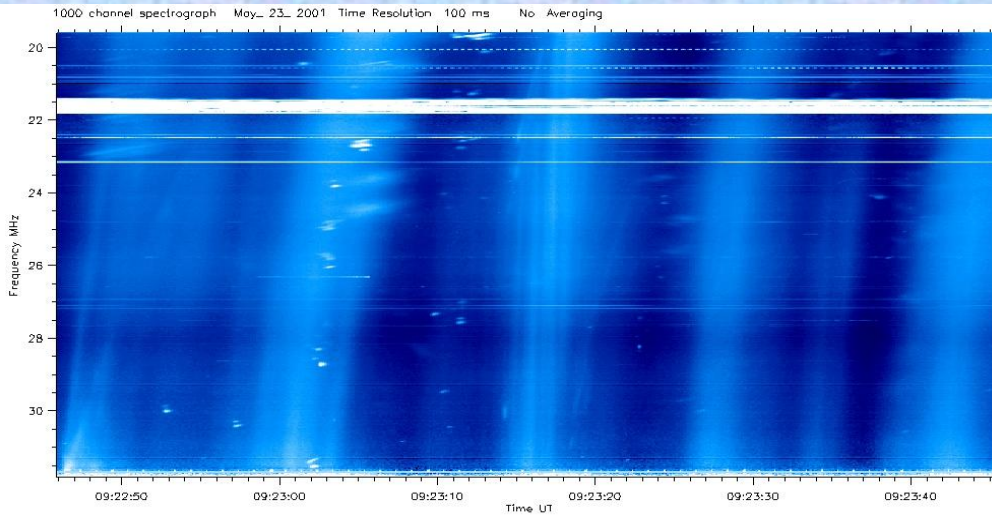
burst drift rate 4 MHz/s

duration 3 s

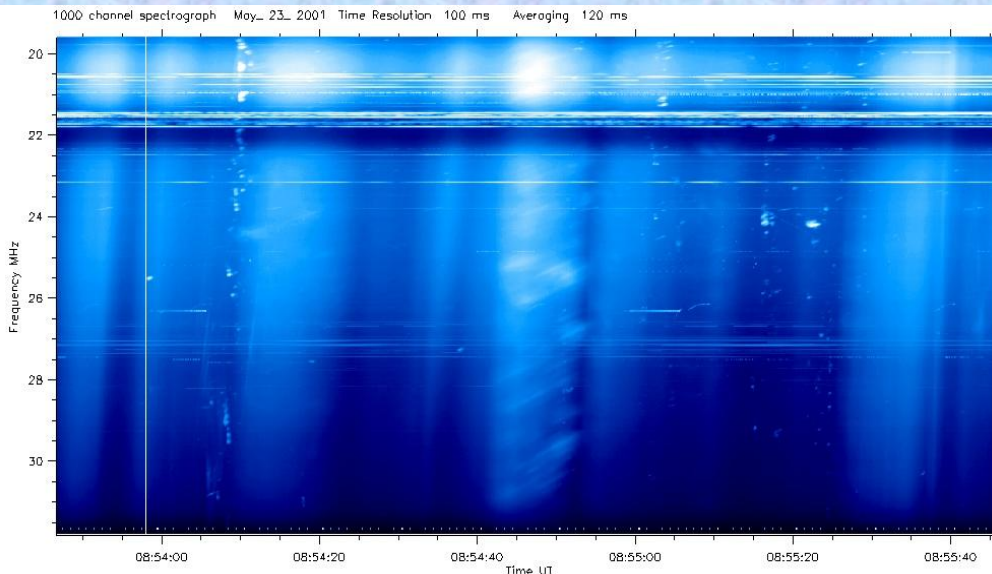
flux density $3 \cdot 10^{-20} \frac{W}{m^2 \cdot Hz}$

Type III bursts with fine structure

There are time-structured Type III bursts with sub-bursts having either *higher* or *lower drift rates* with respect to that of the envelope

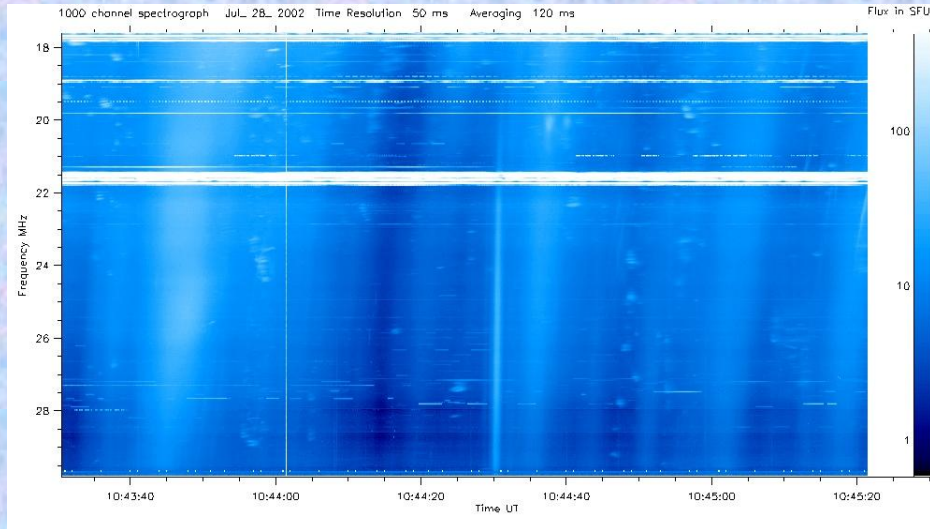


envelope drift rate $3 \div 4$ MHz/s
envelope duration $4 \div 5$ s
flux up to $1 \cdot 10^{-20}$ W/m² · Hz
sub-bursts drift rate > 10 MHz/s
sub-bursts duration 1 s



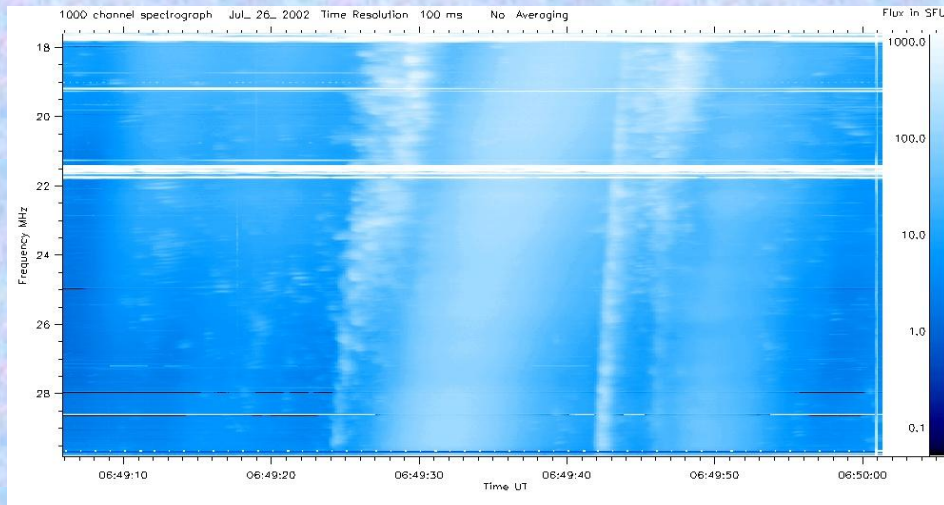
envelope drift rate $3 \div 4$ MHz/s
envelope duration $7 \div 8$ s
flux up to $1 \cdot 10^{-19}$ W/m² · Hz
sub-bursts drift rate 0.1 MHz/s
sub-bursts duration 1 s

Type III-like bursts



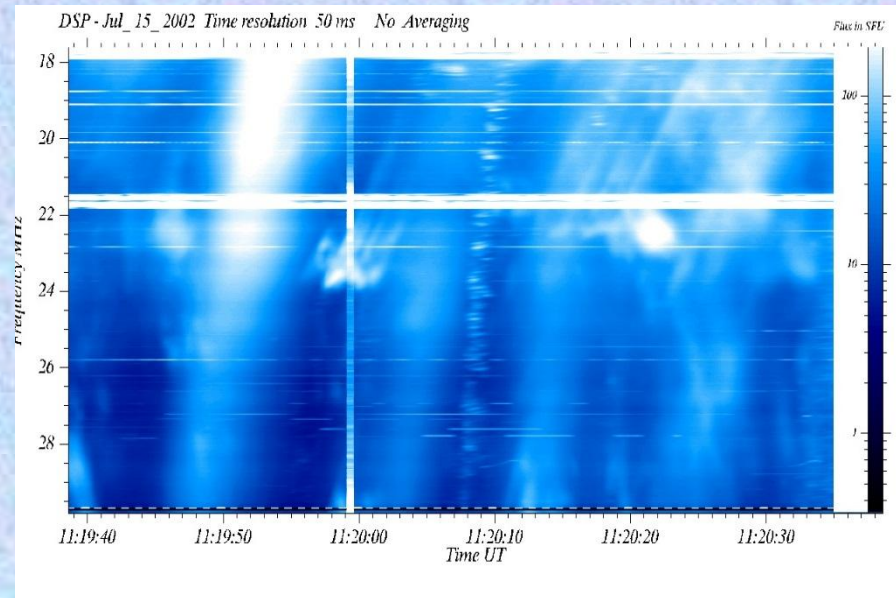
drift rate 5-40 MHz/s
duration about 1s

Type III-like burst (10:44:30) against
a background Type III burst storm



Type IIIb-like bursts similar to
the burst (06:49:42) are observed
for the first time

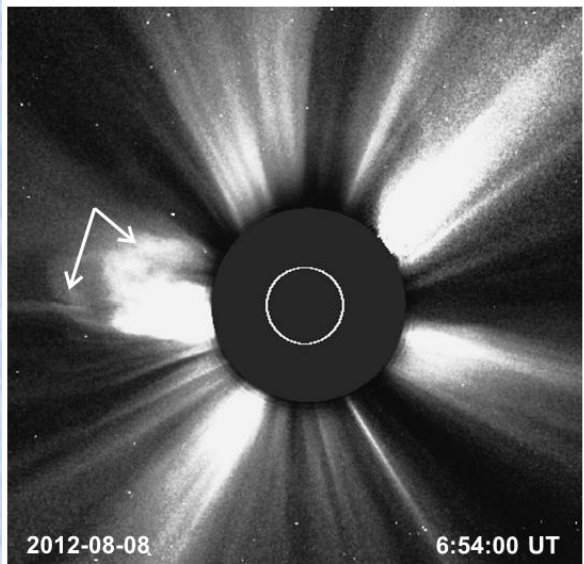
Type IIIb bursts



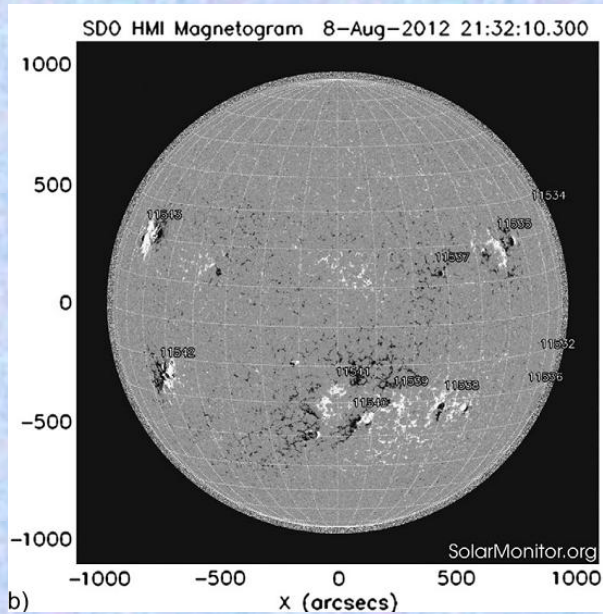
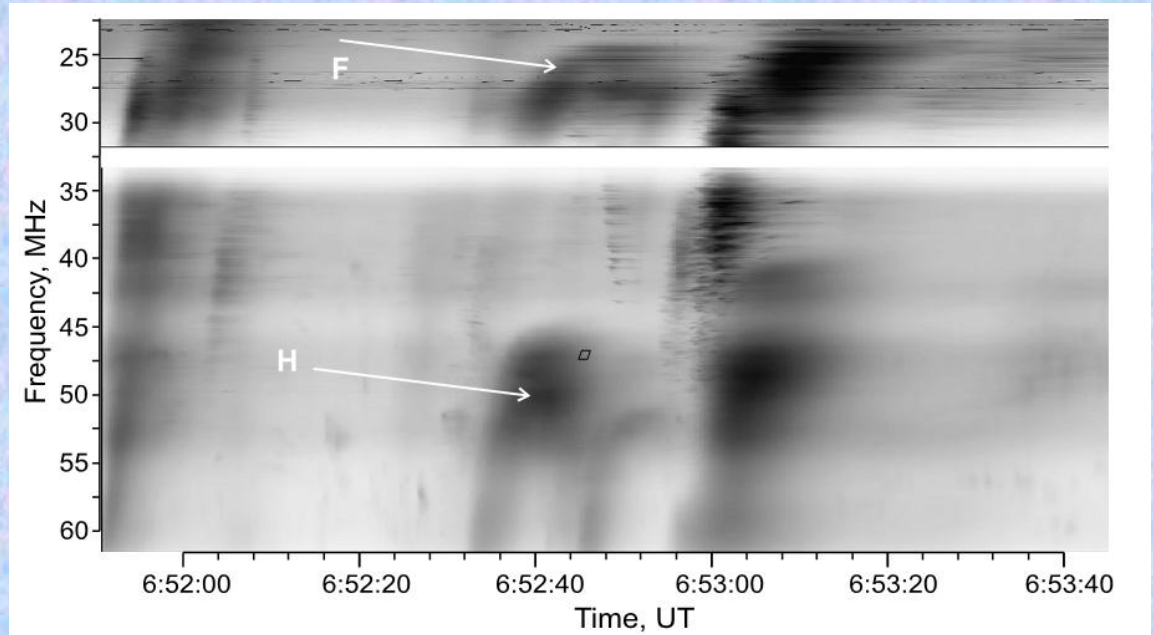
stria duration about 1 s

stria frequency band about 60 kHz

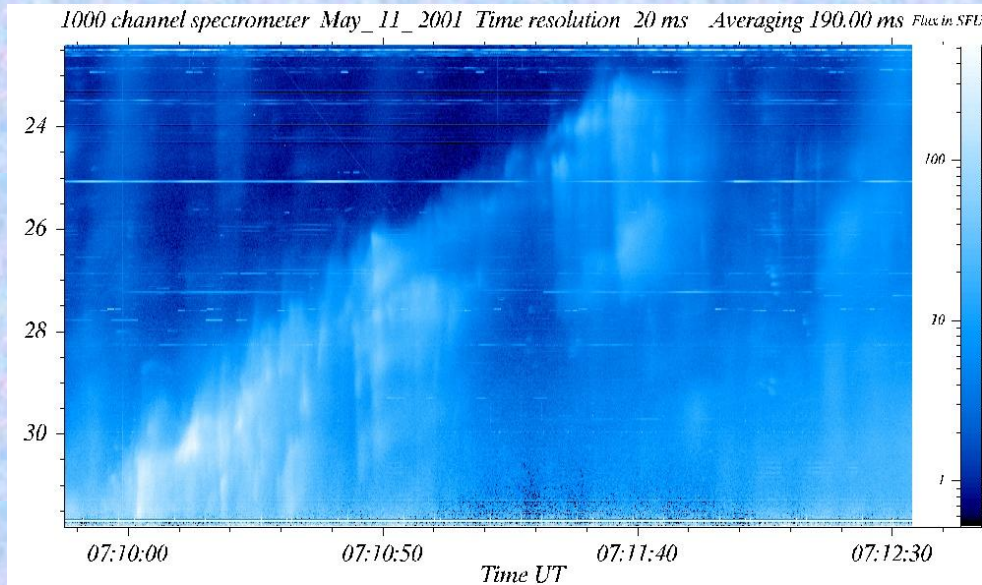
Inverted U-bursts and high coronal loops



UTR-2 + GURT observations



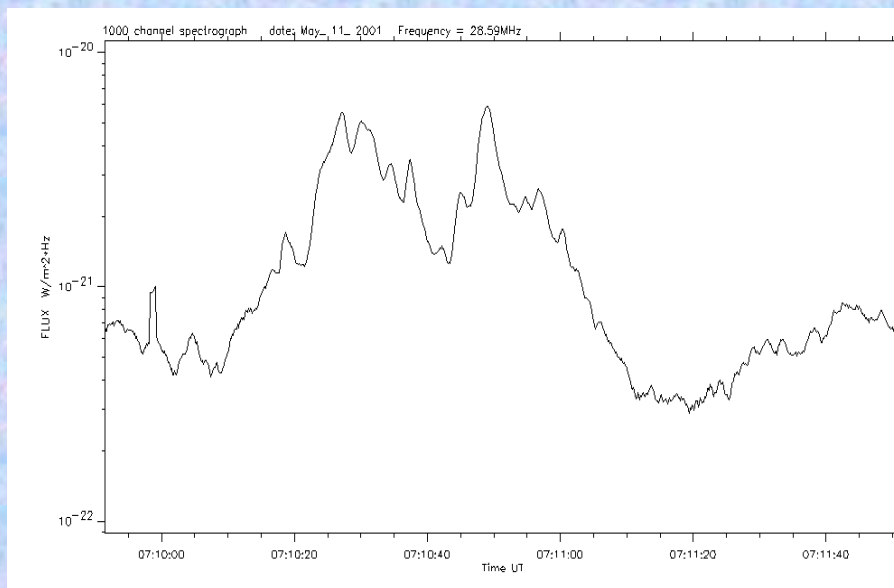
Type II bursts



Type II burst consists of lanes and has a fine structure in the form of sub-bursts

Type II drift rate $df/dt = -0.07 \text{ MHz/s}$

flux $S = 1 \div 5 \cdot 10^{-22} \text{ W/m}^2 \text{ Hz}$

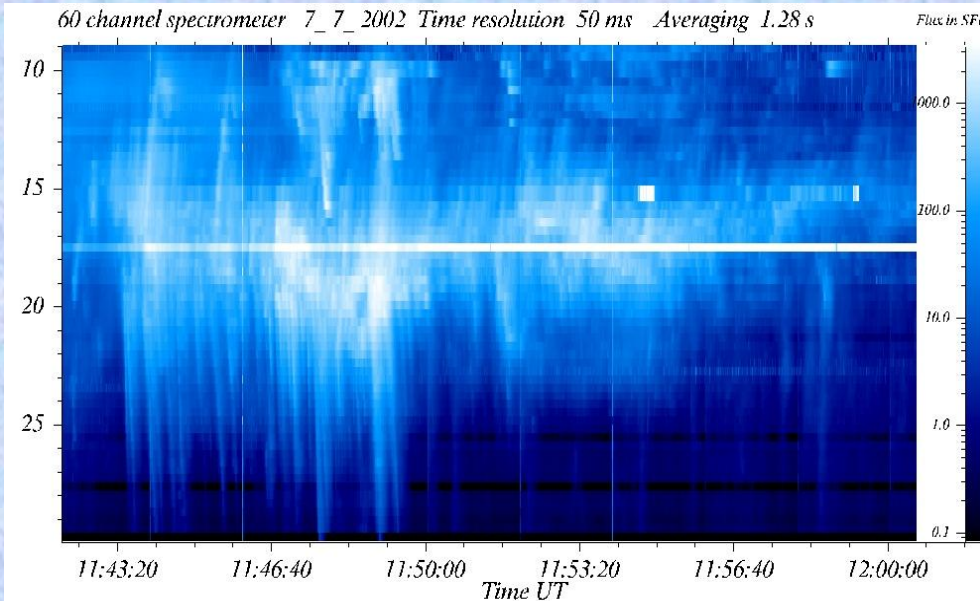


sub-bursts have **positive** and **negative** frequency drifts

$$|df/dt| = 1 \div 3 \text{ MHz/s}$$

sub-burst duration $\approx 1 \text{ s}$

Type II burst with herringbone structure



waving backbone $df/dt \approx 0$

average drift rate $\Delta t = 3 \div 6s$

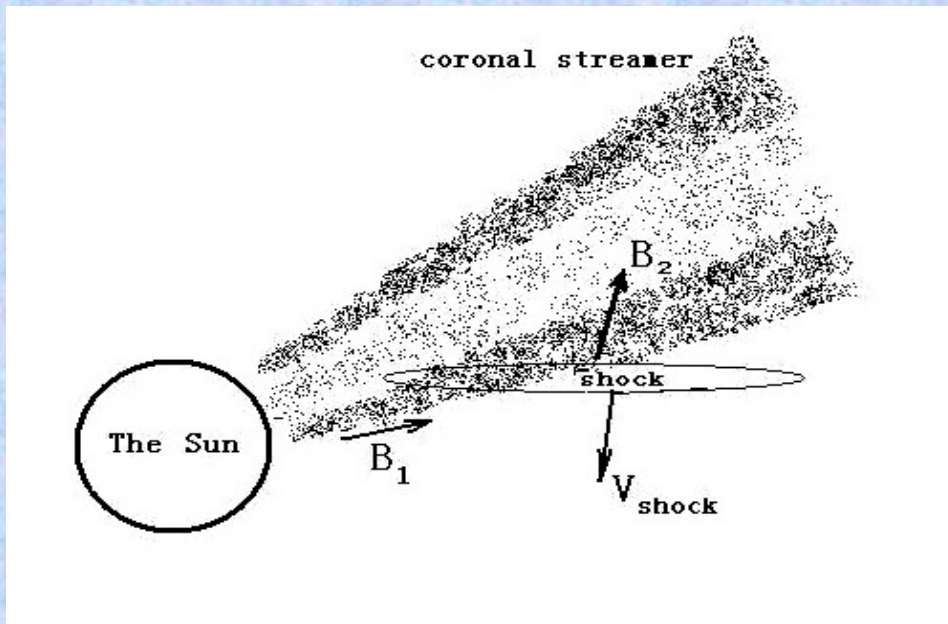
sub-burst durations $|df/dt| = 0.5 \div 1.5 \text{ MHz/s}$
 sub-burst drift rates

**Coronal structure parameters
 found from decameter radio data**

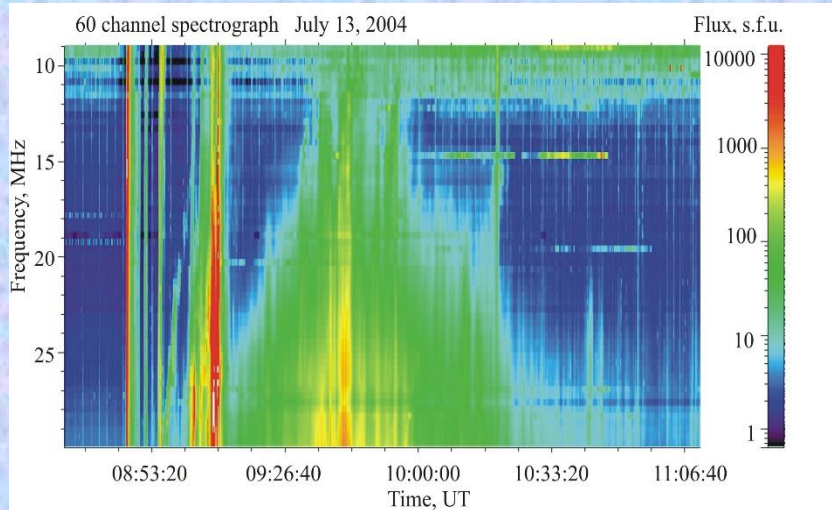
transversal sizes

of coronal structures $\approx 0.1 \cdot R_s$

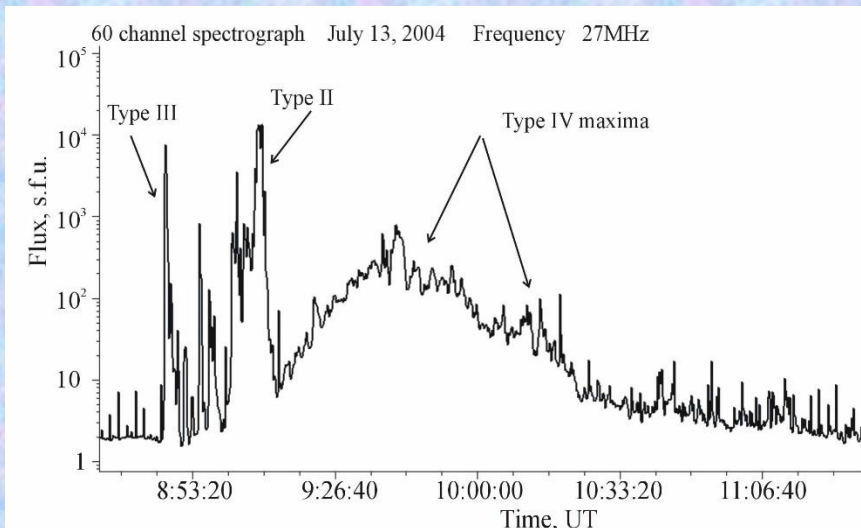
density jump $\Delta n \approx 6 \cdot 10^5 \text{ cm}^{-3}$



Type IV bursts



Decameter Type IV bursts lasts from 2 up to 6 and even more hours. Its radio fluxes from 10 to some 1000 s.f.u. All of them have fine structure in the form of fiber bursts reminding usual Type III bursts

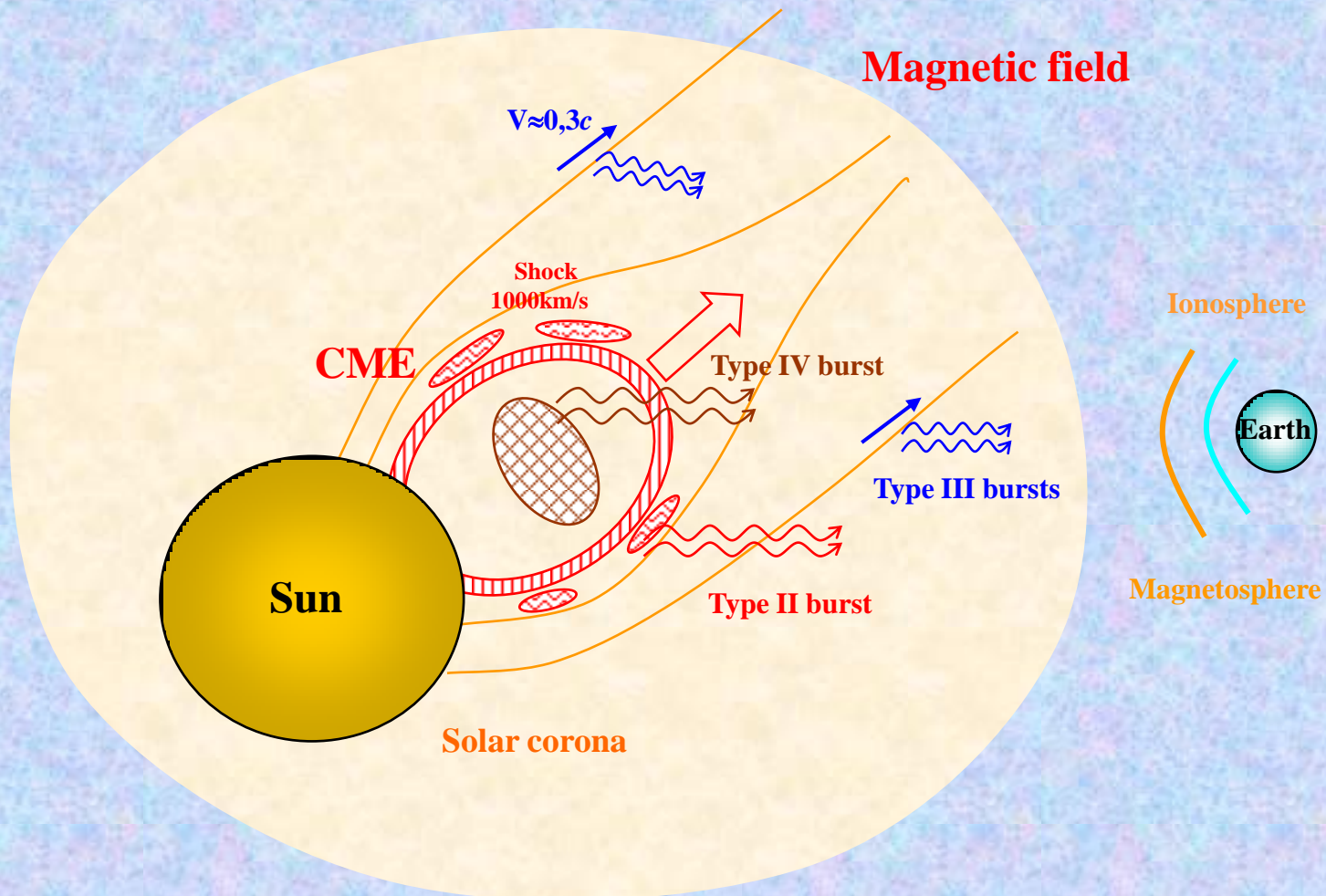


The succession of the events accompanying Type IV bursts in the decameter wavelengths

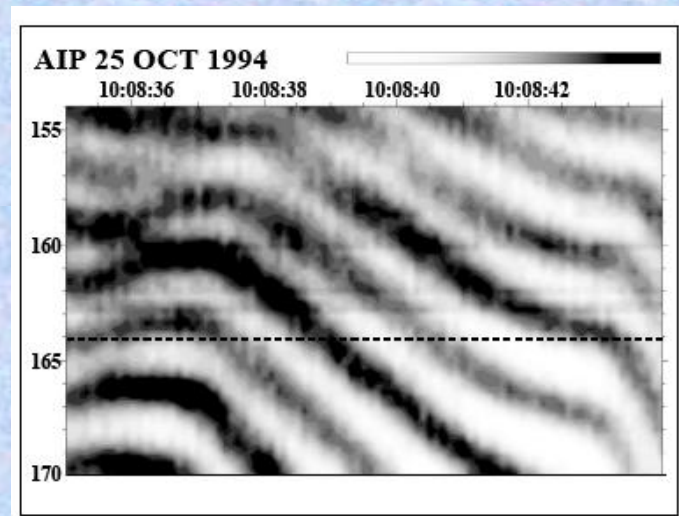
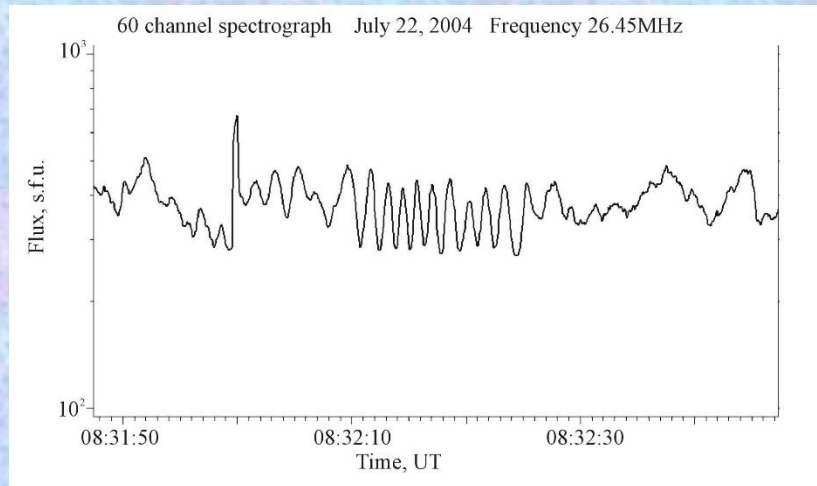
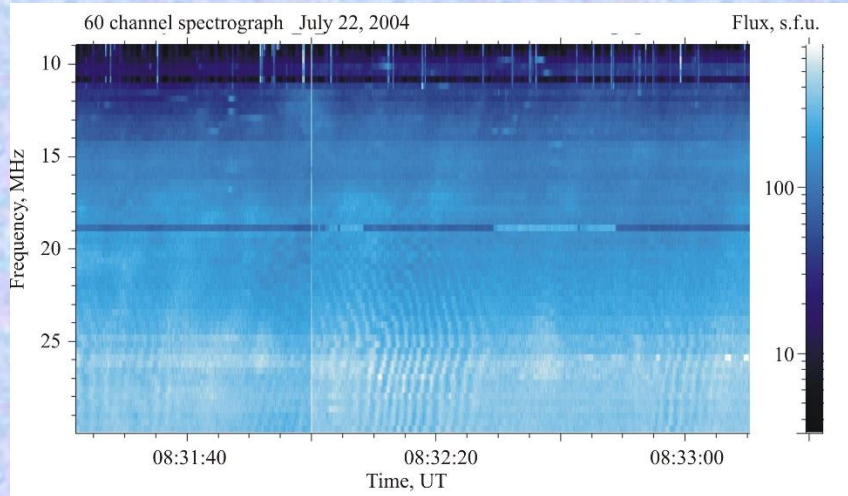
- group of intensive Type III bursts
- shading area or burst in absorption
- Type II burst with the second and even third harmonics

The succession of the events accompanying Type IV bursts in decameter range

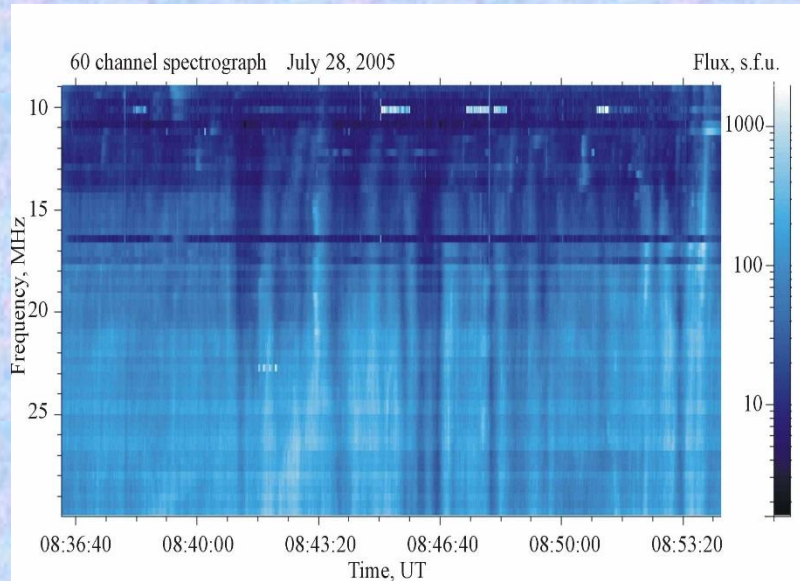
- group of intensive Type III bursts
- shading area or burst in absorption
- Type II burst with the second and even third harmonic



Zebra structure of Type IV bursts

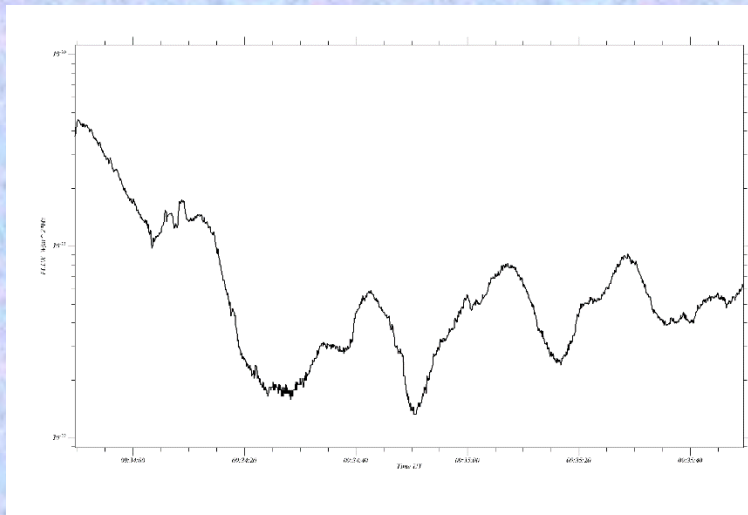


Fiber bursts in emission and absorption as a fine structure of Type IV bursts



Fiber bursts are similar to usual Type III bursts

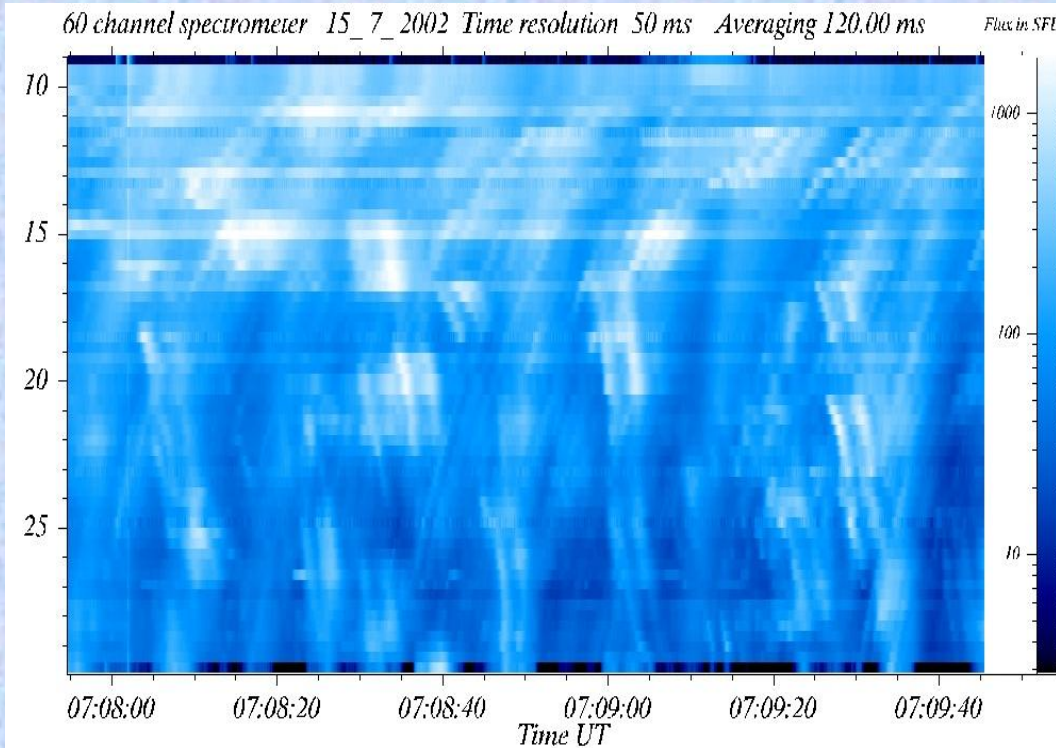
Sometimes they drift from low to high frequency



Duration of bursts in emission equals approx. to 6 s at all frequency from 10 to 30 MHz and does not depend of place of active region on the solar disk.

Drift pairs bursts

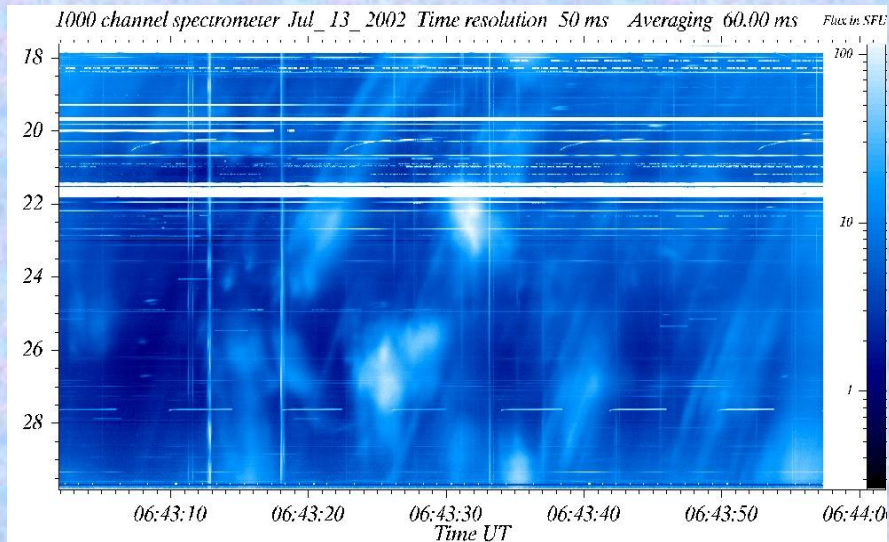
storm of drift pair bursts



drift pairs with **positive** and **negative** drift rates
frequency drift rate 1-2MHz/s
life-time of element 1-1.5s
time delay between elements 1- 2s
frequency band of DP 2.5-4 MHz

In spite of an approximate equality of number of FDP and RDP they have different drift rate values, different drift rate via frequency dependences, delay time values, radio fluxes.

S-bursts



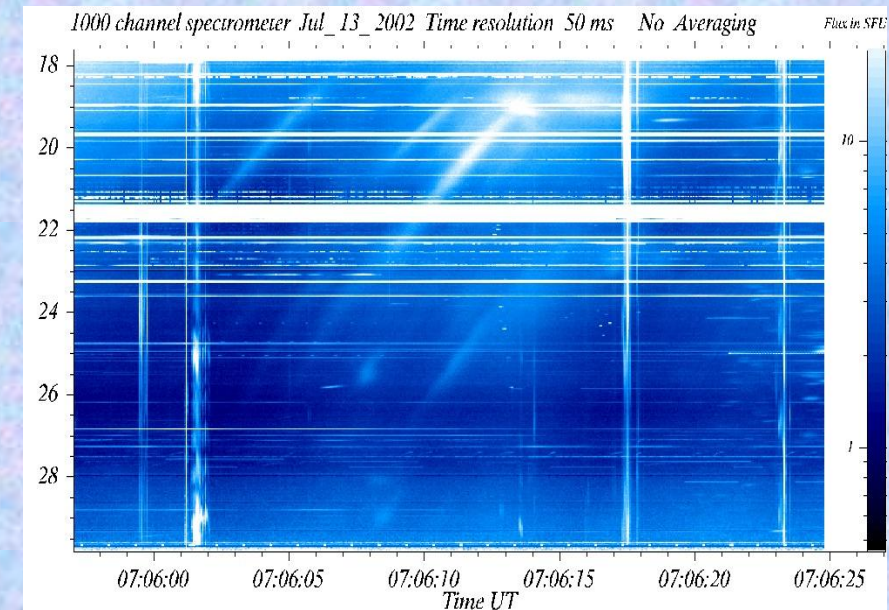
only burst with **negative** drift rates

lack of the second element

s-burst drift rates $|df/dt| = 0.5 \div 1 \text{ MHzz}$

s-burst are the shortest bursts in the decameter range

their duration is $\tau = 0.3 - 0.6 \text{ s}$



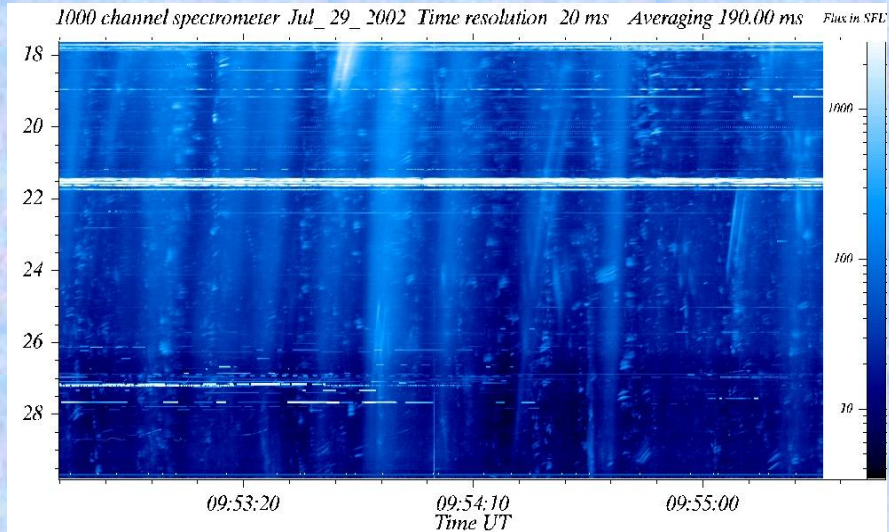
Equation for instantaneous frequency band

$$\Delta f = \alpha \cdot (f - f^*) \text{ , where } \alpha = \omega_{Be}^2 / 2\omega_{pe}^2$$

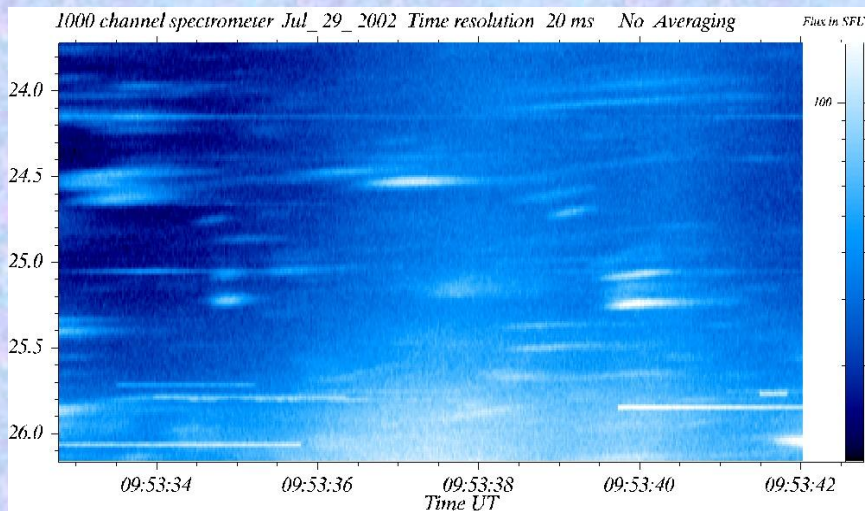
allow to find magnetic field at heights

$$1.5 - 3 \cdot R_s$$

Decameter spikes

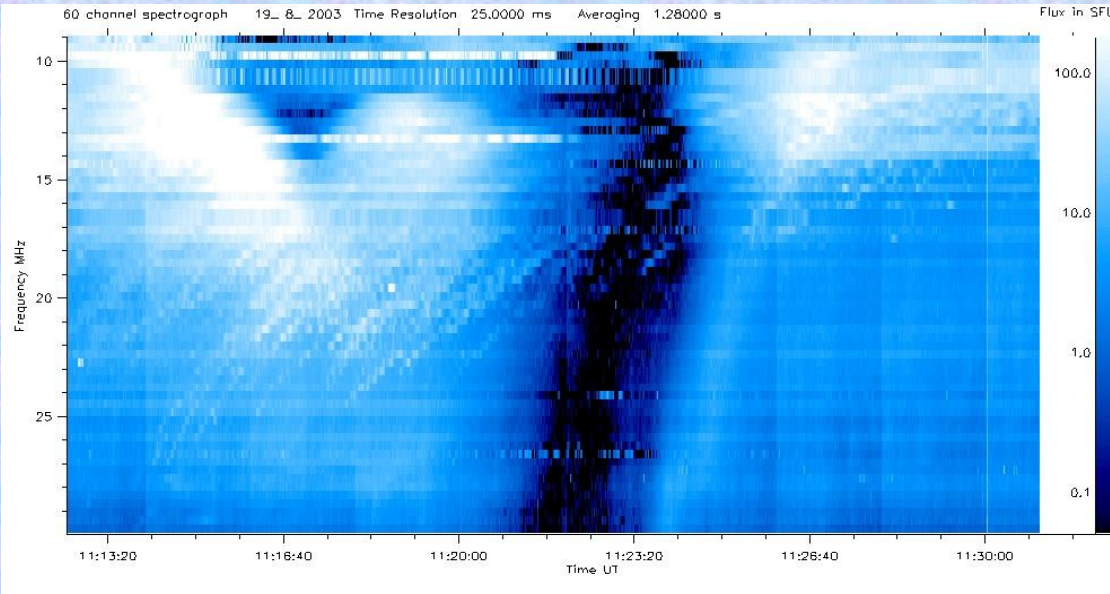


chaotic placed spikes
against Type III bursts storm



spikes with durations about 1s
and frequency width approximately 60kHz

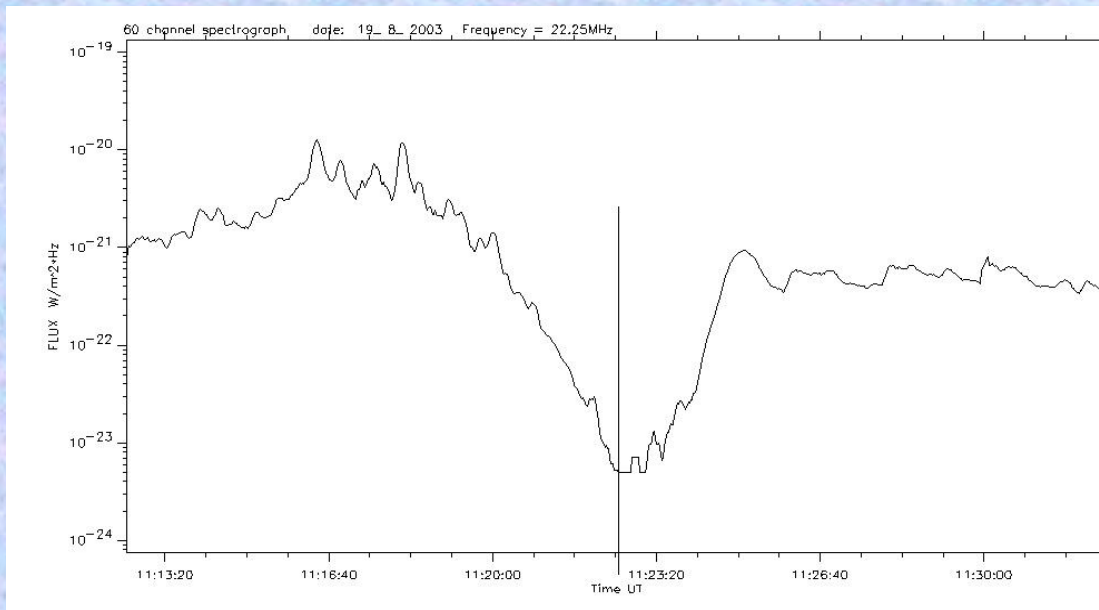
Absorption burst



Drift rate $\approx 120 \text{ kHz} / \text{s}$

Corresponding linear velocity

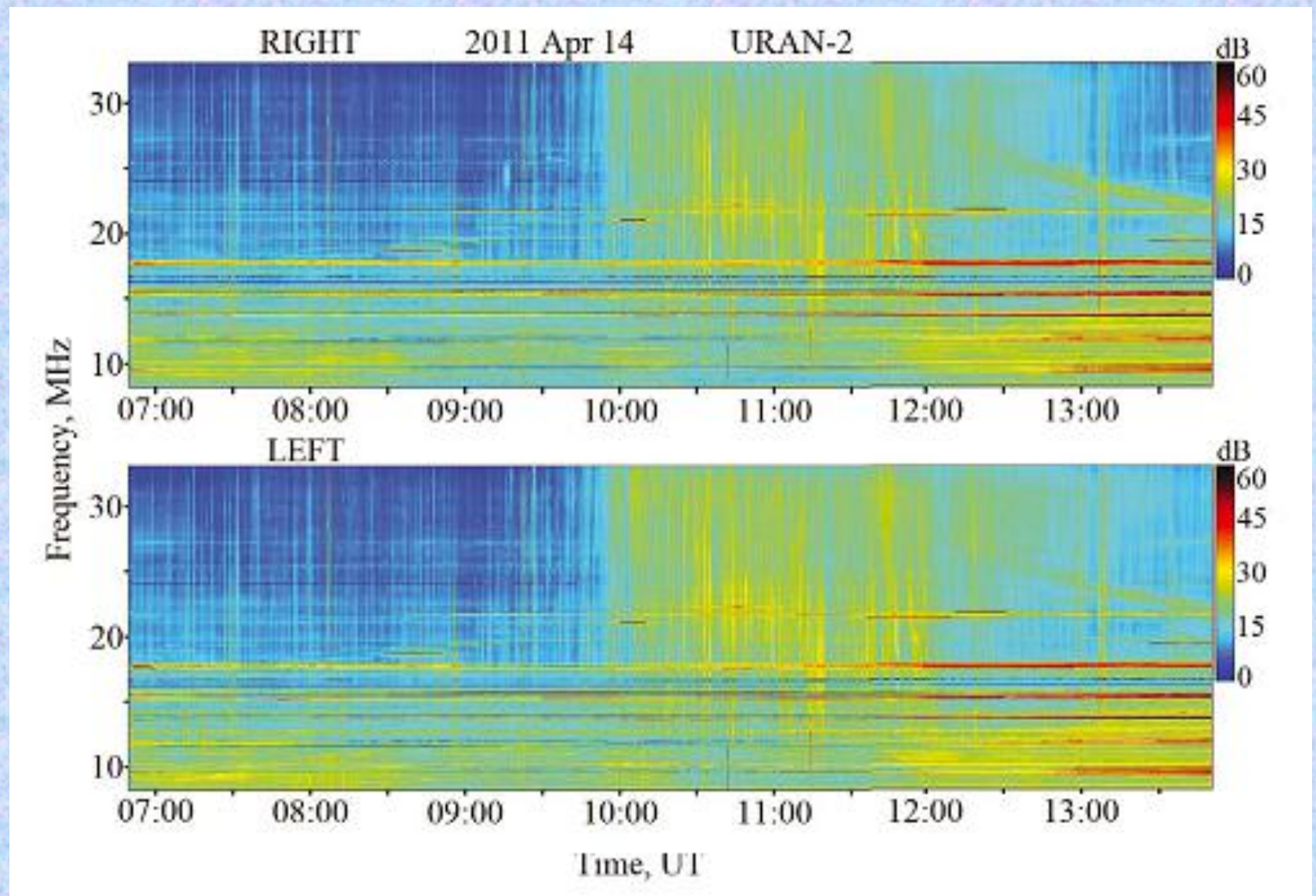
$> 2000 \text{ km} / \text{s}$

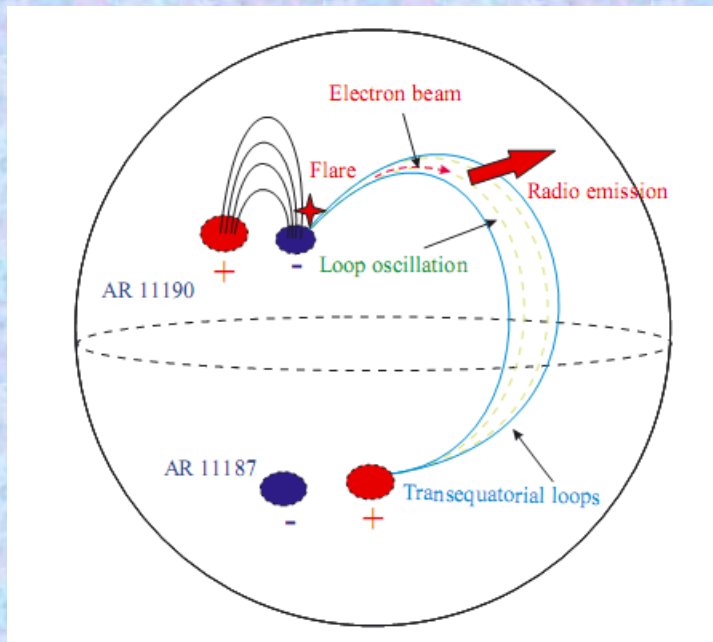
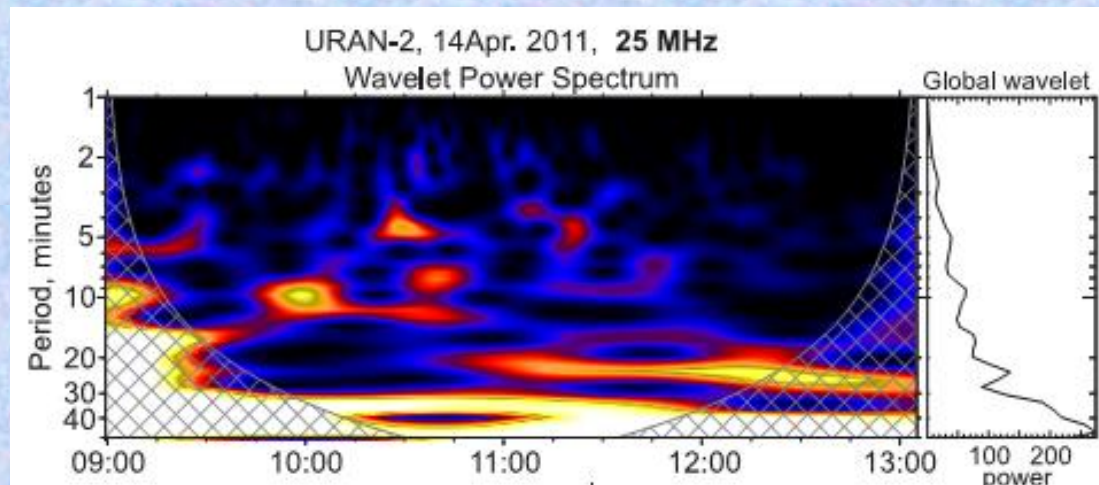


front duration τ_f bigger
than back duration τ_b

$\tau_f \approx 1.5\tau_b = 40 - 50 \text{ s}$

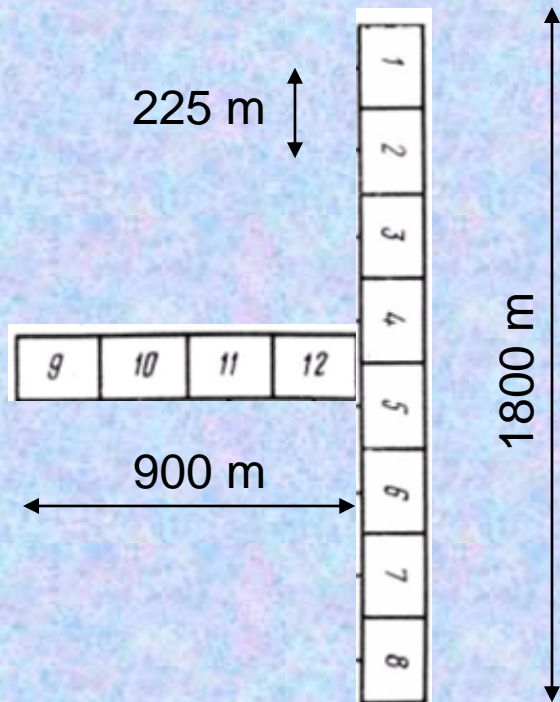
Radio seismology at decameter wavelengths





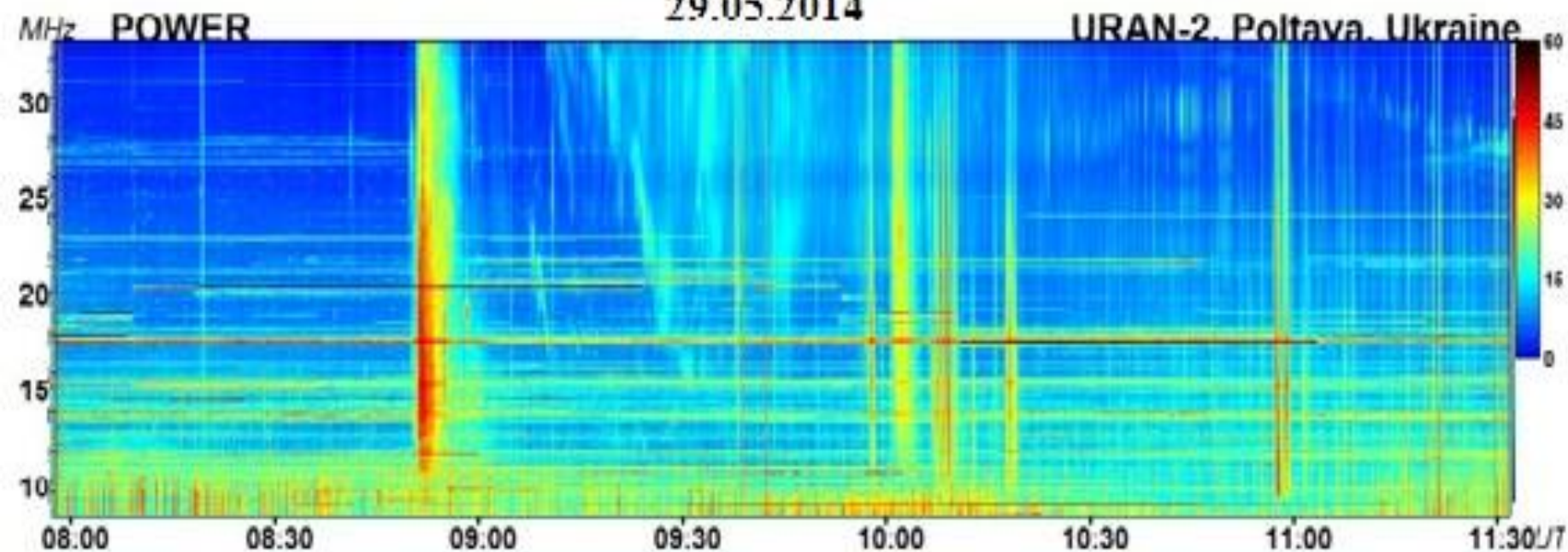
$$V_{A0} = \frac{4L}{T_{\text{obs}}} \sqrt{\frac{1 + \rho_e/\rho_0}{2}} \approx 2000 \text{ km s}^{-1}$$

Interferometer observations by UTR-2 radio telescope

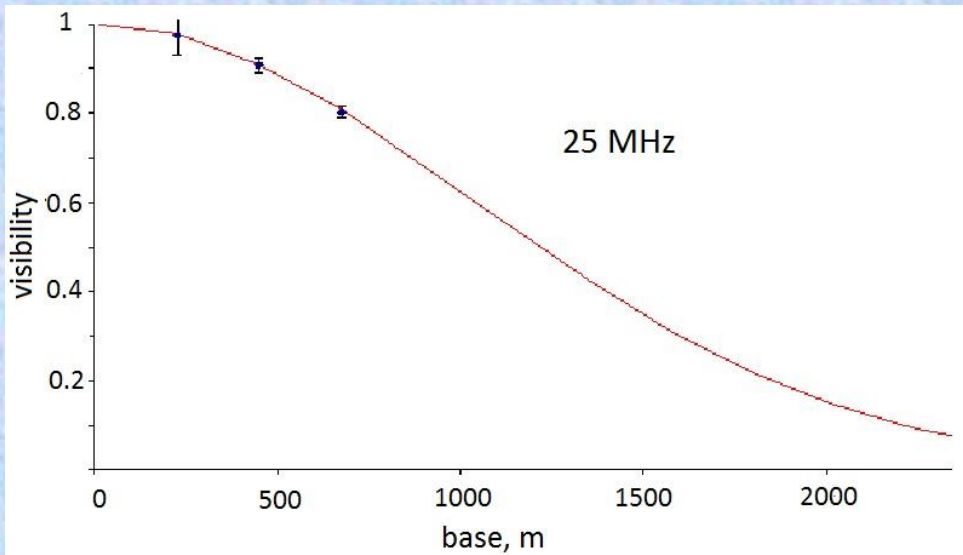


29.05.2014

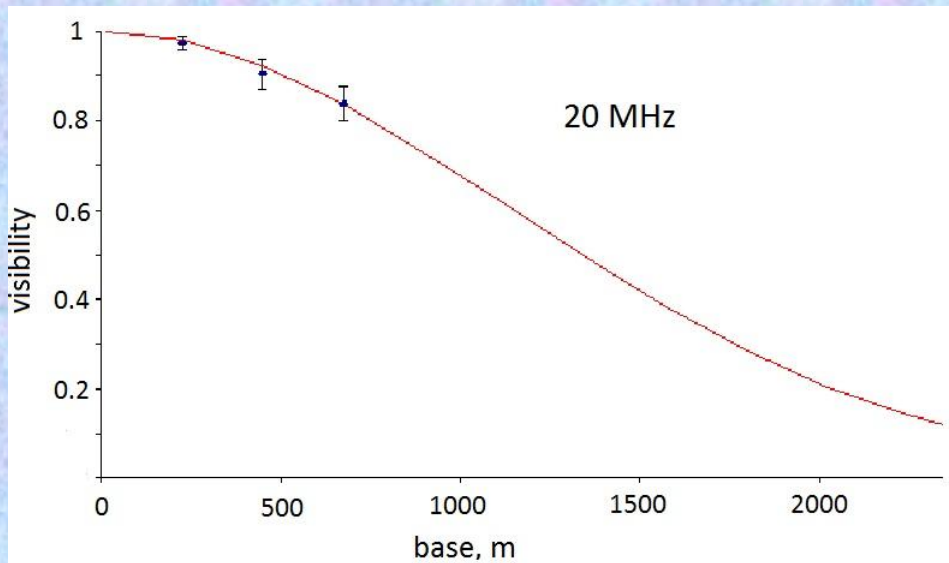
URAN-2, Poltava, Ukraine



Type III burst at 9:41 UT on May 29, 2014

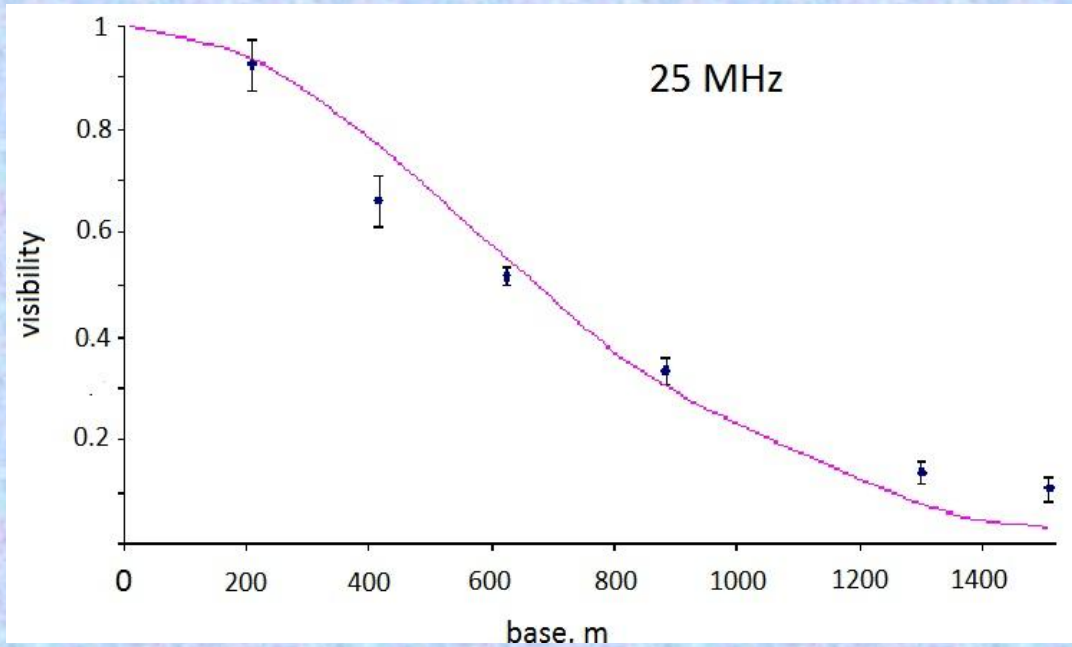


W-E size 14 arcmin

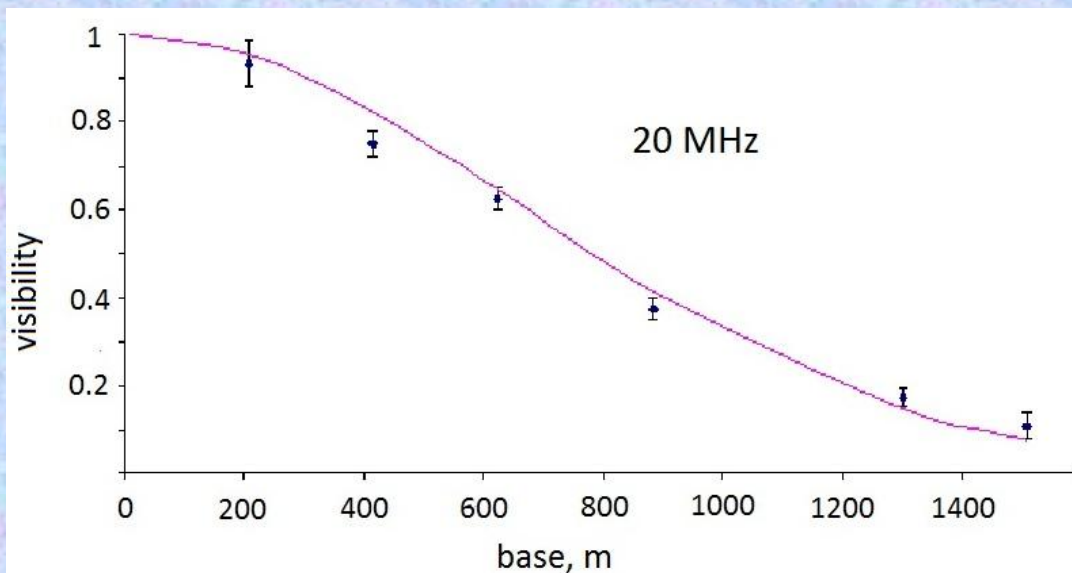


W-E size 16 arcmin

Type III bursts on June 2, 2014



N-S size 27 arcmin



N-S size 29 arcmin

Thank you for your attention