Jupiter's decametric radio emission observed with NenuFAR

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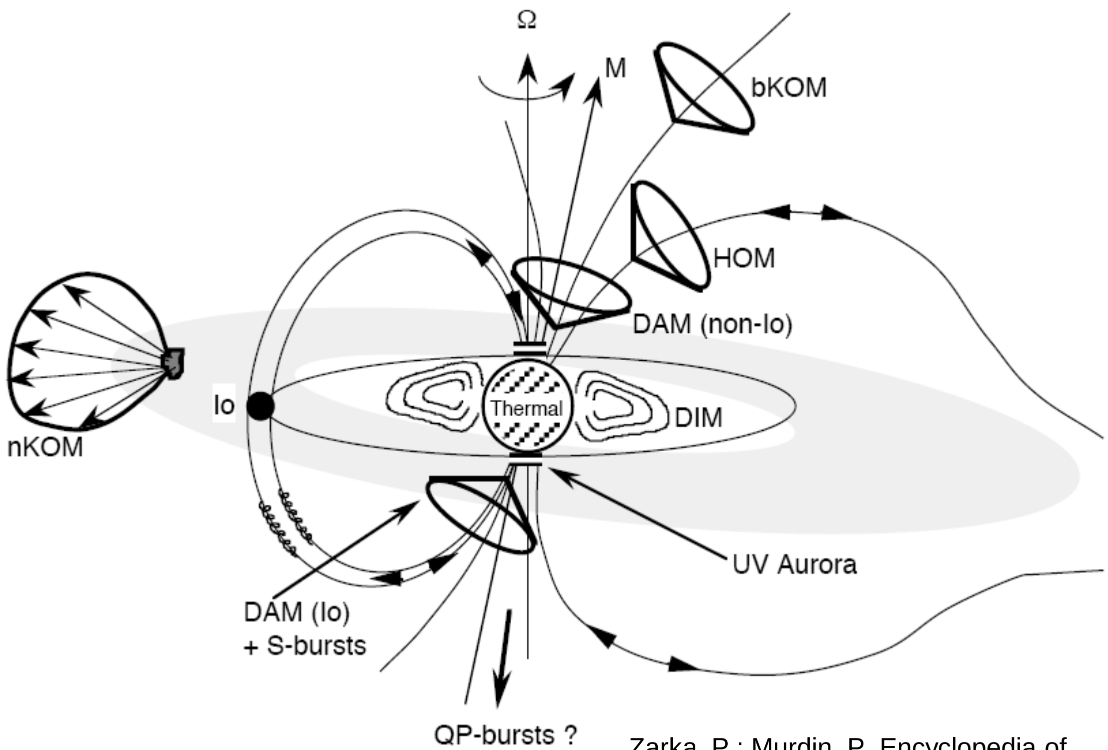
Jovian radio emission



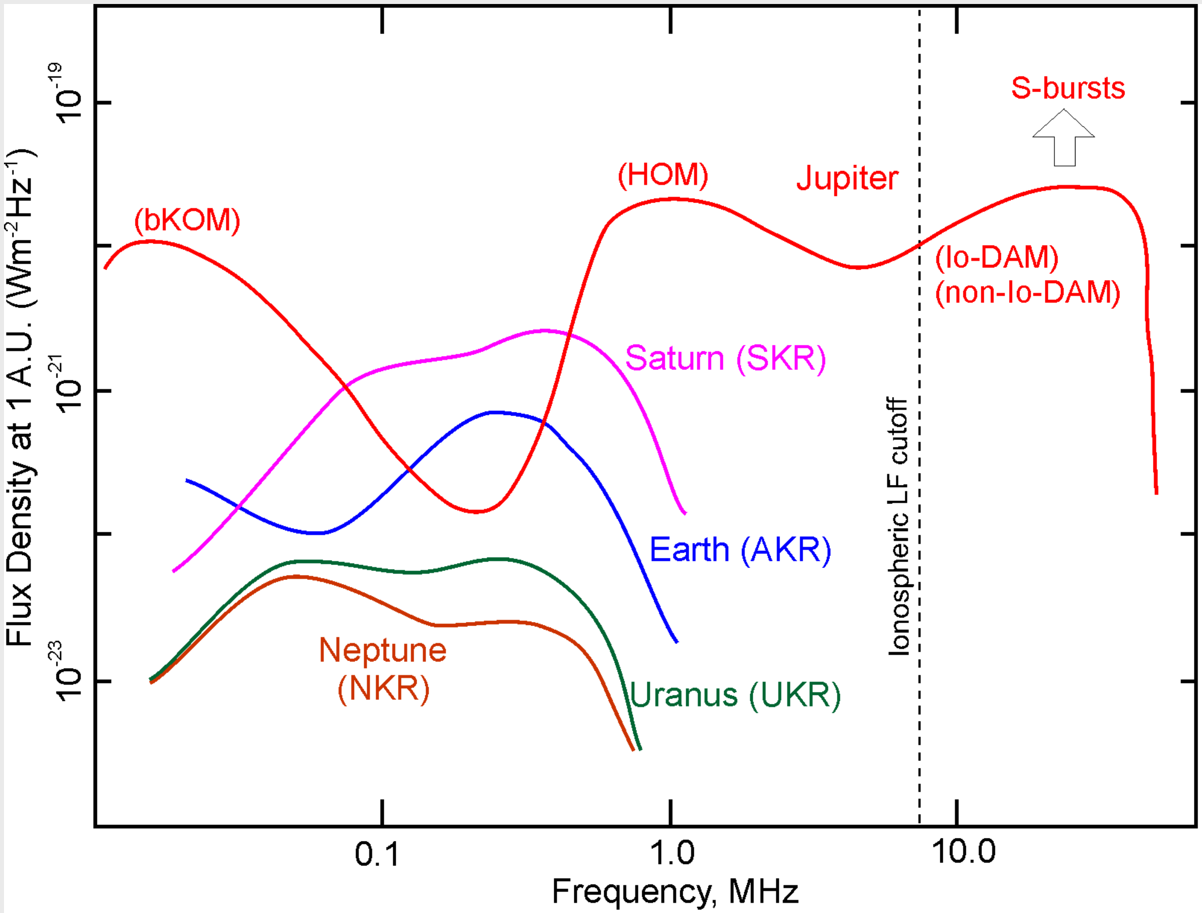
Zarka, P.; Murdin, P. Encyclopedia of Astronomy and Astrophysics, Edited by Paul Murdin,2001

Component Name	Frequency Range	Radiated Power	Source Location	Comments
DIM	~80 MHz - 300 GHz	2 GW	radiation belts	
DAM	2 - 40 MHz	400 GW	Io torus field lines	
HOM	0.2 - 2 MHz	1 GW*	auroral field lines	
bKOM	10 - 1000 kHz	500 MW	Io torus or auroral	
nKOM	40 - 200 kHz	100 MW	Io torus	
Continuum	0.1 - 30 kHz	100 GW	outer magnetosphere	steep (f^{-4}) spectrum
Fast drift	1 - 500 kHz	large	?	

* From *Desch and Kaiser* [1984]. All other table values after *Carr et al.* [1983].

Jupiter with the largest planetary magnetosphere in the solar system is a complex source of a powerful radio emission

Comparative spectra of auroral planetary radio emissions



Comparative spectra of auroral radio emissions normalized to a distance of 1 AU from the source. Adapted from *Zarka 1998, JGR, 103(E9), 20159*

Radio palnets:

- Earth
- Saturn
- Jupiter
- Uranus
- Neptun

Jovian decametric radio emission

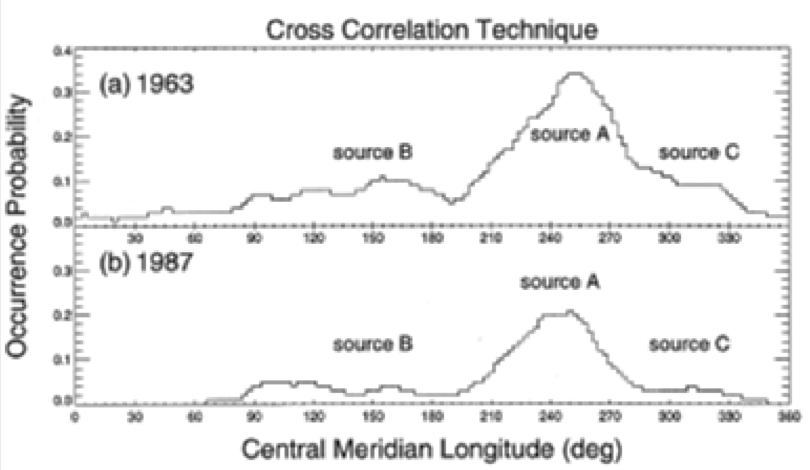
- Discovered in 1955 by B.F. Burke and K.L. Franklin at 22.2 MHz

- Frequency range: a few MHz up to 40 MHz.

- Generation mechanism: cyclotron maser instability, radiation in the R-X mode at a frequency just above the local electron gyrofrequency [Carr et al., 1983].

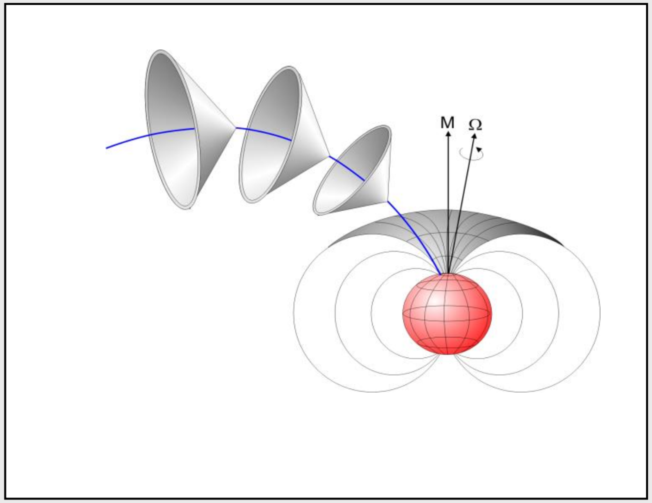
- Higly polarized radio emission [Dulk et al., 1994] (elliptical polarization)

- Radio emission is mainly observed in the form of long (L) bursts, short (S) bursts and narrow band events.

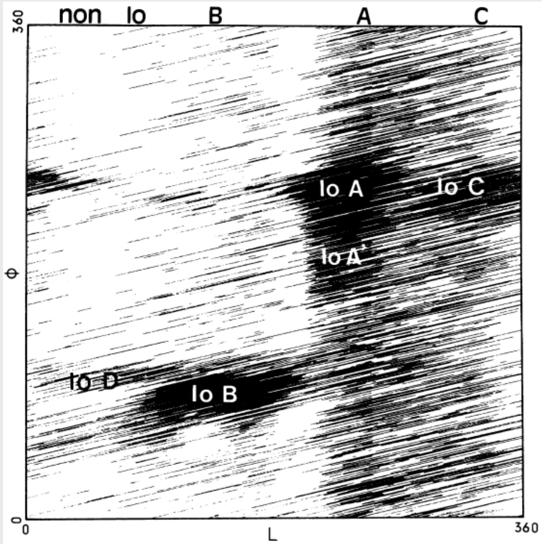


from Higgins et al. [1996]

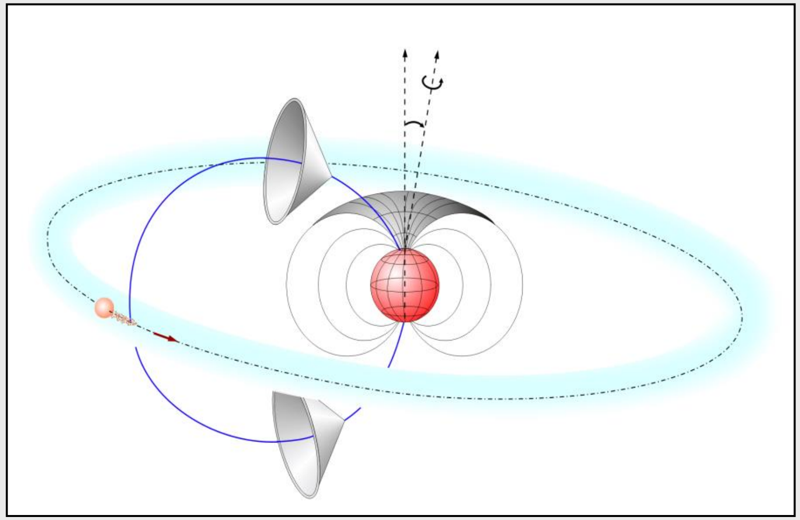
9h 55m 29s – System III

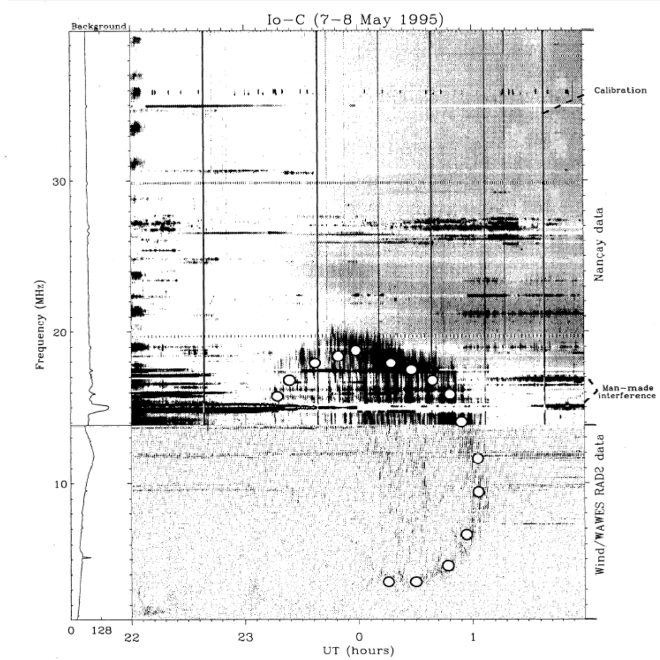


Io controlled DAM

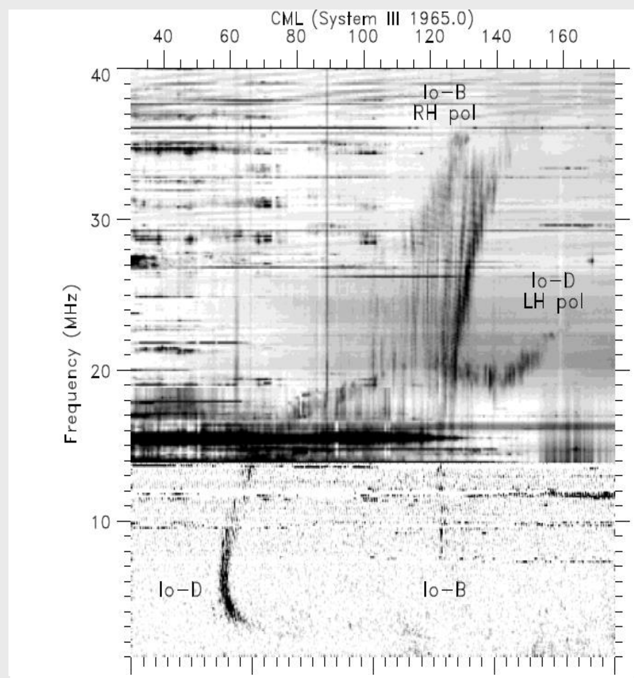


Genova, Source location of planetary radio emissions, PRE I





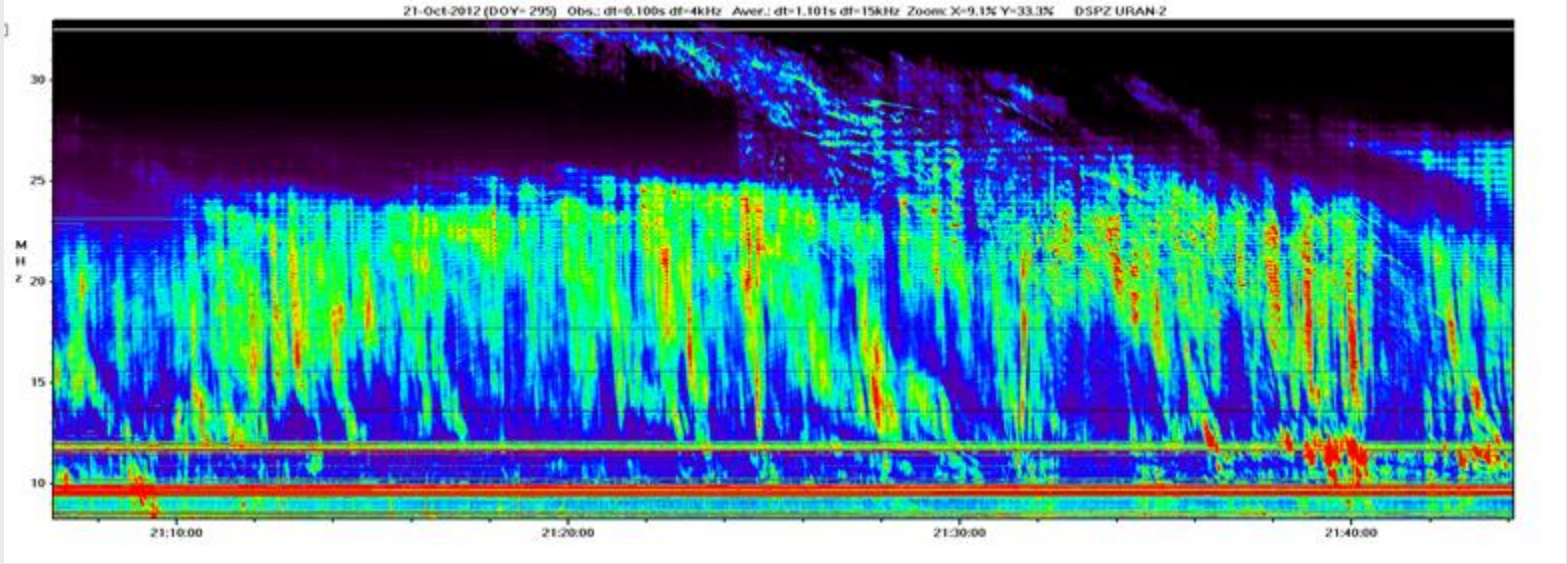
Queinnec, J., and P. Zarka , JGR., 103, 26649, 1998



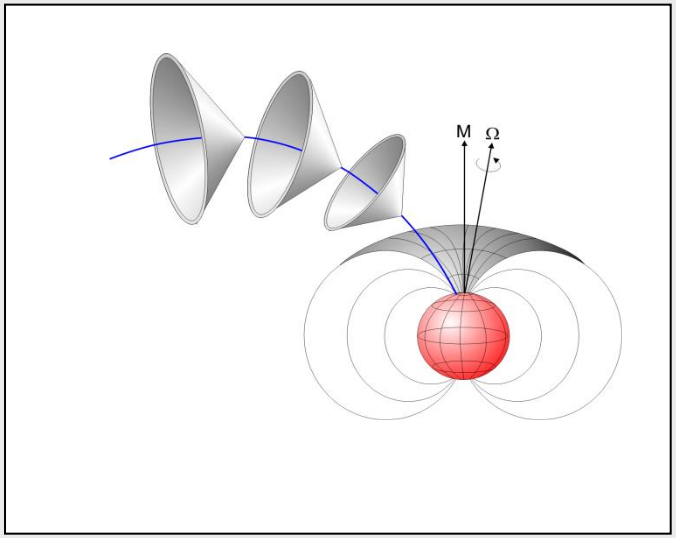
Lecacheux et al., Astron.Astrophys. 329, 776 1998

Occurrence of Io-DAM strongly depends on Jupiter's magnetic System III longitude and Io orbital position

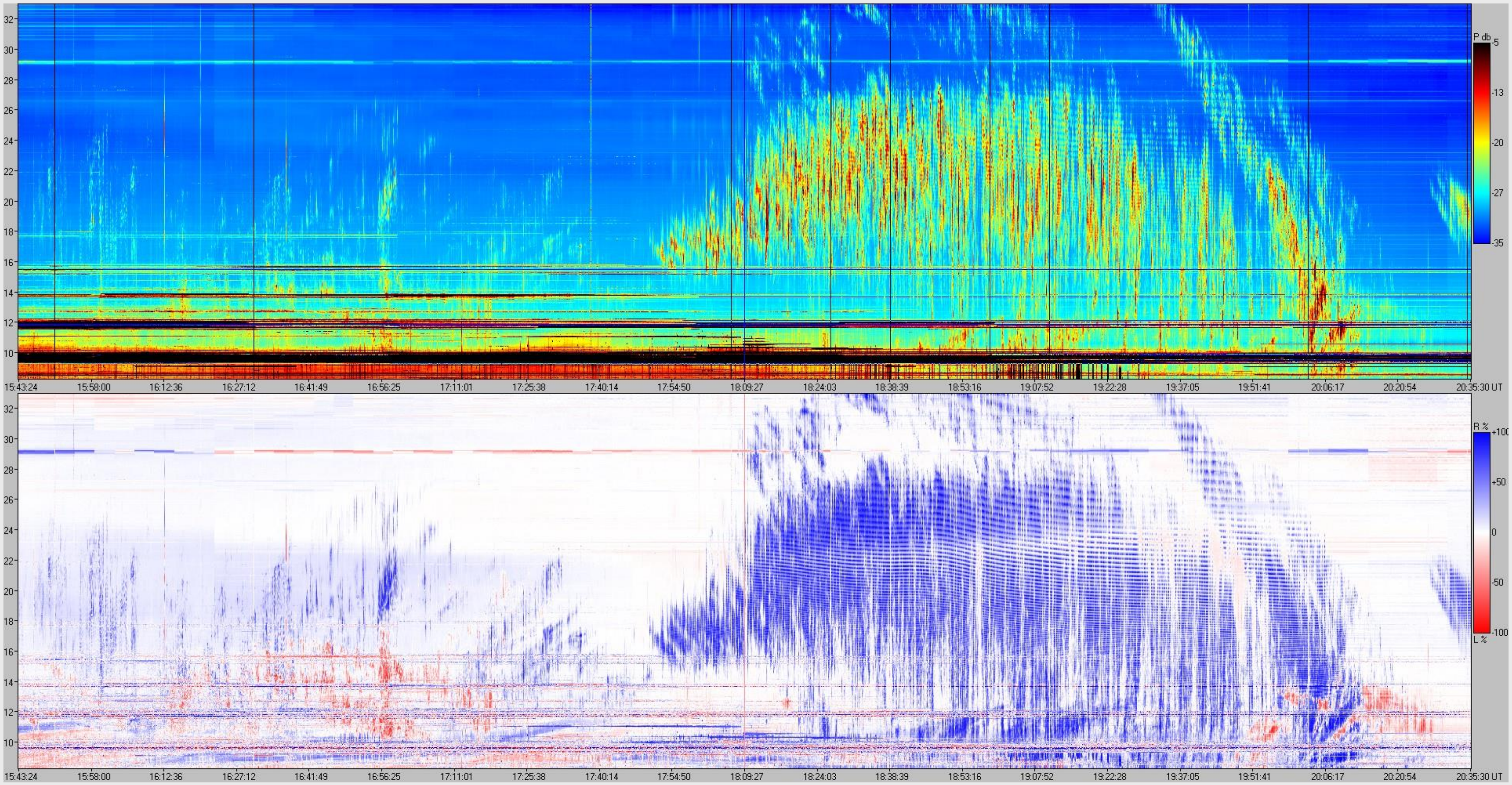
non-Io controlled DAM



- sporadic radio emission modulated by planet's rotation
- sources at high altitudes of auroral lines;



non–Io DAM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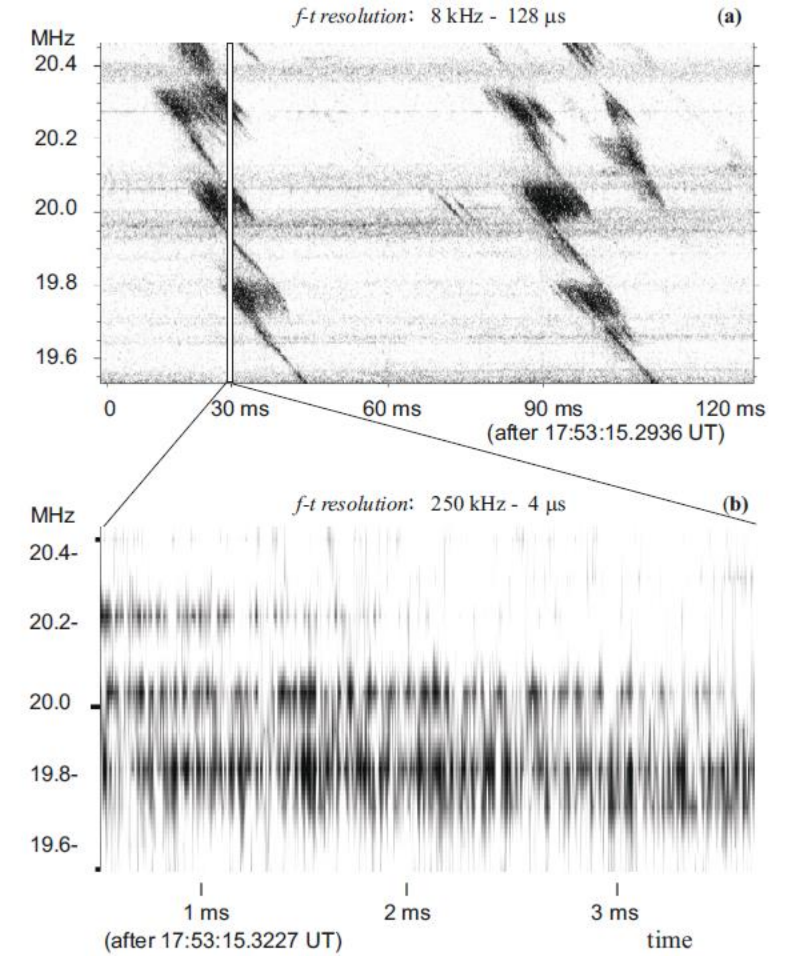
15:43:24
15:58:00
16:12:36
16:27:12
16:41:49
16:56:25
17:11:01
17:25:38
17:40:14
17:54:50
18:09:27
18:24:03
18:38:39
18:53:16
19:07:52
19:22:28
19:37:05
19:51:41
20:06:17
20:20:54
20:35:30 UT
P db
-5
-13
-20
-27
-35
R %
+100
+50
0
-50
-100
L %

S-bursts



a) Z-envelope dynamic spectra (UTR-2 +DSP, Io-B source), **b)** "superfine" structure of the S-burst.

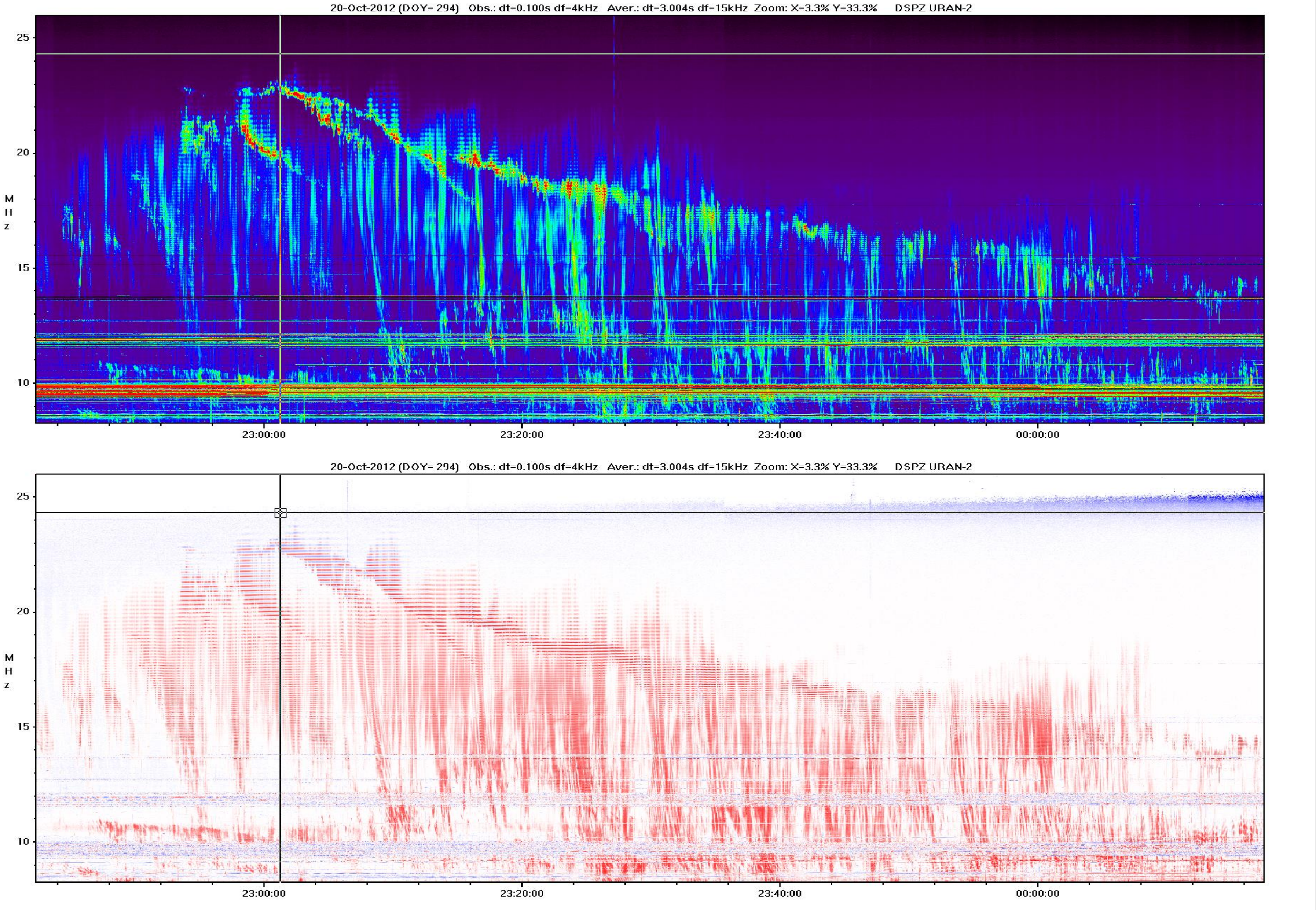
Litvinenko et al., 2009

S bursts - very short in duration, instantaneous bandwidth - few kHz fast negative frequency drift

Duration - few milliseconds

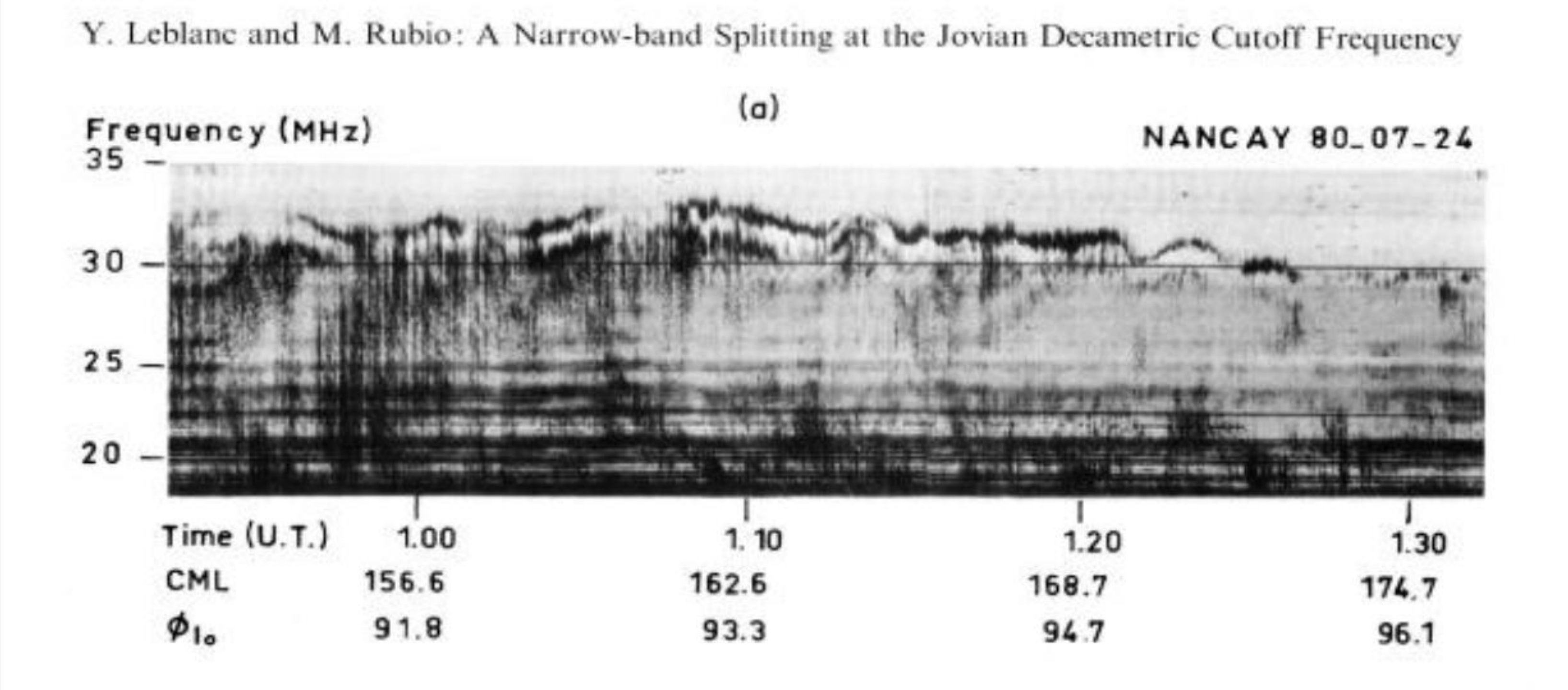
Generated by streams of keV electrons accelerated by electric fields between Jupiter and Io

Narrow-band emission

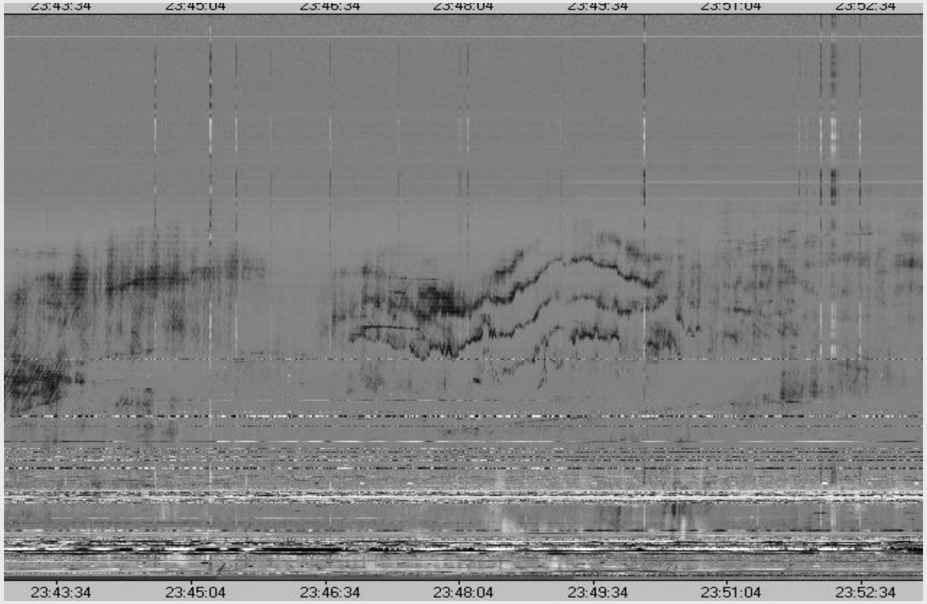


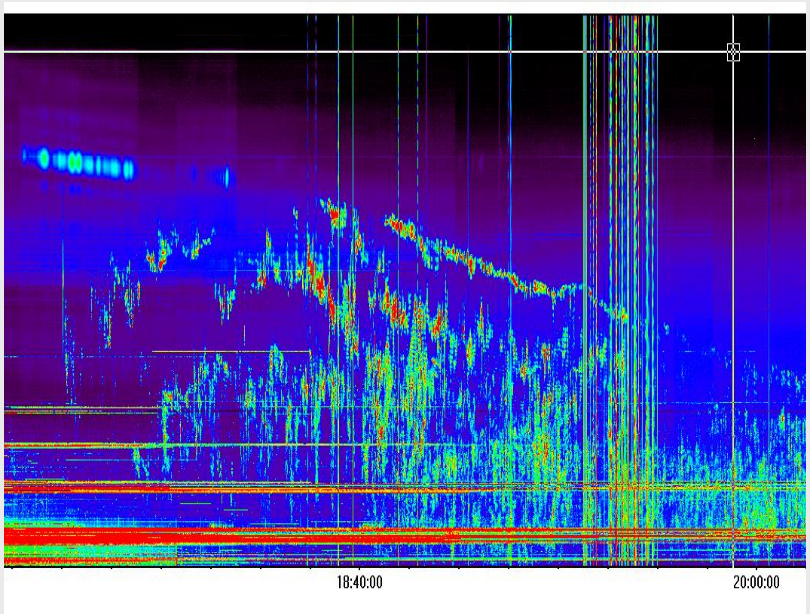
Narrow-band splitting events

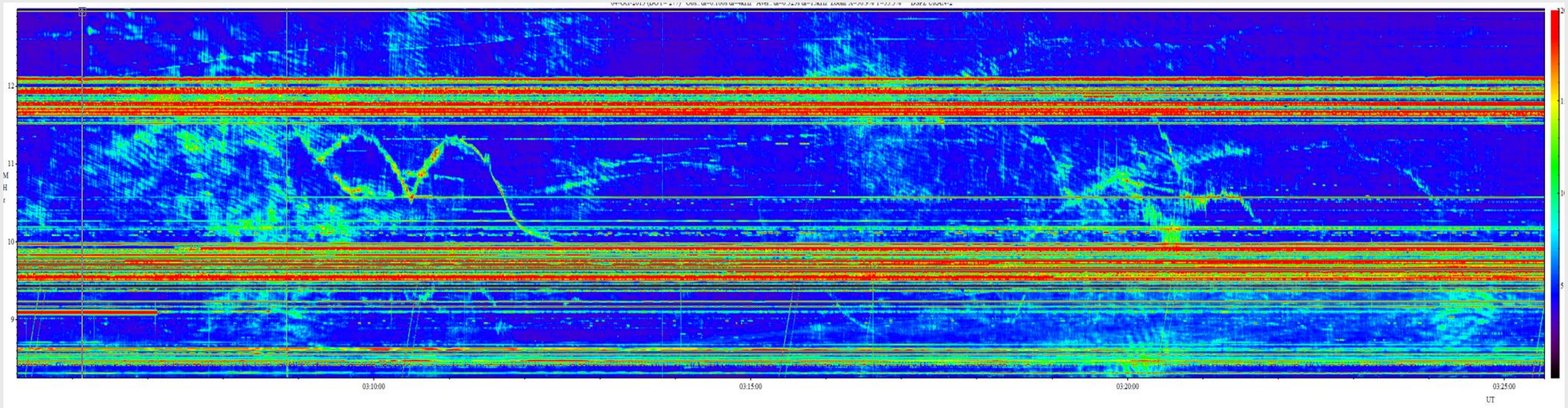
- narrowband events or splitting events – diffraction on the phase changing plasma structures in the Io torus (Lecacheux et al., 1981) or plasma waves converted into electromagnetic radiation (Shaposhnikov & Zaitsev, 1996)



Fine structures

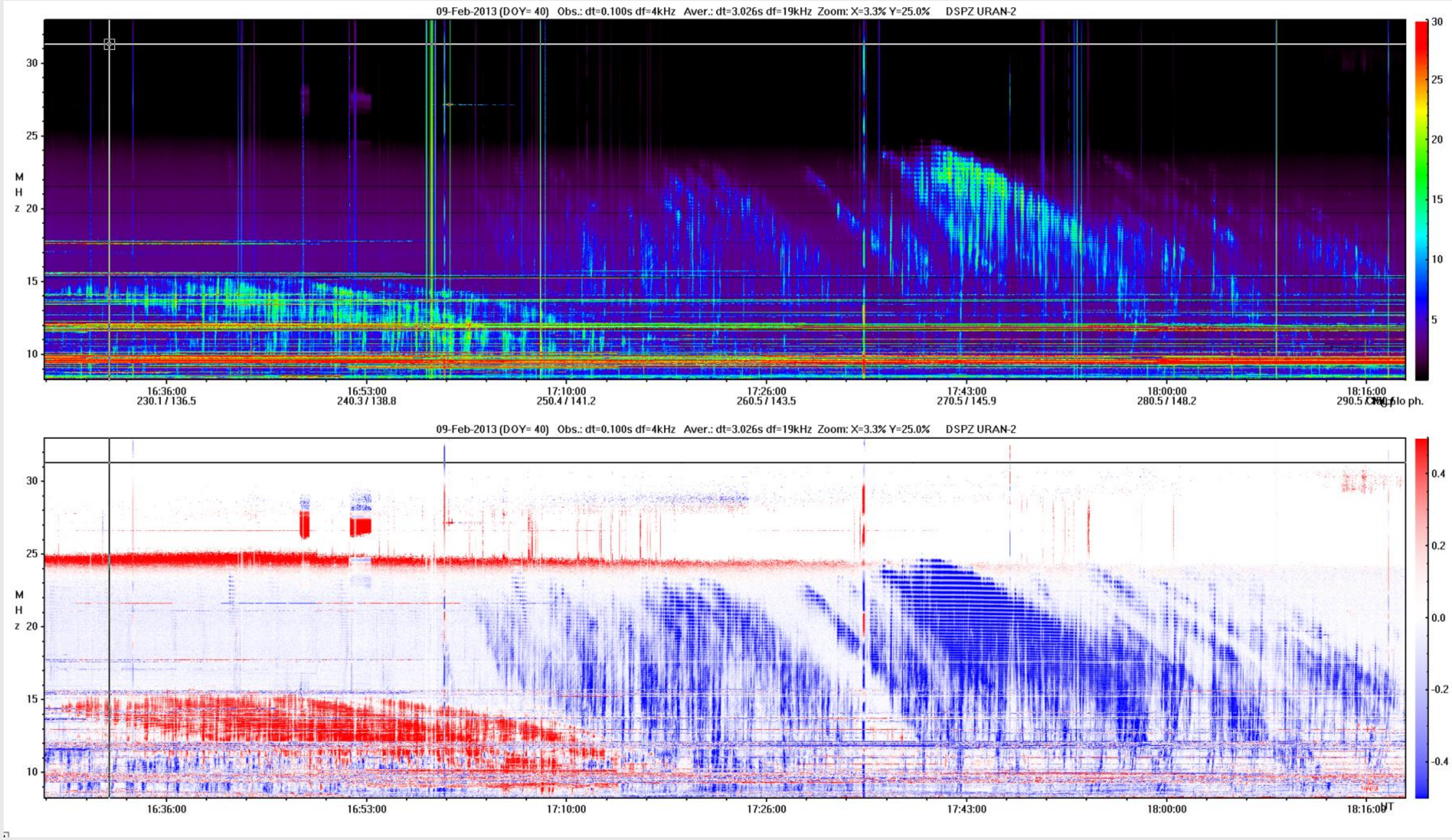






DAM is strongly elliptical polarized emission

- CMI generation mechanism predict RX mode of emission -> RH polarized from Northern and LH from Southern hemisphere



Polarization measurements and Faraday rotation

Faraday rotation - change in orientation of the polarization ellipse depending on wave frequency and the plasma density across the emission ray path.

The amount of Faraday rotation is proportional to the plasma density along the emission path and depends on frequency.

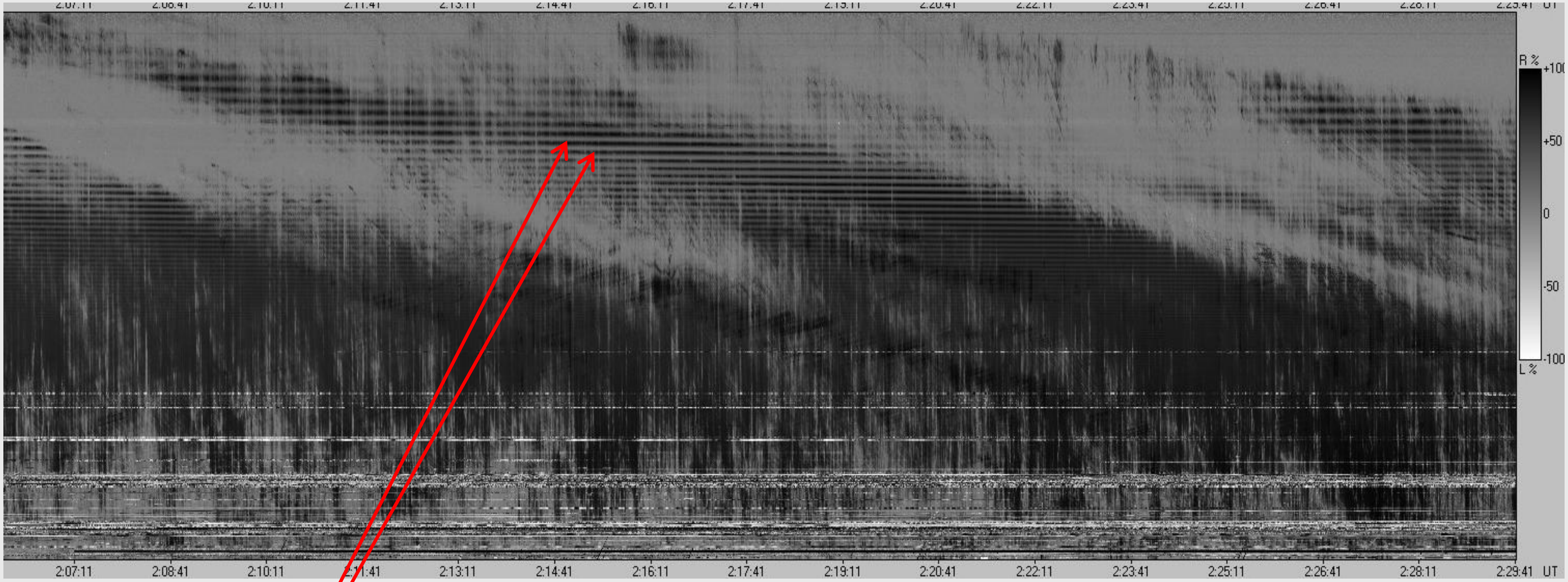
$$\Omega = RM\ \lambda^2 \qquad RM = \int_L n_c(l) B(l) \cos\theta(l) \mathrm{d}l$$

The main regions producing the Faraday rotation are:

- terrestrial ionosphere(~70–90)%
- Jupiter's magnetosphere and Io plasma torus (~10-30%),
- interplanetary medium (a few %)

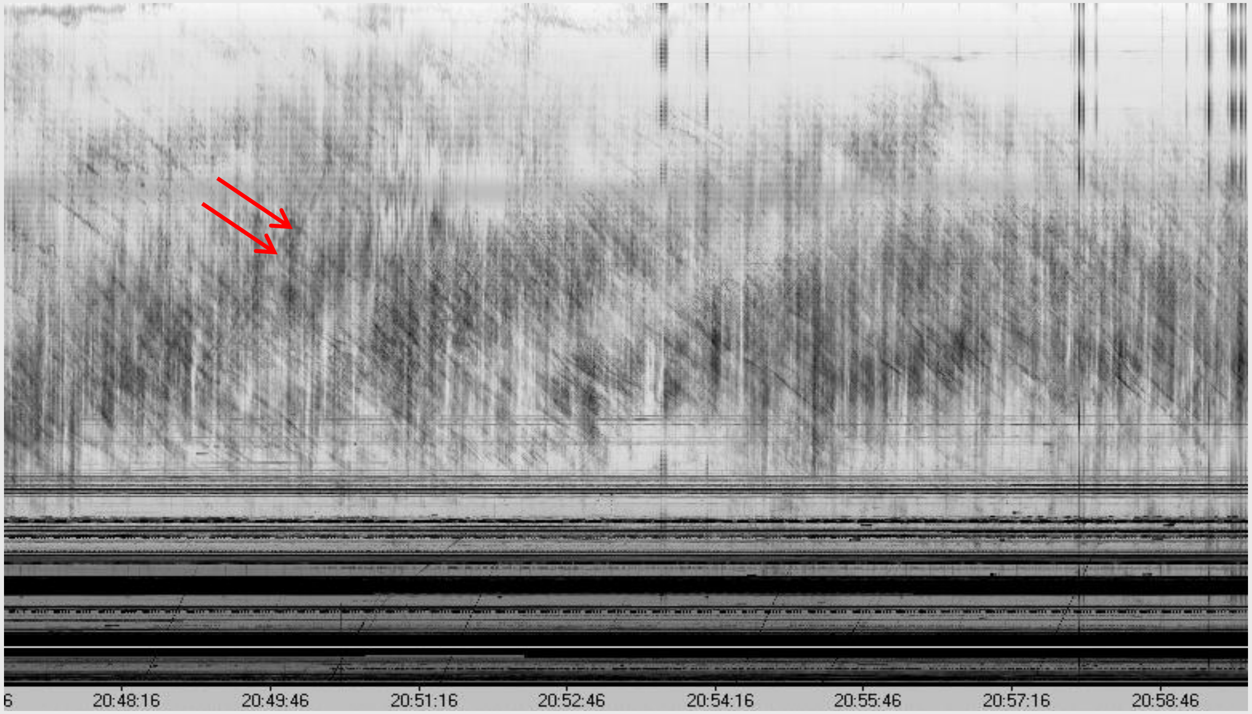
Highly elliptically polarized Jovian DAM observed by linearly polarized antenna exhibits Faraday fringes on the dynamic spectra

Faraday rotation



- Faraday fringes can be used to estimation of the electron density variation in the Io plasma torus (e.g. Shaposhnikov et al., 1999).

Modulation Lines



- Modulation lanes are observed as lane structures drifting in the time-freq. domain [Riihimaa, 1970, 1979]. The main explanation - radiation scattering on the regular field-aligned inhomogeneities [Riihimaa, 1970, Imai et al., 1997, 2002] or on scattering the depleted field line tubes in the Jovian magnetosphere [Arkhypov and Rucker, 2013].

- Modulation lanes can be used for localization of magnetospheric inhomo-geneities as well as of radio sources [Imai et al, 1997, 2002] .

Optimal parameters of NenuFAR receiver for study of the DAM

- Frequency range 10 - 40 MHz, full band – dynamic spectral studies
- High spectral resolution (time and frequency resolution) – study of the S-burst, narrow bands and fine structures of DAM
- Full polarization measurements – polarization properties of DAM, Faraday rotation of the DAM as a possible tool to monitoring of the electron inhomogeneity of the Io plasma torus

NenuFAR in standalone mode

- Long-lasting continuous observations of DAM – variation of the DAM intensity, relation with solar wind activity around Jupiter, relation to the visible UV auroral oval;

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- Simultaneous observations (“stereoscopic” or supplementary observations) with other LF radio telescopes (NDA, UTR-2, URAN-2, GURT etc.) – reductions of the ionospheric scintillations and radio interferences, increasing of the detection probability of the radio features.

NenuFAR in standalone mode

- NenuFAR as stand alone station- long lasting continuous observations of DAM – systematic survey, variation of the DAM intensity, relation with solar wind activity around Jupiter, relation to the visible UV auroral oval;
- Simultaneous observations ("stereoscopic" or supplementary observations) together with other existing and future LF radio telescopes (NDA, UTR-2, URAN-2, etc.) – reductions of the ionospheric and manmade interferences, increasing of the detection probability, study of the emission geometry of S-bursts.
- Support of spacecraft missions (JUNO, JUICE)

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NenuFAR as a LOFAR extension:

- High resolution imaging of the DAM sources – localization and motion of the DAM sources