Fine Structure in Jovian Decametric Emission: LWA1 Observations

Chuck Higgins, Middle Tennessee State University
Tracy Clarke, Naval Research Lab

Long Wavelength Array (LWA1), Socorro, NM

Collaborators:
Kazumasa Imai, Kochi National College of Technology, Japan
Francisco Reyes, U. of Florida
Jim Thieman, NASA/GSFC
Masafumi Imai, Kyoto University
Jinhie Skarda, student, Stanford University

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First Jupiter paper with LWA data is submitted

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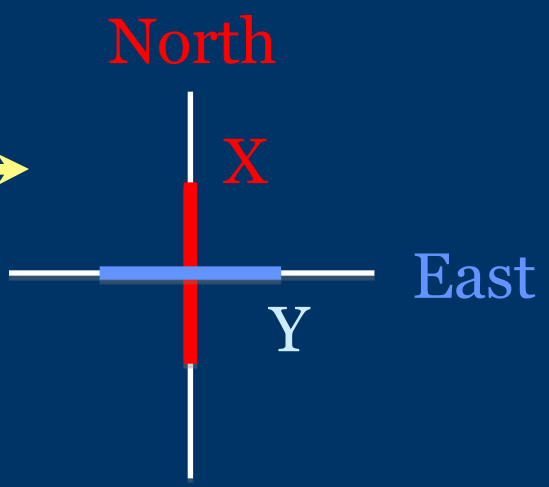
Probing Jovian Decametric Emission with the Long Wavelength Array Station 1

T. E. Clarke[1], Chuck Higgins[2], Jinhie Skarda[3], Kazumasa Imai[4], Masafumi Imai[5], Francisco Reyes[6], Jim Thieman[7], Ted Jaeger[8], Henrique Schmitt[1] Nagini Paravastu Dalal[9], Jayce Dowell[10], S. W. Ellingson[11], Brian Hicks[1], Frank Schinzel[10], G. B. Taylor[10]

Abstract. New observations of Jupiters decametric radio emissions have been made with the Long Wavelength Array Station 1 (LWA1) which is capable of making high quality observations as low as 11 MHz. Full Stokes parameters were determined for bandwidths of up to 16 MHz for six Io-related events at resolutions as fine as 0.25 ms. Preliminary LWA1 data show excellent spectral detail in Jovian DAM such as simultaneous LHC and RHC polarized Io-related arcs and source envelopes, modulation lane features, S-bursts structures, narrow band N-events, and interactions between S-bursts and N-events. Initial results show that the LHC component of the Io-C source region begins as early as CML III 235° at 11 MHz. Modulation lane structures appear continuous across LHC and RHC emissions, suggesting that both polarizations may originate from the same hemisphere of Jupiter. S-bursts have been definitively detected during an Io-D event and show drift rates consistent with those from other Io-related sources. Finally, S-N burst events are seen in high resolution and our data indicate that these bursts have cospatial origins in agreement with previous interpretations.

Data Reduction and Analysis



Basis change to r, l

$$r = \frac{(x + iy)}{\sqrt{2}}$$

$$l = \frac{(x - iy)}{\sqrt{2}}$$

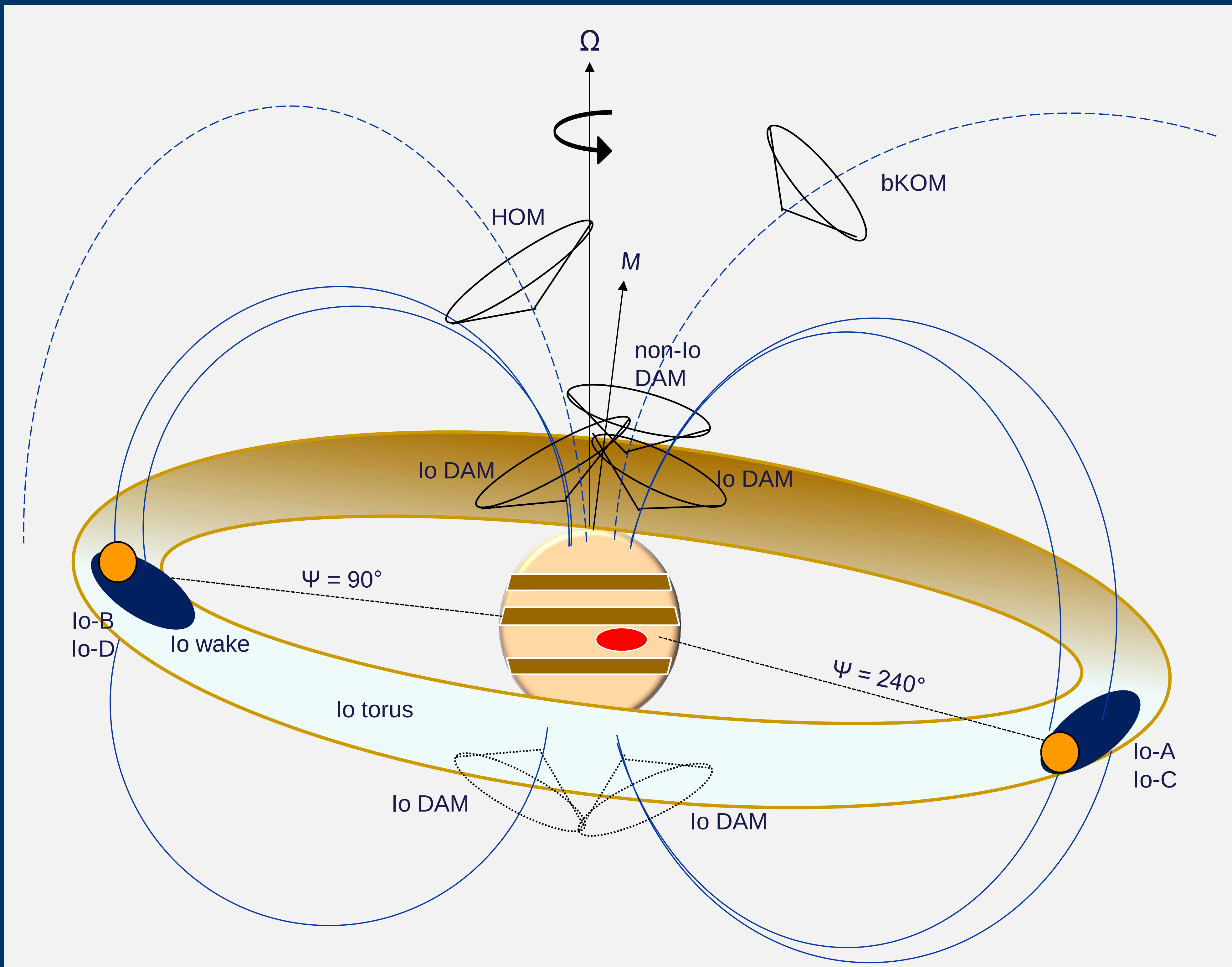
Use Fourier transforms to convert to frequency spectra

Convert to Stokes *V*

$$V = R^2 - L^2$$

Output

Jupiter Radio Emission Overview



bKOM – broadband kilometric emission (auroral origins)

HOM – hectometric emission (auroral)

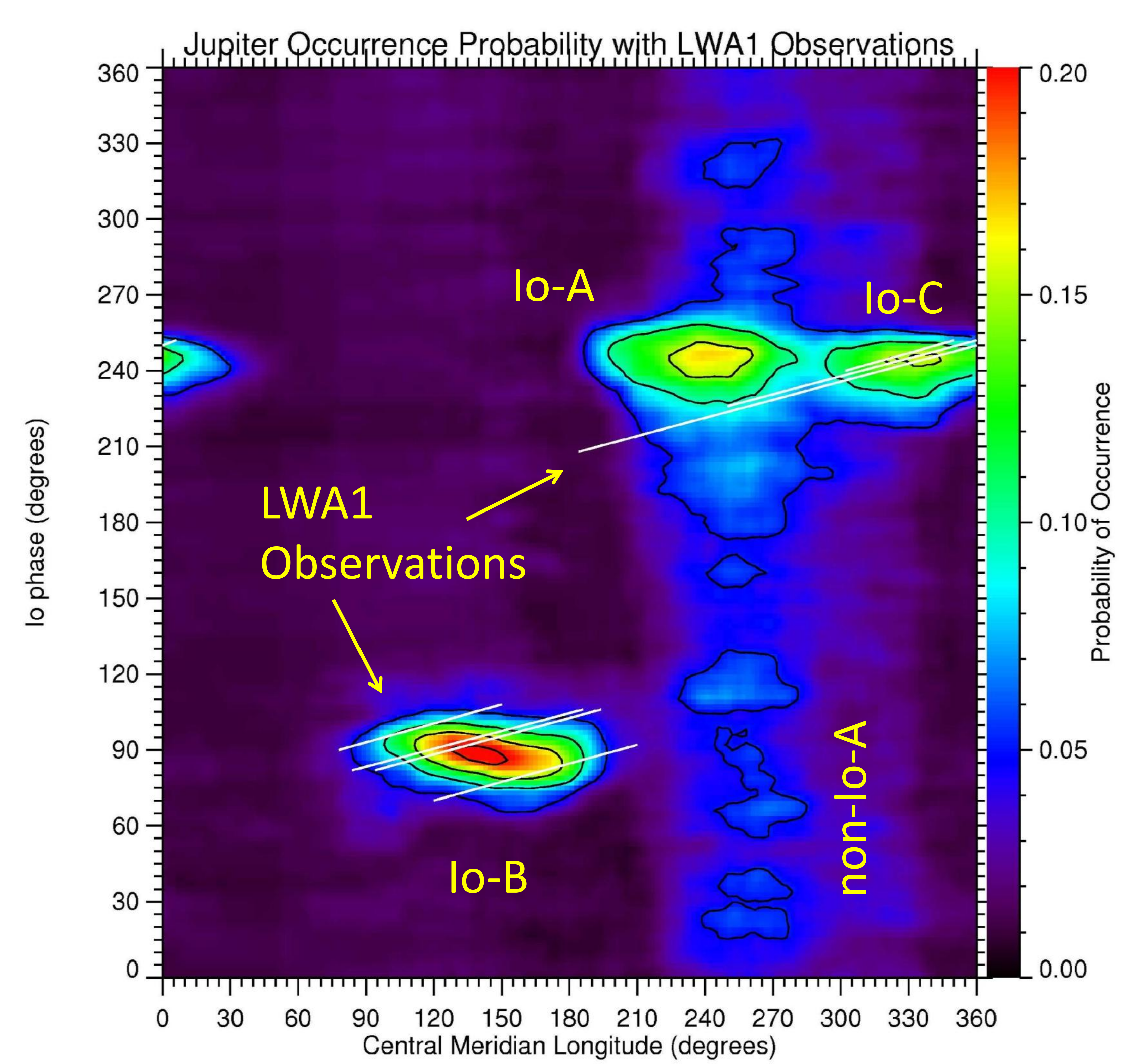
Non-Io-DAM – auroral decametric (related to HOM)

Io-DAM – decametric emission tied to Io flux tube and Io torus

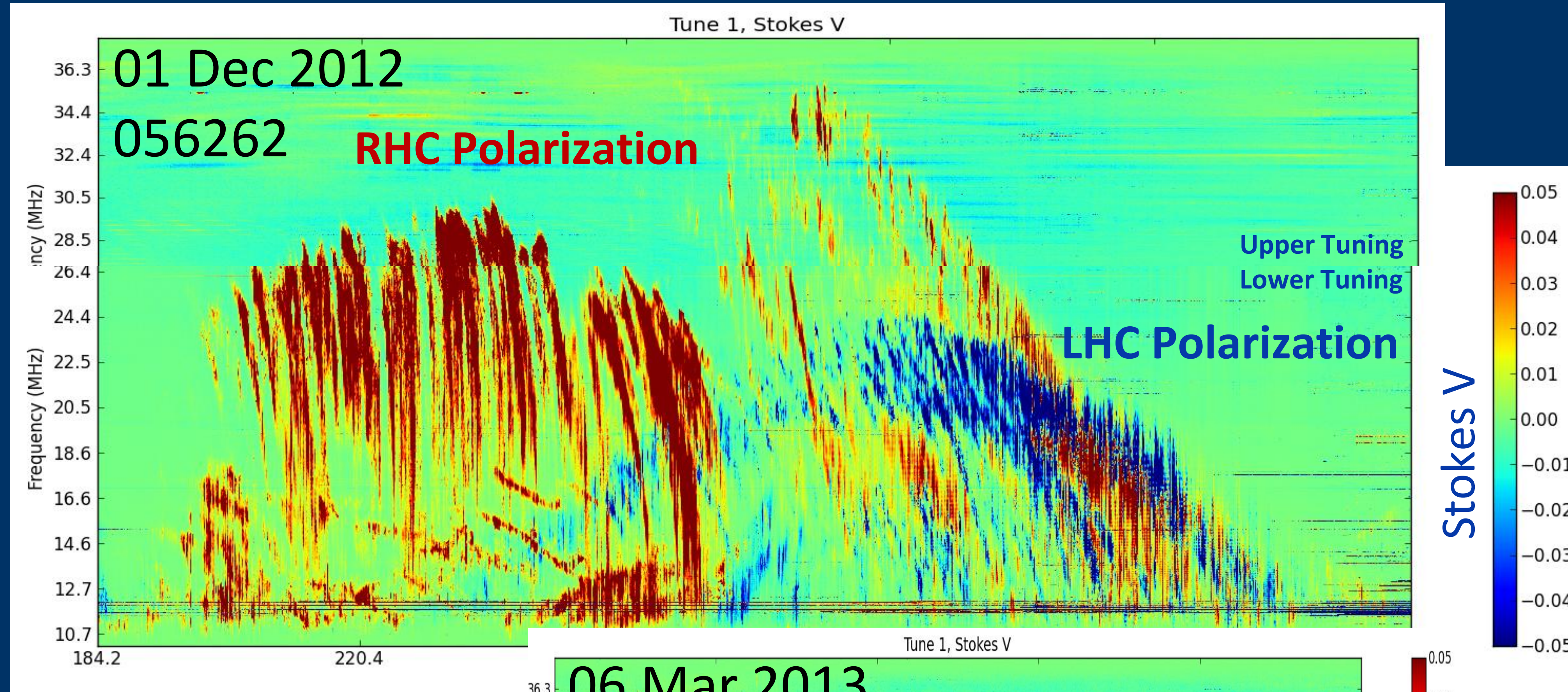
DAM Occurrence Probability Maps

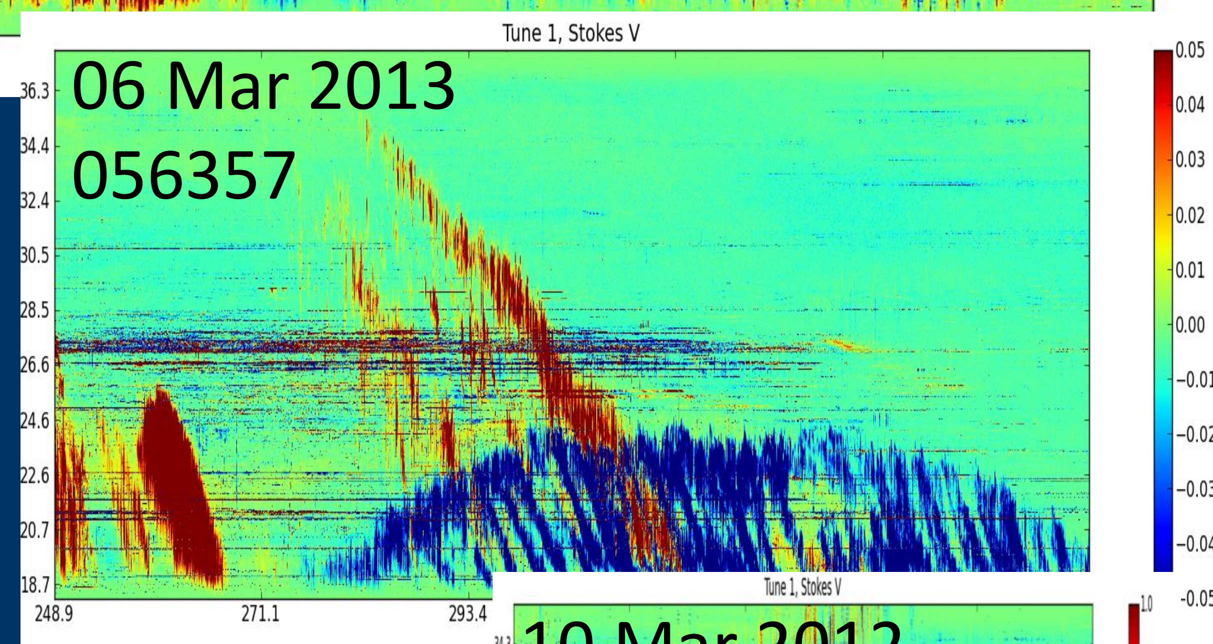
<u>Background</u>
50 years of
University of Florida
Radio Observatory
(UFRO) data

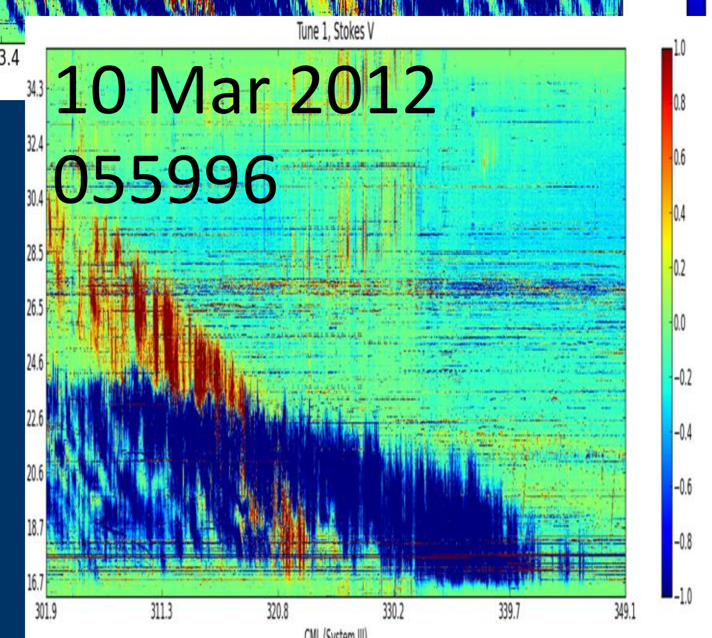
<u>Initial LWA1 Observations</u>
Mar 2012 – Mar 2013



Io-A, Io-C Observations







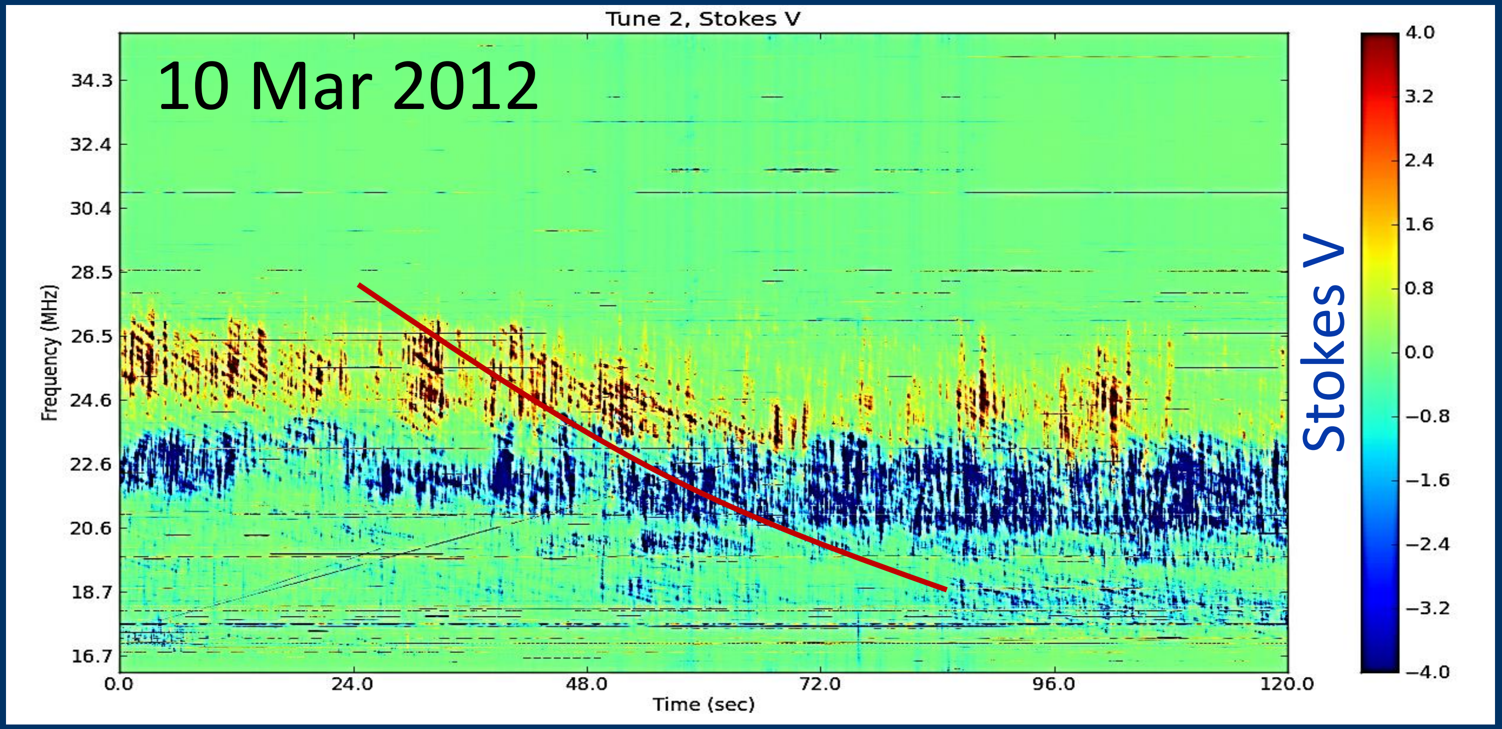
<u>LWA1 Instrument</u>

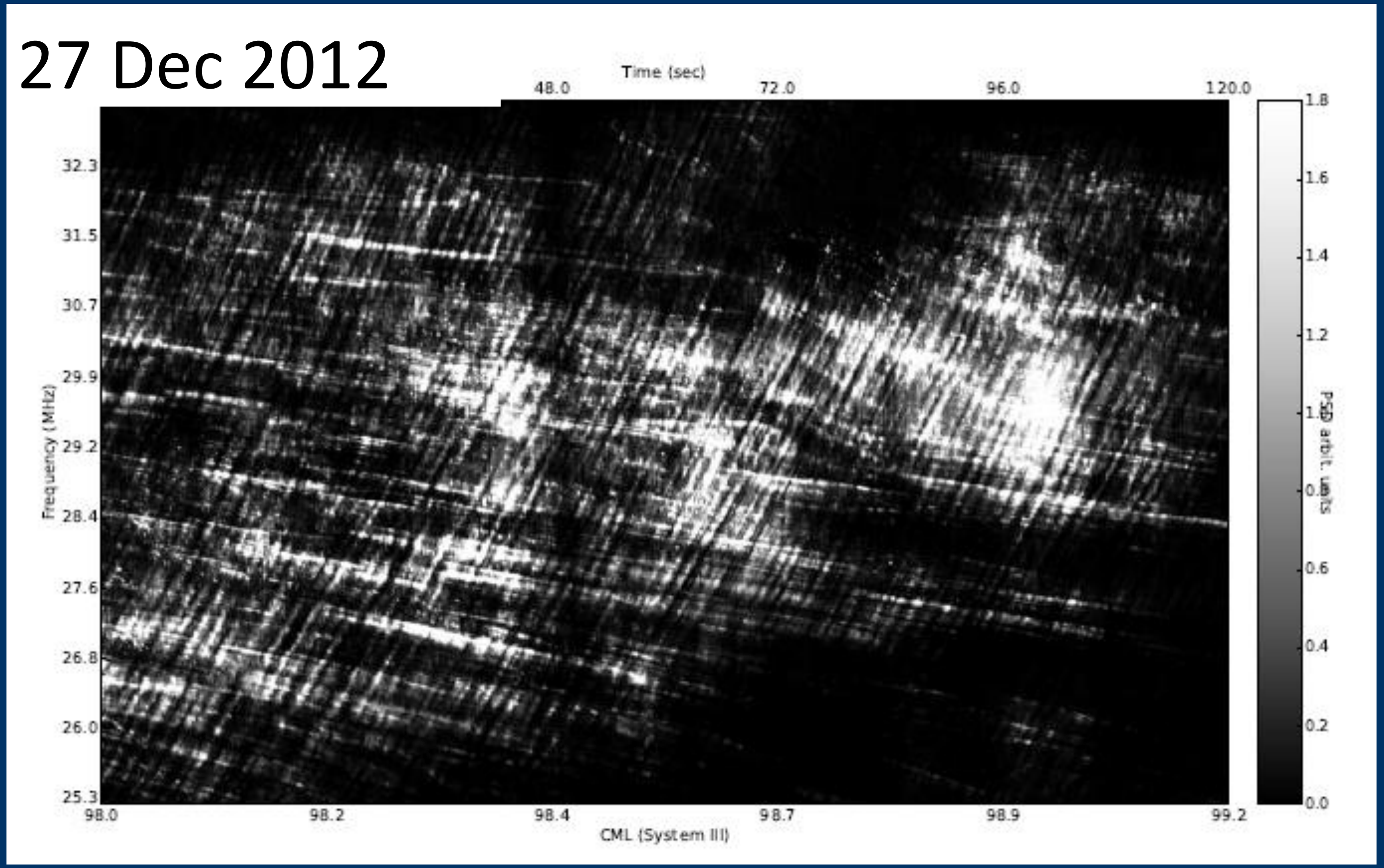
- Excellent observing conditions
- Excellent Temporal & Spectral Resolution showing fine structures in Jovian decameter emissions
- Remarkable Consistency of the Io-A/C Emission Structure

- RH and LH polarizations – good test of the CMI theory
- Are RX and LO modes coming from the same hemisphere?

Io-A/C Modulation Lanes

- Modeled as interference through the Io plasma torus (Imai et al., 1992, 1997)
- Modulation Lanes continuity argues for RH and LH emission from the SAME hemisphere
- Contradicts CMI emission theory – RX mode growth rates are much higher than LO mode
- Other mechanisms
  - Mode conversion?
  - Local Refraction?

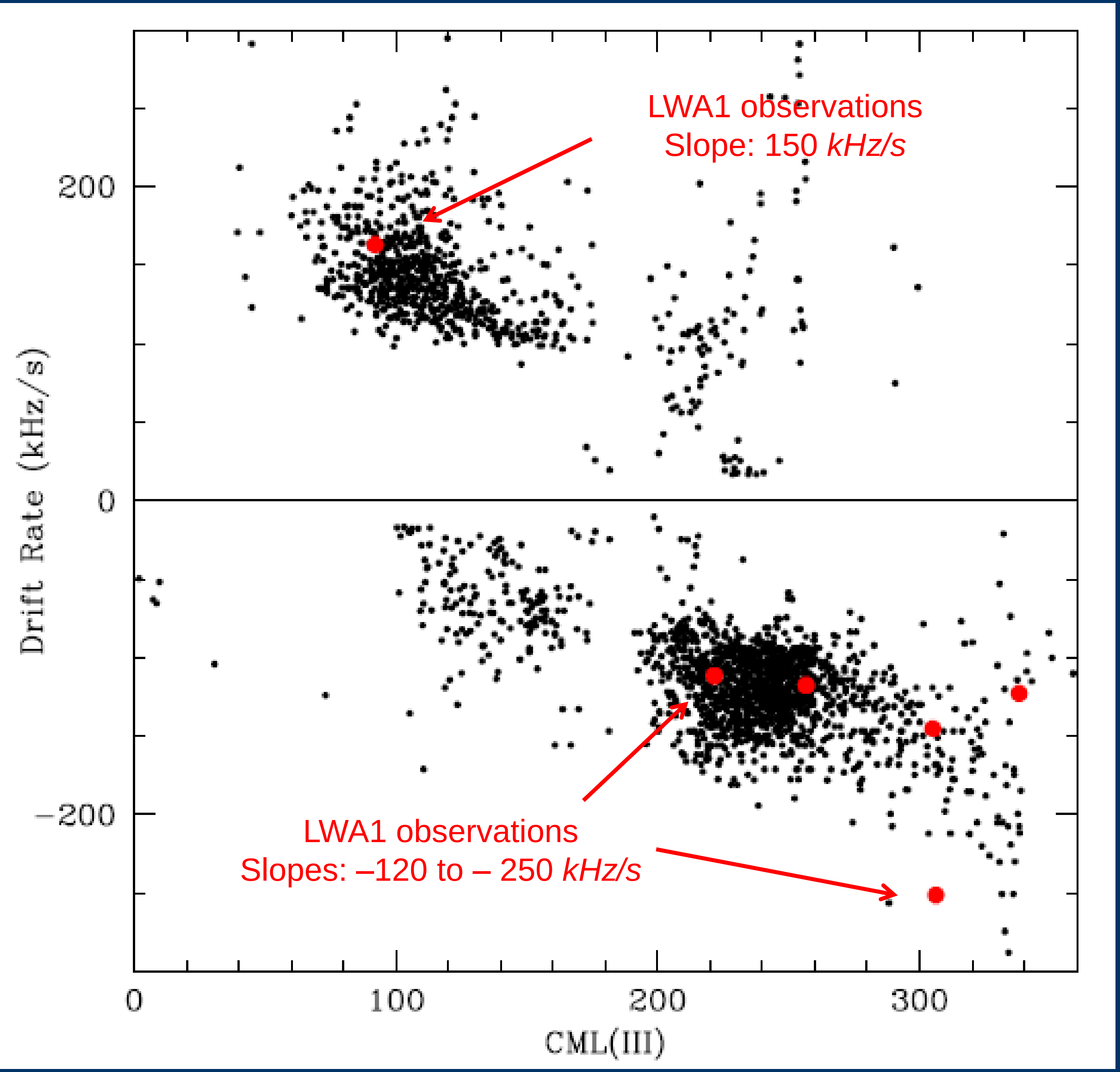




Positive slope modulation lanes from the Io-B burst of 27-Dec-2012. Resolution is 10 ms and 10 kHz.

Io-B Modulation Lane Slopes

Previous data 21-23 MHz observations from 1966 – 1979 (Riihimaa, 1978, 1993)



Modulation lane slope calculations are consistent with previous measurements

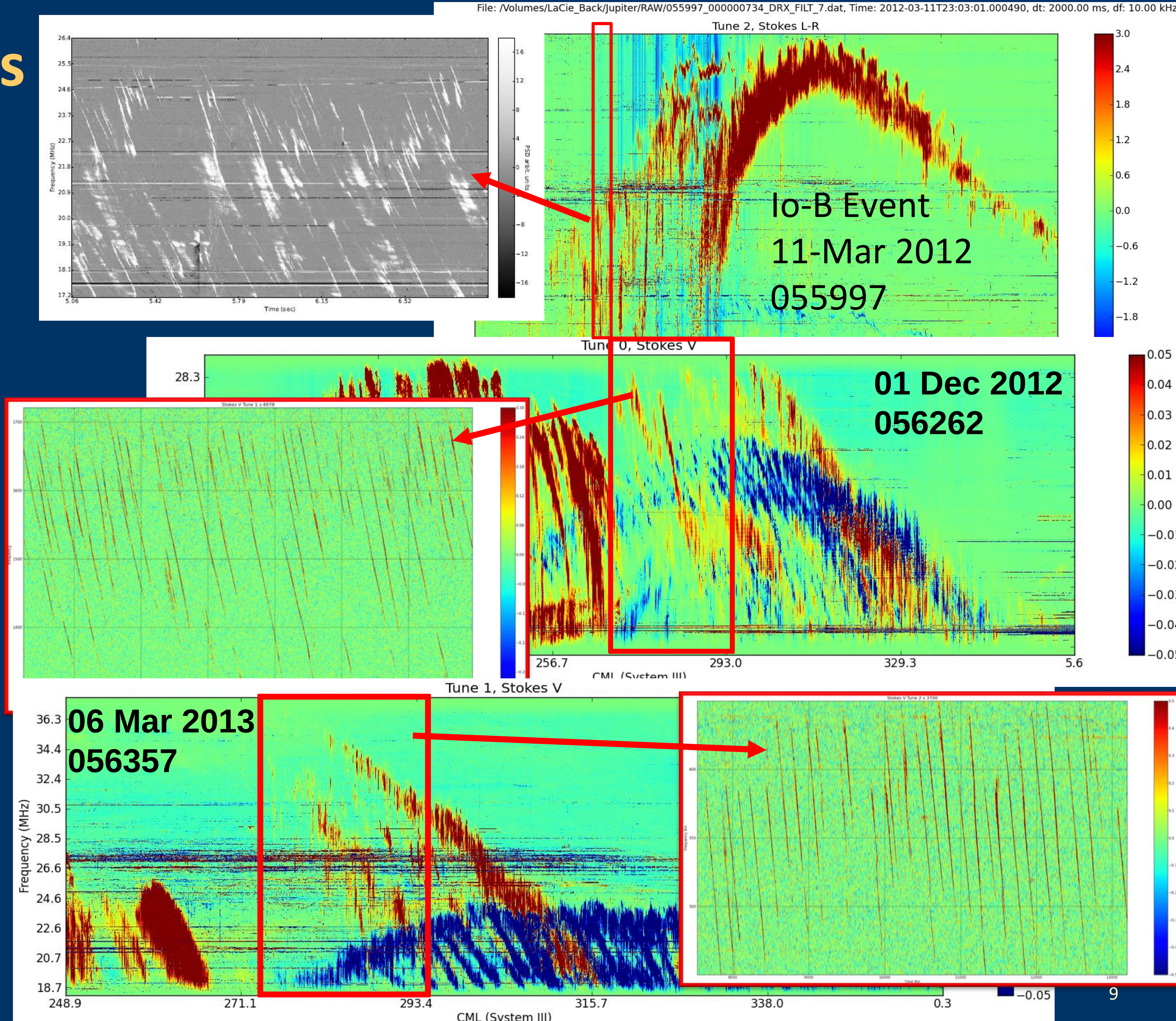
S-Bursts

Drift Rates

Io-B
–15 MHz/s
at 23 MHz

Io-A/C
–18 MHz/s
at 25 MHz

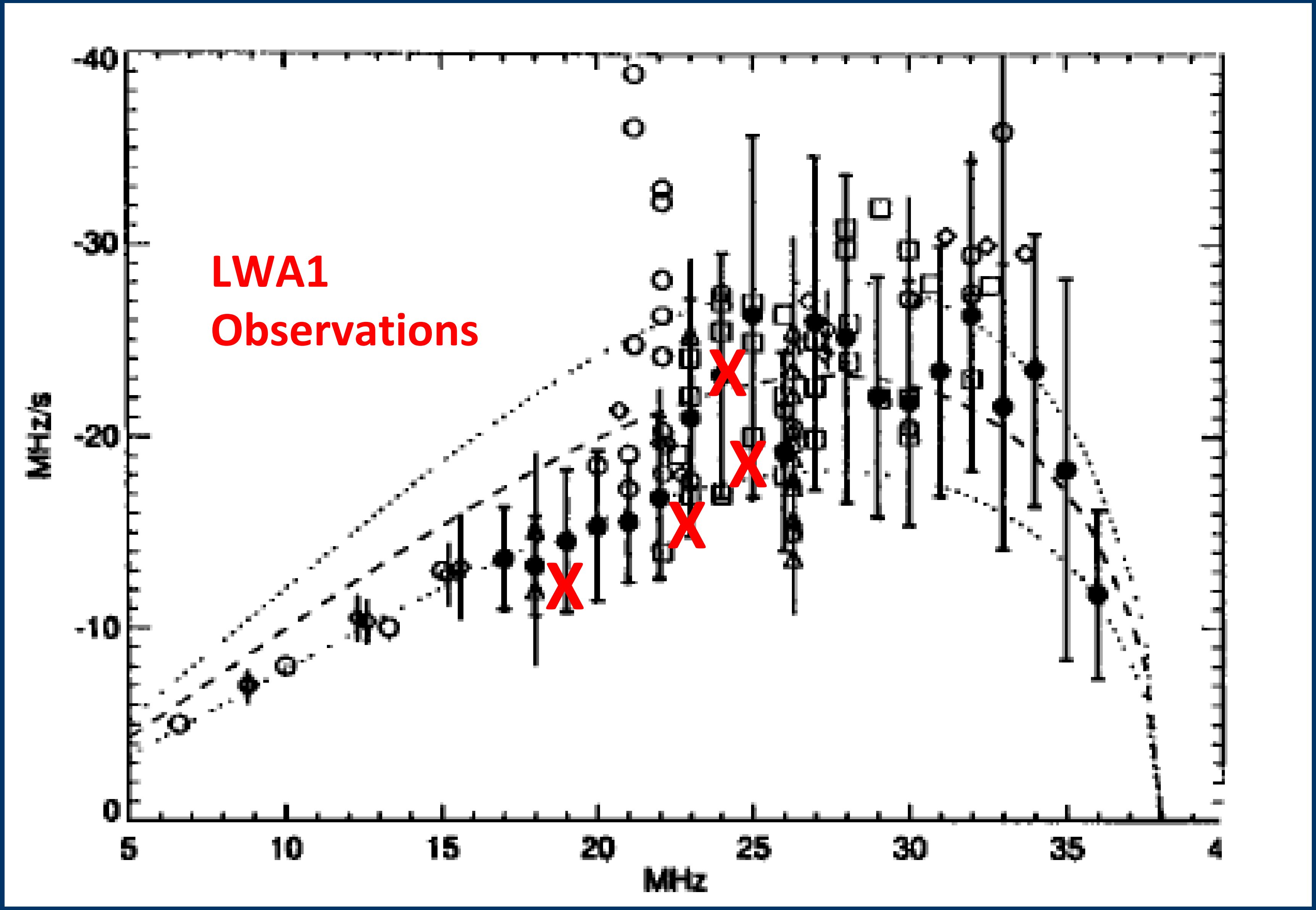
Io-A
–23 MHz/s
at 24 MHz



S-burst Drift Rates

- Io related emission
- High-Intensity millisecond bursts
- CMI emission: ~5 keV electrons accelerated from Io to Jupiter – Mirrored near Jupiter resulting in a loss cone of amplified X-mode waves
- Adiabatic theory predicts the maximum drift rates (~30 MHz/s)

S-burst Drift Rate vs Frequency



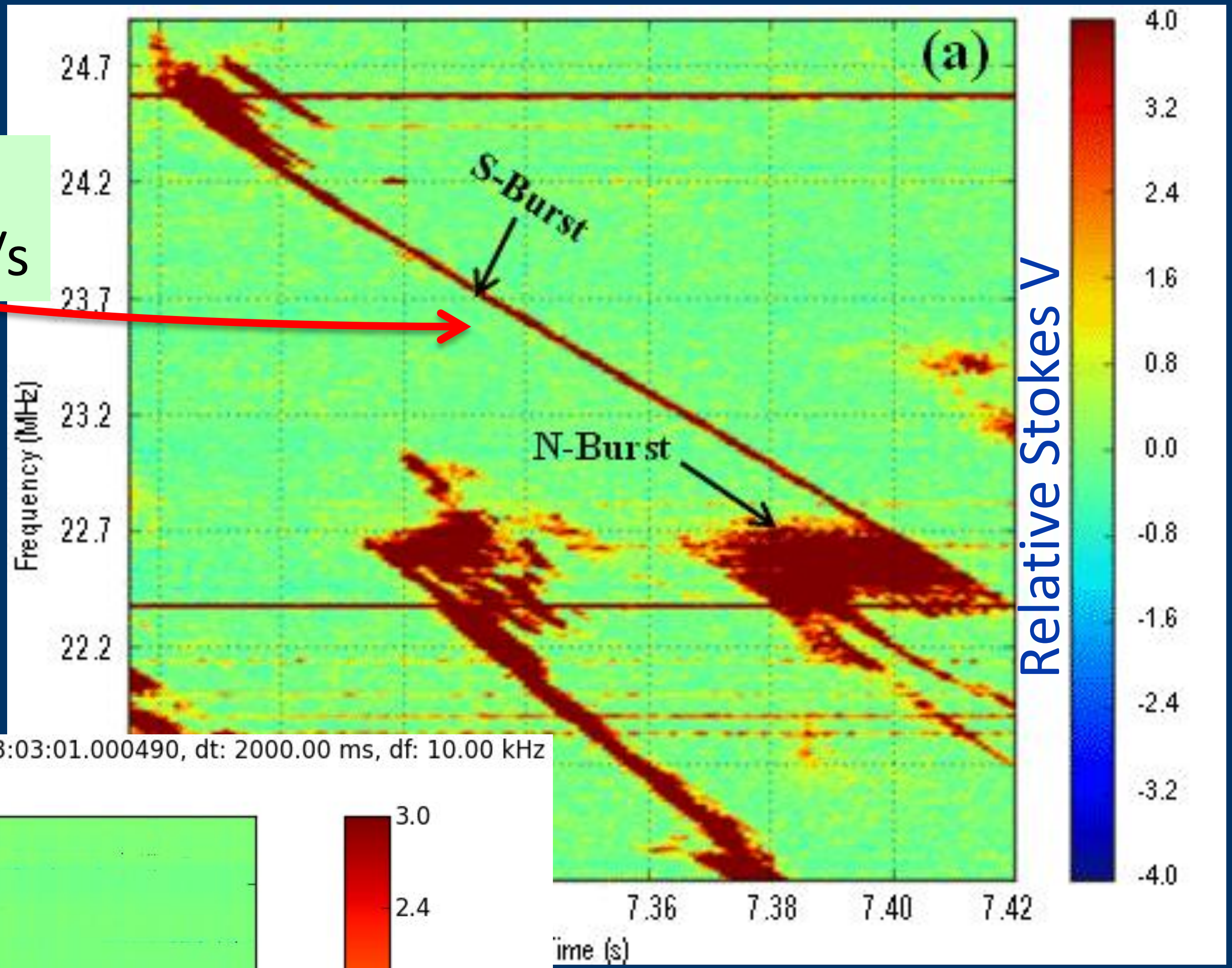
From Zarka et al., (1996)

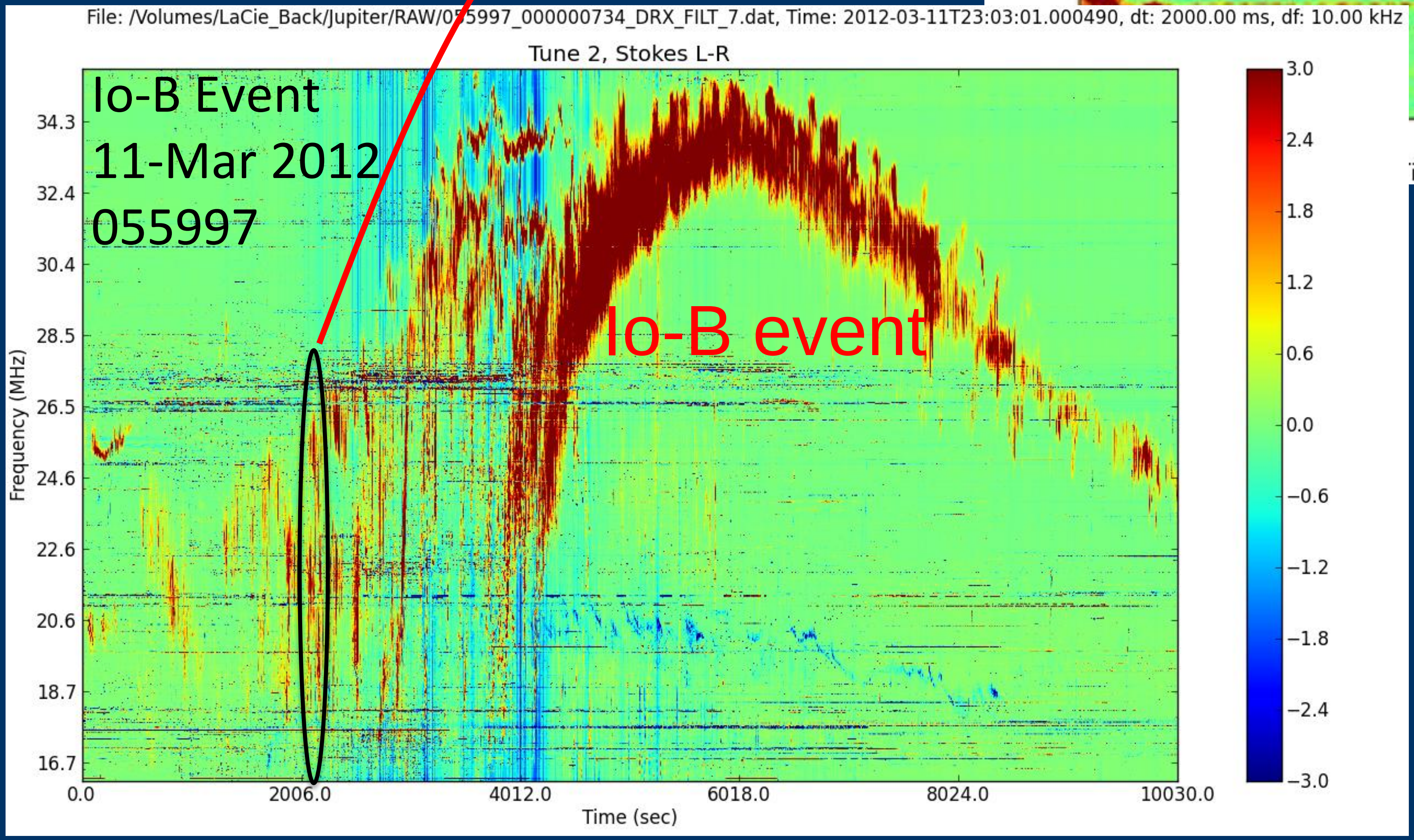
We can use LWA1 data to test this theory.
How do the drift rates correlate with the sources?

S-Bursts and N-events

- S-bursts and Narrow band (N) events show interactions (triggering & quenching)
- Argues for co-spatial sources

Δt ~100 ms
Δν ~ -15 MHz/s

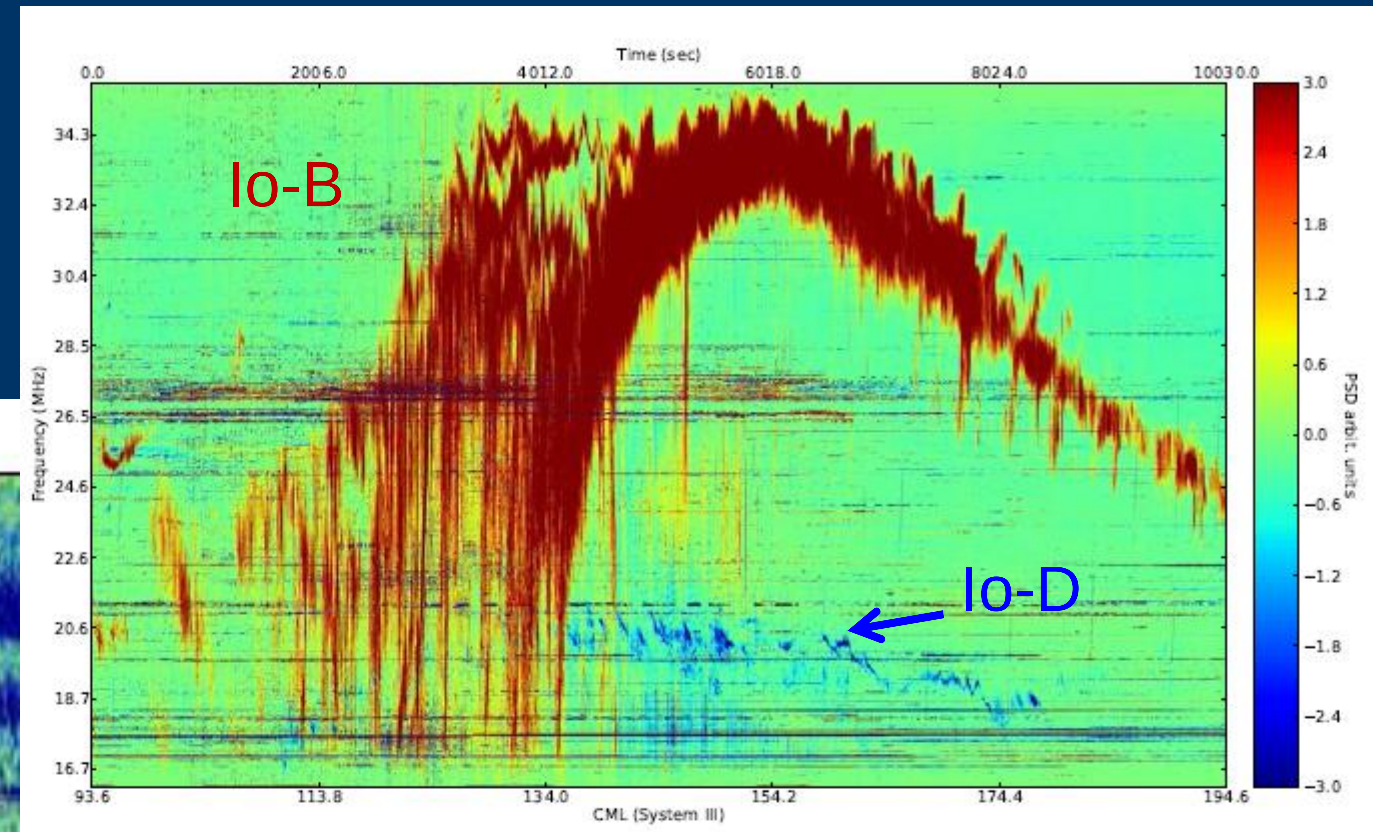


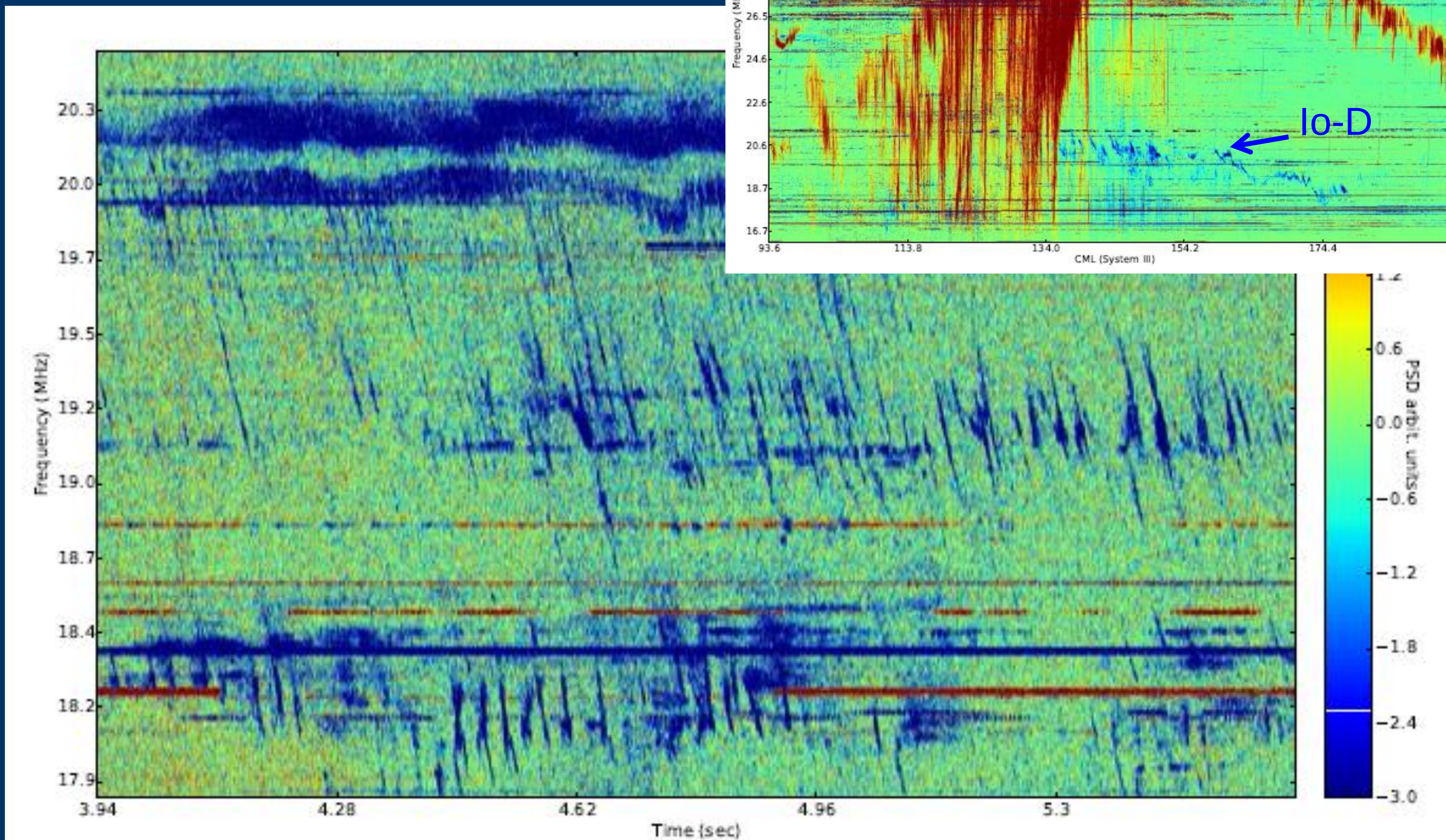


- Better resolution is showing new structure in the S, N, and S-N events
- New physics?

New Io-D S-bursts

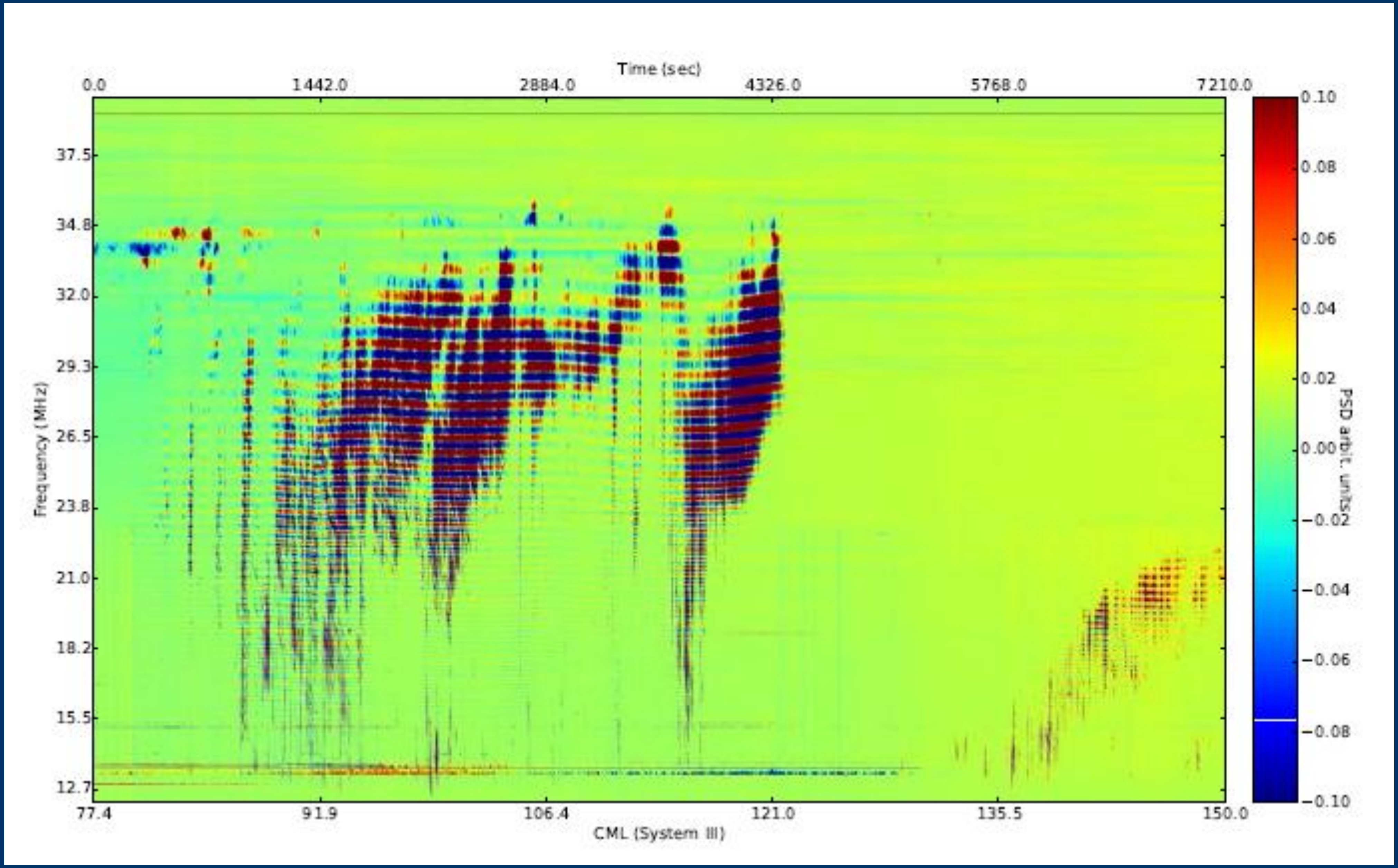
Previously Unknown!





S-bursts for the Io-D event on 11-March-2012. Resolution is 0.25 ms and 10 kHz. Narrow-band emission as well as S-bursts are seen within the LHC Io-D emission.

Faraday Lanes



Plot of 27-Dec-2012 burst showing Faraday fringes in an X-Y spectrogram. The nearly horizontal Faraday fringe bands are seen across the entire Io-B and Io-D emission regions. The fringe separation decreases as the frequency decreases due to the λ^2 nature of Faraday rotation.

Education and Outreach

The Radio JOVE Project

JOVE Team

- NASA
- Raytheon
- University of Florida
- RF Associates
- The INSPIRE Project, Inc.
- Radio-Sky Publishing
- U. of Hawaii, Windward Community College
- Kochi National College of Technology

Voyager 1 Image

For More Information

http://radiojove.gsfc.nasa.gov/

Dr. Jim Thieman
NASA-GSFC
Code 690.1
Greenbelt Maryland 20771
(301) 286-9790
thieman@nssdc.gsfc.nasa.gov

Dr. Chuck Higgins
Dept. of Physics & Astronomy
Middle Tennessee State University, P.O. Box 71
Murfreesboro, TN 37132
(615) 898-5946
higgins@physics.mtsu.edu

RADIO JOVE 2 4

The Radio JOVE Project

Learning Science by Observing and Analyzing Radio Signals from Jupiter, the Sun and our Galaxy

Voyager 1 Image

SOHO Image

Radio Continuum (408 MHz) Bonn, Jodrell Bank, and Parkes

NASA/GSFC Image

Summary of LWA1/Jupiter Studies

- First LWA1 Jupiter paper is submitted
- LWA1 is an excellent instrument for Jupiter decameter studies
  - Excellent spectral and temporal resolution
  - Shows fine structures and polarization
- Possible to learn some new physics at Jupiter
  - Modulation Lanes observations can be used to check CMI theory
  - S-burst drift rates at high frequencies
  - Narrow band (N) event characteristics (S-burst/N-event interactions)

- LH and RH emission can be used for Faraday rotation studies

Recent LWA1 Observations

Oct 2013 – Feb 2014

Juno Mission, ~2015-2017

Coordinated observations?

Recent LWA Coordinated Jupiter observing campaign with JAXA Hisaki (Exceed) mission, and HST, Gemini, Kitt Peak, Suzaku, Chandra, and XMM (thru Apr 2014)