Fine Structure in Jovian Decametric Emission: LWA1 Observations

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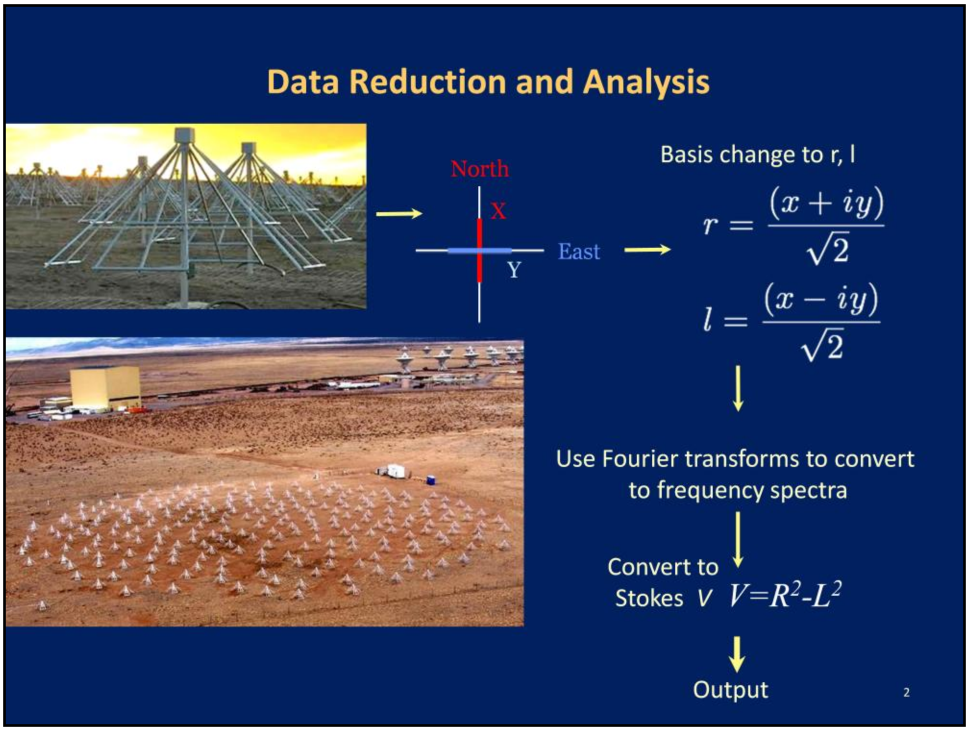
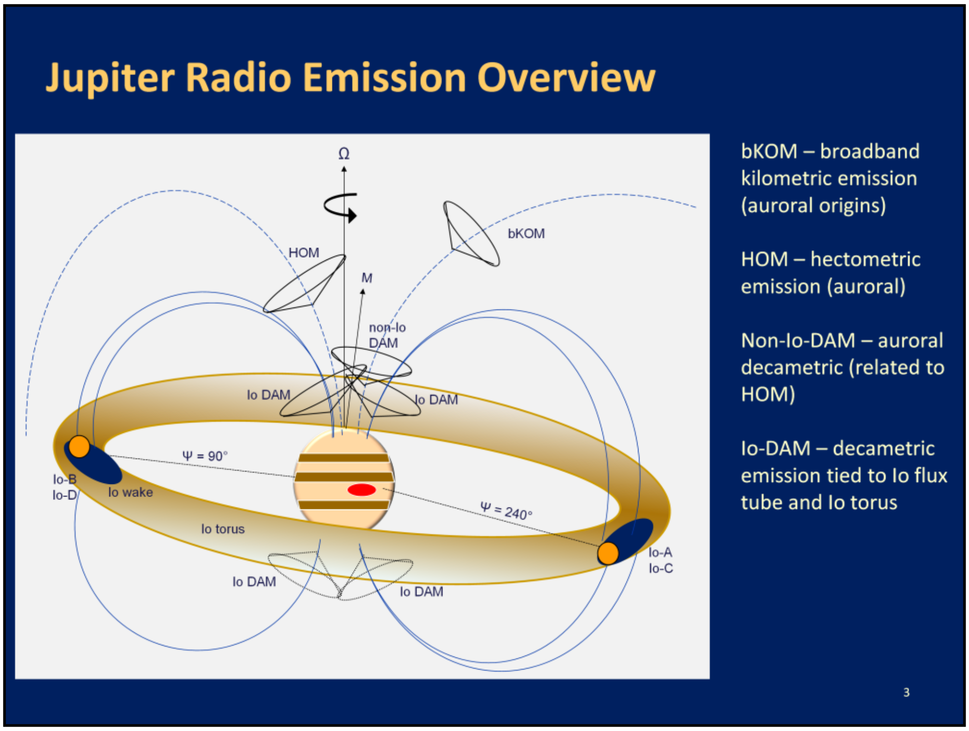
Long Wavelength Array (LWA1), Socorro, NM

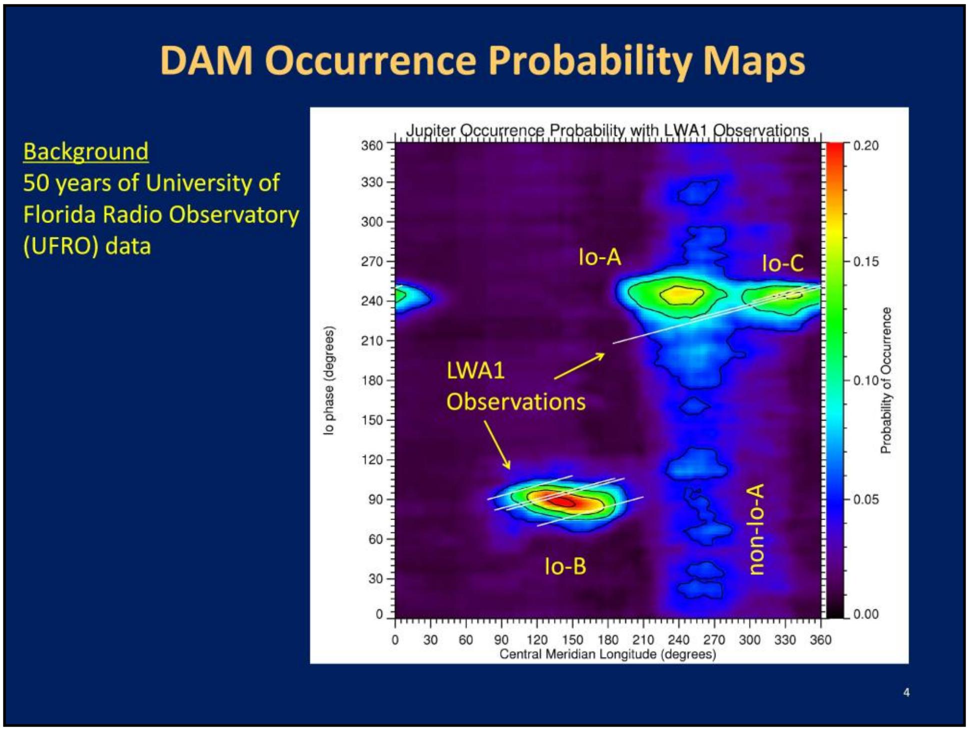
This is the first results of Jupiter observations made with the LWA instrument. The main collaborators are listed here.



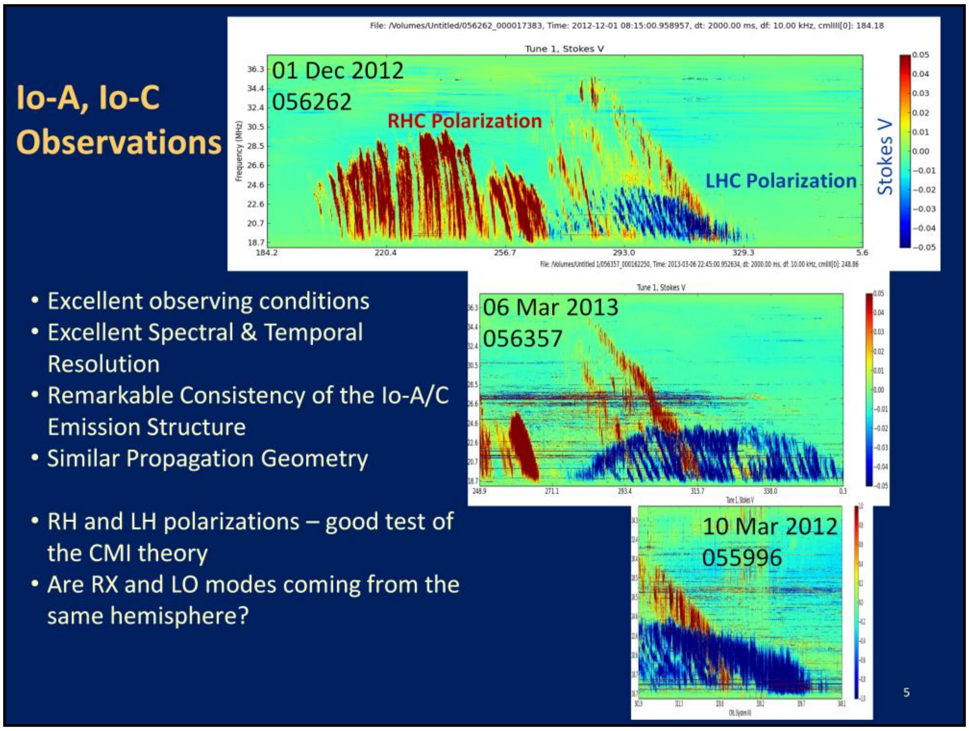
The Long Wavelength Array (LWA) Station 1 is shown here next to the VLA. 256 crossed-dipoles are randomly arranged to make up the antenna consisting of an X and Y beam. Polarization is computed by converting the X and Y voltages to right-hand (RH) and left-hand (LH) circular components. Stokes V represents the degree of circular polarization.



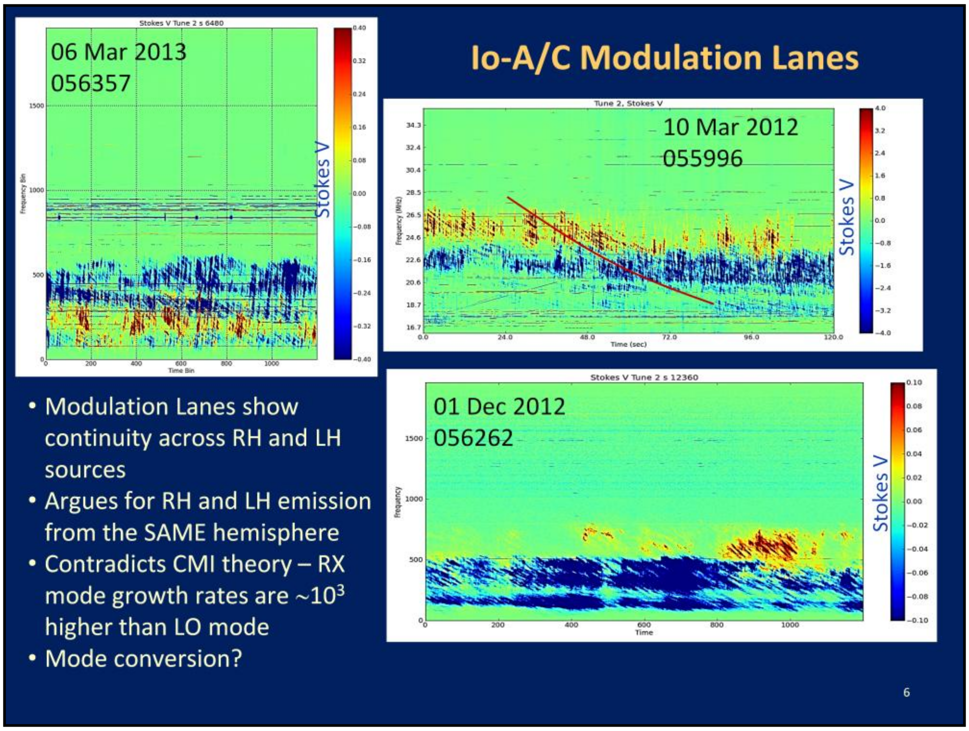
This overview shows the basic picture of many of the source regions of Jupiter's radio emissions. Due to the emission mechanism, the radio waves are emitted in a hollow cone-like beam around active magnetic field lines – some of these are tied to Io while others are tied to higher latitude field lines influenced by the solar wind (auroral field lines). The Io-B and Io-D sources come when Io is about 90 degrees phase, and the Io-A/C sources come from the other side. Io-related emission occurs from both the northern and southern magnetic field regions. Non-Io-DAM, HOM, and broadband KOM (bKOM) come from auroral field lines.



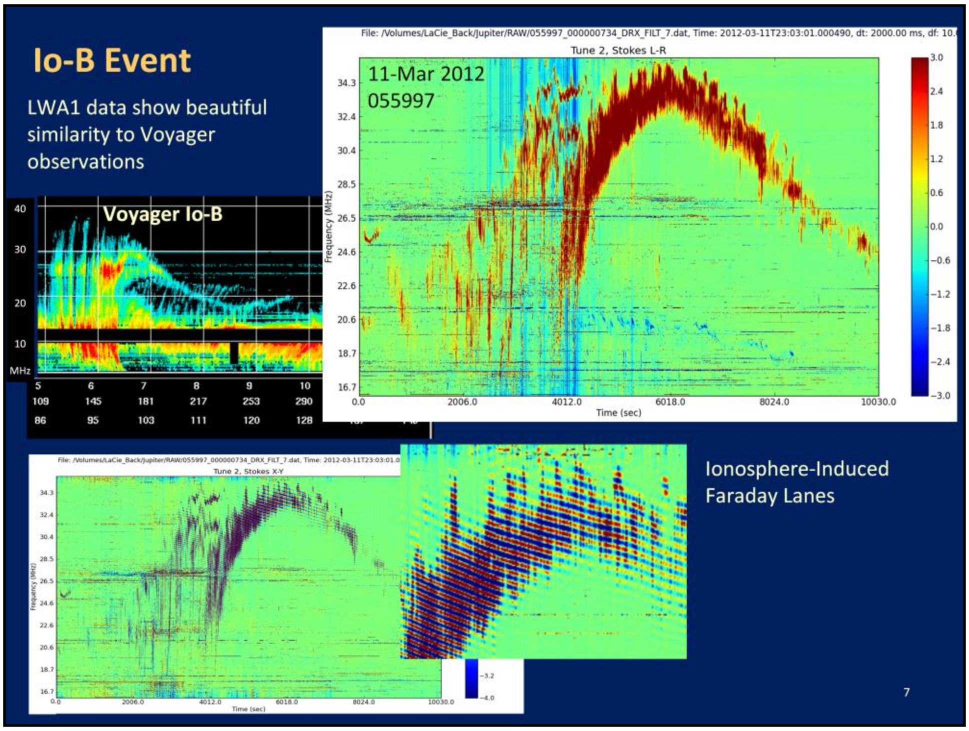
This a map of the probability of receiving Jupiter's radio emissions at and near 20 MHz. The y-axis shows the Io orbital position and the x-axis is the Jupiter longitude. High probability regions are shown in red and yellow; they are labeled Io-B, Io-A, and Io-C. The observations made and analyzed with the LWA are shown as the diagonal yellow lines.



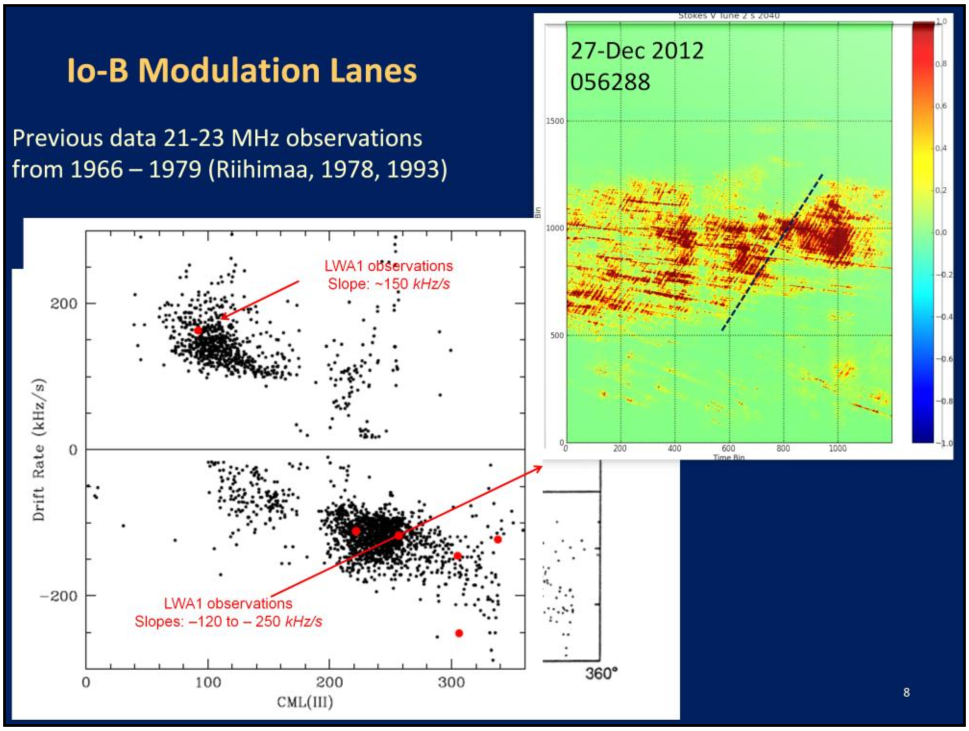
Three Io-A/Io-C events are shown here with RH polarization shown in red and LH circular polarization shown in blue. The ordinate shows the frequency ranging from 18 – 36 MHz, and the abscissa shows the time as Jupiter CML longitude. Notice the arc-like structures of the Io-A and Io-C sources and the similar structure seen in different events.



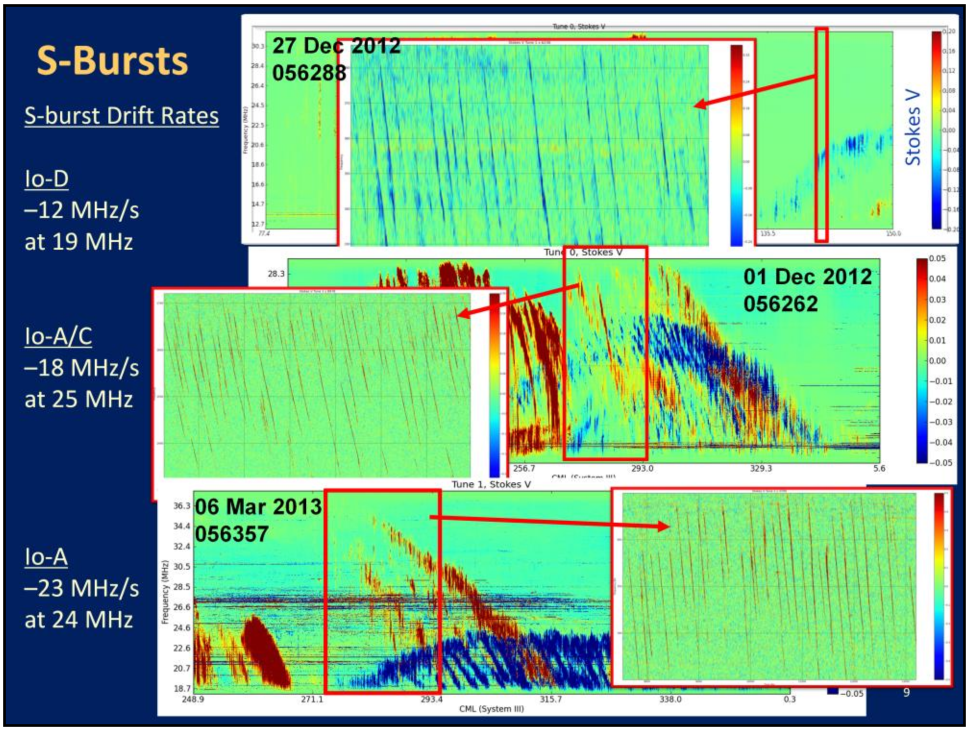
These are three examples of modulation lanes seen in the Io-A/C events. Again the RHC polarization is red and LHC is blue. The arced red line shown on the 10-Mar 2012 event highlights the modulation signature. The modulation lanes are seen to be continuous across both polarizations indicating that both emissions are coming from the same hemisphere. This challenges the current theory about emission.



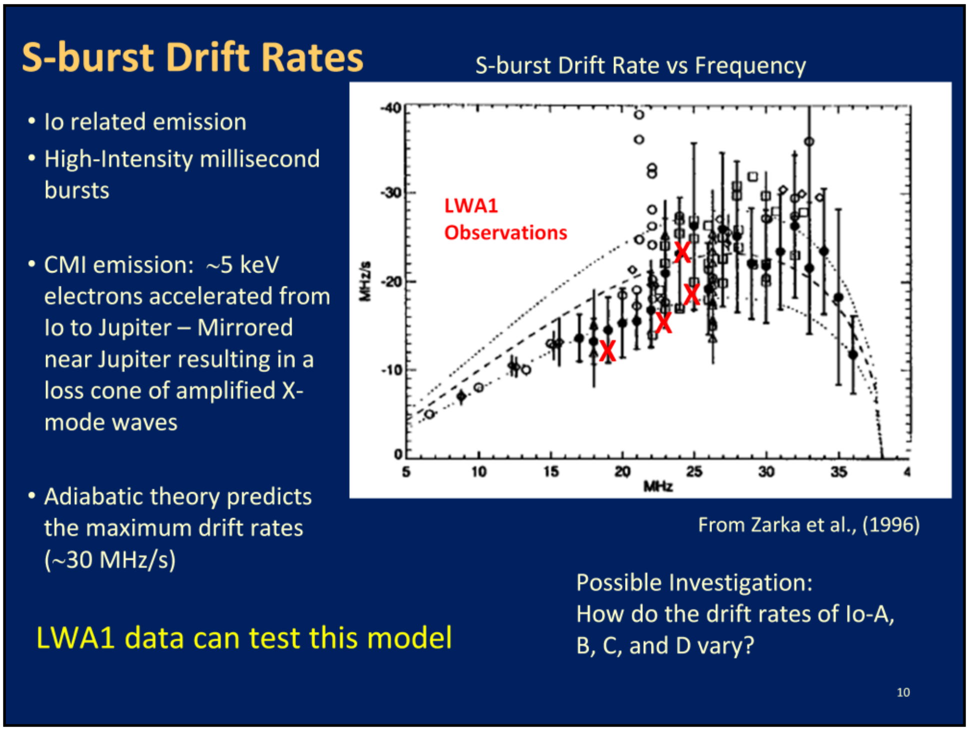
This is an example of a classic Io-B event on 11-Mar 2012. The beginning of the event shows S-bursts and then the envelope of the burst increases in frequency to a maximum before decreasing in a long tail. This is similar to the Voyager data. Also displayed are the X and Y outputs of the telescopes showing the Faraday lanes caused by propagation through Earth's ionosphere. Each polarization travels at a slightly different speed through the plasma.



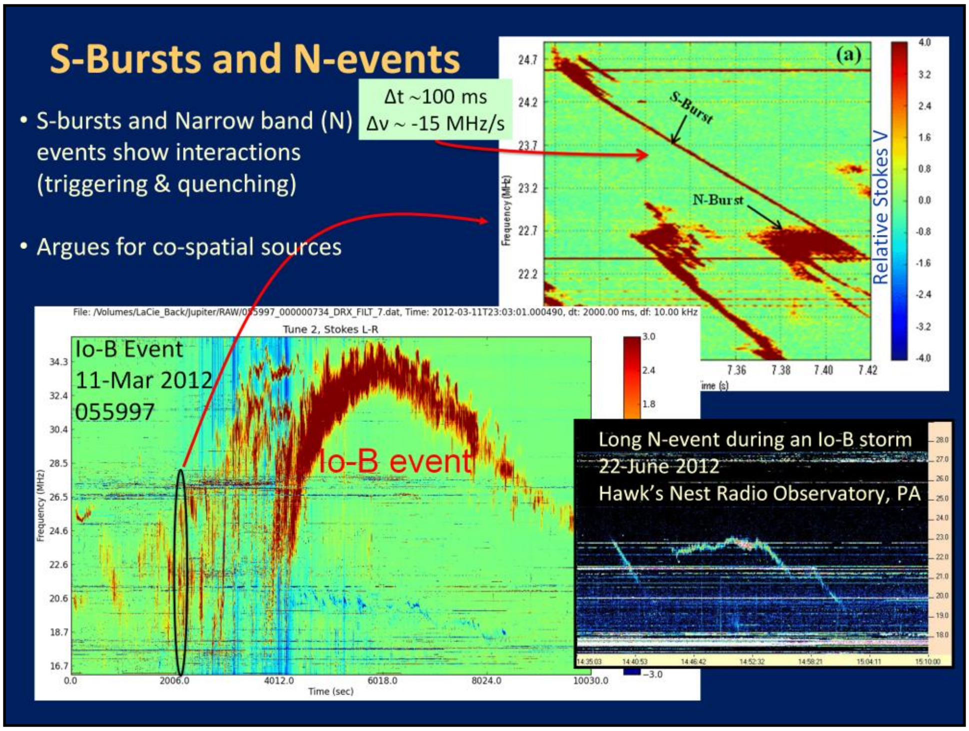
The slopes of many of the modulation lanes observed by the LWA telescope were measured and compared with previous data from Riihimma. Our measurements are consistent with previous data.



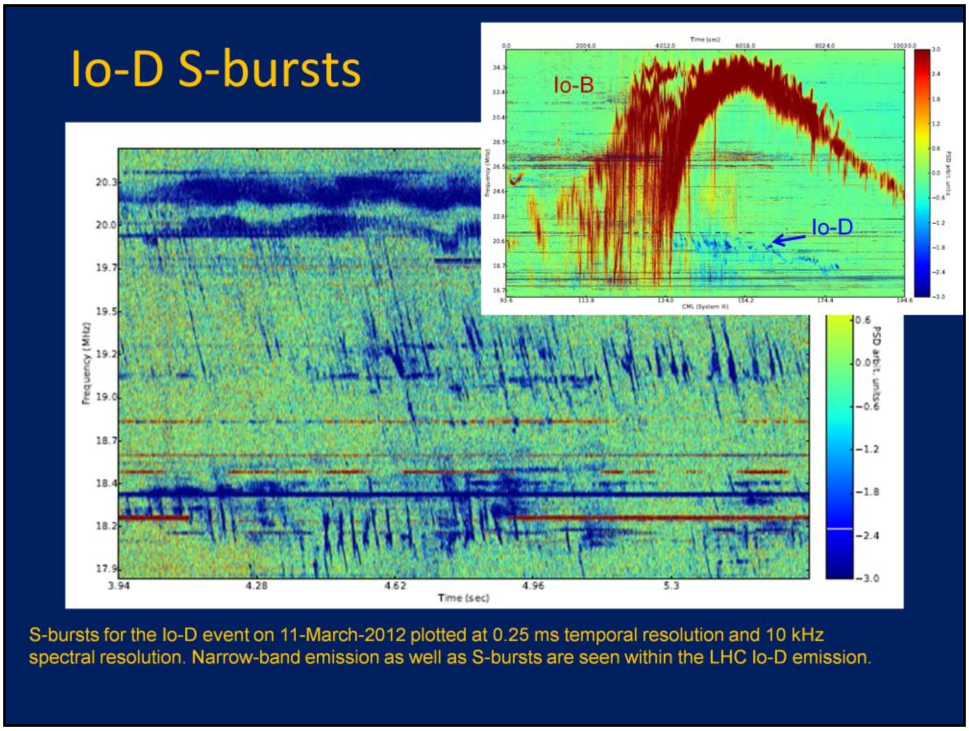
S-bursts were also seen in different Jupiter events. Analyzing the data at 0.25 ms resolution, the structure and drift rate of the S-bursts are seen. Drift rate measurements are consistent with previous data.



S-bursts drift rates are plotted on a graph of previous data (from Zarka et al., 1996) showing the drift rate (in MHz/s) versus frequency (in MHz). Our data are consistent with previous data; the negative values of the drift rates indicate that the electrons have mirrored near Jupiter's ionosphere and are propagating away from Jupiter during this emission. High frequency measurements can test the theory of how S-bursts are accelerated along Io-related magnetic field lines.



High frequency and time resolution of S-bursts show fantastic structure. In this example S-bursts appear to be interacting with N-events, triggering and quenching them as they drift in frequency and in time. This interaction argues that both S-bursts and N-events have co-spatial sources.



S-bursts for the Io-D event on 11-March-2012 (see Figure 7) plotted at 0.25 ms temporal resolution

and 10 kHz spectral resolution. Narrow-band emission as well as S-bursts are seen within the LHC Io-D emission.

As far as we know, this is the first time S-bursts have been detected during an Io-D event.

First Jupiter paper with LWA data is submitted

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Probing Jovian Decametric Emission with the Long Wavelength Array Station 1

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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.

This is the title and abstract of the first Jupiter paper submitted using LWA observations.

Summary of LWA1/Jupiter Studies

- LWA1 is an excellent instrument for Jupiter decameter studies
  - Observations show excellent spectral and temporal resolution
  - Allows for the analysis of fine structures, polarization and source boundaries
- Modulation Lanes observations can be used to check CMI theory
  - Are the RX and LO modes coming from the same hemisphere?
- S-burst drift rates at high frequencies
  - CMI amplified waves after electron acceleration by Alfvèn waves in Io's wake
  - Test the adiabatic model along the Io Flux Tube (max frequency)
- Narrow band (N) event characteristics (S-burst/N-event interactions)
- LH and RH emission can be used for Faraday rotation studies
- First Jupiter paper is submitted

Recent LWA1 Observations

Oct 2013 – Feb 2014

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

Juno Mission, ~2015-2017
Anticipated Coordinated observations?