Studying Jovian Radio Bursts with the Radio JOVE Spectrograph

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Goals:

• Import Radio JOVE spectra into Interactive Data Language (IDL) to study the structure of Jovian radio bursts.

• Continue developing educational outreach tools associated with Radio JOVE.

Radio JOVE Background:

• Radio JOVE allows amateur radio astronomers, from students to adults, to observe the Sun and Jupiter either directly by building their own radio telescope with the Radio JOVE kit or remotely by logging onto other telescopes using free downloadable software. Radio JOVE kits operate at a central frequency of 20.1MHz

• The newest additions to the Radio JOVE network are the spectrographs located at the Univ. of Florida Radio Observatory (UFRO) and the Univ. Of Hawaii Windward Community College Radio Observatory (WCCRO). These spectrographs can observe over a frequency range of 18-40 MHz and 17-30 MHz, respectively.

Jovian Radio Emission:

• Jovian radio emission comes in bursts and storms. In the 1950's, C. A. Shain discovered that the probability of radio storm detection depended on the position of Jupiter's central meridian longitude (CML), i.e. which part of Jupiter was facing the Earth. A decade later, E. K. Bigg discovered it also depended on the phase of Io.

•Fig. 1 top left is a plot of the probability of detecting a radio storm as a function of CML and Io Phase. There are three distinct regions of high probability, which are called Io-A, Io- B, and Io-C.

• Radio signals are emitted because of the interaction between Io and Jupiter's magnetic field. Io's numerous volcanoes (Fig. 1 top right) constantly spew particles into space, where they are ionized by solar radiation. These charged particles flow along the magnetic field lines that intersect Io and form flux tubes. Flux tubes for each of the Galilean moons are illustrated in magenta in Fig 1. bottom right.

•The radio emission mechanism is cyclotron radiation, which occurs when charged particles spiral around magnetic field lines. Fig. 1 top middle illustrates the hollow cone of radio emission. Earth receives a signal or radio storm whenever a wall of the cone is directed into our line of sight.

• Spectra of radio storms reveal structure including: short S-bursts (10's ms), long L-bursts (1-5 s), N-bursts, and "modulation lanes," which appear as a frequency drift and can have either a positive or negative slope or both.

• Fig 1 bottom left illustrates L-bursts and modulation lanes in an Io-A storm.

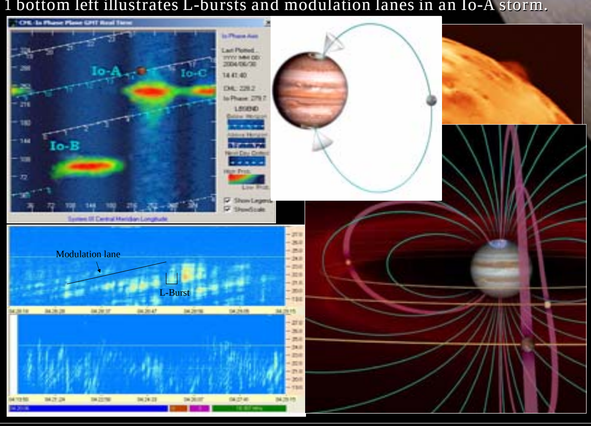

Figure 1: (top L) Probability diagram. *Radio Sky Publishing;* (top C) Cone of radio emission; (top R) Volcanic plume of Io; (bottom L) WCCRO data from 4/24/204 of an Io-A storm; (bottom R) Flux tube interactions of the Galilean moons and Jupiter's magnetosphere. *Clarke et al. 2002*

Past Work and Preliminary Results:

•Previous studies indicate that the average slope of modulation lanes is about 100 kHz/s.

• L-bursts also exhibit a frequency drift that creates slanted envelopes of emission that are often curved. They occur with a frequency of about 300 kHz.

➢Fig. 2 (L) illustrates a spectrum of an Io-B storm that has both L-burst envelopes that have positive slopes and modulation lanes that have negative slopes.

➢Fig. 2 (R) is a spectrum from the same storm that contains both positively and negatively sloping modulation lanes.

• Both the orientation and magnitude of modulation lane slopes depend on CML, and this relationship can be seen in Fig. 3, adapted from Riihimaa (1970).

• By simply measuring the slopes of the modulation lanes of the JPEG spectrograph files in the Radio JOVE archive, I measured an average slope of the modulations lanes to be 91 kHz.

➢Fig. 4 is a plot of the modulation lane and L-burst envelope slopes for Io-A, Io-B, and Io-C storms on six different dates. The data points show roughly the same trend as Fig. 3* even though there are fewer data pointes. *Note the difference in vertical scale.

• These measurements are just a first approximation and have high errors. These errors will be reduced once we can fit slopes to the modulation lanes in IDL.

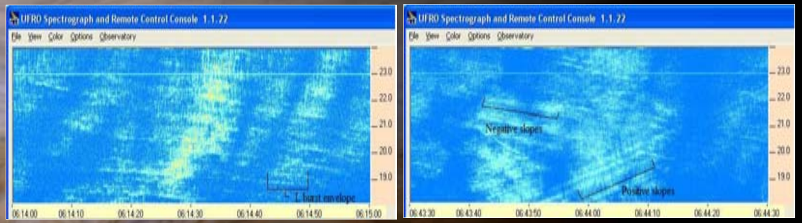

Figure 2: Two spectra of the Io-B storm of 2/16/04 taken from the Radio JOVE archive. (L) An example of the L-burst envelopes. (R) A spectrum showing both positively and negatively sloped modulation lanes.

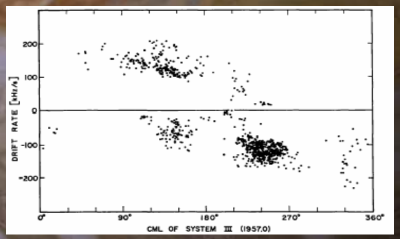

Figure 3: Frequency drift rate as a function of CML; *Riihimaa, J.J., A&A, 4:180 (1970)*

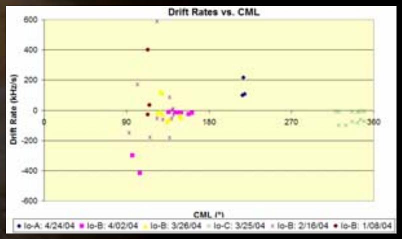

Figure 4: Drift rate as a function of CML for six storms found in the Radio JOVE archive.

Personal Contributions:

• Made 1st order measurements of modulation lane slopes and found consistency with known values.

• Wrote a program that can read Radio JOVE sky pipe files (single frequency files) into IDL, plot the data, filter out noise, and save the data to arrays (see Fig. 5 & 6).

• (expected) Write a program that will import spectrograph files into IDL.

• (expected) Investigate ways to minimize storage space of files.

• (expected) Use IDL to measure frequency drifts of modulation lanes, determine dependence on CML and Io phase, and compare our results to published values.

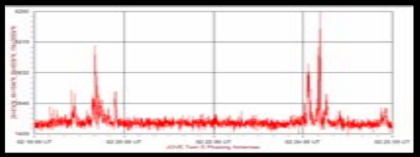

Figure 5: Strip chart read-out of a sky-pipe data file of an Io-A burst recorded on 6/2/04.

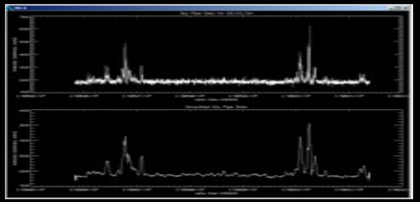

Figure 6: (top) The same data file as Fig. 5 plotted using IDL. (bottom) The noise is significantly reduced after using a simple box-car average.

Education and Outreach:

My efforts include the following:

• Spoke to recent high school graduates in the College Freshman Internship Program (CFIP) about pursuing technical majors in college.

• Presented Radio JOVE to the Society of Amateur Radio Astronomers (SARA) conference in Greenbank, WV with Chuck Higgins (Fig. 7)

• Helping to develop Radio JOVE activities, projects, and lesson plans to teach scientific concepts.

Figure 7: (L) My presentation to the SARA conference. (M) The audience of SARA members. (R) Group photo of the 2004 SARA conference participants.

Future Work:

Converting files into IDL is one of the first steps in using Radio JOVE as a research grade network of instruments. Once completed, the data in the JOVE archives can be used for long term scientific studies of both Jupiter and the sun by allowing more accurate measurements of the intensities, durations, and structure of solar and Jovian radio bursts.

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