Listening to Jupiter's Radio Storms

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Introduction

- Jupiter emissions = Jupiter radio storms
  - Move at the speed of light
  - Travel at least 590 million kilometers to be heard on Earth
  - Categorized as L-bursts (long-bursts) and S-bursts (short-bursts) to indicate their relative durations
- They are powerful
  - Each burst is neighborhood of 500 billion watts
  - Regular short wave receivers used by listening enthusiasts and amateur radio operators can detect them
  - Simple radio telescopes work well

Public domain sound files courtesy NASA

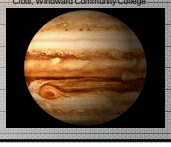
Contents

Jupiter

- Largest planet in the solar system
  - 11X Earth diameter: 142,800 km
  - 0.4X Earth rotation period: 9.9 hours
  - 318X Earth mass: 1.9×10^{27} kg
- Fifth planet from the Sun
  - 5.2X Earth distance: 5.2 AU
  - 12X Earth orbit: 12 years

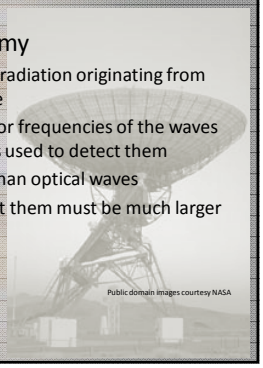
Public domain image courtesy NASA

Movie file courtesy of Professor Joe Ciotti, Windward Community College



Introduction

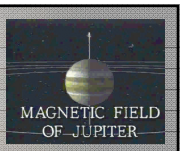
- Radio and optical astronomy
  - Both examine electromagnetic radiation originating from outside the Earth's atmosphere
  - They differ in the wavelengths or frequencies of the waves being studied and the methods used to detect them
  - Radio waves are much longer than optical waves
  - Radio telescopes used to detect them must be much larger than optical telescopes



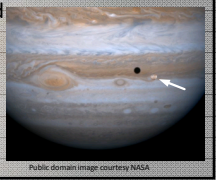
Public domain images courtesy NASA

Jupiter

Movie file courtesy of Professor Joe Ciotti, Windward Community College



- Magnetic field
  - Magnetic induction ~14X – 23X Earth's field
    - At equator: 420,000 nT
    - At poles: 1,400,000 nT
  - Very strong magnetic field enables radio emissions in the high-frequency (HF) band
- Moons and rings
  - 63 known moons
  - 1 thin ring
  - Io (right) has important effect on emissions



Public domain image courtesy NASA

History

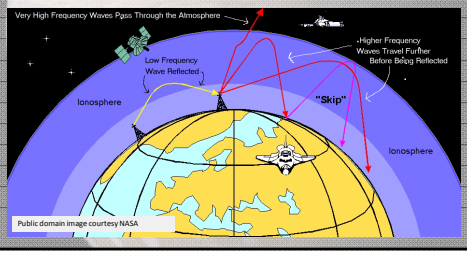
- The emissions were first detected in 1950 but the investigators at the time did not know they were anything unusual
- Their source was determined in 1955 by other investigators
- Methods by which the emissions are generated are not yet fully understood

Source: http://radiojove.gsfc.nasa.gov/library/sci_briefs/discovery.htm

Co-discoverers: Bernard Burke & Kenneth Franklin

Jupiter Emissions

- Earth's ionosphere more transparent at frequencies above approximately 15 MHz
  - Varies with Sun's activity and day and night
  - Below about 15 MHz ionosphere blocks extraterrestrial emissions



History

Mills Cross Array, near Seneca MD

Source: http://radiojove.gsfc.nasa.gov/library/sci_briefs/discovery.htm

Jupiter Emissions

- Probabilities of detecting Jupiter emissions strongly depend on
  - Jovian Central Meridian Longitude (CML)
  - Io Phase
  - Jovi-centric declination of the Earth (D_e)
- **Definitions**:
  - CML: System III longitude of Jupiter facing the Earth at a certain time
  - Io Phase: Orbital position of Io with respect to Jupiter and Earth. The Io phase is 0 degrees when Io is directly behind Jupiter as seen from Earth. The Io phase increases as Io orbits until it becomes 180 degrees when Io crosses in front of Jupiter as seen from Earth
  - D_e: Declination (angular distance north or south of the celestial equator) of the Earth as seen from Jupiter

Jupiter Emissions

- Frequency of the most intense emissions
  - Approximately 50 kHz to 40 MHz
  - 50 kHz = VLF band
  - 40 MHz = VHF band
- Emissions have broad bandwidth
  - Precisely tuned receiver not necessary
  - Frequency of 20.1 MHz is a common receiver setting
    - Far enough above the ionospheric cutoff frequency
    - Not on manmade transmission frequencies that would interfere

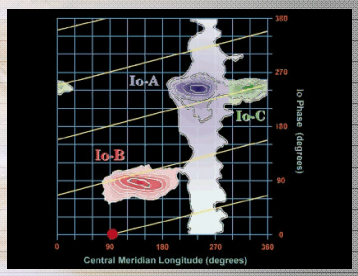
Jupiter Emissions

Source	CML (°)	Io-Phase (°)	Type
Io-Controlled			
Io-A	200 – 290	195 – 265	Mostly L-bursts
Io-B	90 – 200	75 – 105	Mostly S-bursts
Io-C	290 – 10	225 – 250	Both
Non-Io-Controlled			
A	200 – 290		
B	90 – 200		
C	290 – 10		

Emissions are more likely to be received for higher D_e.
- D_e varies about -3.3 to +3.3 degrees over an 11 year cycle
- Next positive peak: 2012

Jupiter Emissions

- CML
- Io-Phase

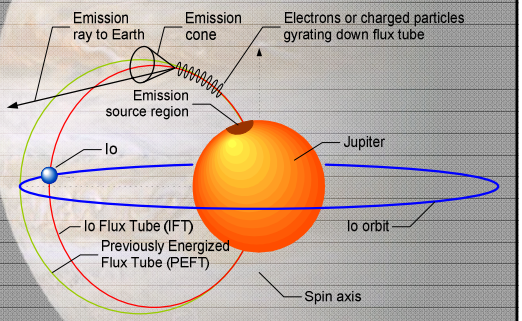


Movie file courtesy of Professor Joe Ciotti, Windward Community College

Factors Affecting Detection

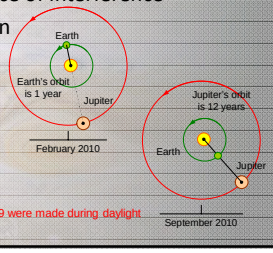
- Earth's ionosphere
  - Best: Nighttime, a few hours after sunset and before sunrise
    - Ionosphere is less dense (less opaque at frequencies of interest)
    - Ionosphere will not reflect as much manmade and lightning noise toward the receiving station
  - Best: Low sunspot cycle
    - Earth's ionosphere more transparent
    - Sun has been very quiet this year – I have received Jupiter emissions in the daytime

Jupiter Emissions – Model



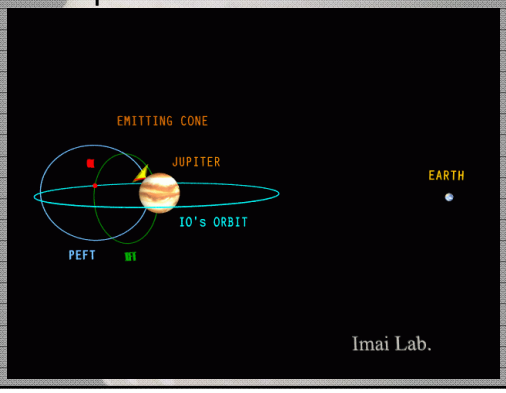
Factors Affecting Detection

- Relative positions of Jupiter and Earth in their orbits around the Sun
  - Sun is a huge source of interference
  - Worst: Conjunction
    - January 2009
    - February 2010
  - Best: Opposition
    - August 2009
    - September 2010



Note: All of my recordings from April 2009 were made during daylight

Jupiter Emissions – Model



Used with permission of Imai Lab., Rochi National College of Technology

Factors Affecting Detection

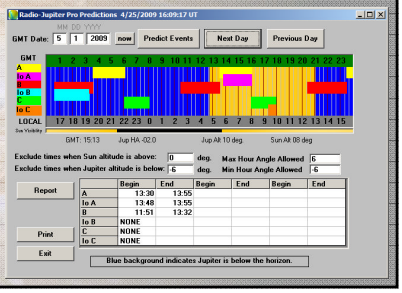
- Jupiter's position in the sky as seen by your antenna
  - Above the horizon at your location
    - If below horizon, Earth blocks the emissions
  - Northern latitudes add to difficulty
    - Jupiter may be low on horizon for much of the listening season

Factors Affecting Detection

- Emissions are directional
  - Cannot be detected if Earth not in the beam
    - Like a flashlight that must be beamed toward Earth
  - Emissions are predictable, mostly
    - Orbits of Jupiter, Io and Earth are well known
    - Locations of the sources on Jupiter are well known
    - Emission sources vary in intensity so it is possible nothing will be received

Software Prediction Tools

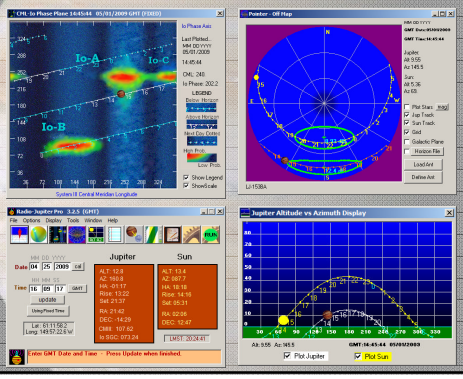
- Radio-Jupiter Pro 3
  - www.radiosky.com
  - Cost ~$20
  - Free trial for 30 days



Predictions

- Online sources
  - NASA
    - radiojove.gsfc.nasa.gov/observing/predictions.htm
  - University of Florida Radio Observatory (UFRO)
    - www.astro.ufl.edu/juptables.html
  - Astronomy magazine websites can be used to determine if Jupiter
    - Daytime or nighttime sky
    - Above or below the horizon
  - Other websites allow you to visualize the orbital relationships of the planets
    - www.fourmilab.ch/cgi-bin/Solar

Software Prediction Tools

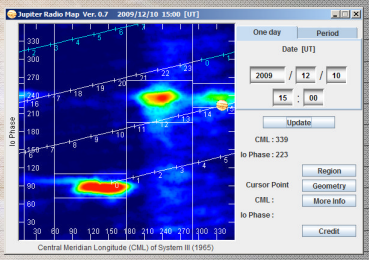


Predictions

- Is there an easier way to determine the best observing times at a specific location?
  - Without converting UTC to local time
  - Looking through tabulated data
  - Making corrections for latitude
- *Radio-Jupiter 3 Pro* by Radio-Sky Publishing
- *Jupiter Radio Map* by the Internet Jupiter Radio Observatory

Software Prediction Tools

- Jupiter Radio Map
  - http://jupiter.kochi-ct.jp/jrm/jrm007.jar
  - Cost: Free
  - Different data source (slight difference in times)



What to Listen for

- L-bursts sound like ocean surf on a beach and can have a swishing sound
  - The burst structure mostly is the result of Solar Wind modulations

Reeve: L-bursts
April 24, 2009

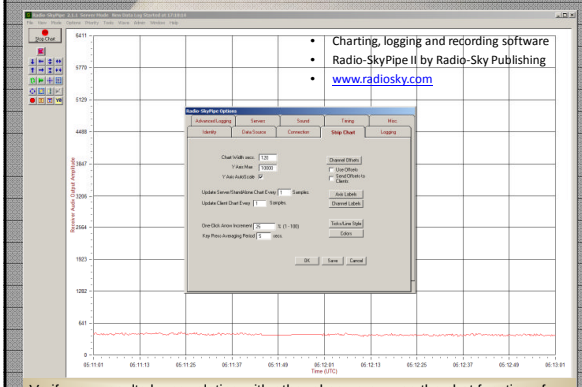
What to Listen for

- Actively listen during the predicted times while also recording the audio
  - Make a log entry of likely events in real time
  - Listen to recording at your leisure
- When predicted listening times are not convenient
  - Set software (next slide) to record the audio and make a chart at predicted times
  - Review when more convenient
  - I use the software for all charting

What to Listen for

- S-Bursts sound like pebbles thrown on a tin roof or the snapping and popping sound of cooking popcorn or a kind of spitting sound
  - Each S-burst lasts for a few thousandths of a second
  - Occur at rates as high as several dozen per second

Reeve: S-bursts
April 25, 2009



- Charting, logging and recording software
- Radio-SkyPipe II by Radio-Sky Publishing
- www.radiosky.com

Verify your results by correlating with other observers – use the chat function of Radio-SkyPipe, or use the Radio JOVE listserver, or Yahoo Group

What to Listen for

- Common mistake: Every pop, click, buzz and hiss heard on the receiver is from Jupiter
- Sometimes Jupiter emissions are very weak
  - Best to listen to your receiver in a very quiet room or with headphones
- Practice by listening to known emissions
  - Recordings available online from the NASA Radio JOVE data archive or www.reeve.com
  - jovearchive.gsfc.nasa.gov
  - http://www.reeve.com/radiojove.htm

Build Your Own Radio Telescope

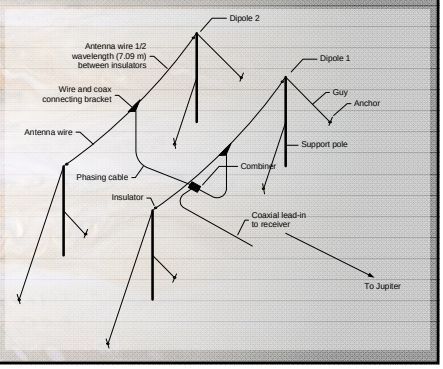
- Two basic ways to observe Jupiter emissions
  1. Use your own receiver and antenna with a method of charting, recording and logging the results (for example, Radio-SkyPipe)
     - Allows you to have the most control over what you see and hear but requires the most equipment (receiver, antenna, PC and software)
  2. Observe remotely on your own PC using free or paid version of Radio-SkyPipe
     - Requires a PC and an Internet connection

Build Your Own Radio Telescope

- Receiver
  - Capable of tuning in the range of 20 MHz
  - General coverage HF receiver designed for short wave listening (SWL) covers this frequency
  - Receiver fixed tuned to 20.1 MHz is more than adequate if it has at least some tuning range, say ± 100 – 200 kHz
    - Tuning range needed to tune around interference
  - An important receiver feature is the ability to disable the Automatic Gain Control (AGC) function
    - AGC, also called AVC or Automatic Volume Control, is needed to smooth the audio volume for manmade communications when the radio signals vary due to propagation effects
    - AGC is not desirable when listening for Jupiter emissions because you want to be able to hear the variations
  - Software defined radios (SDR) hold a lot of promise for use in radio astronomy

Build Your Own Radio Telescope

- Dual Dipole Antenna



Build Your Own Radio Telescope

- Antenna – <u>The most important component in any radio project</u>
- Best antennas have some gain and are directional
  - *<u>Gain</u>* means the antenna will receive more signal than a reference antenna with no gain. A gain of 4 to 10 times (6 to 10 dB) above a half-wave dipole is fine
  - *<u>Directional</u>* means the antenna will receive more signal in certain directions than in other directions
    - Typical directional antenna receives more signals from the front than the back or the sides
    - Directional antenna helps reduce interference.

Build Your Own Radio Telescope

Build Your Own Radio Telescope

- A single half-wave dipole has worked fine for many observers
  - Current recommendation is a dual-half-wave dipole with each dipole separated by about one-half wavelength (next slide)
- Yagi, log-periodic and Moxon antennas designed for the desired frequency range also should work well
  - I use a 3-element Yagi antenna
- Some observers have had good results with random-length (untuned), long-wire antennas
  - Probably will not work in Alaska
  - I have had no luck with random-length, long-wire antennas
- Horizontal or vertical loop that is a full wavelength long (15 m) probably will receive the more powerful emissions

Build Your Own Radio Telescope

- Not Recommended
  - Active antennas with or without vertical whips
  - Active small loop antennas
  - Passive small loop antennas

Build Your Own Radio Telescope

- It is important that directional antennas be pointed in the direction of Jupiter as it transits the sky
- In northern hemisphere, depending on the part of the listening season, this could be anywhere from east through south to west
- In northern hemisphere good compromise direction for the single or dual dipole antenna is south

Build Your Own Radio Telescope

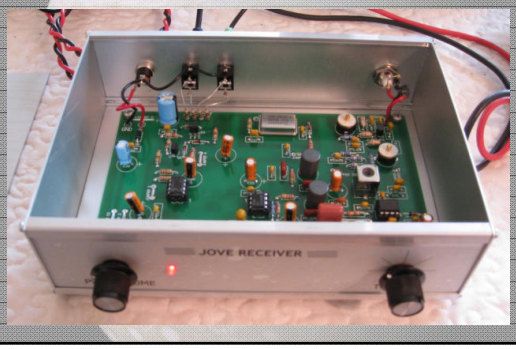
- Alternative
  - Jupiter Receiver kit
    - Slightly easier to build than Radio Jove Receiver kit
  - Available from Altronics in Perth Australia
    - www.altronics.com.au/index.asp?area=item&id=K1127
  - About US $100, delivered
  - Includes material for single dipole antenna
  - Testing so far in my lab indicates this radio is not better than the Radio Jove Receiver or Icom R-75 HF receiver

Build Your Own Radio Telescope

- Purchase a complete listening kit from NASA
  - Receiver specially designed for the project
  - Parts to assemble a dual-half-wave dipole antenna
  - CD with software and educational materials
  - Complete kit costs US $190 plus shipping
  - http://radiojove.gsfc.nasa.gov/office/kit_requests.htm
- Built versions of the receiver or just the antenna parts and CD also available
- Lesson plans for educators also available (free)

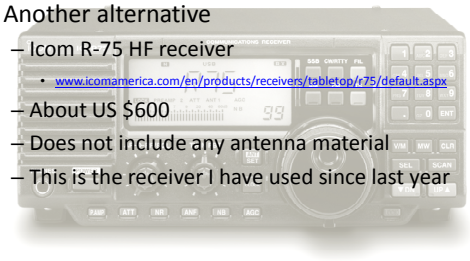
Build Your Own Radio Telescope

Build Your Own Radio Telescope



Build Your Own Radio Telescope

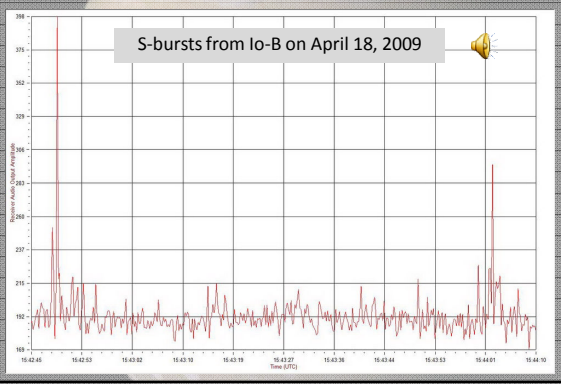
- Another alternative
  - Icom R-75 HF receiver
    - www.icomamerica.com/en/products/receivers/tabletop/r75/default.aspx
  - About US $600
  - Does not include any antenna material
  - This is the receiver I have used since last year



Build Your Own Radio Telescope

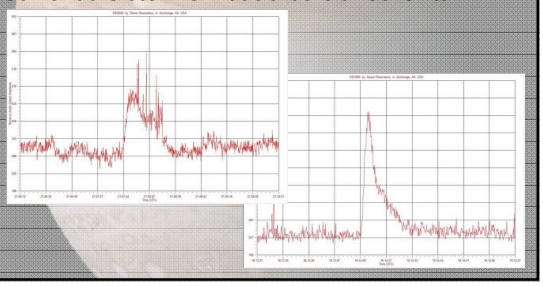
Results

S-bursts from Io-B on April 18, 2009



Build Your Own Radio Telescope

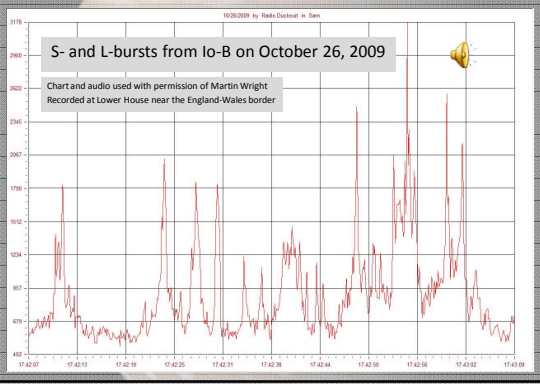
- The same setup can be used to listen to the Sun's radio storms – but that is another talk



Results

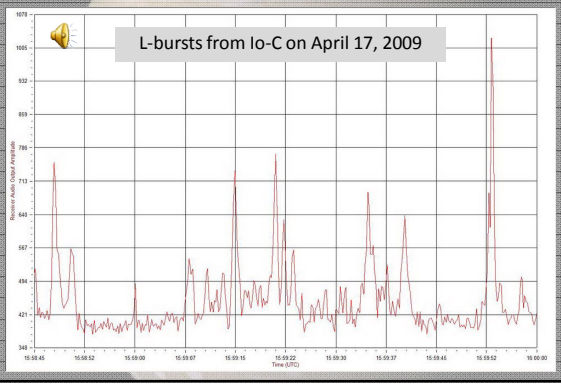
S- and L-bursts from Io-B on October 26, 2009

Chart and audio used with permission of Martin Wright
Recorded at Lower House near the England-Wales border



Results

L-bursts from Io-C on April 17, 2009



Resources

- NASA
  - radiojove.gsfc.nasa.gov/
  - Bulletin/newsletter
  - Teleconference calls
  - Listserver
- Yahoo Group
  - tech.groups.yahoo.com/group/Radio_JOVE/

Resources

- *Listening to Jupiter*, Richard Flagg (available from http://www.radiosky.com/booksra.html)
- *Listening to Jupiter Radio Storms*, Whitham D. Reeve, Radio User magazine, September & October 2009: http://www.reeve.com/Documents/RadioScience/Jupiter%20Complete.pdf
- Frequently Asked Questions: http://radiojove.gsfc.nasa.gov/help/faq1.htm

- Software
  - Radio-Jupiter Pro
  - Radio SkyPipe II
  - Jupiter Radio Map

- Web sites
  - http://radiojove.gsfc.nasa.gov/index.html
  - http://tech.groups.yahoo.com/group/Radio_JOVE/
  - http://www.obs-nancay.fr/a_index.htm
  - http://www.radiosky.com/
  - http://www.reeve.com/Radio_Science.htm

Conclusions

- Next Jupiter observing season is just around the corner
  - Meanwhile, you can observe the Sun's radio emissions
- Using an ordinary high-frequency receiver probably will yield good results
  - Use the recommended Radio JOVE antenna or similar
  - Or, observe remotely
- If you have problems or need additional information
  - Contact experienced people through forums and NASA's Radio JOVE project