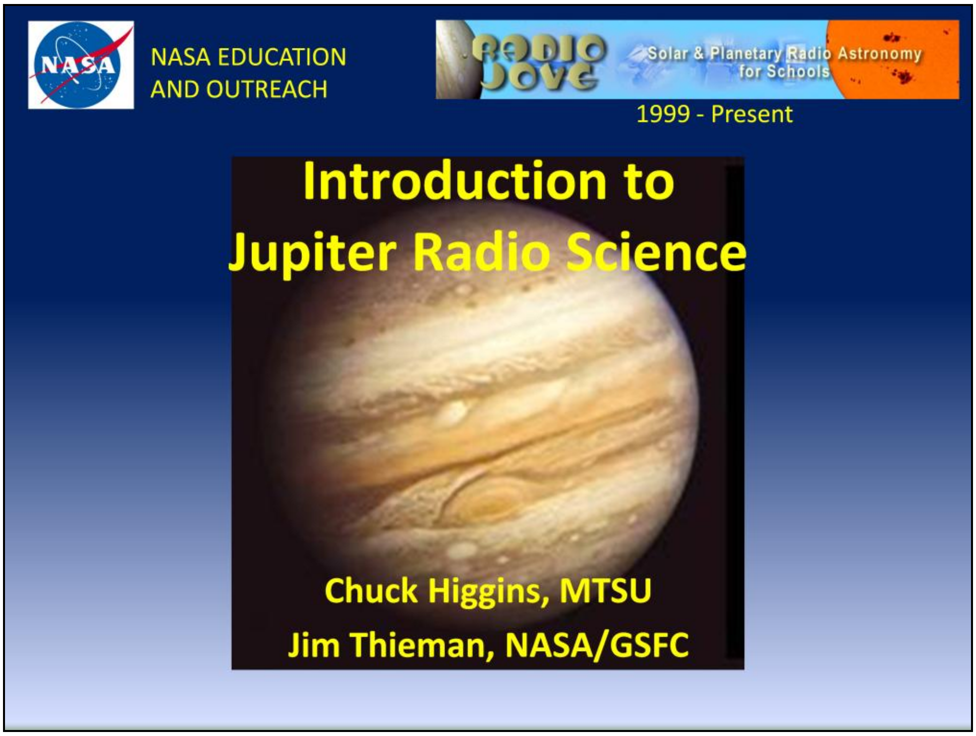
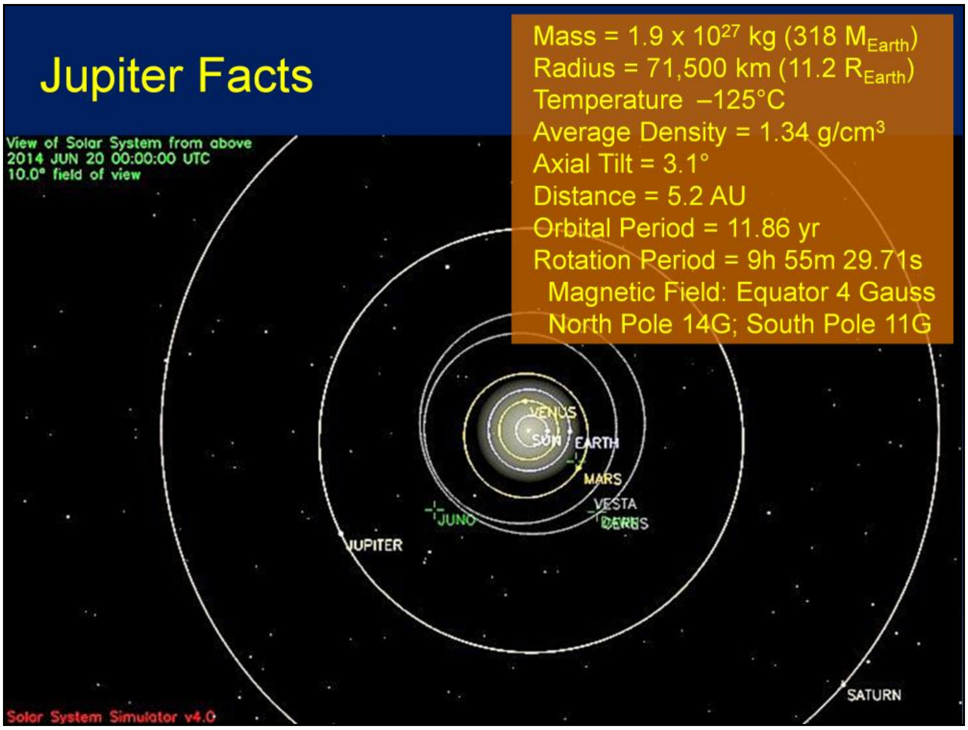


This presentation is an introduction to the radio science of Jupiter.

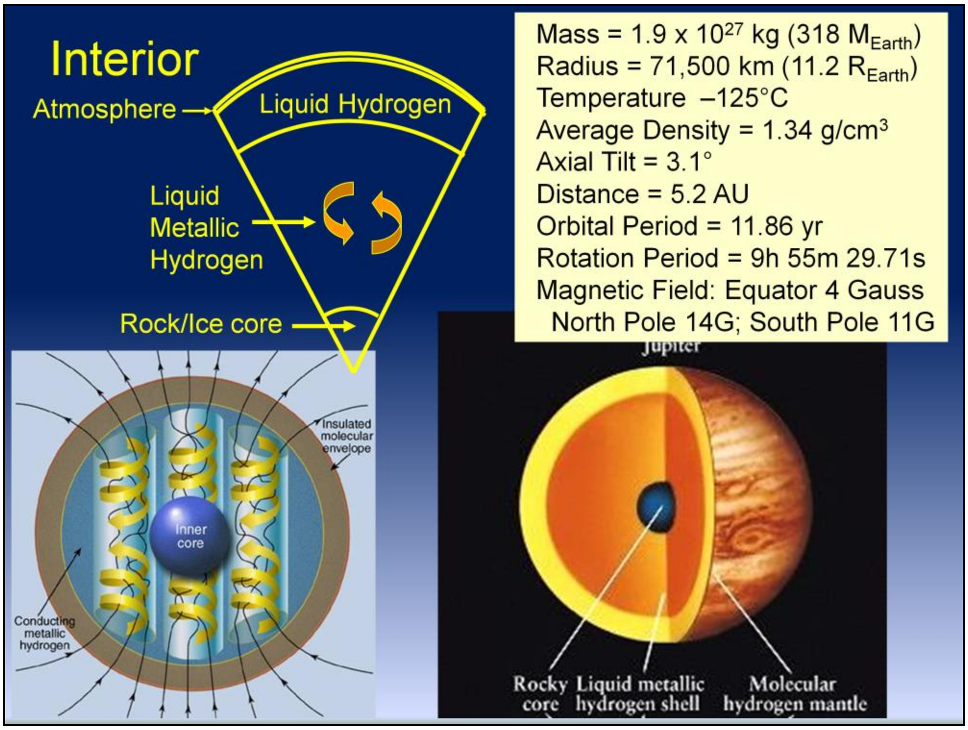
Jupiter Science Outline

- Jupiter Facts
- Discovery of Jupiter Radio Waves
- Magnetosphere and Io Torus
- Jupiter Radio Sounds
- Io Connection – CML and Io Phase
- Decameter Emission Mechanism
- Summary

Outline

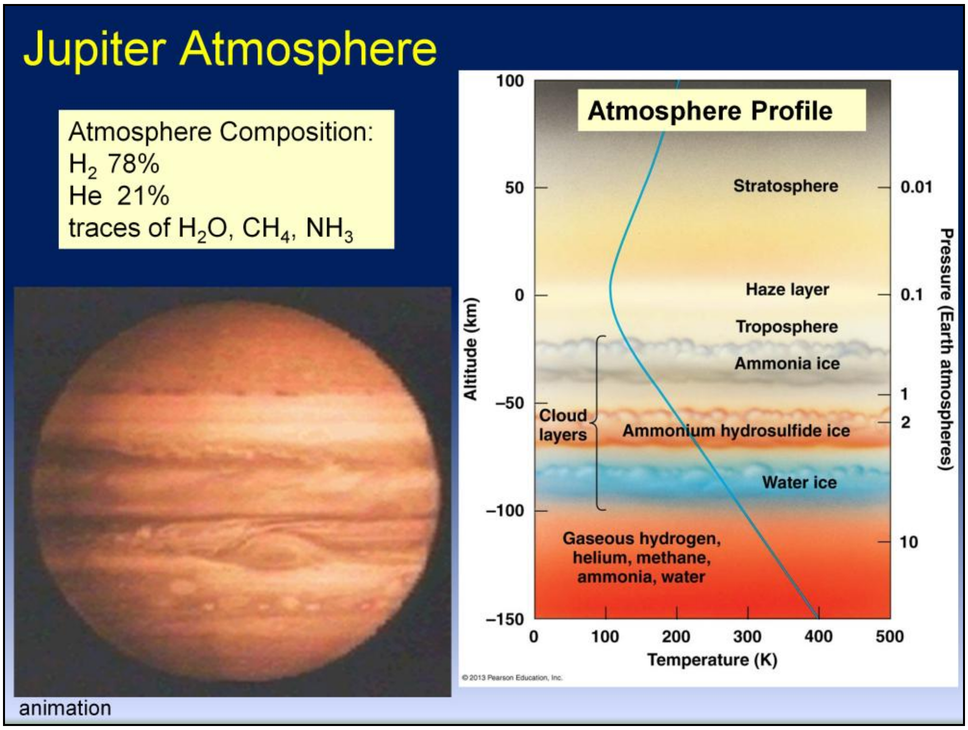


Jupiter, a gas giant planet, is made up of hydrogen and helium and has an average density of 1.34 g/cm3. It is 11 times larger than Earth and is 318 times more massive than Earth. It has an 11.86 yr orbit period and is 5.2 A.U. from the Sun.

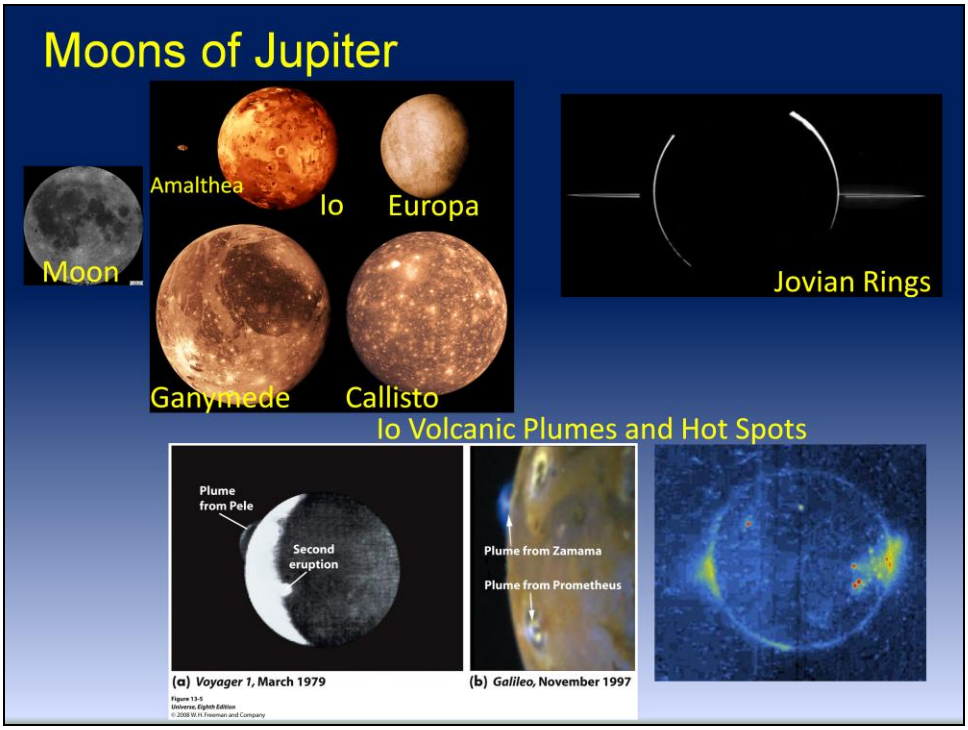


Jupiter's interior structure is not well know, but it has a large magnetic field generated by a planetary dynamo. The dynamo mechanism requires an electrically conducting liquid material that is rotating reasonably quickly; in Jupiter's case the rotation period is about 10 hours. Jupiter's high pressure renders the gaseous

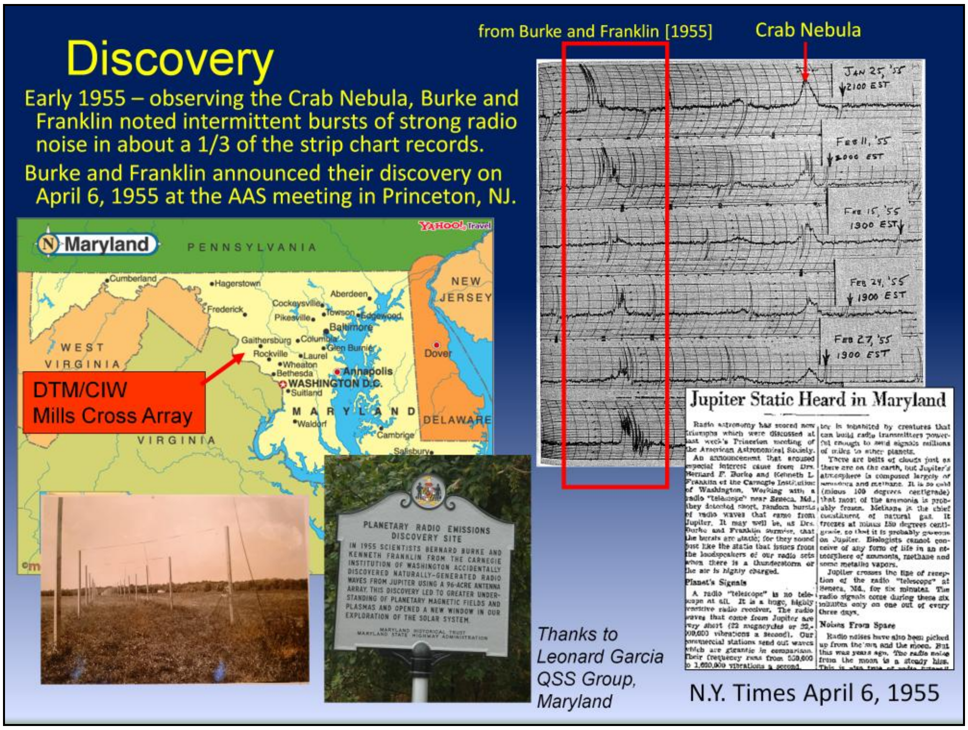
hydrogen liquid at increasing depths; at still lower depths the hydrogen changes into a metallic phase able to conduct electricity. This moving electrically conducting material generates a global magnetic field that is about 14 times stronger than Earth's magnetic field (i.e. about 14 Gauss). The core is thought to consist of rock/ice under extreme pressure.



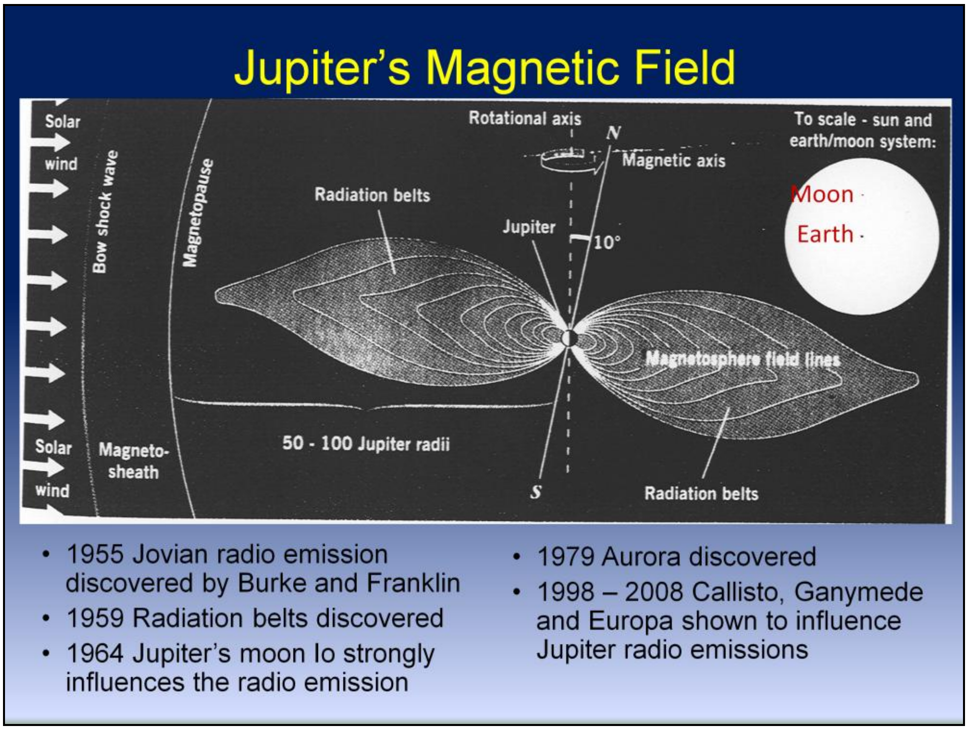
Jupiter's atmosphere is about 78% molecular hydrogen and 21% helium, with trace gaseous elements of water, methane, ammonia. Due to the low atmospheric temperatures (–125 K), the upper cloud layers are ices. Some of the wind speeds are as high as 360 km/hr (223 mi/hr) in the zonal flows. Many vortices form because of the Coriolis forces of a rotating gaseous body.



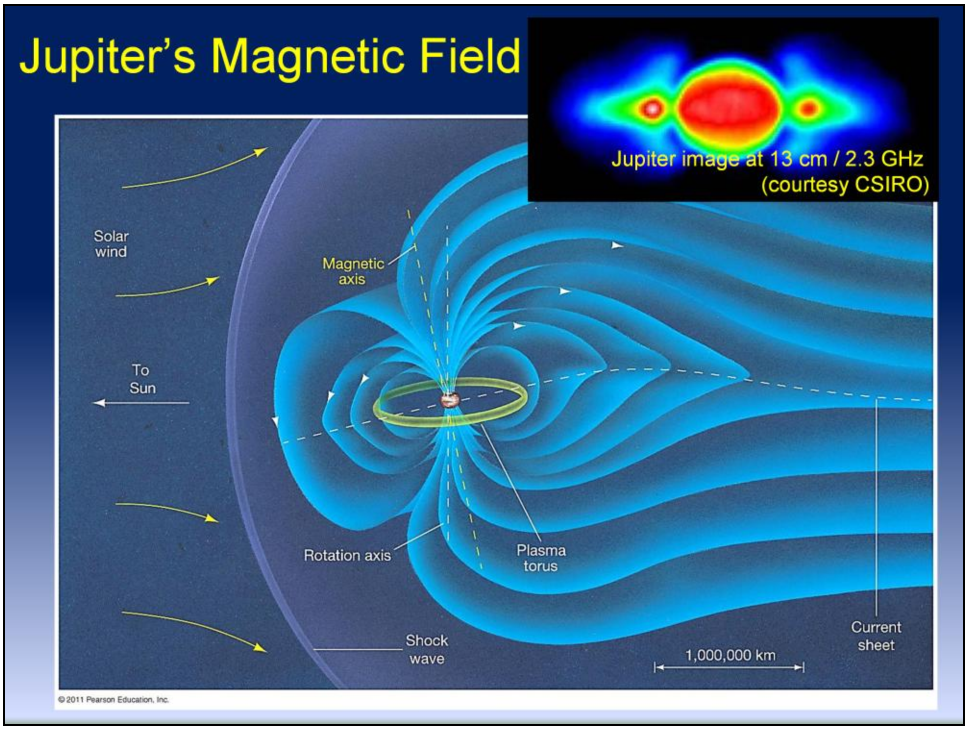
Jupiter has a faint ring system and has 67 known moons, the four largest are called the Galilean moons. Io the closest Galilean moon, is slightly larger than our Moon, was predicted to have a molten interior in the 1960s due to a large tidal forces from Jupiter. Voyager 1 confirmed the theory in 1979 when volcanic plumes were photographed.



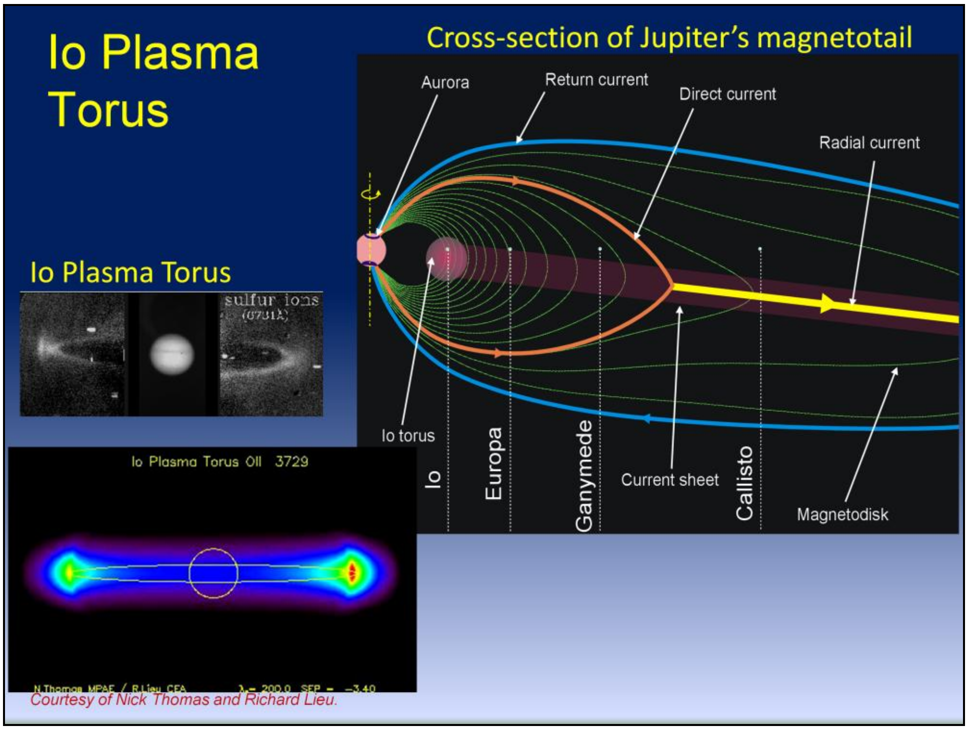
Jupiter radio emissions were discovered accidentally in 1955 by Burke and Franklin using a “Mills Cross” type array in Maryland. They were observing the crab nebula at low frequencies (22 MHz) and also observed what they thought was local interference. On further observations they confirmed the source of the interference must be Jupiter (see strip chart tracing), and they made their announcement at the American Astronomical Society meeting. A roadside plaque is now erected near the discovery site.



Jupiter's magnetosphere is huge! It spans about 100 Jovian radii and is 4 times larger than the Sun. The magnetic pole is tilted about 10 degrees from the rotational axis causing the entire magnetosphere to wobble back-and-forth on a 10 hour rotation period. After the initial discovery of radio emissions in 1955, the radiation belts were discovered by radio astronomers in 1959 (the same year Explorer 1 confirmed Earth's radiation belts). Soon after Io's influence on the radio emissions were discovered and after the Galileo spacecraft mission the other moons were shown to have a small influence on the radio emissions. Voyager 1 discovered the aurora on Jupiter in 1979.



Jupiter's magnetic field is shown with the dayside bow shock and the nightside magnetotail. The current sheet provides an outward radial current flow connected back to Jupiter along high latitude magnetic field lines to close the "circuit". The Io plasma torus caused by the volcanism of Io is shown at 6 Jovian radii. A 13 cm / 2.3 GHz map of Jupiter's radiation belts is shown in the upper right.



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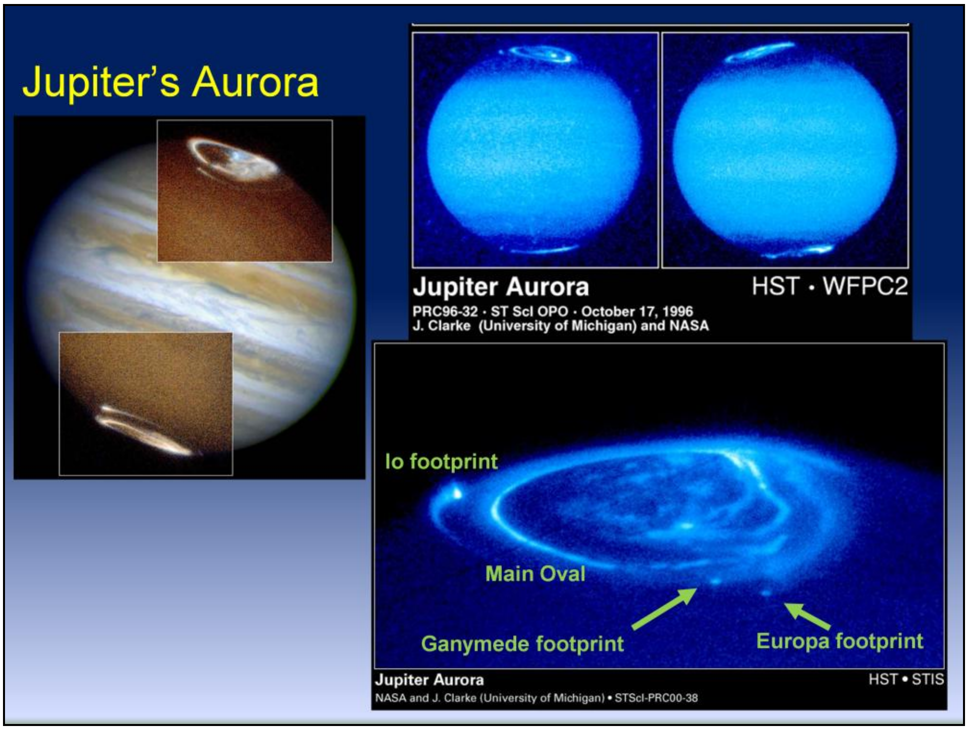
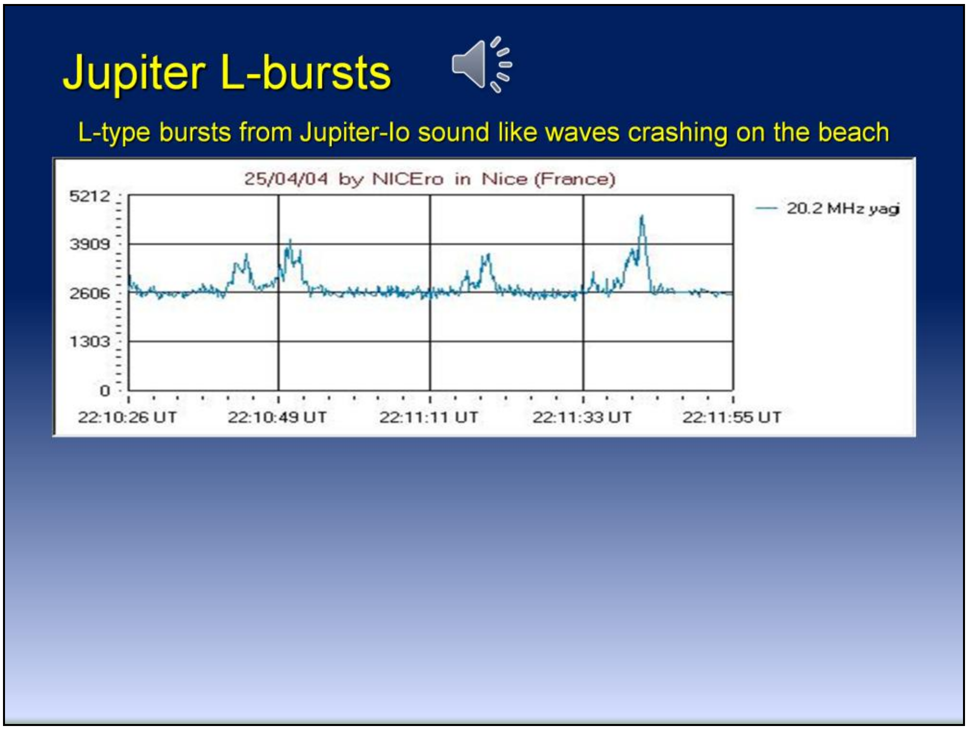
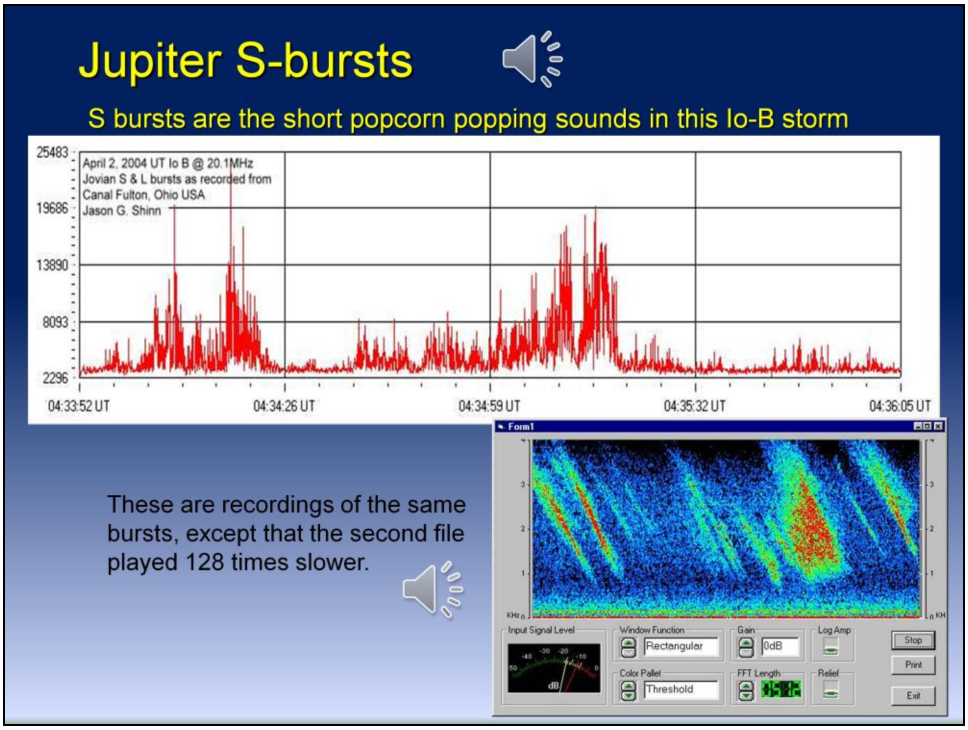


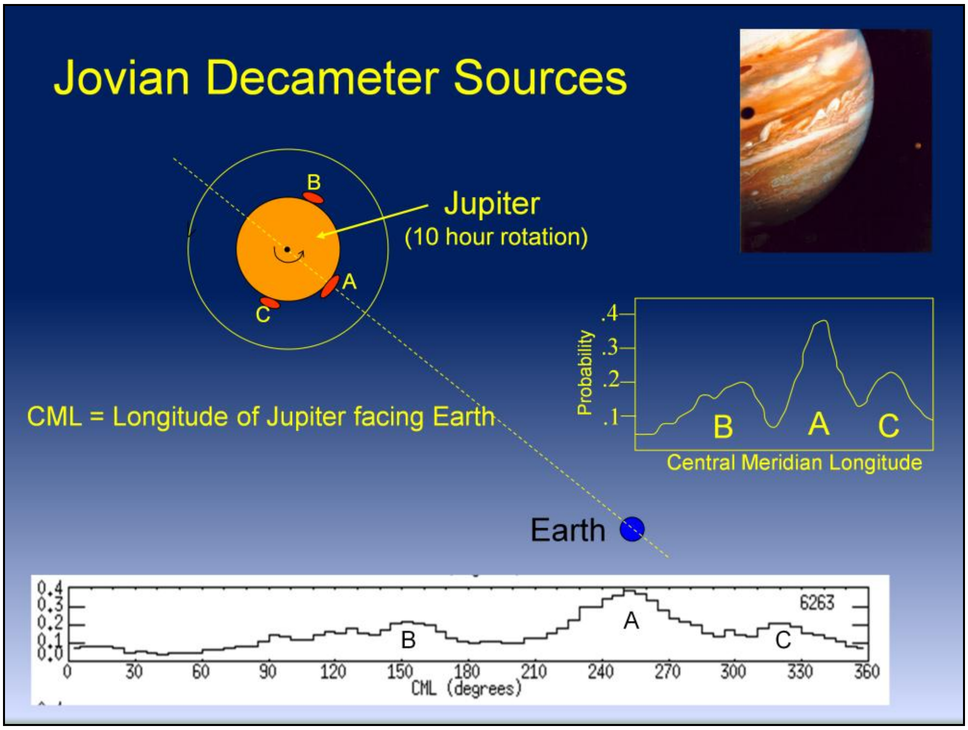
The solar wind interaction with Jupiter causes incredible aurora as seen in these UV images. Notice the vast difference in the dawn-side and dusk-side aurora. Also seen in some images are the electrical footprints of the plasma interactions with the satellites Io, Europa, and Ganymede.



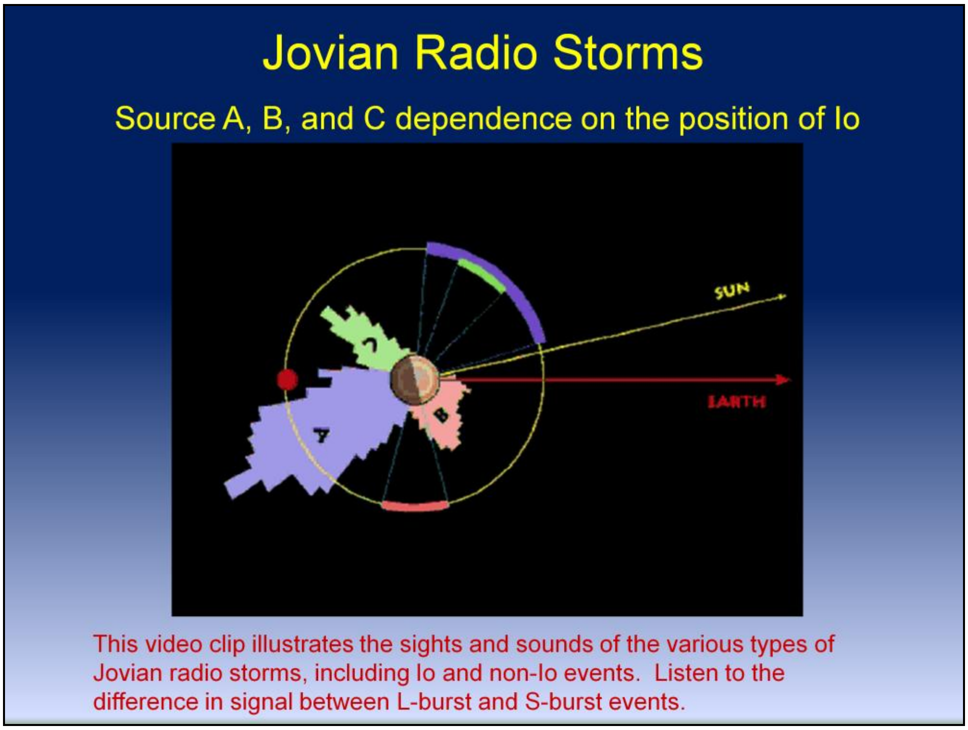
This is a strip chart recording of some 20 MHz radio L-burst emissions from Jupiter. These L-bursts sound like waves crashing on an ocean shore and the modulation is due to interplanetary scintillation of the radio waves.



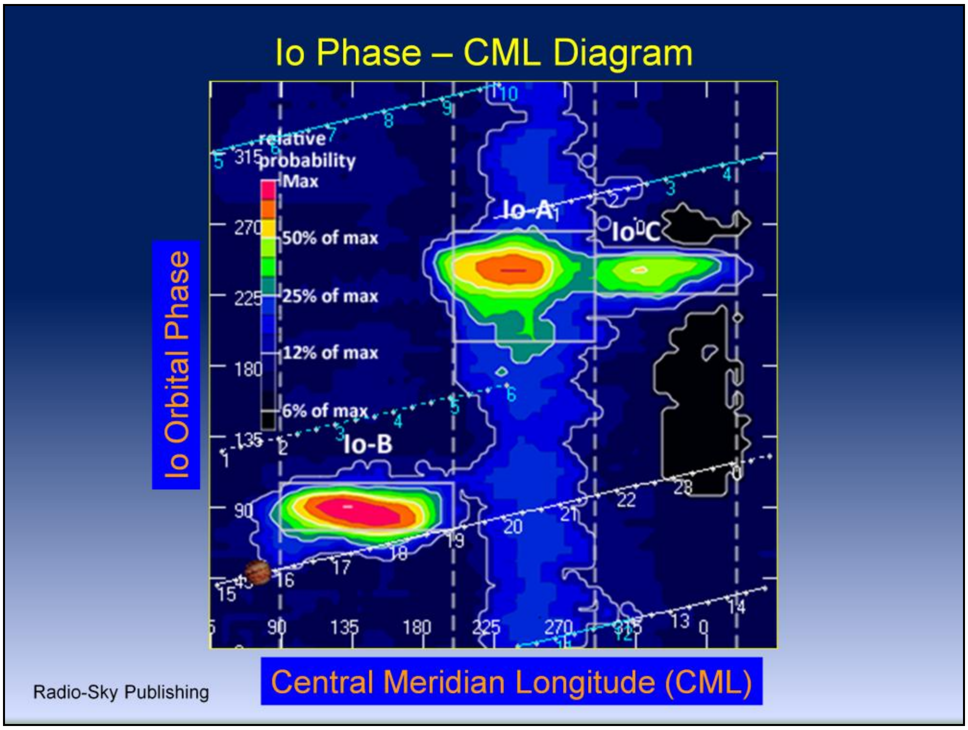
This is a strip chart recording of some 20 MHz radio S-burst emissions from Jupiter. These S-bursts sound like popcorn popping in a microwave. Also shown/heard are the S-bursts recorded at high speeds over a few MHz bandwidth and played back at 128 times slower. The high-to-low frequency whistling demonstrates that the electrons are moving up magnetic field lines, away from Jupiter after reflecting at the mirror points.



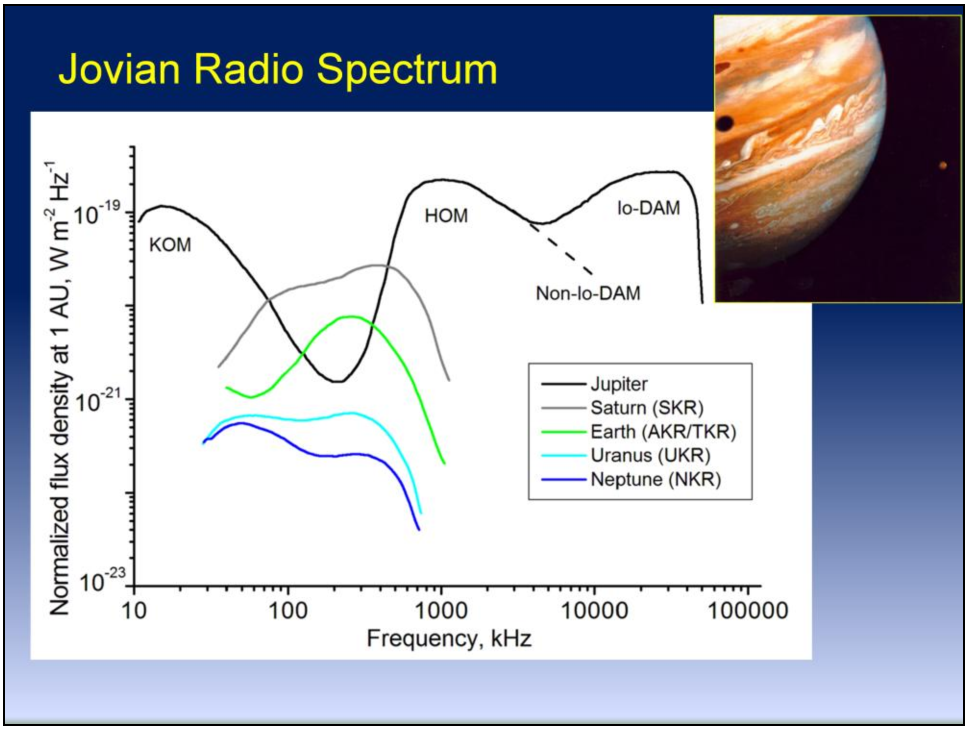
Jupiter’s radio emission probability of occurrence has been mapped over many months and years of observations. Three main source areas have be found and are labeled A, B, and C in Jupiter’s longitude system. The Central Meridian Longitude (CML) is defined to be the longitude of Jupiter that is facing the observer (usually Earth) based on a fixed rotation period. Actual occurrence probability data from 1962-63 is shown in the lower graph.



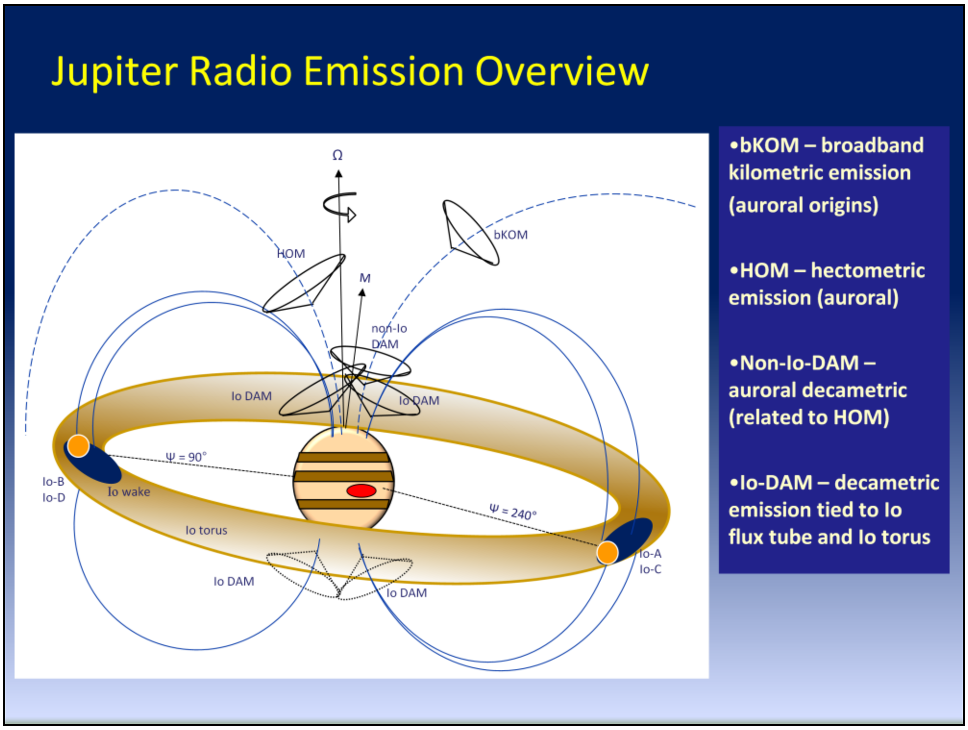
As mentioned earlier, it was also found that the orbital position of Io influence the radio emission. This is a video animation of the A, B, and C source geometries and their dependence on Io.



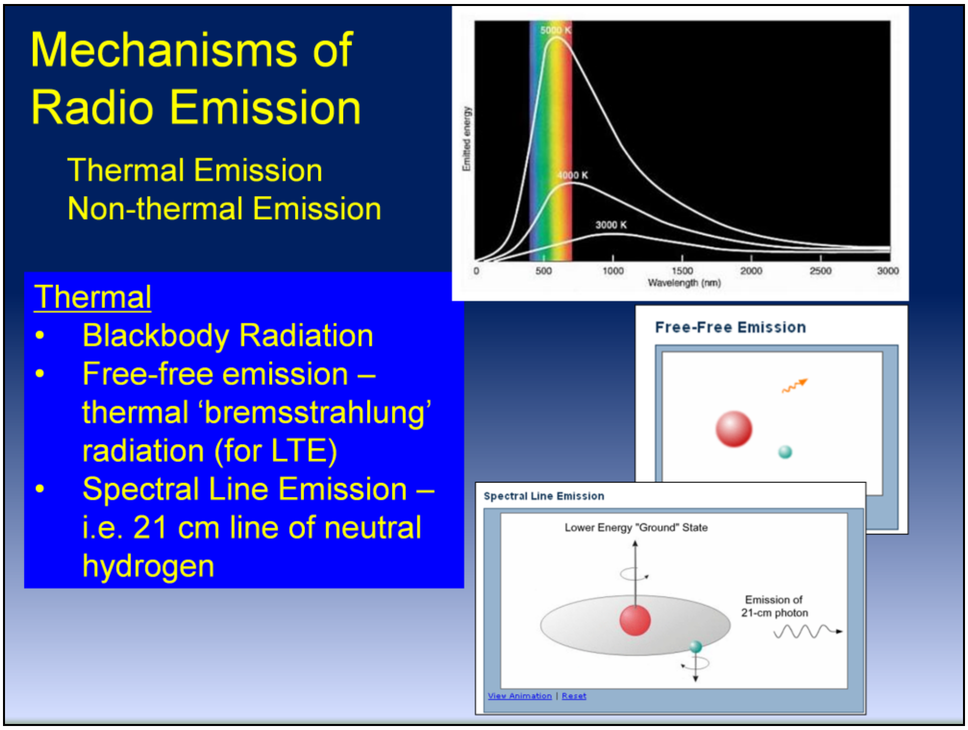
This a map of the probability of receiving Jupiter's radio emissions at and near 20 MHz. The y-axis shows the Io orbital position and the x-axis is the Jupiter longitude. High probability regions are shown in red and yellow; they are labeled Io-B, Io-A, and Io-C.



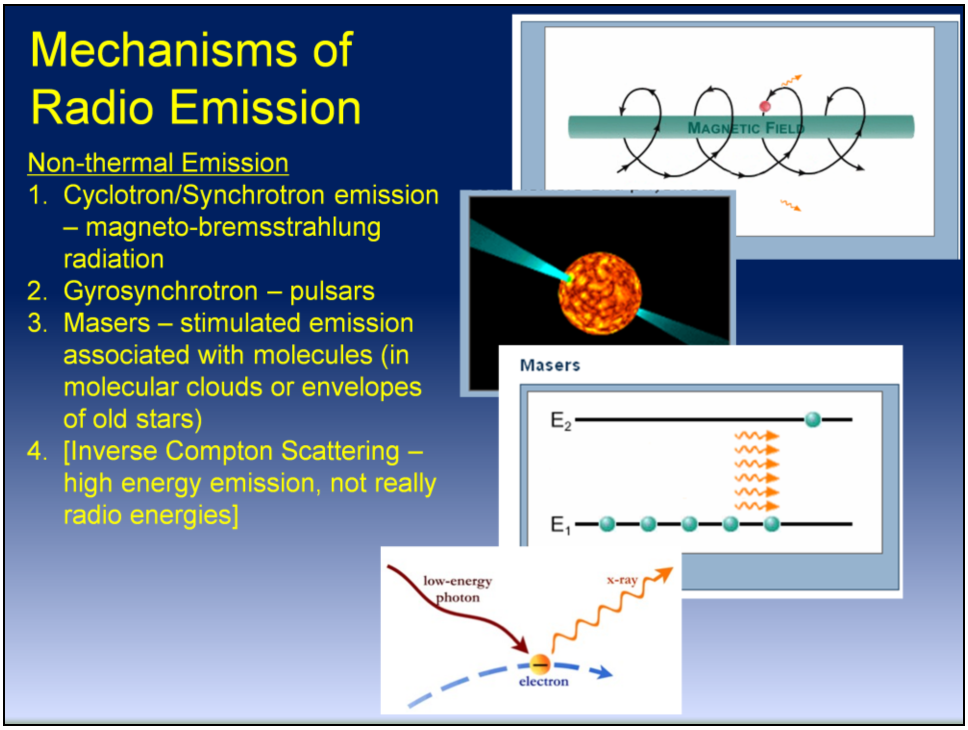
This graph shows the radio spectrum of Jupiter from about 10 kHz to 40 MHz. Plotted is the normalized flux density of the radio emission (at 1 AU distance) versus frequency. Jupiter kilometric radio emissions (KOM) and hectometer emissions (HOM) are shown along with the decameter emissions (DAM). DAM emissions are further separated as Io-dependent and non-Io dependent emissions. Also plotted for comparison are the radio spectra of Saturn, Earth, Uranus, and Neptune.



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.

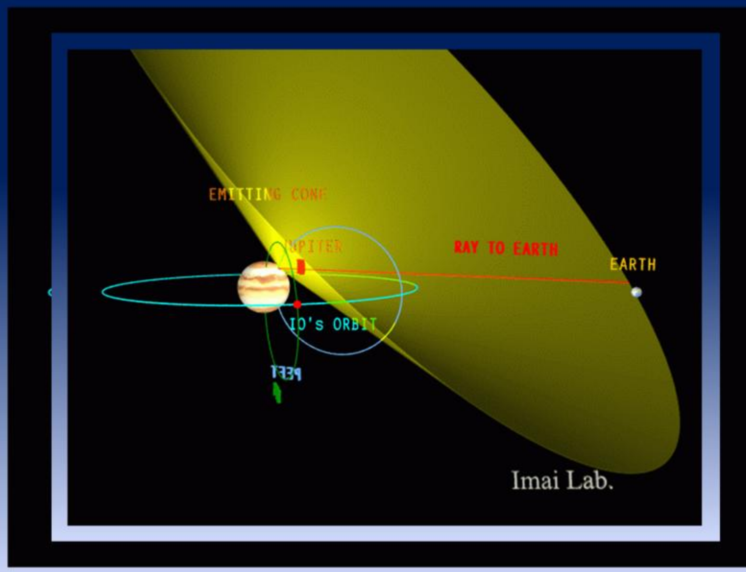


Radio waves can be generated by thermal and non-thermal sources. Thermal radio emissions are generated by blackbody radiation, electron-proton/nuclei interactions called free-free emission, and from spectral line emission from electronic transitions within the atom. The most famous radio emission is the 21 cm emission line from the electron "spin flip" transition in the hydrogen atom.

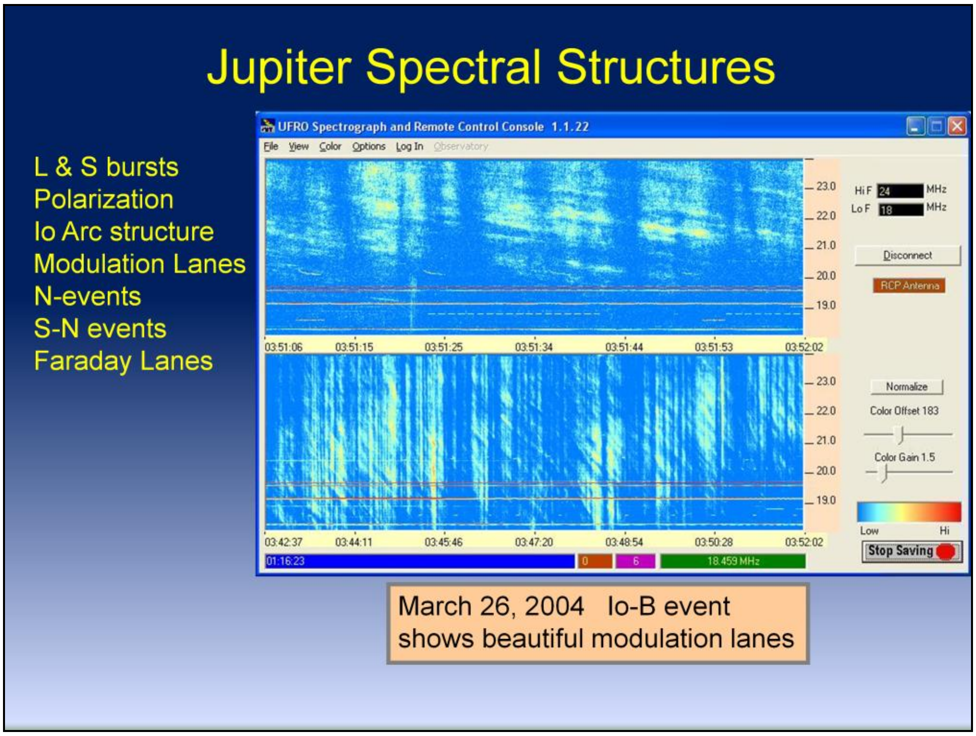


Non-thermal radio emissions are caused by spiraling electrons in a magnetic field. This magneto-bremsstrahlung radiation can come at non-relativistic (cyclotron) and relativistic (synchrotron) energies. Jupiter's emission is caused by the cyclotron emission mechanism. Other types of non-thermal emissions are masers in molecular clouds. Inverse Compton scattering is a non-thermal emission mechanism, but it is mainly an x-ray source.

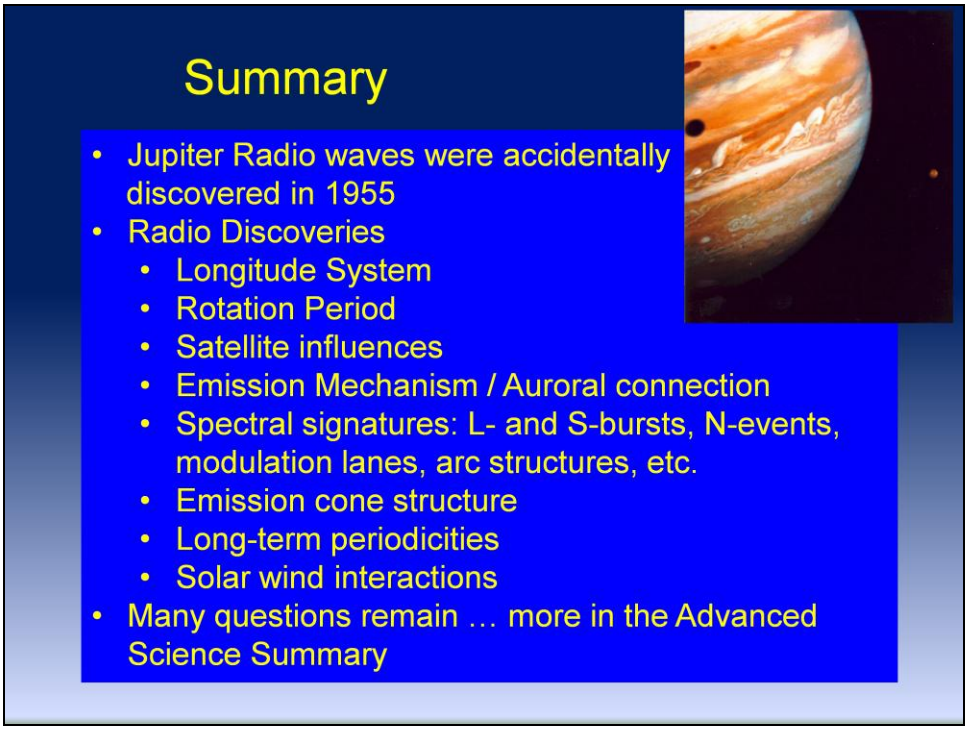
The Jovian Hollow Cone



This is an animation of Jupiter's emission as a hollow cone emanating from the source in the northern hemisphere. This example is one of an Io-related emission where the instantaneous flux tube (IFT) and previously energized flux tube (PEFT) are shown. These flux tubes carry electrons from Io to Jupiter and stimulate the radio emission.



The spectrograph allows scientists to analyze the nature of Jupiter's radio emission. This example shows a 6-MHz wide display of radio emissions versus time. The intensity is given as the color on the diagram. Many types of fine structures are seen in a spectrograph including L and S burst structures, arc-structures, modulation lanes, and N events, S-N event interactions, and Faraday lanes. These will be explained in a later talk.



A summary of Jupiter radio science.