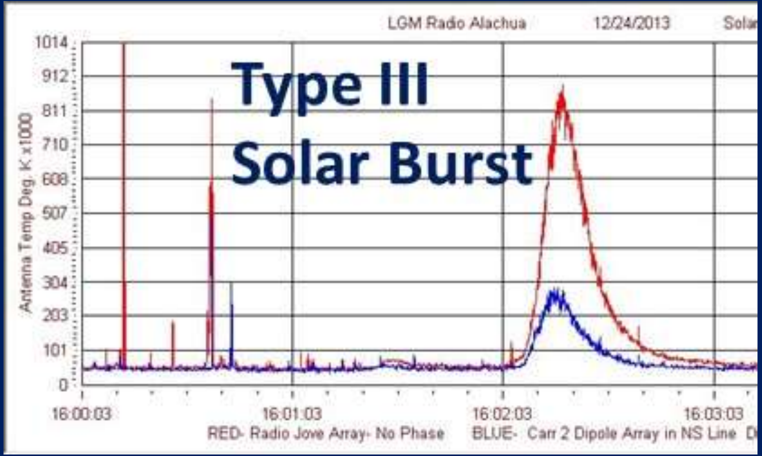
radiojove.gsfc.nasa.gov

The Radio Universe and The Radio JOVE Project

Chuck Higgins
Middle Tennessee State University



Goals:

- Overview the radio universe
- Citizen Science via radio astronomy and space physics
- Science literacy with NASA education partners (NSSEC)
- Provide a hands-on experience in radio astronomy
- Enable access to Online observatories and real data


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

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

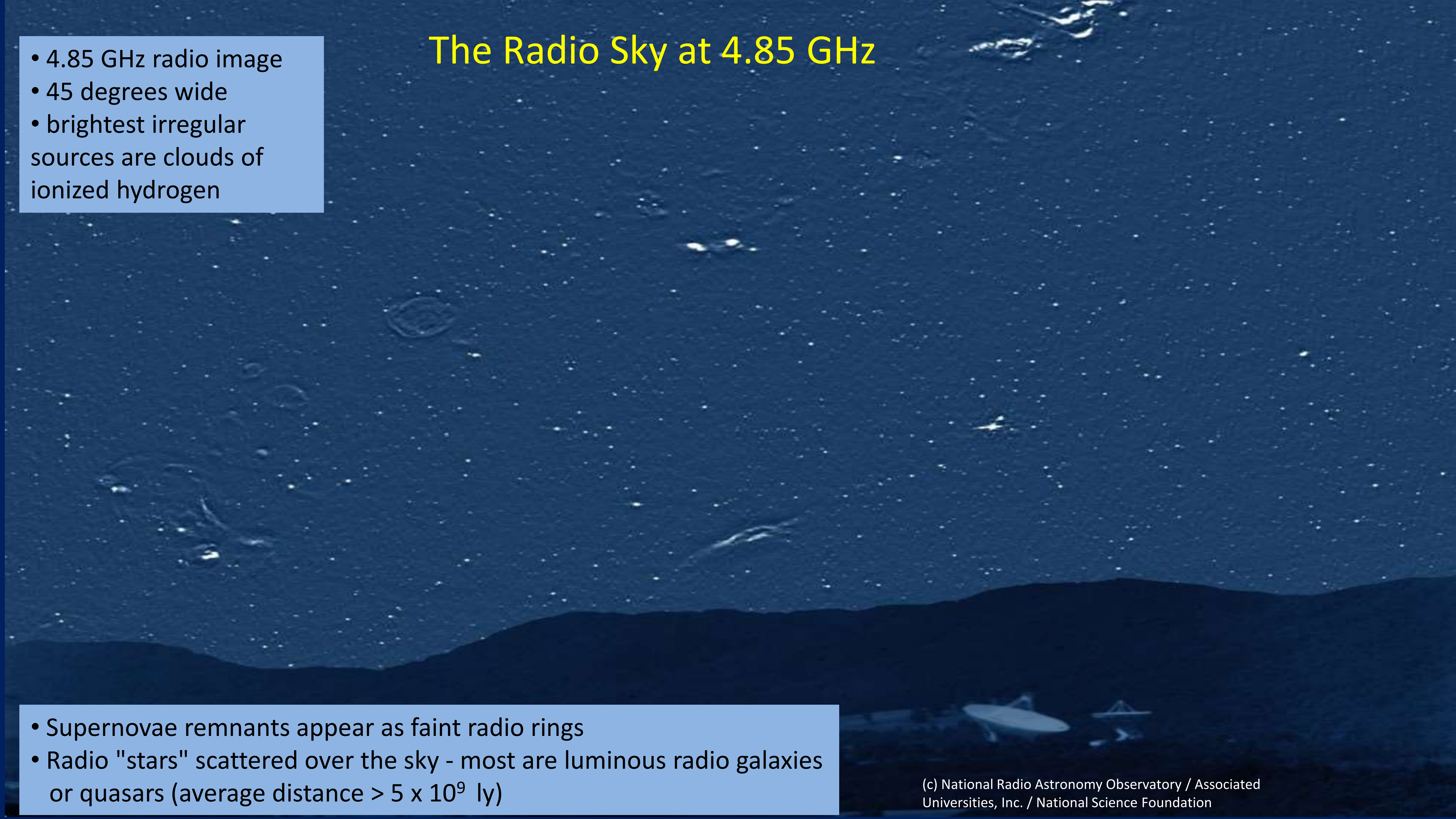
Dr. Chuck Higgins
Dept. of Physics & Astronomy
Middle Tennessee State University, P.O. Box 71
Murfreesboro, TN 37132
(615) 898-5946
higgins@physics.mtsu.edu

The Radio JOVE Project

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

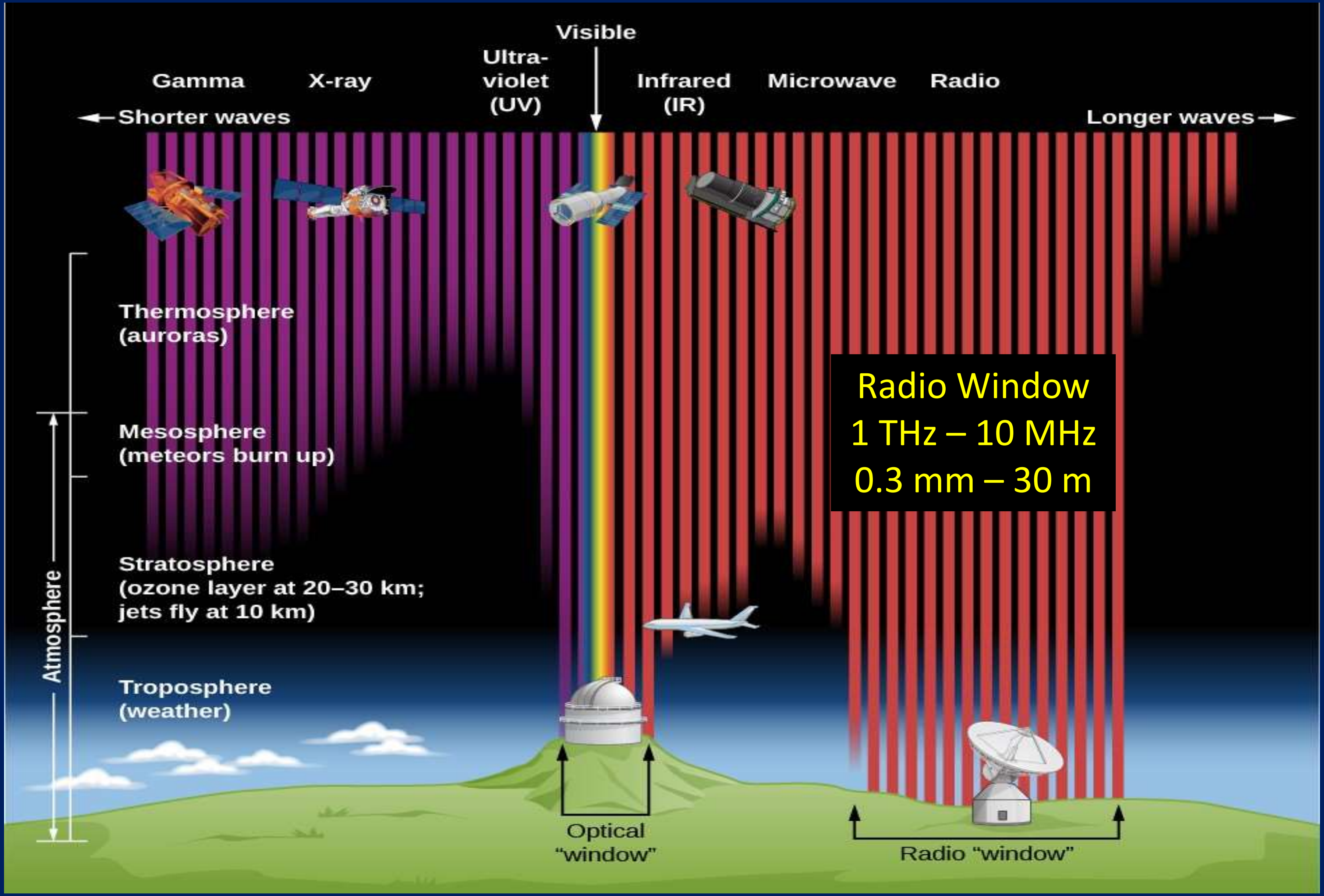
The Radio Sky at 4.85 GHz

- 4.85 GHz radio image
- 45 degrees wide
- brightest irregular sources are clouds of ionized hydrogen



- Supernovae remnants appear as faint radio rings
- Radio "stars" scattered over the sky - most are luminous radio galaxies or quasars (average distance > 5 x 10^9 ly)

Radio Window



Credit: Adapted from STScI/JHU/NASA

Radio Telescopes

Green Bank Telescope (NRAO, NSF)

Concept Drawing of the Square Kilometer Array, Australia

VLA, New Mexico (NRAO, NSF)

Fast Radio Telescope (China)
500 m dish

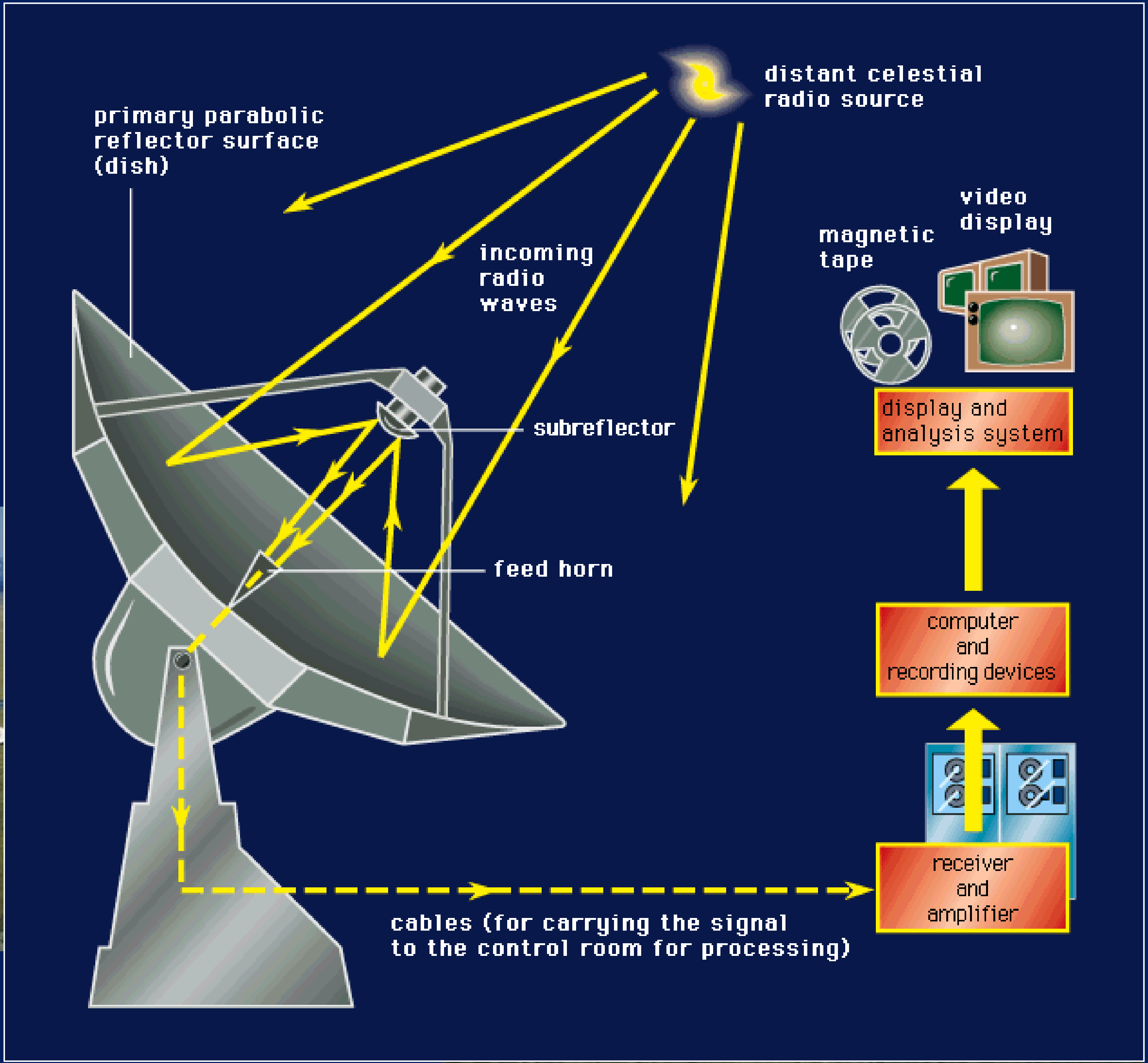
Itty Bitty Radio Telescope

Radio Telescopes

Green Bank Telescope (NRAO, NSF)

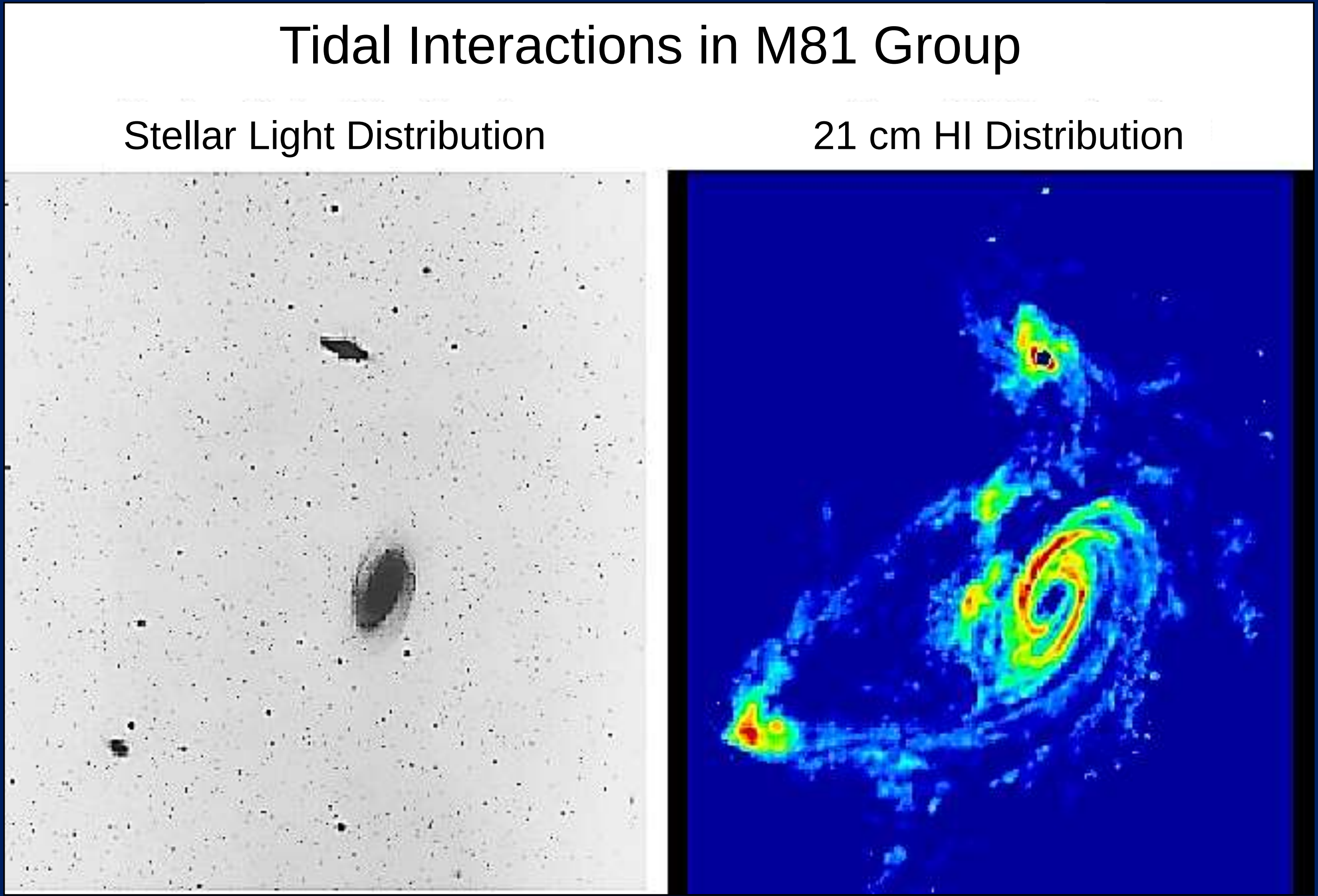
VLA,

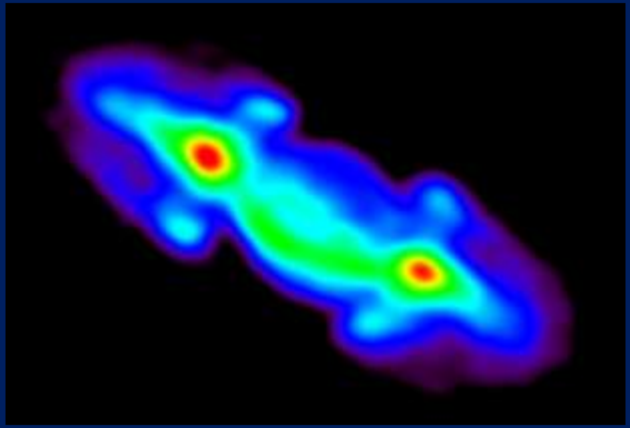
Itty Bitty Radio Telescope



Why Radio Astronomy?

- Some objects are “invisible” at Earth and in space
- We can learn something new about the universe





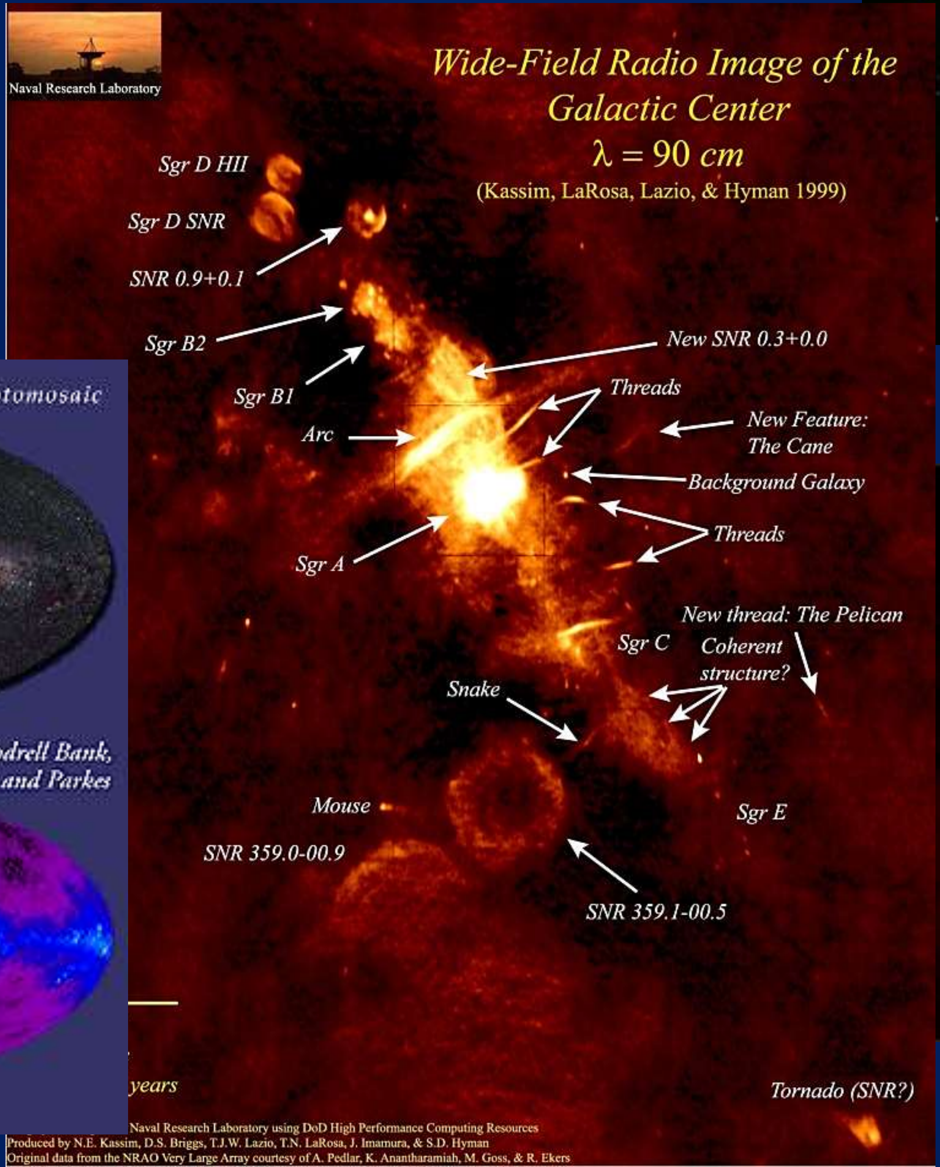
Jupiter (GHz)

M81
Galaxy Group

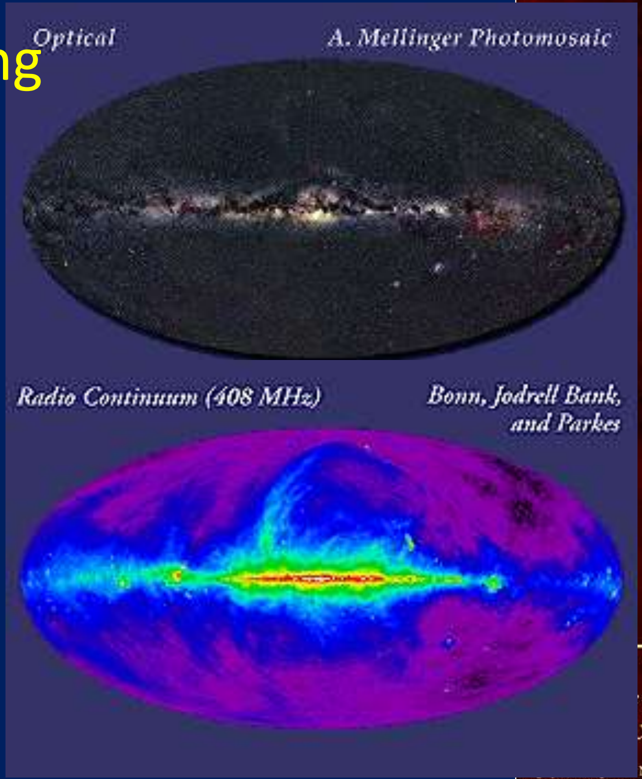
Major Discoveries

- Radio Galaxies – powered by black holes
- Cosmic Microwave background
- Gravitational radiation
- Cold interstellar gas
- Neutron stars (pulsars)
- Exoplanets
- Gravitational lensing
- Gravity Waves?

The Galactic center



The Galaxy



Centaurus A

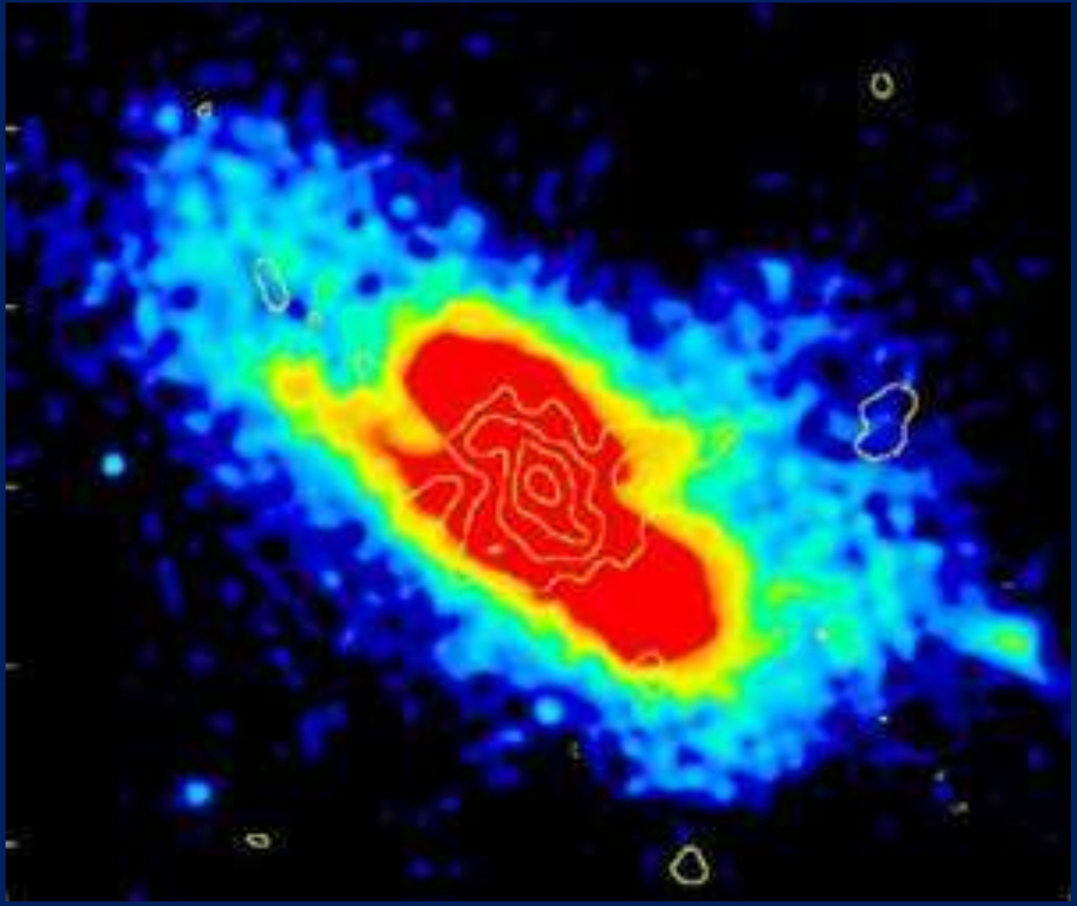
Planetary Disk

HL Tau (ALMA)

Sources of Radio Emission

- Solar System - sun, planets
- Milky way - star forming regions, old stars, supernova remnants
- Extragalactic - quasars, radio jets
- Molecules

Quantitatively, an image is really a radio intensity distribution map



Emission Mechanisms

- Thermal Emission – blackbody radiation, free-free emission, spectral lines
- Non-thermal emission – cyclotron, synchrotron, gyrosynchrotron, masers

Nebulae in Orion

Image 1: Optical “image” from a planetarium program showing the stars of Orion – green outlines the nebulae

Nebulae in Orion

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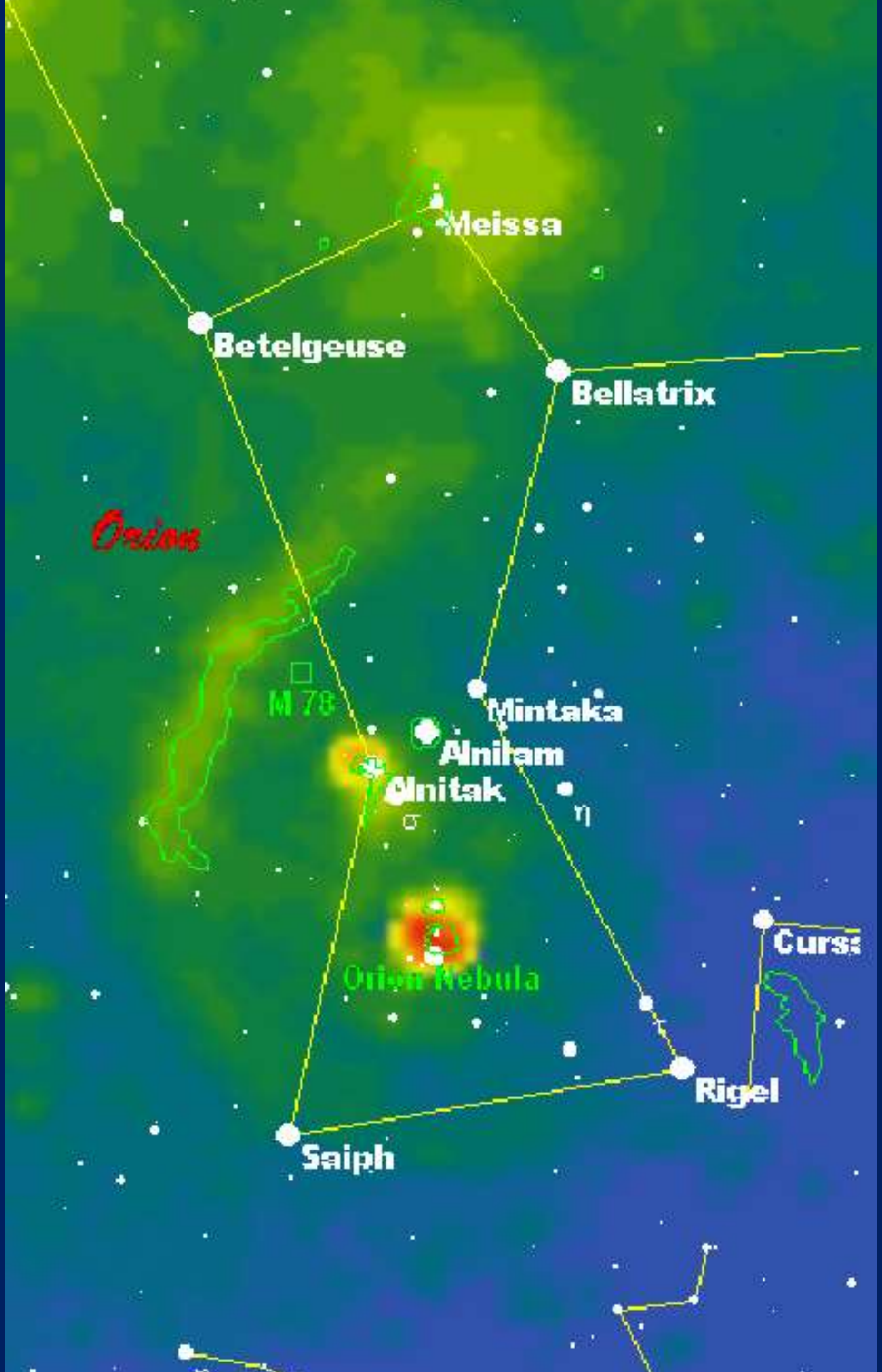

Nebulae in Orion

Image 1: Optical "image" from a planetarium program showing the stars of Orion – green outlines the nebulae

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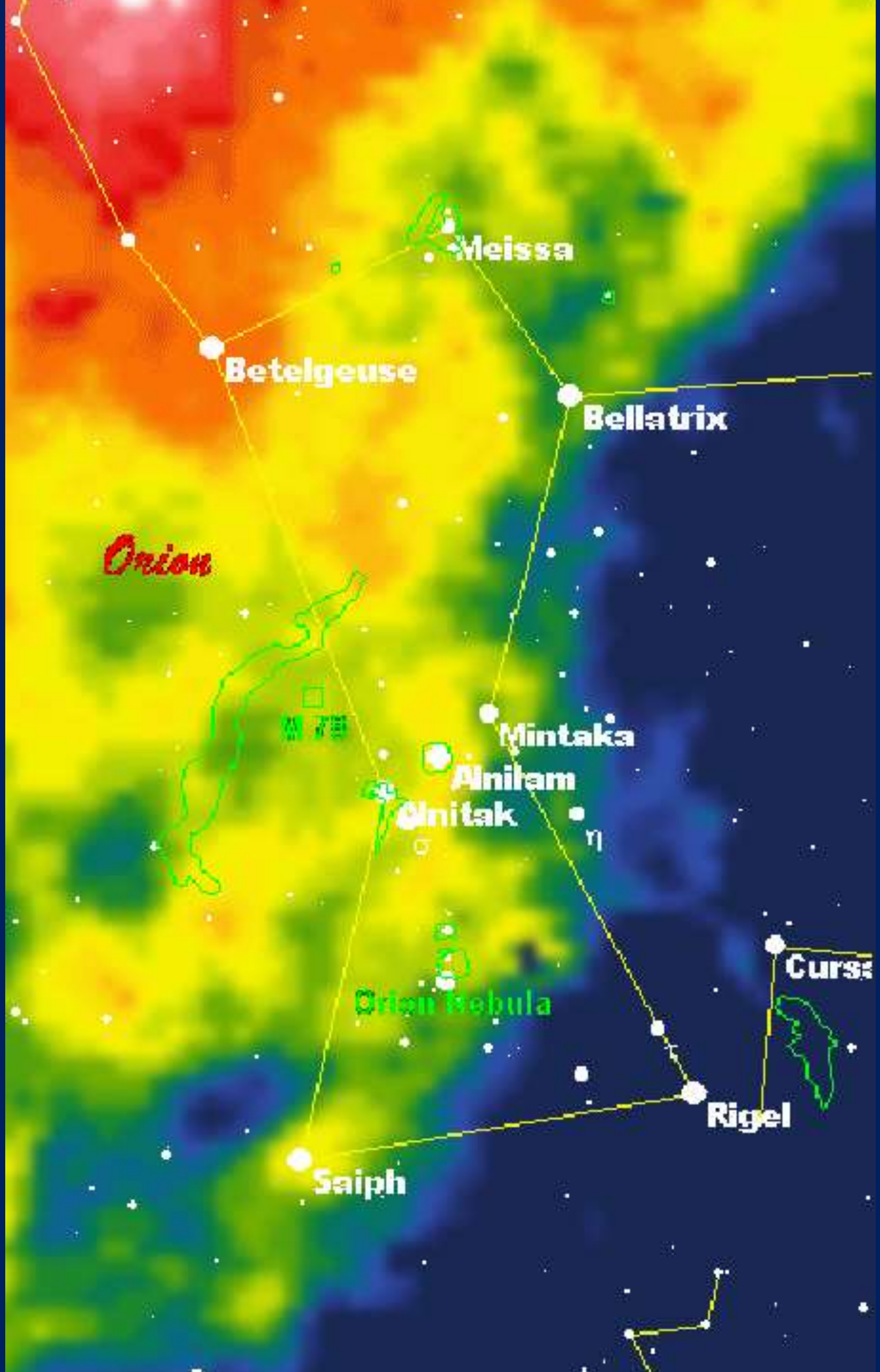
Image 3: Atomic hydrogen. Very different. Galactic plane begins in the upper left.



Nebulae in Orion

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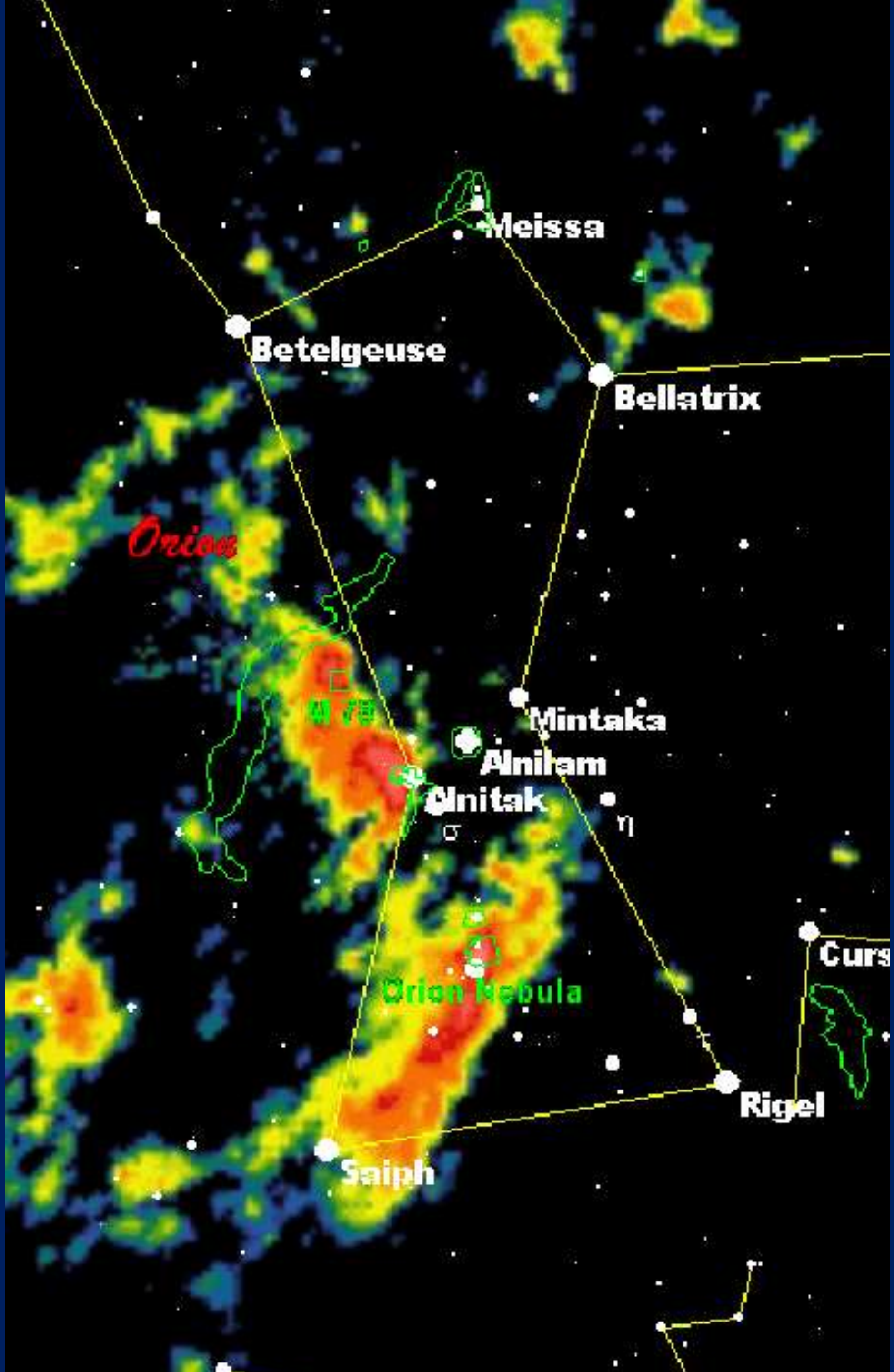
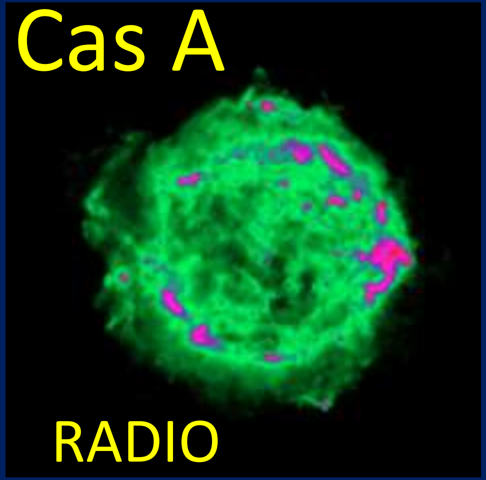
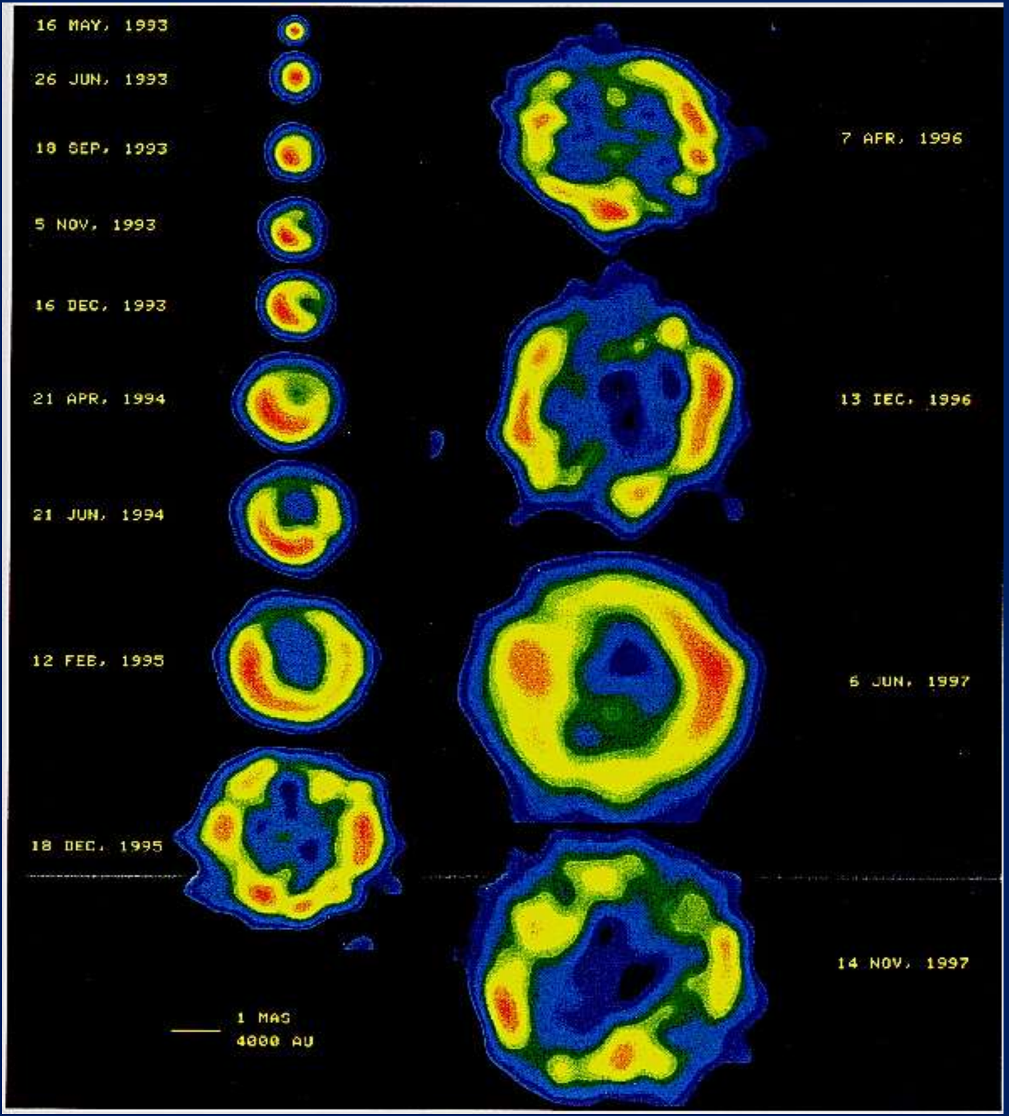
Image 4: Molecules (Carbon monoxide) shows giant molecular (H_2) clouds where new stars form.



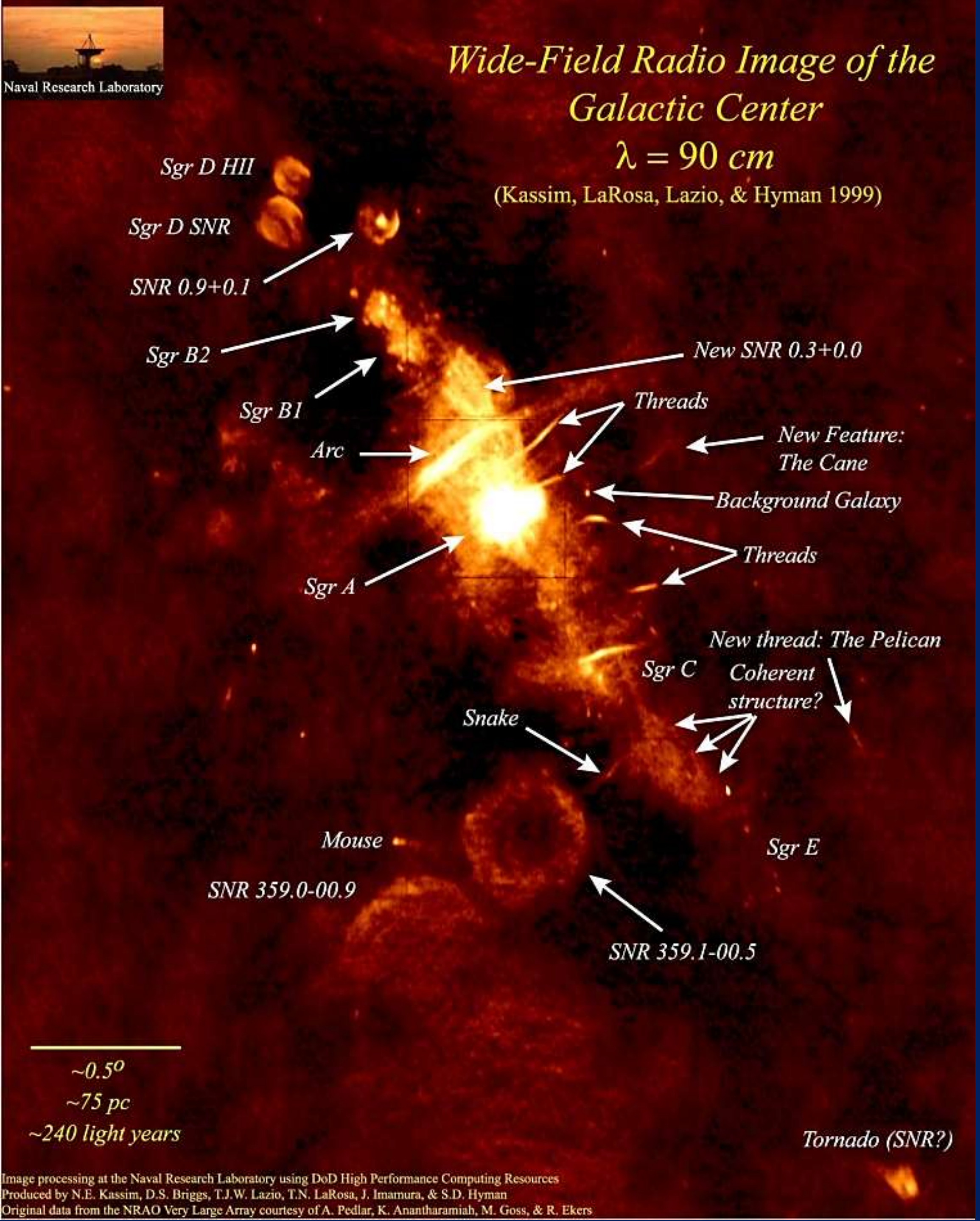
Stellar Phenomena – pulsars, supernovae



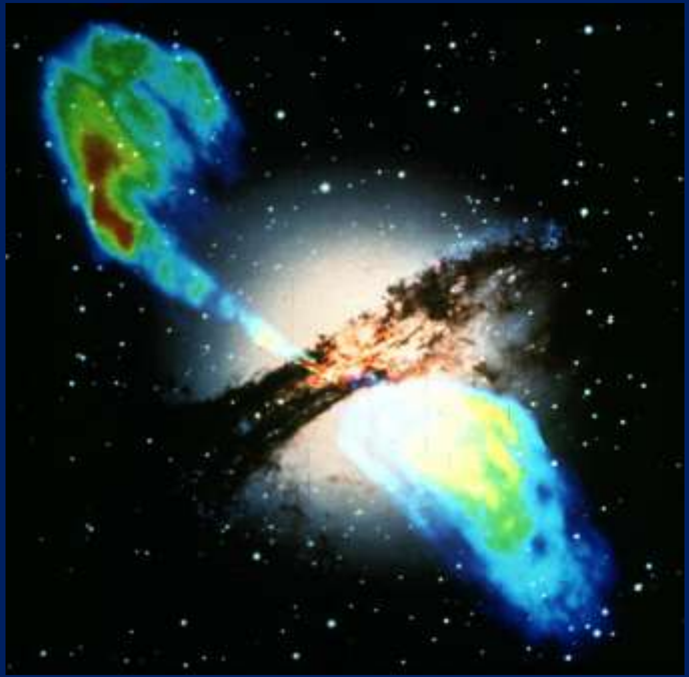


8 GHz VLBI sequence of a supernova in M81 (1993-1997)

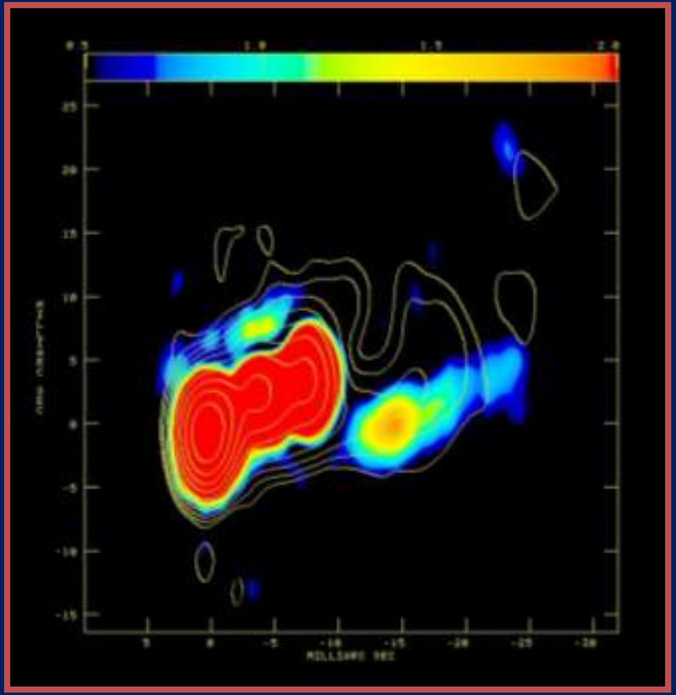
Galaxies



The Galactic center



Centaurus A

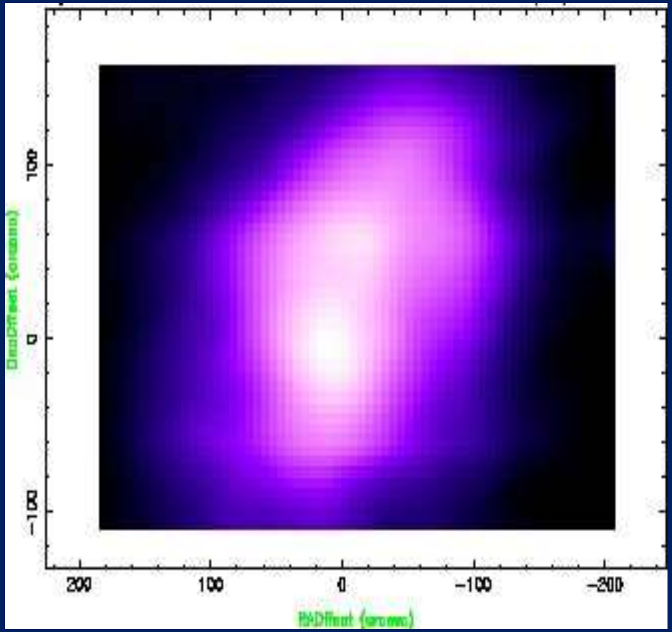


Blazar 1055+018

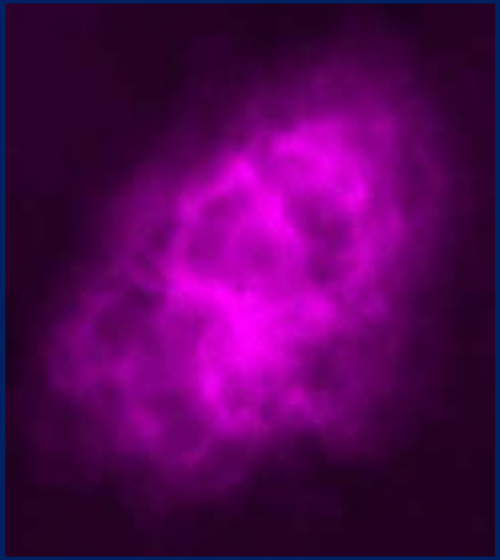
Active Galactic Nuclei

Resolution - Interferometry

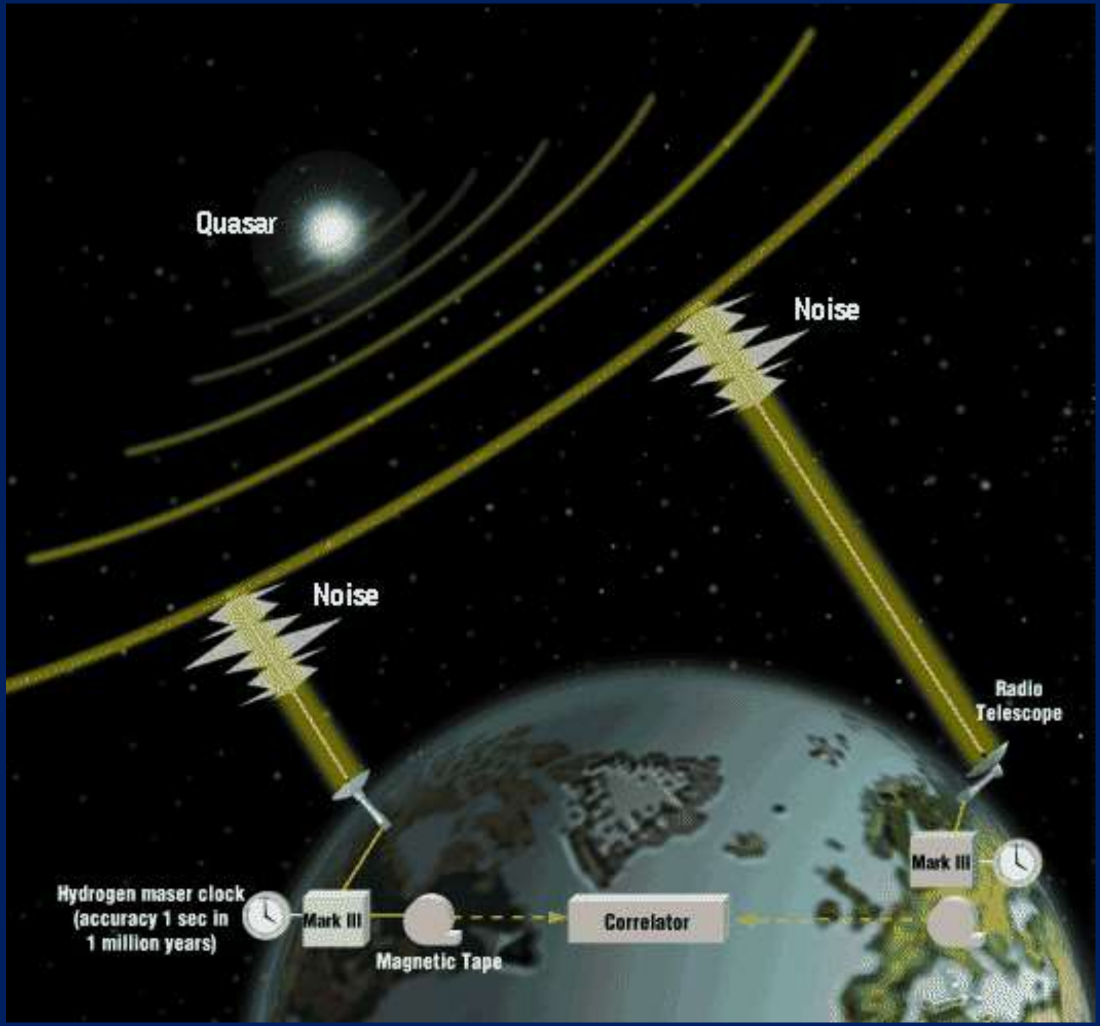
Radio image from Haystack 37-m single dish telescope at a frequency of 43 GHz



Radio image made with the 27-element Very Large Array.



M1 Supernova Remnant



Supermassive Black Hole

First Image of a Supermassive Black Hole
A supermassive black hole lies at the heart of the galaxy M87, about 55 million light-years distant in the Virgo cluster of galaxies. A glowing disk of light is bent around the black hole by its enormous gravity.

Supermassive Black Hole

Credit: Event Horizon Telescope Collaboration
https://eventhorizontelescope.org/

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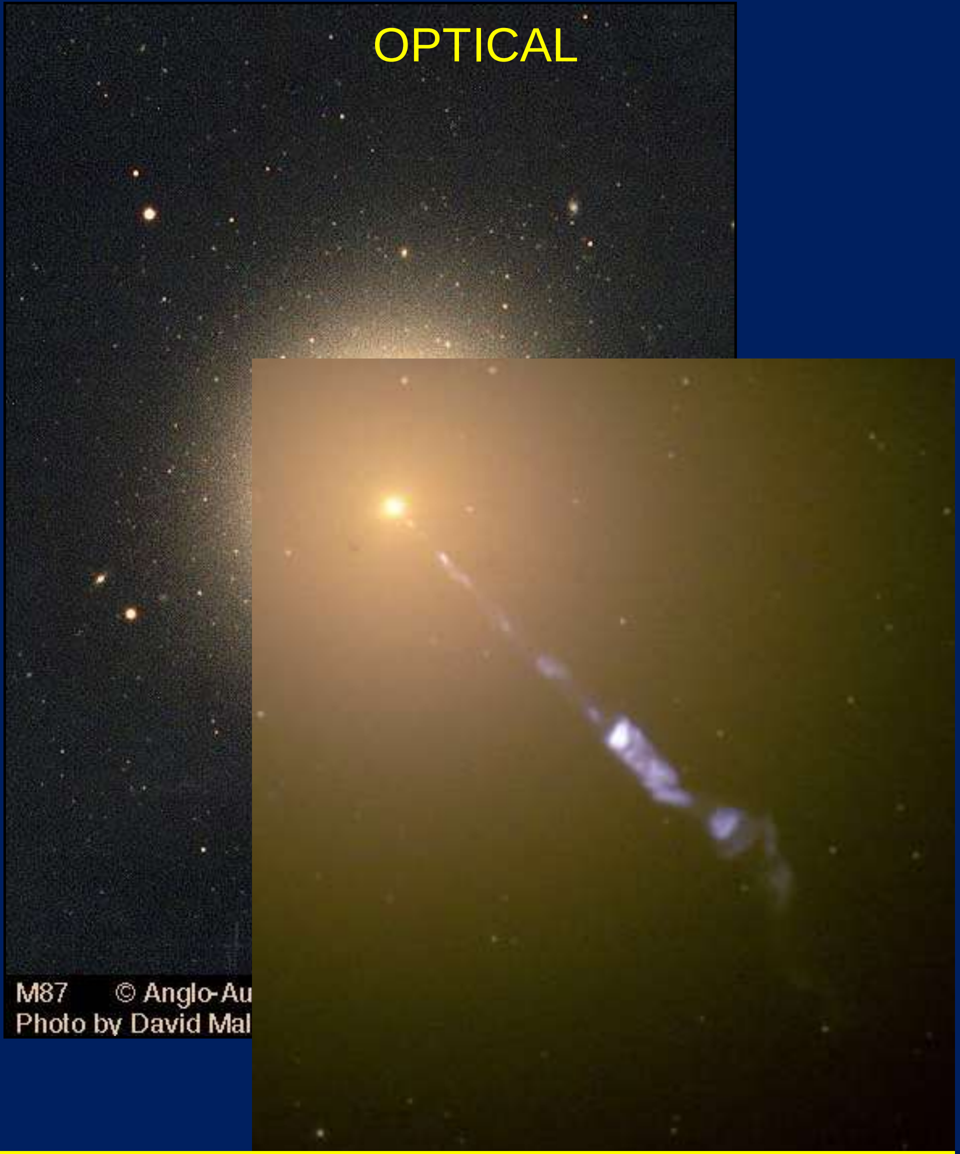
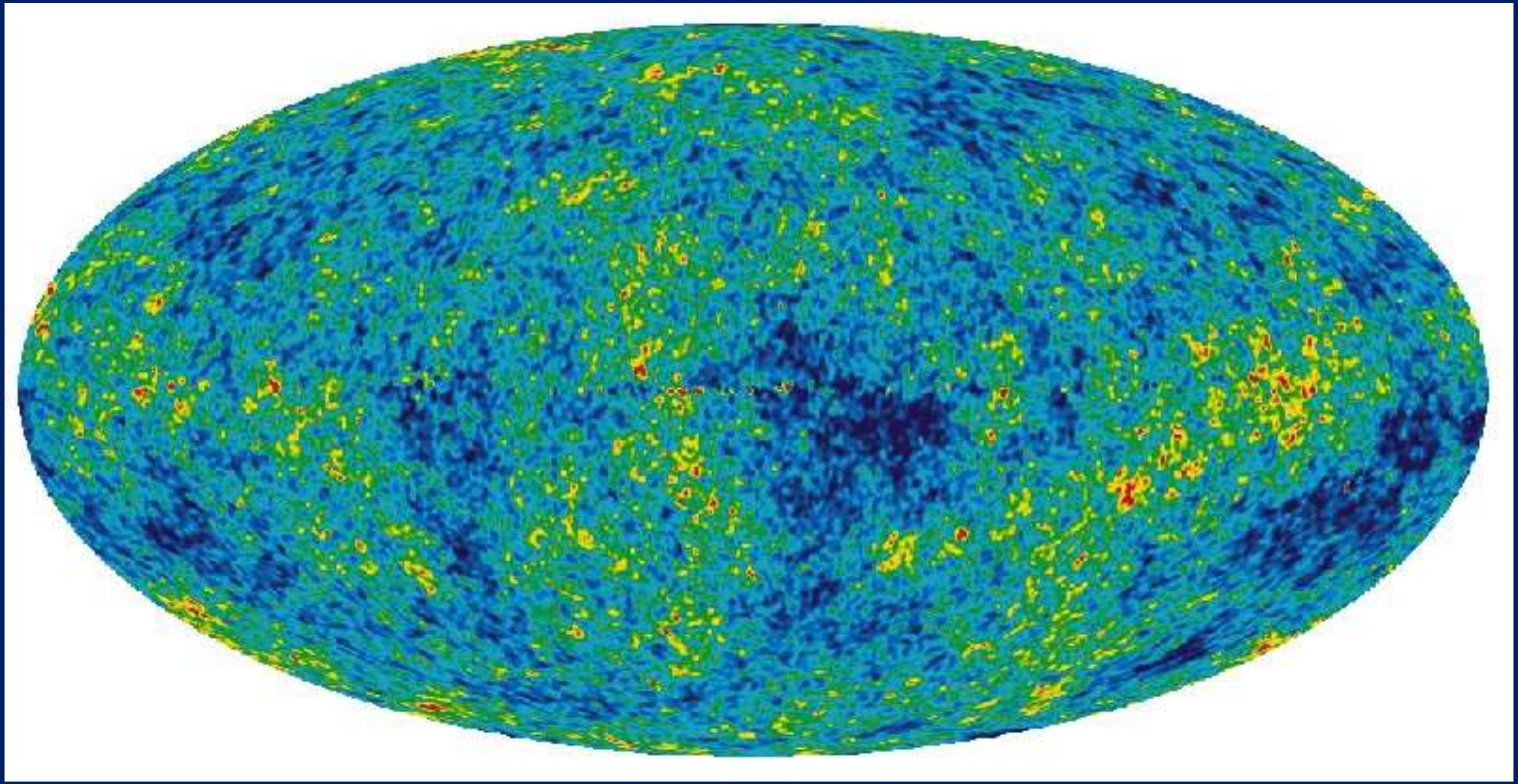


M87 black-hole-powered jet of subatomic particles.***Credits: NASA and (STScI/AURA)***

The Universe



Cosmic Microwave Background
at 22 – 90 GHz

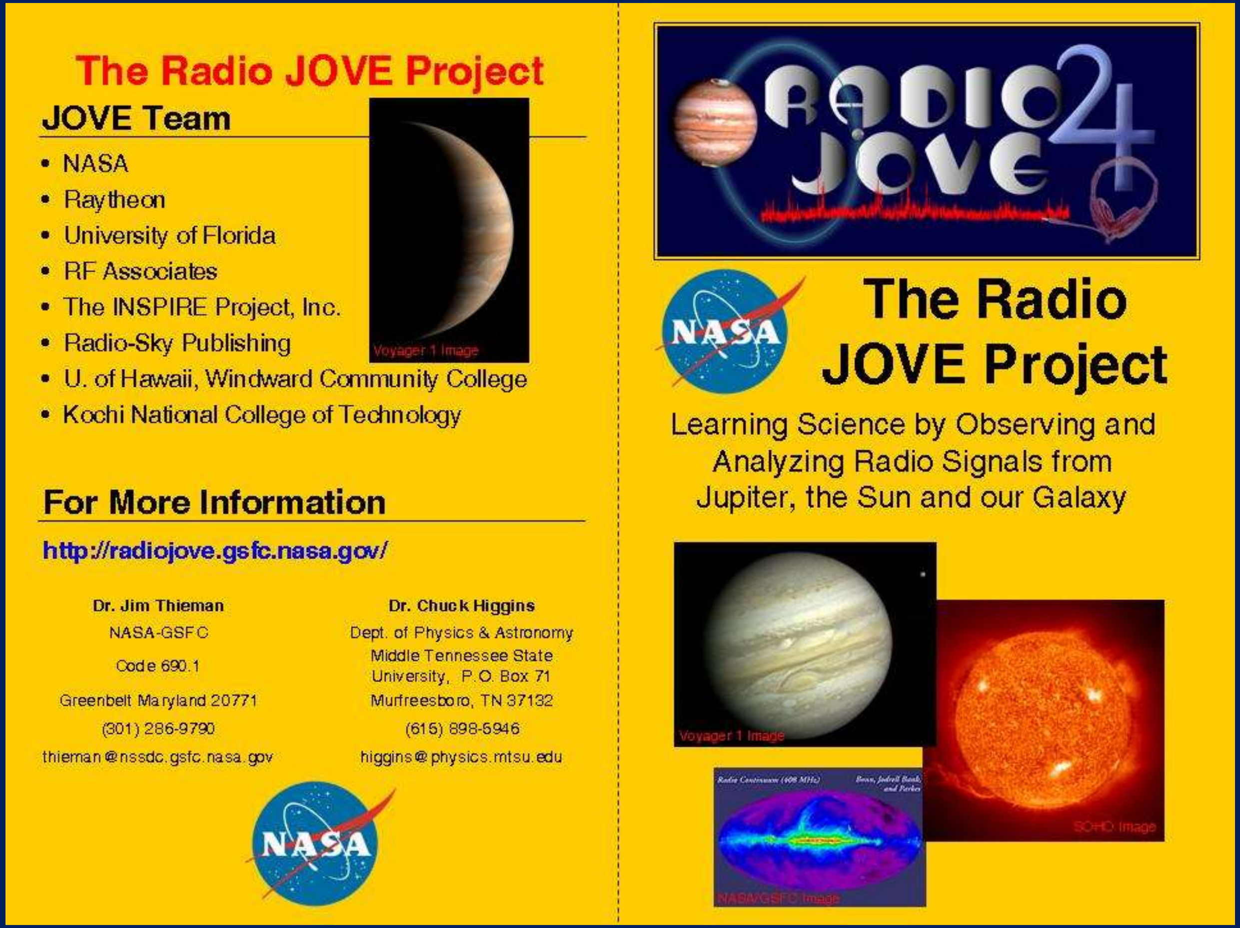
Credit: NASA/WMAP Science Team

The Radio JOVE Project

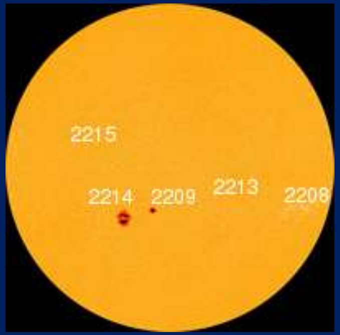
radiojove.gsfc.nasa.gov

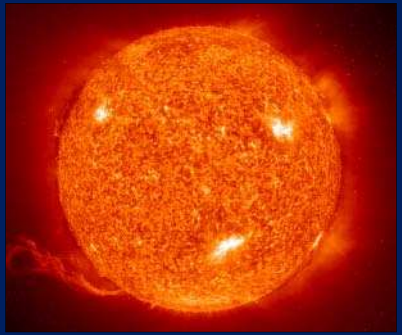
MIDDLE TENNESSEE STATE UNIVERSITY

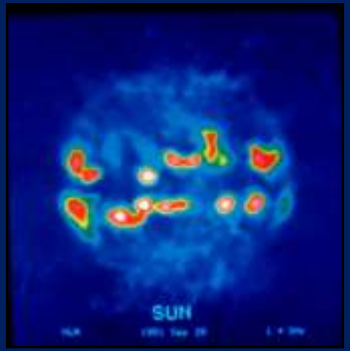
NSSEC NASA SPACE SCIENCE EDUCATION CONSORTIUM

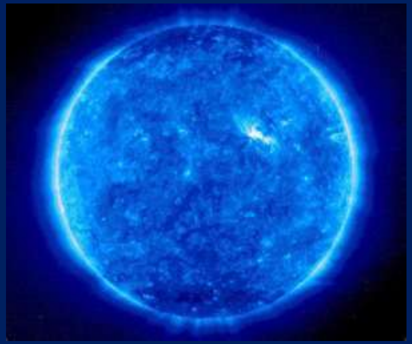


Radio Sun

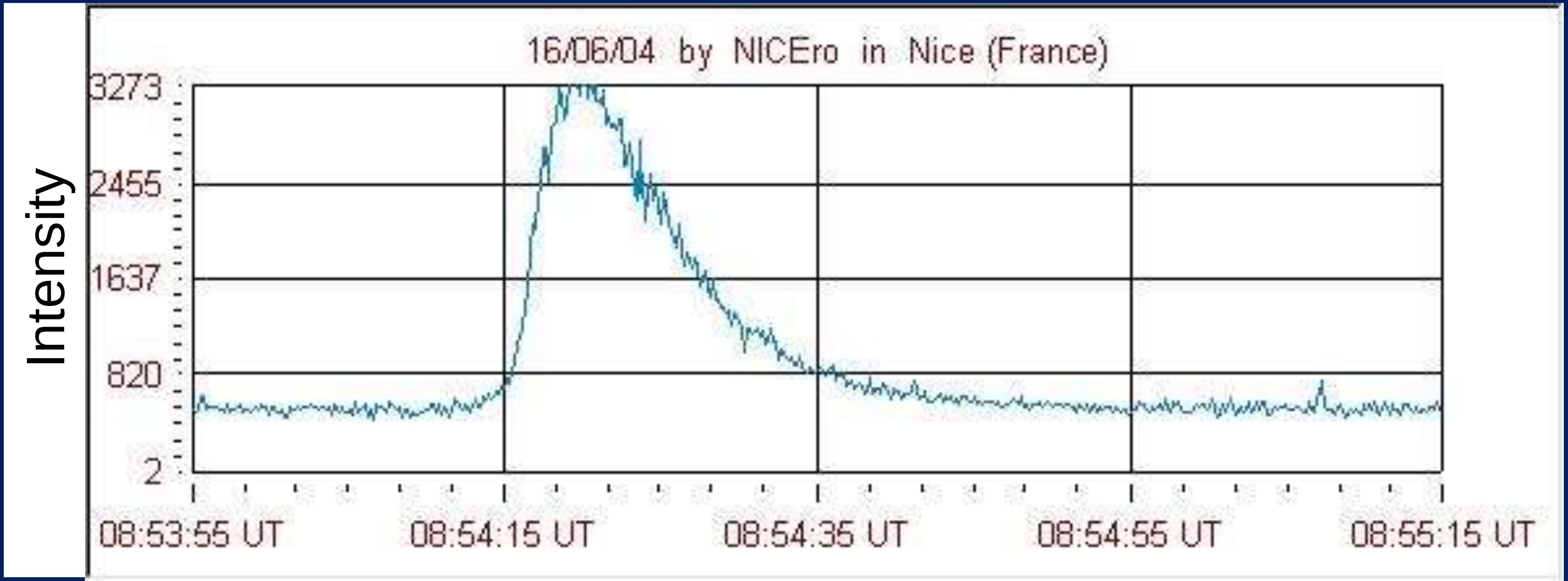






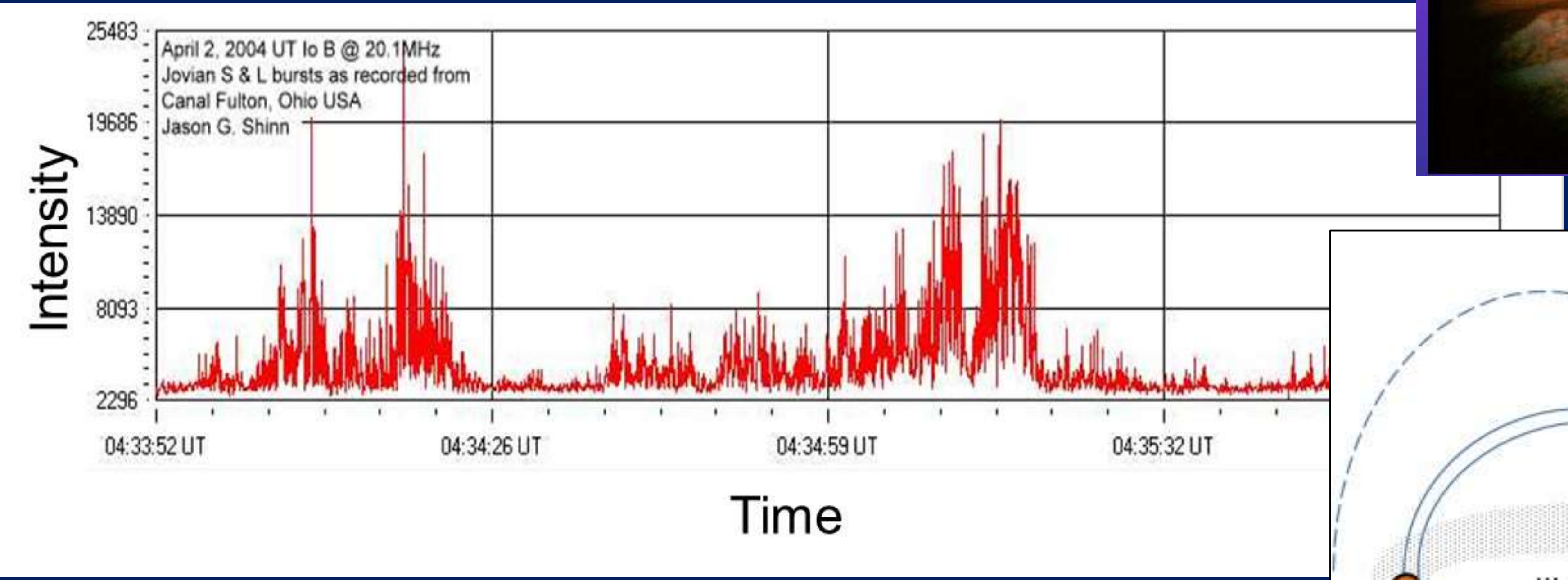


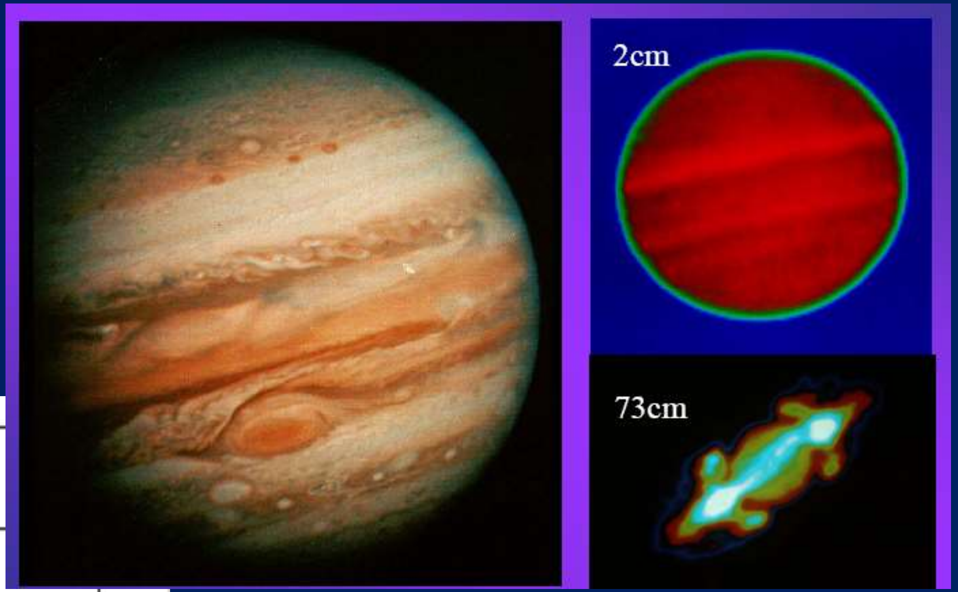
Solar Radio Burst at 20 MHz – notice the sharp rise and the gradual decline of the burst. This is typical of Type III solar bursts.

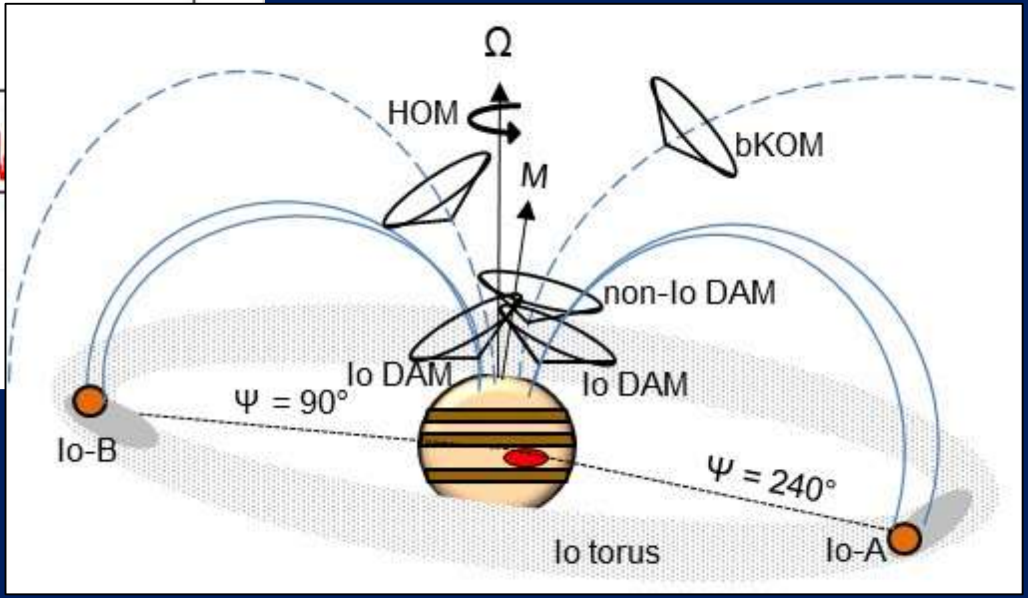


Radio Jupiter

Jupiter S-bursts are the short popcorn popping sounds in this Io-B storm







Jupiter S-bursts

Slowed down by 128x

Radio Jove Participants

1999 - present

70 Countries have participated in Radio Jove
More than 2400 kits sold

- Citizen Scientists
- Interested amateurs
- High Schools
- Colleges & Universities

Mexico

Japan

Ethiopia

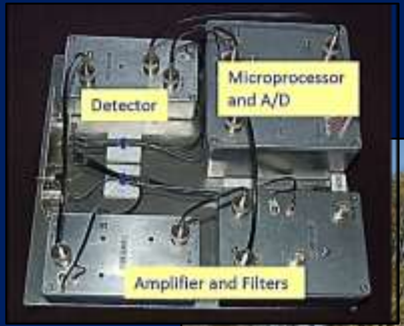
India

Hardware and Software

Radio Jove
20 MHz Receiver

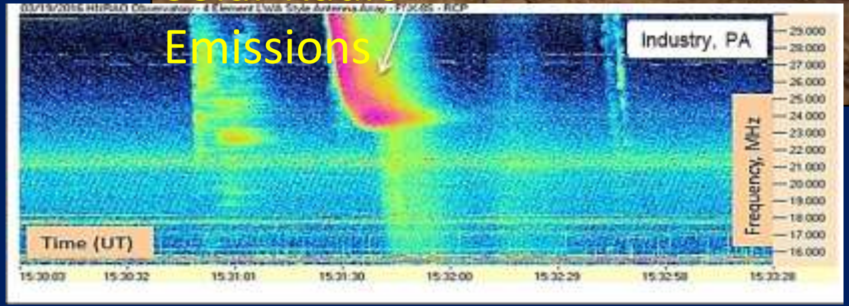
Dual Dipole Antenna

- You build it
- You operate it
- You collect data
- You analyze data
- You archive data
- You do science

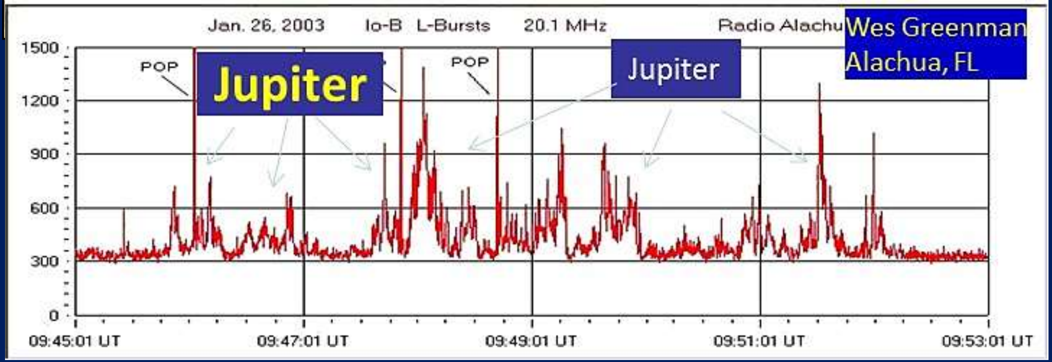


Spectrograph and Wide Band Antenna

Solar Radio Emissions



Observing Software from **Radiosky.com**



Observing Software from **Radiosky.com**

Basic System

- 20 MHz Receiver
- Dipole Antenna
- Recording and Analysis Software
- $300 + computer

Advanced Systems

- 15-30 MHz Radio Spectrograph
- Software Defined Radio (SDR)
- Spectrograph Software
- $2500 + computer

Space Science Education Partners

Partner #1. **NASA Space Science Education Consortium (NSSEC)**
- 26 Space Science Education Partners
- Collaborate in Education and Public Outreach

Partner #2. **Citizen Scientists**
- 11 spectrograph stations established in the USA
  Jupiter/Solar radio emissions, ionosphere, and space weather
- Society of Amateur Radio Astronomers (SARA)

Partner #3. **Juno Mission**
- Support the Juno Mission with observations
- Collaborate with professional radio observatories

Partner #4. **Worldwide Data Archives**
- NASA-Planetary Data System (PDS)
- Virtual Wave Observatory (heliophysics wave data)
- VESPA – Virtual European Solar and Planetary Access


Radio JOVE Archive Calendar

Radio JOVE Homepage — Return to Welcome Page

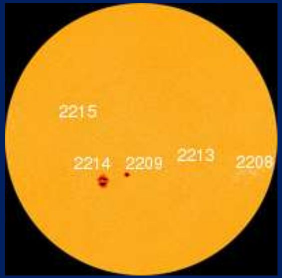
Return to Current Year & Month

<-- previous month | --Month-- | --Year-- | show | next month -->

May 2019

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 Sun	2	3	4
5 Galactic Background	6 Galactic Background Sun	7 Sun	8	9	10 Galactic Background	11
12 Galactic Background	13	14	15	16	17	18
19	20	21	22	23 Jupiter	24	25
26	27	28	29 Galactic Background	30 Galactic Background Jupiter	31 Galactic Background	

Research and Projects

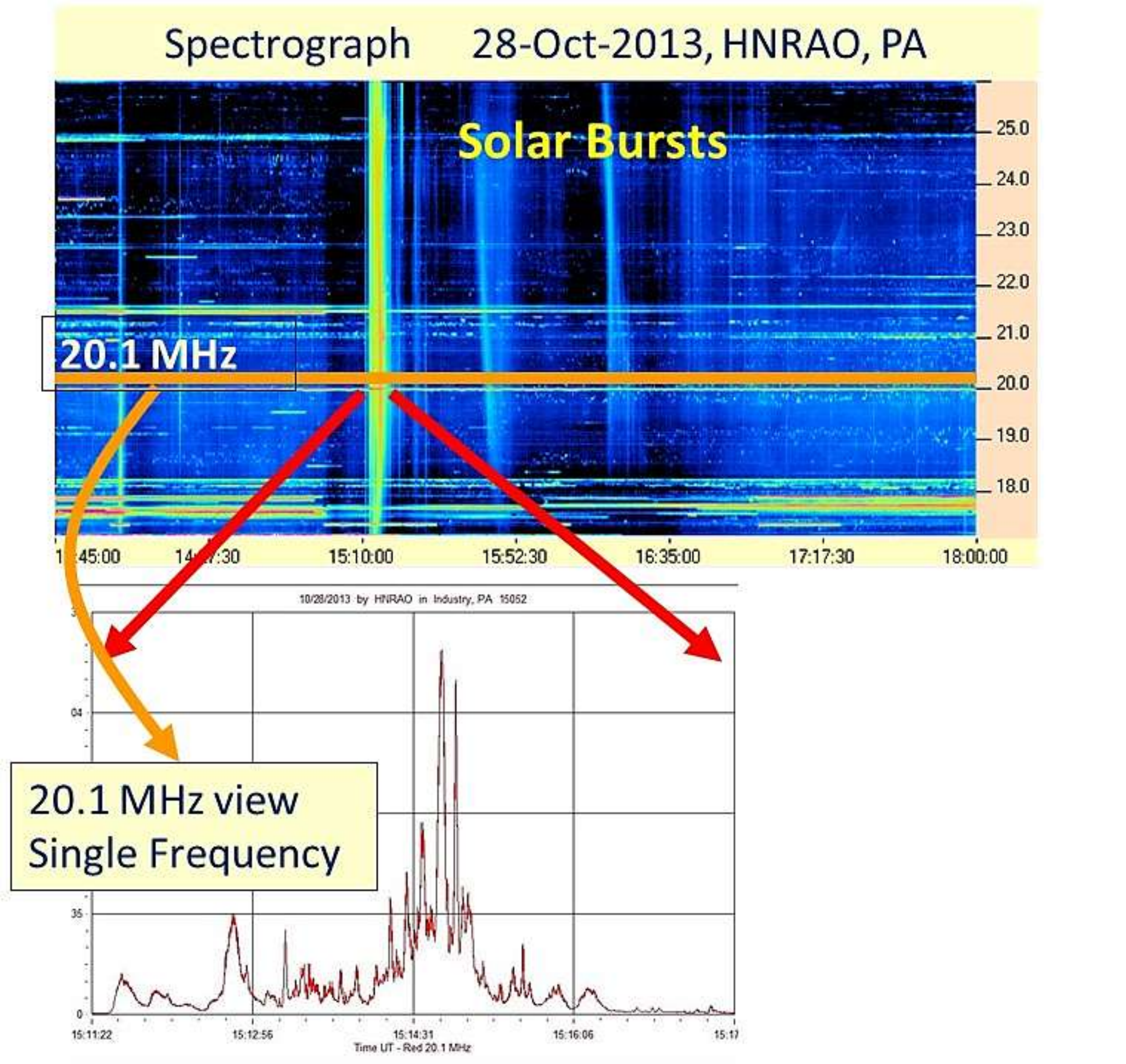


Research Interests

- Jupiter Radio Emission Structure
- Solar Radio Emissions
- Ionosphere Radio Wave Propagation
- Milky Way Galaxy

Projects

- Build a radio telescope
- Make Observations (coordinated sessions)
- Analyze, Compare, and Archive Data
- Advanced Projects (spectrographs, ionosphere, long-term studies)

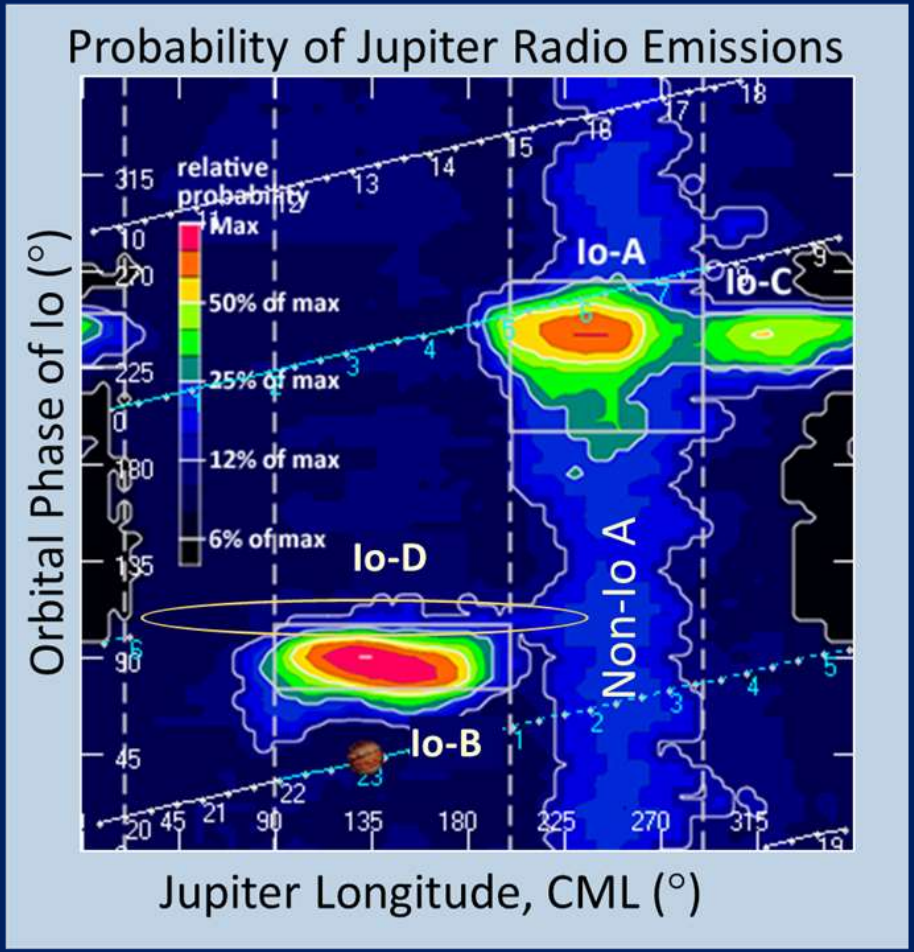


Comparison observations with a spectrograph (top) and a single frequency receiver (bottom). [Data from J. Brown]

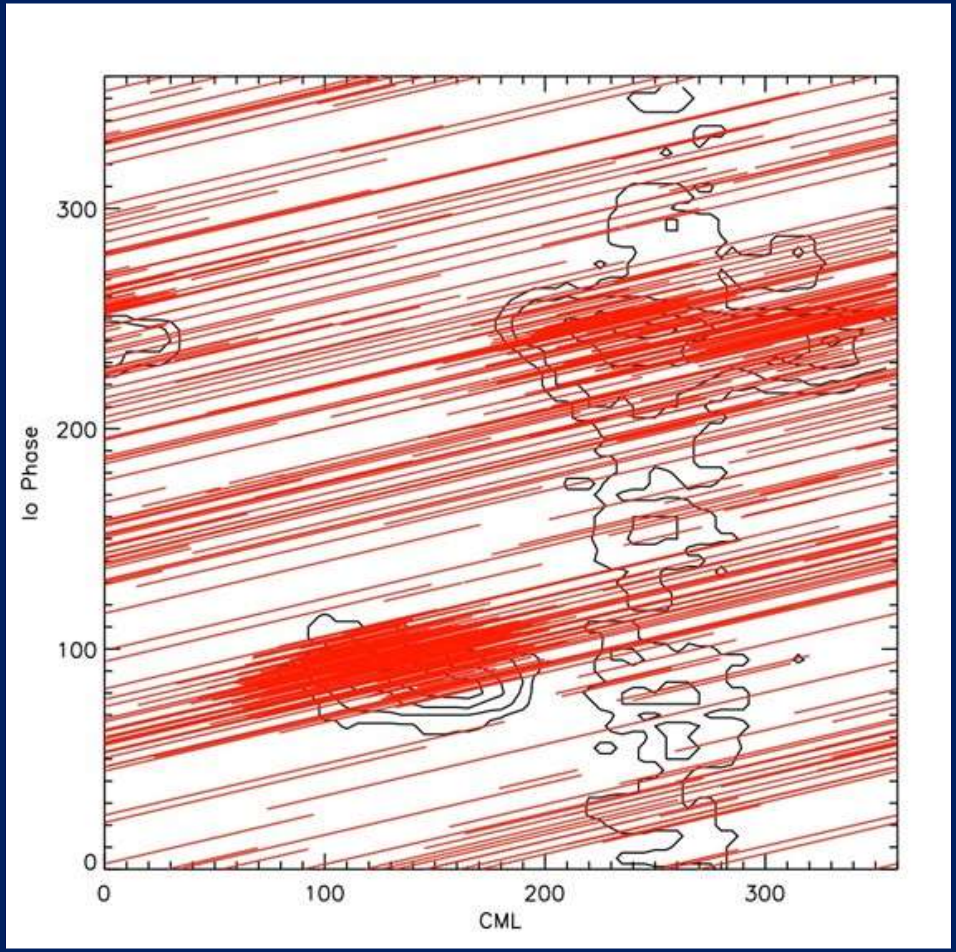
Research and Projects

Projects

- Maps of the Jupiter Radio sources
- Jupiter Emission microstructure
- Radio wave propagation



Jupiter radio emission occurrence probability plotted as a function of orbital phase of Io and Jupiter longitude (CML). [J. Sky, **radiosky.com**]



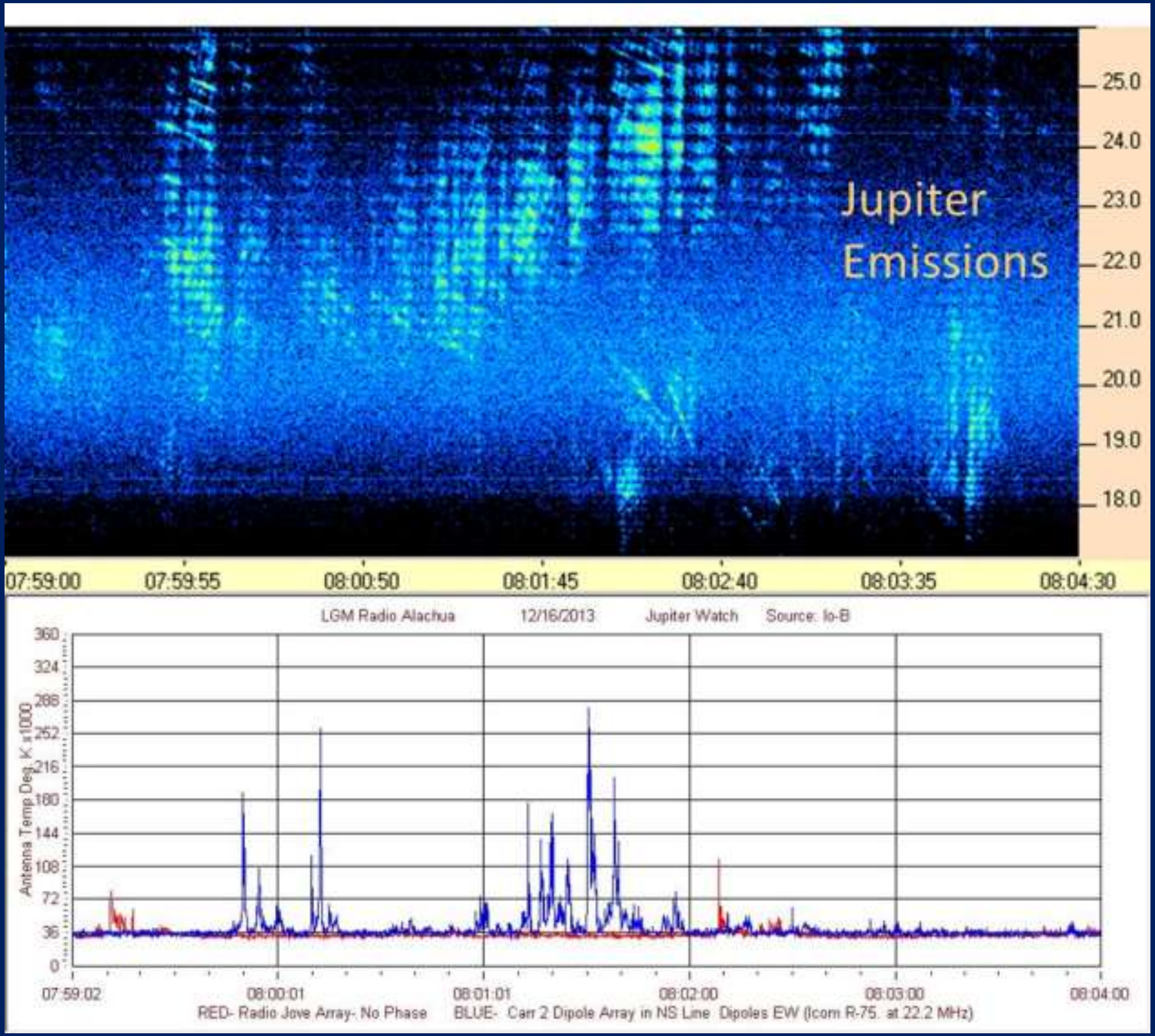
About 750 Jupiter radio observations in the Radio Jove archive over an Io Phase vs Jupiter Longitude (CML) plot. The observations are most concentrated near Io-related Jupiter radio storms. [L. Garcia]

Research and Projects

Projects

- Maps of the Jupiter Radio sources
- Jupiter Emission microstructure
- Radio wave propagation

Jupiter observations with a spectrograph and a 20 MHz receiver. Jupiter emissions show fine spectral structure such as modulation and Faraday lanes due to propagation effects.
[J. Brown and W. Greenman]



Research and Projects

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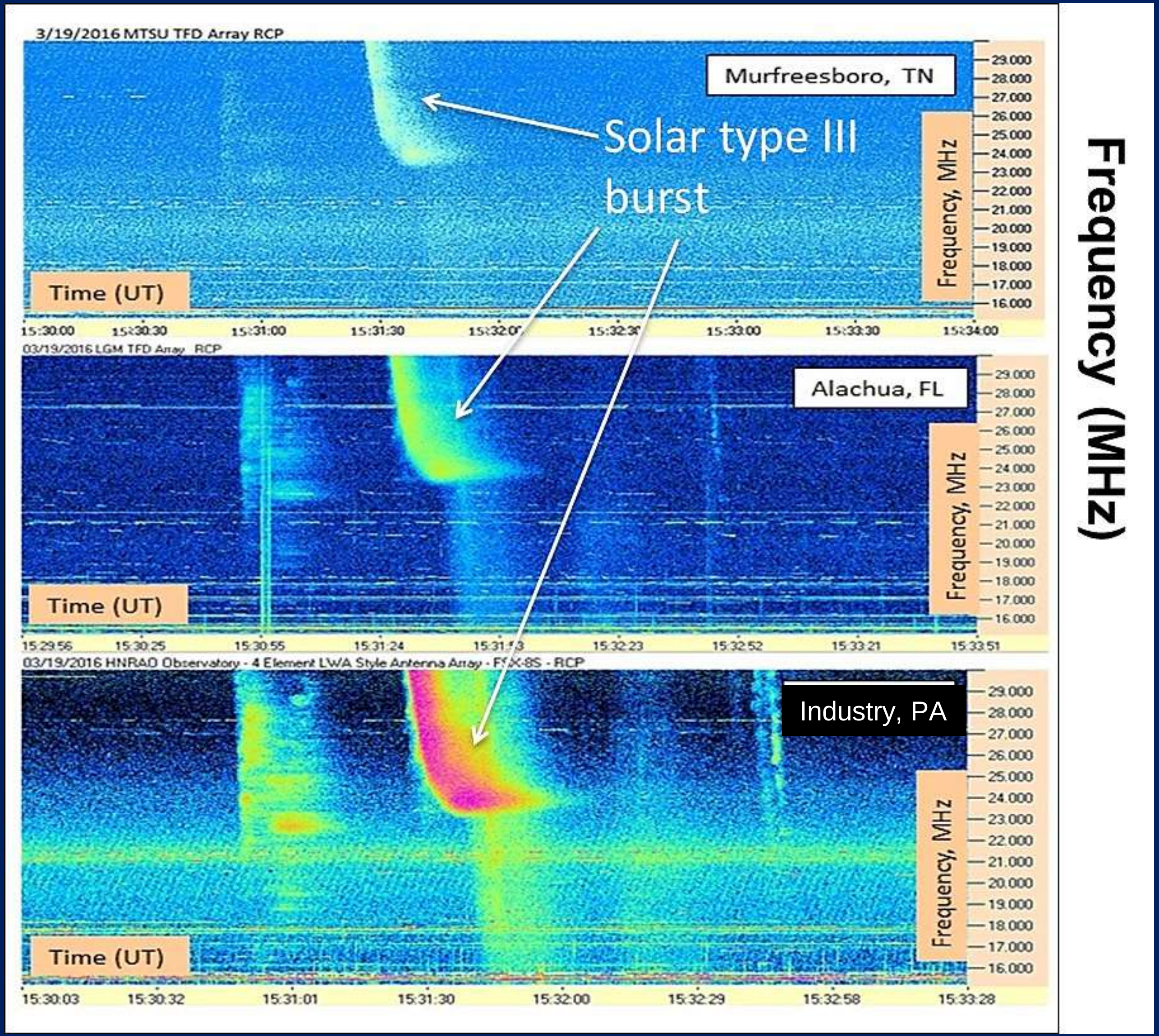


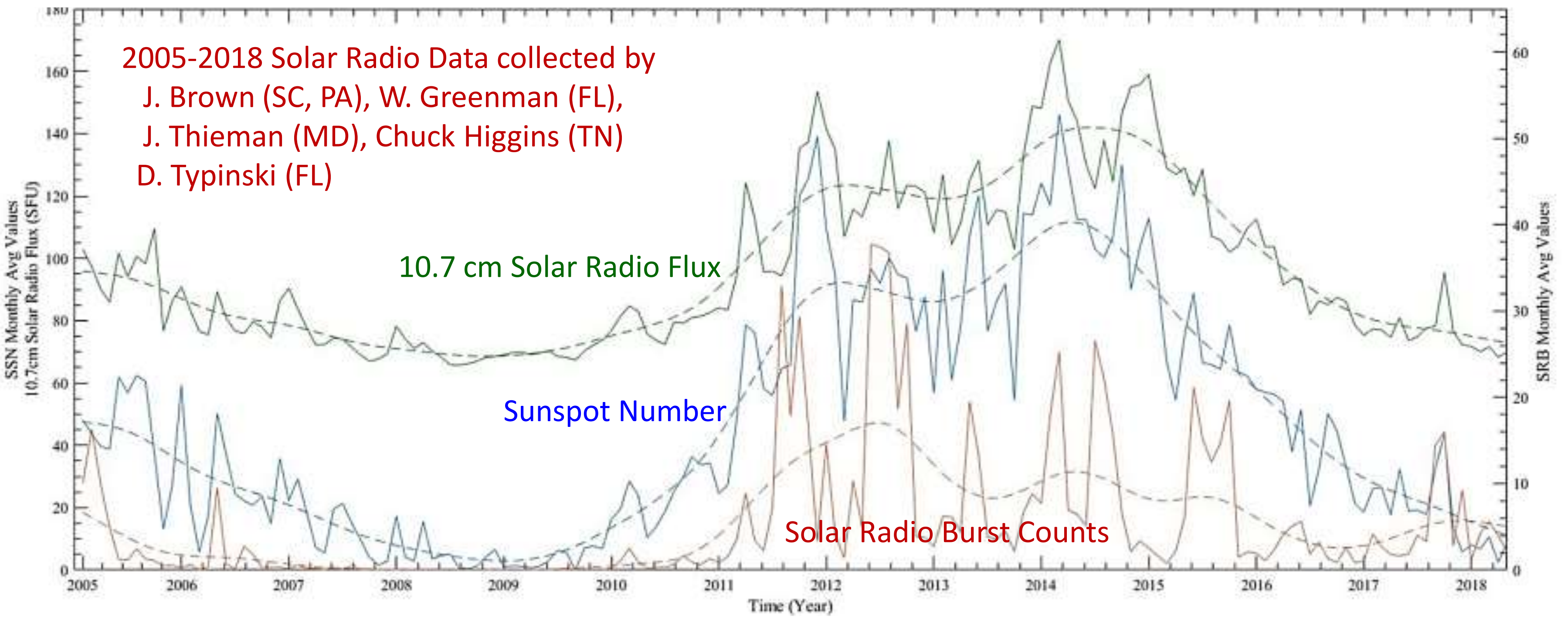
Frequency-time spectrogram comparison observations of solar radio bursts seen by different observers.
[C. Higgins, W. Greenman, and J. Brown]

Solar Radio Citizen Science

Solar Radio Burst Counts

1. Observe the Sun with a Radio Jove telescope
2. Count daily solar bursts
3. Compute average for 1 month
4. Send Data to Radio Jove
5. Your name added to a graph

2005-2018 Monthly Solar Data Counts



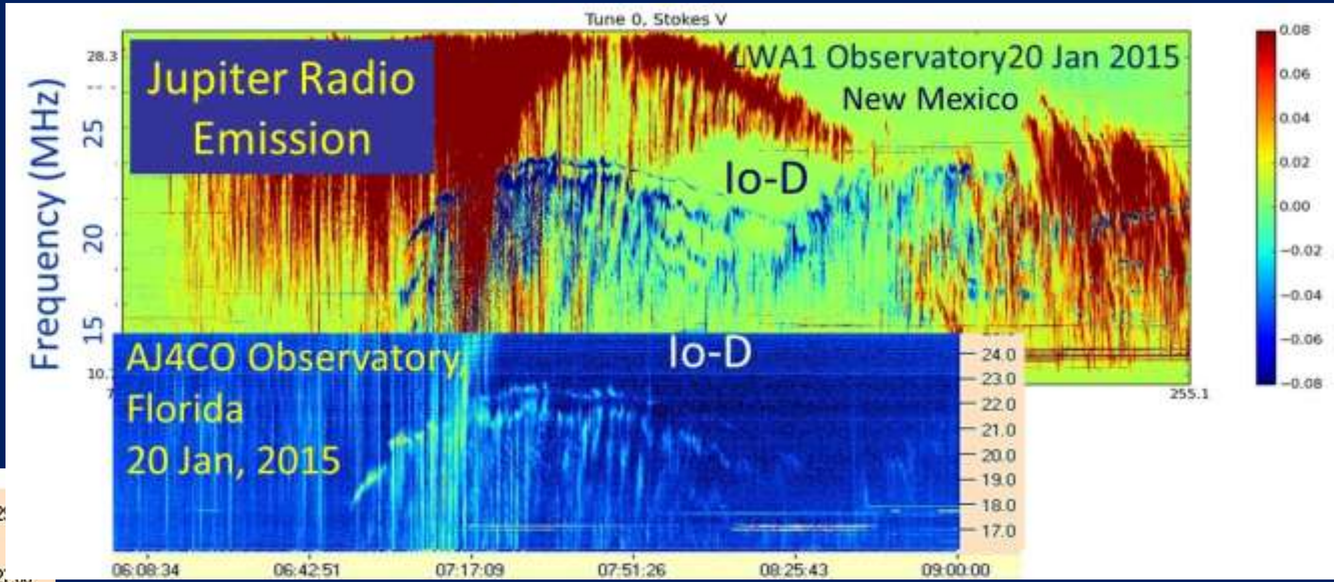
MTSU Undergrads: Monica Villarreal, Jacob Burleson, Luke Garner, Courteney Gibson, Beverly Warner, Travis Marlow

2005 – 2018 Monthly Solar Radio Burst Counts (SRB) at 20 MHz correlate well with the visible Sunspot Number (SSN) and the 10.7 cm (2800 MHz) Radio Flux data.

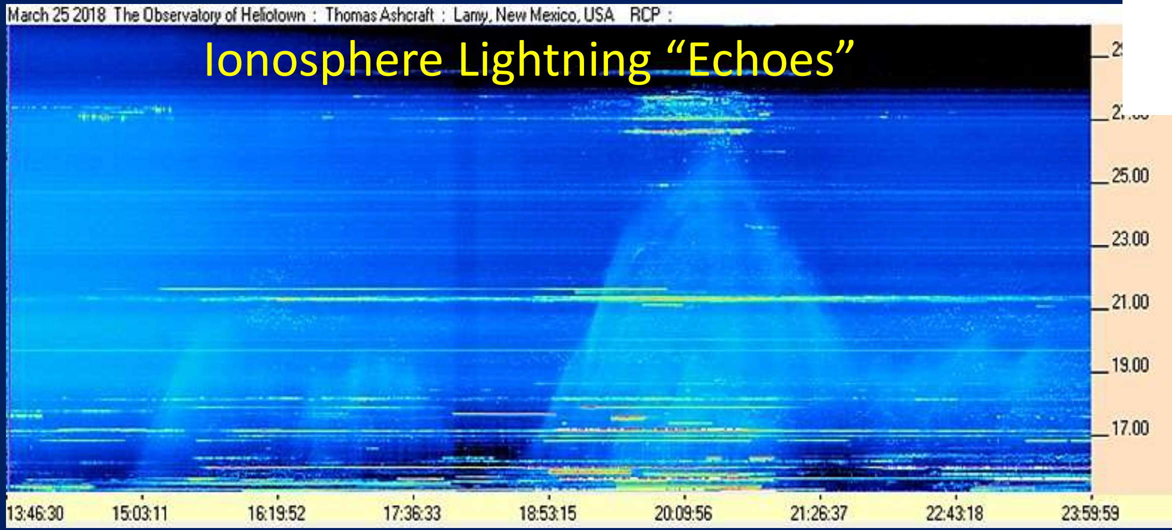
Research and Projects

Research Interests

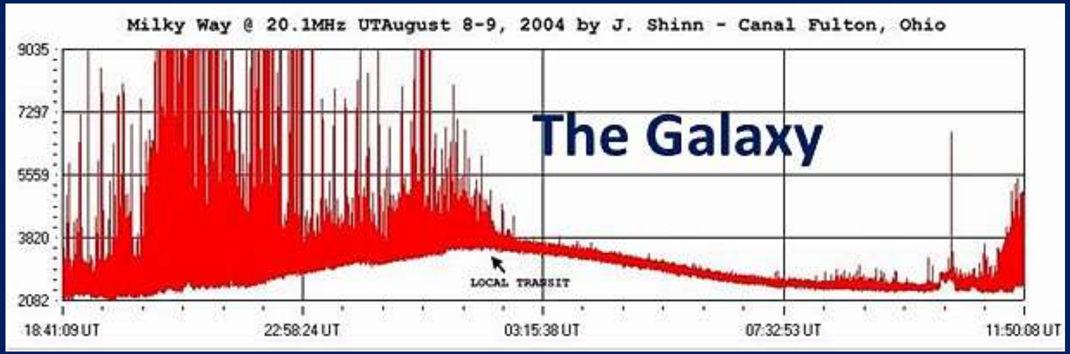
- Jupiter Radio Emission Structure
- Solar Radio Emissions
- Ionosphere Radio Wave Propagation
- Milky Way Galaxy



Polarized spectroscopic observations of Jupiter's spectral structure. [D. Typinski]



Frequency-time data of lightning and interference propagation in Earth's ionosphere [T. Ashcraft]



24-hr intensity-time radio emission from the Galaxy [J. Shinn]

First Radio JOVE Citizen Science paper: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020GL087307

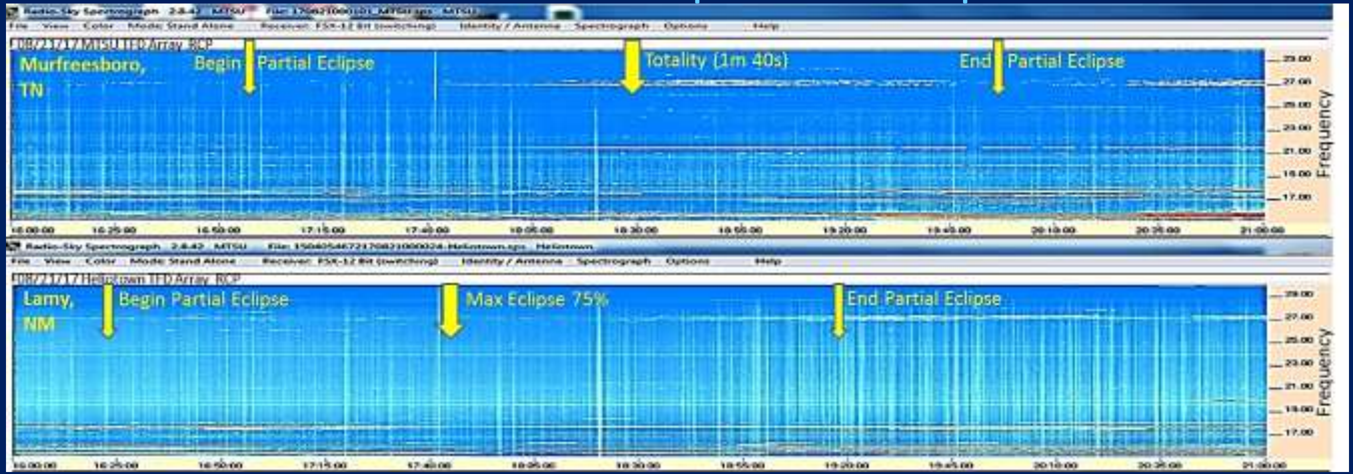
2017 Solar Eclipse

Twenty-five Radio Jove observers are shown on the map for the August 21, 2017 total eclipse. [Background: eclipse.gsfc.nasa.gov]

2017 Coordinated Activity

- 25 Radio Jove groups observed the solar eclipse
- Only 7-8 observers made science-quality observations
- Citizens Scientists → Large Learning Curve
- Two stations show evidence that the lunar shadow affected the received solar emissions

Example Solar Eclipse Observations



Frequency-Time spectrograph solar eclipse observations on August 21, 2017 from 16-21 UT at 15-30 MHz in TN (100% eclipse) and NM (75% eclipse). Radio burst intensity are reduced near the time of totality in the Murfreesboro, TN data as compared with the data from Lamy, NM.

New effort for
2024 Solar Eclipse

Radio JOVE Summary

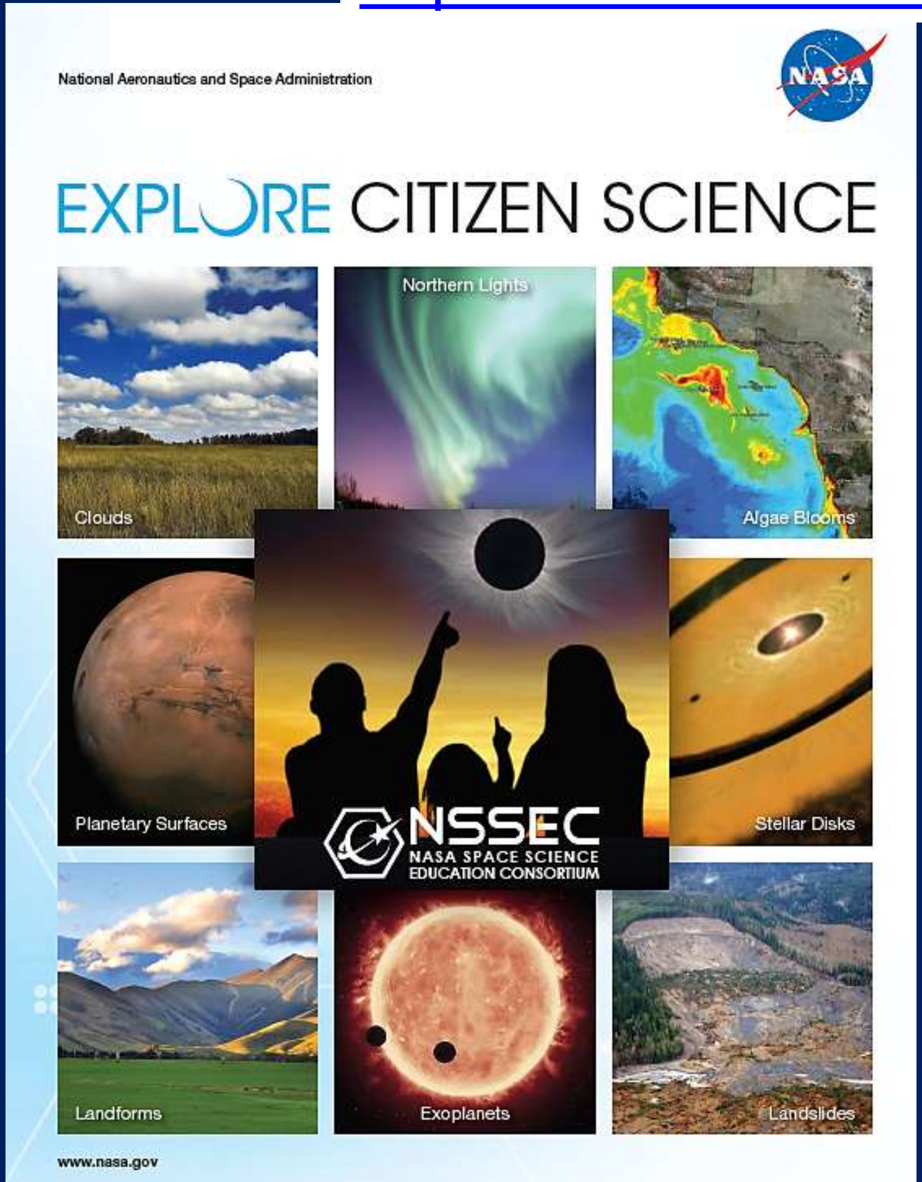
radiojove.gsfc.nasa.gov

- Radio JOVE is an active citizen science project
- 4 Partnerships: NASA Education (NSSEC), Citizen Scientists, Juno Mission, and Data Archives
- Collaborate in Science, Education, and Public Outreach
- 11 active citizen scientists; more coming soon
- Continue to coordinate observations to support science
- Jupiter, Solar, Ionosphere research projects

Brochures available

NASA Citizen Science Projects

https://science.nasa.gov/citizenscience



Love NASA Science?

Join a NASA Citizen Science Project!

Citizen science projects at NASA and beyond are scientific collaborations between scientists and interested members of the public. Through these collaborations, volunteers, or **"citizen scientists,"** have made thousands of important scientific discoveries, including:

- More than half of the known comets.
- Hundreds of extrasolar planets.
- The oldest protoplanetary disk and the oldest disk around a white dwarf.
- A new kind of aurora.

Along the way, citizen scientists have co-authored publications in professional scientific journals, observed with telescopes around the world, and made many lasting friendships. They have learned about climate change, interstellar dust grains, the surface of Mars, meteors, penguins, mosquitos, and gravitational waves, and they have helped protect people from landslides.

Most projects require no prior knowledge, experience, or special tools beyond a computer or cell phone. Some projects invite you to use your smartphone to photograph or record information and upload this data to a project website. People with advanced degrees or other relevant training are also invited to work with NSSEC on these projects!

All citizen science projects aim to teach you everything you need to know as you go along—**so don't worry if you never studied science or math in school!**

Just be forewarned: NASA citizen science is the real thing. There are no guaranteed results, and sometimes the answers will remain unknown. But if you're tired of just reading about other people's ground-breaking discoveries and ready to get your hands on scientific data nobody has ever seen before, go to one of the URLs listed here and get started. **Join NSSEC on the journey to discover more about our universe!**

Are you an educator or a student? NASA also supports educational projects for hands-on and more advanced exploration. For example, Radio JOVE (radiojove.gsfc.nasa.gov) welcomes participants to help establish a network of low-cost, ground-based radio receivers to study the Sun and Jupiter by observing their radio emissions. Through Radio JOVE, students and amateur scientists can also discover how space weather affects parts of the Earth's atmosphere.

For more information about NASA citizen science, please visit: science.nasa.gov/citizenscientists

For more about NASA crowdsourcing in general, please visit: www.nasa.gov/solve

Image Credits: Top) GLOBE Observer Clouds (Wikipedia: Piccolo Namek); Aurorasaurus (Joshua Strang:USAF); California Algal Blooms (MODIS); Middle) Disk Detective (Jonathan Holden); Mars Mappers (NASA/JPL); Center) NASA/Shadia R Habbal, Miloslav Druckmuller and Petar Aniol; Bottom) GLOBE Program (Wikipedia:Yinan Chen); Planet Hunters (NASA/STScI/J.De Wit); Landslide Reporter (USGS).

Citizen Science Projects with NASA

NASA has been involved with citizen science since the 1990's. Here is a list of the currently active projects as of 2018.

Astrophysics
- Planet Hunters TESS
  - www.planethunters.org
- Backyard Worlds: Planet 9
  - www.backyardworlds.org
- Disk Detective
  - diskdetective.org
- Gravity Spy
  - gravityspy.org

Earth Science
- Citizen-Enabled Aerosol Measurements for Satellites
  - csu-ceams.com
- Clouds — GLOBE Observer
  - observer.globe.gov/do-globe-observer
- Floating Forests
  - floatingforests.org
- GLOBE
  - www.globe.gov
- Lake Observer
  - www.lakeobserver.org
- Land Cover — GLOBE Observer
  - observer.globe.gov/do-globe-observer
- Landslide Reporter
  - landslides.nasa.gov
- Mapping Application for Penguin Populations and Projected Dynamics (MAPPPD)
  - www.penguinmap.com/
- Mosquito Habitat Mapper — GLOBE Observer
  - observer.globe.gov/do-globe-observer
- Trees — GLOBE Observer
  - observer.globe.gov/do-globe-observer

Planetary Science and Heliophysics
- Aurorasaurus
  - www.aurorasaurus.org
- COSMIC
  - www.zooniverse.org/projects/wkiri/cosmic
- Fireballs in the Sky
  - fireballsinthesky.com.au
- International Astronomical Search Collaboration
  - iasc.hsutx.edu
- JunoCam
  - www.missionjuno.swri.edu/junocam
- Planet Four
  - www.planetfour.org
- Stardust@Home
  - stardustathome.ssl.berkeley.edu
- Sungrazer Project
  - sungrazer.nrl.navy.mil
- Target Asteroids
  - www.asteroidmission.org/get-involved/target-asteroids

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The End

Chuck Higgins
chiggins@mtsu.edu

Thank you!

2017 Solar Eclipse
MTSU Media Services

Extra Slides

Radio Bands

HF: below 30 MHz   decameter (3 - 30 MHz)

Shortwave radios, CBs

AM band (0.5 - 1.7 MHz)

VHF: 30-300 MHz meterwave (TV/FM)

UHF: 300 – 3000 MHz decimeter

(phones, LAN, cable TV, microwave ovens, GPS)

Microwave: 1000-30,000 MHz

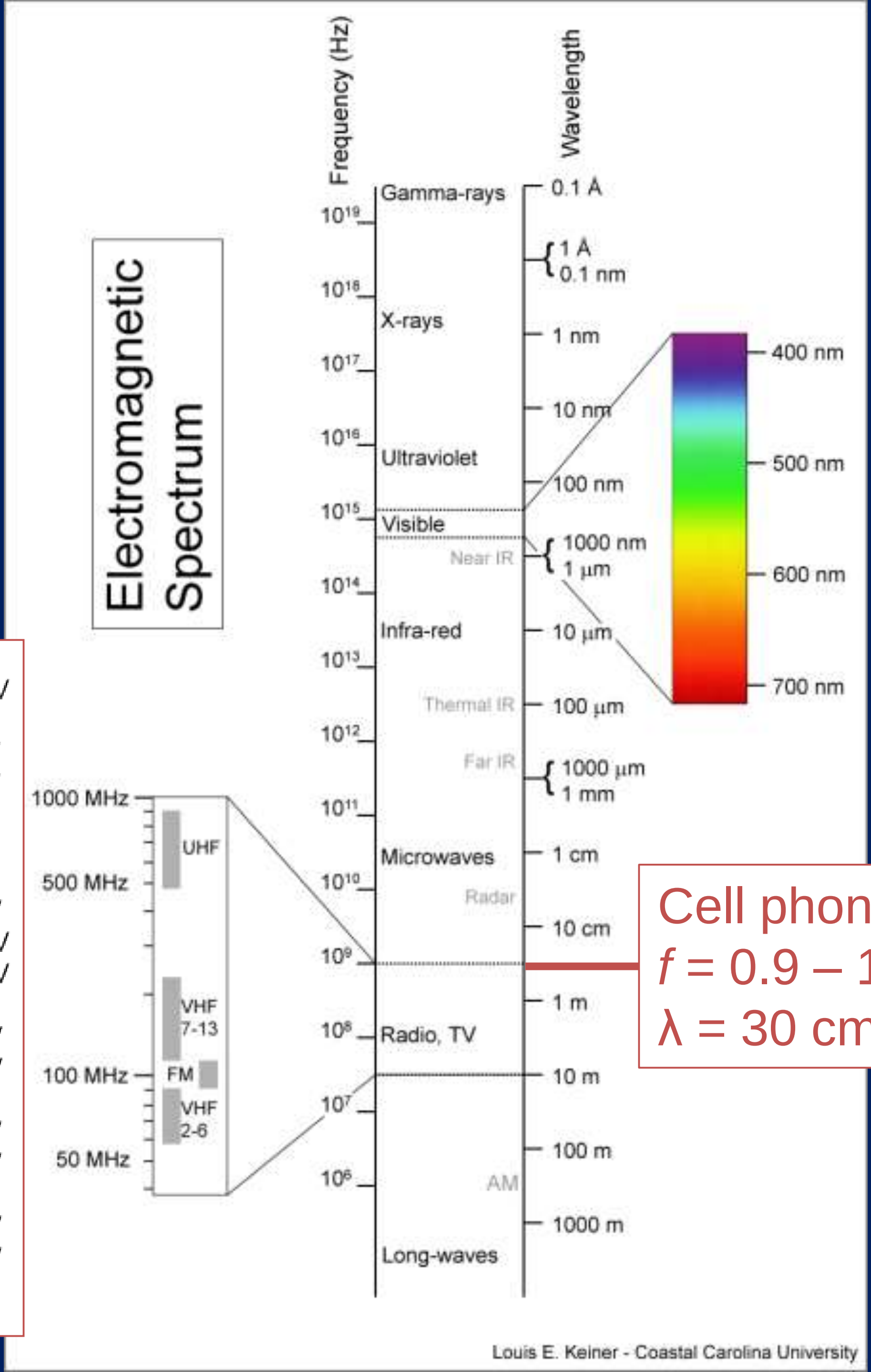
SHF: microwave (3 - 30 GHz) radars

EHF: millimeter (30 - 300 GHz)

Infrared: sub-millimeter (300 - 700 GHz)

Microwave Bands
L-band ~ 20 cm
S-band ~ 10 cm
X-band ~ 3 cm
Ku(or U)-band ~ 2 cm
K-band ~ 1 cm

CLASS	FREQUENCY	WAVELENGTH	ENERGY
Y	300 EHz	1 pm	1.24 MeV
HX	30 EHz	10 pm	124 keV
SX	3 EHz	100 pm	12.4 keV
	300 PHz	1 nm	1.24 keV
EUV	30 PHz	10 nm	124 eV
NUV	3 PHz	100 nm	12.4 eV
NIR	300 THz	1 μm	1.24 eV
MIR	30 THz	10 μm	124 meV
FIR	3 THz	100 μm	12.4 meV
EHF	300 GHz	1 mm	1.24 meV
SHF	30 GHz	1 cm	124 μeV
UHF	3 GHz	1 dm	12.4 μeV
VHF	300 MHz	1 m	1.24 μeV
HF	30 MHz	10 m	124 neV
MF	3 MHz	100 m	12.4 neV
LF	300 kHz	1 km	1.24 neV
VLF	30 kHz	10 km	124 peV
VF/ULF	3 kHz	100 km	12.4 peV
SLF	300 Hz	1 Mm	1.24 peV
ELF	30 Hz	10 Mm	124 feV
	3 Hz	100 Mm	12.4 feV



Cell phones
$f = 0.9 – 1.9$ GHz
$\lambda = 30$ cm

History of Radio Astronomy

1930s

1932 – Karl Jansky, extraterrestrial "hiss" (MW at 20 MHz)

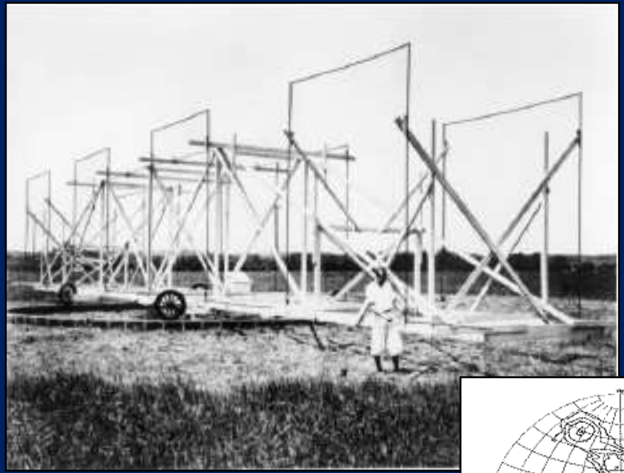
1938 – Grote Reber, maps the Galaxy at 160 MHz (non-thermal emission) ["Controversial" paper published in 1940]

1940s

- 1942 Hey and Southwood - intense solar radio interference
- 1944 Oort, van de Hulst predict the 21-cm line of H
- 1945 end of WWII – radio telescopes built in Holland, England, and Australia (Interferometers)
- radar reflections off the Moon
- Cygnus A and Cassiopeia A sources identified
- 1949 optical and radio sources identified

1950s

- synchrotron mechanism proposed
- 1951 Ewen and Purcell find the 21-cm line of H
- 1955 Radio emission from Jupiter accidentally discovered
- Radar studies of planets and the 1st satellite!



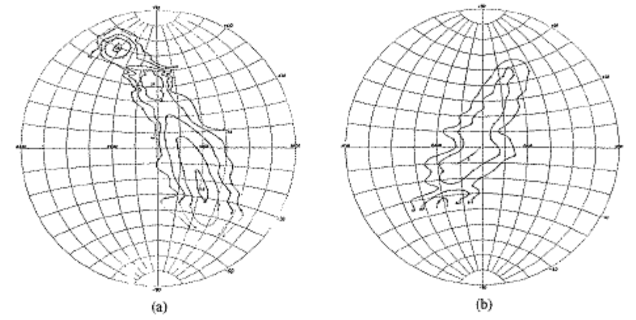


Fig. A3.1. Reber's 1944 map of the radio sky.

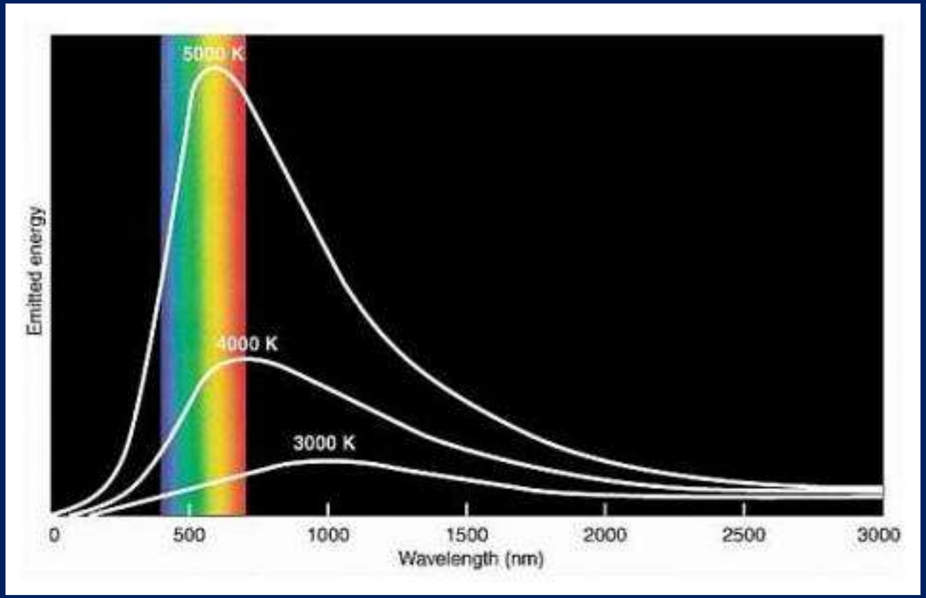
1960s

- Quasars discovered
- SETI begins
- Interstellar molecular lines
- 1965 Cosmic microwave background
- 1967 Pulsars discovered

1970s, 1980s, 1990s, 2000s

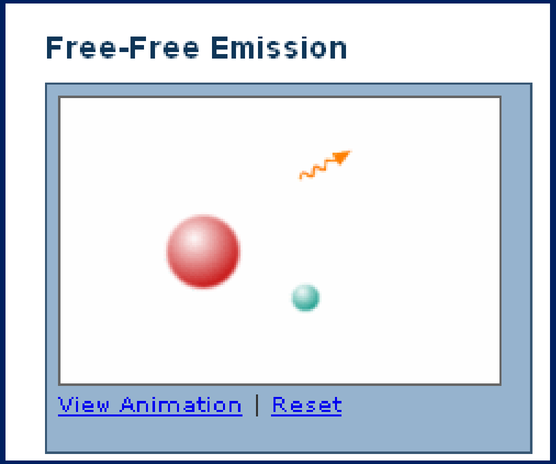
Increased technology and large arrays

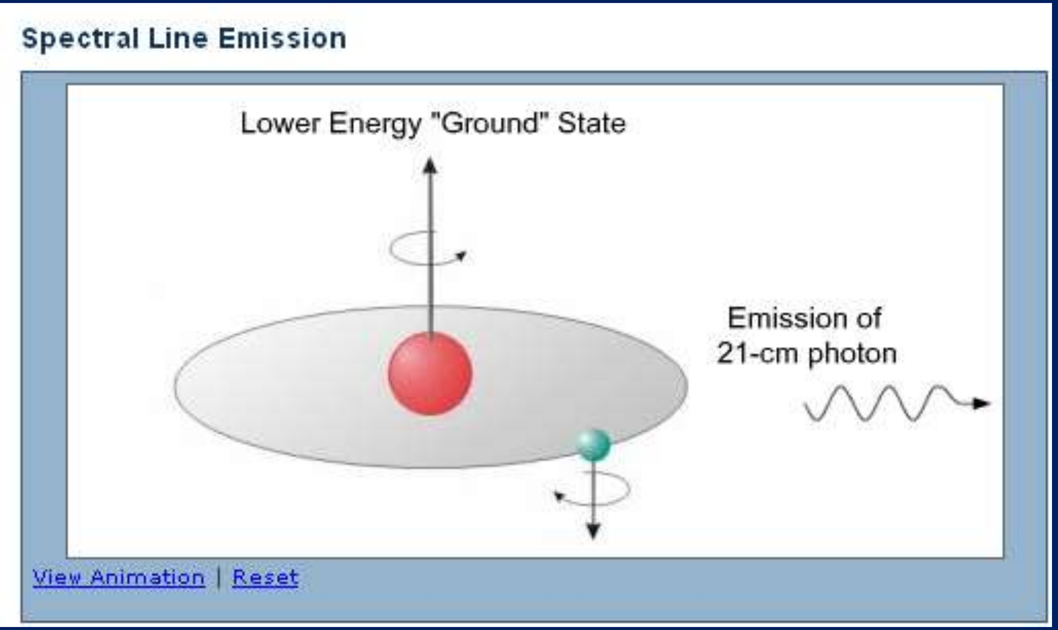
Mechanisms of Radio Emission



Thermal Emission

1. Thermal Emission – blackbody radiation
2. Free-free emission – thermal 'bremsstrahlung' radiation (for local thermodynamic equilibrium (LTE)
3. Spectral Line Emission – i.e. 21 cm line of H





Mechanisms of Radio Emission

Non-thermal Emission

1. Cyclotron/Synchrotron emission – magnetobremsstrahlung radiation
2. Gyrosynchrotron – pulsars
3. Masers – stimulated emission associated with molecules (in molecular clouds or envelopes of old stars)