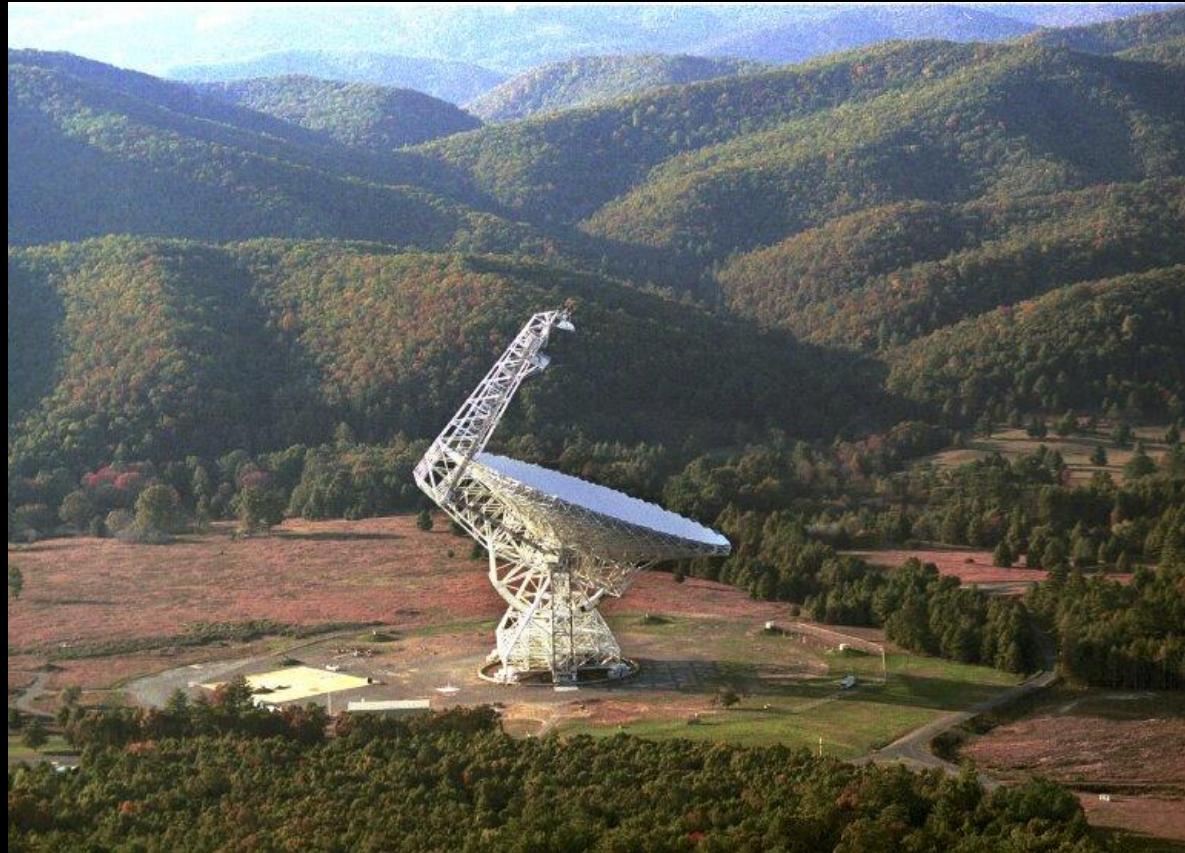


Radio Astronomy



Nguyen Luong Quang

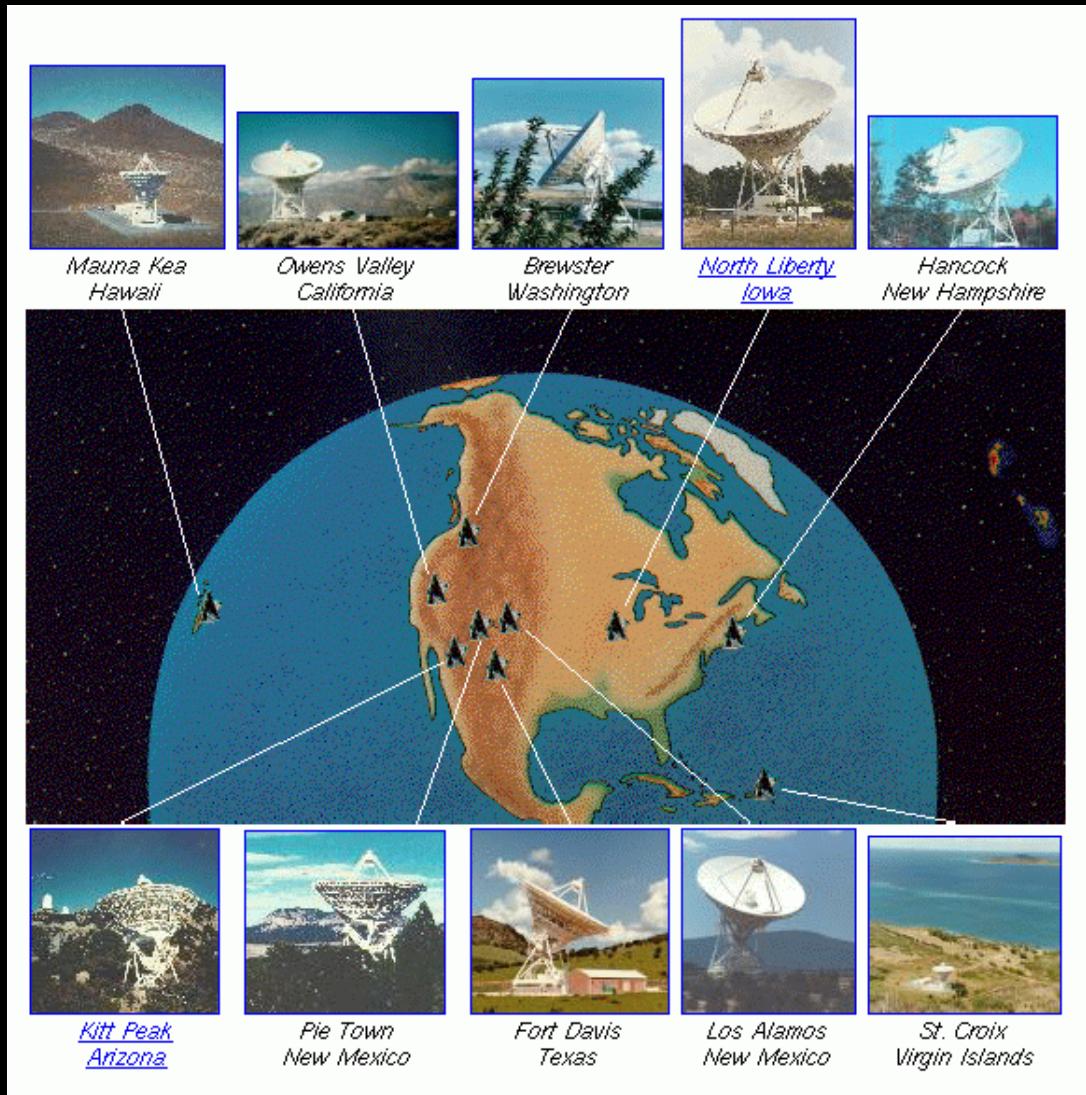
The Very Large Array (VLA)

- *1980 dedication.
Upgraded 2012.*
- *Twenty-seven 25-m
antennas in
reconfigurable array
outside of Socorro, NM.*
- *Has produced more
published science than
any other telescope on
the face of the Earth!*



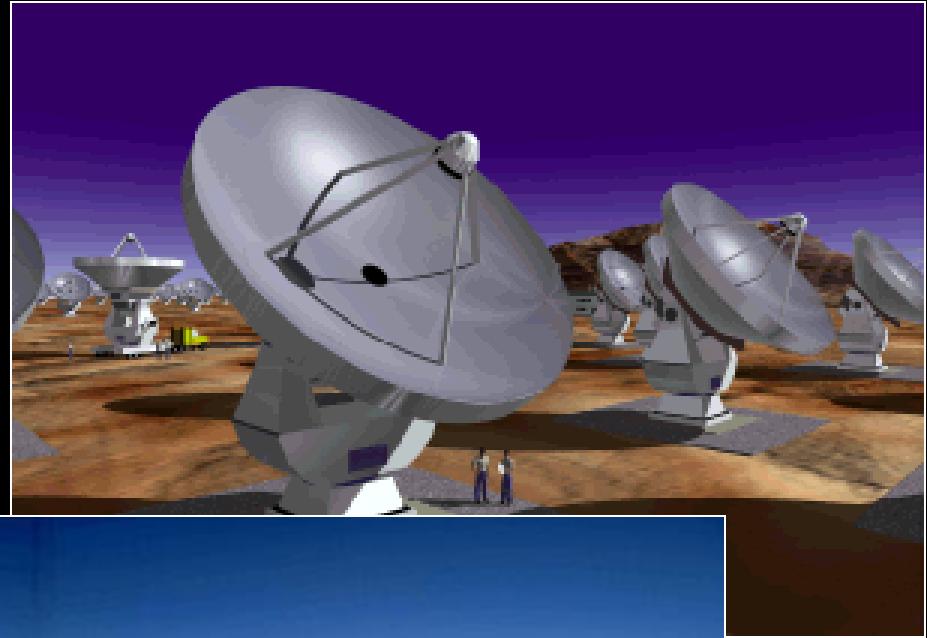
Very Long Baseline Array (VLBA)

- *1993 dedication.*
- *Operated from Socorro.*
- *Ten 25-m antennas spread across US, Canada, P.R.*
- *Highest resolution imager in astronomy.*



Atacama Large Millimeter Array

- 64 12-meter diameter dishes for millimeter and sub-millimeter-wave imaging.
- Presently under construction in Chile. Early Science underway



Robert C. Byrd Green Bank Telescope

- *2000 dedication.*

- *100 x 110m,
novel offset
design.*

- *Most versatile
telescope: 100
MHz-100 GHz.*

What is the Radio Universe Like?

The Visible Sky, Sagittarius Region



The Radio Sky

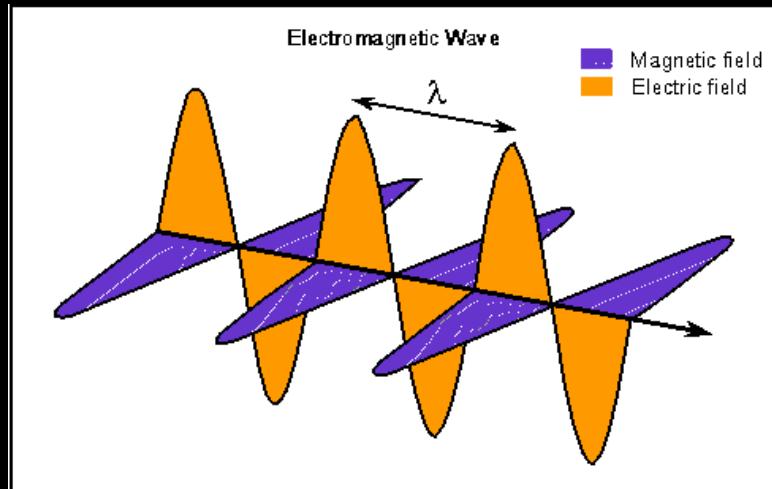


Electromagnetic radiation

- *A traveling, massless packet of energy --OR an oscillating electric and magnetic field*
 - Also known as: radiation, light wave, photon

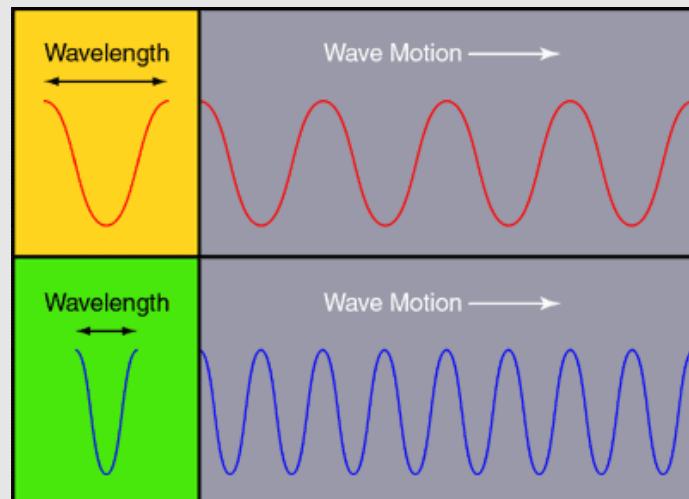
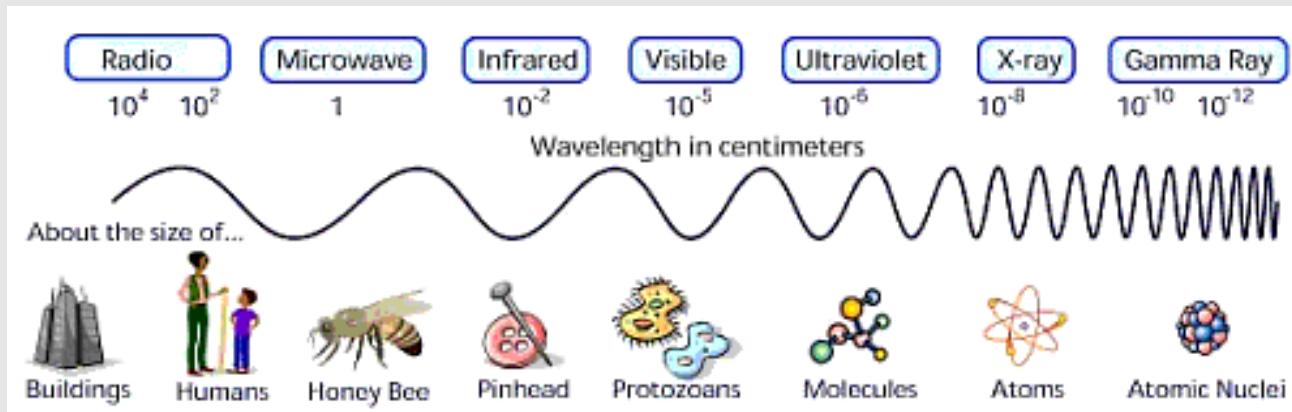
Travels at the speed of light (by definition).

Remarkably, all radiation travels at this speed, regardless of whether it carries a lot of energy or only a little



Animation from Nick Strobel's Astronomy Notes
(www.astronomynotes.com)

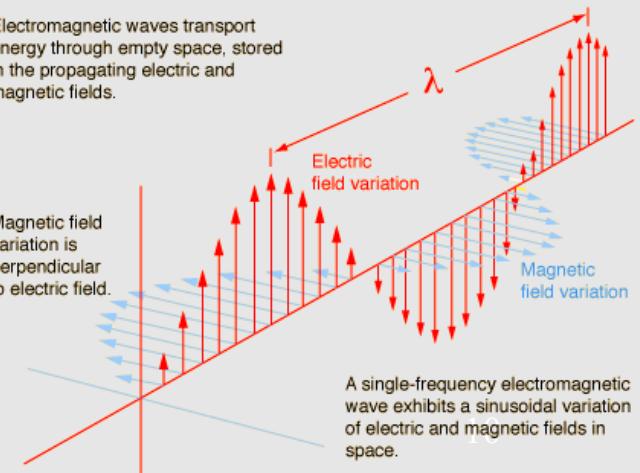
A light wave is a light wave, no matter how long...



NRAO/AUI/NSF

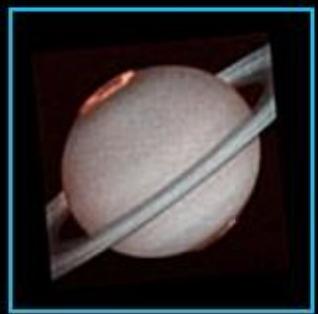
Electromagnetic waves transport energy through empty space, stored in the propagating electric and magnetic fields.

Magnetic field variation is perpendicular to electric field.



Radio Waves are NOT sound!





Ultraviolet
J. Trauger JPL/NASA



Visible
NASA/JPL/Voyager



Infrared
E. Karkoschka UA/HST/NASA



Radio
NRAO



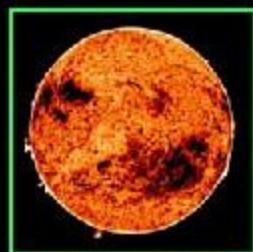
X-Ray (Yohkoh)



Ultraviolet (SOHO)



Visible (BBSO)

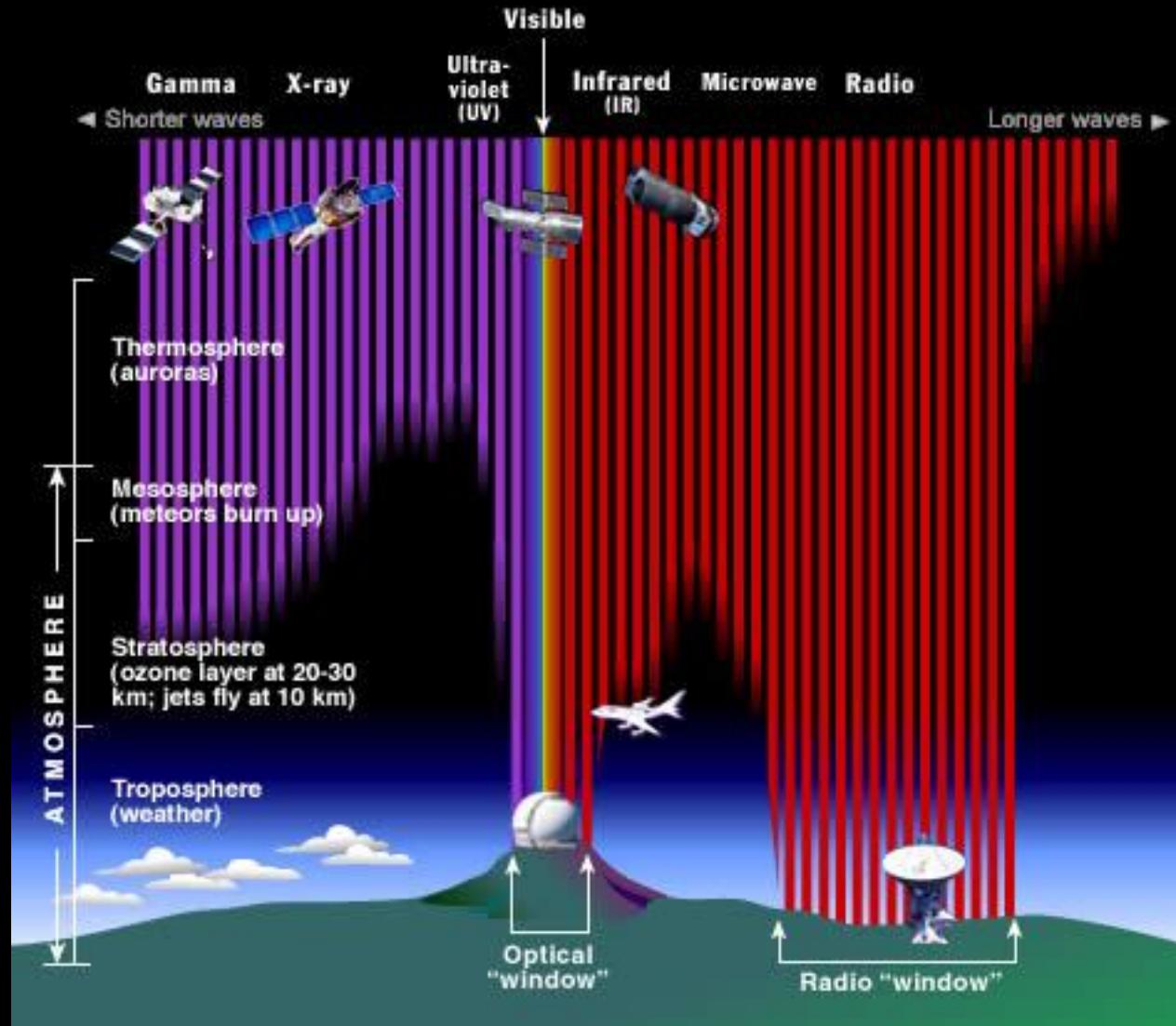


Infrared (NSO)

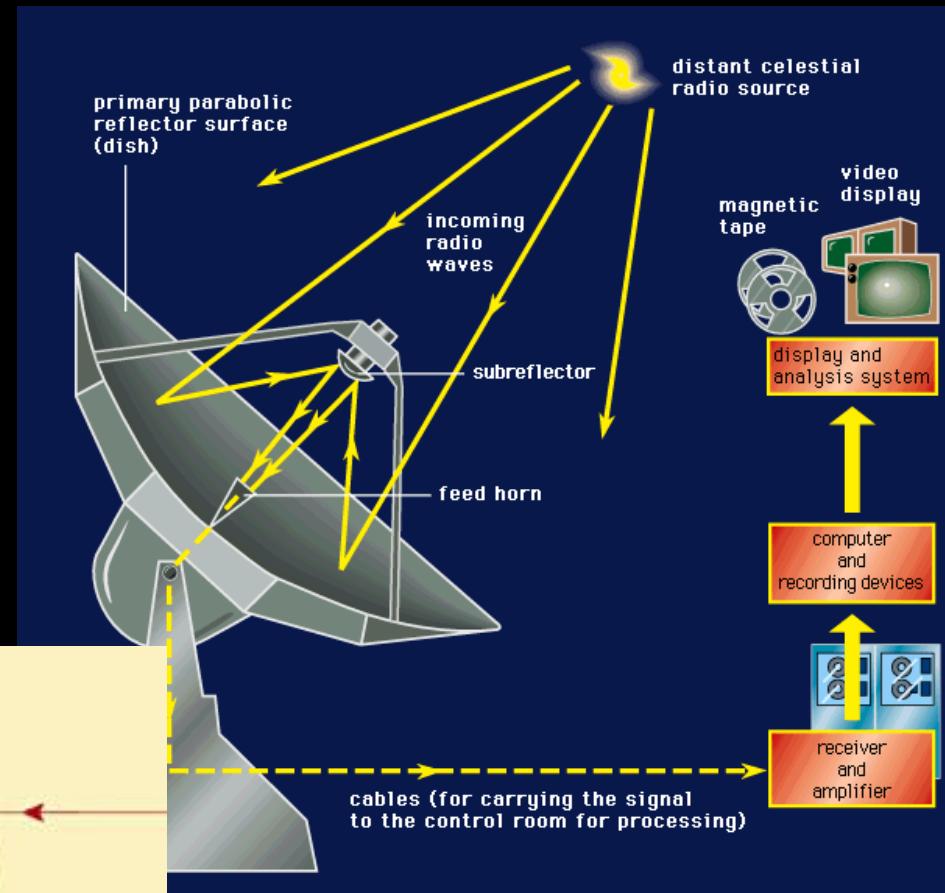


Radio (Nobeyama)

Optical and Radio can be done from the ground!



Radio Telescope



Optical Telescope



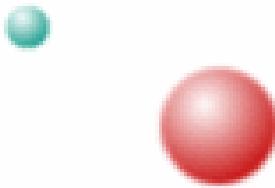
Nowadays, there are more similarities between optical and radio telescopes than ever before.

What emits radio waves?

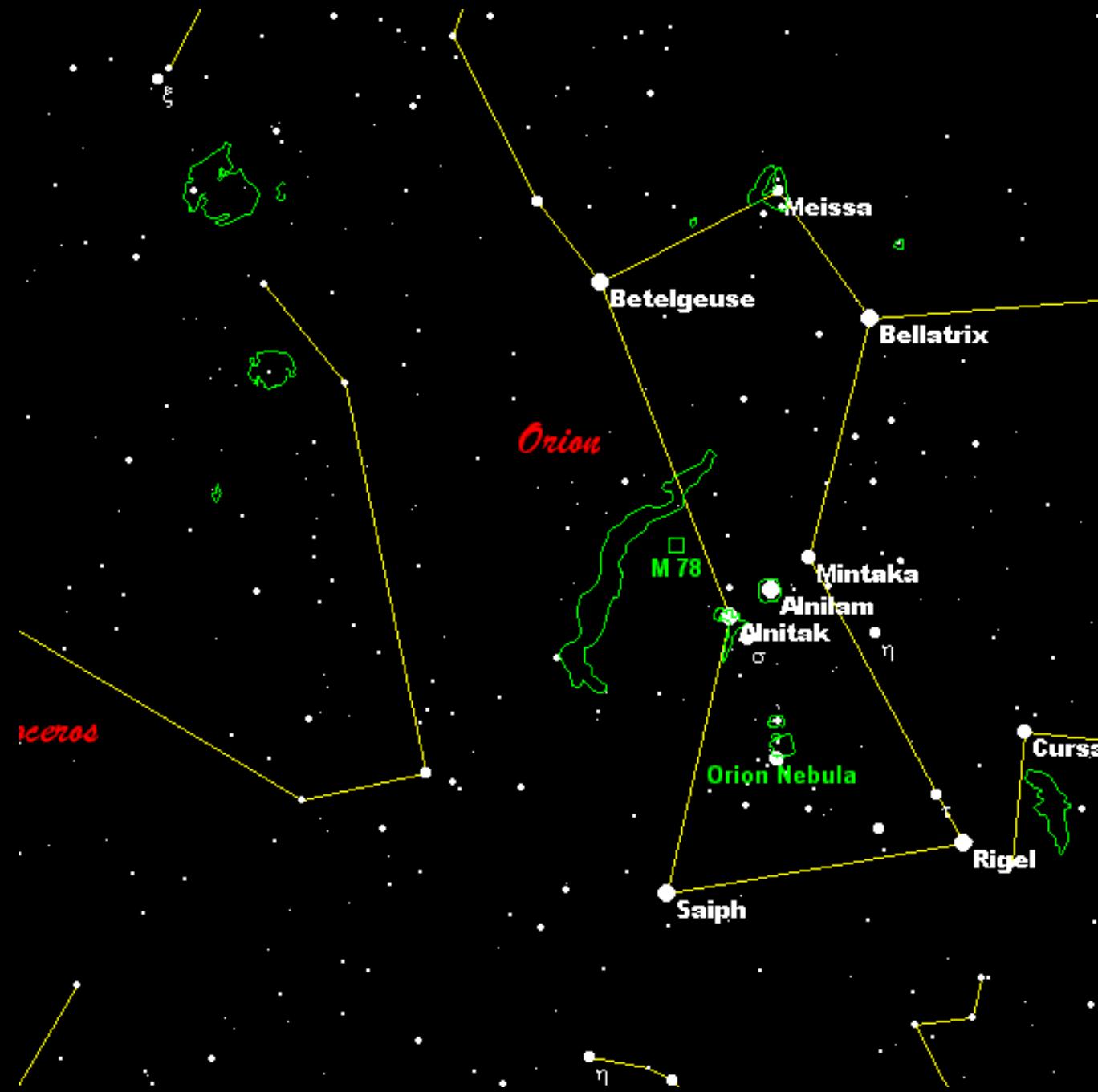
Recipe for Radio Waves

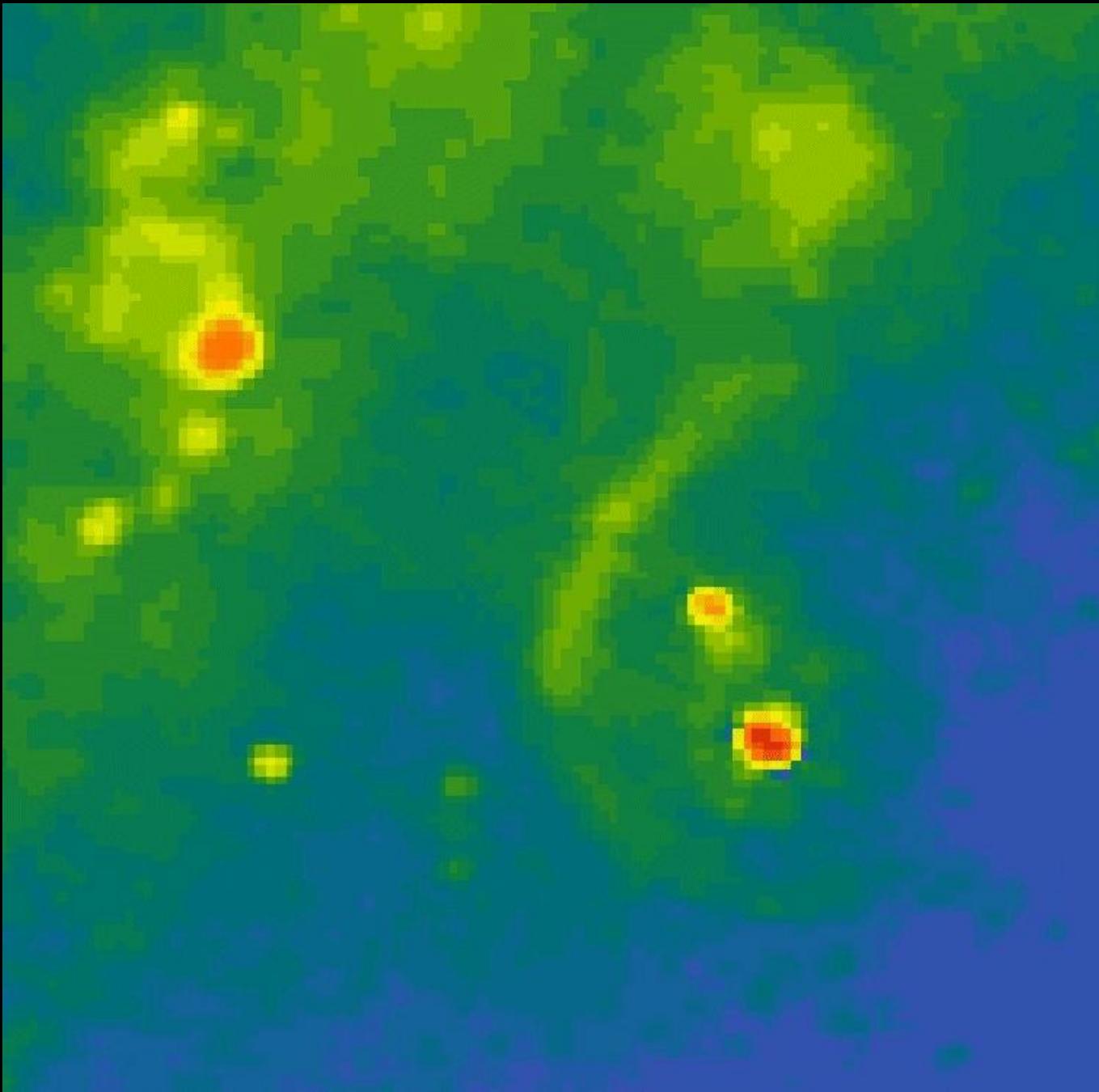
1. Hot Gases

Electron accelerates as it passes near a proton.



EM waves are released

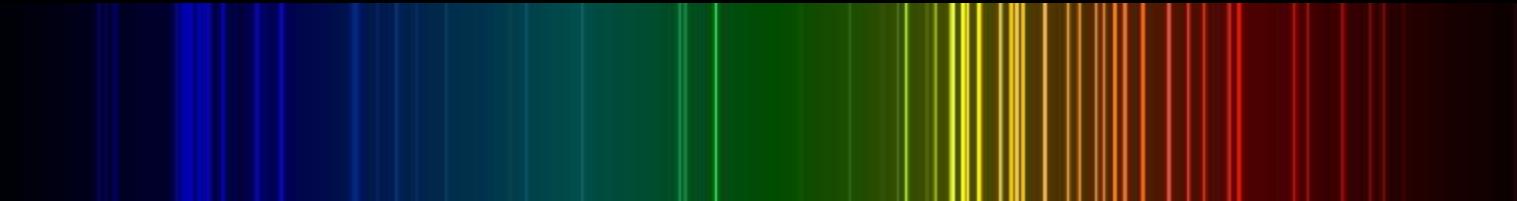




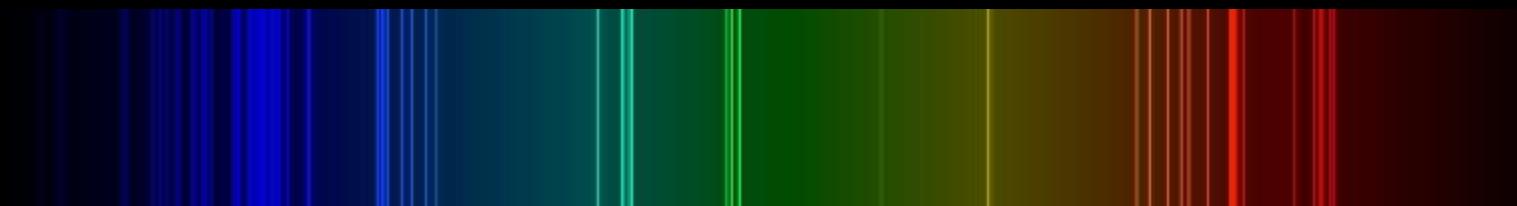


Recipe for Radio Waves

2. Atomic and molecular transitions (spectral lines)



Neon



Sodium



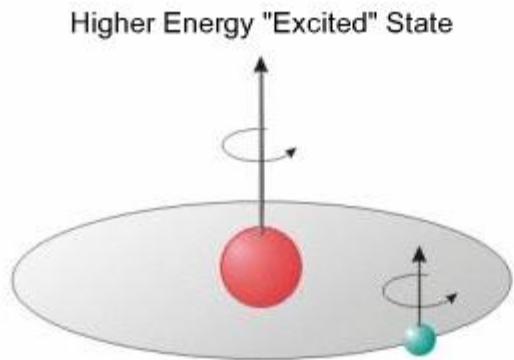
434 nm

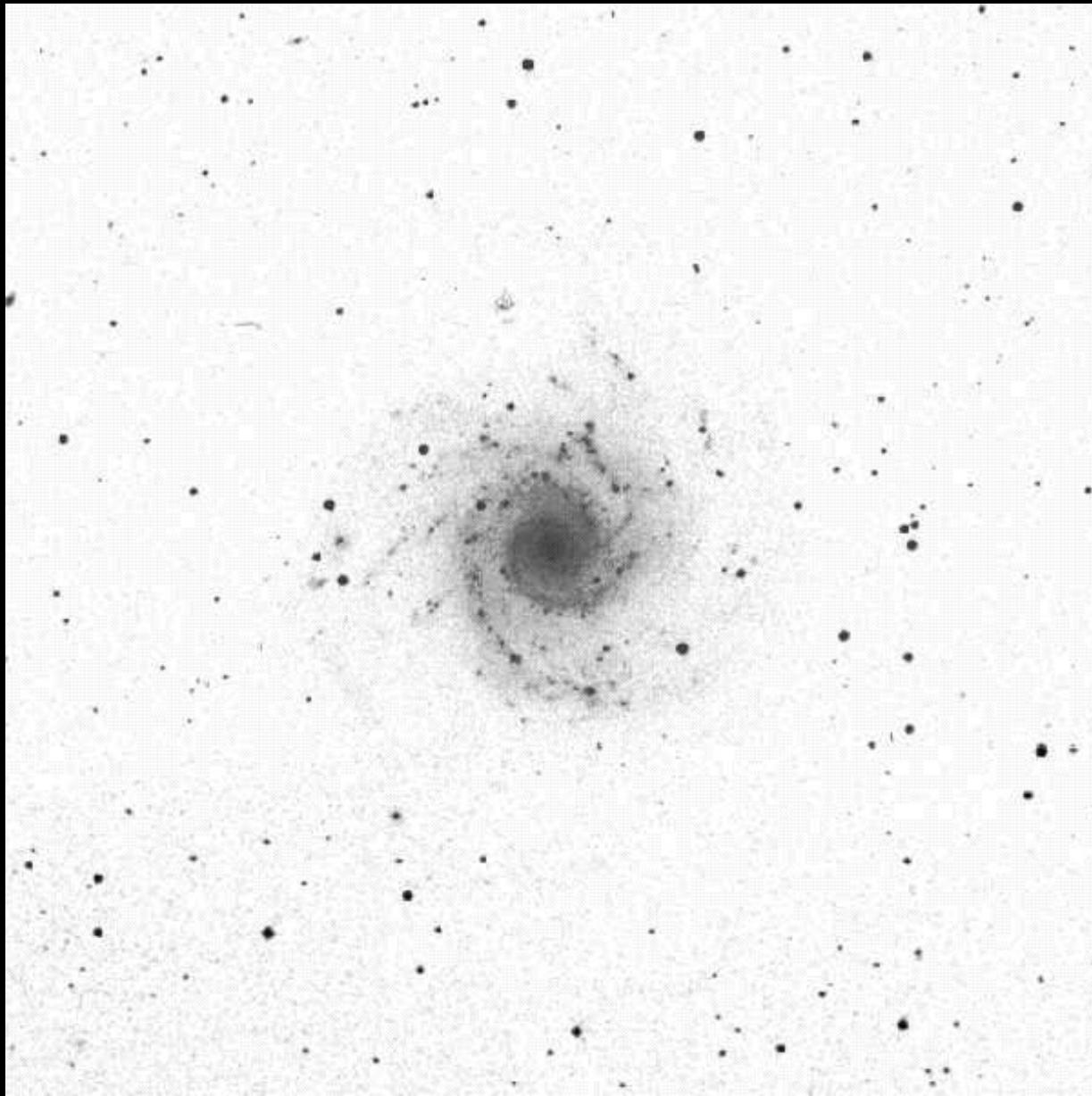
486 nm

656 nm

Hydrogen

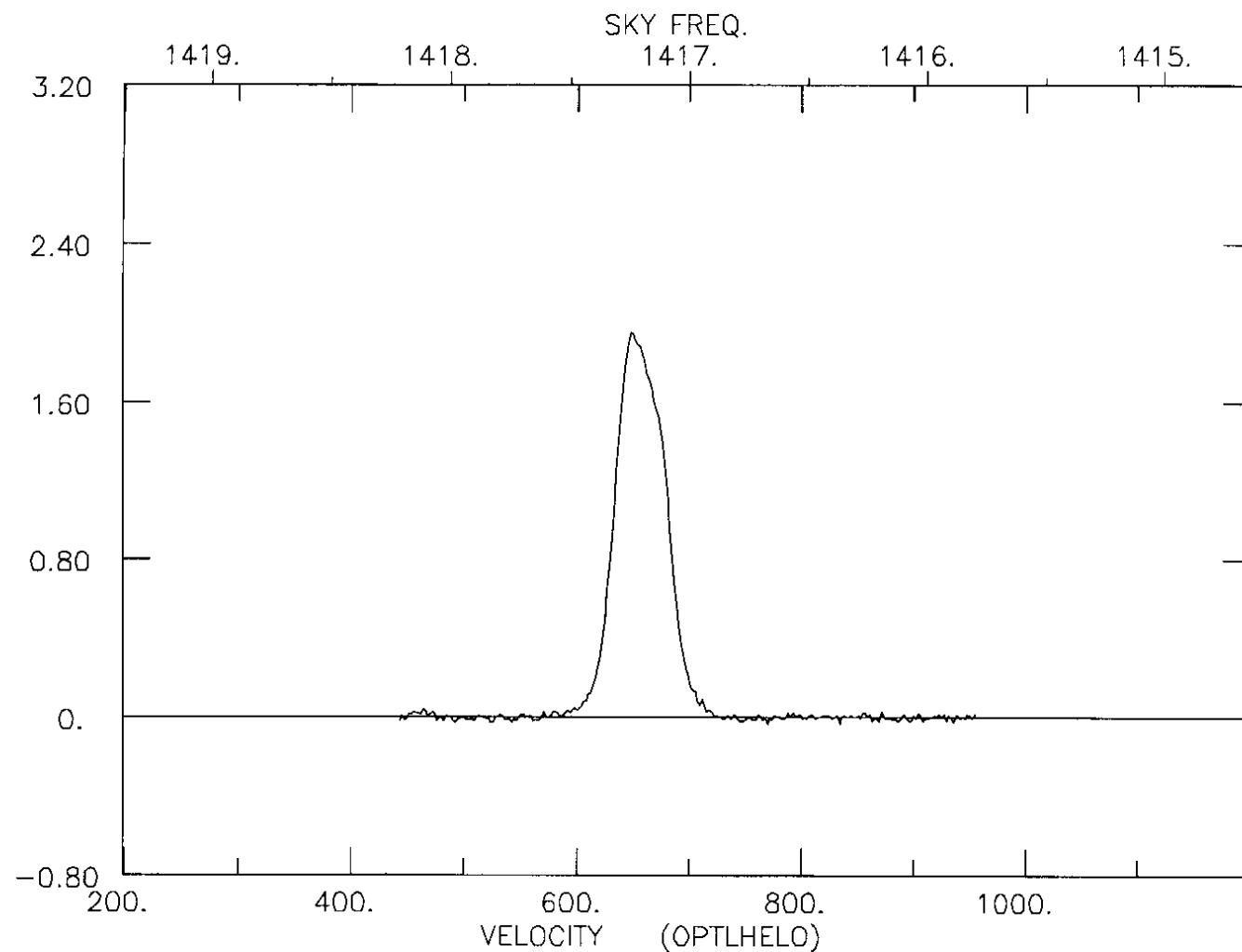
Electron accelerates to a lower energy state





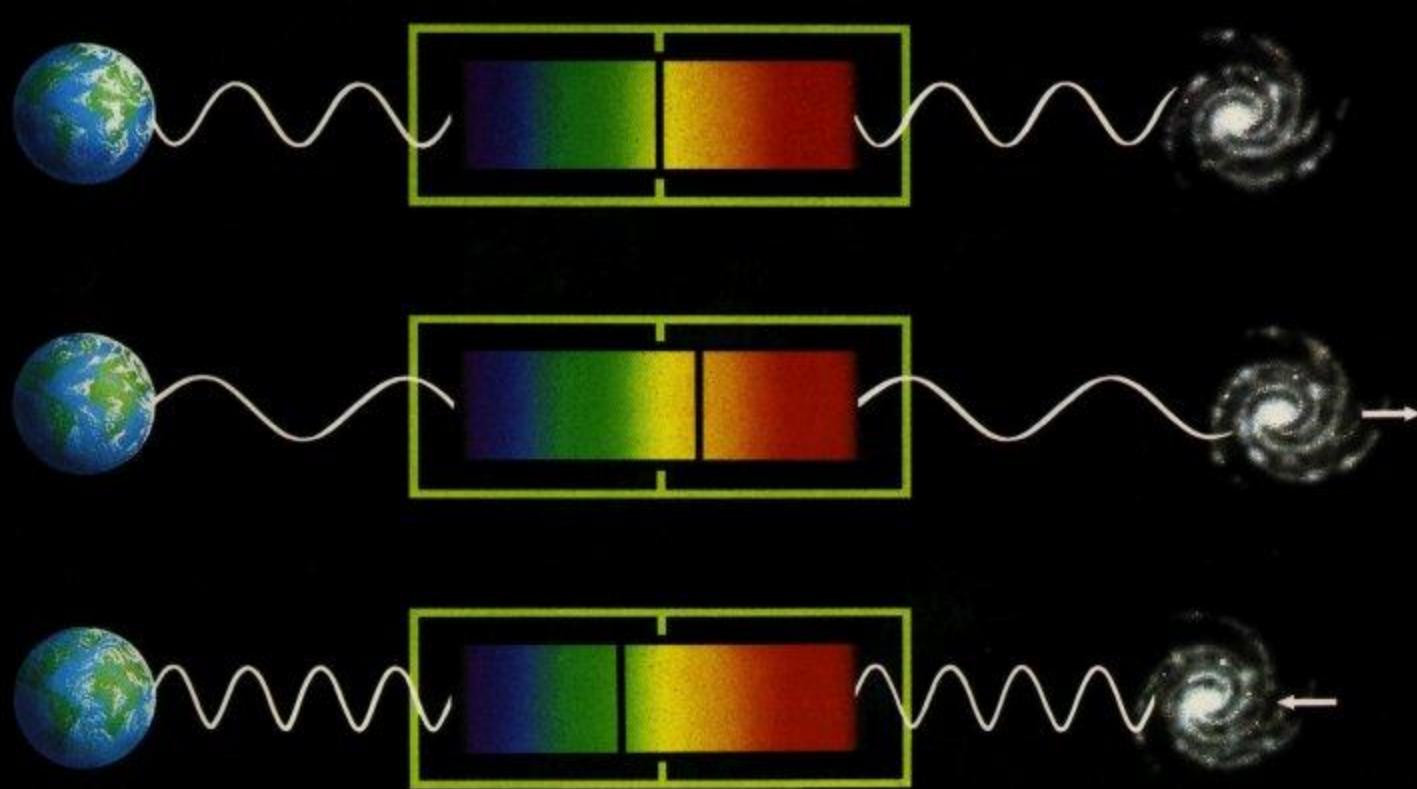
NRAO/AUI/NSF

24



N628 2 SCANS: 8339.01 – 8339.02 INT= 00:20: 0 DATE: 02 DEC 95
EPOCRADC=01:34: 0.6 15:31:55 CAL= 1.6 TS= 23
REST= 1420.40580 SKY= 1418.18395 IF=249.99 DFREQ= 9.766E-03 DV= 2.1

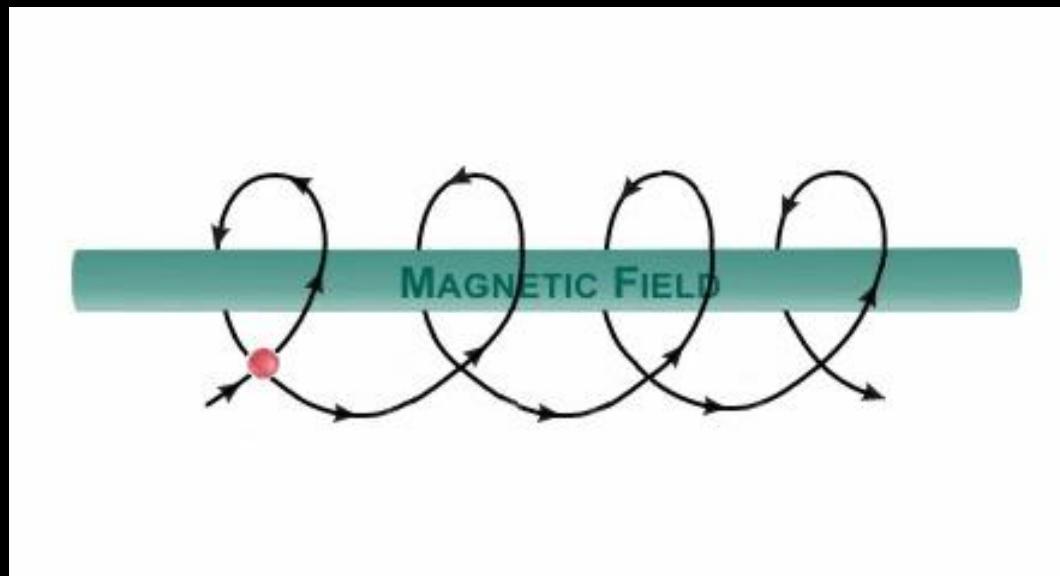
Doppler Shift

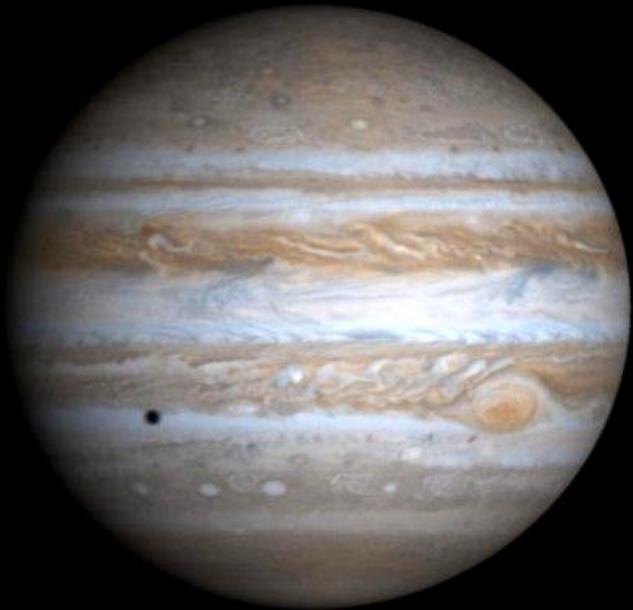


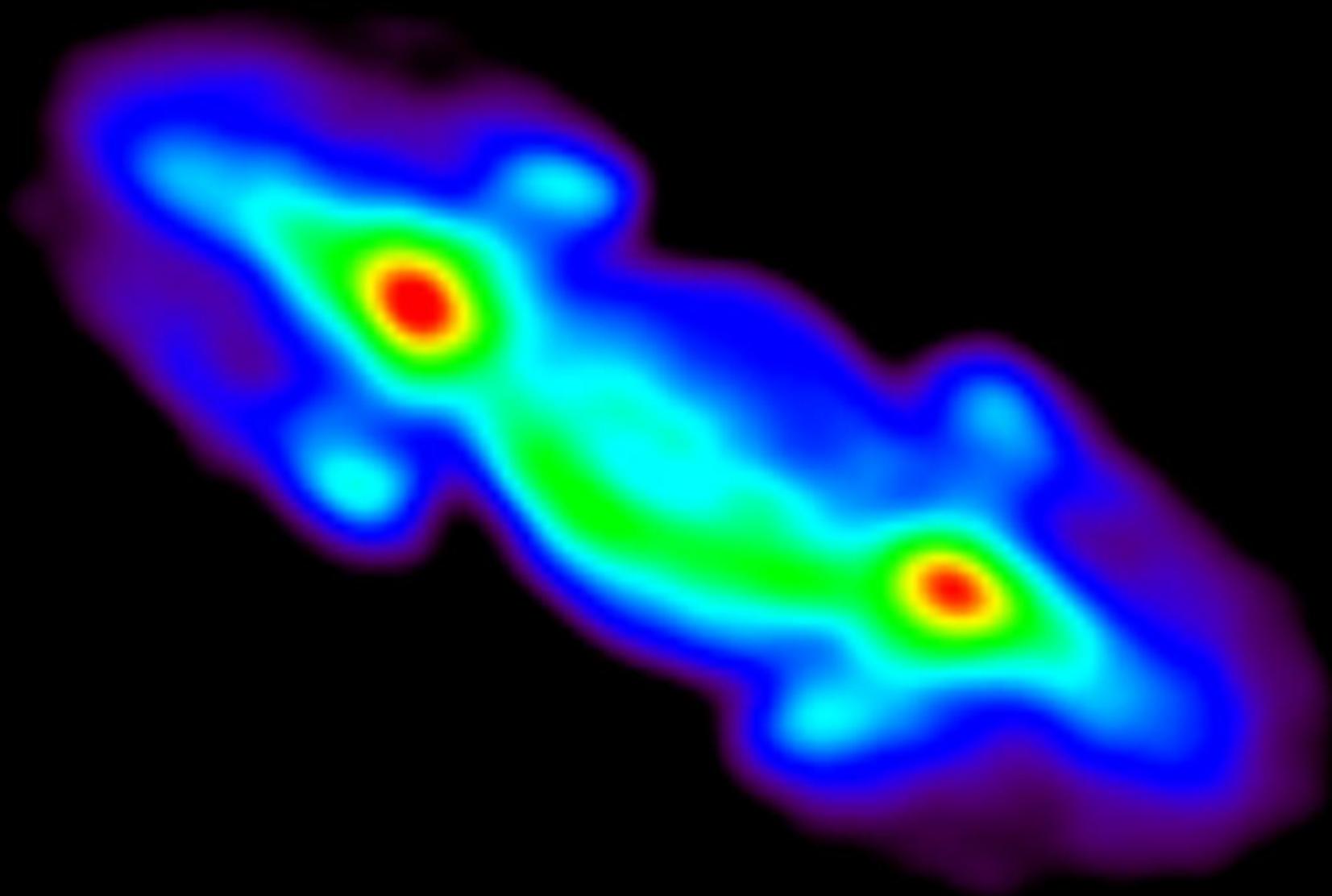
Recipe for Radio Waves

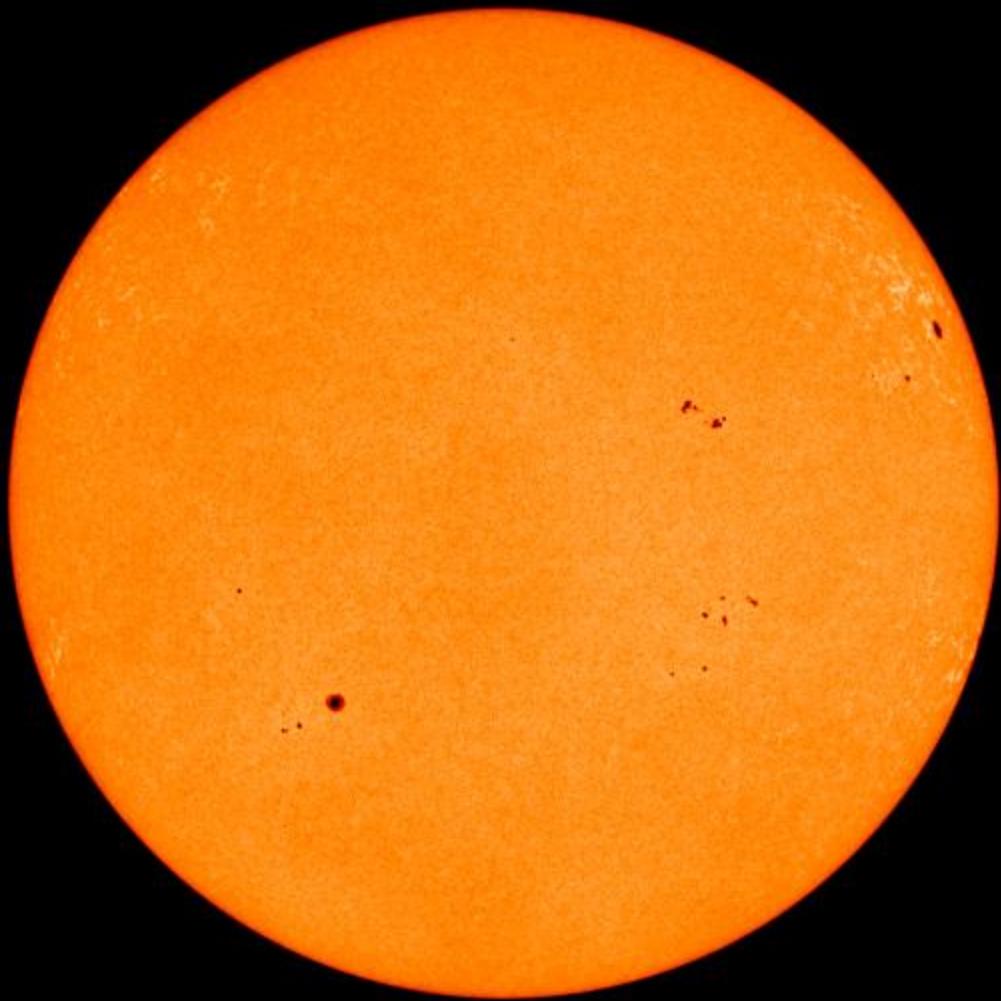
3. Electrons and magnetic fields

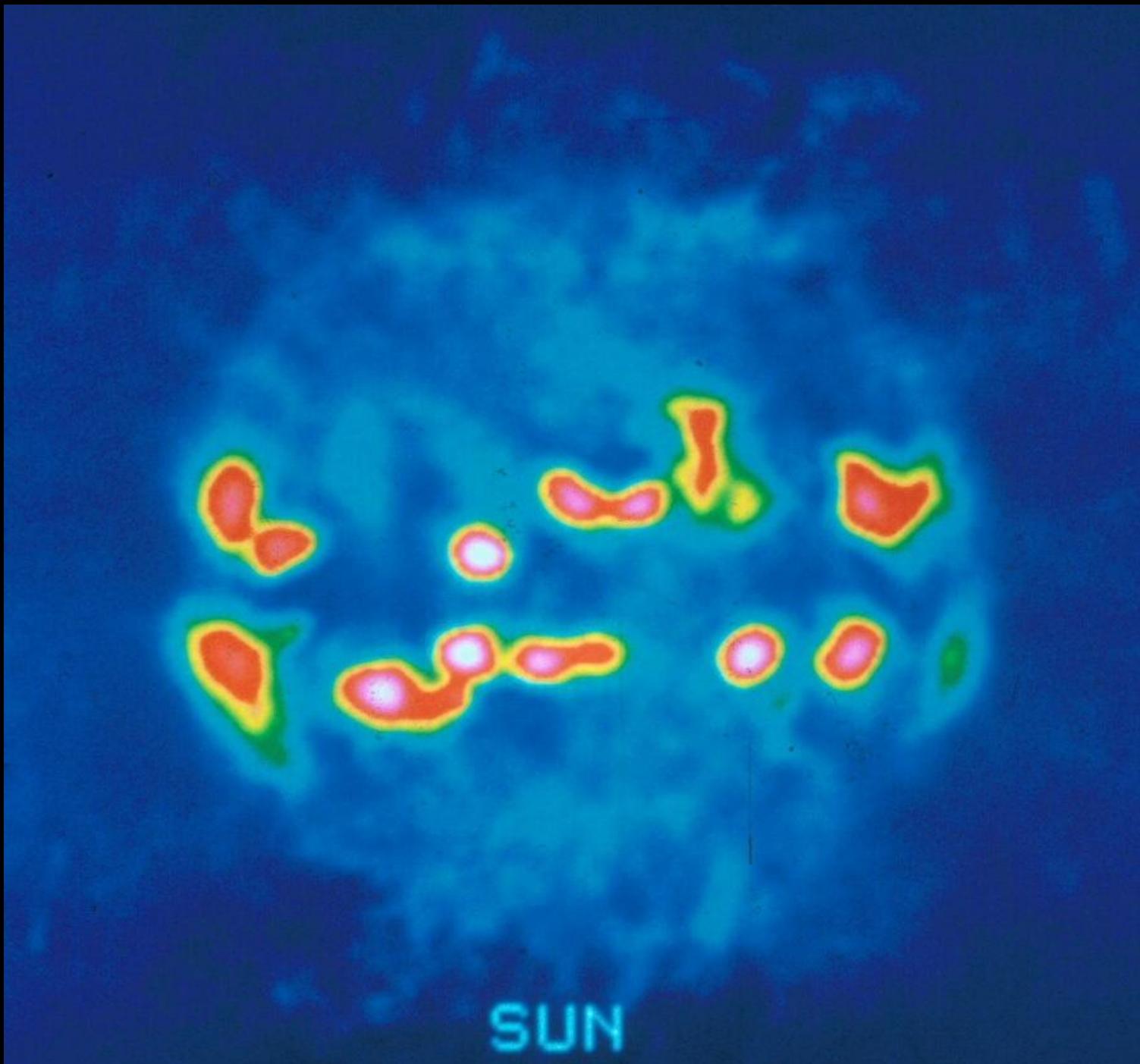
Electrons accelerate around magnetic field lines



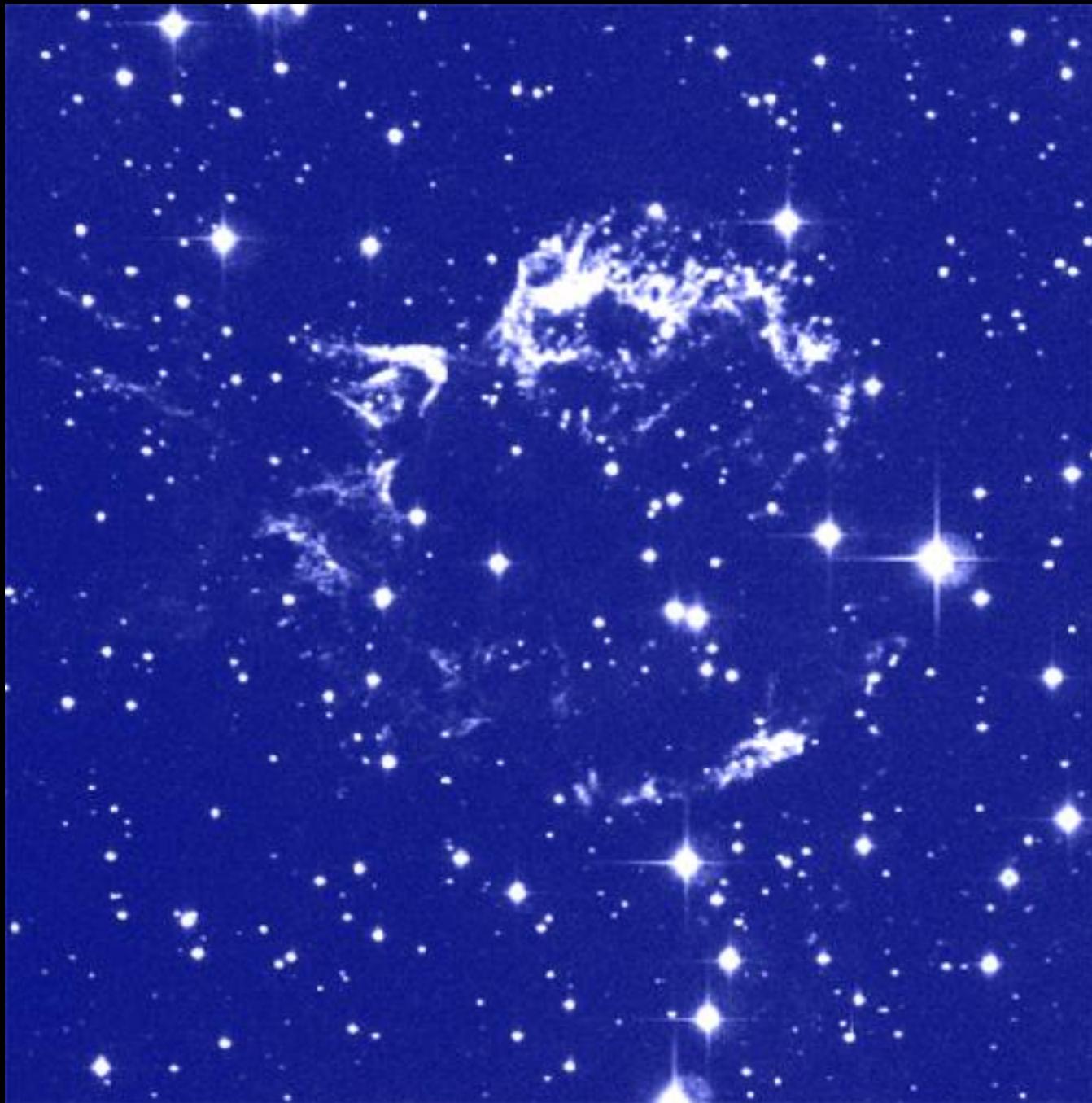


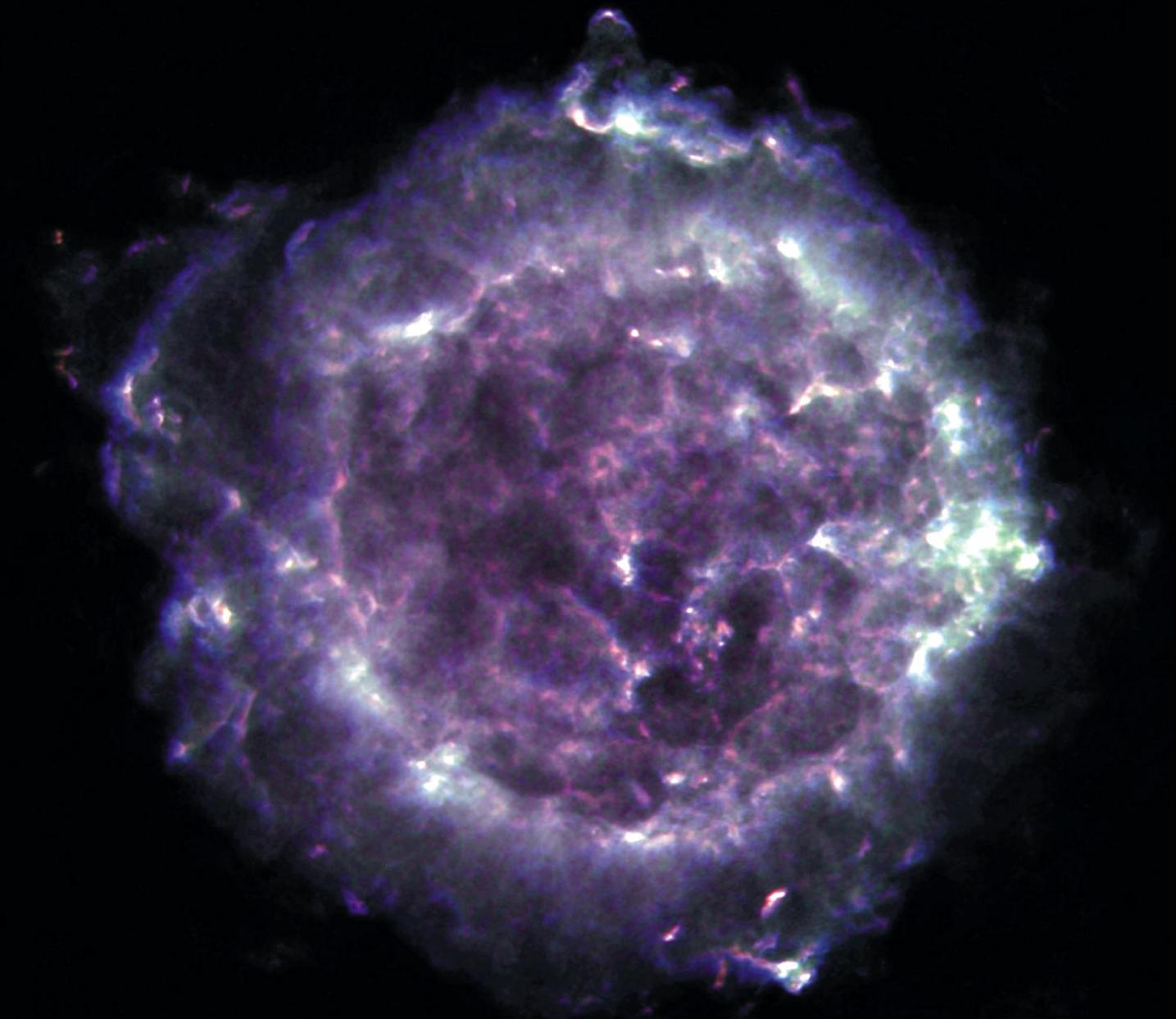






SUN







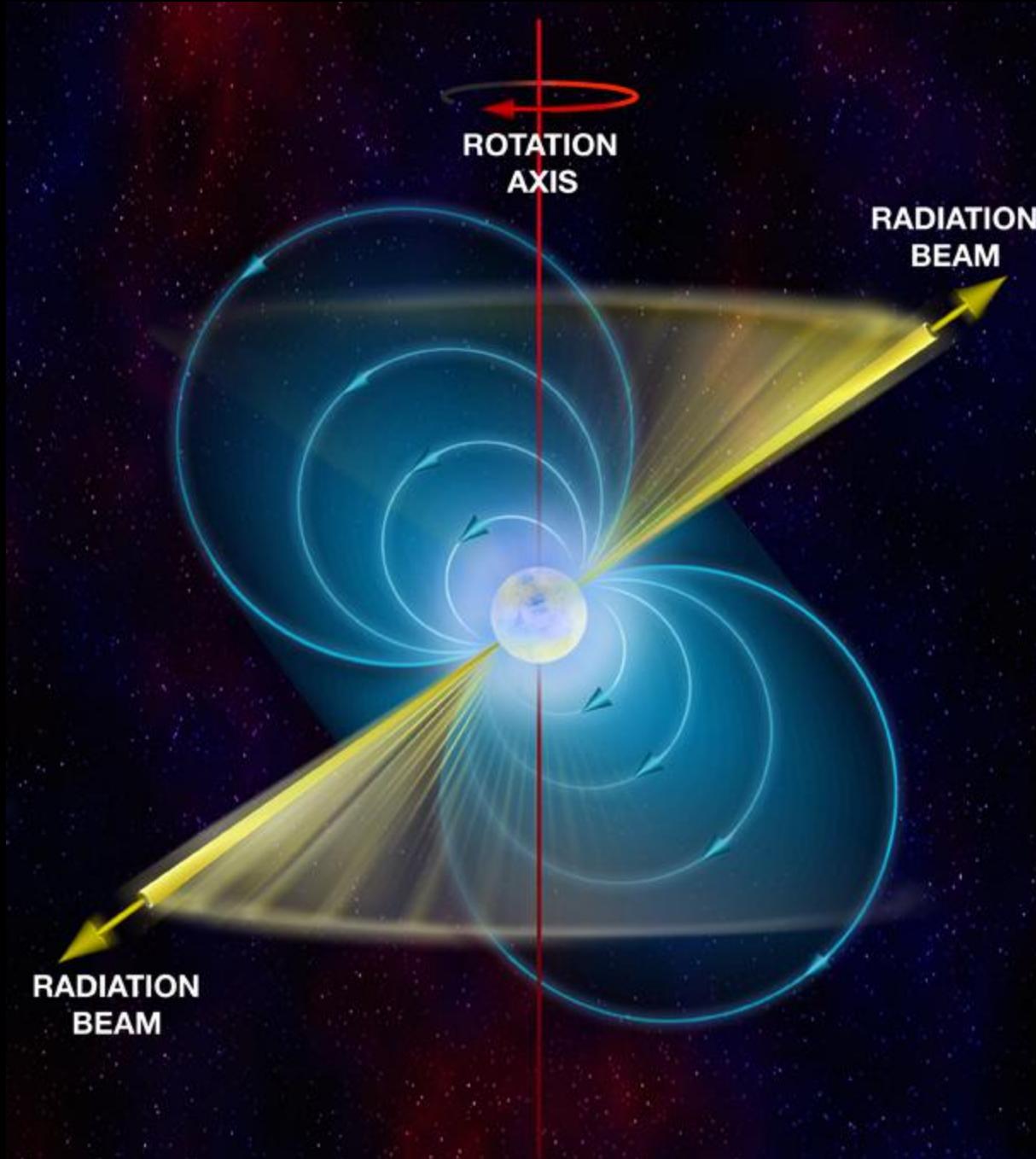
0329+54

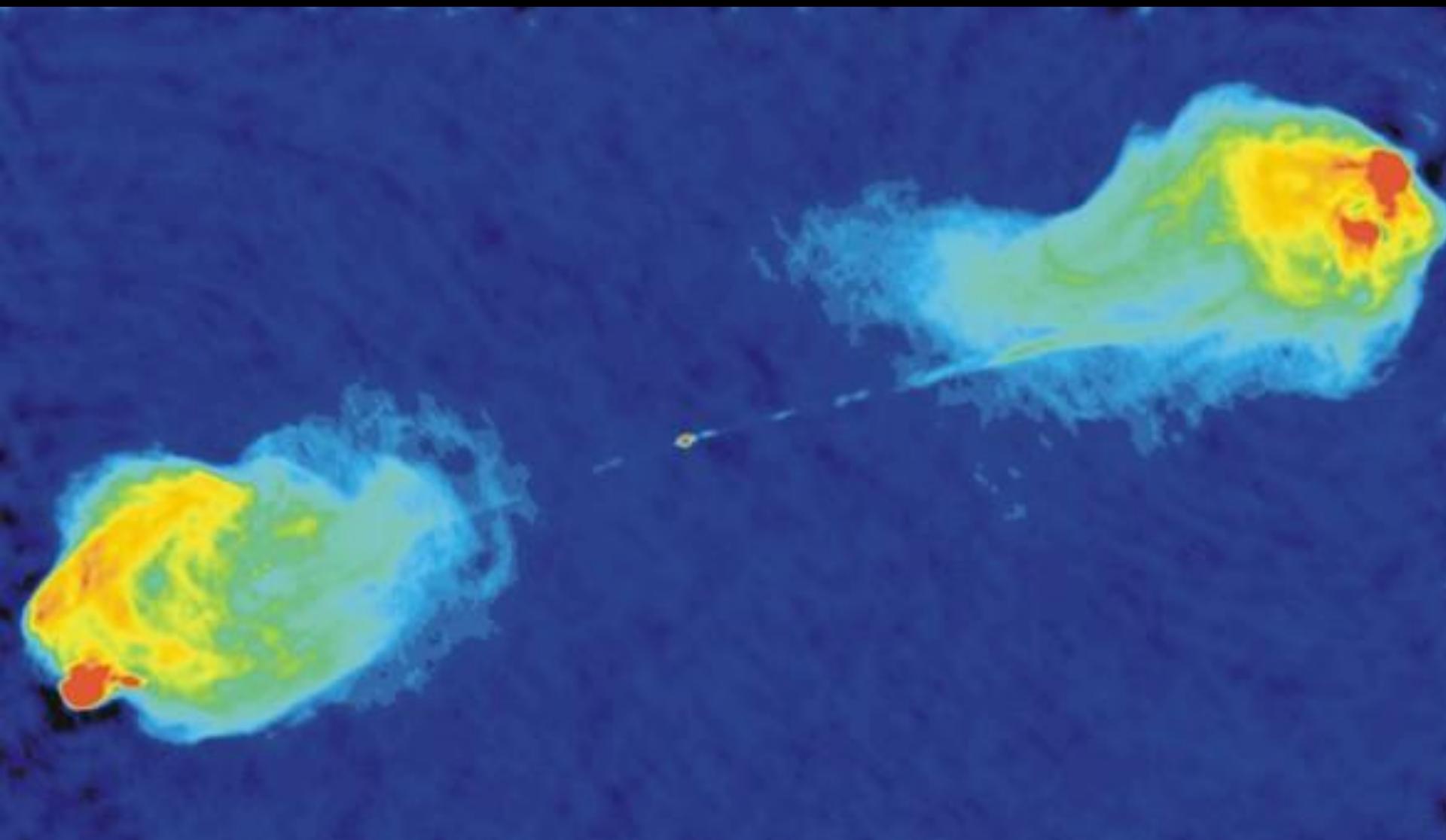


Vela

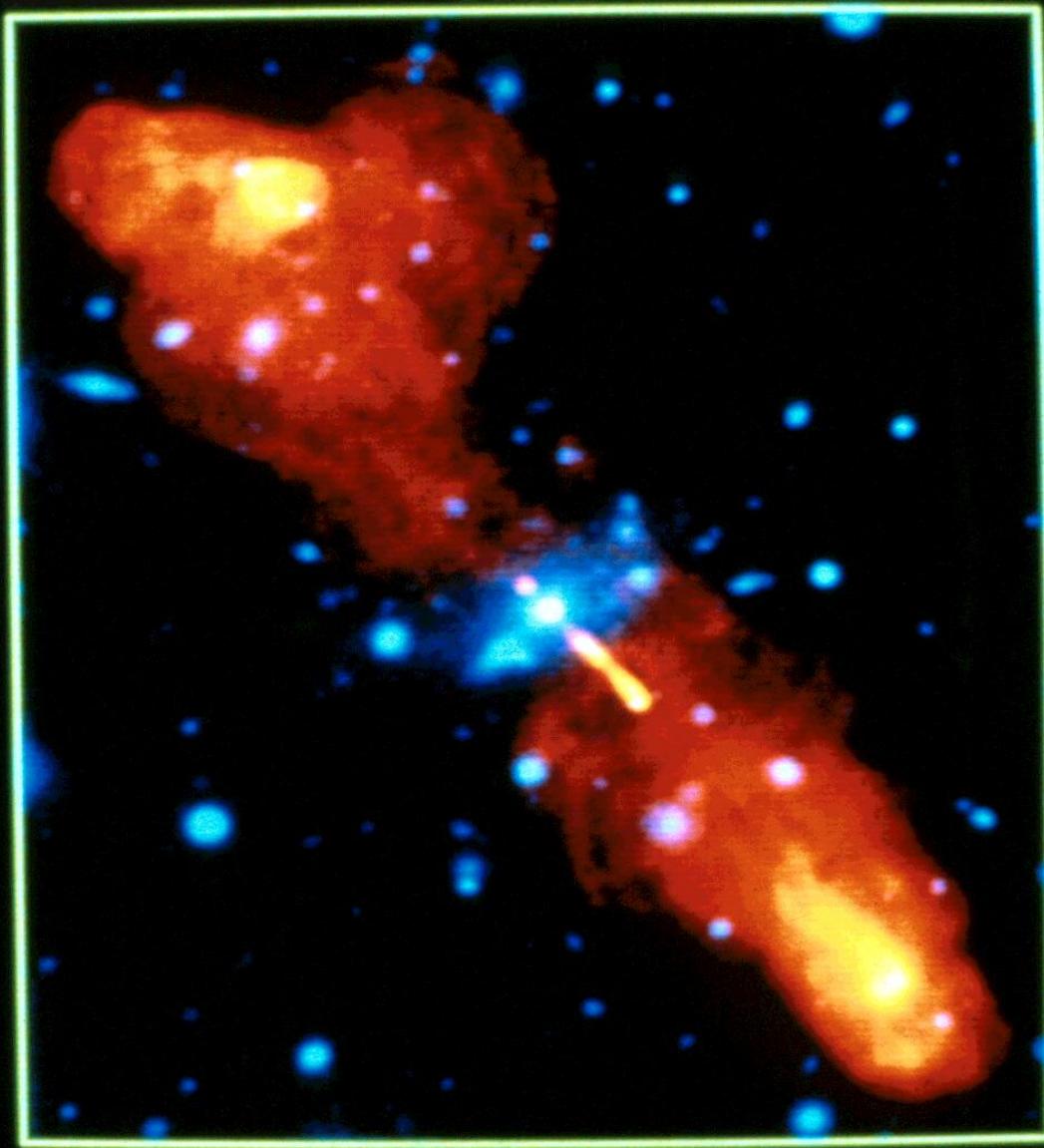


0531+21





3C219



BLUE = V BAND
RED = 22 CM



Big Point:

*Any accelerating charge emits
radio waves!*

Big Point # 2:



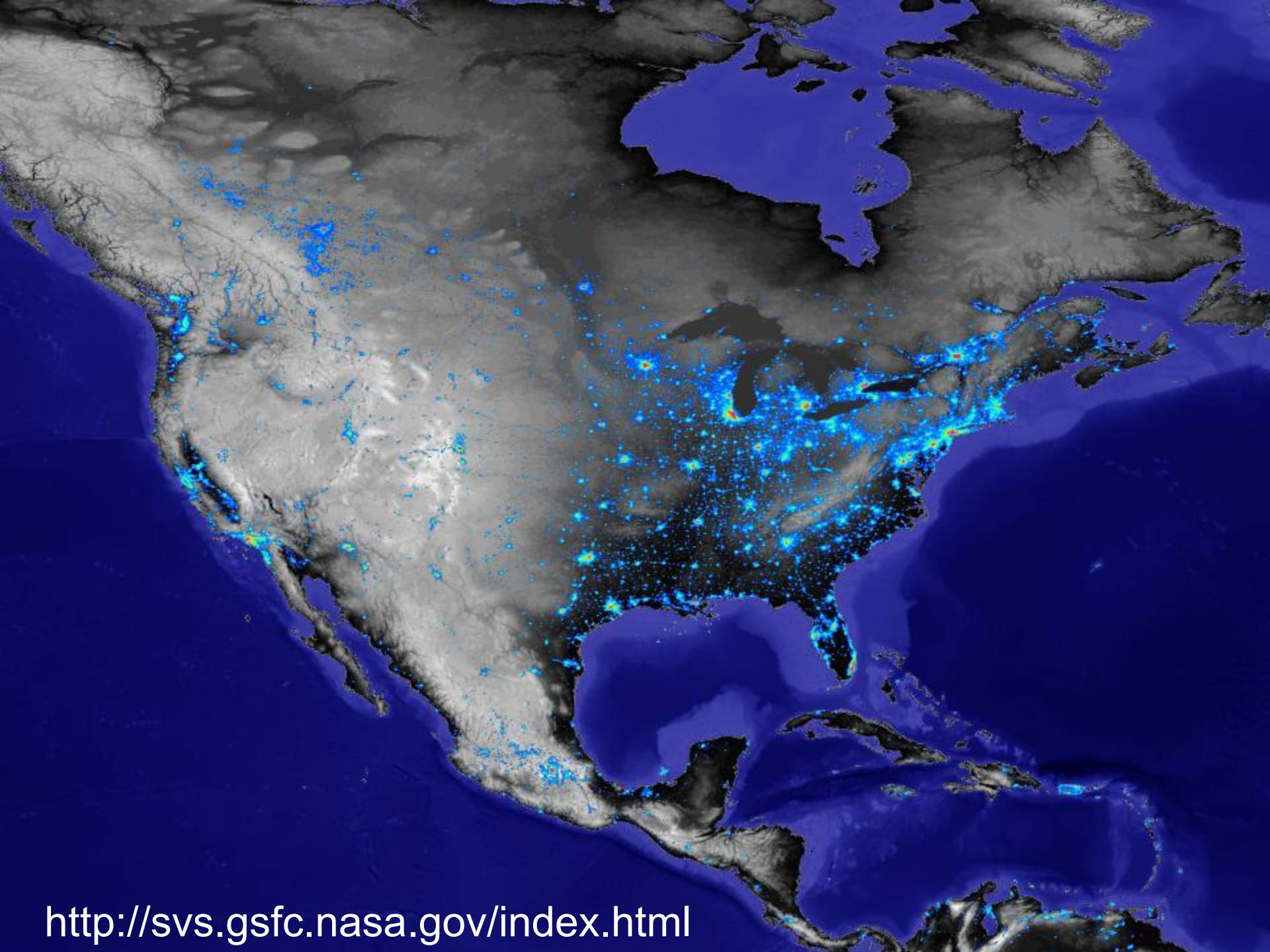
NRAO/AUI/NSF

41

The Rest of the Story:

What else emits radio waves?

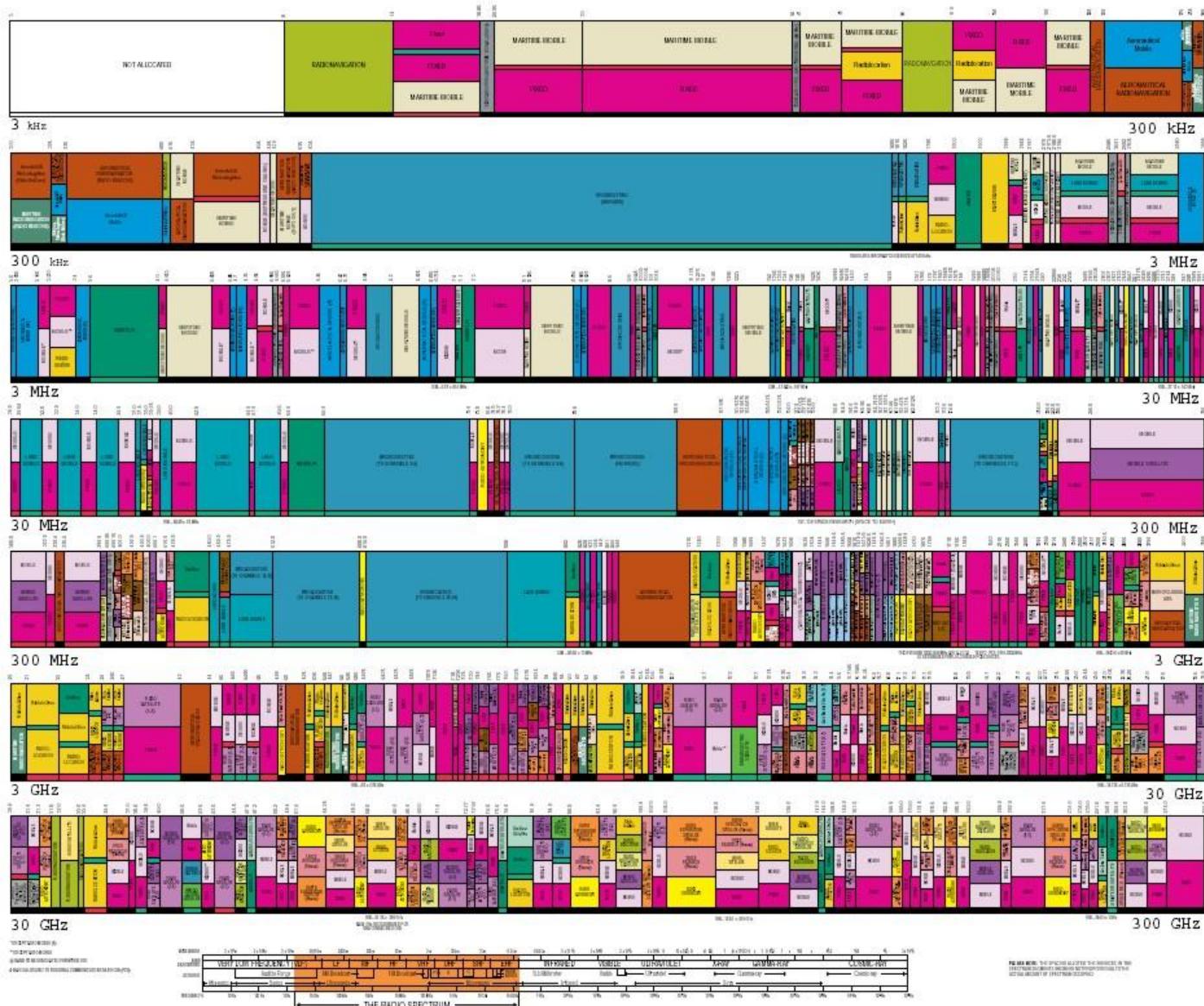
Everything!!



<http://svs.gsfc.nasa.gov/index.html>

**UNITED
STATES
FREQUENCY
ALLOCATIONS**

THE RADIO SPECTRUM



<http://www.ntia.doc.gov/osmhome/allocchart.html>

PCs



TV Cable



Unintentional Emitters



Power Line

Intentional Emitters

Broadcast TV
Cell Phone Service
Radar

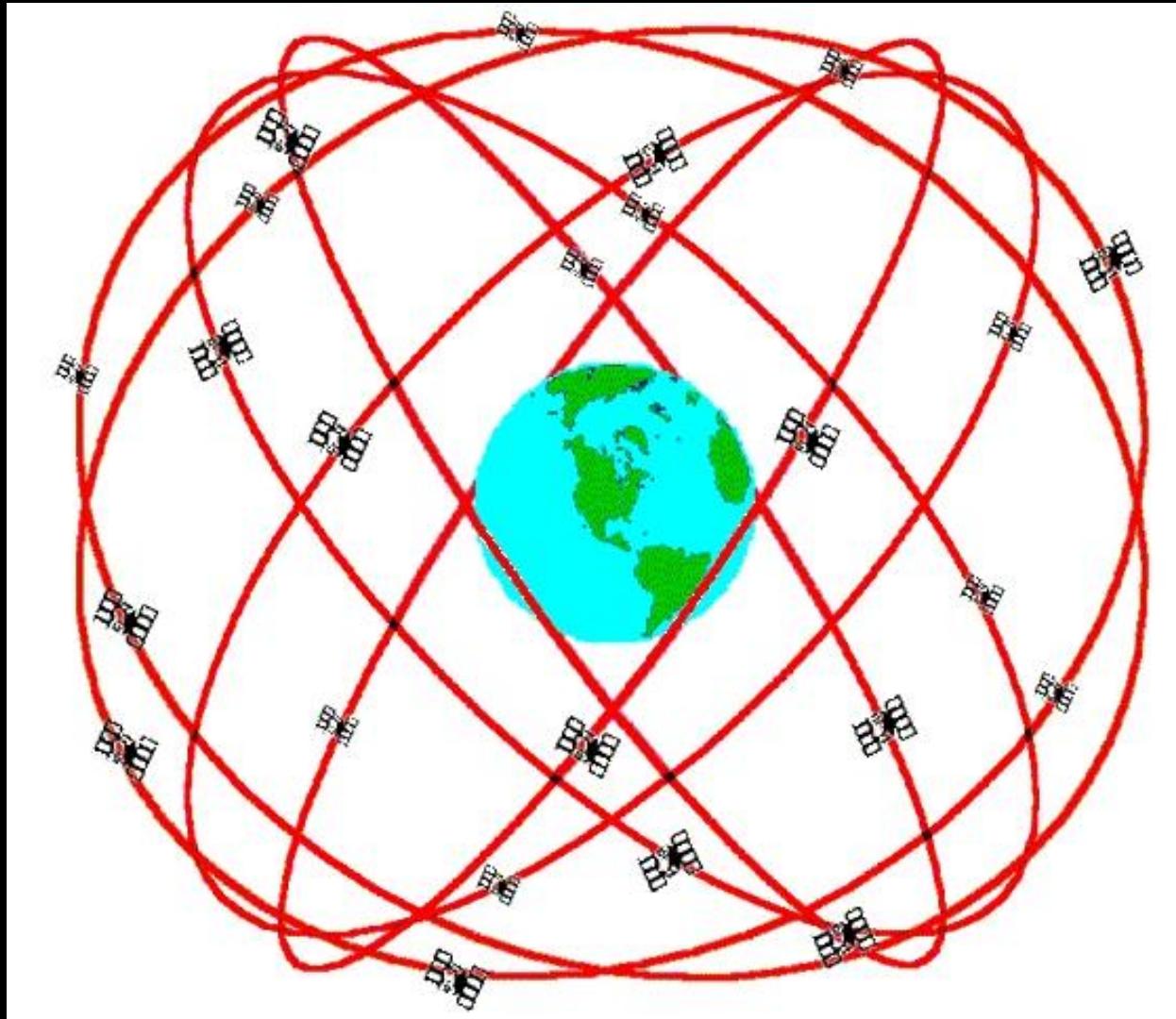


824-849 MHz



and...

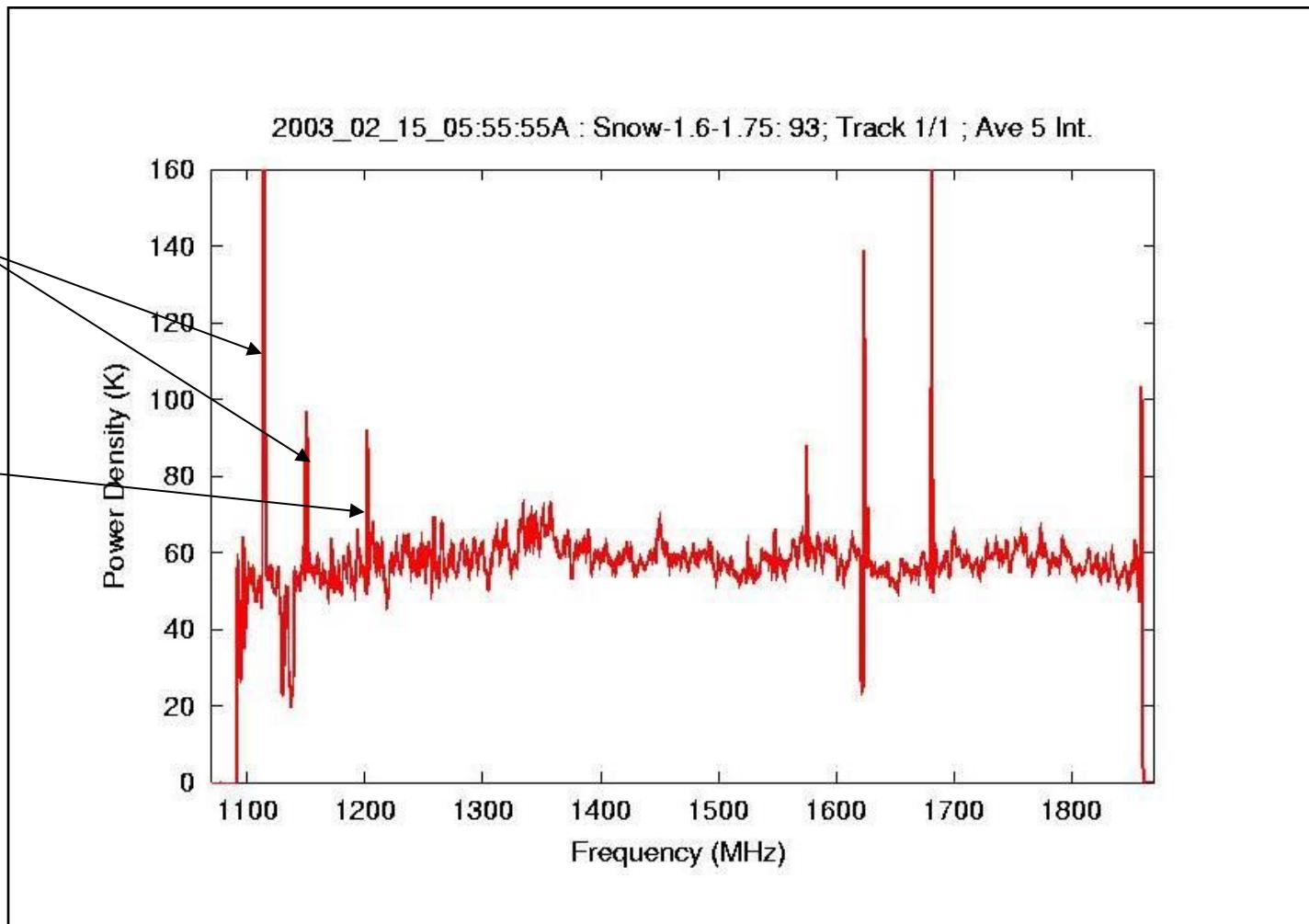
Satellites!



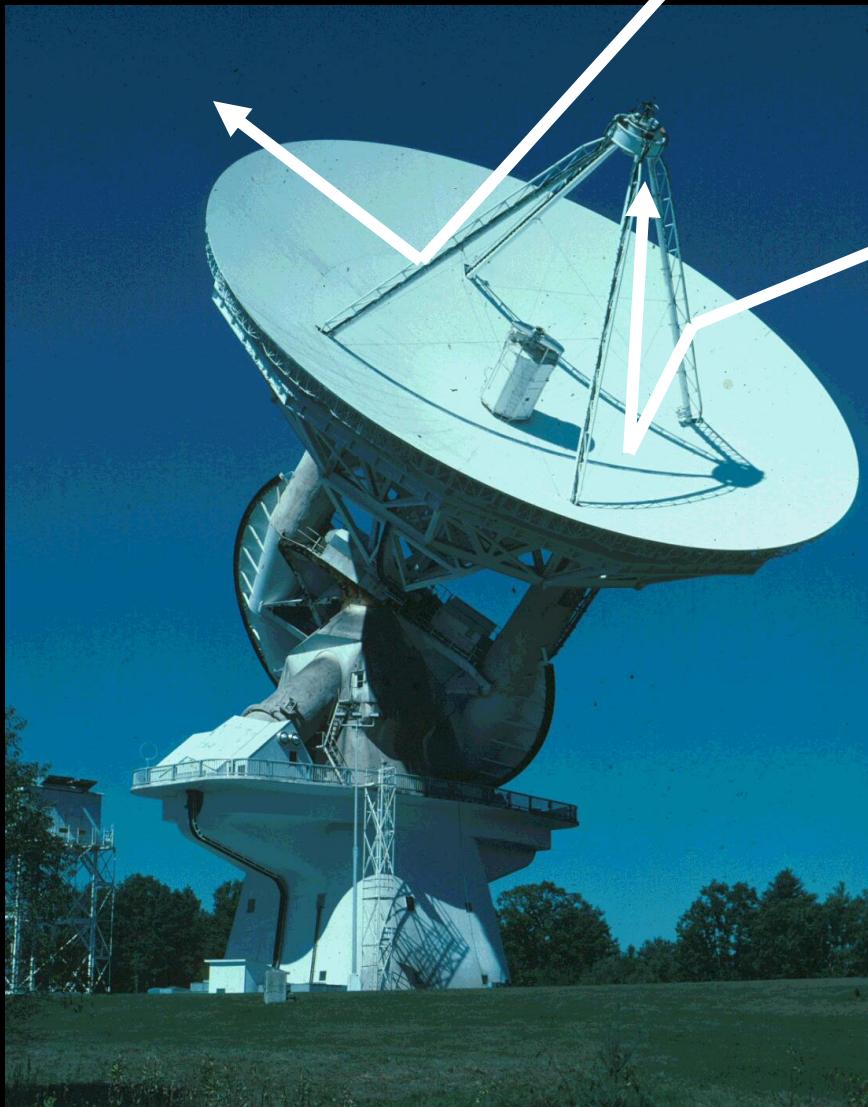
GPS (and GLONASS) 1.22-1.25 GHz

Radar altimeter

GPS

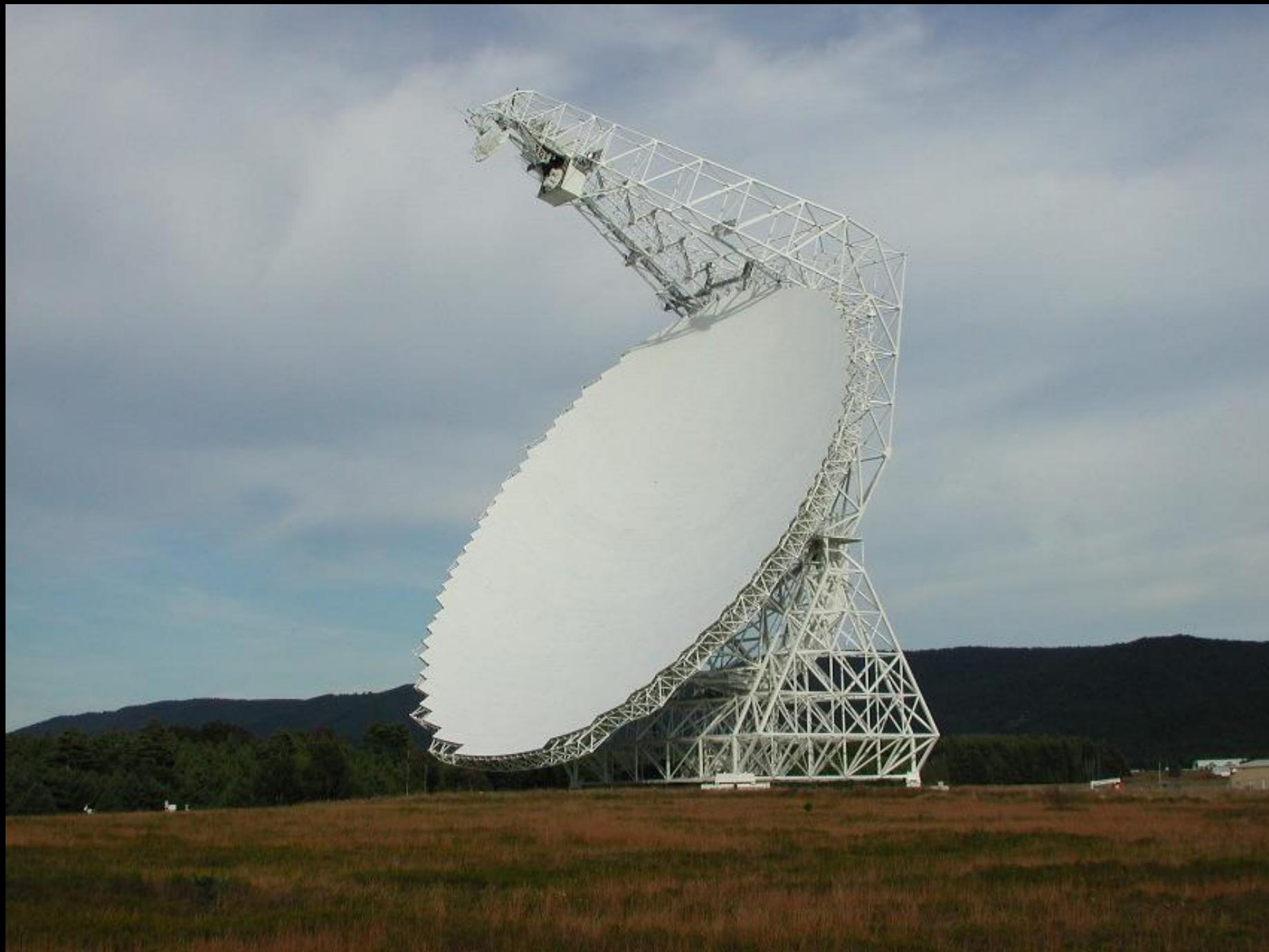


GBT!



NRAO/AUI/NSF

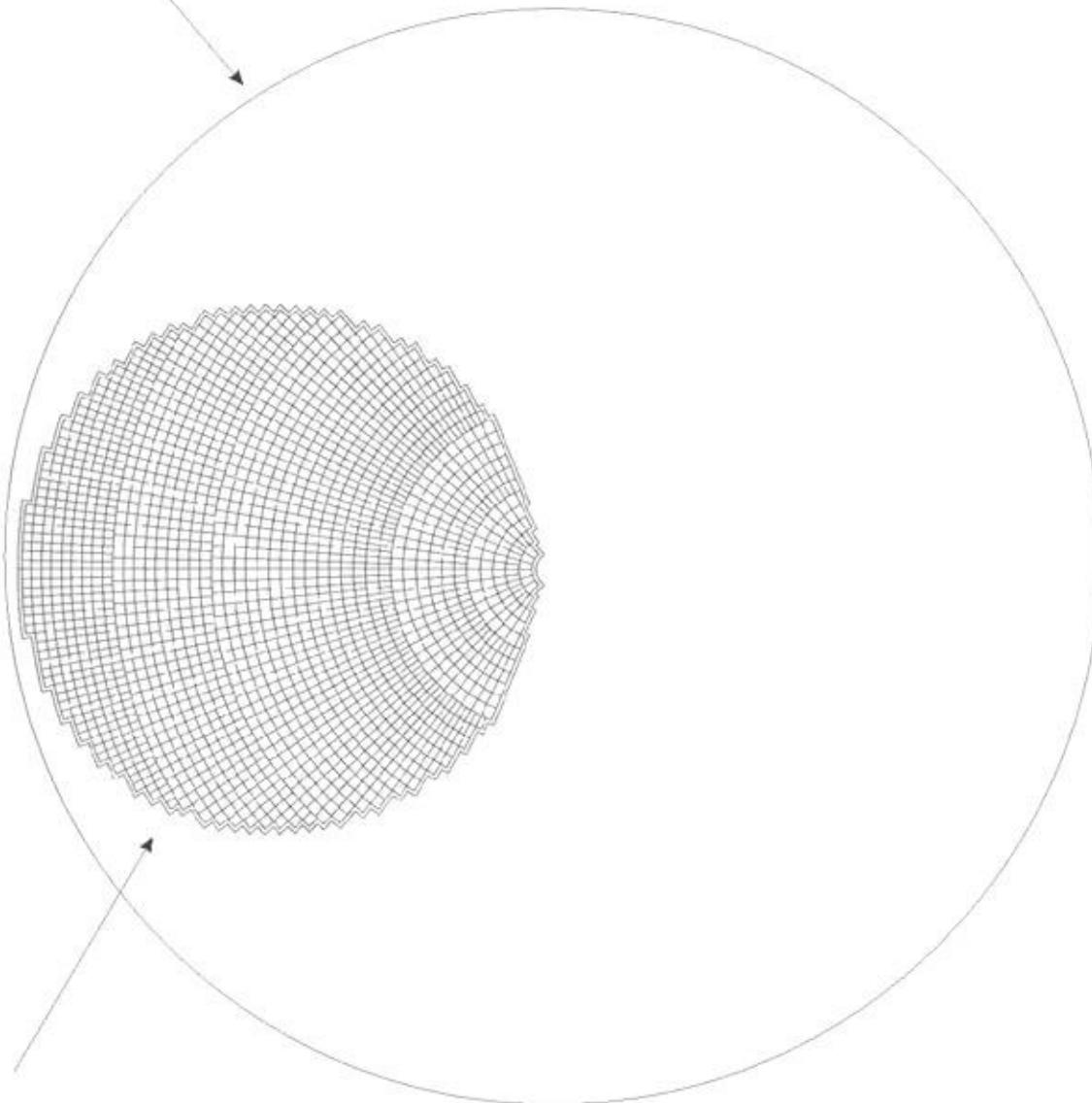
50



Robert C. Byrd Green Bank Telescope



208 m parent (virtual) parabola



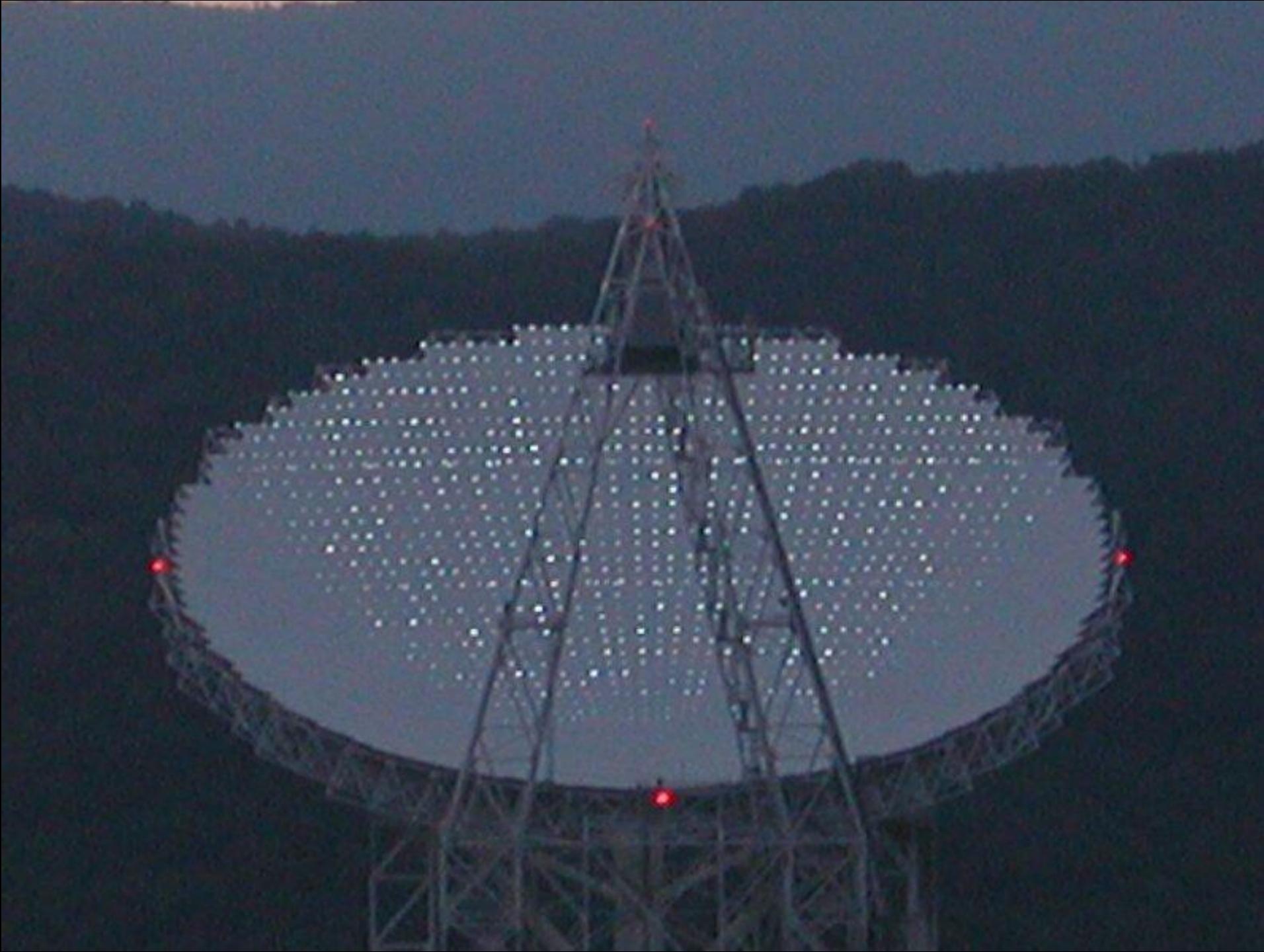
GBT 100 x 110 m Parabola Section

GBT Feed Arm



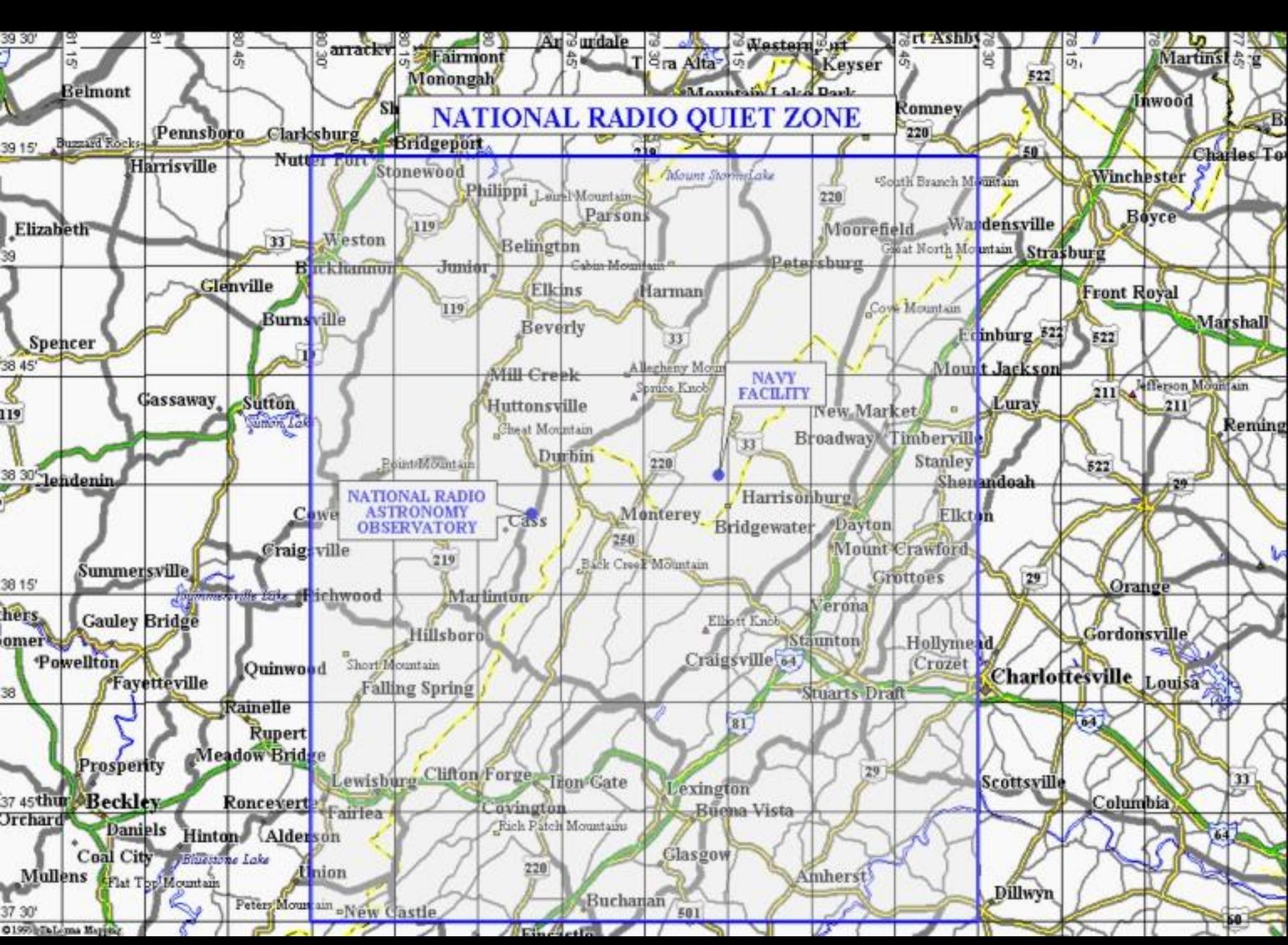






The Observatory in Green Bank





Whew!

What do we get?

Pulsars

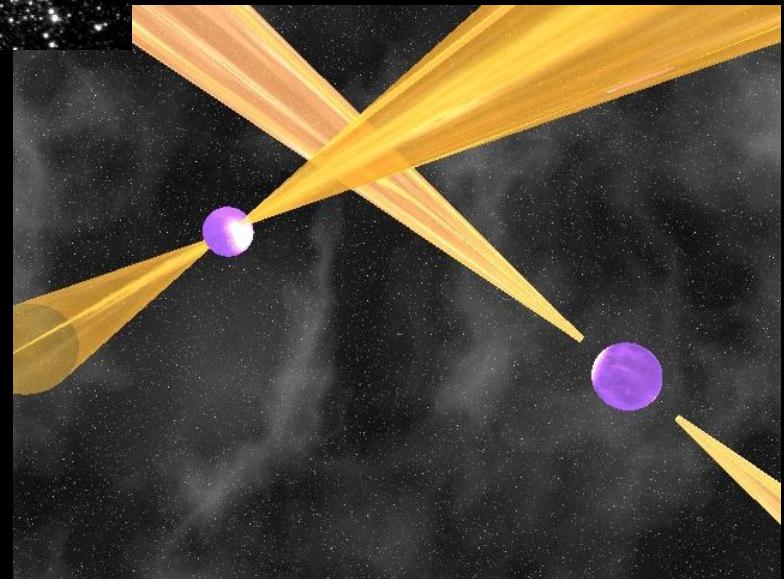
55 discovered in
globular clusters
(Ransom et al).



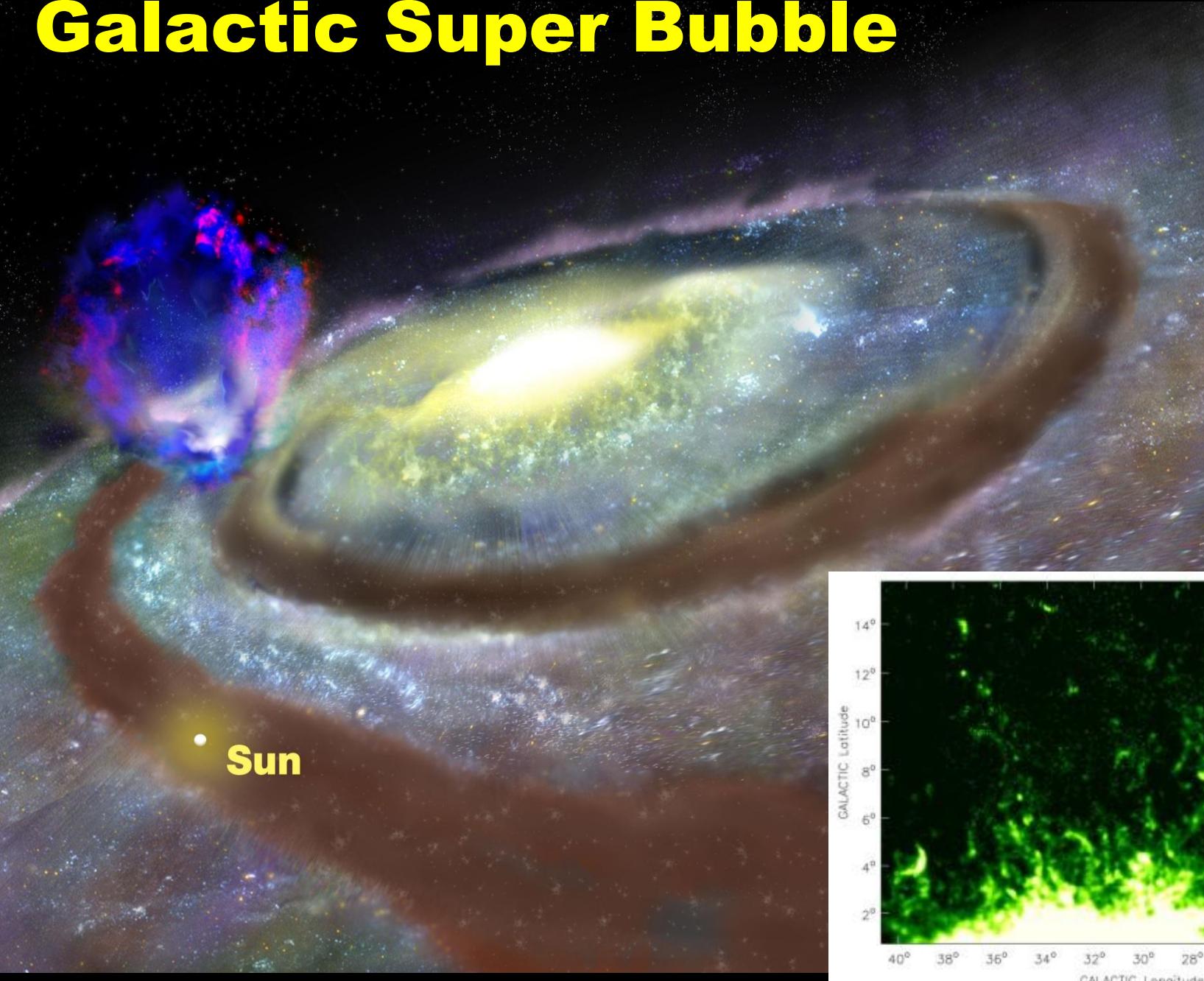
Ter5ad



- Compact object orbiting the 23-millisecond pulsar PSR J0737-3039A, is not only another neutron star, but is also a detectable pulsar.
- Powerful laboratory for GR!

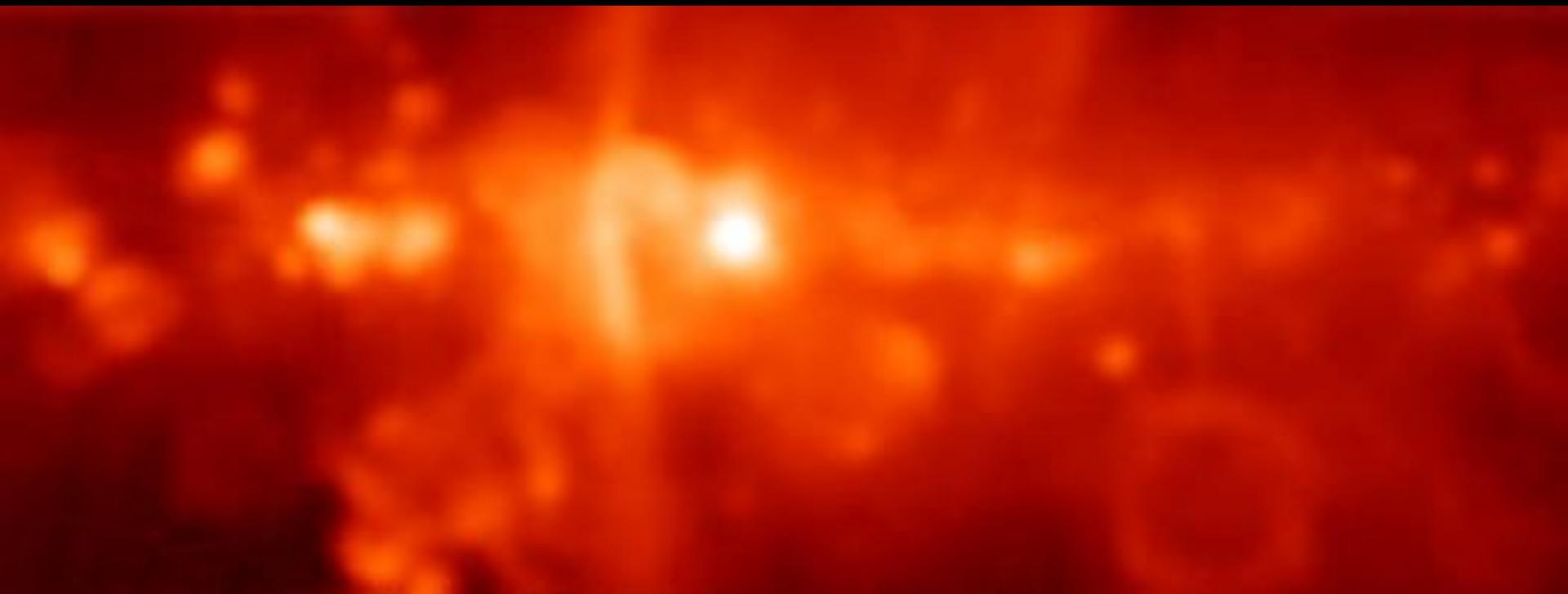


Galactic Super Bubble



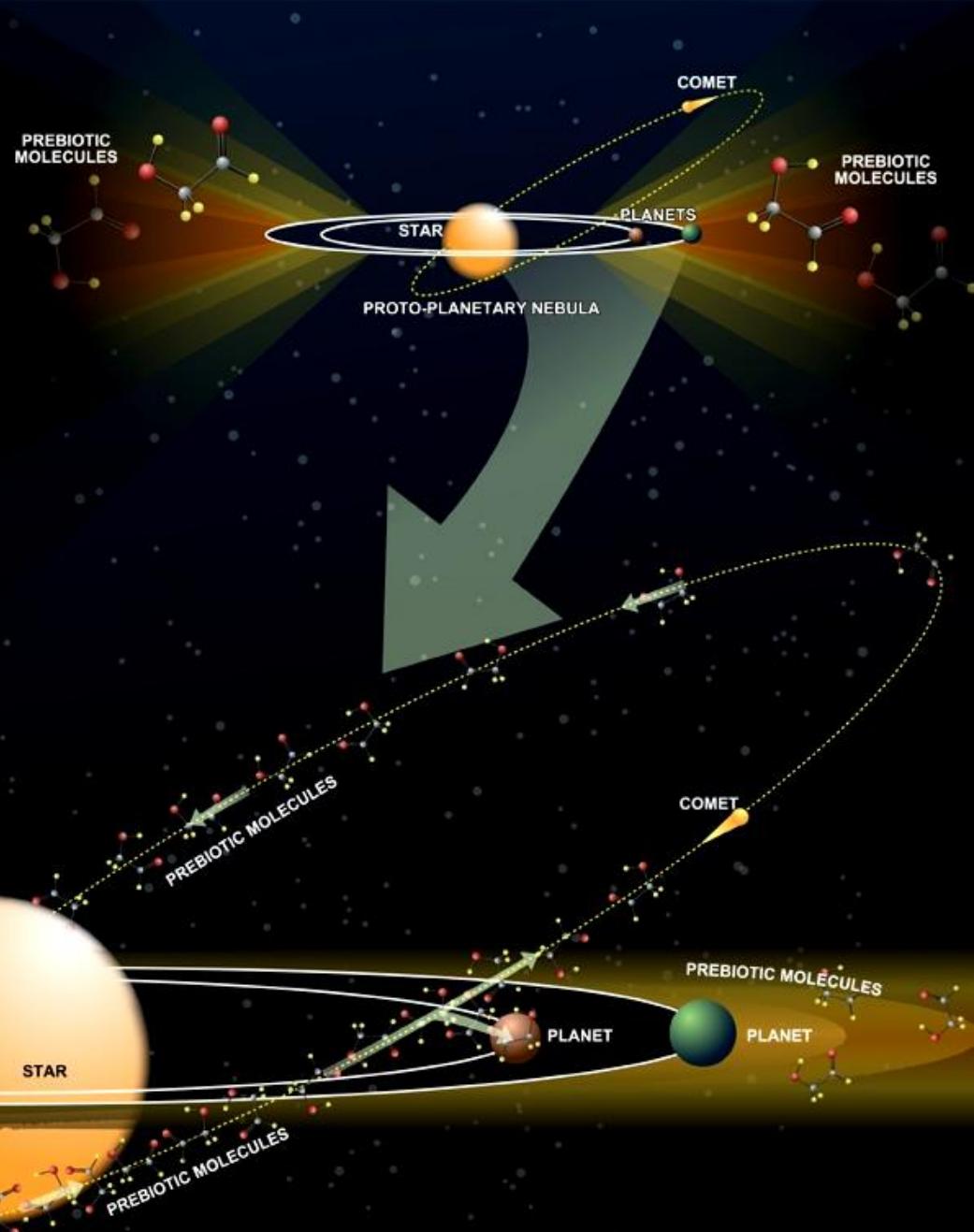
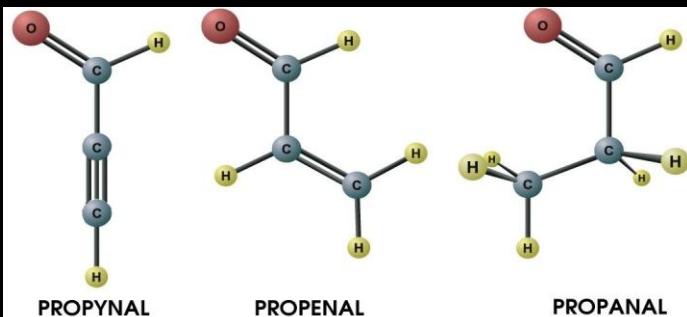
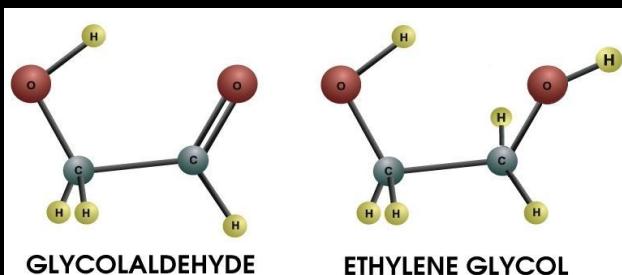
Black Holes

Radio View of the Galactic Center

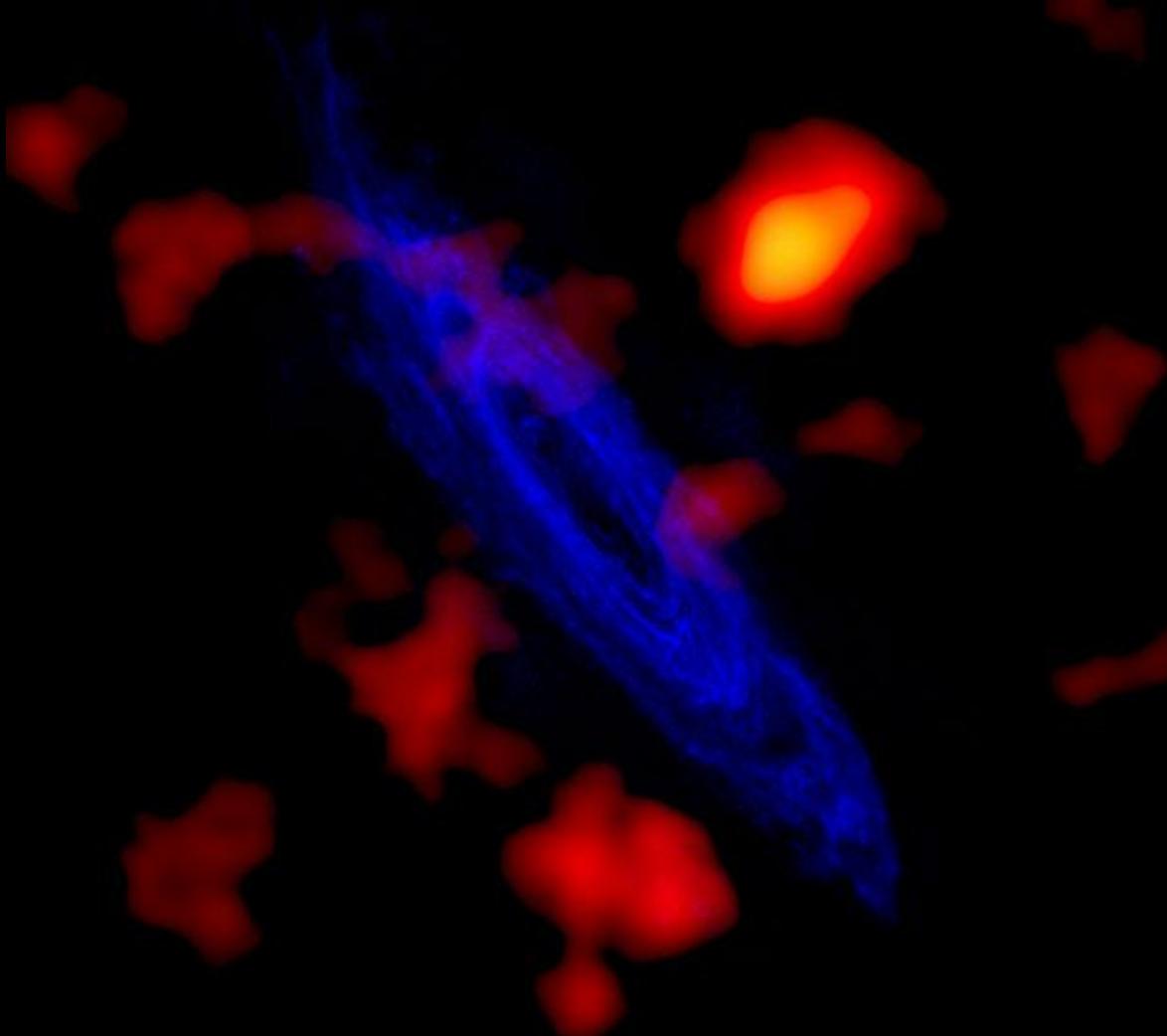


Organic Molecules;

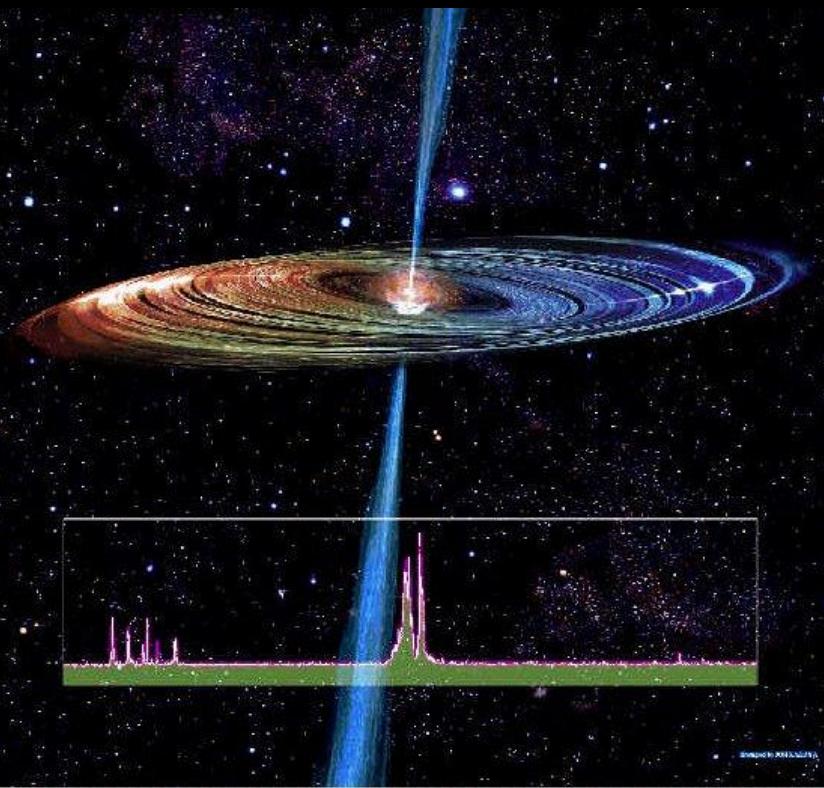
Seeds of Life



Galactic Building Blocks



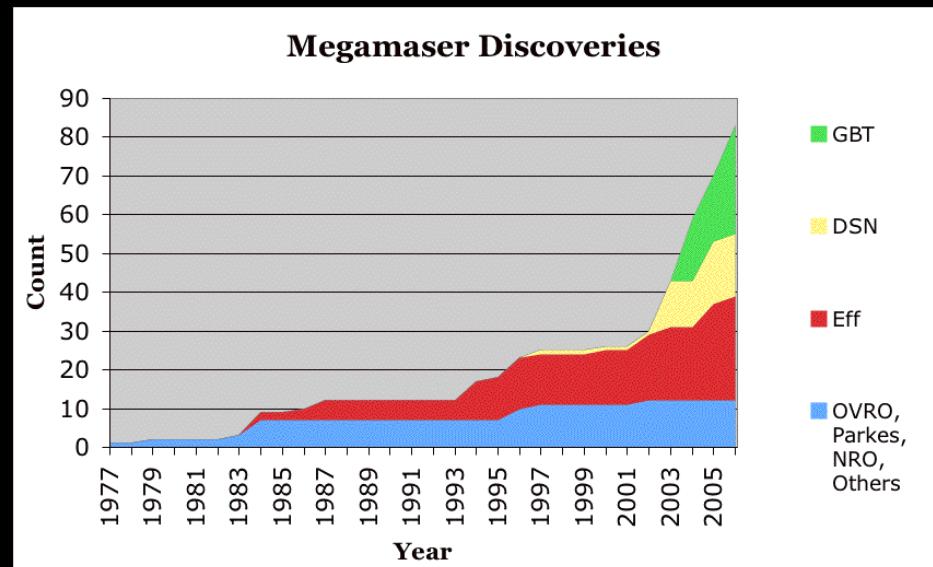
Distances to H₂O Megamasers



NGC 4258

Goal:

- 10+ distances to obtain H₀ with better than 3% uncertainty



Making Radio telescopes at the summer school



- *Complex*
- *High precision*
- *Billions of dollars*

Low cost solutions

- *Software defined radio*
- *RTL-SRD*
- *GNU-Radio*

What is Software Defined Radio (SDR)?

Definition:

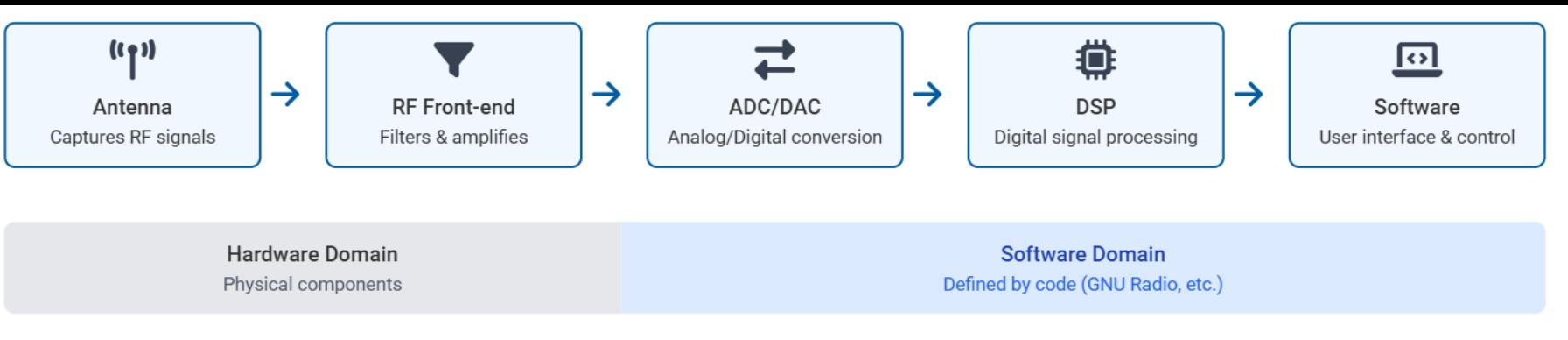
A radio communication system where components traditionally implemented in hardware (mixers, filters, amplifiers, modulators/demodulators) are instead implemented through software on a computer or embedded system.

Traditional Radio

Software Defined Radio

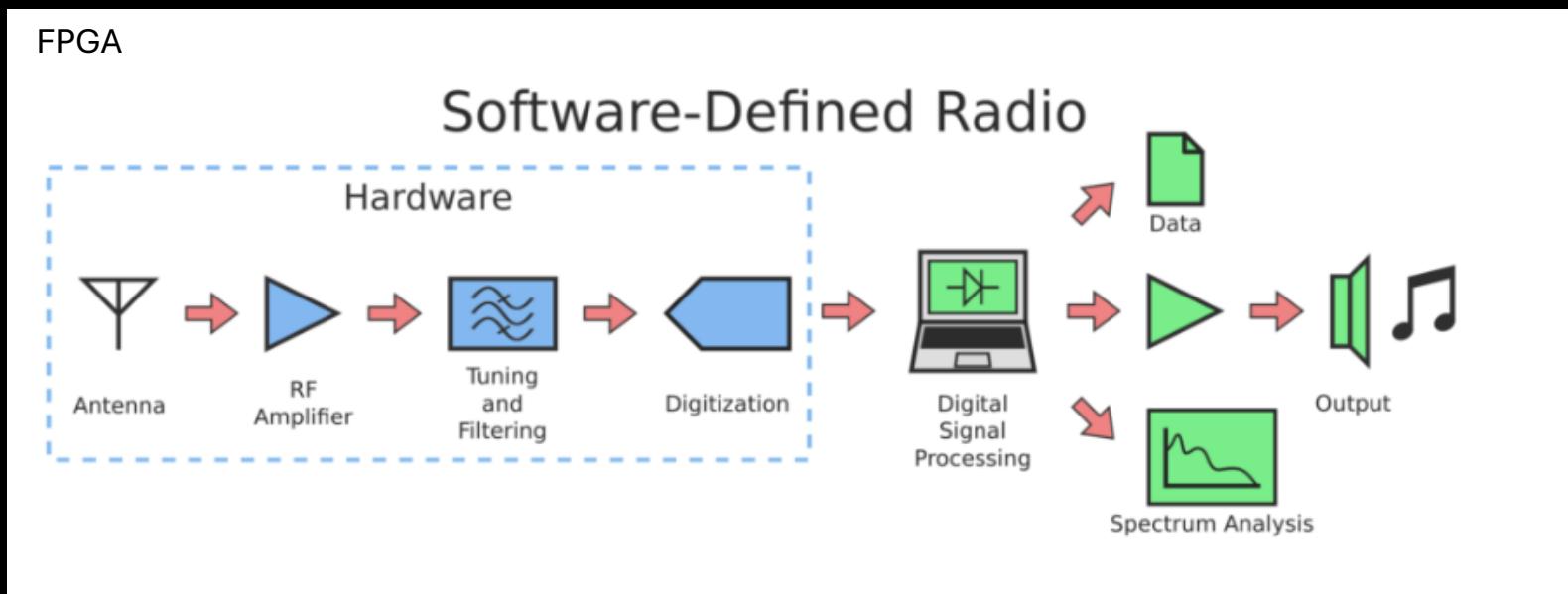
- Fixed hardware components
- Single purpose design
- Hardware changes required for upgrades
- Higher component count
- Software defined radio
 - Reconfigurable for multiple purposes
 - Upgradable through software updates
 - Simplified hardware design

SDR Architecture Overview



- ***RF Front-end: Filters unwanted signals, amplifies the received signal, and performs frequency conversion (mixing) to manageable frequencies.***
- ***ADC: converts analog signals to digital for***

What is Software Defined Radio (SDR)?

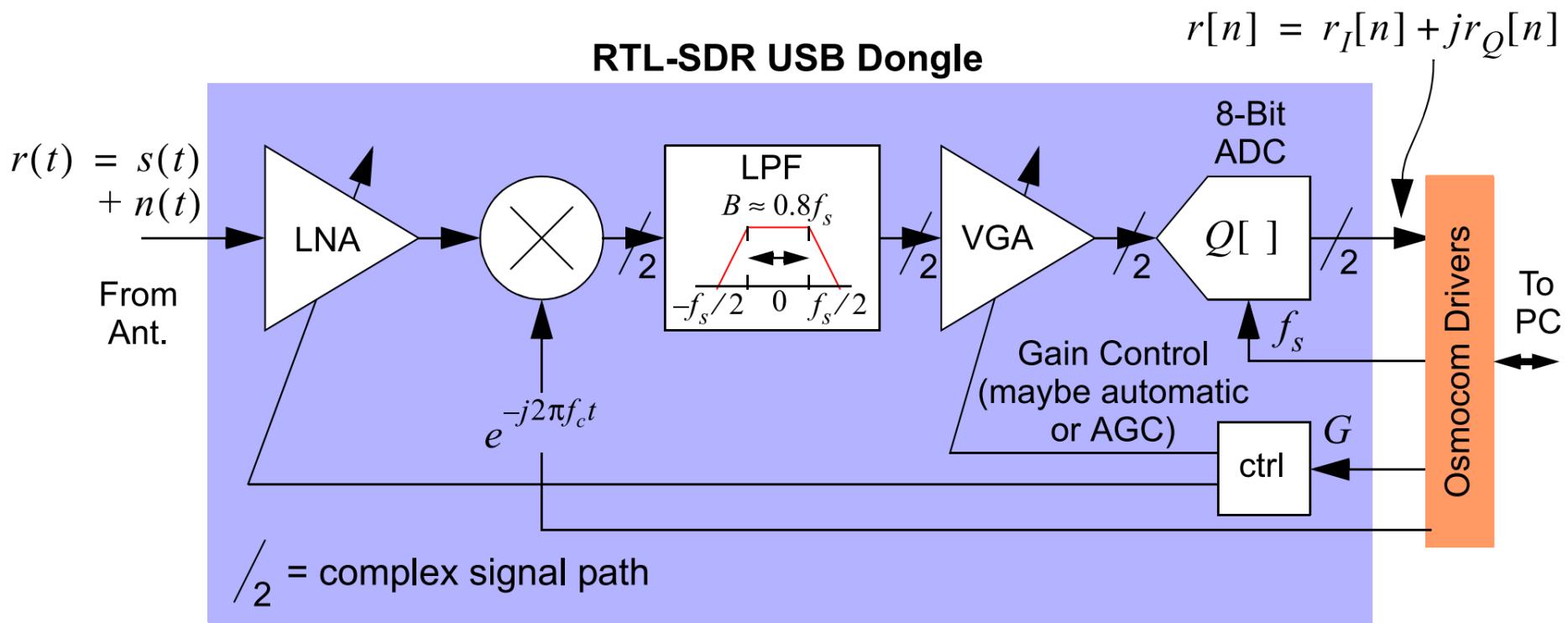


What is the RTL-SDR?

- *A very cheap RX Software Defined Radio*
 - 2.4 MHz bandwidth, tuning range 24 – 1.7 GHz.
- *Originally (and still is) a DVB-T TV Tuner*
 - Highly mass produced in China – very cheap
- *Hardware hackers found the SDR feature*
 - Originally designed for FM radio reception
- *Opened up a whole new world of experimentation.*
 - New (and old) blood returning to the radio scene.
 - 8 bits = (2^8)



RTL-SDR USB Dongle



What can it do

📻 Radio Communications

- **FM/AM Radio Reception - Listen to broadcast radio stations**
- **Police/Fire Scanner - Monitor public safety communications**
- **Amateur Radio - Receive HAM radio transmissions**



✈️ Aviation & Transportation



- **ADS-B Aircraft Tracking - Track aircraft positions and flight paths**
- **ACARS Messages - Aircraft communication and reporting system**
- **VOR Navigation - Aviation navigation beacon reception**

📡 Satellite Communications

• **Weather Satellite Images - NOAA weather**

What is GNU-Radio?

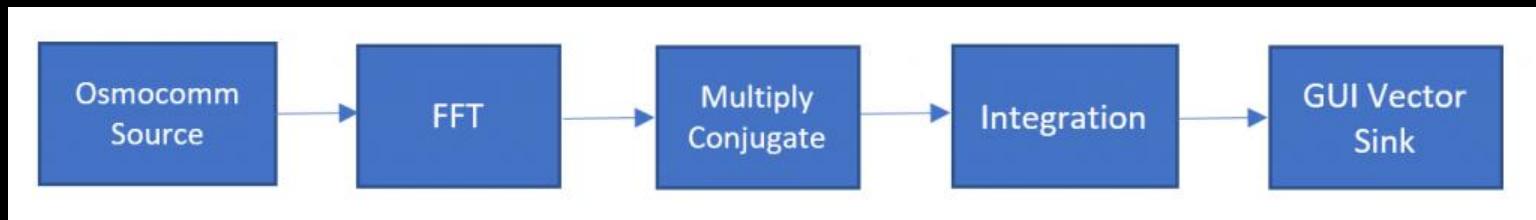
- *A signal processing library*
- *Designed for real-time*
- *The software part of an SDR*
- *Not a radio application*
- *The tool to build your own transceivers*
- *FOSS: Free and Open Source Software*



How to set up an RTL-SDR GNU Radio system

- *Works on Windows, Linux, Raspberry Pi, MacOS*
 - Windows: GNU-Radio, SDR#, SDR-Console, SDRpp, HDSDR
 - Raspberry Pi: GNU-Radio, Command line tools, SDRpp, GQRX
 - Linux/MacOS: GNU-Radio, GQRX

Signal processing with SDR



PROJECTS AT THE 3SOA25 school

- *Radio Scanner (Dr Shih-Hao Wang)*
- *2-antenna interferometer (Dr NLQ)*
- *CMB Radiometer (Nguyen)*
- *QNO Observations (Tomomi)*
- *NRO45m data (Prof Dobashi)*
- *Galaxy (Binh Nguyen)*