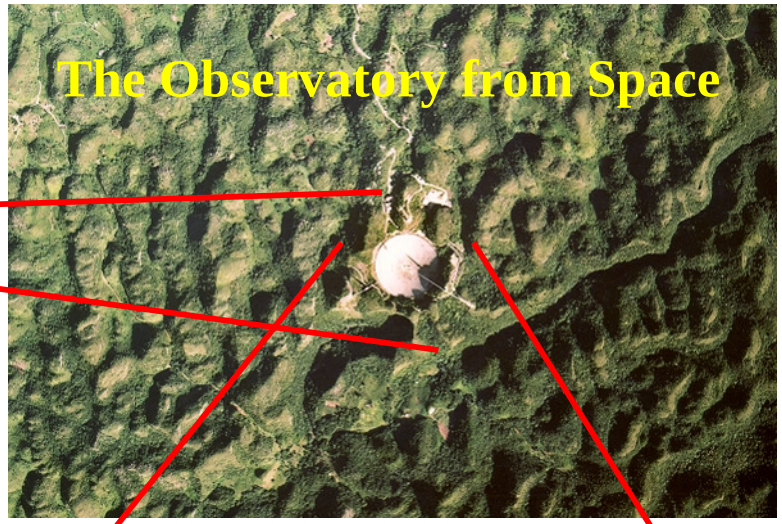
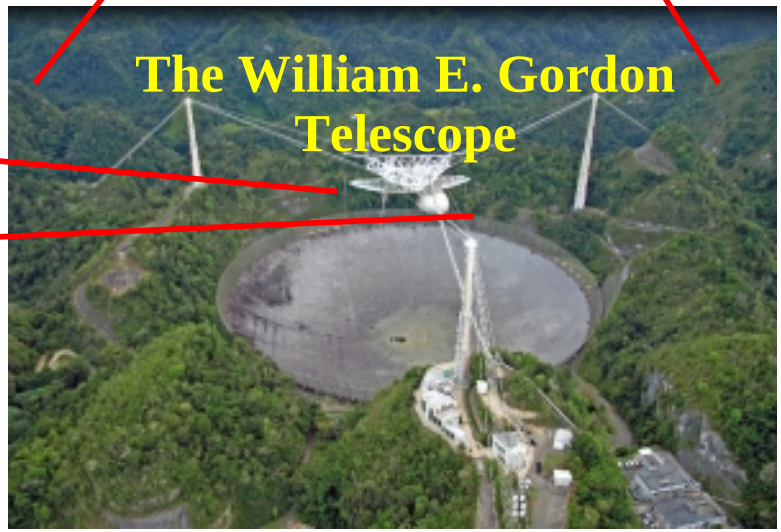
Arecibo Observatory: 57 Years of Unprecedented Discoveries

Chris Salter

Arecibo Observatory (Retired)

Geographical Context





Incoherent Scattering of Radio Waves by Free Electrons with Applications to Space Exploration by Radar*

W. E. GORDON†, MEMBER, IRE

Summary—Free electrons in an ionized medium scatter radio waves weakly. Under certain conditions only incoherent scattering exists. A powerful radar can detect the incoherent backscatter from the free electrons in and above the earth's ionosphere. The received signal is spread in frequency by the Doppler shifts associated with the thermal motion of the electrons.

On the basis of incoherent backscatter by free electrons a powerful radar, but one whose components are presently within the state of the art, is capable of:

1) measuring electron density and electron temperature as a function of height and time at all levels in the earth's ionosphere and to heights of one or more earth's radii;
2) measuring auroral ionization;
3) detecting transient streams of charged particles coming from outer space; and
4) exploring the existence of a ring current.

The instrument is capable of

1) obtaining radar echoes from the sun, Venus, and Mars and possibly from Jupiter and Mercury; and
2) receiving from certain parts of remote space hitherto-undetected sources of radiation at meter wavelengths.

* Original manuscript received by the IRE, June 11, 1958; revised manuscript received, August 25, 1958. The research reported in this paper was sponsored by Wright Air Dev. Ctr., Wright-Patterson Air Force Base, O., under Contract No. AF 33(616)-5547 with Cornell Univ.

† School of Elec. Eng., Cornell Univ., Ithaca, N. Y.

Proceedings of IRE
Nov 1958

1960 - 1963 – (AIO)
CONSTRUCTION

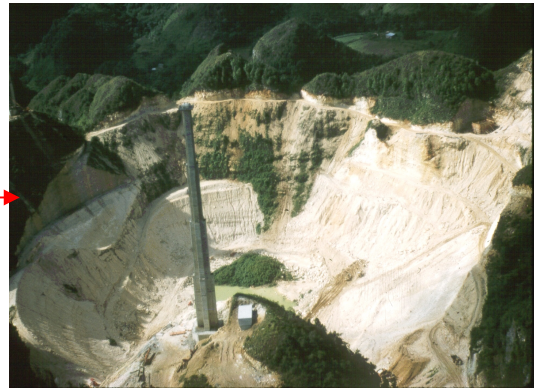
Inauguration in Nov 1963
William Gordon – Director

Proc IRE 58

The Arecibo bowl, as it looked in June 1960, when it was still a tobacco farm

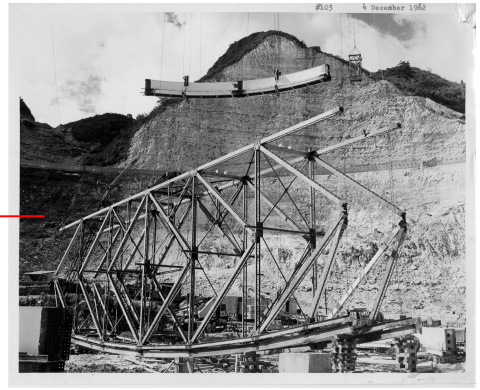
The Arecibo Ionospheric Observatory (AIO) takes Shape

27 April 1961

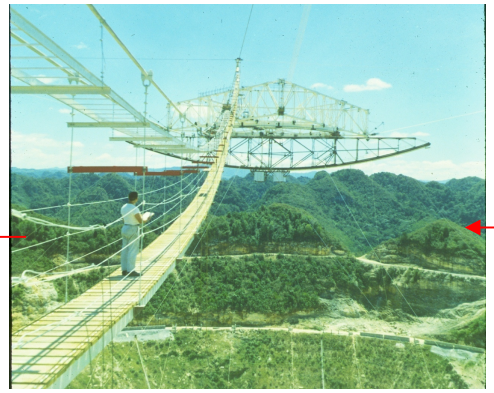


Late 1961

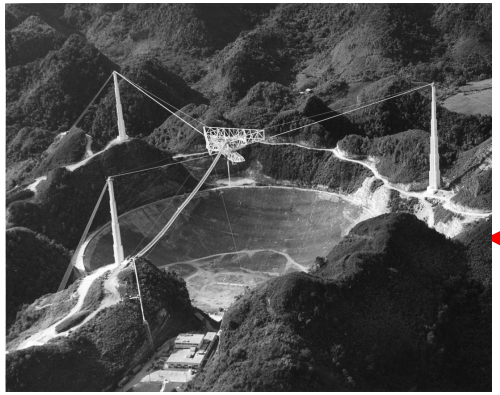
June 1962



Late 1962



28 February 1963



1 November 1963

The Early Years (1963 - 1972)

1963 Arecibo Ionospheric Observatory Commissioned for service, 1st November, 1963. [Cost $9.7M]

1965 Established the **rotation rate of Mercury to be 59 days** rather than the previously guesstimate of 88 days.

1967 Participation in the earliest "Very Long Baseline Interferometry" (VLBI) operations with Canada.

1968 Sporadic radio pulses from the direction of the Crab Nebula supernova remnant found at Green Bank were shown by Arecibo to come from a 33-ms period pulsar situated at the center of the nebula.

1969 The National Science Foundation took over operations from DoD on 1 October, 1969. AIO became the National Astronomy and Ionosphere Center (NAIC) in 1971.

1972-1974: FIRST ARECIBO UPGRADE

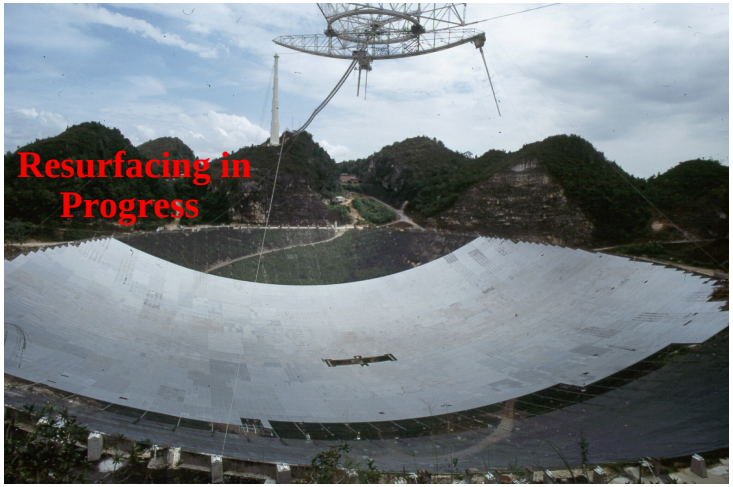
NEW SURFACE (RMS < 3mm) – Replace "chicken wire mesh" by 38,778 perforated aluminium panels.

HIGHER FREQUENCY OPERATION (SPECTRAL LINE OF NEUTRAL HYDROGEN AT 1420.405 MHz)

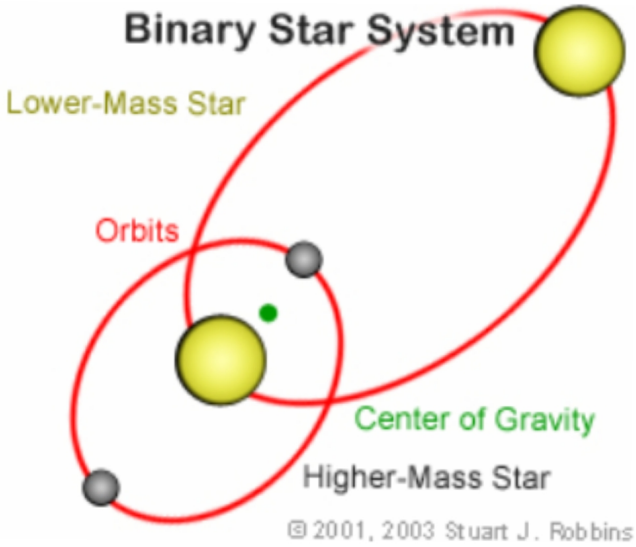
AND A NEW 2380 MHz RADAR (S-BAND).

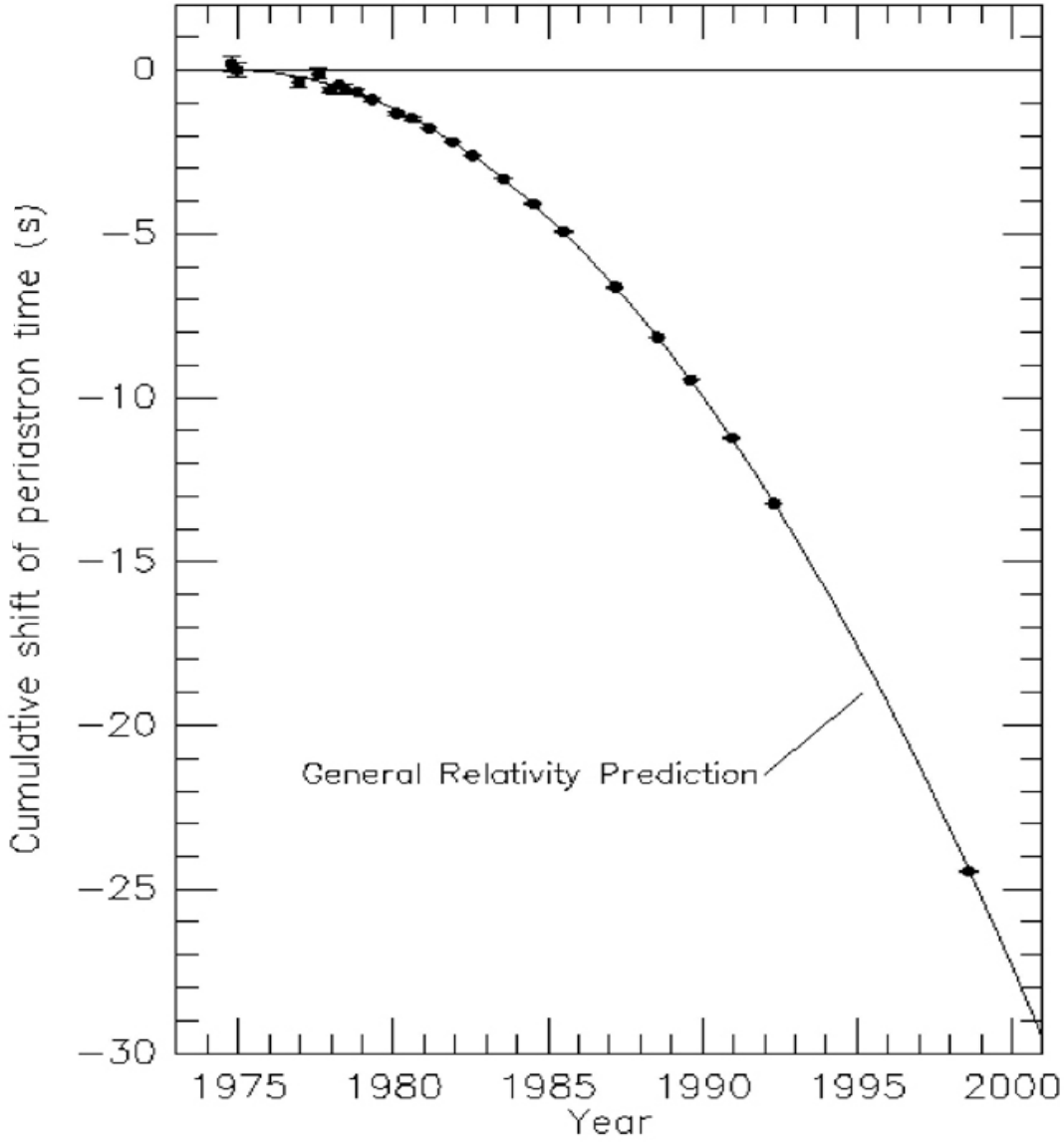
JULY 1974 - PSR 1913+16 FIRST DETECTED (Joe TAYLOR & Russ HULSE)

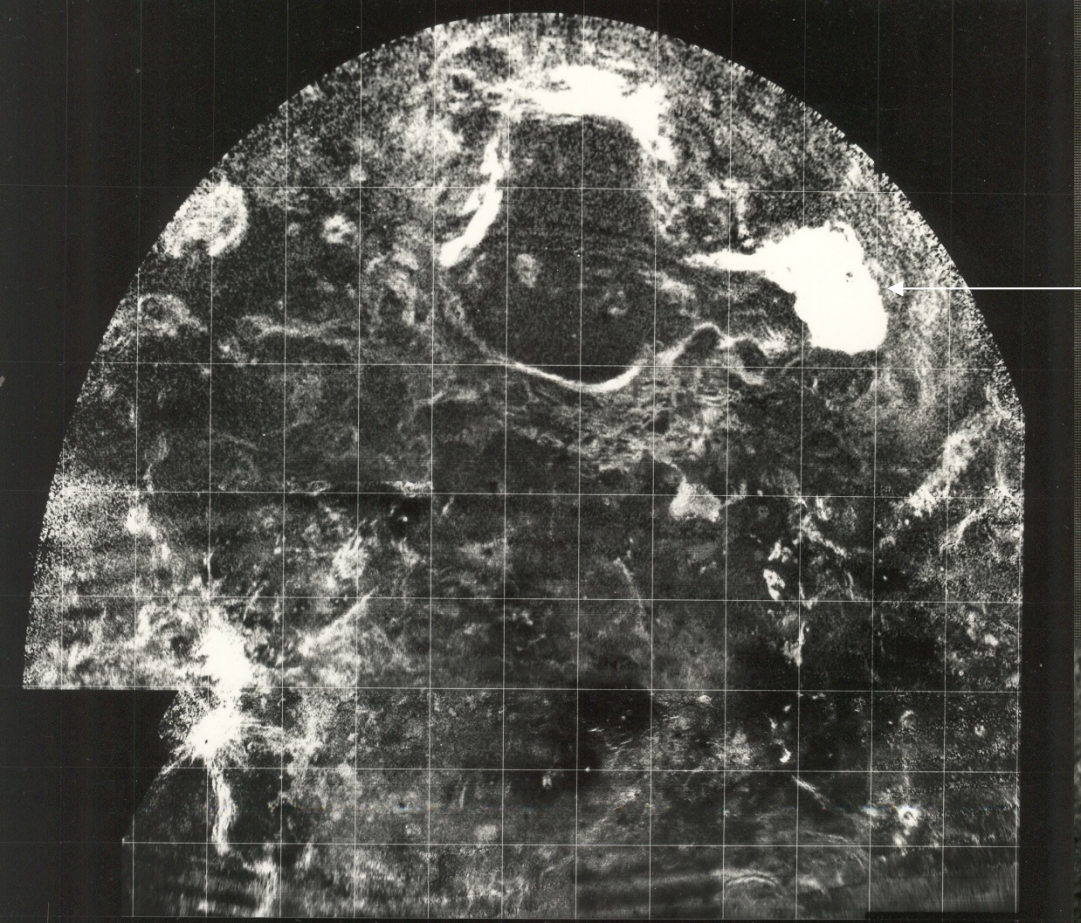
The First Upgrade 1972-74

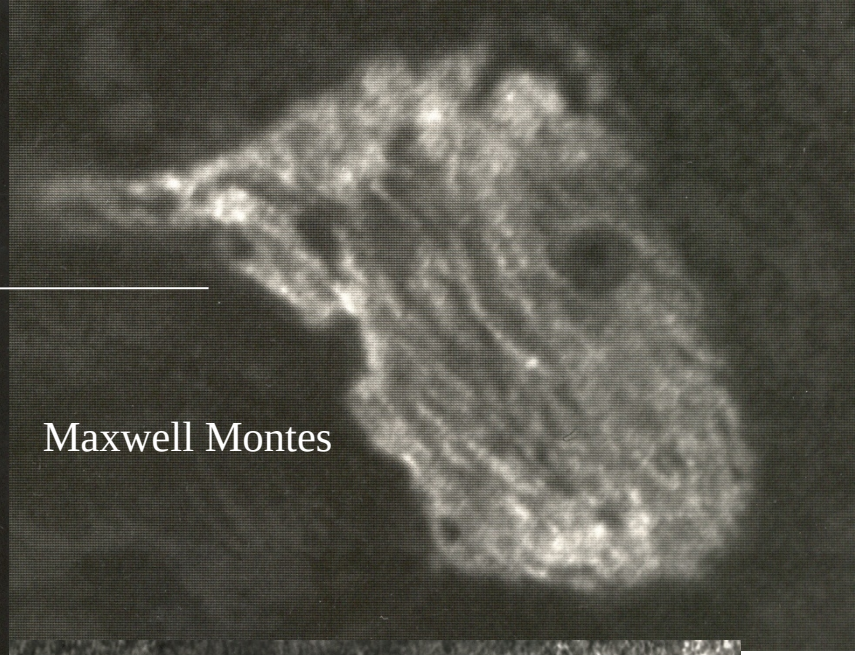


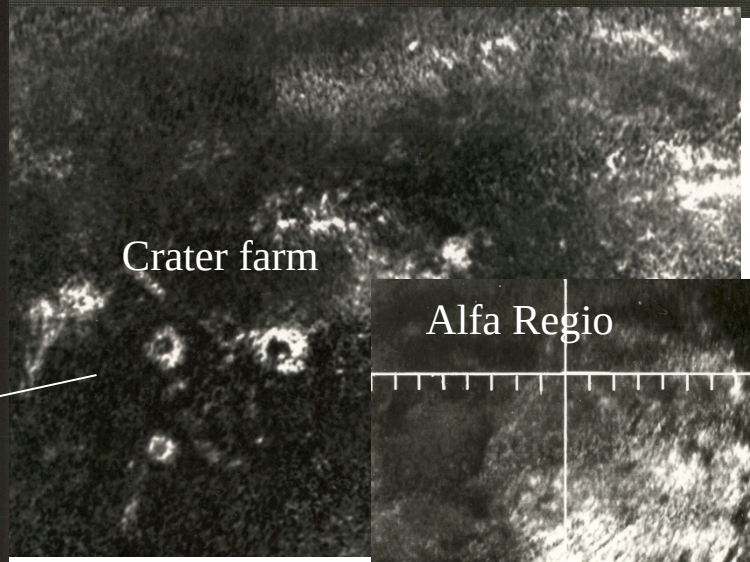
Hulse - Taylor Nobel Prize: 1993

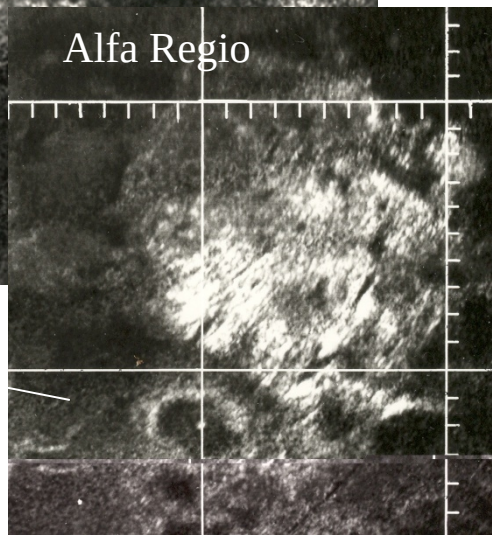


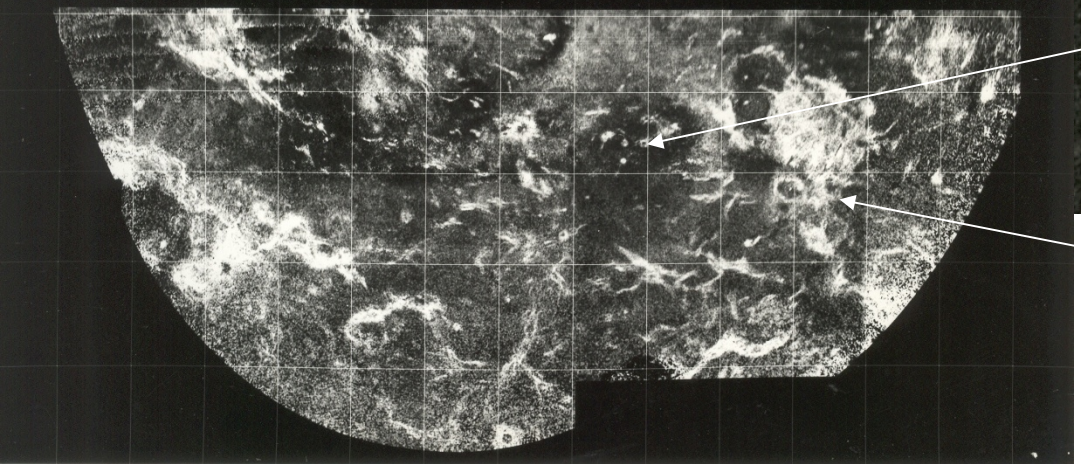






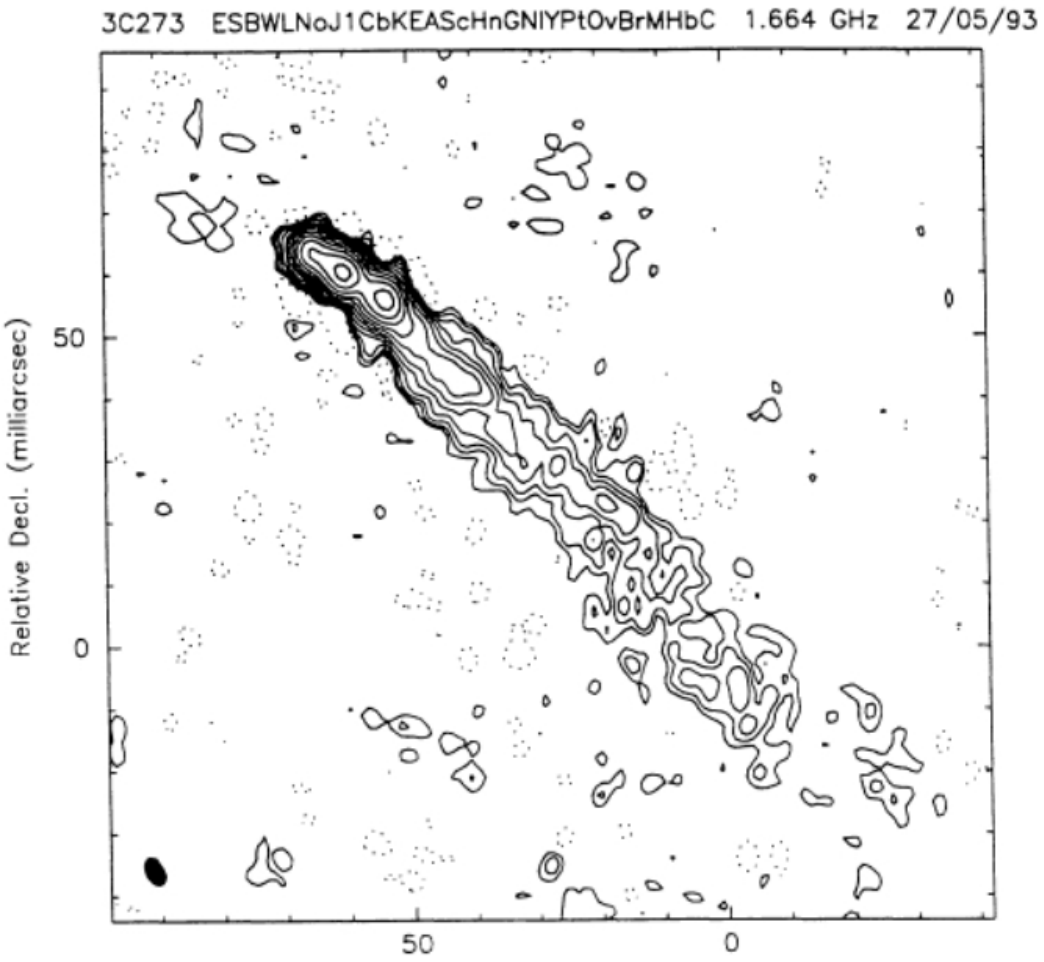






VENUS
1975-77

RETURN TO VLBI



“The Whole-Earth Array” (28 Antennas) in 1993 – **3C273**

Gregorian Upgrade 1993 –1997 (Second Upgrade)

1 – Replace most line feeds with a a dual-reflector feed in a "Gregorian Dome" producing an achromatic system

2 – Improve surface accuracy of primary reflector (dish) to reach 10 GHz

3 – New receivers (complete coverage 1 to 10 GHz)

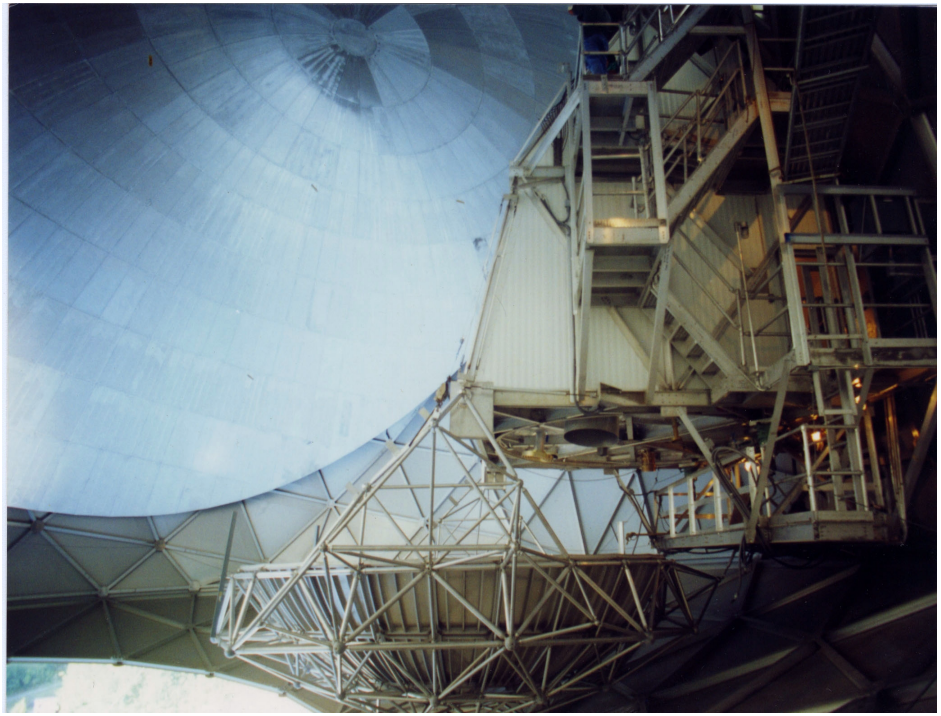
4 – New S-band transmitter with twice the power

5 – New drive systems including active platform tie-downs

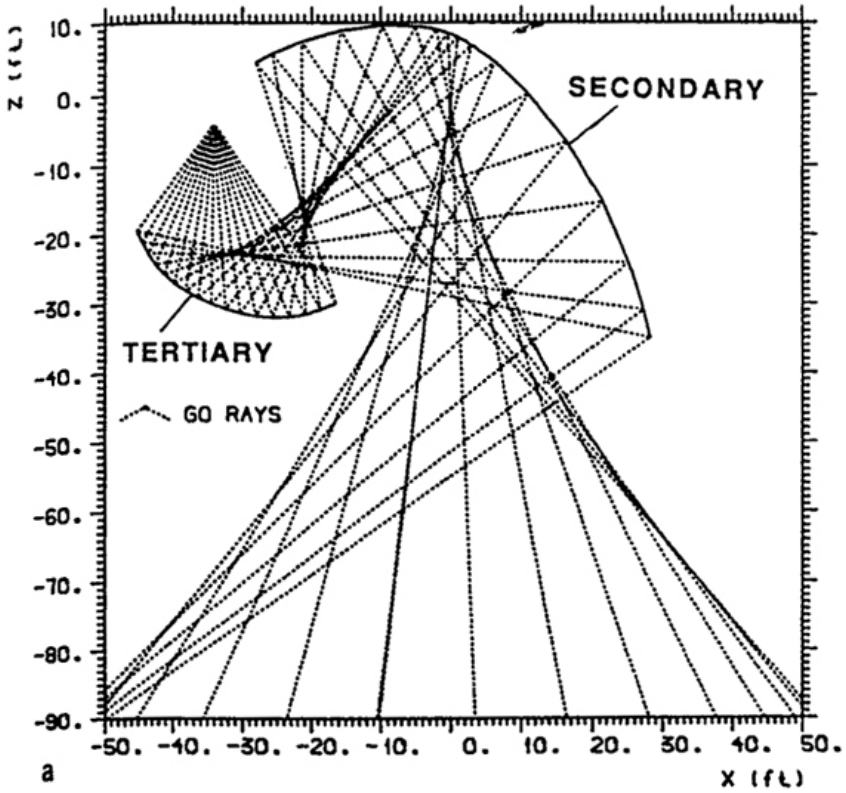
6 – Ground Screen to reduce spillover noise

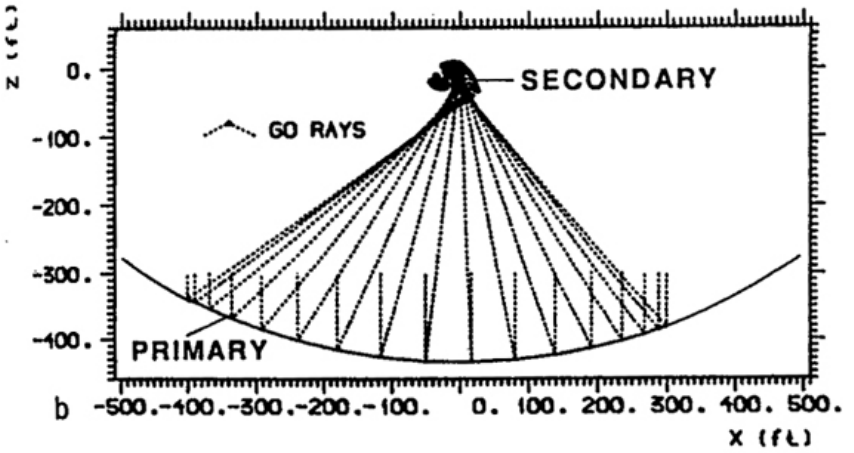
“Parabolizing” The Sphere

Post 1997: Totally Achromatic



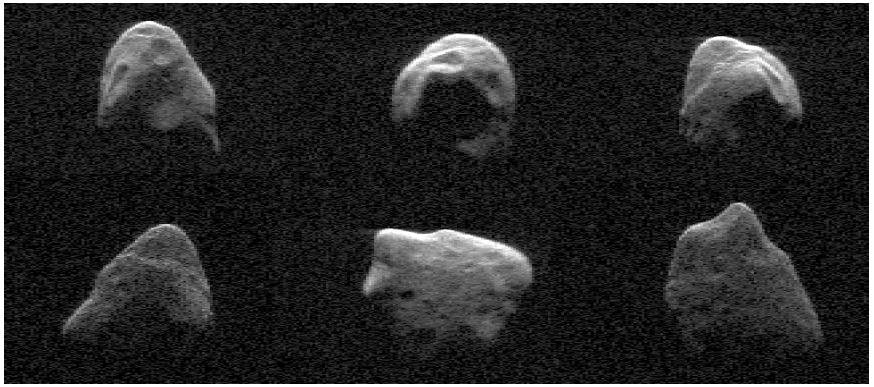
Inside the Gregorian Dome



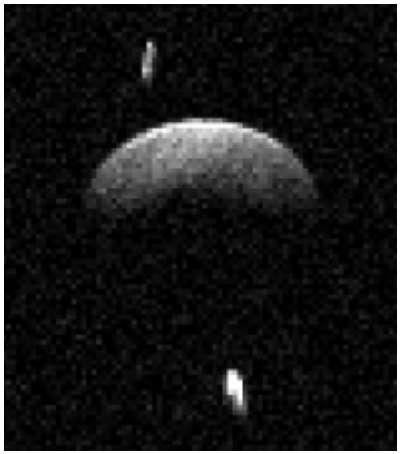


Radar Astronomy: Near-Earth Asteroid

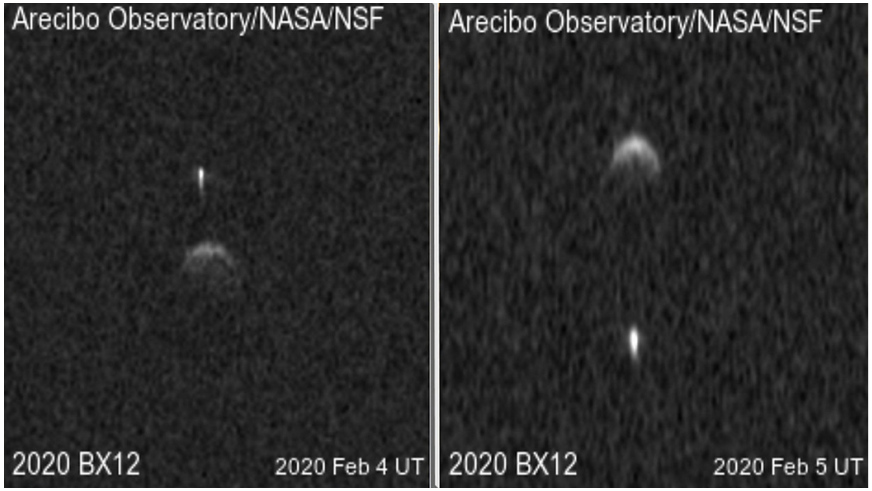
(Guarding the Earth against “Potentially Hazardous Asteroids”)

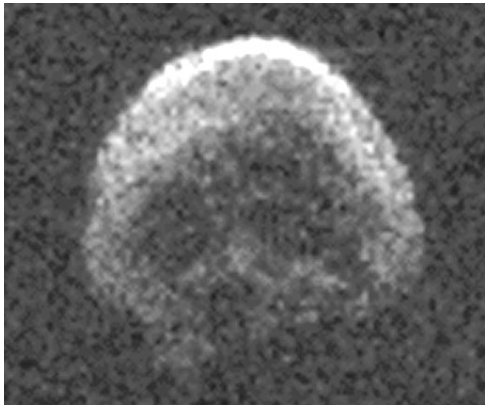


JM8



SN263

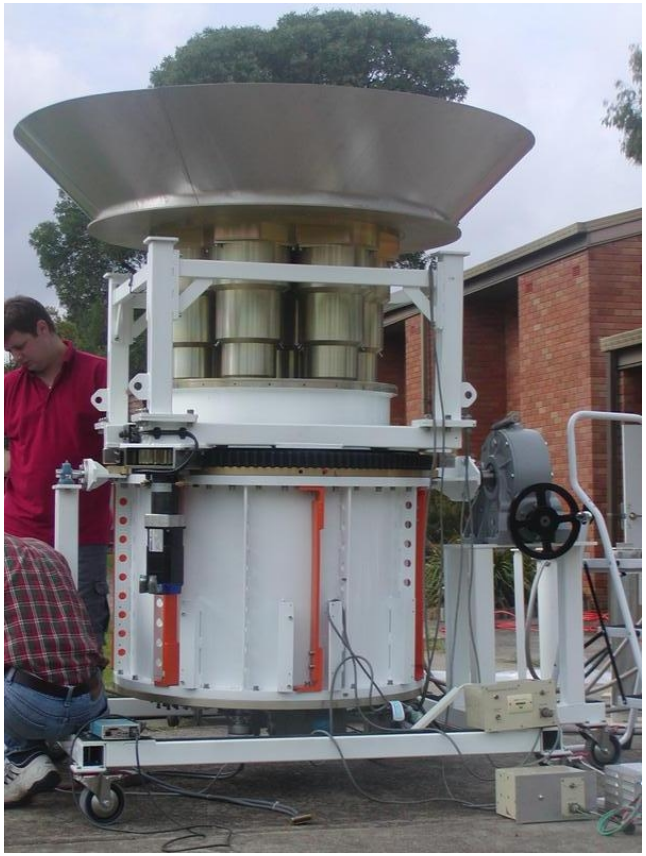




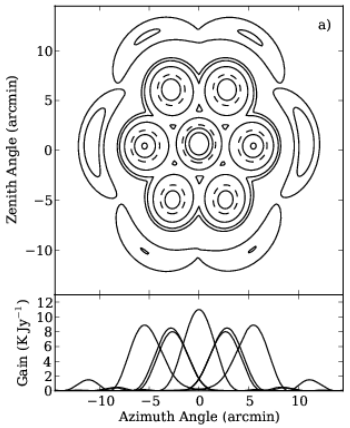
“Spooky”

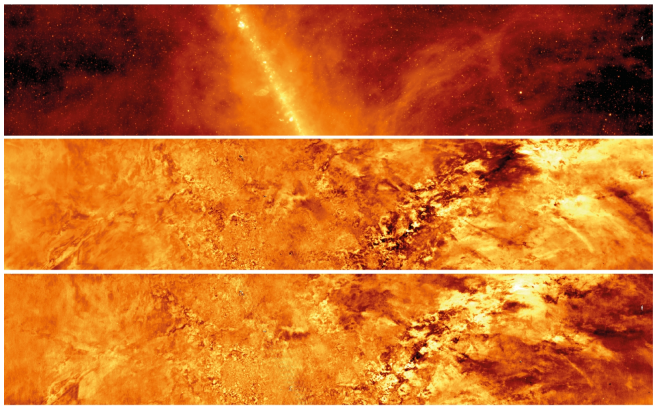
The ALFA 7-beam Focal-Plane Array

(Upgrade 2.5)



(Built by CSIRO)

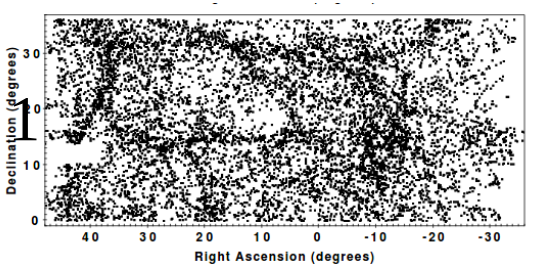




The Inner Galaxy at 1.4 GHz: Continuum Stokes I Q and U.
(Taylor et al.)

ALFA Science

The Extragalactic HI Wedding Cake

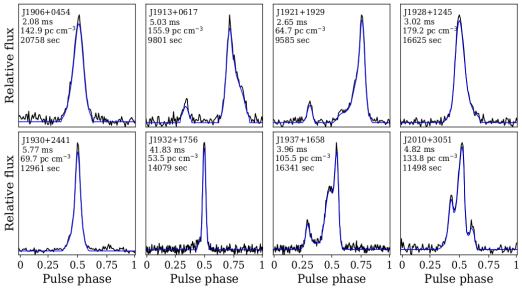


ALFALFA: A wide-area, shallow survey away from the Galactic plane. Detected ~31,500 galaxies for $z < 0.06$ by their HI emission alone.

AGES: Detection of HI emission in different galaxy environments from voids to rich clusters.

AUDS: The Arecibo Ultra-Deep Survey that spent 700 hr surveying 1.35 deg^2, to a rms ~80 μJy/beam.

Pulsars

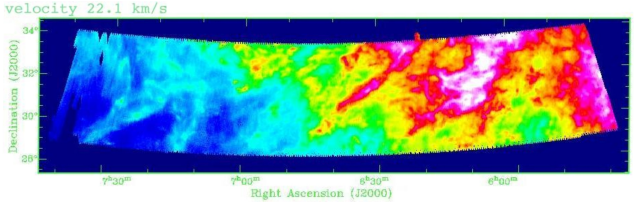


The **PALFA** low-latitude pulsar search covers |b|<5°, 32°<l<77°, (with also partial coverage of the Anticenter.) It has discovered 207 new pulsars, 46 of which are msec-period objects.

Continuum Emission

GALFACTS has imaged the complete Arecibo sky in all four Stokes parameters, I, Q, U and V.

Galactic HI



I-GALFA has mapped the HI in the inner Galaxy for |b| <10°

TOGS is a commensal HI survey imaging the whole Arecibo sky **at *practically no cost*!**

Other Surveys

ALFAZOA detects HI from galaxies obscured by the Galactic plane); **WAVES** has imaged HI emission from the Virgo cluster; **SIGGMA** is a survey of L-band Galactic recombination lines.

Other Notable Astronomy Contributions

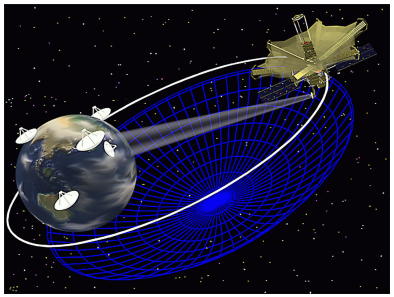
- In 1992 the **first ever** three exoplanets were detected at Arecibo around the millisec-period pulsar PSR1257+12 by Wolszczan & Frail.

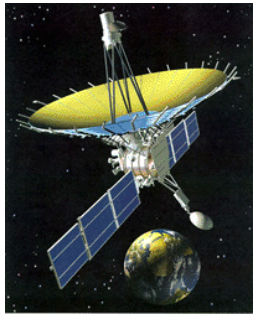
- The North American Nanohertz Observatory for Gravitational Waves (NANOGrav) very recently announced the detection of very long-wavelength gravitational waves via timing an array of miilisec pulsars. Their principal measurements have been made at Arecibo and Green Bank.

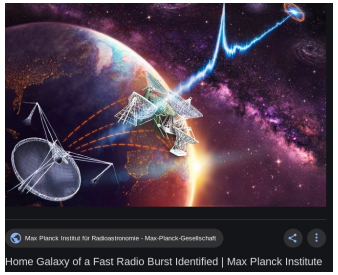
- Molecular-line studies up to 10 GHz.

- VLBI with antennas in space, (a) from 1999 to 2001, VLBA & Ar co-observed with this Japanese 8-m orbiting antenna, HALCA/VSOP. (b) From 2012, GBT & Ar co-observed with the Russian 10-m Radioastron antenna in space, with Ar participating in over 400 such VLBI sessions.

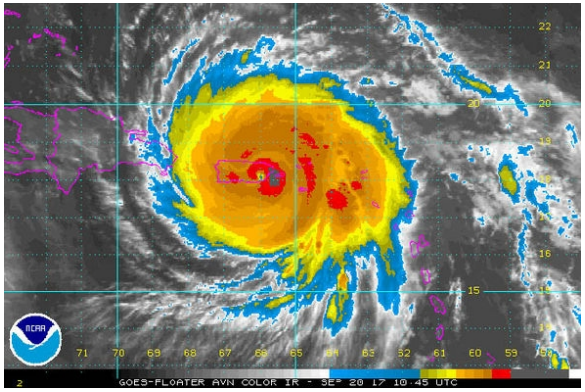
- Successful VLBI of the first repeating FRB by Ar and the EVN.







The Arecibo Telescope: Difficult Times, and the Future?



- **Hurricane Maria struck Puerto Rico on Sept. 20th, 2017, as a Cat. 4/5 storm with winds up to 135 mph, and 85 cm of rain in 24 hr.**
- **Despite serious damage, observations were recommenced within a short time.**
- **From the beginning of 2020 a sequence of hundreds of earthquakes up to mag. 6.4 were experienced.**
- **On Aug. 10th, 2020 an auxiliary cable to the platform fell, followed by the breaking of a main cable of Nov. 6th.**
- **On Dec. 1st, 2020 the platform collapsed, and the support towers fractured.**

The NSF decreed the decommissioning of Arecibo Observatory, effective August 14th, 2023. They have issued a solicitation for a 5-year cooperative agreement to operate an “Arecibo Center for STEM Education and Research” (ACSER) at the observatory site.


Muchas
Gracias