The Arecibo Observatory:
What is Being Done Today

Bob Kerr
Director, Arecibo Observatory

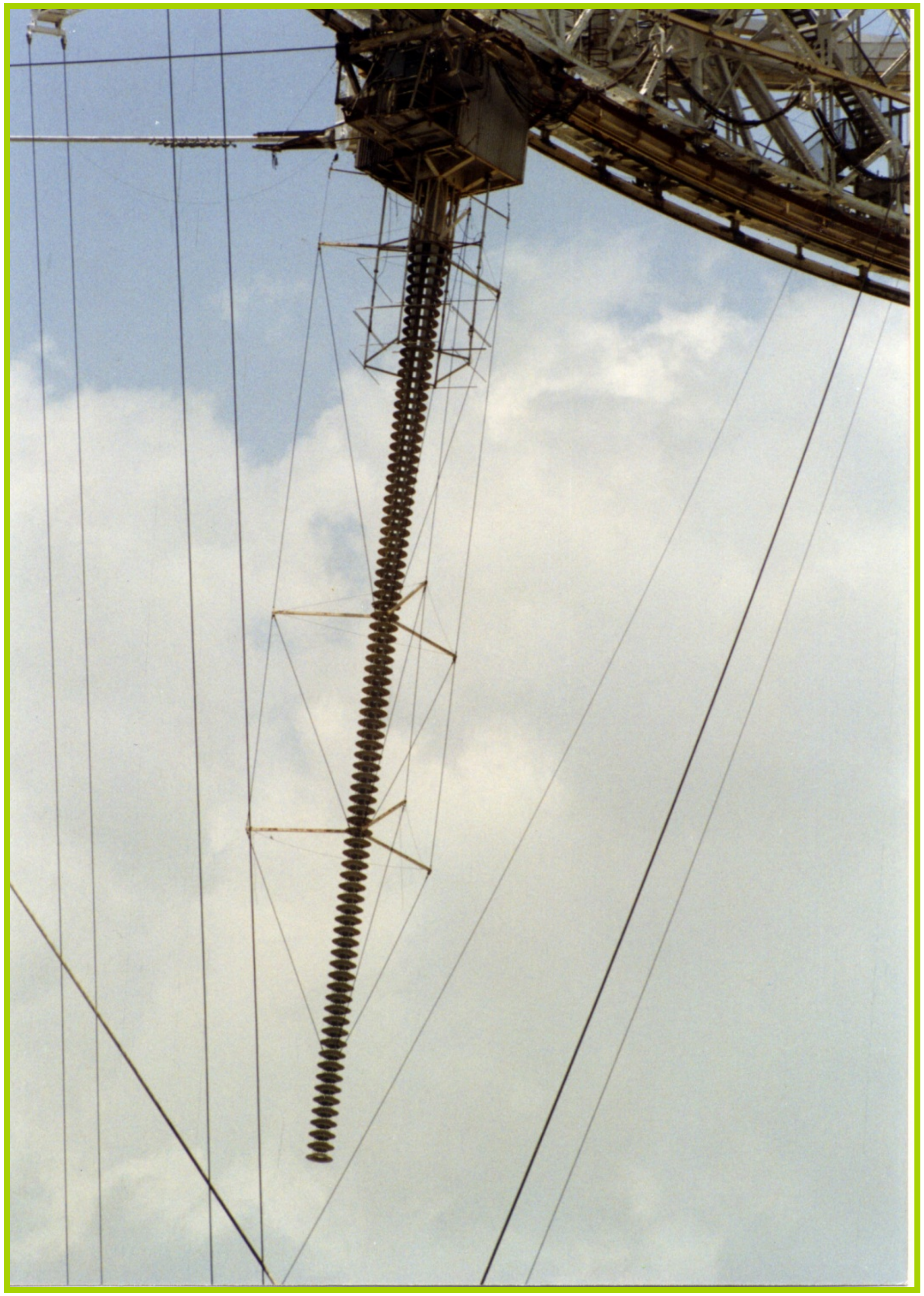
ISR Summer School
July 25, 2014

ARECIBO OBSERVATORY
THE WILLIAM E. GORDON TELESCOPE
ARECIBO PUERTO RICO

Arecibo: Aug 1963

430 MHZ TRANSMITTER

(STILL THE ORIGNAL)



The 430 Antenna

- 96 ft. in length.
- It receives and transmits radio waves of 430 MHz.
- Main instrument used to study the ionosphere.

Today, Arecibo Observatory is involved in three core scientific research areas:

Astronomy, Planetary Science, & Atmospheric Science

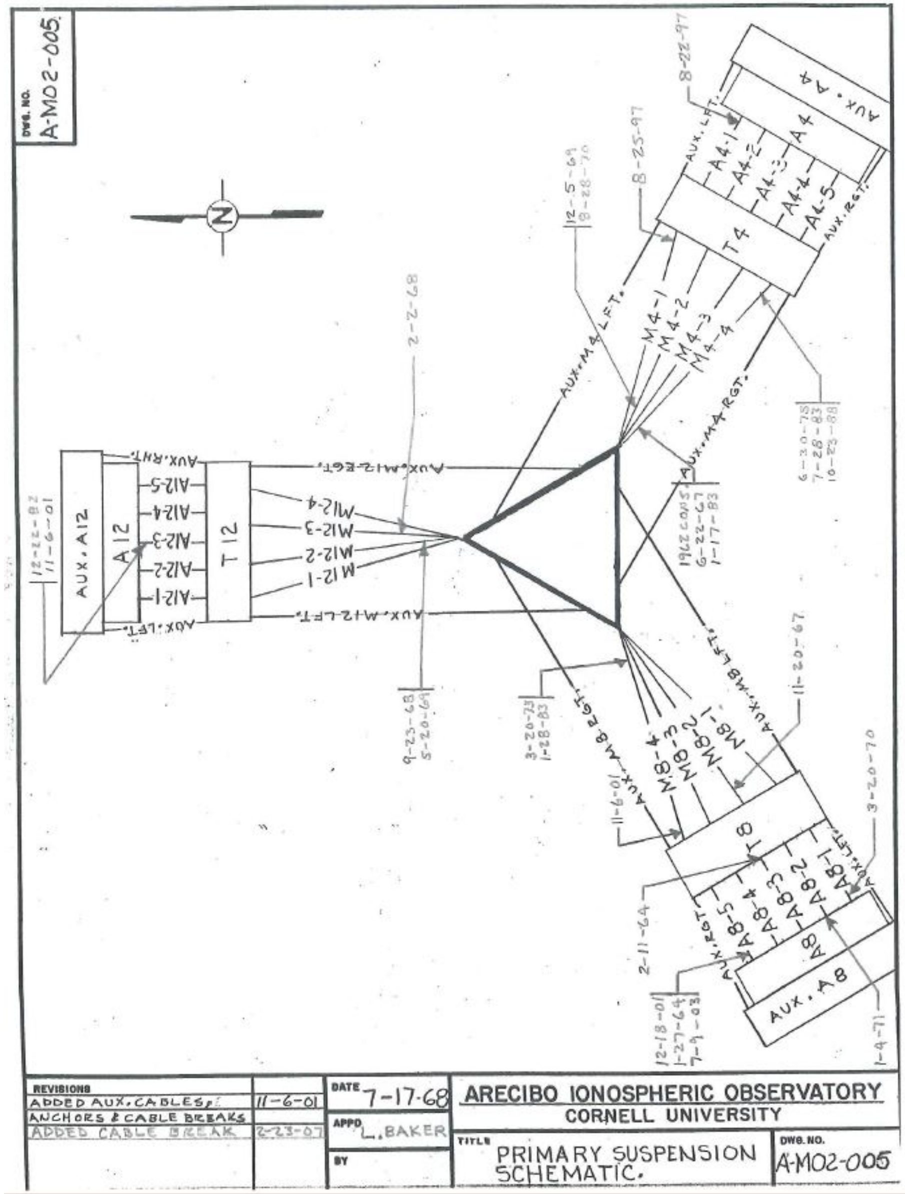
- No other observatory can match the proficiency, the breadth, nor the accomplishments of Arecibo Observatory in these combined efforts.

- No other astronomical telescope, (excepting “Goldstone”), transmits to its targets as well as passively samples.

- Cutting-edge research at Arecibo Observatory applies directly to four identified natural threats – Gamma Ray Bursts, Asteroid or comet impact, Space Weather, and Global Climate Change. No other observatory can claim that breadth of significance to modern civilization.

Today, AO is formally recognized as an “Electrical Engineering Milestone” by the IEEE, and a “Mechanical Engineering Landmark” by the IMSE. AO is also a “National Historical Landmark”.

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REVISIONS
ADDED AUX. CABLES, 11-6-01
ANCHORS & CABLE BREAKS
ADDED CABLE BREAK 2-23-07
DATE 7-17-68
APP'D L. BAKER
BY
ARECIBO IONOSPHERIC OBSERVATORY
CORNELL UNIVERSITY
TITLE PRIMARY SUSPENSION SCHEMATIC.
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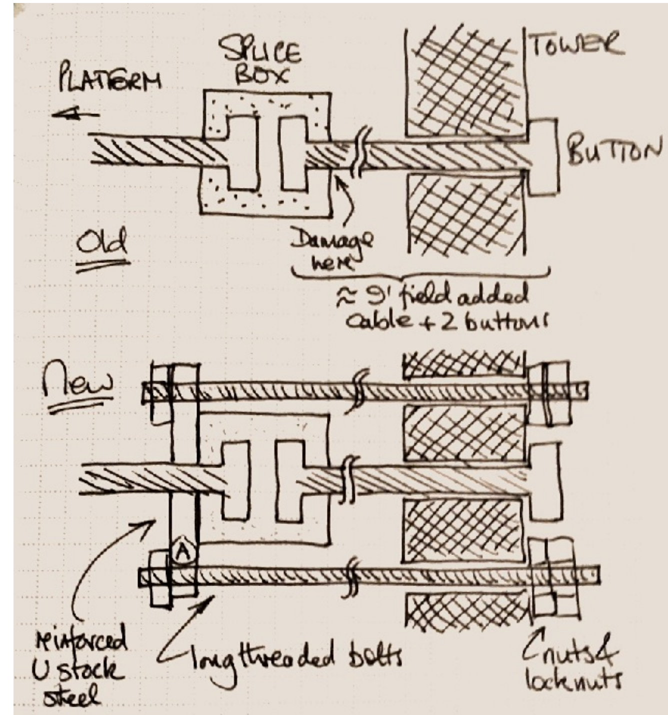
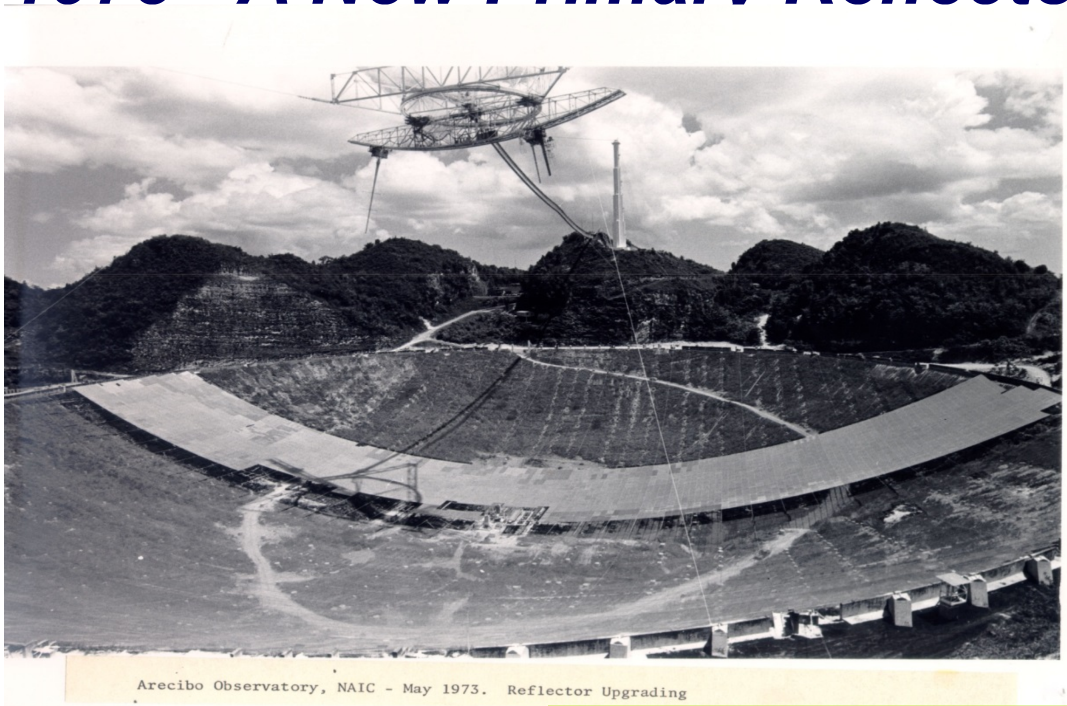

PLATFORM
SPLICE BOX
TOWER
BUTTON
Old
Damage here
≈ 9' field added cable + 2 buttons
New
A
reinforced U stock steel
long threaded bolts
nuts & lock nuts


COOL LINE
TATA

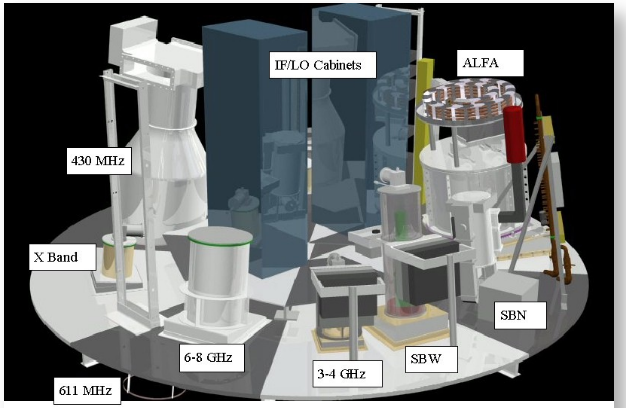
The Arecibo Observatory is now 50 years old, but the Telescope and nested instrumentation are NOT!

- Passive optical instruments for study of the upper atmosphere began to be added in 1965
- Surface upgrade completed in 1973 allowed frequency response to 2 GHz
- "S-band" 2380 MHz (13 cm) transmitter added in 1973 permits radar studies of planet surfaces
- High power lasers ("LIDAR") added for studies of the middle and upper atmosphere in 1995
- Major upgrade completed in 1997 converted line focus of the spherical reflector to a point focus, using "Gregorian optics".
- Ground-screen added in 1997 lowers edge spillover losses, and reduces RFI reflection from the surrounding mountains.
- "S-band" transmitter upgraded to a 1 MW sytem in 1997
- Visitor Center outreach and education facility added in 1997
- A radio "camera" permitting broad sky coverage and imaging completed in 2004
- A High Frequency transmitter and a mesh secondary antenna is being added in 2014 for active plasma experiments in the Earth's Ionosphere

1973 - A New Primarv Reflector



- 38,000 aluminum panels
- It is suspended above ground by a cable network.
- Each panel is individually adjusted in order to maintain the spherical curvature (~2.5 mm).

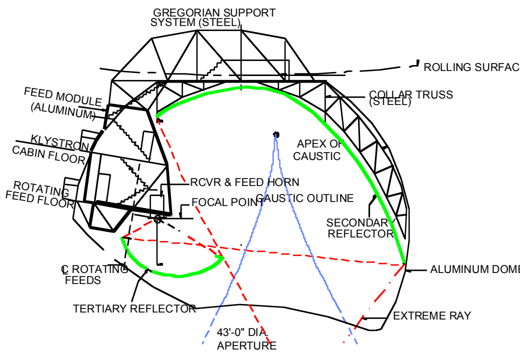


Rotary floor simulation of topside showing receivers and IF/LO cabinets where the downconversion stages for all the receivers is performed.

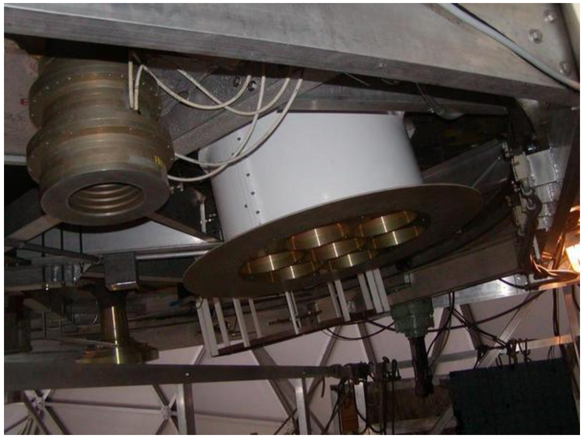
1997 Upgrade

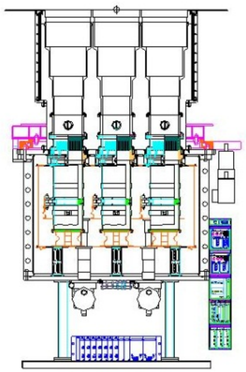
Ground Screen
Cable Strengthening
Gregorian Dome
New S-band Transmitter

- Upgrade allowed for operation at frequencies as high as 10 GHz.
- Created a dual beam Incoherent Scatter Radar
- A vast increase in the number and complexity of the receiver and signal processing systems.



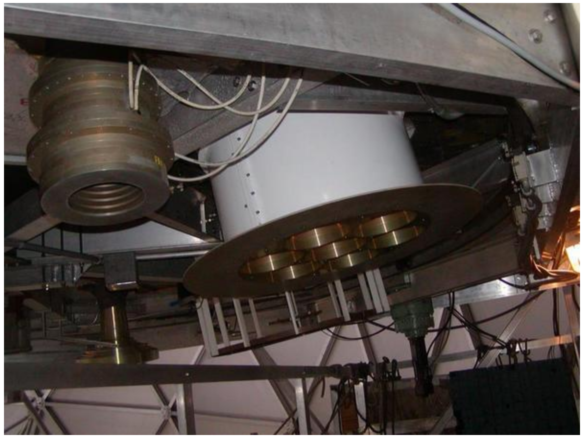
2004: ALFA - A Camera for Arecibo





- Installed 2004 Apr
- Surveys initiated Feb 2005
- 7 beams x 2 pol (linear) = 14 “pixels”
- 1225-1525 MHz full range
- Unmatched sensitivity (SEFD = 2.4 to 3 Jy)
- 3.3’ x 3.8’ beams on 11’ X 13’ ellipse
- Unprecedented capability for mapping the sky
- Survey consortia self-organized by community

Reinventing AO 2004: ALFA - A Camera for Arecibo



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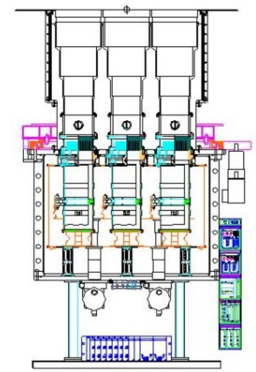


NATIONAL ASTRONOMY AND IONOSPHERE CENTER

Receiver Designation	Freq Range (GHz)	System Temp[a] (K)	Gain[a] K/Jy	SEFD[a,b] Jy (at zenith)	HPBW[a,f] Az × ZA (Arcmin)
Carriage House					
47	-	T_{sky}	-	-	94 × 110
430ch	0.425 – 0.435	70 - 120	10 - 20	3.5 - 10	10 × 12
Gregorian Dome: Single-Pixel Receivers					
327	0.312 – 0.342	90 + T_{sky}	10.5	11	14 × 15
430	0.425 – 0.435	35 + T_{sky}	11	5	10 × 12
800	0.705 – 0.800	110	9.5	12	∼6 × 7
lbw	1.120 – 1.730	25	10.5	2.4	3.1 × 3.5
sbw	1.800 – 3.100	32	9.5	3.4	1.8 × 2.0
sb	2.240 – 2.340	25	10	2.5	1.8 × 2.0
	2.330 – 2.430	25	10	2.5	1.8 × 2.0
sbh	3.000 – 4.000	29	8.8	3.3	1.35 × 1.5
cb	3.850 – 6.050	31	8	3.9[c]	0.9 × 1.0
cbh	6.000 – 8.000	28	5.5	5[d]	0.65 × 0.75
xb	8.0 – 10.0	33	4.5	7.5[e]	0.5 × 0.6
Gregorian Dome: Feed Array					
ALFA					
Center Pix	1.225 – 1.525	30	11	2.8	3.3 × 3.7
Outer Pixs	1.225 – 1.525	30	8.5	3.5	3.3 × 3.7

Receiver Notes

a) T_{sys}, Gain and SEFD all vary with zenith angle (and to a lesser degree with azimuth). T_{sys} and SEFD increase with zenith angle, while Gain decreases. The HPBW in ZA increases with zenith angle.

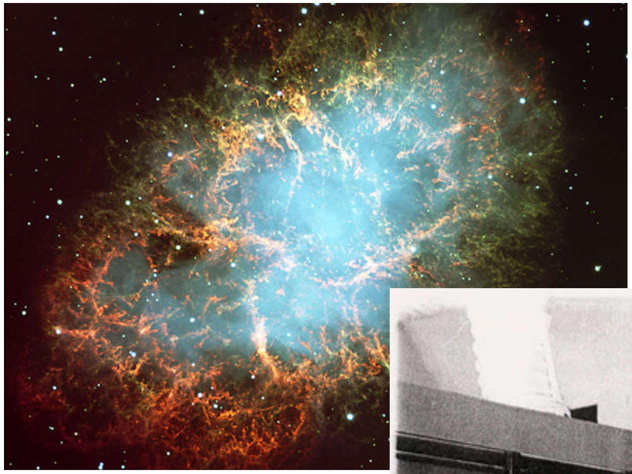
b) SEFD, the System Equivalent Flux Density (= T_{sys}/G) is the system temperature expressed in Jy/beam.

c) At 5 GHz.

d) At 6.9 GHz.

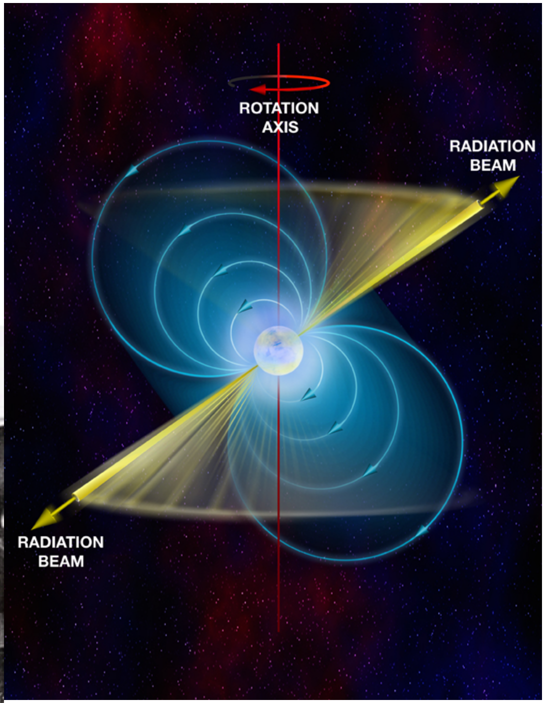
e) At 9 GHz.

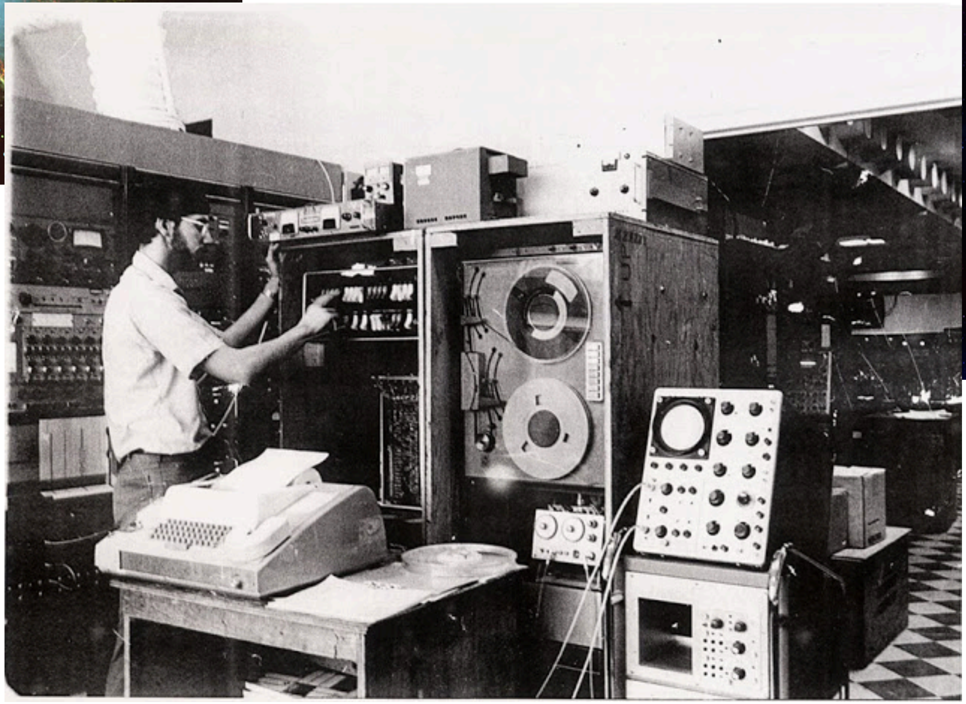
f) HPBW is the Half-Power Beam-Width.

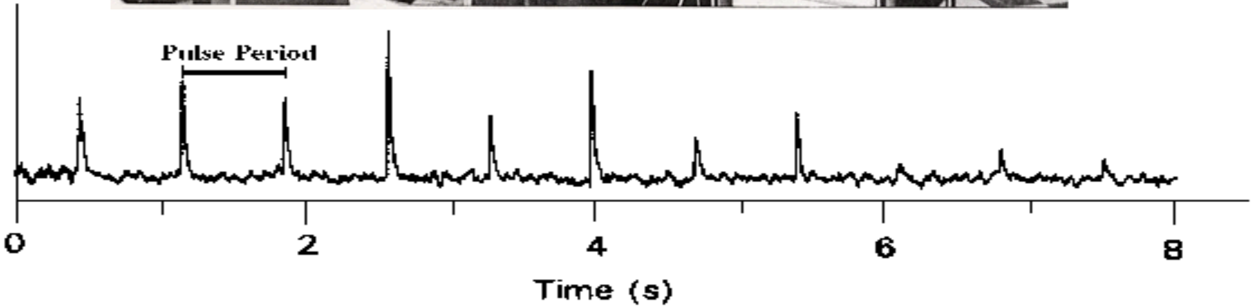


Pulsars

- Bell & Hewitt, 1967 (LGM-1)
- Hulse & Taylor 1974 (binary)
- Backer 1982 (millisecond pulsars)
- Wolsczam 1993 (extrasolar planets)



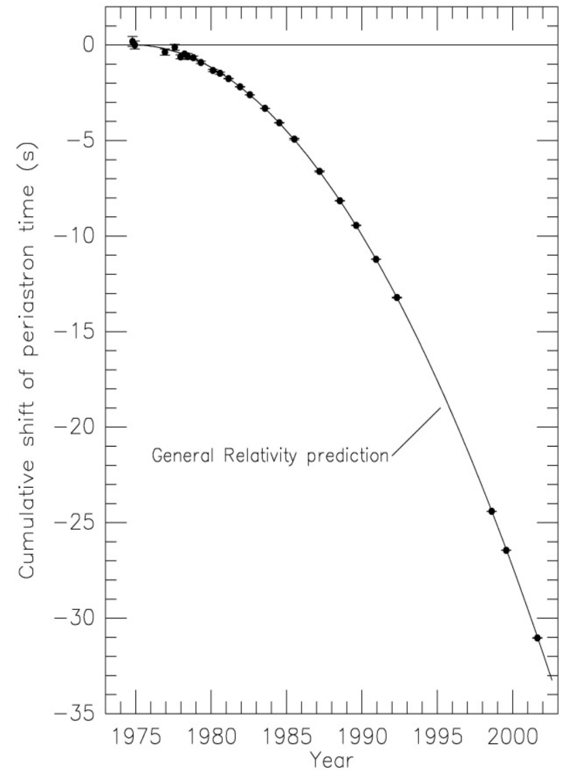




The Binary Pulsar

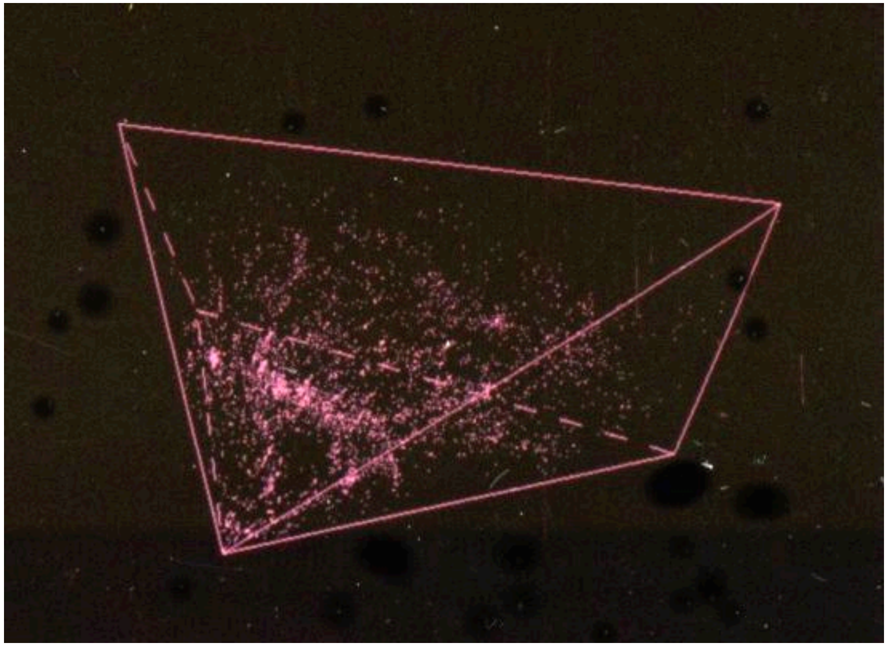
PSR B1913+16

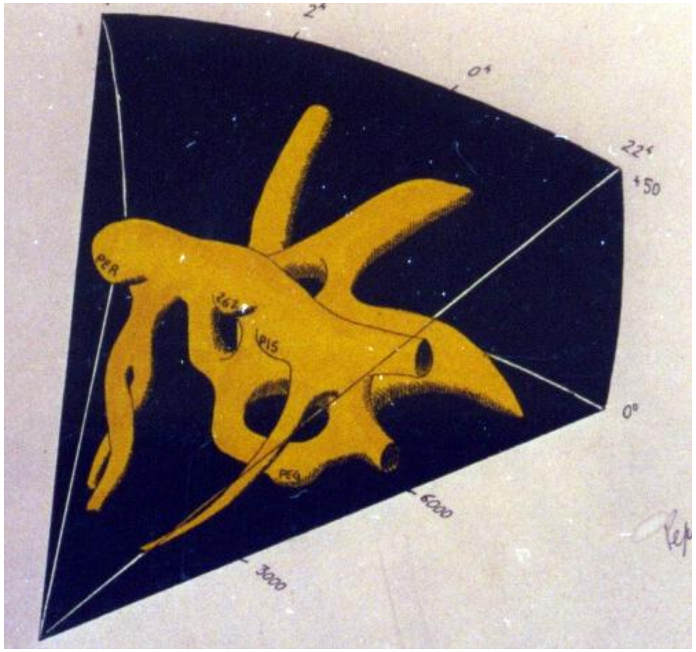
In 1974, Russ Hulse and Joe Taylor discovered the binary motion of PSR 1916+13 revealing evidence that the system is losing energy by the emission of gravitational radiation, just as predicted by Einstein's theory of General Relativity.



In 1993, Hulse and Taylor received the Nobel prize in physics for "the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation."

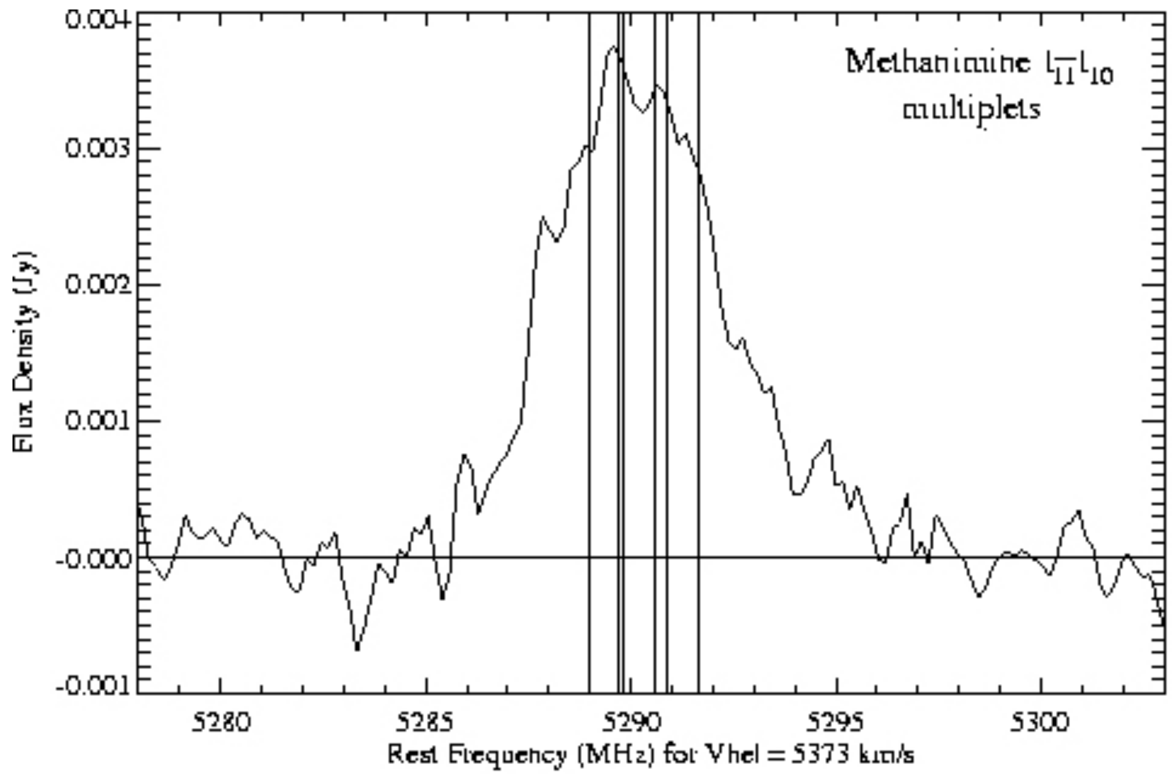
Arecibo as a Redshift Machine





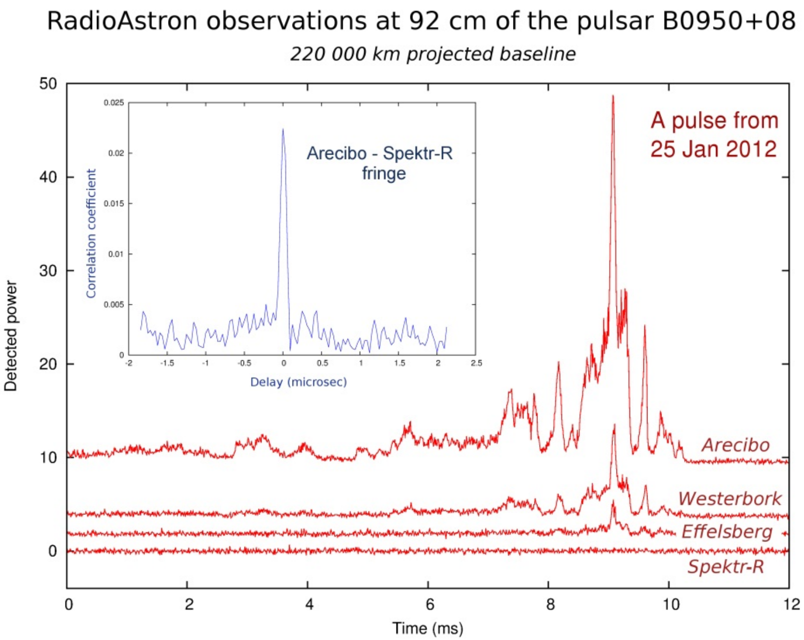
In 1989, the Henry Draper Medal of the National Academy of Sciences was awarded to Riccardo Giovanelli and Martha Haynes for their work demonstrating the filamentary nature of the Pisces-Perseus Supercluster which exploited Arecibo's high sensitivity spectroscopic and signal processing capabilities.

Using an 800 MHz bandwidth, allowed by the new dual "WAPP" configuration, a dozen molecular lines are resolved in the starburst galaxy ARP 220 – including the 1st evidence of the organic molecule methanimine outside our galaxy. CH_2NH combines with HCN (also detected) in the presence of water to produce the simple amino acid glycine. The organic chemistry giving rise to life on Earth is present in its constituent form outside the Milky Way.



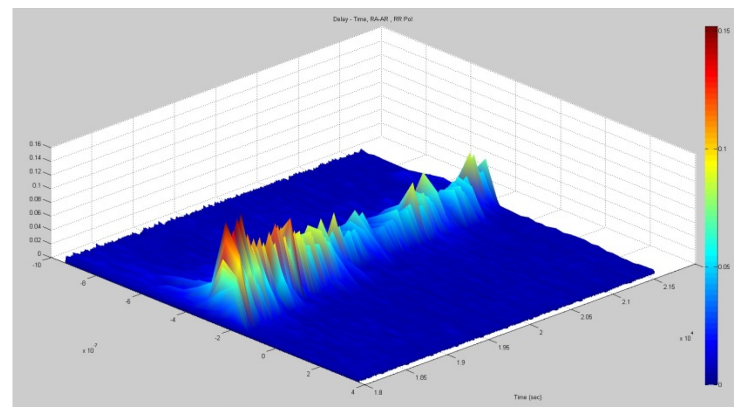
Russians, Americans and Europeans work together to set records for celestial detail.

Records were made this January when the *RadioAstron* satellite was joined by ground-based telescopes, forming a radio telescope 220,000 km across – roughly 20 times larger than the Earth.



Profiles of a single pulse from the pulsar B0950+08 detected individually (in red) by the three ground telescopes and *RadioAstron*. The inset presents the interferometer signal between *RadioAstron* and Arecibo for this single pulse. (*Image credit:Yuri Kovalev, Lebedev Physical Inst.)*

The *RadioAstron* orbital antenna (10-meter diameter); the Arecibo *William E. Gordon Telescope* (305-m diameter); the Westerbork Synthesis Radio Telescope (14 × 25-m diameter antennas), and the Effelsberg dish (100-m diameter). (*Images from http://asc-lebedev.ru, www.naic.edu, www.nentjes.info/Kijkers/telescopes-a.htm, and credit: N. Tacken, MPIfR)*

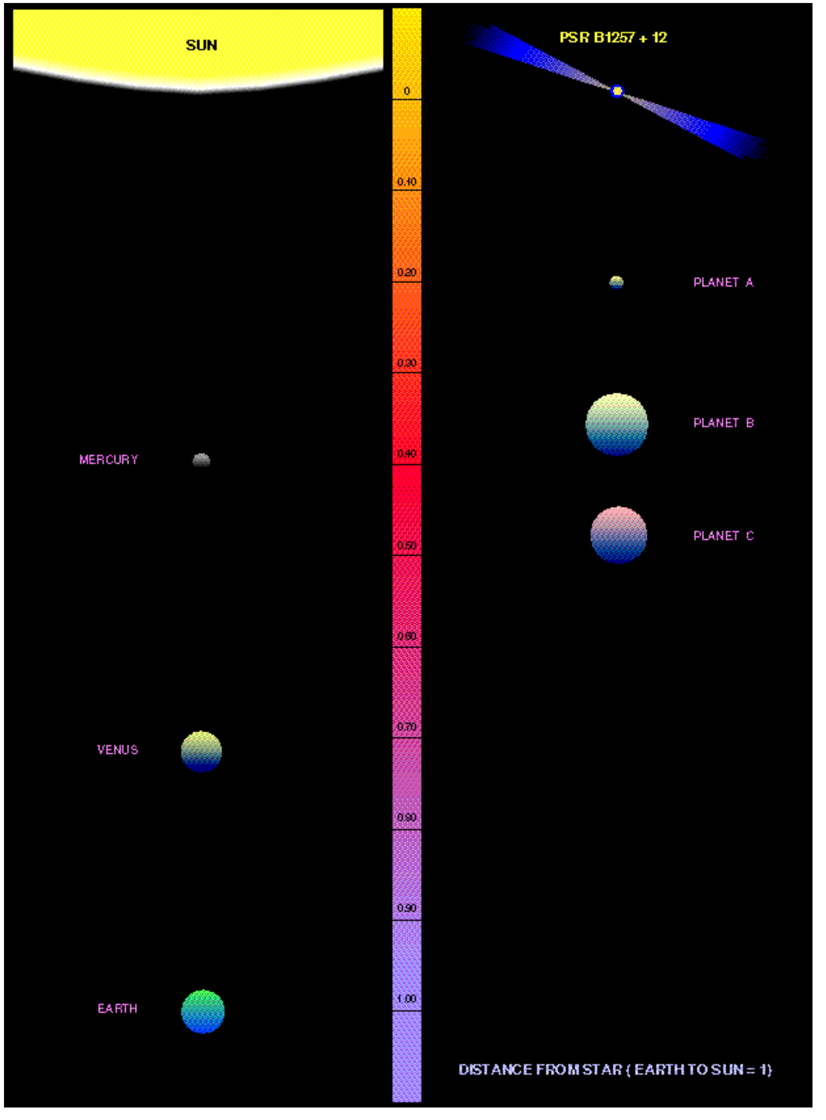


The interferometer signals between *RadioAstron* and Arecibo for the pulsar B0950+08 for the full one hour long session. On the axes: time (sec), interferometric delay (sec), and the interferometer signal I n color. The signal variations in time are due to interstellar s cintillations of the pulsar emission.
(*Image credit: Yuri Kovalev, Lebedev Physical Inst.)*

The First ExtraSolar Planets

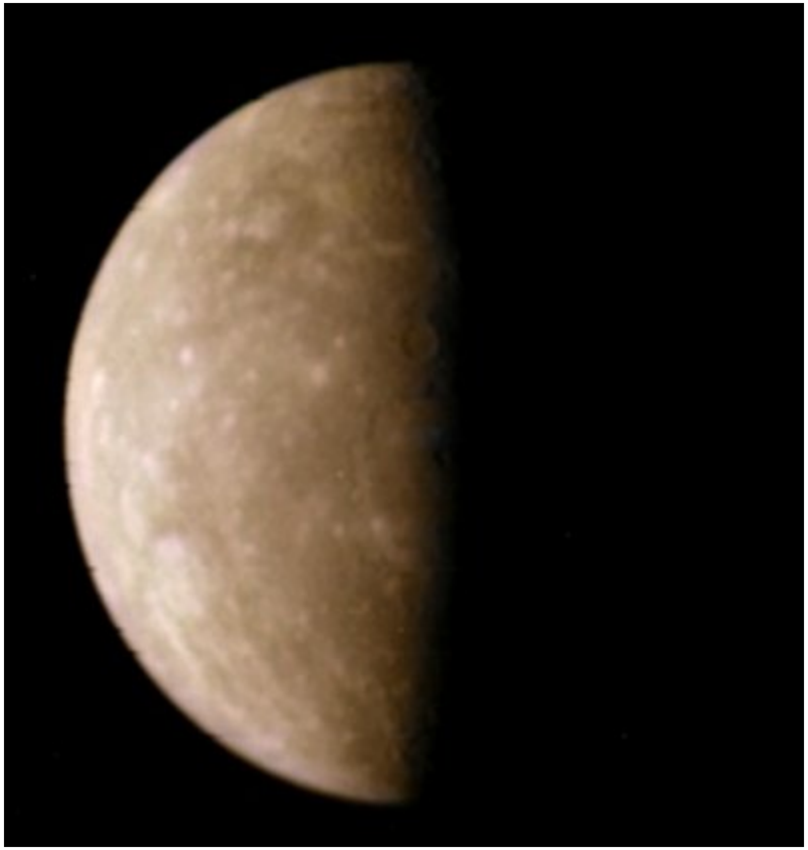
In 1992, Alex Wolszczan and Dale Frail used precise pulsar timing measurements to detect the first ExtraSolar planetary system. The pulsar's motion can be explained by the presence of at least 3 planets in tight orbit around the pulsar.

The 1996 Beatrice Tinsley Prize of American Astronomical Society was awarded to Wolszczan for his precision timing of the pulsar planets.



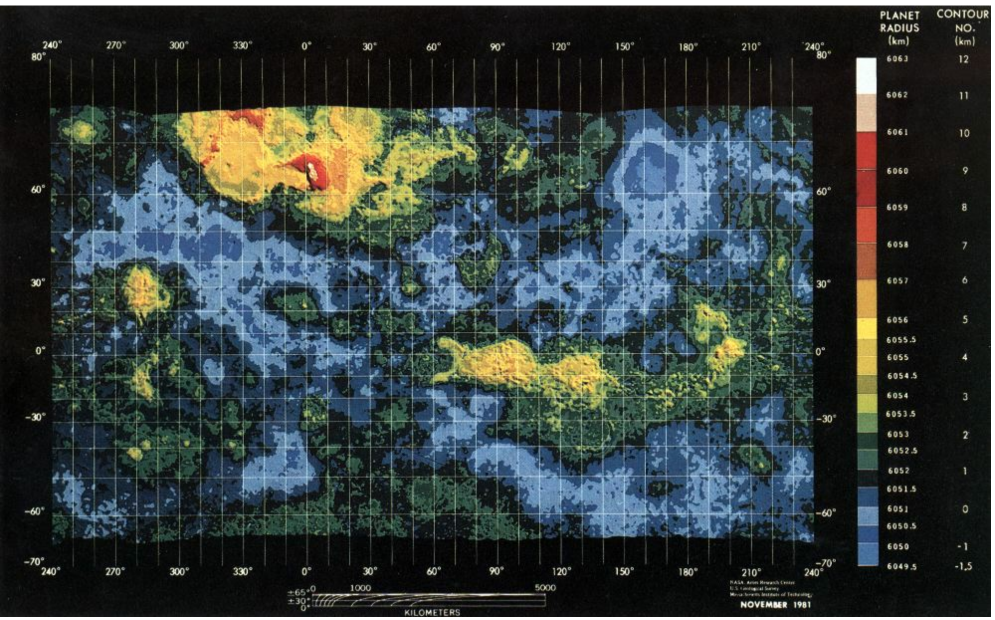
Mercury

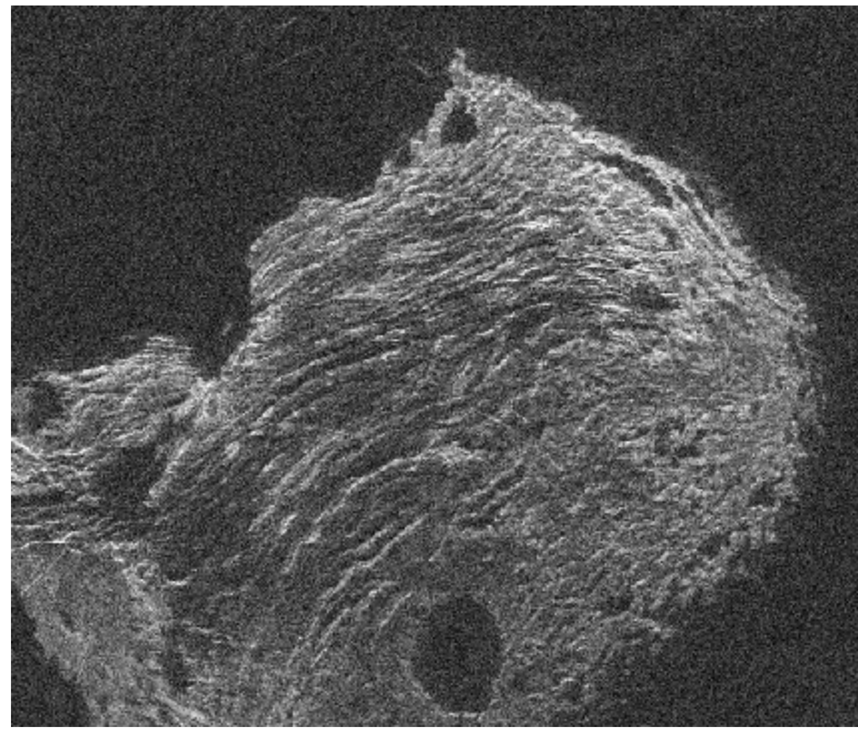
1965: The rotation rate of Mercury was found to be 58.6 days, NOT 88 days as previously thought. Mercury is in a 2/3 rotation rate: revolution period, not 1:1



Venus

The first geologic maps of Venus were published in 1981, after being mapped by the Observatory S-band Radar, that was established during the 1974 upgrade.

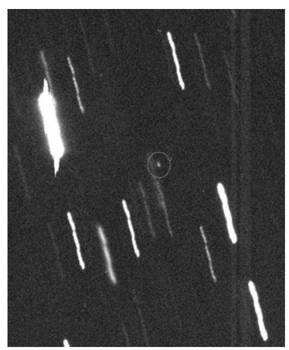


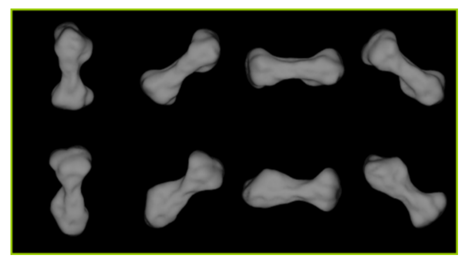


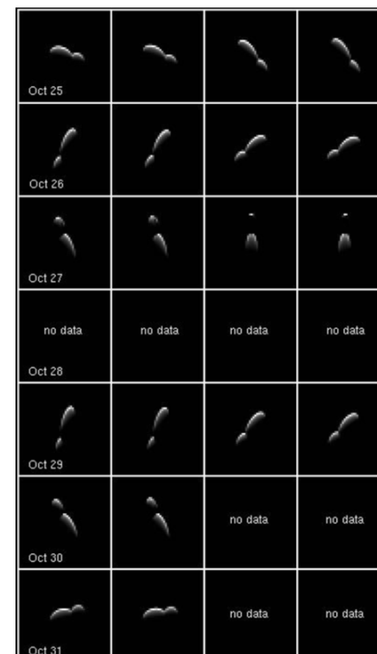
This “same sense circular polarization Tx/Rx” (SC) image shows a portion of Maxwell Montes, spatially averaged to 1.2 km resolution.

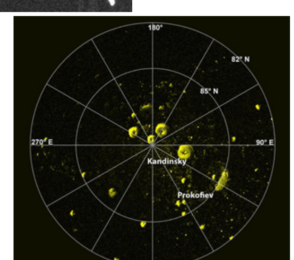
The Planetary Radar: A Legacy of Discovery

1965: Rotation rate of Mercury determined to be in 2/3 tidal lock with the orbital period
1980: First radar ranging to Earth crossing asteroid
1981: Radar maps of the surface of Venus
1992: Radar reflectivity indicates water ice at the North Pole of Mercury
2000: Radar images show that NEA 216 Kleopatra has a dog bone shape
2003: Radar reflectivity indicates that Titan features hydrocarbon lakes, but not oceans
2007: Core of planet Mercury determined to be molten
2008: First triple asteroid system identified
2010: Comet 103P Harley imaged, and EPOXI spacecraft encounter guided by AO
2012: Illustrating AO capability, asteroid 2012 LZ1 is found to have twice the dimension expected
2013: Imaging of binary asteroid 1998 QE2 suggests primordial surface
2013: Arecibo radar measurements in 2005, 2006, and 2013, demonstrate that 99942 Apophis has a negligible chance of hitting Earth in 2068





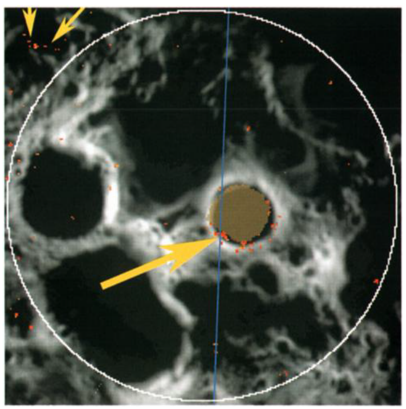


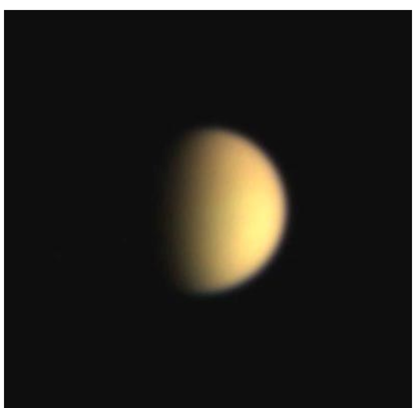


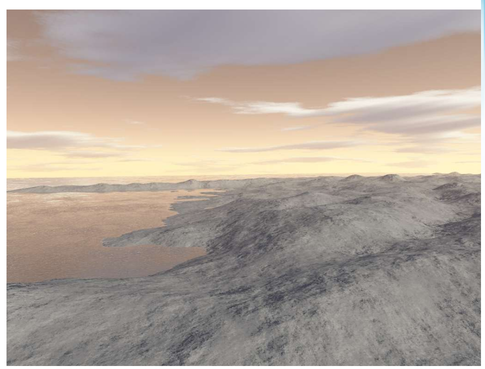
AO now serves as the preeminent source of accurate NEO orbit determination, and ground based imaging.

Recent work

- Search for water at the lunar S. pole
- Search for water at the poles of Mercury
- Search for hydrocarbon oceans or lakes on Titan
- Subsurface geology on Mars
- Core of planet Mercury is determined to be liquid







PRESS RELEASES

Arecibo Observatory Finds Asteroid 2012 LZ1 To Be Twice As Big As First Believed

June 21, 2012
Contact: Stacy Bowles, USRA
410-730-2656

Arecibo, PR, June 21, 2012 - Using the **planetary radar system** at Arecibo Observatory, astronomers have determined that asteroid 2012 LZ1 is twice as large as originally estimated based on its brightness, and large enough to have serious global consequences if it were to hit the Earth. However, a new orbit solution also derived from the radar measurements shows that this object does not have any chance of hitting the Earth for at least the next 750 years.

Asteroid 2012 LZ1 was discovered on June 10, 2012, at Siding Spring Observatory in Australia, and was classified as potentially hazardous by the Minor Planet Center because its preliminary orbit brings it close to Earth (within 20 lunar distances). Scientists at Arecibo observed the asteroid on June 19, 2012, to measure its orbit more precisely and to determine its size, rotation rate, and shape, and found it to be about 1 kilometer (0.6 miles) in its largest dimension. The new size determination suggests that 2012 LZ1 must be quite dark, reflecting only 2-4% of the light that hits it.

"The sensitivity of our radar has permitted us to measure this asteroid's properties and determine that it will not impact the Earth at least in the next

RELATED MEDIA

Asteroid 2012 LZ1 is roughly spherical and rotates once around every 10-15 hours. This detailed image was taken when the asteroid was 10 million kilometers (6 million miles) away. The resolution is 7.5 m (25 feet), equivalent to seeing a basketball in New York City from Puerto Rico.

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Science Press releases in the past 2 years:

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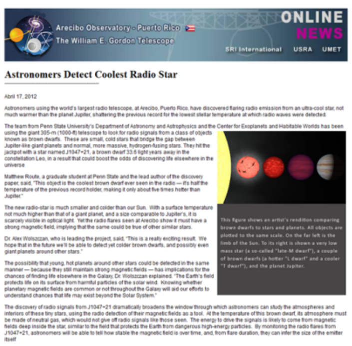
May 8, 2012: Russians, Americans, and Europeans Work Together To Set Records For Celestial Detail
June 21, 2012: Arecibo Observatory Finds Asteroid 2012 LZ1 To Be Twice As Big As First Believed
Nov. 29, 2012: NASA Spacecraft Finds New Evidence For Water Ice on Mercury
Jan. 7. 2013: Massive Outburst in Neighbor Galaxy Surprises Astronomers
Jan. 9, 2013: Mapping The Milky Way: Radio Telescopes Give Clues to Structure, History
April 25, 2013: Arecibo Telescope Used To Study Neutron Star Twice As Massive As The Sun, Orbiting Every Two Hours: Einstein's Theory Of Gravitation Passes With Flying Colors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Astronomers Detect Coolest Radio Star


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Russians, Americans and Europeans work together to set records for celestial detail.


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Arecibo Observatory - Puerto Rico
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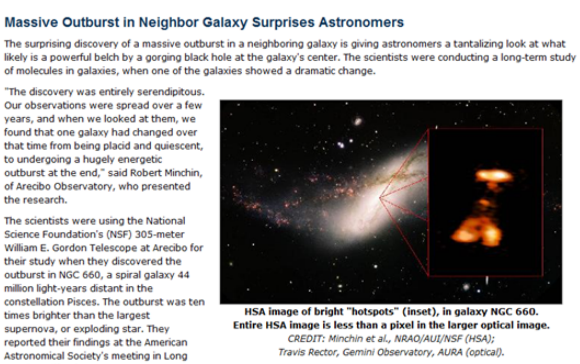
RELEASE 12-411
NASA SPACECRAFT FINDS NEW EVIDENCE FOR WATER ICE ON MERCURY

Mercury's North Polar Region Acquired By The Arecibo Observatory


Massive Outburst in Neighbor Galaxy Surprises Astronomers

The surprising discovery of a massive outburst in a neighboring galaxy is giving astronomers a tantalizing look at what likely is a powerful belch by a gorging black hole at the galaxy's center. The scientists were conducting a long-term study of molecules in galaxies, when one of the galaxies showed a dramatic change.

"The discovery was entirely serendipitous. Our observations were spread over a few years, and when we looked at them, we found that one galaxy had changed over that time from being placid and quiescent, to undergoing a hugely energetic outburst at the end," said Robert Minchin, of Arecibo Observatory, who presented the research.

The scientists were using the National Science Foundation's (NSF) 305-meter William E. Gordon Telescope at Arecibo for their study when they discovered the outburst in NGC 660, a spiral galaxy 44 million light-years distant in the constellation Pisces. The outburst was ten times brighter than the largest supernova, or exploding star. They reported their findings at the American Astronomical Society's meeting in Long Beach, California.

HSA image of bright "hotspots" (inset), in galaxy NGC 660. Entire HSA image is less than a pixel in the larger optical image.
CREDIT: Minchin et al., NRAO/AUI/NSF (HSA); Travis Rector, Gemini Observatory, AURA (optical).


Mapping the Milky Way: Radio Telescopes Give Clues to Structure, History

Astronomers have discovered hundreds of previously-unknown sites of massive star formation in the Milky Way, including the most distant such objects yet found in our home Galaxy. Ongoing studies of these objects promise to give crucial clues about the structure and history of the Milky Way.

Red areas mark locations of a string of newly-discovered HII regions stretching across a portion of the Milky Way.


PRESS RELEASES

Arecibo Telescope Used to Study Neutron Star Twice as Massive as the Sun, Orbiting Every Two Hours: Einstein's Theory of Gravitation Passes with Flying Colors

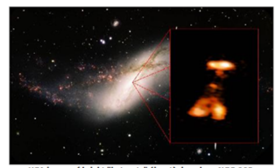
04/25/2013
Contact: Fernando Camilo
410-302-0299
camilo@naic.edu

RELATED MEDIA
Click for video: An artist's impression of the PSR J0348+0432 binary system. Credit: Luis Calçada/ESO

Arecibo, Puerto Rico, April 25, 2013. An international research team led by astronomers from the Max Planck Institute for Radio Astronomy (Germany) has used a variety of large optical and radio telescopes including the world's largest, the U.S. National Science Foundation's Arecibo radio telescope in Puerto Rico to study PSR J0348+0432, an extreme stellar system. The observations of this pulsar/white dwarf binary revealed a neutron star that weighs twice as much as the Sun, making it the most massive measured to date. Together with the unusually short orbital period of only 2.5 hours, this makes the system a strong emitter of gravitational radiation. The energy loss caused by this radiation has been measured in radio observations of the pulsar, particularly due to the exquisite sensitivity of the Arecibo 1,000-foot (305-meter) diameter telescope. These results, which so far are consistent with expectations from Einstein's theory of General Relativity, make the pulsar system a laboratory for gravity in extreme conditions not previously accessible.

PY 2013/14 Science Press Releases:

Nov. 29, 2012: NASA Spacecraft Finds New Evidence For Water Ice on Mercury
Jan. 7. 2013: Massive Outburst in Neighbor Galaxy Surprises Astronomers
Jan. 9, 2013: Mapping The Milky Way: Radio Telescopes Give Clues to Structure, History
April 25, 2013: Arecibo Telescope Used To Study Neutron Star Twice As Massive As The Sun, Orbiting Every Two Hours: Einstein's Theory Of Gravitation Passes With Flying Colors
June 14, 2013: Arecibo Observatory Catches the Most Detailed Radar Images Ever of Asteroid 1998 QE2 and its Newly Discovered Moon
Jan. 16, 2014: Pulsar In Stellar Triple System Makes Unique Gravitational Laboratory



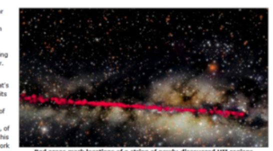
Massive Outburst in Neighbor Galaxy Surprises Astronomers

The surprising discovery of a massive outburst in a neighboring galaxy is giving astronomers a tantalizing look at what likely is a powerful belch by a gorging black hole at the galaxy's center. The scientists were conducting a long-term study of molecules in galaxies, when one of the galaxies showed a dramatic change.

"The discovery was entirely serendipitous. Our observations were spread over a few years, and when we looked at them, we found that one galaxy had changed over that time from being placid and quiescent, to undergoing a hugely energetic outburst at the end," said Robert Minchin, of Arecibo Observatory, who presented the research.

The scientists were using the National Science Foundation's (NSF) 305-meter William E. Gordon Telescope at Arecibo for their study when they discovered the outburst in NGC 660, a spiral galaxy 44 million light-years distant in the constellation Pisces. The outburst was ten times brighter than the largest supernova, or exploding star. They reported their findings at the American Astronomical Society's meeting in Long Beach, California.

HSA image of bright "hotspots" (inset), in galaxy NGC 660. Entire HSA image is less than a pixel in the larger optical image.
CREDIT: Minchin et al., NRAO/AUI/NSF (HSA); Travis Rector, Gemini Observatory, AURA (optical).



Mapping the Milky Way: Radio Telescopes Give Clues to Structure, History

Astronomers have discovered hundreds of previously-unknown sites of massive star formation in the Milky Way, including the most distant such objects yet found in our home Galaxy. Ongoing studies of these objects promise to give crucial clues about the structure and history of the Milky Way.

The scientists found regions where massive young stars or clusters of such stars are forming. These regions, which astronomers call HII (H-two) regions, serve as markers of the Galaxy's structure, including its spiral arms and central bar.

"We're vastly improving the census of our Galaxy, and that's a key to understanding both its current nature and its past history, including the history of possible mergers with other galaxies," said Thomas Bania, of Boston University. Bania and his colleagues presented their work to the American Astronomical Society's meeting in Long Beach, California.

Red areas mark locations of a string of newly-discovered HII regions stretching across a portion of the Milky Way.

PRESS RELEASES

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04/25/2013
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RELATED MEDIA

Click for video: An artist's impression of the PSR J0348+0432 binary system. Credit: Luis Calçada/ESO

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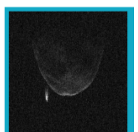
Related Headlines

- April 8, 2013 NICER selected for implementation through NASA's Astrophysics Explorers Program



PRESS RELEASES

June 14, 2013
Contact: Alessondra Springmann
787-878-2612 x337

Arecibo, Puerto Rico, June 14, 2013 - Arecibo Observatory catches the most detailed radar images ever of asteroid 1998 QE2 and its newly discovered moon as they safely pass our planet.

Arecibo Observatory continues to take radar images of asteroid 1998 QE2 and its moon as the space rock sails safely passed earth this week. The images show a dark cratered asteroid 3 kilometers across (1.9 miles) with a companion moon 750 meters (2,500 feet) in size. The asteroid and its moon passed 6 million kilometers (3.75 million miles) from earth, far enough from our planet not to worry, close enough to study this rocky world with the most sensitive radar telescope in the world, the U.S. National Science Foundation's Arecibo Observatory in Puerto Rico. "Asteroid QE2 has no chance of hitting earth," said USRA's Dr. Michael Nolan, head of the asteroid radar group at Arecibo Observatory who took the images.

Radar images of Asteroid 1998 QE2 taken on June 7, 2013 as the asteroid and its moon safely passed Earth. The asteroid appears lit from the bottom while we The light is from the powerful radio waves from the radar transmitter. The Earth is at the bottom of this image: the "side view" is a result of the radar imaging method. Several craters are visible on the asteroid, and the moon appears as a bright streak. Each pixel is 7.5 meters (25 feet). Image credit: Arecibo

USRA UNIVERSITIES SPACE RESEARCH ASSOCIATION
10211 Wincopin Circle, Suite 500 • Columbia, MD 21044-3432
410-730-2656 • 410-730-3496 (fax) • www.usra.edu

RELEASE EMBARGOED
UNTIL 01/05/2014, 13:00 EST
Contact: Fernando Camilo
410-302-0299
camilo@naic.edu

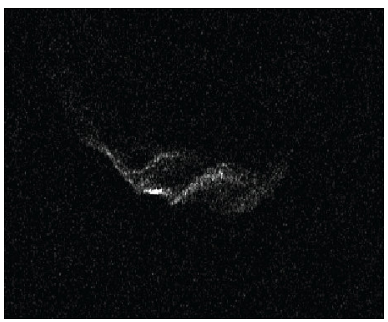
(NOTE: PRESS CONFERENCE at 10:15 EST, Monday, 6 January 2014, at 223rd AAS meeting. For online access to press conference, contact Rick Fienberg, AAS Press Officer, at rick.fienberg@aas.org.)

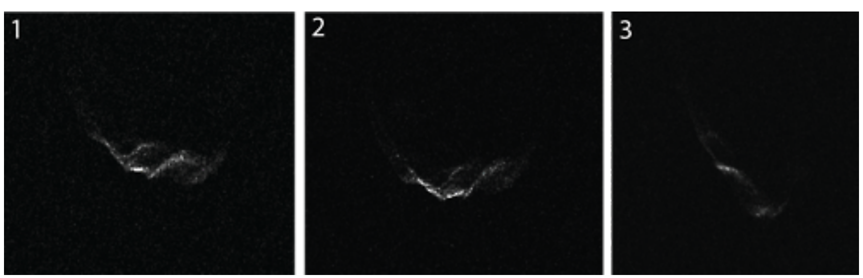
PULSAR IN A STELLAR TRIPLE SYSTEM MAKES UNIQUE GRAVITATIONAL LABORATORY

PLANETARY RADAR SCIENCE

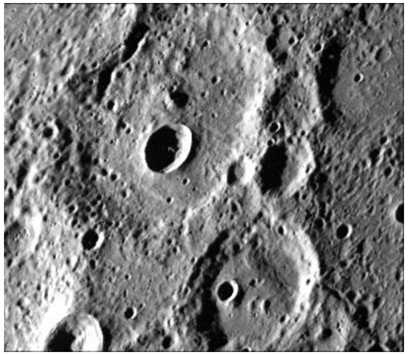
Comet 209P/Linear
- May 23 – May 27, 2014
-1.2 x 1.5 miles in dimension
-25’ resolution
-4th nucleus imaged from Earth (7 have been imaged)

Asteroid 2014 HQ124
- June 8, 2014
- 800,000 miles from Earth (3 lunar distances)
- About 1,200 feet across
- 12 ‘ resolution

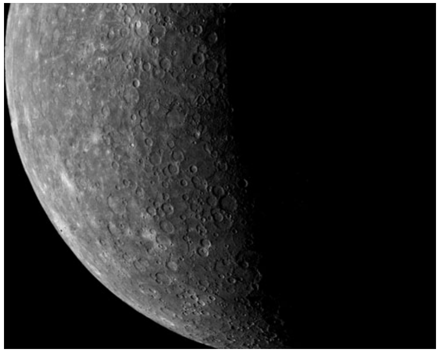




There is plenty of evidence for spectacular impacts, throughout our solar system:



Moon



Mercury

Arizona

Mimas (Uranus)

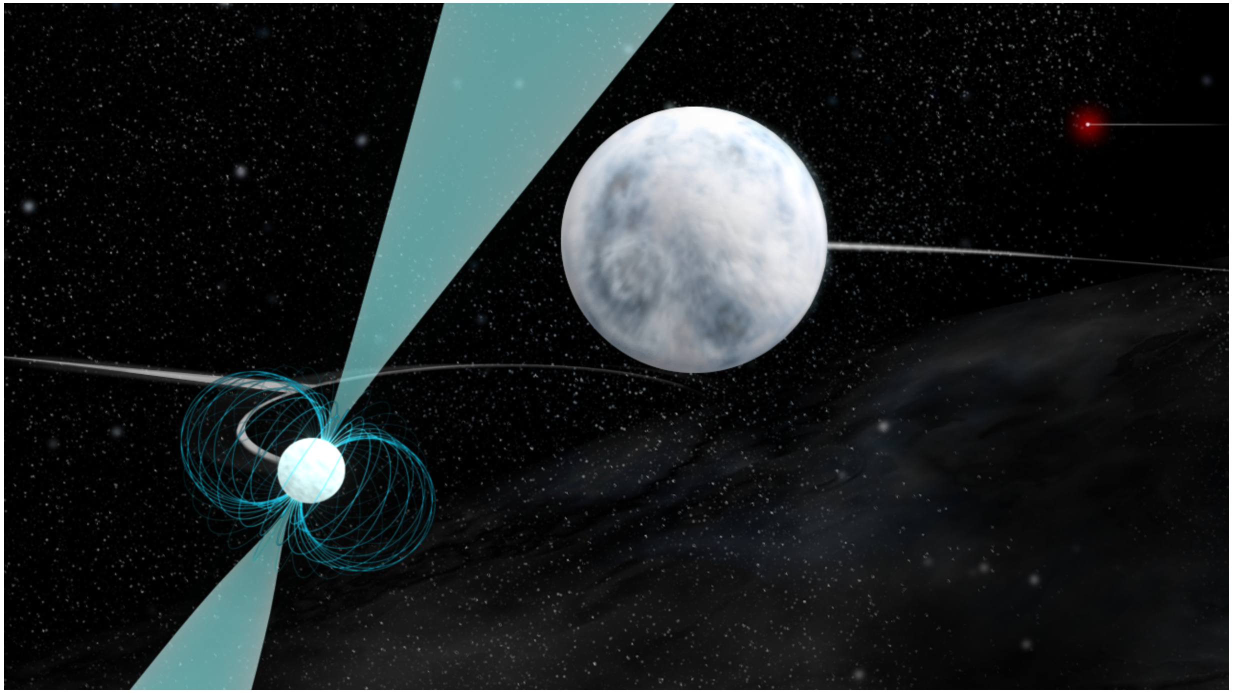
Tunguska, 6/30/1908

Peekskill, NY 10/9/1992

Arecibo Observatory will very likely identify the next major threat to species on Earth – and therefore mitigate that threat!

FREQUENCY OF IMPACTORS:
Pea-size meteoroids - 10 per hour
Walnut-size - 1 per hour
Grapefruit-size - 1 every 10 hours
Basketball-size - 1 per month
50-m rock that would destroy an area the size of New Jersey - 1 per 100 years
1-km asteroid - 1 per 100,000 years
2-km asteroid - 1 per 500,000 years
A "nemesis" parabolic comet impactor would give us only a 6-month warning.

PULSAR IN A STELLAR TRIPLE SYSTEM MAKES UNIQUE GRAVITATIONAL LABORATORY



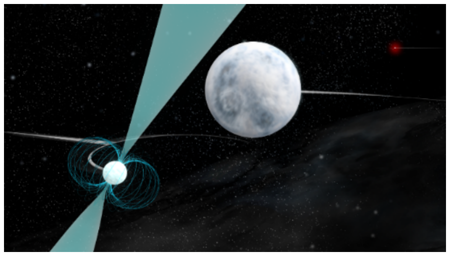
Detailed studies of this system may provide a key clue for resolving one of the principal outstanding problems of fundamental physics -- the true nature of gravity. **1/5/2014**

“While Einstein's Theory of General Relativity has so far been confirmed by every experiment, it is not compatible with quantum theory. Because of that, physicists expect that it will break down under extreme conditions,” [Scott] Ransom explained. “This triple system of compact stars gives us a great opportunity to look for a violation of a specific form of the equivalence principle called the Strong Equivalence Principle,” he added.

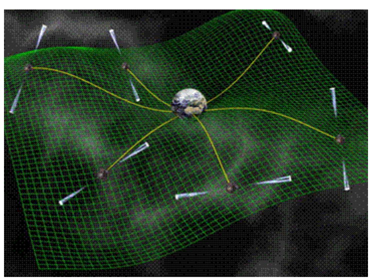
When a massive star explodes as a supernova and its remains collapse into a superdense neutron star, some of its mass is converted into gravitational binding energy that holds the dense star together. The Strong Equivalence Principle says that this binding energy still will react gravitationally as if it were mass. Virtually all alternatives to General Relativity hold that it will not.

RADIO ASTRONOMY

What is the nature of gravity ?

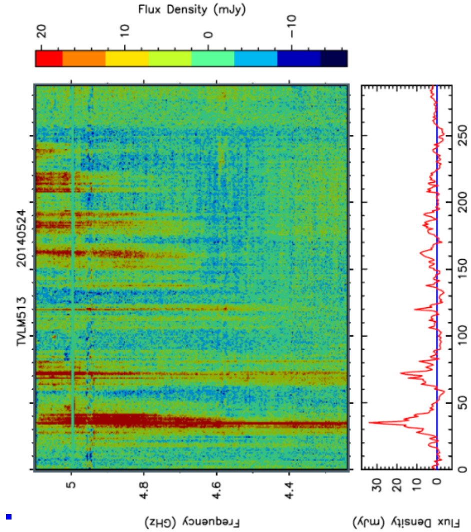


A Pulsar in a stellar triple system makes a unique cosmic gravitational laboratory. Orbital decay will test the Einstein "equivalence principle" – which suggests that the binding energy will react to gravity as though it were mass.



An array of pulsars is being developed to allow detection of "gravitational waves".

Strong Radio pulses from the magnetospheres of brown dwarfs



Unexplained radio bursts….

McGill

FOR IMMEDIATE RELEASE
Montreal, xxxxxx xx, 2014

July 10, 2014

Radio-burst discovery deepens astrophysics mystery

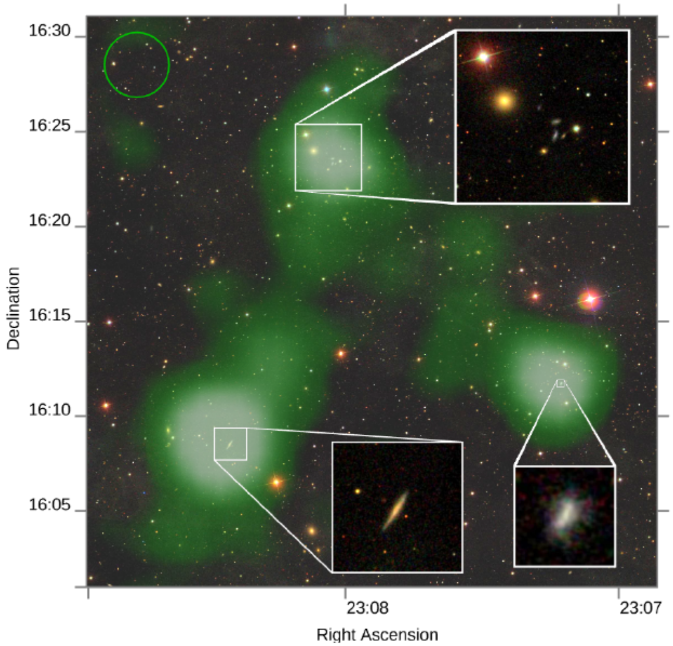
- Discovered at Parkes, Australia, 2007
- 5 more discovered at Parkes since (2013)
- Few ms pulse. – BRIGHT
- Dispersion indicates extra-galactic source (3 bLY [Milky Way 100,000 LY diameter])
- 11/2/2012 PALFA survey at AO sees another example!
- 10,000 every day, across the sky …

- WHAT **IS** THIS PHENOMONON ?

And another … Soon!

Largest known stream of gas found by Arecibo survey

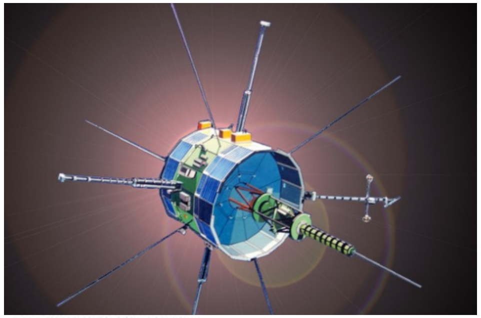
Astronomers and students using the Arecibo Telescope in Puerto Rico have found a bridge of gas 2.6 million light years long between galaxies 500 million light years away.



The bridge of gas (shown in green) stretches from the large galaxy at the bottom left to the group of galaxies at the top. A third nearby galaxy to the right also has a shorter stream of gas attached to it. Picture credit: Rhys Taylor/Arecibo Galaxy Environment Survey/The Sloan Digital Sky Survey Collaboration, http://www.sdss.org

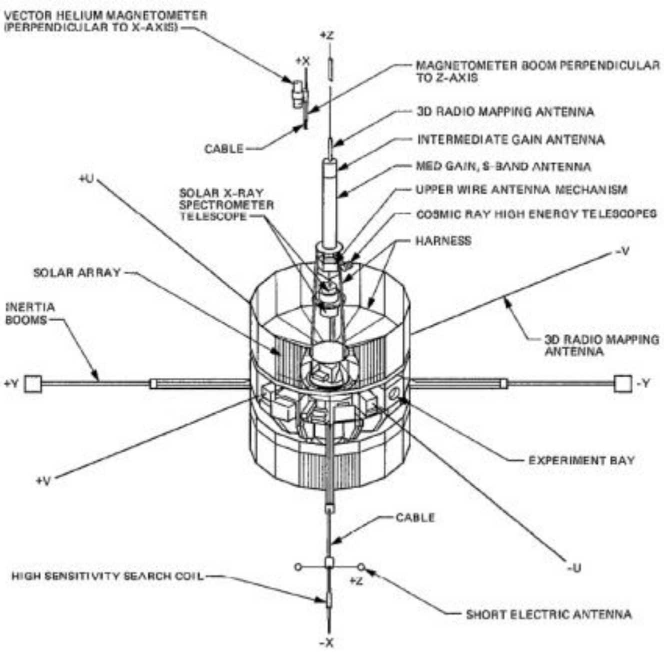
The stream of atomic hydrogen gas is the largest known, a million light years longer than a gas tail found in the Virgo Cluster by another Arecibo project a few years ago. Dr. Rhys Taylor, a researcher at the Czech Academy of Sciences and lead author of the paper, said "This was totally unexpected. We frequently see gas streams in galaxy clusters, where there are lots of galaxies close together, but to find something this long, and not in a cluster, is unprecedented."

It is not just the length of the stream that is surprising, however, it is also the amount of gas found in it. Roberto Rodriguez, a 2014 graduate from The University of Puerto Rico Humacao who worked on the project as an undergraduate, explained "We normally find gas inside galaxies, but here half of the gas – 15 billion times the mass of the Sun – is in the bridge. That's far more than in the Milky Way and Andromeda galaxies combined!"

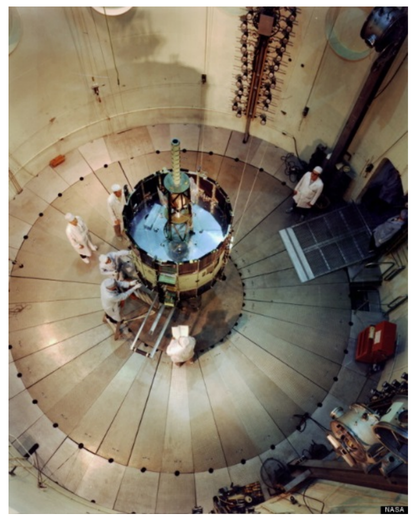


REBOOTING A SATELLITE

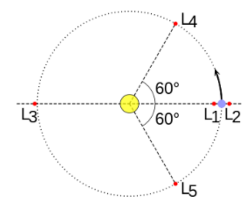
International Sun-Earth Explorer ISEE-3



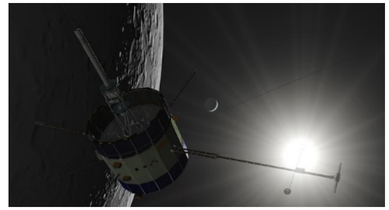
ICE spacecraft



- 8/12/78 Launch. Cape Canaveral. 390 kg
- 1st International mission (NASA/ESA)
- 1st craft in "Halo" orbit



- 6/10/82 Redirected for comet encounter (ICE)
- 12/12/83 119.4 km from Moon surface
- 1984 heliocentric orbit established
- 9/11/85 7800 km from Giacobini-Zinner
- 1st craft to encounter a comet
- 3/86 28 million km from Comet Halley
- 5/5/1997 NASA decommissioning
- 1999 DSN contact, ISEE donated to Smithsonion
- 9/18/2008 DSN contact. 12/13 instruments operating.



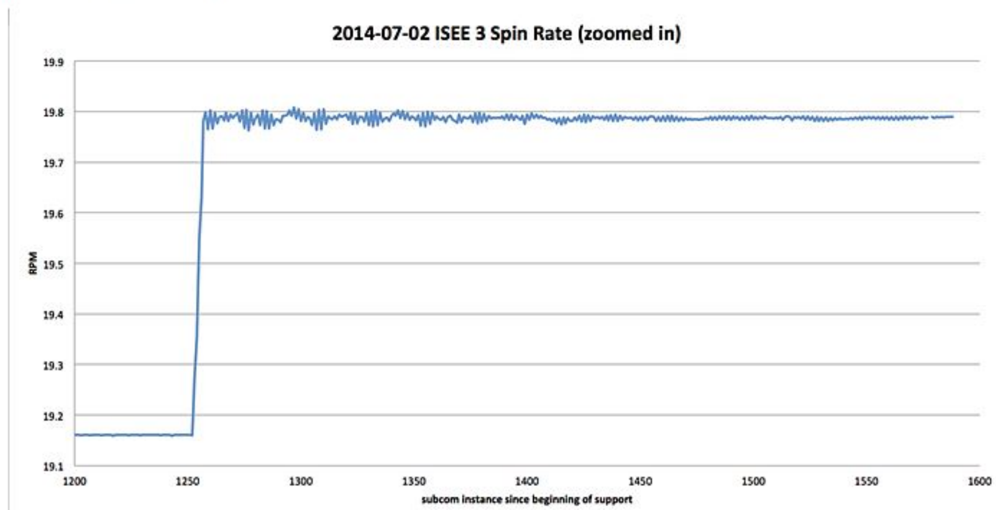
2014 Arecibo and Citizen Scientists (SkyCorp) re-establish control

-"Handshaking" with ISEE-3 from Arecibo established 5/29/14
-Coverage by BBC, FOX, NBC, NY Times, Sky & Tel., Huffington Post, etc.
-6/5/14: Demodulated telemetry indicating +28 W power, ALL instruments responding
-6/20/14: "Coherent" mode ranging established
-7/2/14: Successful "spin-up"
-Improved ephemeris for Moon maneuver back to L1 ?
-1st Citizen/NASA cooperation for NASA satellite "hand-off"

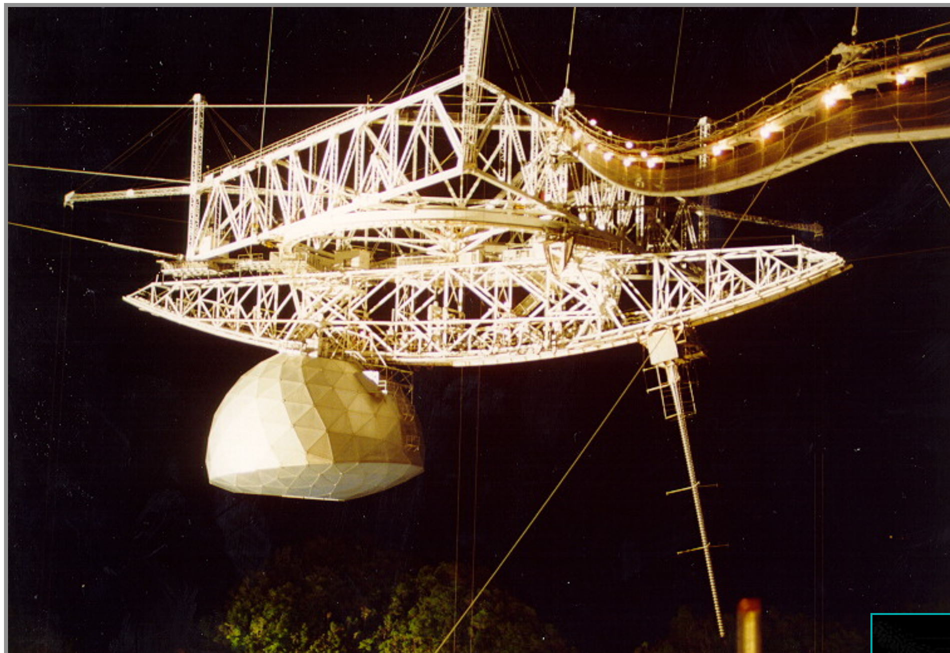
http://spacecollege.org/

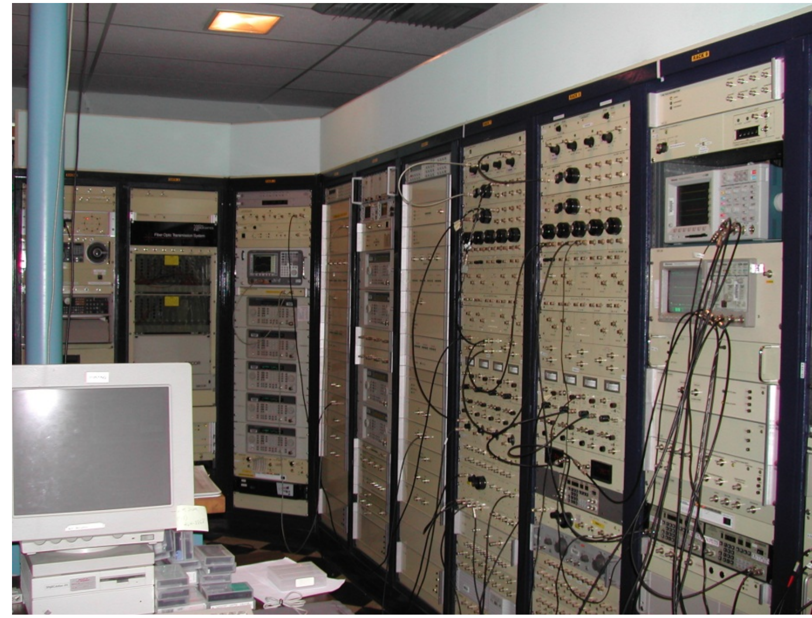
Additional ISEE-3 Spin-up Confirmation

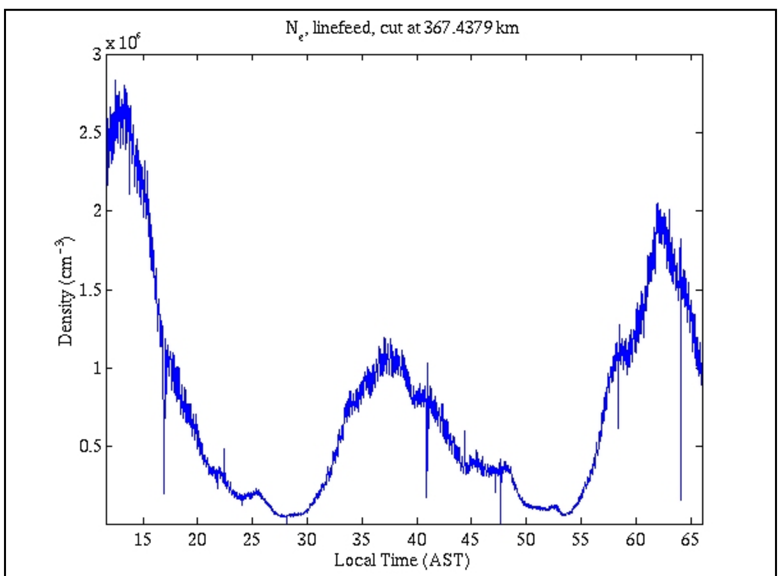
By Keith Cowing on July 3, 2014 12:17 PM



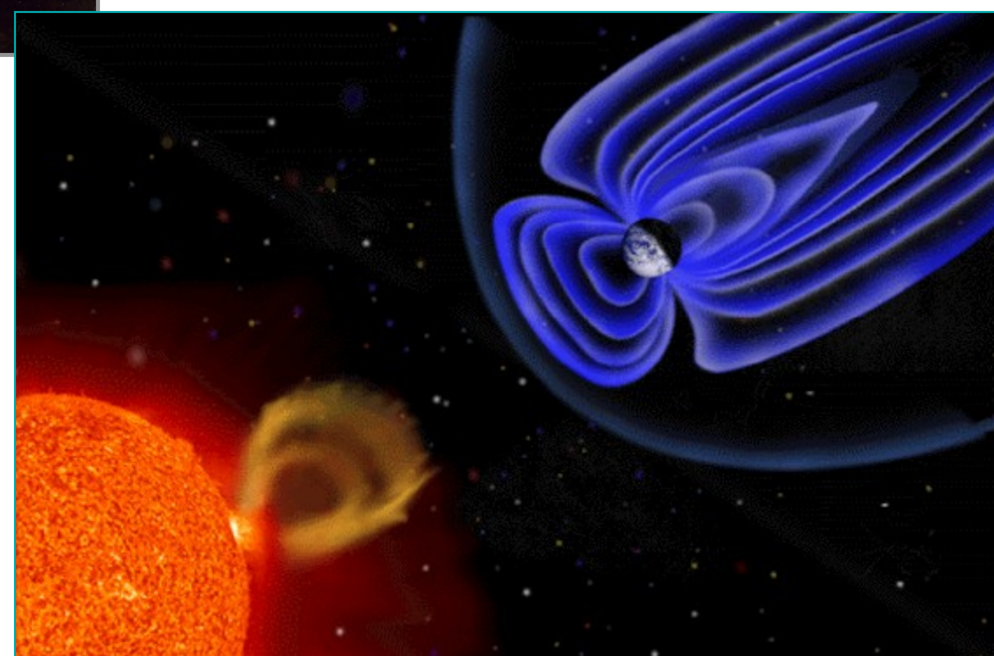
Further confirmation of the ISEE-3 spin-up burn yesterday. Before the burn (actually 11 pulses on the spacecraft's hydrazine thrusters) the spin rate of ISEE-3 was 19.16 rpm. After spin-up burn it was 19.76 rpm. The original mission specifications for ISEE-3 called for a spin rate of 19.75 +/- 0.2 rpm. Bullseye.







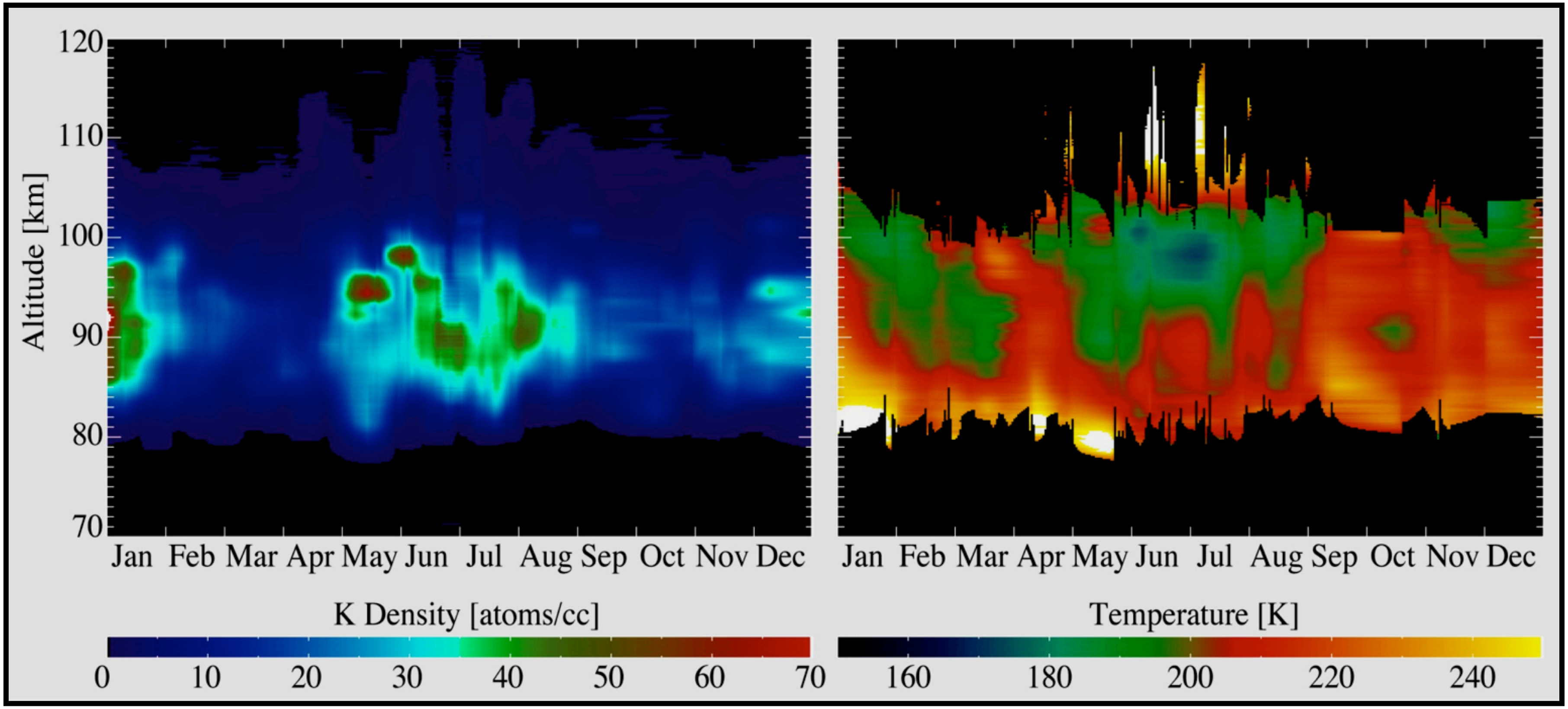
N_e, linefeed, cut at 367.4379 km
x 10^6
3
2.5
2
1.5
1
0.5
Density (cm^-3)
15
20
25
30
35
40
45
50
55
60
65
Local Time (AST)



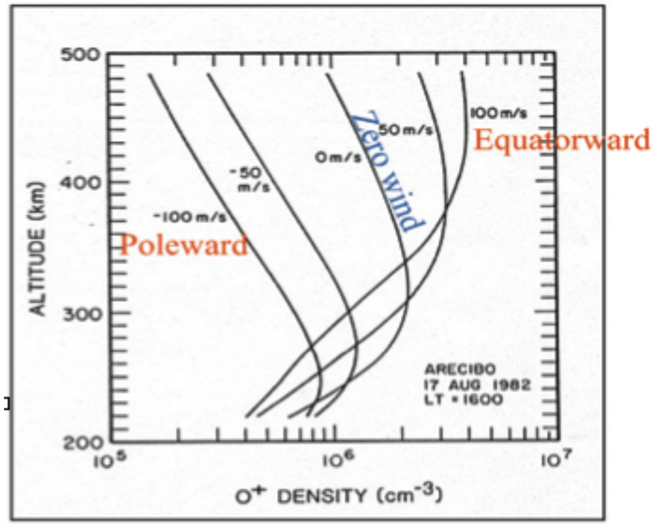
"Other" Arecibo Instruments

- Three Fabry-Perot Interferometers
- One Ebert-Fastie Spectrophotometer
- Two Tilting-Filter Photometers
- Three all-sky imagers
- Nd:YAG Doppler Rayleigh Lidar
- Alexandrite Doppler Resonance Lidar
- Two Dye-lasers (Resonance Lidars)
- 3 GPS receivers
- 2 digisondes
- 2 solar radiometers
- 2 cloud sensors
- 2 reiometers
- A microbarograph
- Accelerometer
- 12-m steerable S/X band antenna

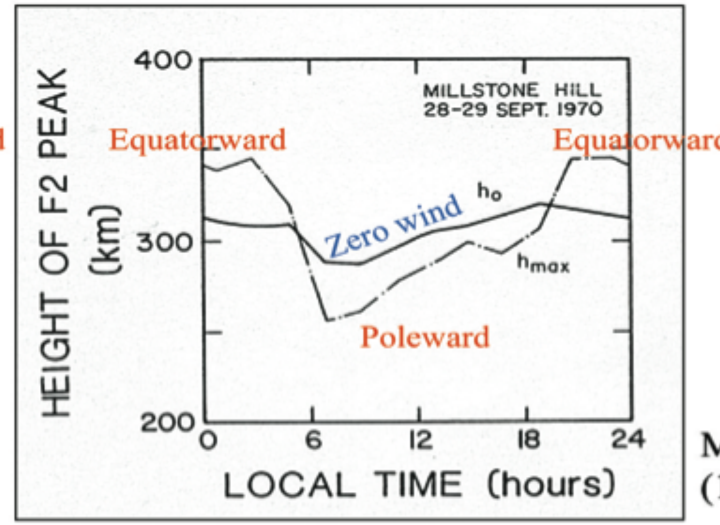
Seasonal Variation of Potassium Density and Temperature of the Mesopause Region During 2½ Years (2001-03)



Neutral winds have significant effect upon F-region density



⇒ O^+ density profiles calculate d from ionospheric model with v arious winds



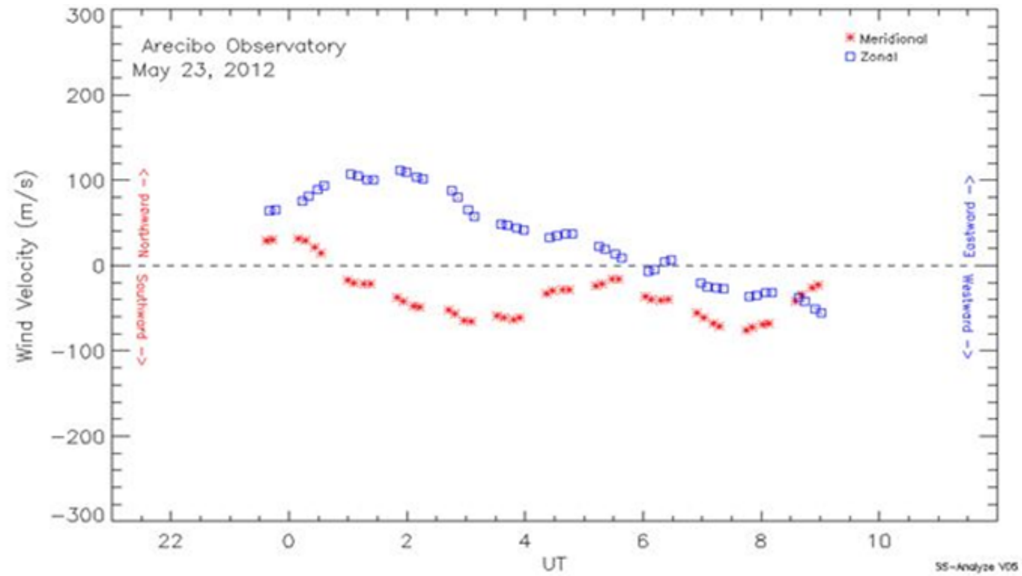
Miller et al. (1986)

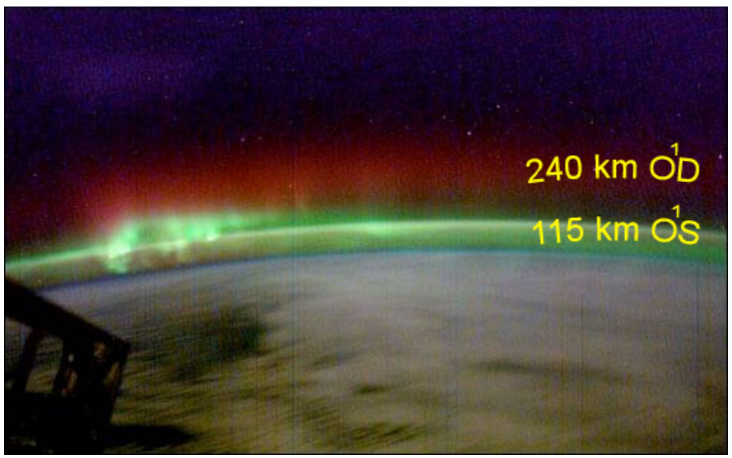
⇒ Measured height (h_{max}) and comp uted height (h_0) with zero wind at Millstone Hill, Sept. 28-29, 1970

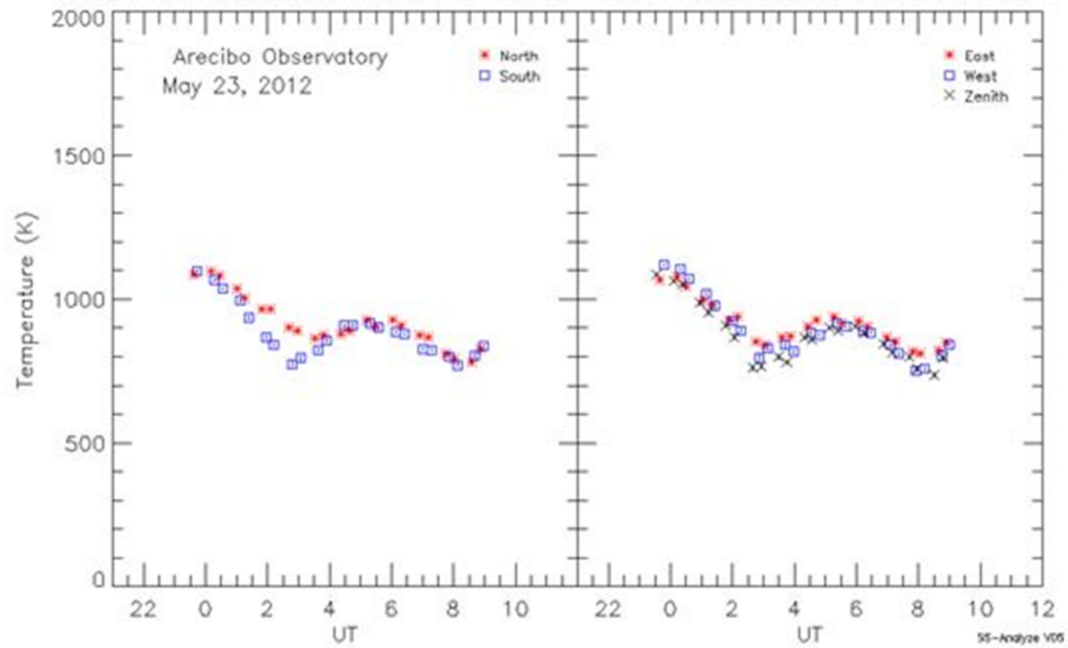
- The electron density at a given altitude may vary an order of magnitude depending upon the direction and speed of the wind.

- h_{max} heights may vary by 100 km depending on direction of meridional component

We now publish neutral winds and temperatures At LEO altitudes each morning, from the night previous.

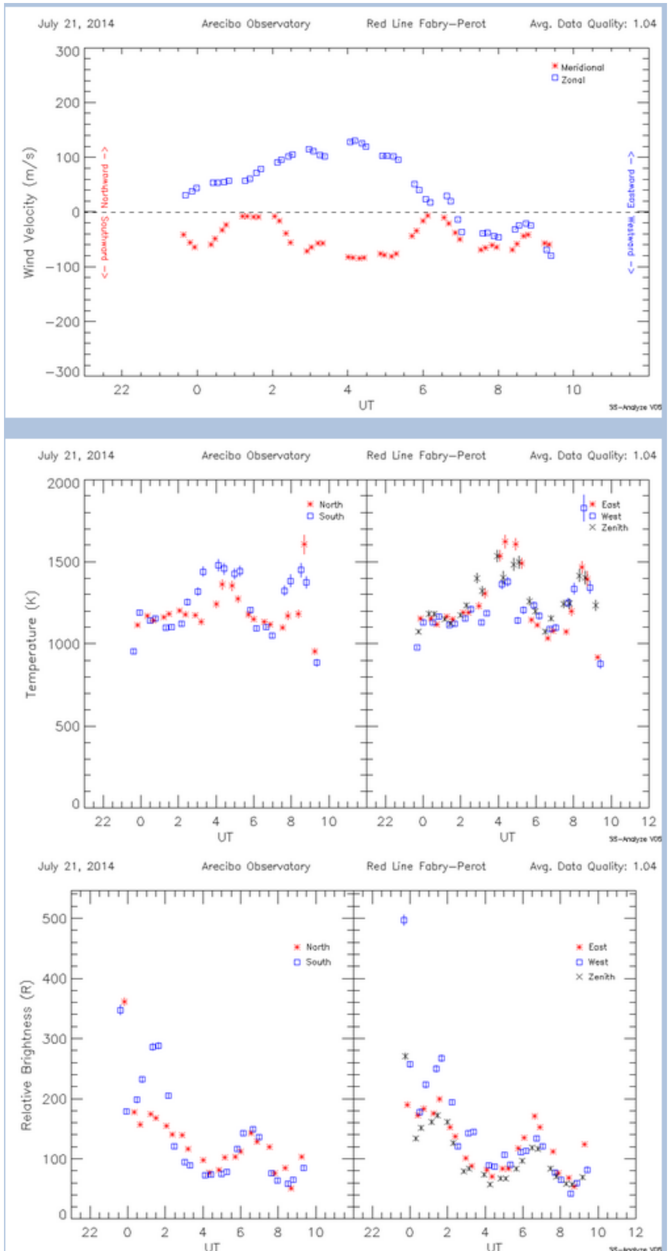


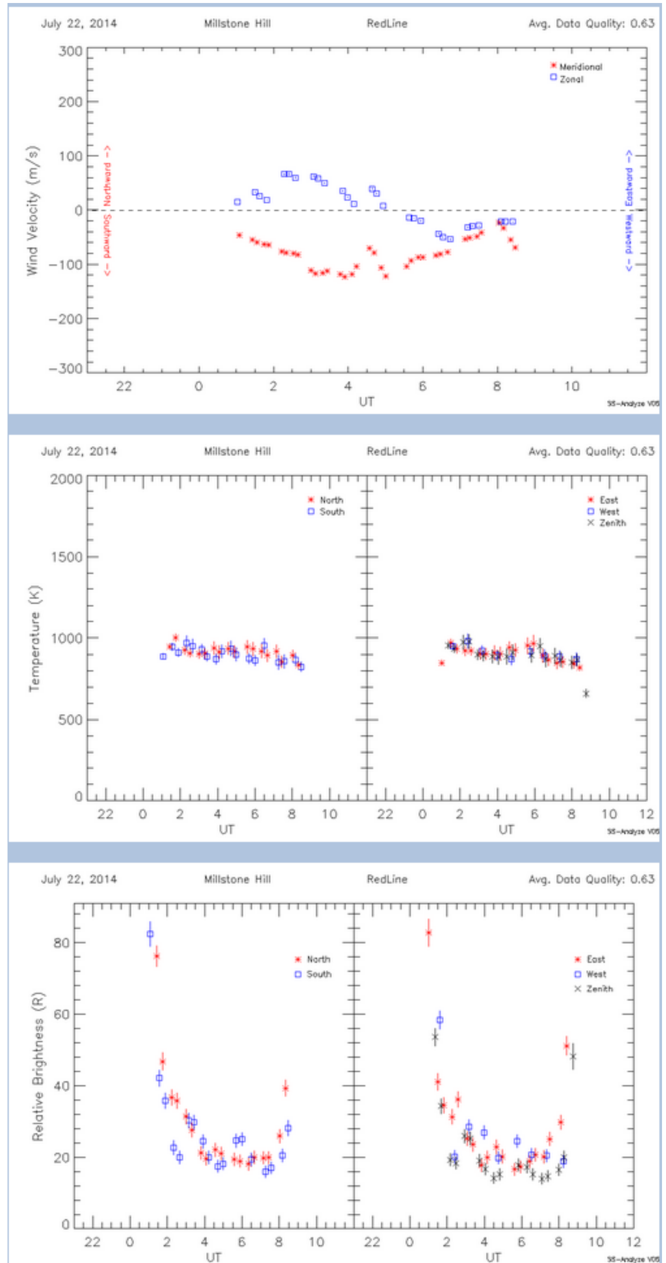


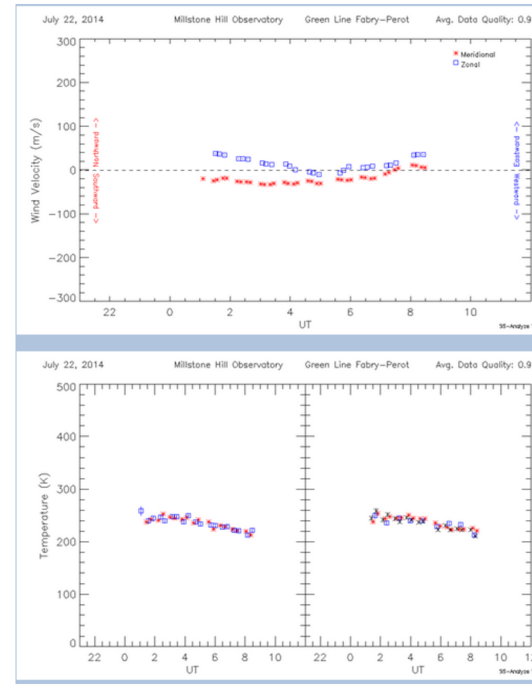


You don’t need a weather man to know which way the wind blows…

www.neutralwinds.com/





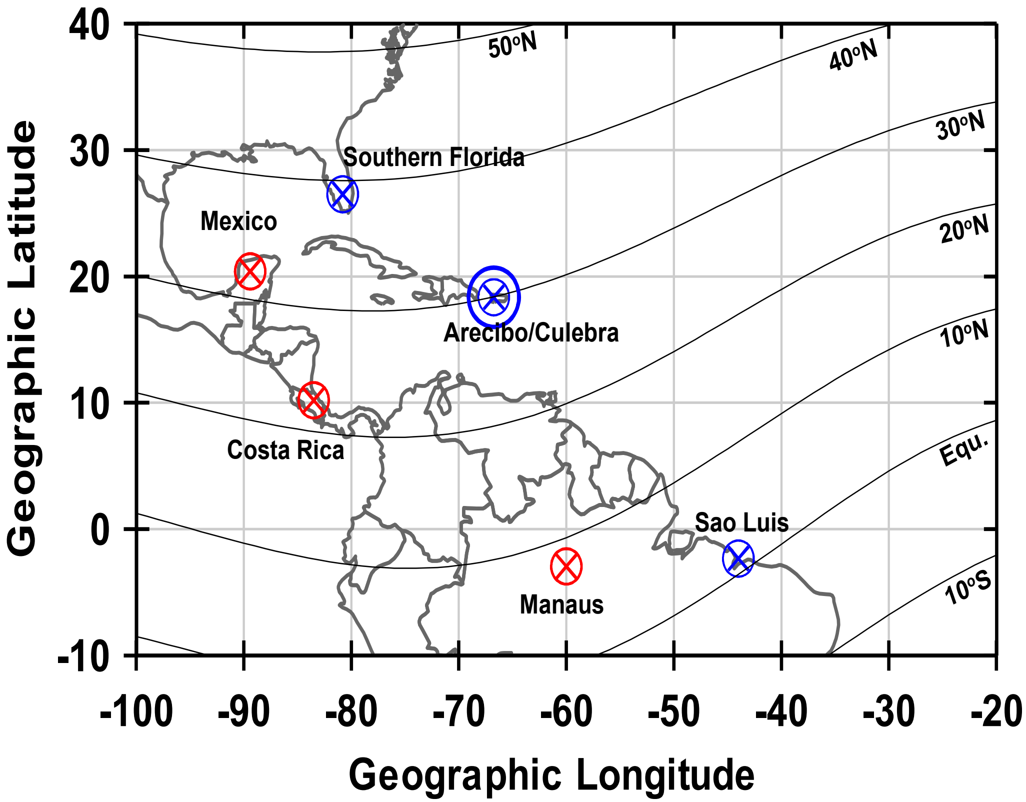


A new era of automated operation

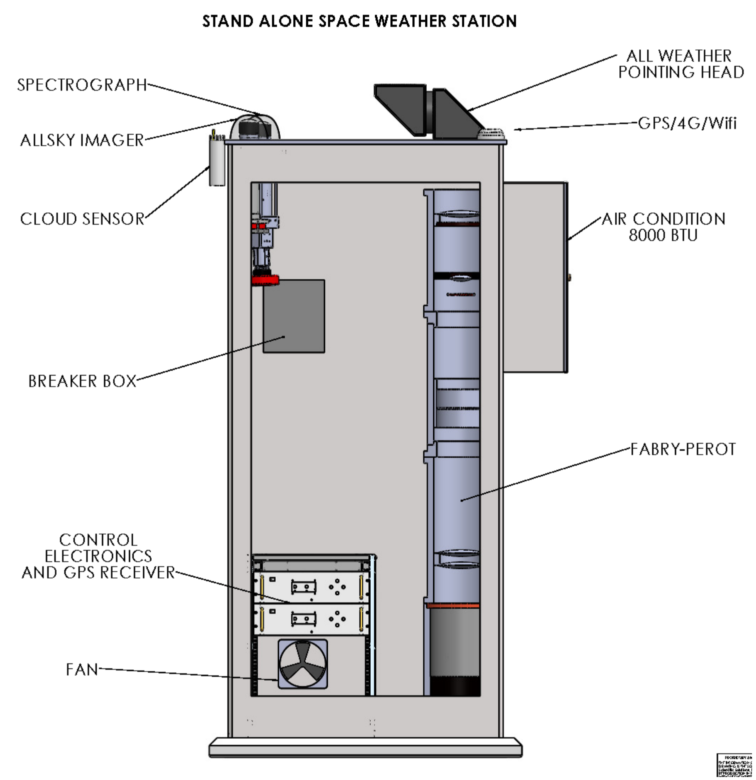
Ground-Based Fabry-Perot 6300 Å Temperature							
Arecibo	18.7°, 67.5°	250	2012–2013	night	430	43,558	Noto *et al.*
Renior	-7.0°, -38.5°	250	2009–2012	night	899	61,525	Makela *et al.*
Jicamarca	-12.0°, 76.9°	250	2009–2013	night	318	9,919	Meriwether *et al.*
Movil	-15.0°, 74.9°	250	2011–2013	night	460	11,012	Meriwether *et al.*
Pisgah	35.2°, 82.9°	250	2013–2013	night	259	22,460	Makela *et al.*

Fabry-Perot Interferometer							
Arecibo	18.4°N, 66.8°W	250	1980 – 1999	night	473	14,198	*Burnside and Tepley* [1989]
Arequipa	16.2°S, 71.4°W	250	1983 – 2001	night	1048	32,238	*Meriwether et al.* [1986]
Arrival Heights	77.8°S, 116.7°E	250	2002 – 2005	night	535	54,214	*Hernandez et al.* [1991]
Halley Bay	75.5°S, 26.6°W	250	1988 – 1998	night	799	82,614	*Crickmore et al.* [1991]
Millstone Hill	42.6°N, 71.5°W	250	1989 – 2002	night	1,770	68,333	*Sipler et al.* [1982]
Mount John	44.0°S, 170.4°E	89, 96, 250	1991 – 1996	night	560	2,660	*Hernandez et al.* [1991]
Søndrestrøm	67.0°N, 51.0°W	250	1984 – 2004	night	1,223	69,734	*Killeen et al.* [1995]
South Pole[d]	90.0°S	86, 250	1989 – 1999	night	1,091	163,044	*Hernandez et al.* [1991]
Svalbard[e]	78.2°N, 15.6°E	250	1980 – 1983	night	44	7,472	*Smith and Sweeny* [1980]
Thule	76.5°N, 68.4°W	250	1987 – 1989	night	172	21,500	*Killeen et al.* [1995]
Resolute Bay	74.7°N, 94.9°E	250	2003 – 2005	night	166	5,299	*Wu et al.* [2004]
Watson Lake	60.1°N, 128.6°W	250	1991 – 1992	night	135	28,000	*Niciejewski et al.* [1996]

Automated Space Weather Observing Station



Perfect for arrays and chain observations!



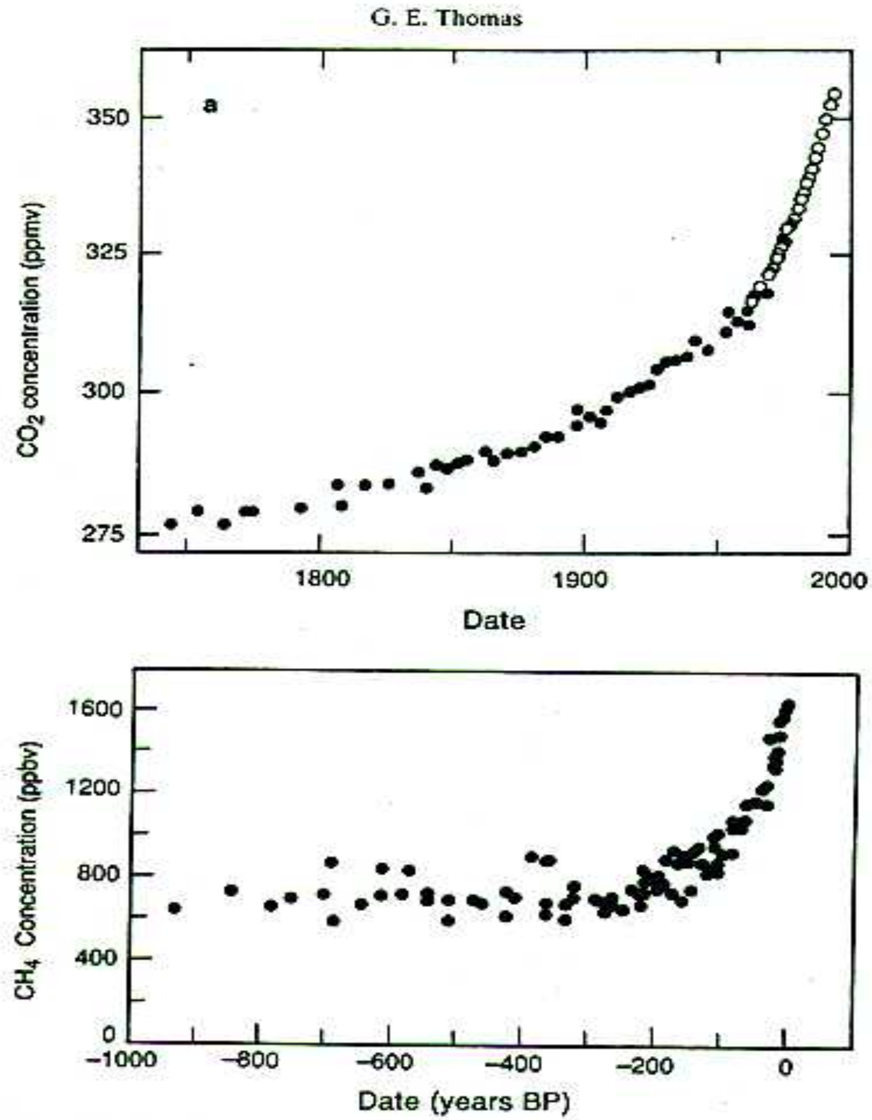
A new opportunity

Culebra Island

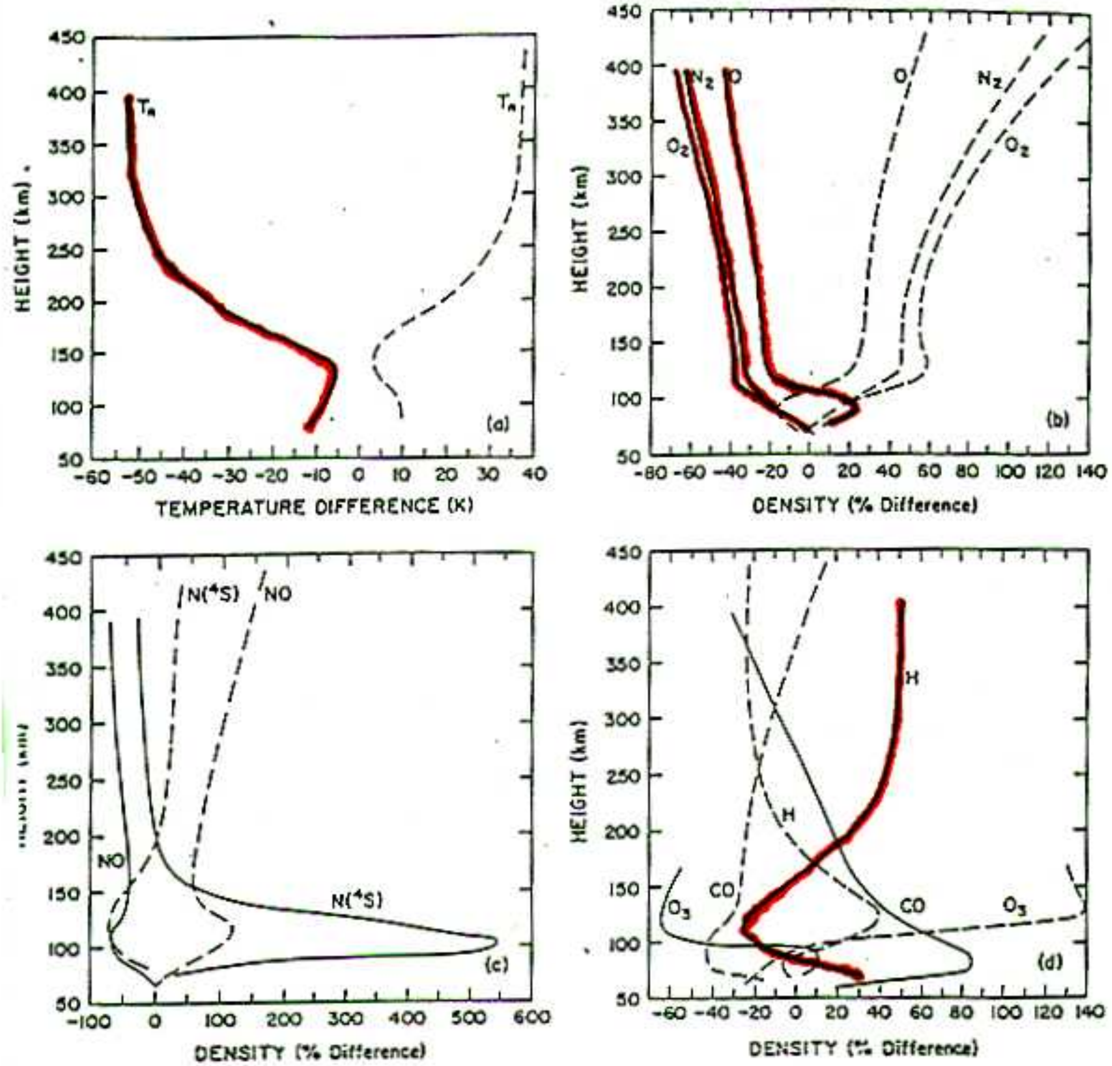
✓Darker skies & Drier climate
✓Can be automated from the ground up
✓common volume observations w/ Arecibo

Opportunity to upgrade:

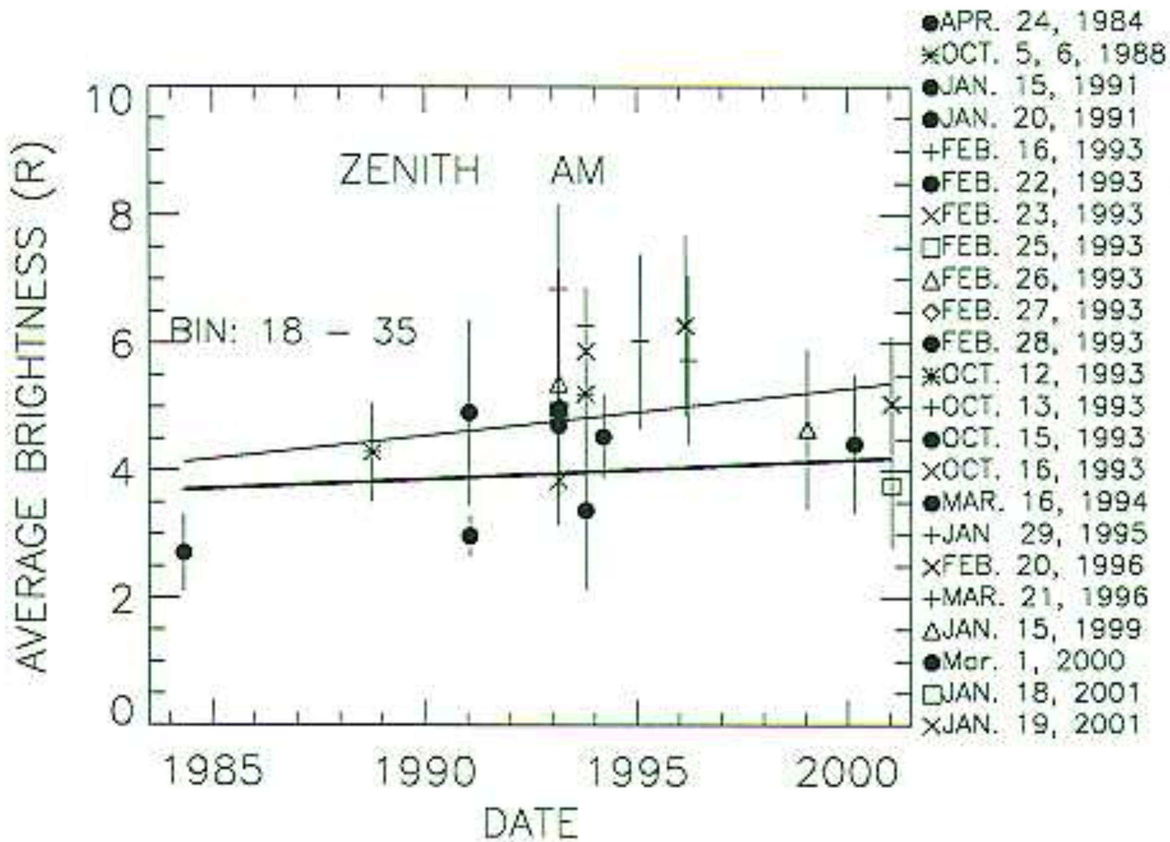
✓Photometers
  CCD detection
  no-tilting
✓Spectrograph
  CCD detection



The familiar tropospheric enhancement of CO_2 conciding with the inducstrial revolution as measured at remotes sites (top panel), and of troposheric methane (bottom panel) in the past 1000 yrs. This presentation of the data was offered by G.E. Thomas, *J. Atmos. And Terr. Phys.,* 1996.



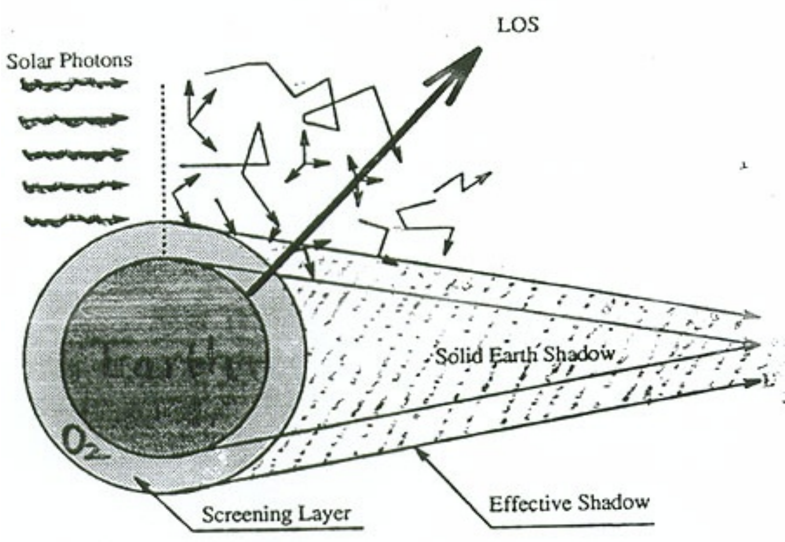
A model of the atmospheric response to a doubling of CH_4 and CO_2 (solid lines) and a halving of both species (dashed lines). Note the projected 50% enhancement of thermospheric H, the projected 50% reductions of thermospheric O_2, N_2, and O, and the 50 K decrease in thermospheric neutral temperature when both CH_4 and CO_2 are doubled. (From Roble and Dickinson, *Geophys Res. Lett, 16, No. 12,* 1989.)



Zenith data binned between 18^0 - 35^o solar depression angle are averaged for the dates shown. Error bars are one root mean square deviations of those averages. The light solid line is the best linear fit through the data. The heavier solid line is linear fit through corresponding model values. The data begin with solar medium conditions in 1984, and include two solar maximum periods 1988 - 1991 and 1999 - 2001. Prior to the recent solar maximum, the data appear to brighten with time. Recent solar maximum data, however, do not support a long term secular increase in Balmer-alpha brightness.

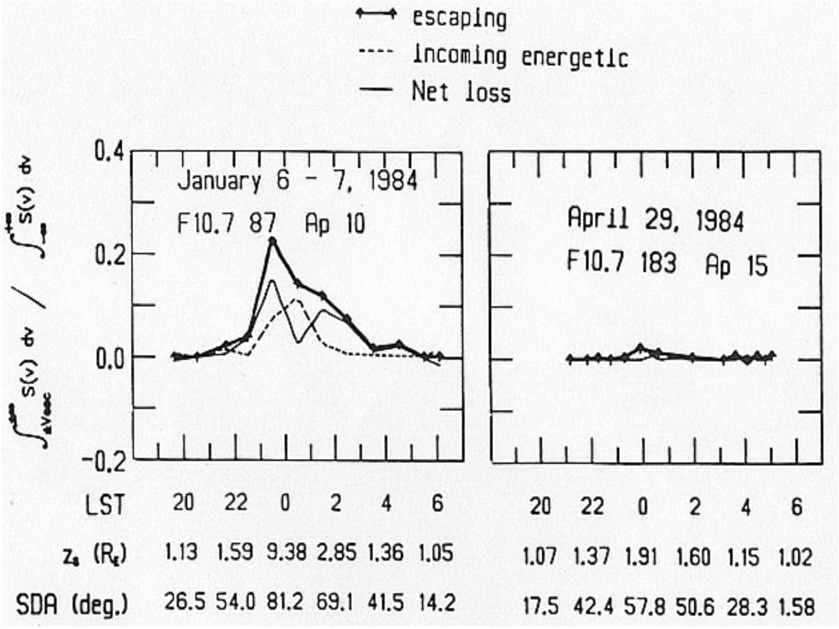
Hydrogen

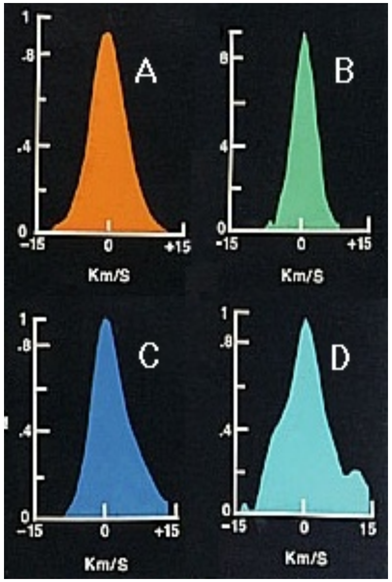
The Doppler profile of the 6563 Å profile was 1st measured by John Meriwether at Arecibo in 1980.

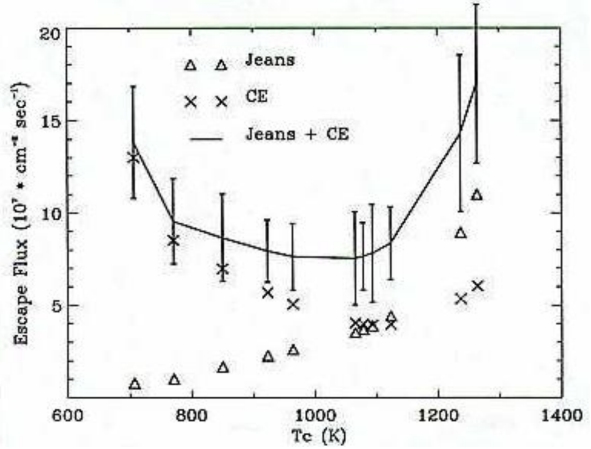


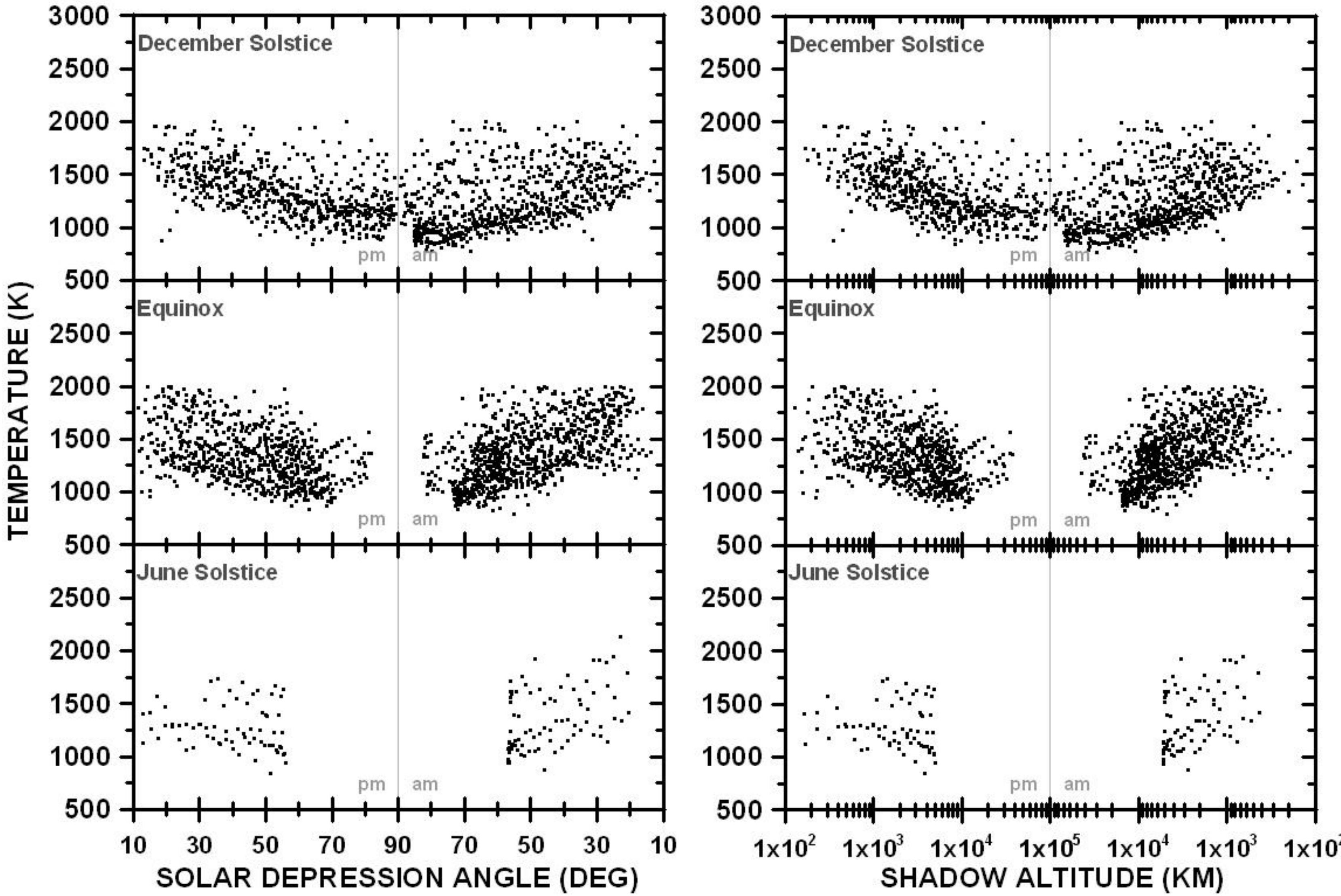
The emission is generated by resonant fluorescence of solar Ly-ß, and multiple scattering is an important component of the feeble signal at high shadow heights.

Achievements: The Arecibo data demonstrate that the H escape flux at mid-latitudes is preferentially supplied during the solar minimum winter solstice, when the H+/O+ transition height descends to near the exobase, and C.E. escape via $H^+ + H$ is most efficient.









Scatterplots of effective neutral exospheric temperature derived from the 6563Å emission line width in 2007 and 2008 with the upgraded V-FPI at Arecibo. The general decrease of H temperature with altitude (gravitational cooling) is evident.

B. Kerr: **The future of Space and Atmospheric Science** does not lie entirely in the important challenge of space weather forecasting, but in improving our understanding of atmospheric evolution, the detection of life beyond earth, identification of space resources and threats, and space commercialization.

How is out atmosphere evolving, and what sustains our oceans while Venus And Mars have lost theirs?

-As of 7/22/14 we know of 1811 planets in 1126 planetary systems
-On 1/2/2013, astronomers publicly concluded that as many as 400 billion exoplanets exist in the Milky Way
-There are 11 billion potentially habitable "earths" in the Milky Way, 40 billion if you include red dwarf stars as hosts

Why are there no aeronomy experiments at AO currently looking for the molecular signatures of life on exoplanets?

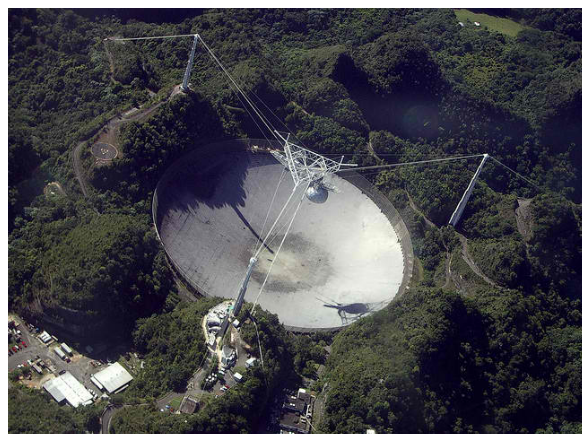
-We know of nearly 9,000 asteroids in solar orbits near earth. 1,500 are easier to travel to than the moon. Iron, Nickel, rare platinum group metals, are easily accessible on undifferentiated asteroids.
-There are 5 known major mass extinction events (70%-90% of all species), and some 13 other lesser events. Many are believed associated with asteroid impact.

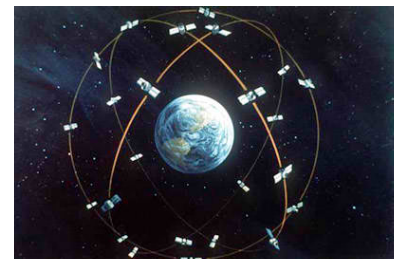
….. let's consider the smallest known M-type asteroid, the near-Earth asteroid known as 3554 Amun (two kilometers in diameter): The iron and nickel in Amun have a market value of about $8,000 billion, the cobalt content adds another $6,000 billion, and the platinum-group metals add another $6,000 billion.

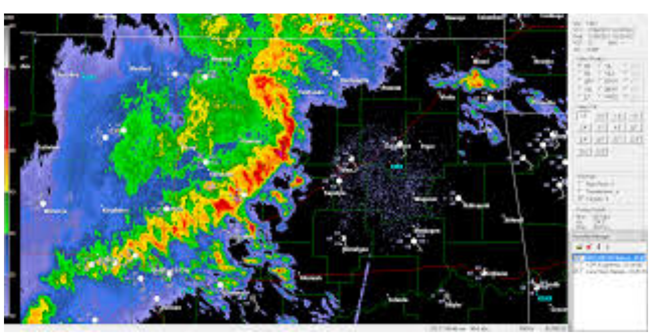
— John S. Lewis, *Mining the Sky*.

- Other stuff: Solar energy from orbit, space planes, spacecraft propulsion ….

This generation is at the cusp of change from space discovery, to space pioneering. Space Research and Arecibo Observatory drove that evolution, and remain on the front-edge of that wave. Being a Radio Scientist and an aeronomer, is **still** a growth industry.







Formal Education Development

Pre-School:	The AO mascot
K-12:	Saturday Academy (H.S.) High School Vocational students (H.S.) Inspiration to Science (K-12)
Undergraduate:	REU IAU Aguadilla Interns National University interns Study Abroad
Graduate:	Ph.D. granting program at Univ. of Granada