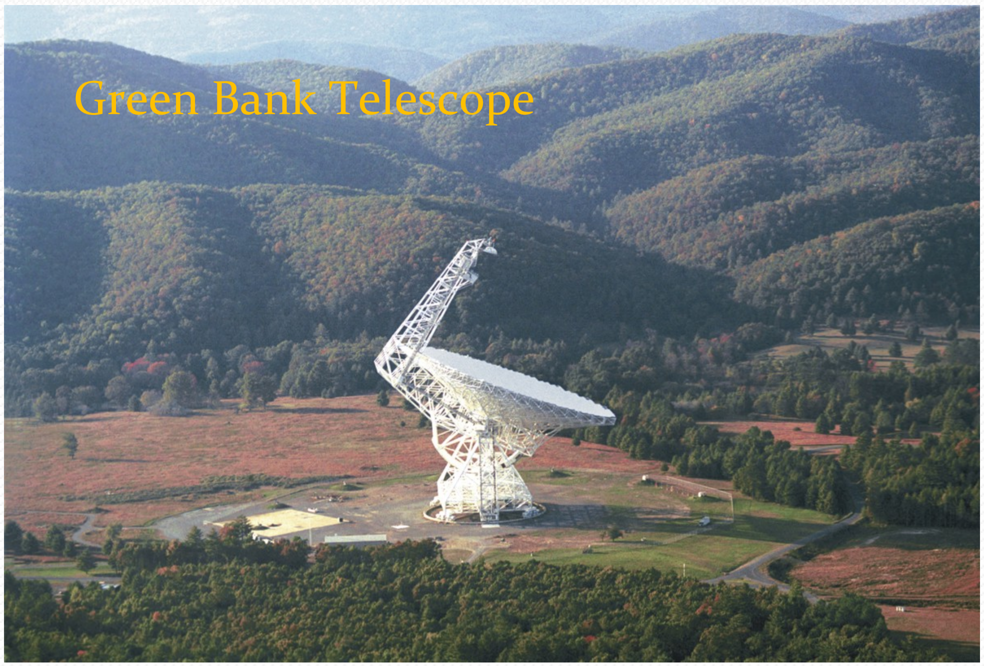
Space Radio Astronomy Spectrum Protection

Glen Langston

Spectrum Management School
Santiago Chile
April 8, 2014

Glen Langston -- Introduction

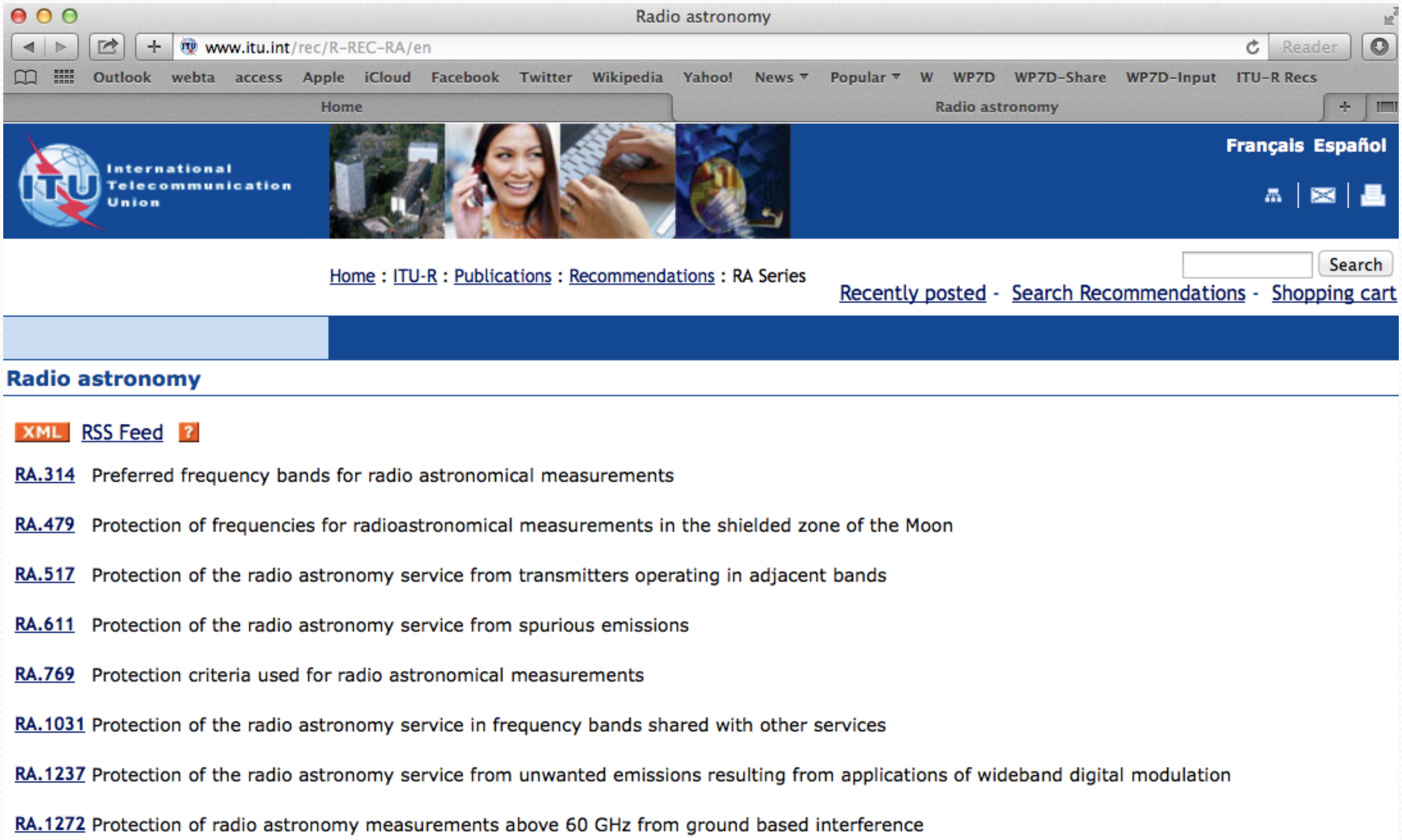


- Radio Astronomer - GBT/VLA/VLBA and Space VLBI Experience
- Particular interest in Astro-chemistry
  - Science requires occasional access to all radio frequencies
- Program Director at NSF

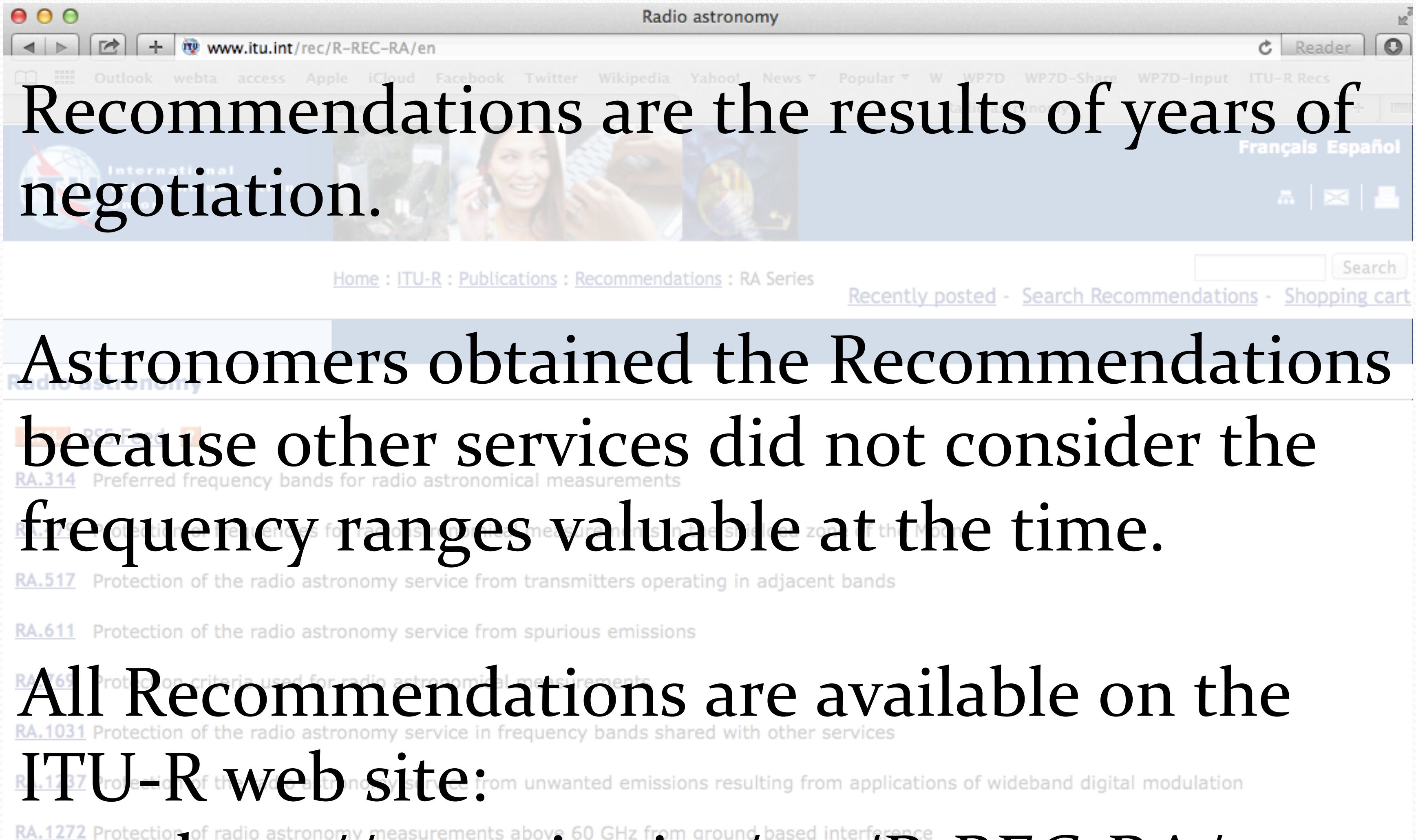
Boundaries of Spectral Protection: *Time*

- Radio Astronomy was first recognized by the ITU as a protected service by the World Radio Conference (WRC) in 1959. Primary passive frequencies were allocated below 20 GHz and included about few % of the spectrum.
- At the 1979 WRC frequencies above 20 GHz were allocated to RAS
- At the 2000 WRC RAS was allocated most of the usable frequency ranges between 71 and 275 GHz.

ITU-R Spectral Protection comes from *Recommendations*



ITU-R Spectral Protection comes from ***Recommendations***



Recommendations are the results of years of negotiation.

Astronomers obtained the Recommendations because other services did not consider the frequency ranges valuable at the time.

All Recommendations are available on the ITU-R web site:

http://www.itu.int/rec/R-REC-RA/en

14 RAS Recommendations

Radio astronomy

www.itu.int/rec/R-REC-RA/en

Outlook webta access Apple iCloud Facebook Twitter Wikipedia Yahoo! News Popular W WP7D WP7D-Share WP7D-Input ITU-R Recs

Home | Radio astronomy

RA.479 Protection of frequencies for radioastronomical measurements in the shielded zone of the Moon

RA.517 Protection of the radio astronomy service from transmitters operating in adjacent bands

RA.611 Protection of the radio astronomy service from spurious emissions

RA.769 Protection criteria used for radio astronomical measurements

RA.1031 Protection of the radio astronomy service in frequency bands shared with other services

RA.1237 Protection of the radio astronomy service from unwanted emissions resulting from applications of wideband digital modulation

RA.1272 Protection of radio astronomy measurements above 60 GHz from ground based interference

RA.1417 A radio-quiet zone in the vicinity of the L2 Sun-Earth Lagrange point

RA.1513 Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy on a primary basis

RA.1630 Technical and operational characteristics of ground-based astronomy systems for use in sharing studies with active services between 10 THz and 1 000 THz

RA.1631 Reference radio astronomy antenna pattern to be used for compatibility analyses between non-GSO systems and radio astronomy service stations based on the epfd concept

RA.1750 Mutual planning between the Earth exploration-satellite service (active) and the radio astronomy service in the 94 GHz and 130 GHz bands

RA.1860 Preferred frequency bands for radio astronomical measurements in the range 1-3 THz

Space Missions

- Discuss three ITU-R RA Recommendations
- If the spacecraft is less than 100,000 km from Earth, the protection levels are specified by Recommendation ITU-R RA.769

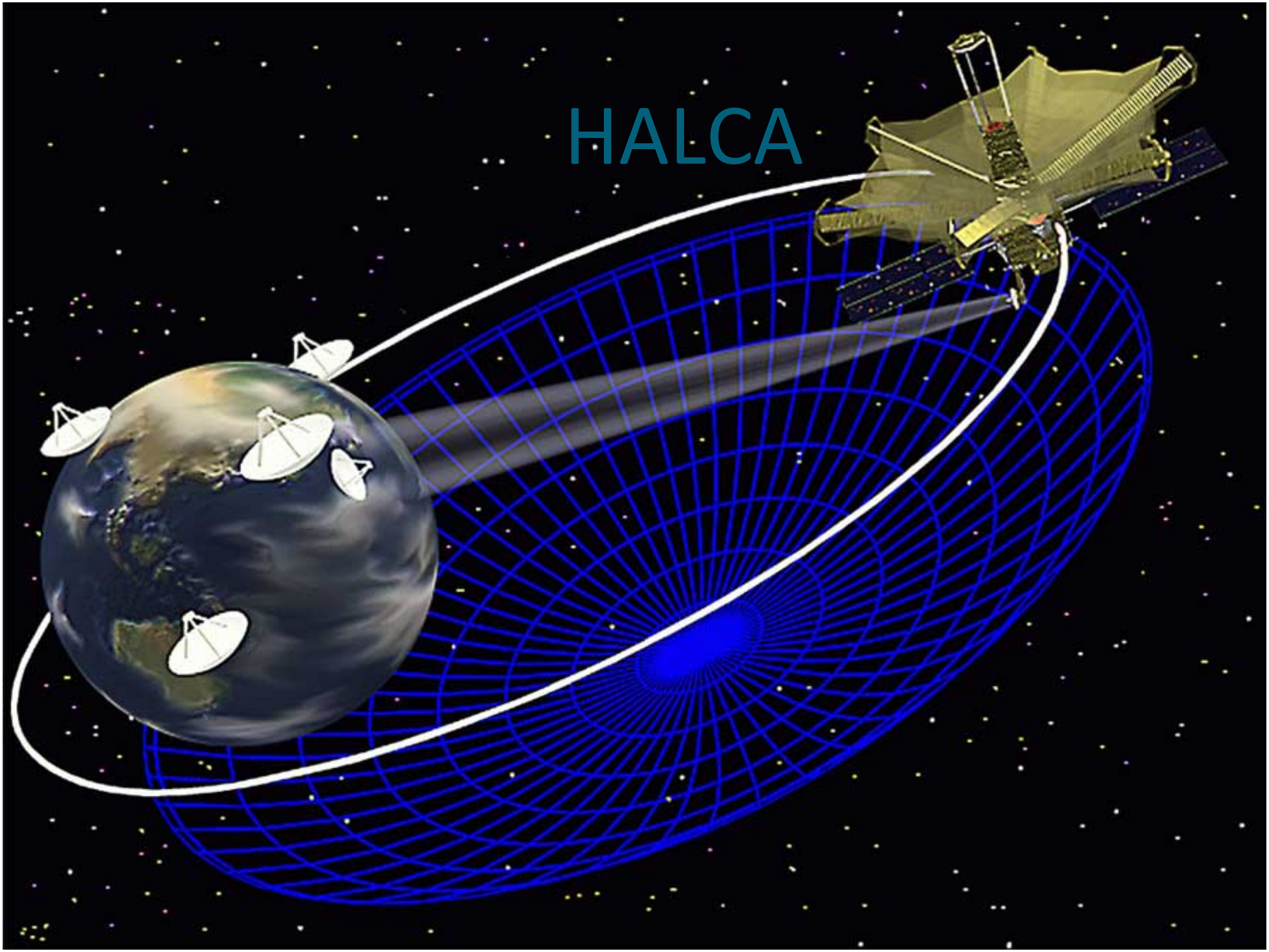
RA.769 Protection criteria used for radio astronomical measurements

Early Space Missions

- Sweden launched Odin in a low earth orbit.
  - A 1.1m diameter telescope operating at 119 and 500 and 560 GHz.
- NASA's SWAS mission operated in the mm wavelength range
- Space VLBI started with the Japanese HALCA mission launched in 1997 and operated until 2003.
  - HALCA operated at 1.60-1.73, 4.7-5.0, 22.0-22.3 GHz
  - Co-observed with 40 ground antennas
  - Apogee 21000 km

Space VLBI Missions

Mission / Experiment	Dates	Orbit parameters	Antenna diameter	Observing bands [GHz]
TDRSS VLBI experiment	1986 - 1988	Geosynchronous 38 000 km	4.9 m	2.271-2.285 15.35-15.43
VSOP / HALCA	1997 - 2003	Apogee: 21,400 km Perigee: 560 km Inclination: 31°	8 m	1.60 - 1.73 4.7 - 5.0 22.0 - 22.3
Radioastron	2011 --	Apogee: 280,000 – 353,000 km Perigee: 7,100 – 81,500 km Inclination: 5° – 85°	10 m	0.316 - 0.332 1.652 - 1.684 4.812 - 4.852 22.212 - 22.252
Millimetron	2019	Sun-Earth L_2 point, 1.5×10^6 km from Earth	10 m	18-26, 31-45, 84-116, 211-275, 602-720, 787-950
Long-mm-Wavelength Space VLBI Array	2020	Apogee: 60,000 km Perigee: 1,200 km Inclination: 28.5°	Dual 10-m Antennas	6 – 9 20 – 24 40 - 46

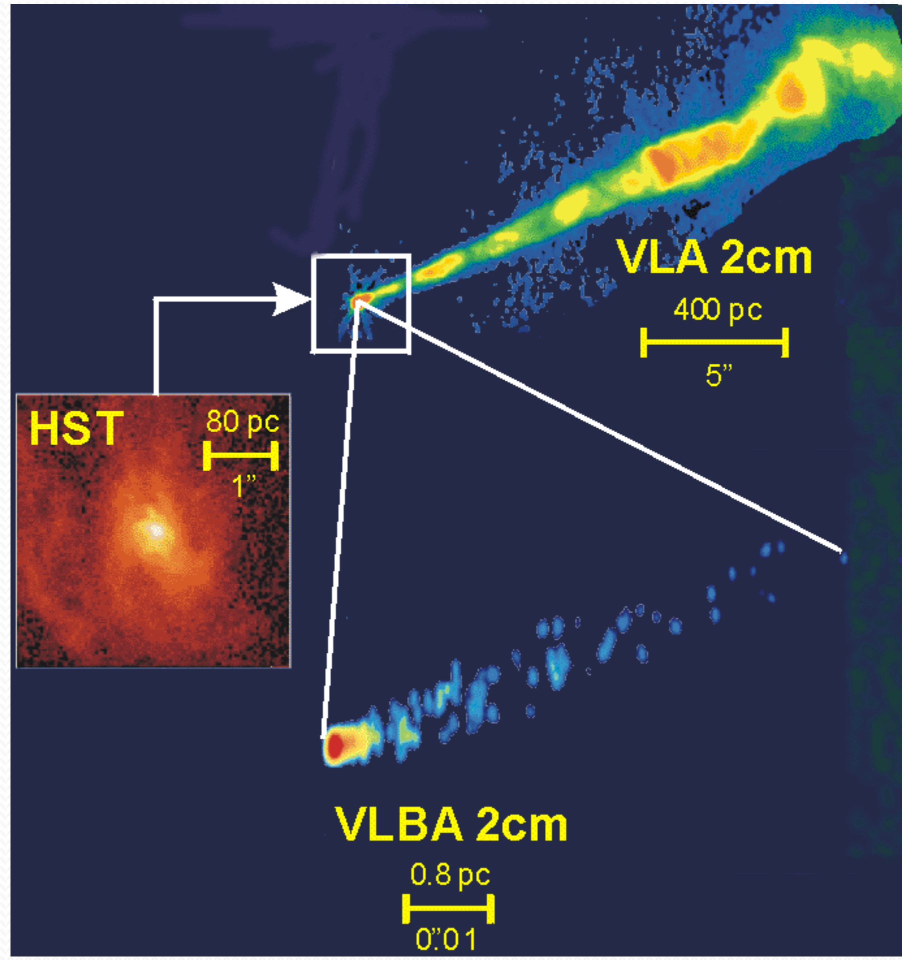

HALCA

HALCA Team

RadioAstron Mission Goal: Finest Resolution

- 1 Micro-arc second resolution
  - 35 Times Ground-only VLBI resolution
- 6,000 Times HST, Chandra resolution
  - Guide to other NASA missions
- Potential Gravitational Wave Studies

12



RISC tour of Lavachkin Association, 2008

RadioAstron – Development Years

National Aeronautics and
Space Administration

Office of the Administrator
Washington, DC 20546-0001

MAR 2 1994

Academician Yu. S. Osipov
President of Russian Academy of Sciences
Chairman of Russian Space Council
Leninski prospect, 14
117901, Moscow, V-71
RUSSIA

Dear Dr. Osipov:

Thank you for your letter of December 30, 1993, concerning the Radioastron project and NASA's cooperation with the Academy.

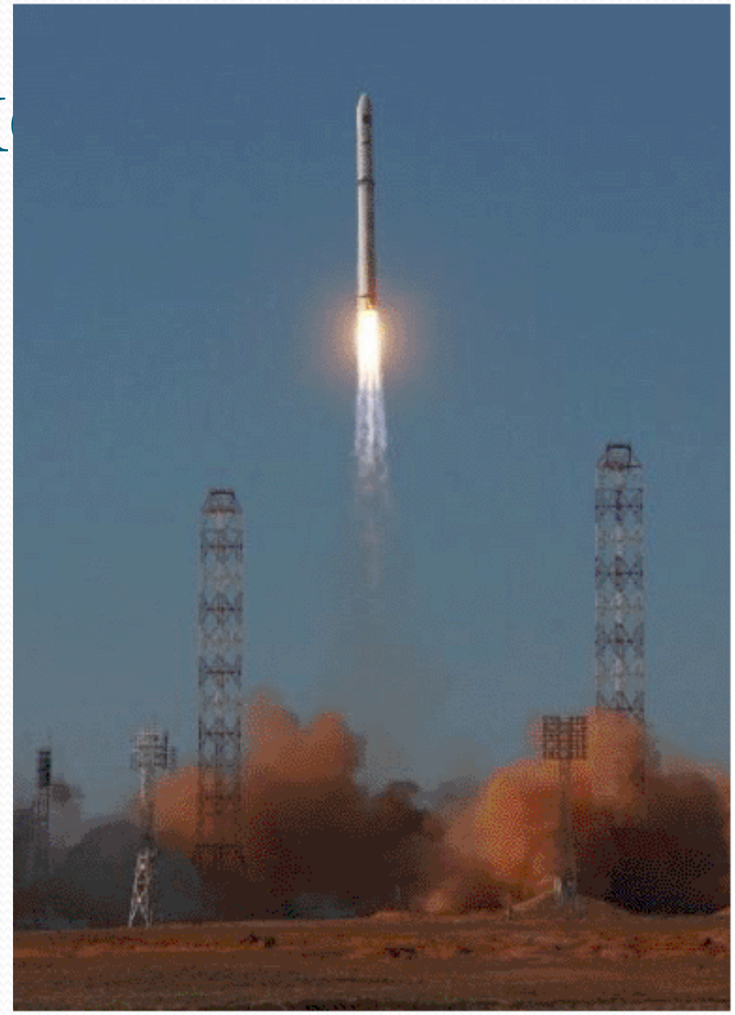
NASA is strongly committed to this project and recognizes its importance. We are developing a proposed agreement, which will be forwarded to the Russian Space Agency for consideration when it is completed in the near future.

Sincerely,

Daniel S. Goldin
Administrator

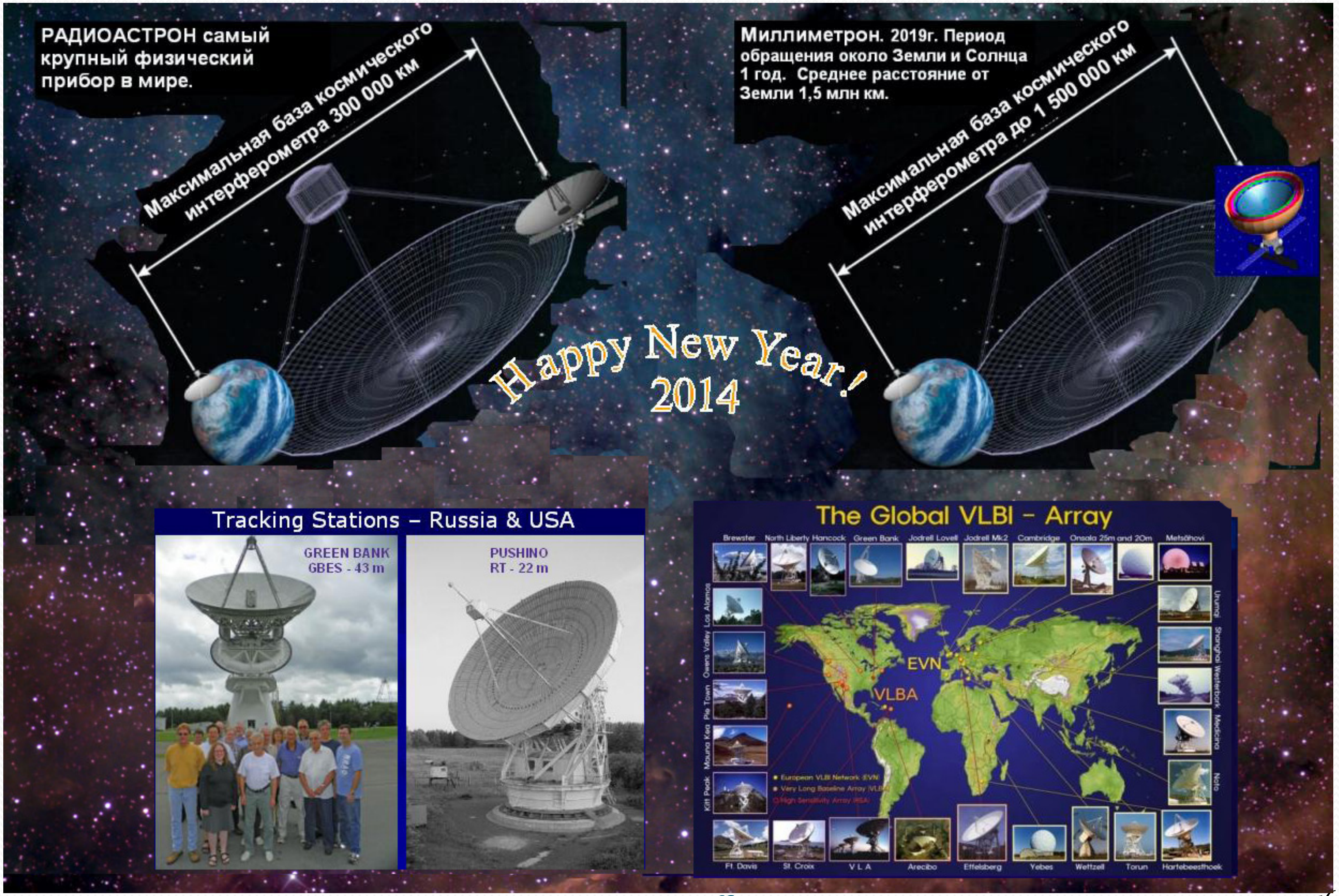
cc:
S/Dr. W. Huntress
SZ/Dr. D. Weedman
Russian Space Agency/Mr. Y. Koptev
Russian Academy of Sciences/Dr. R. Sunyaev
Russian Academy of Sciences/Dr. N. Kardashev

1994 NASA Letter leading to NRAO Station



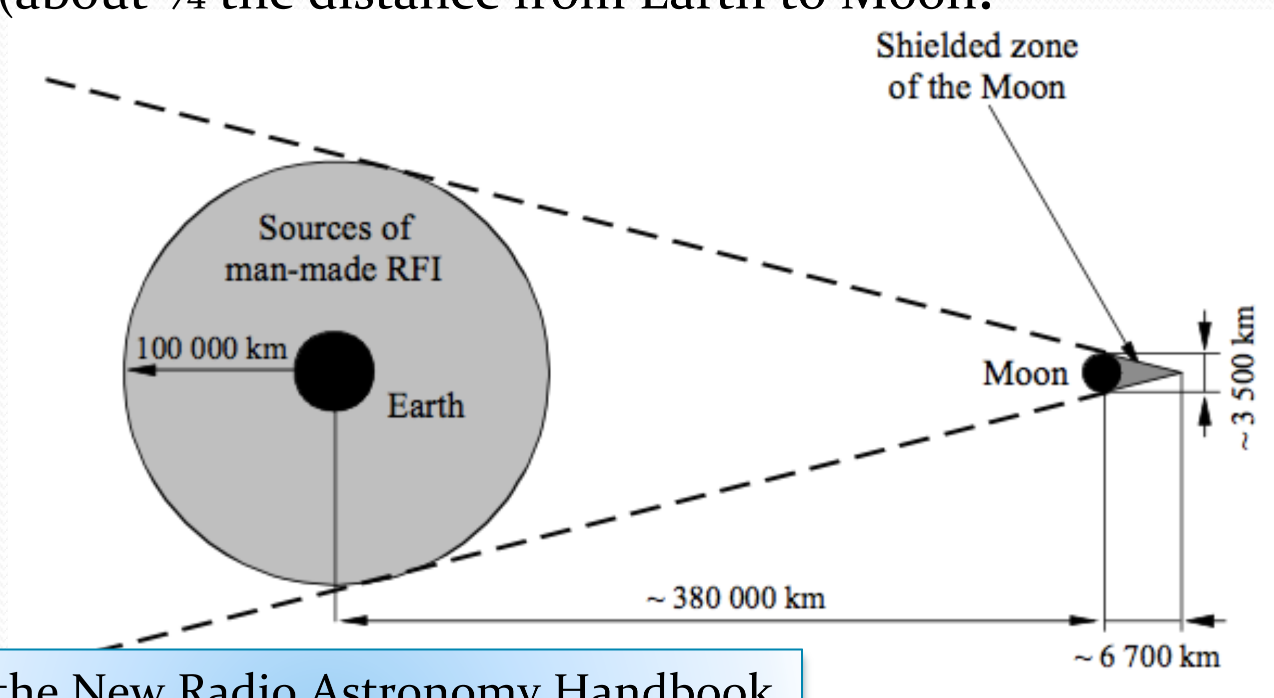
RadioAstron Launch: 2011 July

Operating Mission: RadioAstron



Boundaries of Spectral Protection: ***Earth Radius***

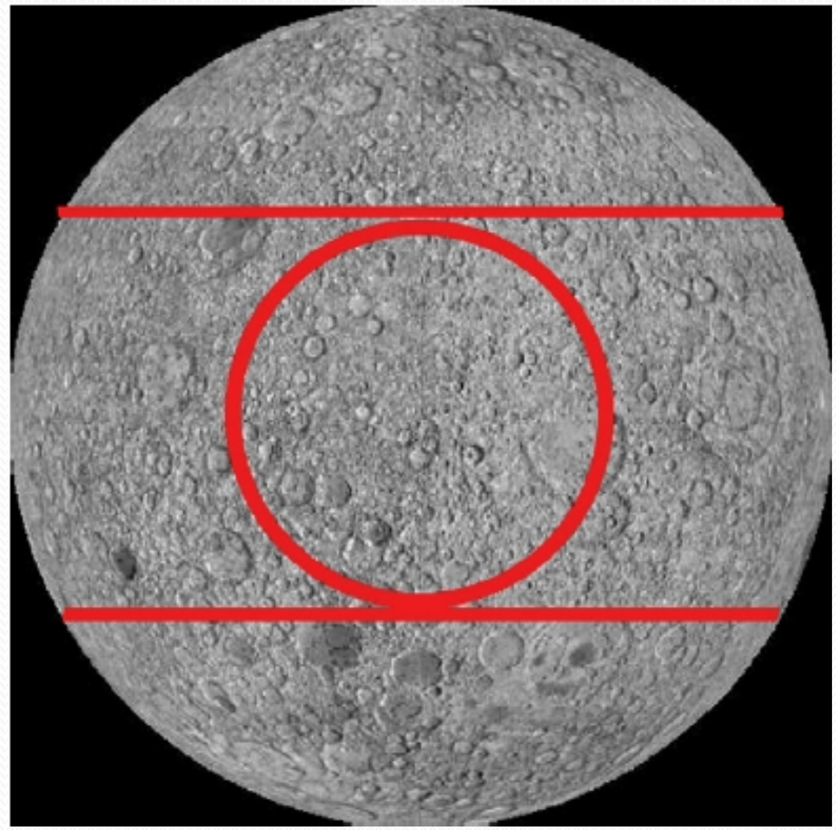
- The ITU-R Recommendations are limited to a region near the surface of the Earth. Coordination is applicable out to a distance of 100,000 km (about ¼ the distance from Earth to Moon.



From the New Radio Astronomy Handbook

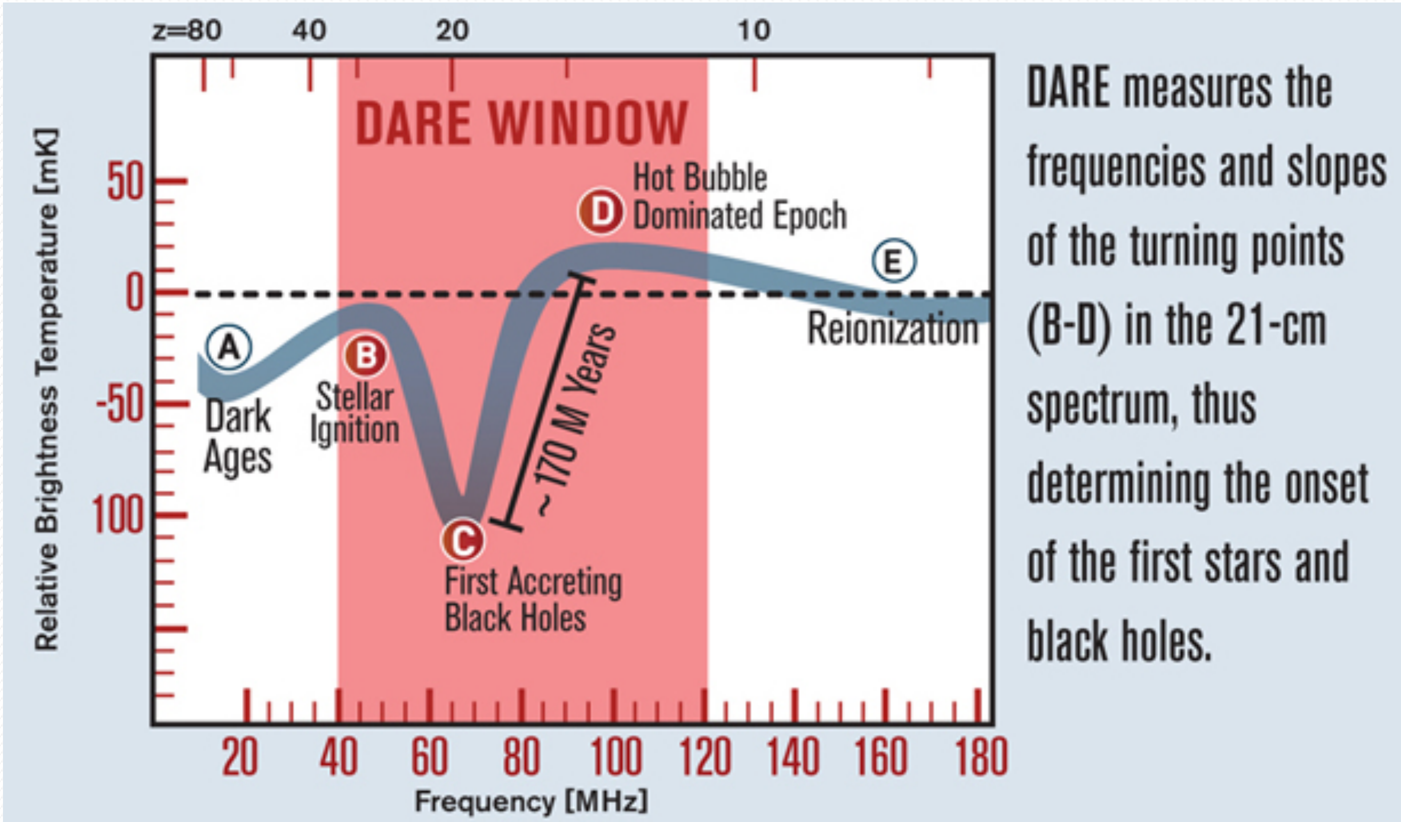
Boundaries of Spectral Protection: ***Moon***

RA. 479-4 Recommends that radio communication transmissions in the shielded zone of the Moon be limited to the band 2-3 GHz, but that an alternate band at least 1 GHz wide be identified for future operations on a time-coordinated basis



Quiet Side of the Moon: Proposed Mission

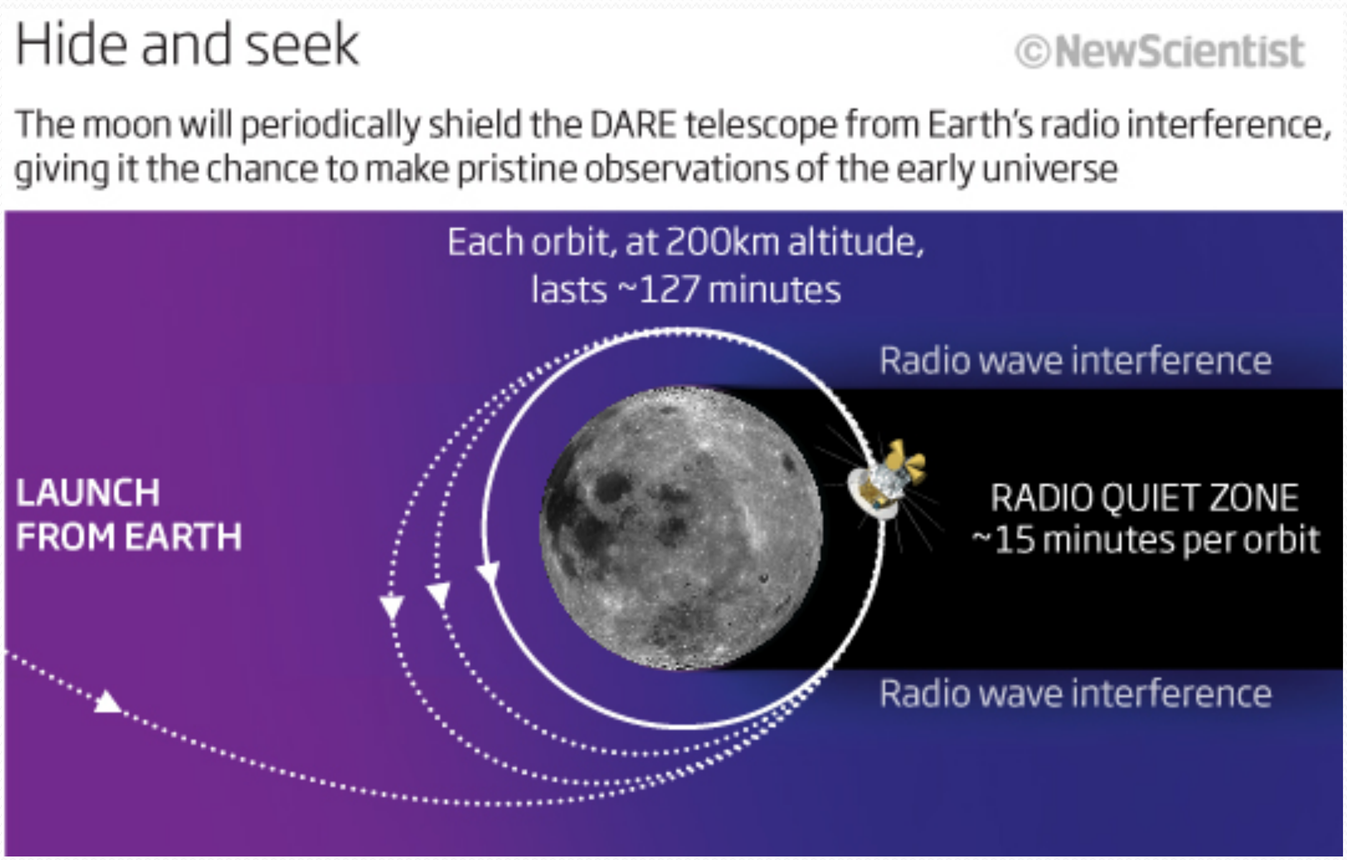
DARE: Frequency Range



Ground telescopes with Epoch of Re-ionization Science Goal: Precision Array for Probing the Epoch of Re-ionization (PAPER), Low Frequency Array (LOFAR), Murchison Wide-field Array (MWA), Giant Metrewave Radio Telescope (GMRT), and the Large Aperture Experiment to Detect the Dark Ages (LEDA).

RA.479: Lunar Quiet Zone

RA.479 Protection of frequencies for radioastronomical measurements in the shielded zone of the Moon

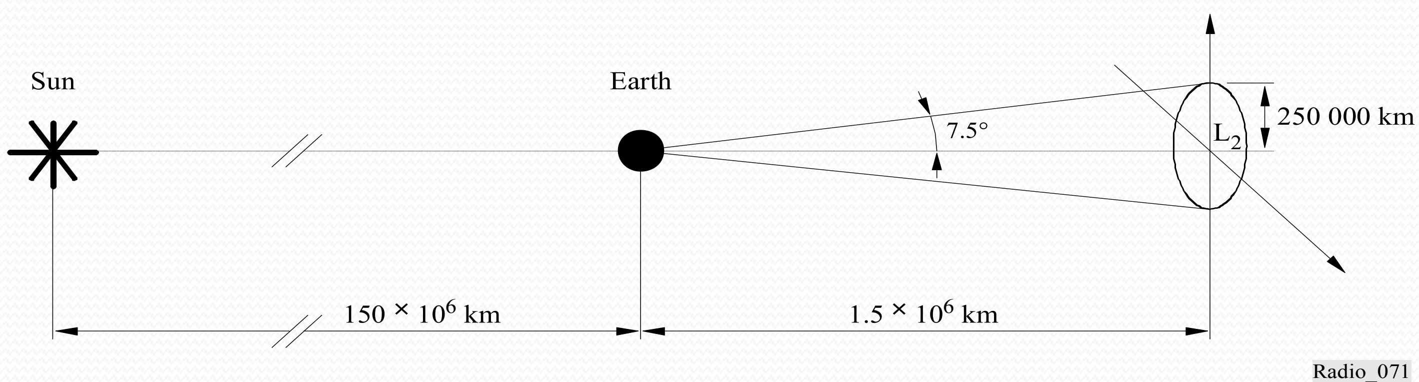


More Distant Quiet Zone: RA.1417

- Protection of the electromagnetic environment near the L2 point is the subject of Recommendation ITU-R RA.1417, which recommends that a volume of space of radius 250000 km centred on the L2 point should be protected as a coordination zone of low electromagnetic emission.

FIGURE 7.1

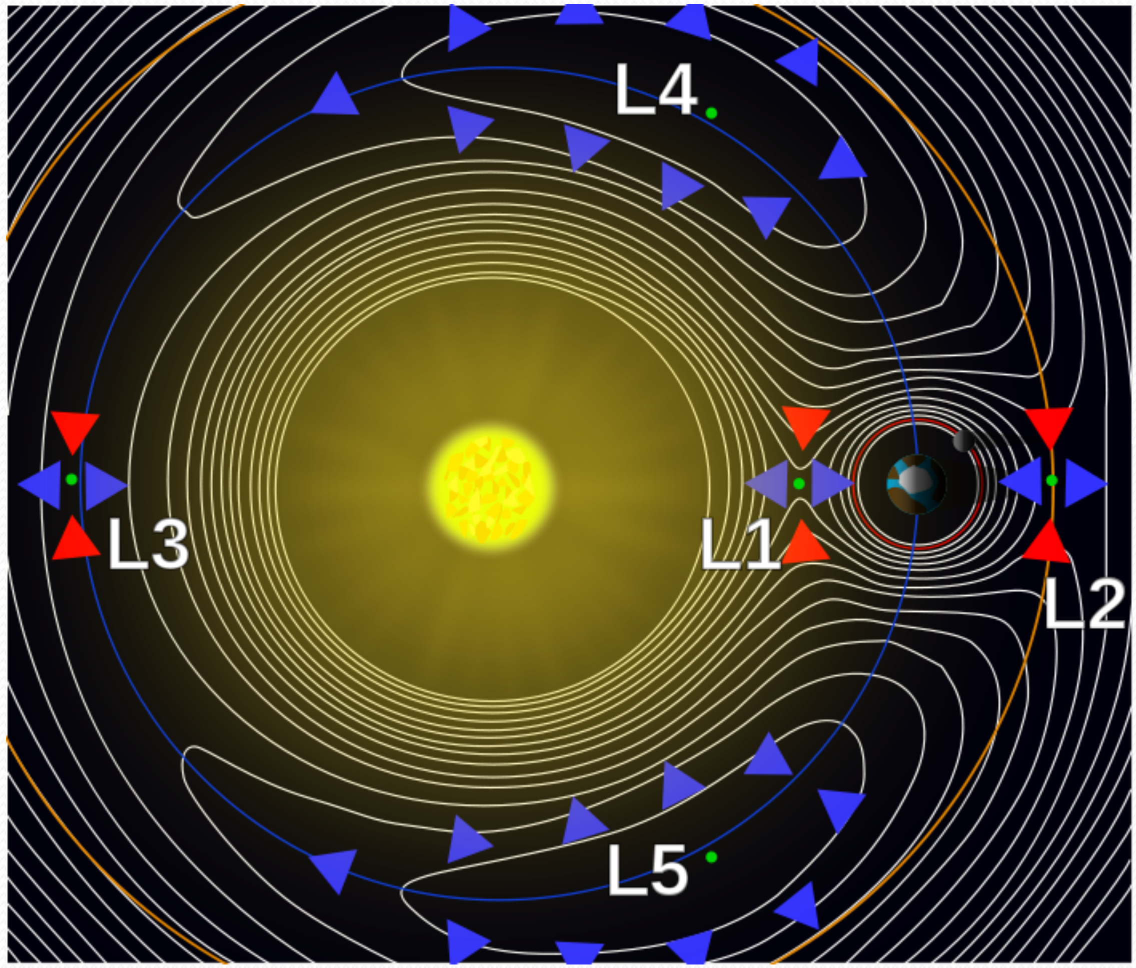
Typical geometry of an L_2 orbit



What is a Lagrange Point?

Legrange points are the 5 fixed (stable) stable orbital points in the Sun-Earth fixed reference Frame.

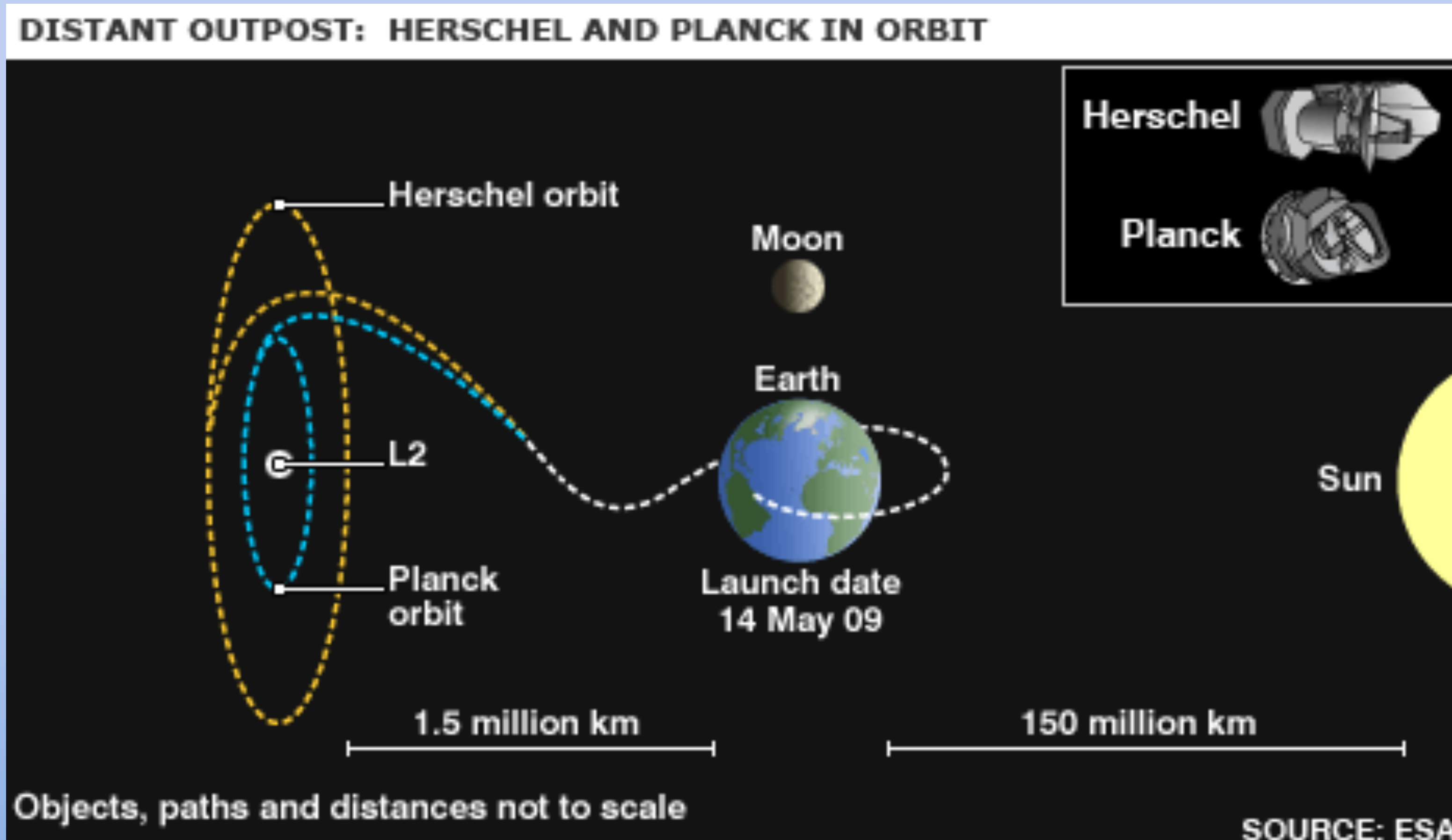
L2 is outside the orbit of the Earth around the Sun, so the Sun, Earth and Moon are all in the same area of the sky and the telescope can point away from these bodies.



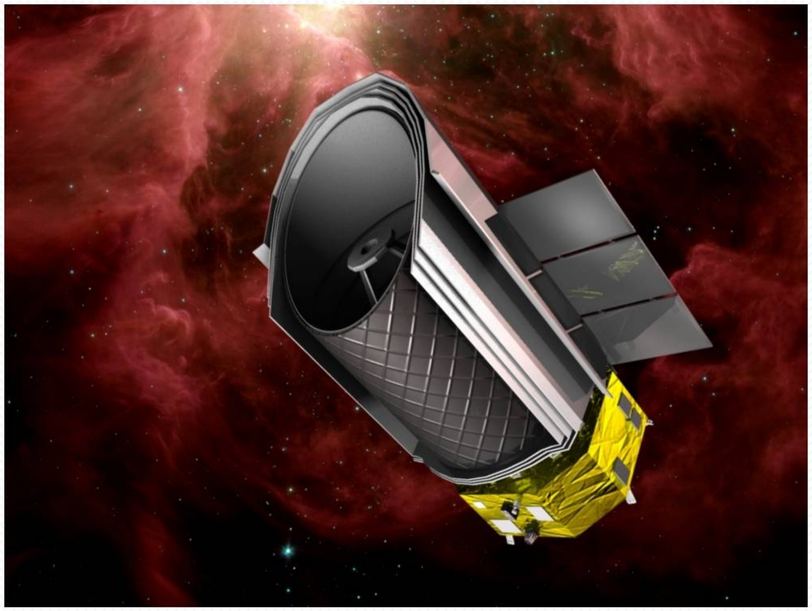
RA.1417: Quiet Zone at L2

Radio astronomy

RA.1417 A radio-quiet zone in the vicinity of the L2 Sun-Earth Lagrange point



L2 missions



Spica Mission JAXA

Mission/operator aperture	Type of mission observing mode	Dates of operation	Observing frequency bands (GHz)
MAP/NASA 1.4m × 1.6 m	Single dish continuum imaging of the cosmic microwave background Continuum	2001-2009	18-96
-PLANCK/ESA 1.5 m × 1.9 m	Single dish continuum imaging of the cosmic microwave background Continuum	2009-2012	30 ± 3 44 ± 4.4 70 ± 7 100 ± 10 150 ± 28 217 ± 40 353 ± 65.5 545 ± 101 857 ± 158.5
Herschel/ESA 3.5 m	Single dish radio astronomy Spectral line and continuum	2009 -2013	490-642 640-802 800-962 960-1 122 1 120-1 250 1 600-1 800 2 400-2 600
Millimetron/ ROSKOSMOS 12 m	Single dish radio astronomy and space very long baseline inter-ferometry (sVLBI)Spectral line and continuum	2015-2030	18-4 800
SPICA/JAXA 3.5 m	Single dish radio astronomy/spectral line and continuum	2018	1 500-10 000

Radio Astronomy Vision

- Radio Astronomers have greatly benefited from an early appreciation of the value of the Radio Spectrum (before the other services)
- Next generation needs to have a bold vision for the future experiments
- Prediction, based on past experience:
  - In the future the Radio Quiet Zone on the Moon will be greatly desired by the other services.

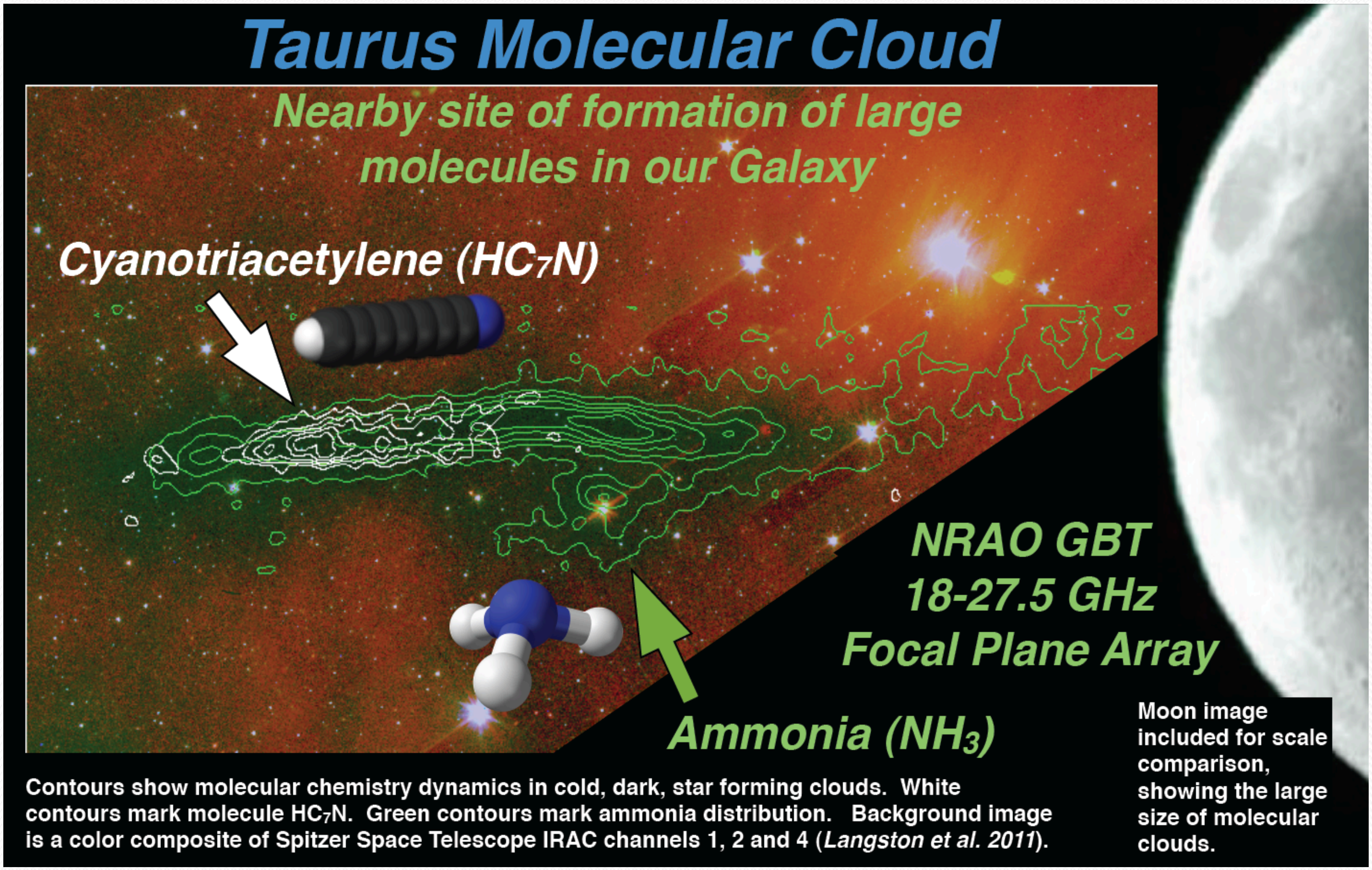
Thank you!

New Opportunity and Challenge: Nanosatellites

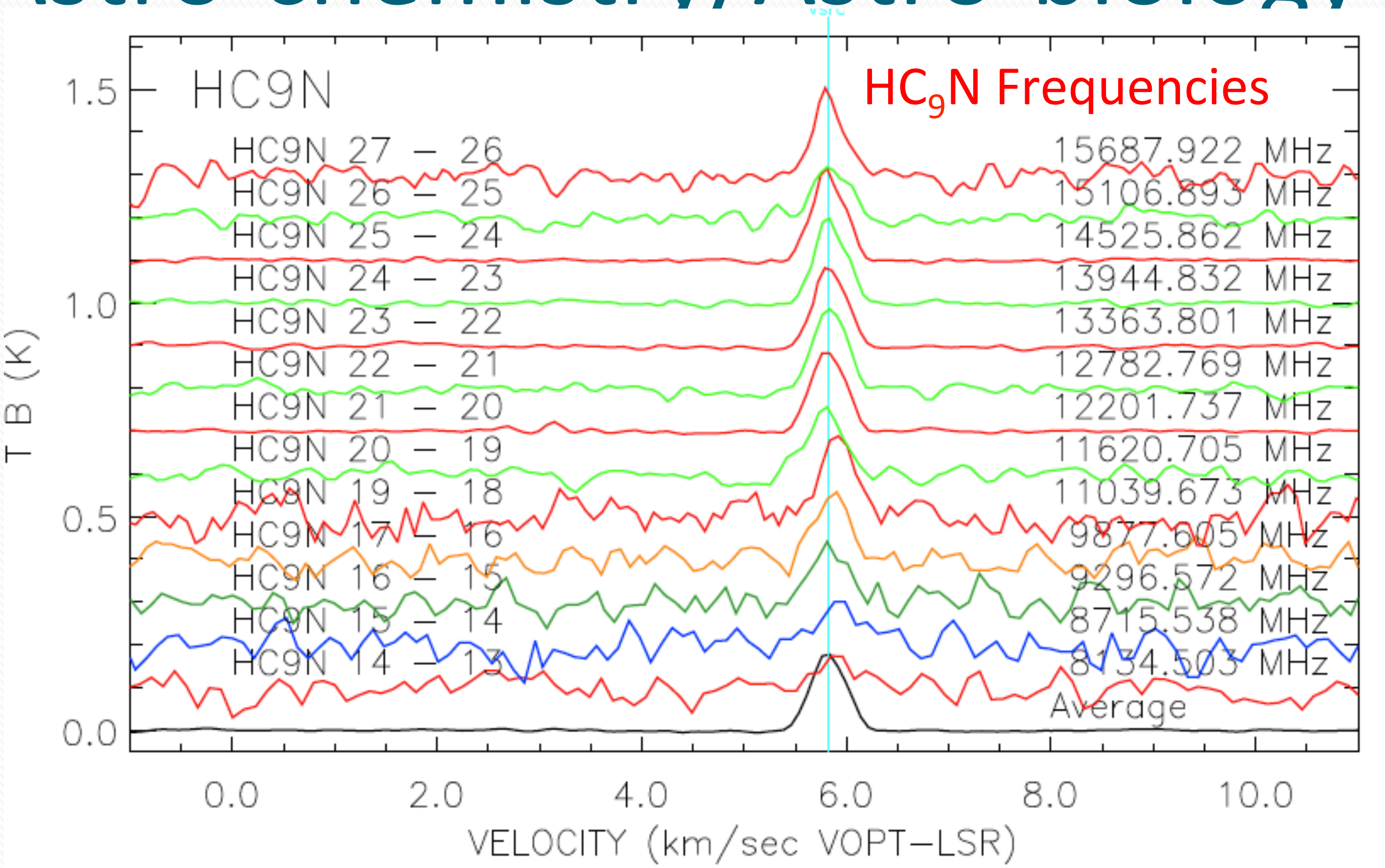
- NSF is working domestically and internationally to streamline regulatory requirements for Cubesats
  - Not a minor issue, as current procedures are based on decades of entrenched policies and procedures
- Potential benefits of Cubesats to science community is immense, so better facilitating their use is a priority area for ESMU
- Some Cubesats could potentially create interference for radio astronomy, but we are "self coordinating" in most instances (so far)

INTERNATIONAL ISSUES

NH_3 and Cyanopolyyenes



Entire Spectrum Valuable for Astro-chemistry/Astro-biology



Spectrum Management Challenges 2013 - 2015

- Spectrum protections and coordination for the new generation of broadband radio astronomy systems
  - EVLA (1-50 GHz), ALMA (30 – 950 GHz), GBT (1-100 GHz), ARECIBO (e.g. 1.15-1.73 GHZ; 3-4 GHz)
  - Hydrogen Era of Reionization Array (HERA) systems (MWA, SKA, etc.) & low-frequency systems (i.e., LWA) operate in some of the most crowded spectral regions – Require interference mitigation or excision
- Picosatellite systems (Cubesats)
  - Increasingly used in research (Ionospheric research, astronomy)
  - International issue, but even getting past national regulators is difficult
- World Radiocommunication Conference (WRC-15)
  - Many issues to follow –in large number of groups
  - Availability of travel funds

Mm-wave issue - Car radars (1)

- Allocation of 77.5-78 GHz to the radiolocation service for vehicular radars on WRC-15 Agenda
  - Allocation is a near certainty (most of the world supportive, pressure from car industry)
- At the operational power levels envisioned (~ 5 Watts/radar) and millions of vehicles on the road, interference to radio telescopes (ALMA, GBT in US, Bonn in Europe, in Japan) is certain
- Some indication that radio astronomy may be protected via a footnote

Mm-wave issue - Car radars (2)

- How to protect radio telescopes?
  - Exclusion zones require switching off radars
    - Manually or Under (GPS) control?
    - Exclusion zone radii ~ 100 km (see IUCAF doc. by Harvey Liszt)
    - Timing?

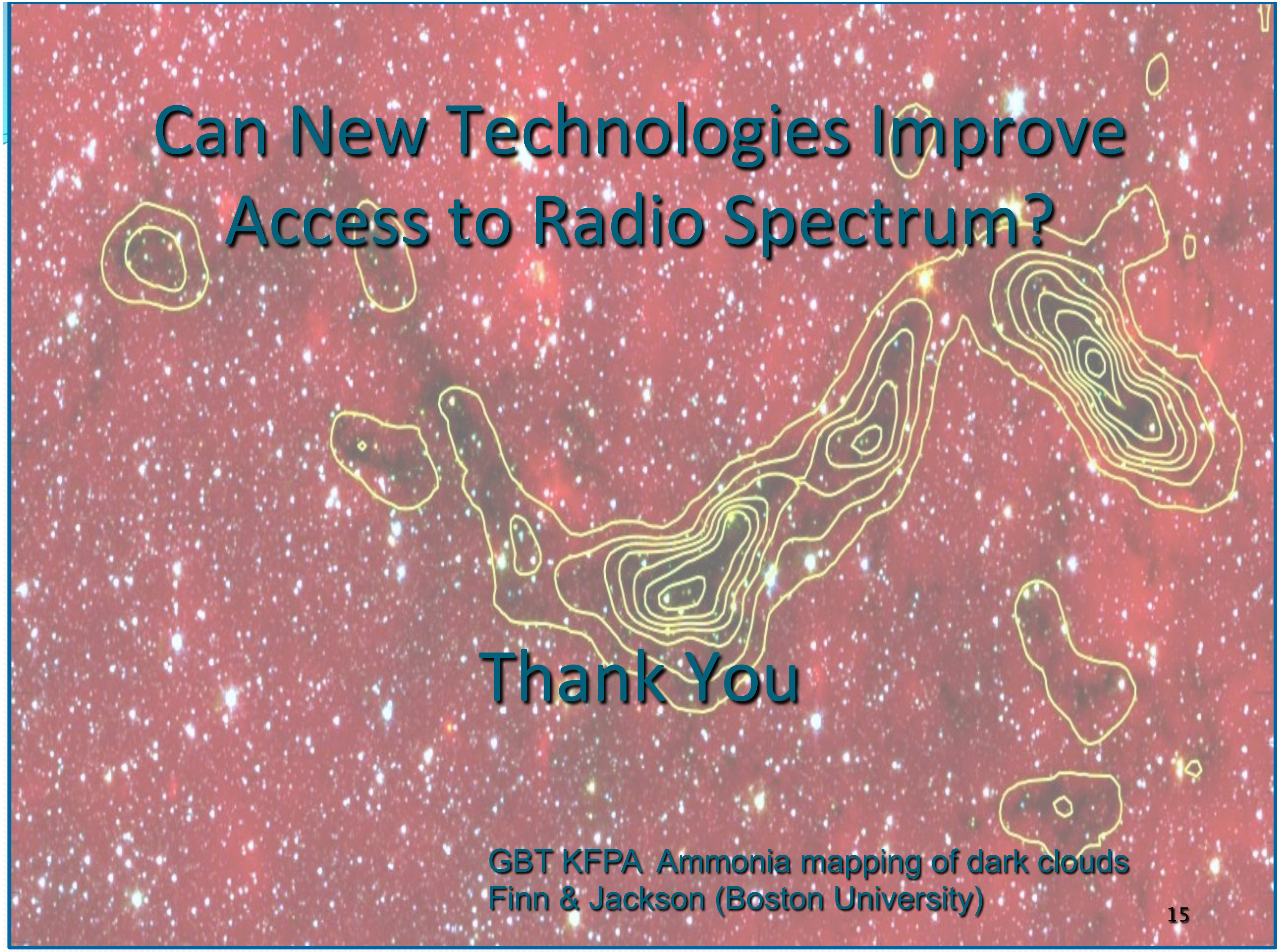
  Opposed by car industry – safety issue – even if car radars can't operate as safety of life devices!
- Footnote limiting power levels (or creating exclusion zones)
  - Power levels sufficiently low to protect radio astronomy are unrealistic for radars?
- Harmonics? (2nd and 3rd harmonics fall in RA bands)
  - What strategy should the radio astronomy community adopt?

Science Access via Database Exclusion

TV Whitespace Model?

- Background: US Spectrum Access Push
  - Issue: Channel 37 – 608-614 MHz desired
- NSF default response: No Change
- *Alternative*:
  - Add all Radio observatories to Whitespace database?
  - Seek passive protection via database?

Can New Technologies Improve Access to Radio Spectrum?



Thank You

GBT KFPA Ammonia mapping of dark clouds
Finn & Jackson (Boston University)