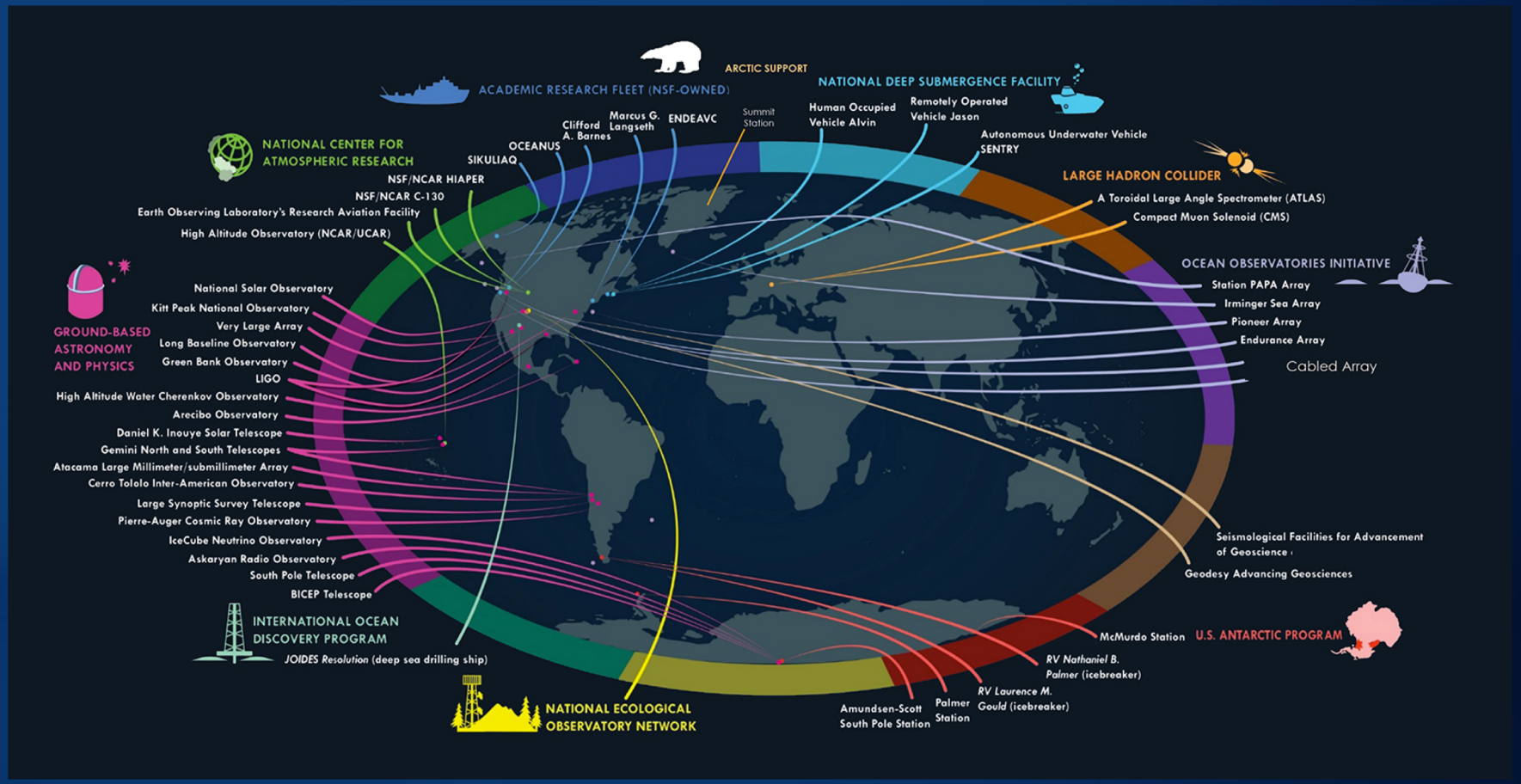
National and **Regional** Regulatory Structures and how they feed into the International Structure:

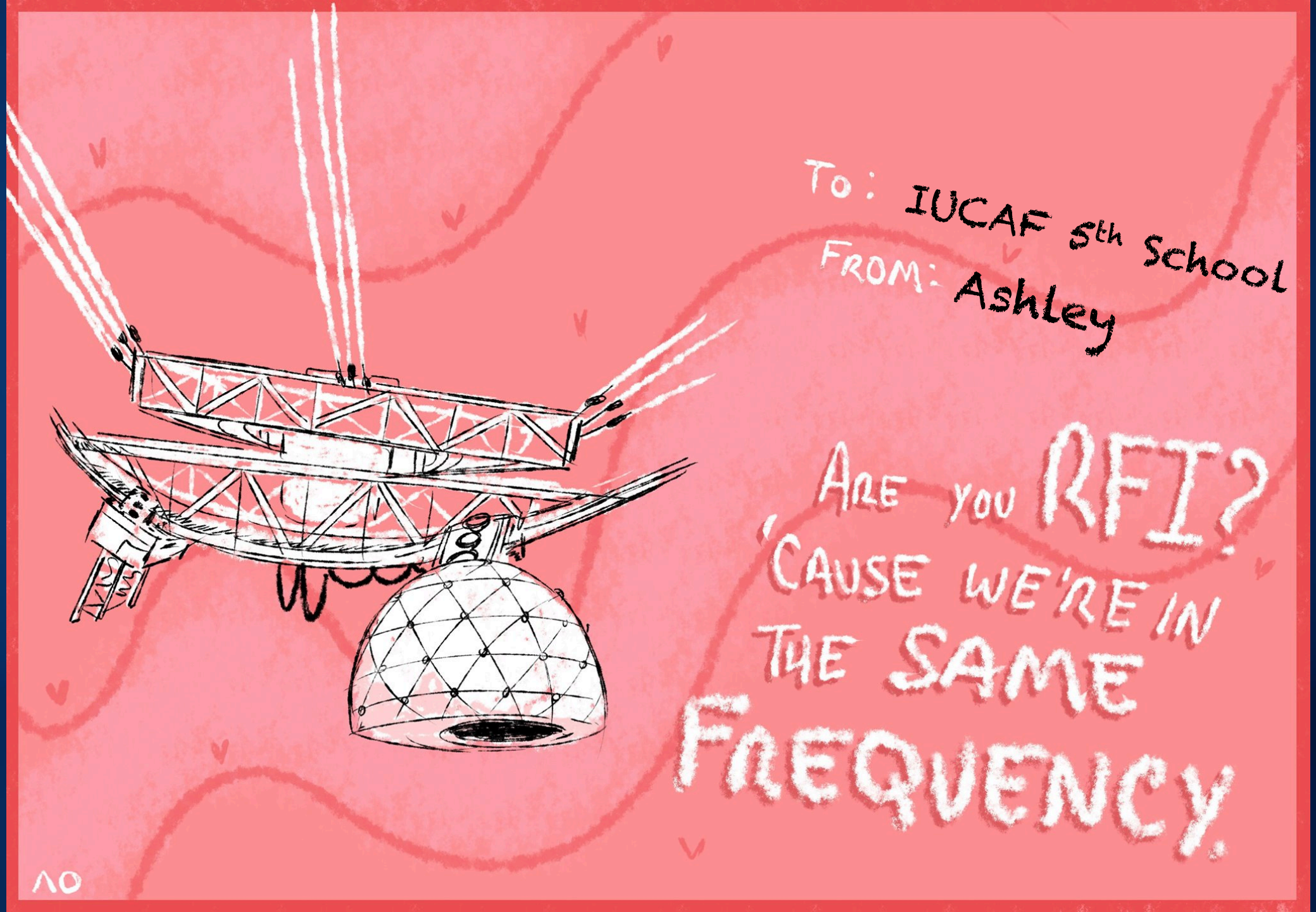
USA



https://www.nsf.gov/bfa/dcca/csb/

Bevin Ashley Zauderer
Division of Astronomical Sciences
National Science Foundation

March 2, 2020
IUCAF 5th School
Stellenbosch, South Africa


To: IUCAF 5th School
From: Ashley
Are you RFI?
'Cause we're in
the SAME
FREQUENCY.
AO

I. Radio Astronomy: intrinsic value and spectrum needs

II. Process is complicated: many stakeholders

III. Getting involved is simple: contribution driven

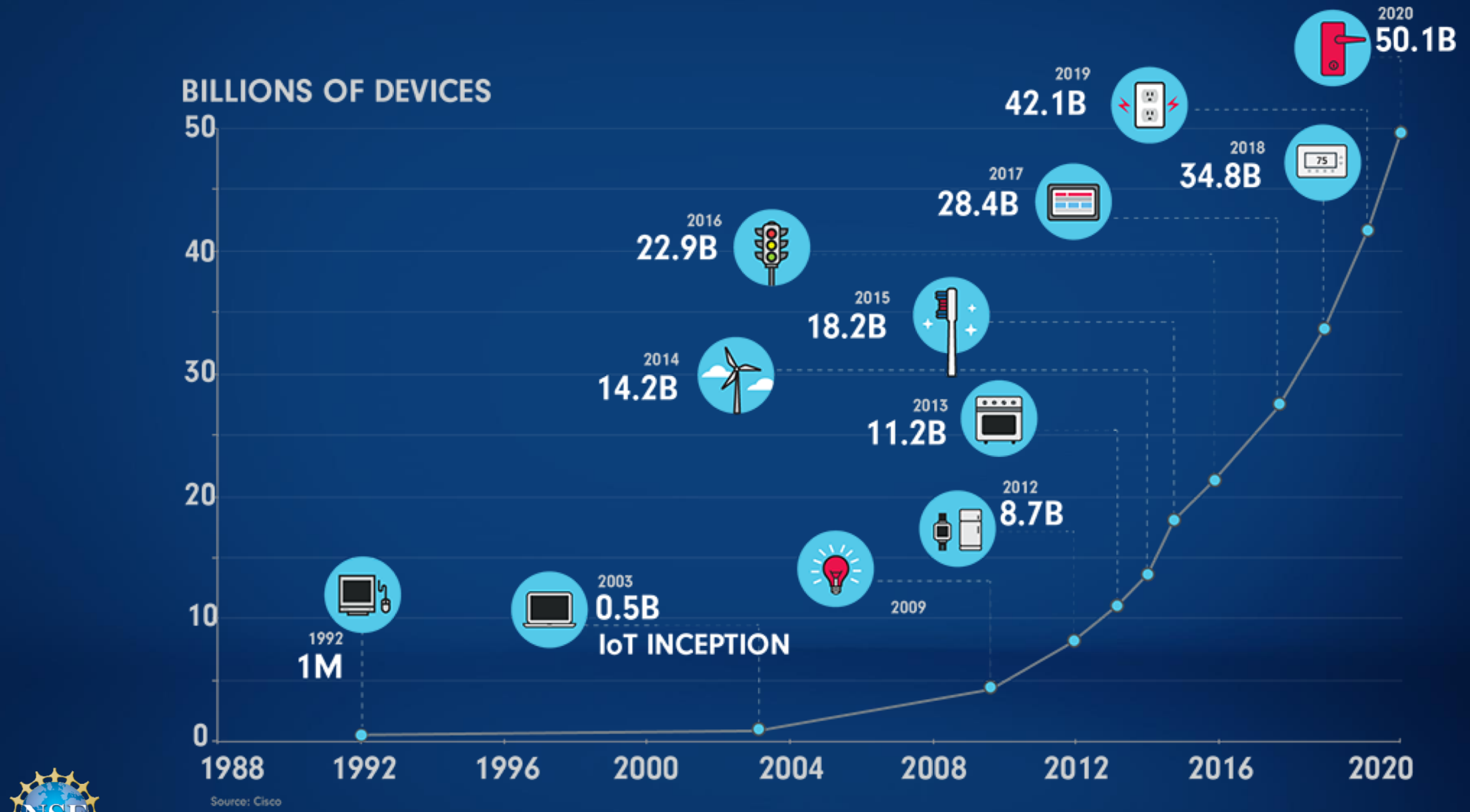
I. <u>Radio Astronomy: intrinsic value and spectrum needs</u>

II. Process is complicated: many stakeholders

III. Getting involved is simple: contribution driven

"Not everything that ***counts*** **can** be **counted**, **and not** everything that **can** be **counted** ***counts***."

- Einstein


BILLIONS OF DEVICES
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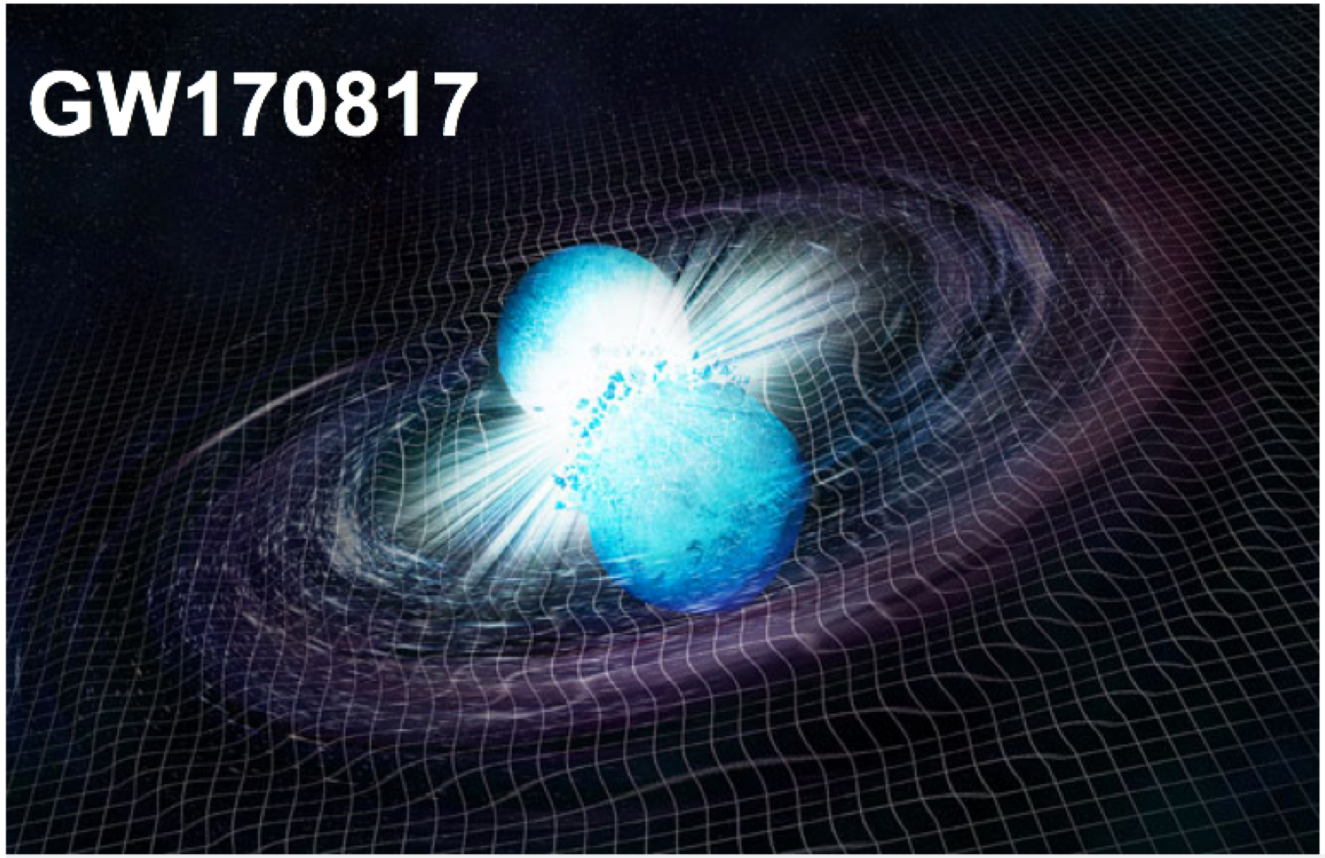
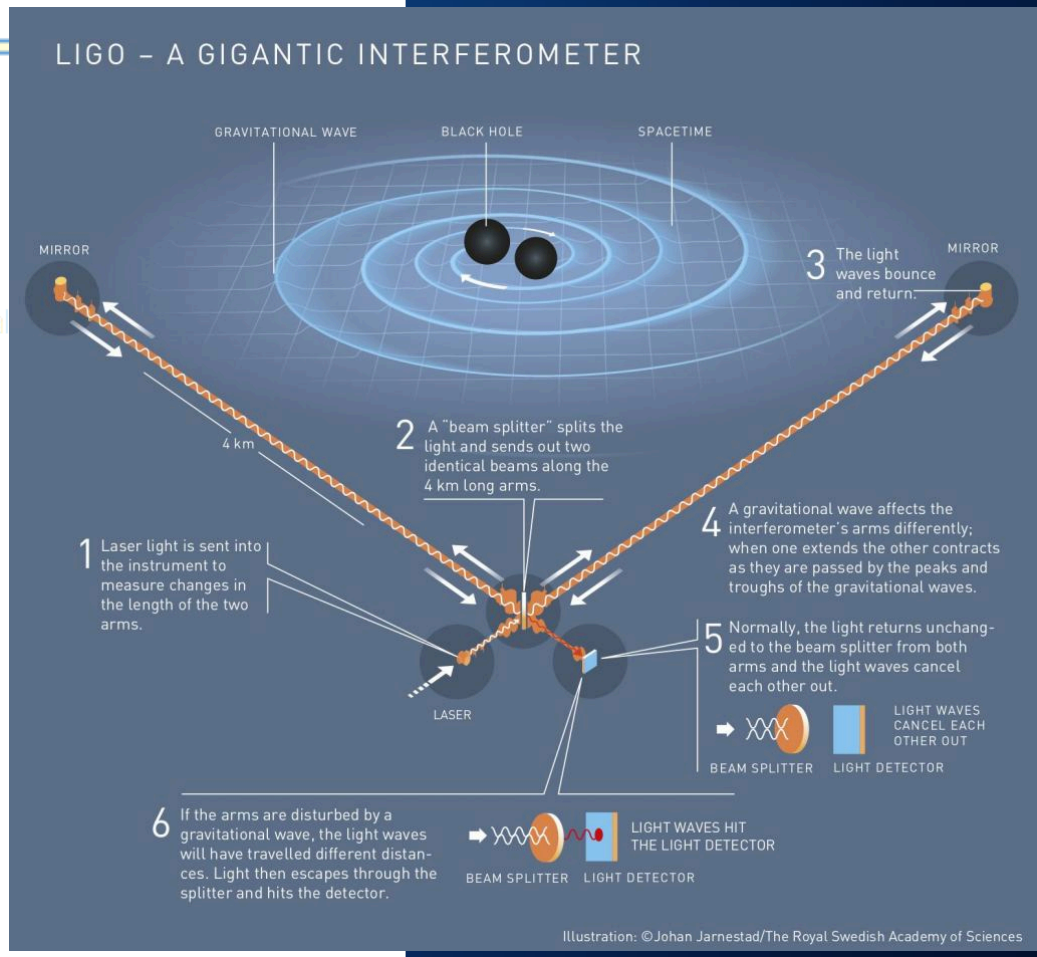
34.8B
2019
42.1B
2020
50.1B
Source: Cisco

Multi-messenger & Time-Domain Astronomy



Artist's illustration of the merger of two neutron stars. A new study suggests that the neutron-star merger detected in August 2017 might have produced a black hole.
NASA/CXC/M.Weiss



A radio counterpart to a neutron star merger

G. Hallinan[1,*,†], A. Corsi[2,†], K. P. Mooley[3], K. Hotokezaka[4,5], E. Nakar[6], M. M. Kasliwal[1], D. L. Kaplan[7], D. A. Frail[8], S. T. Myers[8], T. …

+ See all authors and affiliations

Science 22 Dec 2017:
Vol. 358, Issue 6370, pp. 1579-1583
DOI: 10.1126/science.aap9855

GROWTH observations of GW170817

The gravitational wave event GW170817 was caused by the merger of two neutron stars (see the Introduction by Smith). In three papers, teams associated with the GROWTH (Global Relay of Observatories Watching Transients Happen) project present their observations of the event at wavelengths from x-rays to radio waves. Evans *et al.* used space telescopes to detect GW170817 in the ultraviolet and place limits on its x-ray flux, showing that the merger generated a hot explosion known as a blue kilonova. Hallinan *et al.* describe radio emissions generated as the explosion slammed into the surrounding gas within the host galaxy. Kasliwal *et al.* present additional observations in the optical and infrared and formulate a model for the event involving a cocoon of

Why does access to the radio spectrum matter?

10 uJy at 3 GHz ~2 weeks

2 GHz BW (~1.4 GHZ after RFI excision)

<50 MHz is
RAS primary

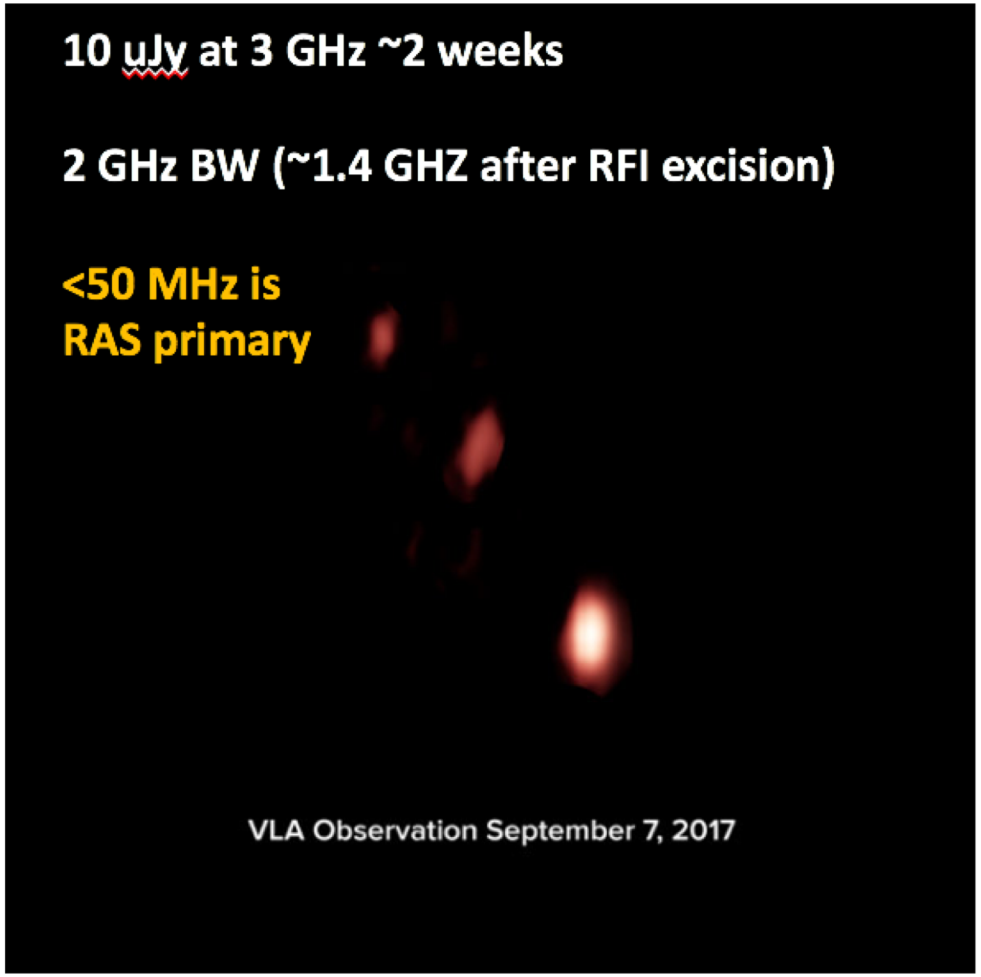
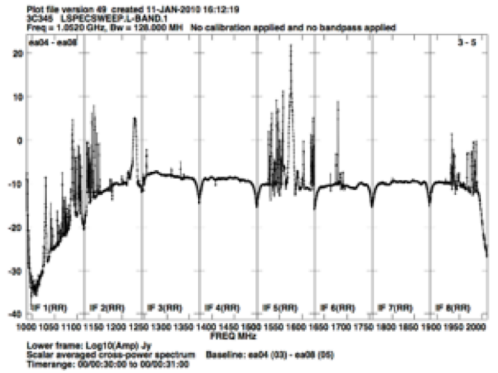
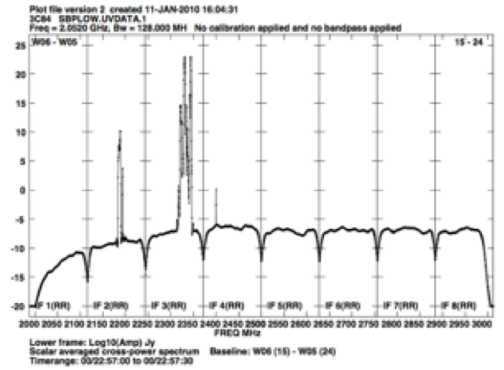


Image Credit: Hallinan et al., Science (2017)





Why does access to the radio spectrum matter?

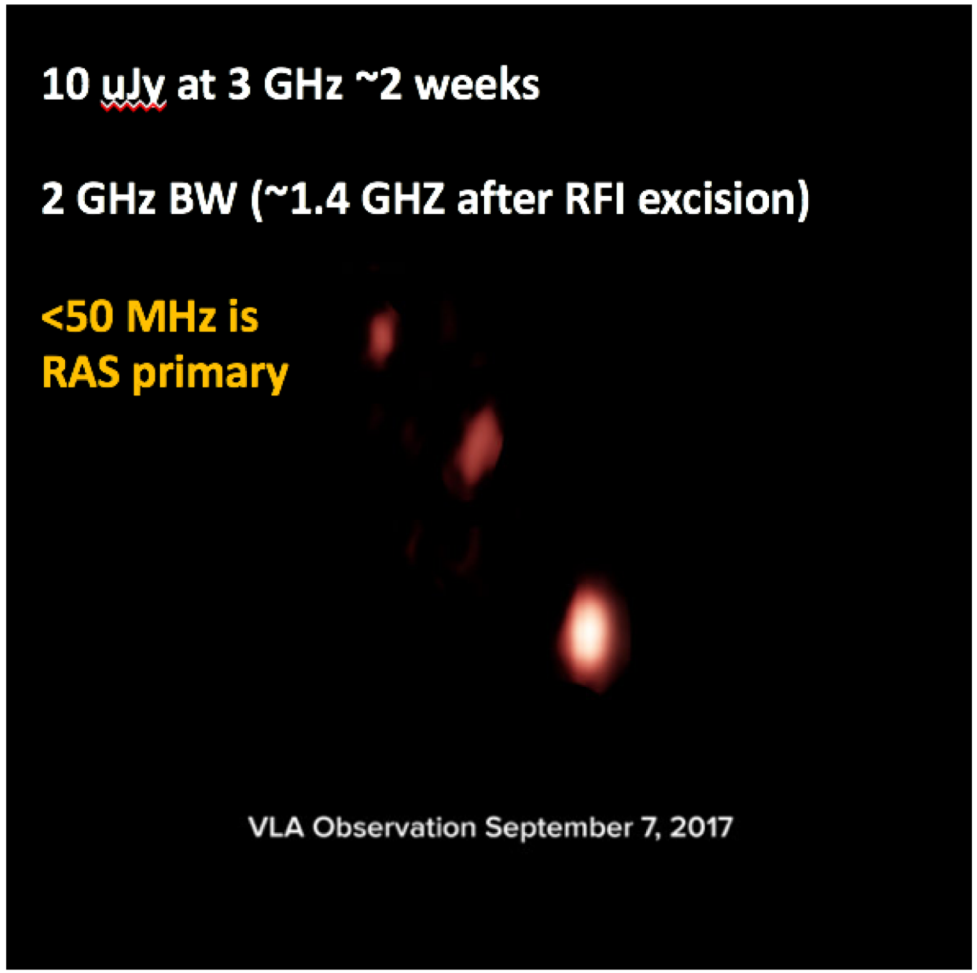
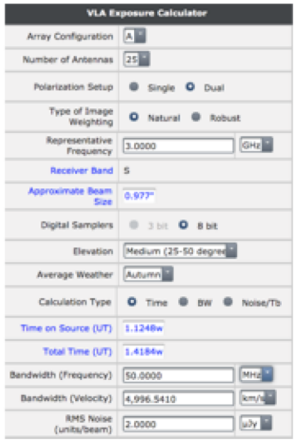


Image Credits: Hallinan et al., Science (16 Oct 2017)

To achieve 2 uJy RMS
requires integration time on source of:

2 GHz bandwidth:
5.5 hours



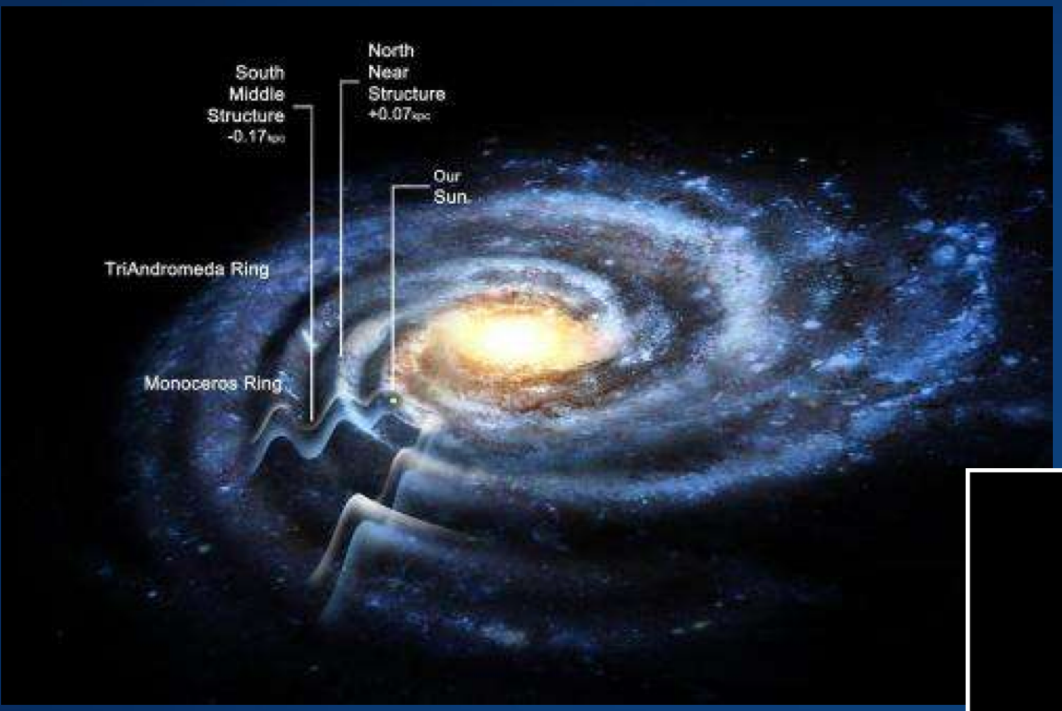
1.4 GHz bandwidth:
6 hours

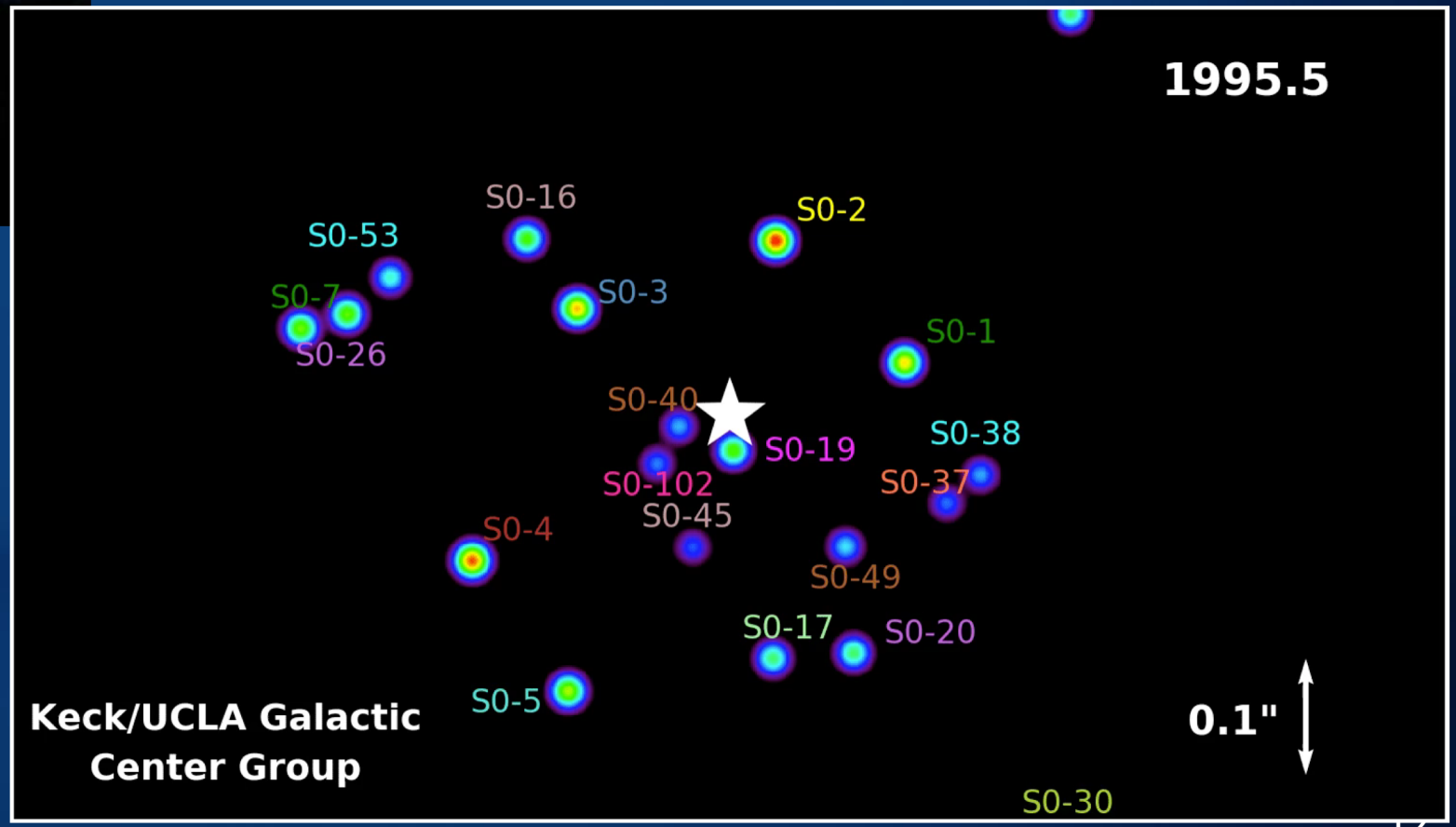
50 MHz bandwidth:
185 hours (more than one week)

Exposure is too long
That is a lot of VLA time on one source. You may want to change your values for noise and bandwidth.

Image credit: Event Horizon Telescope Collaboration

Why care about black holes?


South
Middle
Structure
-0.17kpc
North
Near
Structure
+0.07kpc
Our
Sun
TriAndromeda Ring
Monoceros Ring


1995.5
S0-16
S0-2
S0-53
S0-3
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S0-1
S0-26
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S0-102
S0-37
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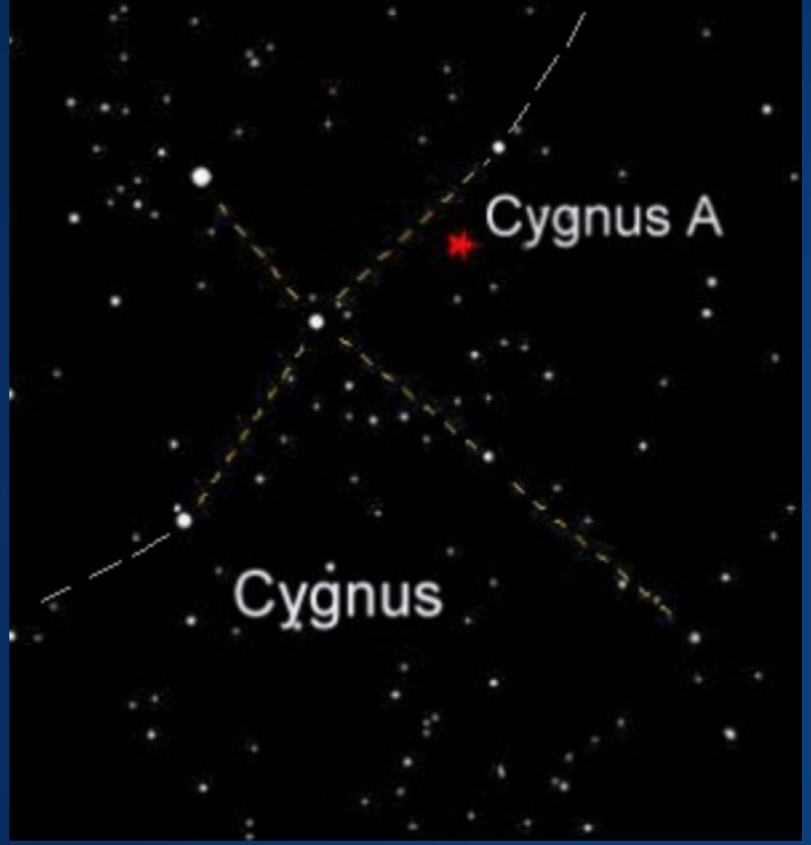
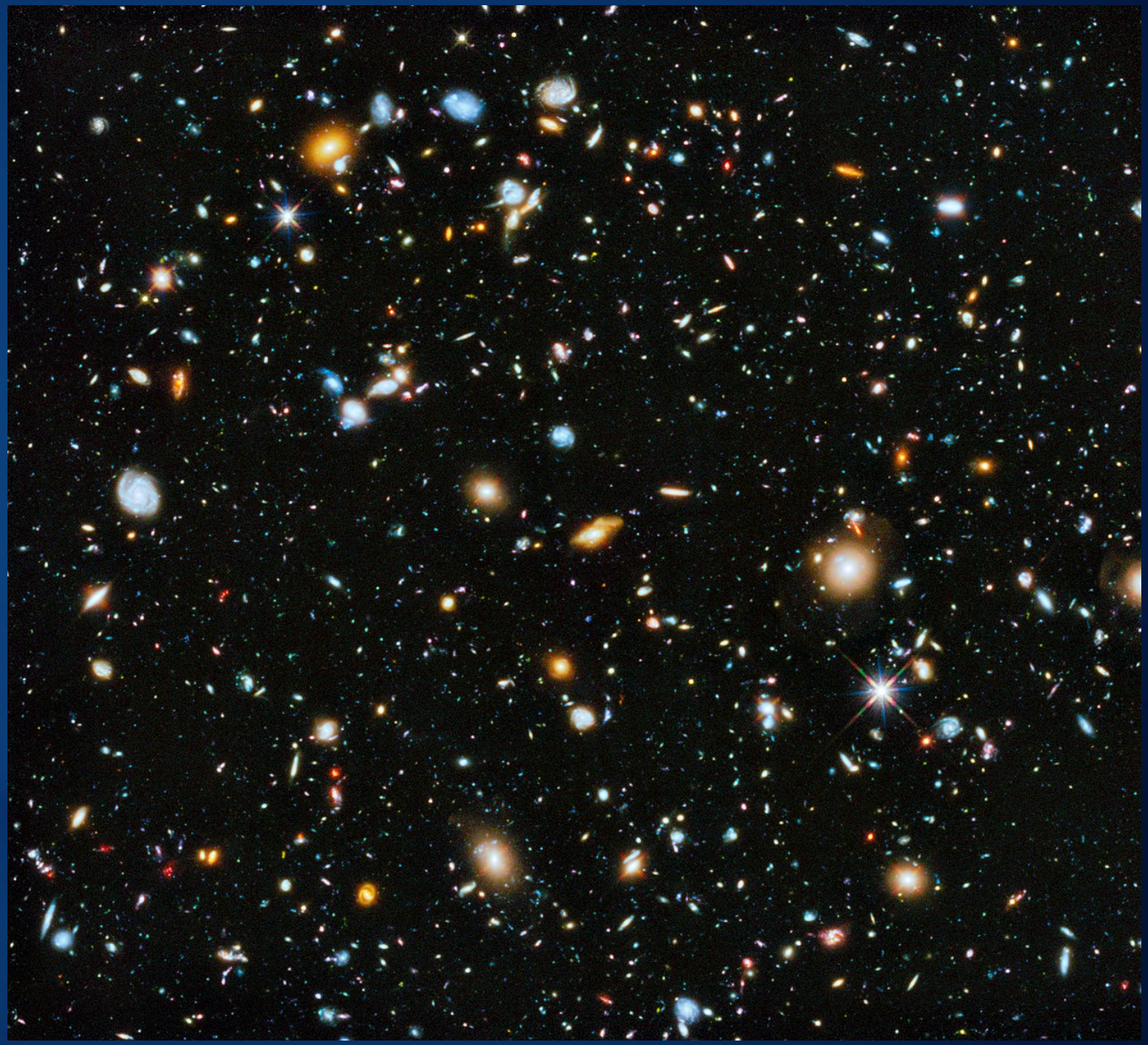
Keck/UCLA Galactic
Center Group
0.1"
S0-30





Hubble Ultra Deep Field, NASA

Radio Galaxies – precision astrometry with VLBI

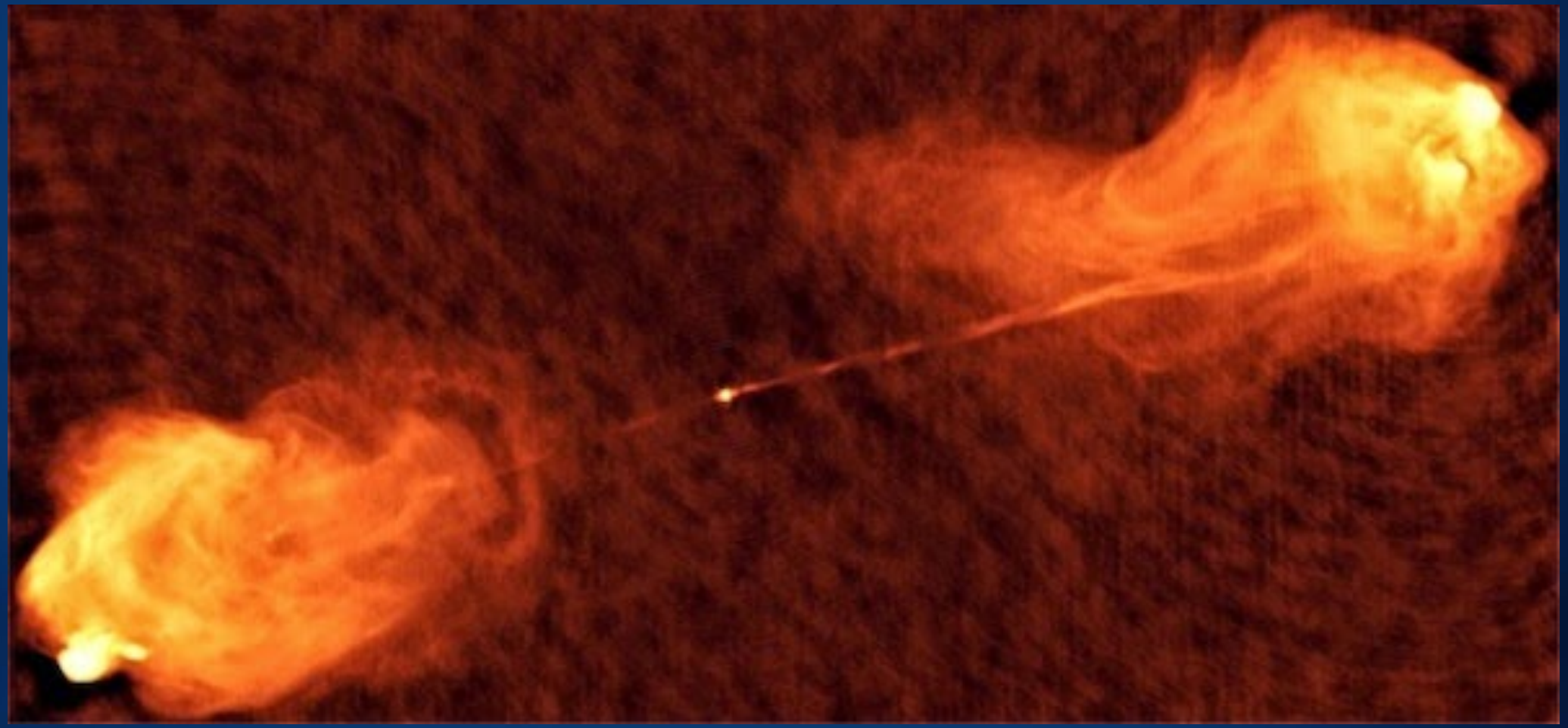
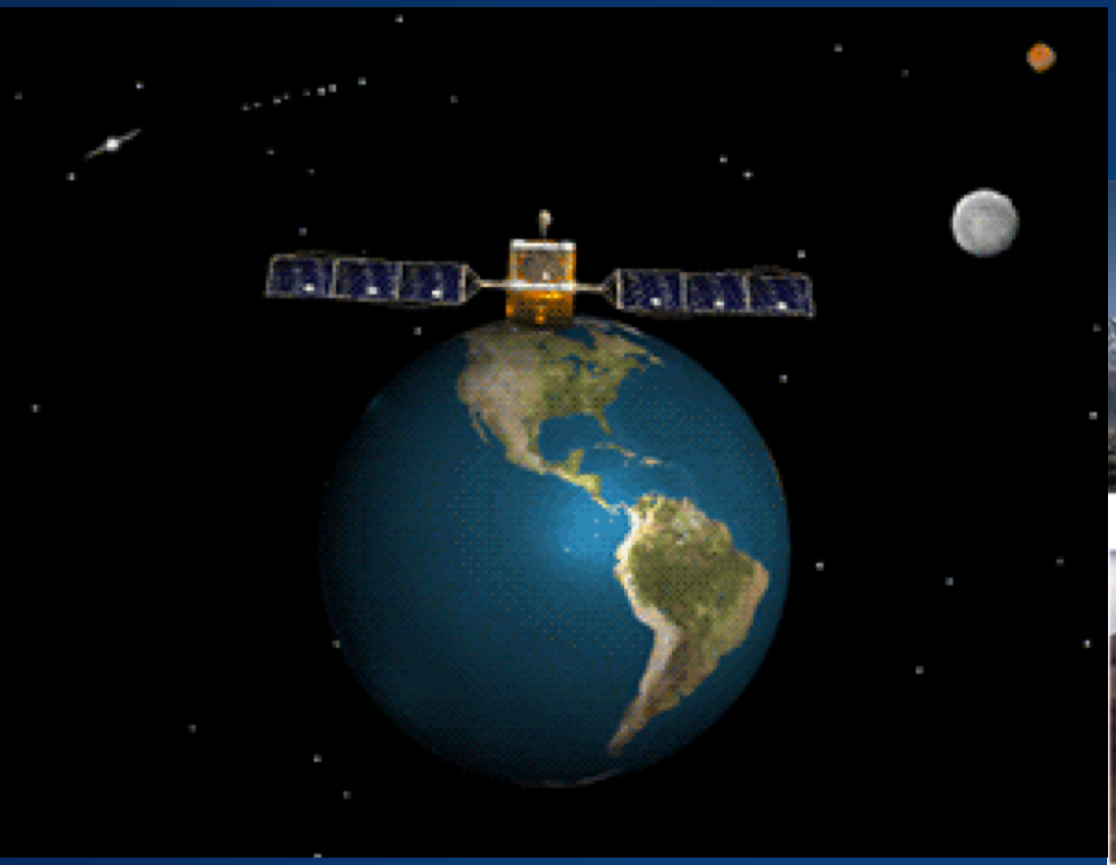
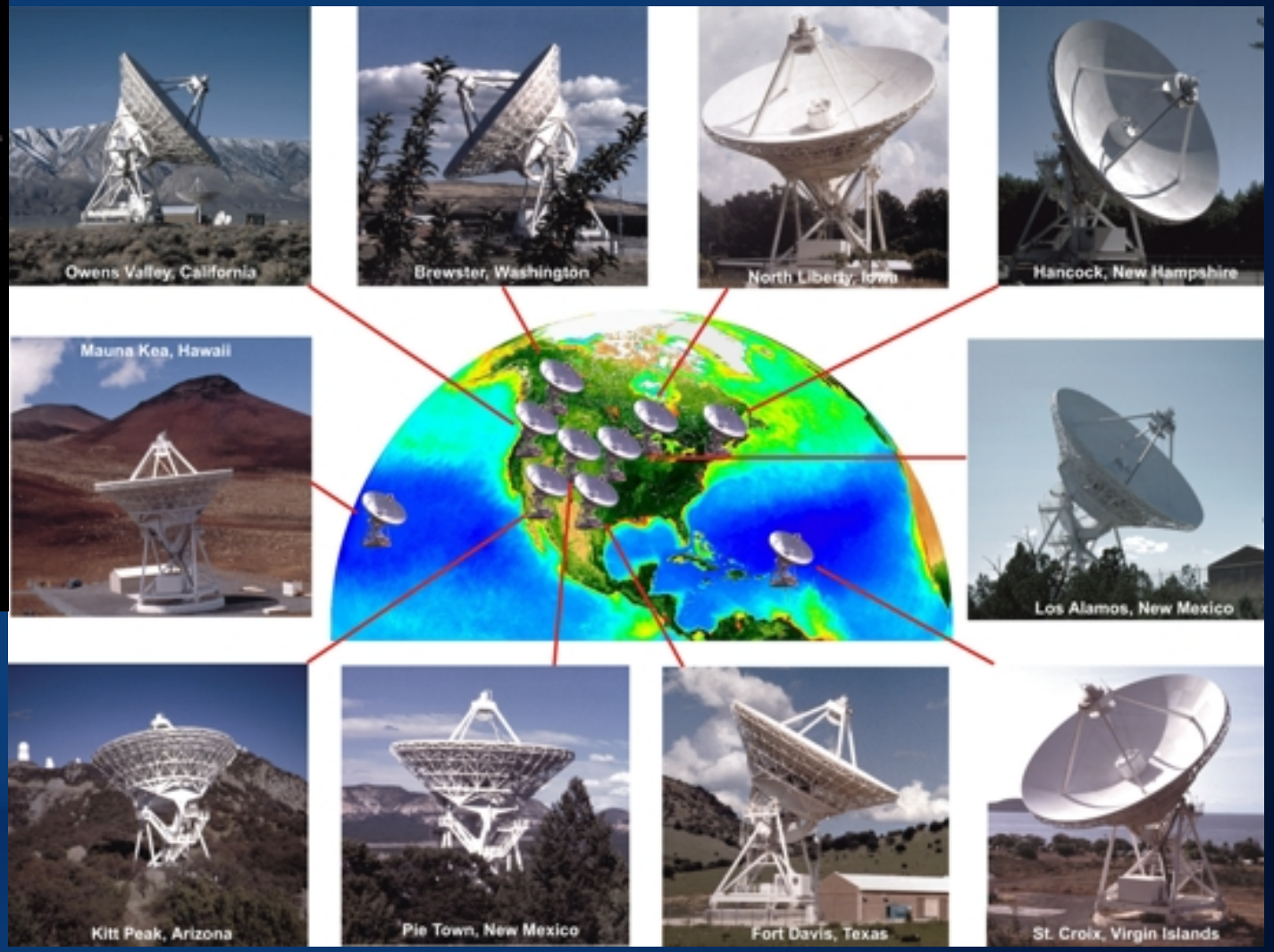
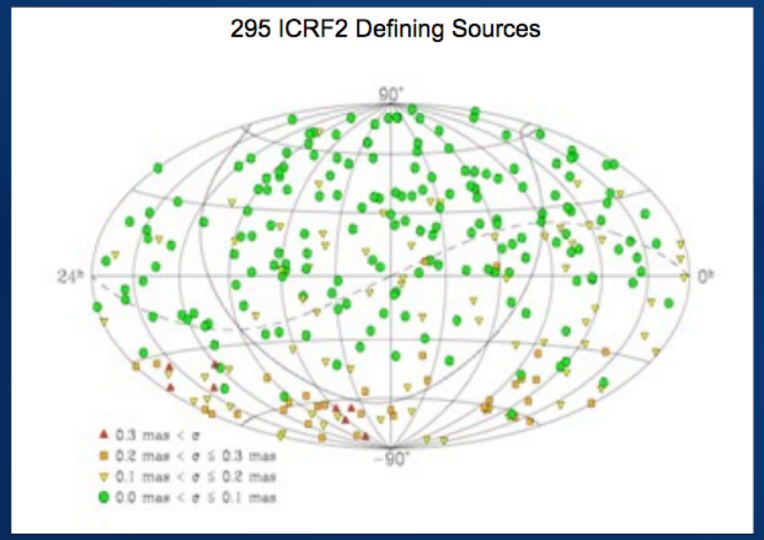


Photo Credit: NRAO/AUI

International Celestial Reference Frame







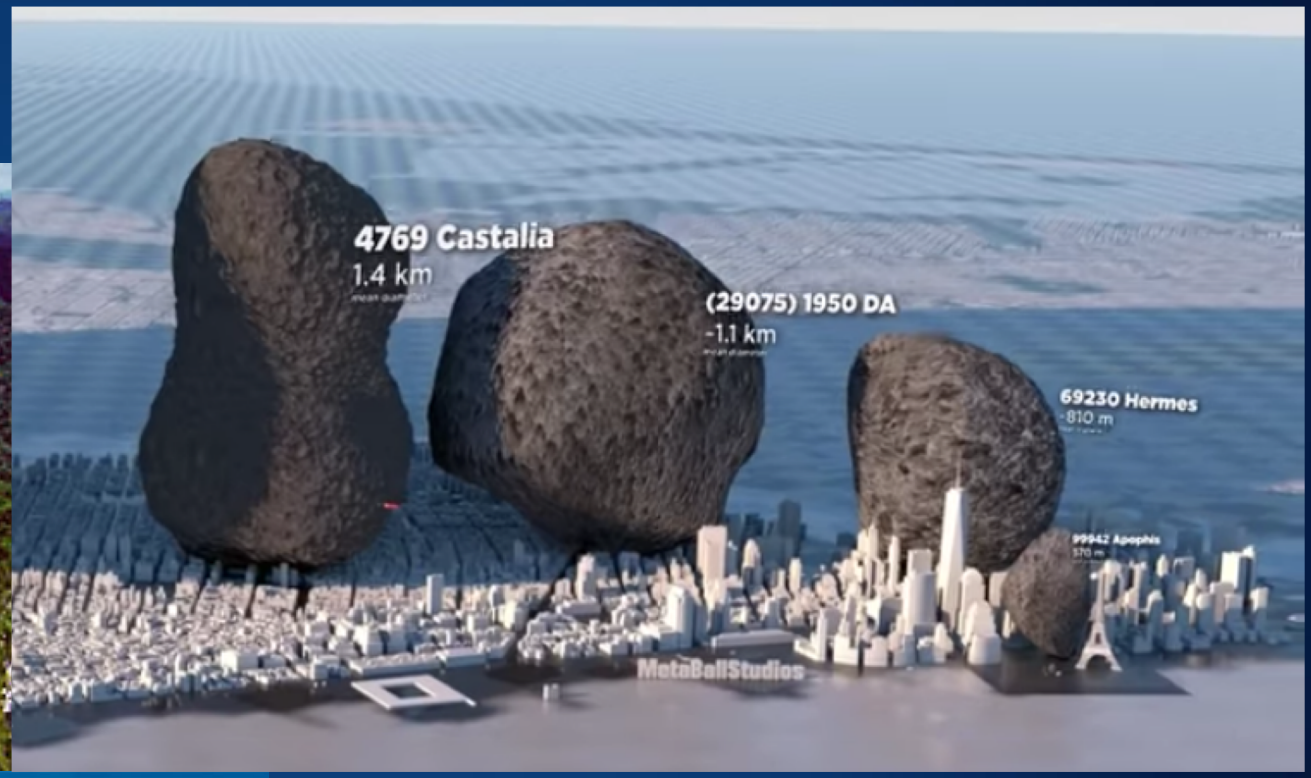
Very Long Baseline Array

Credits: D. Boboltz, K. Johnston (US Naval Observatory), bestanimations.com, NRAO

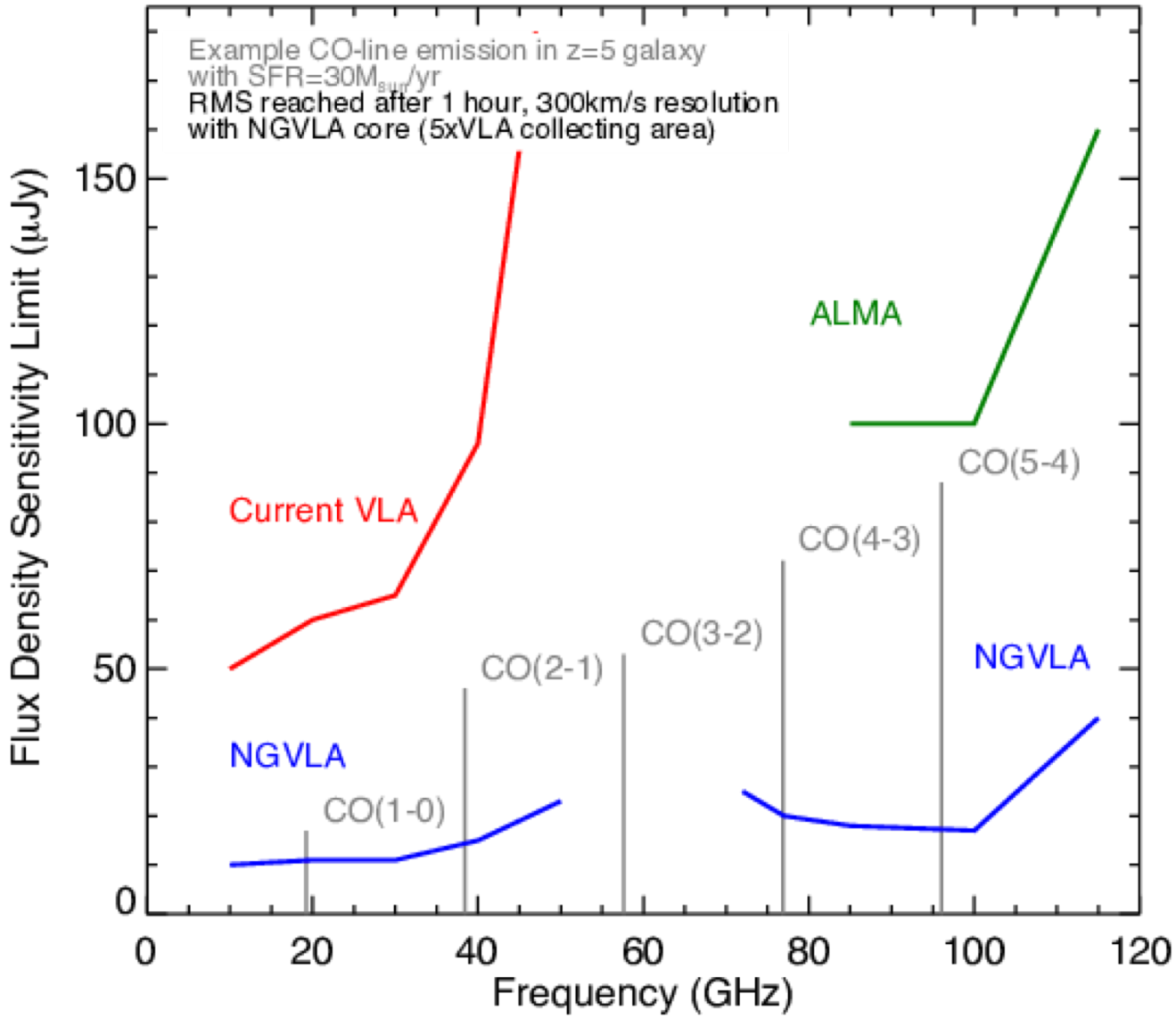
Near Earth Objects (NEOs)

Arecibo Observatory, Puerto Rico

Green Bank Telescope, Green Bank, WV



https://laughingsquid.com/size-of-asteroids-compared-to-new-york-city/



Federal Communications Commission

Spectrum Frontiers > 24 GHz
https://www.fcc.gov/document/spectrum-frontiers-ro-and-fnprm

Spectrum Horizons > 95 GHz
https://www.fcc.gov/document/fcc-opens-spectrum-horizons-new-services-technologies

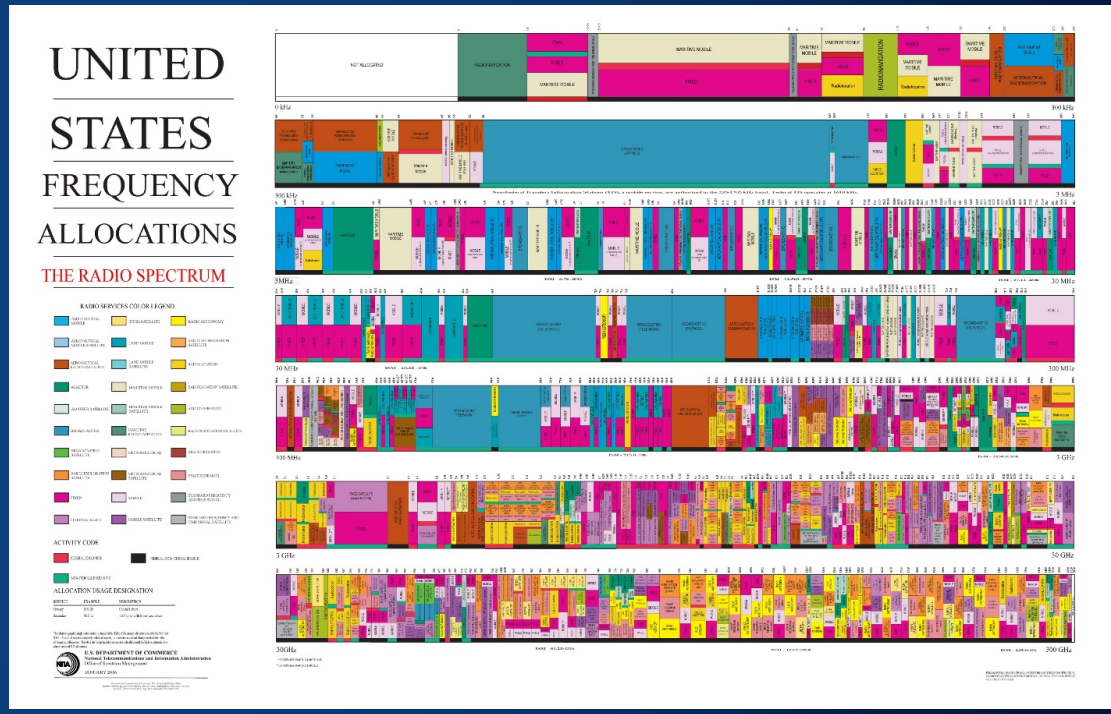
Science with an ngVLA. Cold gas in High-z Galaxies: The molecular gas budget - Decarli, R. *et al.* ASP Conf.Ser. 517 (2018) 565 arXiv:1810.07546 [astro-ph.GA]

The RFI environment as we know it is changing… *rapidly*.

Science missions are requiring expanded spectrum usage.

Frequency Usage Takeaways

- **Protected frequency bands include *most important identified spectral lines for studying the local universe* (e.g. HI, CO, OH masers), but *doppler-shifted lines* from sources further away in the Universe fall into non-protected bands. Frequencies used for observation are often non-interchangeable, and much observation is done opportunistically.**



Epoch of Reionization

HI: 21 cm -> 1.5 m

Freq ~ 1420 MHz -> 200 MHz

$$1 + z = \frac{f_{\text{emit}}}{f_{\text{obsv}}}$$

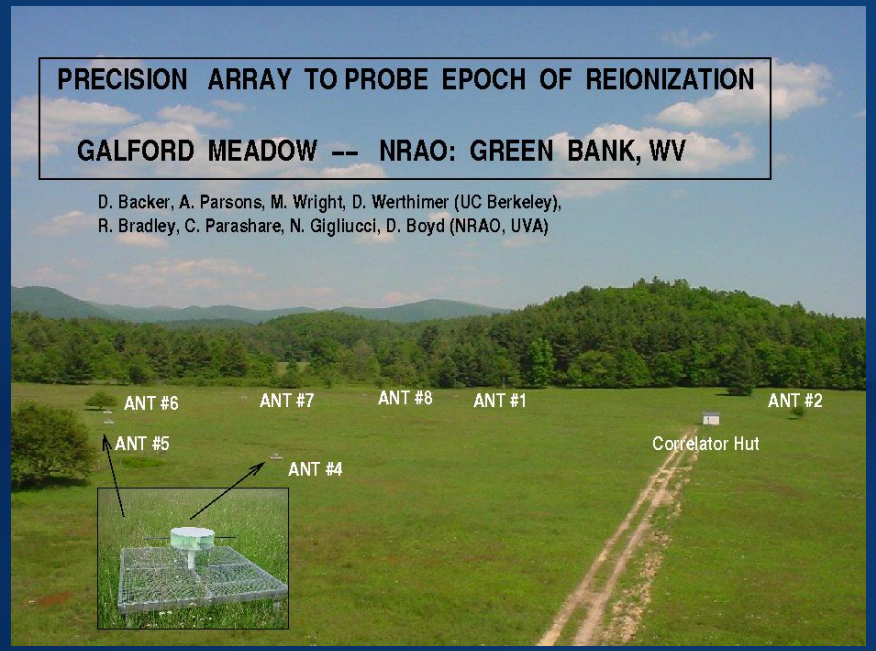


Image Credit: w.astro.berkeley.edu

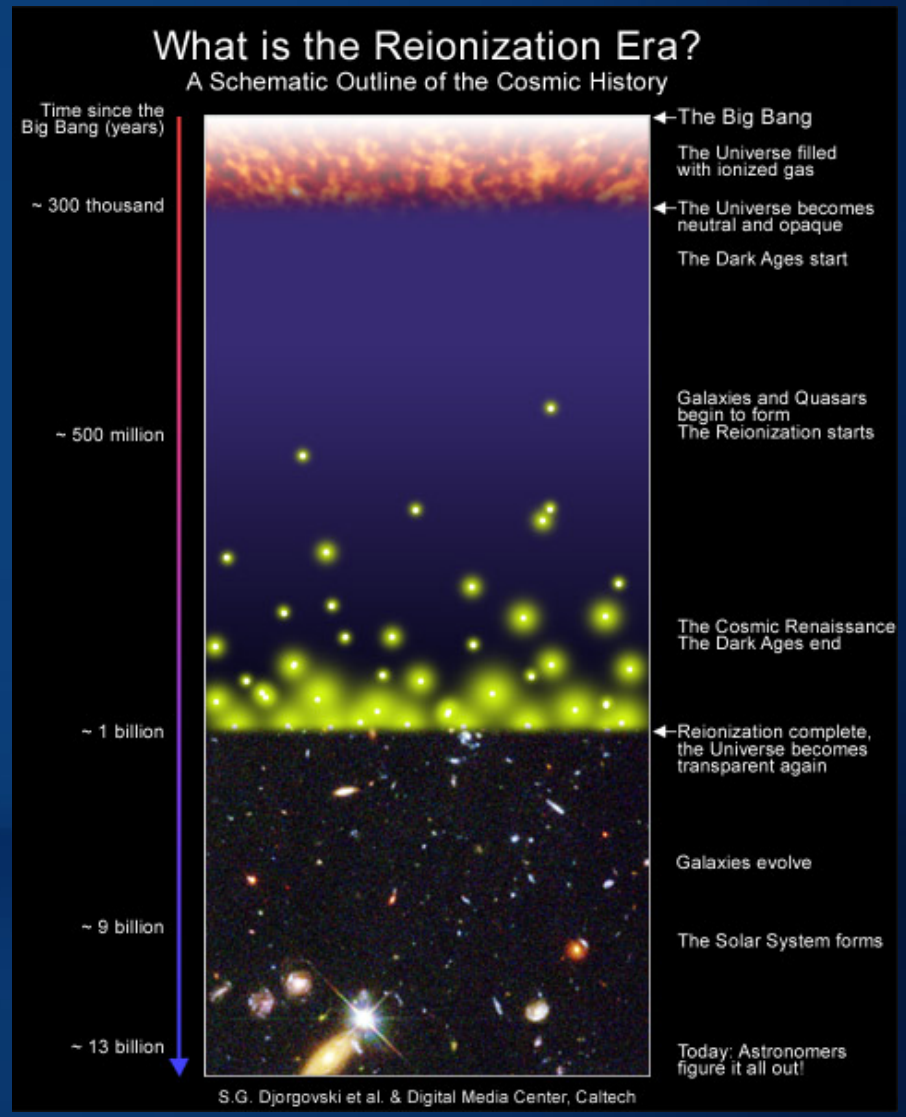
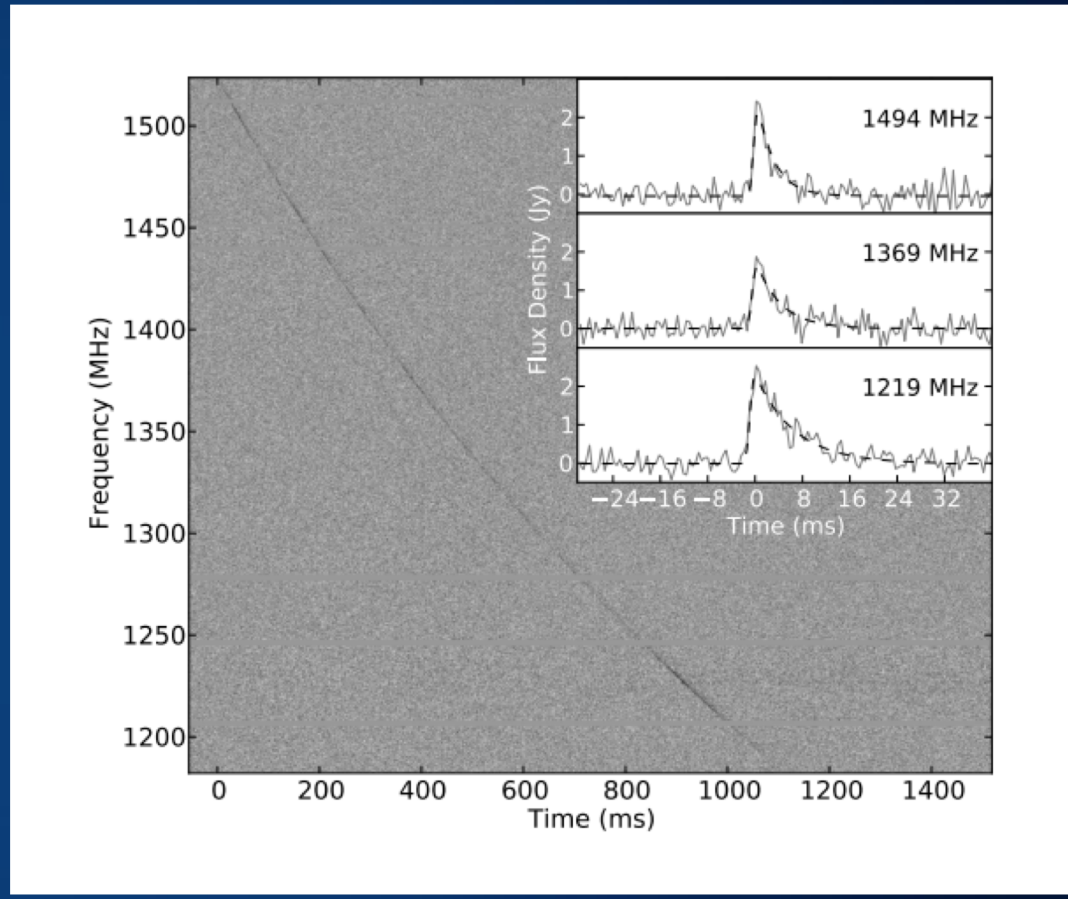


Image Credit: Djorgovski et al. (Caltech); www.haystack.mit.edu

Frequency Usage Takeaways

- **It is imperative that the increasing demands for spectrum take into consideration the challenges to scientific progress; efforts to coordinate and to limit out-of-band emissions are crucial; Astronomy observations also include continuum emission (thermal, non-thermal).**



Thornton et al., 2013, Science

Table 1: Overall EVLA Performance Goals			
Parameter	VLA	EVLA	Factor
Continuum Sensitivity (1-σ, 9 hr)	10 μJy	1 μJy	10
Maximum BW in each polarization	0.1 GHz	8 GHz	80
Log (Frequency Coverage over 1–50 GHz)	22%	100%	5

Table and Image Credit: NRAO

Frequency Usage Takeaways

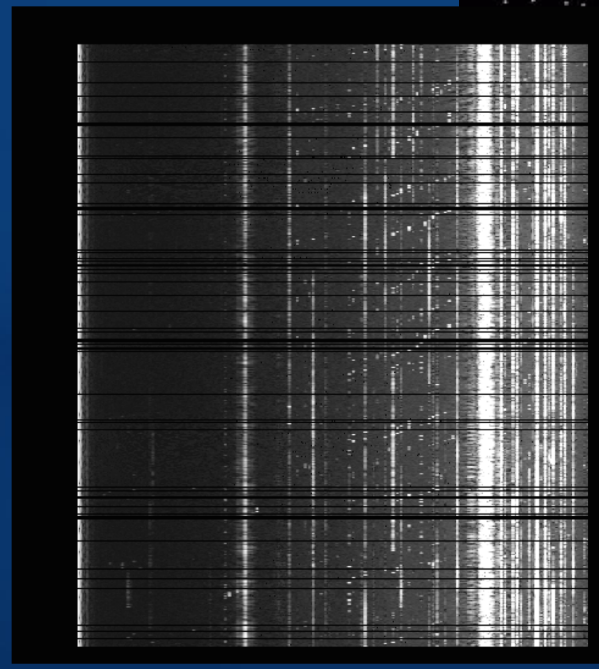
Image credit: almaobservatory.org

- **The United States has significant scientific assets / large facilities outside of its national borders.**

- **Observatories tend to be in geographically remote sites, but radio emission from moving emitters: car radars, satellites and high altitude delivery systems will be an increasing challenge.**

What is coming…

- Constellations of thousands of satellites (20-50 GHz regime) such that from any location you would always “see” at least one, preferably (in mind of satellite providers) up to 3 or 4 satellites
- Mobile telecommunications
- High Altitude Platform Systems



Credit: University of Southampton

How do we preserve access to the spectrum for the next decade and beyond?

- **NRQZ (established 1958) needs updated protections from airborne transmitters; other radio telescopes need also need newly established quiet/coordination zones**

The National Radio Quiet Zone (NRQZ) was established by the Federal Communications Commission (FCC) in Docket No. 11745 (November 19, 1958) and by the Interdepartment Radio Advisory Committee (IRAC) in Document 3867/2 (March 26, 1958) to minimize possible harmful interference to the National Radio Astronomy Observatory (NRAO) in Green Bank, WV and the radio receiving facilities for the United States Navy in Sugar Grove, WV. The NRQZ is bounded by NAD-83 meridians of longitude at 78d 29m 59.0s W and 80d 29m 59.2s W and latitudes of 37d 30m 0.4s N and 39d 15m 0.4s N, and encloses a land area of approximately 13,000 square miles near the state border between Virginia and West Virginia.

Credit: Green Bank Observatory

Credit: NRAO

I. Radio Astronomy's Value and Spectrum Needs

II. Process is complicated: many stakeholders

III. Getting involved is simple: contribution driven

US Domestic Spectrum Policy

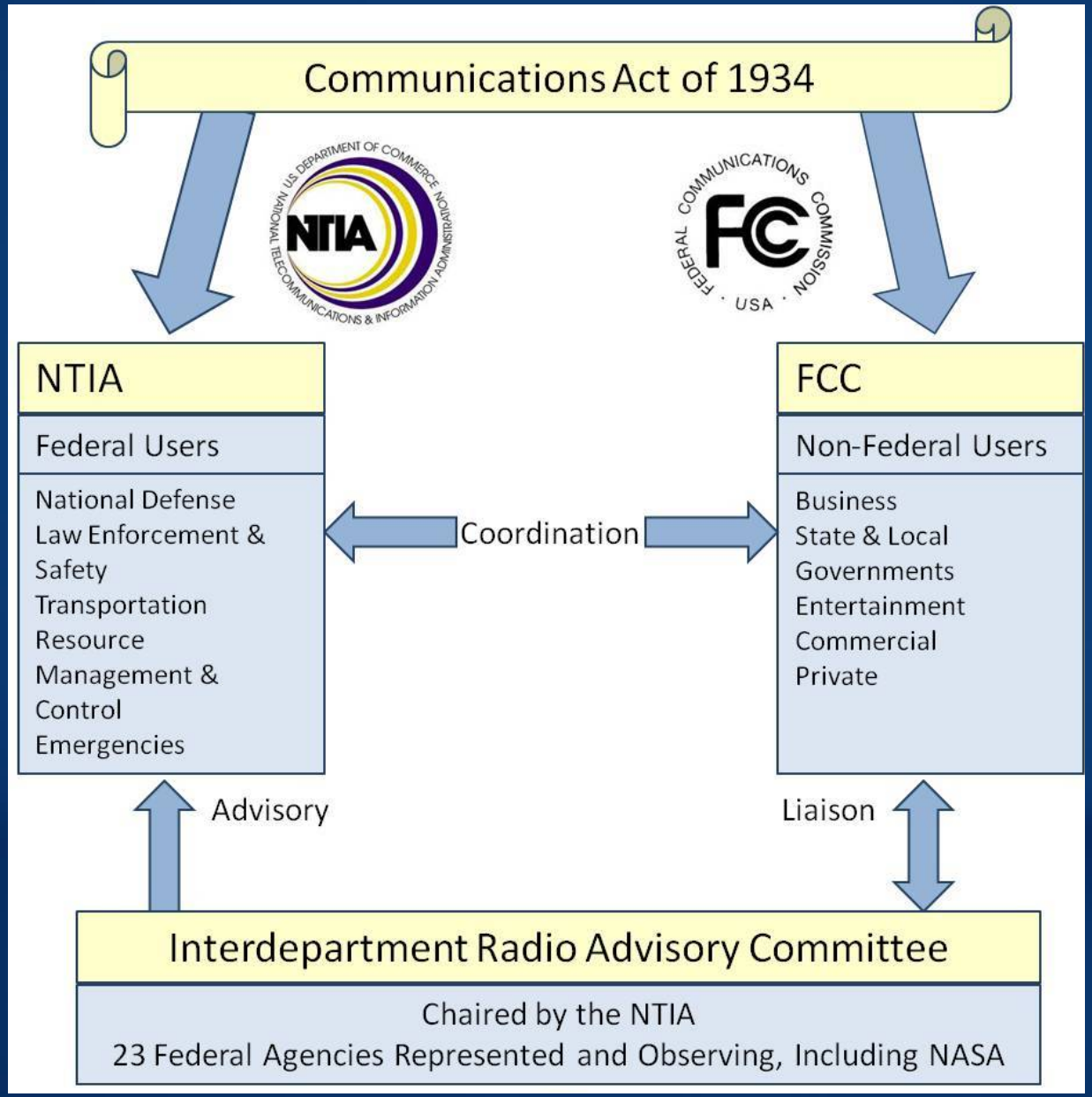
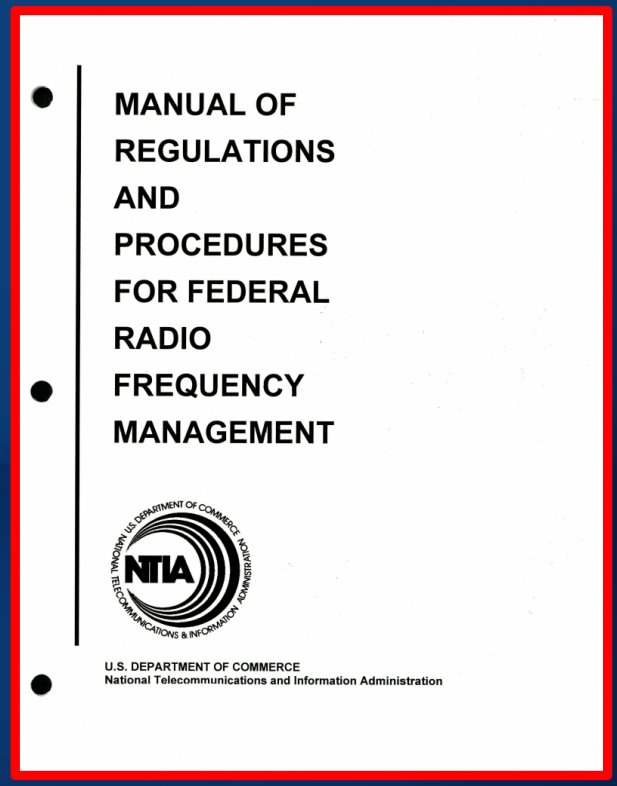


Image Credit:
www.nasa.gov
National Spectrum Management Plan

Allocations and Coordination

- Radio Regulations:
  - (1) International (ITU-R Radio Regulations; www.itu.int)
  - (2) National (USA: NTIA - www.ntia.doc.gov; FCC - www.fcc.gov)



Astronomical Input to formulating NSF's position

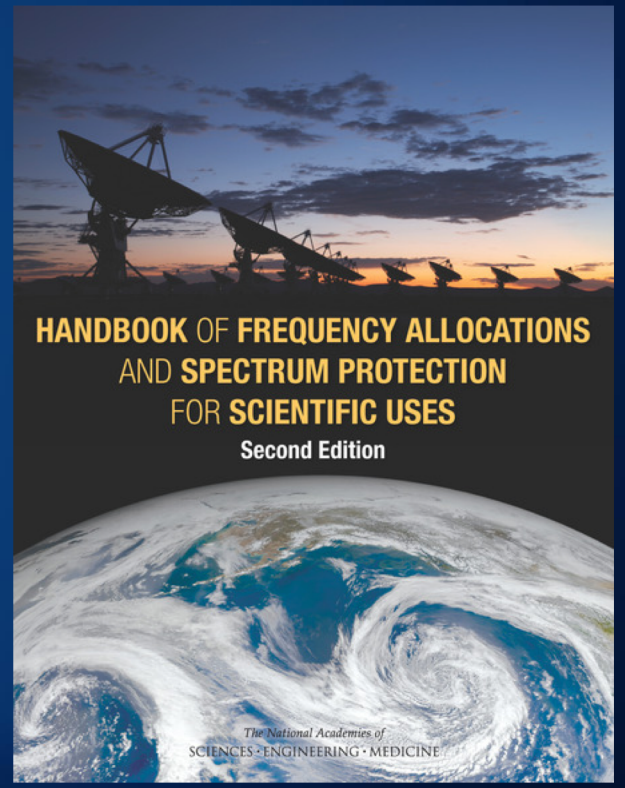
- CORF – Committee on Radio Frequencies, National Academies
  - Chair: Liese van Zee
- IUCAF – International Committee working in field of spectrum management on behalf of passive radio sciences (set up in 1960 by URSI, IAU and COSPAR; http://www.iucaf.org/)
  - IUCAF Secretariat: Harvey Liszt
- CRAF – European Science Foundation's Committee on Radio Astronomy Frequencies, 22 member countries (https://www.craf.eu)
  - Chairman: Michael Lindquist; Frequency Manager: Waleed Madkour
- Spectrum Managers at telescopes and/or their Managing Organizations

  NRAO: Harvey Liszt

  Very Large Array: Dan Mertely

  Arecibo: Angel Vazquez

  Green Bank: Paulette Woody
- Astronomers and Telescope Staff



NSF ESM Unit Activities

- At NSF – Coordination with other Directorates and Divisions with spectrum needs, manage spectrum related grants portfolio (CORF, Enhancing Access to the Radio Spectrum Solicitation; EARS)
- Coordinate with other US Agencies
- Interface with commercial interests to advocate for their taking "practicable" steps to not cause interference to passive services

NSF ESM Unit Activities

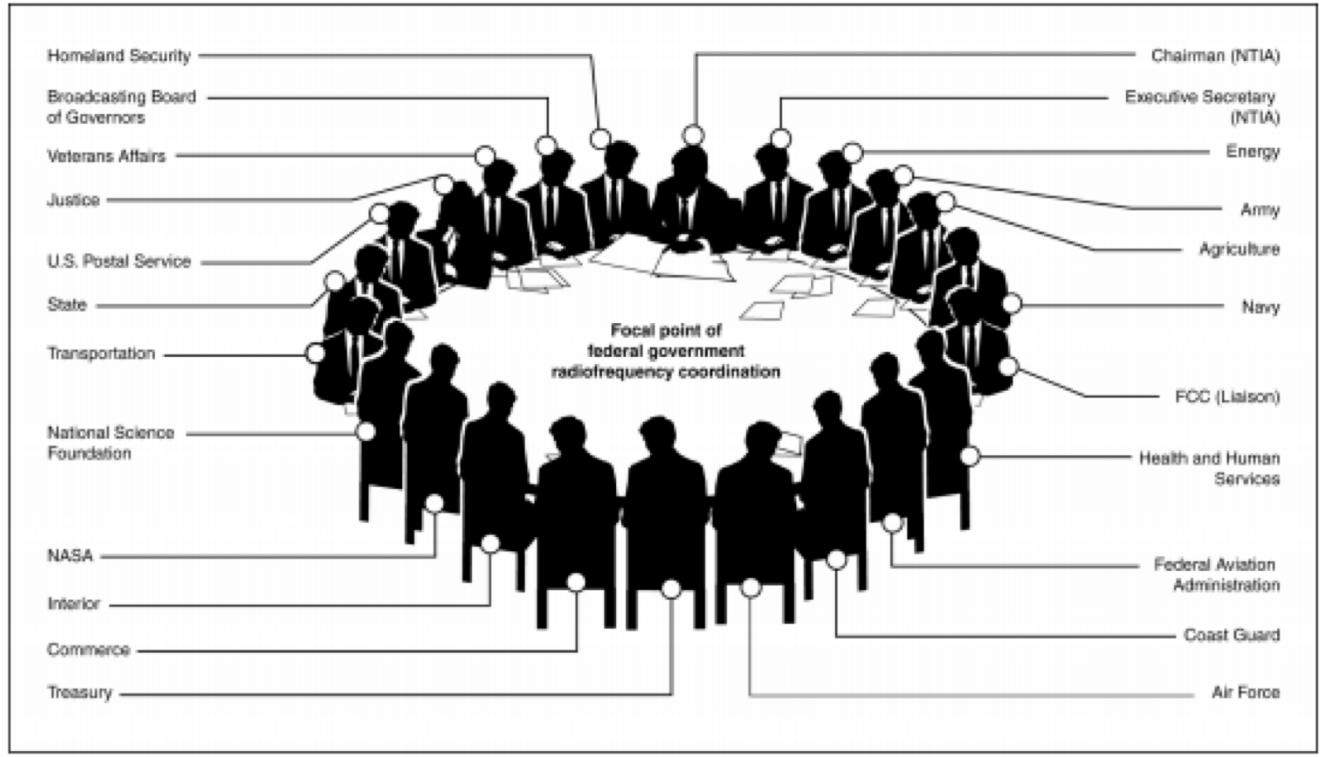
- Represent NSF as a Federal Agency to the National Telecommunications and Information Administration
  - 10 subcommittees including
    - IRAC
    - FAS (NRQZ coordination)

- Representation on official U.S. Delegations to the Inter-American Telecommunications Commission (CITEL) of the Organization of American States (OAS)

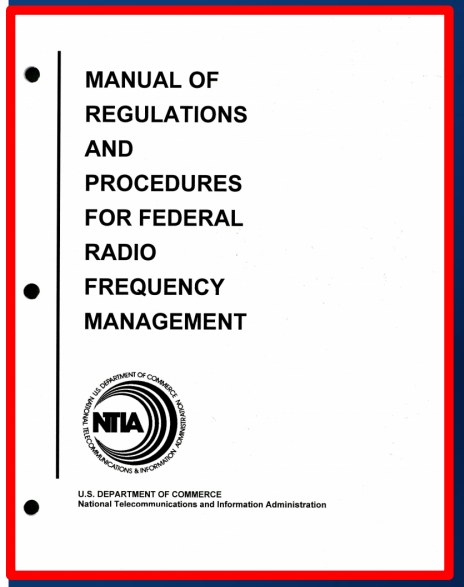
- Representation on official U.S. Delegations to the International Telecommunication Union's World Radiocommunication Conference (WRC 2019), including leading 7D – Radio Astronomy

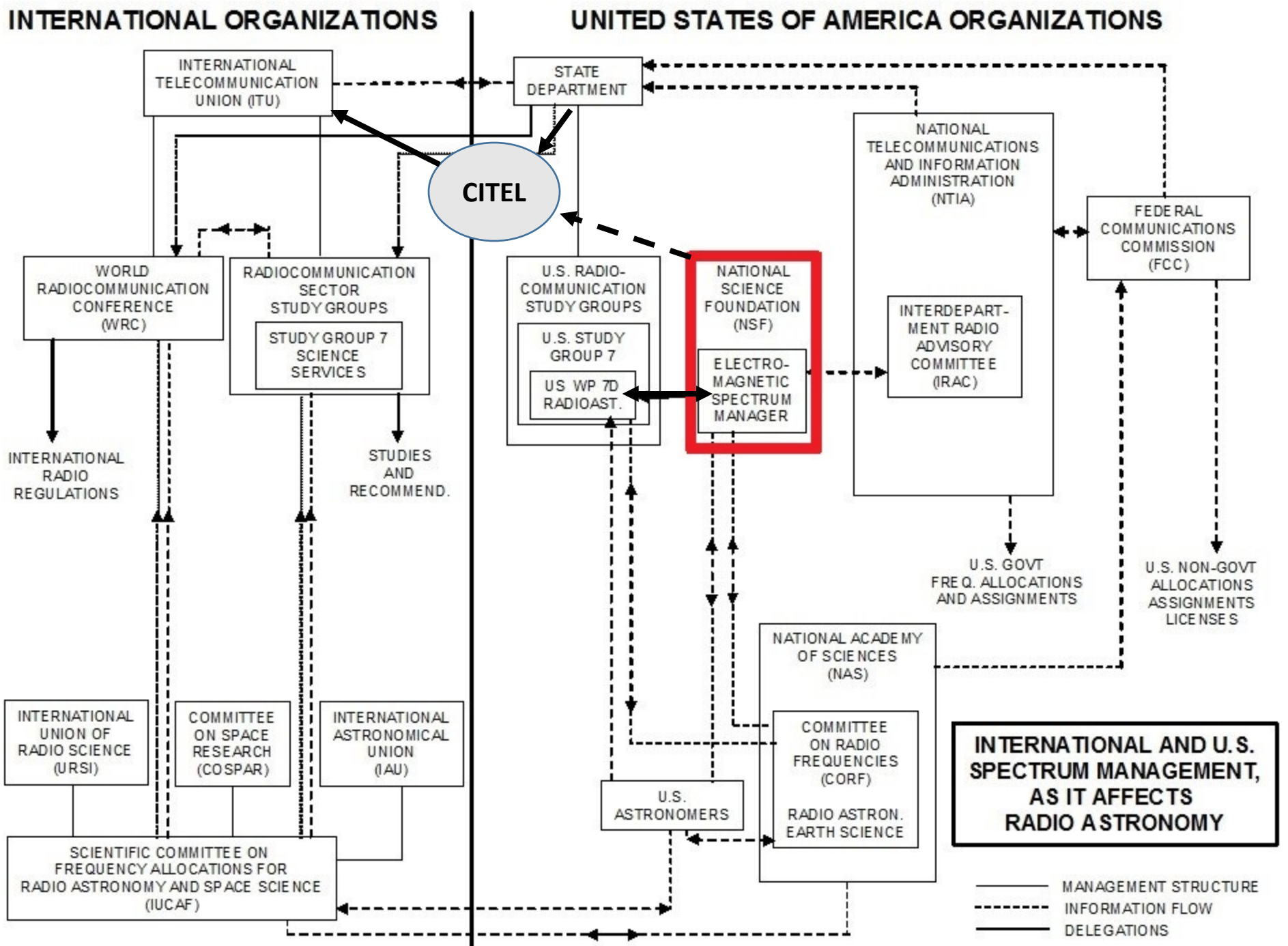
Interdepartment Radio Advisory Committee

- FAS - Frequency Assignment Subcommittee
- SPS - Spectrum Planning Subcommittee
- RCS - Radio Conference Subcommittee
- SSS - Space Systems Subcommittee
- TSC - Technical Subcommittee
- EPS - Emergency Planning Subcommittee
- PPSG – Policy and Plans Steering Group
- Ad Hocs: US-Mexico, US-Canada, NTIA manual modernization



Source: NTIA.




INTERNATIONAL ORGANIZATIONS
UNITED STATES OF AMERICA ORGANIZATIONS
INTERNATIONAL TELECOMMUNICATION UNION (ITU)
STATE DEPARTMENT
CITEL
NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION (NTIA)
FEDERAL COMMUNICATIONS COMMISSION (FCC)
WORLD RADIOCOMMUNICATION CONFERENCE (WRC)
RADIOCOMMUNICATION SECTOR STUDY GROUPS
STUDY GROUP 7 SCIENCE SERVICES
U.S. RADIO-COMMUNICATION STUDY GROUPS
U.S. STUDY GROUP 7
US WP 7D RADIOAST.
NATIONAL SCIENCE FOUNDATION (NSF)
ELECTRO-MAGNETIC SPECTRUM MANAGER
INTERDEPART-MENT RADIO ADVISORY COMMITTEE (IRAC)
INTERNATIONAL RADIO REGULATIONS
STUDIES AND RECOMMEND.
U.S. GOVT FREQ. ALLOCATIONS AND ASSIGNMENTS
U.S. NON-GOVT ALLOCATIONS ASSIGNMENTS LICENSES
NATIONAL ACADEMY OF SCIENCES (NAS)
INTERNATIONAL UNION OF RADIO SCIENCE (URSI)
COMMITTEE ON SPACE RESEARCH (COSPAR)
INTERNATIONAL ASTRONOMICAL UNION (IAU)
COMMITTEE ON RADIO FREQUENCIES (CORF)
RADIO ASTRON. EARTH SCIENCE
U.S. ASTRONOMERS
SCIENTIFIC COMMITTEE ON FREQUENCY ALLOCATIONS FOR RADIO ASTRONOMY AND SPACE SCIENCE (IUCAF)
INTERNATIONAL AND U.S. SPECTRUM MANAGEMENT, AS IT AFFECTS RADIO ASTRONOMY
MANAGEMENT STRUCTURE
INFORMATION FLOW
DELEGATIONS

World Radiocommunication Conference

- 2019 World Radiocommunication Conference (WRC-19) in Sharm El-Sheikh, Egypt
- Technical preparatory work done in the ITU Radiocommunication Sector Study Groups (ITU-R)
- US Regulators oversee conference preparations by Federal Government (NTIA) and private sector (FCC)
- Conference Preparatory Meeting (CPM) report contained approaches (Methods) for satisfying each agenda item (technical basis upon which Administration proposals are made)

Radiocommunication Study Groups

- www.itu.int/en/ITU-R/study-groups

- SG 1: Spectrum Management
- SG 3: Radiowave Propagation
- SG 4: Satellite Services
- SG 5: Terrestrial Services
- SG 6: Broadcasting Services
- SG 7: Science Services
  - Working Party 7A – Time signals and frequency standards
  - Working Party 7B – Space Radiocommunication applications
  - Working Party 7C – Remote sensing systems
  - Working Party 7D – Radio astronomy

Bi-annual meetings in Geneva for all Study Groups and Working Parties, monthly national preparatory meetings leading up to International meetings

I. Radio Astronomy: intrinsic value and spectrum needs

II. Process is complicated: many stakeholders

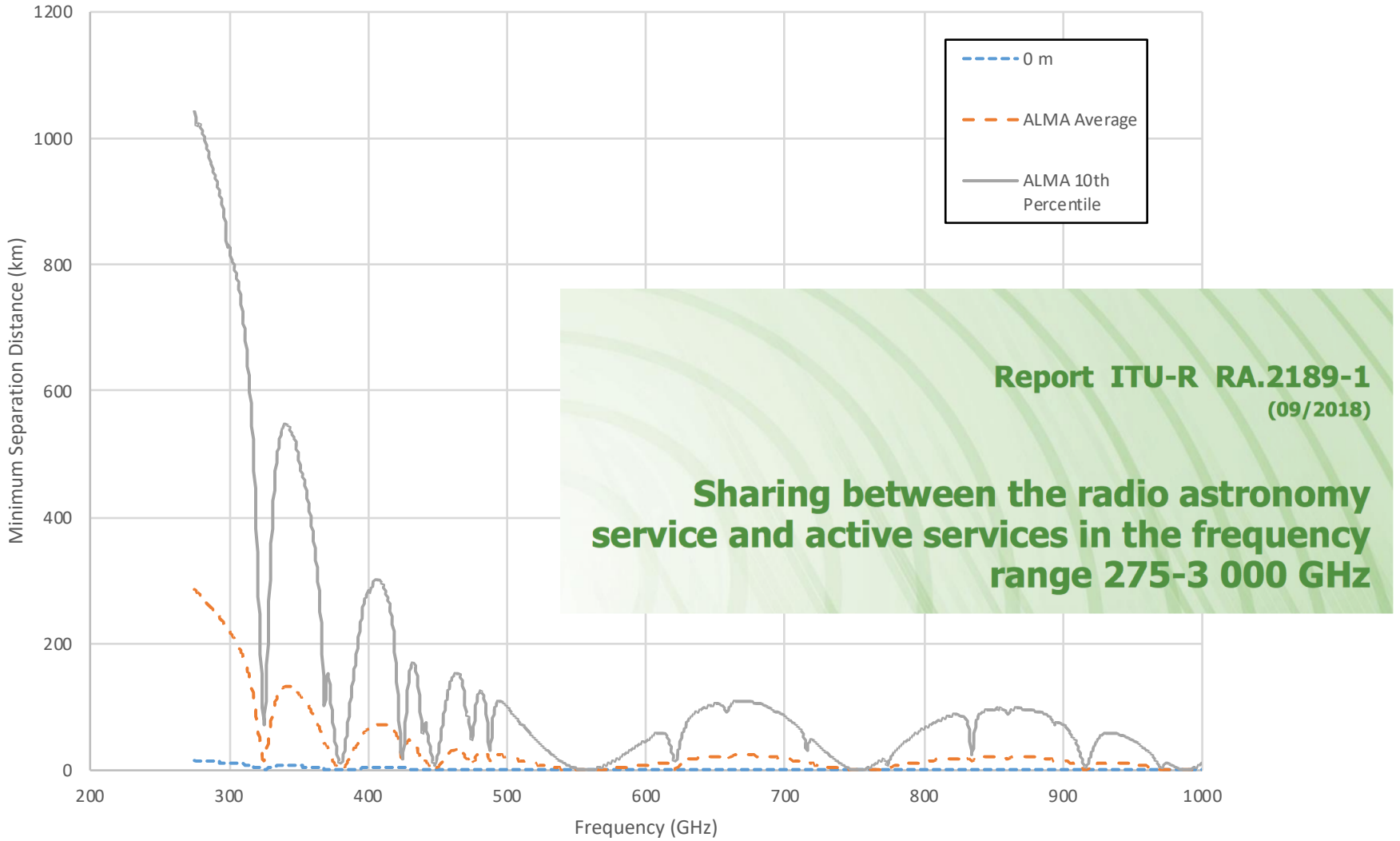
III. <u>Getting involved is simple: contribution driven</u>

"If [we] fail to plan, [we] are planning to fail!" – B. Franklin

Cooperation and Teamwork is vital

World Radio Conference 2019 Agenda Item 1.15: mm-wave

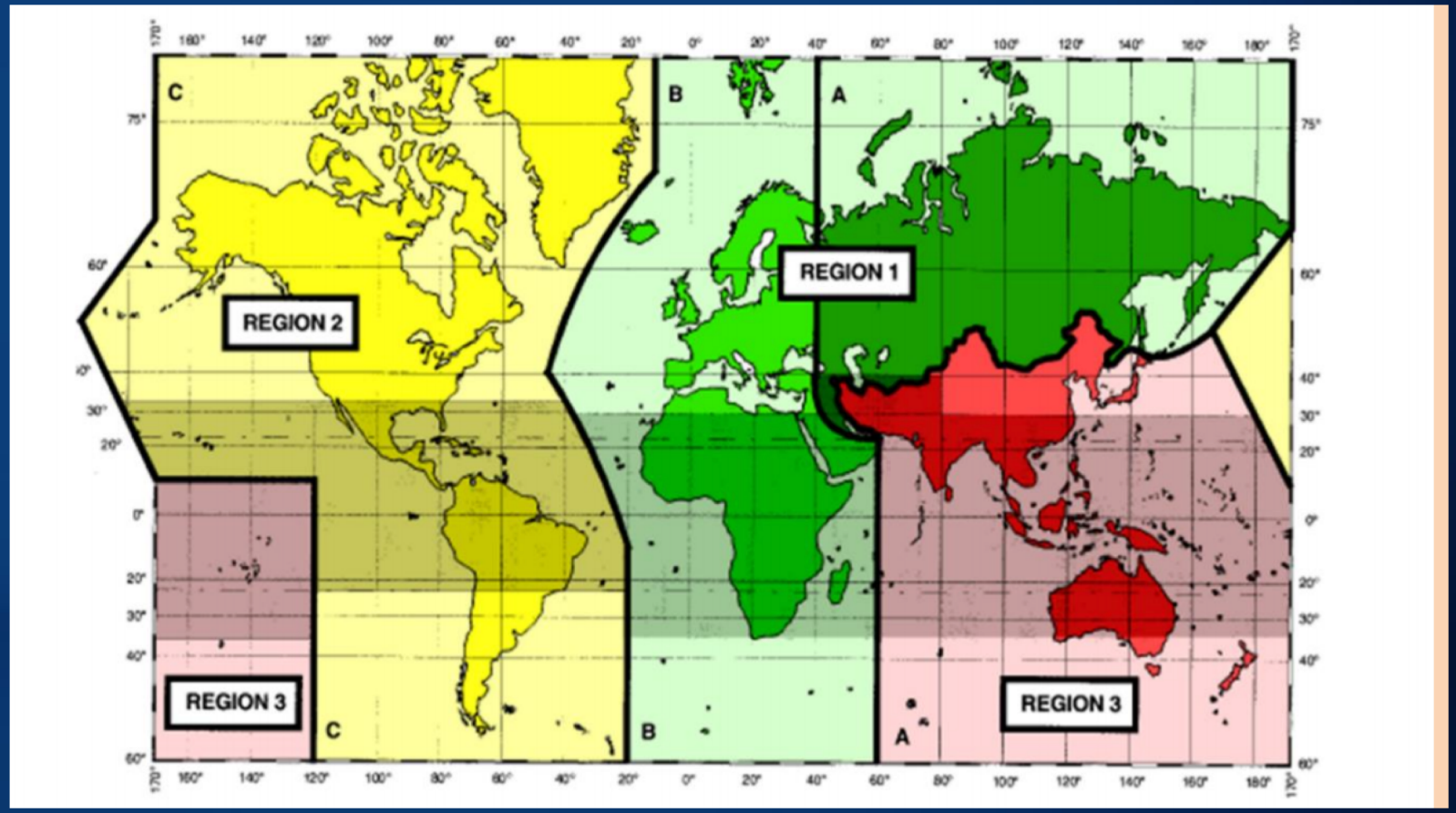
http://www.itu.int/pub/R-REP-RA.2189-1-2018



Updated Fall 2018

National and **Regional** Regulatory Structures and how they feed into the International Structure:

Americas, CITEL



Source: ITU

Bevin Ashley Zauderer
Division of Astronomical Sciences
National Science Foundation

March 2, 2020
IUCAF 5th School
Stellenbosch, South Africa

Organization of American States

Member States

All 35 independent states of the Americas have ratified the OAS Charter and are members of the Organization.

- Antigua and Barbuda
- Argentina
- Barbados
- Belize
- Bolivia
- Brazil
- Canada
- Chile
- Colombia
- Costa Rica
- Cuba [1]
- Dominica (Commonwealth of)
- Dominican Republic
- Ecuador
- El Salvador
- Grenada
- Guatemala
- Guyana
- Haiti
- Honduras
- Jamaica
- Mexico
- Nicaragua
- Panama
- Paraguay
- Peru
- Saint Kitts and Nevis
- Saint Lucia
- Saint Vincent and the Grenadines
- Suriname
- The Bahamas (Commonwealth of)
- Trinidad and Tobago
- United States of America
- Uruguay
- Venezuela (Bolivarian Republic of)

Comisión Interamericana de Telecomunicaciones (CITEL)

Mission Statement

Organization of American States

Vision

The full integration of the American States into the World Information Society and the digital economy, with a view to enabling and accelerating social, economic, cultural, and environmentally sustainable development for all the region's inhabitants through the development of telecommunications and information and communication technologies (ICTs).

Mission

To facilitate and promote the integral and sustainable development of interoperable, innovative, and reliable telecommunications/ICTs in the Americas, under the principles of universality, equity, and affordability.

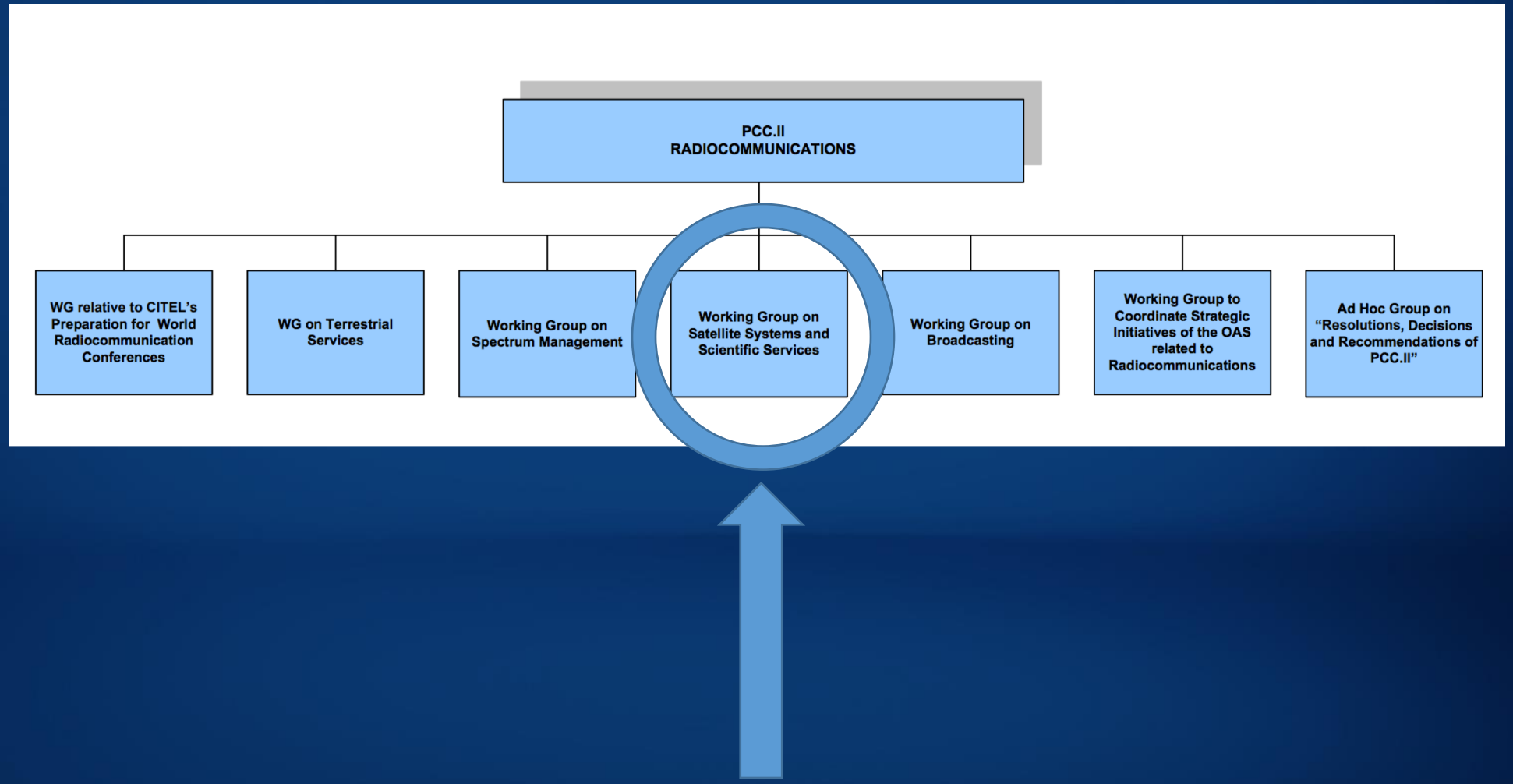
CITEL Strategic Plan 2018 – 2022: OBJECTIVES

1. To ***increase telecommunication/ICT access, penetration, and coverage***.
2. To increase the ***affordability*** of telecommunication/ICT services and devices.
3. To ***increase digital literacy and capabilities*** relative to telecommunications/ICTs, as well as to build capacities to develop and keep communication networks in remote areas.
4. To ***bridge the digital divide and reduce inequality***, particularly in underserved areas and regarding gender, disabilities, older persons, or persons with specific needs.
5. To ***increase interoperability and interconnectivity***, of telecommunications/ICTs in the Americas, including international connectivity and harmonization of spectrum use.
6. To increase the budget of both the regular fund and specific fund, and the contributions of nonfinancial resources by the OAS.
7. To ***increase the participation and positioning*** of CITEL in the regional and international ICT/digital ecosystem.
8. To ***increase the participation*** of Member States and Associate Members in all meetings of CITEL.
9. To ***improve CITEL's procedures and support tools*** (website, search engine, data bank, access to hosted information, communication tools, etc.).

CITEL Structure

PCC.I - Telecommunications
PCC.II – Radiocommunications

OAS | CITEL


PCC.II
RADIOCOMMUNICATIONS
WG relative to CITEL's Preparation for World Radiocommunication Conferences
WG on Terrestrial Services
Working Group on Spectrum Management
Working Group on Satellite Systems and Scientific Services
Working Group on Broadcasting
Working Group to Coordinate Strategic Initiatives of the OAS related to Radiocommunications
Ad Hoc Group on "Resolutions, Decisions and Recommendations of PCC.II"

CITEL PCC.II Working Groups

1. Working Group relative to CITEL's Preparation for World Radiocommunication Conferences.
2. Working Group on Terrestrial Services.
3. Working Group on Spectrum Management.
4. Working Group on Satellite Systems and Scientific Services.
5. Working Group on Broadcasting.
6. Working Group to Coordinate Strategic Initiatives of the OAS Related to Radiocommunications.
7. Ad Hoc Group on "Resolutions, Decisions and Recommendations of PCC.II"

Questions and Comments

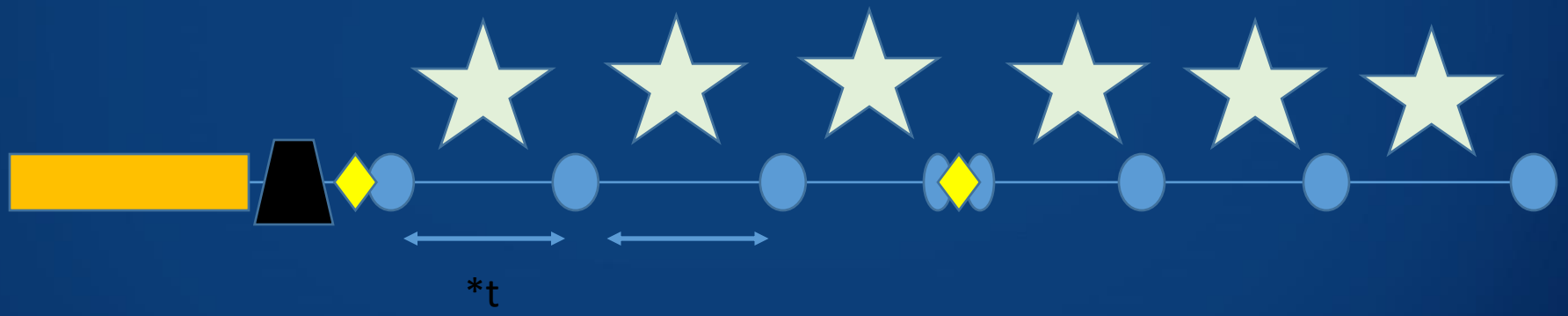
esm@nsf.gov

Thank you!

Credit: Sophia Dagnello, NRAO/AUI/NSF; NASA, STScI

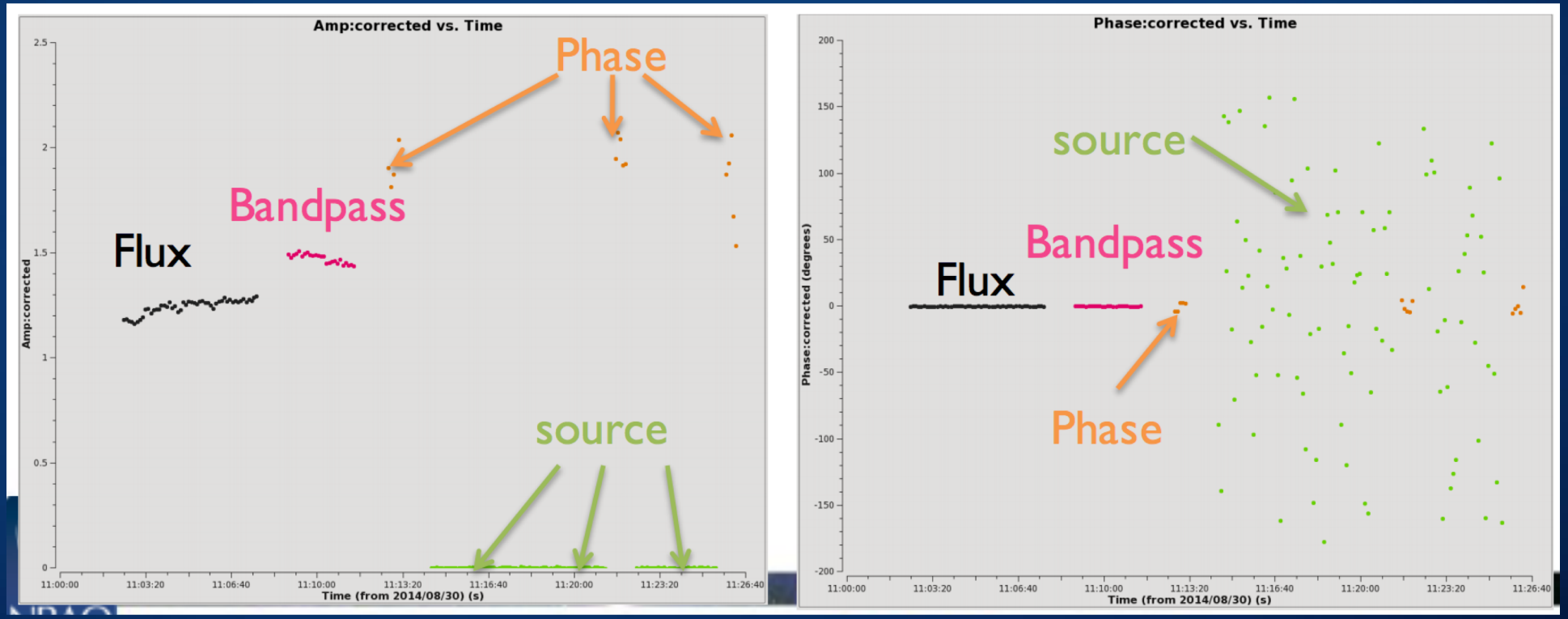

NSF

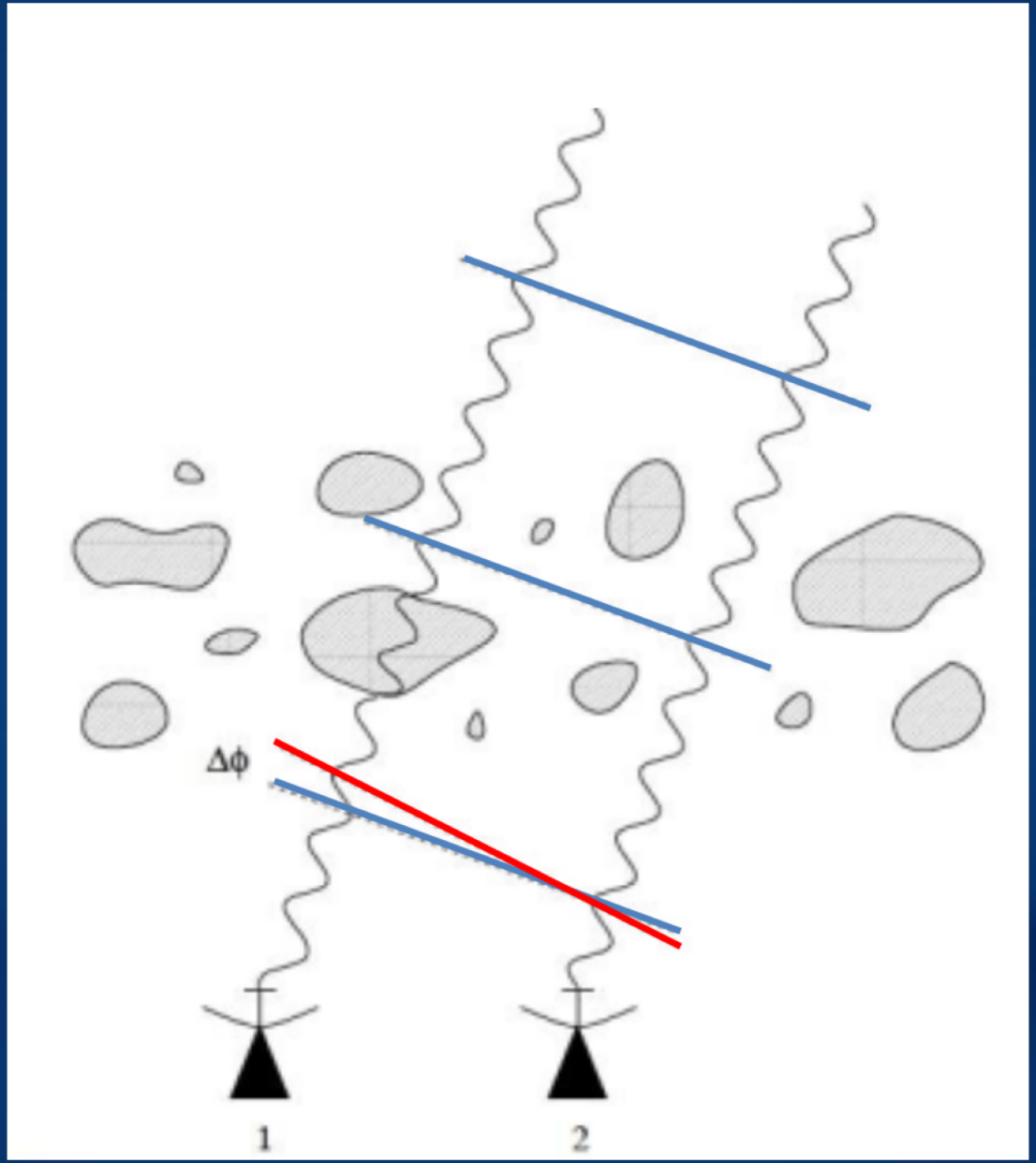
A sample Observation

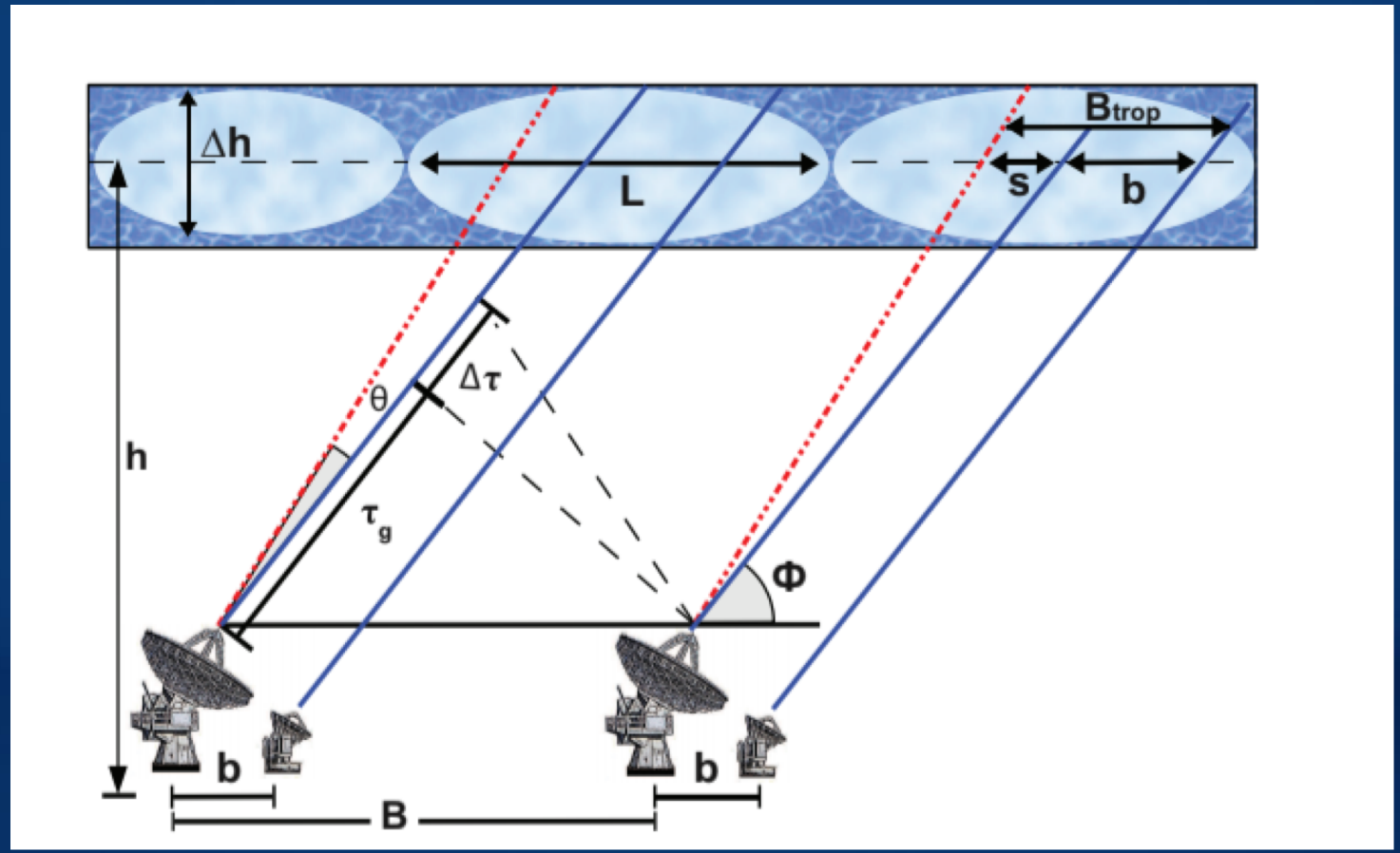


*t - Time depends on…

- Frequency of observation
- Weather conditions
- Science goal
- Phase correction techniques (WVR, paired antennas, etc.)


Amp:corrected vs. Time
Phase
Bandpass
Flux
source
Amp:corrected
Time (from 2014/08/30) (s)
Phase:corrected vs. Time
source
Bandpass
Flux
Phase
Phase:corrected (degrees)
Time (from 2014/08/30) (s)


Δϕ
1
2


Δh
L
Btrop
s
b
h
θ
Δτ
τg
Φ
b
b
B

Phase calibration