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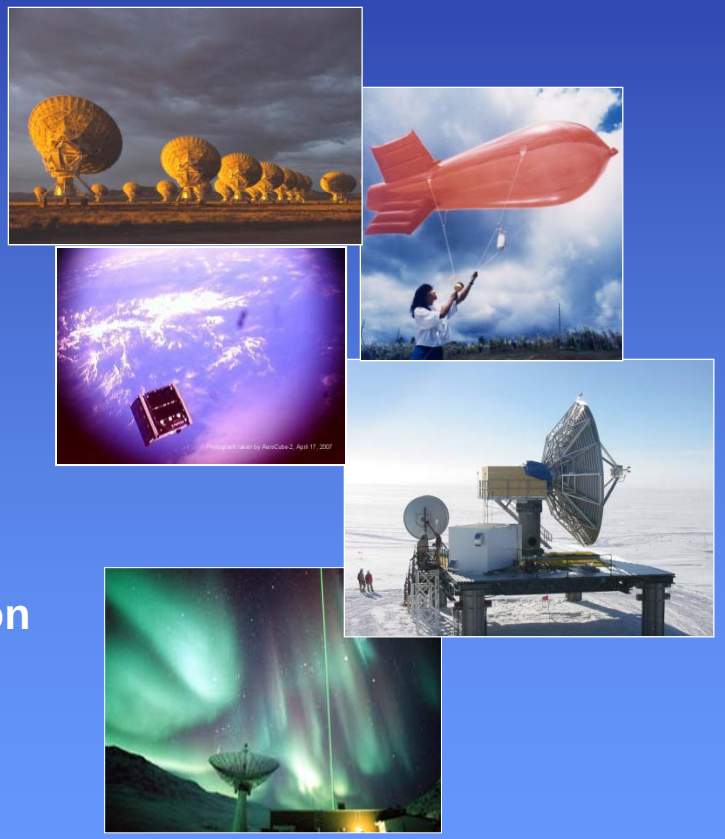
NSF and the Radio Spectrum

Mission:

Ensuring the access of the (NSF supported) scientific community to portions of the radio spectrum needed for research purposes

NSF facilities and grantees rely on access to the radio spectrum for a large variety of scientific research

- Radio & radar astronomy
- Remote sensing
  - Now moving into satellite arena with CubeSats
- Meteorology
- Atmospheric science
- Ionospheric research
- Space weather modeling and prediction
- Oceanographic research
- Arctic/Antarctic science and logistics
- Cyber-networking
- Satellites
- Biohazard/explosives detection
- Many others…



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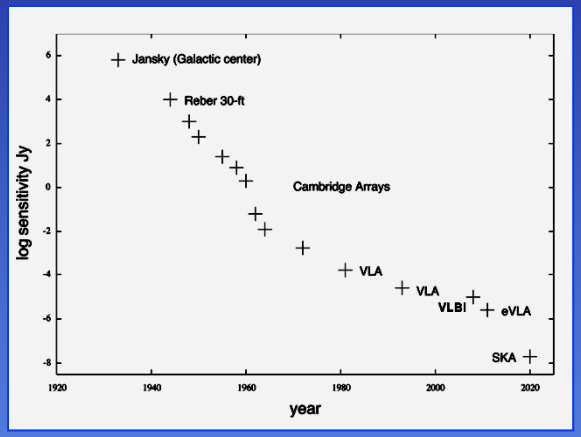
Science Requirements

Increasingly, radio astronomers desire access to the whole spectrum, as dictated by the science:

- **Desire to observe fainter sources, facilitated by increase in sensitivity**
- **Access to spectral lines (including those in non-RA spectrum)**
  e.g. Deuterium, at 327.384 MHz, detected in 2005, Helium ($^3He^+$) at 8 665.650 MHz, and Methanol (CH_3OH) at 6 668.5 MHz and 12.178 GHz
- **High Redshift**



Universal expansion shifts spectrum

Spectra of objects farther away are shifted more

Shift gives the distance and look-back time

HI line			
z = 0	0	Gyr	f (H^0) = 1420 MHz
z = 1	~ 8	Gyr	710 MHz
z = 3	~ 11,5	Gyr	355 MHz
z = 10	~ 13	Gyr	129 MHz

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Science Requirements are Reflected in the Frequency Coverage of Receivers

Single Dish Telescopes

- **Arecibo 305-m (USA)**
  - 1120 - 1730 MHz
  - 1800 - 3100 MHz
  - 3950 - 6050 MHz
  - 8 - 10 GHz
- **GBT (USA)**
  - 680 - 920 MHz
  - 1150 - 2600 MHz
  - 3950 - 5850 MHz
  - 8000 - 10100 MHz
  - 12 - 15.4 GHz
  - 18 - 26.5 GHz
- **LMT (Mexico)**
  - 70 – 350 GHz
- **MPI 100-m Telescope (Germany)**
  - 800 - 1700 MHz
  - 13 - 36 GHz
  - 40 - 50 GHz
- **Sardinia Telescope (Italy)**
  - 0.3 to 100 GHz

Interferometers

- **EVLA (USA)**
  - 1 – 50 GHz
- **ATA (USA)**
  - 0.5 - 11.2 GHz
- **ALMA (USA)**
  - 30 - 40 GHz
  - Continuous coverage: ~67 – 950 GHz
- **Milleura WFA (Australia)**
  - 80 - 1400 MHz
- **LOFAR (Netherlands--)**
  - 30 - 240 MHz
- **SKA (?)**
  - 100 MHz – 20 GHz

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Dynamic Scheduling

- Science requirements, optimal telescope use (weather) and maximum efficiency all lead to: dynamic scheduling at most advanced telescopes
- For example, the monthly schedule of the eVLA displays the available "dynamic" time (currently close to 100%). To fill the dynamic time, the most appropriate proposal from the dynamic scheduling queue is selected. The selection typically occurs a few hours before the dynamic time begins, and is based on many factors, such as the proposal's rating and the state of the array, including the weather conditions.

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The existing regulatory regime does not satisfy radio astronomy requirements!

Some Questions:

- **Are (Exclusive/Primary) radio astronomy bands (still) needed? Worldwide?**
- **Do/can passive bands satisfy the simultaneous requirements of the EESS and RA communities? (RA requirements are local, EESS requirements are mostly global)**
- **Should the radio astronomy community consider trading exclusive/primary allocations (probably not!) for high level (Rec. 769) protection across *most* of the spectrum, at a few remote locations (ALMA, SKA, eVLA, etc.) worldwide (yes!).**
- **Radio astronomers will need to develop/take advantage of**
  - > appropriate interference mitigation techniques (and use them)
  - > Cognitive radio techniques (observing in unused spectrum)
  - > Dynamic spectrum access/ Cooperative Spectrum Usage

Some of these issues are beginning to be explored, see e.g.

"Spectrum Management for Science in the 21st Century"

National Research Council, Washington, DC, 2010

" Nascent technologies exist for cooperative spectrum usage, but standards and protocols (regulation) do not" (p. 186)

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Giving up Radio Astronomy Bands Is Not Likely to Be the Answer!

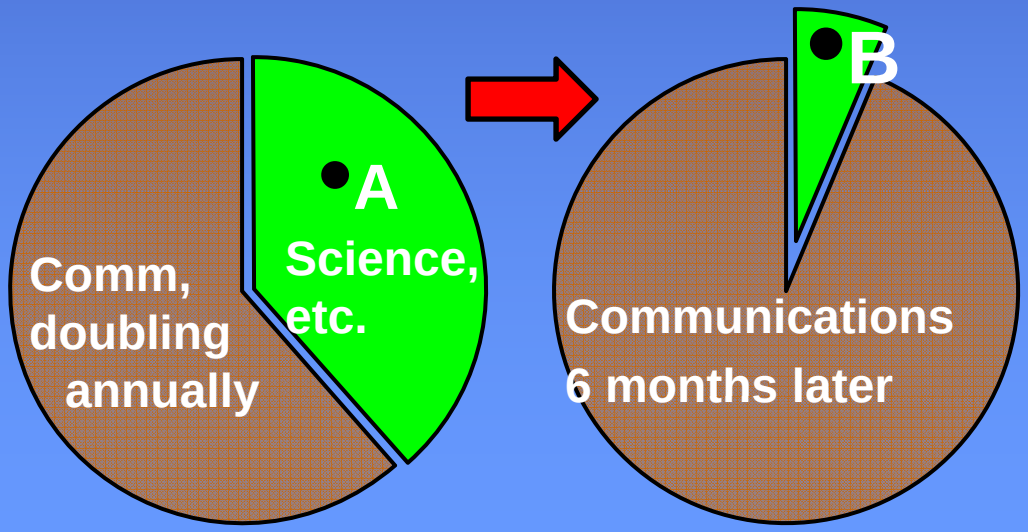
Science utilization: Roughly proportional to number of scientists, ~ steady

Communications: Exponential growth

Consider a spectral region where communications double annually

- If communications occupies 2/3 and other users yield to communications, others would shrink from "A" to "B"

-Yielding buys only six months before communications becomes 100%; science uses might represent only one month of growth.



Conversely, if Science doubled, communications capacity would again shift only ~one month

- D. Staelin
- April 2010

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NSF-sponsored Research Related to the Radio Spectrum

- **NSF funds a wide variety of engineering, scientific, and economics research directly related to wireless technology and policy**
  - > **Wireless networks, RF hardware, propagation, auction and market theory, antennas, security & encryption, policy and standards, etc.**
- **Approximate direct investment is $64 million per year, $700 million over past 11 years**
- **Research results have been incorporated into a large number of highly successful applications:**
  - > **802.11 and 802.16 (Wi-Fi and WiMAX), 911 cell phone location technology, explosives and biohazard detection, ground-penetrating radar, digital TV, adaptive antennas, SDR/CR...**

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Enhancing Access to the Radio Spectrum (EARS) and the NSF Mission: A proposed cross-directorate initiative

- Basic question to be addressed: How can an ever-increasing number of diverse users share a valuable, finite resource?

- Objective: Bring the talents of NSF-funded researchers to bear on the challenges of spectrum efficiency and access

- NSF is uniquely poised to fund research on cutting-edge topics that will improve access to the radio spectrum in a number of areas:
  Software-defined and cognitive radios, Wireless networking, Large scale integration technologies, Spectrum efficiency/modulation techniques, RFI mitigation

- The Impact of Such Research Would Be Wide-ranging:
  Commercial telecommunications, Personal, local, and wide-area networks, Remote sensing, Polar science, Weather prediction, Physics of the Universe

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Back-up slides

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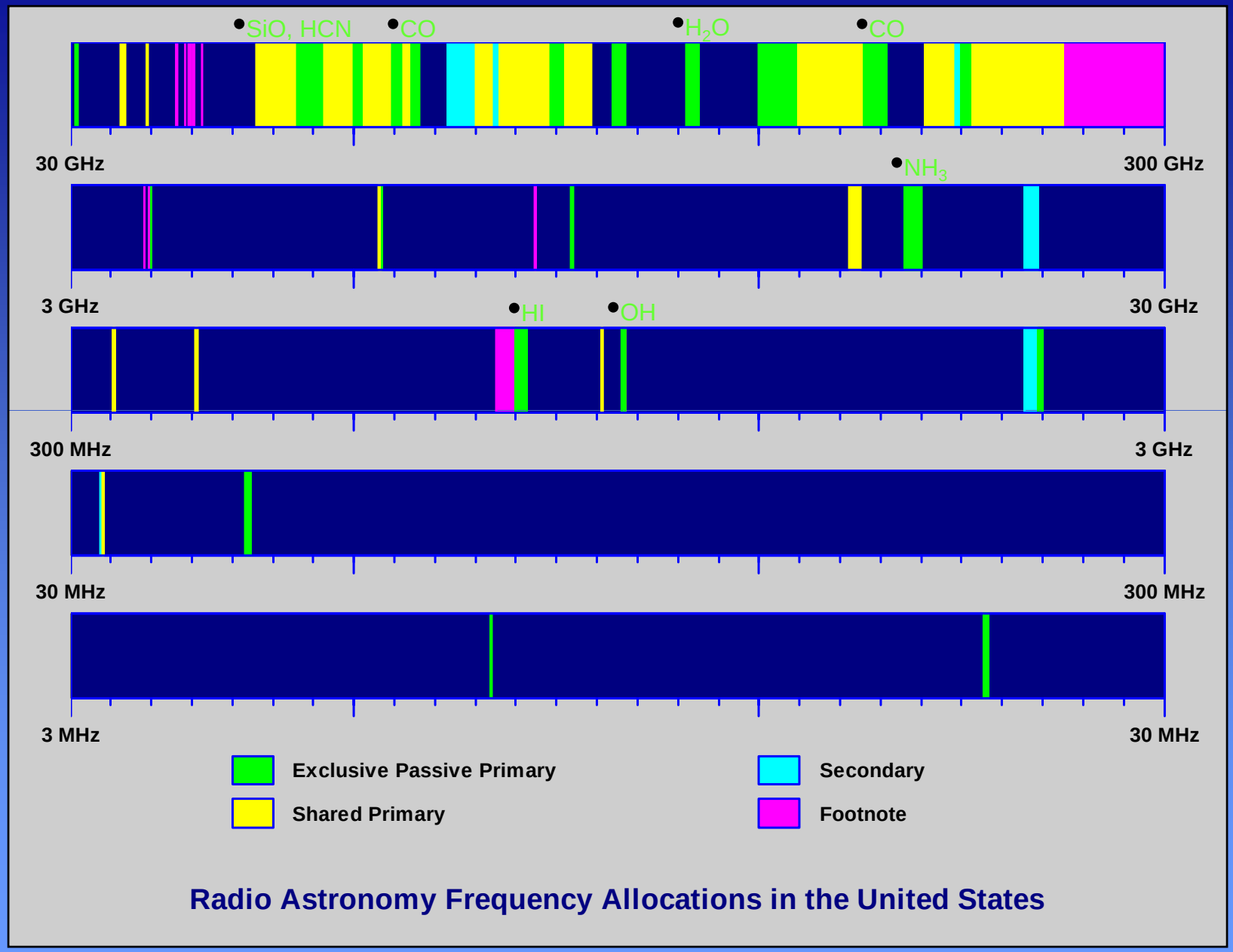

Radio Astronomy Frequency Allocations in the United States

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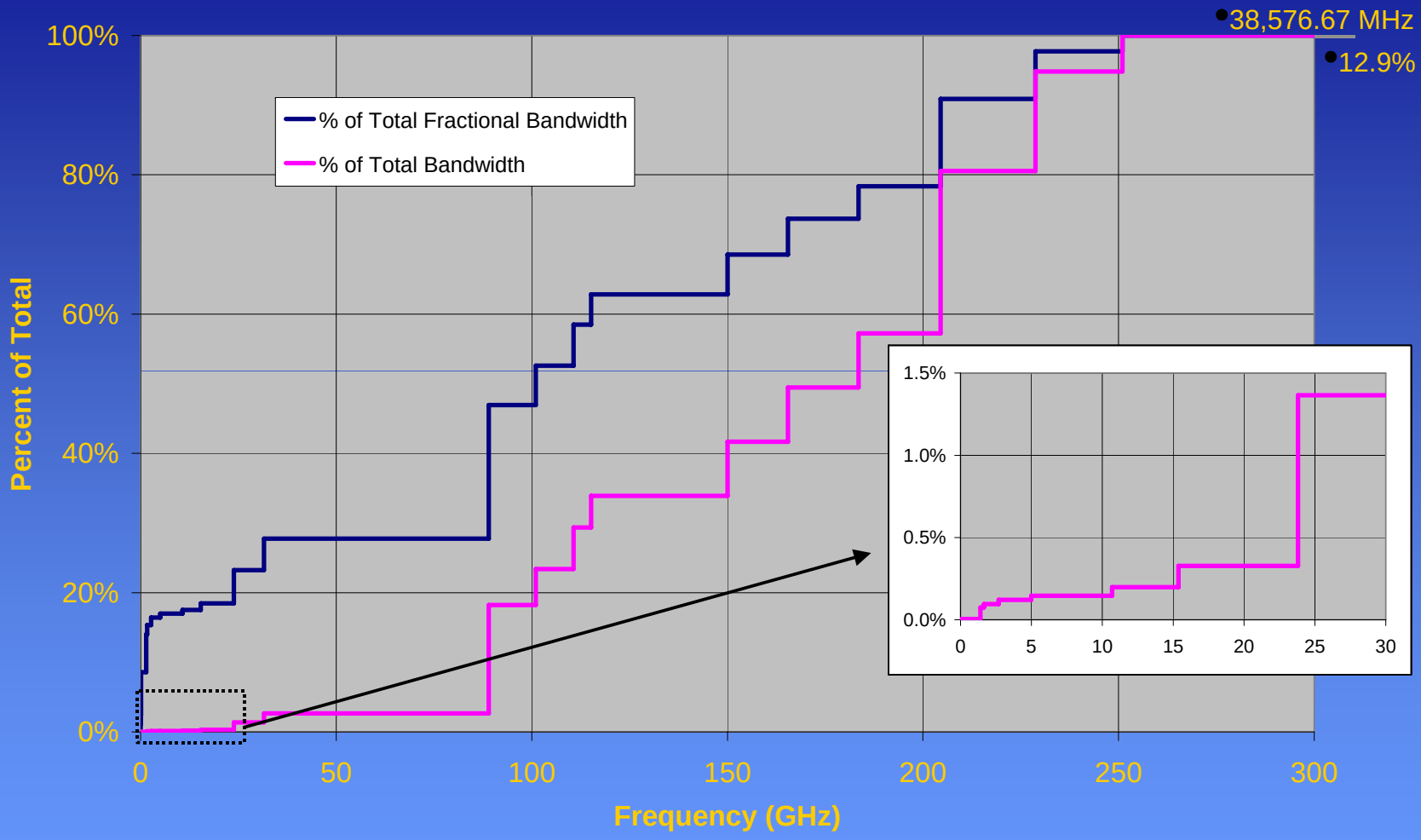
Cumulative Distribution of Exclusive Passive Spectrum Allocations



- Less than 1.5% of exclusive passive spectrum is below 30 GHz