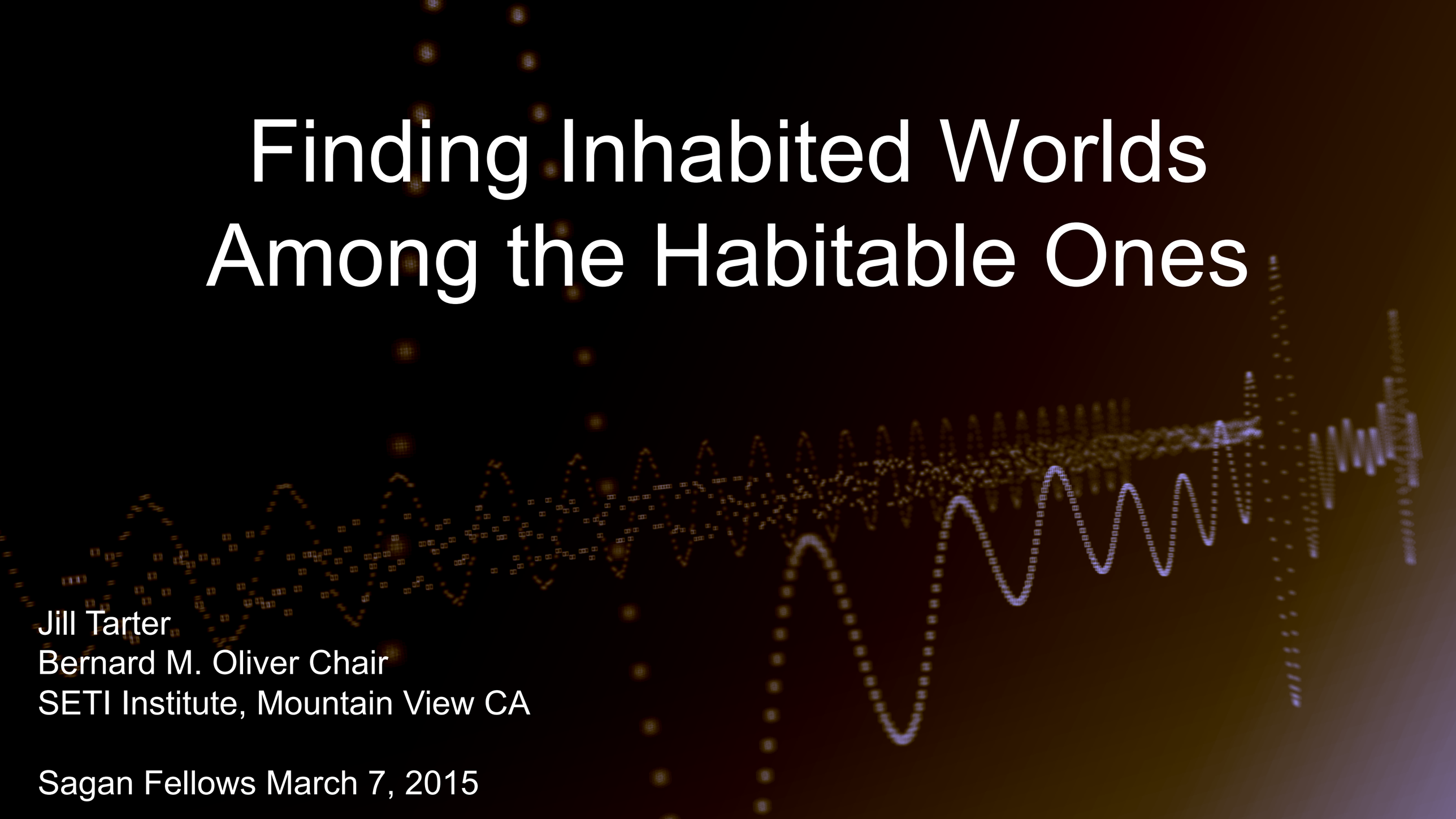
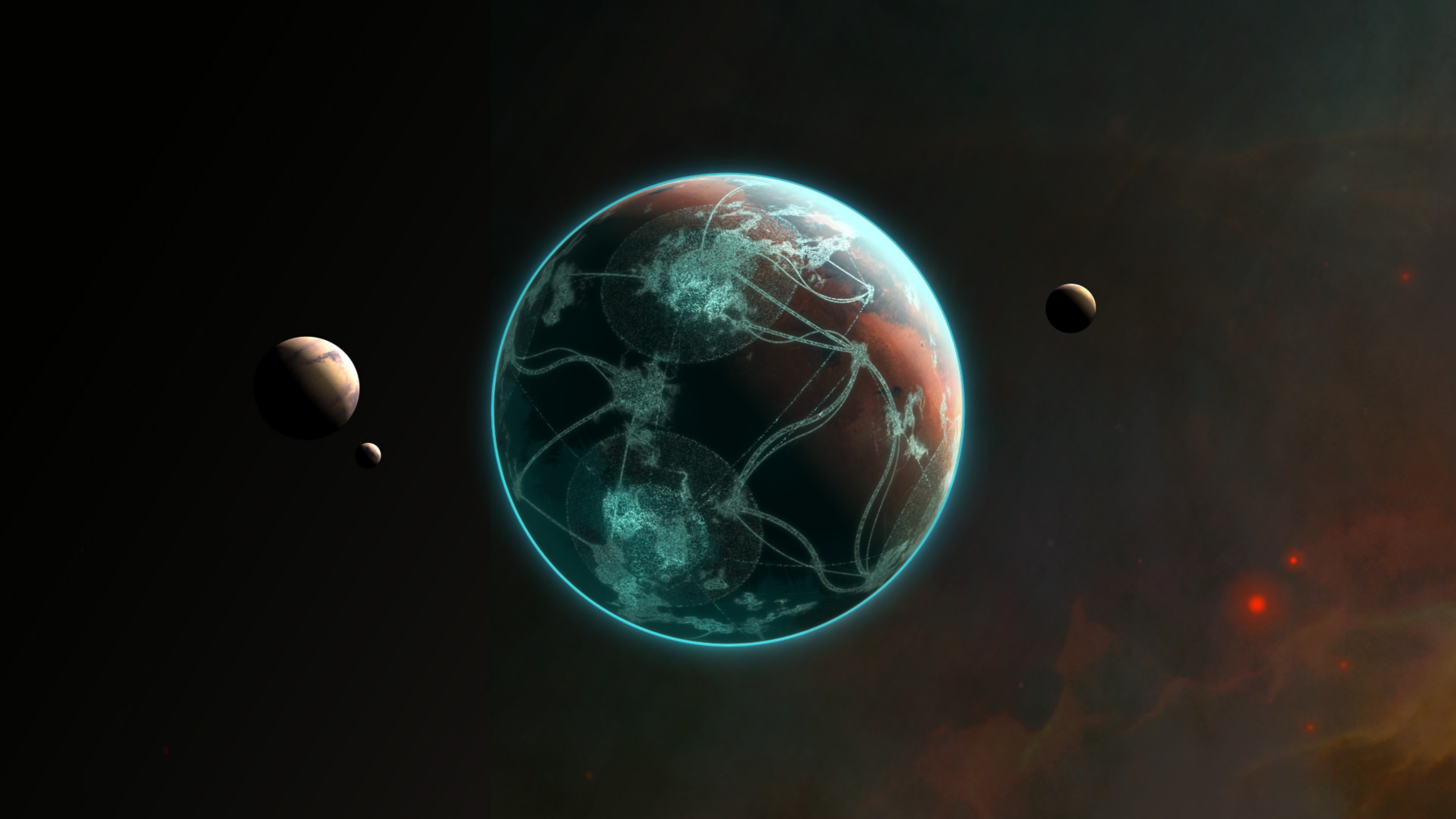
Finding Inhabited Worlds Among the Habitable Ones



Jill Tarter
Bernard M. Oliver Chair
SETI Institute, Mountain View CA

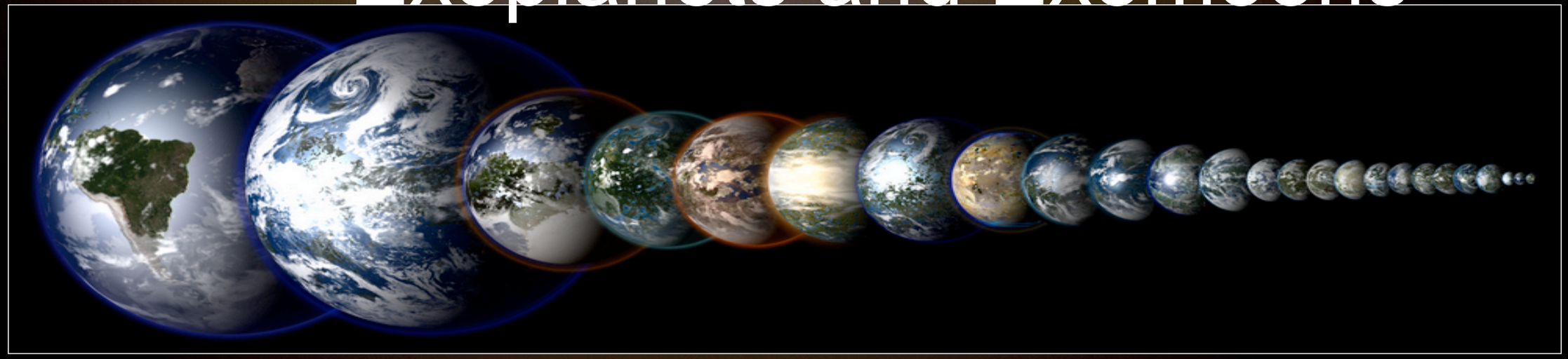
Sagan Fellows March 7, 2015

21st Century:
The Century of Biology
On Earth and Beyond



GAME CHANGERS
FROM THE 20TH CENTURY

Exoplanets and Exomoons

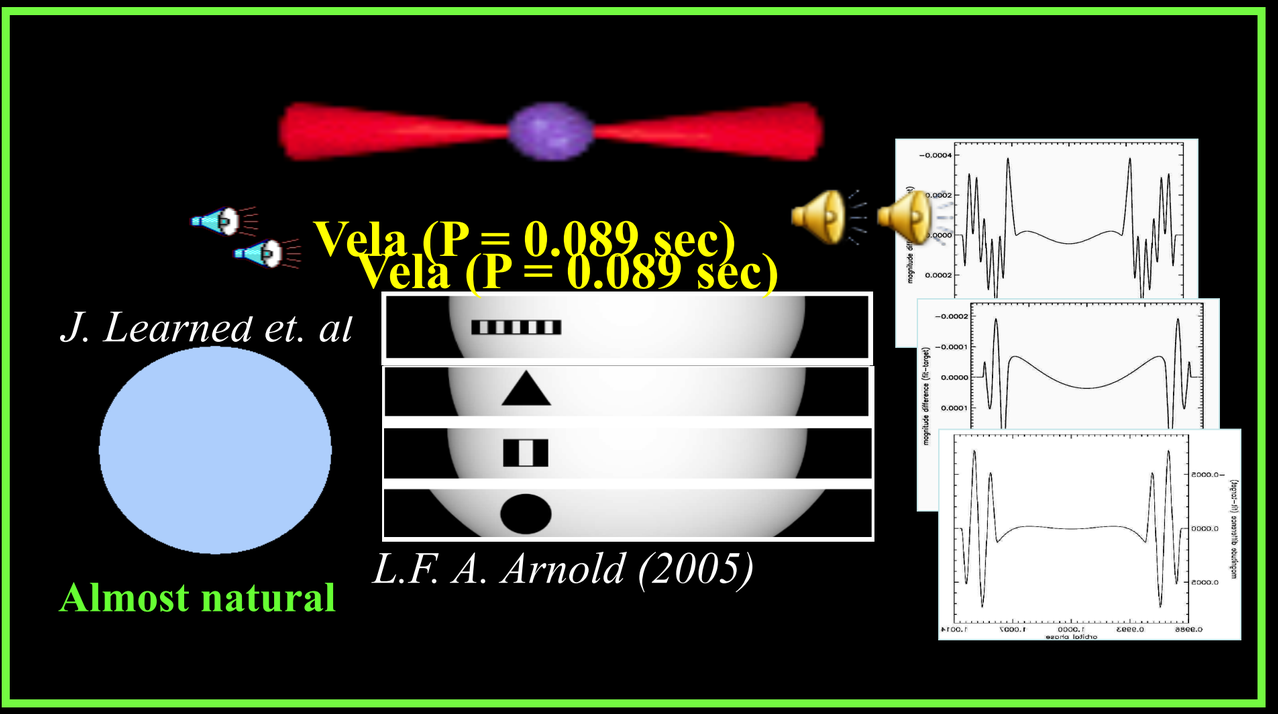


Two Kinds of Deliberate Signals

Observational consequences:
•Do astronomy!

- Signals might appear
  - Almost natural
  - Engineered

- **Build dedicated telescopes**



Single frequency on dial

Single nanosecond in time

Obviously

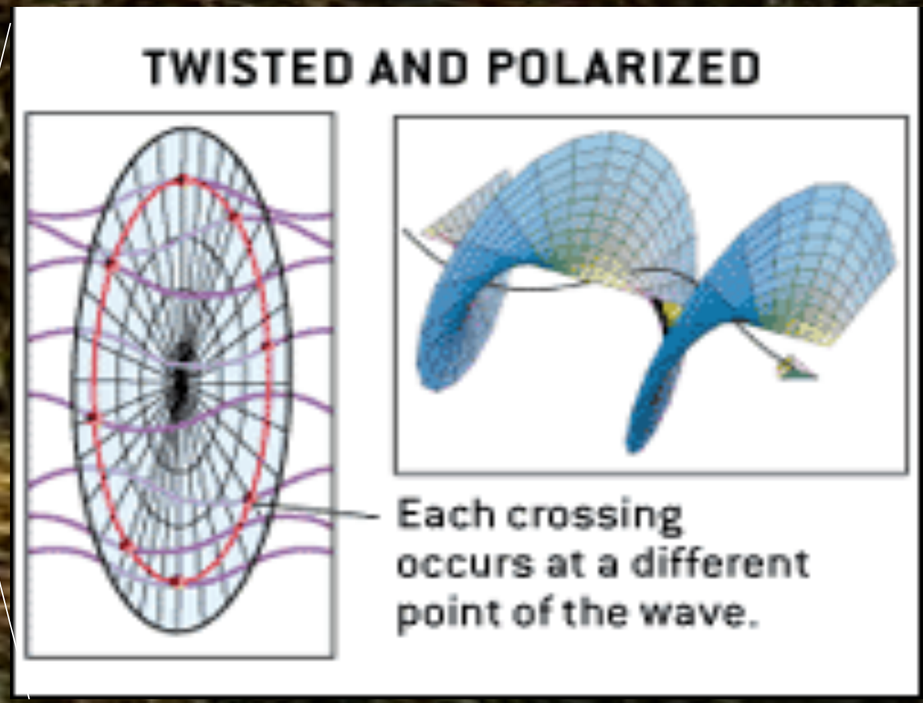
Engineered

The Cosmic Haystack Is Huge

Nine Dimensional

- **3 – space**
- **1 – time**
- **2 – polarizations**
- **1 – frequency**
- **1 – modulation scheme**
- **1 – sensitivity**

9



Current SETI Searches Work on Simple Artifacts

Frequency compression: radio CW & pulses

Δt

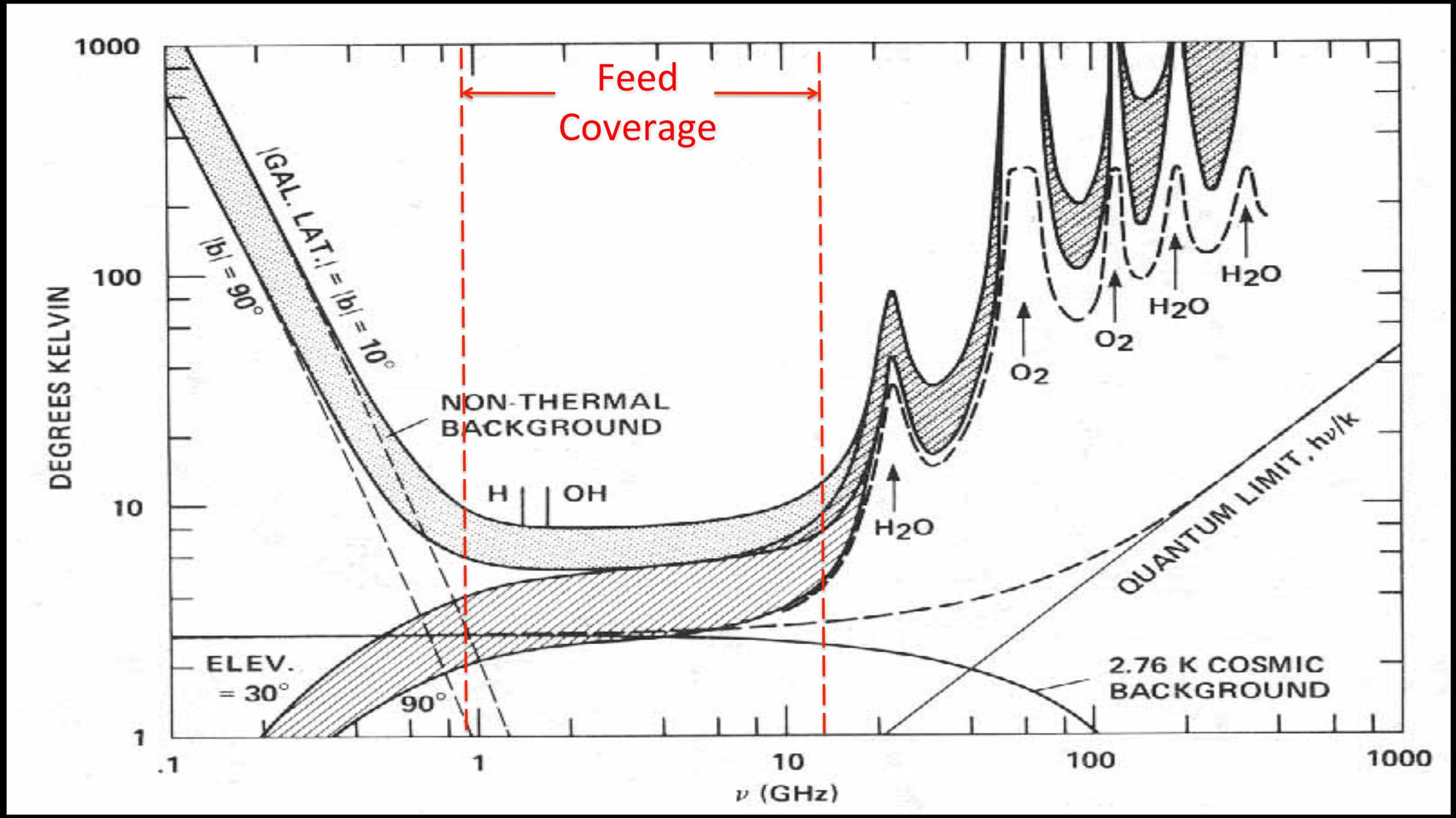
Nature doesn't

Technology can approach limit

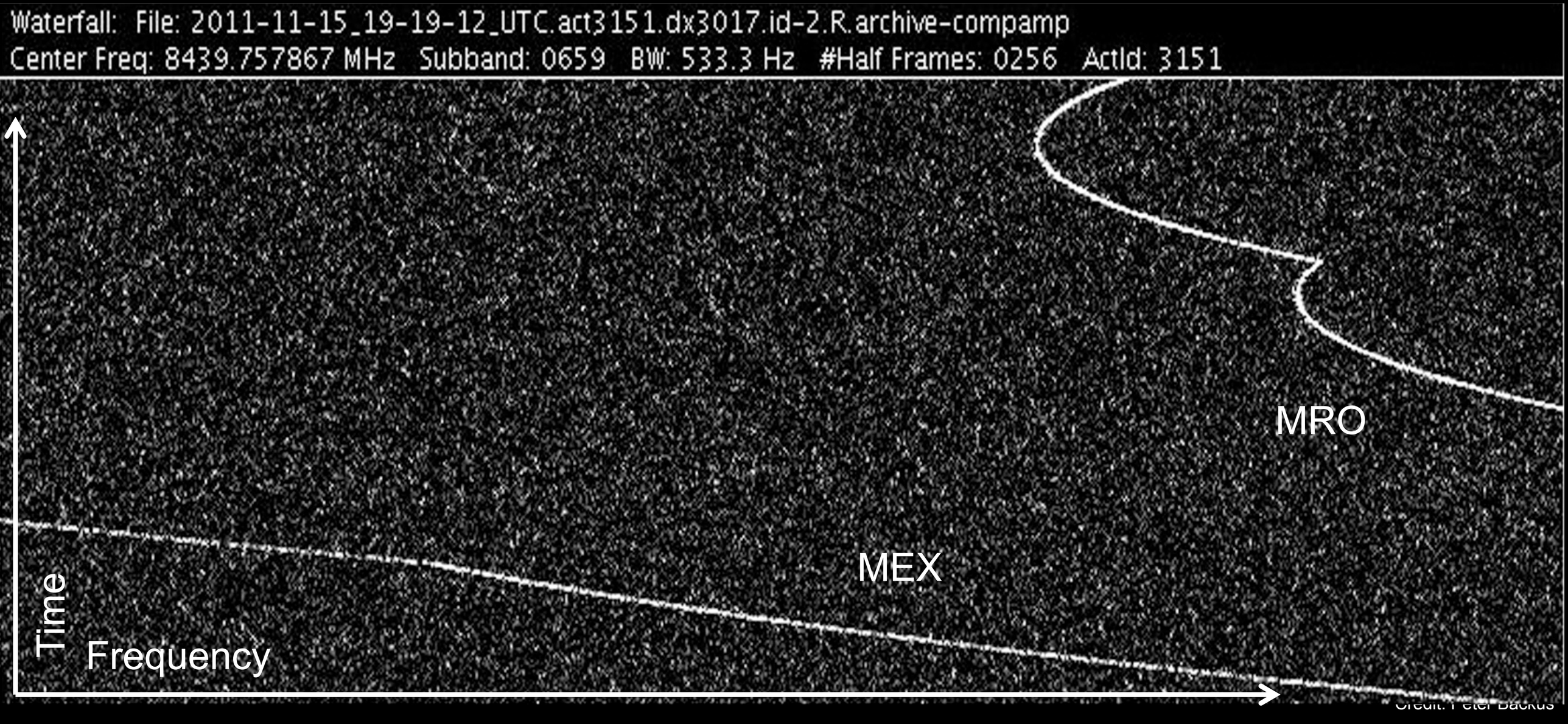
$\Delta t \, \Delta \nu \geq 1$ Uncertainty Principle

Time compression: broadband optical pulses

Terrestrial Microwave Window

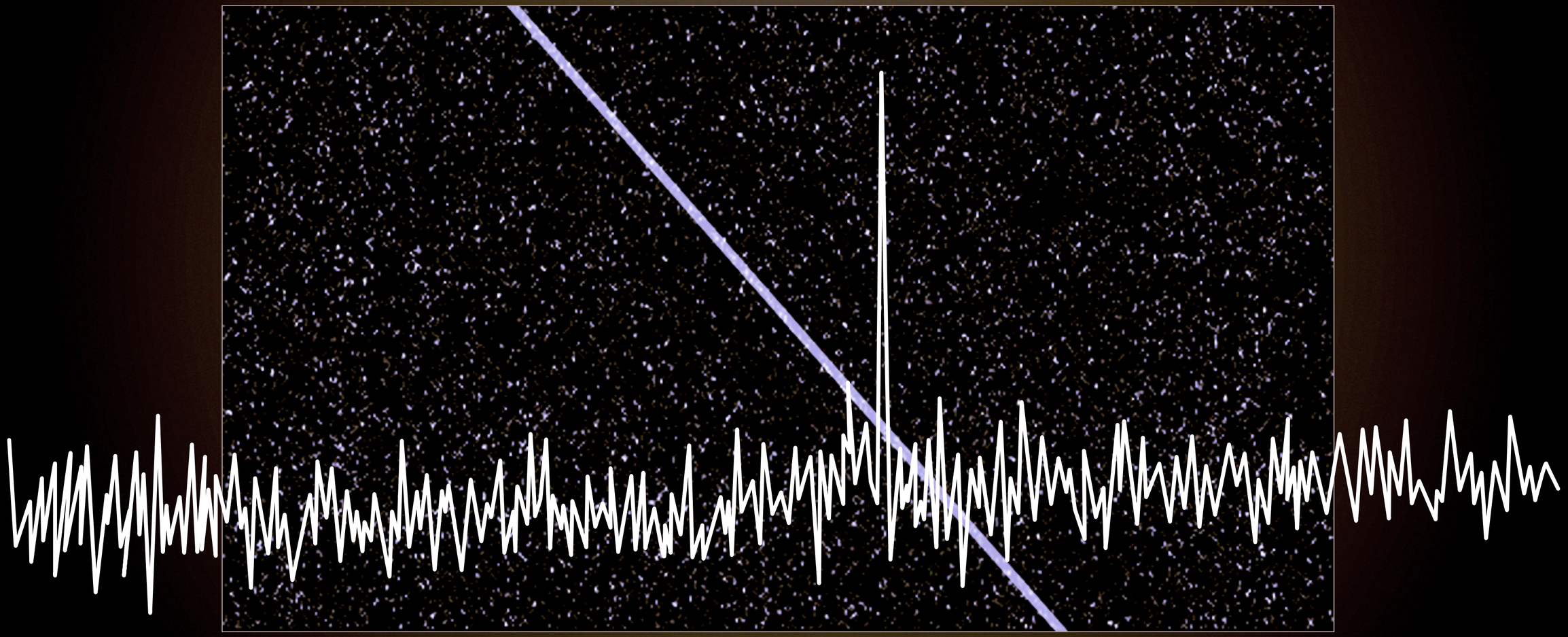


Radio: Natural vs. Engineered



Credit: Peter Backus

VOYAGER 1 SIGNAL: 106 AU AWAY



Project Phoenix: 1994 – 2004

1000 stars x 1700 MHz = 1.7 x 10^6 Star-MHz

Mopra

Parkes

2.2 x 10^5 Star-MHz

Woodbury

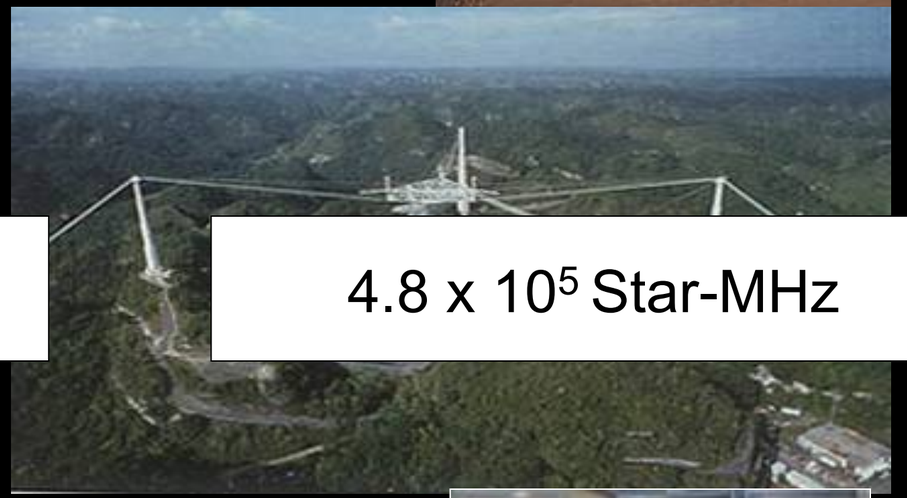
140 Ft.

2.9 x 10^5 Star-MHz

NASA-derived
TSS: full custom

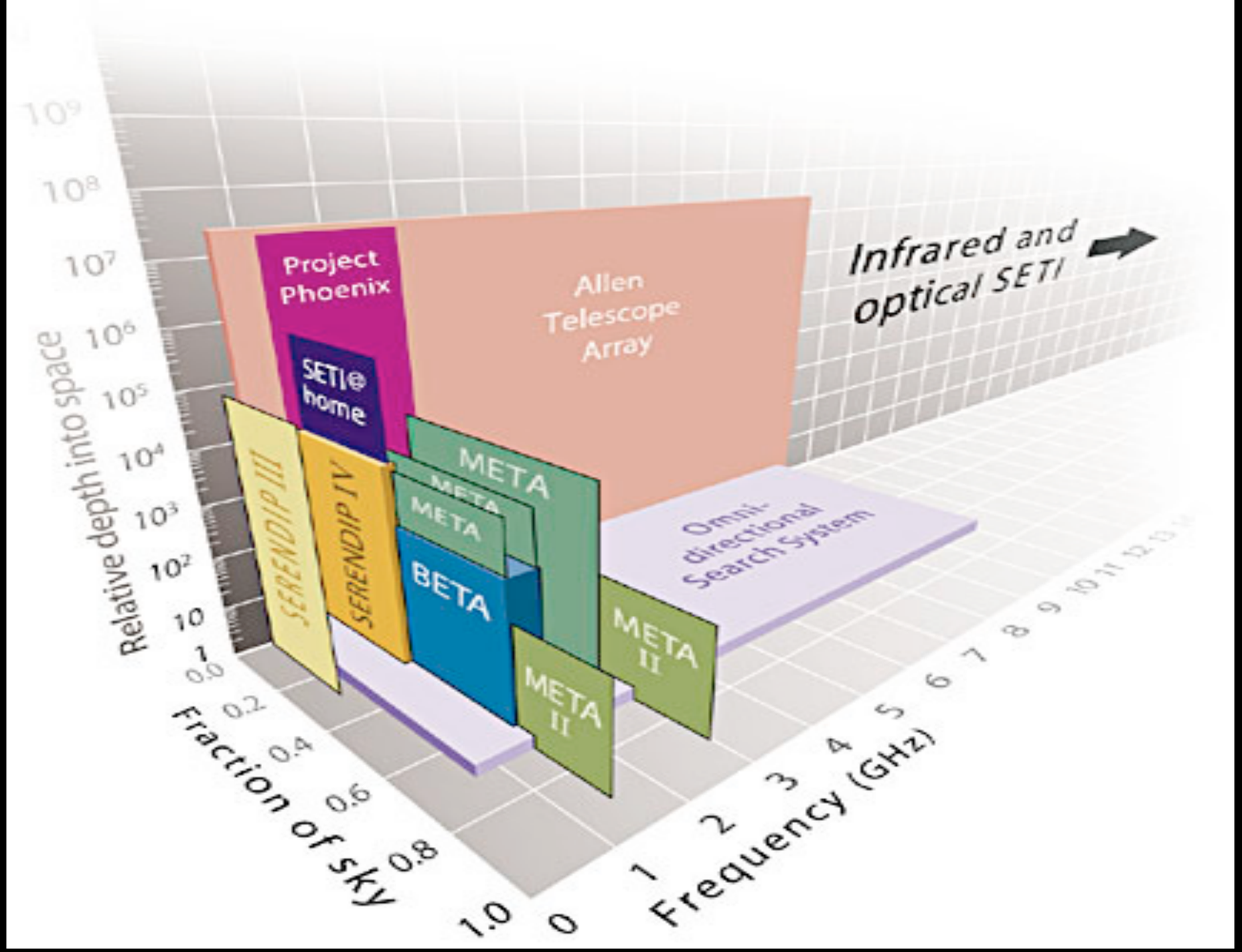
Lovell

Arecibo

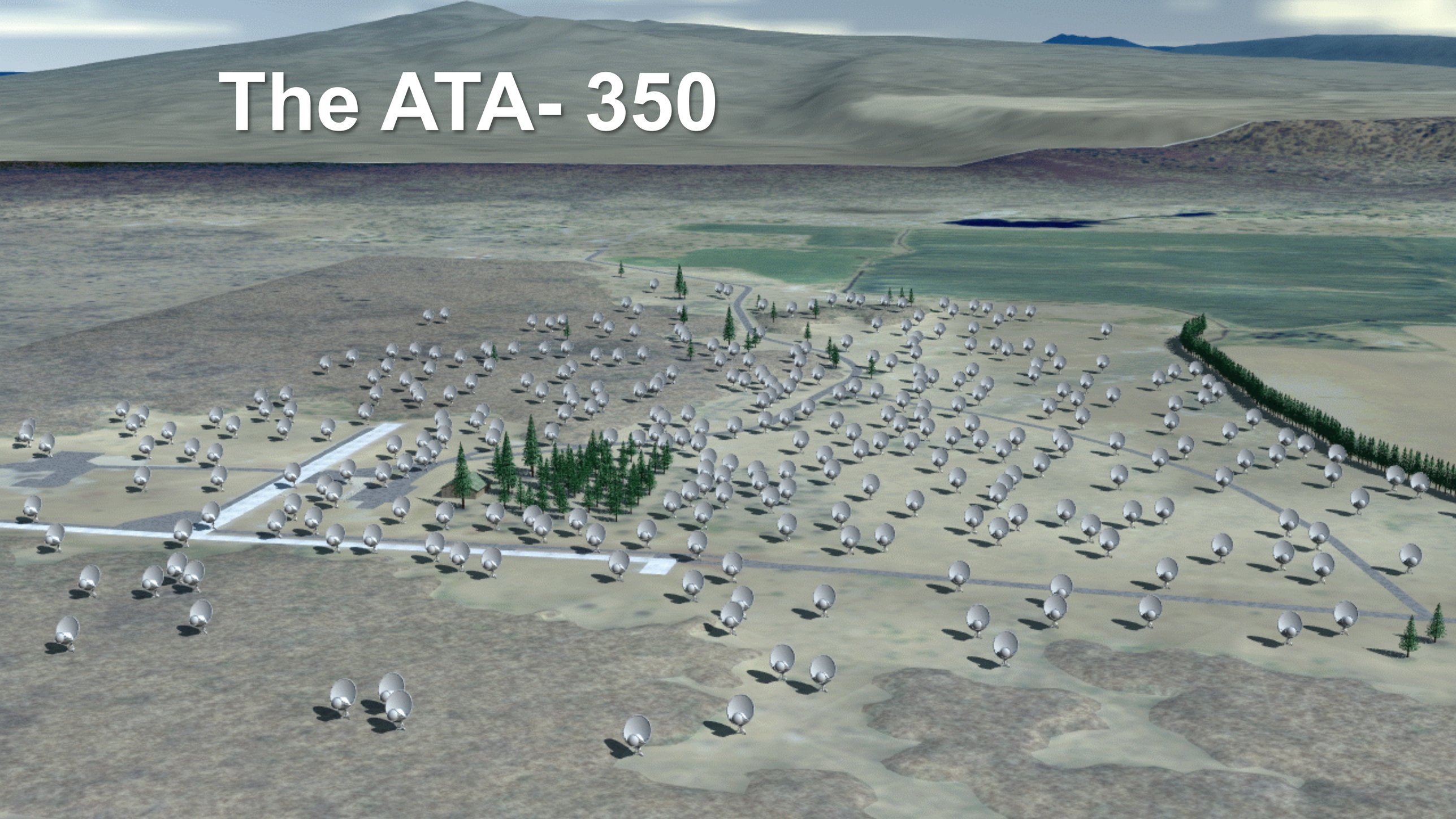


4.8 x 10^5 Star-MHz

NSS: PCs
+ accelerators


Project Phoenix
SETI@ home
Allen Telescope Array
Infrared and optical SETI
SERENDIP III
SERENDIP IV
META
META
META
BETA
META II
META II
Omni-directional Search System
Relative depth into space
Fraction of sky
Frequency (GHz)

The ATA- 350



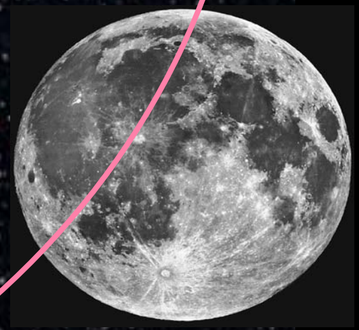
The ATA-42

6.1 m Offset Gregorian Antenna - LNSD

Andromeda Galaxy

2.5 degrees

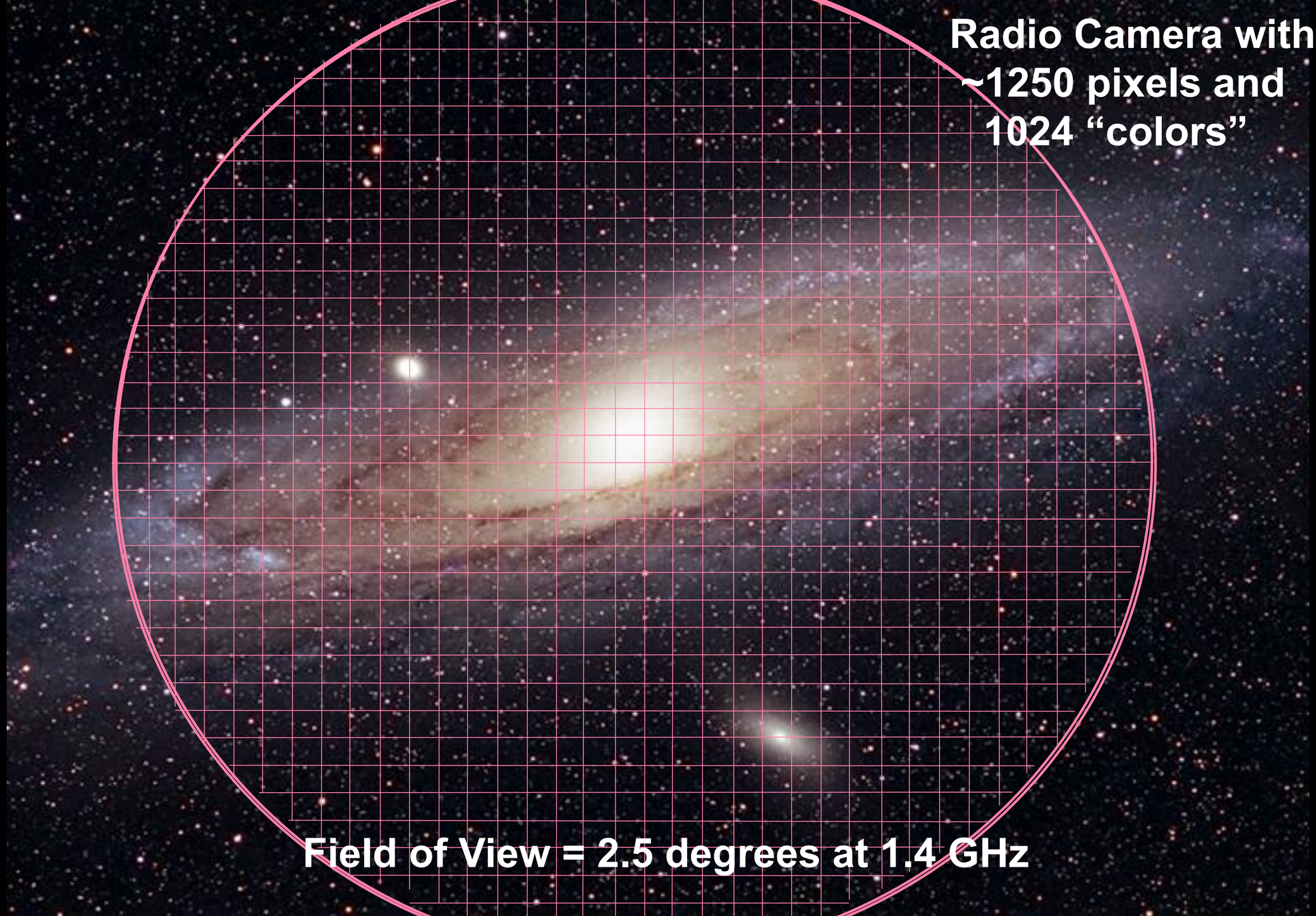
A familiar object
for scale

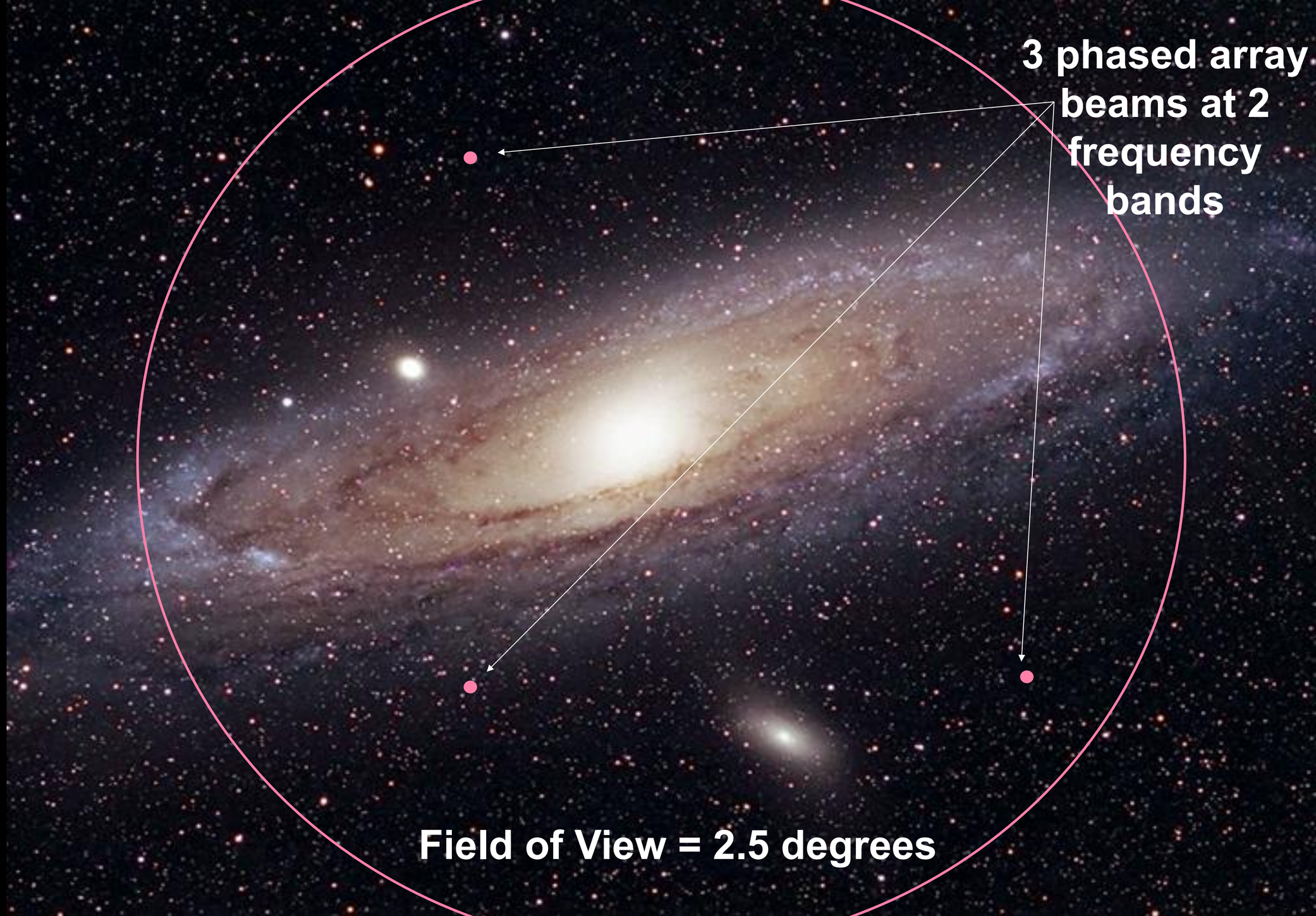


0.5 degrees

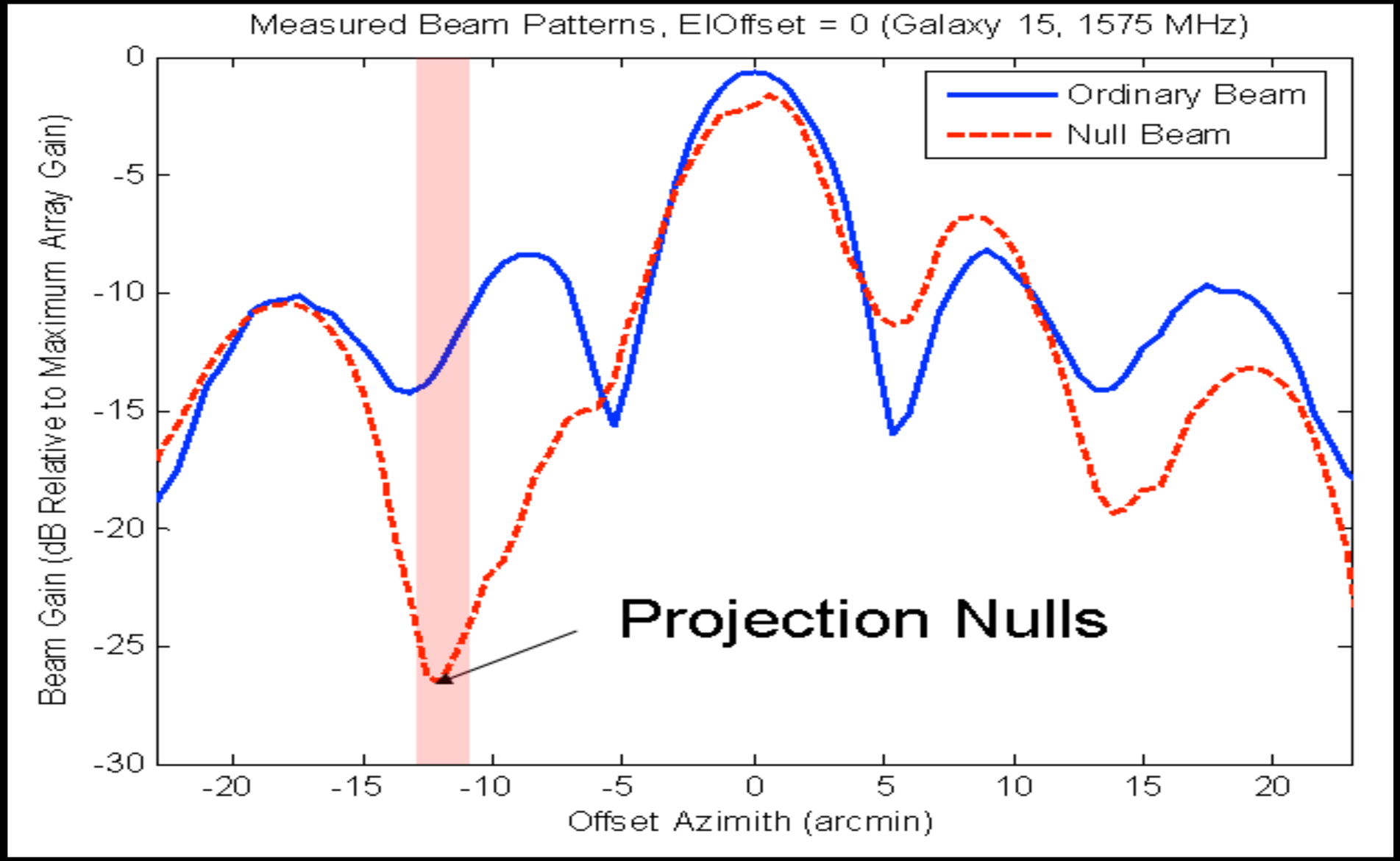
ALFA Field of View

Arecibo Field of View


Radio Camera with
~1250 pixels and
1024 “colors”
Field of View = 2.5 degrees at 1.4 GHz

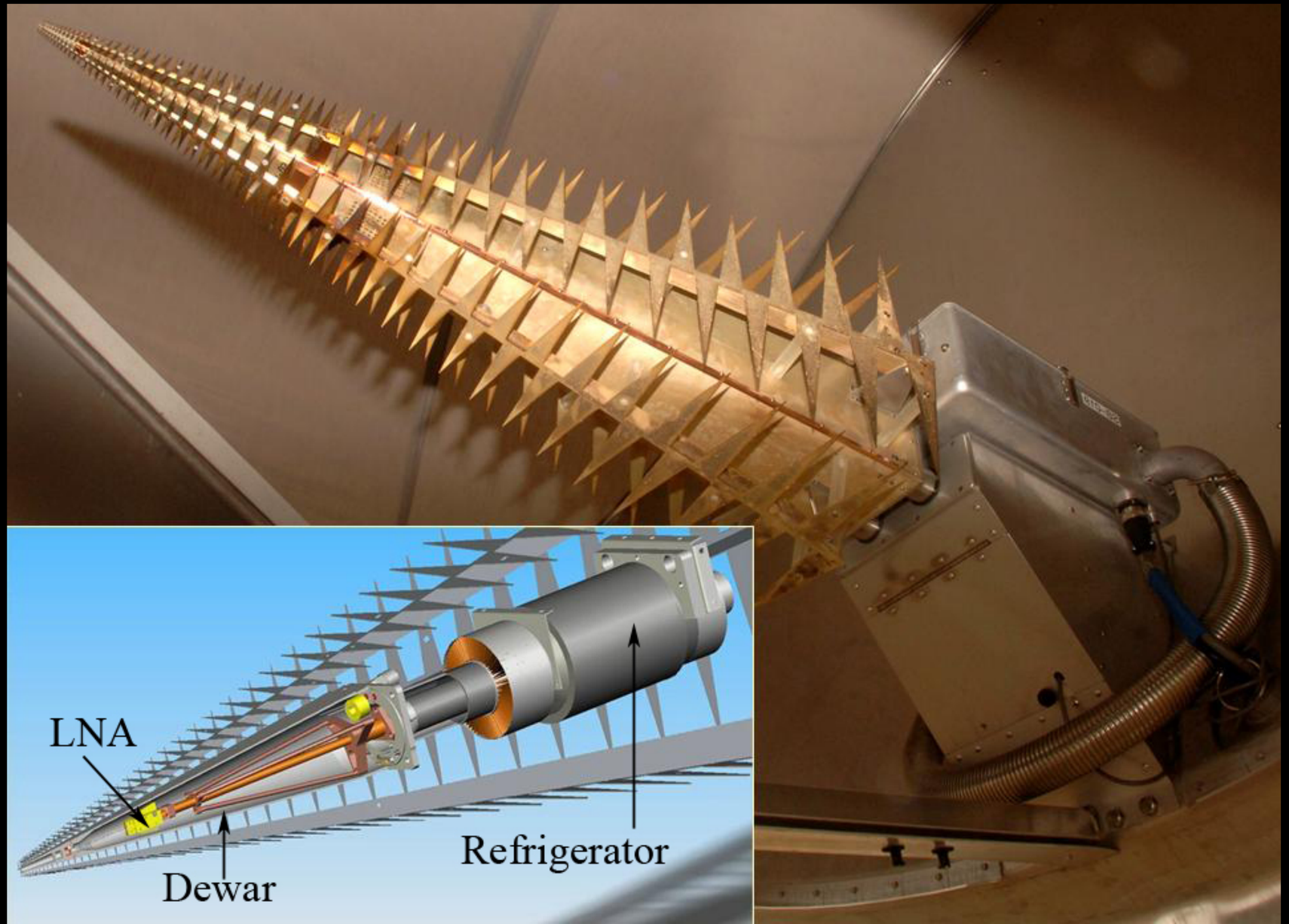

3 phased array beams at 2 frequency bands
Field of View = 2.5 degrees

Beam Plus Offset Null

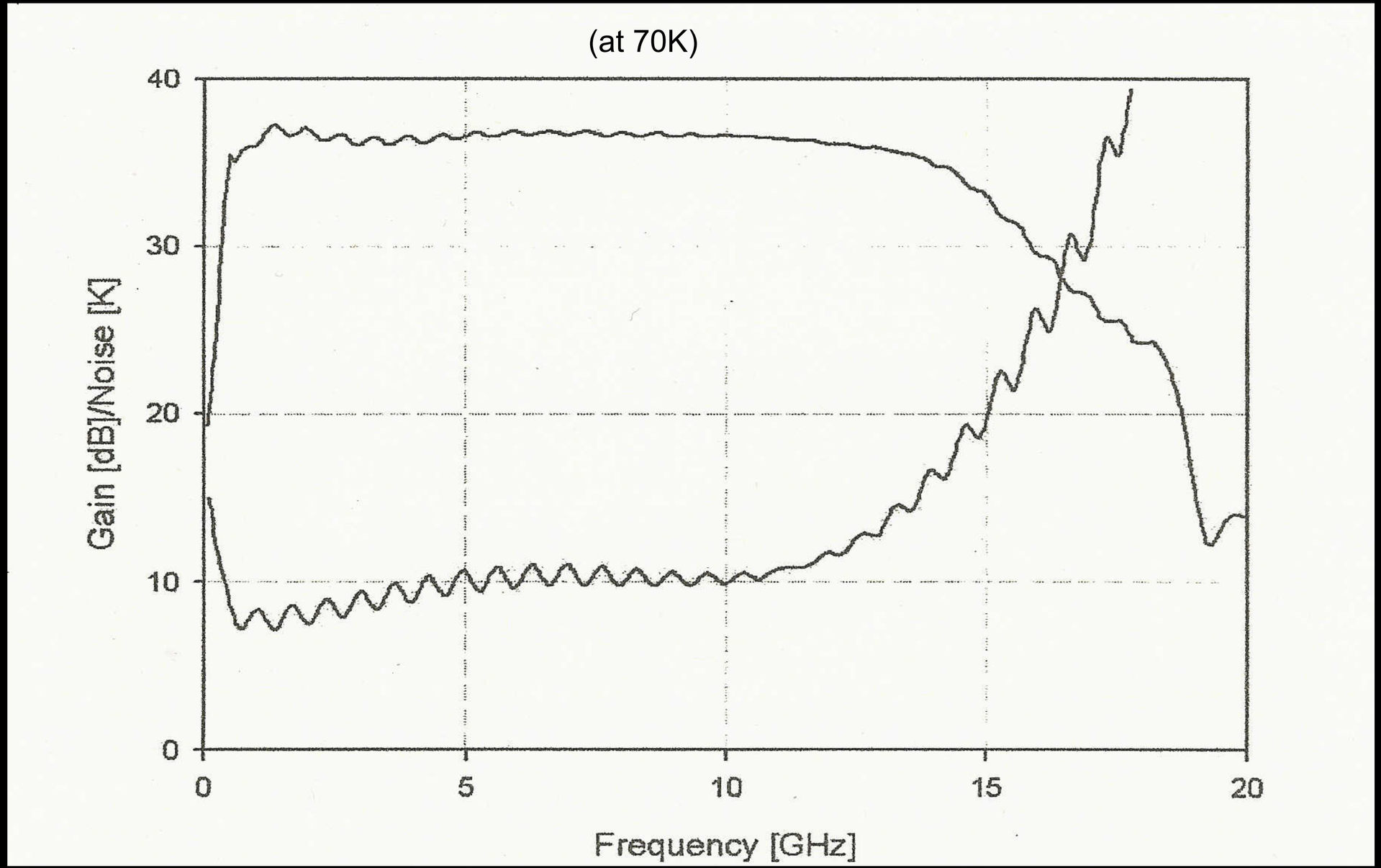


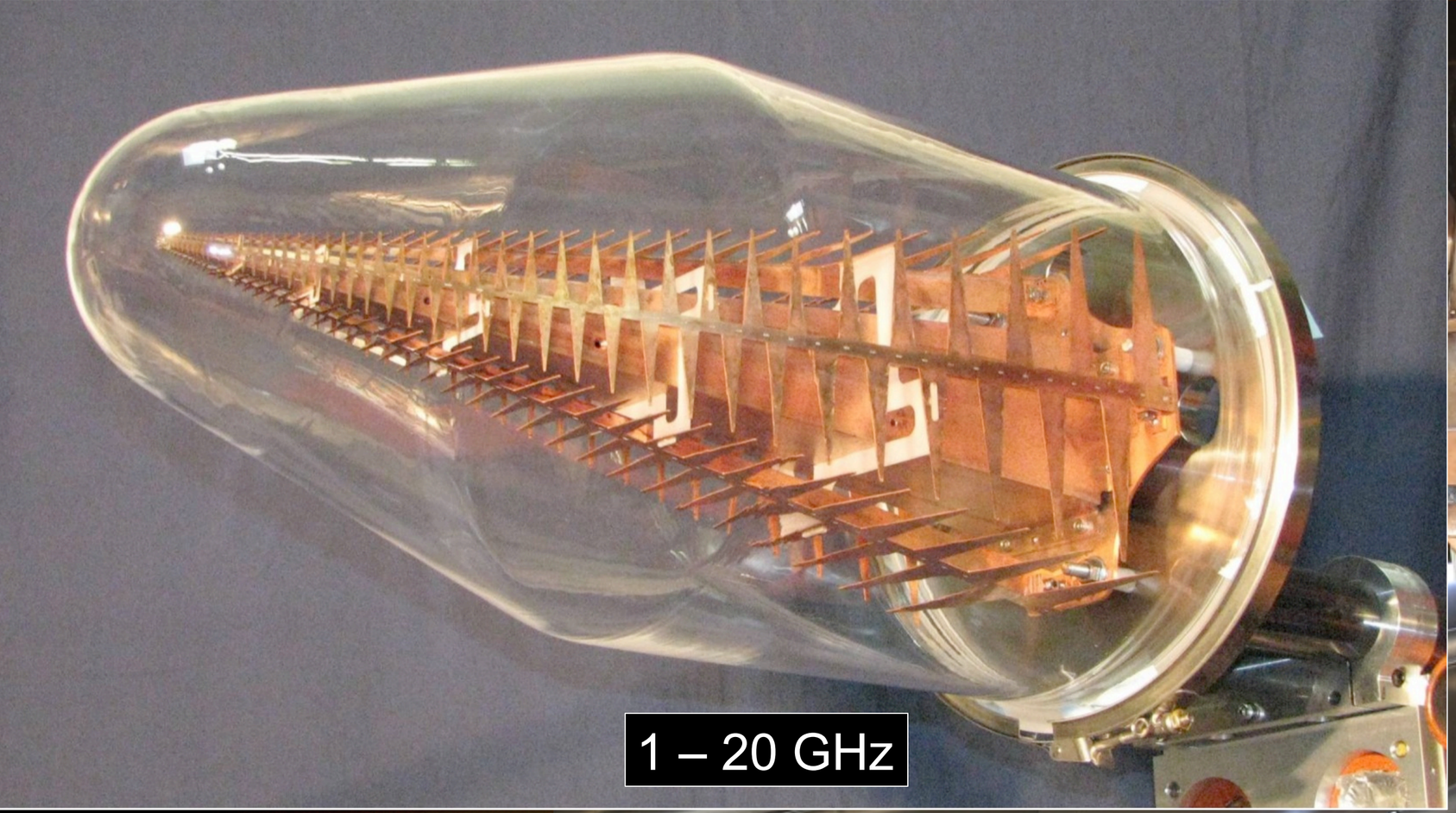
0.5 – 10 GHz

Log-Periodic Feed – Frequency Independent

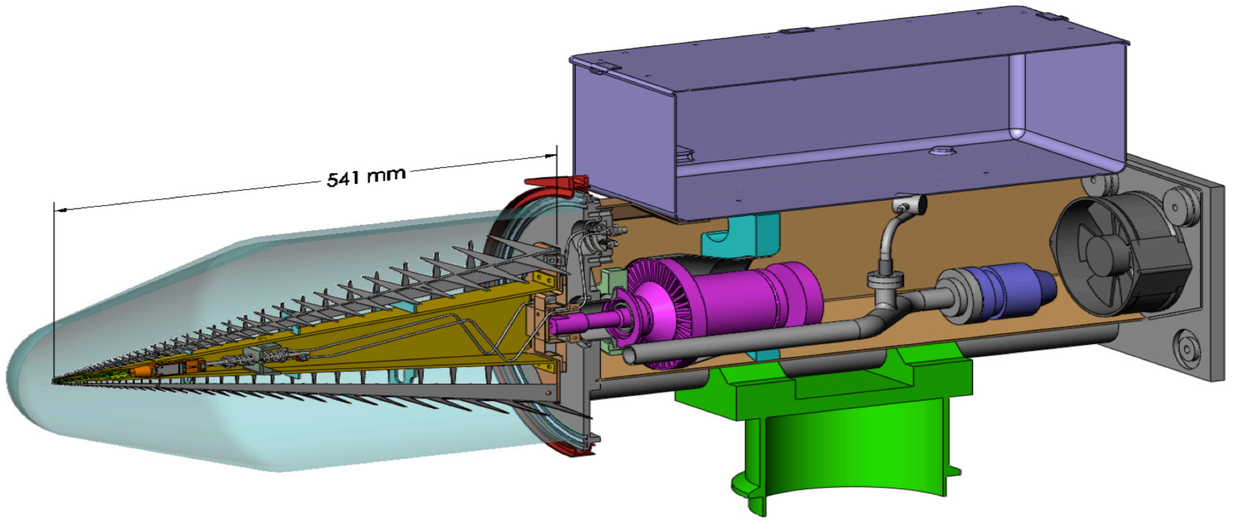


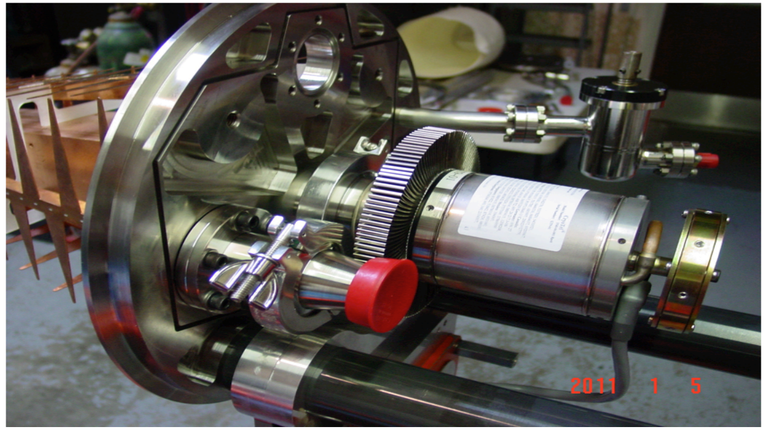
WBA 13 Noise Temp – Sandy Weinreb

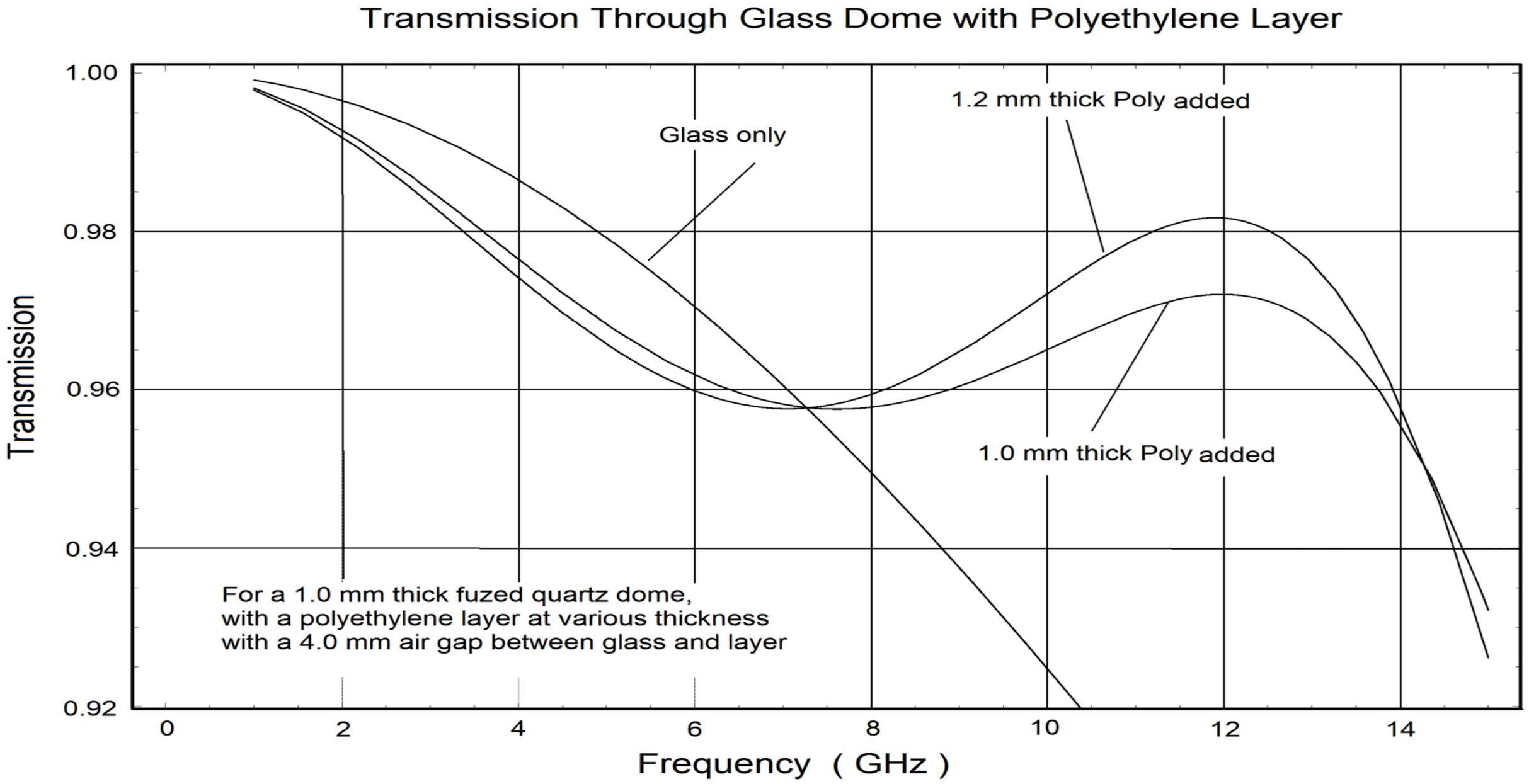


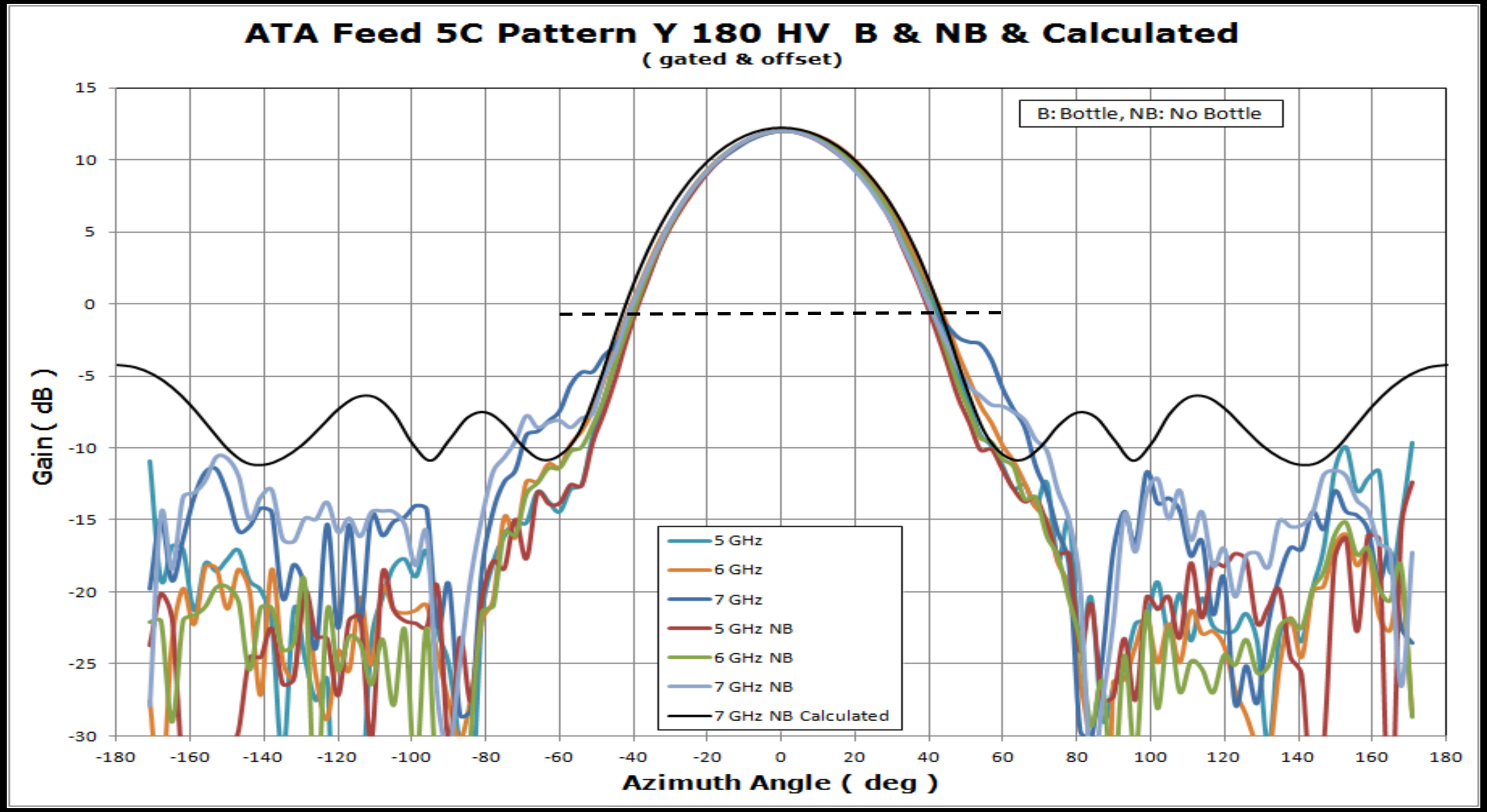

1 – 20 GHz


0.5 – 10 GHz

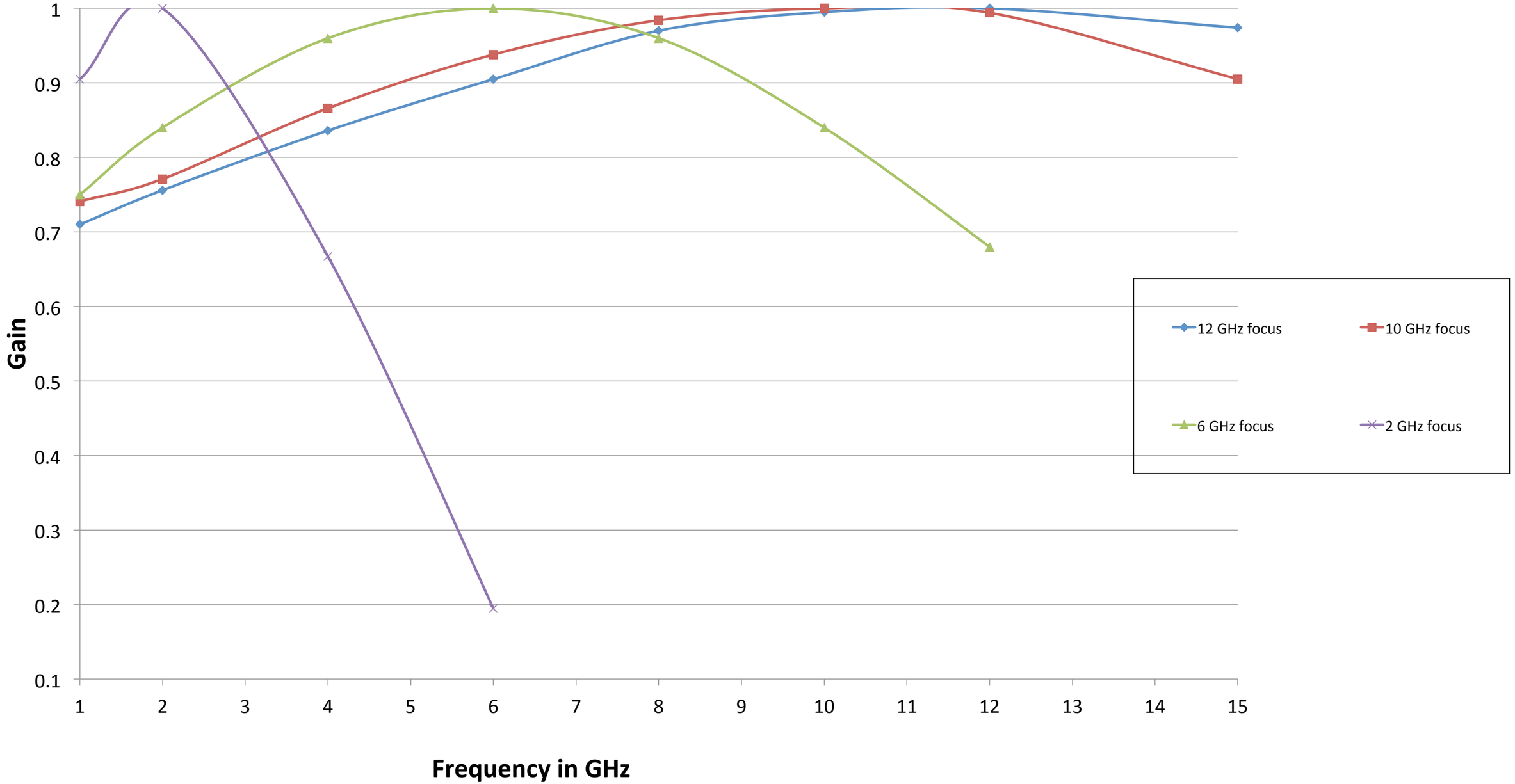

541 mm


2011 1 5

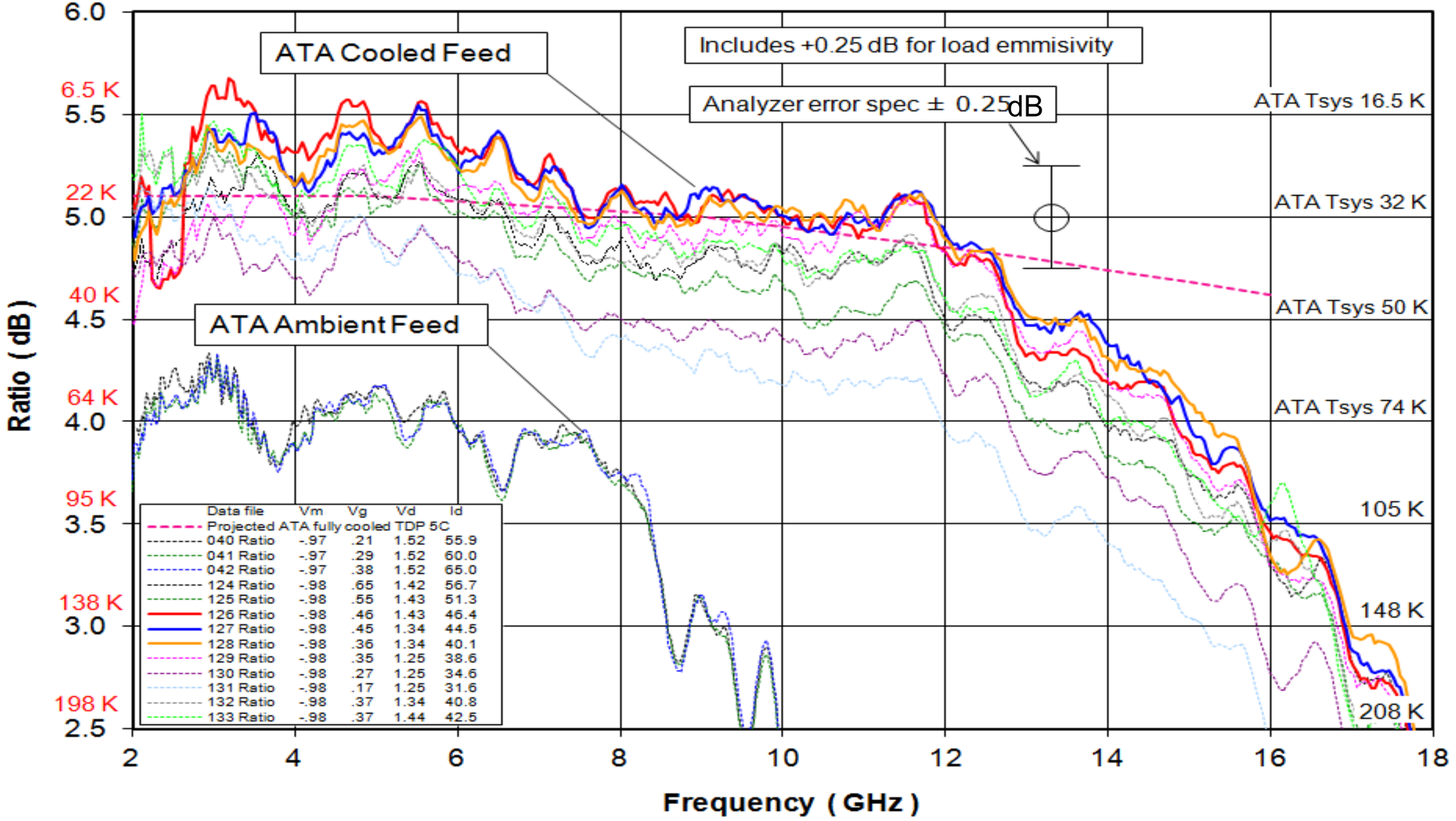

Transmission Through Glass Dome with Polyethylene Layer
1.00
0.98
0.96
0.94
0.92
Transmission
0
2
4
6
8
10
12
14
Frequency (GHz)
Glass only
1.2 mm thick Poly added
1.0 mm thick Poly added
For a 1.0 mm thick fuzed quartz dome,
with a polyethylene layer at various thickness
with a 4.0 mm air gap between glass and layer

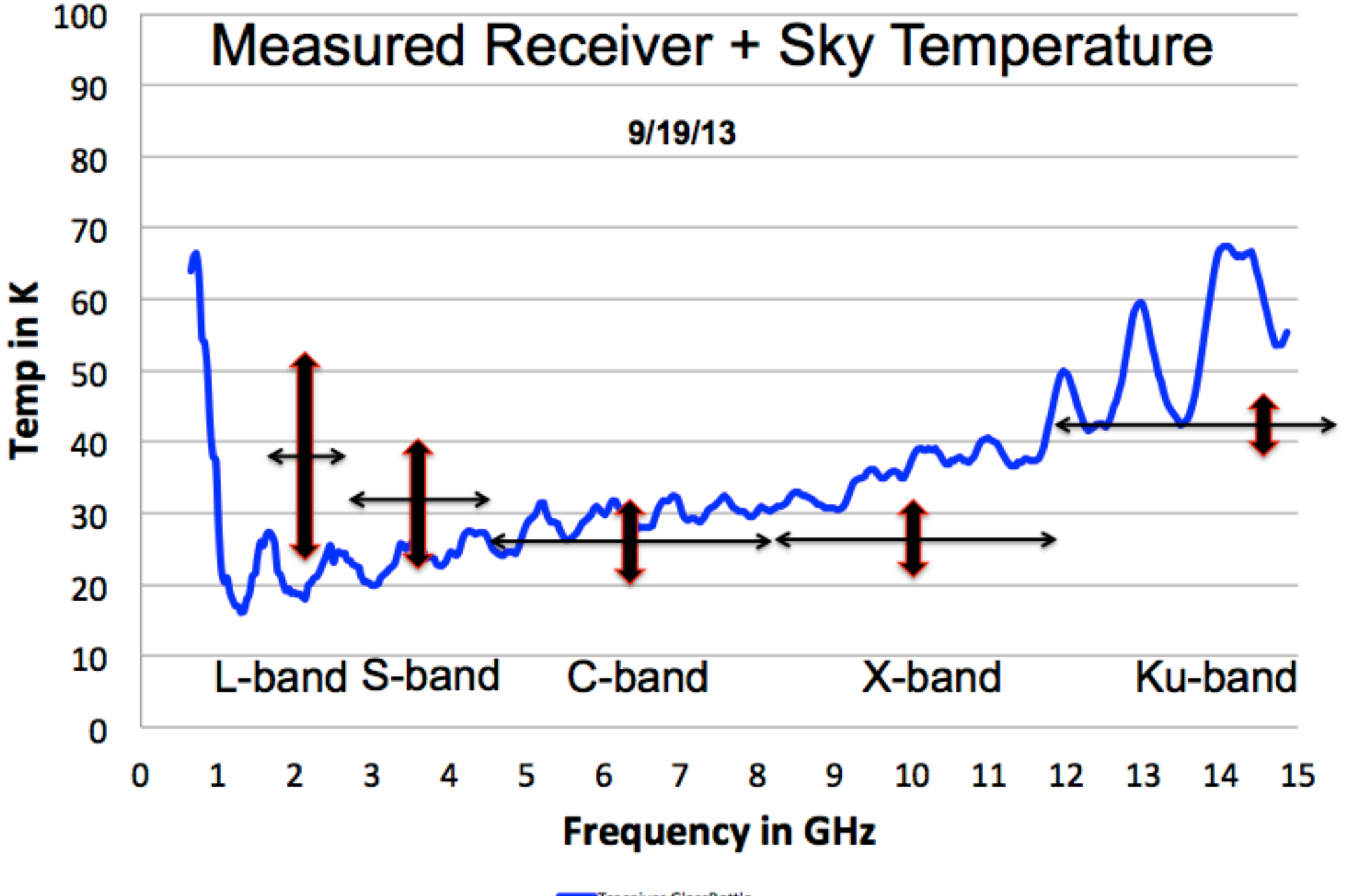

ATA Feed 5C Pattern Y 180 HV B & NB & Calculated
(gated & offset)
B: Bottle, NB: No Bottle
Gain (dB)
Azimuth Angle (deg)
5 GHz
6 GHz
7 GHz
5 GHz NB
6 GHz NB
7 GHz NB
7 GHz NB Calculated
15
10
5
0
-5
-10
-15
-20
-25
-30
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180

Gain Curves for High Frequency ATA Feed



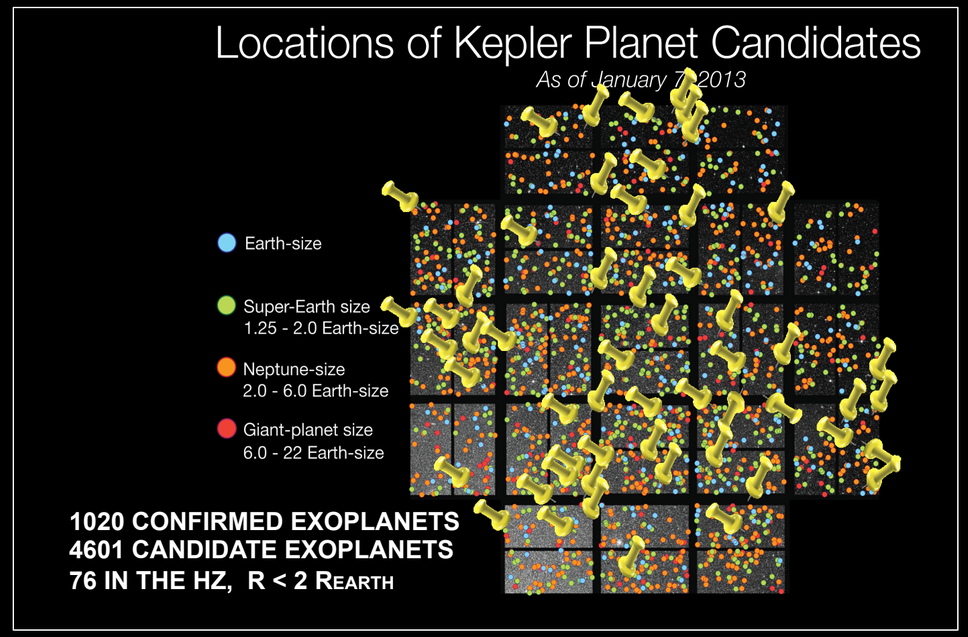
5C, X-pole, ABB-081, Test 15 Noise Ratio
Various Bias Settings, 2011-12-05 With SB-038-B(2), Y-pole, ABB-169, Test 15 Noise Ratio 2010-04-08

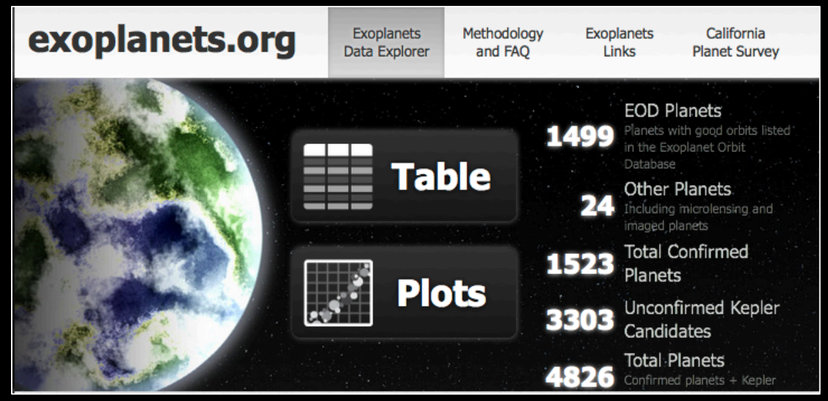



Measured Receiver + Sky Temperature
9/19/13
Temp in K
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Frequency in GHz
L-band
S-band
C-band
X-band
Ku-band
Treceiver GlassBottle

SonATA (SETI on the ATA) Since 2011

- Use 3 Beamformers to target 3 systems simultaneously with 100 million channel detectors
  - <u>All</u> Kepler candidates
  - Exoplanets from *exoplanets.org* $\delta > -30°$
- Over the entire terrestrial MW window 1-10 GHz





4.5×10^7 Star-MHz

http://setiquest.info/data/obsinfo

setiQuest Info Service

Extra information to help the search for intelligent signals from Outer-Space!

Observation Status

FOV: 2.24° Az: 325.45° El: -20.26°, RA: 19h47m Dec: 50°35',* 10/5/14, 10:01:17 PM CDT

now

time

date

11:00 p

10:00 p

9:00 p

45

0

-45

W

N

E

S

Sun | Planets | Const. | SETI | Events | Prefs | Inbox | Store | Help

htt

Distant Suns-Max: Unleash Your Inner Astronaut

By First Light

Open iTunes to buy and download apps.

View In iTunes

This app is designed for both iPhone and iPad

$9.99

Category: Education
Updated: Nov 15, 2012
Version: 3.4.2
Size: 63.3 MB
Language: English
Seller: Mike Smithwick
© 2012
Rated 4+

Requirements: Compatible with iPhone, iPod touch, and iPad. Requires iOS 4.3 or later.

Customer Ratings

Current Version:
★★★★½ 18 Ratings

All Versions:
★★★★ 395 Ratings

Description

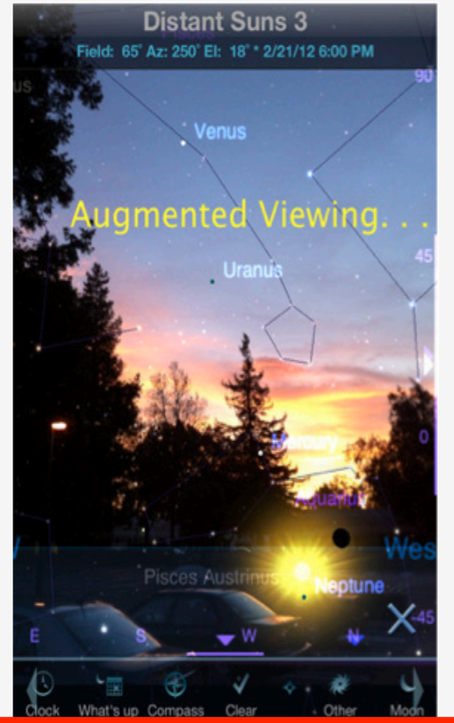
"Distant Suns is easy to use and understand. The graphics are amaz
people the stars." Lee Brandon-Cremer, Space Shuttle Almanac

Distant Suns-Max: Unleash Your Inner Astronaut Support ›

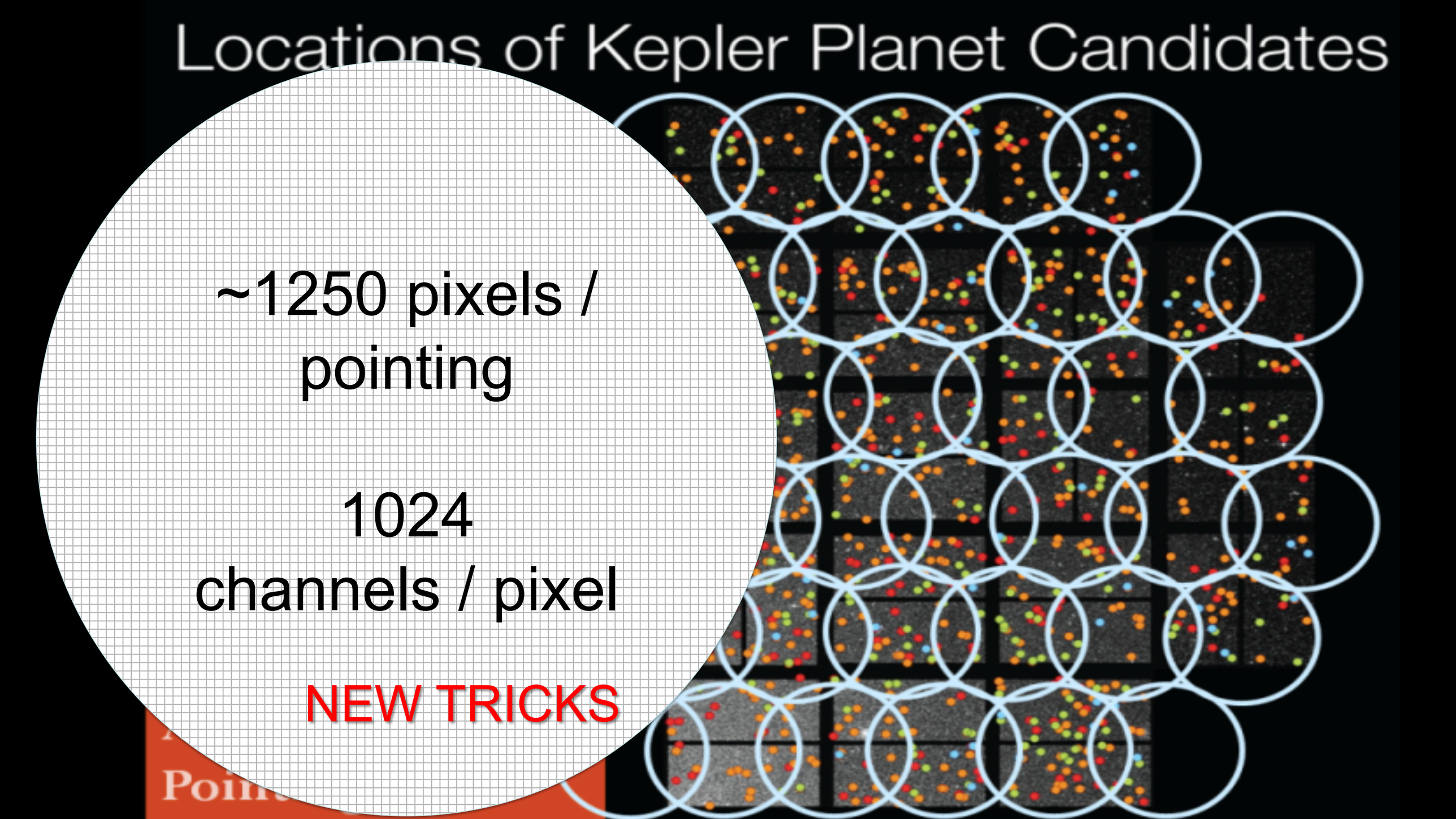
What's New in Version 3.4.2

•Astronomy Magazine Newsticker shows up-to-date space & astron
•Tweaked up some UI bits for the iPad mini
•Fixed a problem with the GPS that would cause it to use the default

Screenshots



Locations of Kepler Planet Candidates

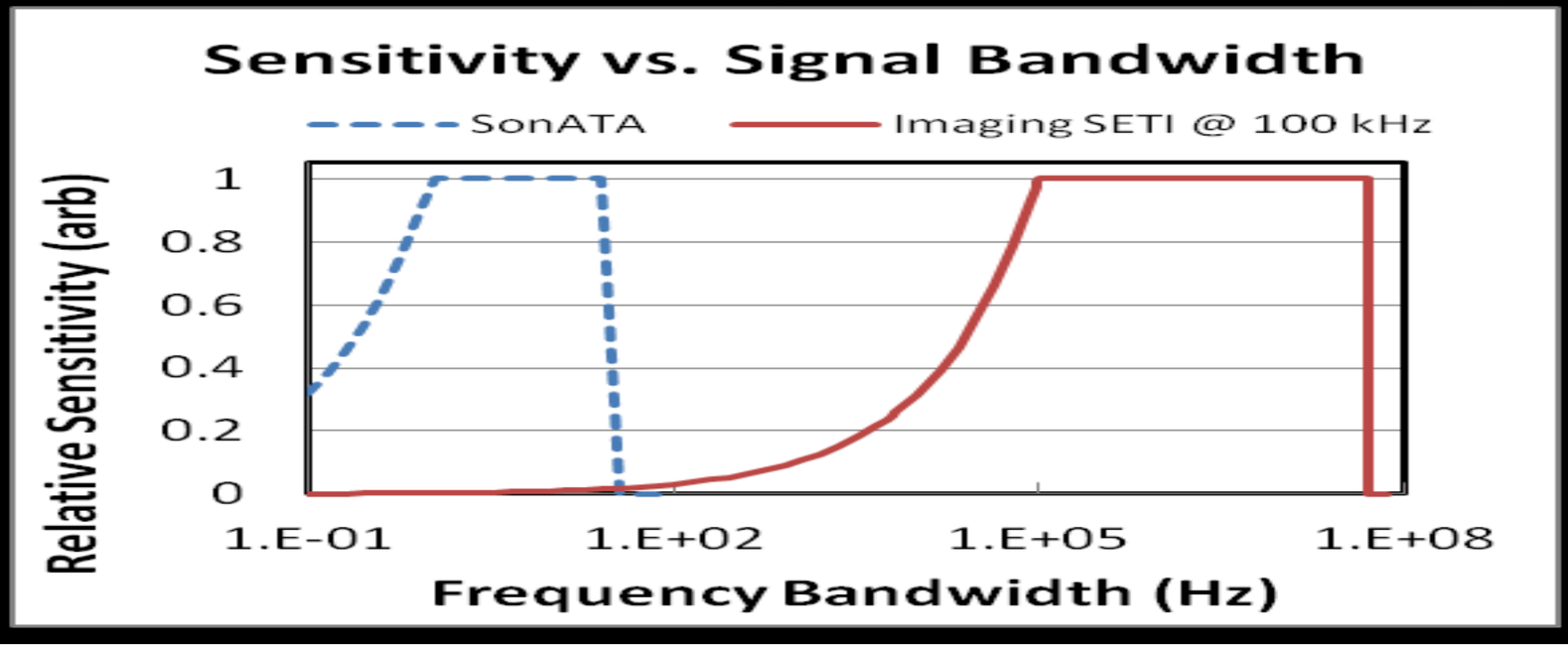


~1250 pixels / pointing

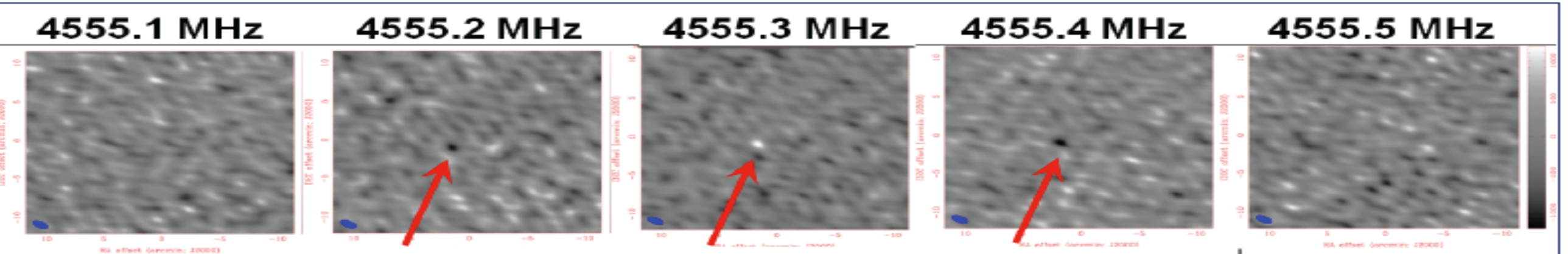
1024 channels / pixel

NEW TRICKS

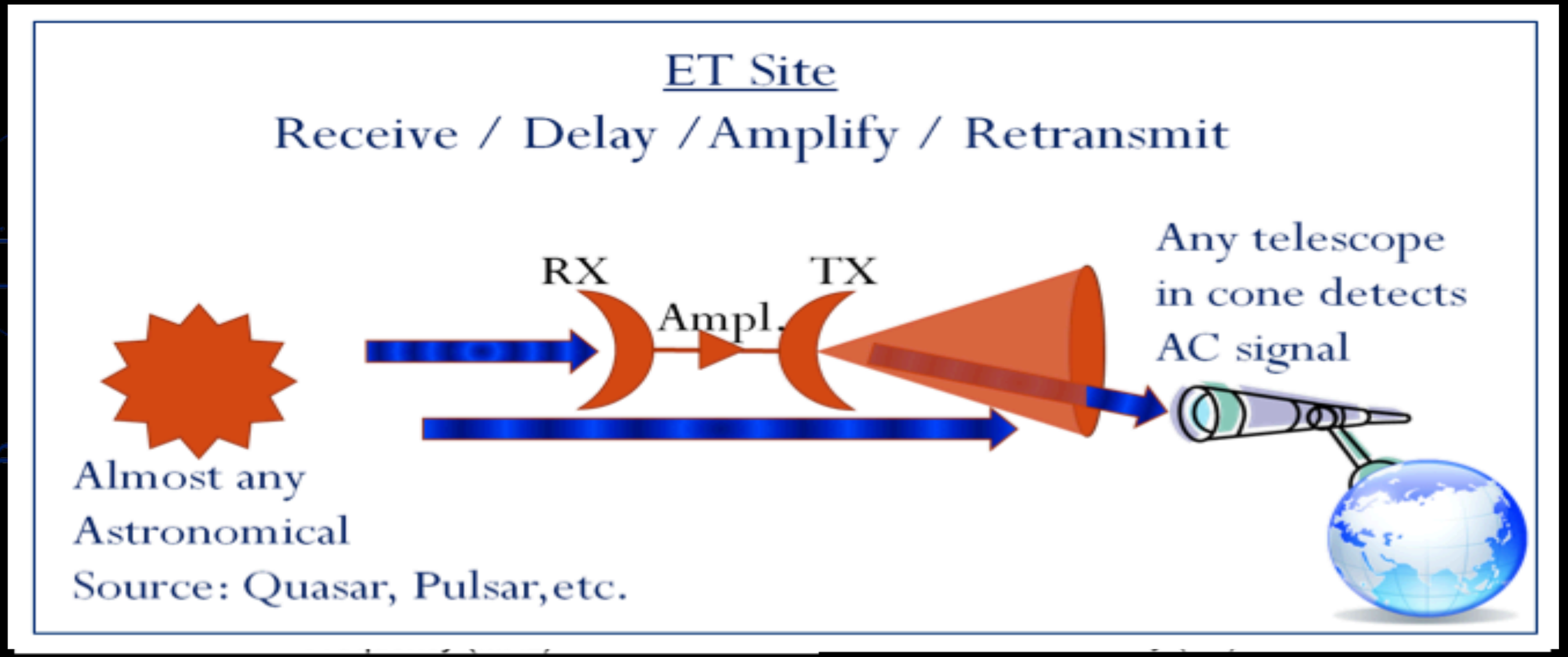
‘Narrowband’ Signals in Image



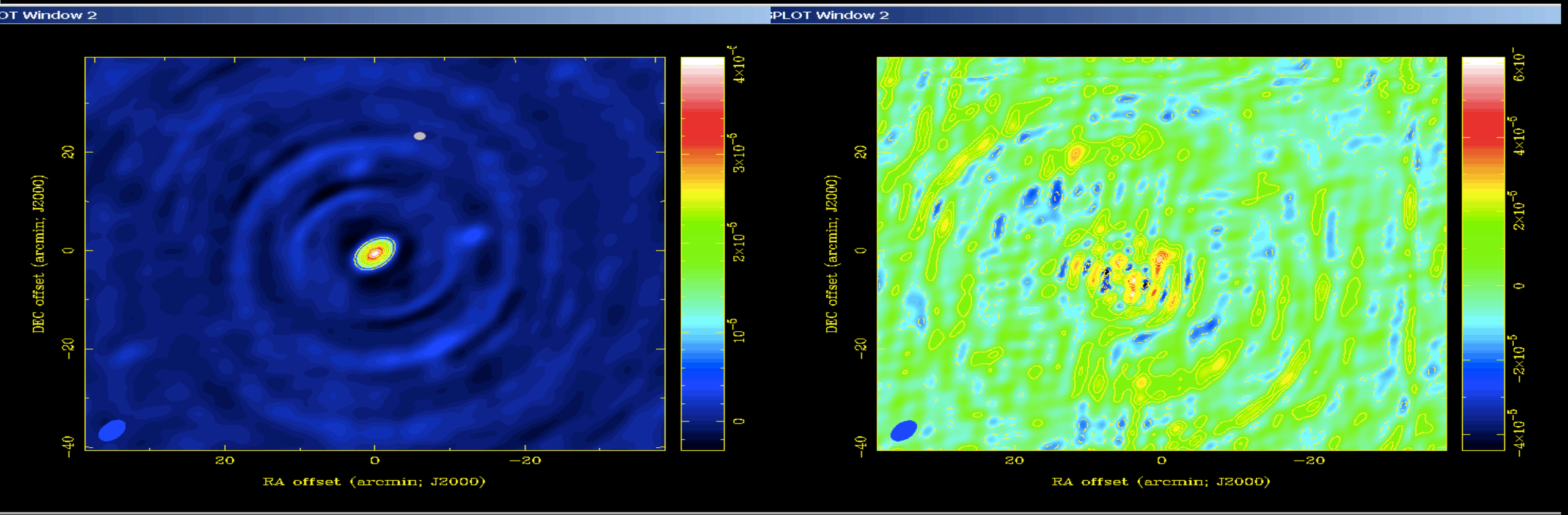
$$\frac{d^2\ \mathrm{Image}(n)}{df^2} \approx 2\ \mathrm{Image}(n) - \mathrm{Image}(n-1) - \mathrm{Image}(n+1)$$



Search in Time Domain
Rather than Frequency Domain

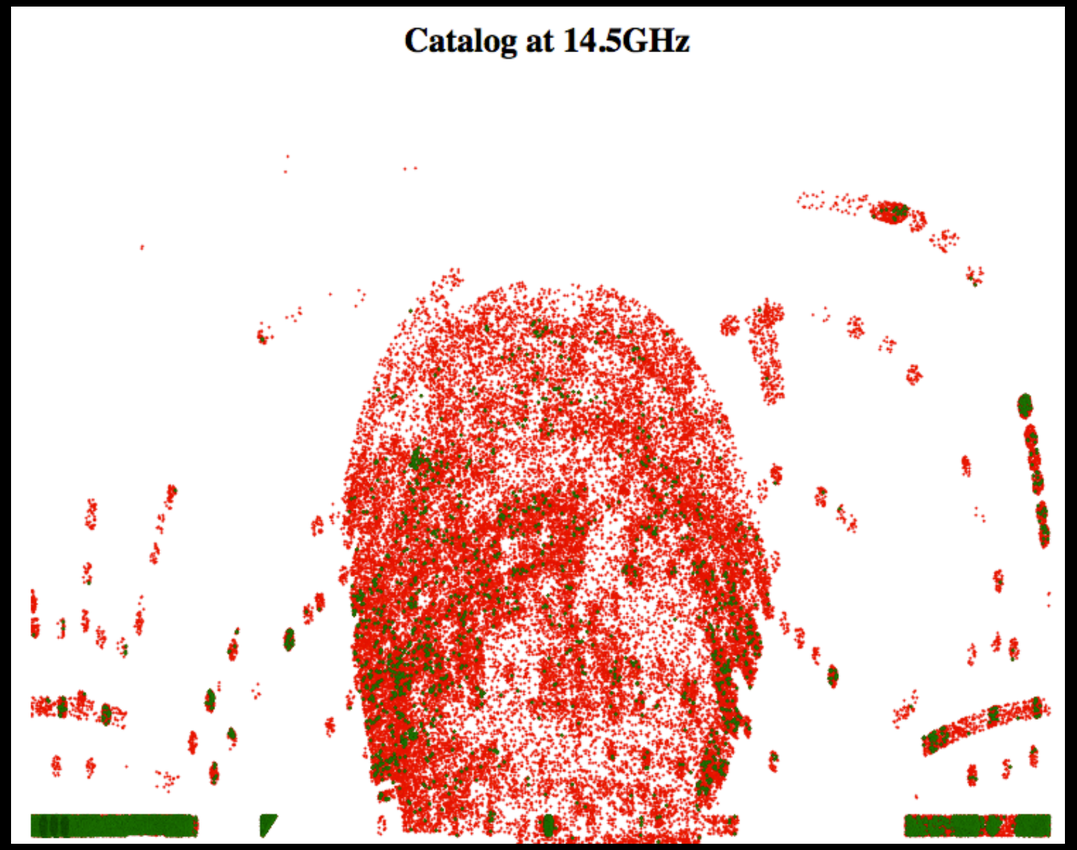


‘Fast’ Time Variable Sources



Now gathering training sets for ML

70,408 Red Dwarfs

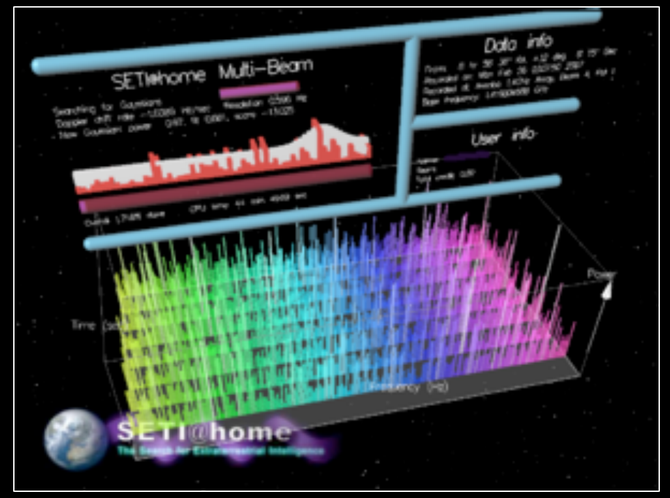


More SETI Today

LOFAR
Low Frequency Transients

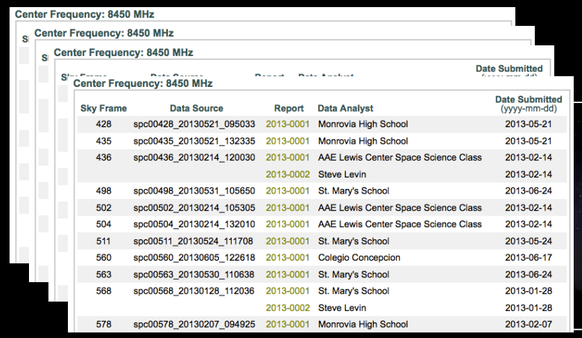
Project Dorothy
15 Countries

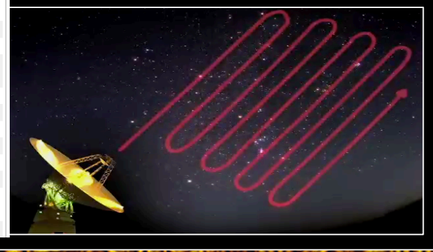
Green Bank Telescope
800 MHz record
+ SETI@home
off-line processing



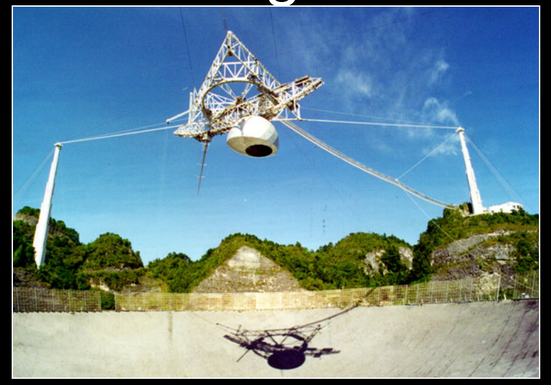
SETI@home

SETI Italia

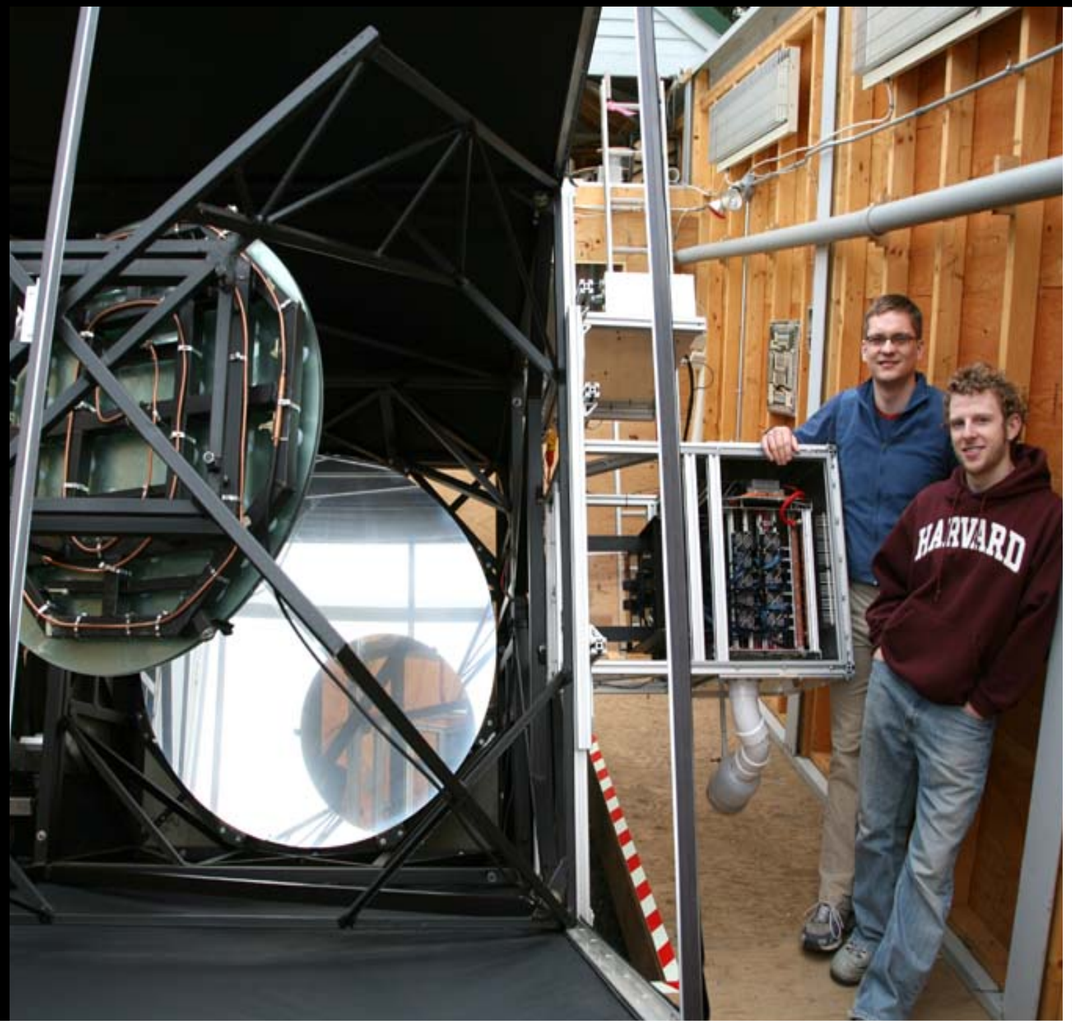


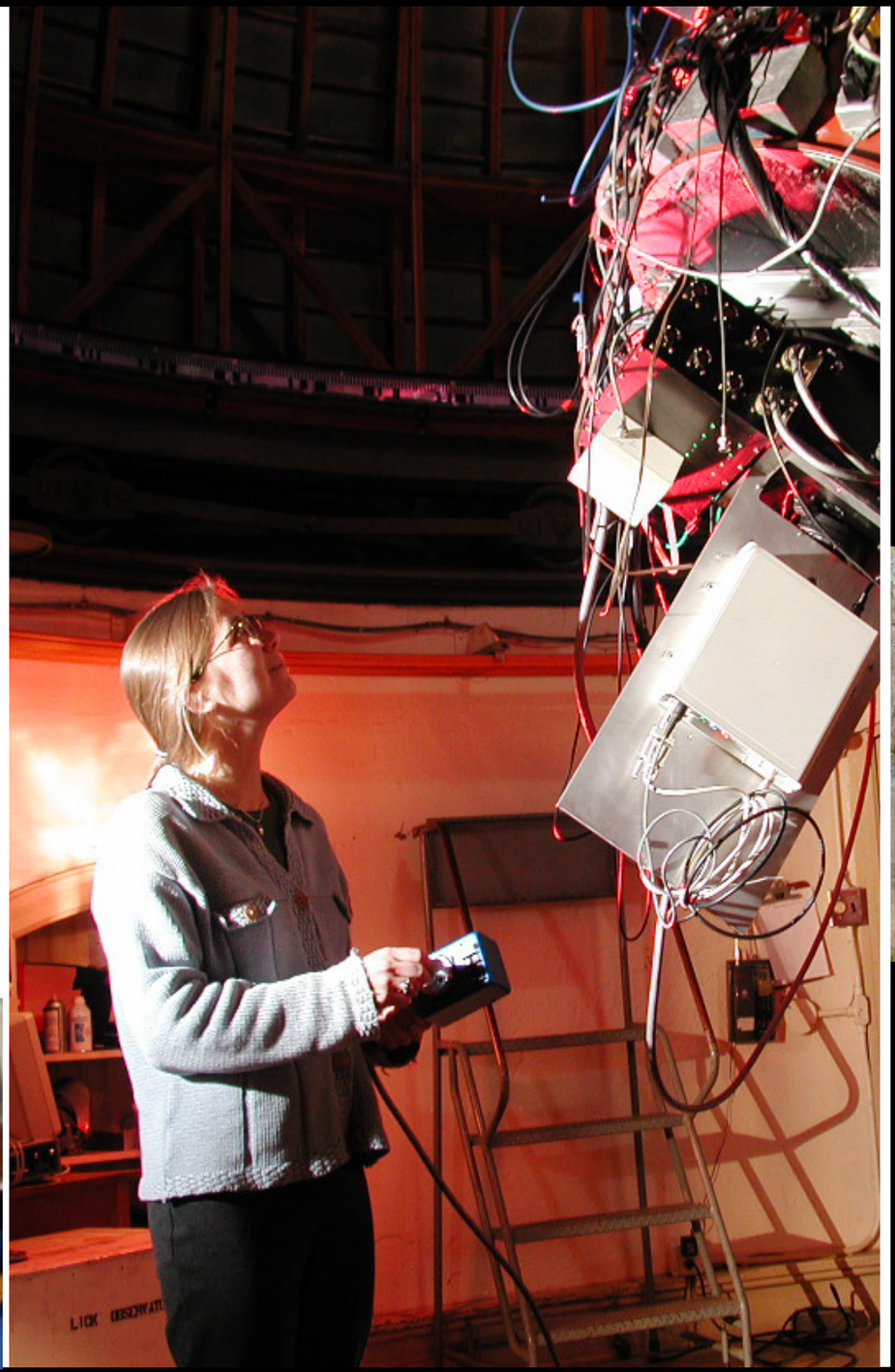


ALFA at Arecibo
Astropulse &
Other signals

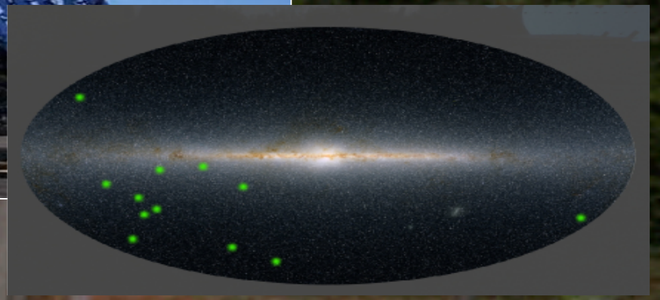


OSETI


HARVARD




FROM THIS SITE
THE FIRST OSETI SEARCH
WAS CONDUCTED BY
DR RAGBIR BHATHAL
IN YEAR 2000



10 Y’ s/m²/ns

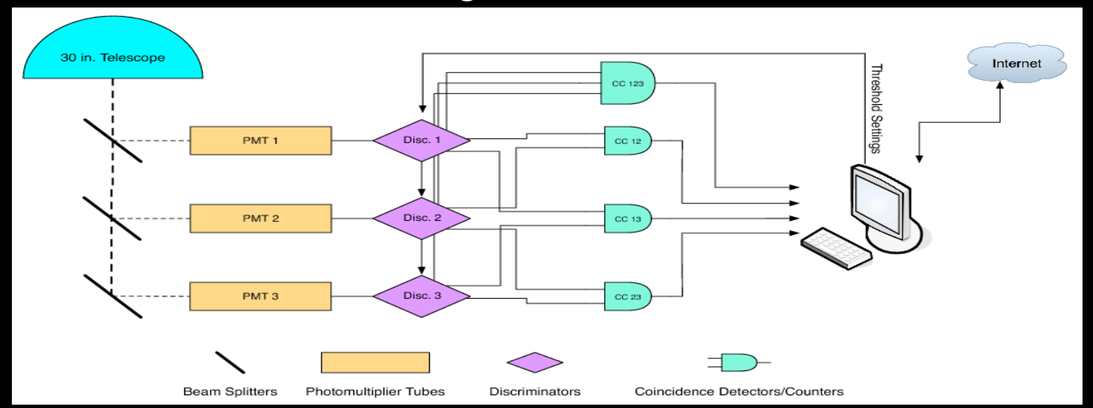
Harvard OSETI Sky Survey of Northern Sky

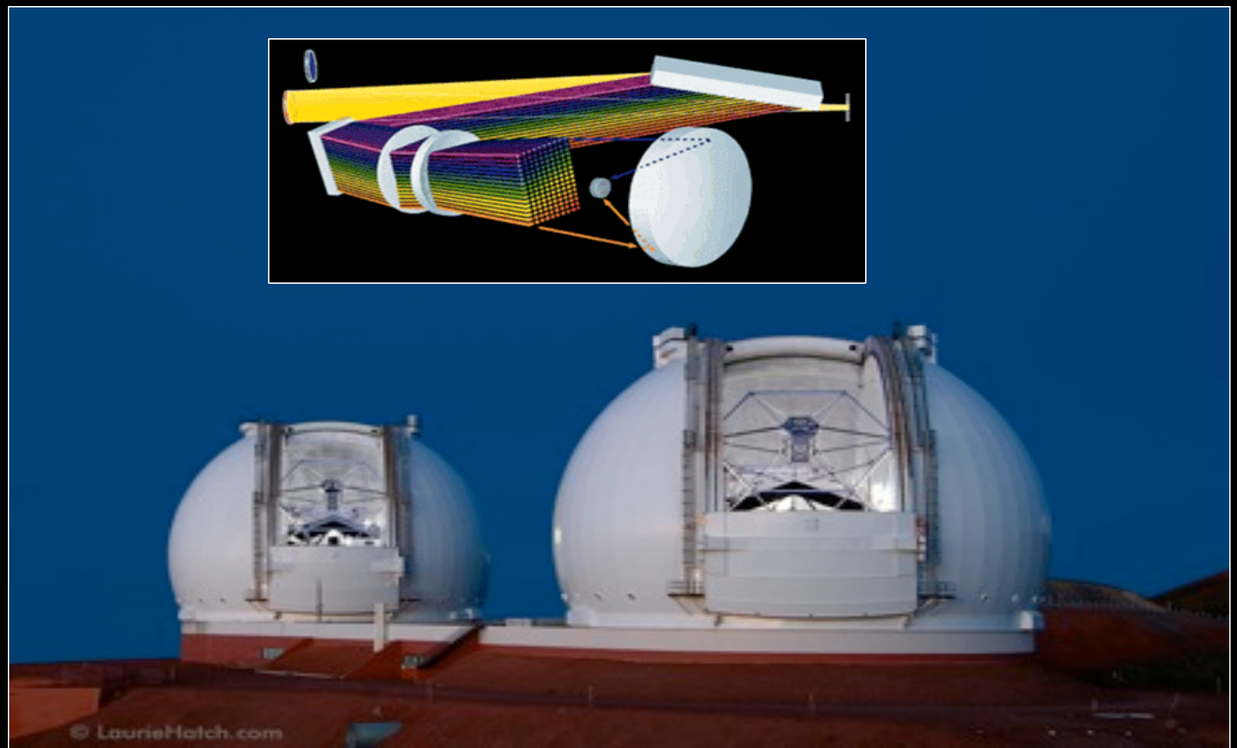
Berkeley Optical SETI

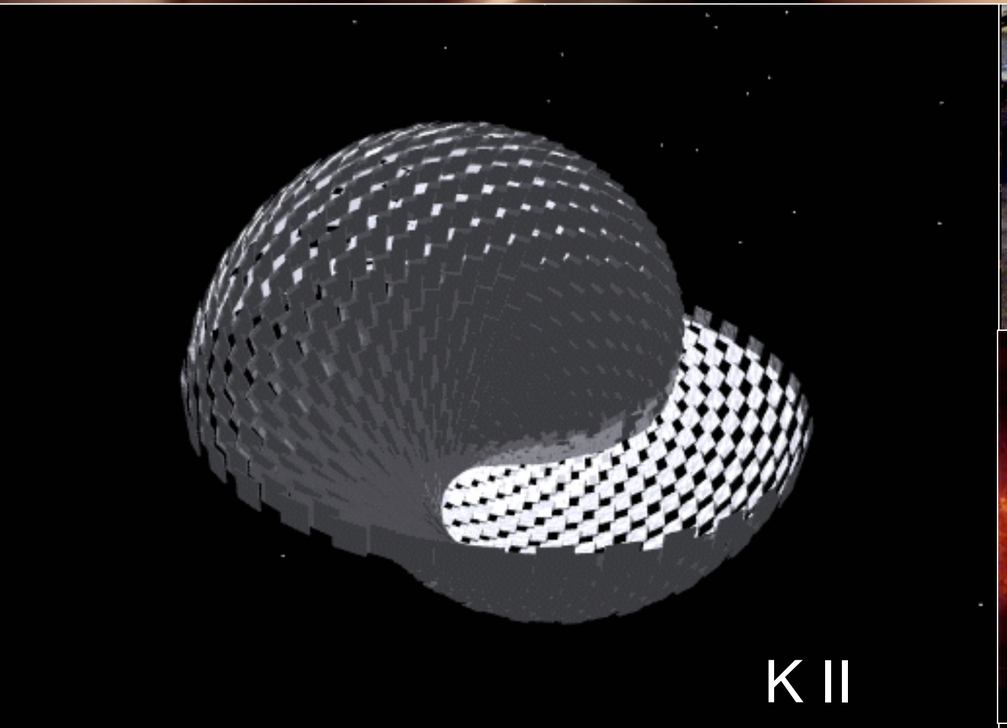
100 γ's s/m²/ns

HIRES at
KECK
Observatory
1000 KOIs
10 γ's /hr in laser line

Leuschner
Observatory

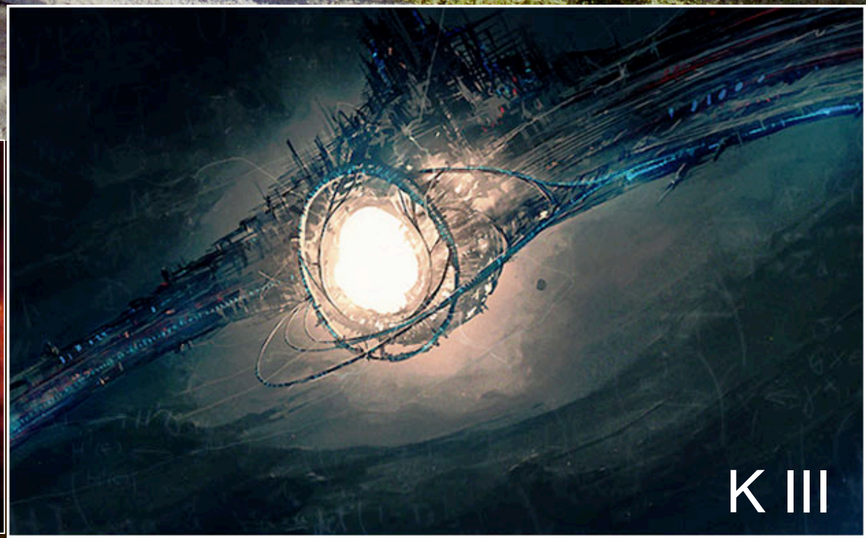


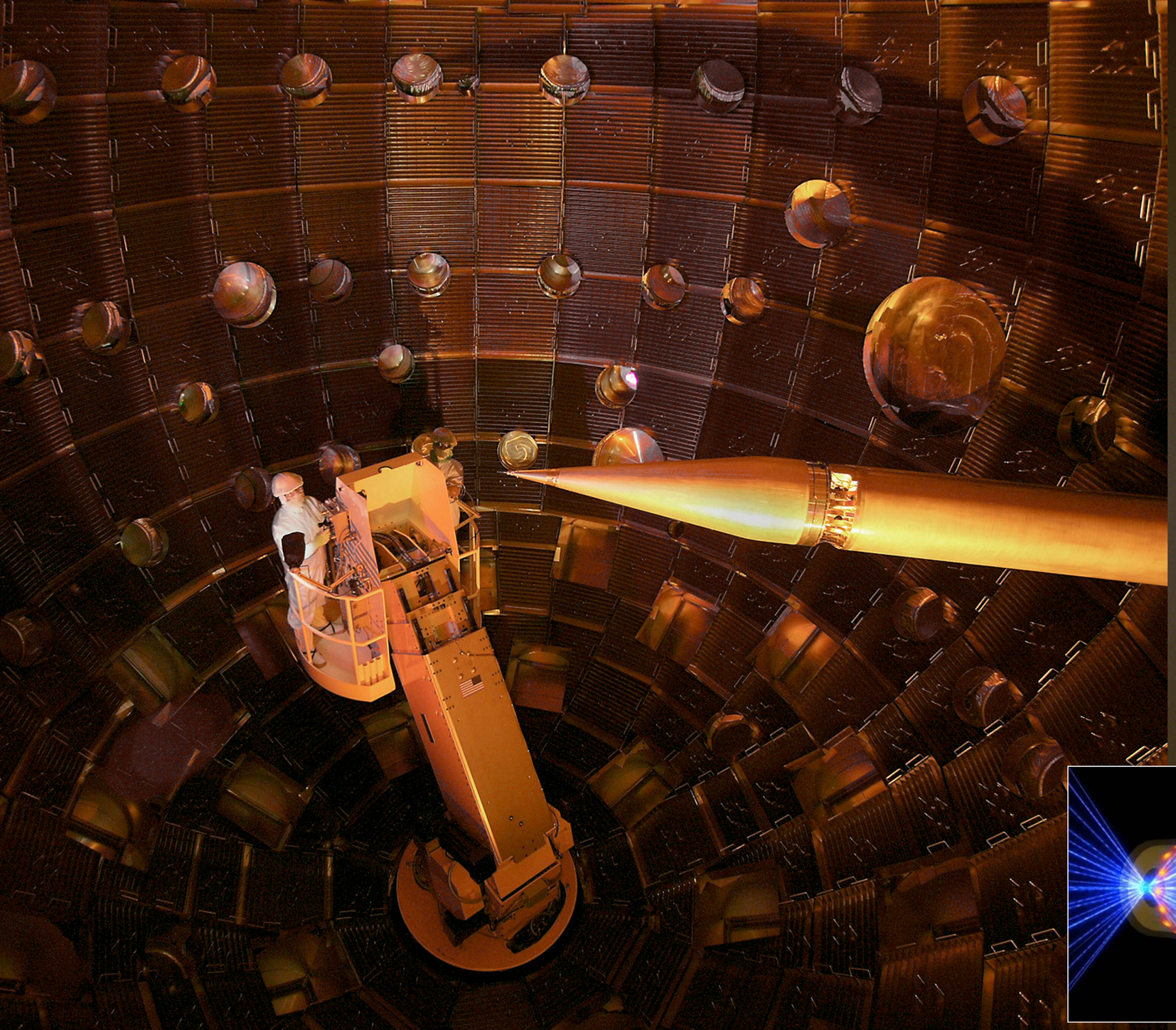



K II

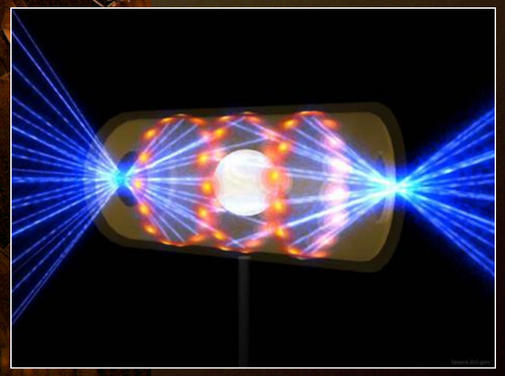

Mt. Wilson

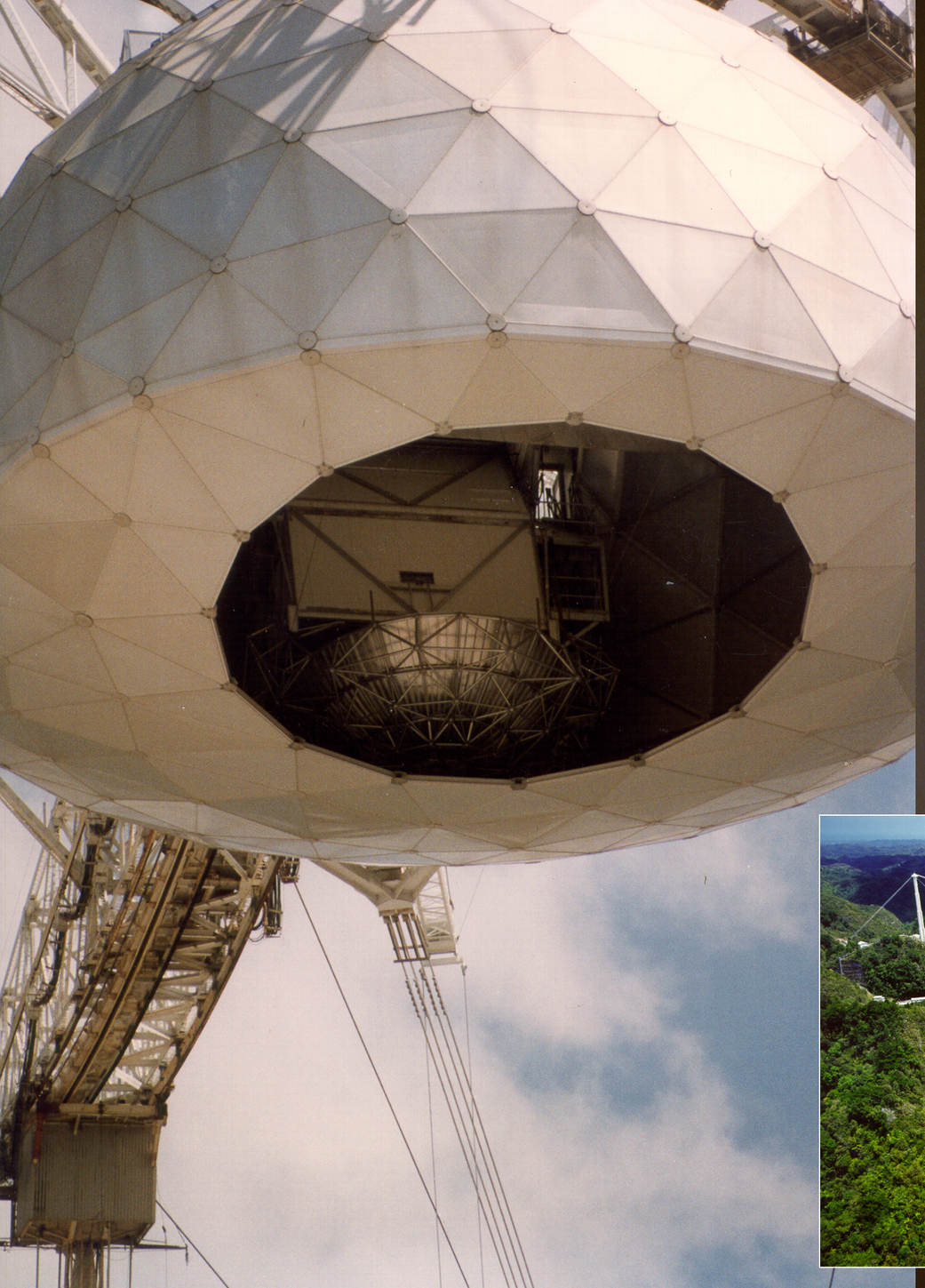

WISE

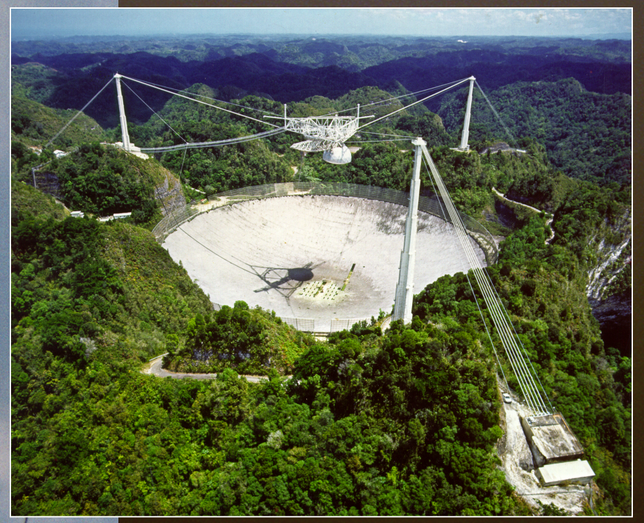

K III



10^{15} W LASER 1000 LY AWAY



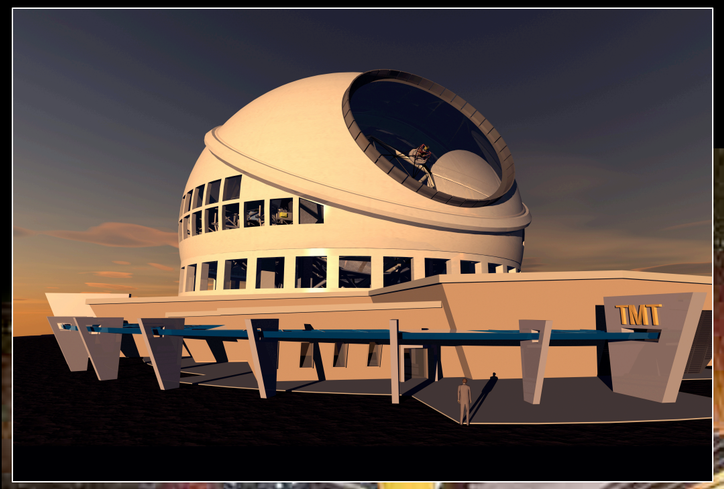




$2x10^{13}$ W RADAR 1000 LY AWAY

~10^6 stars
L ~ 10^5 years

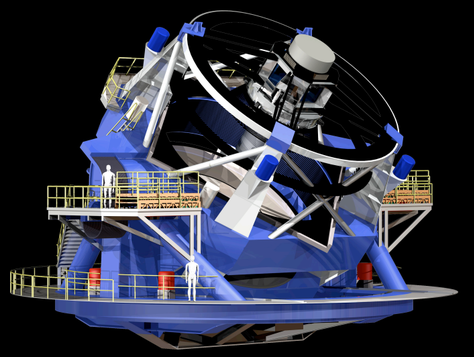
The Future



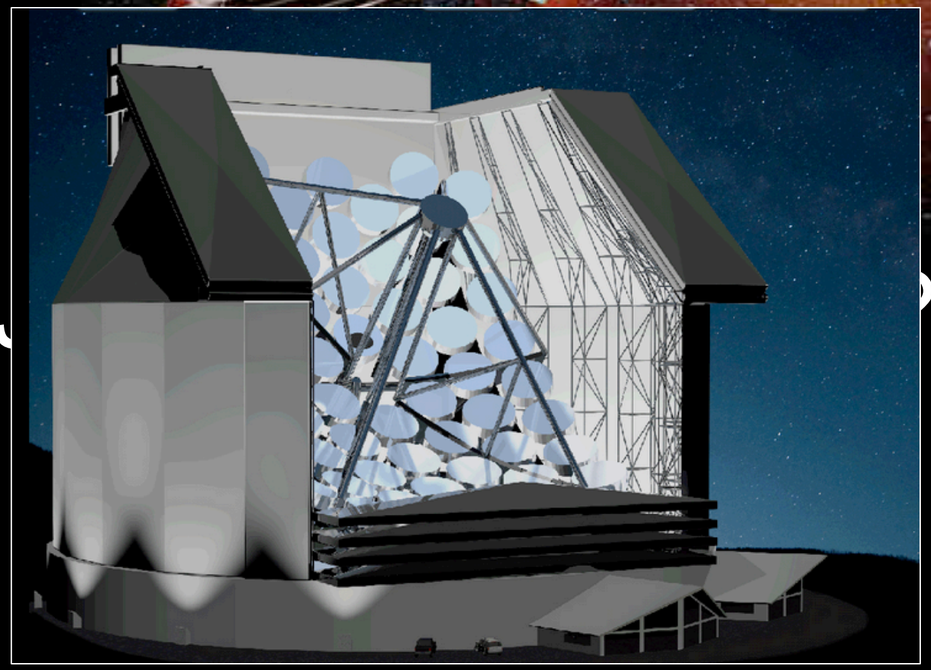
TMT

E-ELT

LSST

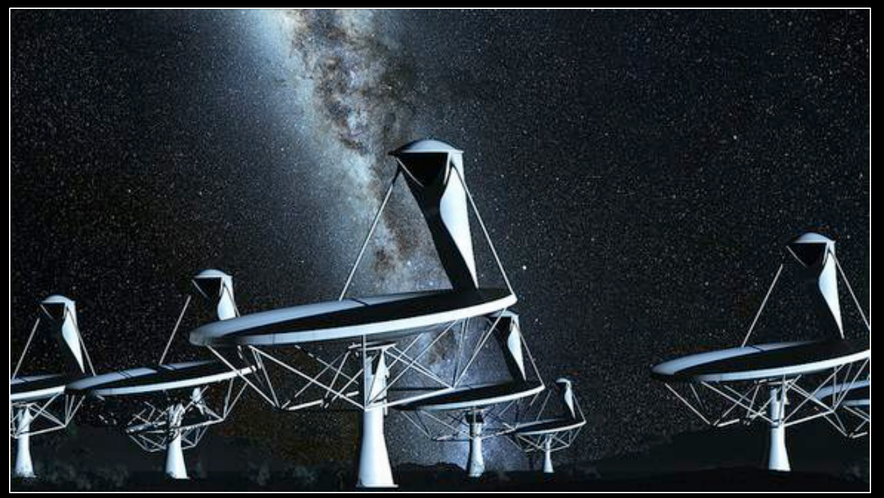


SKA



Colossus

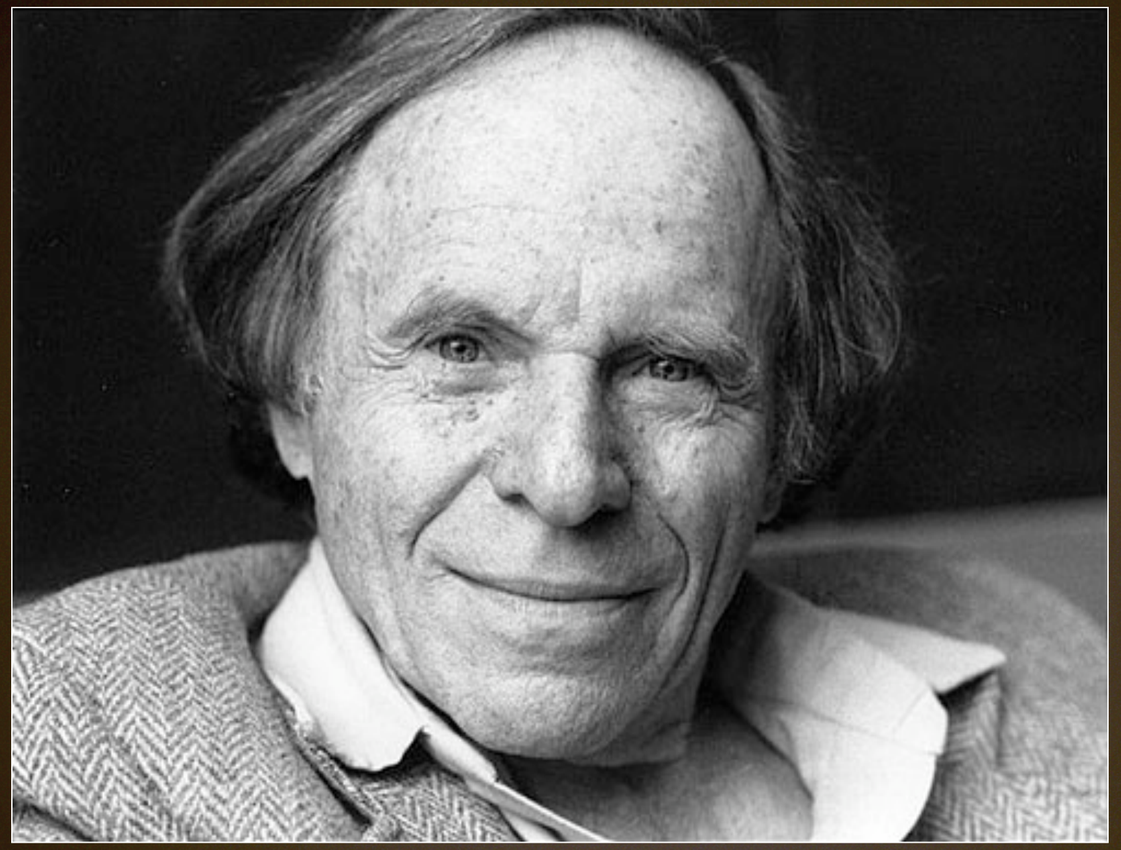
FAST



SETI


Longevity is key

Prof. Philip Morrison



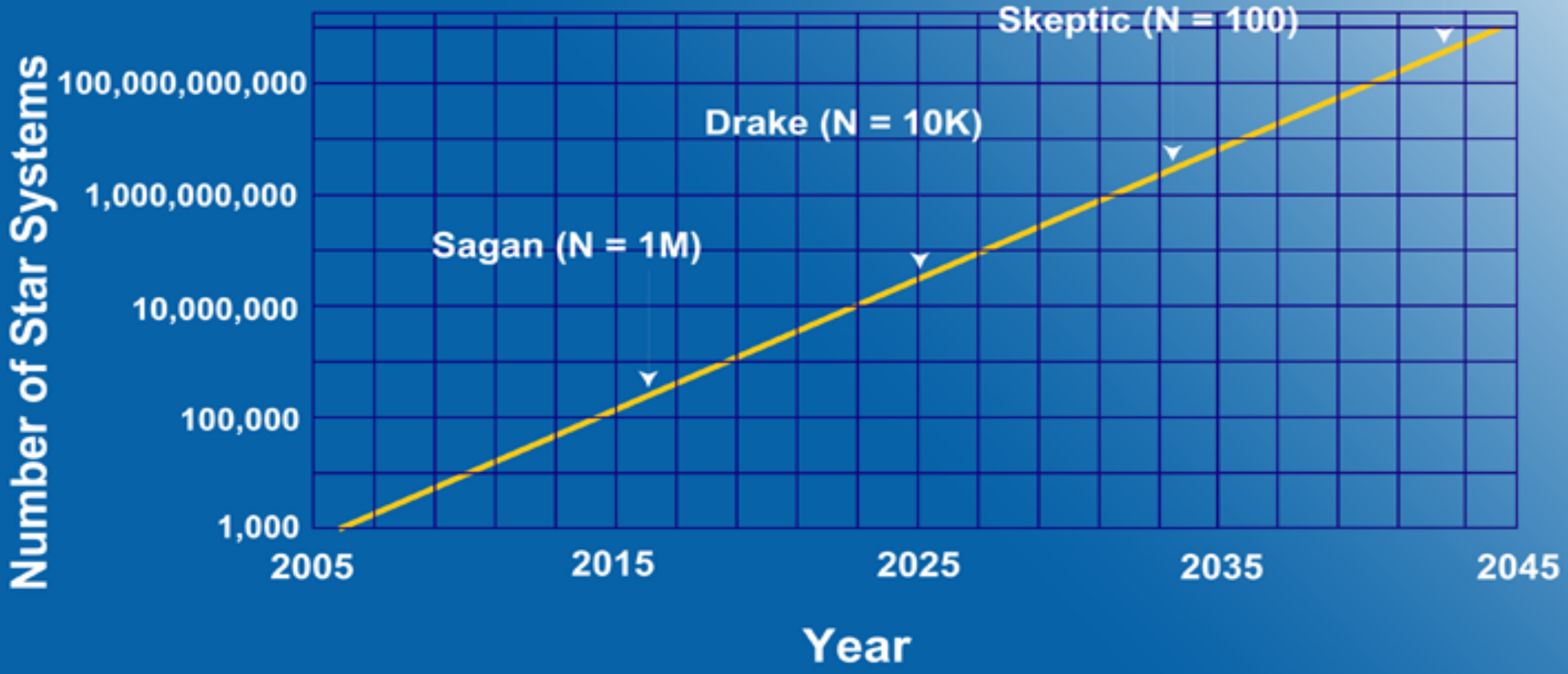
SETI IS THE ARCHEOLOGY OF THE FUTURE

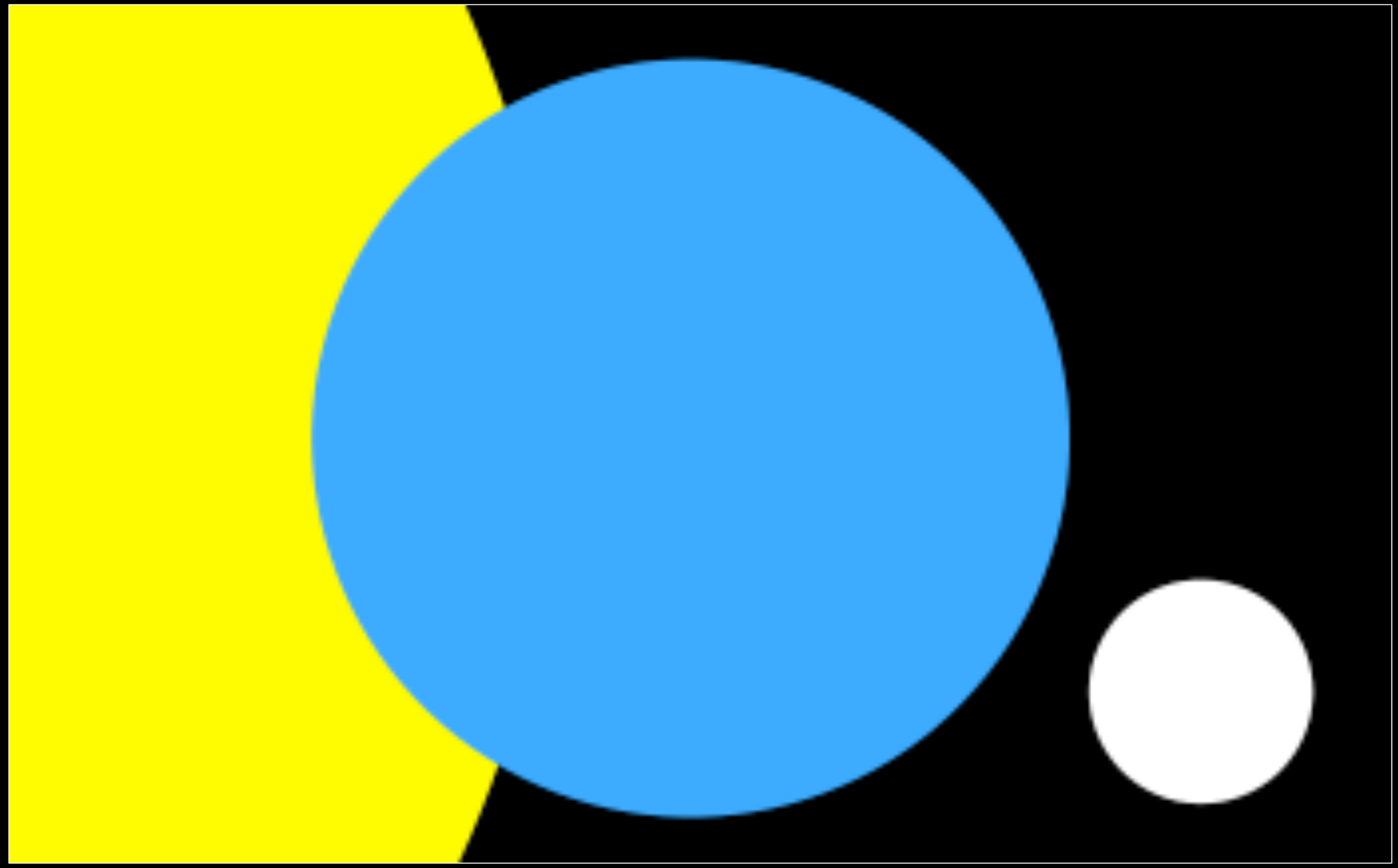
“The probability of success
is difficult to estimate;
but if we never search
the chance of success is zero.”

Cocconi and Morrison, Nature (1959)

Amount of Sky Searched with the ATA

Give Up!





Earthrise/ William Anders/ Apollo 8