SETI Signal Processing With the ATA

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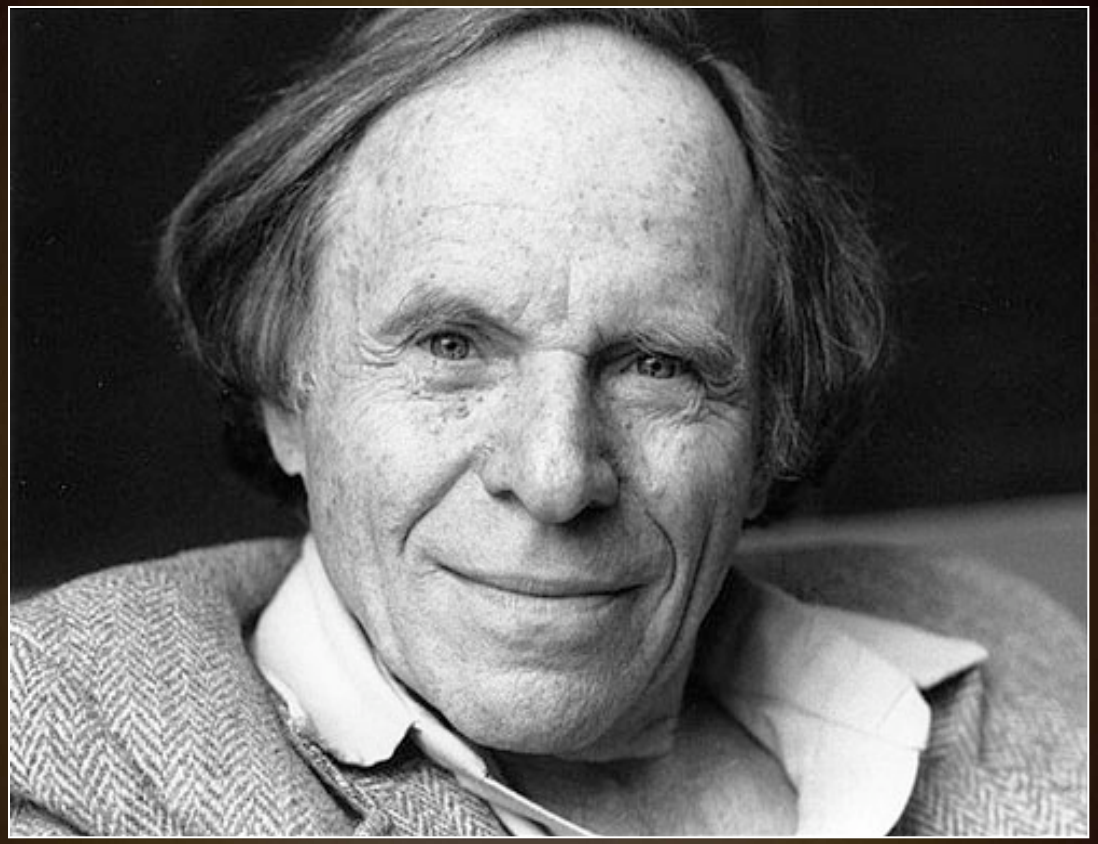
Director, Center for SETI Research
SETI Institute
Mountain View CA

ASTROBIOLOGY: A SEARCH FOR BIOSIGNATURES

SETI: A SEARCH FOR TECHNOSIGNATURES

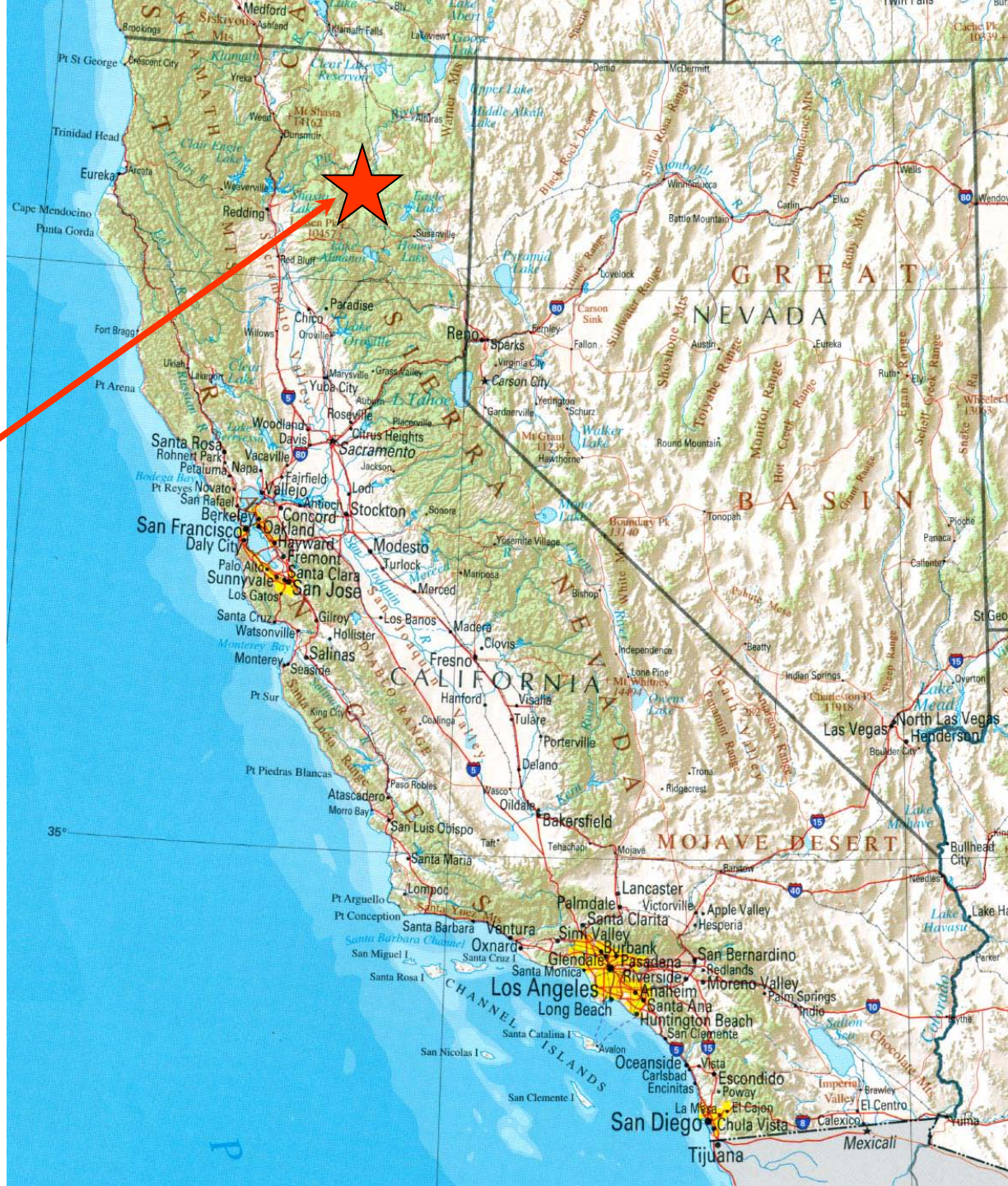
Prof. Philip Morrison



SETI IS THE ARCHEOLOGY OF OUR FUTURE

Quick tour of the ATA

Located in rural Shasta County, CA

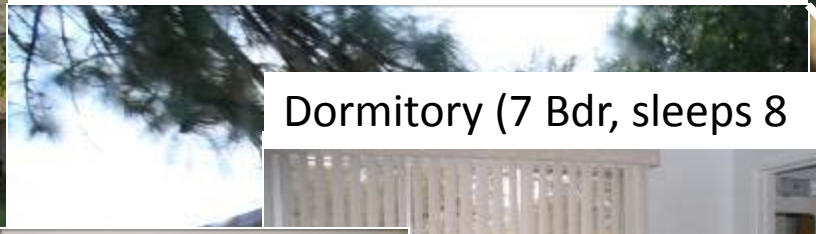


The view from 86P


Forest Route Gr201
STOP
UNIVERSITY OF CALIFORNIA
HAT CREEK
RADIO OBSERVATORY
HAT CREEK
RADIO OBSERVATORY
Open to Visitors
Monday-Friday 9am-3pm
Saturday-Sunday Closed
42231 42233 42235
42237
A
Allen Telescope Array

Berkeley House (3 Bdr, sleeps 5)

Lassen House (3 Bdr, sleeps 5)



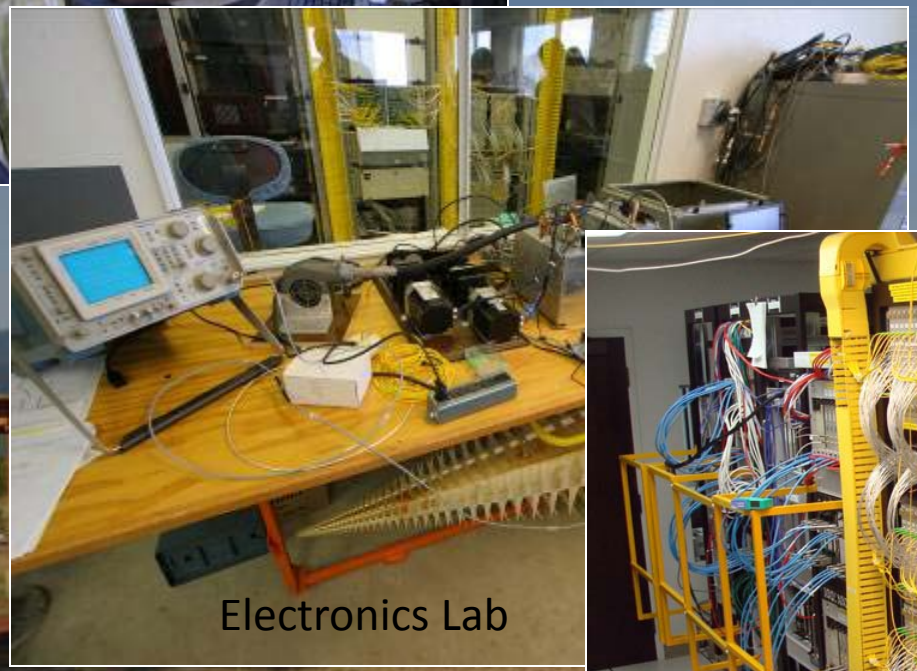
Dormitory (7 Bdr, sleeps 8

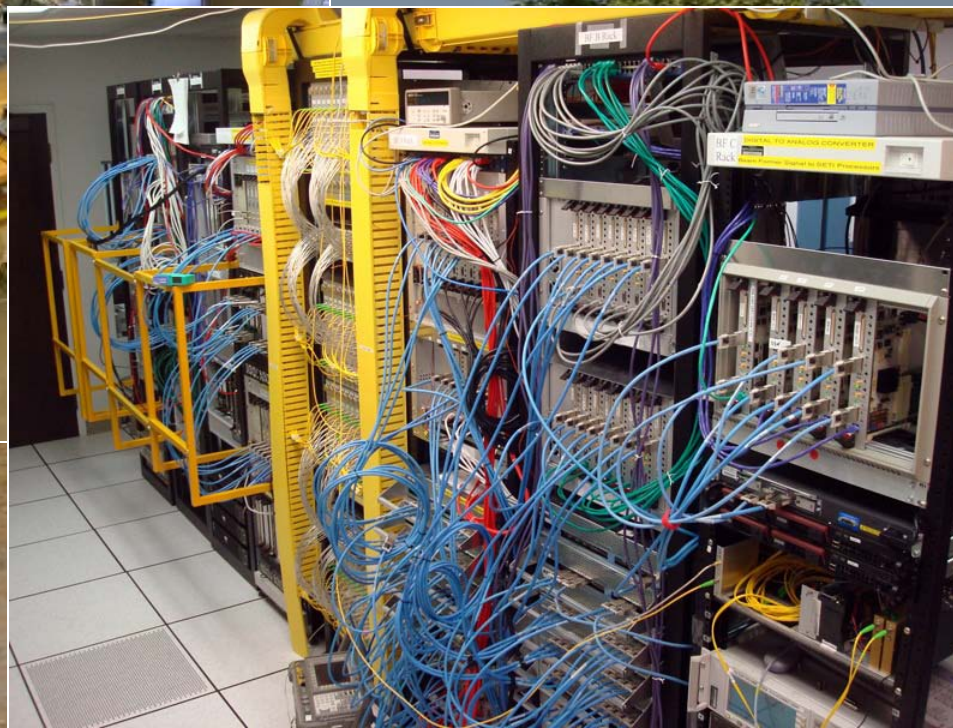
…or more

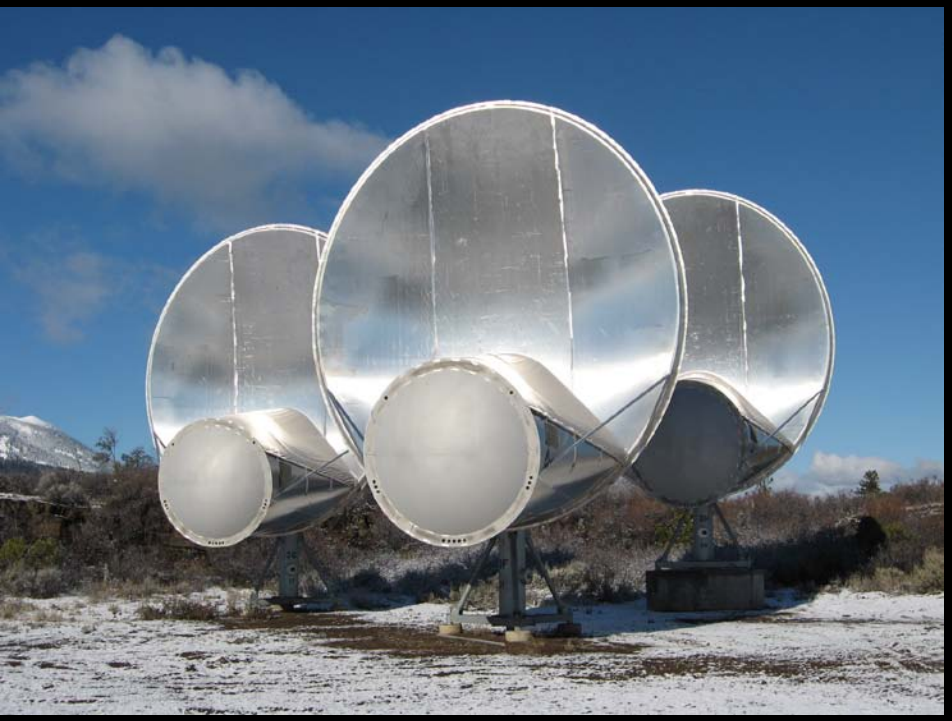
REU students & visitors

Mechanical Shop

Control Building



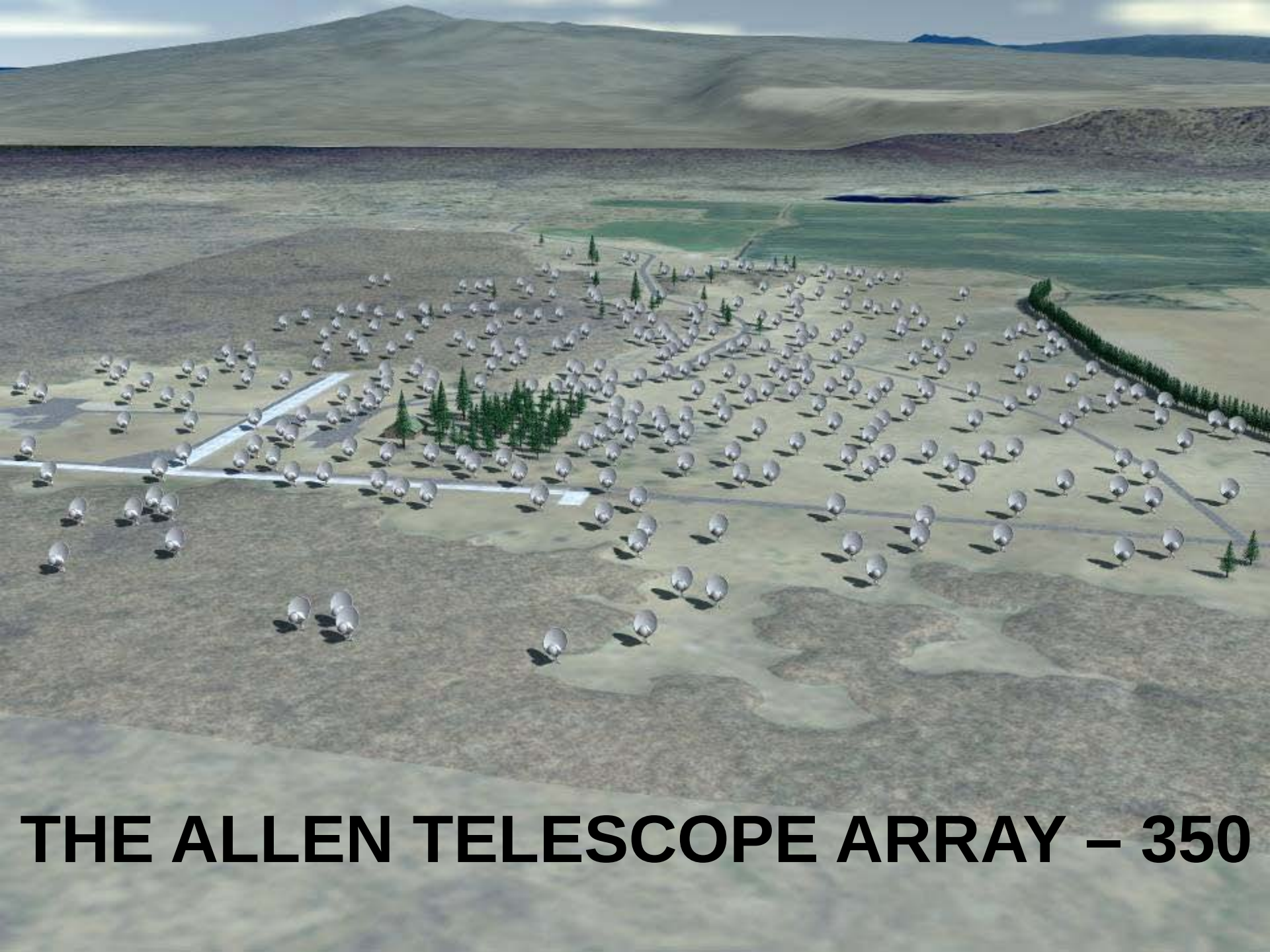




ALLEN TELESCOPE ARRAY

ATA – 42 at Hat Creek

The ATA-42


THE ALLEN TELESCOPE ARRAY – 350

Large N – Small D Array

Improved sensitivity from more dishes; larger collecting area

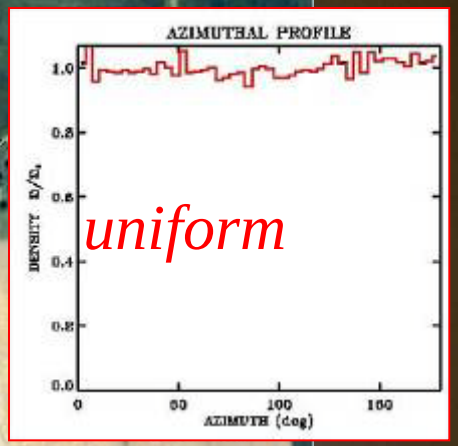
Small dish array images a large area of sky

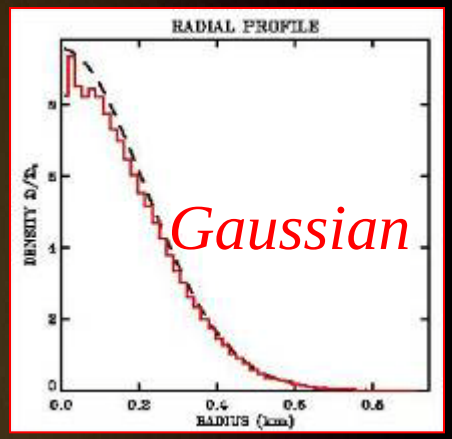
Array FoV set by D of dish, and spatial resolution set by maximum baseline

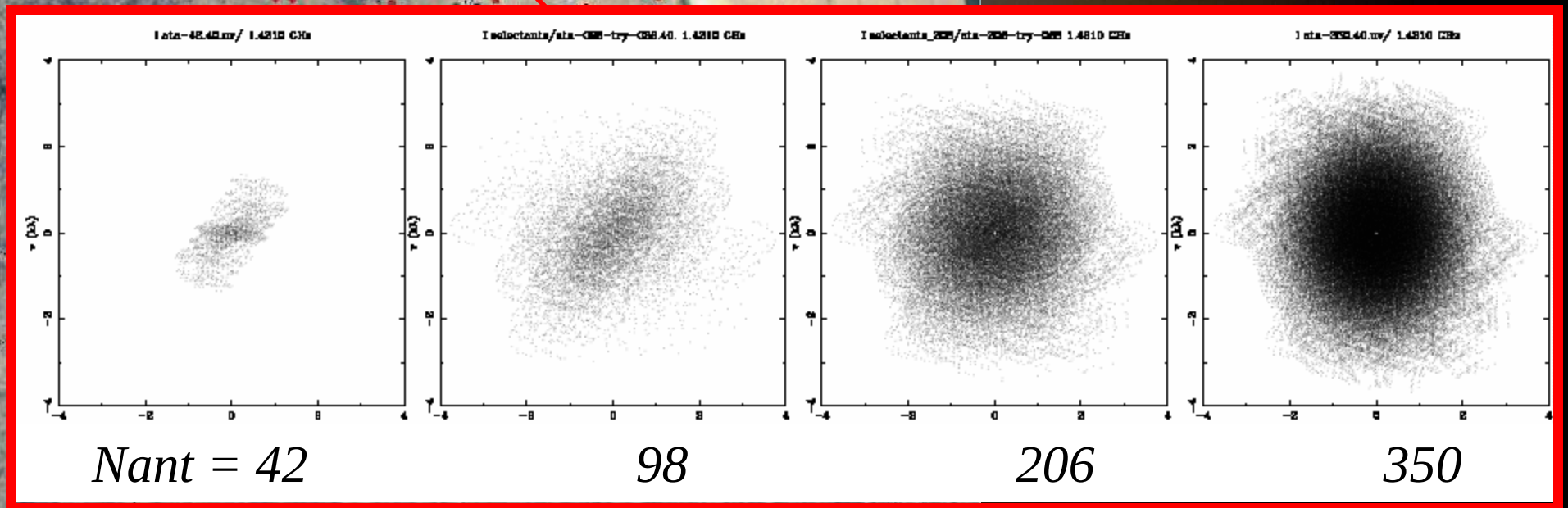
$\Delta\theta \sim \lambda/d$

Single dish - FoV and spatial resolution set by D

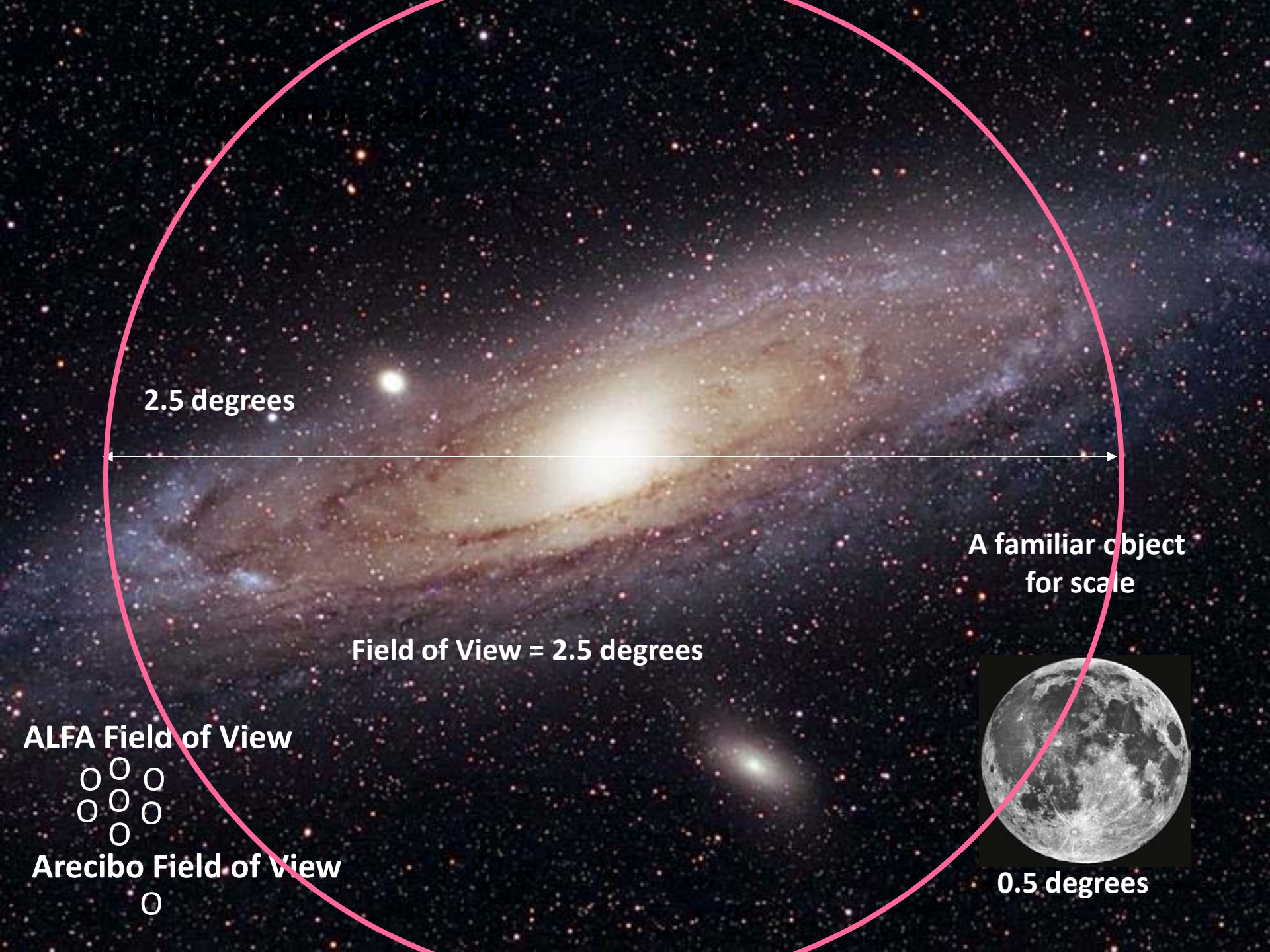
Antenna Configuration Only Looks Random

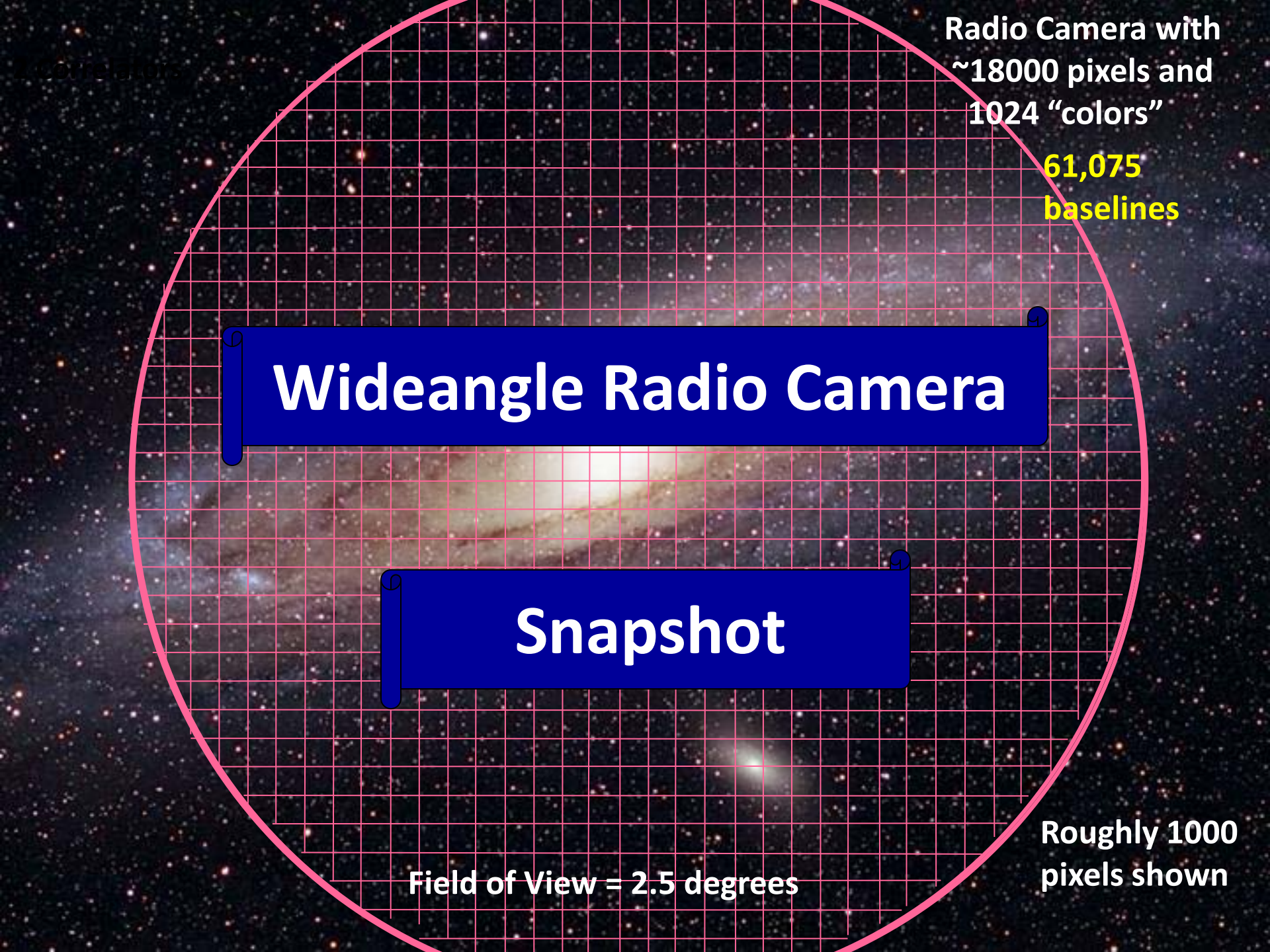


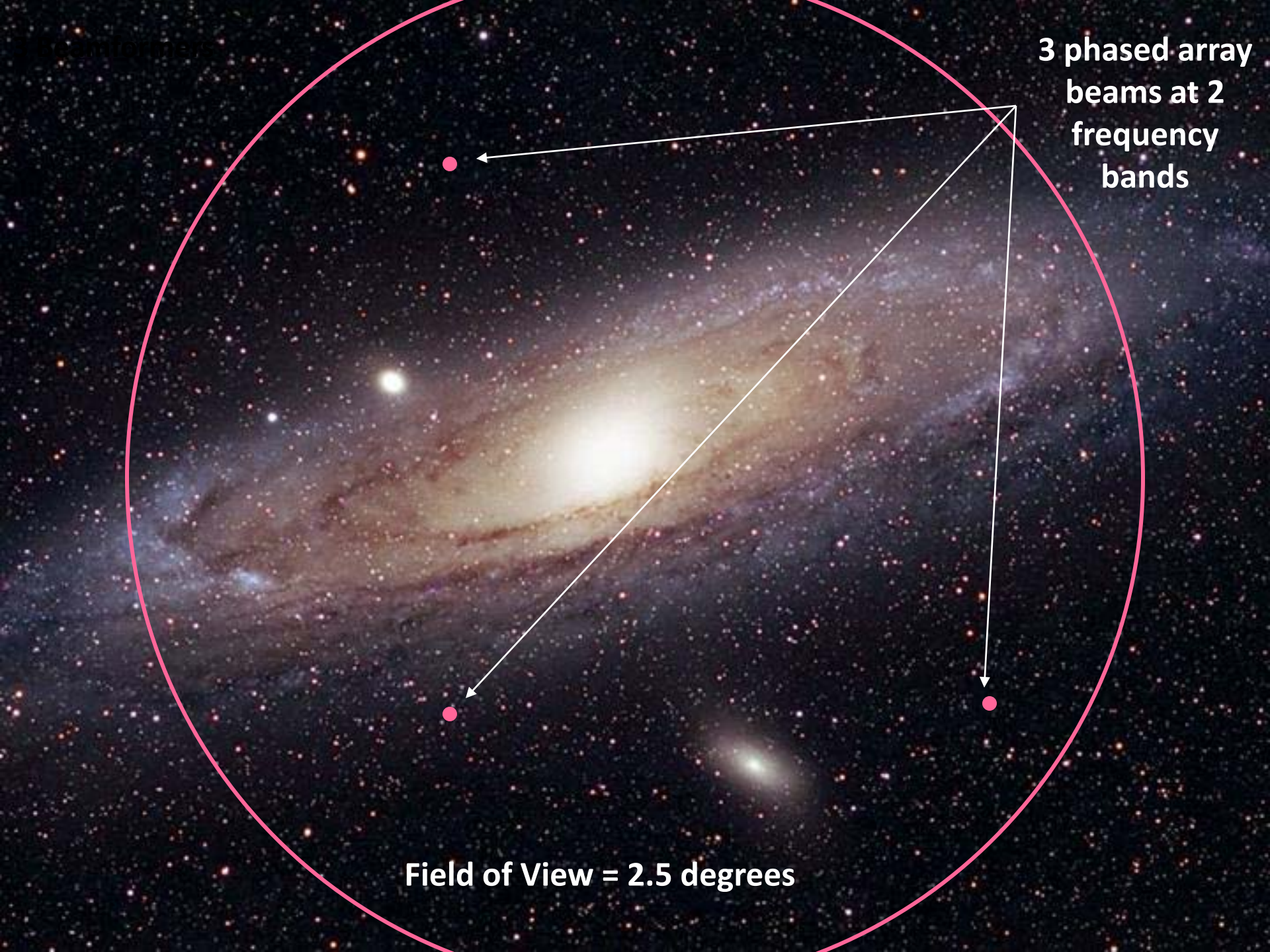




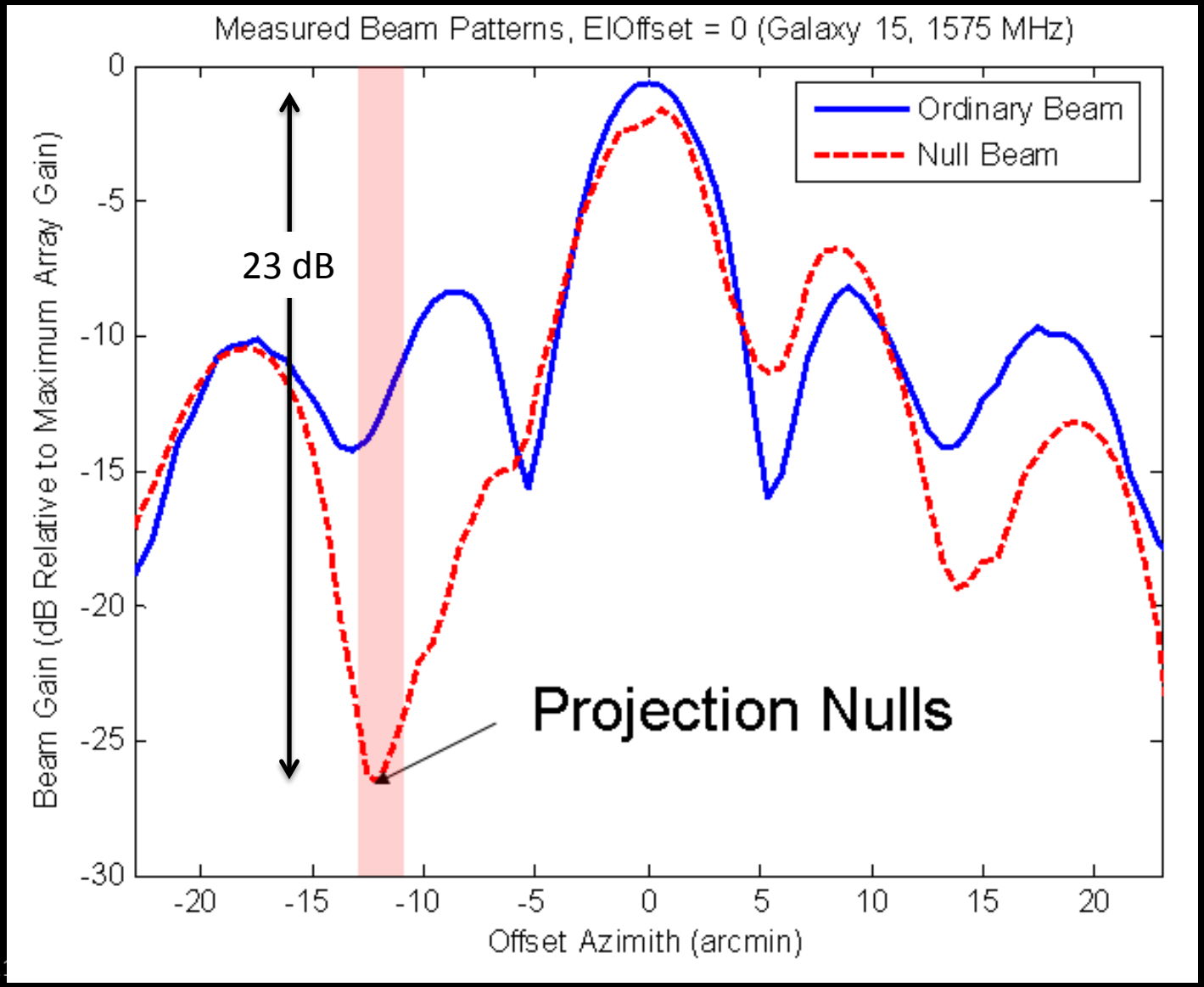
Nant = 42 *98* *206* *350*


The Andromeda Galaxy
2.5 degrees
A familiar object for scale
Field of View = 2.5 degrees
ALFA Field of View
Arecibo Field of View
0.5 degrees


Radio Camera with
~18000 pixels and
1024 “colors”
61,075
baselines
Wideangle Radio Camera
Snapshot
Field of View = 2.5 degrees
Roughly 1000
pixels shown


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

Beam Plus Offset Null



Wide-angle, Panchromatic Radio Camera And Phased-Up Beams

Huge field of view and bandwidth simultaneously available at all times

Field

Lab

Front-End

RF Converter

LO_A

LO_B

LO_C

LO_D

4 simultaneous frequency channels

Digitizer

Digitizer

Digitizer

Digitizer

IP

from other antennas

Radio Camera

Correlator

Correlator

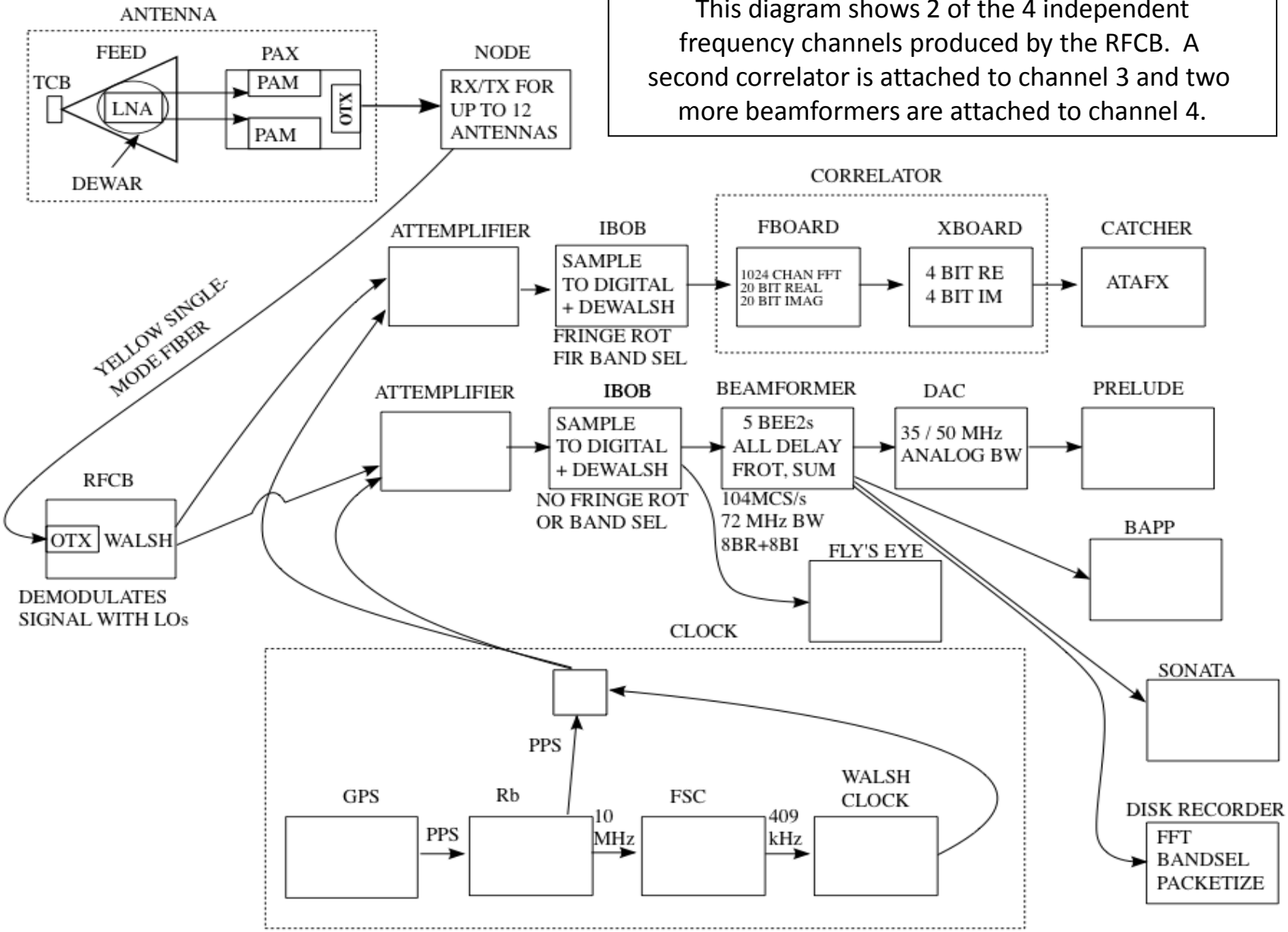
Beam Former

Beam Former

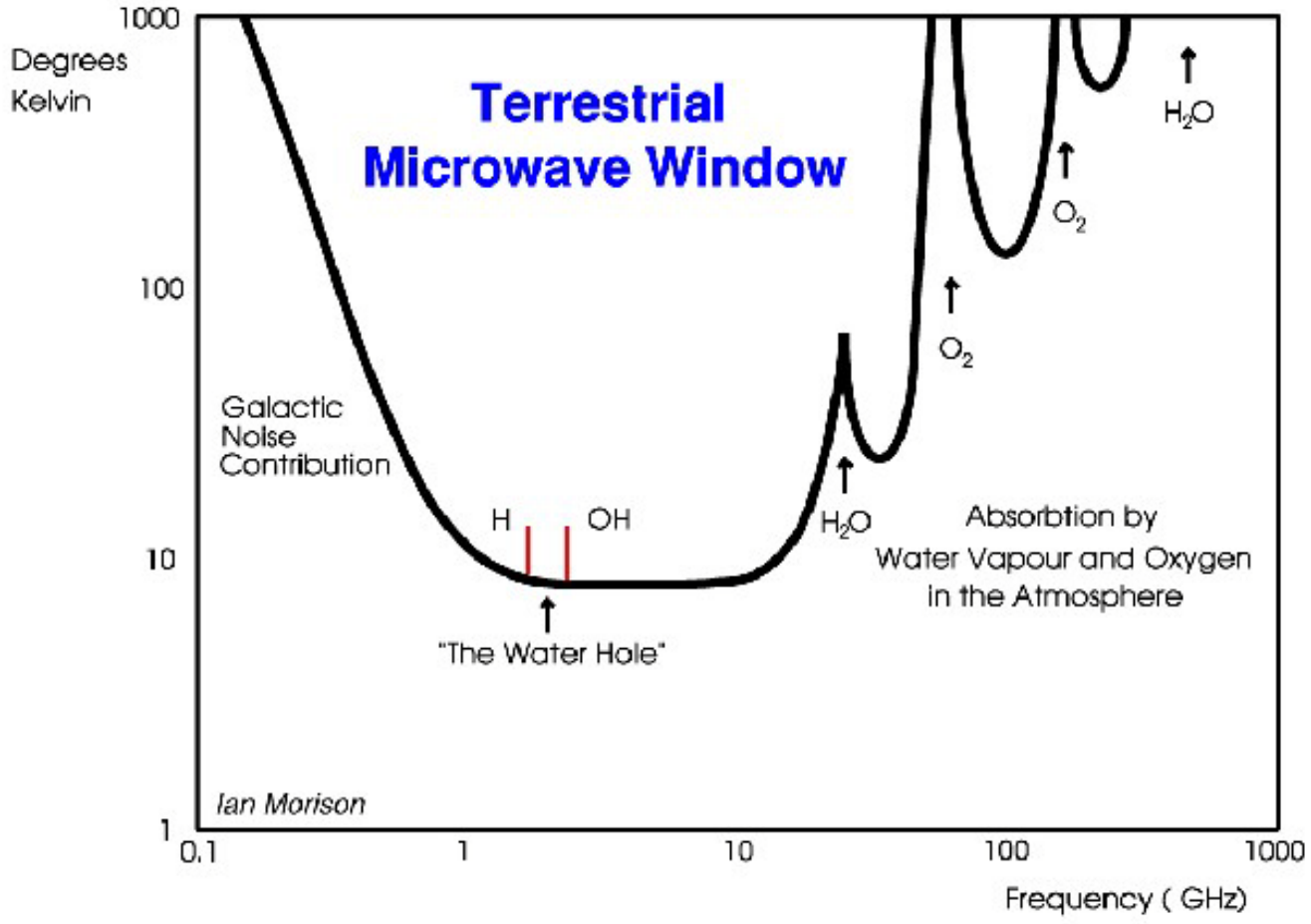
Phased Array Backends Bring your own!

Another Look at Data Flow in the ATA

This diagram shows 2 of the 4 independent frequency channels produced by the RFCB. A second correlator is attached to channel 3 and two more beamformers are attached to channel 4.

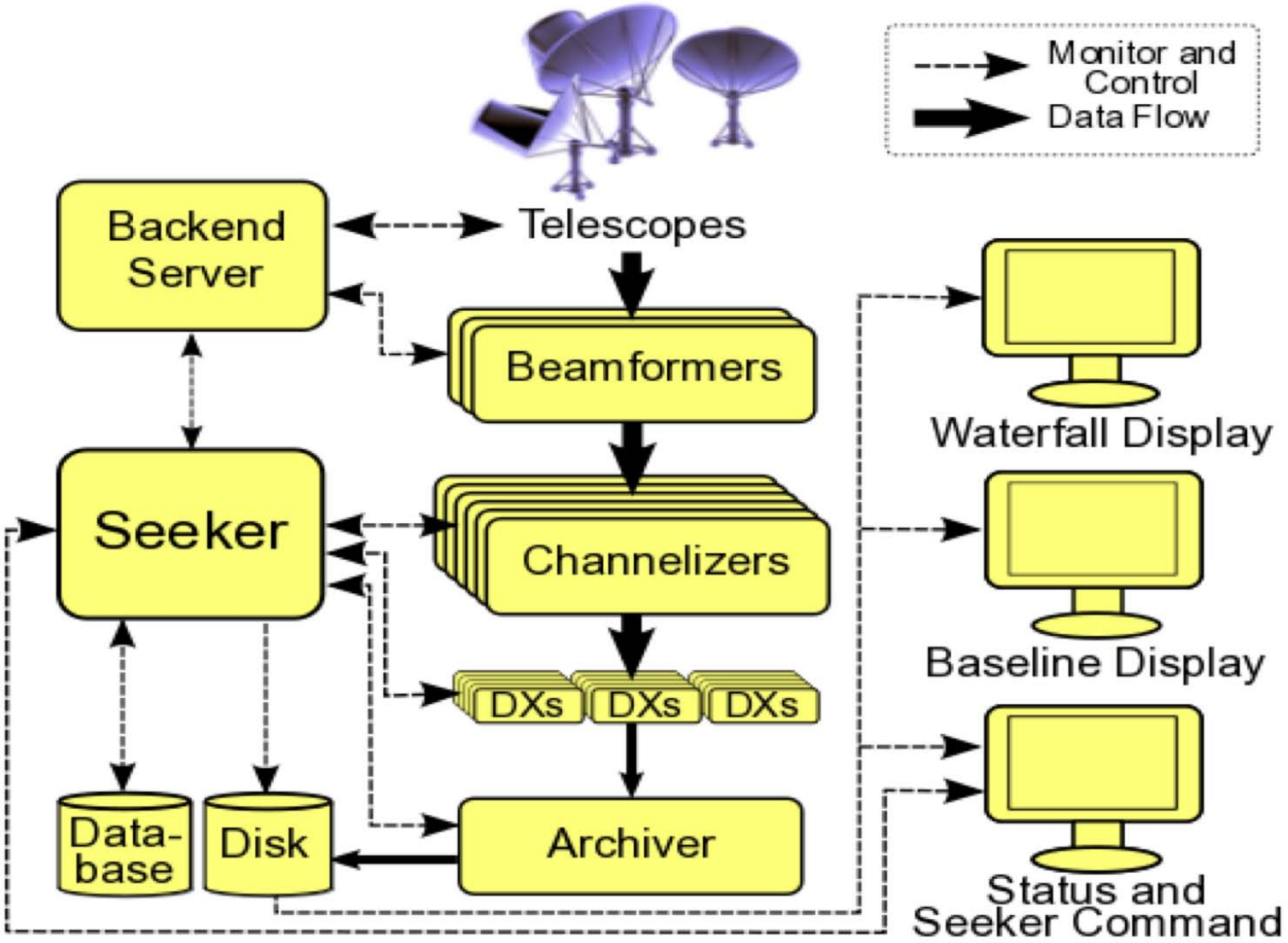


Terrestrial Microwave Window

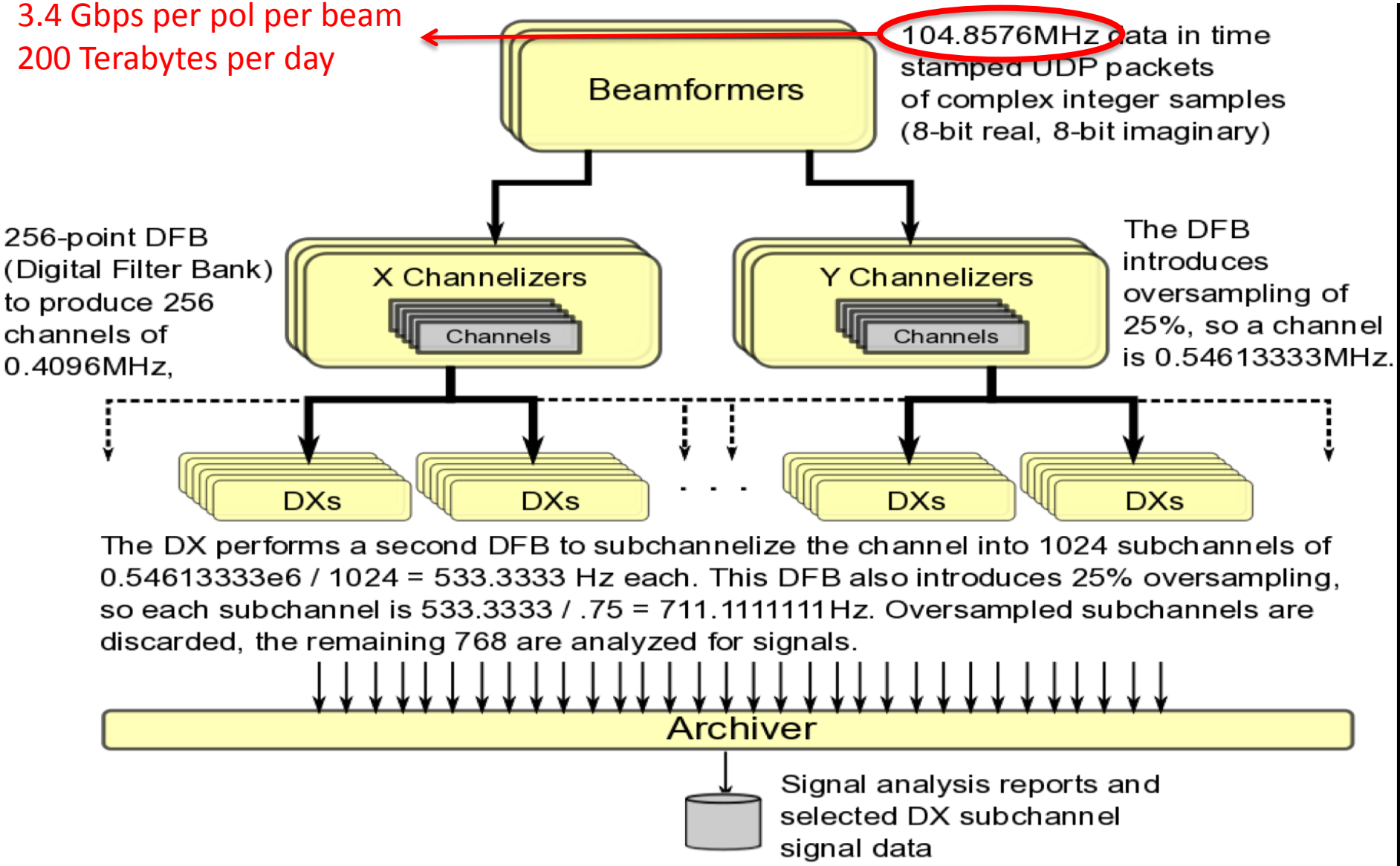


9 Billion 1 Hz Channels

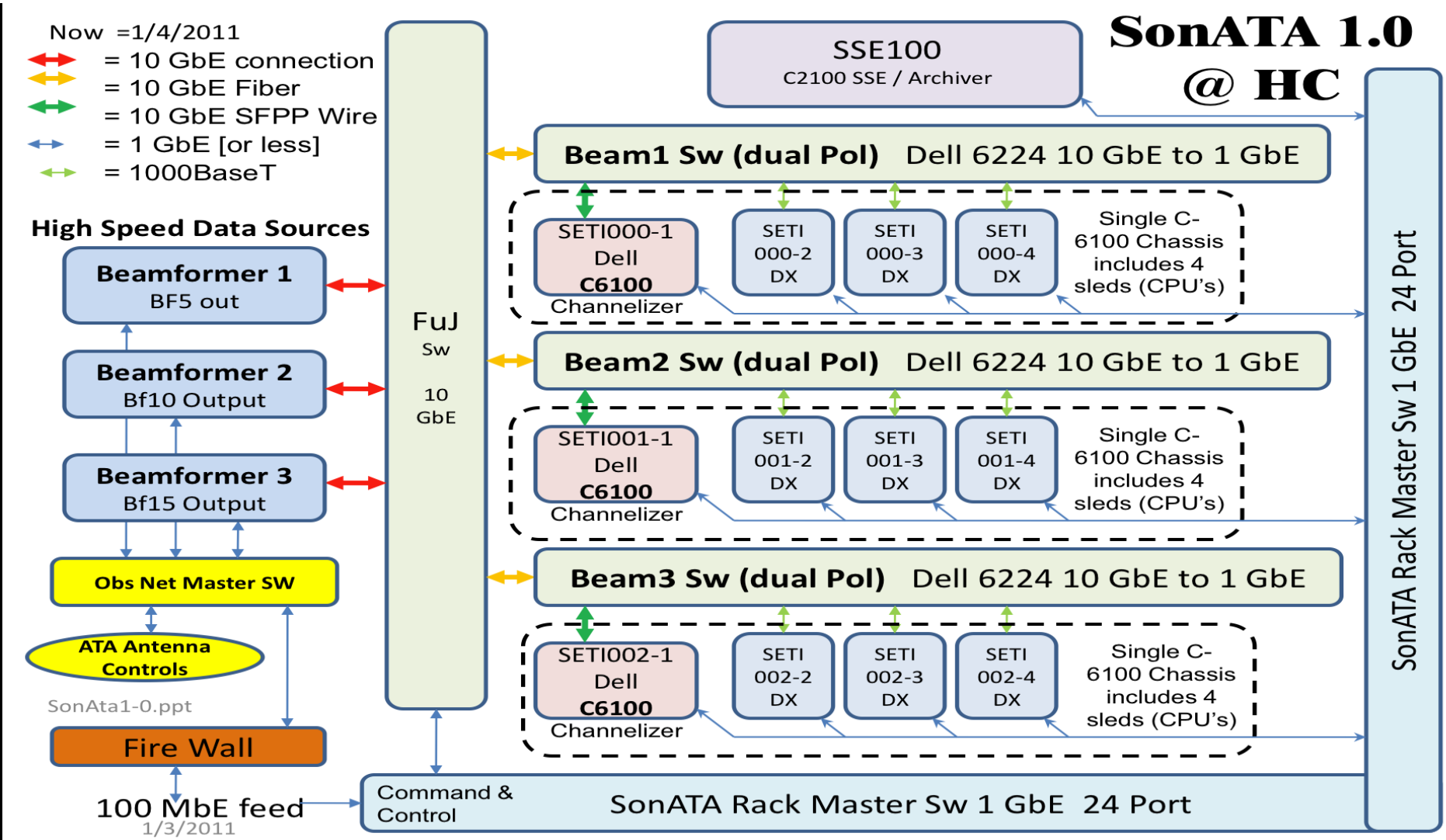
SonATA = SETI on the ATA



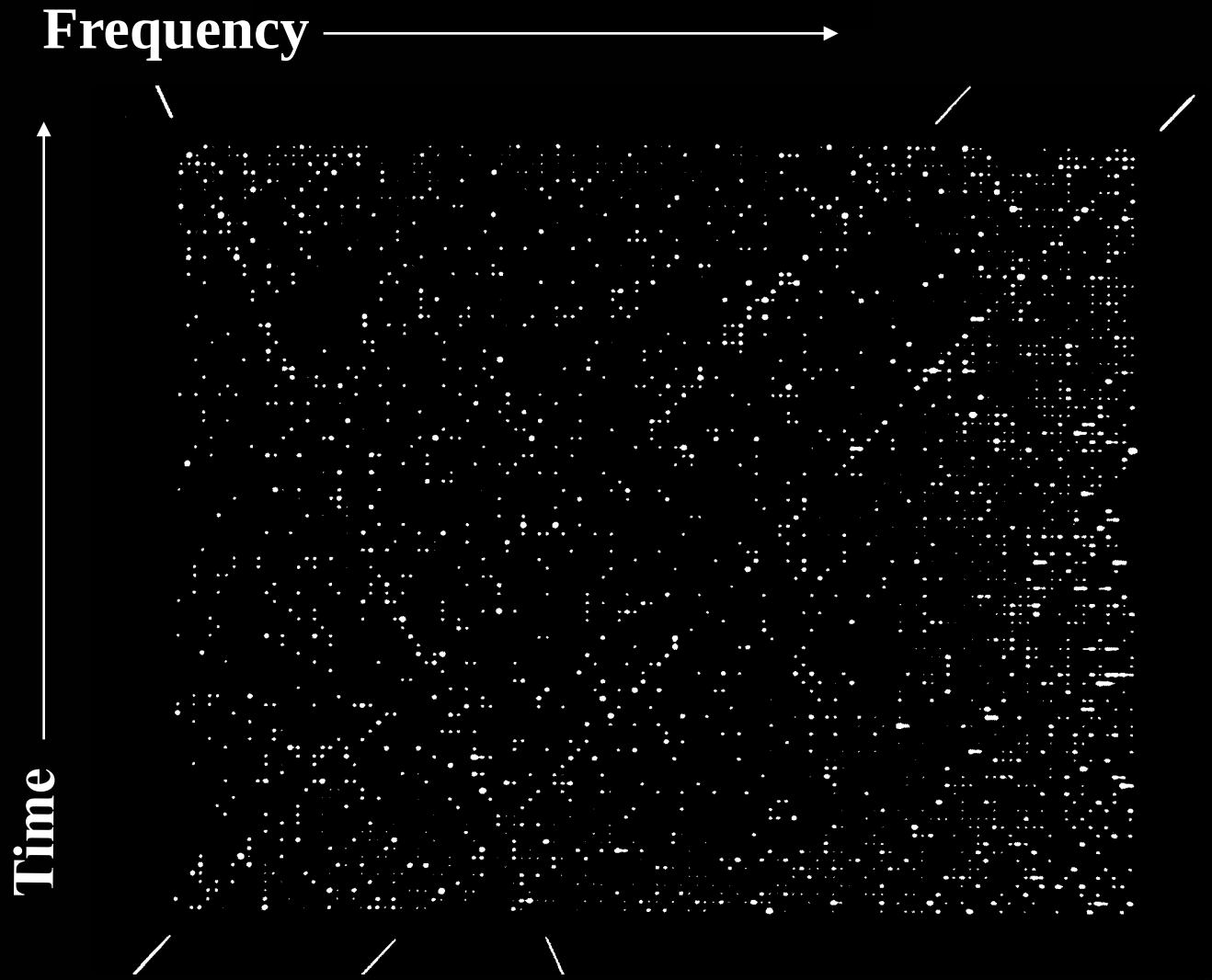
SonATA Architecture



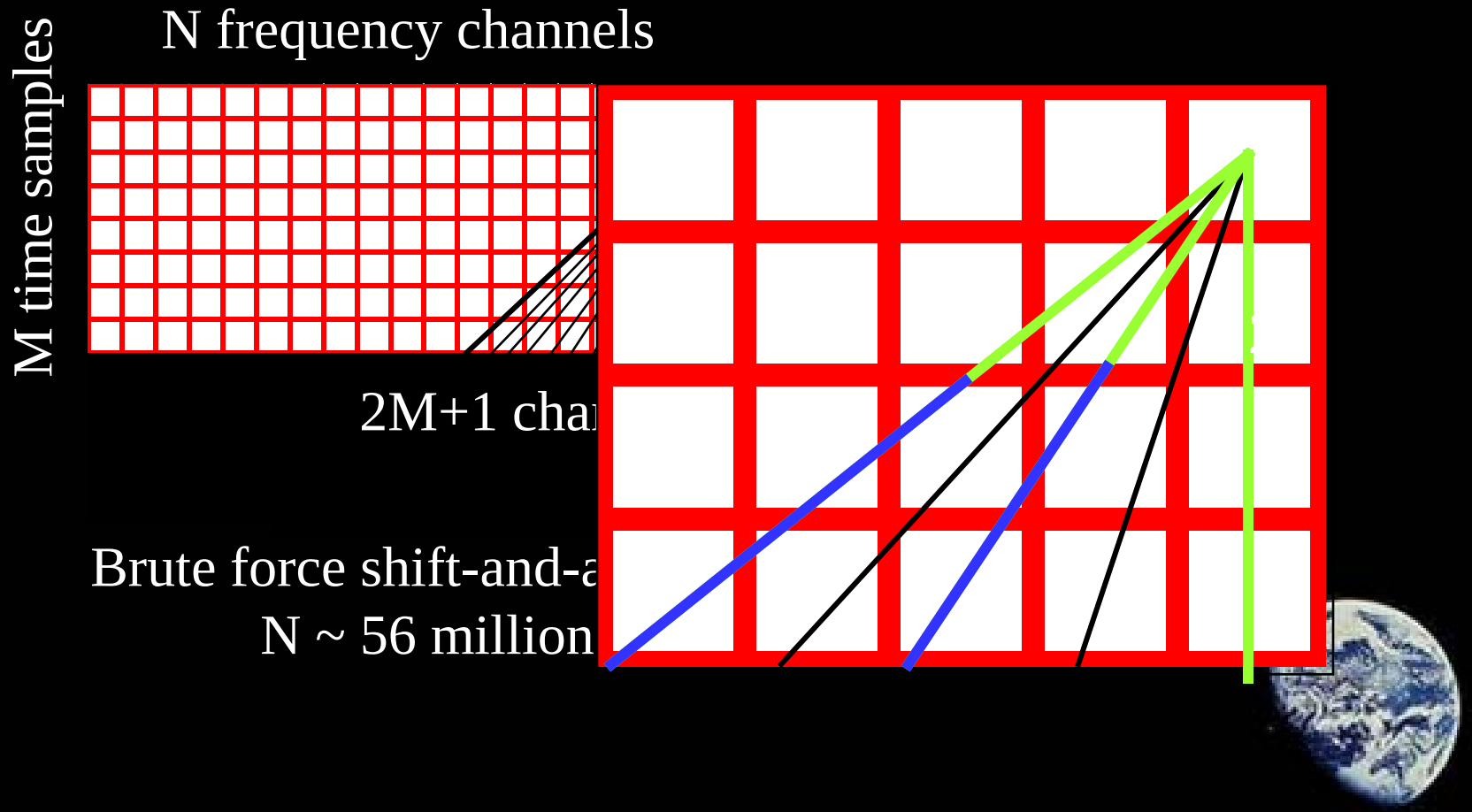
SonATA 1.0 = 20 MHz BW



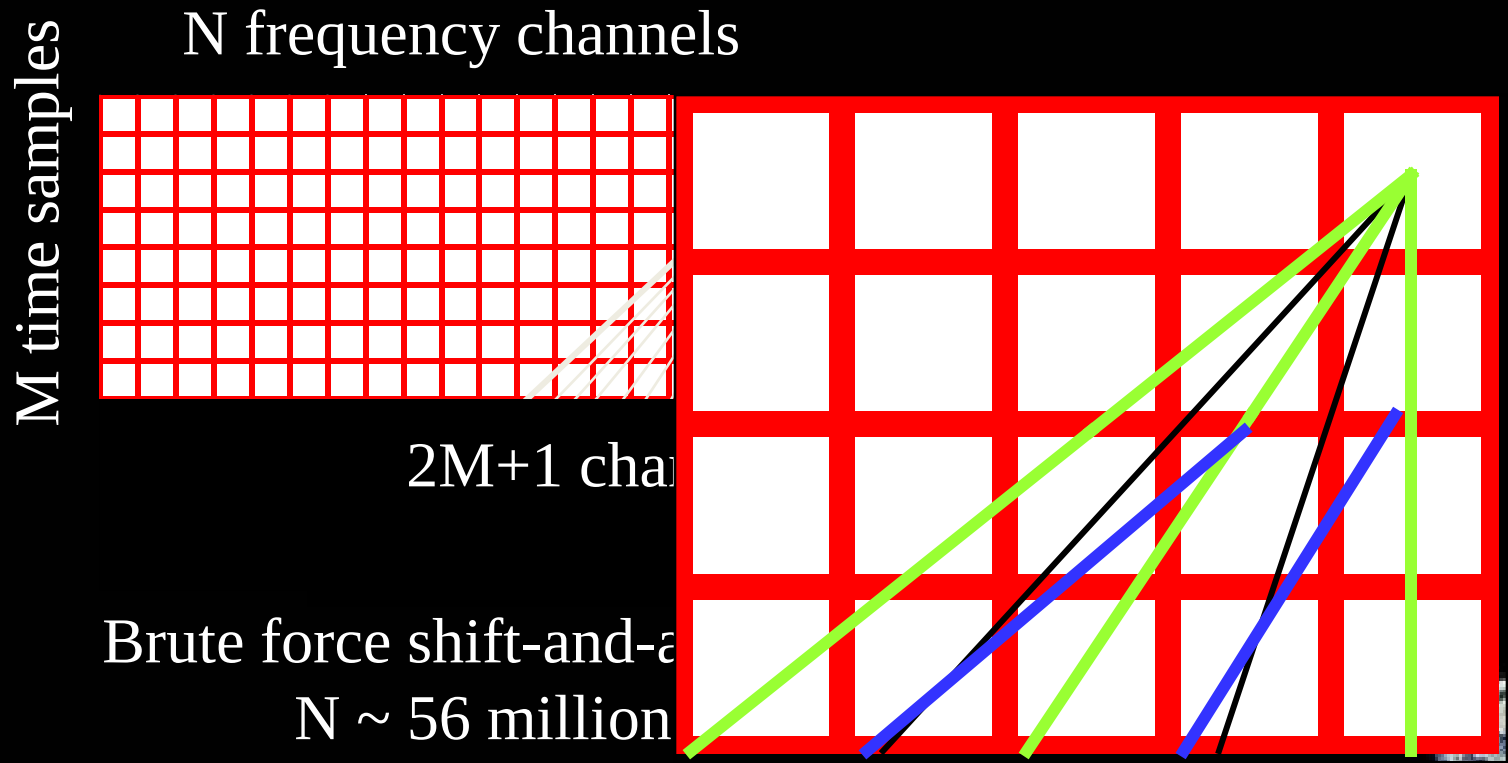
Drifting CW Detection



DADD Algorithm

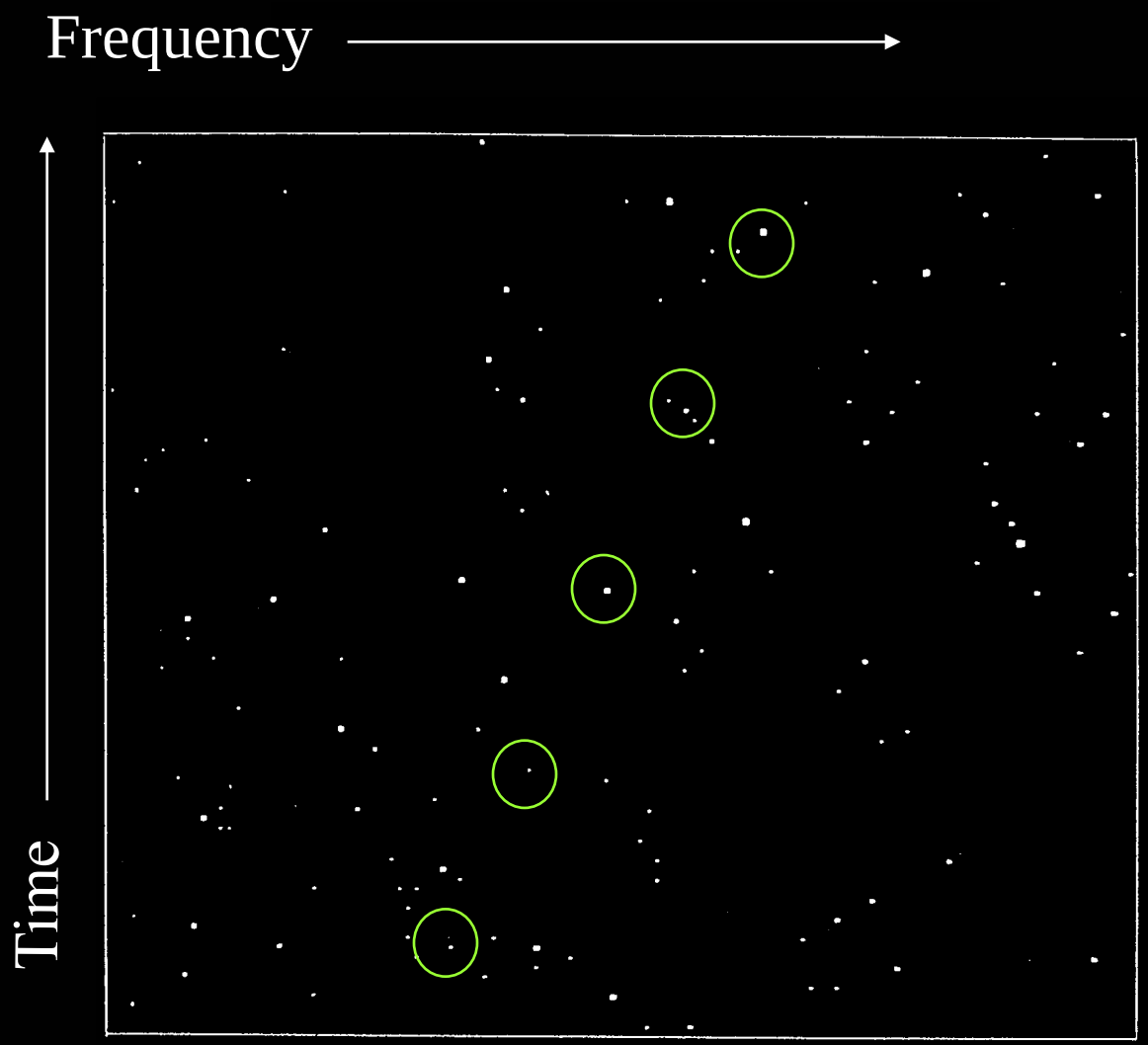


DADD Algorithm



DADD algorithm scales as $2N \log_2(M+1) M$

Triplet Pulse Detection



Thresholded
Sparse
Data Set

Near-Real-Time Pipeline

t= 1	Take data at $f_1 \pm \Delta f$		
t= 2			
t= 3			
t= 4			

Near-Real-Time Pipeline

t= 1	Take data at $f_1 \pm \Delta f$		
t= 2	Take data at $f_2 \pm \Delta f$	Analyze data f_1 compare w. RFI database and null beams →	no candidates
t= 3			
t= 4			

Near-Real-Time Pipeline

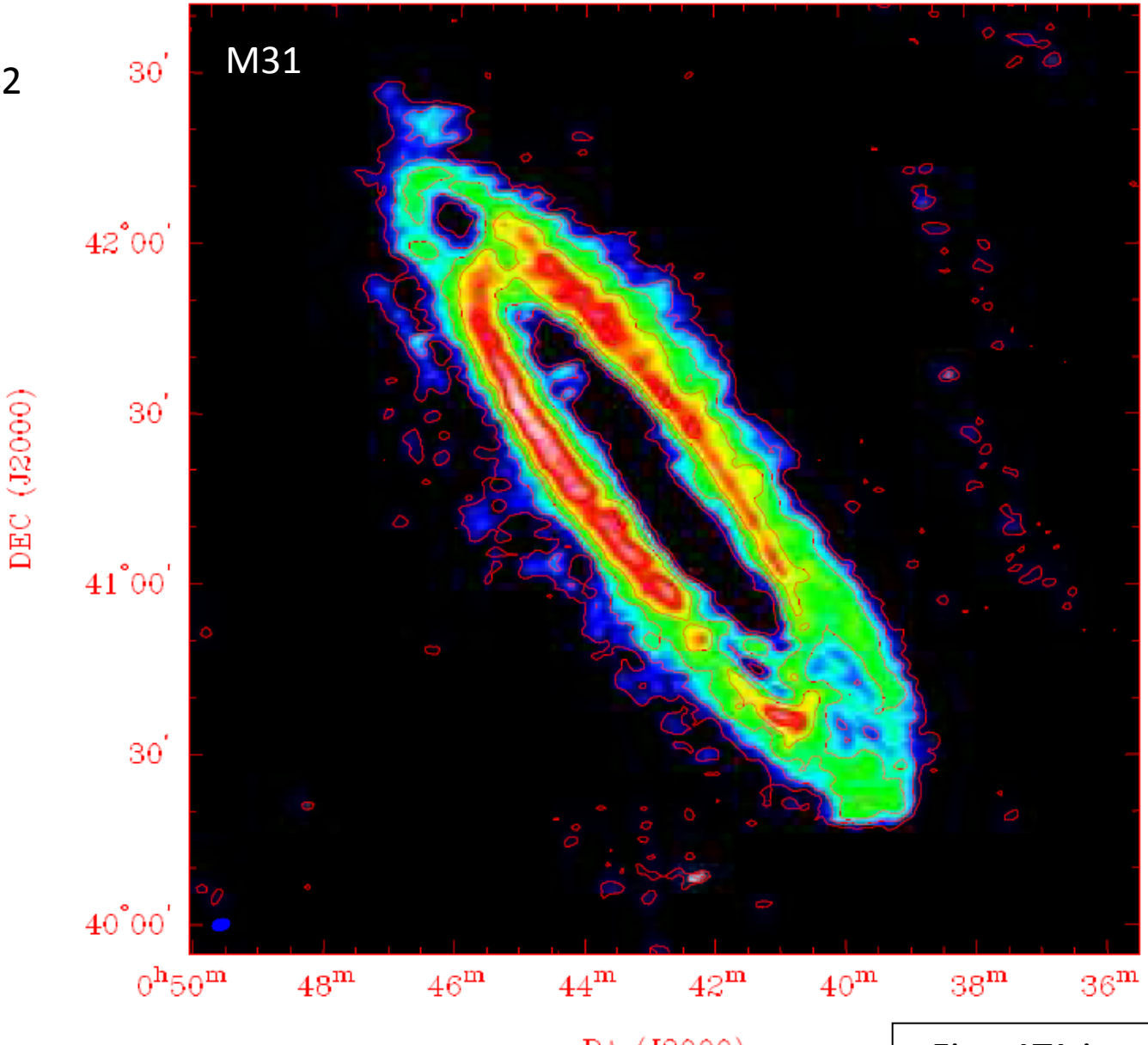
t= 1	Take data at $f_1 \pm \Delta f$		
t= 2	Take data at $f_2 \pm \Delta f$	Analyze data f_1 compare w. RFI database → and null beams	no candidates
t= 3	Take data at $f_3 \pm \Delta f$	Analyze data f_2 compare w. RFI database → and null beams	candidates
t= 4			

Near-Real-Time Pipeline

t= 1	Take data at $f_1 \pm \Delta f$		
t= 2	Take data at $f_2 \pm \Delta f$	Analyze data f_1 compare w. RFI database and null beams →	no candidates
t= 3	Take data at $f_3 \pm \Delta f$	Analyze data f_2 compare w. RFI database and null beams →	candidates
t= 4	~~Take data at $f_4 \pm \Delta f$~~ Follow up at f_2		


M31

ATA-42



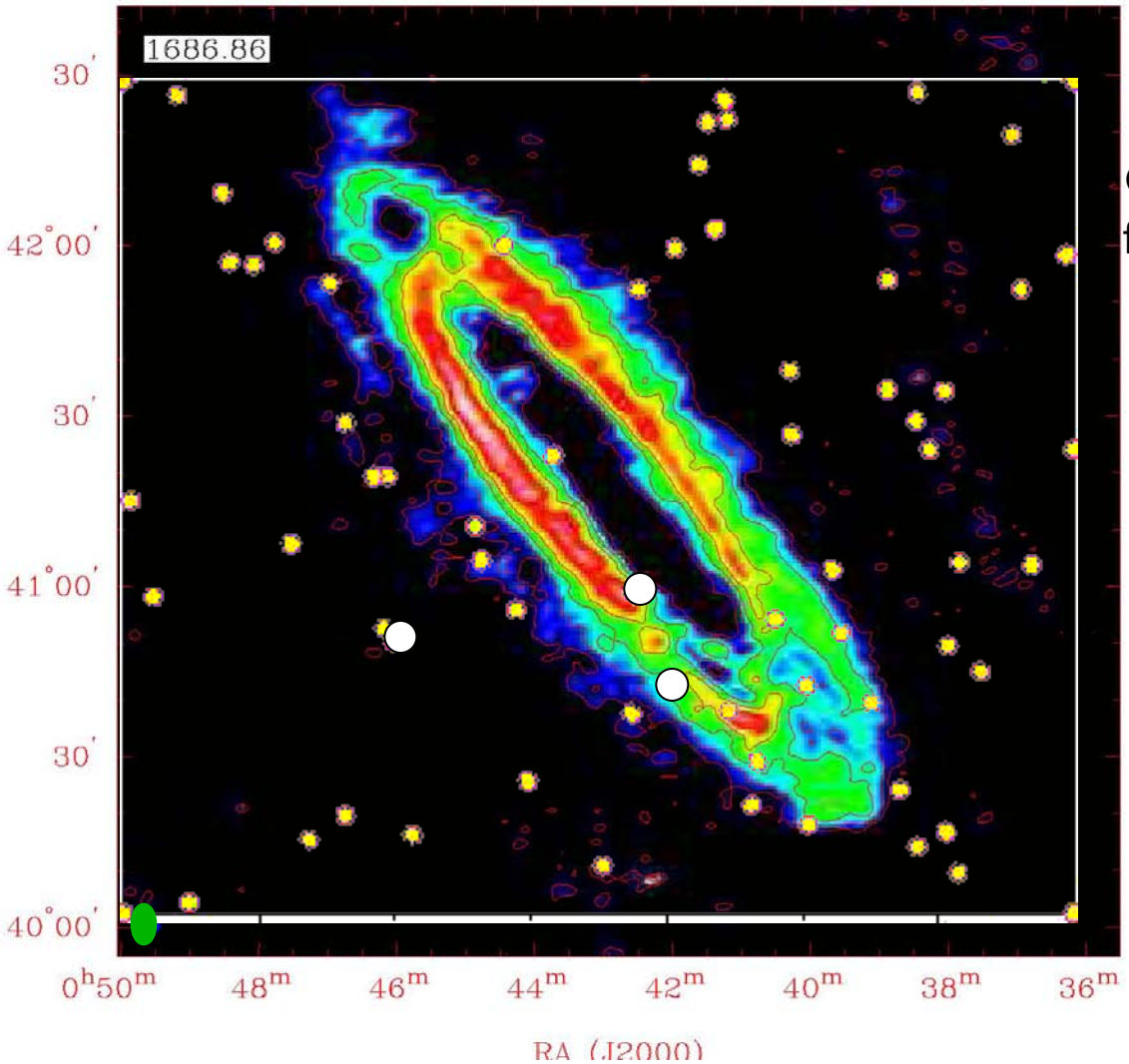
RA, DEC, VELO = 0:42:57.420, 41:18:42.56, 1.68686E+03 km/s at pixel (257.00, 257.00, 1.00)
Spatial region : 135,133 to 385,383
Pixel map image: m31-HI1.cm (m31) Min/max=0.2149/74.35 Range = 7 to 80 JY/BEAM. (log)
Contour image: m31-HI1.cm (m31) Min/max=0.2149/74.35 JY/BEAM.KM/S
Contours : -47.77, -30.14, -19.02, -12, -7.572, 7.572, 12, 19.02, 30.14, 47.77

First ATA image
1420 MHz
October 2007

ATA Team

Ackermann, Rob
Backer, Don
Backus, Peter
Barott, William
Blitz, Leo
Bock, Douglas
Bower, Geoff
Bradford, Tucker
Cheng, Calvin
Cork, Chris
Croft, Steve
D'Addario, Larry
Davis, Mike
DeBoer, Dave
Dexter, Matt
Dreher, John
Engargiola, Greg
Fields, Ed
Fleming, Matt
Forster, Rick
Harp, Gerry
Heiles, Carl
Helfer, Tam
Jordan, Jane
Jorgensen, Susie
Keating, Garrett
Kilsdonk, Tom
Kraybill, Colby
MacMahon, Dave
Milgrome, Oren
Pierson, Tom
Randall, Karen
Ross, John
Tarter, Jill
Thornton, Doug
Urry, Lynn
van Leeuwen, Joeri
Vitouchkine, Artyom
Weinreb, Sandy
Welch, Jack
Werthimer, Dan
Williams, Peter
Wright, Mel

Commensal Targeted Search

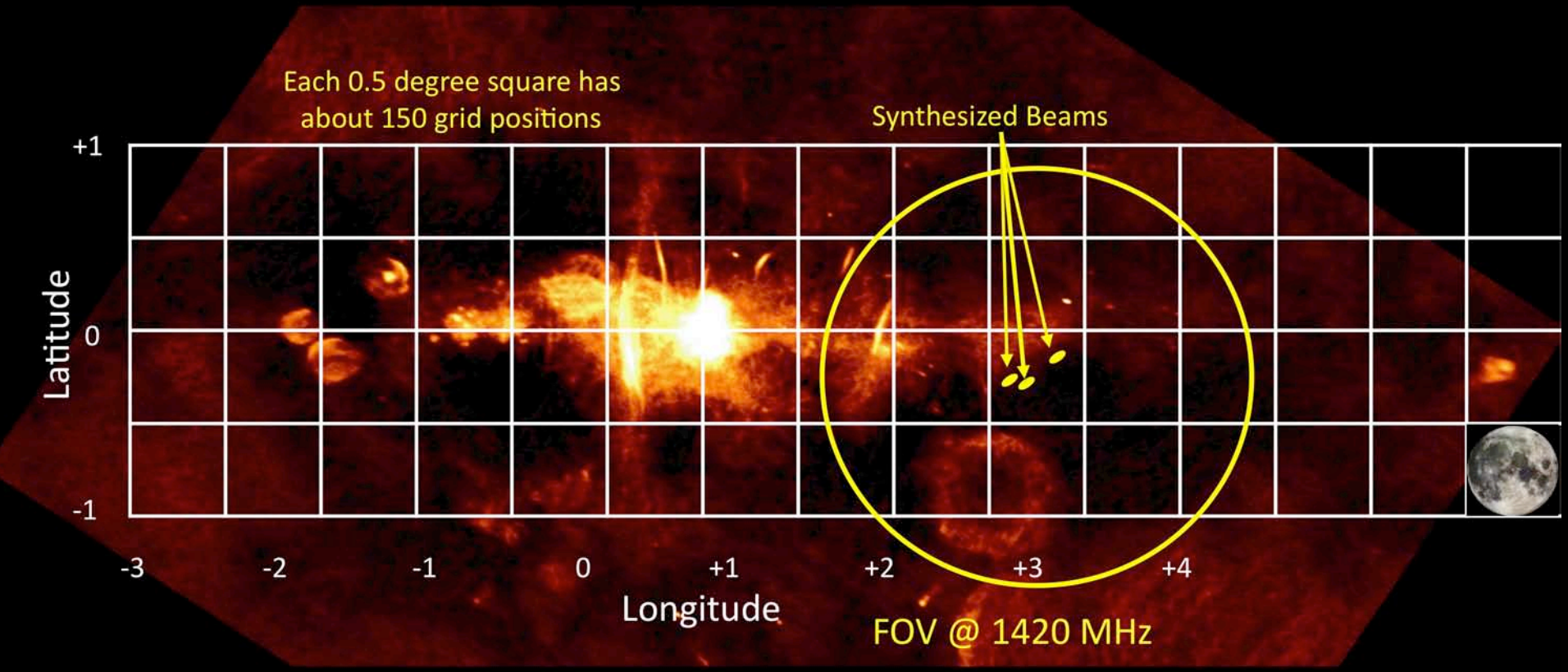


○ Target stars selected from HabCat (13256 stars)

✹ Target stars selected from Tycho (~250,000 stars)

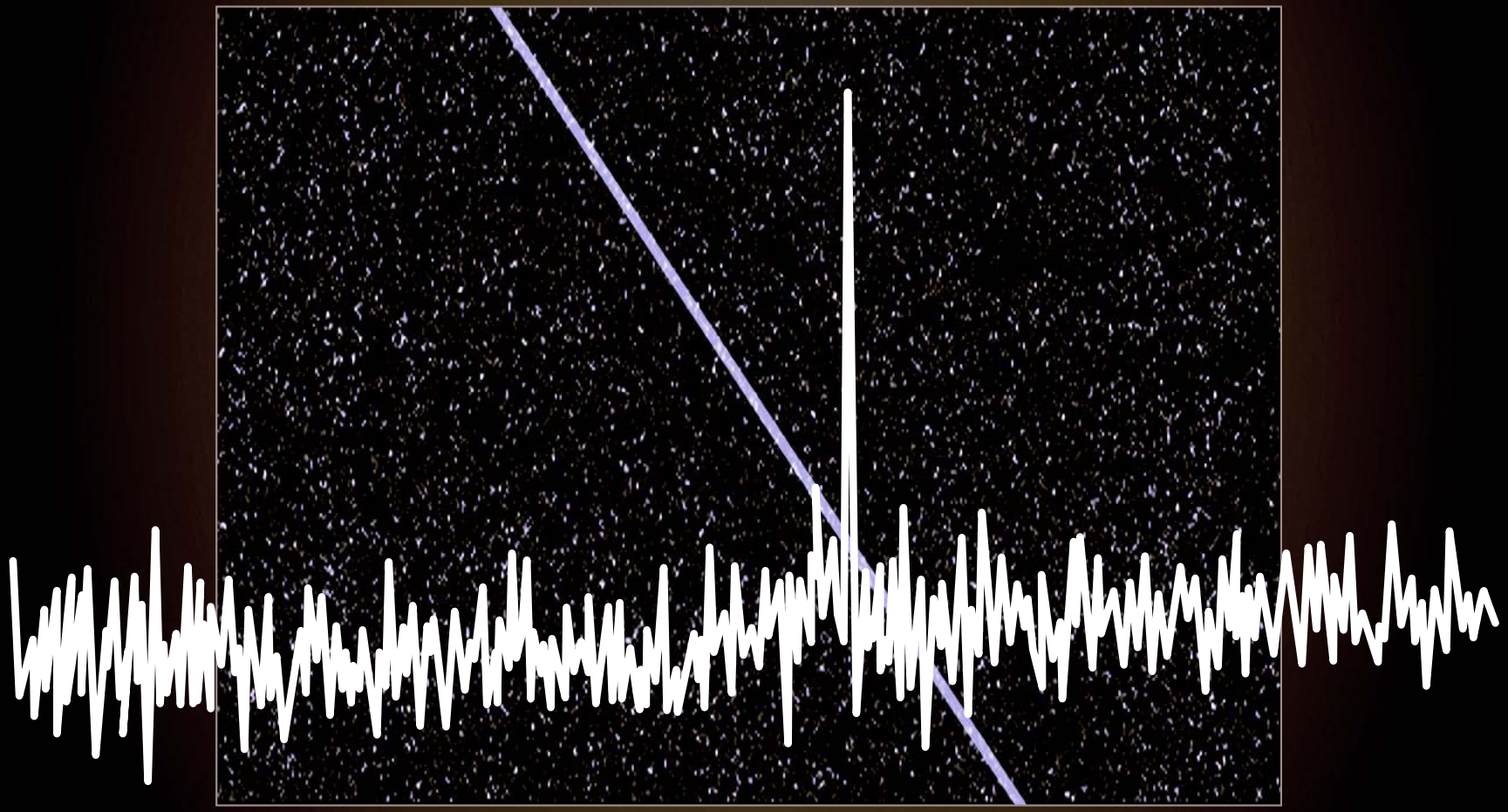
3 dual-pol summed array beams at 1 or 2 frequencies to be placed on target stars

Galactic Center Survey



4-10 Billion stars within 20 square degrees

VOYAGER 1 SIGNAL: 106 AU AWAY



SETI@home
The Search for Extraterrestrial Intelligence

One million earthlings
Bounded by optimism
Leave their PC's on

Dan Seidner

"The number of people in the world actively involved in SETI could fit in a phone booth!"

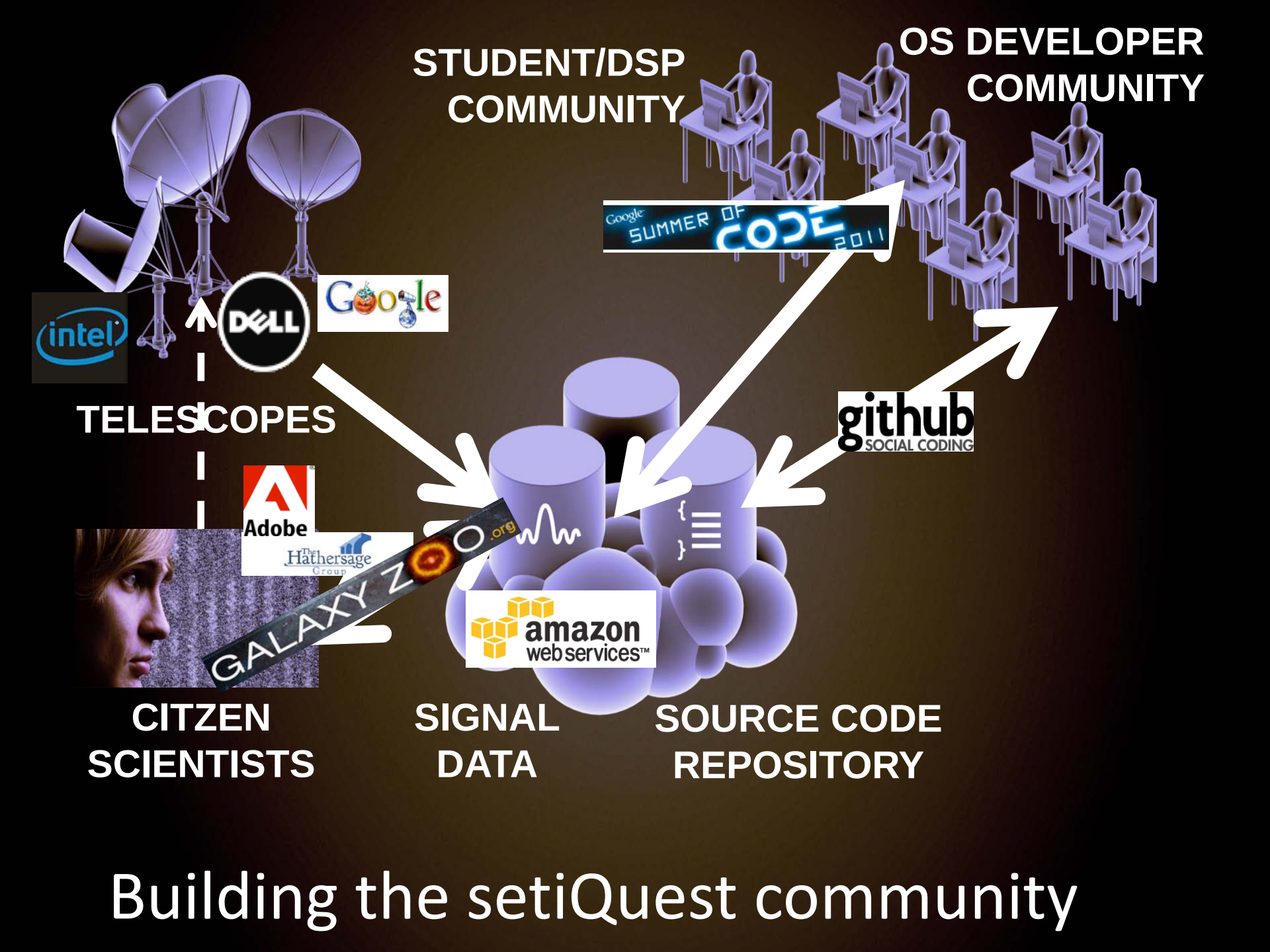
Alan Stern


setiquest:
Actively
Engaging
the World

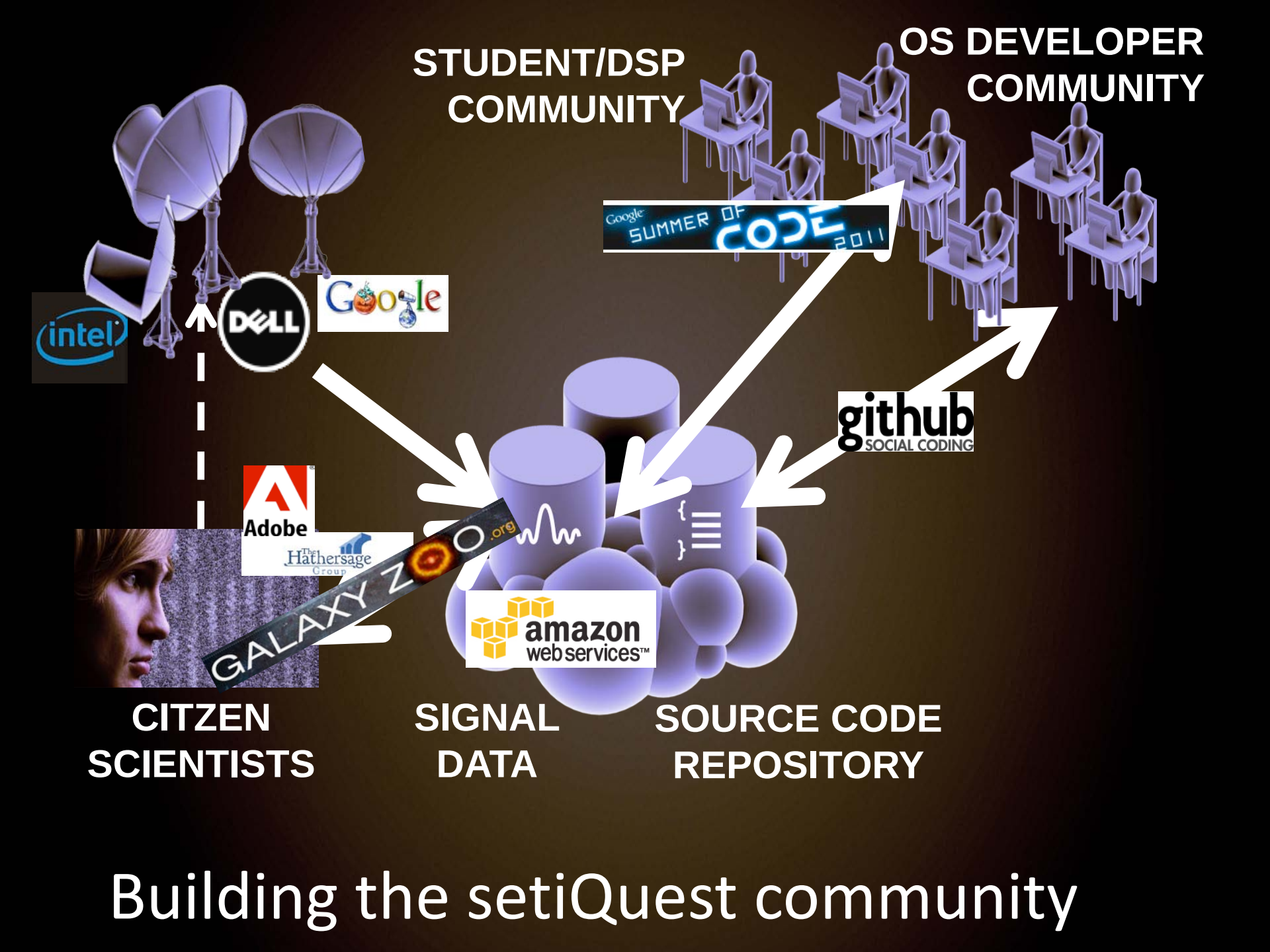
2009 TED PRIZE WISH

TECHNOLOGY ENTERTAINMENT DESIGN

I wish that you would empower Earthlings everywhere to become active participants in the ultimate search for cosmic company.



Building the setiQuest community

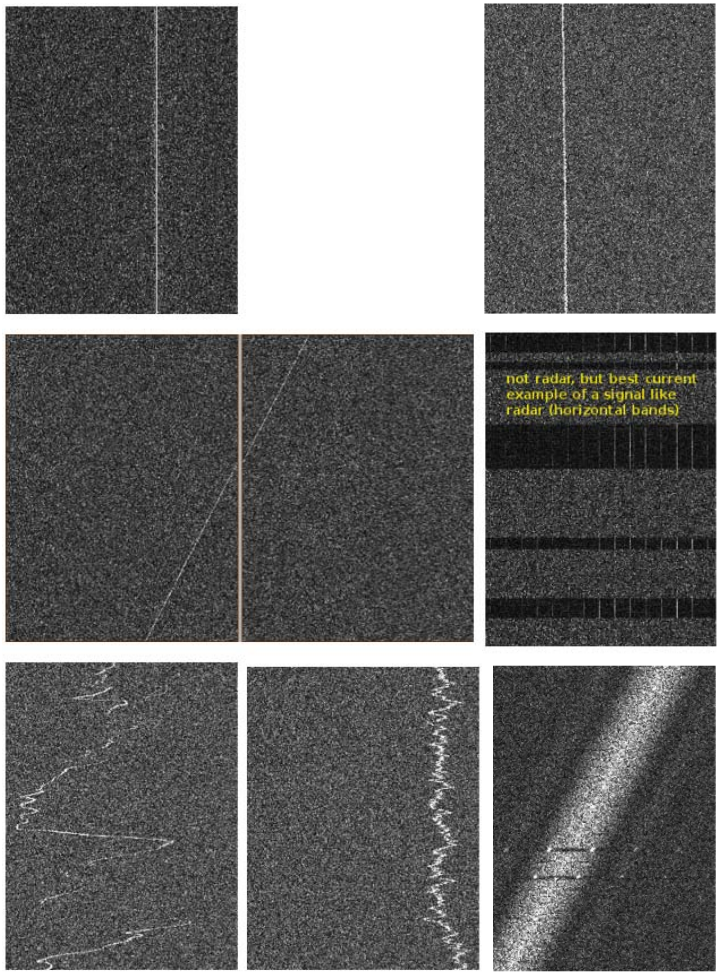


Building the setiQuest community

Signal Zoo

Zero drift

Not Zero drift



Automated Classification
and Re-Observation Follow Up

Seeker oversees queries about signals in archiver and database and reschedules observations with confirmed candidates (NOT zero drift, NOT recent RFI, NOT seen in other beams)

Target Observations

CWSig	PulSig	ZeroDft	RctRfi	CWCand	PulCand	CWConf	PulConf
111091	15439	17751	86959	1809	1438	21	1115

Target1-ON

CWSig	PulSig	ZeroDft	RctRfi	CWCand	PulCand	CWConf	PulConf
39701	8233	1	2	28	1102	0	5

Target1-OFF

CWSig	PulSig	ZeroDft	RctRfi	CWCand	PulCand	CWConf	PulConf
5047	5085	0	0	1	4	1	3

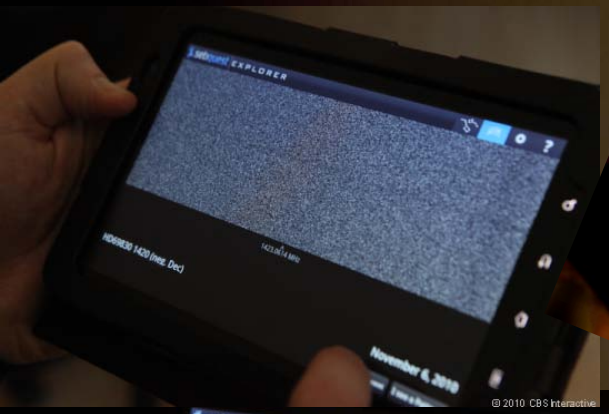
Target2-ON

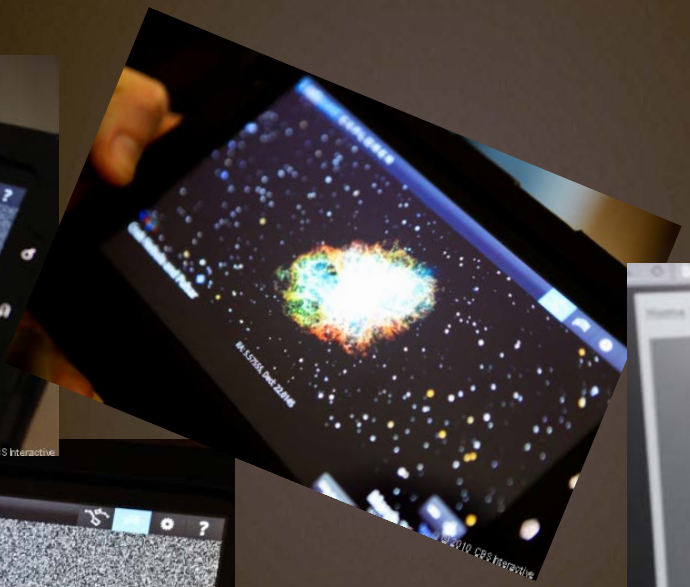
CWSig	PulSig	ZeroDft	RctRfi	CWCand	PulCand	CWConf	PulConf
6004	689	0	0	1	3	0	0

Note: for the follow-up observations the new CW and Pulse detections are not relevant, the system is tracking candidates from the initial observation.

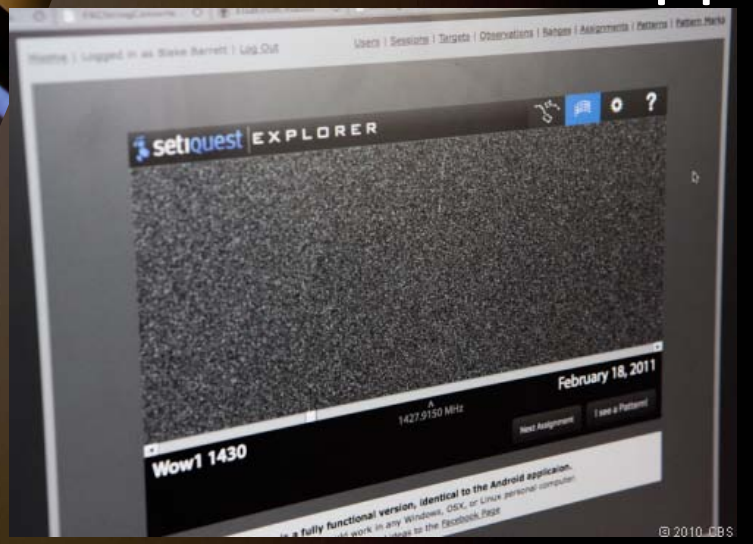
Reobservation sequence: ON1, Off, ON2, OFF, ON3, OFF, ON4, OFF, ON5 !!

setiquest Explorer





browser app

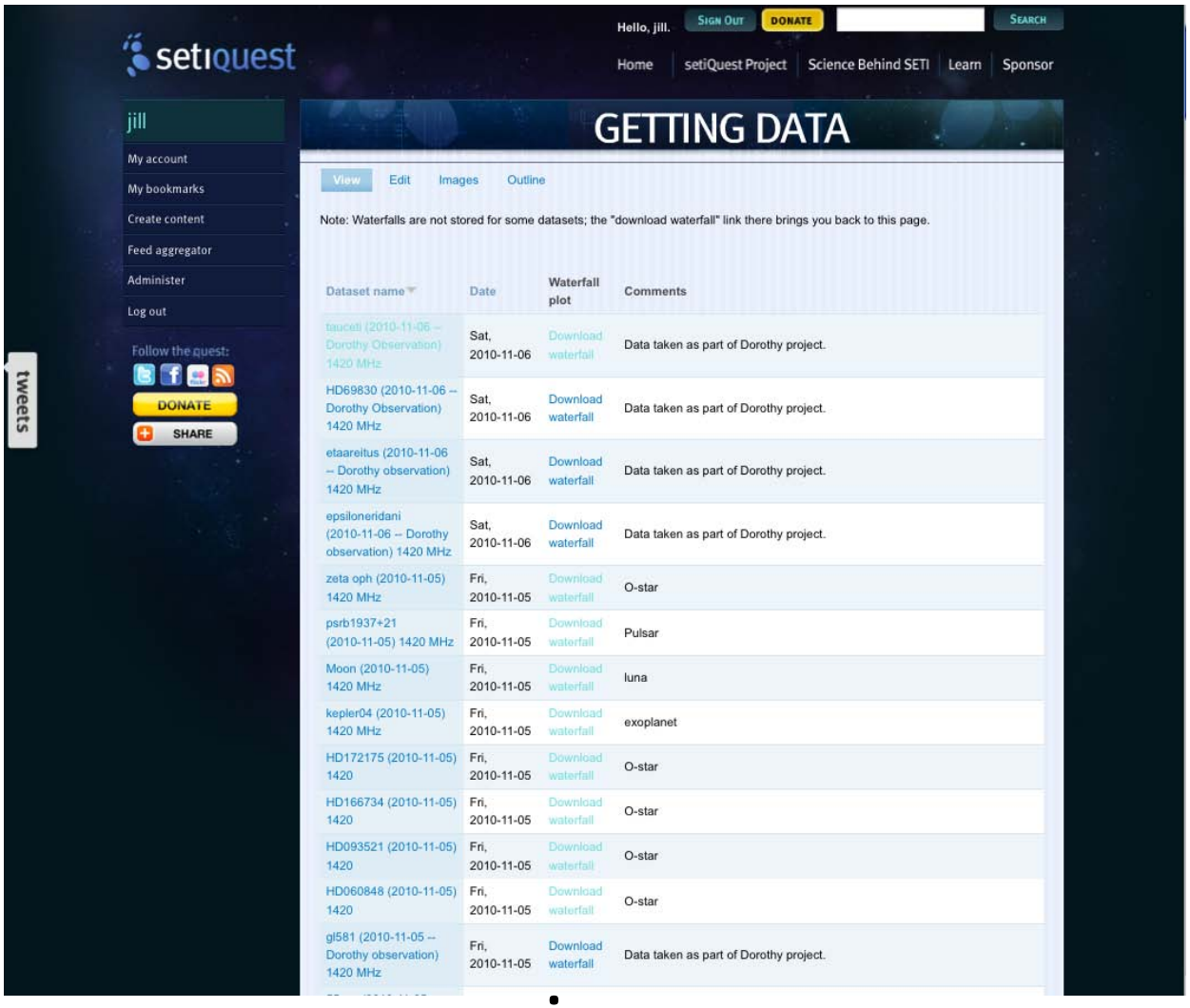


Android mobile app

explorer.setiquest.org

Francis Potter & Hathersage Group

http://setiquest.org/getting-data



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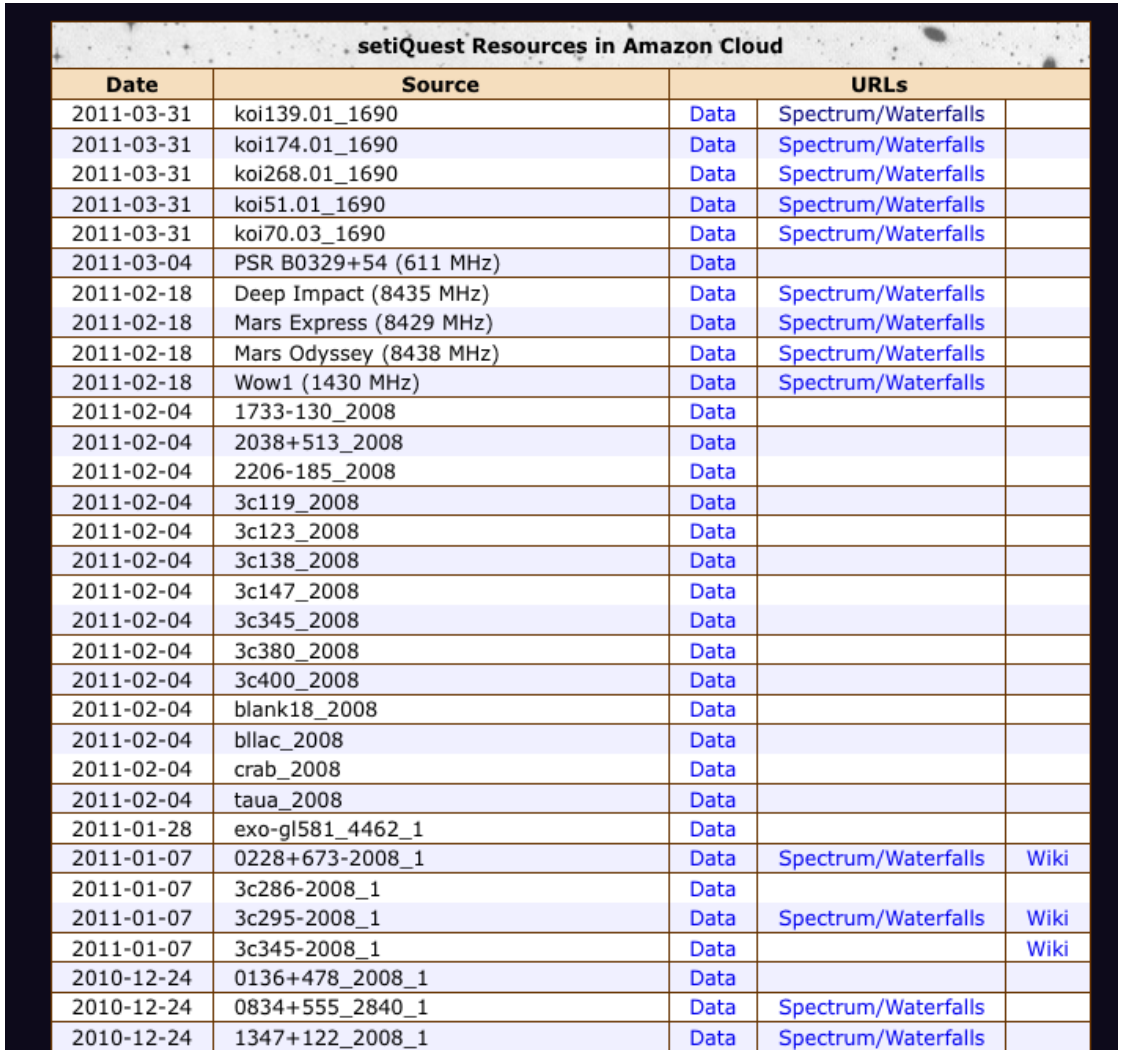
http://setiquest.dyndns.org/all-sources.html

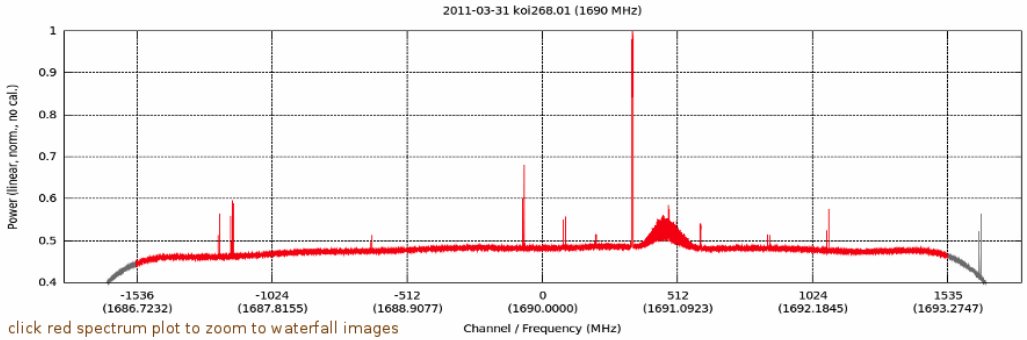


setiQuest Resources in Amazon Cloud

Date	Source	URLs		
2011-03-31	koi139.01_1690	Data	Spectrum/Waterfalls	
2011-03-31	koi174.01_1690	Data	Spectrum/Waterfalls	
2011-03-31	koi268.01_1690	Data	Spectrum/Waterfalls	
2011-03-31	koi51.01_1690	Data	Spectrum/Waterfalls	
2011-03-31	koi70.03_1690	Data	Spectrum/Waterfalls	
2011-03-04	PSR B0329+54 (611 MHz)	Data		
2011-02-18	Deep Impact (8435 MHz)	Data	Spectrum/Waterfalls	
2011-02-18	Mars Express (8429 MHz)	Data	Spectrum/Waterfalls	
2011-02-18	Mars Odyssey (8438 MHz)	Data	Spectrum/Waterfalls	
2011-02-18	Wow1 (1430 MHz)	Data	Spectrum/Waterfalls	
2011-02-04	1733-130_2008	Data		
2011-02-04	2038+513_2008	Data		
2011-02-04	2206-185_2008	Data		
2011-02-04	3c119_2008	Data		
2011-02-04	3c123_2008	Data		
2011-02-04	3c138_2008	Data		
2011-02-04	3c147_2008	Data		
2011-02-04	3c345_2008	Data		
2011-02-04	3c380_2008	Data		
2011-02-04	3c400_2008	Data		
2011-02-04	blank18_2008	Data		
2011-02-04	bllac_2008	Data		
2011-02-04	crab_2008	Data		
2011-02-04	taua_2008	Data		
2011-01-28	exo-gl581_4462_1	Data		
2011-01-07	0228+673-2008_1	Data	Spectrum/Waterfalls	Wiki
2011-01-07	3c286-2008_1	Data		
2011-01-07	3c295-2008_1	Data	Spectrum/Waterfalls	Wiki
2011-01-07	3c345-2008_1	Data		Wiki
2010-12-24	0136+478_2008_1	Data		
2010-12-24	0834+555_2840_1	Data	Spectrum/Waterfalls	
2010-12-24	1347+122_2008_1	Data	Spectrum/Waterfalls	

-
-
-

setiQuest Amazon Cloud

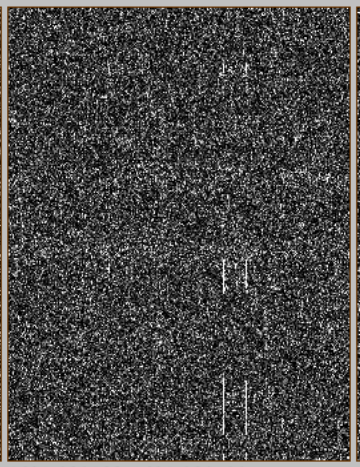


click red spectrum plot to zoom to waterfall images

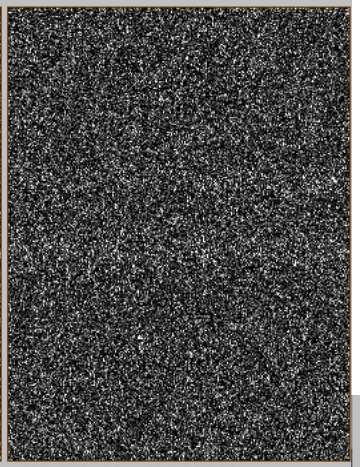
2011-03-31 koi268.01 (1690 MHz)

Home | Previous | Next

1691.037867-1691.038133 MHz

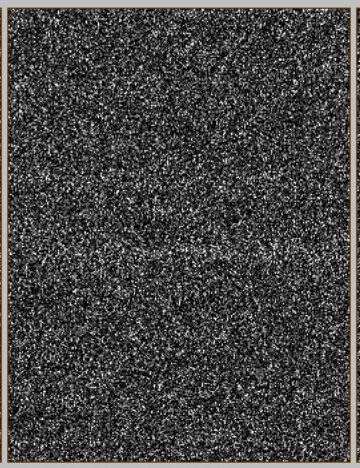


1691.038133-1691.038400 MHz

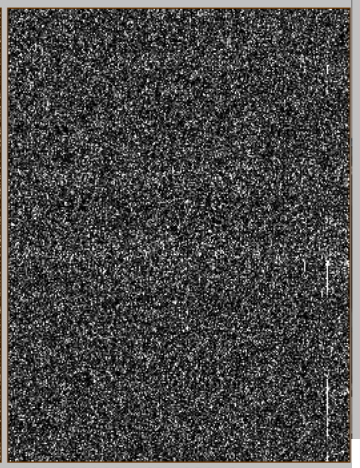


1691.038400-1691.038667 MHz

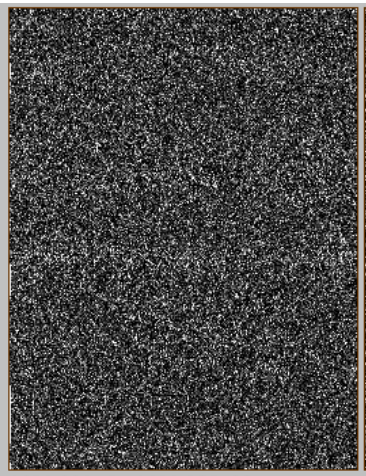
1691.038667-1691.038933 MHz



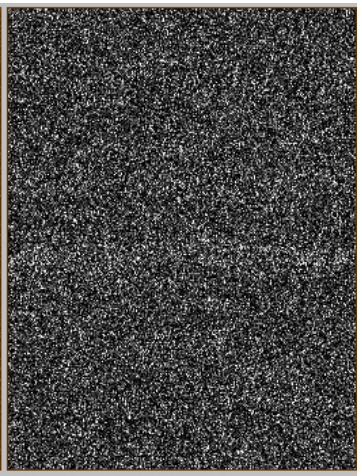
1691.038933-1691.039200 MHz



1691.039200-1691.039467 MHz



1691.039467-1691.039733 MHz



1691.039733-1691.040000 MHz

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Private/Public Help Needed

- Generate new SSA contracts with USAF
- Private donations needed for SETI search
  - Major donors
  - Moderate donors
  - Mini donors
- Corporate sponsorships
  - ET phone here
  - Ultimate search engine
  - High tech backdrop for commercials

seti.org

Oops!

- We now know where to point our array
- We have just launched a two-year exploration of the Kepler worlds and plan to involve Earthlings in the search
- We are successfully building tools to engage the world & improve the search
- But the US/CA/UCB funding situation put the array into hibernation on April 15
- The world has noticed!

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