The Breakthrough LISTEN Search for Intelligent Life: A Wideband Data Recorder for the Robert C. Byrd Green Bank Telescope

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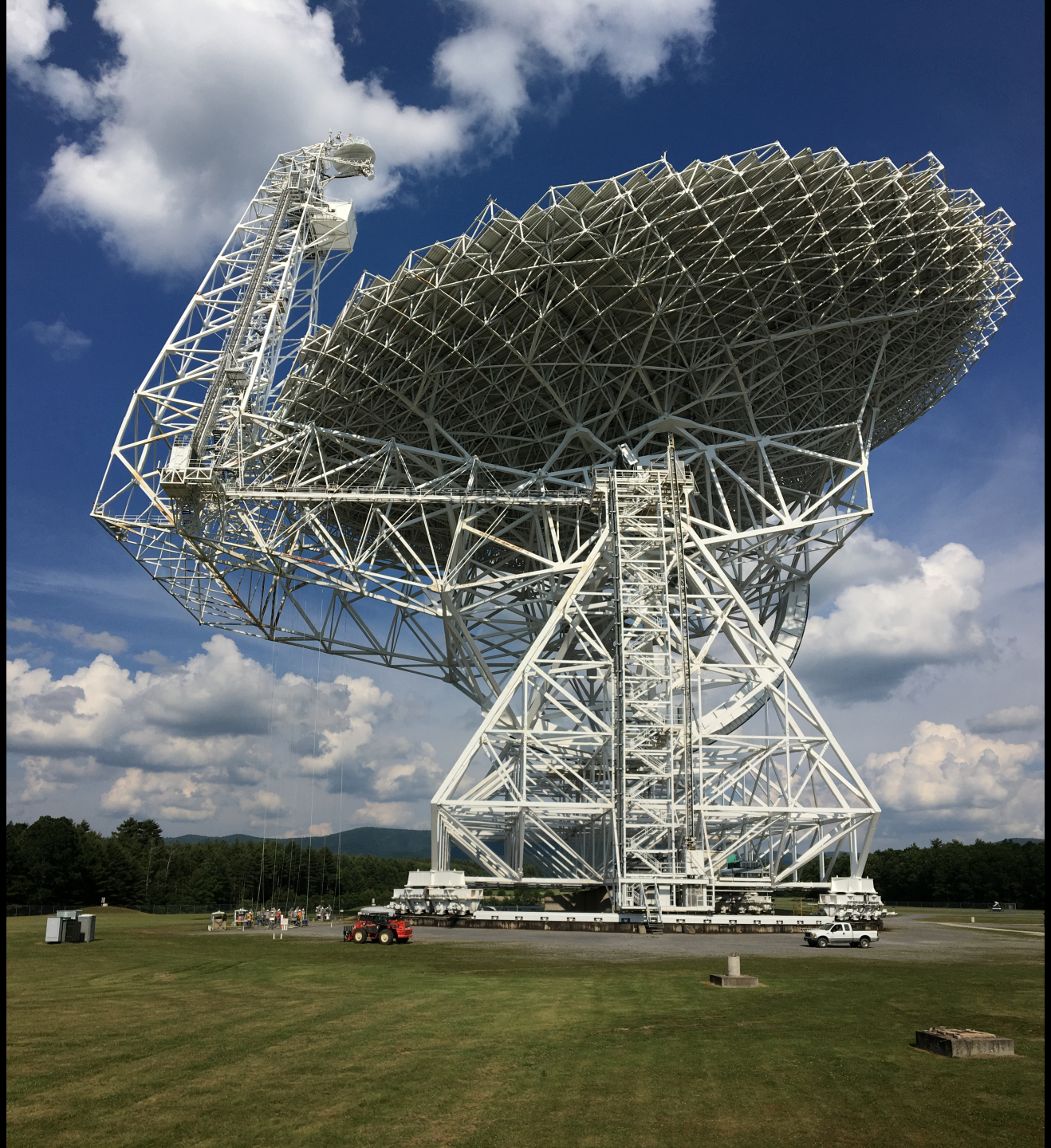
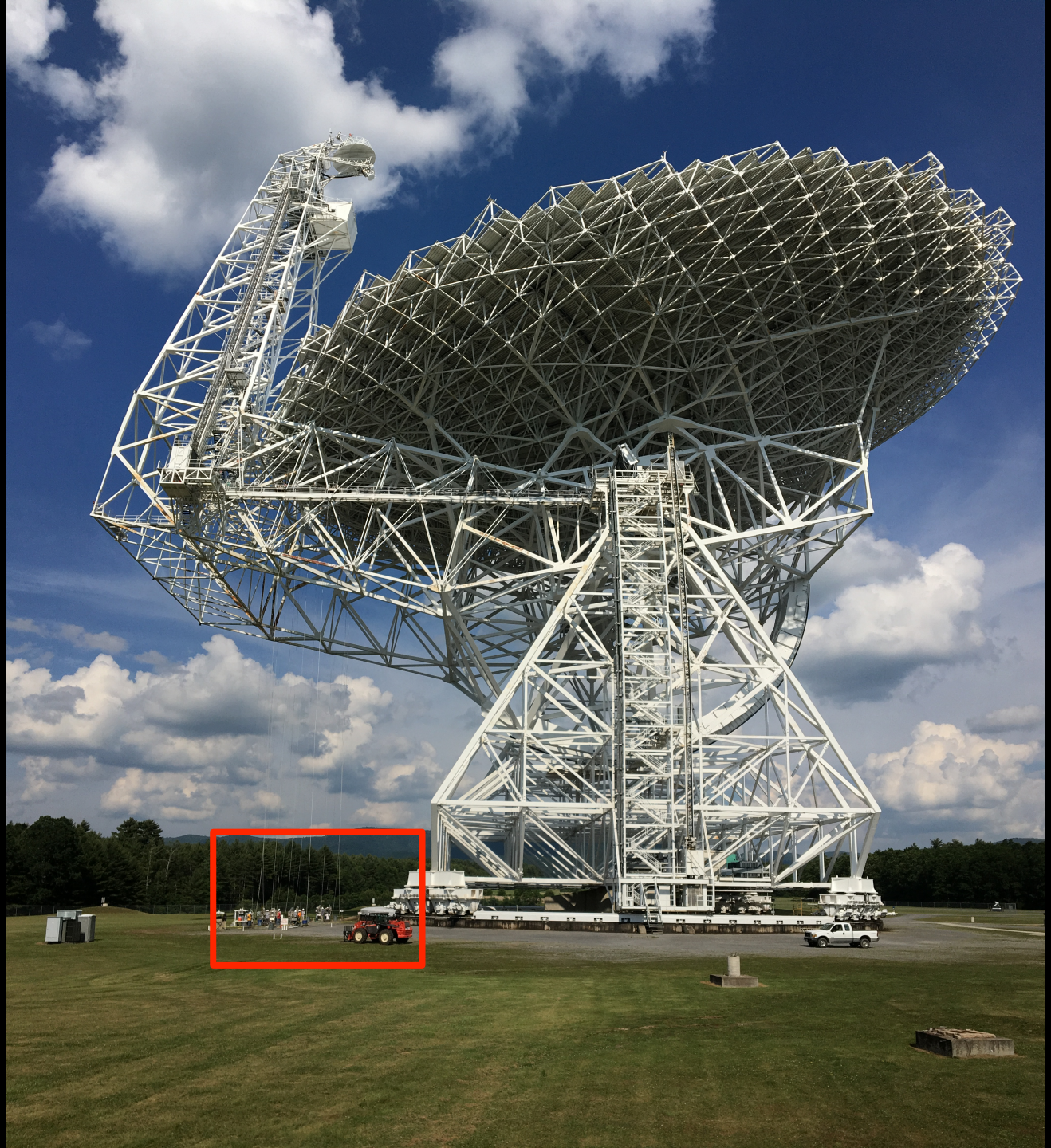
Breakthrough LISTEN SETI Project

- Breakthrough Initiative: $100M over 10 years
- Starting with Green Bank and Parkes Radio Telescopes, as well as Lick Observatory APF (optical SETI)
- 1,000,000 stars; 1,000 galaxies; galactic plane; all sky
- New instrumentation: 10 GHz bandwidth (~10 billion channels)
- SETI@Home analyzes parts of the data
- Open source everything: data, hardware, software, gpuware, gateware

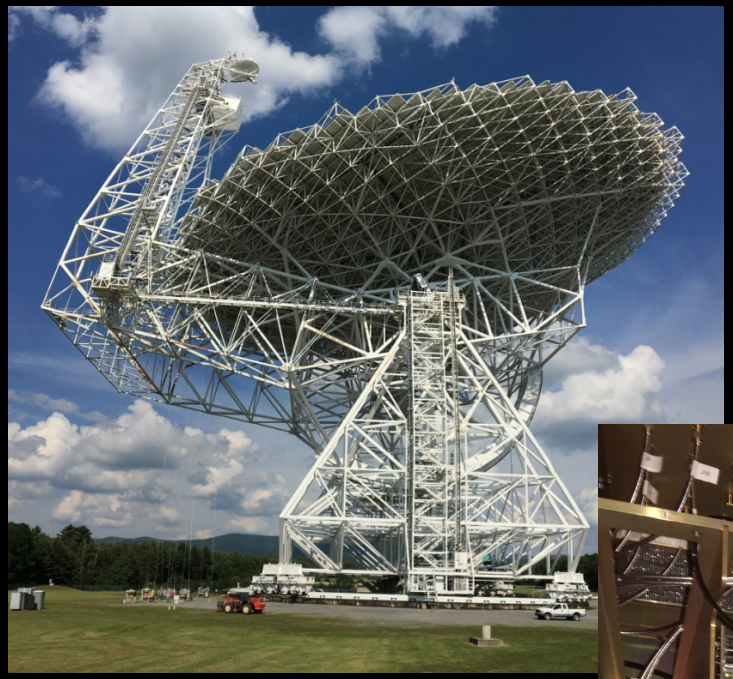
Robert C. Byrd Green Bank Telescope

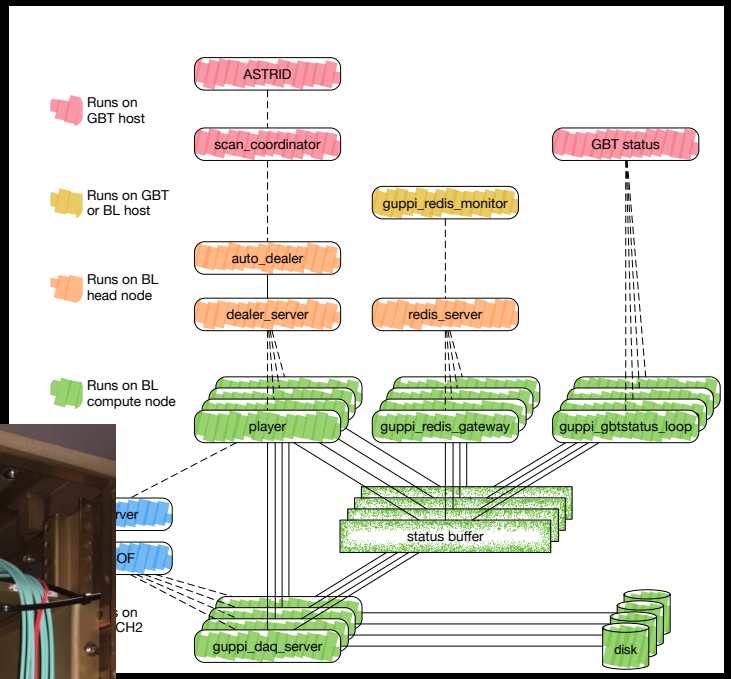
- Located in Green Bank, West Virginia within the National Radio Quiet Zone
- 100 meter unblocked aperture
- Frequency coverage from 100 MHz to 115+ GHz BL using L, S, C bands (1 to 8 GHz) so far
- Active surface comprised of >2000 panels
- World's largest fully steerable radio telescope
- Second largest moveable land object(?)





Reuse at GBT

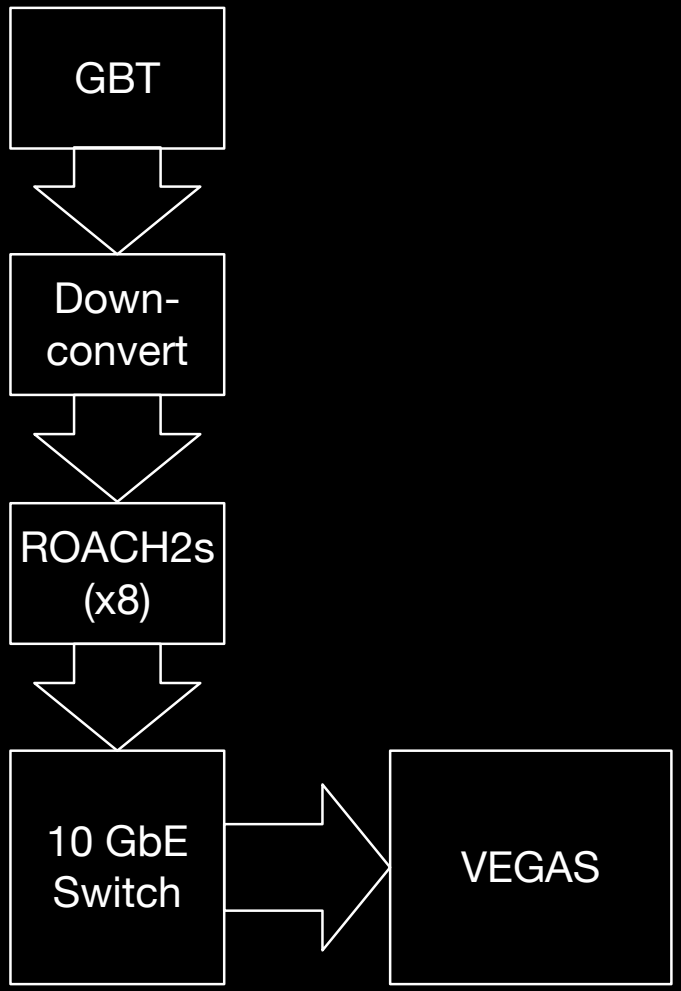




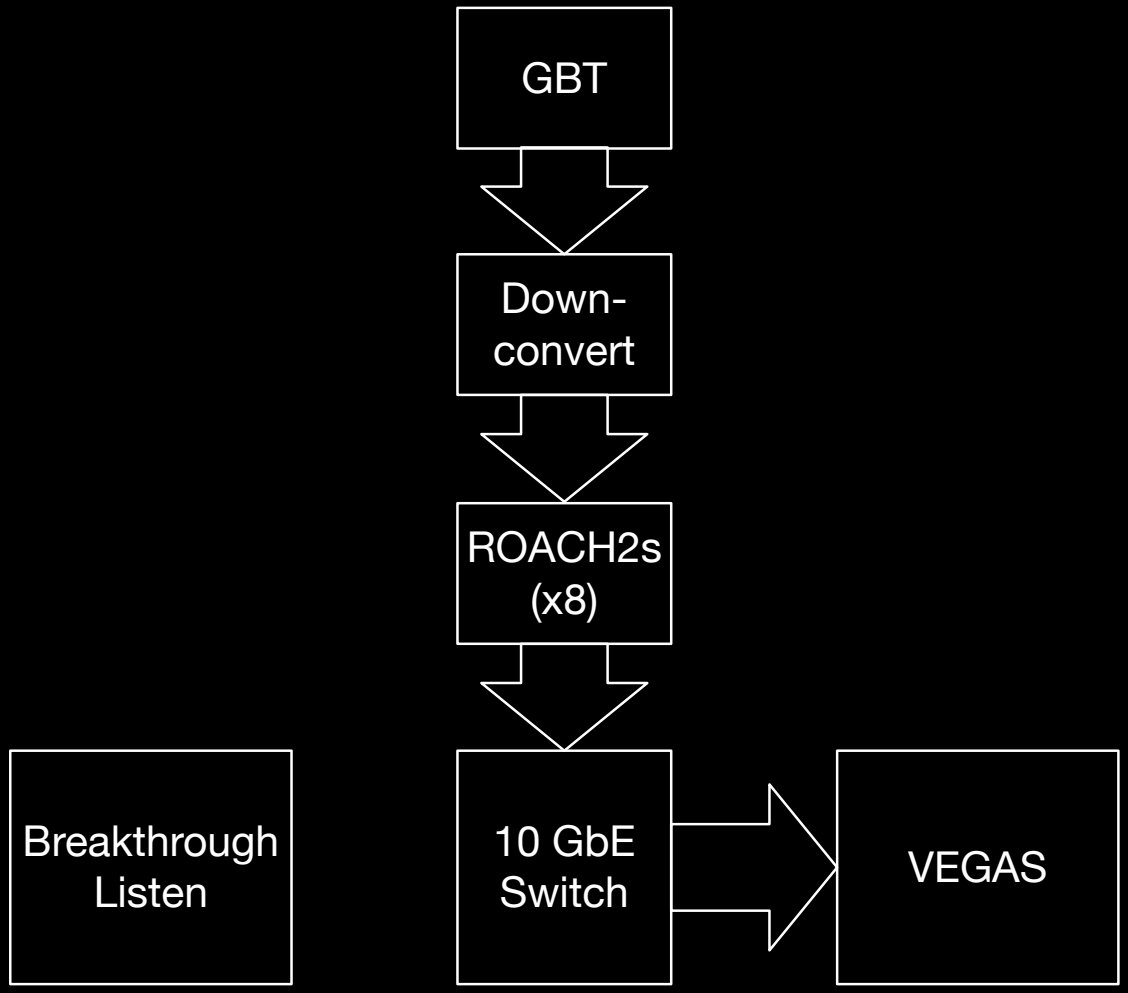
- Existing Antenna
- Existing Digitizers

- Existing Gateware
- Existing Software

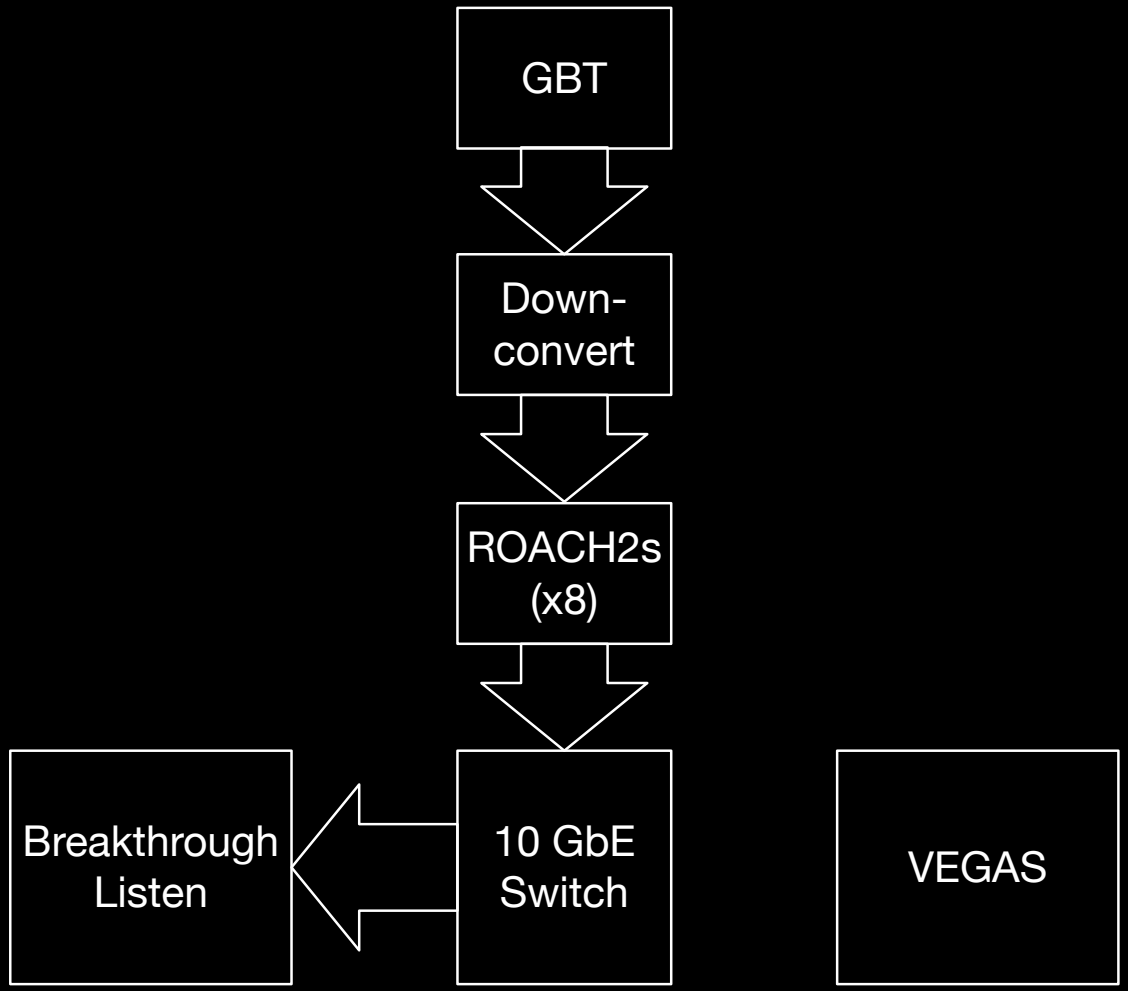
GBT to VEGAS



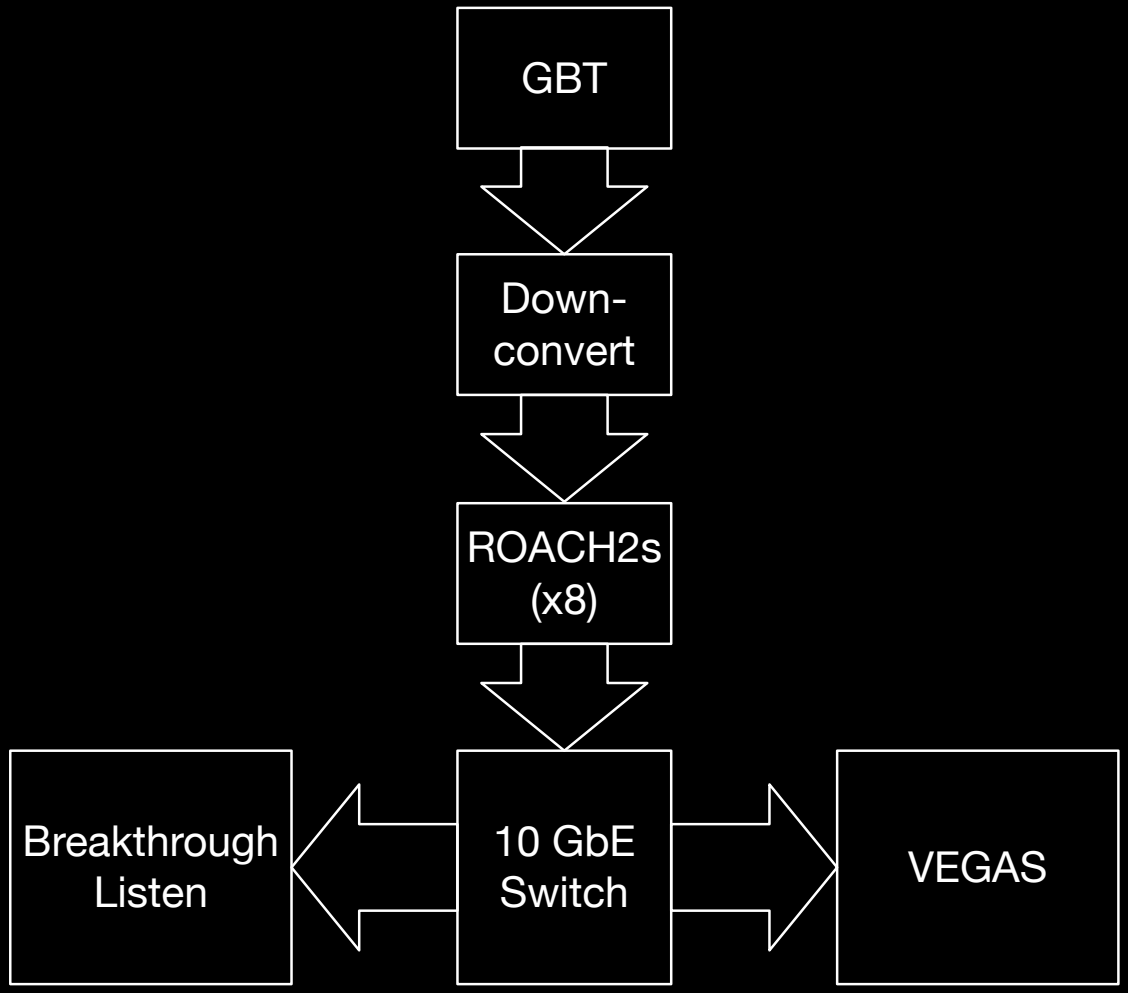
Add BL Hardware



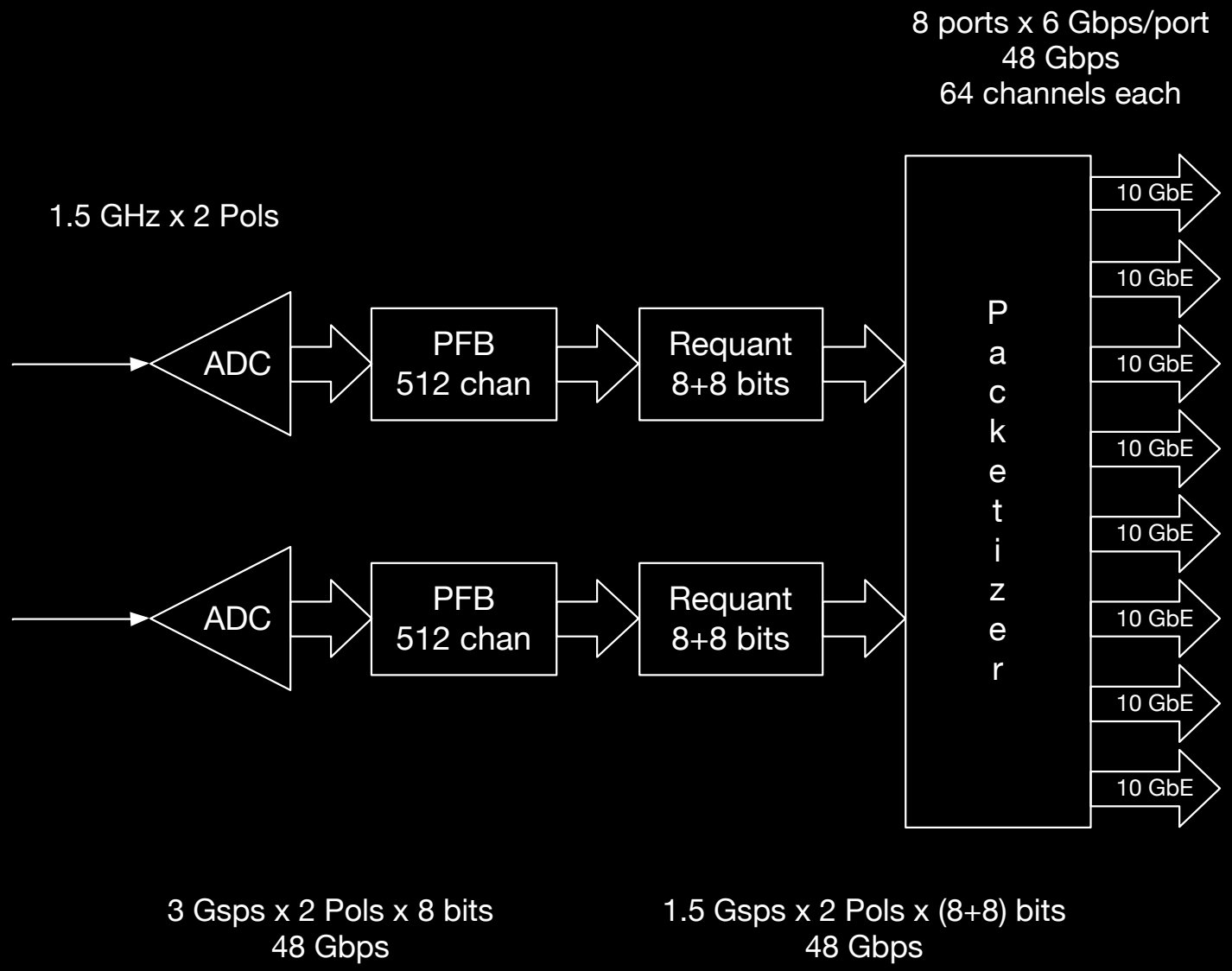
GBT to BL


GBT
Down-
convert
ROACH2s
(x8)
Breakthrough
Listen
10 GbE
Switch
VEGAS

GBT Multicast Future?



ROACH2 VEGAS Pulsar Mode



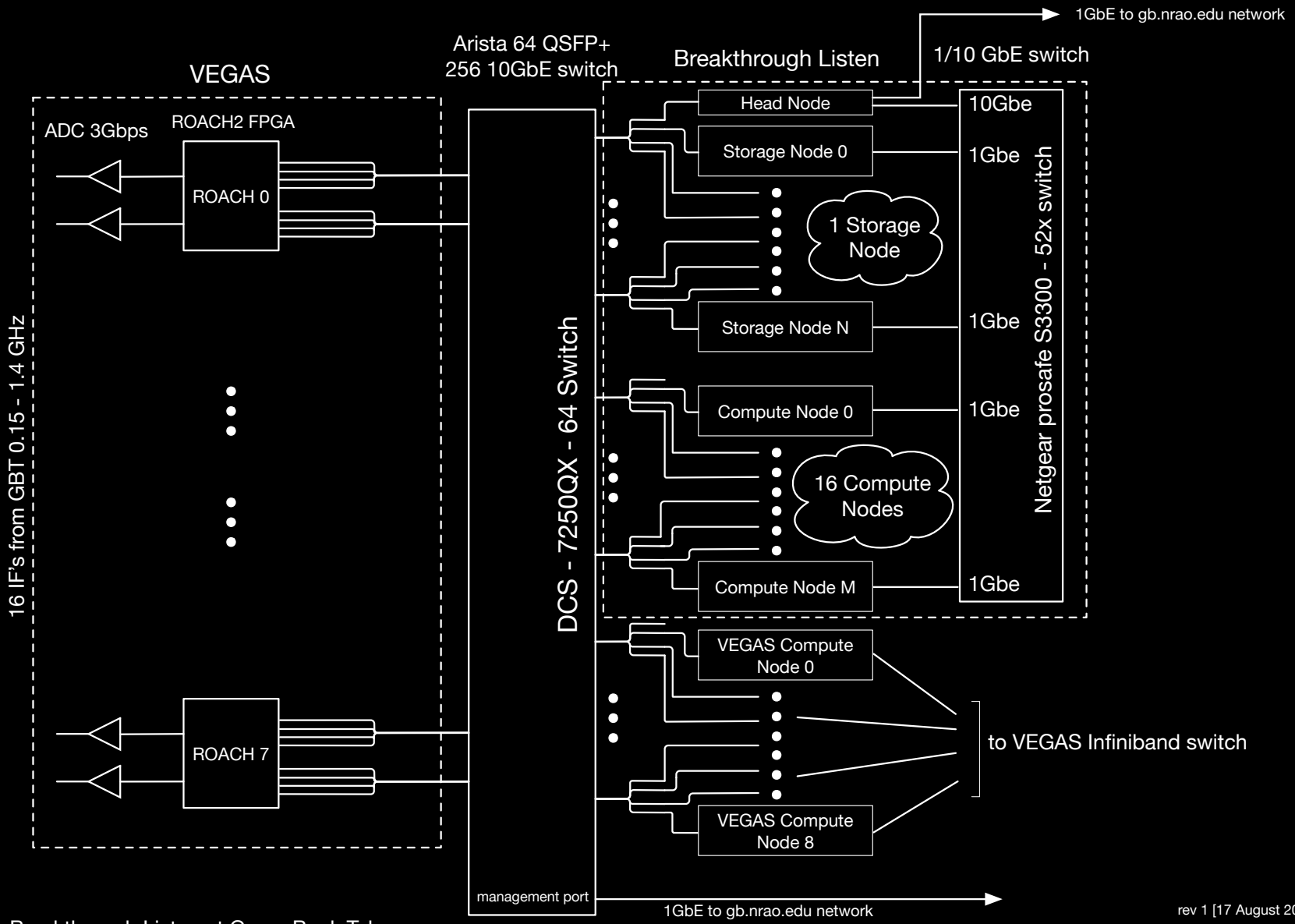
Breakthrough Listen Node Types

- Head Node (x1)
  - 1U Box - Dual Xeon - 64 GB DDR4 DRAM - 550 GB SSD
  - DHCP/DNS/TFTP/NFS/NetBoot server
  - Public face of BL cluster

- Compute Node (x32 + 1 spare)
  - 4U Box - Dual Xeon - 64 GB DDR4 DRAM - Netboot
  - Mellanox 10 GbE dual-port NIC
  - 1 NVIDIA GPU (TITAN X or GTX 1080)
  - 24 x 5 TB Hard Drives
    - 2 x 11 disk RAID6 + 2 hot swap spares
    - Each RAID volume hosts a 46 TB XFS files system

- Storage Node (x4)
  - 4U Box - Dual Xeon - 64 GB DDR4 DRAM - Netboot
  - Mellanox 40 GbE NIC
  - 36 x 6 TB Hard Drives
    - 3 x 11 disk RAID6 + 3 hot swap spares
    - Each RAID volume hosts a 50 TB XFS file system

GBT Block Diagram



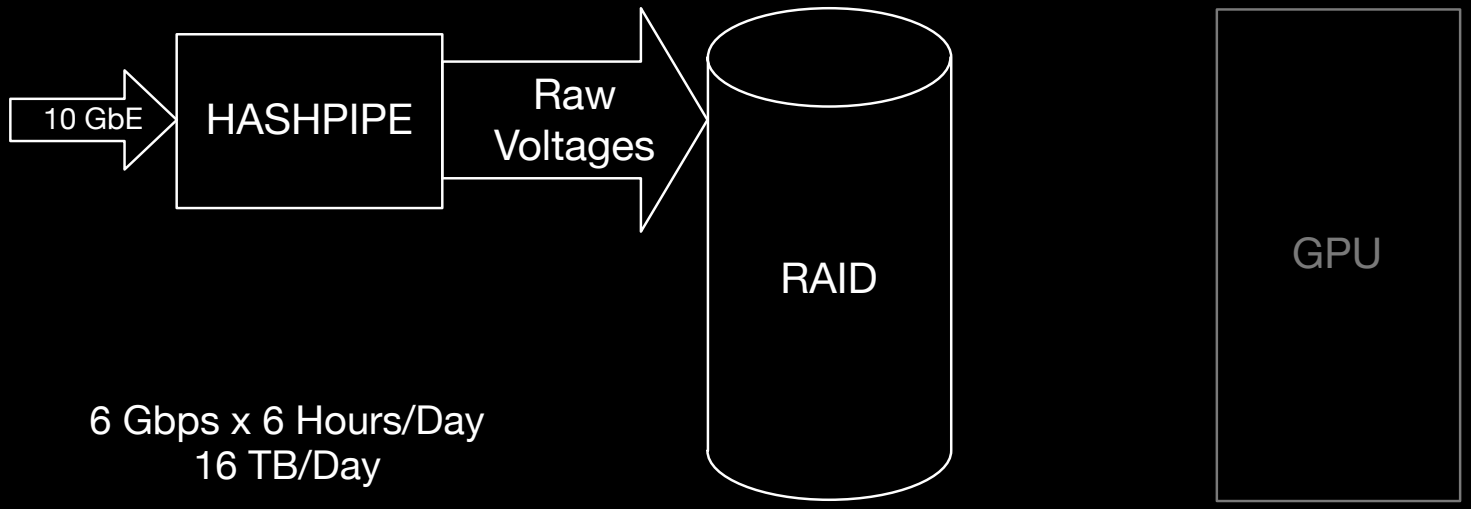
Breakthrough Listen at Green Bank Telescope

rev 1 [17 August 2016]

Dan Werthimer, Dave MacMahon, Zuhra Abdurashidova

BL Compute Node (1 of 8N)

- Record RAW voltages to disk during observations

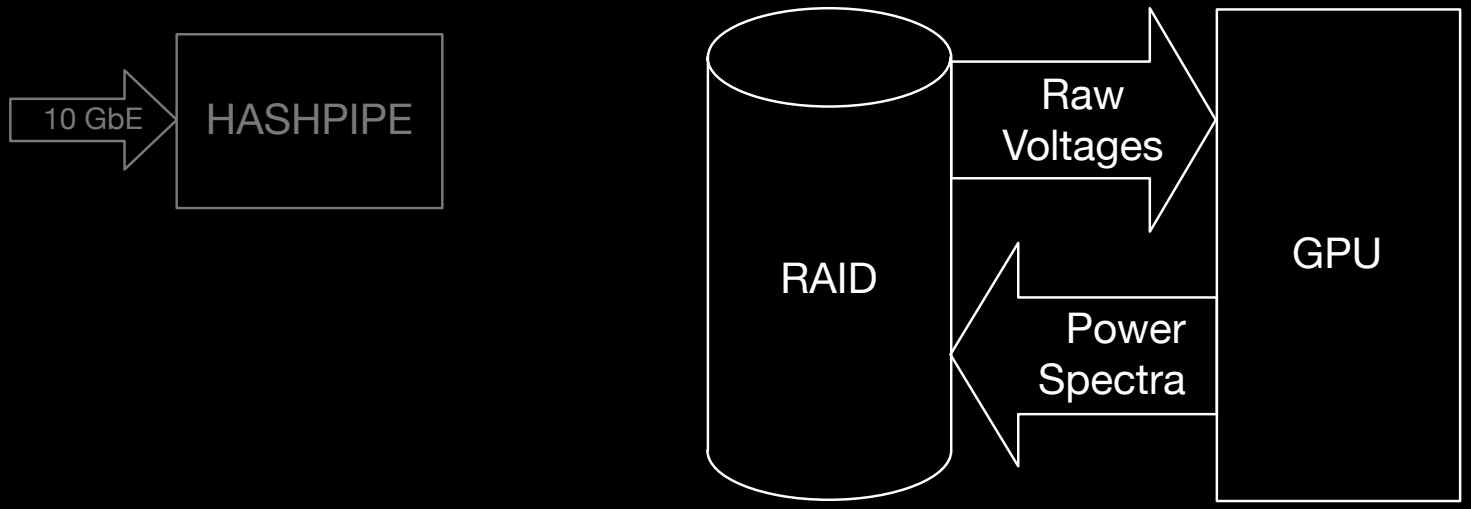


6 Gbps x 6 Hours/Day
16 TB/Day

(really ~12 TB/Day)

BL Compute Node (1 of 8N)

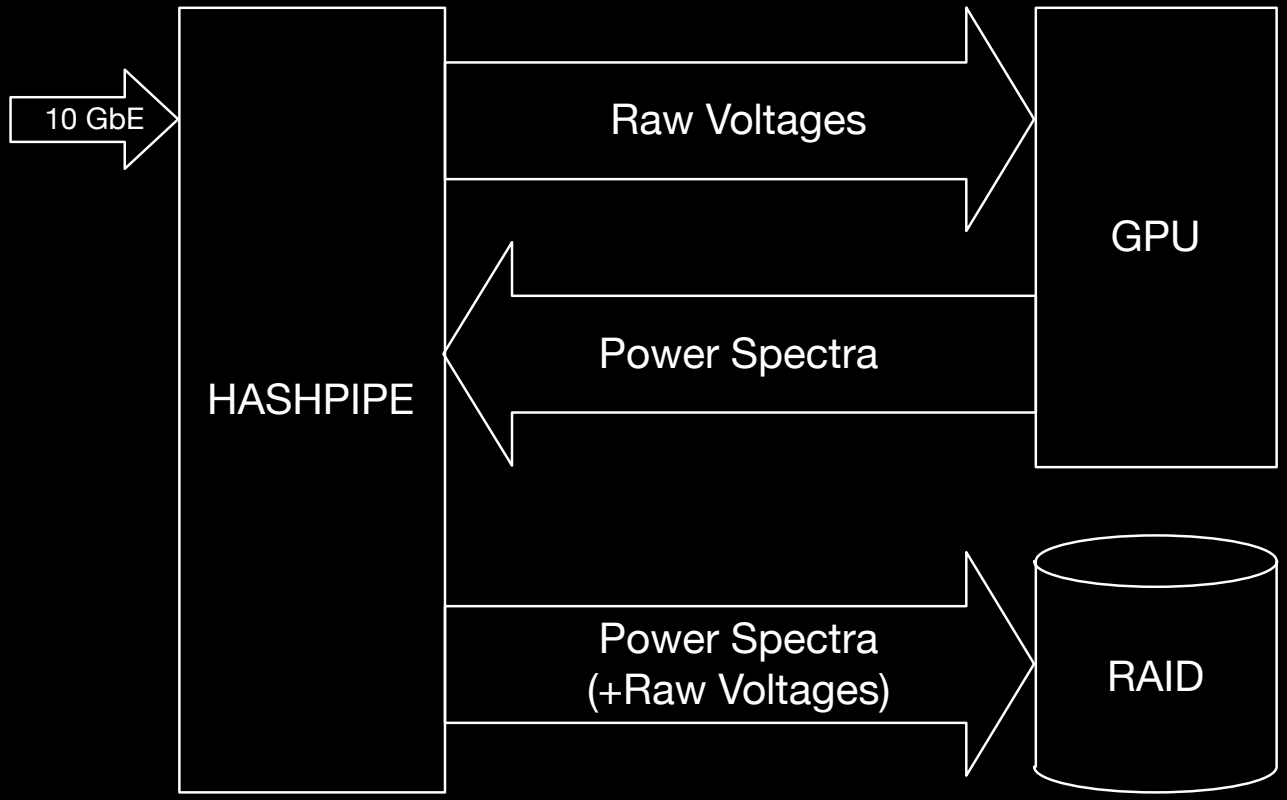
~12 TB/Day
RAW Voltages
(mostly discarded)



- Reduce data between observations

~330 GB/Day
Filterbank Spectra
(retained)

BL Compute Node (1 of 8N)



- Real-time future

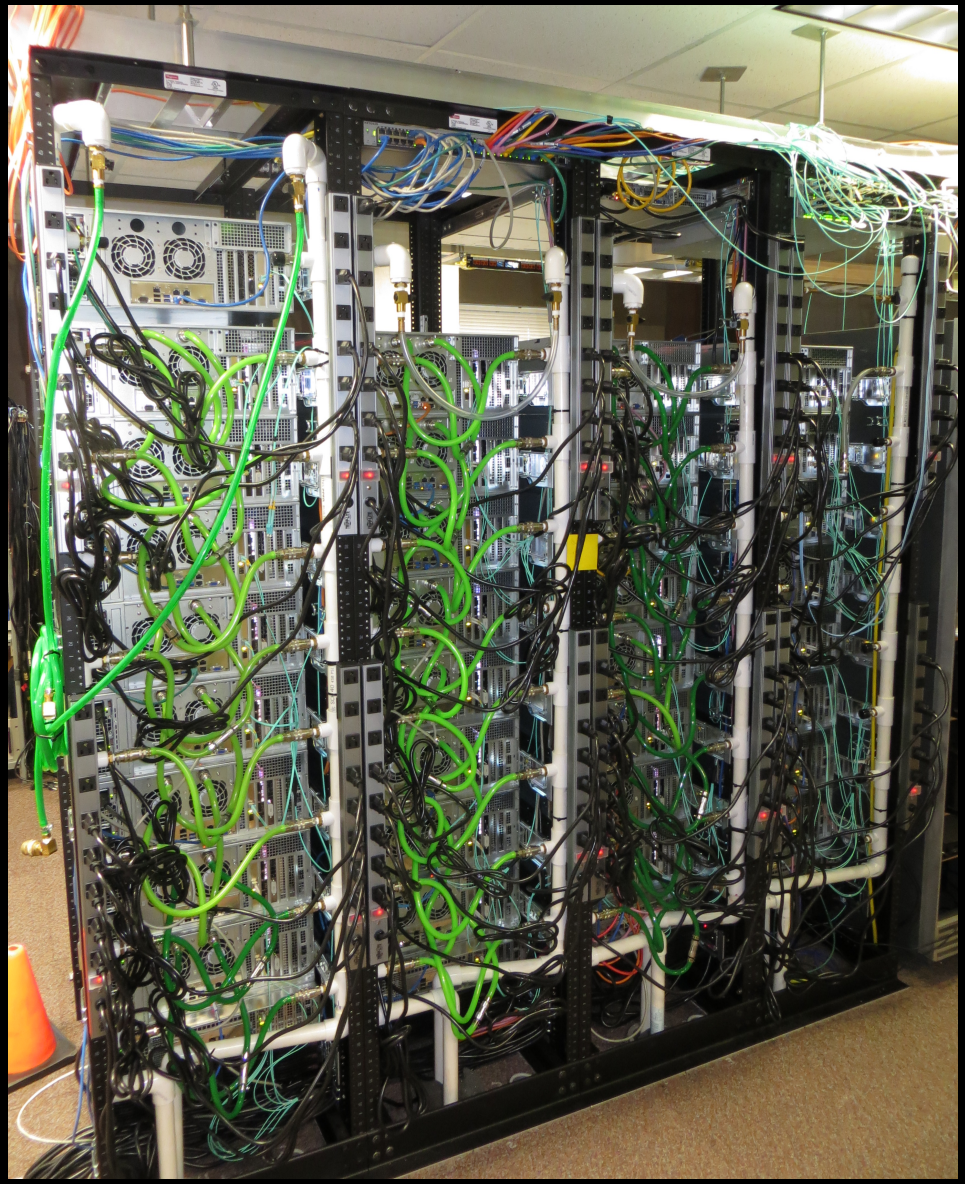
Data Products

- Raw voltage data in GUPPI RAW format (limited retention, 8+8 bit complex)
- Integrated power spectra in Filterbank format (everything, 32 bits floating point)

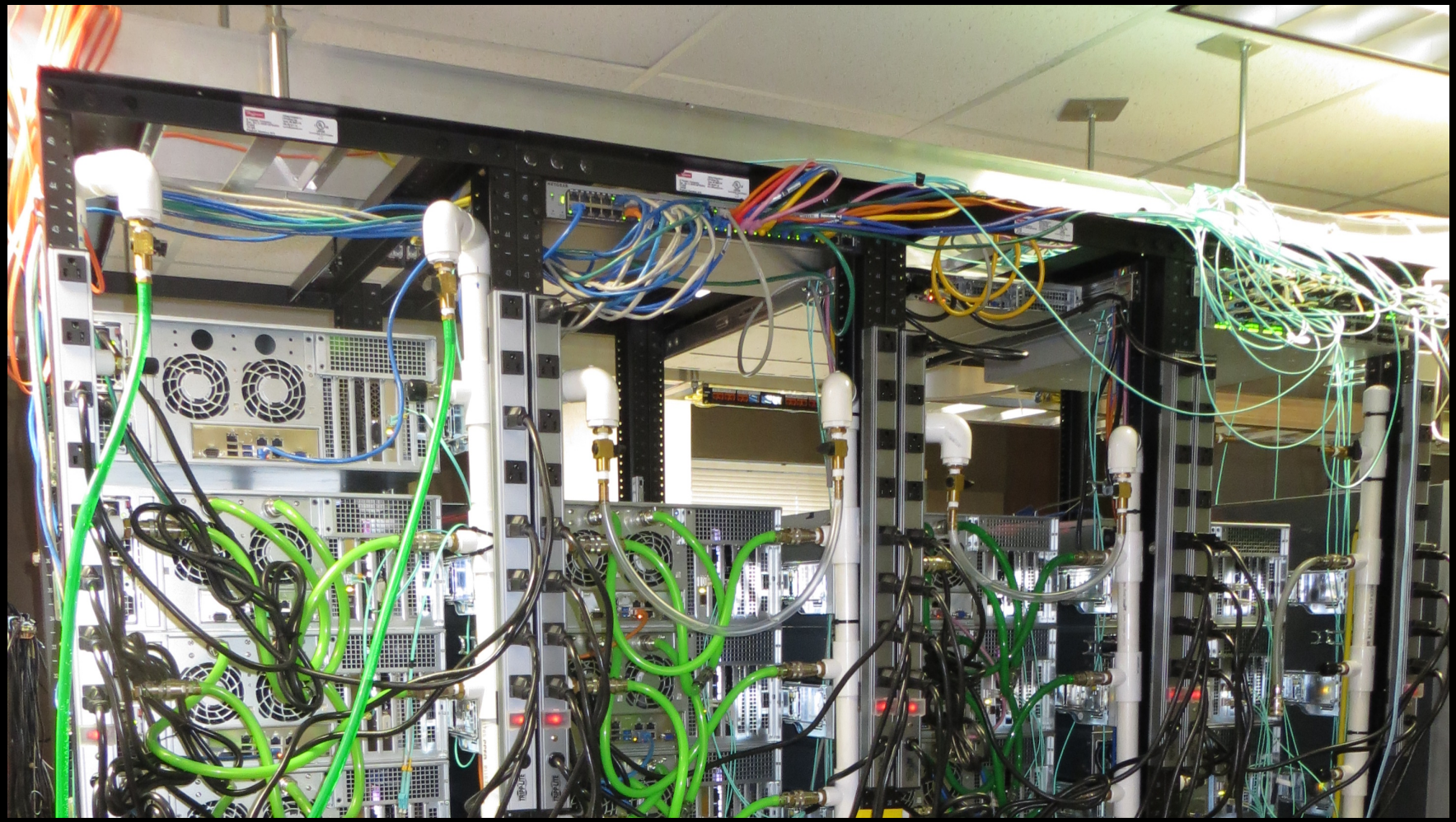
Description	Spectral Resolution	Integration Time
SETI	~3 Hz	~18 seconds
Astrophysical	~3 kHz	~1 second
Fast Transient	~360 kHz	~350 microseconds

BL GBT Cluster

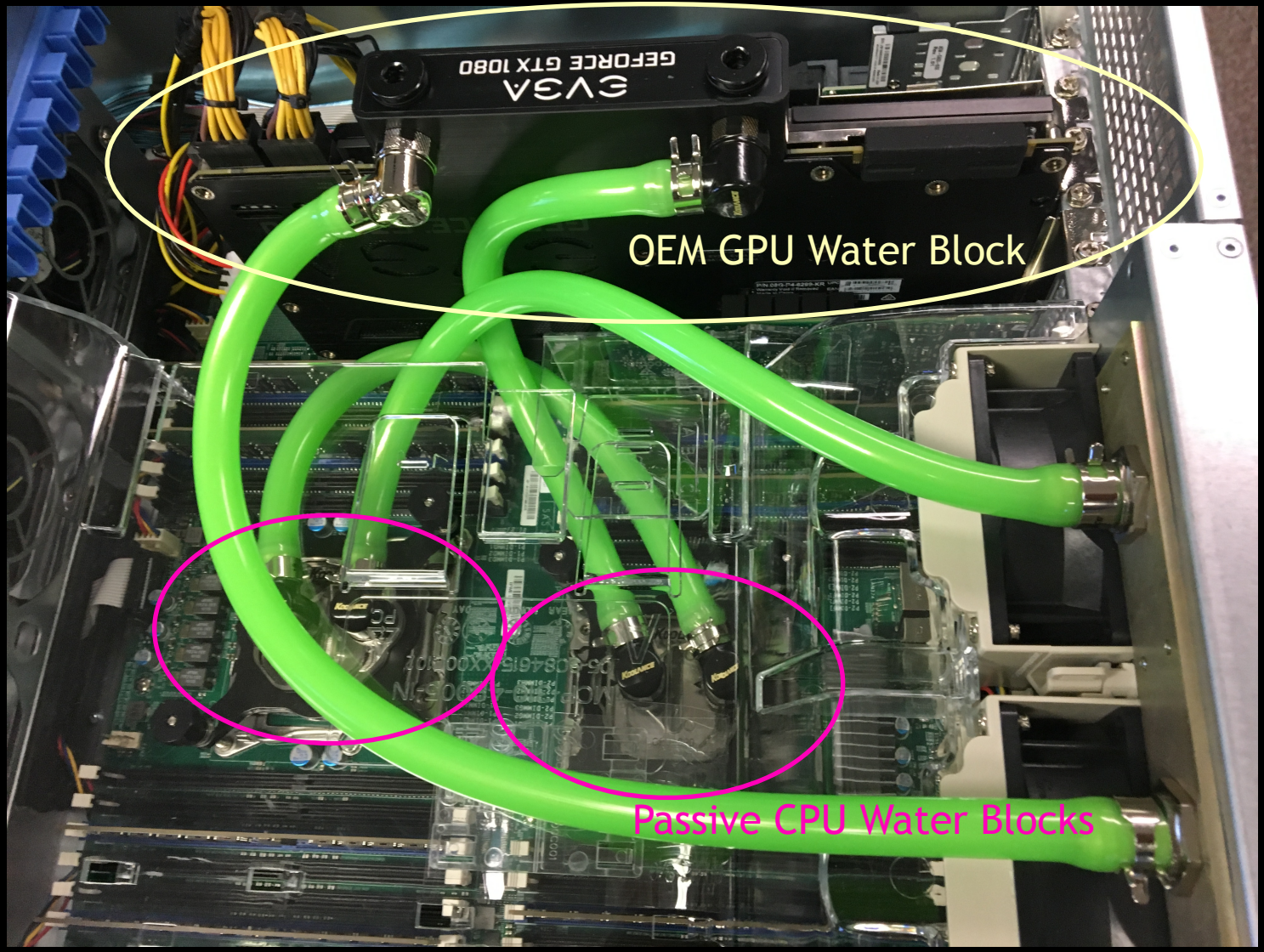
BL GBT Cluster



BL GBT Cluster

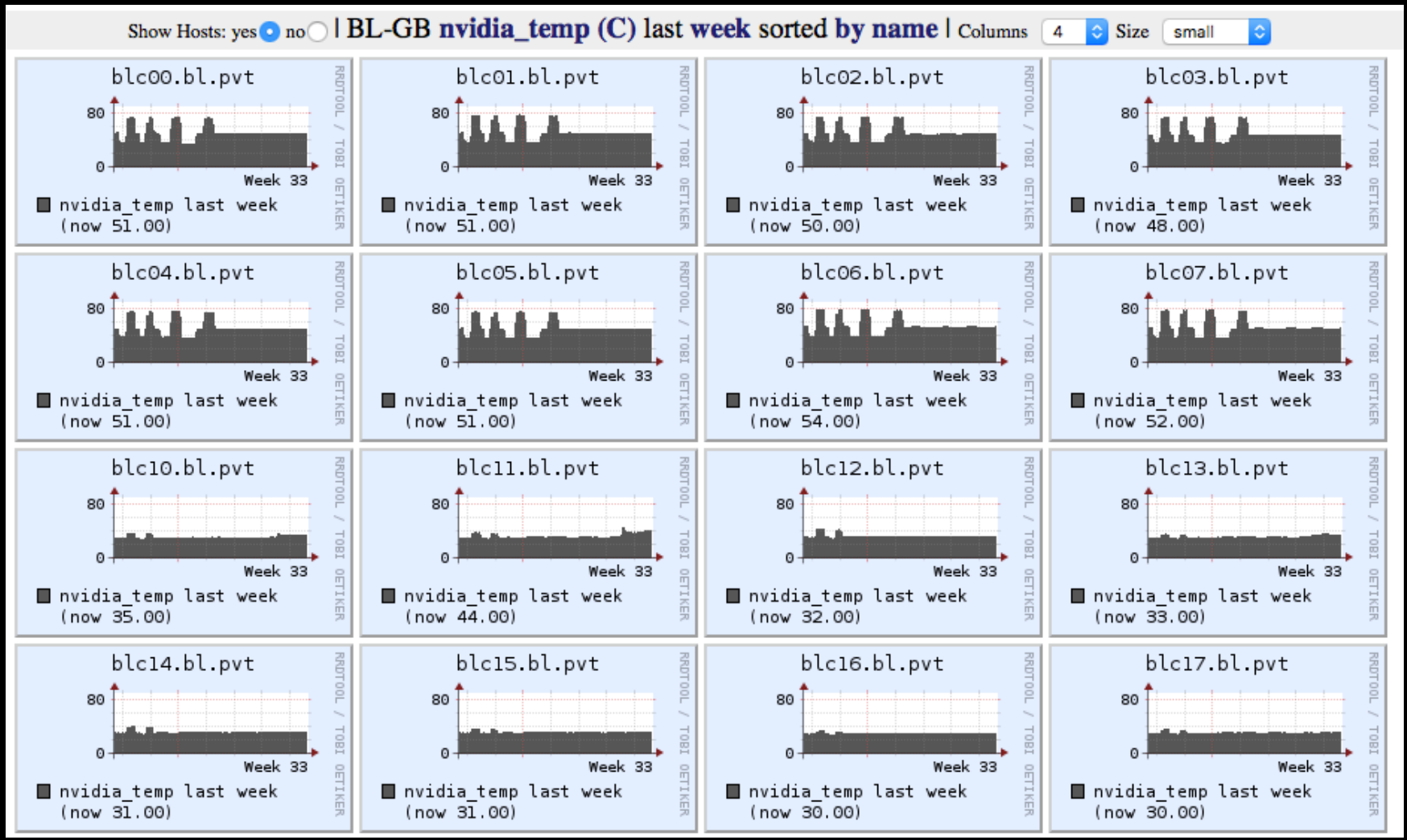


Water Cooling

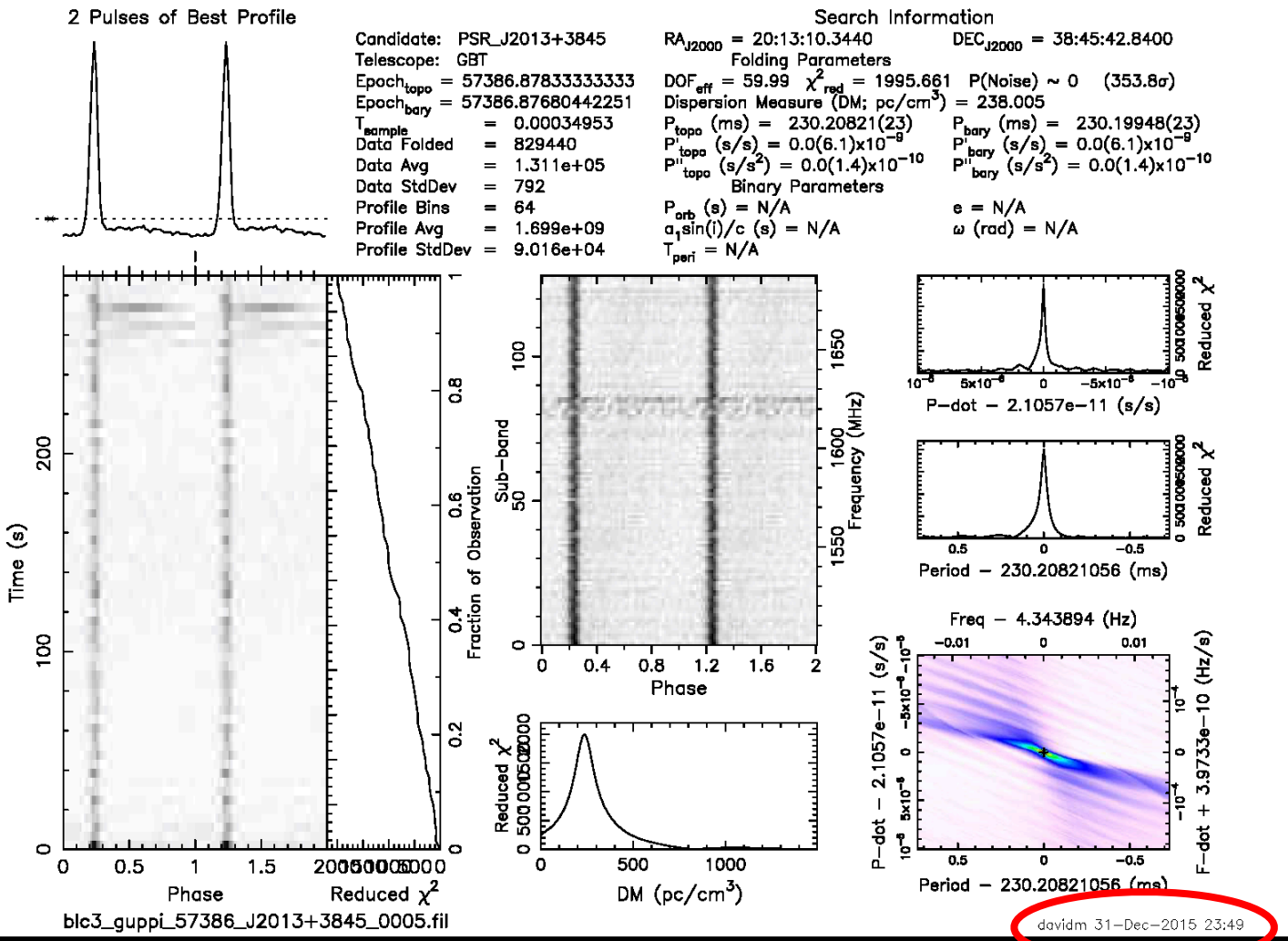


Water Cooling

System Monitoring with Nagios



First Light


2 Pulses of Best Profile
Candidate: PSR_J2013+3845
Telescope: GBT
Epoch_topo = 57386.87833333333
Epoch_bary = 57386.87680442251
T_sample = 0.00034953
Data Folded = 829440
Data Avg = 1.311e+05
Data StdDev = 792
Profile Bins = 64
Profile Avg = 1.699e+09
Profile StdDev = 9.016e+04
Search Information
RA_J2000 = 20:13:10.3440
DEC_J2000 = 38:45:42.8400
Folding Parameters
DOF_eff = 59.99 χ²_red = 1995.661 P(Noise) ~ 0 (353.8σ)
Dispersion Measure (DM; pc/cm³) = 238.005
P_topo (ms) = 230.20821(23)
P_bary (ms) = 230.19948(23)
P'_topo (s/s) = 0.0(6.1)x10⁻⁹
P'_bary (s/s) = 0.0(6.1)x10⁻⁹
P''_topo (s/s²) = 0.0(1.4)x10⁻¹⁰
P''_bary (s/s²) = 0.0(1.4)x10⁻¹⁰
Binary Parameters
P_orb (s) = N/A
e = N/A
a₁sin(i)/c (s) = N/A
ω (rad) = N/A
T_peri = N/A
Time (s)
Phase
Reduced χ²
Fraction of Observation
Sub-band
Frequency (MHz)
DM (pc/cm³)
P-dot − 2.1057e-11 (s/s)
Period − 230.20821056 (ms)
Freq − 4.343894 (Hz)
F-dot + 3.97336e-10 (Hz/s)
blc3_guppi_57386_J2013+3845_0005.fil
davidm 31-Dec-2015 23:49

Jupyter Notebook for Voyager1

https://github.com/UCBerkeleySETI/breakthrough

Let's get started!

Firstly, let's setup the notebook and import the `Filterbank()` class to read the data.

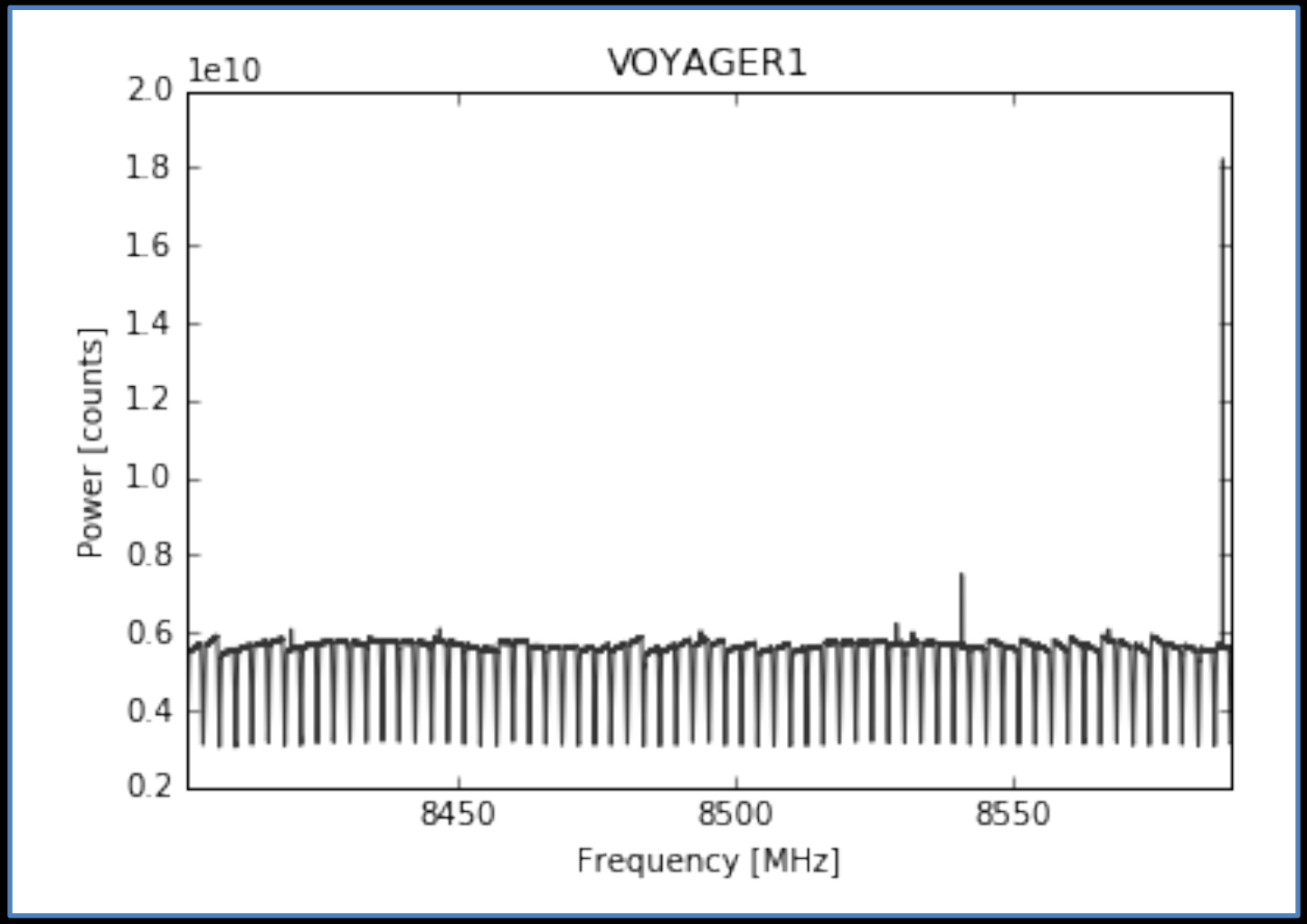
In [1]:
```
%matplotlib inline
```

In [3]:
```
import pylab as plt
from filterbank import Filterbank
```

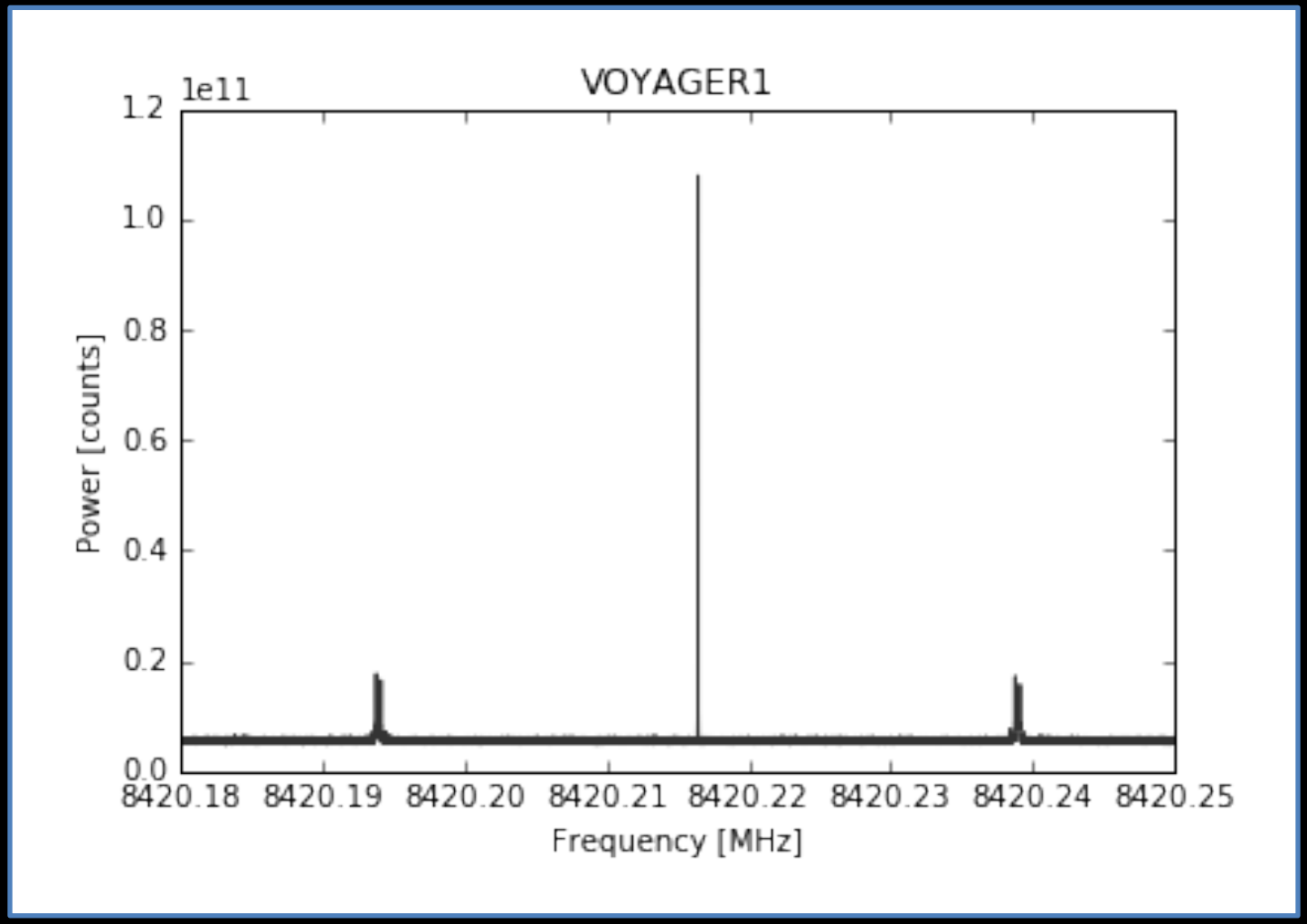
Now, let's read the observation data using `Filterbank()`:

In [4]:
```
obs = Filterbank('voyager_f1032192_t300_v2.fil')
```

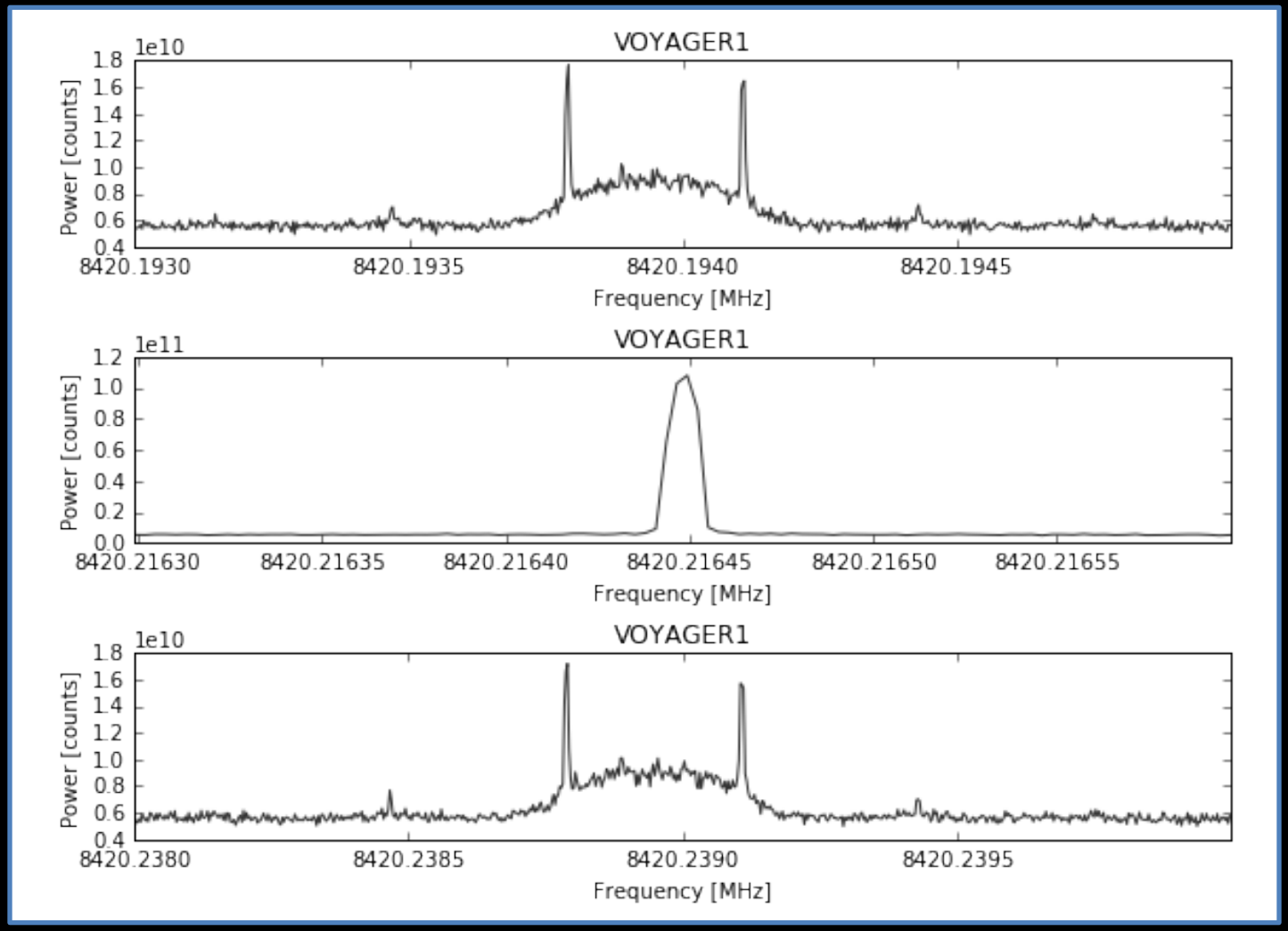
Jupyter Notebook for Voyager



Jupyter Notebook for Voyager



Jupyter Notebook for Voyager



arXiv:1707.06024v2

THE BREAKTHROUGH LISTEN SEARCH FOR INTELLIGENT LIFE: A WIDEBAND DATA RECORDER SYSTEM FOR THE ROBERT C. BYRD GREEN BANK TELESCOPE

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ABSTRACT

The Breakthrough Listen Initiative is undertaking a comprehensive search for radio and optical signatures from extraterrestrial civilizations. An integral component of the project is the design and implementation of wide-bandwidth data recorder and signal processing systems. The capabilities of these systems, particularly at radio frequencies, directly determine survey speed; further, given a fixed observing time and spectral coverage, they determine sensitivity as well. Here, we detail the Breakthrough Listen wide-bandwidth data recording system deployed at the 100-m aperture Robert C. Byrd Green Bank Telescope. The system

Thank
You!