The Canadian Hydrogen Intensity Mapping Experiment (CHIME): Update and Status

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Yale University
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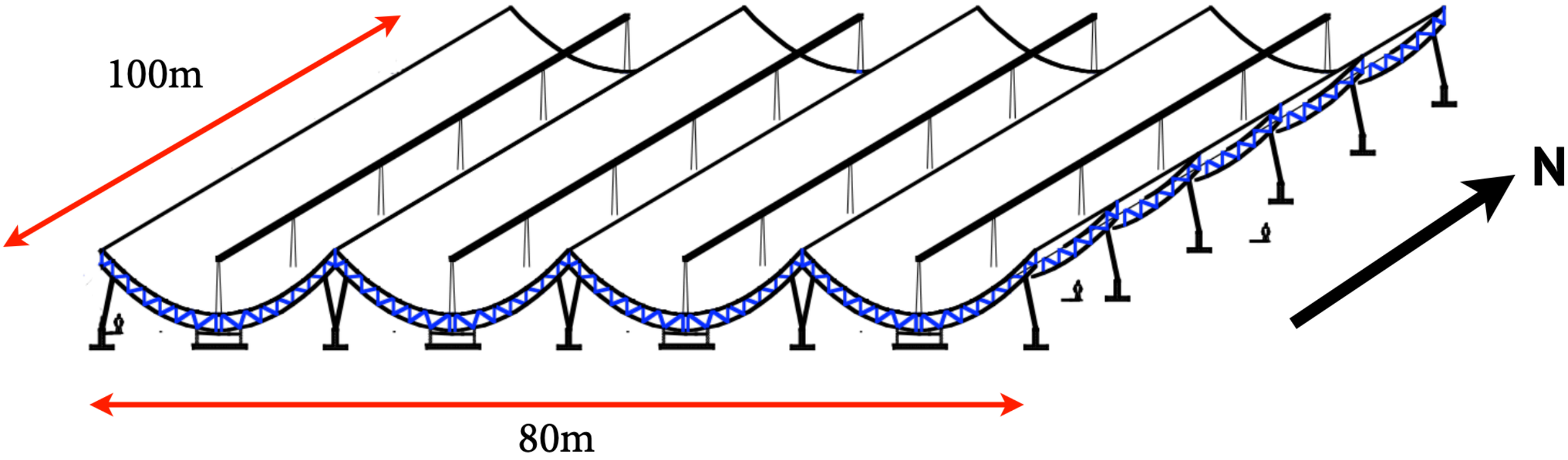
Photo credit:
K Vanderlinde

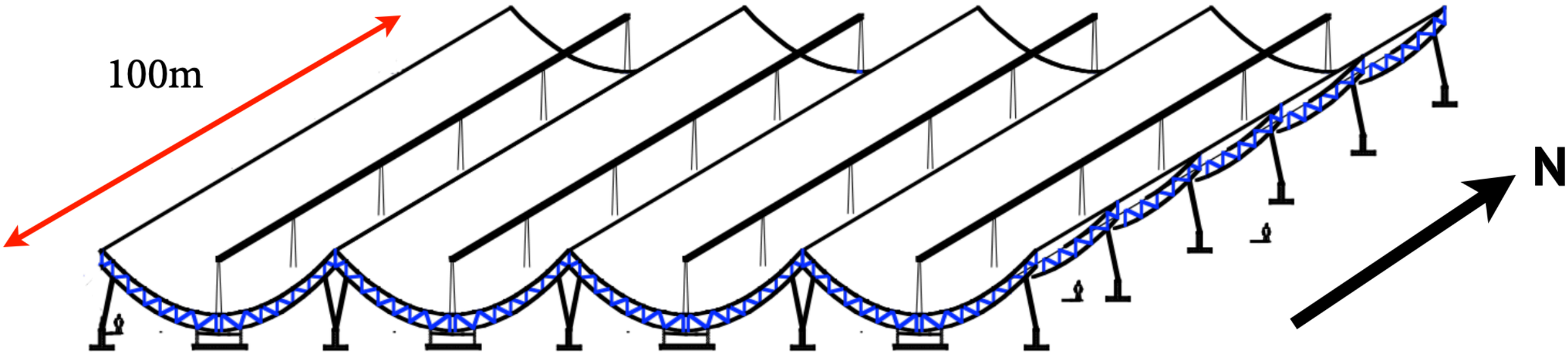
The Canadian Hydrogen Intensity Mapping Experiment (CHIME)

CHIME Overview



- Transit radio interferometer
  - Observe between 400—800 MHz
  - 1024 dual-pol antennas (Trec = 50K)
- Located @ DRAO in Penticton, BC, Canada

CHIME Overview



80m

- Transit radio interferometer
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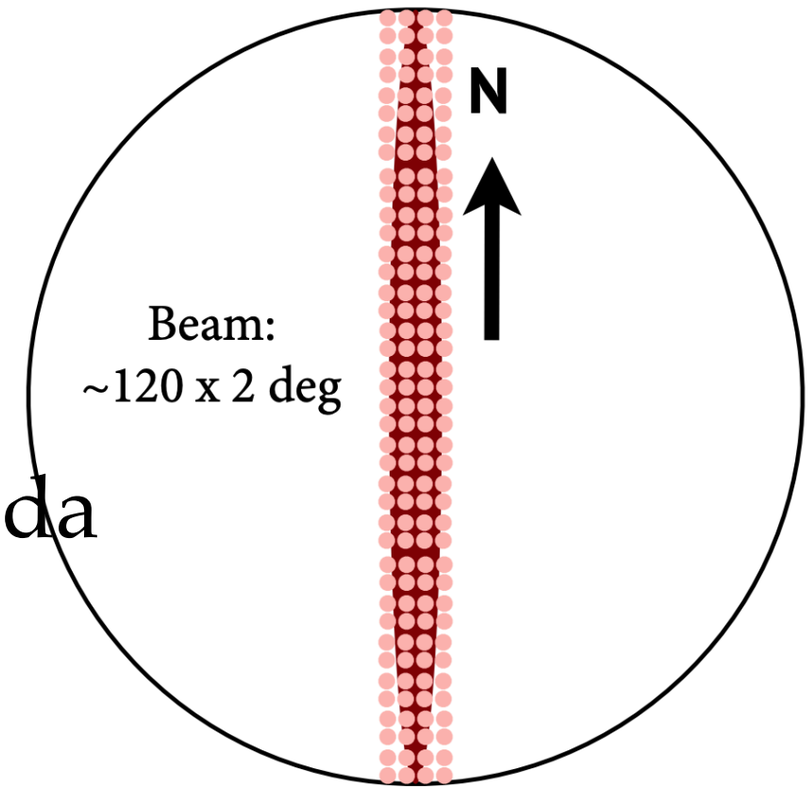
- Located @ DRAO in Penticton, BC, Canada
- 120 x 2 degree FOV
- 7 x 511 beams = 15 arcmin resolution



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  - Observe between 400—800 MHz
  - 1024 dual-pol antennas (Trec = 50K)
- Located @ DRAO in Penticton, BC, Canada
- 120 x 2 degree FOV
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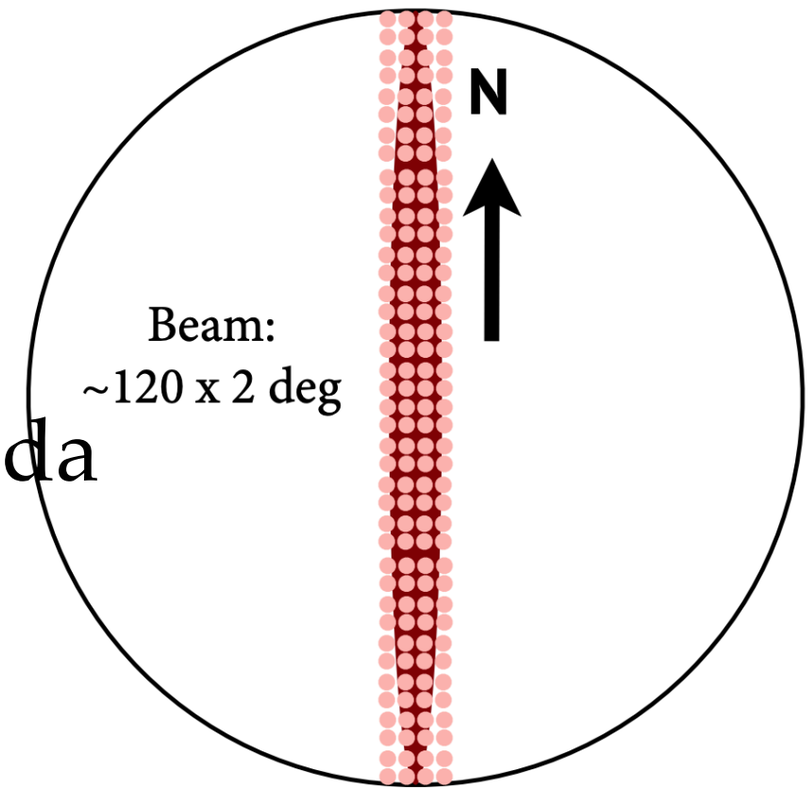
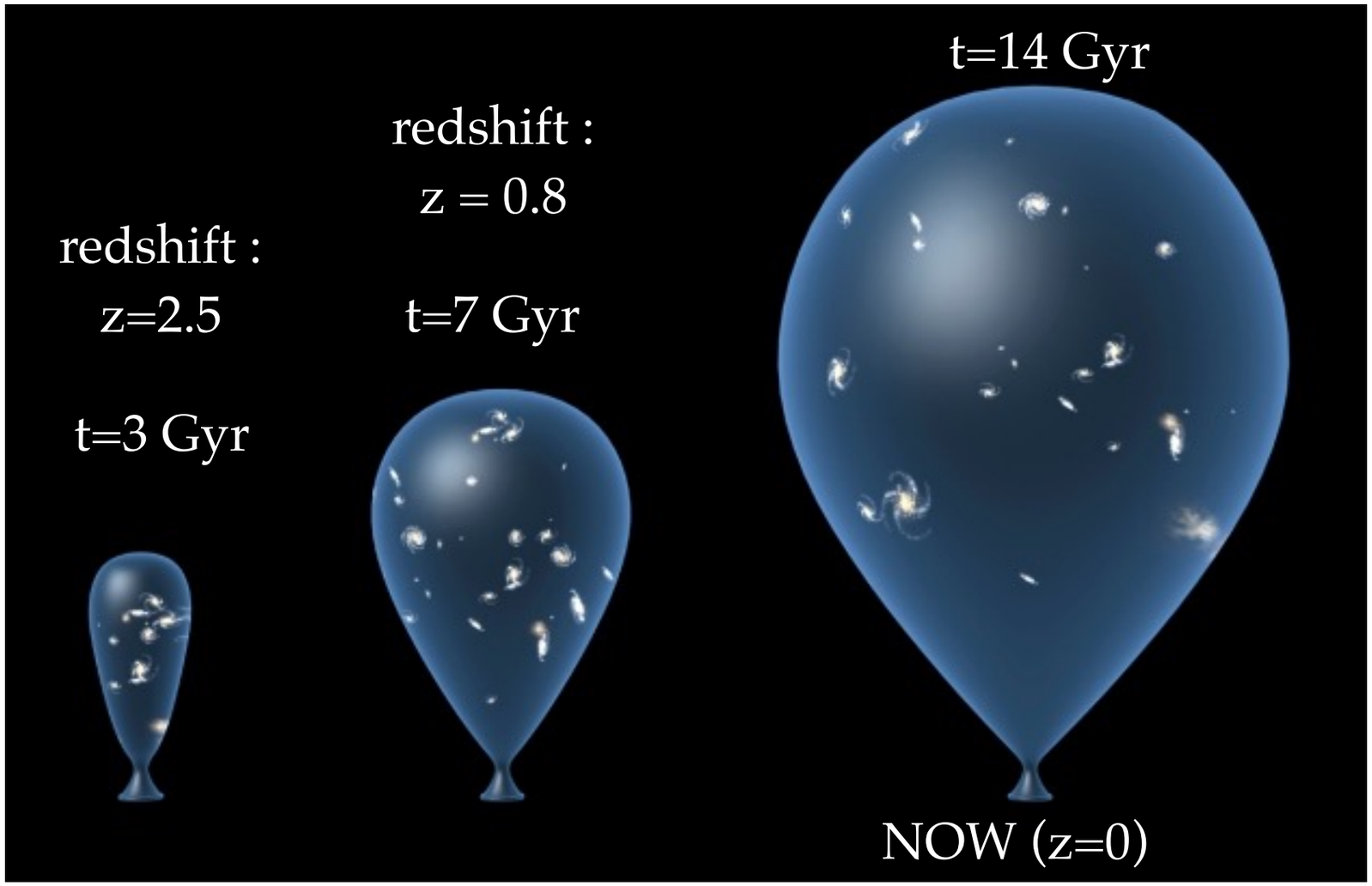
- Observations started March 2018



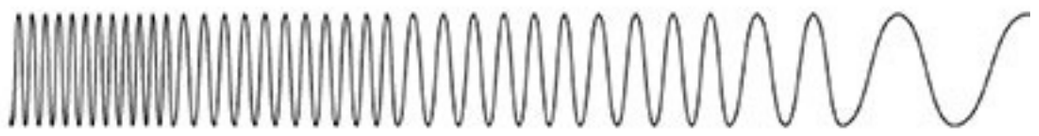
CHIME Science Goals

- **Hydrogen Intensity Mapping for BAOs (this talk)**
- Fast Radio Bursts (see next talk)
- Pulsars

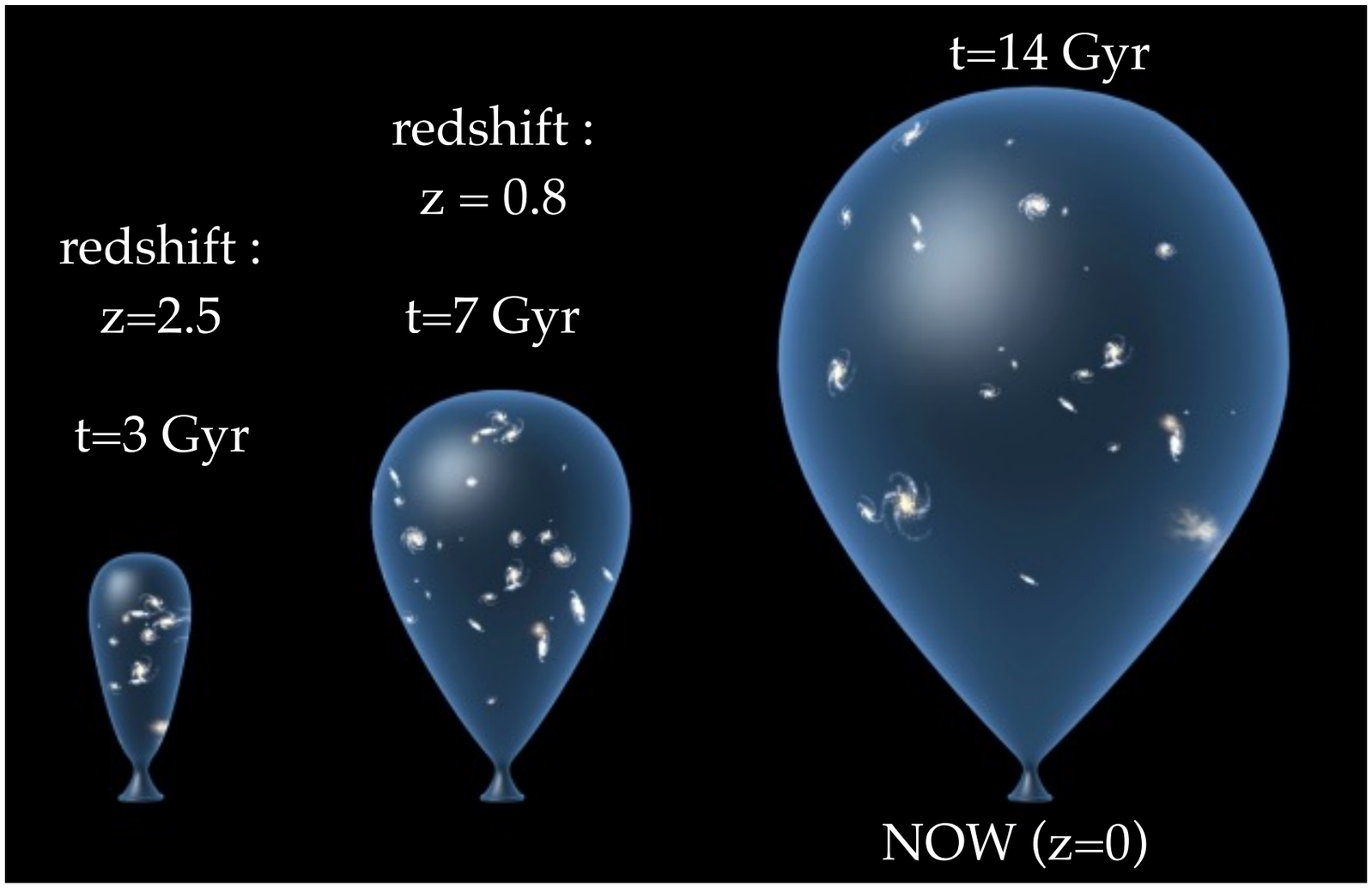
HI Intensity mapping : at what redshift?



21cm  75cm (400 MHz)

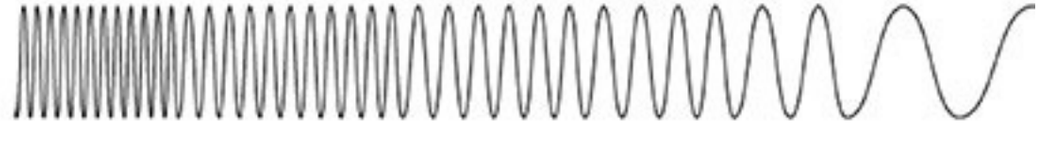
21cm  38cm (800 MHz)

HI Intensity mapping : at what redshift?



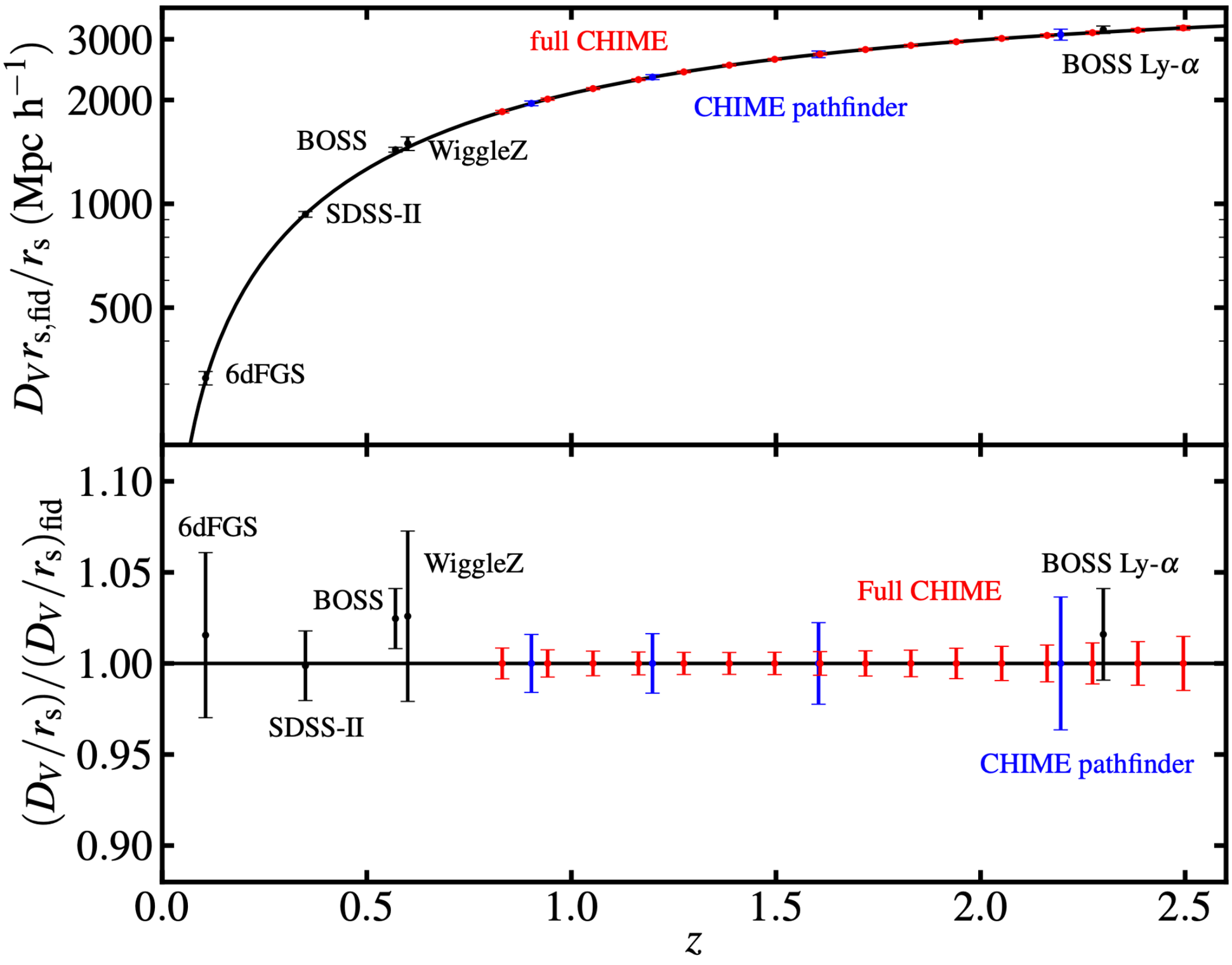
z~0.8 HI has been detected in cross-correlation (GBT and WiggleZ/ Deep2)

21cm

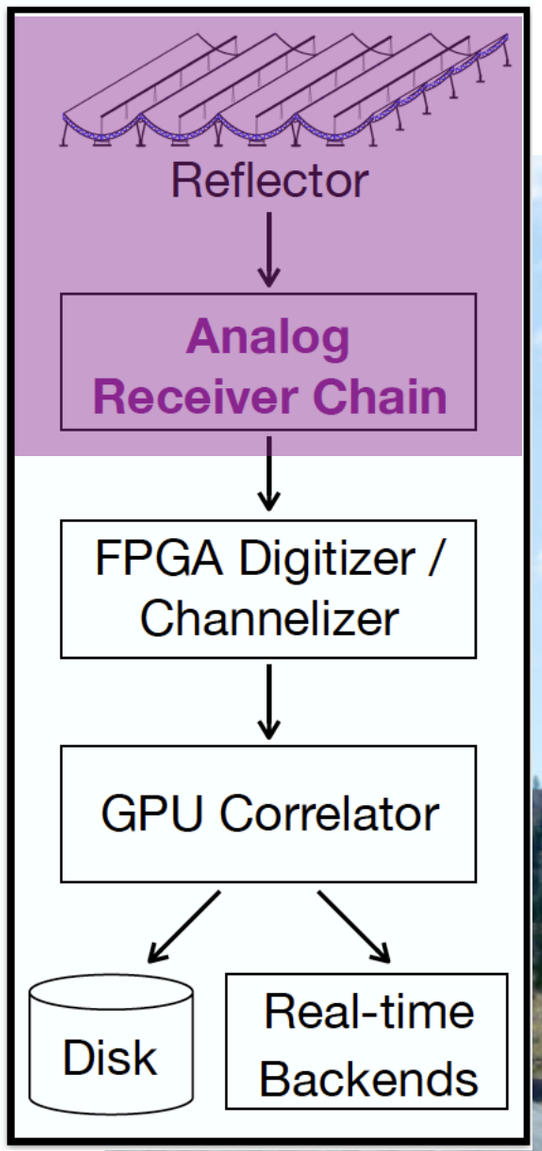


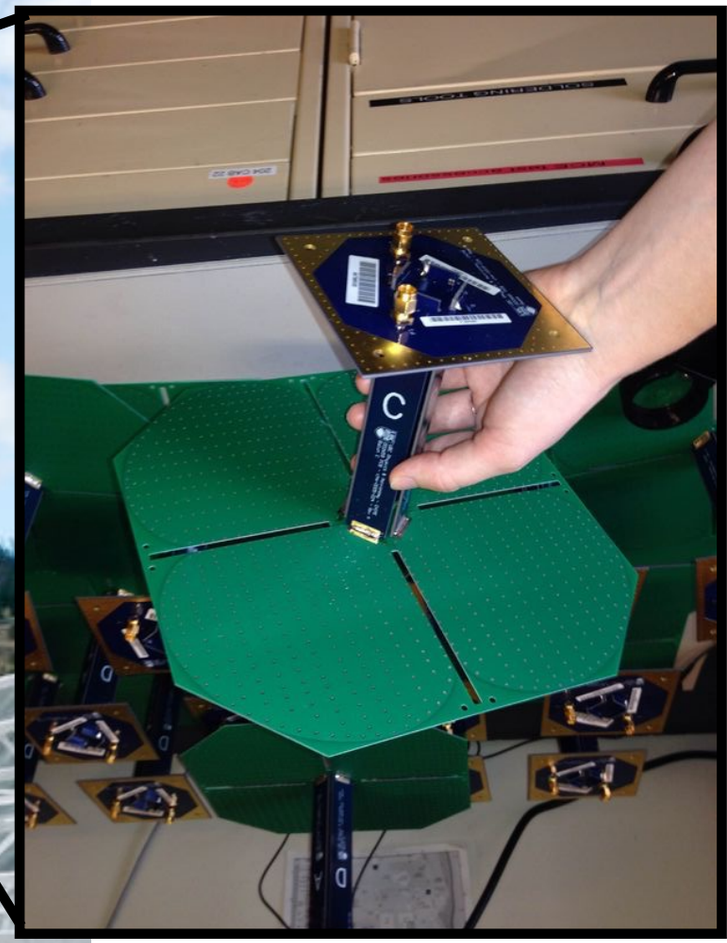
38cm (800 MHz)

BAO Forecast



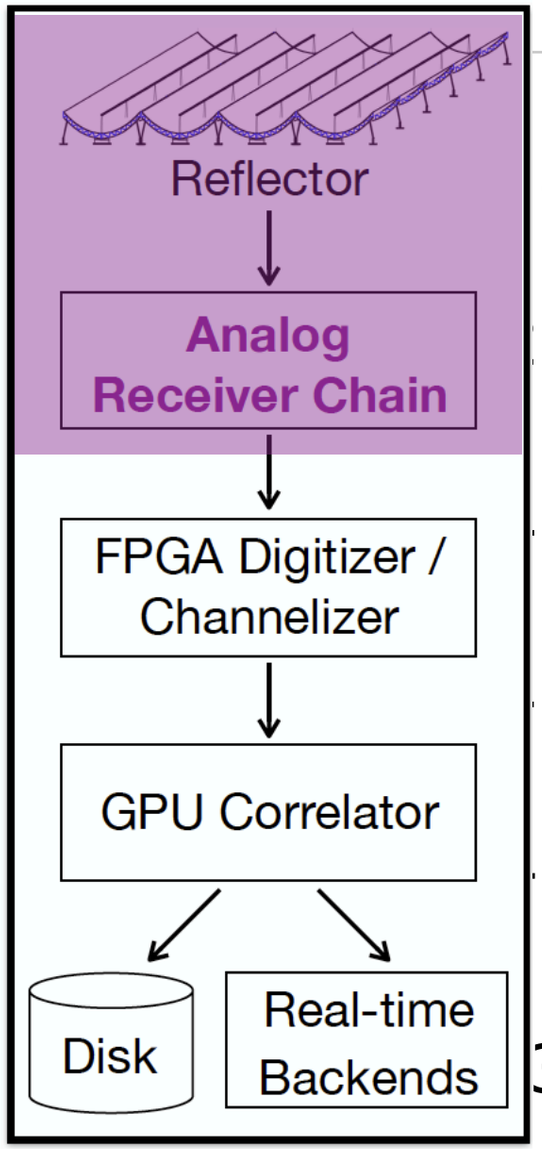
Front End: Reflector + Feeds

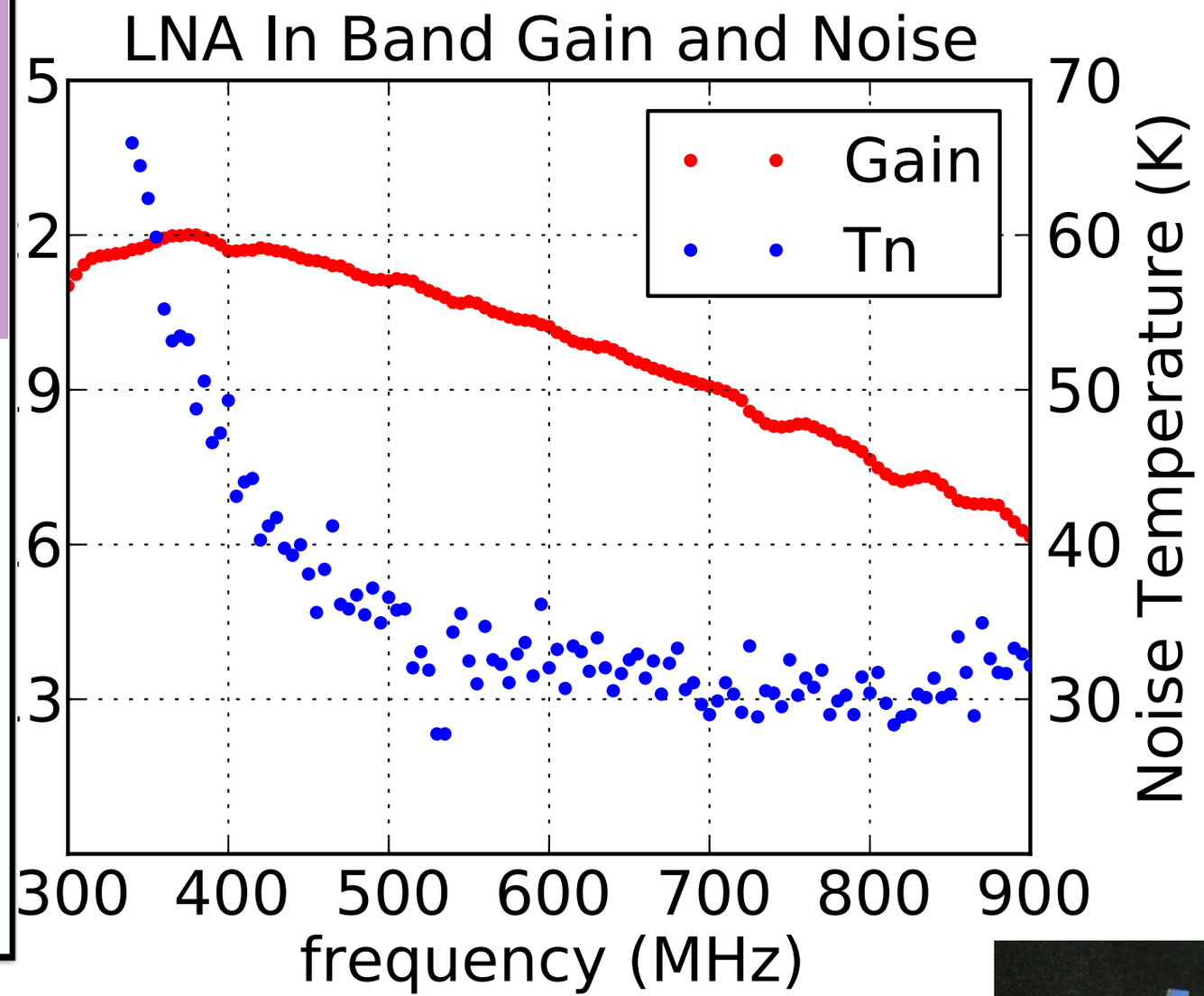


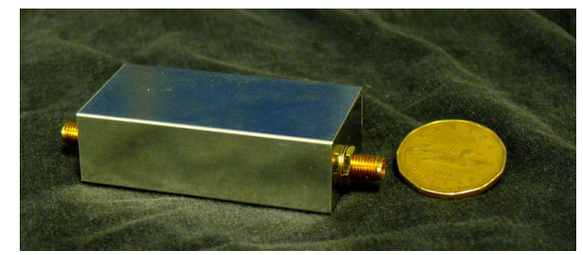


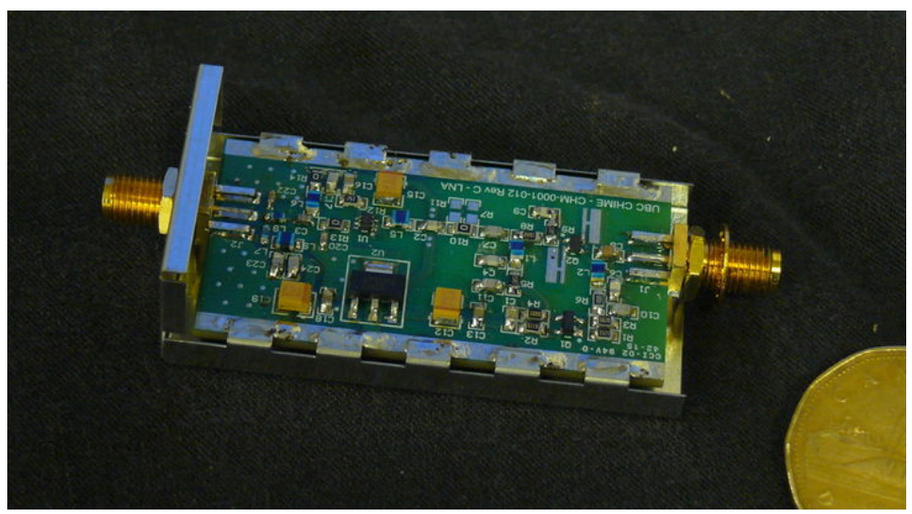
Deng et al, 2014

Front End: Low Noise Amplifiers

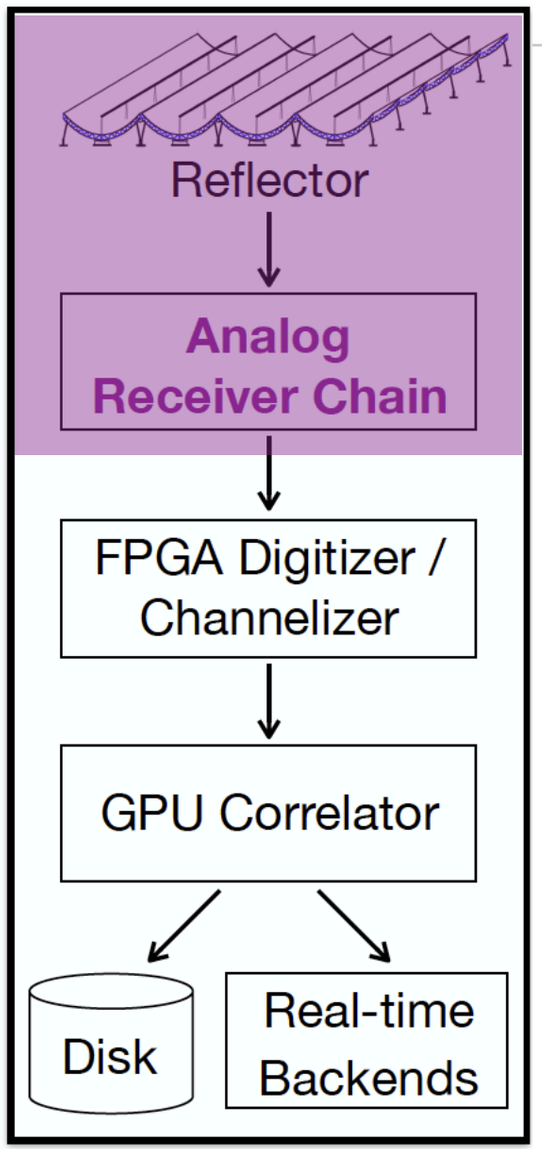


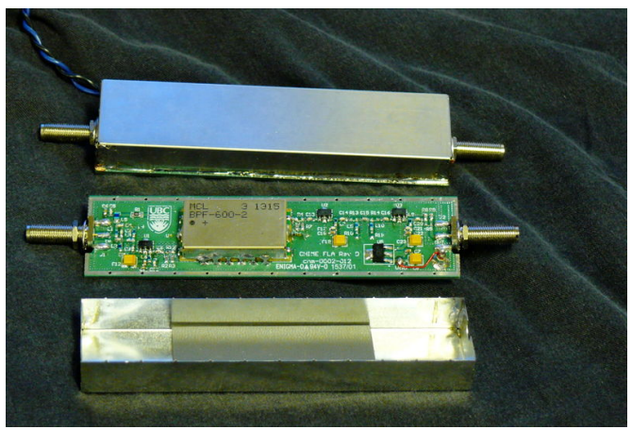






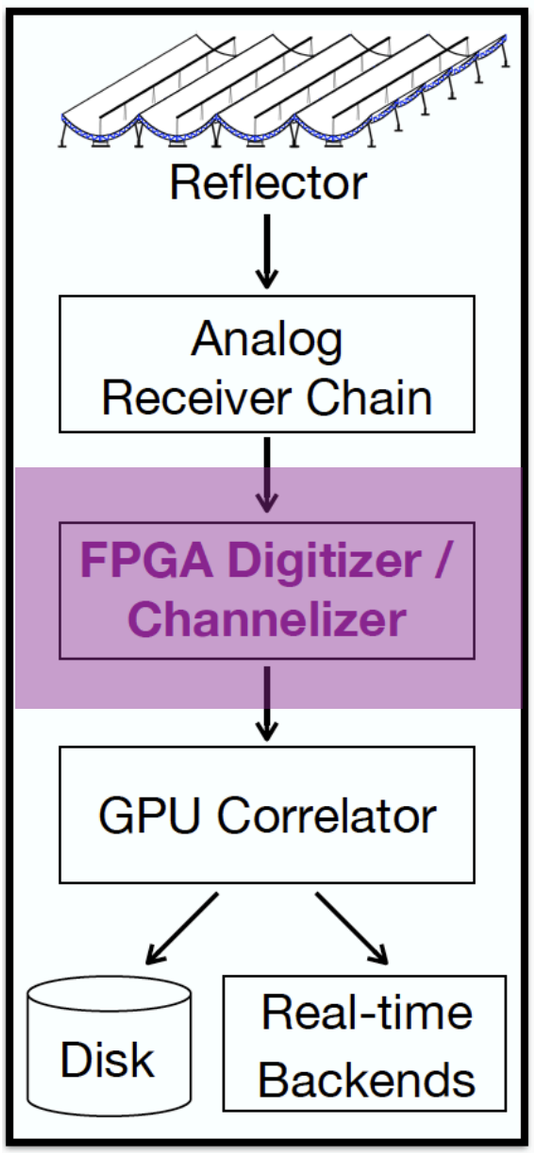
Front End: Filter Amplifiers



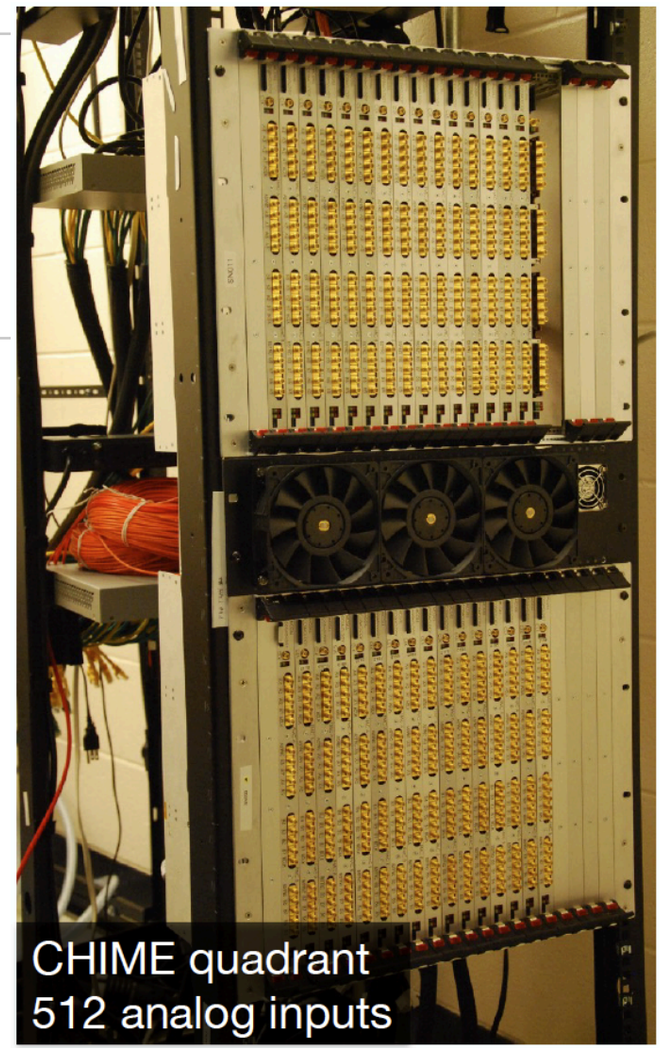


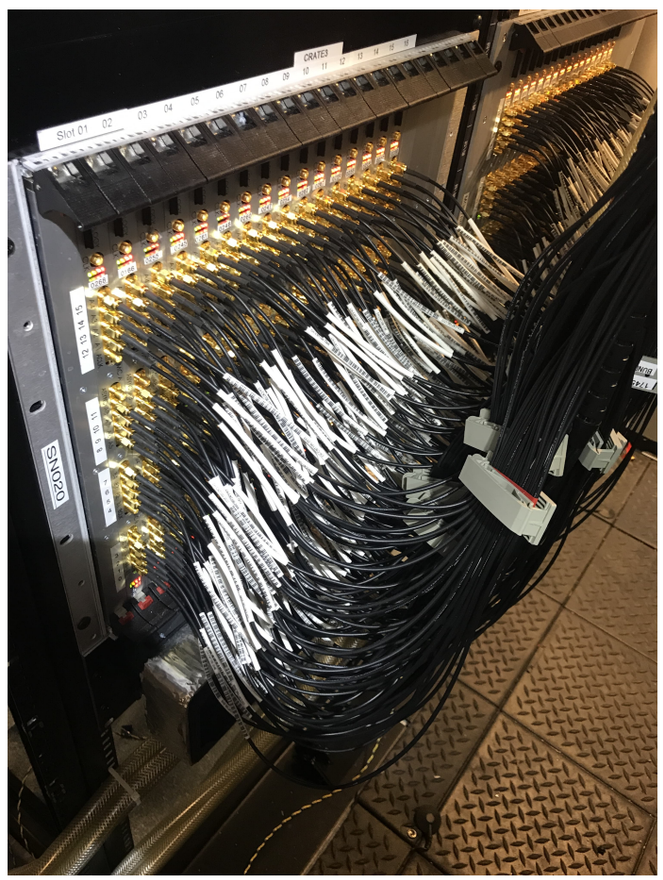
Shipping container

Correlator F-engine

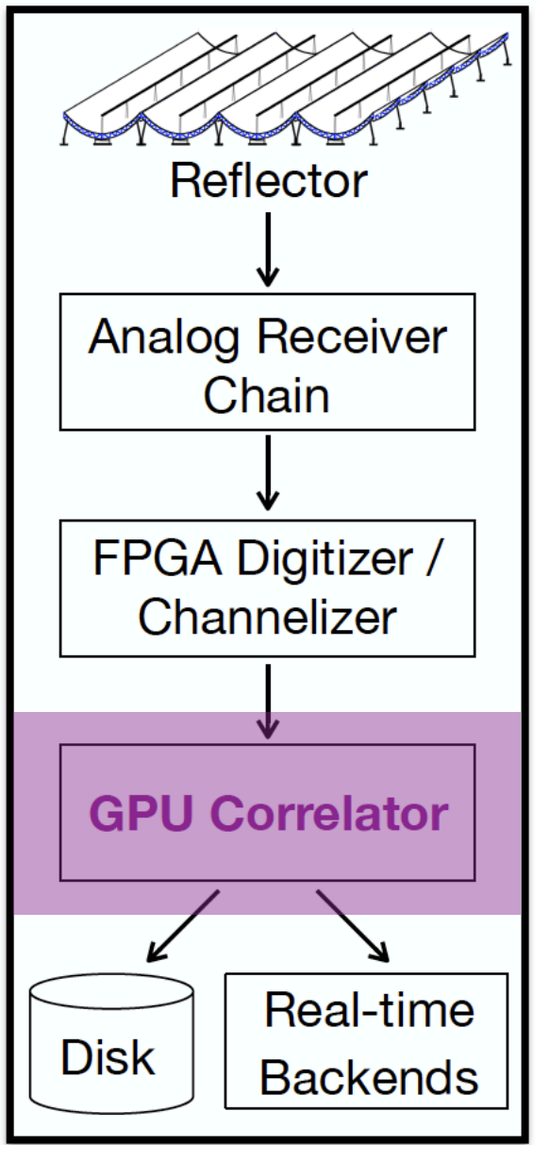


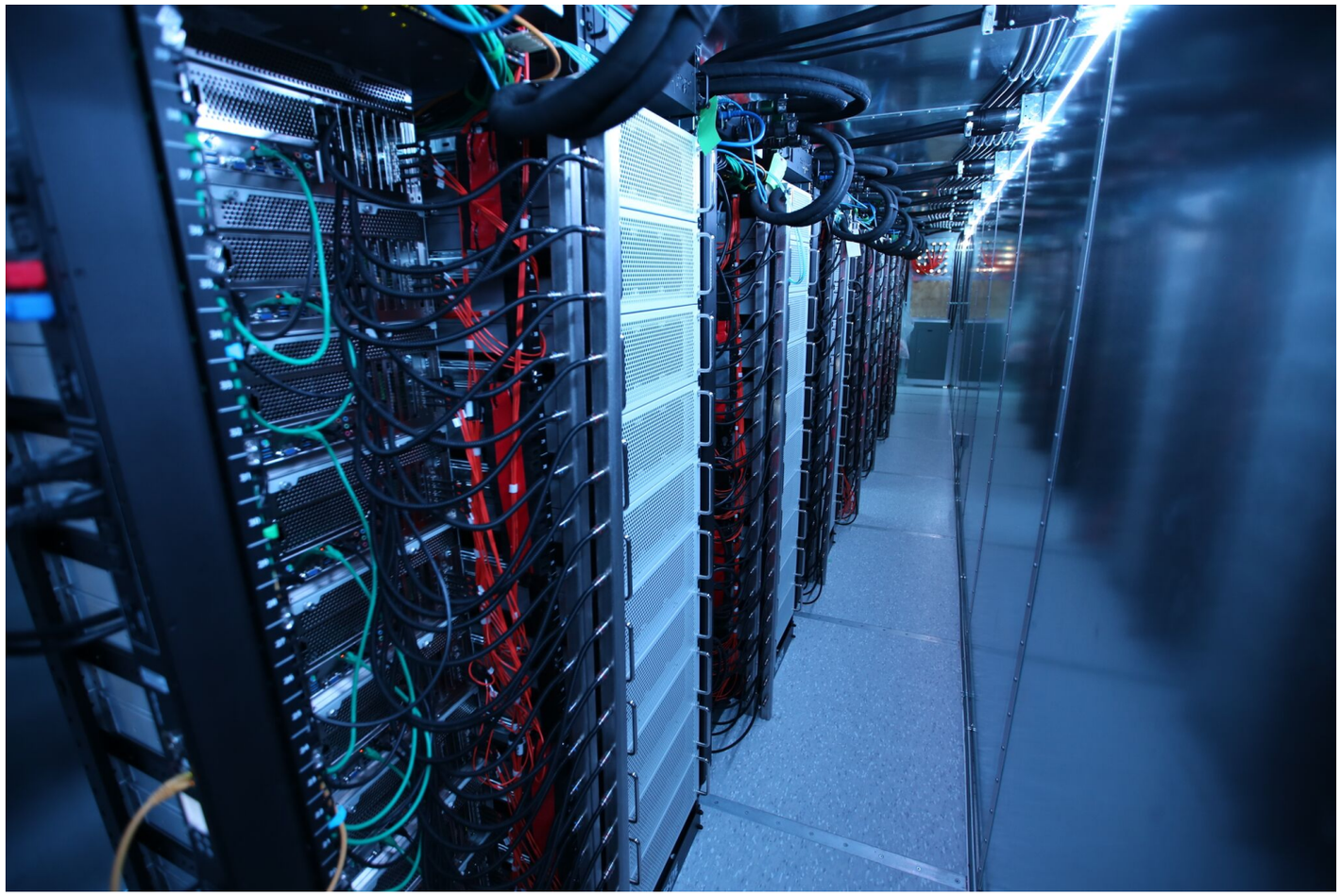
- Uses 'ICE' boards developed by a team at McGill
- Signal from each antenna sampled at 800 MHz
  - each board processes 16 inputs @ 8 bits = 96 Gbps
  - CHIME has 128 boards = 13 Tbps
  - Raw time stream turned into frequency channels in FPGAs


CHIME quadrant
512 analog inputs

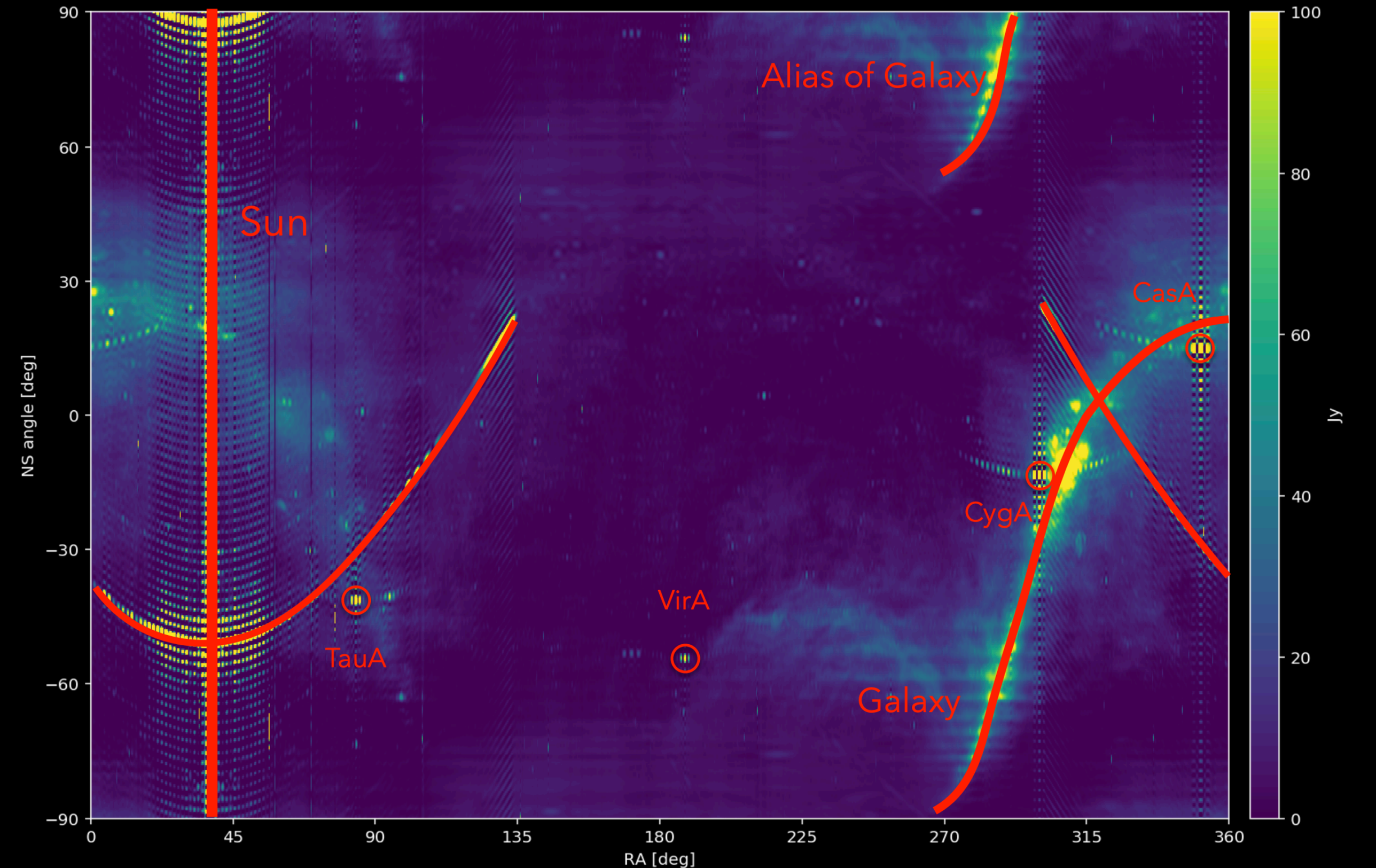


Correlator X-engine





- Full pairwise multiply, accumulation in time
- Computationally hard
  - Use GPUs (1024 AMD Fiji cores)
  - Efficient : 50 GigaOp/W
  - Developed by team at U Toronto



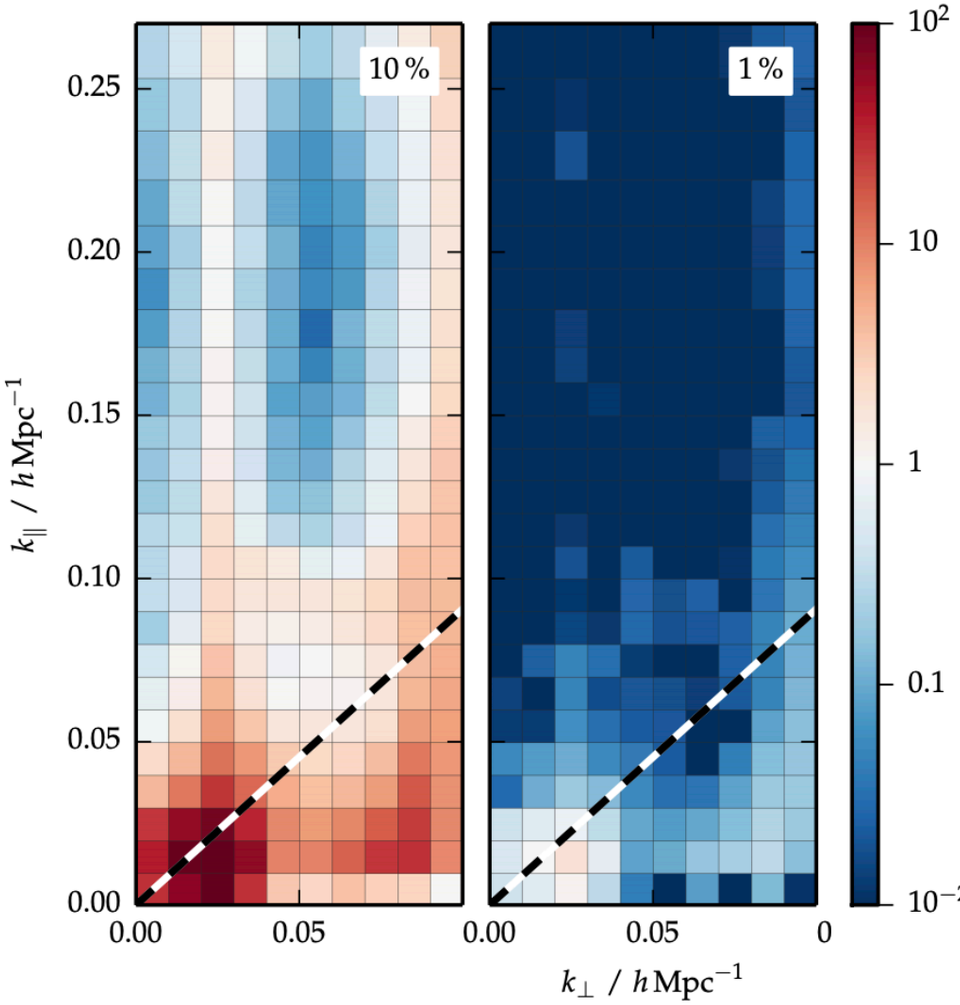
Map uses 10^{-6} of all CHIME data collected so far

Map from Seth Siegel

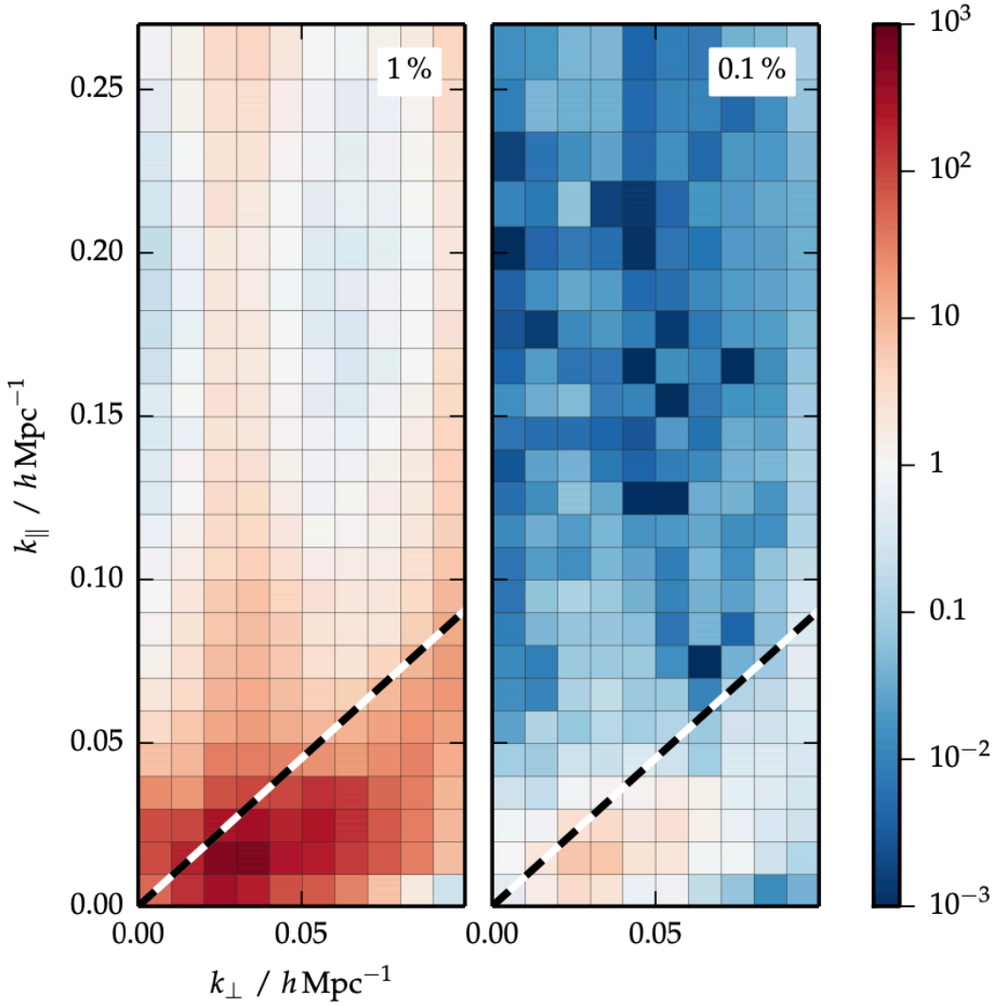
Calibration requirements

Systematic bias (red > 1σ; blue < 1σ)

Instantaneous Gain



Beam width



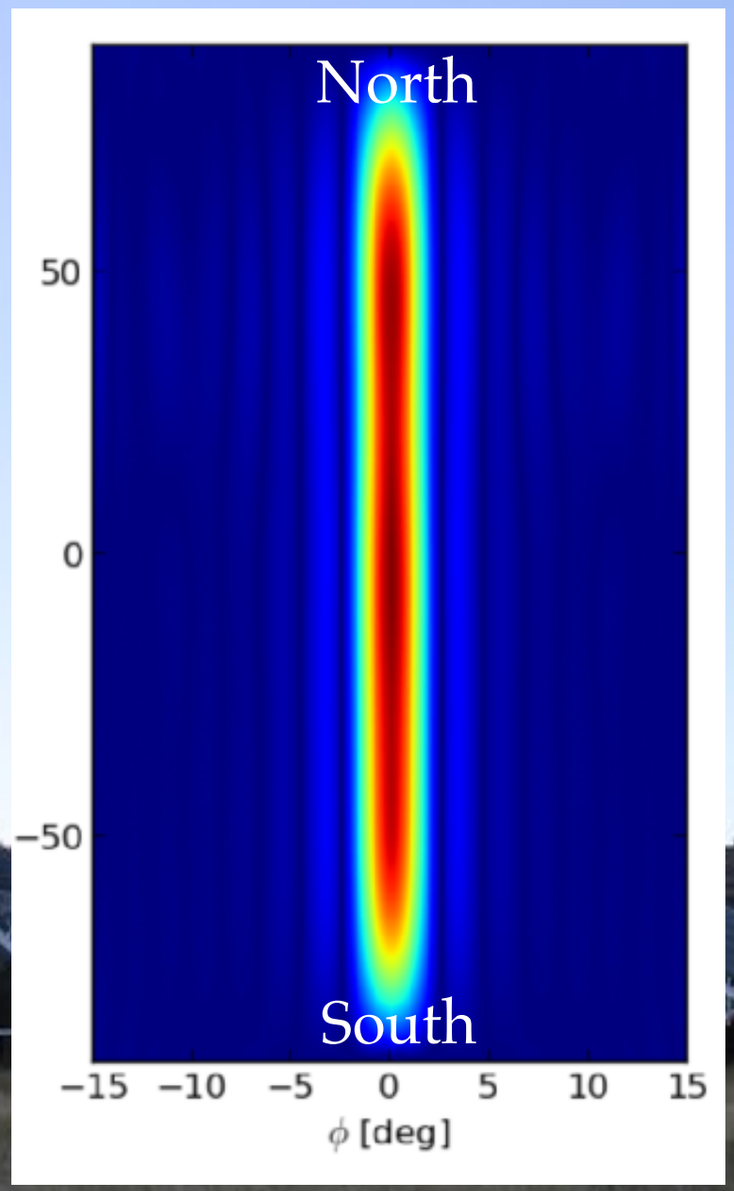
Need better than 1% gain calibration: Thermal models (*Sidhant Guliani, Mateus Fandino*); noise injection (*Juan Mena Parra*)

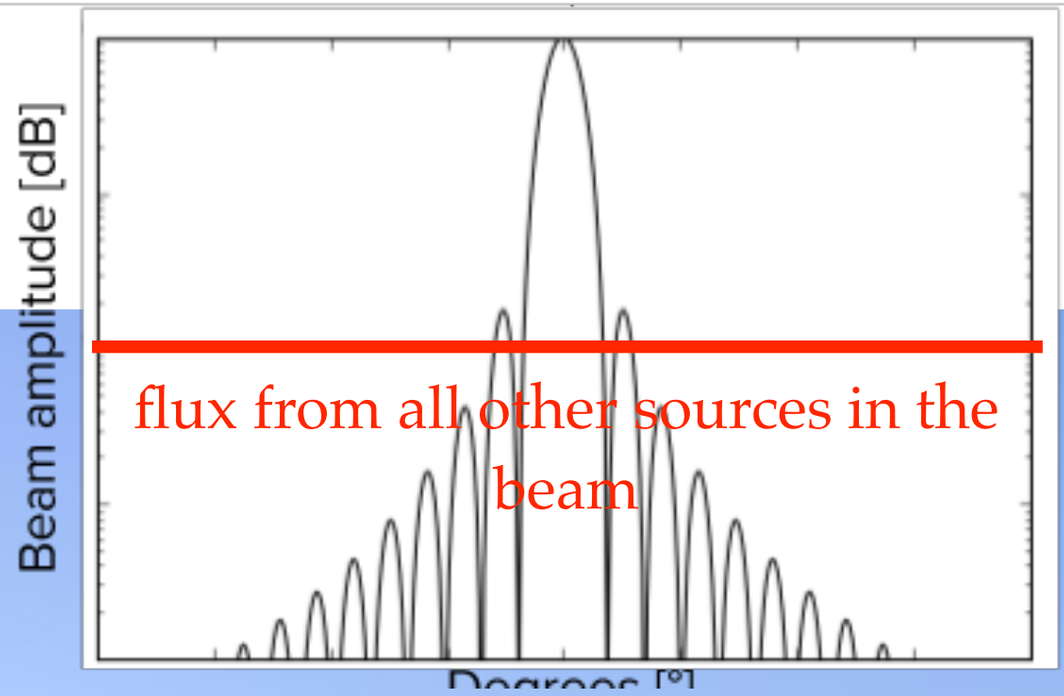
Need to understand beams at 0.1% level: Simulations (*Meiling Deng*); holography (*Alex Hill, Laura Newburgh, Phil Berger*)

(slide from Richard Shaw)

Shaw et al. 2015, *arXiv:1401.2095*

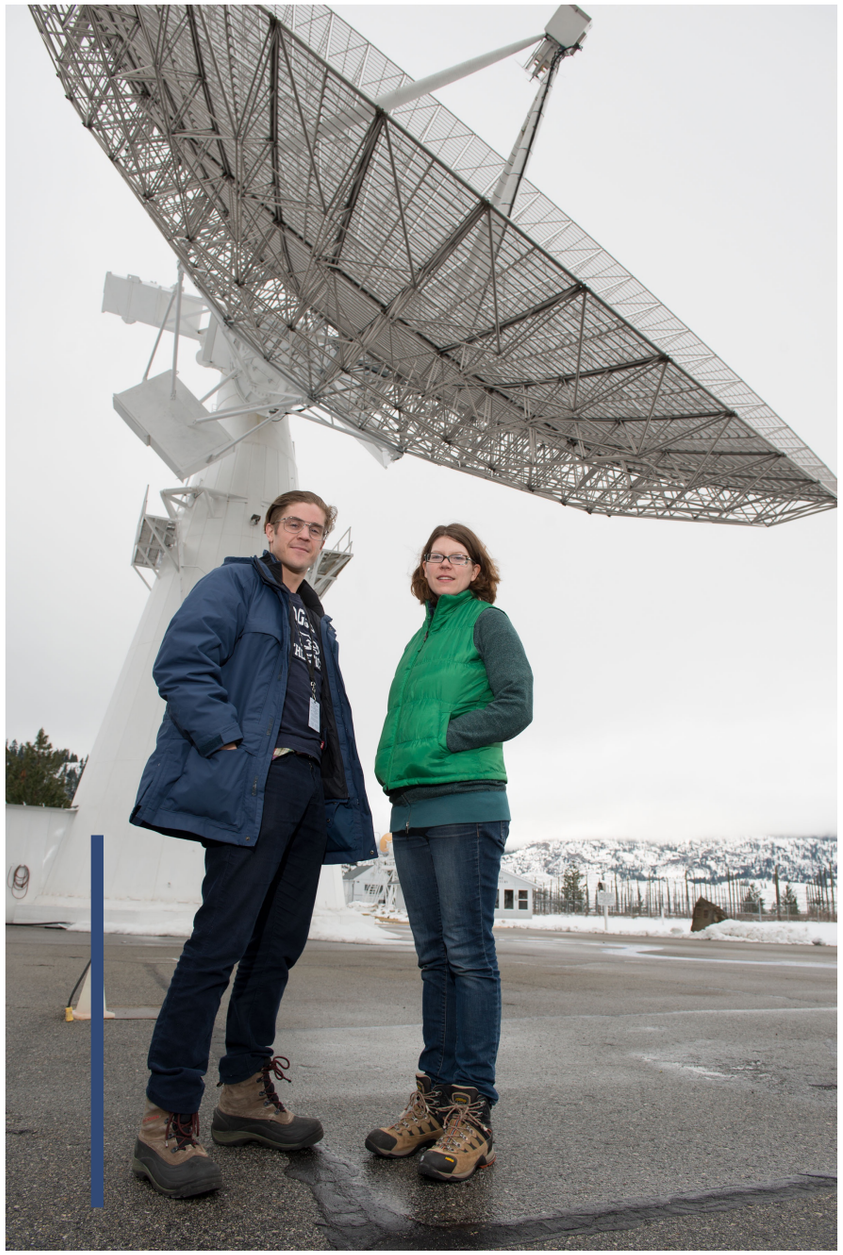
The reason this is hard…

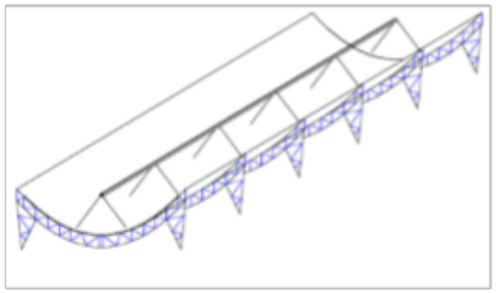


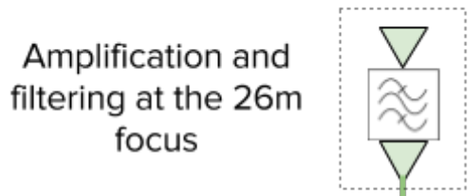


Calibrate with Holography

Tracking dish

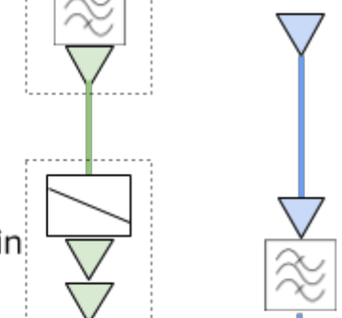






Amplification and filtering at the 26m focus

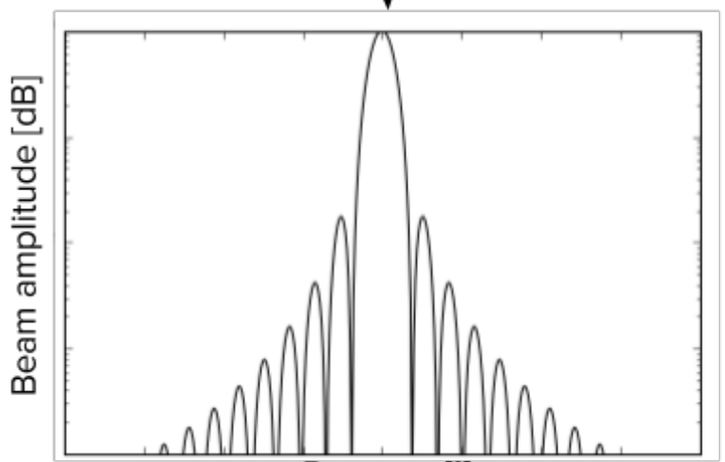
Amplification at the CHIME focus



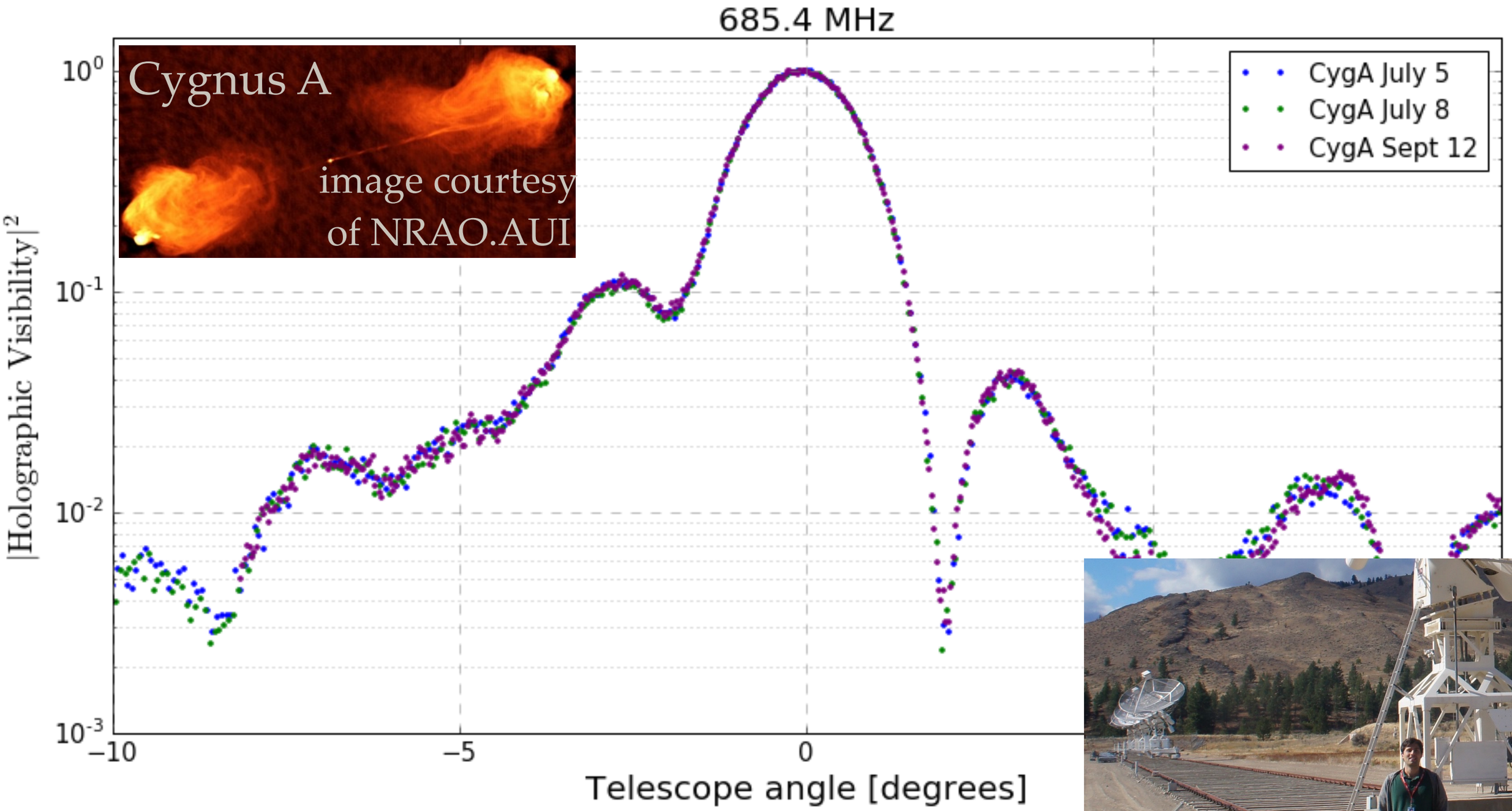
Amplification and signal equalization in the 26m control room

Amplification and filtering at CHIME

Digitization and correlation in the CHIME correlator

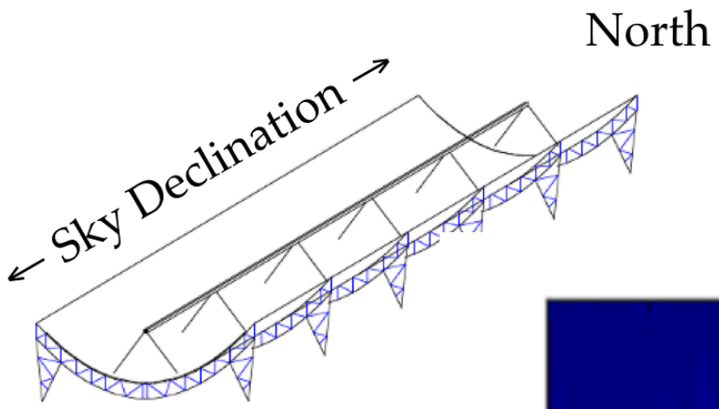


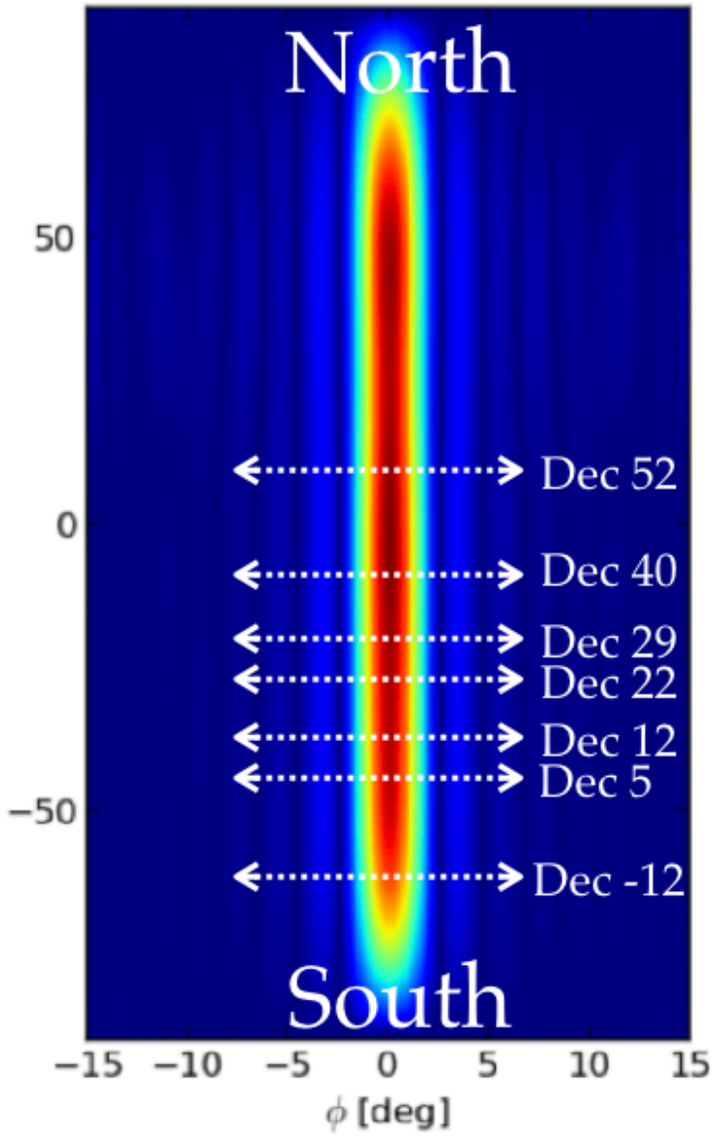
Holographic beam scans from CygA



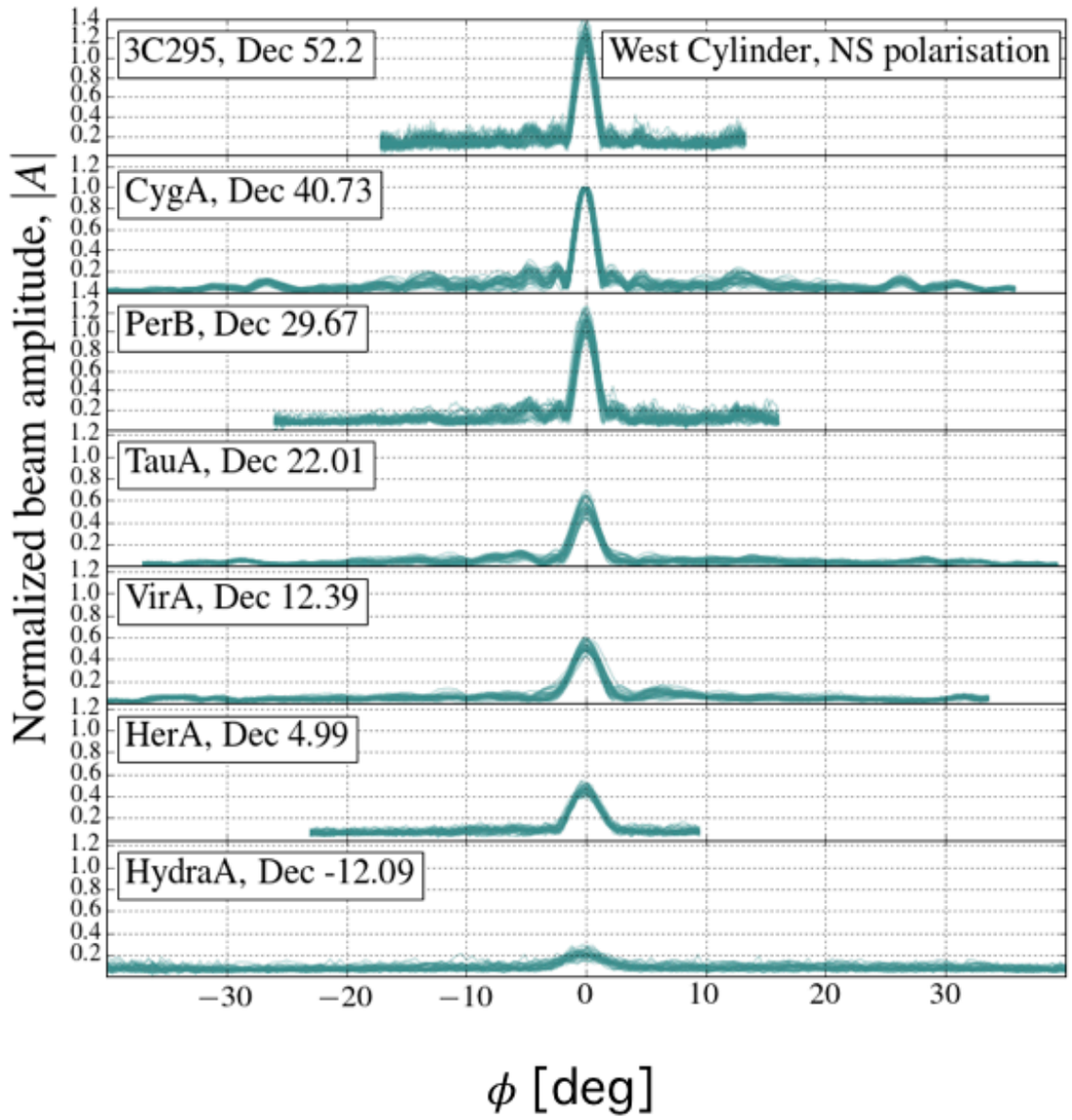
Analysis by grad student Phil Berger

Holographic beam scans from multiple sources





Berger et al 2016



Can also use … Drones!

Summary

- CHIME will measure BAO from z~0.8-2.5
  - Sept 7, 2017: First light
  - March 2018: Began collecting reduced resolution and partial frequency science data
  - Sept 2018: Began collecting compressed full-resolution and full-band data
- 21cm observations are hard because of foregrounds, but removal is feasible with tight control/understanding of calibration, primary beam shape, RFI cleaning/other masking, etc
- Scope and size of problem needs innovative techniques

Thanks!