Status of CHIME: The Canadian Hydrogen Intensity Mapping Experiment

Seth Siegel
Postdoctoral Researcher
McGill University

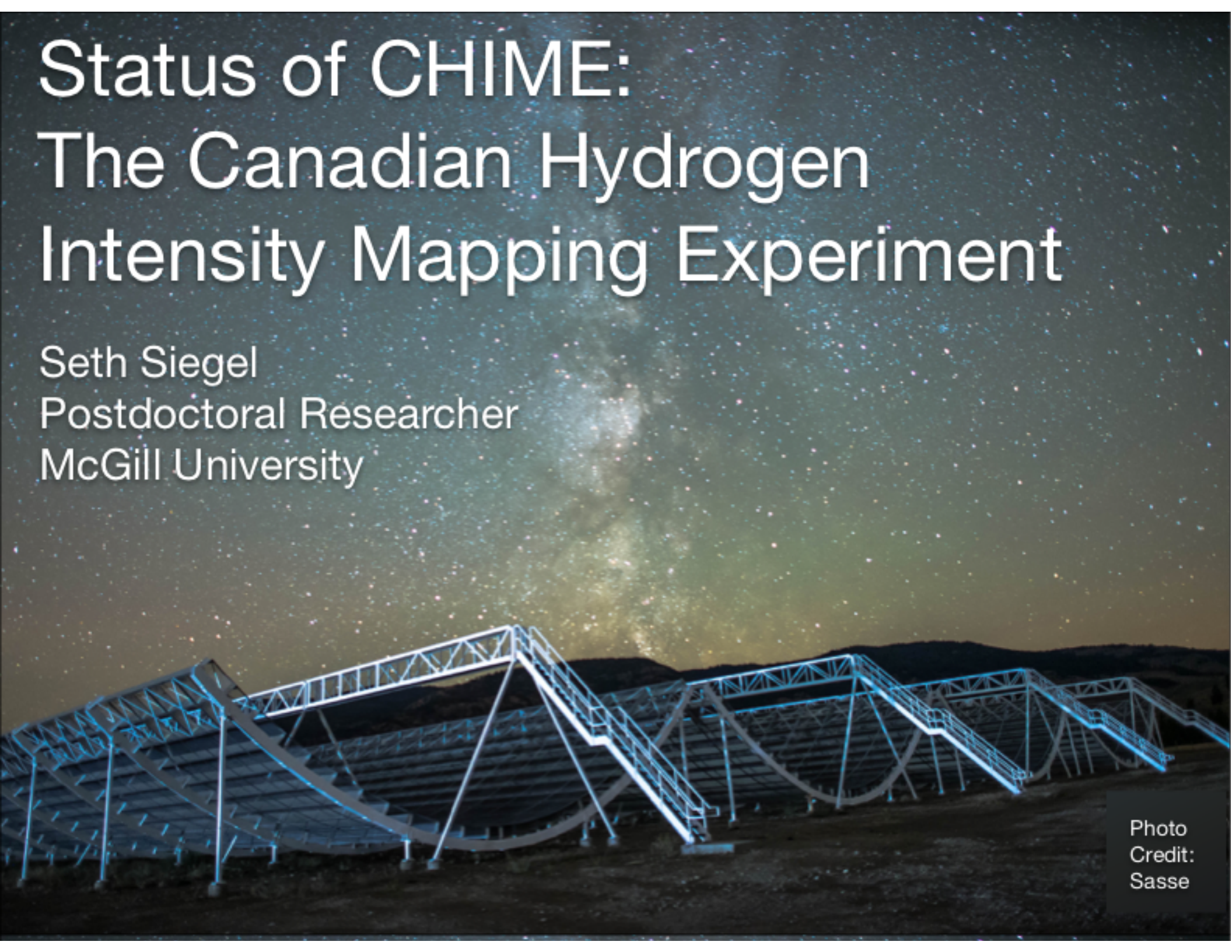
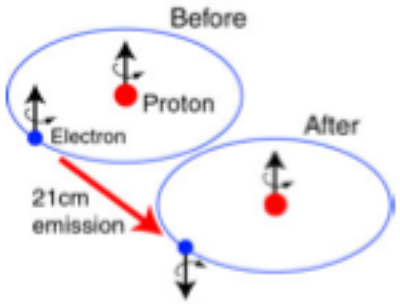
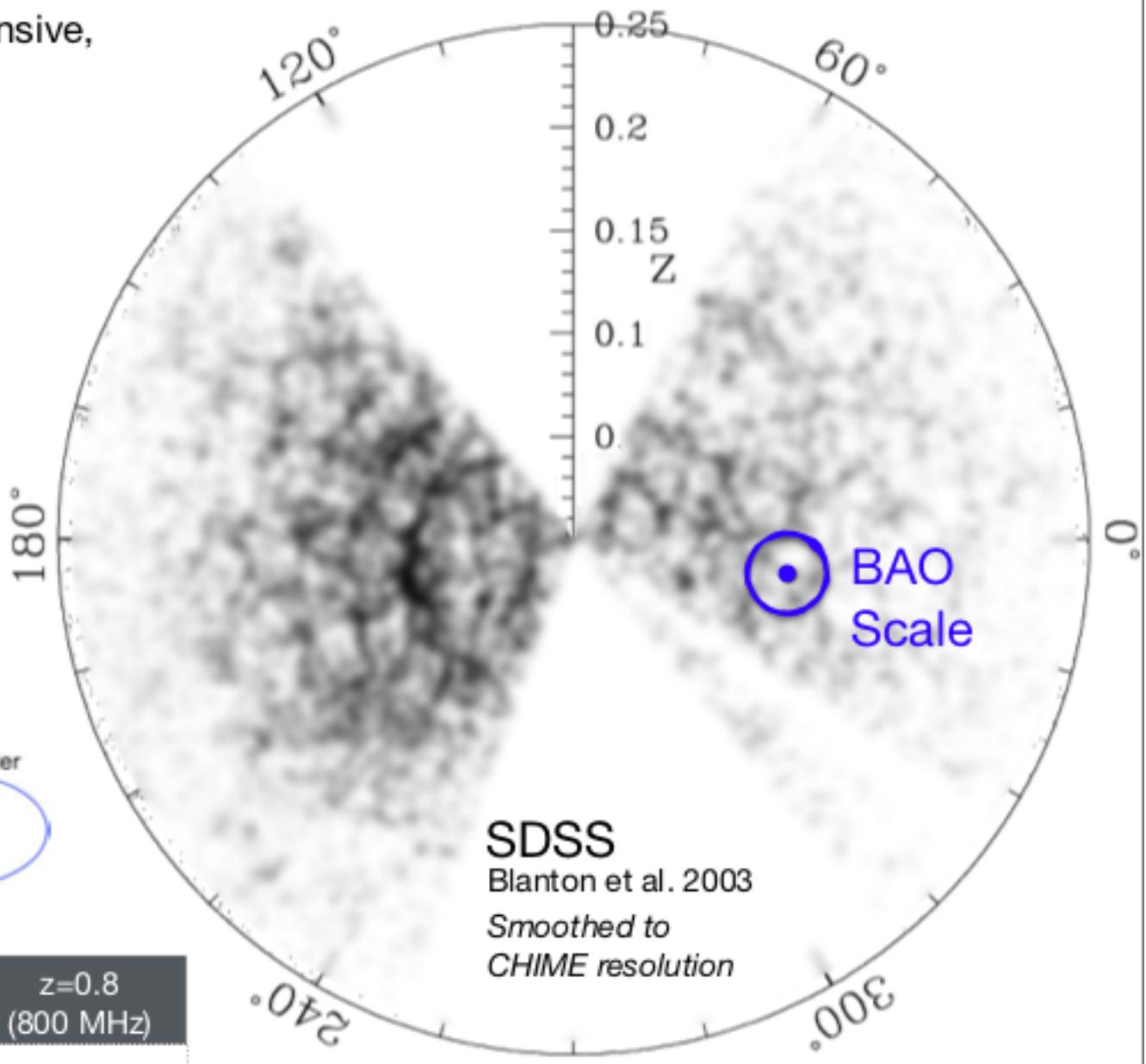


Photo Credit: Sasse

Hydrogen Intensity Mapping

- Spectroscopic galaxy surveys expensive, difficult at high-z
- Interested in much larger scales, do not need to resolve individual galaxies
- Instead, measure the aggregate 21 cm emission from neutral hydrogen
  - Observing frequency maps to redshift slice
  - Probe "redshift desert" ($1.4 < z < 2.5$)





-

Observable	z=2.5 (400 MHz)	z=0.8 (800 MHz)
$\Delta\theta_{BAO}(z) = r_s/D_M(z)$	1.35°	3°
$\Delta z_{BAO}(z) = r_s H(z)/c$	12 MHz	20 MHz

a collaboration between

THE UNIVERSITY OF BRITISH COLUMBIA

UNIVERSITY OF TORONTO

McGill

NRC · CNRC

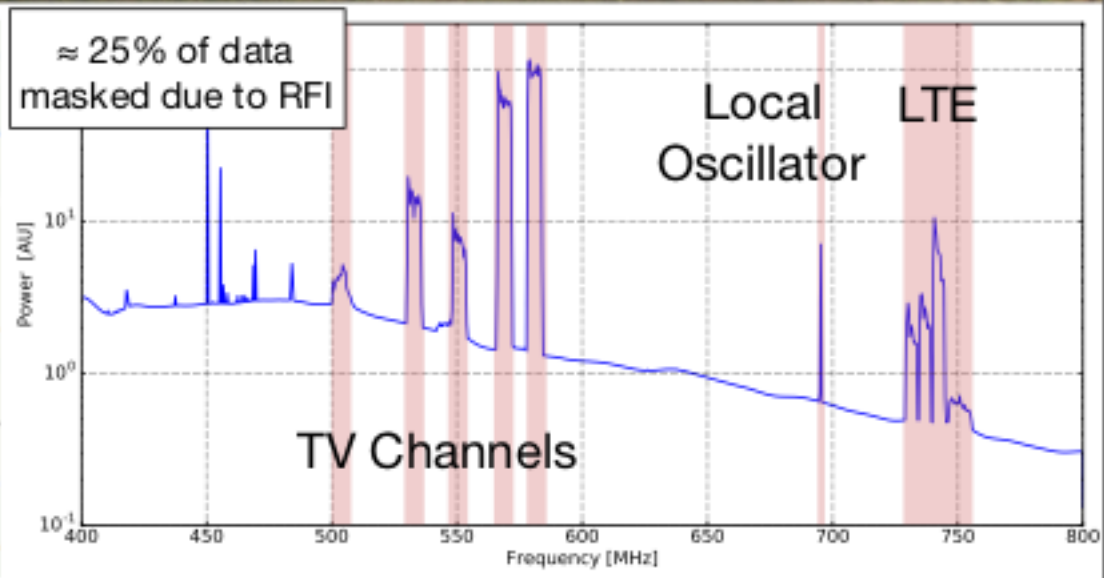
Dominion Radio Astrophysical Observatory

with partners at

Yale University

Drone Flight Over CHIME

Dominion Radio Astrophysical Observatory



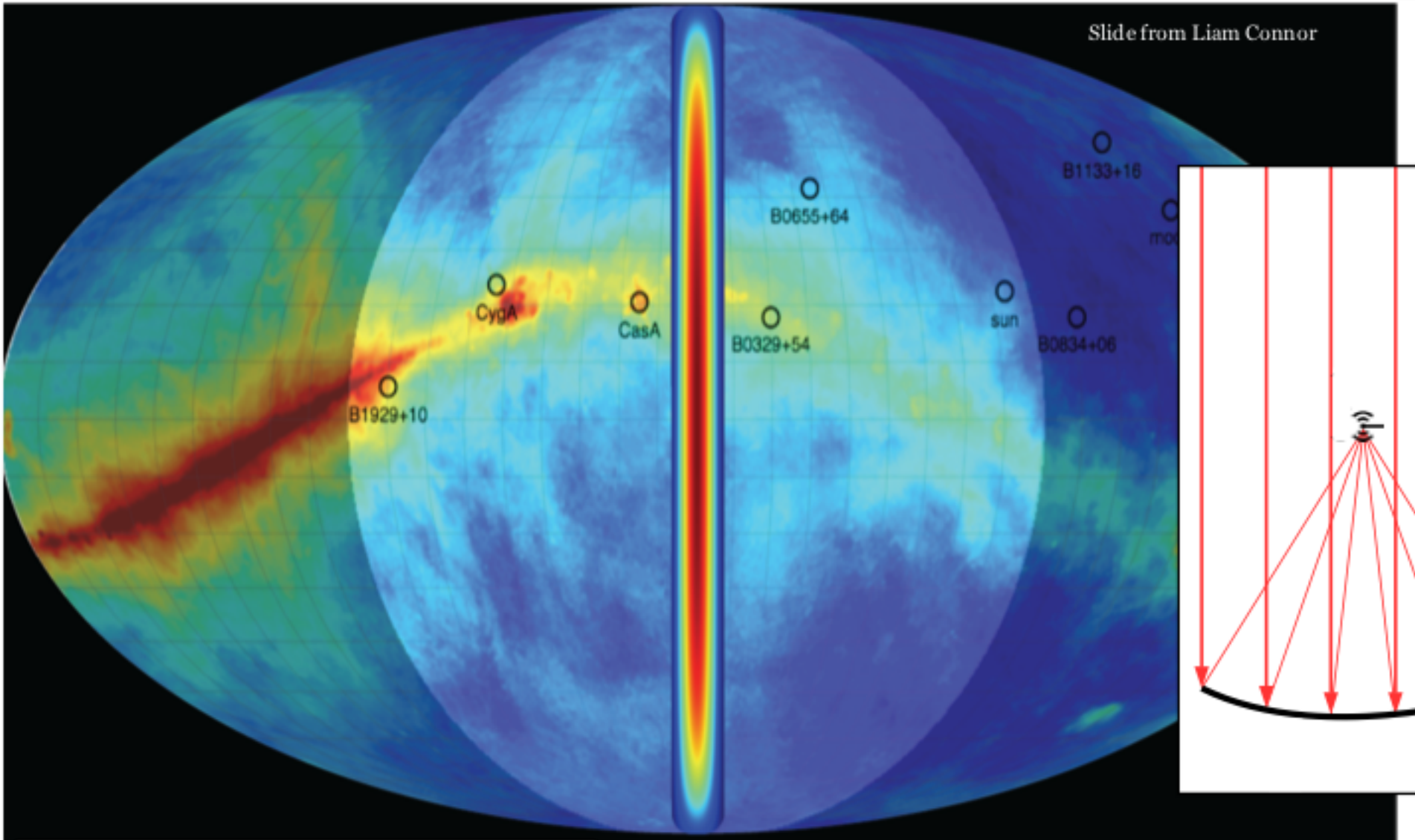
Cylindrical Transit Interferometer

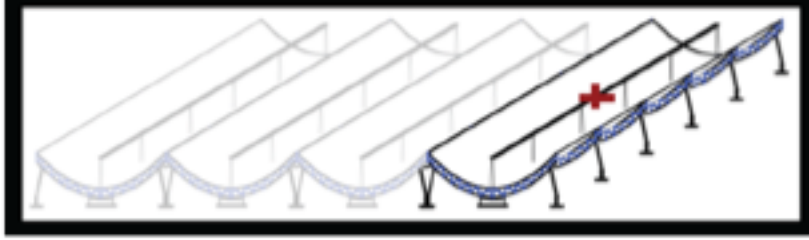
$\mathcal{E} \longleftrightarrow \mathcal{W}$

Movie by Peter Klagge

Cylindrical Transit Interferometer

Slide from Liam Connor



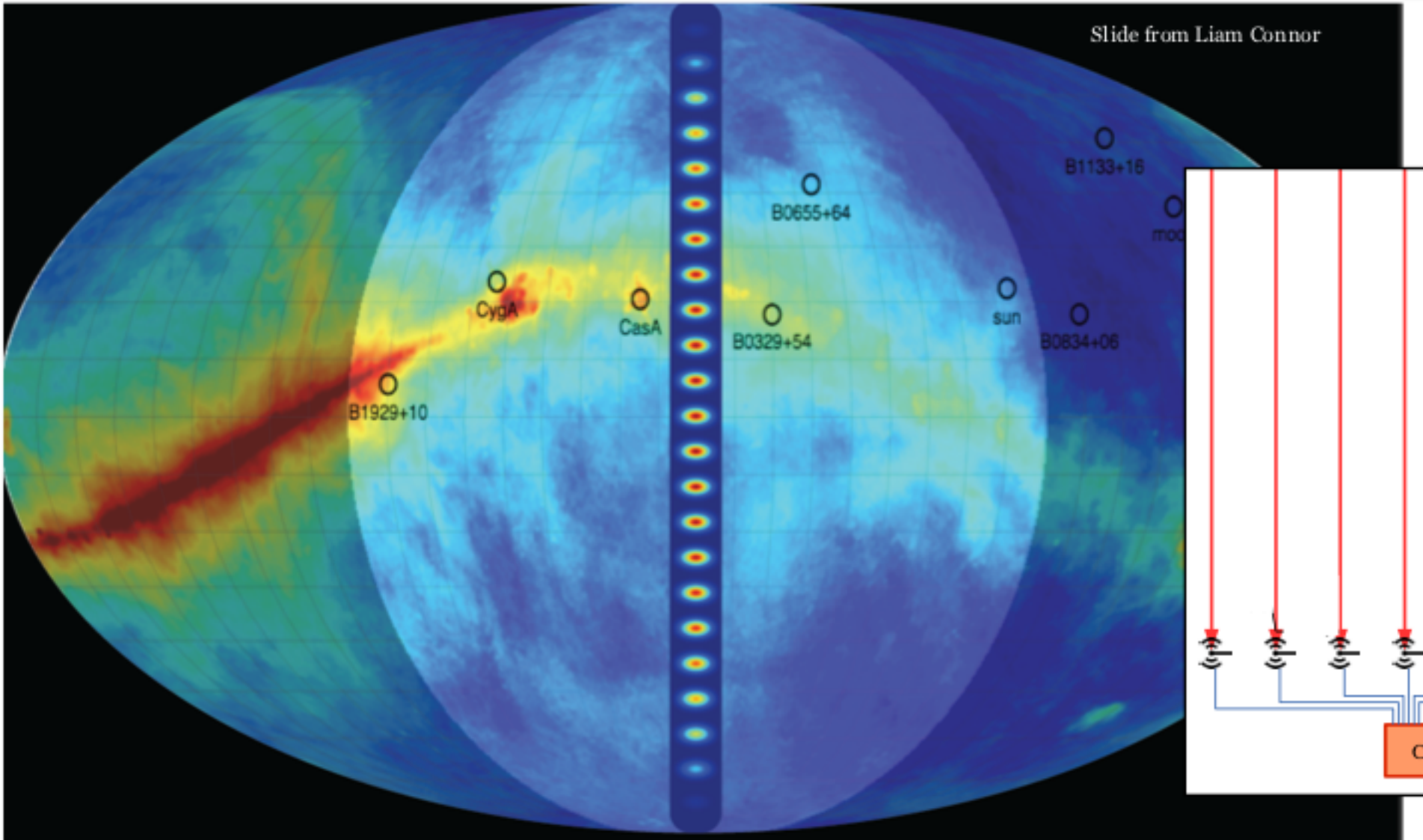


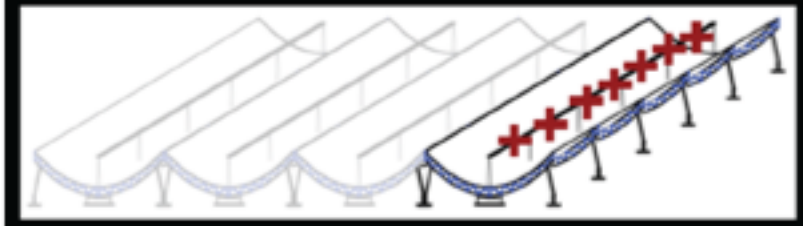
- Cylinder focuses light only in EW direction
- Gives us large FOV

Cylindrical Transit Interferometer

Cylindrical Transit Interferometer

Slide from Liam Connor



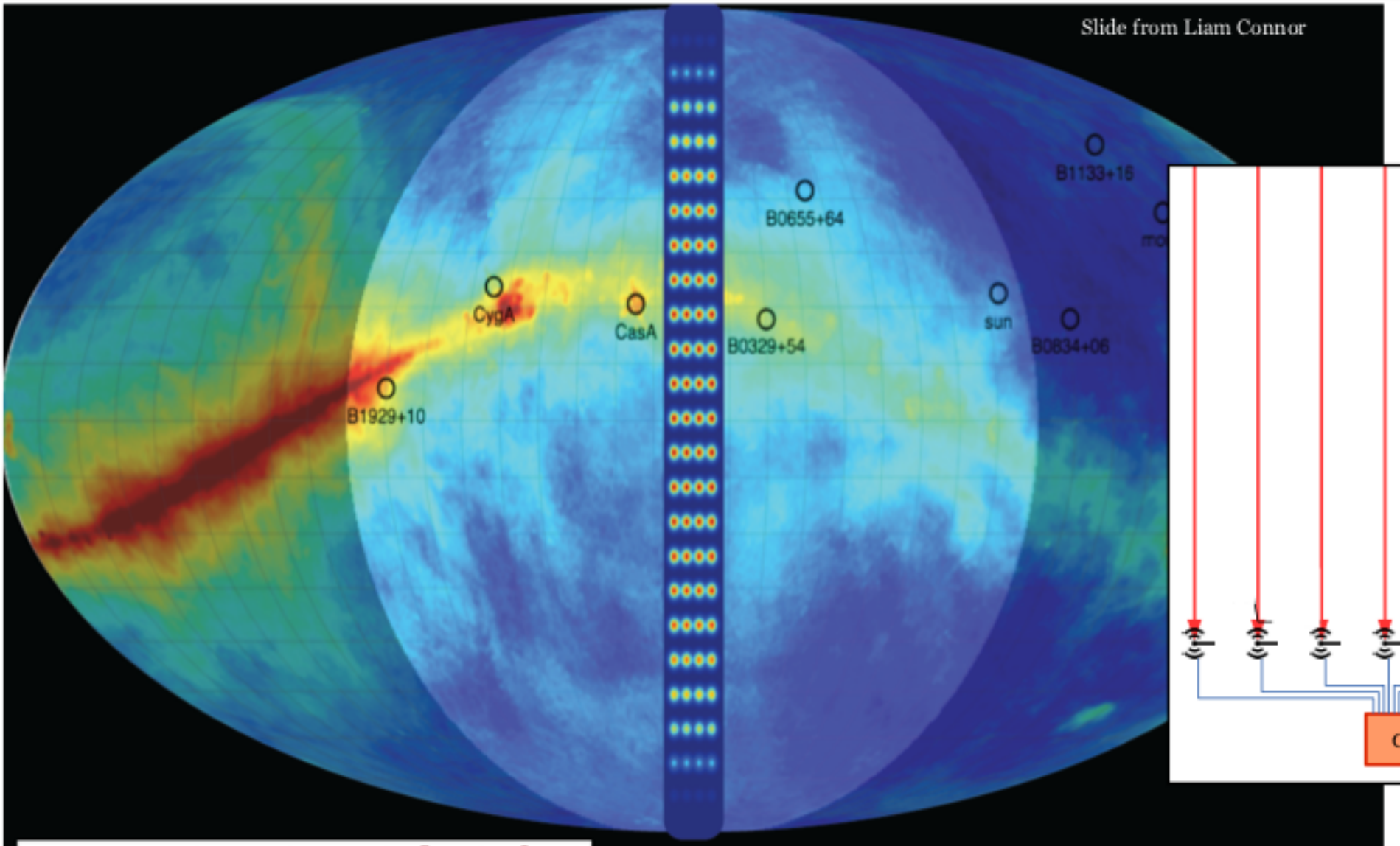


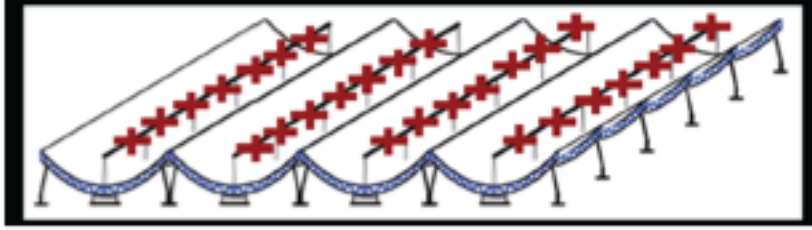
- FFT telescope in NS direction
- 256 beams per cylinder

Cylindrical Transit Interferometer

Cylindrical Transit Interferometer

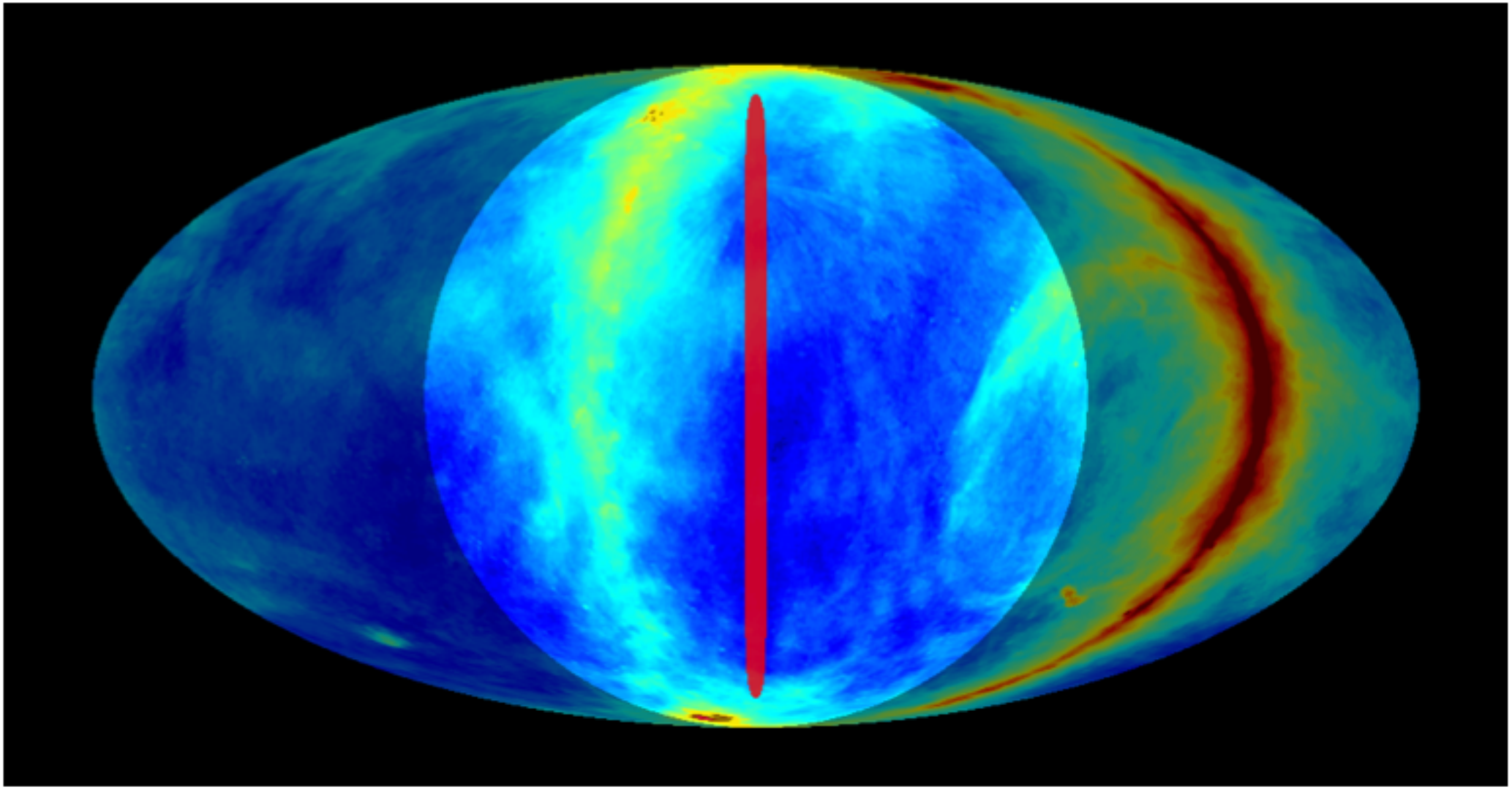
Slide from Liam Connor





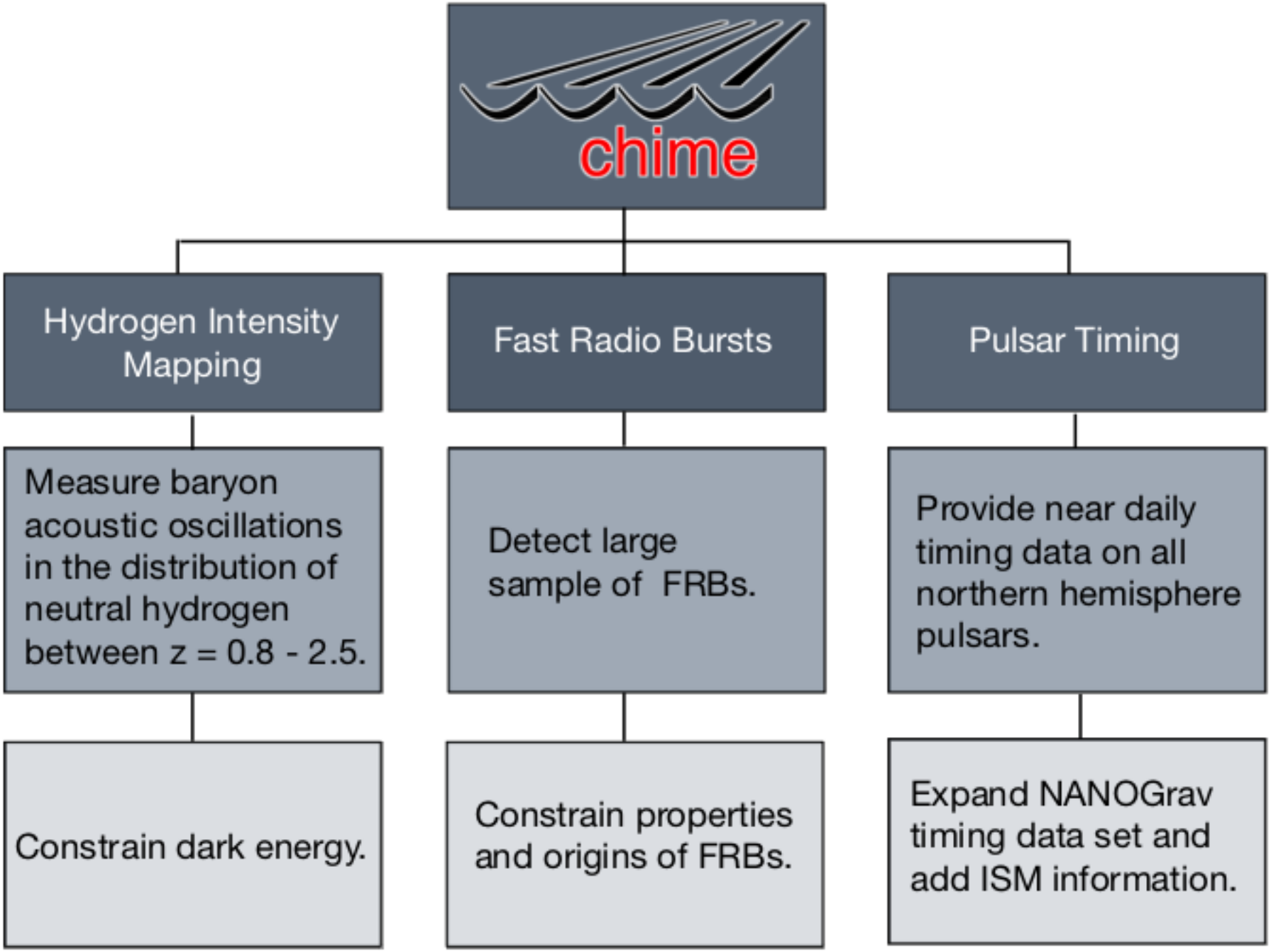
- 1024 beams from full 4-cylinder CHIME

Cylindrical Transit Interferometer

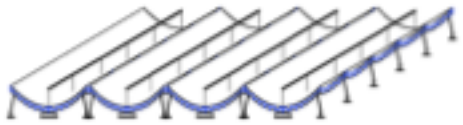


Haslam 408 MHz Map

CHIME Science Objectives


chime
Hydrogen Intensity Mapping
Fast Radio Bursts
Pulsar Timing
Measure baryon acoustic oscillations in the distribution of neutral hydrogen between z = 0.8 - 2.5.
Detect large sample of FRBs.
Provide near daily timing data on all northern hemisphere pulsars.
Constrain dark energy.
Constrain properties and origins of FRBs.
Expand NANOGrav timing data set and add ISM information.

Reflector



Reflector

↓

Analog Receiver Chain

↓

FPGA Digitizer / Channelizer

↓

GPU Correlator

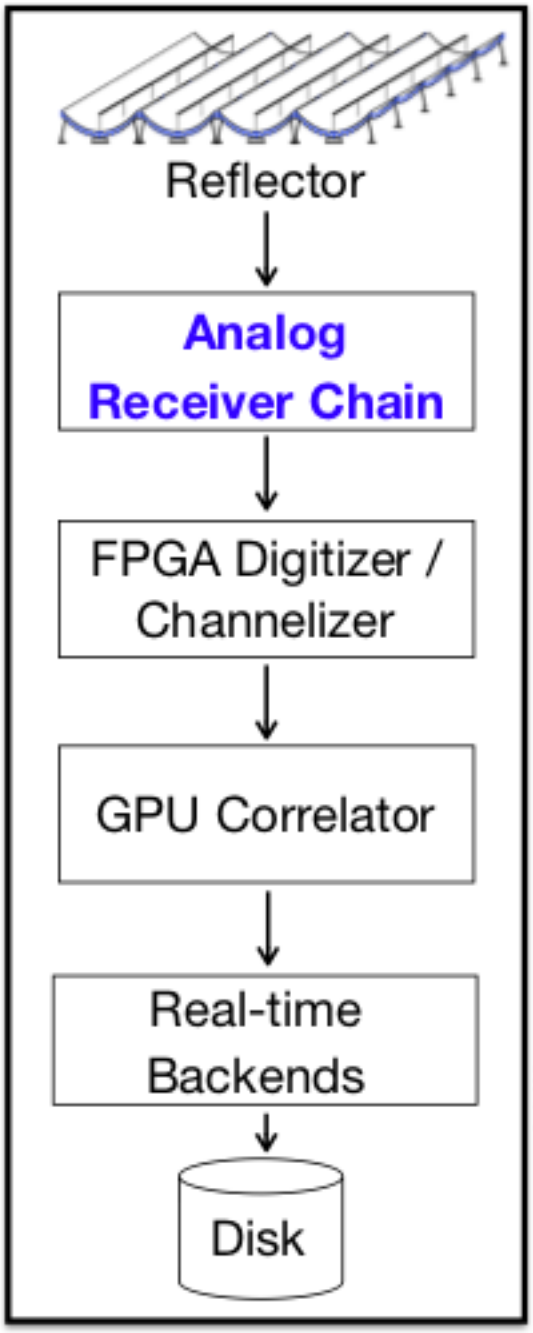
↓

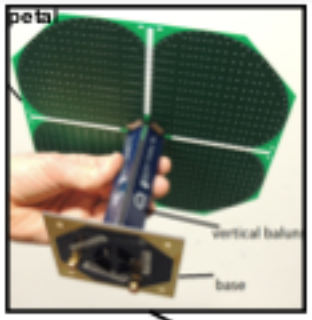
Real-time Backends

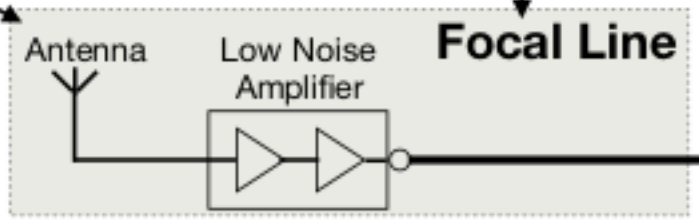
↓

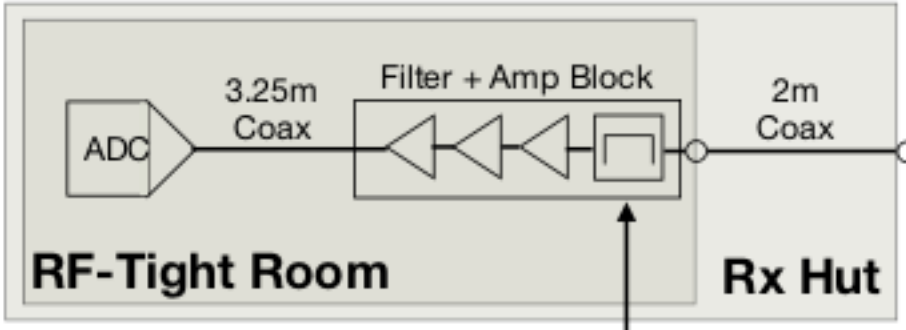
UBC graduate student Meiling Deng
who led design of CHIME cloverleaf antennas

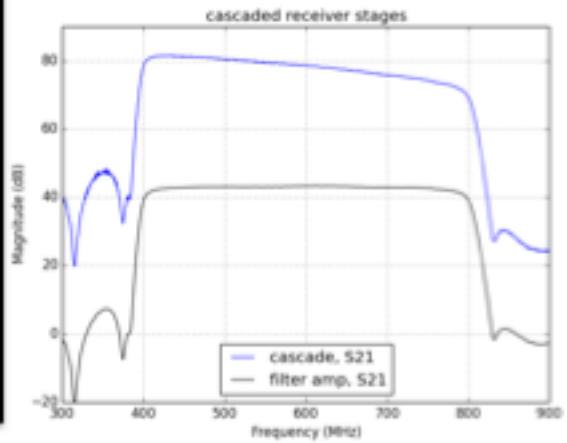
Analog Receiver Chain

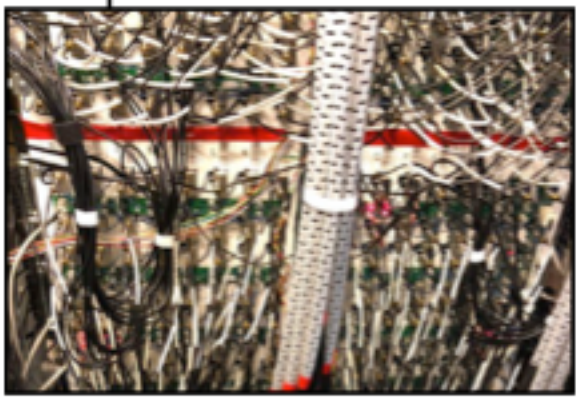












FPGA Digitizer and Channelizer (F-Engine)

Reflector

↓

Analog Receiver Chain

↓

FPGA Digitizer / Channelizer

↓

GPU Correlator

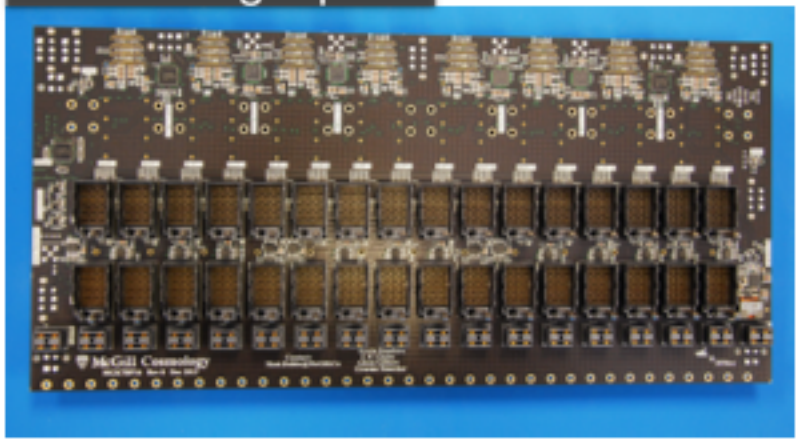
↓

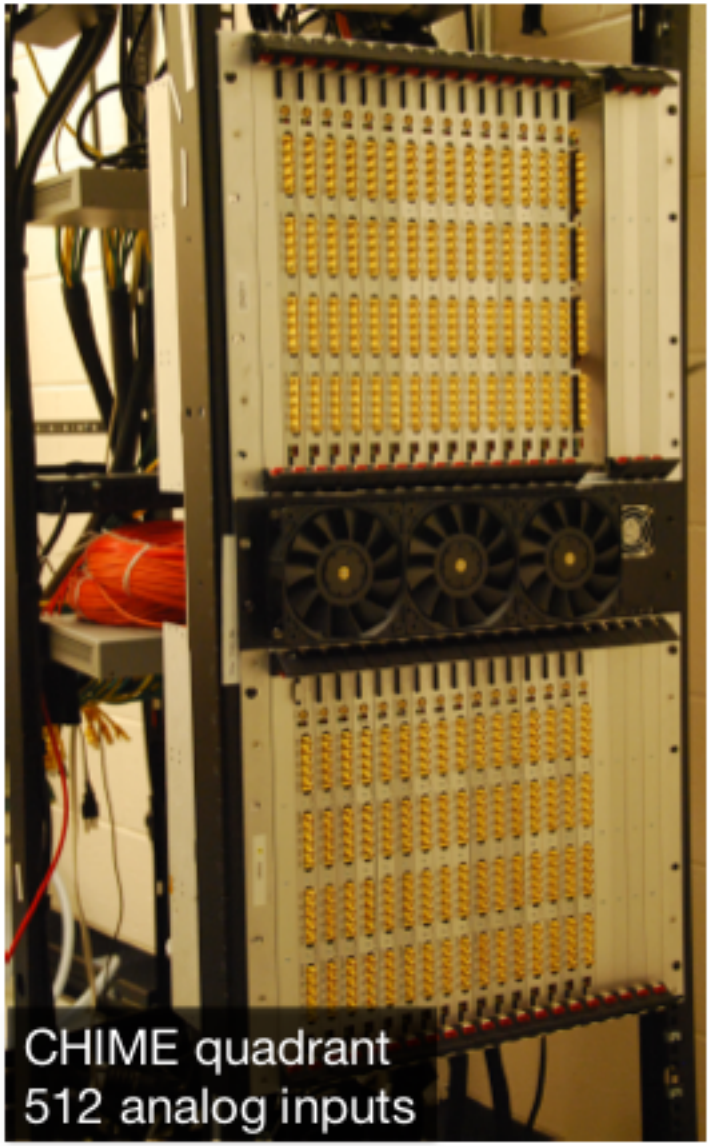
Real-time Backends

↓

Motherboard
16 analog inputs

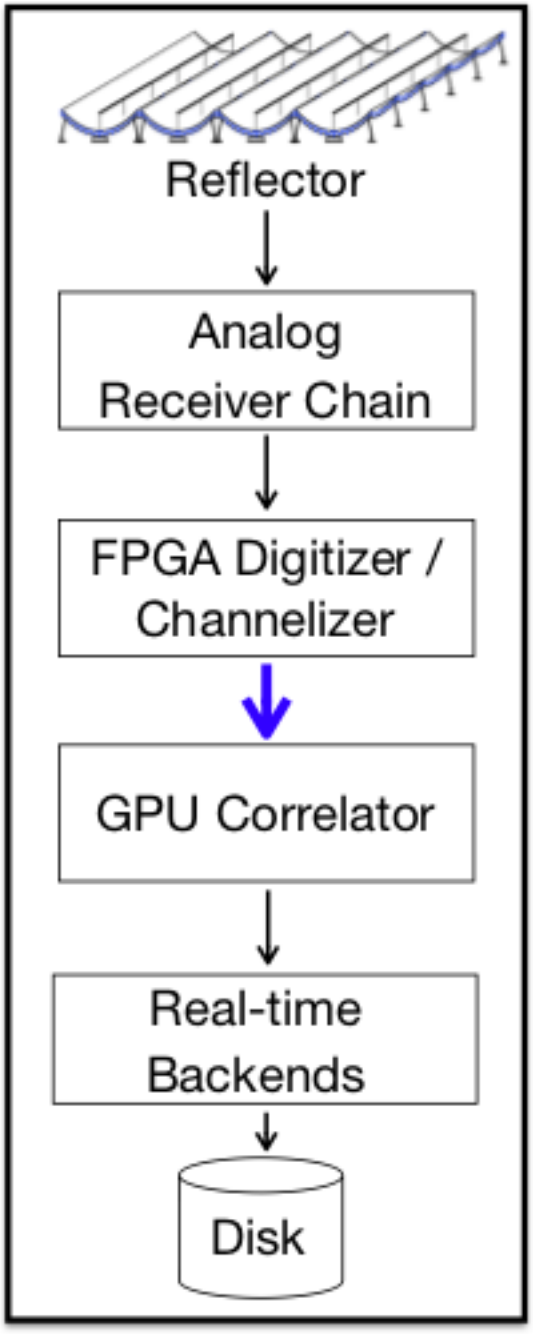
Backplane
256 analog inputs

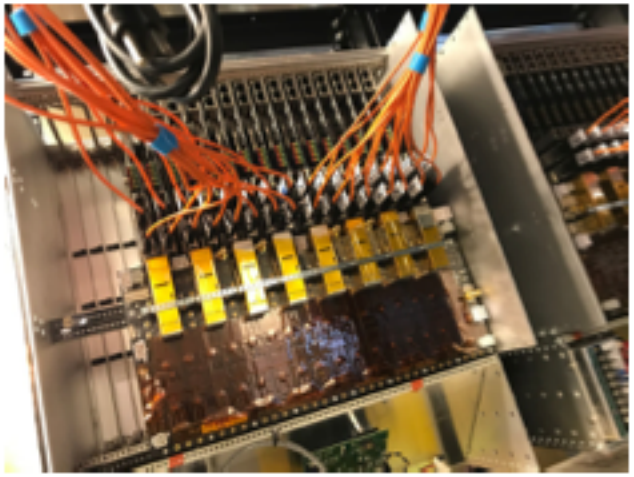


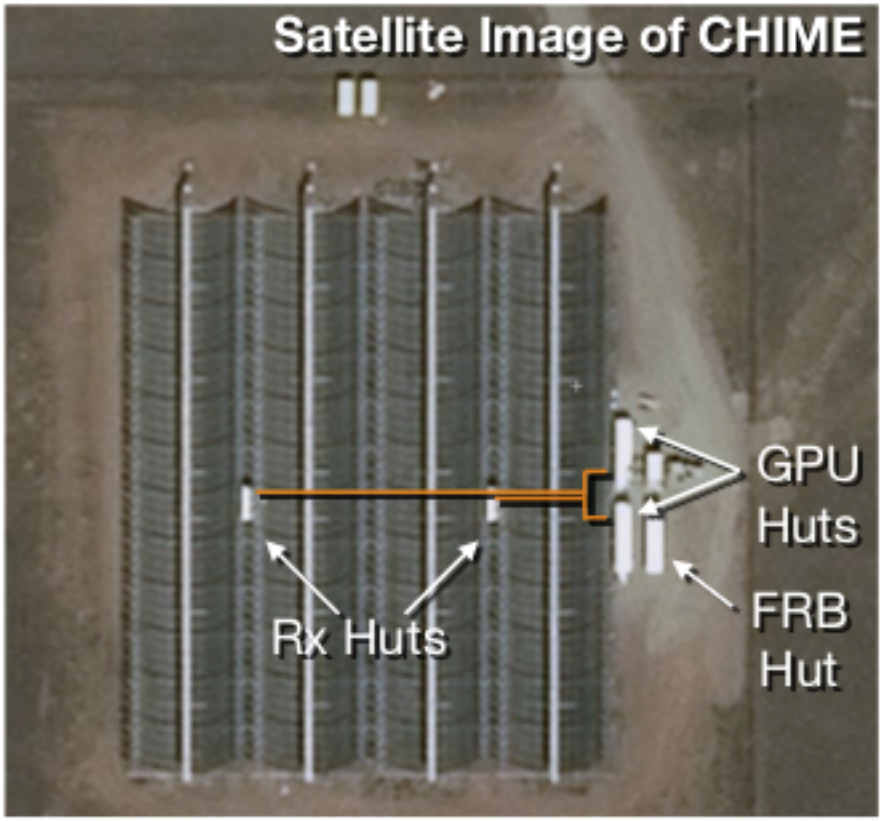


Bandura et al. 2016, JAI

10 Gbit/s Link over Optical Fiber (x1024)







GPU Correlator (X-Engine)

Reflector

↓

Analog Receiver Chain

↓

FPGA Digitizer / Channelizer

↓

GPU Correlator

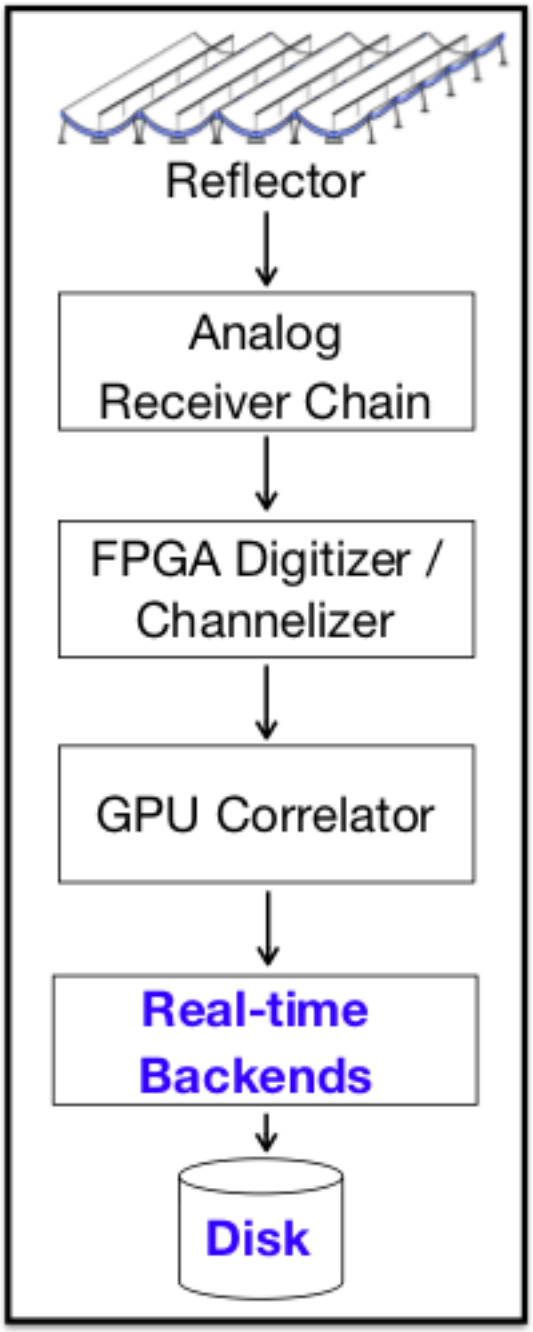
↓

Real-time Backends

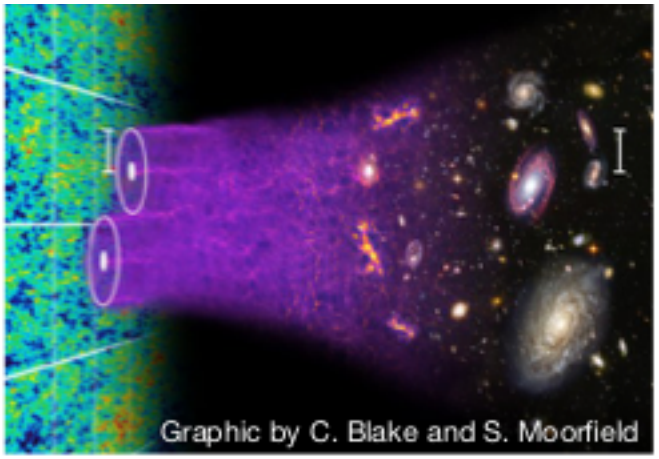
↓

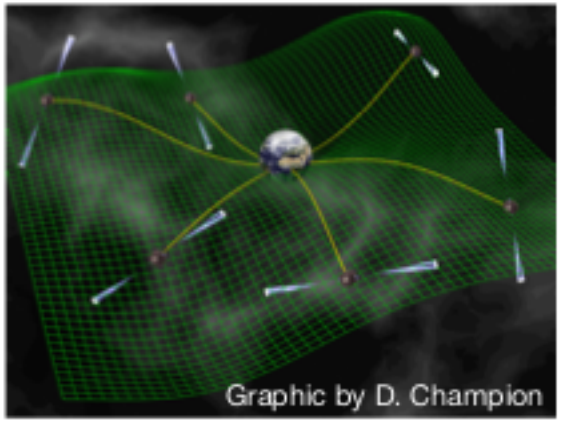
Denman et al. 2015

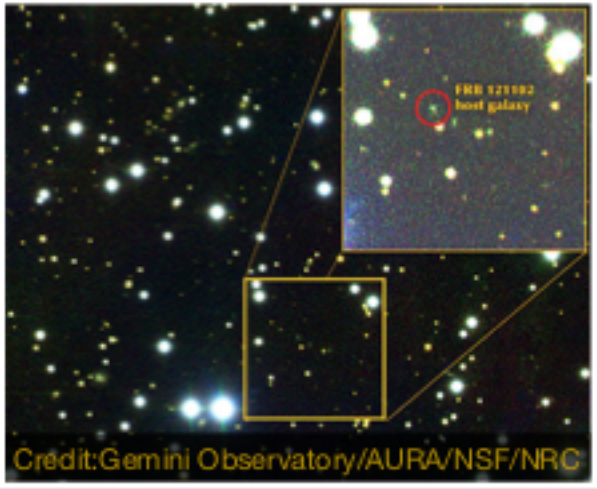
Backends



- **Cosmology**
  - Full N^2 visibility matrix
  - 10 sec cadence
  - 210 TB/day
  - Real time flagging and gain calibration
  - Data compression through redundant baselines (1.0 TB/day)
- **Pulsar timing**
  - 10 steerable beams
  - 2.56 μs cadence
- **Fast Radio Burst**
  - 1024 stationary beams
  - 1 msec cadence
  - 16k frequency bins







Status

- **September 7, 2017** First light ceremony

- **April 2018** Began collecting science data at a reduced capacity.
  - Compression through truncation:
    - Saving 25% of all frequency channels
    - Saving 25% of all N^2 baselines

- **September 2018** Reached full capacity.
  - Compression through averaging redundant baselines.
  - Monthly software upgrades.

- **December 2018** Started "long winter run".

- **Going forward**
  - Foreground removal
    See Richard Shaw's talk tomorrow.
  - Beam calibration and improvements to complex gain calibration.
    See Kevin Bandura's talk tomorrow.

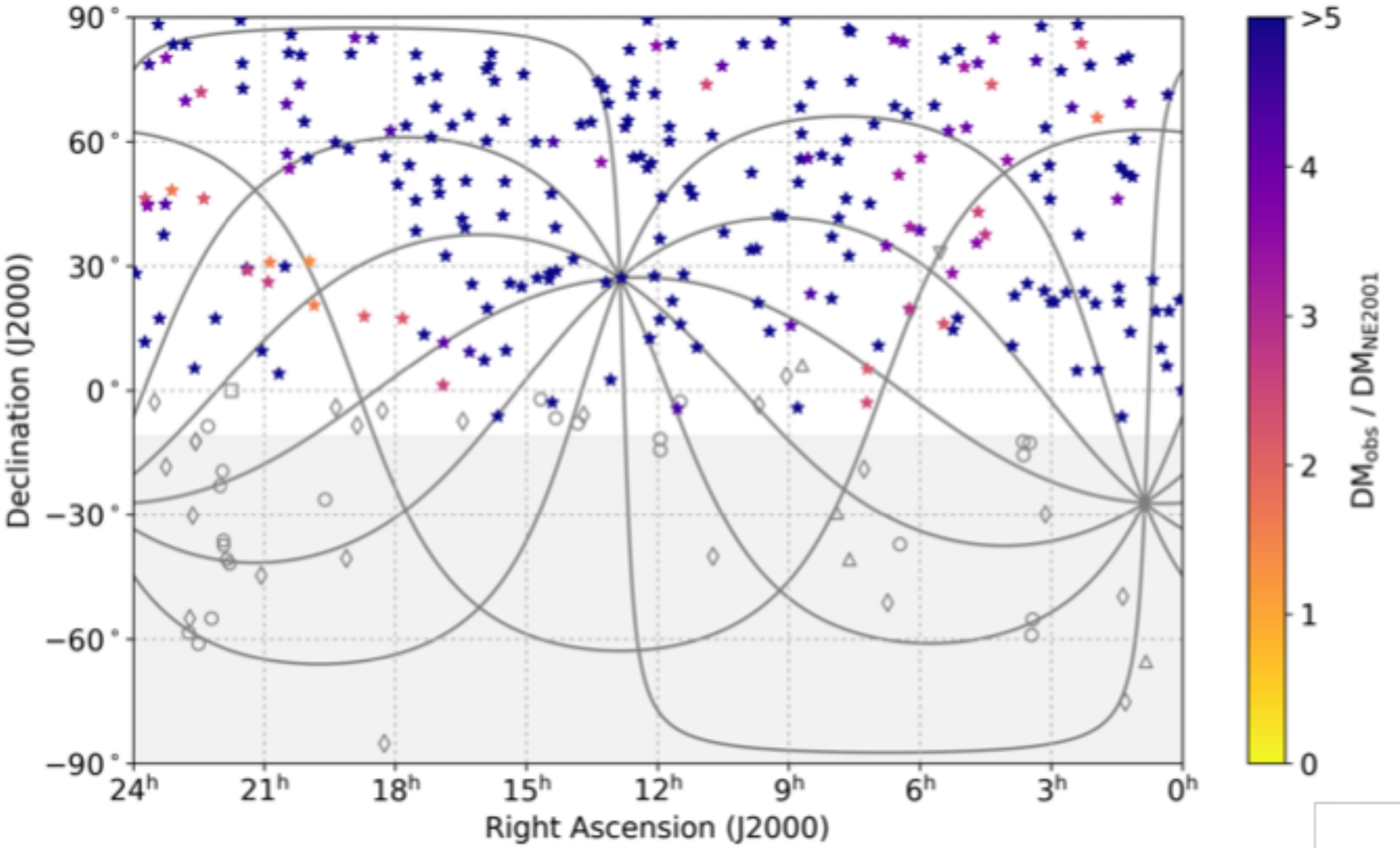
- **Early results from CHIME FRB Commissioning**
  (CHIME/FRB Collaboration, 2019, Nature):
  - 13 new FRBs
  - 1 new repeating FRB (with 6 bursts)

February 14 2019

250+ FRBs Discovered with CHIME

Sky distribution

Preliminary

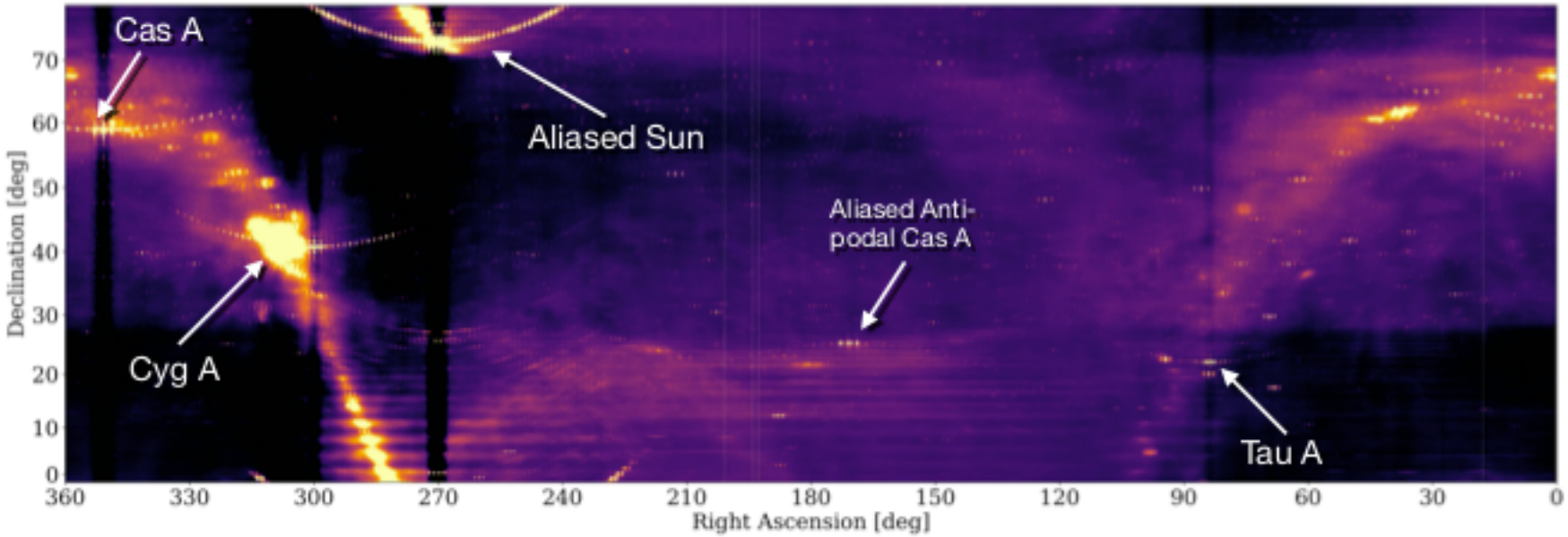


NB Not corrected for exposure!

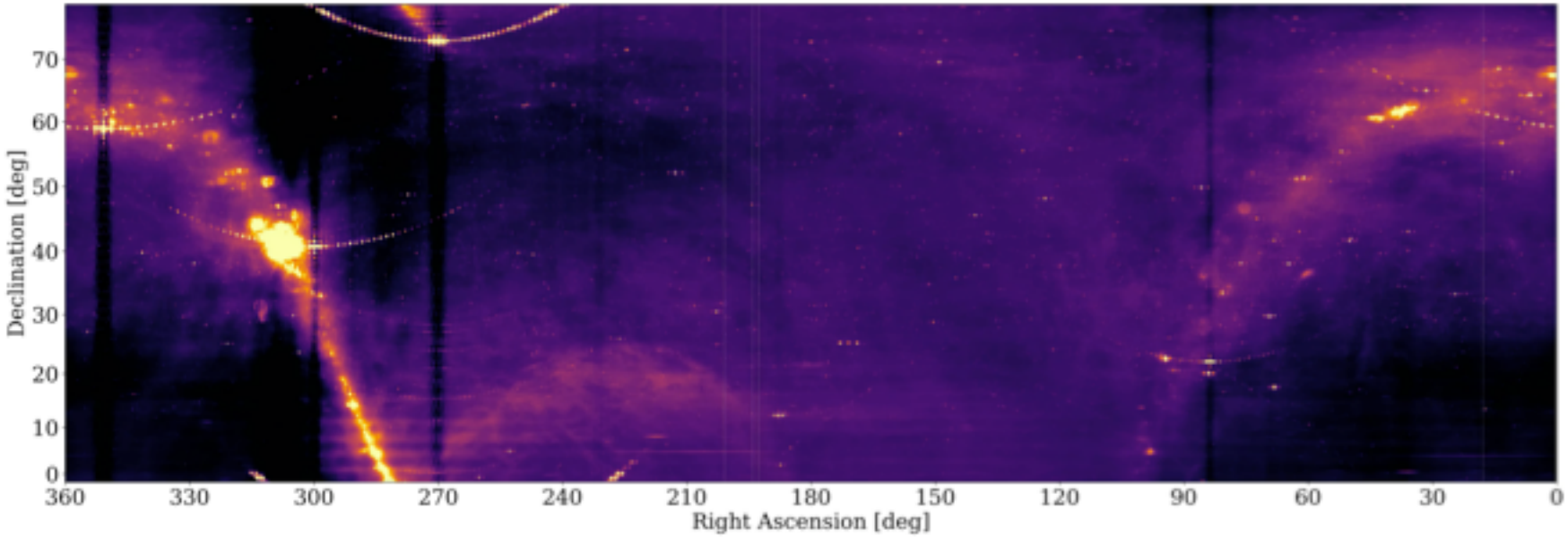
Ziggy Pleunis

Radio Sky as seen by CHIME

725.00 MHz, XX Pol

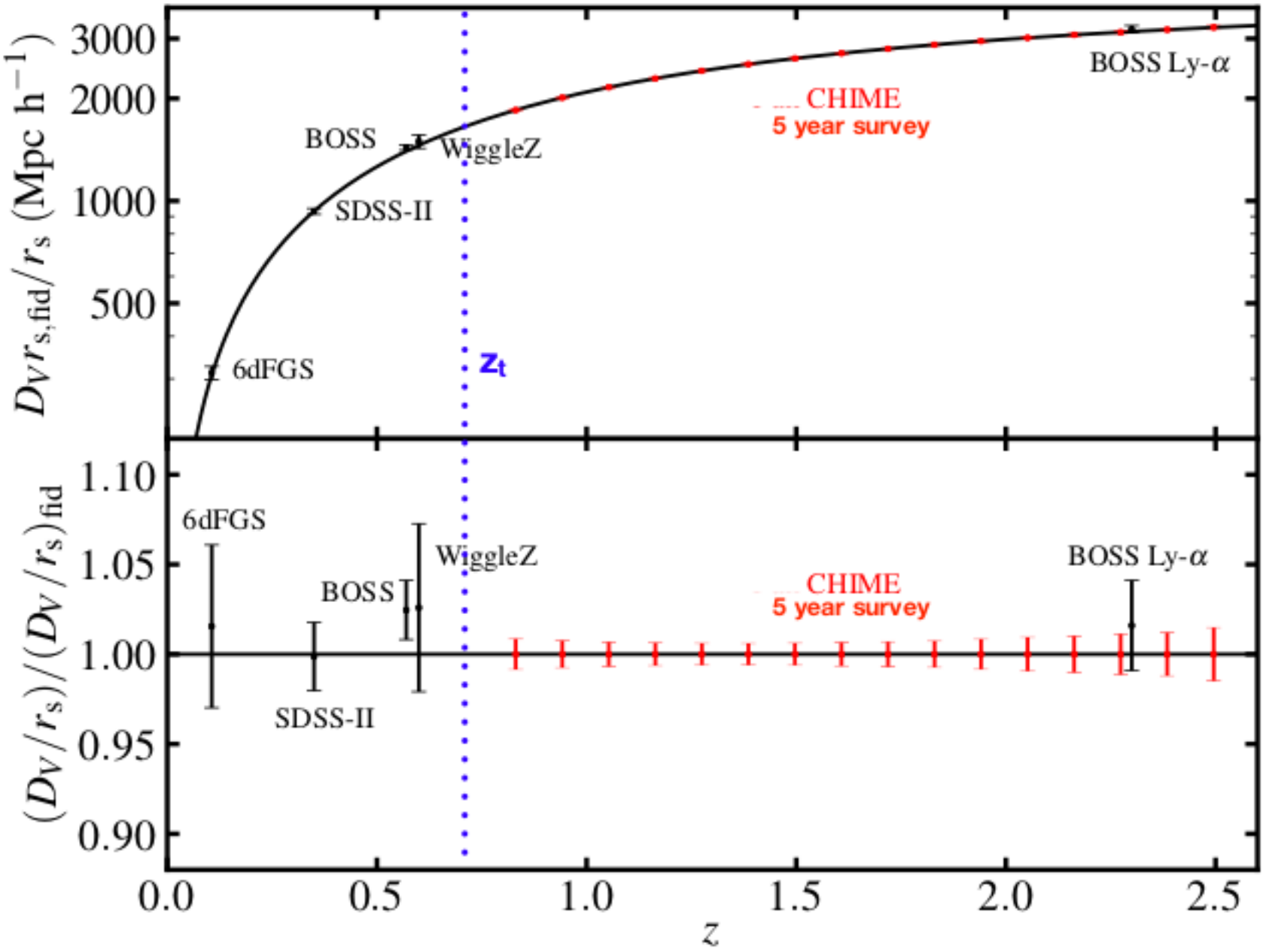


725.00 MHz, YY Pol

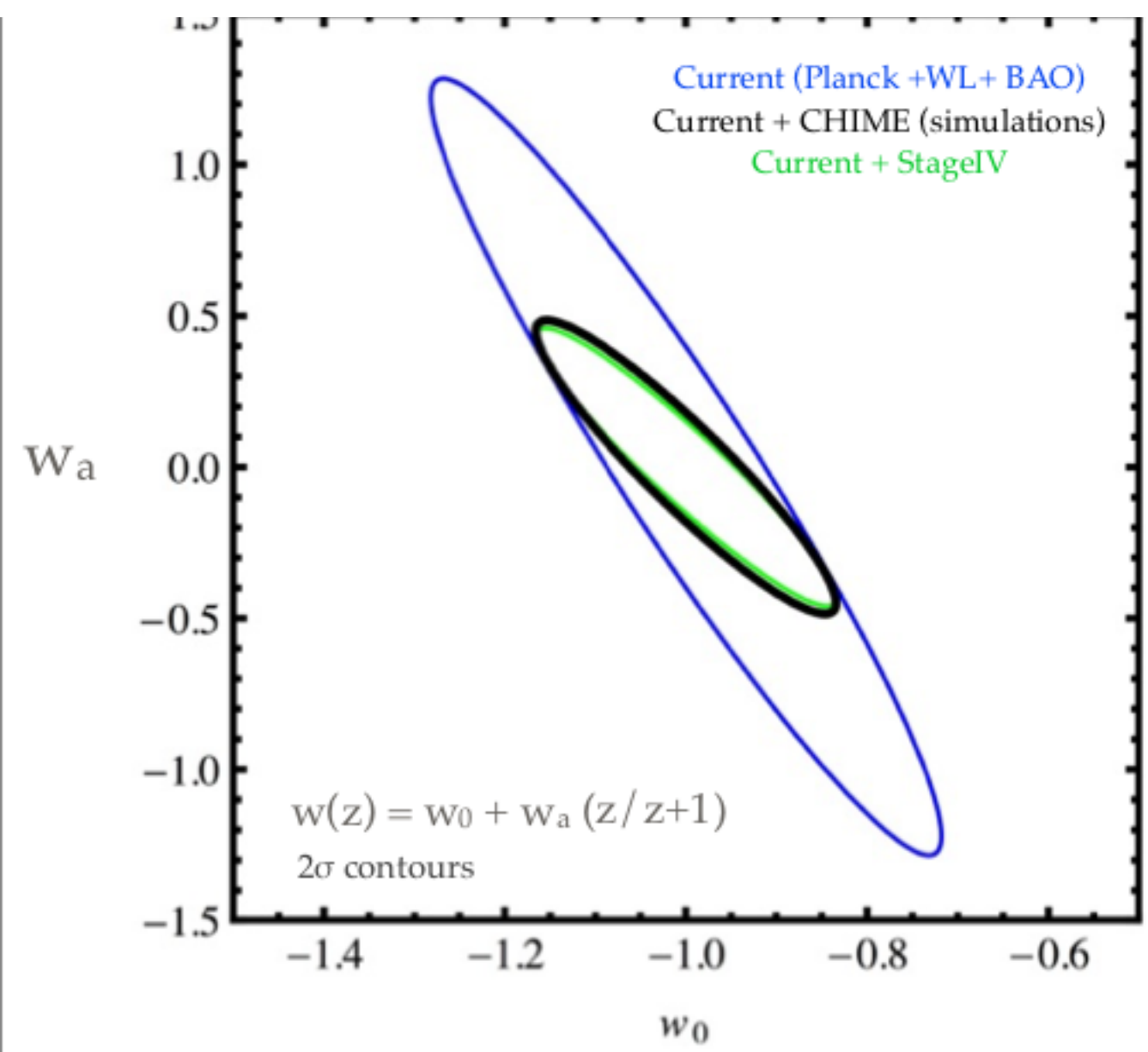


Cosmology Forecast

Figure courtesy of Kevin Bandura



Cosmology Forecast



Constraints on dark energy equation of state $w = p / \rho$ from 5 year survey competitive with DOE Stage IV experiments (e.g., DESI, Euclid)

Figure courtesy of Richard Shaw

Thank you!

Check out our website at: www.chime-experiment.ca