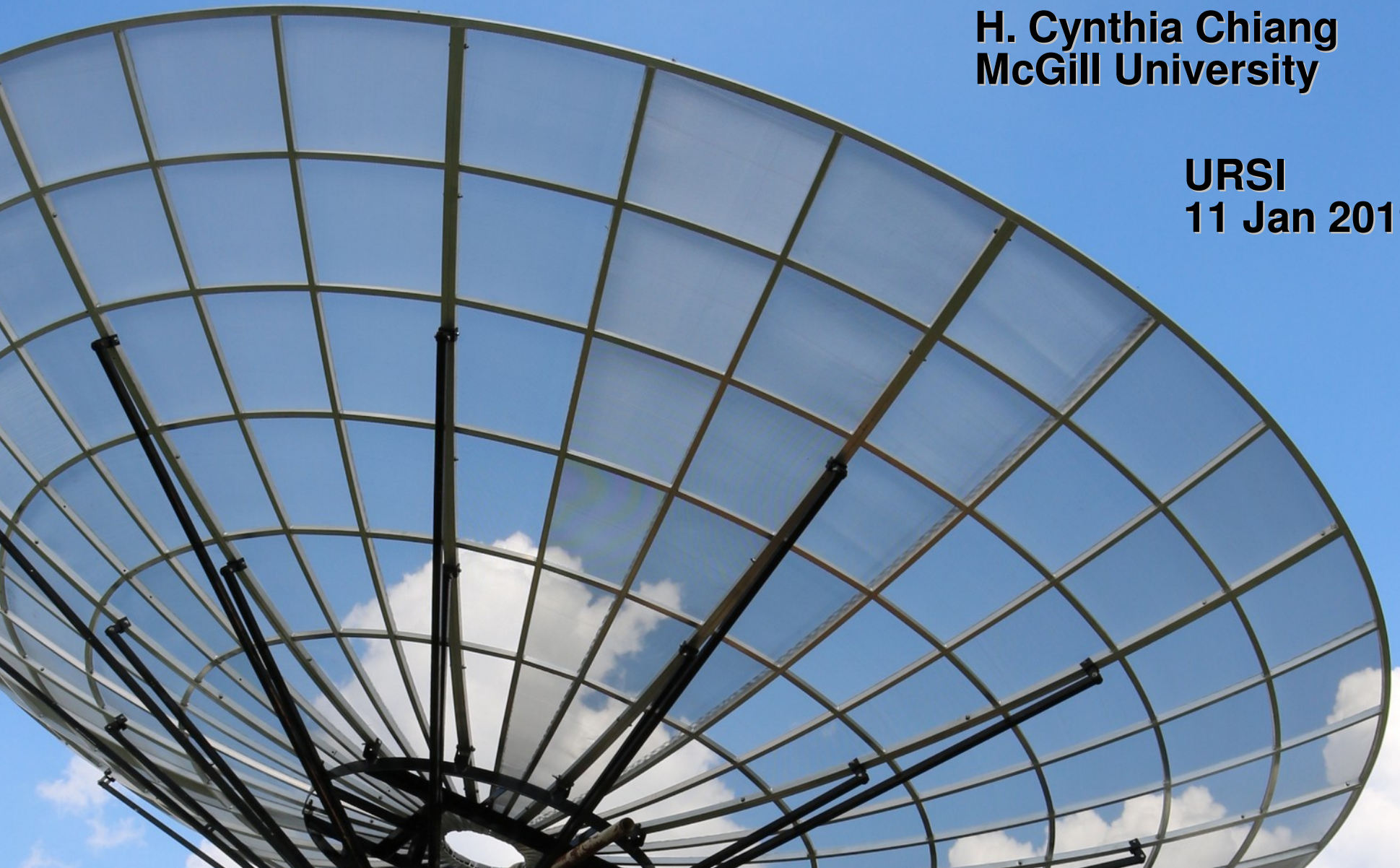
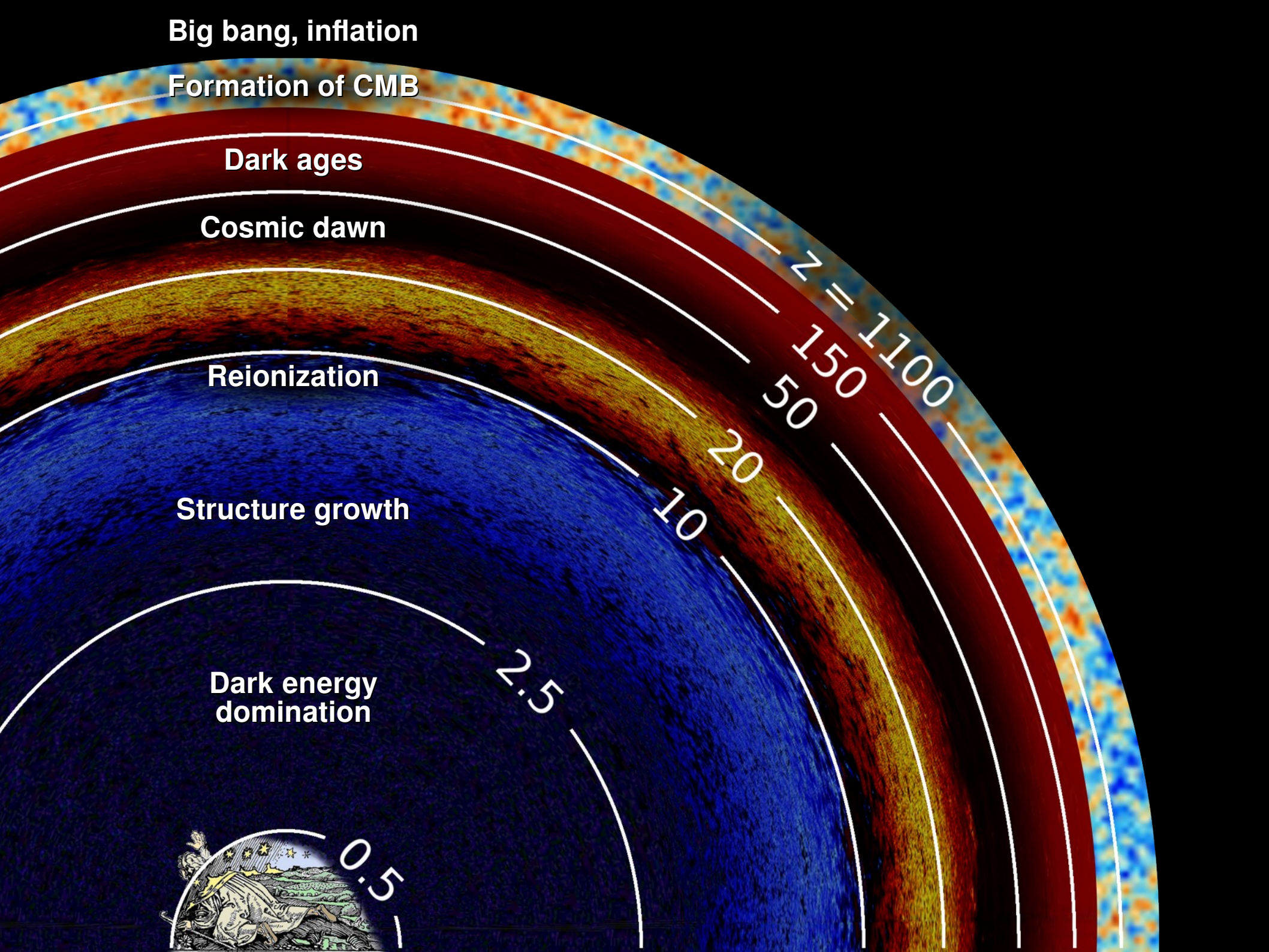
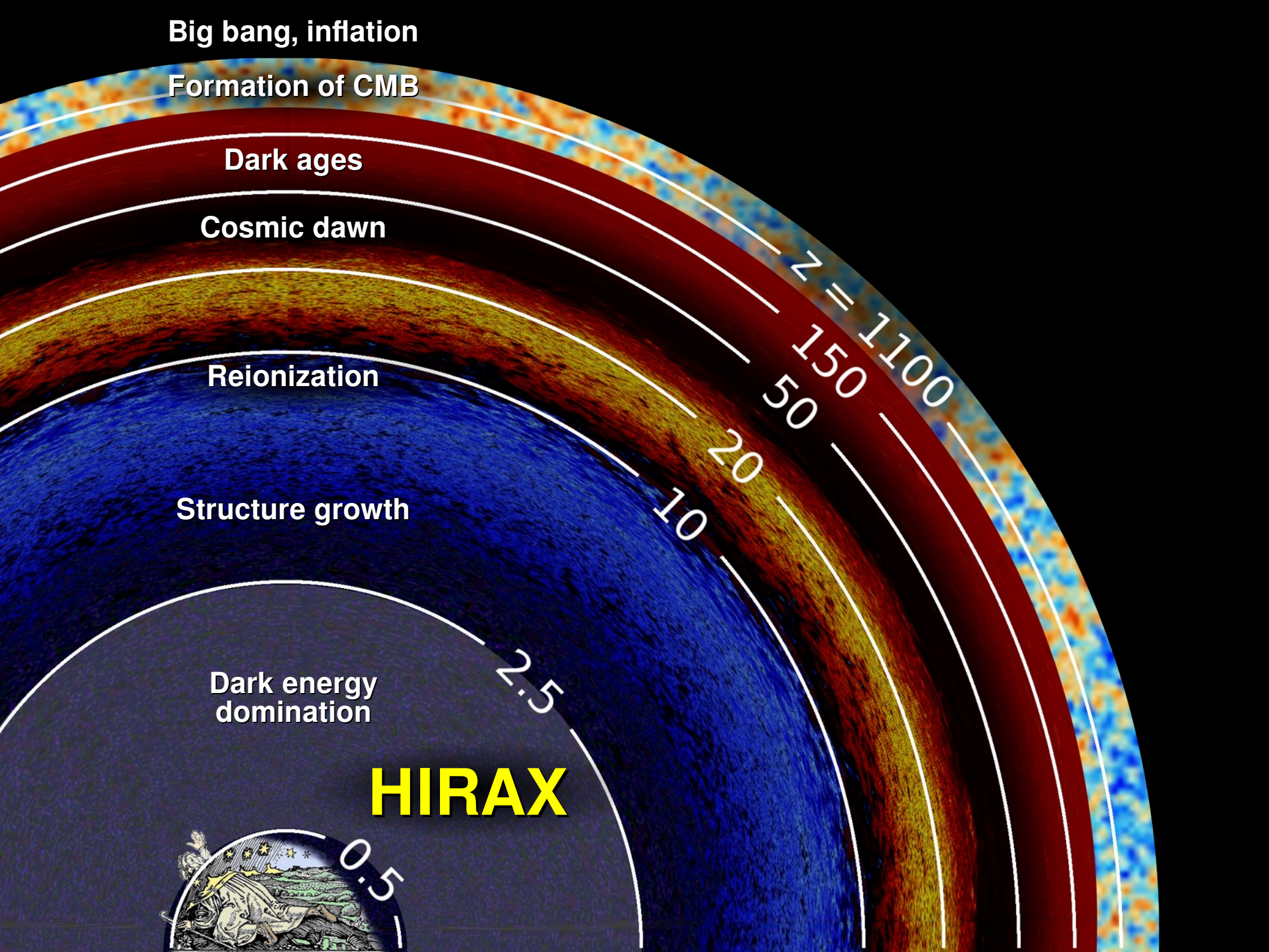
Mapping the universe's accelerated expansion with HIRAX



H. Cynthia Chiang
McGill University

URSI
11 Jan 2019


Big bang, inflation
Formation of CMB
Dark ages
Cosmic dawn
Reionization
Structure growth
Dark energy domination
z = 1100
150
50
20
10
2.5
0.5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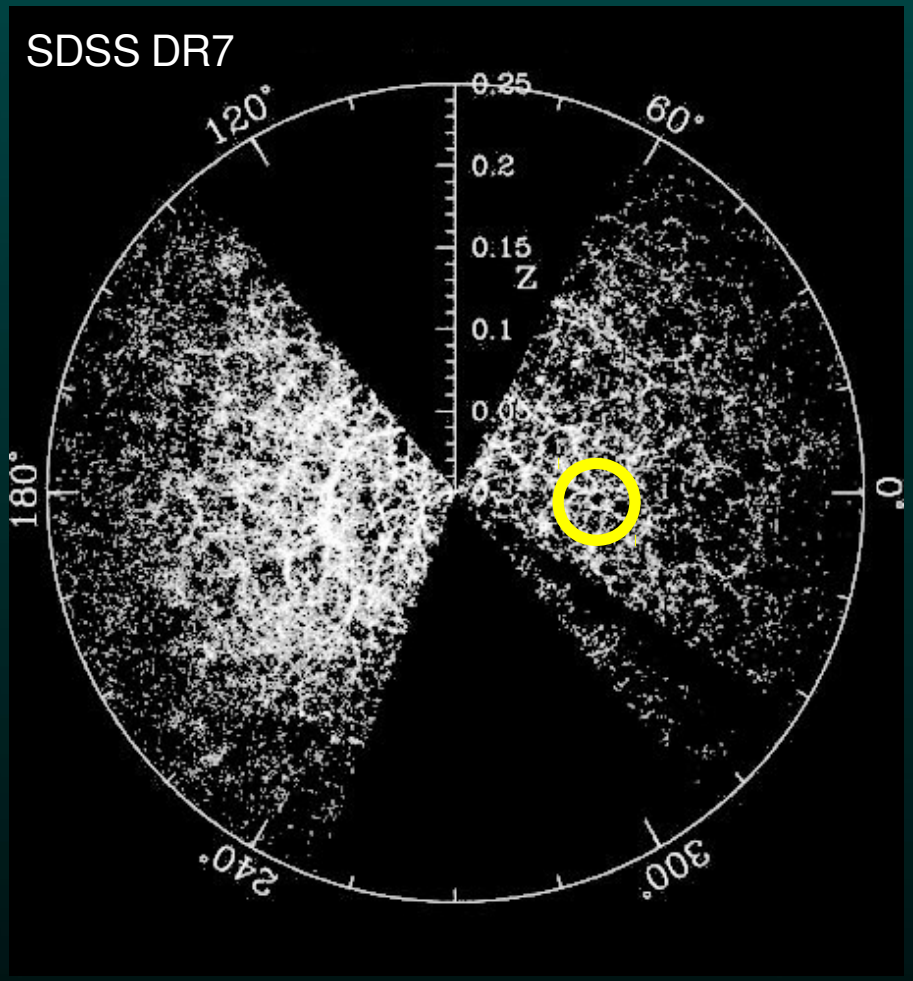
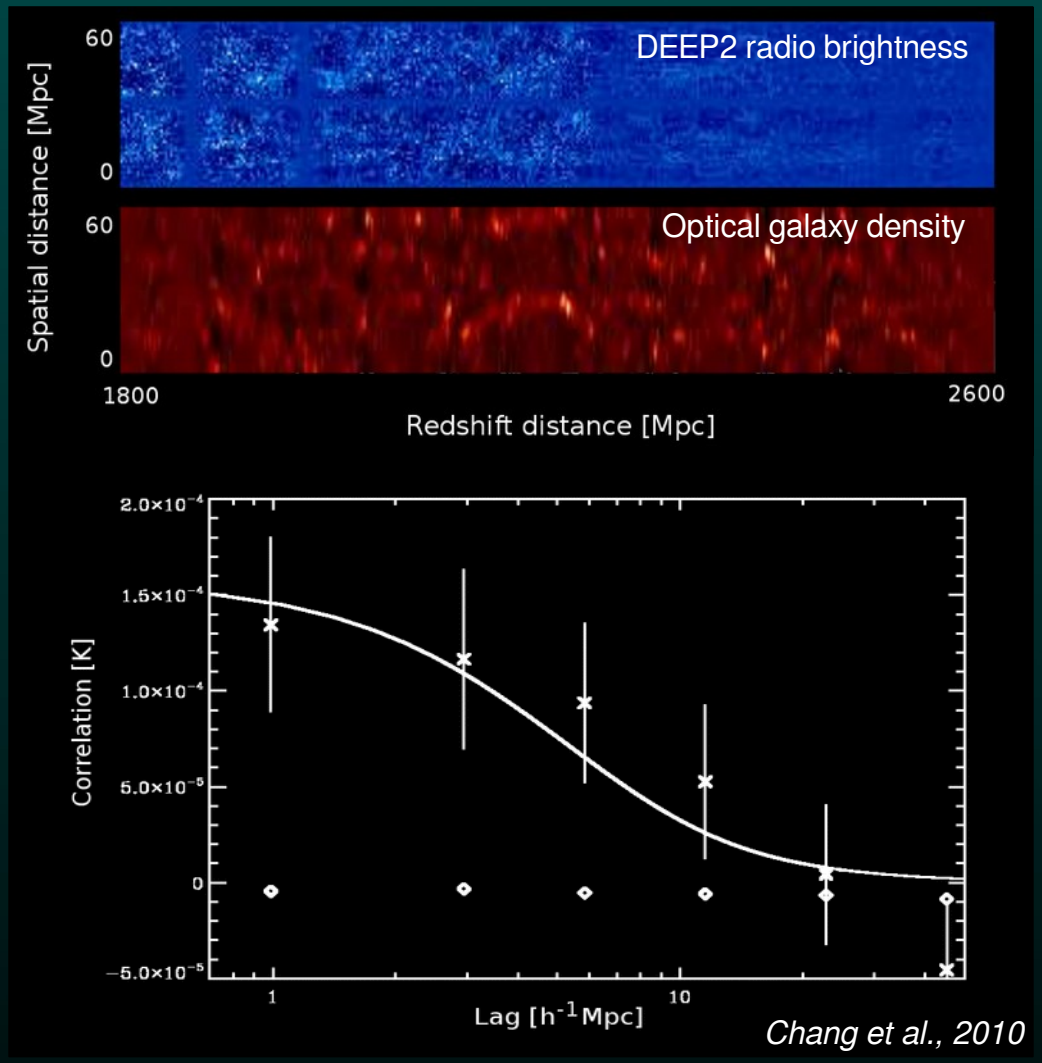
BAOs with hydrogen intensity mapping





We want large volumes (large sky, large *z* range) for precision cosmology

...but counting individual galaxies is hard, and getting to high redshifts is challenging

150 Mpc scale is big (degree scale)

Throw away resolution: use HI intensity mapping to measure matter distribution AND obtain redshift information.

Use BAO peak as a standard ruler to chart the universe's expansion history, probe dark energy.

Required specs for BAO intensity mapping

- Maximize sensitivity on scales of interest
  → Use compact array geometry
- Redshift range of interest: $0.8 < z < 2.5$ to capture dark energy domination at $z \sim 2$
  → Required frequencies: 400 – 800 MHz
- BAO 150 Mpc angular scale: 3 – 1.3 degrees at $0.8 < z < 2.5$
  → Required baseline lengths: 15 – 60 meters
- BAO scale along line of sight: 20 – 12 MHz at $0.8 < z < 2.5$
  → Required freq resolution: minimum ~100 channels, more for foregrounds and higher order peaks
- BAO signal level: ~0.1 mK
  → Low system temperature, large collecting area

The Hydrogen Intensity and Real-time Analysis eXperiment

Science goals:

Measure baryon acoustic oscillations with HI intensity mapping

Characterize dark energy

Radio transient searches

Pulsar searches

Neutral hydrogen absorbers

Diffuse polarization of the Galaxy

Instrumental approach:

1024 close-packed 6-m dishes

Dishes are stationary but can be tilted

Operating frequency: 400 – 800 MHz, equivalent redshift = 0.8 – 2.5

Working closely with CHIME: channelize with FPGA ICE boards, correlation with GPUs

Location: Karoo, near SKA site

The acronym:

Rock hyrax / dassie

HIRAX

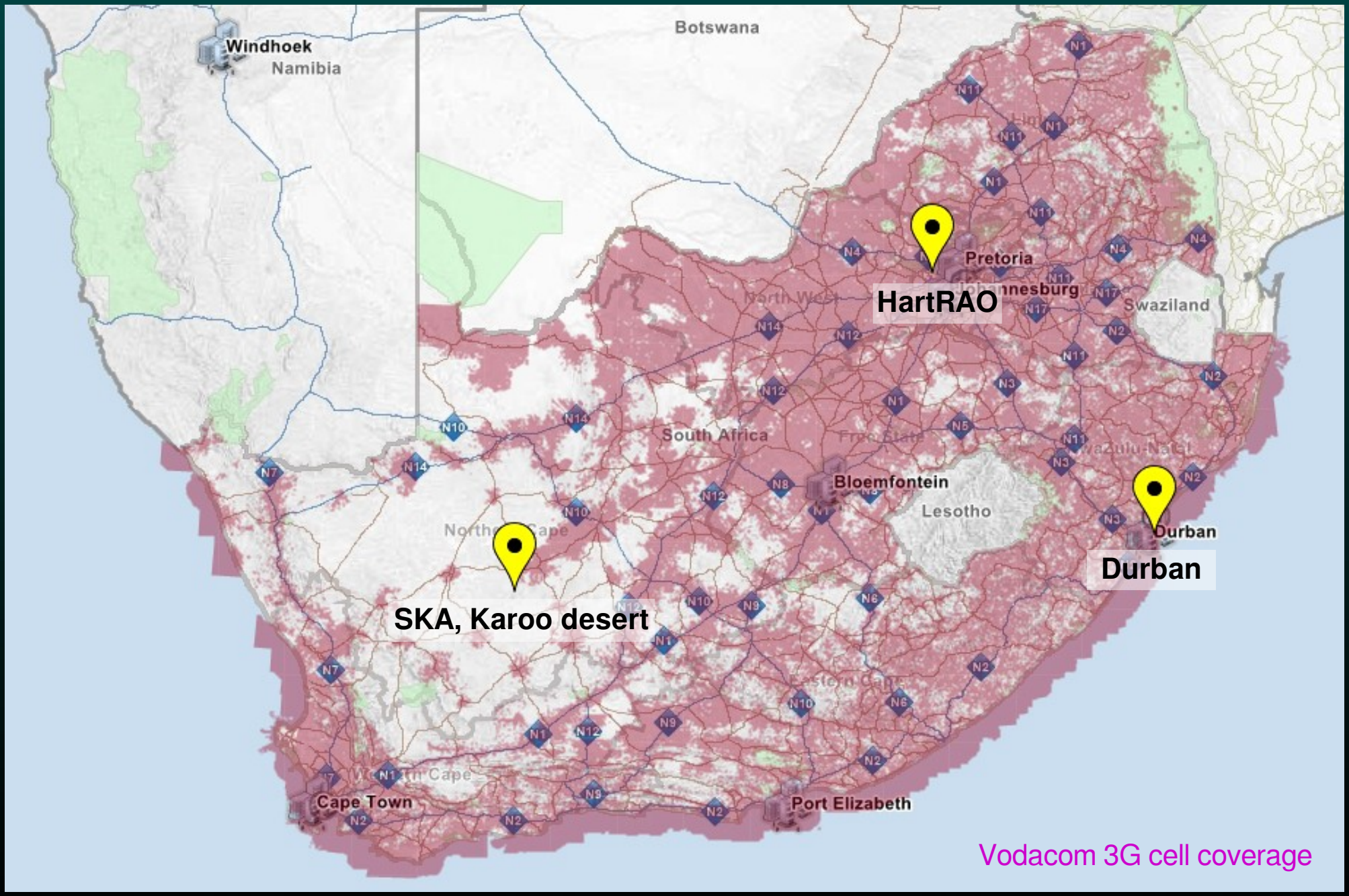
http://www.acru.ukzn.ac.za/~hirax

Complementarity with CHIME

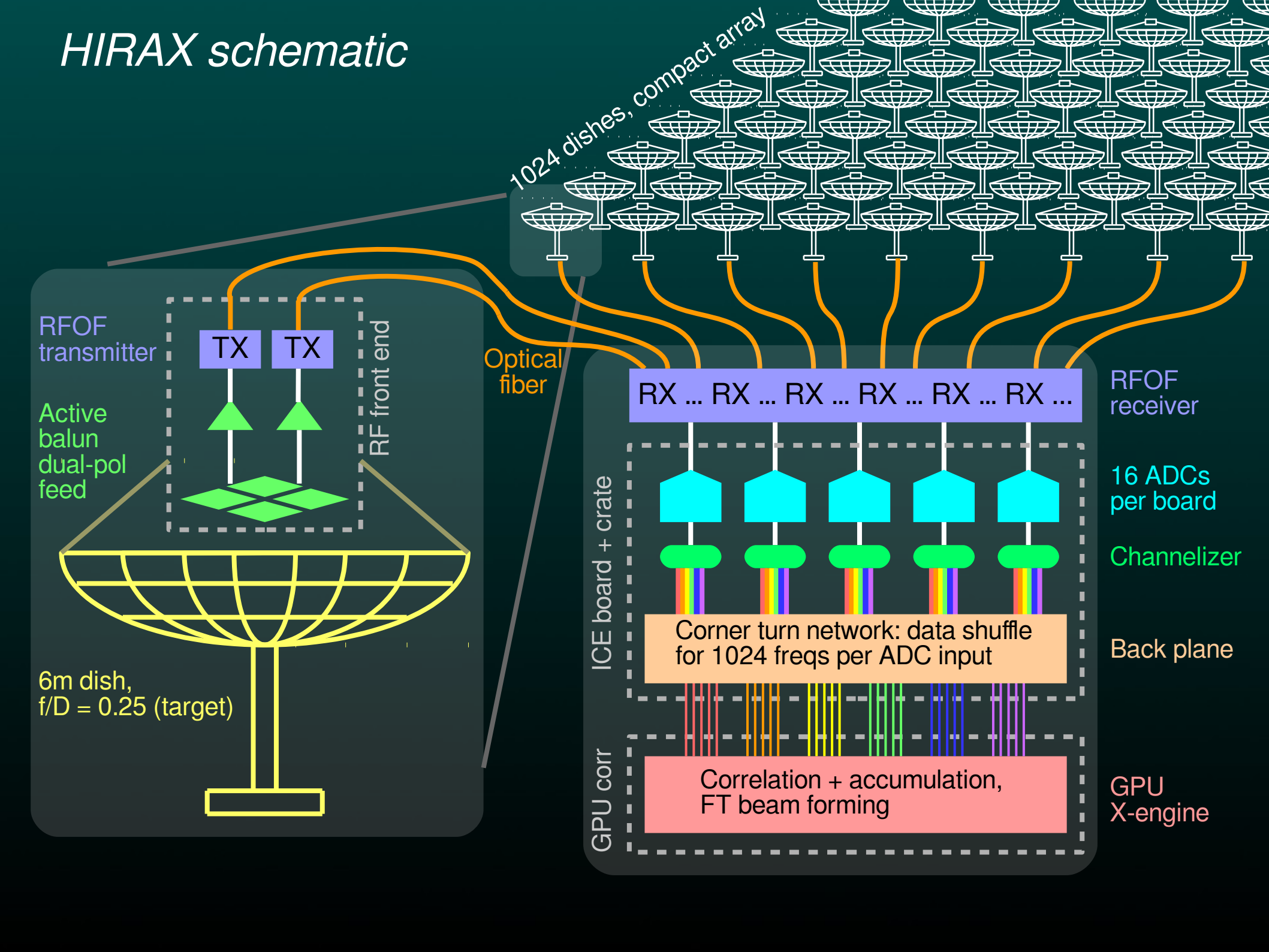
	CHIME	HIRAX
Site	DRAO, Canada	Karoo (lower RFI, no snow)
Telescope	Cylinder array	Dish array (different systematics)
Field of view	100° NS, 1°– 2° EW	5° – 10° deg
Beam size	0.23° – 0.53°	0.1° – 0.2°
Collecting area	8000 m^2	28,000 m^2
Sky coverage	North	South

Optical surveys in the south, esp. LSST: cross-correlate for foreground mitigation and other science. More pulsars in the south.

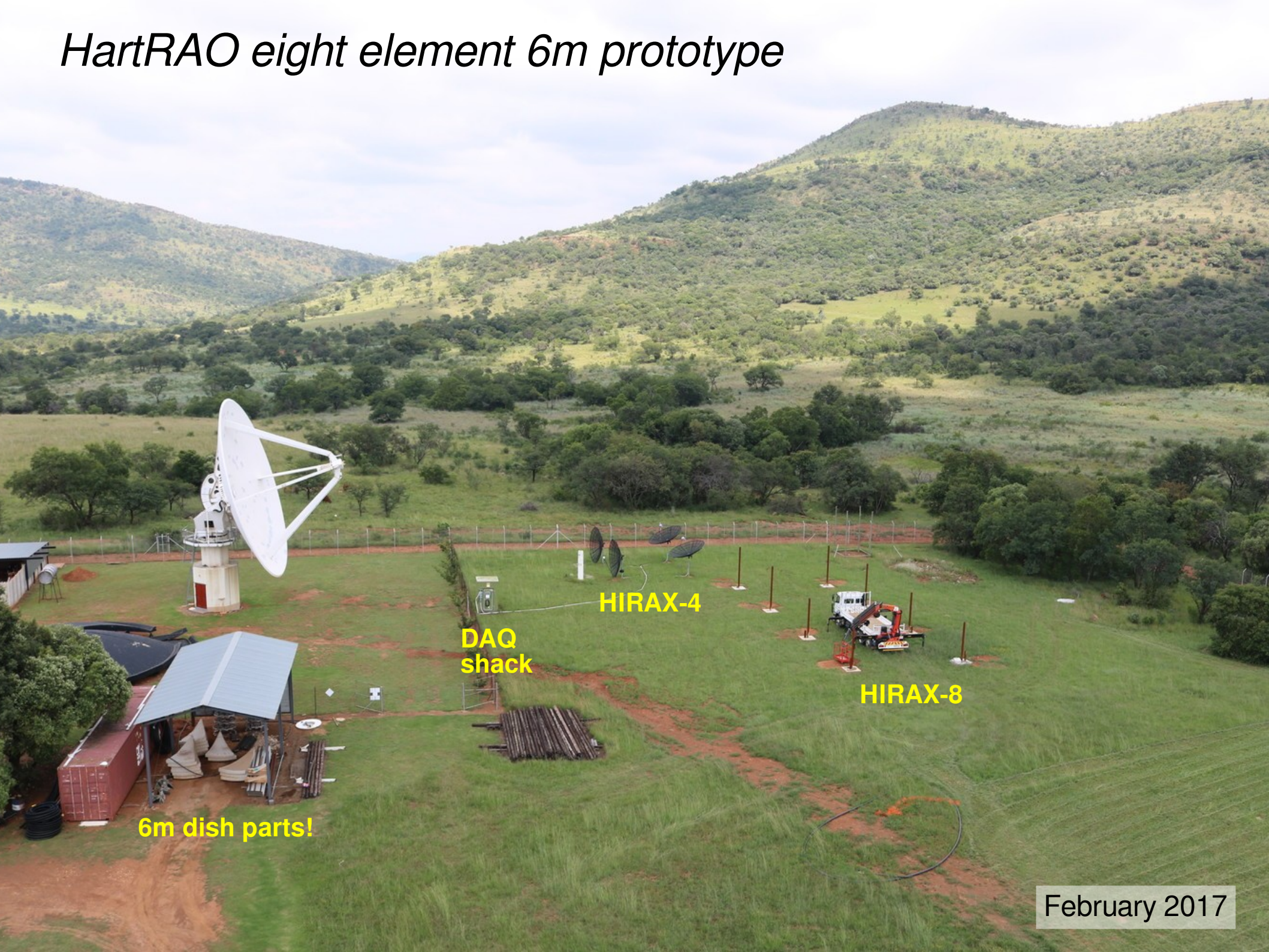
Where we are in South Africa



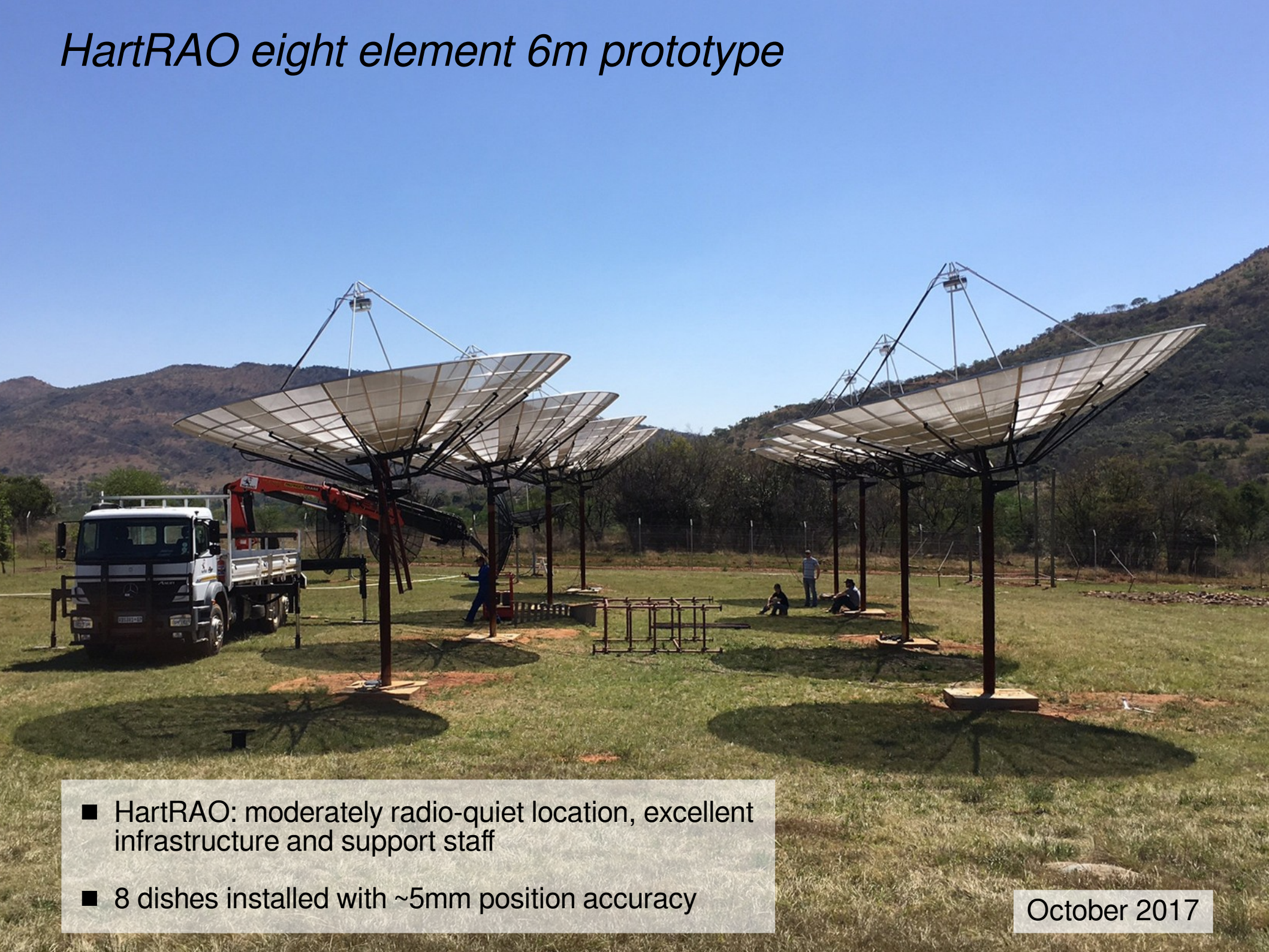
HIRAX schematic



HartRAO eight element 6m prototype



HartRAO eight element 6m prototype



- HartRAO: moderately radio-quiet location, excellent infrastructure and support staff
- 8 dishes installed with ~5mm position accuracy

October 2017

HIRAX-8 commissioning in progress

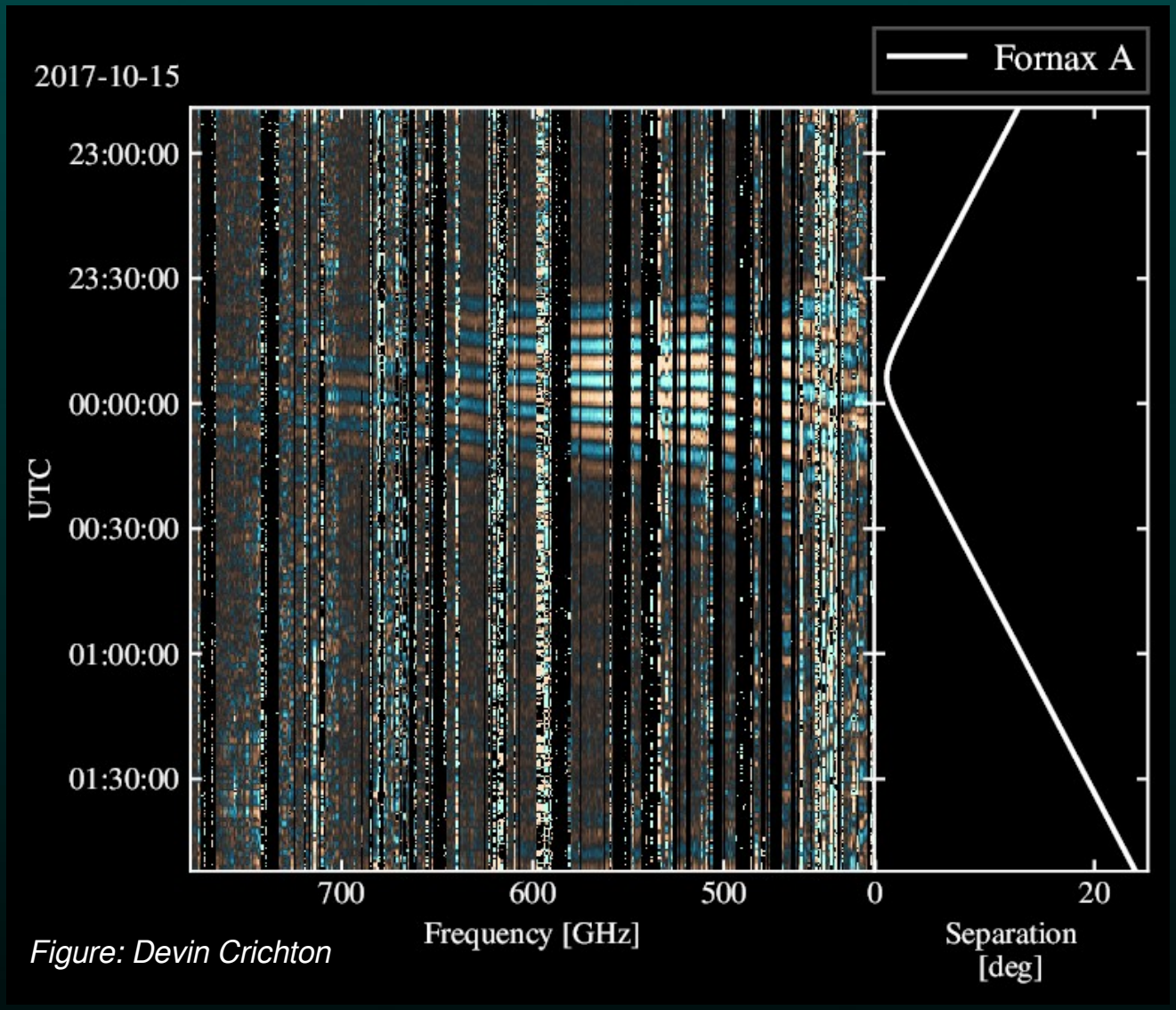


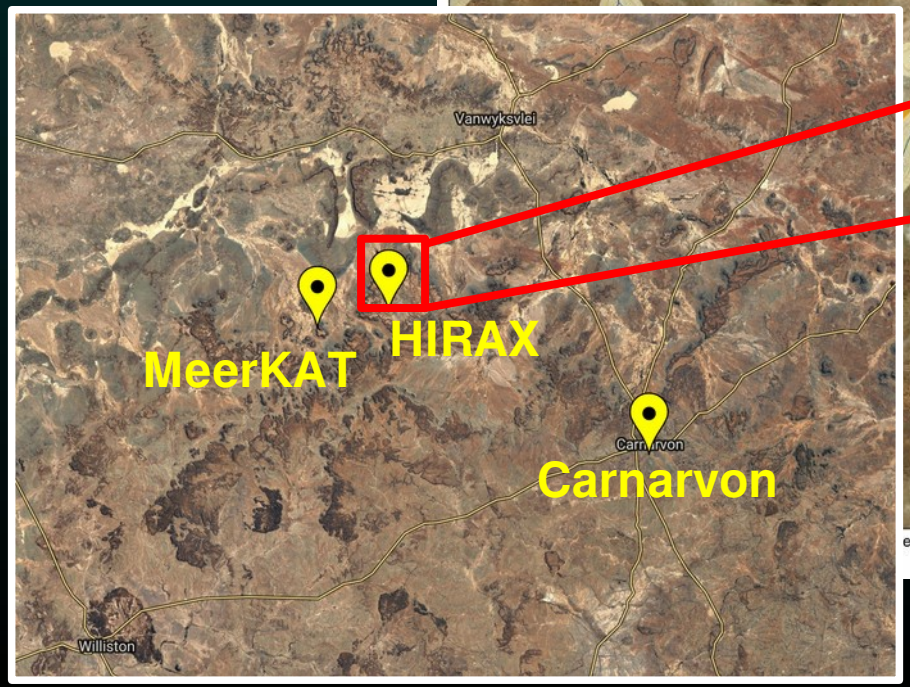
Figure: Devin Crichton

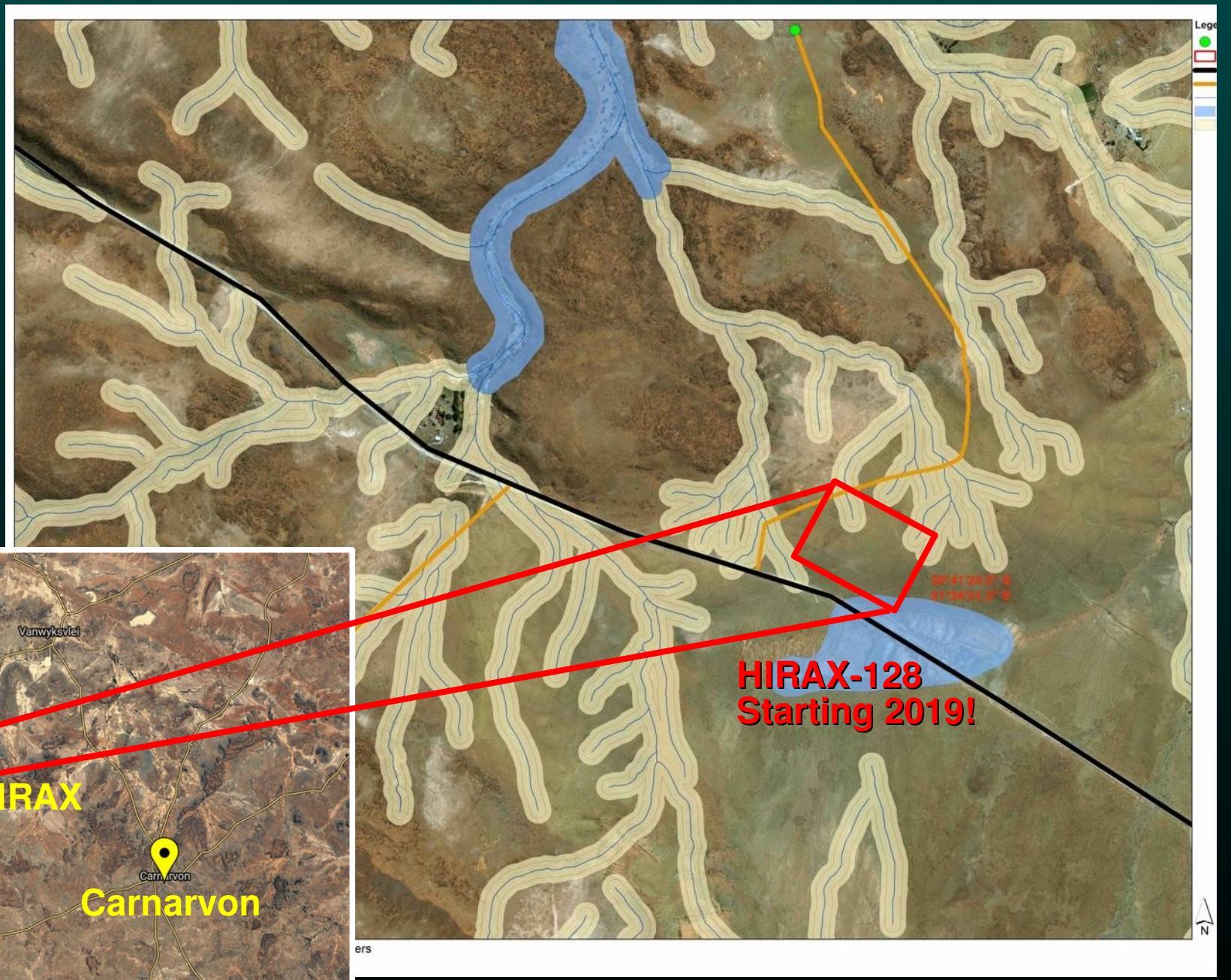
- All dishes instrumented, commissioning and troubleshooting in progress
- First tests of active-balun feeds, RFOF modules, ICE board, GPU correlator
- We've seen fringes! But lots of work ahead...
- Current plan: further subsystem tests at HartRAO, including 2 new dish options

New dish options

- Monolithic fiberglass dish concept developed at NRC in Canada, to be fabricated by MMS in South Africa
  - Material cost: ~$1500 each
  - 3m mold RMS: 0.3 mm
  - 3m dish RMS: 0.4 mm
  - Mold-to-part error ratio: 1.4
- Laser cut metal dish concept developed at Rebcon in South Africa
- Two of each dish types to be tested at HartRAO, early 2019

Next phase: 128 element array in the Karoo





Swartfontein, Karoo desert
30°41′18.73″S 21°34′07.98″E

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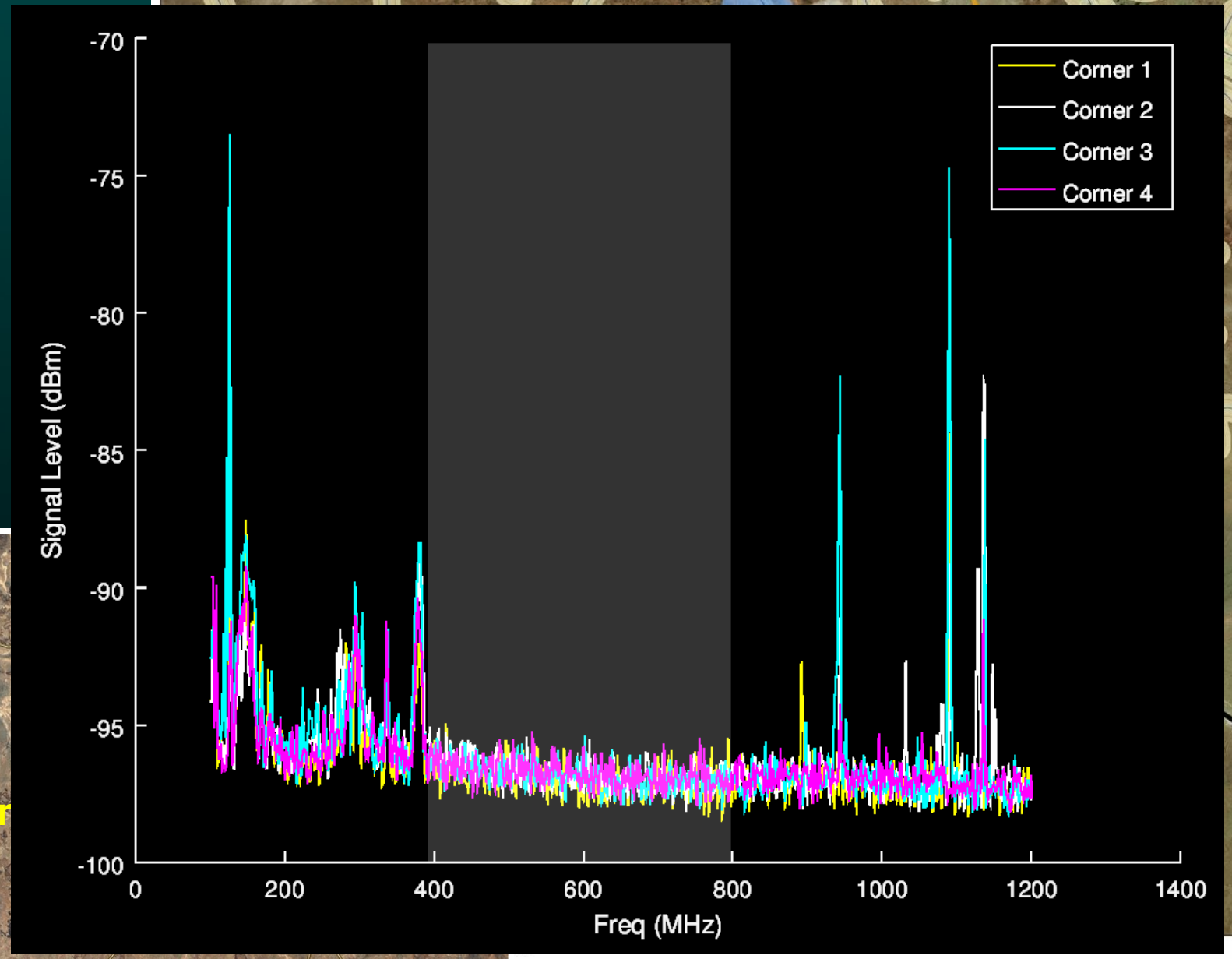
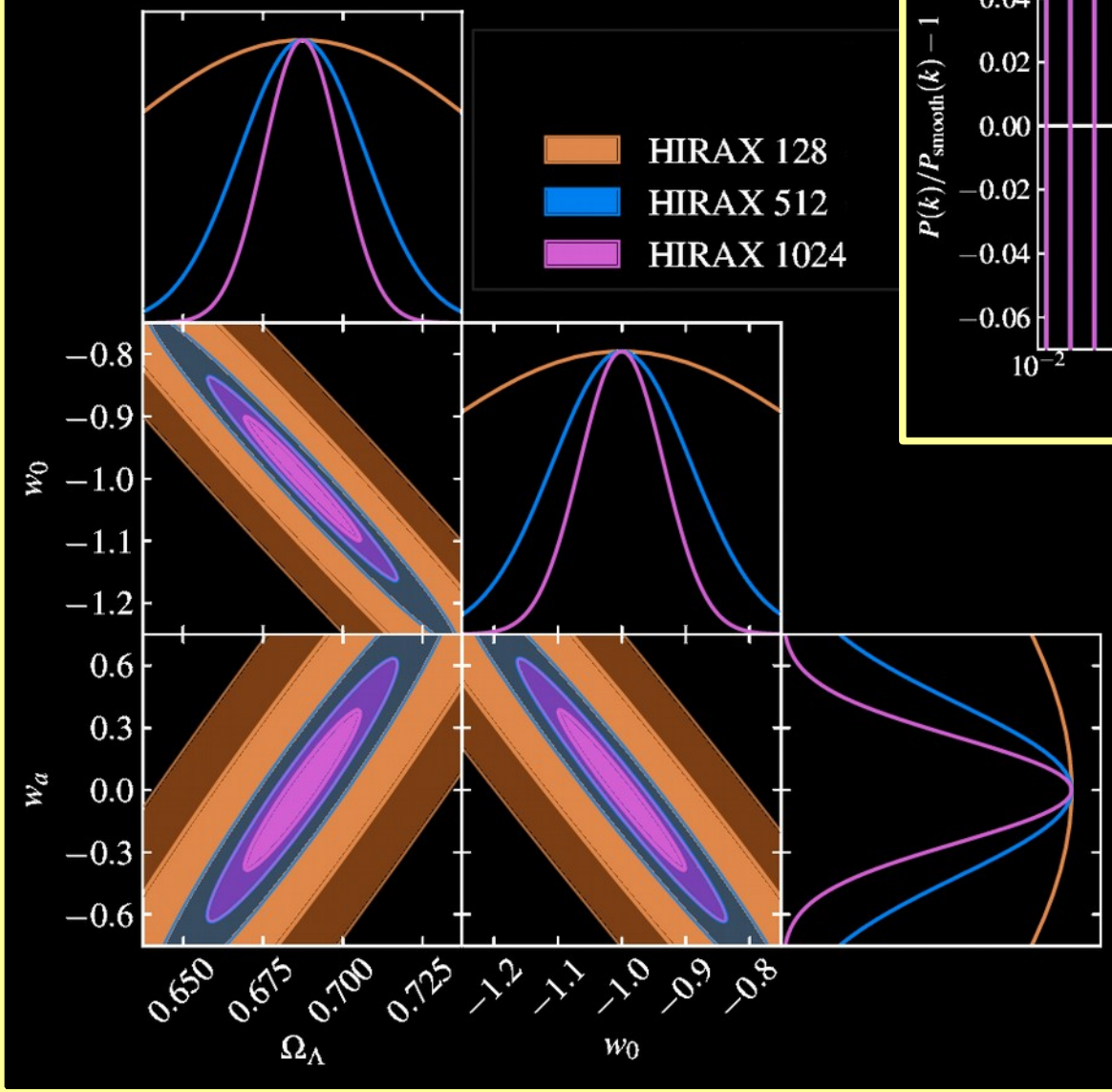


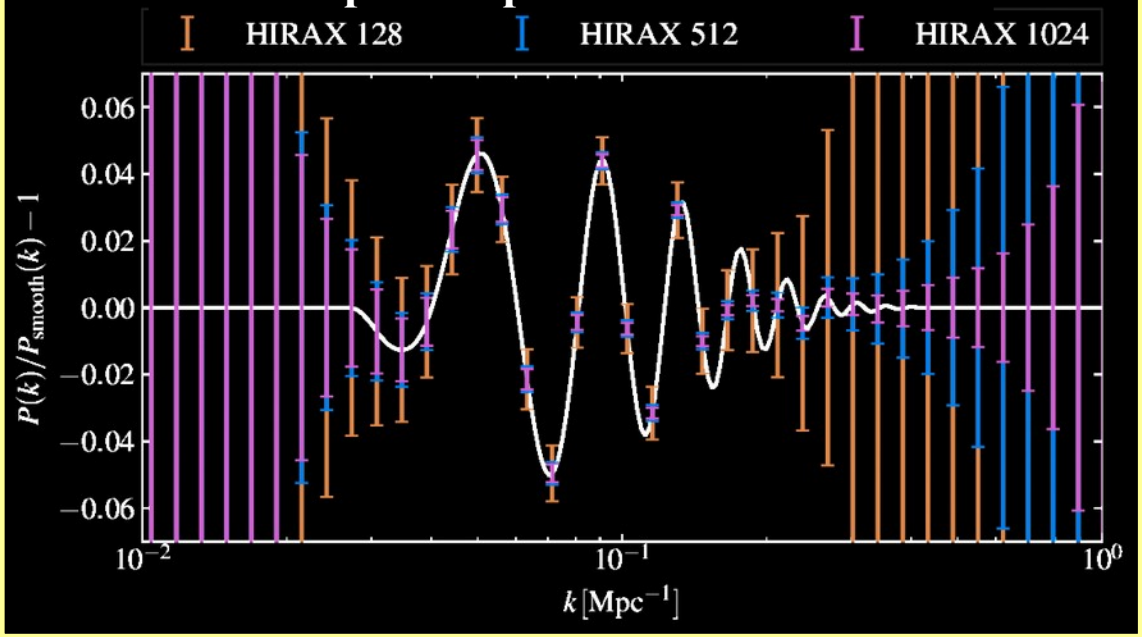
Swartfontein, Karoo desert
30°41′18.73″S 21°34′07.98″E

Parameter forecasts

Dark energy constraints
4 year survey (50% eff.), 15,000 deg^2



BAO power spectrum constraints



Dark energy figure of merit:

HIRAX 128 : 9

HIRAX 512 : 103

HIRAX 1024 : 285

Analysis by
Devin Crichton

Summary & future prospects

- HIRAX will do hydrogen intensity mapping to study BAOs and the universe's expansion history at $0.8 < z < 2.5$
- Eight element prototype is being commissioned at HartRAO, have obtained first fringes
- Site agreement for the Karoo finalized in August 2018
- Next phase: 128 elements in the Karoo, aiming for first installs in 2019
- Outrigger stations for FRB localization: site testing has begun