The Hydrogen Intensity and Real-time Analysis eXperiment: Mapping the Southern Sky (in 21cm emission)

Kavilan Moodley (UKZN) for the HIRAX Collaboration

Cosmic Visions Dark Energy Workshop, LBNL

14 November 2017

Overview

- Multi-institutional international collaboration
- Current flagship project funding (~$1.5M) from UKZN and South African NRF/DST - (more than) sufficient for 128 elements
- Applying for further NRF funding to build up to 512 elements
- Goal: build 1024 6m dishes operating at 400-800 MHz, nominal 4 year survey
- To be sited in the Karoo Radio Astronomy Reserve in SA

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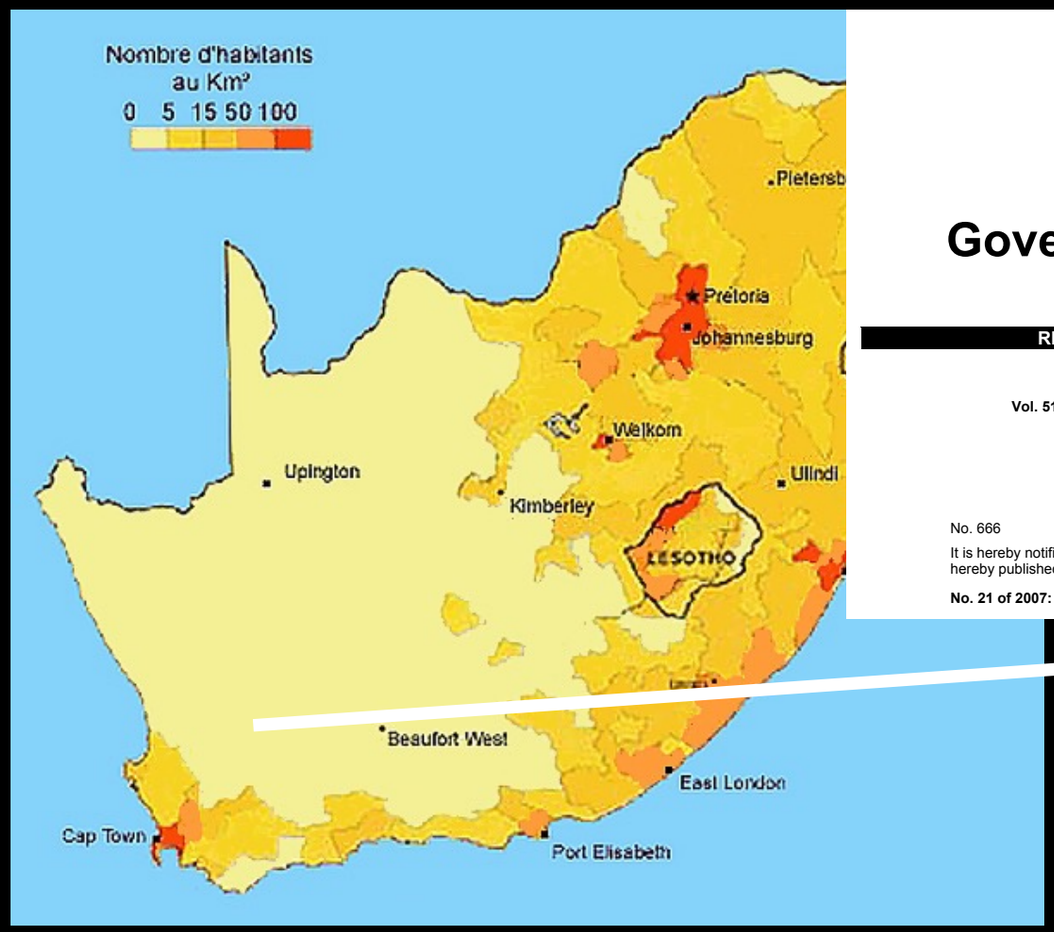
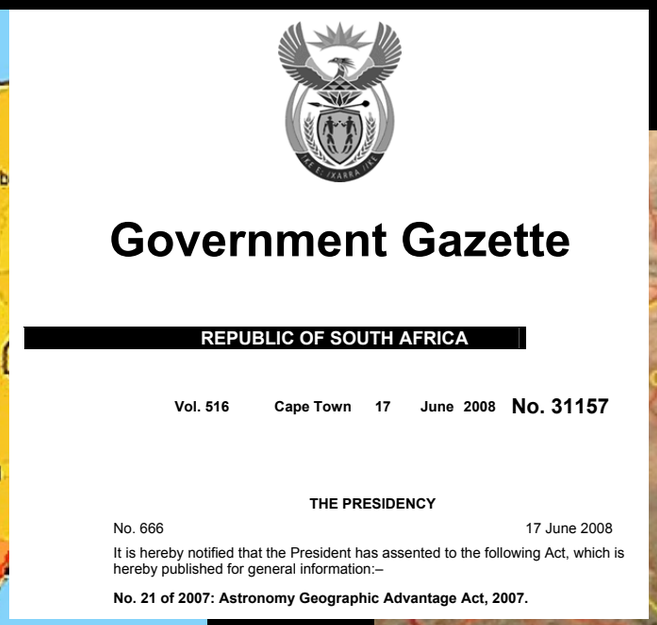
Karoo Astronomy Reserve





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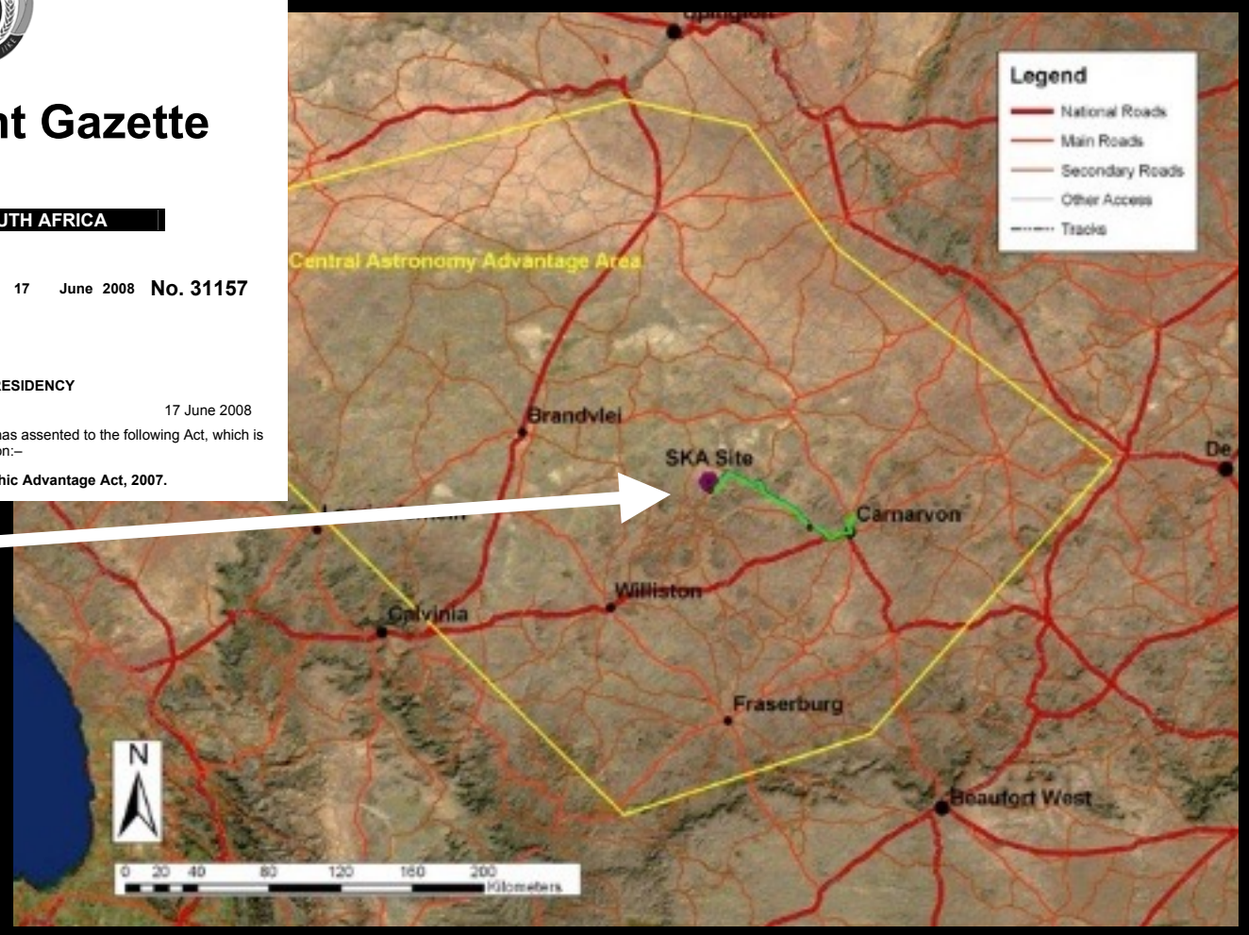
THE PRESIDENCY

No. 666 17 June 2008

It is hereby notified that the President has assented to the following Act, which is hereby published for general information:–

No. 21 of 2007: Astronomy Geographic Advantage Act, 2007.



- Karoo astronomy reserve protected by Astronomy Geographic Advantage Act.
- Investment in site infrastructure for MeerKAT and SKA - roads, power, data line.

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Site

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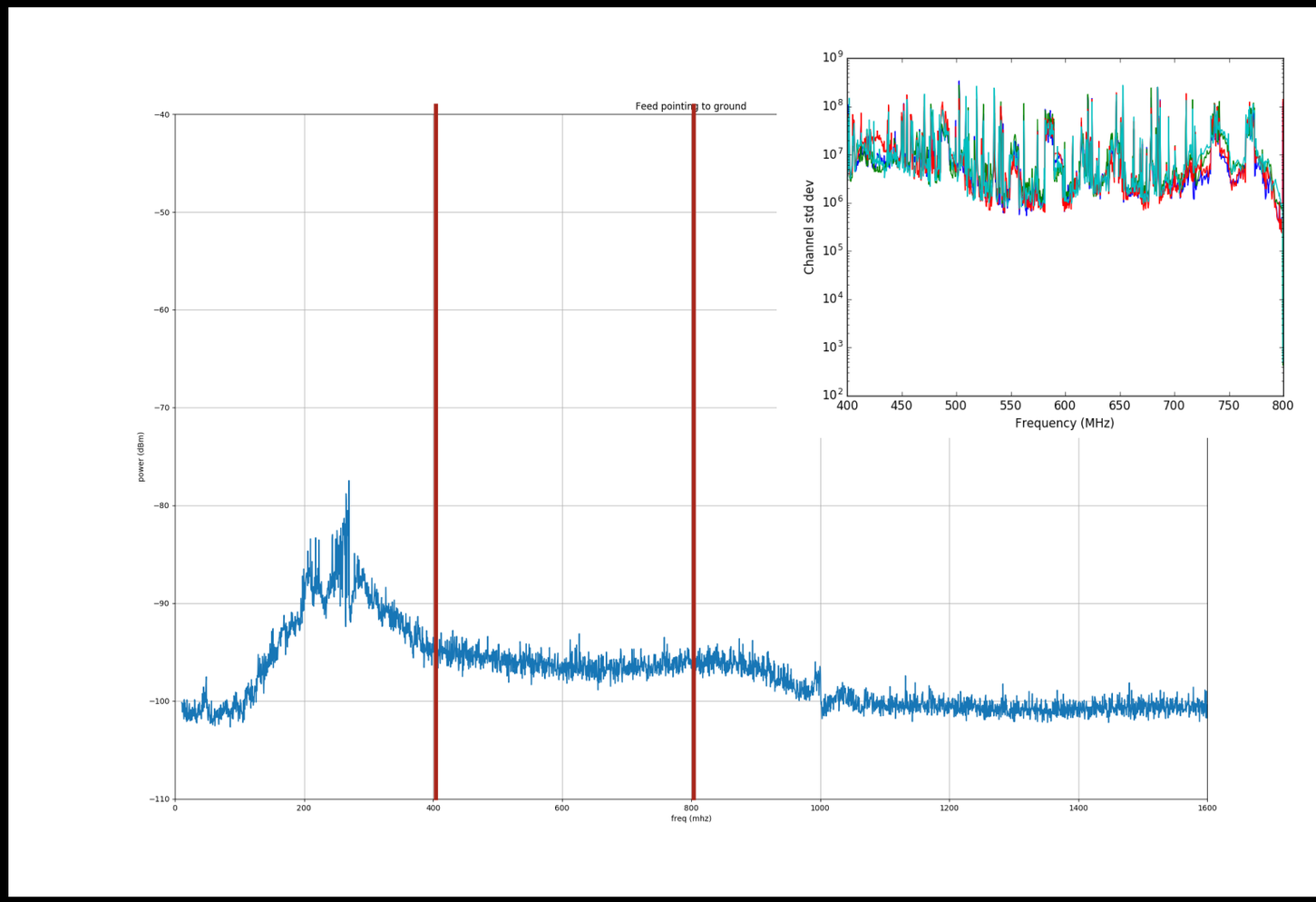
Site RFI

Jeff Peterson at HIRAX site in Karoo. Conditions look spectacular! (Inset - interference at HartRAO)



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Telescope

Frequency Range	400–800 MHz
Frequency Resolution	390 kHz, 1024 channels
Dish size	6 m diameter, f/D=0.25
Interferometric layout	32×32 square grid, 7 m spacing
Field of View	15 deg^2–56 deg^2
Resolution	∼5’–10’
Beam Crossing Time	17–32 minutes
System Temperature	50 K

Newburgh et al (1607.02059)

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Design Plan

- 1024 close-packed 6m dishes.
- Operate between 400-800 MHz, 1000 channels
- Channelizing on FPGA ICE boards (Matt Dobbs, McGill)
- Correlation on GPUs (Keith Vanderlinde, Toronto).
- Dishes tilt N/S: when “deep enough” on a strip, tilt over to increase f_{sky}. Get to $f_{sky} \sim 0.35$ in 4 years.
- Beamform in correlator for FRBs; small subset of beams (~20) to external processing for pulsar search + monitoring, HI absorbers…

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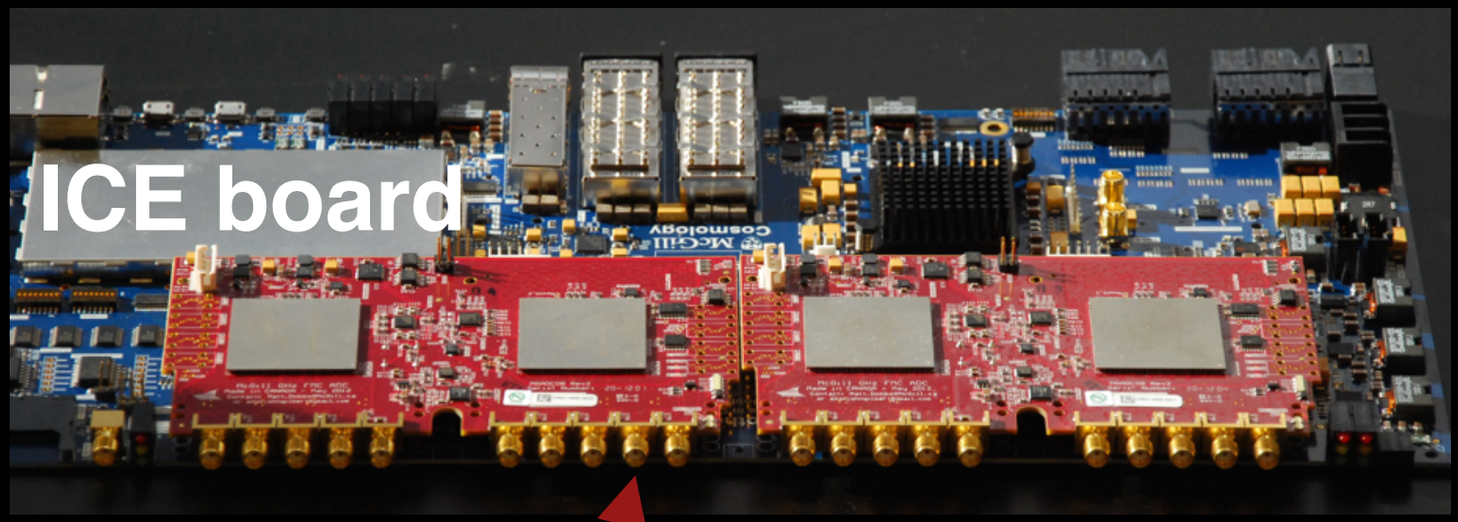
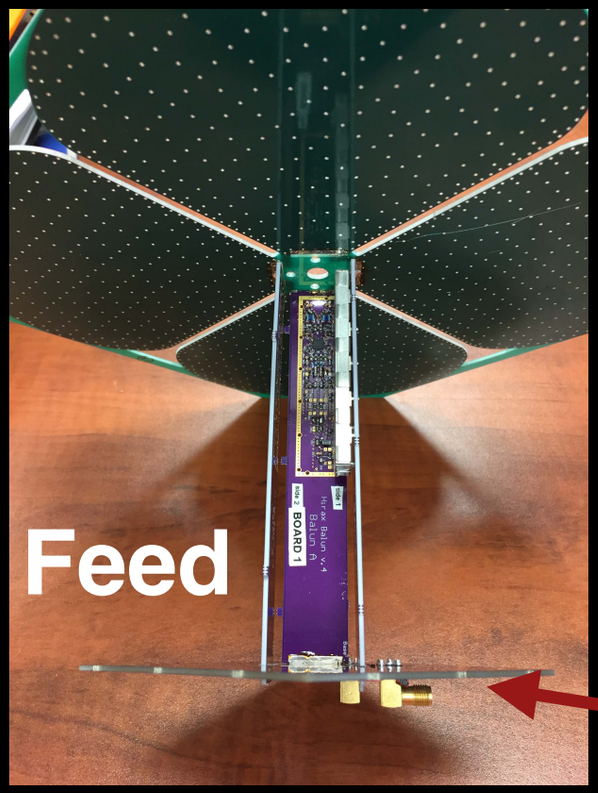
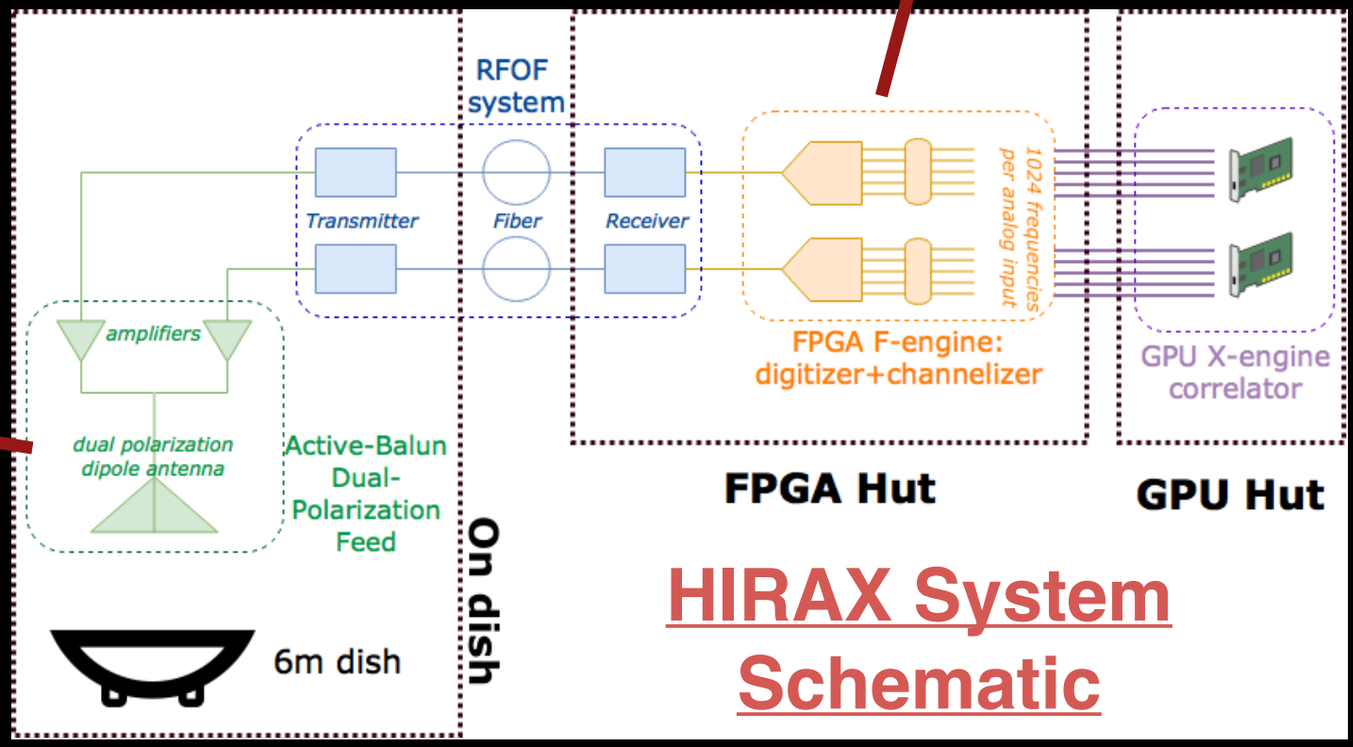
Instrumentation







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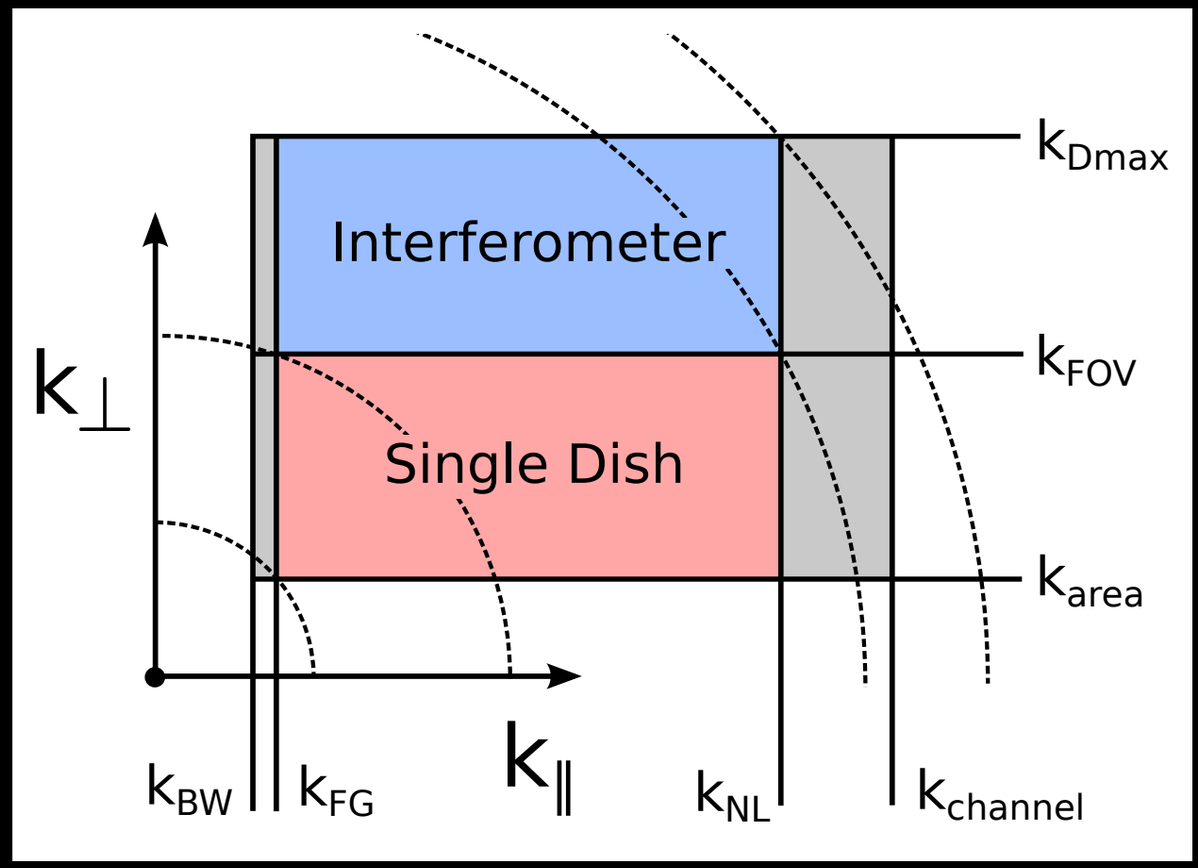
Cosmological Modes

- Wide redshift coverage: z ~ 0.8 : 2.5
- Survey area: target ~15,000 deg^2
- Angular coverage: ℓ ~ 40 - 2000 ; k_{perp} ~ [10^{-2}, 1] h Mpc^{-1} at z~1
- Frequency coverage: y ~ 20 - 20000 ; k_{par} ~ [10^{-3}, 1] h Mpc^{-1} ; limited by foregrounds and nonlinearities.
- Sensitivity: 12 uJy/beam daily, 1 uJy/beam full survey



Bull et al (1405.1452)

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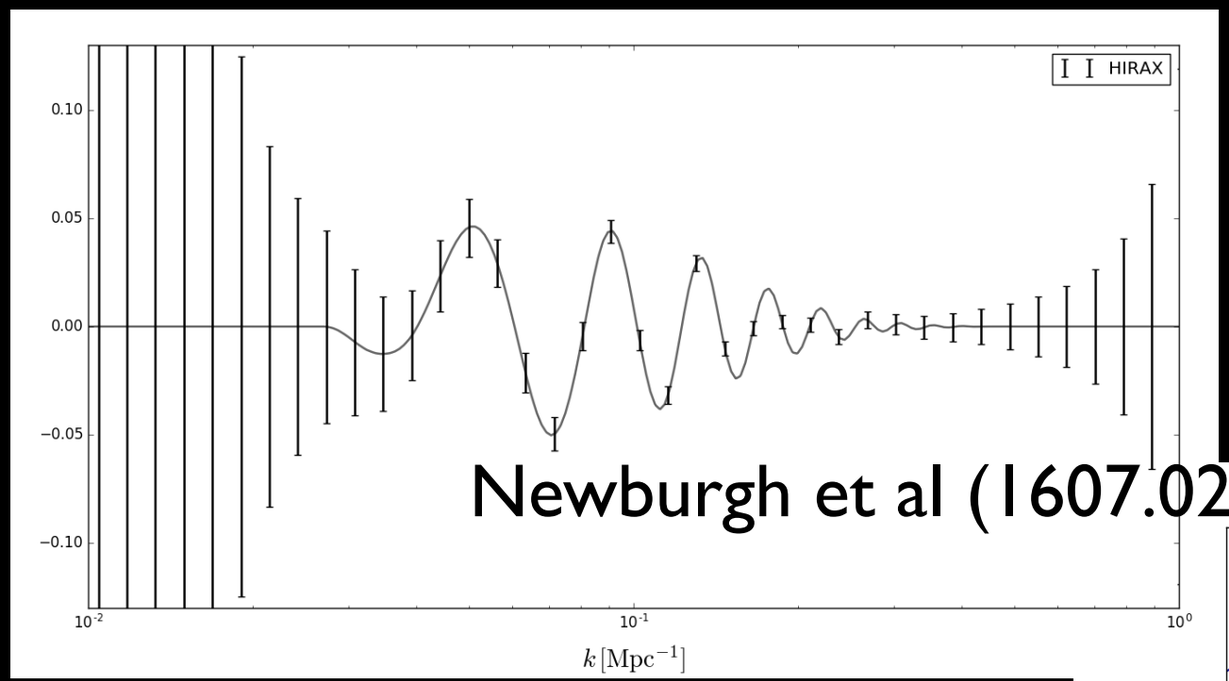
BAOs and Cosmology



Newburgh et al (1607.02059)

10,000 hr survey with 1024 element forecast with fsky=0.05. Aim is to complete 4 year survey with fsky~0.35.

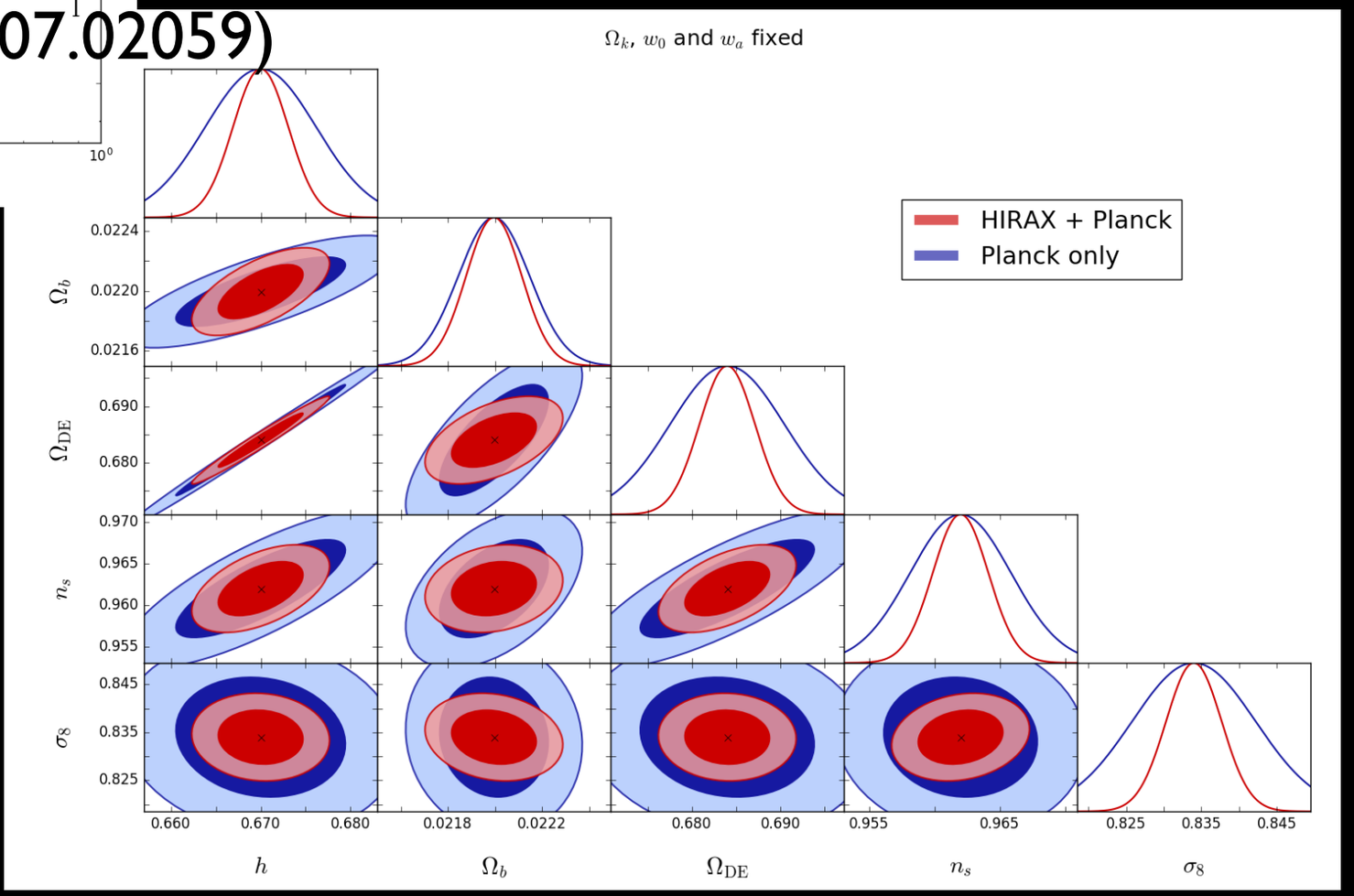


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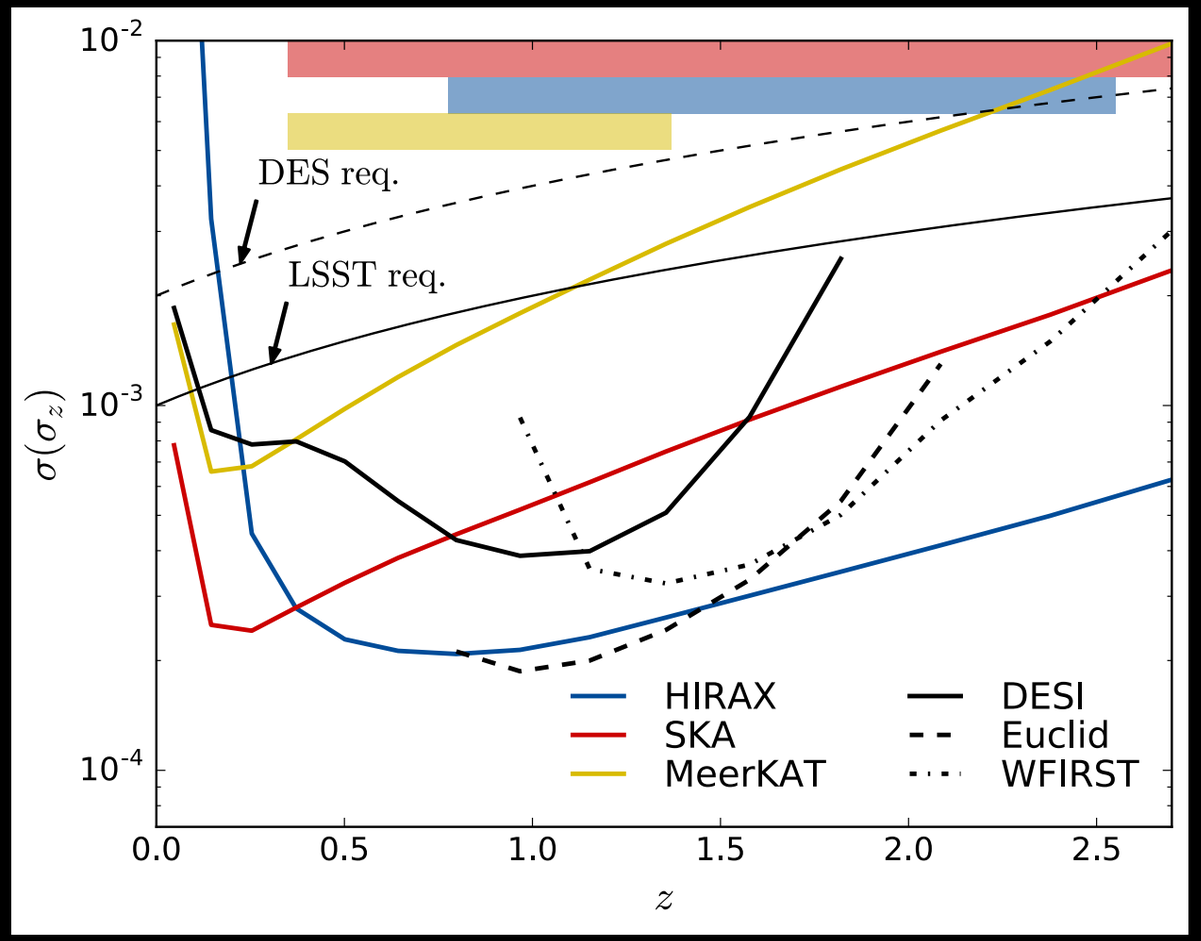
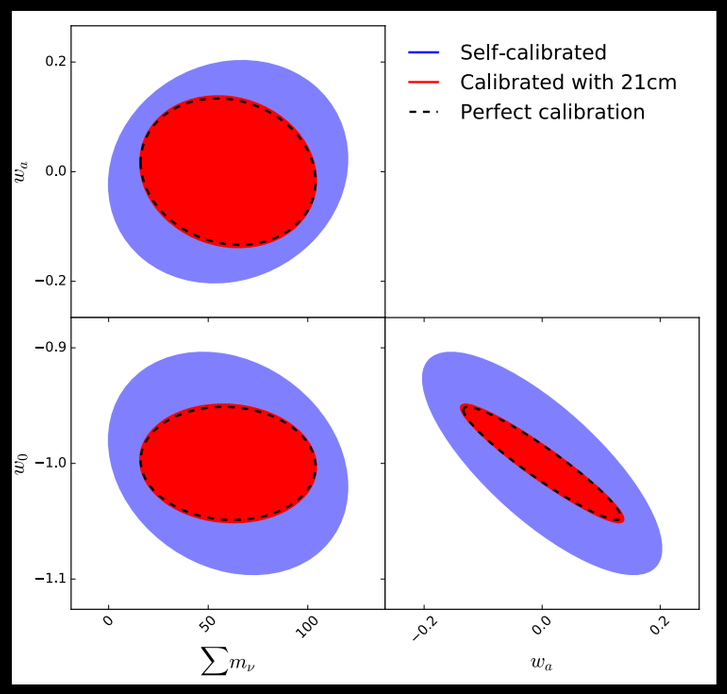
Photo-z calibration

- Cross-correlation with LSST photometric survey can provide photo-z calibration via the clustering redshifts method (Alonso et al, 1704.01941) and improve parameter constraints.





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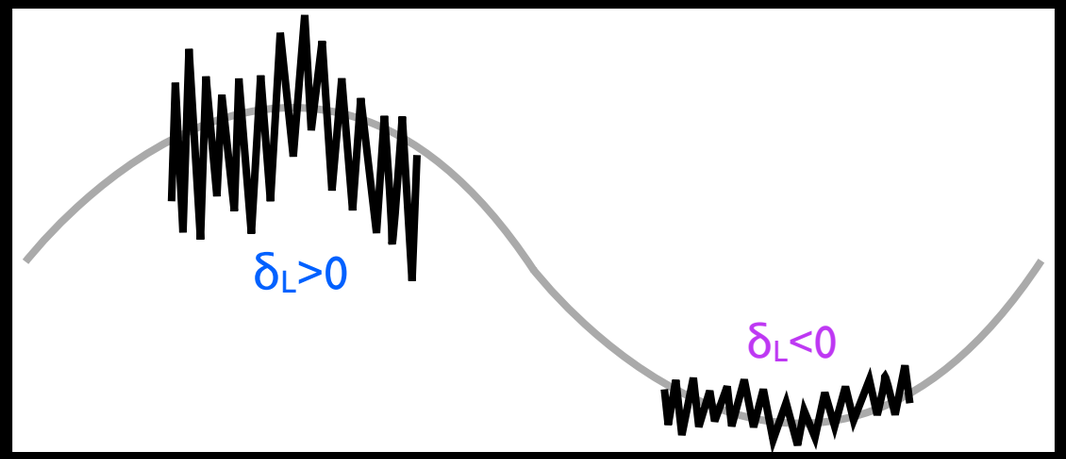
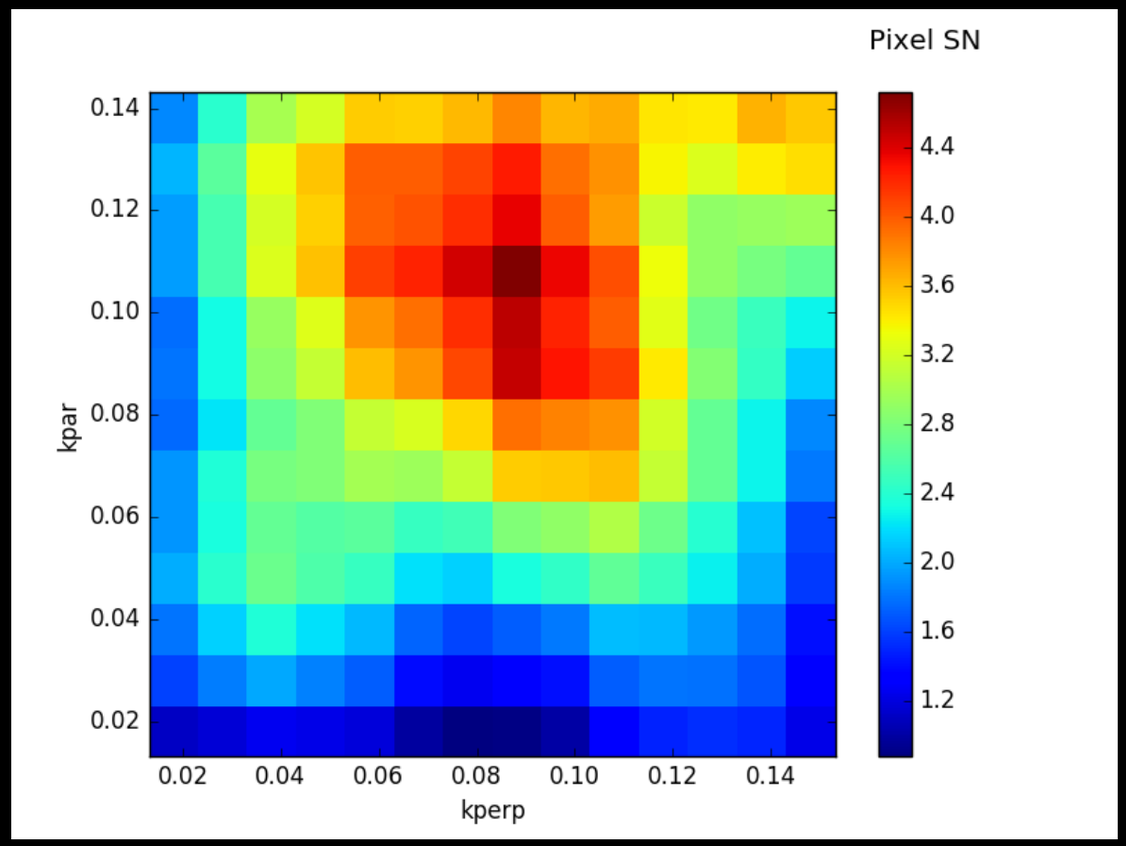
21cm-CMB lensing cross-correlation

- Direct 21cm-CMB lensing correlation vanishes because of loss of low k_{par} 21cm modes
- Construct a bispectrum estimator that uses two copies of the 21cm intensity field and one copy of the CMB lensing field.
- Estimator relies on modulation of small-scale 21cm modes by large-scale (super-sample) modes to recover the line-of-sight long wavelength modes that are required for correlation with CMB lensing.
- Signal to noise is promising - can derive useful cosmological constraints (Moodley et al *in prep*).





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HIRAX Prototype @ HartRAO

Top Left: HartRAO technician Andrew Masiteng, UKZN PhD student Onkabetse Sengate and UKZN MSc student Kabelo Kesebonye assemble 6m dish

Top Middle: Yale student Emily Kuhn and HartRAO technician Jacques Grobler Install feeds.

Top Right: Onkabetse Sengate, Nivek Ghazi and Cynthia Chiang work on RFI testing, while Austin Gumba works on RF over fibre.

Right: Jon Sievers, Ben Saliwanchick,Jeff Peterson pose with just-assembled dish.

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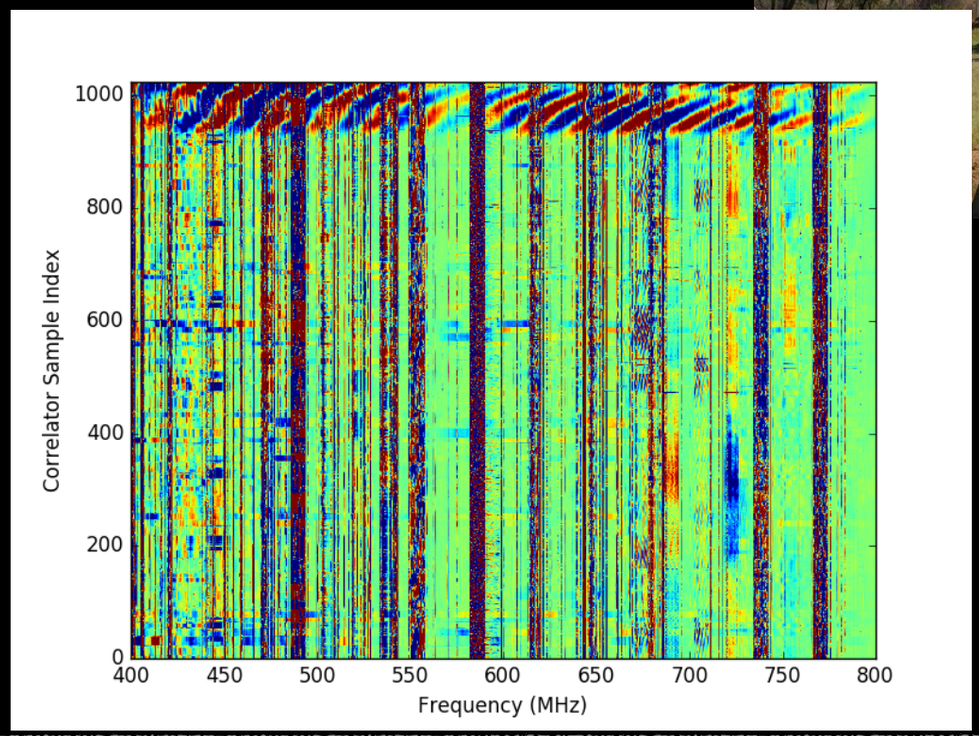
HIRAX Prototype @ HartRAO

Devin Crichton &
Heiko Heilgendorff

- All eight dishes fully instrumented.
- Six dishes currently taking data.



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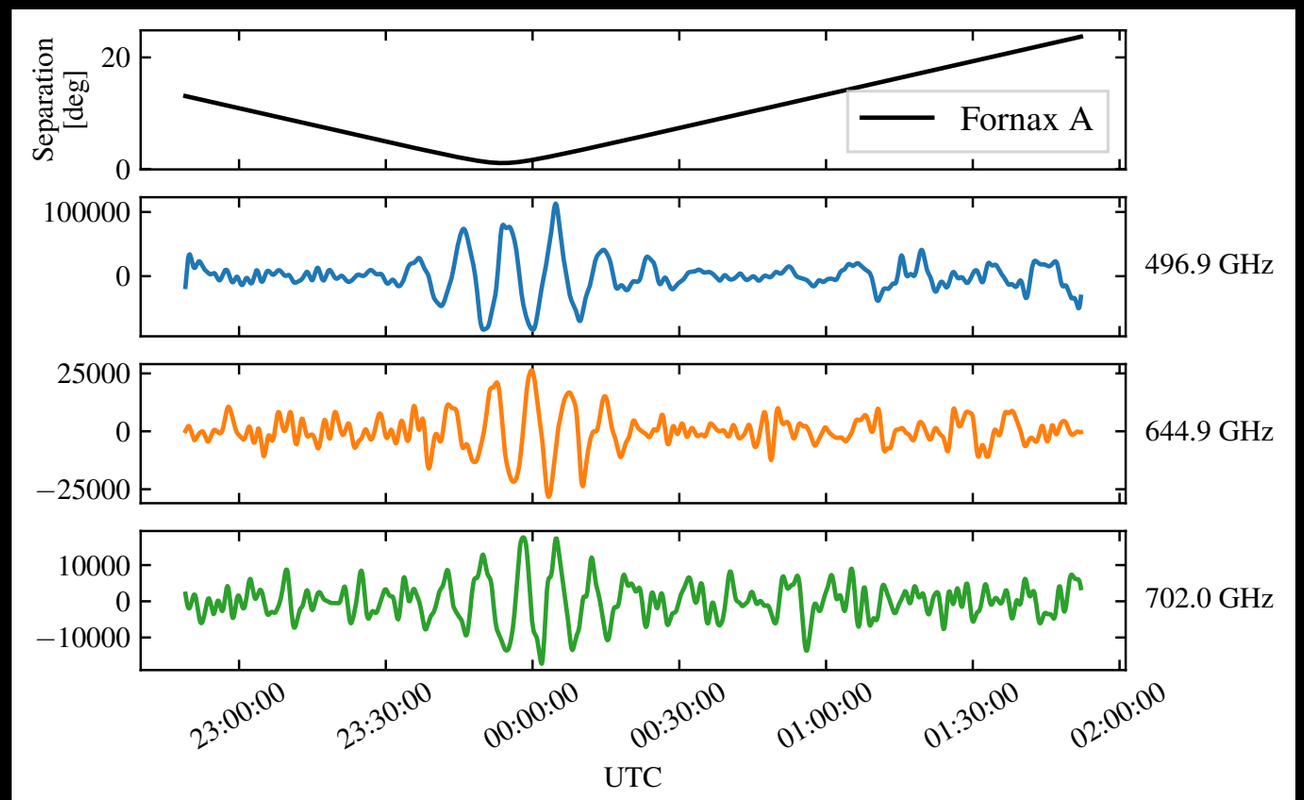
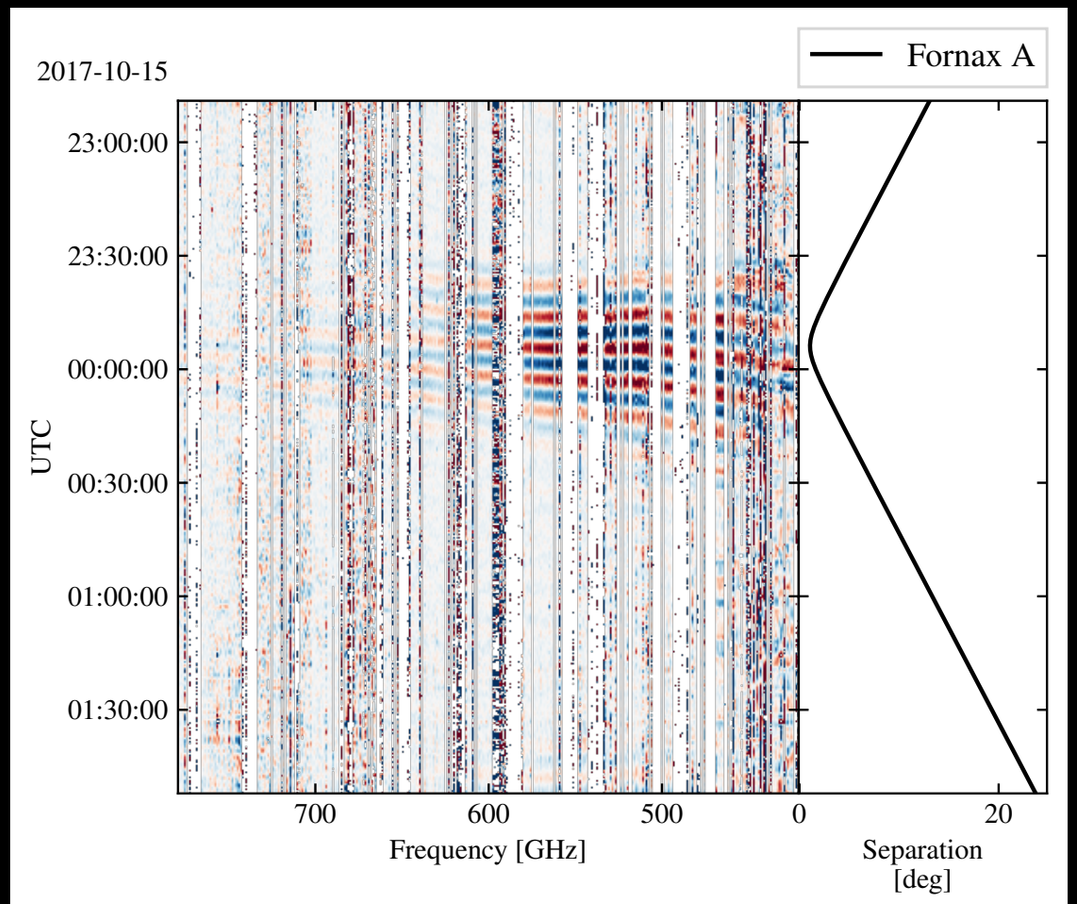
Prototype Data Analysis

- We see fringes!
- Currently characterizing instrumental properties from the data





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Current Status & Plans

- Funded for 128+ elements. Applying for funding to build up to 512 elements then 1024 elements.
- 8 elements built at HartRAO, with feeds.
- Core site in Karoo, construction can start Q3 2019
- In the interim plan to expand HartRAO to 32 dishes and build 2-3 outrigger stations. Will use f/D 0.25 dishes - currently being designed.
- HartRAO+outriggers should be enough to find ~1 FRB/ month *with accurate positions*.

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