HIRAX Overview

Hydrogen Intensity and Real-time Analysis eXperiment

Alexandre Refregier (ETH Zurich) and the HIRAX collaboration

HIRAX

Hydrogen Intensity and Real-time Analysis eXperiment

- Interferometric array up to 1024 6m dishes operating at 400-800 MHz
- Scalable array built in stages: 2 (qualification), 8, 128, 256 (funded) then expand to 1024 and operate full array for 4 years
- SARAO Karoo site co-located with SKAO in South Africa
- Dishes stationary and tiltable
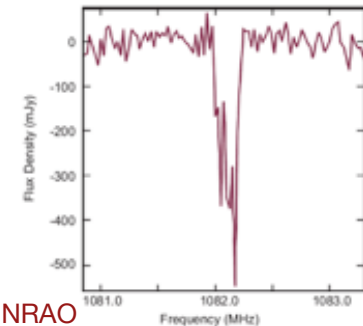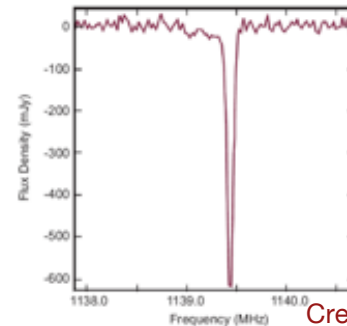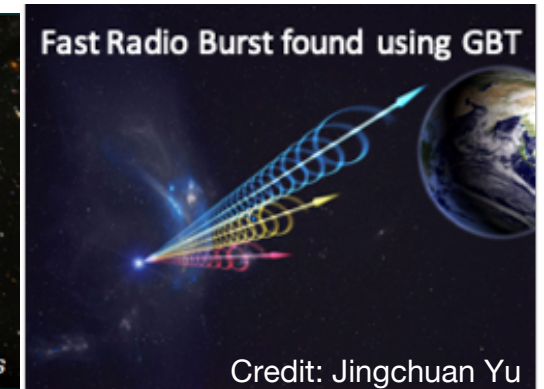- 15,000 deg^2 Neutral Hydrogen survey with redshifts between 0.8 and 2.5

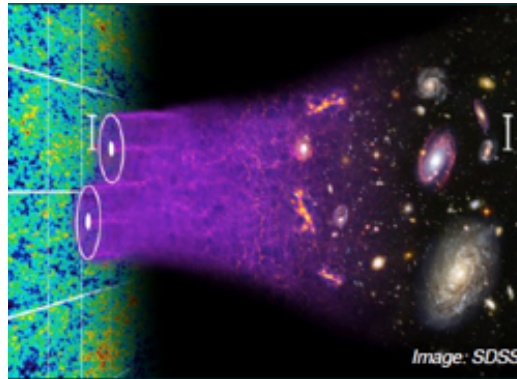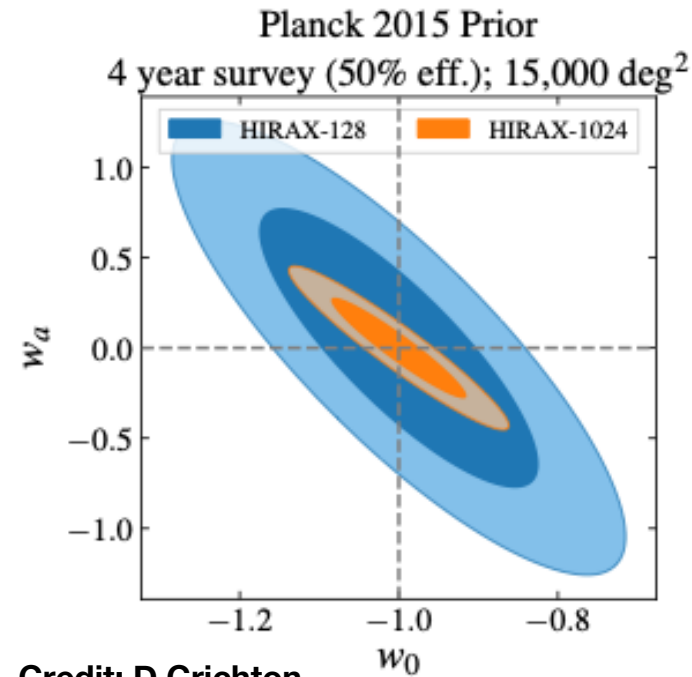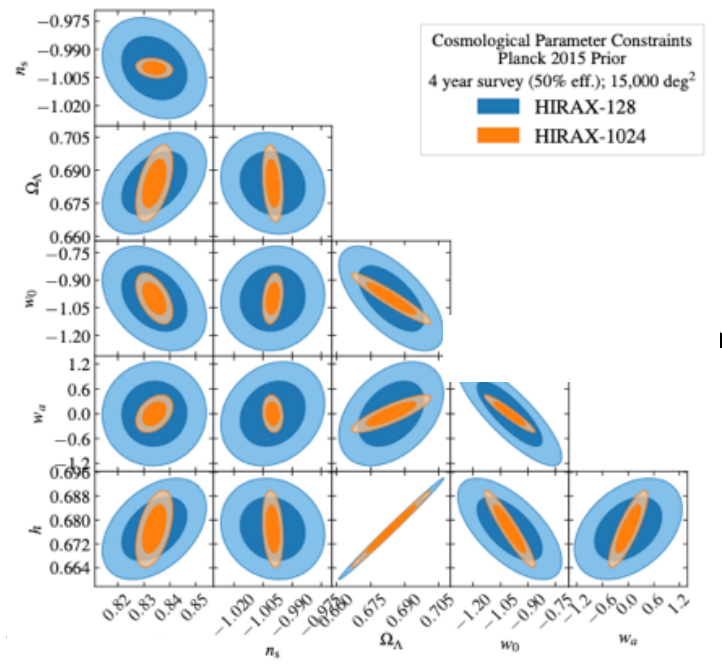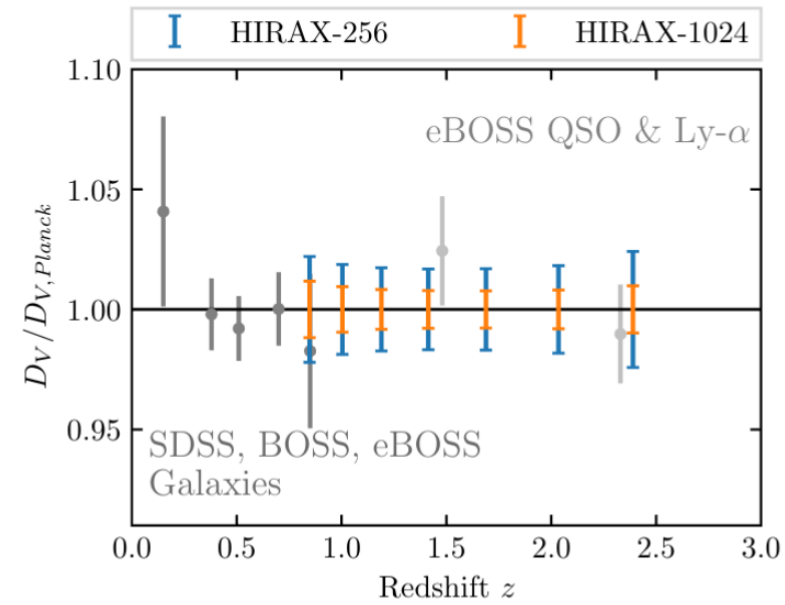|	
Dish diameter	6 m
Dish focal ratio	0.23
Collecting area	7200 m^2
Frequency range	400–800 MHz
Frequency resolution	1024 channels, 390 kHz
Field of view	5°–10°
Resolution	0.2°–0.4°
Target system temperature	50 K

Crichton+ (2022)

Science Goals

- Measure baryon acoustic oscillations with 21cm intensity mapping: characterise dark energy

- Cross-correlation with other cosmological surveys

- Radio transient searches, fast (FRBs) and slow

- Pulsar searches: 15 uJy/scan - search in each of 10-20 beams, galactic centre searches

- Neutral hydrogen absorbers: up-res frequency in beam-formed data (FFTs on GPUs)

- Diffuse galactic polarization

Image: SDSS

Fast Radio Burst found using GBT

Credit: Jingchuan Yu

Credit: NRAO

Haslam map (mK)
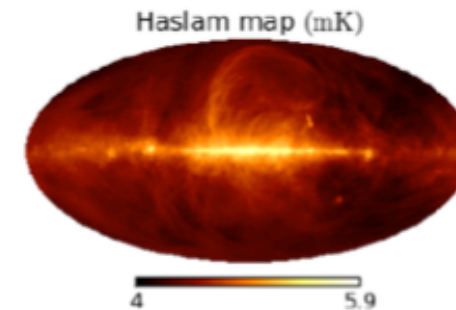
Cosmology with HI IM
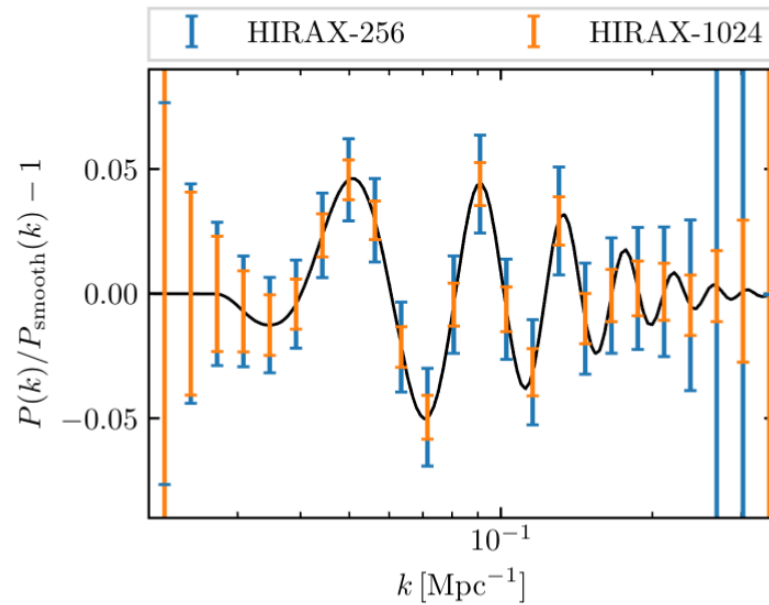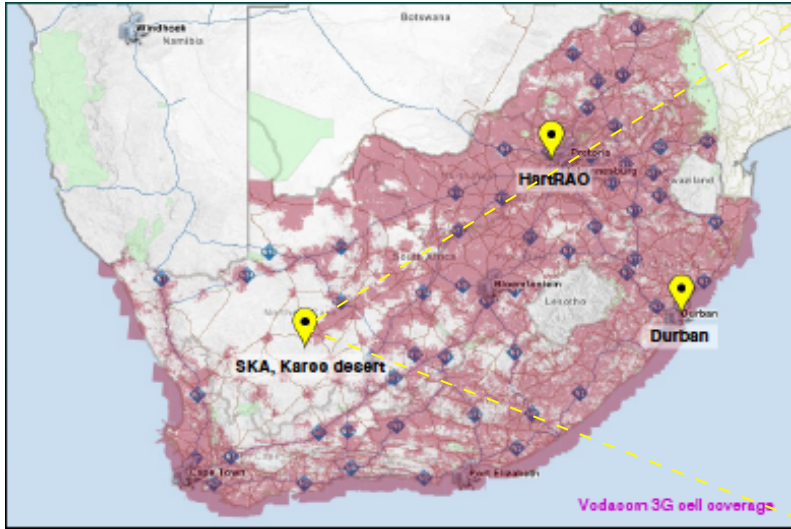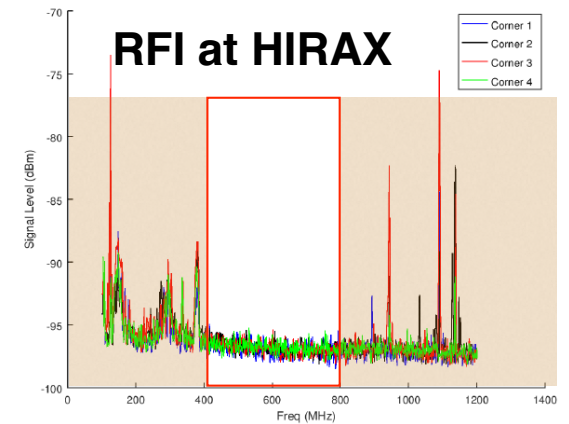

Credit: D Crichton

Site

- SARAO Karoo site co-located with SKAO
- Existing infrastructure (roads, power, data)
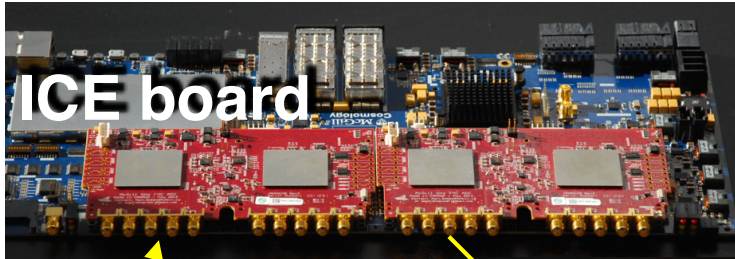- Low levels of RFI - site protected
- Access to southern skies

Design

- Goal of 1024 close-packed 6m dishes. Fibre-glass fabrication in South Africa by AFF, design from NRC (Canada). Partnership approved by NRF.

- Cloverleaf dual-polarisation feed, RF over fibre

- Operate between 400-800 MHz, 1024 channels

- Channelizing on FPGA ICE boards

- Correlation on GPUs

Instrument

Feed

RFoF TX System

ICE board

Metal

dish

Composite

F-engine (CHIME)

X-engine

HIRAX System Schematic

RFOF system

Transmitter

Fiber

Receiver

amplifiers

dual polarization dipole antenna

Active-Balun Dual-Polarization Feed

FPGA F-engine: digitizer+channelizer

1024 frequencies per analog input

GPU X-engine correlator

FPGA Hut

GPU Hut

6m dish
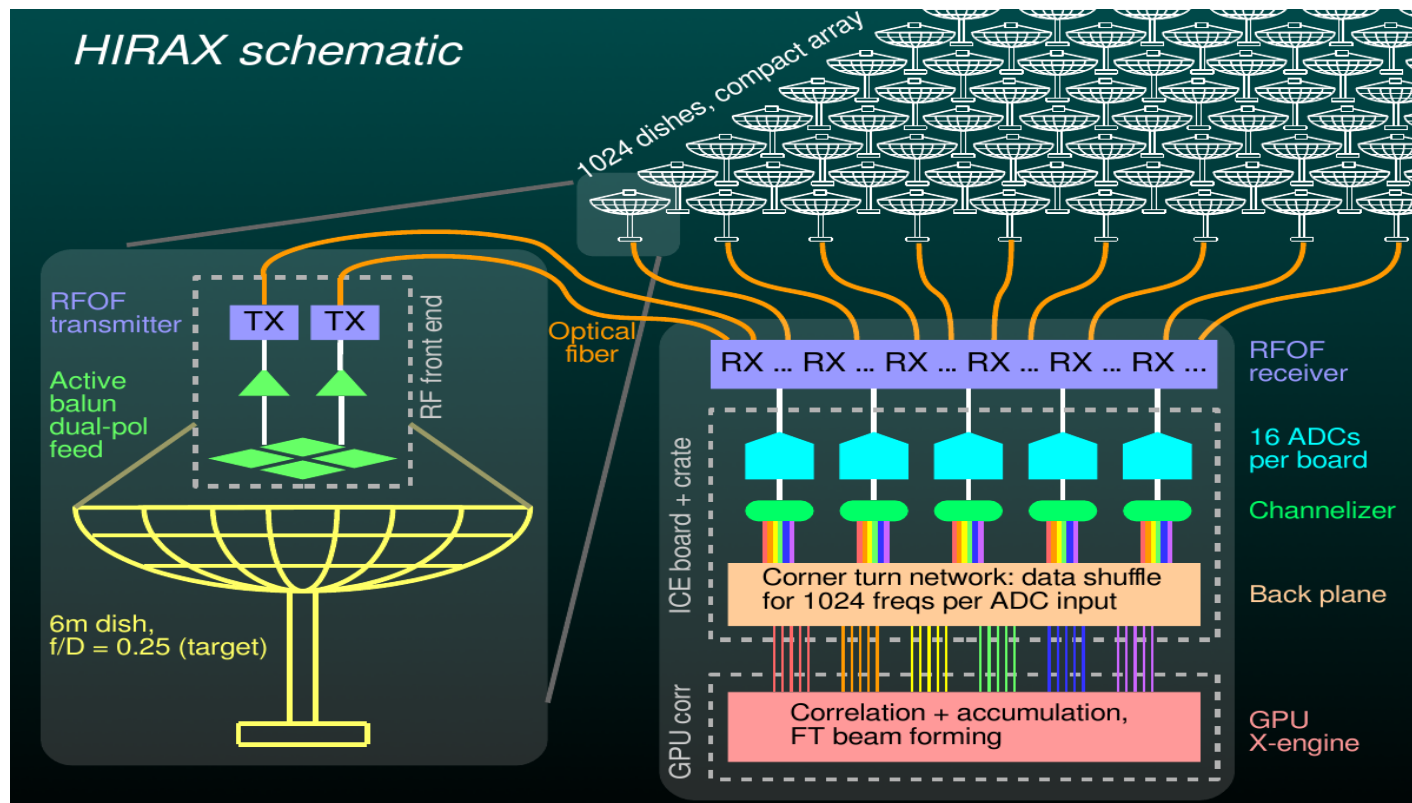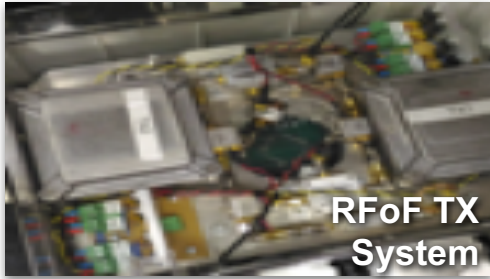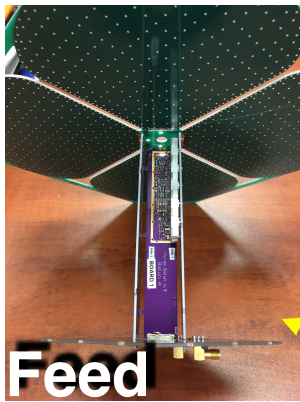
On dish
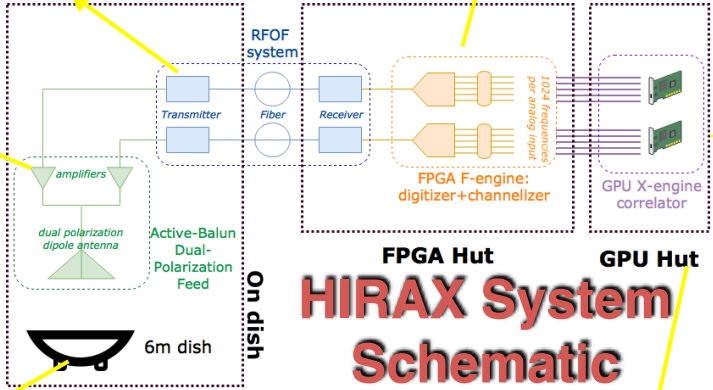
Digital Correlator

HIRAX 256 X-engine:

Dense GPU-based system

8 nodes (128 channels, 50 MHz bandwidth each)

Produce raw visibilities with integration ~10s

1.6 Tbps data processing

Kotekan software

Tested in lab and at Bleien observatory

| Parameters	Value
Motherboard	GIGABYTE G482-Z52
Processor	2x AMD EPYC™ 7452 – 32 cores
RAM	1TB
GPU	2 x NVIDIA A40, PCIe 4.0
F-Engine Network	4 x SILICOM PE31640G2QI71-QX4 - 2x40 Gbps
Outgoing Data Network	2x25 Gbps

Science Data Processing Unit

Science Data Processing (SDP) unit includes the systems required for the immediate post-processing and compression, and the real-time analysis backends (FRB and pulsar) that will be operating on the beam-formed data for the 256 array
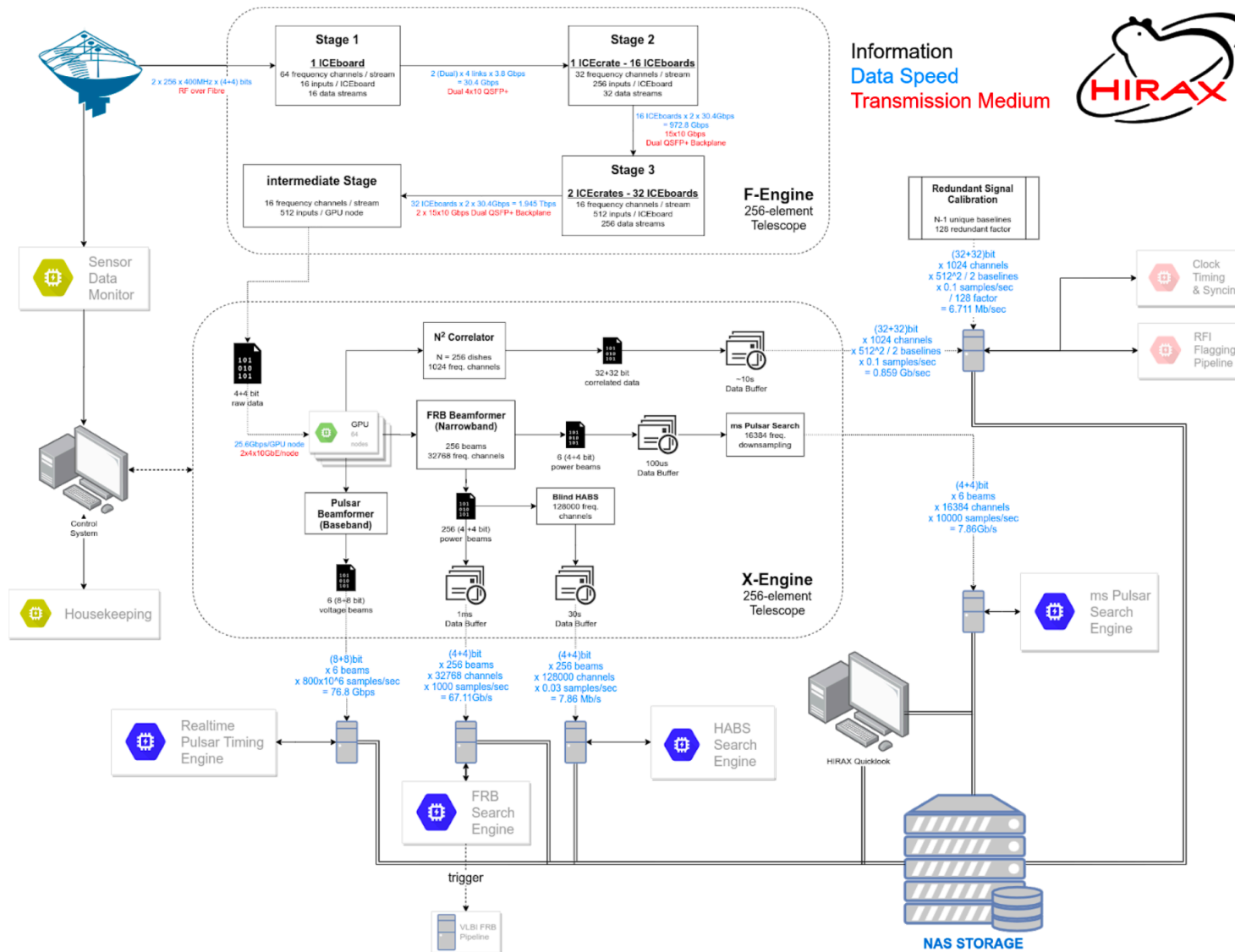
Collaboration and Funding

- UKZN and South African NRF flagship funding secured for site infrastructure and pathfinder array. SARAO providing site, power and data.

- Swiss SNF funding secured for 512 channel X-engine (GPU correlator) and Science Data Processing system. McGill funding for F-engine up to 512 channels (ICE boards).

- NRF strategic research equipment (SRE) funding secured to expand pathfinder array.

- Sufficient budget to build up to 256 dishes. Recent funding from Simons Foundation.

Schedule

Upcoming:

- Develop HIRAX Karoo Klerefontein testbed site by Q1 2023

- Develop HIRAX Karoo Swartfontein main site by Q2 2023

- Commission 2-element qualification dishes at Klerefontein site by Q2/3 2023:
  verify dish precision and measure telescope beams

- Commission 8-element prototype at Swartfontein site by Q3/4 2023:
  verify RF performance and stability

- Commission 128-element pathfinder array at Swartfontein site by Q1/2 2024:
  verify redundant calibration approach

# Swiss HIRAX Contribution

Swiss contributions include:

Design, Construction and testing of Digital correlator (X-engine) with Canada

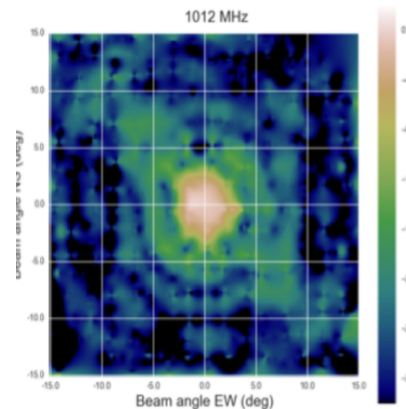Design, Construction and testing of Science Data Processing Unit (ongoing)

Beam calibration using Drone and Holography

Tests at Bleien Observatory

Science: sky and telescope simulations, analysis pipeline, systematics (Cf. Devin Crichton and Pascal Hitz's talks)
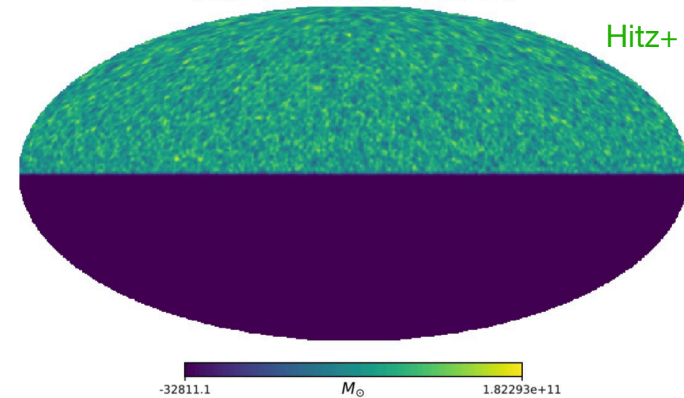

Chang+ (2015)

1012 MHz

Beam angle EW (deg)
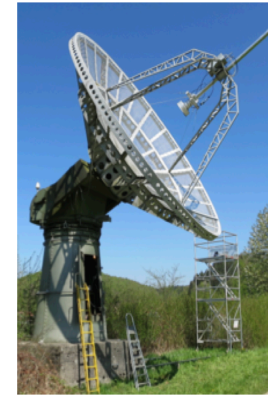
f[MHz] ∈ [720.0, 725.0] or z ∈ [0.959, 0.973]

Hitz+ (2022)

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Further information on HIRAX:

https://hirax.ukzn.ac.za/

Crichton et al., 2022, Journal of Telescope, Instrument and Systems, 8(1), 011019, arXiv:2109.13755