Searching for the cosmic dawn from the sub-Antarctic

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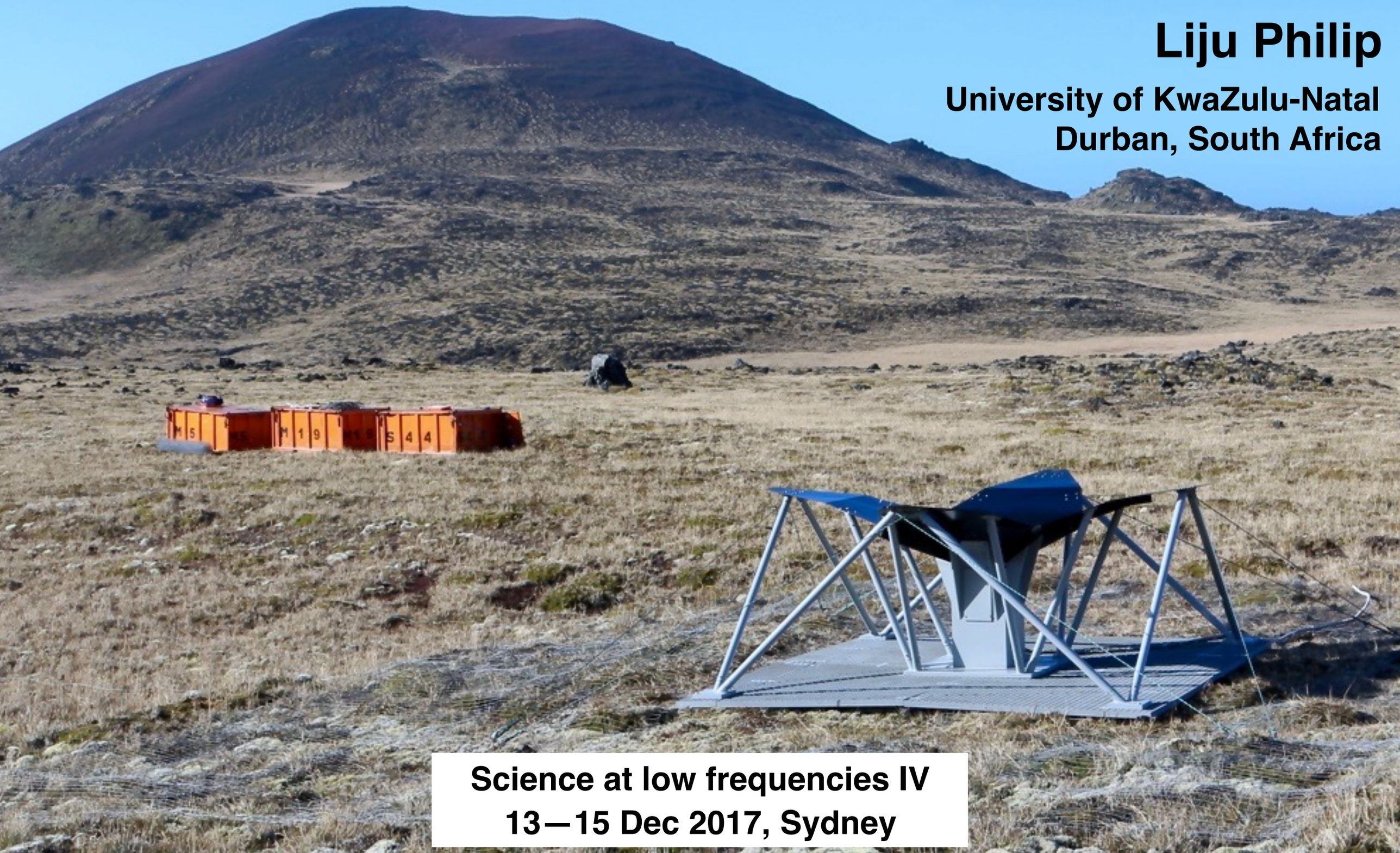
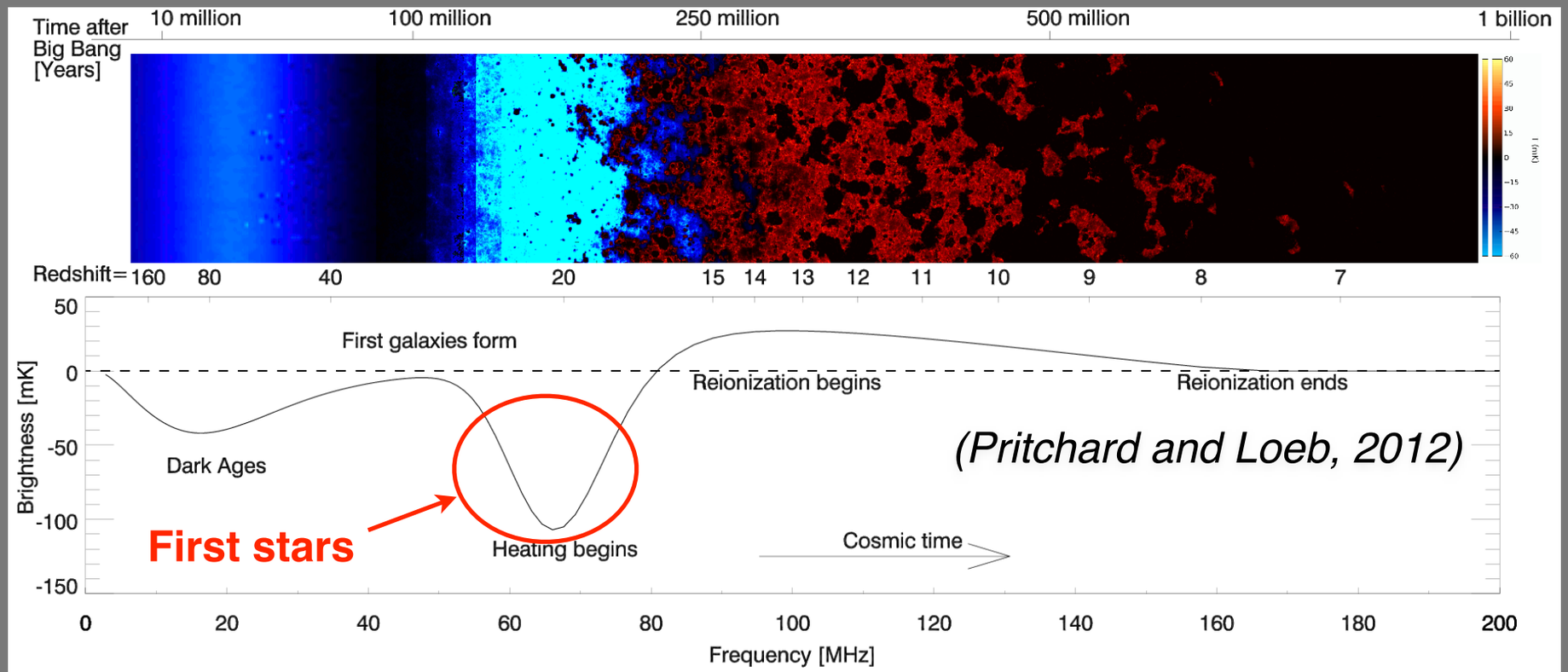
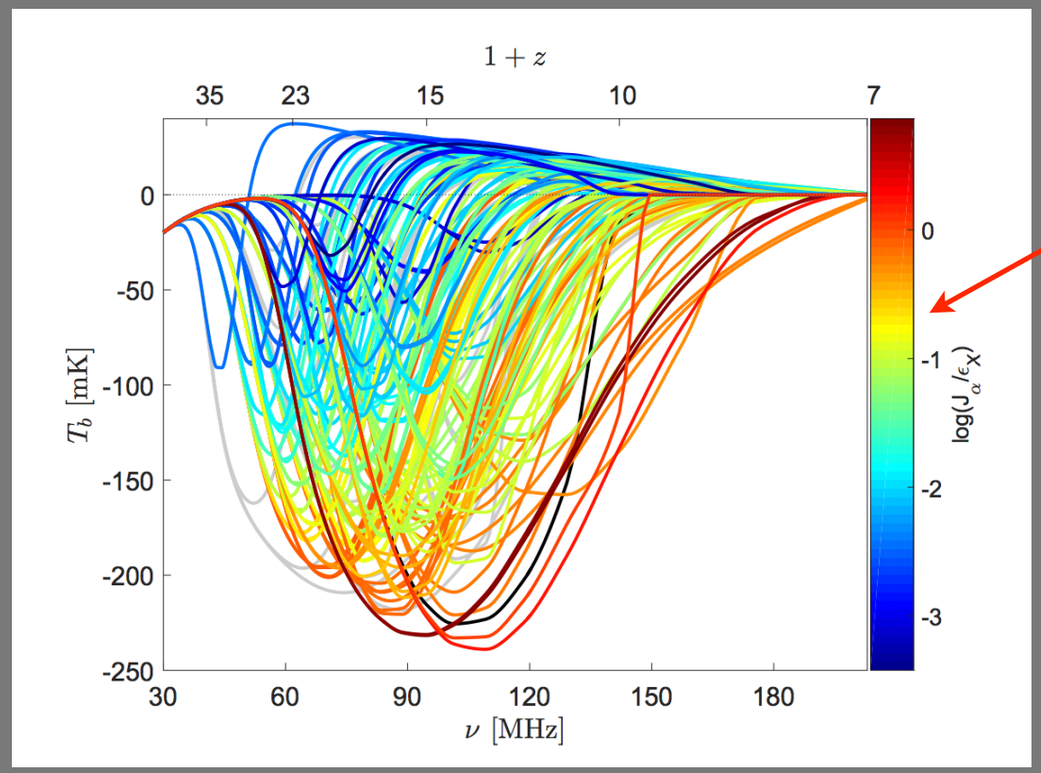


Science at low frequencies IV
13—15 Dec 2017, Sydney

Exploring the cosmic dawn with the global 21-cm



$$\delta T_b \propto x_{HI}(1+z)^{1/2}(T_s - T_{CMB})/T_s$$



colorbar = $\dfrac{\text{Ly-alpha intensity}}{\text{x-ray heating rate}}$

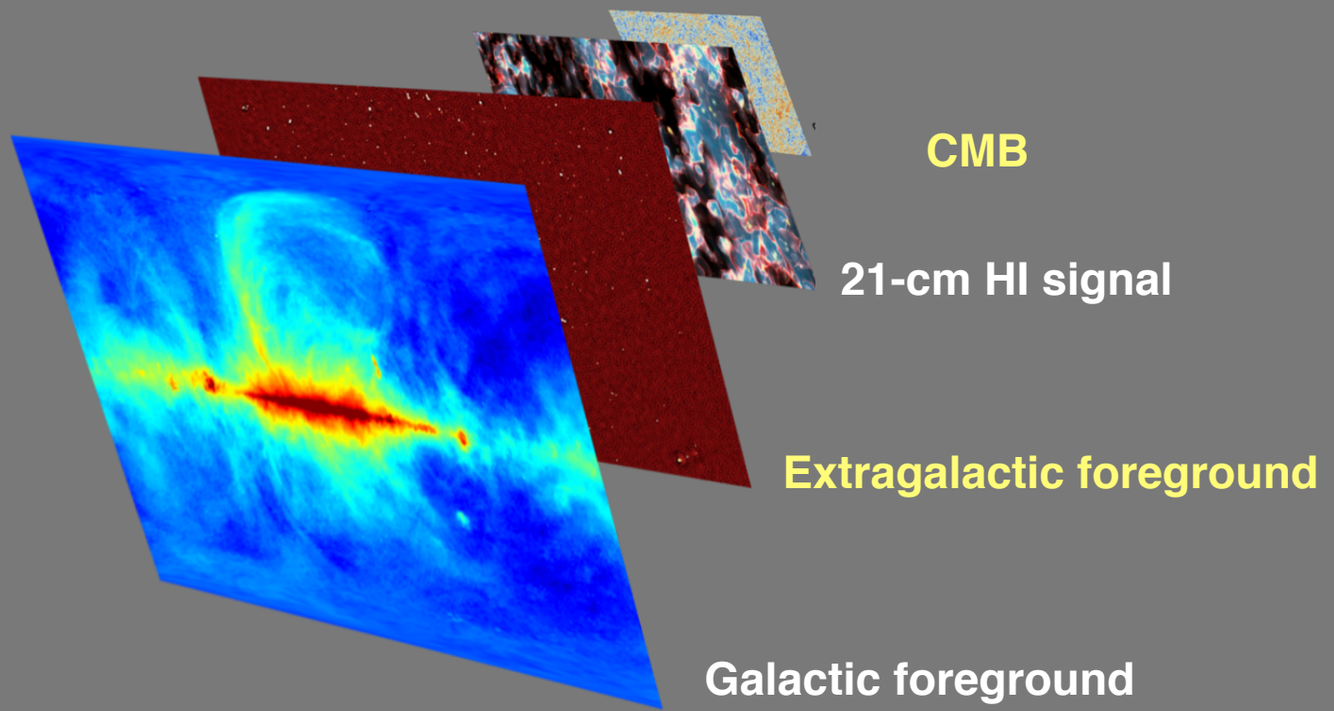
Blue : early x-ray heating
Red : more stars, wider dip

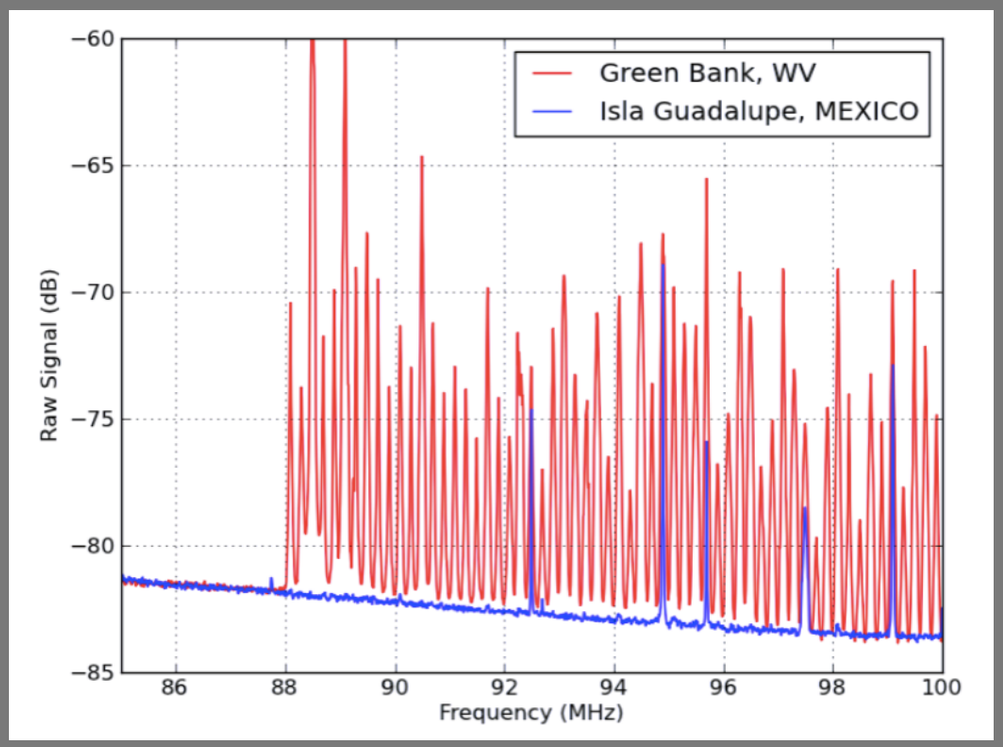
Challenges in the 21-cm experiment

Astrophysical foreground

4-5 orders of magnitude

brighter than the 21-cm signal





Terrestrial RFI

FM radio, TV, cellphone etc.

Ionosphere

Free electrons in the ionosphere modifies EM wave propagation

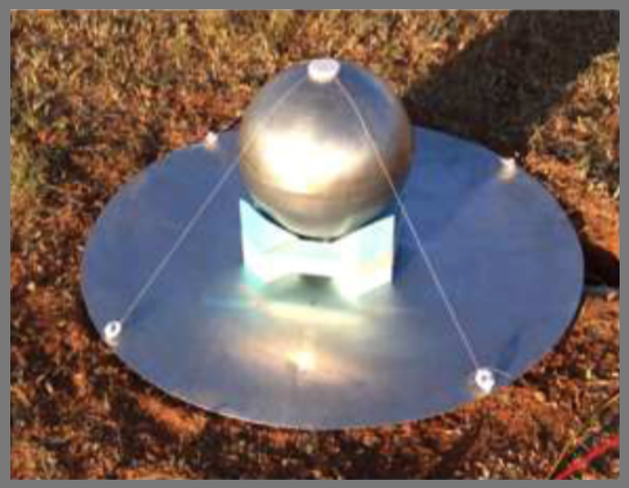
The 21-cm experiment family

EDGES
50—100, 100—200 MHz
Murchison Radio Observatory, Australia

HYPERION
30—120 MHz
UC Berkeley

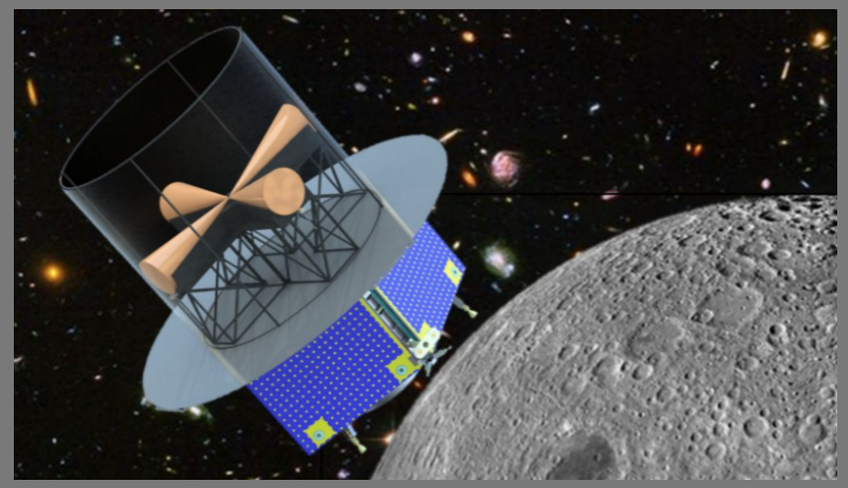
BIGHORNS
50—200 MHz
Western Australia

SARAS 2
40—200 MHz
Bangalore, India



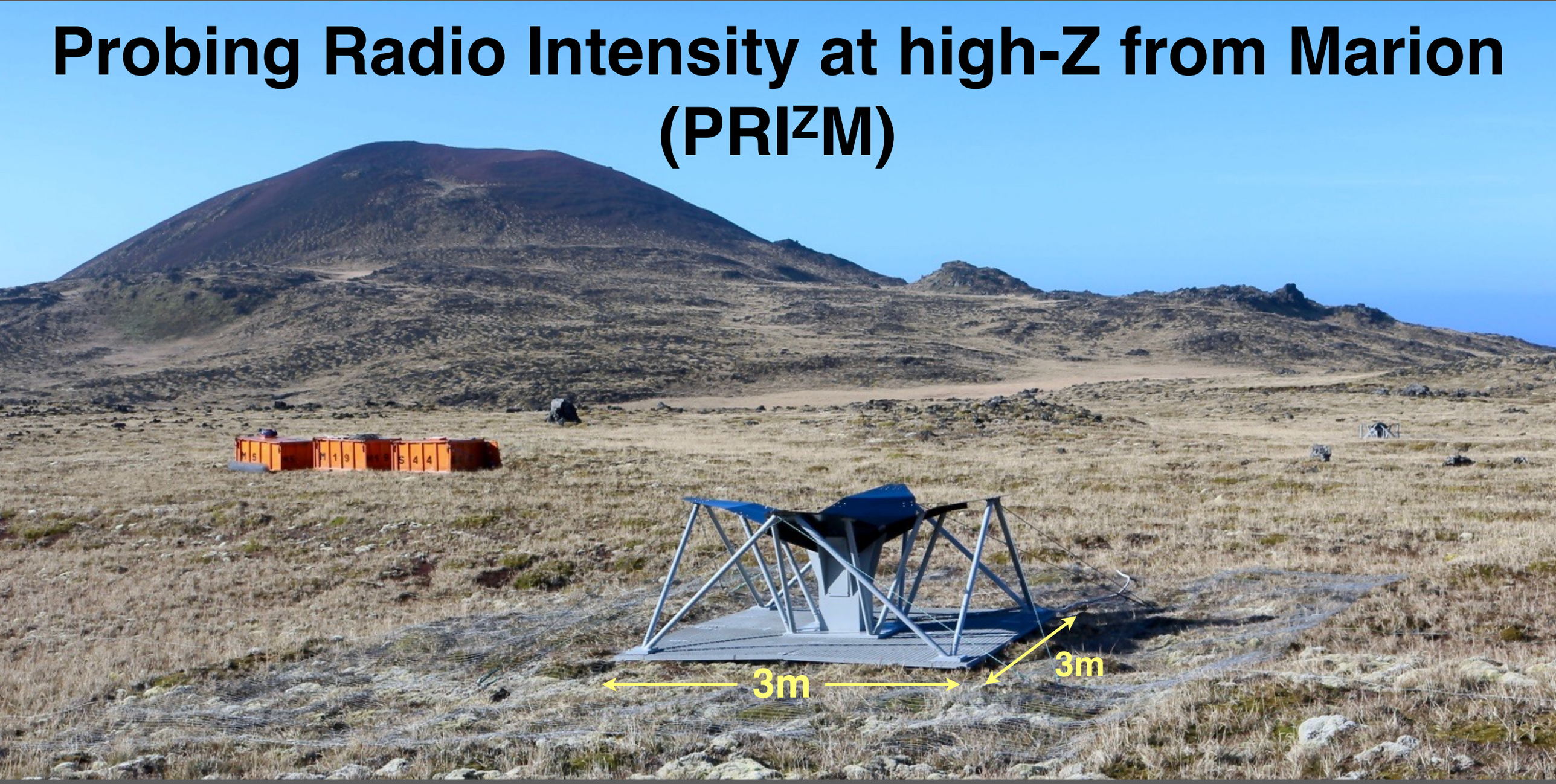
LEDA
40—85 MHz
OVRO, California

DARE
40—120 MHz
Far side of the moon



(proposed)

Probing Radio Intensity at high-Z from Marion (PRI^{Z}M)



Dual polarization antenna

Operating frequency : 30—200 MHz

Two antennas to span the frequency range

The Team

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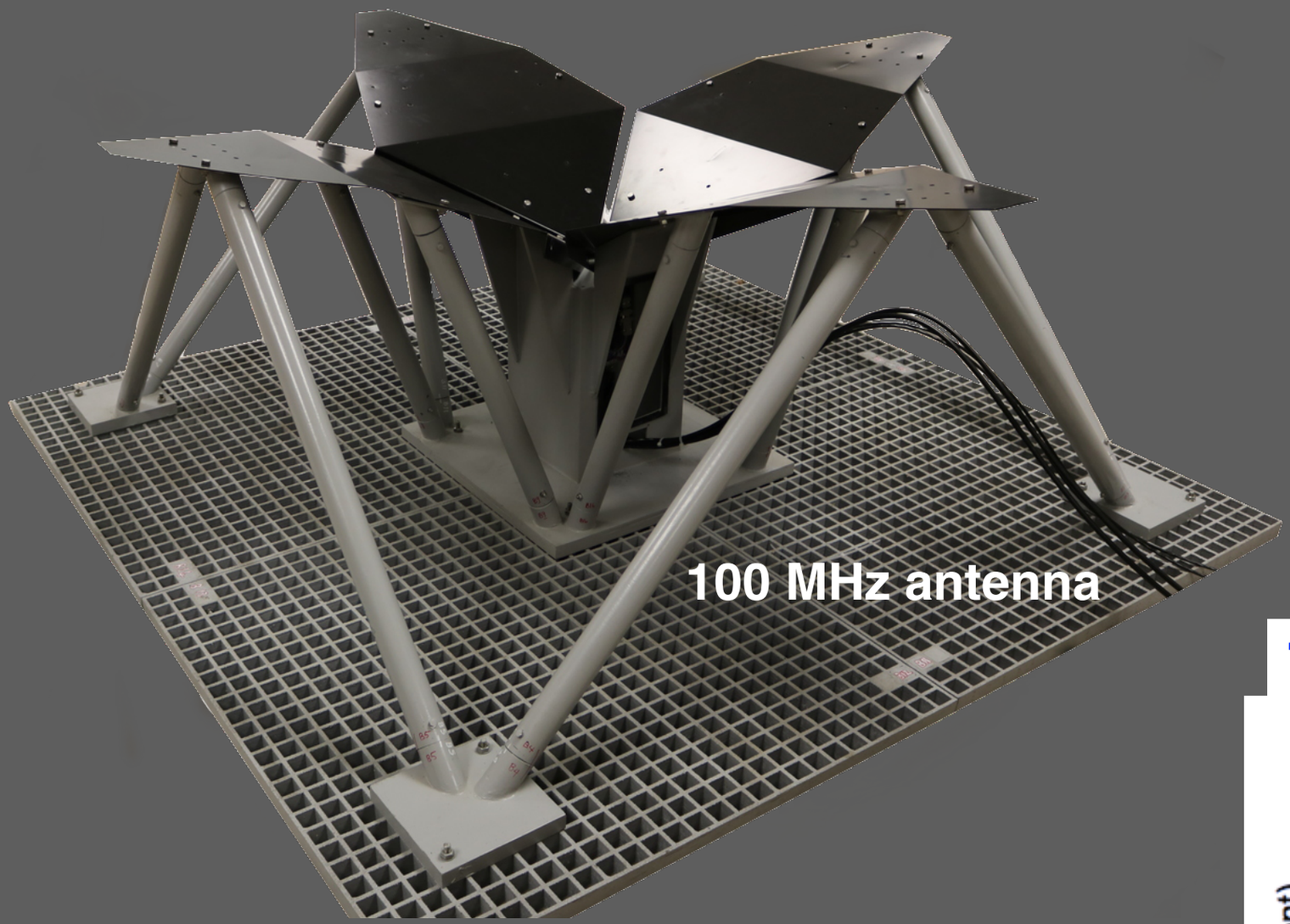
SKA AFRICA
SQUARE KILOMETRE ARRAY

Rupert Spann

Antenna

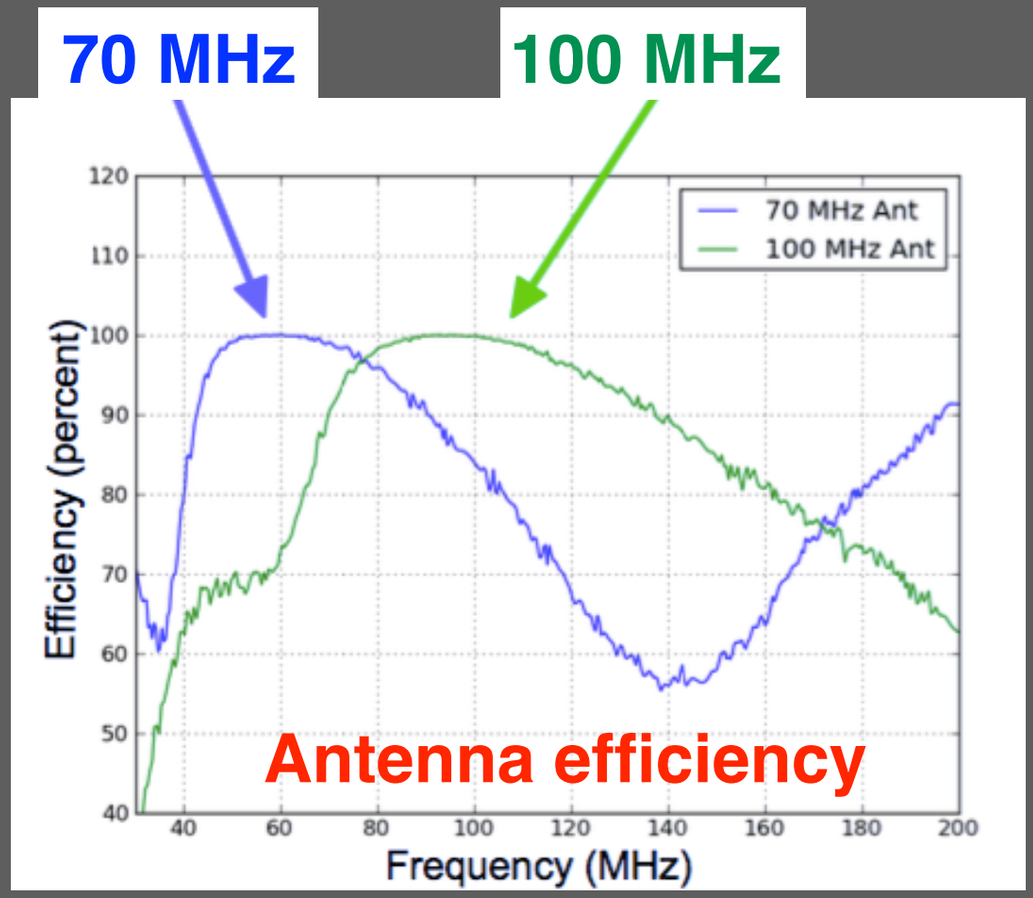


Crossed-dipole

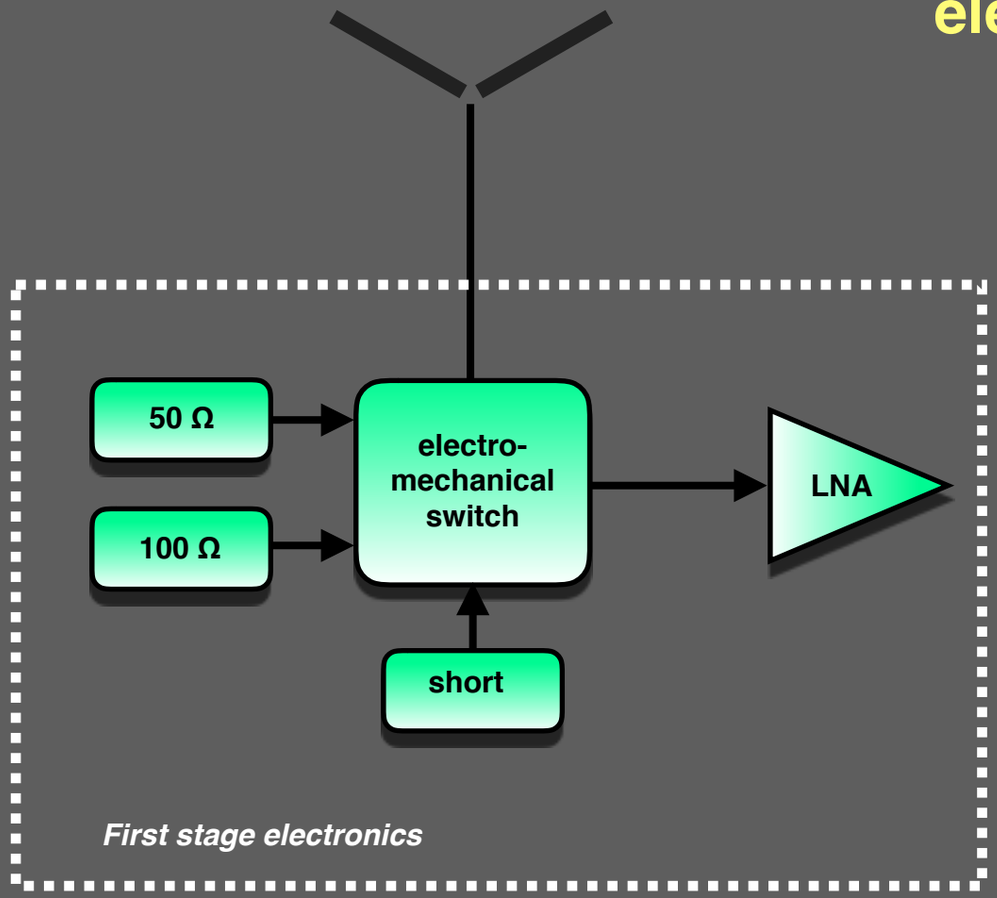
Modified version of a four-square antenna (Ja´uregui-Garc´ıa et al. 2017)

Minimized beam variation across the observing frequency range

Optimized with FEKO

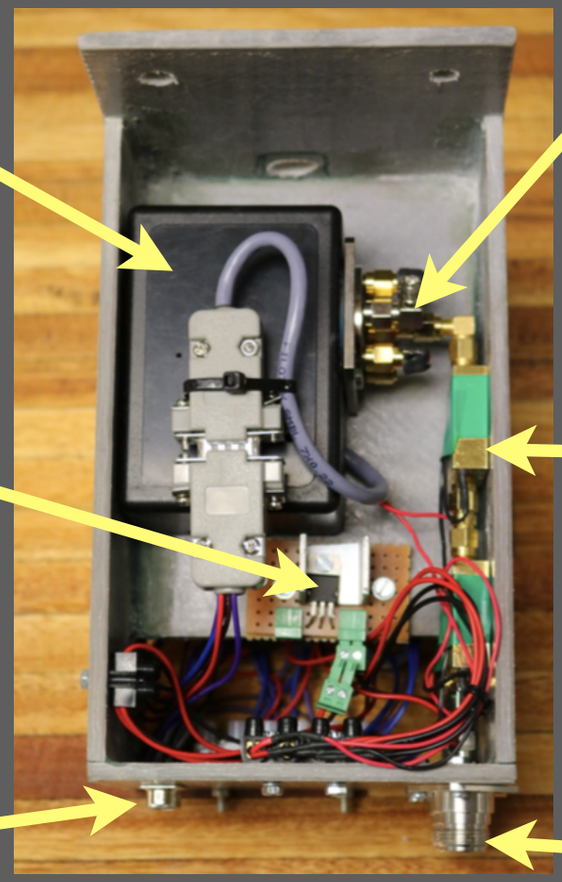


First stage electronics



electromechanical switch

input from antenna



LNA voltage regulator

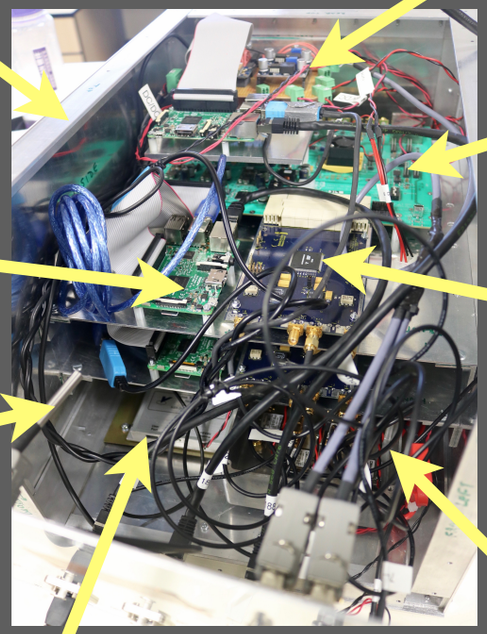
LNA

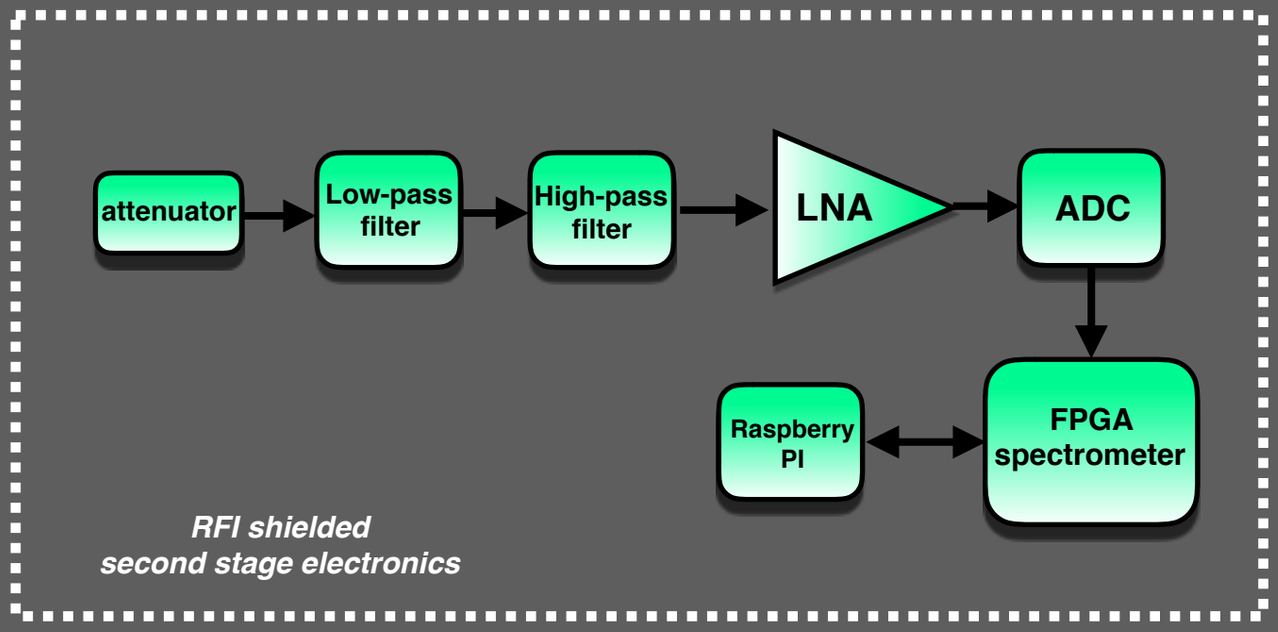
power + control signal input

LNA output

Sits directly underneath the antenna petals

Second stage electronics





Placed 50 m away from the antenna to avoid contamination from self-generated RFI

- iADC : sampling rate 500 MHz
- SNAP board : 4096 frequency channels
- Bandpass : 30 - 200 MHz

~80W power draw by the 70 and 100 MHz systems combined
~1 week of uninterrupted observation when batteries are fully charged

Marion Island

2000+ km from the
nearest mainland

halfway between
Africa and Antarctica

20 km x 12 km

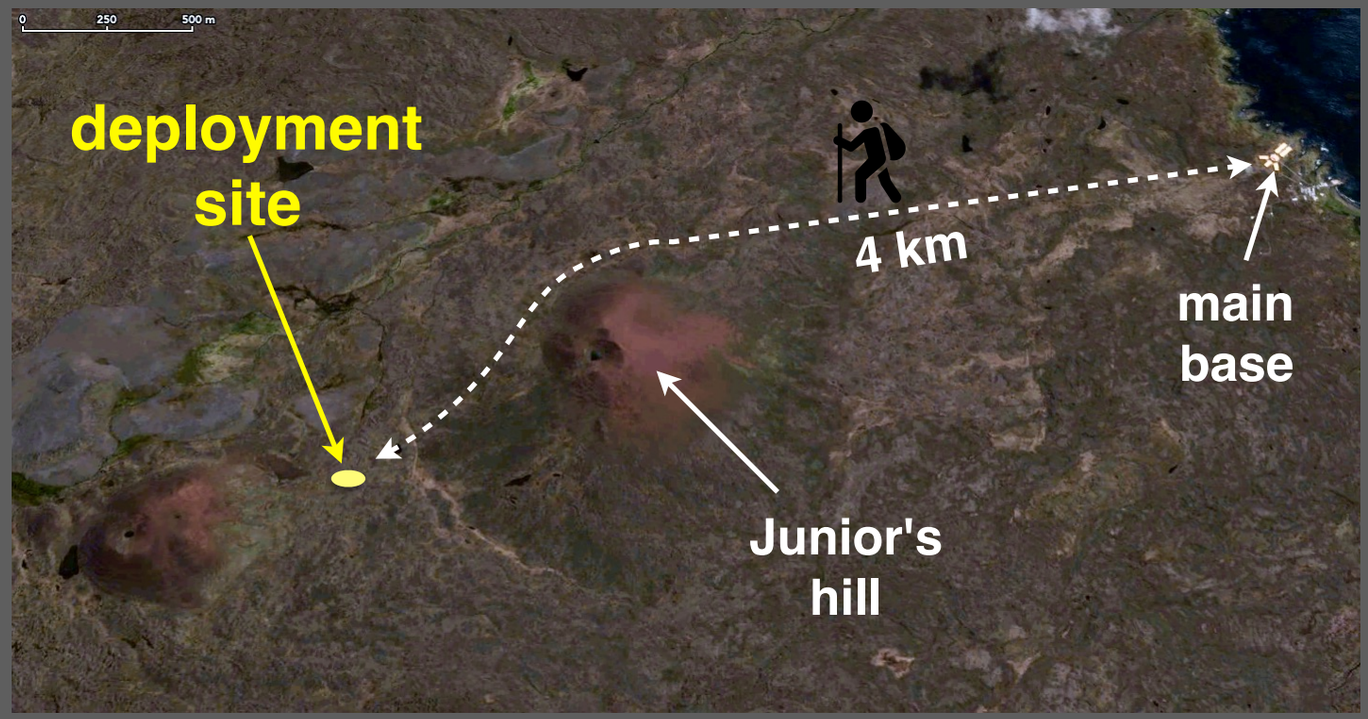
Cold : mean minimum temp. ~ 2.8 deg C
Windy : 80 knots gusts, horizontal rain etc.
lava rocks
mice

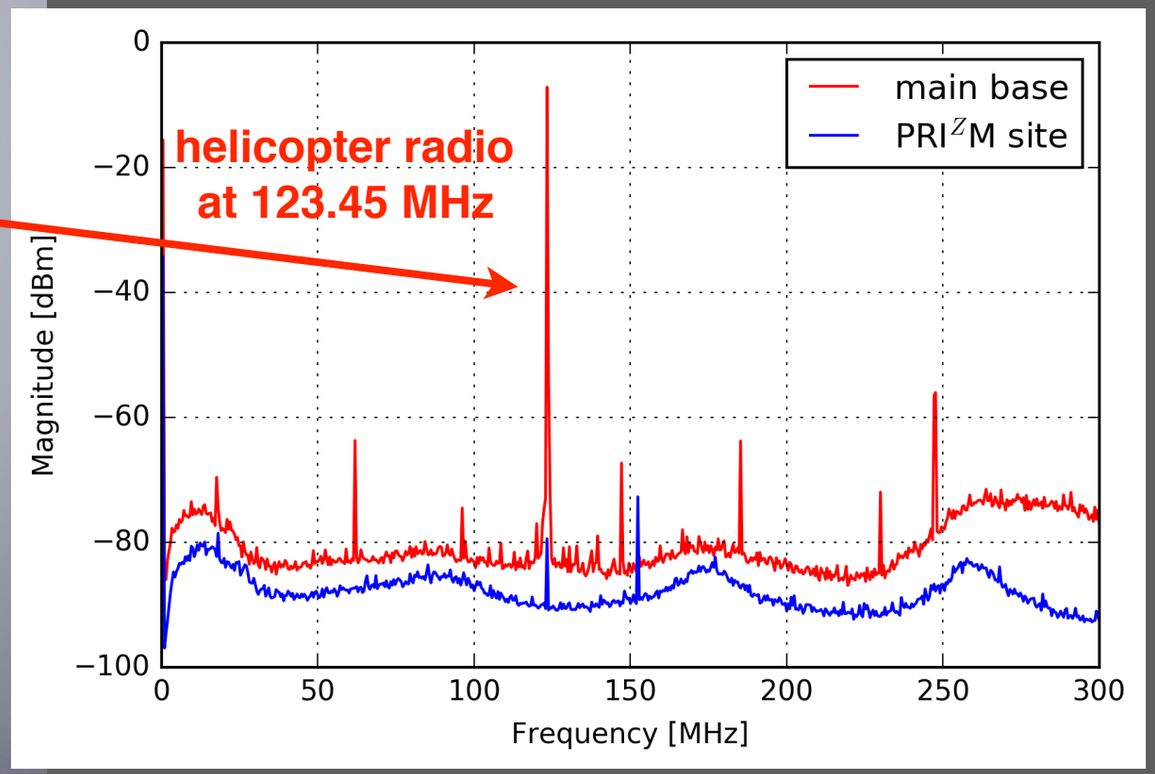
Serviced annually by SA Agulhas II

No trees
No roads
Thick layer of fern
hidden mires

Takeover : **3 weeks**
Winter-overing : 13 months

RFI survey / Site selection



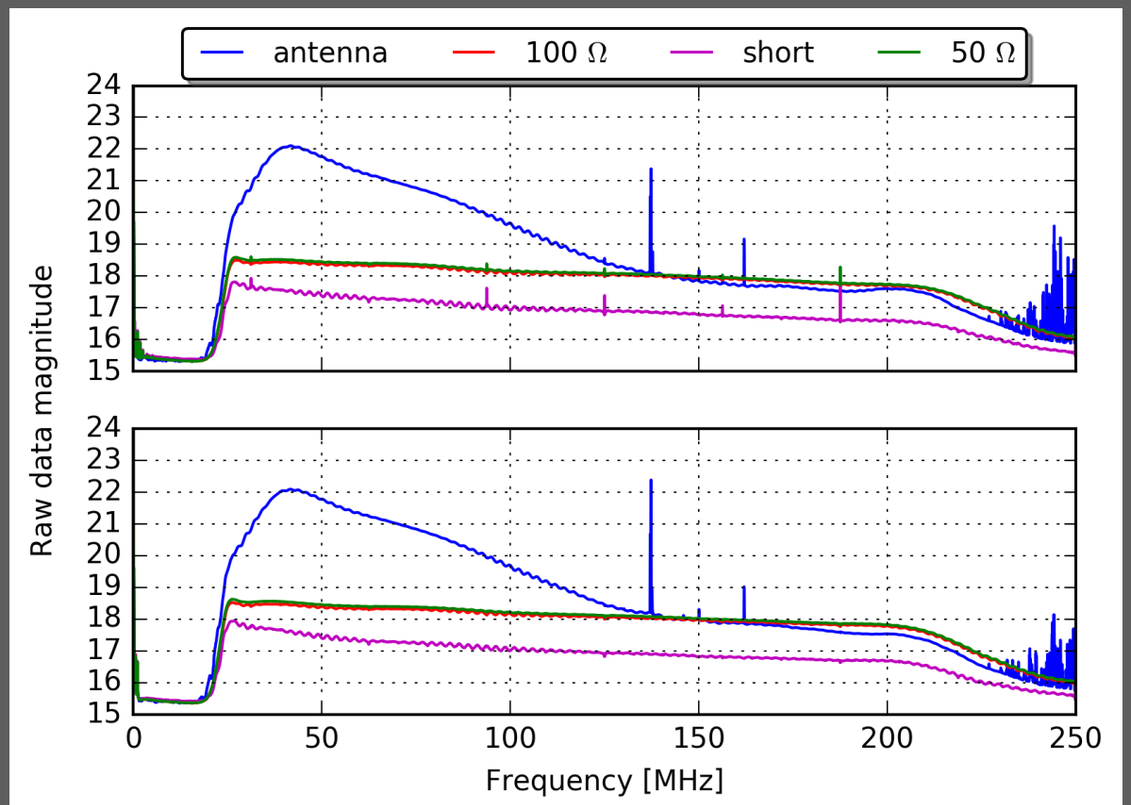


~60 dBm difference between the deployment site and base

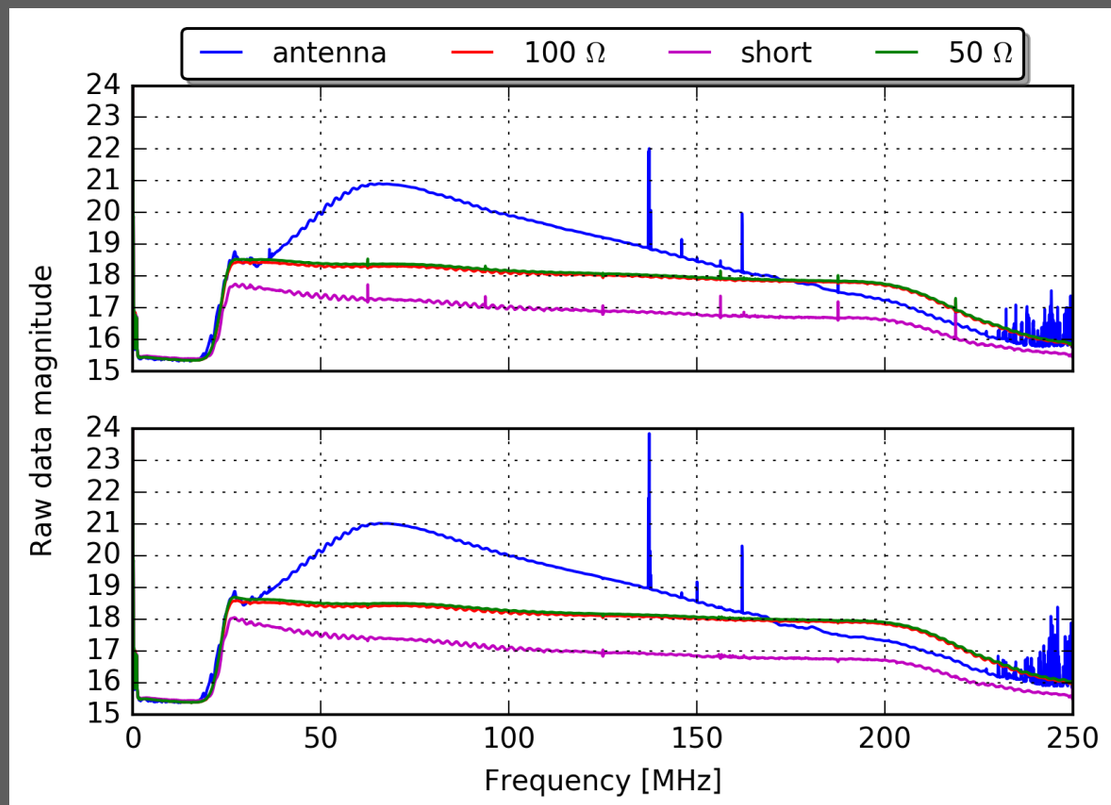
Installation timeline

First light
100 MHz : 21 April
70 MHz : 22 April

Raw data



70 MHz



100 MHz

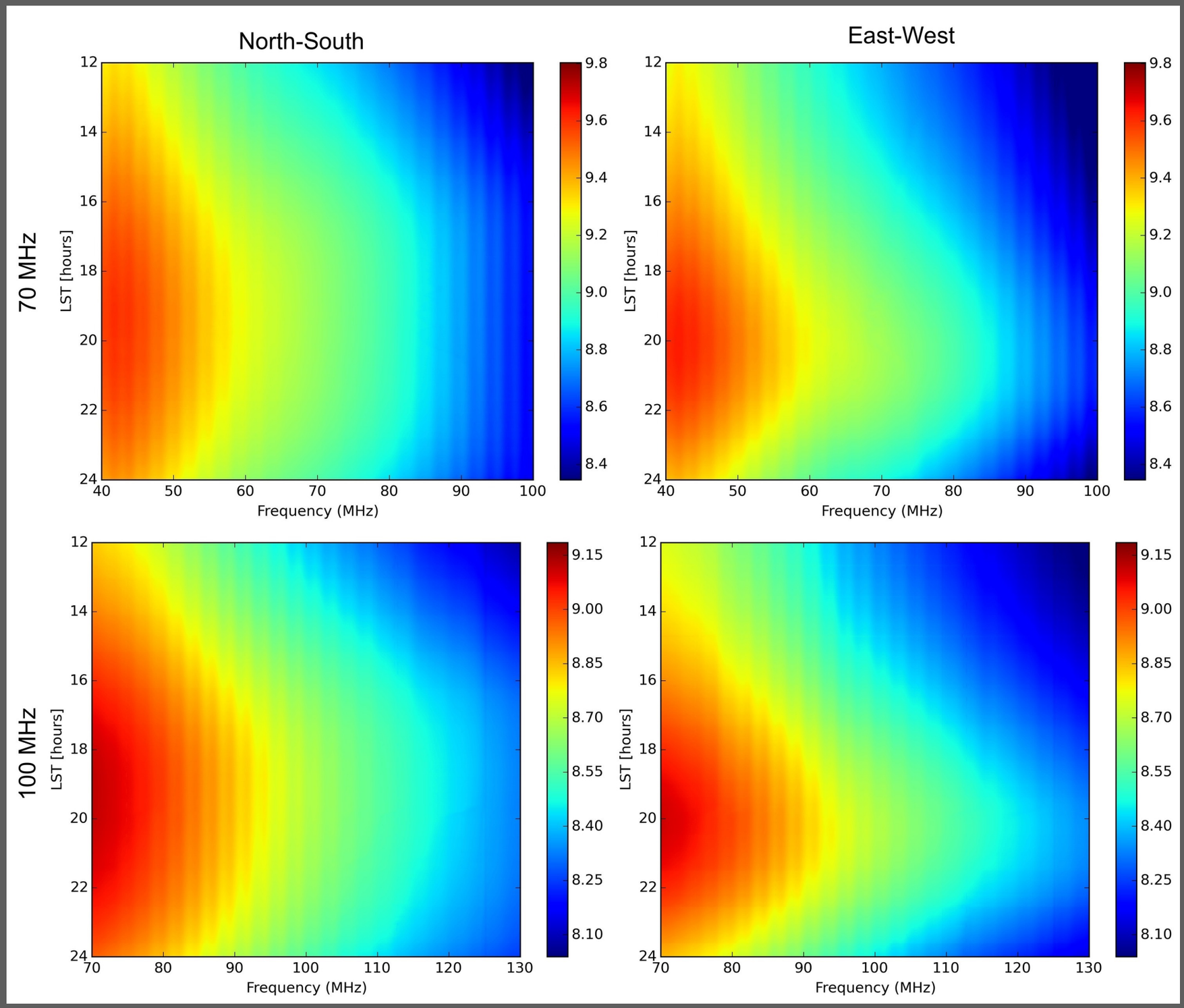
One spectrum per polarization on both systems every ~4 seconds

Data rate ~900 MB per day, both systems combined

Data stored on a micro-SD card on the Raspberry PI.
Several months of data can be stored on a 128 GB card.

12 hour waterfall plot

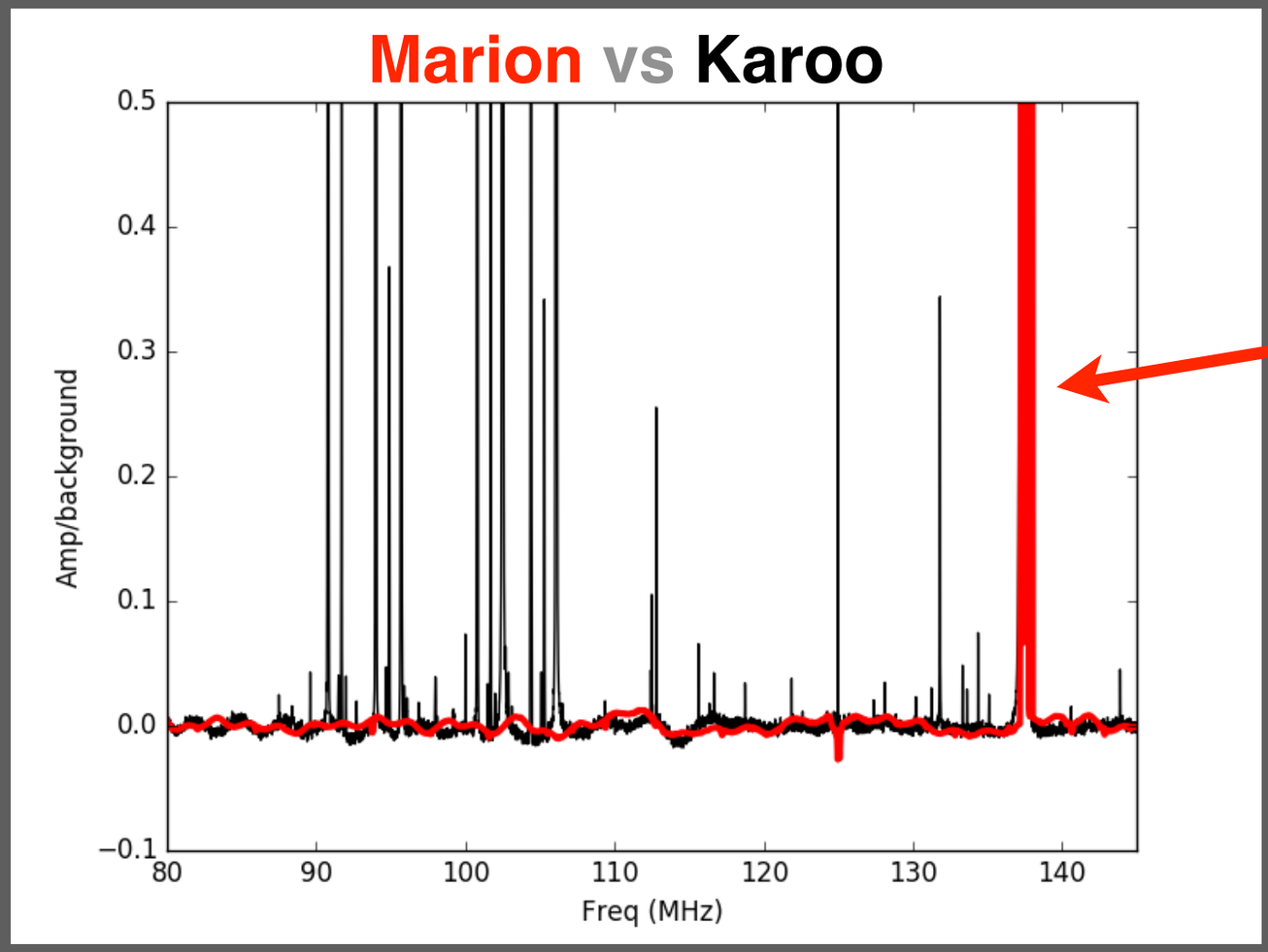
70 MHz



100 MHz

North-South East-West

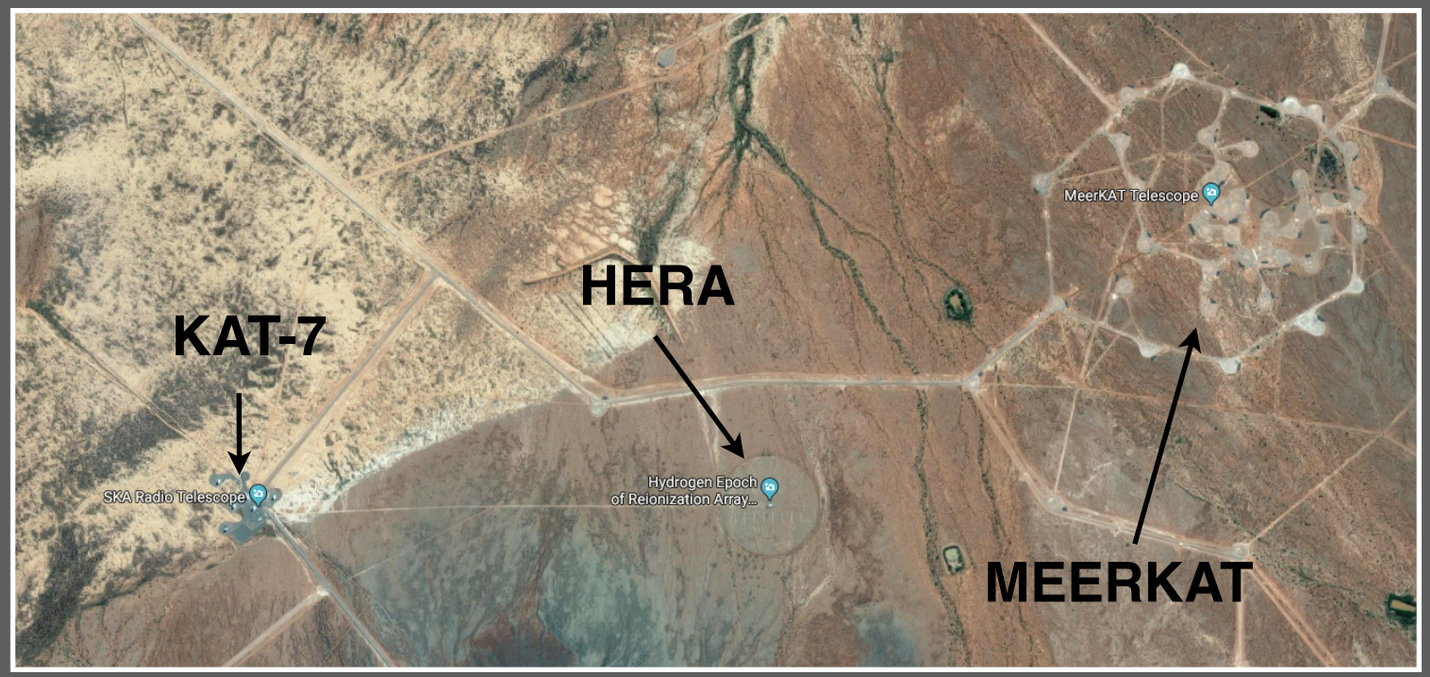
RFI levels — Marion vs SKA site (RSA)



Orbcomm satellite
137—138 MHz

Marion has pristine radio-quiet FM band

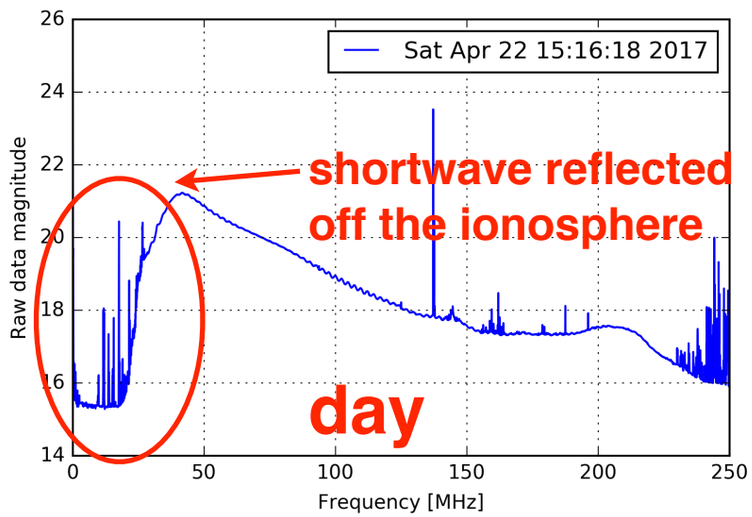
Karoo desert will host the upcoming SKA radio telescopes in South Africa

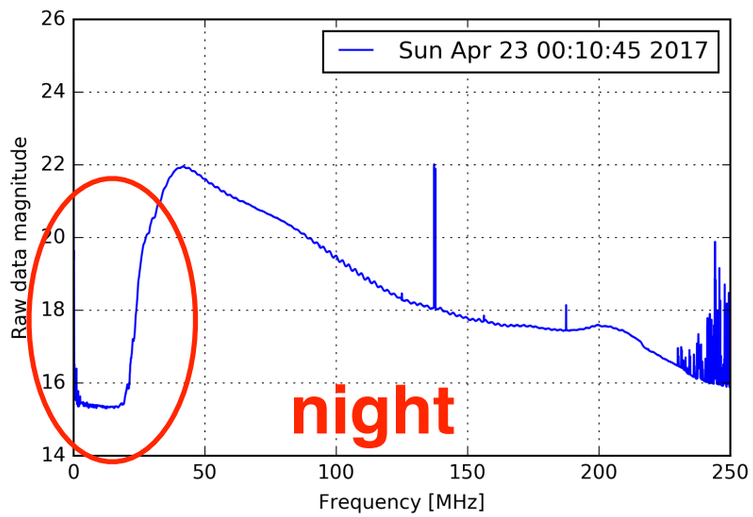


Future works

Instrument paper
coming out soon!

Proposal renewed for the next 3 years !!!





Deploy new instrument to observe lower frequencies during the 2019-20 solar minimum

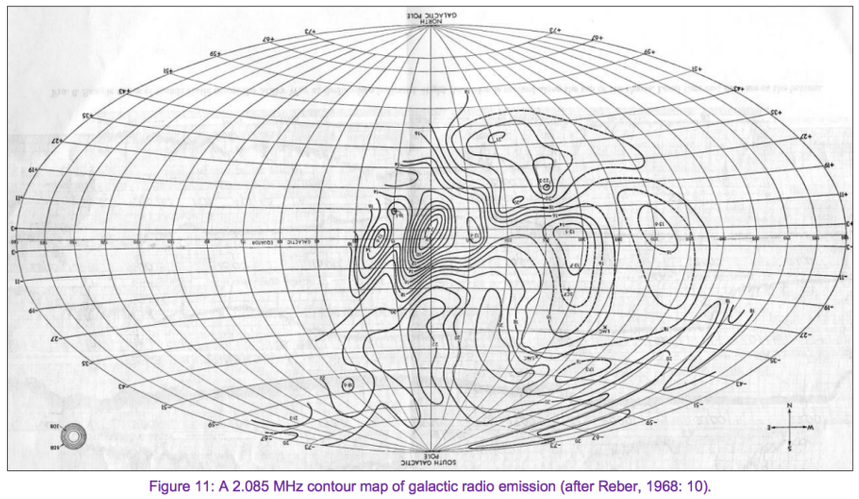
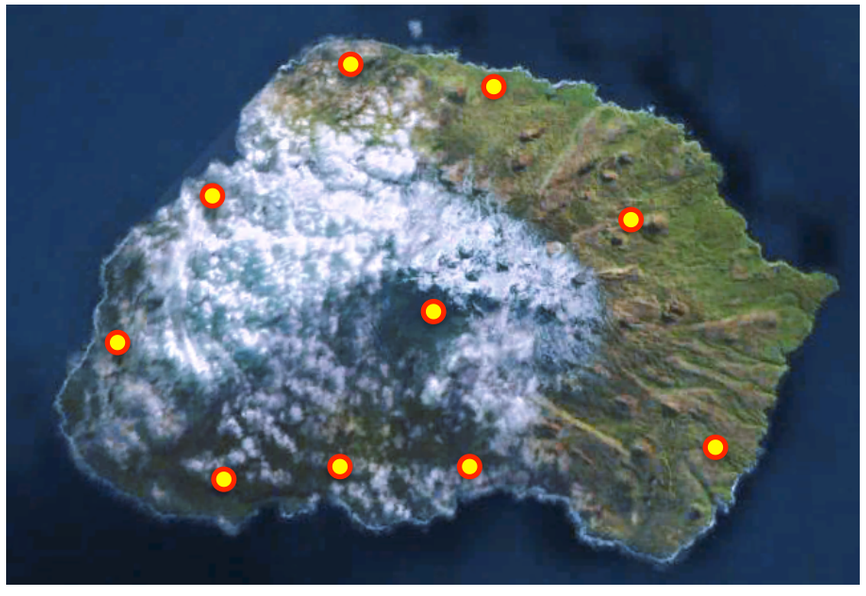


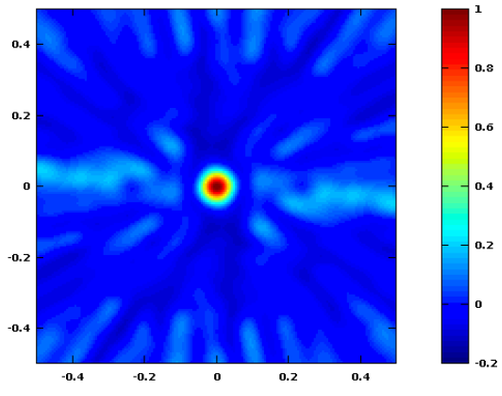
Figure 11: A 2.085 MHz contour map of galactic radio emission (after Reber, 1968: 10).

Grote Reber map from Tasmania (1968)

2.085 MHz, ~5 deg resolution



existing huts provide infrastructure and convenient baselines for new low-frequency antennas



5 MHz beam from Marion, 8' FWHM