HERA

The Hydrogen Epoch of Reionization Array

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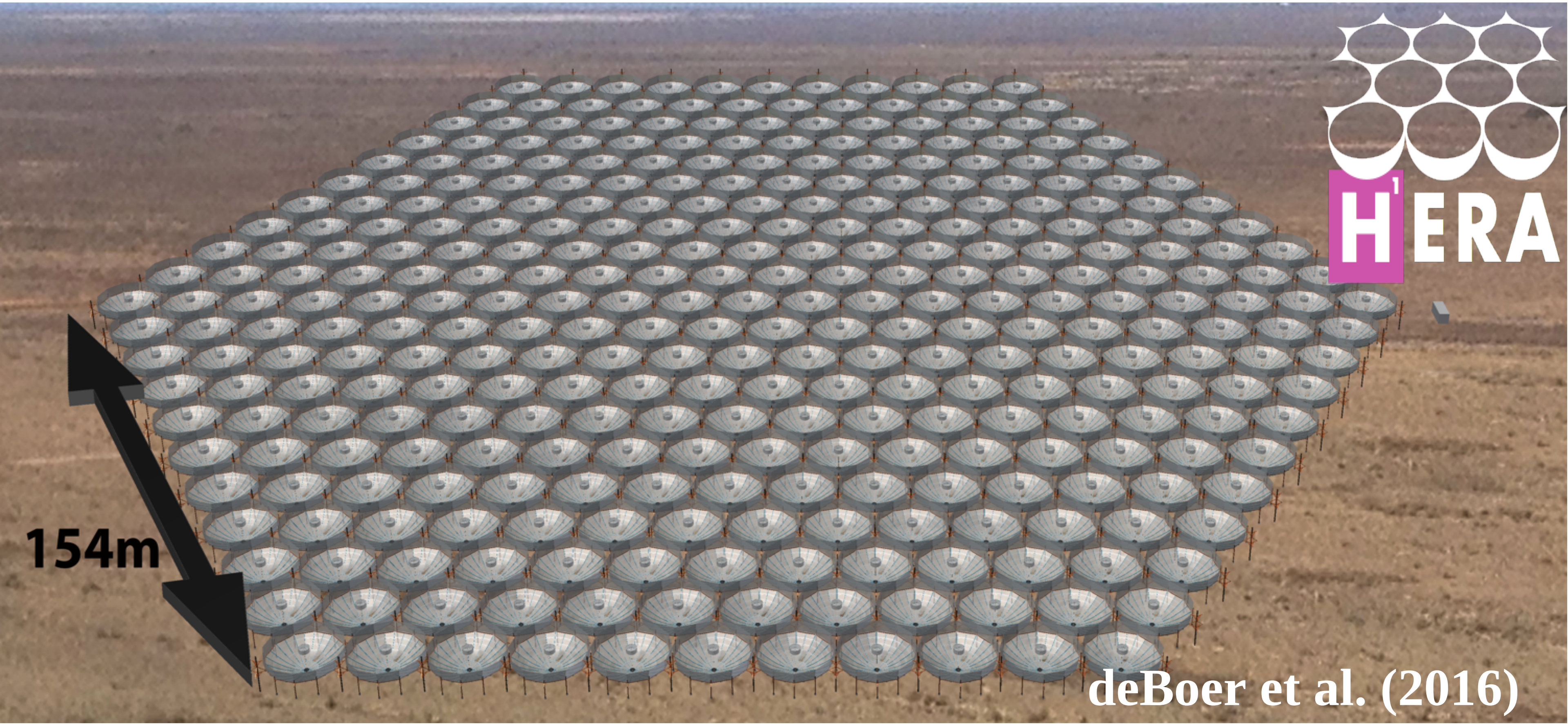
on behalf of the HERA collaboration

(special thanks to J. Aguirre, C. Carilli, A. Ghosh, T. Grobler and N. Kern)

"SALF IV", Sydney, 13/12/2017

HERA

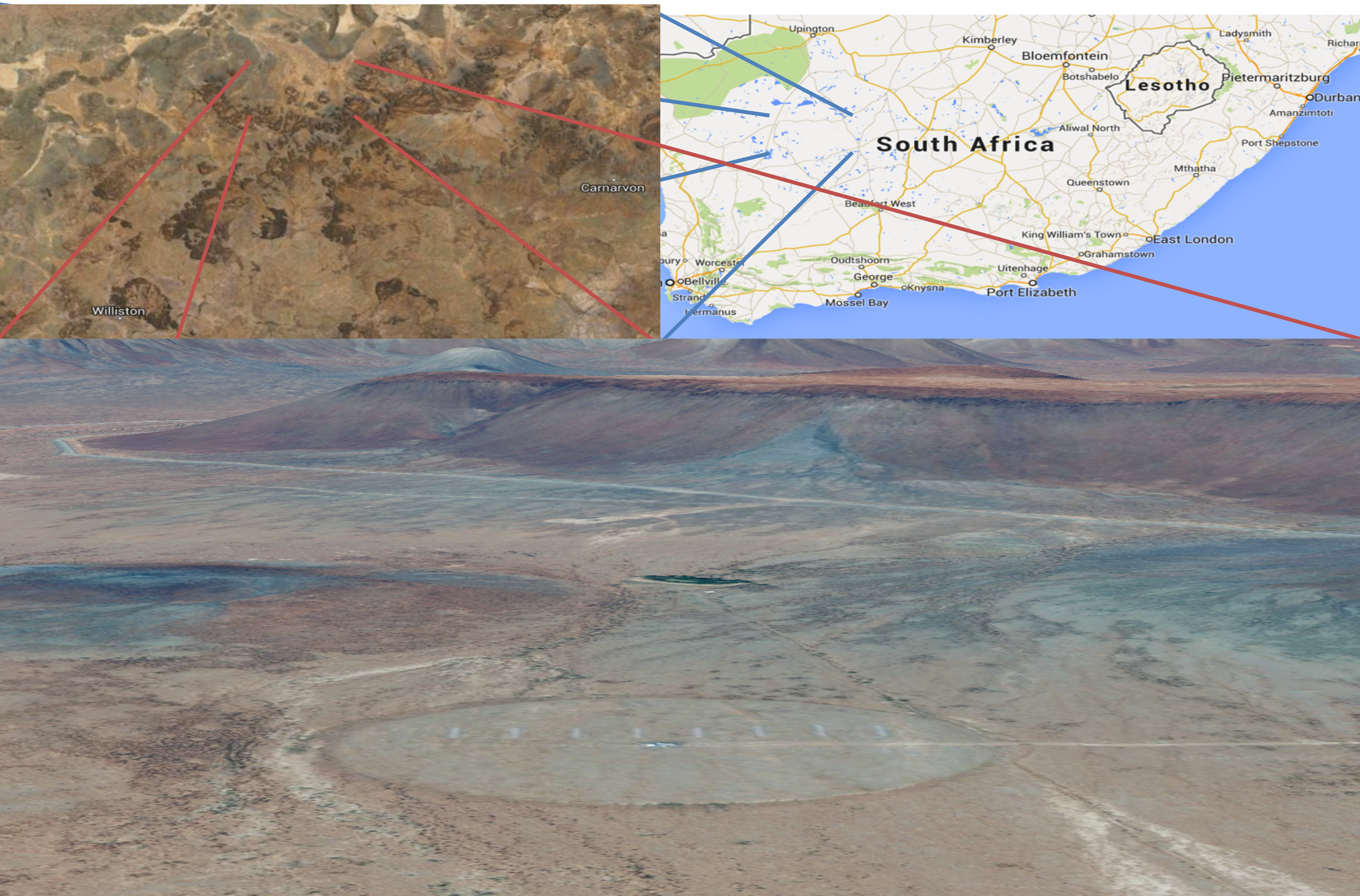


HERA

Instrument Design Specification	Observational Performance
Element Diameter: 14 m	Field of View: 9°
Minimium Baseline: 14.6 m	Largest Scale: 7°8
Maximum Core Baseline: 292 m	Core Synthesized Beam: 25′
Maximum Outrigger Baseline: 876 m	Outrigger Synthesized Beam: 11′
EOR Frequency Band: 100–200 MHz	Redshift Range: $6.1 < z < 13.2$
Extended Frequency Range: 50–250 MHz	Redshift Range: $4.7 < z < 27.4$
Frequency Resolution: 97.8 kHz	LoS Comoving Resolution: 1.7 Mpc (at $z = 8.5$)
Survey Area: ~1440 deg^2	Comoving Survey Volume: ~150 Gpc^3
T_{sys}: $100 + 120(\nu/150\,\text{MHz})^{-2.55}$ K	Sensitivity after 100 hr: 50 μJy beam^{-1}

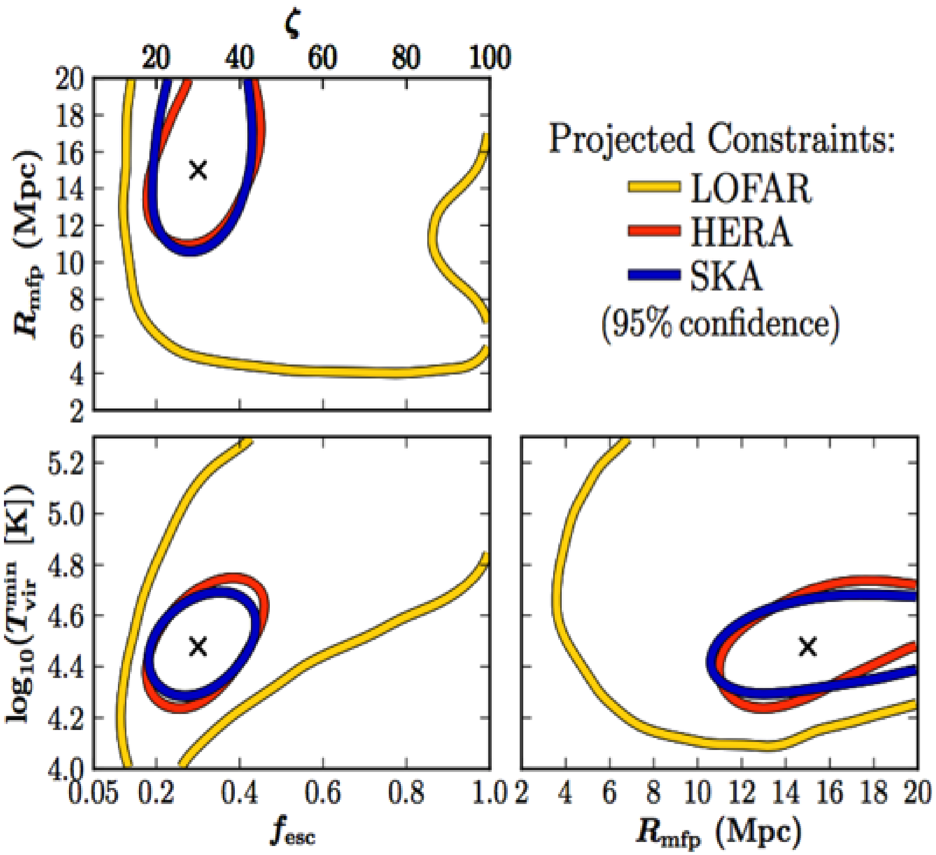
Note. Angular scales computed at 150 MHz.

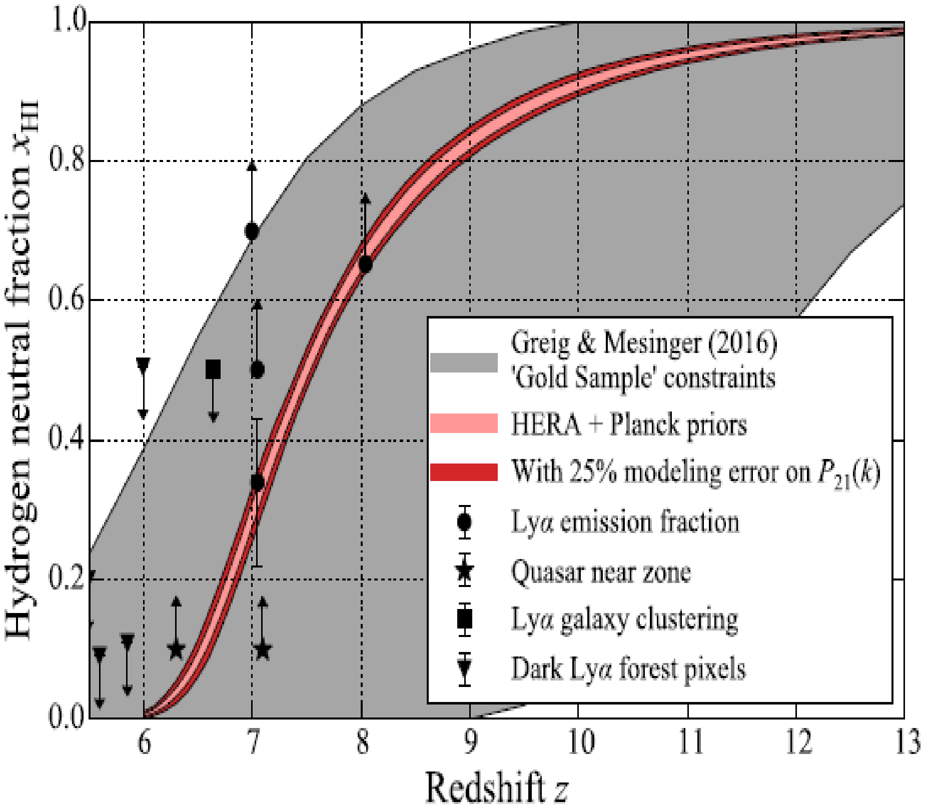
Where?


Carnarvon
Williston
Upington
Kimberley
Bloemfontein
Botshabelo
Lesotho
Ladysmith
Richards
Pietermaritzburg
Durban
Amanzimtoti
Aliwal North
Port Shepstone
South Africa
Mthatha
Queenstown
Beaufort West
King William's Town
East London
Grahamstown
Worcester
Oudtshoorn
Uitenhage
George
Bellville
Knysna
Port Elizabeth
Strand
Mossel Bay
Hermanus

Where?

HERA's scientific rationale: precise constraints on reionization





deBoer et al. (2016), Greig & Mesinger (2016)

deBoer et al. (2016), Liu & Parsons (2015)

HERA's drivers/pillars:

1) boosted power spectrum sensitivity at certain k modes;

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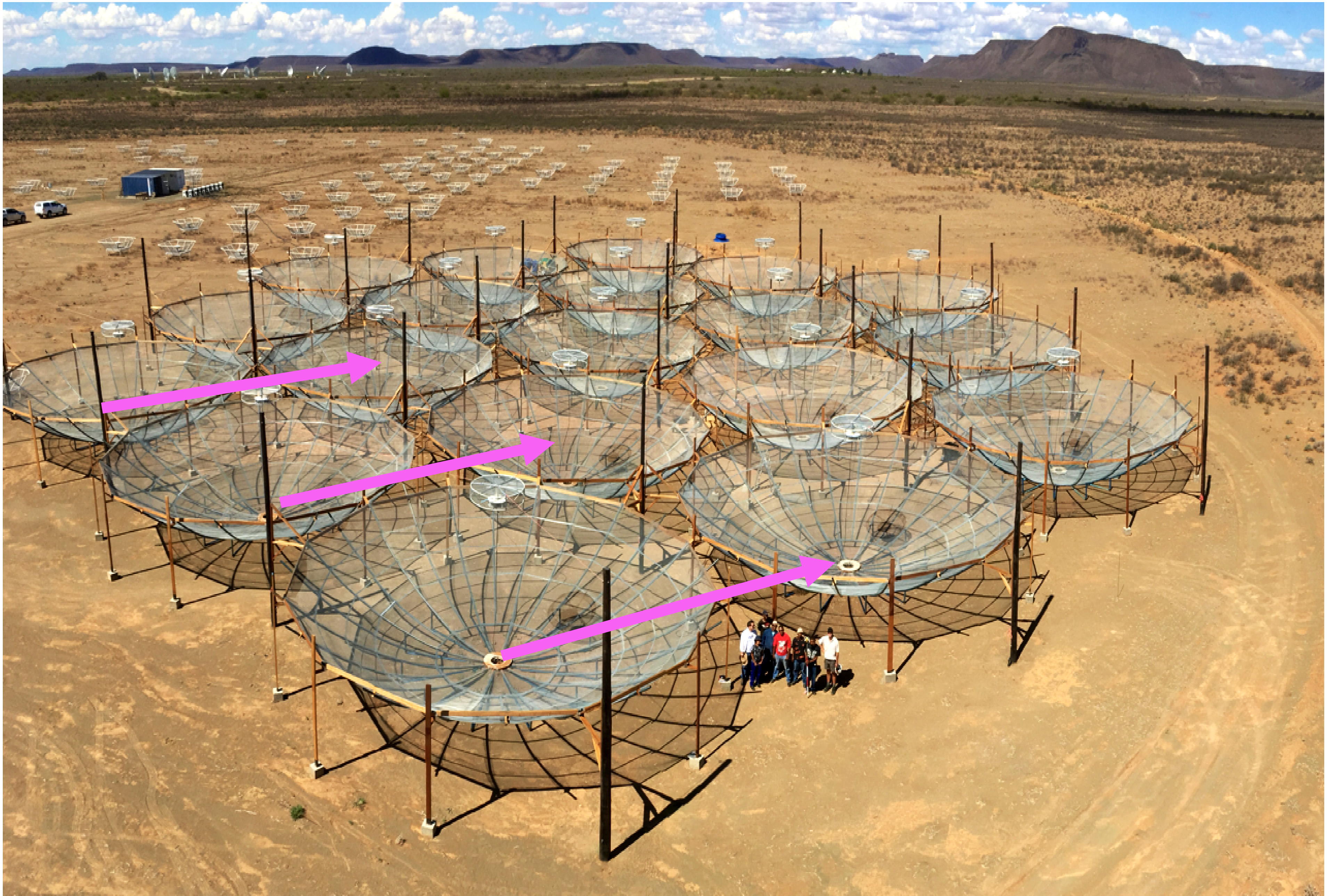
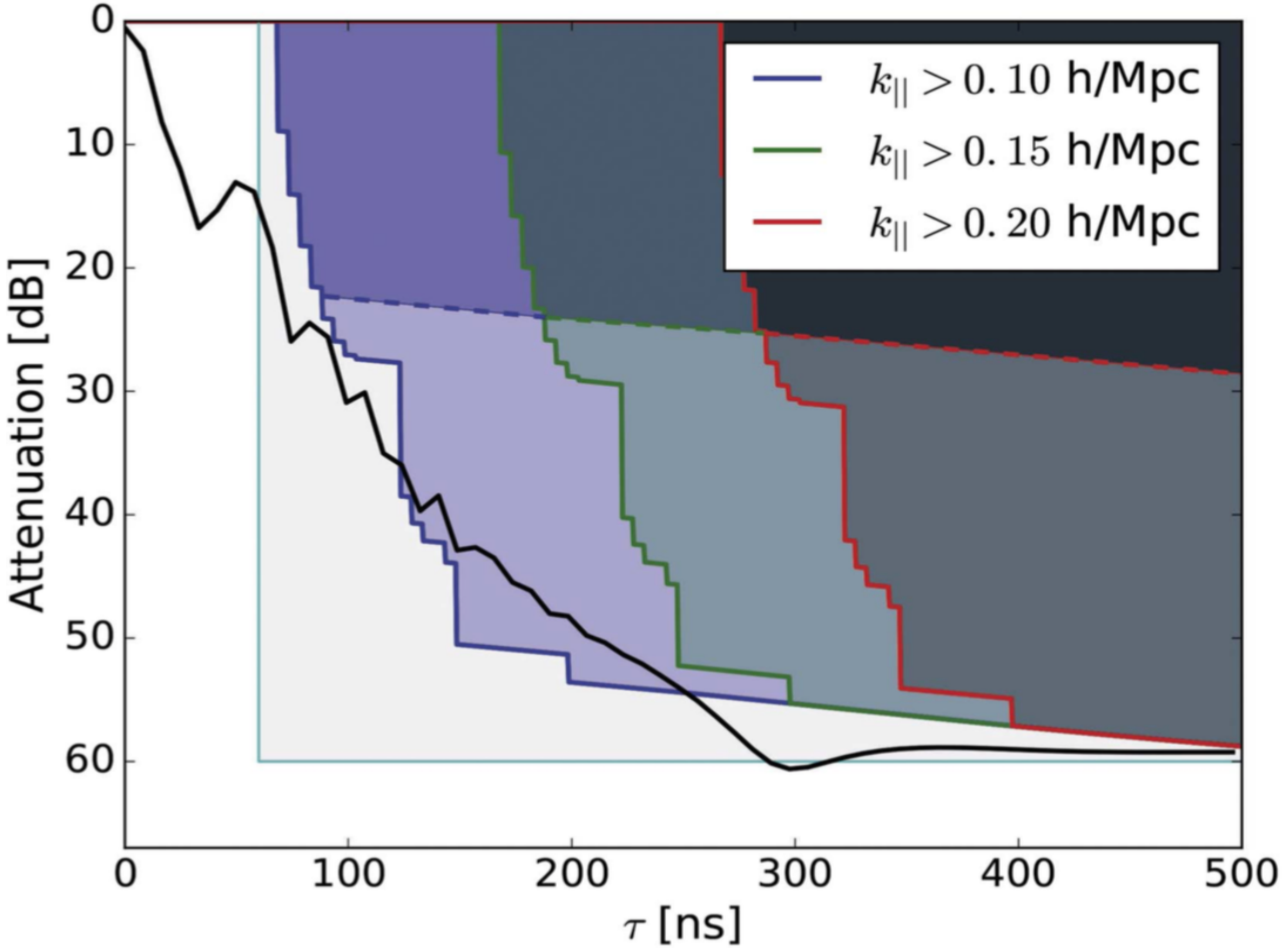
(also allowing for accurate calibration, see Ali's poster)



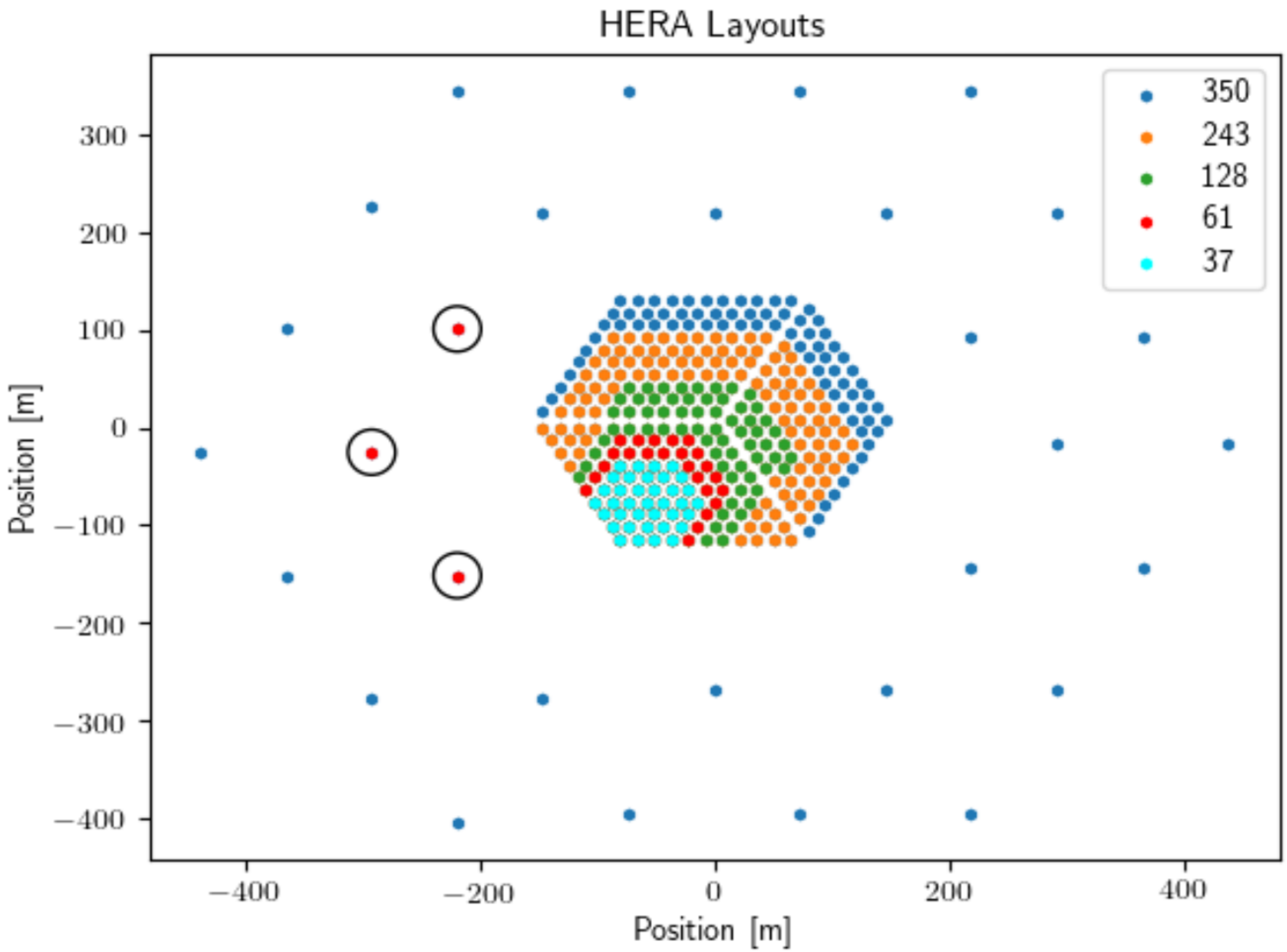
HERA's drivers/pillars:

1) boosted power spectrum sensitivity at certain k modes;
2) design choices that preserve the intrinsic frequency smoothness of foregrounds (i.e. confined at the lowest $k_{||}$ possible);



Thyagarajan et al. (2016)
(see also Neben et al. 2016,
Ewall-Wice et al. 2016,
Patra et al. 2017)

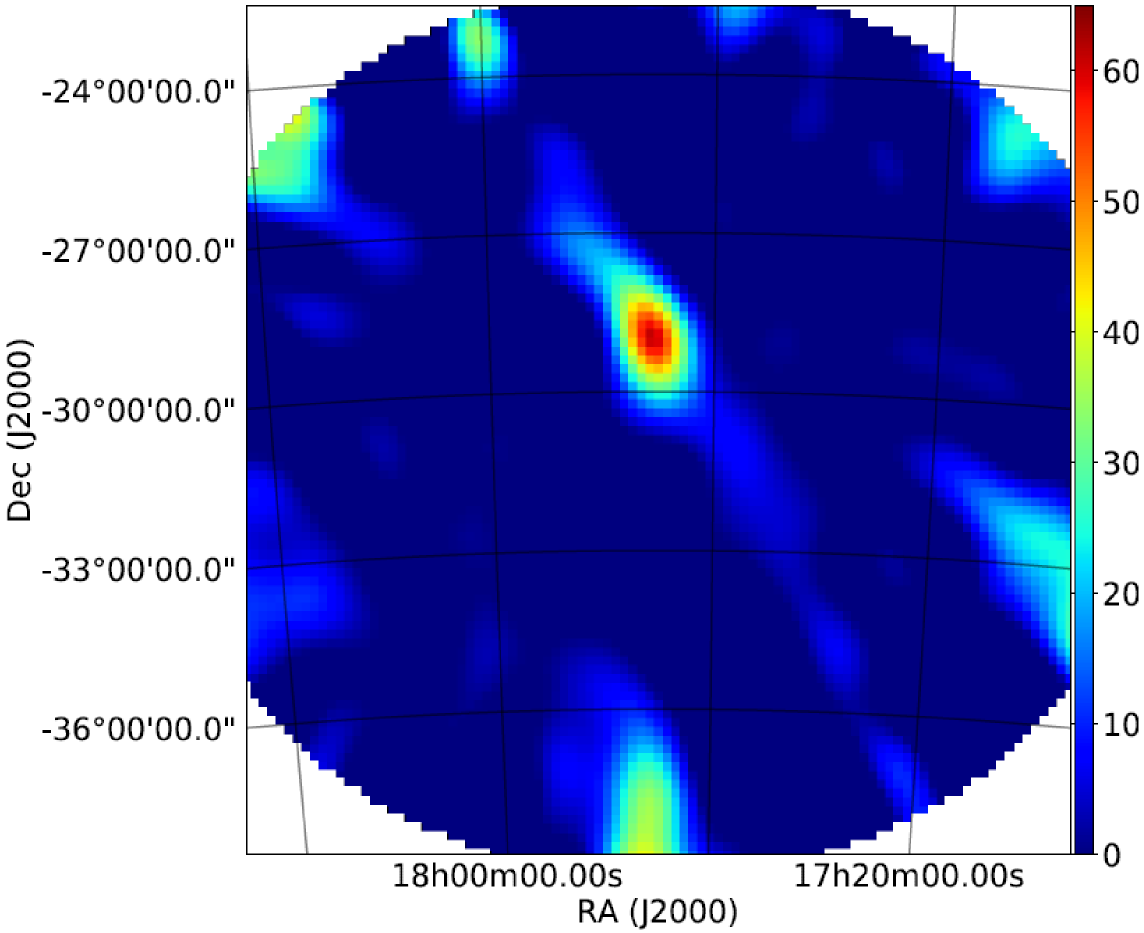
A staged build out: first 19 dishes (HERA-19)



The first 19 dishes

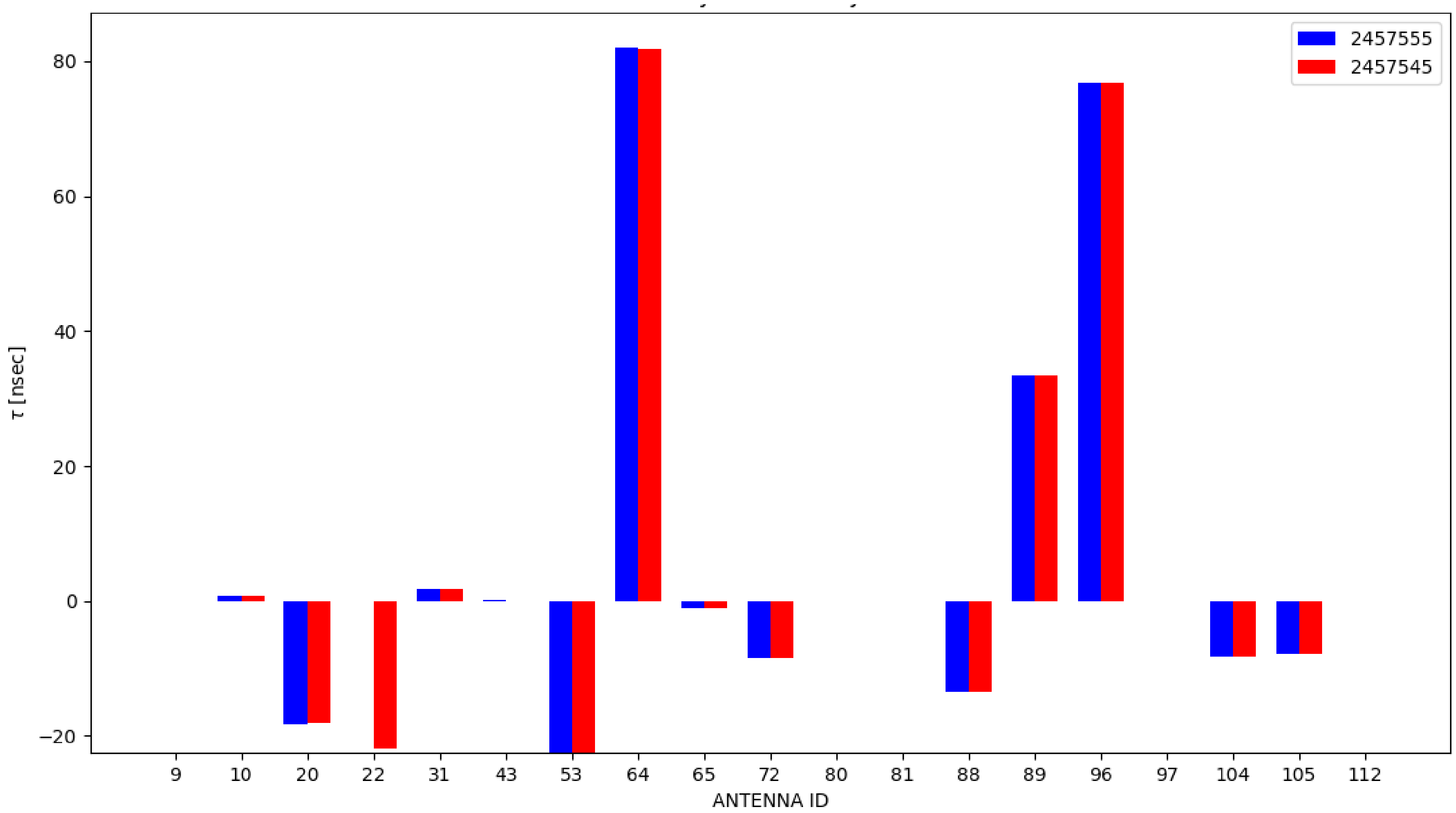
HERA-19 observations, commissioning and early results

- An “unpopular” route: sky-based calibration (i.e. not taking advantage of redundancy) and “see what happens”;
- use of the Galactic centre as a point source calibrator;
- fix the absolute flux density calibration a posteriori;
- observe the (possible) spectral structure induced on foregrounds;



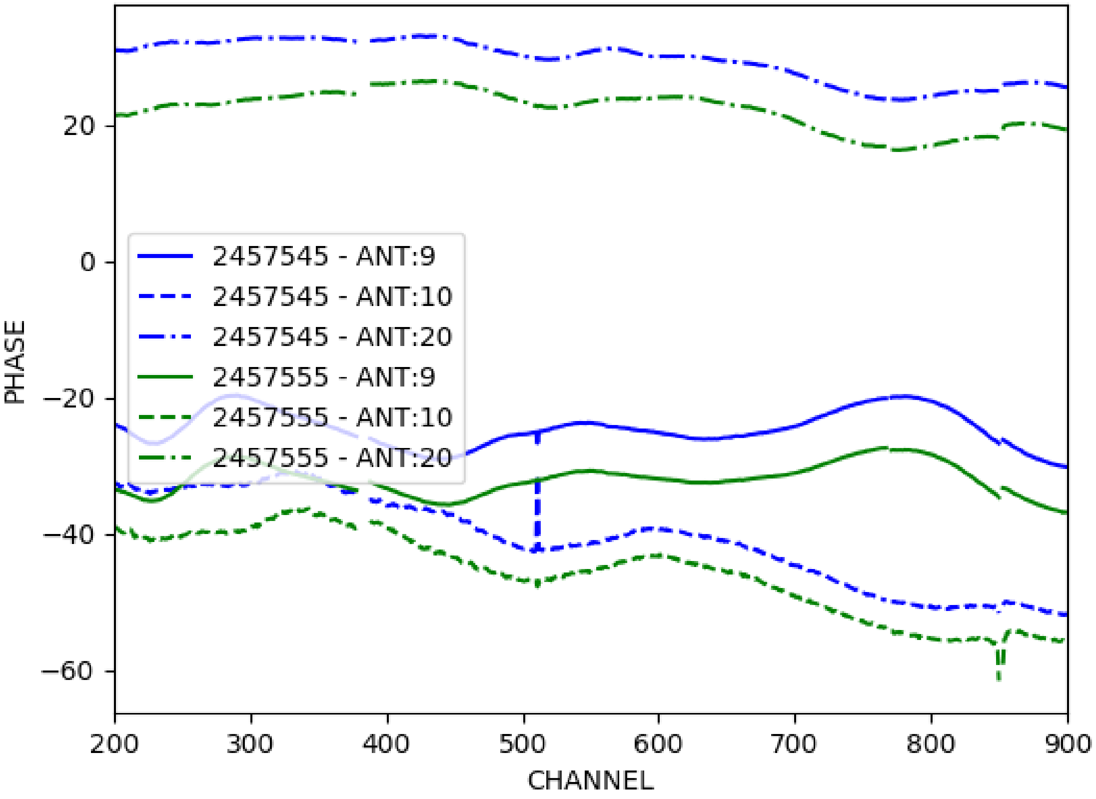
- 60 MHz bandwidth (120-180 MHz);
- ~2 degree angular resolution;

Instrument performances

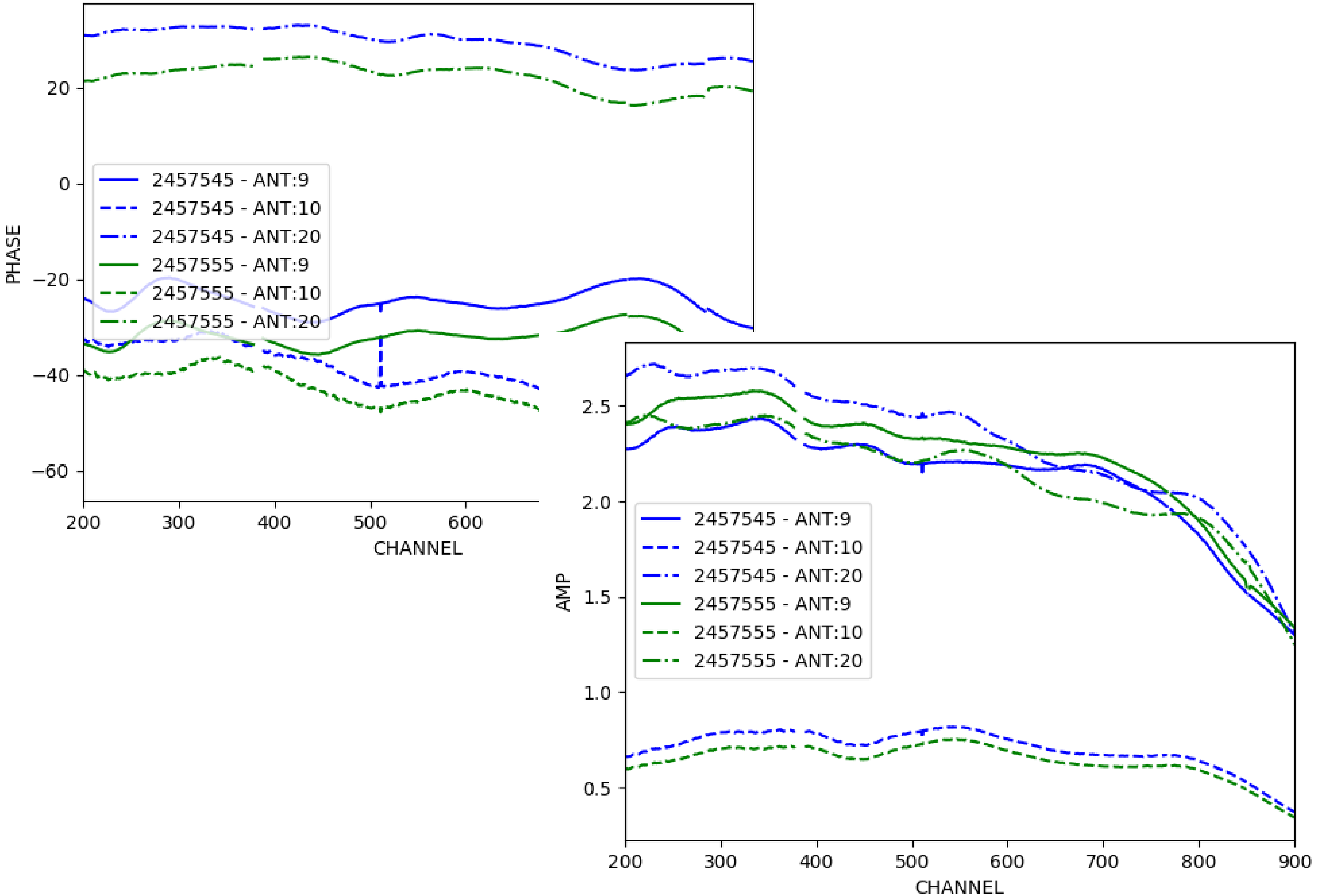


Antenna delays are stable within a few nsec over ten days

Instrument performances

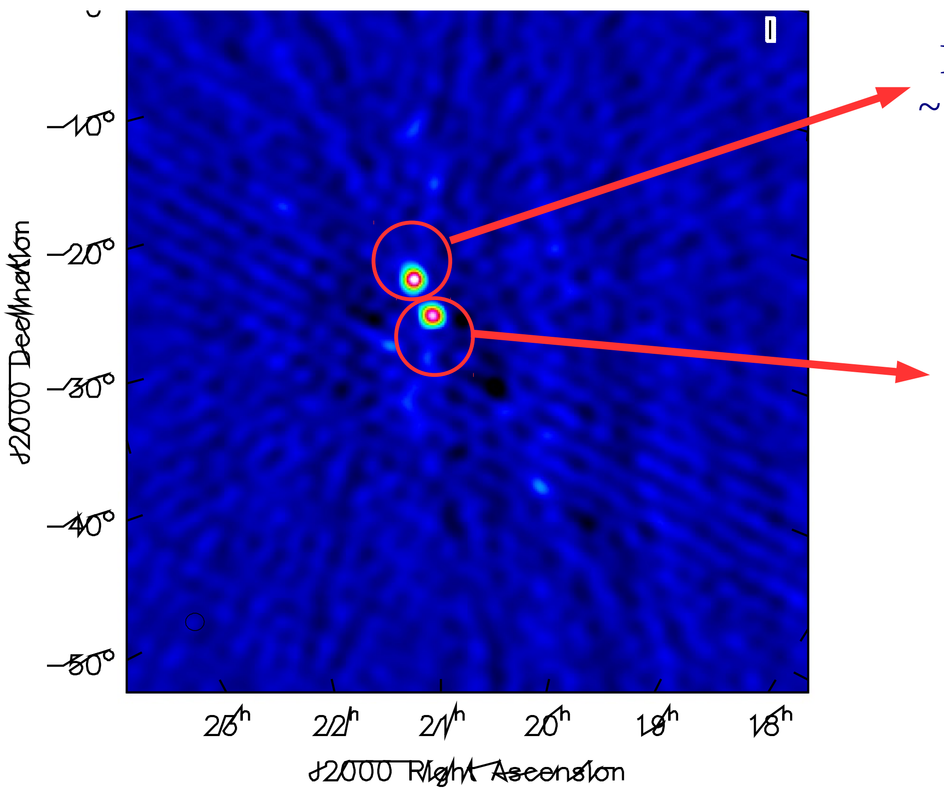


Instrument performances

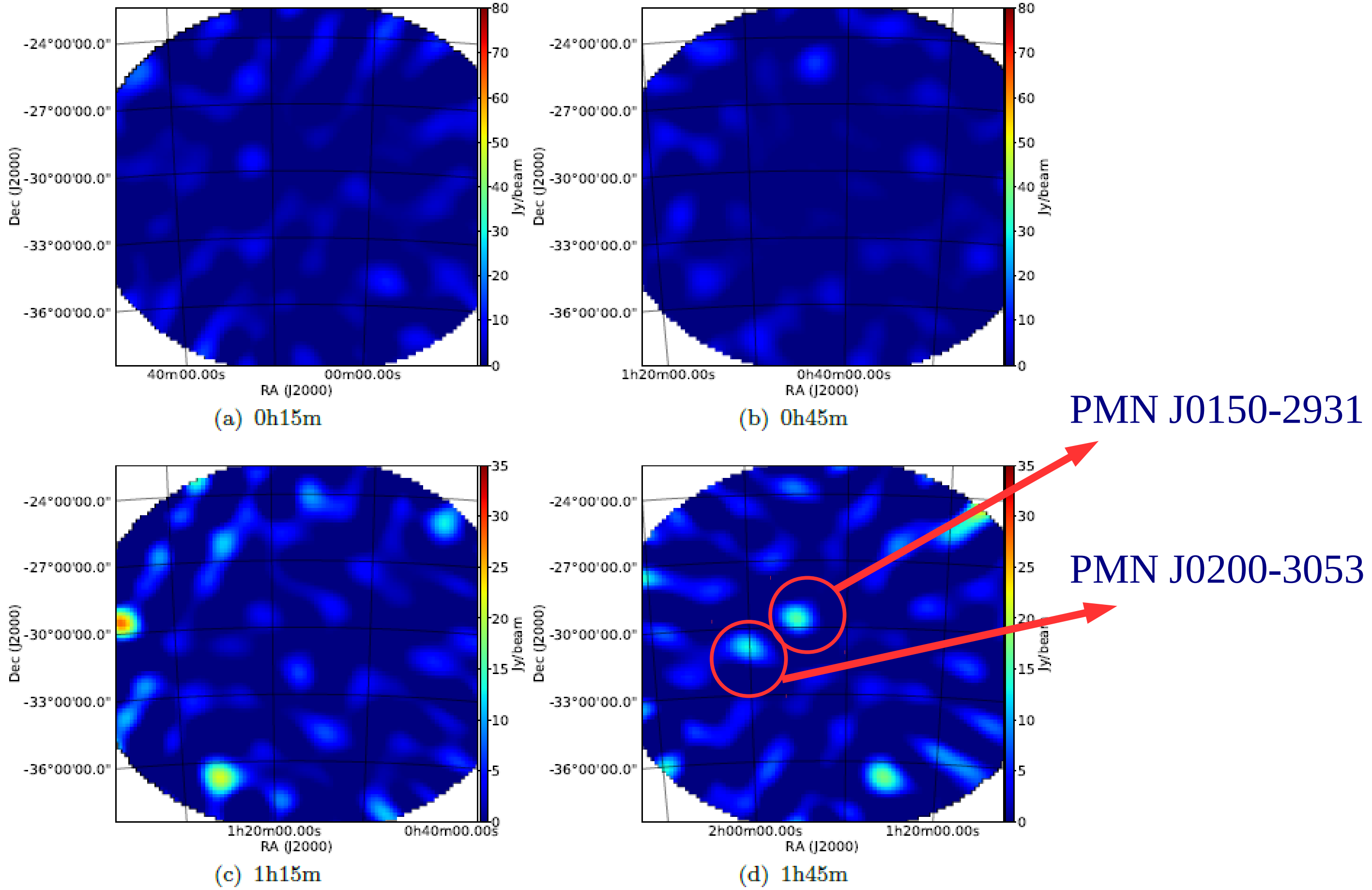


Absolute calibration

Two known sources can be seen by just applying solutions from the Galacti centre and can be used to set the absolute flux density scale

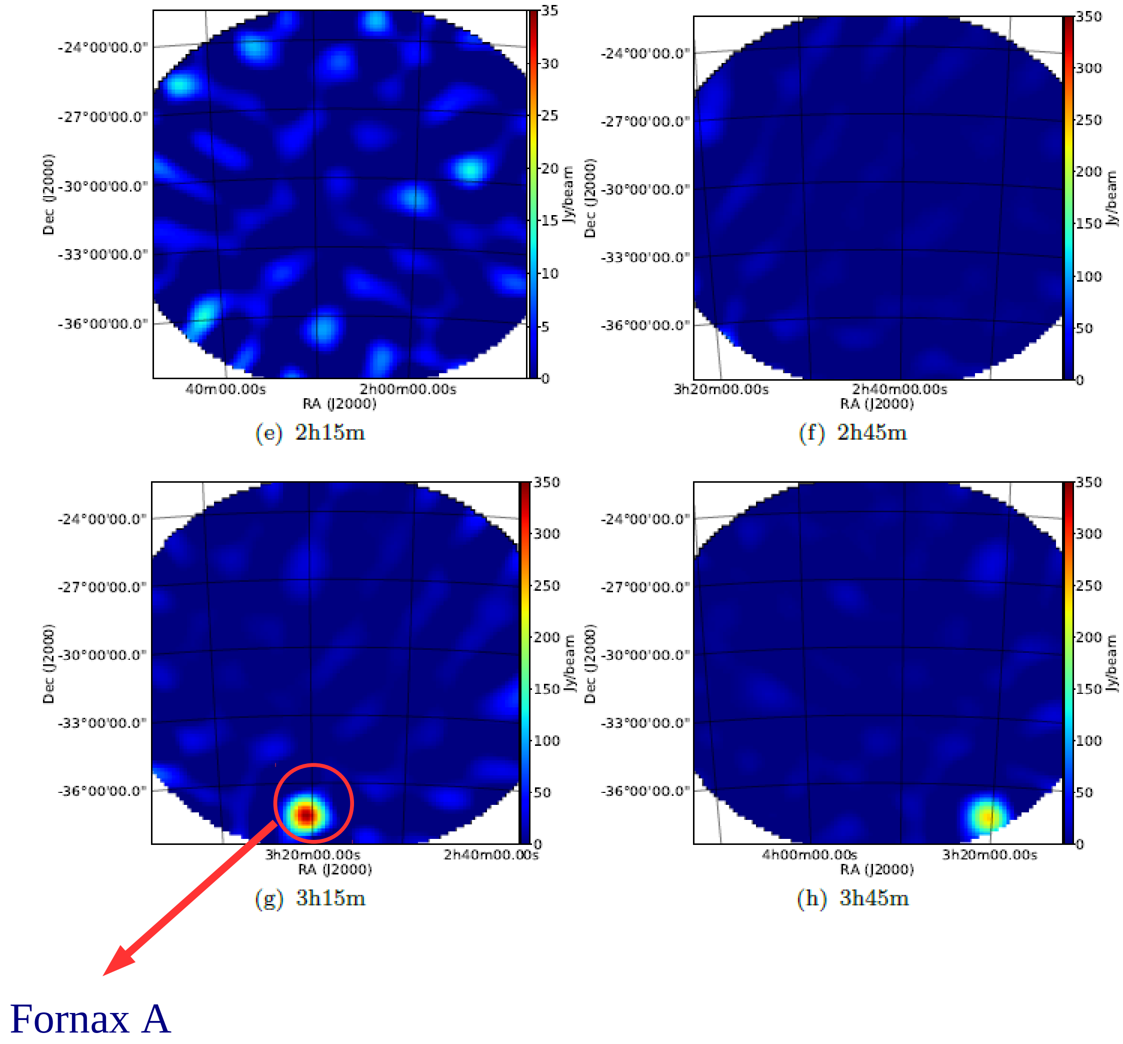


The sky seen by HERA-19



24 hours of data, spanning 0 < α < 14. Complex gains computed once (GC), absolute flux density calibration computed once

The sky seen by HERA-19



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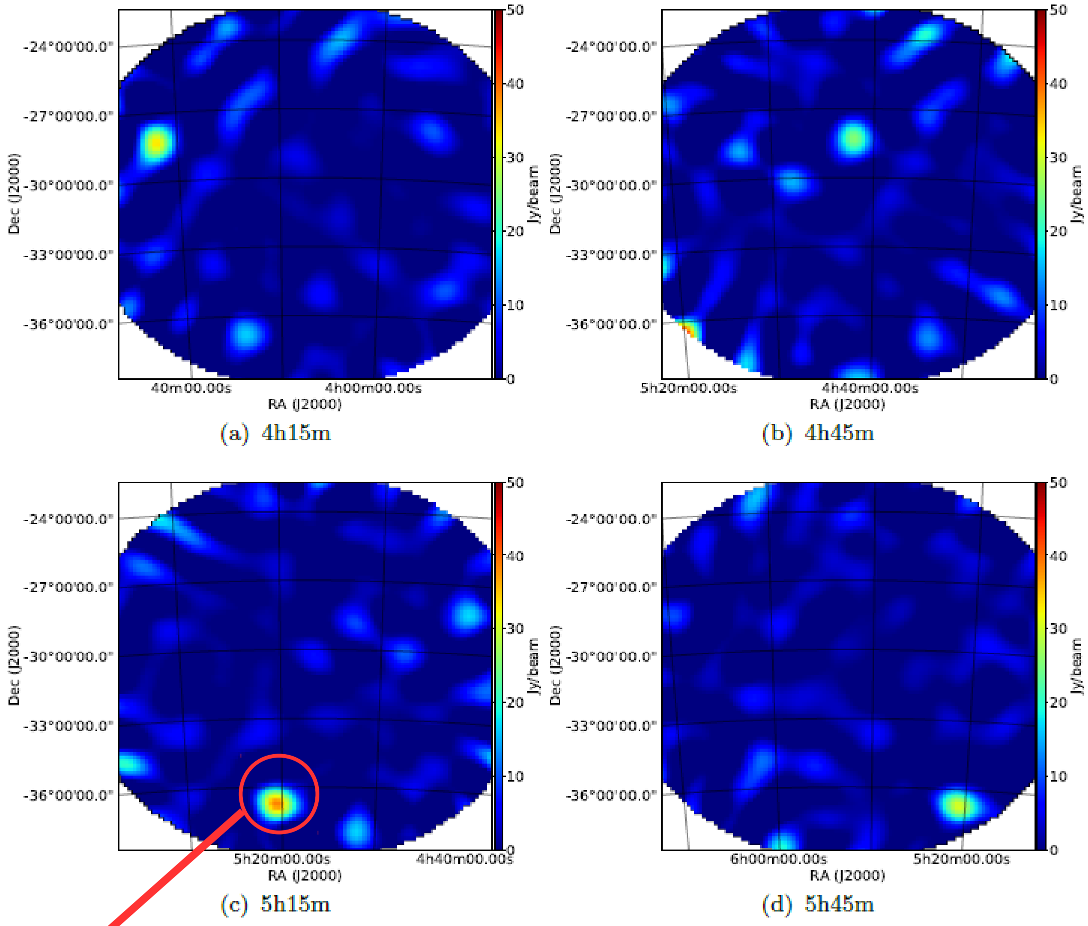
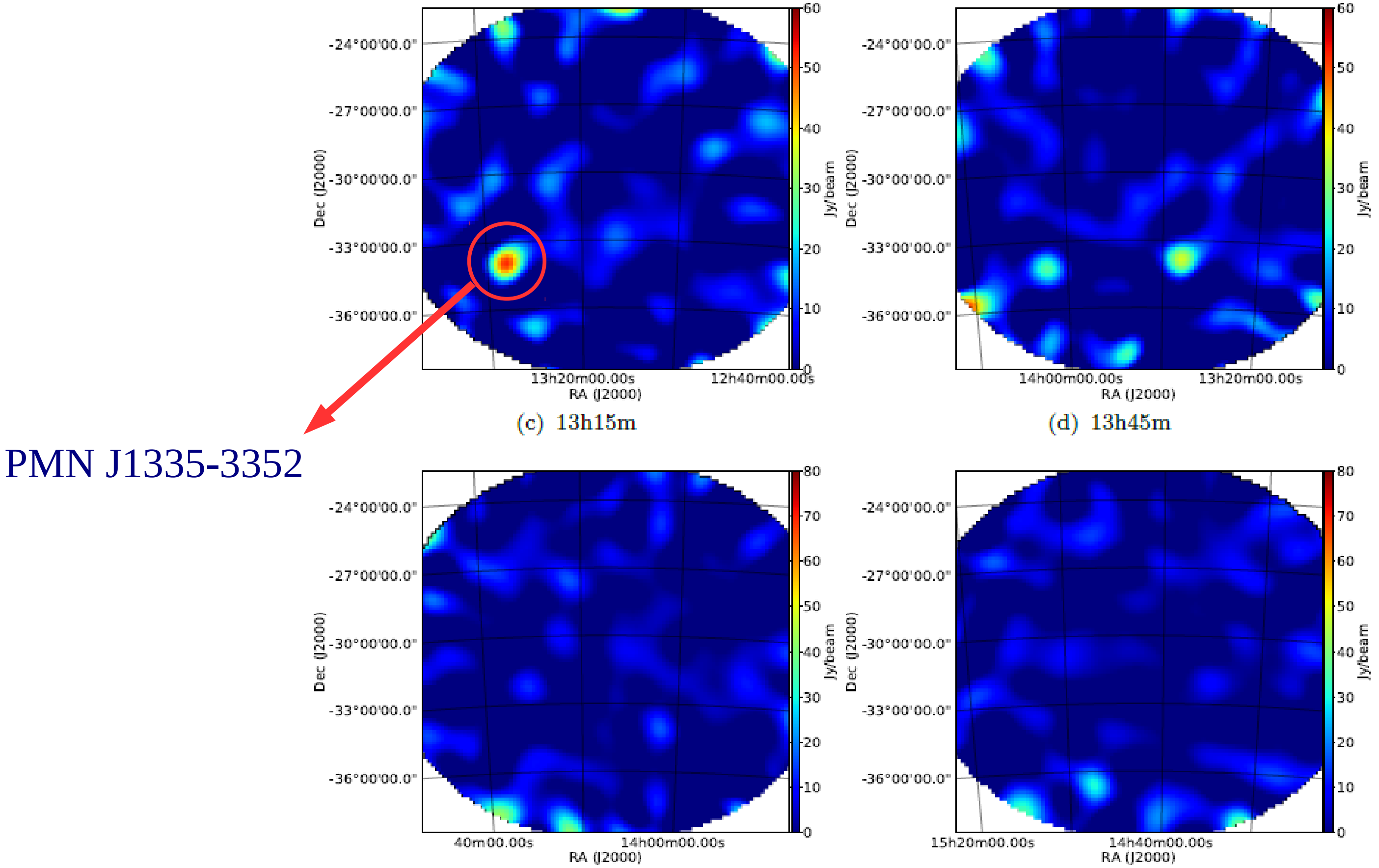


PMN J0522-3628
~ 57 Jy @ 150 MHz

The sky seen by HERA-19



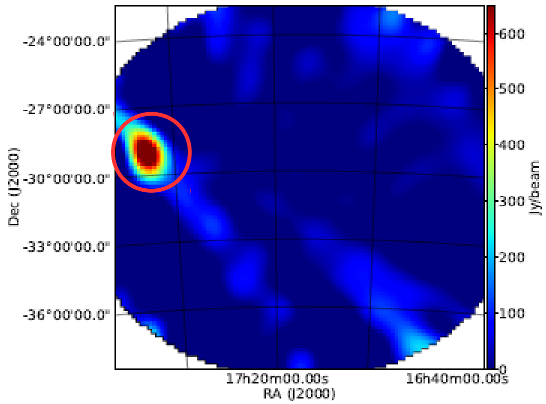
(c) 13h15m

(d) 13h45m

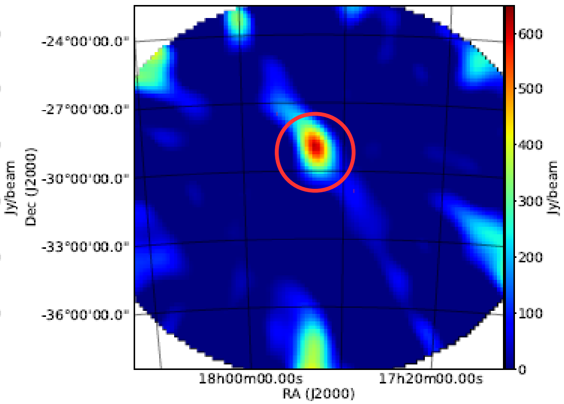
(e) 14h15m

(f) 14h45m

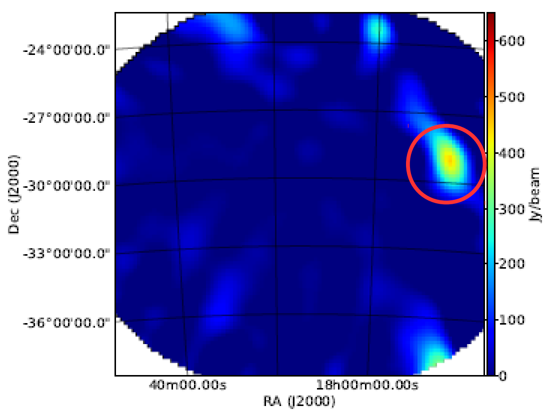
The sky seen by HERA-19



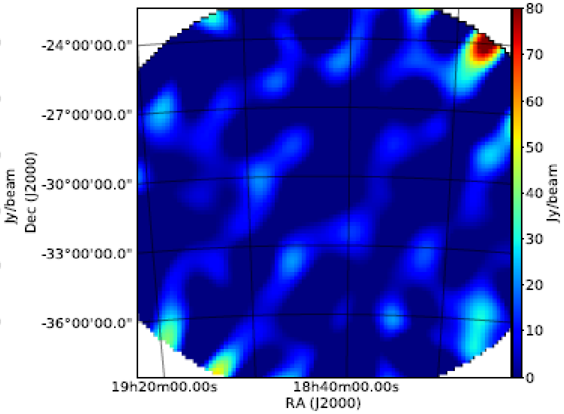
(c) 17h15m



(d) 17h45m



(e) 18h15m

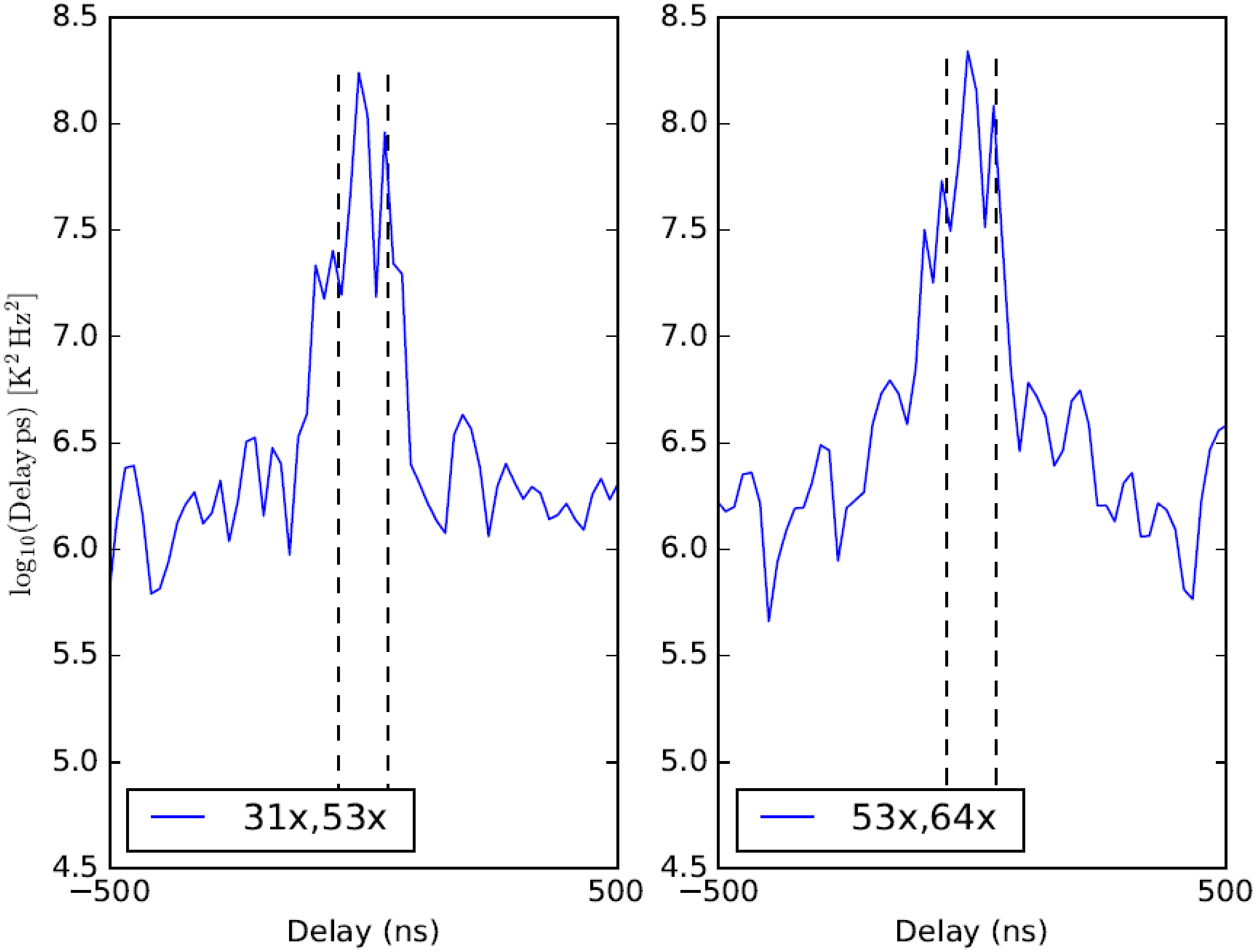


(f) 18h45m

Delay transforms (foreground isolation)

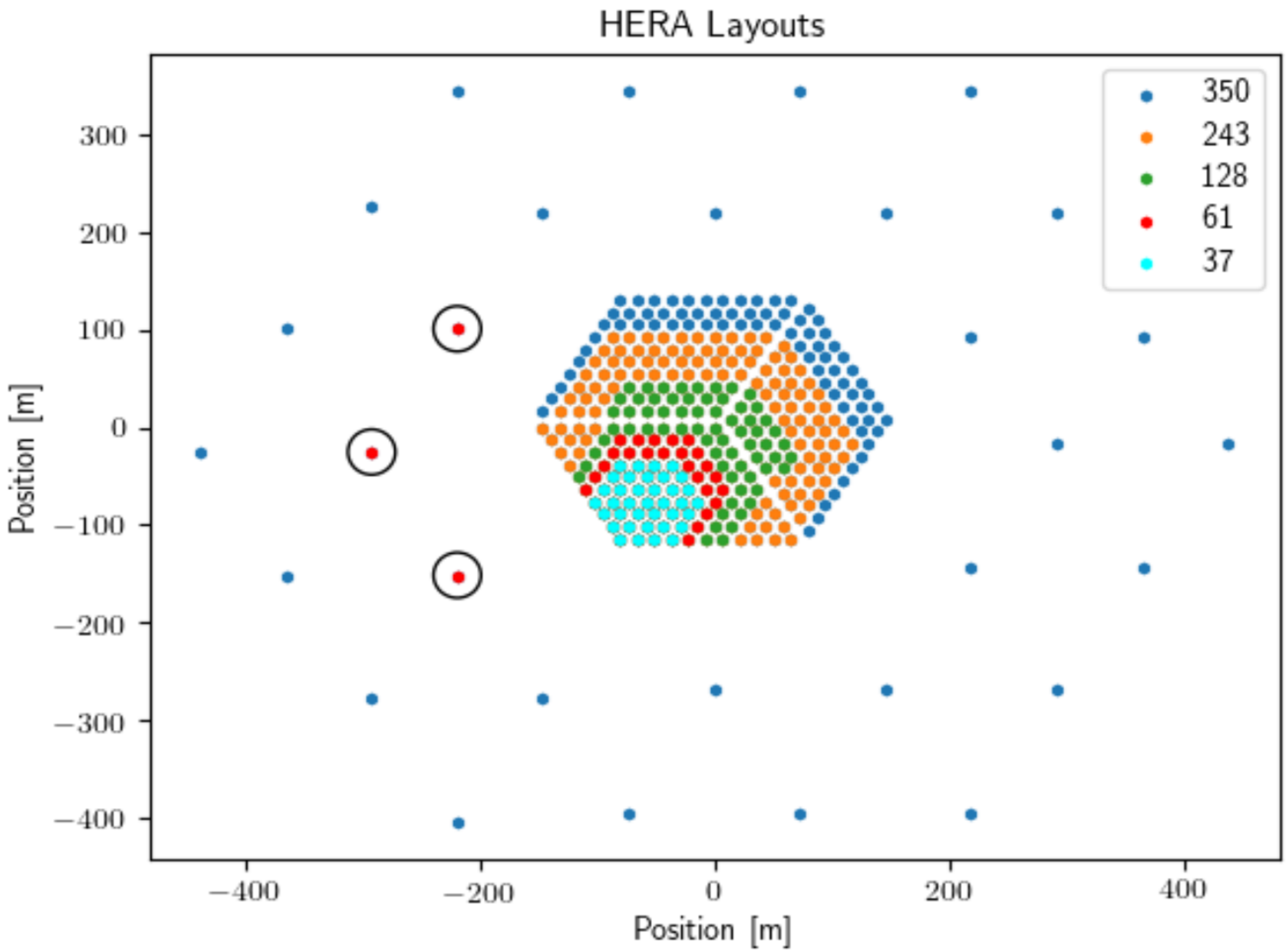
$$\tilde{v}(\mathbf{b},\tau) = \int_B w(\nu) v(\mathbf{b},\nu) e^{-2\pi i \nu \tau} d\nu$$

$$p(k) = p(\sqrt{k_\perp^2 + k_\parallel^2}) \propto |\tilde{v}(|(\mathbf{b}|,\tau)|^{\mathbf{2}}$$

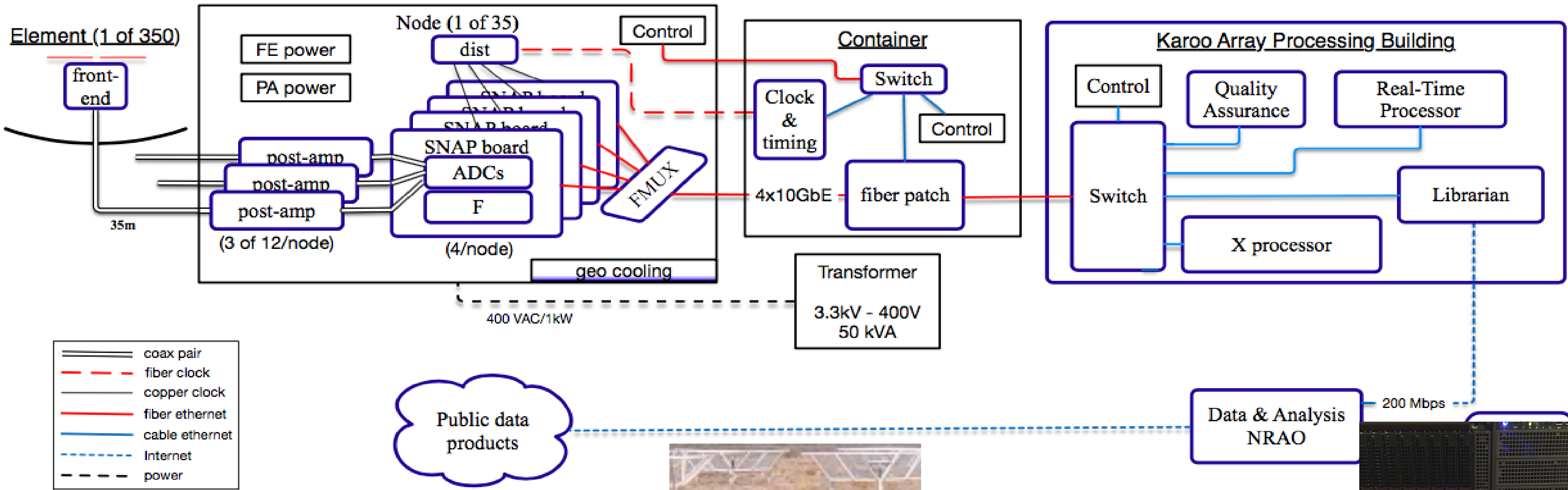


14.6 m baselines

Coming up next: HERA-61



Coming up next: HERA-61



35 m coax cable

10 Gb link

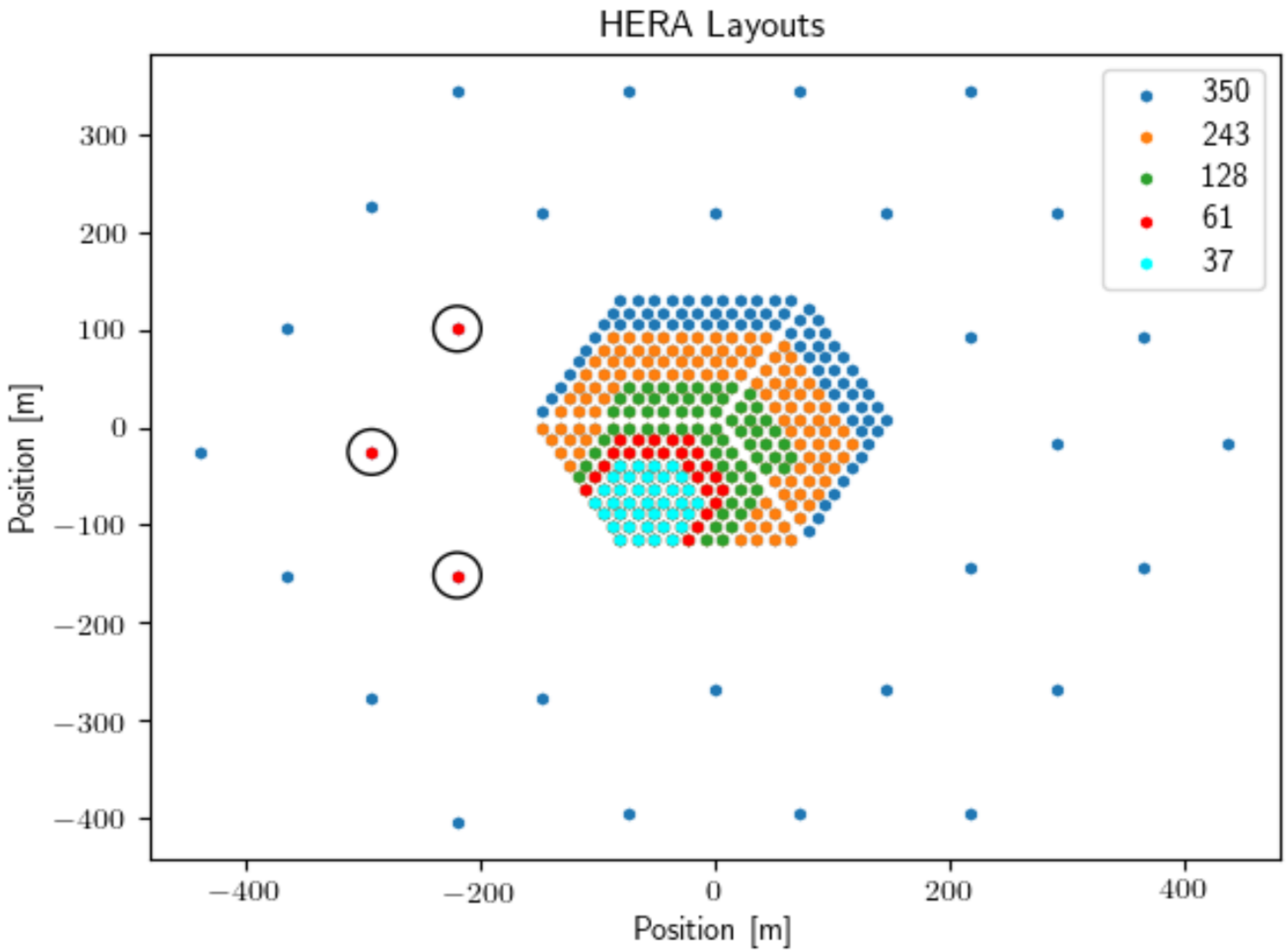
new low frequency feed design

SNAP nodes: ADC and FT

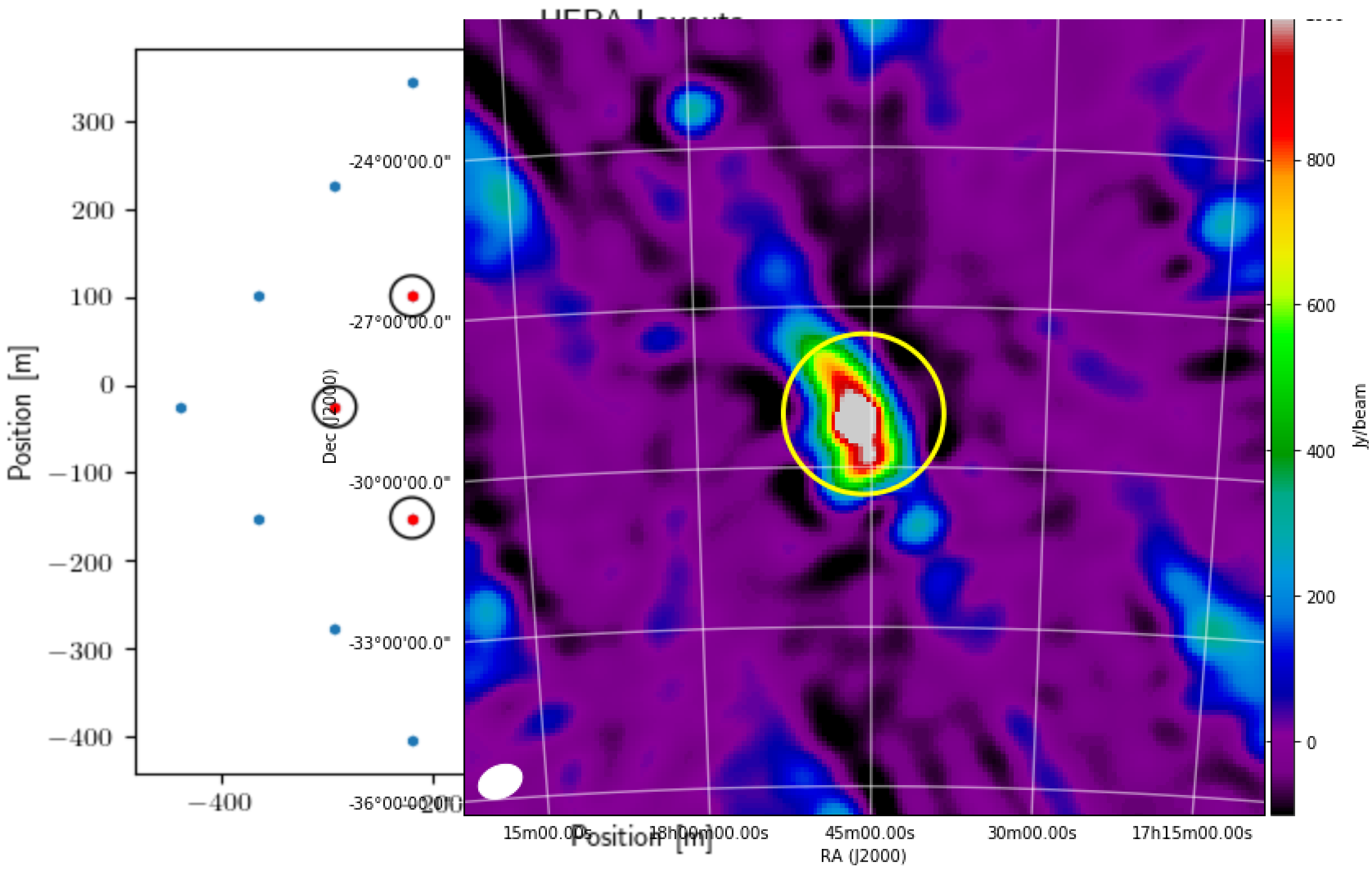
GPU X-engine

internet

Current: HERA-47



Current: HERA-47



Conclusions

- HERA's purpose is to provide a high sensitivity measurement of the 21 cm signal in order to characterize cosmic reionization;

- Instrumentation choices are aimed to preserve the intrinsic frequency smoothness of foregrounds. Sensitivity requirements drive array redundancy (including calibration);

- HERA is currently under construction in the Karoo (SA), 47 elements down, 284 to go;

- Observations with the first 19 elements represent a positive test of the integrated system, HERA-61 observations may improve current constrains on the 21 cm signal;

Conclusions