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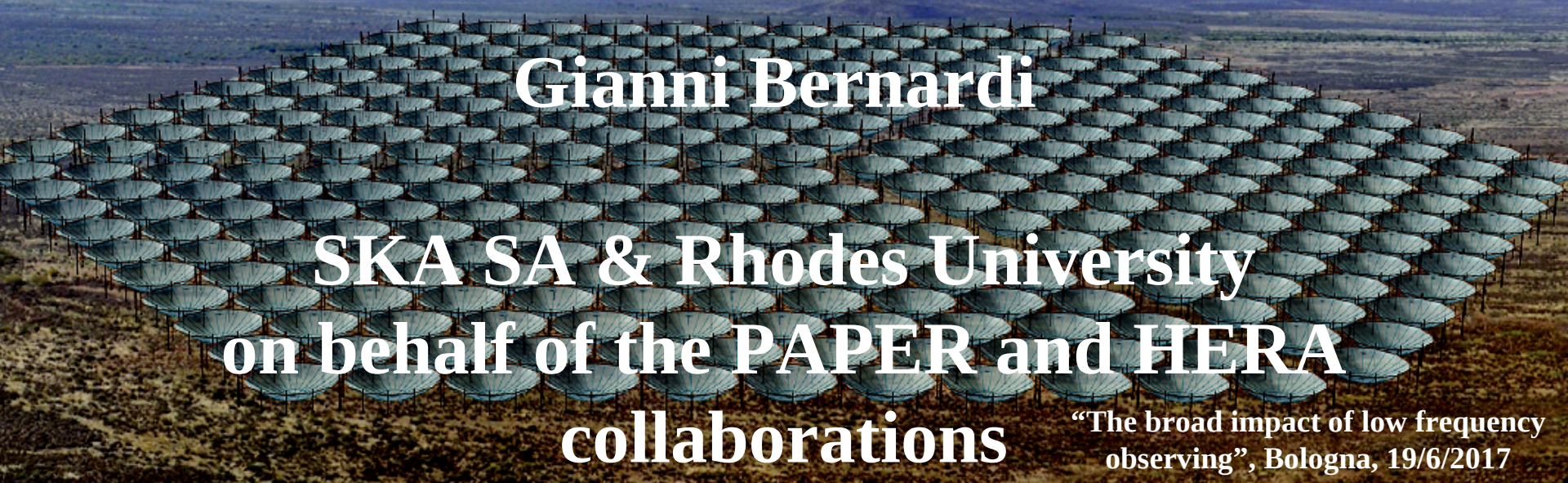
BROWN

# The Hydrogen Epoch of Reionization Array

Gianni Bernardi

SKA SA & Rhodes University  
on behalf of the PAPER and HERA  
collaborations

“The broad impact of low frequency observing”, Bologna, 19/6/2017



# **Before HERA: measuring the EoR with the Precision Array to Probe the Epoch of Reionization (PAPER)**

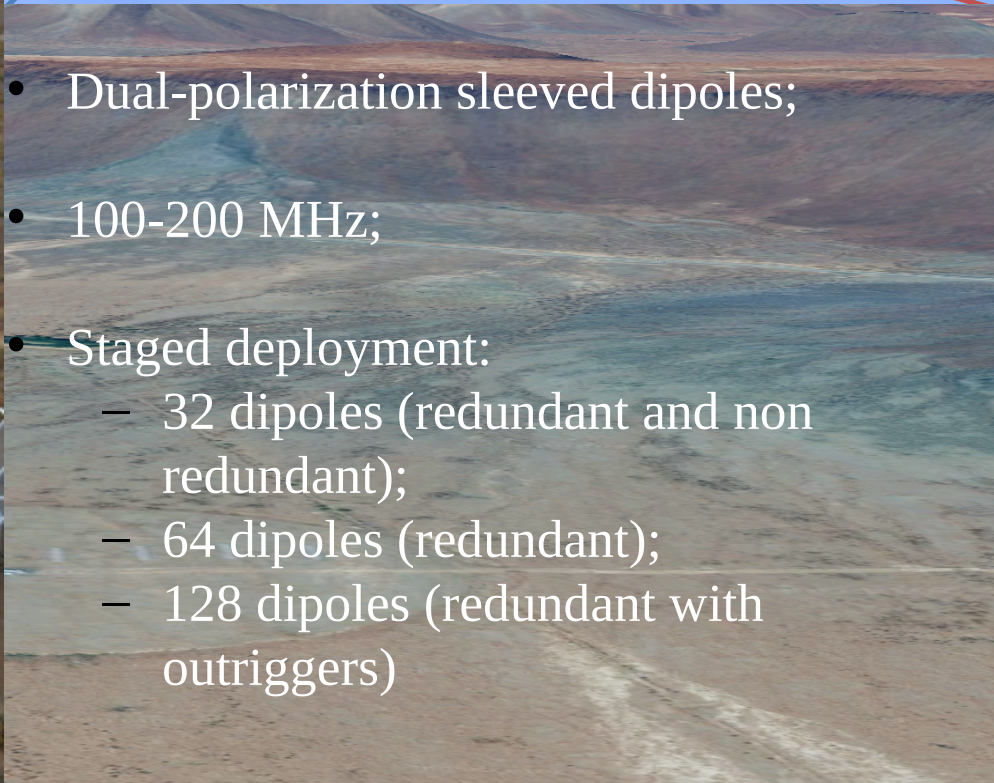


# Before HERA: measuring the EoR with the Precision Array to Probe the Epoch of Reionization (PAPER)





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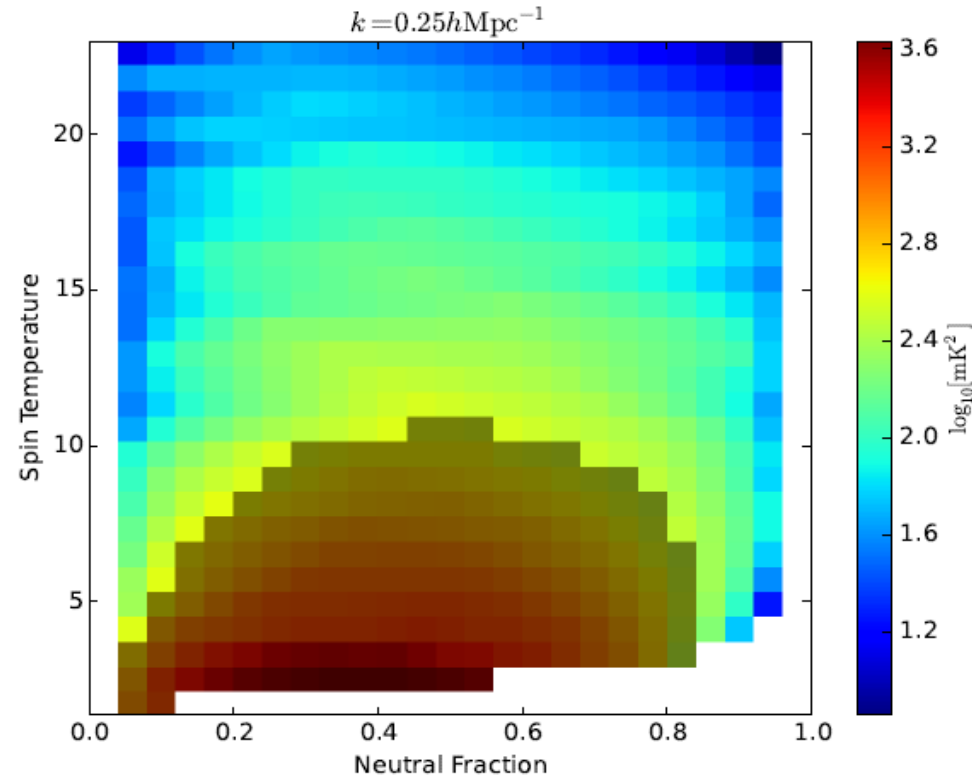
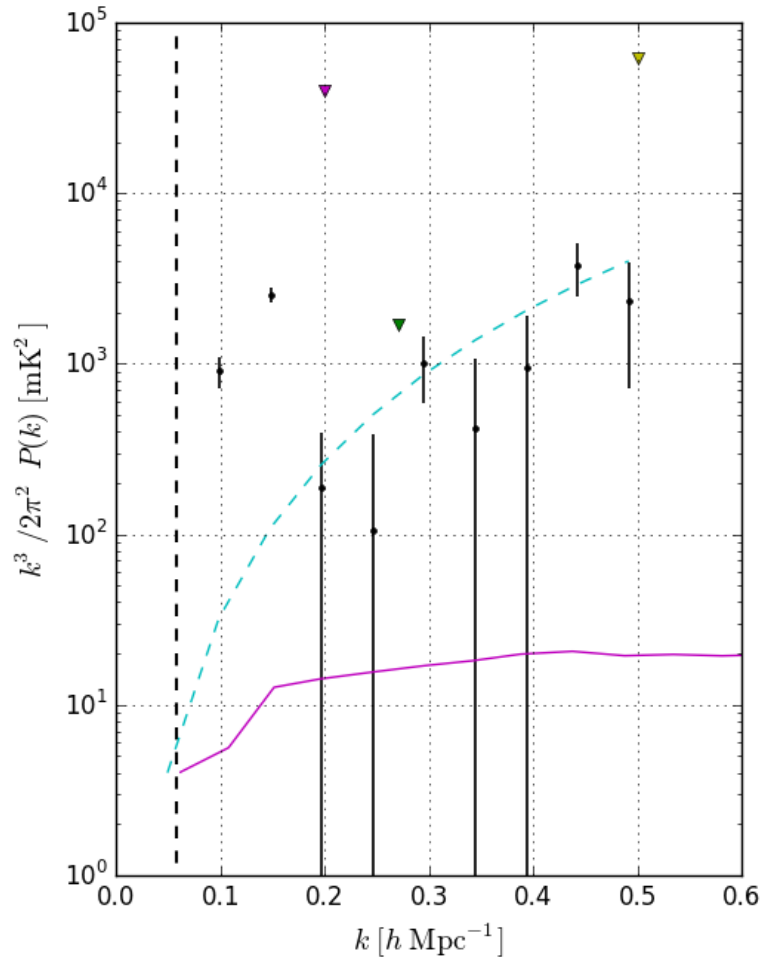


- Dual-polarization sleeved dipoles;
- 100-200 MHz;
- Staged deployment:
  - 32 dipoles (redundant and non redundant);
  - 64 dipoles (redundant);
  - 128 dipoles (redundant with outriggers)



# PAPER-32 and PAPER-64 results: evidence for heated IGM @ $z > 8$

(Parsons et al. 2014, Jacobs et al. 2015, Ali et al. 2015, Pober et al. 2015)

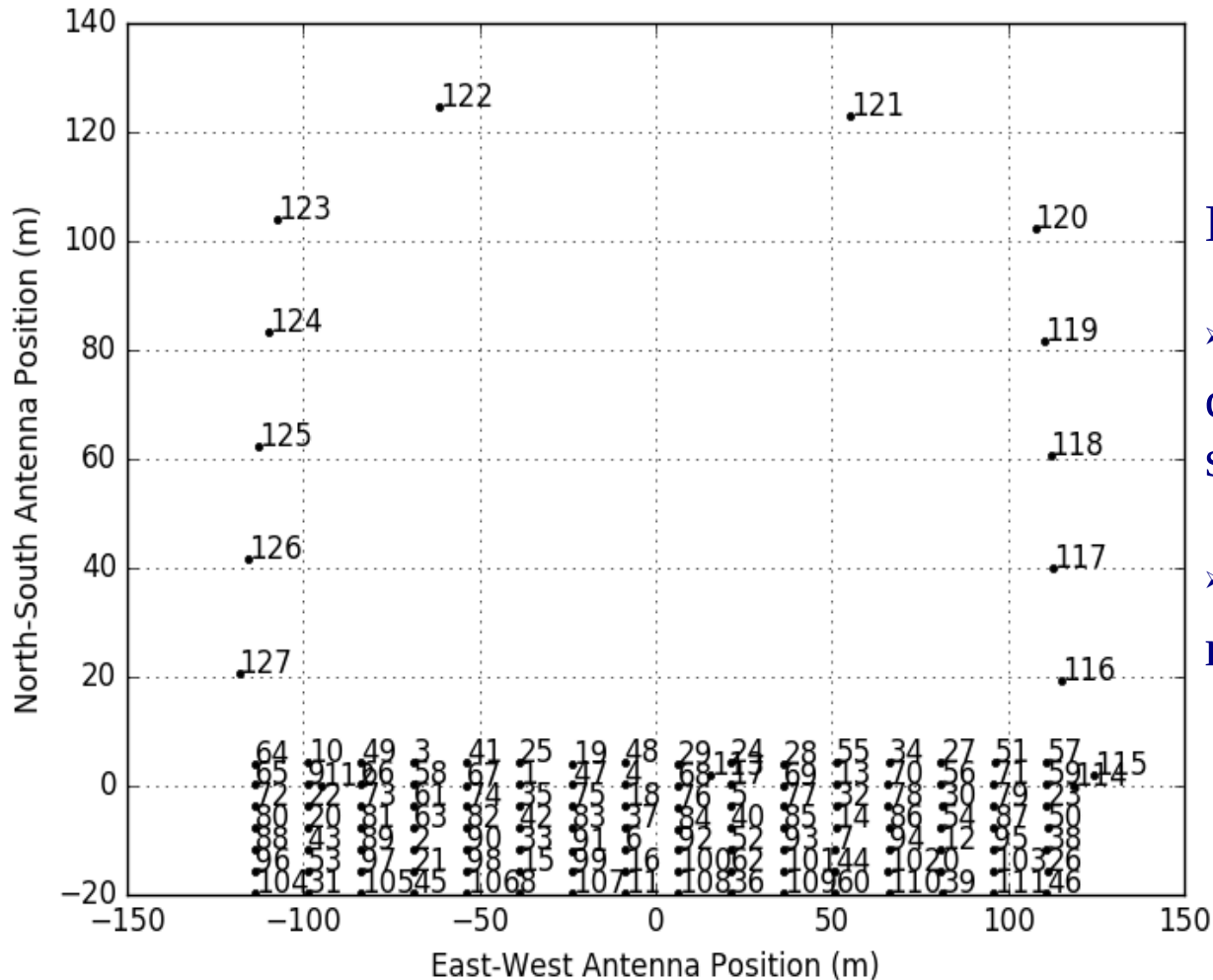


$$\delta T_b \propto 27 x_{\text{HI}} (1 + \delta) \left( 1 - \frac{T_\gamma}{T_s} \right) \text{ mK}$$

$T_s = T_k > 10 \text{ K} @ z = 8.4$  for  $15\% < x_{\text{HI}} < 80\%$

Unheated IGM:  $T_k \sim 1 \text{ K} @ z = 8.4$

# PAPER-128 (final) results upcoming (work in progress):

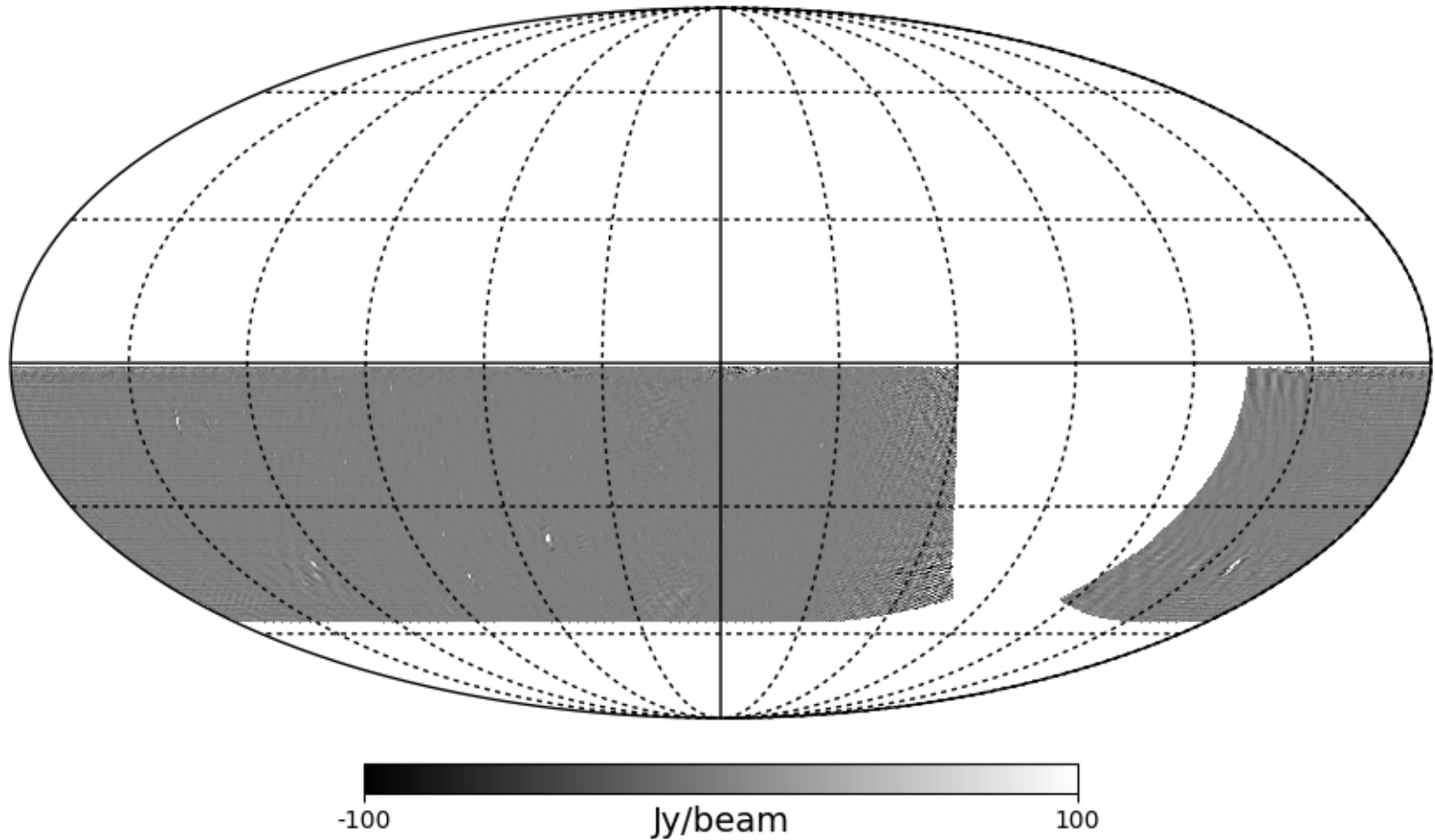


Hybrid configuration:

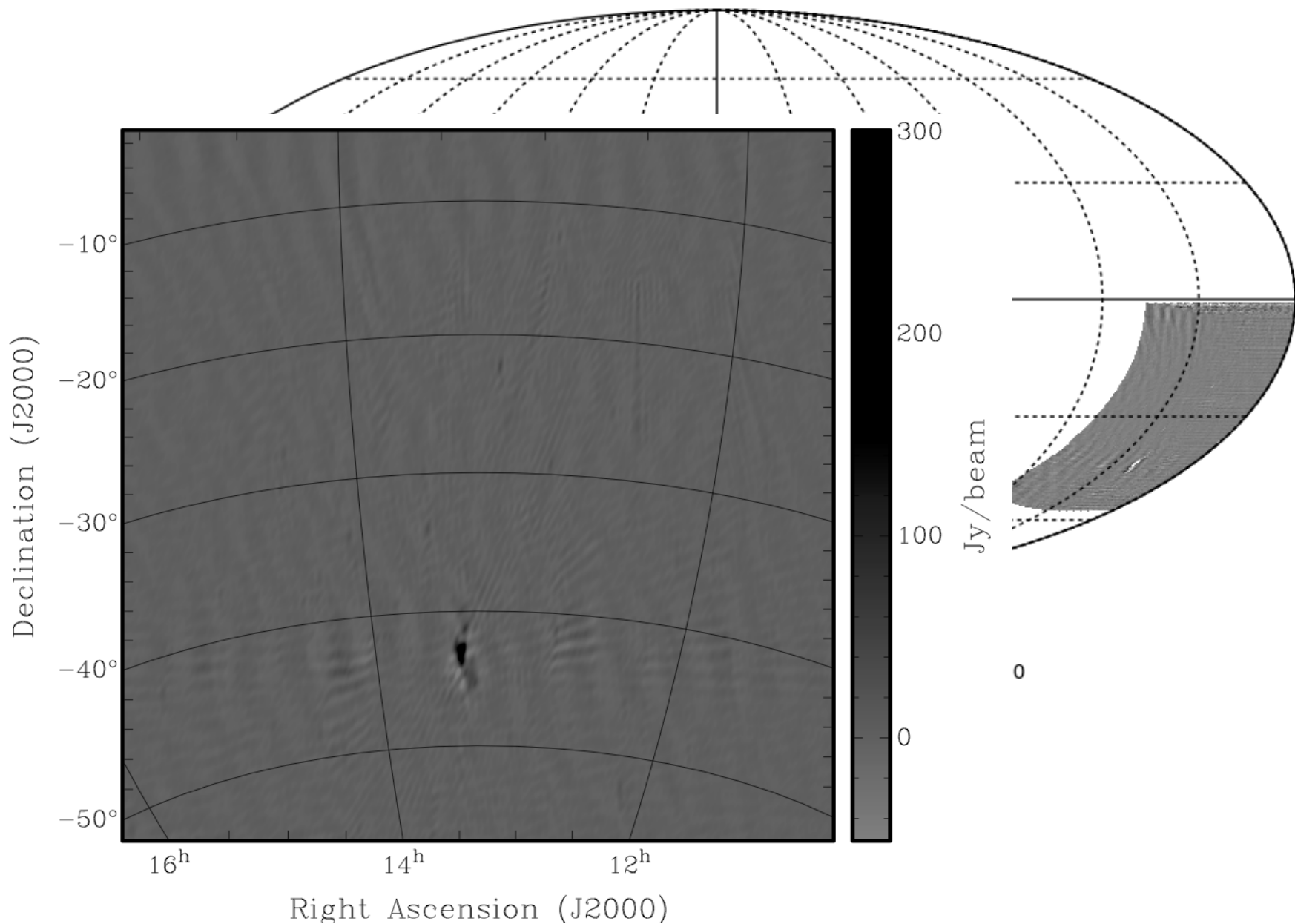
- > highly redundant configuration for power spectrum;
- > outriggers for improved resolution and uv coverage



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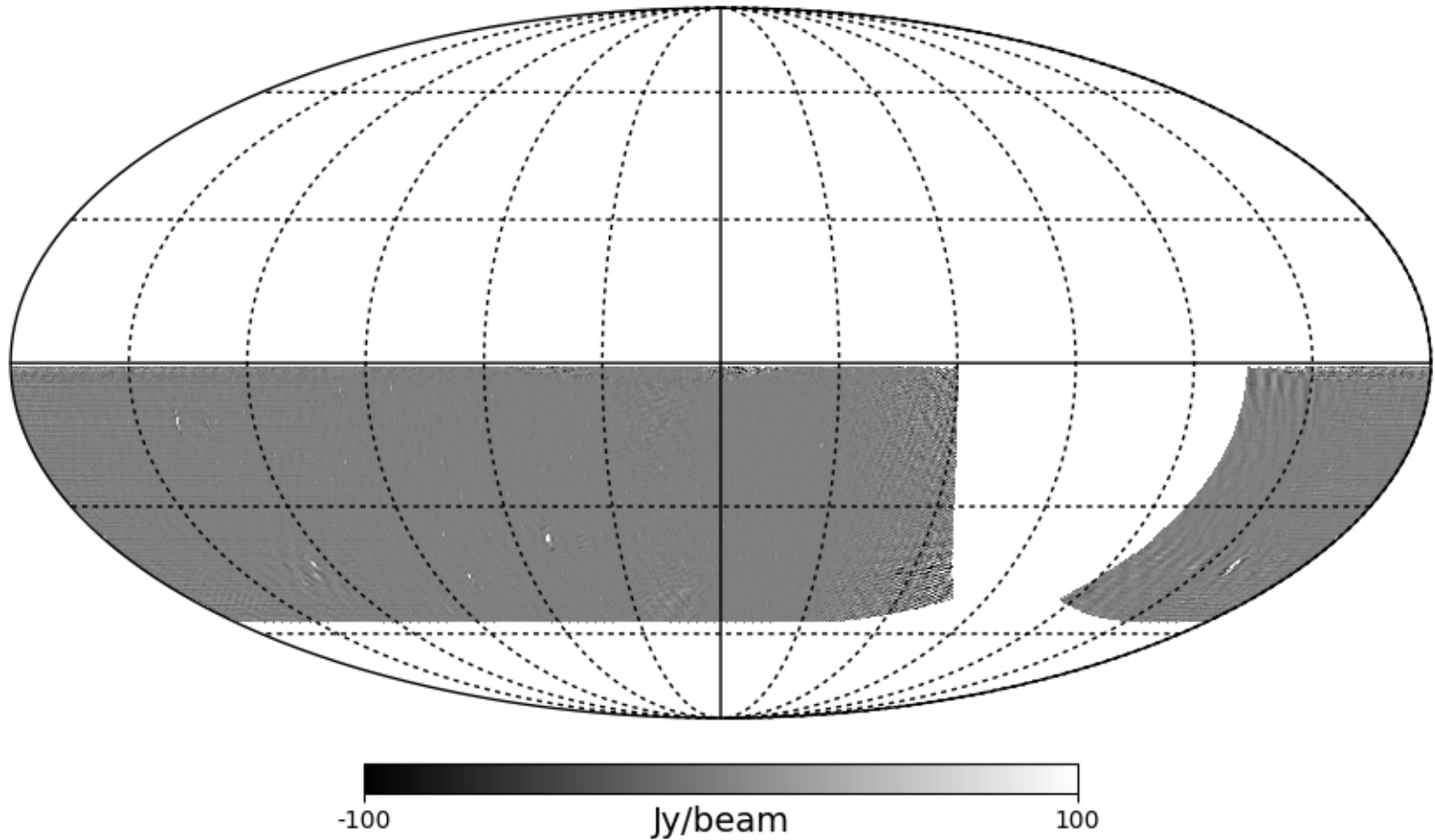


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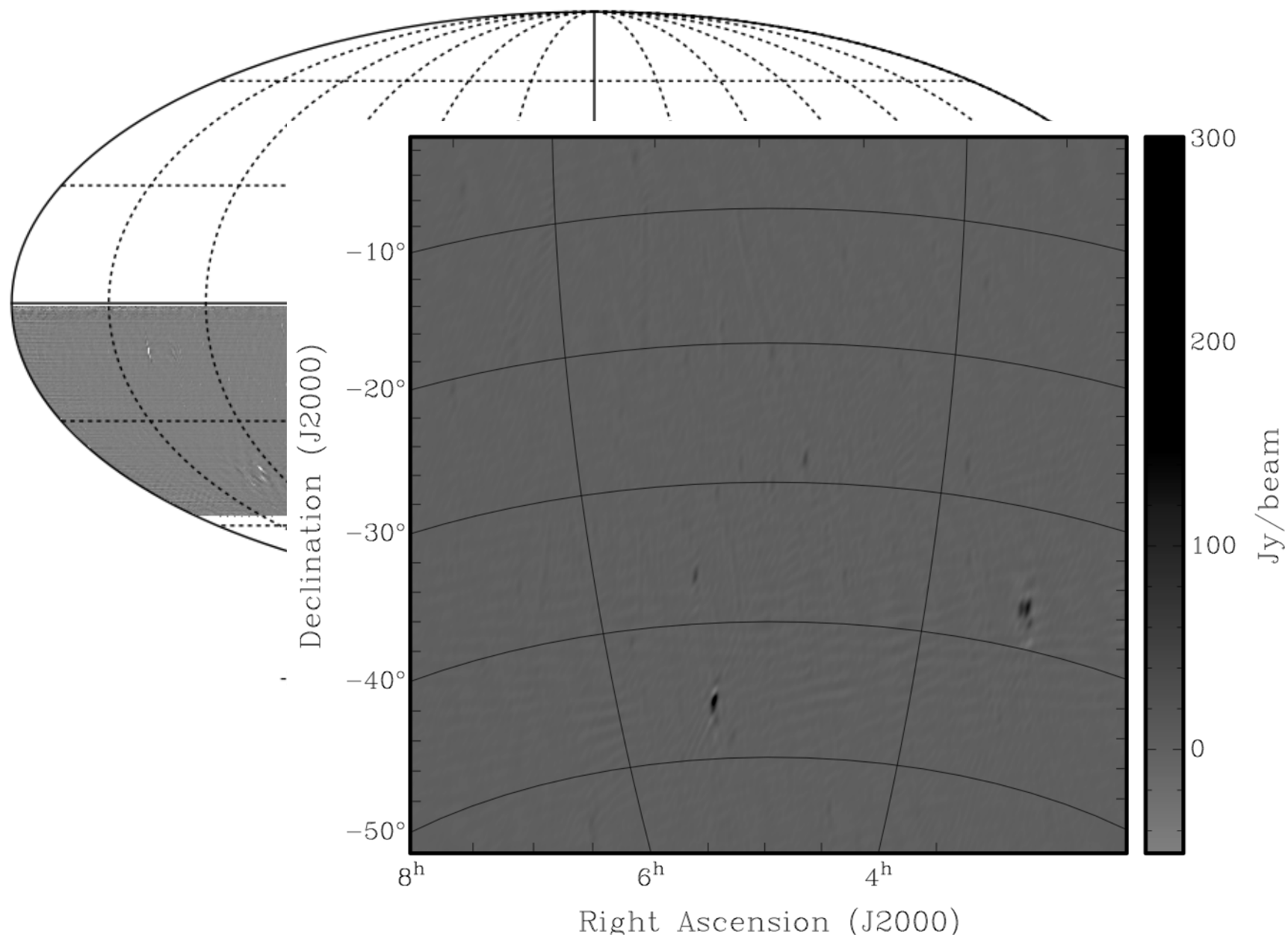




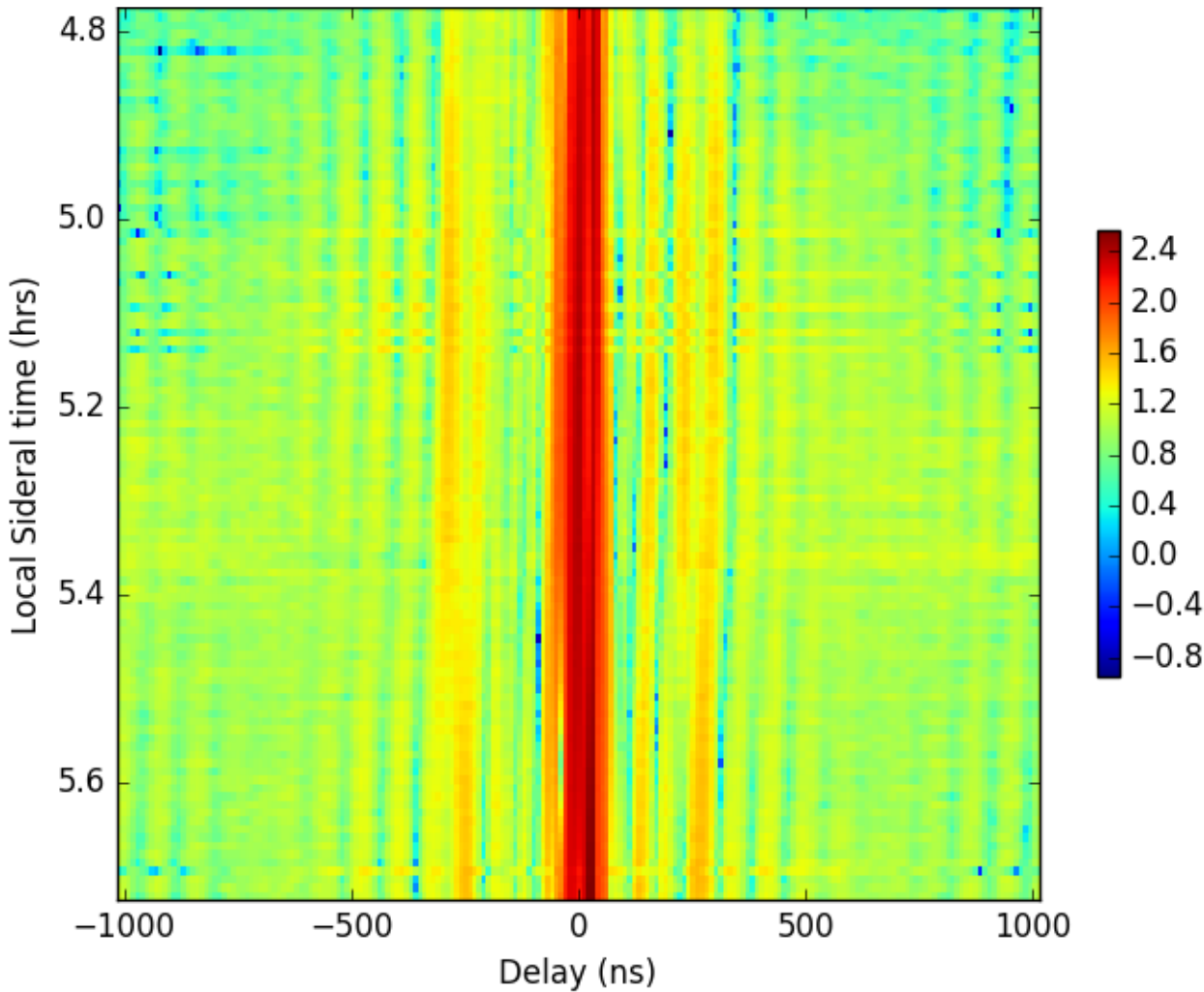
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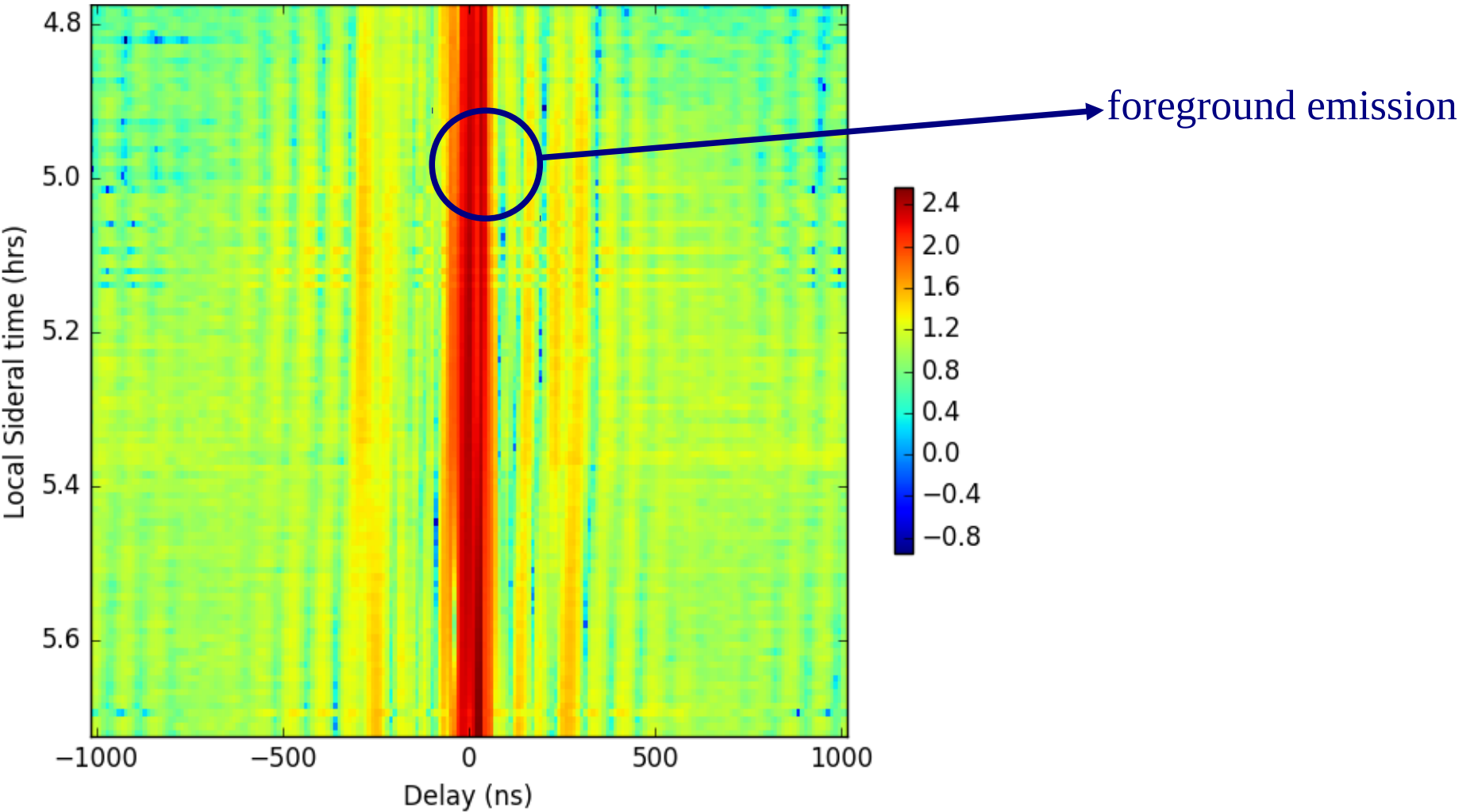
# PAPER-128 (final) results upcoming (work in progress):



Example of delay transformed visibilities for a 15 m baseline integrated over 20 days

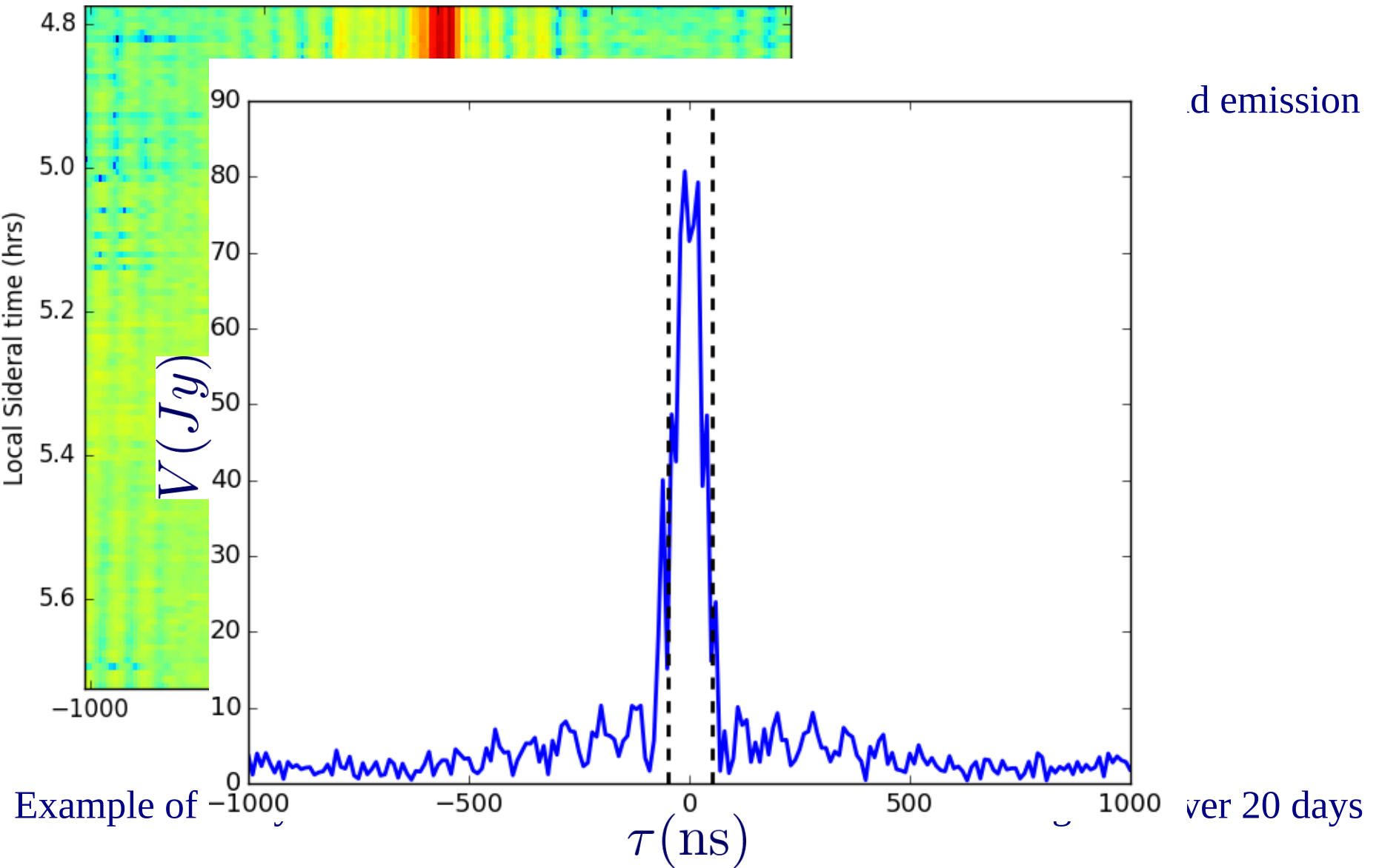


# PAPER-128 (final) results upcoming (work in progress):



Example of delay transformed visibilities for a 15 m baseline integrated over 20 days

# PAPER-128 (final) results upcoming (work in progress):



# HERA

**Location:**  $S30^{\circ} 34'$ ,  $E21^{\circ} 25' E$  (South Africa)

**Configuration:** 331 hex-pack, 21 outriggers

- **Min baseline:** 14.6m ( $7.8^{\circ}$  scale)

- **Max baseline:** 1066m (9' beam)

**Array core:** 310m diameter

**Element:** 14m diameter ( $9^{\circ}$  fov @150 MHz)

**Frequency**

- **Digitized:** 50 - 250 MHz

- **EOR band:** 100 - 200 MHz

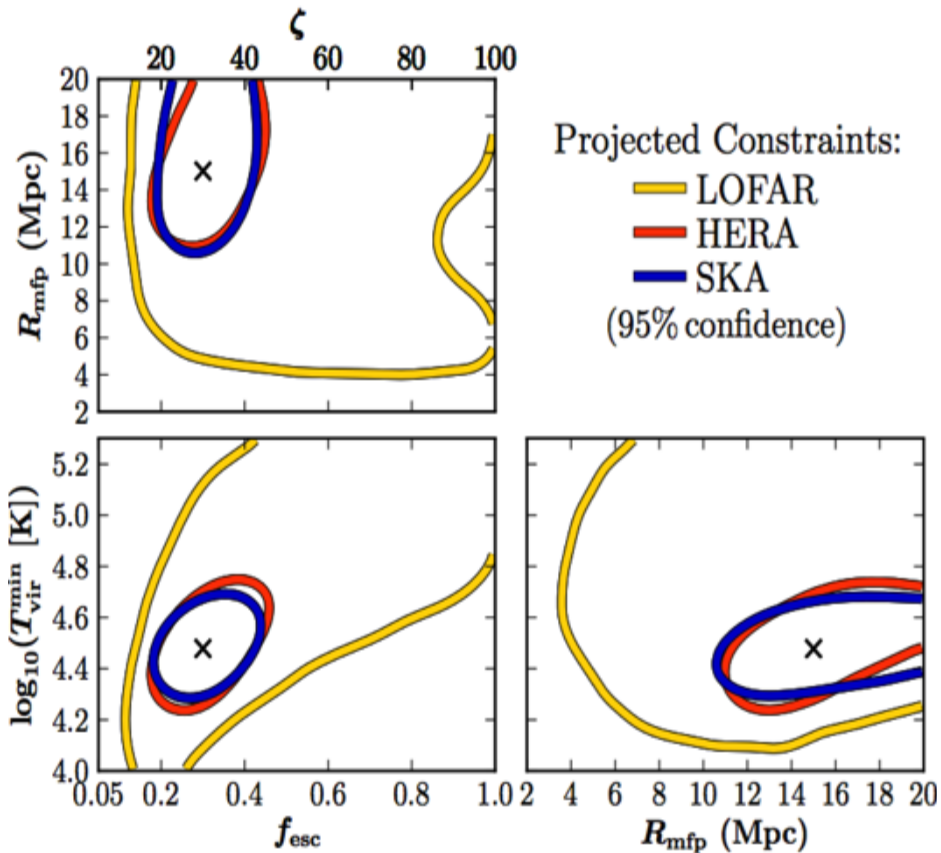
- **Channel:** 97.7 kHz

$$T_{\text{sys}} = 100 + T_{\text{sky}}$$

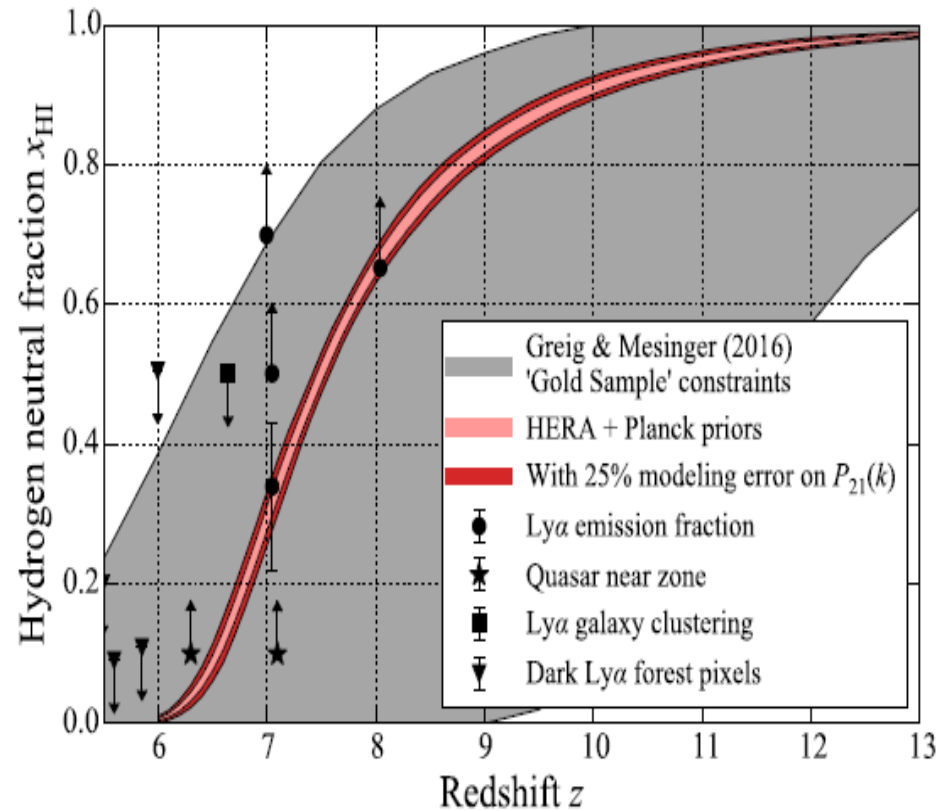




# HERA constraints on reionization



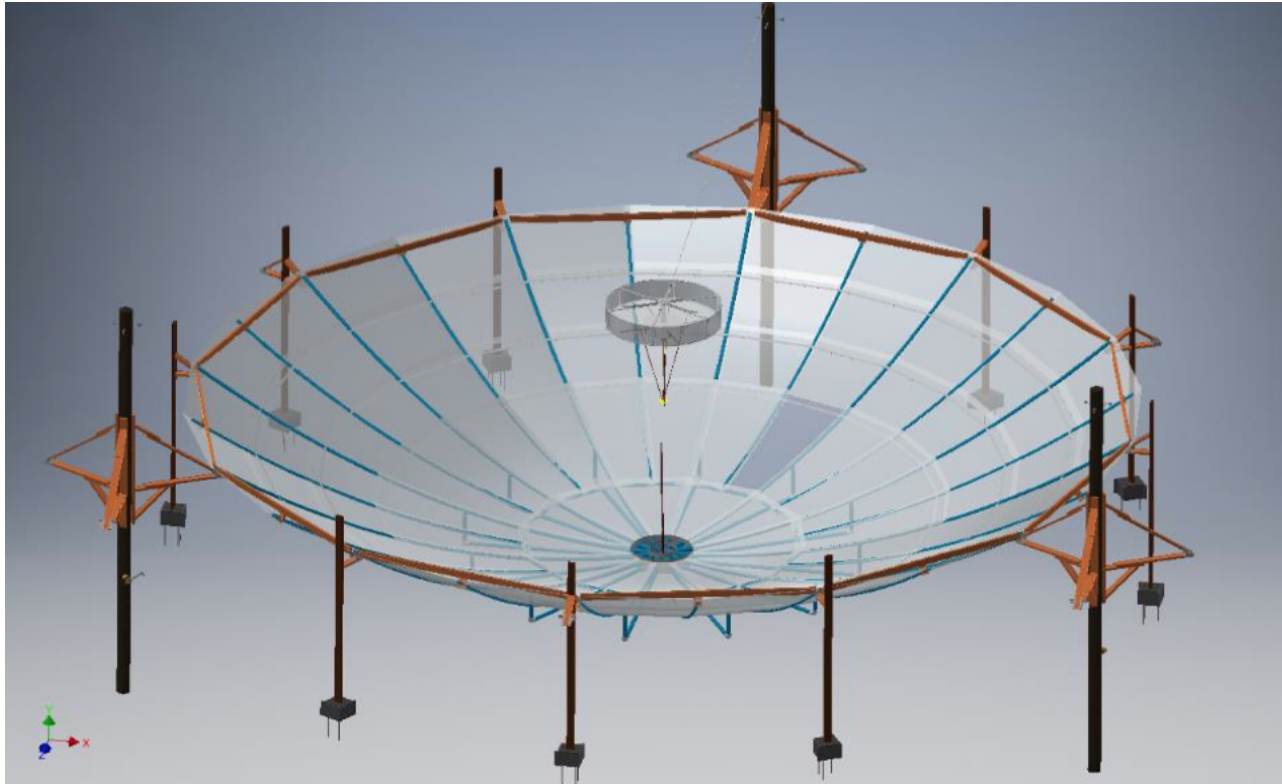
deBoer et al. (2016),  
Greig & Mesinger (2016)



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



# HERA status: 19 dishes, commissioning observations



**Ewall-Wice et al. (2016),  
Neben et al. (2016),  
Thyagarajan et al. (2016)**

# HERA status: 19 dishes, commissioning observations















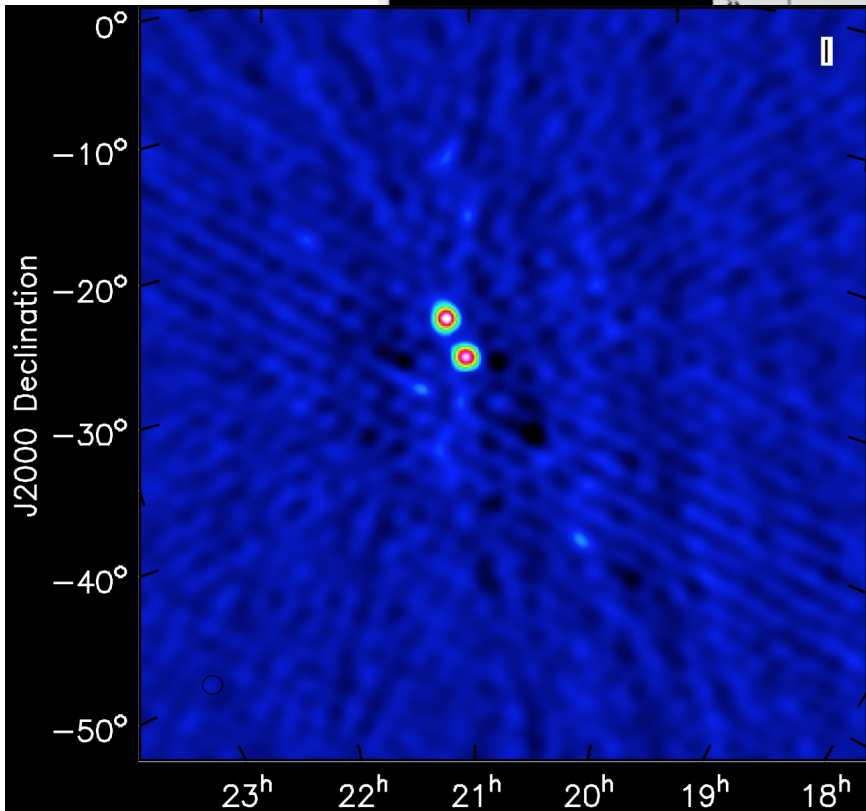
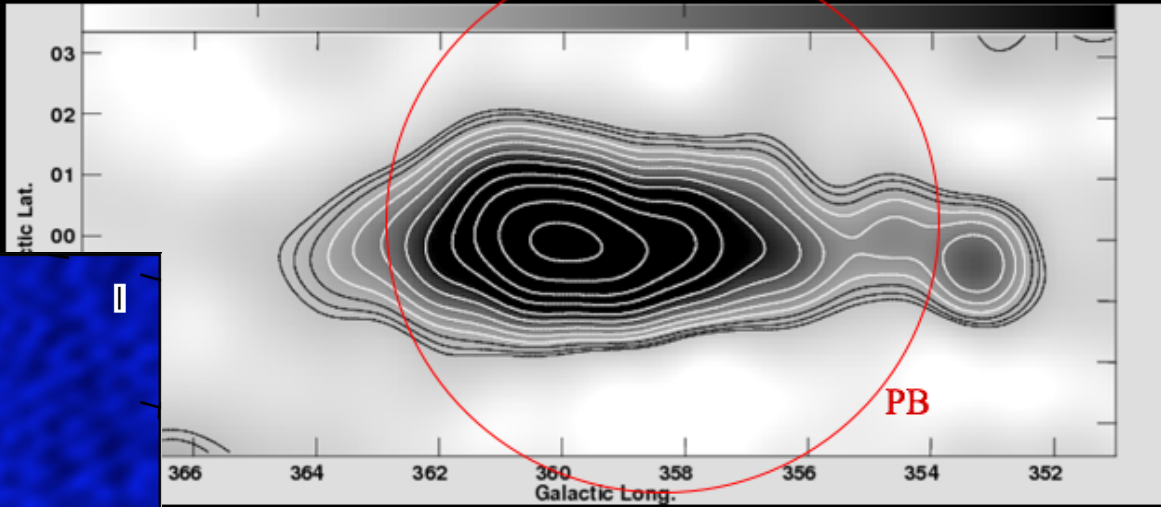


# The sky seen by HERA-19

(see Grobler's poster!)

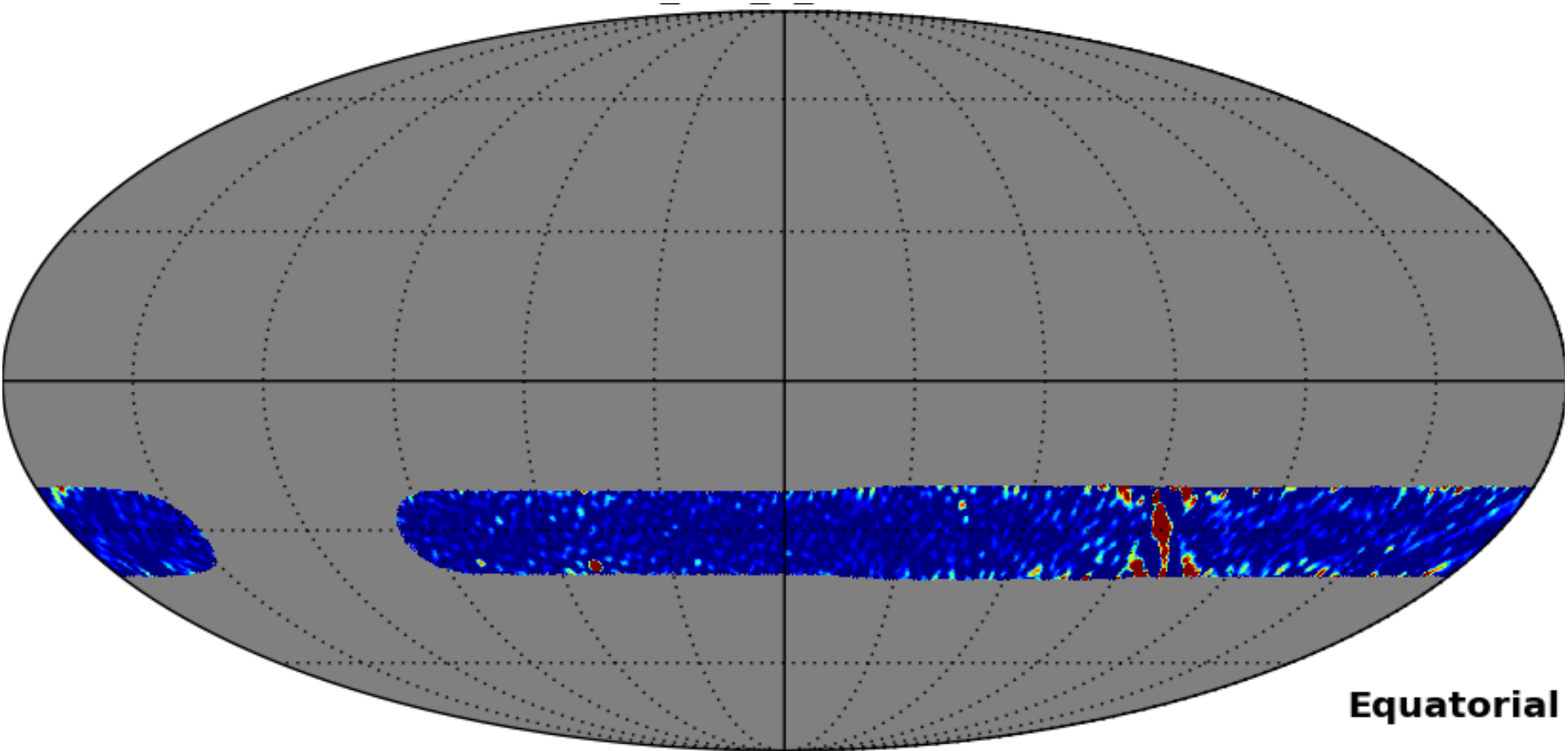
HERA first image: Galactic Center (Nikolic/Carilli)

18ants  
2° res  
DNR ~ 200



# The sky seen by HERA-19

(see Grobler's poster!)

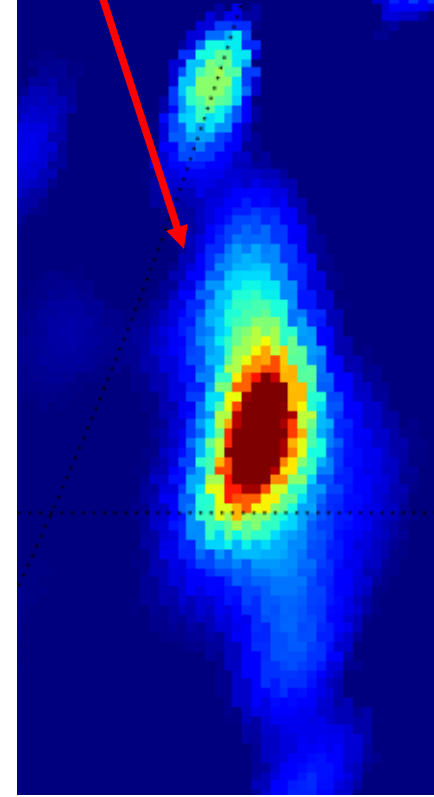
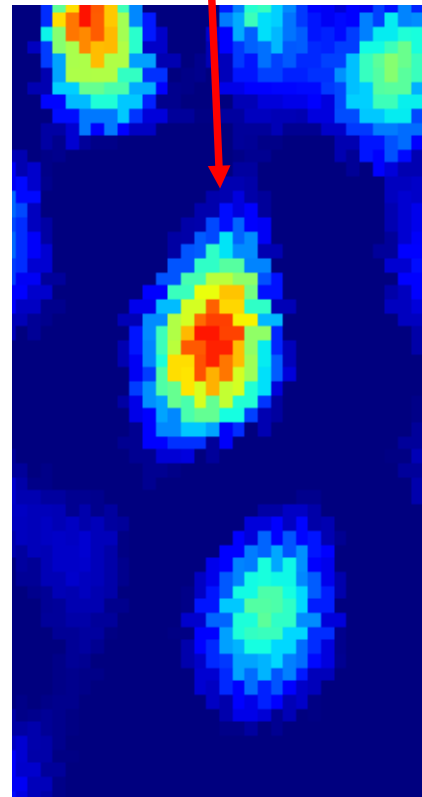
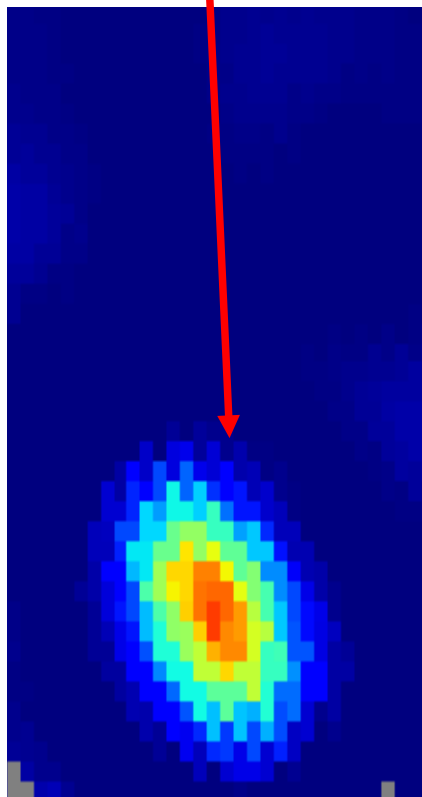
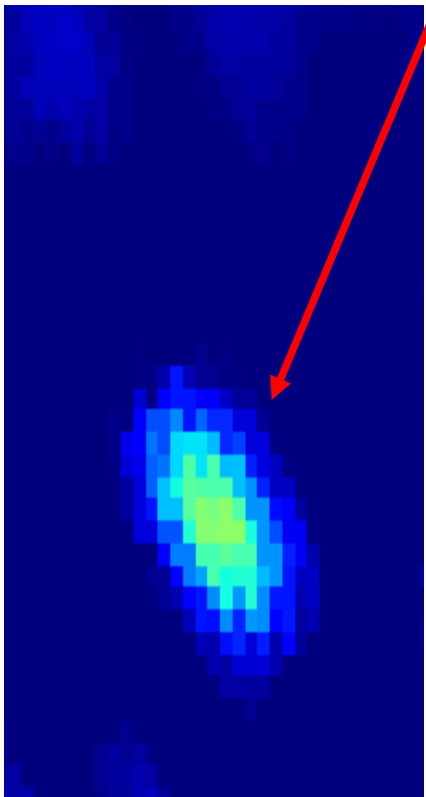
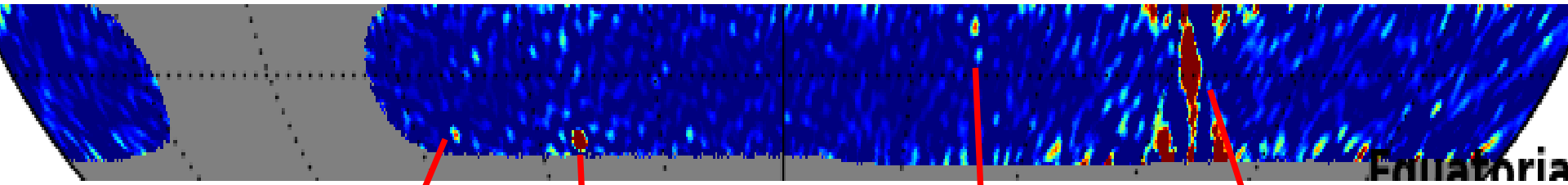


- three nights of drift scan observations resampled on the Healpix sphere;
- 2 degrees angular resolution;
- averaged over 60 MHz bandwidth;

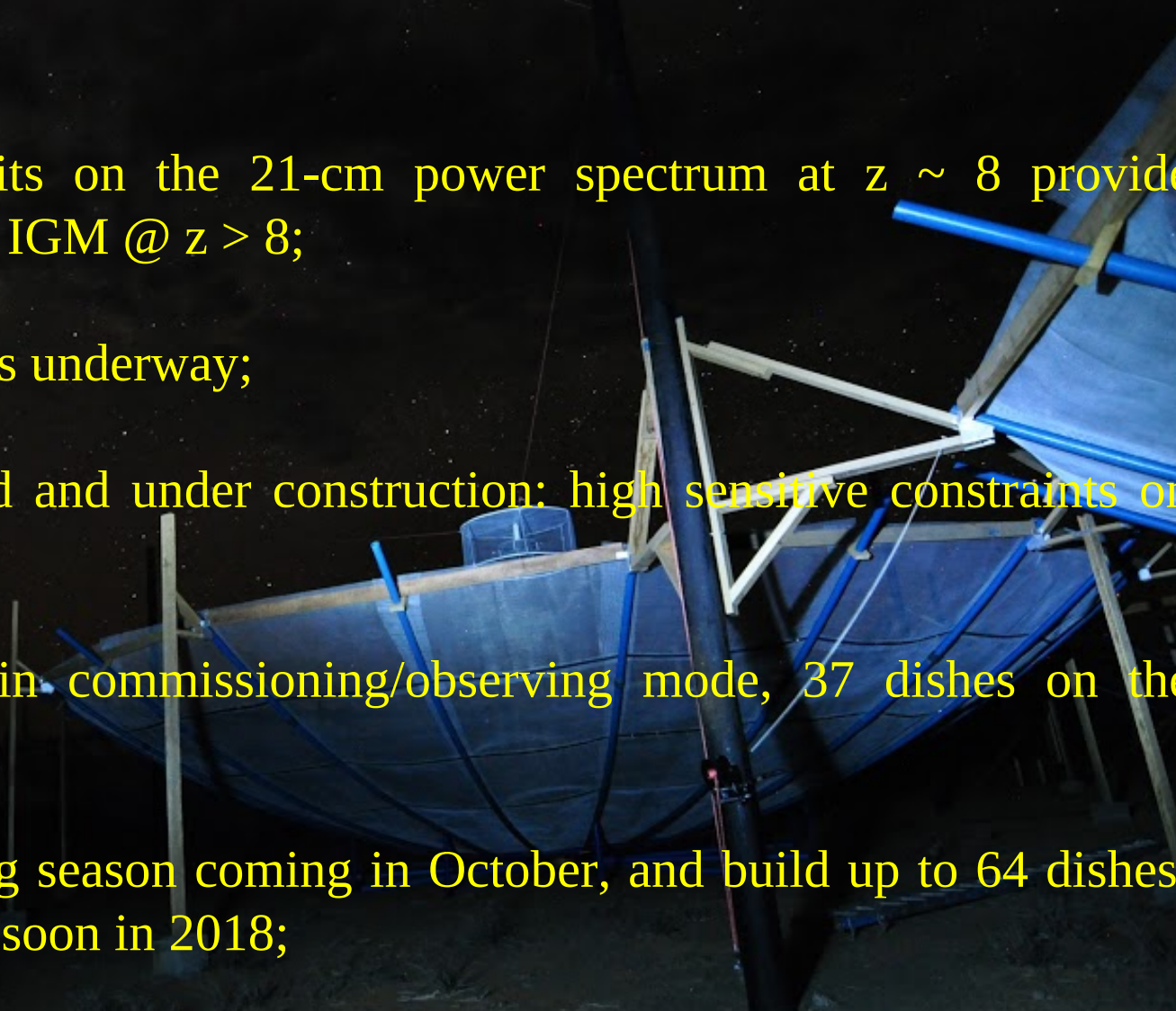


# The sky seen by HERA-19

(see Grobler's poster!)



# Conclusions

- PAPER upper limits on the 21-cm power spectrum at  $z \sim 8$  provide evidence for heated IGM @  $z > 8$ ;
  - Final PAPER results underway;
  - HERA fully funded and under construction: high sensitive constraints on reionization;
  - 19 HERA dishes in commissioning/observing mode, 37 dishes on the ground now;
  - First deep observing season coming in October, and build up to 64 dishes: first results coming soon in 2018;
- 

# Conclusions

**THANK YOU**

A night photograph of a large, blue, dome-shaped structure under construction. The structure is illuminated by a bright light source, possibly a spotlight, which creates a strong glow and casts long shadows. The structure is supported by a wooden frame and blue pipes. The background is a dark sky with stars. The text "THANK YOU" is overlaid on the image in a large, bold, yellow font.