Measurements of the global signal from the Cosmic Dawn

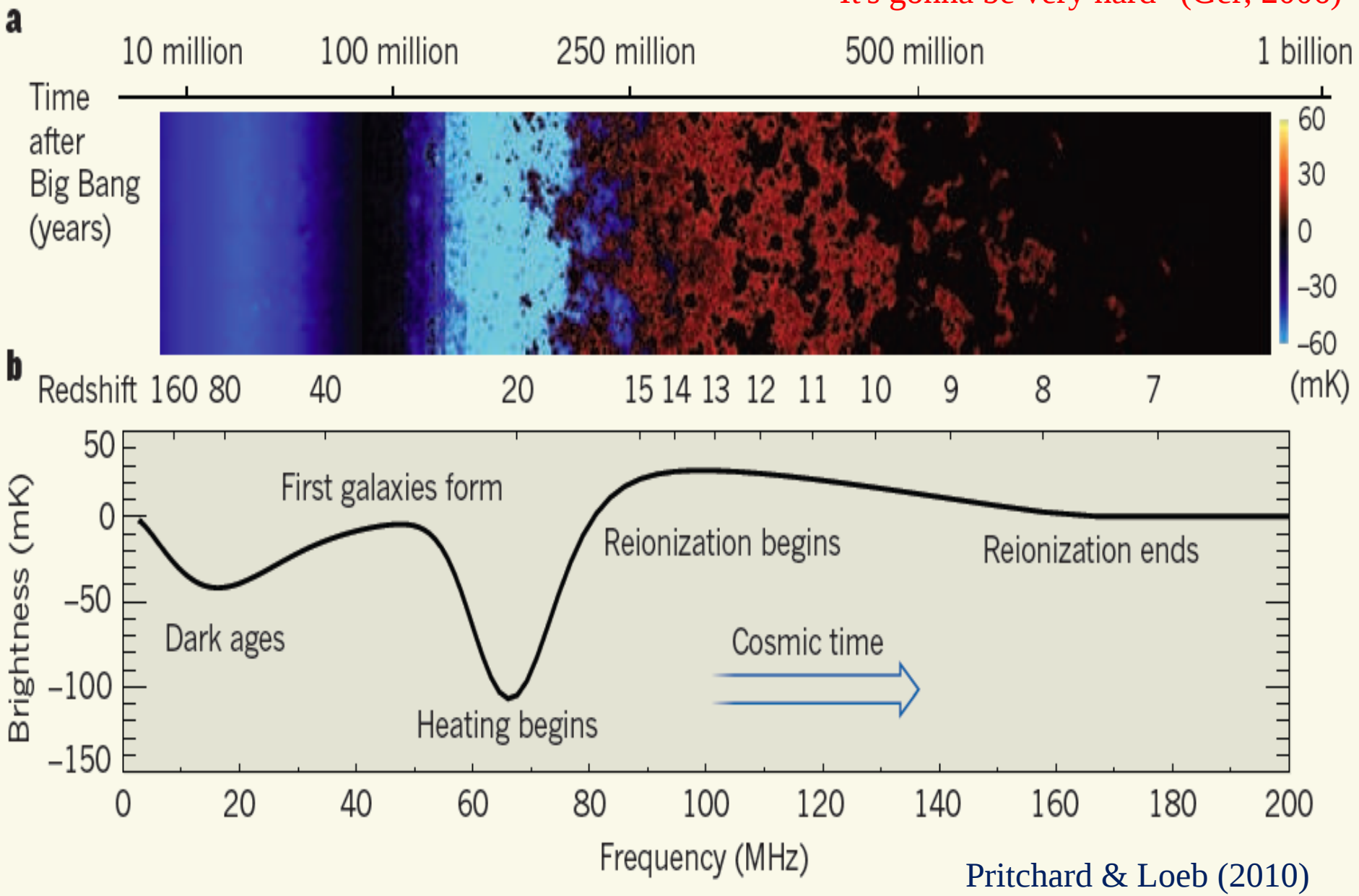
Gianni Bernardi

IRA-INAF & Rhodes University
(thanks to the LEDA collaboration)

IAUS333, Dubrovnik, October 2-6th 2017

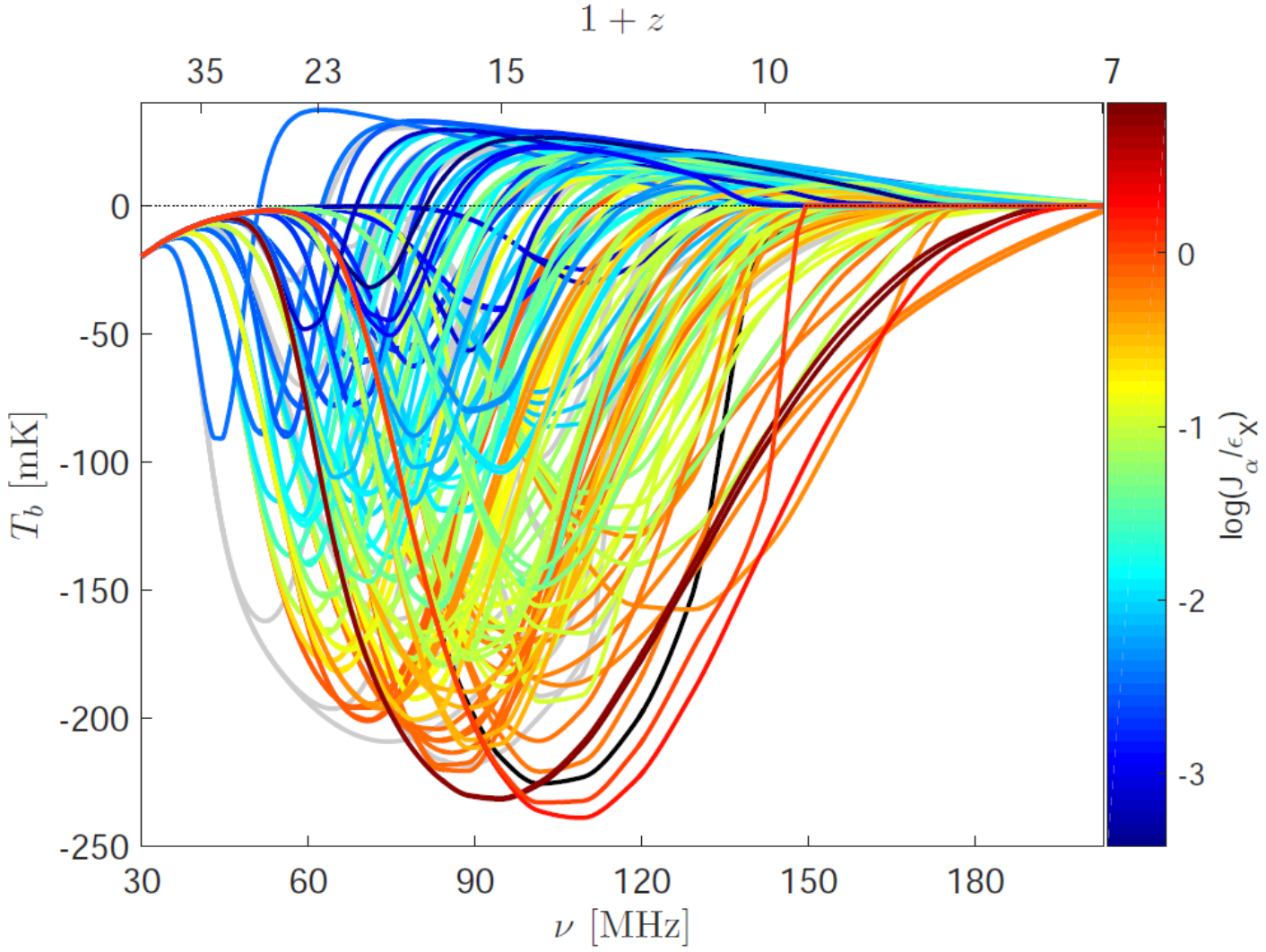
An 8 year old slide (Aspen 2010)...

"It's gonna be very hard" (Ger, 2006)



Pritchard & Loeb (2010)

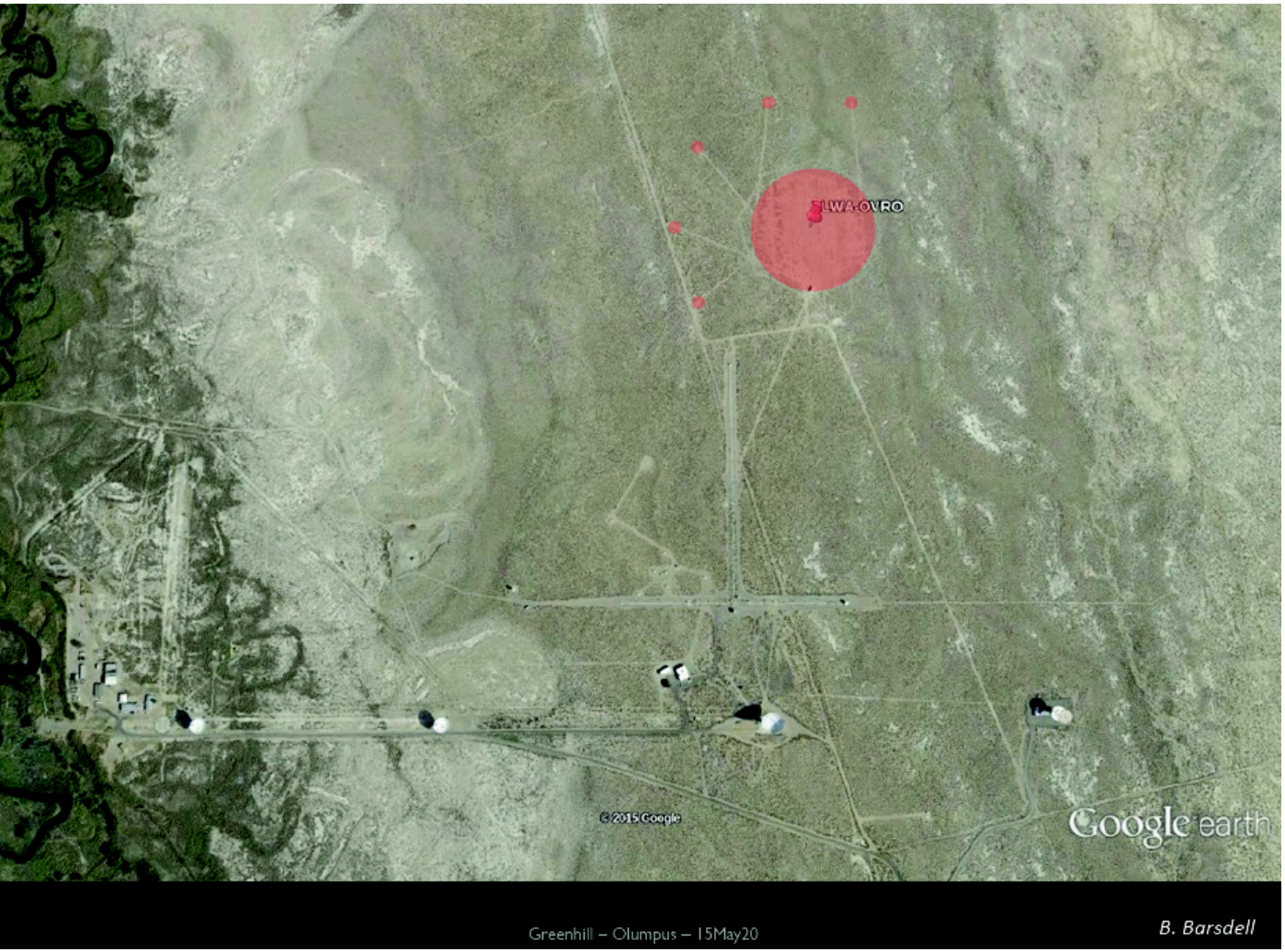
All possible models (almost, see Bowman's talk) still allowed



Cohen, Fialkov & Barkana (2016),
see also Fialkov's and Mesinger's talks

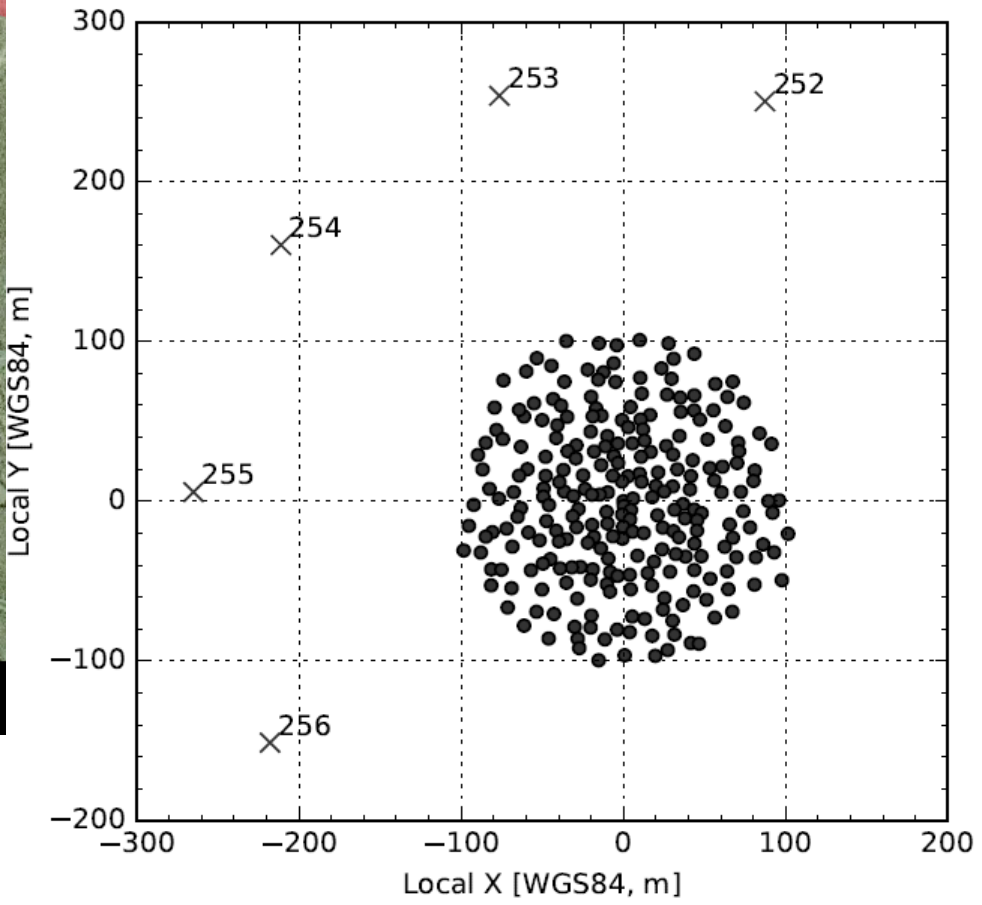
Large-Aperture Experiment to detect the Dark Ages

(PIs: L. Greenhill, D. Werthimer, G. Taylor, S. Ellingson, G. Hallinan)



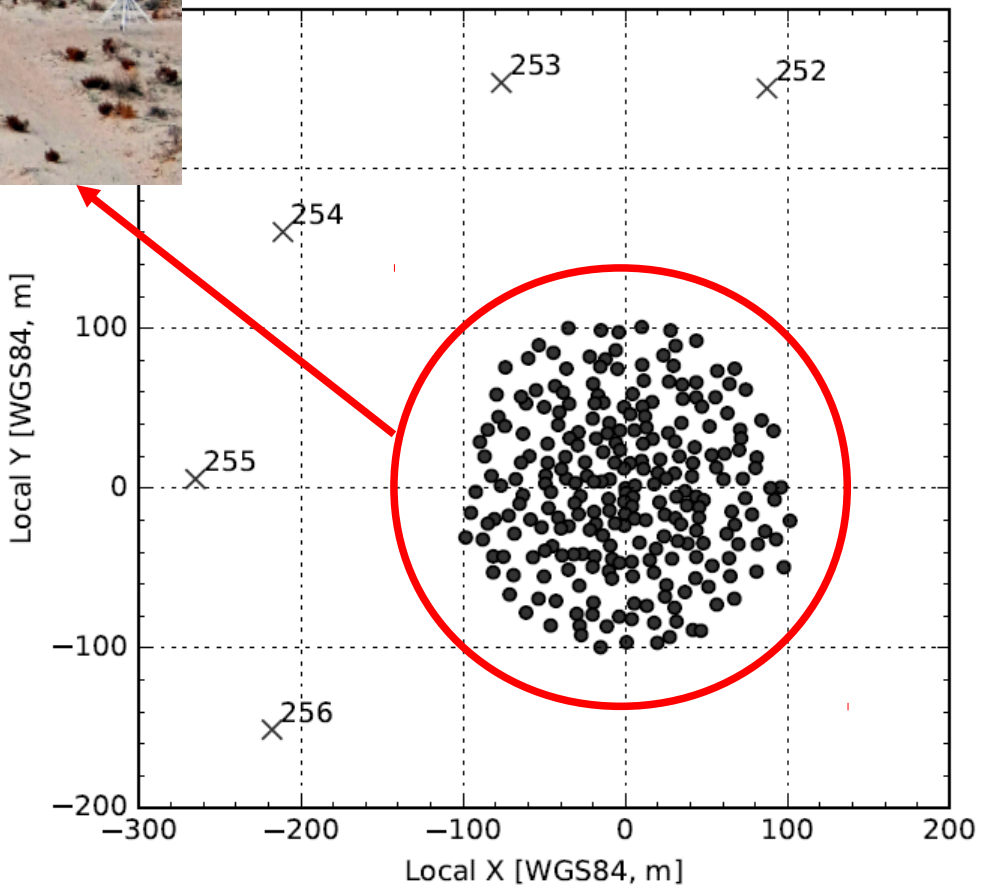
Large-Aperture Experiment to detect the Dark Ages

(PIs: L. Greenhill, D. Werthimer, G. Taylor, S. Ellingson, G. Hallinan)



Large-Aperture Experiment to detect the Dark Ages

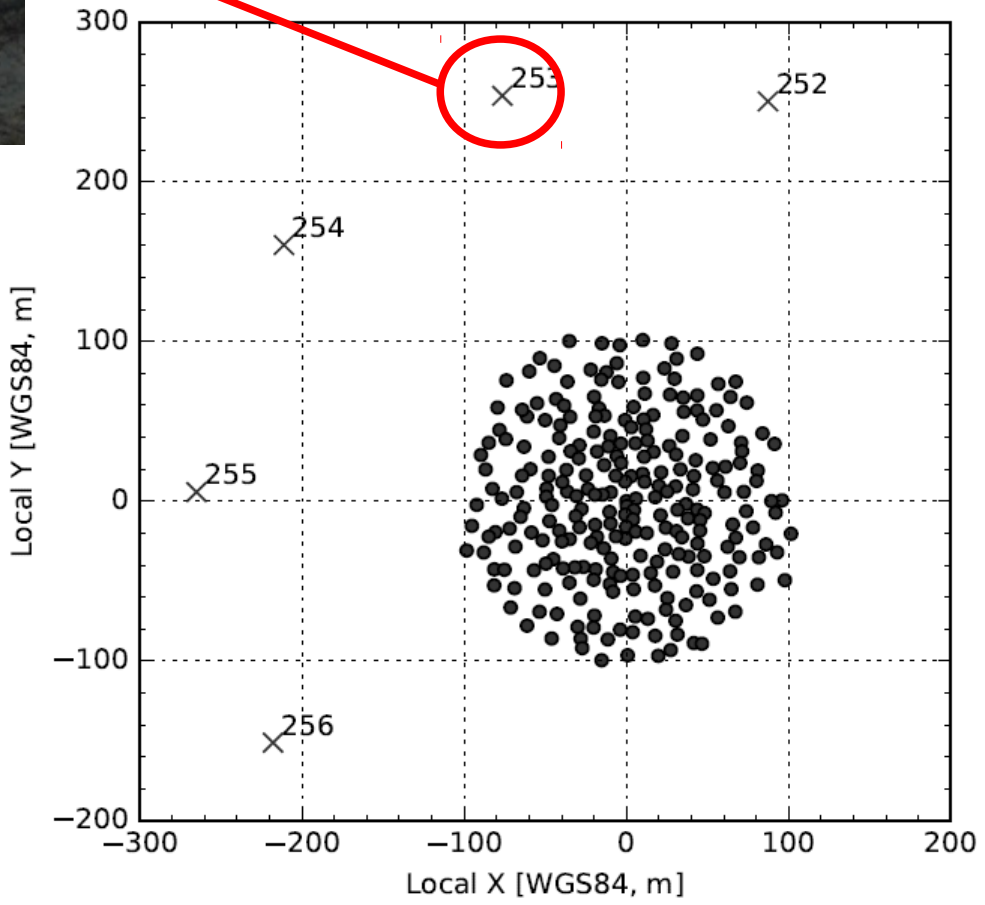
(PIs: L. Greenhill, D. Werthimer, G. Taylor, S. Ellingson, G. Hallinan)



- 20-90 MHz V-inverted dipoles;
- LEDA @ OVRO-LWA, LOL: 256 dipoles (dual pol, ~58 MHz bandwidth), pseudo-random configuration spread over ~200 m diameter, with a few outriggers up to 1.8 km;
- They operate as an interferometric array (see M. Eastwood's talk!)

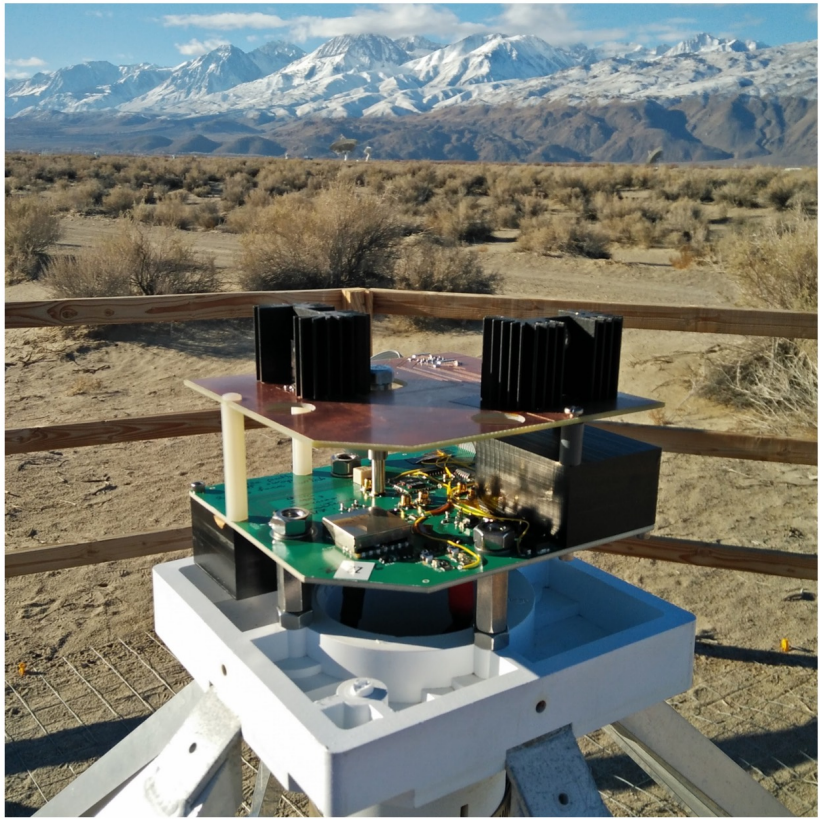
Large-Aperture Experiment to detect the Dark Ages

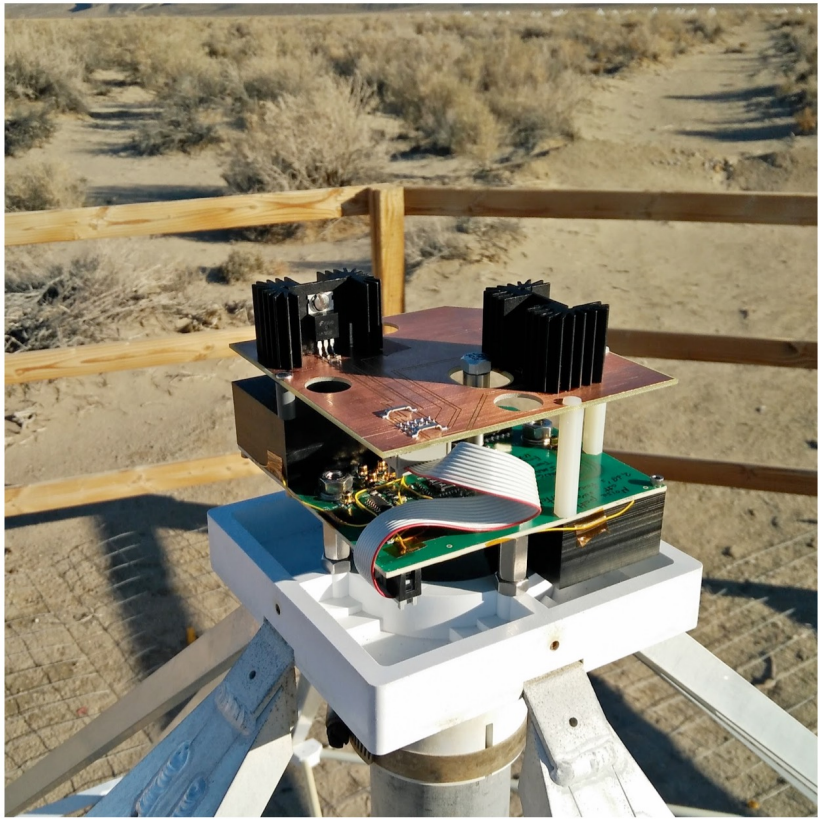
(PIs: L. Greenhill, D. Werthimer, G. Taylor, S. Ellingson, G. Hallinan)



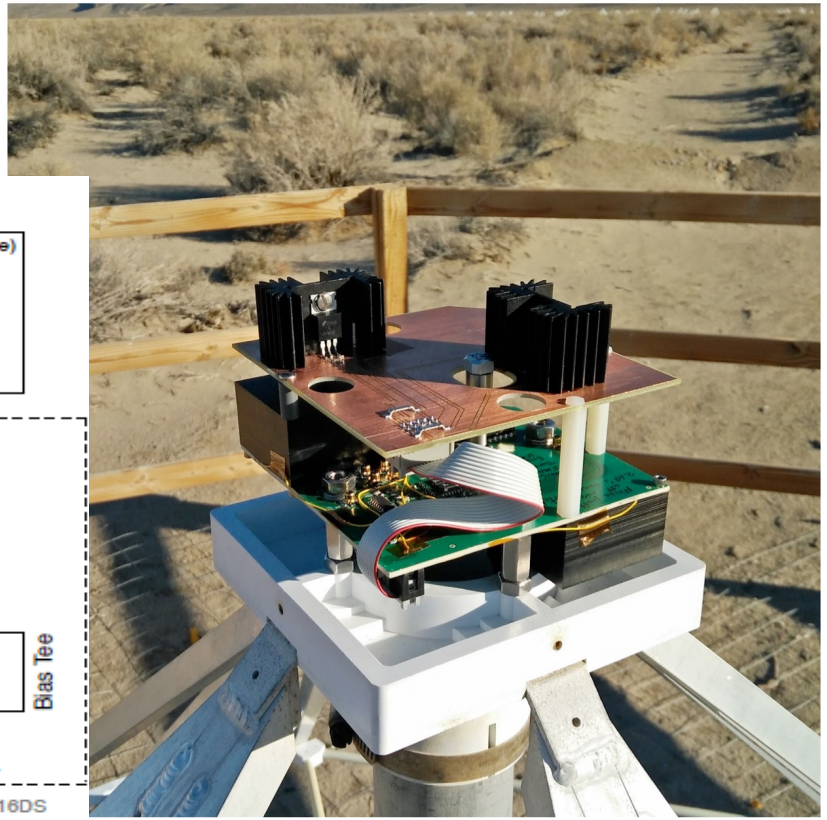
- 20-90 MHz isolated V-inverted dipoles with custom designed front ends for radiometry → detection of the global 21-cm signal in the $15 < z < 30$ range;

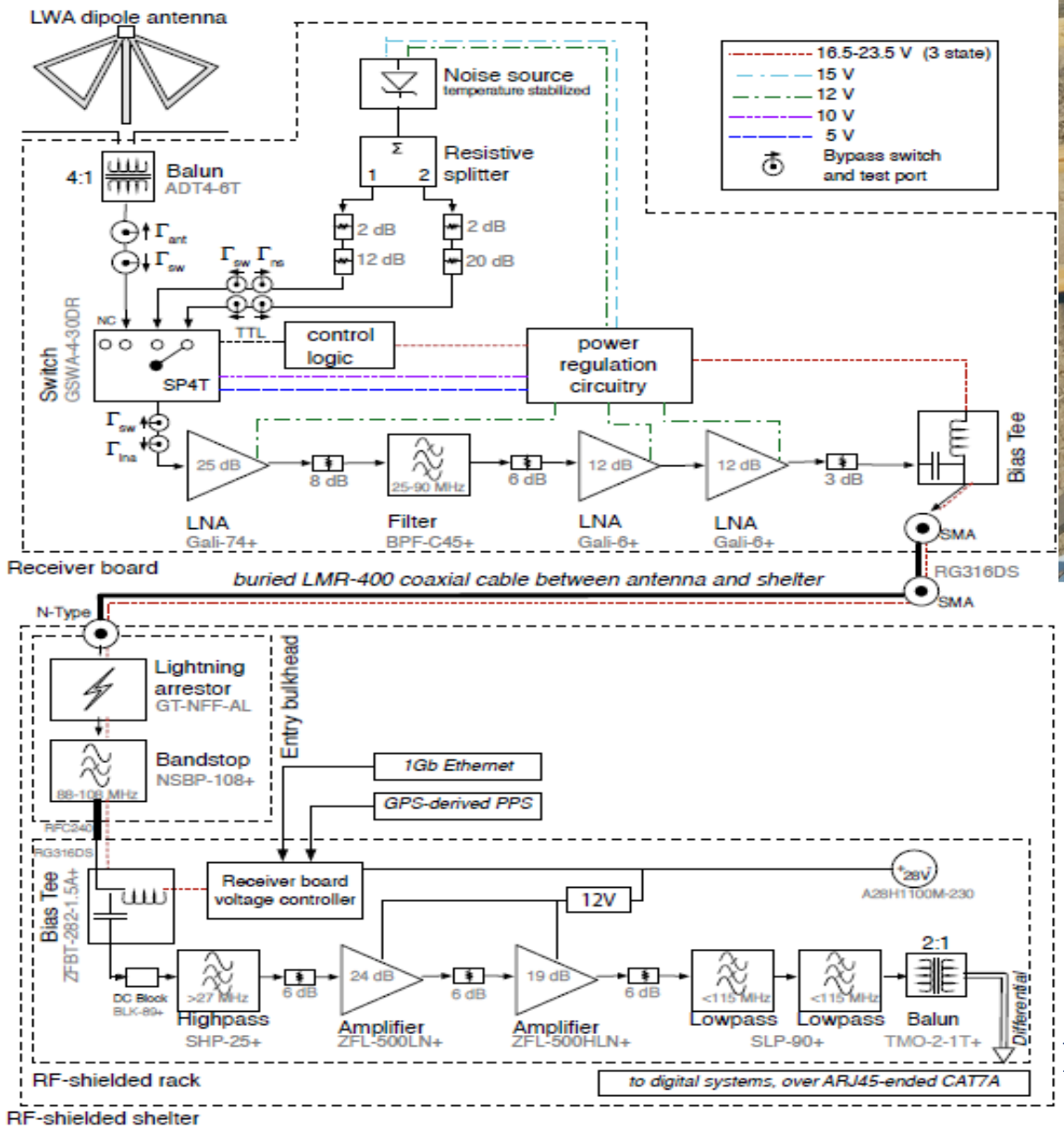
- combination of radiometry and interferometry may aid calibration of the global signal (gain pattern, ionosphere, i.e. GB, McQuinn & Greenhill 2015);





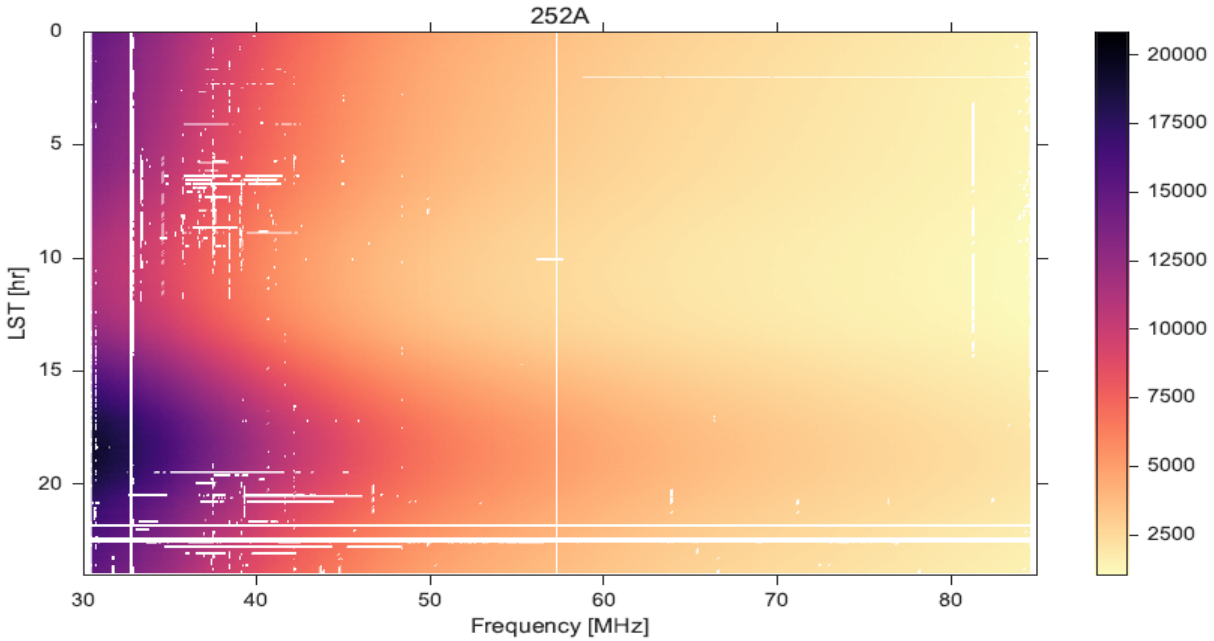
Price, Greenhill, Fialkov, GB et al.,
(2017, arXiv:1709.09313)

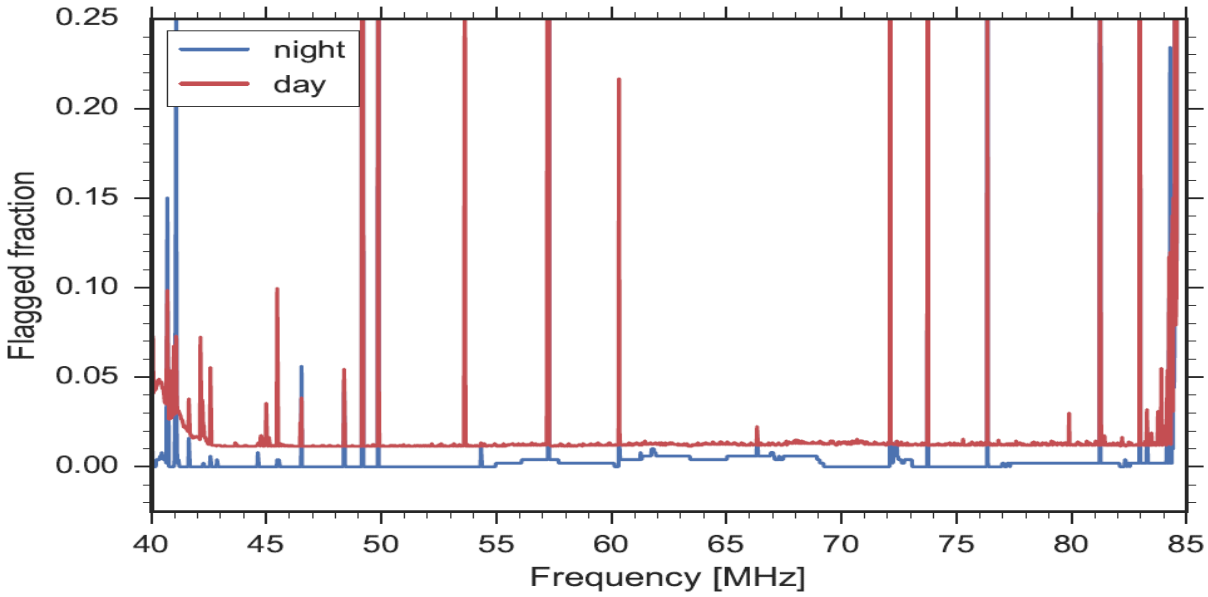




Price, Greenhill, Fialkov, GB et al., (2017, arXiv:1709.09313)

Early results

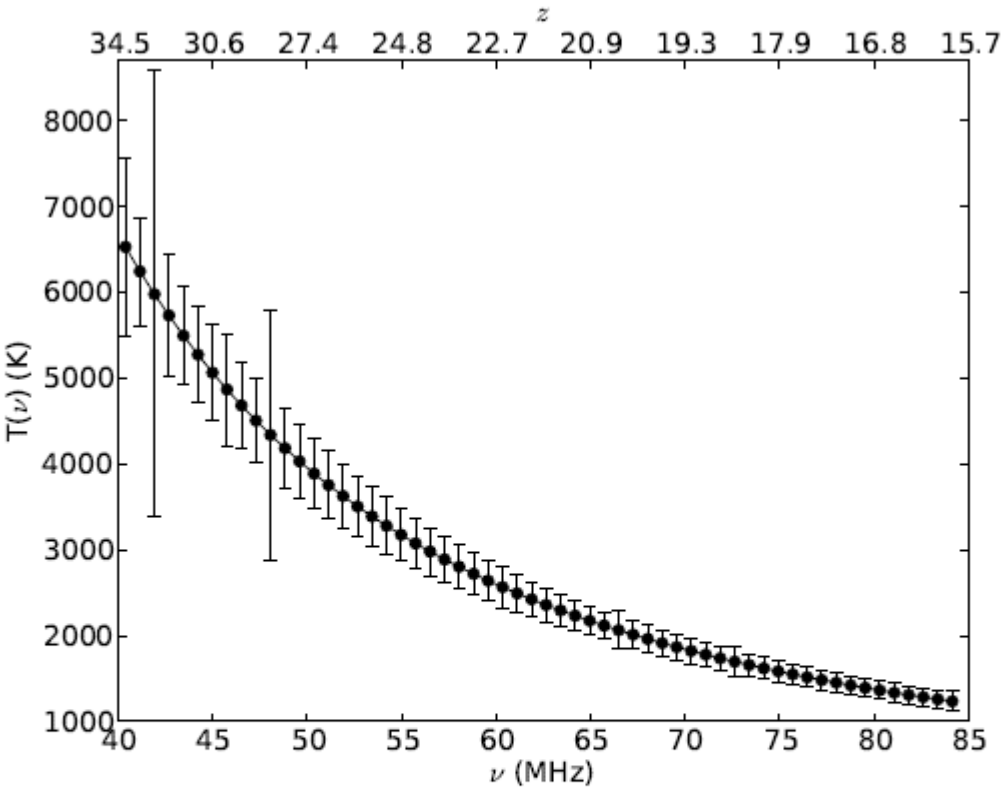




OVRO is a relatively RFI-free environment, good for CD science

Price, Greenhill, Fialkov, GB et al., (2017, arXiv:1709.09313)

Upper limits on the global 21-cm in the 16 < z < 35 range



- 2 hours on February 12 2016, 9.5 < LST < 11.5 (error bars inflated by 1000);
- ~1150 sec effective integration time;
- 40-85 MHz band, covered by 58, 768 kHz wide channels;
- three-state calibration switch + reflection coefficients corrections + sky model based calibration;

"It's impossible, but if they make it, I'll take my hat off" (Ger, 2007, on global signal measurements)

GB et al. (2016)

21-cm upper limits in the 16 < z < 35 range

Bayesian separation of foregrounds from a Gaussian-like 21-cm signal:

$$\mathcal{L}_j(T_{ant}(\nu)|\boldsymbol{\Theta}) = \frac{1}{\sqrt{2\pi\sigma^2(\nu)}} e^{-\frac{[T_{ant}(\nu)-T_m(\nu,\boldsymbol{\Theta})]^2}{2\sigma^2}}$$

$$T_m(\nu_j) = T_f(\nu_j) + T_{HI}(\nu_j) = 10^{\sum_{n=0}^{N} p_n \left[\log\left(\frac{\nu_j}{\nu_0}\right)\right]^n} + A_{HI} e^{-\frac{(\nu_j-\nu_{HI})^2}{2\sigma_{HI}{}^2}}$$

Harker et al. (2012)

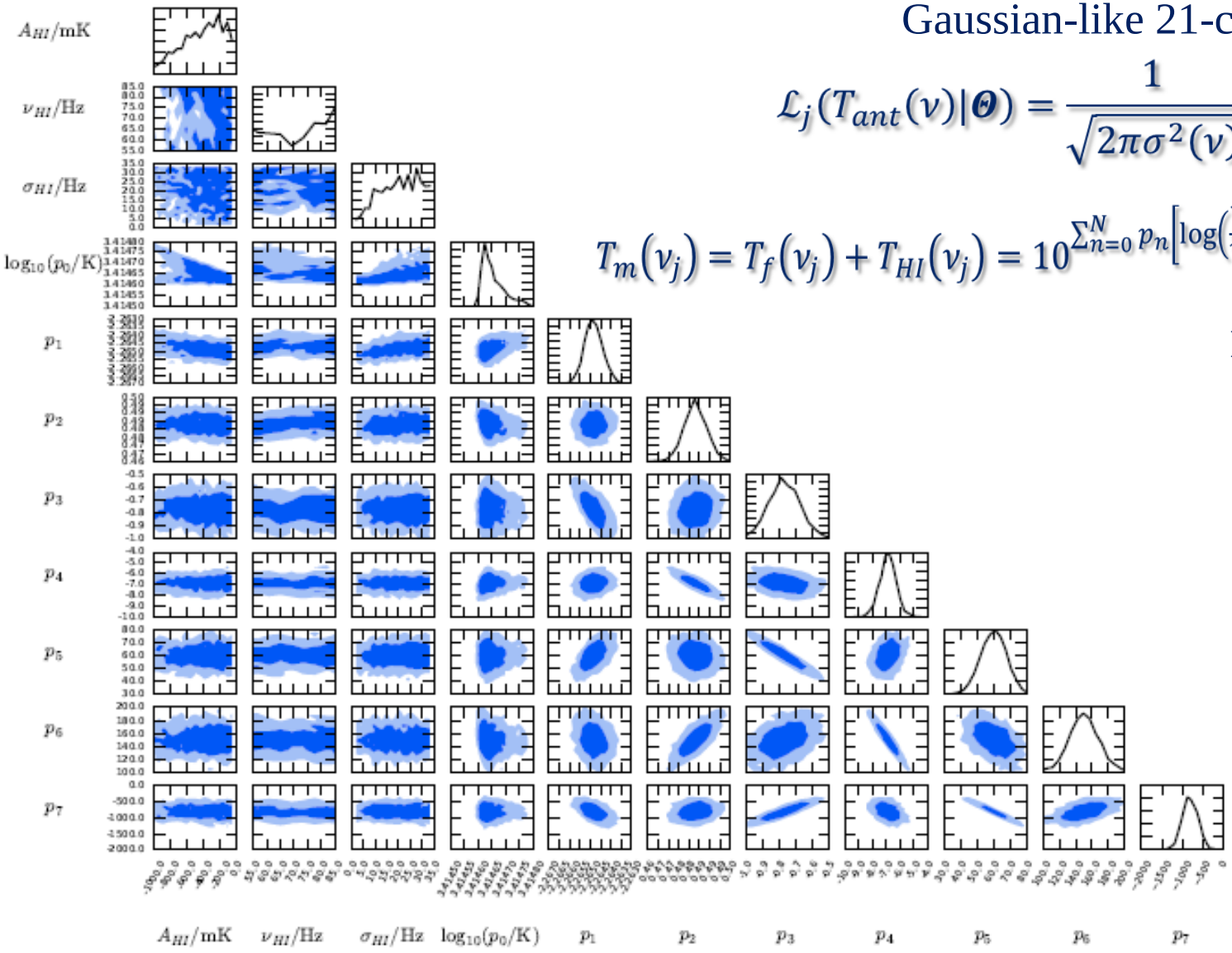
21-cm upper limits in the 16 < z < 35 range

Bayesian separation of foregrounds from a Gaussian-like 21-cm signal:

$$\mathcal{L}_j(T_{ant}(\nu)|\boldsymbol{\Theta}) = \frac{1}{\sqrt{2\pi\sigma^2(\nu)}} e^{-\frac{[T_{ant}(\nu)-T_m(\nu,\boldsymbol{\Theta})]^2}{2\sigma^2}}$$

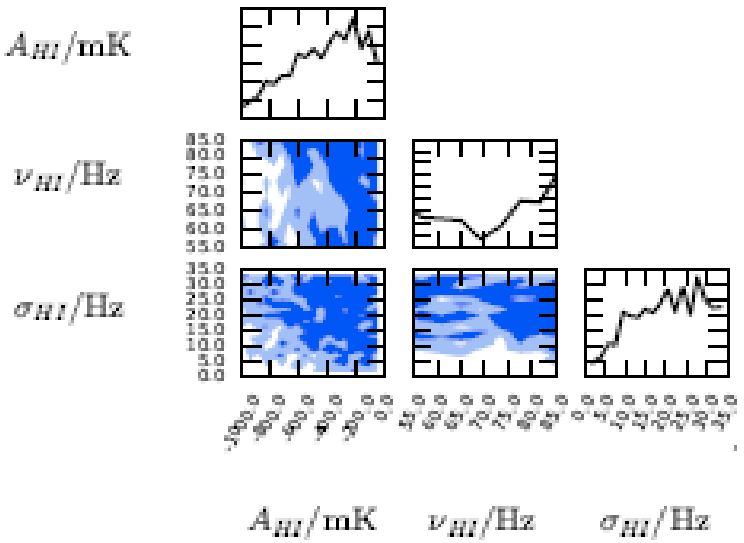
$$T_m(\nu_j) = T_f(\nu_j) + T_{HI}(\nu_j) = 10^{\sum_{n=0}^{N} p_n \left[\log\left(\frac{\nu_j}{\nu_0}\right)\right]^n} + A_{HI} e^{-\frac{(\nu_j-\nu_{HI})^2}{2\sigma_{HI}^2}}$$

Harker et al. (2012)



GB et al. (2016)

21-cm upper limits in the 16 < z < 35 range



$-905 < A_{HI} < 0$ mK @ 95% confidence level

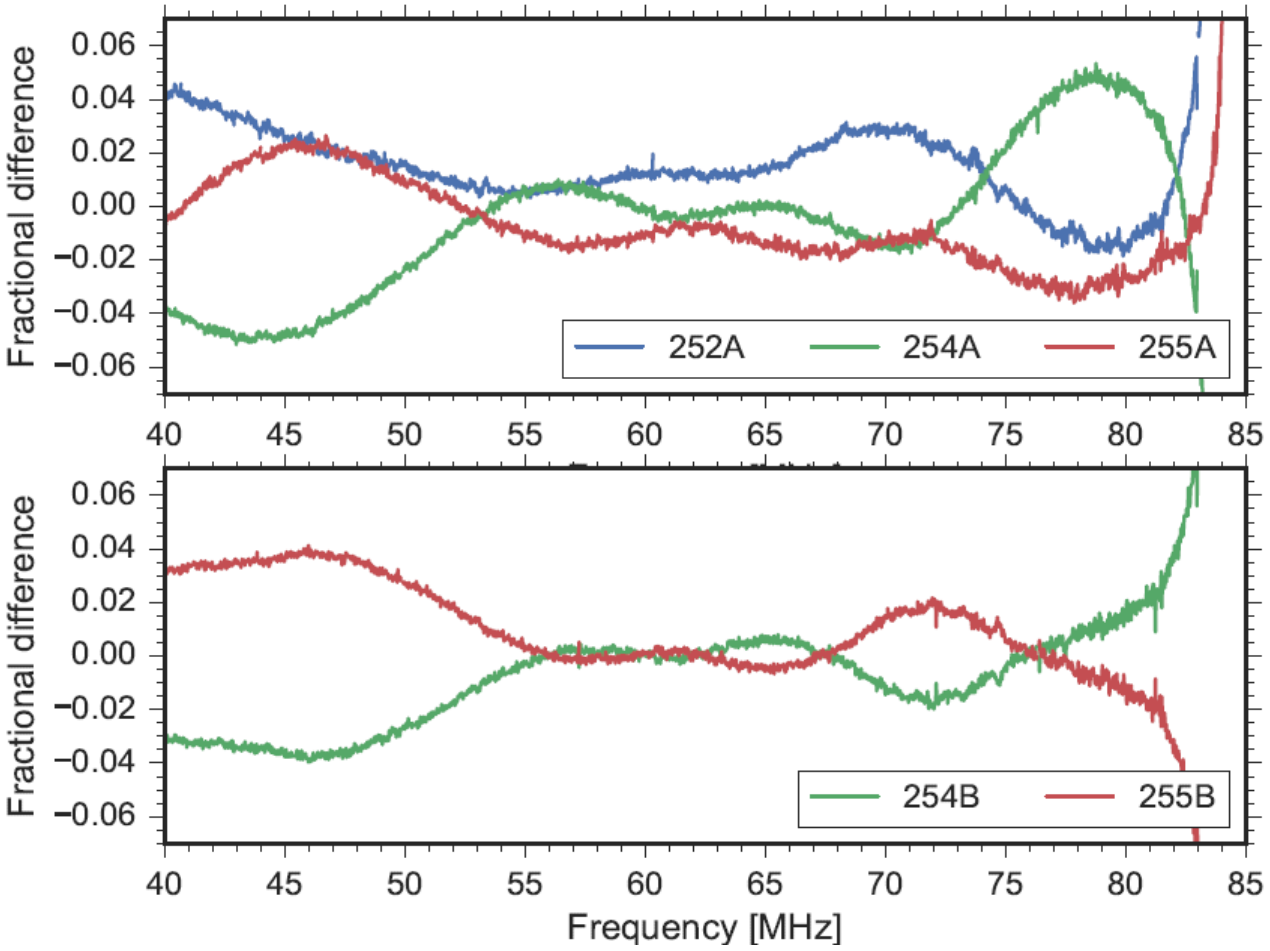
$\sigma_{HI} > 5.2$ MHz @ 95% confidence level

An extreme model with no heating down to z = 16, fully neutral IGM and instantaneous Lyα coupling leads to $A_{HI} \sim -300$ mK... no meaningful constraints on the parameter space yet

GB et al. (2016)

Future outlooks

"Who calibrates the calibrator? We use the sky!" (Ger, 2008)



Price, Greenhill, Fialkov, GB et al., (2017, arXiv:1709.09313)

- much improved temperature stabilization (10x specs);
- FE temperature sensors to correct short time gain variations;
- Characterization of the antenna/balun impedance time variations (0.5 Ω)

→

improved analysis of 1000h data taken in 2017!

Conclusions

- The 21-cm signal from the CD may be detectable with HERA ad SKA;
- LEDA targets the global signal from the CD (cheaper in many ways, not necessarily much easier...), aiming to constrain the formation of the first luminous sources (e.g. star formation in the first DM halos, feedback mechanisms) as well as the epoch of (likely) X-ray heating;
- First (weak) constraints from LEDA (A_{HI} > 900 mK) that is now observing with four dipoles → improved sensitivity and robustness to systematic effects... stay tuned for new results!!!

Conclusions

Conclusions