Neutral Hydrogen 21cm Intensity Mapping with the Tianlai Experiment

Shifan Zuo & The Tianlai Collaboration
NAOC

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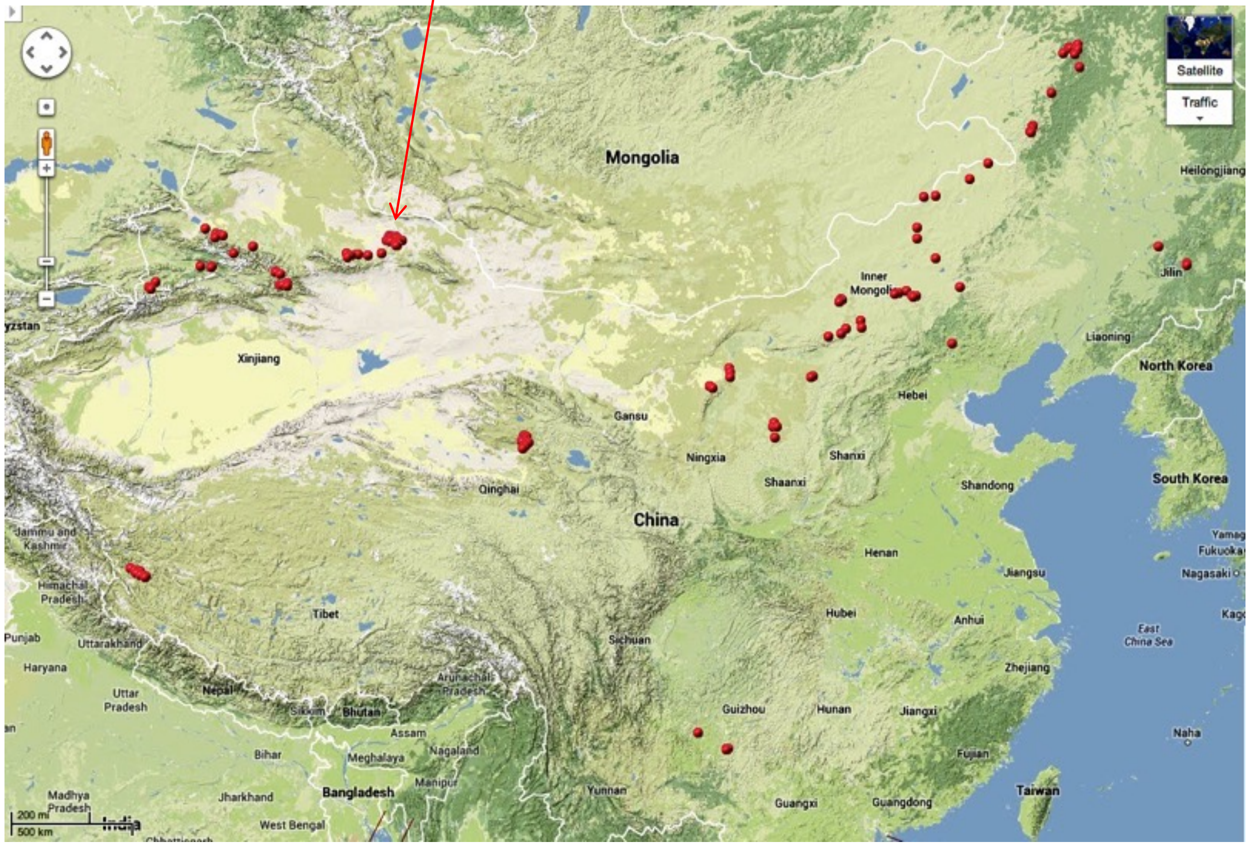
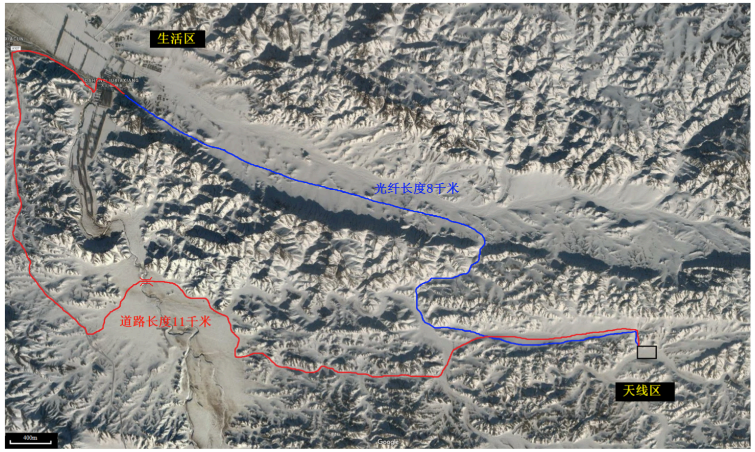
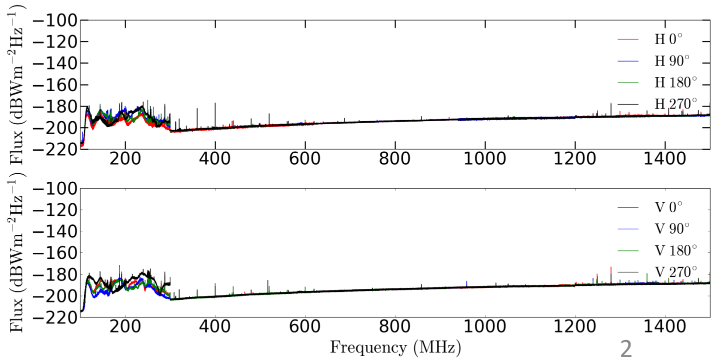
The Tianlai Site

红柳峡站址（新疆哈密地区巴里坤县）

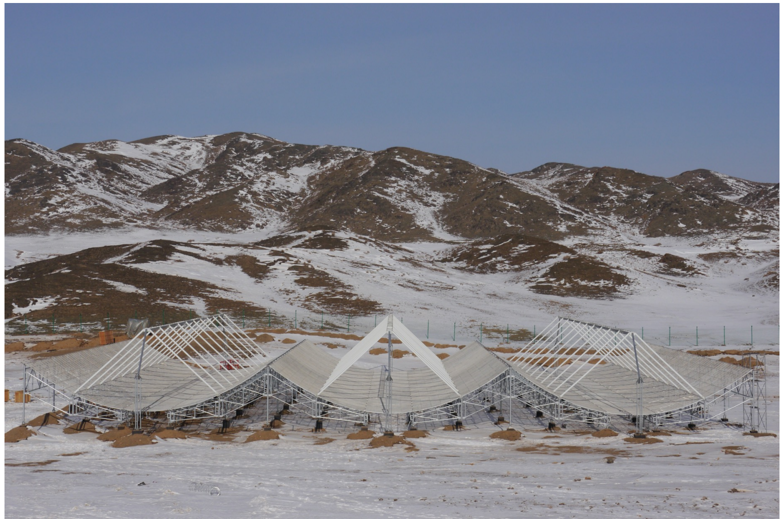


天线阵和站房

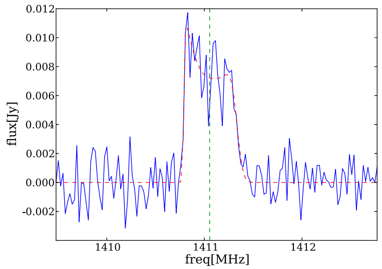




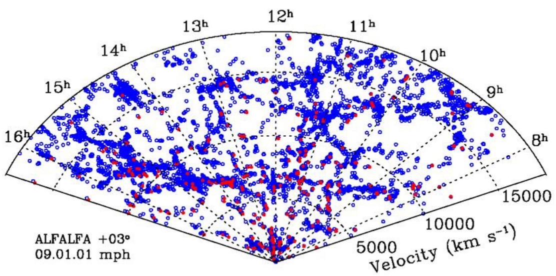
The Tianlai Arrays



21cm Intensity Mapping

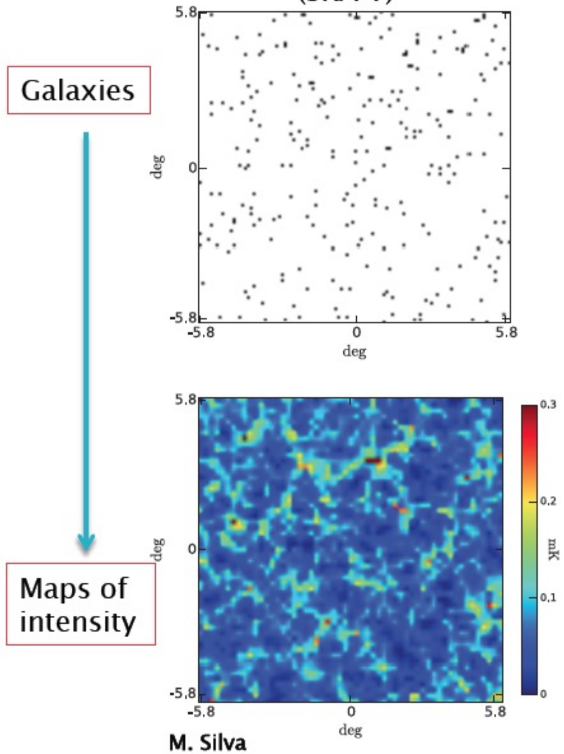


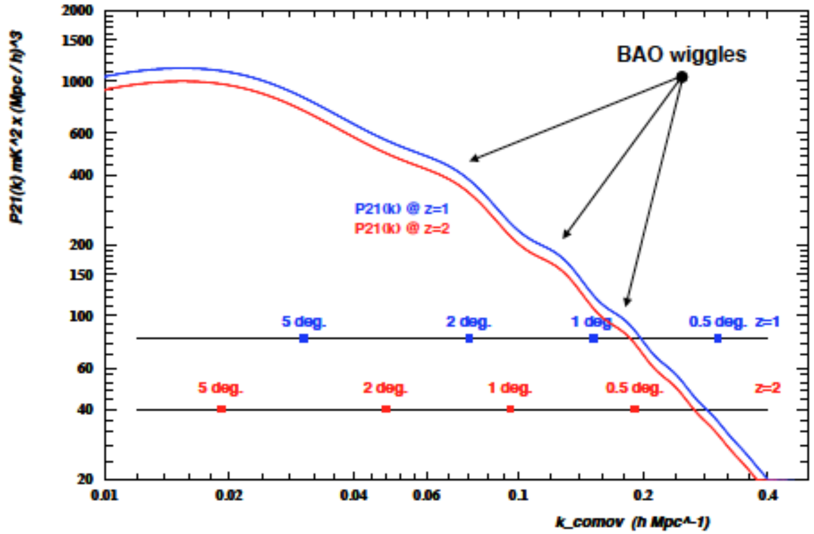
HI galaxy spectrum



HI galaxy survey

z ~ 0.6, 1 MHz slice
(SKA 1)



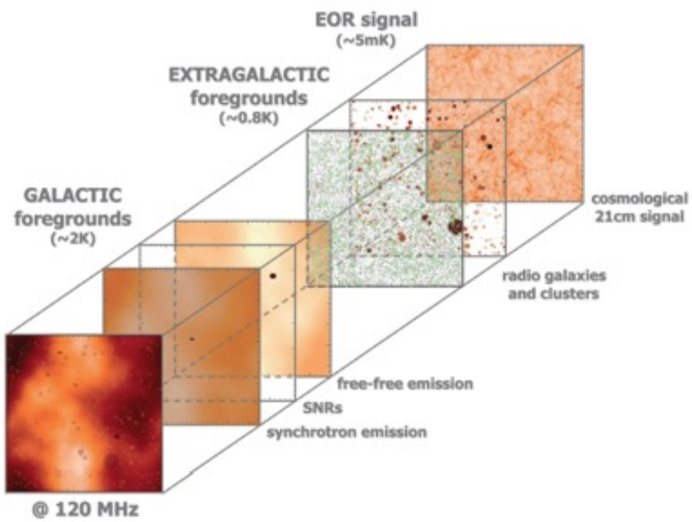


Challenge: Foreground

raw signal to noise ration (SNR) ~ 10^{-5}

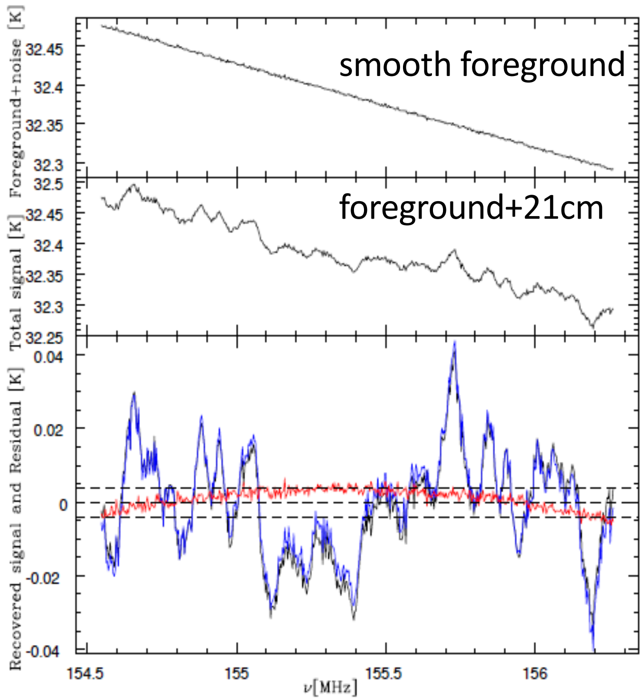
$$\Delta T \sim \frac{T_{\rm sys}}{\sqrt{\Delta\nu t_{int}}} \qquad T_{sys} \approx T_{\rm sky} + T_{\rm rec} + T_{\rm gpk}$$

$$T_{\rm sky} \approx 825 \times \left(\frac{\nu}{100\,\rm MHz}\right)^{-2.5} \rm K$$



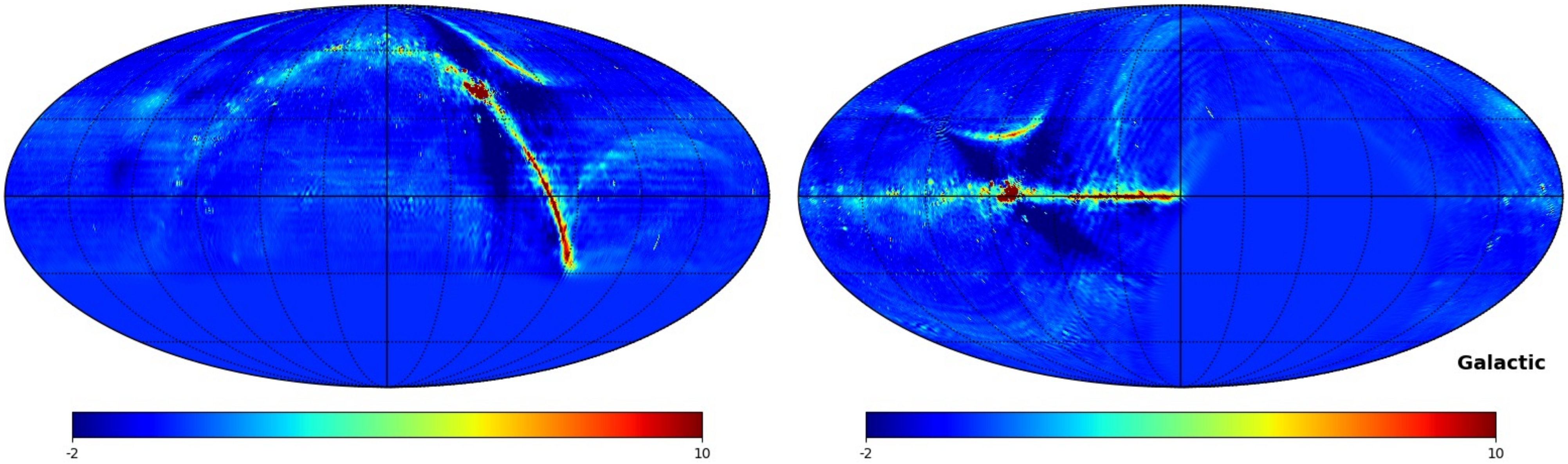
V. Jelic et al. (2010)

In principle, smooth foreground can be subtracted



X. Wang et al. (2006)

Sky Map Observed by Tianlai Cylinder Array (single freq 750MHz)



Angular Power Spectrum

$$\langle a_{lm}(\nu)\, a^{*}_{l'm'}(\nu')\rangle = C_l(\nu, \nu')\, \delta_{ll'}\, \delta_{mm'},$$

The MAPS $C_l(\nu,\nu')$ of the sky can be written as the sum of several different components,

$$C_l(\nu,\nu') = C_l^{\rm fg}(\nu,\nu') + C_l^{21}(\nu,\nu') + C_l^{\rm n}(\nu,\nu'). \quad (17)$$

A common paramterization of the MAPS for the foreground is [1]

$$C_l^{\rm fg}(\nu,\nu') = \sum_i A_i \left(\frac{l}{l_0}\right)^{-\alpha_i} \left(\frac{\nu\nu'}{\nu_0^2}\right)^{-\beta_i} \exp\left(-\frac{(\log\nu - \log\nu')^2}{2\zeta_i^2}\right), \quad (18)$$

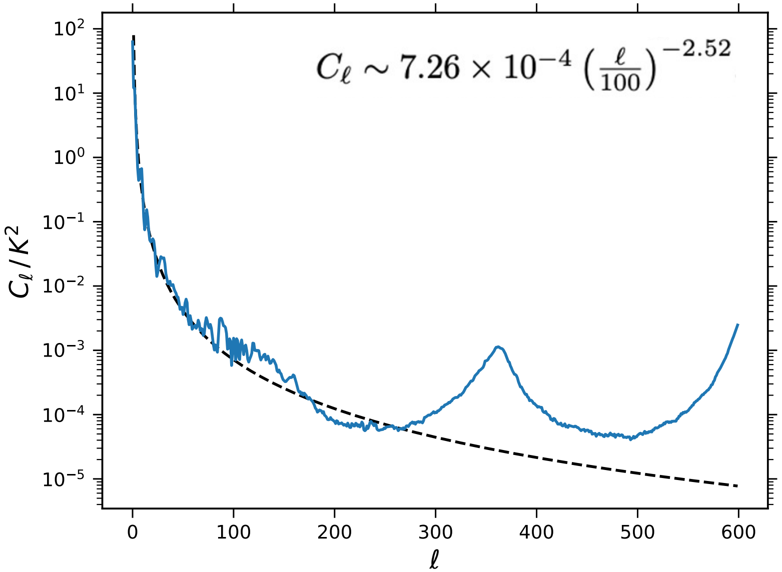
where A_i represents the overall amplitude of a foreground component; α_i determines its angular spectrum, β_i determines its frequency spectrum, and ζ_i controls the degree to which nearby frequency channels are correlated. The statement that foreground emission is spectrally smooth here implies $\zeta_i^2 \gg \log^2(\nu/\nu')$ for each component. This parameterization allows for multiple power-law foreground components and ensures that the covariance matrix is positive definite. If we assume $\zeta_i^2 \gg \log^2(\nu/\nu')$ and there is only a single foreground component, then Eq. 17 can be written as

$$C_l^{\rm fg}(\nu,\nu') = \sqrt{C_l^{\rm fg}(\nu) C_l^{\rm fg}(\nu')}, \quad (19)$$

where $C_l^{\rm fg}(\nu) = C_l^{\rm fg}(\nu,\nu)$ is the single-frequency angular power spectrum.

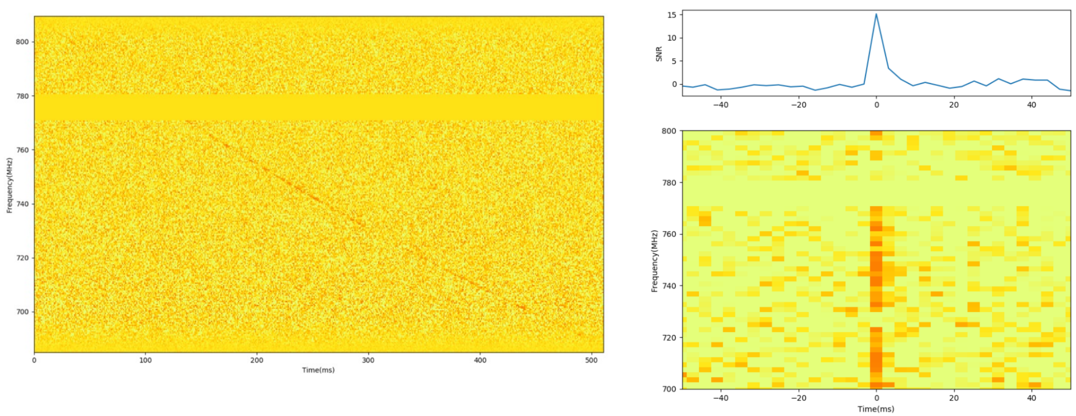
Assume there is only one foreground component, we have

$$C_\ell(\nu) = A\left(\frac{\ell}{\ell_0}\right)^{-\alpha}\left(\frac{\nu}{\nu_0}\right)^{-2\beta}$$



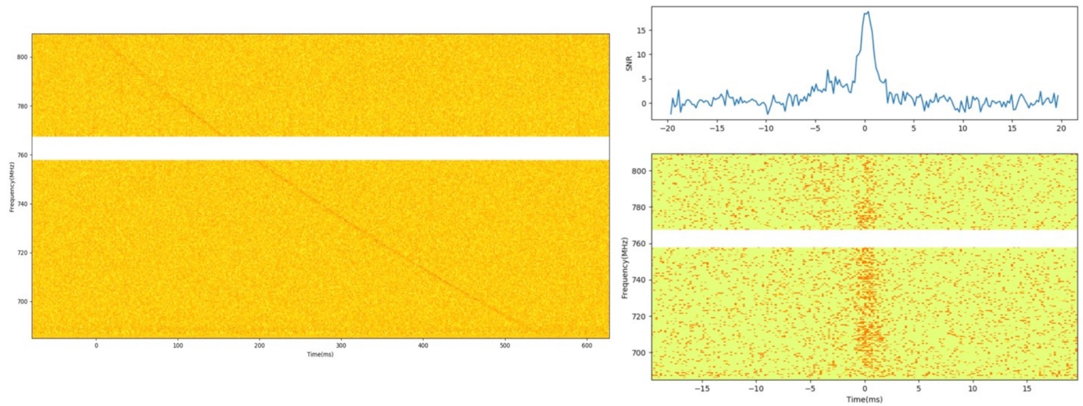
Tianlai FRB detections

cylinder



Blind Search 2022.04.14, 17:26:40.368 UT
DM=208.1±0.5 pc cm^{-3}
S_{peak} = 128.4 Jy,   fluence = 204 Jy ms, z<0.24

Dish

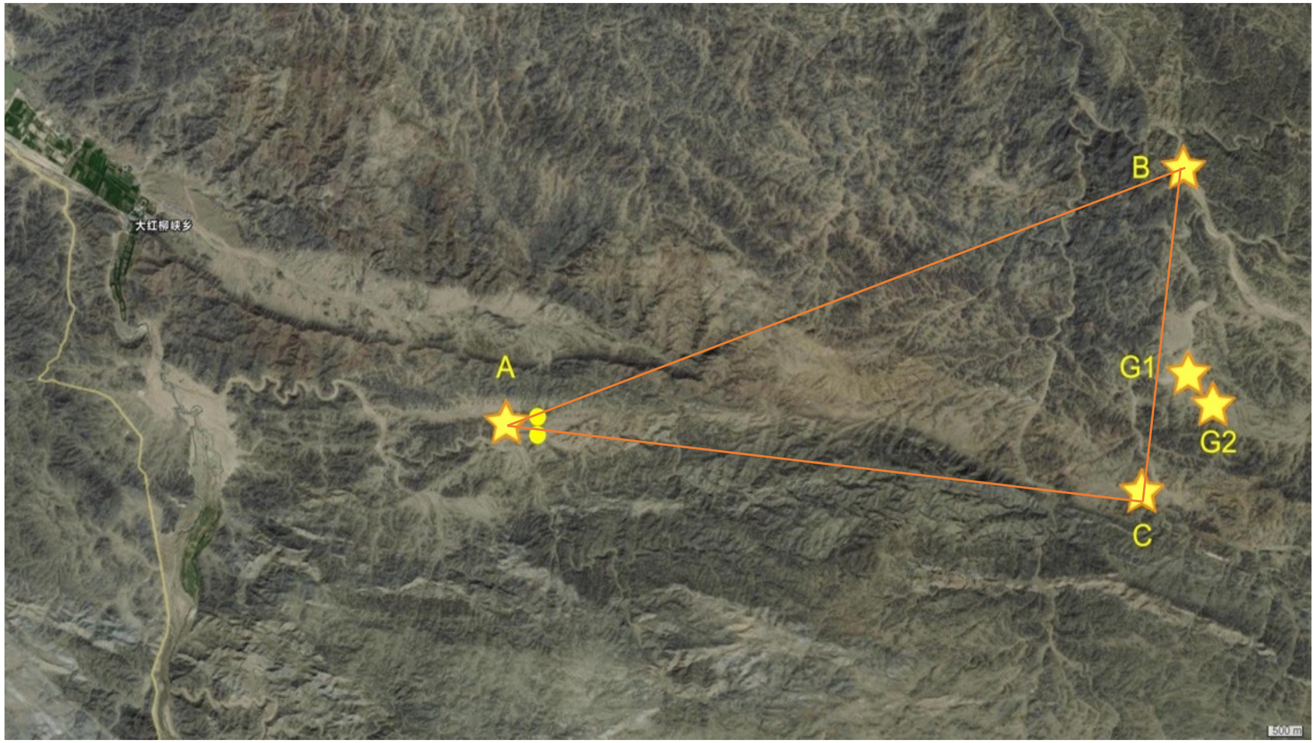


Observation of repeat FRB 20220912A detection on 2022.11.05 15:02:46.017 UT

DM =219.8
S_{peak}=285 Jy, fluency=600 Jy ms

Tianlai II Project

- Cylinder at A for imaging
- Cylinder B,C as FRB outtriger
- Dishes at A for better calibration
- Global Spectrum Experiment at G1, G2



Conclusion

- The 21cm cosmology has great potential, but requires very high precision and sophisticated analysis.

- The Tianlai experiment is an experiment to learn about the required key techniques. Though limited in sensitivity, we can already learn many valuable lessons about real world data analysis, and there is good opportunity for FRB research with Tianlai.

- We welcome domestic and international collaborations!

Thanks!