Tianlai Project

Xuelei Chen

National Astronomical Observatories, CAS

Center of High Energy Physics, Peking University

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21cm Cosmology

The observable Universe in comoving scale

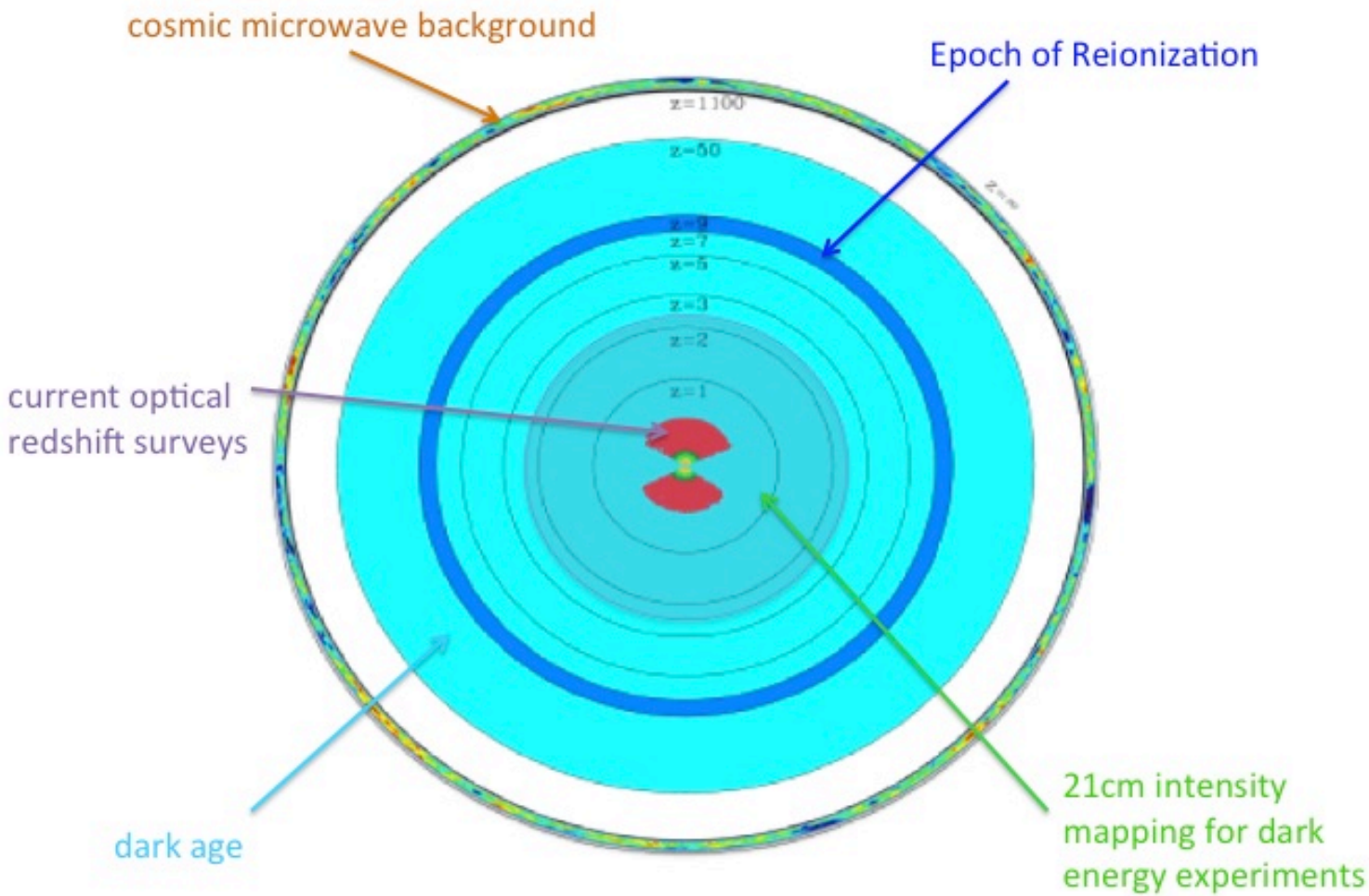
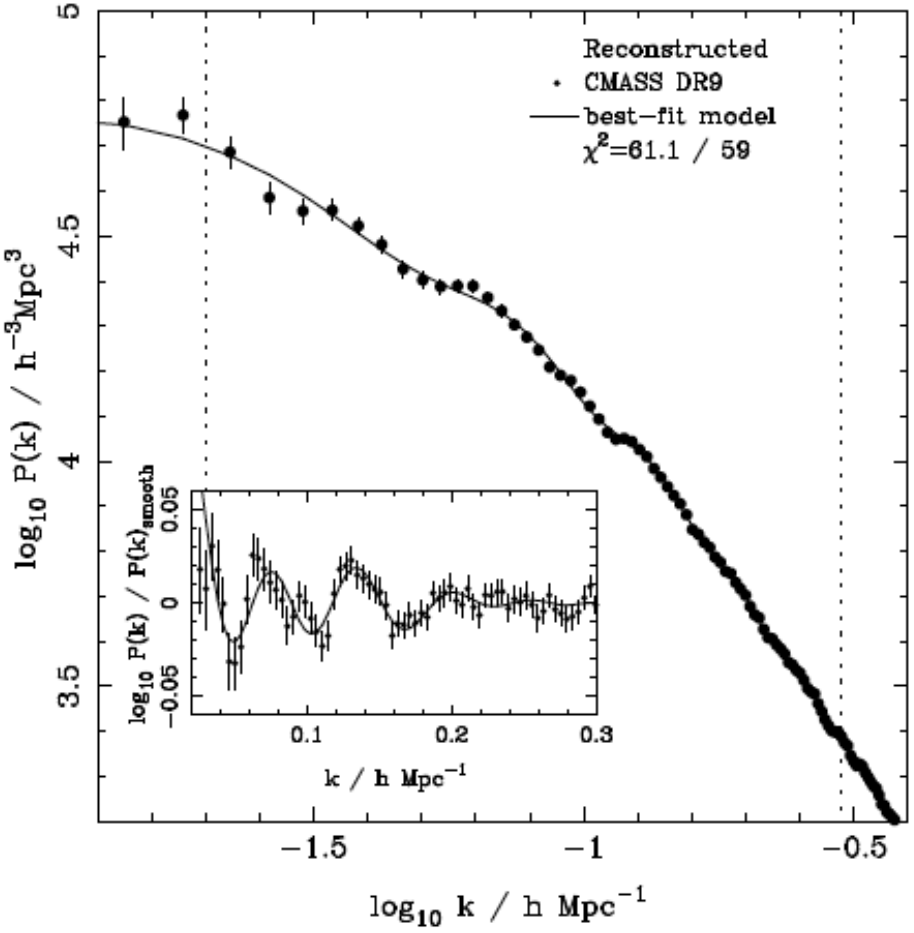
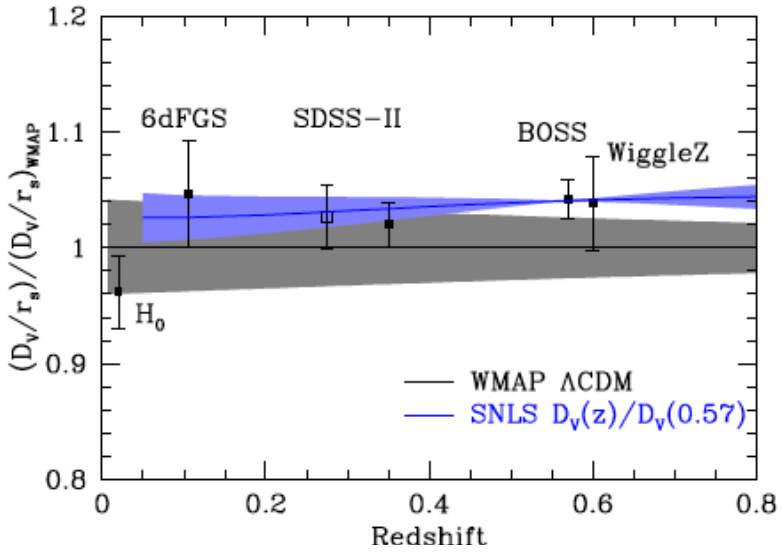
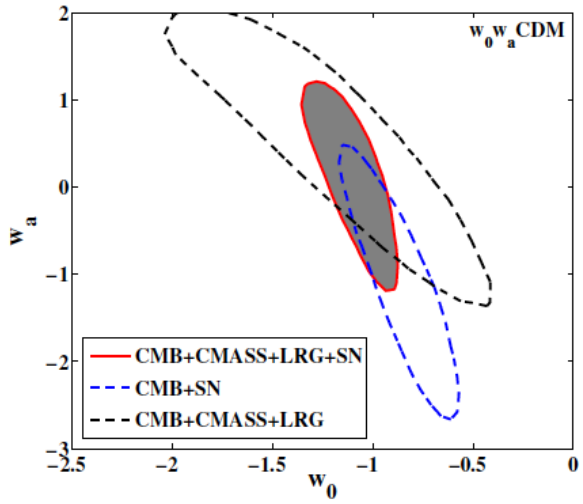


Figure inspired by Yi Mao & Max Tegmark

BAO measurements







Anderson et al.(BOSS collab.), arxiv:1203.6594

Advantage of 21cm for intensity mapping

Y. Gong et al. (ApJL 2011)

Intensity mapping may be contaminated by different spectral lines:

$$(1+z_1)\lambda_1 = (1+z_2)\lambda_2.$$

The low frequency 21cm does not have significant contaminants, we considered OH 18cm line. In such contamination, incoherent superposition (power spectra adds)

Thompson, Moran & Swenson (2001)

TABLE 1.1 Some Important Radio Lines

Chemical Name	Chemical Formula	Transition	Frequency (GHz)
Deuterium	D	$^2S_{\frac{1}{2}}, F = \frac{3}{2} \rightarrow \frac{1}{2}$	0.327
Hydrogen	HI	$^2S_{\frac{1}{2}}, F = 1 \rightarrow 0$	1.420
Hydroxyl radical	OH	$^2\Pi_{\frac{3}{2}}, J = \frac{3}{2}, F = 1 \rightarrow 2$	1.612[a]
Hydroxyl radical	OH	$^2\Pi_{\frac{3}{2}}, J = \frac{3}{2}, F = 1 \rightarrow 1$	1.665[a]
Hydroxyl radical	OH	$^2\Pi_{\frac{3}{2}}, J = \frac{3}{2}, F = 2 \rightarrow 2$	1.667[a]
Hydroxyl radical	OH	$^2\Pi_{\frac{3}{2}}, J = \frac{3}{2}, F = 2 \rightarrow 1$	1.721[a]
Methyladyne	CH	$^2\Pi_{\frac{1}{2}}, J = \frac{1}{2}, F = 1 \rightarrow 1$	3.335
Hydroxyl radical	OH	$^2\Pi_{\frac{1}{2}}, J = \frac{1}{2}, F = 1 \rightarrow 0$	4.766[a]
Formaldehyde	H_2CO	$1_{10} - 1_{11}$, six F transitions	4.830
Hydroxyl radical	OH	$^2\Pi_{\frac{3}{2}}, J = \frac{5}{2}, F = 3 \rightarrow 3$	6.035[a]
Methanol	CH_3OH	$5_1 \rightarrow 6_0 A^+$	6.668[a]
Helium	$^3He^+$	$^2S_{\frac{1}{2}}, F = 1 \rightarrow 0$	8.665
Methanol	CH_3OH	$2_0 \rightarrow 3_{-1} E$	12.179[a]
Formaldehyde	H_2CO	$2_{11} \rightarrow 2_{12}$, four F transitions	14.488
Cyclopropenylidene	C_3H_2	$1_{10} \rightarrow 1_{01}$	18.343
Water	H_2O	$6_{16} \rightarrow 5_{23}$, five F transitions	22.235[a]
Ammonia	NH_3	$1, 1 \rightarrow 1, 1$, eighteen F transitions	23.694
Ammonia	NH_3	$2, 2 \rightarrow 2, 2$, seven F transitions	23.723
Ammonia	NH_3	$3, 3 \rightarrow 3, 3$, seven F transitions	23.870
Methanol	CH_3OH	$6_2 \rightarrow 6_1, E$	25.018
Silicon monoxide	SiO	$v = 2, J = 1 \rightarrow 0$	42.821[a]
Silicon monoxide	SiO	$v = 1, J = 1 \rightarrow 0$	43.122[a]

$$\bar{I}_{\rm OH}(z) = f_{\rm OH} \int_{M_{\rm min}}^{M_{\rm max}} dM \frac{dn}{dM} f_{\rm IR}(M) \frac{L_{\rm OH}(M,z)}{4\pi D_L^2} y(z) D_A^2$$

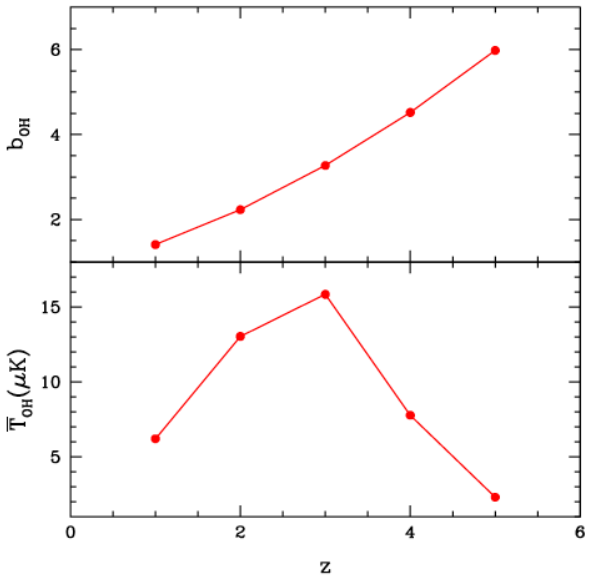
OH – IR relation (Darling & Giovanelli 2002):

$$\log L_{\rm OH} = (1.2 \pm 0.1) \log L_{\rm IR} - (11.7 \pm 1.2).$$

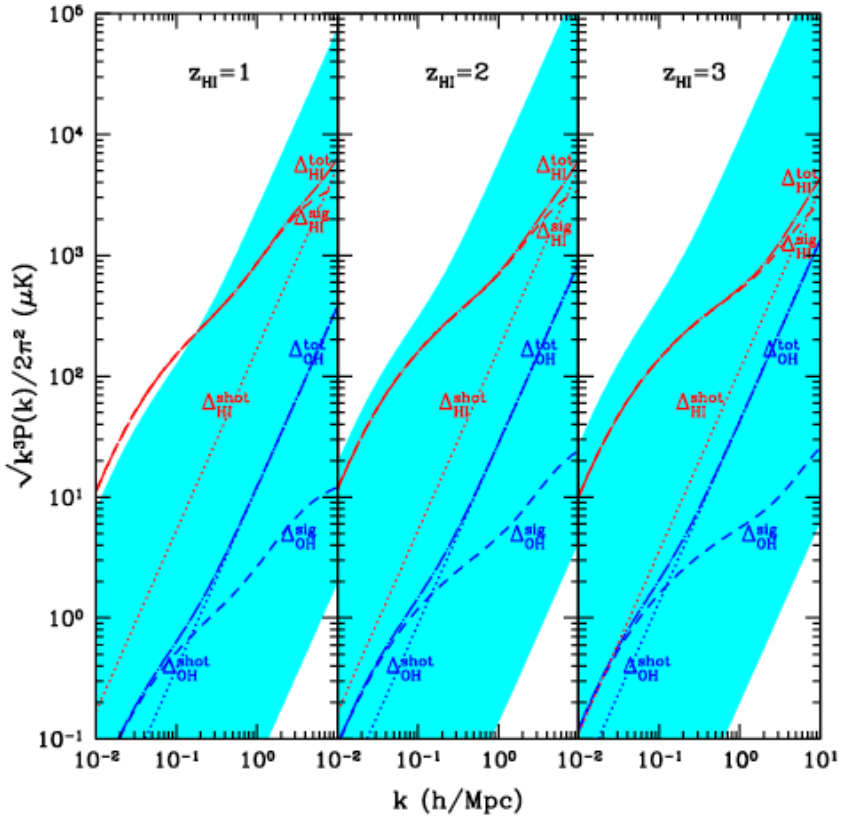
IR-SFR relation (Magnelli et al. 2011)

$$L_{\rm IR}\ [L_\odot] = 5.8 \times 10^9\ {\rm SFR}\ [{\rm M}_\odot {\rm yr}^{-1}].$$

Using SKA sky simulation model to obtain halo a (Obreschkow et al. 2009)



The OH power is several orders of magnitude smaller than the 21cm power, so the contamination is insignificant



The Tianlai （天籁, Heavenly Sound) Project: 21cm intensity mapping experiment in China

The concept of "tianlai" (the cosmic sound) was introduced by Taoist philosopher Chuang-Tzu (369BC-286BC)

The Collaboration:

Academic: NAOC(Chen), CITA(Pen), CMU (Peterson), LAL/U. Paris-Sud (Ansari), U. Wisconsin (Timbie), Fermilab, ASIAA(Chang), Peking U., Hangzhou Dianzi U.,

Industry: CETC-54, Institute of Automation

Design Considerisions

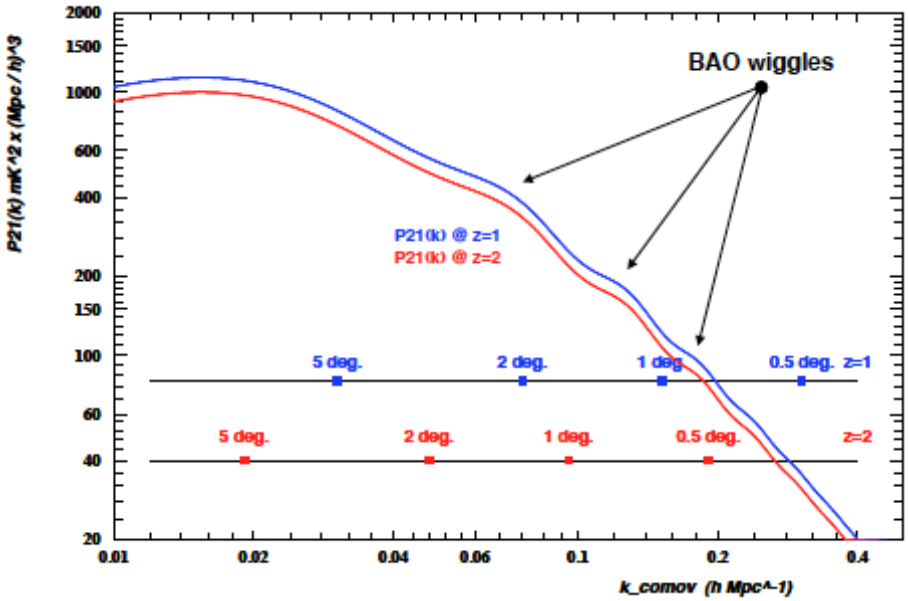
- Drift Scan (less cost, more stable)

- 0<z<3, first probably z=1 (sensitive to dark energy, avoids cell phone band at 850-950 MHz), alternatively z=0.2-0.3 (better optical coverage, smaller antenna)

- Angular Resolution: 15arcmin, to resolve the high order BAO peaks

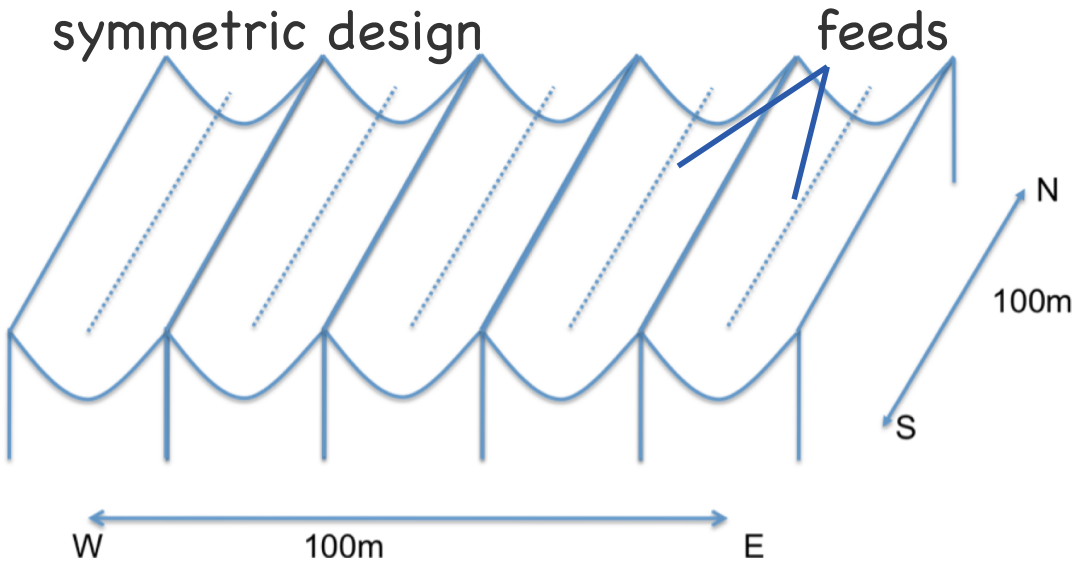
- An array of about 100m size

- For 1st BAO peak, the array can be smaller

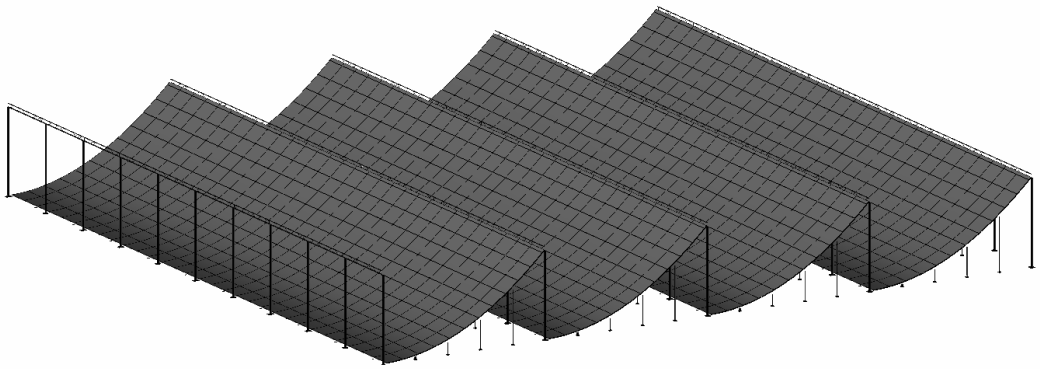


Ansari et al., 1108.1474

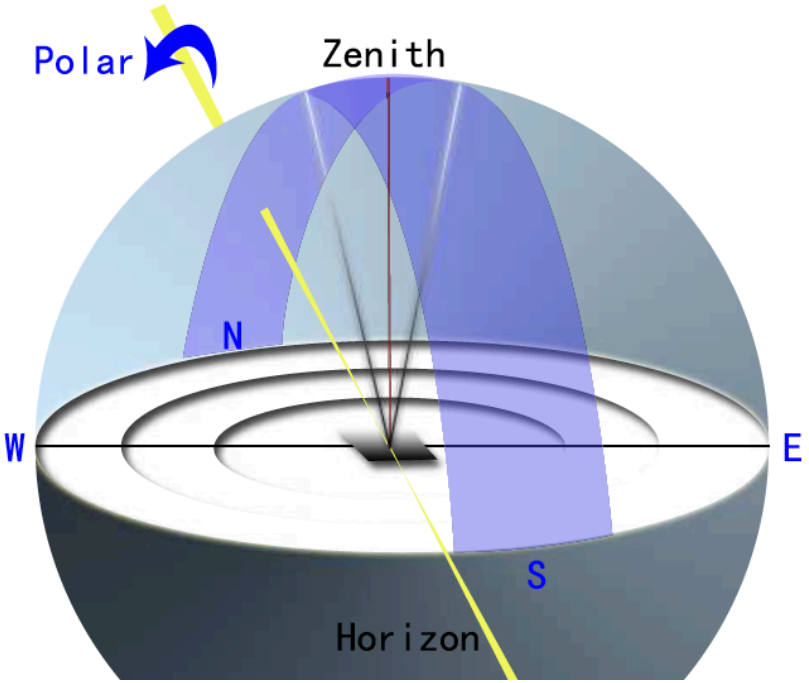
Cylinder Radio Telescope



asymmetric design



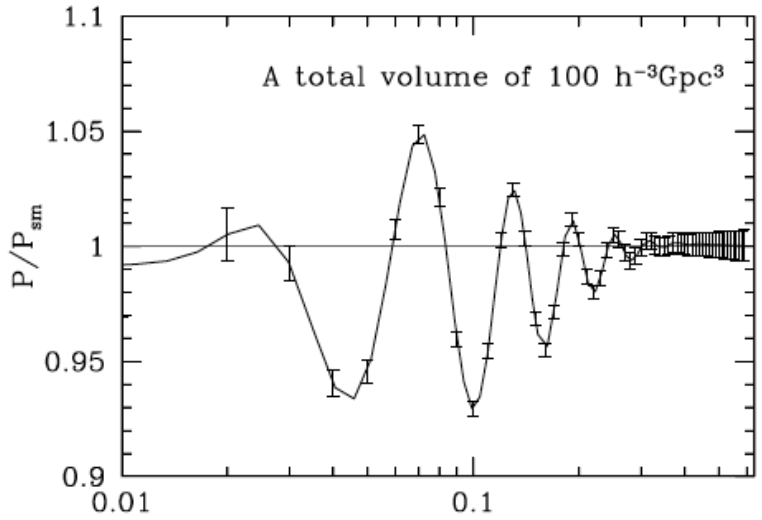
Jeff Peterson et al. 2006



instant field of view

Experimental Design Study

H. Seo et al. 2009



X. Wang & X. Chen, in preparation

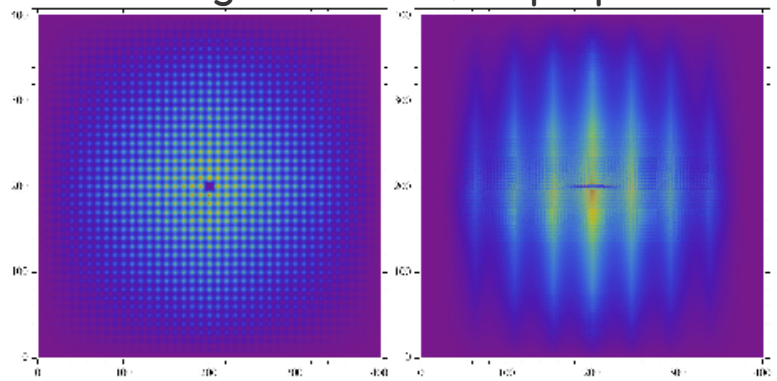
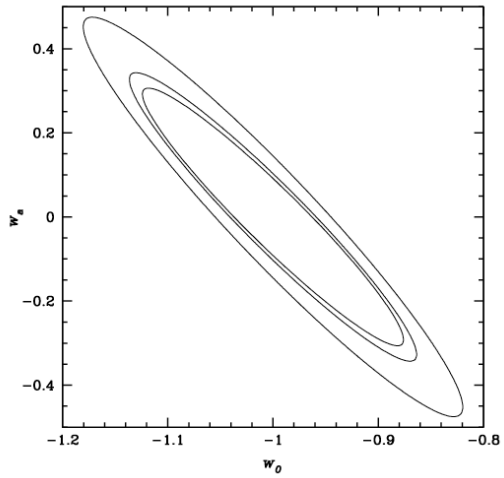
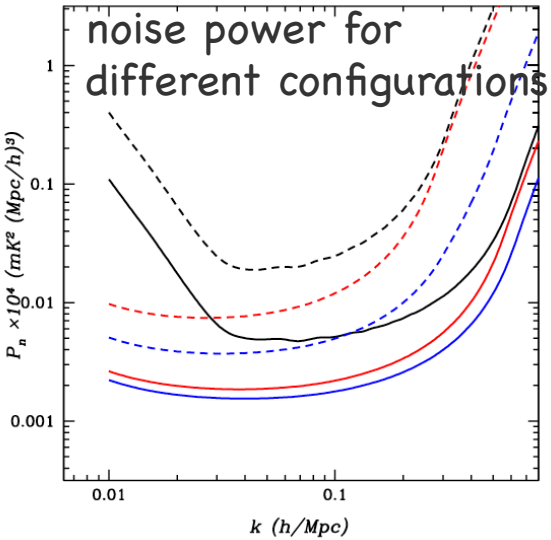


Fig. 4.— u-v coverage of natural map for both dishes (*left*) and cylinder(*right*).

X. Wang & X. Chen, in preparation



dish vs cylinder

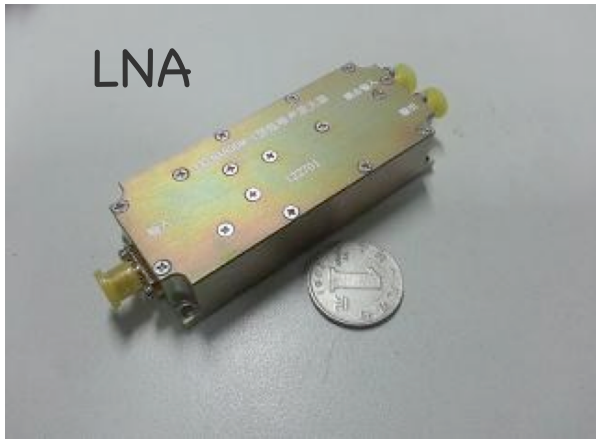


Pilot Experiment

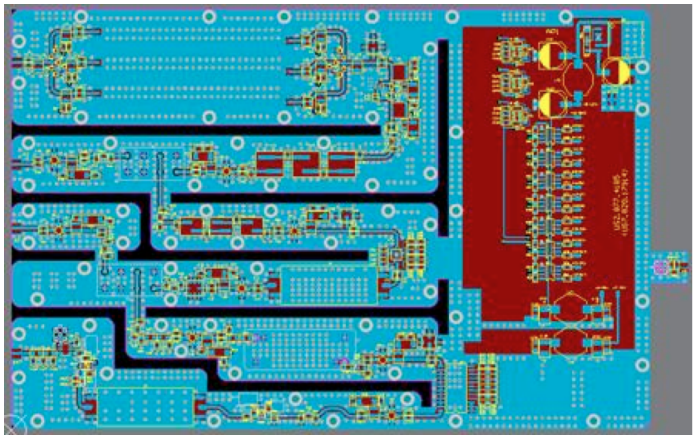
- A small pilot experiment to check the basic principles and designs, find out potential problems
- 3x15x40m cylinders (can expand if additional fund available)
- 4 years
- allow using later technology at the full scale experiment
- whole project: about 8-10 years
- Alternative: instead of cylinders, use small dishes (about 5-10m)

Analog front end components

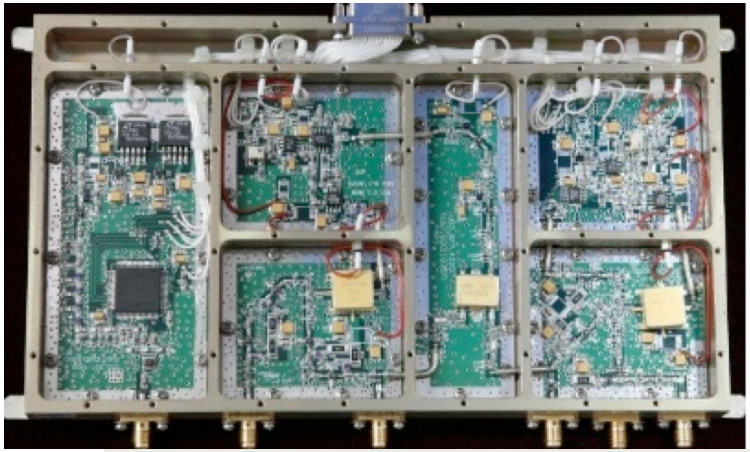
LNA

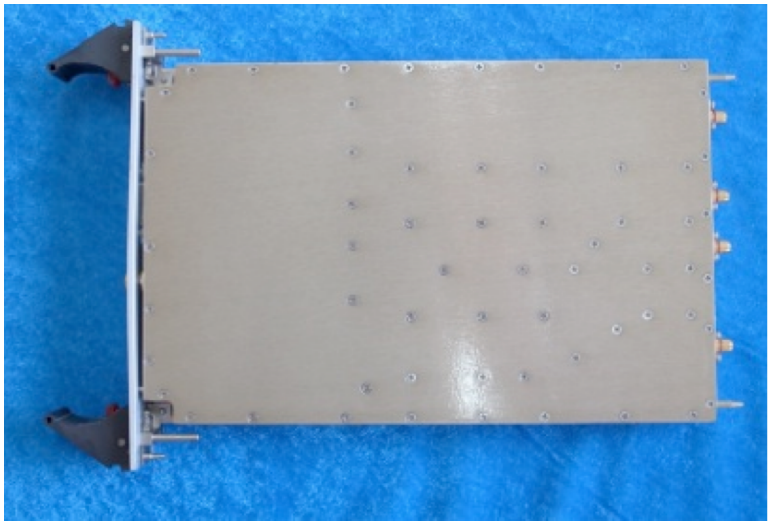


mixer



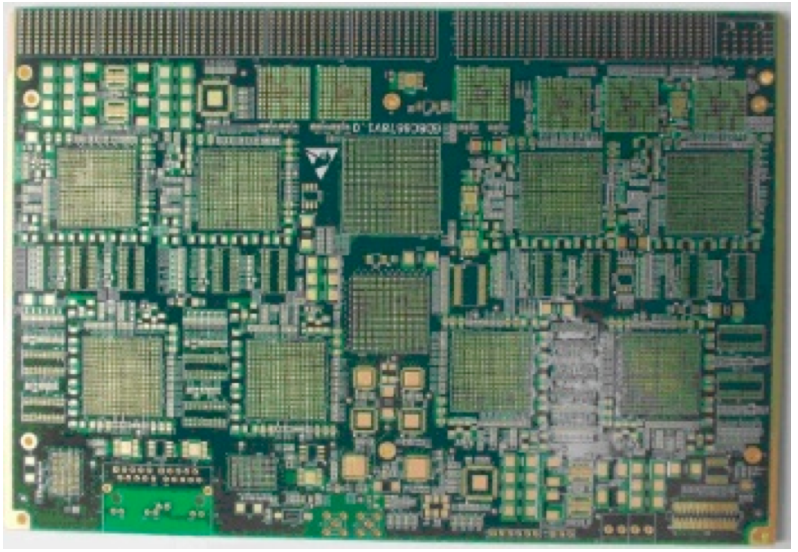
LO





Digital Components

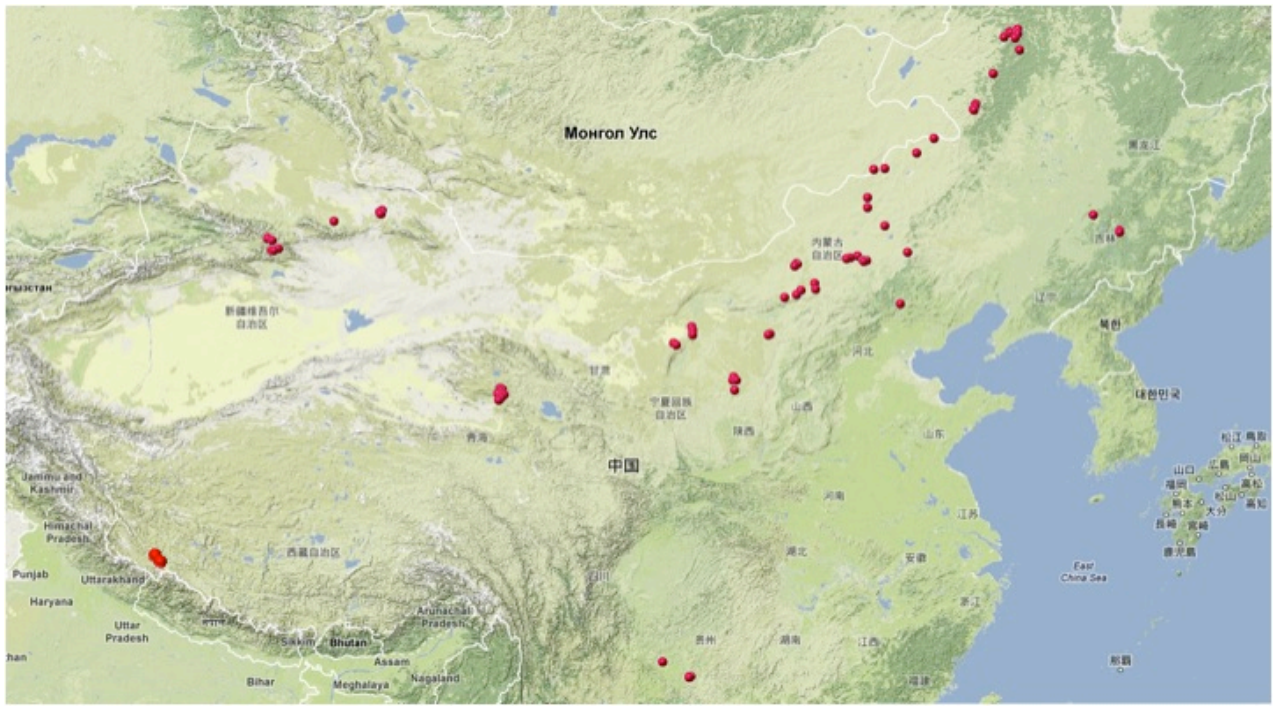
AD board

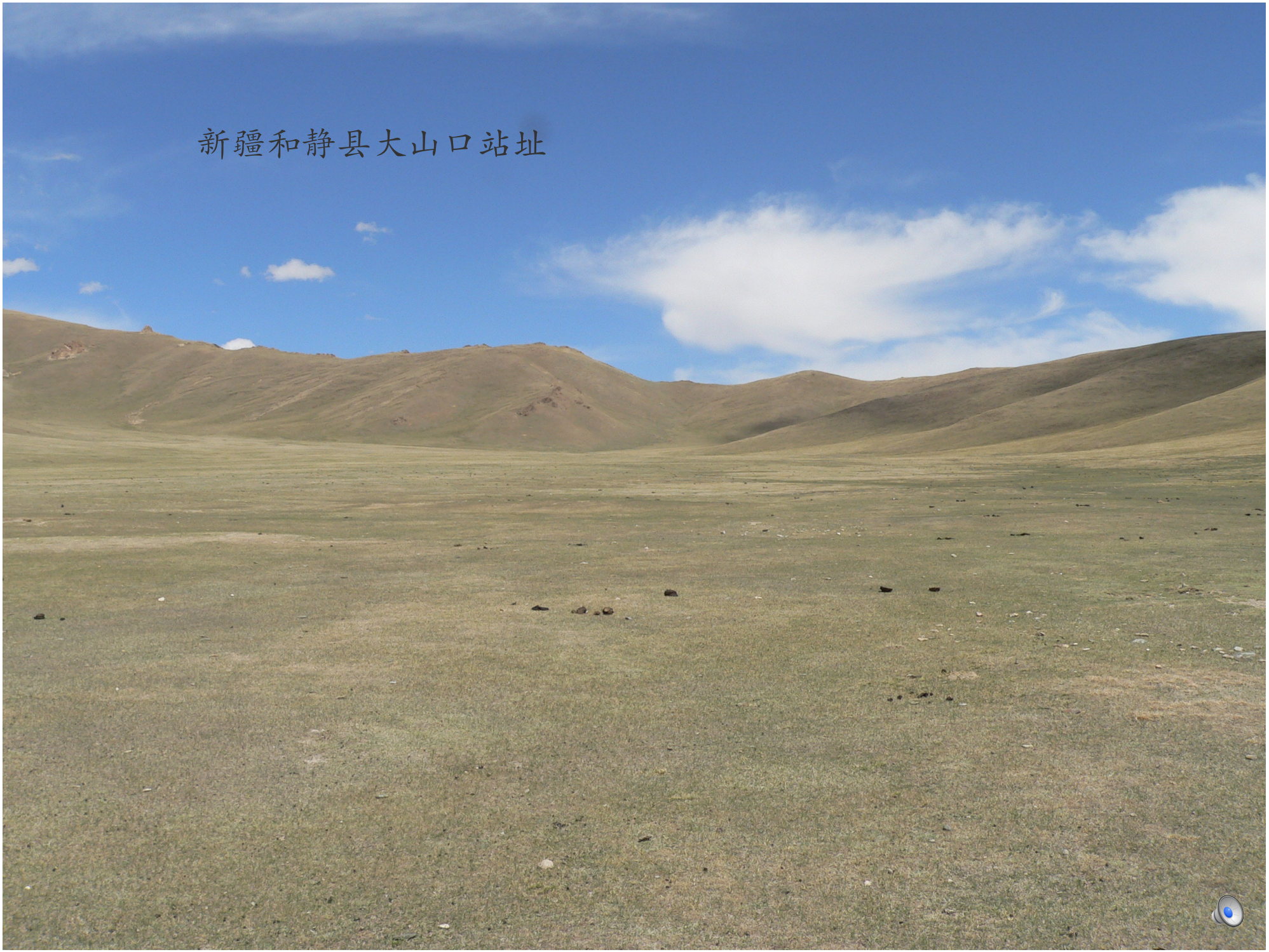


Processing board

Site Surveys in China

- Low RFI (low population density, shielded by mountains)
- wide open terrain
- convenience in logistics, electricity,communication




新疆和静县大山口站址

Thanks