Tianlai Workshop

The Tianlai 21cm intensity mapping experiment

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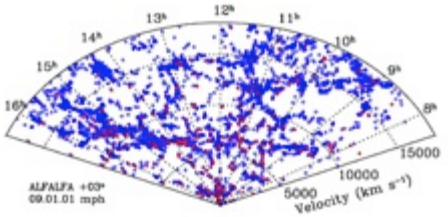
National Astronomical Observatories,
Chinese Academy of Sciences

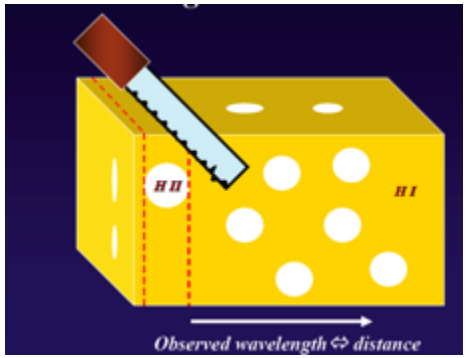
Fermilab, 2016.09.26

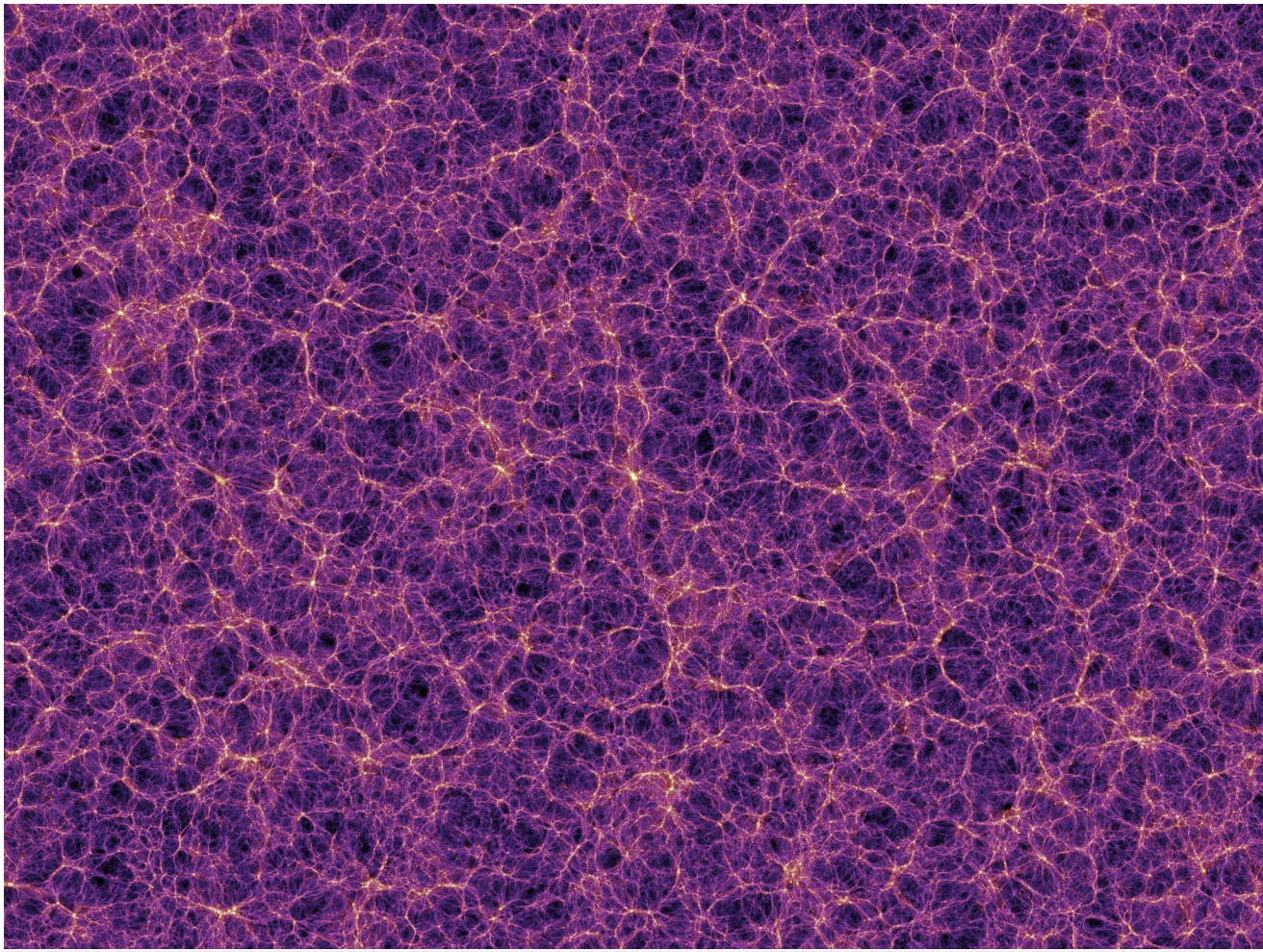
Probe the Large Scale Structure with 21cm

HI galaxy survey



21cm tomography

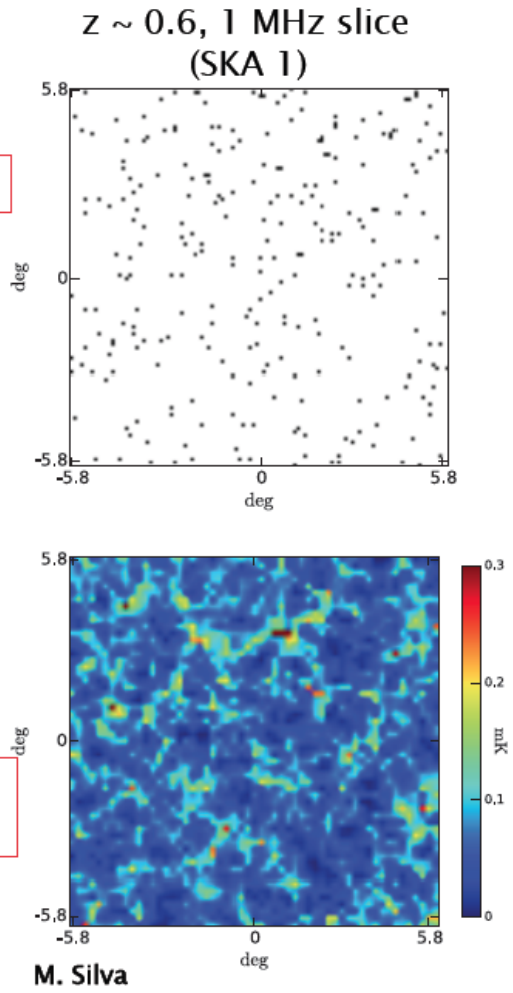




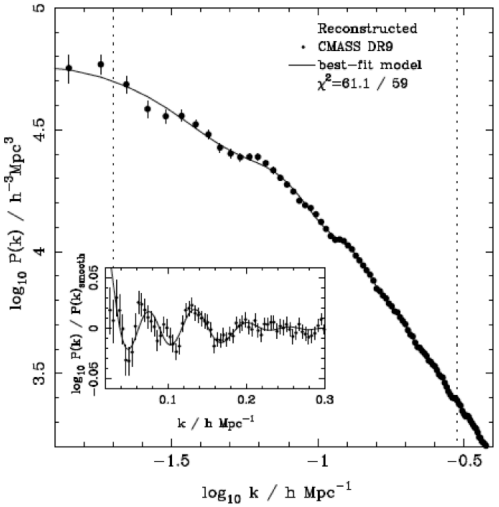
Intensity Mapping

Galaxies

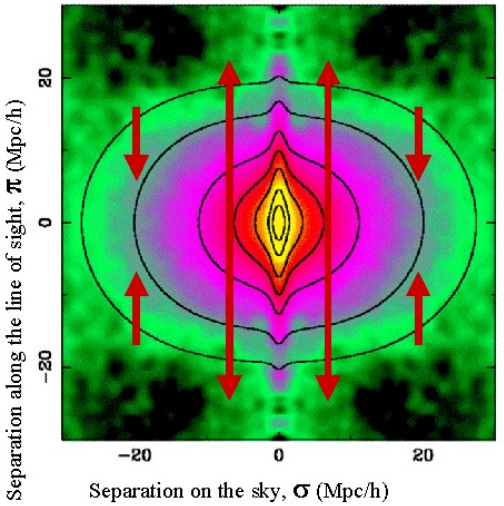
Maps of intensity



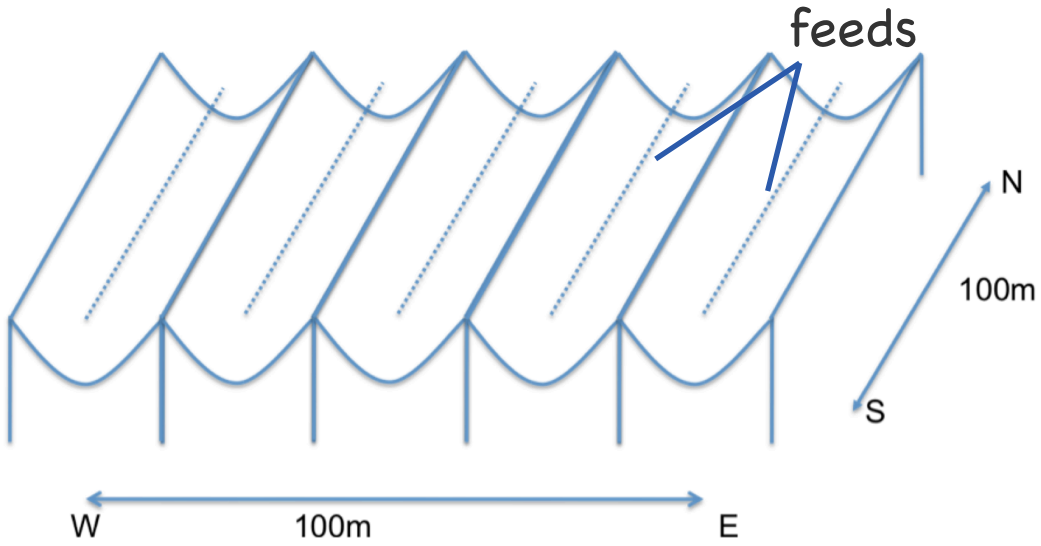
Baryon Acoustic Oscillation (BAO)

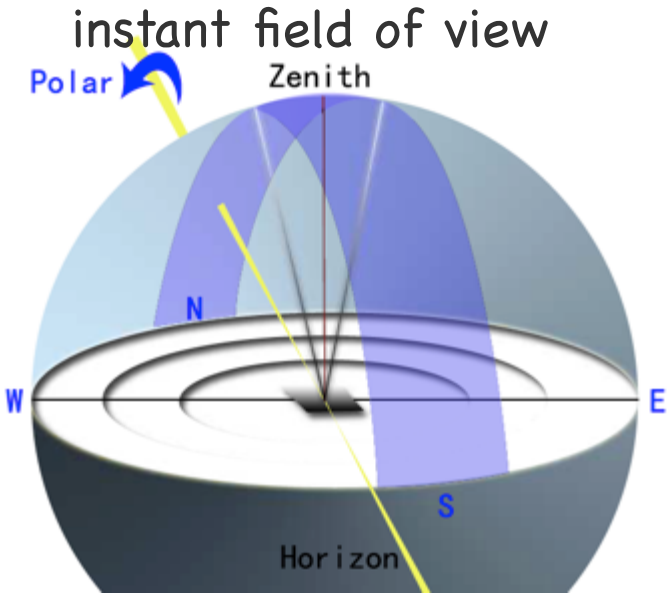


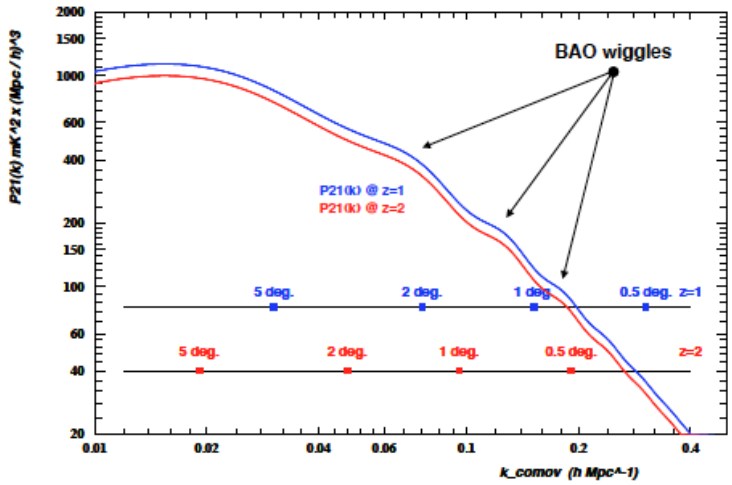
Redshift Space Distortion (RSD)



Cylinder for Intensity Mapping







Ansari et al., 1108.1474

Brief History

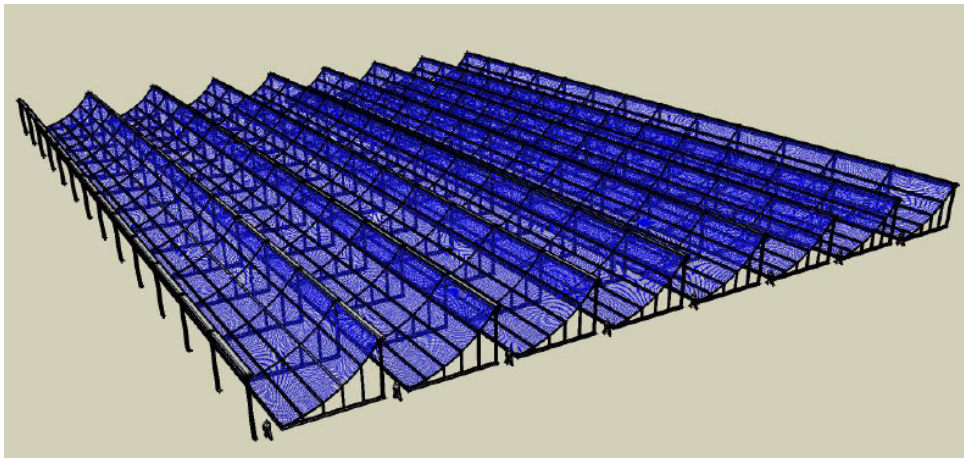
Drift Scan Cylinders (Bandura, Peterson & Pen 2006)

Intensity Mapping (Chang et al. 2008, Ansari et al. 2008, Seo et al. 2009)

Fermilab studies (Stebbins, McGinnis, Marriner, …)

African desert site

Figure 10. Moroccan Site Map



Pittsburgh Cylinder

Tianlai's Origin

Jeff Peterson & XC conversation in 2005

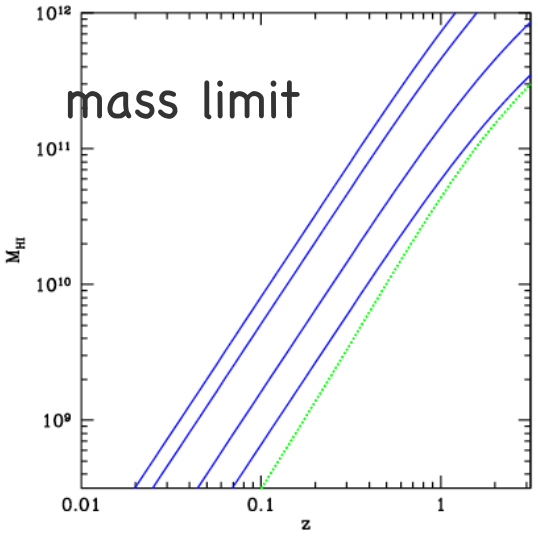
FAST study (2007)

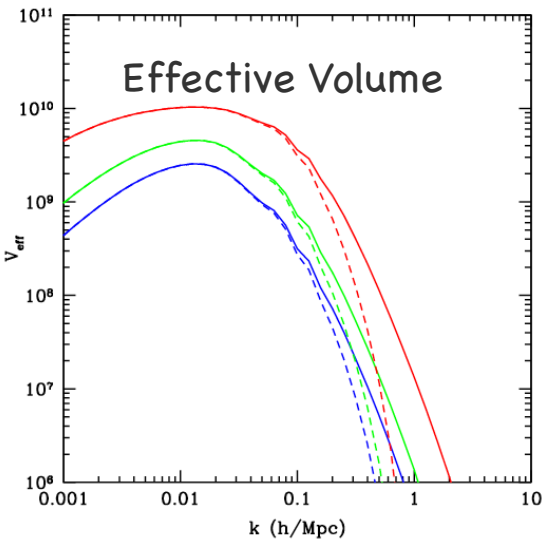
$$\theta \sim \frac{21(1+z)\ \mathrm{cm}}{30000\ \mathrm{cm}} \sim 3(1+z)\ \mathrm{arcmin}$$

Talking with Ue-Li Pen in Japan in 2009

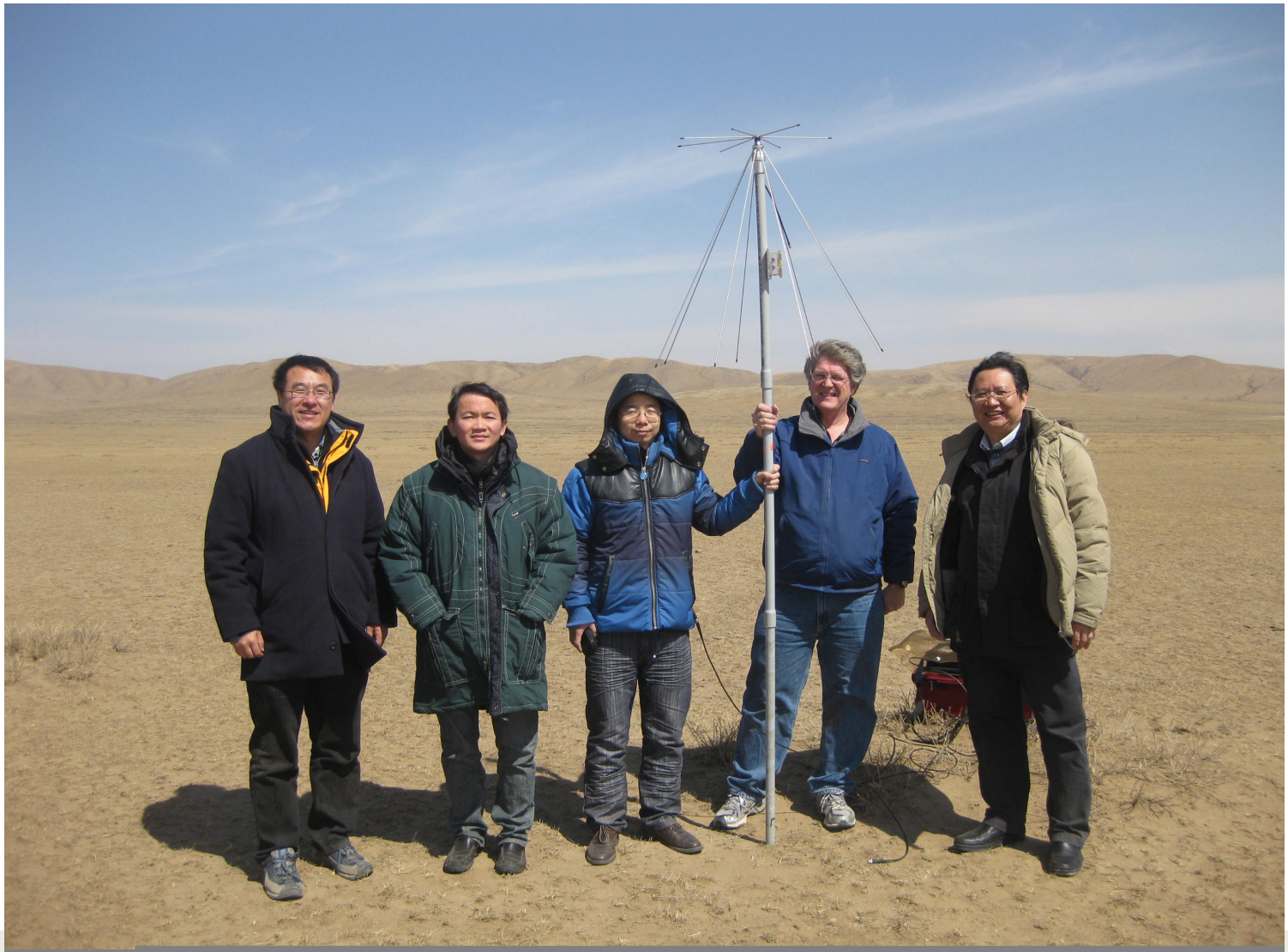
Join collaboration and start applying fund in 2010

Project start in 2012





April 2010, visit of Inner Mongolia site



The Tianlai （Heavenly Sound) Project

NAOC, Xinjiang Observatory, CETC-54, Institute of Automation, Hangzhou Dianzi U.

US: CMU(Peterson), U. Wisconsin (Timbie), Fermilab(Stebbins)

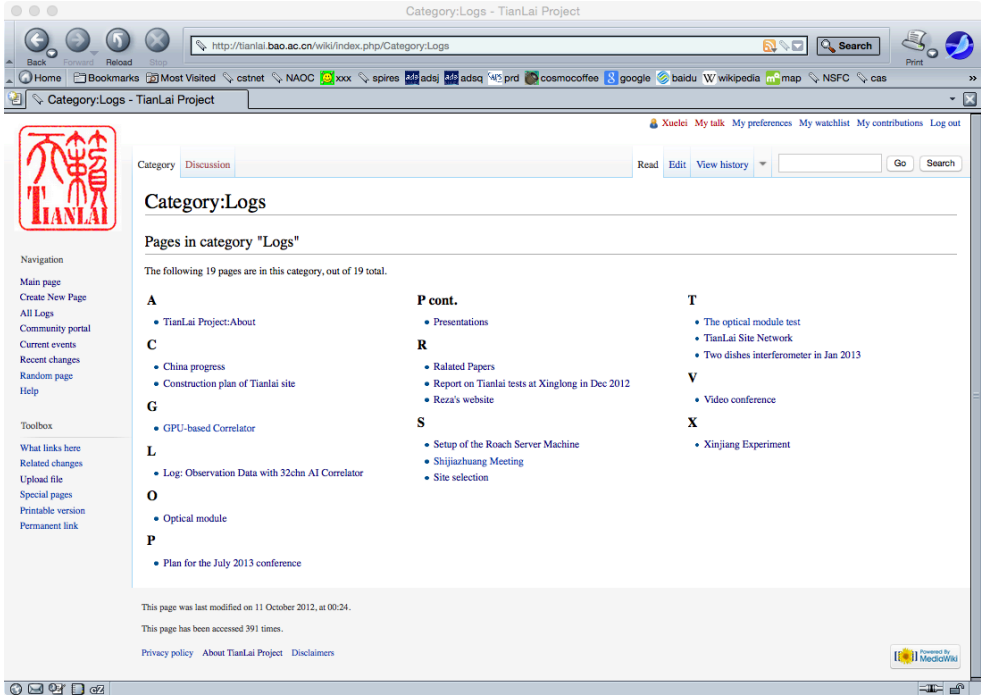
LAL/IN2P3 (R. Ansari, J.E Campagne, M. Moniez), Obs. Paris (J. -M. Martin, P. Colom) , IRFU-CEA(C. Magneville, C. Yeche), CITA(Pen), KASI (Song), ASIAA(Chang)

Monthly Telesconf and annual Collaboration Meeting since 2010, possibly a US meeting next year

The concept of "tianlai" -- the heavenly sound was coined by ancient Chinese philosopher Zhuang-Zi (Chuang-Tzu, 369BC-286BC)

Activities

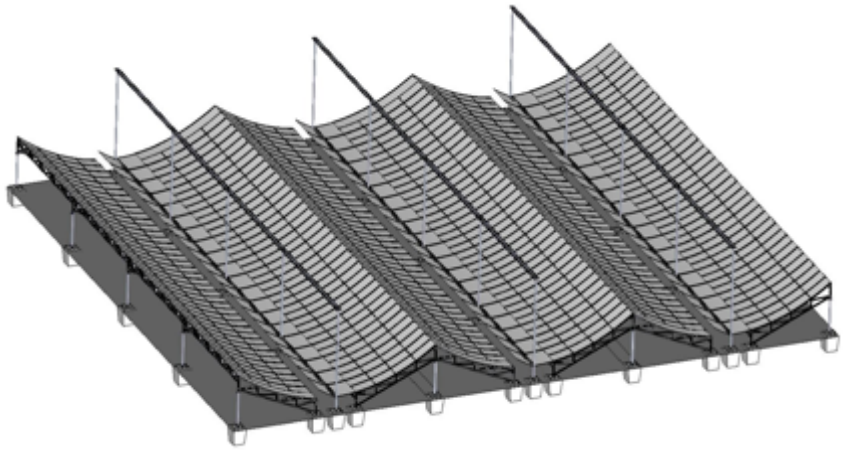
- Yearly Meeting since 2010
- Monthly Teleconference (14:00 UTC second Thursday each week)
- Ad hoc Teleconference on specific issues
- Project Wiki: http://tianlai.bao.ac.cn/wiki (members can apply for account)

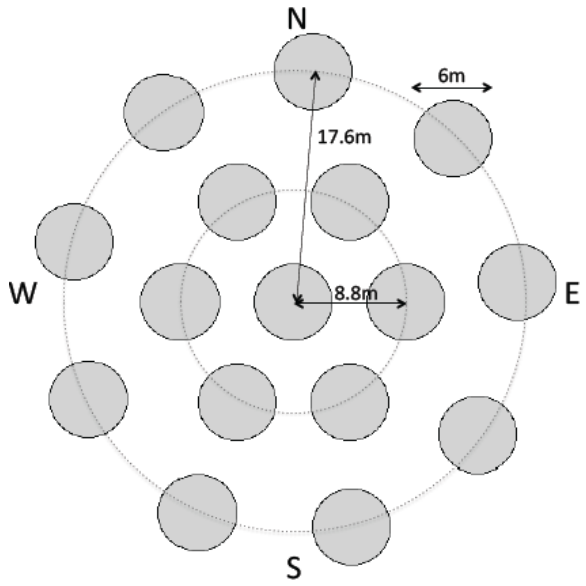


The wiki would be renewed and provide update on status of array, data storage, code, etc.

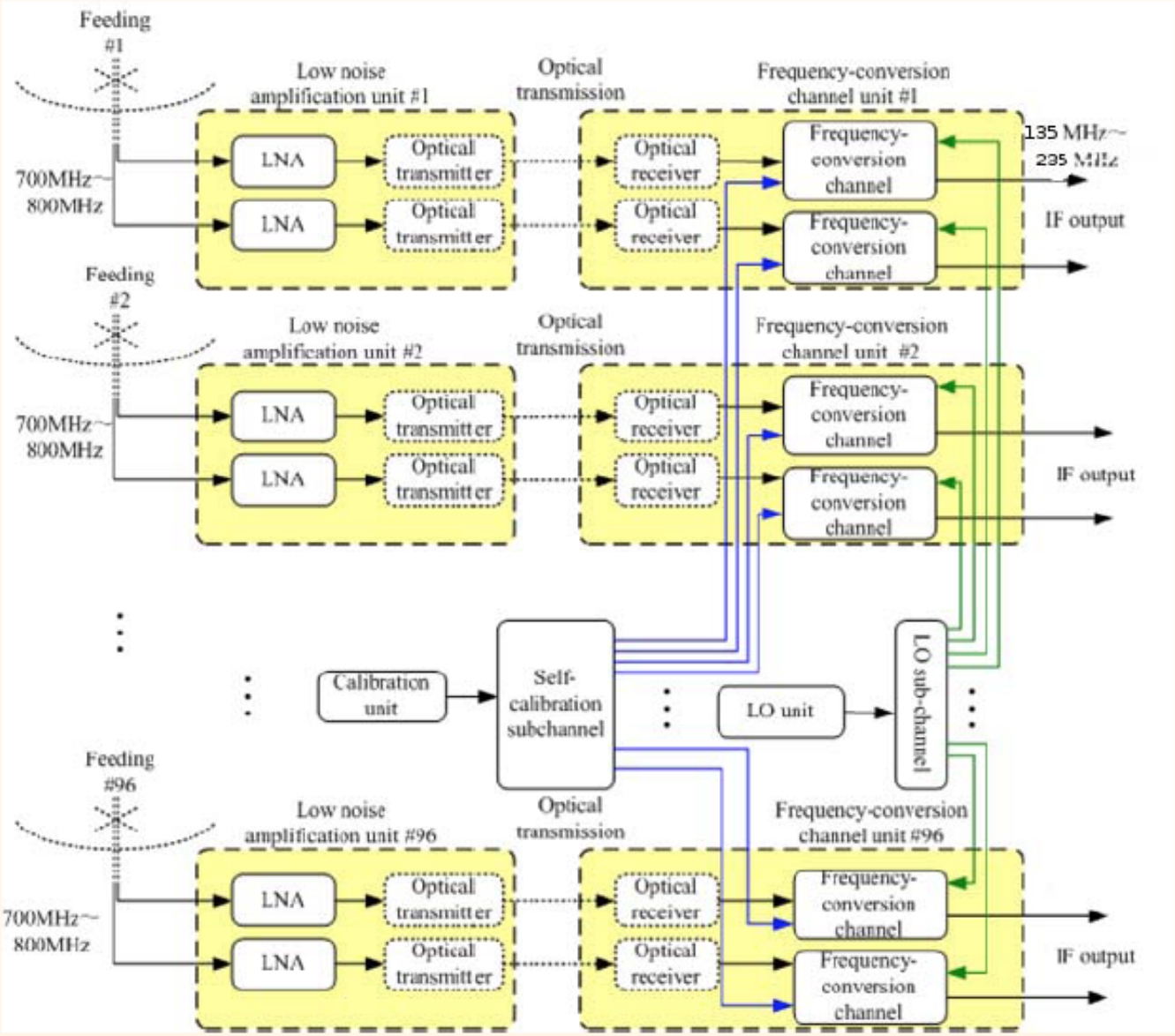
Tianlai pathfinder experiment

- A small pathfinder experiment to check the basic principles and designs, find out potential problem
- 3x15x40m cylinders, 96 dual polarization receiver units
- 16 x 6m dishes
- observe 700-800MHz, can be tuned in 600-1420MHz
- If successful: expand to full scale 120mx120m, 2500 units



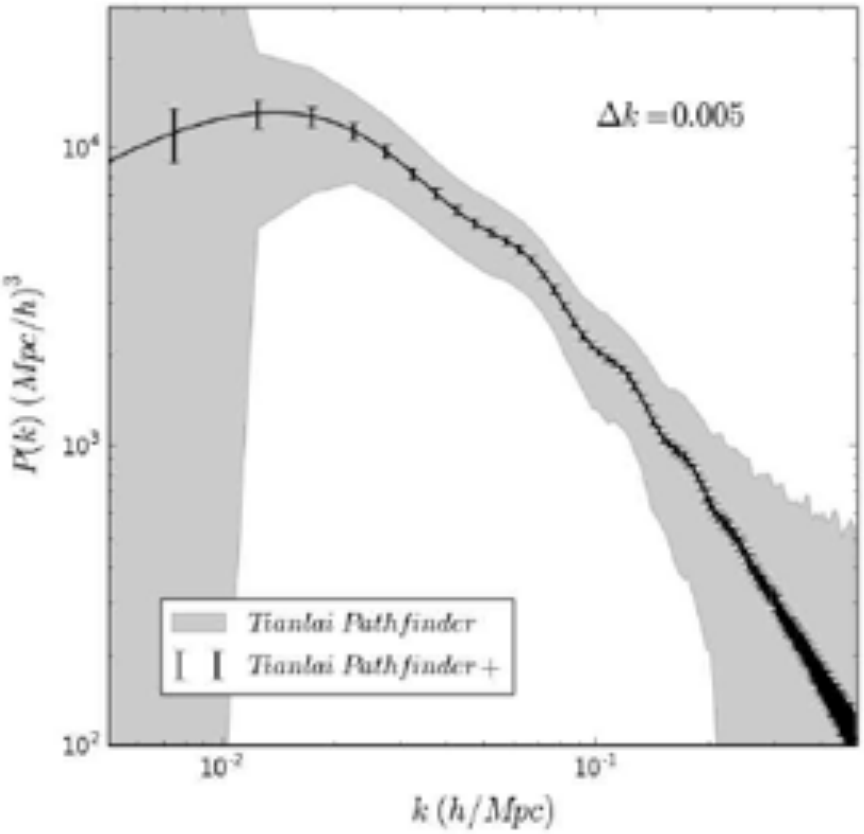


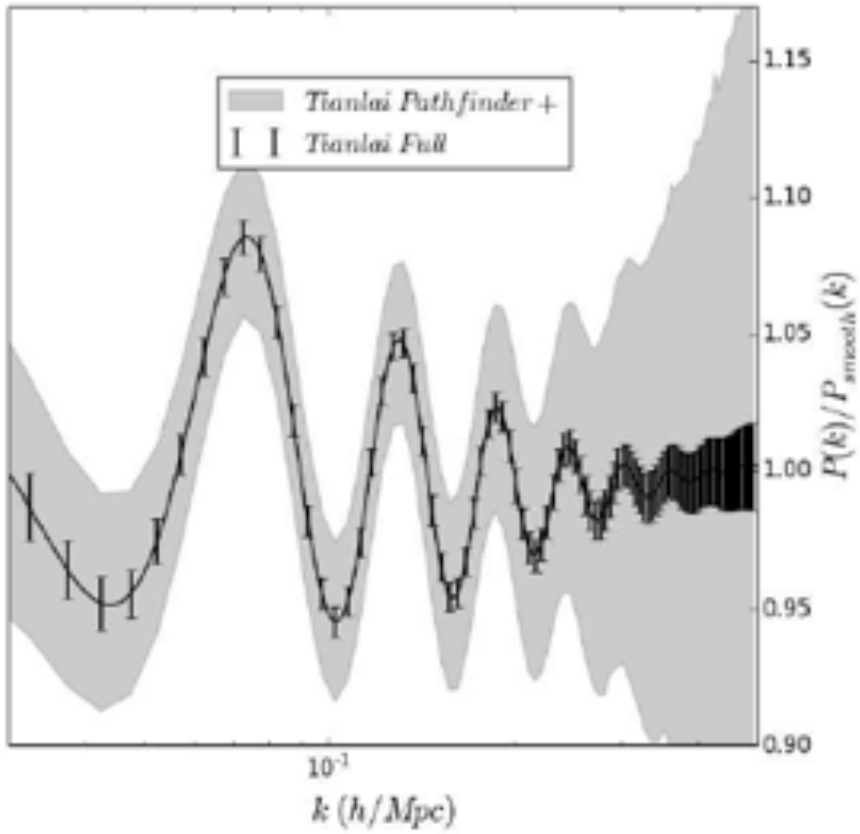
Electronic system



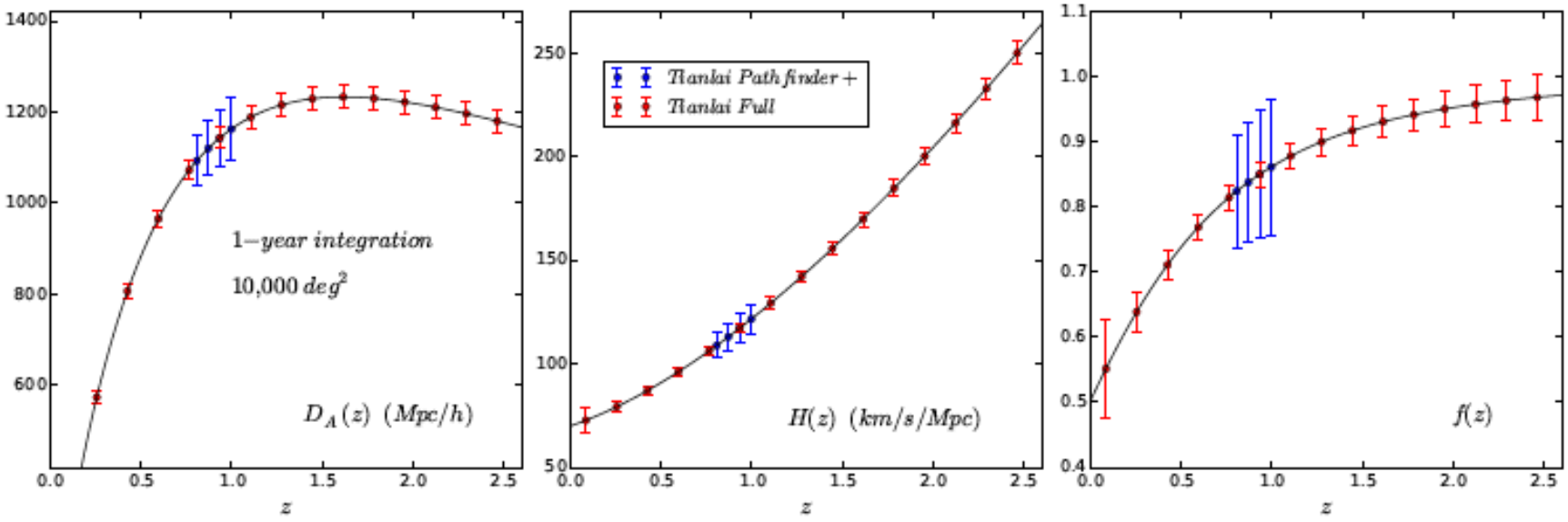
Performance Forecast

Xu, Wang & Chen, ApJ 2014,

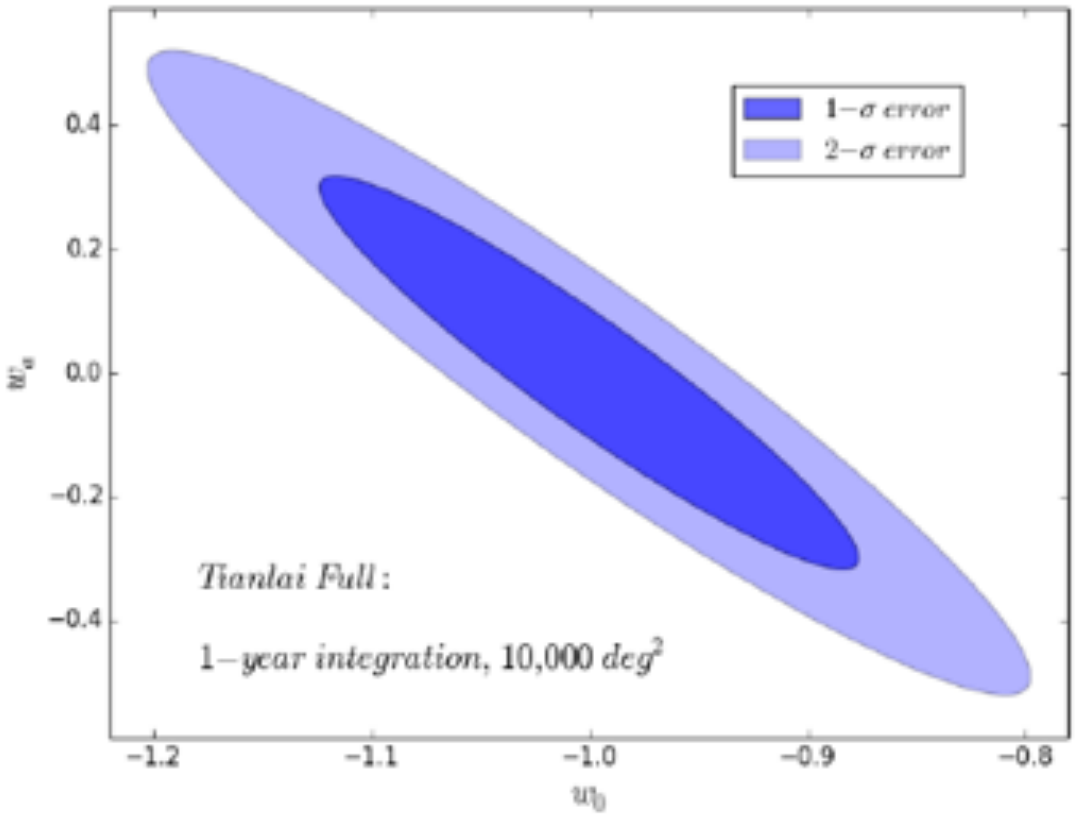




Measurement of Distance and growth factor

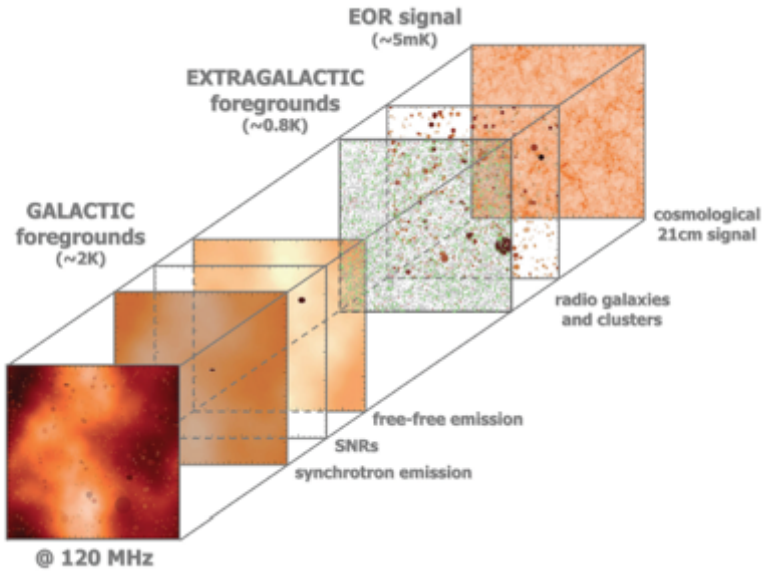


Dark Energy equation of state



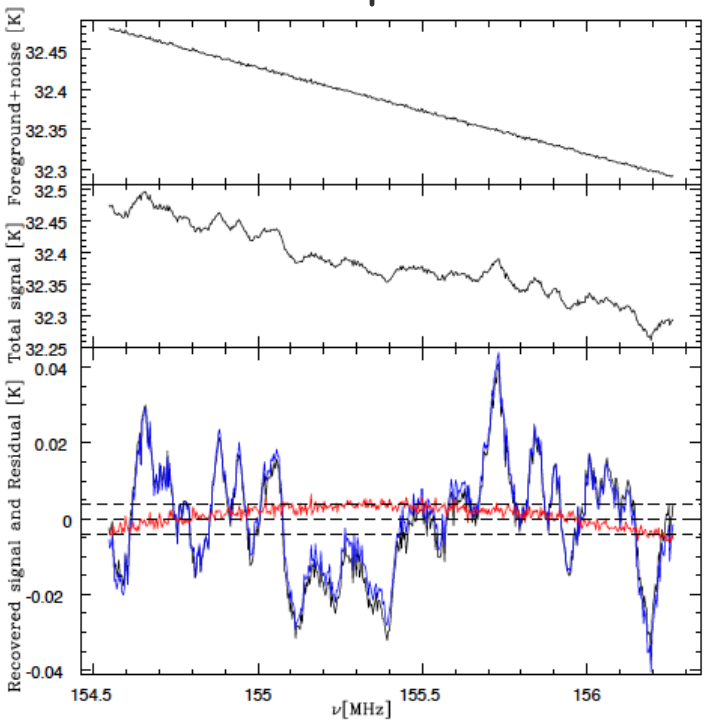
The challenge: strong foreground

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



V. Jelic et al. (2010)

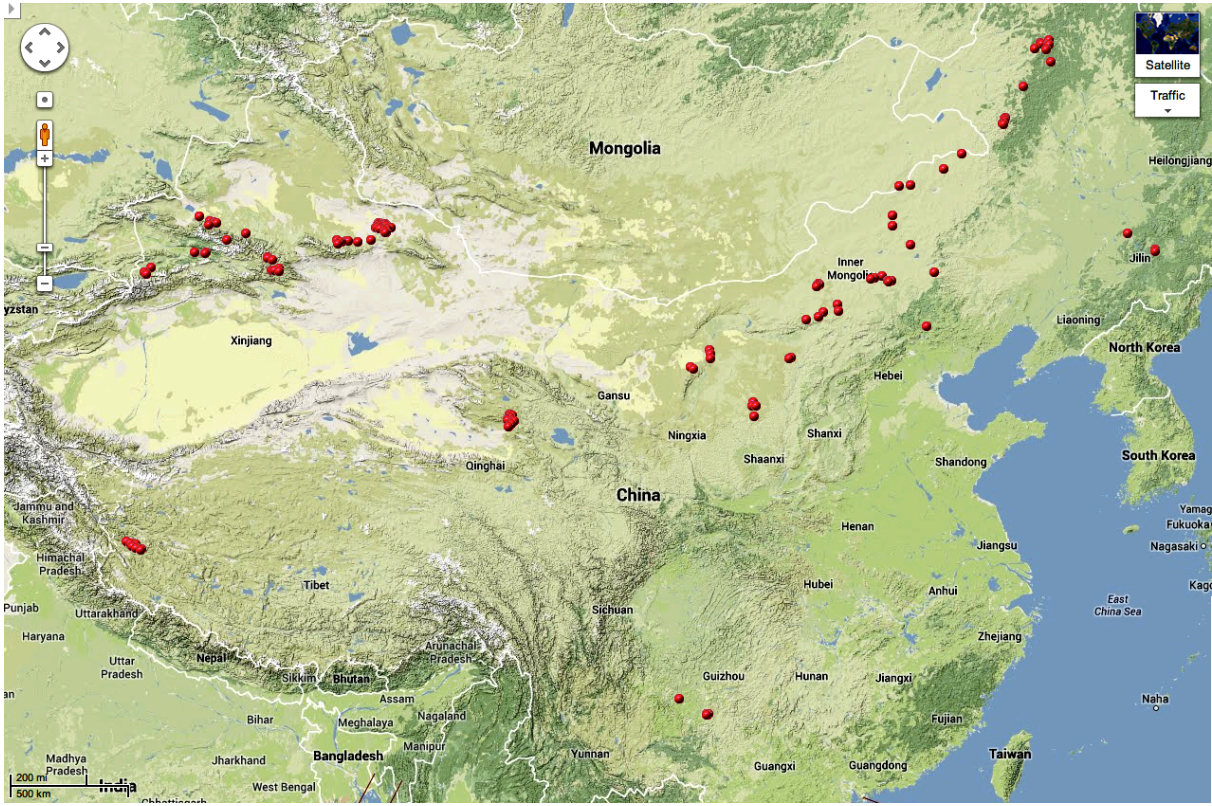
removable: foreground
smooth in spectrum



Wang et al. (2006)

Site Surveys in China

- Low RFI (low population density, shielded by mountains)
- wide open terrain
- convenience in logistics, electricity,communication
- We checked for about 100 potential sites (found on Google Earth) near existing astronomical research facilities

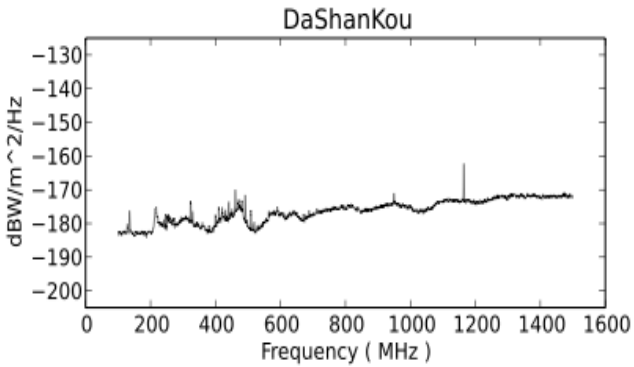


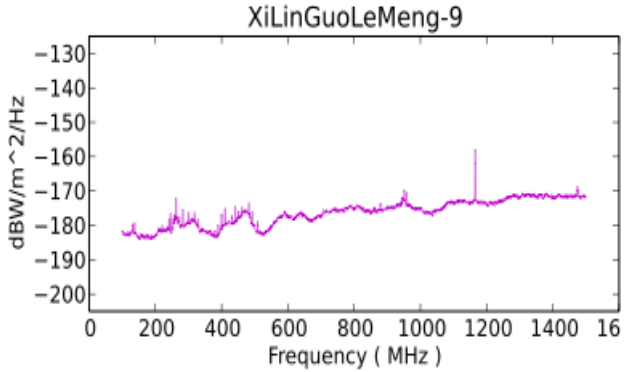
A site in Baiqi, Inner Mongolia

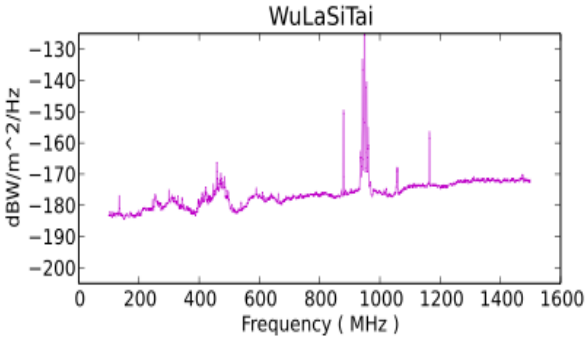
a site in Guizhou near FAST

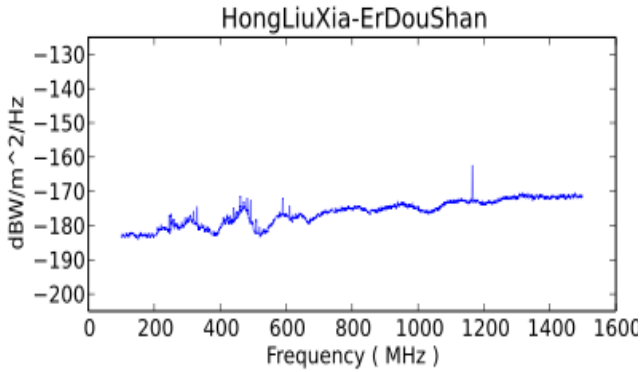
A site in Jiaohe, Jilin, NE China

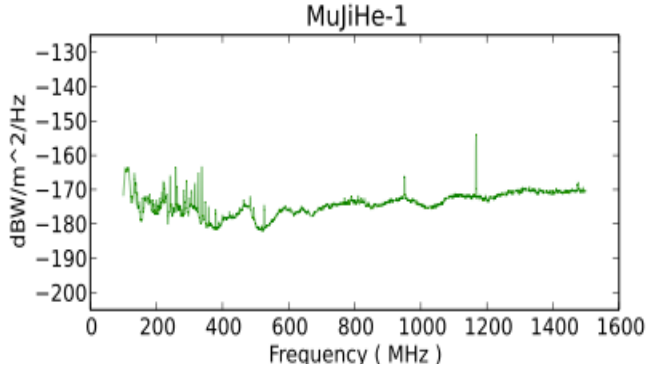
a site in Ali, Tibet

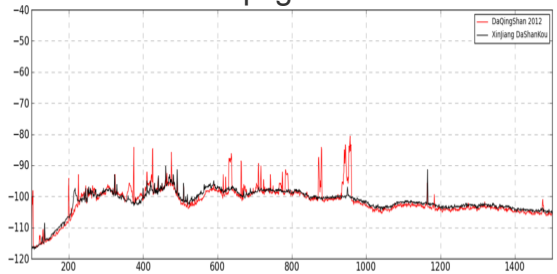

DaShanKou
dBW/m^2/Hz
Frequency (MHz)

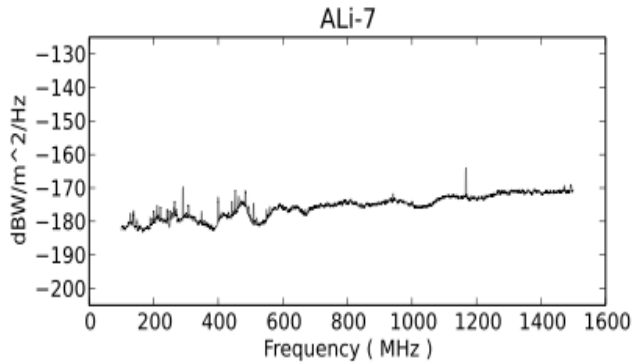

XiLinGuoLeMeng-9
dBW/m^2/Hz
Frequency (MHz)

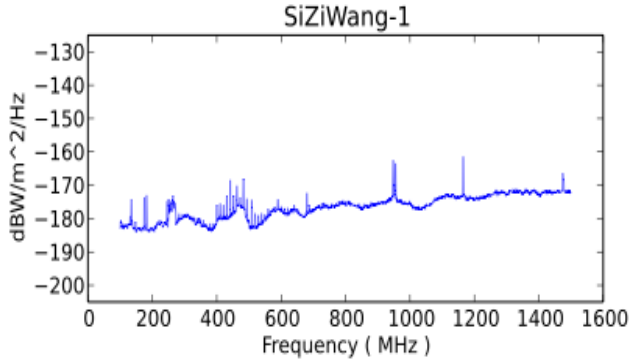

WuLaSiTai
dBW/m^2/Hz
Frequency (MHz)

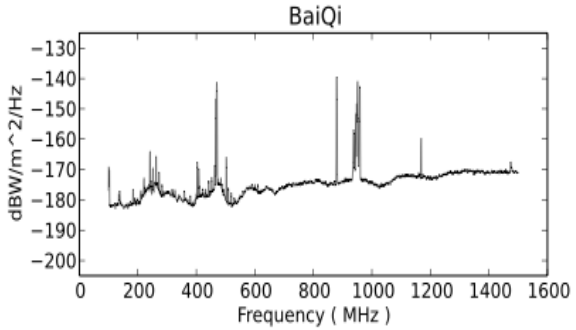

HongLiuXia-ErDouShan
dBW/m^2/Hz
Frequency (MHz)


MuJiHe-1
dBW/m^2/Hz
Frequency (MHz)


Daqingshan
DaQingShan 2012
XinJiang DaShanKou

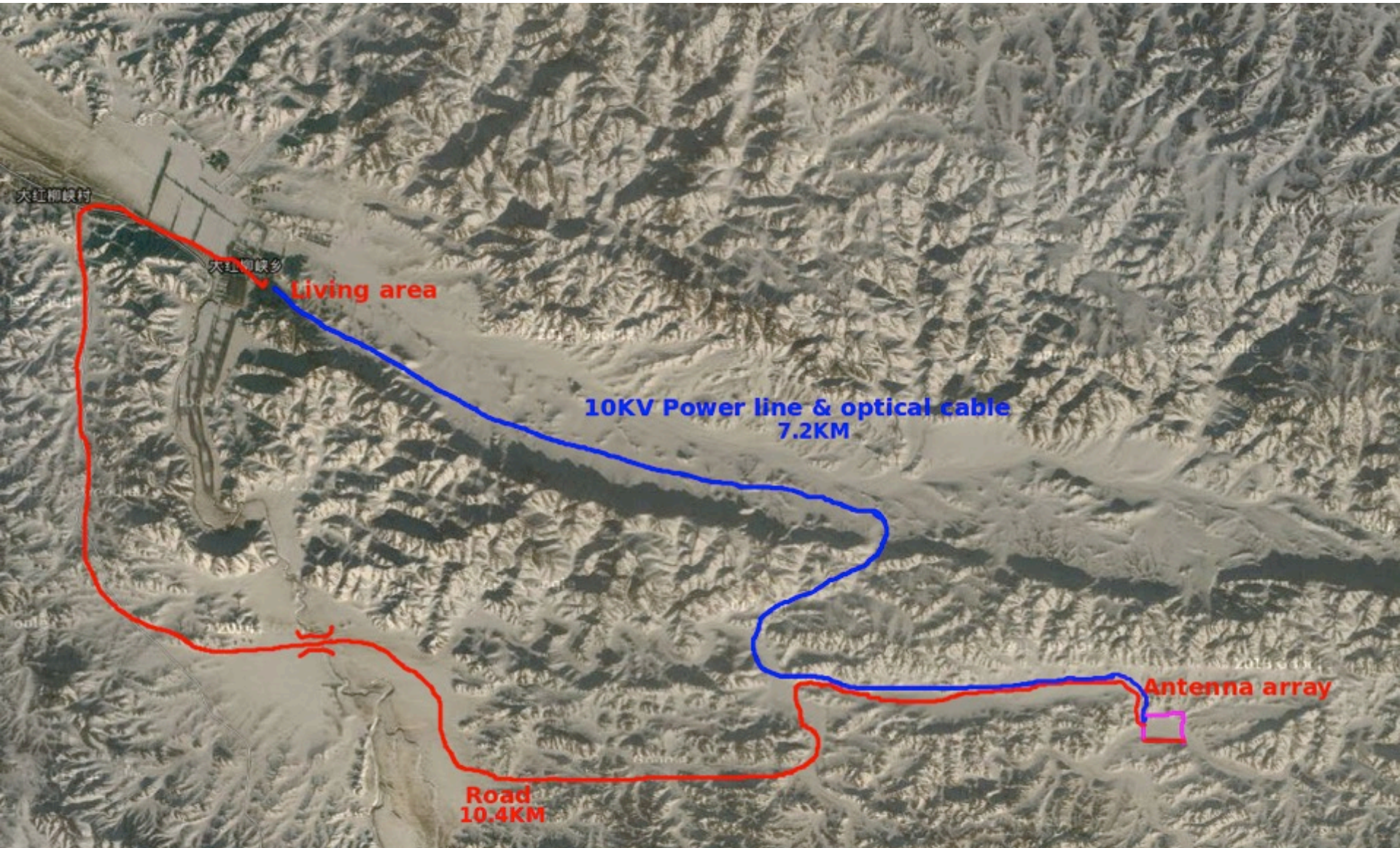

ALi-7
dBW/m^2/Hz
Frequency (MHz)


SiZiWang-1
dBW/m^2/Hz
Frequency (MHz)

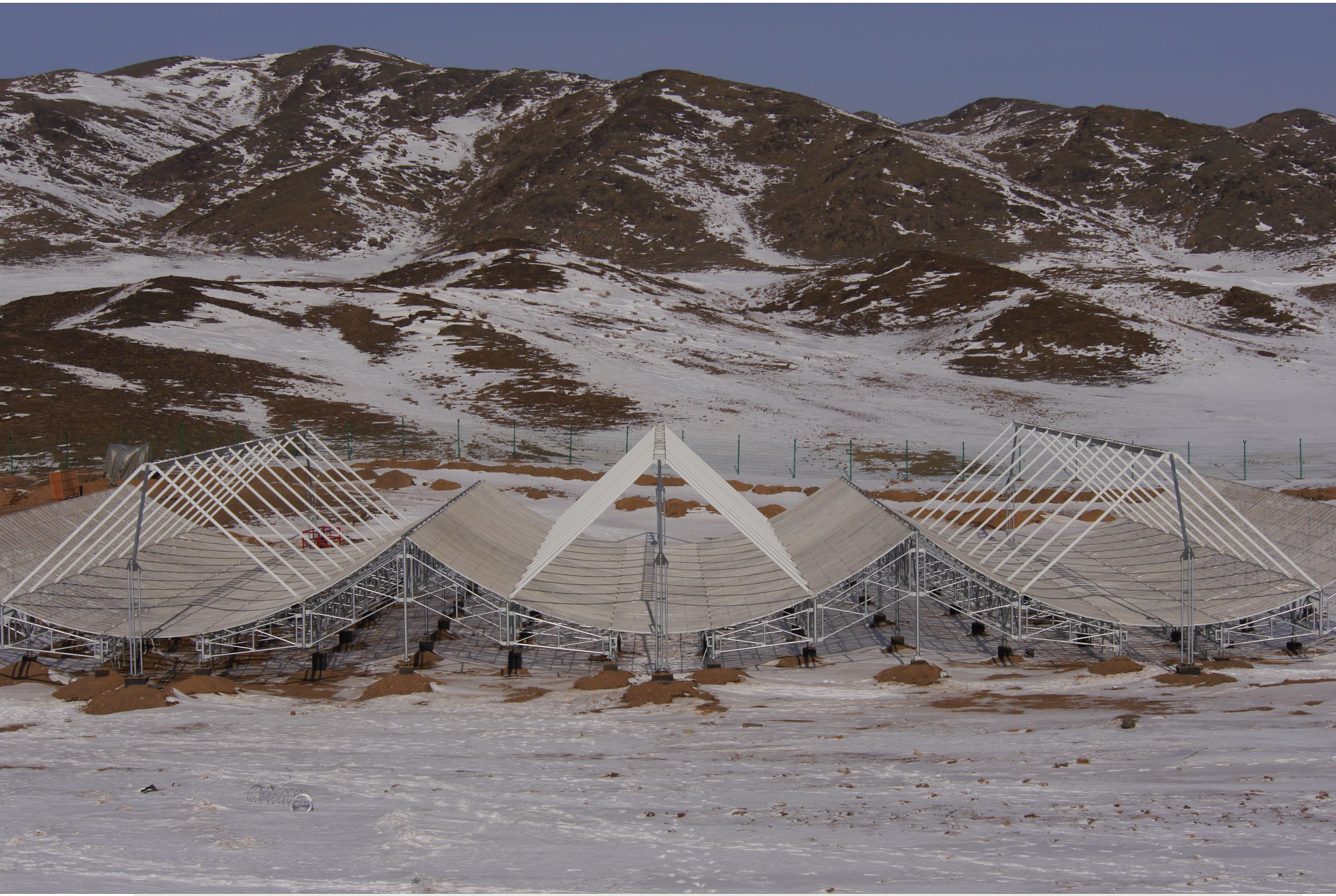

BaiQi
dBW/m^2/Hz
Frequency (MHz)


Новосибирск
Астана
Astana
Қазақстан
Улаанбаатар
Ulaanbaatar
Монгол Улс
A
Алматы
Almaty
Бишкек
Bishkek
Кыргызстан
Тошкент
Samarqand
Тоҷикистон
北京
북한
Pyongyang
평양
서울
대한민국
Sea of Japan
札幌
日本
東京
名古屋
広島
大阪
福岡
Kabul
افغانستان
راولپنڈی
Rawalpindi
لاہور
Lahore
中国
成都
重庆
武汉
上海
East China Sea
پاکستان
New Delhi
नेपाल
Bhutan
Jaipur
Lucknow
کراچی
Karachi
Ahmedabad
India
বাংলাদেশ
Kolkata
Myanmar (Burma)
Hà Nội
广州
香港
Hong Kong
澳門
ประเทศลาว
Mumbai
Pune
Hyderabad
ရန်ကုန်
Yangon
ประเทศไทย
กรุงเทพมหานคร
Việt Nam
South China Sea
Maynila
Luzon
Pilipinas
Kabisayaan
Palawan
Isla sang Negros
Leyte
Mindanao
Sulu Sea
Chennai
Bangalore
Bay of Bengal
Andaman Sea
Gulf of Thailand
Thành Phố Hồ Chí Minh
กัมพูชา
Sri Lanka
地图数据 ©2014 GS(2011)6020 Basa

Site Arrangement



House



Receiver and Correlator （SKA pathfinder?)

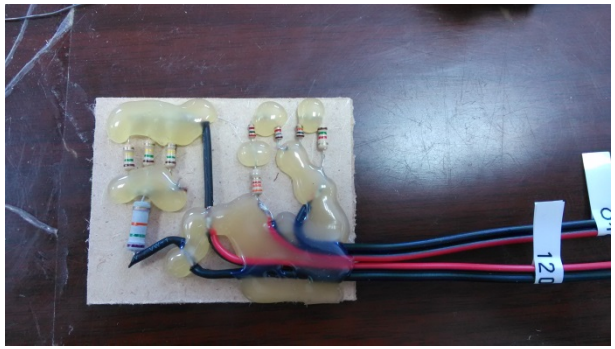
Getting the system to Work

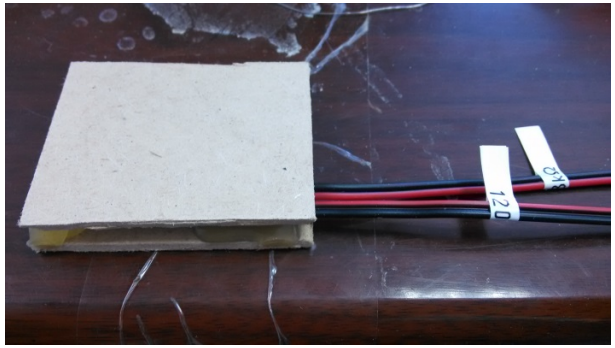
- Computer Room air conditioning and power
- Dish Array
- Calibration source
- Correlator
- self-generated RFI

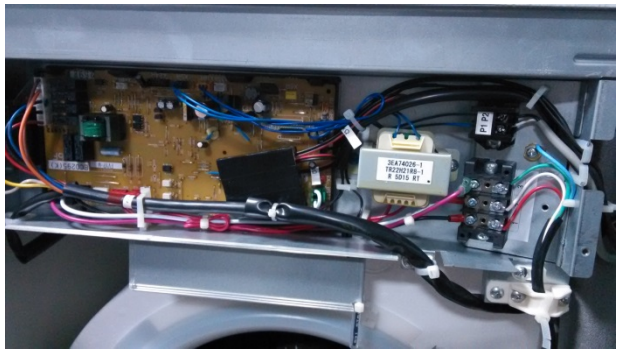
Computer Room AC

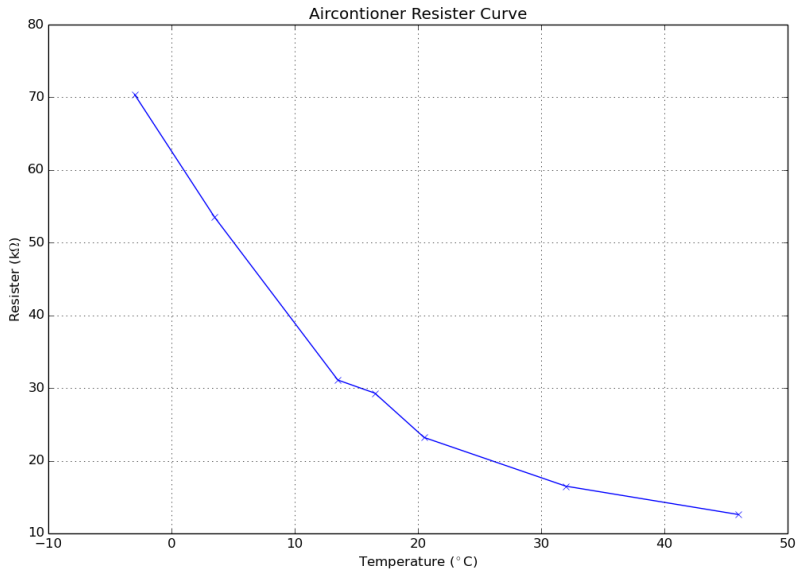
- Digital correlator a strong heat source, 8.5 kW
- Small computer room, correlators are tightly arranged, need active cooling even during winter
- Added fan to help cooling, still insufficient
- The civil use AC we purchased (same as used in IA) does not work in winter due to freezing of compressor, added heater

- Working room temperature too high: cheated sensor by changing thermistor resistence, so that 5°C is realized (Jixia Li)









Thermistor resistance as function of temperature.

working, but still problematic

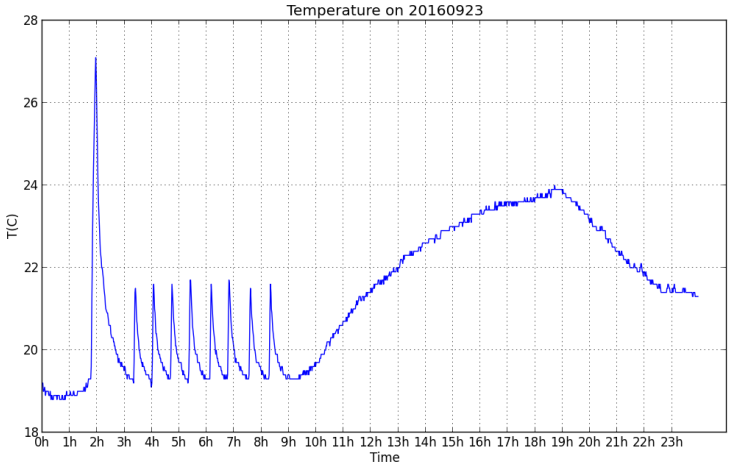
Refrigerating fluid pressue too low

High: 1.25MPa; Low: 0.8MPa

Normal values:
High: 2.4~2.5MPa; Low: 0.6~0.9MPa

Note: we added fluid according to weight written in the label of the compressor (R410A/3.2kg)

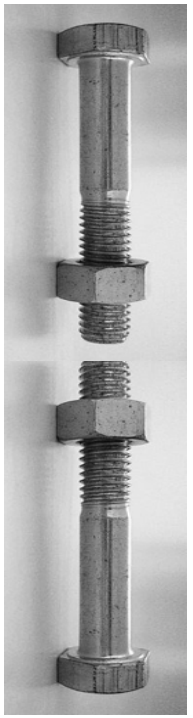
We decide to replace with an industrial AC soon



Dish Array Problems

- Antenna Sloshing:

the two opposite bolts along one line are too long and blocking each other, these are now replaced with one single long bolt (fixed in Nov. 2015)



- Stuck at high elevation angle

restricted to <88.5 degree

- Pointing precision too low

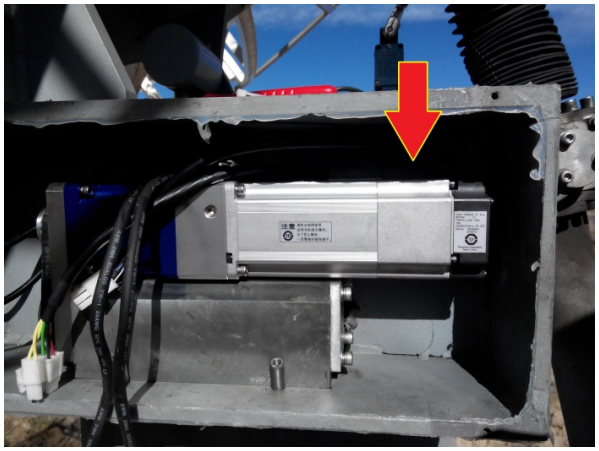
reprogrammed firmware on antenna motor controller, improved pointing precision from 0.5 degree to < 0.04 degree.

- No response at low temperature

a warning LED fail at low temperature, removed this LED

- Antenna Stuck and brocken belt

slack screw drive, added dowel to help fix the motor (Nov. 2015), and rotate antenna for break in. Store the belt on site (relatively easy to replace).



- Pointing shift under wind

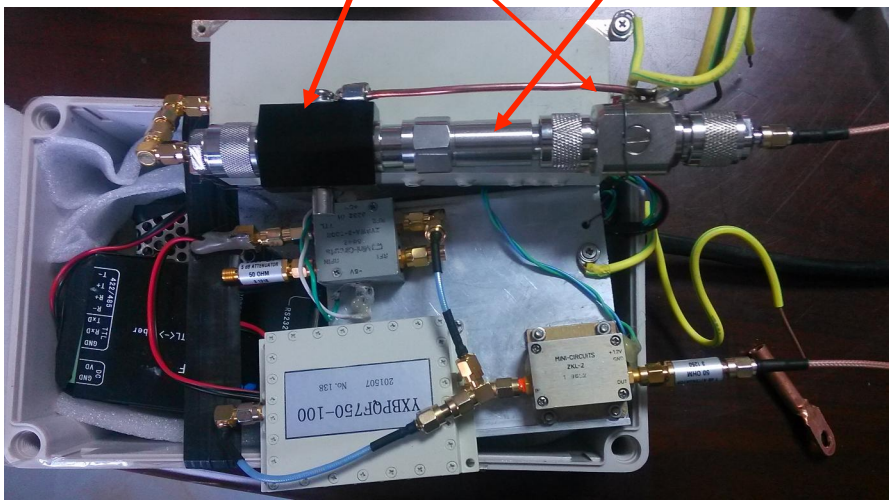
the motor lacks self-locking mechanism, replaced with new motors on Sep. 25 2016

Calibrator Source

- Damaged a few times due to lightning
  Added insulation and surge protector

- Amplitude too high or too low
  Adjust amplitude of the system

- Temperature variation from 1-3 dB (day time) to 9-12 dB (night time)
  will add temperature controlled box



RF System and optical fiber

- Connector malfunction (1 case),

replaced with a new one.

- SMA-SMB cable bad conncetion cause reflection

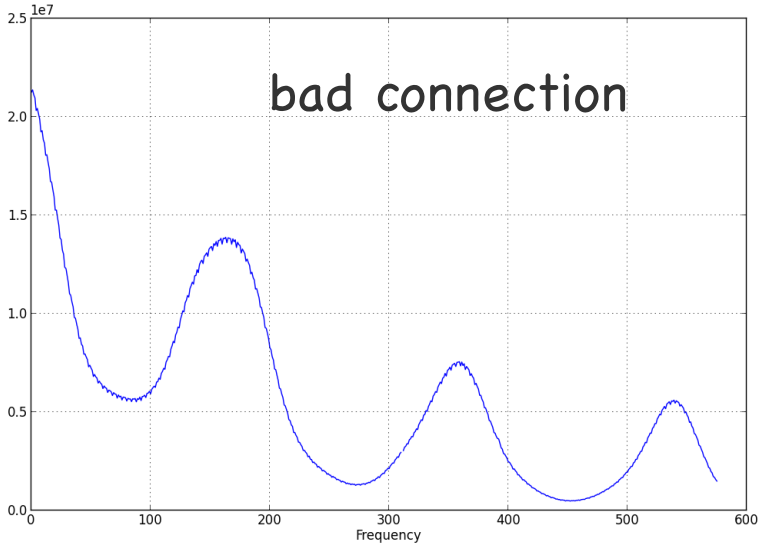
reconnected with a new cable

- Optic transmitter malfunction

1 case, replaced

- Optic receiver malfunction:

1 case, DC power failed, repaired.

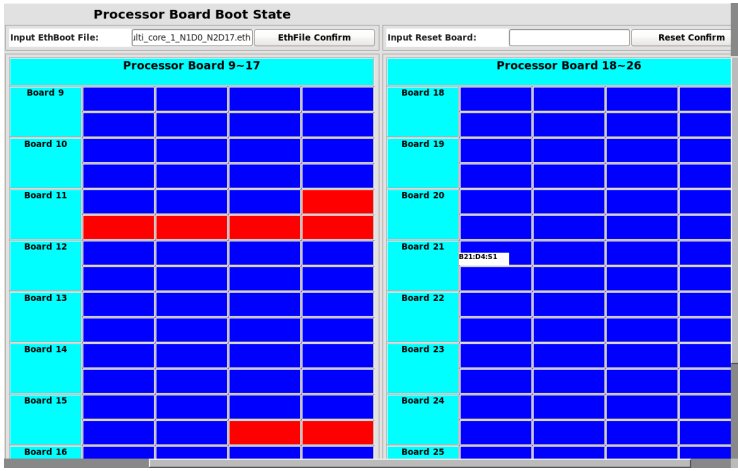


Correlator

DSP board malfunction

- 9 DSP boards malfunctioned
- suspect AC power supply voltage ripples? Added UPS but no improvement

- Inhomogeneous cooling contact generate thermal stress,broken pin.



FPGA8 board malfunctioned

- Replaced with a new one still not work
- Replace with a new power cable

Data Loss

Loosing Data packages when strong source (Sun, Calibrator) are present

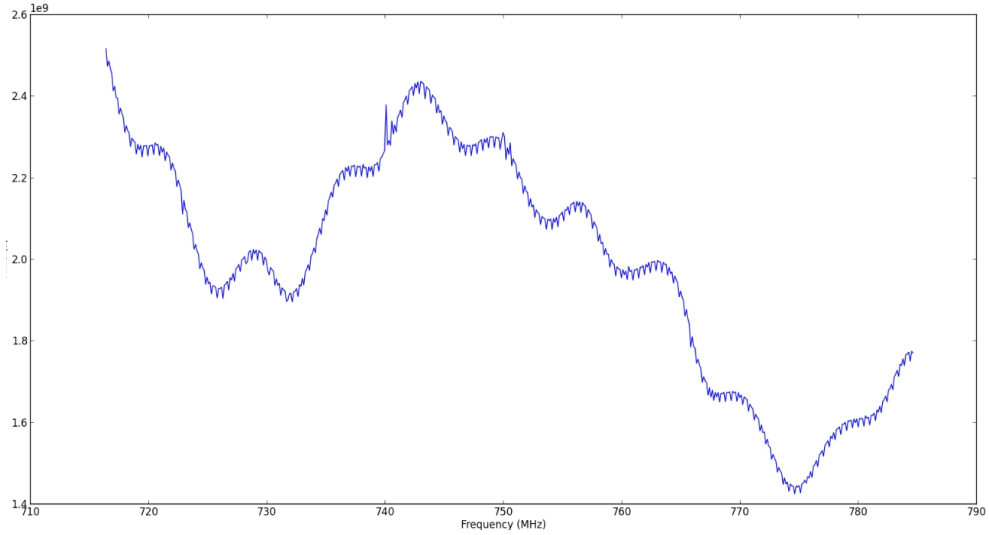
The DSP want into a power-save mode when lot of signals are 0, when suddenly have strong source, insufficient power. Problem solved

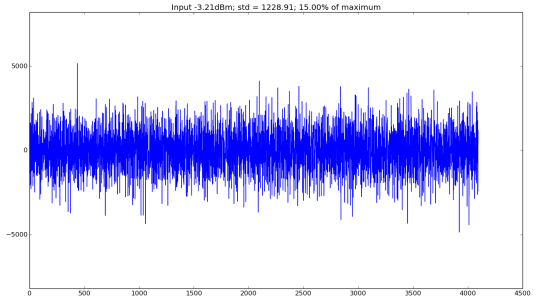
Abnormal Output-1

Trough every 4 frequency channels:

after much test, we found that analog input level too low (<0.5%)

Now, we set the level to be 5~6%, leaving much space for the Sun (<8dB) and calibrator source (~10dB).

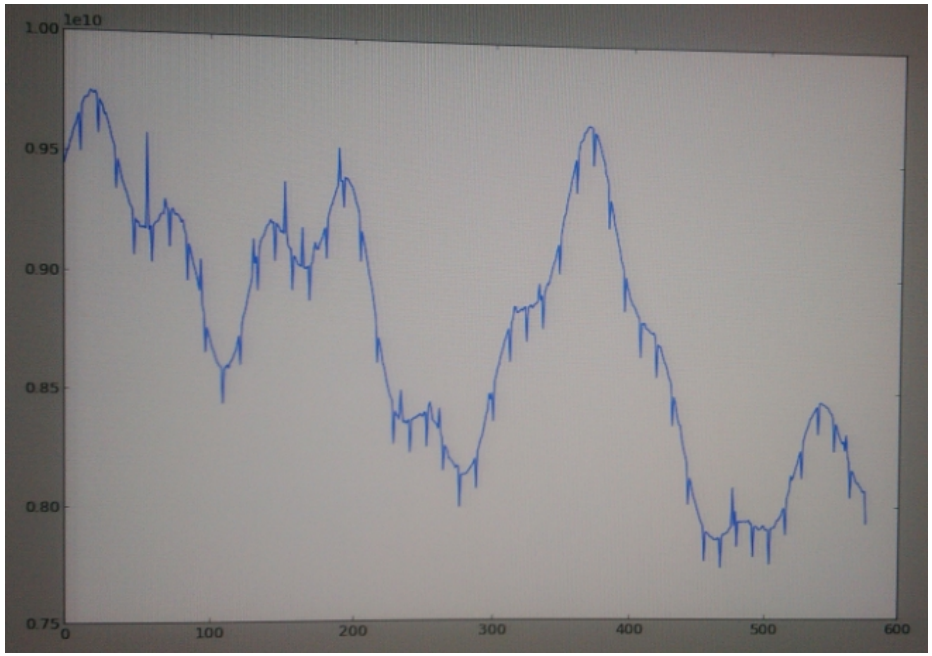




Abnormal Output-2

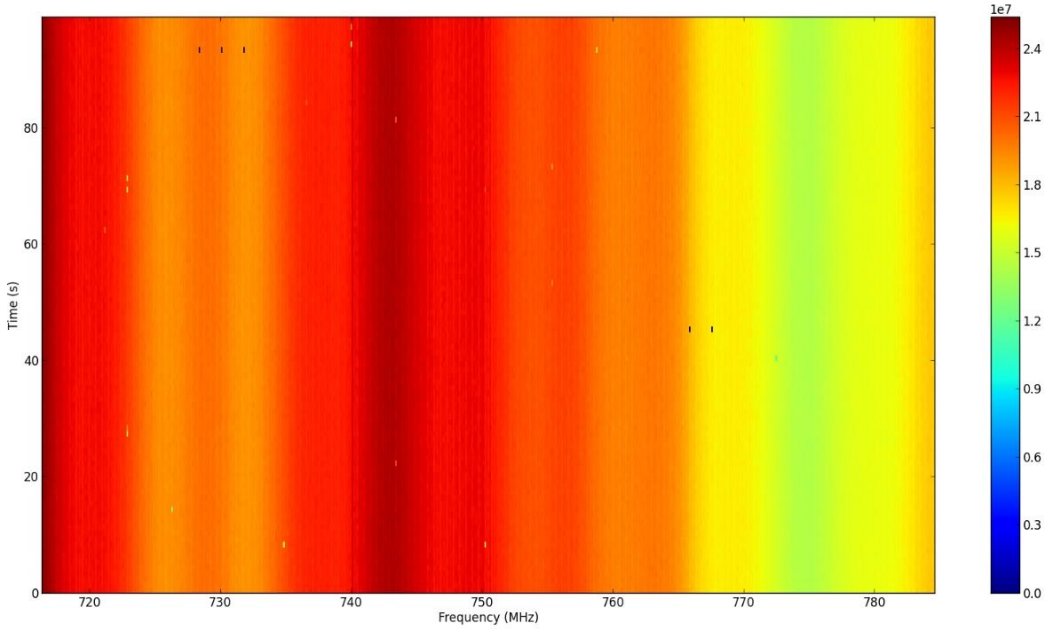
- Trough every 12 frequency points in channels 117-115

Time delay in DSP core improperly set



Abnormal Output-3

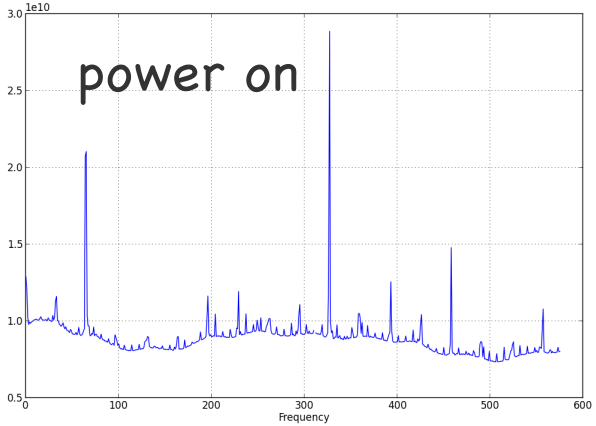
- Data loss randomly due to too heavy computing load



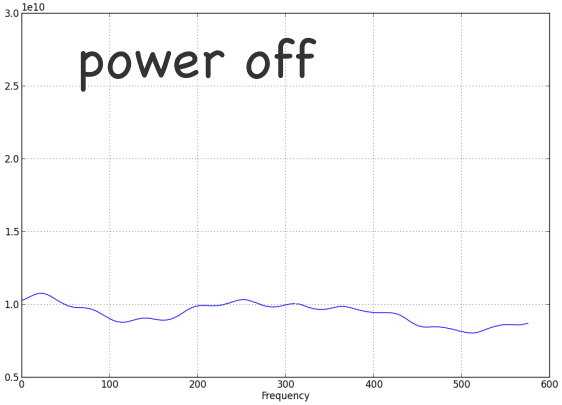
RFI

RFI came from various devices on site.

- Motors of dish antennas
- Serial server
- Telephone
- Network devices
- PDU (Power Distribution Unit; network man
- Camera, weather station…



Shield with copper net but no effect



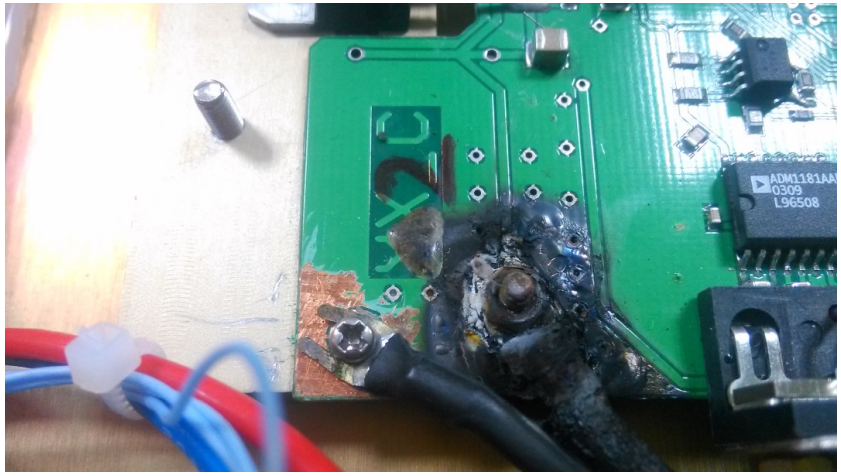
10kV transformer

build a cage made of aluminum

Front view

Back view

- **Frequency down converter:** The inner DC power lines are not properly connected to the circuit board. It results in short circuit.
- All of the 17 converters have been repaired now.



The burnt cable

The design itself is bad. The positive line is isolated from the negative area by a plastic sheet. When it's working, this area is hot and the plastic get burnt.

The Future Plan

- We have received some funding for operation and survey in the next few years
- Add FRB search

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- The NAOC Pilot Research Program
- The John Templeton Foundation and NAOC "Beyond the Horizon" program


Thanks !