4th International Workshop on Gravitomagnetism and large-scale Rotation Measurement (GRM), Pisa, Italy

Multi-geophysical observations in HDUL, China

Ultra-high precision multi-physical field observations in deep underground

China University of Geosciences, Beijing

Yun WANG

June 15, 2023

yunwang@mail.iggcas.ac.cn

Outline

- Deep space of coal mines in China
- Physical characteristics in deep underground environment
- Deep underground observations
- Problems and challenges
- Prospect


Acknowledgements

Main participants

① Gravity and earthquake：Heping SUN、Sidao NI、Guangyu FU ……

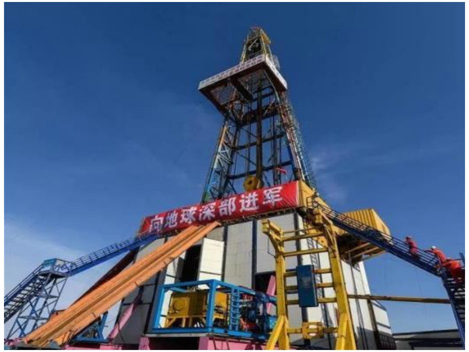
② Geomagnetic：Aimin DU、Lianghui GUO、Yufeng SHI、Liangliang RONG……

③ Electromagnetic：Chengliang XIE、Sheng JIN……

④ Radioactivity：Yaxin YANG、Zhimin WANG……

⑤ Seismic：Qingju WU、Zhengbin LI、Yuanhong YANG、Dongming ZHANG……

⑥ Underground biology：Huimin YU、Aiguo HOU……



1.Deep space of coal mines in China

General situation

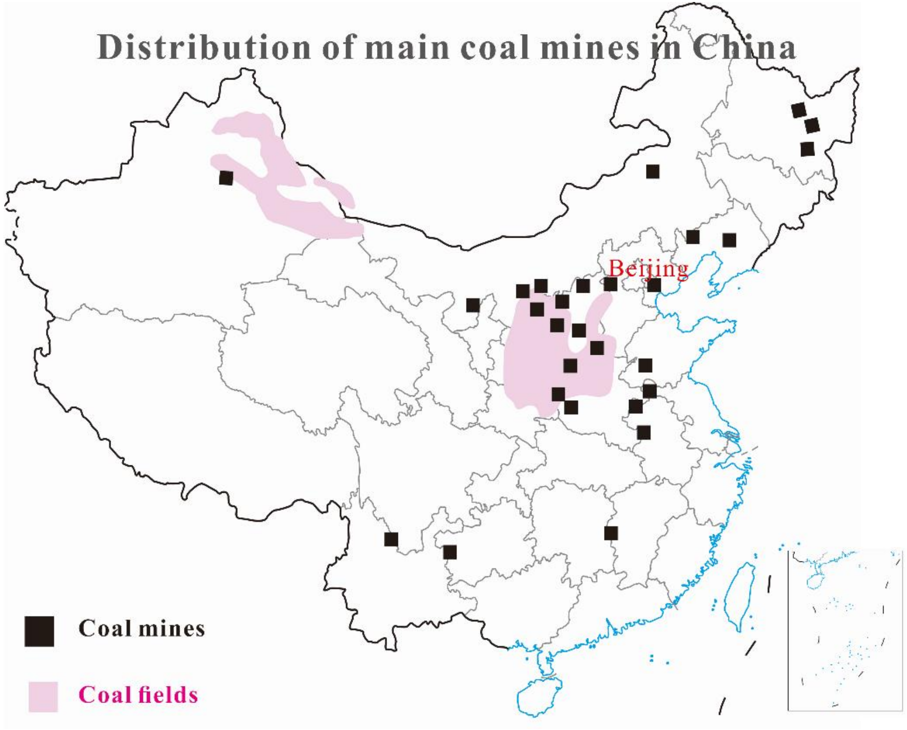
① Shut down for resource depletion or carbon neutralization

② Depth: 300-1500 meters

③ Space capacity: 7 billion m^3

④ Huge cost of construction ever

Main coal mines



1.Deep mine resources in China

Conditions of underground space

① Convenient transportation and access

② Perfect surface facilities for work and living

③ At least three large-diameter vertical shafts（4.5-8.0m）

④ Intersecting tunnels at different depths

⑤ Tunnel sections (width × height): 2.5-6.5 m × 2.5-4.5 m, length: 20-50 km

⑥ Well-developed facilities for underground power supply, ventilation, drainage, etc.

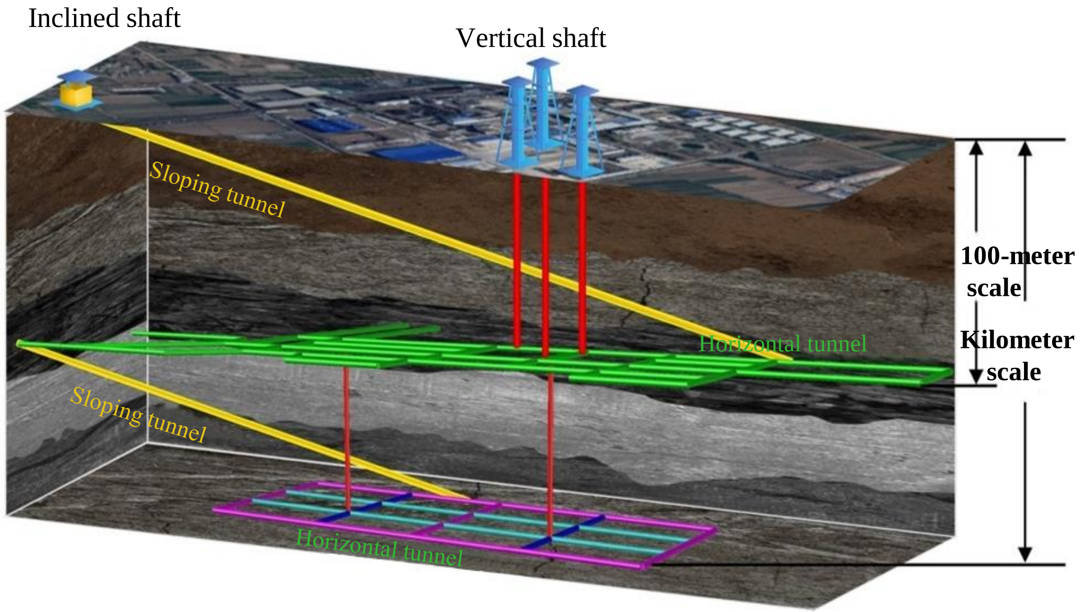
⑦ Surrounding rocks primarily composed of sandstone, mudstone, shale, and limestone

⑧ Reinforced concrete support with anchor spraying

⑨ Inclined or vertical shafts, with man cars, cages (high-speed elevators), and rail access to the surface

⑩ Design of the main tunnel: 50 years to permanent.

Simplified model of typical coal mine



2. Physical characteristics of deep underground environment

Deep underground observations

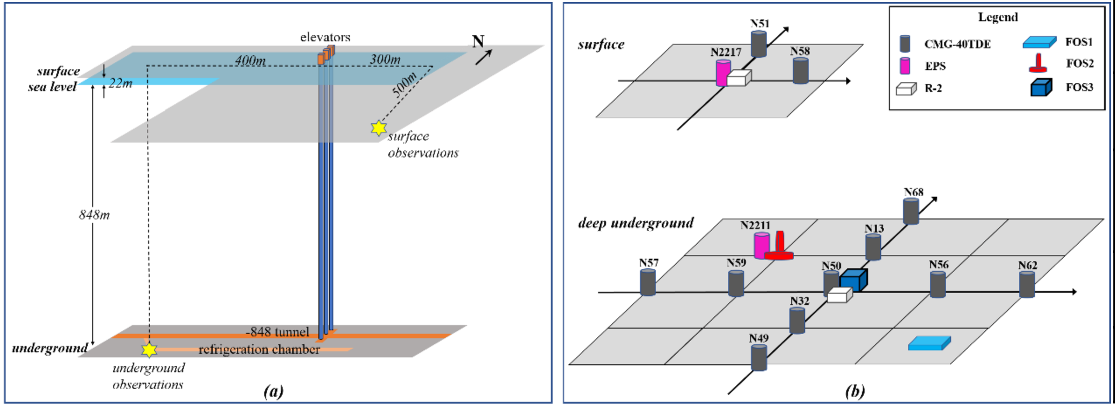
① Surface and deep underground synchronous observation

② December 2019 till now

③ Multi-physical fields

- Radioactivity
- Gravity
- Geomagnetic
- Electromagnetic
- Earthquake
- Dark micro-bios

Observation	Equipment
① Rotation	R-2、FOG、ixBlue-3A
① Translation	Microseismometers、Short –term and broadband seismometer(30-120s)
① Geomagnetism	Proton、Fluxgate、Optical pump、SQUID
① Micro creature	Water/rock samples、Species、Genome
① Magnetotelluric	Broadband、Long-term、Whole band continuous
① Gravity	Spring gravimeter、CG5/CG6
① Radioactivity	γ rays, neutron, water/air radon, U, Th and K in rocks



2. Physical characteristics of deep underground environment

■ **Observation conclusion**

① Radioactive safety and human habitable.

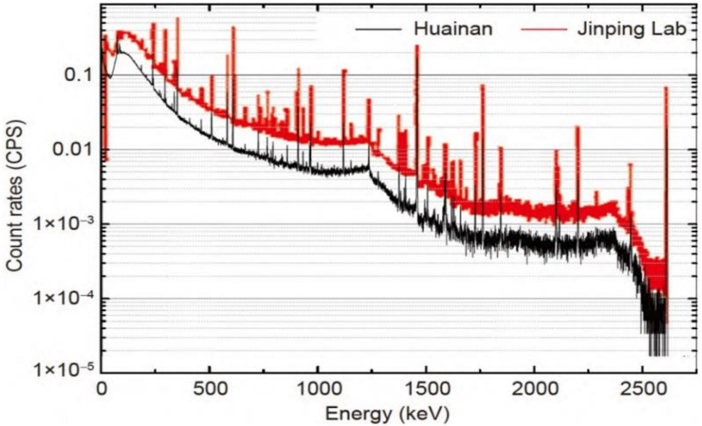
② **Neutron, radioactive nuclide, and γ energy spectrum comparable to top international laboratories.**

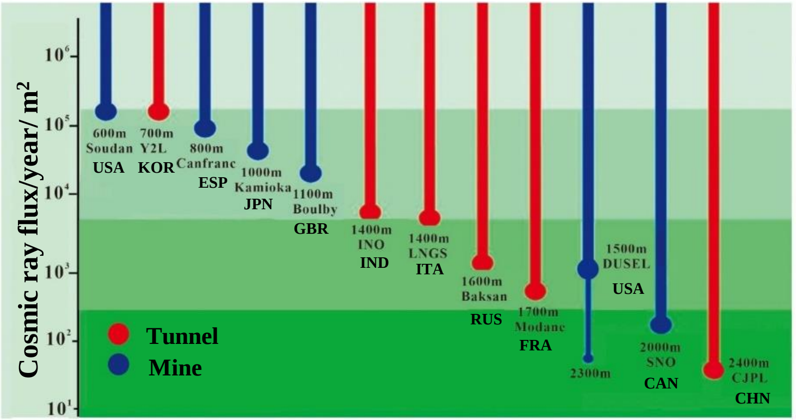
③ Ambient noises lower than that at the surface, especially for 3600s long-period signals.

④ Magnetic noise lower than the surface by two orders of magnitude, with significant high-frequency suppression.

⑤ High-frequency electric field superior to the surface by nearly two orders of magnitude.

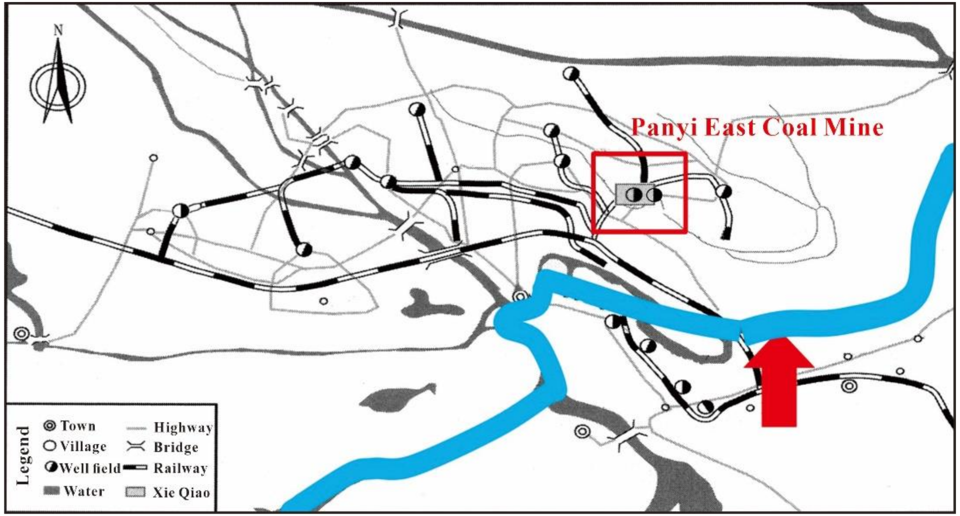
⑥ Background vibrations at 10s - 8Hz are better than that at the surface about 20 to nearly 100 times.





2. Physical characteristics of deep underground environment

① Ultra-silent（vibration、gravity）
② Ultra-clean（electromagnetic）
③ In-situ（biology and medicine）
④ Low cosmic ray background
⑤ Large fully shielded space
⑥ Suitable for human access
⑦ Convenient transportation
⑧ Perfect living facilities
⑨ Perfect working facilities

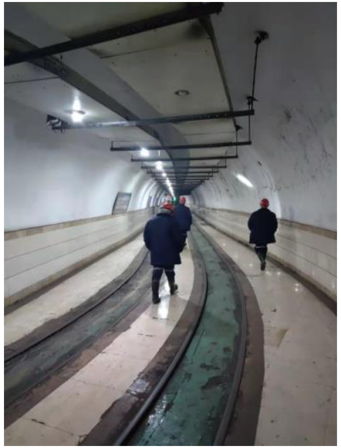


High operating cost

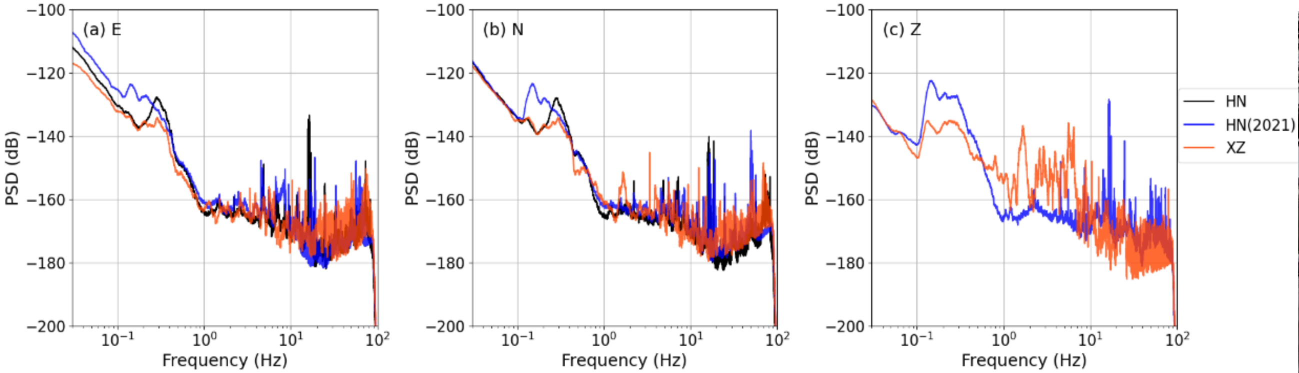
- Surface environment
- Drilling environment
- Tunnel space

2. Physical characteristics of deep underground environment

Xuzhou Longdong Coal Mine



- Coal mining under Weishan Lake: -260 m horizontal layer
- Depth of the lake: 0-10 m
- Resource exhaustion and shut down now
- Approximately 20 kilometers of underground tunnels are preserved
- On the surface, there are living facilities such as bathing facilities, cafeteria, dormitories, office buildings, etc.

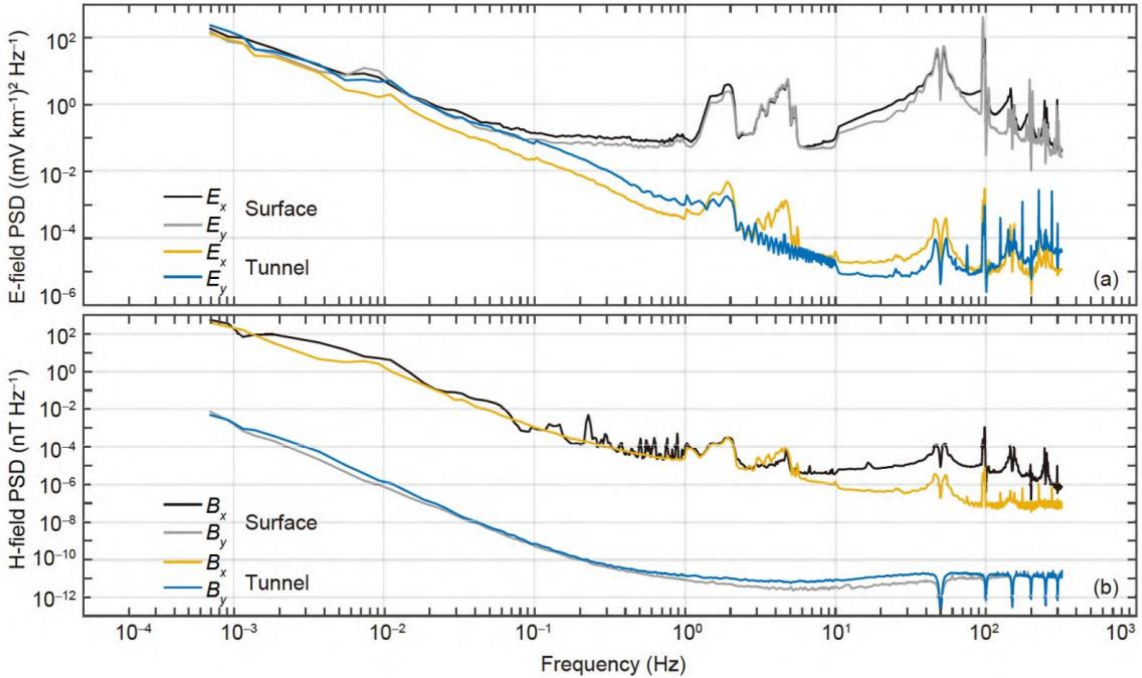


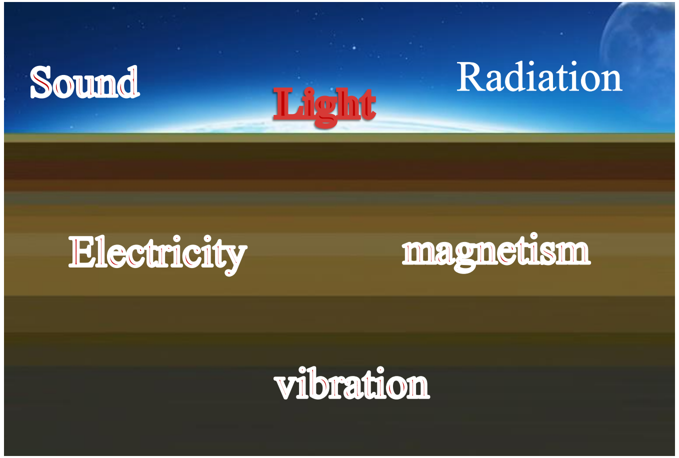
Comparison of Underground Noise Power Spectral Density (PSD) between Huaian and Xuzhou (with a difference of over 500 meters).

3. Deep underground observations

■ Why conduct deep underground observations

① To avoid surface interference





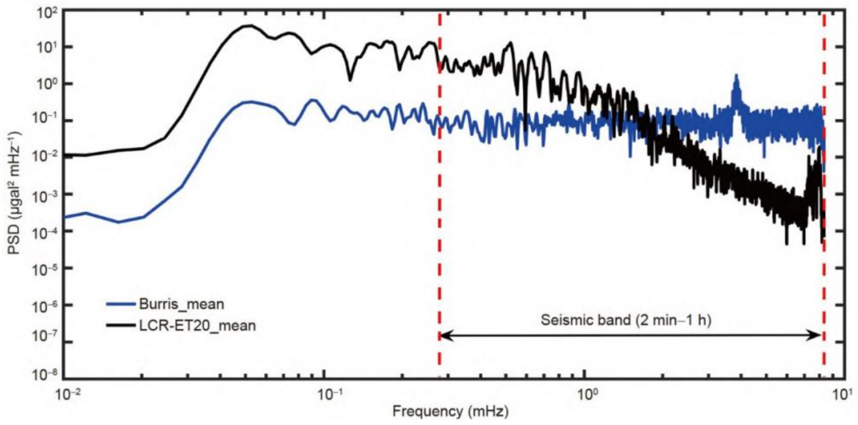
3. Deep underground observations

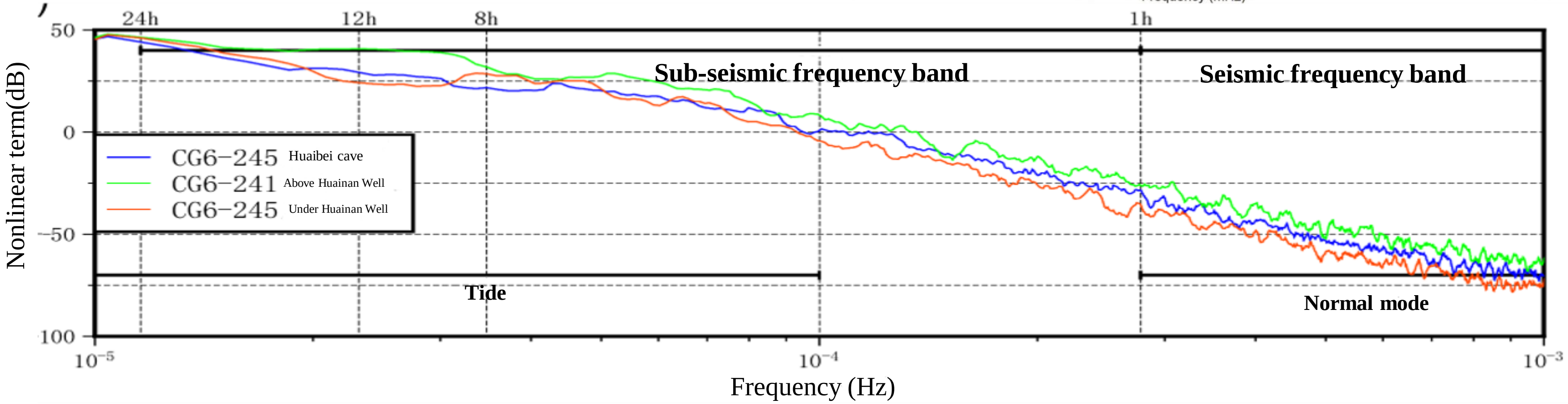
■ Why conduct deep underground observations

② Is it only for observations without noises?

✓3600s long-term surface noise is two orders of magnitude stronger than that of the underground

✓Compared with the surface and Mengcheng Station, underground environment is better



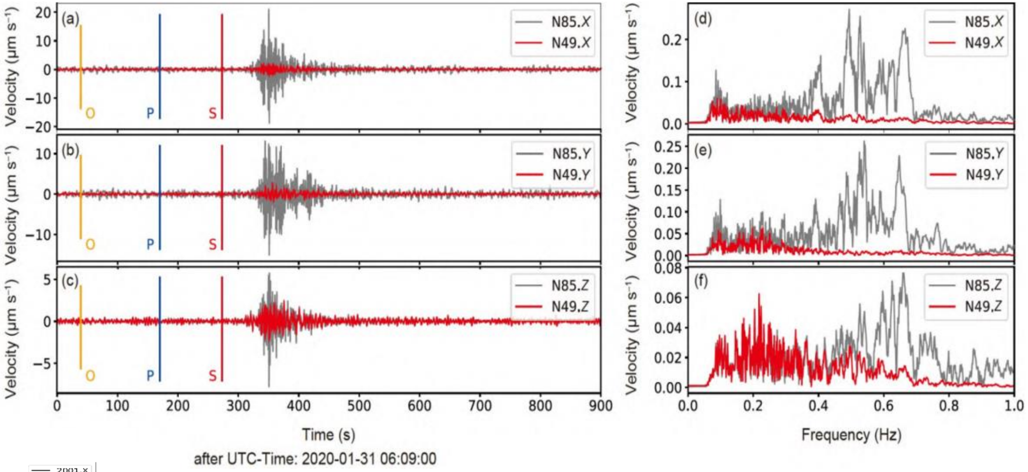


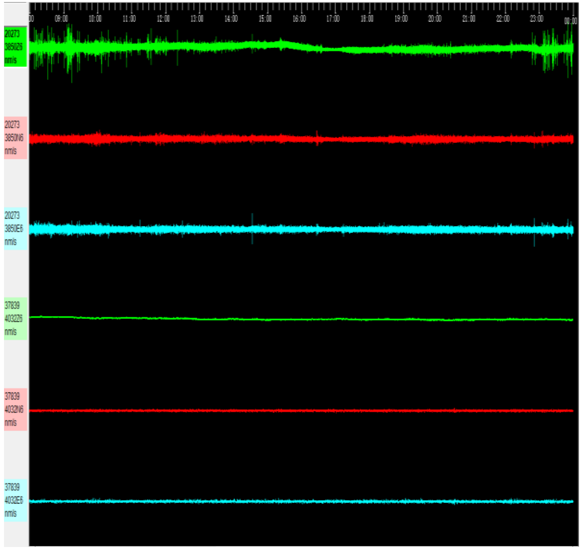
Why conduct deep underground observations

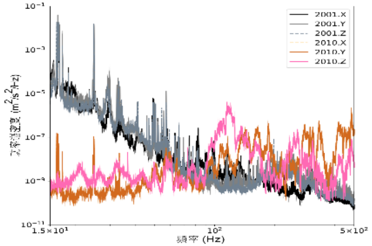
③ Correction of ground-based observations.

- ✓ Noise characterization and separation.
- ✓ Site effects correct

Waveforms and amplitude spectra of the M4.2 earthquake near the Yilan Sea, Taiwan Province, China.
(a)–(c) are the NS, EW and vertical components, respectively, and (d)–(f) are their amplitude spectra



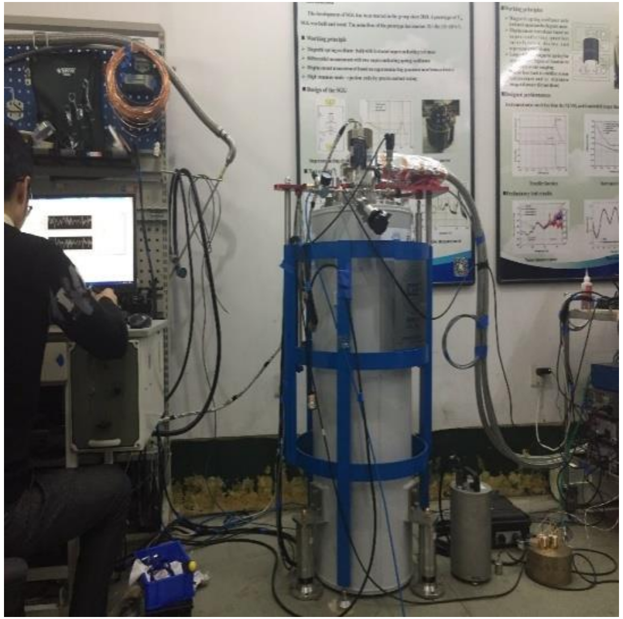




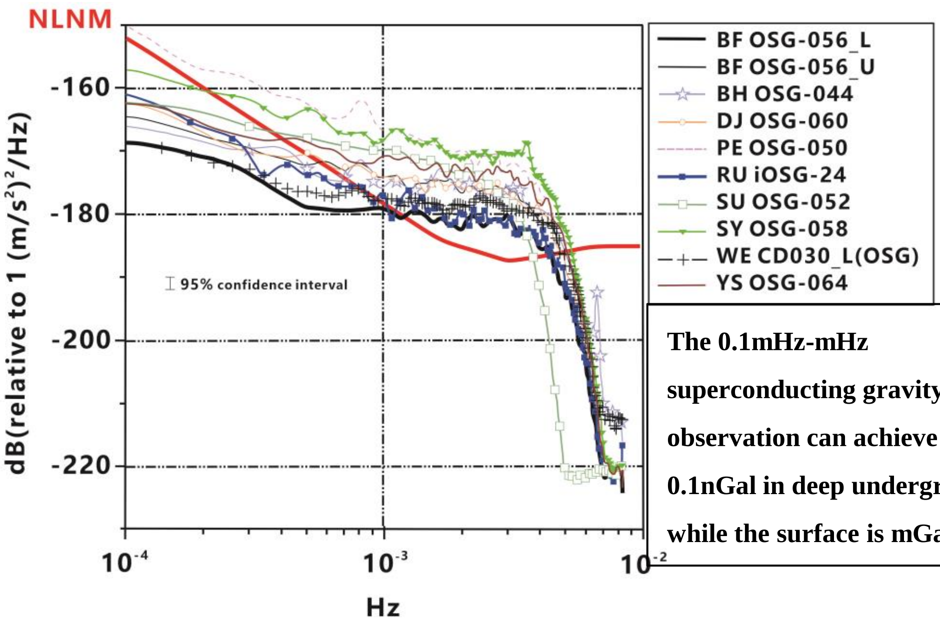
Denoising with machine learning

Why conduct deep underground observations

④ Ultra-high precision observations is possible



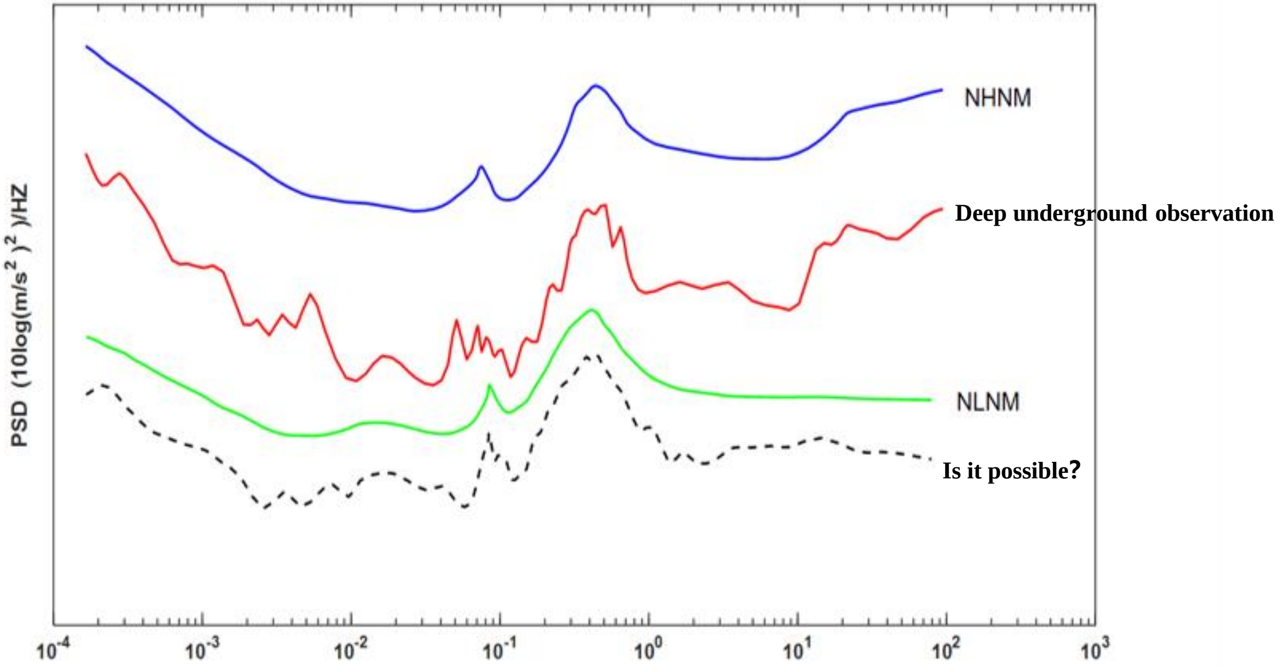
Blue: background noise PSD of LSBB in France



The 0.1mHz-mHz superconducting gravity observation can achieve nGal-0.1nGal in deep underground, while the surface is mGal level

■ Why conduct deep underground observations

⑤ Achieve ultra-long-period stable 4D observation



Slow earthquake， earth pulsation, tide

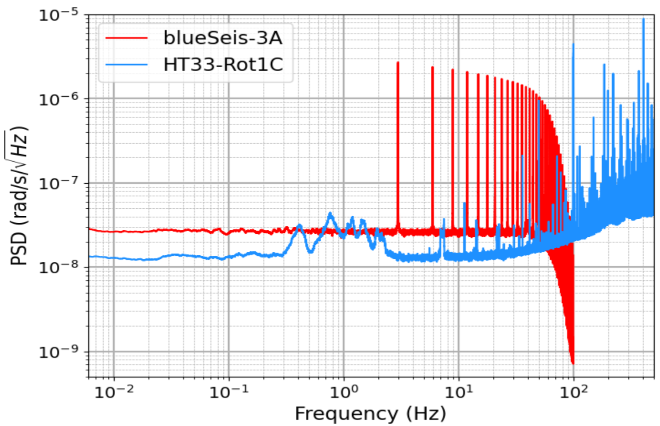
Natural earthquakes with different seismic phases

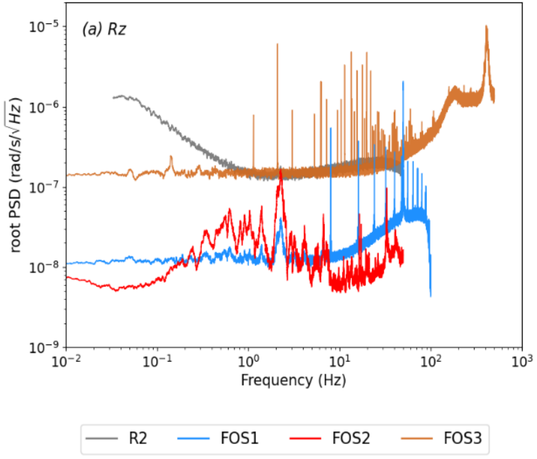
Microearthquake

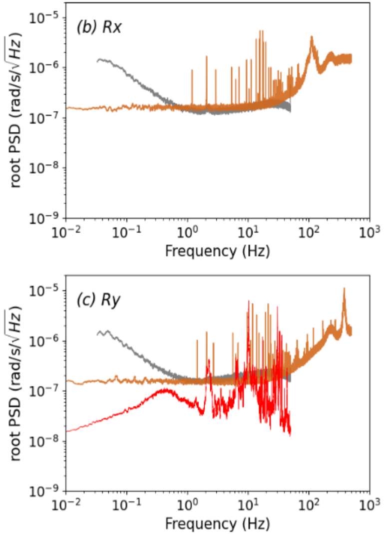
3. Deep underground observations

■ Why conduct deep underground observations

⑥ Comparison and calibration of instruments with different levels of accuracy.





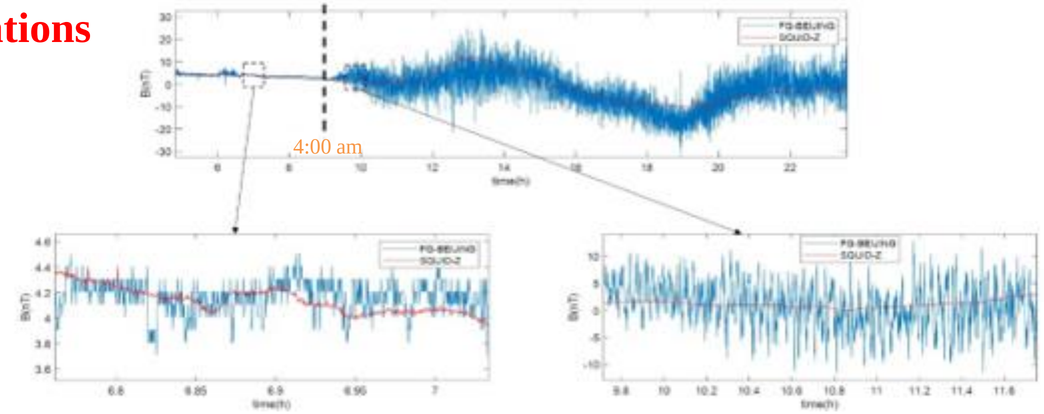


Comparison, calibration, measuring station

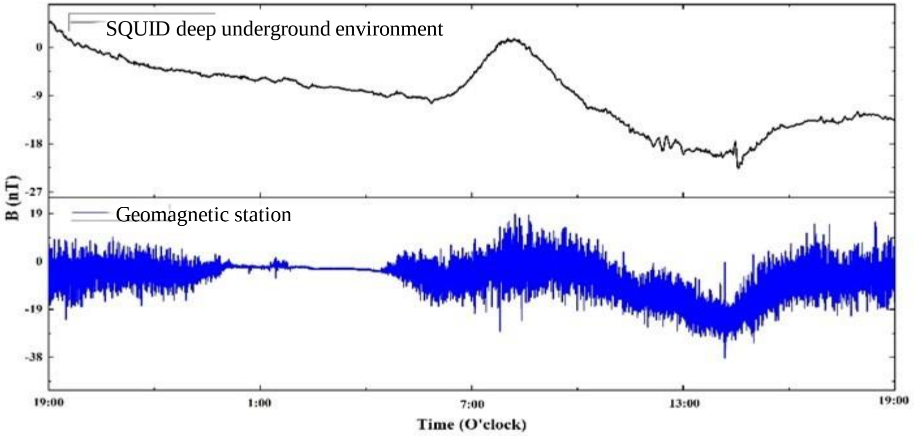
3. Deep underground observations

■ Why conduct deep underground observations

⑦ Standard station



Comparison with Beijing Baijiatuan geomagnetic station



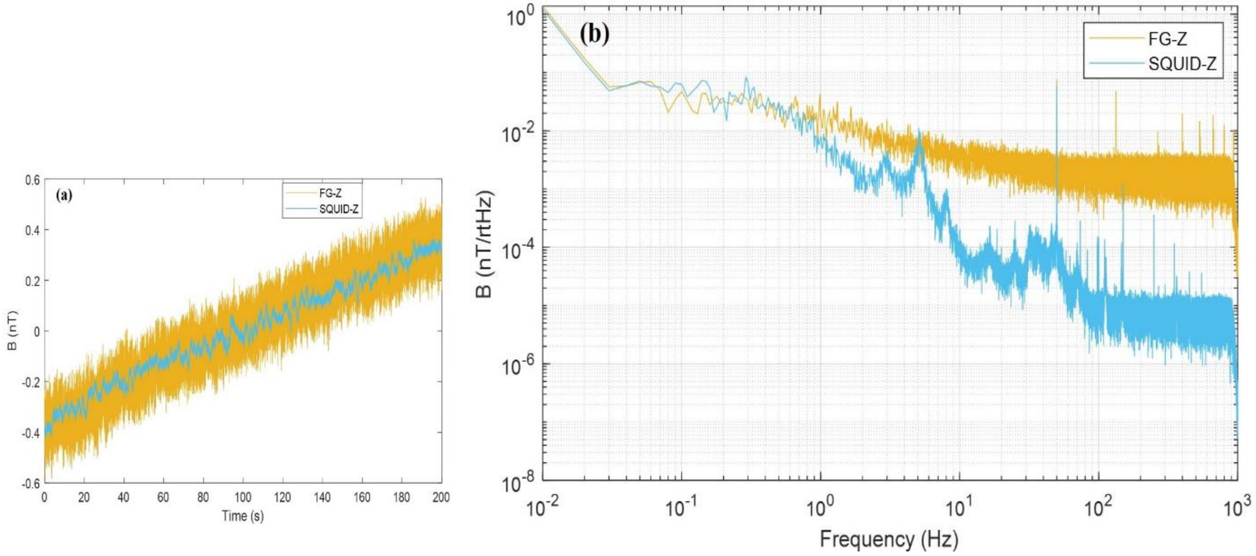
Comparison with LSBB in France

	LSBB	Huainan
Depth	-515m	-848m
Geomagnetic field	Attenuation to 1/6~1/8	Almost no attenuation
space	Small	Large
System noise	**~2fT**	**~5fT(Potential for improvement)**
Test content	Comprehensive	To be carried out

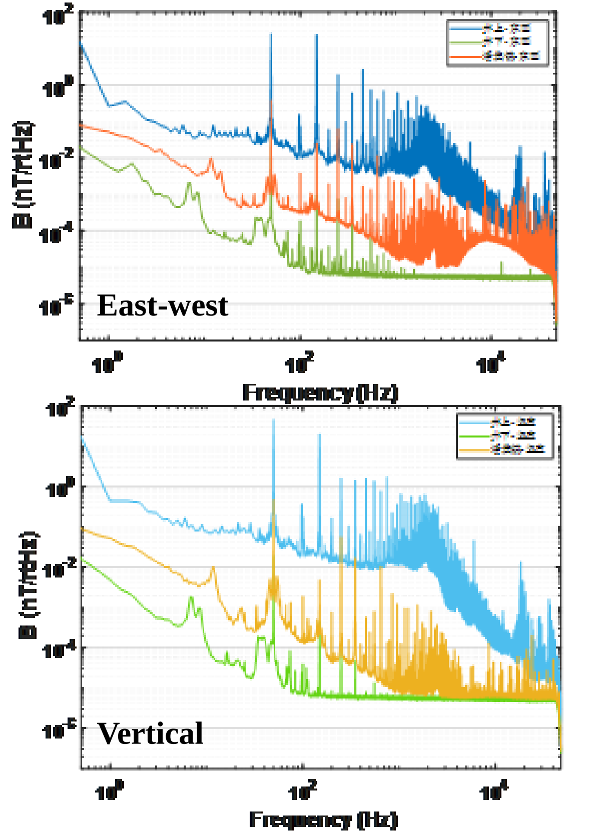
3. Deep underground observations

■ Why conduct deep underground observations

⑧ **Development of wide-band ultra-low background instruments.**



Comparison of SQUID and fluxgate results at underground measuring points



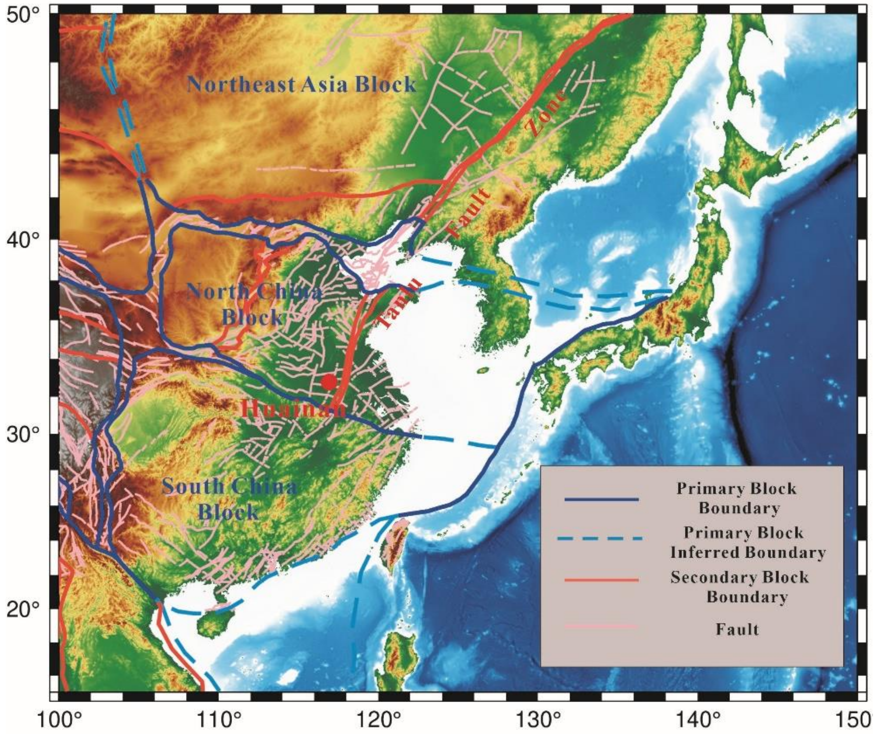
Comparison of SQUID PSD in surface (blue), suburban (orange) and underground (green)

3. Deep underground observations

- **Is it possible to capture slow earthquakes from the seismic zone of Japan or from the Tanlu faults, intra-plate seismic zone by using ultra-high sensitivity, ultra-broad band displacement, gravity and seismic observations in deep underground?**

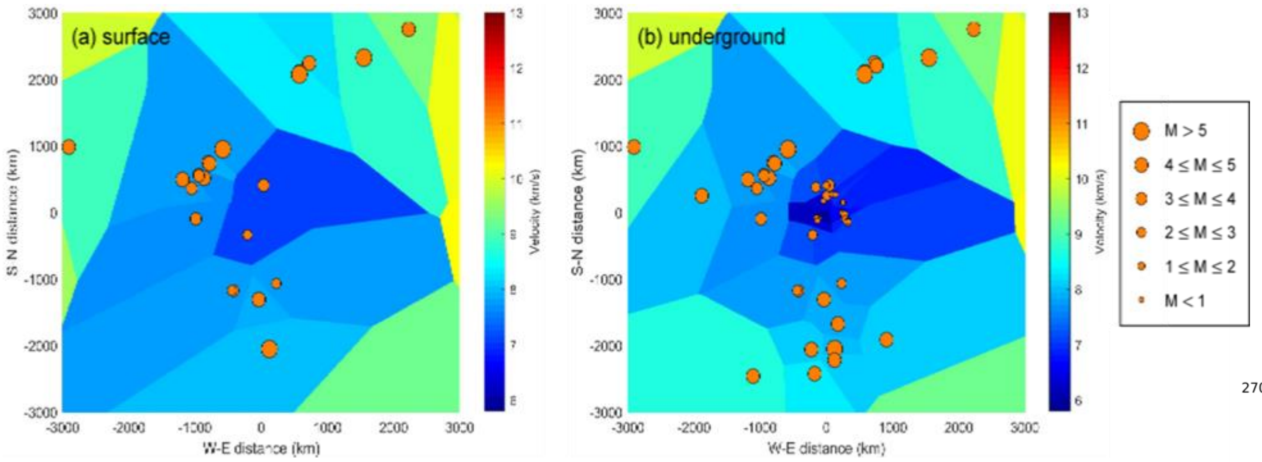
✓**Gravity observations of nGal sensitivity are theoretically required for slow earthquake recording from Japan**

✓**Whether there is slow shocks from Tanlu fault zone?**

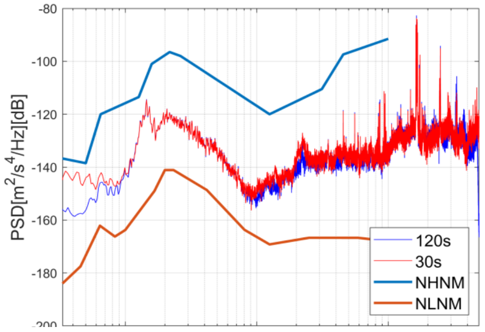


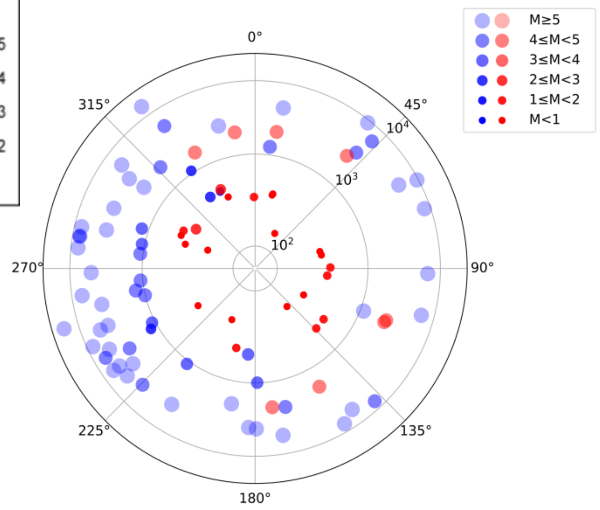
3. Deep underground observations

- **More accurate inversion of source mechanism and medium structure can be realized with seismic observations in deep underground**



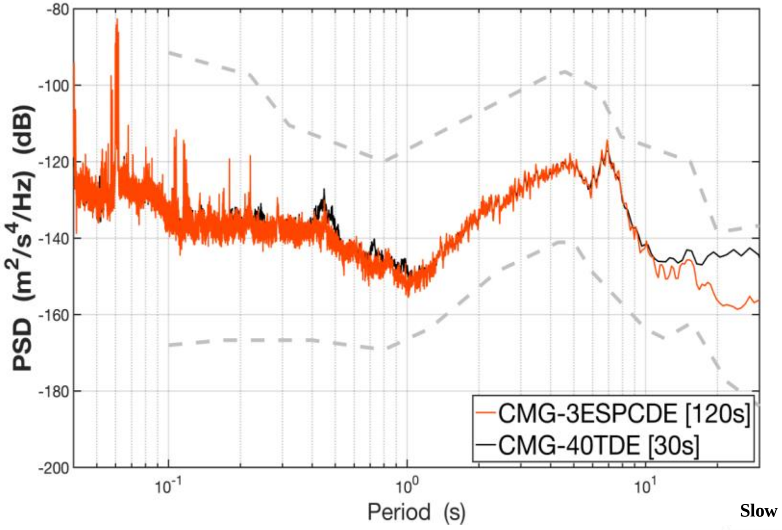
Comparison of equivalent velocity models revealed by surface (a) and underground (b) observations
(Based on triangulation nearest neighbor interpolation)

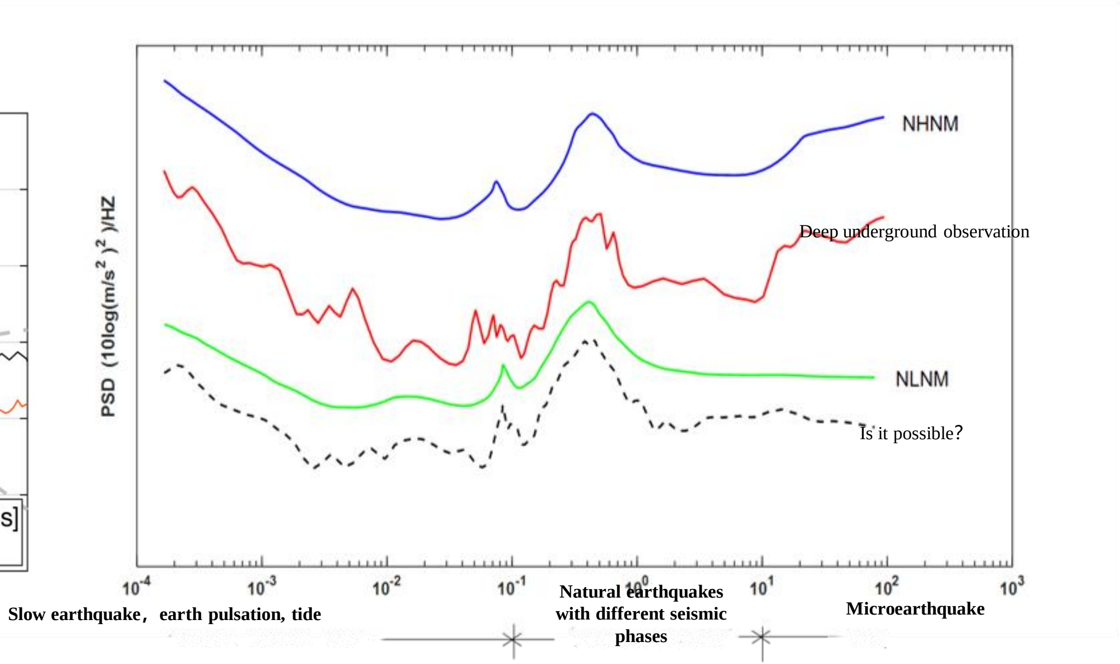




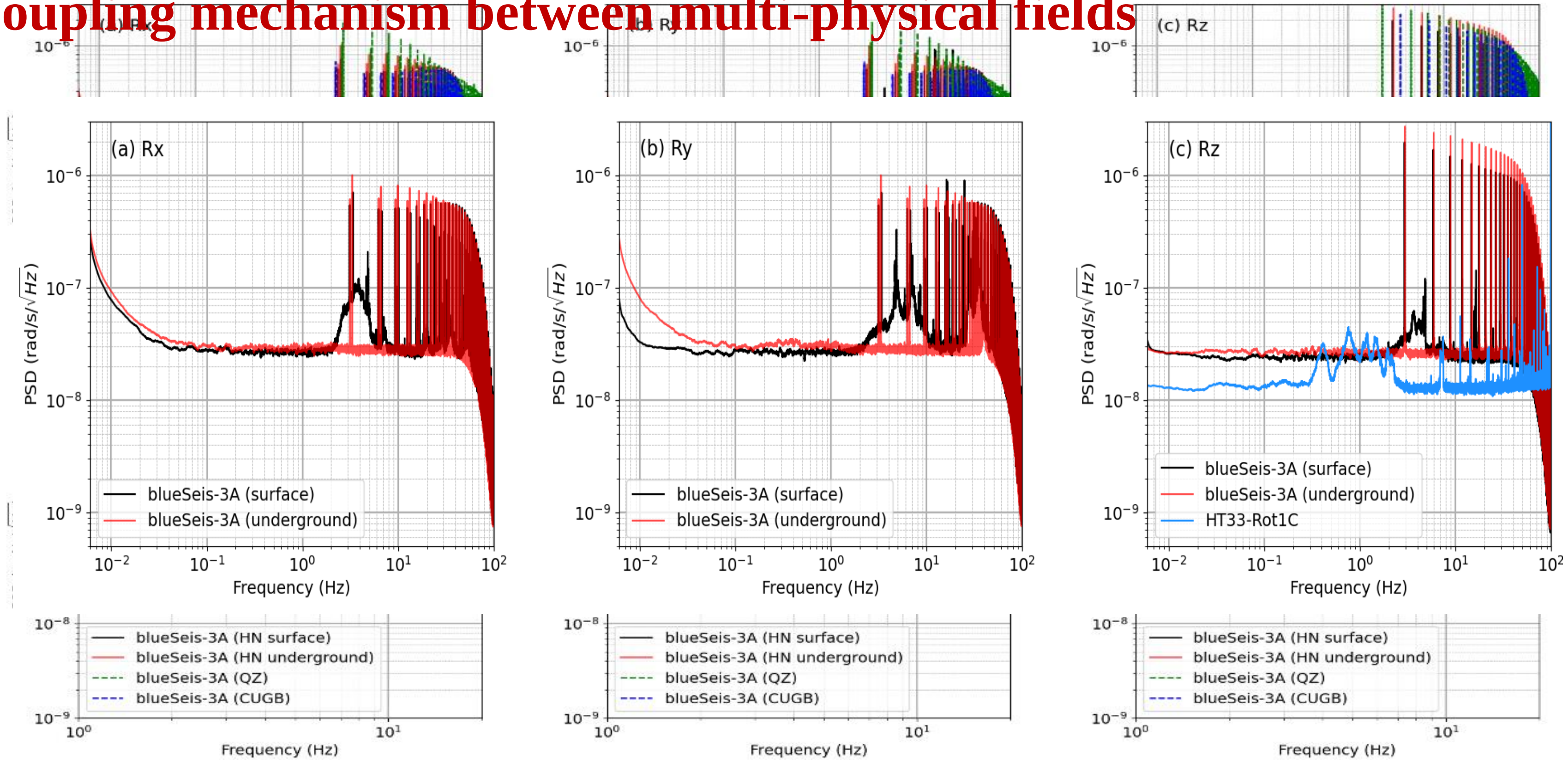
3. Deep underground observations

- **If ultra-high sensitivity and ultra-broad band seismic observations are used to monitor the first and second pulse peaks and mHz weak long-period signals, it is possible to explore the correlation between earth's deep structure, planet movement and earthquakes.**



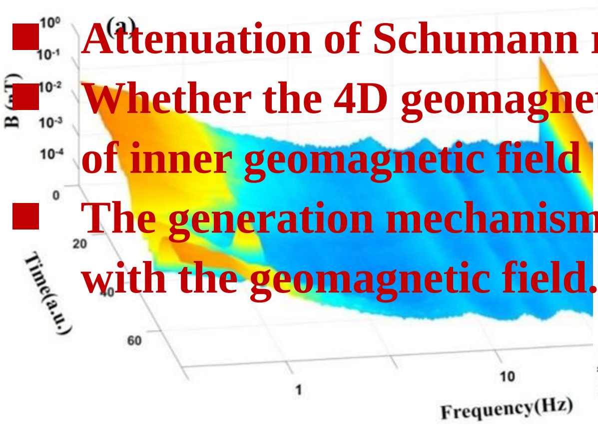


■ Coupling mechanism between multi-physical fields

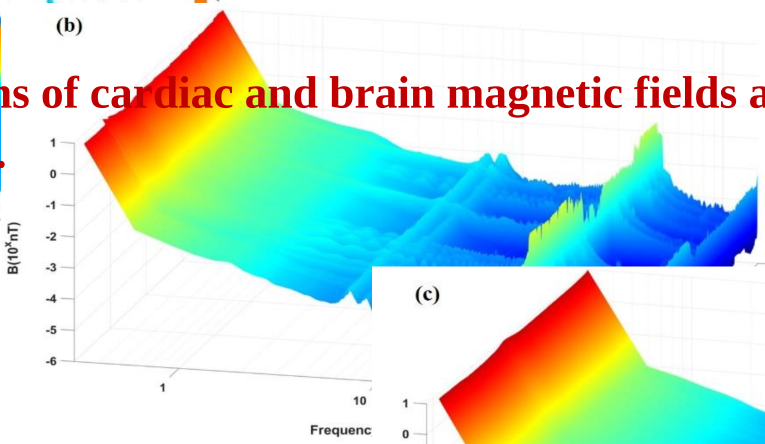


3. Deep underground observations

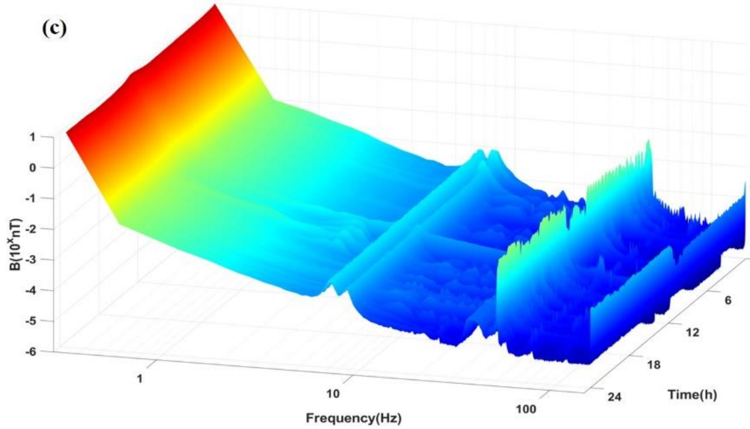
- **Attenuation of Schumann resonance in deep underground**
- **Whether the 4D geomagnetic observation of fT level can provide reliable data for the study of inner geomagnetic field**
- **The generation mechanisms of cardiac and brain magnetic fields and their interaction with the geomagnetic field.**



Horizontal magnetic field in Shanghai suburban



Horizontal magnetic field in



Vertical magnetic field in Huainan deep underground

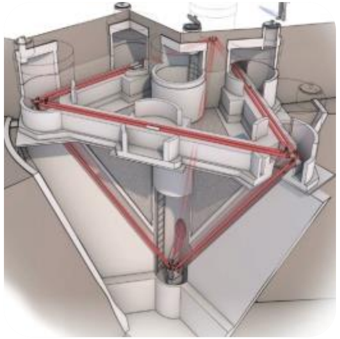
4. Problems and Challenges

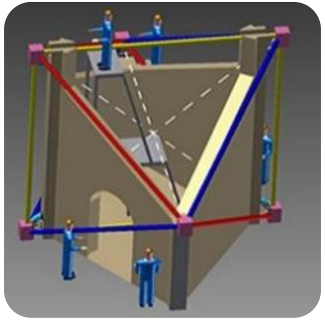
Observtions currently faced by

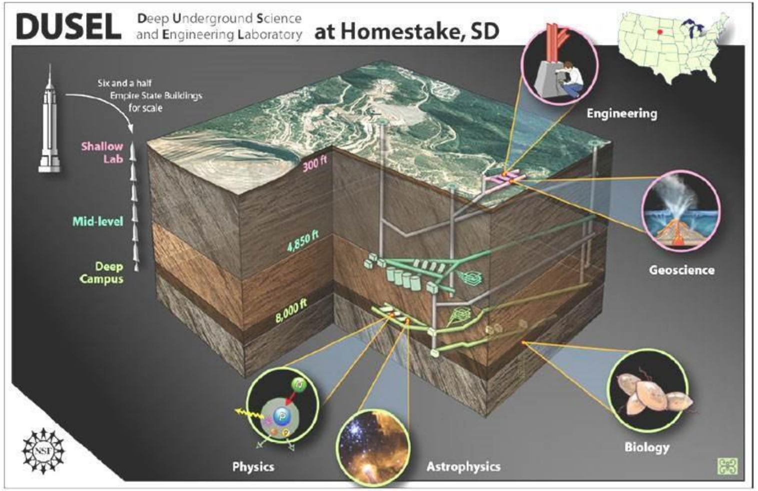
① Ultra-high precision instrument not enough

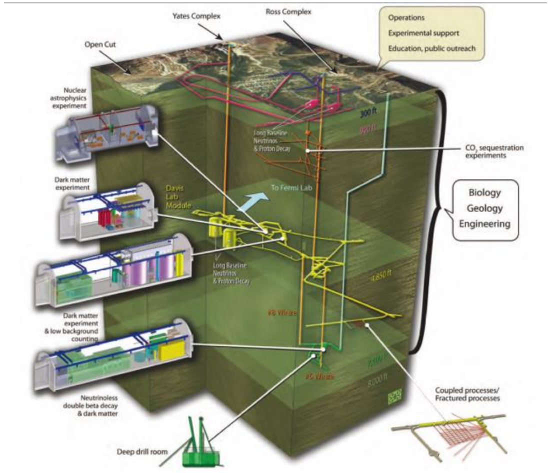
② Electrode existing zero drift

③ Laboratory reconstruction



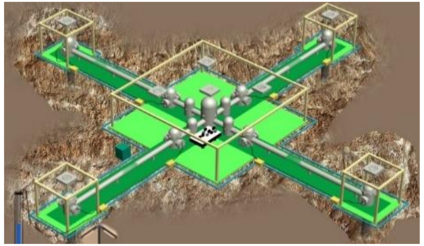




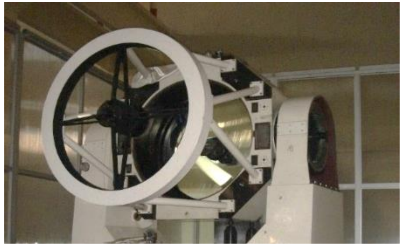
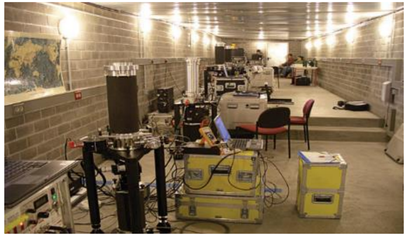


4. Problems and Challenges

- Timing and positioning of instruments at deep underground space
- Automatic data cleaning techniques since underground interference unavoidable
- The necessity of monitoring and real-time data transmission
- lack of high-precision equipment

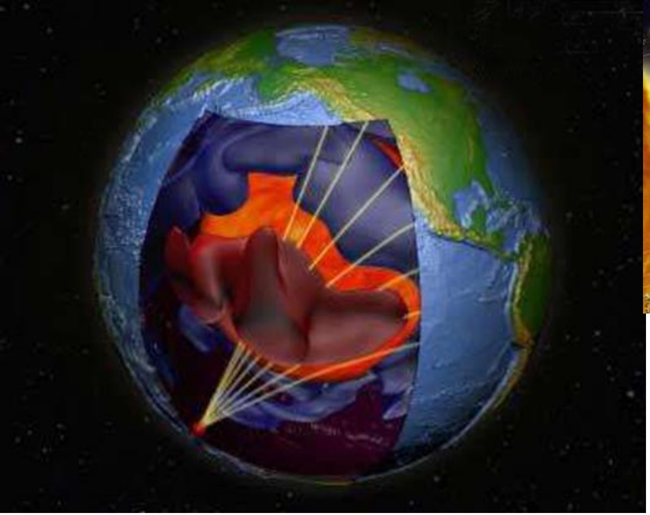


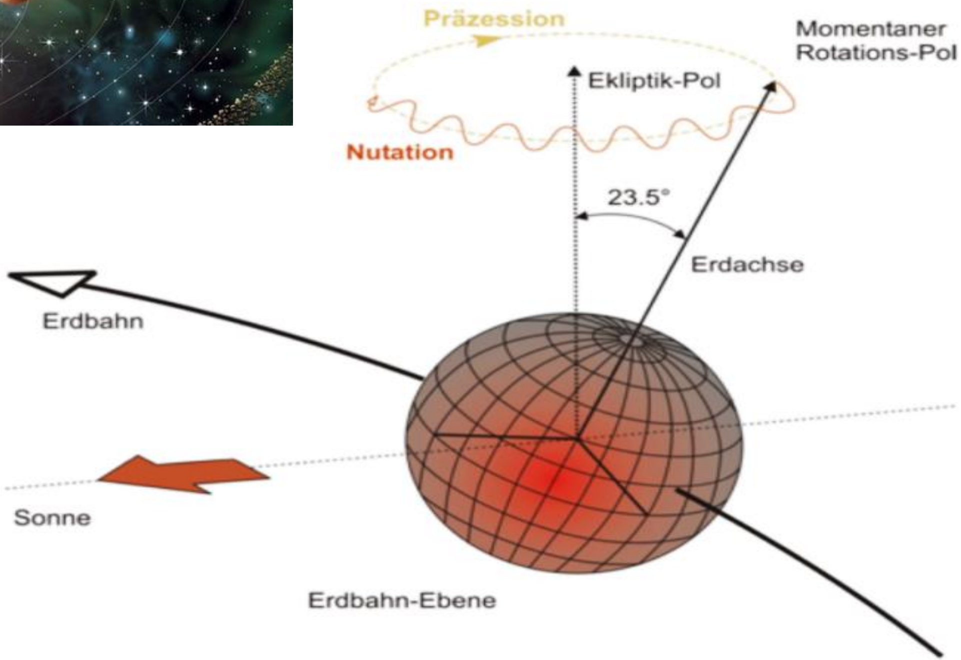


5. Prospect

- **Just beginning, a beginner and learner**
- **3 coal mine underground Labs planed**
- **More sites needed along the Tanlu Faults to compose a deep underground network**
- **National Underground Lab for multiple disciplines**





THANKS !

The deep underground space permit more interesting imagination.

References about our preliminary exploration

■Chinese Journal of Geophysics, Issue No. 1, Deep underground section

Wang Y , Jian Y F , HE Y S, et al. 2022. Underground laboratories and deep underground geophysical observations. *Chinese J. Geophys*. (in Chinese),65(12):4527-4542,doi:10.6038/cjg2022Q0404.

Sun H P, Chen X D, Wei Z G, et al. 2022. A preliminary study on the ultra-wide band ambient noise of the deep underground based on observations of the seismometer and gravimeter. *Chinese J. Geophys*. (in Chinese), 65(12):4543-4554 ,doi:10.6038/cjg2022Q0559.

Wang Z Y, Wang Y, Xu R G , et al. 2022. Environmental noise assessment of underground gravity observation in Huainan and the potential capability of detecting slow earthquak . *Chinese J. Geophys*. (in Chinese), 65(12):4555-4568 ,doi: 10.6038/cjg2022Q0375.

Chen C, Wang Y, Guo G Y, et al. 2022. Deep underground observation comparison of rotational seismometers. *Chinese J. Geophys*. (in Chinese), 65(12):4569-4582 ,doi: 10.6038/cjg2022Q0318.

And articles on the road

- **Issue No. 2**

Q0565	淮南深地实验室分布式光纤地震立体台阵观测数据分析 版权	包丰	张丽娜	已修回
Q0911	淮南深地地磁总场连续观测与时变特征 基金 版权	郭良辉 1	郭良辉，王赟	已修回
Q0963	面向深地探测的光纤重力梯度仪测量原理与研制进展 基金 版权	王文伯 1	陈彦钧	已修回
R0104	地面与深部地下地震背景噪声对比分析 基金	王赟	王赟	复审

① 基于低温超导的深地fT级地磁观测及其挑战，邱隆清，王赟

② 深地小弱震的识别，陈畅，王赟

③ 深地电磁观测与地电结构反演，谢成良，王赟