中国科学院 CHINESE ACADEMY OF SCIENCES

上海天文台 Shanghai Astronomical Observatory

The Software Correlator of the Chinese VLBI Network

Weimin Zheng, Ying Quan, Fengchun Shu,
Zhong Chen, Shanshan Chen, Weihua Wang, Guangli Wang

Shanghai Astronomical Observatory,
Chinese Academy of Sciences

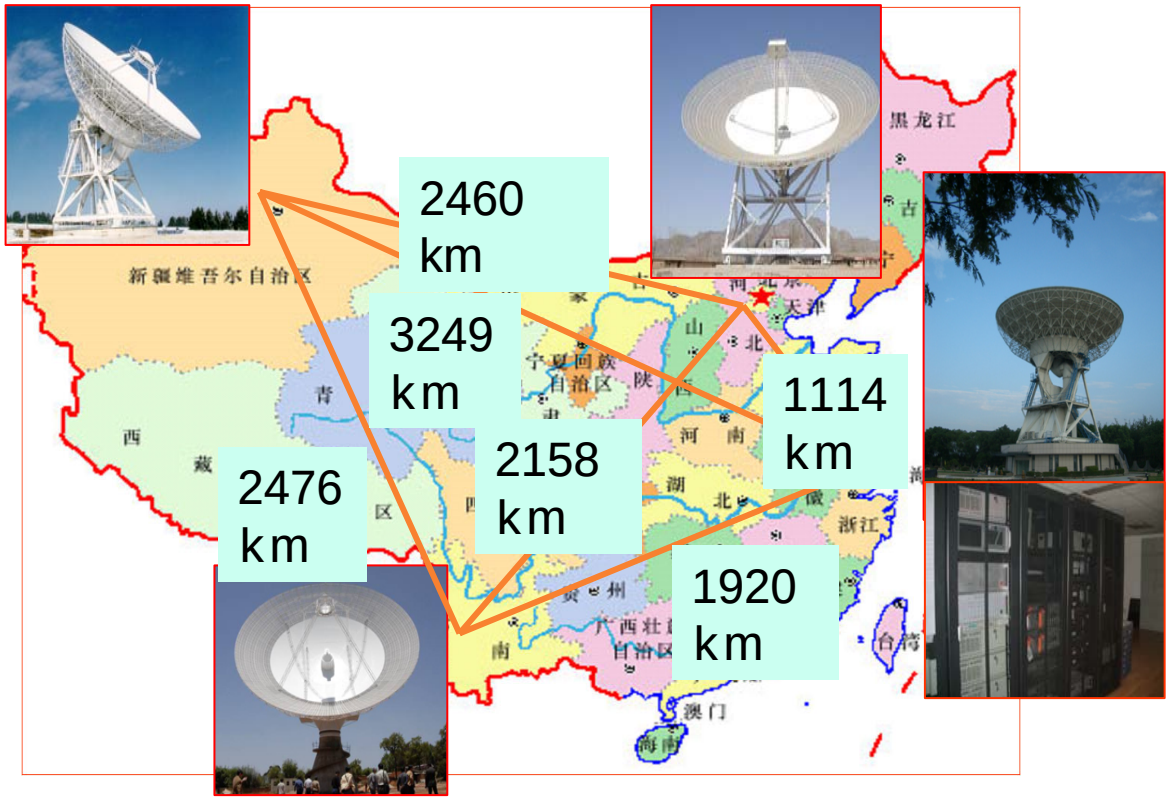
Sixth IVS General Meeting, February 9, 2010, Hobart

Contents

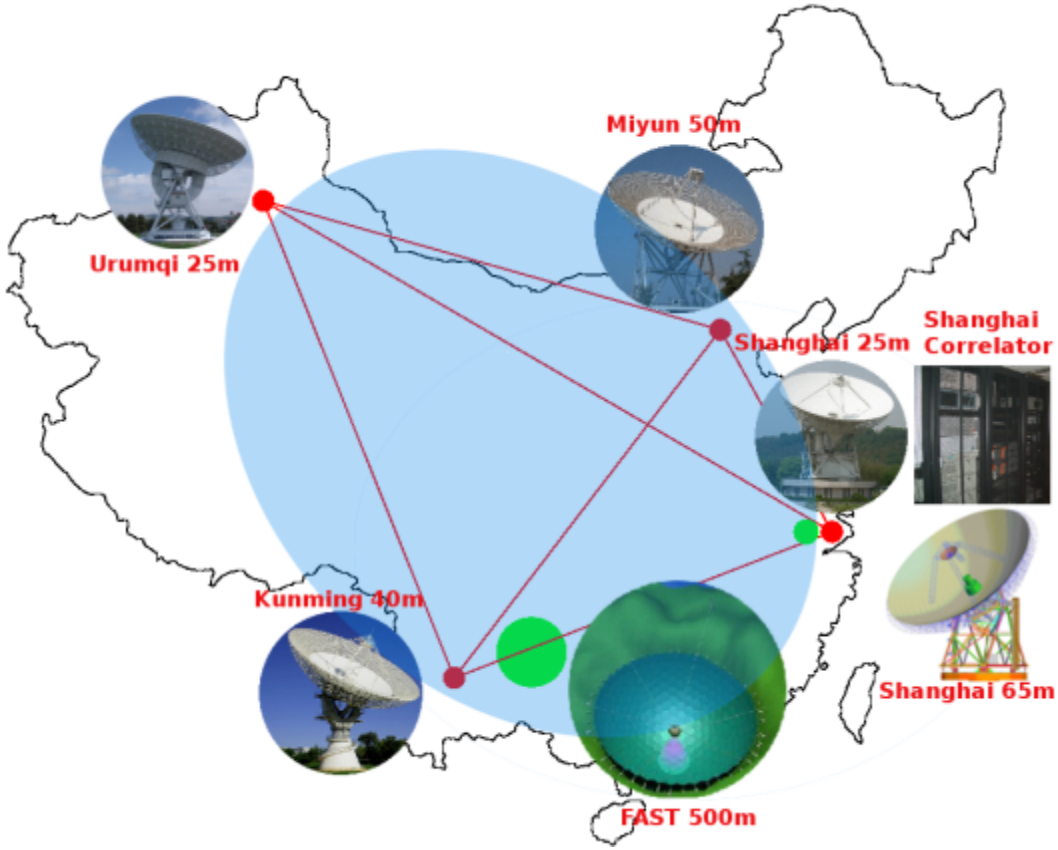
1. Background
2. SMP software correlator
3. Cluster software correlator
4. Plan of 2010

1. Background

Current Chinese VLBI Network (CVN) = 4 stations + 1 data center



2012 Chinese VLBI Network (CVN)

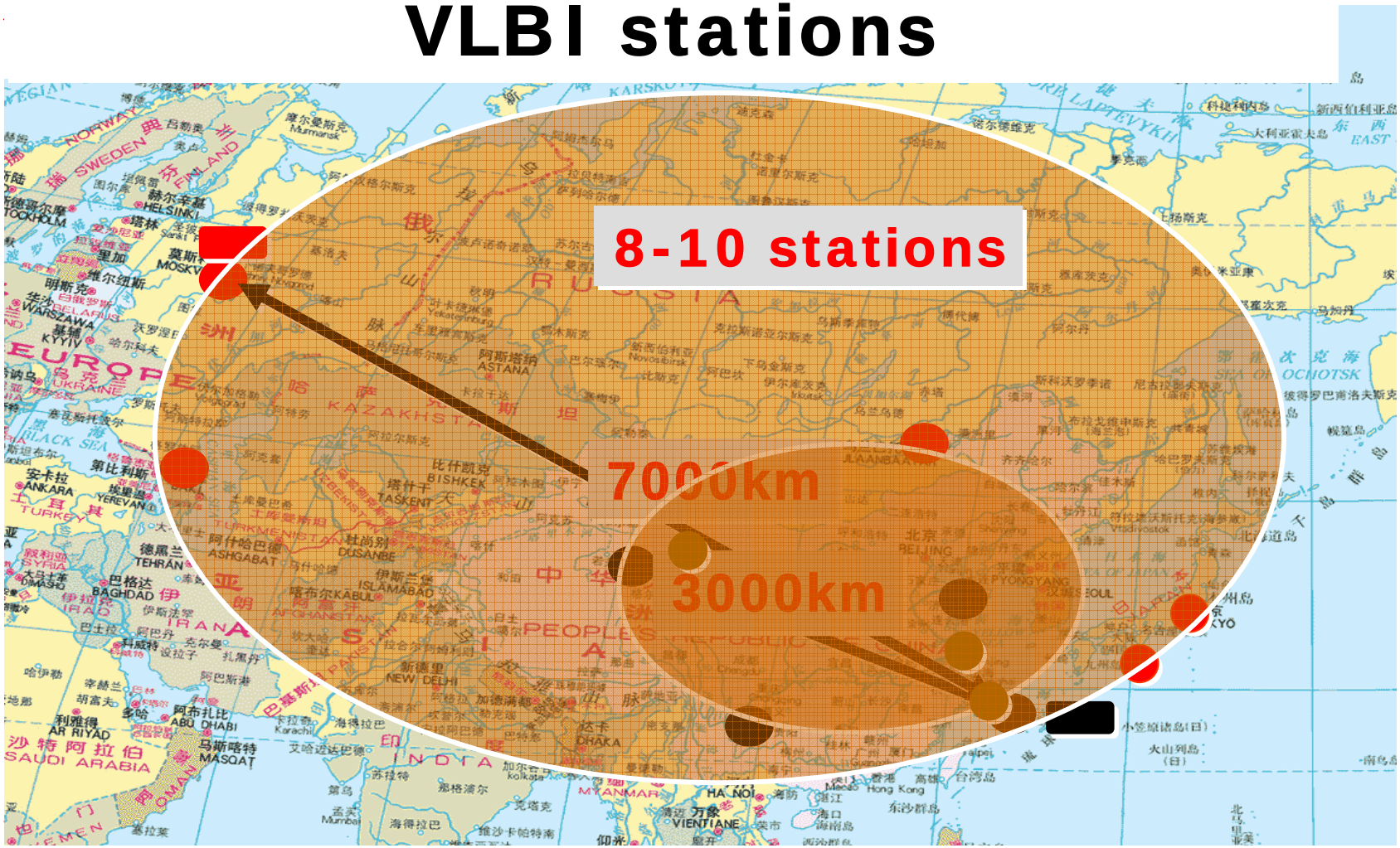


Shanghai 65m telescope will improve 42% sensitivity of CVN

中国科学院
CHINESE ACADEMY OF SCIENCES

上海天文台
Shanghai Astronomical Observatory

Sino-Russian-Japanese VLBI stations



CVN Applications

1) Astronomy
   Maser Imaging

2) Geodesy
   Project Crustal Movement Observation Network of China (CMONC)
   rapid dUT1 measurement

3) Deep space exploration
   Lunar, Mars probe tracking

CVN Correlator requirements

1) Software correlator is a good choice

2) Astronomy & Geodesy
   Station: 5~10
   Data rate: ~1Gbps
   Disk based VLBI or Real time VLBI
   Standard data output format:
      FITS-IDI, NGS

CVN Correlator requirement

3) Deep space exploration
   Station: 4~6 (Domestic observation)
   > 5 (International observation)
   High reliability
   Real time VLBI or Disk VLBI
   (data turnover < 1 minute)
   Data rate: 16~128Mbps
   Special functions:
   Fast fringe search
   DOR (Differential of One-way Ranging)

Two software correlators

Application	Navigation	Scientific usage
Parallel computing	pthread	MPI + pthread
Platform	SMP server	SMP cluster
Speed	Low speed /Fringe searching	High speed

2. SMP software correlator

- 10-station FX type correlator
  4-station in CE-1 project

- Near real time correlation ability (< 3 min)

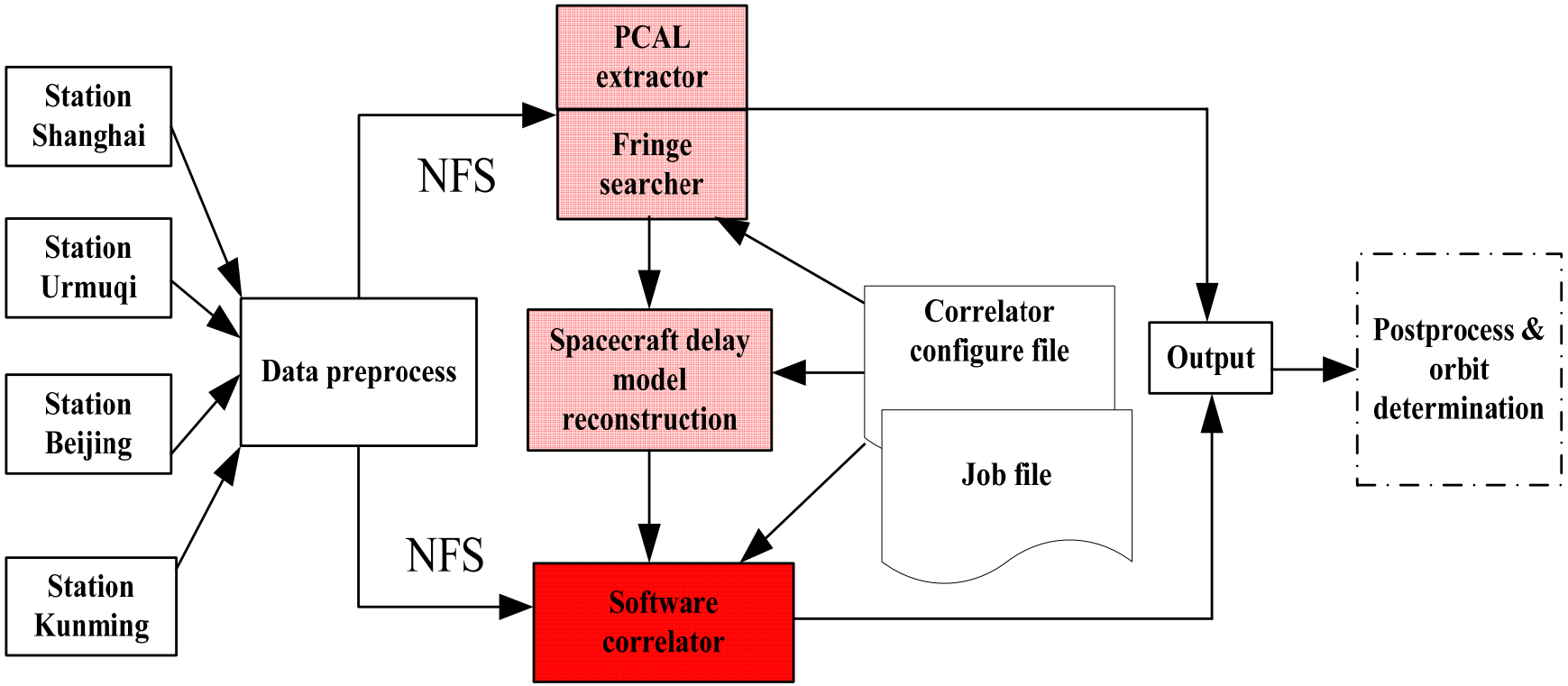
- Special functions:
  - Fast fringe search and model reconstruction
  - Full PCAL detection ability, CE-1 mode
    8 PCALs, 4-channel, 2MHz/channel
    64PCALs,8-channel, 8MHz/channel

- **Hardware platform:**
  - **SMP (Symmetric Multiple Processor)**
  - **X86 PC server**
  - **4 CPU (dual core → quad core), 2.2GHz**
- **Software platform:**
  - **Linux enterprise OS**
- **Correlation speed:**
  - **>128Mbps/station,2bit sample, 4 stations**

Correlator Capabilities

Correlation station number	1~10
IF number	1~16
FFT points/ IF	32 ~65536/IF
Input data format	Mark5A, Mark5B
Sampling	1bit, 2 bit
Output data format	CVN/FITS/NGS
Fringe search	2-4 stations
Correlation speed	>128Mbps/station (4 stations, 1024/IF)
Data latency	< 3 minutes
PCAL detection	Yes

Block diagram



NFS: Network File System

Applications in CE -1 project

- Processed 1006.9 hours data

I. Critical flying mission (Oct 25,-Nov, 30, 2007)

- Near-real time mode:15hous/day
- Data latency < 3 minutes.
- Data rate: 16Mbps/station, network

- 36 experiments:336.55 hours
- Sent out 336.55 hours

Applications in CE -1 project

II. Long-term in-orbit operation (Dec 18,2007-Mar 1, 2009)

- Disk VLBI mode: 2days/week
- Data latency < 2 wakes
- Data rate: 128Mbps/station, Mark5A

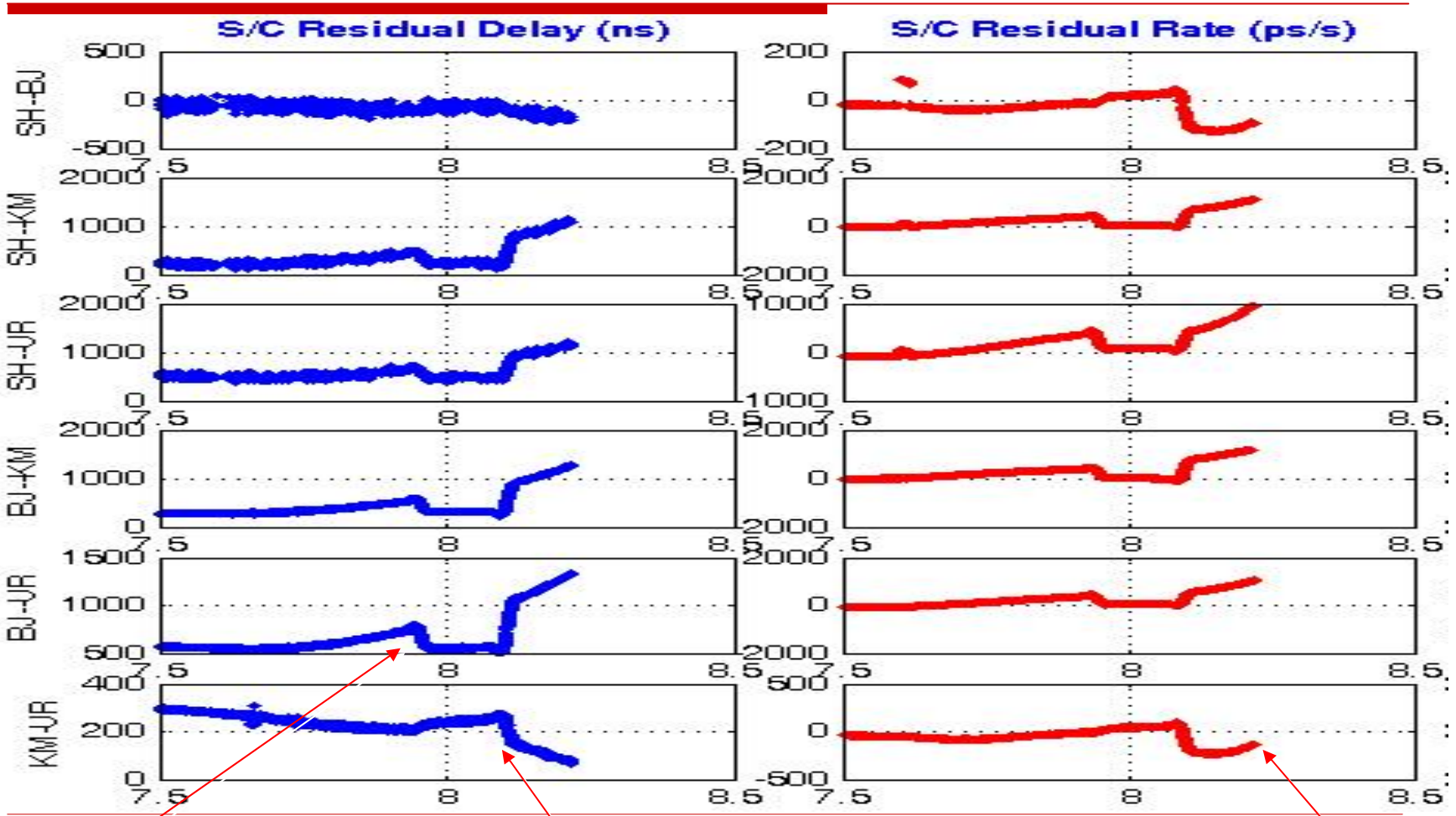
- Processed all the data of special stages:
- Orbit Change experiments
- Moon Impact

中国科学院 CHINESE ACADEMY OF SCIENCES

上海天文台 Shanghai Astronomical Observatory

Delay/rate change of CE-1 impacted moon

2009-3-1

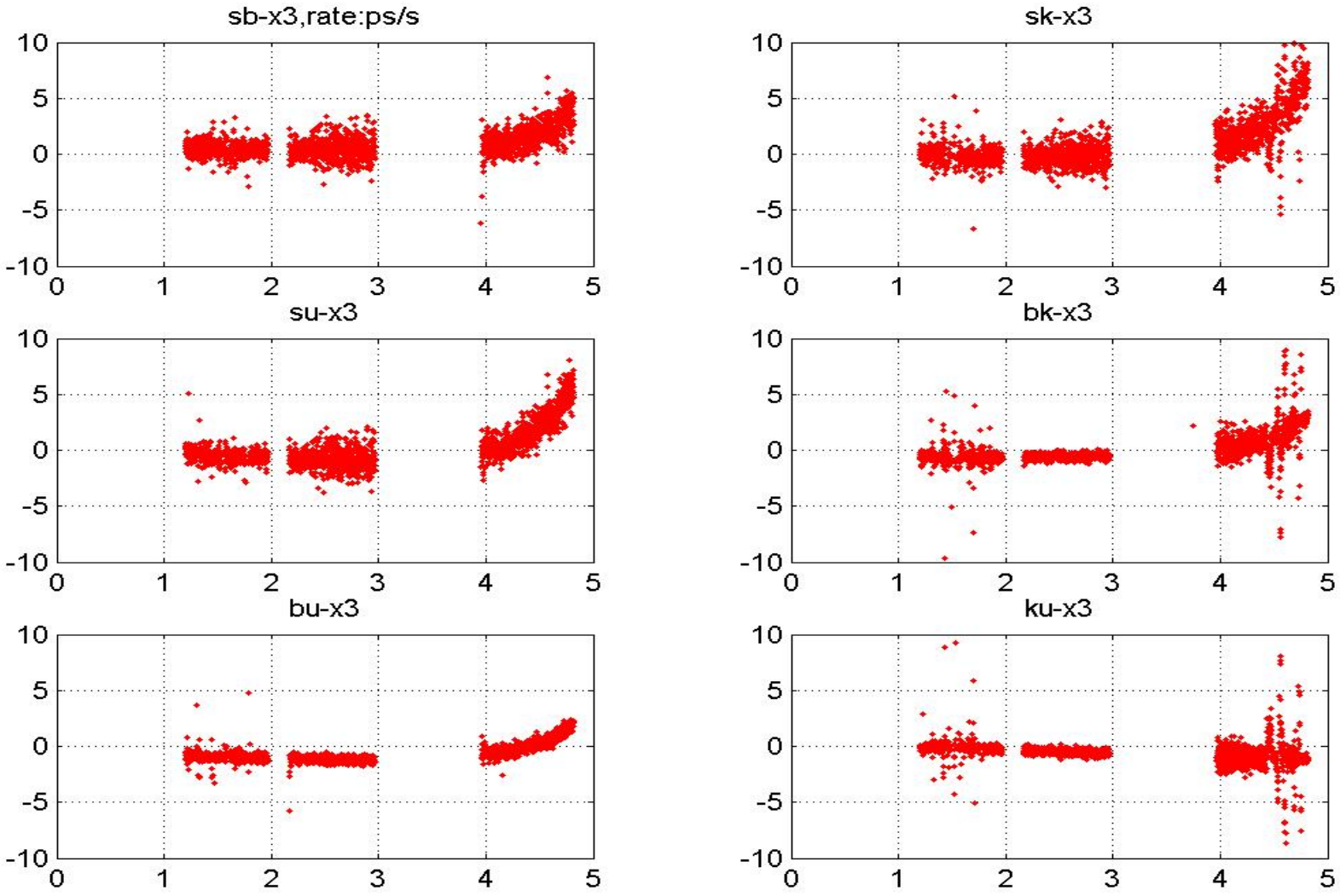


15:36 Last orbit control

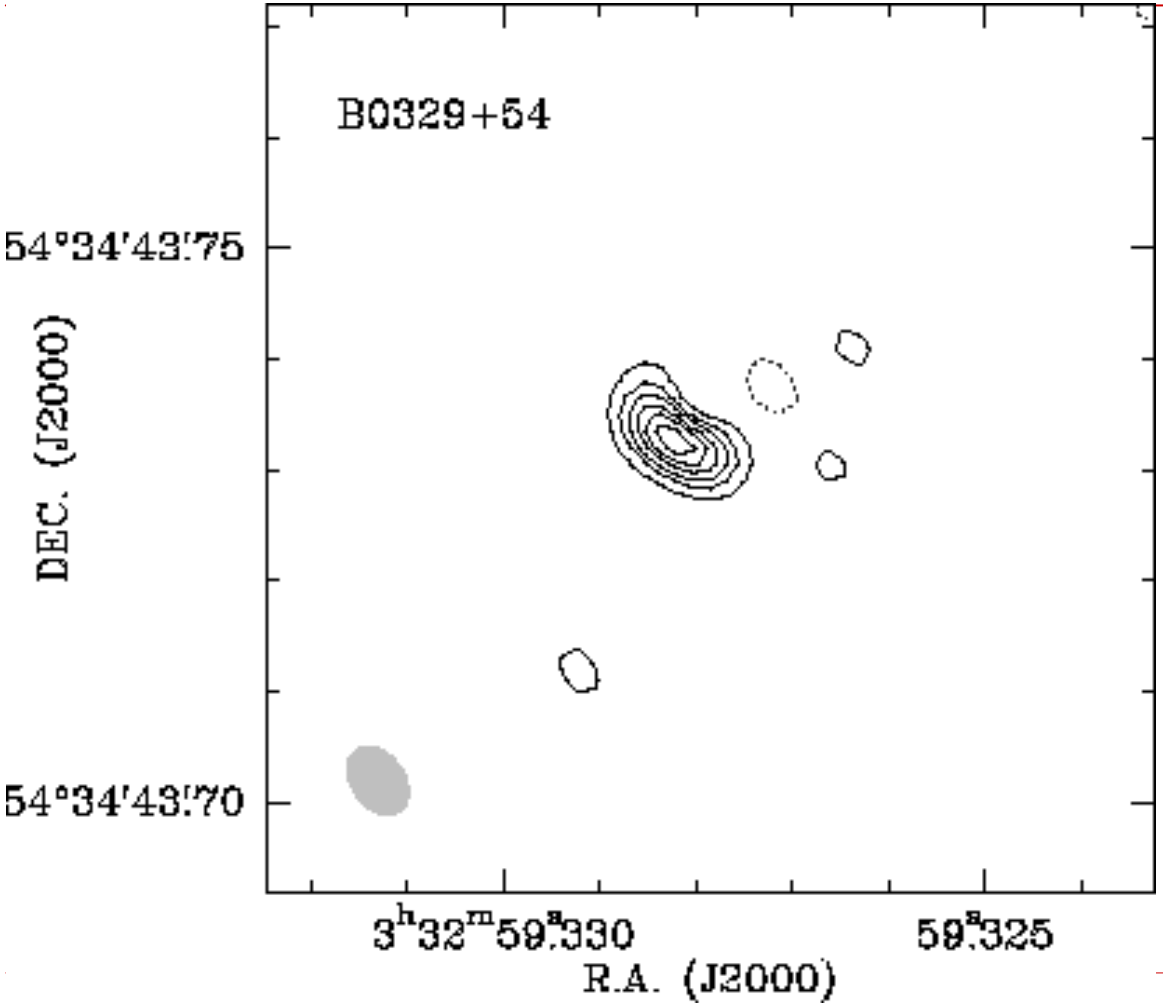
15:56 Last orbit control

16:13 Impact moon

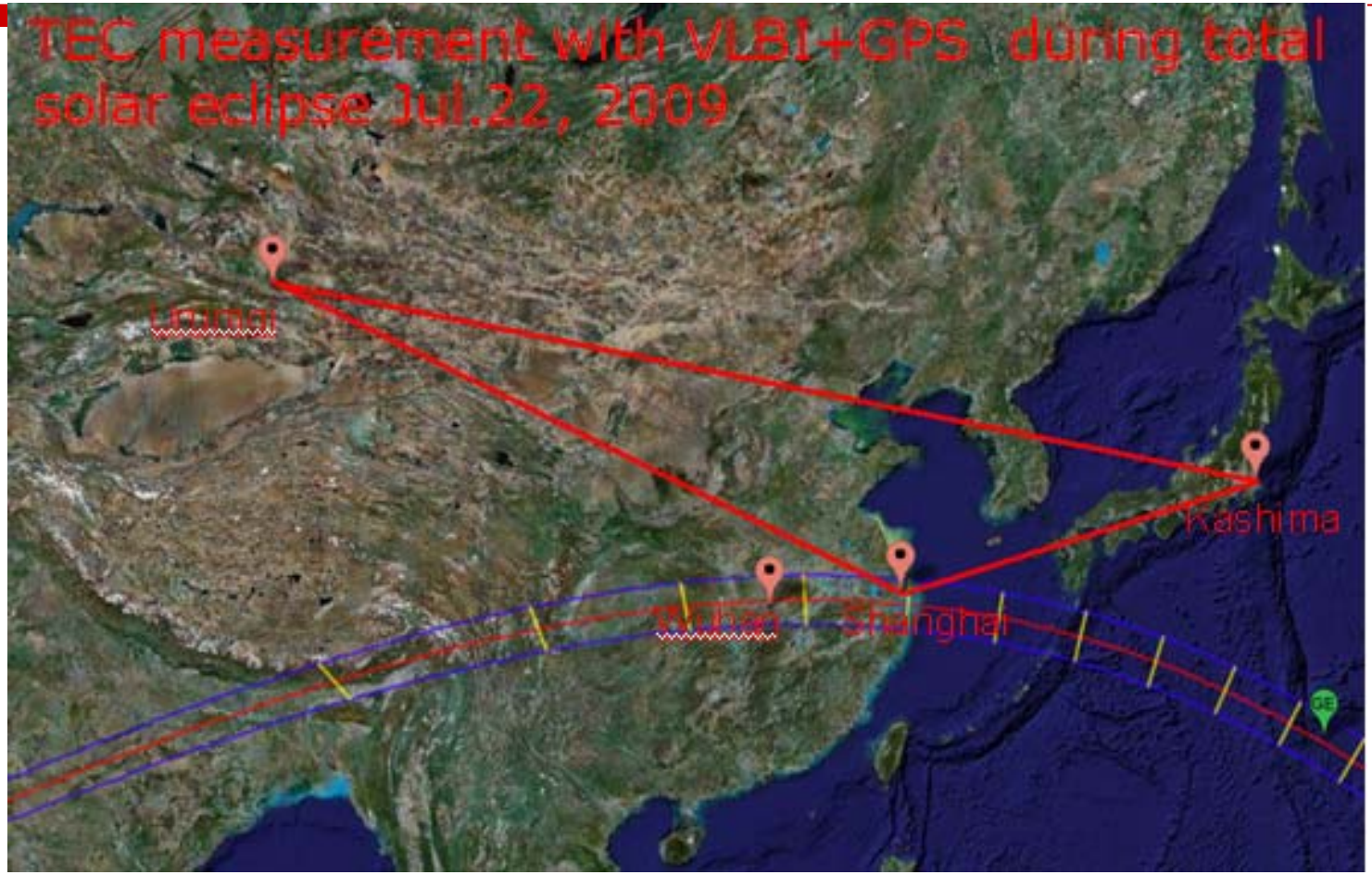
MEX VLBI delay/rate



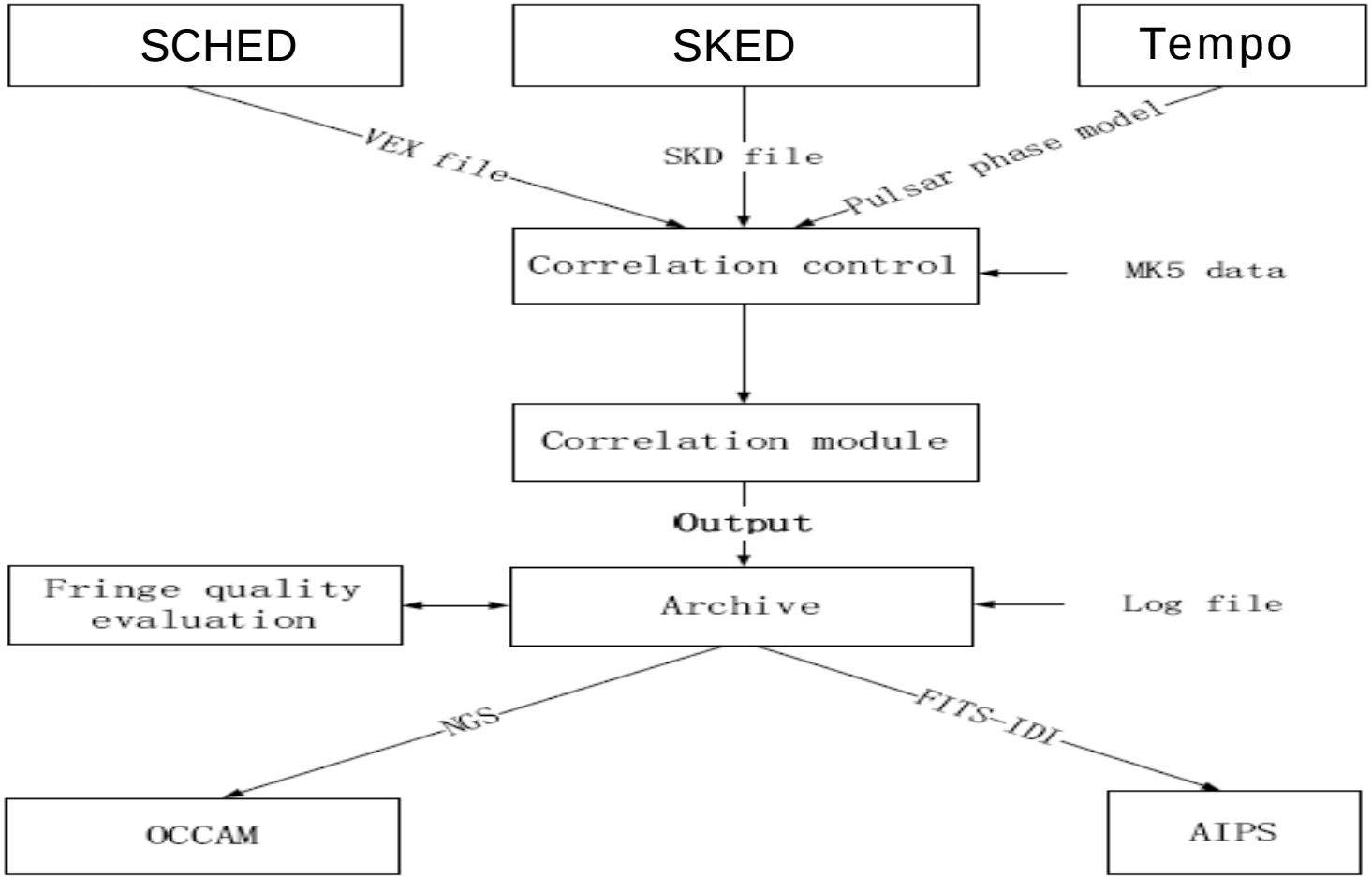
First CVN image



(Dr. Guo Li, under verification)


TEC measurement with VLBI+GPS during total solar eclipse Jul.22, 2009
Lhasa
Kashima
Wuhan
Shanghai

3. Cluster software correlator



- **PC cluster with Two-level parallelisms:**

  - **Intra-node shared-memory programming mode (pthreads)**

  - **Inter-node Message-Passing Programming mode (MPI)**

Prototype Correlator Capabilities

Correlation station number	1~10
IF number	1~16
FFT points/ IF	32 ~8192/IF
Input data format	Mark5A, Mark5B
Sampling	1bit, 2 bit
Output data format	CVN/FITS/NGS
Correlation speed (1024/IF)	>1Gbps/station (2 stations) >512Mbps/station (4 stations)

10-station SMP cluster prototype correlator

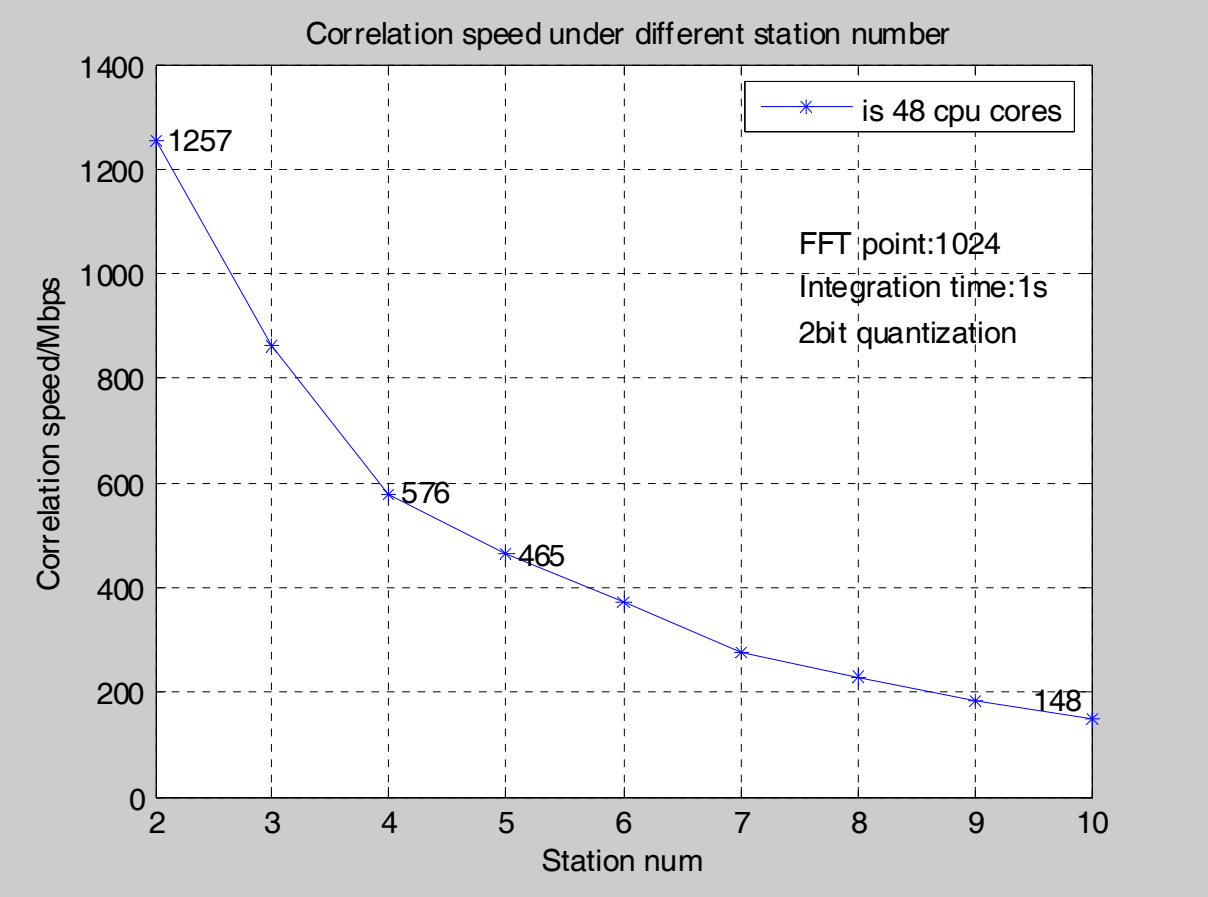
Quad Core E7430 (1Gb NIC)

↓

Dual Core X5570 (10Gb NIC or IB)

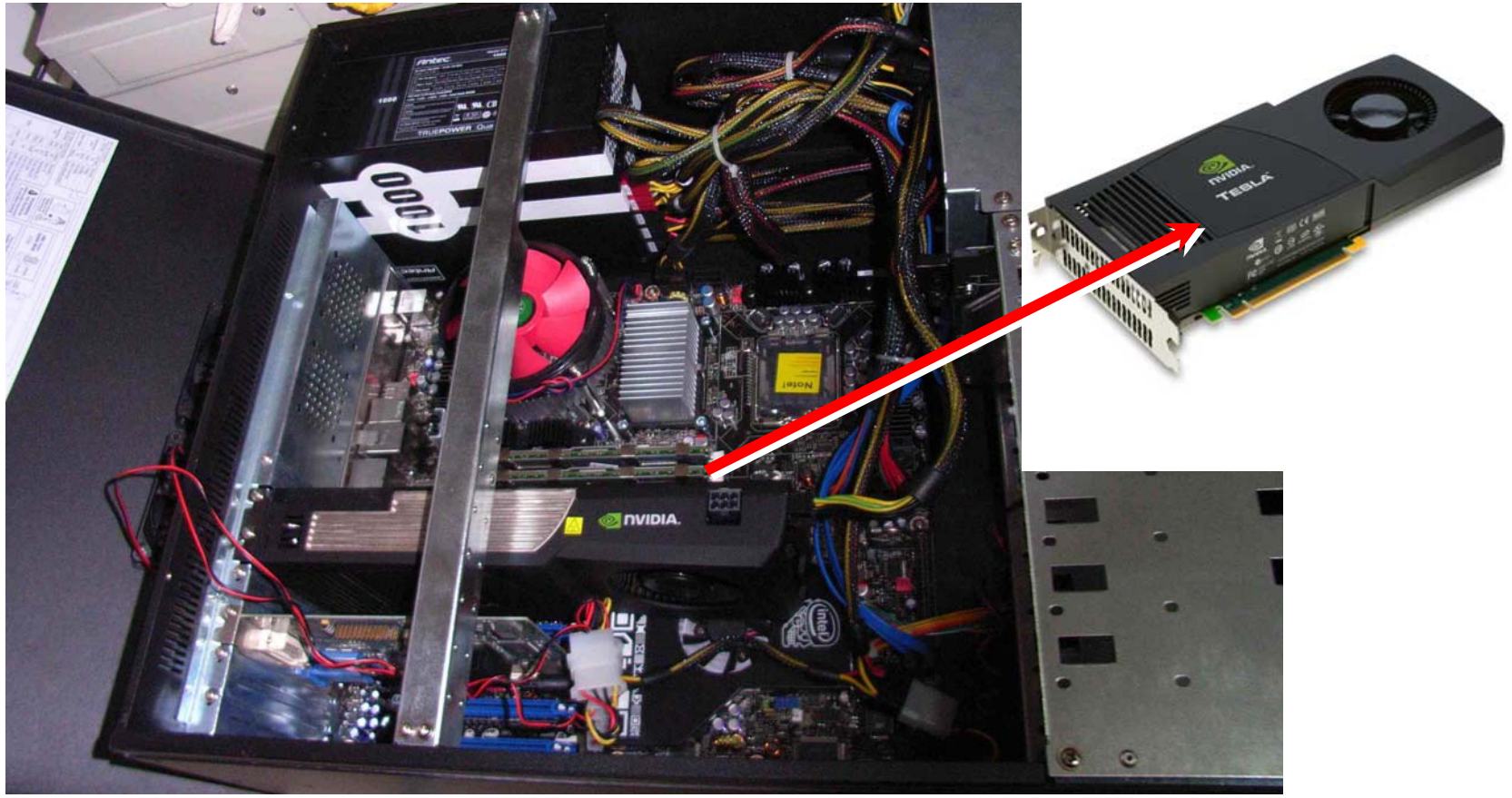
↓

Speed upto 30-40%



Correlator speed vs. station number

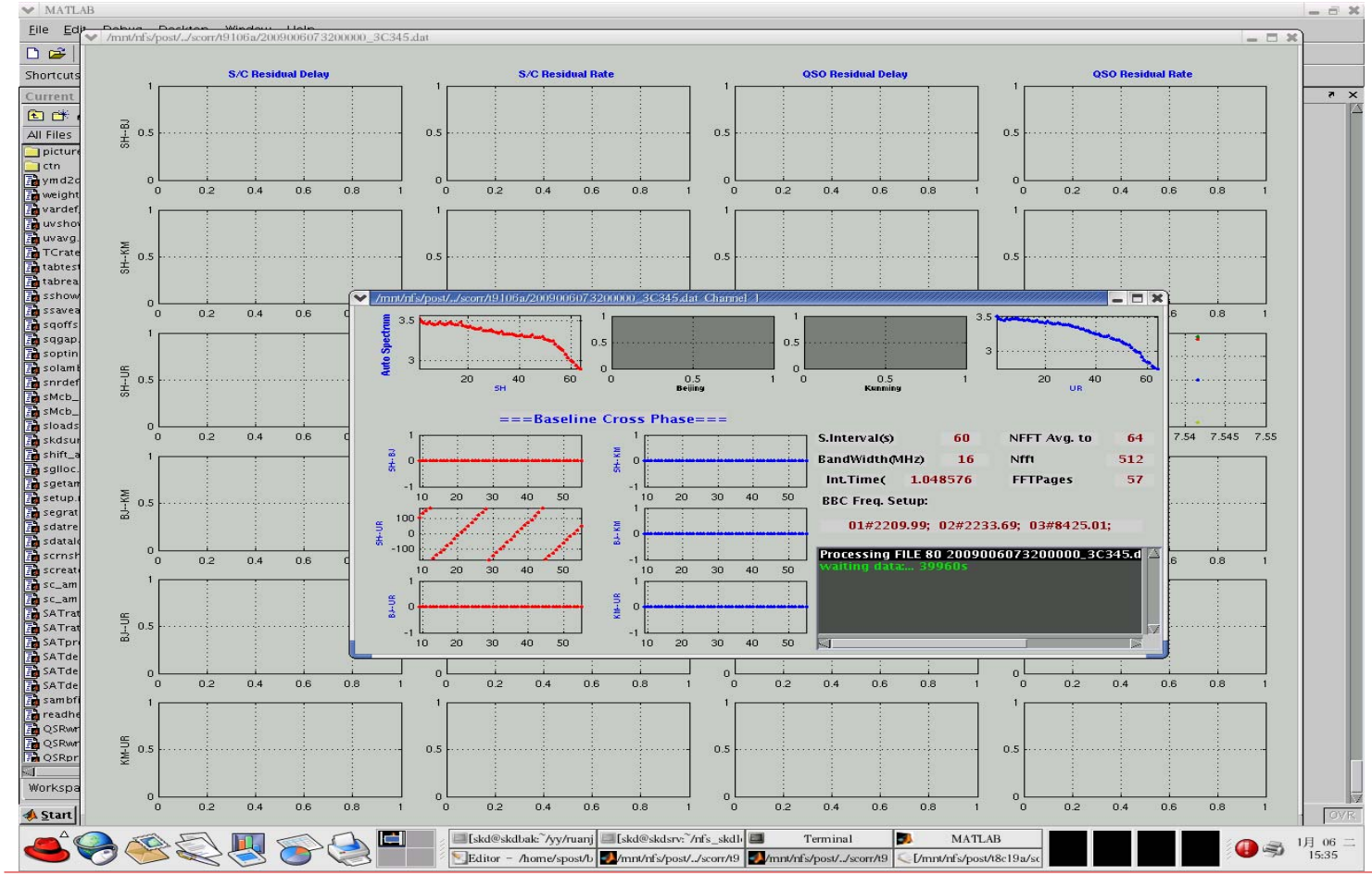
GPU accelerator



中国科学院 CHINESE ACADEMY OF SCIENCES

上海天文台
Shanghai Astronomical Observatory

Sh-Ur baseline e-VLBI experiment



2009-1-6, data rate:256Mbps/station

4. Plan of 2010

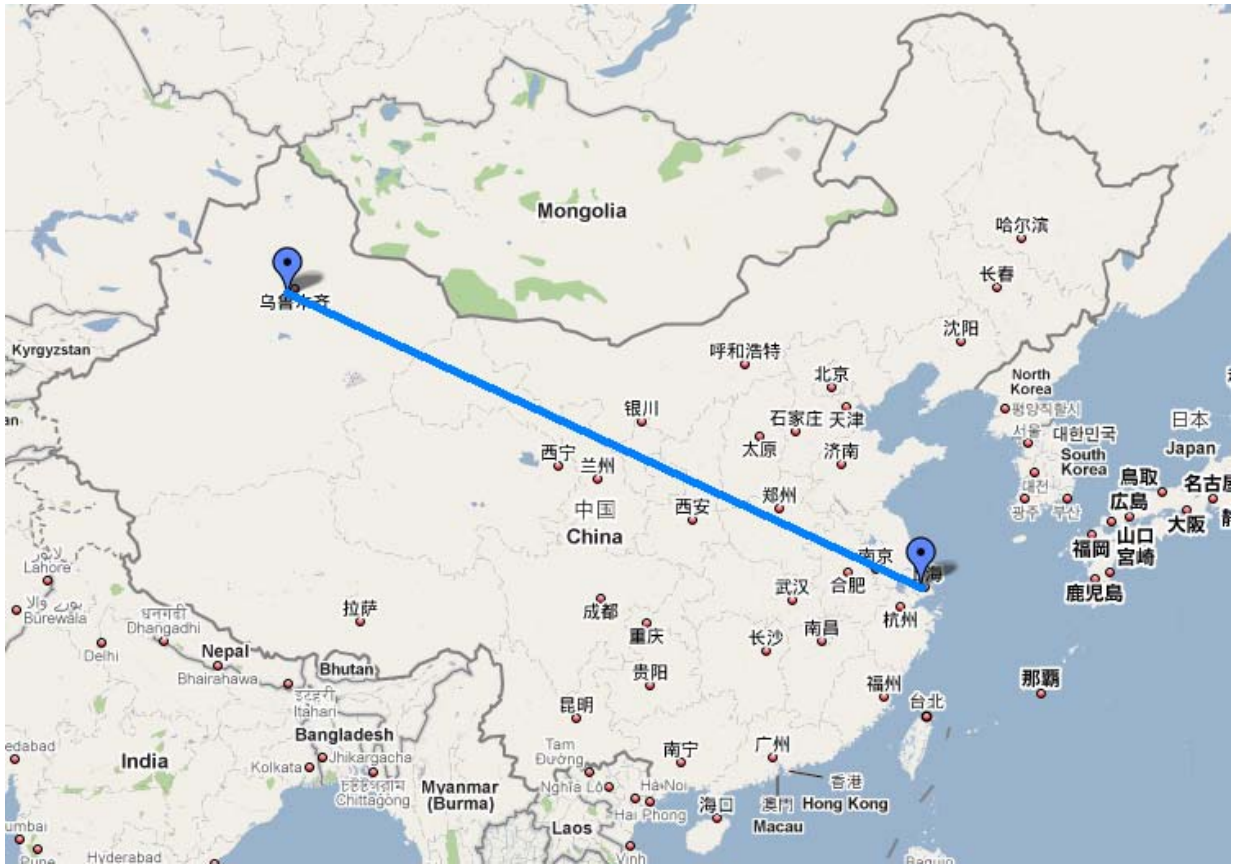
1. Platform: Move to a blade cluster Operation for Project Crustal Movement Observation Network of China

2. Rapid dUT1 measurement

3. Rapid e-VLBI imaging

Blade cluster

Sh-UR baseline for rapid △UT1 measurement



Thanks for your attention