e-VLBI:
Connecting the Global Array of Radio Telescopes through High-Speed Networks

Participating U.S. organizations:

- MIT Haystack Observatory
- MIT Lincoln Laboratory
- NSF
- NASA/GSFC
- Information Sciences Institute
- Internet2
- Mid-Atlantic Crossroads
- Univ. of Maryland
- AMPATH

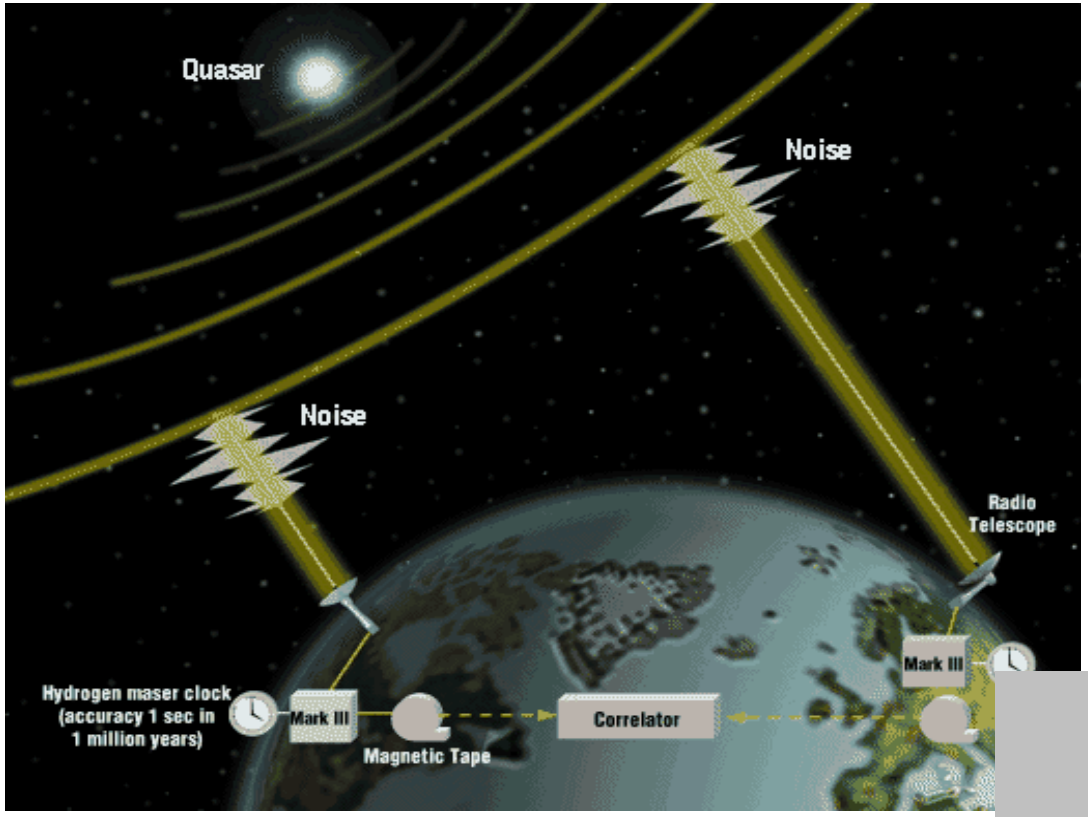
Participating international organizations:

- Joint Institute for VLBI in Europe (JIVE)
- National Institute of Communications and Technology (Japan)
- National Astronomical Observatory (Japan)
- Australia Telescope National Facility
- Bundesamt fur Kartographie und Geodasie (Germany)
- Onsala Space Observatory (Sweden)
- Jodrell Bank Observatory (England)

Alan R. Whitney
MIT Haystack Observatory
for
Chinese-American Networking Symposium
1 Dec 2004

The Very-Long Baseline Interferometry (VLBI) Technique

(with traditional data recording)



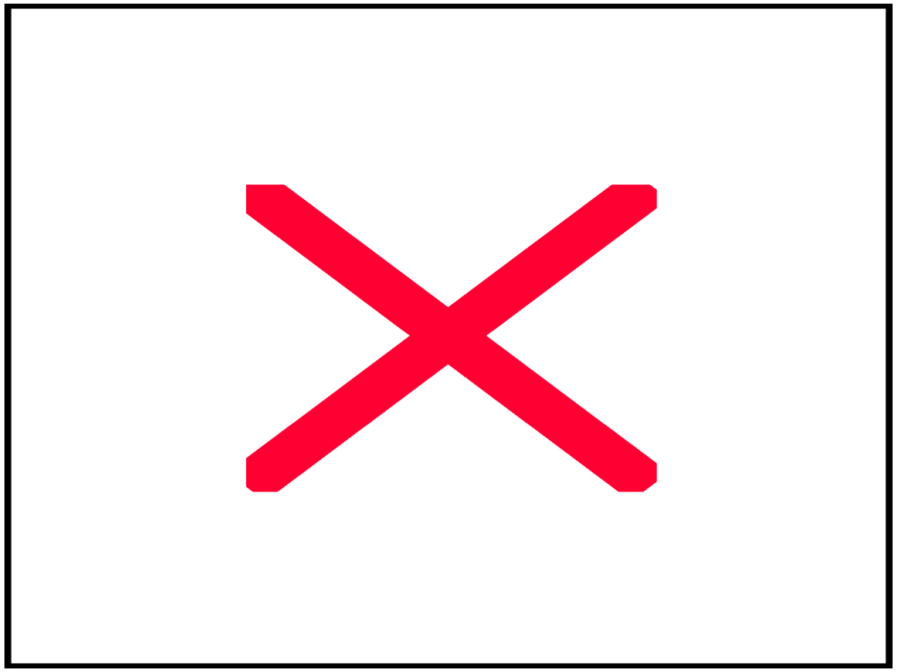
The Global VLBI Array

(up to ~20 stations can be used simultaneously)

VLBI Science

ASTRONOMY

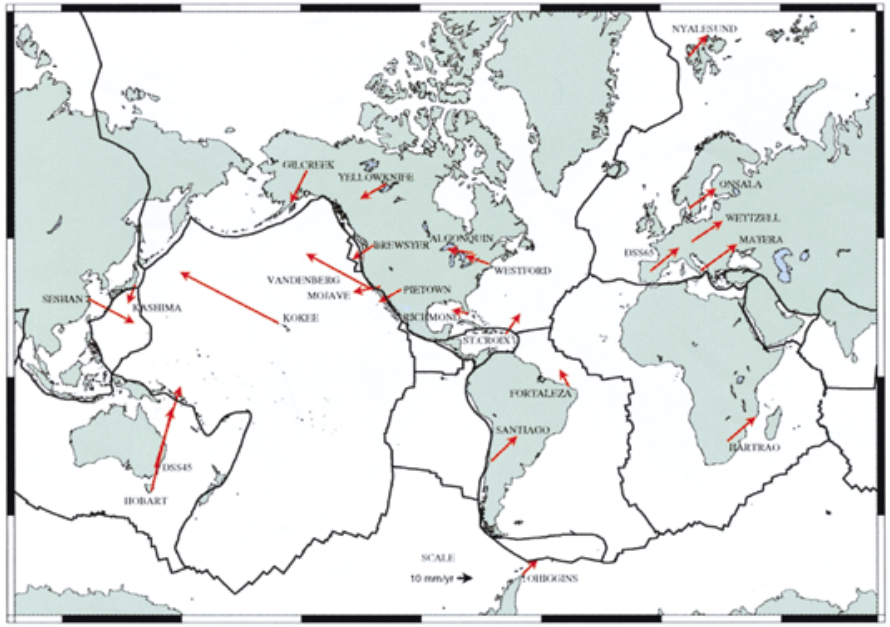
- Highest resolution technique available to astronomers – tens of microarcseconds
- Allows detailed studies of the most distant objects



GEODESY

- Highest precision (few mm) technique available for global tectonic measurements
- Highest spatial and time resolution of Earth's motion in space for the study of Earth's interior
  - •Earth-rotation measurements important for military/civilian navigation
  - •Fundamental calibration for GPS constellation within Celestial Ref Frame

Plate-tectonic motions from VLBI measurements



Some VLBI statistics

- VLBI is inherently an international, global activity
- ~50 radio telescopes worldwide from more than 20 countries participate in global VLBI observations on a regular basis
- ~3 Petabytes of VLBI data are now collected annually, most of which are recorded on magnetic disk or tape and physically transported to one of the few VLBI correlator sites (3 in U.S., 2 in Europe, 2 in Japan, 1 in China); expect this data volume to increase rapidly in coming years.
- Disks/tapes are erased and re-cycled to telescopes after correlation processing
- e-VLBI has been developing rapidly in past 2-3 years, with increasing amounts of data transferred electronically; estimate ~50 TB transferred in 2004; project ~300 TB e-VLBI transfer in 2005

Advantages of e-VLBI

- Bandwidth growth potential for higher sensitivity
  - VLBI sensitivity (SNR) proportional to square root of Bandwidth resulting in a large increase in number of observable objects
    (only alternative is bigger antennas – hugely expensive)
  - e-VLBI bandwidth potential growth far exceeds recording capability
    (practical recordable data rate limited to a few Gbps)
- Rapid processing turnaround
  - Astronomy
    - Ability to study transient phenomena with feedback to steer observations
  - Geodesy
    - Higher-precision measurements for geophysical investigations
    - Better Earth-orientation predictions, particularly UT1, important for military and civilian navigation
- Other benefits
  - Elimination of expensive disk/tape media and shipping costs
  - Increased reliability
  - Full station automation

e-VLBI status

- e-VLBI activity is expanding rapidly, particularly in U.S., Europe, Japan and Australia.
- Japan has been leader in e-VLBI, developing dedicated Japanese e-VLBI networks since late 1990s.
- Real-time e-VLBI over public networks has been demonstrated at 512 Mbps at MIT Haystack Observatory; expect 1024 Mbps soon
- All international e-VLBI data are transported over public high-speed R&E networks hosted by various countries and international organizations
- U.S., Europe, Japan, Australia are now connected via R&E links of at least 10 Gbps.
- International standardization of e-VLBI data formats and data-transport protocol is nearly complete
- Biggest problem for e-VLBI is ‘last mile’ high-speed connection to telescopes, though increasing number are being connected.

Current antenna connections to global network

(outside of China)

Westford Observatory	Massachusetts, USA	10 Gbps	
JIVE	Netherlands	6 Gbps	
Haystack Observatory	Massachusetts, USA	2.5 Gbps	
NASA/GSFC GGAO	Maryland, USA	2 Gbps	
Westerbork array	Netherlands	1 Gbps	
Torun	Poland	1 Gbps	Plan 2 Gbps
Jodrell Bank	UK	1 Gbps	Plan 2.5Gbps soon
Onsala	Sweden	1 Gbps	
Medicina	Italy	1 Gbps	
Kashima	Japan	1 Gbps	
Tsukuba	Japan	622 Mbps	
Arecibo	Puerto Rico	155 Mbps	
Wettzell	Germany	30 Mbps	
Kokee	Hawaii	25 Mbps	

VLBI Stations in China

Seshan (Shanghai)

Nanshan (Urumqi) at sunrise

VLBI and China

- China plays a crucial role in global VLBI observations.
- Geographic placement of antennas in China is vitally important for astronomy and geodesy VLBI observations.
- Urumqi (25m diam) and Shanghai (25m diam) stations are both members of European VLBI Network (http://www.evlbi.org) for astronomy observations
- Urumqi and Shanghai stations are both members of International VLBI Service for high-precision geodetic and earth-orientation measurements (http://ivscc.gsfc.nasa.gov)
- Two new major VLBI stations, near Beijing (50m diam) and Kunming (40m diam), will come on-line in 2007.
- As China develops its high-speed network infrastructure, e-VLBI should be considered as an important component.

Impact of international e-VLBI Program

- Opens new doors for astronomical and geophysical research.
- Represents an excellent match between modern Information Technology and a real science need.
- Motivates the development of a new shared-network protocol that will benefit other similar applications.
- Drives an innovative IT research application and fosters a strong international science collaboration.

Thank you!

- e-VLBI contacts in China
  - Prof. Xiaoyu HONG, the head of the VLBI group in China; also the head of Seshan (Shanghai) VLBI station.
  - Prof. Jin ZHANG, the head of Nanshan (Urumqi) VLBI station (zhangj@ms.xjb.ac.cn)
  - Prof Xiuzhong ZHANG, the head of VLBI laboratory (xzhang@shao.ac.cn)