

Joint CN-NL VLBI science: *present and future*



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Heritage



- **VLBI collaboration VLBI since mid 1980s**
 - dozens of Chinese long-term guests at NFRA/JIVE/ASTRON
 - a number of PhD projects – both Chinese and Dutch
 - 1994-1997: JIVE/EVN Quality Assurance Programme (QASP) for new telescopes
 - *Sheshan (Shanghai) 25 m*
 - *Nanshan (Urumqi) 25 m*
 - *Full members of EVN since*
 - NAOC a member of JIVE Foundation since 2005
 - *JIV-ERIC participating organisation since 2015*
- **From training-driven to science-driven projects**
 - *Earth-based astrophysics (“traditional” VLBI)*
 - *Space VLBI, from mm to ULW, incl. VSOP and RadioAstron*
 - *Planetary science (near-field VLBI) applications*





Outlook of collaborative VLBI science

- **Objectives:**

- enhance sci output via collaboration of established groups
- achieve cutting-edge results in areas of specific expertise
 - *transients*
 - *AGN, individual and surveys*
 - *FRB*
- enhance training (MSc, PhD) component (*in both countries*)
- exploit in full new instrumental possibilities
 - *especially FAST*
 - *also Kunming, Miyun and other new radio telescopes*
 - *advanced correlators (SFXC, UniBoard, etc.)*
- Pioneering science with ULWA aboard Chang'E-4
 - *interferometric issues in particular*

VLBI Surveys



- **Multi-disciplinary applications**

- Evolution of AGN (mJy-level sources, $\sim 10^3$ targets)
 - *synergy with surveys in other domains, e.g. SDSS and LSST*
 - *preparation for SKA*
- Cosmological analysis
- Exploitation of existing and new VLBI surveys data
 - *Including Space VLBI (VSOP – complete, RadioAstron – on-going)*
- Input for near-VLBI tracking experiments with planetary probes
 - *Synergy with long-term projects of studying outer planets*
 - Mars and its satellites
 - Jovian system

RadioAstron AGN Survey



- The goal: to measure and study brightness temperature of AGN cores in order to better understand physics of their emission while taking interstellar scattering into consideration
- 270 brightest AGN from Earth-based surveys
 - $S_{\text{corr}} > 600$ mJy at the longest Earth-based baselines (8 GHz)
 - Plus several targets of special interest (IDV and high- z sources)
 - Plus 20 highest kinematics AGN from 15 GHz MOJAVE (Lister+ 2003)
- Status as of April 2017:
 - 1100 segments (experiments) processed;
 - 360 detections on **90 sources**
 - A series of papers in preparation
- Detection records:

▫ 18 cm:	0048–097	27 D_{Earth}
▫ 6 cm:	0716+714	23 D_{Earth}
▫ 1.35 cm:	OJ287	15.5 D_{Earth} (fringe spacing $\sim 14 \mu\text{as}$)

Cosmic conspiracy: *Earth, a very special place*



Brightness temperature of a slightly resolved source:

$$T_b = \frac{2 \ln 2 S_{\text{core}} \lambda^2 (1+z)}{\pi k \theta_{\text{maj}} \theta_{\text{min}}}$$

$\sim B^2$

For a “typical” AGN:

$$z \sim 1$$

$$S_{\text{core}} \sim 500 \text{ mJy}$$

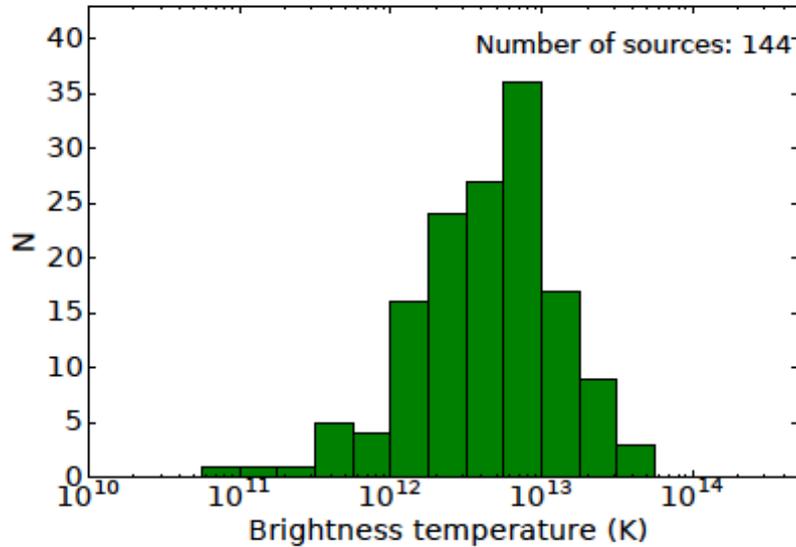
$$T_b \sim 10^{12} \text{ K (Inverse Compton limit, Kellermann & Pauliny-Toth 1969)}$$

$$B \sim 10^4 \text{ km}$$

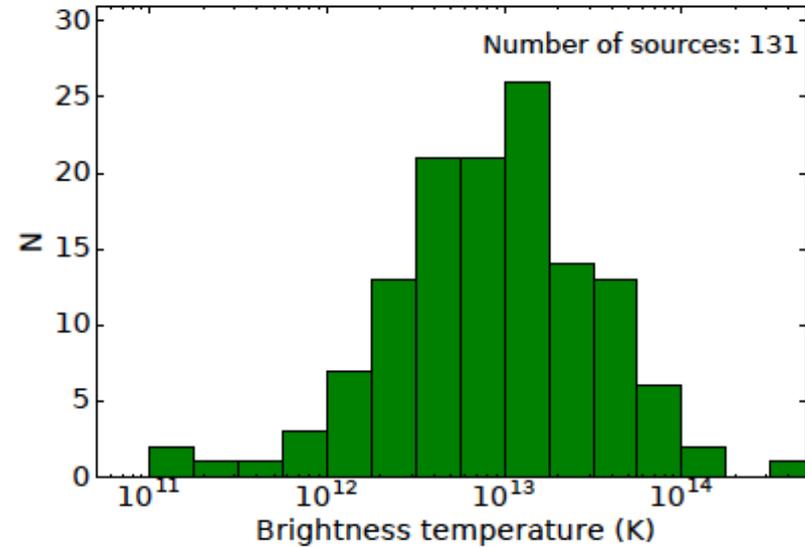
The data are available, crying for attention!

RadioAstron AGN Survey: results *(April 2017)*

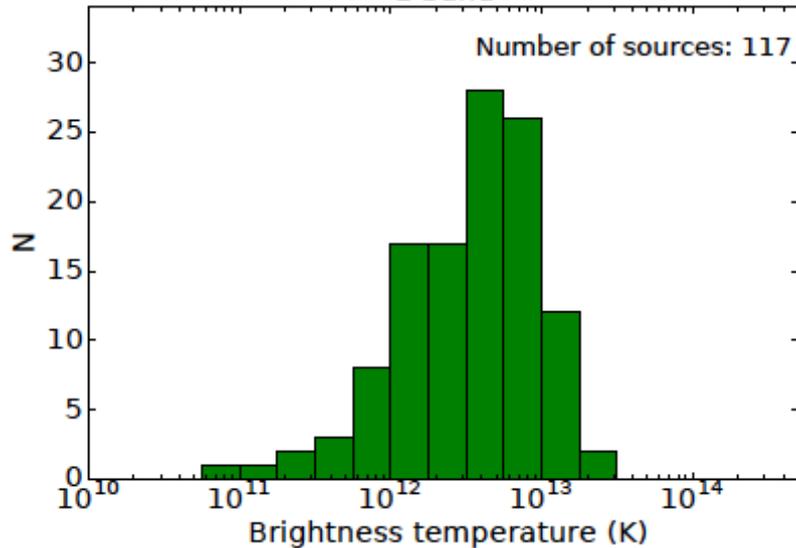
Lower limits:
C-band *(Lobanov 2015)*



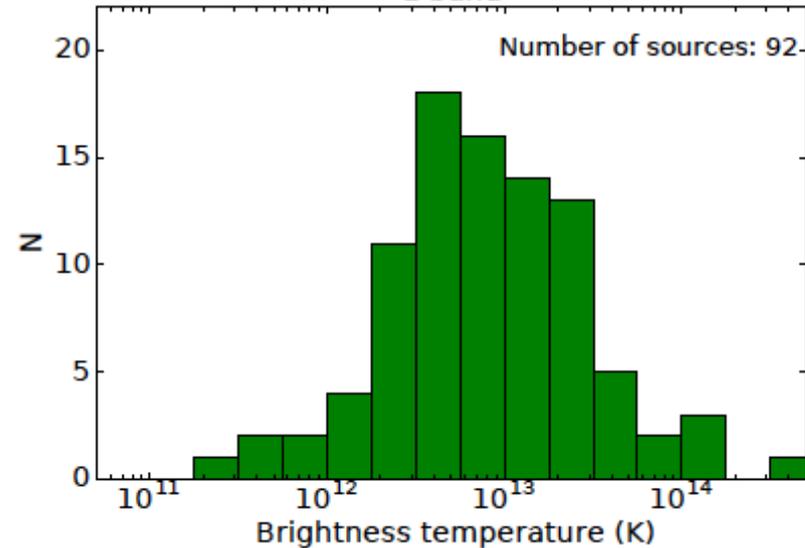
Gaussian fit estimate:
C-band



L-band



L-band

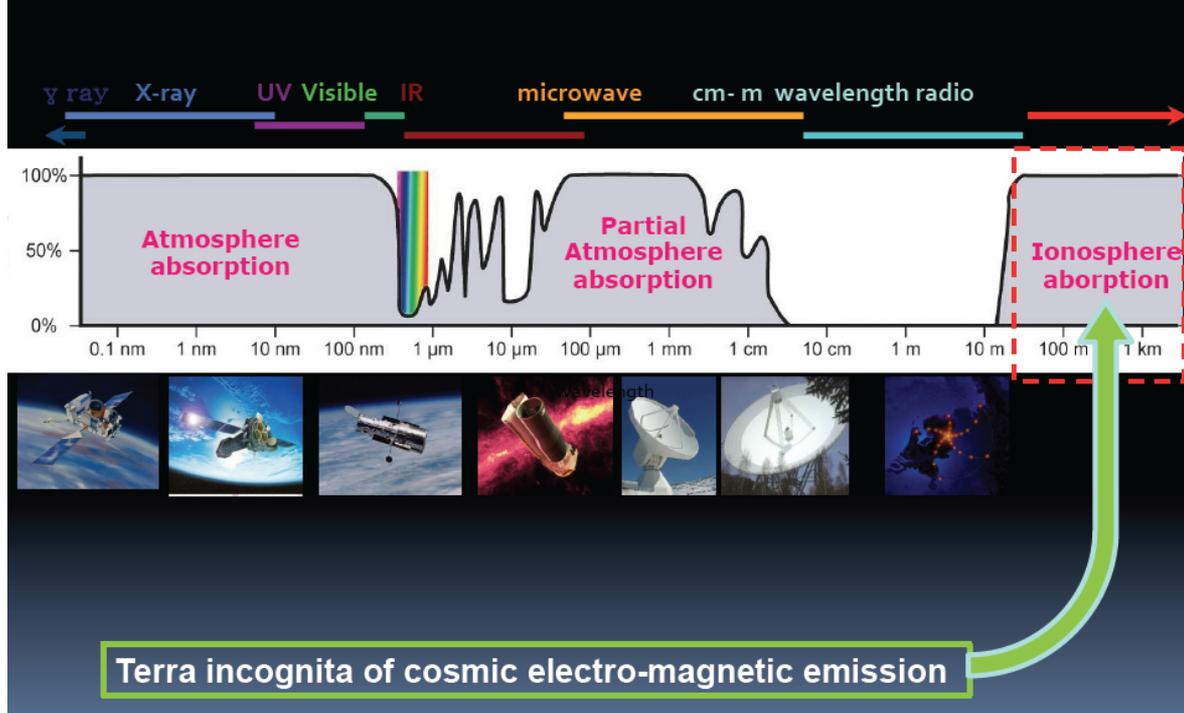


ULWA interferometry in space



- **Major on-going collaborative activity**
 - NCLE (in the framework of Chang'E-4) and DSL
 - *calibration and fringe-search at ULW regime (VLBI “know-how”)*

Why ULWA (radio!) in Space?

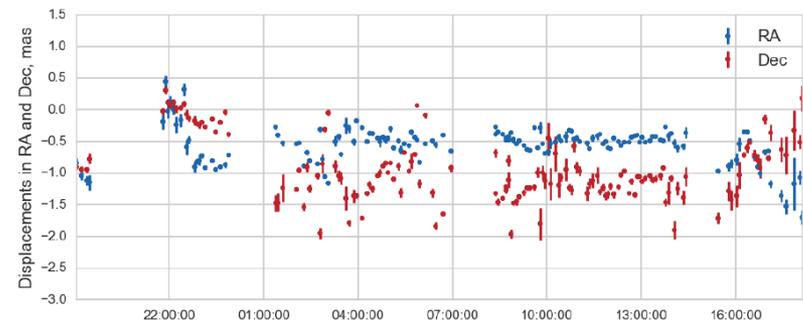
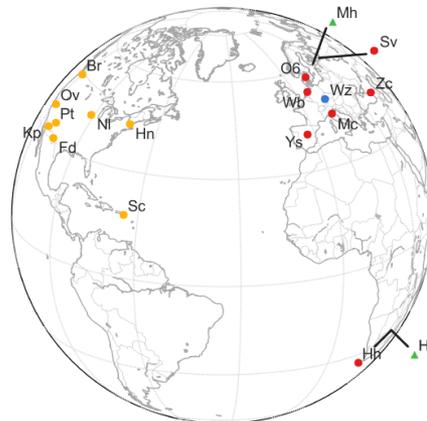
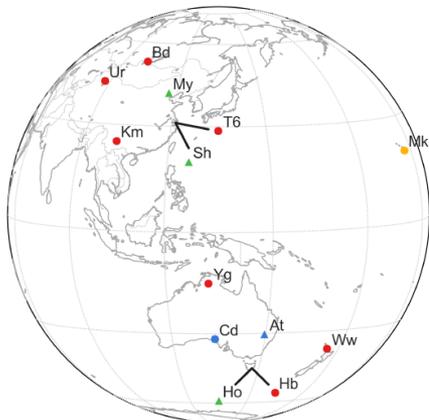


Near-field VLBI



- **Technique developed at JIVE and ShAO**
 - successfully demonstrated for Huygens (2005) and Chang'E-1(2007)
 - recognised as an efficient multi-disciplinary tool for
 - *Chang'E programme*
 - *ESA's JUICE (Jupiter Icy Satellites Explorer): PRIDE (Planetary Radio Interferometry and Doppler Experiment)*
 - *on-going observations of MarsExpress and upcoming ExoMars*

MEX/Phobos flyby, GR035



Displacement between measured and predicted MEX celestial position

Formal precision (3σ):

RA	34 μ as	35 m
Dec	58 μ as	60 m

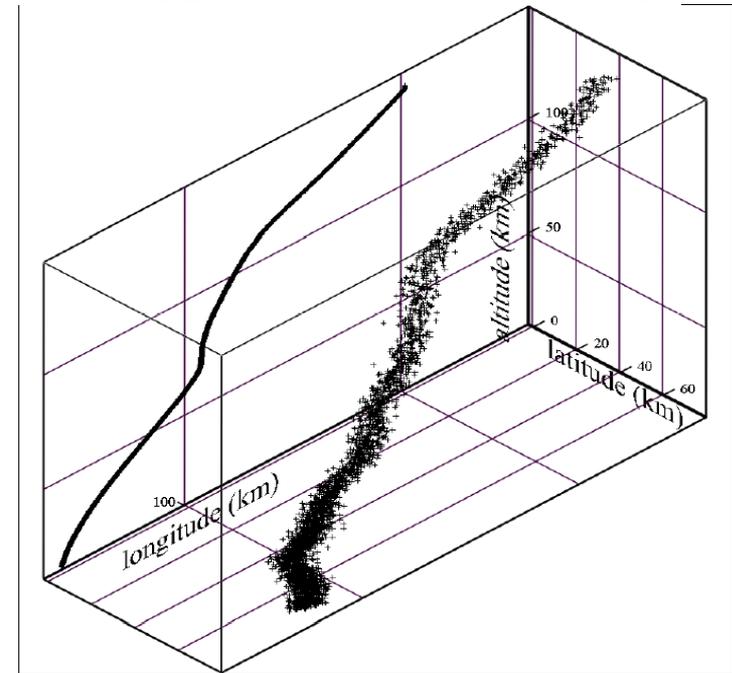
Huygens VLBI heritage: 20 photons/dish/s



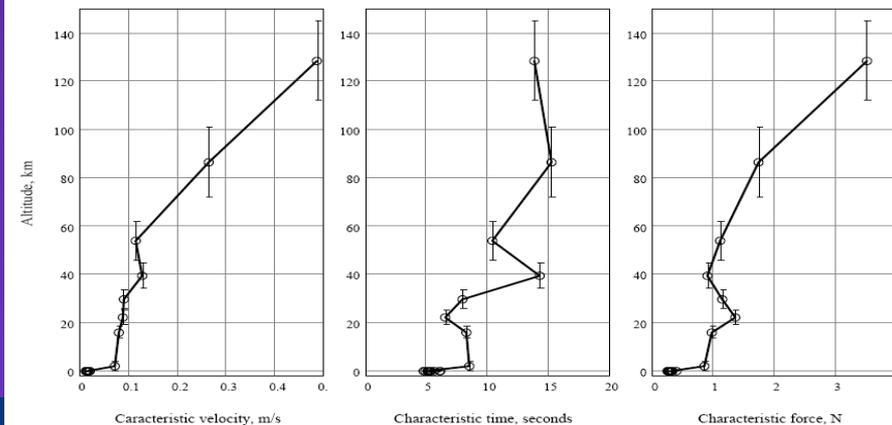
Titan, 14 January 2005

- Ad hoc use of the Huygens “uplink” carrier signal at 2040 MHz
- Utilised 17 Earth-based radio telescopes
- Non-optimal parameters of the experiment (not planned originally)
- Achieved 1 km accuracy of Probe’s descent trajectory determination
- Assisted in achieving one of main science goals of the mission – vertical wind profile

3D Huygens descent trajectory



Titan atmosphere turbulence signature



Generic PRIDE configuration

PRIDE: a multidisciplinary enhancement of the mission science return with minimum on-board instrumentation

We are here

**Planetary
Radio
Interferometry &
Doppler
Experiment**

$$R_{nf} \propto \frac{B^2}{\lambda}$$



Potential milestones (*next ~5 years*)



Achieve state-of-the-art level in joint VLBI studies

- ultra-sensitive VLBI studies with the largest dishes
 - *and enhanced data-handling techniques (flexbuf, UniBoard correlator)*
 - *with new telescopes in China (FAST, others?)*
 - *VLBI astrometry of transients and FRB*
 - *synergy with near-field VLBI (*
- science “mining” in new advanced VLBI survey’s
 - *...and revisits in the available older VLBI surveys’ data, incl. Space VLBI*
- pioneering “VLBI” studies in the new spectral domain of ULW
 - *opportunity for transitional science with Chang’E-4/NCLE/DSL*
- “Frontier” VLBI science
 - *Transients*
 - *FRB*