

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



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**and**

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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	$27 D_{\text{Earth}}$
▫ 6 cm:	0716+714	$23 D_{\text{Earth}}$
▫ 1.35 cm:	OJ287	$15.5 D_{\text{Earth}}$ (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:

$$z \sim 1$$

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

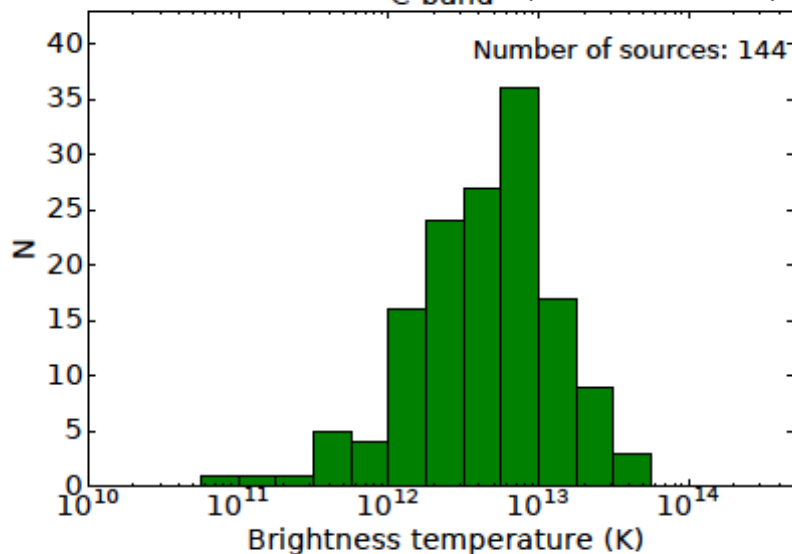
$$T_b \sim 10^{12} \text{ K (Inverse Compton limit, Kellermann & Pauliny-Toth 1969)}$$

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

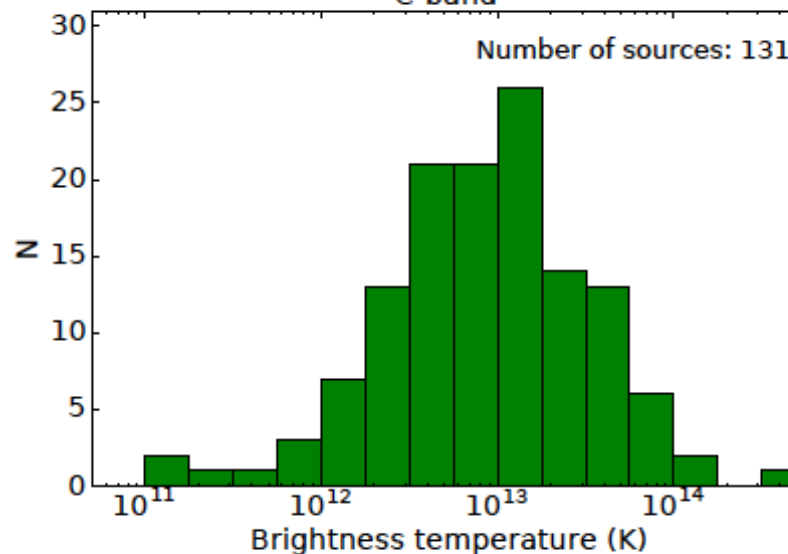
*The data are available, crying for attention!*

# RadioAstron AGN Survey: results *(April 2017)*

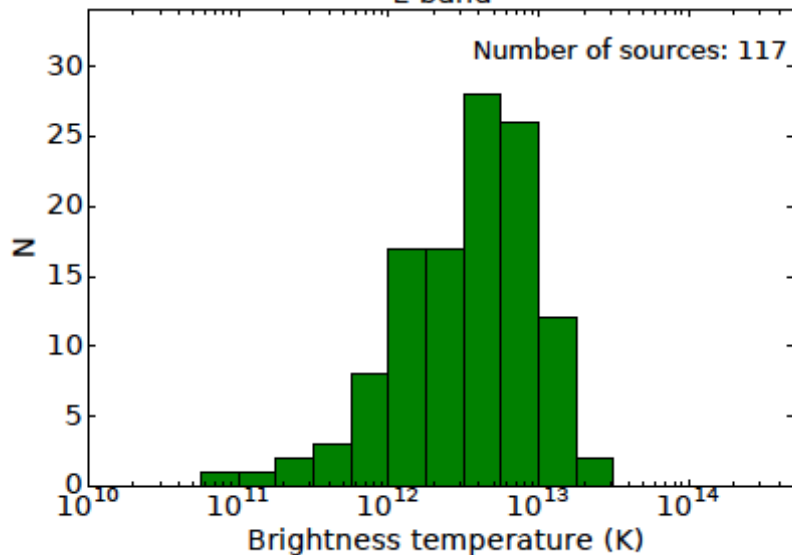
Lower limits:  
C-band *(Lobanov 2015)*



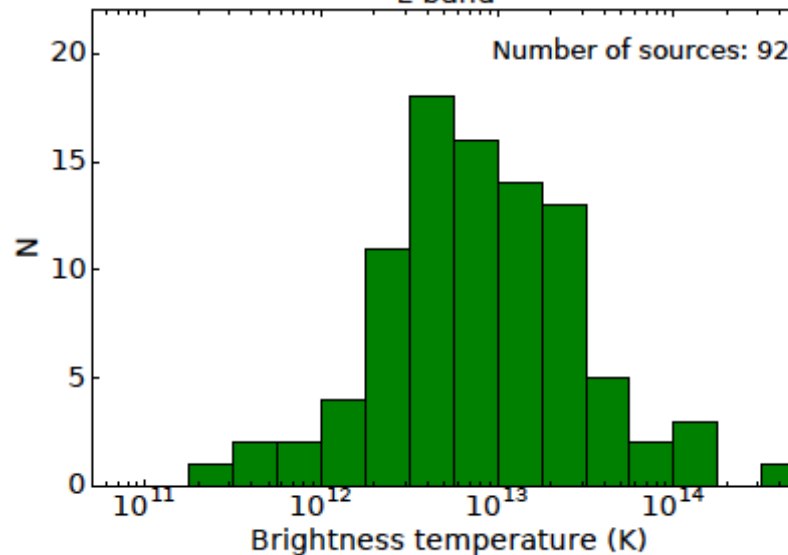
Gaussian fit estimate:  
C-band



L-band



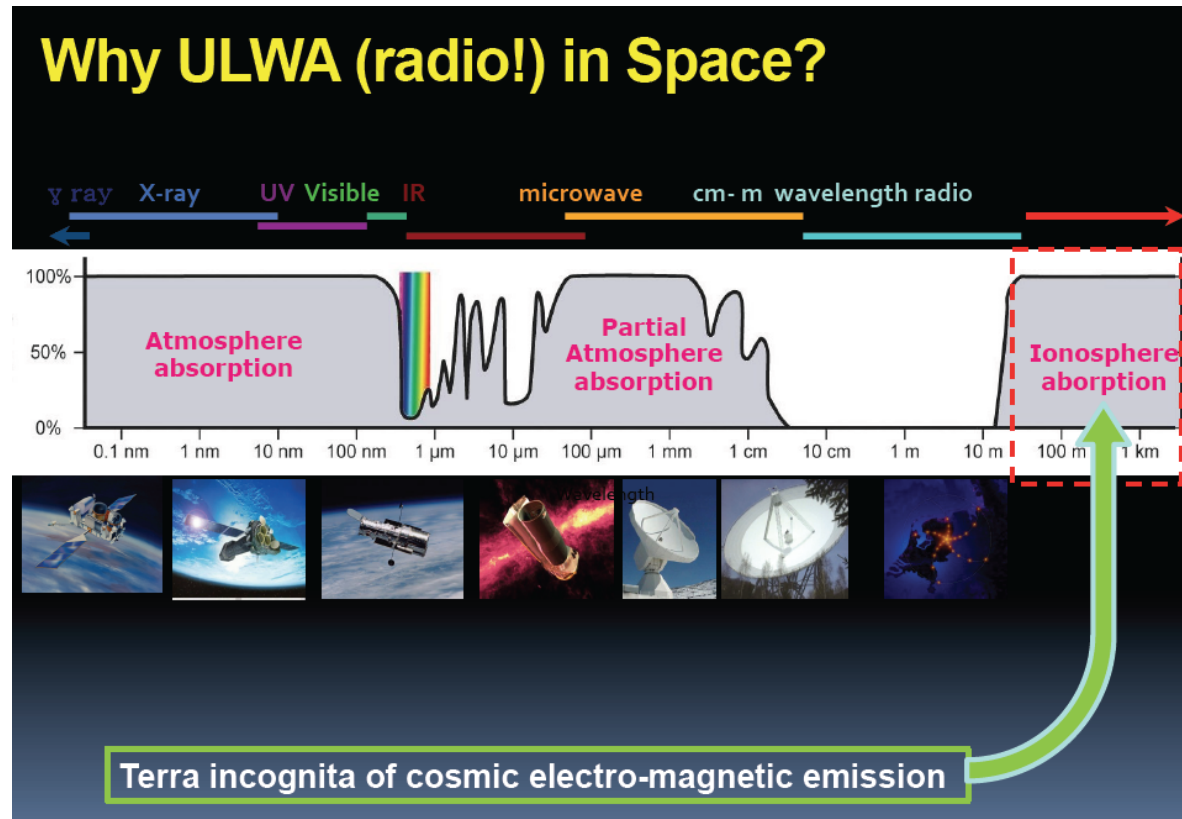
L-band



# 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”)*

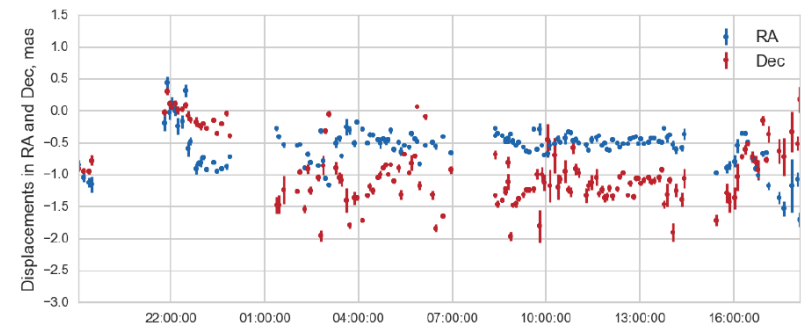
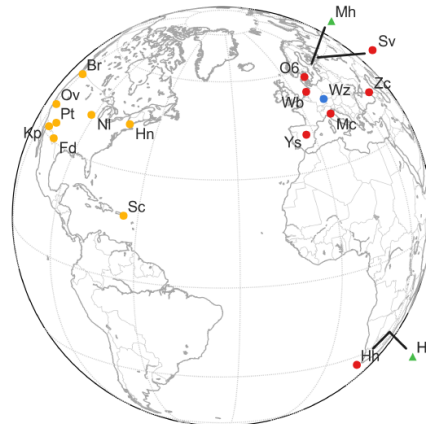
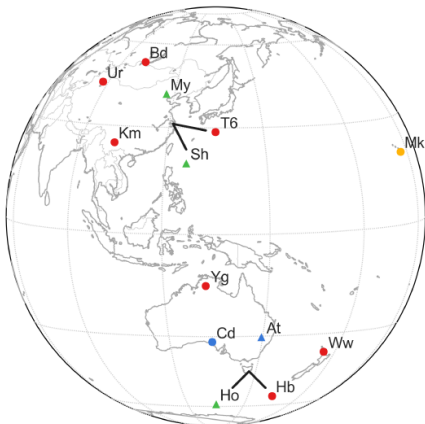


# Near-field VLBI



- **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 ( $3\sigma$ ):

RA	34 $\mu$ as	35 m
Dec	58 $\mu$ as	60 m

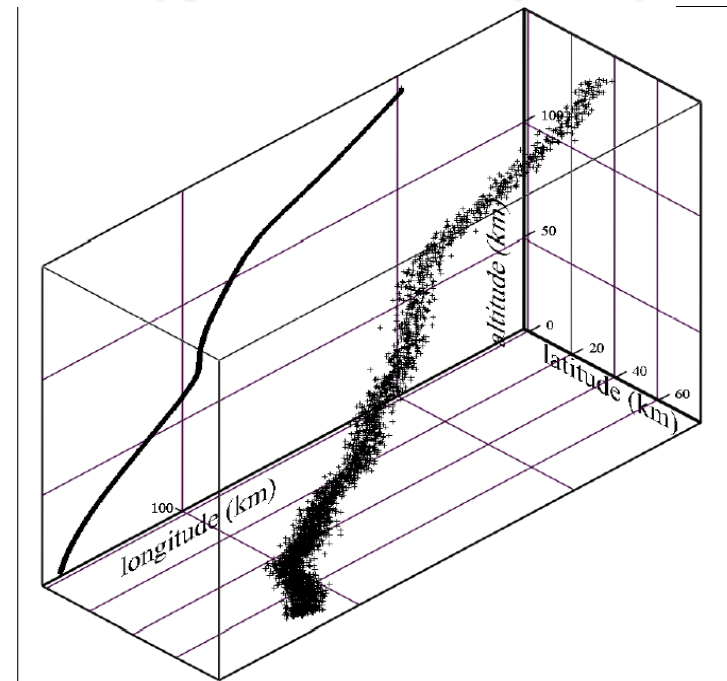


# Huygens VLBI heritage: 20 photons/dish/s

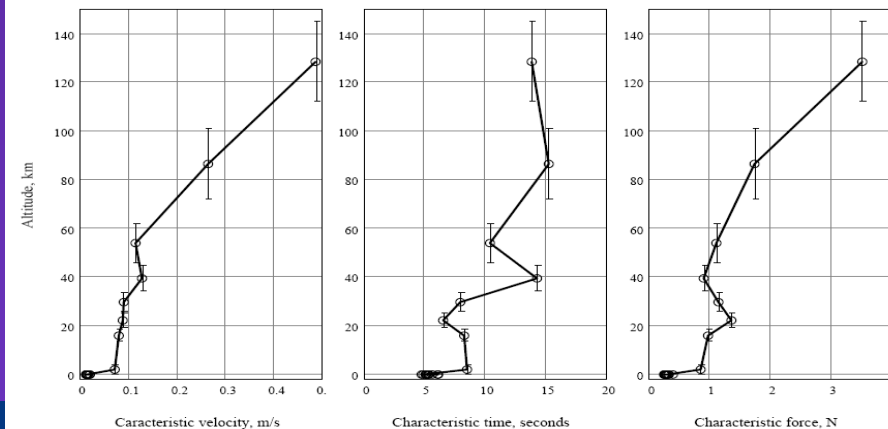


- Ad hoc use of the Huygens “uplink” carrier signal at 2040 MHz
- Utilised 17 Earth-based radio telescopes
- Non-optimal parameters of the experiment (not planned originally)
- Achieved 1 km accuracy of Probe’s descent trajectory determination
- Assisted in achieving one of main science goals of the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