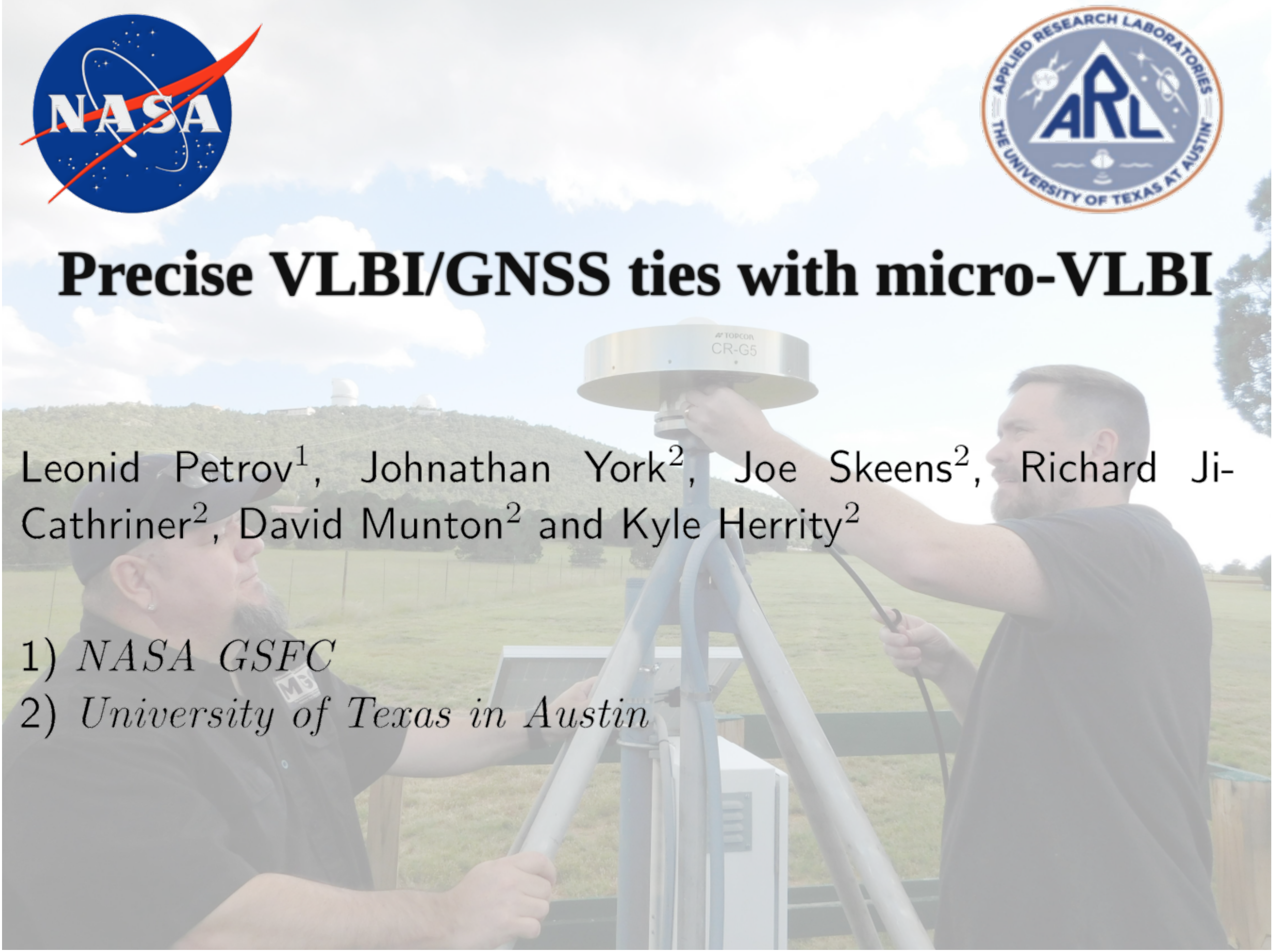

Precise VLBI/GNSS ties with micro-VLBI

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Why ties are important?

Each techniques has its strengths and weaknesses.

- Temporal resolution (GNSS)
- Spatial coverage (DORIS)
- Reference to the inertial space (VLBI)
- Reference to the center of mass (SLR)

Tying GPS,DORIS,VLBI,SLR, we create a virtual “super-site”

In order to exploit all benefits, ties should be

- **accurate**
- **reliable**

Benefits of precise VLBI/GNSS ties

- VLBI+GPS super-site positions are anchored to the same origin

- VLBI+GPS super-site orientation is anchored to the inertial space

- Combined processing VLBI+GPS will determine UT1 and the residual rotation of the of GNSS satellite nodes.
  As a result, GNSS will be able densify UT1 time series.

Ties between techniques: why it so difficult?

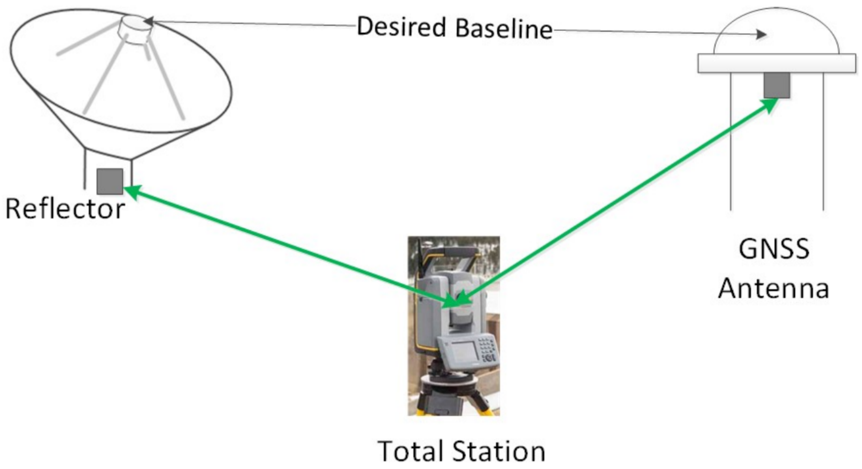
- Technique "A" does not see objects of technique "B"
- Reference points of techniques "A" and "B" are virtual
- Reference points account for systematic errors
- Intermediate objects are introduced with known(?) offsets
- Ties are measured vector between intermediate objects with technique "C"
- Technique "C" may have excellent repeatability, but unknown biases

Can we overcome these difficulties?

We need new ideas . . .

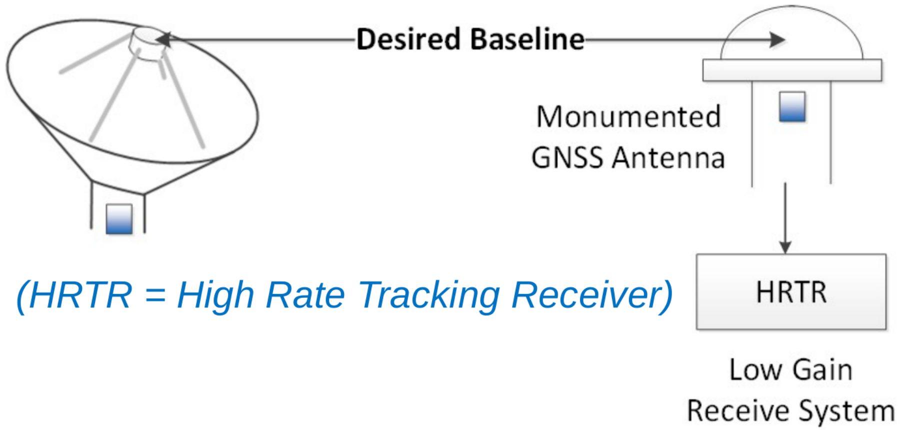
Measurement concept

Conventional Approach



Optical Tie Vector Measurement

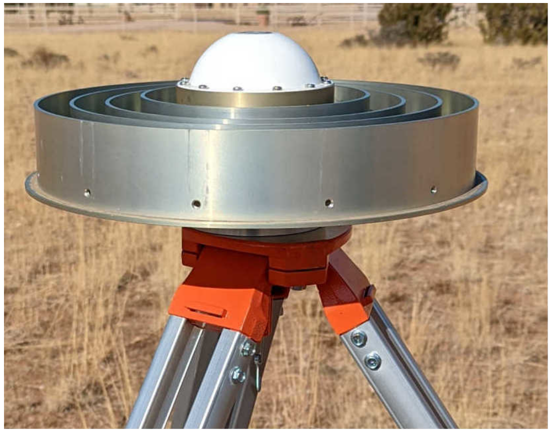
Proposed Approach



VLBI Tie Vector Measurement

Determine the baseline between electrical phase centers directly

Receiver modification



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1. remove a filter
2. attach a coaxial cable to get amplified RF signal
3. digitize a RF signal within 1.0–2.0 GHz band
4. record a stream of samples

GNSS antenna element remains unchanged

Signal processing

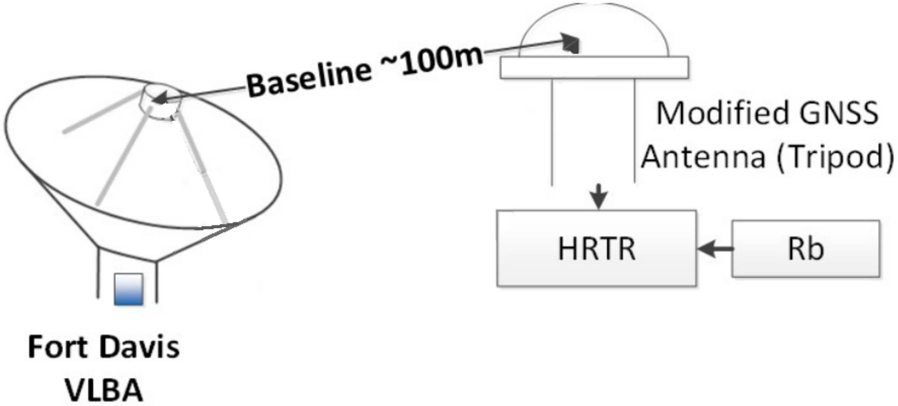
1. **Computation of pseudorange**

   - Downconversion and filtering
   - Replica generation
   - Integration

2. **Computation of phase and group delays**

   - Polyphase resampling to 64 MHz
   - Conversion to VDIF format (VLBI standard)
   - Correlation with DiFX
   - Fringe fitting with PIMA
   - Computation of theoretical path delay with VTD
   - Parameter estimation with pSolve

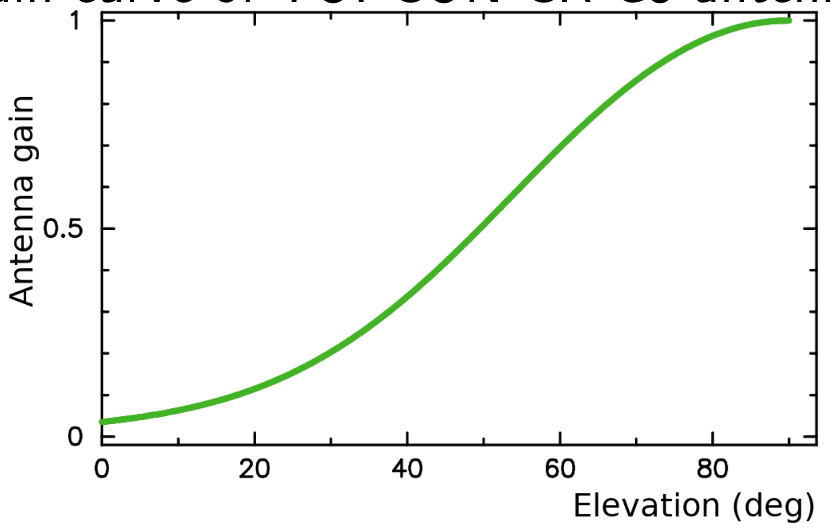
Scheme of a VLBI experiment at FD-VLBA/GNSS



FD-VLBA/GNSS interferometer

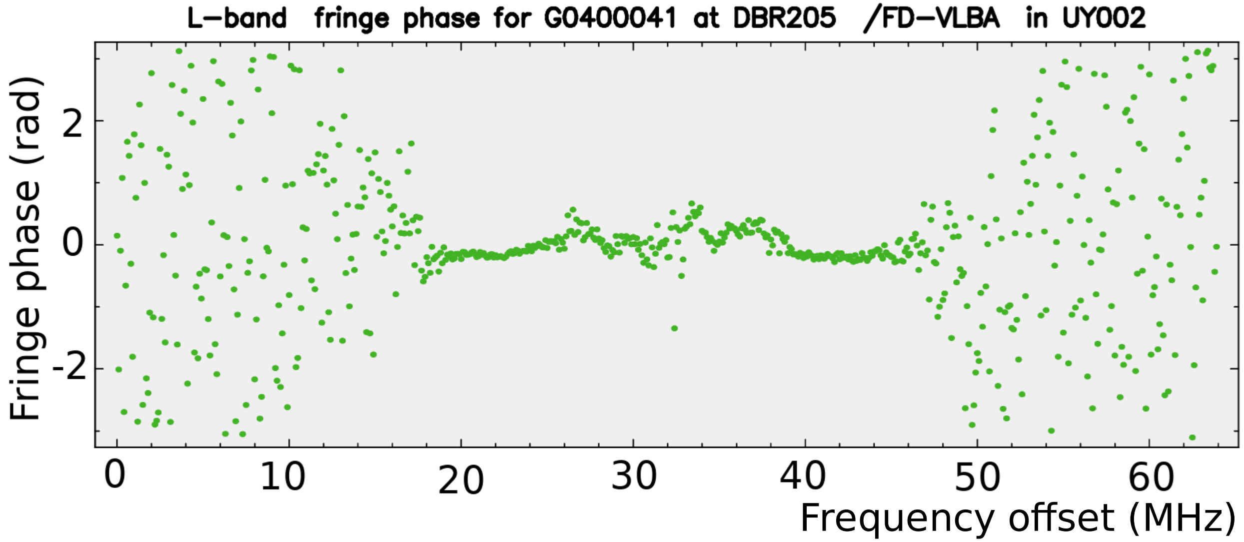
	FD-VLBA	GNSS
Diameter:	25 m	0.38 m
Zenith sensitivity	300 Jy	2 MJy
Clock	H-maser	Rubidium
Recorded bandwidth	2x128 MHz	8x40.912 MHz
Slewing rate	$1.5°$/s	∞
Baseline length	90 m	

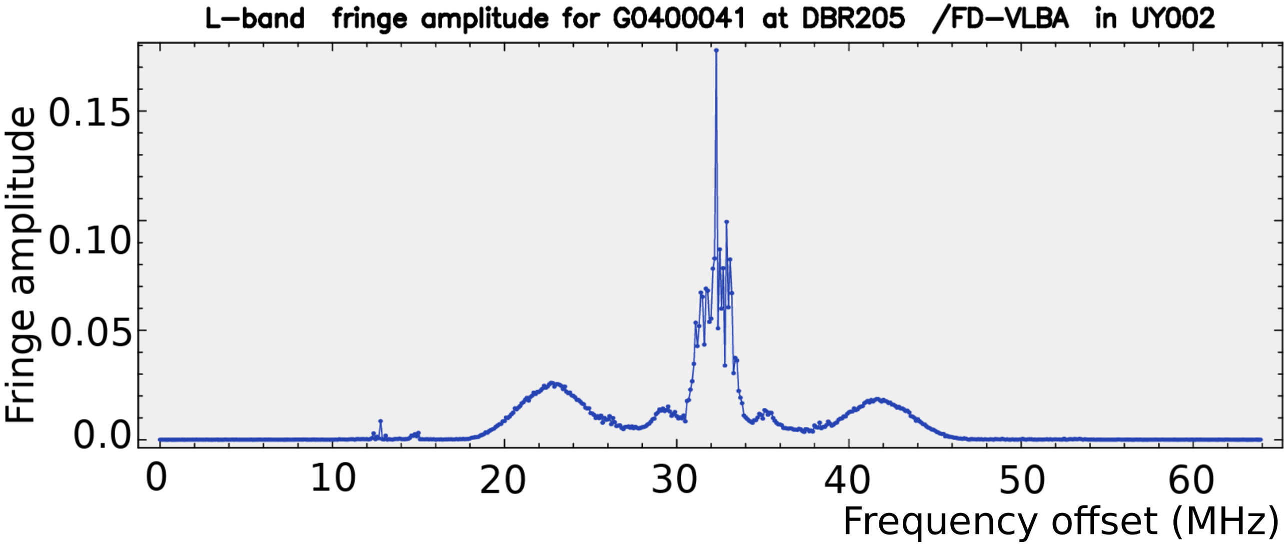
Gain curve of TOPCON CR-G5 antenna



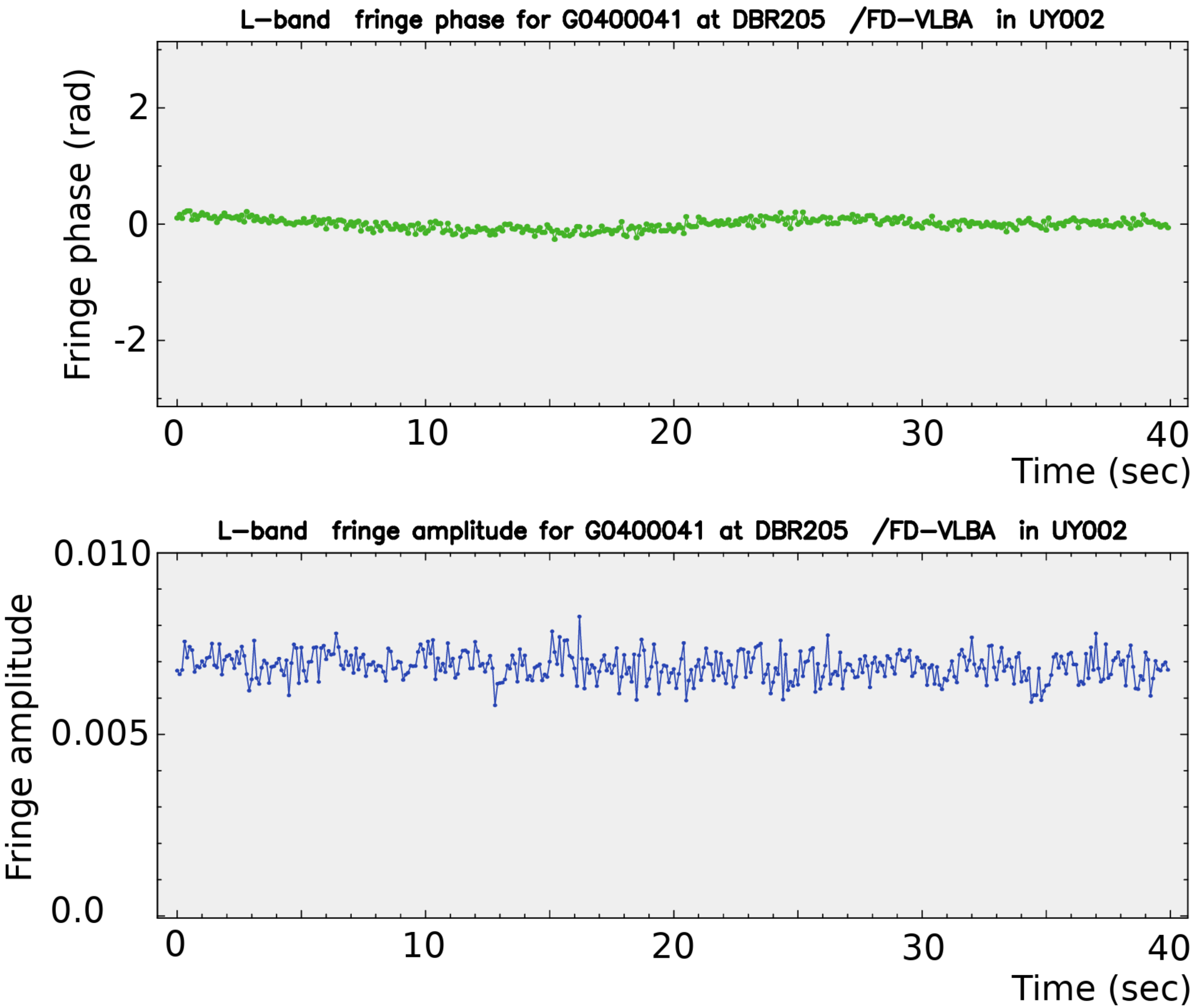
Detected signal from a GNSS satellite

Frequency range: [1543.112, 1607.112] MHz





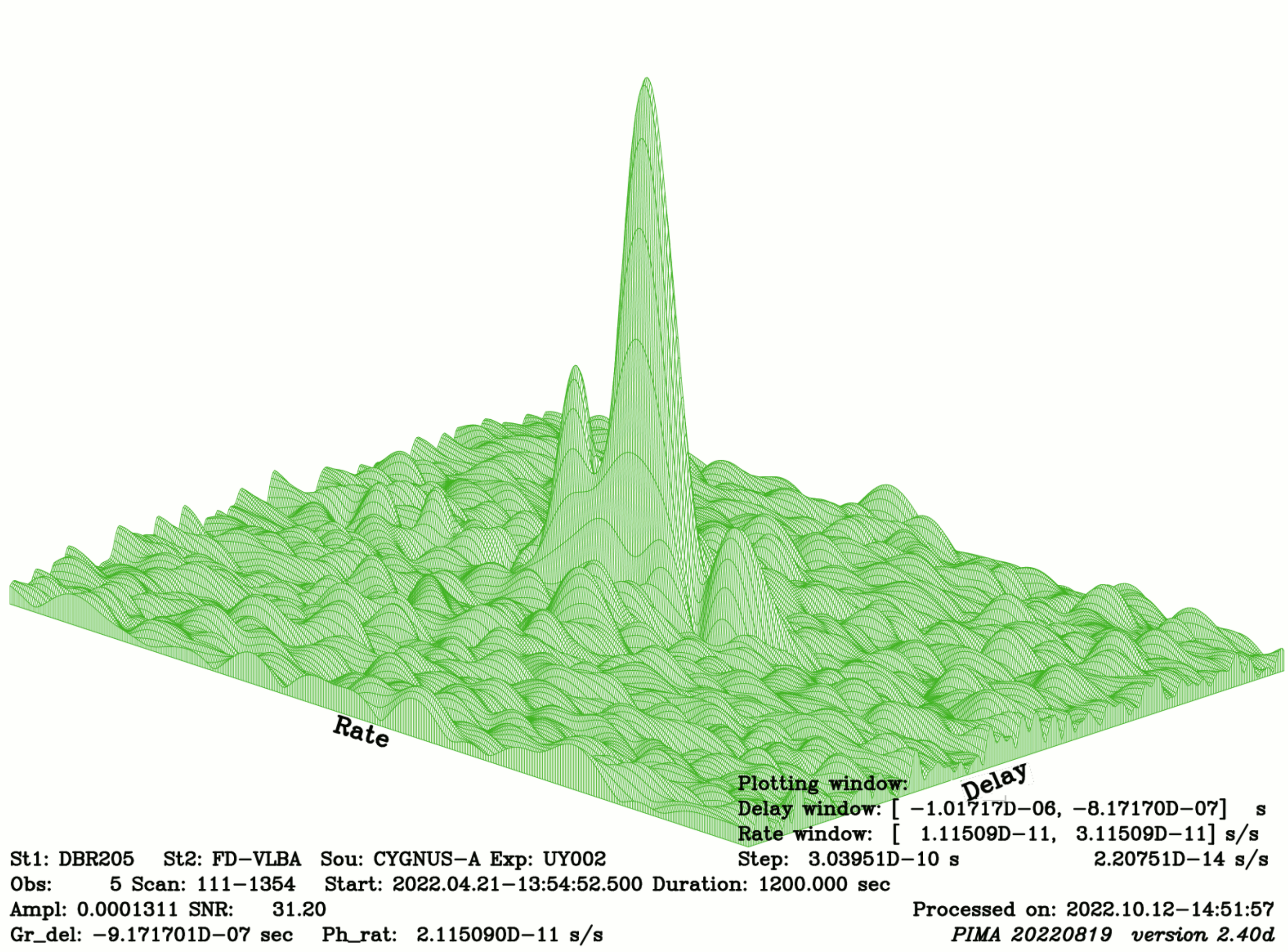
Detected signal from a GNSS satellite



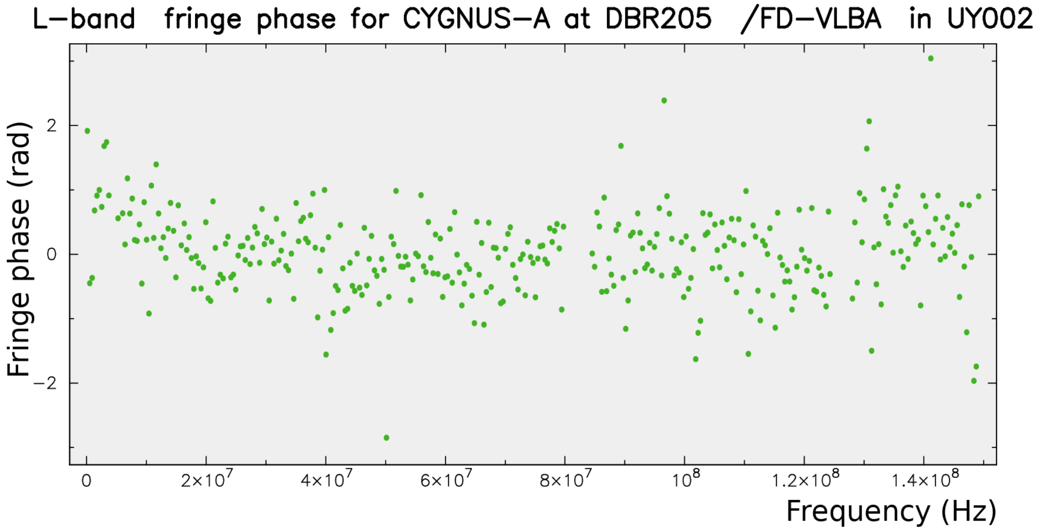
Detected radio galaxies

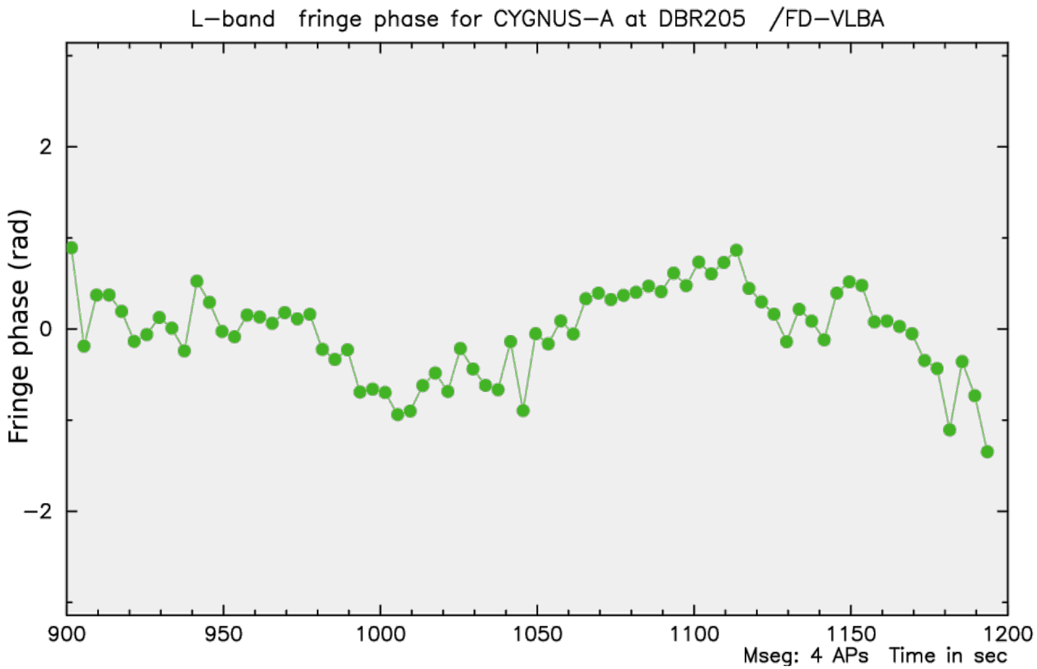
3C84: distance $3.7 \cdot 10^{14} R_{\oplus}$, SNR = 7.1

Cyg A: distance $1.1 \cdot 10^{15} R_{\oplus}$, SNR = 31.2



Fringe phase of Cyg A





To do list

- Process observations of galactic OH masers (2022)
- Run observations with an H-maser (2022)
- Get phase delays of the signal carrier (2023)
- Develop capabilities to process VLBI observations of GNSS satellites at short and long baselines (2023)
- Estimate a tie vector FD-VLBA and permanent GNSS (2024)
- Extend the frequency range of VGOS antennas down to 1.5 GHz

Summary:

- New technology of micro-VLBI with a GNSS antenna has emerged
- Stable fringes were found in observations of GNSS satellites
- Radiogalaxies were detected at a baseline between a GNSS antenna and VLBA
- **Tie measurements between VLBI and GNSS antennas using VLBI are feasible**

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