VLBI Observations of Spacecraft with EVN Radio Telescopes

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YERAC-2011, Jodrell Bank Observatory, University of Manchester, UK

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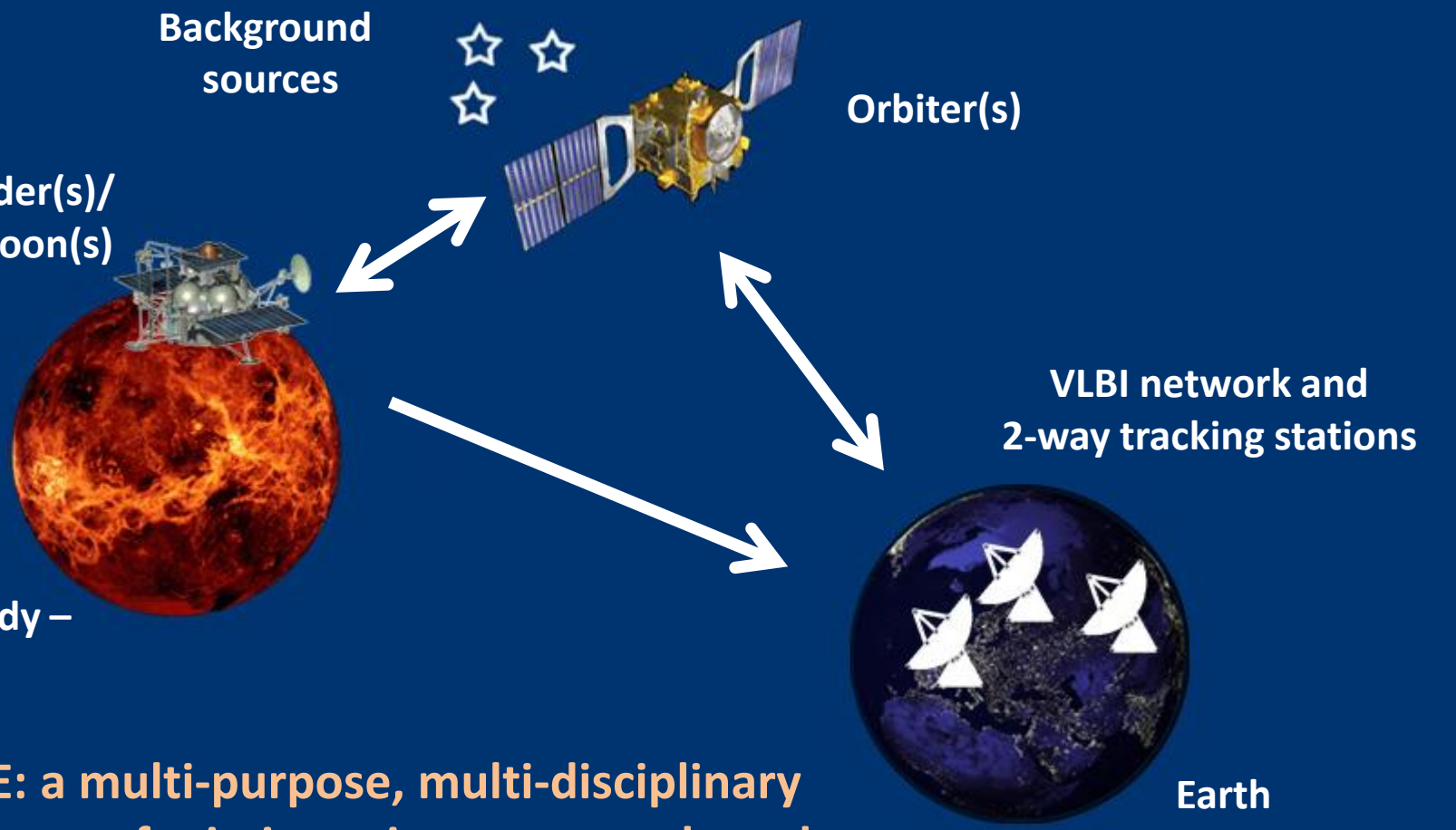
Overview

- PRIDE overview
- Results of VLBI observations of ESA's Venus Express (VEX) spacecraft and GNSS satellites
- Conclusions and outlook

Generic PRIDE configuration

Planetary **R**adio **I**nterferometry and **D**oppler **E**xperiment



PRIDE: a multi-purpose, multi-disciplinary enhancement of mission science return, based on the phase-referencing VLBI technology and science

Science with PRIDE

VLBI estimates of the S/C state vector

- Ultra-precise celestial mechanics of planetary systems;
  - measurements of tidal accelerations of the satellites may be possible
- Geodynamics, internal structure and composition;
  - Powerful constraints on the interior structure of the moons can be obtained from the joint analysis of topography and gravity field data.
- Shape and gravimetry;
  - multiple flybys can be used to define the low order gravity field parameters.
- Electric properties of icy satellite surfaces and their environments;
  - PRIDE will bring in multi-antenna detections enabling “stereoscopic” view on the phenomena under study.
- Anomalous accelerations of deep space probes and other ***fundamental physics effects***.

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“Cruise” science plus mission diagnostics (“health check”)

Direct to Earth (DtE) radio link

Science with PRIDE

VLBI estimates of the S/C state vector

PRIDE (prospective) customers:

Mercury: ESA-JAXA BepiColombo, 2014
Venus: VEX, CNES EVE and RSA Venera-D, >2018?
Moon: ESA NEXT and Chinese Chang'E-2
Mars + Phobos: RSA Phobos-Grunt, 2011, ESA ExoMars, 2016?
Jupiter + Europa, Ganymede, Callisto
ESA-NASA Europa-Jupiter System Mission (EJSM), 2020?
Saturn + Titan, Enceladus
ESA-NASA-JAXA Titan Saturn System Mission (TSSM), 2022?

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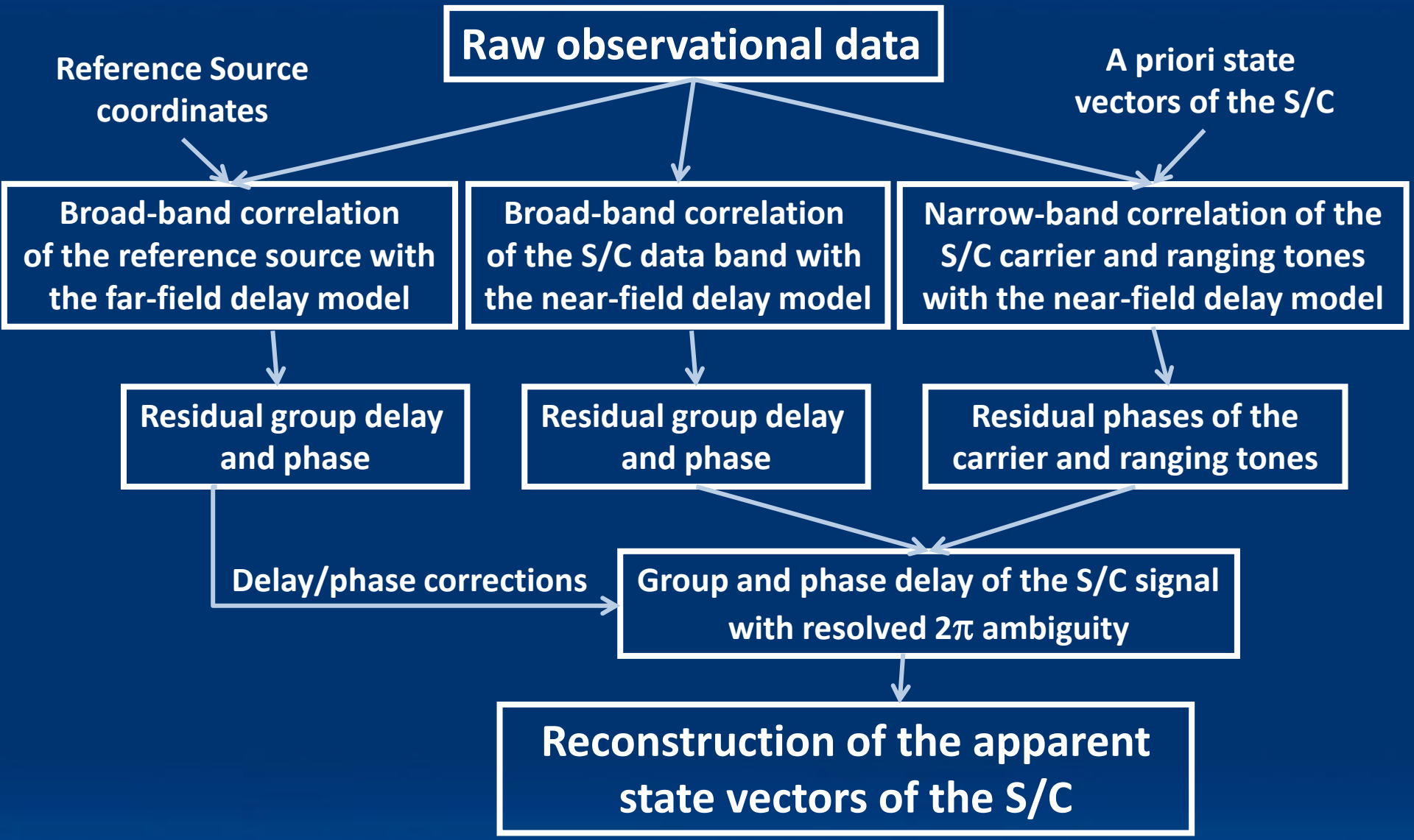
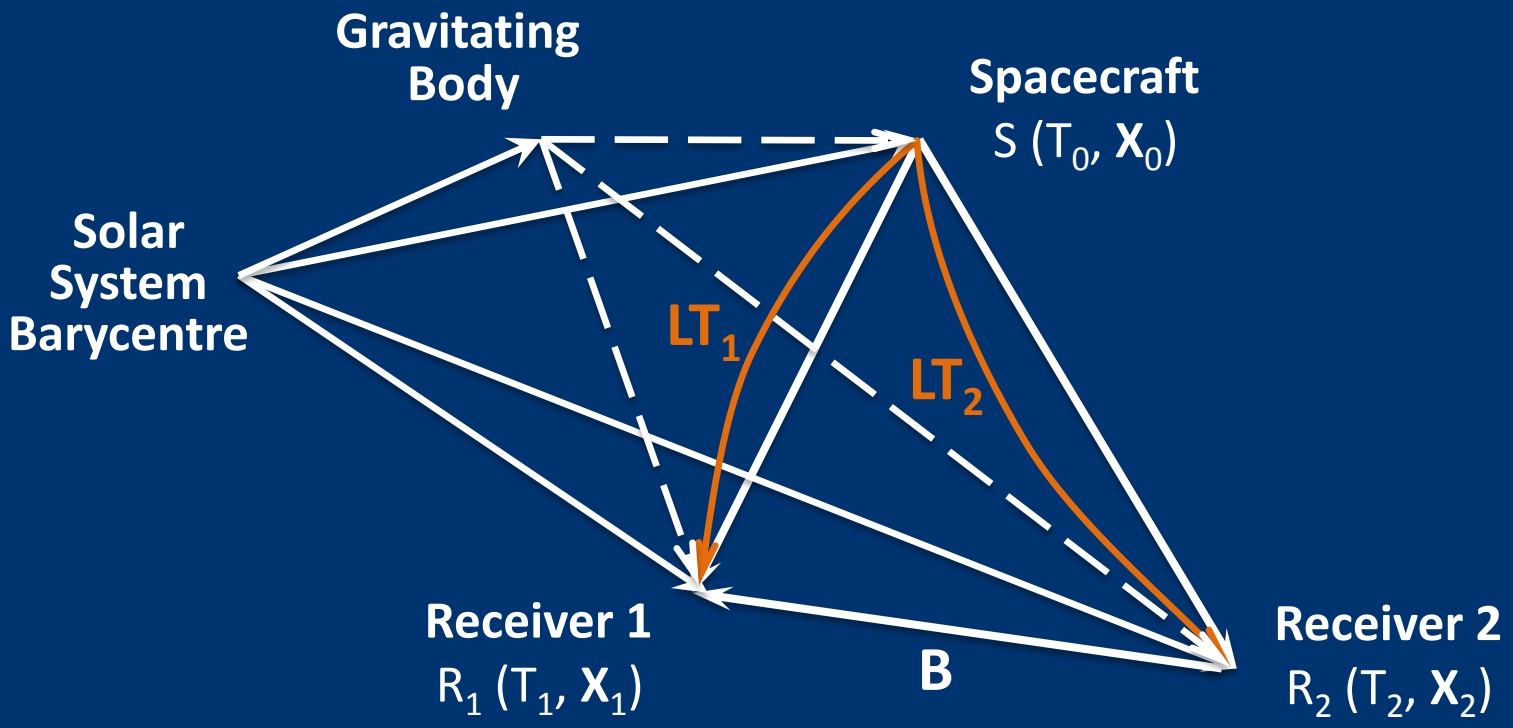
"Cruise" science plus mission diagnostics ("health check")

Direct to Earth (DtE) radio link

Block-diagram of data processing and analysis

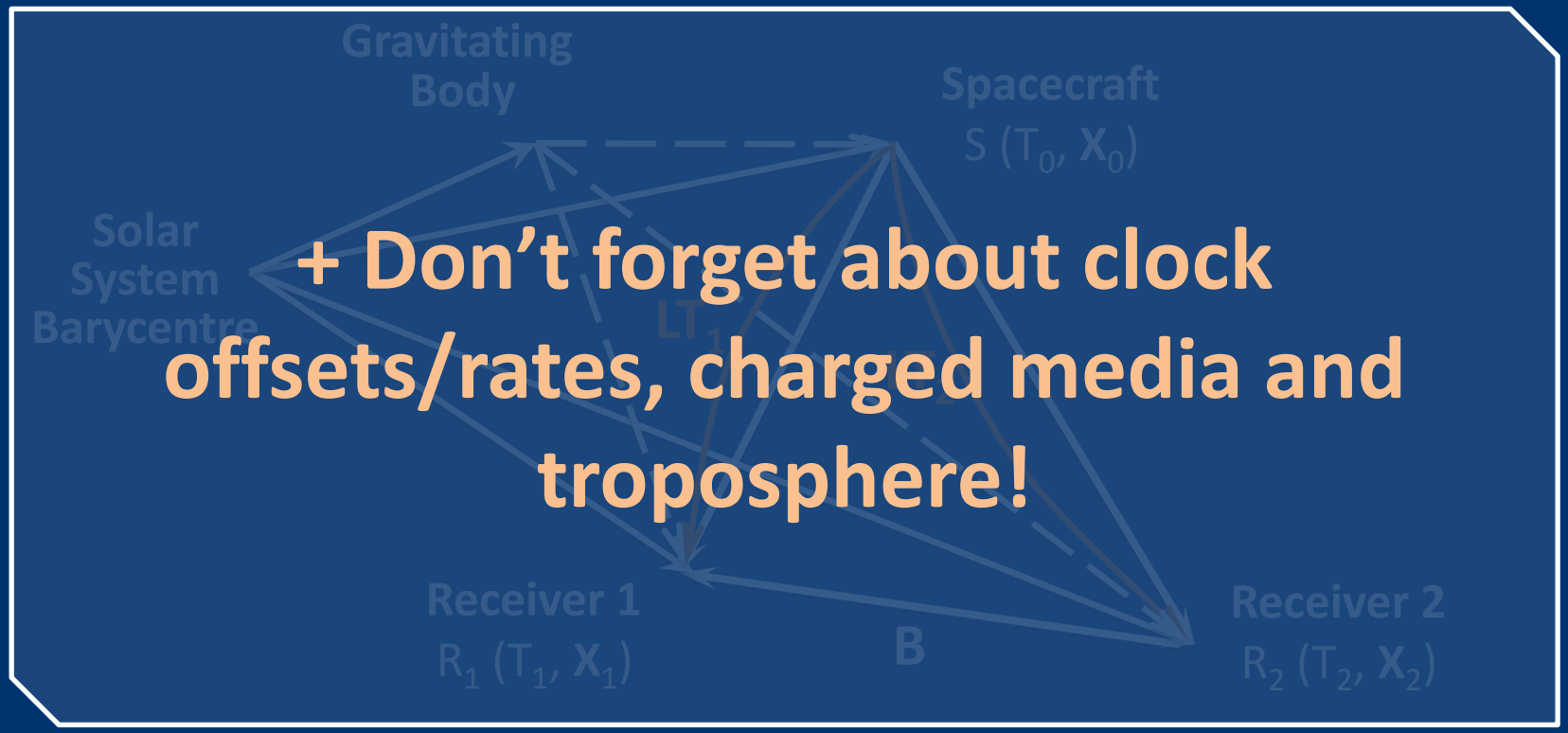


Near-field delay model



Geometry of VLBI observations of spacecraft in the Barycentric celestial reference frame

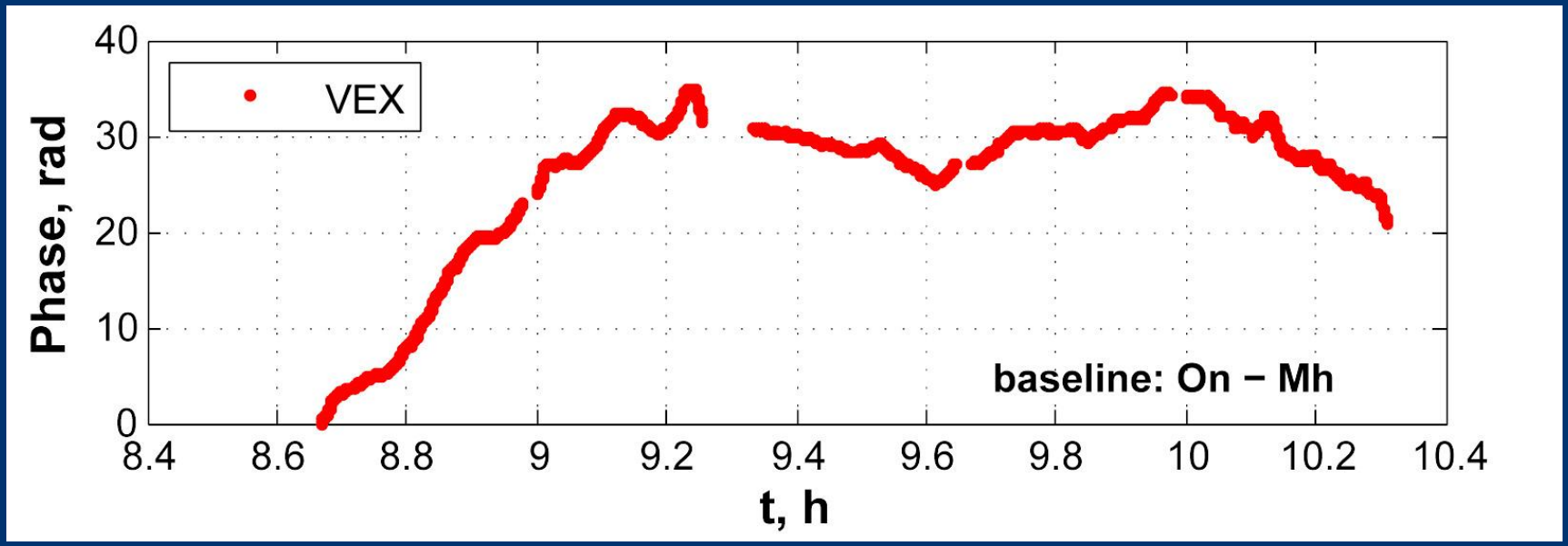
Near-field delay model



+ Don't forget about clock offsets/rates, charged media and troposphere!

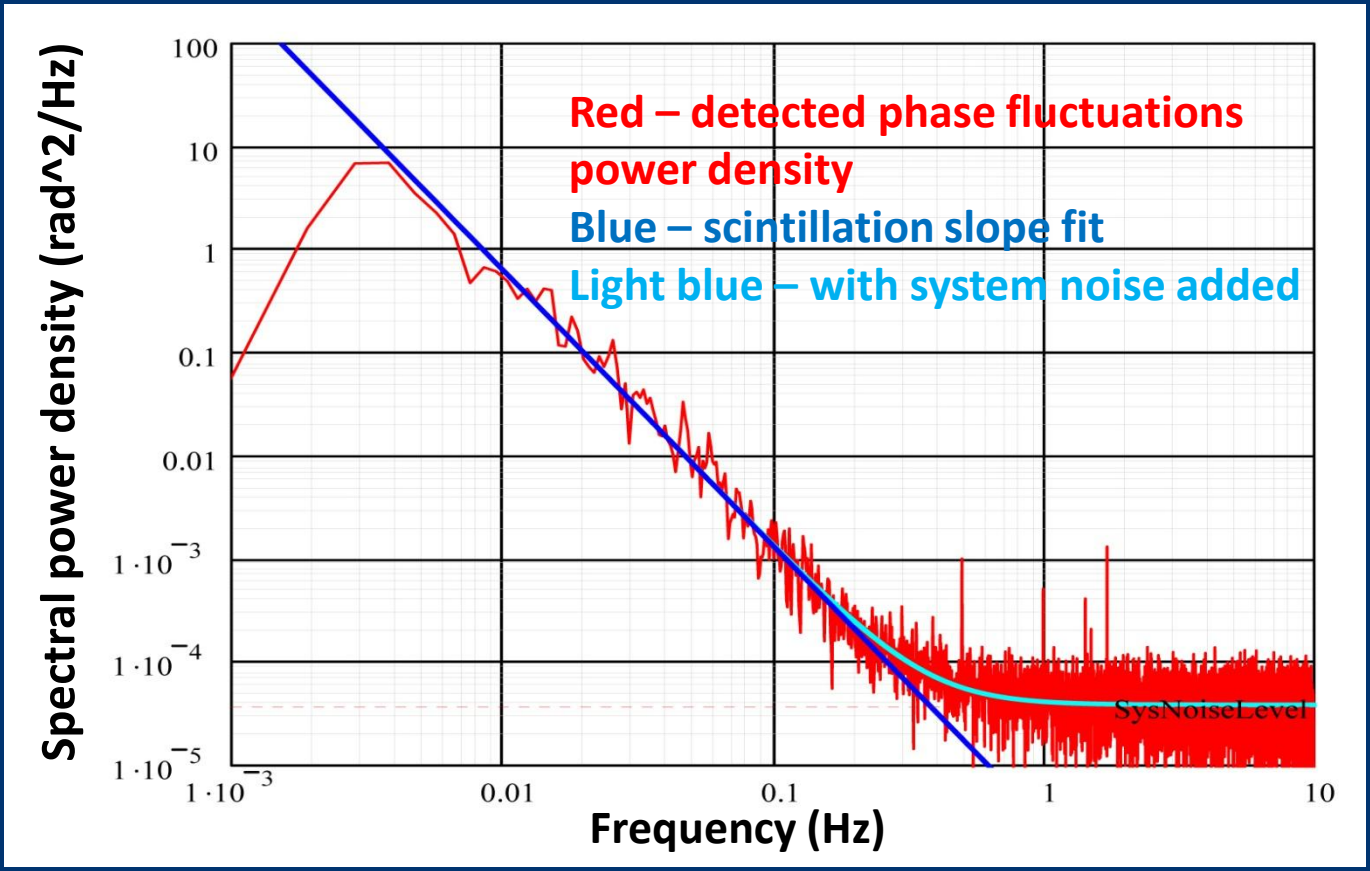
Geometry of VLBI observations of spacecraft in the Barycentric celestial reference frame

Why phase-referencing?



VEX phase behaviour on the baseline Onsala – Metsahovi, 25.03.2011, no phase referencing

Why phase-referencing?



Kolmogorov spectrum of phase scintillations, Onsala, 25.03.2011

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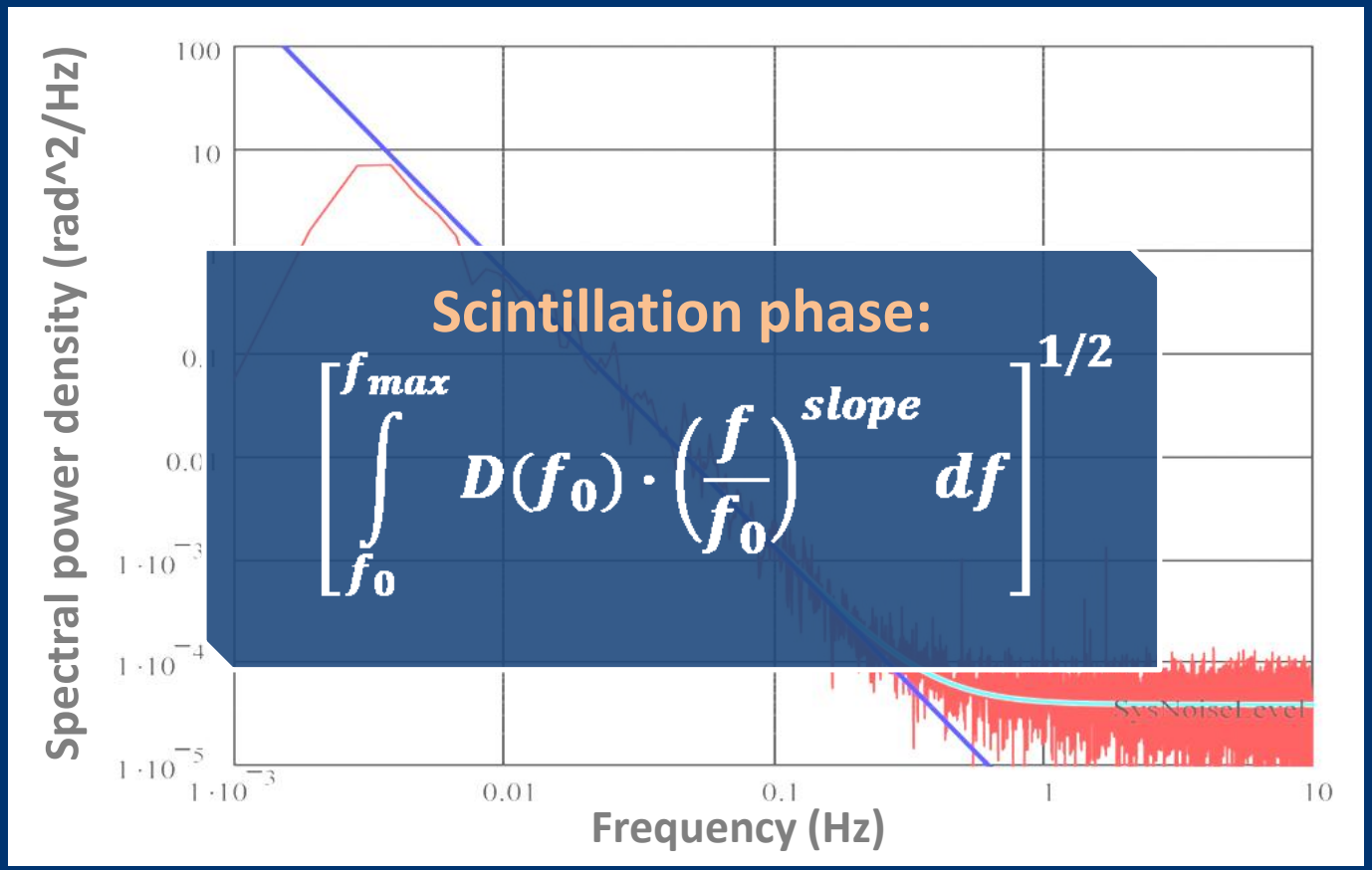

Kolmogorov spectrum of phase scintillations, Onsala, 25.03.2011

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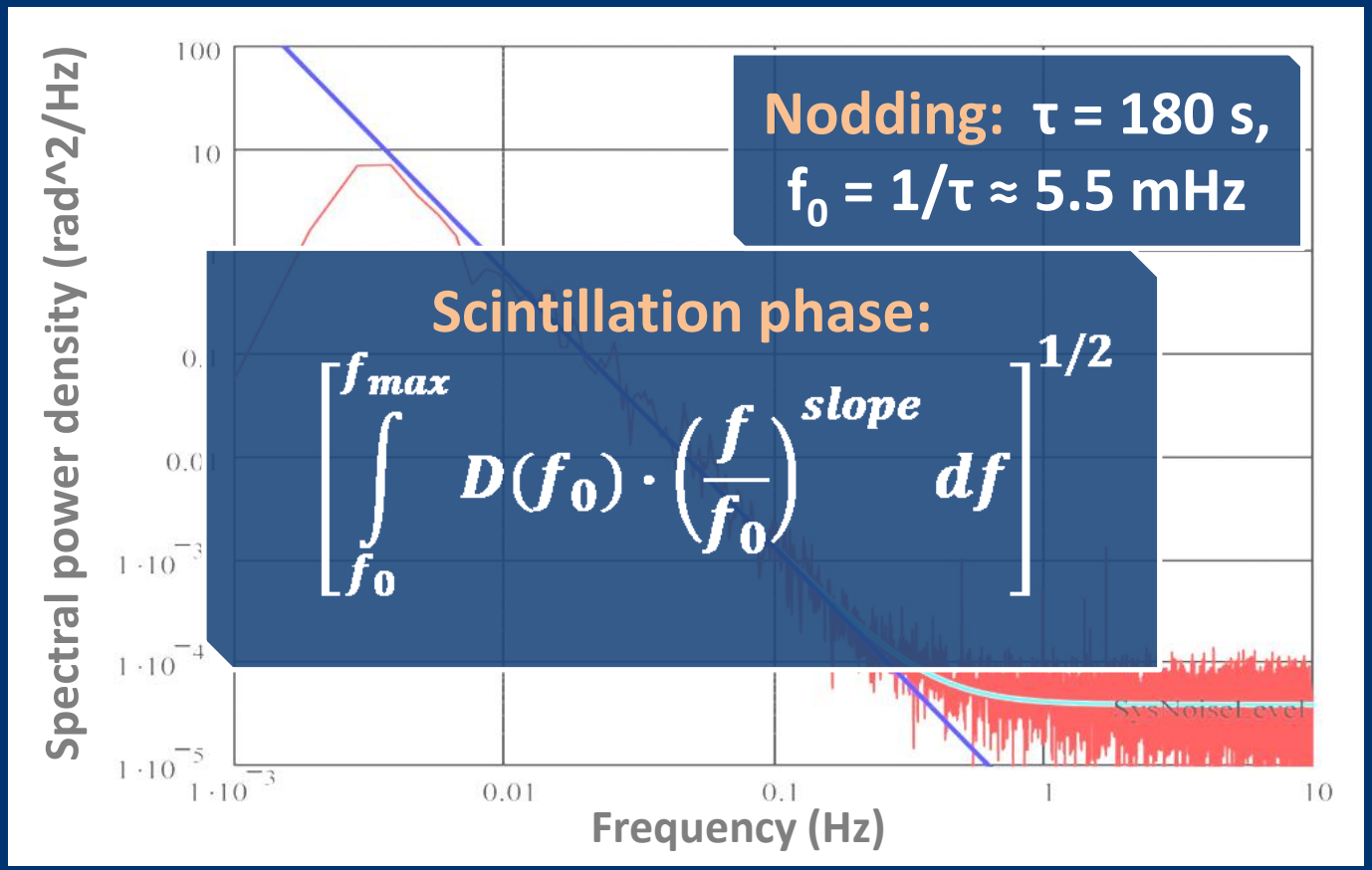

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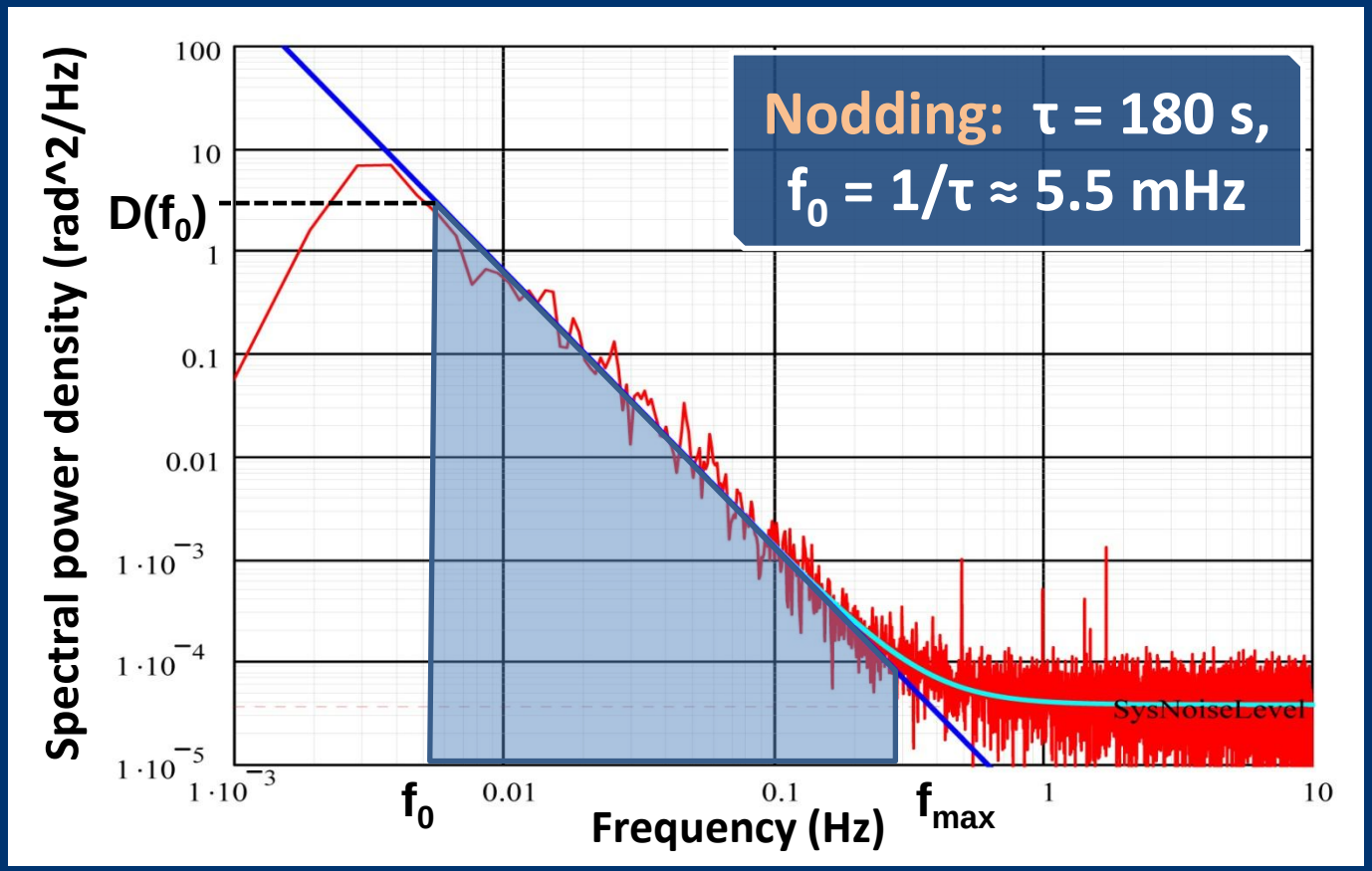
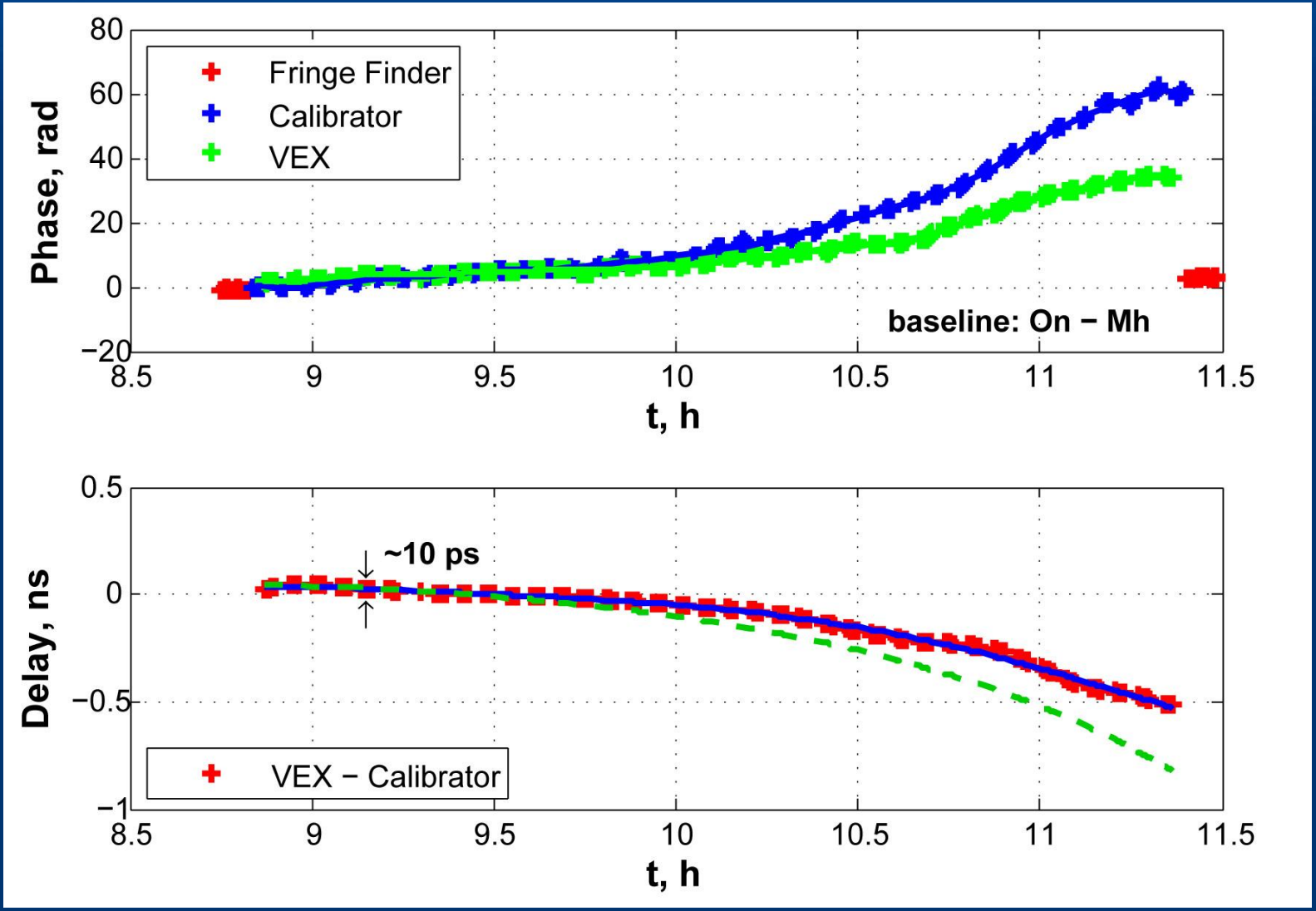


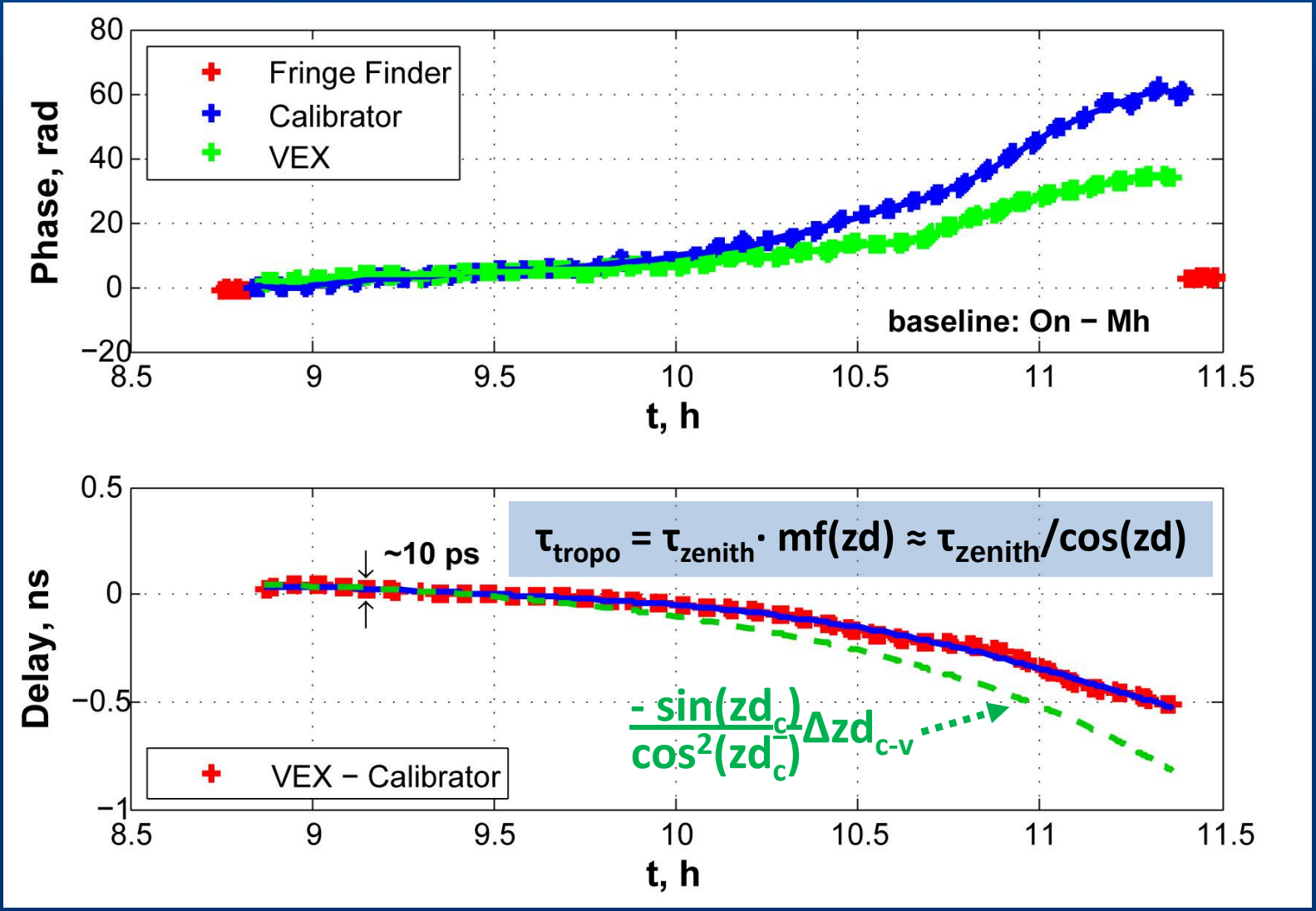
Kolmogorov spectrum of phase scintillations, Onsala, 25.03.2011

Phase-Referencing VLBI Experiment em081c

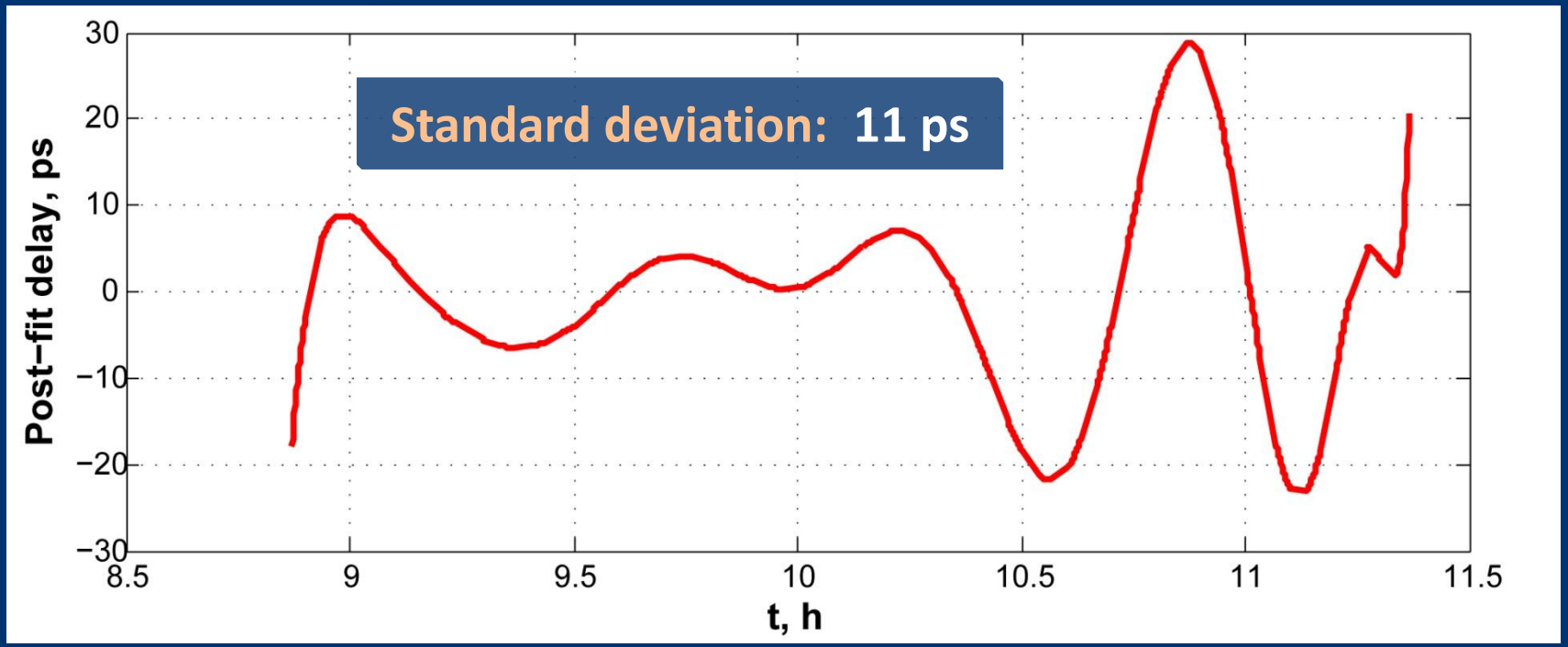
- Telescopes:
  - *Onsala (SE)*
  - *Metsähovi (FI)*
  - *Hartebeesthoek (ZA)*
  - *Svetloe, Zelenchuk (RU)*
  - *Wettzell (DE)*
  - *Medicina, Matera (IT)*
  - *Yebes (ES)*
  - *St. Croix (US)*
- ESA VEX Spacecraft
  fringe finder - J2225-0457, calibrator - J2211-1328
- 8.45 - 11.30 UT, 28 March 2011
- Mark5A, 16 MHz bandwidth @ X-band



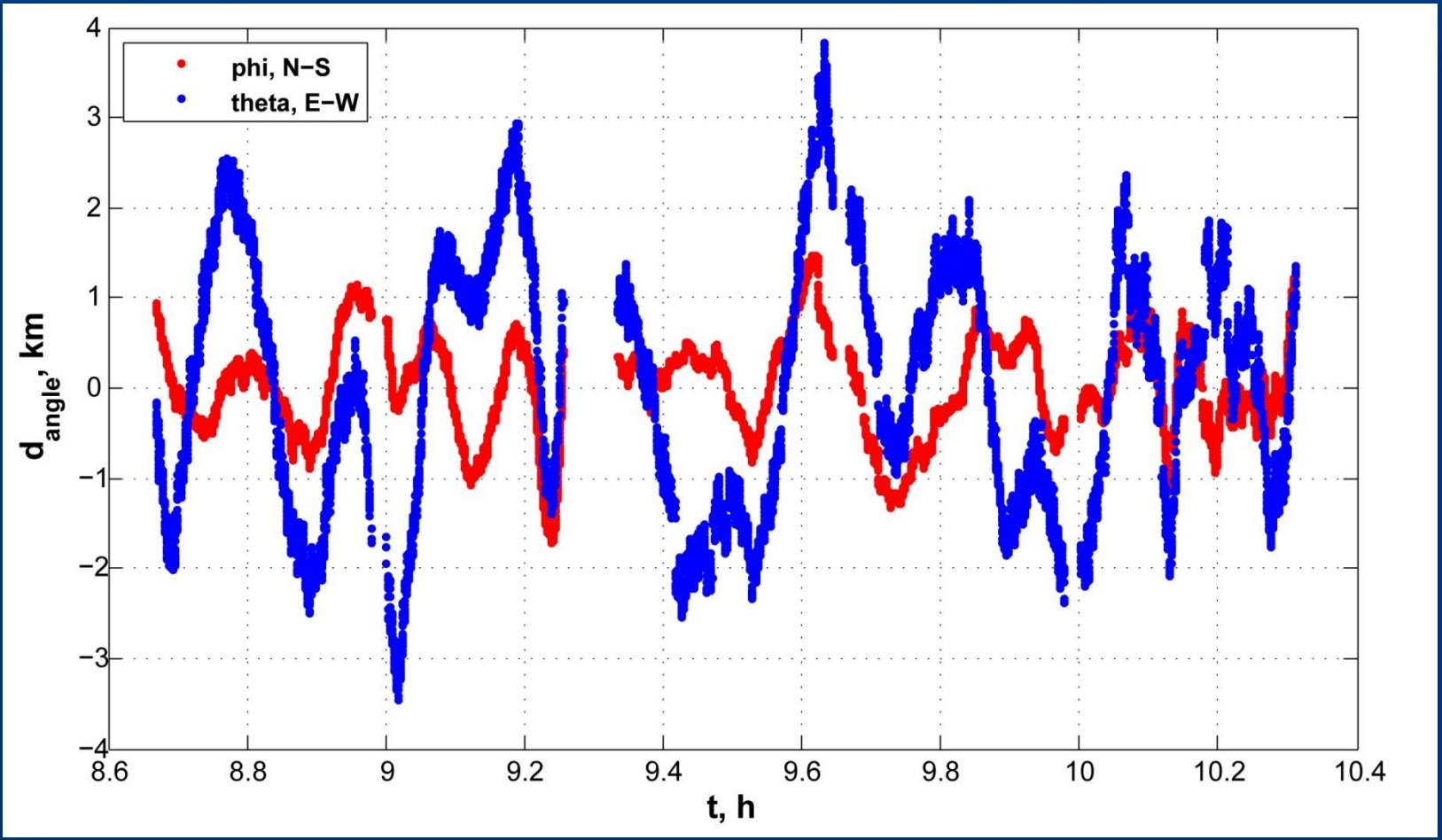
Phases of the fringe finder, calibrator and VEX + calibrated delay of the VEX spacecraft. Baseline Onsala - Metsahovi, em081c, 28.03.2011



Phases of the fringe finder, calibrator and VEX + calibrated delay of the VEX spacecraft. Baseline Onsala - Metsahovi, em081c, 28.03.2011



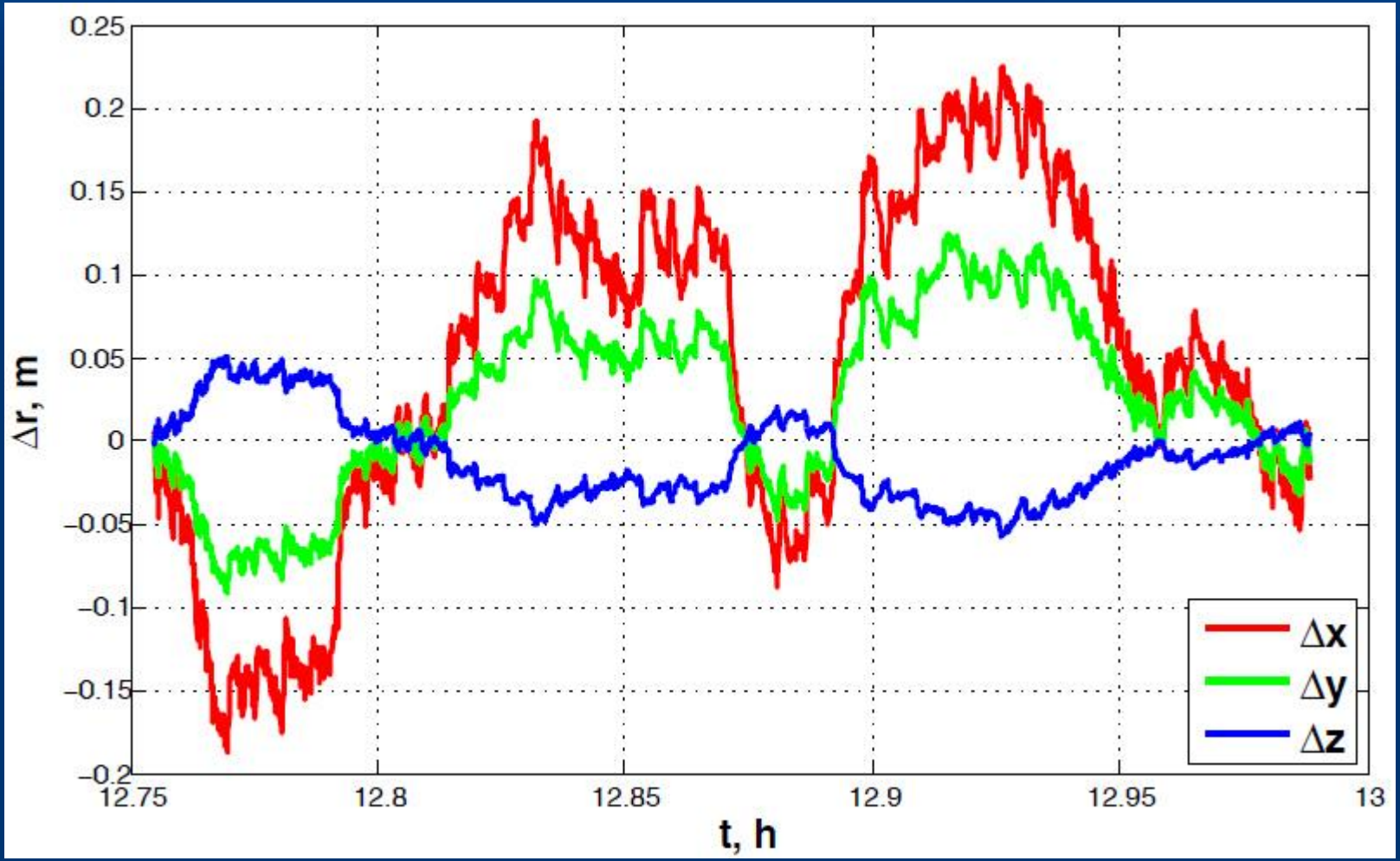
Post-fit delay. Baseline Onsala - Metsahovi, em081c, 28.03.2011



Lateral VEX a-priori coordinate deviations, baselines On-Mh, On-Pu, Mh-Pu. 25.03.2011. No phase referencing.

Test Experiment g100816

- Telescopes
  - *Onsala (SE), Medicina (IT)*
- GLONASS satellites, 16 August 2010
  - *PR21, 12.45 - 13.00 UT*
  - *PR13, 13.30 - 13.45 UT*
- Mark5A, 16 MHz bandwidth @ L-band
- PIs – V. Tornatore (Politecnico di Milano, IT), R. Haas (Chalmers University, SE)



Corrections to the GLONASS PR21 satellite ITRF position, Baseline Onsala - Medicina, 16.08.2010

Conclusions and Outlook

- Spacecraft positioning with a very high accuracy is achievable with PRIDE
- We attract new users to EVN and JIVE
- A lot of work in the pipeline fine-tuning (including scheduling, tracking, processing and analysis) is still required

We would like to express a sincere gratitude to the personnel of the telescopes which took part in the observations

Thank you for your attention!