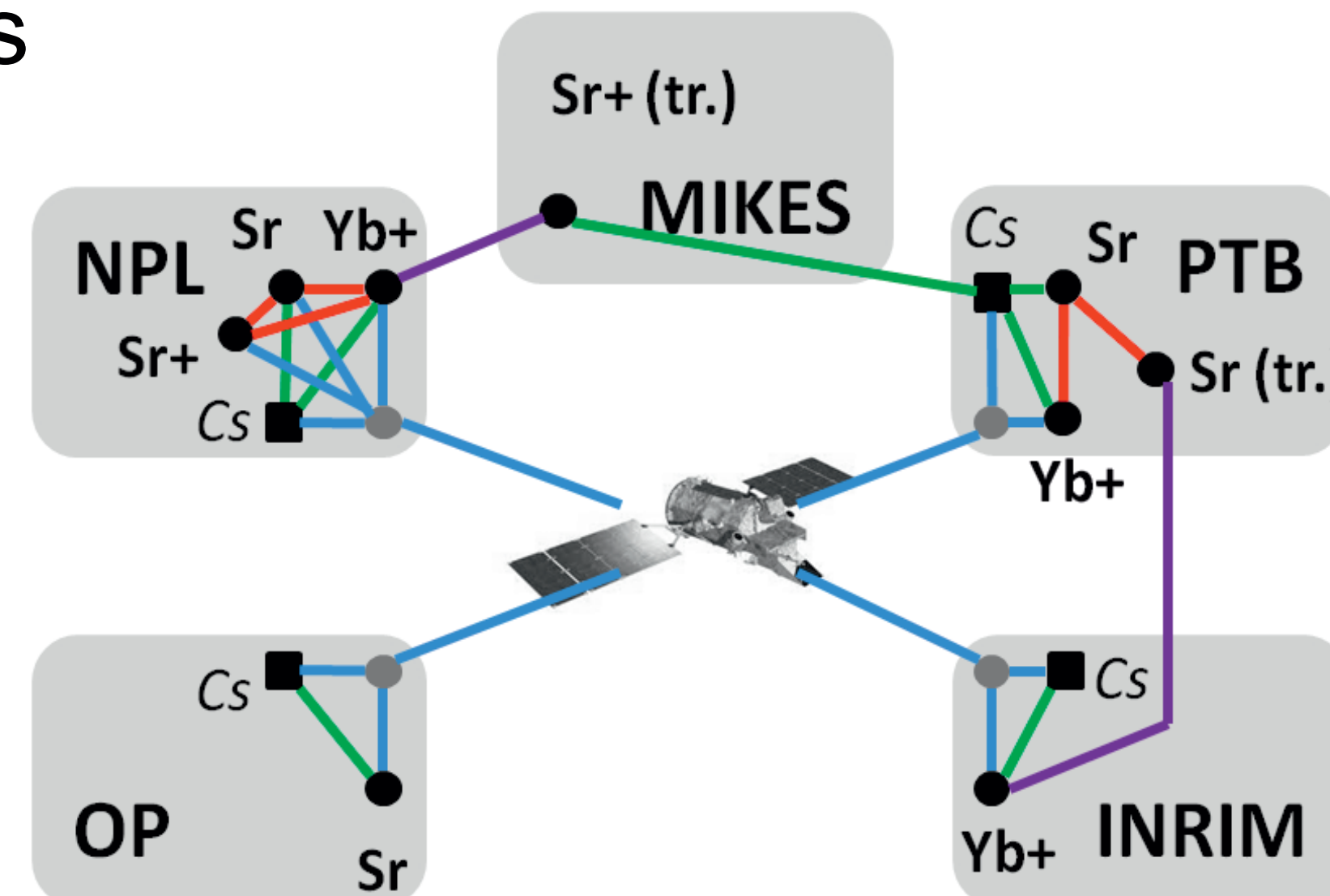


Satellite link performance for optical clock comparison

F. Riedel¹, E. Benkler¹, D. Piester¹, J. Leute¹, J. Achkar², P. Delva², I. Sesia³, G. Cerretto³, M. Rotondo³, P. B. Whibberley⁴, S. Shemar⁴, H. S. Margolis⁴, P. Defraigne⁵

Towards timescales with optical clocks

- enhancement of frequency transfer techniques for future applications of optical clocks as primary frequency standards
- EMRP JRP SIB55:**
"International Timescales with Optical Clocks" (ITOC)
- using 20 Mchip/s modulation bandwidth to gain an instability of 10^{-16} at 1 day (broadband TWSTFT)
- broadband TWSTFT links between four European NMIs for optical clock comparisons



ITOC consists of a coordinated program for frequency comparison of optical clocks:

- local optical frequency comparisons
- frequency comparisons using transportable optical clocks
- frequency comparisons using broadband TWSTFT
- absolute frequency measurements

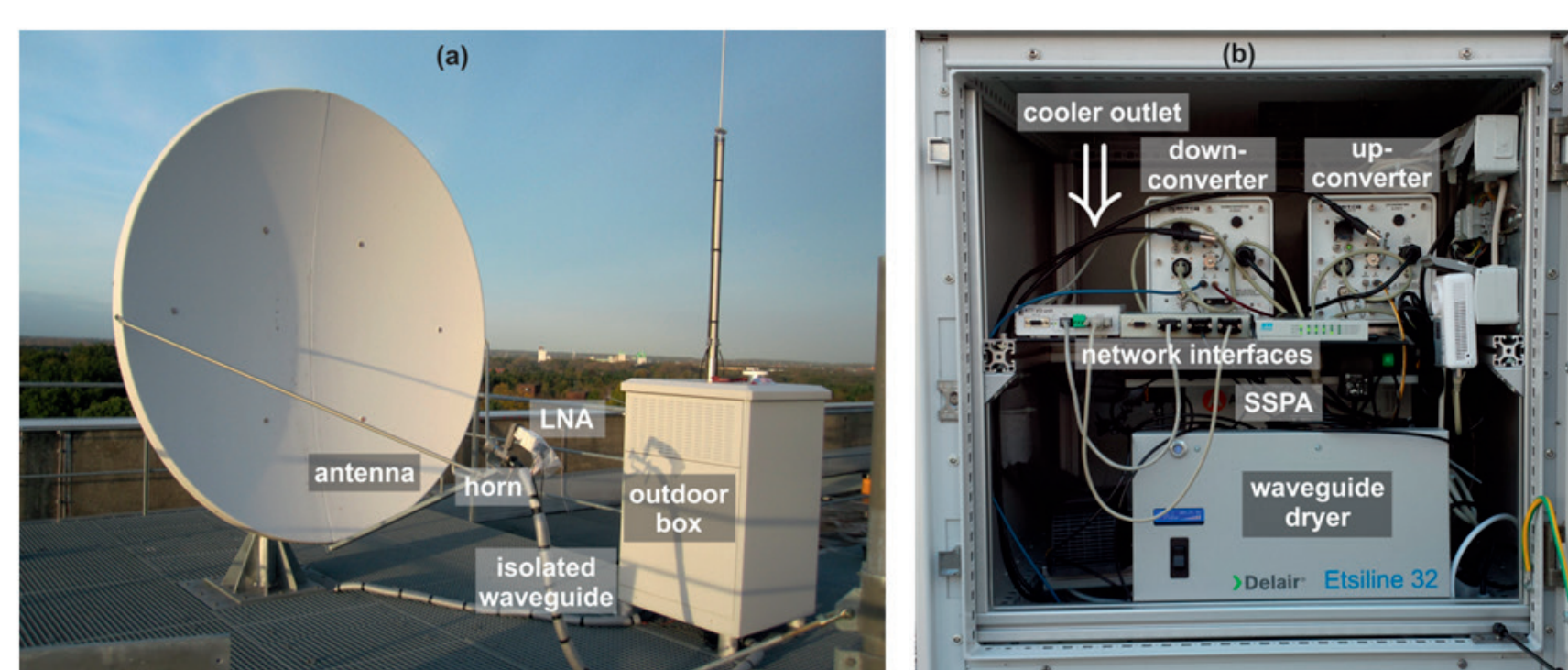
- determination of a frequency ratio matrix
- analysis of relativistic effects on clock comparisons
- investigation of the impact of dead times on timescale steering with optical clocks

[1] Margolis et al., Proceedings EFTF 2013

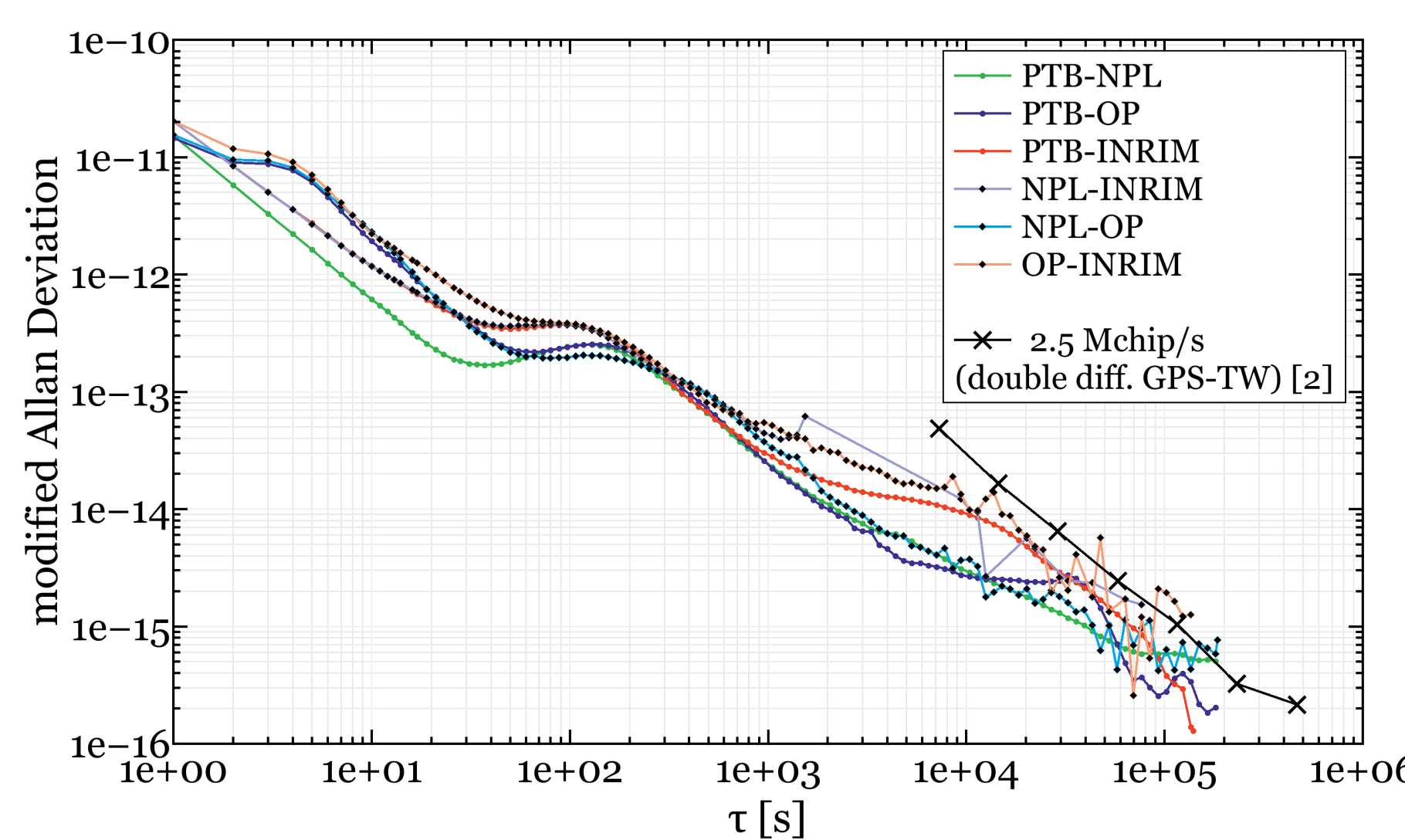
Broadband TWSTFT link test

1-week campaign in October 2014

- link performance test with H-maser vs. H-maser
- Cs fountains simultaneously measured against maser
- comparison with GPS PPP
- identify critical issues and find strategies for circumvention



Outdoor equipment at PTB:
(a) antenna;
(b) temperature-controlled outdoor box

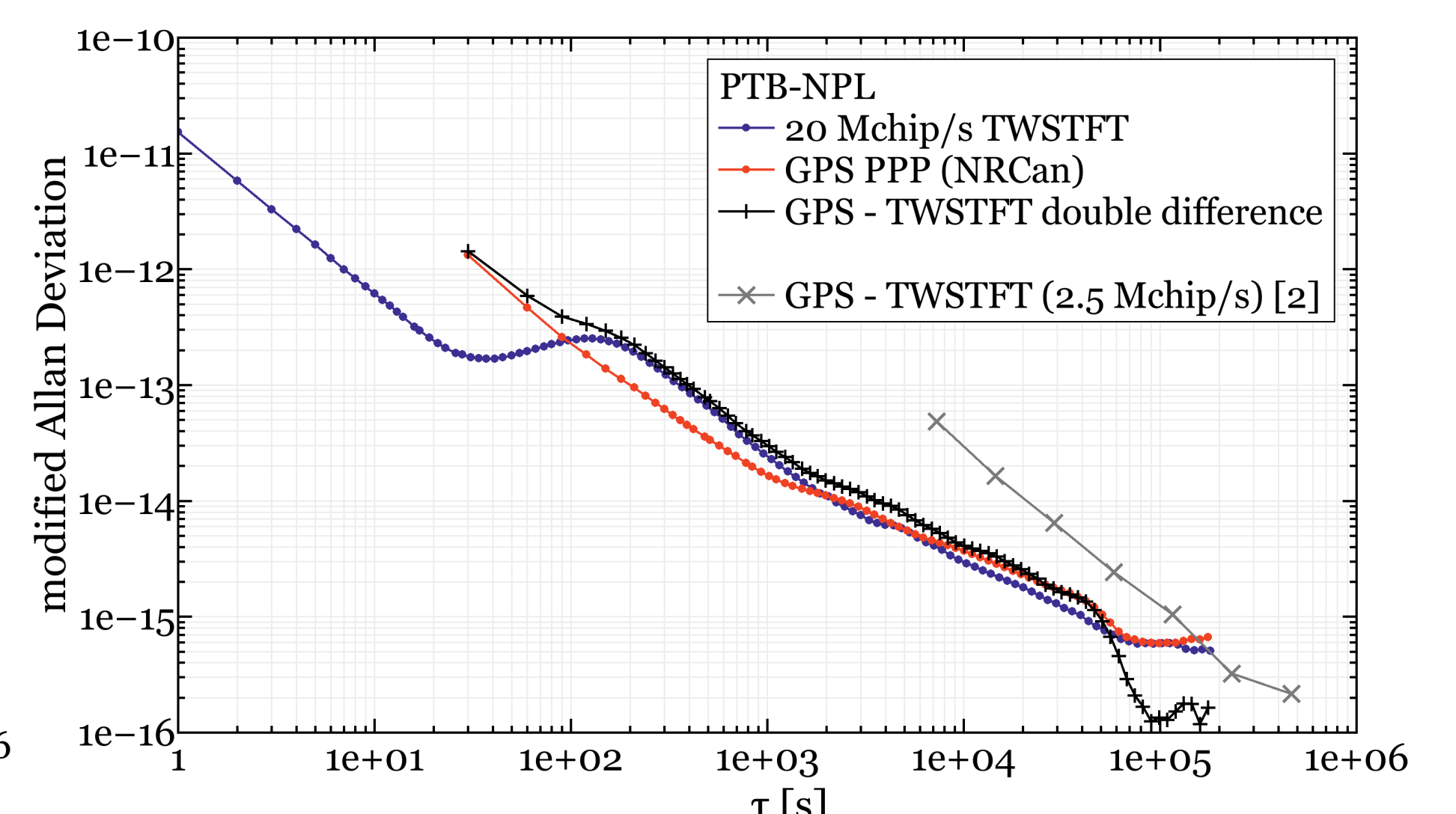


Link performance:

- mod. Allan Deviations of all 20 Mchip/s TWSTFT links,
- instability of regular 2.5 Mchip/s for comparison
- lowest instability at less than 5×10^{-16} at 1 day

Disturbances on link performance:

- temperature-induced diurnals
- fast frequency modulated oscillation (signal reflection in cables in combination with sat. movement)
- disturbance of unknown origin on all links at ~ 200 s
- scattering at high τ due to gaps on some links (switching of link combinations)



Comparison with GPS PPP (NRCAN):

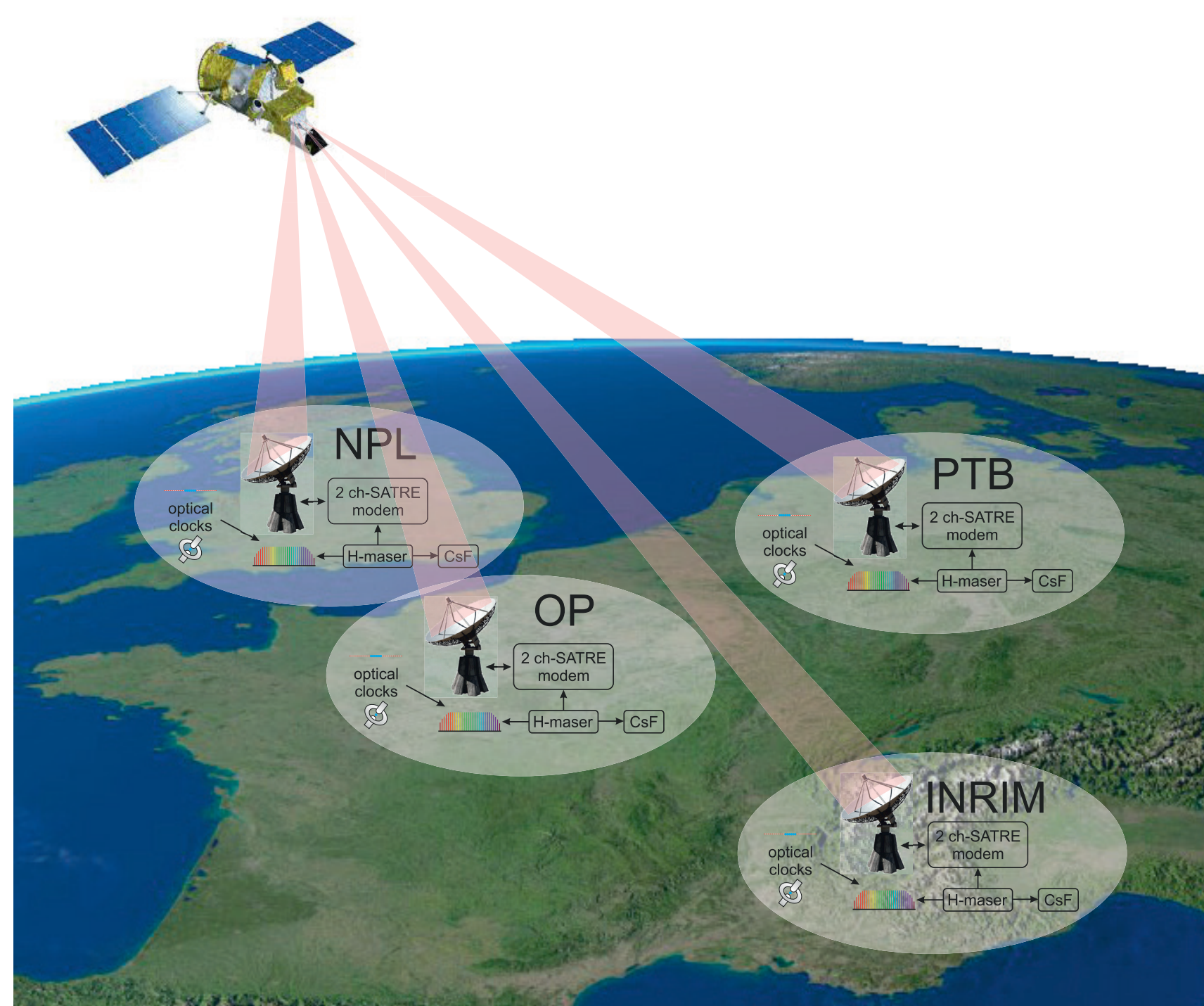
- both techniques similar performance
- double difference: instability of less than 3×10^{-16} at 1 day
- double difference at lower chip rates limited by TWSTFT

[2] Bauch et al., Metrologia 43, 109 (2006)

Clock comparison campaign

3-week campaign in June 2015

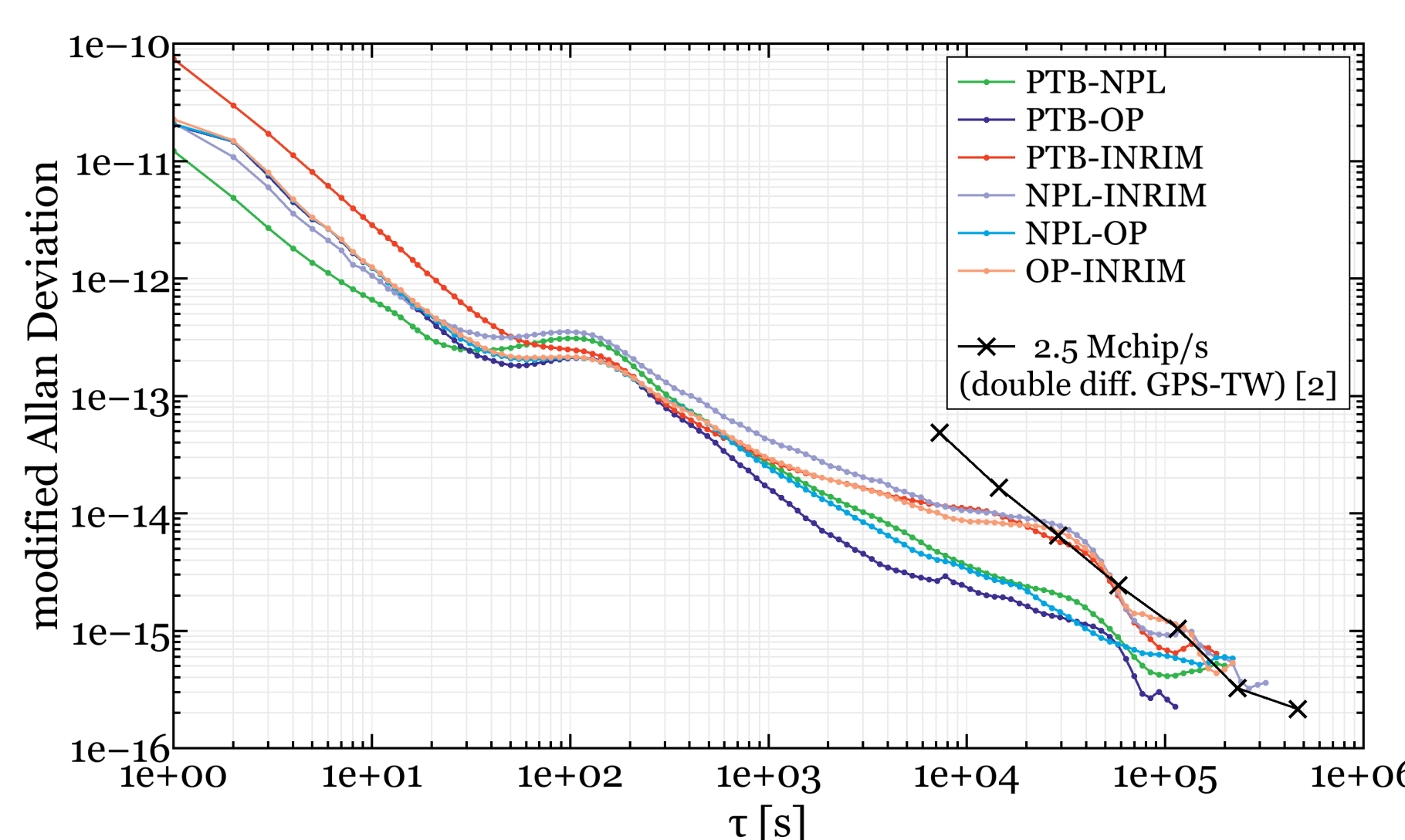
- H-maser as reference for TW modems and GPS receivers
- optical clocks and Cs fountains simultaneously measured against maser
- same satellite and modem settings as in link test
- TWCP between PTB and OP running simultaneously (carried out by NICT)



Conclusion:

- instability at 1 day of broadband TWSTFT within low 10^{-16} for both campaigns
- careful treatment of data gaps and technical disturbances for calculation of optical clock frequency ratio and respective estimation of statistical uncertainties

Preliminary results:

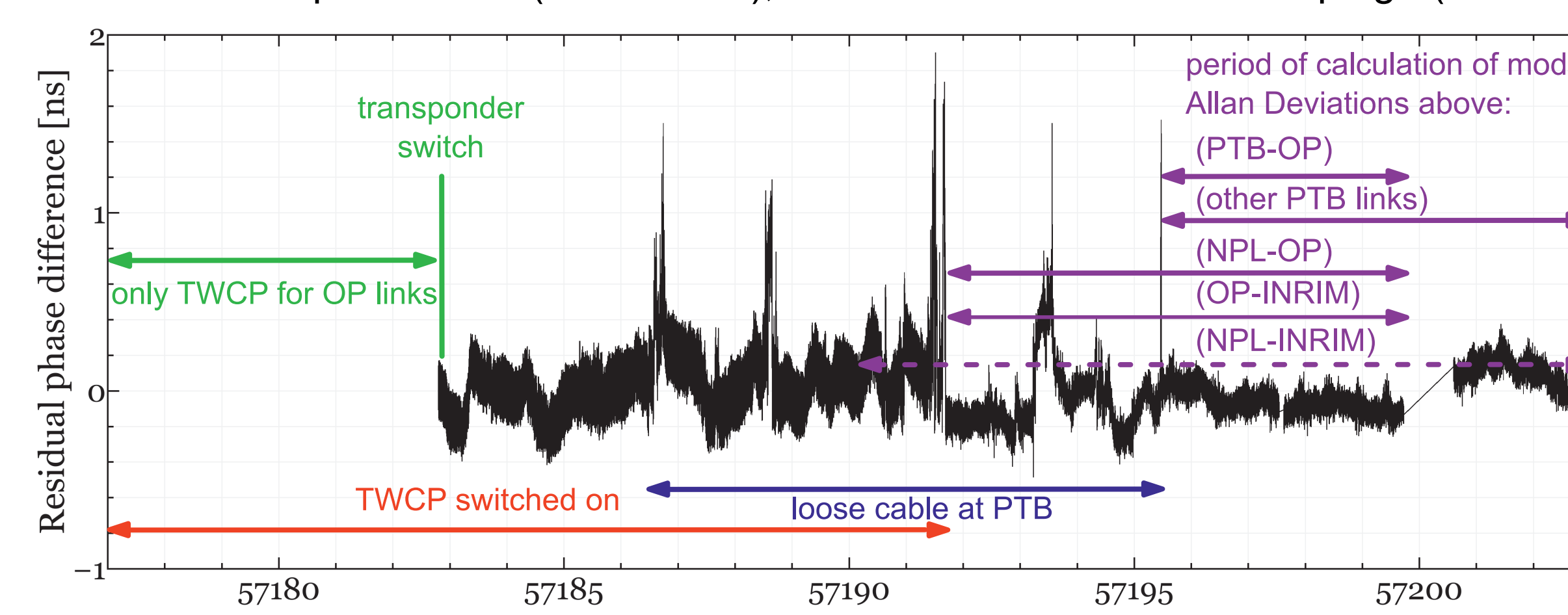


Link performance:

- for selected period similar performance as for link test
- continuously running links (no switching)

Technical disturbances limit averaging time for several TW-links:

PTB-OP TW phase data (HM vs. HM), lin. drift removed: whole campaign (MJD 57177-57203)



Disturbances:

- signal from military station in Paris (transponder switch on 57182)
- loose cable connection at PTB
- signal interferences at TWCP equipment at OP (removed after TWCP switch-off)

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