Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Portable Sr Lattice Clock

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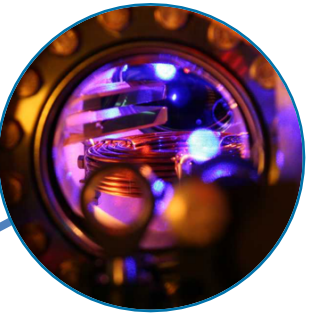
IAG JWG 2.1 2018, Sèvres
October 10, 2018

Comparisons at PTB

PTB Sr lattice clock



building A building B

Yb^+ single ion clock

"Space Optical Sr Clock"

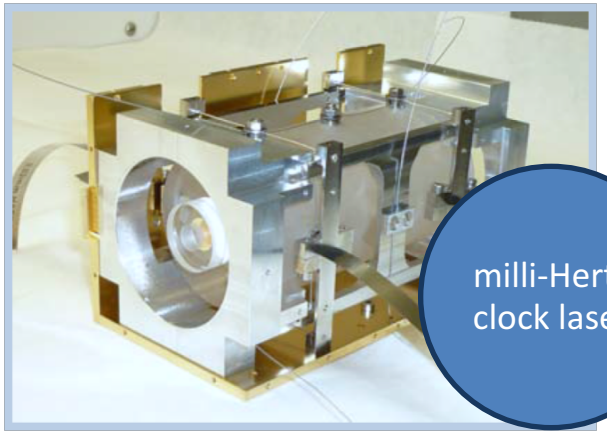
Outline:

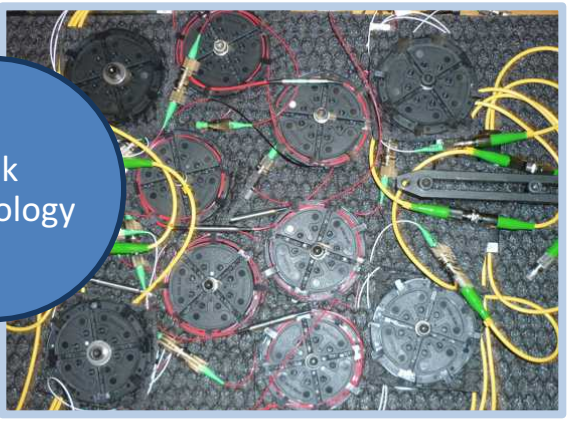
- Evaluation at PTB

- Campaign 2017: Paris – Braunschweig

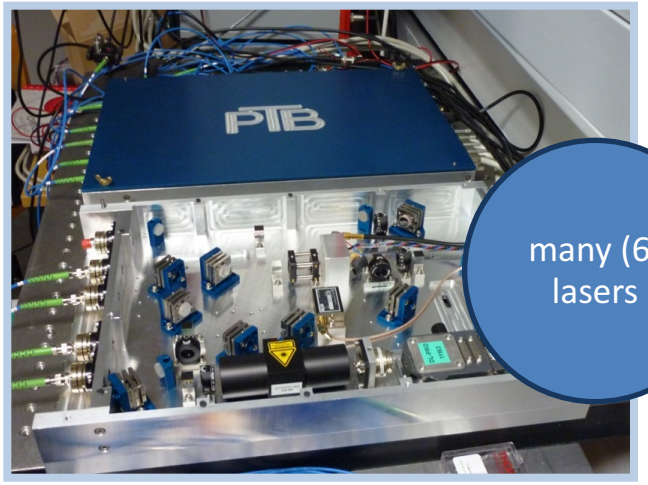
- Campaign 2018: Munich – Braunschweig

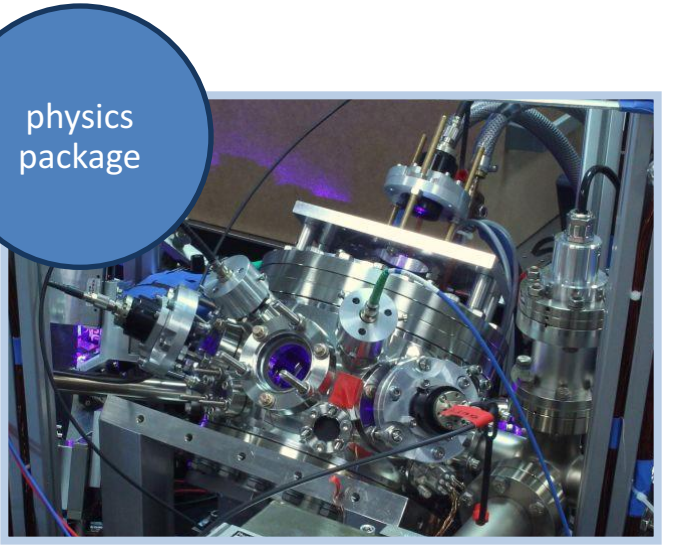
Transportable lattice clock



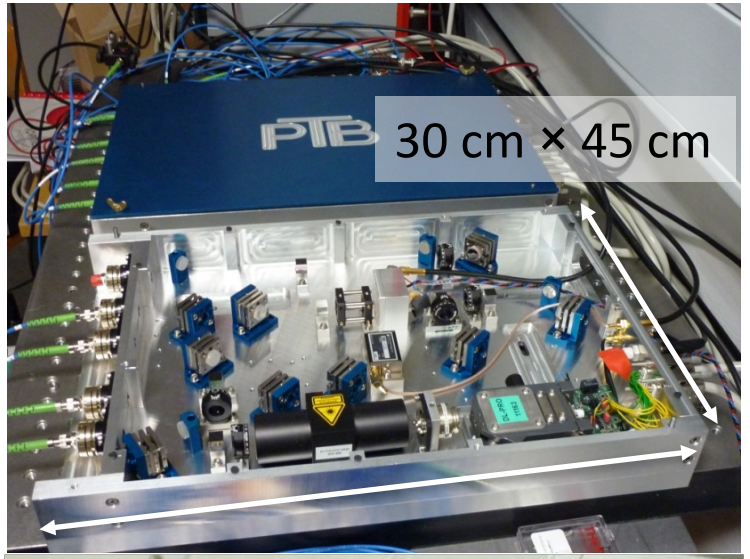


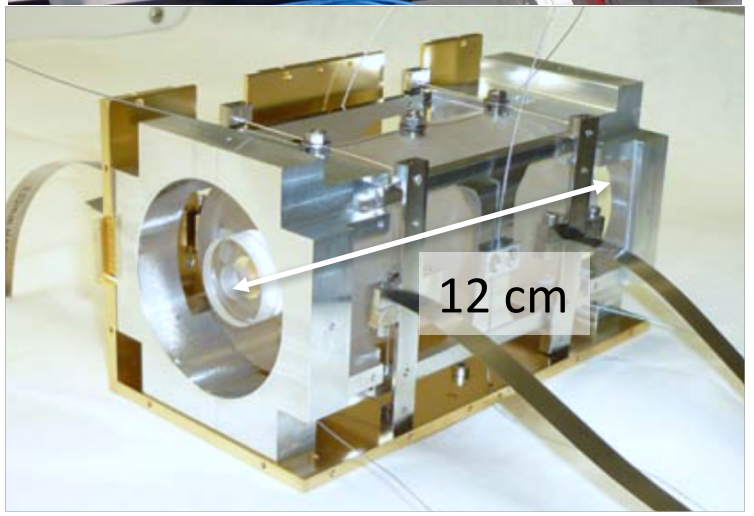
Sr

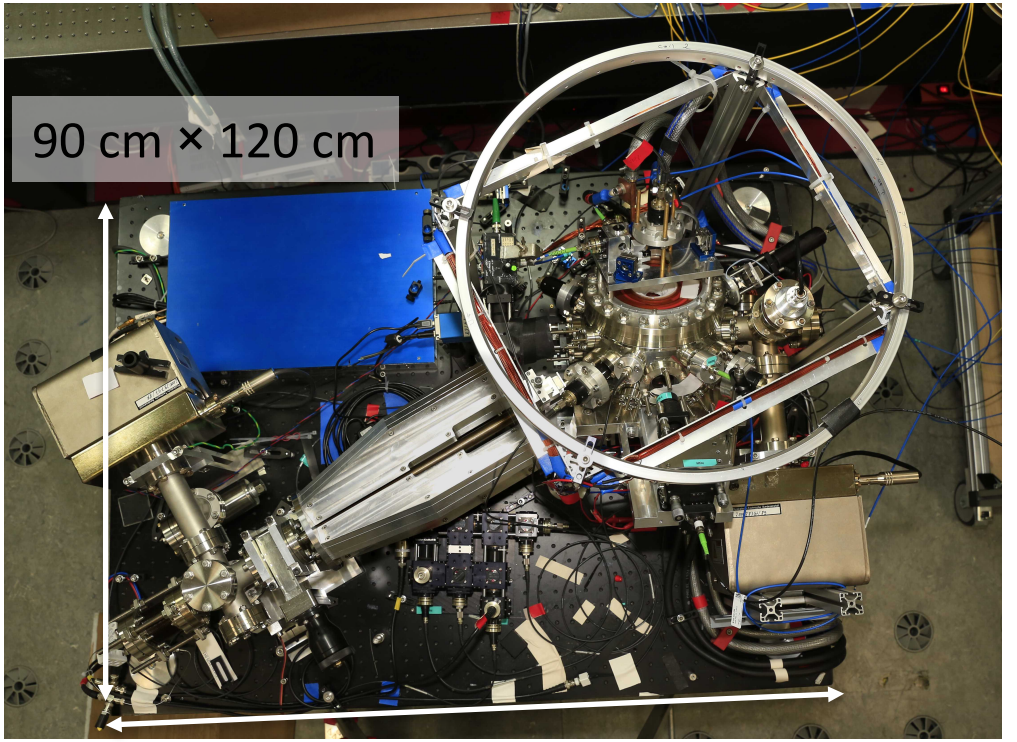




Making the Sr clock transportable





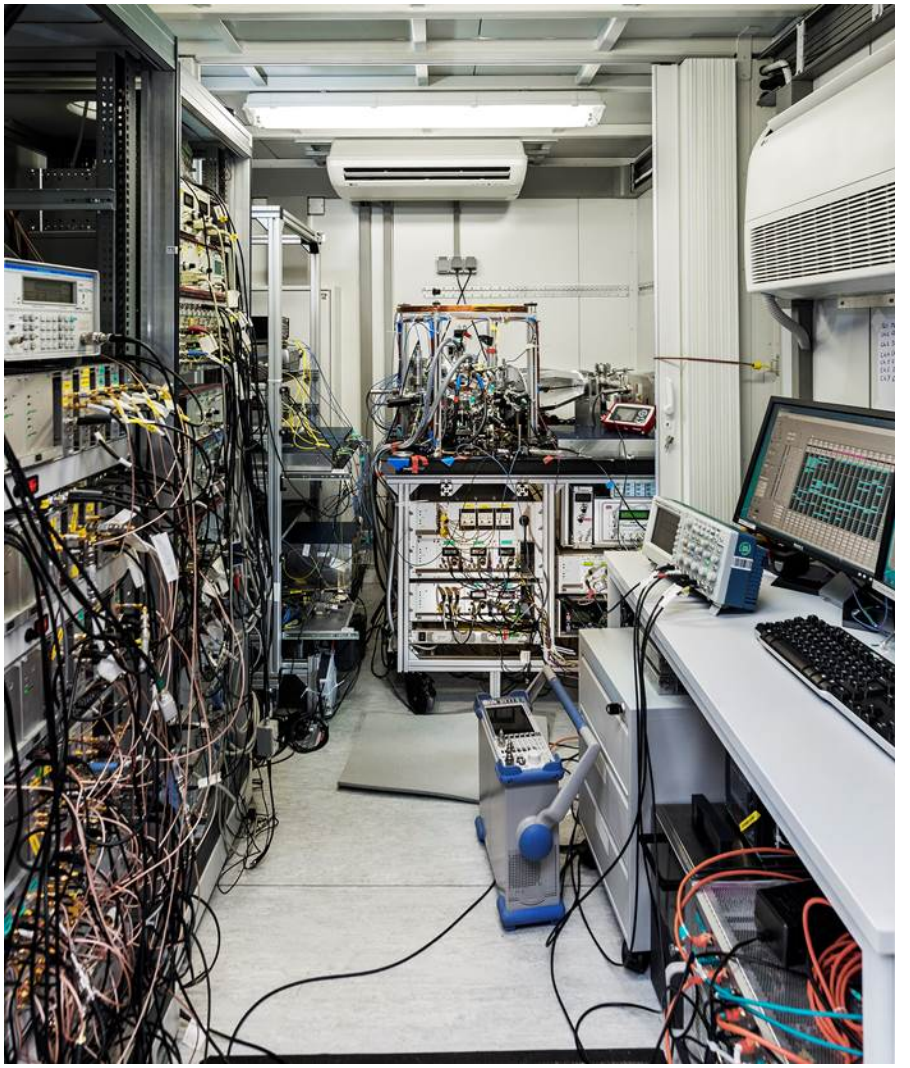


S. Vogt *et al.*, J. Phys.: Conf. Ser. **723**, 012020 (2016)
S. Koller *et al.*. Phys. Rev. Lett. **118**, 073601 (2017)

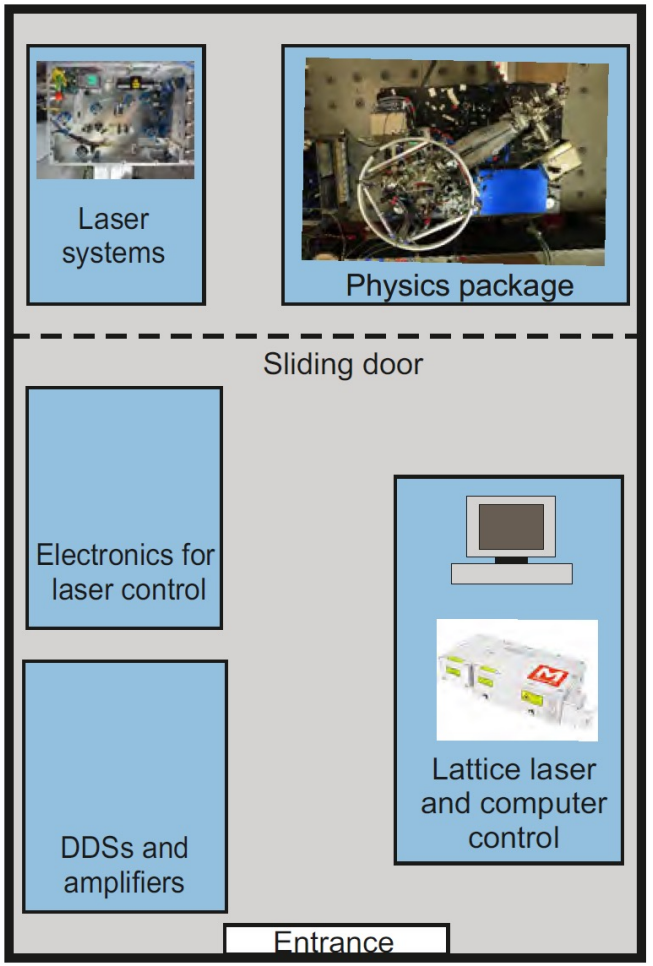
Transportable optical clocks

Car trailer housing the clock

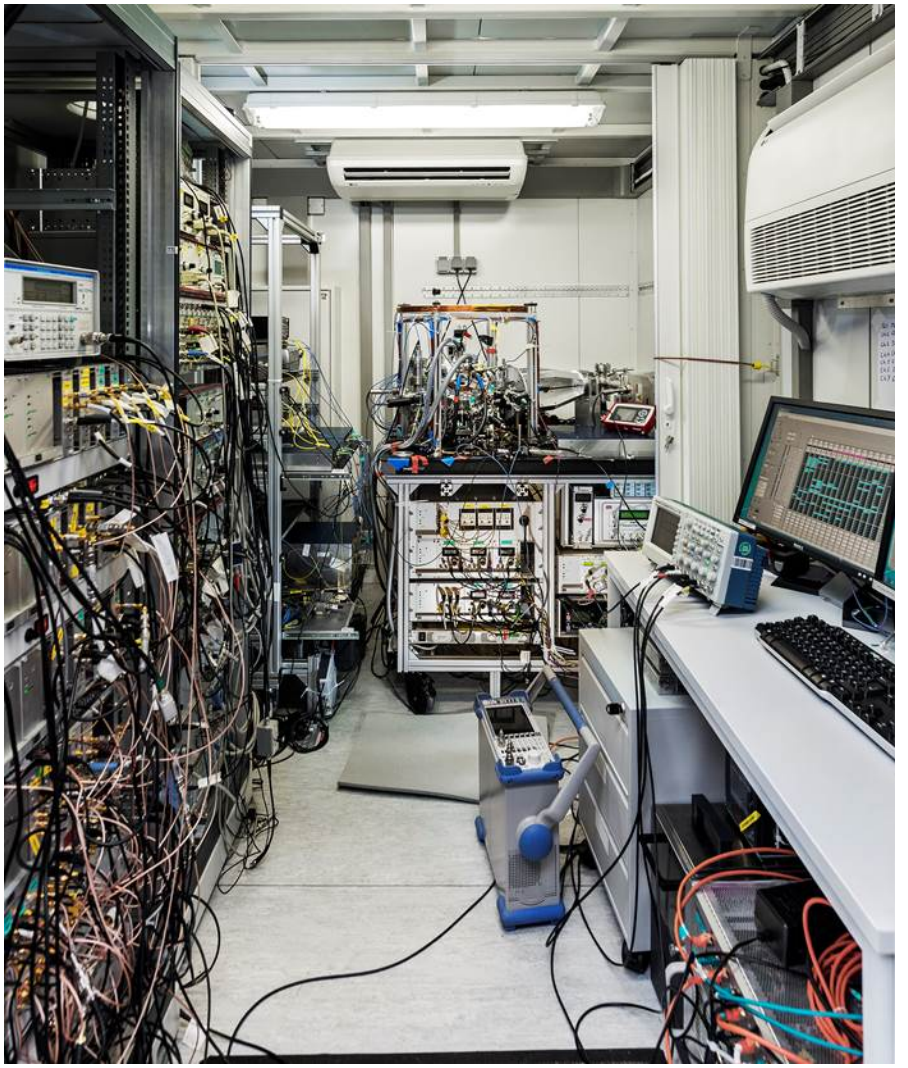
View into the car trailer ▶



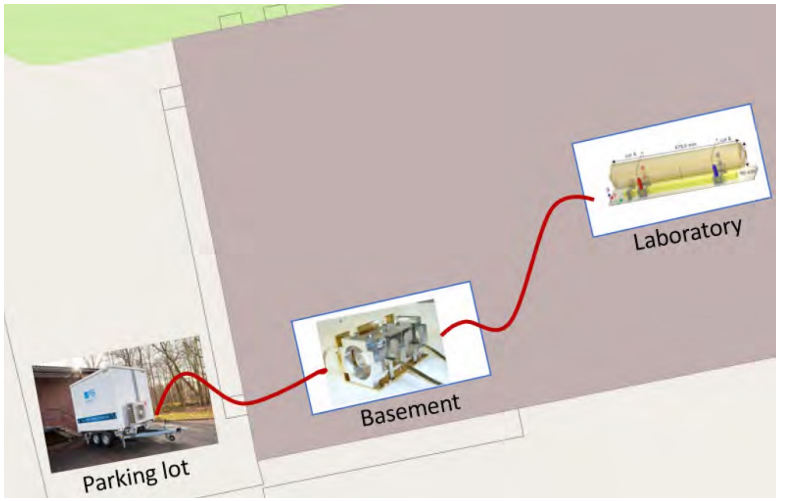
Transportable optical clocks

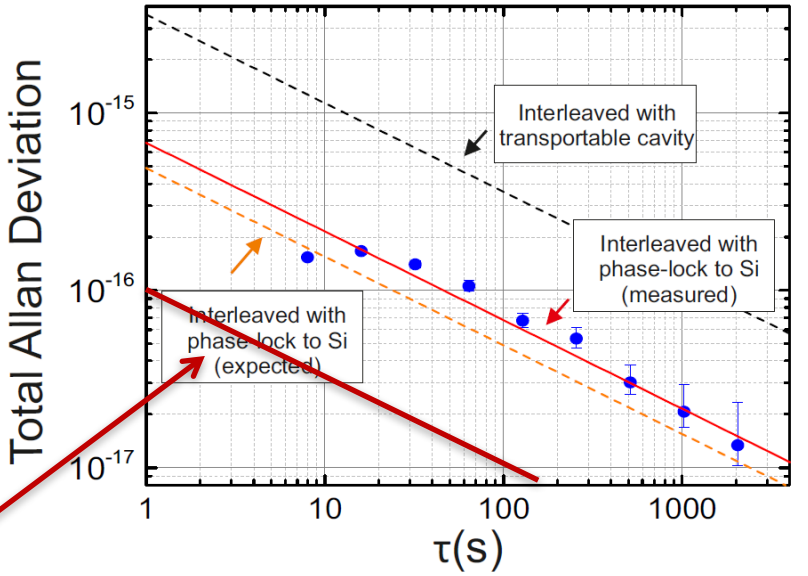


View into the car trailer ▶



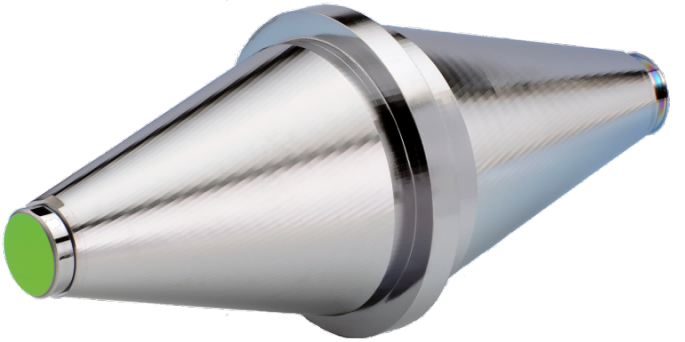
Further testing at PTB – know your clock



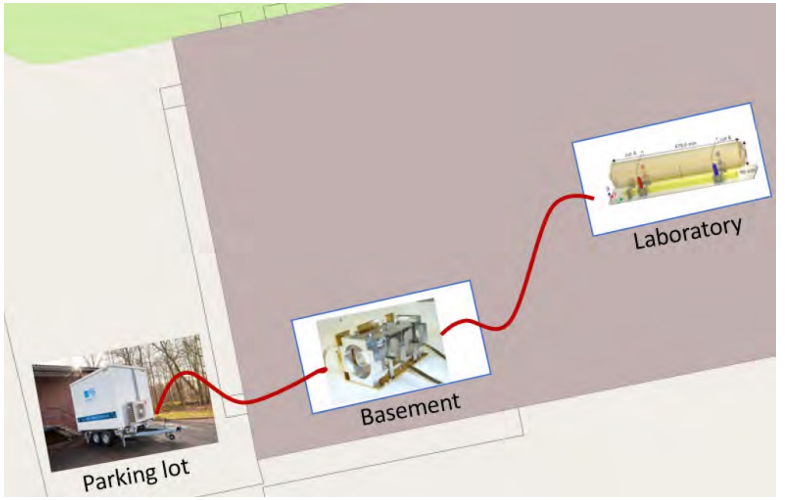


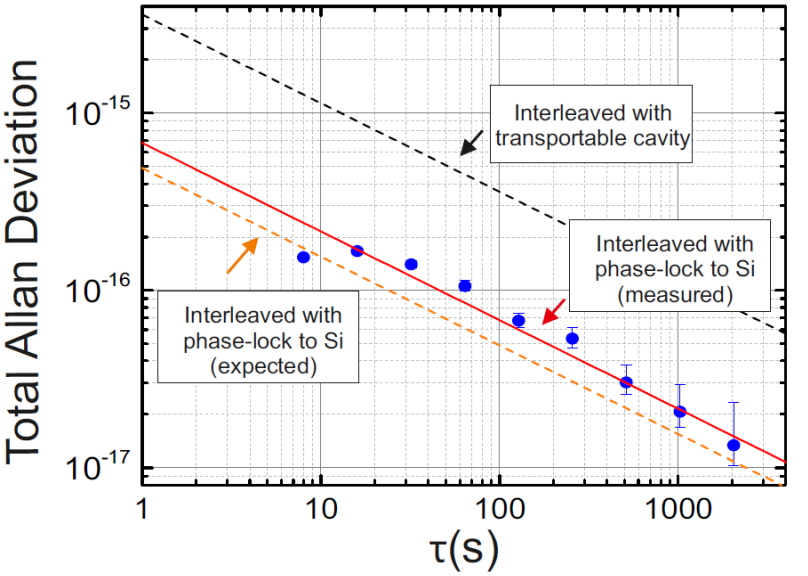
expected instability of Sr laboratory clock

faster averaging using laboratory lasers

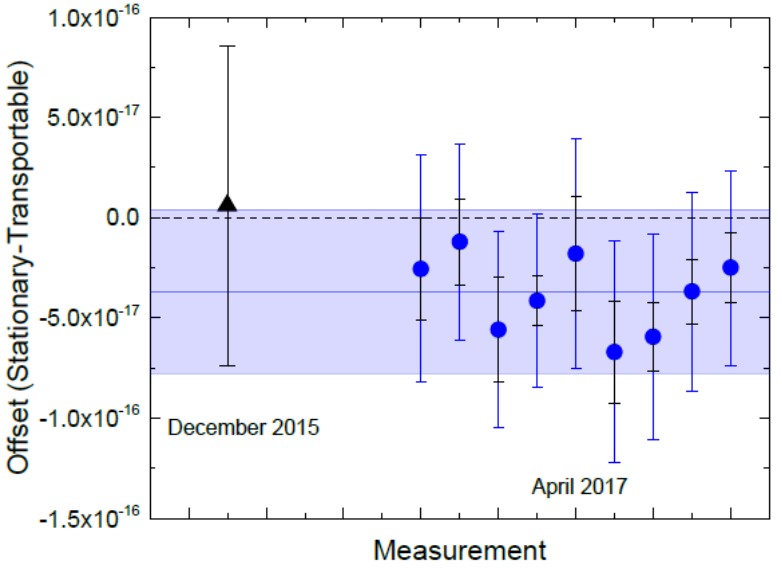


Further testing at PTB – know your clock



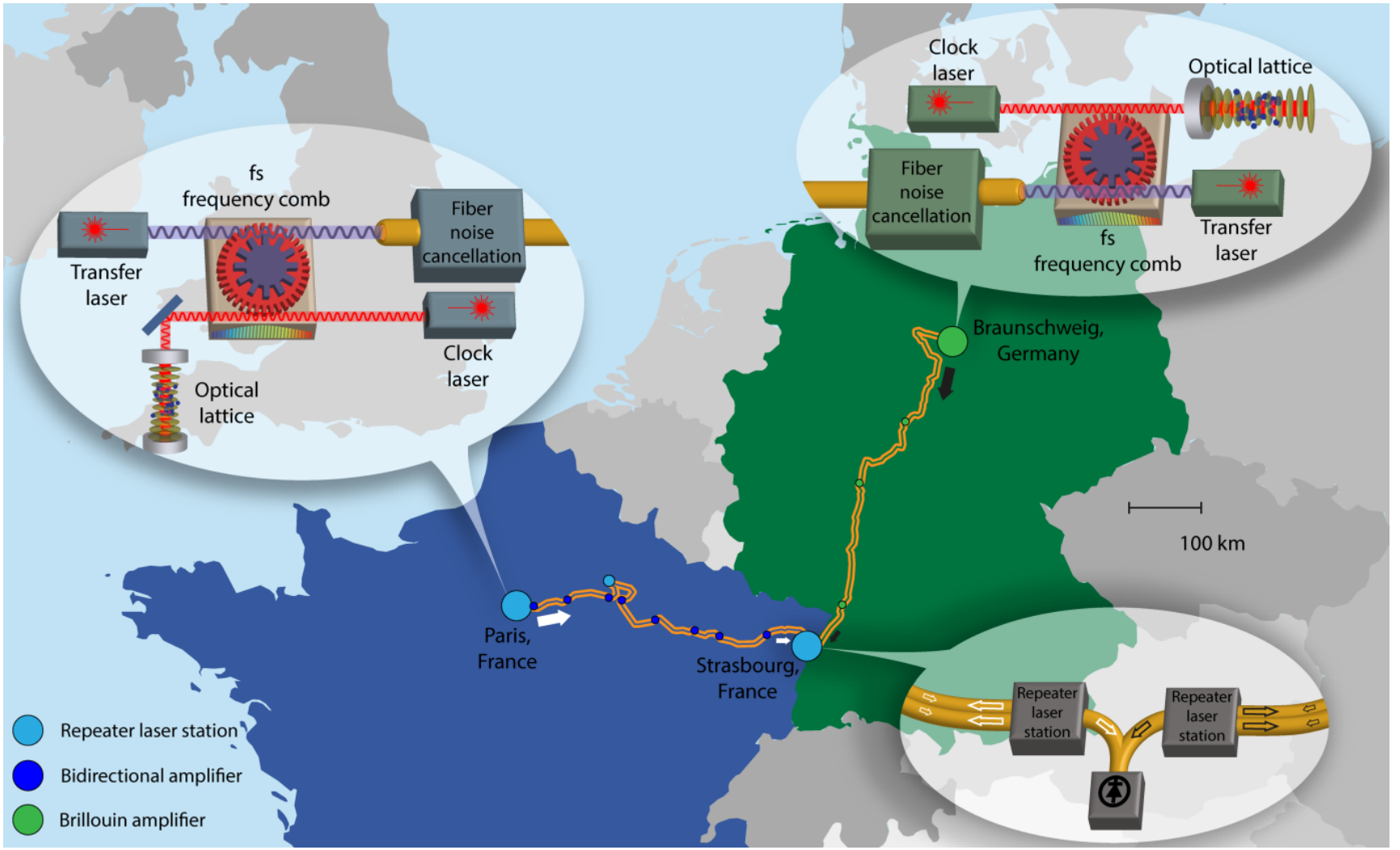


faster averaging using laboratory lasers



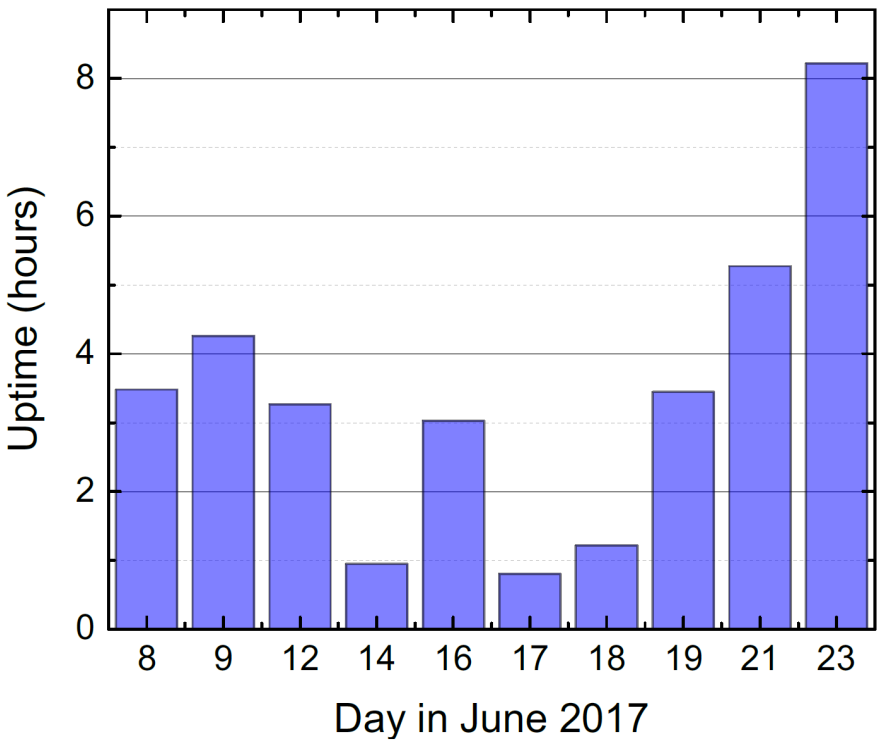
$\nu_{stat}/\nu_{trans} - 1 = -37(41)\times10^{-18}$

Second campaign: Paris – Braunschweig 2017



Second campaign: Paris – Braunschweig 2017

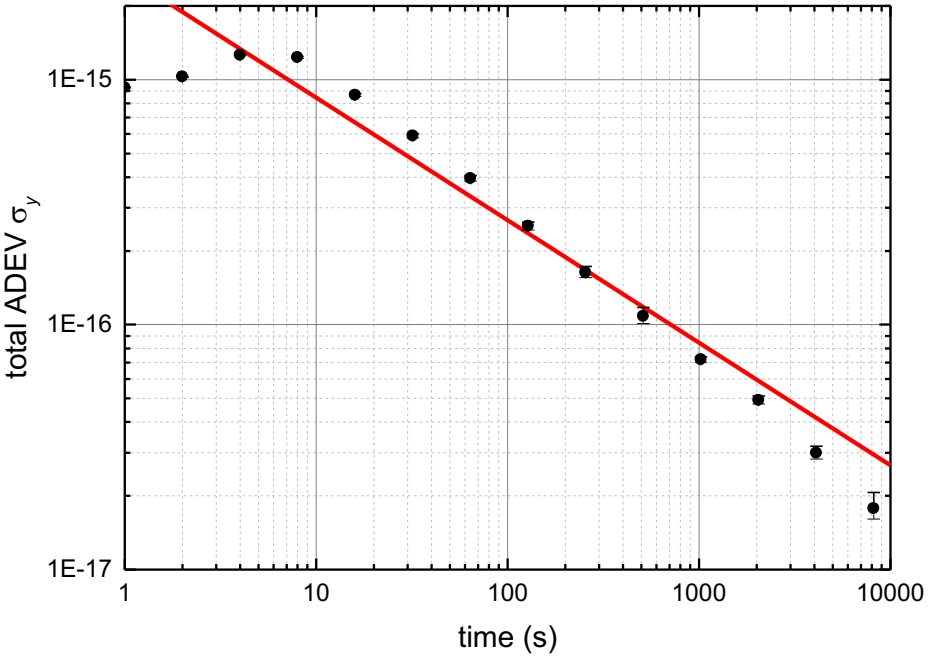
Recording data:



Systematic effect	Correction	Uncertainty
Lattice light shift	0.17	0.96
BBR Ambient	534.05	0.68
BBR oven	0.98	0.98
2^{nd}-order Zeeman shift	11.21	0.46
Collision	0.43	0.79
Probe light shift	0.036	0.036
DC Stark shift	0	<0.1
Servo error	0	0.97
Optical path length	0	<0.1
AOM switching	0	0.2
Background gas collision	0.5	0.5
Total	**547.4**	**2.1**

values in 10^{-17}

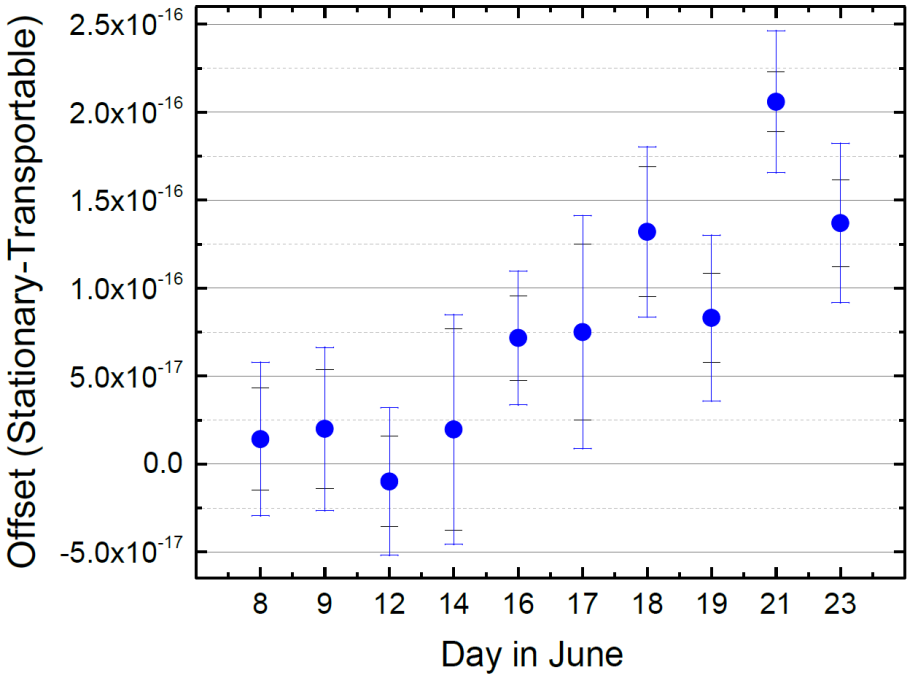
Second campaign: Paris – Braunschweig 2017

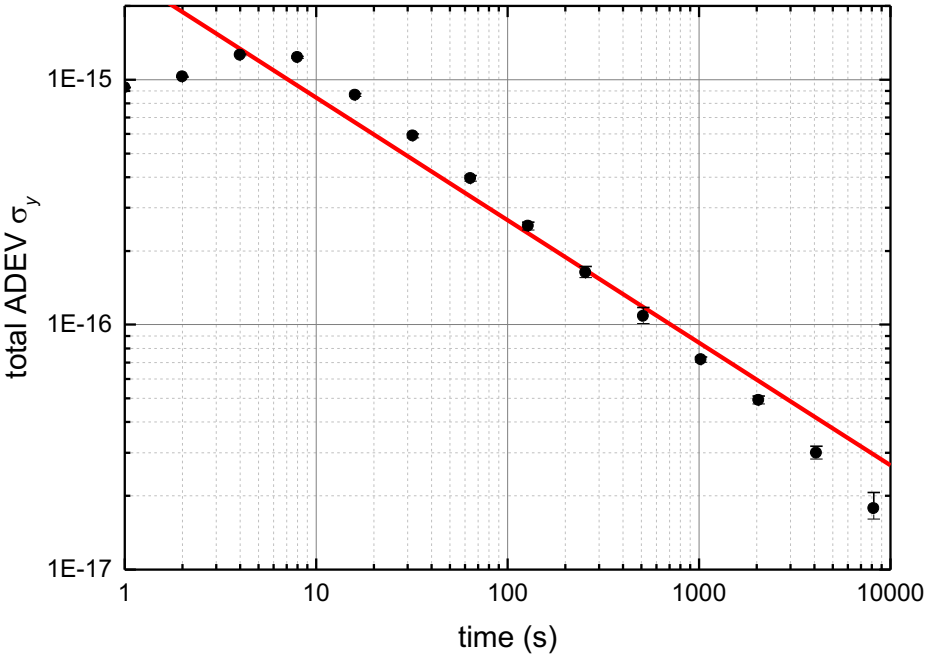


Combined uncertainty ≈ 3×10^{-17} or 30 cm in 3 hours.

Gravity potential correction from geodesy: $-247.2(4)\times10^{-17}$

Second campaign: Paris – Braunschweig 2017





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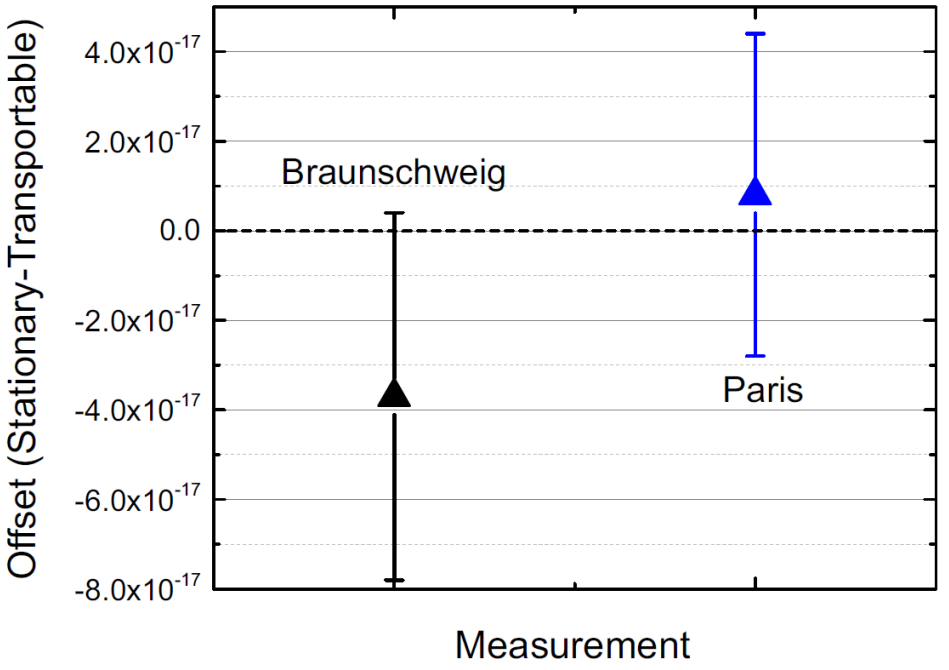
Gravity potential correction from geodesy: $-247.2(4)\times10^{-17}$

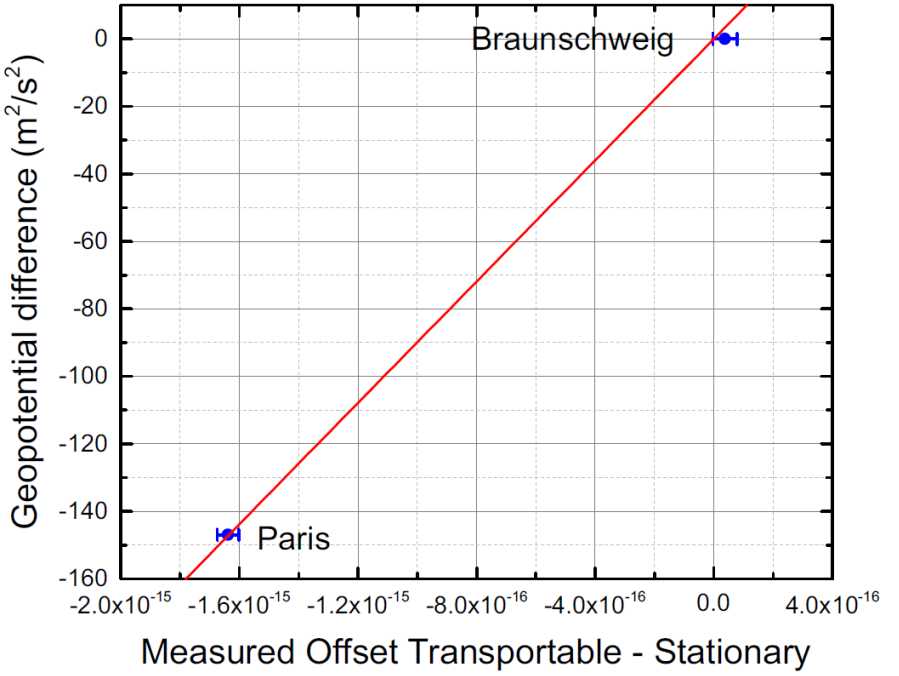
unfortunately: ‘anomaly’ in the second half of the campaign

Second campaign: Paris – Braunschweig 2017

Searching for the reason of the drifting ratio after day 4.

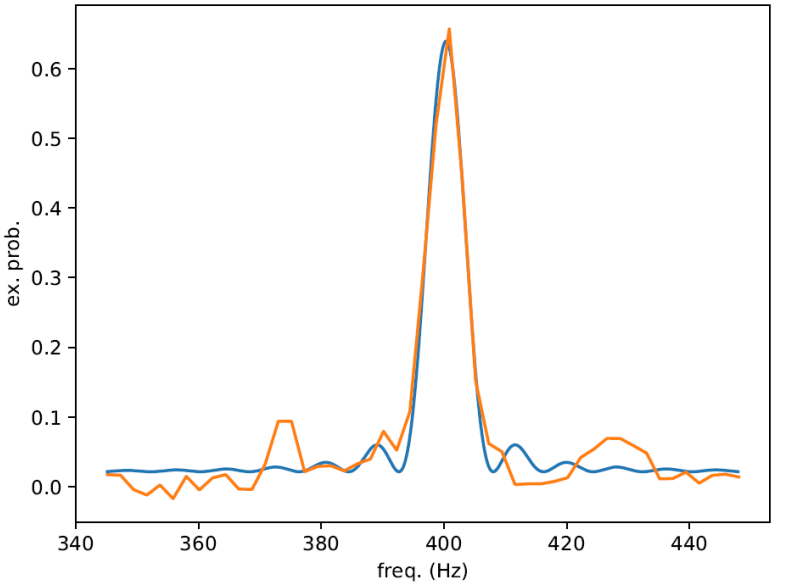
If we can ignore data after that things are quite nice.





Third campaign: Munich – Braunschweig 2018

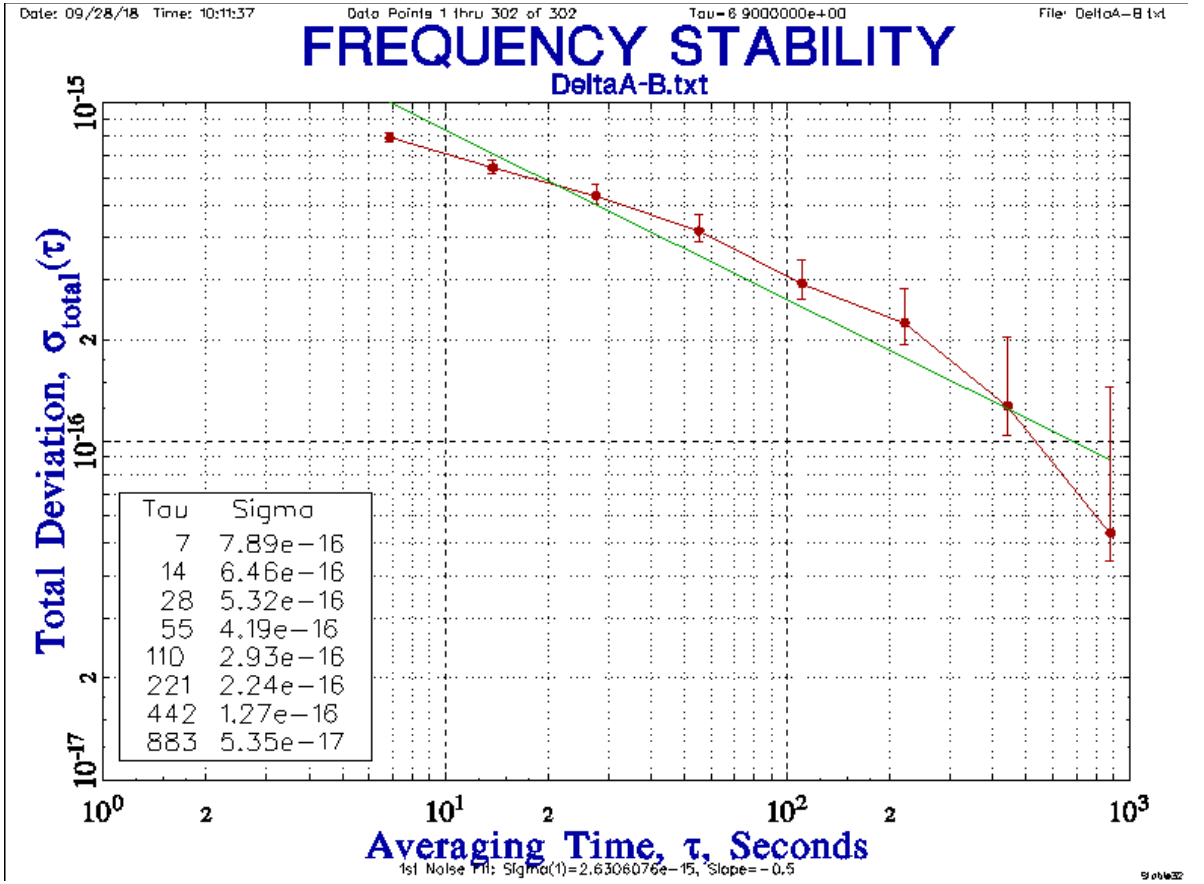
- Need for further practise and improvements
- 5 days after arrival: atoms in the lattice
- second week: problems with spectroscopy perturbation of the clock laser



Third campaign: Munich – Braunschweig 2018

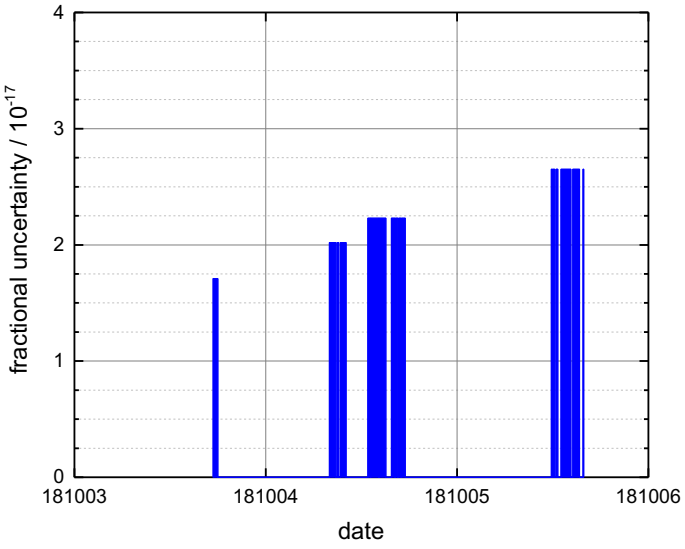
- Clock instability with laser sidebands (self comparison, evaluation of systematics)

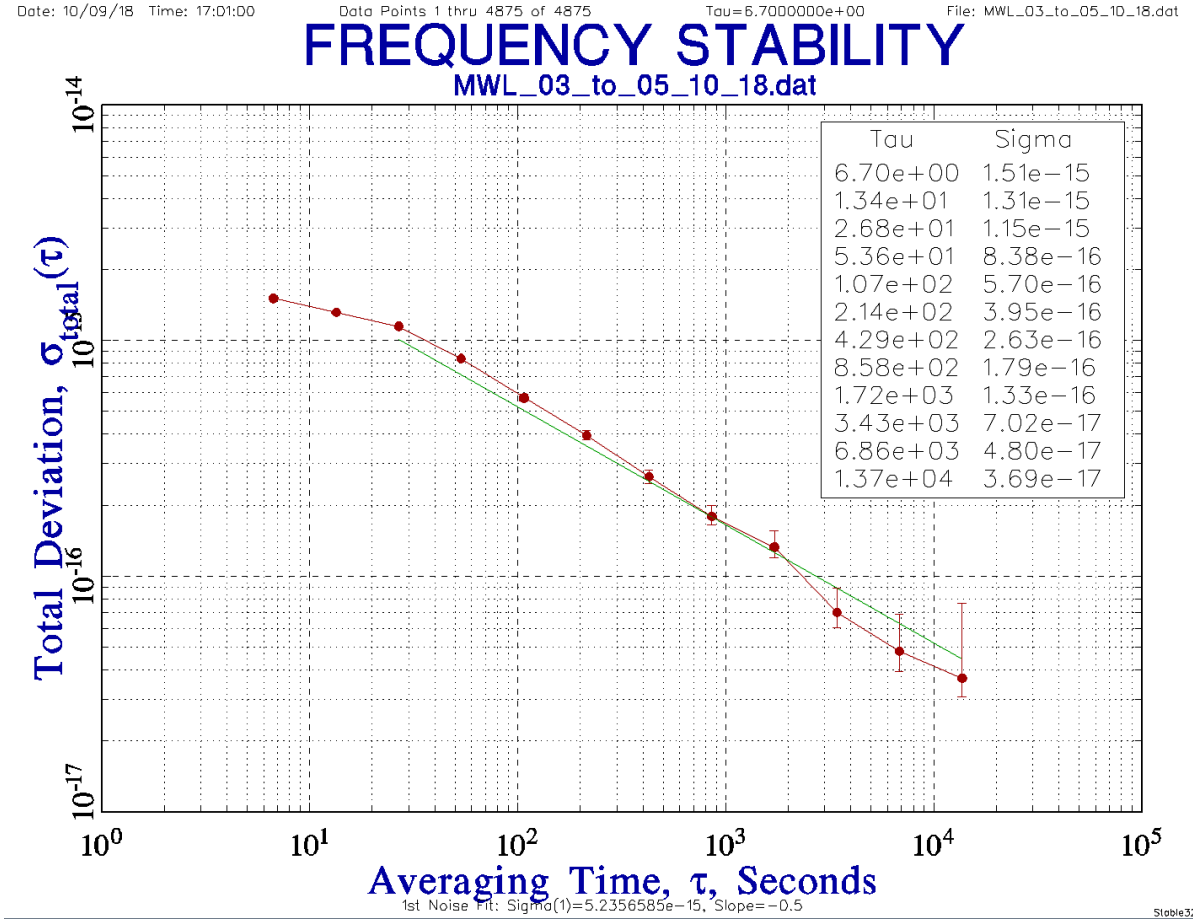
$3\times10^{-15}\,\tau^{-1/2}$



Third campaign: Munich – Braunschweig 2018

- Third week: Clock laser sidebands removed (fibre between clock laser and cavity)
- instability: $5\times10^{-15}\,\tau^{-1/2}$





In conclusion:

- There is always something new …
- Reliability is still an issue

  procedures for ‘quality management’ have to be improved

  hardware improvements are ongoing
- I still think that we can do this!

Many thanks to:

Strontium:

J. Grotti
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S. Dörscher
A. Al-Masoudi
R. Schwarz

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S. Häfner
E. Benkler
D. Matei
T. Legero
U. Sterr

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S. Koke
A. Kuhl
T. Waterholter
G. Grosche
H. Schnatz

Geodesy (U Hannover):

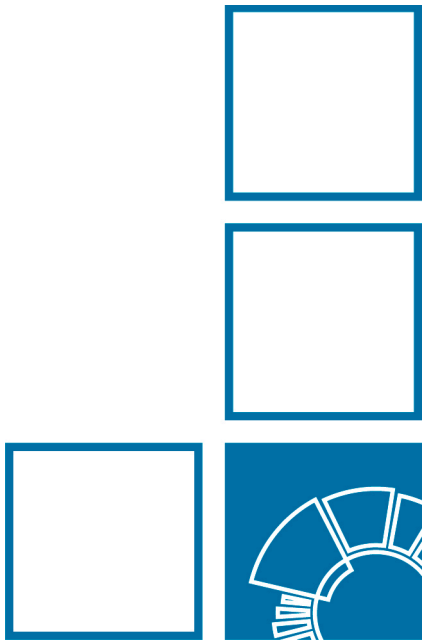
H. Denker
L. Timmen

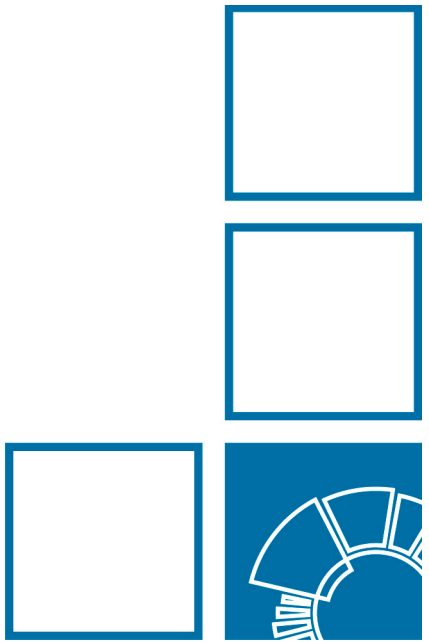
Teams Paris – Braunschweig:

R. Le Targat (SYRTE)
P.-E- Pottie (SYRTE)
O. Lopez (LPL)
A. Amy-Klein (LPL)

Teams Munich – Braunschweig:

Gulnarat (MPQ)
Michele (MPQ)
Lothar (MPQ)
Thomas (MPQ)
Ronald (MPQ)





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Stand: 02/17

Strontium lattice clock

Experimental sequence

200 ms	Zeeman slower 1st stage MOT (461 nm), $T \backsim$ mK
90 ms	2nd stage MOT (689 nm)
90 ms	3rd stage MOT (689 nm), $T \backsim$ µK
65 ms	state preparation in 1D optical lattice
0.8 s – 2.6 s	Rabi interrogation (698 nm) in 1D optical lattice
	balanced detection

Partial level diagram