

Time Biases in Laser Ranging measurements

Impacts on geodetic products

Reference Frame and Orbitography

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GGOS objectives

Accuracy: 1 mm

Stability: 0.1 mm/yr

[Plag, H.-P. and Pearlman, M. 2009]



Laser Ranging

Range measurement

Scale factor

Geocenter coordinates

Systematics errors

Range Bias and Time Bias

[Appleby et al., 2016], [Belli, PhD, 2017], [Exertier et al., 2017]

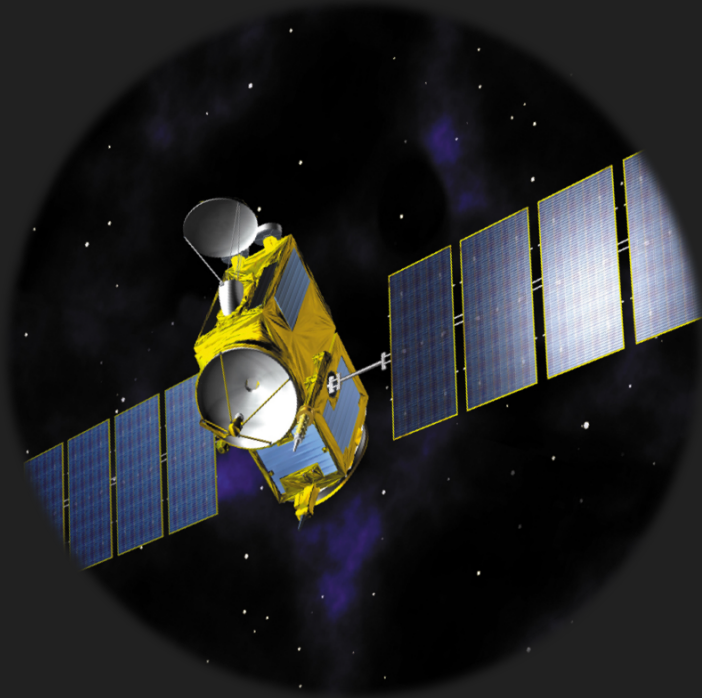


ILRS recommendations

Synchronization at +/- 100 ns wrt

UTC

[Pearlman, M., et al. 2002]



Jason-2

- *Oceanographic satellite*
- 06/20/2008 - now
- 1336 km, $i = 66^\circ$, $T \sim 110$ mn



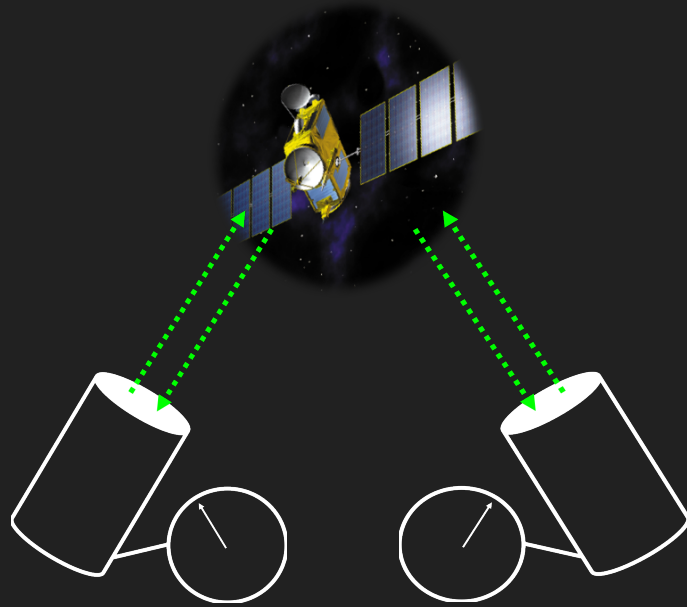
T2L2 + LRA [Samain, et al. 2008]

- *Time Transfer by Laser Link*
- Optical Time transfer
- Remote clocks synchronization
- Time biases determination



Common View Time Transfer

On-board oscillator instabilities neglected



Accuracy: 150 ps

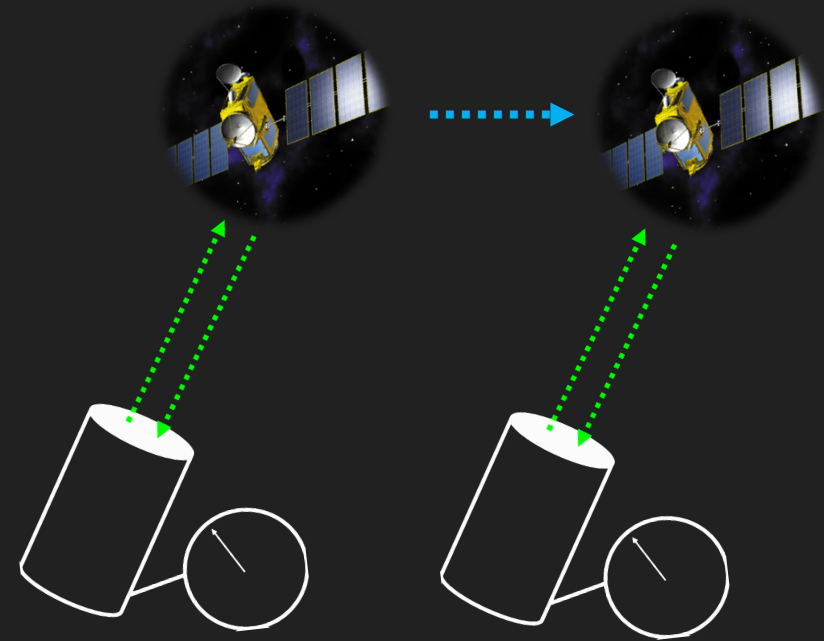
[Exertier et al., 2014]

Stability: ~ ps @ 75 s

[Exertier et al., 2010]

Non-Common View Time Transfer

On-board oscillator instabilities took into account



Integration of an on-board model for the oscillator

Accuracy: +/- 5 ns

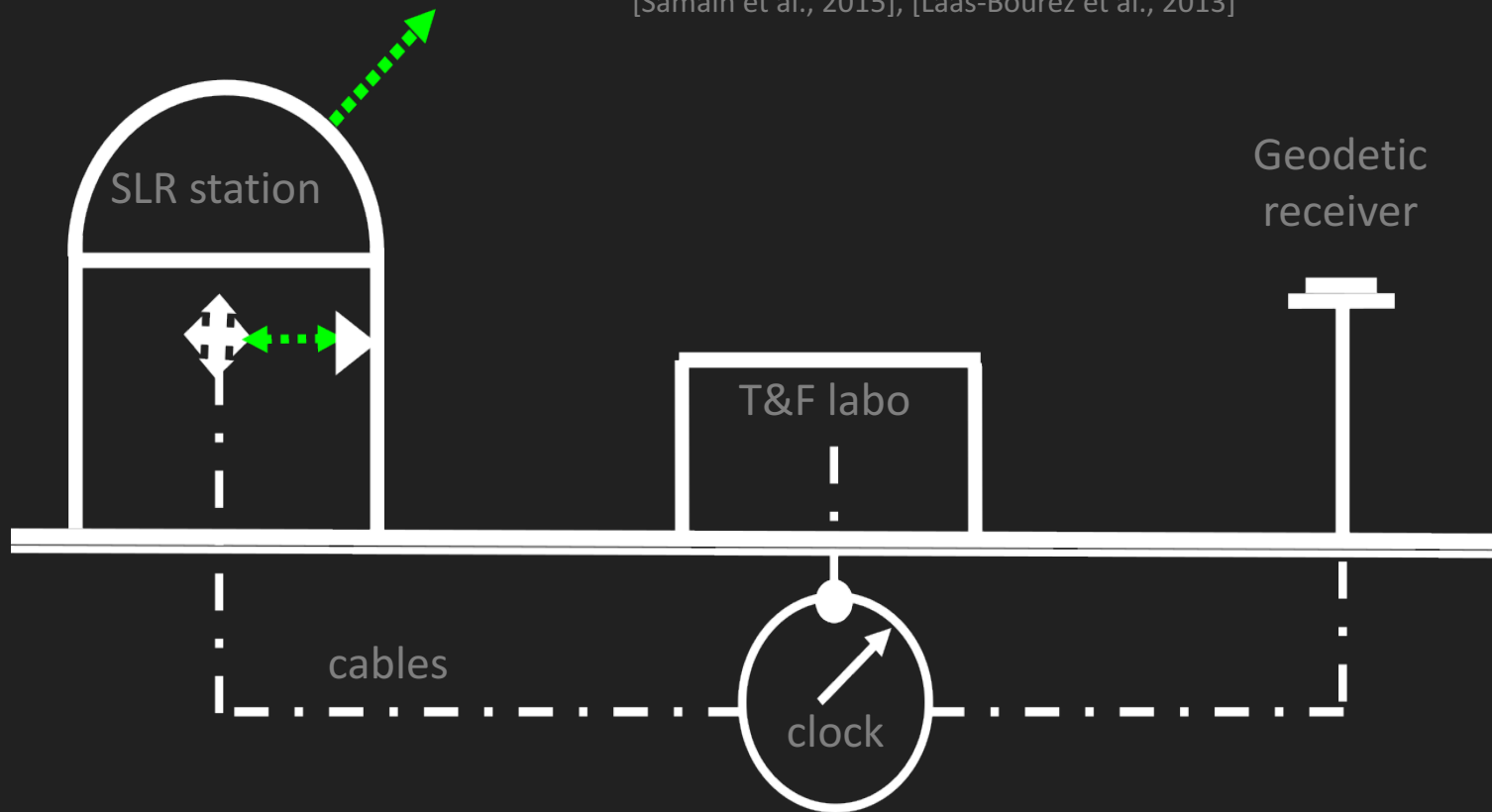
[Belli, PhD, 2017], [Exertier et al., 2017]

Compared to GPS: 0.2 ns

[Samain et al., 2017 (submitted)]

A station linked to UTC/TAI as reference: [Grasse 7845](#)

[Samain et al., 2015], [Laas-Bourez et al., 2013]



Time Biases monitored +/- 5 ns UTC

Time Biases include :

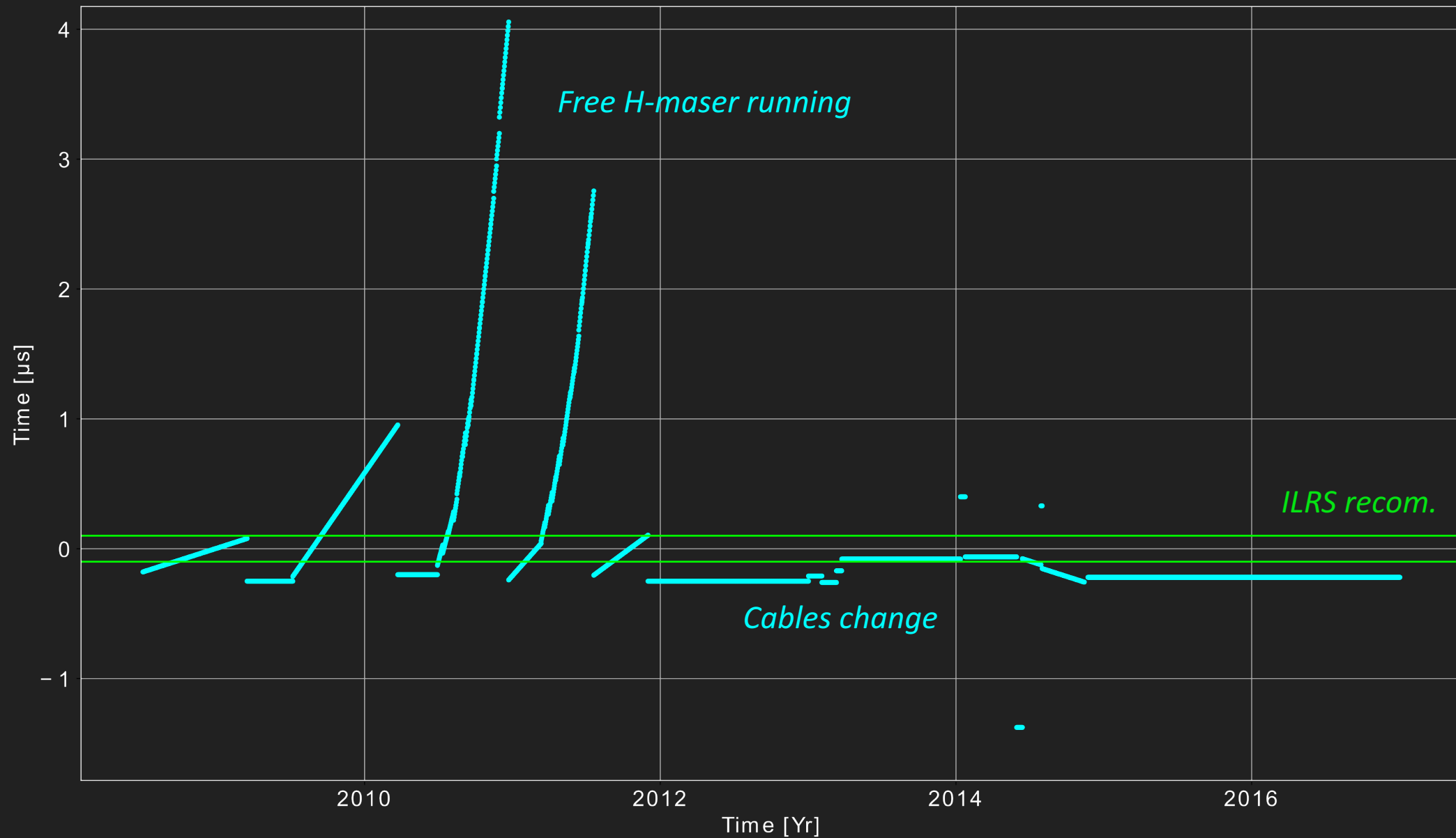
- Stability of the clock
- Calibration (antenna, cables...)
- Event timer (ns, ps resolution)
- Manual operation, changes...

$$E(t)_i = E(t)_{UTC,i} + TB_i$$

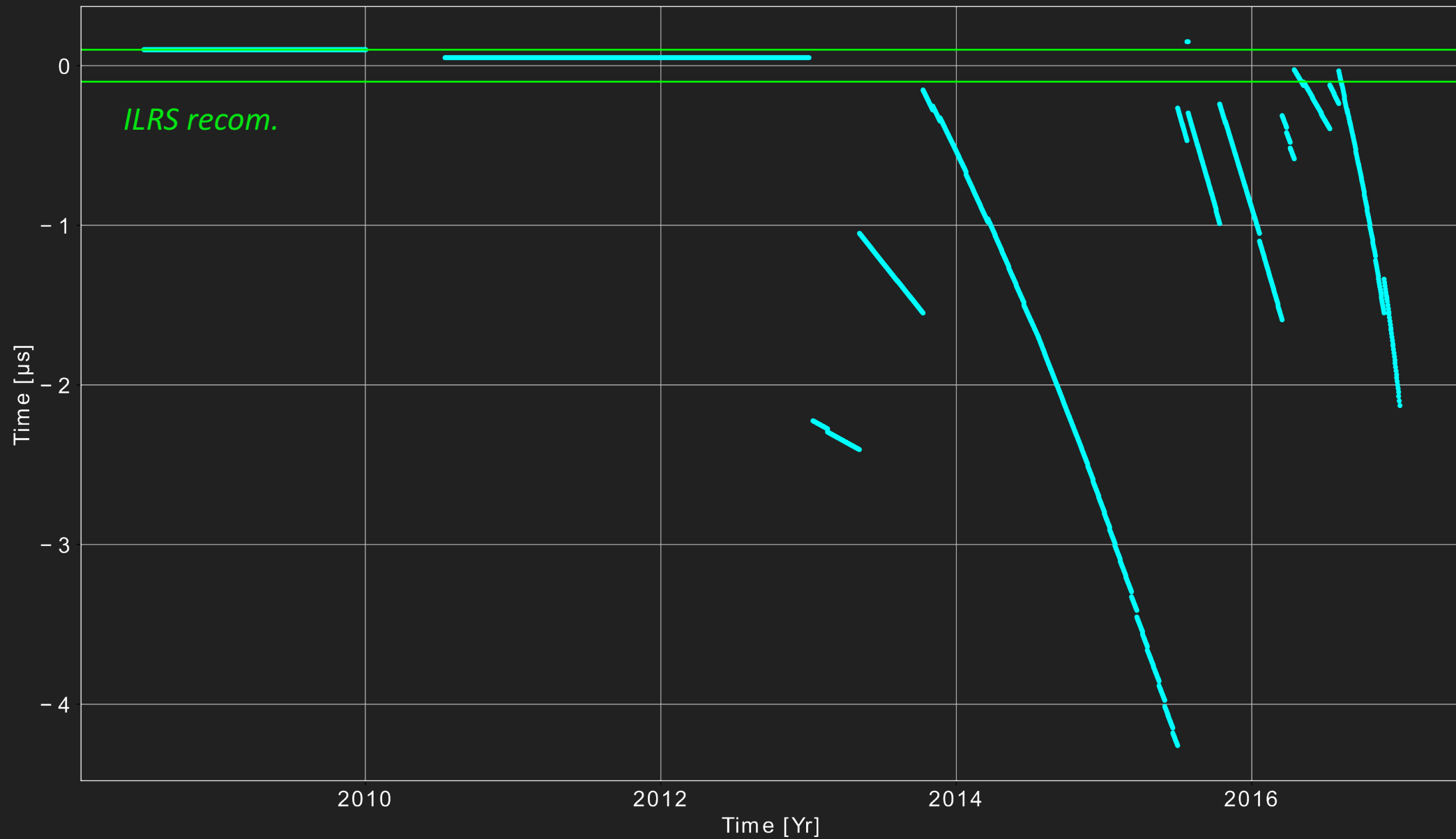
Data available: *warn the ILRS community*

	2008-2017		2016-2017		2009-20017		2008-2011
7080	7237	1888	1824		7308		7832
7090	7810	1889	1831		7838		
7105	7811	1890	1873				
7110	7821	1891	1873		2012-2017		2010-2017
7124	7824	7407	1893		7406		7119
7403	7825	7394	1868				
7501	7848	1884	1874		2010-2011 (5 mths)		2011 (5 mths)
7840	7841	1886	1824		7358		7822
7841	7941						
7845	8834						

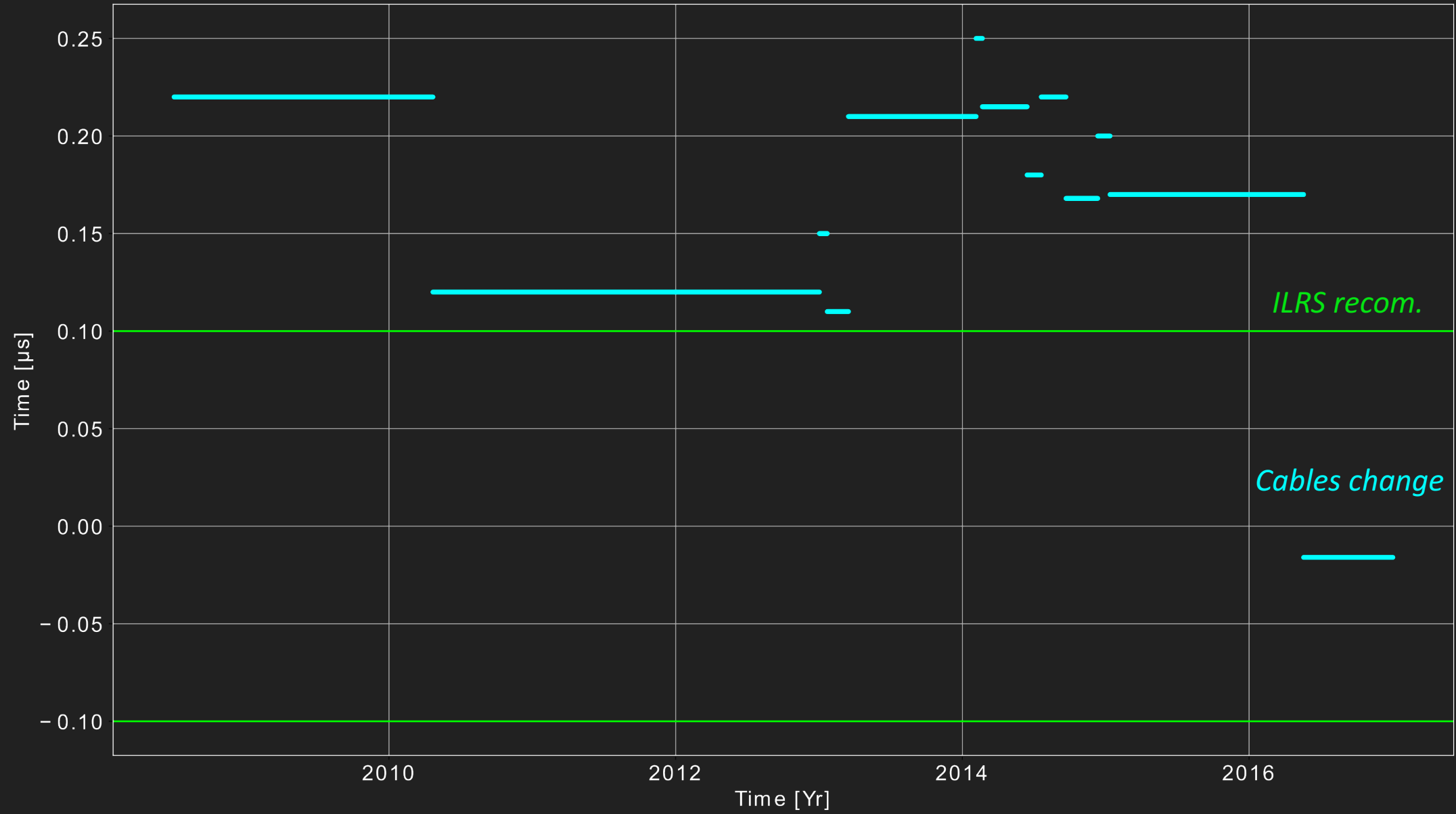
7845



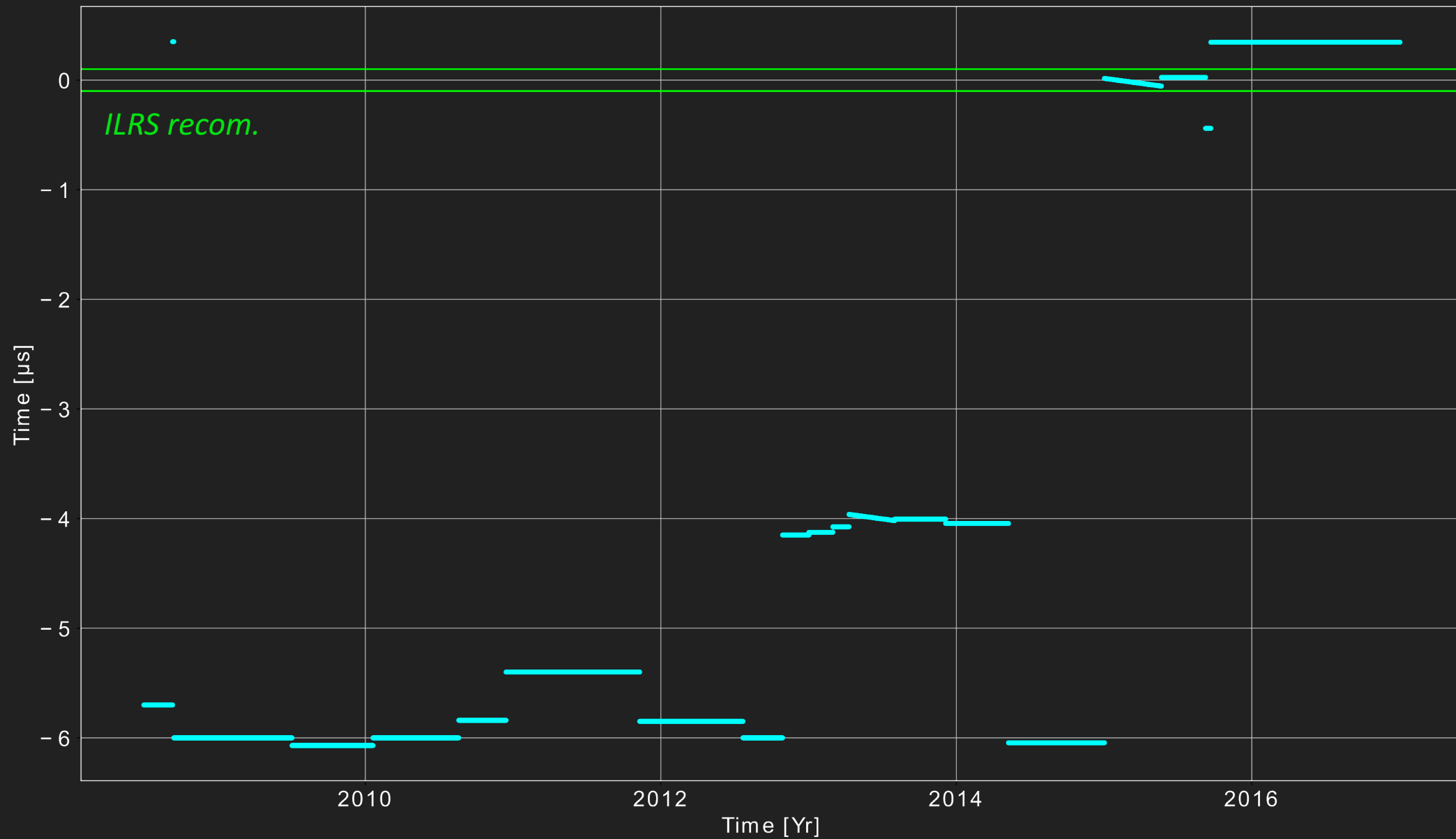
8834



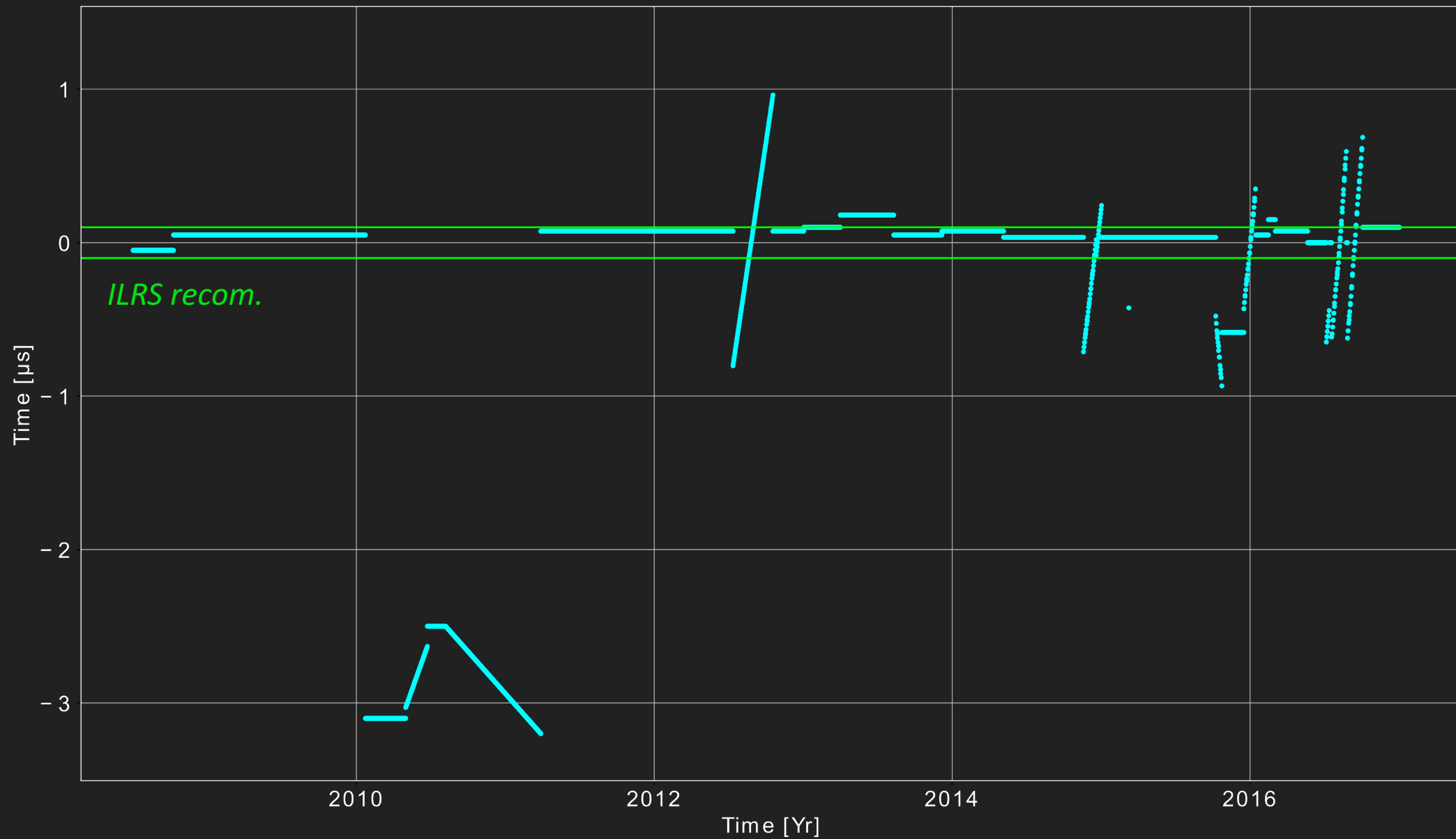
7840



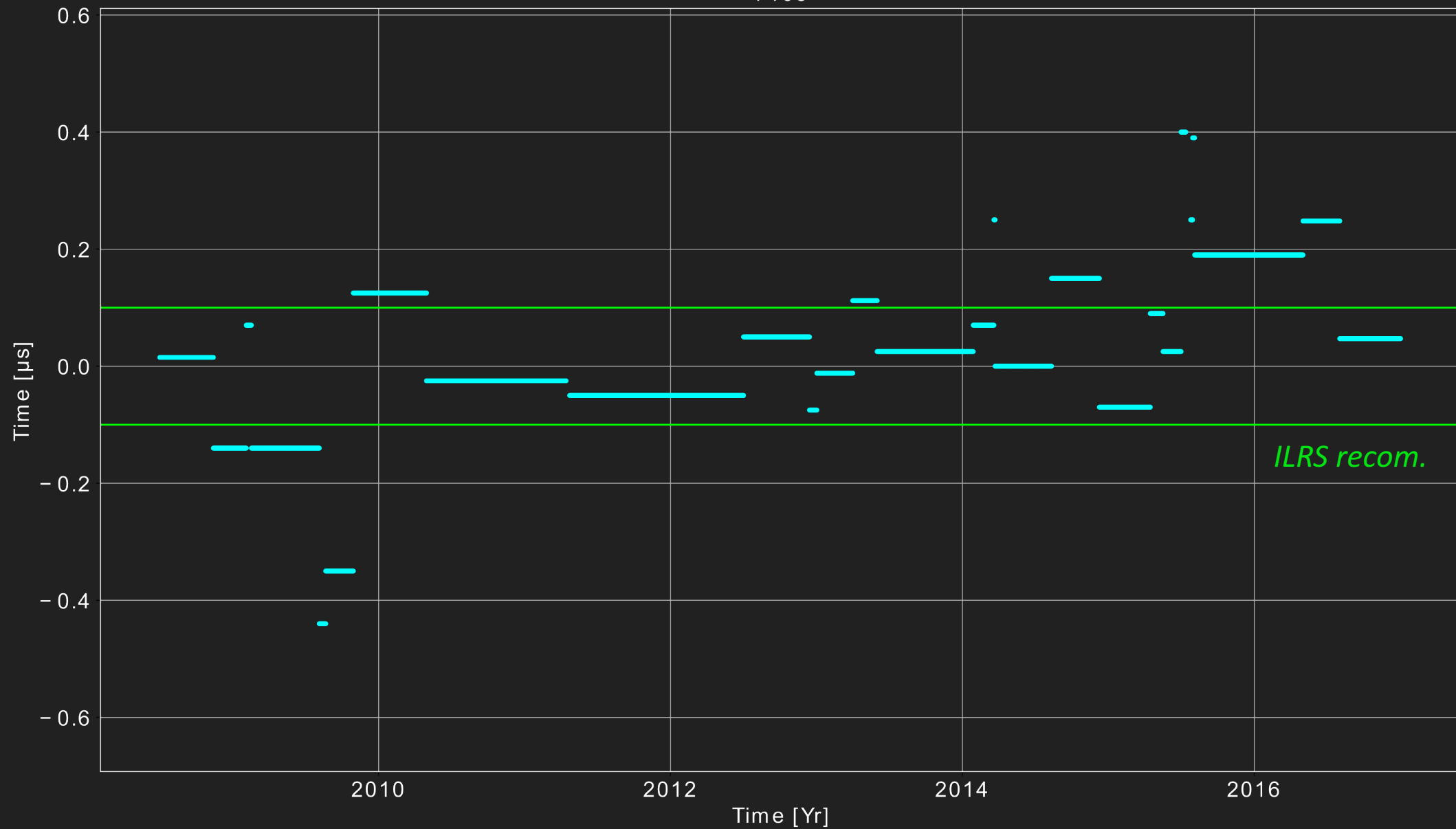
7501



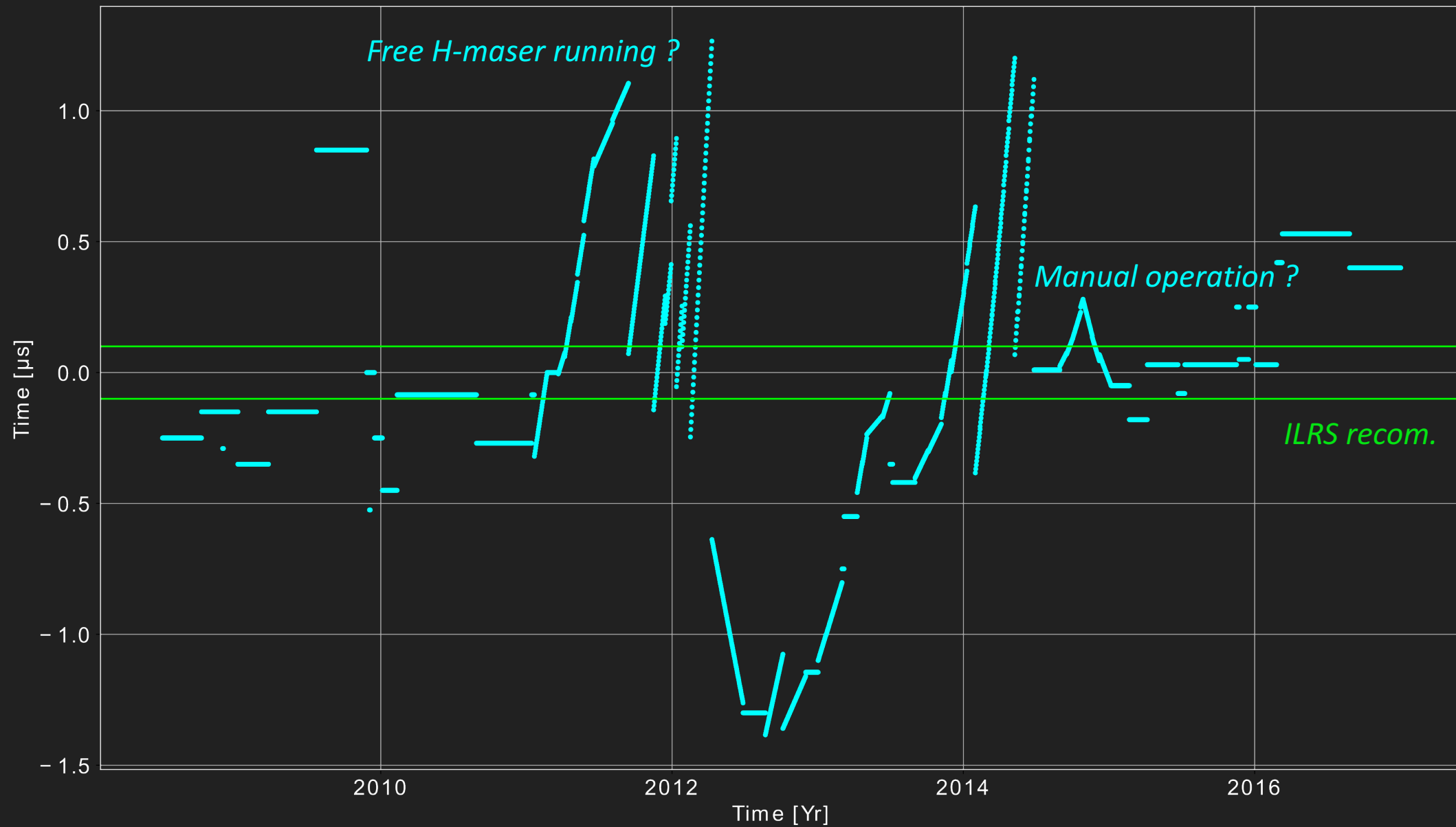
7237



7105



7090



Dealing with Time Biases

- Complete **calibration** (cables, time distribution, antenna (GPSDO))
- **Stability** of the clock (e.g., free running oscillators)
- **Event timer** (good resolution = ps)
- Following **continuously** Time Biases
- Every **changes** on the technology should be noticed

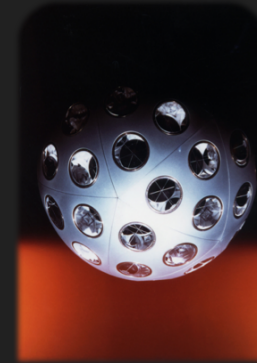
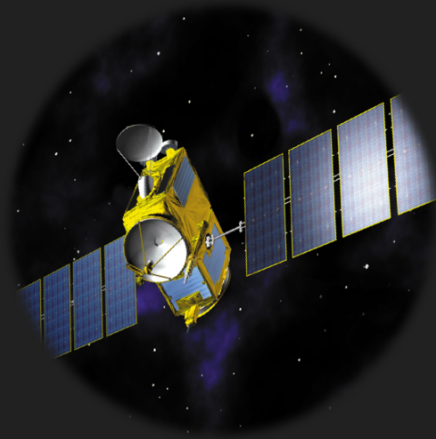


Effects on geodetic products

e.g. 2013-2014

P.O.D Jason-2 (mean)

- Along-track: 4 mm
- Cross-track: 2 mm
- Radial: 1 mm



P.O.D Starlette (R.M.S)

- Global: 0.3-0.5 mm



P.O.D Lageos 1 & 2 (R.M.S)

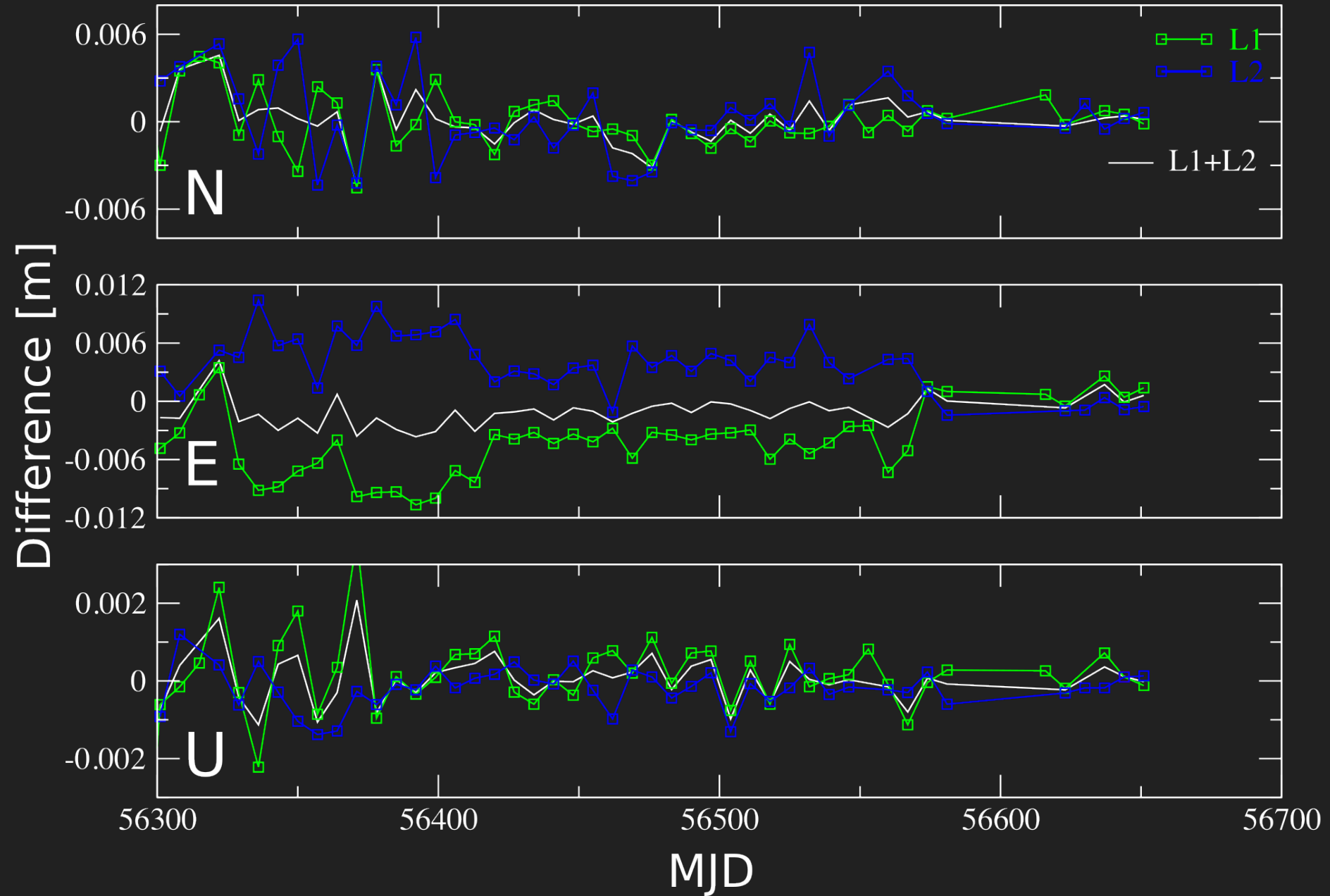
- Negligible: < 1 mm

DORIS Time bias improvement

- Accuracy: 1 μ s



Residuals w/wo Time Bias (8834)



Conclusions

- New method thanks T2L2 to determine Time Bias
- **Direct** and **independent** of the orbit calculation
- First intercontinental and optical time transfer. **Accuracy = 5 ns**
- Compared to GPS at 0.2 ns (2016 Campaign)
- **Non negligible effects on orbit components and on the station coordinates**

μs Time Bias = *mm* effects

Thank you for your attention !

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Exertier, P., Belli, A., Lemoine, J.M., 2017.

***Time biases in laser ranging observations: A concerning issue
of Space Geodesy.***

Advance in Space Research, Volume 60, Issue 5, 1 September 2017, Pages 948-968