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

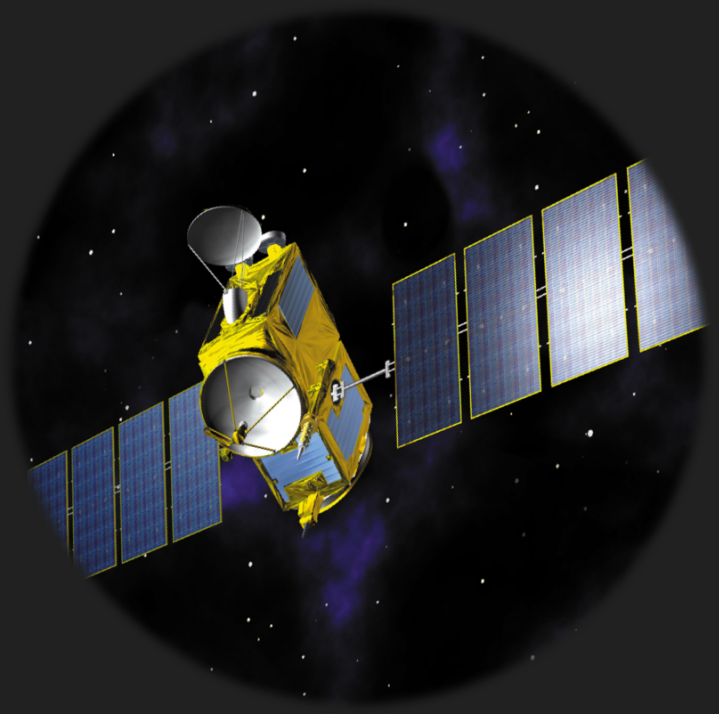
Range measurement
Scale factor
Geocenter coordinates

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

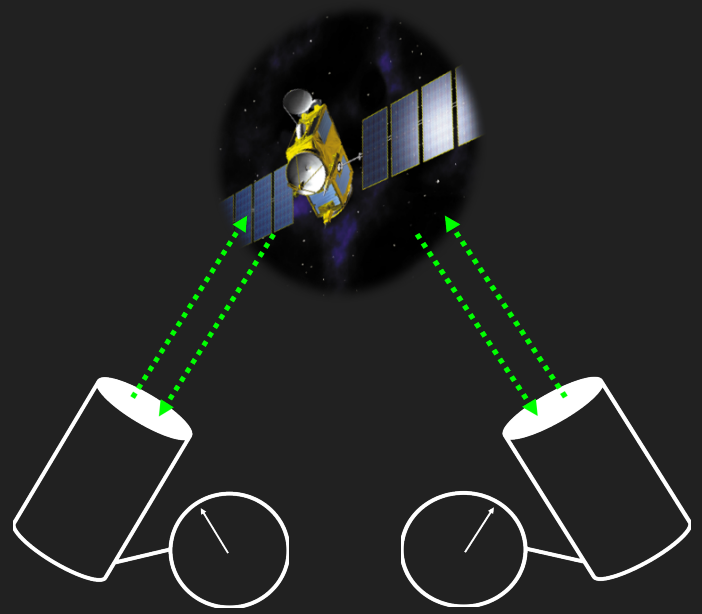
- *Oceanographic satellite*
- 06/20/2008 - now
- 1336 km, i = 66°, T ~ 110 mn

T2L2 + LRA [Samain, et al. 2008]

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

Common View Time Transfer

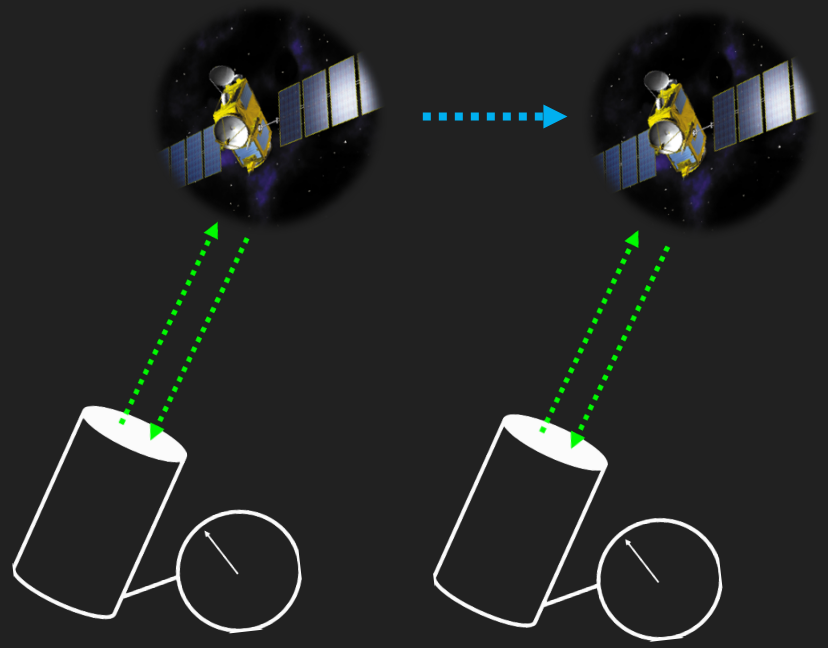
On-board oscillator instabilities **neglected**



Accuracy: 150 ps
[Exertier et al., 2014]
Stability: ~ ps @ 75 s
[Exertier et al., 2010]

Non-Common View Time Transfer

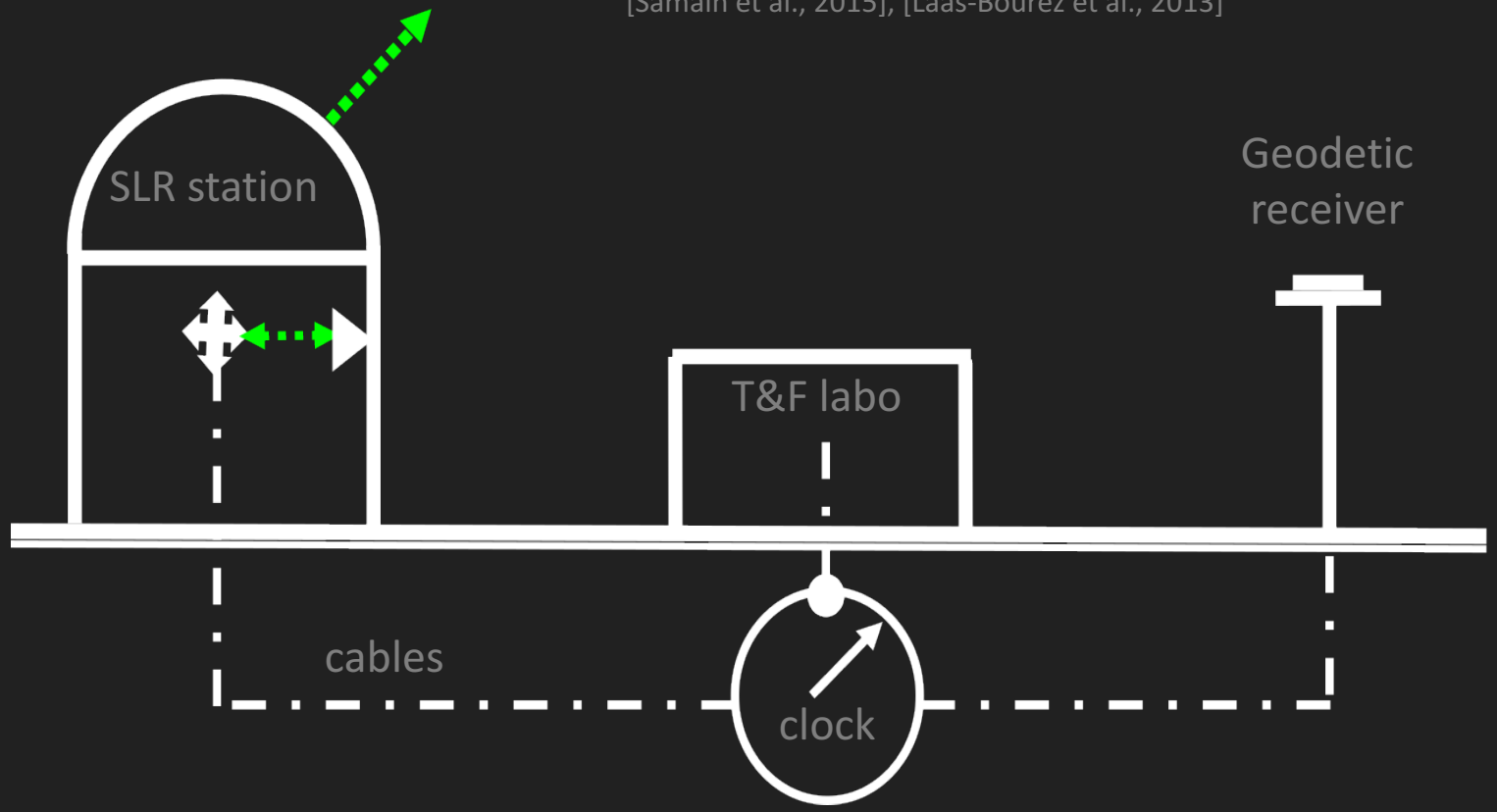
On-board oscillator instabilities **took into account**



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

7080
7090
7105
7110
7124
7403
7501
7840
7841
7845

7237
7810
7811
7821
7824
7825
7848
7841
7941
8834

2016-2017

1888
1889
1890
1891
7407
7394
1884
1886

1824
1831
1873
1873
1893
1868
1874
1824

2009-20017

7308
7838

2012-2017

7406

2010-2011 (5 mths)

7358

2008-2011

7832

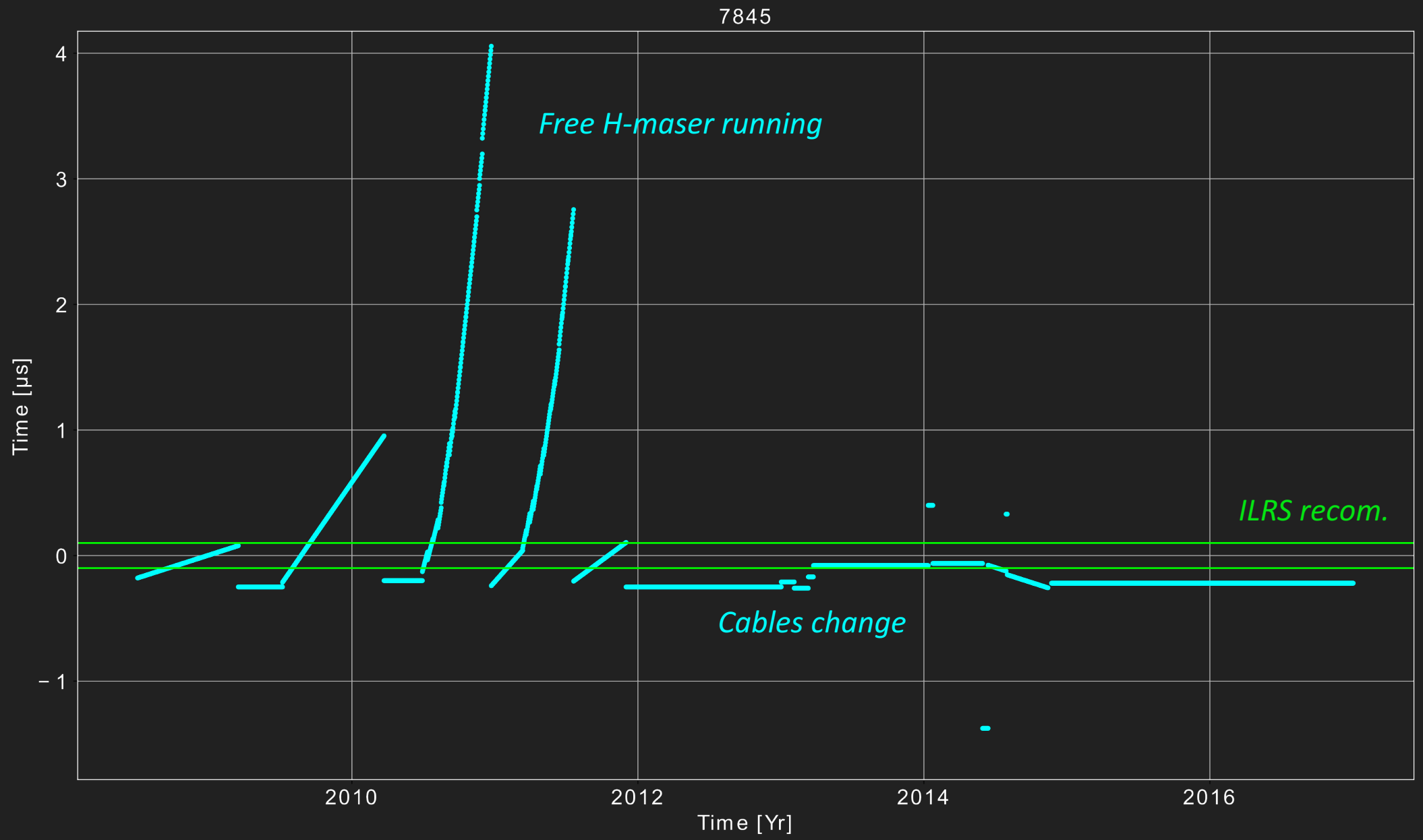
2010-2017

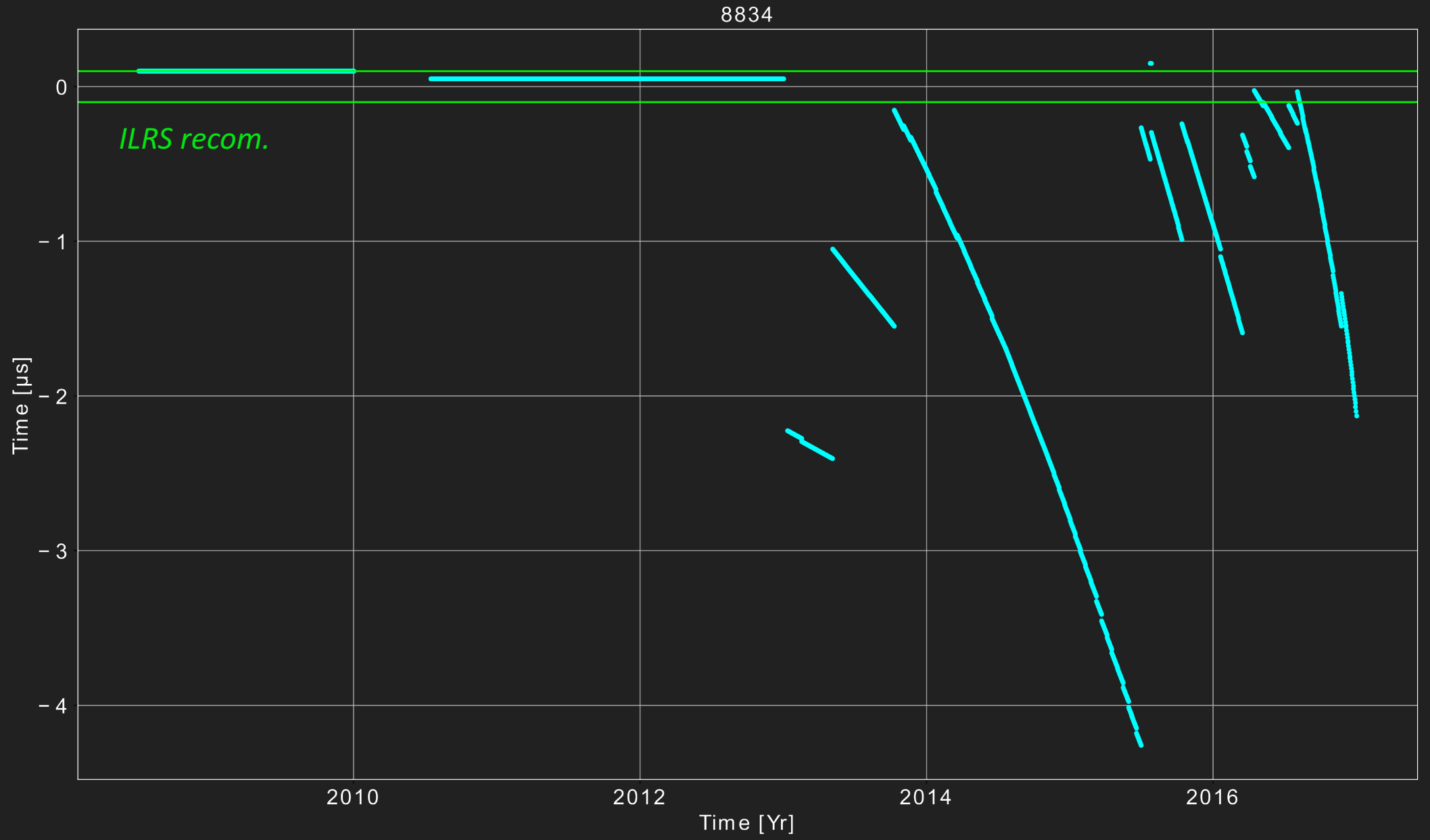
7119

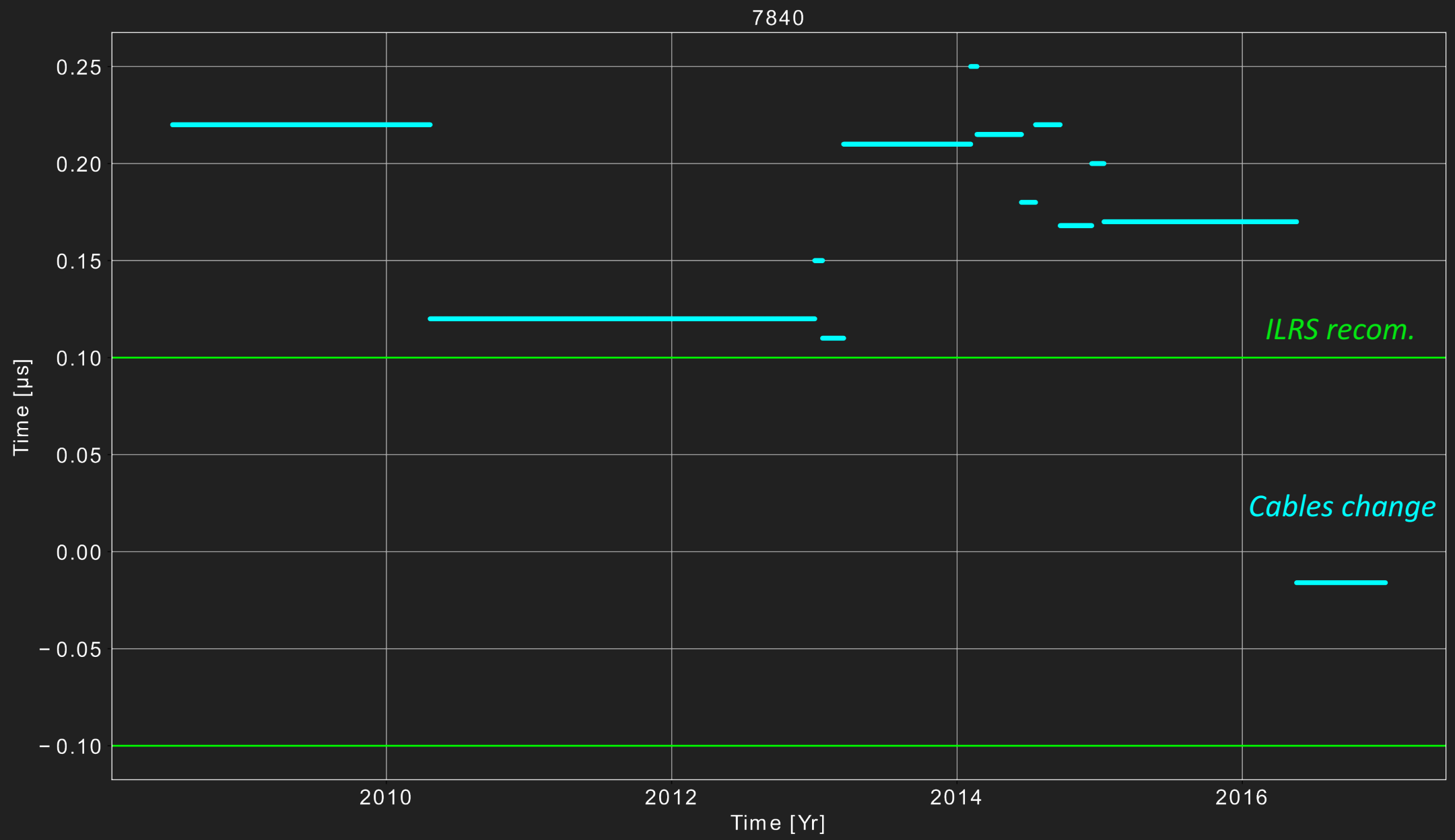
2011 (5 mths)

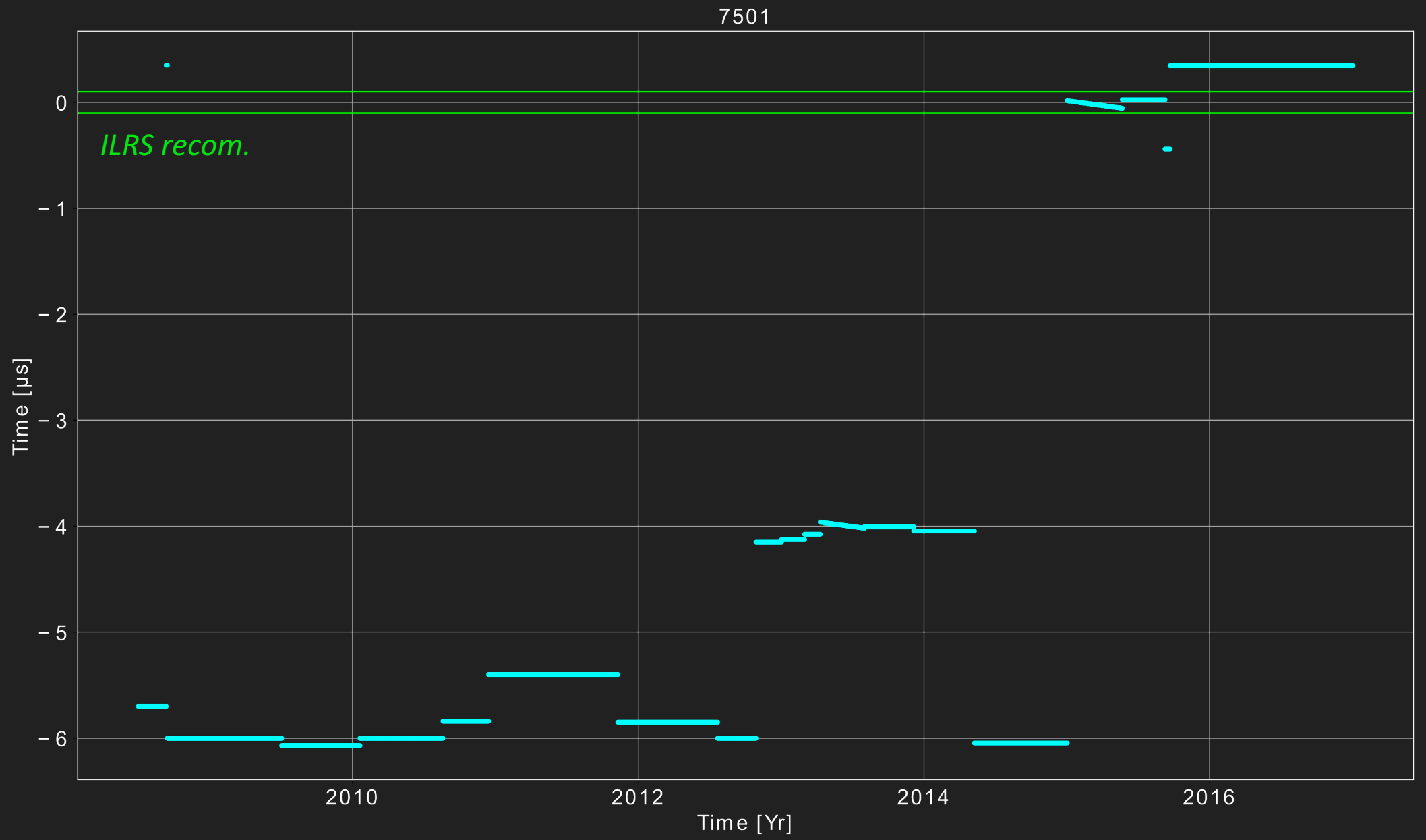
7822

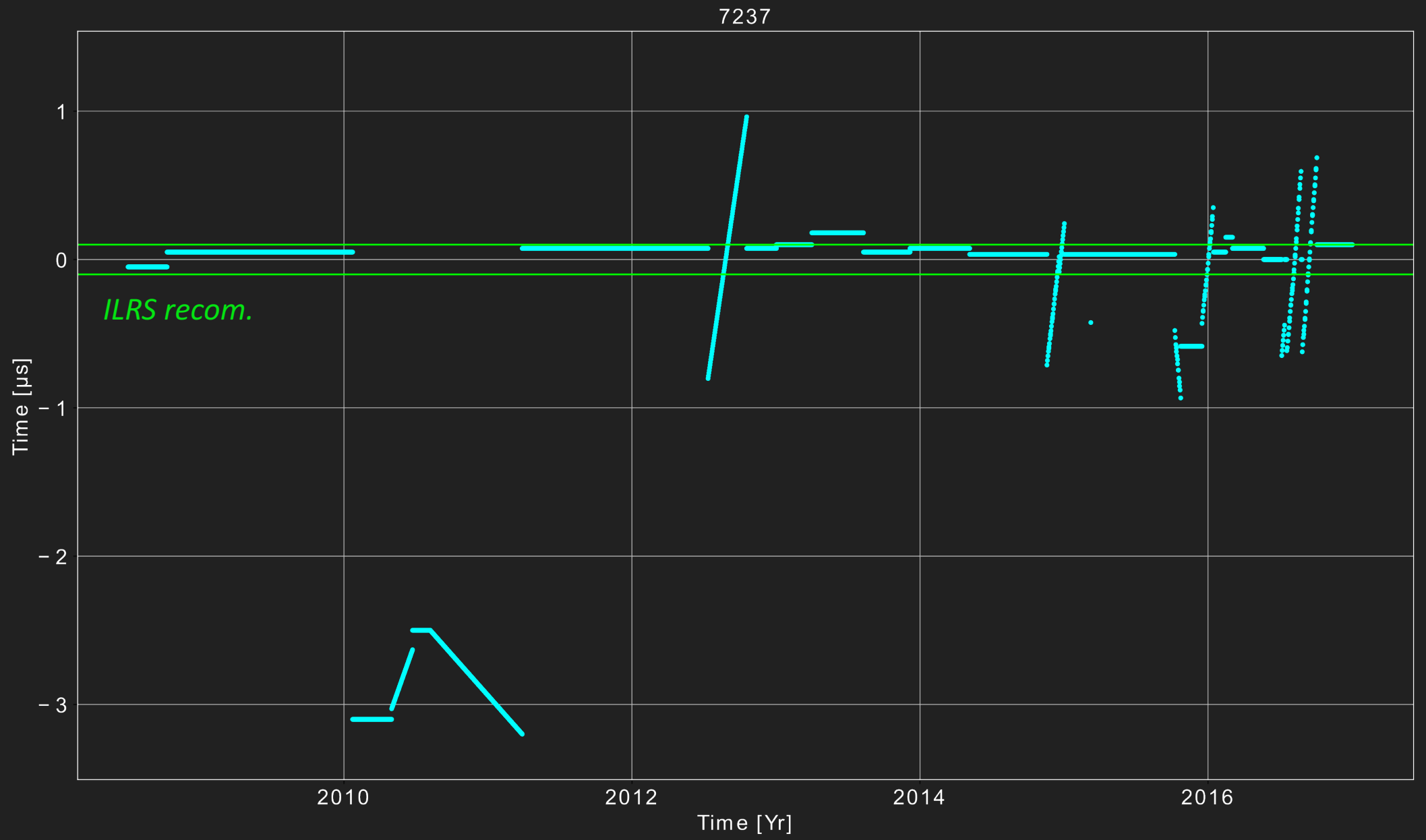
http://www.geoazur.fr/t2l2/en/data/v4/

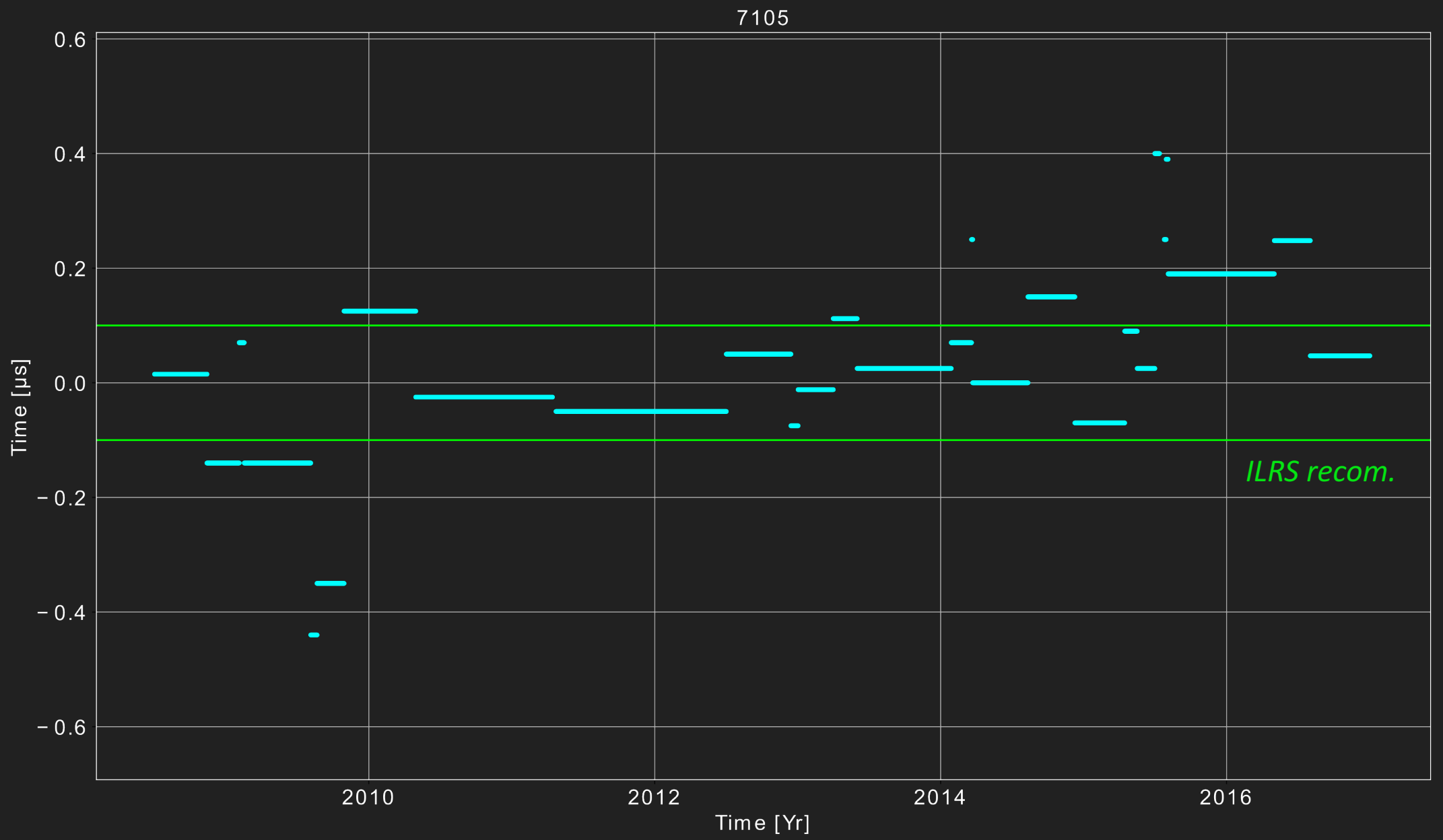

7845
Free H-maser running
ILRS recom.
Cables change
Time [µs]
Time [Yr]
4
3
2
1
0
– 1
2010
2012
2014
2016

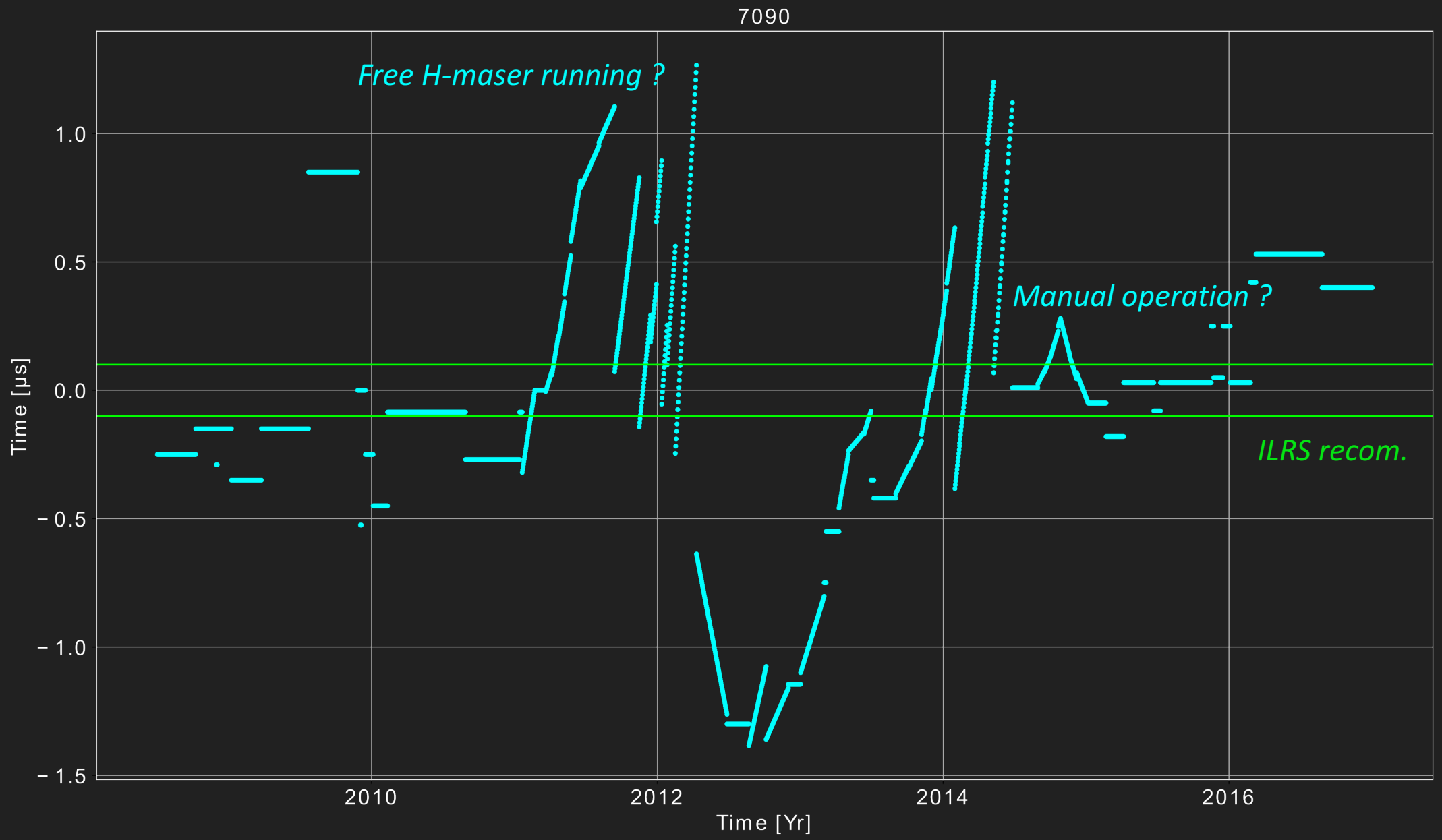

8834
ILRS recom.
0
− 1
− 2
− 3
− 4
Time [µs]
2010
2012
2014
2016
Time [Yr]


7840
0.25
0.20
0.15
0.10
0.05
0.00
− 0.05
− 0.10
Time [µs]
2010
2012
2014
2016
Time [Yr]
ILRS recom.
Cables change


7501
ILRS recom.
0
− 1
− 2
− 3
− 4
− 5
− 6
Time [µs]
2010
2012
2014
2016
Time [Yr]


7237
1
0
− 1
− 2
− 3
Time [µs]
ILRS recom.
2010
2012
2014
2016
Time [Yr]


7105
0.6
0.4
0.2
0.0
− 0.2
− 0.4
− 0.6
Time [µs]
2010
2012
2014
2016
Time [Yr]
ILRS recom.


7090
Free H-maser running ?
Manual operation ?
ILRS recom.
1.0
0.5
0.0
− 0.5
− 1.0
− 1.5
Time [µs]
2010
2012
2014
2016
Time [Yr]

Dealing with Time Biases

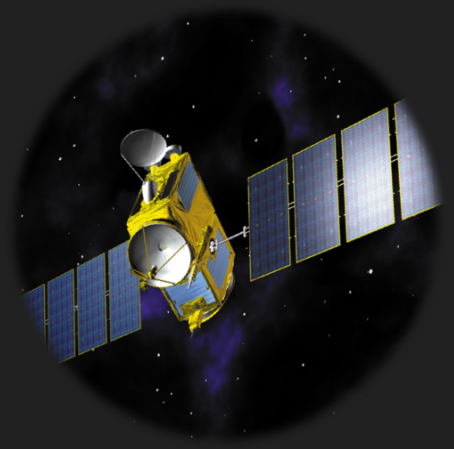
- Complete calibration (cables, time distribution, antenna (GPSDO))
- Stability of the clock (e.g., free running oscillators)
- Event timer (good resolution = ps)
- Following continuously Time Biases
- Every changes on the technology should be noticed

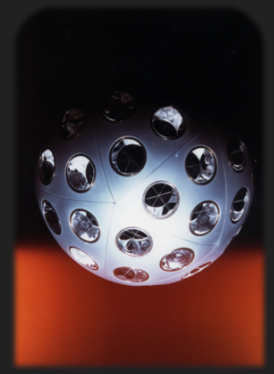
Effects on geodetic products

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)

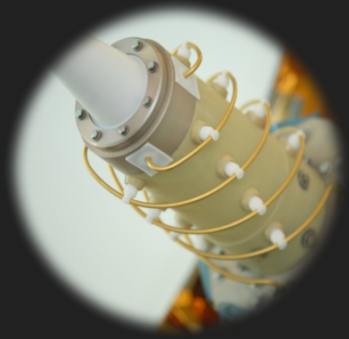
- Global: 0.3-0.5 mm

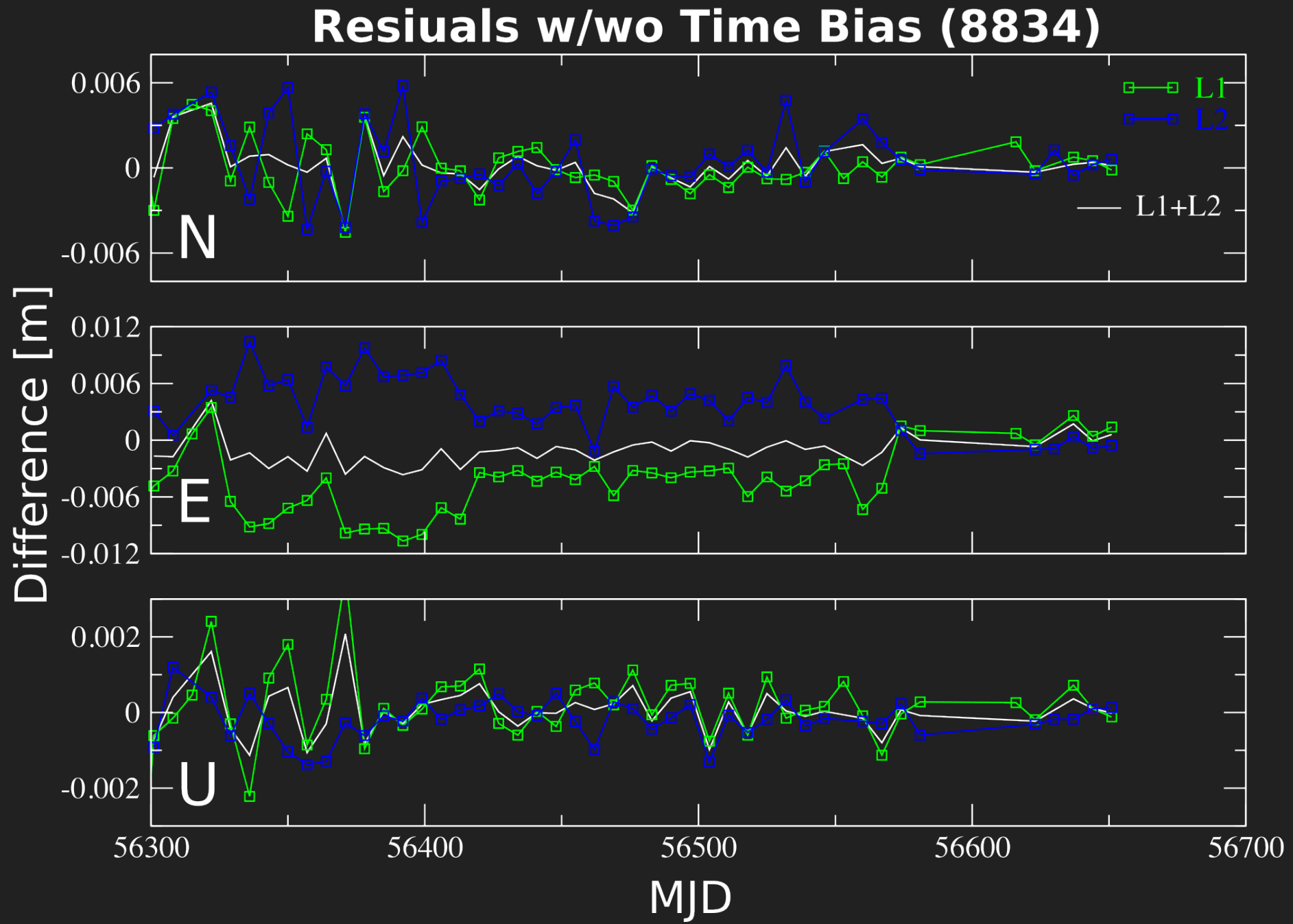
P.O.D Lageos 1 & 2 (R.M.S)

- Negligible: < 1 mm

DORIS Time bias improvement

- Accuracy: 1 µs




Resiuals w/wo Time Bias (8834)
L1
L2
L1+L2
N
E
U
0.006
0
-0.006
0.012
-0.012
0.002
-0.002
Difference [m]
56300
56400
56500
56600
56700
MJD

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*

http://www.geoazur.fr/t2l2/en/data/v4/