Monitoring the Time Bias in laser ranging stations thanks to the T2L2 experiments

***Alexandre Belli**, Pierre Exertier and Frank G. Lemoine*

NASA Goddard SPACE FLIGHT CENTER

ILRS

Geo AZUR
TERRE - OCÉAN - ESPACE

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Context

GGOS Recommendations

Network accurate at **1 mm** and stable at **1 mm/y**

[Plag et al. 2009]

ILRS Recommendations

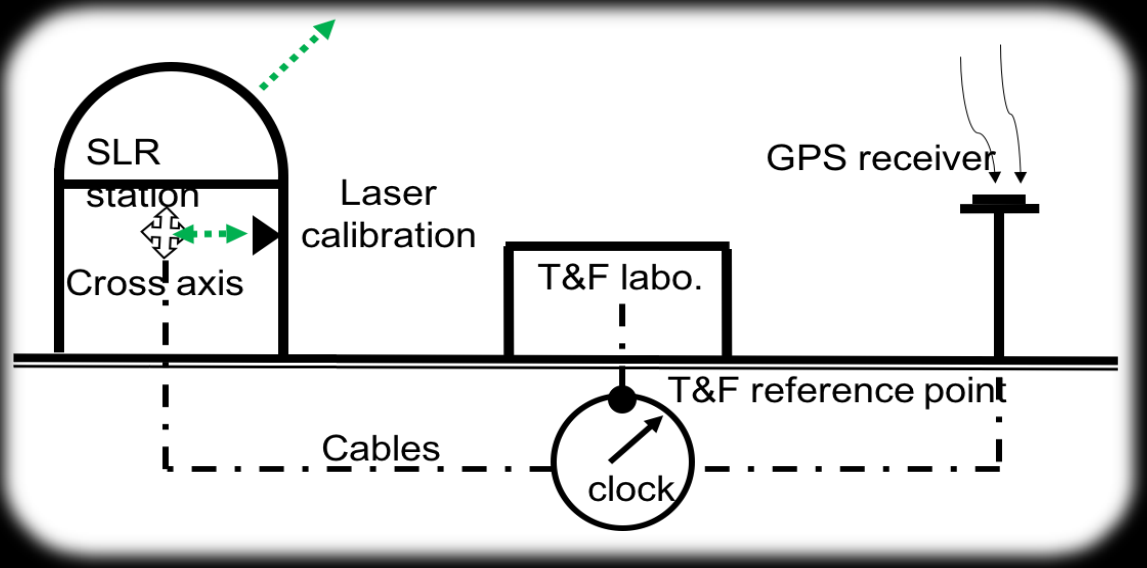
Laser Ranging stations synchronized at +/- 100 ns w.r.t. UTC

[Pearlman et al. 2002]

Detect and reduce the systematic errors

Time Biases

Origin of Time Biases in laser ranging stations



Origin	What is impacted?	
	Stability	Accuracy
Clock	✓	
Cables		✓
Event Timer		✓
Reference points and calibration		✓
Receiver [Lombardi 2008]	✓	✓
Human factor	✓	✓

T2L2 experiment on-board Jason-2 (Time Transfer by Laser Link)

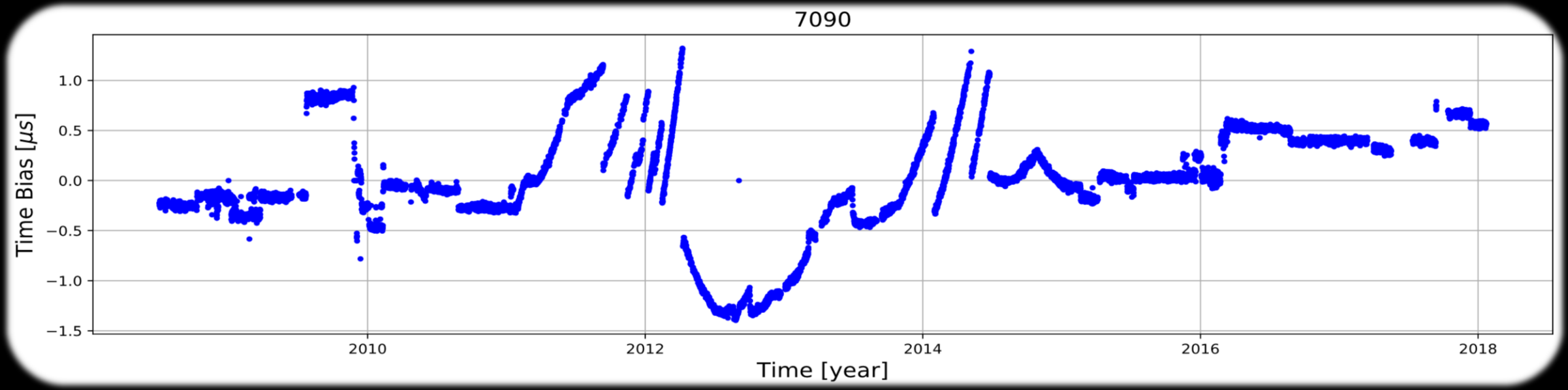
T2L2:

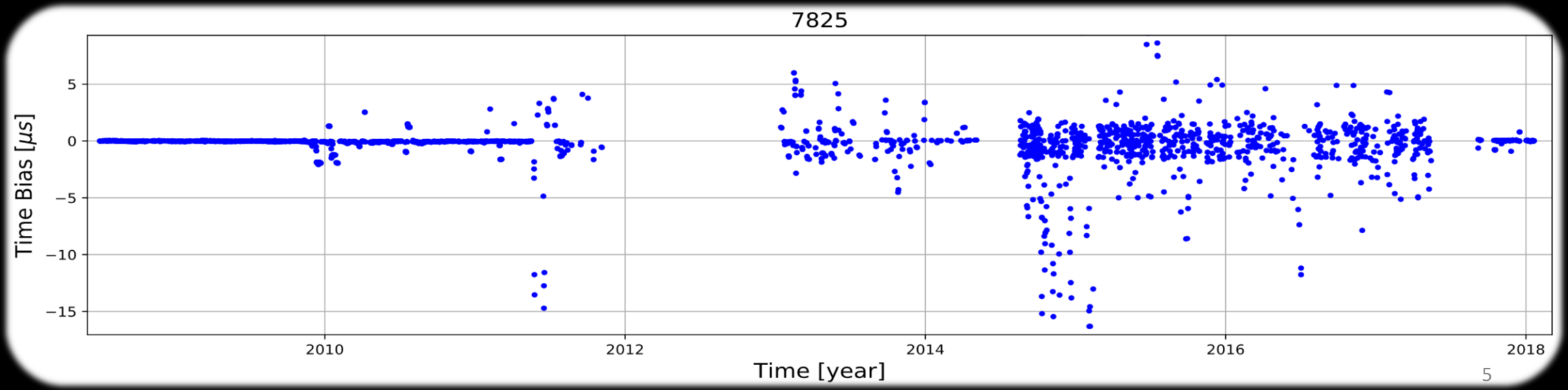
- On-board Jason-2 Satellite [Samain et al. 2008]
- Operational from June 2008 to April 2018
- Aims to synchronize on-board and ground clocks
- Time colocation in space

TIME BIAS DETERMINATION:

- Direct and independent
- Received the GPS PPS, accuracy at: 10/15 ns [Exertier 2010]
- Ground to Ground synchronization at ns level accuracy [Exertier et al. 2014, 2017] and sub-ns [Samain et al. 2018, IEEE]

Time Bias history for almost 10 years (Yarragadee and Mt Stromlo)

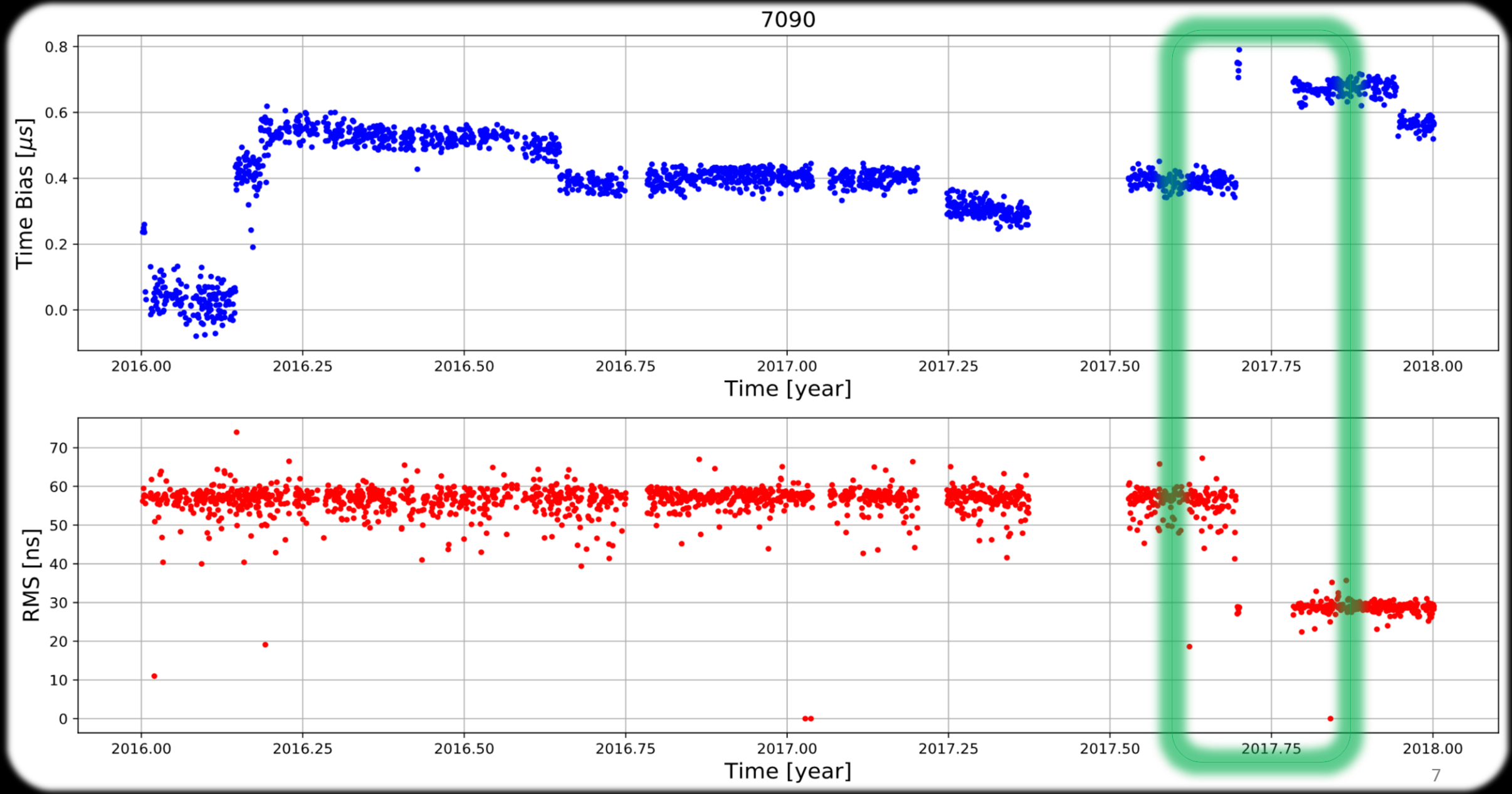




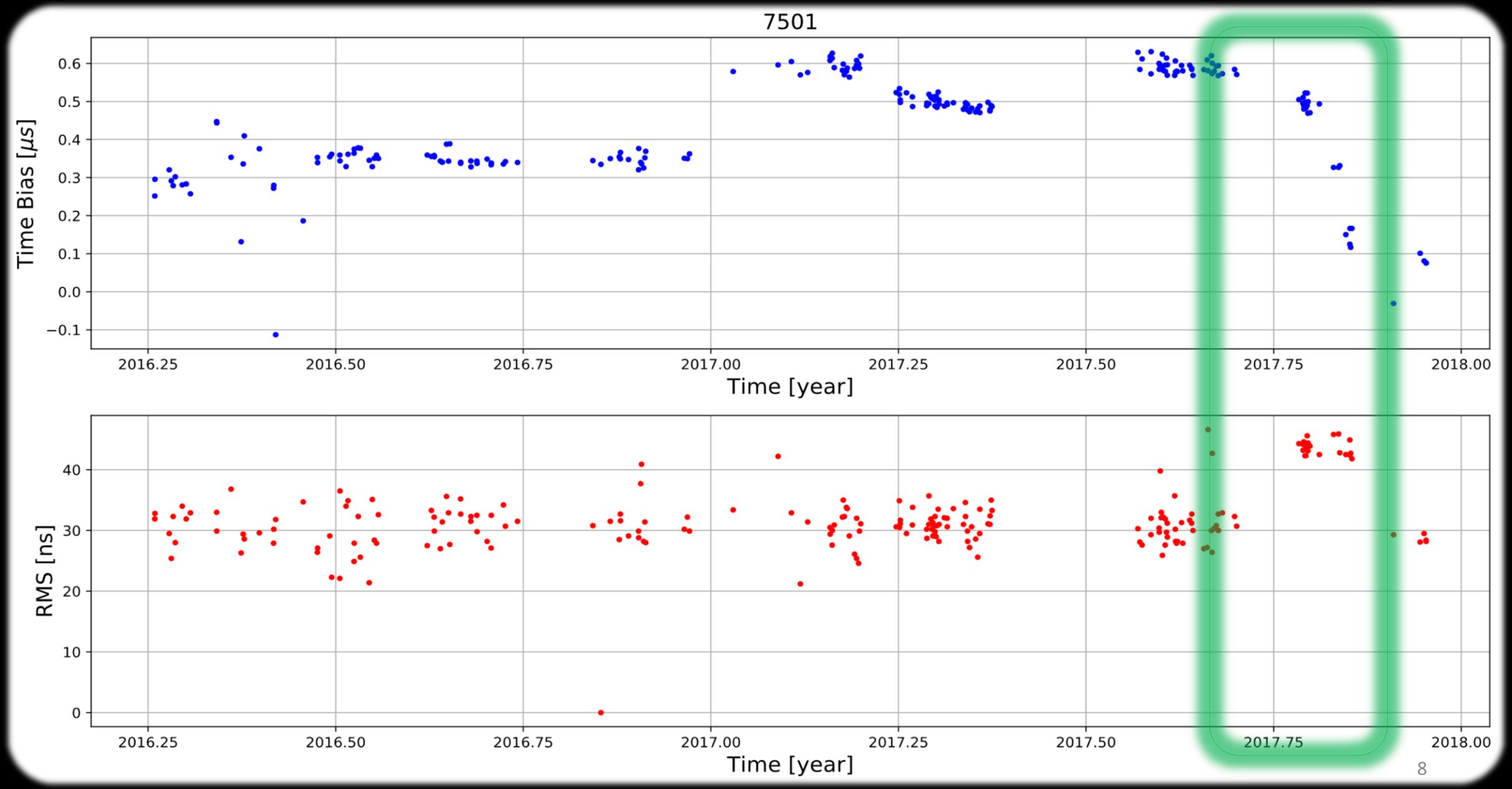
What we learnt from T2L2

- Powerful tool (direct and independent) to determine time bias.
- Laser Ranging station are NOT synchronized to the UTC into the 100 ns requirement, and could even reach several of microseconds.
- Time biases evolve rapidly and randomly and are correlated to the events in the laser station.
- Microsecond time biases lead to millimeter effects on geodetic products (Station positioning, POD) [Exertier et al., 2017]
- [Belli et al. 2017]

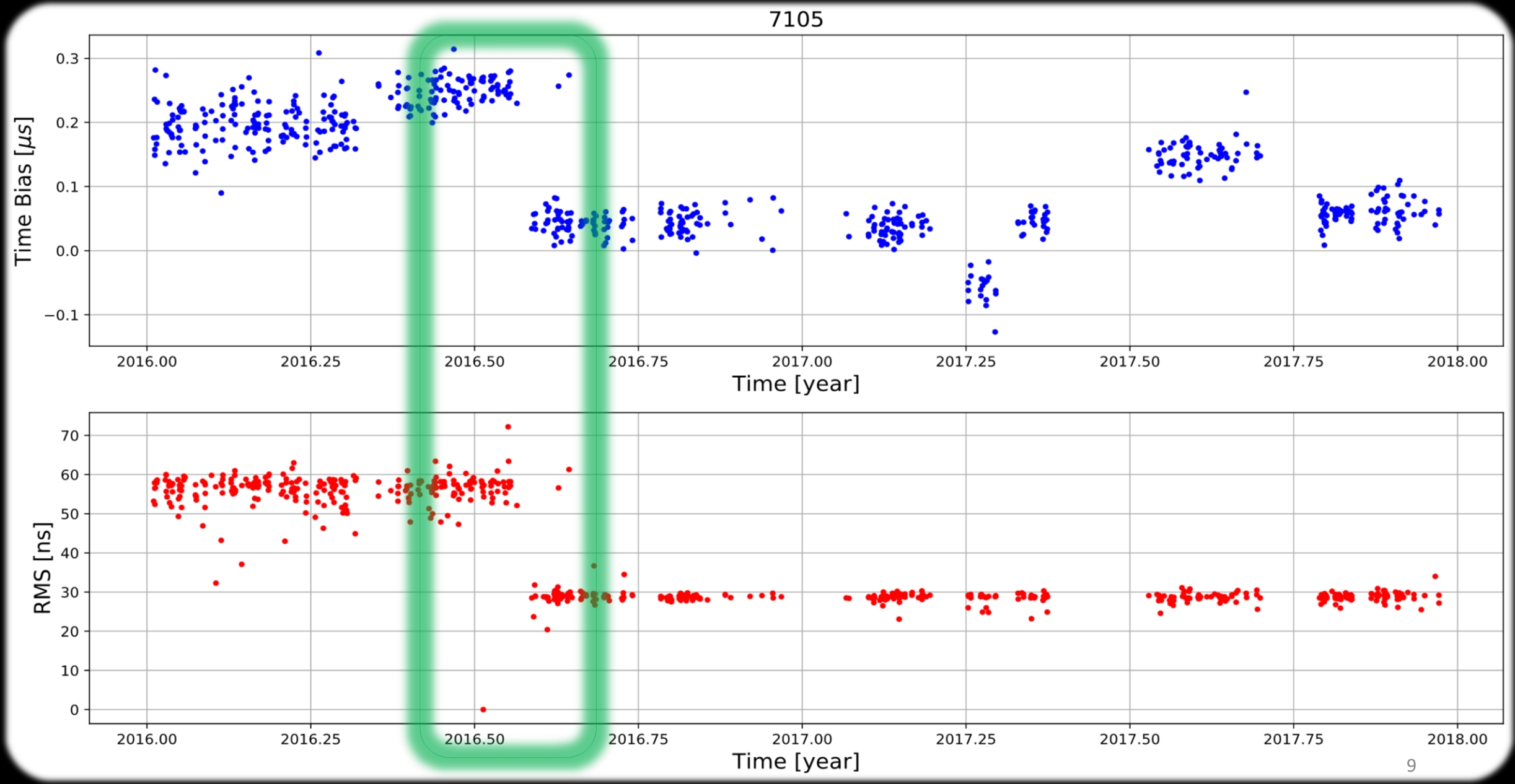
Yarragadee Moblas-5: E.T. changed 9/11/2017



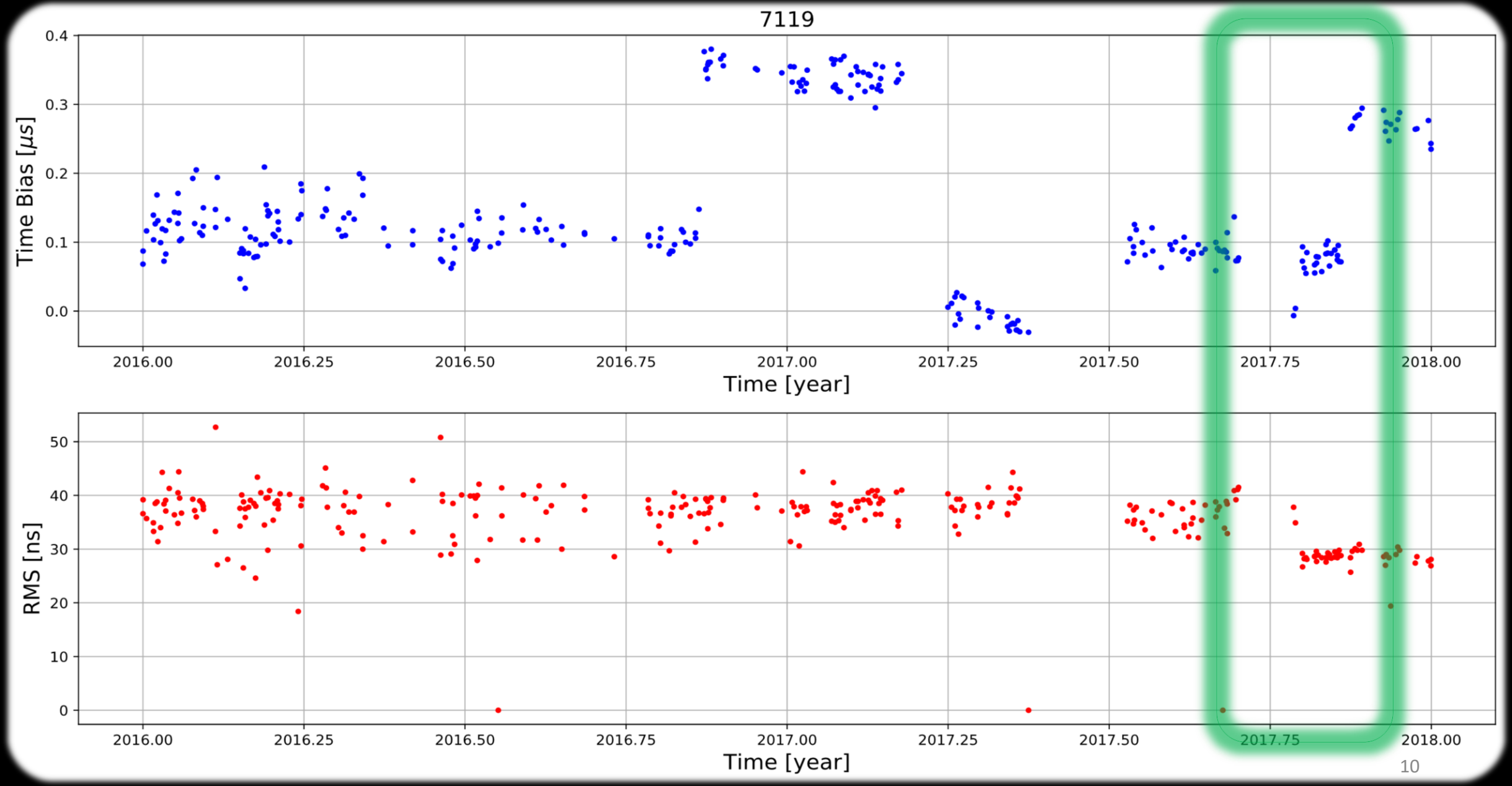
Hartebeesthoek Moblas-6: E.T. changed 11/29/2017



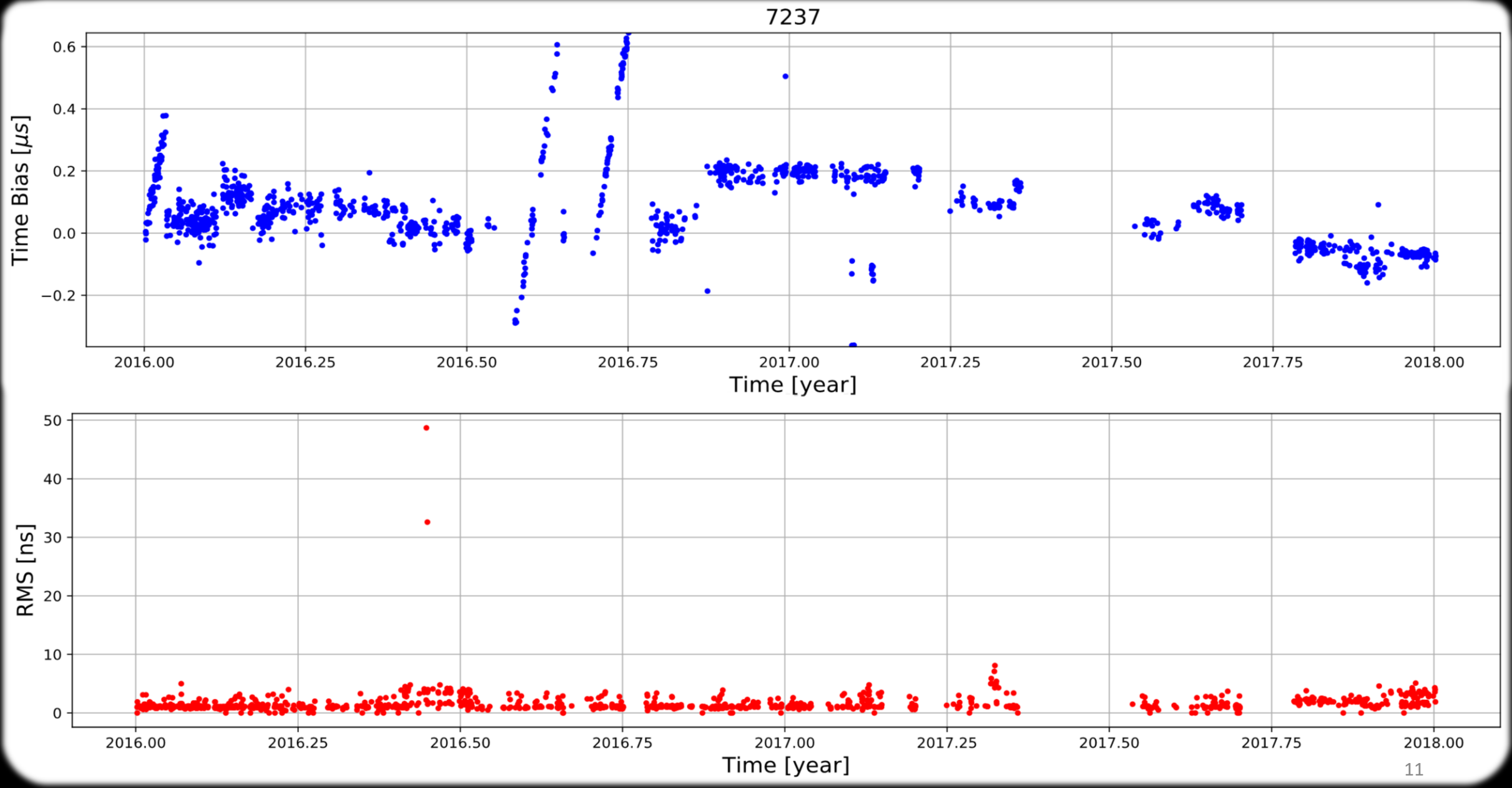
Greenbelt Moblas-7: E.T changed 07/27/2016



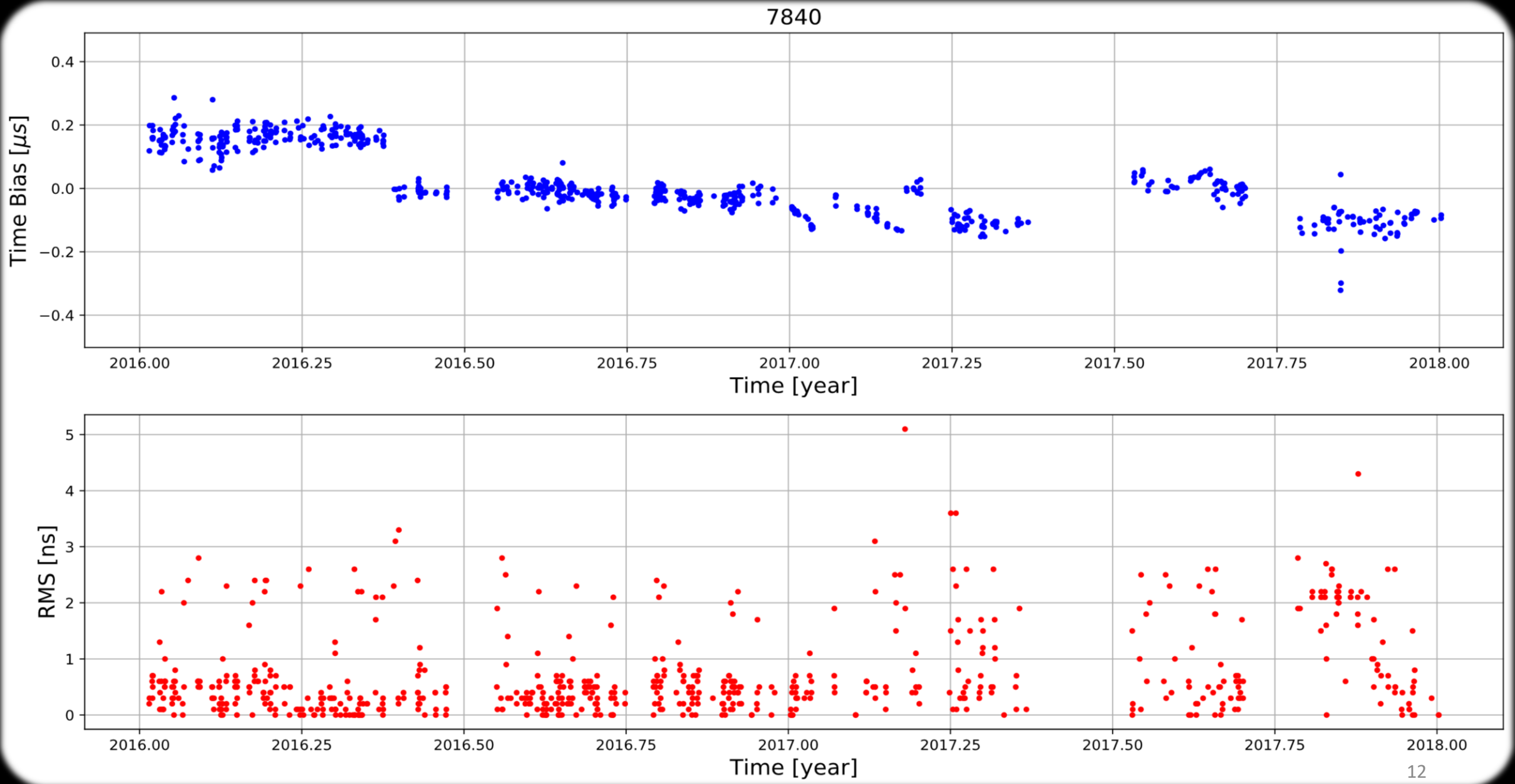
Haleakala TLRS-4: E.T. changed 10/17/2017



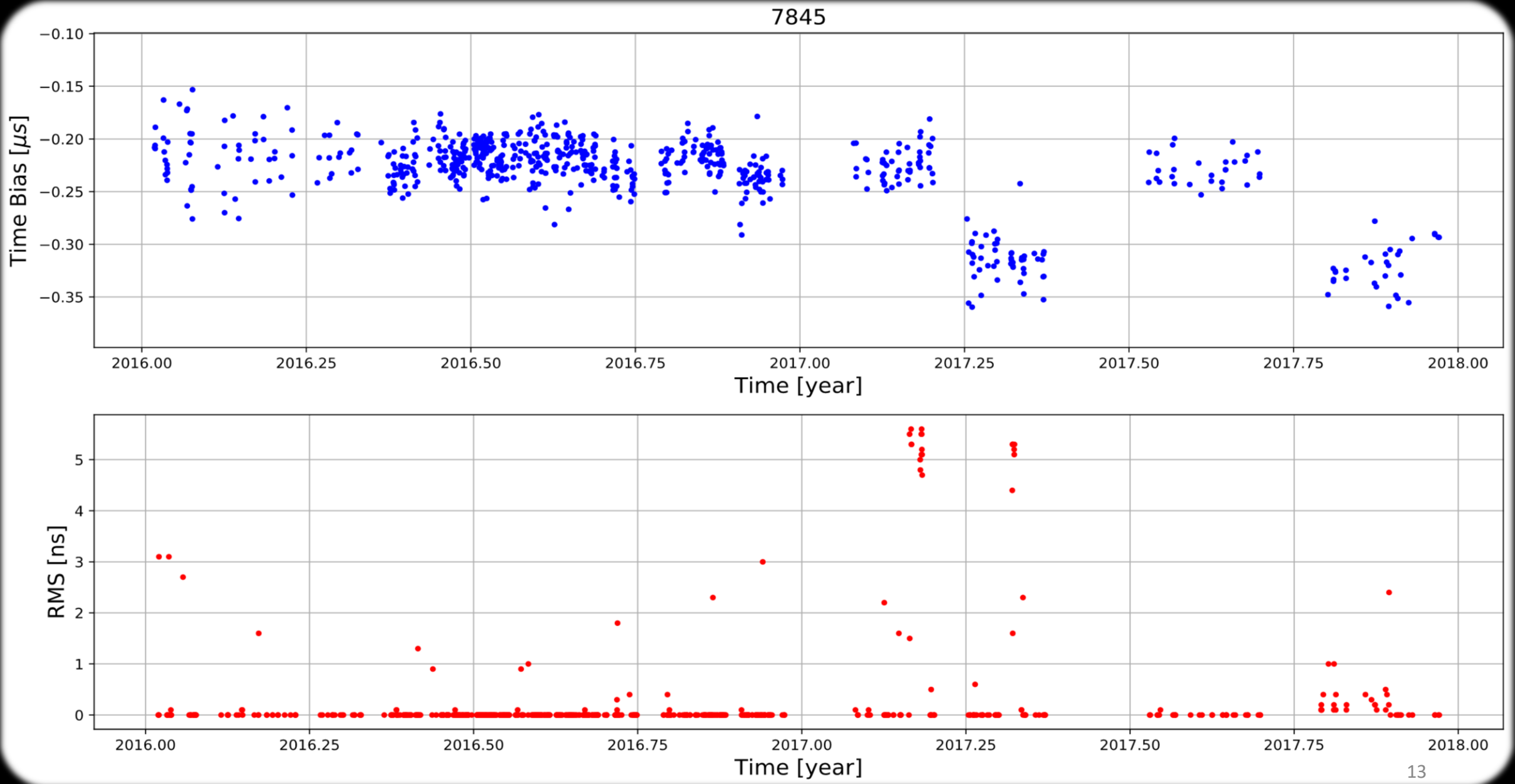
Changchun


7237
Time Bias [μs]
0.6
0.4
0.2
0.0
−0.2
2016.00
2016.25
2016.50
2016.75
2017.00
2017.25
2017.50
2017.75
2018.00
Time [year]
RMS [ns]
50
40
30
20
10
0
2016.00
2016.25
2016.50
2016.75
2017.00
2017.25
2017.50
2017.75
2018.00
Time [year]

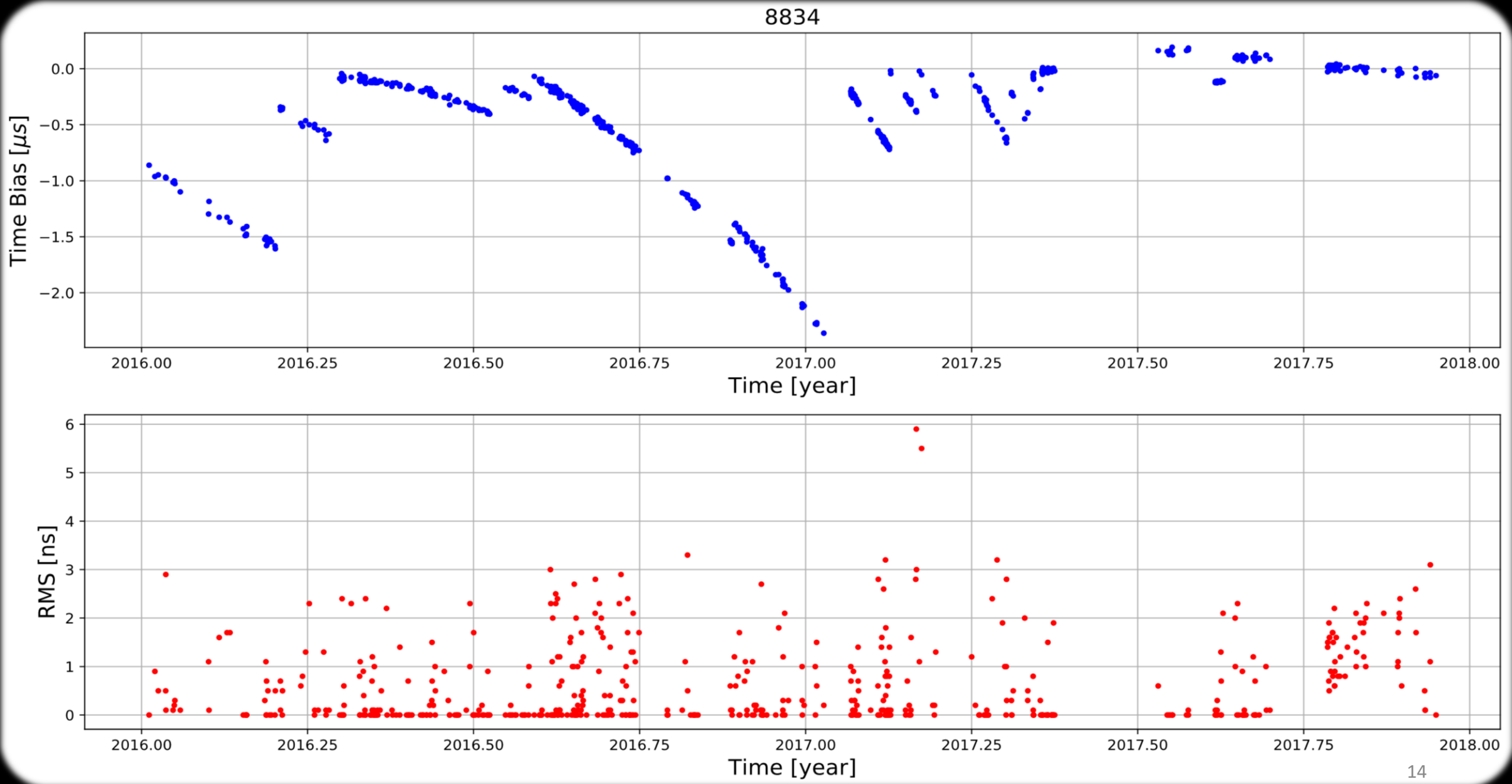
Herstmonceux



Grasse


7845
Time Bias [μs]
−0.10
−0.15
−0.20
−0.25
−0.30
−0.35
2016.00
2016.25
2016.50
2016.75
2017.00
2017.25
2017.50
2017.75
2018.00
Time [year]
RMS [ns]
0
1
2
3
4
5
2016.00
2016.25
2016.50
2016.75
2017.00
2017.25
2017.50
2017.75
2018.00
Time [year]

Wettzell


8834
Time Bias [μs]
0.0
−0.5
−1.0
−1.5
−2.0
2016.00
2016.25
2016.50
2016.75
2017.00
2017.25
2017.50
2017.75
2018.00
Time [year]
RMS [ns]
6
5
4
3
2
1
0
2016.00
2016.25
2016.50
2016.75
2017.00
2017.25
2017.50
2017.75
2018.00
Time [year]

After T2L2 and conclusions

ACES-ELT – ISS (2020)

New “T2L2”, on GNSS (i.e. LTT)?

Stations need to calibrate the time distribution!

Geodesy, navigation…
[Exertier et al. 2018]

- T2L2 determined Time bias with a ns accuracy
- Independent from orbit and direct method
- Stations improved, but still need to meet the ILRS recommendation
- We noticed TB changes (e.g. Event timer)

Thank you for your attention!

www.alexandrebelli.com

Bibliography

[Plag et al. 2009]: Plag, H. P., Rothacher, M., Pearlman, M., Neilan, R., & Ma, C. (2009). The global geodetic observing system. *Advances in Geosciences: Volume 13: Solid Earth (SE)*, 105-127. https://doi.org/10.1142/9789812836182_0008

[Pearlman et al. 2002]: Pearlman, M. R., Degnan, J. J., & Bosworth, J. M. (2002). The international laser ranging service. *Advances in Space Research*, *30*(2), 135-143. https://doi.org/10.1016/S0273-1177(02)00277-6

[Samain et al. 2008]: Samain, E., Weick, J., Vrancken, P., Para, F., Albanese, D., Paris, J., Torre, J.-M, Zhao, C., Guillemot, P., & Petitbon, I. (2008). Time transfer by laser link–the T2L2 experiment on Jason-2 and further experiments. *International Journal of Modern Physics D*, *17*(07), 1043-1054. https://doi.org/10.1142/S0218271808012681

[Belli et al. 2017]: Belli, A., Exertier, P., Pavlis, E. C., & Lemoine, F. G. (2017). Time bias of laser ranging observations. In *Proceeding of the ILRS technical workshop improving ILRS performance to meet future GGOS requirements. Riga, Latvia*. https://cddis.nasa.gov/2017_Technical_Workshop/docs/papers/session2/ilrsTW2017_s2_paper_Belli.pdf

[Samain et al. 2018]: Samain, E., Rovera, G. D., Torre, J. M., Courde, C., Belli, A., Exertier, P., ... & Han, X. (2018). Time Transfer by Laser Link (T2L2) in Noncommon View Between Europe and China. *IEEE transactions on ultrasonics, ferroelectrics, and frequency control*, *65*(6), 927-933. https://doi.org/10.1109/TUFFC.2018.2804221

[Exertier et al. 2010]: Exertier, P., Samain, E., Bonnefond, P., & Guillemot, P. (2010). Status of the T2L2/Jason2 experiment. *Advances in Space Research*, *46*(12), 1559-1565. https://doi.org/10.1016/j.asr.2010.06.028

[Exertier et al. 2014]: Exertier, P., Samain, E., Martin, N., Courde, C., Laas-Bourez, M., Foussard, C., & Guillemot, P. (2014). Time transfer by laser link: data analysis and validation to the ps level. *Advances in Space Research*, *54*(11), 2371-2385. https://doi.org/10.1016/j.asr.2014.08.015

[Exertier et al. 2017]: Exertier, P., Belli, A., & Lemoine, J. M. (2017). Time biases in laser ranging observations: a concerning issue of space geodesy. *Advances in Space Research*, *60*(5), 948-968. https://doi.org/10.1016/j.asr.2017.05.016

[Exertier et al. 2018]: Exertier, P., Belli, A., Samain, E., Meng, W., Zhang, H., Tang, K., A. Schlicht, U. Schreiber, U. Hugentobler, I. Prochàzka, & Sun, X. (2018). Time and laser ranging: a window of opportunity for geodesy, navigation, and metrology. *Journal of Geodesy*, 1-16. https://doi.org/10.1007/s00190-018-1173-8