# PRECISE ATTITUDE DETERMINATION OF DEFUNCT SATELLITE LASER RANGING TARGETS

20th International Workshop on Laser Ranging
October 9 - 14, 2016
Potsdam, Germany

J-N. Pittet[1], J. Silha[1], T. Schildknecht[1]

[1]Astronomical Institute, University of Bern, Switzerland

## Introduction

The Satellite Laser Ranging (SLR) technology is used to determine the dynamics of objects equipped with so-called retro-reflectors or retro-reflector arrays (RRA). Recent studies showed that these measurements can be used also for the attitude determination purposes. Non-active spacecraft, which are not any more attitude controlled, tend to start spinning or tumbling under the influence of the external and internal torques. This poster introduce the methods used to process the data (SLR residual and photometry) obtain with the Zimmerwald Laser and Astrometry Telescope ZIMLAT (Fig. 1).

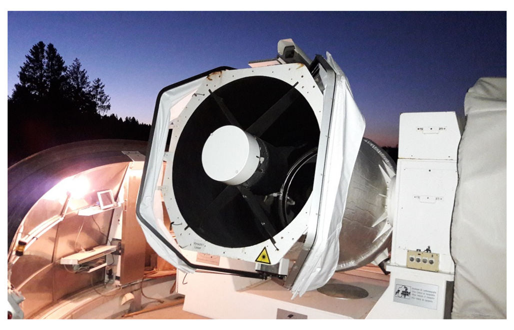

**Figure 1:** ZIMLAT, the multi-purpose 1-meter telescope of the Zimmerwald observatory.

## Acquisition attempts

Fig. 2 shows the numbers of attempts and successful hits for ENVISAT fromt the Zimmerwald SLR station for the years 2015 and 2016, respectively. ENVISAT is regular tracked after the contingency in 2013. Currently, the measurements are used only internally for the attitude estimation.

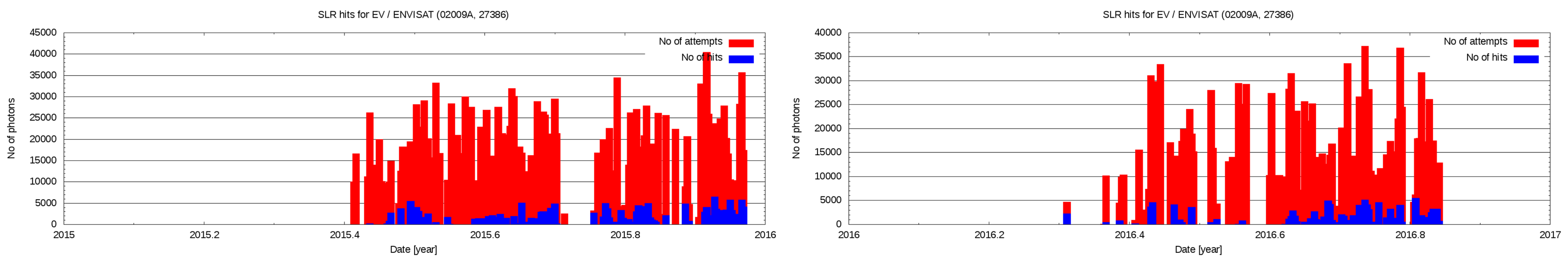

**Figure 2:** Number of attempts and successful hits for ENVISAT from the Zimmerwlad SLR station for 2015 (left) and 2016 (right).

Fig. 3 shows the numbers of attempts and successful hits for TOPEX/Poseidon from the Zimmerwald SLR station for the years 2015 and 2016, respectively. After its decommissioning, TOPEX/Poseidon has been tracked first time in Autumn 2015. Currently it is difficult to track this target, resulting in only 3 successful observations in 2016.

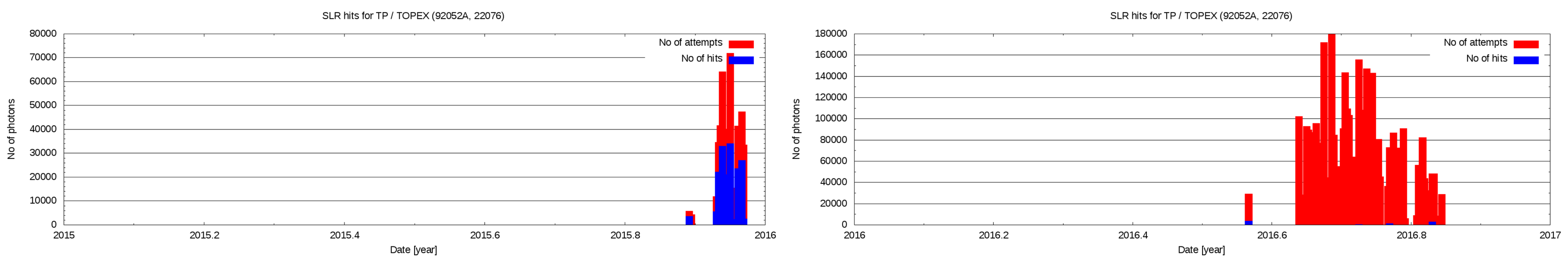

**Figure 3:** Number of attempts and successful hits for ENVISAT from the Zimmerwald SLR station for 2015 (left) and 2016 (right).

## SLR residual preprocessing

During the pre-processing of the residuals, the noise is removed and then, the trend is corrected by adjusting the orbit. These algorithms are under development and will be adapted such that they can be used for any SLR debris.

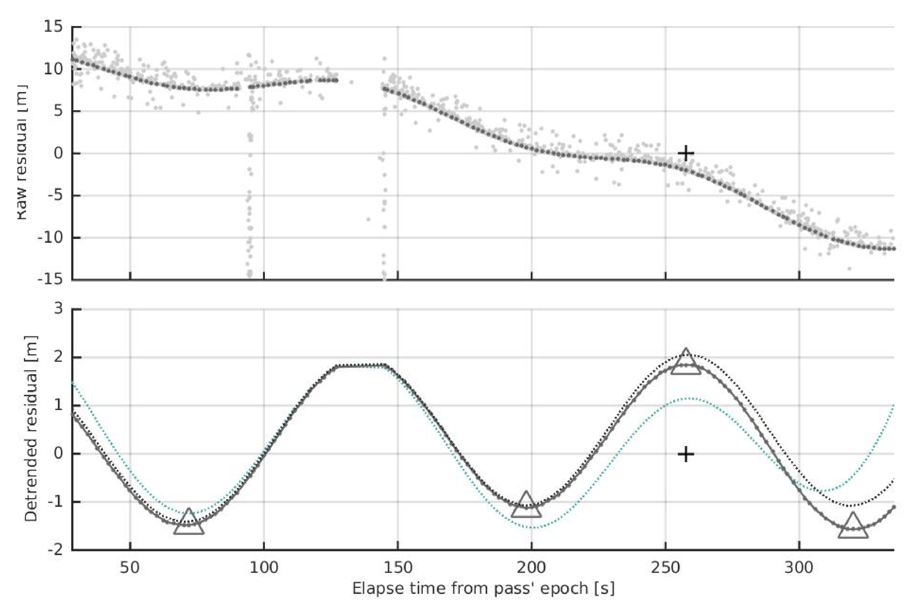


**Figure 4:** The upper part shows the raw residuals in light grey, and the data after the noise rejection and binning in dark grey. On the lower part, the residuals are detrended, either by adjusting the orbital elements (dark line), or by a polynomial fit (blue). The method adjusting the orbit shows better results. The detrending after the parameter estimation is shown in light grey.

## Attitude characterization and parameter estimation

The rotation of the RRA around the spacecraft's centre of mass can create both a oscillation pattern of laser range signal and a periodic signal interruption when the RRA is not visible from the station.

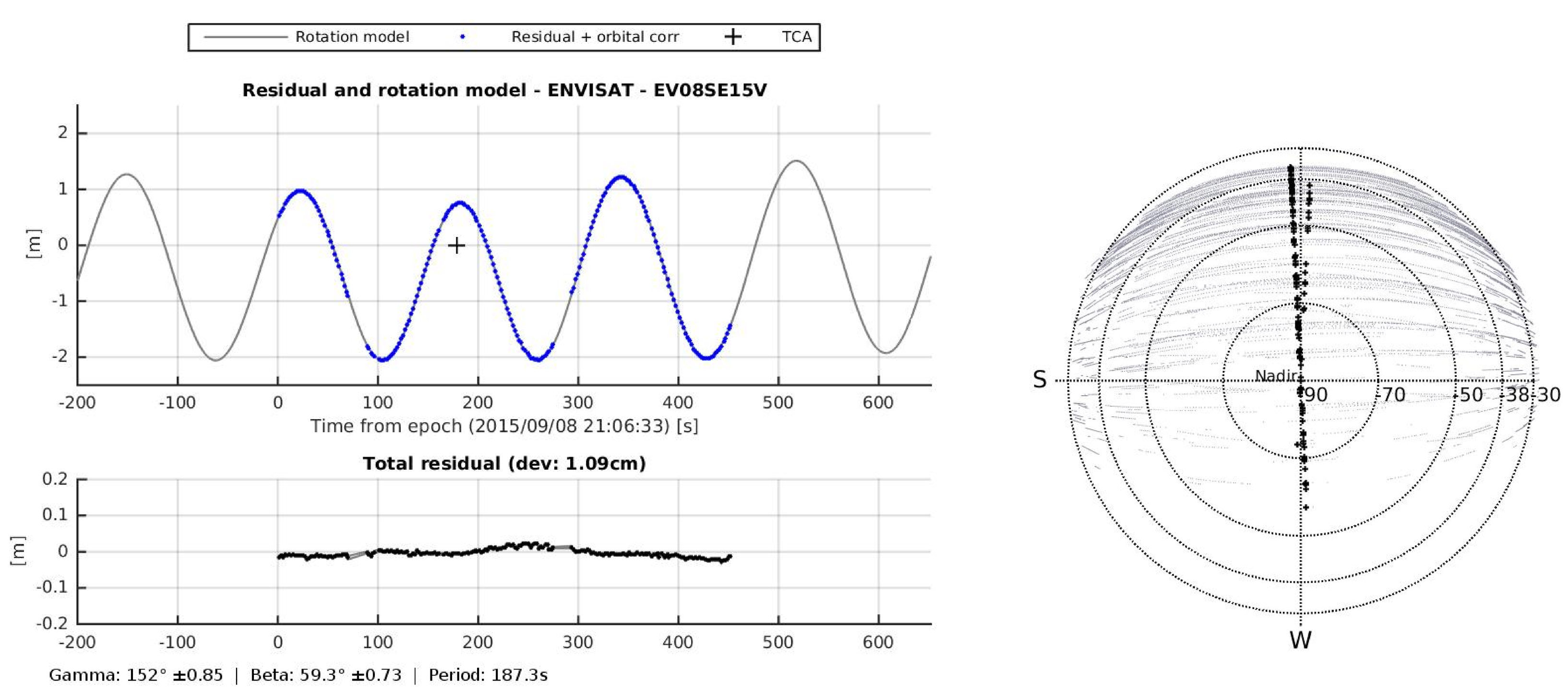


**Figure 5:** The attitude can be determined with different methods. The figure in the left shows the result when attitude parameters are estimated using the range residuals, while in the right the attitude can be studied using the return pattern.

## Evolution

The apparent spin period can be determined by using the time intervals between de-trended residual extrema (see Fig. 4). With an assumption on the spin axis orientation, the inertial spin period can be obtained with a sign ambiguity, namely clock-wise (CW) or counter-clock-wise (CCW) direction. Figure 6 shows the time evolution of the apparent and the two options for the inertial period. Further analysis shows the CCW solution to be the right one.

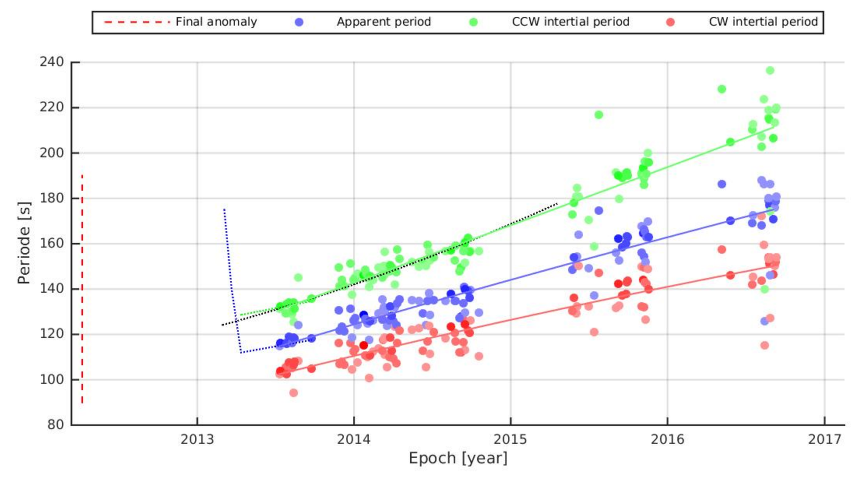


**Figure 6:** Evolution of the spin period of ENVISAT while being uncontrolled. The dotted lines are the results found by [Kucharski 2014].

## Simultaneous observations

Fig.7 shows SLR residuals and a light curve acquired during the same pass with ZIMLAT telescope at 25th of August 2016. Fusing these measurement types leads to more refined attitude estimations. Fig. 8 shows simultaneous observations for TOPEX/Poseidon with ZIMLAT at 18th of November 2015.

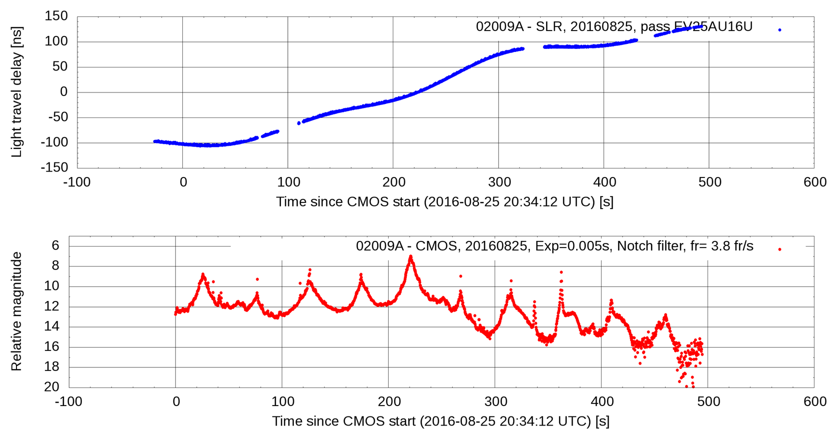

**Figure 7:** SLR residual (top) and light curve (bottom) acquired with ZIMLAT for ENVISAT during the night 2016-08-25.

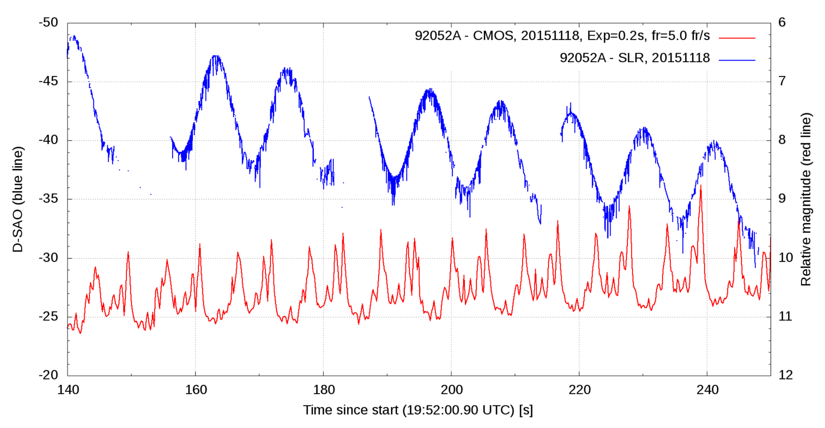

**Figure 8:** SLR residuals (blue line) and light curve (red line) of TOPEX/Poseidon simultaneously acquired by ZIMLAT during night 2015-11-18.

## Simulation with iOTA (ESA tool)

Another example how the SLR residuals and the light curve data can be used for the attitude estimation is to assume the satellite attitude behavior, generate synthetic data and compare it with the real measurements for model confirmation. Such an approach have been used with the iOTA tool of the European Space Agency (ESA) currently under development [Silha et al. (2016)]. Fig. 9 shows a comparison of real residuals of ENVISAT acquired by ZIMLAT during night 2016-08-25 and synthetic residuals generated for the same pass with the iOTA tool.

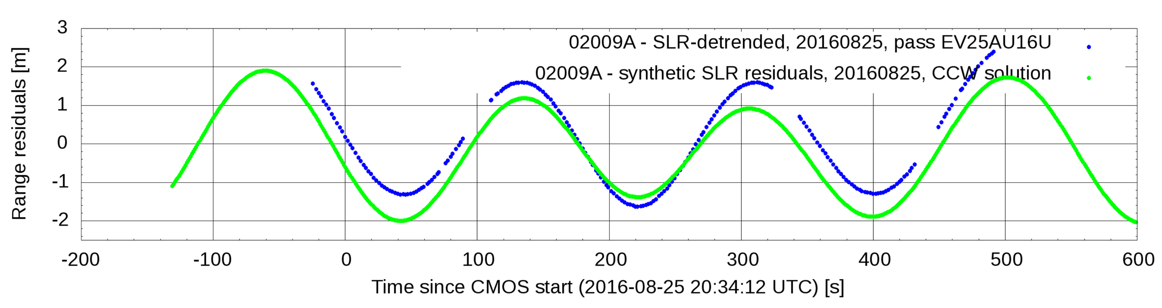


**Figure 9:** Real SLR residuals (blue line) and synthetic SLR residuals generated by iOTA tool by assuming specific attitude state for ENVISAT (green line). The real residuals were acquired by ZIMLAT during night 2016-08-25

## Conclusion

- Information about observations without returns are useful. Clear definition of "no returns" should be agreed before sharing such data.
- De-trending is delicate and is critically depending on the noise filter used. Collaboratives efforts within the community would be beneficial.
- The availability of accurate prediction is critical for the observations.
- At the current point of development, precise attitude determination (spin rate and spin axis orientation) is possible with our internal tool for SLR observations lasting more than 2.5 apparent rotations.
- The simultaneous light-curve acquisition along with SLR measurement allow refining the determination of the attitude state for any SLR target.

## References

Silha, J., Schildknecht, T., Pittet, J.-N., Bodenmann, D., Kanzler, R., Karrang, P., Krag, H., Comparison of ENVISAT's attitude simulation and real optical and SLR observations in order to refine the satellite attitude model, Proceedings of AMOS Conference, Maui, Hawaii, 2016.

Kucharski, D., Kirchner, G., Koidl, F., Cunbo Fan, Carman, R., Moore, C., Dmytrotsa, A., Ploner, M., Bianco, G., Medvedskij, M., Makeyev, A., Appleby, G., Suzuki, M., Torre, J.-M., Zhang Zhongping, Grunwaldt, L., Qu Feng, Attitude and Spin Period of Space Debris Envisat Measured by Satellite Laser Ranging IEEE transactions on geoscience and remote sensing, 12, 7651-7657, 2014.

## Contact address

Thomas Schildknecht (thomas.schildknecht@aiub.unibe.ch)
Astronomical Institute, University of Bern
Sidlerstrasse 5
3012 Bern (Switzerland)