Submillimeter SLR: Ajisai as the zero-signature satellite

Daniel Kucharski[1] (daniel@kasi.re.kr), Georg Kirchner[2], Toshimichi Otsubo[3], Franz Koidl[2]
[1] Korea Astronomy and Space Science Institute, Daejeon, Korea
[2] Space Research Institute, Austrian Academy of Sciences, Graz, Austria
[3] Geoscience Laboratory, Hitotsubashi University, Tokyo, Japan

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Abstract

The complete attitude model of Ajisai applied during the post-processing of Graz kHz SLR data allows to select the range measurements to the single corner cube reflector panels of the satellite and to form the normal points which indicate the physical distance between the ground station and the center of mass of Ajisai.

This method completely eliminates the satellite signature effect from the distribution of the post-fit range residuals and improves the average single-shot RMS per normal point from 15.44 mm to 3.05 mm. The normal point RMS per pass is reduced from 2.97 mm to 0.06 mm - a value expected for the zero-signature satellite.
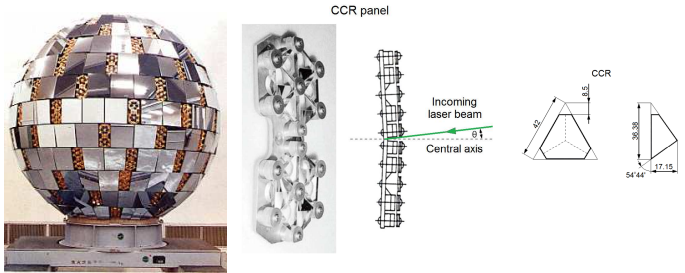
Graz kHz SLR measurements of Ajisai

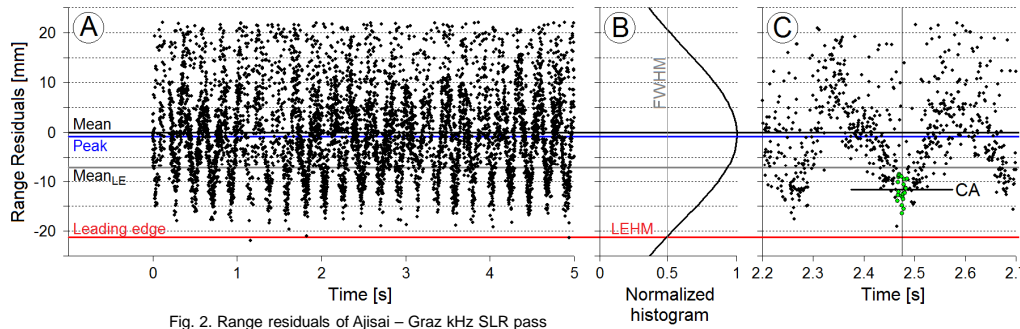Fig. 1. Ajisai and its components, courtesy of JAXA

Fig. 2. Range residuals of Ajisai – Graz kHz SLR pass

A) Ajisai range residuals (RMS=8.81 mm)
B) Histogram of the range residuals distribution (Sinclair algorithm, obtained with 15 mm smoothing coefficient).
C) V-shape data peak represents change of the distance to the single CCR panel due to the spin of the satellite; the closest approach CA of the panel is indicated. The significant levels of the data distribution are marked: mean of the range residuals after 2.5 sigma clipping, peak, mean of the leading edge points (Mean$_{LE}$), leading edge at half maximum LEHM.

Reflector filter for normal point formation

The standard normal points are generated from the post-fit range residuals obtained after polynomial fitting and an iterative sigma clipping. The standard normal points refer to the mean reflection point calculated as the arithmetic mean of the post-fit range residuals.

The proposed 'reflector filter' allows to identify the laser echoes given by the single CCR panels of Ajisai (accepted are the range residuals from the closest approaches only).
The accepted range measurements at given closest approach refer to the single CCR panel with known XYZ position on the satellite's body, and thus each data point can be corrected by the accurate CoM vector in order to give the range to the center of mass of the satellite.
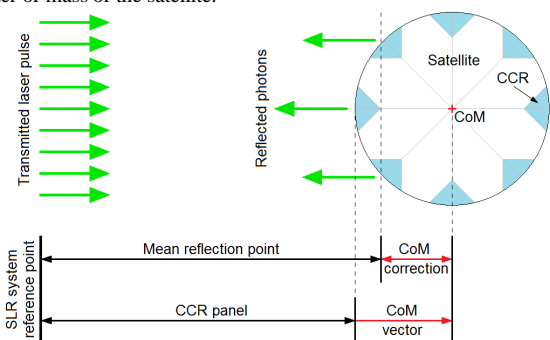

Fig. 3. The reference points for normal points

Zero-signature SLR measurements

The identified range measurements to the single CCR panels throughout the pass are corrected by the CoM vector and indicate the physical distance between the SLR station and the satellite's center of mass. The presented method eliminates the satellite signature effect from the SLR measurements of Ajisai and thus allows to improve accuracy of the normal points.
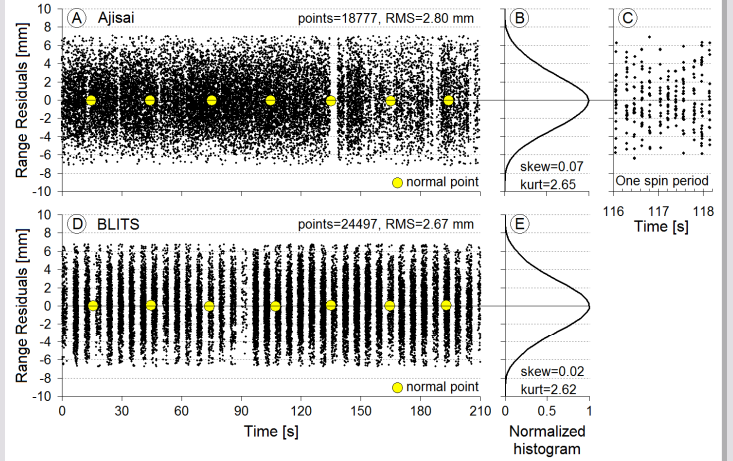

Fig. 4. Zero-signature range residuals and normal points of Ajisai and BLITS

Tab1. Mean values of parameters calculated from 2731 passes – Ajisai, 450 – BLITS

	Ajisai	BLITS
Pass RMS of range residuals [mm]	3.04 ±0.29	3.17 ±0.31
NP RMS per pass [mm]	0.06 ±0.02	0.09 ±0.05
Single-shot RMS per NP [mm]	3.05 ±0.36	3.21 ±0.32
Return rate per NP [%, point]	1.6 % 960	5.8 % 3480

Zero-signature normal points of Ajisai

We processed 11 years of Graz kHz SLR data and calculated normal points with the standard post-processing approach (NP) and with the 'reflector filter' (NP$_{CCR}$).
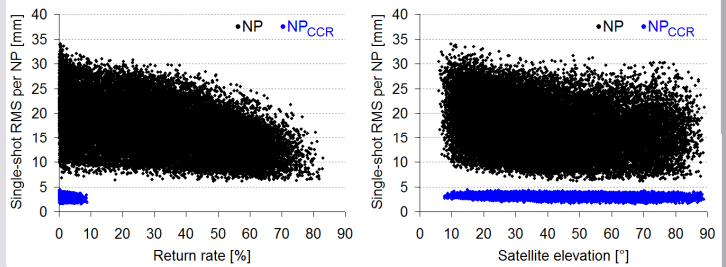
The mean single-shot RMS per NP is 15.44 ±5.23 mm; NP$_{CCR}$: 3.05 ±0.36 mm.

Tab2. Distance between the significant levels of the range residuals distribution (Fig. 2) and Ajisai center of mass. The physical distance between the outer surface of the CCRs and the satellite's center of mass is 1053 ±5 mm.

	Physical distance to CoM [mm]	Optical distance to CoM [mm]	RMS [mm]
Closest approach	1052	1027	0.4
Mean$_{LE}$	1048	1023	1.7
Peak	1041	1016	2.6
NP (Mean)	1037	1012	4.7

Conclusions

-The attitude model of Ajisai applied during the post-processing of the kHz SLR data allows to select the range measurements to the single CCR panels and to form normal points which indicate the physical distance between the ground station and the satellite's center of mass
- This process eliminates the satellite signature effect from the distribution of the post-fit range residuals and improves the average single-shot RMS per normal point from 15.44 mm to 3.05 mm. The NP RMS per pass is reduced from 2.97 mm to 0.06 mm - a value expected for the zero-signature satellite.