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Changchun Tiangong-1 Space Debris Joint Observation

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Changchun station tracked decommissioned Tiangong-1 spacecraft since March 2016, until its reentry in April 2018. The station acquired 105 passes during this period, of which 27 were daylight passes. The 1 kHz ranging data exhibited multiple reflection patterns, corresponding to its multi-LRA design.

Key Words: Space debris, Tiangong-1, Attitude measurement

Introduction

The Tiangong-1 spacecraft is a space-lab module operated by China National Space Administration (CNSA). It was launched in September 2011 and reentered in April 2018. In March 2016, the spacecraft was reported malfunctional, and afterwards it was treated as space debris target. Changchun station joined the campaign to monitor its orbital descent, obtaining 105 passes in total. Months before its reentry, the campaign was raised to high priority.

Table 1. Tiangong-1 laser ranging passes in Changchun

Year	Total Passes	Daylight Passes
2016	22	8
2017	52	15
2018:Q1	31	4

The laser reflector array (LRA) system of Tiangong-1 spacecraft was designed to serve rendezvous missions. It consists of one corner-cube reflector (CCR) as near-field (NF) LRA, and a CCR array as far-field (FF) LRA. The design and function was described in detail by Li Pu et al. in *The design of laser retro-reflectors for the onboard lidar and its application in the docking mission of Chinese Tiangong-1 space lab module* in 18th IWLR, Fujiyoshida in year 2013. Fig. 1 shows the appearance of FF and NF LRAs.

a) Far Field (FF) LRA   b) Near Field (NF) LRA

Figure 1. Tiangong-1 LRAs Appearance.
Photograph courtesy of Shanghai Astronomical Observatory, CAS.

Range Data Analysis

In the range data two type of phenomena exist for multiple reflectors.
The first type arises from range difference between NF and FF LRAs, shown in Fig. 2, where the thicker line represents the FF LRA, while the thinner one the NF LRA. The two lines intersect at specific epoch, when the two LRAs had equal range from the ranging station. In the left end of lines, the NF line appear above FF line, implying farther range of NF LRA. However, in normal cases the NF line was rarely seen above the FF line, partly due to spacecraft attitude, but more importantly due to SPAD depletion by the strong FF signals.

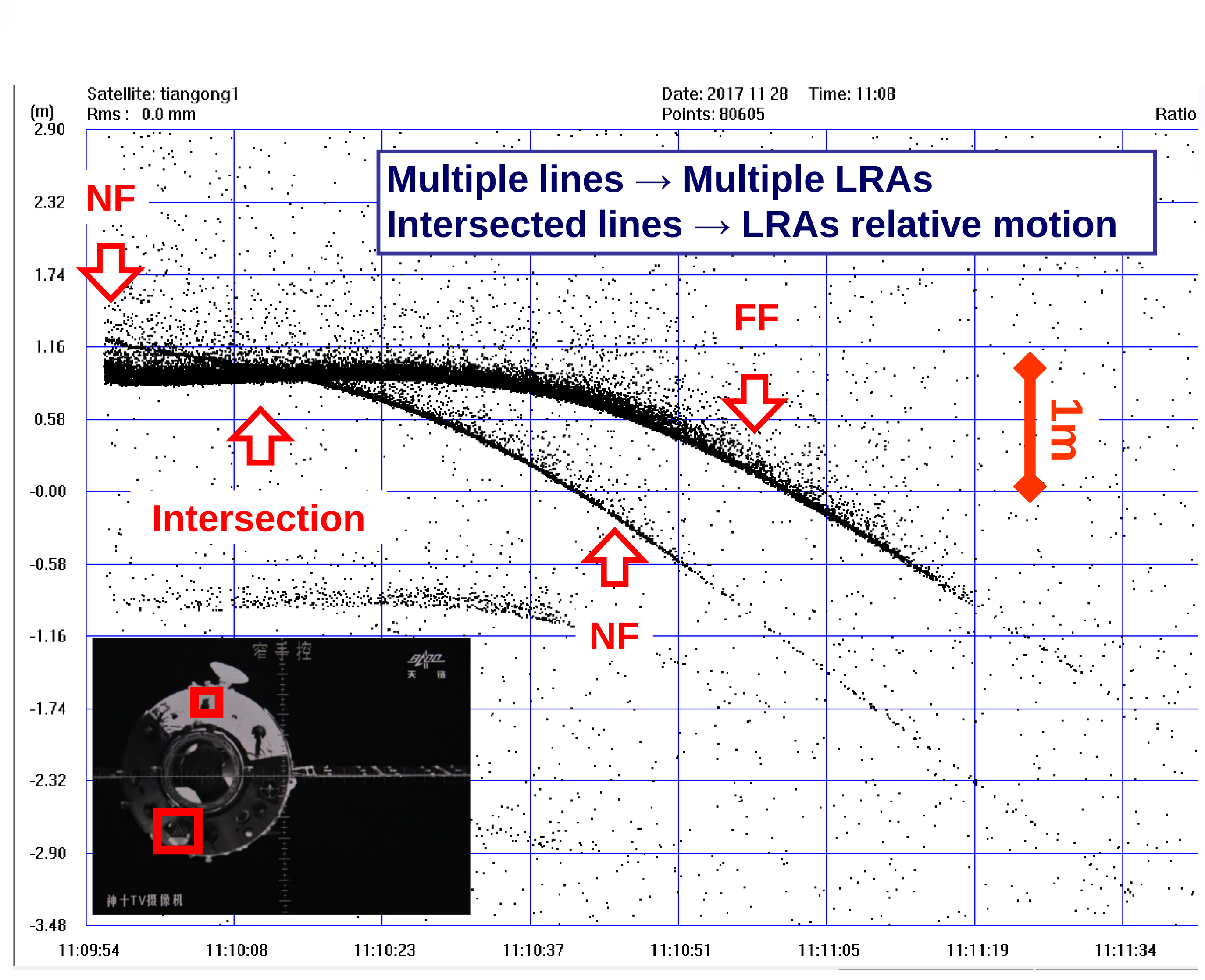

Fig. 2 Data of NF and FF LRAs

The second type is brought by fine structure of the FF LRA. The FF LRA is honeycomb-like, holding one CCR in each cell. In certain incidence angles, it is possible to divide the CCRs into several clusters, each has similar range from the ranging station. As is shown in Fig.3, the data formed a stratified pattern, for more than 10 seconds. One can distinguish at most 4 layers, but they soon blurred into a whole. CCR arrays also were used in GNSS LRAs, but no similar phenomenon was seen, probably because of the weak signal and the controlled attitude.

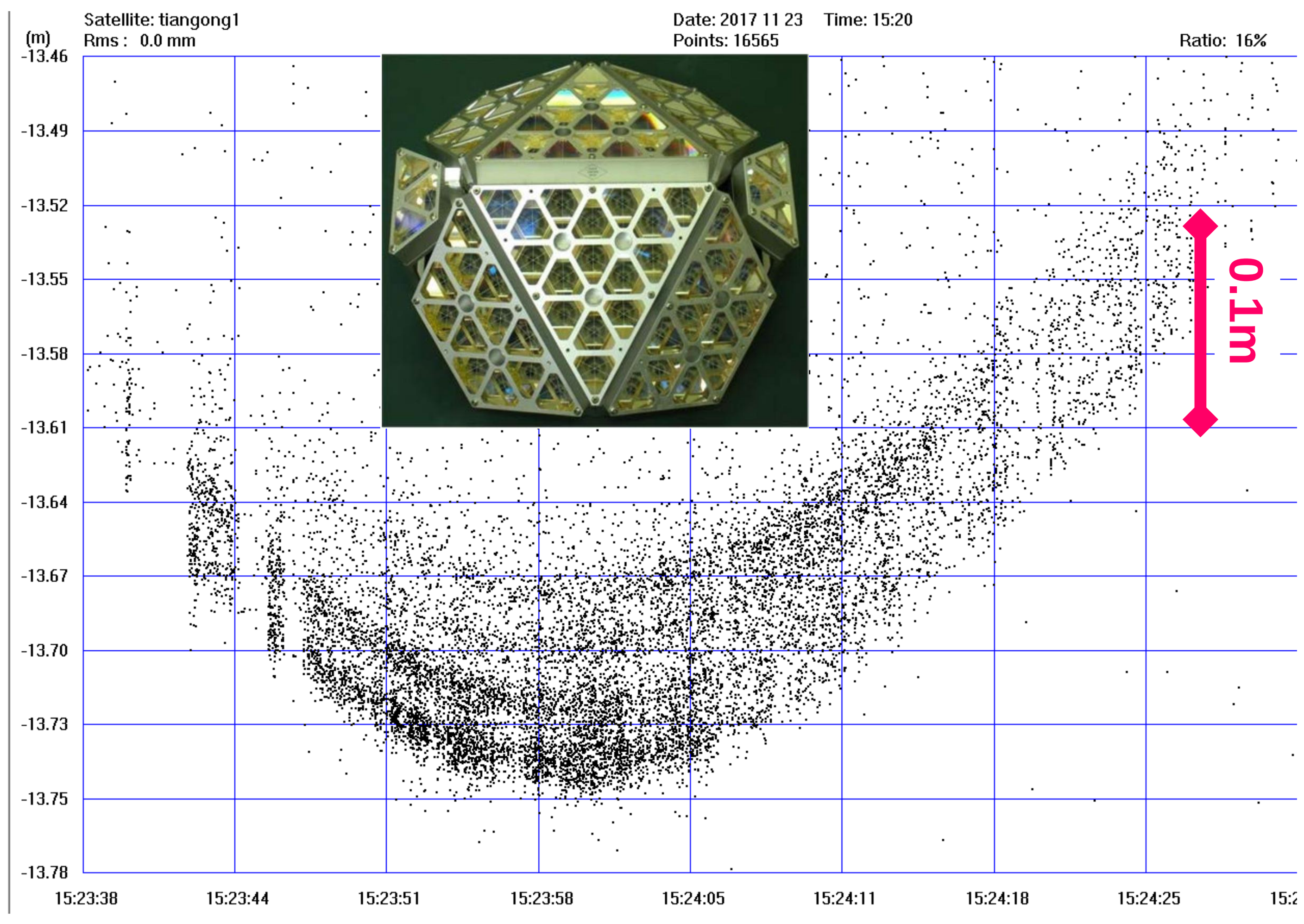

Fig. 3 Data Fine Structure of FF LRA

Discussion

Fine structure of the range data can provide attitude information. For those malfunctional spacecrafts carrying multiple LRAs, laser ranging is an effective technique to acquire spacecrafts' attitude. Although not designed to do so, the Tiangong-1 LRAs had given valuable attitude measurements during its final descending period. In addition to geometric configuration, laser ranging laws also affect measurement results.