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# THREE DIMENSION POSITION OF SPACE DEBRIS WITH LASER RANGING AND OPTICAL ASTROMETRY

Y. Yu[1], Y. Li[1], Y. D. Mao[1], J. J. Cao[1], Z. H. Tang[1], and Z. P. Zhang[1]

RESUMEN

La tasa de éxito y confiabilidad de la determinación de órbitas de la basura espacial, mejora sustancialmente si las coordenadas celestes de la misma son conocidas al momento de hacer la medición de distancia por láser. En este trabajo presentamos un método para la localización 3D de basura espacial usando distancia por láser y astrometría. Una plataforma de prueba se estableció al instalar un equipo fotográfico en el telescopio de 60 cm del sistema de distancia por láser del Observatorio Astronómico de Shangai. Las observaciones fueron realizadas sobre el objetivo escogido, el satélite Ajisai. Los resultados demuestran que este metodo es factible y que la incertidumbre en la medición del ángulo del el satélite Ajisai, es de alrededor de 5 segundos de arco.

ABSTRACT

According to the principles of space debris orbit determination, its success rate and reliability will be improved if the celestial coordinates are known at the time of the laser ranging. The method of determining the 3D location of space debris by laser ranging and optical astrometry is presented. A test platform is established by installing a photographic equipment on the 60cm satellite laser ranging telescope system of the Shanghai Astronomical Observatory. Experimental observations are carried out and the satellite Ajisai is chosen as the target. The results show this method is feasible and the angle measurement accuracy of the satellite Ajisai is about 5 arc second.

*Key Words:* instrumentation: detectors — methods: data analysis — techniques: image processing



## 1. INTRODUCTION

In order to guarantee the safety of orbiting spacecraft and the sustainable development of space activities, it is necessary to develop a new method for space debris monitoring to enhance the space debris environment analysis and early warning capabilities.

Optical observations mainly use satellite laser ranging (SLR) or optical angle measurement mode. SLR technology has been greatly improved in last 40 years, and it is one of the highest precision technologies for targets which are covered with mirrors or have corner-cube reflectors. But for most targets, such as space and rocket debris, which do not have corner reflectors, we have to apply diffuse reflection laser ranging technology. Thus, in the field of space monitoring, diffuse reflection laser ranging has wider applications.

In recent years, several institutions have carried out experiments and research on diffuse reflection laser ranging (Greene et al. 2002; Zhang et al. 2012). These tests showed that SLR with diffuse reflection could obtain high ranging accuracy at the meter level, although the success rate of this technology was not very high.

[1]Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai 200030, China (yuy@shao.ac.cn).

At present, diffuse reflection laser ranging is still in the experimental stage and the orbits of objects can hardly be determined by ranging data only from one single station, which restricts the application of diffuse reflection laser ranging. According to the principles of orbit determination, its success rate and reliability will be improved if the celestial coordinates of the object are known while laser ranging. In the following we present the method of three dimensional positions of space debris with laser ranging and optical astrometry.

## 2. METHODS

A test platform for laser ranging and optical astrometry is established by installing photographic equipment with a large field of view (FOV) to the 60cm SLR telescope of Shanghai Astronomical Observatory (SHAO) as shown in Figure 1. In order to reduce the impact of laser scattering on the target image, a special 532nm blocking filter is placed before the focal plane of the CCD camera. Satellite Ajisai was chosen as the target to get a more reliable assessment of angle measurements for the target, since Ajisai's ephemeris data is very precise and it can be used as a standard.

Data processing includes image preprocessing, star image extracting, reference star matching and

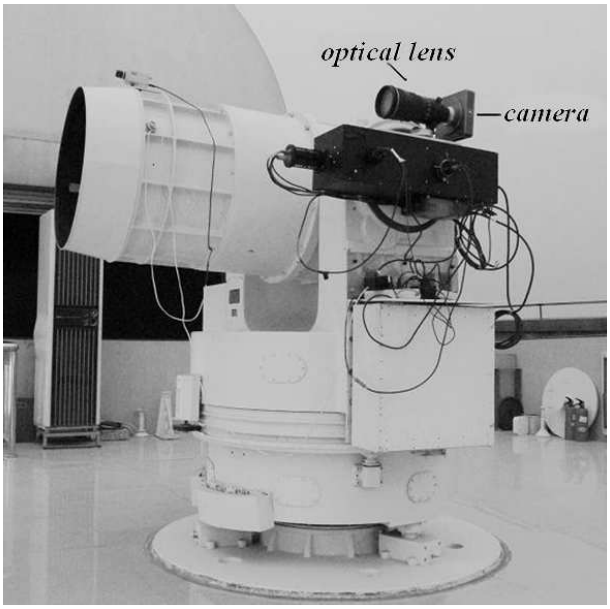


Fig. 1. Test platform for laser ranging and optical astrometry.

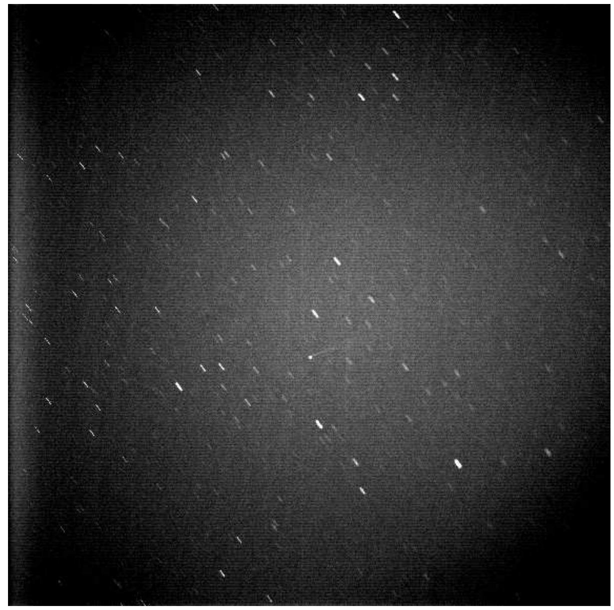

Fig. 2. Example of image of optical astrometry in the case of tracking the satellite Ajisai.

astronomical position determination for the target. The method for star image extraction is based on algorithm of interconnected domain. Reference star matching accomplished by the arc length matching method (Yu et al. 2010). The Hipparcos Catalogue was used as a reference and there are about 80 reference stars on each CCD image.

After the position of the target has been measured, the influence of atmospheric refraction needs to be removed. For near-Earth targets, such as Ajisai, atmospheric refraction parallax should be considered as

$$p = \frac{510".2 \cdot \tan z \cdot \sec z}{d} \tag{1}$$

where $z$ is the zenith distance and $d$ is the distance between target and observer.

## 3. RESULTS

With the test platform, we carried out the integration experiments by means of laser ranging and optical astrometry for obtaining three dimension positions of the target in 2012. Figure 2 shows an example of an image, where the round image close to the center of the field of view is the satellite Ajisai and the other elongated images are stars.

We obtained a total of 20 passes for Ajisai and calculated the standard errors between observation and ephemeris. For Ajisai, the accuracy of angle measurement in azimuth is 5.4 arc second, while 4.3 arc second in elevation direction.

## 4. CONCLUSION

Our results show that integrating laser ranging and optical astrometry is feasible and that the angular measurement accuracy for the satellite Ajisai is around 5 arc second. Using the present platform, we will further explore how to improve the accuracy of angle measurement, including: (1) Optimizing the algorithm for centering elongated star images to improve the accuracy of the stellar reference frame. (2) Figure 2 shows that there are still remnants of the laser beam illumination which can pollute the target image. We need to choose a more appropriate filter to further weaken the scattering of the laser beam. In addition, an algorithm for background removal should also be developed.

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