B11

# ライトカーブ観測と H-2A R/B モデルを用いた再現実験

## Light Curve Observation and Reproduction Experiment Using Model of H-2A R/B

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積極的デブリ除去（Active Debris Removal, ADR）は、宇宙活動の安全を確保し、持続可能な宇宙開発を実現するために有望な方法の 1 つであるが、デブリを捕獲する場合等、事前にターゲットの姿勢や運動が必要になる場合がある。そのためターゲットのライトカーブのみを使用してターゲットの姿勢や運動に関する情報を得られれば、デブリ除去ミッション実現に向け前進となる。そこで 60cm 望遠鏡と CMOS センサを使用して、ADR 対象候補の一つである、日本の H-2A ロケットの 2 段目のライトカーブ観測を開始した。また、観測したライトカーブを模擬するために、光学シミュレーターと呼ばれる実験設備で実験を実施した。光学シミュレーターでは、H-2A R/B のスケールモデルを使用し、軌道上での物体の姿勢や運動、太陽方向を考慮して、地上望遠鏡で観測した場合のライトカーブを再現できる。また、ライトカーブの網羅的な傾向を検討するために、CG を使用したライトカーブシミュレーションツールを開発した。これにより、光学シミュレーターを使用してライトカーブを取得するための実験時間が大幅に短縮できると期待される。

Active debris removal (ADR) is one of the most promising methods for ensuring safe space activities, free from the danger of debris. In order to carry out an ADR mission, the attitude and motion of the target must be determined precisely in advance. Developing methodology to extract these values using only the target's light curve would be a great step forward. We started the light curve observations of the ADR candidates, 2nd stages of Japanese H-2A rockets using the 60cm telescope and the CMOS sensor. In addition, we developed an optical simulator in the laboratory to mimic observed light curves. The simulator can reproduce the exact light curve that considers the attitude, movement, and lighting conditions using a scale model of the H-2A R/B. We also developed a light curve simulation tool using CGs that can estimate the overall tendency of the light curve, which will dramatically reduce experimental times for simulating light curve using the optical simulator.

# LIGHT CURVE OBSERVATION AND REPRODUCTION EXPERIMENT USING MODEL OF H-2A R/B

## ライトカーブ観測とH-2A R/Bモデルを用いた再現実験

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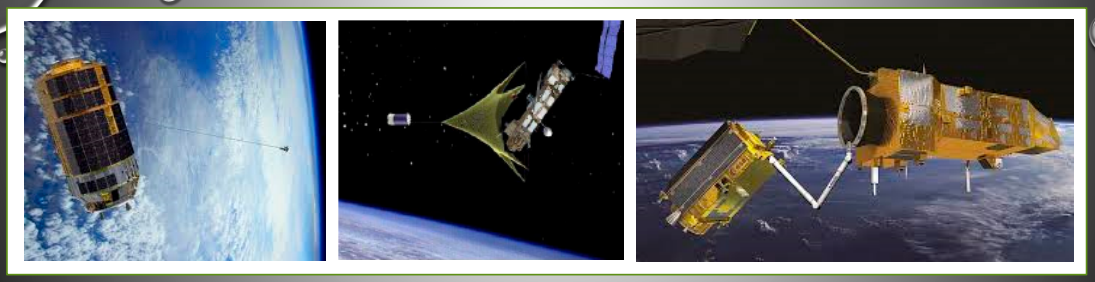
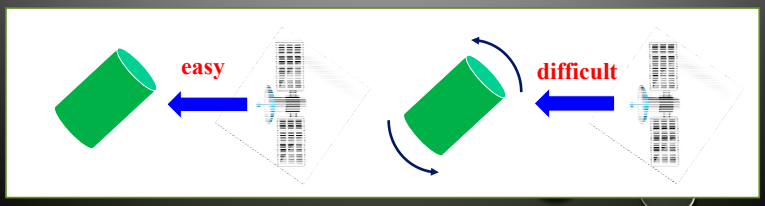
## Abstract

Active debris removal (ADR) is one of the most promising methods for ensuring safe space activities, free from the danger of debris. In order to carry out an ADR mission, the attitude and motion of the target must be determined precisely in advance. Developing methodology to extract these values using only the target's light curve would be a great step forward. We started the light curve observations of the ADR candidates, 2nd stages of Japanese H-2A rockets using the 60cm telescope and the CMOS sensor. In addition, we developed an optical simulator in the laboratory to mimic observed light curves. The simulator can reproduce the exact light curve that considers the attitude, movement, and lighting conditions using a scale model of the H-2A R/B. We also developed a light curve simulation tool using CGs that can estimate the overall tendency of the light curve, which will dramatically reduce experimental times for simulating light curve using the optical simulator.

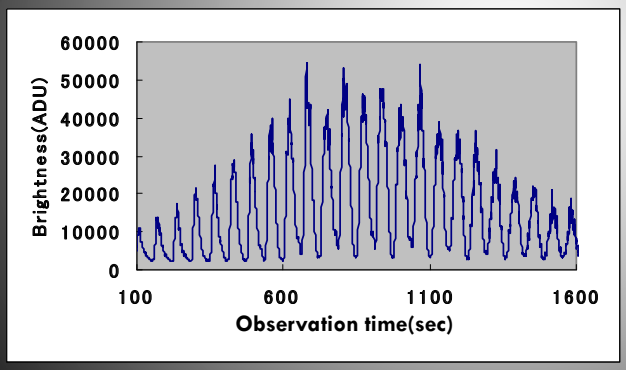
## Background

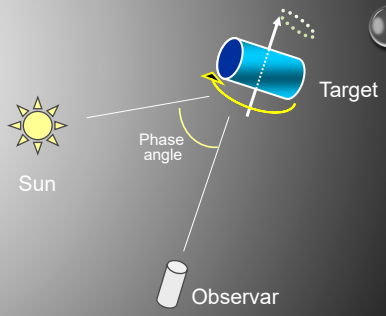


- ADR is needed to secure the space environment.
- Understanding the motion and attitude of the target in advance is very important for the ADR mission.




## Light Curve Observation

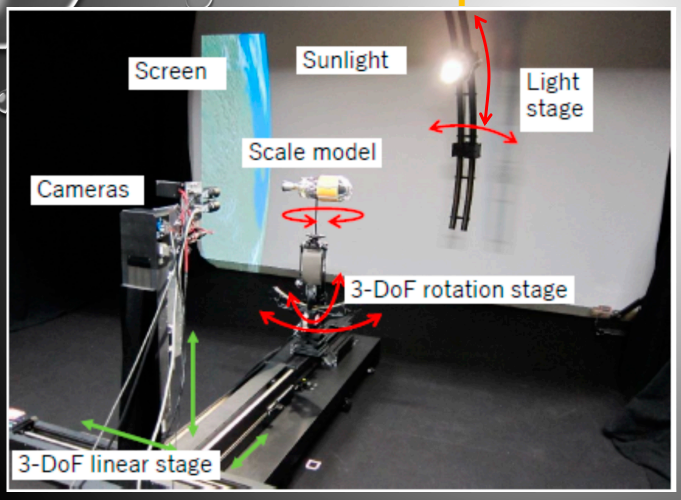



- Light curve observation is easy and cost effective as compared with the direct imaging with the adaptive optics.
- Technologies to estimate motions and attitudes of targets must be developed.

The optical simulator for simulating light curves was developed.

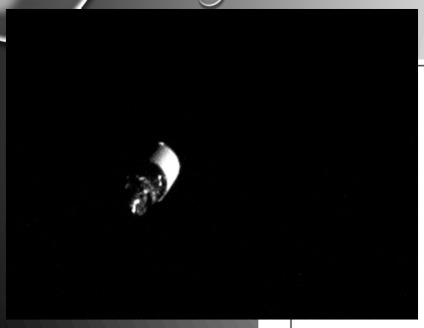
## Optical simulator



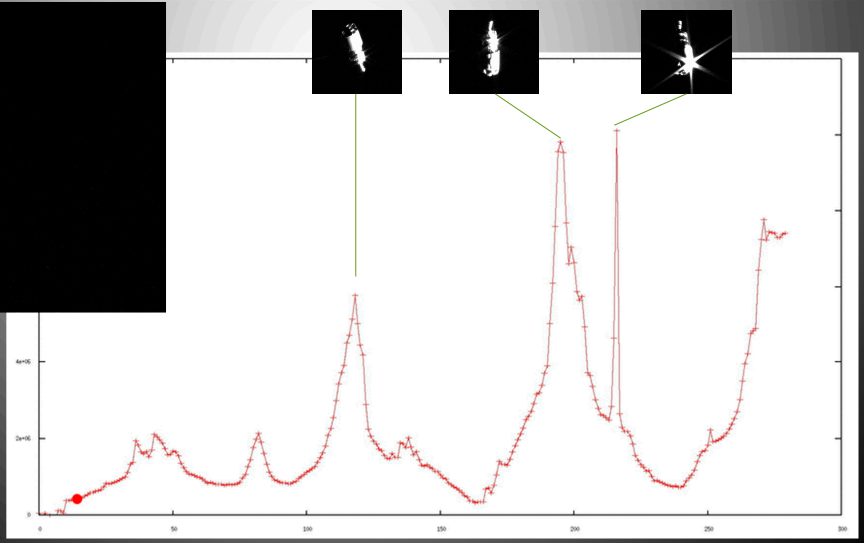

The scale model of H2A R/B

- The optical simulator consists of a 3-DoF (degree of freedom) linear stage, a 3-DoF rotation stage, a light stage, a scale model of the target, and CCD cameras.
- The optical simulator can simulate the orbital environment including lighting condition, attitude and motion of the target.
- Simulated light curve is created analyzing images taken by the CCD camera

## Optical simulator

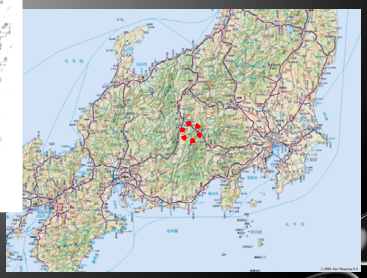


CCD images of the scale model of H2A R/B



The simulated light curve. The scale model is rotating at 3 deg/s about the minor axis.

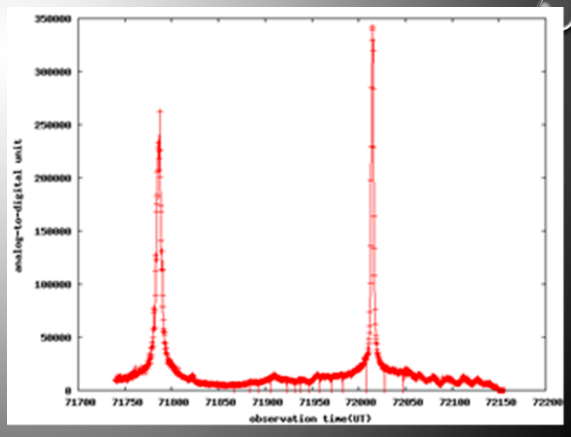
## Mt. Nyukasa Optical Observatory



N 35˚54’05”, E 138˚10’18”, Altitude 1,870m

Mt. Nyukasa in Nagano prefecture, Japan

## Light curve observations of H-2A R/Bs



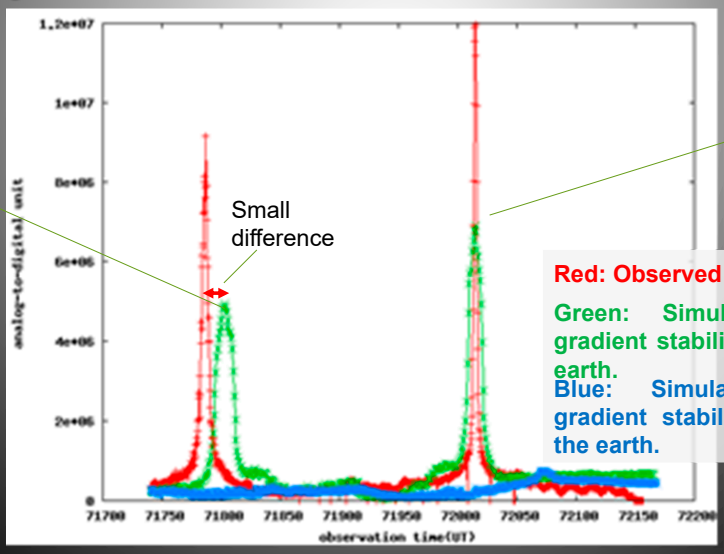

Light curve observations of 4 H-2A R/Bs are being carried out using 60cm telescope

The light curve of 39771 observed on March 19, 2019. Two strong peaks are observable

Light curve simulations were carried out using the optical simulator

## Light curve simulation





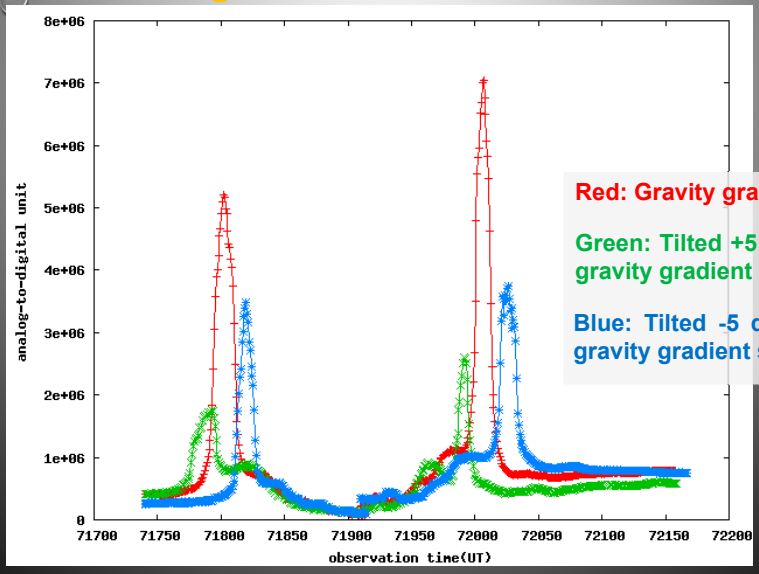

Red: Observed light curve

Green: Simulated one. Gravity gradient stabilization. PAF faces the earth.

Blue: Simulated one. Gravity gradient stabilization. Nozzle faces the earth.

Observed light curve is well explained by the gravity gradient stabilization of the H2A R/B

## Light curve simulation



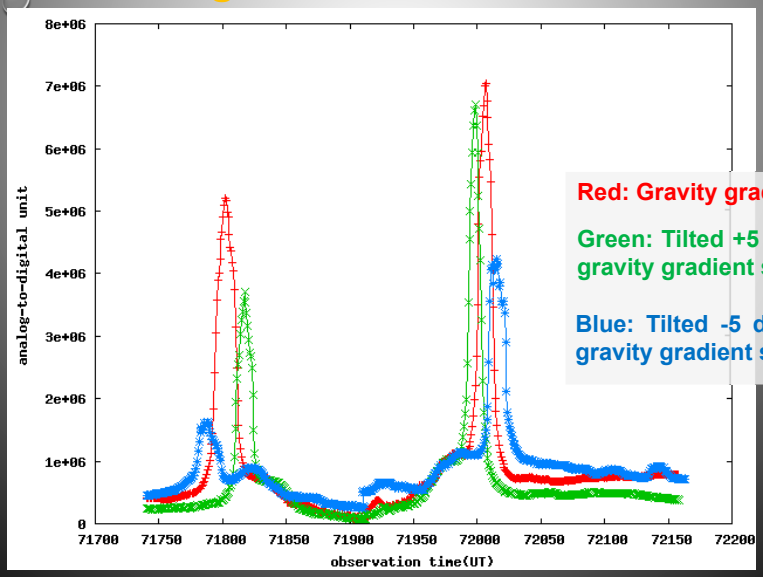

Red: Gravity gradient stabilization

Green: Tilted +5 deg from the line of gravity gradient stabilization

Blue: Tilted -5 deg from the line of gravity gradient stabilization

Peak timing is shifted when the scale model is tilted in the orbital plane

## Light curve simulation




Red: Gravity gradient stabilization

Green: Tilted +5 deg from the line of gravity gradient stabilization

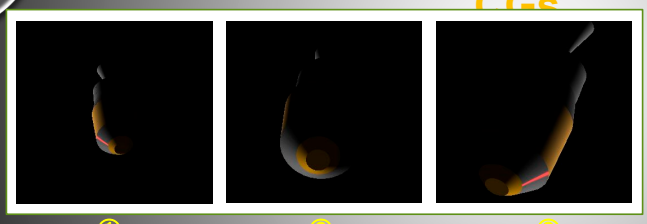
Blue: Tilted -5 deg from the line of gravity gradient stabilization

Peak interval is changed when the scale model is tilted outside the orbital plane

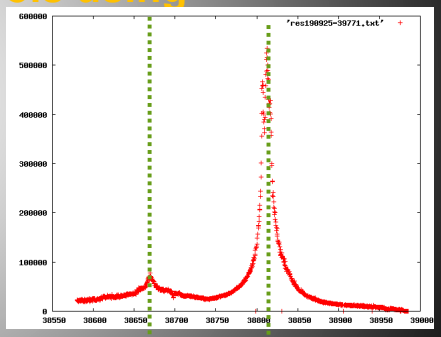
## Light curve simulation

- Observed light curve of H2A R/B is well explained by the gravity gradient stabilization of the target.
- Peak timing changes as the attitude of the target changes.
- Peak timing enable us to understand the attitude of the targets.
- The result explained here is just one example.
- A lot of observation and simulation are needed for total understanding.

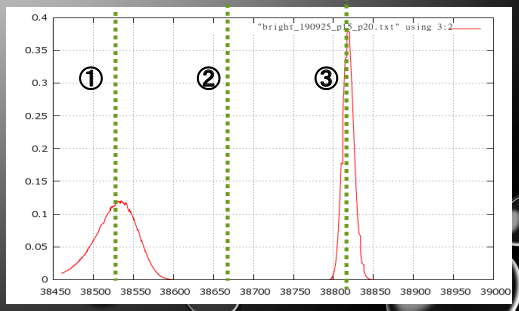
## Light curve simulation tools using CGs




CGs of each timing




A light curve simulation tool using CGs is being developed to reduce actual experimental time for simulations.
The tool creates light curves of each component considering its reflective properties, attitude, and lighting condition.




Simulated light curve of PSS

## Conclusions

The experiments using the optical simulator showed that the light curve of the H2A R/B (SSC#: 39771) observed on March 19, 2019 is explained by the attitude of the gravity gradient stabilization where the payload attach fitting of the H2A R/B was directing to the earth. It was also established that a few degrees of tilt of the target shifts peak timing. This means the attitude of the target may be determined using the times of the peaks in some cases. Although this is one case out of countless situations, simulating exactly the same light curve is the one step toward the total understanding of the ADR targets from light curves. Many more light curve observations and the simulations under the various conditions are needed to extract additional information on the H2A R/B for actual ADR.