F7

低軌道デブリのライトカーブ観測

Light curve observations of LEO debris

○黒崎裕久, 柳沢俊史(宇宙航空研究開発機構)
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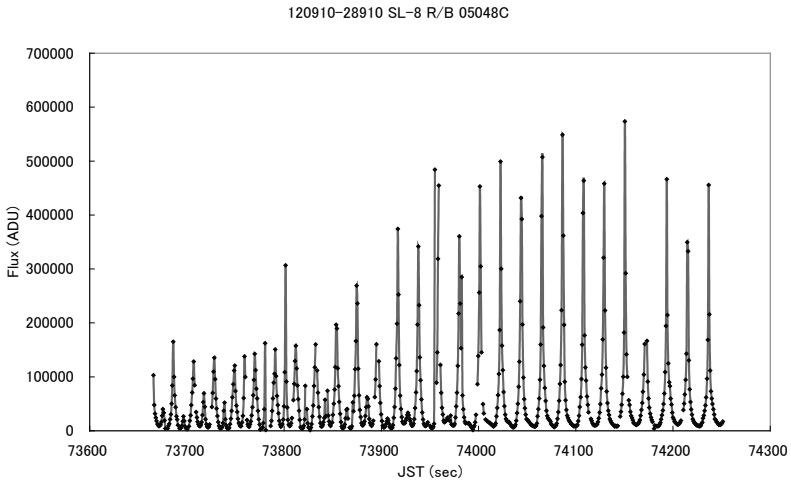
多くの宇宙物体(人工衛星、ロケット、デブリなど)が地球を回っている。これらの軌道は光学観測やレーダー観測によって常時観測されているが、物体の姿勢状態はあまり知られていない。光学観測による光度変化を見ると、スピン衛星や異なる反射面を持つ物体が回転している場合には、周期的な明るさの変化がみられる。
将来のデブリ除去では対象の回転状態によって捕獲方法を検討する必要がある。
我々はとくに SL-8 R/B の光度変化を調べている。これはロシアの COSMOS-3M ロケットの 2 段目である。ロケットボディは軌道上では安定しているという1説もあるが、観測すると光度変化しているロケットボディもいくつかある。ここでは低軌道の SL-8 R/B の光度変化の観測結果について報告する。

Many space objects (space satellite, rocket, and debris, etc.) are orbiting the earth. As for these, the orbit is always observed by the optical observation and the radar observation. However, the state of attitude of the object is not known so much. As for the change in brightness, when the object on a spinning satellite and a different reflection side rotates, the periodic change is seen. In the debris removal in the future, it is necessary to examine the capture method according to the rotating state of the object.
We are especially examining the change in the brightness of SL-8 R/B. This is the second stage of the COSMOS-3M rocket of Russia.
In one theory, it is said that the rocket body is steady on the orbit. However, there are some things that brightness has changed if the rocket body is observed. It reports on the observational result of the change in the brightness of the SL-8 R/B in the low earth orbit.



Light curve of LEO debris (SL-8 R/B)

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Introduction

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However, the state of attitude of the object is not known so much.
As for the change in brightness, when the object on a spinning satellite and a different reflection side rotates, the periodic change is seen.
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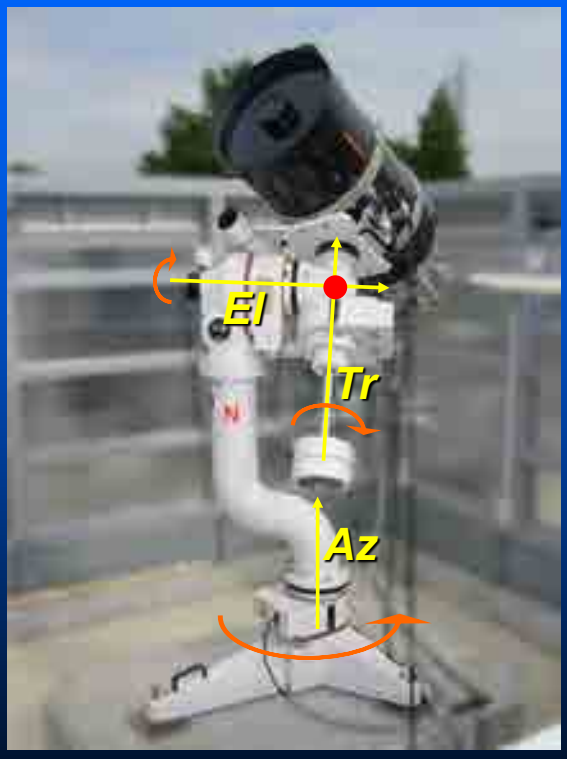
It reports on the observational result of the change in the brightness of the SL-8 R/B in the low earth orbit.

Optical observation system

Observation Site
JAXA, Aerospace Research Center
Chofu, Tokyo
Lat. 35°40′42″
Long. 139°33′24″
Alt. 55m

(35cm low earth orbit satellite tracking system)

Tri-Axial alt-azimuth Mount



3 axes
Azimuth (Az)
Elevation (El)
Tracking (Tr)
are controlled independently.

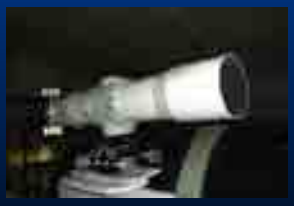
This alt-azimuth mount
No singular point on the celestial sphere, and can track any space debris even passing through the zenith.

For tracking a target, the Tr axis is used mainly that enables a stable tracking.
The hand controller can adjust the angular speed of El and Tr axes.

Telescope & CCD Camera

Schmidt Cassegrain SC355L
Diameter 355mm
Focal Length 3910mm F11
(2400mm (F7) with reducer)

BITRAN
Pixel Number 1.4M
(1360x1024)
Pixel size □6.45μm
CCD size 8.8×6.6mm
A/D 16bit
Trans time 0.7sec
Cooling Perche



Guide Telescope

Guide Camera

This mount operates by a special system software.

The azimuth and the elevation at visible time are calculated from TLE of the object.
This calculation makes the timetable every ten seconds.

⇩

Next, an azimuth and elevation value is converted into the value of the mount of three axes (azimuth, elevation, and tracking).
Neither the azimuth nor the elevation of the mount are the azimuths and the elevations of the object.
The calculation of this conversion makes the timetable every 0.5 seconds.

⇩ Object (Azimuth, Elevation) → Mount (azimuth-axis, elevation-axis, tracking-axis)

The mount moves to the position of the start time and it stands by.

⇩

The tracking starts at the start time.

⇩

The tracking axis smoothly moves to passing the object, and the azimuth axis and the elevation axis move slightly for the correction.

The gap is caused by the accuracy of TLE in the tracking passing.

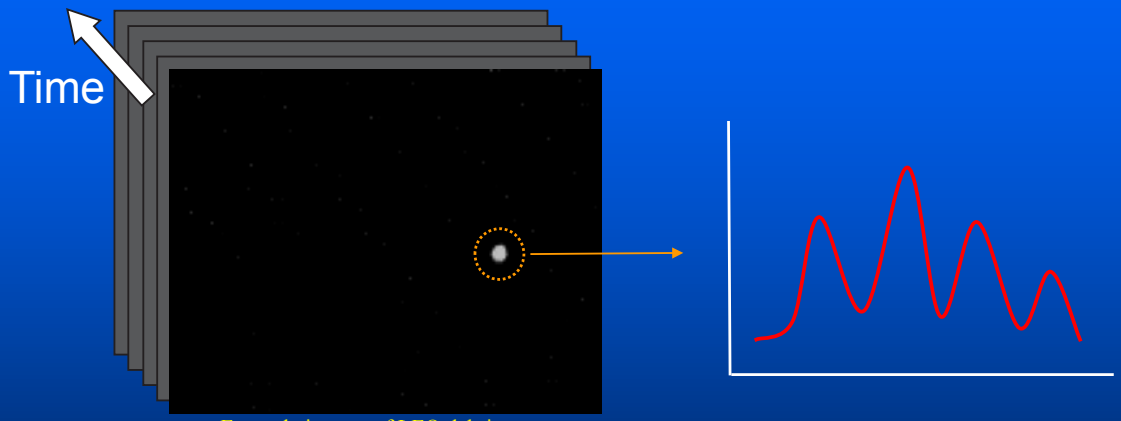
⇩ Hand Operation

The guide telescope applied to the telescope is monitored, and the object is kept at the center of the monitor by the hand controller.
The hand set can adjust the position in a tracking axis and a elevation axis.
In addition, each acceleration of two axes can be adjusted.
(In this part, there is a studying experience of the auto adjustment by the image recognition, too.)

⇩

The drive of the mount stops at the tracking end time.

Light curve

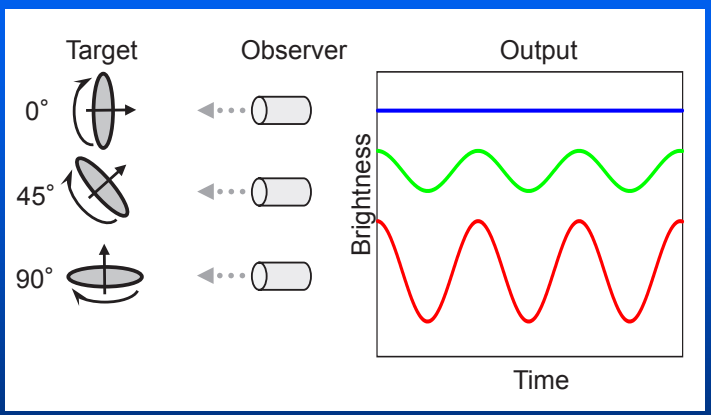


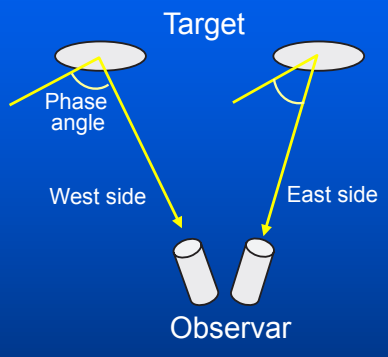
Example images of LEO debris

Brightness is obtained from the acquired image.

The intensity value of the pixels of the space object was added from each image, and a light curve was drawn in a graph.

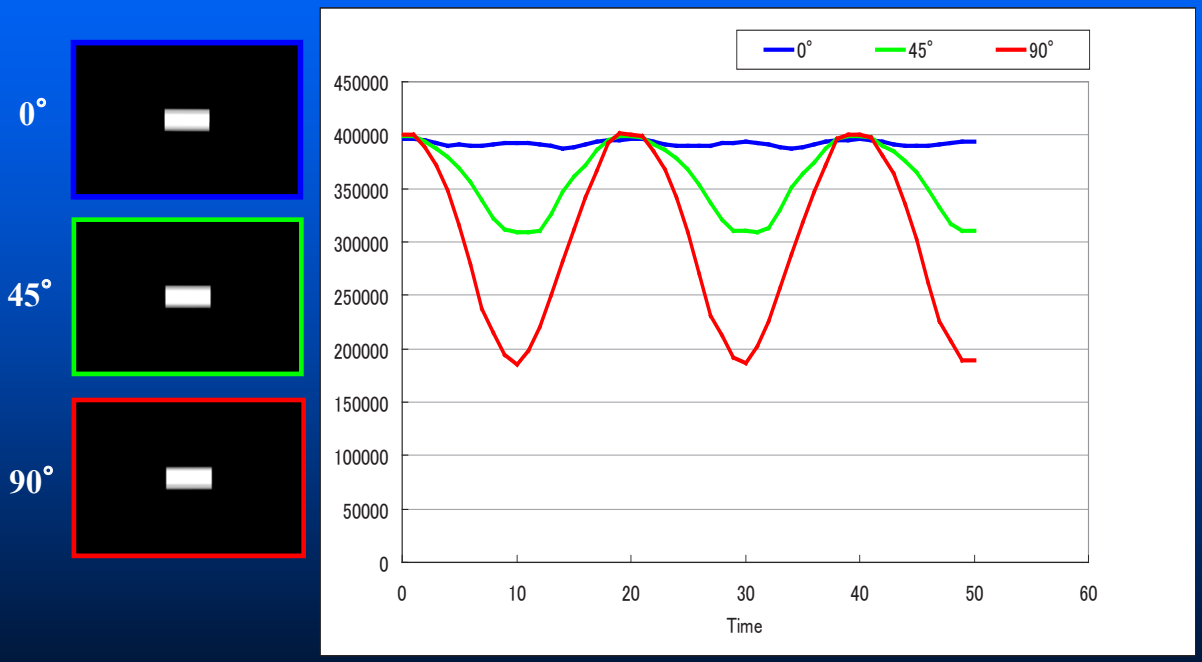
Light curves





The light curve changes by object, sun, and observer's geometry

Light curve simulation of circular cylinder



Targets of Observation

✧ SL-8 R/B

2nd stage of Cosmos-3M rocket of Russia

Shape	Cylindrical	Diameter	2.4 m
		Length	6.4 m
		Dry Weight	8.9 ton

Decision of object of observation

The object is decided with orbit calculation software (Orbitron).

Extraction of object from TLE catalog
Good visible condition is extracted
Original application (made by oneself)

Observed Object (SL-8 R/B)

120822	18986	SL-8 R/B	88023B	1
120827	10121	SL-8 R/B	77059B	1
	16012	SL-8 R/B	85079B	1
	11681	SL-8 R/B	80007B	1
	10521	SL-8 R/B	77119B	1
120828	18986	SL-8 R/B	88023B	2
	16012	SL-8 R/B	85079B	2
	15293	SL-8 R/B	84100B	1
	10521	SL-8 R/B	77119B	2
	20805	SL-8 R/B	90083B	1
120829	10521	SL-8 R/B	77119B	3
	12092	SL-8 R/B	80099B	1
	06708	SL-8 R/B	73042B	1
	21015	SL-8 R/B	90111B	1
	08344	SL-8 R/B	75094B	1
	17160	SL-8 R/B	86093B	1
120905	09638	SL-8 R/B	76128B	1
	08597	SL-8 R/B	76005B	1
	10732	SL-8 R/B	78028B	1
	12443	SL-8 R/B	81041B	1
	09044	SL-8 R/B	76070B	1
120910	18586	SL-8 R/B	87098B	1
	20805	SL-8 R/B	90083B	2
	10677	SL-8 R/B	78019B	1
	27437	SL-8 R/B	02026B	1
	22676	SL-8 R/B	93036B	1
	28910	SL-8 R/B	05048C	1

121001	12836	SL-8 R/B	81091B	1
	14966	SL-8 R/B	84043B	1
	10892	SL-8 R/B	78074B	1
	11870	SL-8 R/B	80056B	1
	18403	SL-8 R/B	87087B	1
	19257	SL-8 R/B	88053B	1
	25592	SL-8 R/B	98076B	1
	21231	SL-8 R/B	91029B	1
121009	24955	SL-8 R/B	97052C	1
	13649	SL-8 R/B	82109B	1
	11427	SL-8 R/B	79060B	1
	15598	SL-8 R/B	85022B	1
	13028	SL-8 R/B	82001B	1
121022	23093	SL-8 R/B	94024B	1
	20046	SL-8 R/B	89042B	1
	13618	SL-8 R/B	82102B	1
	13950	SL-8 R/B	83023B	1
121025	11170	SL-8 R/B	78122B	1
	20509	SL-8 R/B	90017B	1
	12508	SL-8 R/B	81053B	1
121029	20046	SL-8 R/B	89042B	2
	26819	SL-8 R/B	01023B	1
	18945	SL-8 R/B	88016J	1
	06207	SL-8 R/B	72074B	1
	13618	SL-8 R/B	82102B	2
	23432	SL-8 R/B	94083B	1
	07426	SL-8 R/B	74069B	1

121031	06320	SL-8 R/B	72102B	1
121101	13618	SL-8 R/B	82102B	3
	13950	SL-8 R/B	83023B	2
	10918	SL-8 R/B	78053B	1
	19827	SL-8 R/B	89017B	1
121107	25723	SL-8 R/B	99022C	1
	18586	SL-8 R/B	87098B	2
121115	05685	SL-8 R/B	71111B	1
	20104	SL-8 R/B	89050B	1
	10492	SL-8 R/B	77109B	1
121120	17067	SL-8 R/B	86086B	1
	11546	SL-8 R/B	79084J	1
	22308	SL-8 R/B	93001B	1
	11751	SL-8 R/B	80026B	1

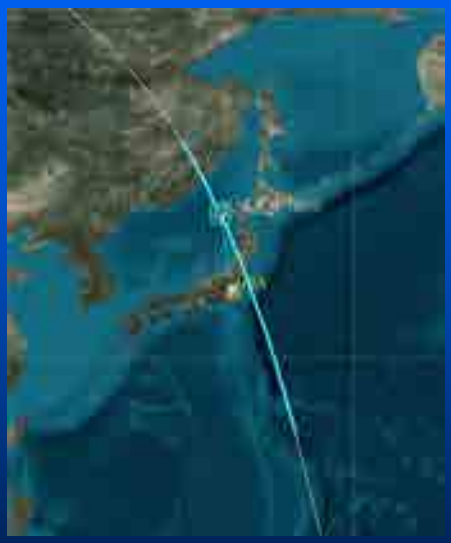
SL-8

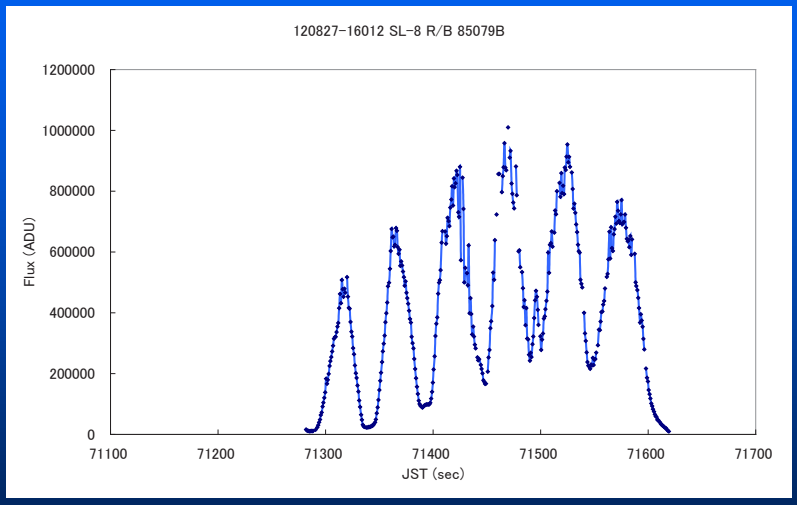
～2012.11.20

58／295（TLE Catalog）

SL-8 R/B 85079B

120827-16012



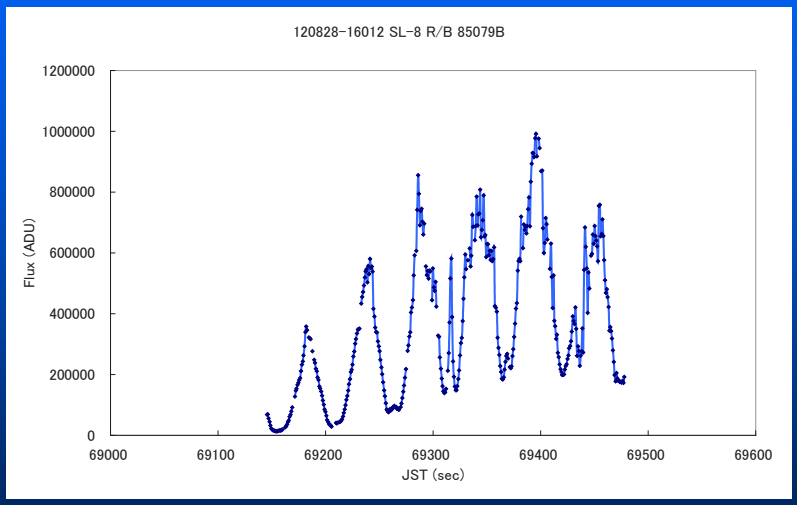


DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-08-27	10:46:12	16012	SL-8 R/B	347.2	20.0	6.5	1718	297.1	-18.0
2012-08-27	10:49:53	16012	SL-8 R/B	72.5	78.7	4.7	784	297.7	-18.7
2012-08-27	10:52:40	16012	SL-8 R/B	155.7	28.4	5.8*	1397	298.2	-19.2

388sec

SL-8 R/B 85079B

120828-16012

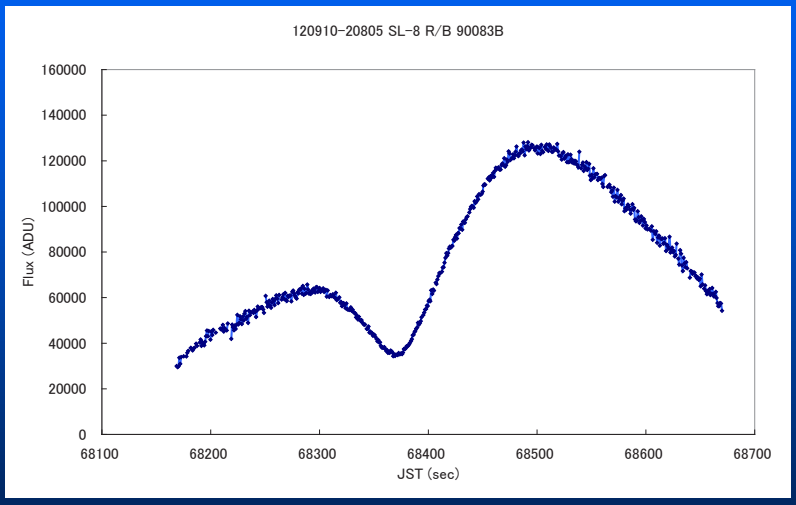


DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-08-28	10:10:56	16012	SL-8 R/B	4.4	20.0	6.5	1717	290.9	-11.8
2012-08-28	10:14:15	16012	SL-8 R/B	68.5	45.1	5.3	1035	291.5	-12.4
2012-08-28	10:17:34	16012	SL-8 R/B	132.7	20.0	6.3	1714	292.0	-13.0

398sec

SL-8 R/B 90083B

120910-20805

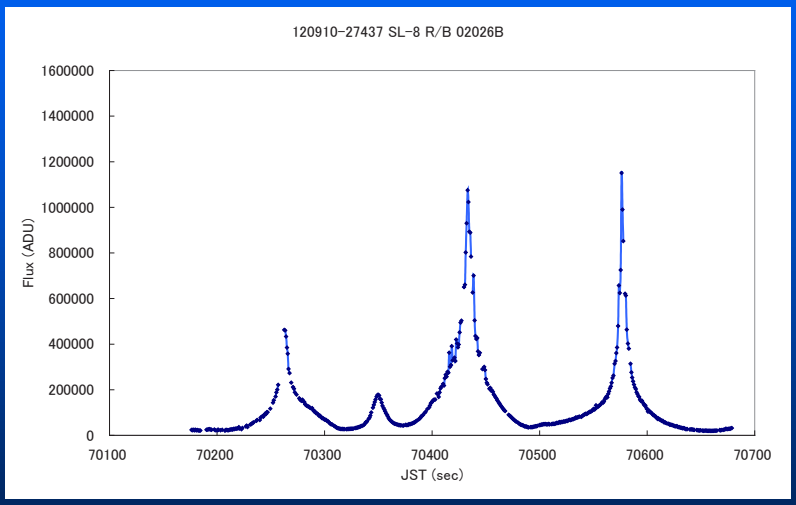


DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-09-10	09:55:38	20805	SL-8 R/B	189.1	20.1	6.9	2124	285.4	-12.7
2012-09-10	10:00:15	20805	SL-8 R/B	276.4	82.5	5.3	1013	286.1	-13.6
2012-09-10	10:04:53	20805	SL-8 R/B	3.1	20.1	7.0	2132	286.8	-14.5

555sec

SL-8 R/B 02026B

120910-27437

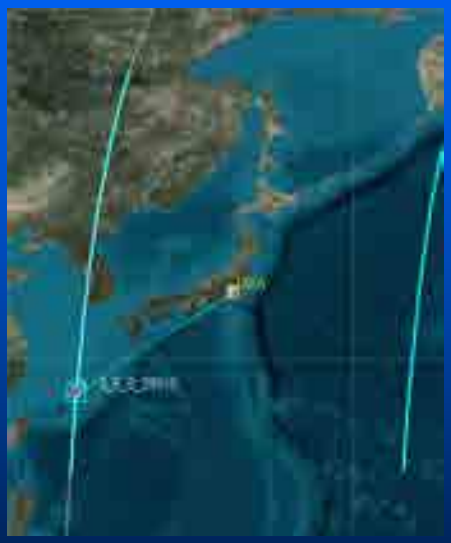


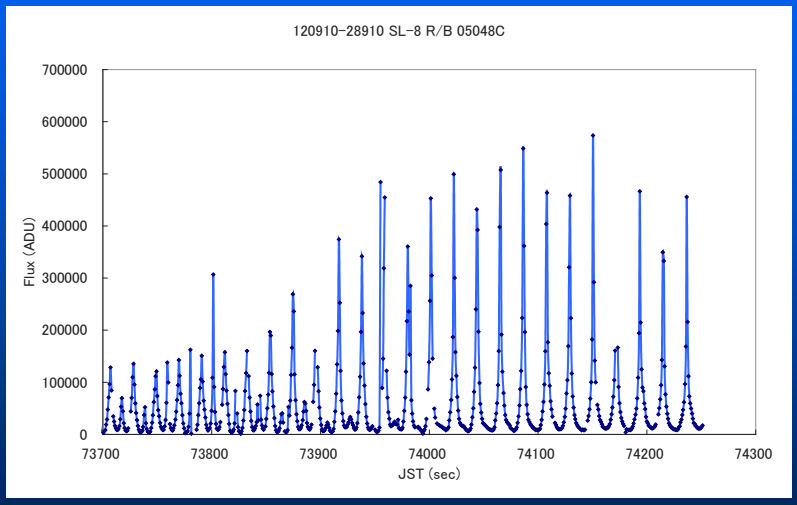
DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-09-10	10:29:11	27437	SL-8 R/B	191.6	20.1	6.8	2138	290.8	-19.1
2012-09-10	10:33:49	27437	SL-8 R/B	275.7	78.3	5.3	1032	291.6	-20.0
2012-09-10	10:38:29	27437	SL-8 R/B	1.5	20.0	6.9	2146	292.5	-20.9

558sec

SL-8 R/B 05048C

120910-28910



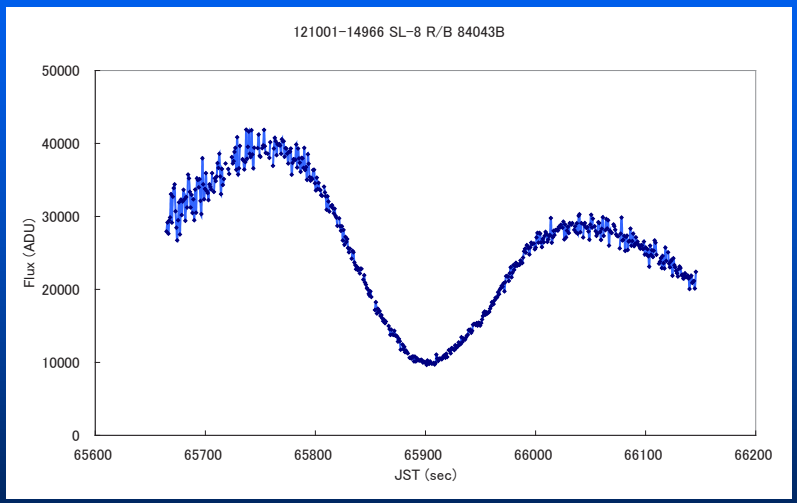


DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-09-10	11:26:41	28910	SL-8 R/B	222.0	20.0	?	2861	301.6	-29.6
2012-09-10	11:32:20	28910	SL-8 R/B	283.5	43.9	?	1921	302.8	-30.6
2012-09-10	11:37:59	28910	SL-8 R/B	344.9	20.0	?	2861	304.0	-31.6

678sec

SL-8 R/B 84043B

121001-14966

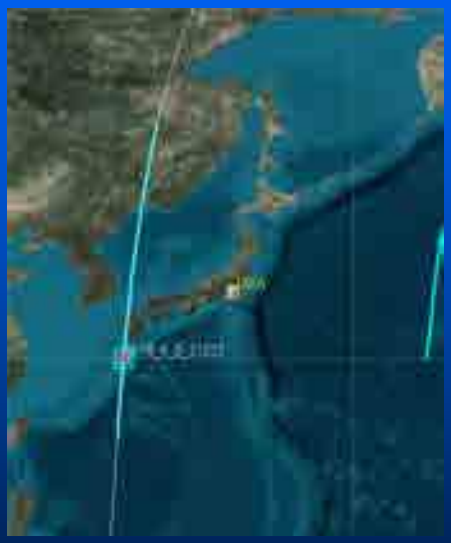


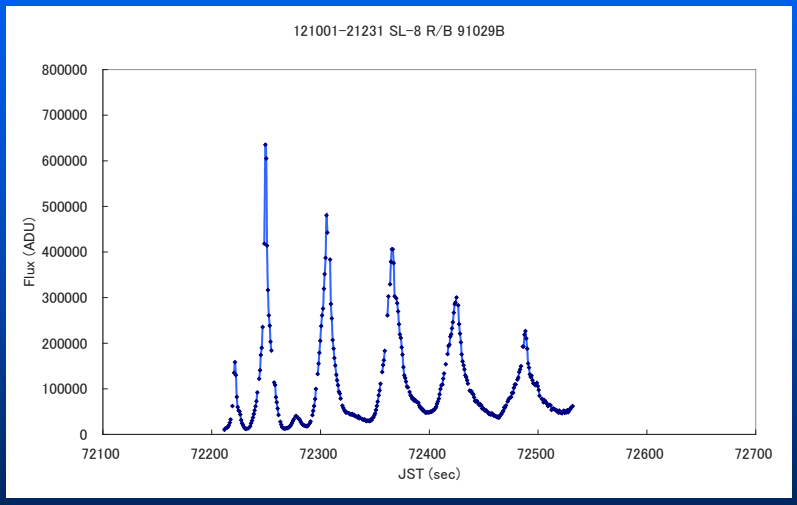
DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-10-01	09:13:41	14966	SL-8 R/B	201.1	20.0	7.0	2116	273.4	-10.6
2012-10-01	09:18:10	14966	SL-8 R/B	278.3	63.7	5.6	1095	274.1	-11.5
2012-10-01	09:22:39	14966	SL-8 R/B	355.2	20.0	7.0	2120	274.8	-12.4

538sec

SL-8 R/B 91029B

121001-21231



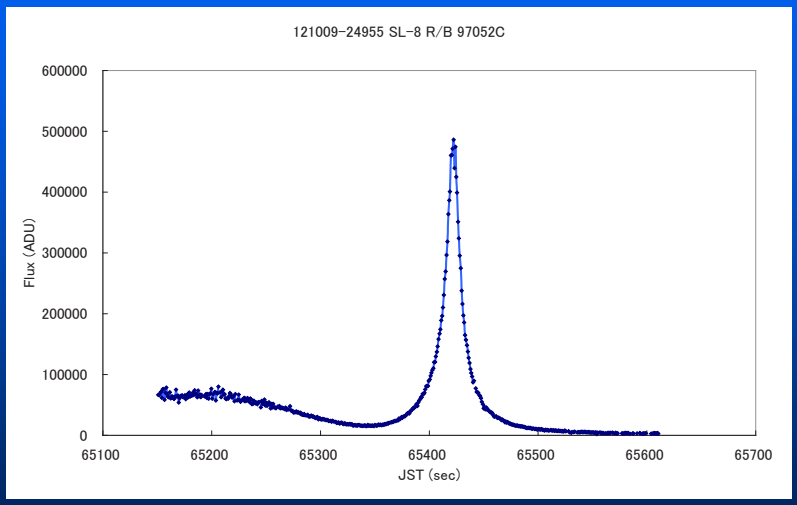


DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-10-01	11:01:02	21231	SL-8 R/B	217.6	20.0	6.7	2052	291.1	-31.9
2012-10-01	11:04:59	21231	SL-8 R/B	280.8	44.7	5.7	1290	291.8	-32.6
2012-10-01	11:08:59	21231	SL-8 R/B	344.1	20.0	6.7	2074	292.6	-33.4

477sec

SL-8 R/B 97052C

121009-24955

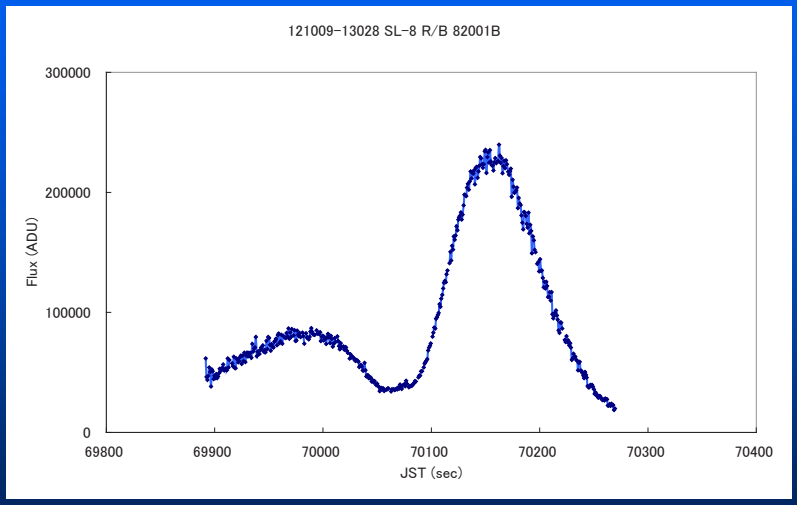


DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-10-09	09:04:30	24955	SL-8 R/B	347.6	20.0	7.0	2097	269.9	-11.0
2012-10-09	09:09:00	24955	SL-8 R/B	266.3	73.8	5.4	1013	270.5	-11.9
2012-10-09	09:13:26	24955	SL-8 R/B	184.9	20.1	6.9	2068	271.2	-12.8

536sec

SL-8 R/B 82001B

121009-13028

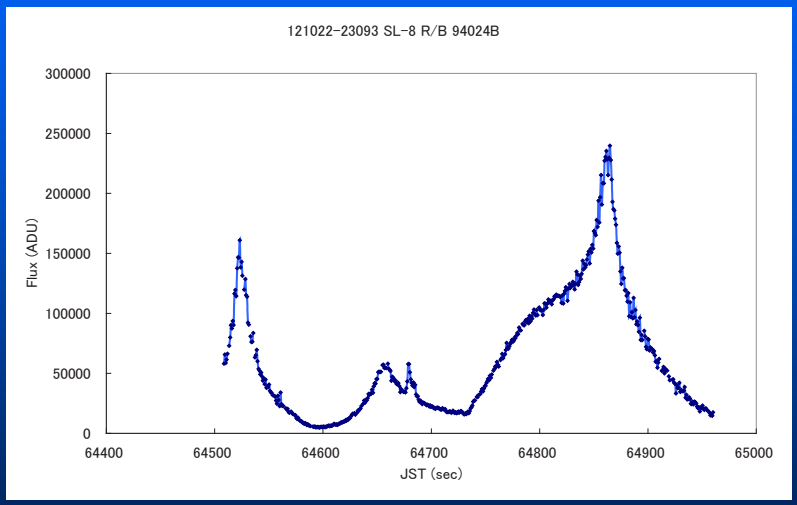


DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-10-09	10:24:00	13028	SL-8 R/B	208.7	20.0	6.3	1698	282.1	-27.0
2012-10-09	10:27:36	13028	SL-8 R/B	289.2	68.1	4.7	813	282.7	-27.7
2012-10-09	10:31:11	13028	SL-8 R/B	8.5	20.1	6.2*	1698	283.3	-28.5

431sec

SL-8 R/B 94024B

121022-23093



DATE	TIME	SSC	NAME	Az	El	Mag.	Ran	Az(Sun)	El(Sun)
2012-10-22	08:54:18	23093	SL-8 R/B	193.9	20.1	7.0	2067	264.8	-12.2
2012-10-22	08:58:44	23093	SL-8 R/B	276.4	74.5	5.3	1003	265.4	-13.1
2012-10-22	09:03:12	23093	SL-8 R/B	359.9	20.0	6.8	2075	266.1	-14.0

534sec

Next Step

- Repetition observation of the same object
- Detection at rotational period by Fourier analysis
- Estimation of rotation axis
- Estimation of posture
- Comparison with simulation

Each analysis has the experience in the past.

→ We make a tool.