

Detection and orbit determination of
un-cataloged GEO objects at
Nyukasa Observatory and
Bisei Spaceguard Center.

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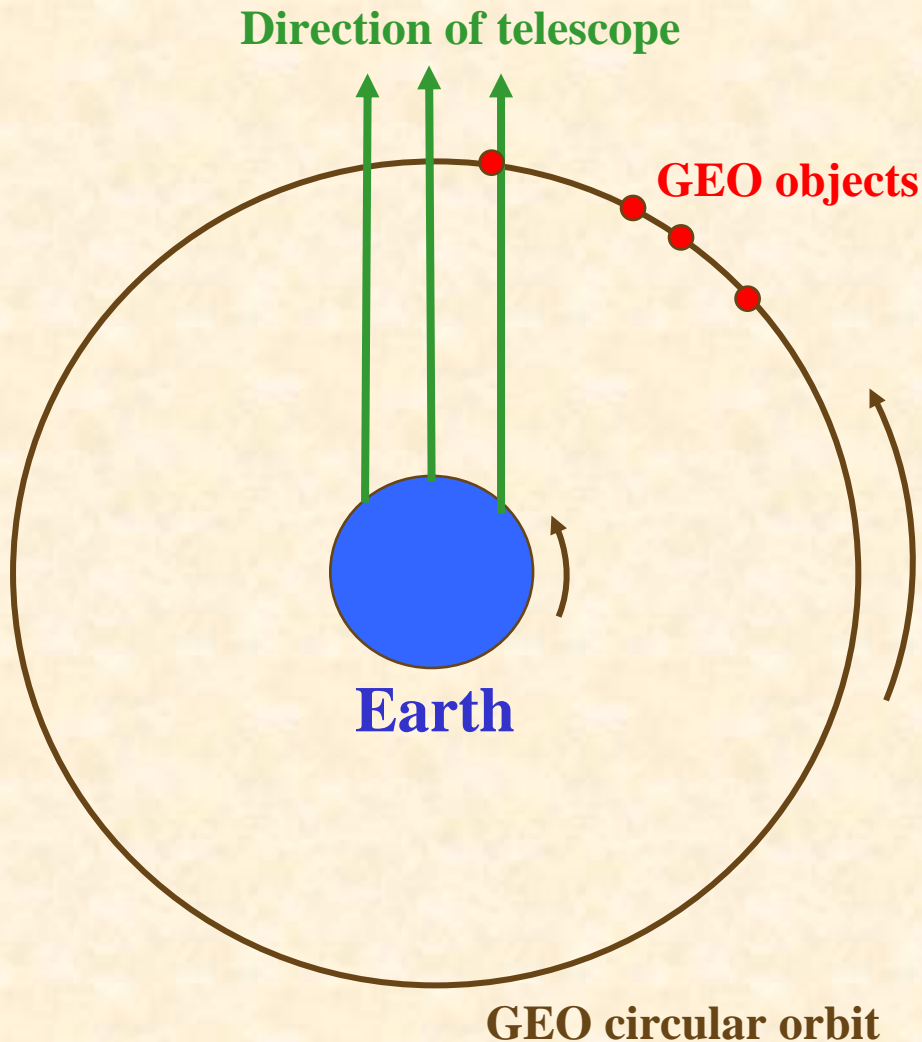
Abstract

We have succeeded in detection of un-cataloged GEO objects and determination of their orbits using a new observation strategy.

This strategy is able to carry out survey- and chase-observation effectively.

So far, about 30 un-cataloged GEO objects were detected and their orbits were determined by the cooperative observation between Nyukasa observatory of JAXA and Bisei Spaceguard Center.

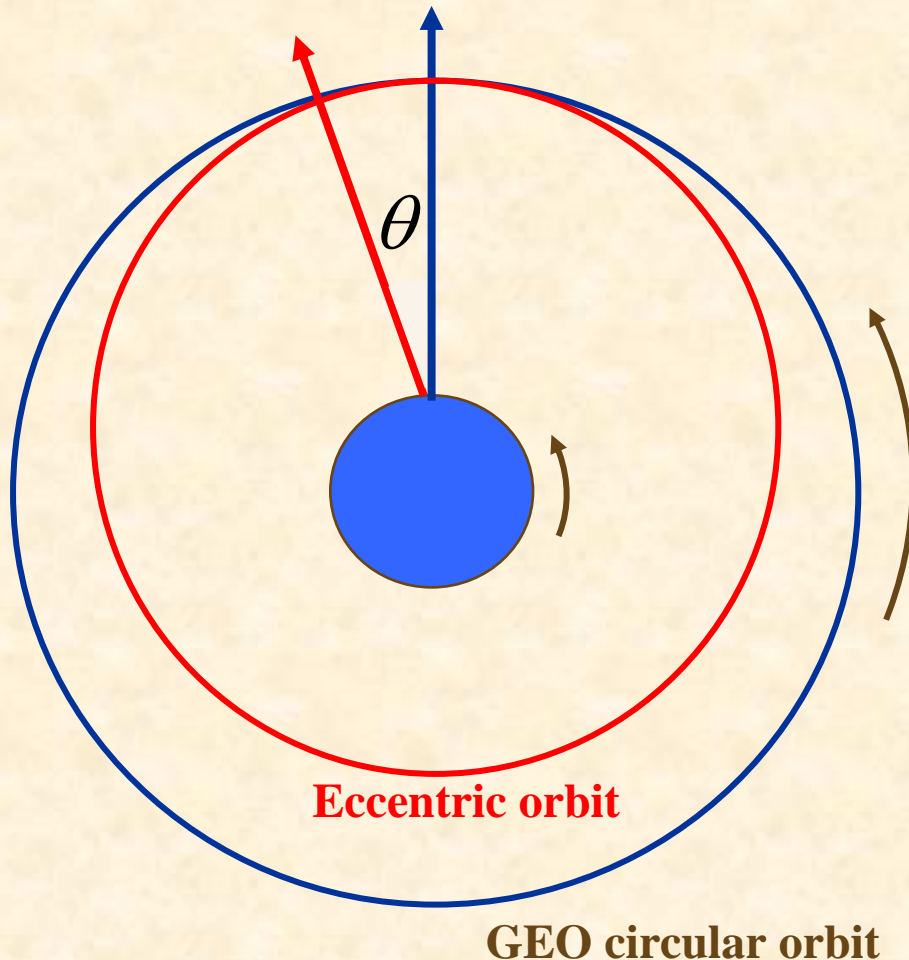
Typical observation strategy



Observe one RA and Dec region for a few hours or one night.

Observing one RA and Dec region is good for statistical study of GEO objects because many objects are detectable.

Weak point of this strategy



Circular orbit is assumed to detect GEO object a few hours later or on the second night. But it is impossible to detect eccentric GEO objects because of a quite narrow field of view.

Long continuous observation is needed for one object to get a long arc which is enough for determination of eccentric orbit.

e	4h $\theta (^{\circ})$	24h $\theta (^{\circ})$
0.1	6.9	55.5
0.05	3.4	27.4
0.01	0.7	5.4

Typical field of view is only a **1.0 × 1.0**-degree.

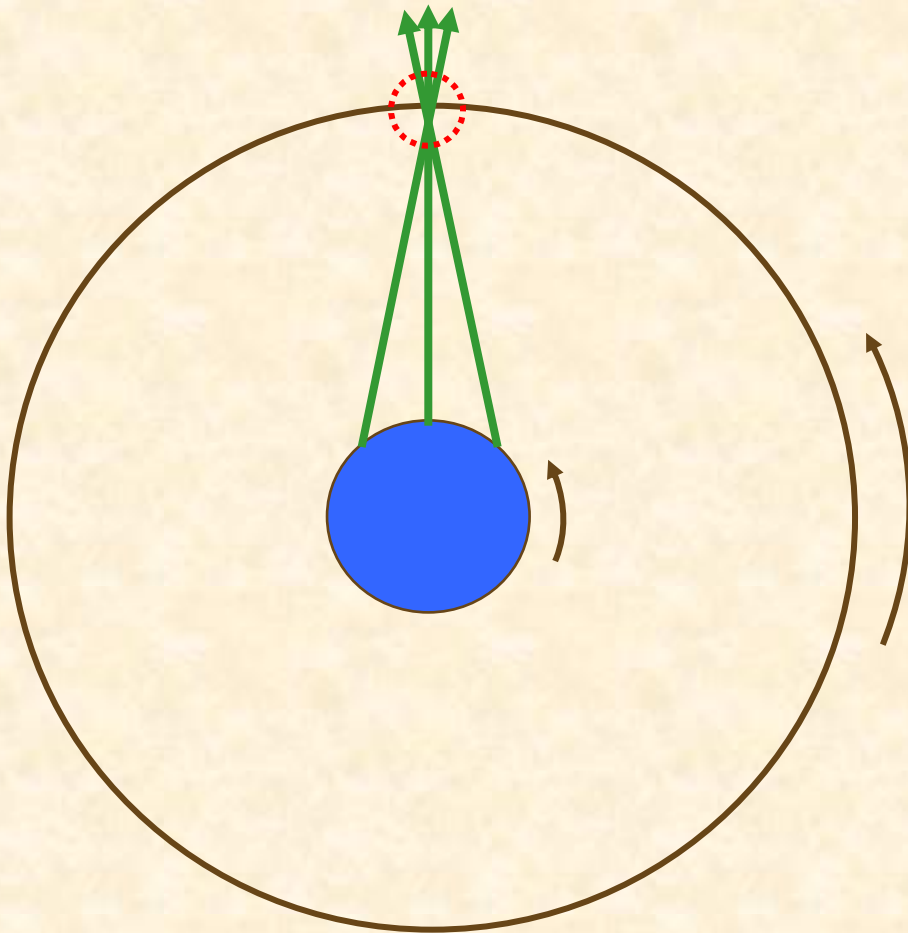
New observation strategy

Two nights' observations of one inertia position around GEO altitude.

Follow up observation assuming minimum eccentric orbit on the third night.

New observation strategy

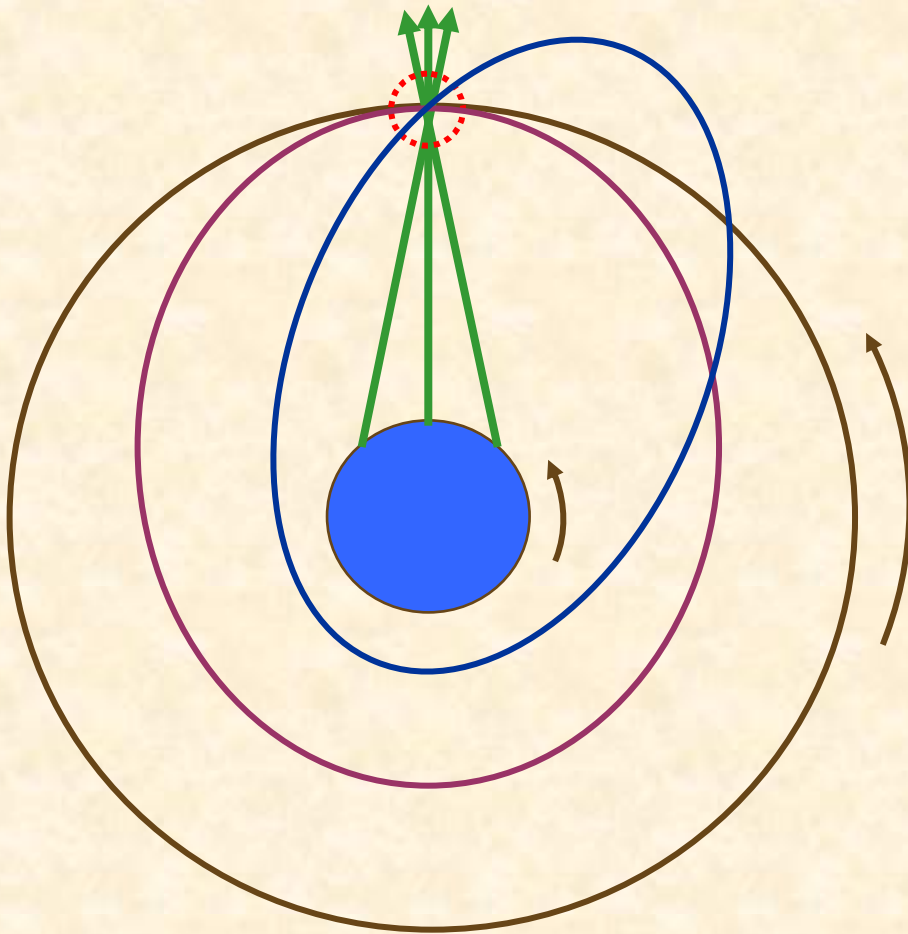
First and second night



Observing one inertia position around GEO altitude is different from observing one celestial region. Telescope must change its direction many times during the observation.

New observation strategy

First and second night



If we detect some objects in the first night, those objects must pass same position in the second night.

We don't know when those objects come back in the second night. It depends on their semi-major axes.

How to identify same object

Assume circular orbit from one night data. And compare its semi-major axis (a' , not true one), inclination (i) and RAAN (Ω) to search pairs.

First night objects

	1.	2.	3.	4.	5.	6.
a' (km)	42150	43052	41937	42236	42278	41875
i (°)	10.5	7.6	2.3	15.1	4.9	12.3
Ω (°)	90.3	16.7	45.0	120.2	62.1	58.6

Second night objects

	1.	2.	3.	4.	5.	6.
a' (km)	41954	42136	43007	42245	41903	42312
i (°)	2.4	10.4	7.4	15.0	12.3	4.8
Ω (°)	44.8	89.7	17.1	122.0	59.2	63.3



Minimum eccentric orbit

Once a pair is identified, we can calculate the true semi-major axis (a) from its orbital period. We can also estimate the minimum eccentricity (e').

Observational time of the
first and second night



Orbital period

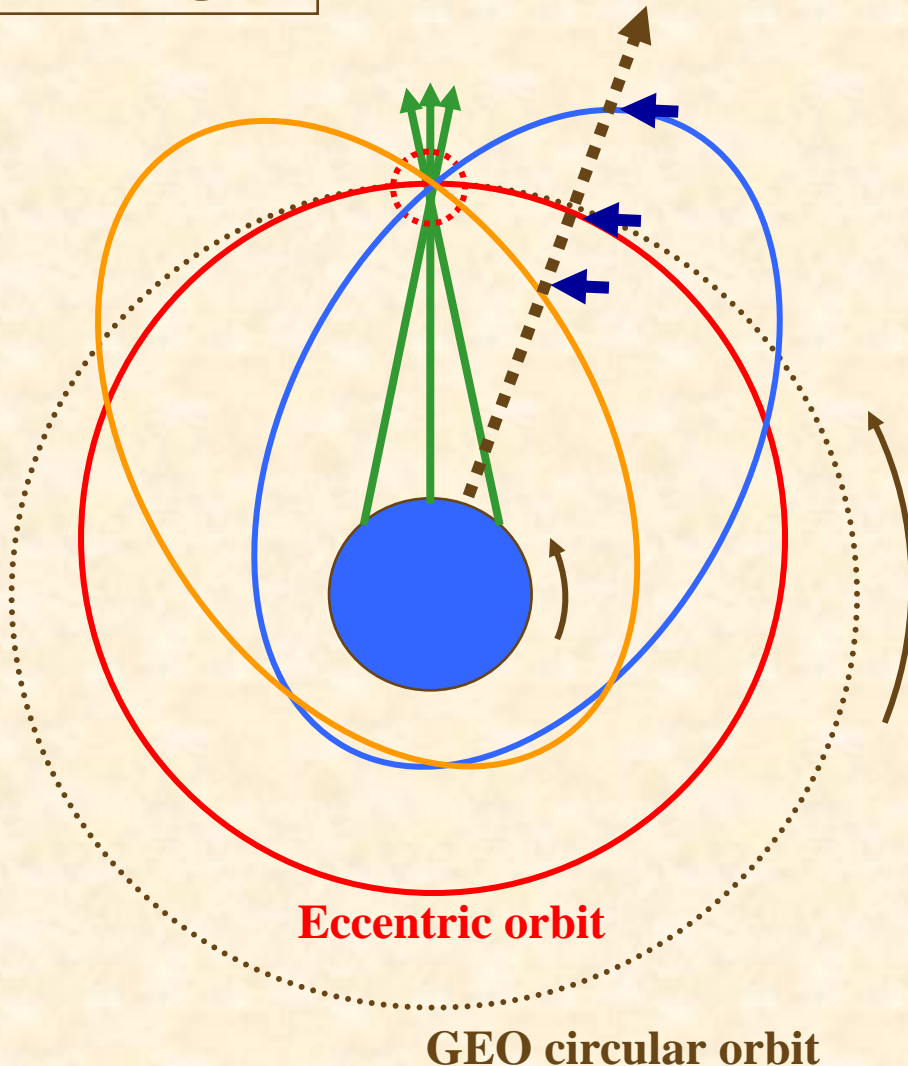


True semi-major axis (a)

$$a = 42164.170 \times \left(\frac{P}{23.93447} \right)^{\frac{2}{3}}$$

Third night observation

Third night



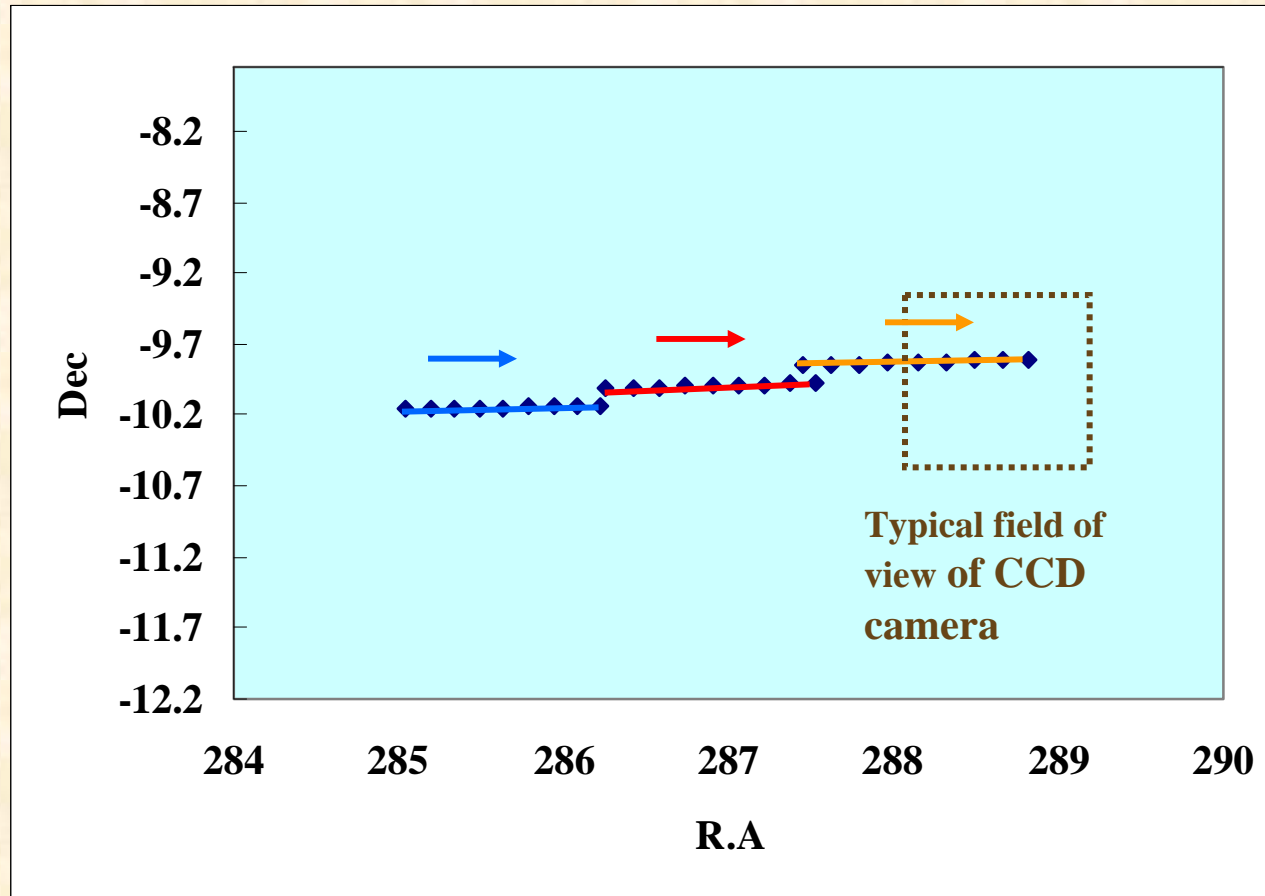
$$e' = \frac{|a' - a|}{a}$$

$$e \geq e'$$

To determine true eccentricity and argument of perigee, separated region from first two nights is observed on the third night.

Third night observation

30 degrees from the first two nights' region.



**Third night is used to follow up. 20 min for each object is enough.
By using 3 nights' data, we can determine their orbits precisely.**

Observation for un-cataloged GEO object

1. Detection and initial orbit determination (IOD) using the new strategy is carried out at Nyukasa observatory. Total observation time for one object is about 25 minutes for IOD.
2. Detailed chase observation and precise orbit determination is carried out at Bisei Spaceguard Center.



Bisei Spaceguard
Center



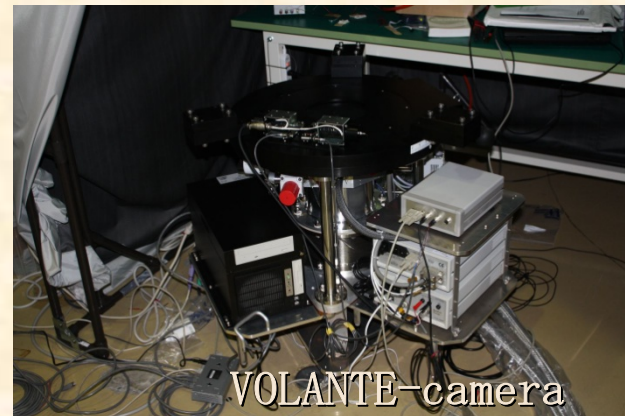
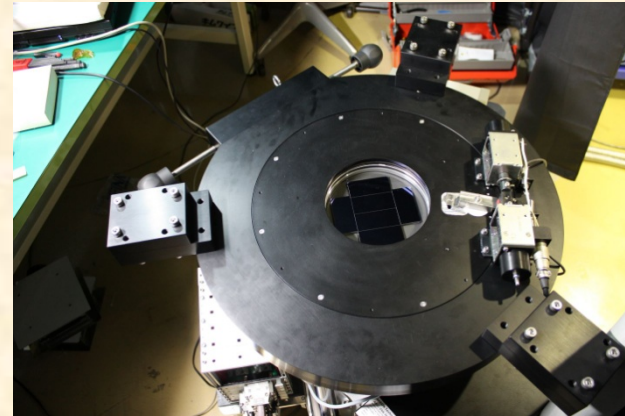
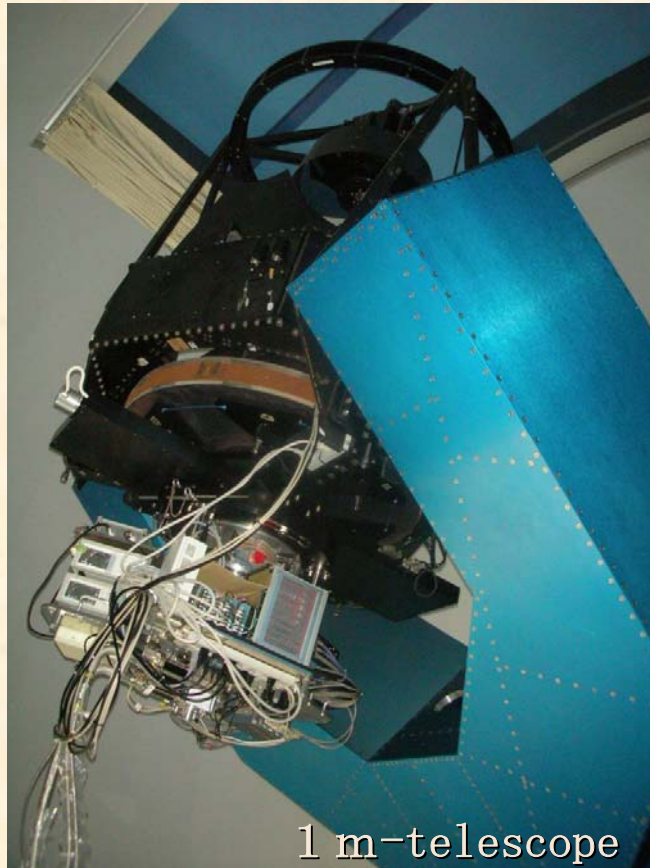
Nyukasa observatory

Observational equipments (Nyukasa)



Telescope: Takahashi ε -350
D=350mm
f=1248mm F/3.5
Equatorial mount: SHOWA Fork-type 25EF
CCD camera: N. I. L. FCC-104B
Chip: Marconi
CCD42-40

Observational equipments (Bisei)



Telescope:

D=1000mm f=3000mm

F/3

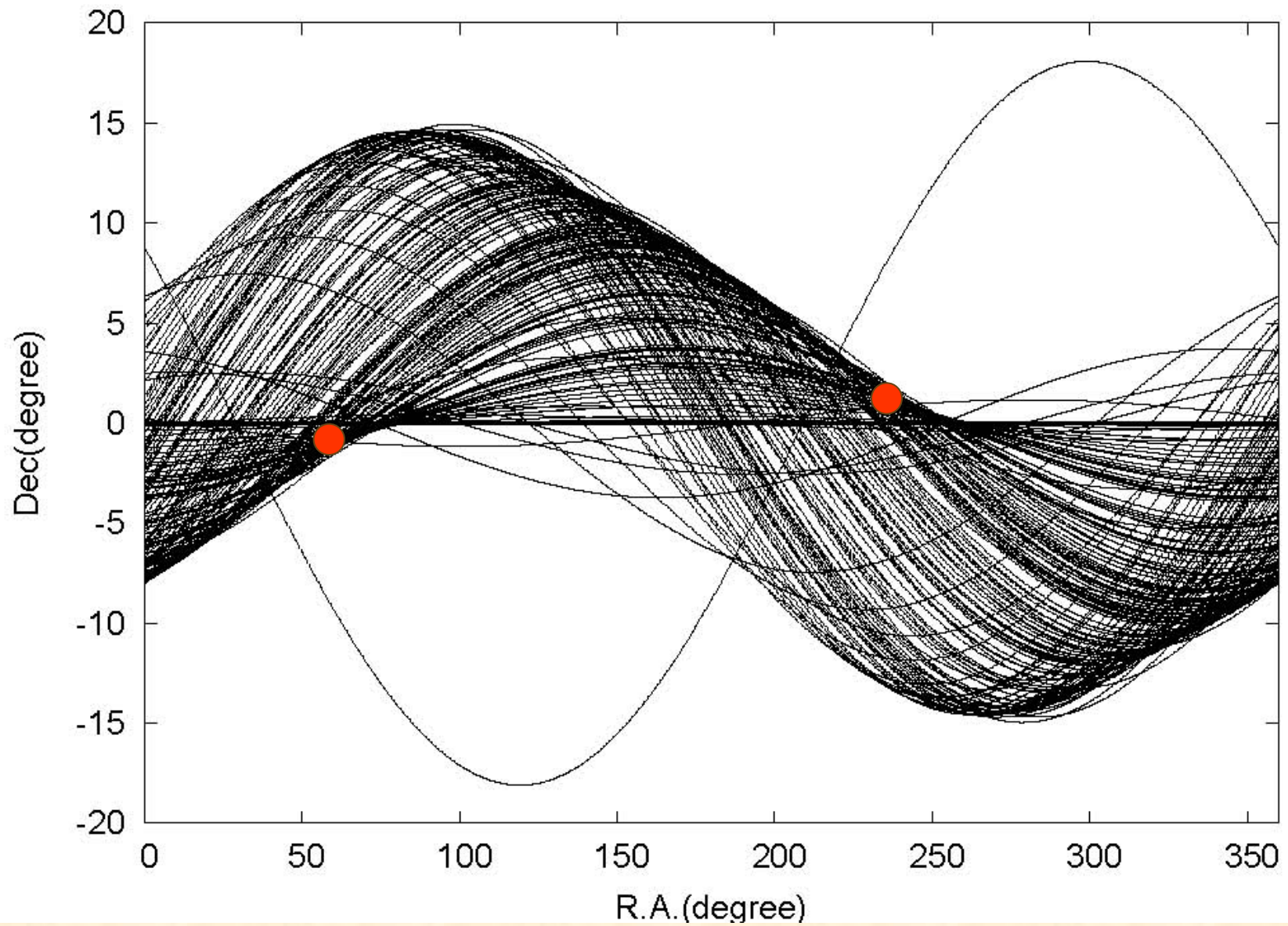
CCD camera:

VOLANTE

Chips:

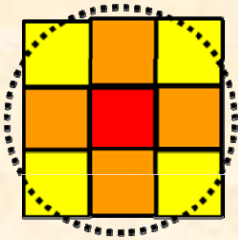
Hamamatsu2K4K×4

Observed region

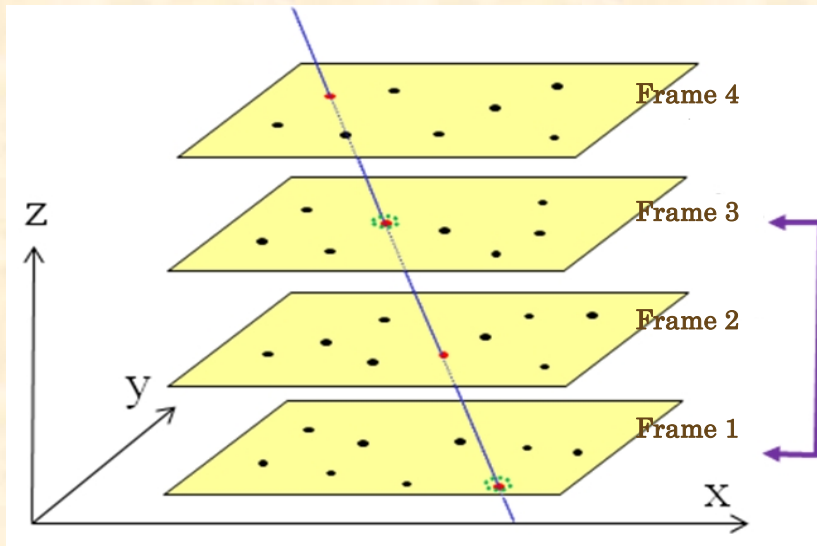


Data analysis process : Line identifying technique

The line identifying technique was developed to detect straight line features on consecutive frames.



Shape parameter =
Total value of nine pixels / value of central pixel



Concept of the line-identifying technique

Many frames



Candidates are detected using a proper threshold and the shape parameter



Straight lines are searched

Advantages :

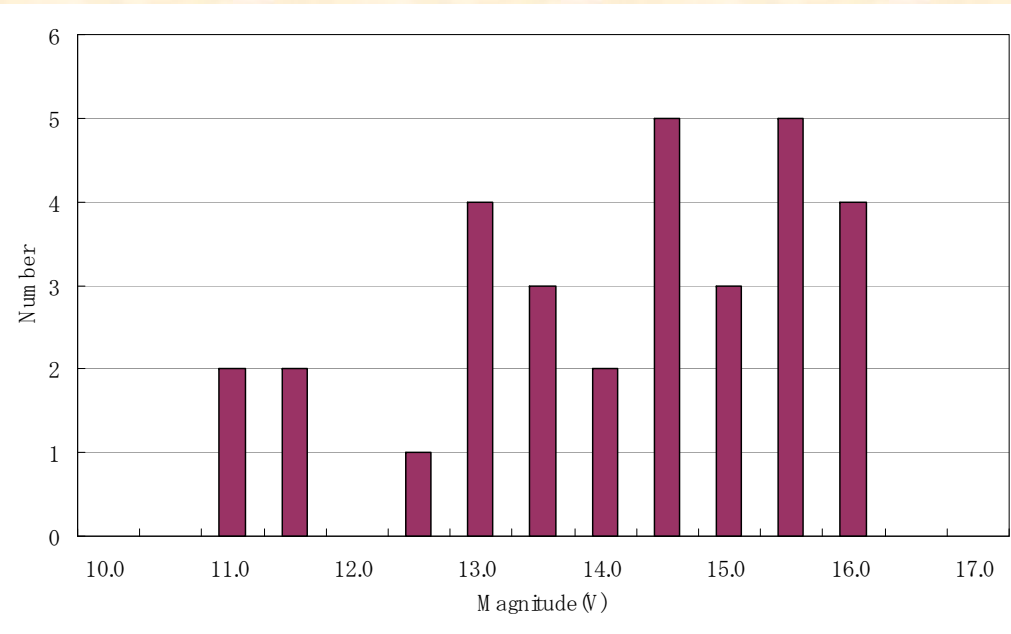
1. Every movement is not needed to investigate.
2. Number of candidates is adjusted to fit the performance of PC.



The technique was being used for the actual observation at Mt. Nyukasa.

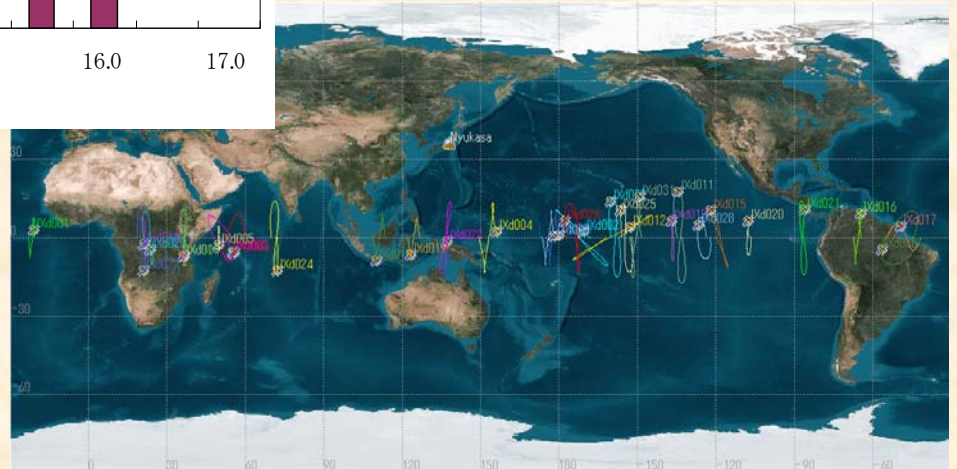
Result

So far, 31 un-cataloged GEO objects were detected and their orbits were determined. Some of their orbits are determined so well that they are observable after a few circling the earth. Some are not. Maybe they are high A/M ratio objects.



Brightness distribution of 31 uncataloged GEO objects

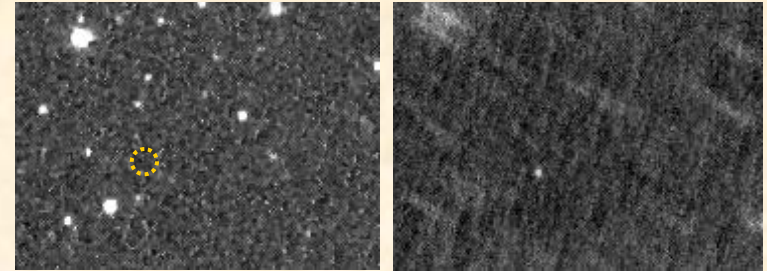
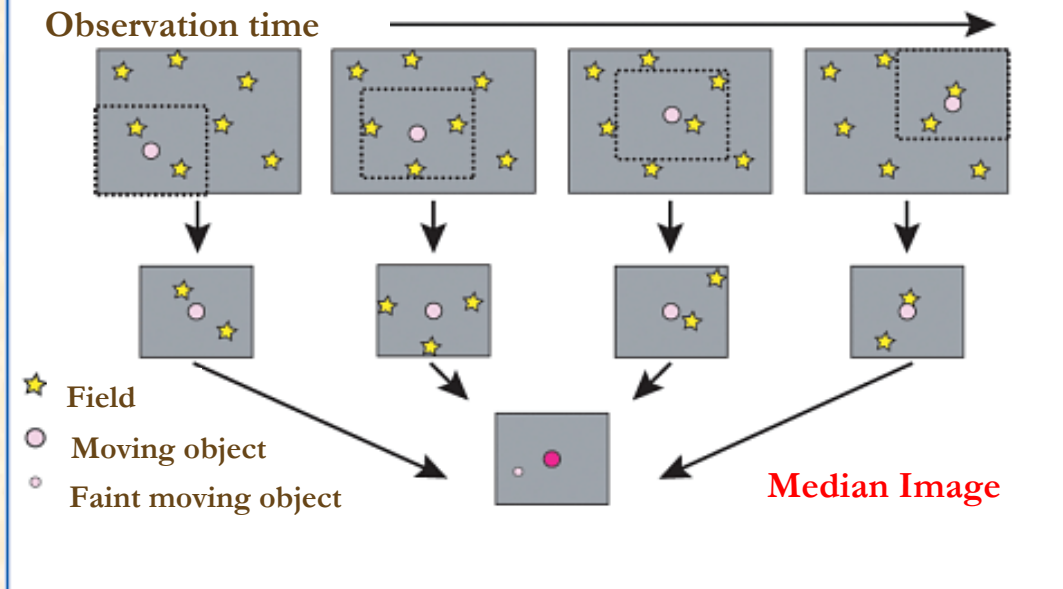
31 un-cataloged GEO objects detected by the new strategy



Future works

We are developing powerful detection technique called the stacking method. It uses multiple CCD images to detect very faint objects that are undetectable on a single CCD image. We would like to apply this method to the observation of un-cataloged GEO objects in the near future.

Concept of the stacking method



An asteroid detect with the stacking method. One CCD image (left) and the stacked image (right).



FPGA system for the method has been developed to reduce analysis time to 1/1000.

Sub-images are cropped from many CCD images to follow the presumed movement of moving objects. Faint objects are detectable by making the median image of these sub-images.

Many asteroids were discovered by the method.

Conclusion

We have succeeded in detection of un-cataloged GEO objects and determination of their orbits using a new observation strategy.

This strategy is able to carry out survey- and chase-observation effectively.

So far, about 30 un-cataloged GEO objects were detected and their orbits were determined by the cooperative observation between Nyukasa observatory of JAXA and Bisei Spaceguard Center.

We would like to apply FPGA based stacking method to the observation to increase our capability of detection and orbit determination of un-cataloged GEO objects.