NEO search using small telescopes
―Discovery of two NEOs, 2017 BK and 2017 BN92―

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Abstract

The research and development division of JAXA is developing observation technology for faint moving objects such as asteroid and space debris. JAXA has started the collaboration with National Astronomical Observatory of Japan and Japan Spaceguard Agency on the R&D for the new NEO search system since last April.

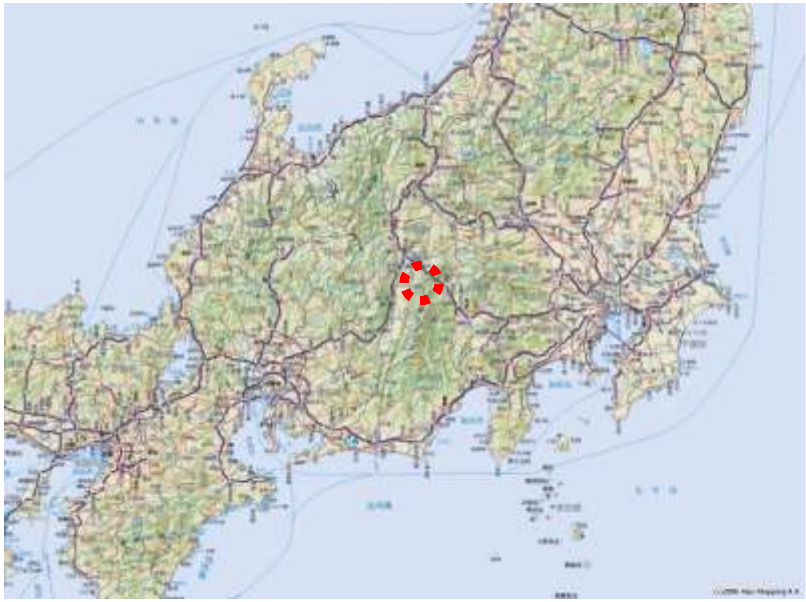
The system has very different strategy for NEO observation from the existing NEO search programs like Pan-Starrs, CSS and so on. The system may innovate on the present NEO survey concept.

We discovered two NEOs using the 18cm telescopes this January. The discovery of NEOs in Japan was after a lapse of about 9 years. In this talk, the detail of the new system, the comparison with the existing NEO survey and the test observation in which two NEOs were discovered, will be explained.

Optical Observational Facility of JAXA at Mt. Nyukasa

Location
Longitude: 138° 10′ 18″ E
Latitude: 35° 54′ 05″ N
Altitude: 1870m

MPC Code: 408 Nyukasa



Optical Observational Facility of JAXA at Mt. Nyukasa

Overview of the facility

Observational equipments:
35cm telescope and 2K2K CCD camera

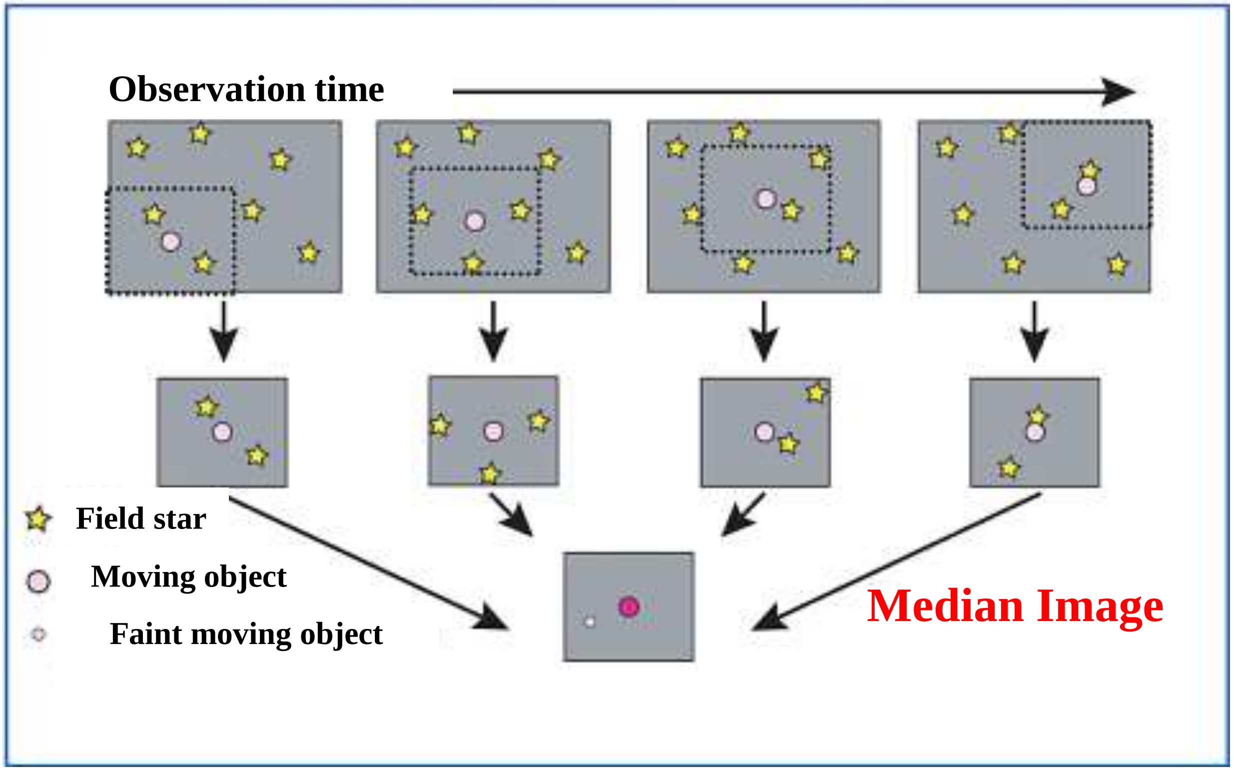
Telescope: Takahashi ε-350
D=355mm f=1248mm F/3.6
Equatorial mount: Showa fork-type 25EF

CCD camera: FLI ML23042
chip: 2K2K back-illuminated(e2v)
cooling: peltier device(-30°)
FOV: 1.4×1.4°

Data analysis process：Stacking method

The stacking method uses multiple CCD images to detect very faint objects that are undetectable on a single CCD image.

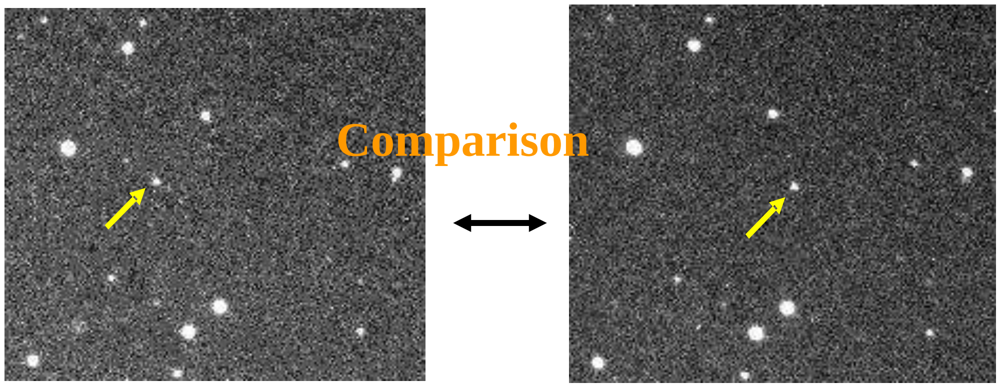
Concept of the stacking method



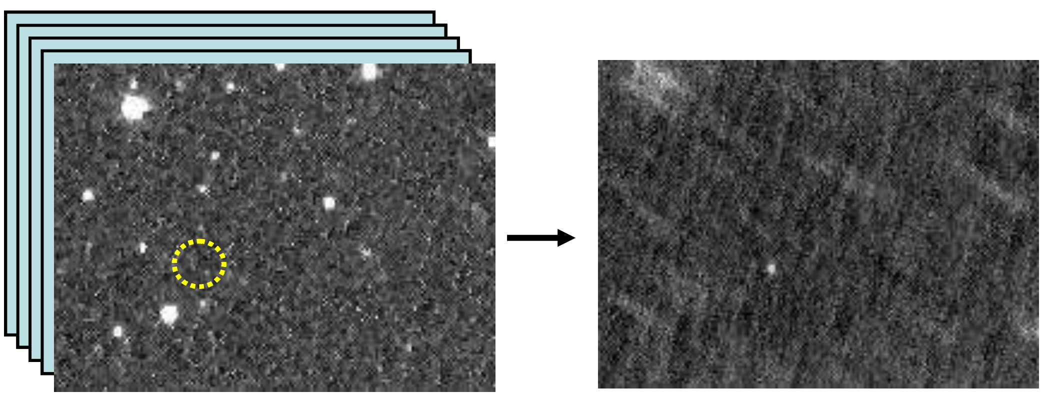
Sub-images are cropped from many CCD images to follow the presumed movement of moving objects. Faint objects are detectable by making the median image of these sub-images.

Data analysis process：Stacking method

Blink method



Stacking method

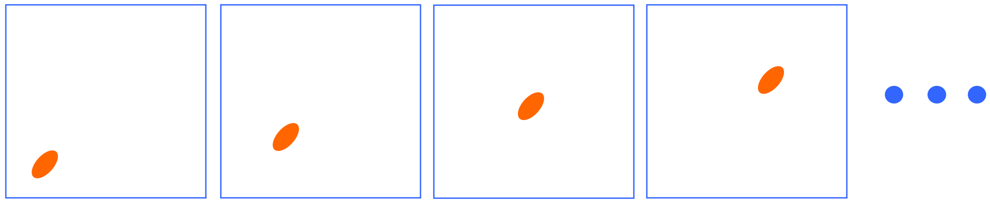


An asteroid detected by the stacking method. Before(left) and after(right).

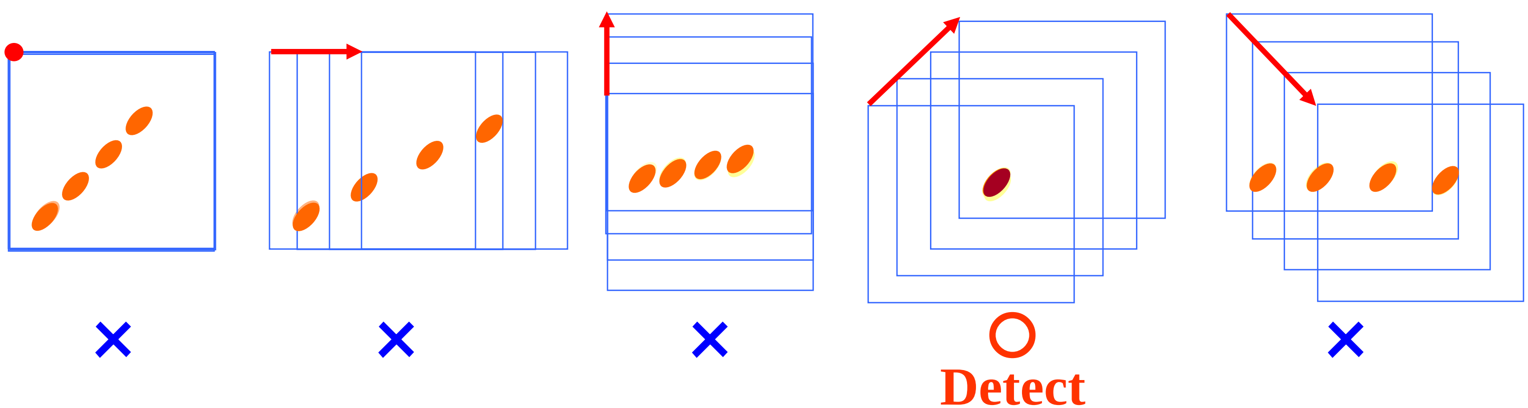
About 350 asteroids were discovered by this method.

Data analysis process：Stacking method

The only weak point of the method is taking time to analyze the data in case of detecting unseen object whose movement is not known, because various movements of the faint object have to be presumed. Finding new NEOs is difficult.



Many CCD image are taken with telescope-fixed mode.

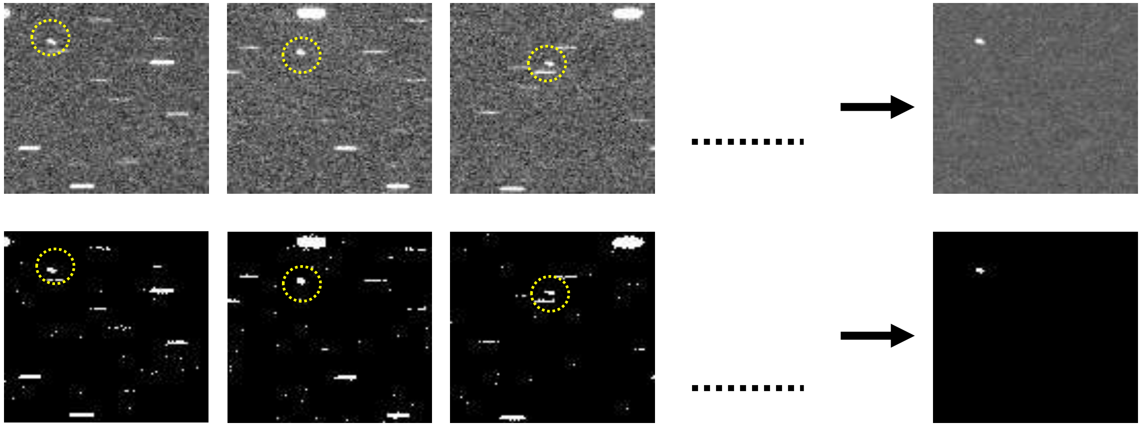


Images are stacked in many ways, as various shift values are presumed. Once a object is detected, its movement is also determined. 280 hours are needed to analyze 32 1K×1K-frames for the objects within the motion of 256×256 pixels.

FPGA(field programmable gate array) system is being developed to reduce analysis time.

Data analysis process：Stacking method

A new algorithm and FPGA board for the stacking method are being developed to reduce analysis time.



Deference between the original algorithm of the stacking method (upper) and the new algorithm using binarized images.

FPGA board H101-PCIXM manufactured by Nallatech

The FPGA board will reduced analysis time by hundreds times!!

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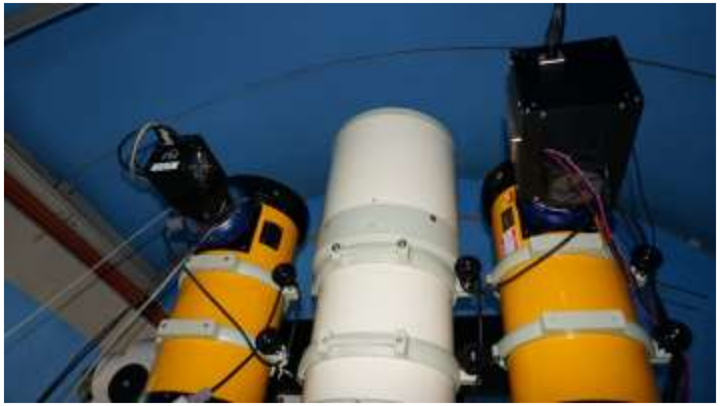
This will enable us to find new NEOs real-time basis.

Test Observation

Test observations were carried out using the 18cm-telescopes at Mt. Nyukasa optical facility in Jan 17, 25, 26, 31 of 2017.



Telescope: Takahashi ε180ED (D:180mm F: 500mm)×2

Sensor: FLI ML23042, Canon CMOS

Observation mode: 24-sec exposure ×32 frames ×40 sets / day

Total sky coverage: 986 square degrees /day

Limiting magnitude: 18.4-magnitude up to 5.3-degree/day

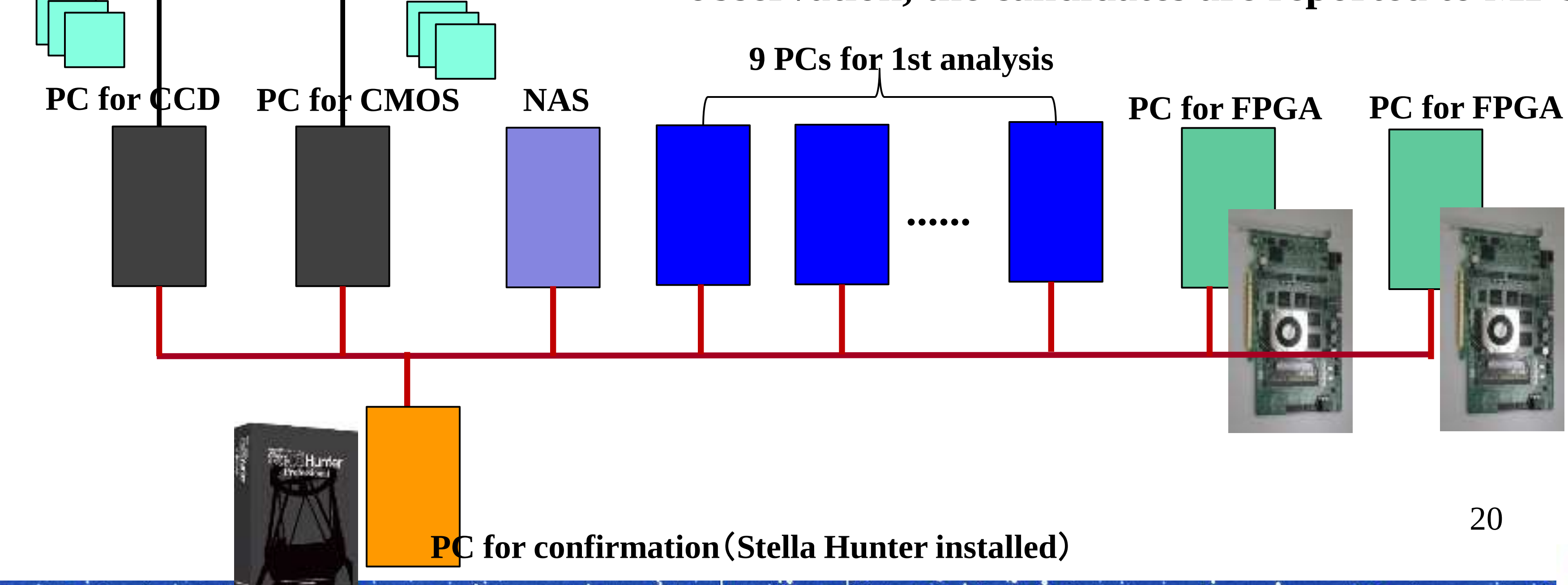
We've discovered two NEOs (2017 BK, 2017 BN92)!!

Test Observation

Change FOV every 15 minutes. 24-second exposure times 32 frames for 1 region.

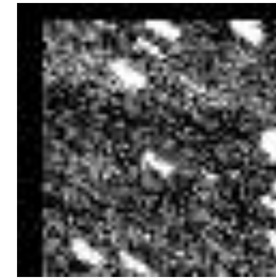
The first analysis are paralleled using 9 PCs. Data of 1 region is analyzed within 2 hours. Semi-real-time analysis is possible.

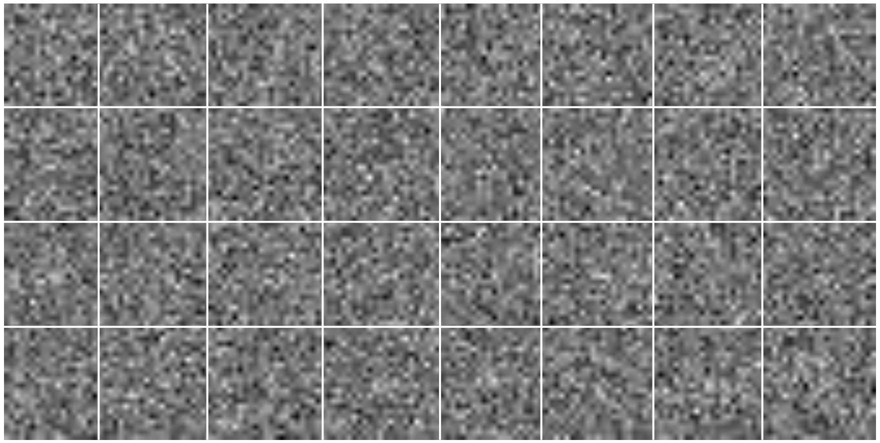
The candidates are confirmed with visual inspection. The positions are estimated using the Stella Hunter software. After follow-up observation, the candidates are reported to MPC.



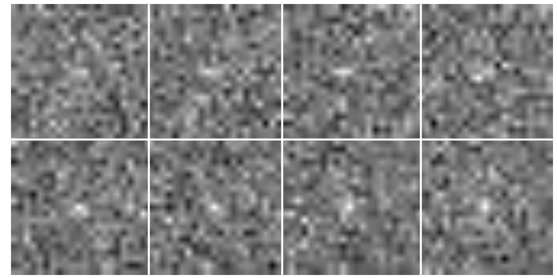
Test Observation

2017 BK

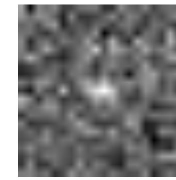




Candidates in the 32 original frames.

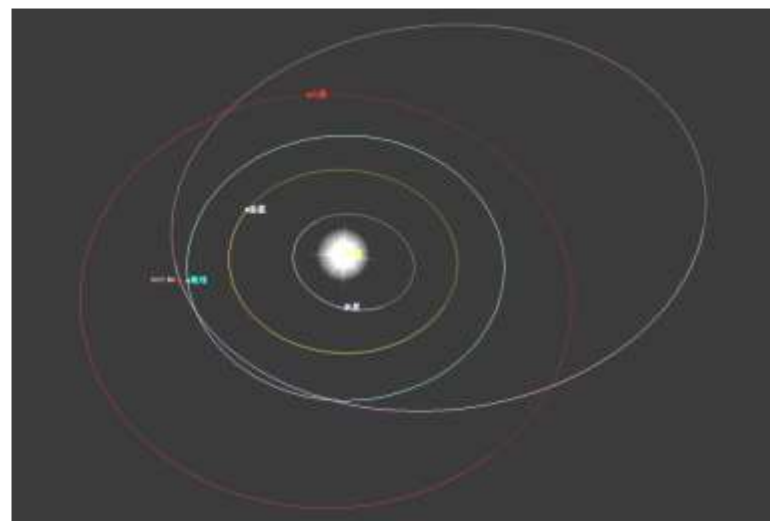


8-frames-stacked images



32-frames-stacked image

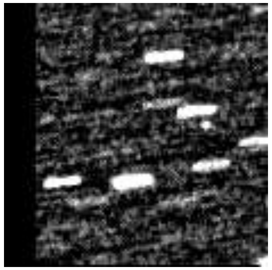
Epoch	2017-02-16.0
eccentricity	0.4902647
semi-major axis(AU)	1.9107853
inclination (°)	6.64014
RAAN(°)	110.92190
argument of perigee(°)	39.62114
mean anomaly(°)	0.82779
absolute magnitude	24.0
slope parameter	0.15



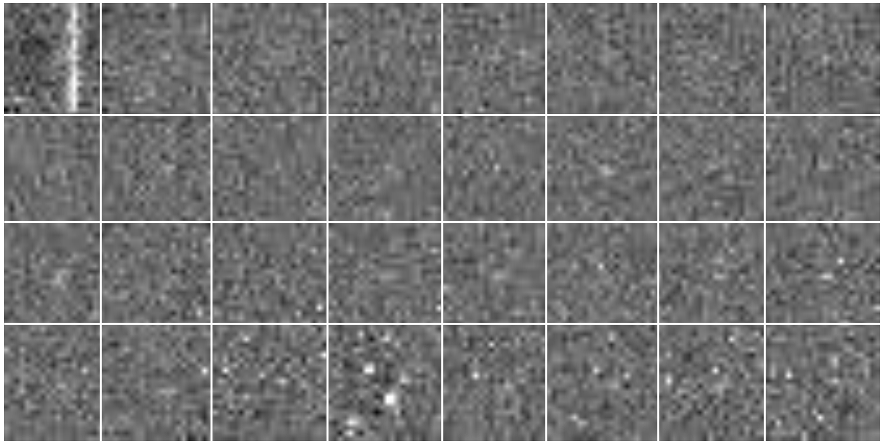
Temporal orbit of the candidate

50m in size. Closest distance to the Earth is 6 millions km (16 lunar orbits) on Jan 22nd 2017.

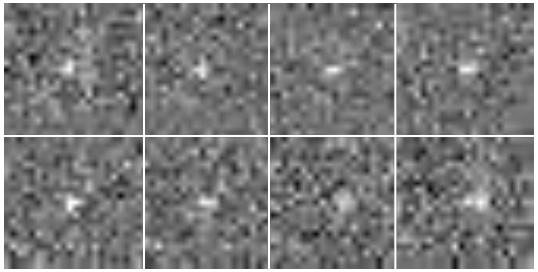
Test Observation



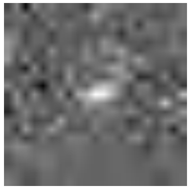
2017 BN92



Candidates in the 32 original frames.

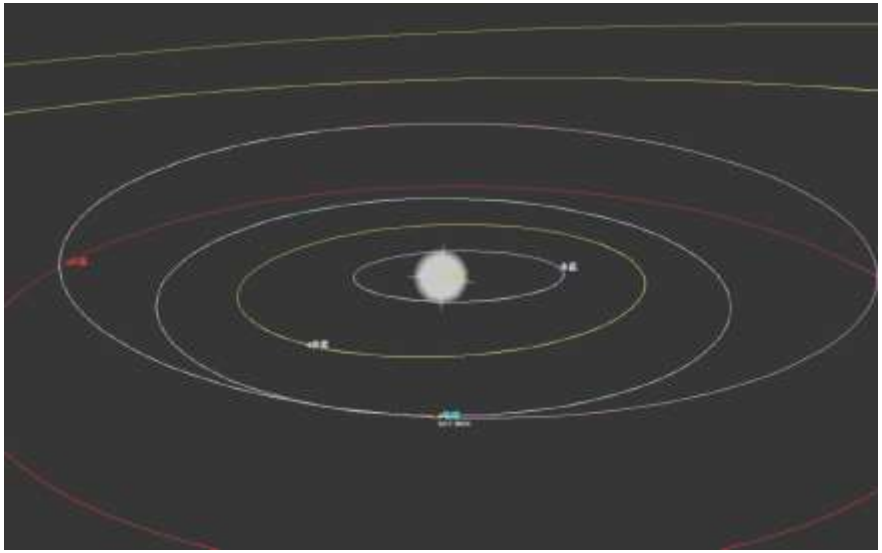


8-frames-stacked images



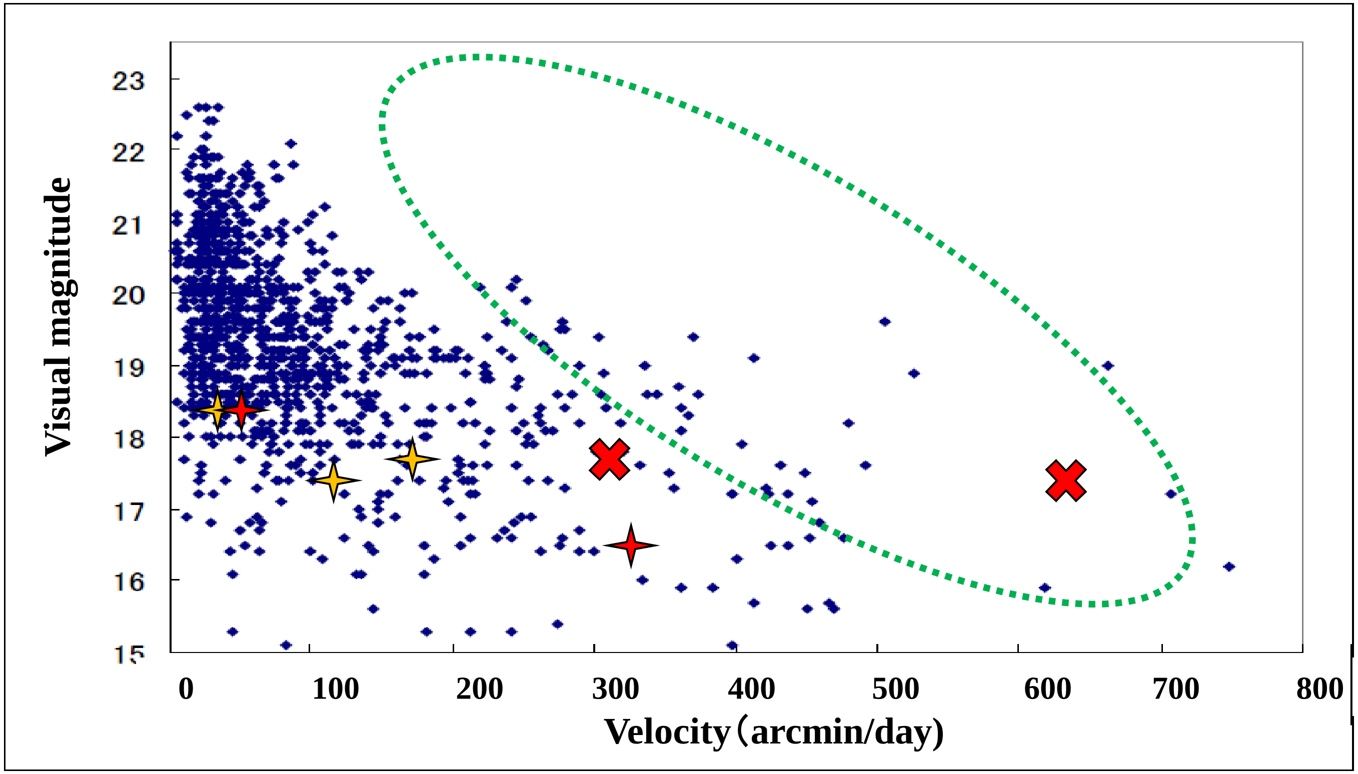
32-frames-stacked image

Epoch	2017-02-16.0
eccentricity	0.4833413
semi-major axis(AU)	1.9227120
inclination(°)	1.07370
RAAN(°)	324.10877
argument of perigee(°)	159.83225
mean anomaly(°)	7.94639
absolute magnitude	25.6
slope parameter	0.15



30m in size. Closest distance to the Earth is 1.86 millions km (5 lunar orbits) on Feb 1st 2017.

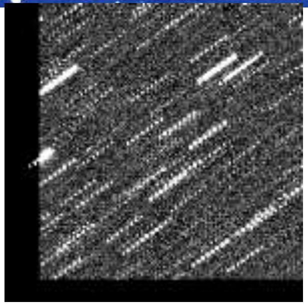
Test Observation

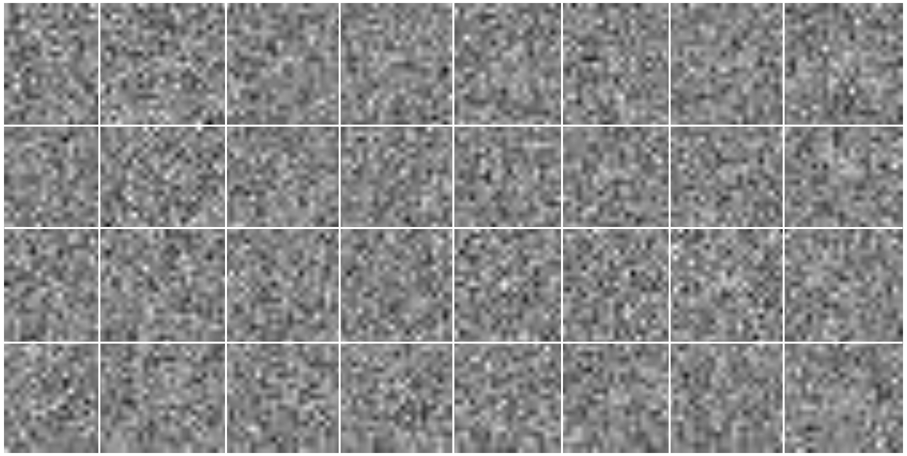


Distribution of NEO at the first detection in the velocity vs magnitude space

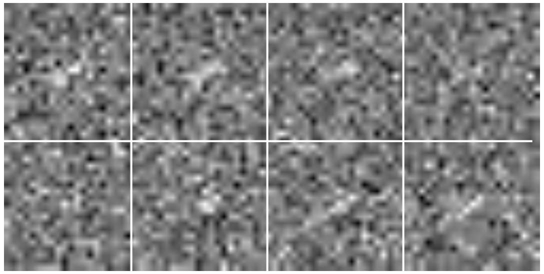
Test Observation

JAX506

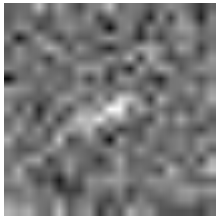




Candidates in the 32 original frames.



8-frames-stacked images



32-frames-stacked image

JAX506 was a very fast moving NEO (36.5-degree/day) with 16.4 magnitude when we discovered it on Mar 3rd.

We lost the JAX506 because of the bad weather condition. Follow-up site which is located on the west side of our observatory is needed.

Discussion

- We showed that the small telescope with the sophisticated image-processing was able to detect un-cataloged fast moving NEO.
- There may be a lot of NEOs which are missed by the existing survey programs.
- The new method can establish a large scale NEO survey program with relatively low cost.
- The method will contribute to not only NEO search but also the solar system astronomy.
- Follow-up observation is needed.

Summary

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