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Development of asteroid detection application “COIAS” for the Subaru HSC data

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Background
Subaru Telescope HSC (Hyper Suprime-Cam) and the archived data

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- HSC: Super wide field camera mounted with the prime focus of 8.2 m Subaru telescope. FoV is 1.5 degree in diameter.
- SSP (Subaru Strategic Survey) :A deep multi-band survey of 1400 deg^2 of the sky.
- For small solar system bodies: Some ecliptic plane surveys were also conducted without the SSP.
- HSC archive data: All the HSC data are archived and opened a year and half later from the observation.

Problem

- A large number of asteroids (including NEOs) with diameters smaller than 300 m will be imaged in HSC archived data.
- The coordination and brightness of these asteroids were not reported effectively to the MPC.
- There was no useful application system which can conduct the detection, measuring coordinates, photometry, and reporting to the MPC for asteroid.

COIAS (COmmon! Impacting ASteroid)

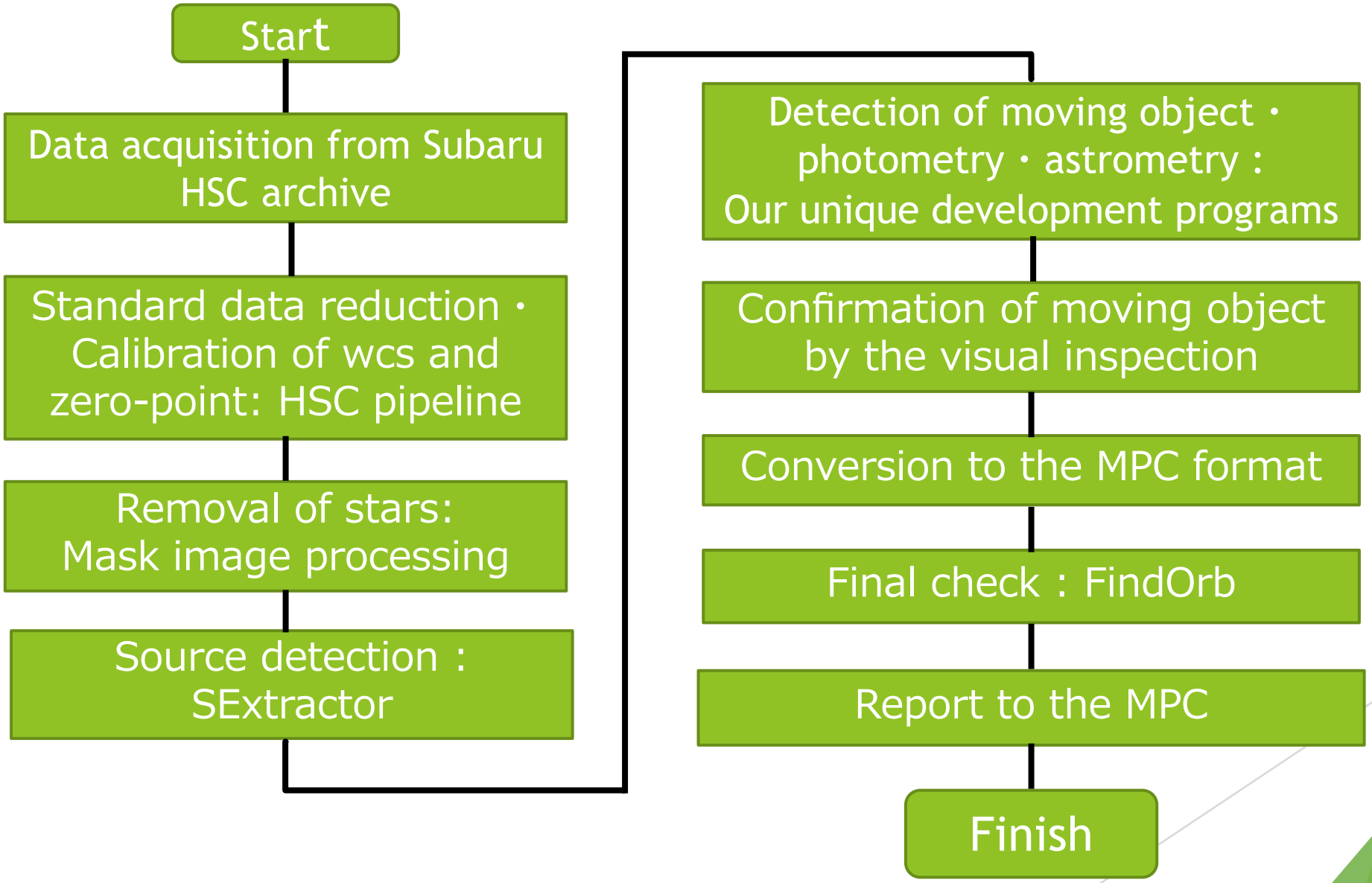
COIAS: An application system for detecting, measuring coordinates, photometry, and reporting to the MPC.
COIAS is composed of our developed programs and the relevant system.

Why COIAS?

The name COIAS comes from a Japanese animation, K(C)oisuru Asteroid (its abbreviated name is K(C)oias), the English title is “Asteroid in Love”. This animation is a story of high school students who try to discover asteroids.

We have a plan to use COIAS for education. We adopted this animation title for our application name considering the educational and public relations effect.

Flowchart of COIAS



Why do we use the visual inspection?

- The HSC data were obtained under a variety of conditions, such as exposure time, filter, and survey area. The machine learning algorithms has a potential to increase detection efficiency in the future, however it is difficult to be applied for the variety of conditions in the current situation.
- The other reason is the educational effect by using GUI (Graphical User Interface). The visual inspection gives citizens and students the delight of asteroid discovery and is expected to have a high educational effect.

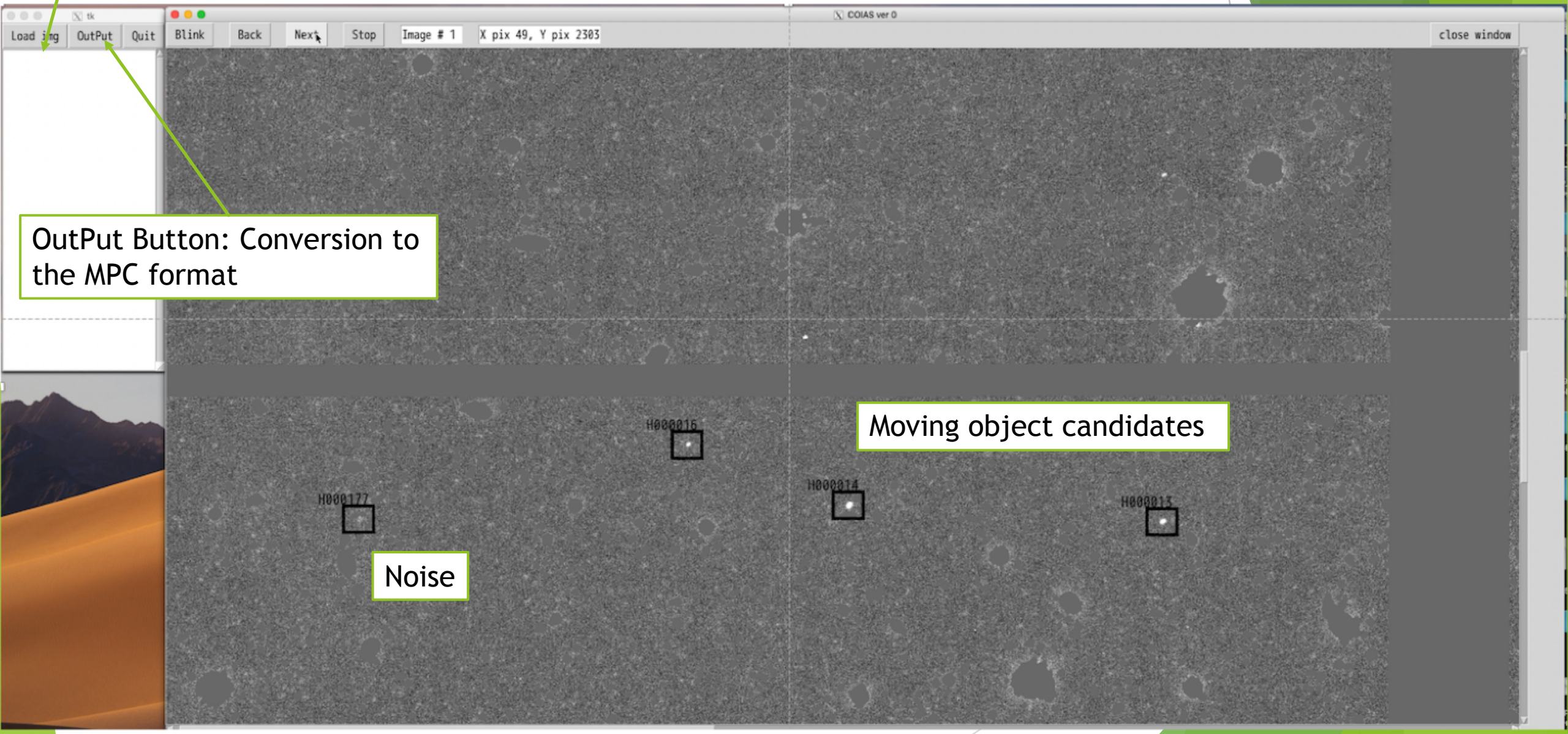
Asteroid detection test

- Observation date: 26, January 2015
- Survey area: Jupiter Trojan region that is located around opposition on the ecliptic plane. (PI. F. Yoshida, Co-author, T. Terai, and S. Urakawa)
- Exposure time: 240 sec
- Filter: *g*,*r*
- Number of images : 5 images for the same area at appropriate time interval.
- The candidate of moving object is defined as the source that is detected more than four times.

An example of COIAS

Input personal number of moving objects

OutPut Button: Conversion to the MPC format

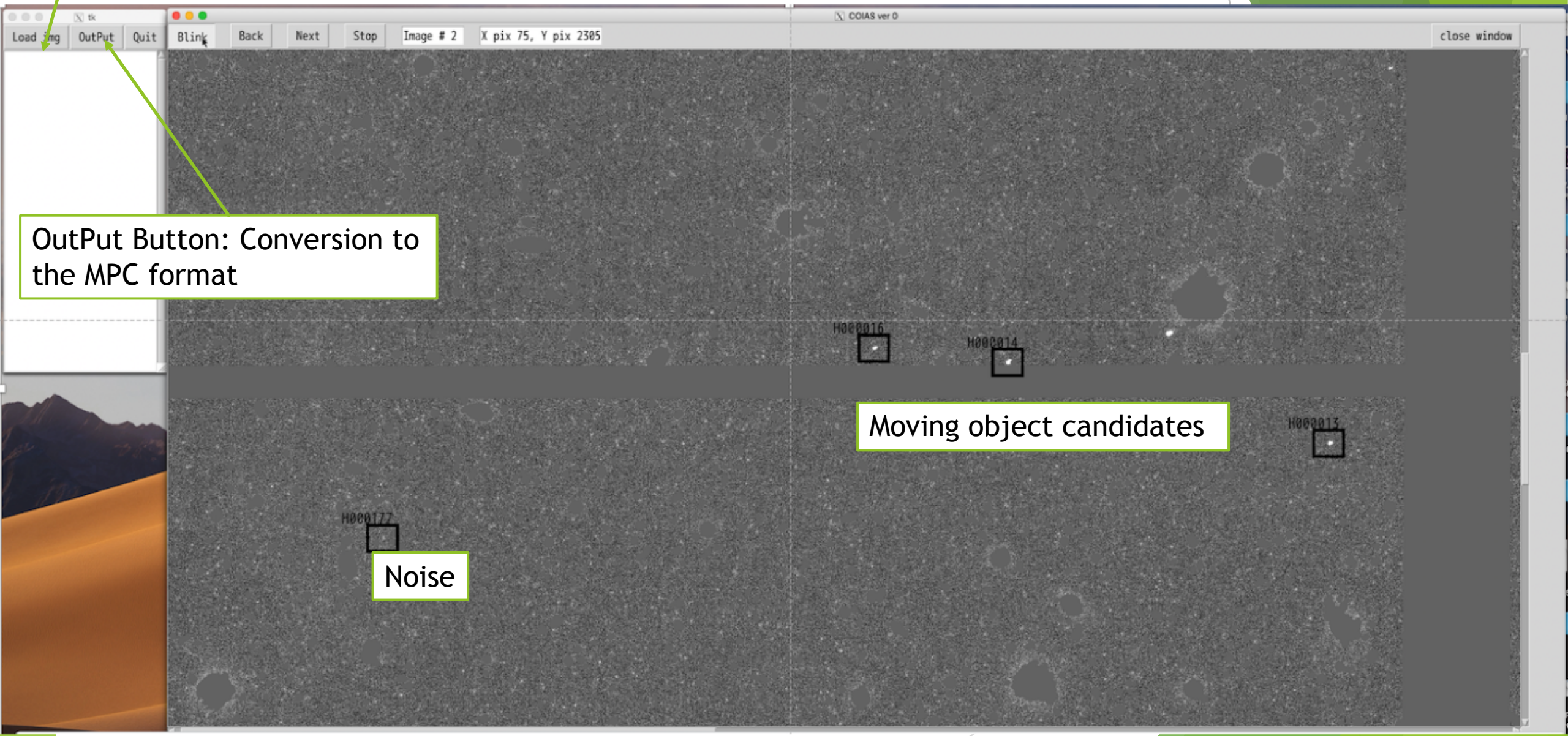


Moving object candidates

Noise

An example of COIAS

Input personal number of moving objects



OutPut Button: Conversion to the MPC format

Moving object candidates

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An example of COIAS

Input personal number of moving objects

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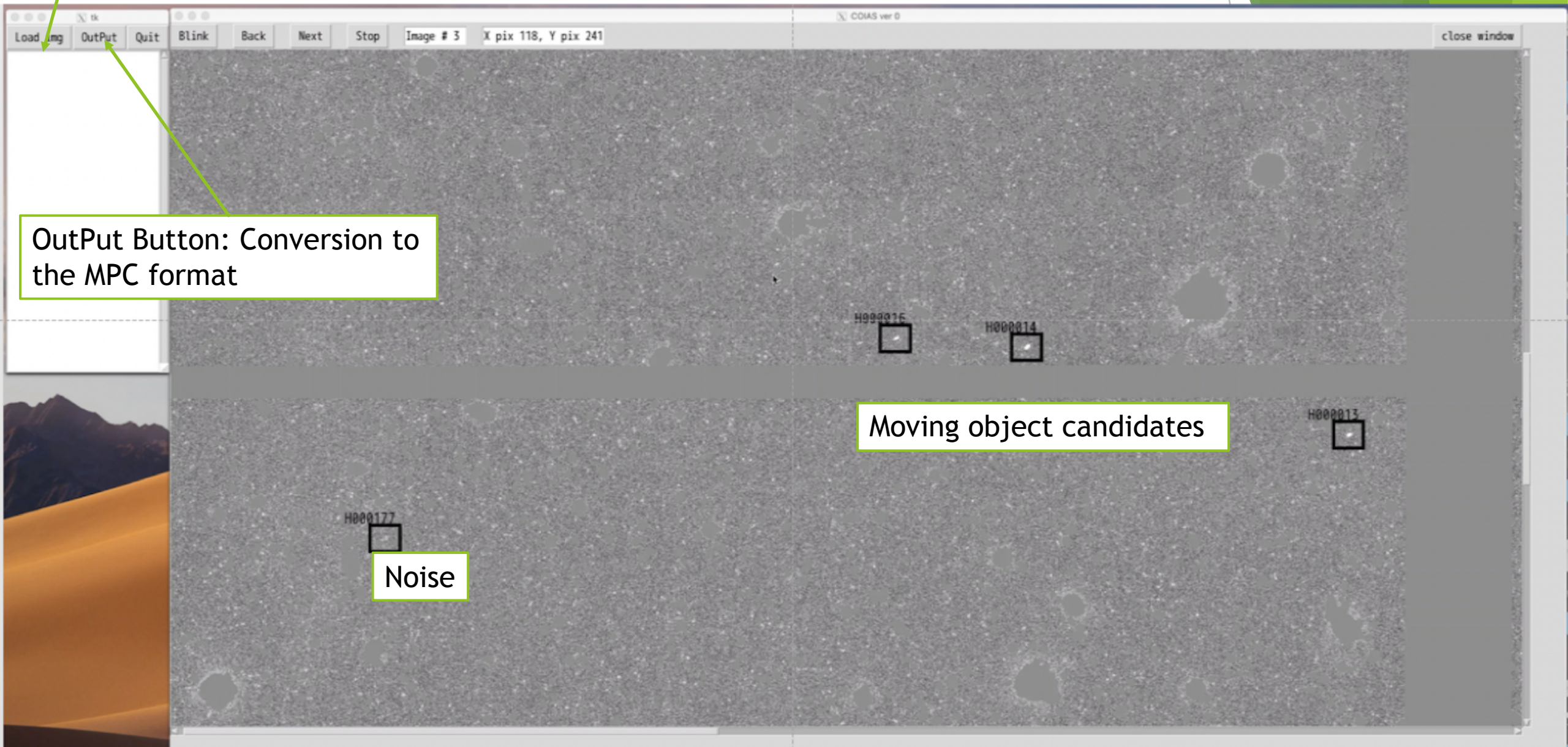
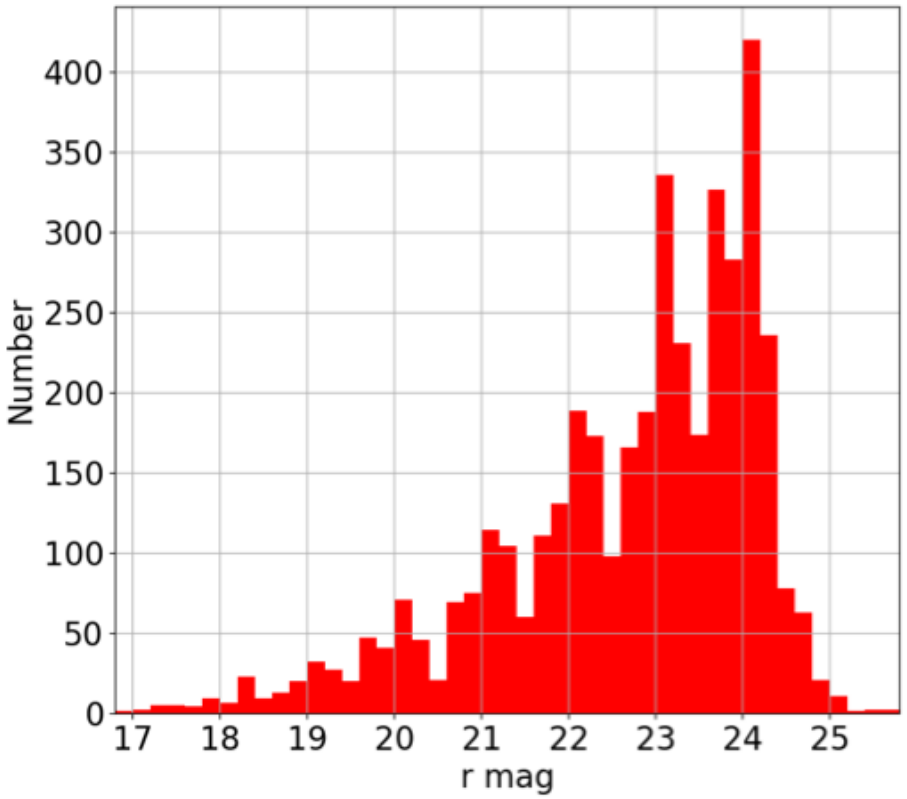


Test results

- Detection of 4141 unknow object and 874 known objects from the area of 16 deg^2
- Main-belt asteroid candidates: About 90%
- Hungaria group candidates: 7-8 %
- Near-earth asteroid candidates: 2-3 %

- Asteroids up to about 24.2 mag have been detected validly. Assuming the albedo of 0.1 and the semi-major axis of 2.5 au, the brightness of 24.2 mag roughly corresponds to 200 m in diameter.



Magnitude distributions in the *r* band.

Summary and future work

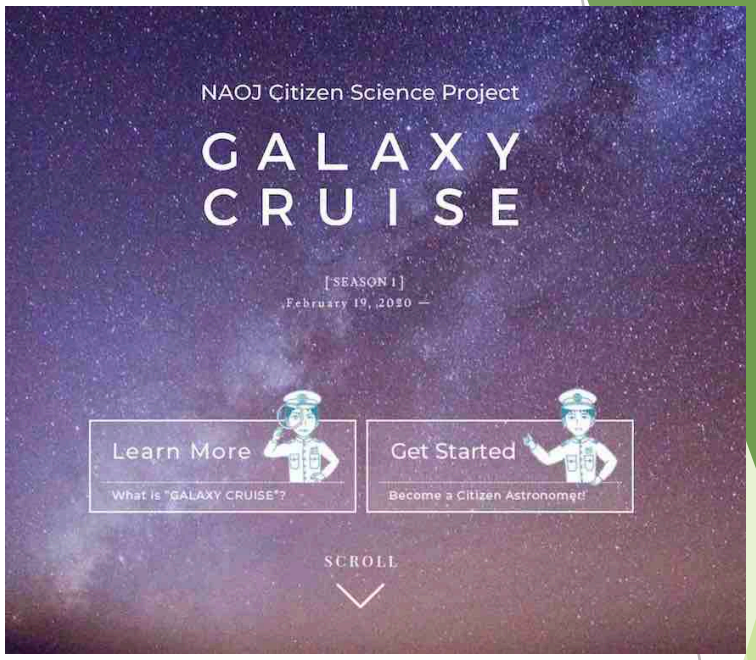
- We started to develop the asteroid detection application COIAS for Subaru HSC data.
- COIAS is in an early phase of development. The detection of moving object takes about 15 minutes per 10 % of the field of view (= 0.17deg^2). The visual inspection requires around 15 minutes for the same area.
- We cannot say that the usability of the present GUI is user-friendly because some processes run by command line interface.
- We launch a new effort to improve the usability of COIAS by collaborating with the private corporation. In parallel, we will continue to improve the programs and increase the efficiency of the automatic asteroid detection.
- HSC archive data will continue to increase in the future. COIAS will contribute to the discovery of asteroids, including NEOs.

Thank you for your attention.

Background
Small asteroid population

- Small asteroid population
  - Most of the discovered asteroids in the main-belt region have diameters larger than 1 km. The orbital distributions of asteroids cover the range of 300 m in diameter have not been clarified.
  - Small asteroid population is a key information to understand the formation of asteroid family, and the Yarkovsky effect.
- Citizen Astronomy
  - GALAXY CRUISE: Citizen astronomy project by using Subaru HSC data
  - Developments an application system like GALAXY CRUISE for asteroid discovery

  => Educational effect



How to detect moving objects

1. Source detection in the first image at the time of t1. The coordinate is expressed as $[x_{1(}t_1),y_1(t_1)]$.
2. Calculation of moving velocity between the first image and the second image. The moving velocity is written in $\Delta x = (x_2(t_2)\text{-}x_1(t_1))/(t_2\text{-}t_1)$, $\Delta y = (y_2(t_2) - y_1(t_1))/(t_2\text{-}t_1)$.
3. The estimated coordinate in the third image is described $x_3 = x_2 + \Delta x(t_3\text{-}t_2)$, $y_3 = y_2 + \Delta y(t_3\text{-}t_2)$
4. Search for a point source within 3.6 arcsec around the estimated coordinates.
5. The same procedure is applied for the fourth image and fifth image. The candidate of moving object is defined as the source that is detected more than four times.