GALAXY CRUISE: Accessible Big Data of the Subaru Telescope for Citizen Astronomers

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Abstract. The Universe is full of galaxies of various shapes; some galaxies have spiral arms and others don't. Why do galaxies show such diversity? How were galaxies formed and evolved? Galaxies are thought to grow by interacting and merging with other galaxies, and the galaxy mergers may be the key process creating the variety. GALAXY CRUISE is the first citizen science project conducted by National Astronomical Observatory of Japan (NAOJ) to unlock galaxies' secrets using the big observational data. We made the superior quality big data taken by the Subaru Telescope accessible to the public and invited them to participate in data classification. Here we report how we designed the website and its first-year progress.

Keywords. Citizen Science, Big Data, Online Resources

1. hscMap: Making the Latest Big Data Accessible to the Public

The Subaru Telescope is an optical-infrared telescope operated by NAOJ near the summit of Maunakea, on the Island of Hawai'i. It has a primary mirror diameter of 8.2 meters, making it one of the largest monolithic mirrors in the world. Hyper Suprime-Cam (HSC), the wide-field imaging camera mounted on the Subaru Telescope, has 870 million pixels and can cover nine times the area of the full moon in each exposure. The Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) is an unprecedented, extensive survey program started in 2014 to observe for 300 nights with HSC. Its first and second datasets were released to the public in February 2017 (Aihara *et al.* 2018) and May 2019 (Aihara *et al.* 2019), respectively. The second dataset includes 3.8 years of data which corresponds to 174 nights of observations. To make the big data accessible to the public, we released hscMap public version (http://hscmap.mtk.nao.ac.jp/hscMap4/), the user-friendly website to display the HSC-SSP data by modifying its original version for professional researchers (Usuda-Sato *et al.* (2018a) & Usuda-Sato *et al.* (2018b)). Fig 1 shows the initial screen of hscMap. When you start zooming into one of the green areas, a cosmic image captured with HSC appears. If you keep zooming deeper into the Universe, thousands of tiny points of light start to gush out, even from dark, starless areas. Each dot corresponds to one galaxy with hundreds of billions of stars. Using hscMap, anyone can easily explore the vast cosmic images taken by the Subaru Telescope.

2. GALAXY CRUISE: Galactic Journey with Citizen Astronomers

Among the countless galaxies in the vast cosmic images of HSC-SSP, many interacting galaxies are found affecting each other's shapes through their mutual gravitation.
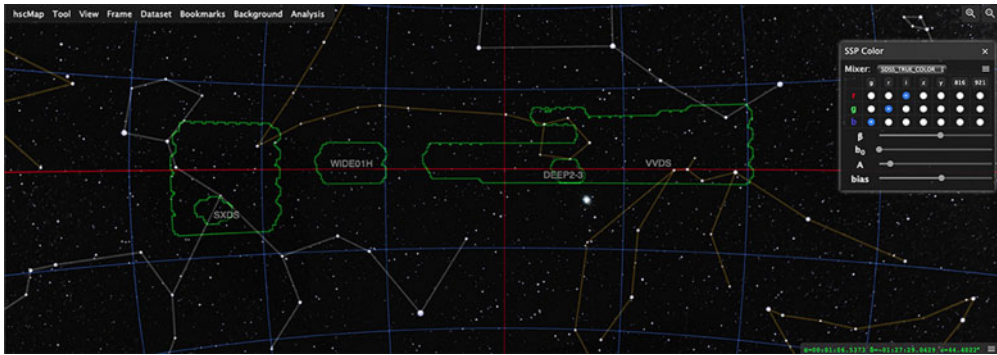
Figure 1. The initial screen of hscMap with the color mixer window. Anyone can easily explore the vast cosmic images taken by the Subaru Telescope inside the green areas using a mouse or a touch panel.
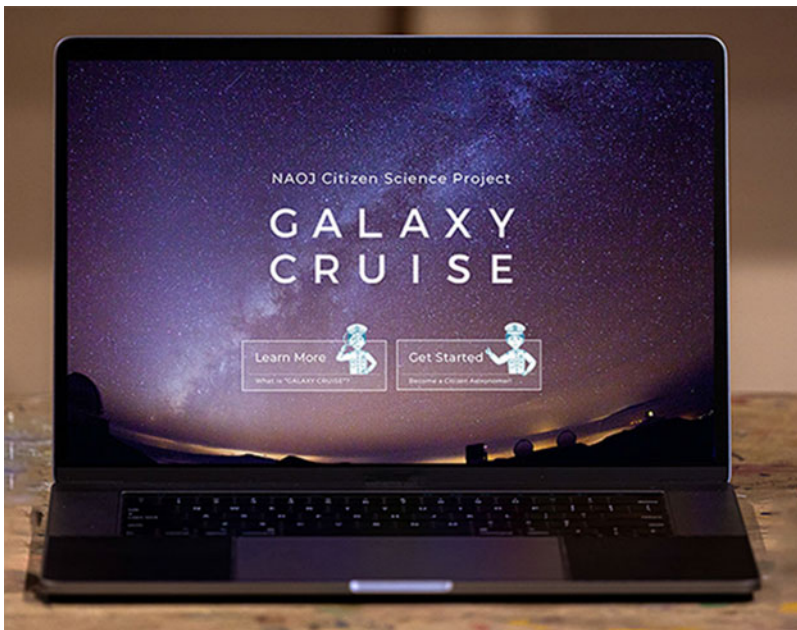

Figure 2. The GALAXY CRUISE website. Anyone can access the site through the internet using a PC or tablet to participate in the galaxy classification.

Studying the shapes of interacting galaxies and counting their number allows us to unlock the secrets of galaxy evolution and to understand the diversity of galaxies. However, it is very challenging for researchers to conduct such studies on their own because innumerable galaxies are found in the vast cosmic images.

GALAXY CRUISE (https://galaxycruise.mtk.nao.ac.jp/en/) is the first citizen science project conducted by NAOJ. Citizen Astronomers classify and identify interacting galaxies in the second dataset of HSC-SSP, which are displayed one after another on a PC or tablet screen. The Japanese site opened on November 1, 2019, and the English site (Fig 2) opened on February 19, 2020. Our project is likened to a cruise ship where many crew members sail together in the cosmic ocean. With the cruise map or the nautical chart developed from the observation map of HSC-SSP, we created the original world view of GALAXY CRUISE. There are four small and deep observation fields and six wide fields.

Figure 3. The voyage log of a Citizen Astronomer. The number of classified galaxies, the cabin class, and the cruise map can be seen. Every Citizen Astronomer starts with a fourth-class cabin and upgraded as the number of completed stages increases. On the cruise map, the anchor marks are added in the completed towns, and the completed continents are colored in brown.

In GALAXY CRUISE, we call small fields "towns", and wide fields "continents" and each town and continent corresponds to one stage. Citizen Astronomers classify galaxies while exploring the four towns and six continents to complete all ten stages.

The GALAXY CRUISE site has the following unique features to motivate many people to participate in this project and to maintain their interest.

(1) Thorough Training and Practice Menus
Before Citizen Astronomers register to start classification, they are required to complete the three training sessions to obtain a basic knowledge of galaxies. After login, the Practice Course is also available so that they can compare their classification results with those of the Captain (a galaxy researcher). These features enable non-professionals to classify galaxies confidently.

(2) Gamification Events
Every town or continent is divided into multiple areas. Citizen Astronomers can earn a souvenir (commemorative illustration) when they complete a certain number of areas. Also, when they complete a stage (town or continent), a departure stamp will be added to the passport. The voyage log (Fig 3), passport stamps, and souvenirs can be seen at the welcome page of each Citizen Astronomer.
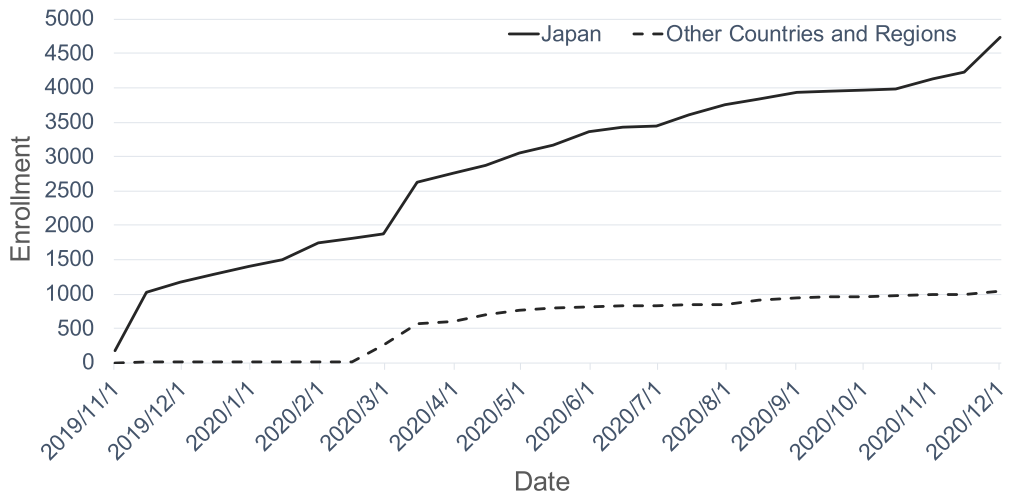
Figure 4. Change in enrollement in Japan (solid line) and in other countries and regions (dashed line).

(3) Exploration of the Vast Universe

As the hscMap engine is used for GALAXY CRUISE classification page, so that Citizen astronomers enjoy exploring the vast cosmic images captured by the Subaru Telescope.

To maintain active interaction with Citizen Astronomers, we upload a new topic as a NEWS article on each month's first day. In some months, we introduce received questions from Citizen Astronomers with the answers by the Captain. In other months, we report updates of the project. Sometimes we present unique shaped interacting galaxies reported by them on the official Twitter (@Galaxy_Cruise_e) and Instagram (galaxycruise_naoj) accounts. We also publish Citizen Astronomers' names who completed Stage 10 (the last stage) on the website recognition of their efforts.

3. The First Year of GALAXY CRUISE

Fig 4 shows the number of enrolled Citizen Astronomers. Within two weeks since the Japanese site opened on Movember 1, 2019, the enrollement reached 1000 thanks to many online news articles. When the English site opened on February 19, 2020, this event was covered by many online news sites and other websites in various languages such as English, Russian, French, and German. At the beginning of March 2020, most schools in Japan were temporarily closed due to the COVID-19 pandemic situation. GALAXY CRUISE was introduced as a recommended online science content on multiple sites. The number of people enrolled in Japan grew rapidly among the younger generation under 20. After April, the enrollment is gradually increasing.

As of December 1, 2020, a total of 5779 Citizen Astronomers from 80 countries and regions have registered. About 80% of them (4731 people) are from Japan. Outside of Japan, the countries with the highest enrollments are the Russian Federation (304 people), the United States (252 people), Ukraine (90 people), and Canada (54 people). The total classification results have exceeded 958,000. We will continue providing information and progress reports to Citizen Astronomers, and at the same time, will plan the next steps such as classfication of fainter galaxies as "Season 2", and combination Citizen Astronomy and machine learning to classify much more galaxies.

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