



P15: Results From the Search for New Horizons Targets in the Distant Kuiper Belt Using Subaru Hyper Suprime-Cam

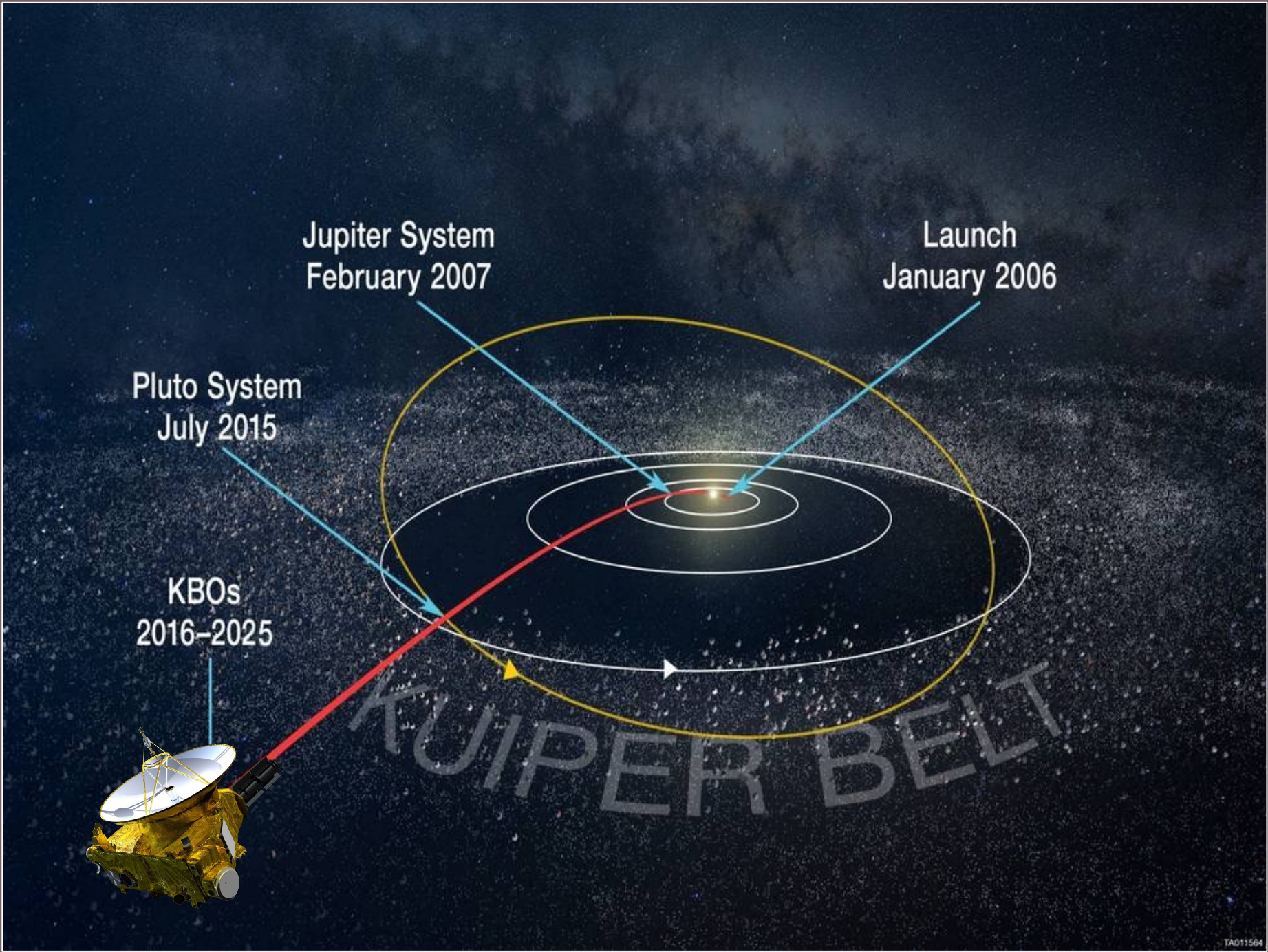


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Abstract

We present progress and results from our search program (S22A-TE049-K, S22B-TE071-K) using Subaru Hyper Suprime-Cam (HSC) to discover and improve the orbits of Kuiper belt objects (KBOs) for the New Horizons spacecraft to observe or possibly encounter at close range during its extended mission. Since 2020, we have used HSC with its r2 filter during each semester to probe the region of the sky toward which the spacecraft, currently at 55 au, is flying. In 2022B, we used for the first time the new extended broadband (EB-gri) filter, provided by the New Horizons Project for community use, to conduct the deepest searches yet, reaching magnitude $m_{\text{gri}} \sim 26.3$. Machine learning techniques applied to our 2020 HSC images found 154 new KBOs which have been submitted to the Minor Planet Center.

New Horizons has already observed 36 KBOs, some of which were discovered by Subaru HSC, at solar phase angles exceeding the maximum ~ 2 degrees achievable from Earth. These New Horizons observations at higher phase angles enable determinations of the shape, rotation, and surface scattering properties of these KBOs, and when possible, higher spatial resolution also enables searches for close satellites. New Horizons will observe KBO 2020 KS11, another Subaru-HSC discovery, later in 2023.

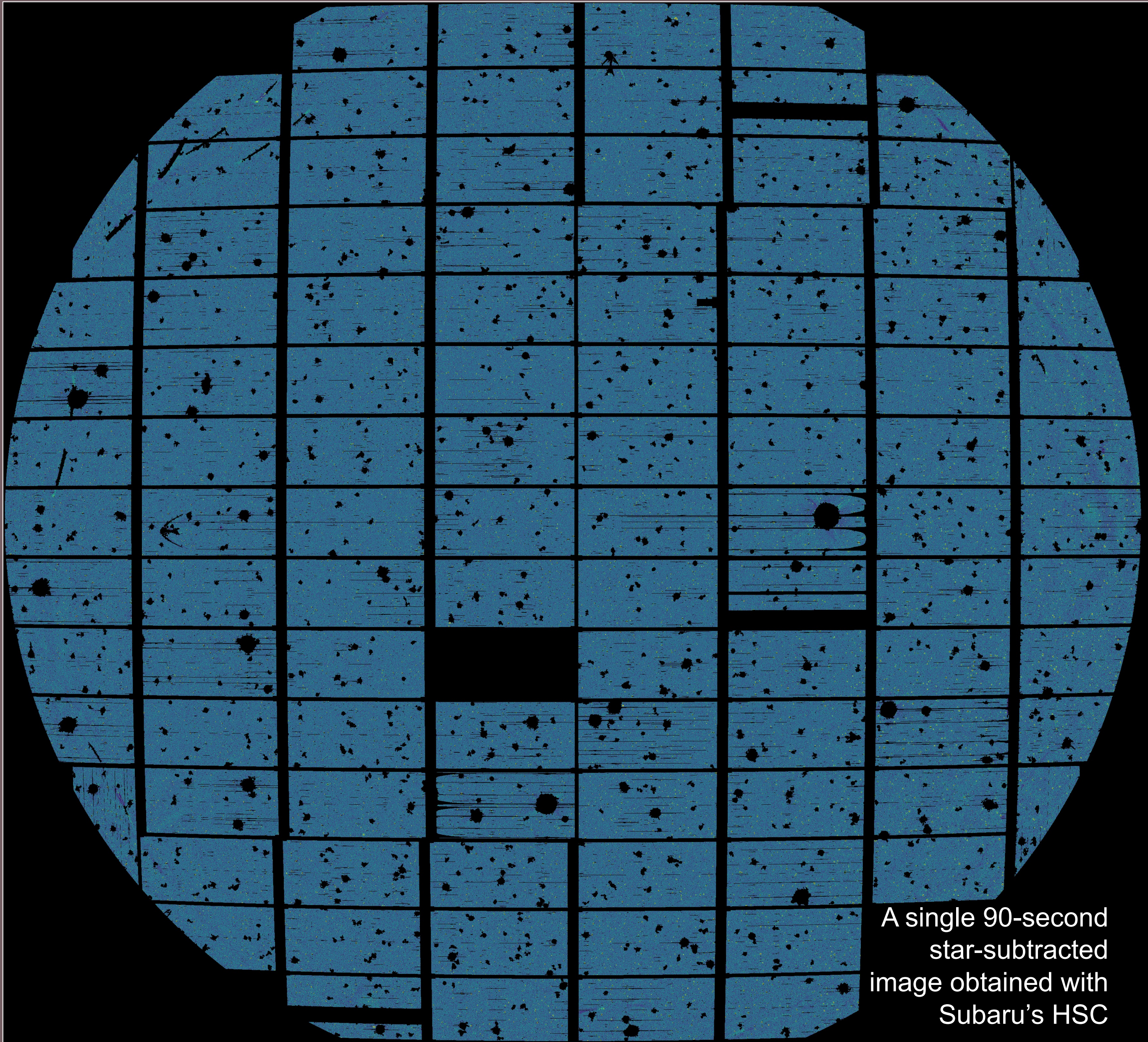


New Horizons' Journey Through the Solar System

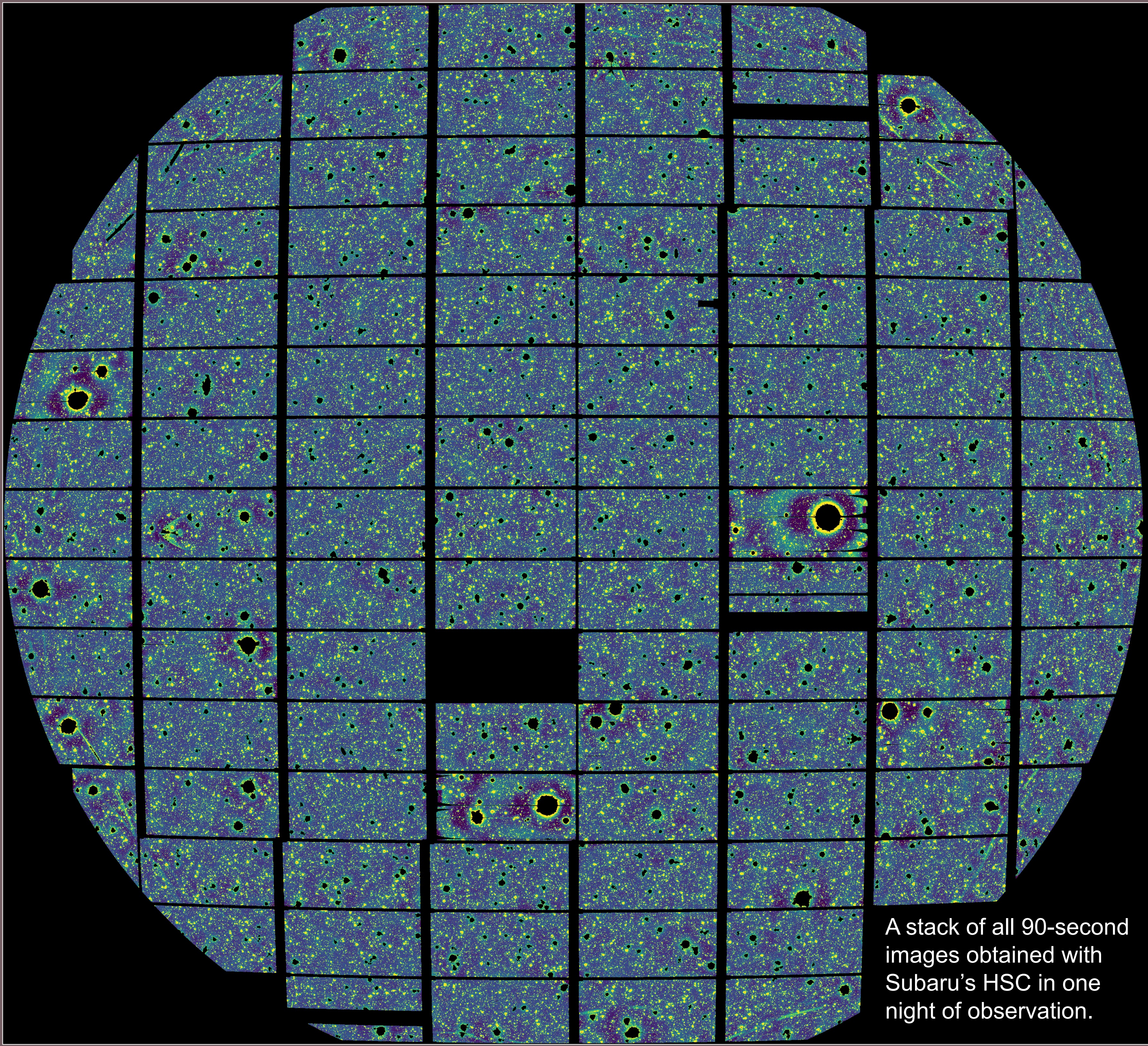
NASA's New Horizons spacecraft travels ~ 3 astronomical units (au) per year on a trajectory (red arrow at right) that has taken it outward from the Sun, intersecting Pluto's orbit (yellow oval) in 2015 and KBO (486958) Arrokoth in 2019. The spacecraft is currently 55 au from the Sun, 56 au from the Earth, and 12 au from Arrokoth.

The New Horizons Search Images

The New Horizons team has been searching for new KBO targets along the spacecraft's trajectory for more than a decade. Recent campaigns using Subaru's HSC acquire hundreds of 90-second images per night. Background stars are removed and images are stacked to find the faintest objects moving at rates characteristic of objects at heliocentric distances greater than 30 au.



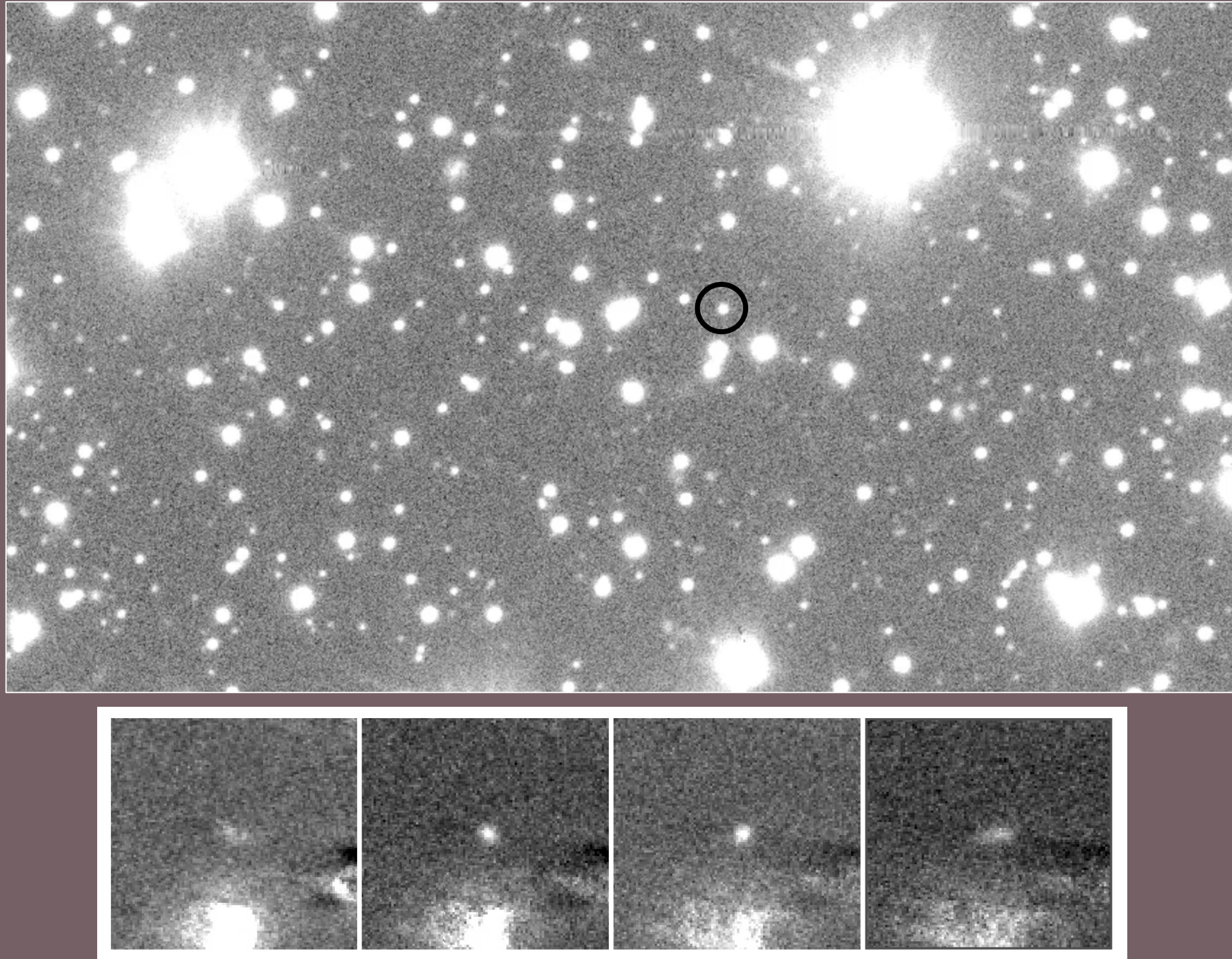
A single 90-second star-subtracted image obtained with Subaru's HSC



A stack of all 90-second images obtained with Subaru's HSC in one night of observation.

Sample New Horizons Search Image

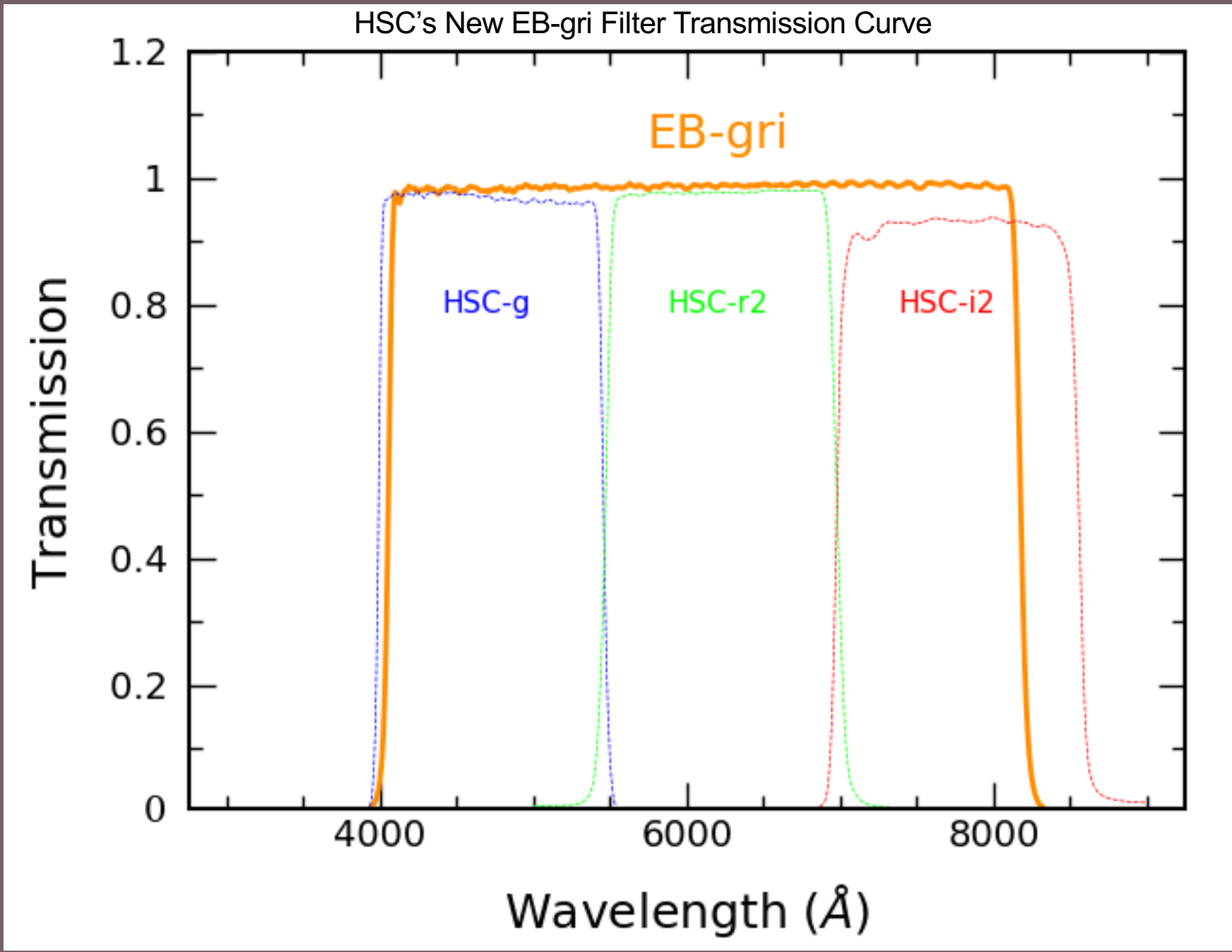
The New Horizons search team has developed machine learning techniques to find moving objects among myriad background stars. A single CCD image below reveals a newly-discovered KBO (circle) Subaru/HSC has found *hundreds* of new KBOs. New Horizons has already observed several and will observe more in its 2nd extended mission.



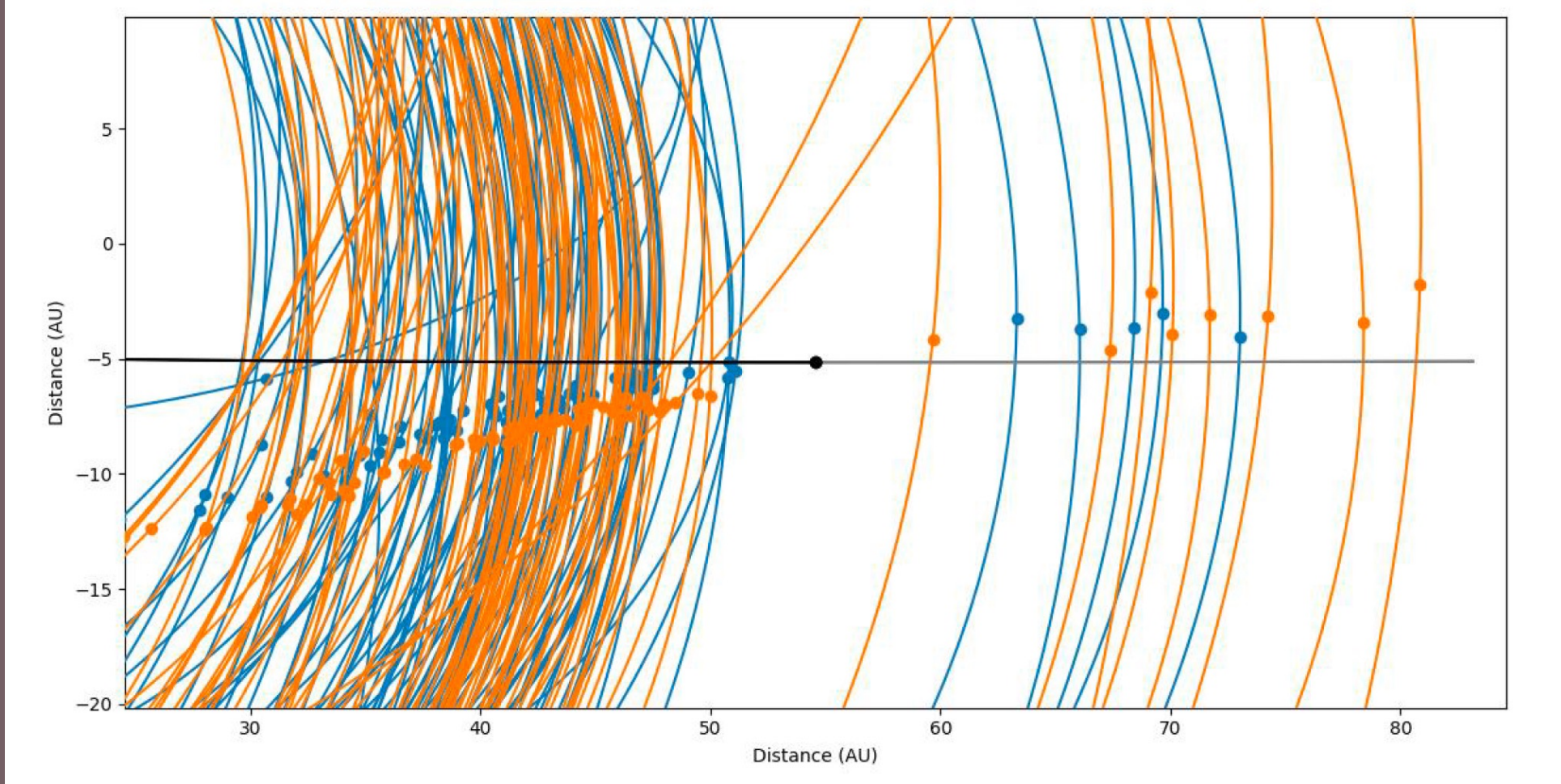
Example shift-and-stack imagery for a real KBO detected using our machine learning pipeline. From left to right, rates of motion are 1.5"/hr to 3.0"/hr in increments of 0.5"/hr. At this epoch, this newly-discovered KBO is moving at 2.4"/hr, corresponding to a heliocentric distance of 45 au. Our detection efficiency is 70% or better for $r < 25.5$, with a limiting magnitude of $r \sim 26.6$, despite observing at galactic latitude $b \sim 10^\circ$.

New Horizons Project Provides a New HSC Filter for Community Use

NASA's New Horizons mission has provided a new filter for Subaru Telescope's HSC, the Extreme Broadband gri (EB-gri) filter. The bandpass of the EB-gri filter spans nearly the fully combined bandpasses of the HSC-g, r2, and i2 filters (below). The New Horizons search team used the new EB-gri filter for the first time during first quarter nights in October 2022. Preliminary analyses of images acquired with the EB-gri filter allow deeper searches than ever before, finding KBOs ~ 0.5 magnitude fainter than those found using the r2 filter alone.



A Population of Objects Beyond the Known Kuiper Belt?



176 KBOs with one-month arcs discovered in by Subaru/HSC in 2021 and 2022 (blue and orange dots, respectively) at the point in their orbits (blue and orange lines) when the New Horizons spacecraft is closest to them. Black line is the spacecraft trajectory with the current heliocentric position show by the black dot at 55 au. New Horizons will pass the 60 au mark in October 2024.

The locations of these detections tentatively reveal an empty region extending from the outer edge of the Kuiper belt at ~ 50 au to ~ 60 au and also the presence of a hitherto undetected and significant population of objects beyond the known Kuiper belt.

Upcoming HSC observations with the EB-gri filter in 2023A (S23A-TE006-K) near opposition will be ideally suited to discover more potential targets for New Horizons from this new population.

This research is based in part on data collected at the Subaru Telescope, which is operated by the National Astronomical Observatory of Japan. We are honored and grateful for the opportunity of observing the Universe from Maunakea, which has the cultural, historical, and natural significance in Hawaii. Work supported by the New Horizons Project.

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