POTENTIAL EXTENDED KUIPER BELT SEARCHES FOR *NEW HORIZONS* OBSERVATIONS WITH THE VERA C. RUBIN OBSERVATORY AND ROMAN SPACE TELESCOPE.

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Introduction: Wide-area ground-based Kuiper Belt (KB) surveys have systematically reached magnitude 26.5 [1,2,3]. The Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST), operational soon, is projected to reach m_r=28.5 in some deep fields with the development of multi-night stacking techniques, and the Nancy Grace Roman Space Telescope (RST), to be launched in 2027, has the ability to reach m_{F146}=30.5 using its wide F146 filter and stable PSF using similar stacking techniques. Both of these facilities reach critical depths for finding objects in the outer KB. Likewise, the *New Horizons* spacecraft will be in the known Kuiper Belt for another ~ 5-7 years, so if a Kuiper Belt object (KBO) near enough to its trajectory to allow a close flyby, an otherwise unachievable scientific bonanza in the study of distant KB planetesimals, will become possible. And even if such a close flyby target is not found, numerous other KBOs are likely to be accessible to *New Horizons* for study from unique geometries to determine phase curves, shapes, and other characteristics that cannot be accomplished from Earth or Earth orbit. Utilizing Rubin and RST for an extended search for *New Horizons* KBOs provides a golden opportunity for both expanded exploration of the third zone in our solar system, as well as for transiting exoplanet, and the astrophysical discoveries that will be possible using the *New Horizons* trajectory field datasets.

Survey Designs: Rubin and RST have different strengths and will work best when used in series. The Rubin wide field camera footprint covers 9.6 square degrees allowing the entire search space for the *New Horizons* trajectory field to be observed in a single pointing. The RST has a smaller field of view, only 0.28 square degrees, but reaches deeper in less integration time with its fast optics and stable PSF. Both facilities offer filters optimal to *New Horizons* needs: Rubin *r* RST's F146. The *New Horizons* strategy is to propose to search the entire field of interest with Rubin to a depth of m_r~27.5 as part of a proposed 30-hour micro-survey taking the field one magnitude deeper than have our past (Subaru Hyper Superime-Cam) searches [2]. This survey then be followed by a search of the central area of the search field with RST (3 RTS FOVs, 0.9 deg^2) to a depth of m_{F146}~30.5 (Figure 1). Both surveys require observations spanning multiple lunations in a single year with follow-up the following year to secure the orbits of newly discovered bodies.

As noted above, these surveys will find objects for *New Horizons* to observe as point sources (but with resolution higher resolution than HST and JWST within 1au of the spacecraft), and hold the possibility of discovering a close flyby object (Rubin yield: >730 KBOs, 3 objects within 1 au of *New Horizons)*. Roman yield: >960 KBOs, 13 objects within 1 au of *New Horizons*). In addition, these surveys will also elucidate the distant Kuiper Belt's radial structure in ways otherwise currently unachievable [4].

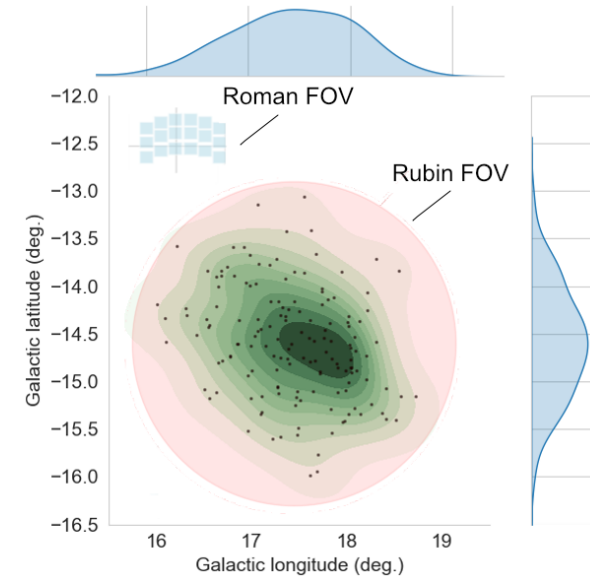

Figure1. Search area for Rubin and RST fields of view with density overlay for the *New Horizons* trajectory search area. The green contours show the concentration of potential objects in a given location and the black points are objects that pass within 1 au of *New Horizons* between 2027 and 2040 and have V < 28.5 in July 2026, based on the 20× oversampled extended Kuiper Belt model of [5].

Analysis Techniques: Because the mission's primary original target, Pluto, was traversing the galactic plane when *New Horizons* flew by it, most of the search region for *New Horizons* KBO flyby targets is also necessarily in similarly highly populated stellar fields. The Rubin and RST surveys will propose to search the specified location, enabling both characterization of the distant Kuiper Belt and the search for an of an extremely distant KBO flyby target.

As a part of past *New Horizons* KB surveys using Subaru, special machine learning techniques have been developed to cope with high background fields and false positives [6,2]. Additionally, techniques have also been developed to stack sets of short exposures collected close in time to be compared with later sets of close-in-time exposures for tracking these objects and determining their orbits [2,3]. These techniques will be applied to the proposed Rubin and RST survey datasets.

Impacts on Kuiper Belt Research: Current ground-based detections of distant KBOs [2,3], as well as measurements by the *New Horizons* Student Dust Counter [7], give evidence for a potentially sizable component to the Kuiper Belt at distances beyond, even well beyond, 70 au. Because of both survey depth and pointing requirements near the galactic plane, the Rubin and RST *New Horizons* surveys will characterize the deep, extended Kuiper Belt and investigate the KBO size distribution there in detail. In particular, these surveys will enable studies of the separation of objects into the two main KBO orbital groups of 'cold' and 'excited' orbits with Rubin. Since this survey will go broad and deep, it will be able to directly connect the large-object (D>200 km) and small-object (D<10 km) size frequency distribution (SFD) slopes to provide a robust measure of the size scale of the Kuiper Belt's planetesimal population. Ultimately, RST will provide an unprecedented constraint on solar system formation scenarios, including properties such as the primordial pebble size, the accretion efficiency, and the masses of the initial clouds required to produce planetesimals [8-11]. To confidently detect and characterize this small KBO SFD requires detecting objects with diameters well below ~100m [effective magnitudes of $m_r \sim 29$ assuming 0.12 albedos; the absolute detection limit of even the JWST pencil beam survey [12]], which is impossible from anything other than this proposed RST survey.

Broader Impact for Non-KBO Science: While these surveys focus is on moving objects in the Solar System, their basic requirements for our observations support other science cases that benefit from longer duration stares and long time bases. The RST search as defined is somewhat similar to that of the Multiband Imaging Survey for High-Alpha PlanetS (MISHAPS) which searches for hot Jupiters in the Galactic bulge and their occurrence rates from the ground [13]. The stars in the *New Horizon*s search field will mostly be from the low-metallicity thick disk and halo populations, and while the occurrence rate of hot Neptunes is higher than for hot Jupiters, our dataset would be sensitive to both of them over a smaller range of magnitudes, so the yield for both might be comparable. These observations might also help microlensing models to constrain Galactic star counts.

Summary: In summary, Rubin, and in particular RST have the capability to uncover a hitherto unknown extensive population of KBOs beyond the current Kuiper Belt. With *New Horizons* now beyond 60 au and a projected lifetime to 2050, the mission is uniquely positioned to study this unexplored region of the solar system for the first time providing new insights into solar system formation. The same dataset can be exploited for exoplanet and astrophysics applications.

Acknowledgments: This work was supported by the *New Horizons* KEM2 Extended Mission (NASW-02008).

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