Roman Early-Definition Astrophysics Survey Opportunity

(1) Submission Title or Survey Name:

Solar System Small Body Compositions using Roman WFI Spectrophotometry

(2) Contact author:

Cristina Thomas, Northern Arizona University
cristina.thomas@nau.edu
Dept of Astronomy and Planetary Science, PO Box 6010, Flagstaff, AZ 86011

(3) Co-authors (names and institutions only):

Bryan Holler (Space Telescope Science Institute), Andy Rivkin (Applied Physics Laboratory), David Trilling (Northern Arizona University)

(4) Do you support the selection of a Roman Early-Definition Astrophysics Survey

Yes, the selection of a Roman Early-Definition Astrophysics Survey will enable studies of scientific questions outside of those in the Core Community Surveys. There are a large number of observational programs that are not currently represented in the selected surveys and the addition of another survey would increase the scientific engagement from other aspects of the astronomical community. In particular, the current surveys do not address any studies within our own Solar System. Studies of the small body populations (e.g., asteroids, Kuiper Belt Objects) shed light on the formation and evolution of our Solar System, which can have applications to our understanding of other stellar systems.

(5) Describe the science investigations enabled by the survey

Large spectrophotometric data sets of small bodies in the Solar System enable impactful studies of the compositions of these small body populations. Past work has demonstrated that the 100,000 known moving objects within the Sloan Digital Sky Survey (SDSS) Moving Object Catalog are a valuable resource. SDSS data has been used to investigate the distribution of taxonomic types across the main belt (Carvano et al. 2010; DeMeo & Carry 2013), the colors of the main belt families (Parker et al. 2008), and space weathering trends (Nesvorný et al. 2005, Thomas et al. 2012). These works have demonstrated that spectrophotometry can be used to distinguish between asteroid taxonomic classes and determine spectral slopes (an indication of space weathering).

We propose a spectrophotometric survey of the Solar System small body populations using the Roman Wide Field Instrument (WFI) filters. With Roman, we can expand our studies of Solar System small bodies to smaller sizes (suggested limiting magnitude V ~24) than previous surveys and complement the data to be obtained by the Rubin/LSST survey by extending wavelength coverage into the near-infrared (Fig 1; LSST will produce a moving object catalog that is complete to *r* ~ 24.5). While visible wavelength spectrophotometry can assign a *likely* asteroid taxonomic type, there is still some uncertainty on the classification and, consequently, the potential composition. Inclusion of NIR data removes much of ambiguity because the shapes of many spectral types diverge near 2μm (Fig 2). A Roman survey would improve our understanding of the distribution of material in the Solar System (specifically the Main Asteroid Belt) and expand that study to smaller asteroid sizes to examine phenomena such as mixing of materials and space weathering.

There are a number of studies that could be performed with this dataset. Work on near-Earth objects have demonstrated that there are clear differences in the compositional distribution of the largest objects compared to the smallest objects in the population. This difference in spectral types (Devogele et al. 2019) has been speculated to be due to different source populations (both location and object size) in the Main Asteroid Belt (MB). An improved understanding of the MB population with a focus on smaller objects would help address this open question. Additionally, LSST will discover ~40,000 Trans-Neptunian Objects (TNOs) down to the nominal single exposure depth of ~24.5 (LSST Science Book). TNO colors will allow compositional studies of a large number of small TNOs and probe the origins of the TNO population (e.g., Fraser and Brown 2012, Fraser et al. 2015, Terai et al. 2018, Schwamb et al. 2019).

The design of a survey of moving targets is limited by the lack of non-sidereal tracking. We set our limiting magnitude (V< 24) such that objects could be observed in each filter with SNR>10 with minimal streaking (3-4 pixels, inner MB) in each individual 55 second exposure. With this requirement, we can sample from the inner MB to the outer Solar System, but planning would be required to target the innermost objects at their slowest non-sidereal rates.

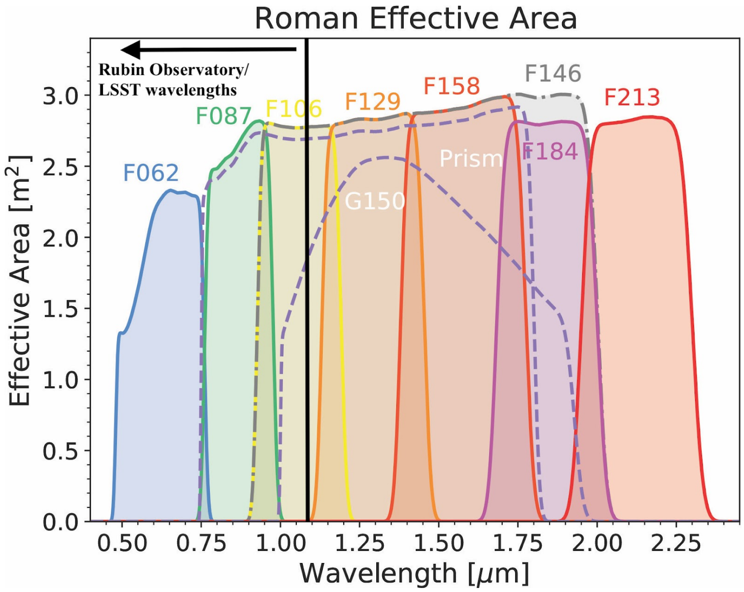

Figure 1:
We propose to use Roman WFI filters (F062, F087, F106, F129, F158, F184) to obtain spectrophotometry of small bodies in the Solar System. Much of the data obtained from these filters complements the Rubin/LSST visible wavelength data. The small overlap will help us effectively link the datasets.

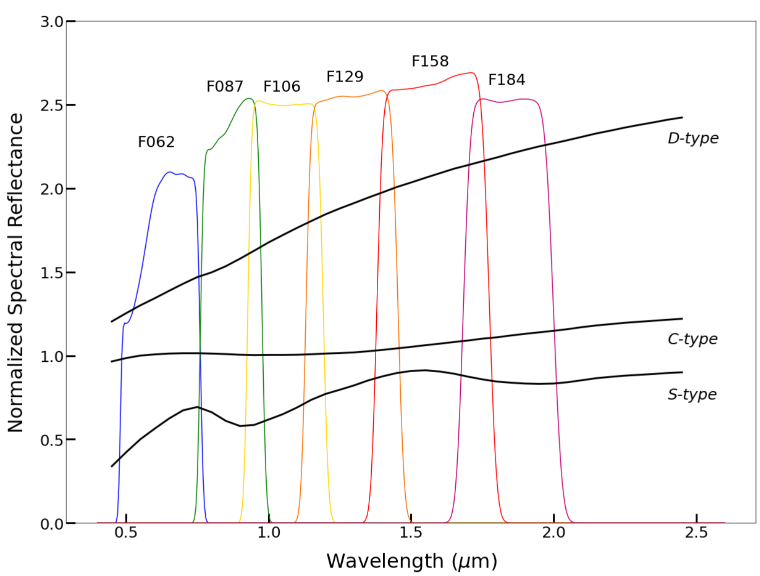

Figure 2:
For an accurate interpretation of asteroid results, it is critical to reach wavelengths near ~2μm where the spectral types diverge. Three key taxonomic types are shown here compared to the proposed filters. The wavelength range covers a large portion of the visible and near-infrared wavelengths that are used to define the Bus-DeMeo taxonomy (DeMeo et al. 2009). The spectra are offset for clarity.

(6) Provide a possible observational outline of the survey

This survey would target known objects (asteroids and TNOs) within the V < 24 limiting magnitude. In addition to the currently known targets, LSST expects to discover millions of Main Belt asteroids and ~40,000 TNOs within their r ~ 24.5 limit. With far more objects that we could realistically observe in < 700 hours, we plan to limit the total sample to ~1,500-2,000 targets. Targets would be selected to sample each small body population while covering a range of object sizes and heliocentric distances. This sample would be far larger than the original surveys that led to our initial understanding of distribution of asteroid types in the Main Belt (e.g., Gradie & Tedesco 1982).

We define the maximum exposure time as 57 sec to mitigate streaking across pixels due to the lack of non-sidereal tracking. This limit was set so that we can select targets throughout the MB (highest non-sidereal motion) and not cross more than ~4 pixels in an exposure. We select the limiting magnitude to enable sampling of a large range of asteroid sizes while keeping the total exposure time for each target reasonable. The table at right shows the number of exposures required for a V=24 target to reach SNR>10 (RAPID readout). We use the total exposure time (with overheads up to 50%) to estimate the number of targets feasible in 700 hours. Most targets would be brighter than V=24, but we use that as the maximum time requested per object. This initial analysis does not include the F213 filter since it is not available on the ETC, but we anticipate it taking longer than the F184 to meet our requirements. If selected, we would consider its addition after examining the ETC results.

Number of 57 sec exposures required for SNR > 10 at V=24	
F062	2
F087	2
F106	2
F129	3
F158	3
F184	10

(7) Describe specific preparatory activities enabled by early definition

1. Perform a more detailed analysis of the long wavelength filters. F184 and F213 would take the longest amount of time to reach the minimum SNR > 10. The wavelength region covered by these filters are particularly important for detecting features near 2μm, but without ETC information from F213 it is difficult to make an informed decision regarding filter choice. As described above, we only choose to use one of these filters, but given the results of the analysis the filter choice or the option to use both could be revisited.
2. Determine criteria for target selection. The launch of the Roman Space Telescope will be years after the start of the Rubin/LSST survey. By the start of a selected Roman survey, we will have a lot of target options available to us. We would need to develop a pipeline to find the smallest non-sidereal rates for MB asteroids (to minimize streaking) that would still enable measurement of various sizes and semi-major axes. Our analysis for this document shows that these targets exist, but did not do the process to optimally select the targets. We would determine the detailed breakdown of targets between the small body populations and the range of parameters to be sampled within each population. Each target

would also be checked for observability within the Rubin/LSST survey to prioritize objects where the Roman data could be combined with the LSST visible wavelength spectrophotometry.

3. Perform a detailed analysis of SNR requirements with respect to the various spectral types present in the Solar System. The SNR>10 requirement given here is estimated from analyses of the SDSS Moving Object Catalog data. However, those studies focus on asteroids in a different wavelength region than the one we propose to use with Roman. We would perform an analysis of how this translates to the specific TNO spectral groups and if we need to change the requirement. Even if we make the requirement more restrictive (e.g., higher SNR or different limiting magnitude), we will still have a large number of potential targets that will be independent of any ground based spectral or spectrophotometric NIR survey.

References:

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