Roman Early-Definition Astrophysics Survey Opportunity:
Submission Template

(1) Submission Title or Survey Name: Roman Deep Survey

(2) Contact author (with institutional affiliation and full contact details, including email):
Sean Bruton, Minnesota Institute for Astrophysics, bruto012@umn.edu

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

(4) Do you support the selection of a Roman Early-Definition Astrophysics Survey (as described in the "Request for Information"; yes/no, with supporting motivation, 10 lines max):
Yes, early definition of this survey will permit supplemental observations with other facilities before their end-of-life and the development of a novel pipeline to construct pseudo-narrow band images using the grism. With this pipeline in place, a new mode of observation with Roman will be possible for the general Astrophysics Surveys' proposals.

[Answer the questions that follow only if proposing a specific survey concept; be aware that the content below may be made public should this concept, or one closely related to it, be documented in the Assessment Committee report.]

(5) Describe the science investigations enabled by the survey (as relevant, briefly describe: key science drivers and breadth of science areas engaged; datasets expected upon survey completion; comparison of science enabled, parameter space opened up, or complementarities with respect to ground/space-based state-of-the-art at time of Roman launch; key differences from, and/or complementarities with, Roman core community surveys; one page max):

Despite dedicated surveys, there are many unanswered questions about reionization which may be addressed by this survey: how long was the reionization process? What are the properties of the objects which drove reionization? How much of an impact does the intergalactic medium (IGM) heating have on star formation in low mass galaxies (Kannan et al. 2021)? Thus, the primary motivation for the deep survey is to identify Lyman-α (Lyα) emitters (LAEs) at $z>7.6$; LAEs which are within the heart of reionization (Planck 2020). LAEs may be used to probe reionization because the Lyα line is resonantly scattered by any neutral hydrogen it encounters, and so a neutral IGM attenuates the Lyα photons while they propagate towards us. This has the effect of decreasing the number of observed LAEs, affecting both their luminosity function and clustering properties. Thus, both measurements carry with them information about reionization. The Roman Space Telescope's wide field-of-view, slitless spectroscopy, and ability to push to luminosities fainter than the predicted Lyα luminosity function knee in a relatively short amount of time (Figure 1) make it the optimal tool to finally answer some of the most fundamental questions about reionization.

By dedicating a significant amount of time to grism slitless spectroscopy on one field-of-view at many different orientations, it will be possible to create a pseudo-narrow band image, as demonstrated in Barger et al. 2012 with GALEX grism data. This permits an emission line search over the entire field and wavelength range covered by the grism. A significant benefit of this method is identifying "orphan" emission lines which would otherwise be missed because the host galaxy's continuum flux is below the detection threshold. Thus, one may extract a flux limited sample of emission lines, simplifying luminosity function analyses and ensuring high equivalent width lines are not missed. Based on simulating LAEs in a reionization simulation populated with dark matter haloes, we predict to identify ~150 LAEs at z~7.6 down to a luminosity limit of 1.9*10^42 ergs/s, assuming a global neutral fraction of 0.5 (Figure 1). These LAEs would be spread over one field-of-view, 0.28 square degrees, and this creates a high space-density which allows the topology of reionization to be seen by looking at the footprint of the LAEs (Figure 2). A clustering analysis of such a sample would permit an inference on the characteristic size of ionized bubbles in the universe during reionization, which holds information about the sources of the ionizing photons. Such a large sample of spectroscopically confirmed LAEs at z>7.3 is unprecedented and will yield crucial information about the middle times of reionization.

Further auxiliary science will be possible through the grism observations, which will detect optical emission lines such as the Balmer series and the [OII] and [OIII] doublets at 1.5 ~< z ~< 3.7. These lines may be used to characterize: star formation rate from the Balmer lines, gas extinction from the H-alpha/H-beta ratios, obscured star formation from H-alpha/Paschen-beta ratios, and many other galaxy property diagnostics.

The addition of observations to m<30 for F062, F087, F106, and F129 permits the opportunity to eliminate contaminating low-z galaxies single line emission galaxies by photometrically selecting galaxies on the Lyman break. This color selection, along with deep spectra for each of the objects, will minimize any contamination in our LAE sample, as demonstrated in Bagley et al. 2017. Further, it allows slitless spectra to be extracted in the more traditional manner—using the footprint of continuum selected galaxies. The identification of "orphan" emission lines on top of this sample using the method from Barger et al. 2012 will build a truly impressive emission line sample.

(6) Provide a possible observational outline of the survey (as relevant/known, touch upon: survey area covered, possible location, and/or (types of) targets observed; optical element (filters/grism/prism) choices; cadence or other timing constraint (if relevant); depth to be achieved; total time needed including estimated overheads; how the survey leverages the unique observational capabilities of Roman; half-a-page max):

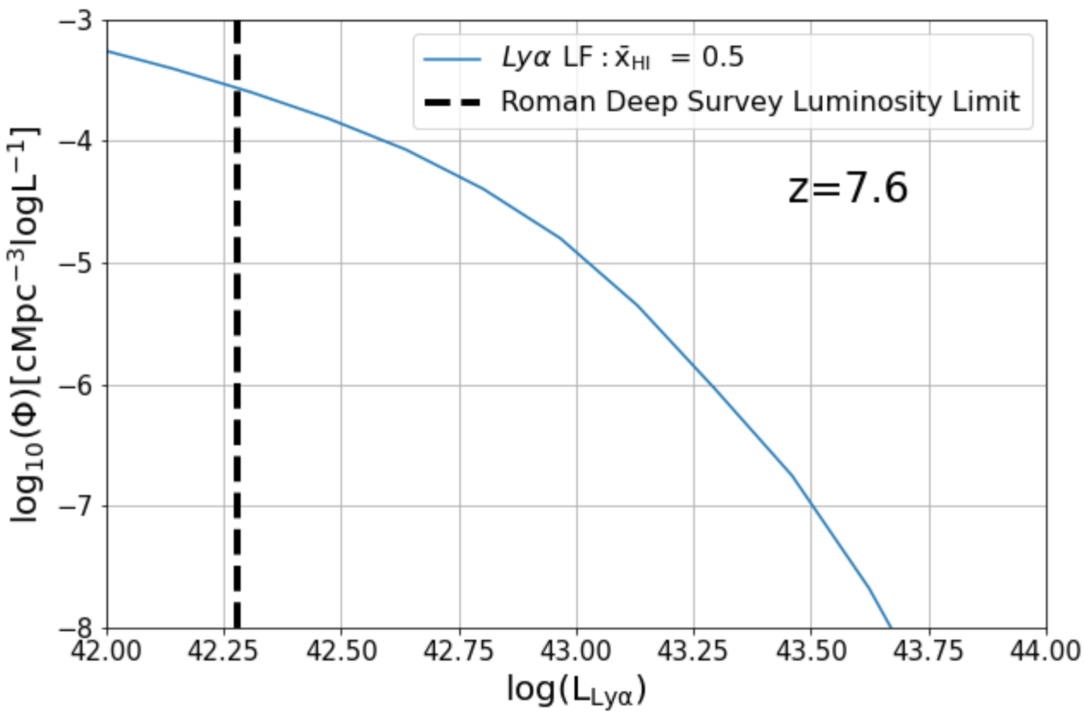
The deep survey will cover one field-of-view, 0.28 square degrees, for 420 hours. The field will be observed with the grism in many (several hundred) orientations, totaling 350 hours of observation. The same field of view will be observed in the F062, F087, F106, and F129 filters to a limiting depth of m=30 using a total of ~70 hours of observations. For these calculations, we have assumed 1.2x the minimum zodiacal light, corresponding to position near the ecliptic pole in the continuous viewing zone. We propose to position the field overlapping the center of the Euclid Deep Field North, which will be the target of many additional ground observing campaigns, ensuring coverage of the field in many wavelengths.

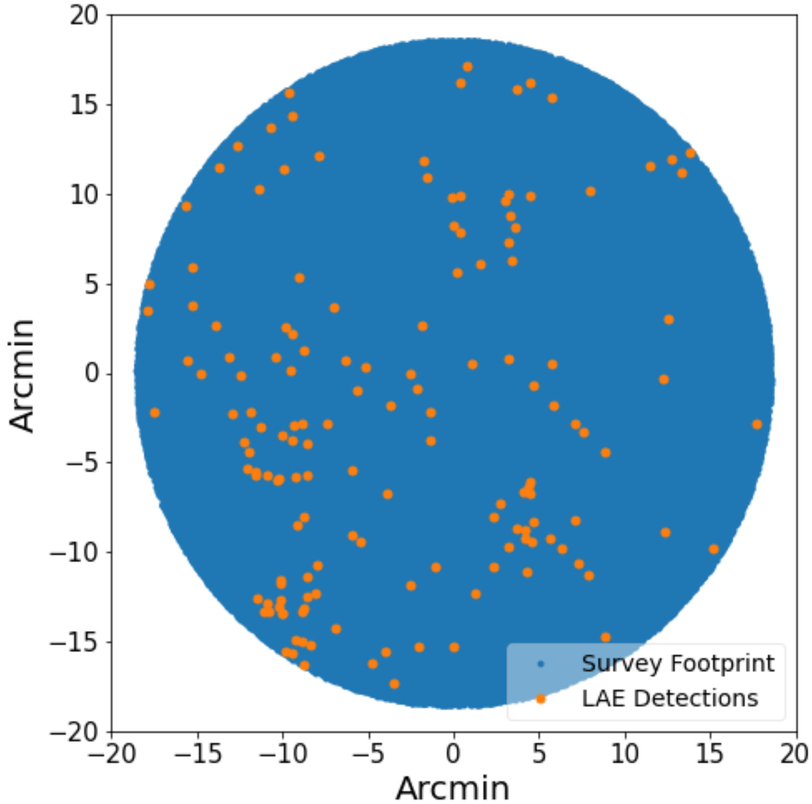
The survey is unique in which of Roman's capabilities it focuses on—the depth, rather than the area. Roman will typically be used to construct large area surveys to moderate depth, but we propose to invert this and push to phenomenal depths over a more modest (but still impressive) area. Carrying out such a survey in a relatively short amount of time is a unique capability of Roman. Such a deep survey would have a limiting line flux of ~3*10^-18 ergs/s/cm^2 and a magnitude limit of m<30 over an area larger than the moon.

(7) Describe specific preparatory activities enabled by early definition (e.g., supporting facility observations, software development work, theoretical/simulation efforts etc.; describe the benefits of conducting these activities early; half-a-page max):

The proposed observation strategy of taking many hundreds of grism observations at different orientations and producing a pseudo-narrow band data cube requires a specific new pipeline to be developed. This would take a dedicated effort, but by defining this survey early and developing this pipeline ahead of the general proposals we effectively open a new observing mode for proposals within the Astrophysics Surveys. Without the early selection of this survey, the pipeline would not be developed until the general Astrophysics Survey proposals, if ever, eliminating the chance to use this unique observing mode for more than one survey.

A second point, applicable to any early definition survey: the overlap between JWST's mission lifetime and the current back end of the Roman launch date is only 1 month. Even taking into account that the Astrophysics Survey proposals will start about 1 year prior to the launch, there is not time to coordinate JWST observations with a Roman survey—this is something which is best done through an early definition survey for the most flexibility. We should not take for granted that JWST will outlive its mission lifetime, given the complexity of space telescope missions. The Roman Deep Survey, with its large area and extreme depth, will discover rare bright objects at extremely high redshift, objects prime for more detailed JWST follow up. If we do not identify these objects early in Roman's life, our opportunity to follow up with JWST may be missed.





Bagley, M. B., Scarlata, C., Henry, A., et al. 2017, ApJ, 837, 11, doi: 10.3847/1538-4357/837/1/11

Barger A. J., Cowie L. L., Wold I. G. B. 2012, ApJ, 749, 106. doi:10.1088/0004-637X/749/2/106

Planck-Collaboration et al. 2020, A&A, 641, A6, doi: 10.1051/0004-6361/201833910