Roman Early-Definition Astrophysics Survey Opportunity:
(1) Title:

Roman Deep Survey of the Euclid Deep Fields

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(4) Do you support the selection of a *Roman* Early-Definition Astrophysics Survey:
Based on our collective experience in constructing galaxy surveys using ground- and space-based observatories over the last 25 years, it is essential that survey fields be selected as soon as possible and well before the main observations of the field are planned. This allows for the ancillary observations to be performed and analyzed before the main survey is carried out. Such supporting data will allow careful characterization and optimization of the main survey depth, areal coverage, and tiling strategies, and provides a focus and support for the major science goals of the survey. This is particularly important for surveys with entirely new instrument capabilities – as is the case with the *Roman*. Furthermore, given the limited lifetime of space observatories, early identification of primary survey fields is essential to enable acquisition of key data from current observatories before they are decommissioned. This is a major requirement for selected fields targeted by the *Roman*.

(5) Describe the science investigations enabled by the survey:
Roman will be transformative for galaxy evolution surveys given its wide field and sensitivity in the near-IR bands. No ground-based facility can reach the infrared sensitivities accessible from space (due to the high infrared background of night sky), and the most direct precursor to *Roman*, the ESA-led *Euclid* satellite launching just a few years earlier, has significantly lower angular resolution in the near-IR due to a combination of mirror aperture and pixel size as well as very broad filters. The combined field of view, resolution, wavelength coverage and sensitivity of the *Roman* (Figure 1) will enable new science topics. Given the characteristics of the *Roman*, we have identified the unique science that can be conducted by observing *Roman Deep Fields* (next section), as listed below:

- Search, identification and spectroscopy of $z > 9$ galaxies;
- Calibration of the High-Latitude, Wide-Area core community survey (e.g., photometric redshifts and shape measurements);
- Statistical properties of galaxies (e.g., mass and luminosity functions) to the highest redshifts using large, unbiased samples;
- Evolution of morphological types of galaxies and the origin of the morphologies;
- Nature of the old and most massive galaxies at highest redshifts;
- Identification of protoclusters and early evolution of galaxies in different environments;
- Identification of the cosmic web and the filamentary structures. Study of properties of galaxies and the IGM in filaments;
- Spectroscopic study of mass-metallicity-SFR relation and its evolution with redshift;
- Extensive study of the small-scale (pixel scale) distribution of the SFR, dust and stellar mass in galaxies; and
- Time-domain studies, including supernovae for cosmological studies.

To address the above science topics, we need to formulate surveys that could best serve our science goals. Figure 2 compares the depth vs. area for the major surveys currently available. We use this to constrain the *Roman* Deep Fields survey parameters complementary to the existing surveys, given the allocated time of 700 hours for this program category, the number of filters and the depth in each filter. We adapt two scenarios to perform multi-waveband surveys- (1). Cover a total area of 20 deg^2 to medium deep levels with five filters (2). Cover an area of 40 deg^2 to shallower depths with the same filters. The proposed filters, depths and exposure times for both scenarios for the *Roman Deep Field* Surveys are listed in Table 1.

As noted above, we recommend that the locations for the fields be identified as soon as possible to allow the community to begin preparatory work amassing complementary data that will enhance the science value of the *Roman* data once it becomes available. Specifically, we recommend developing the *Roman Deep Fields* to spread over at least two fields to account for the cosmic variance. The two surveys proposed above and discussed in the next section can be developed to be complementary to one another in a "wedding cake" configuration. However, the most important at this stage, is the selection of the fields and their location so that the community could concentrate in performing the ancillary observations. In the next section we set out our criteria for selecting the location of the Roman Deep survey fields.

(6) Provide a possible observational outline of the survey:
We select the *Euclid* Deep Fields as the location for the proposed *Roman* survey (Figure 3). This is an incontrovertible choice. **These fields have some of the deepest Spitzer pointing within them.** Given that Spitzer is decommissioned and there are no plans for a successor for it, the deep mid-IR imaging in these fields will remain unique for the foreseeable future (i.e., into the 2040s). Accordingly, these were selected as the *Euclid* Deep fields with Euclid *YJH* observations planned. **Our team has started deep optical imaging and spectroscopic observations for a total of 20 deg^2 covering two of the three *Euclid* Deep Fields: EDF-North near the North Ecliptic Pole (EDF-N; 10 deg^2) and EDF-Fornax in the south (EDFF; 10 deg^2)** – (Fig 3). This is part of the Hawaii-20 (H20) program, for which 30 nights of Subaru/Hyper SupremeCam (HSC), ~70 hours of CFHT/MegaCam and 15 nights of Keck/DEIMOS were allocated. Optical HSC imaging observations in *griz* bands are performed and complemented by u-band observations by the MegaCam and targeted spectroscopy of galaxies from the H20 photometric catalogs. The two fields provide constraints on the cosmic variance and are accessible by facilities from both hemispheres. The strengths of the H20 fields are listed in Table 2. The filters and estimated depth from the proposed *Roman* observations for the H20 are presented in Table 1. The spectral energy distribution (SED) of a typical galaxy from the H20 is shown in Figure 1.

Alternatively, we consider extending H20 to a wider but less deep survey covering the additional 20 deg^2 of the EDF-South field, for a total survey of 40 deg^2. The extension field is selected to be within the CVZ, to have Spitzer coverage and to fulfill requirements for the SNe search. EDF-S has relatively shallower Spitzer data and no ground-based u-band, deep optical or significant spectroscopic coverage thus far. The EDF-S will be the target for the Rubin Telescope (LSST) to obtain multi-waveband optical imaging data like the existing data for the two fields of the H20, providing homogeneous data over the entire 40 deg^2 of the H40 fields. Details about the depth of the H20 and H40 programs are listed in Table 1 with the proposed fields compared with the existing surveys in Figure 2. The H20/H40 depth and wavelength coverage is also shown in Figure 1.

(7) Describe specific preparatory activities enabled by early definition:
Early selection of the *Roman* Deep Fields will enable the community to rally behind these fields for the necessary preparatory work. Though significant efforts are already underway to obtain deep optical and u-band imaging in the *Euclid* Deep Fields to support *Euclid,* the greater aperture of *Roman* will require yet deeper imaging. Relatedly, significant efforts are also underway to obtain highly robust spectroscopic redshifts within the *Euclid* Deep Fields and the calibration fields (these will be used to calibrate photometric redshifts as well as forming the basis of science with these data). The *Roman* weak lensing survey will be conducted on fainter galaxies at higher redshifts, which will require additional concerted spectroscopic efforts as soon as possible to ensure sufficiently reliable photometric redshifts at the *Roman* depths by the time *Roman* launches. The significant advantages of the H20 fields are the availability of very deep Spitzer imaging data which do not exist for any other fields of comparably wide area, as well as the expected deep *Euclid* near-IR data and the currently available deep multi-waveband optical imaging data (Table 2). The photometric catalog and measurements of the photometric redshifts and stellar masses for H20 galaxies will be finalized before the *Euclid* launch.

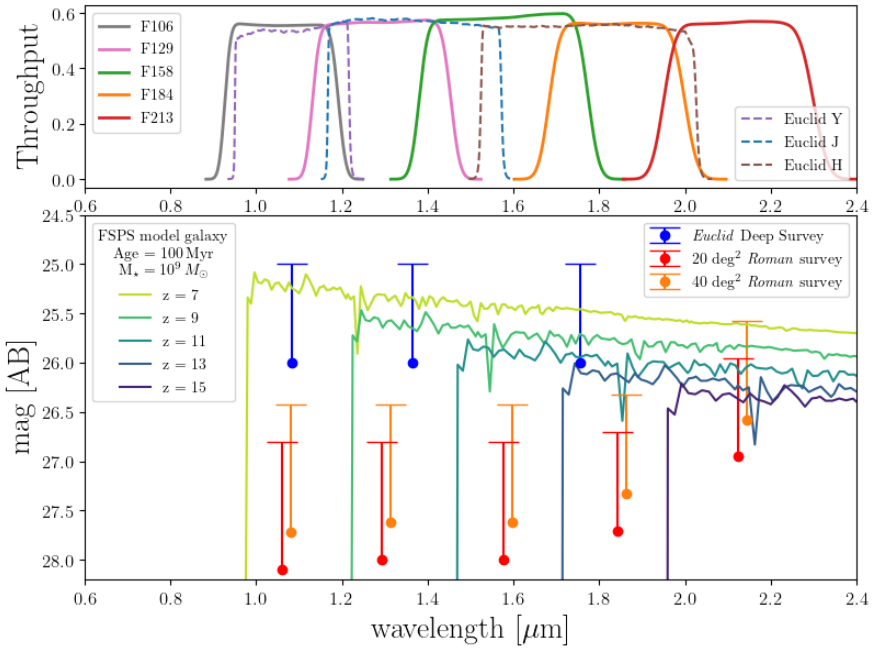

Figure 1: *Top panel*: *Roman* and *Euclid* filter transmission curves. *Bottom panel:* Estimated magnitude limits for the *Euclid* (blue points) and proposed H20 and H40 *Roman* deep fields (red and orange points) superimposed on FSPS model galaxy spectra for a range of redshifts (see left legend). Extended and point source limits are indicated with the top bar and bottom point, respectively.

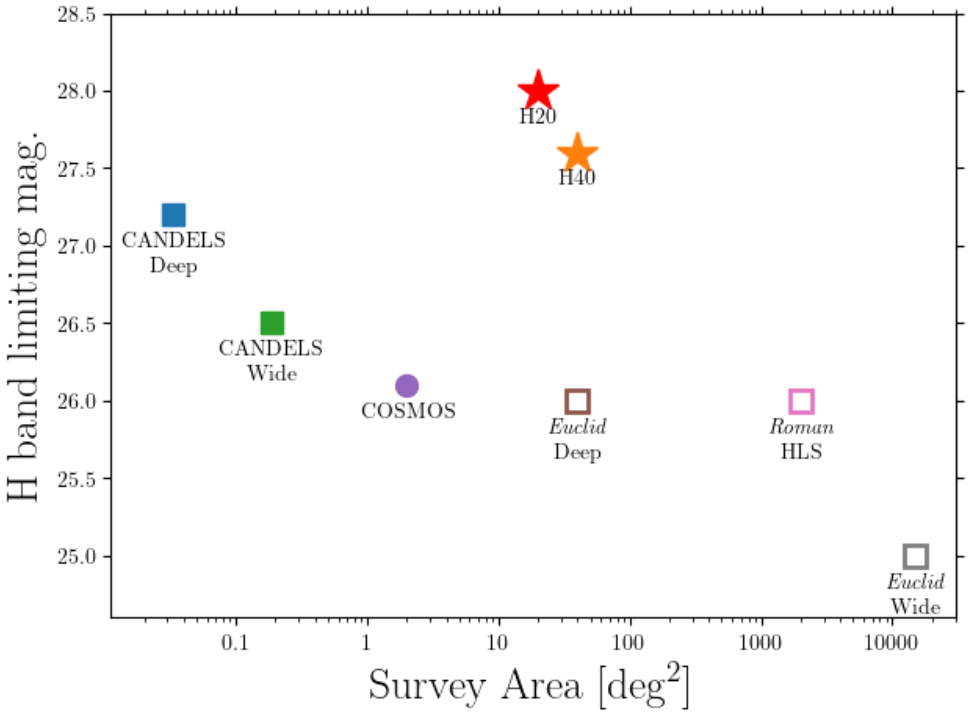

Figure 2: H-band depth vs. area for existing and future (open symbols) surveys. The proposed H20 and H40 are shown with colored stars.

Figure 3: All sky projection showing the locations of the H20 (and H40) fields. The solid blue line shows the ecliptic, The dashed blue lines indicate ecliptic latitudes of ±54° which will be the boundary of the continuous viewing zone for the *Euclid* and *Roman* missions. The dotted blue lines show the continuous viewing zone for JWST at ±85°.

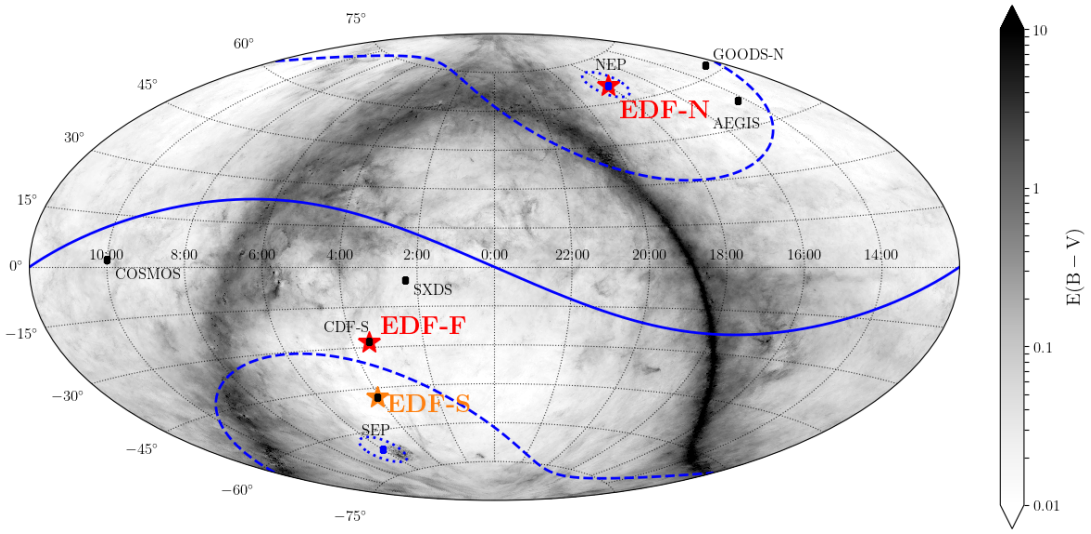

Table 1: Estimated magnitude limits for H20 (and H40) *Roman* deep fields

Filter	F106	F129	F158	F184	F213
Mag Limit (5σ point src)	28.0 (27.6)	28.0 (27.6)	28.0 (27.6)	27.7 (27.3)	27 (26.6)
Exp. Time (hr)	1 (0.5)	1 (0.5)	1 (0.5)	1.75 (0.88)	4 (2)

Table 2: Strengths of Targeting the H20/*Euclid* Deep Fields

HSC *griz* data are available to deep levels over the 20 deg^2 area.
u-band CFHT- MegaCam data available for the entire 20 deg^2
Very deep warm-Spitzer data are available for the entire 20 deg^2
The entire H20 area will be observed by deep *Euclid* observations in *YJH* bands.
DEIMOS spectroscopy is available for selected targets in the H20 fields
Photometric redshifts and stellar mass measurements will be measured and cataloged well before the Euclid launch and *Roman* observations.
HSC narrow-band data are available over the H20 fields.
H20 is a target field for Subaru-PFS, and spectra will be available before the *Roman* is launched.

Roman Deep Survey of the *Euclid* Deep Fields