***Roman* CCS White Paper**

Achieving *Roman* Requirements for Flux Calibration of the High Latitude Surveys

***Roman* Core Community Survey:** High Latitude Time Domain and Wide Area Surveys

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1 Introduction

Roman's High Latitude Time Domain (HLTDS) and High Latitude Wide Area (HLWAS) Surveys will address one of the key questions in cosmology: "*What physics drives the cosmic expansion and large-scale evolution of the universe?*", because "*the unknown physical natures of dark matter and dark energy, both discovered through astronomical measurements, remain outstanding grand challenges in both physics and astronomy*." by measuring light curves and redshifts of thousands of high redshift SNe Ia. However, achieving *Roman*'s full potential requires calibrations with uncertainties that are factors of a few to 10 times better than provided by current facilities. For example, *Roman*'s requirements on photometry are 0.3% uncertainty over 11 magnitudes and 0.5% uncertainty in the absolute color. In order to meet its FoM objective, *Roman*'s SNe Ia cosmology survey (HLTDS) requires stringent control of *systematic* sources of uncertainties, since with measurements of many thousands of SNe Ia statistics are not a limitation.

The sources of SNe Ia systematic uncertainty that affect the FoM are flux calibration, including bandpass zeropoints, color calibration, wavelength zeropoints and dispersion; detector non-linearity; selection effects; astrophysical effects such as dust extinction and peculiar velocities; and analysis methods. Typically, flux standards[footnote] are used to determine total system throughputs (zeropoints) and absolute colors, estimate flat-fielding precision, spatial dependence, and, monitor time-dependent behavior through regular (annual) observations of a few standard stars.

To address the calibration need for *Roman* to achieve its requirements, is is essential to

1. Establish and exploit a network of celestial calibration sources (stars, PNe) through pre-launch ground and space (HST, JWST) observations With 18 large IR detectors, it is impractical to use single standard stars to calibrate the entire *Roman* WFI field of view through all optical elements by "stepping" across each detector. In the current calibration plan at least 10% the time allocated to calibration is to step a single star over 2-5 regions per detctor. A more practical approach is to use standard reference fields that are large and contain multiple, stable spectrophotometric stars, which results in a multiplex advantage.

2. Allocate adequate observing time over the course of the *Roman* life cycle to ensure that contributions to systematic errors in flux measurements are quantitatively monitored and minimized. In the most recent calibration plan, approximately 80 hours per year is allocated for imaging and spectral calibrations.

2 Calibration with Standard Reference Fields

A Standard Reference Field (SRF) can have a crucial role in transferring the absolute flux calibration of standard stars to all WFI observations, and in particular to SNe Ia measurements. The ideal SRF is an area in the sky that contains a sufficient (not too sparse, not too dense) density of stars in a range of brightness and spectral types, that enables calibration of a wide field-of-view (FoV) with a minimum set of pointings. SRFs should be located in or near *Romans*'s continuous viewing zones, thereby accessible at any time. Each field is selected according to a set of criteria for the type of calibrations for which it will be used. A SRF for photometry is useful for determining the relative photometry across the *Roman* WFI focal plane and for monitoring changes in the total system throughput over the telescope's operational lifetime. Thus, a photometric SRF would provide calibrated secondary and tertiary standard stars. A SRF for spectroscopy needs sources whose spectral features have well-characterized wavelengths and can be used to determine the wavelength zeropoints and dispersion over the FoV.

We think it is imperative to identify and characterize standard reference fields before launch to verify and enable precision photometric and spectroscopic calibrations of all Wide Field Instrument filters and dispersive optical elements once Roman in in orbit. These include:

Establish the blue wavelength edge position on each detector in the WFI dispersed spectral images. and its spatial dependence.

Measure wavelength zeropoints and dispersion solutions. In-orbit dispersion solutions can be applied during the 2D spectral calibration phase prior to source decontamination.

Relative flux calibration correction. Light passing through the full *Roman* optical path will result in field-dependent responsivity for each optical element, which leads to position-dependent colors. The functional form of the pattern can be recovered by obtaining multiple observations of one or more standard reference fields.

Absolute flux calibration. If absolute spectrophotometric standard stars are available in the standard reference field, then absolute flux calibration of science targets is simplified. Else, pointed observations of a set of about 14–16 spectrophotometric calibration stars (still to be determined) would be required. This will result in a 1D sensitivity function applied to each spectrally extracted source, and in the filter sensitivity functions applied to each photometered source.

Count rate non-linearity corrections. Observations of standard reference fields can be carried out in combination with the on-board Relative Calibration System in Lamp-on/Lamp-off mode to determine non-linearities.

3 Conclusion

Establishing calibrated, carefully selected, standard reference fields for *Roman* imaging and spectroscopic calibrations will provide multiplex advantages to the its calibration program, including providing calibration for the F213, "K-ish", filter. It may allow reducing the number of pointings, and hence time allocated to calibration. Specifically, standard reference fields will enable more accurate and precise measurements of:

Imaging- Photometric Uniformity (large-scale and small scale), Temporal stability, Spectrophotometric Response over the FoV, Geometric Distortion, PSF calibration, and Cross-Survey Calibrations.

Spectroscopy-Wavelength Zeropoints, Dispersion Solutions, Trace Calibration Spatial dependence of flux calibration, spectral flux calibration, Spectrophotometric Stability and Spectral PSF.