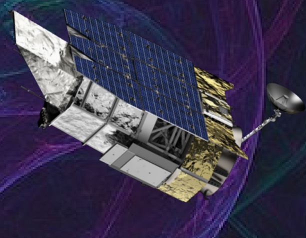
NANCY GRACE ROMAN SPACE TELESCOPE

Cosmology with Roman

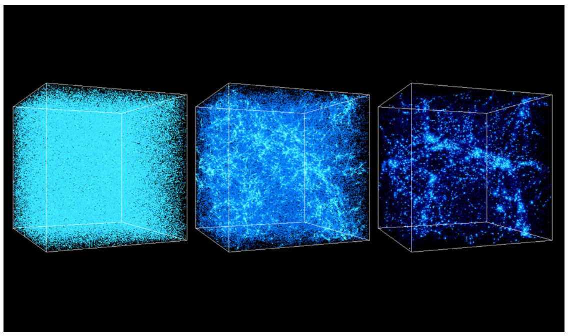
NASA's Nancy Grace Roman Space Telescope will have the near-infrared sensitivity, high-resolution imaging and spectroscopy, expansive field of view, precise pointing control, and high survey speed required to collect the big data needed to address—and perhaps answer—the most important questions driving cosmological research today.



Hubble-Like Resolution ~0.1'' **Near-Infrared Imaging and Spectroscopy** 0.48–2.3 μm **Expansive Field of View** 0.281 deg^2 **All Data Nonproprietary** ~4 Pb/yr

Complementing Other Observatories HST, JWST, Rubin, Gaia, Euclid, TESS, and more **Propelling Future Discoveries** All of Astrophysics

Big Data to Address Big Questions



Simulation of the formation of clusters and large-scale filaments in the CDM model with dark energy, from $z \approx 30$ (l), to $z \approx 5$ (m), to present (r); box dimension = 43 million parsecs. (A. Kravtsov and A. Klypin)

Roman is uniquely designed to collect the data needed to significantly narrow constraints surrounding the nature of dark energy and dark matter, and the evolution of large-scale structure in the universe. Roman's survey programs and other investigations will provide exceptionally large sample sizes and repeat observations, ideal for robust statistical and machine learning analyses, to address cosmological questions such as:

- How and why has the expansion rate of the universe changed over time?
- How has the structure of the universe changed over time?
- Does our current understanding of gravity explain cosmic structures at large scales?

To answer these questions, Roman will:

- Employ a Wide Field Instrument comprising 18 4k × 4k near-IR detectors; several filters spanning 0.48–2.0 μm; and two slitless spectroscopy modes spanning 0.8–1.93 μm
- Provide wavefront stability of <1 nm for precise measurements of position, brightness, and redshift
- Enable multiple robust, independent probes of gravity and cosmological parameters
- Grant open access to all data via the Mikulski Archives for Space Telescopes (MAST), providing opportunities for cross-checks and development of new analytical methods

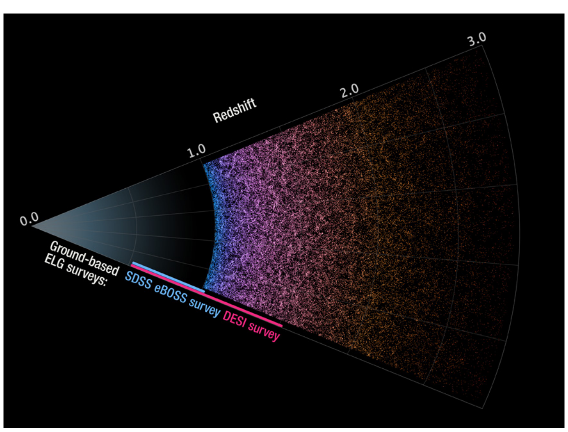
Type Ia Supernova Survey

SN 1994D, a Type Ia supernova located in NGC 4526. (NASA, ESA, the Hubble Key Project Team, and The High-Z Supernova Search Team)

Roman's planned Supernova Deep and Wide Imaging Surveys will enable detection and light-curve monitoring of thousands of Type Ia supernovae to $z \approx 2$. The combination of high-resolution imaging and spectroscopy for precision brightness and redshift measurements will make it possible to reduce the uncertainty of the dark energy equation of state by 70%, quantify temporal variations, and identify inflection points in the recent expansion rate. Roman will provide:

- Potential wide and deep time-domain surveys with 5-day cadence, and an estimated yield of more than 500 SNIa per month
- A three-tiered imaging approach with maximum exposure depths >26 mag for deep surveys (YJHF bands), 24.8 for medium (RZYJ), and 22.0 for shallow (RZYJ)
- Slitless spectroscopy mode covering 0.8 – 1.8 μm with R = 70 – 140, enabling redshift measurements of SNe and their host galaxies
- Opportunities to propose new observations of additional fields with deep imaging and spectroscopy

Mapping Distribution of Galaxies

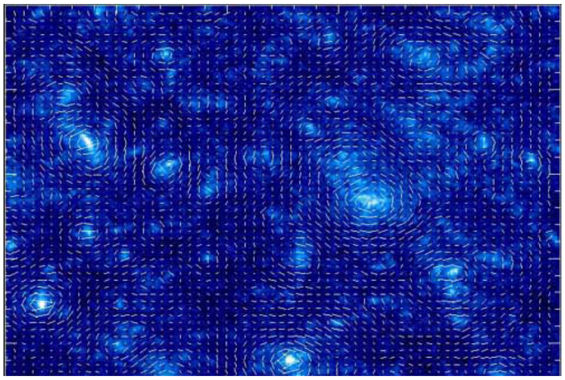


Visualization of simulated Roman emission-line galaxy distribution data used to measure BAO and RSD. The wedge shown covers an RA sweep of 45° with a DEC thickness of 1°, and includes more than 215,000 galaxies. (Data provided by Z. Zhai and Y. Wang, Caltech/IPAC. Visualization by J. DePasquale, STScI.)

Roman will enable precise measurements of the position and redshift of millions of distant galaxies, further probing the cosmic expansion history based on baryonic acoustic oscillations (BAO) and the growth-rate of large scale structures based on redshift space distortions (RSD). Roman will provide:

- Potential High-Latitude Survey (HLS) covering 2,000 deg² with imaging and slitless spectroscopy over the same fields of view
- Imaging in four near-IR bands with imaging depth of >26.25 mag and expected spectroscopic depth of 1.0×10^{-16} erg/s/cm² at 1.80 μm
- Expected total yield of ~10 million Hα redshifts at $z = 0.5$–1.9 and ~3 million [OIII] redshifts at $z = 1.0$–2.8, enabling detailed 3D mapping of galaxy and galaxy cluster distribution from $z \approx 0.5$–3
- Sample sizes large enough for precisely measuring BAO in both radial (probing expansion history) and transverse (probing angular diameter distance) directions
- Sufficiently dense sampling of redshifts at $z \approx 1$–2 to enable higher-order statistical measures of the evolution of large-scale structure and tighten the constraints on dark energy
- The ability to differentiate galaxies from QSOs and other objects used as tracers of larger-scale structure, and the potential to use quasars to map BAO out to $z > 7$

Weak Lensing

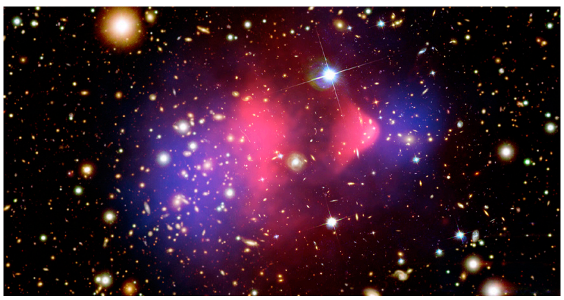


Simulation of cosmic shear in a CDM model. Line segments represent amplitude and direction of lensing shear produced by over-densities (light blue) and voids (dark blue). (B. Jain, U. Seljak, & S. White 2000, ApJ, 530, 547)

Roman will enable measurements of millions of galaxy shapes with high signal-to-noise in four bands, providing the best controlled weak-lensing experiment: unique in depth, detail, and control of measurement and astrophysical systematics. The high density of lensed galaxies will make it possible to produce high-resolution maps of dark matter with redshift that can be used to better understand the growth of large-scale structures and provide additional constraints on key cosmological parameters. In addition to mapping galaxy distributions, Roman's potential High-Latitude Survey will enable:

- Wide-area, 4-NIR-band imaging of 170 deg²/month, with a possible total yield of 4×10^8 weak-lensed shapes (40 – 50 galaxies per square arcminute in the stacked images)
- 4-band photometric redshifts for all of the galaxies, complemented with slitless spectroscopy (1.0 – 1.93 μm) for the same areas of sky
- Detection of >20,000 galaxies/month at $z > 8$, and 1,500 galaxies/month at $z > 10$
- Imaging depth of 26.9 in Y, J, H bands

Other Cosmological Studies

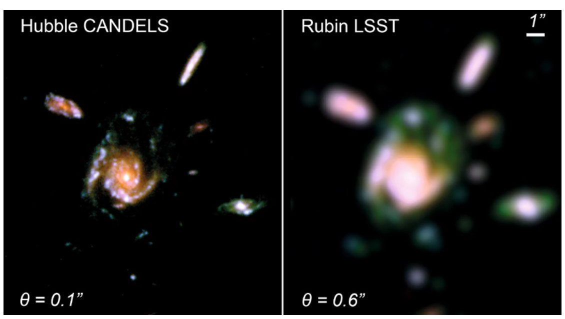


Optical image of galaxy cluster MACS J0025, overlaid with X-ray image of cluster gas (pink) and map of dark matter lensing (blue). (NASA, ESA, CXC, M. Bradac, and S. Allen)

With powerful core community surveys, 25% of the 5-year primary mission dedicated to new observations and archival research programs, and all data non-proprietary and immediately available, Roman will provide the ability to develop innovative investigation methods and explore a wide variety of other cosmological phenomena, including:

- Measuring the halo growth factor via galaxy cluster counts, weak lensing, and topological measurements of the filamentary structure to test models of modified gravity
- Using gravitationally-lensed QSOs to measure the Hubble expansion parameter at a variety of redshifts and constrain expansion history, and to test whether the substructure within galaxy-sized dark-matter halos agrees with the predictions of the CDM model
- Using weak and strong lensing to build maps of dark matter in merging clusters of galaxies to provide upper limits to the dark matter self-interacting cross-section
- Using galaxy redshift surveys to constrain the mass of neutrinos
- Determining the abundance of high-mass galaxy clusters to describe the non-Gaussianity of the power spectrum at 1 Mpc scales

Synergies



Comparison of Hubble and expected Rubin Observatory LSST data resolution. (L) BVz color image from the Hubble CANDELS field with $\theta = 0.1''$ and $r \approx 28.5$. Roman will have comparable resolution. (R) Simulated Rubin LSST image made by degrading Hubble data to Rubin resolution of $\theta = 0.6''$. In the Rubin image, the galaxy is blended with surrounding objects. Correlating overlapping Rubin and Roman imagery would make it possible to develop machine learning algorithms to deblend Rubin imagery that does not overlap with Roman. (B.E. Robertson, et al. 2019, Nat Rev Phys, 1, 450)

Roman's investigative power will be magnified through collaborations with numerous other observatories, including the Vera C. Rubin Observatory, Euclid, and the James Webb Space Telescope. Combining data sets with different sky and wavelength coverage, image resolution and blending, and biases in galaxy sample selection will help better characterize and correct for systematic errors in all of the datasets, providing much greater precision on cosmological parameters than would be possible with each facility individually.

- As the primary sky survey facilities of the 2020s, Roman, Rubin, and Euclid will complement each other in terms of wavelength space, resolution, sky coverage, and depth.
- In combination with advanced machine learning algorithms, Roman and Euclid data will enable astronomers to disentangle overlapping galaxies and decrease source confusion from ground-based surveys such as Rubin's Legacy Survey of Space and Time.
- Complementary data from Roman, Rubin, and Euclid will improve constraints on measured cosmological parameters through better photometric redshift estimates and galaxy shape measurement validation.
- Roman observations will enable weak-lensing mass measurements for galaxy clusters detected by other future and current space- and ground-based observatories, including eROSITA and Athena (X-ray), and CMB-S4 and SPT (microwave to sub-millimeter).

Learn more about the Roman Space Telescope

STScI website: **www.stsci.edu/roman**
Mission/partner websites: **www.stsci.edu/roman/about.html#Partners**
For more about how Roman will explore the universe, see **www.stsci.edu/roman/documentation**

Previously known as the Wide Field Infrared Survey Telescope (WFIRST), the Nancy Grace Roman Space Telescope was named in May 2020 in honor of NASA's first Chief of Astronomy.

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