Deep Field Surveys with Roman Space Telescope

Brant Robertson (UC Santa Cruz)
PI: Roman Extragalactic Potential Observations (EXPO)
Science Investigation Team
Member: Roman Formulation Science Working Group
Brief Observable History of the Universe

Adapted from Robertson et al., *Nature*, 468, 49 (2010)
A New “Golden Age” for Extragalactic Astronomy

Observations with Nancy Grace Roman Space Telescope, ALMA, JWST, Rubin, and TMT will drive astronomical discoveries over the next decade.

Adapted from Robertson et al., Nature, 468, 49 (2010)
Roman Extragalactic Potential Observations (EXPO) Science Investigation Team

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Steve Furlanetto (UCLA)
Jenny Greene (Princeton)
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Brant Robertson (UCSC; PI)
Alice Shapley (UCLA)
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Risa Wechsler (Stanford)
Stan Woosley (UCSC)
**Roman Deep Field Science Questions**

- Can we quantify the **importance of galaxies and quasars for reionization** through the statistical samples finally delivered by Roman?

- How will Roman help us understand galaxy properties in the context of their environments over cosmic time?

- What will Roman spectroscopy teach us about galaxy properties and evolution during the peak era of cosmic star formation?

- Will Roman discover enough exotic, distant supernovae to tell us about the fates of early stellar populations?

- How can we leverage Roman to discover and characterize rare AGN and quasars?
Roman Science Interest Group: Deep Field Discussion

January 22, 2021

B. Robertson (UCSC, Roman EXPO/FSWG)

Roman Provides Cosmic Context

UDF(12)

Beckwith et al. 2006
Koekemoer et al. 2013
Ellis et al. 2013
Illingworth et al. 2013
Roman field of view is \( \sim 100 \times \) HST WFC3, with similar sensitivity.
UDF(12)

Beckwith et al. 2006
Koekemoer et al. 2013
Ellis et al. 2013
Illingworth et al. 2013
The z~7 luminosity function of galaxies has a steep faint-end slope ~-2, meaning most of the light and ionizing radiation are contributed by faint galaxies. Uncertainties dominated by limited volume / cosmic variance. Requires z-band for selection.
Distant, Star-Forming Galaxies

First 7 star-forming galaxies discovered in UDF12 at 8.5<z<12(?)

5σ detections in (160W+140W+125W) stack (m_{AB} < 30.1)

Requirement: 2σ rejection in ultradeep F105W (m_{AB} > 31.0)

Requirement: 2σ rejection in ACS BViz (m_{AB} > 31.3)

Cosmic Variance

Dark Matter Density Field

85h$^{-1}$ comoving Mpc @ $z\sim7$

85h⁻¹ comoving Mpc @ z~7

HST WFC3 or JWST NIRCAM

CV ~ 33%

CANDELS-Wide GOODS-S+ERS

CV ~ 20%

Roman Camera Field of View

CV ~ 12%

See also Trapp & Furlanetto, arXiv:2020.05059

Roman Science Interest Group: Deep Field Discussion

January 22, 2021

B. Robertson (UCSC, Roman EXPO/FSWG)

85$\, h^{-1}$ comoving Mpc @ $z \sim 7$

Reionized Bubbles

Roman Camera Field of View

15 $\, h^{-1}$Mpc
Roman Deep Field Survey Considerations

Astro2020 Science White Paper

Ultra Deep Field Science with WFIRST

Thematic Areas: □ Planetary Systems □ Star and Planet Formation
□ Formation and Evolution of Compact Objects ☑ Cosmology and Fundamental Physics
□ Stars and Stellar Evolution □ Resolved Stellar Populations and their Environments
☑ Galaxy Evolution ☑ Multi-Messenger Astronomy and Astrophysics

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Roman Deep Survey Field Choice

Koekemoer et al. (2019), arXiv:1903.06154
# Field Visibility with Roman

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Koekemoer et al. (2019), arXiv:1903.06154
Roman Deep Field Filter Considerations

Akeson et al. (2019), arXiv:1902.05569
More Applications of *Roman* Extragalactic Surveys

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**Astro2020 Science White Paper**

**Understanding Galaxy Formation via Near-Infrared Surveys in the 2020s**

*Thematic Areas:*
- □ Planetary Systems
- □ Star and Planet Formation
- □ Formation and Evolution of Compact Objects
- ☑ Cosmology and Fundamental Physics
- □ Stars and Stellar Evolution
- □ Resolved Stellar Populations and their Environments
- ☑ Galaxy Evolution
- □ Multi-Messenger Astronomy and Astrophysics

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**Snowmass2021 - Letter of Interest**

**Roman Space Telescope Strong Lensing Probes of Dark Matter Substructure**

*Thematic Areas:*
- □ (CF1) Dark Matter: Particle Like
- □ (CF2) Dark Matter: Wavelike
- ☑ (CF3) Dark Matter: Cosmic Probes
- □ (CF4) Dark Energy and Cosmic Acceleration: The Modern Universe
- □ (CF5) Dark Energy and Cosmic Acceleration: Cosmic Dawn and Before
- □ (CF6) Dark Energy and Cosmic Acceleration: Complementarity of Probes and New Facilities
- □ (CF7) Cosmic Probes of Fundamental Physics
- □ (Other) [Please specify frontier/typical group]

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Contact Email: brant@ucsc.edu
Modeling Roman Surveys

- Single Pointing
- HLS Tile
- 2x3 HLS Tiles

Rubin FoV
Example *Roman* Deep Survey

Single Pointing

Deep Tiling

- **4 dithers**
- **50 dithers**

random 2x SCA gap

random 5x SCA gap
Notional *Roman* Surveys

- **Roman High Latitude Survey (Mission)**
  \(~2000 \text{ deg}^2, \text{YJH}\sim 26.7\text{AB}, g\sim 10^{-16} \text{ ergs/s/cm}^2\)

- **Roman Medium Deep Survey (Mission+GO)**
  \(~20 \text{ deg}^2, \text{ZYJH}\sim 28.5\text{AB}\)

- **Roman Ultra Deep Survey (GO)**
  \(~0.28 \text{ deg}^2, \text{ZYJH}\sim 29.5\text{AB}, g\sim 10^{-17} \text{ ergs/s/cm}^2\)

- **x-scale:** 2x width == 100x area
- **y-scale:** 2x width == 2x flux
Notional *Roman* Surveys

- *Roman Ultra Deep Survey (GO)*
  ~0.28 deg$^2$, ZYJH~29.5AB, g~10$^{-17}$ ergs/s/cm$^2$

<table>
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<th>Filter</th>
<th>Exp. Time</th>
<th>5σ limit$^a$</th>
<th>2σ limit$^a$</th>
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<td>F184</td>
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</table>

$^a$These values are preliminary and subject to change, pending further information on the specifications and performance of the WFIRST instrumentation, incl. detector and filter characteristics.
EXPO team members developed galaxy formation models calibrated to $z>6$ HST observations, provides baseline predictions for Roman surveys.

Lower plot: Empirically determined star formation efficiencies for high-z galaxies, with three different extrapolations to very faint systems.

Right plot: Curves show depth and number densities; solid/dashed/dotted curves are different star formation models.

Predictions for Roman High-z Populations

$N_{\text{gal}}(<m_{\text{AB}})$ [deg$^{-2}$ dz$^{-1}$]

- $z=8$
- $z=10$
- $z=12$
- $z=15$

$\sim 1$ gal deg$^{-2}$
Summary: *Roman* Deep Fields

- *Roman* will be transformative for deep field studies of galaxy evolution and formation.

- *Roman* will provide improved statistical samples for studying early galaxy and quasar populations that cause cosmic reionization.

- *Roman* will provide unprecedented spectroscopic samples during the peak of galaxy formation.

- *Roman* can teach us about the connection between galaxy evolution and cosmic environment.