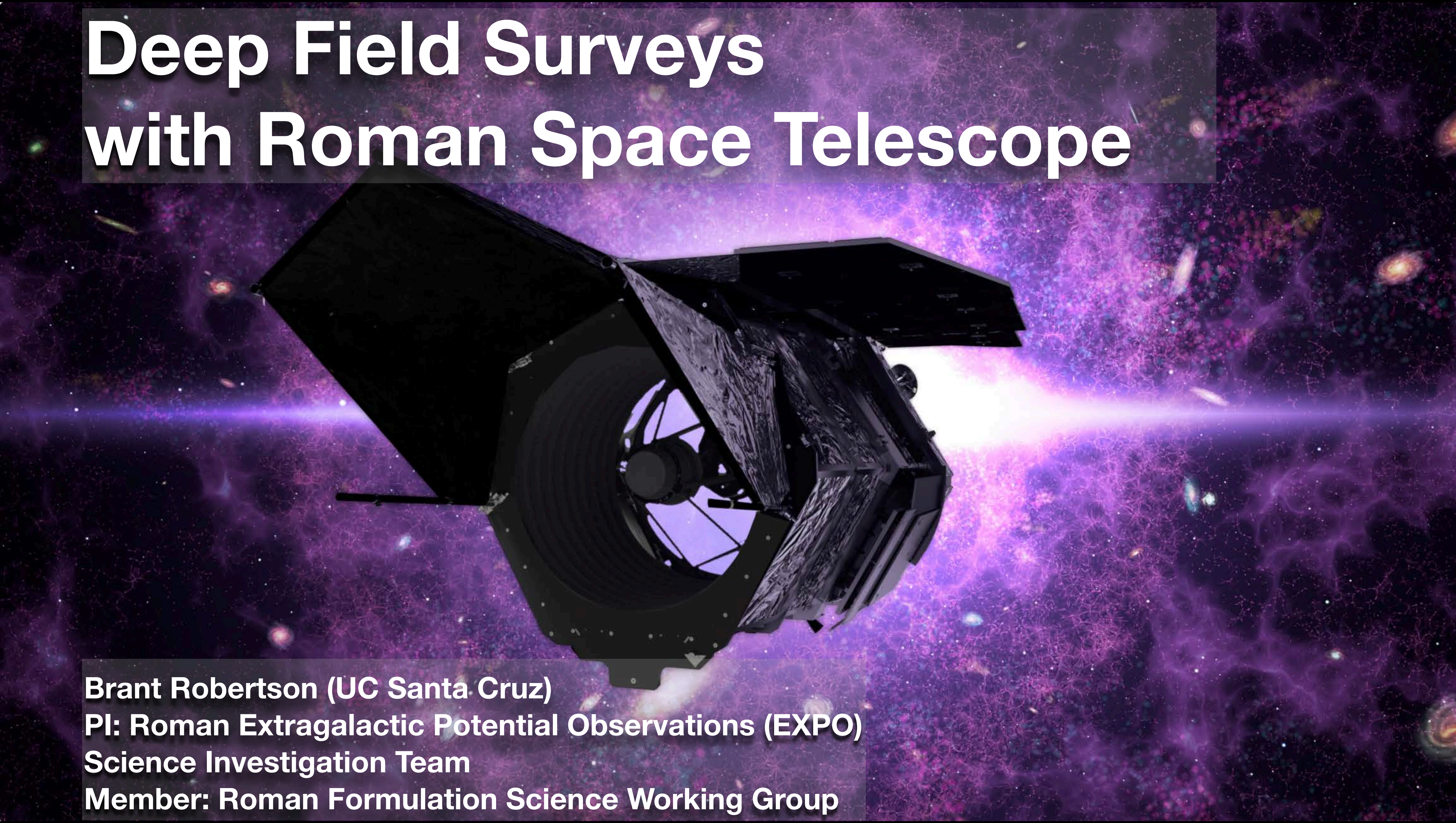
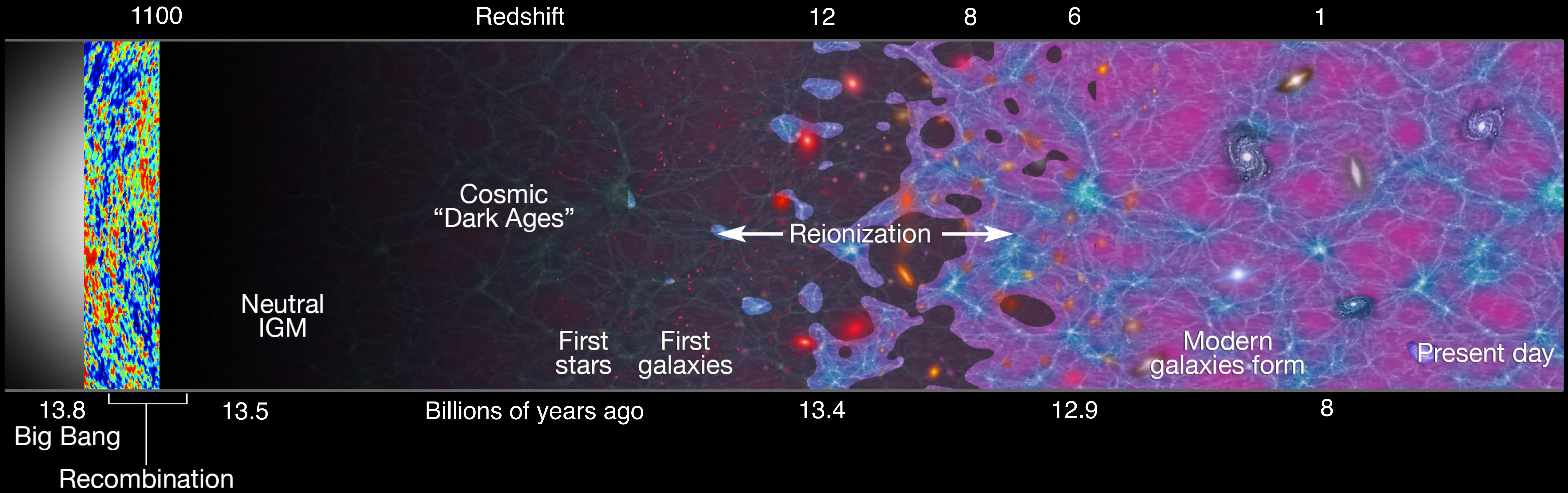
Deep Field Surveys with Roman Space Telescope



Brant Robertson (UC Santa Cruz)
PI: Roman Extragalactic Potential Observations (EXPO)
Science Investigation Team
Member: Roman Formulation Science Working Group

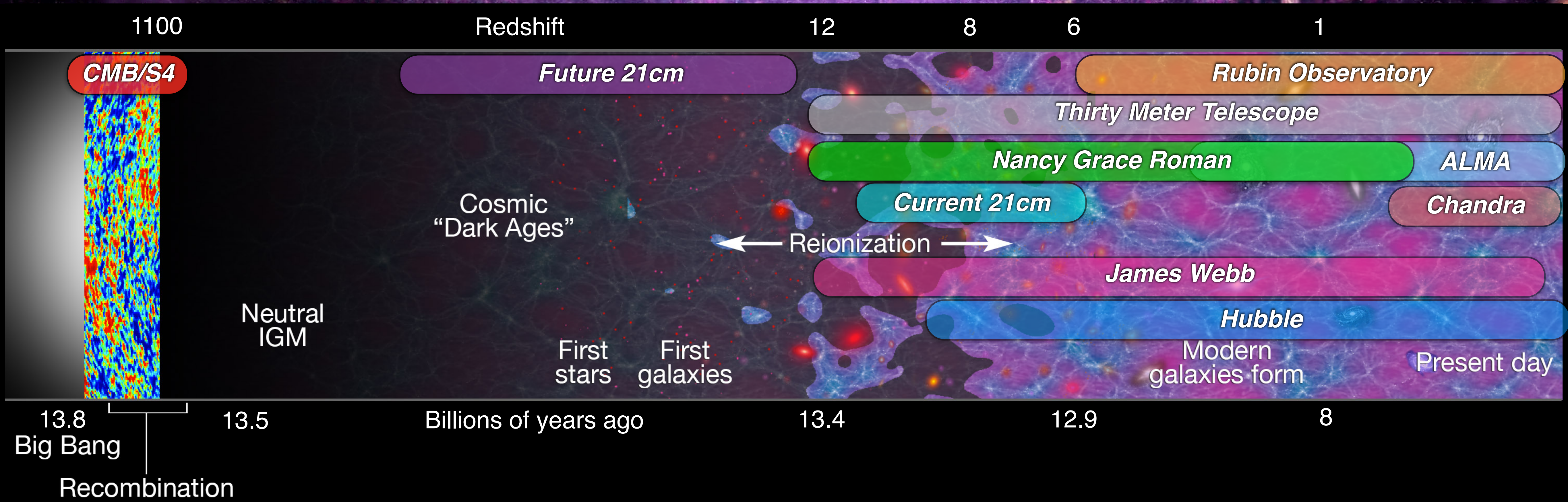
UC SANTA CRUZ

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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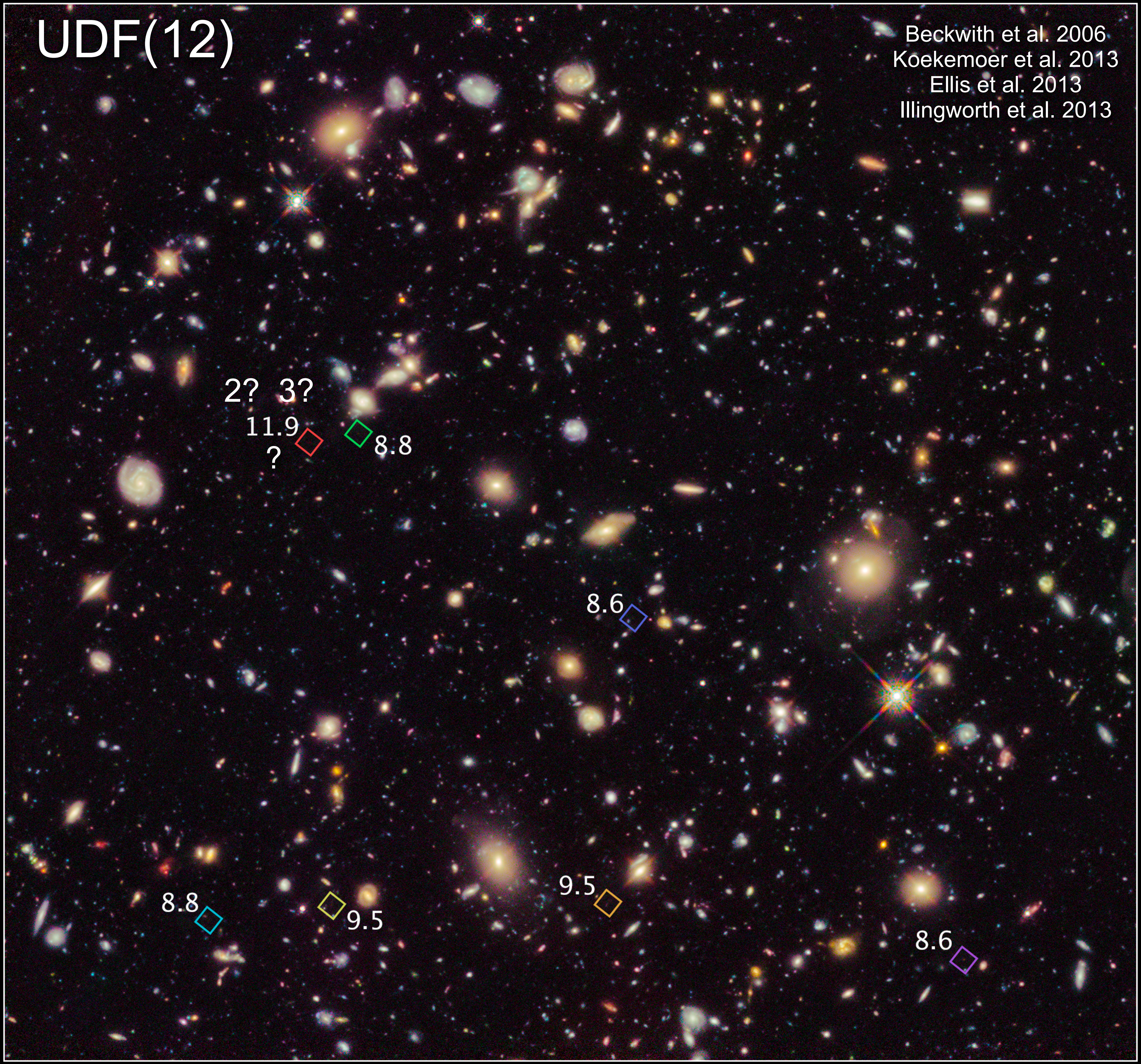
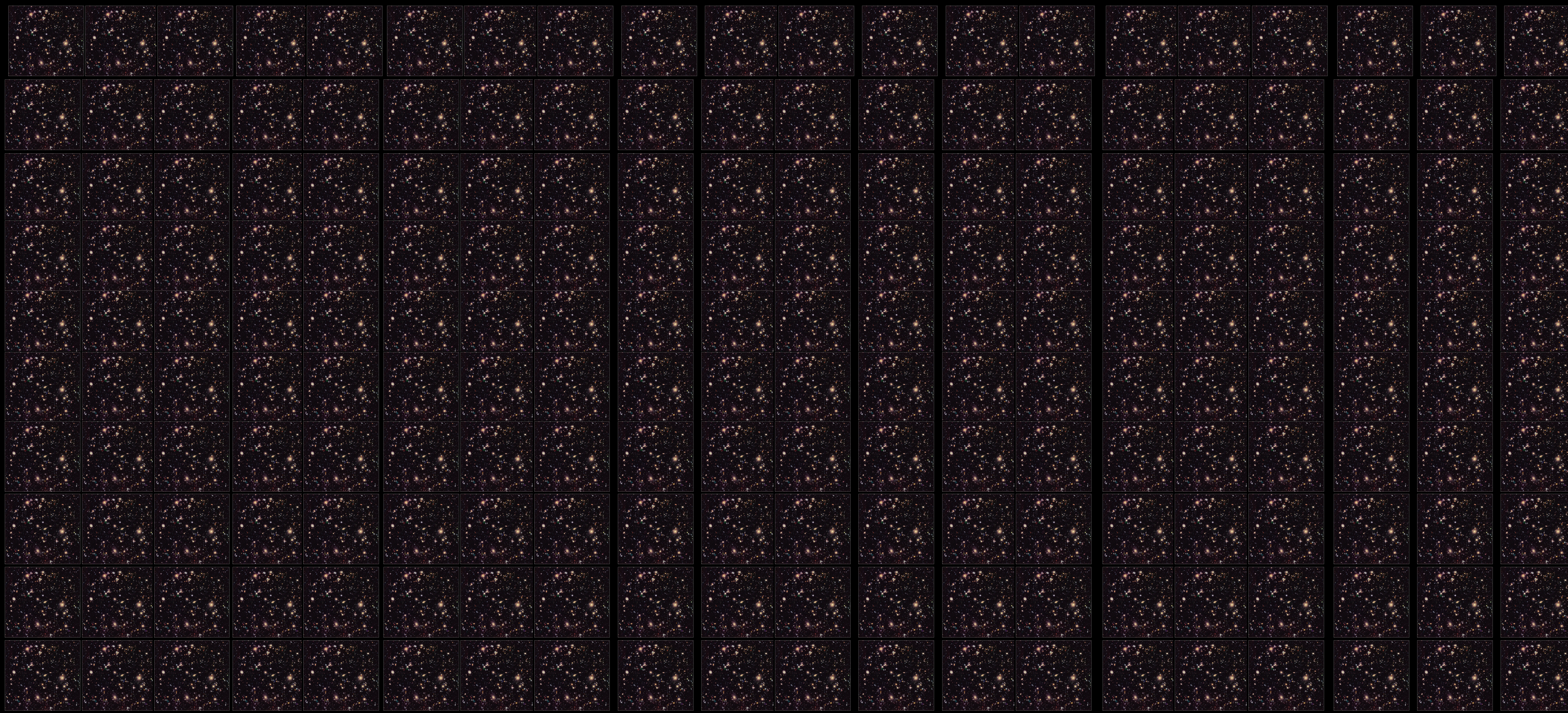
Roman Deep Field Science Questions

- 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?

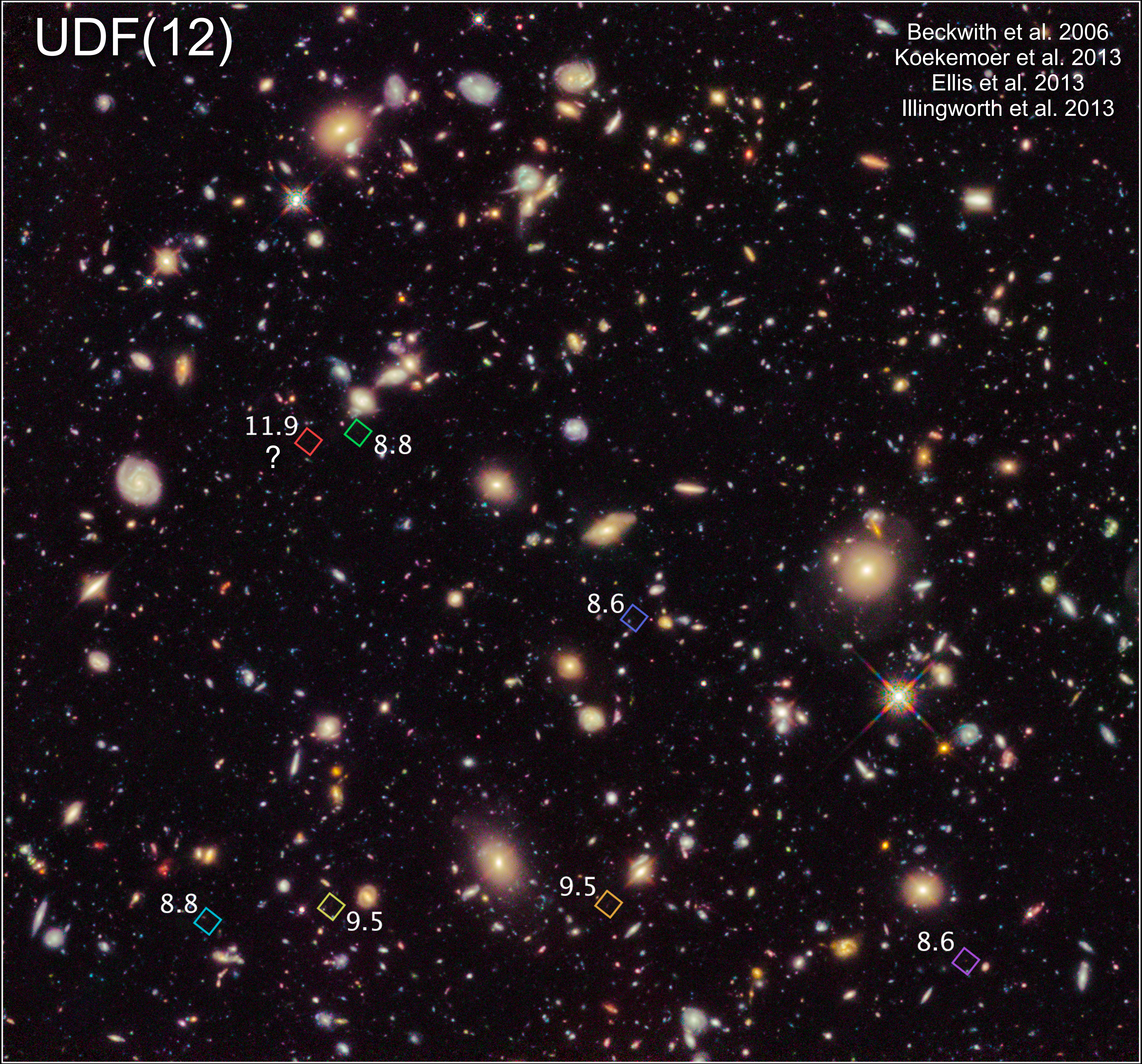


UDF(12)
Beckwith et al. 2006
Koekemoer et al. 2013
Ellis et al. 2013
Illingworth et al. 2013
2? 3?
11.9
?
8.8
8.6
8.8
9.5
9.5
8.6

Roman Surveys Enormous Areas



Roman field of view is ~100x *HST* WFC3, with similar sensitivity.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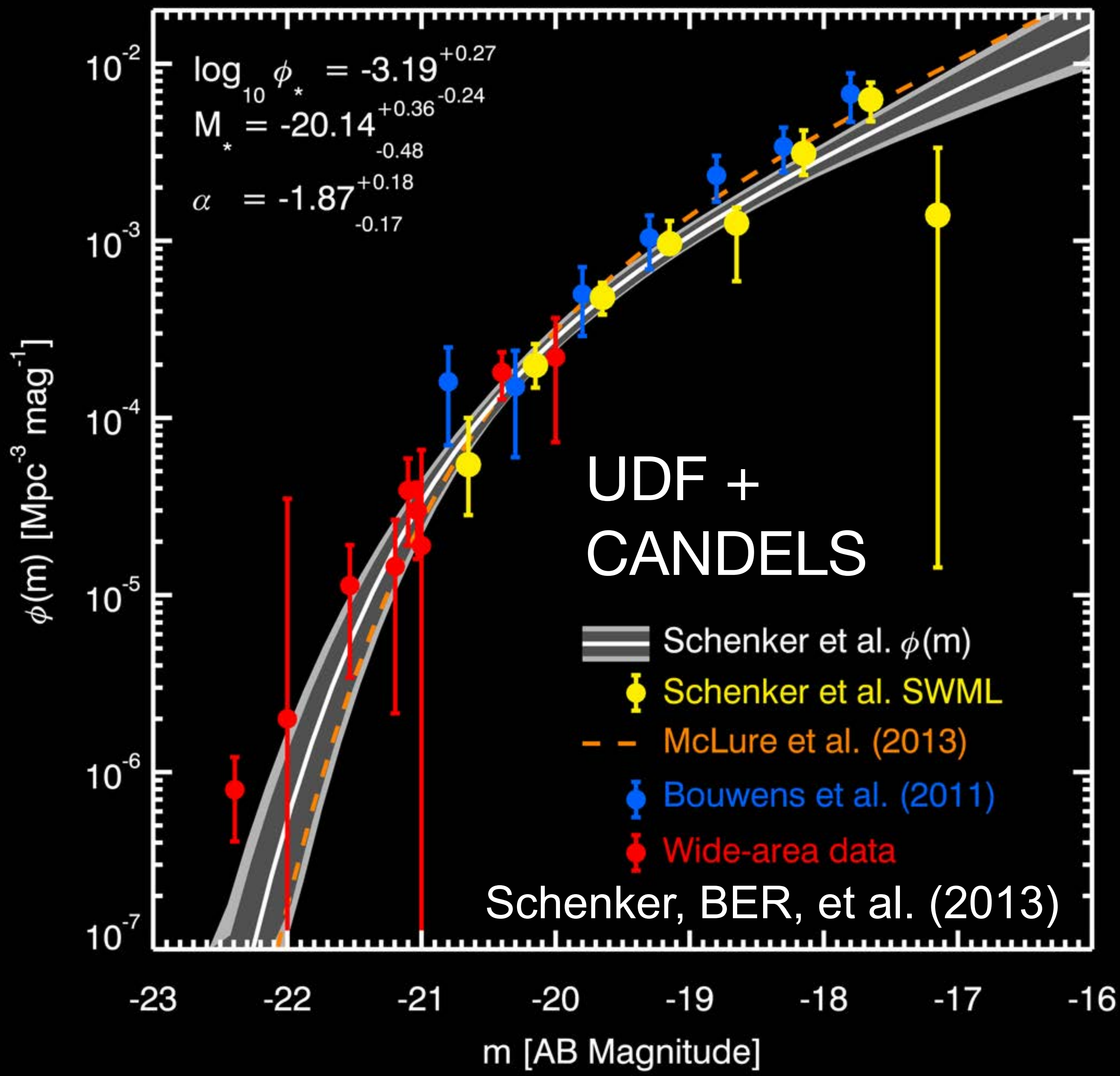
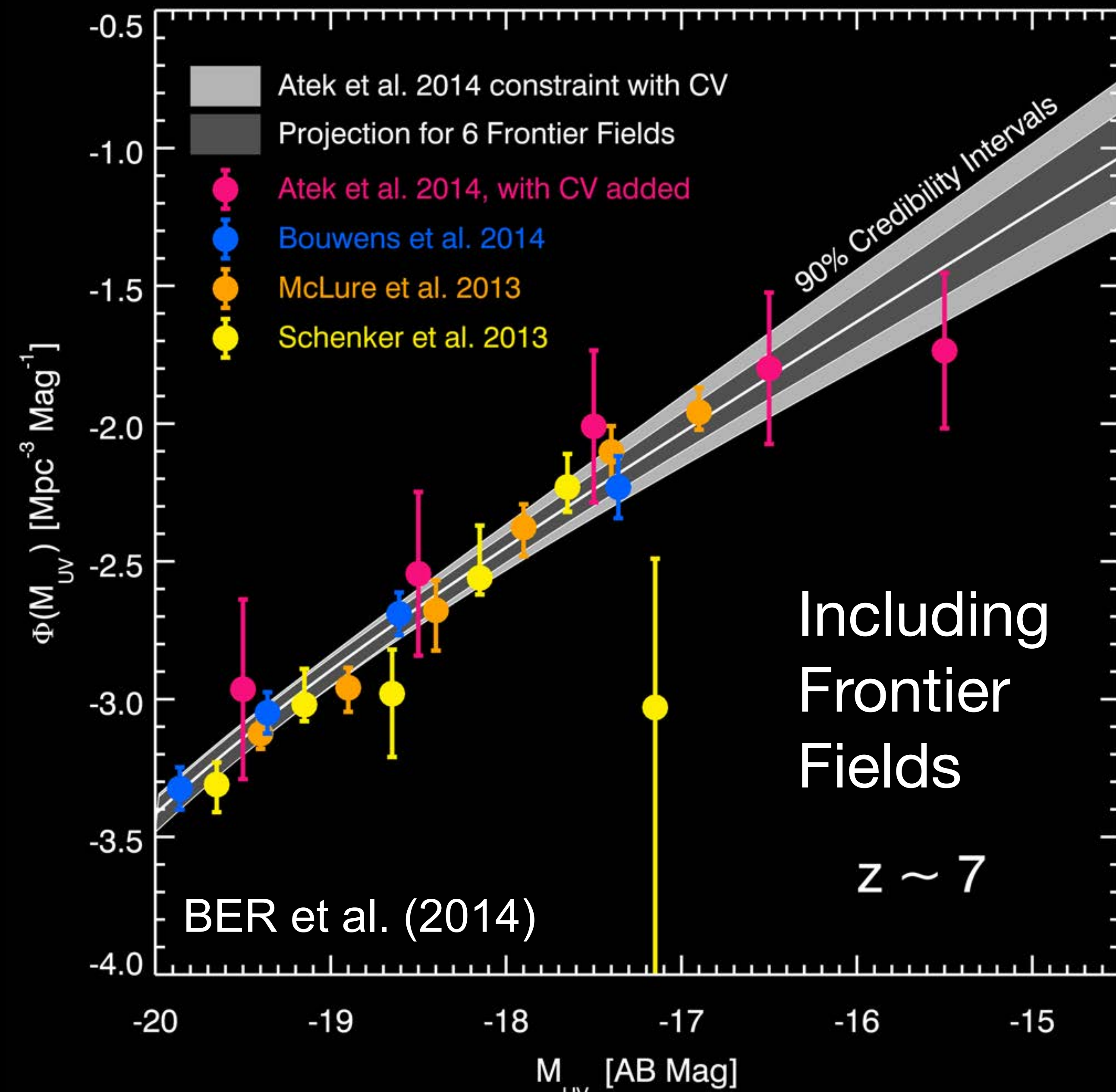
8.6

UV Luminosity Function @ z~7





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.

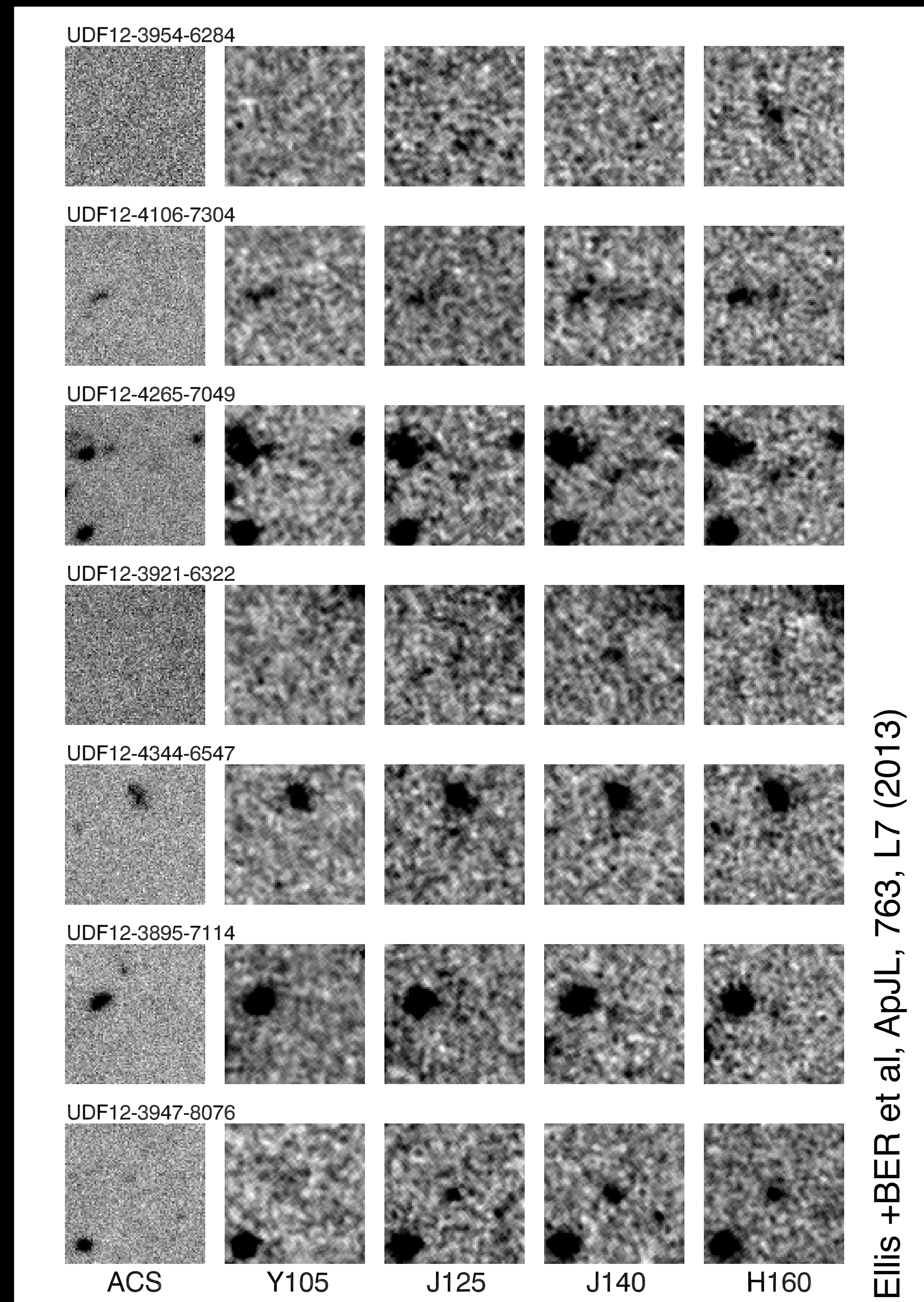
Distant, Star-Forming Galaxies

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 ($m_{AB} > 31.3$)



z=2 or 3 or 12

z=9.5 520 Myr

z=9.5 520 Myr

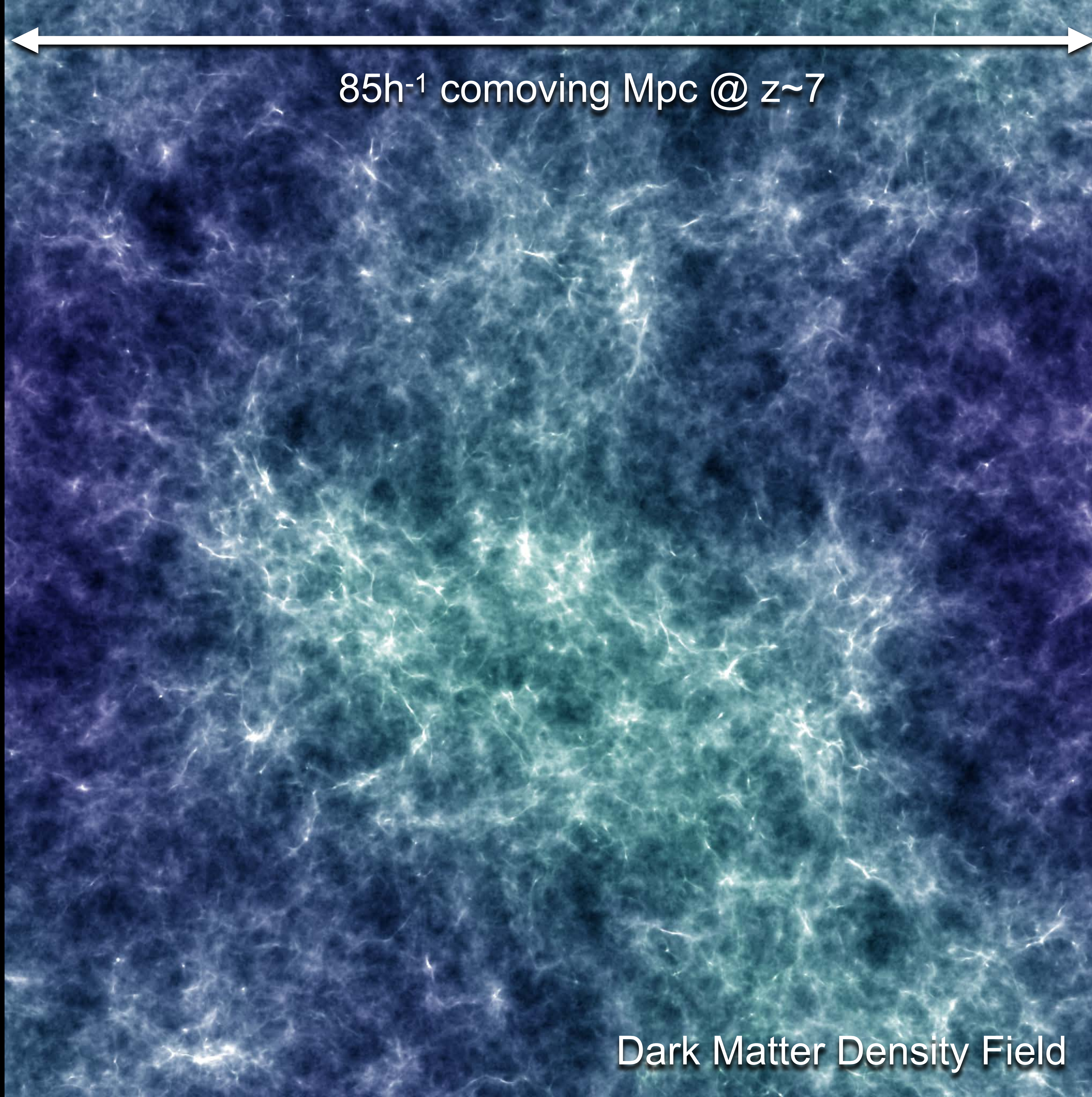
z=8.8 570 Myr

z=8.8 570 Myr

z=8.6 590 Myr

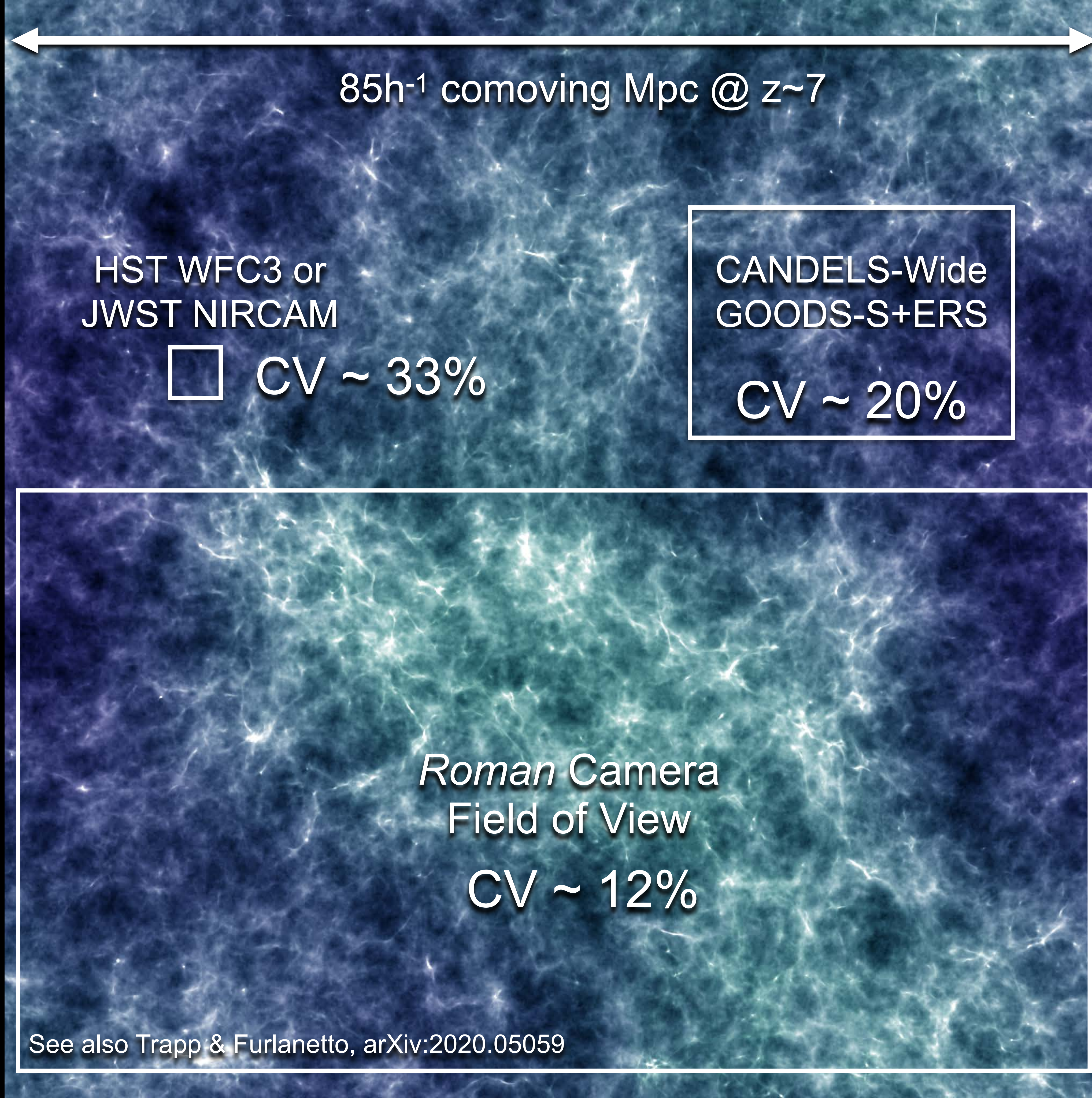
z=8.6 590 Myr

Cosmic Variance



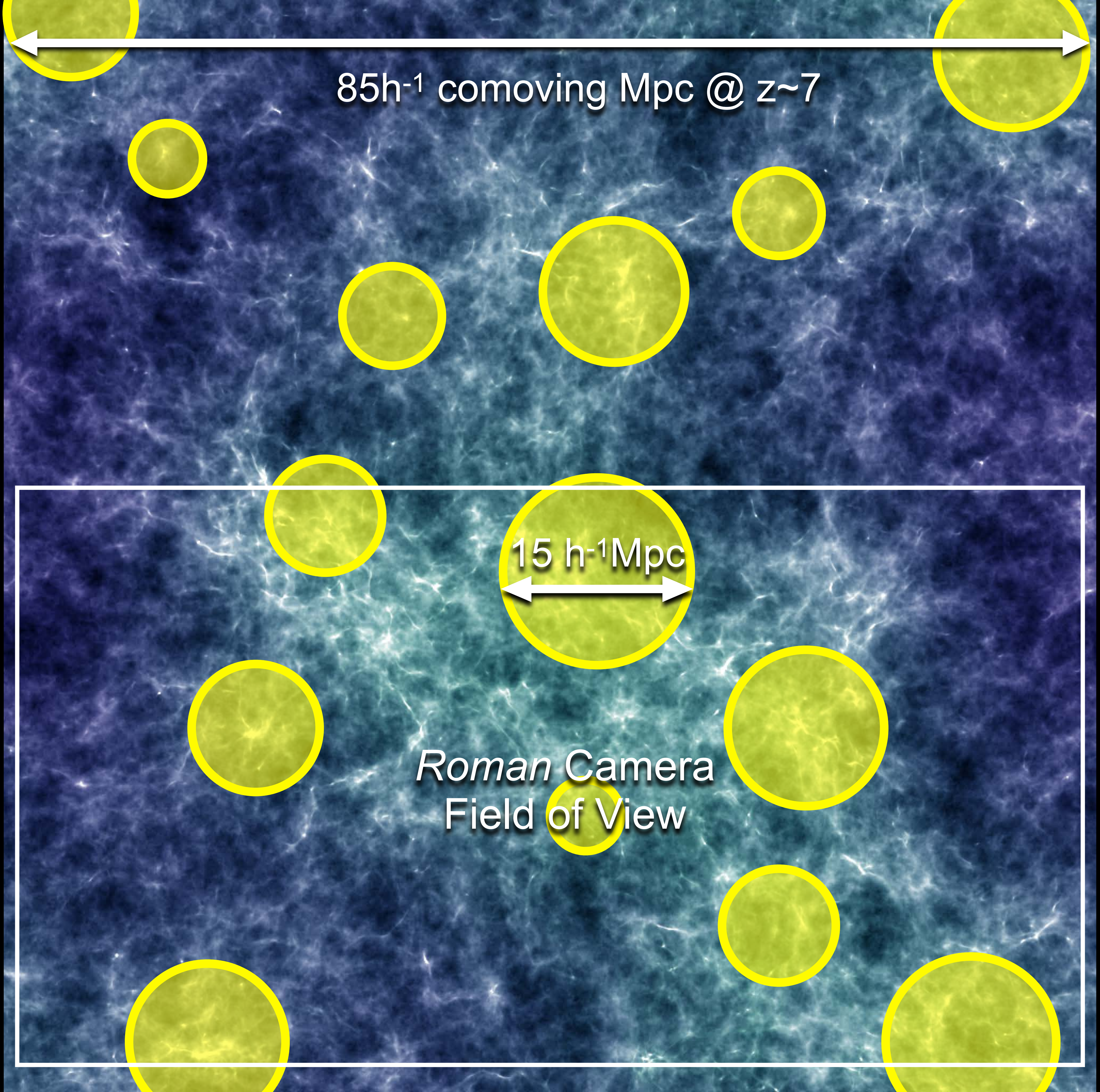
Adapted from Robertson, ApJ, 713, 1266 (2010)

Cosmic Variance



Adapted from Robertson, ApJ, 713, 1266 (2010)

Reionized Bubbles



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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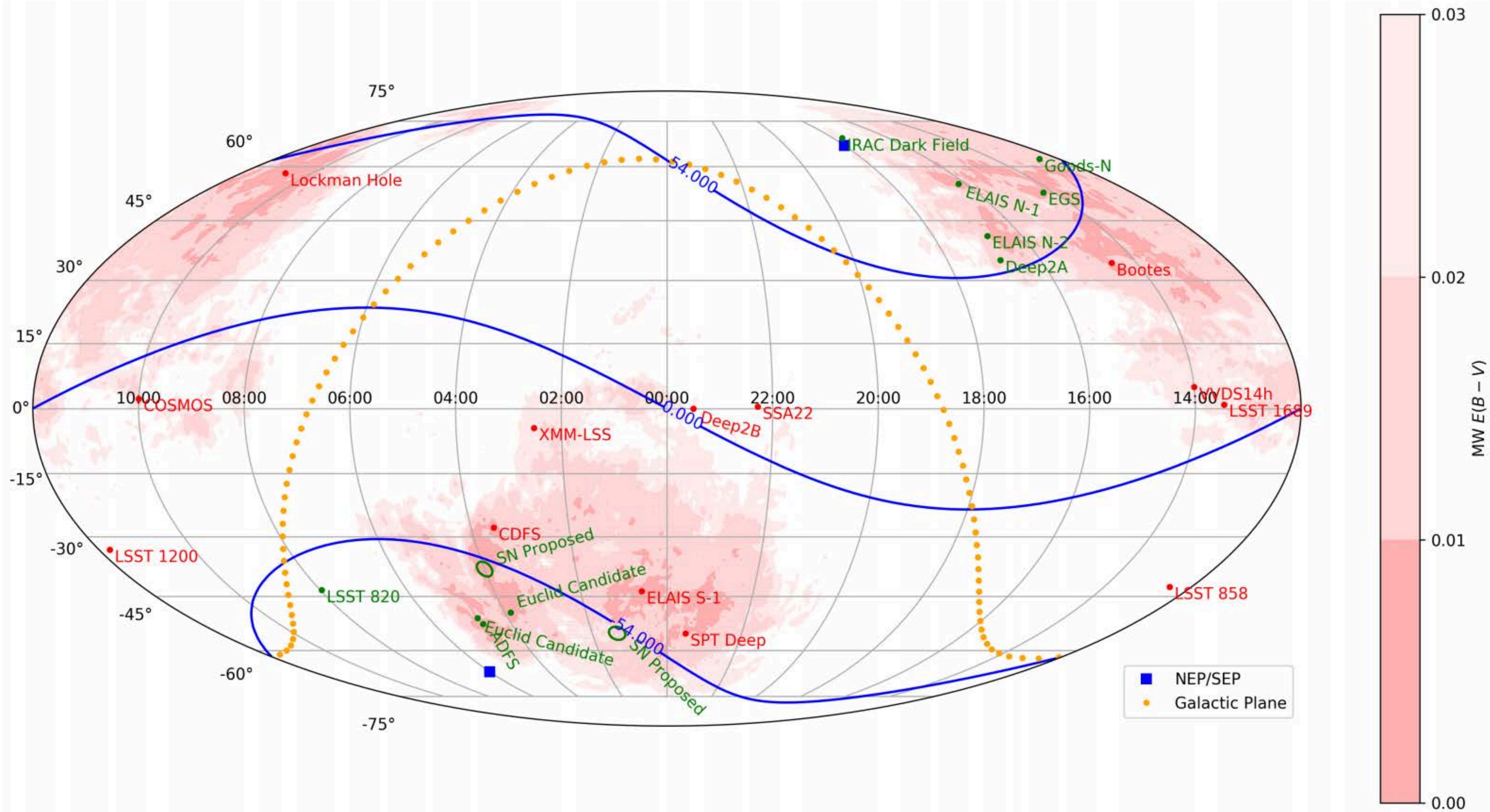
Roman Deep Survey Field Choice



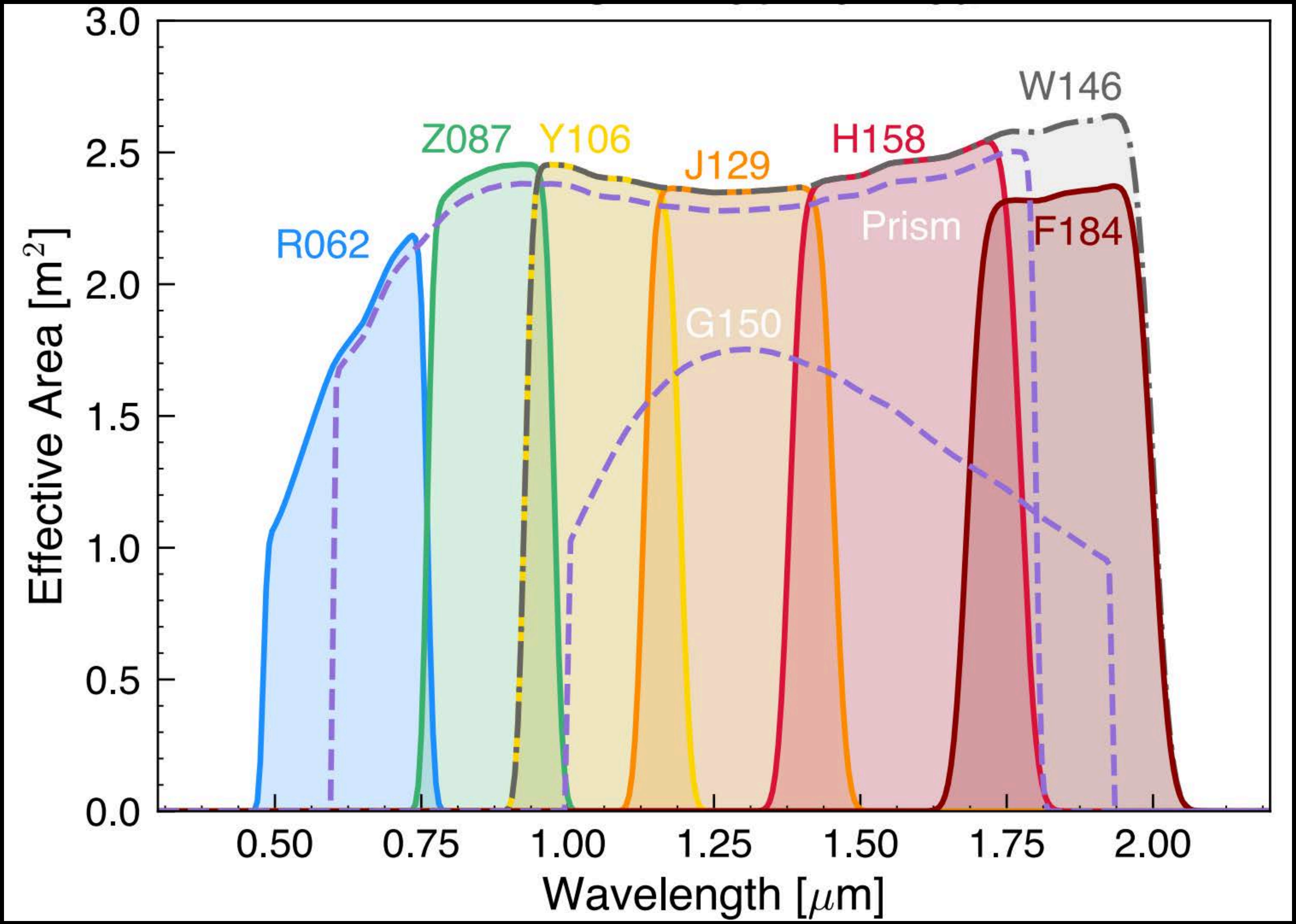
Koekemoer et al. (2019), arXiv:1903.06154

Field Visibility with *Roman*

Field	R.A.	Dec.	Ecl. Lat.	Area (deg^2)	E(B-V)	Rel. Zodi	Days/yr
Polar fields ($< 36°$):							
IRAC Dark Field	17:40	+69:00	+87	0.2	0.043	1.0	365
Extended Groth Strip	14:17	+52:30	+60	0.2	0.009	1.2	365
GOODS-N	12:36	+62:13	+57	0.25	0.012	1.2	365
Deep2A	16:52	+34:55	+57	1	0.018	1.2	365
ELAIS N-2	16:46	+41:01	+63	5	0.014	1.1	365
ELAIS N-1	16:11	+55:00	+73	9	0.008	1.0	365
Akari Deep Field South	04:44	−52:20	−73	12	0.008	1.0	365
JWST-NEP-TDF	17:22	+65:49	+86	0.2	0.042	1.0	365
NEP-Spitzer	18:00	+66:33	+90	10	0.046	1.0	365
SEP-Spitzer	06:00	−66:33	−90	10	0.062	1.0	365
Equatorial fields:							
CDFS	03:32	−27:48	−45	0.3	0.008	1.4	229
Deep2B	23:30	+00:00	+3	1	0.044	19	146
SSA22	22:17	+00:24	+10	4	0.056	5.6	149
COSMOS	10:00	+02:12	−9	2	0.018	6.0	148
VVDS14h	14:00	+05:00	+16	4	0.026	3.6	153
ELAIS S-1	00:35	−43:40	−43	7	0.008	1.5	215
Bootes	14:32	+34:16	+46	9	0.016	1.4	236
Lockman Hole	10:45	+58:00	+45	11	0.011	1.4	229
XMM-LSS	02:31	−04:30	−18	11	0.024	3.2	155
SPT Deep	23:30	−55:00	−46	100	0.010	1.4	236
HERA	07:00	−30:43		1200			

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

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

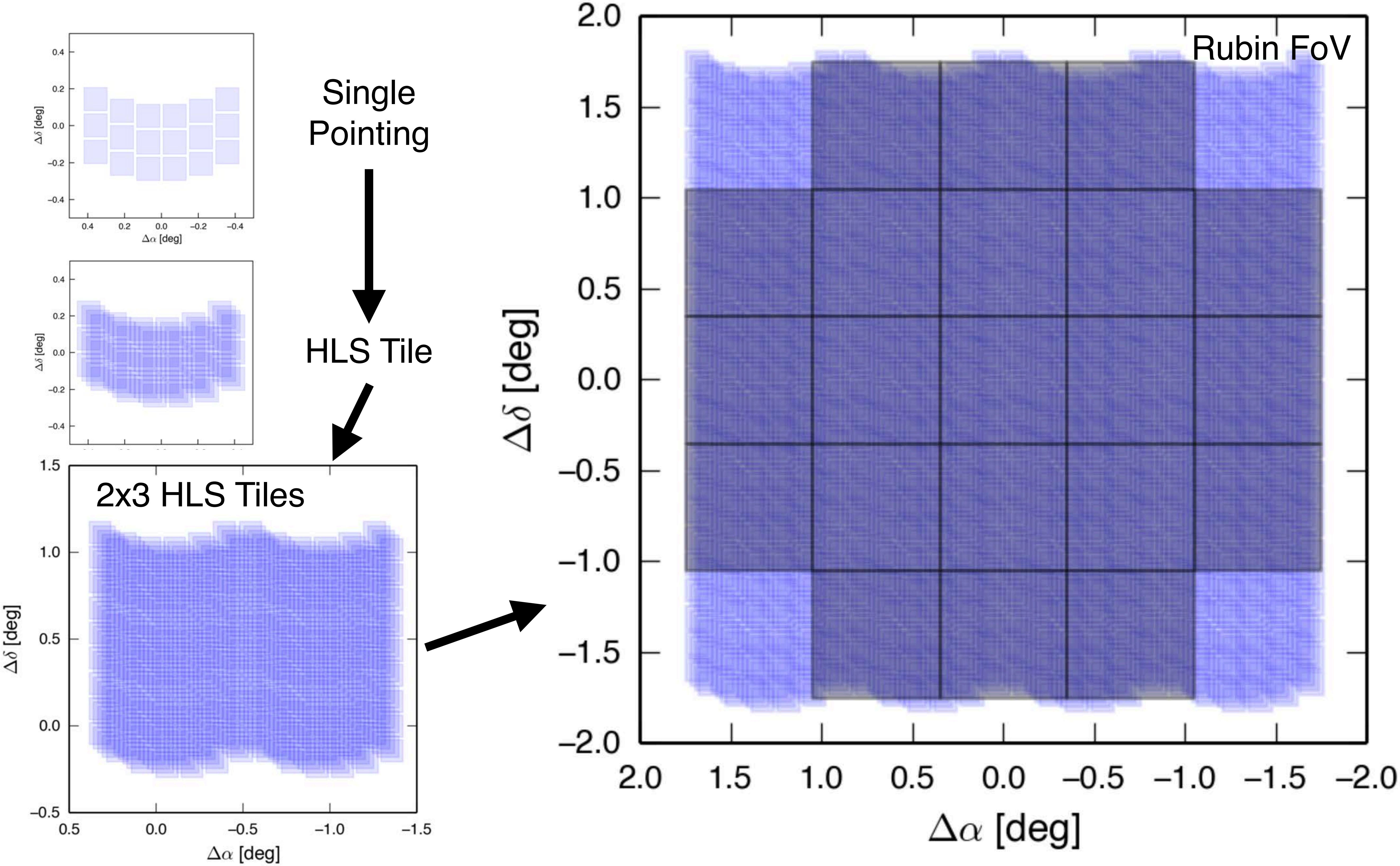
Roman Space Telescope Strong Lensing Probes of Dark Matter Substructure

Thematic Areas: (check all that apply ☐/■)

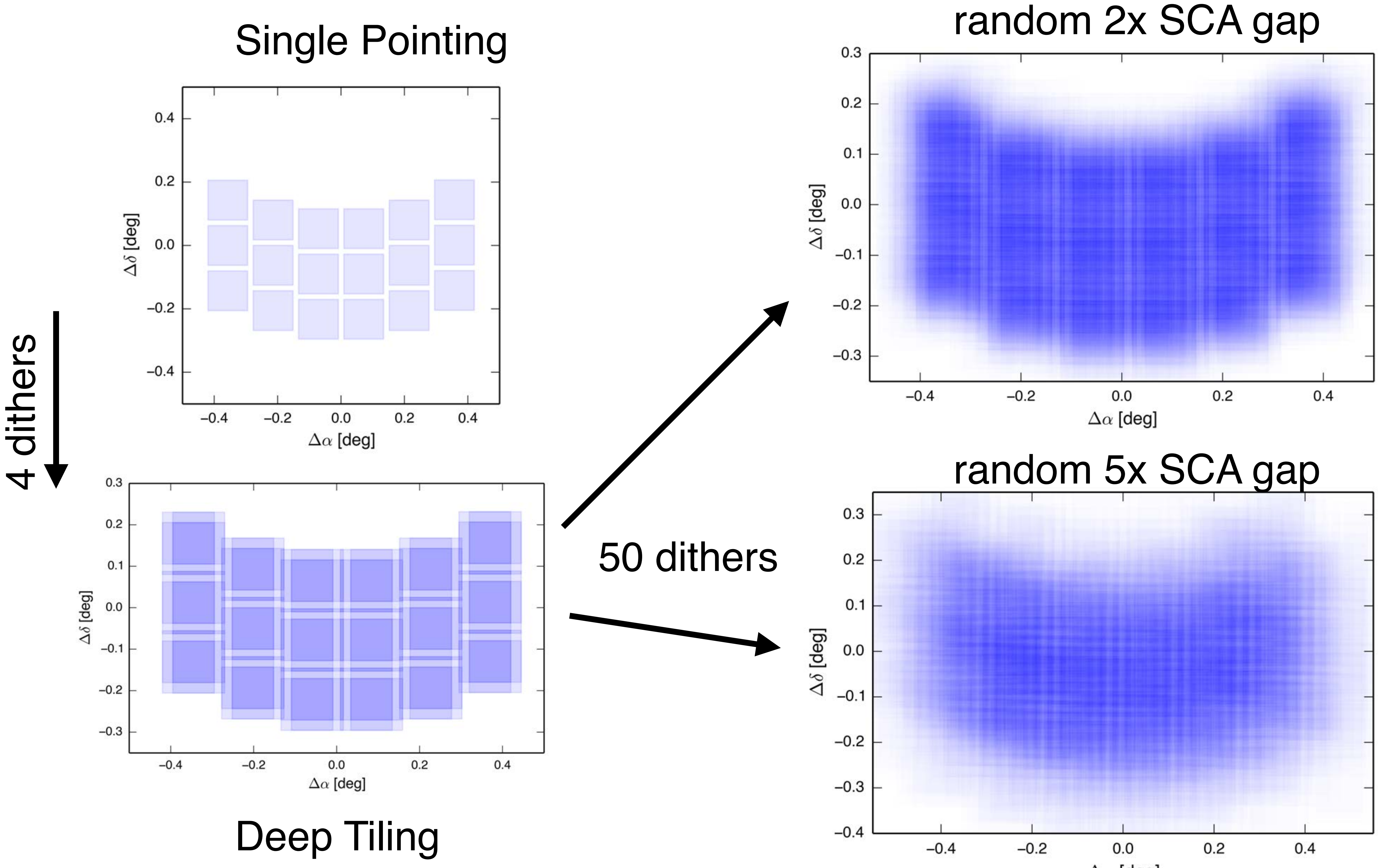
☐ (CF1) Dark Matter: Particle Like
☐ (CF2) Dark Matter: Wavelike
■ (CF3) Dark Matter: Cosmic Probes
☐ (CF4) Dark Energy and Cosmic Acceleration: The Modern Universe
☐ (CF5) Dark Energy and Cosmic Acceleration: Cosmic Dawn and Before
☐ (CF6) Dark Energy and Cosmic Acceleration: Complementarity of Probes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

Contact Information: (authors listed after the text)
Submitter Name/Institution: Brant Robertson (University of California, Santa Cruz
Collaboration: Nancy Grace Roman Formulation Science Working Group
Contact Email: brant@ucsc.edu

Modeling *Roman* Surveys



Example *Roman* Deep Survey



Notional *Roman* Surveys

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

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

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

Ultra Deep

Medium Deep

HLS

x-scale: 2x width == 100x area
y-scale: 2x width == 2x flux

Notional *Roman* Surveys

Ultra Deep

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

Table 2: Example WFIRST UDF: limiting depths (m_{AB})

Filter	Exp. Time	5σ limit[a]	2σ limit[a]
R062	30 h	30.3	31.3
Z087	60 h	30.4	31.4
Y106	70 h	30.4	31.4
J129	90 h	30.4	31.4
H158	40 h	30.0	
F184	60 h	29.7	

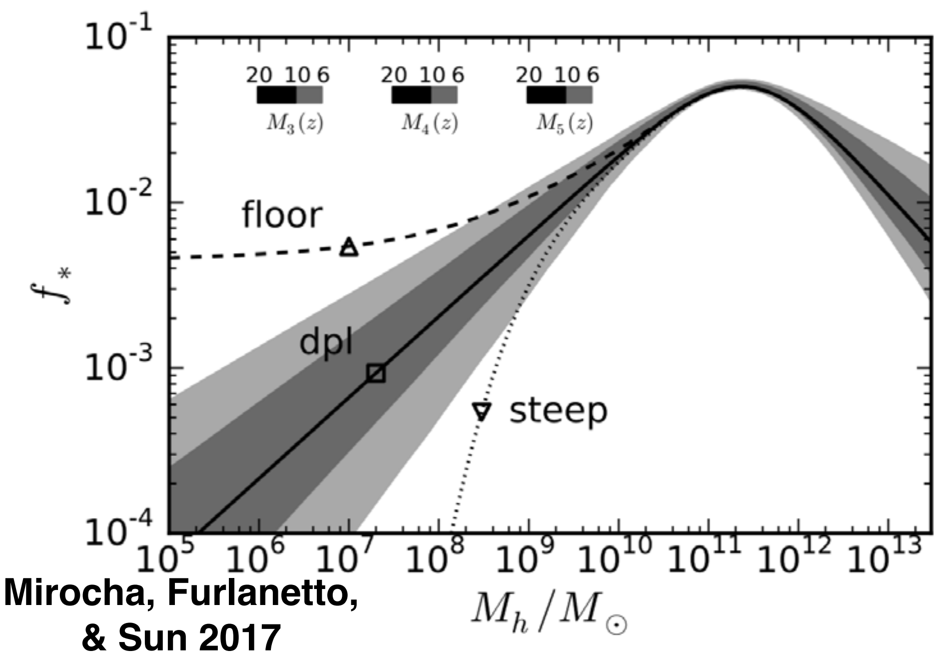
[a]These values are preliminary and subject to change, pending further information on the specifications and performance of the WFIRST instrumentation, incl. detector and filter characteristics.

Predictions for *Roman* High-z Populations

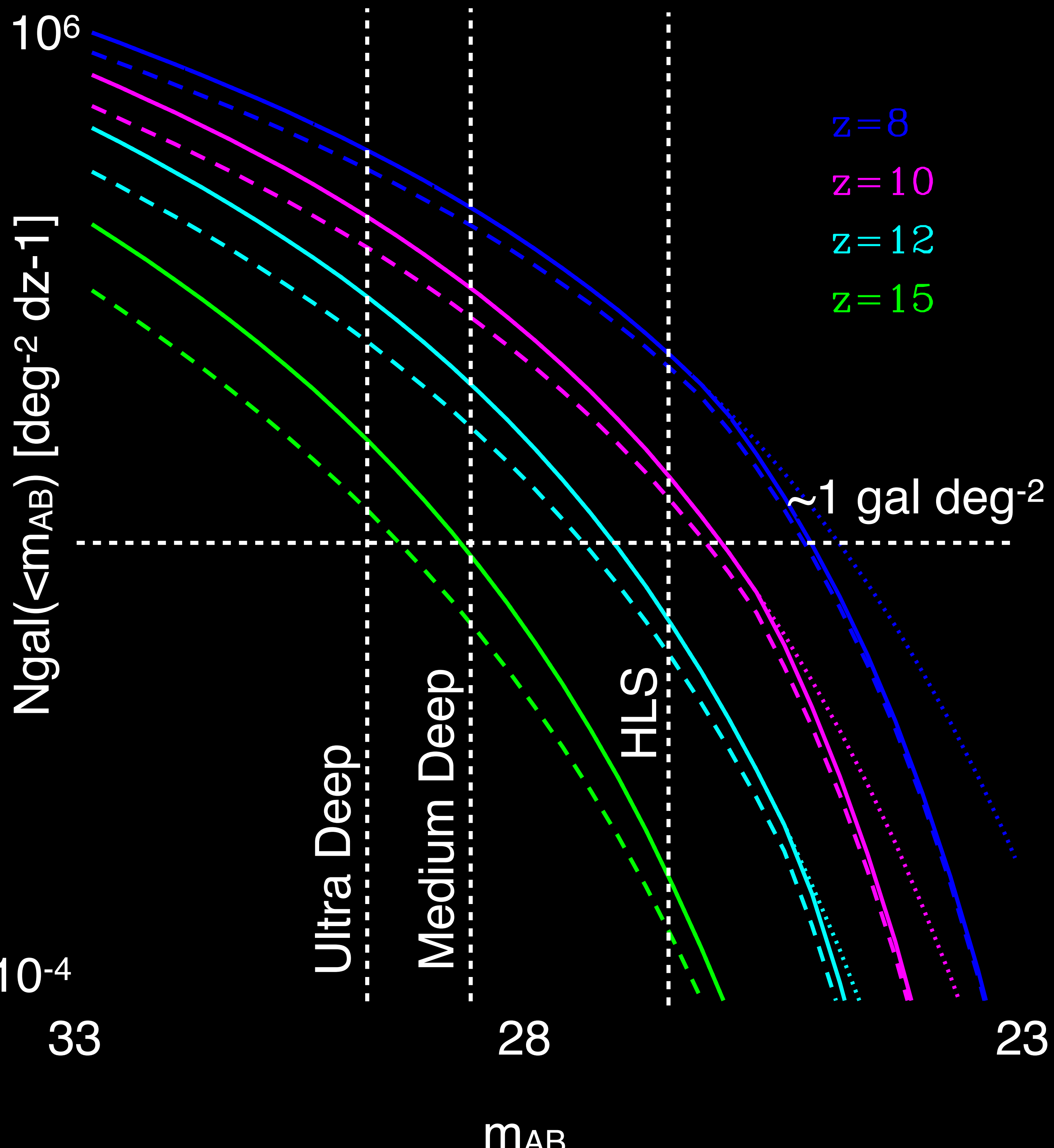
EXPO team members developed galaxy formation models calibrated to z>6 HST observations, provides baseline predictions for Roman surveys

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



Mirocha, Furlanetto, & Sun 2017



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.