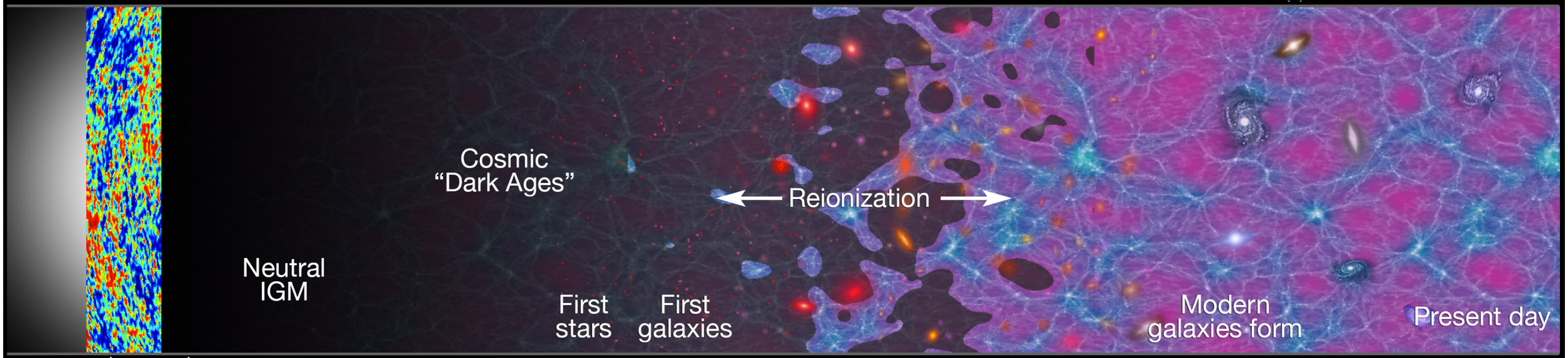
# Studies of Galaxy Evolution with *WFIRST*

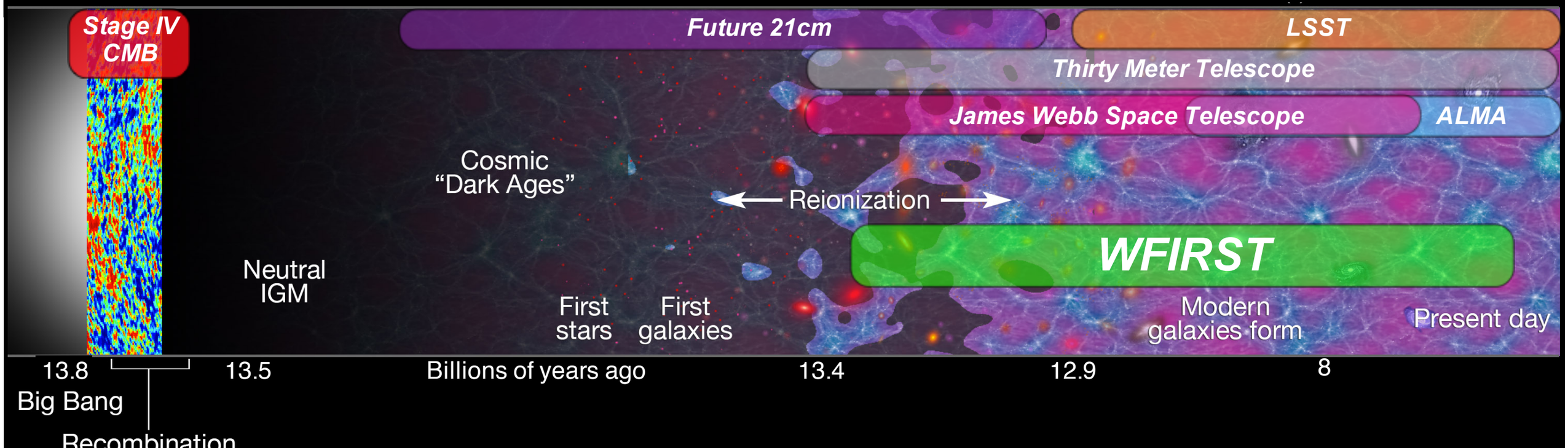
Mark Dickinson
National Optical Astronomical Observatory
*on behalf of Brant Robertson (UC Santa Cruz)*
*and the WFIRST EXPO Team*

# History of Galaxy Evolution over Cosmic Time



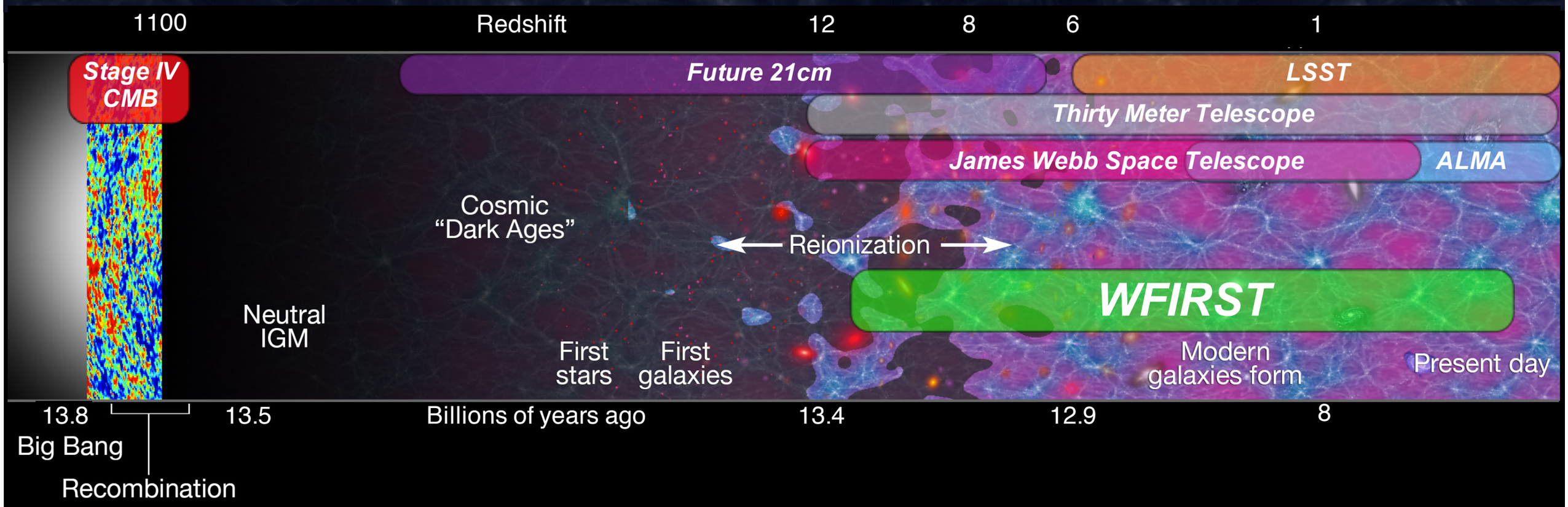

Adapted from Robertson et al. *Nature*, **468,** 49 (2010).

# Astronomical Facilities in the Next Decade




Observations with ***WFIRST***, JWST, TMT/GMT/E-ELT, LSST, ALMA, and 21-cm experiments will drive astronomical discoveries over the next decade.

Adapted from Robertson et al. *Nature*, **468,** 49 (2010).




portant Questions for *WFIRST*

**1.) How do cosmic environments influence galaxy evolution?**

*WFIRST* will provide enormous samples of galaxies that probe all relevant ranges of cosmic density over a broad cosmic timeline**.**

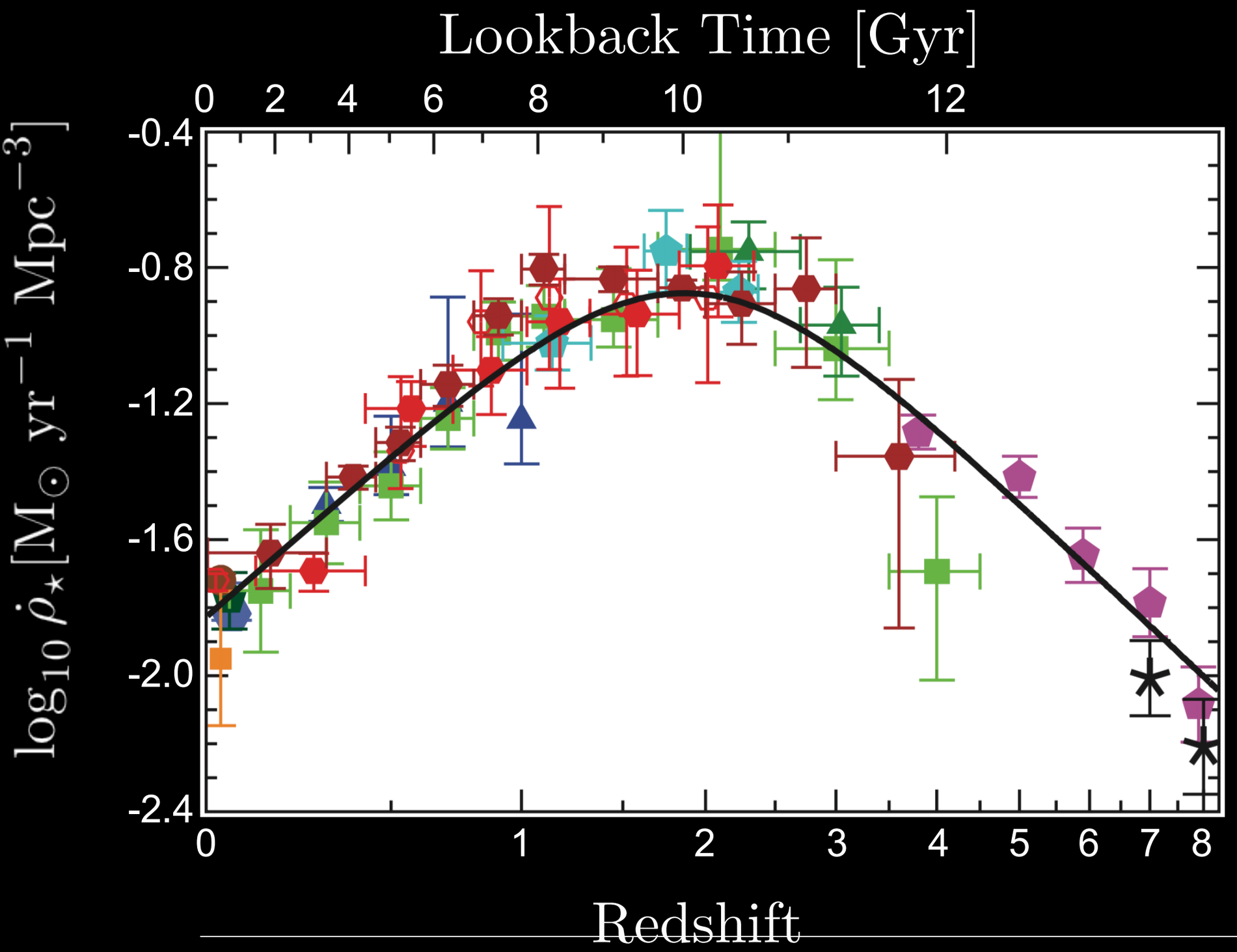
**2.) What can rare objects tells us about galaxy formation?**

*WFIRST* can discover the most luminous galaxies and the most massive black holes back to the first 500 million years of cosmic history.

**3.) How do galaxies and quasars contribute to cosmic reionization?**

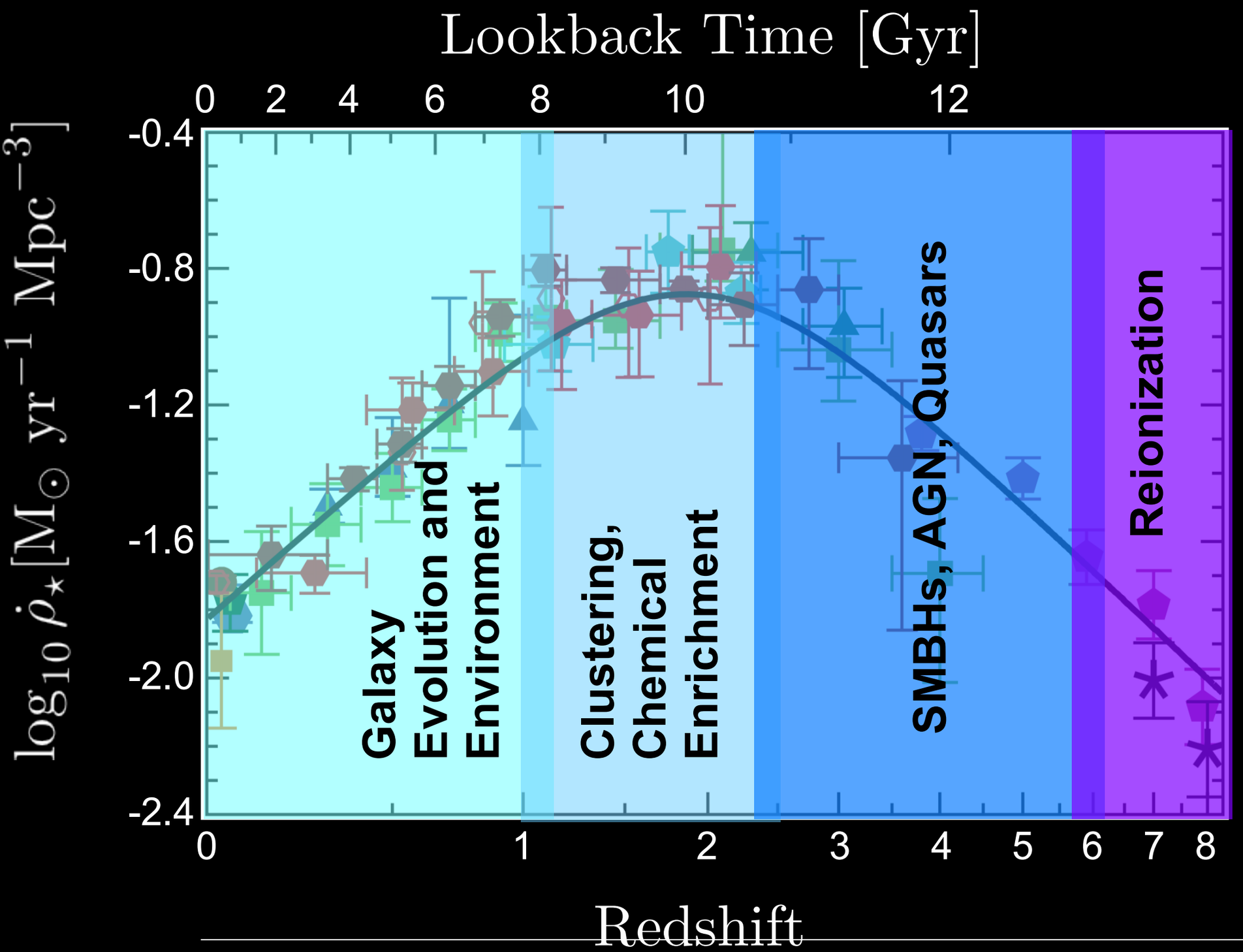
WFIRST can identify representative samples of galaxies and quasars during the reionization epoch, and quantify their relative importance for ionizing the intergalactic medium.

# Cosmic Star Formation History



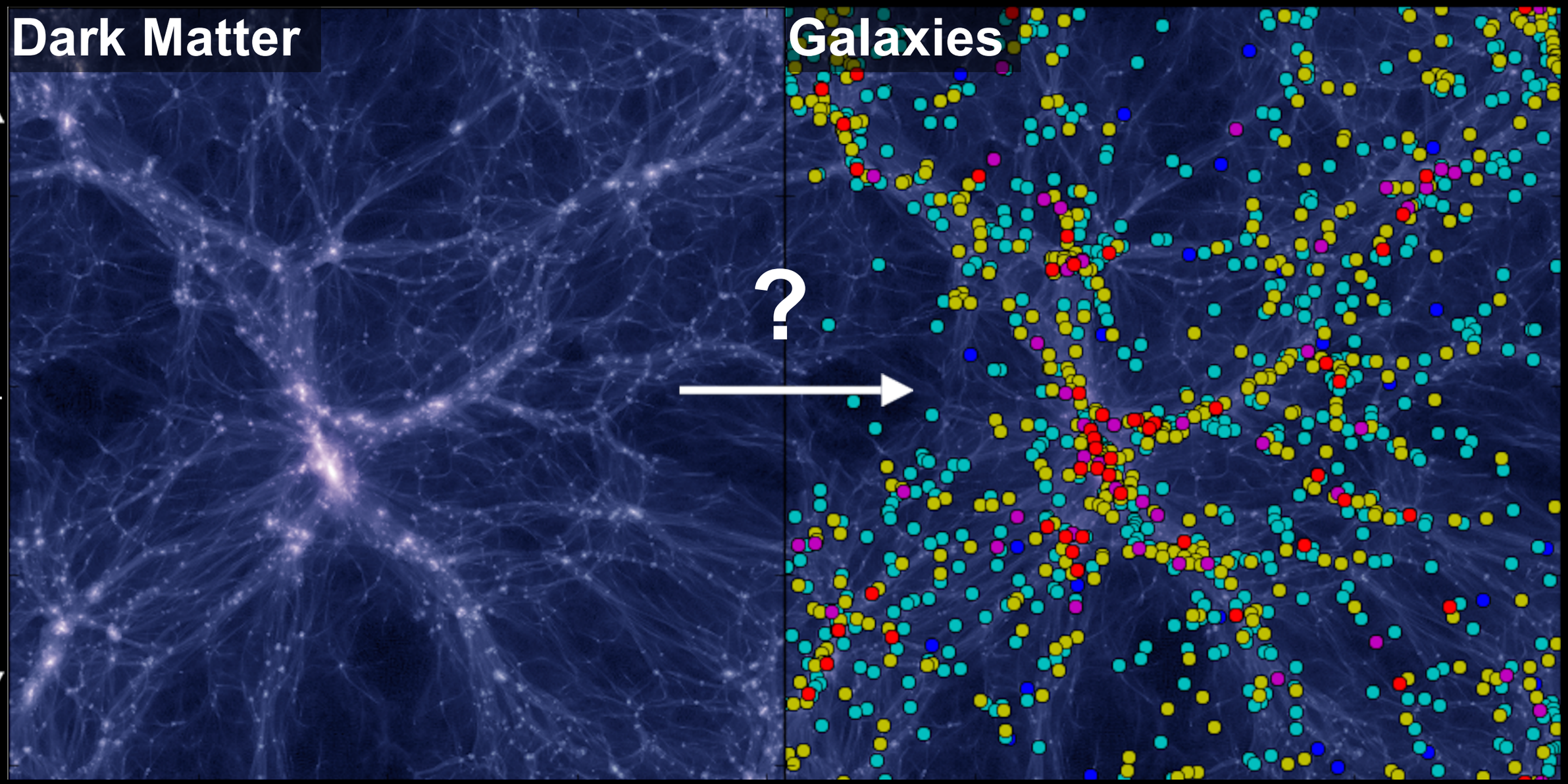

Adapted from Madau & Dickinson, ARAA, **52,** 412 (2014)

# *WFIRST* Science over Cosmic History



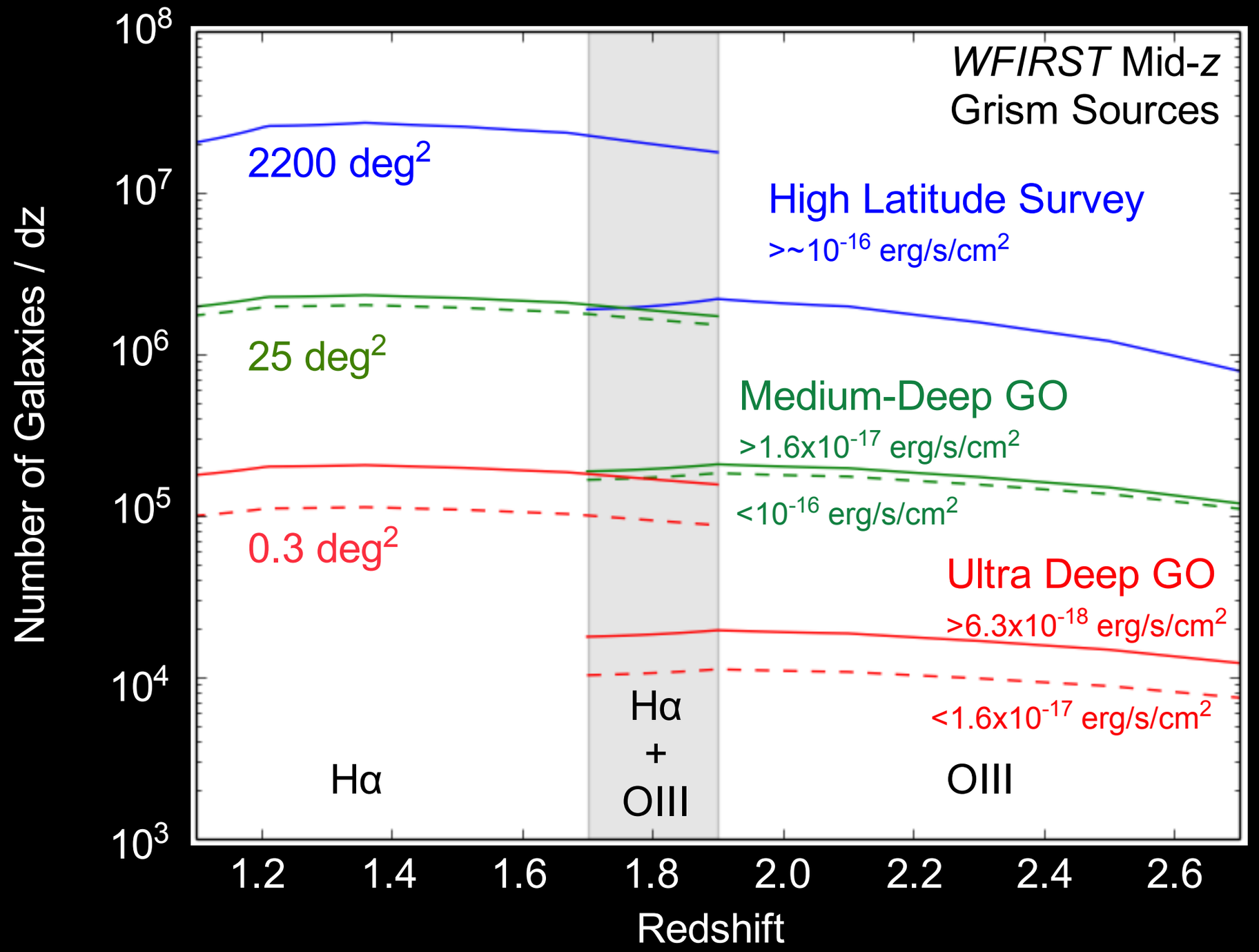

Adapted from Madau & Dickinson, ARAA, **52,** 412 (2014)

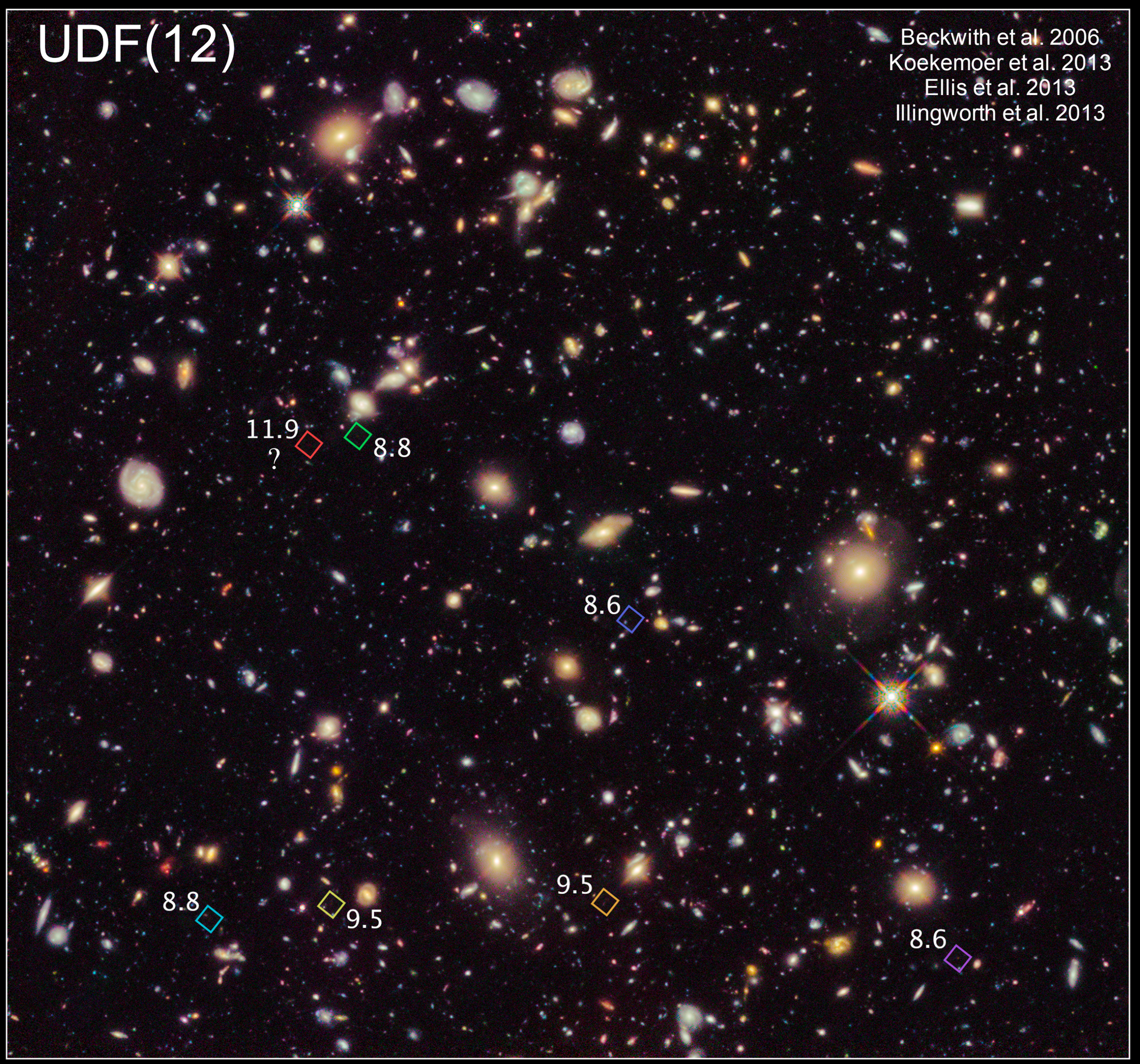
# *WFIRST* Provides a Cosmic Context



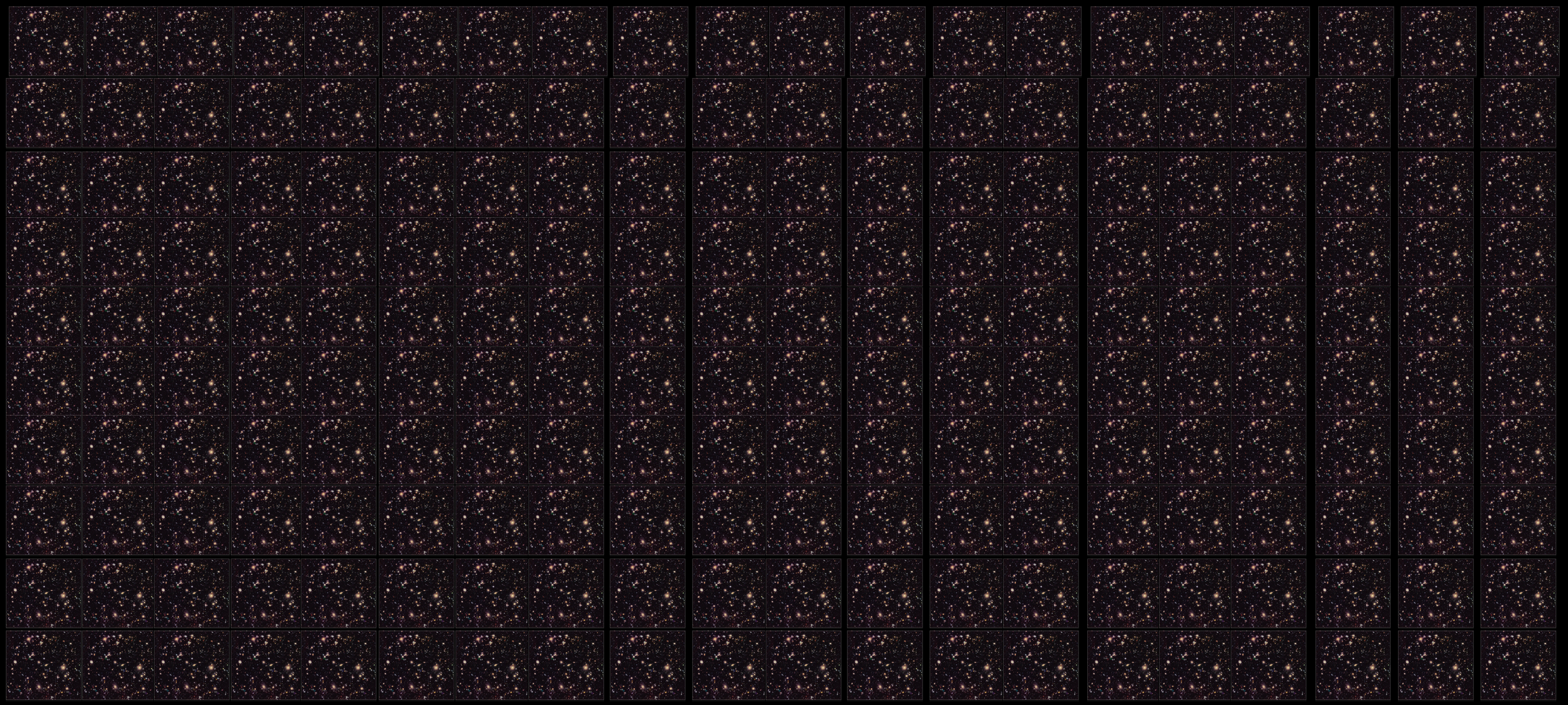

How do galaxy properties map onto dark matter structures?
How does cosmic environment affect galaxy evolution?

# *WFIRST* Spectroscopy at the Peak Epoch of Cosmic Star Formation

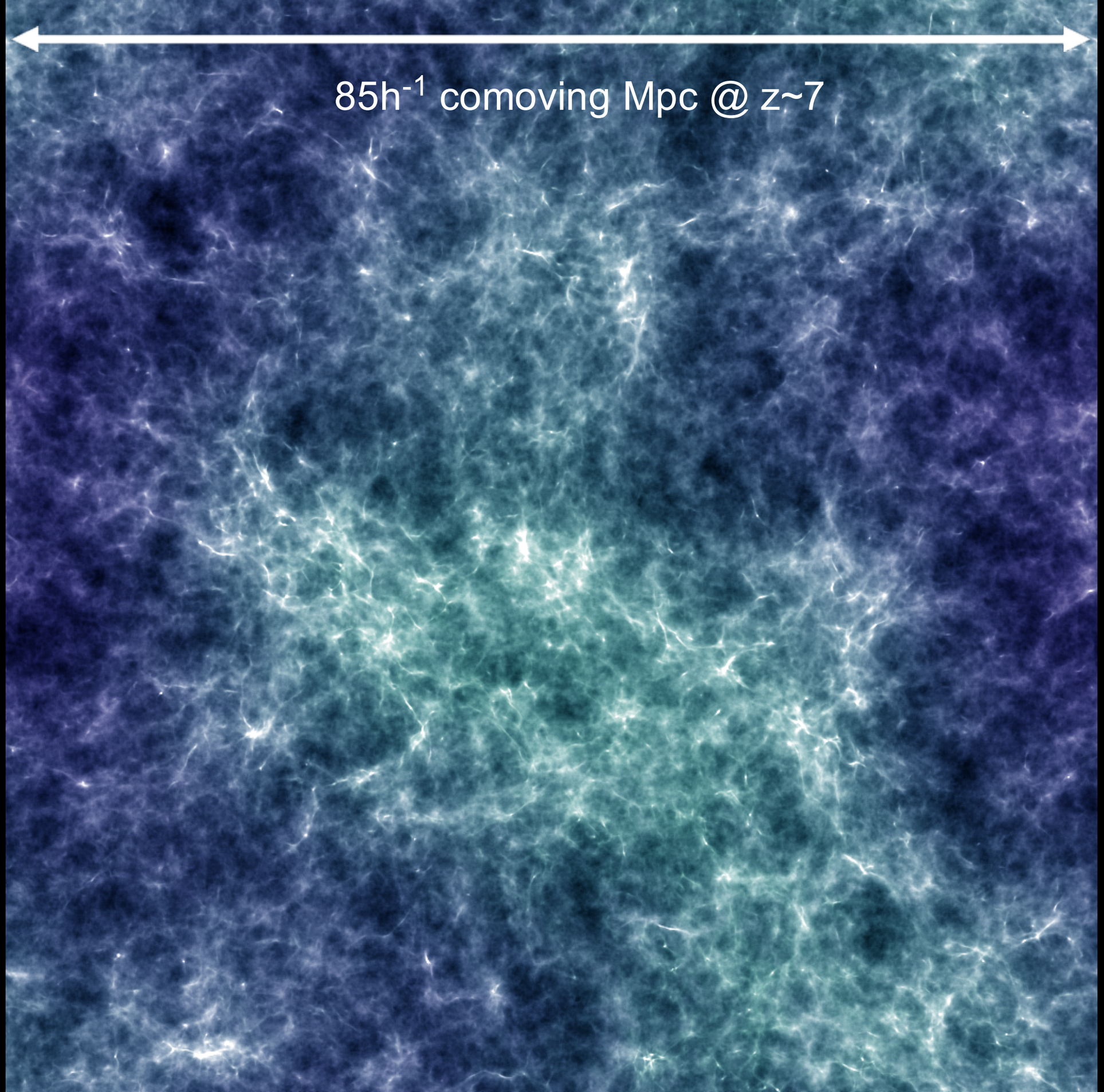


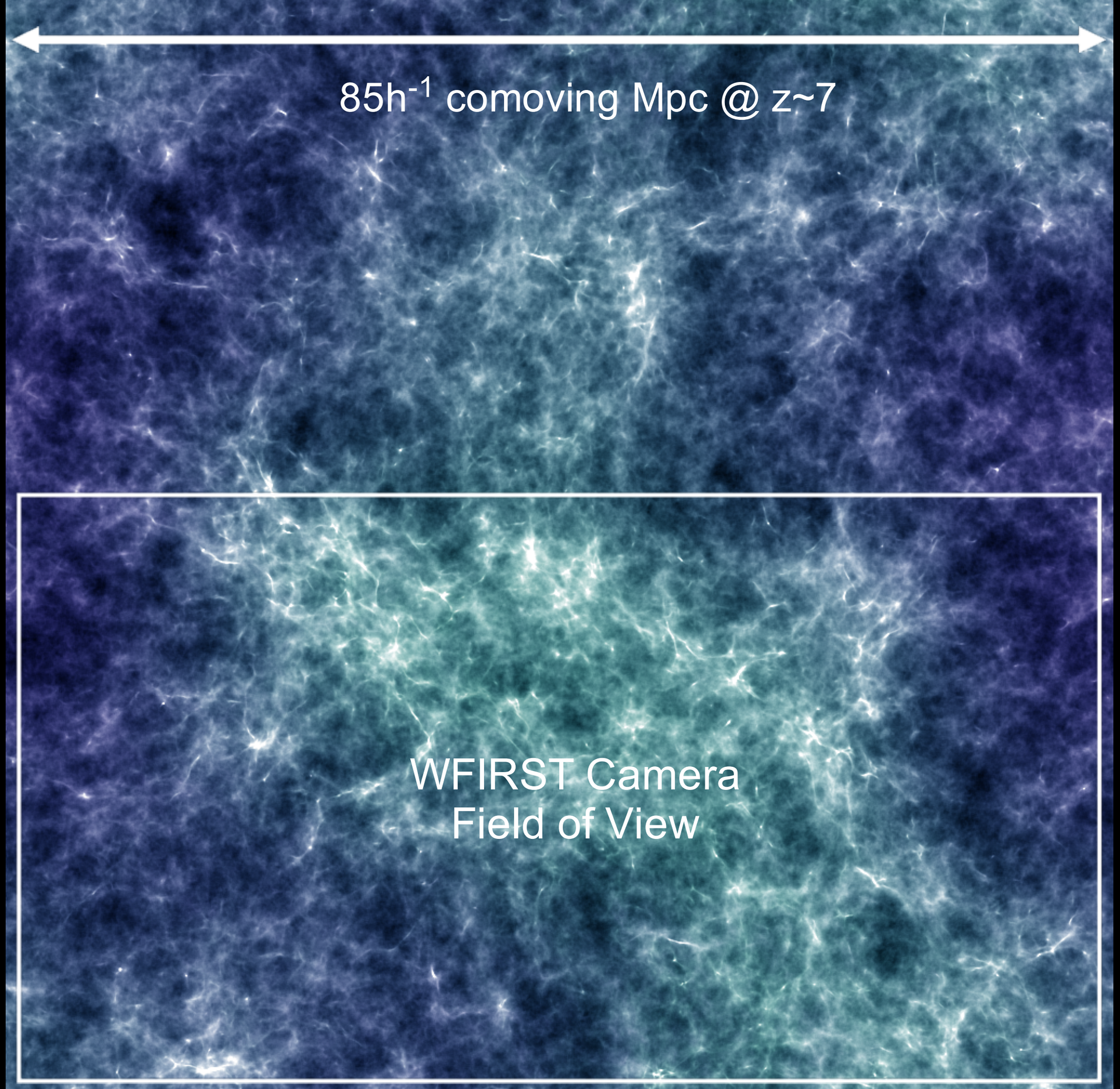

UDF(12)
Beckwith et al. 2006
Koekemoer et al. 2013
Ellis et al. 2013
Illingworth et al. 2013
11.9
?
8.8
8.6
8.8
9.5
9.5
8.6

# *WFIRST* Surveys Enormous Areas



*WFIRST* field of view is ~200x *HST* WFC3, with similar sensitivity.


85h-1 comoving Mpc @ z~7


85h-1 comoving Mpc @ z~7
WFIRST Camera
Field of View

# Cosmic Variance

$85h^{-1}$ comoving Mpc @ z~7

HST WFC3 or
JWST NIRCAM

CV ~ 33%

CANDELS-Wide
GOODS-S+ERS

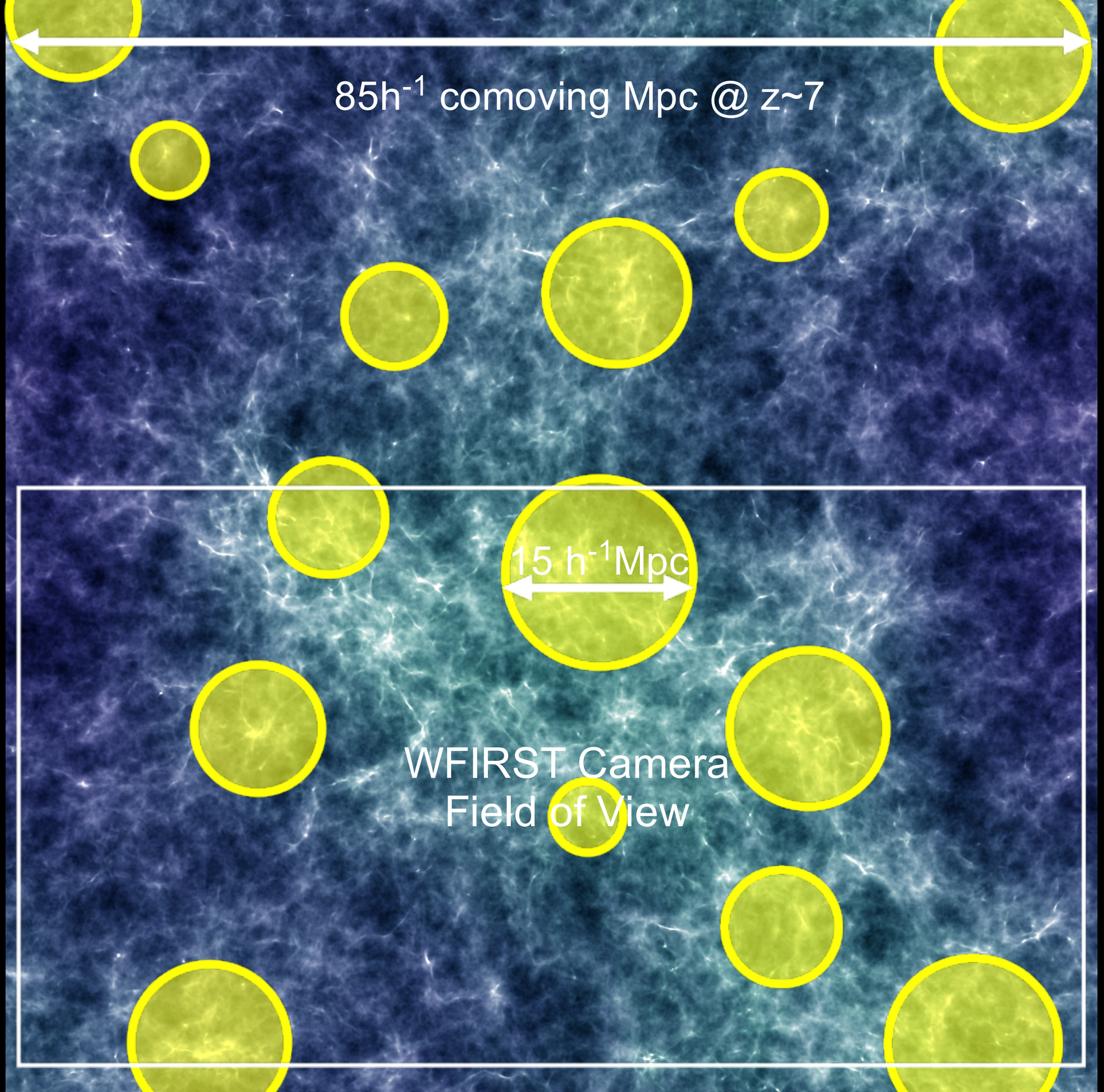
CV ~ 20%

WFIRST Camera
Field of View

CV ~ 12%

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

# Reionized Bubbles



# *WFIRST* Extragalactic Potential Observations (EXPO) Science Investigation Team

Mark Dickinson
(NOAO)

Harry Ferguson
(STScI)

Steve Furlanetto
(UCLA)

Jenny Greene
(Princeton)

Piero Madau
(UCSC)

Dan Marrone
(Arizona)

Brant Robertson
(UCSC; PI)

Alice Shapley
(UCLA)

Dan Stark
(Arizona)

Risa Wechsler
(Stanford)

Stan Woosley
(UCSC)

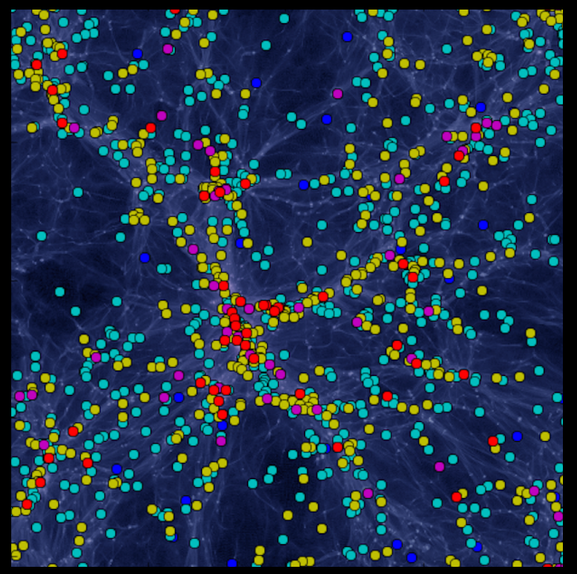
# *WFIRST*-EXPO Science Questions

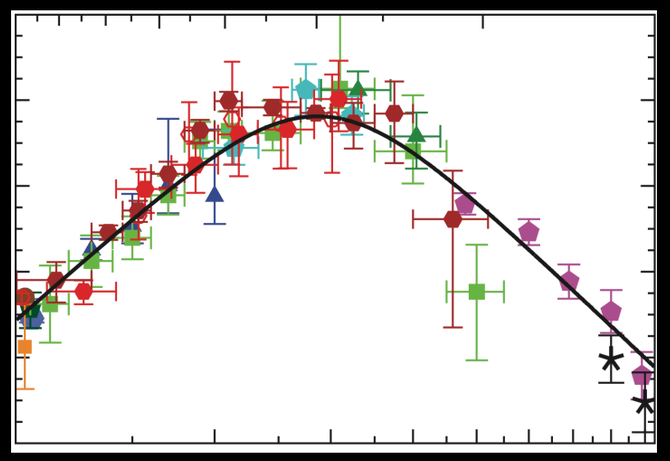
- **How will WFIRST help us understand galaxy properties in the context of their environments over cosmic time?**
- What will WFIRST spectroscopy teach us about galaxy properties and evolution during the peak era of cosmic star formation?
- How can we leverage WFIRST to discover and characterize rare AGN and quasars?
- Will the massive sample of gravitational lenses discovered by WFIRST inform us about the properties of dark matter?
- Can we quantify the importance of galaxies and quasars for reionization through the statistical samples finally delivered by WFIRST?
- Will WFIRST discover enough exotic, distant supernovae to tell us about the fates of early stellar populations?

# *WFIRST*-EXPO Planned Activities

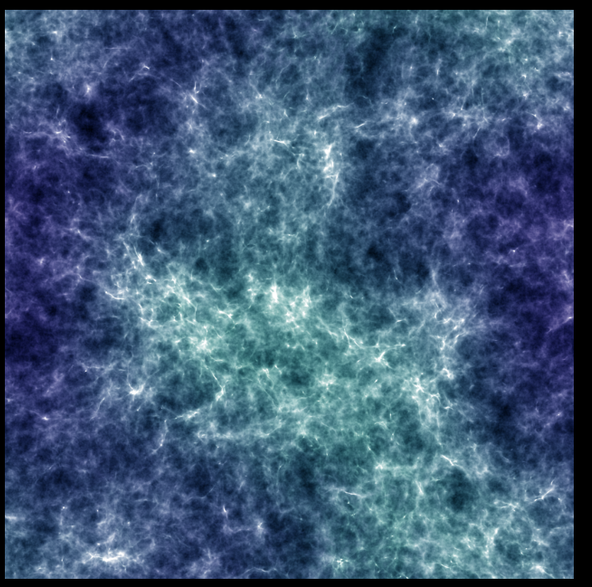
- **Make tools to gener**ate mock catalogs for planning extragalactic astrophysics investigations with the 2200 deg$^2$ High Latitude Survey and Guest Observer (GO) community programs.
- Simulate images and grism spectra for modeling extragalactic GO programs.
- Produce example GO and Guest Investigator (GI) programs, workflows, and metrics for evaluating the WFIRST extragalactic science return.
- Study possible medium- and ultra-deep imaging and spectroscopic GO/GI programs.
- Evaluate WFIRST design choices that influence extragalactic science return.
- Serve as liaisons to JWST, LSST, TMT/GMT/E-ELT, Subaru/PFS, ALMA, and 21cm experiments for coordinating synergistic WFIRST surveys for extragalactic astrophysics.

# Summary



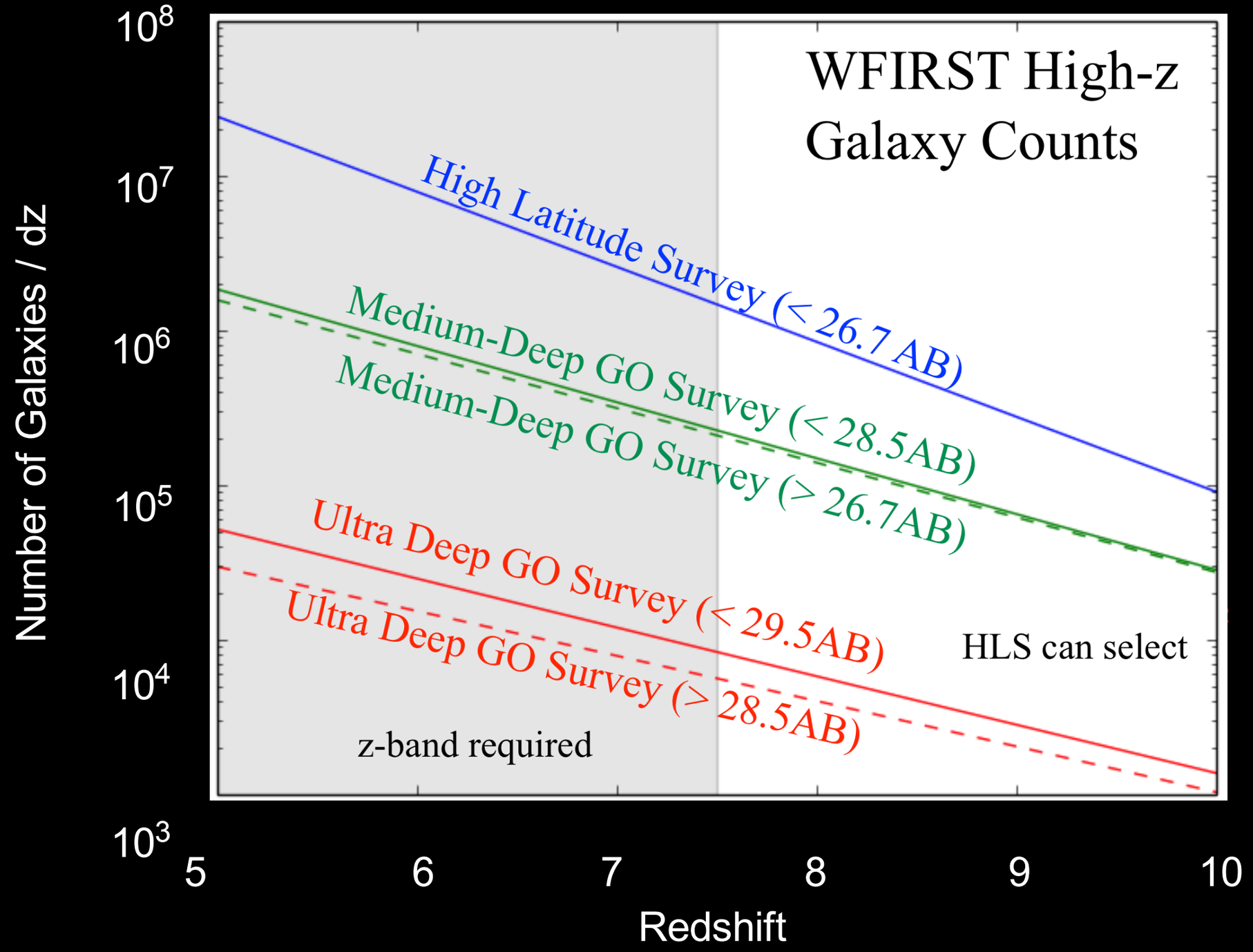


- *WFIRST* will be transformative for studies of galaxy evolution and formation.
- *WFIRST* can teach us about the connection between galaxy evolution and cosmic environment.
- *WFIRST* will provide unprecedented spectroscopic samples during the peak of galaxy formation.
- *WFIRST* will provide the first statistical samples for studying early galaxy and quasar populations that cause cosmic reionization.
- The *WFIRST* EXPO team will investigate the importance of *WFIRST* for galaxy evolution science.

# Extra

# *WFIRST* High Redshift Galaxy Counts




*WFIRST* will find the first statistical samples of EoR galaxies.

# *WFIRST* Spectroscopy at the Peak Epoch of Cosmic Star Formation