Extragalactic Science Drivers for a Large Space-based UV/OIR Mission

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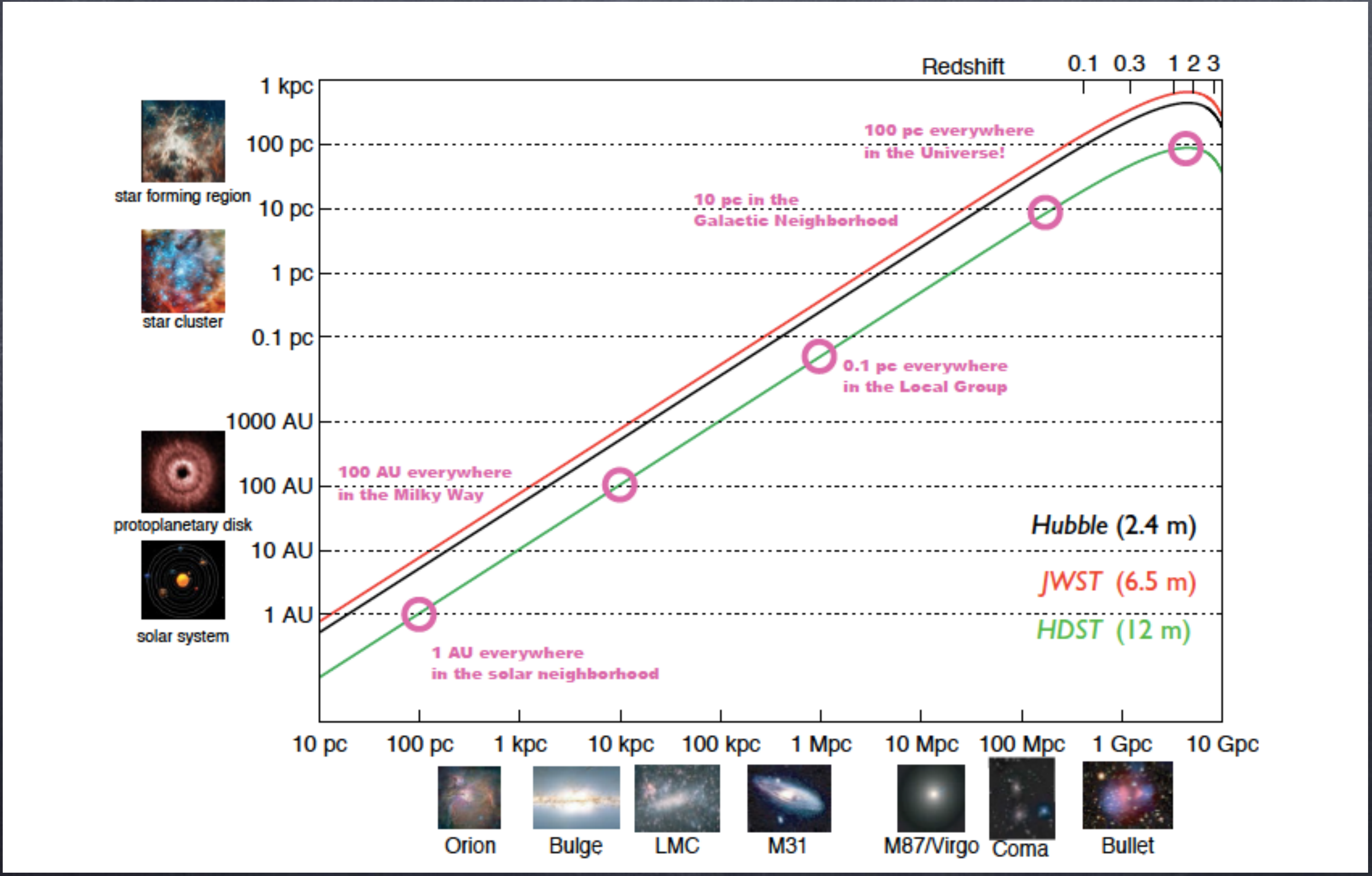
Key Extragalactic Science Drivers for Previous/Planned UV/OIR Space Missions

- HST: H0...(+IGM, deep fields)
- Spitzer: Dusty Universe
- JWST: First light
- WFIRST: w...
- HDST/LUVIOR??

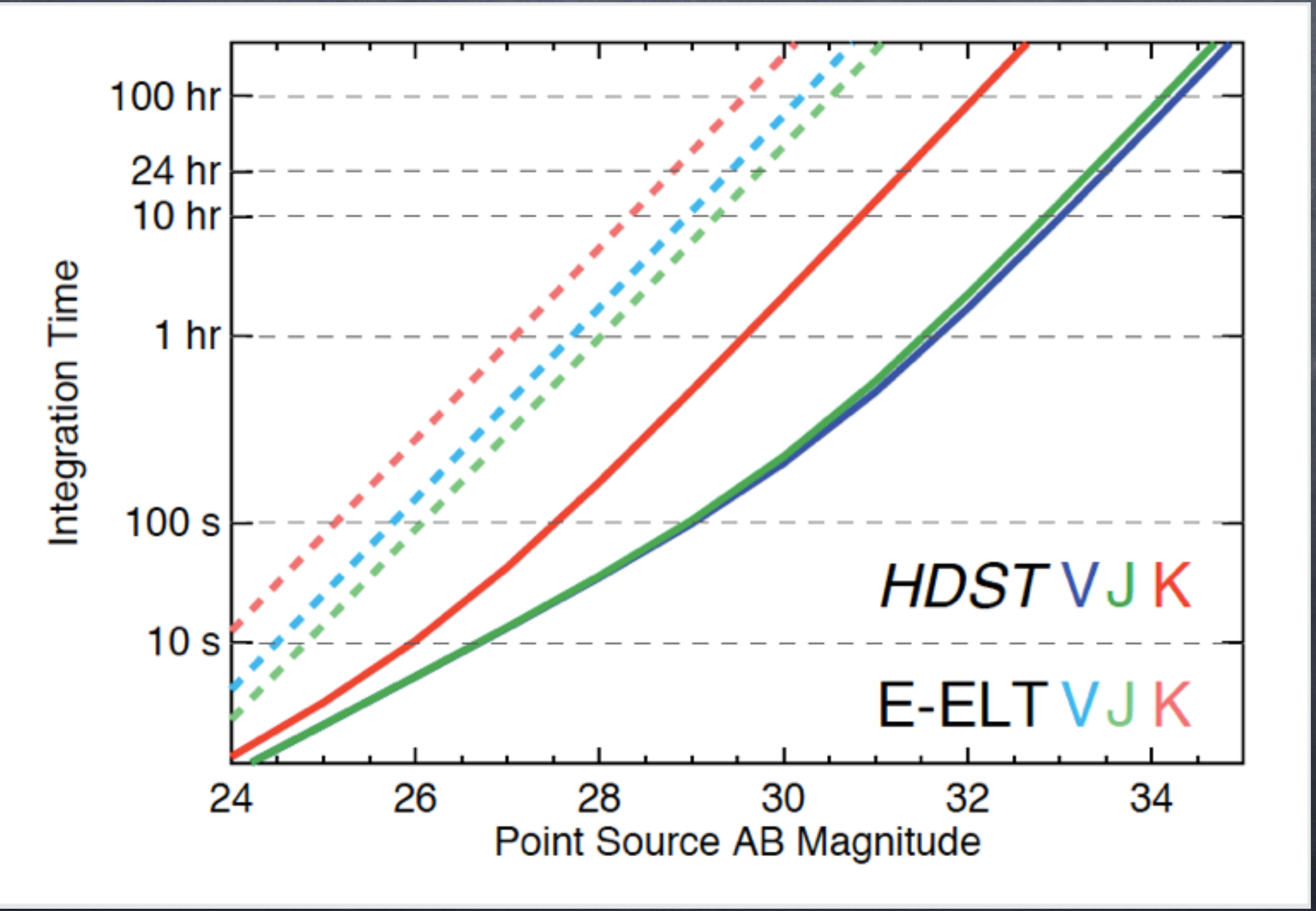
From pre-meeting inputs

- Epoch of Reionization:
  - physics of first light objects beyond JWST
  - IR sensitivity
- Baryon cycle:
  - circum- and inter-galactic medium from cosmic noon
  - UV capability; MOS/IFU
- Galaxy formation in HD:
  - dark matter; galactic star formation and feedback
  - spatial resolution

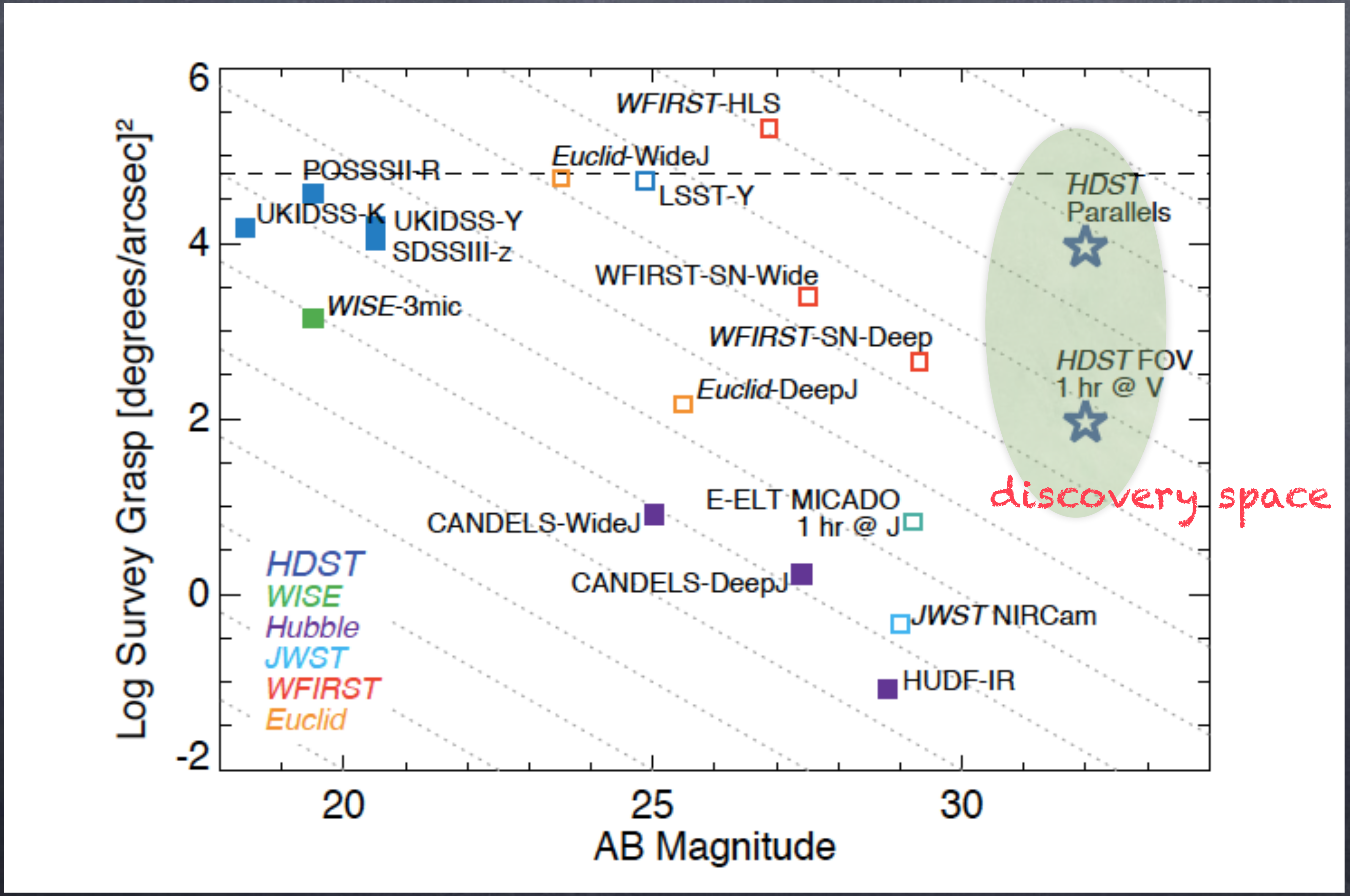
HDST/LUVOIR Capability: Resolution



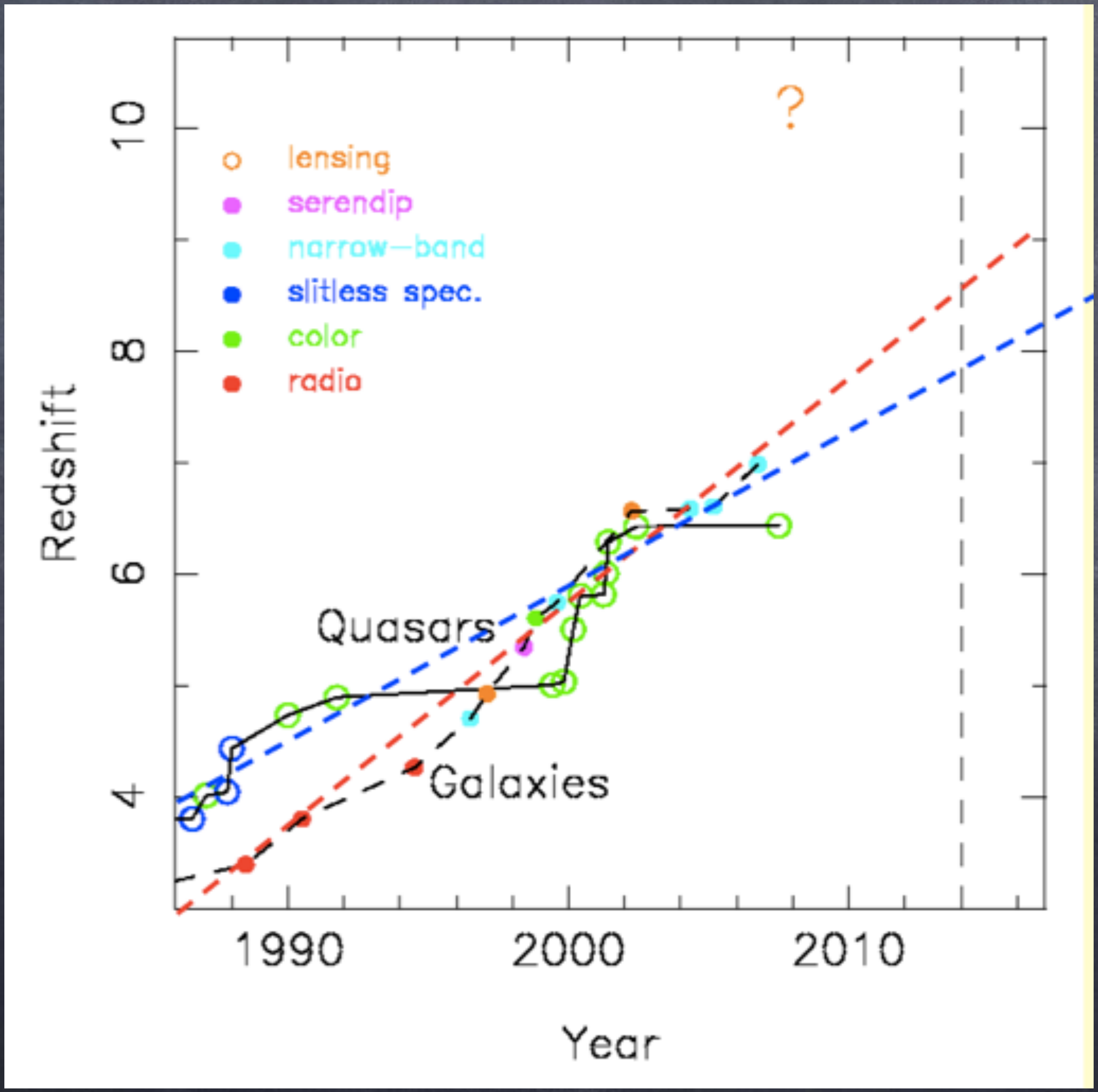
HDST/LUVOIR Capability: Sensitivity



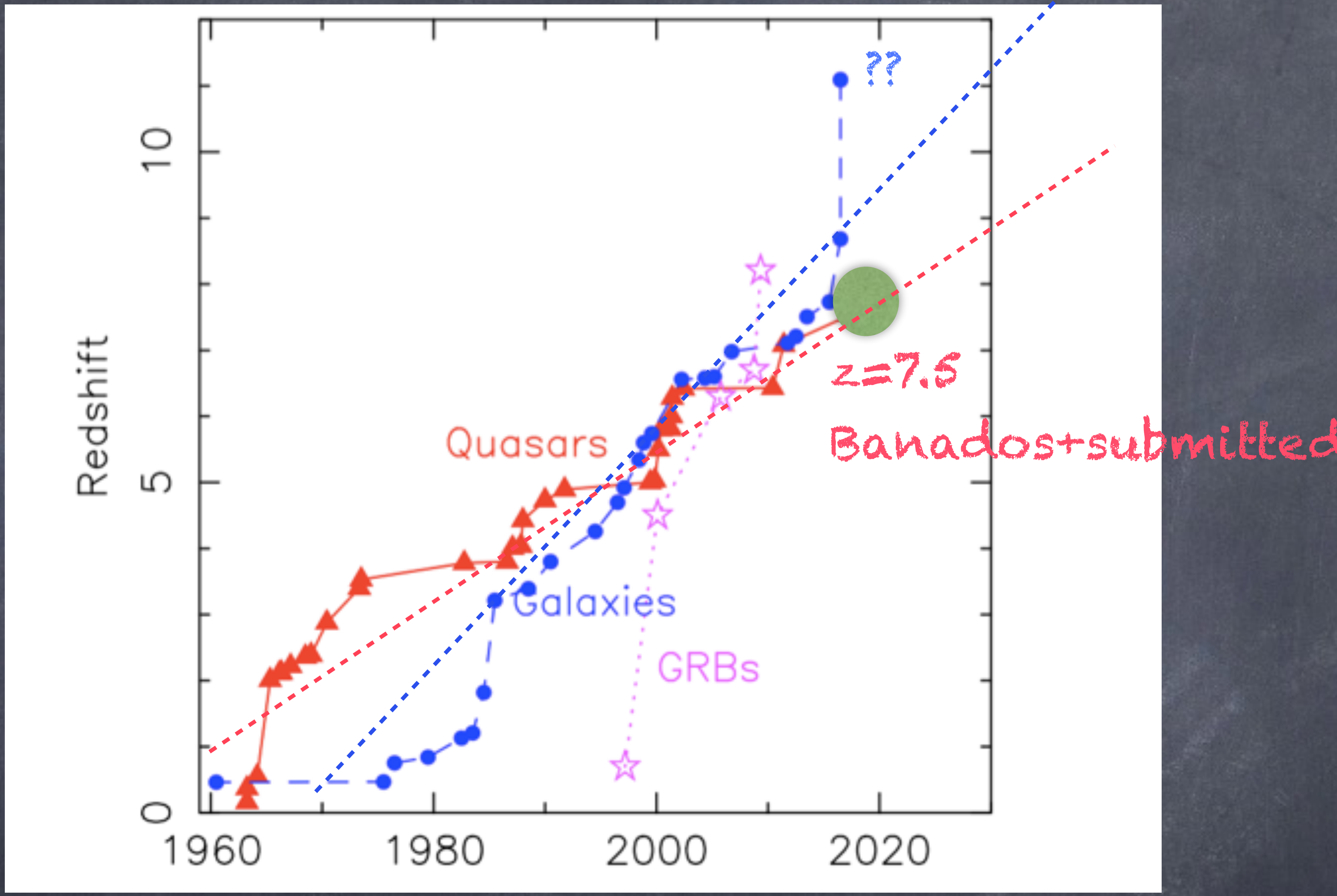
HDST/LUVOIR Capability: Survey Information Content



XF's prediction of the highest redshift frontier from a talk in 2007

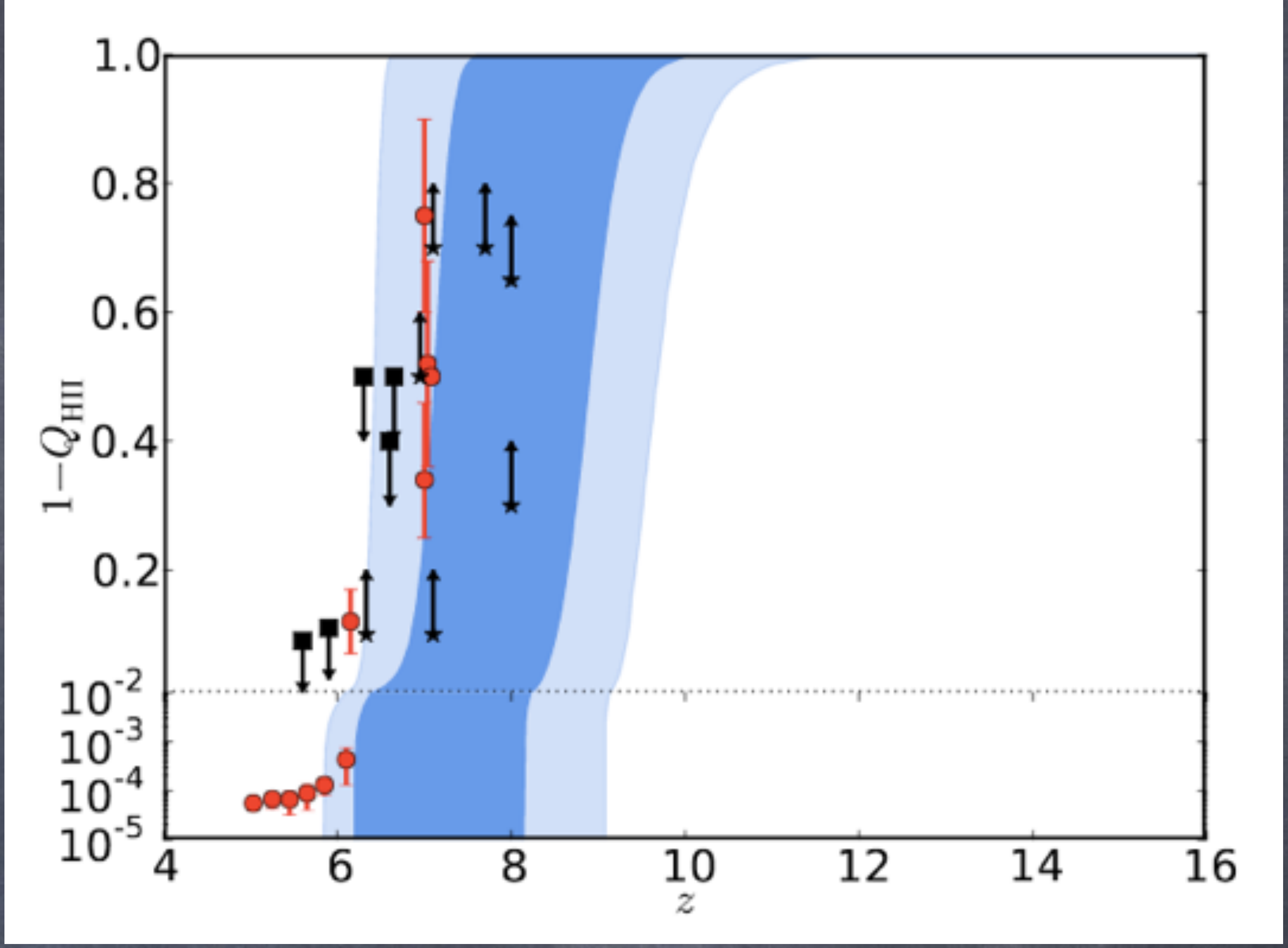


The highest redshift frontier



- Prediction @2035:
  - galaxy: z~18
  - quasar/AGN: z~10

Reionization
after Planck+16



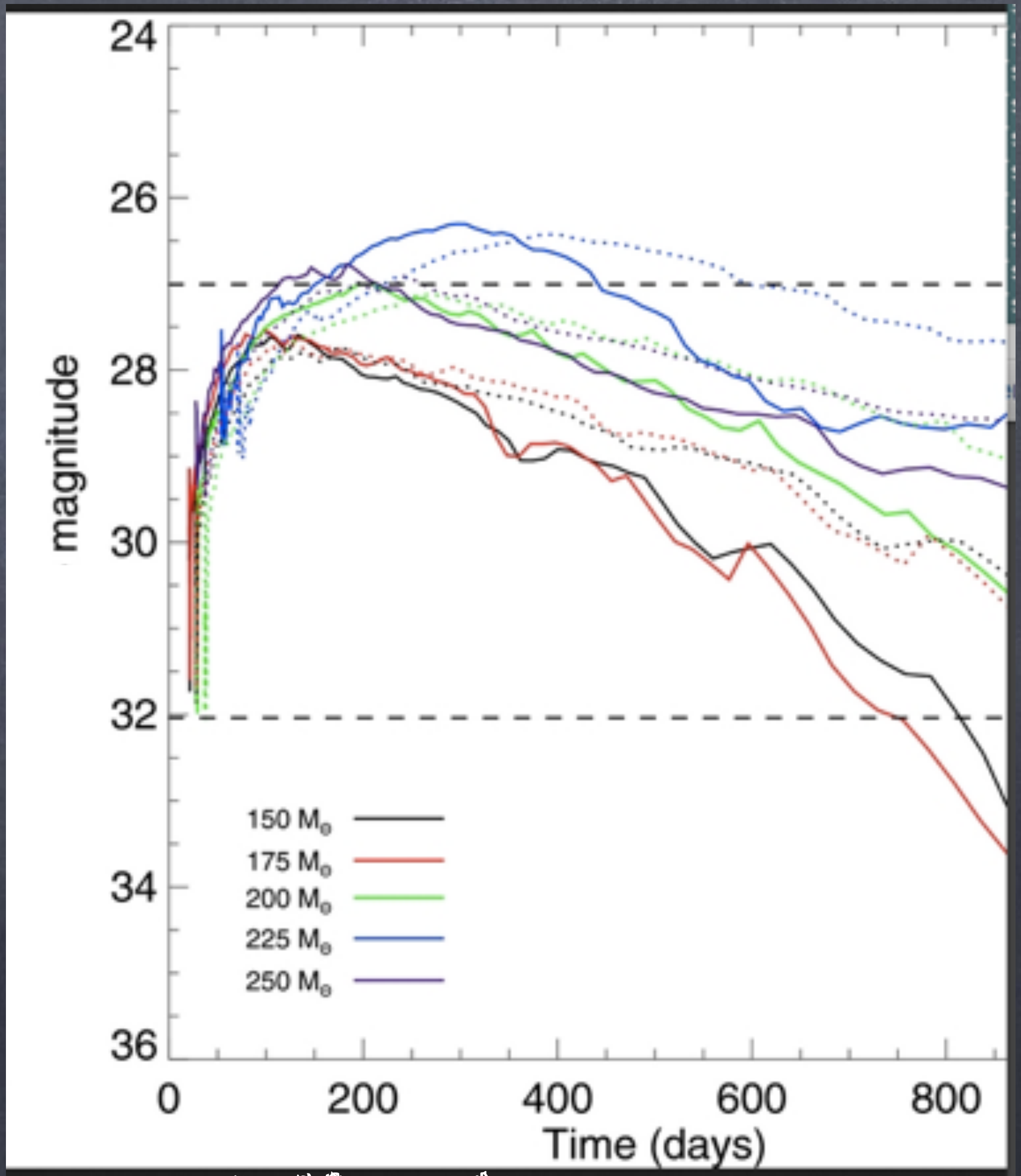
- reionization history probably well-established in the next ten years?
- first light astrophysics?? many open questions even with JWST

JWST vs HDST @ first light

- Galaxies:
  - JWST establishes redshifts of reionization sources
  - HDST studies astrophysics of earliest star formation
- AGN
  - JWST limited to z<=10, luminous sources
  - HDST can detect and take spectra of 10^4 M_sun Eddington-accretion BHs: first supermassive BH seed?
- IGM
  - JWST limited to study H and the strongest systems in the IGM
  - HDST can study first metals in the IGM

First light sources @sub-galactic scales

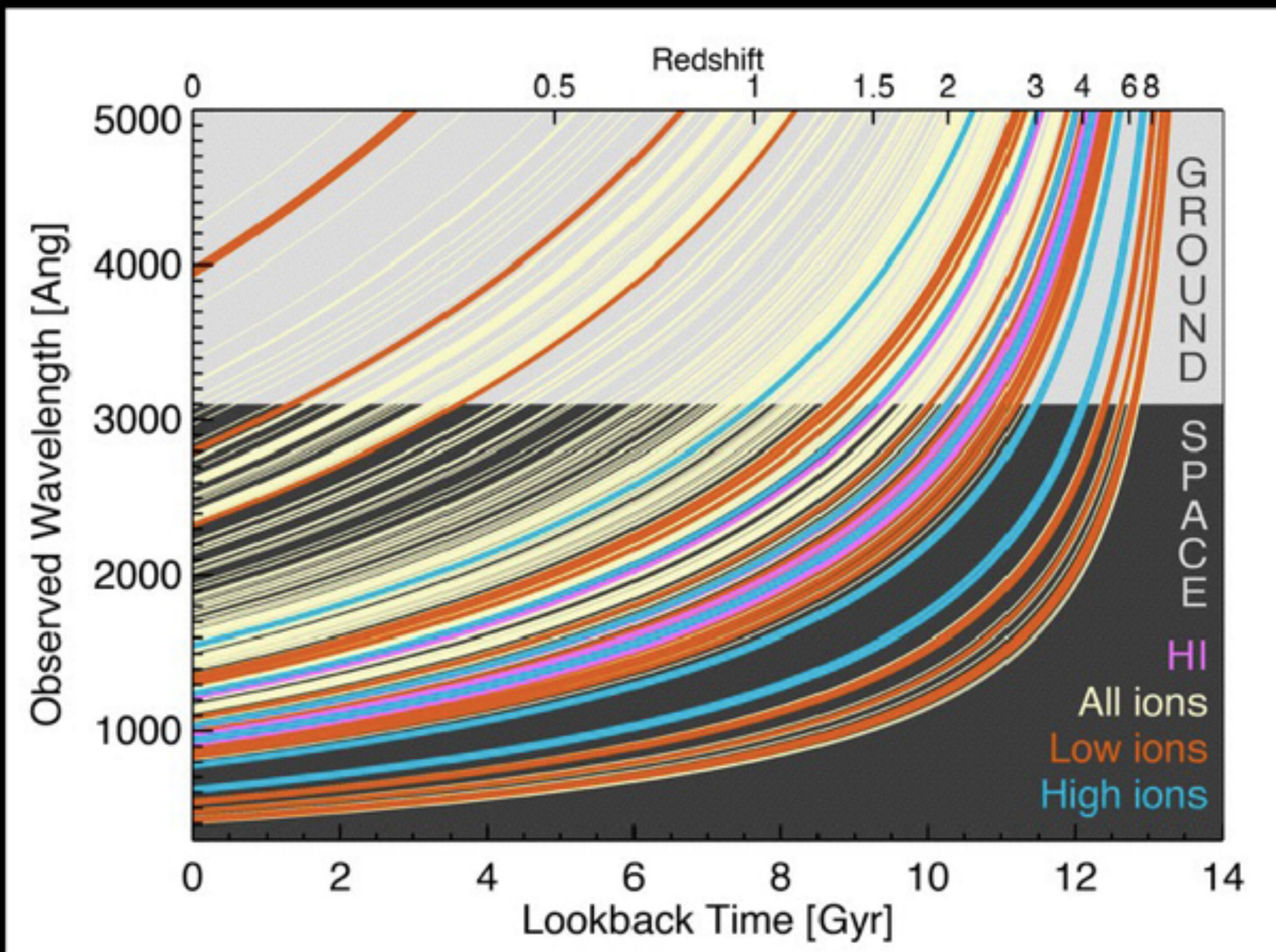
- BH: direct collapse black holes?
- Star: first pair instability supernovae?
- Galaxy: first star clusters?



Whalen+12

Baryon Cycle in the universe: most baryons are in CGM and IGM, hard to observe

UV Access is Essential!



UV spectral features provide the some of the best, *and often unique*, constraints on:

- Ionization state of ISM, IGM
- Structure in ISM, IGM
- Sources of ionization
- Gas Temperature
- Metallicity of ISM, IGM
- Gas Density
- Star formation rate
- Gas kinematics and outflows

High spectral resolution is often required to make such measurements (R > 20,000)

gas fueling and quenching

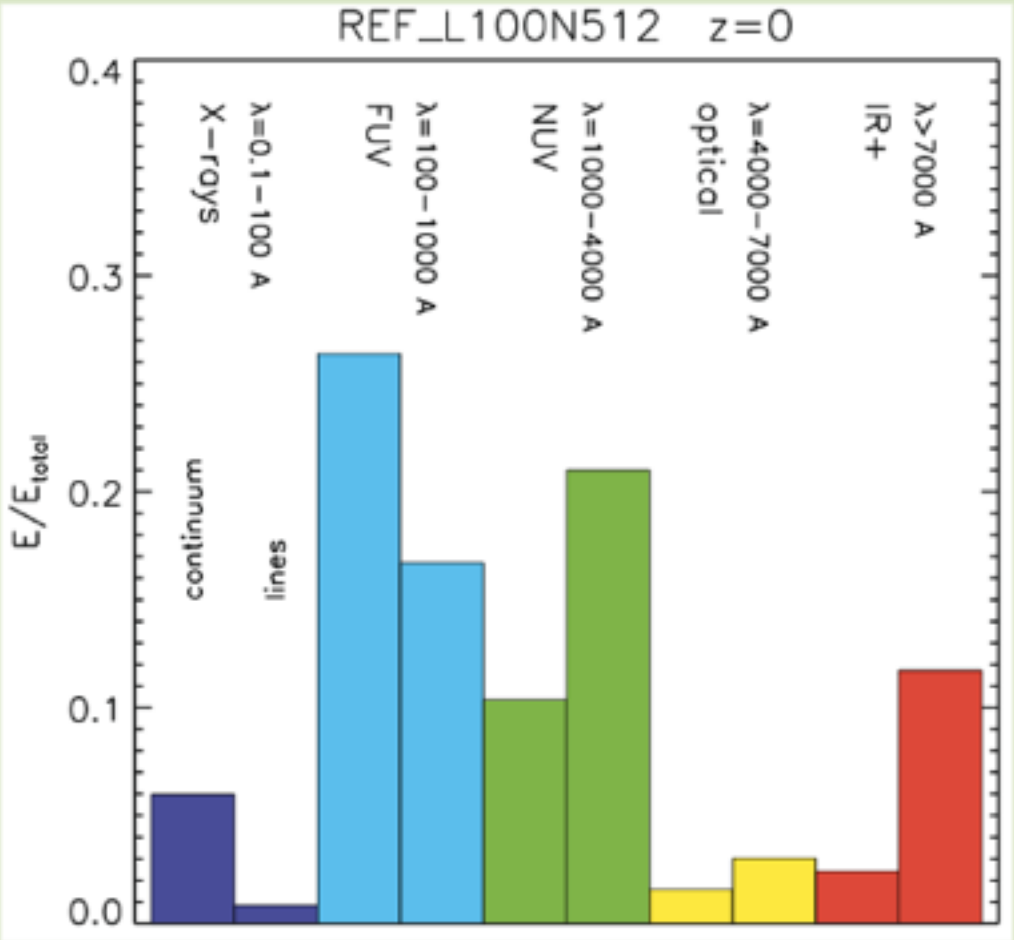


Figure 1: From "How the Diffuse Universe Cools", by Bertone, Aguirre, & Schaye (2013). The bars show the fraction of energy emitted in various rest-frame bands by gas cooling radiation in a hydrodynamical galaxy formation simulation. More than half of the radiation is emitted in the rest-frame FUV (100-1000 Å) and most of the remainder is in the NUV (1000-4000 Å).

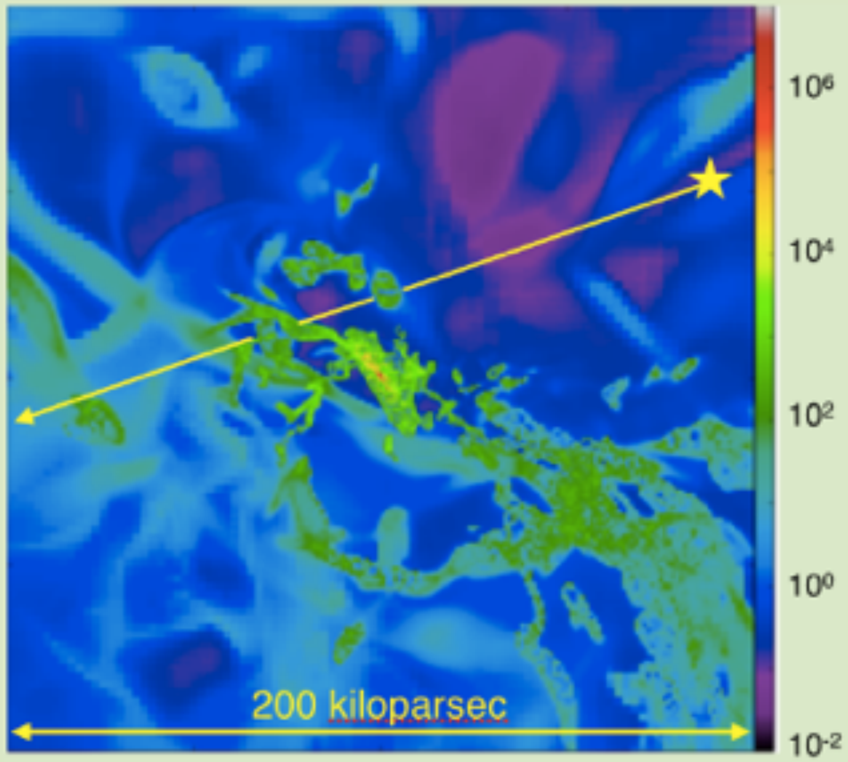
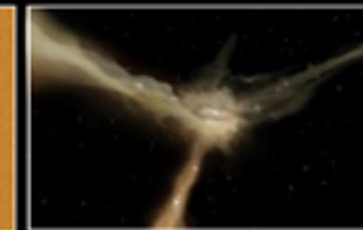


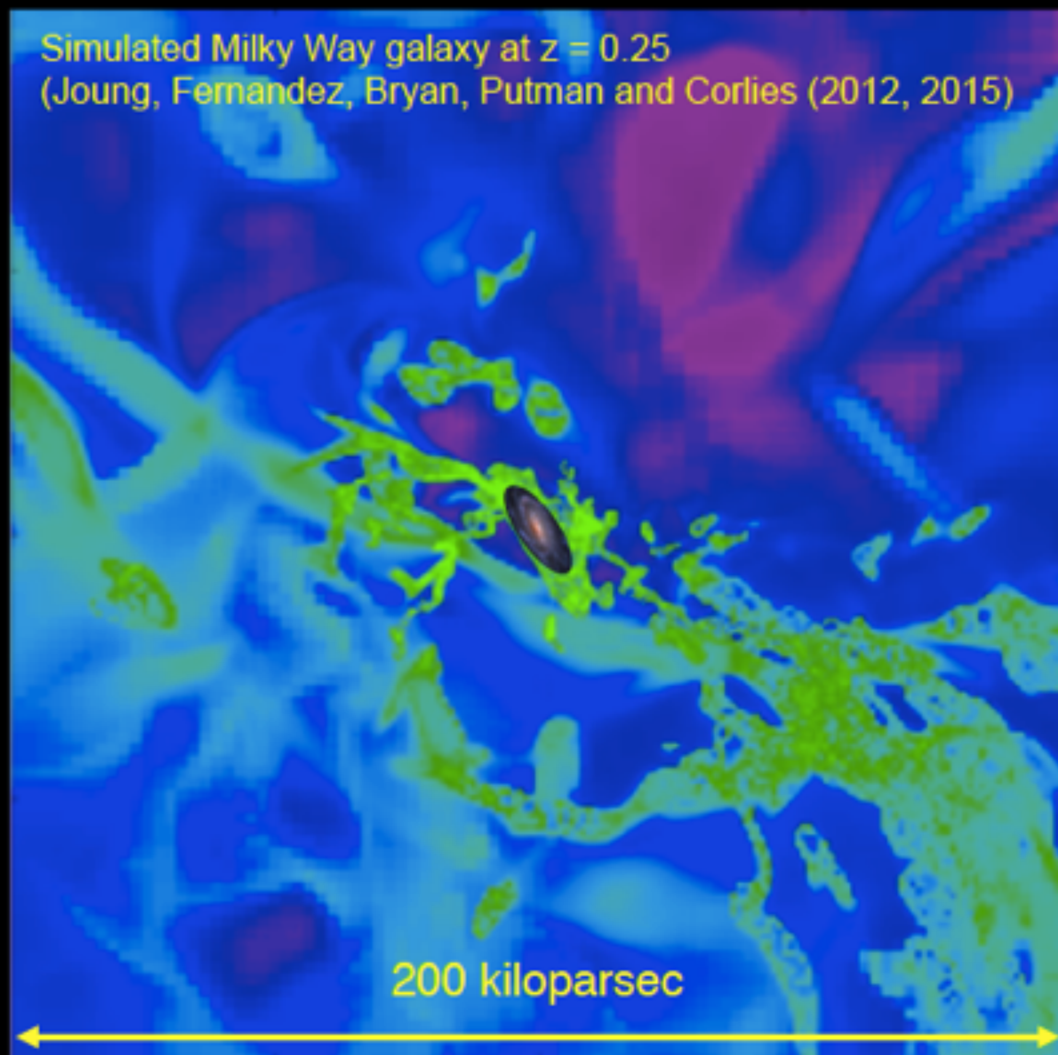
Figure 2: A visualization of the Circumgalactic Medium (CGM) gas fueling a Milky-Way like galaxy at z ~ 0.25. The color renders the strength of UV emission by C IV in the CGM gas in terms of photons cm^{-2} s^{-1} sr^{-1}. For real 2D characterization of the CGM, the LUVOIR Surveyor must reach CGM gas with $S_B \gtrsim 100$ units. The contrast between the 2D image of the CGM and the single hypothetical QSO sightline demonstrates the power of imaging the CGM over continuing to develop statistical maps from single sightlines. Image from Joung, Fernandez, Bryan, Putman and Corlies (2012, 2015).

Tomlinson and Schiminovich white paper

How Do Galaxies Acquire, Process, and Recycle Their Gas?

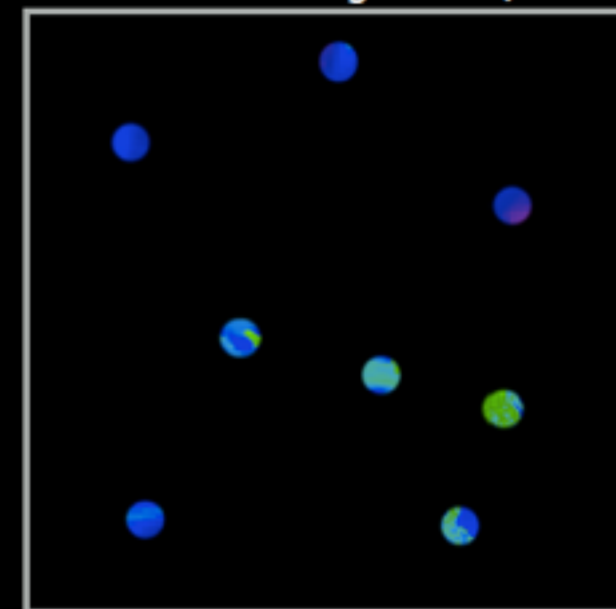
Epoch	Resolution
z < 1	10-100 pc



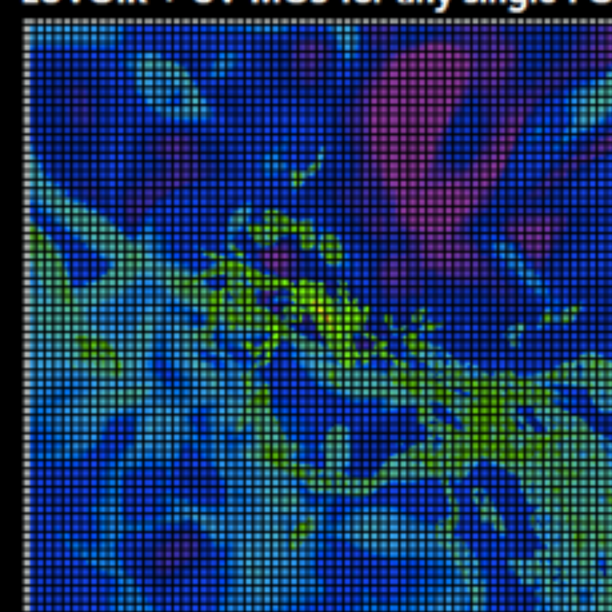


Using powerful and unique multi-object UV spectroscopy, HDST will be able to map the “faintest light in the Universe” emitted from gas filaments entering galaxies and energetic feedback headed back out.

HST+COS & stacking of multiple FOV:

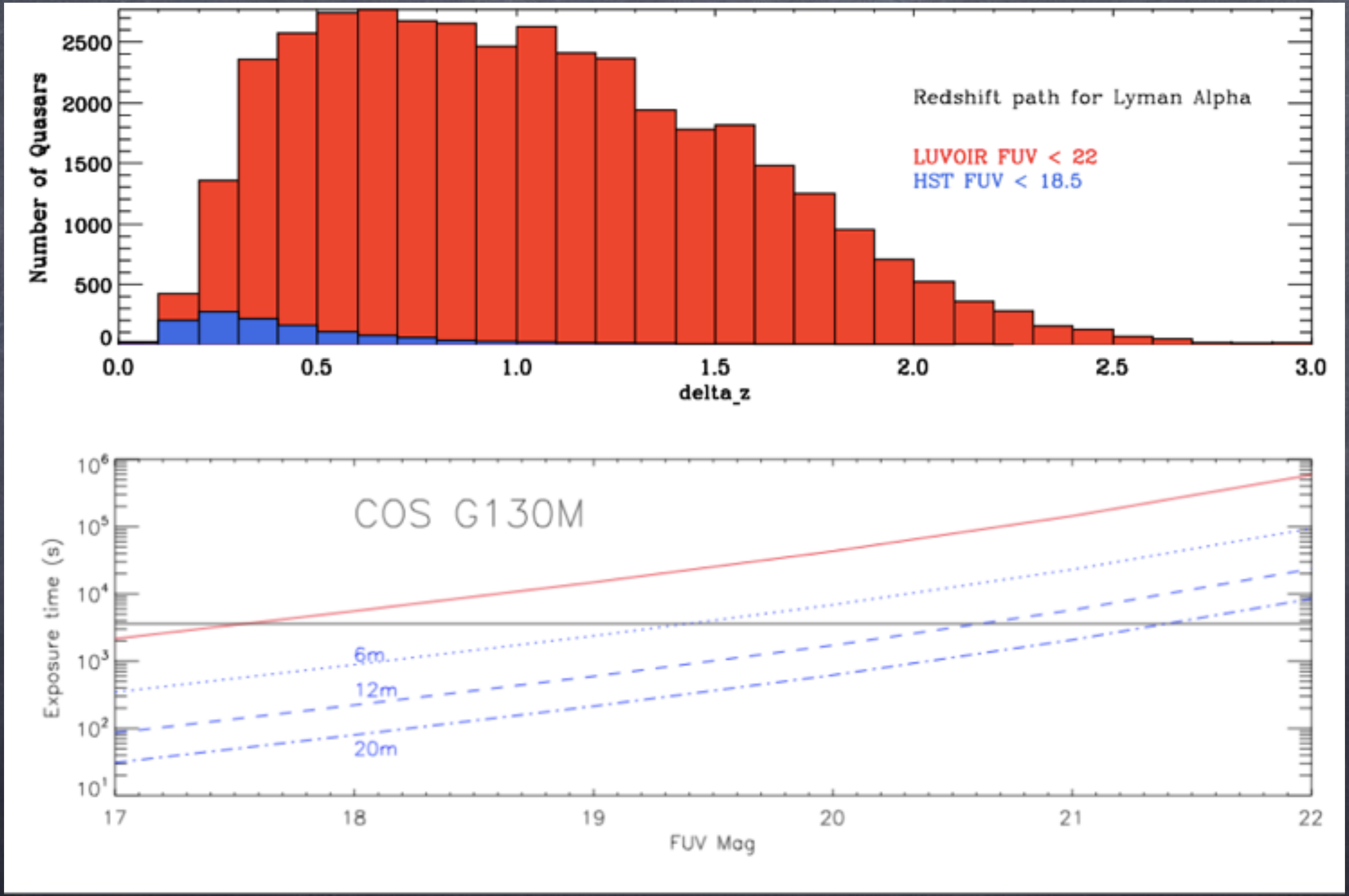


LUVOIR + UV MOS for any single FOV:



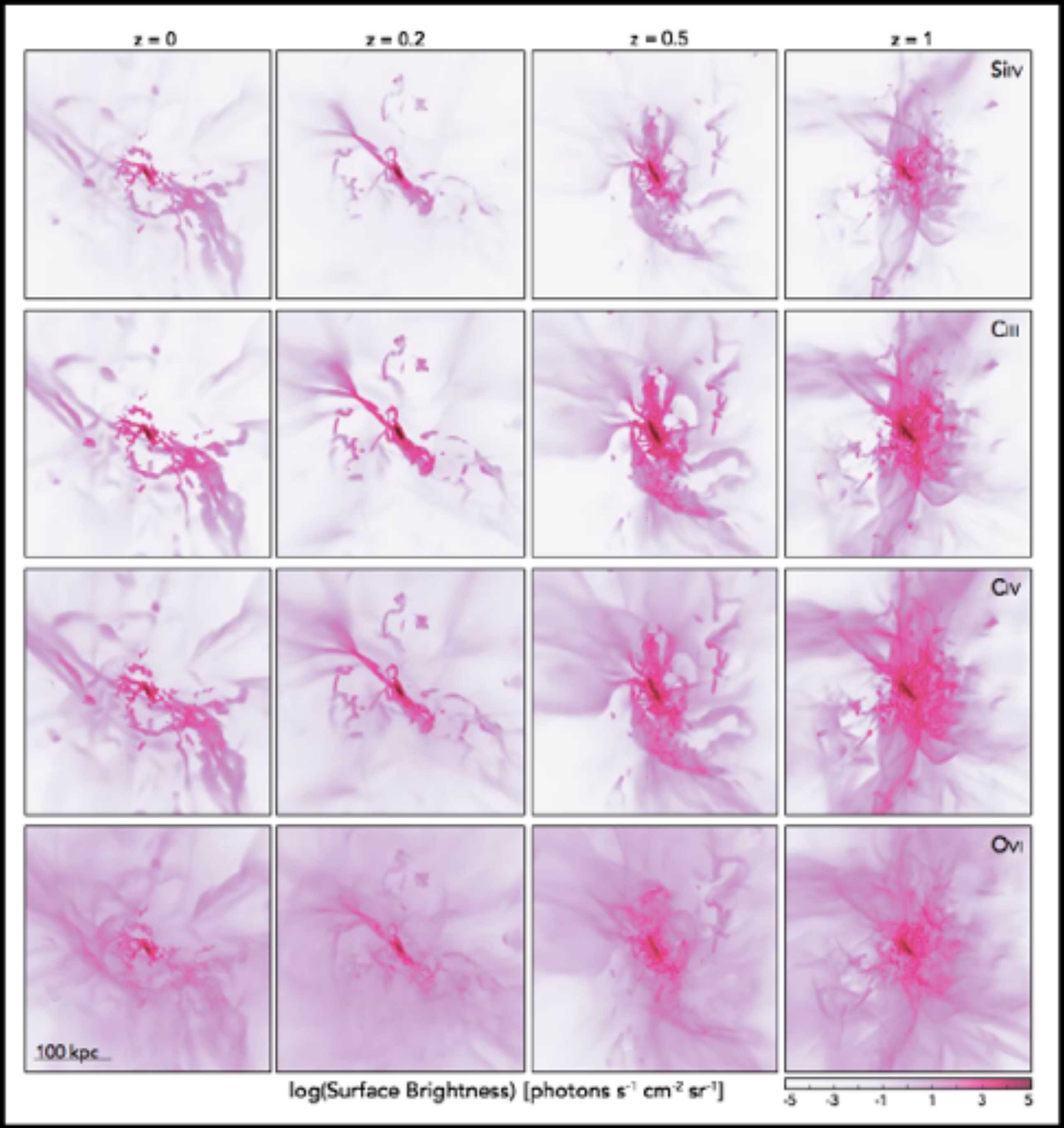
From M. Postman’s talk

case for absorption line spectroscopy

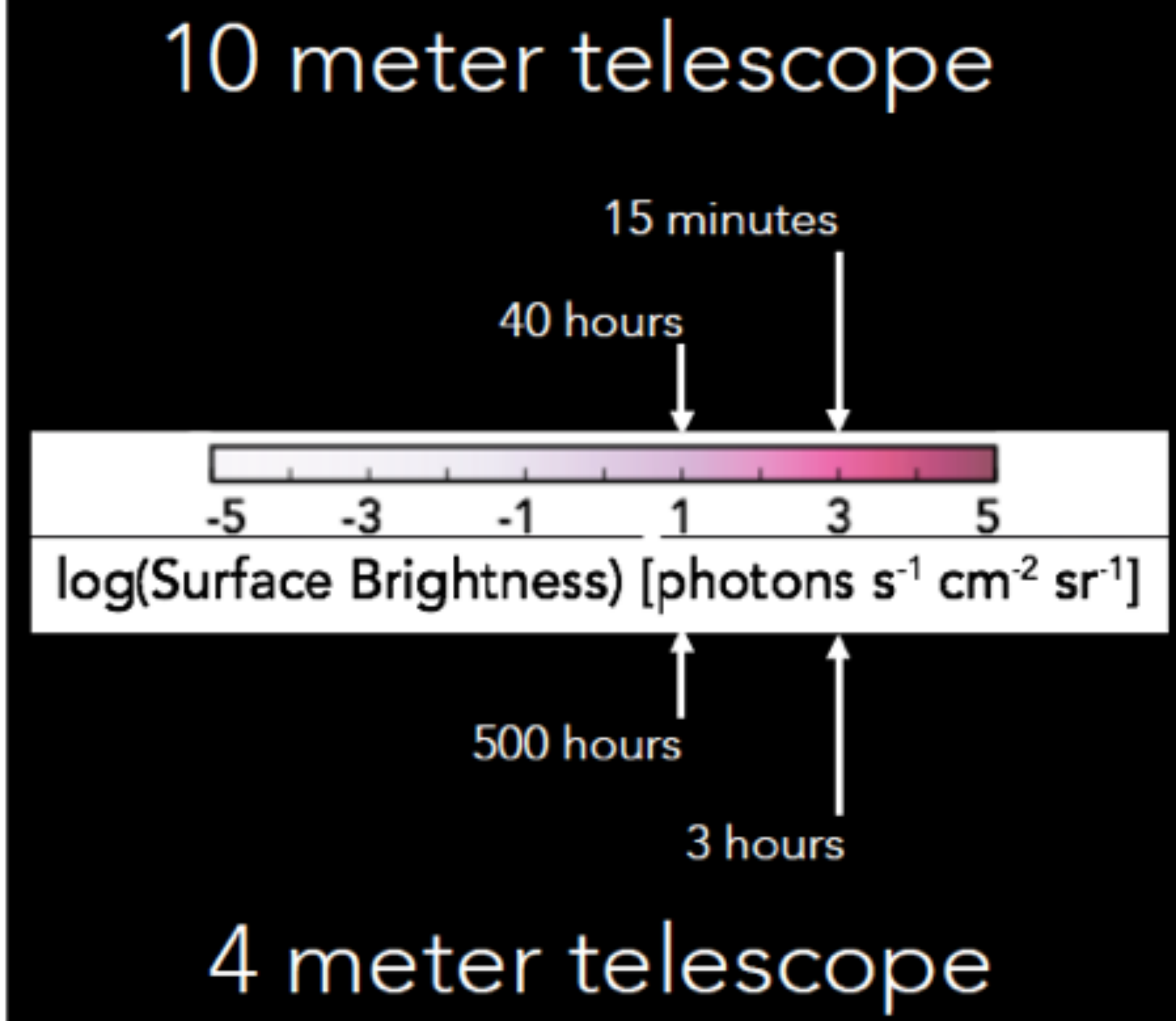


from O'Meara STDT report

- imaging the CGM at z<2 to unravel galaxy fueling and feedback



Corlies & Schiminovich (2016)



Galaxy Formation in HD

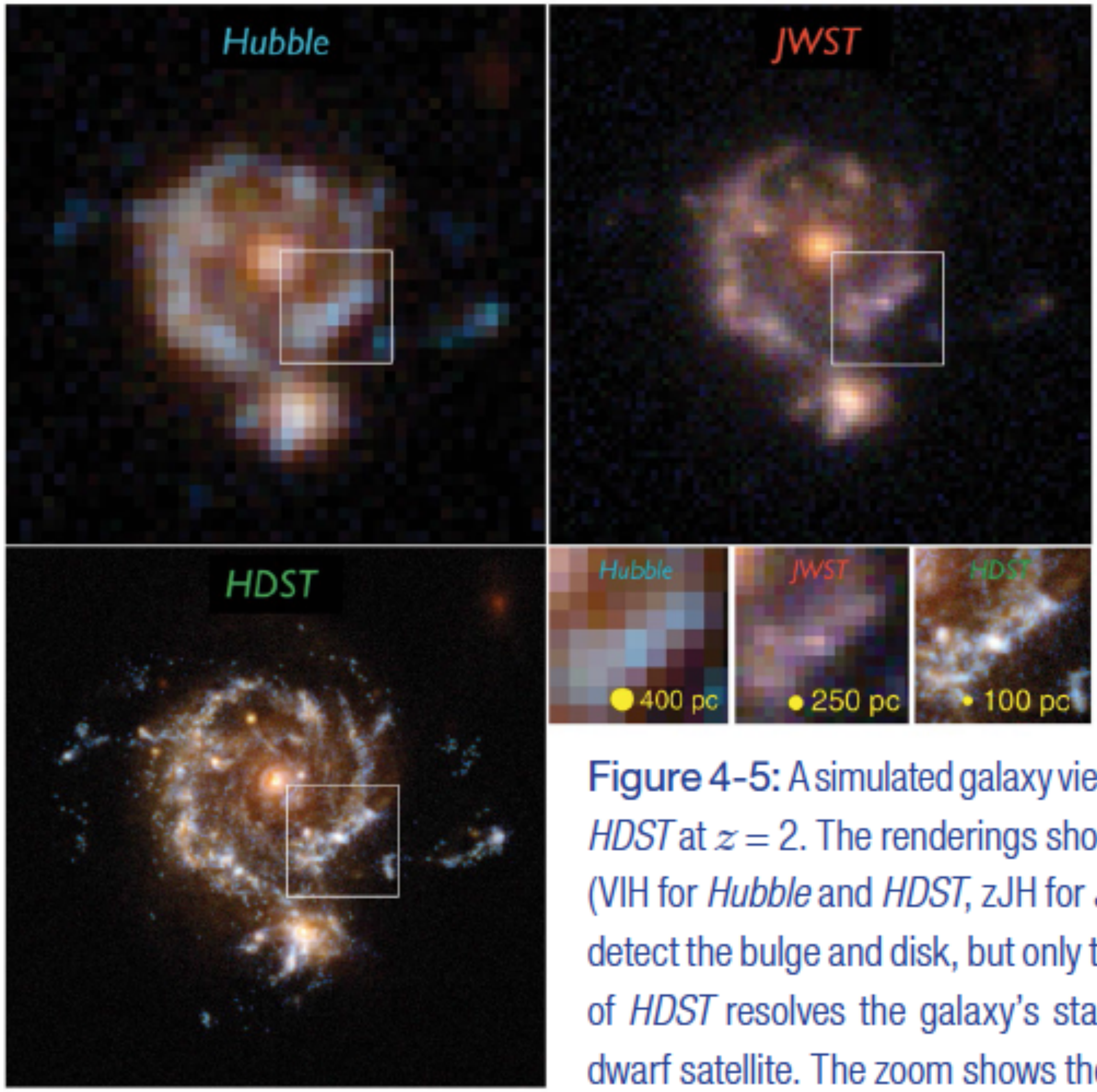
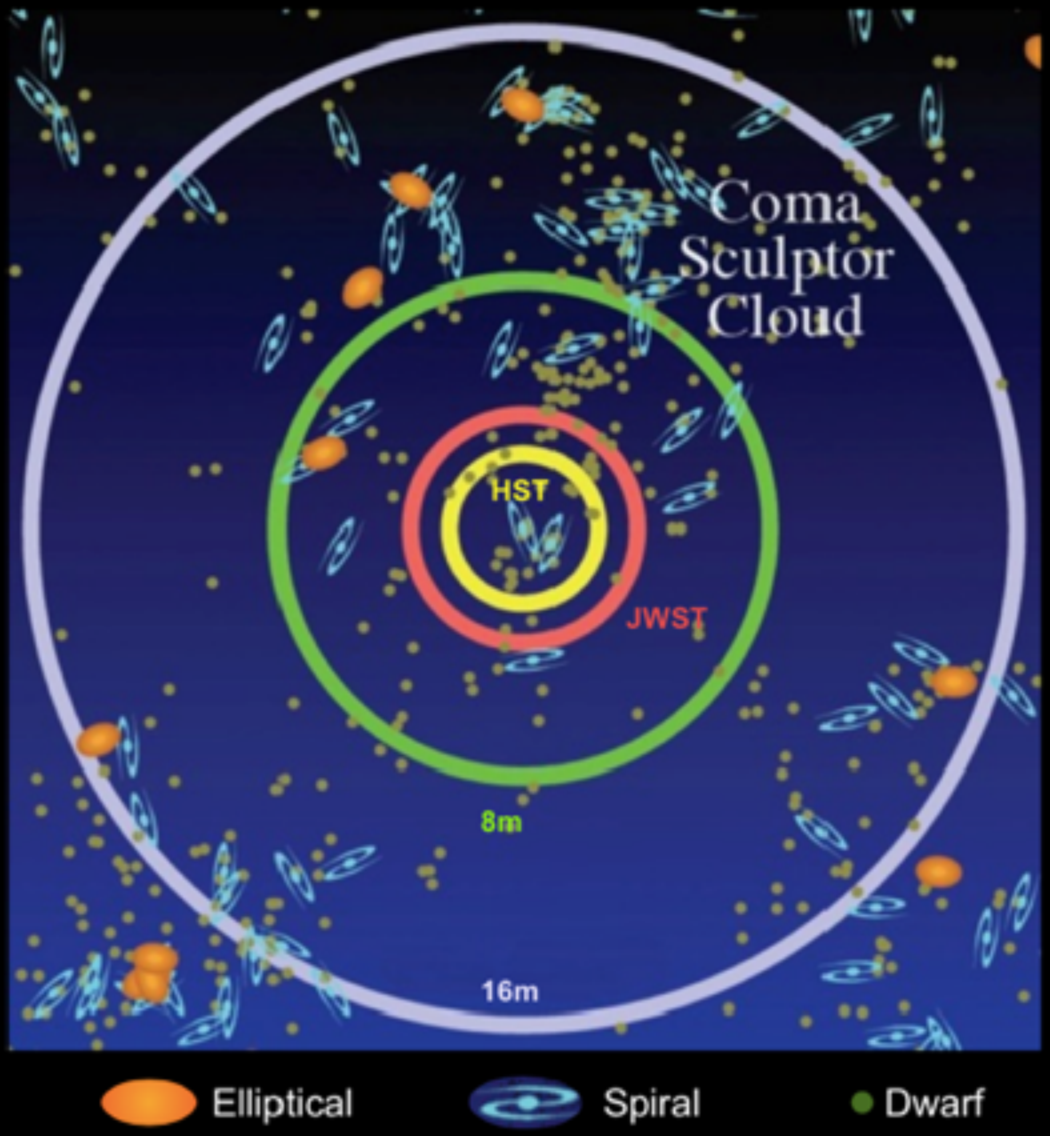
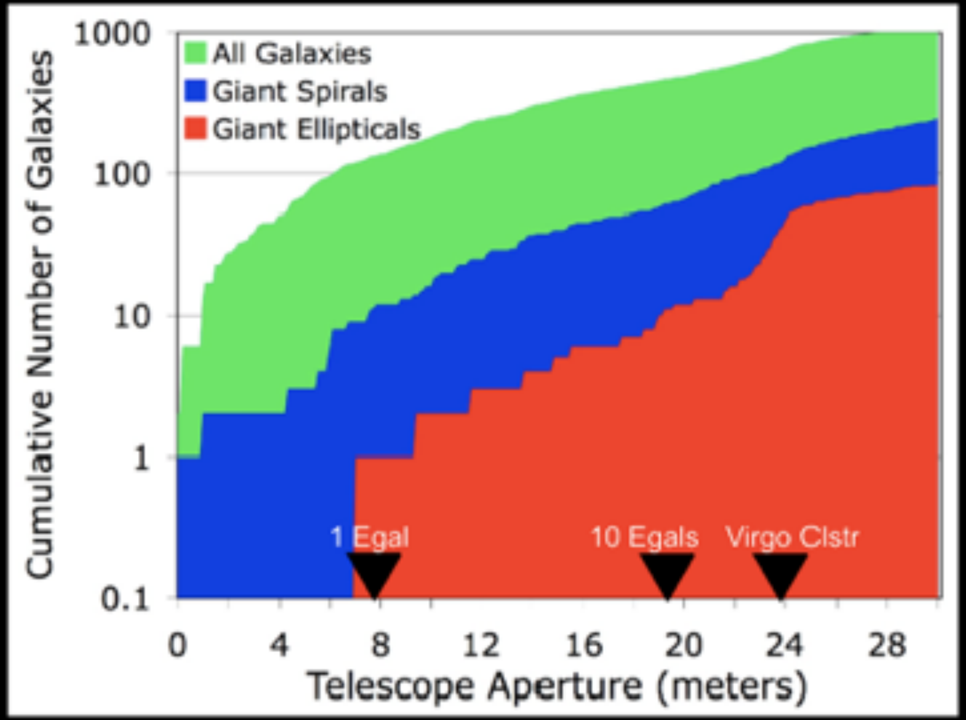


Figure 4-5: A simulated galaxy viewed by *Hubble*, *JWST*, and *HDST* at $z = 2$. The renderings show a one-hour observation (VIH for *Hubble* and *HDST*, zJH for *JWST*). *Hubble* and *JWST* detect the bulge and disk, but only the exquisite image quality of *HDST* resolves the galaxy's star-forming regions and its dwarf satellite. The zoom shows the inner disk region, where only *HDST* can resolve the star-forming regions and separate them from the redder, more distributed old stellar population. Image credit: D. Ceverino, C. Moody, and G. Snyder.

Resolved and semi-resolved stellar populations

- Star formation histories and the IMF

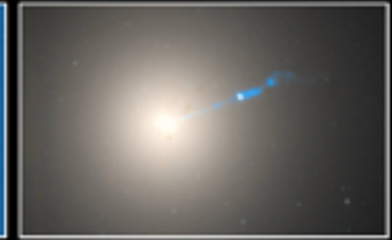




8-12 meter aperture reaches 1-3 giant ellipticals

What is the Dark Matter? How Does Light Trace Mass? How Does Dark Mass Move?

Volume	Resolution
< 10 Mpc	0.1 - 1 pc



Distance	Speed	Example	Goal
10 pc (nearest stars)	10 cm s^{-1} 0.2 mph		planets
100 pc (nearest SF regions)	100 cm s^{-1} 2.2 mph		planets in disks
10 kpc (entire MW disk)	0.1 km s^{-1} 223 mph		dissipation of star clusters
100 kpc (MW halo)	1 km s^{-1} 2200 mph		DM dynamics in dwarf sats.
1 Mpc (Local Group)	100 km s^{-1}		3D motions of all LG galaxies
10 Mpc (Galactic Neighborhood)	500 km s^{-1}		cluster dynamics

A 10-meter telescope can measure proper motions to ~ microarcsec / year precision over a ten-year baseline.

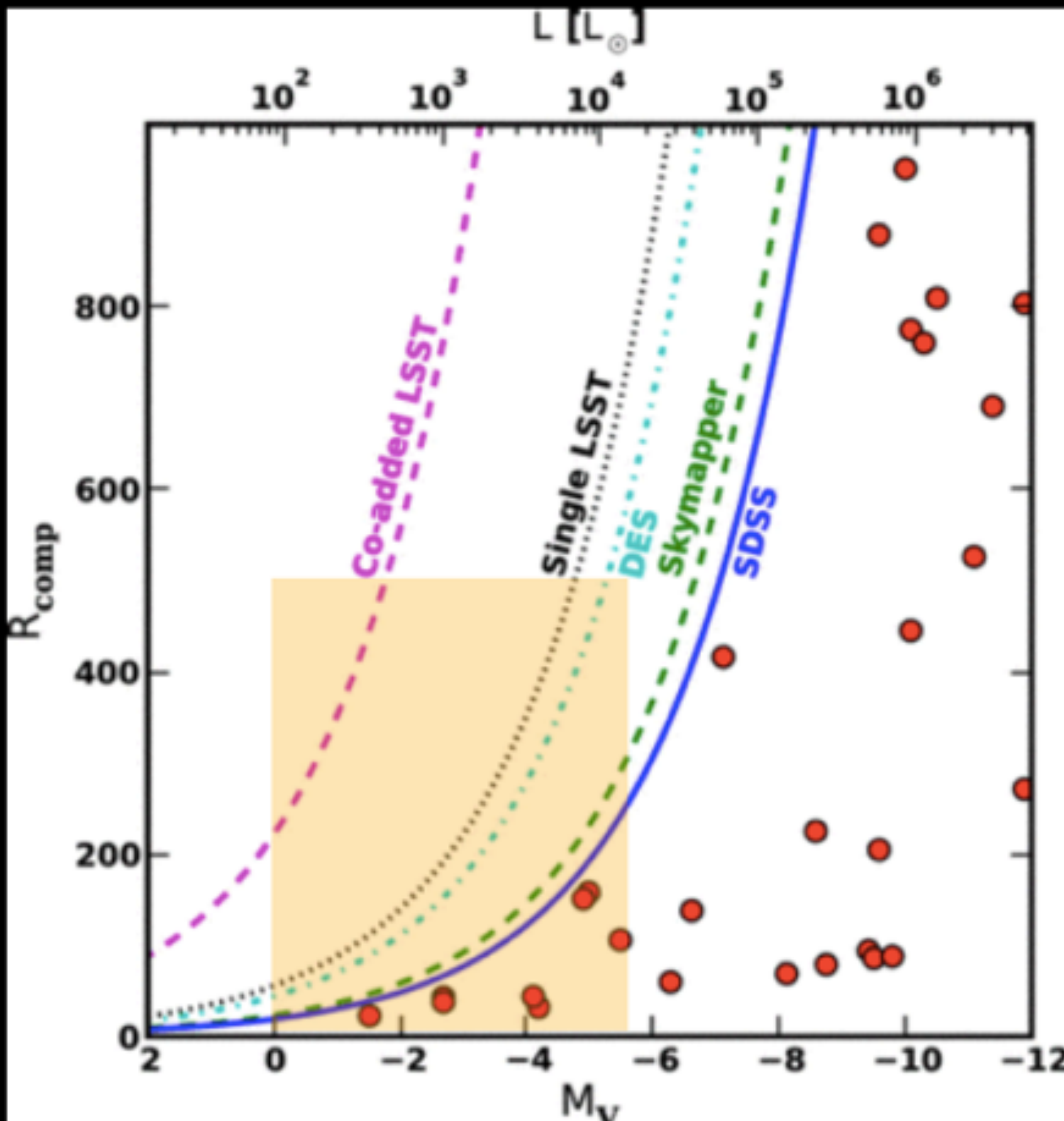
At this level, **virtually everything on the sky moves** - every star in the Milky Way and Local Group and every galaxy in the Galactic Neighborhood.

Aperture driver: A 10+ m is required to reach the motions of virtually ANY Milky Way star, the internal motions of Local Group satellites, and the motions of giant ellipticals in the Virgo cluster (~15 Mpc).

System driver: Extremely stable PSF and low-noise detectors are needed to centroid objects to a few thousandths of a pixel.

From M. Postman's talk

Probe star formation and dark matter in the darkest halos - hundreds of faint MW satellites to be discovered by LSST.



- LSST will reach ~100% "completeness" for the faintest dwarfs out to 400 kpc.
- Measuring their IMF requires reaching 3 mag below main sequence TO.
- 12 m LUVOIR can do this at 500 kpc
- 4 m reaches ~200 kpc, but this is 50x less volume and still inside R_{vir}.

From O'Meara STDT report

Comments

- killer app vs. bread and butter
  - no single scheme; wide range of science
  - need to identify key science goals (JWST etc. discoveries?)
- discovery machine vs. followup observations
  - well positioned to followup WFIRST/EUCLID/LSST/JWST surveys
  - discovery space: surveys at the faintest flux levels
- single technical driver vs. diverse needs
  - UVOIR working together; high multiplex spectroscopy is key
  - >8-10 meter seems to be the essential for most extragalactic science cases