Cosmic Origins Science

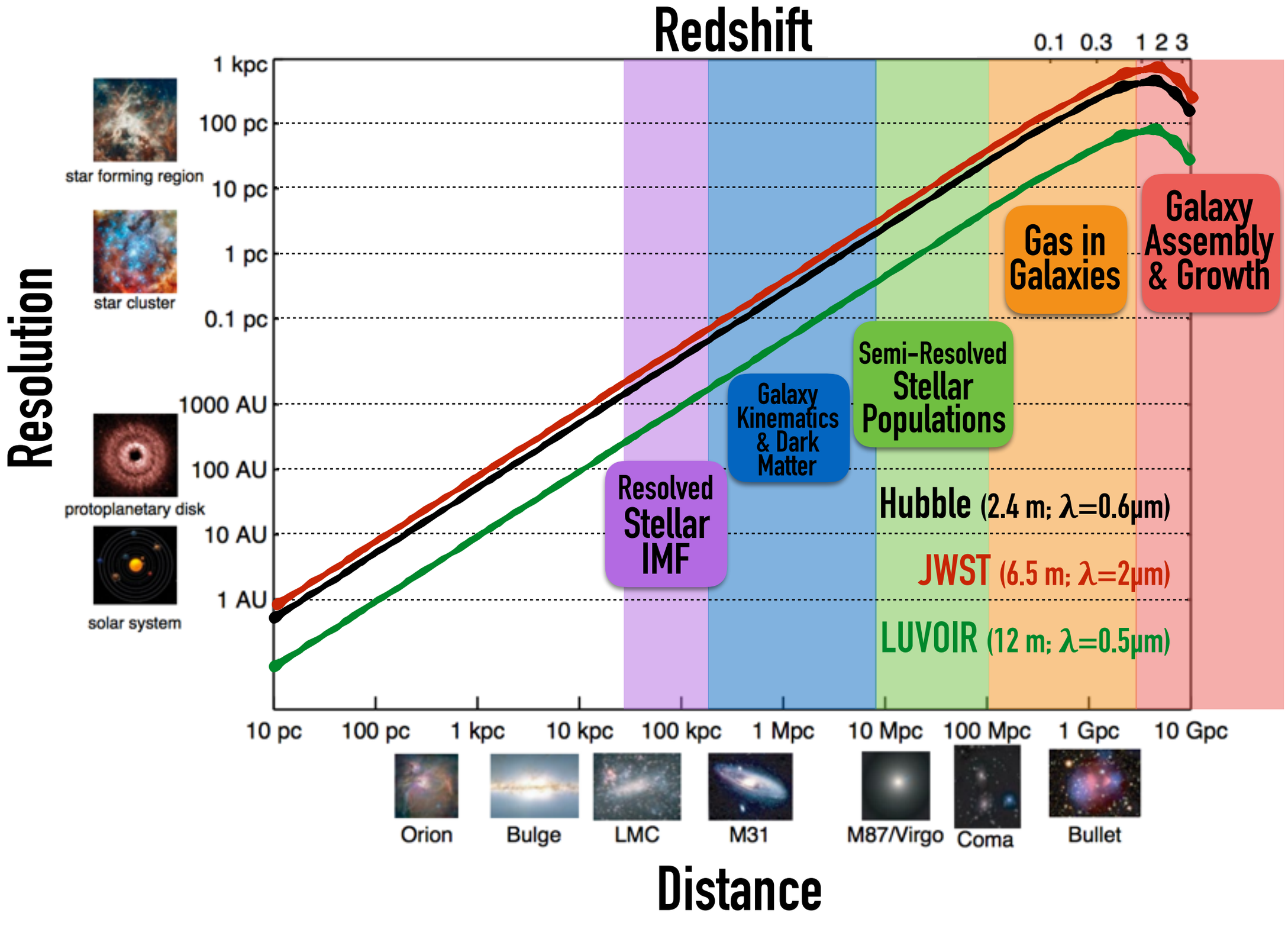
With a Large UVOIR Space Telescope

Ultraviolet, Ultra faint, Ultra precise

Marc Postman
Space Telescope Science Institute

22 March 2017: Venice

Epochs and Science where LUVOIR is uniquely suited to rewrite key chapters in the story of cosmic origins

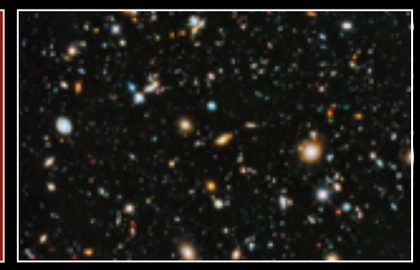


Adapted from AURA Report by Kate Whitaker (U. Mass. Amherst) & Marc Postman

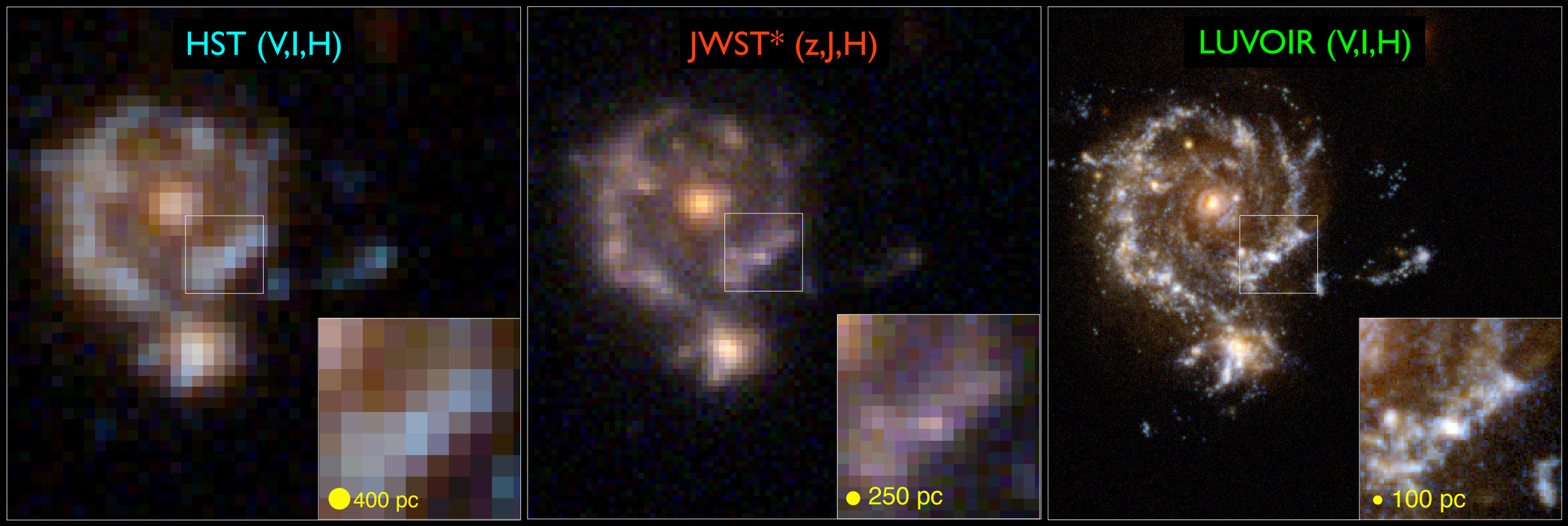
How Did the Milky Way Form from its Earliest Seeds?

Epoch
z = 1 - 8

Resolution
30-100 pc



Milky Way Progenitor at z = 2



With unique 100 parsec resolution in the optical at all redshifts, LUVOIR can resolve the building blocks of galaxies: individual star forming regions and dwarf satellites, including progenitors of the present-day dwarf spheroidals.

These high-resolution images will complement spectroscopy from 30m class ground-based telescopes and ALMA of the galaxies and their molecular gas. LUVOIR will spatially resolve SFR, Hα/Hβ, BPT diagnostics, HeI/Hβ, etc.

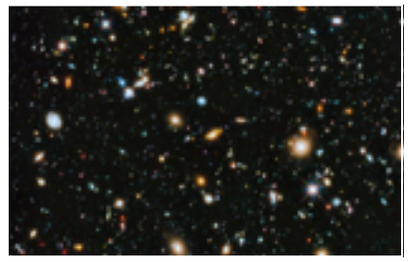
*JWST is optimized for longer infrared wavelengths than this, and is still awesome!

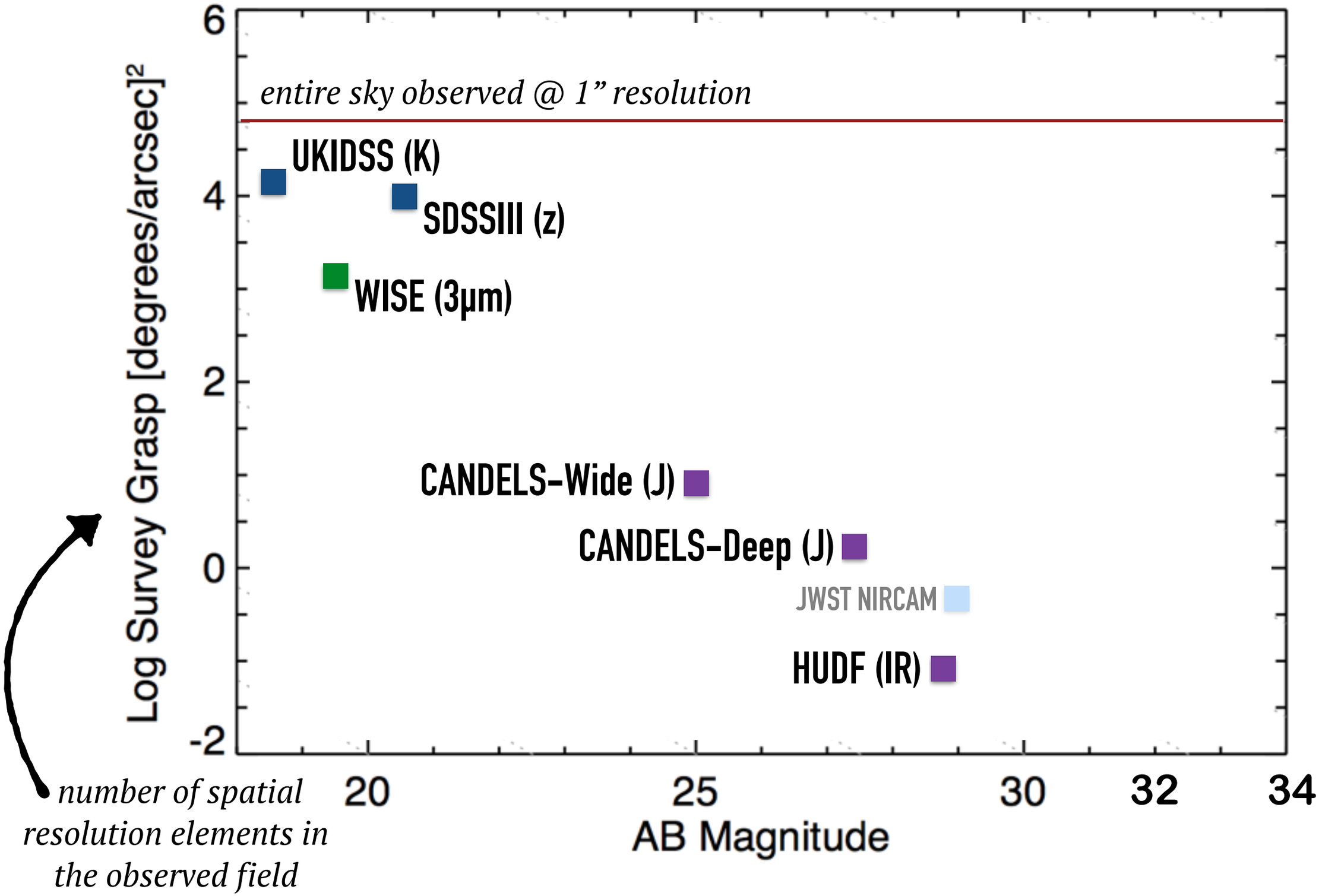
Images simulated by
Greg Snyder (STScI)

How Do Galaxies Grow, Evolve, and Die?

Epoch
z = 1 - 8

Resolution
30-100 pc





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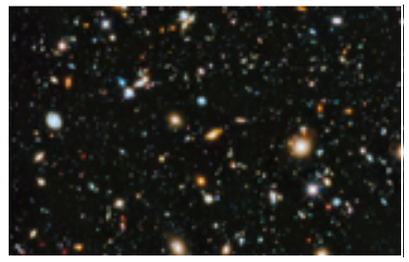

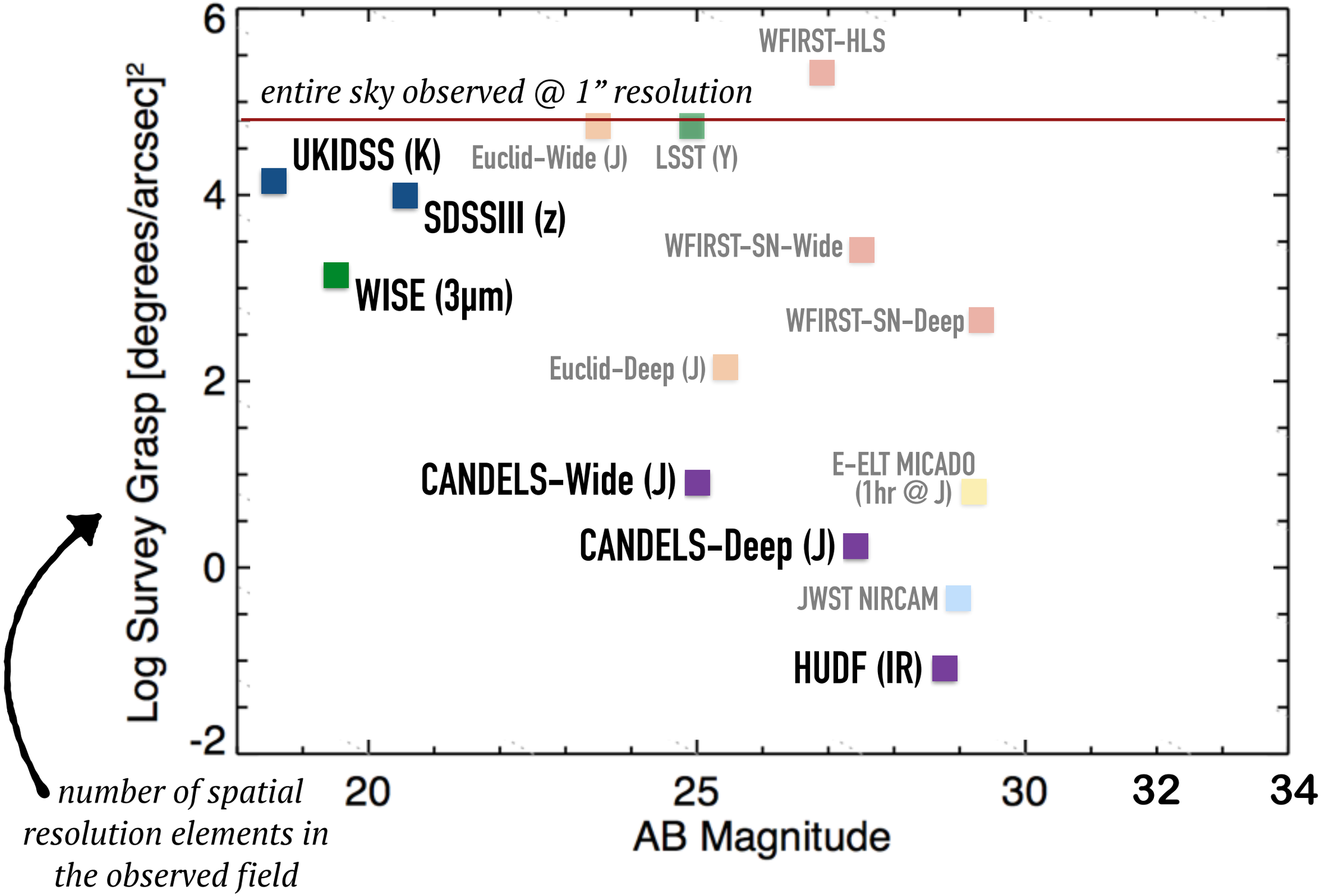

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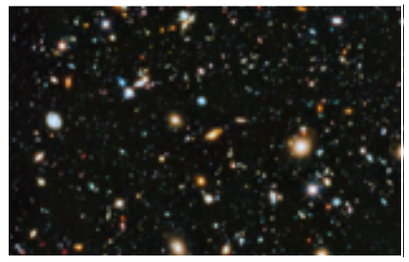

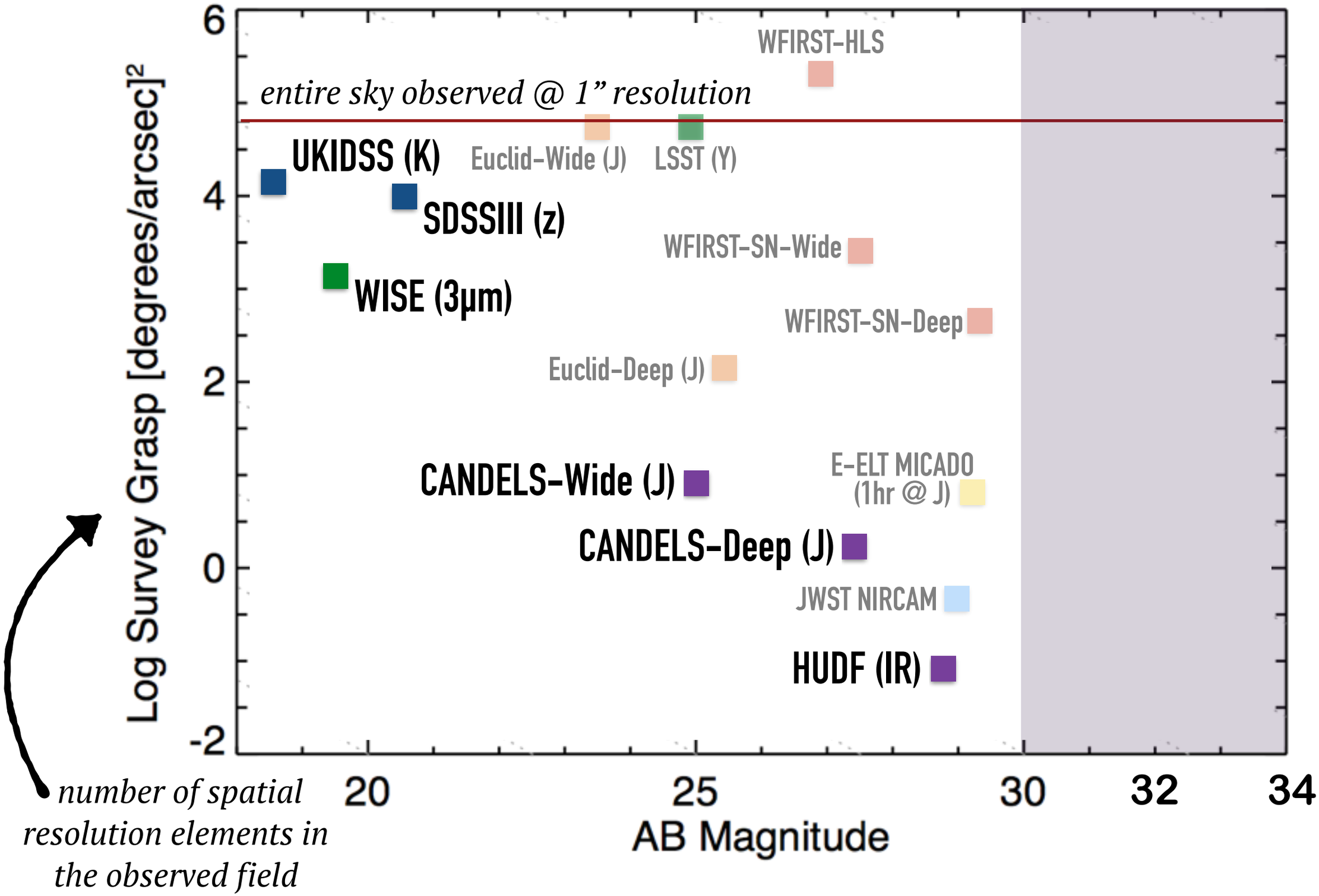

number of spatial resolution elements in the observed field

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How Do Galaxies Grow, Evolve, and Die?

Epoch
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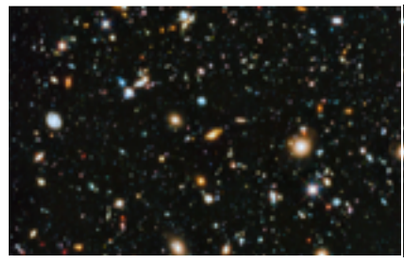
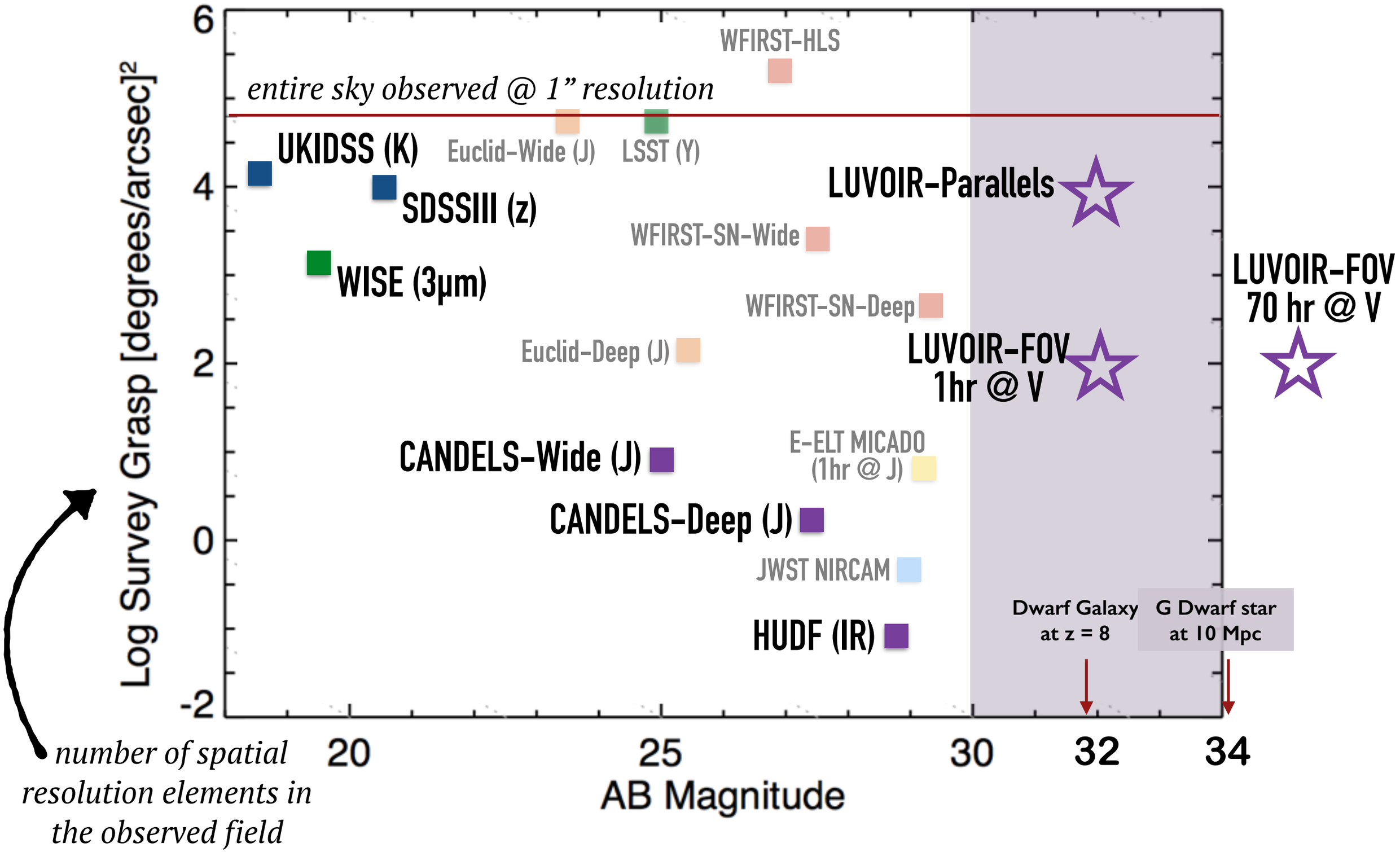
Resolution
30-100 pc





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The Gas - Galaxy Connection

How do galaxies transition to quiescence?
What are the dynamics of flows into and out of galaxies?
How (and where) does the baryonic lifecycle evolve?

FIRE Simulation Team: fire.northwestern.edu

z=30.0 **Stars & dust: u,g,r**

z=30.0 **Gas**

1 LUVOIR resel

10^6K

z=30.0 **Gas**

10^5K

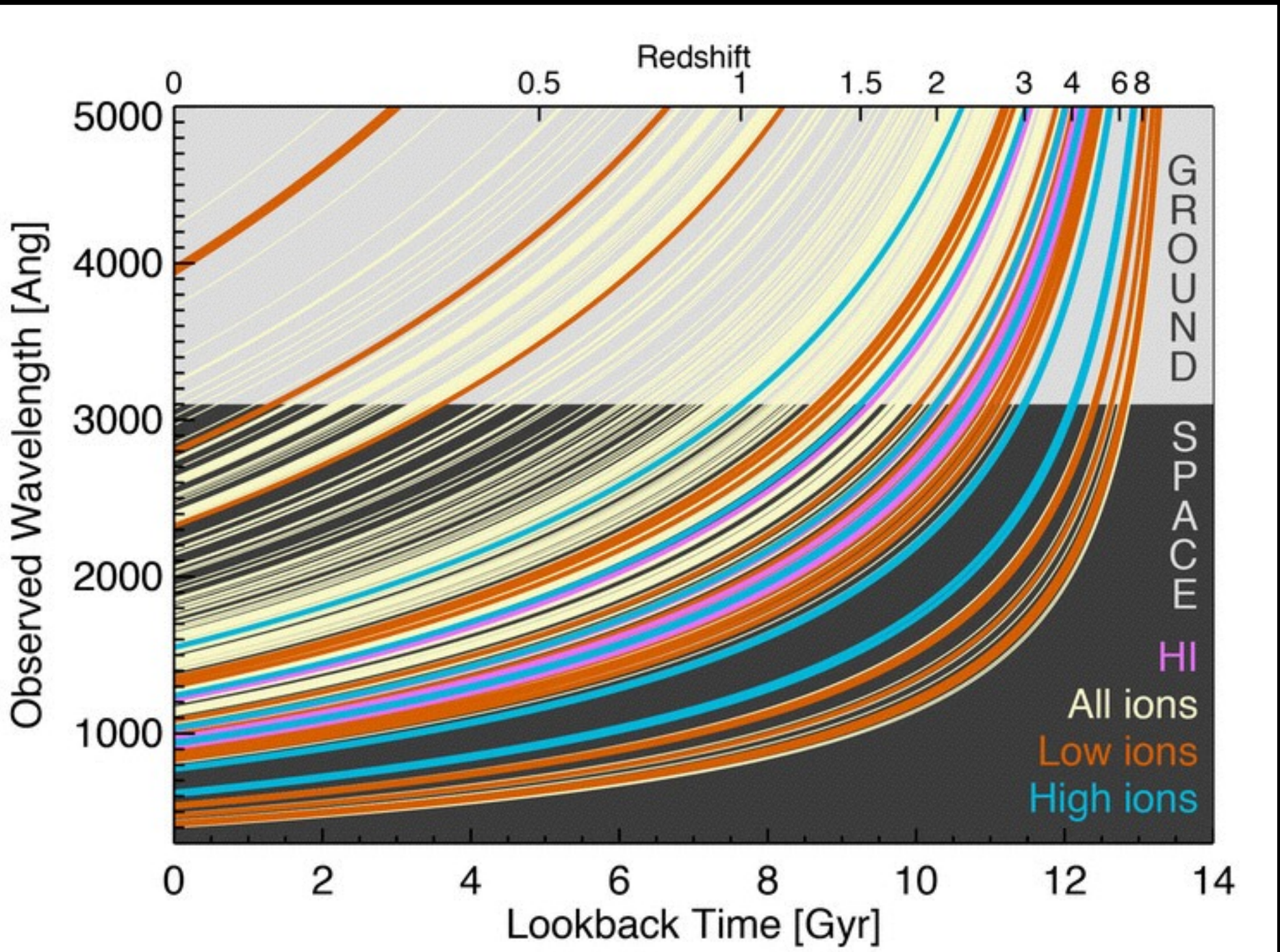
10^4K

10^3K

50 kpc

200 kpc = ~4000 LUVOIR pixels = 1/12th of FOV

UV Access is Essential!



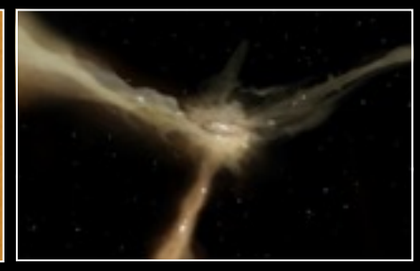
UV spectral features provide the some of the best, *and often unique*, constraints on:

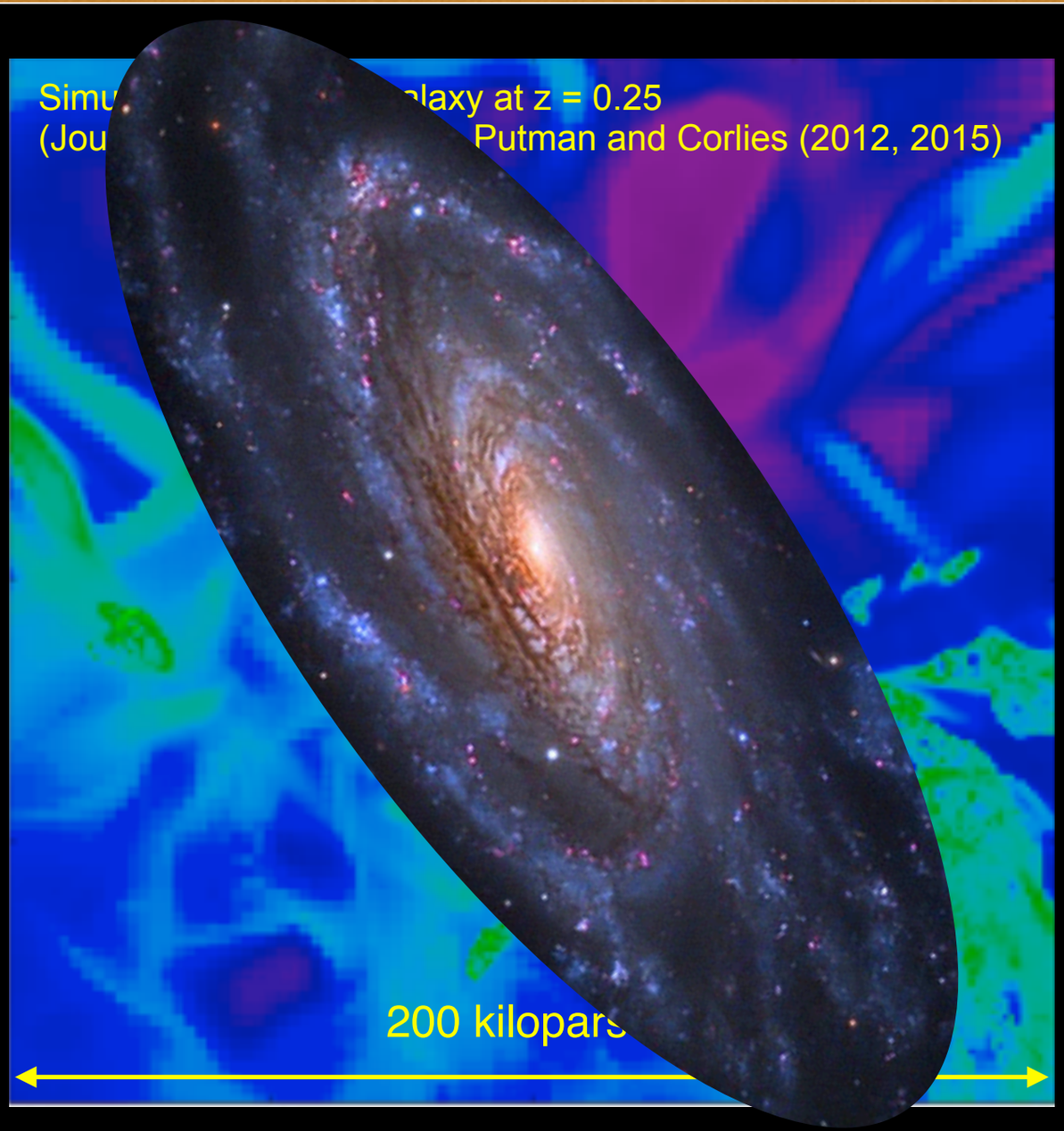
Ionization state of ISM, IGM
Structure in ISM, IGM
Sources of ionization
Gas Temperature
Metallicity of ISM, IGM
Gas Density
Star formation rate
Gas kinematics and outflows

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

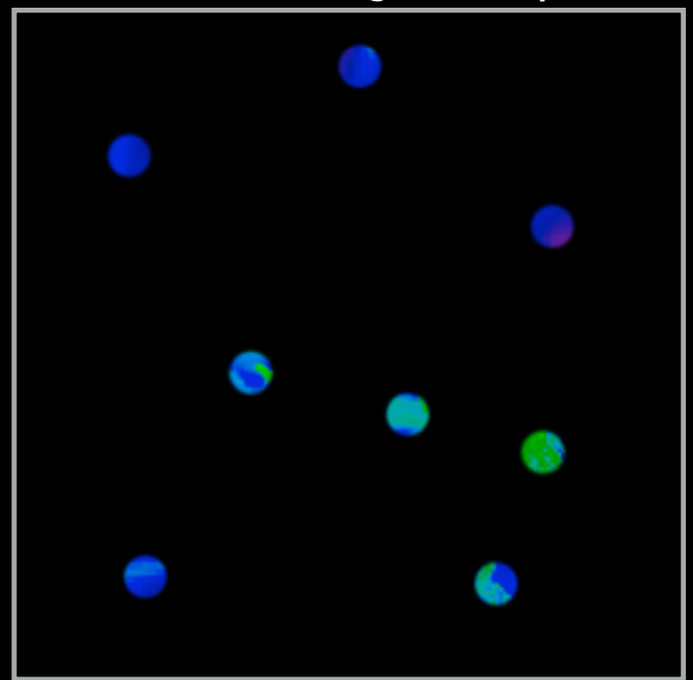
How Do Galaxies Acquire, Process, and Recycle Their Gas?

Epoch	Resolution
z < 1	10-100 pc

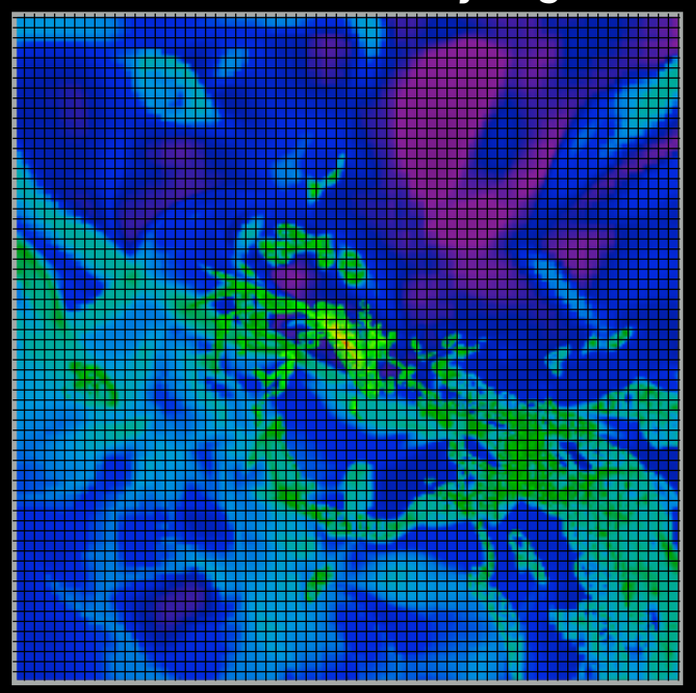




HST+COS & stacking of multiple FOV:



LUVOIR + UV MOS for any single FOV:

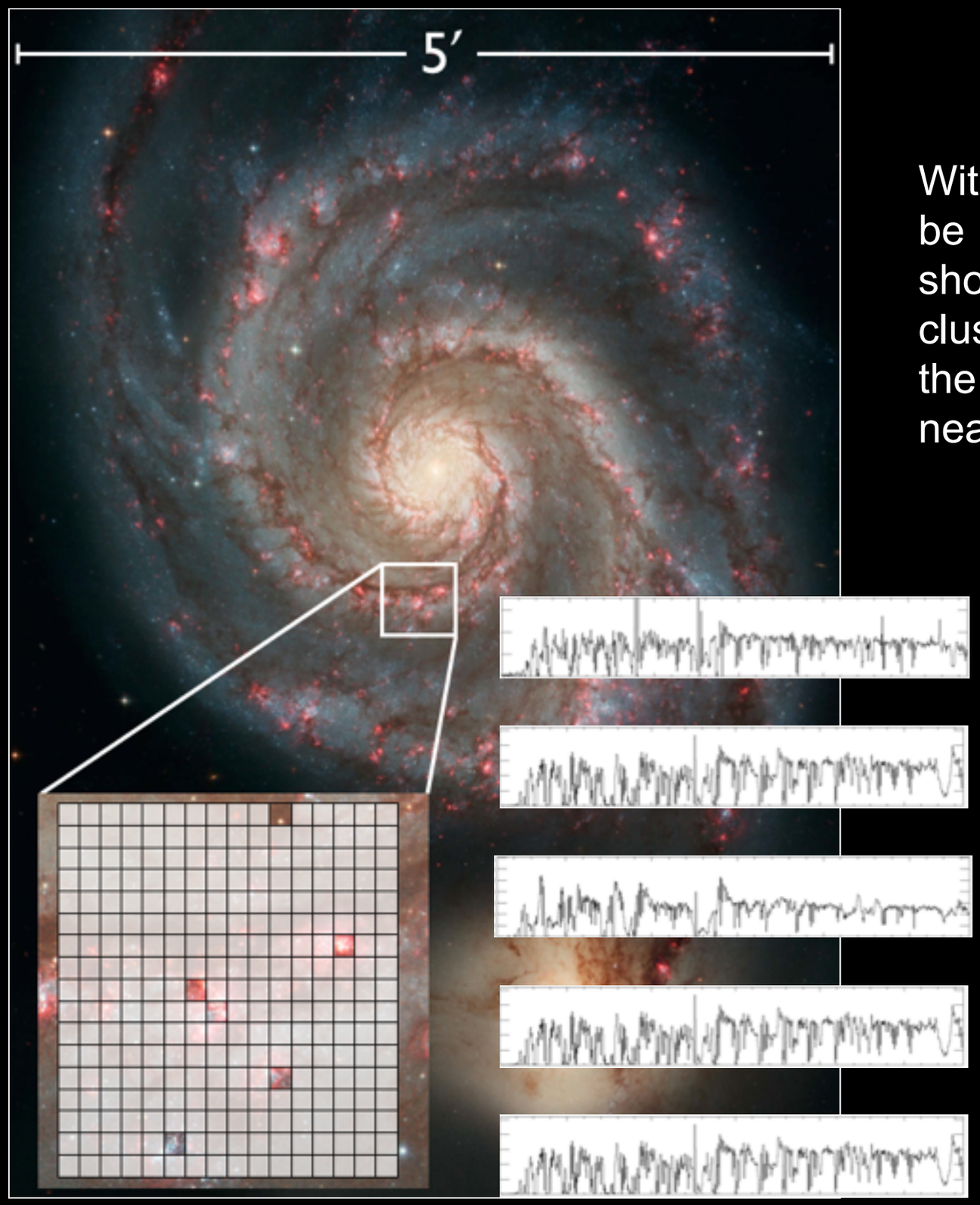


Using powerful and unique multi-object UV spectroscopy, LUVOIR will be able to map the “faintest light in the Universe” emitted from gas filaments entering galaxies and energetic feedback headed back out.

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

Epoch
$z < 1$

Resolution
10-100 pc



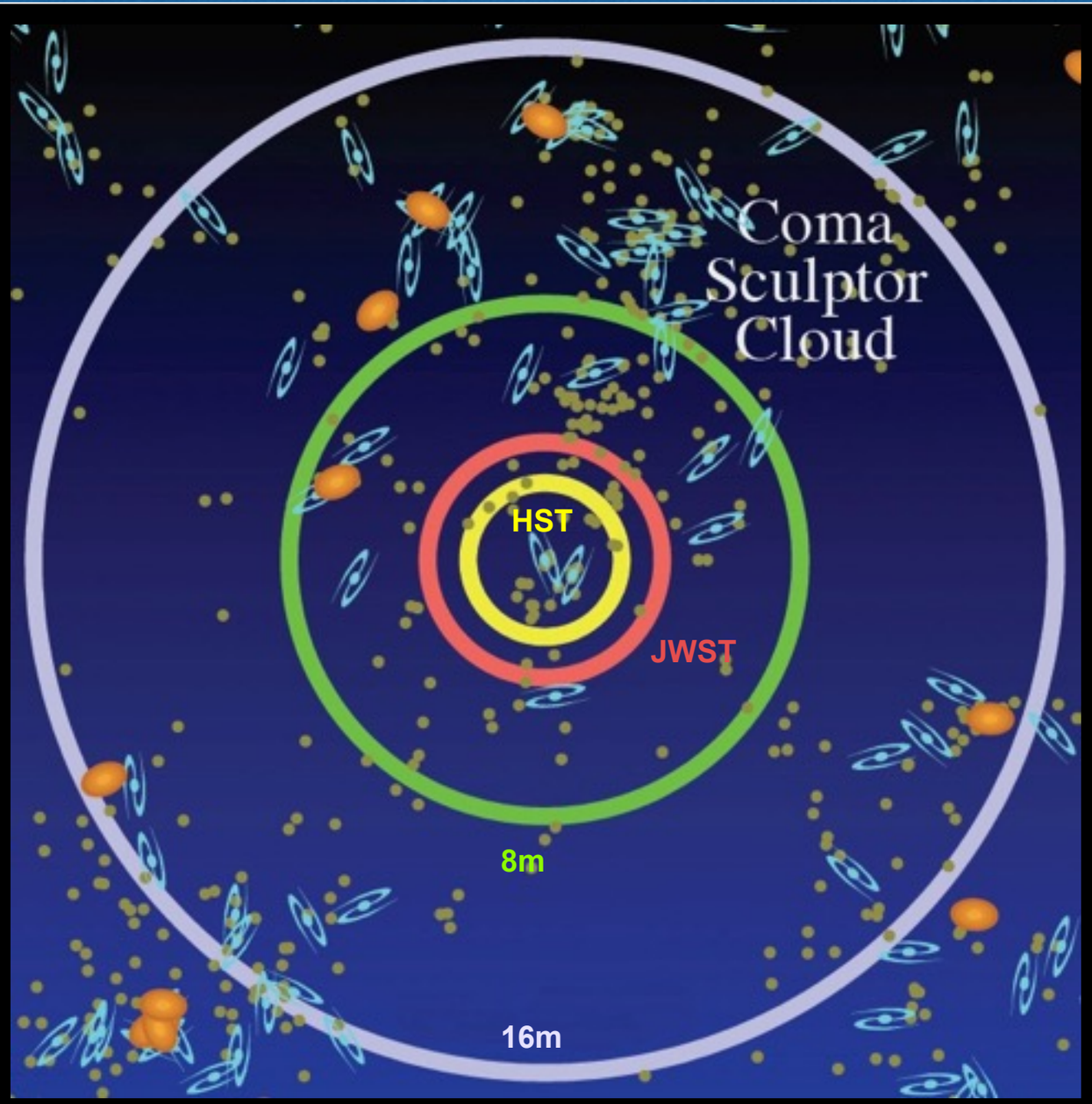
With the same UV multiplexing, LUVOIR will also be able to map (in nearby galaxies, like M51 shown here) the properties of young stellar clusters and, using them as background sources, the outflows they drive into the ISM and IGM in nearby galaxies.

These observations **require** UV capability and a 10 - 15 meter aperture.

How Does Star Formation History Create the Diversity Shapes and Sizes of Galaxies?

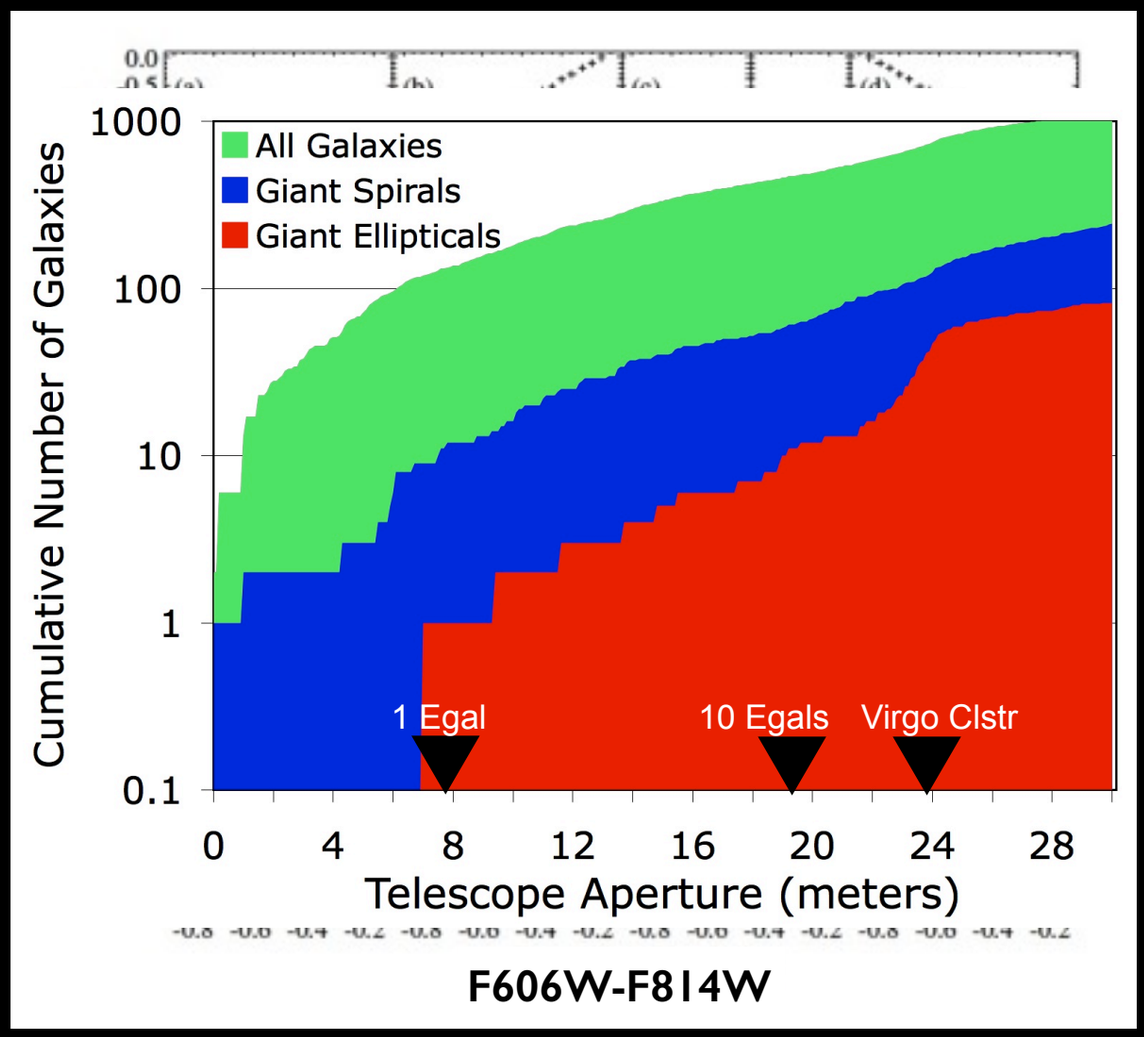
Volume
< 100 Mpc

Resolution
1 - 10 pc



Elliptical Spiral Dwarf

LUVOIR could also determine robust star-count IMFs down to 0.1-0.2 $M_\odot$ throughout the Local Group, including hundreds of new ultra faint dwarf galaxies to be mapped by LSST.

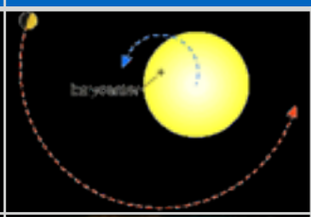


Star formation history sets both chemical evolution and planet formation rates. Visible bands provide best discrimination.

Requires diffraction limited optical imaging and high PSF stability.

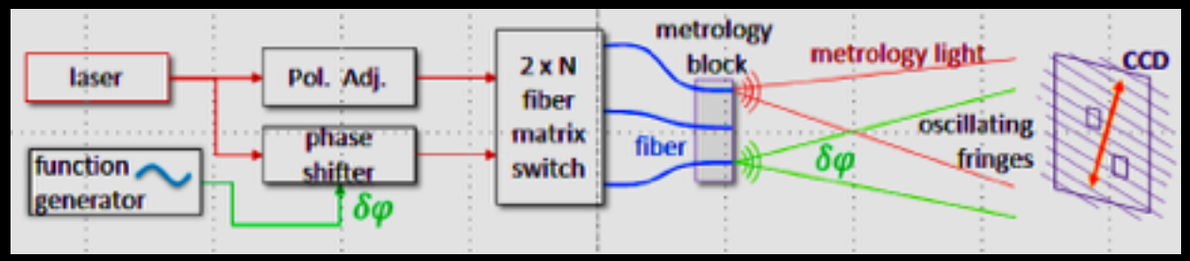
Aperture Driver: ≥10 m needed to resolve stellar pops down to 1 $M_\odot$ out to the nearest giant ellipticals.

What is the Dark Matter? How Does Light Trace Mass? How Does Dark Mass Move?	Volume < 10 Mpc	Resolution 0.1 - 1 pc	

Distance	Speed	Example	
10 pc (nearest stars)	10 cm s^{-1}		Exoplanet detection
100 pc (nearest SF regions)	1 m s^{-1}		Exoplanets in disks
10 kpc (entire MW disk)	100 m s^{-1}		dissipation of star clusters
100 kpc (MW halo)	1 km s^{-1}		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

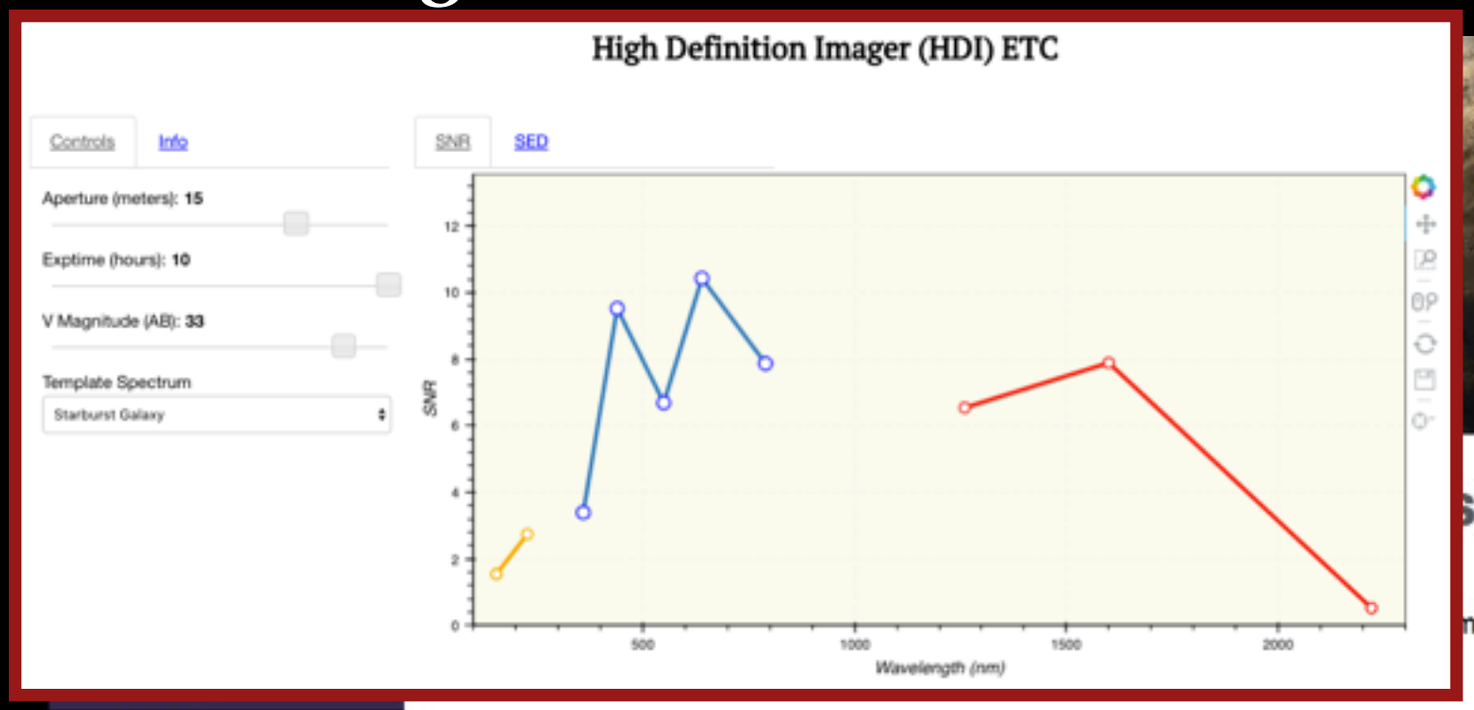
LUVOIR should be able to measure proper motions to ~ microarcsec / year precision over a ten-year baseline.

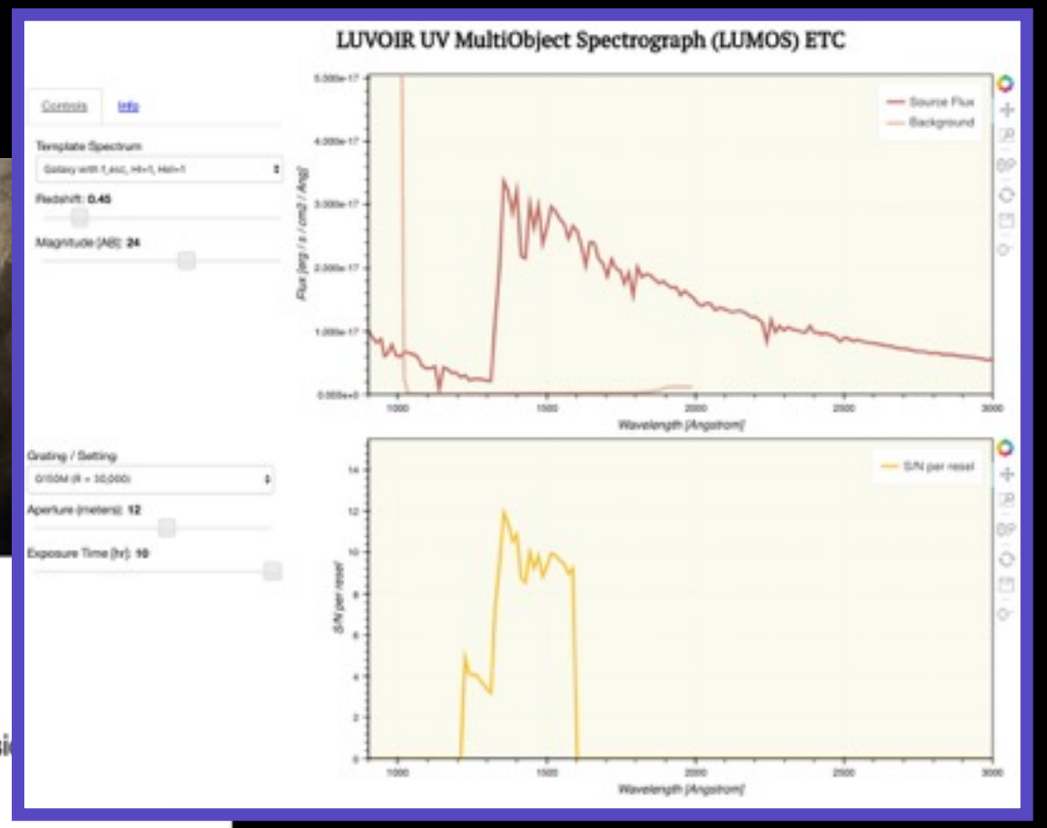
At this level, **virtually everything on the sky moves** - every star in the Milky Way and Local Group and every galaxy in the Galactic Neighborhood.

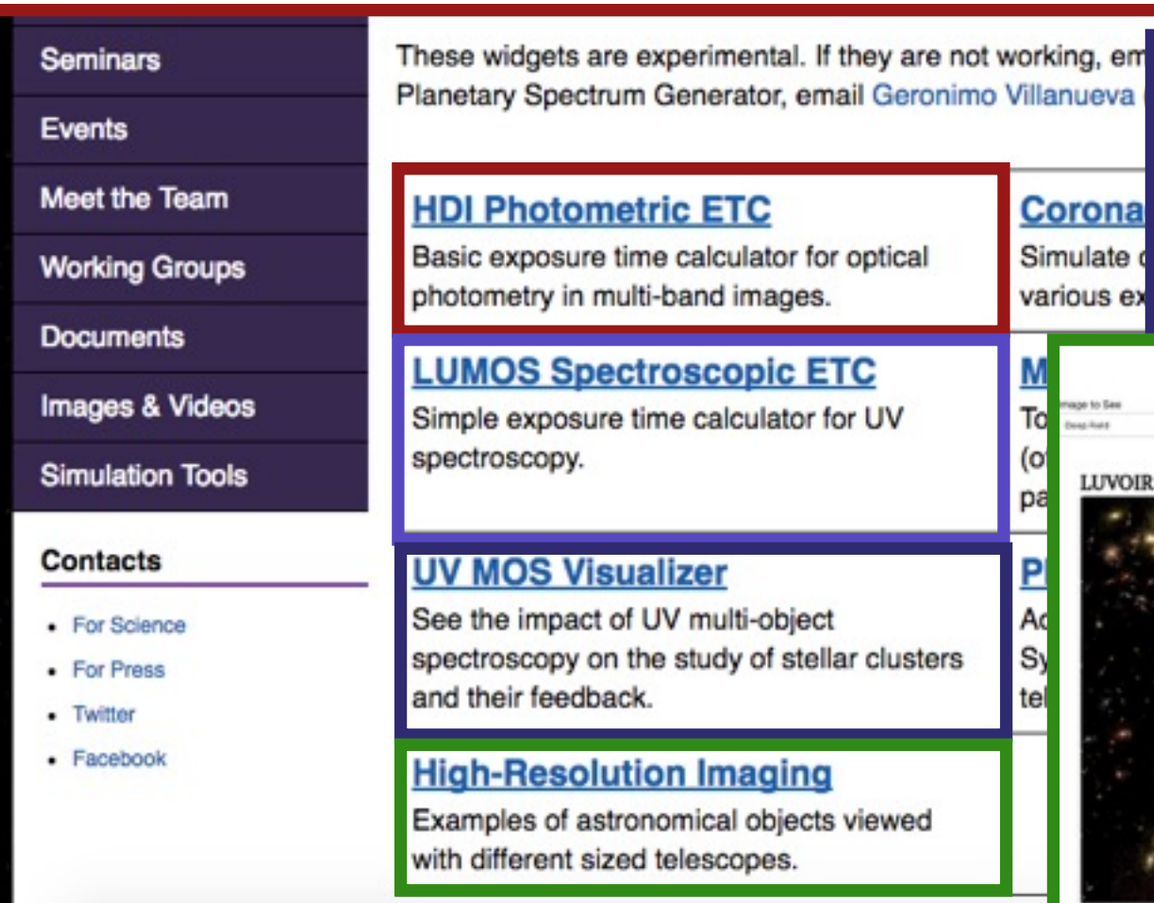


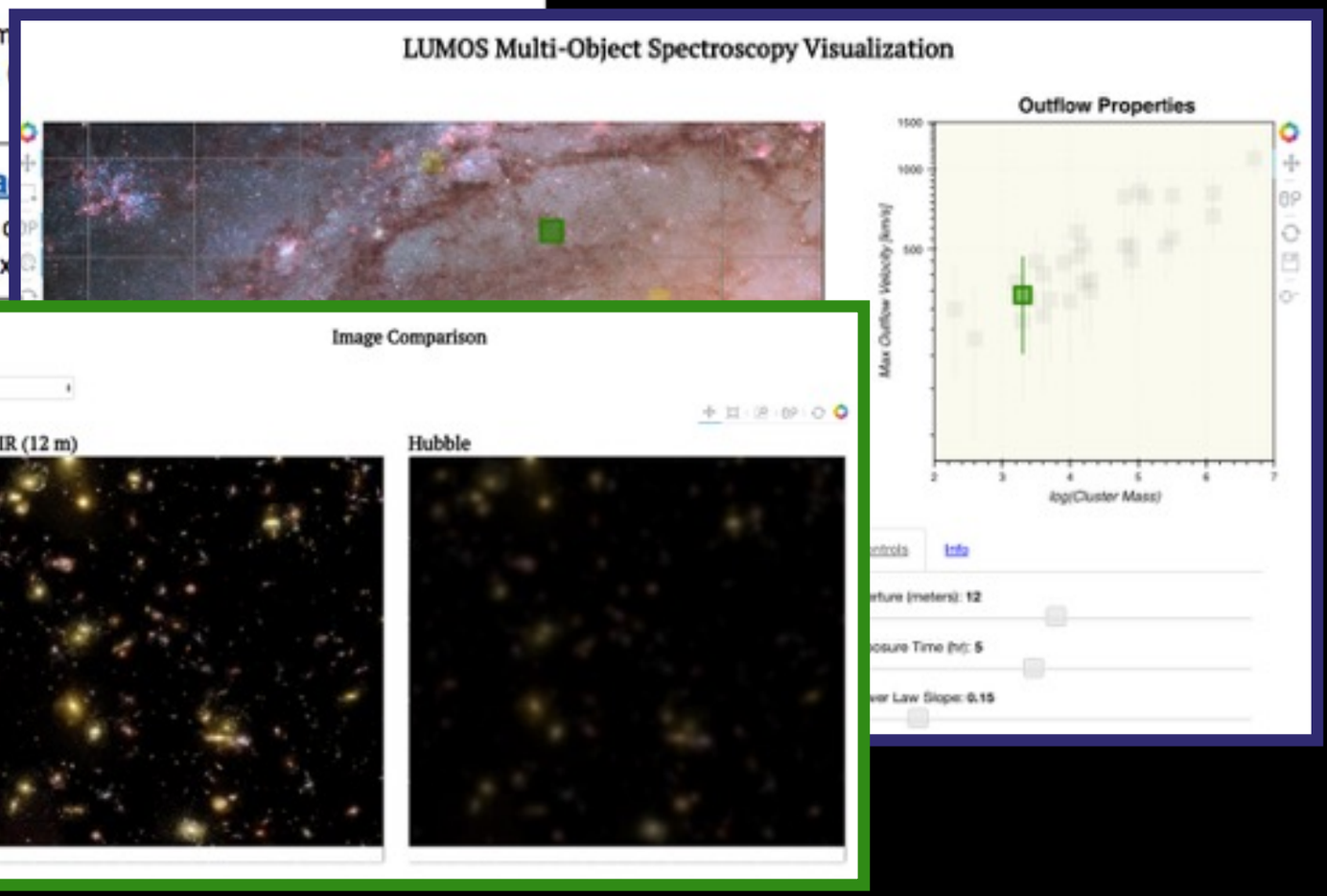
<u>System driver:</u> Extremely well-calibrated detector pixel positions and low-noise detectors are needed to centroid objects to less than 1 thousandth of a pixel. A concept like the one being studied by Shao at JPL would enable this level of accuracy.

Simulating Your LUVOIR Science:









https://asd.gsfc.nasa.gov/luvoir/tools/