Resolving galaxy evolution across cosmic time

Extragalactic Astrophysics Group

Cavendish Laboratory (Department of Physics)

Kavli Institute for Cosmology, Cambridge (KICC)

Extragalactic Astrophysics Group

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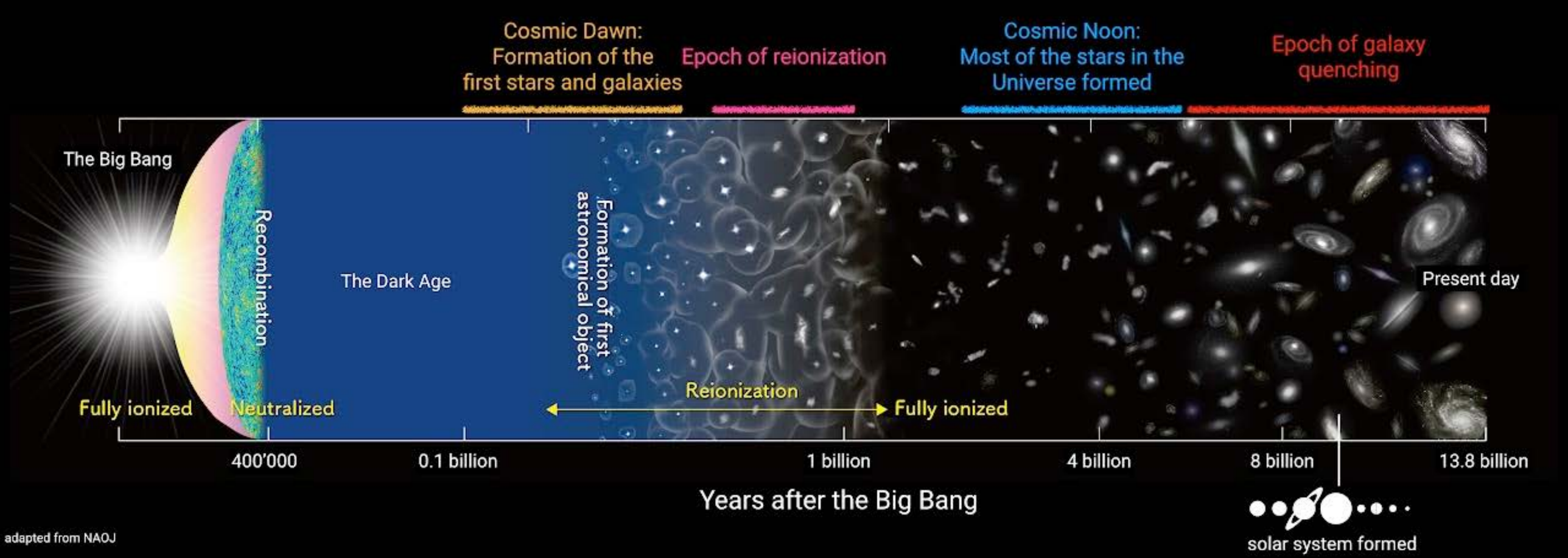
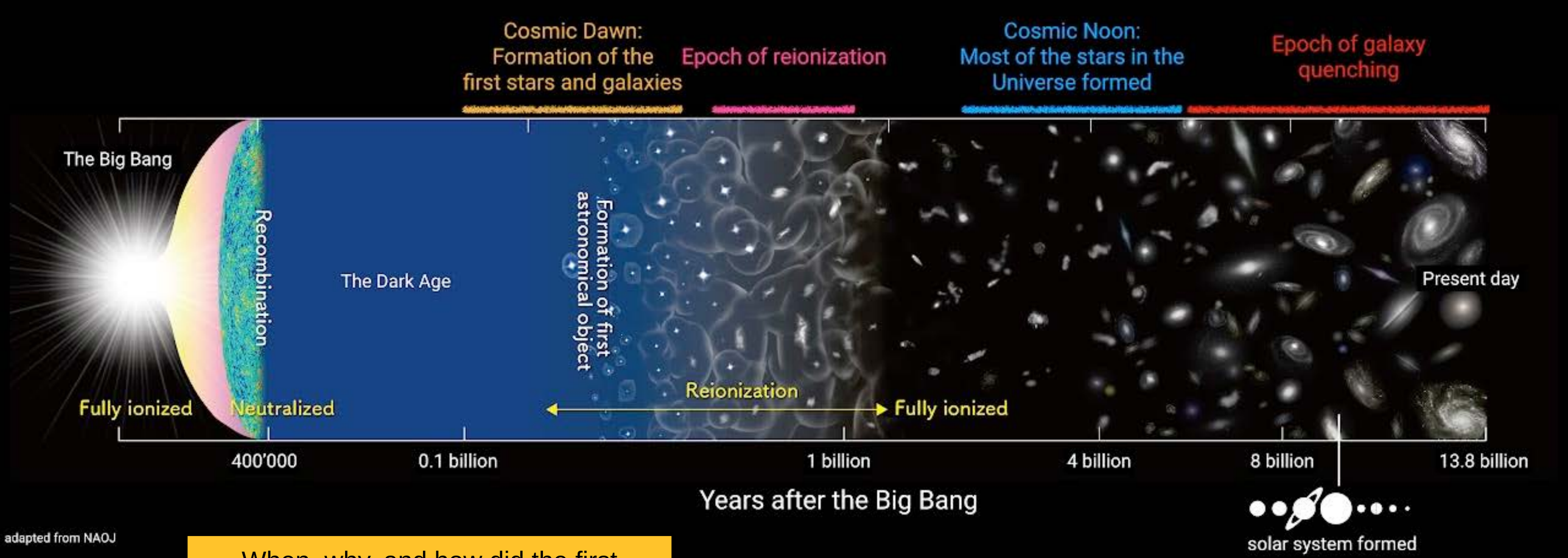
...and greatly supported by Steve & Alison!



adapted from NAOJ



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When, why, and how did the first galaxies form and the Dark Ages end?

How do galaxies chemically enrich?

How do galaxies regulate and quench star formation? Formation of the first quiescent galaxies?

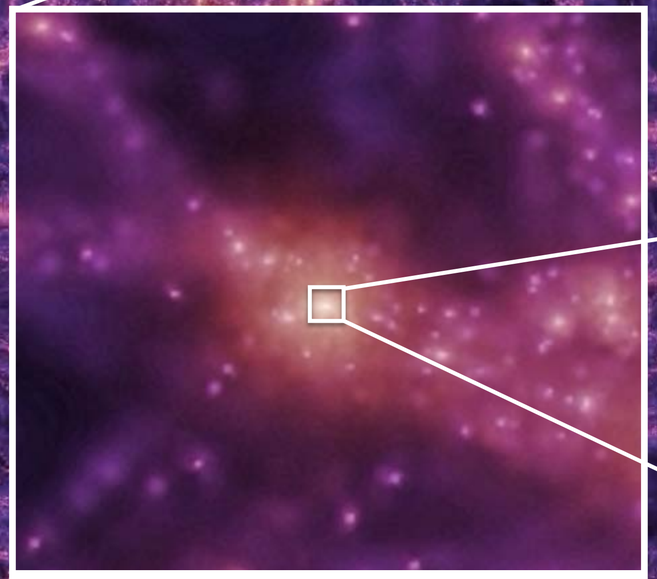
Which sources reionize the Universe?

What are the stellar populations of the first galaxies? PopIII? BH?

When and how do galaxies form their bulge and disk components?

cosmic web (~Gpc)

125 Mpc/h



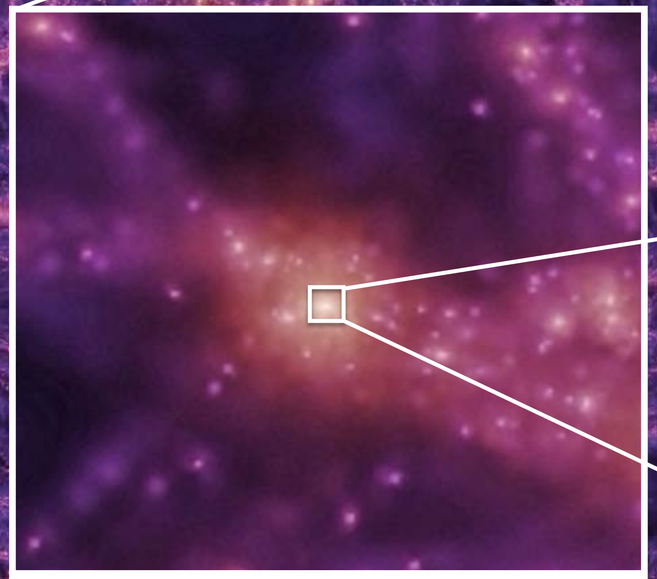
dark matter halos (~Mpc)

galaxies (~kpc)

1 pc = 3 ly = 3×10^{16} m

cosmic web (~Gpc)

125 Mpc/h



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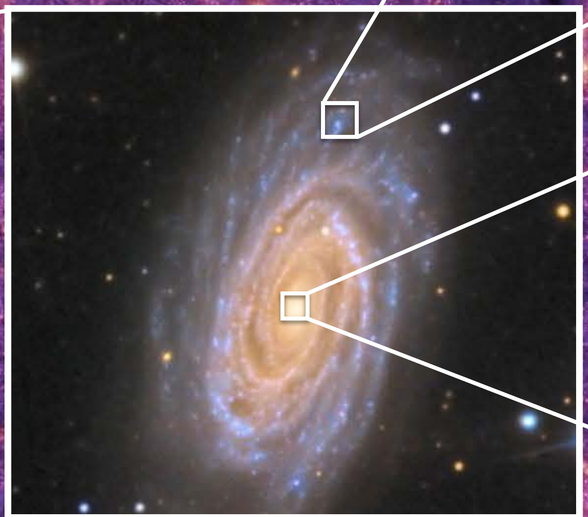
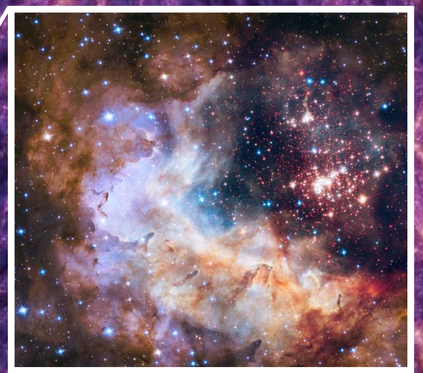
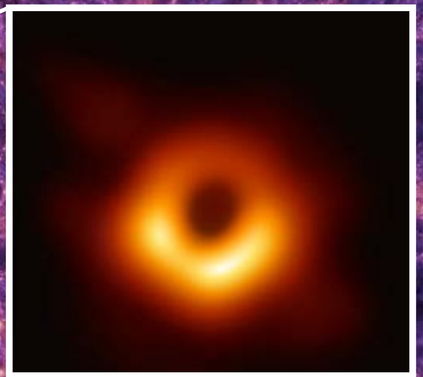


galaxies (~kpc)



star formation (~pc)



black holes (0.01pc)

1 pc = 3 ly = 3×10^{16} m

cosmic web (~Gpc)

125 Mpc/h

formation and diffusion of cosmic rays

formation of stars molecular clouds

gas flow & cooling

supernova explosions

magnetic fields

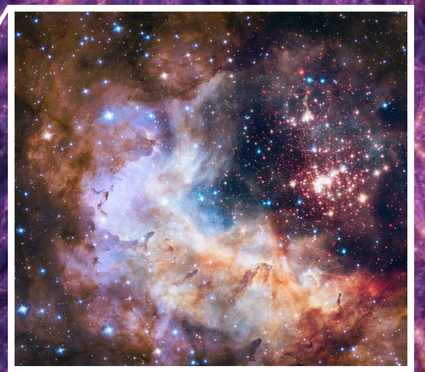
stellar winds

interstellar medium

black hole activity

radiation fields

black hole growth



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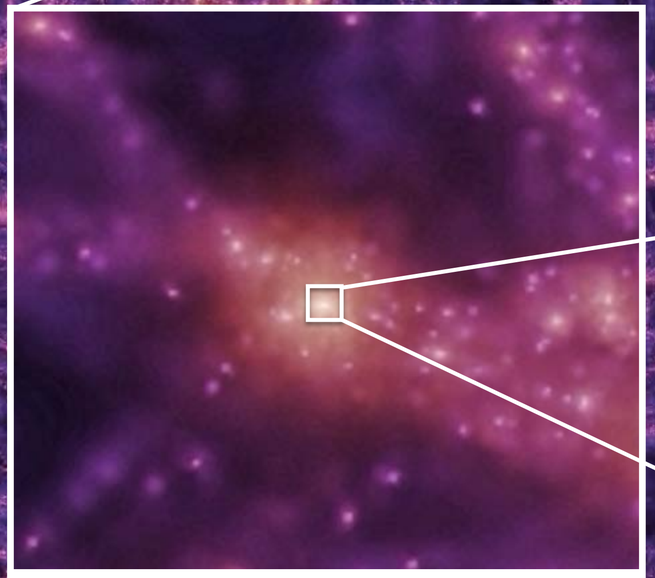

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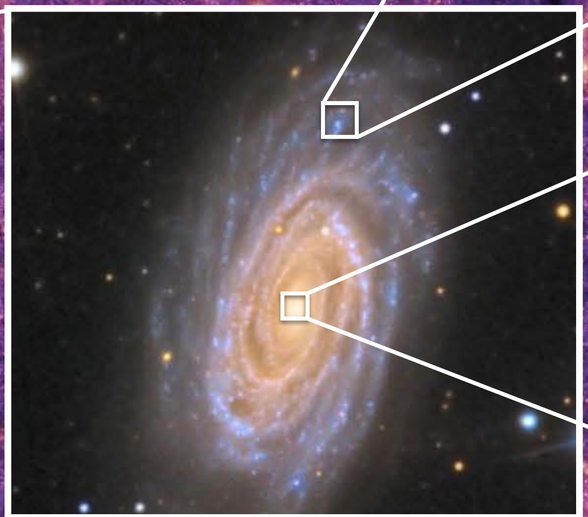

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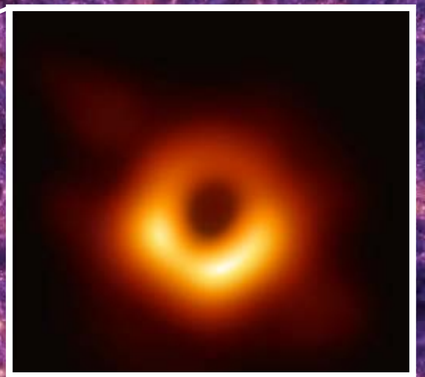

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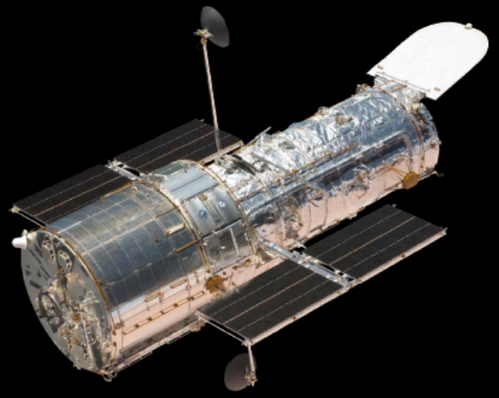
Progress through observational discoveries



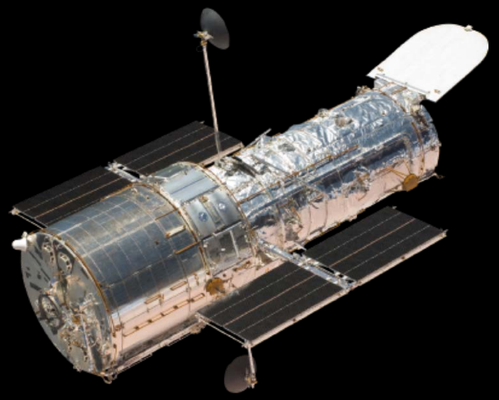
Hubble Space Telescope

Very Large Telescope at Paranal, Chile

ALMA Radio Telescope

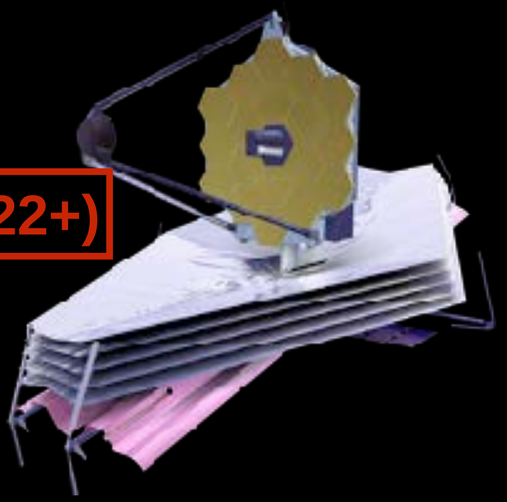
Extremely Large Telescope (ELT)

Progress through observational discoveries



Hubble Space Telescope

JADES (2022+)



James Webb Space Telescope

MOONS (2023+)

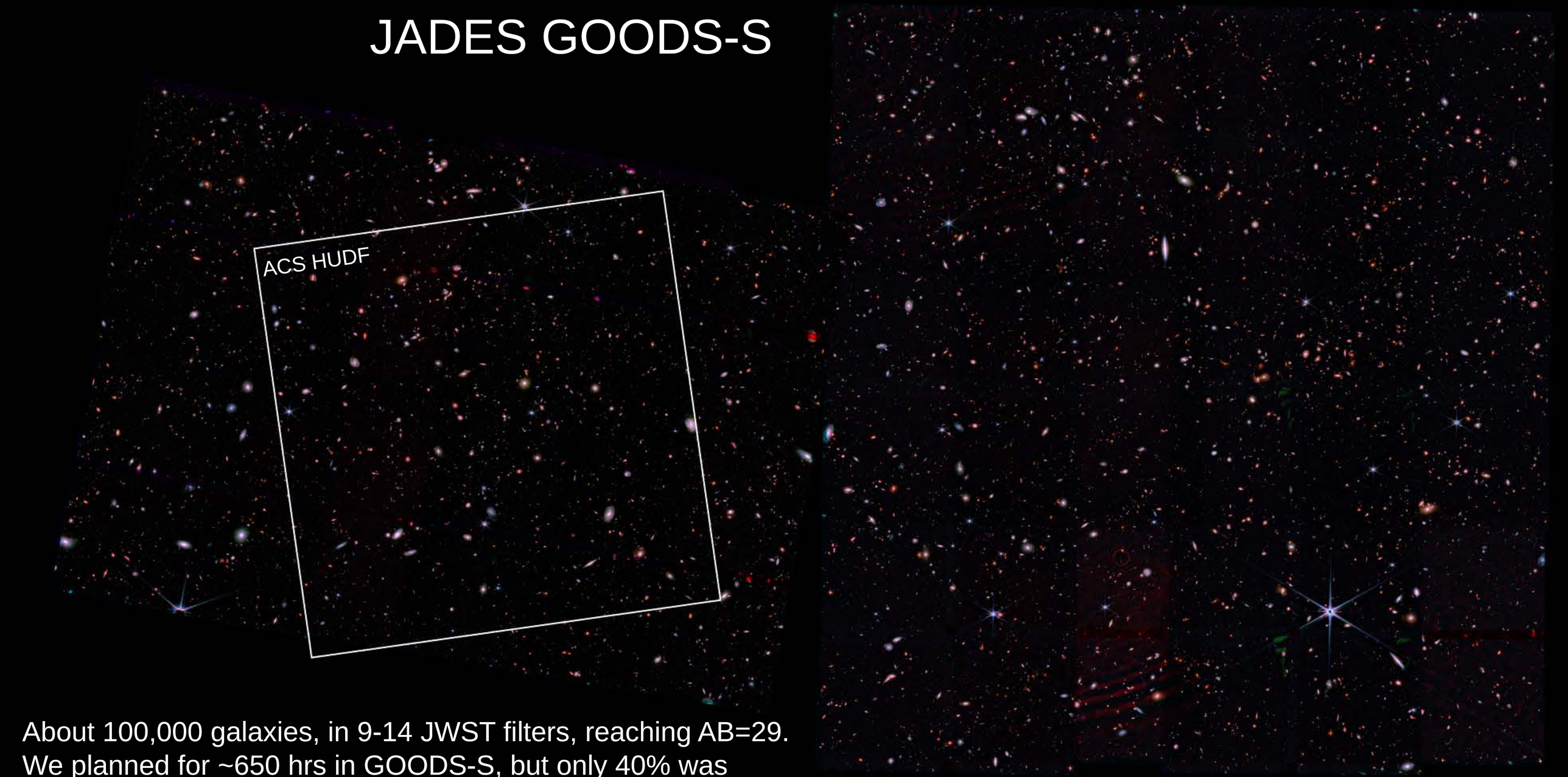
Very Large Telescope at Paranal, Chile

ALMA Radio Telescope

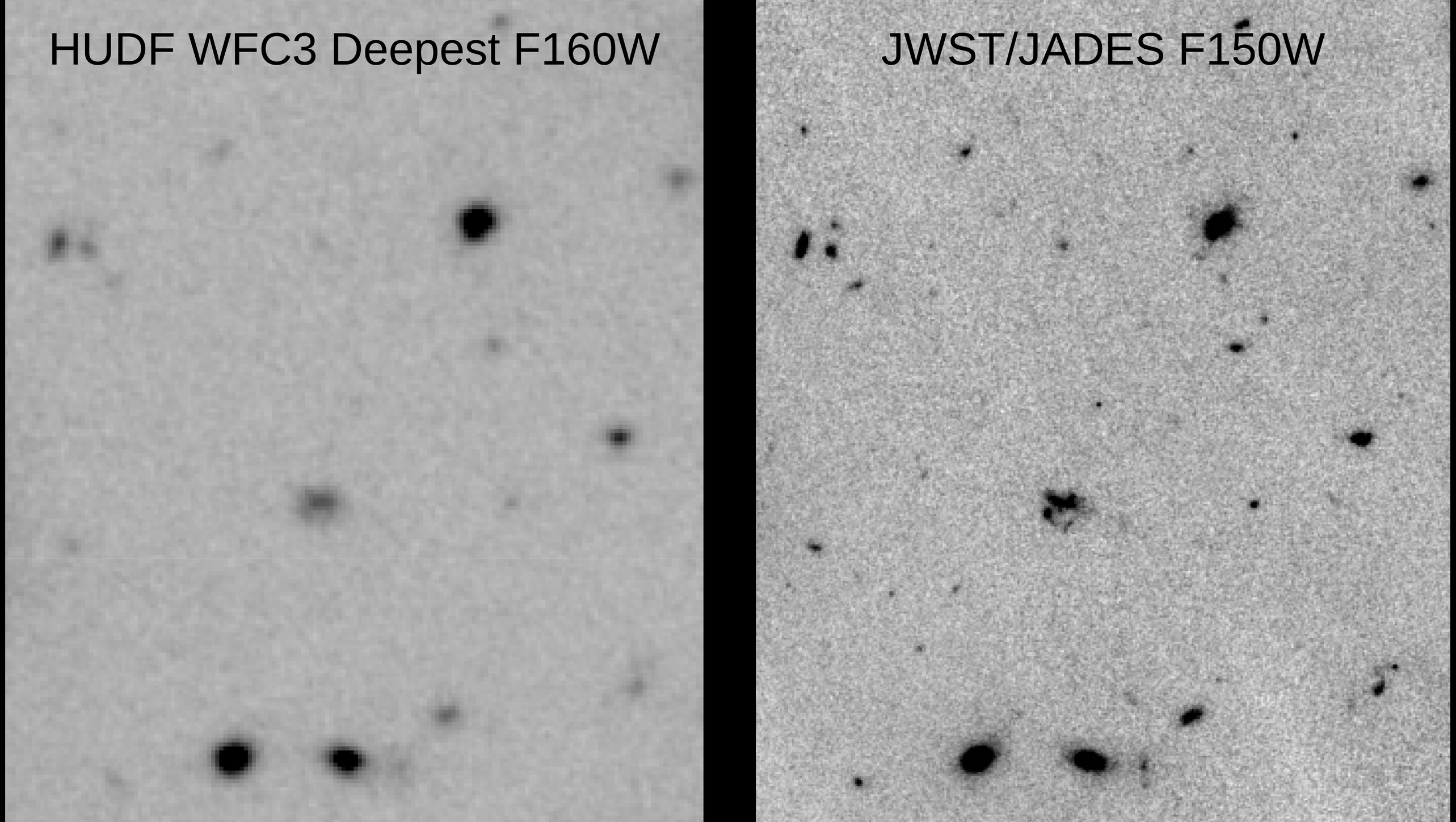
ANDES (2027+)

Extremely Large Telescope (ELT)

JADES GOODS-S



About 100,000 galaxies, in 9-14 JWST filters, reaching AB=29.
We planned for ~650 hrs in GOODS-S, but only 40% was scheduled in Year 1.


HUDF WFC3 Deepest F160W
JWST/JADES F150W

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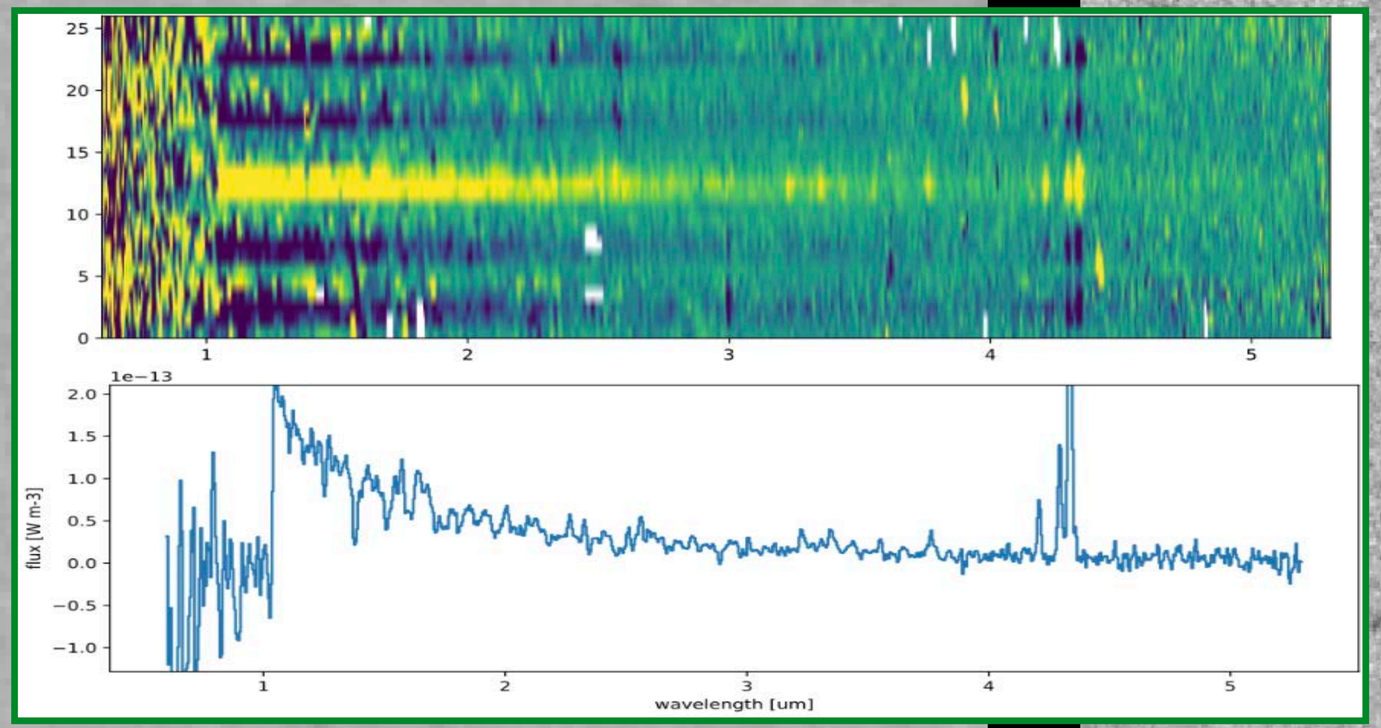

Unprecedented discovery space with MOONS

- MOONS: exceptional combination of large multiplexing, high sensitivity, broad spectral coverage, large area and high fiber density
- Cambridge is part of the MOONS consortium
- MOONRISE: SDSS-like survey around Cosmic Noon (redshift z~1-2.5)

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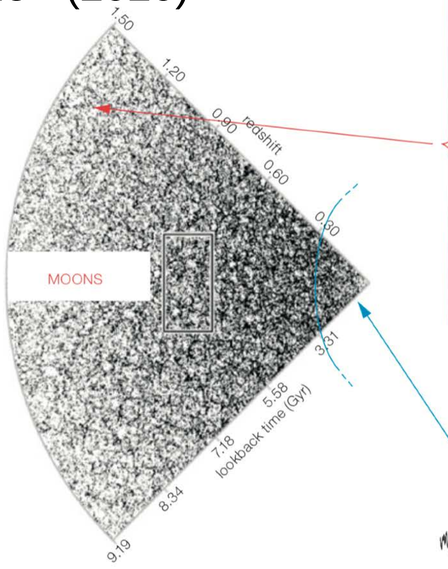
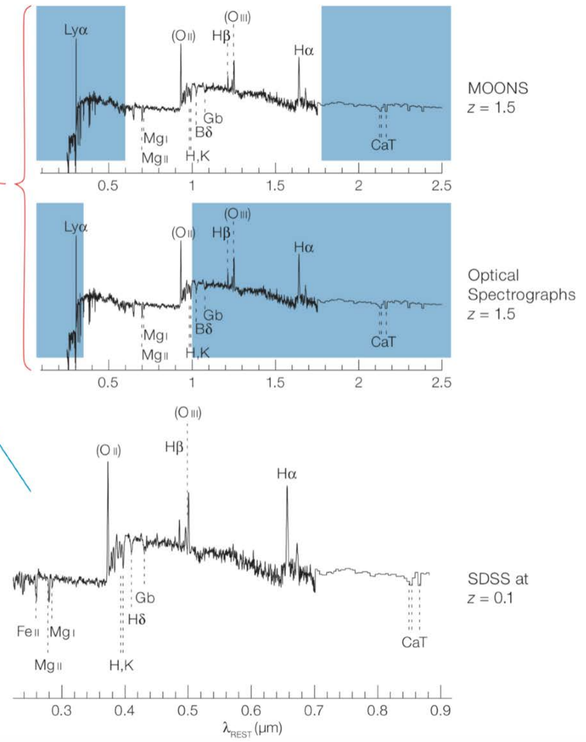
Maiolino+ (2020)



Survey	Redshift	Volume (h^{-3} Mpc^3)	#Objects
SDSS	$0 < z < 0.2$	1×10^6	10^6
MOONS	$0.8 < z < 1.8$	5×10^7	2.5×10^6

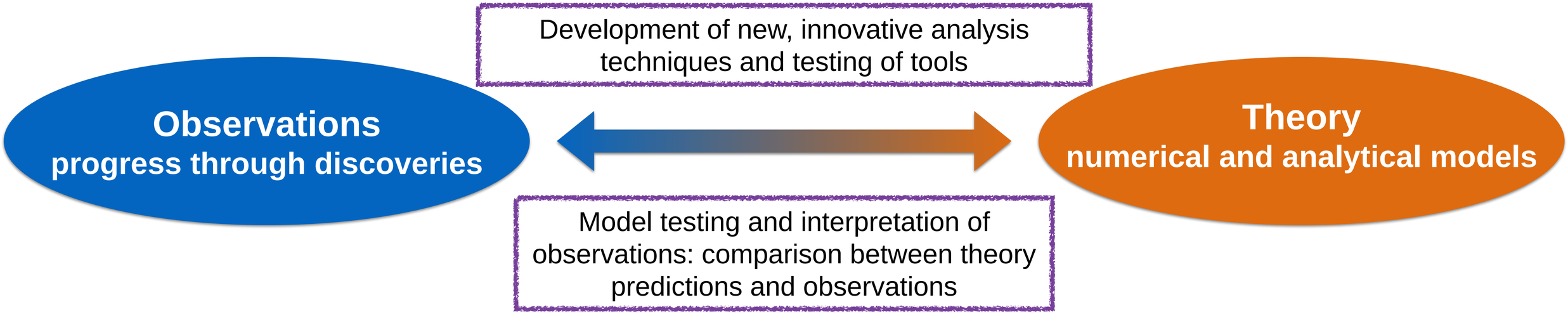


Our key focus:

- Star-formation variability: what regulates star formation?
- Chemical abundances and star-formation histories
- Which role do black holes play in shutting down star formation?
- How does the environment affect the evolution of galaxies?

Integrated approach between observations & theory

➜ “Precision Galaxy Formation Studies”



Integrated approach between observations & theory

➜ “Precision Galaxy Formation Studies”

Development of new, innovative analysis techniques and testing of tools

Observations
progress through discoveries

Theory
numerical and analytical models

Model testing and interpretation of observations: comparison between theory predictions and observations

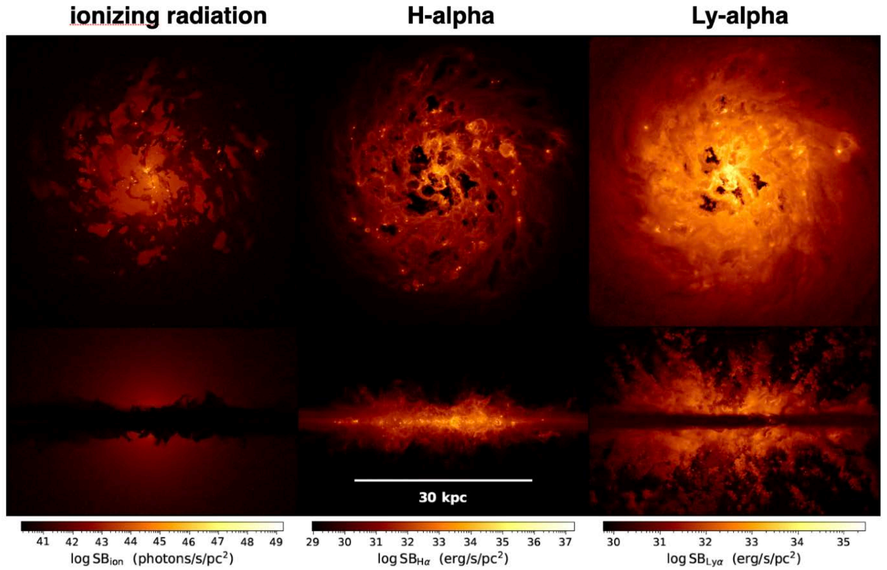
complex

numerical simulations

semi-analytical models

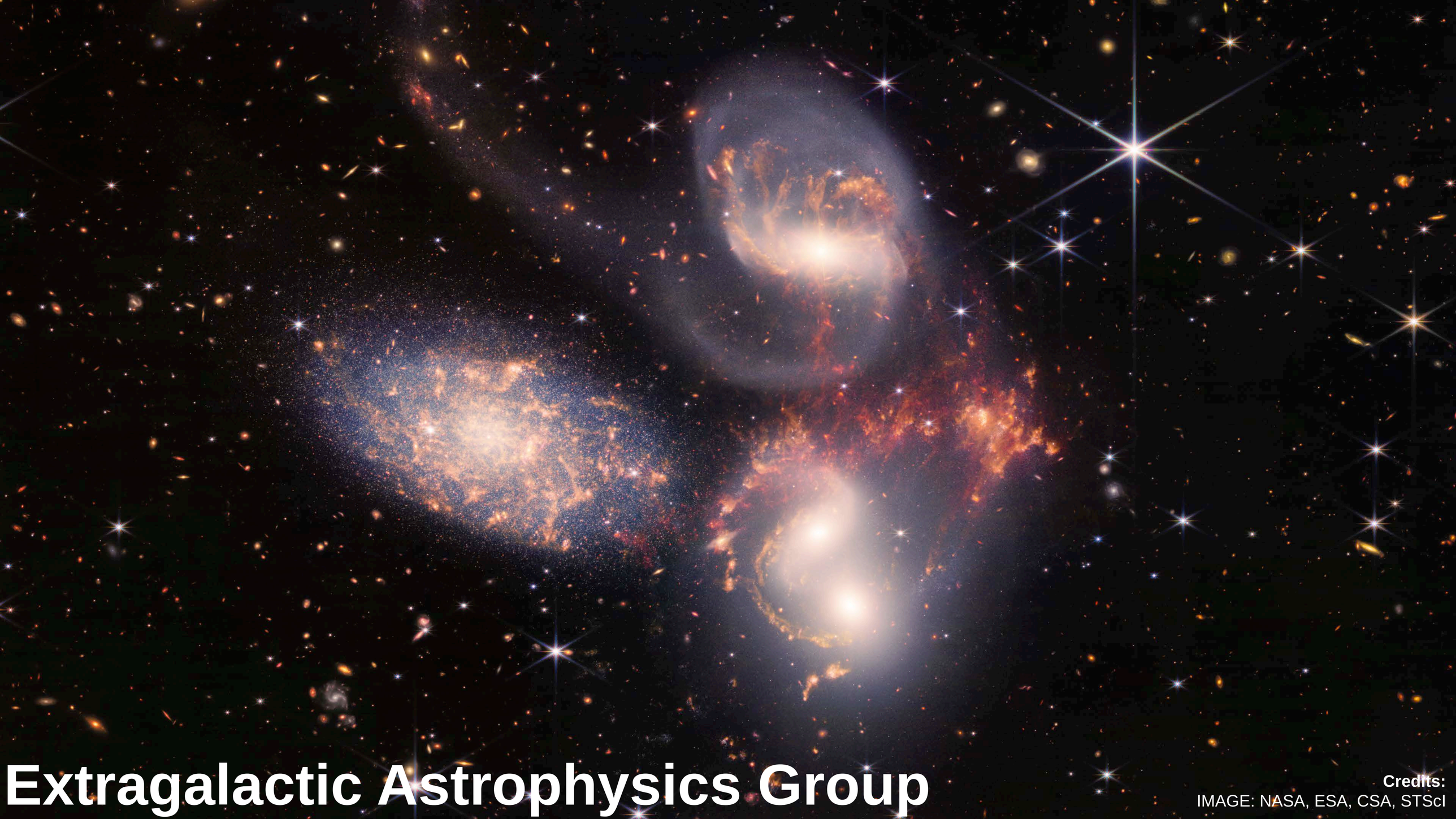
empirical models

simple



detailed radiative transfer (MCRT) analysis that include radiative transfer, non-equilibrium thermochemistry, and dust evolution

Smith, Kannan, Tacchella et al. (2022)
Tacchella et al. (2022c)



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Credits:
IMAGE: NASA, ESA, CSA, STScI