JWST:
eyes to the distant, infrared Universe

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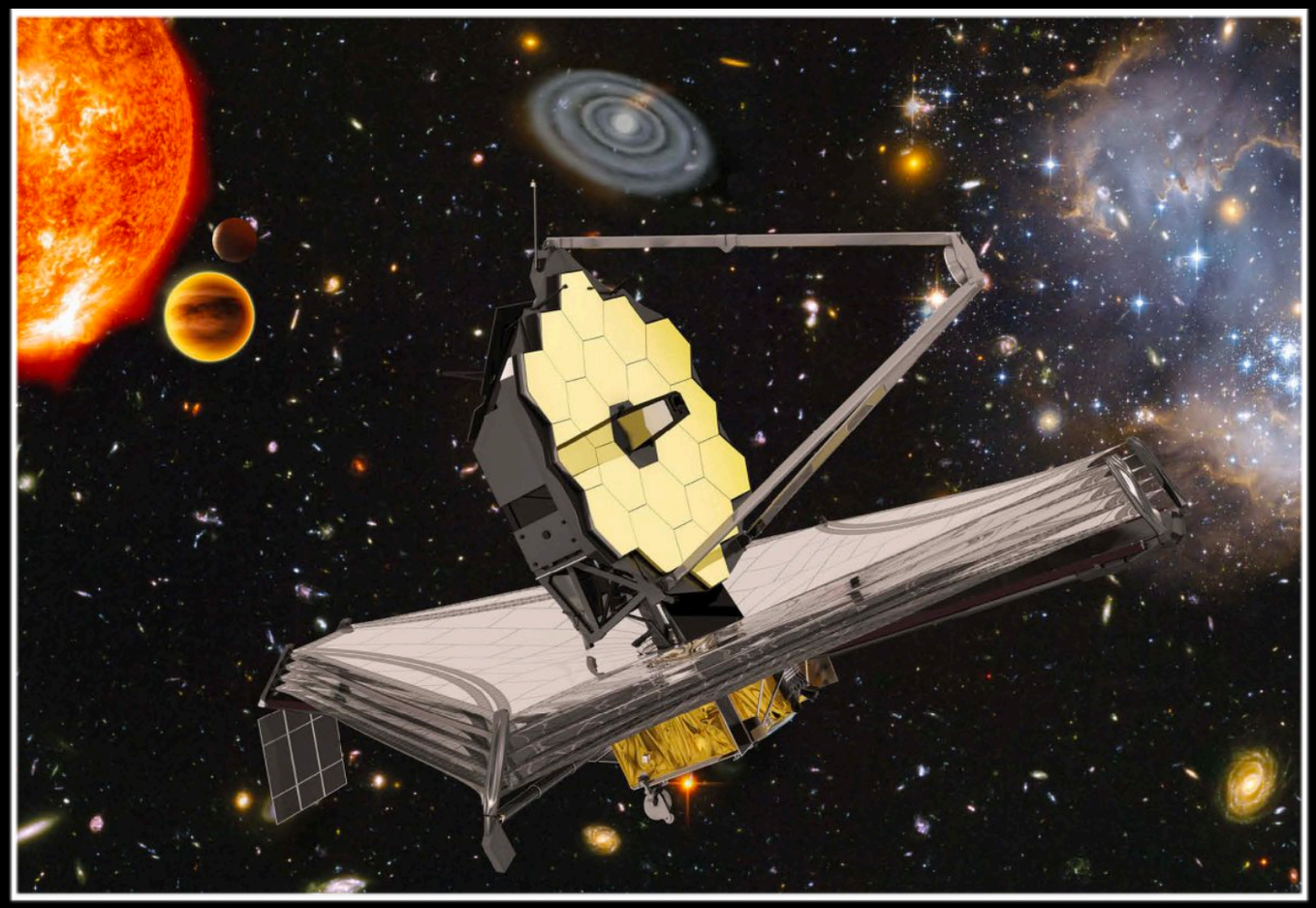
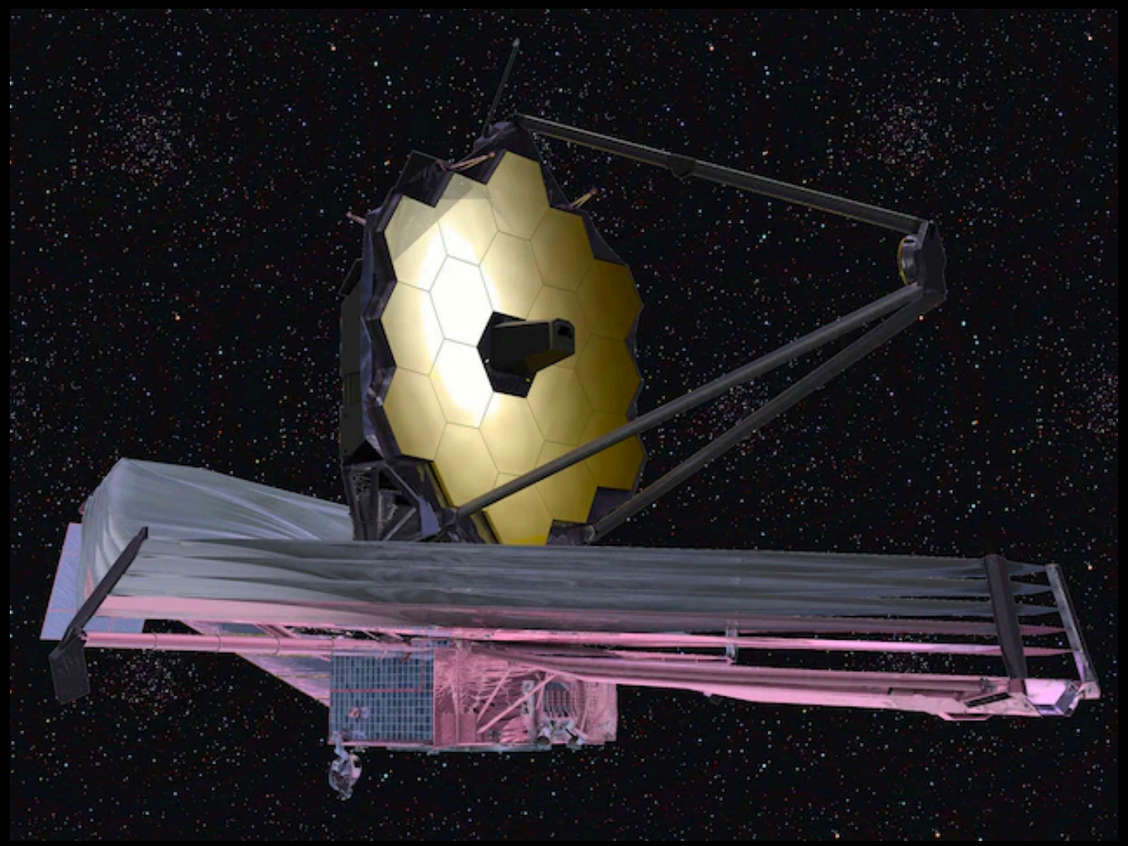


Colloquium, Faculty of Physics, UW, 08/05/2023

Content

1. Advent of astronomical extragalactic research in 21. century
2. Why we need JWST to understand evolution of galaxies?
3. “Unfold the Universe” - how JWST works?
4. Science and first results with JWST



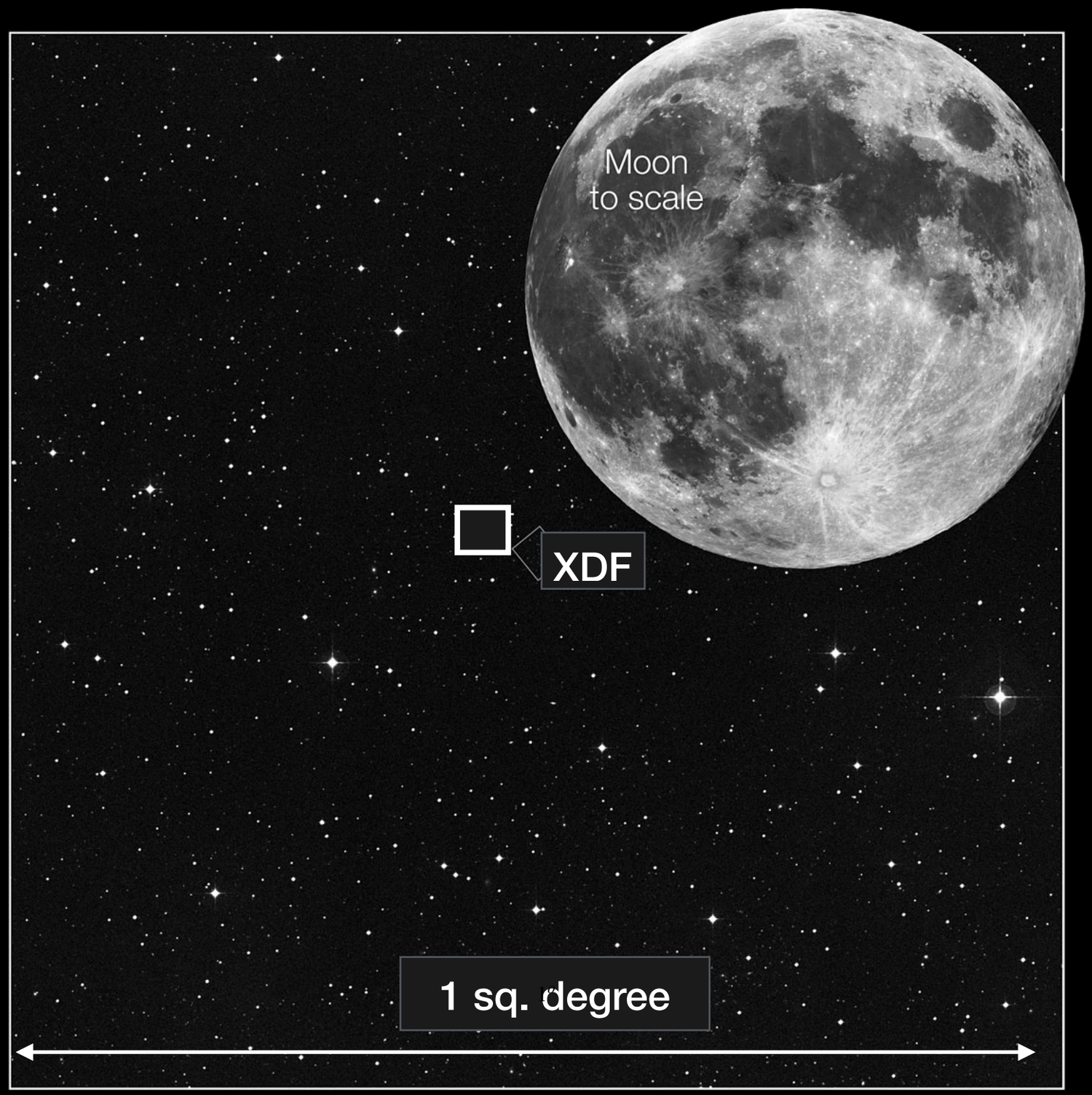
1. Legacy of astronomical discoveries in the last decades

paving the road for JWST

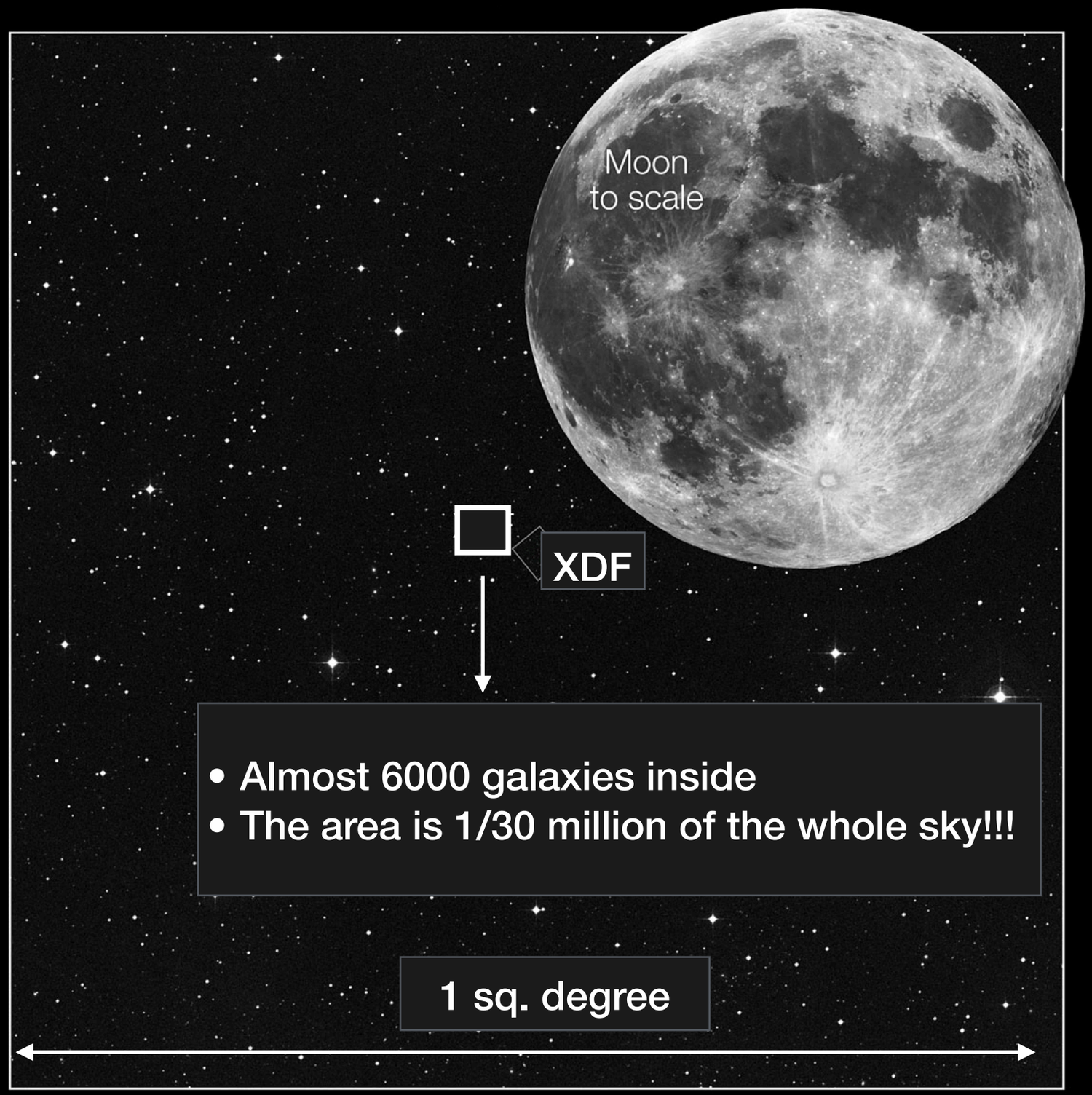
1. Hubble space telescope: *an infinite legacy*

Hubble space telescope (launched 1990)

1.2 Distant Universe: Hubble (eXtreme) Deep Field (XDF)



1.2 Distant Universe: Hubble (eXtreme) Deep Field (XDF)



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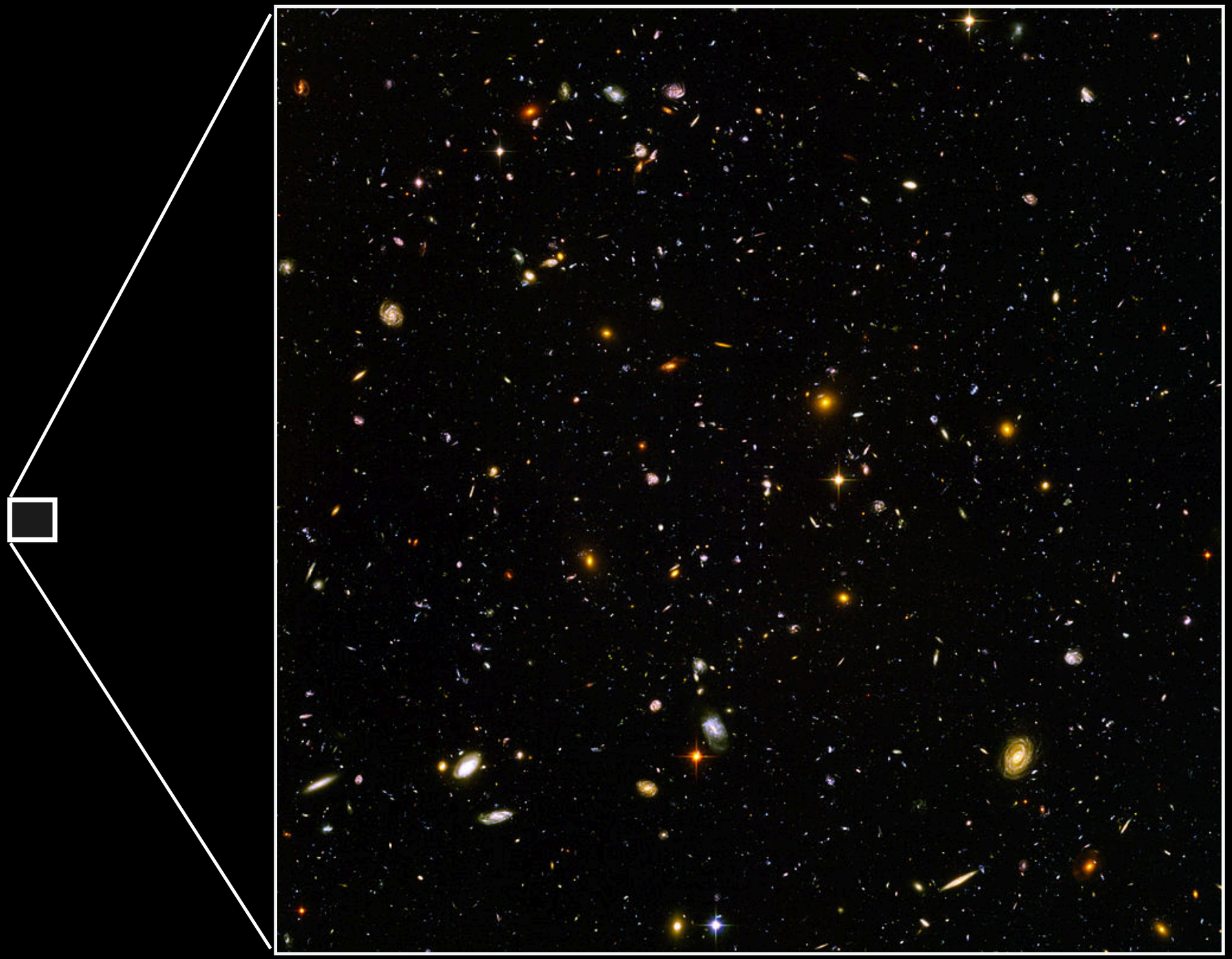
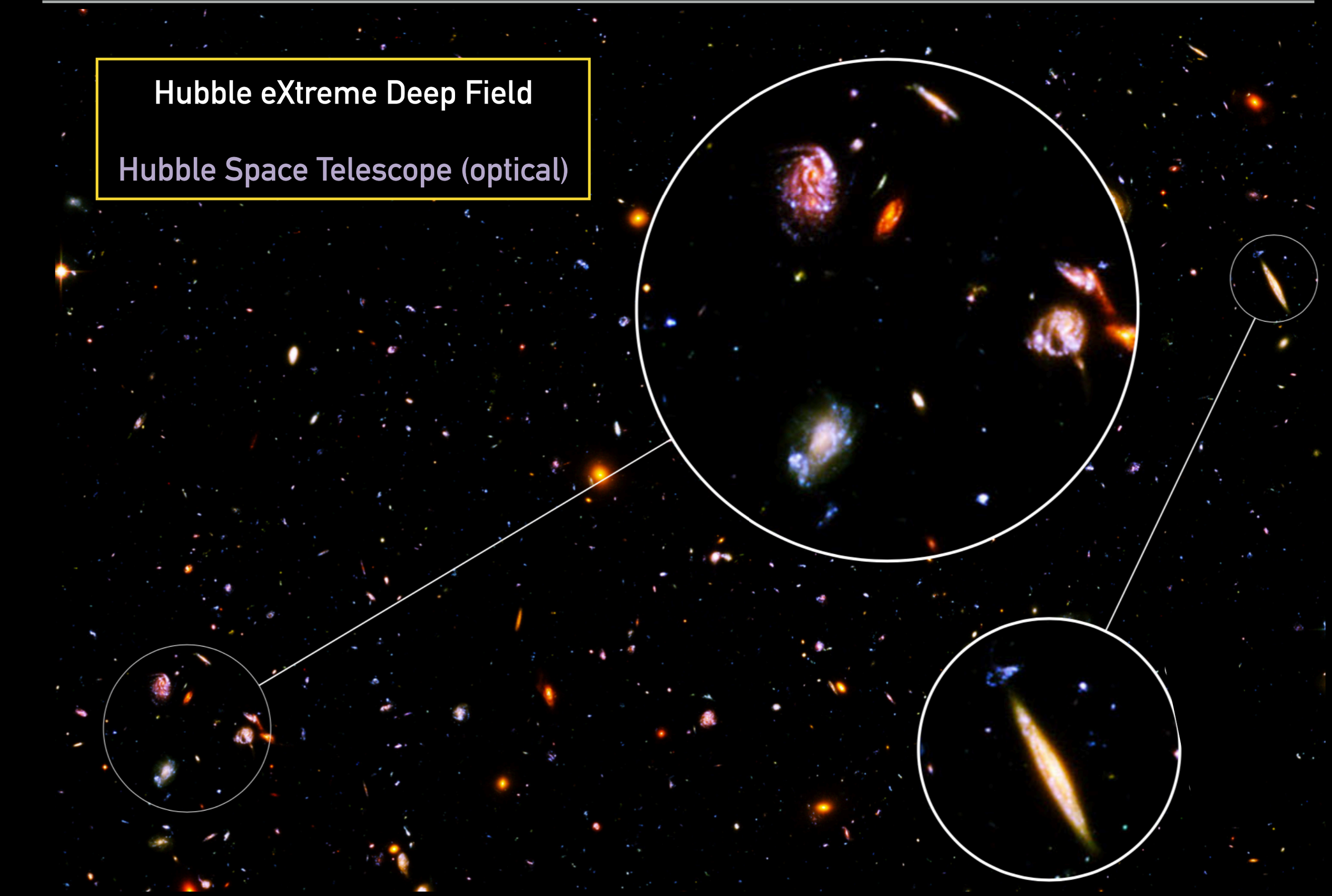


1.3 Galaxy evolution: optical perspective

Hubble eXtreme Deep Field

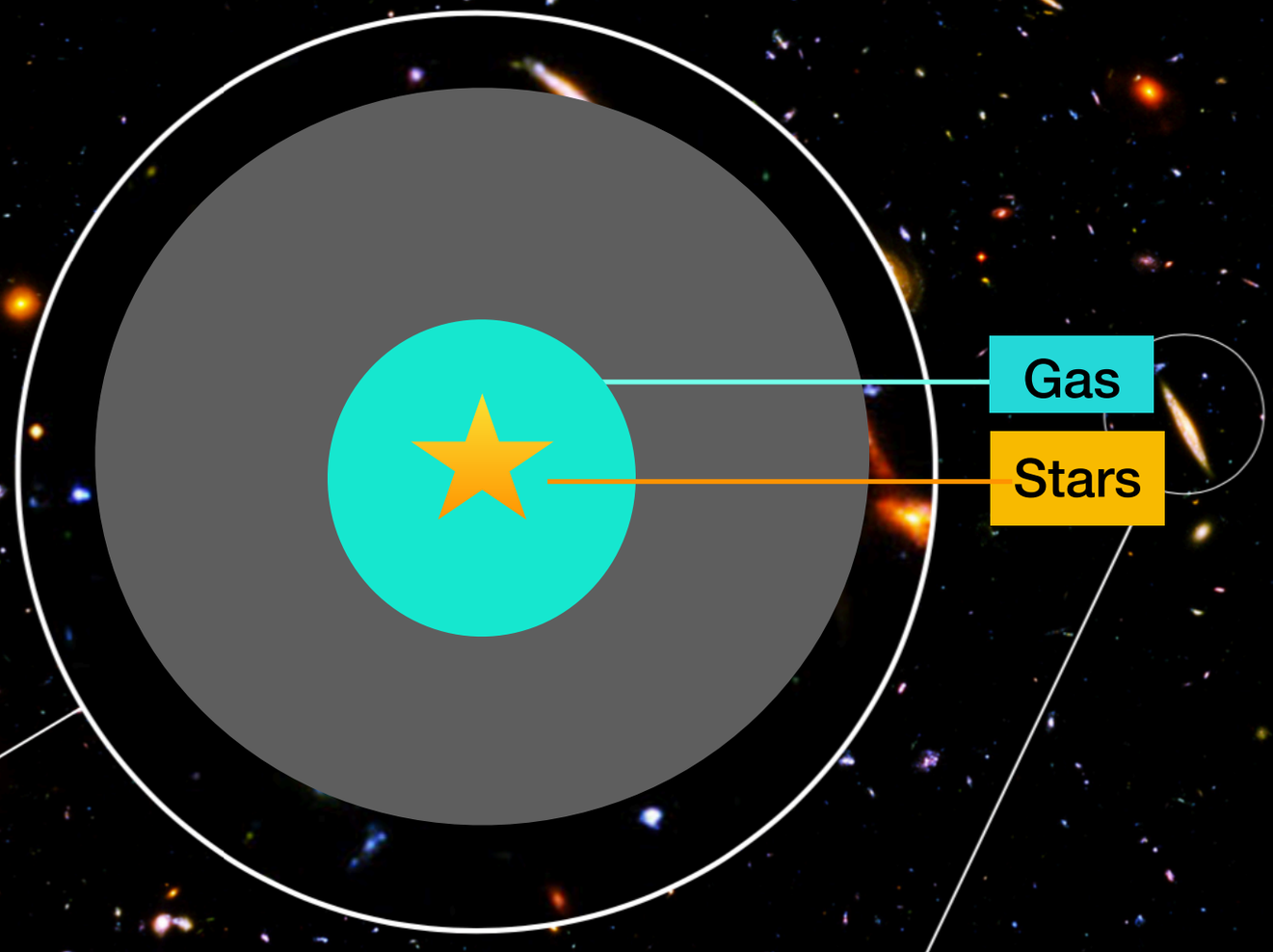
Hubble Space Telescope (optical)



1.3 Galaxy evolution: optical perspective

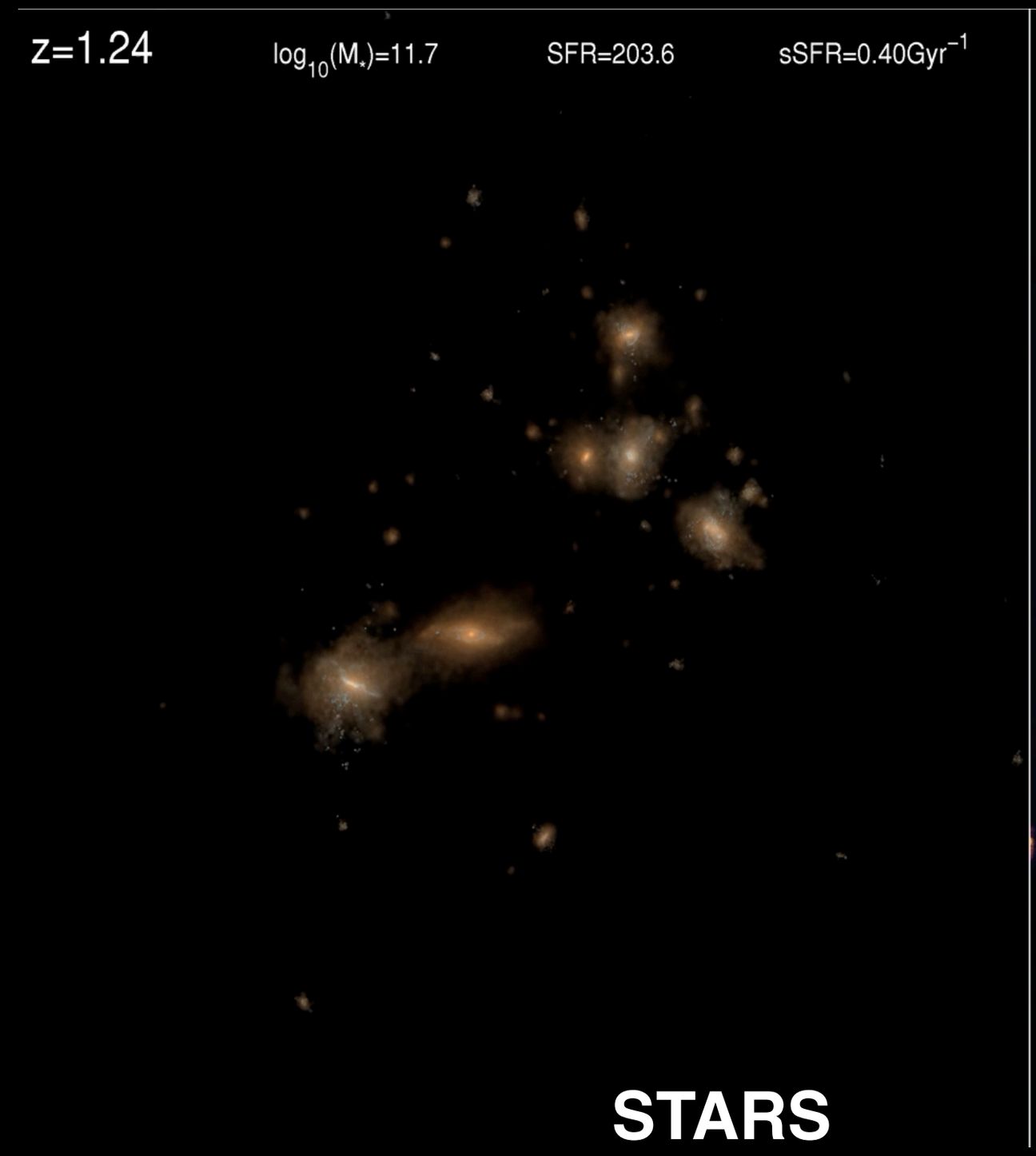
Hubble eXtreme Deep Field

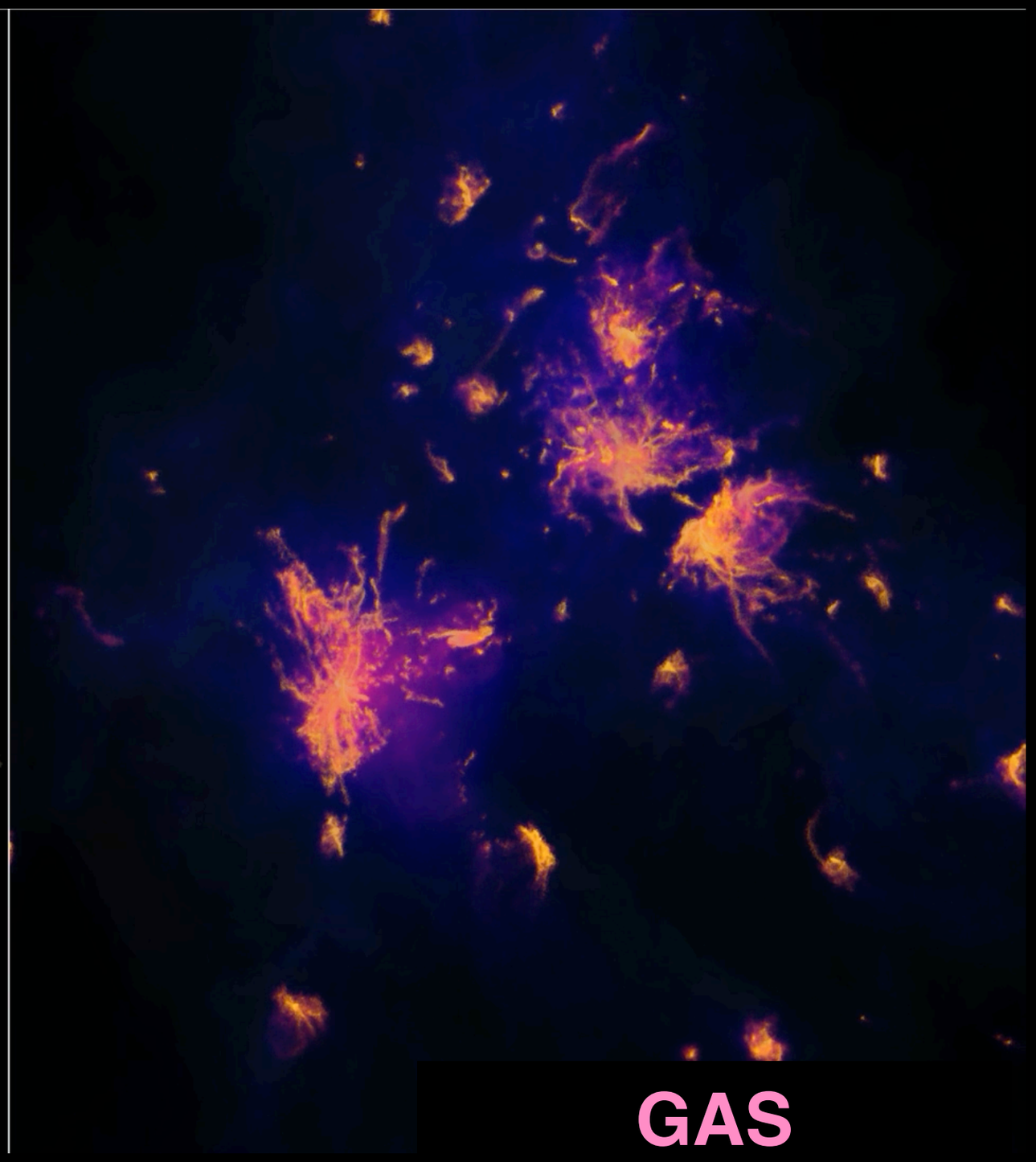
Hubble Space Telescope (optical)



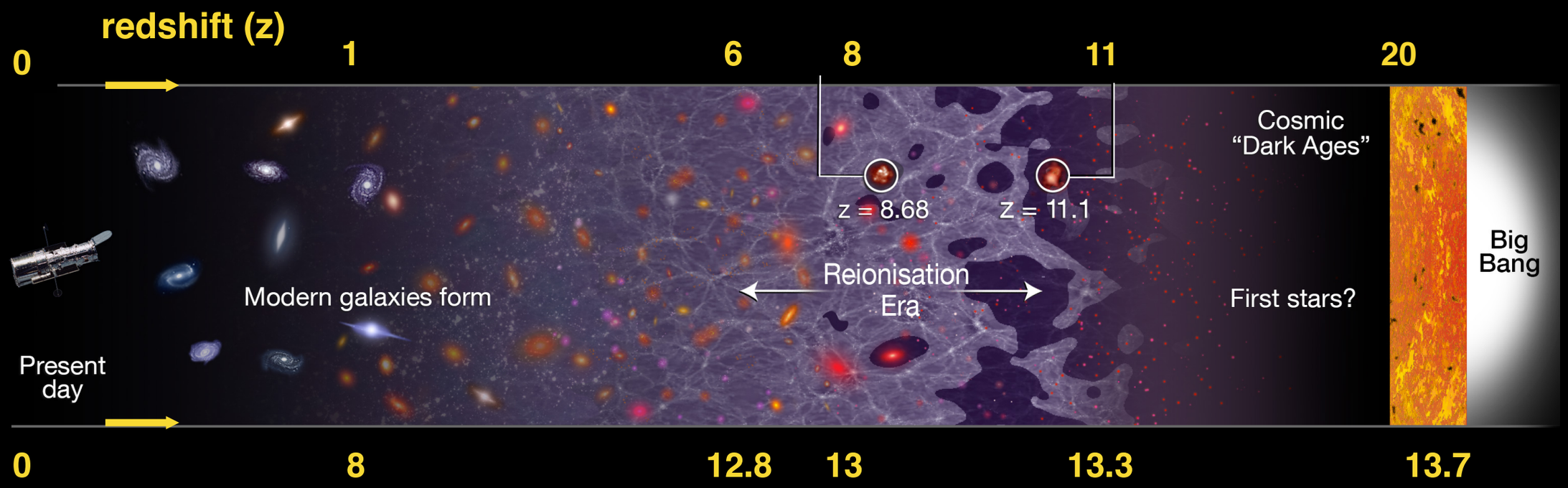
1.3 Galaxy evolution

ILLUSTRIS SIMULATION





1.5 Galaxy evolution in pre-JWST era

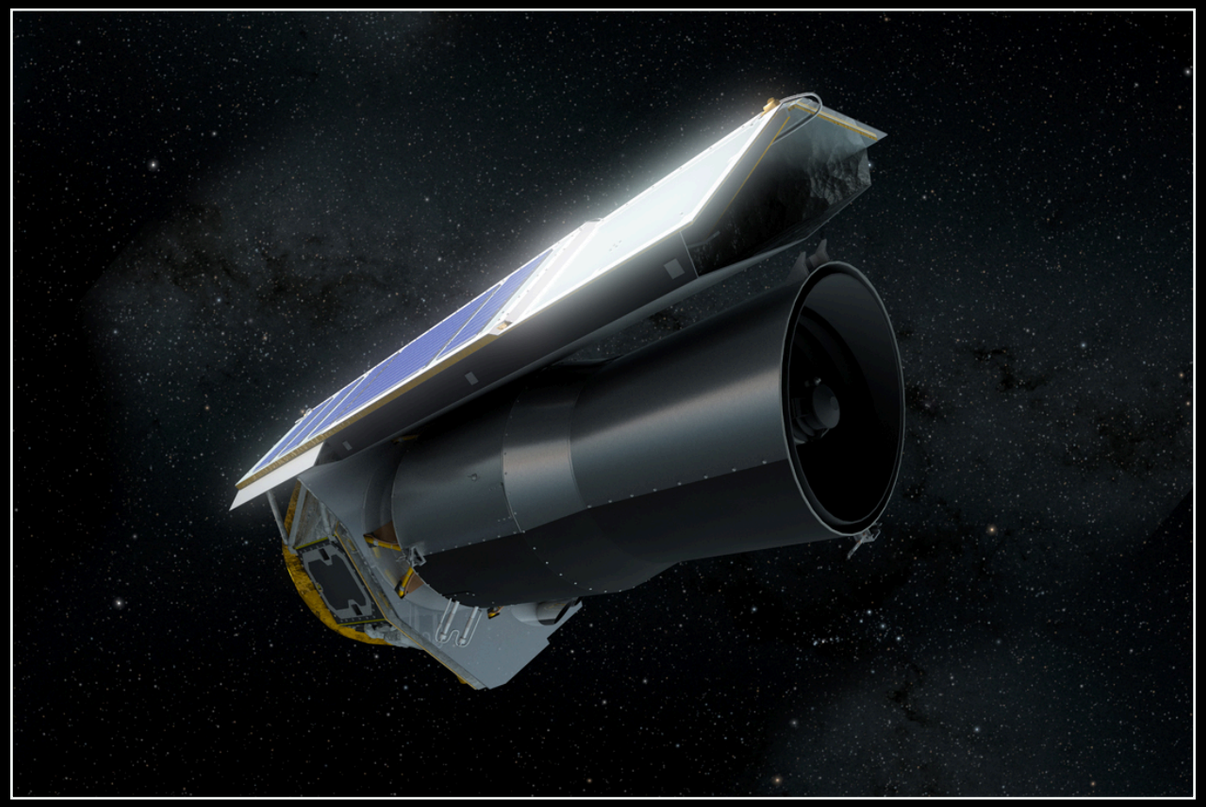


Credit: NASA, ESA, A.Field

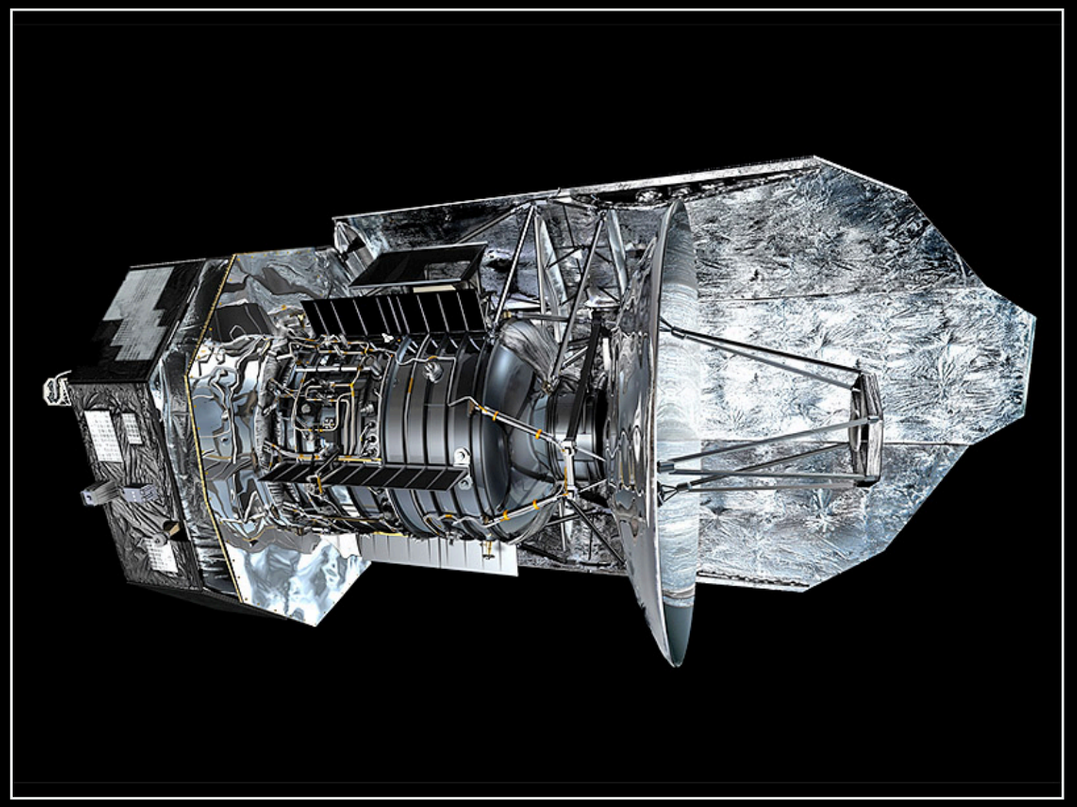
- Current estimate 200 billion galaxies in the Universe identified…
- … but predictions say that we yet have to find 10 times more!!!

2. Why do we need JWST?

2. Galaxy evolution: an infrared window



Spitzer space telescope
(mid-IR)

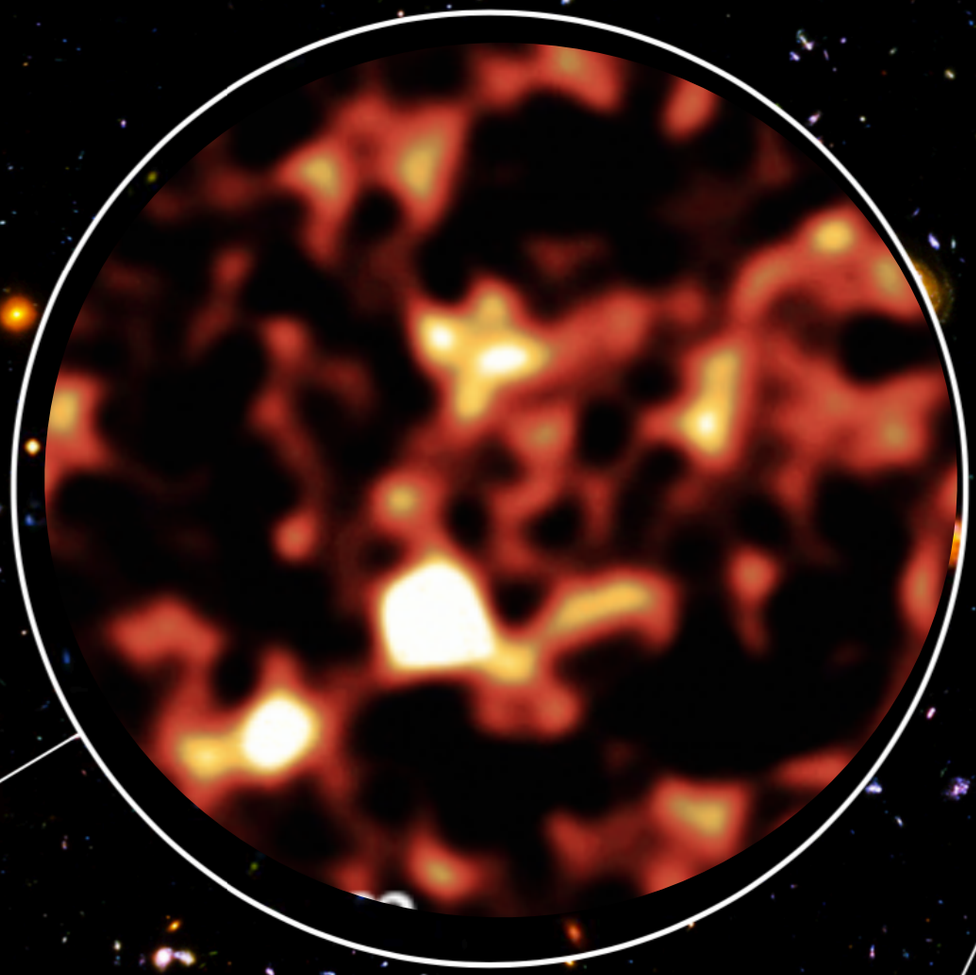


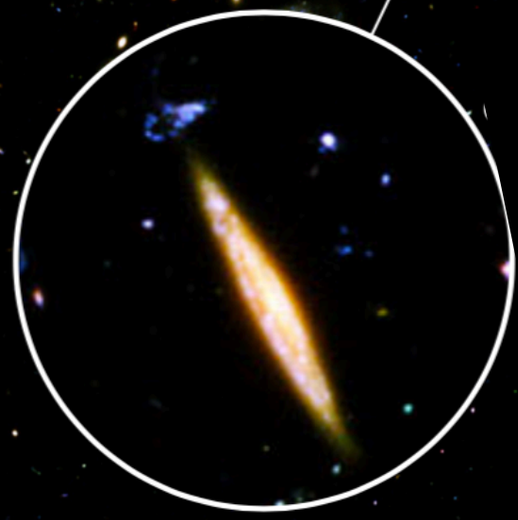
Herschel space telescope
(far-IR)

2. Galaxy evolution: an infrared window

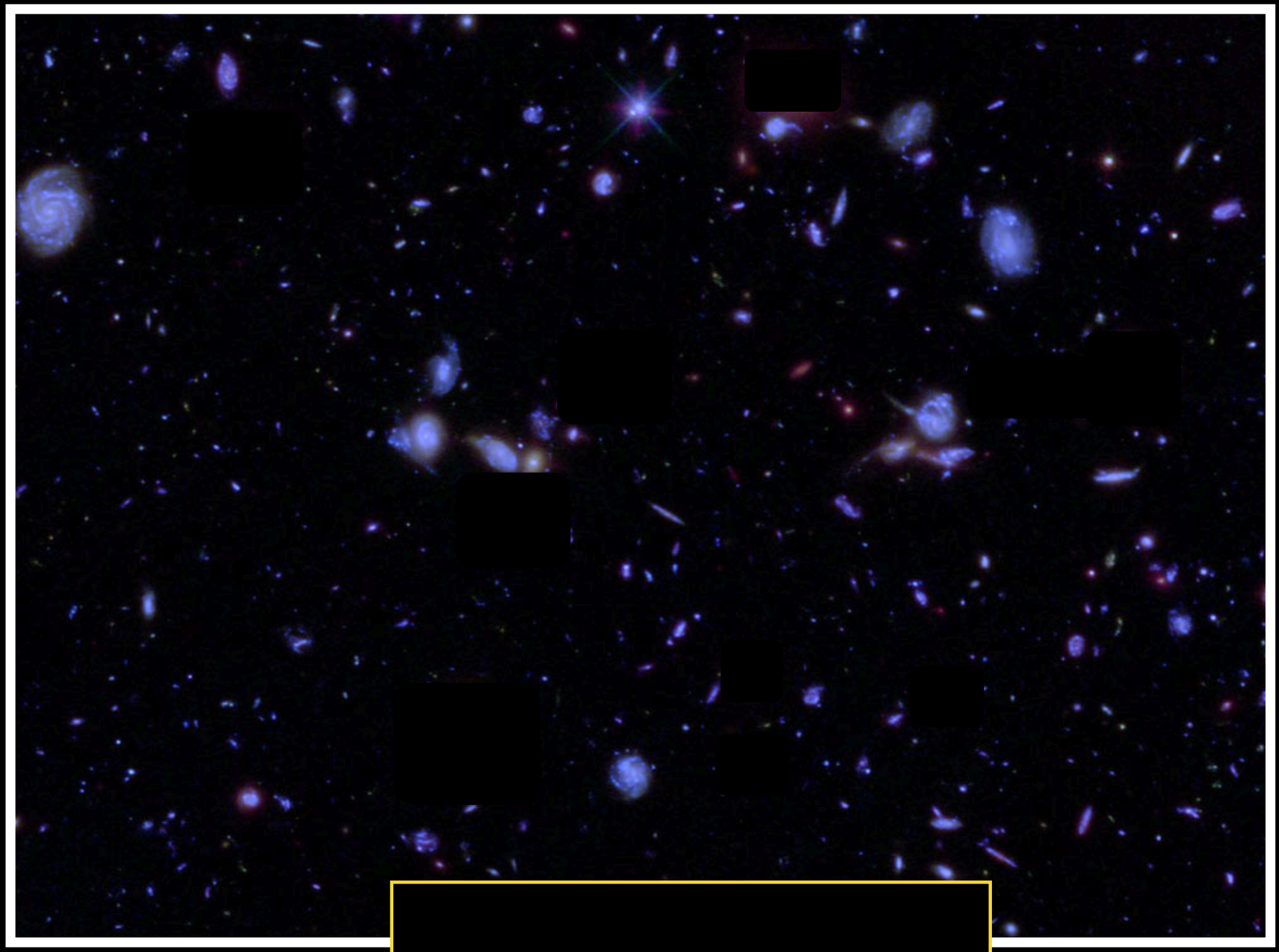
Hubble Ultra Deep Field

Hubble Space Telescope (optical)
SCUBA2 camera (far IR/mm)



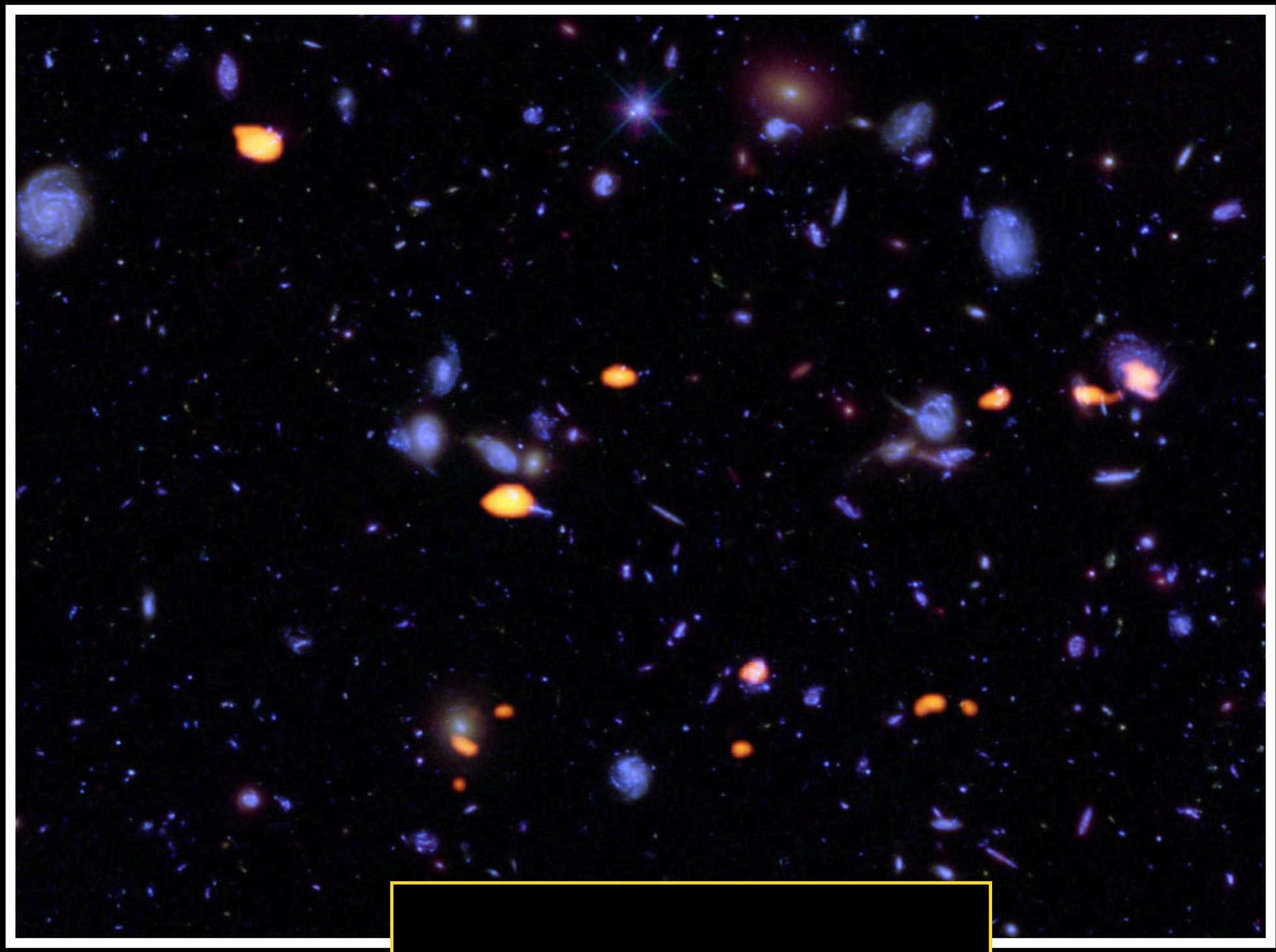


Hubble XDF field without dust emission



Hubble Space Telescope

Hubble XDF field with dust emission

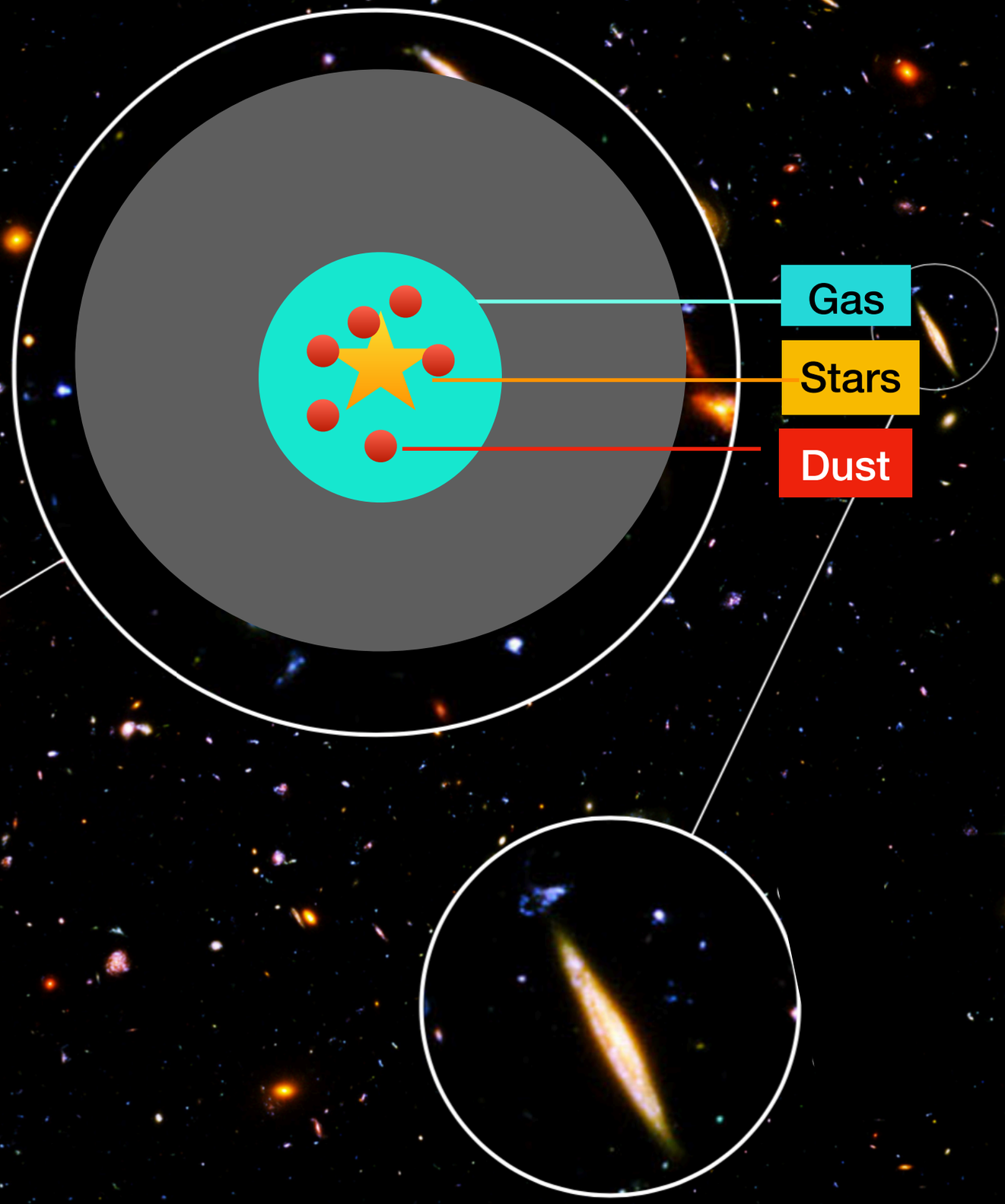


Hubble Space Telescope
ALMA (sub-mm)

2. Galaxy evolution: an infrared window

Hubble eXtreme Deep Field

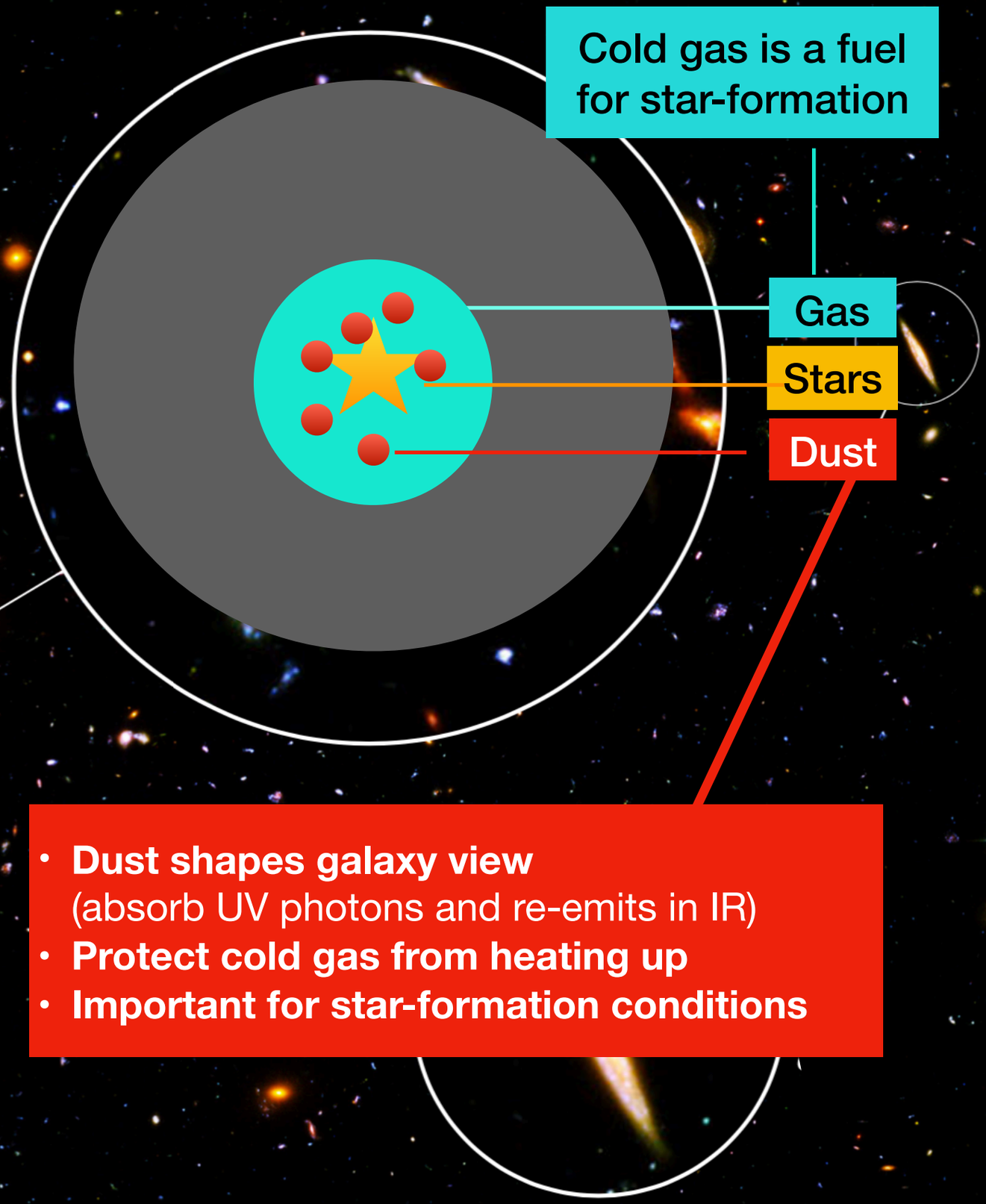
Hubble Space Telescope (optical)



2. Galaxy evolution: an infrared window

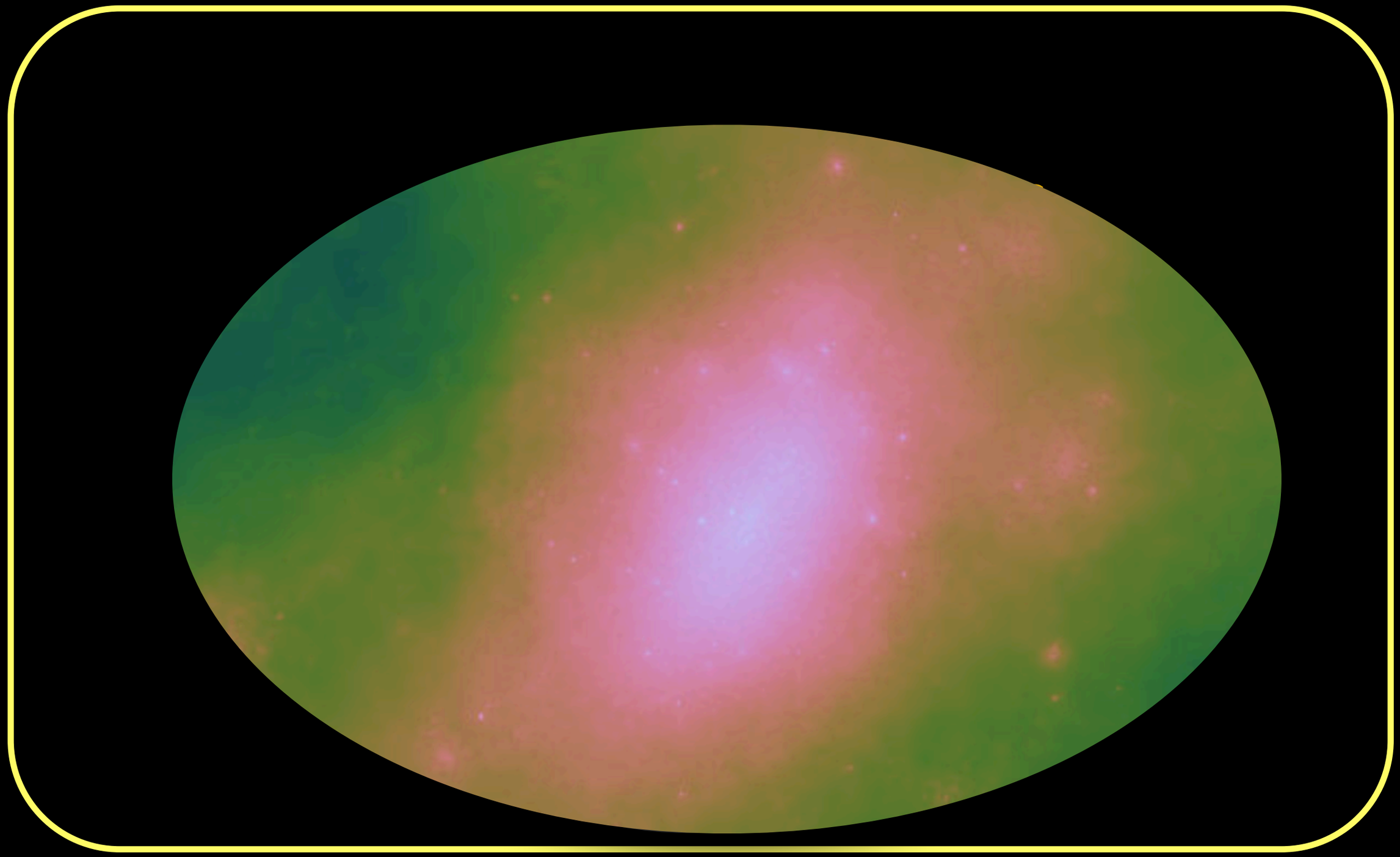
Hubble eXtreme Deep Field

Hubble Space Telescope (optical)



- **Dust shapes galaxy view**
  (absorb UV photons and re-emits in IR)
- **Protect cold gas from heating up**
- **Important for star-formation conditions**

2.1 Why worrying about dust in galaxies?



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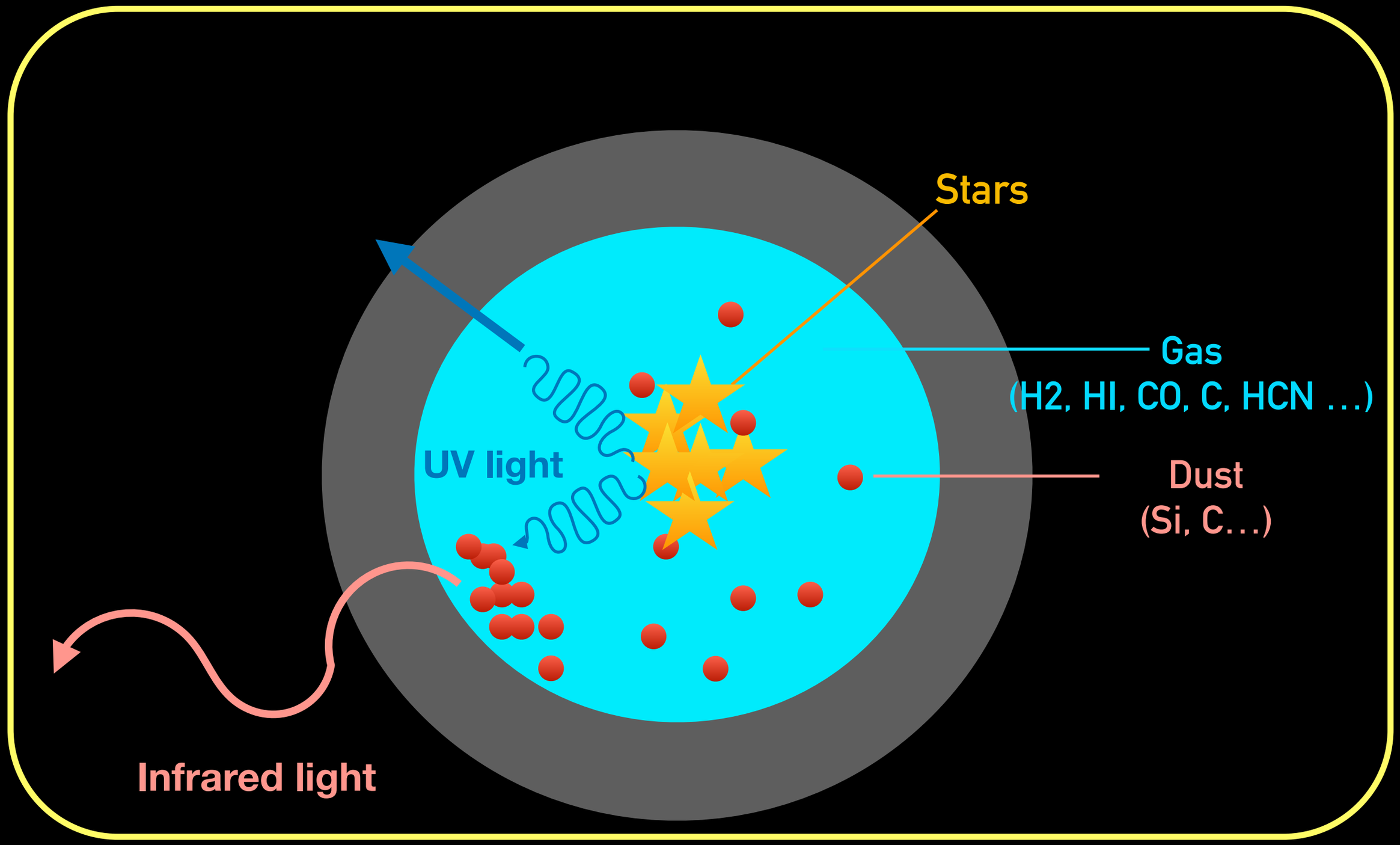
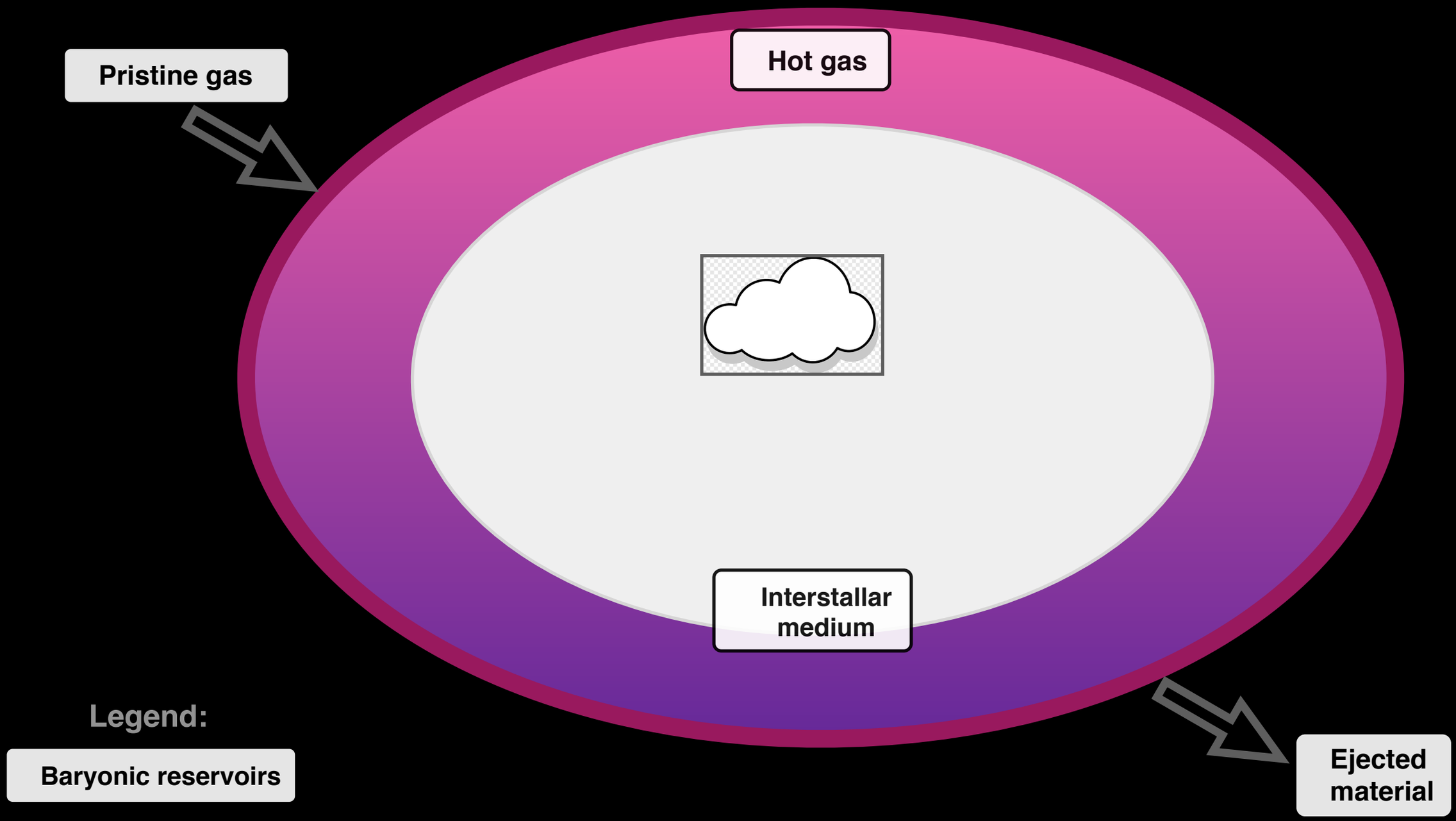
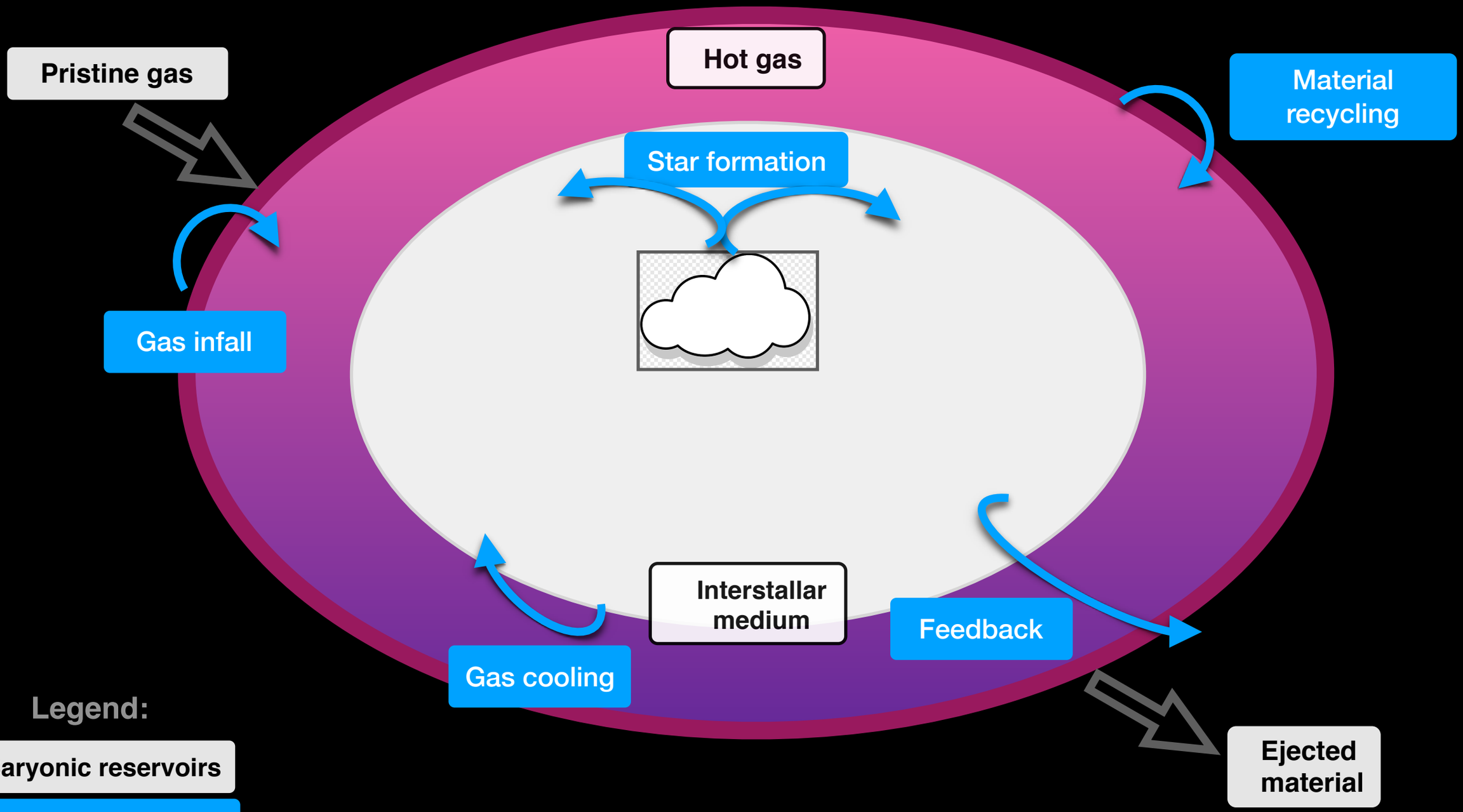


Dust accounts only 1% of the interstellar medium mass, but it's crucial in galaxies!

Interplay of metals, gas, stars and dust in galaxy evolution



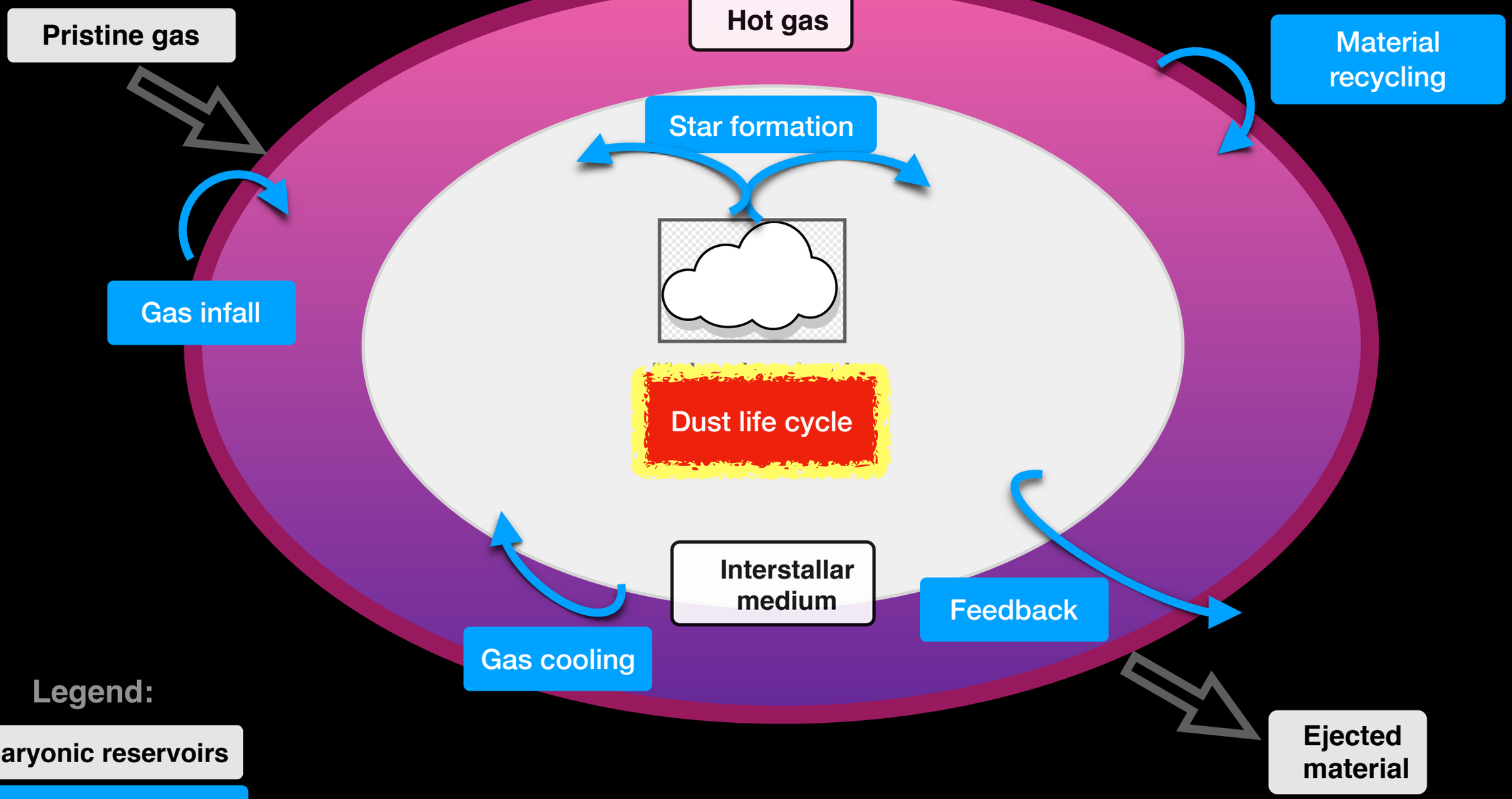
Interplay of metals, gas, stars and dust in galaxy evolution



Legend:

- Baryonic reservoirs
- Baryonic cycle

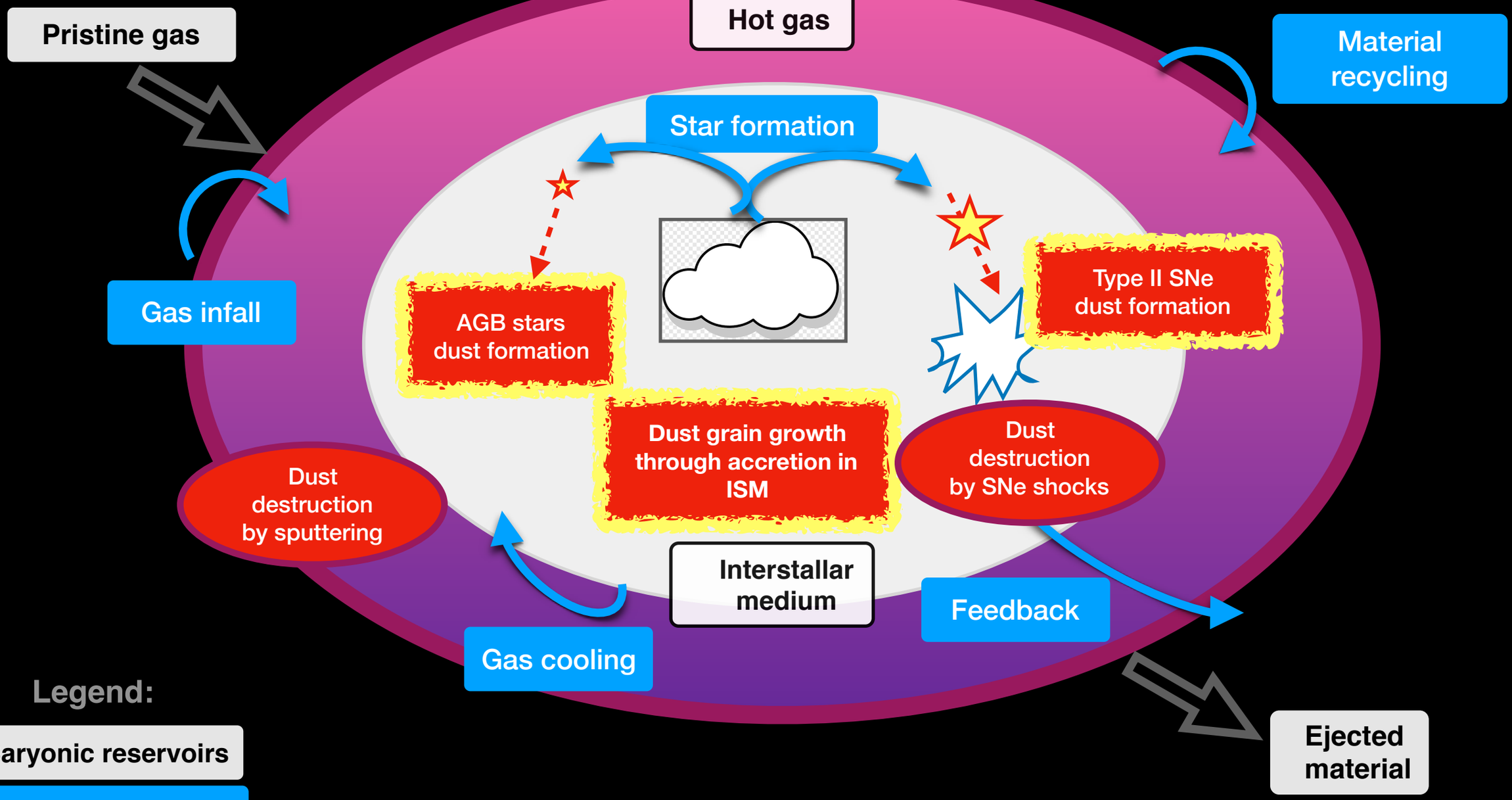
Interplay of metals, gas, stars and dust in galaxy evolution



Legend:

- Baryonic reservoirs
- Baryonic cycle
- Dust cycle

Interplay of metals, gas, stars and dust in galaxy evolution

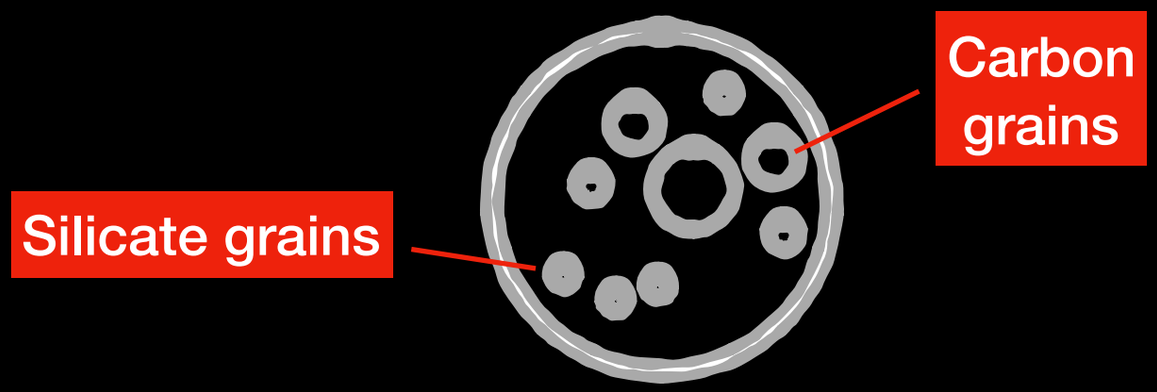


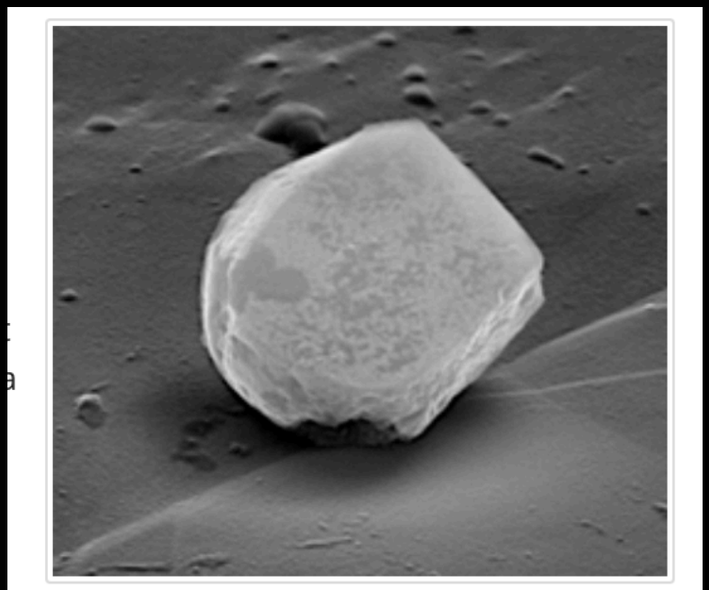
Legend:

- Baryonic reservoirs
- Baryonic cycle
- Dust cycle

Why studying dust and metals over cosmic times?

Evolution of ISM from the early to the local Universe



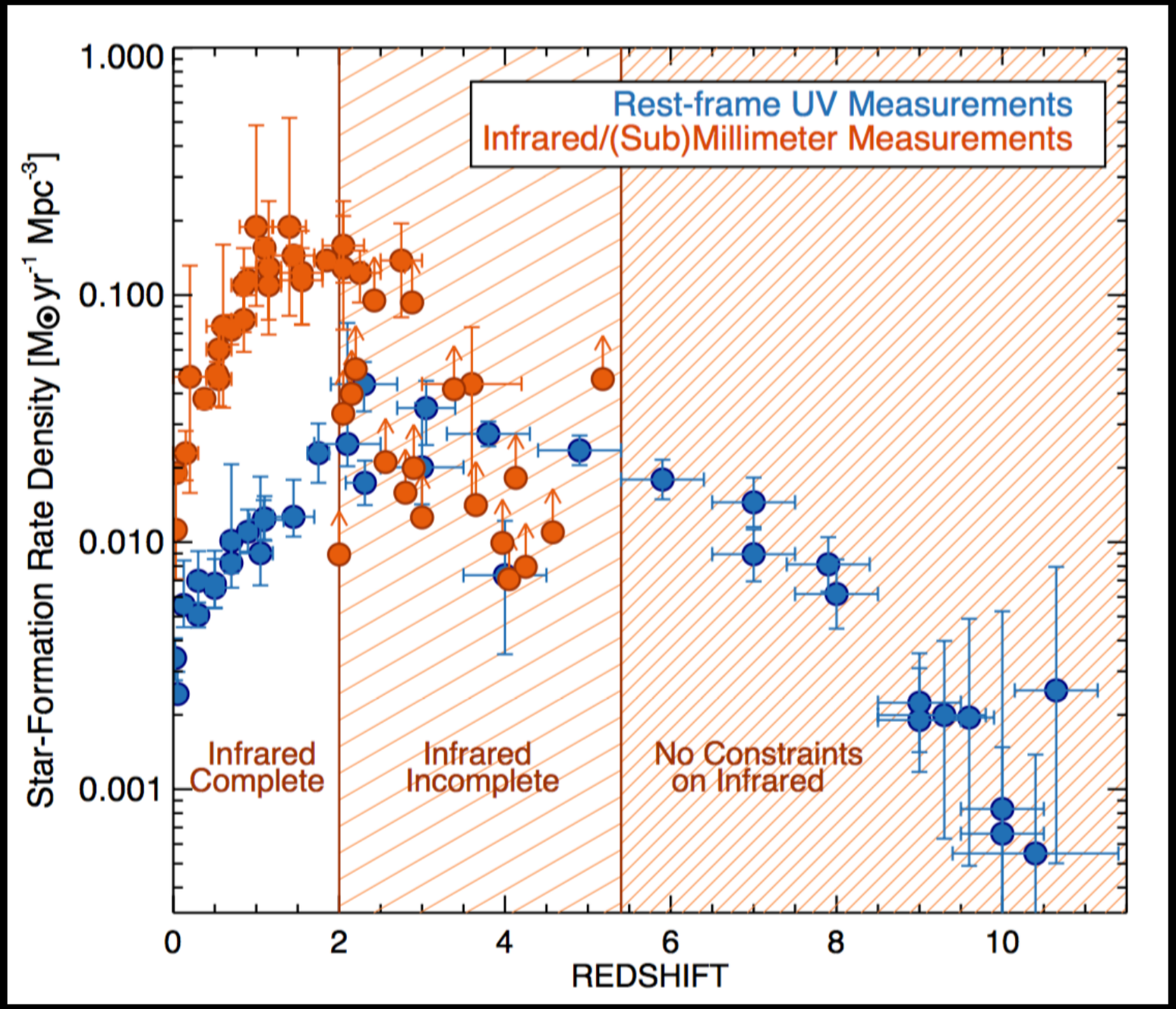


Electron microscope image of dust particles from interstellar space. The dust particles are typically about 100 nanometers (one nanometer is one millionth of a millimeter) and are made up of either carbon (soot) or silicates (fine sand).

Interstellar dust particles

- Solid particles of size 0.3 um<r<3 um
- Made of heavy elements (mainly O, C, Si, Mg, and Fe)
- Mixed with the gas in the ISM.
- Accounting for only 1% of ISM mass…
- … but, they have a radical impact on galaxies!!!

2.2. History of galaxy star-formation



Credit: Casey et al. 2019

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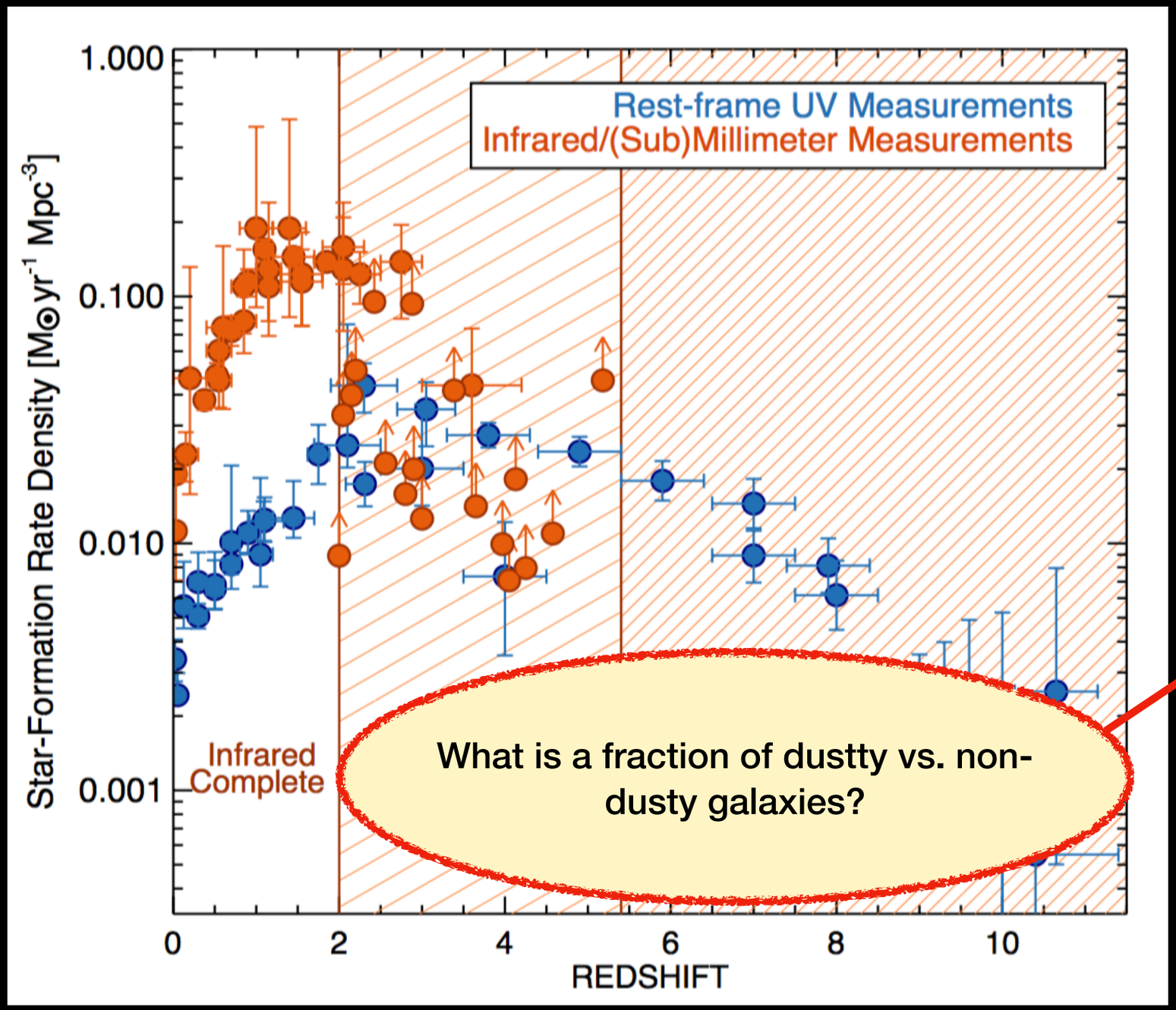
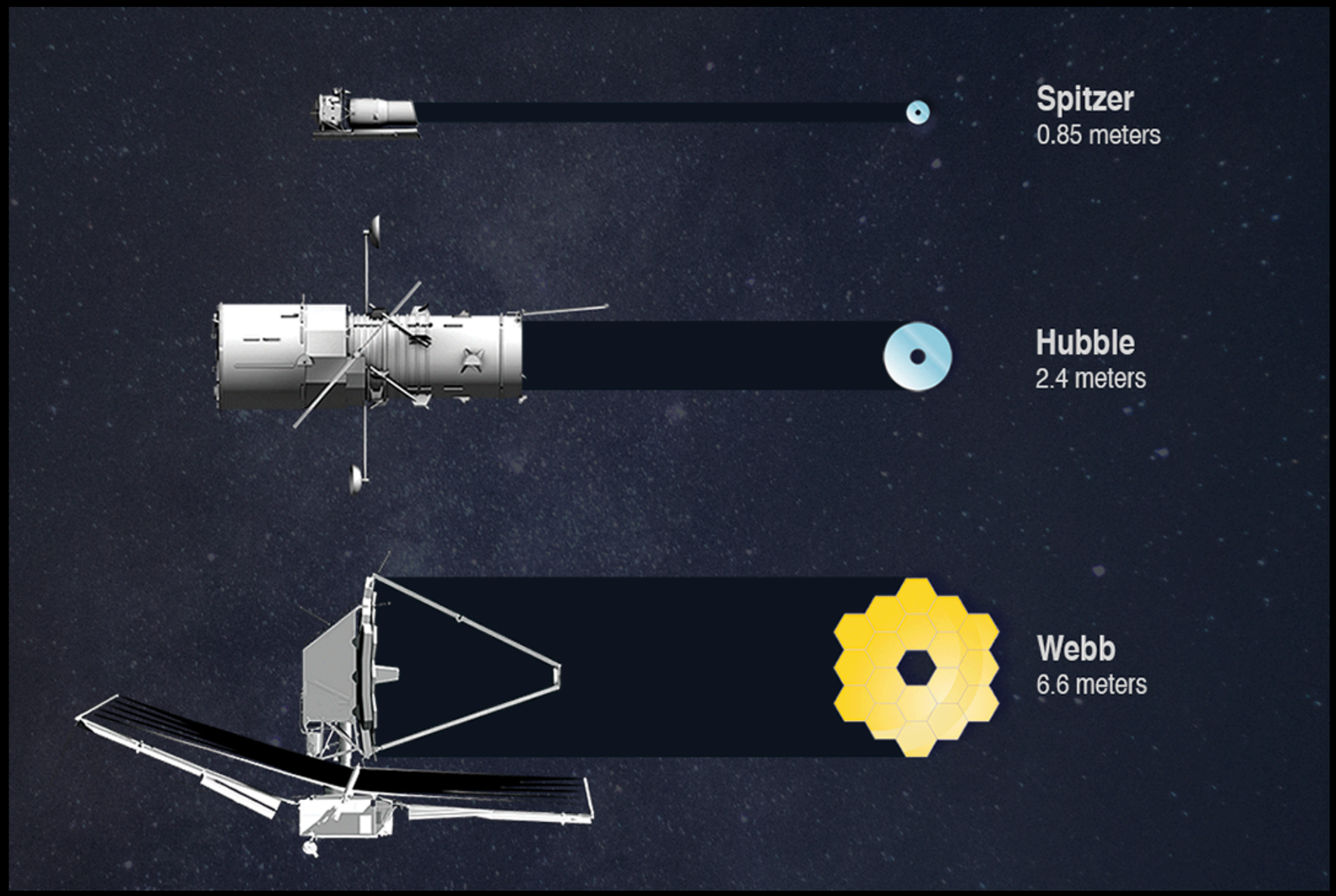


Credit: Casey et al. 2019

3. JWST - “unfold the Universe”

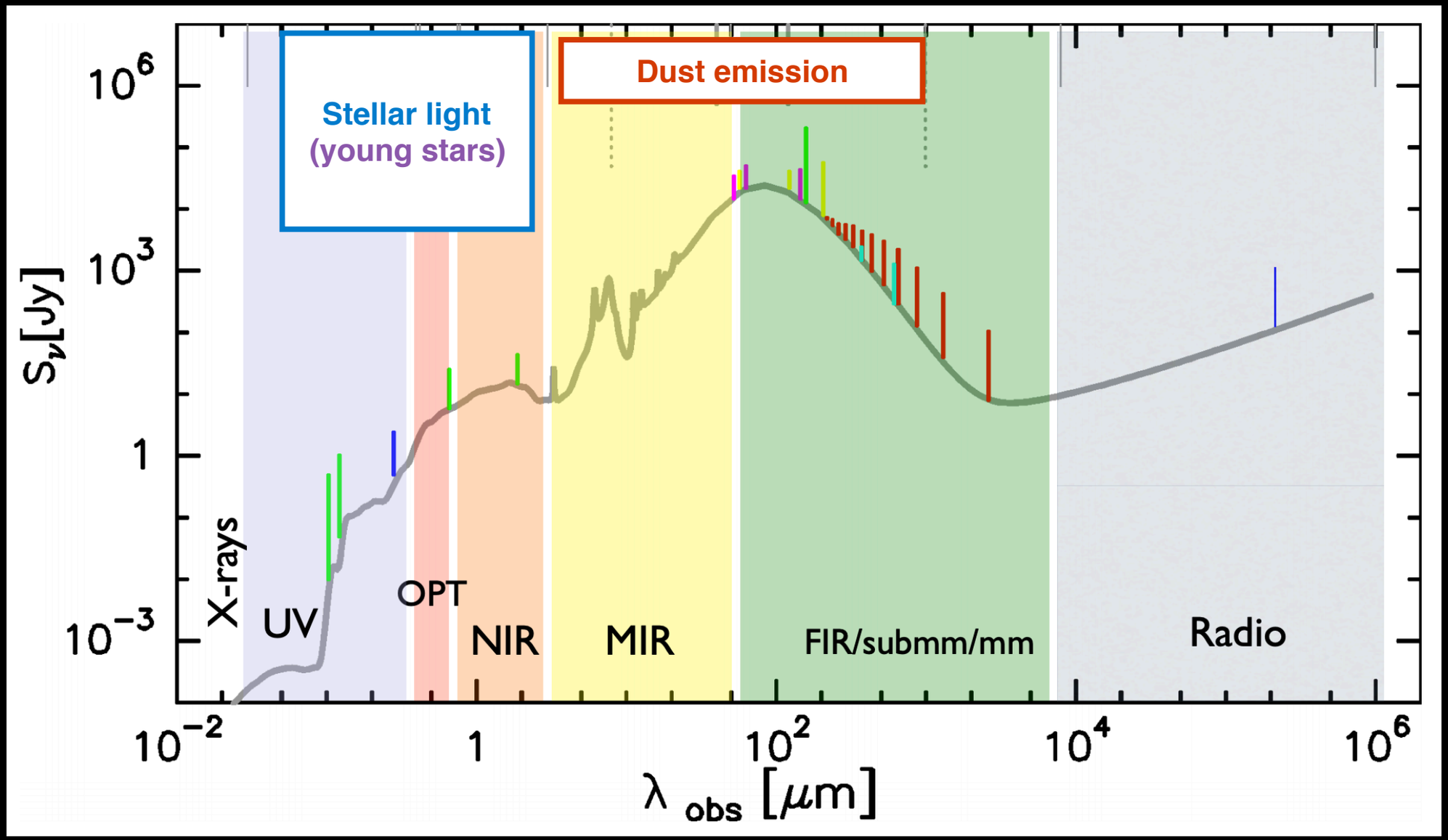
3. Unfold the Universe



JWST primary mirror is the largest ever sent into space

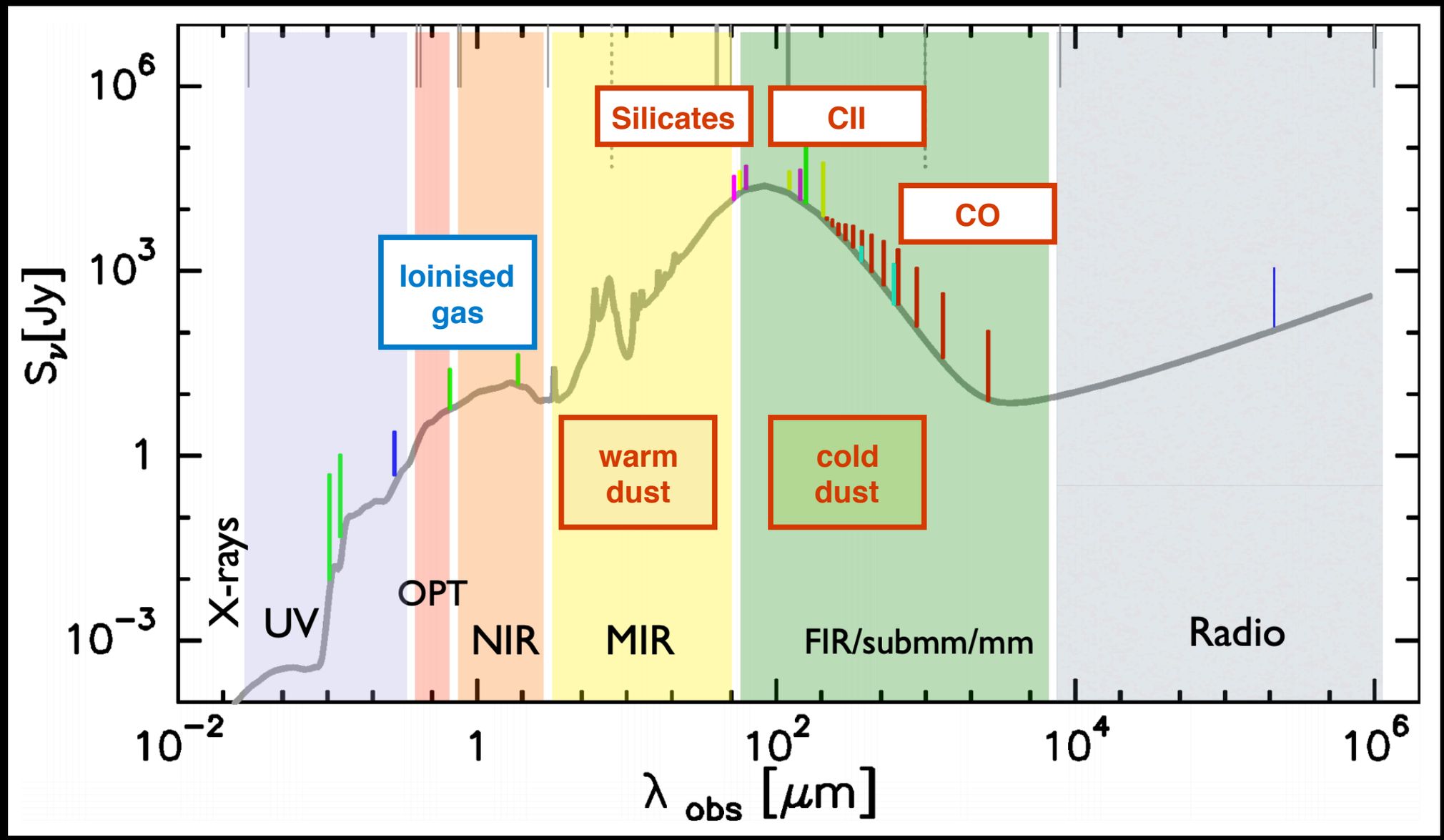
3. Unfold the Universe

Full Spectral Energy Distribution (SED) of galaxies



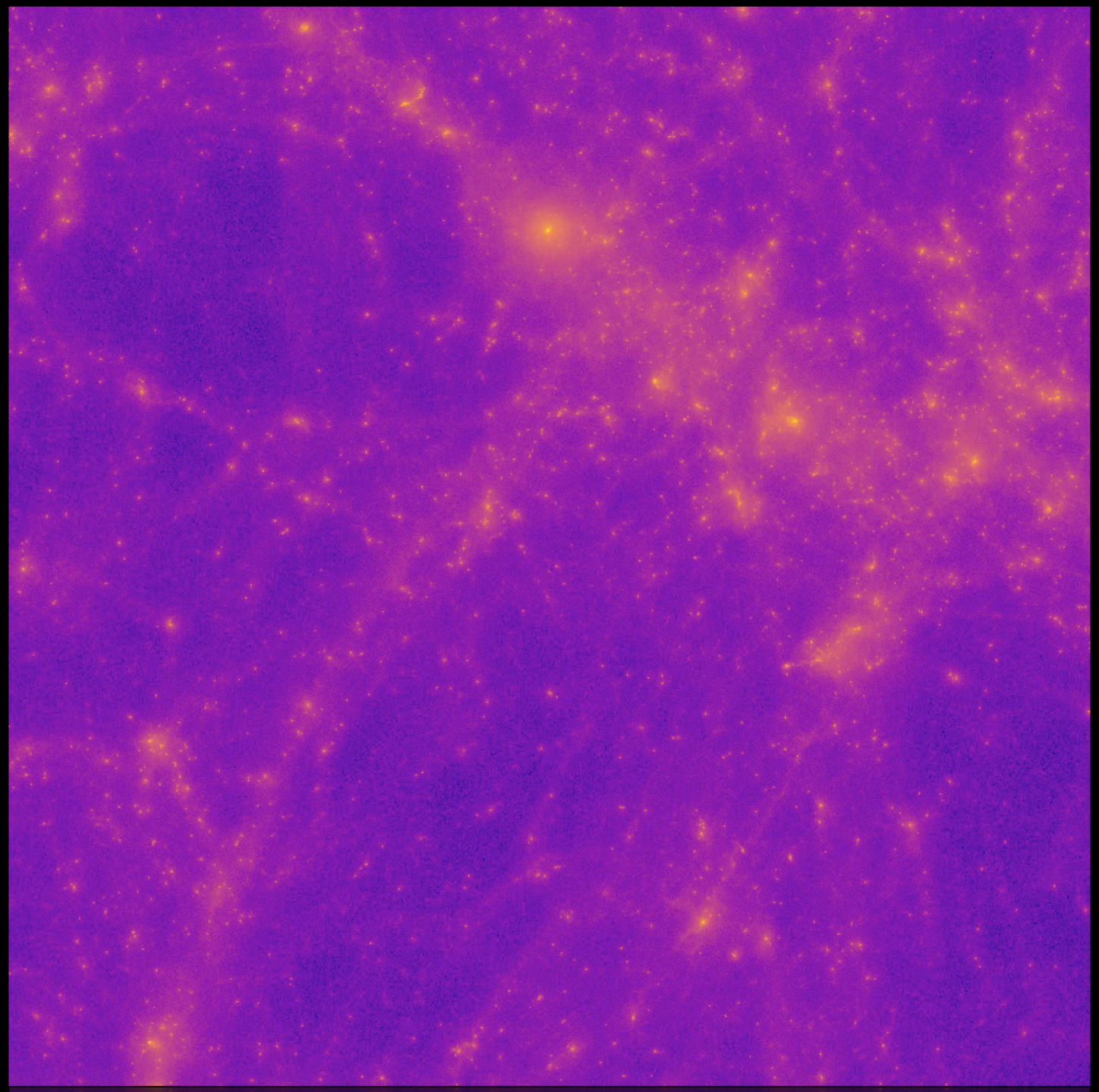
3. Unfold the Universe

Full Spectral Energy Distribution (SED) of galaxies



1.3 Galaxy evolution

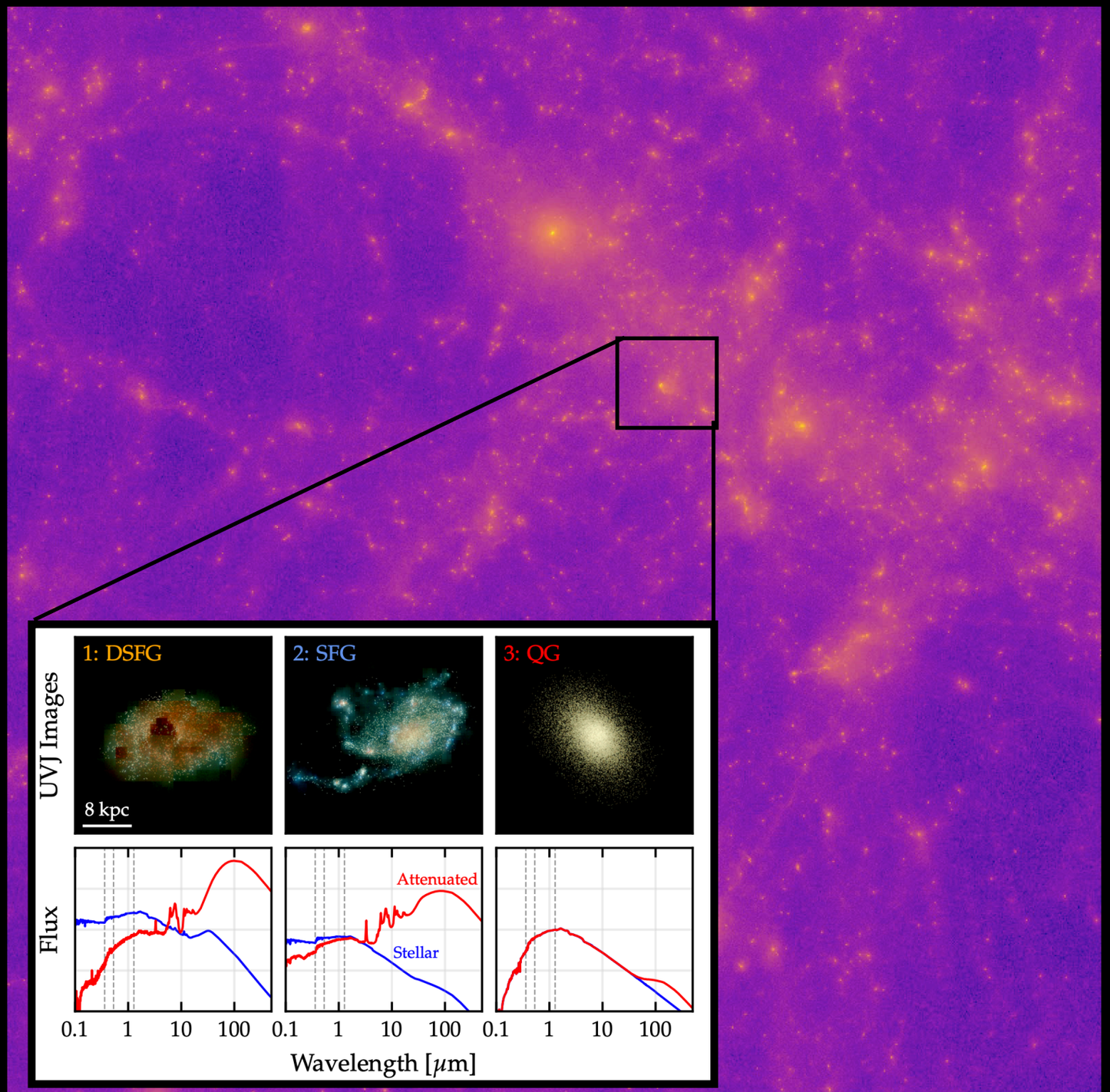
ILLUSTRIS SIMULATION



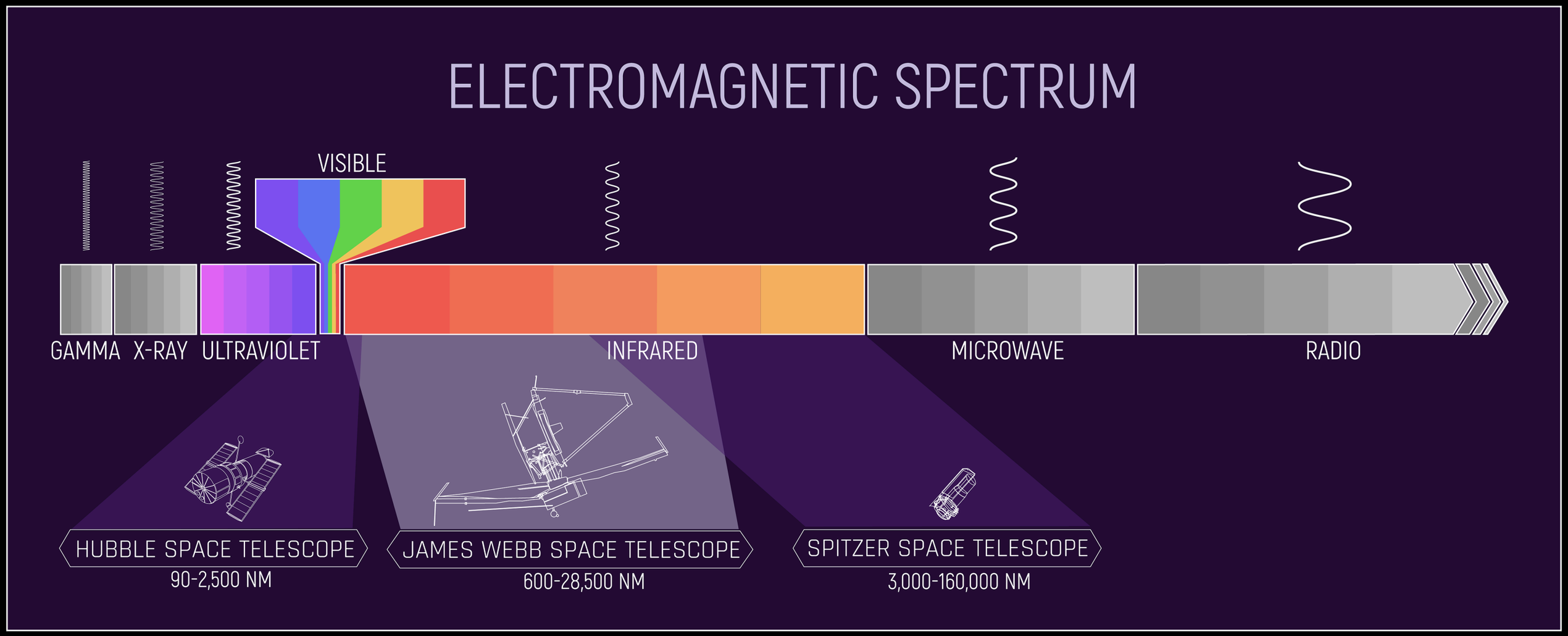
credit: K. Lisiecki, NCBJ

1.3 Galaxy evolution

ILLUSTRIS SIMULATION



2. JWST - new window into (mid)infrared Universe



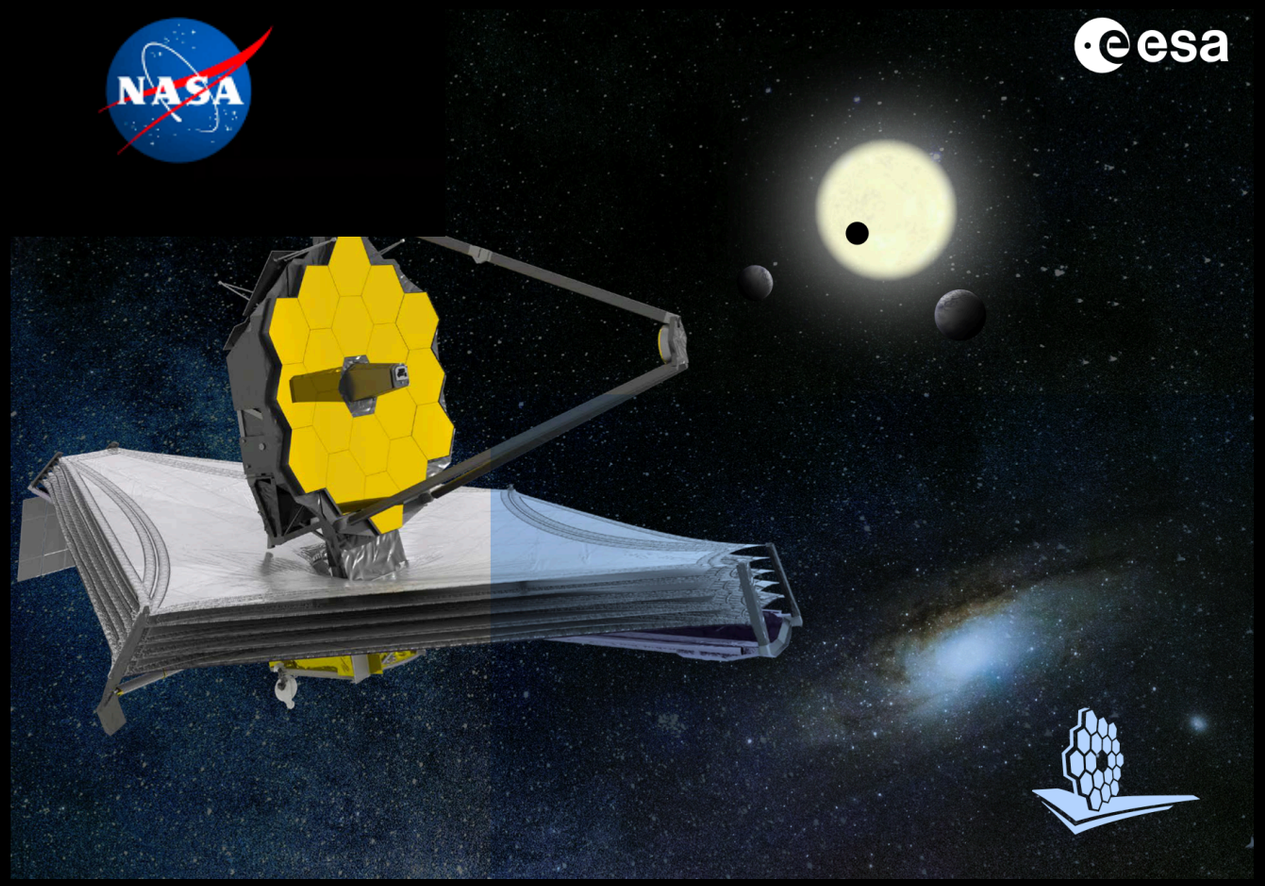
JWST will cover the wide range of near-IR-to-mid-IR

2. JWST - new window into (mid)infrared Universe

James Webb Space Telescope (JWST)

- Collaboration: NASA/ ESA/ Canadian Space Agency
- Primary mirror: D=6.5m
- NIR-instruments and MIR-instruments

JWST in a nuttshell



- In L2 point (1.5 billion km from Earth)
- PRIMARY MIRROR (D= 6.5m) (gold-plated beryllium)
- 18 mirror segments / 5 sunshield layers
- 4 SCIENCE INSTRUMENTS (near-IR and mid-IR)

JWST in a nuttshell

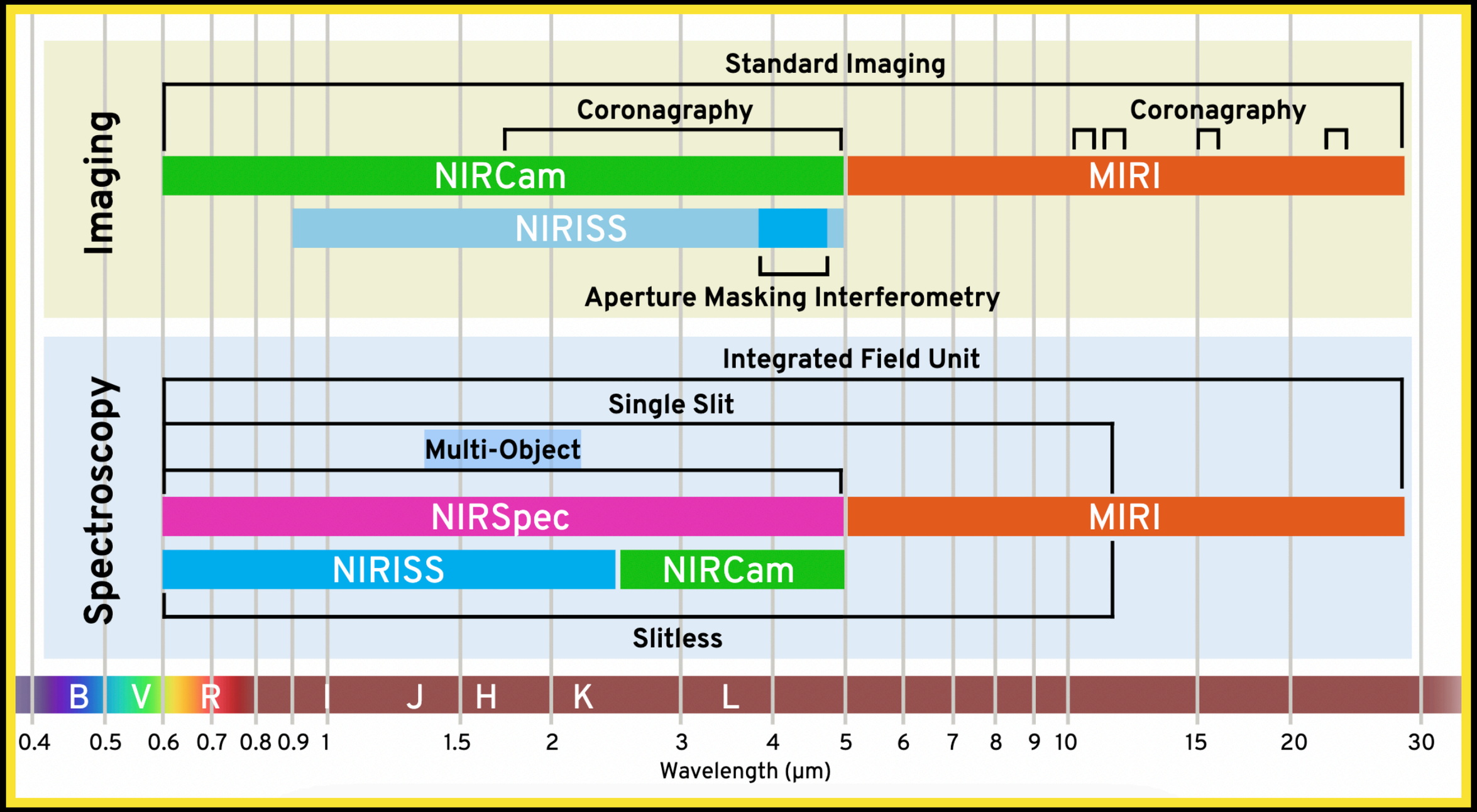
- PRIMARY MIRROR (gold-plated beryllium)
  Diameter = 6.5m

- 18 hexagonal segments
- Collecting area: 25 m2

- SECONDARY MIRROR:
  Diameter = 0.75m

- 132 micro-motors for mirror adjustments

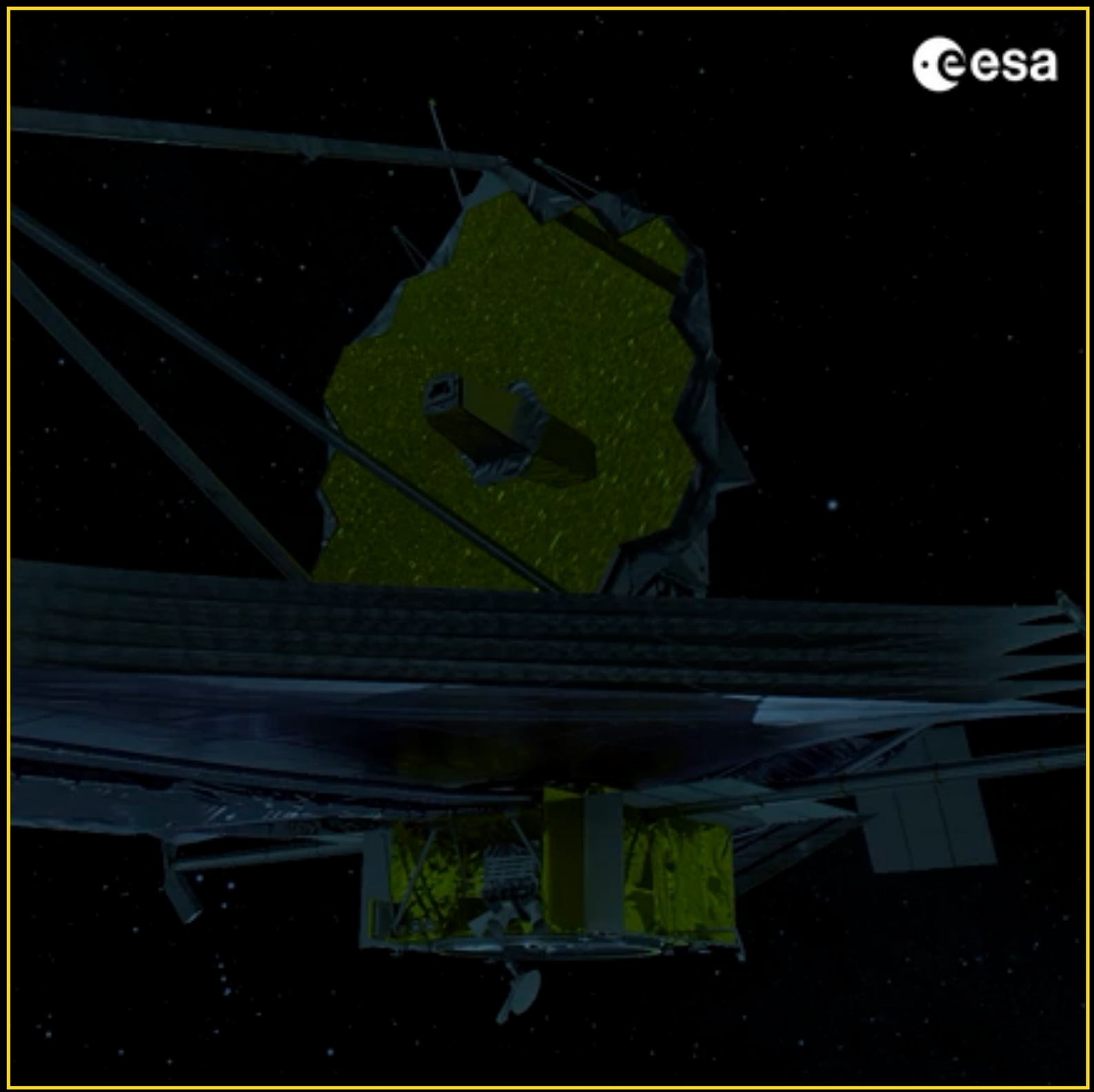
3. JWST: instruments



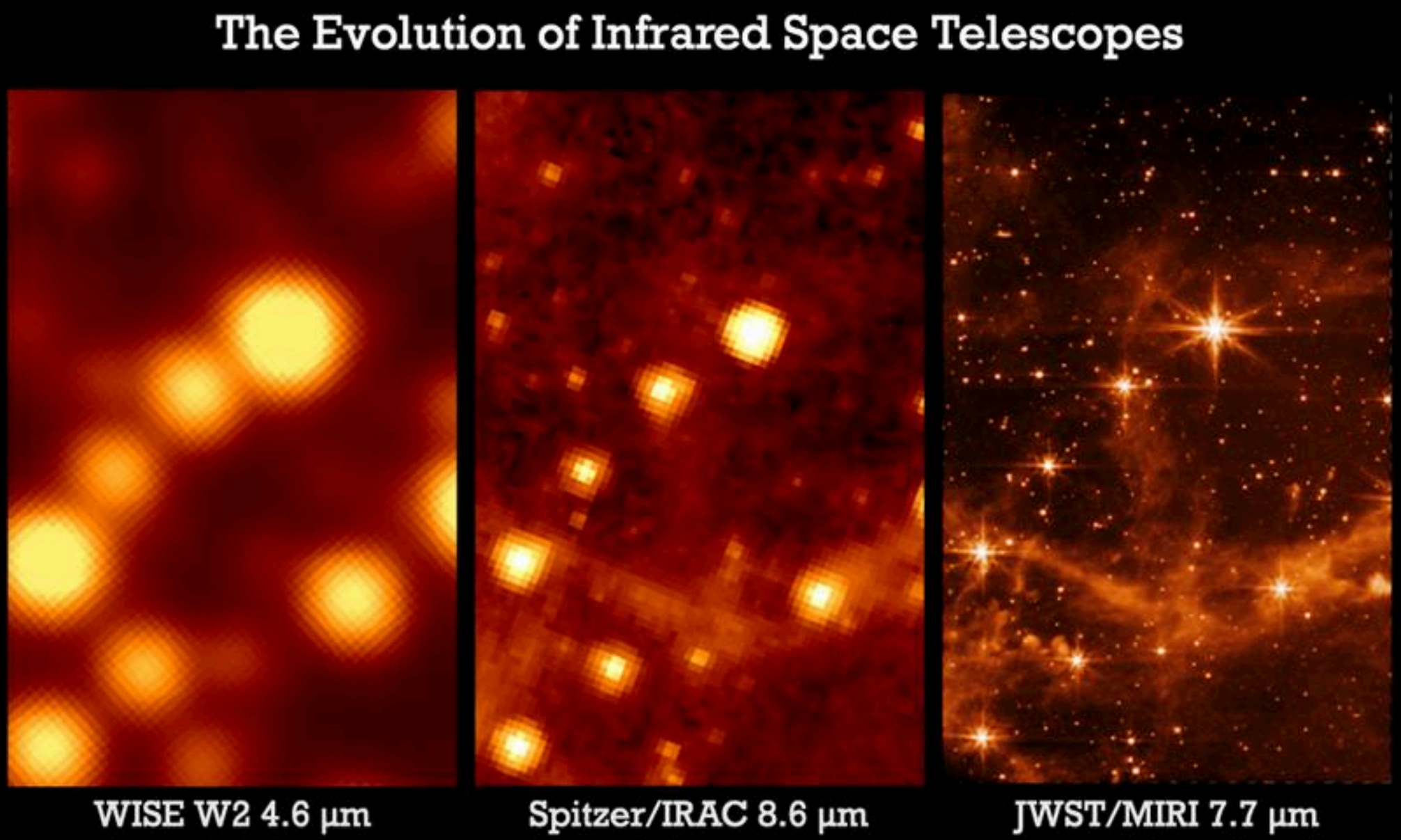
Credit: JWST/NASA

4. Distant dusty galaxies with JWST

JWST as time machine



4.1 Comparing the infrared view with other space telescopes



4.1 Mapping the dust in star-forming regions

IFU spectroscopy: method

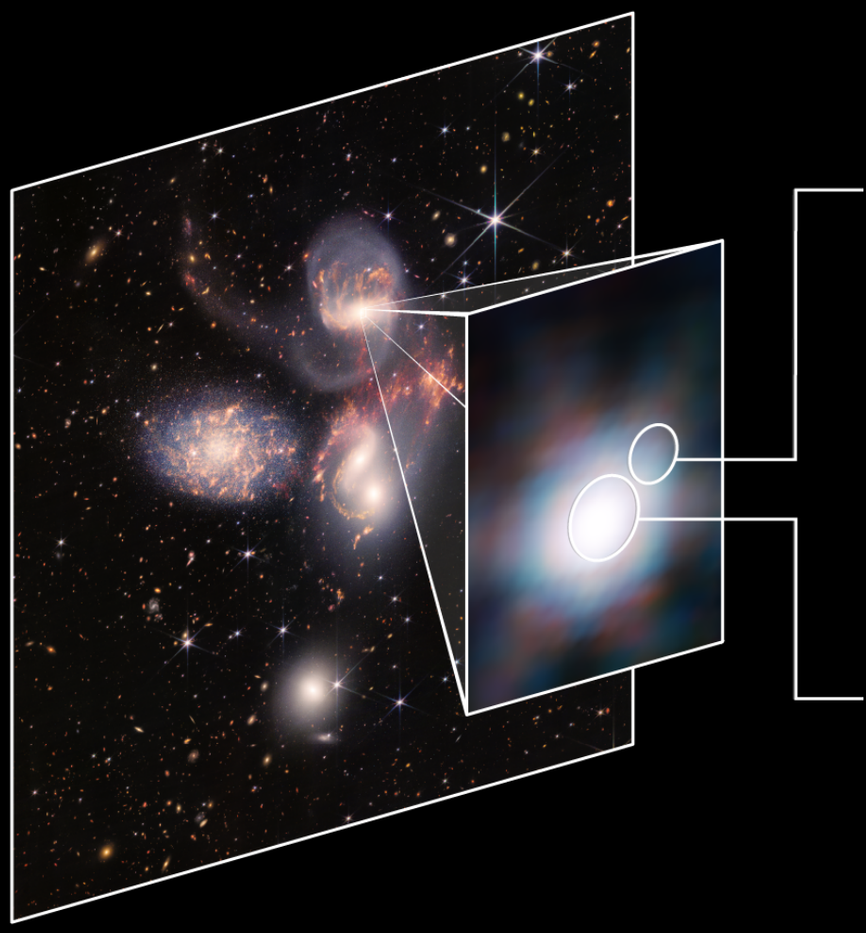
Credit: STSCI/ESA

4.1 Interplay of gas & dust around black holes

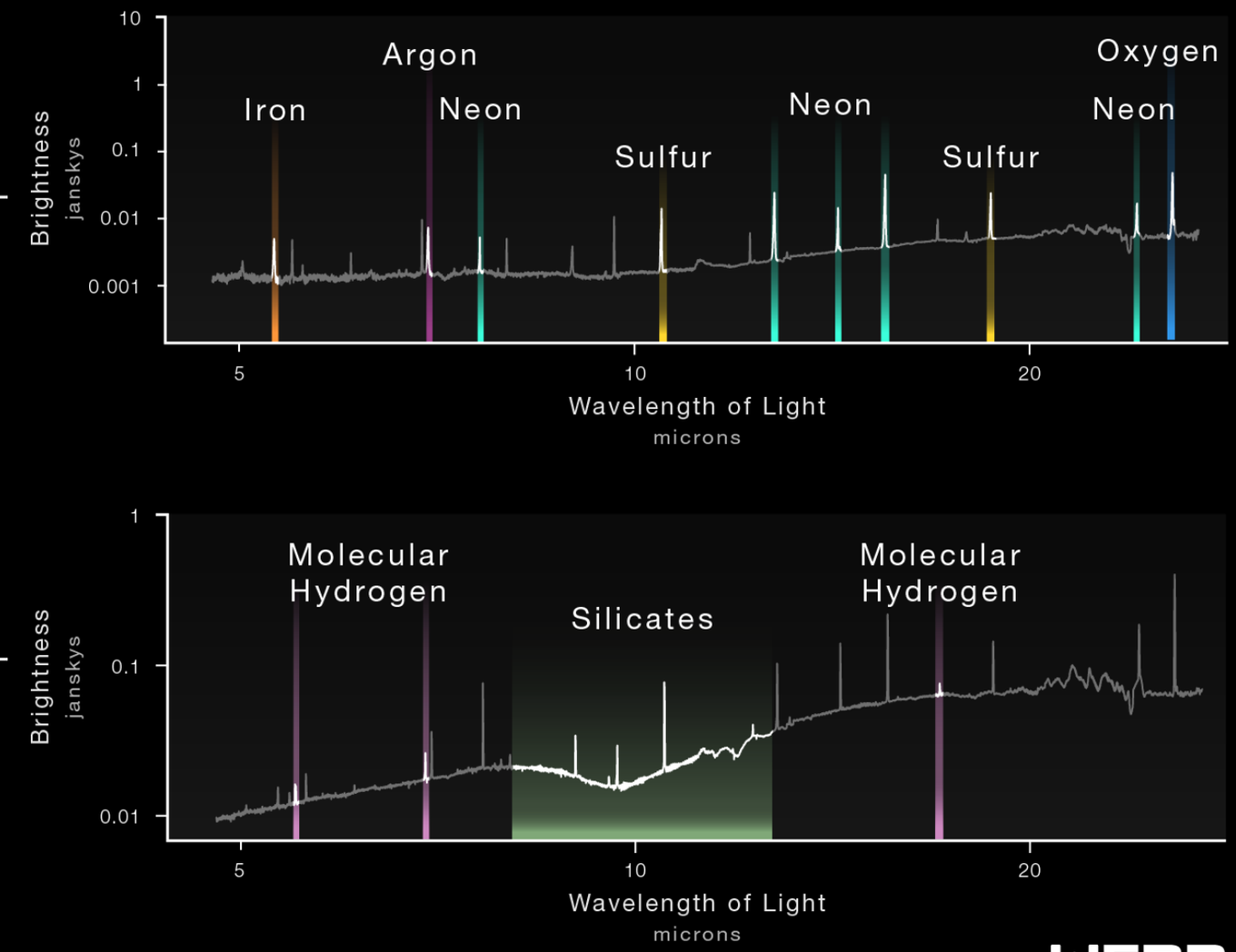
INTERACTING GALAXIES | STEPHAN'S QUINTET

COMPOSITION OF GAS AROUND ACTIVE BLACK HOLE

NIRCam and **MIRI** Imaging



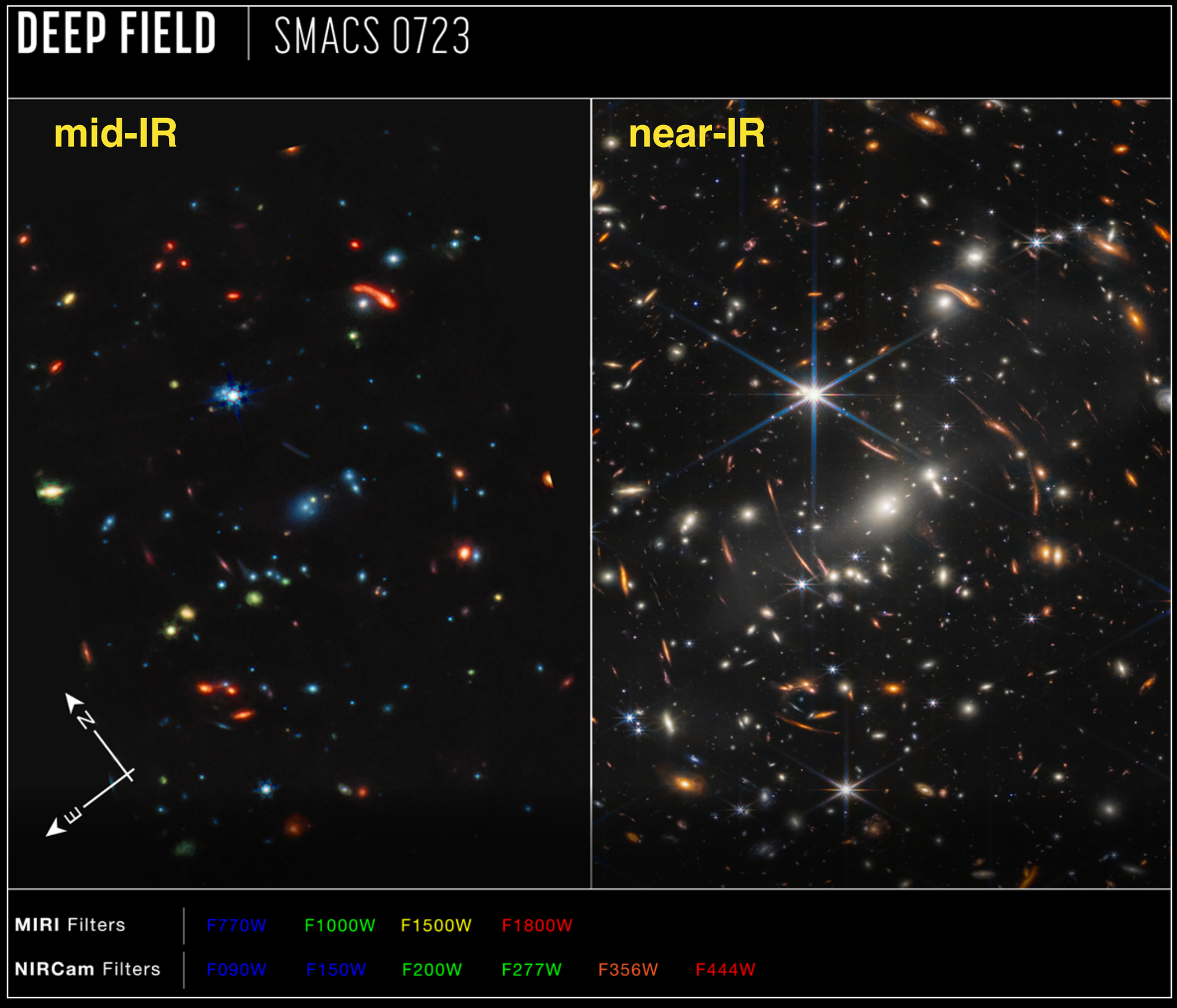
MIRI IFU Medium Resolution Spectroscopy



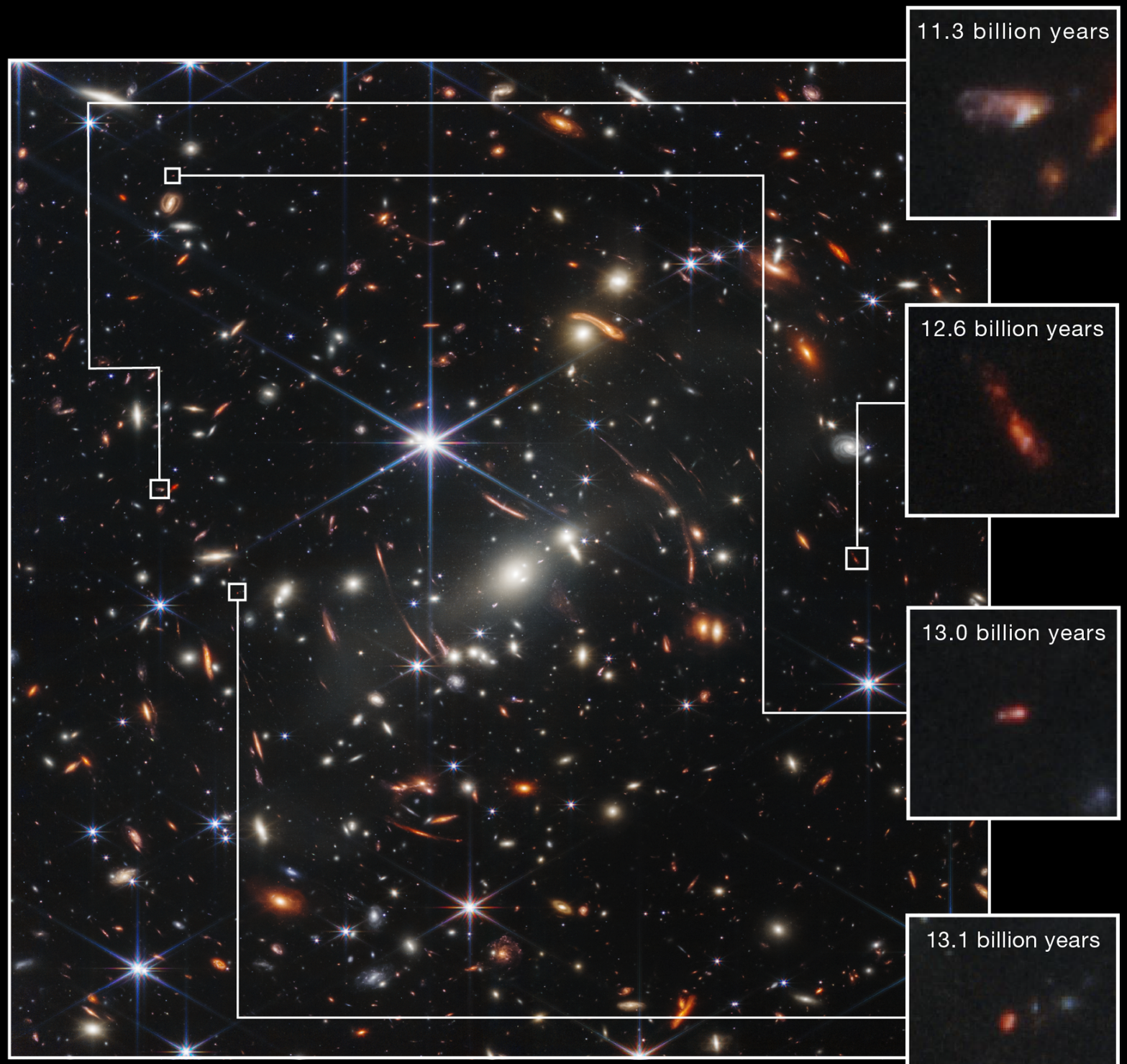
WEBB SPACE TELESCOPE

Credit: STSCI/ESA

4.2 The deepest view of galaxies …. EVER MADE



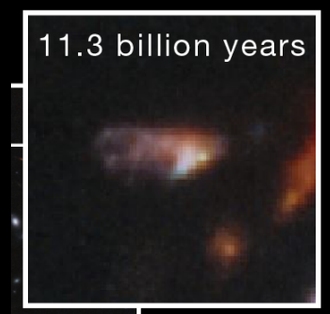
4.2 Images of very distant galaxies with JWST…

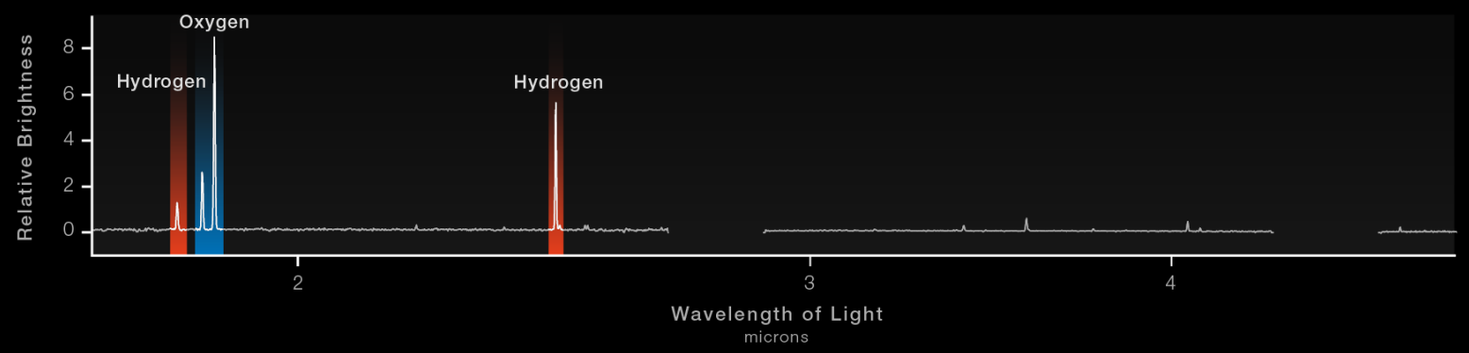


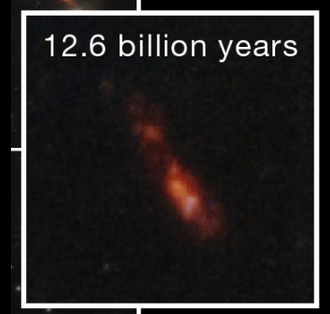
WEBB
SPACE TELESCOPE

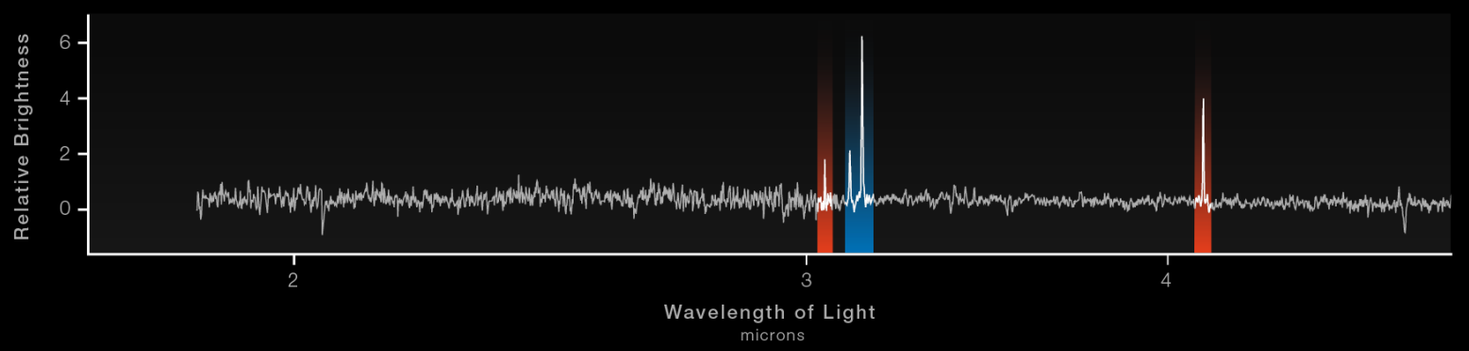
4.2 …and galaxy near-IR spectra with JWST

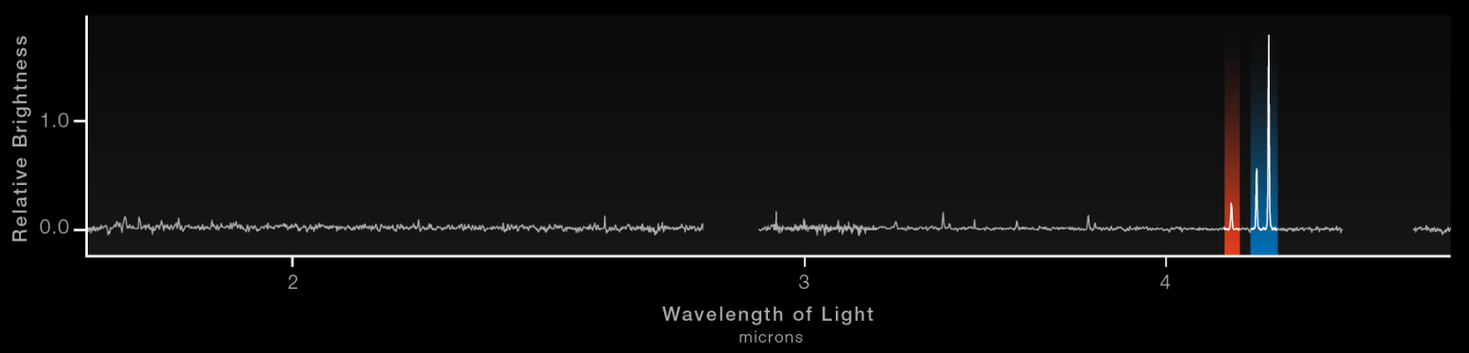
Lowest redshift

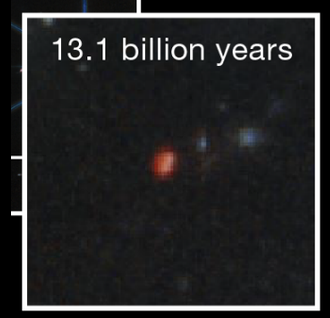


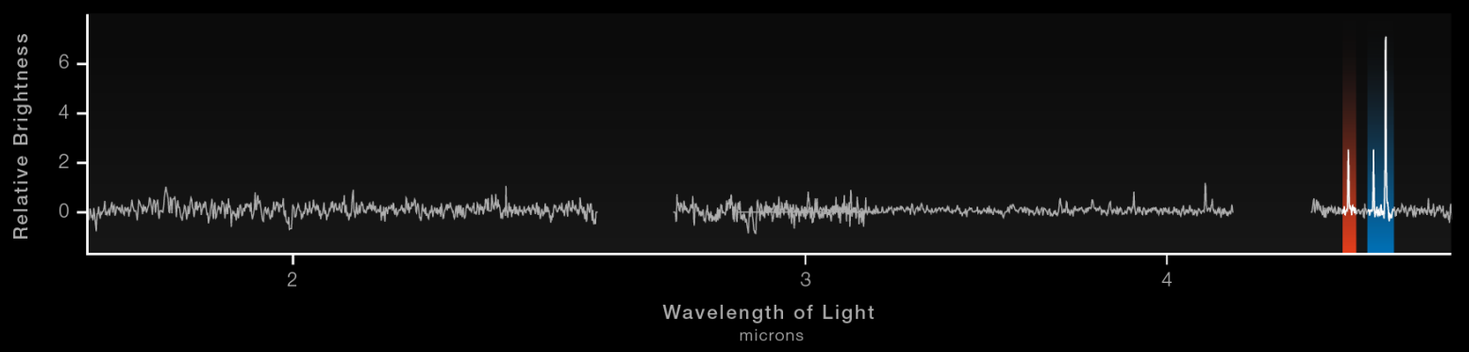








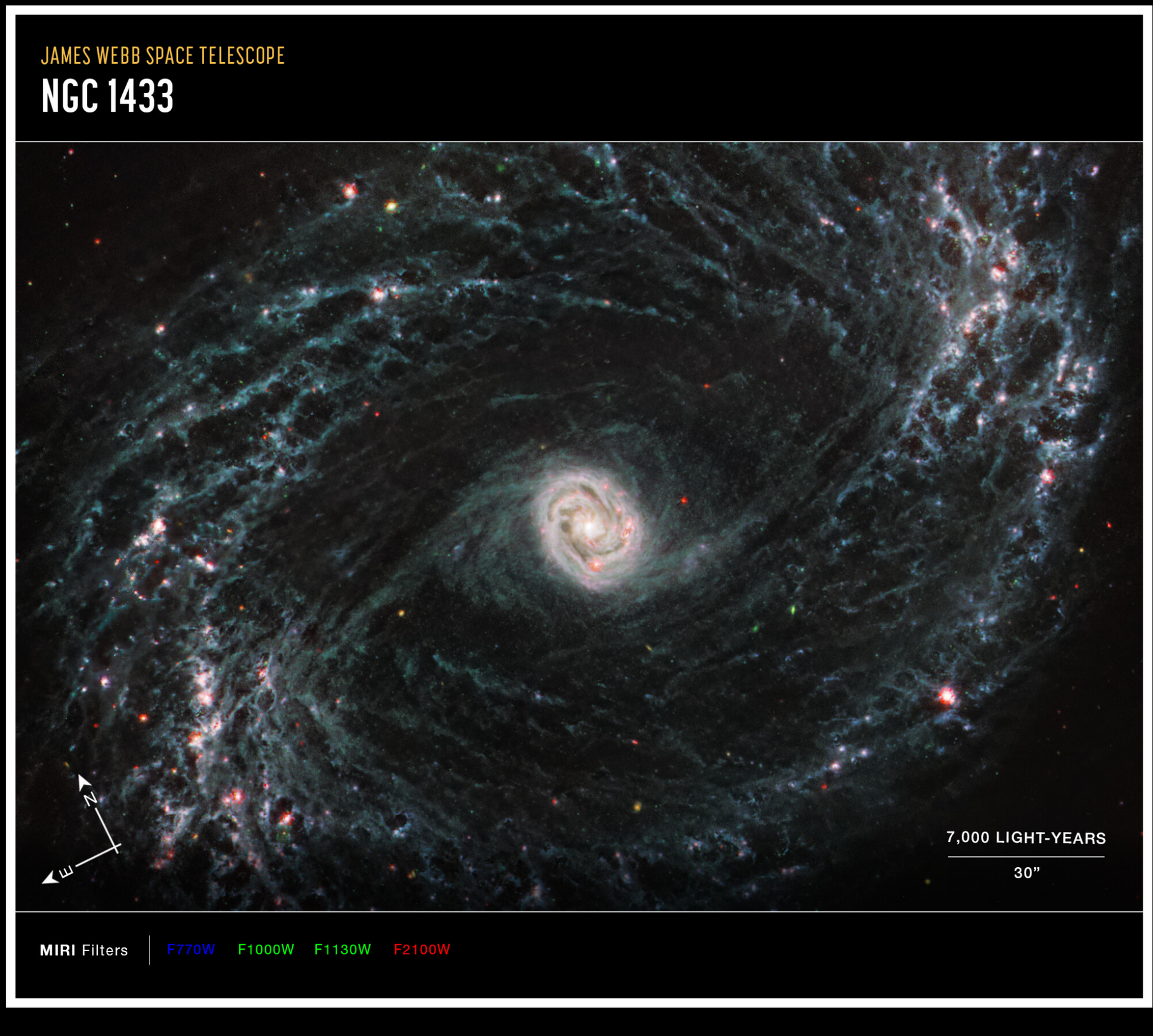




Highest redshift

4.2 Our view on dust in galaxies… NEAR

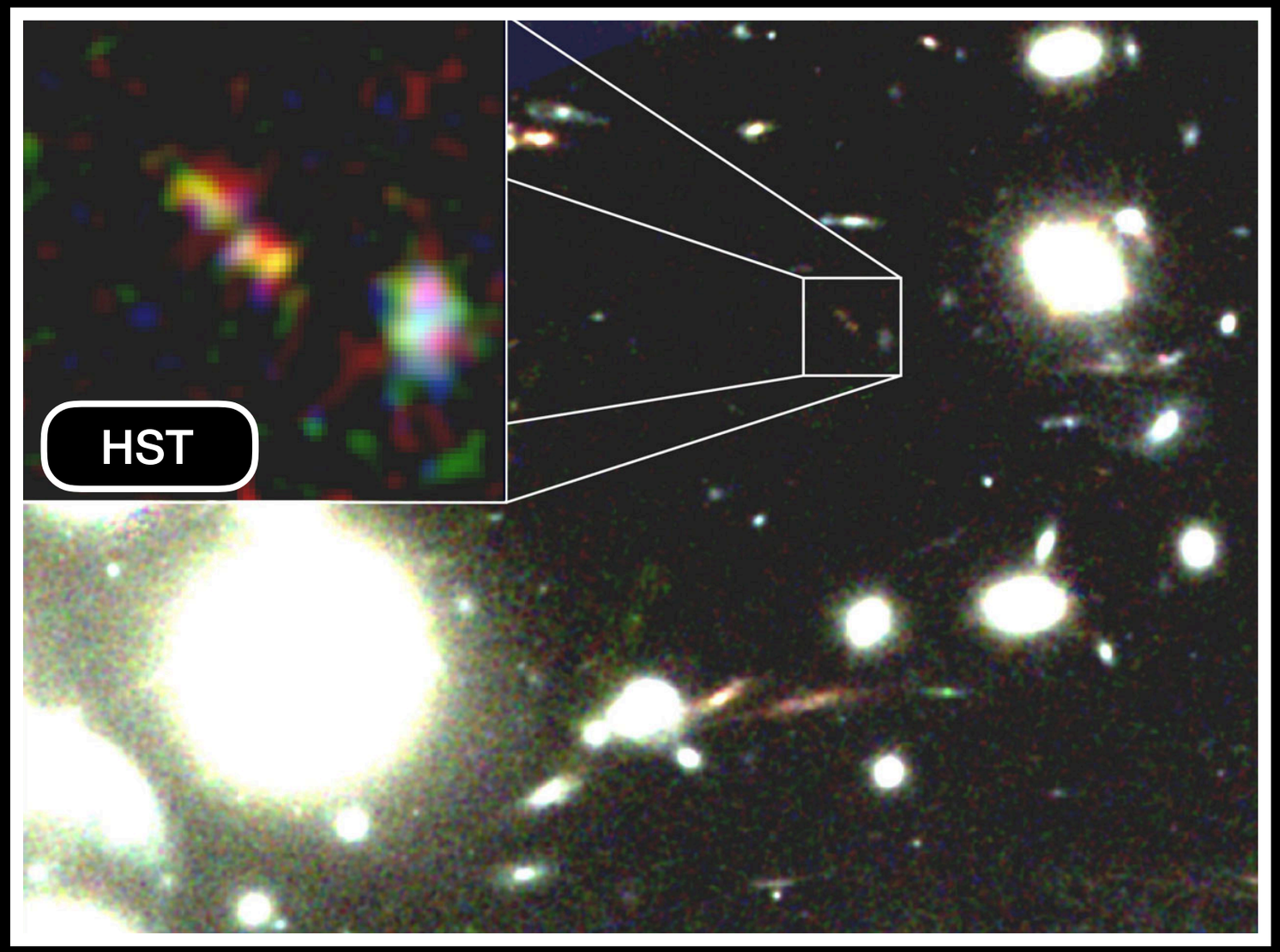
Image of a nearby galaxy NGC 1433 (PHANGS collaboration)



4.2 Our view on dust in galaxies… NEAR

dust in very distant galaxies

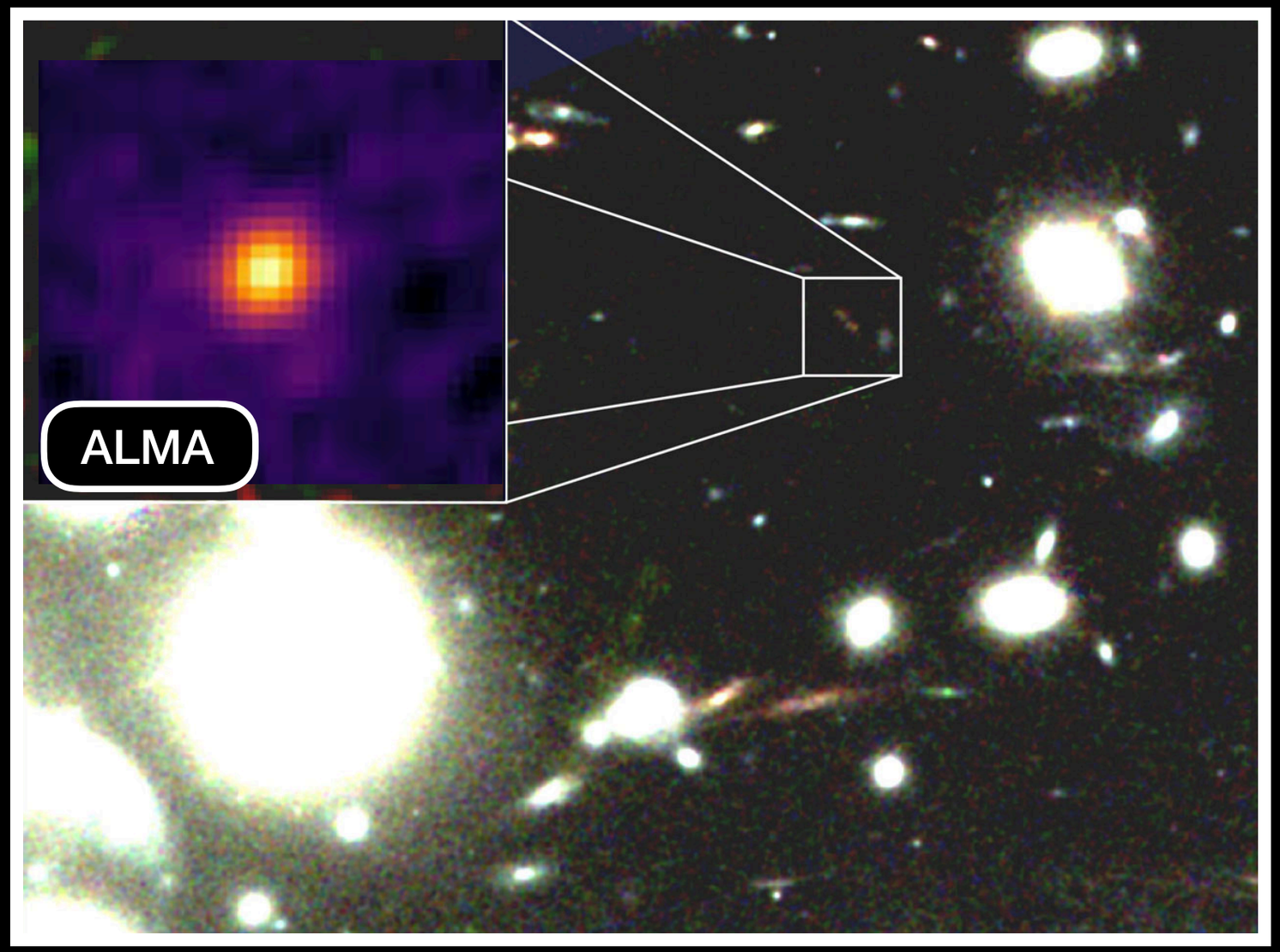
(credit: I. Shivaei)



4.2 Our view on dust in galaxies… NEAR

dust in very distant galaxies

(credit: I. Shivaei)

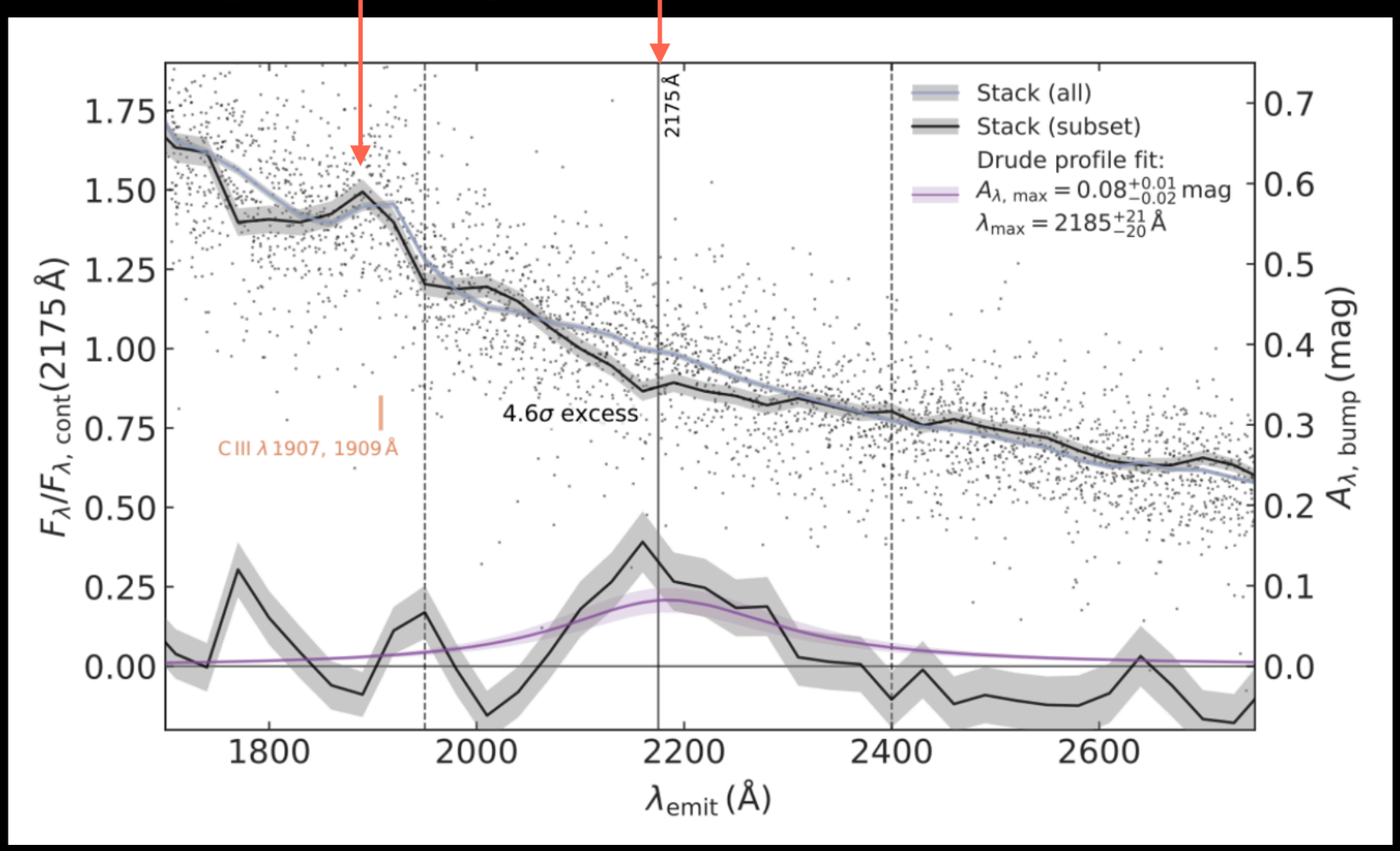


4.2 Our view on dust in galaxies… NEAR dust in very distant galaxies

(credit: I. Shivaei)

Dust absorb the UV light

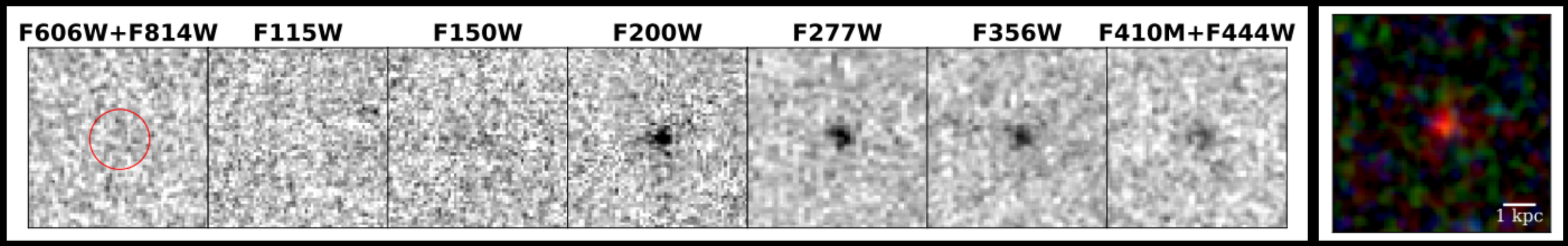
Carbon in the early Universe



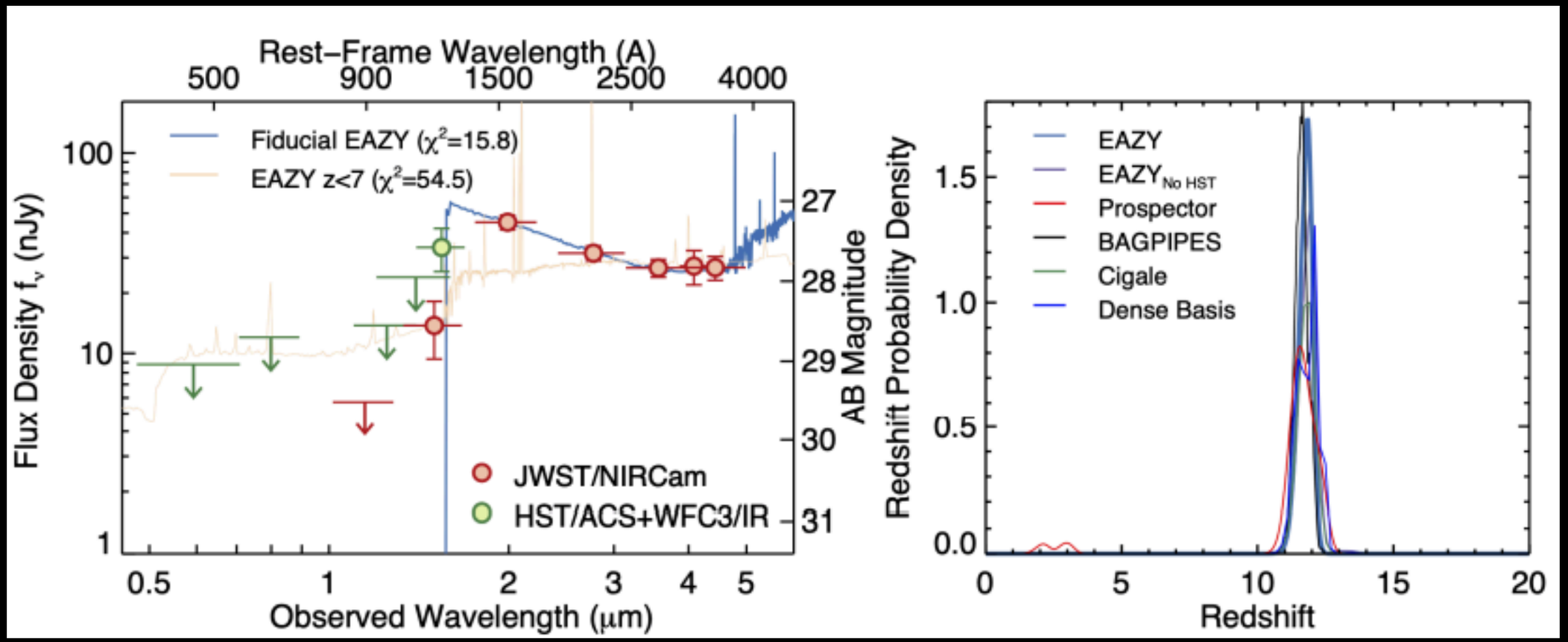
Evidence for carbon dust formation in the early Universe (Witstok et al. 2023)

4.2 The deepest view of galaxies …. EVER MADE

Image of a galaxy @ z=12 (Finkelstein et al. 2022)

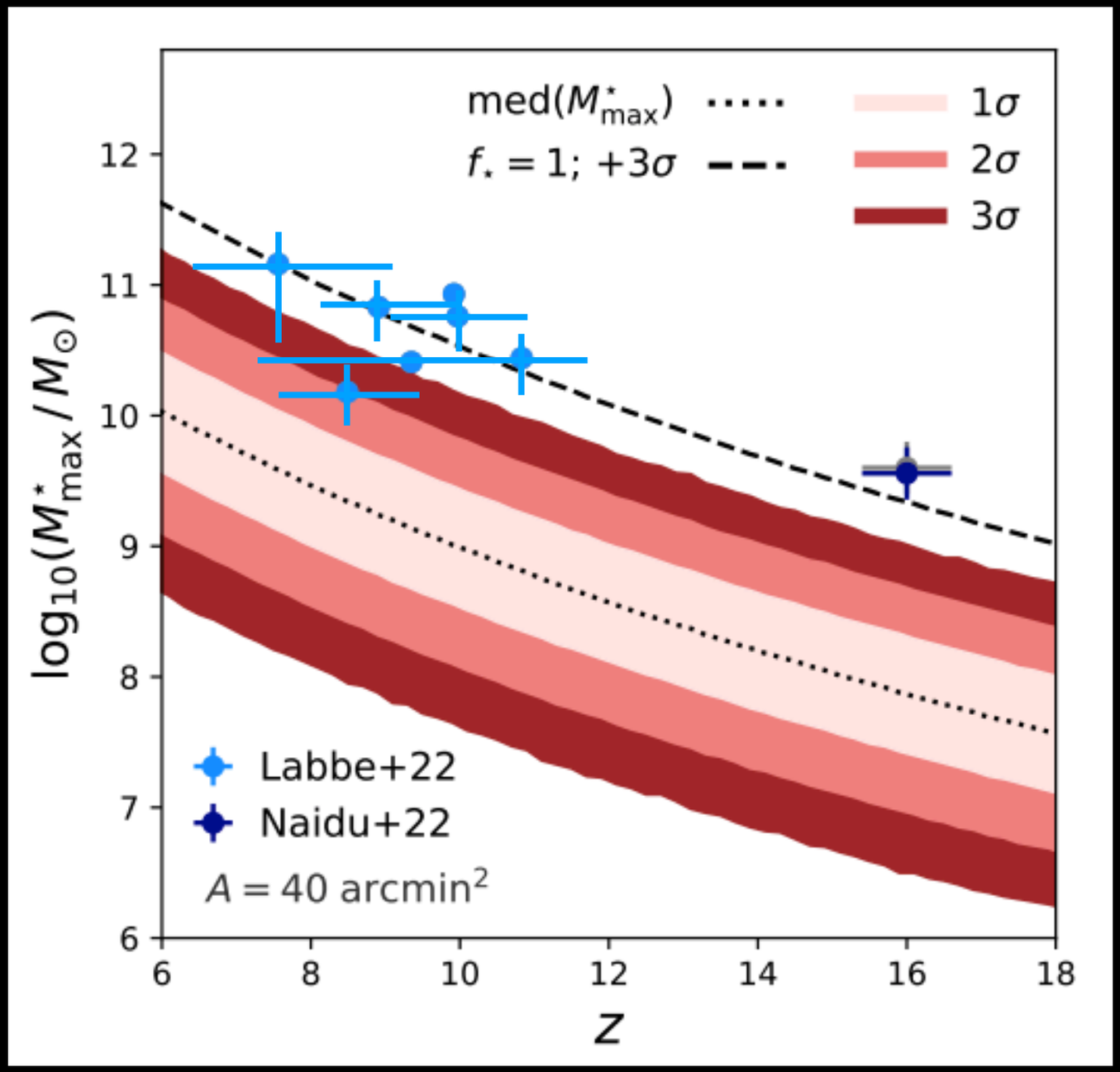


SED of a galaxy @ z=12



4.3 Observations vs. theory: tension with LCDM model?

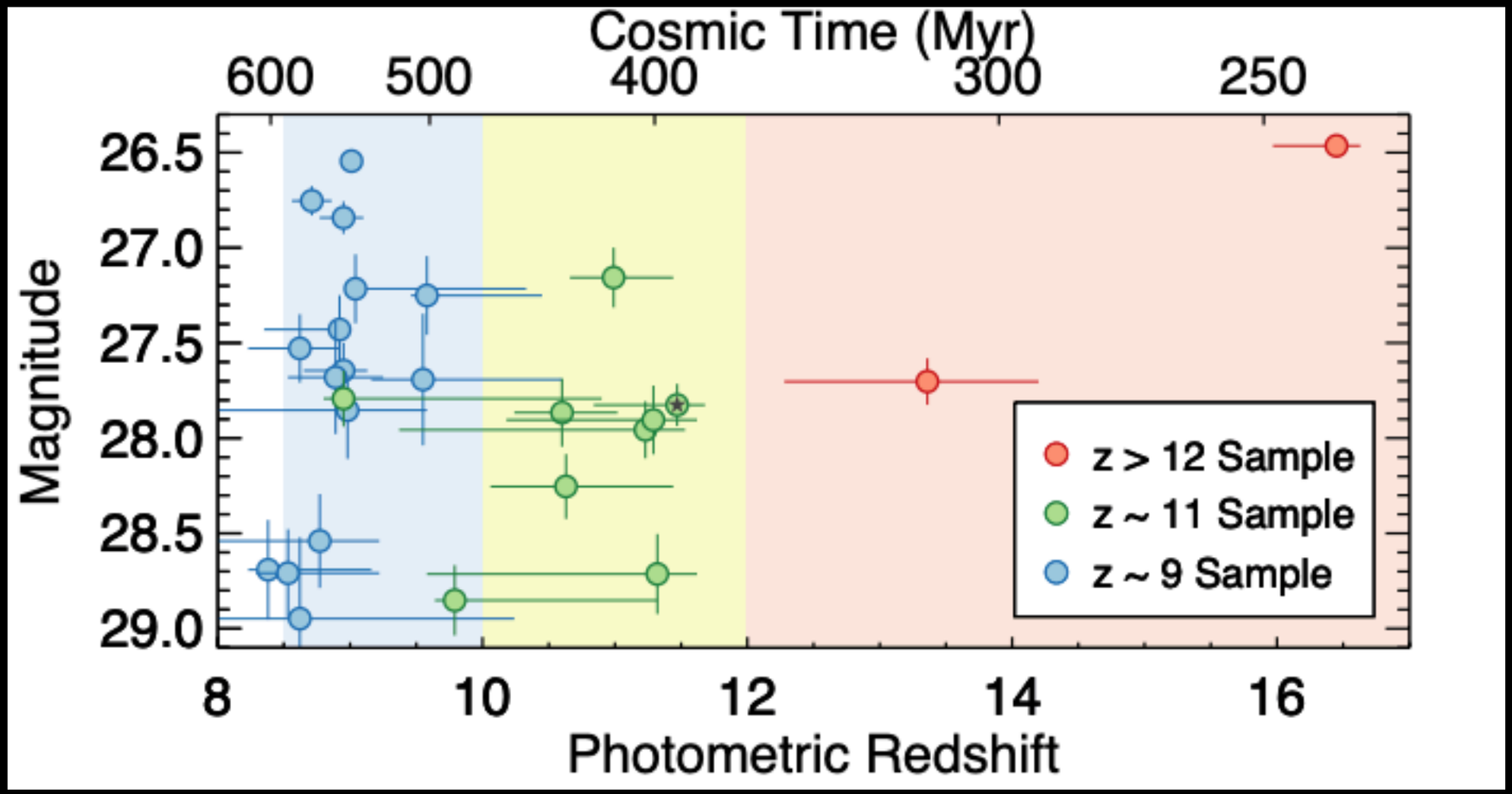
maybe NOT, if we account for all biases…



Credit: Lovell et al. 2022

4.2 The deepest view of galaxies …. EVER MADE

We find many very distant galaxies so far… can we explain them?



(Finkelstein et al. 2022)

Take-away messages

- Dust is critical to many processes regulating gas in galaxies
- JWST will provide completely new view on infrared & distant Universe.

- So far, the number of galaxies found within the first 1 Gyr after the Big Bang is slightly higher than expected from LCDM models.
- Number of dusty galaxies is much larger (x3 times) than expected
  —> New view onto formation of silicate and carbon dust in galaxies!

- Main goals of future surveys are:

1) detailed characterisation of warm dust in distant galaxies
2) unveiling the census of SF vs AGN galaxies @z>7-15
3) answering the question how many of these extremely distant galaxies are mergers or isolated
4) to reveal how fast galaxies enriched with dust and metals

Comments/Questions

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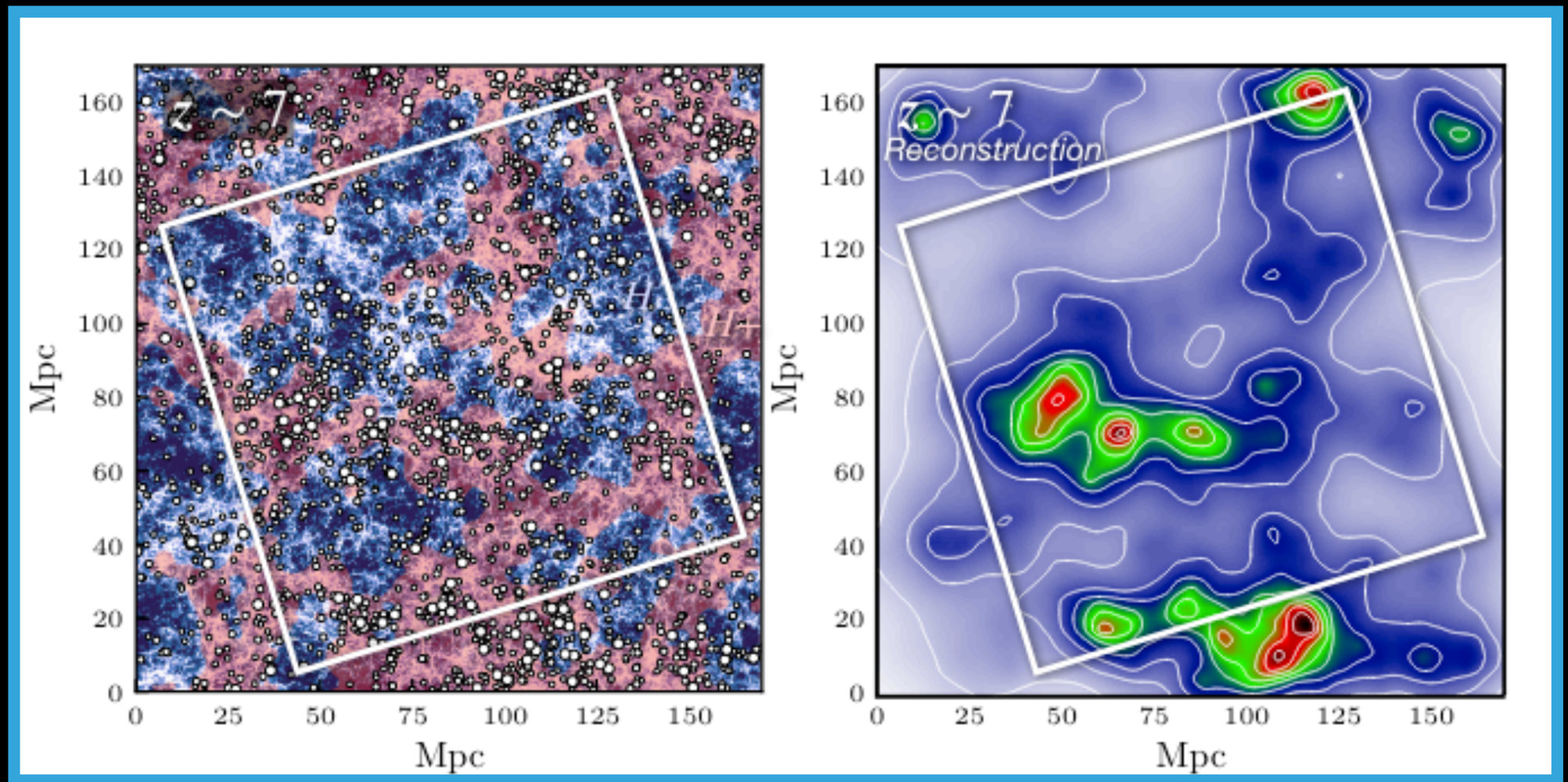
Future with JWST

Are high-z galaxies strongly clustered?



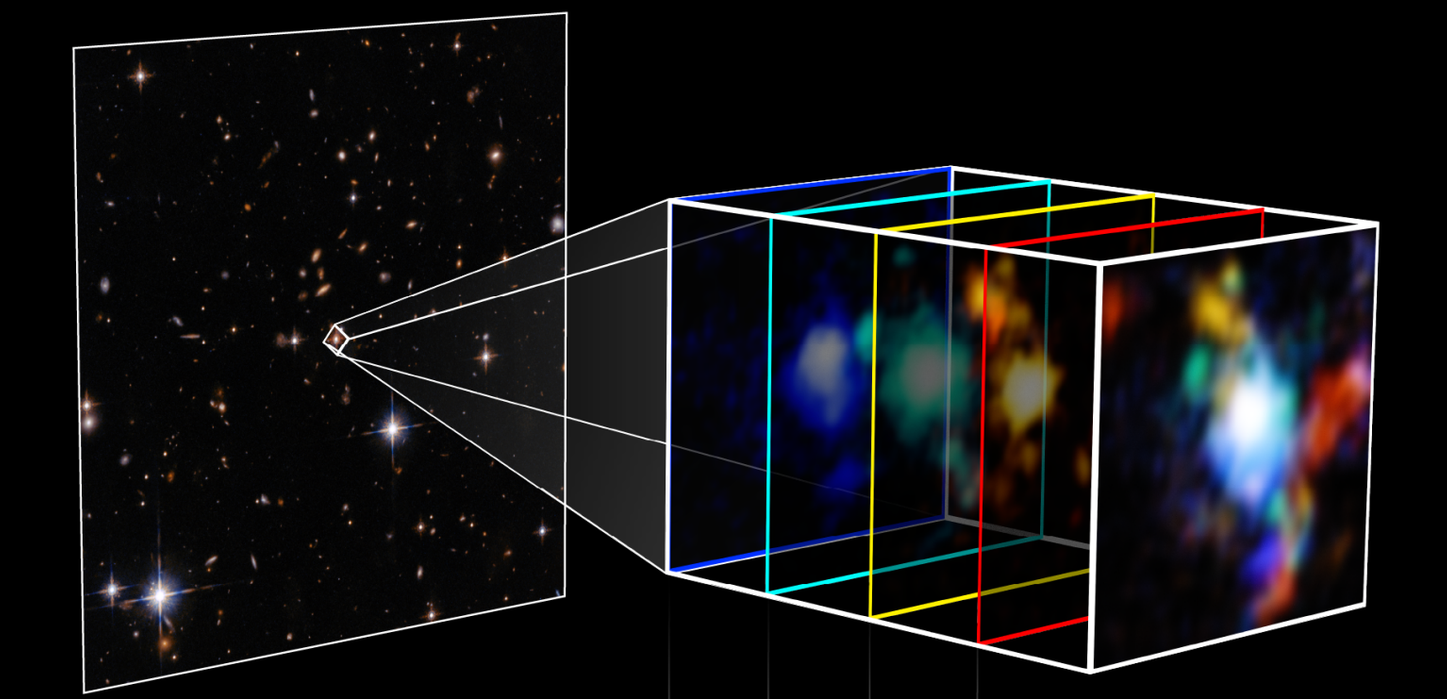
insight from simulations

SDSS J165202.64+172852.3

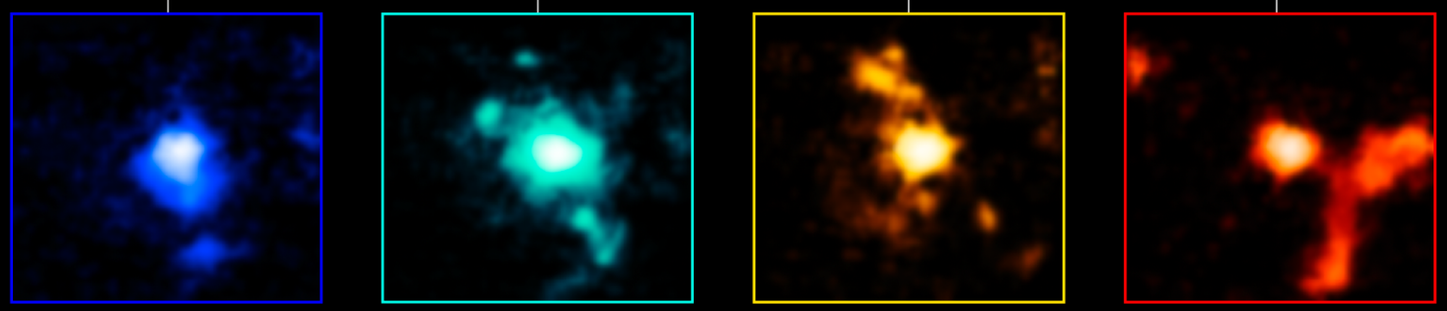
MOTIONS OF GAS AROUND AN EXTREMELY RED QUASAR

Hubble ACS + WFC3 Imaging

Webb NIRSpec IFU Spectroscopy



Emissions from doubly ionized oxygen



-350
kilometers per second

0
kilometers per second

+370
kilometers per second

+700
kilometers per second

Toward — Away

WEBB
SPACE TELESCOPE