

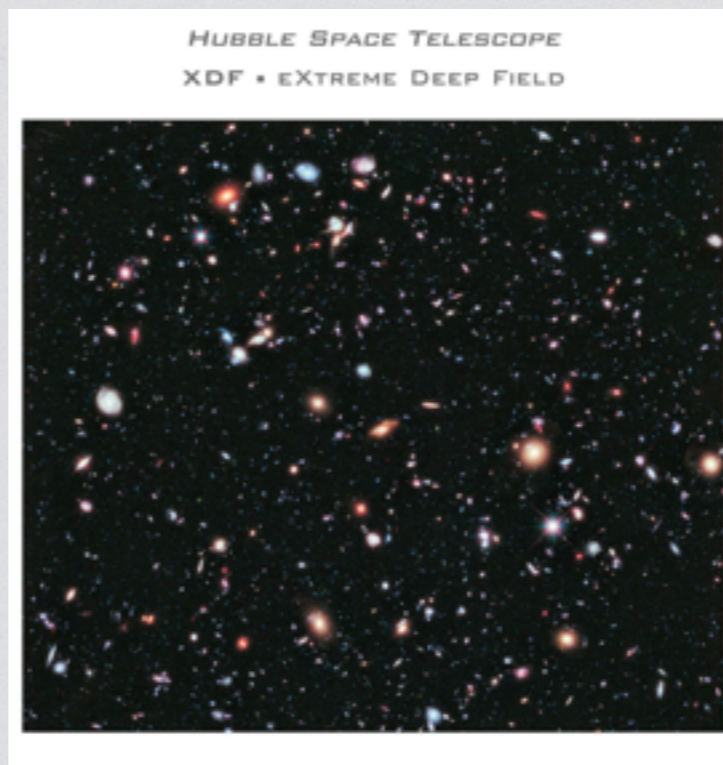
The Furthest Galaxies



Michele Trenti

The University of Melbourne

mtrenti@unimelb.edu.au



Taylor Lakes College

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The night sky (naked eye)



[Yuri Beletsky \(ESO\)](#)

Galaxies appear



What is a galaxy?



★ Andromeda, our closest neighbor

NASA

What is a galaxy: spirals



Galaxy M101, NASA/ESA

What is a galaxy: spirals

★ Spiral galaxies have disk/(pancake)-like shape



Galaxy NGC4710, NASA/ESA

What is a galaxy: ellipticals



Galaxy NGC 1132

NASA/ESA

Irregular/interacting galaxies



The Mice • Interacting Galaxies NGC 4676
Hubble Space Telescope • Advanced Camera for Surveys

NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI), the ACS Science Team and ESA • STScI-PRC02-11d

The need for space telescopes

★ Earth

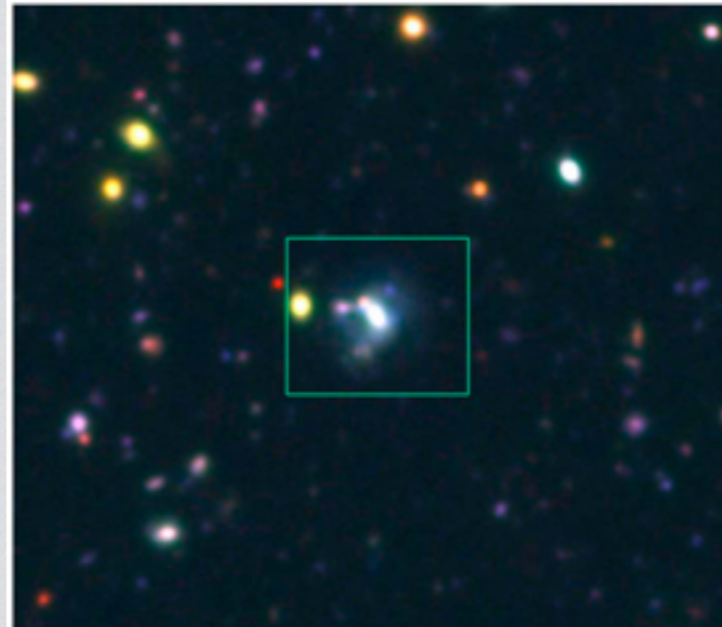
Atmosphere:

★ absorbs light

★ blurs the images

★ Space Telescopes
give sharper
images

Ground: Subaru (8m)



Space: HST (2.4m)



The need for space telescopes

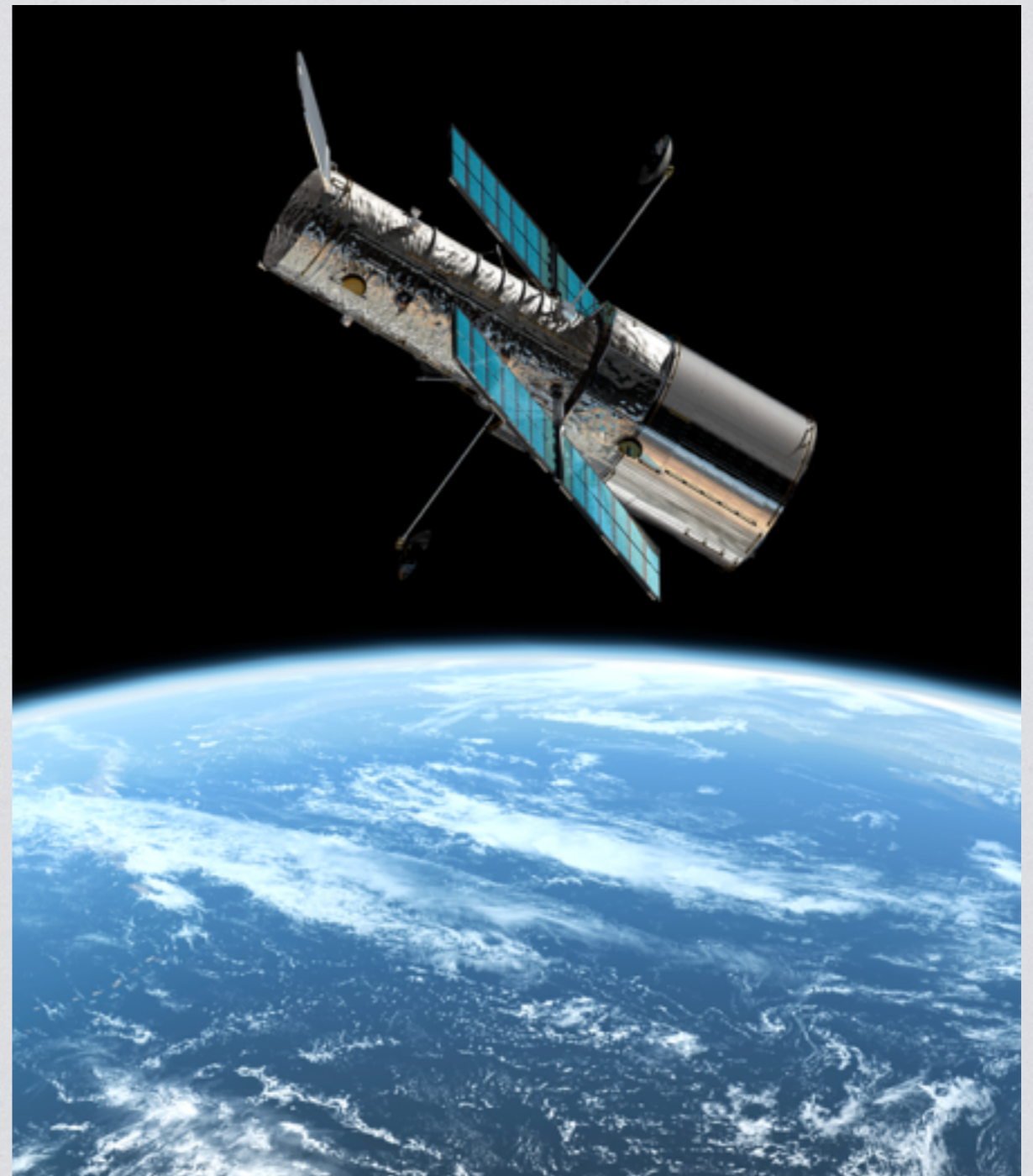
★ Earth

Atmosphere:

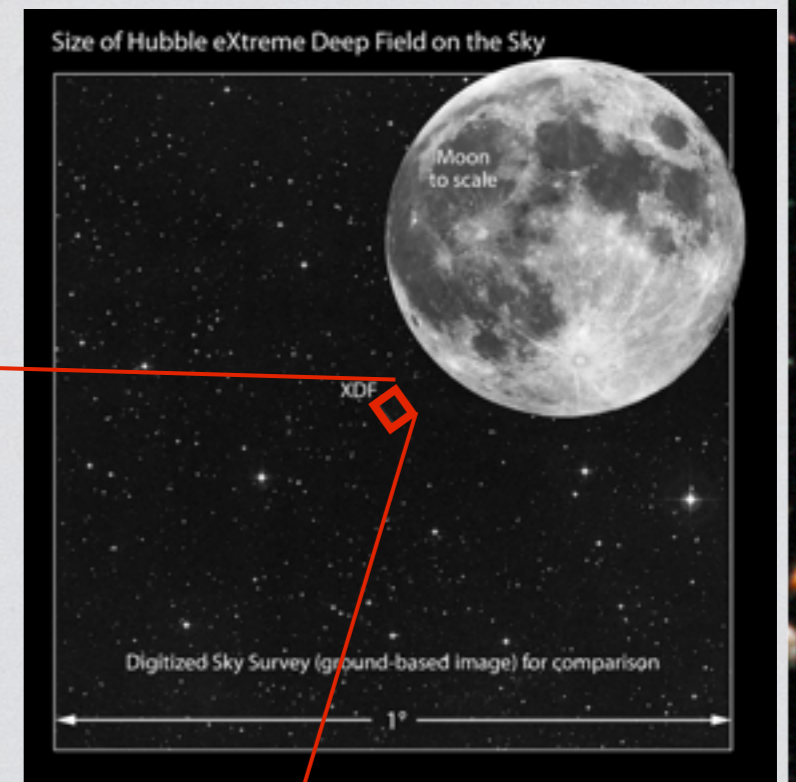
★ absorbs light

★ blurs the images

★ Space Telescopes
give sharper
images



eXtreme Deep Field



★ 23 days
exposure
time with
Hubble!

What we can learn?

NASA/ESA, XDF team

- ★ How many galaxies in the Universe?
- ★ How far?
- ★ How old?
- ★ Are properties evolving with time?



How many galaxies?

NASA/ESA, XDF team

- ★ This image contains
~5500 galaxies
- ★ Area is one part in 13
million of the full sky
- ★ $5,500 \times 13,000,000 \sim$
**70 billion galaxies in
the Universe**



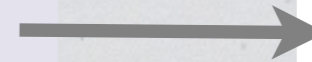
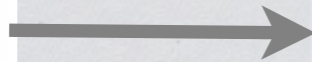
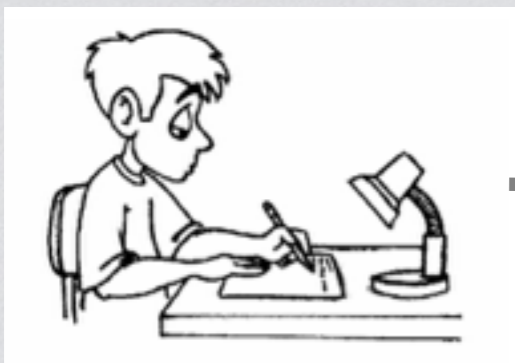
How far and how old?

NASA/ESA, XDF team

- ★ Information compressed in 2D
- ★ But galaxies are at different distances
- ★ Distance and age intertwined
- ★ Light travels at finite speed
- ★ Distant galaxies seen when Universe was young!



Finite speed of light: an analogy



- ★ Photons (light) transport information, much like a letter in the mail
- ★ It takes time for information to reach us
- ★ When we receive it, we get a snapshot of the past

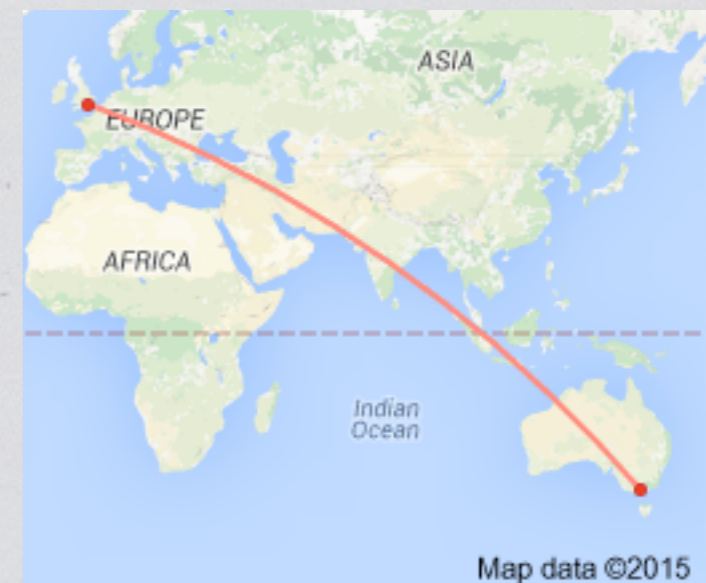
The slowness of light

★ Photons (light) travel at $\sim 300,000$ km/s

★ Almost instantaneous on Earth

★ Tens of nanoseconds to cross this room

★ ~ 50 milliseconds (0.05s) to London



The slowness of light

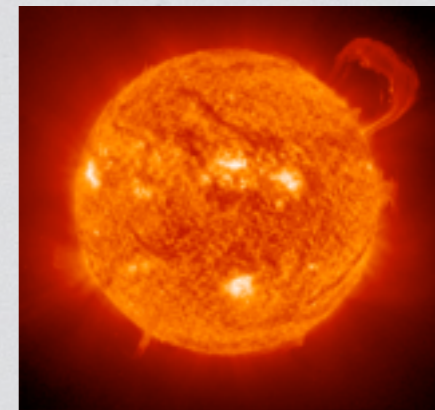
★ Photons (light) travel at $\sim 300,000$ km/s

★ Significant in the solar system

★ 1s to the Moon

★ ~ 8 minutes to the Sun

★ ~ 5 hours to Pluto



The slowness of light

★ Photons (light) travel at $\sim 300,000$ km/s

★ Very slow in the context of galaxies

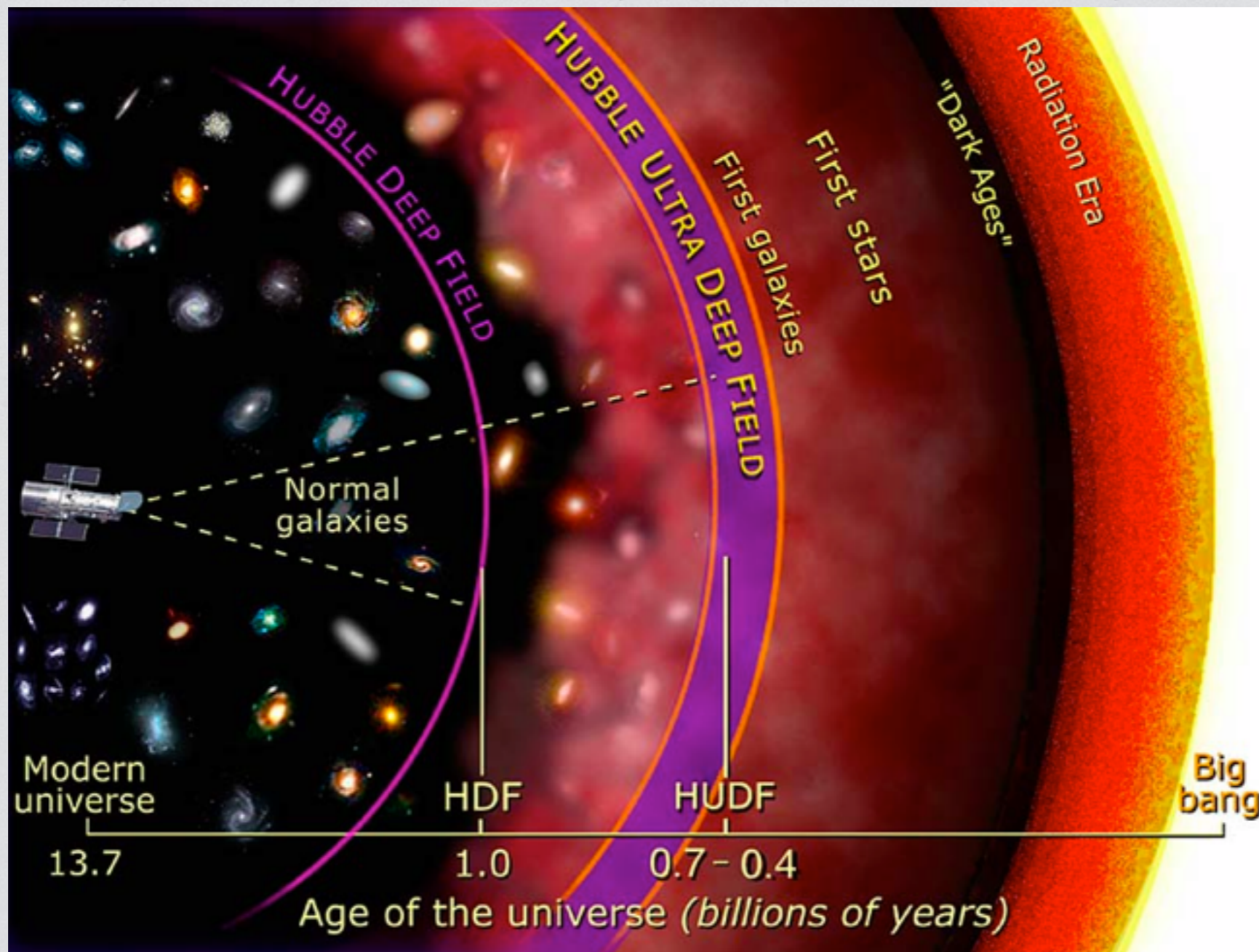
★ Nearest star
[Proxima Cen]: ~ 4 years



★ Nearest large galaxy
[Andromeda]:
 ~ 2.5 million years



The furthest galaxies live in the young Universe



Galaxy colors and distance

★ Galaxies have intrinsic colors

★ Depend on stellar ages and dust



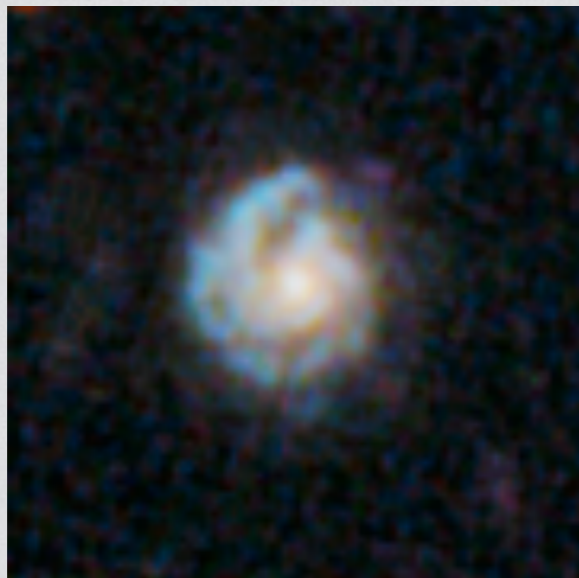
Young stars: Blue



Old/dusty: Red

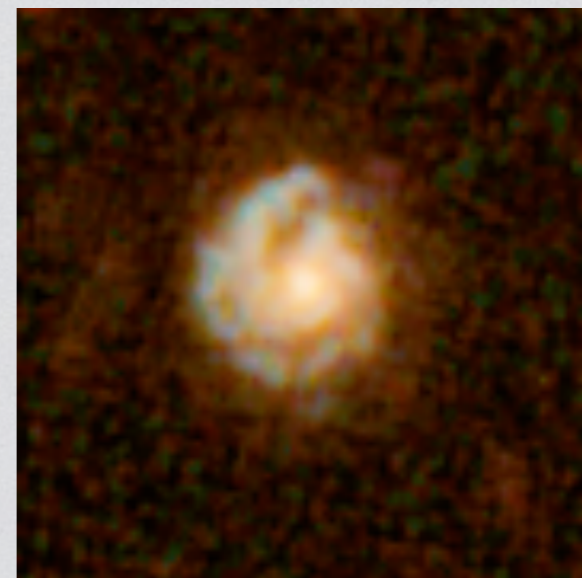
Galaxy colors and distance

- ★ Galaxies have intrinsic colors
 - ★ Depend on stellar ages and dust
- ★ In addition: **observed** colors depend on distance



5 billion light years

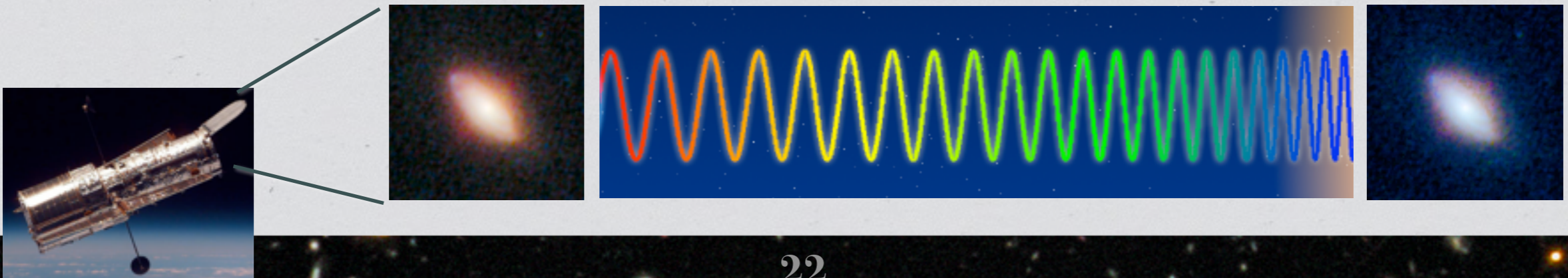
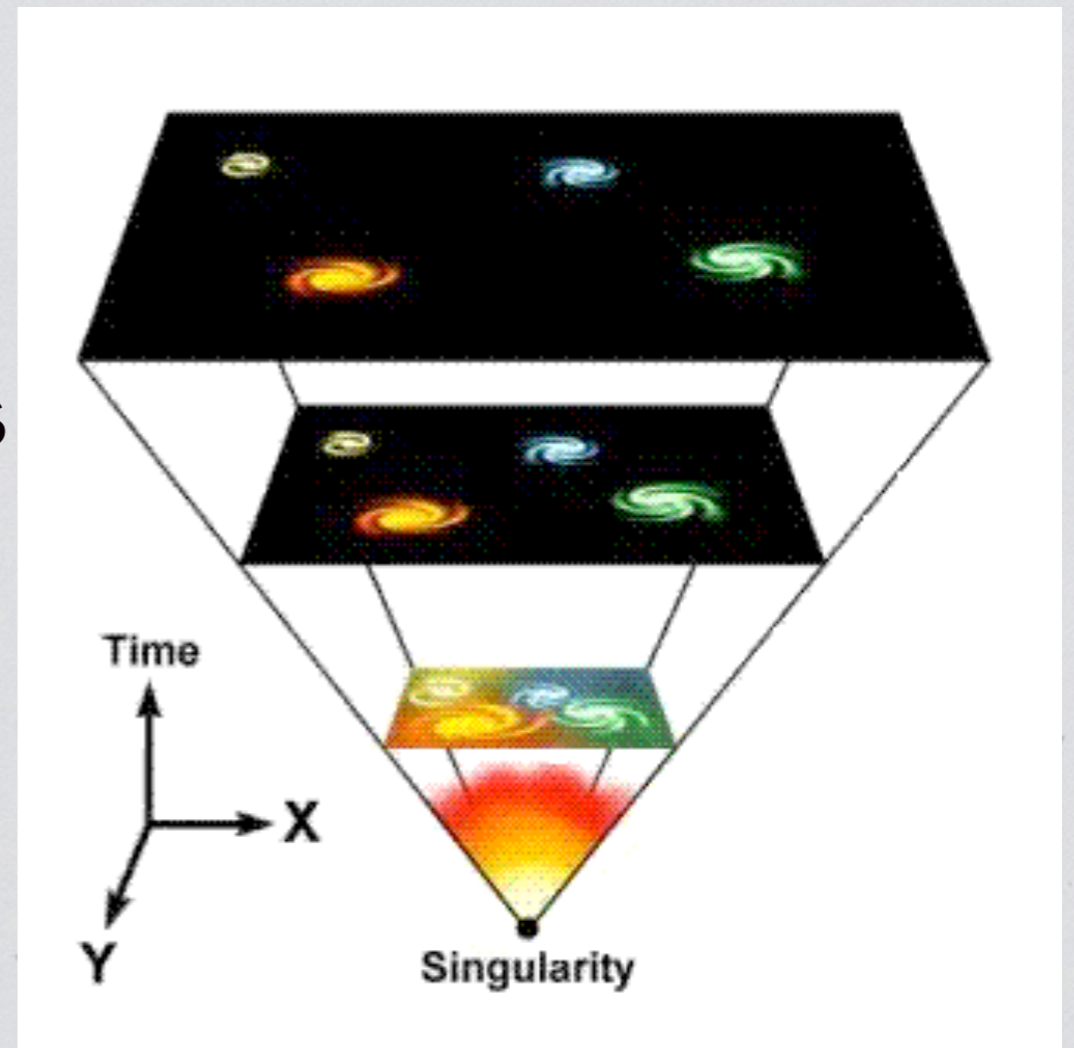
Why?



12 billion light years

Red-shifting of light

- ★ Universe is expanding
- ★ Distant galaxies move away from us as Universe expands
- ★ Doppler-shift of the photons emitted
 - ★ The more distant, the **redder**



XDF: a typical "nearby" spiral



★ This magnificent spiral is "only" 6 billion light years from us

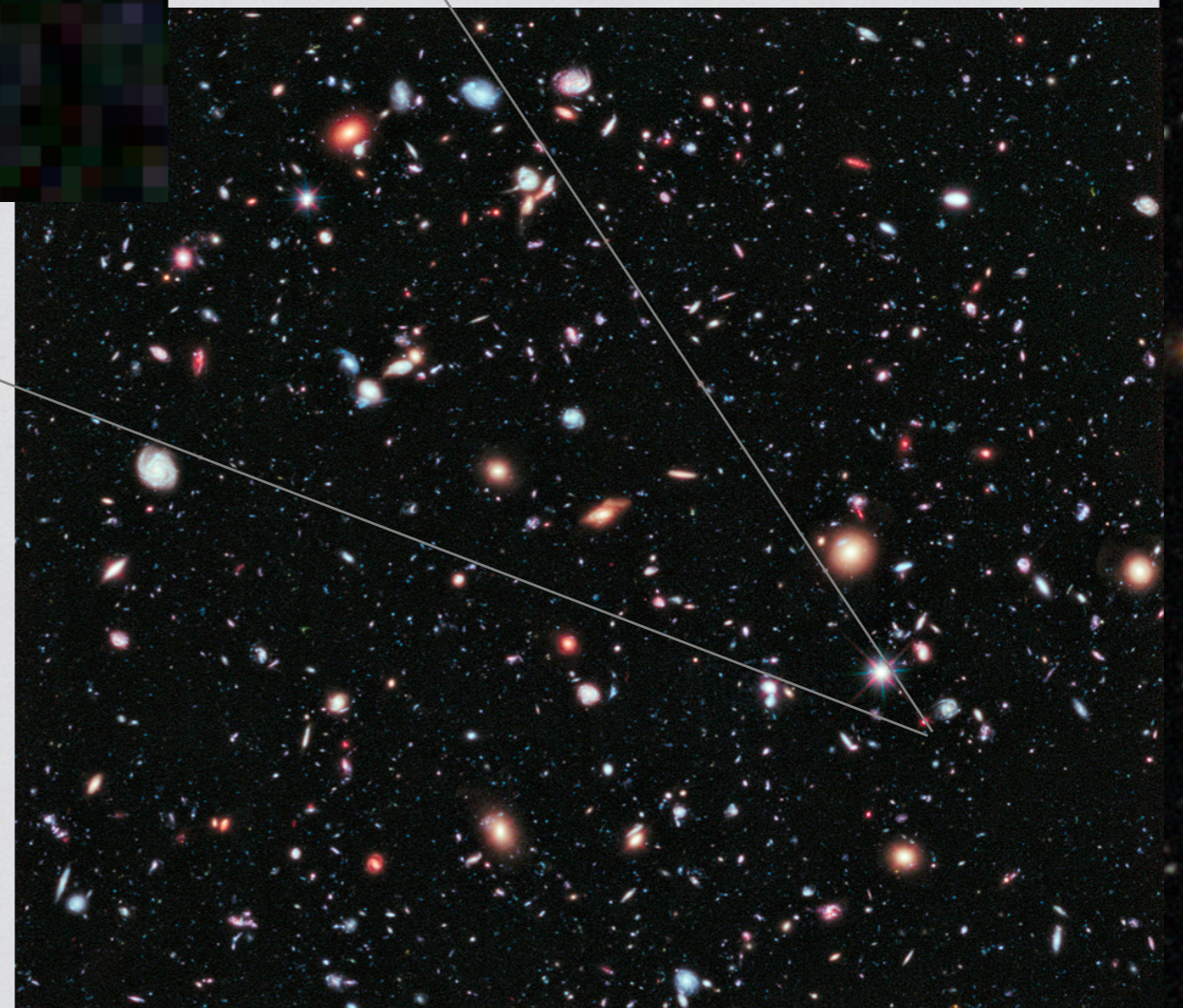
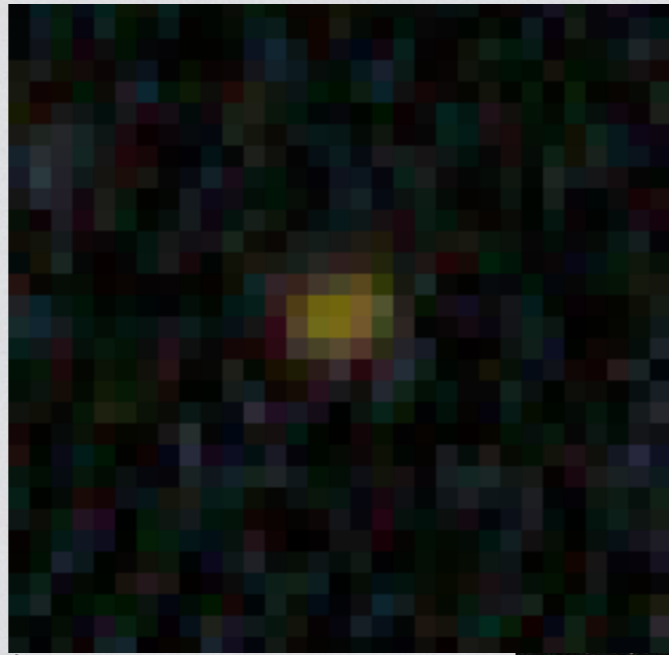
★ It is about 3000 times brighter than faintest galaxies seen in the XDF



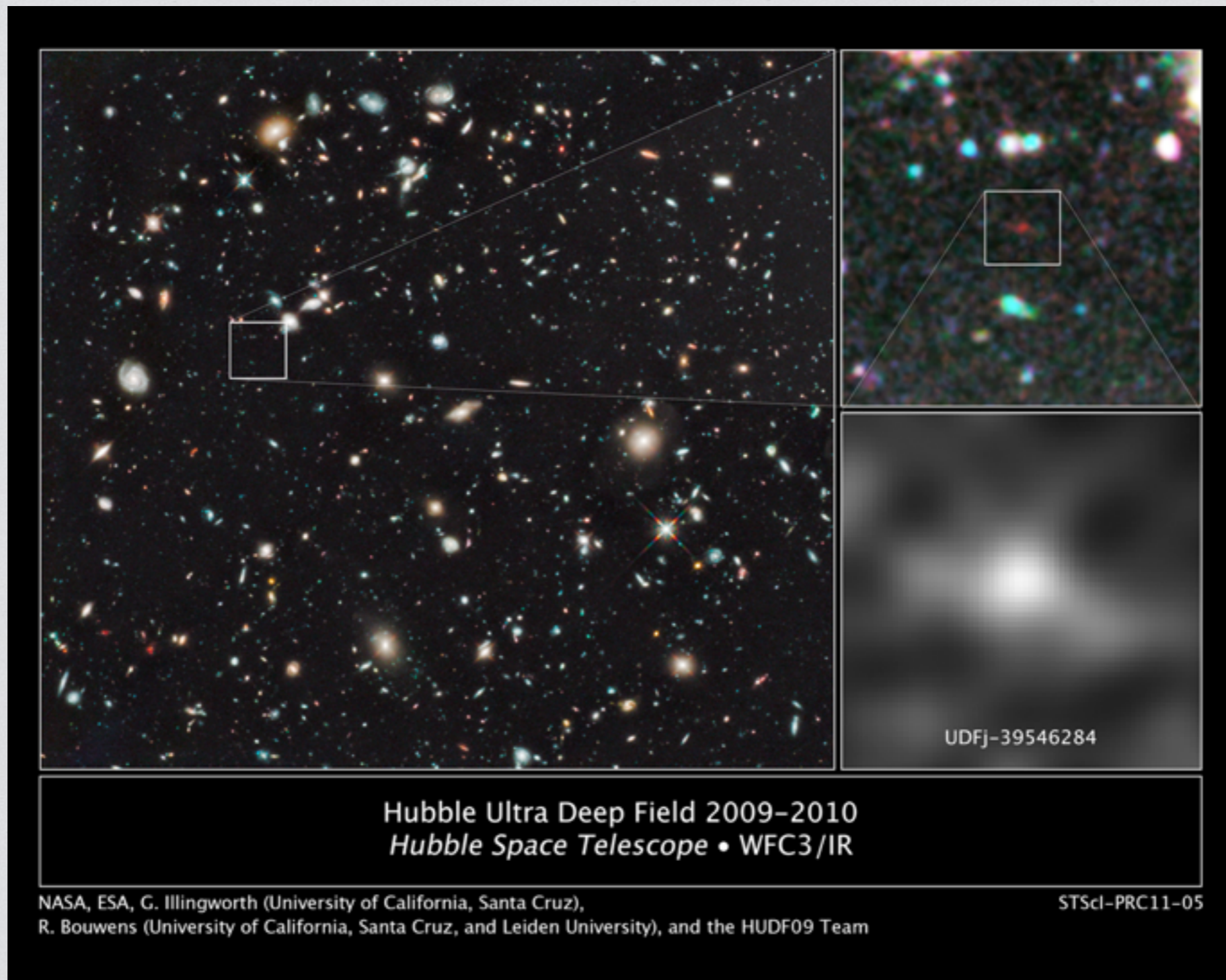
XDF: a typical distant galaxy

★ The light of this tiny dot has traveled for about 12.5 billion years before reaching us

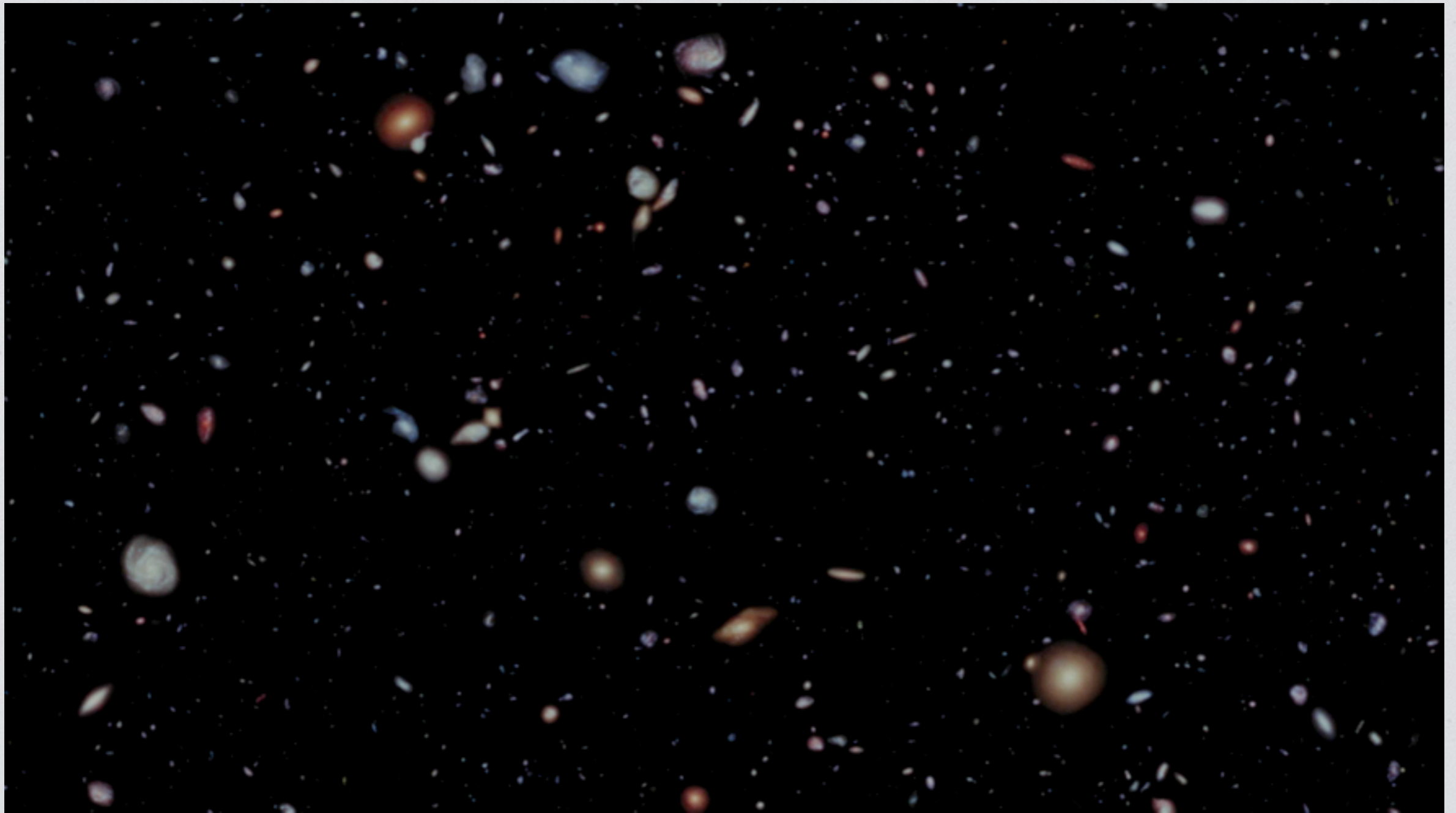
★ There are about 50 galaxies in this image at similar (or higher) distance from us



The distance frontier

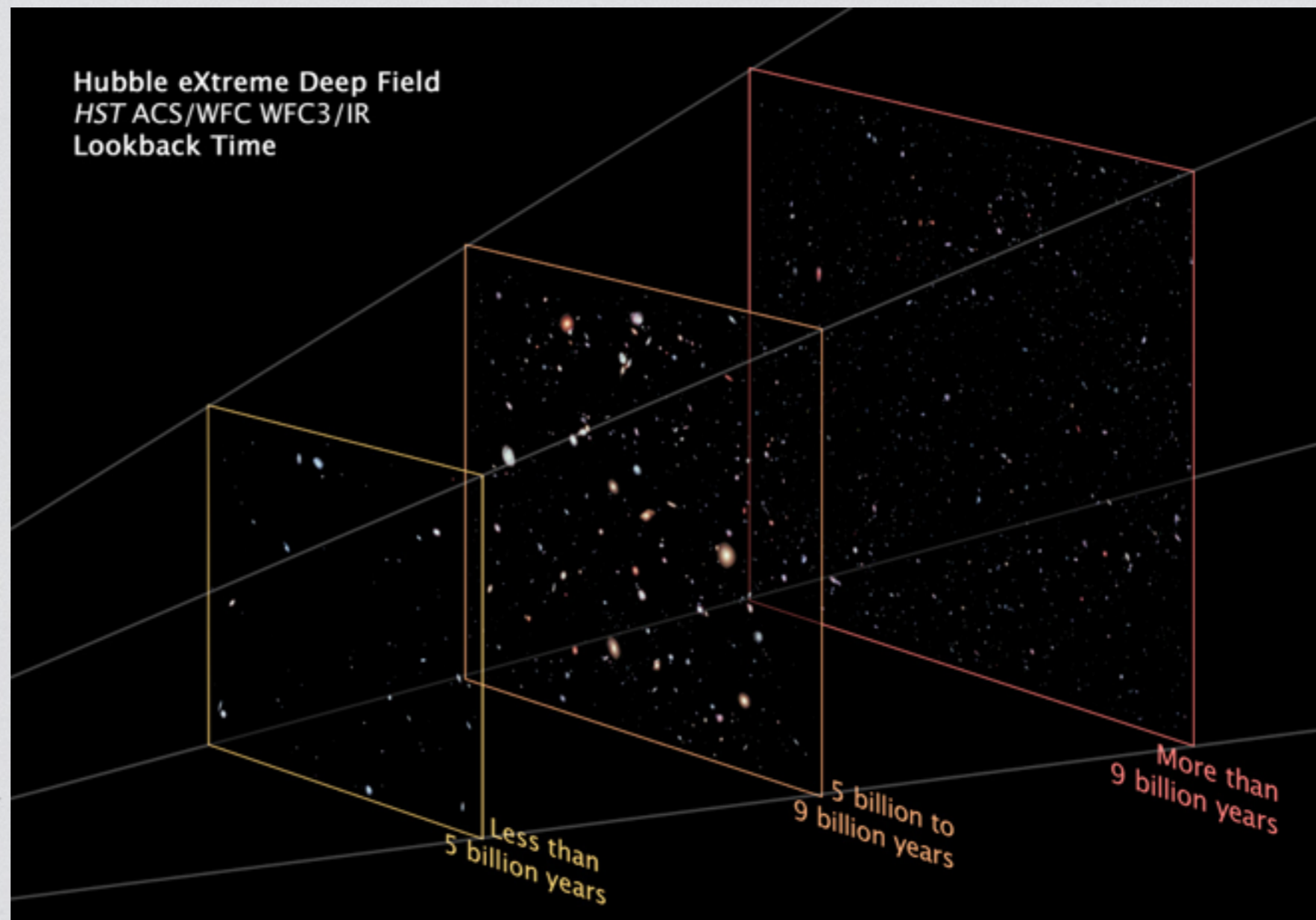


Looking back in time

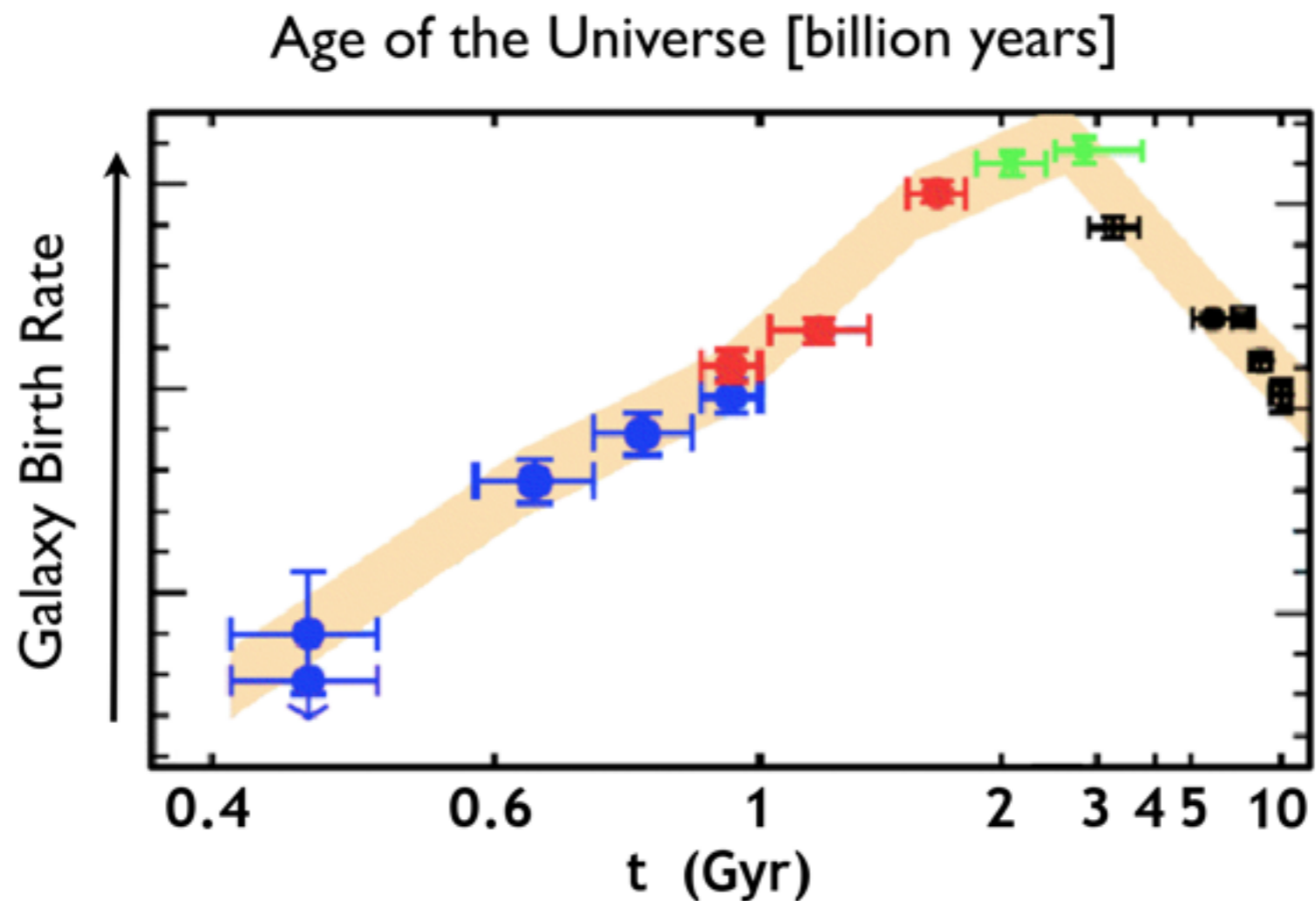
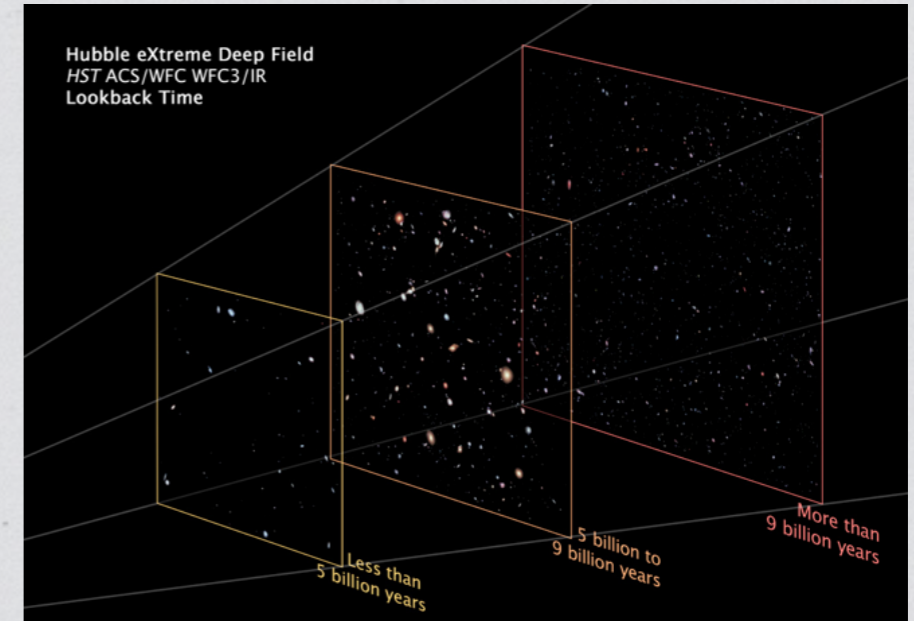


NASA/ESA, XDF team

Galaxy density versus lookback time



Galaxy formation rate versus time



Why study galaxies across time

★ Cosmic origin theme:

★ Where are we coming from?



Recent progress / open questions

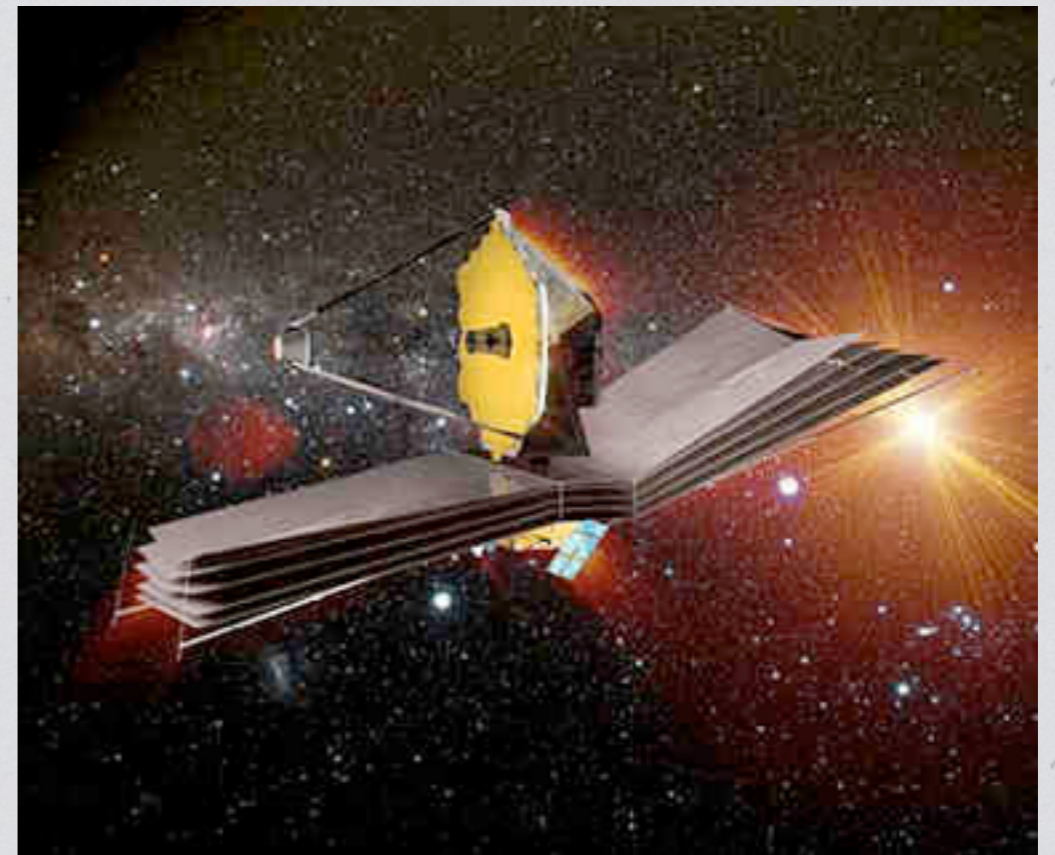
Hubble telescope sees galaxies over 95% of the Universe

- ★ Galaxy formation golden age: 10-12 billion years ago
- ★ How early can galaxies form?
- ★ Are the properties of the first generations of stars different?

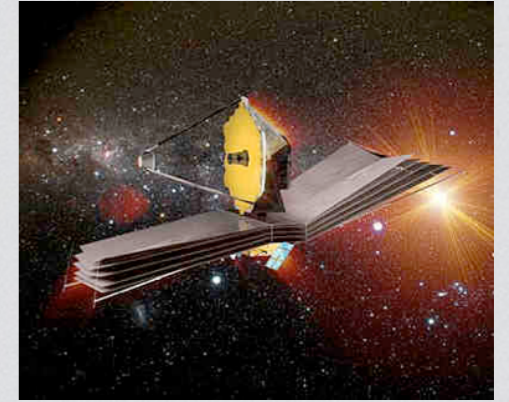


Going where no one has gone before

- ★ 400-500 million years after the Big Bang is Hubble's Detection Frontier
- ★ More distant galaxies are too red to be seen by Hubble
- ★ We need the next generation facility:
- ★ James Webb Space Telescope (2018)



Going where no one has gone before



★ James Webb Space Telescope (2018):

- better sensitivity (6.5m mirror), higher resolution and infrared sensitivity
- It will see the first generation of galaxies, just 300 million years after the Big Bang

Hubble



James Webb

image simulation by
M. Stiavelli, STScI

Resources: Hubble images

Outreach images:
hubblesite.org



Science images:
hla.stsci.edu

