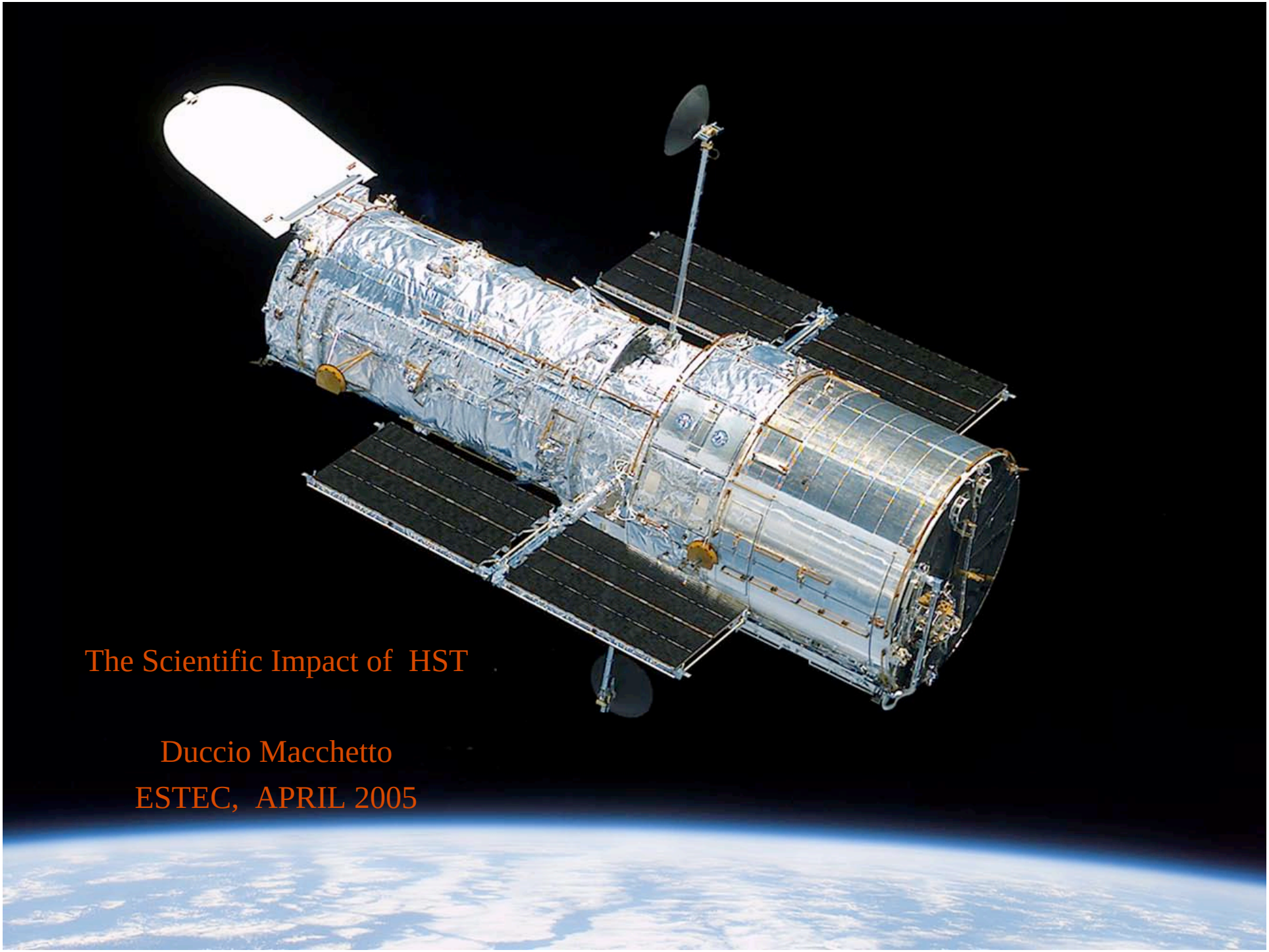
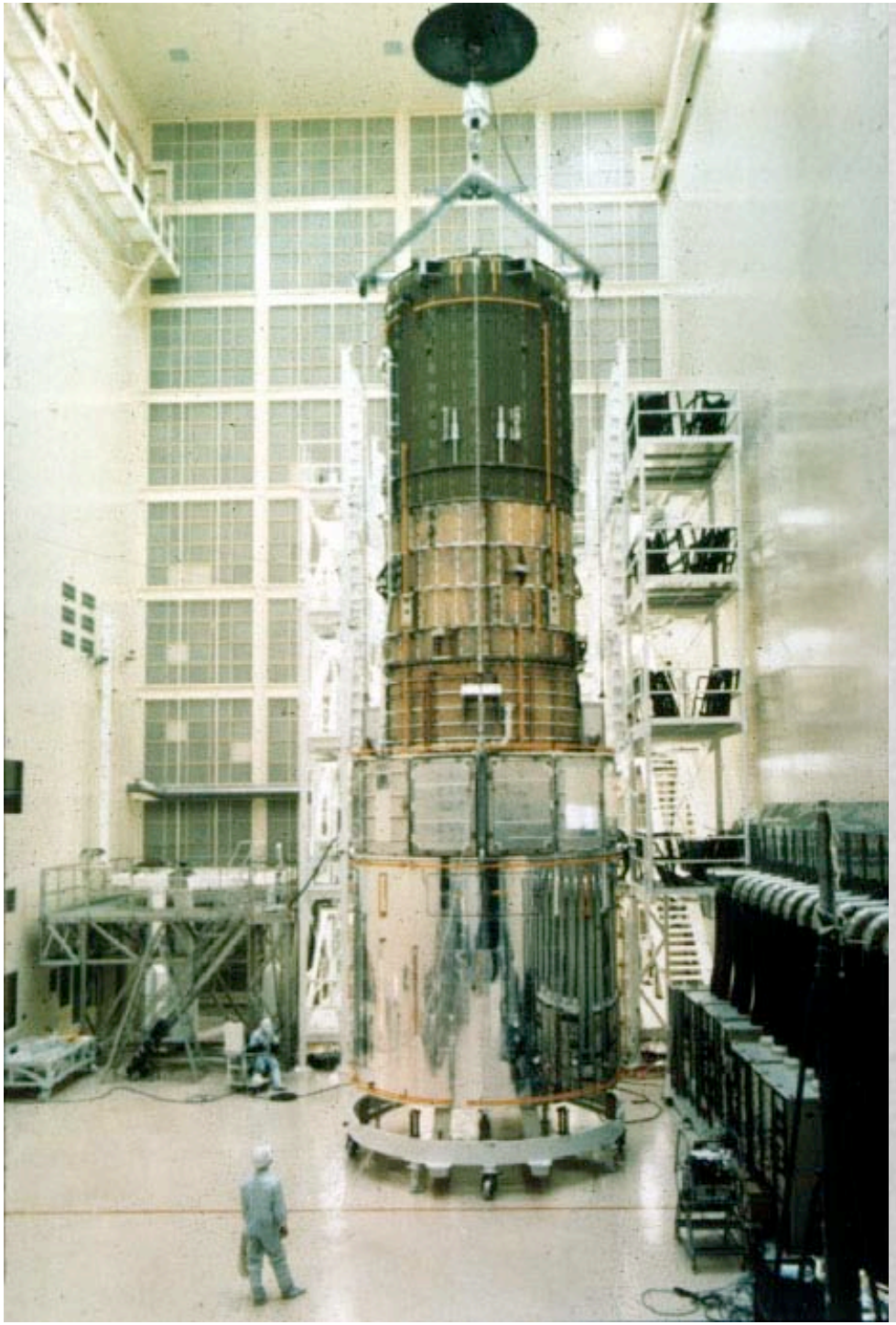


The Scientific Impact of HST

Duccio Macchetto

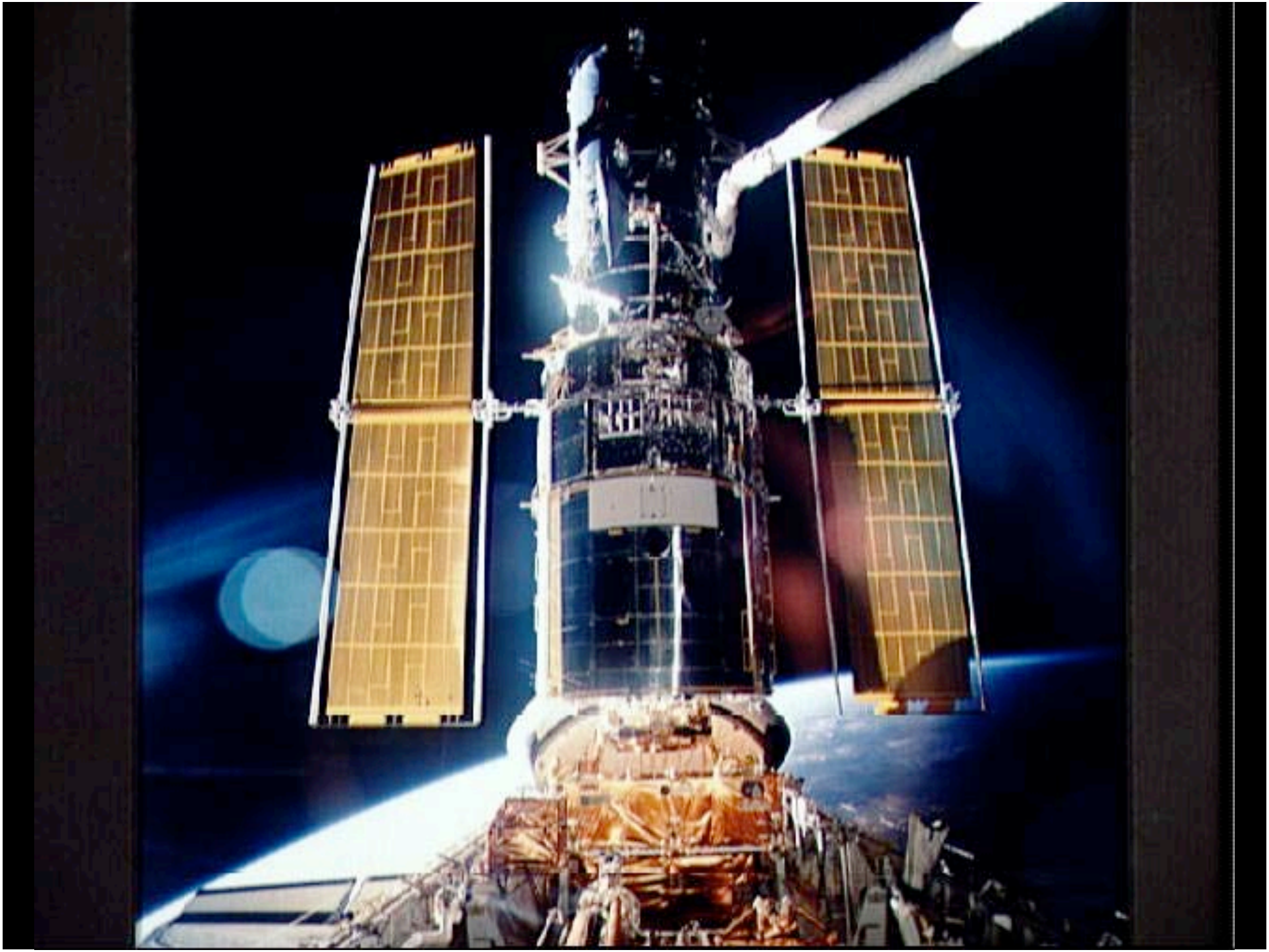
ESTEC, APRIL 2005



Hubble Space Telescope

NASA/ESA COLLABORATION

- Length: 14 m
- Weight: 11,000 kg
- Mirror diameter: 2.4 m
- Launch: April 24, 1990



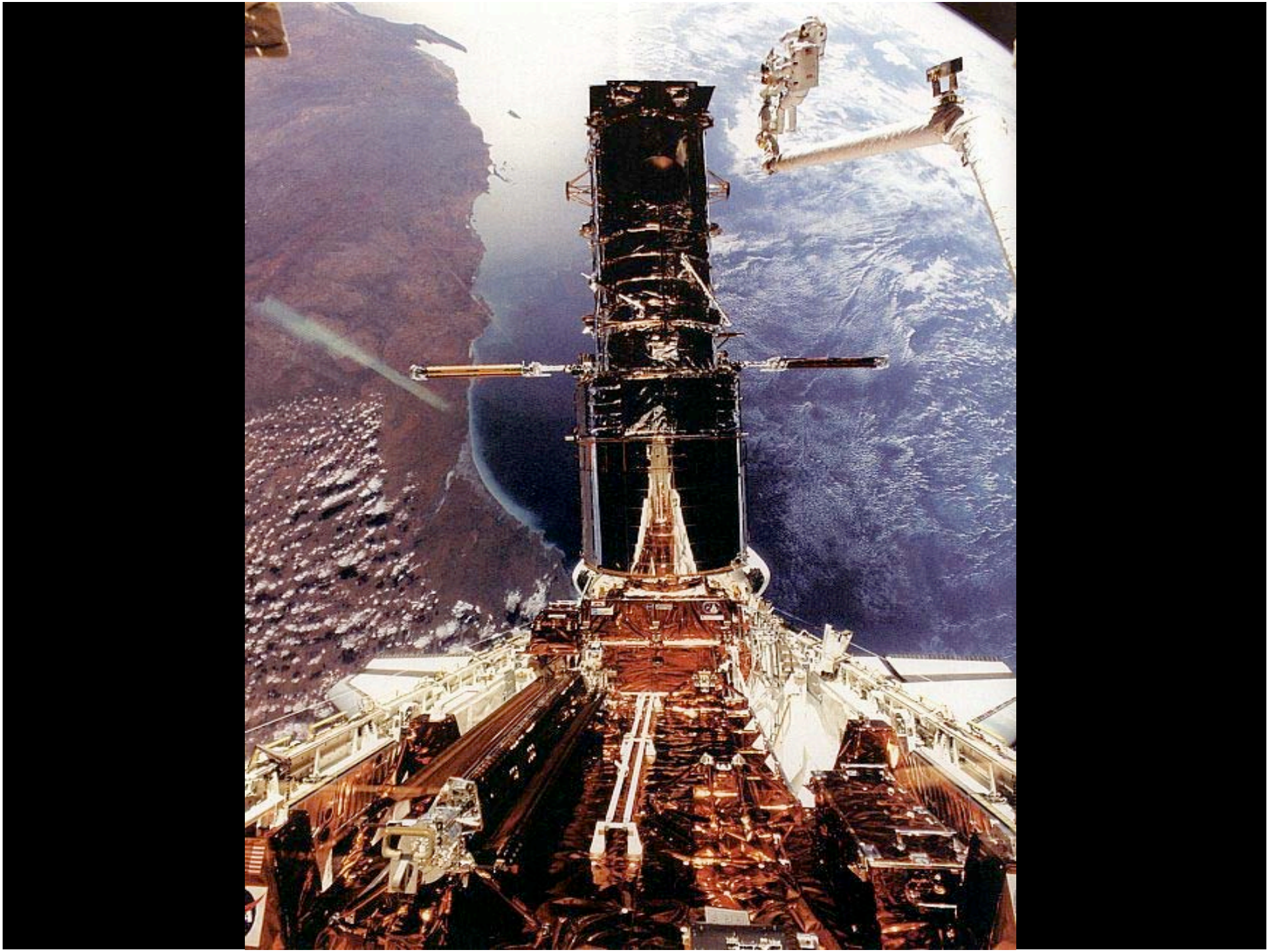
Hubble Servicing Missions

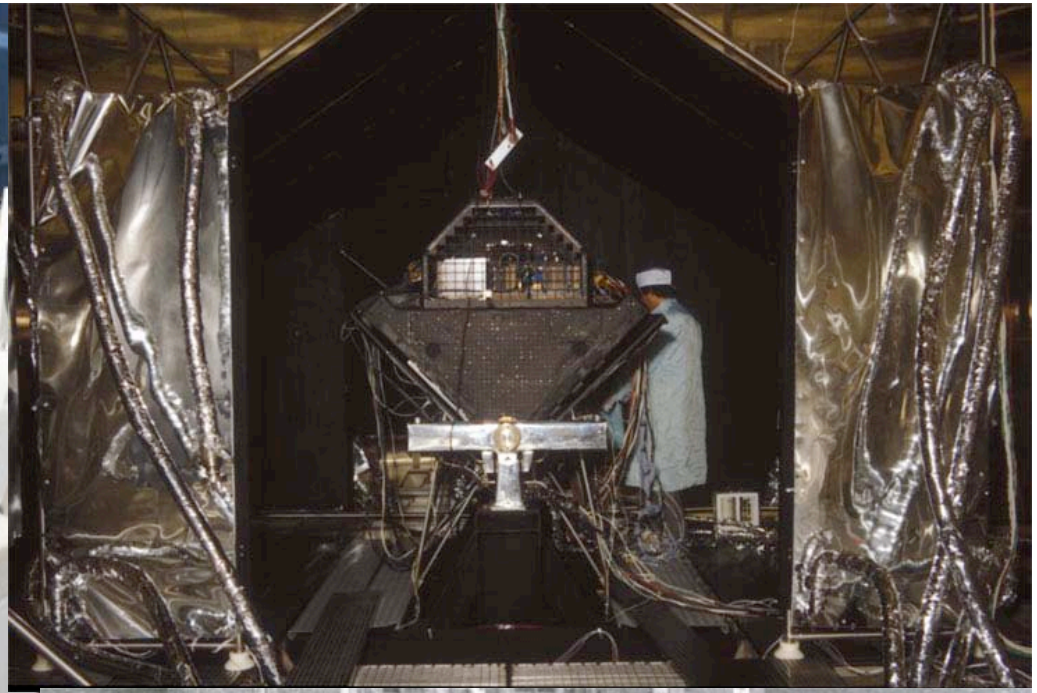
December 1993

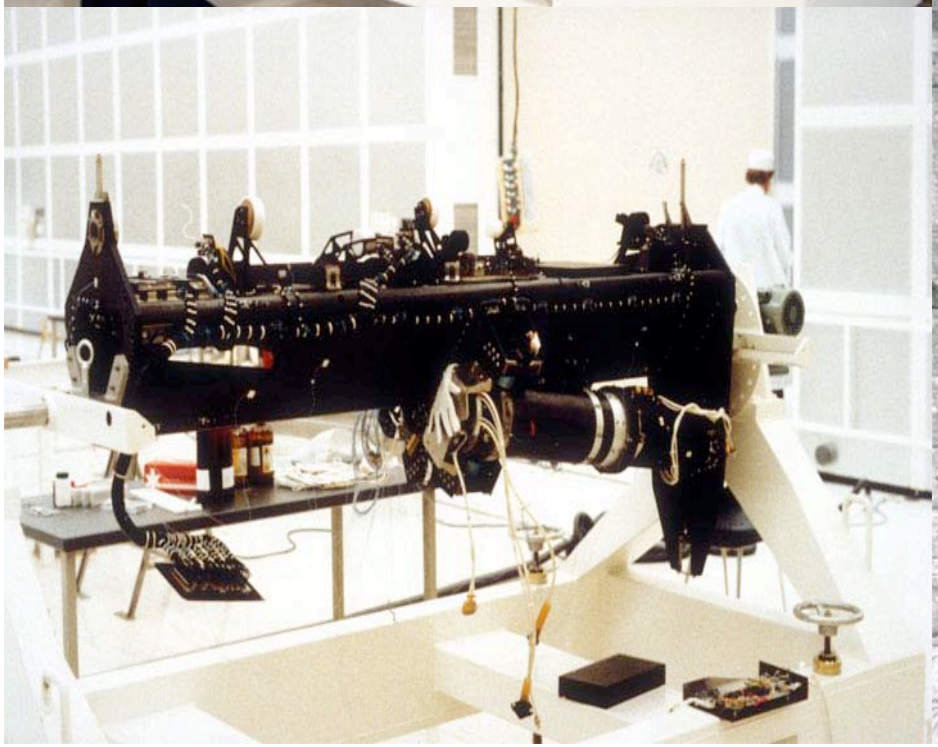
February 1997

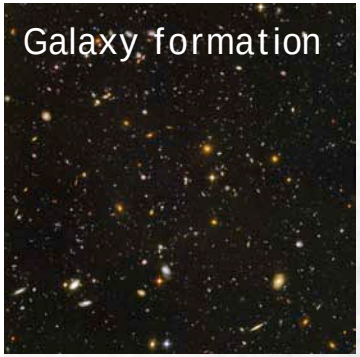
December 1999

March 2002

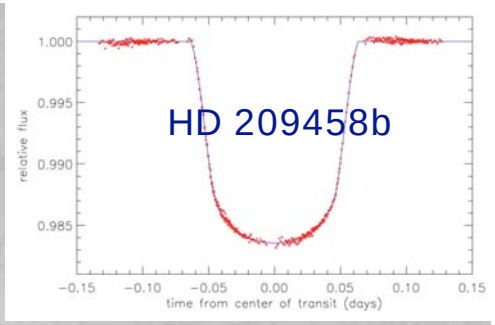






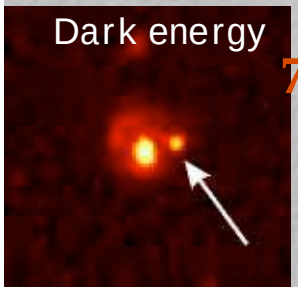


HST high impact science

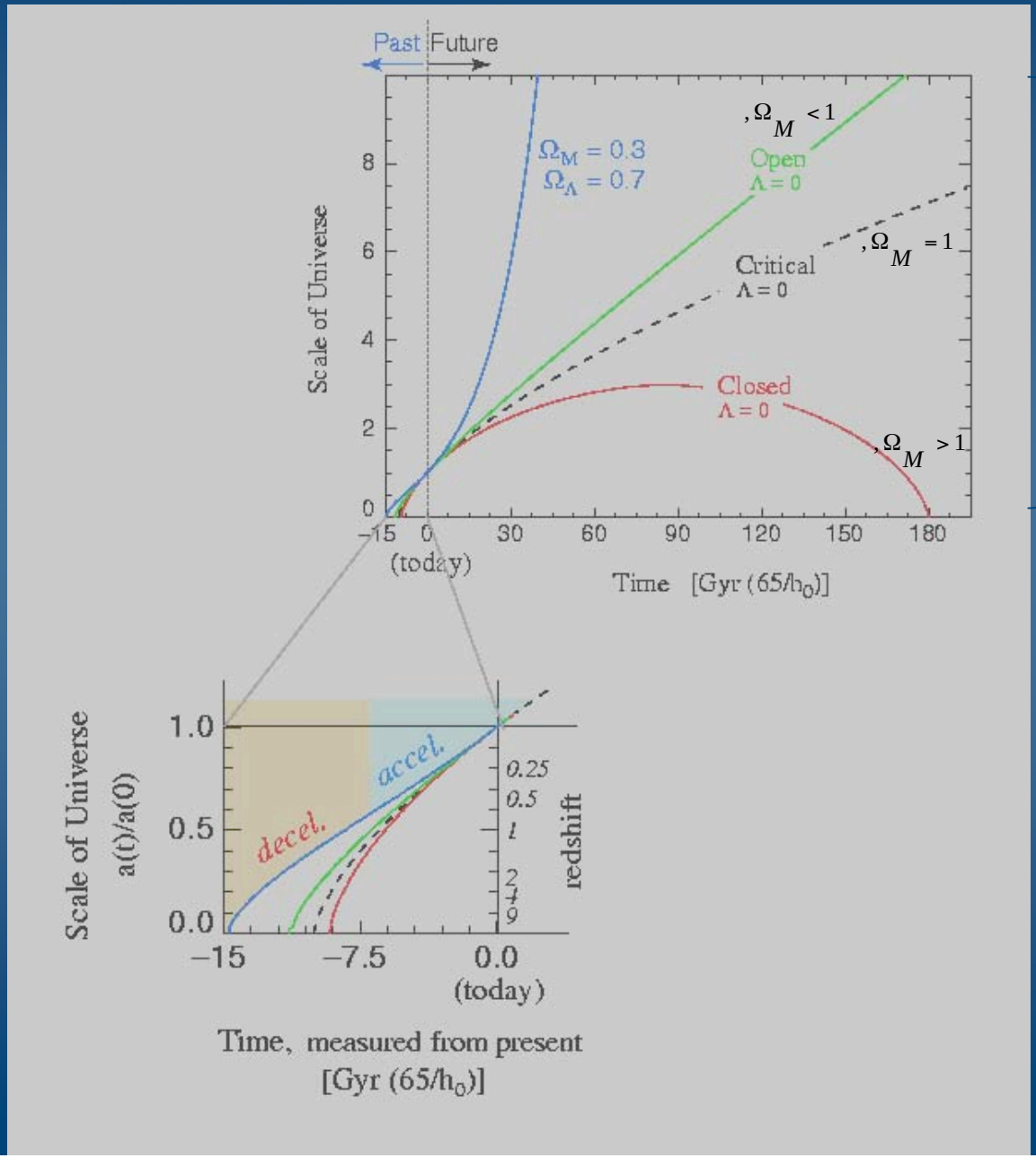


- Anticipated science
  2. **Distance scale: H_0**
     - Diffraction-limited optics
     - Imaging sensitivity
  3. **Black holes in galaxies**
     - Spectroscopy at diffraction limit
  4. **AGN emission lines**
     - UV spectroscopy at diffraction limit
  5. **QSO host galaxies**
     - Diffraction-limited optics
     - High contrast imaging
  7. **IGM/ISM (QAL)**
     - UV spectroscopy

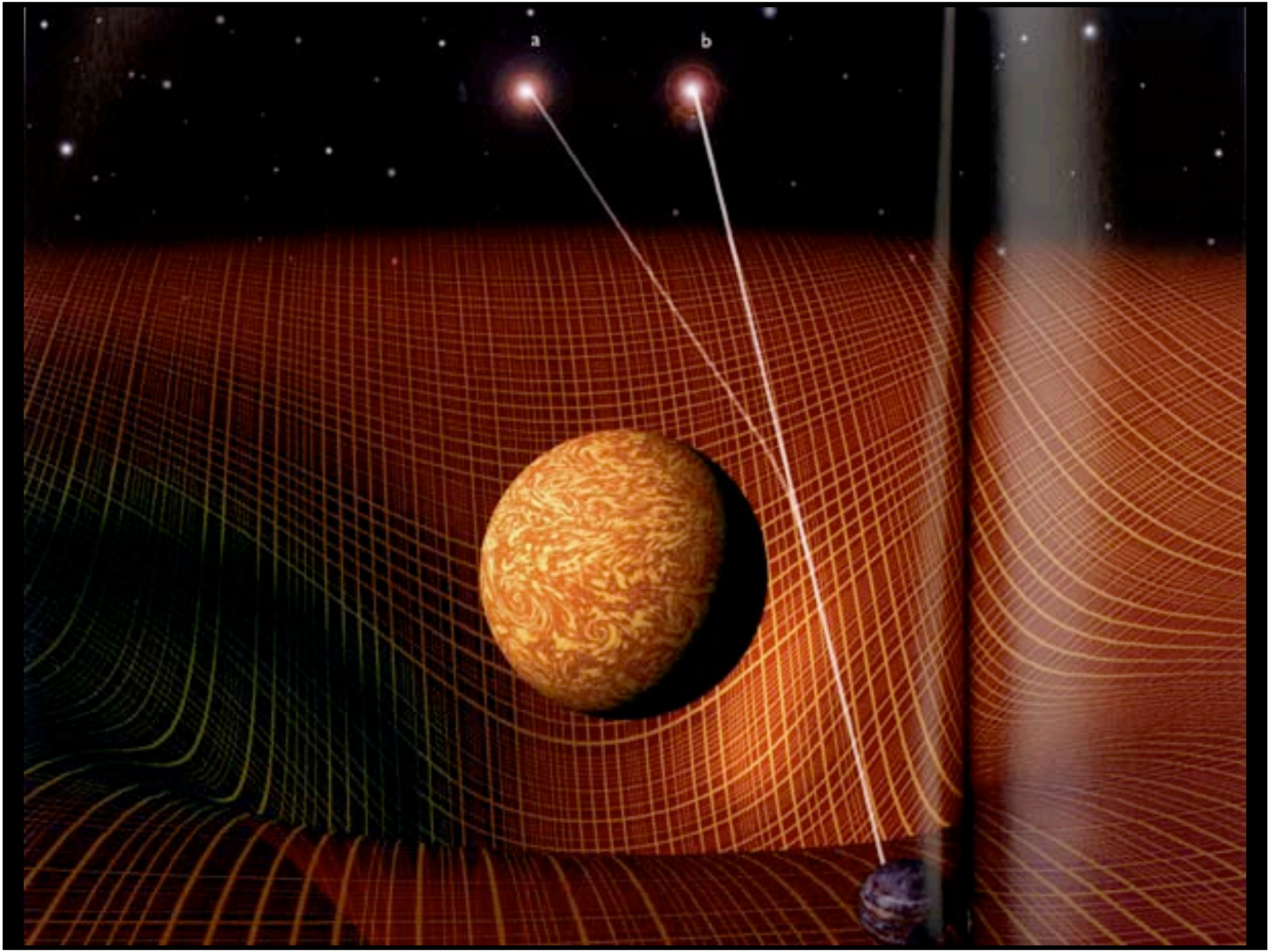
- Unanticipated science
  1. **Galaxy formation: HDF&UDF**
     - Diffraction-limited optics
     - Imaging sensitivity
  6. **Dark energy: SN Ia & Λ**
     - Diffraction-limited optics
  8. **γ-ray bursts: host galaxies**
     - Diffraction-limited optics
  9. **Planet formation: disks**
     - Diffraction-limited optics
     - High contrast imaging
  10. **Extra-solar planets**
     - Photometric stability
     - Spectroscopic stability

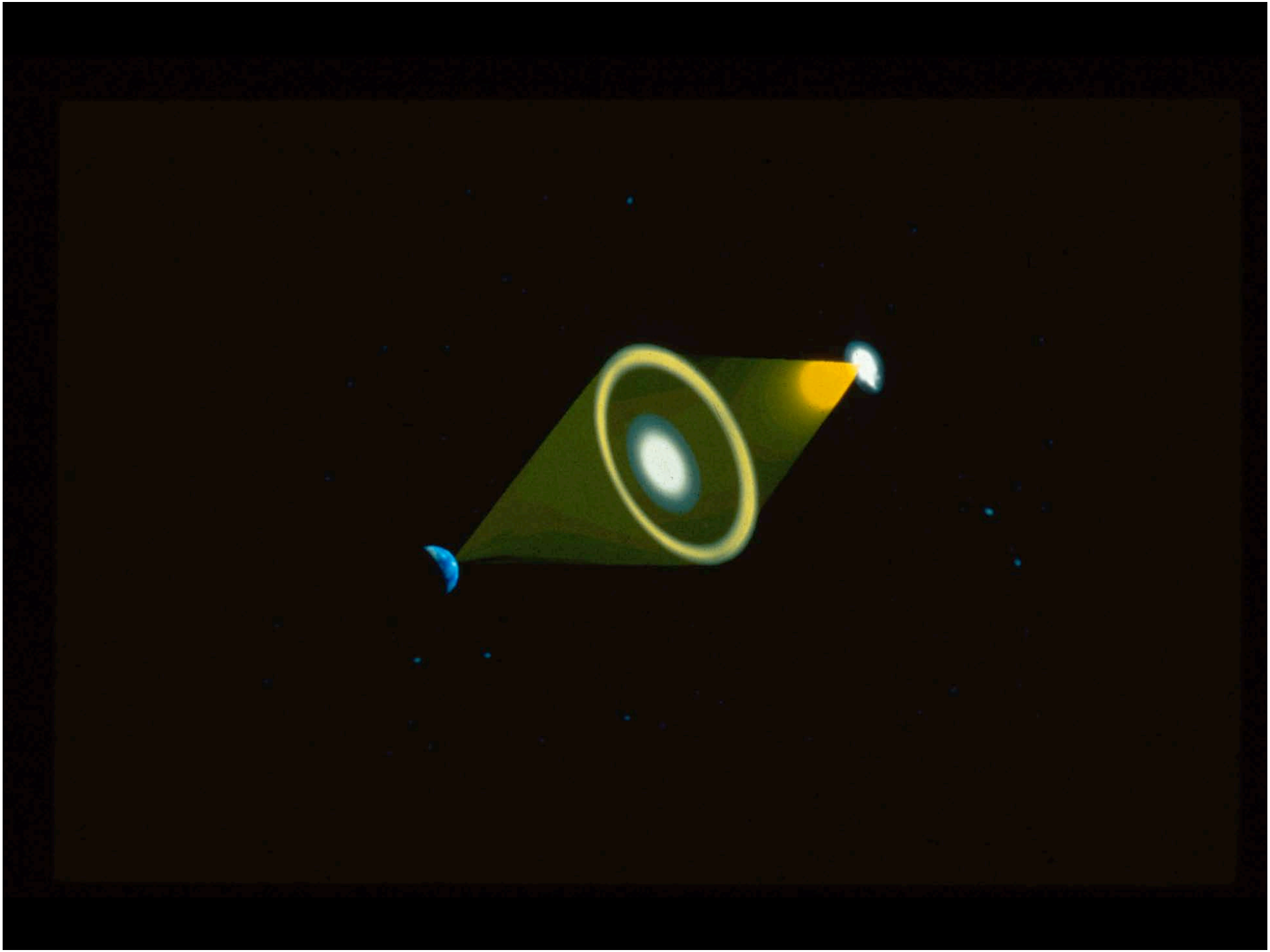


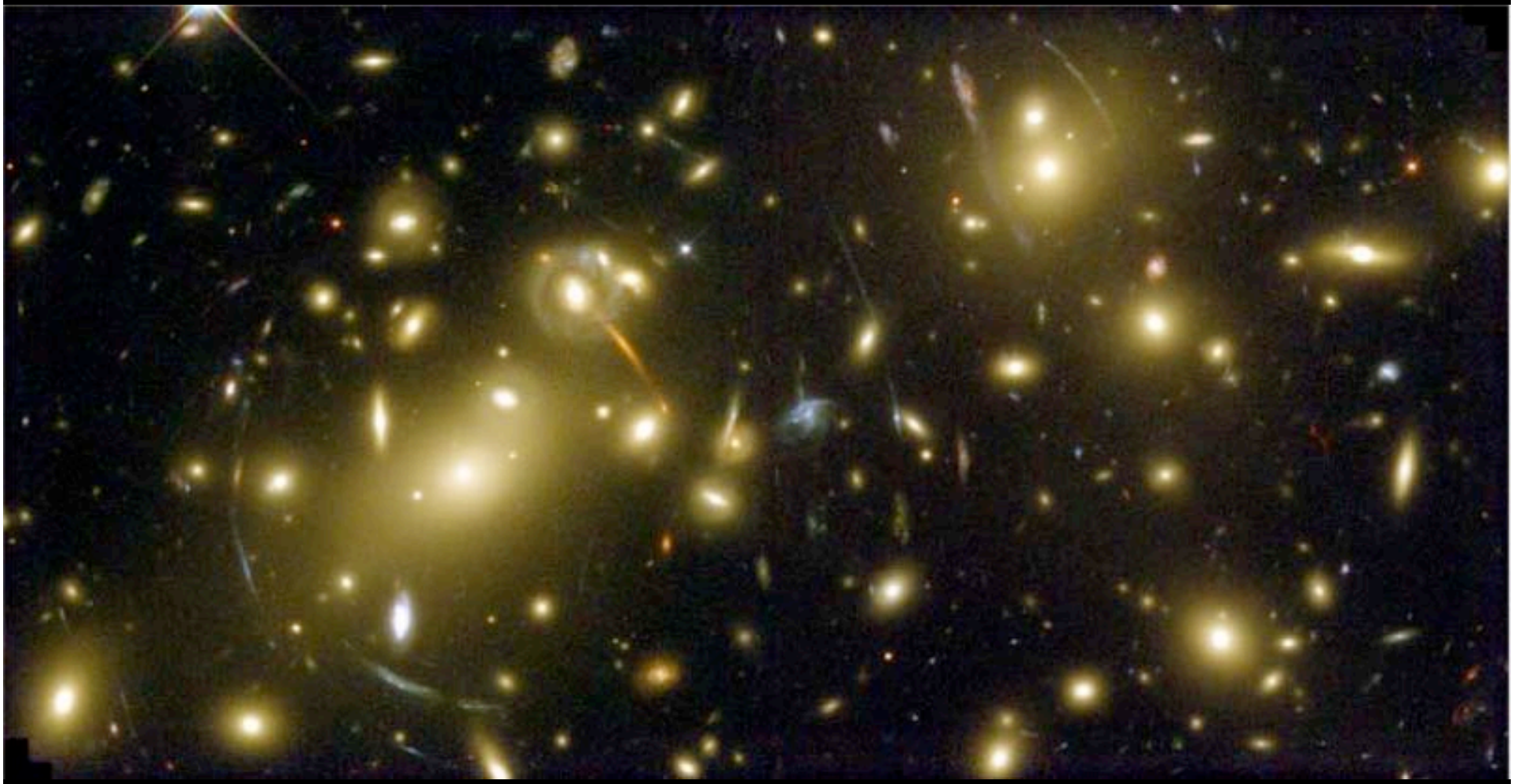
Expansion History of the Universe



Mass & acceleration shape the destiny!


a
b





$\Omega_d = 10\ \Omega_m$

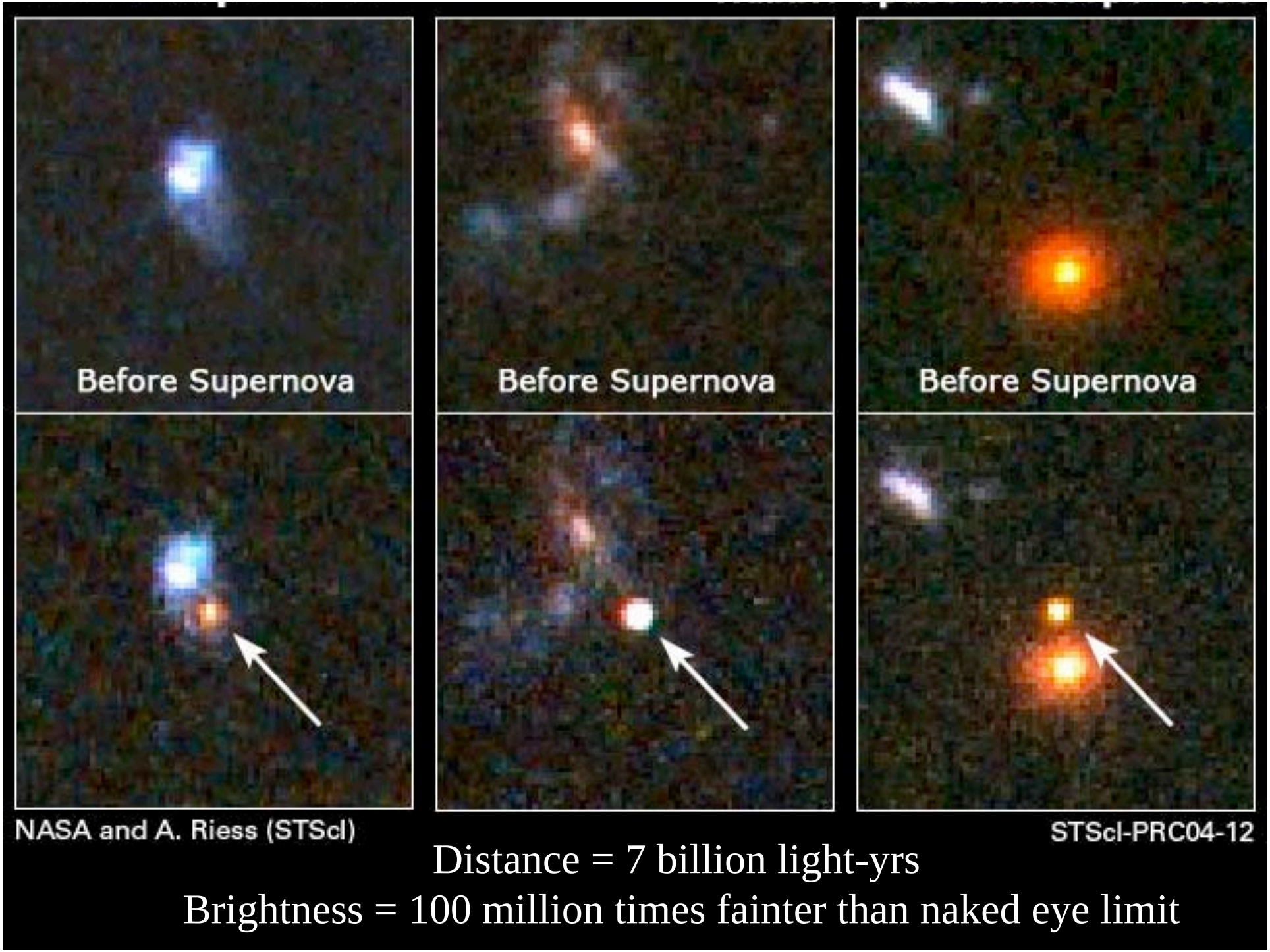
“Standard” Candles

Bright = Near

Dim = Far

Supernovae: Measuring Sticks for the Universe

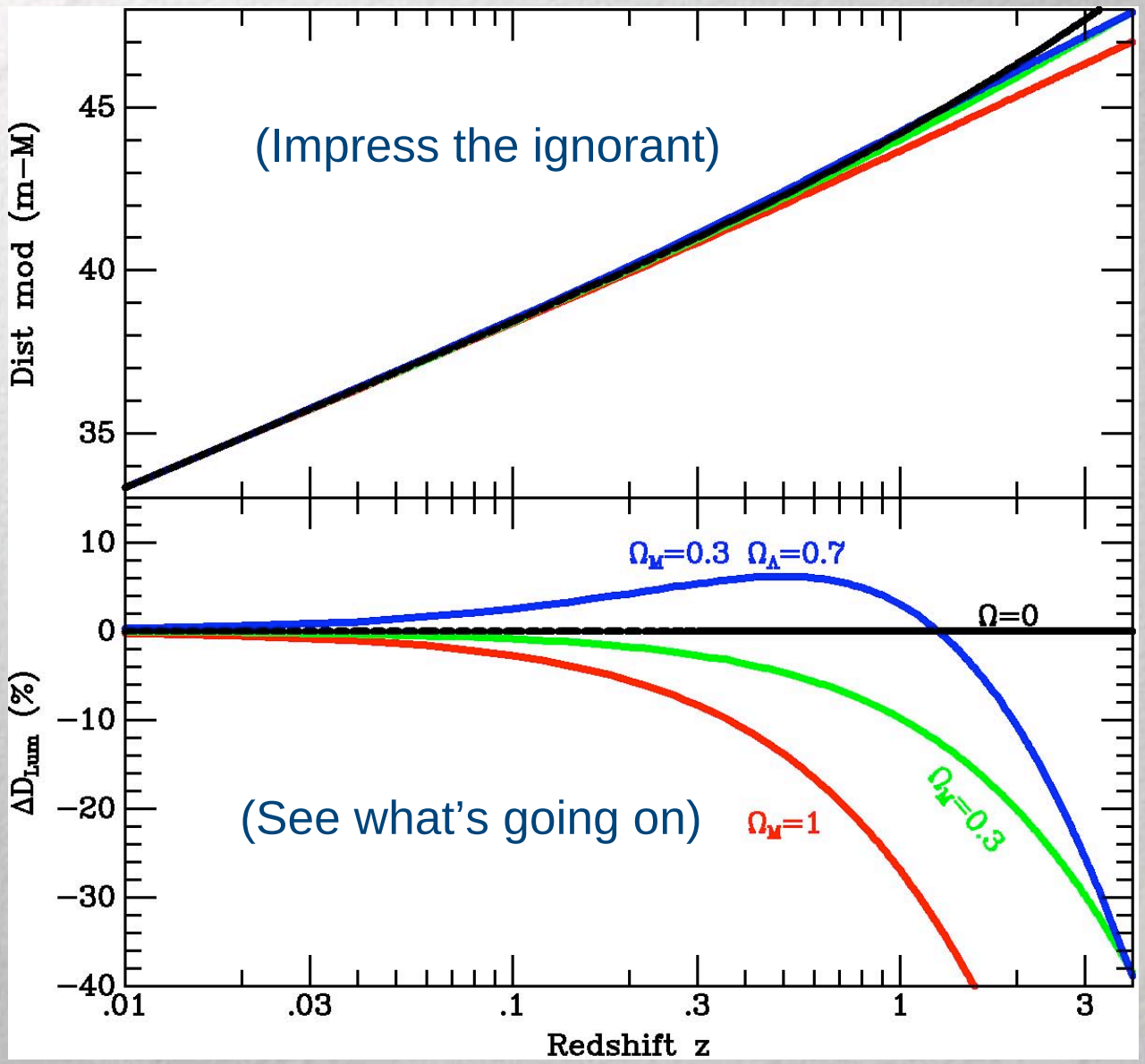
Distant supernovae are far more difficult to separate from their host galaxy



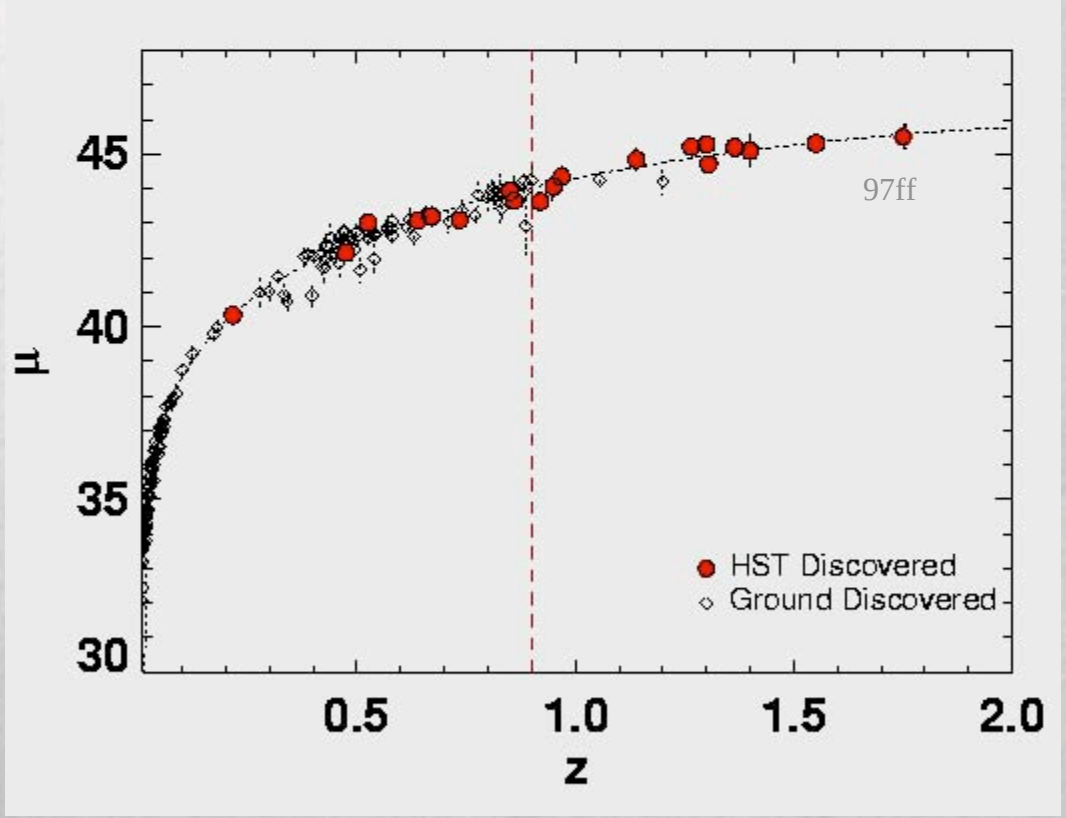
Distance = 7 billion light-yrs

Brightness = 100 million times fainter than naked eye limit

Luminosity Distance and Cosmological Parameters

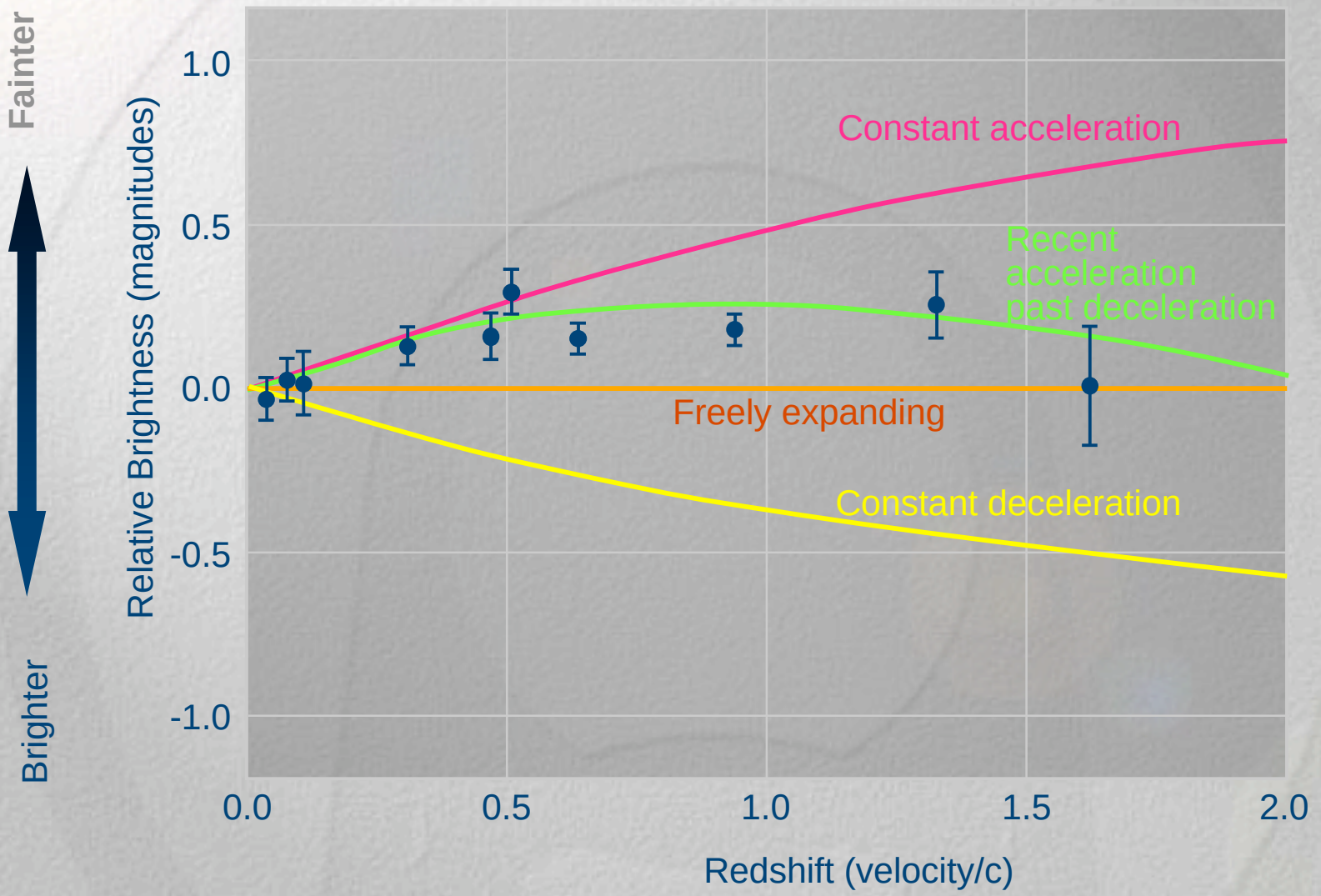


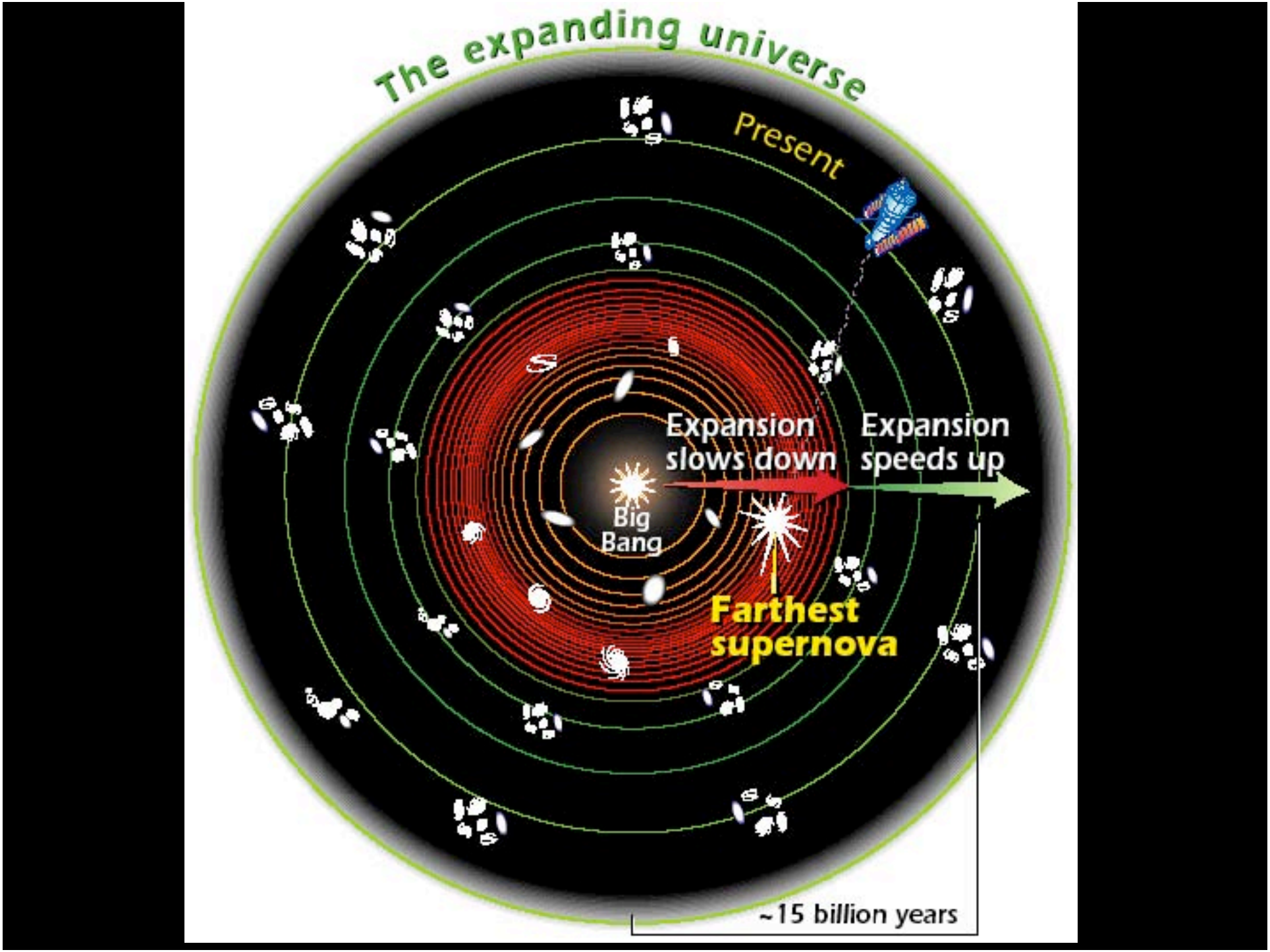
The New SN Ia Hubble Diagram



6 of the 7 highest redshift SNIa

Deceleration gave way to Acceleration, 5 Byr BP



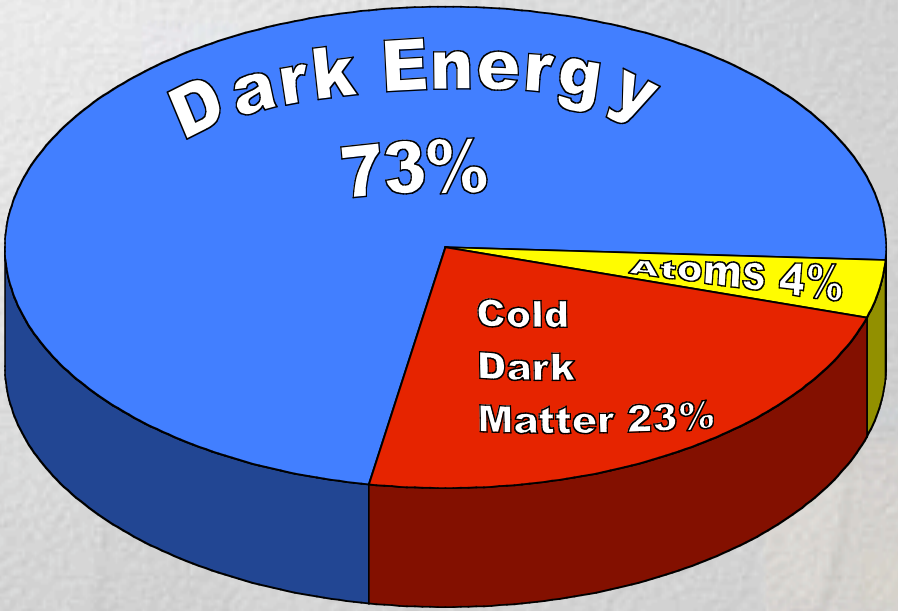

The expanding universe
Present
Expansion slows down
Expansion speeds up
Big Bang
Farthest supernova
~15 billion years

The energy responsible for accelerating the Universe is of **unknown** nature

"The Dark Energy"

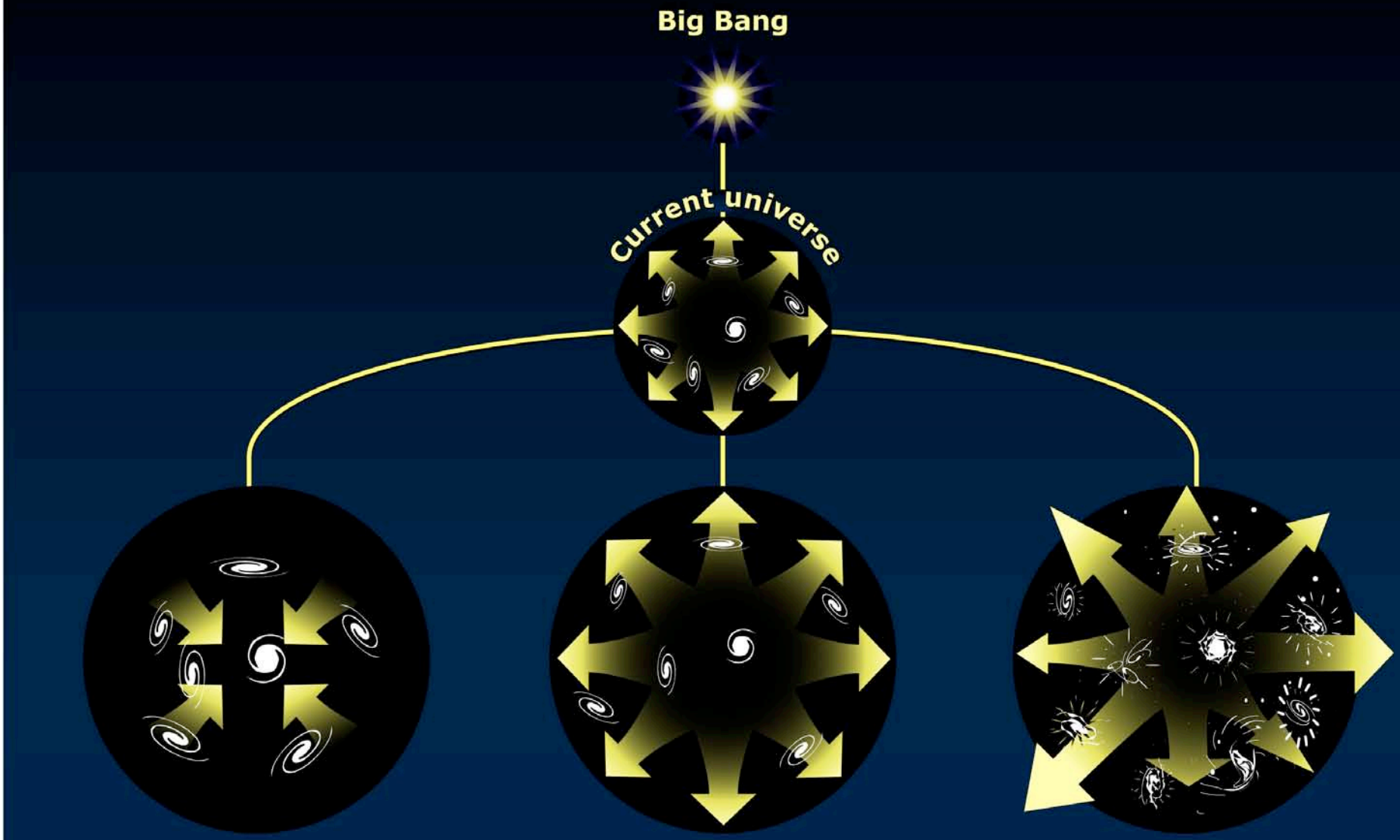
Dark Energy appears to constitute about 73% of the total matter + energy budget of the Universe!!

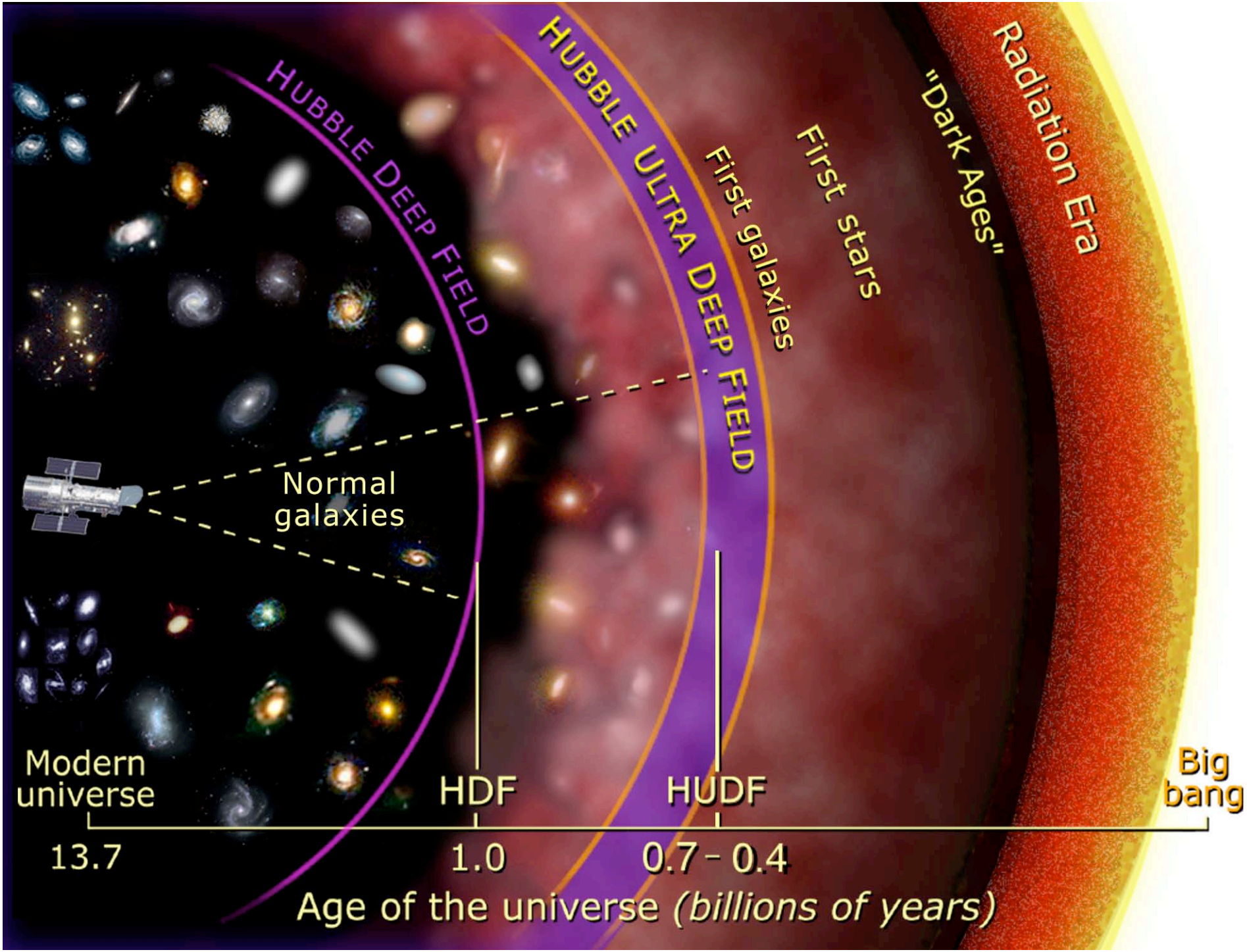
The ultimate Galilean Revolution

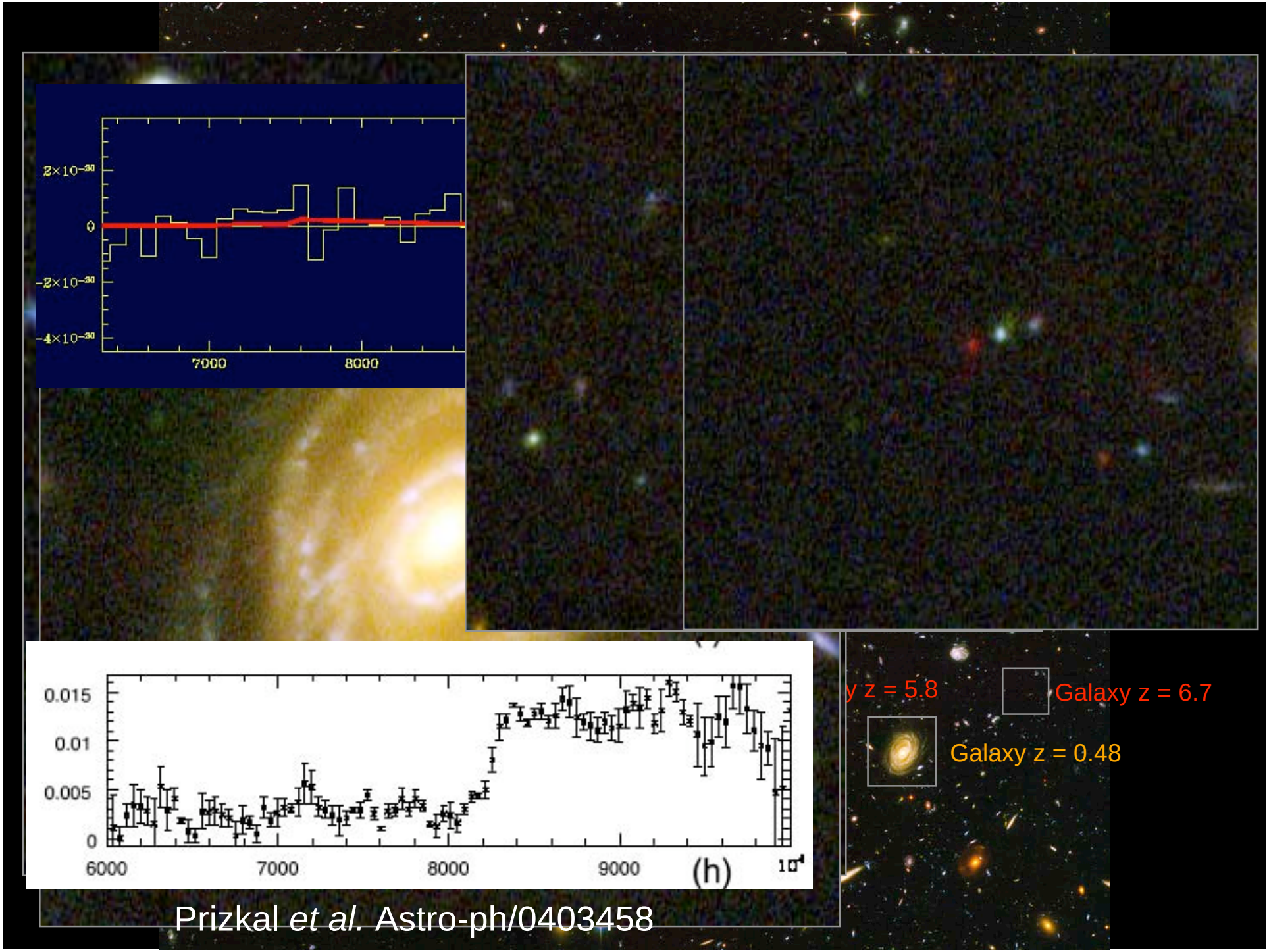


Not only are we not located near the center of the Universe;
we're not even made of what 96% of the Universe is made of!

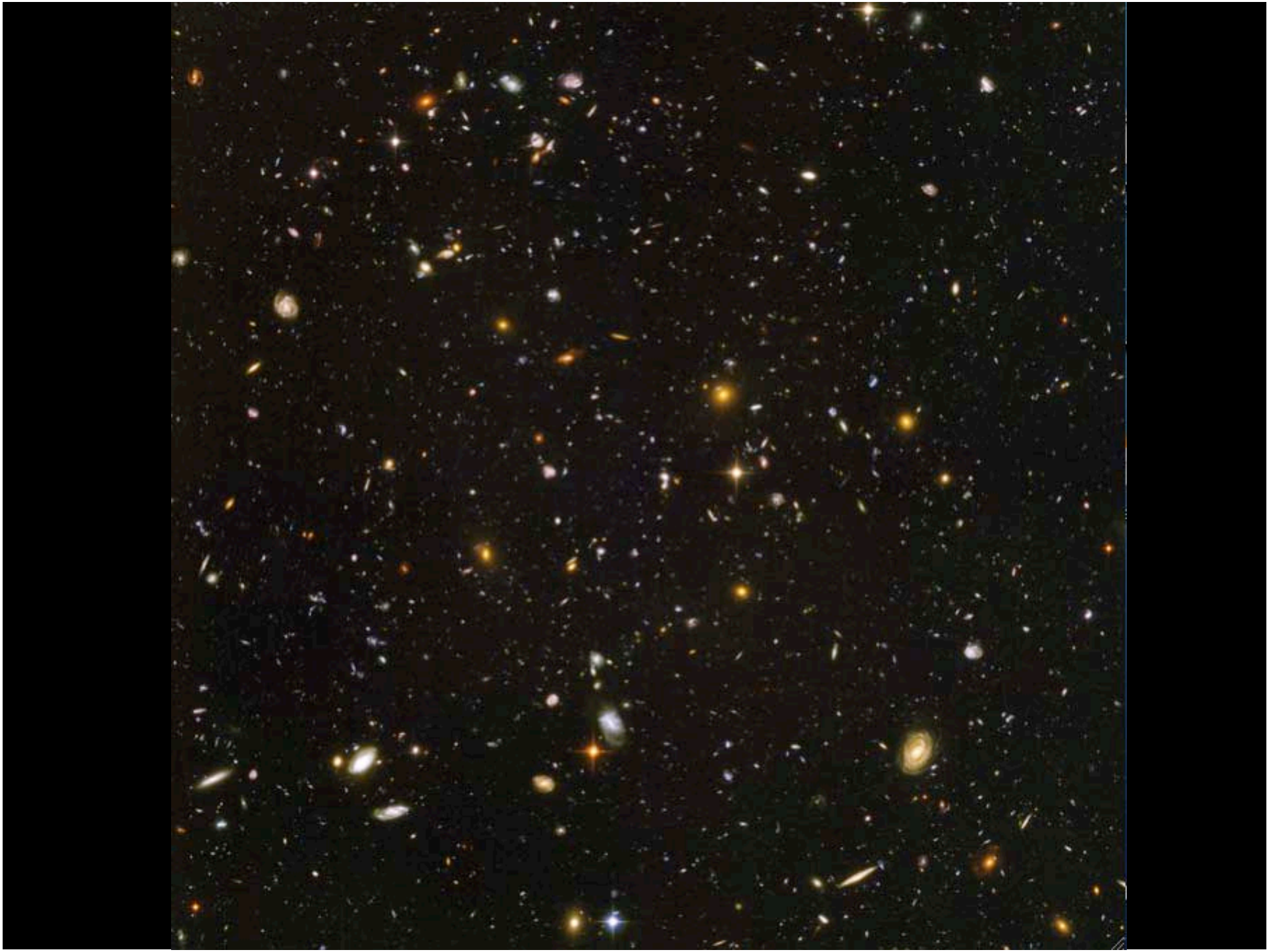
Future fates of the dark-energy universe



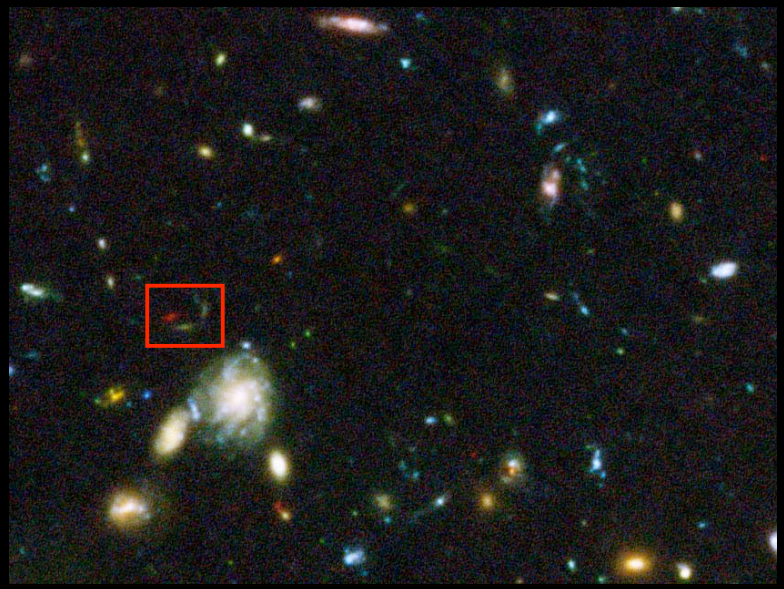

Hubble Deep Field
Hubble Ultra Deep Field
First galaxies
First stars
"Dark Ages"
Radiation Era
Normal galaxies
Modern universe
HDF
HUDF
Big bang
13.7
1.0
0.7 - 0.4
Age of the universe (billions of years)



Prizkal *et al.* Astro-ph/0403458

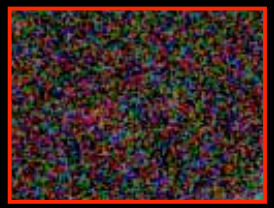


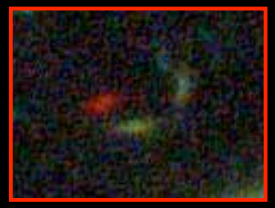
HUDF vs GOODS



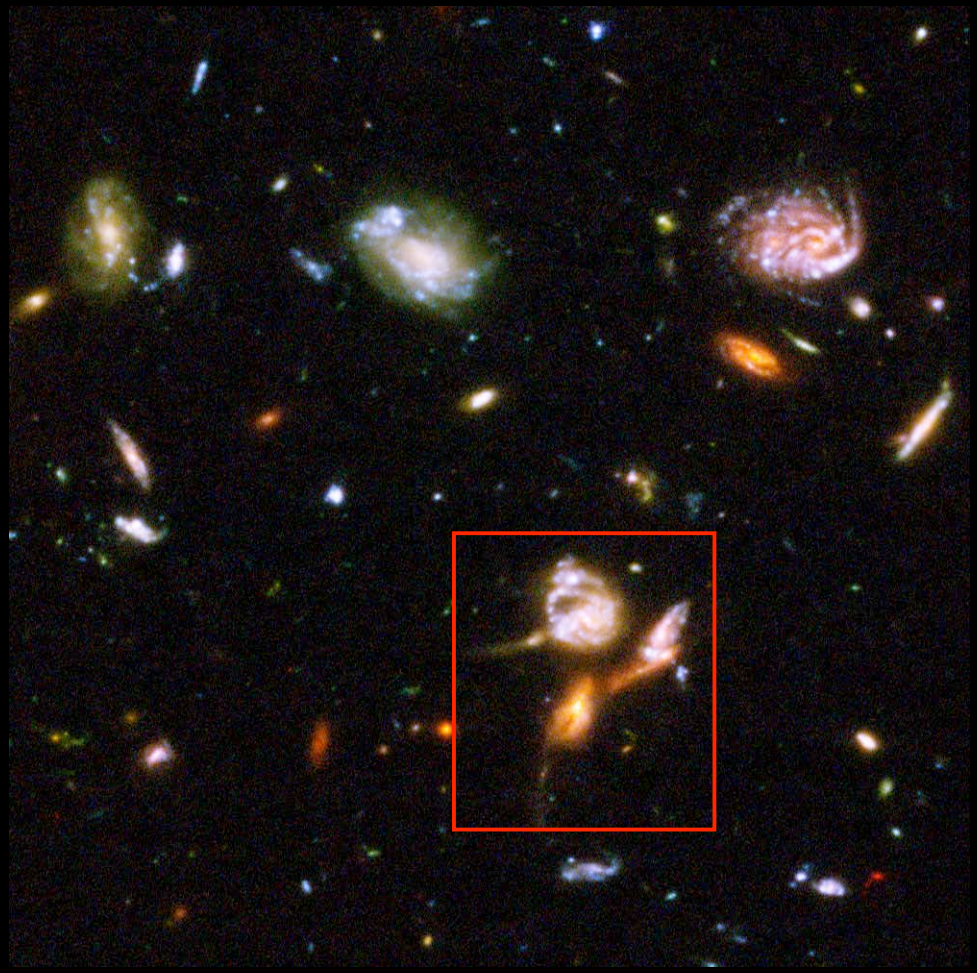
GOODS CDFS – 11 Hrs

HUDF – 300 Hrs

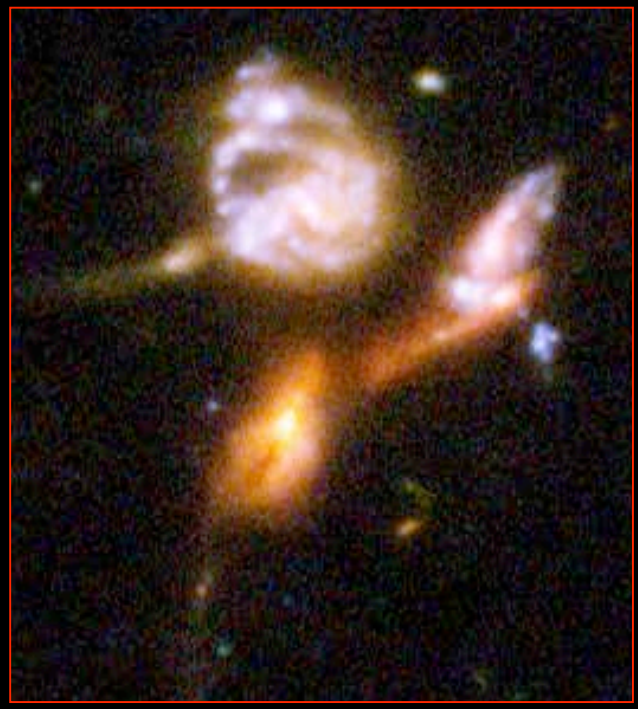




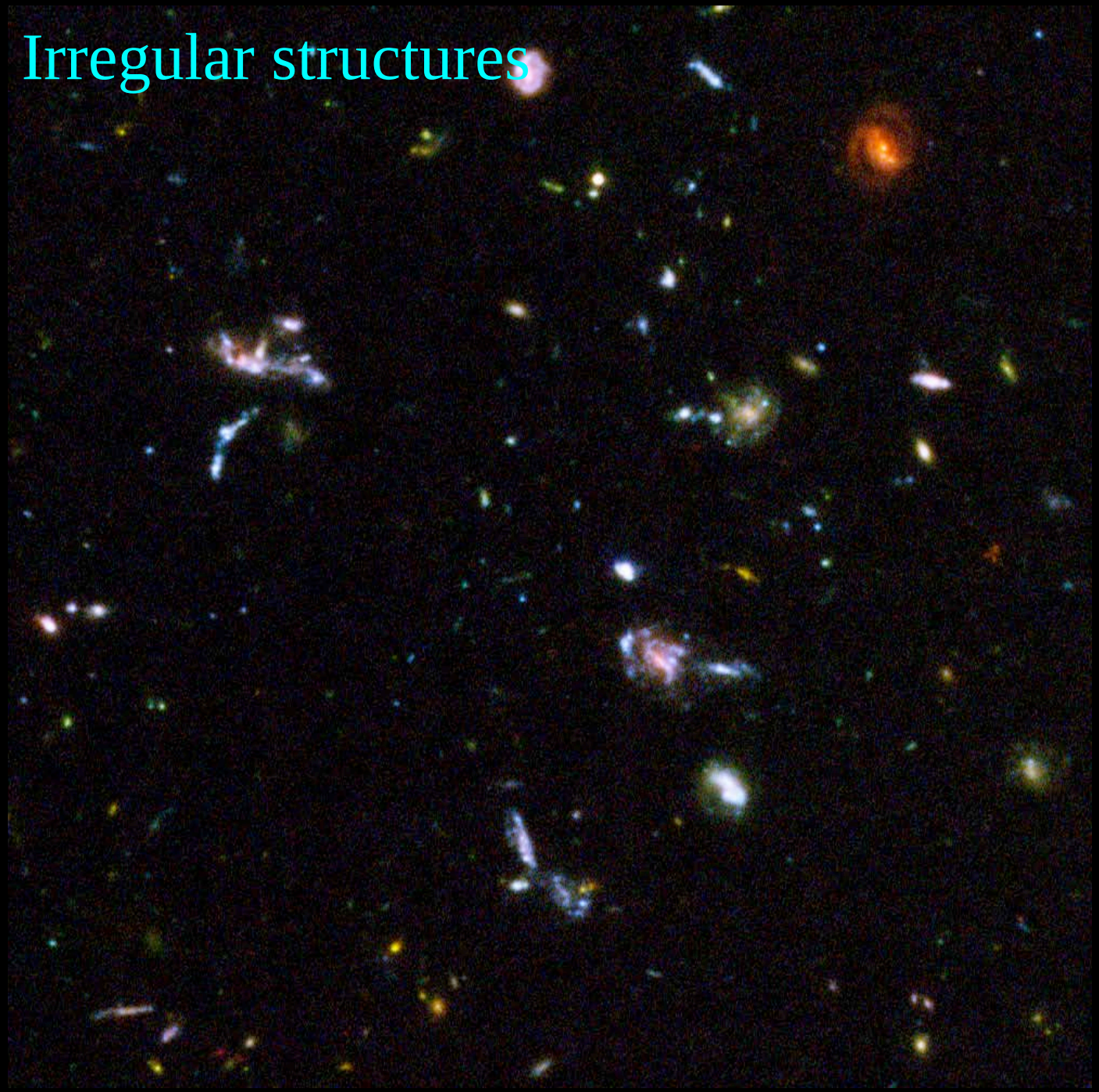
Rich morphologies: interactions



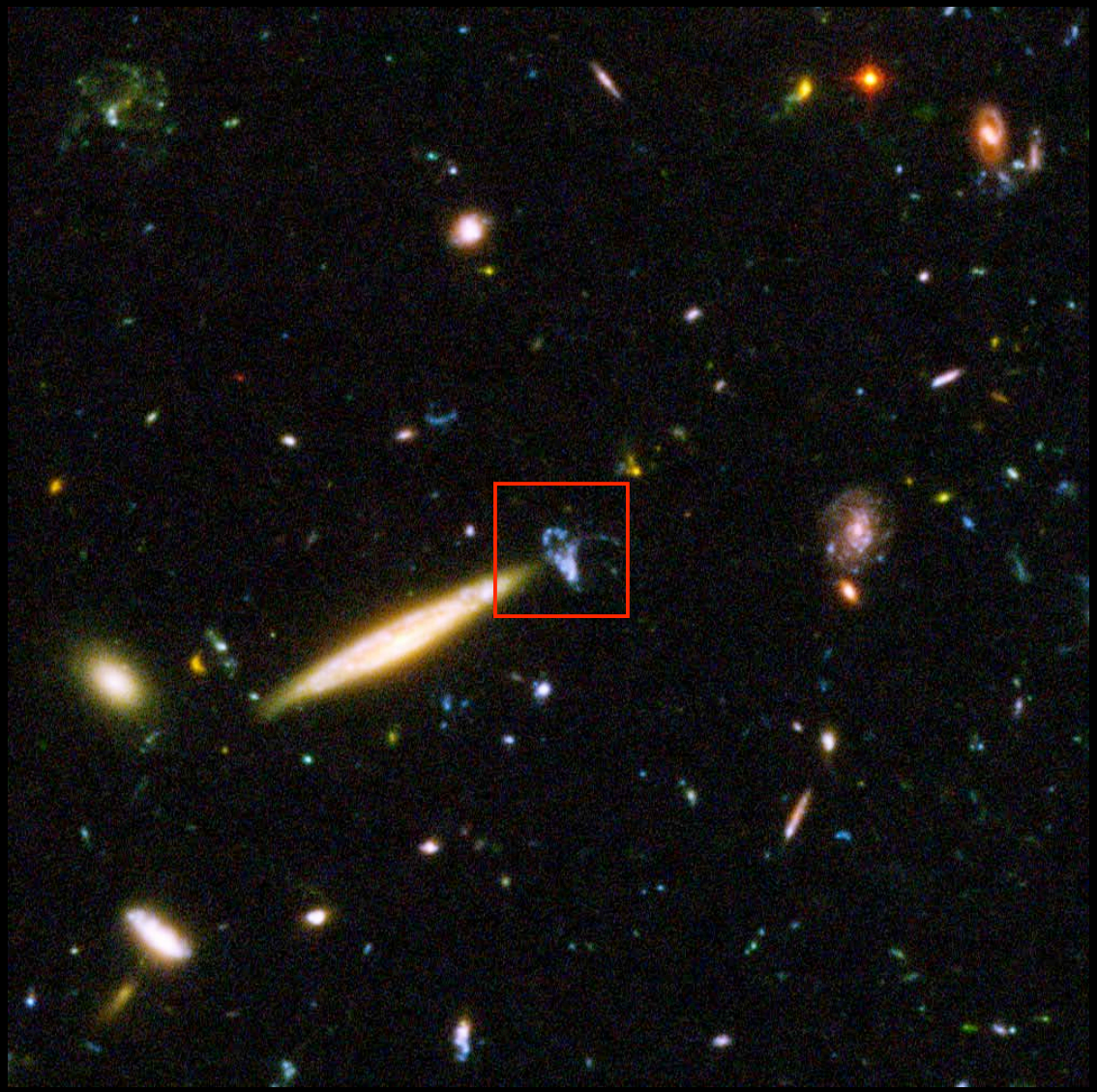
Normal galaxies in interaction



Irregular structures

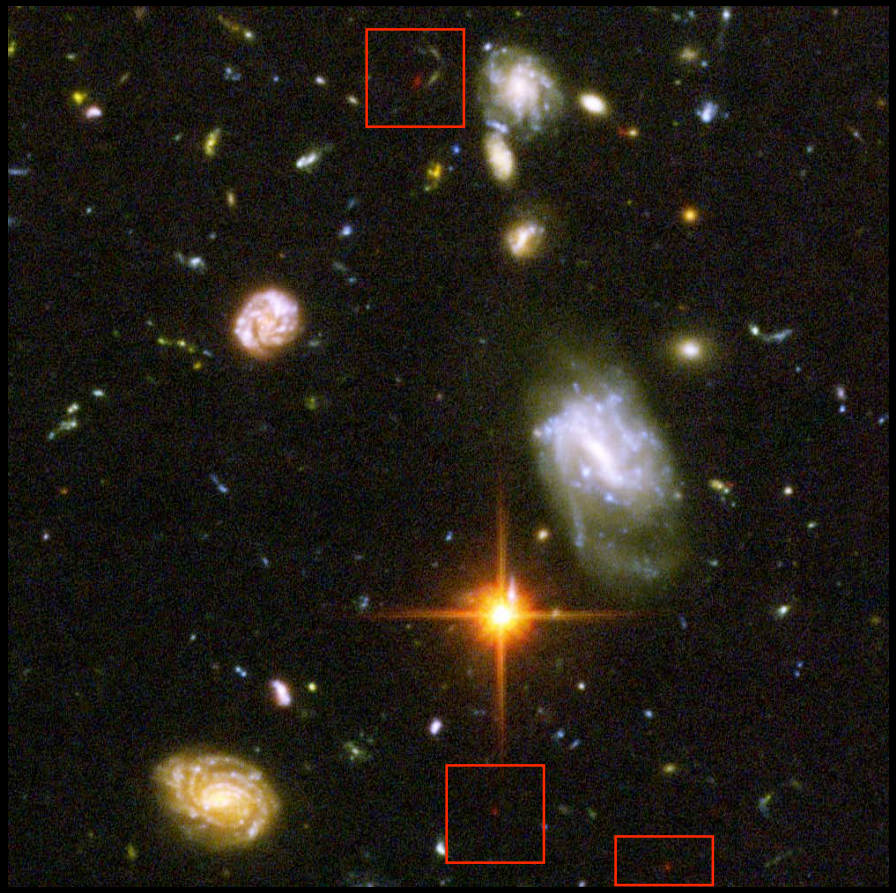


Unusual objects



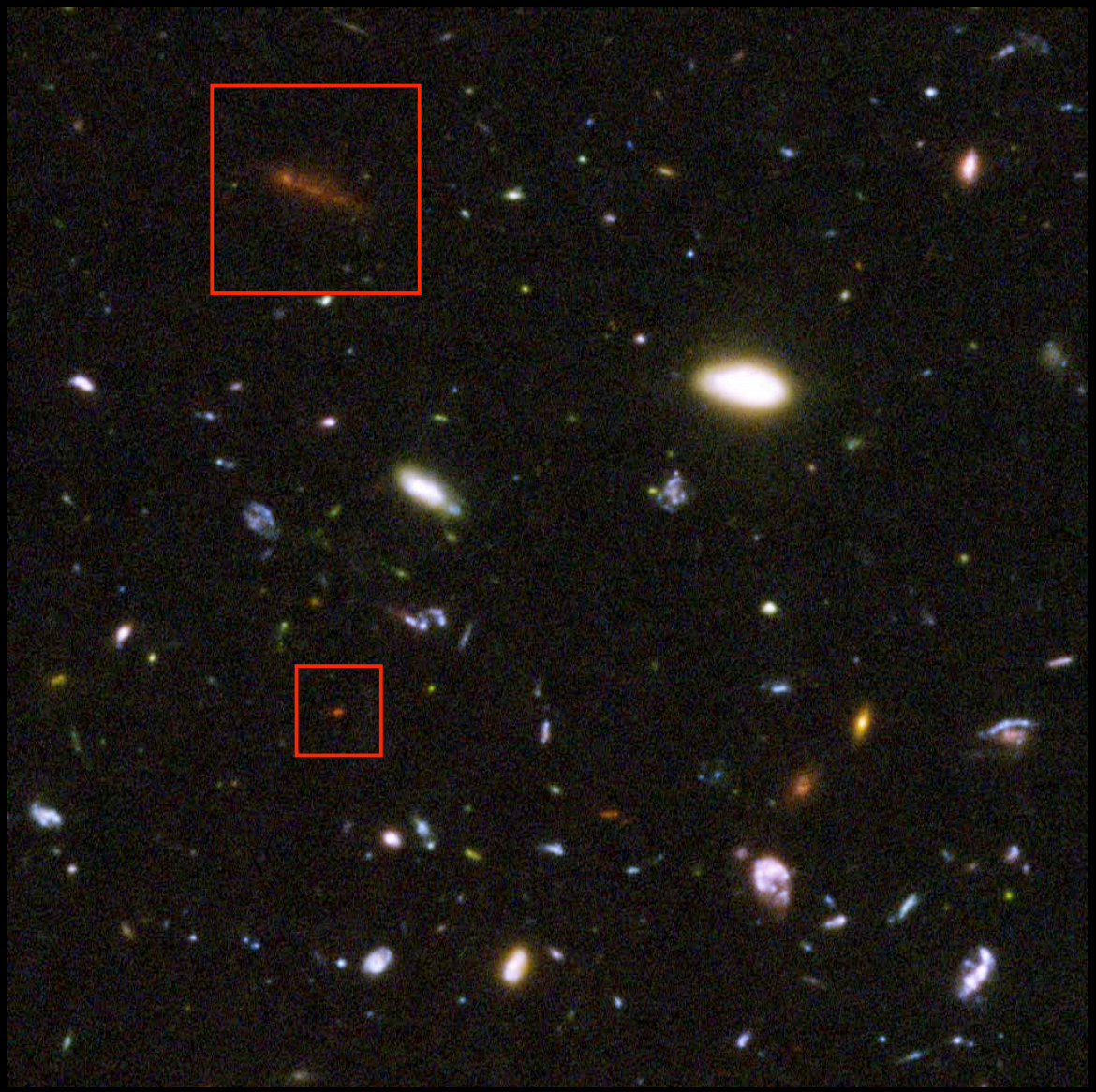
Strange interaction effects

Very Red Objects

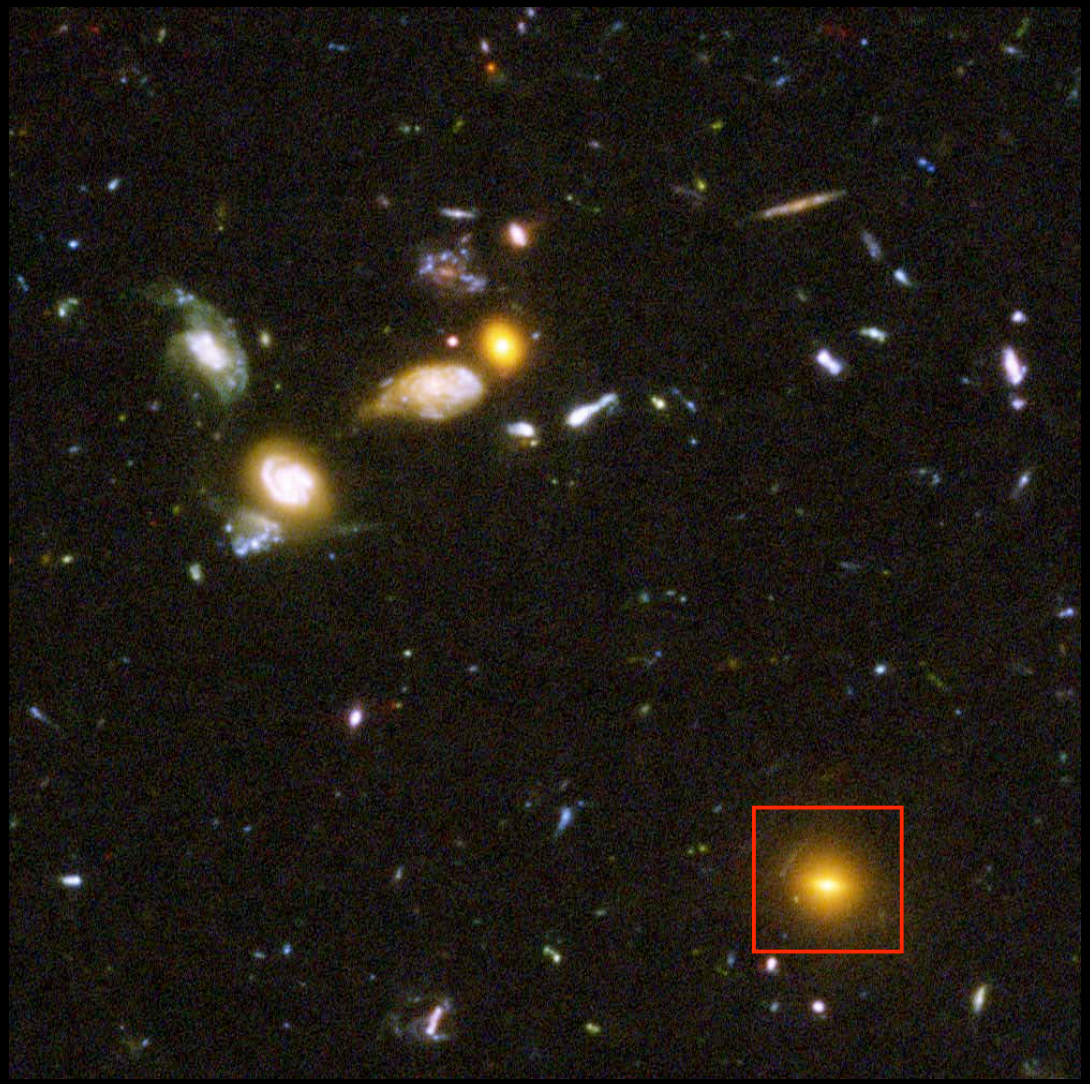


Candidates for galaxies at redshifts greater than 6

Extremely Red Galaxies (EROs)

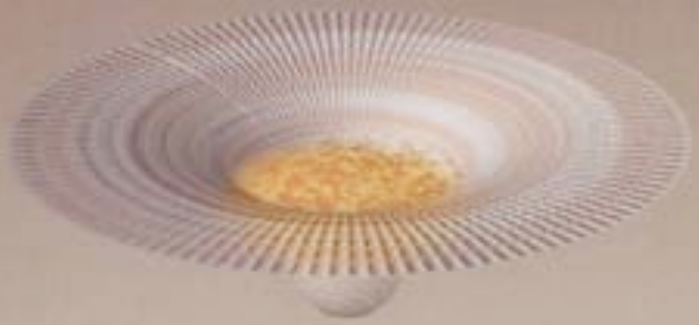


Strong lenses

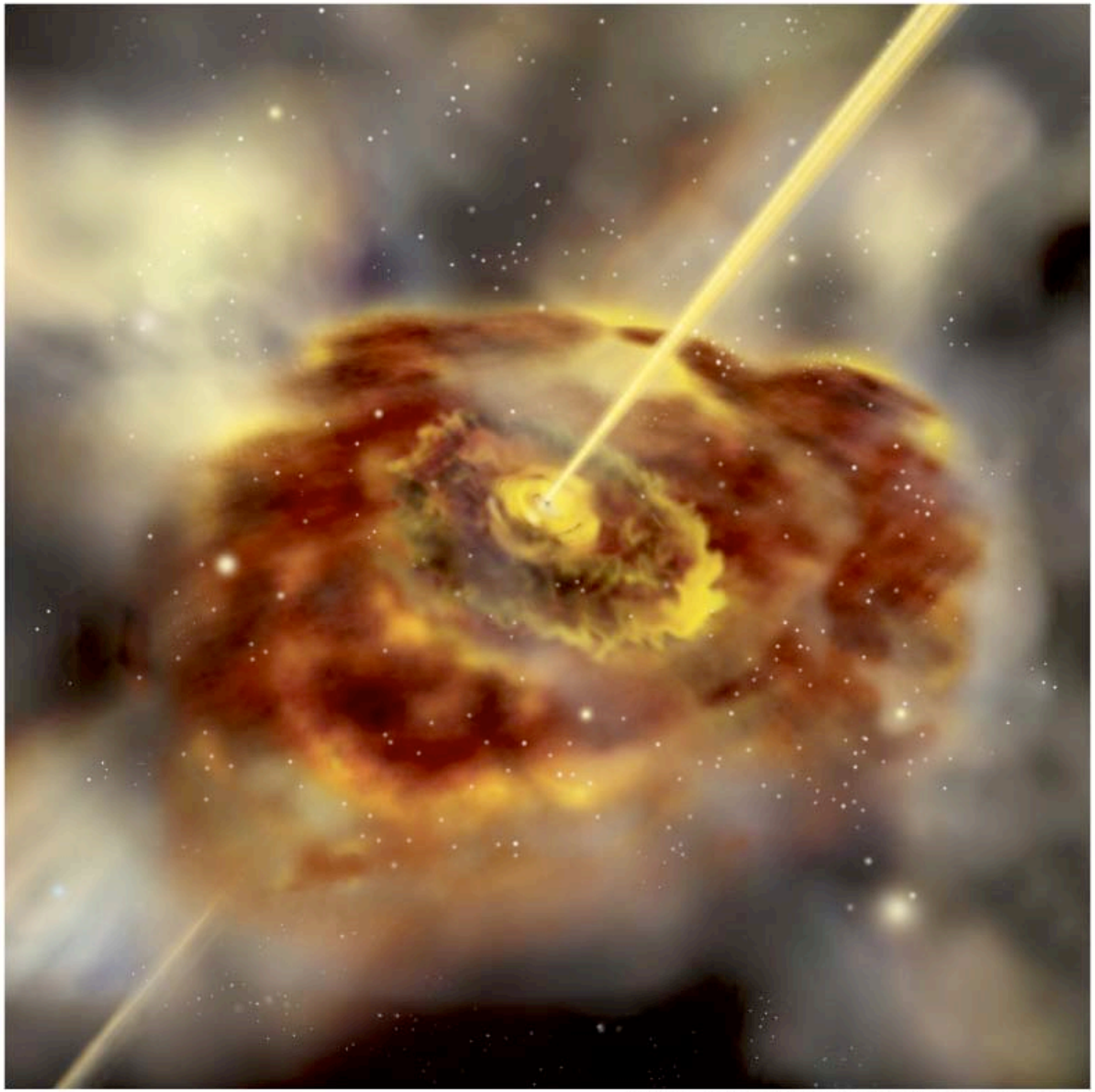


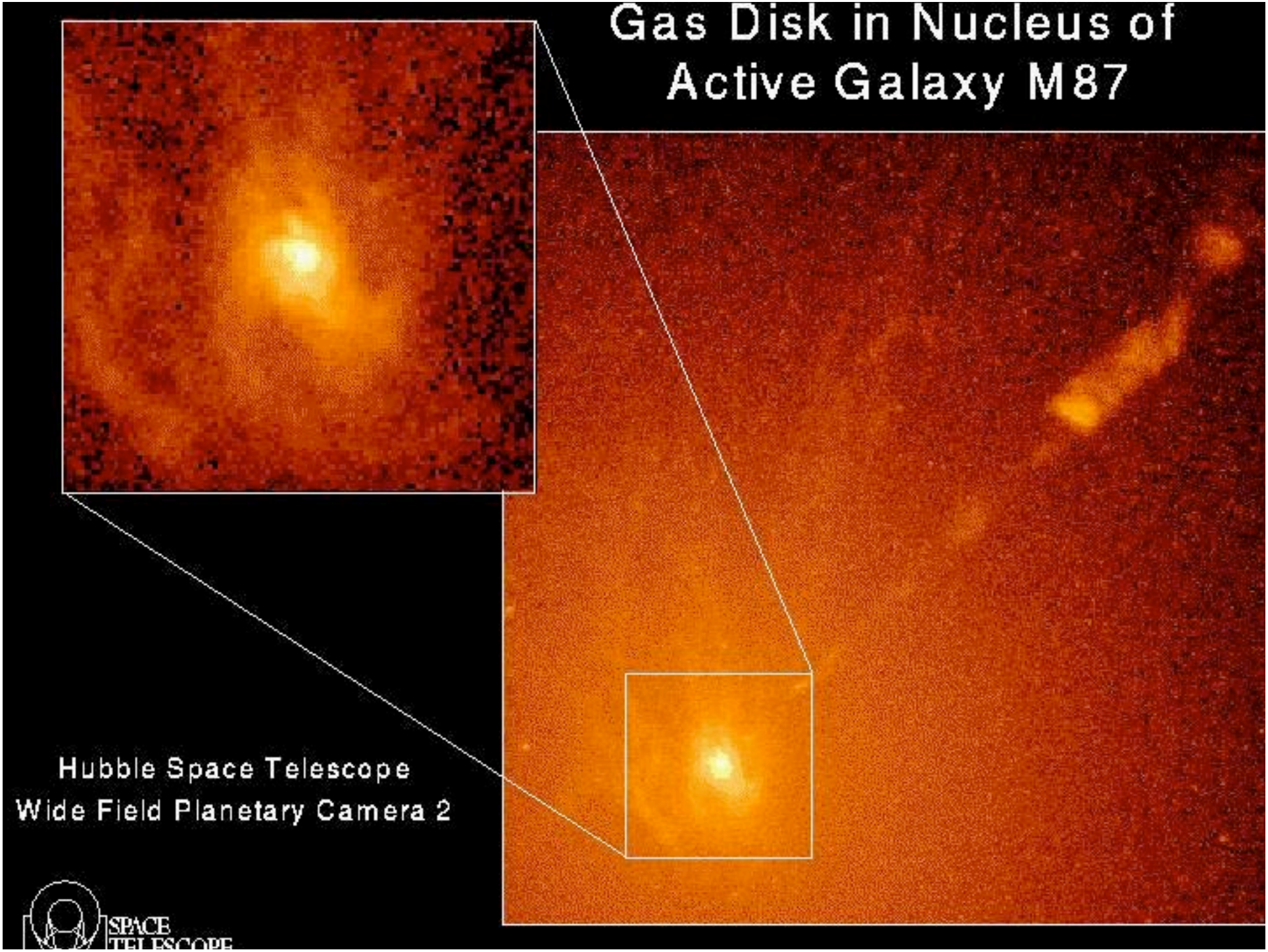
3)
Time comes to an end in a black hole.

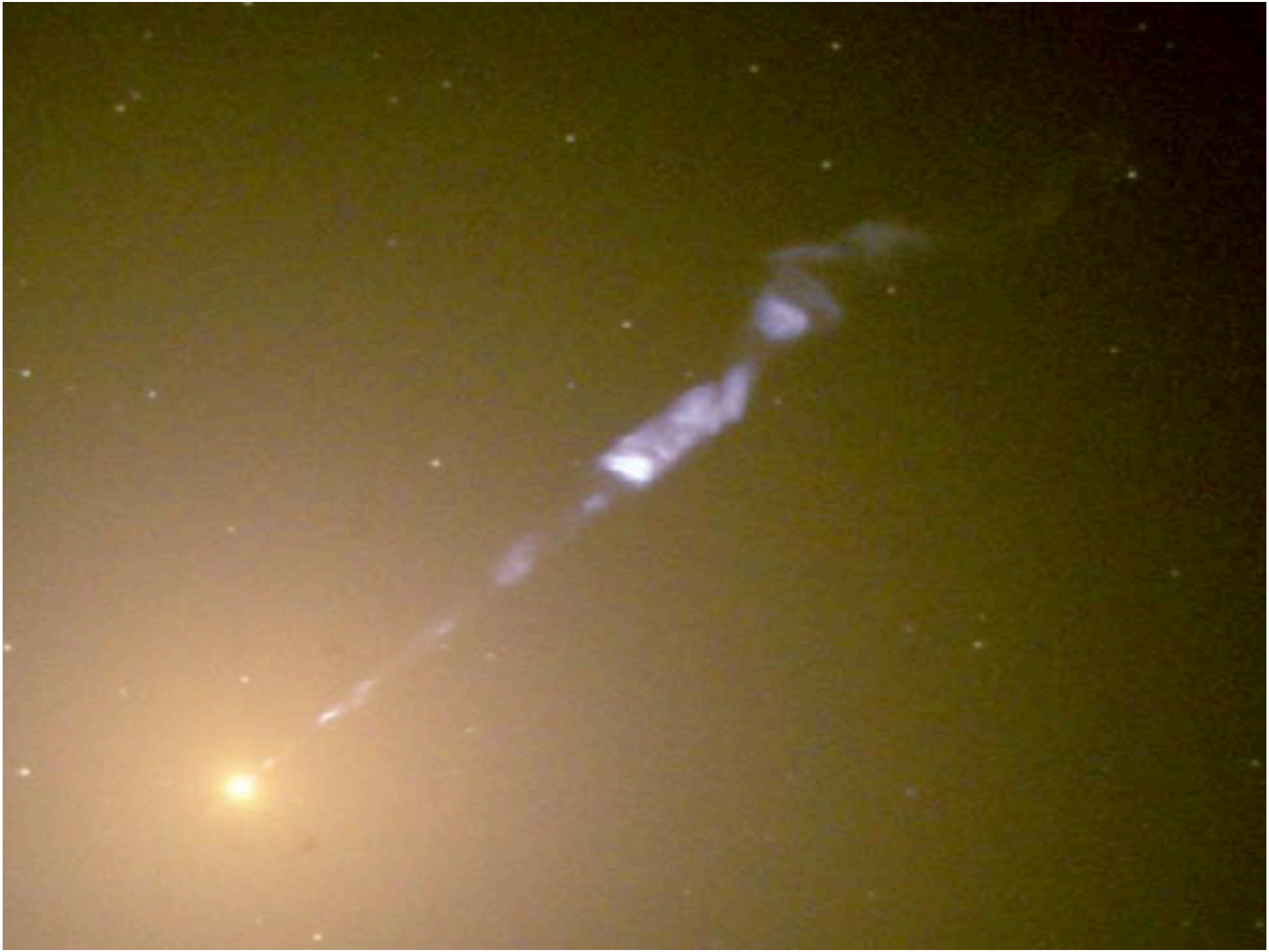
2)
Warping increases as the star contracts

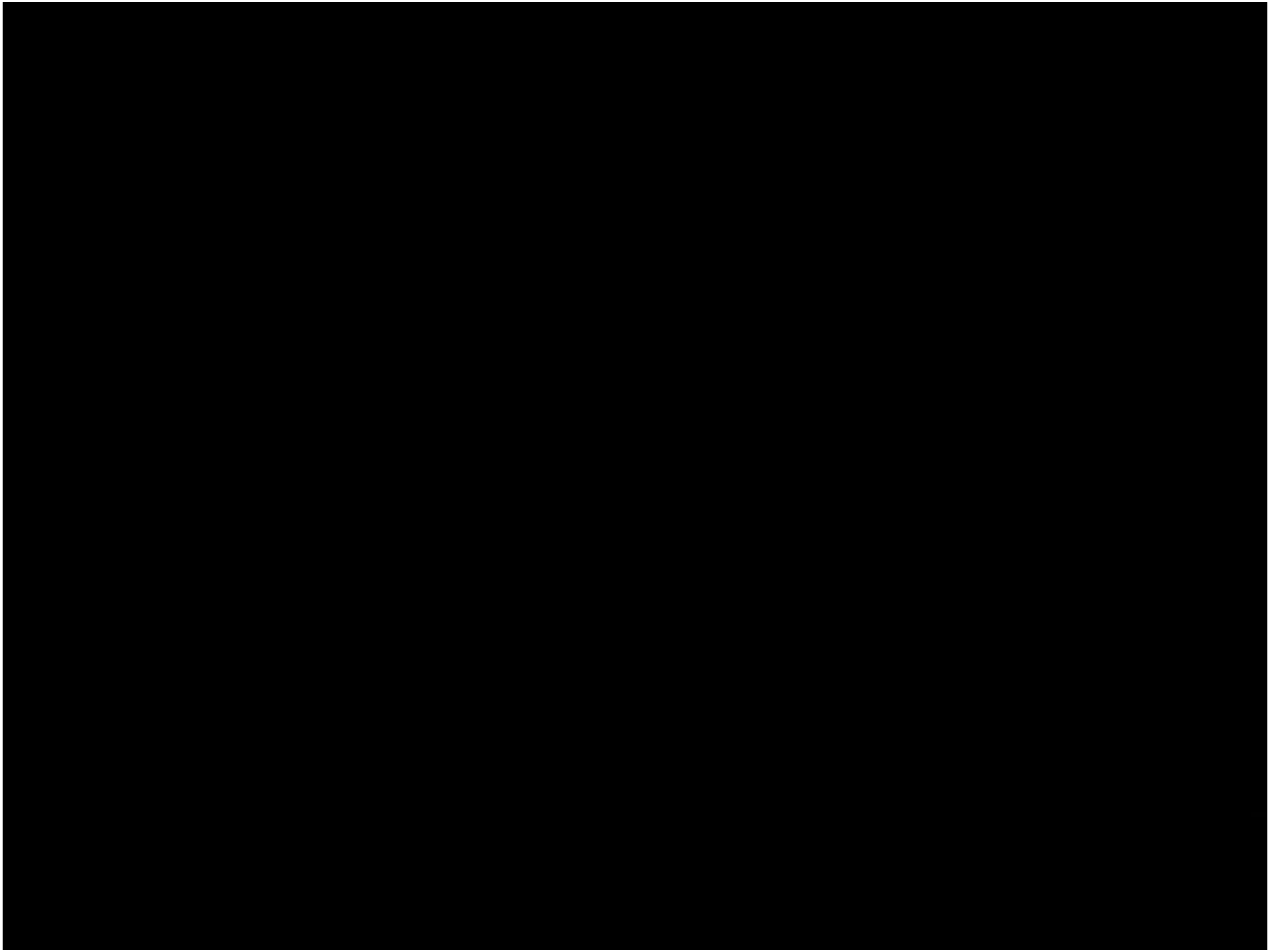


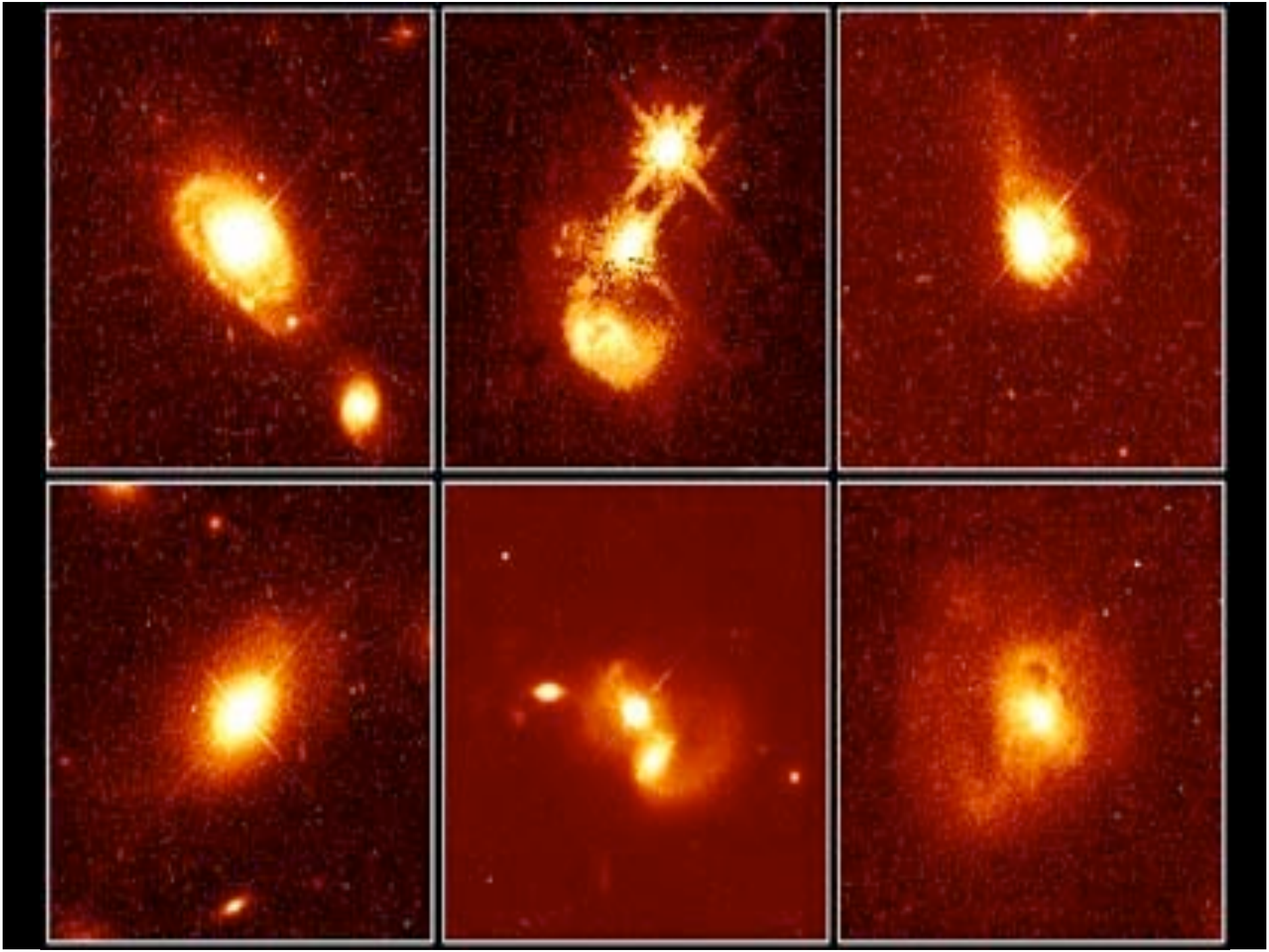
1)
Warping of spacetime around a massive star burning nuclear fuel.

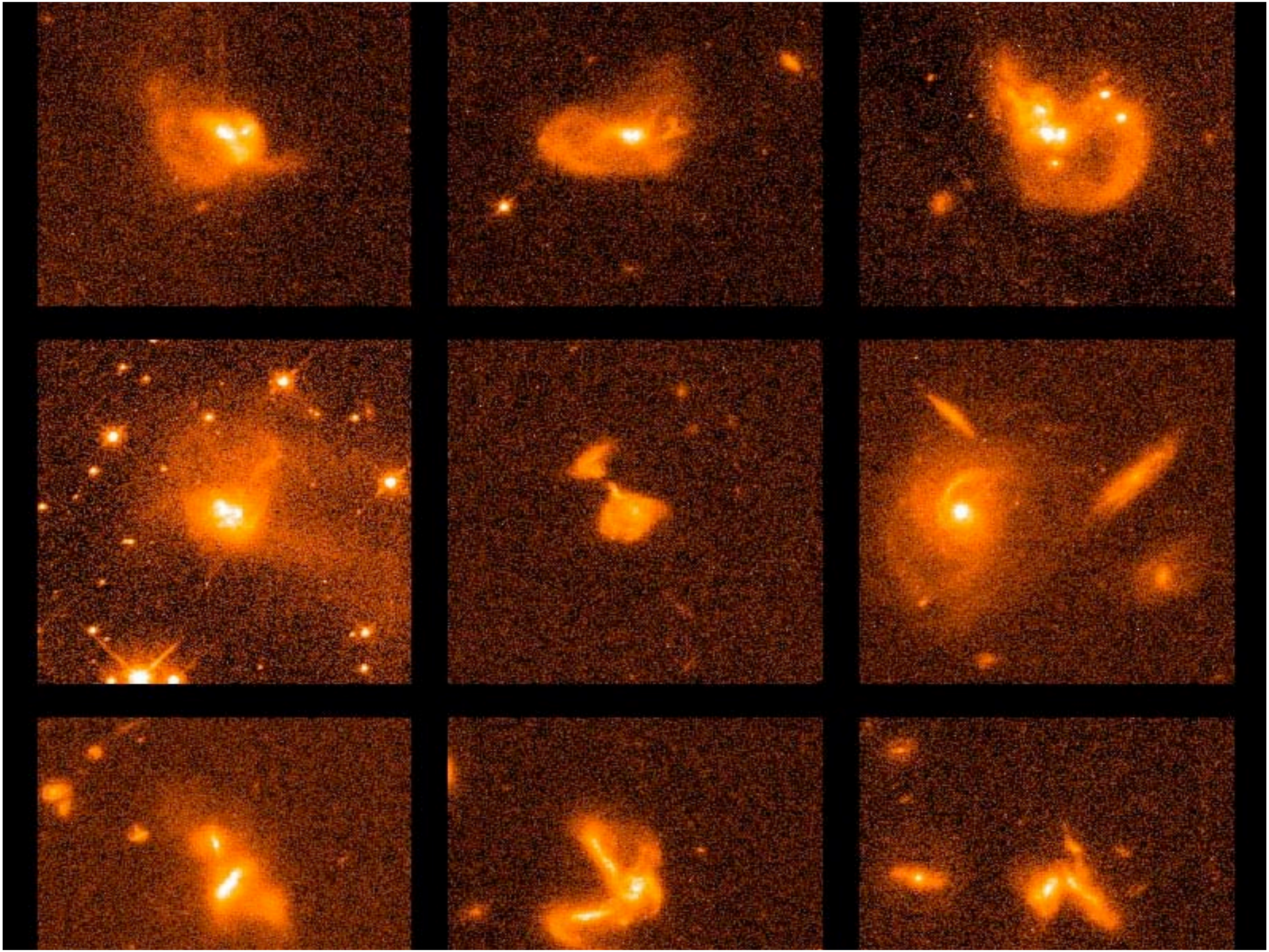


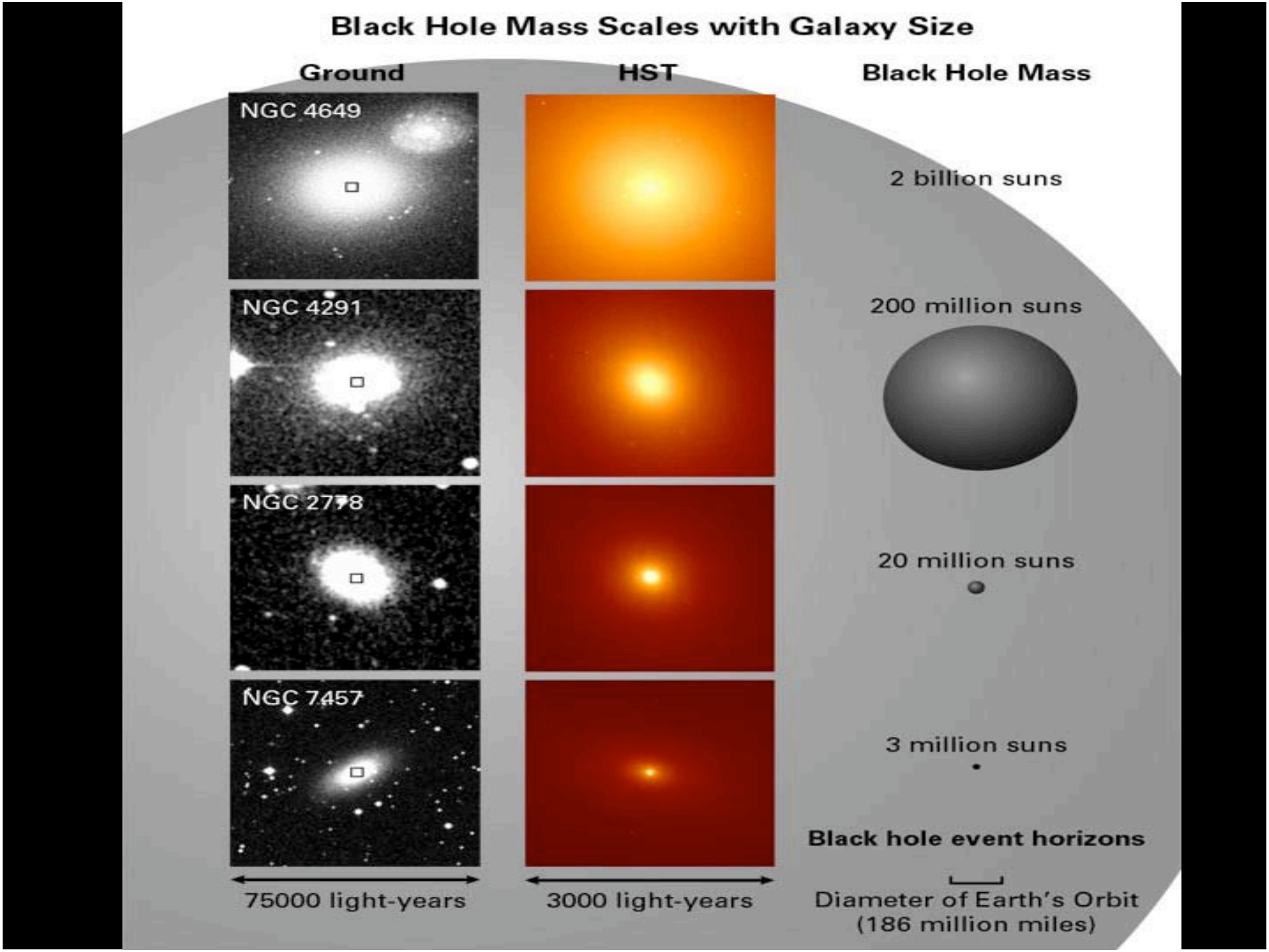

Gas Disk in Nucleus of
Active Galaxy M87
Hubble Space Telescope
Wide Field Planetary Camera 2
SPACE
TELESCOPE





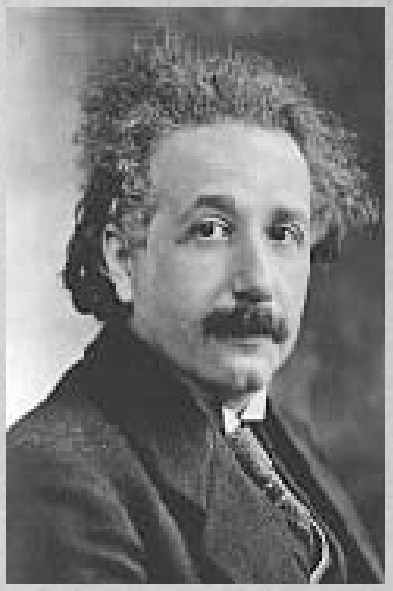





Black Hole Mass Scales with Galaxy Size
Ground
HST
Black Hole Mass
NGC 4649
2 billion suns
NGC 4291
200 million suns
NGC 2778
20 million suns
NGC 7457
3 million suns
Black hole event horizons
75000 light-years
3000 light-years
Diameter of Earth's Orbit
(186 million miles)

- Learn from yesterday
- Live for today
- Hope for tomorrow

- The important thing is not to stop questioning



Albert Einstein