

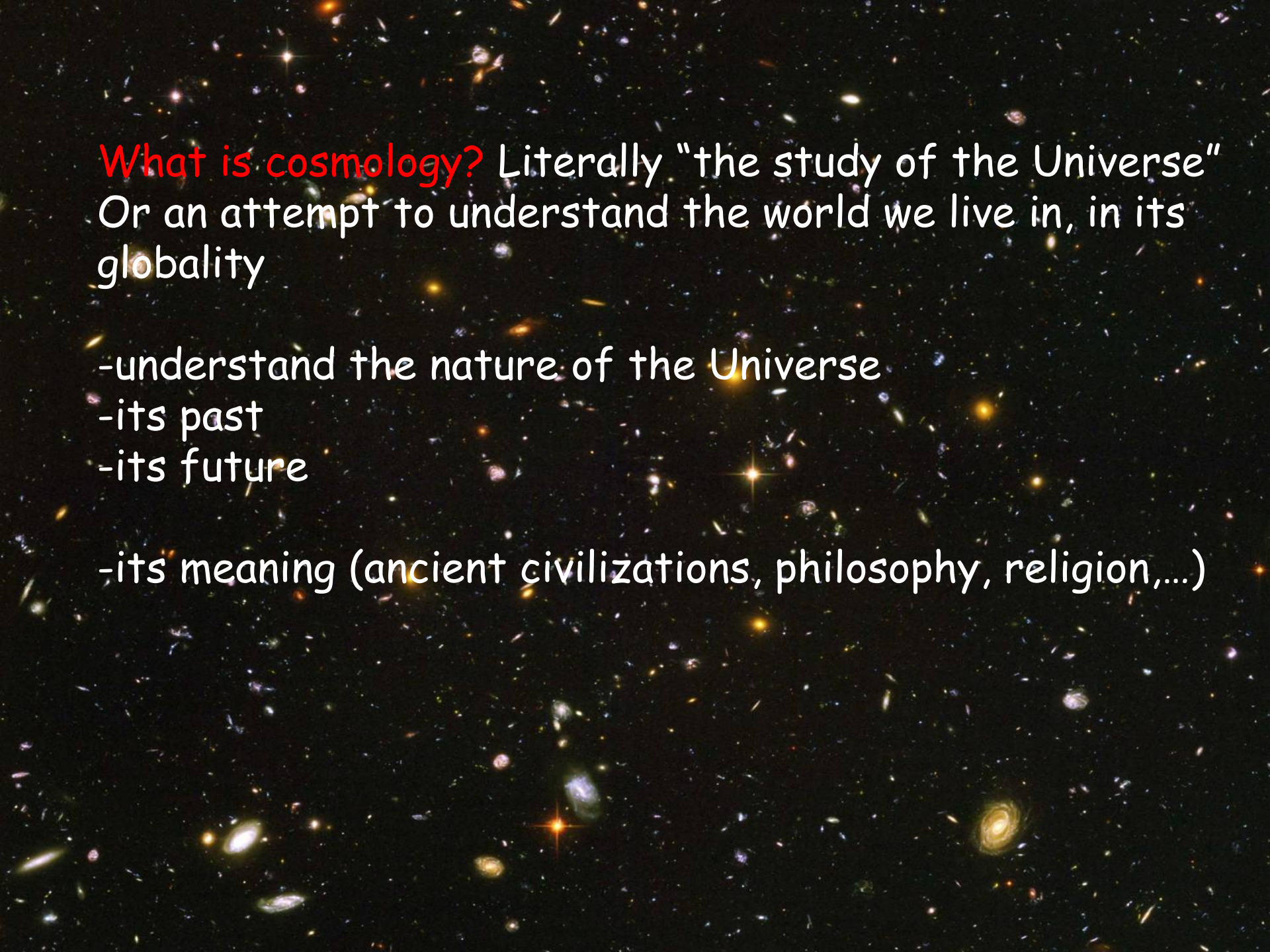
Dark Matter and Dark Energy

L. Van Waerbeke

Triumf Saturday lectures Nov 2009



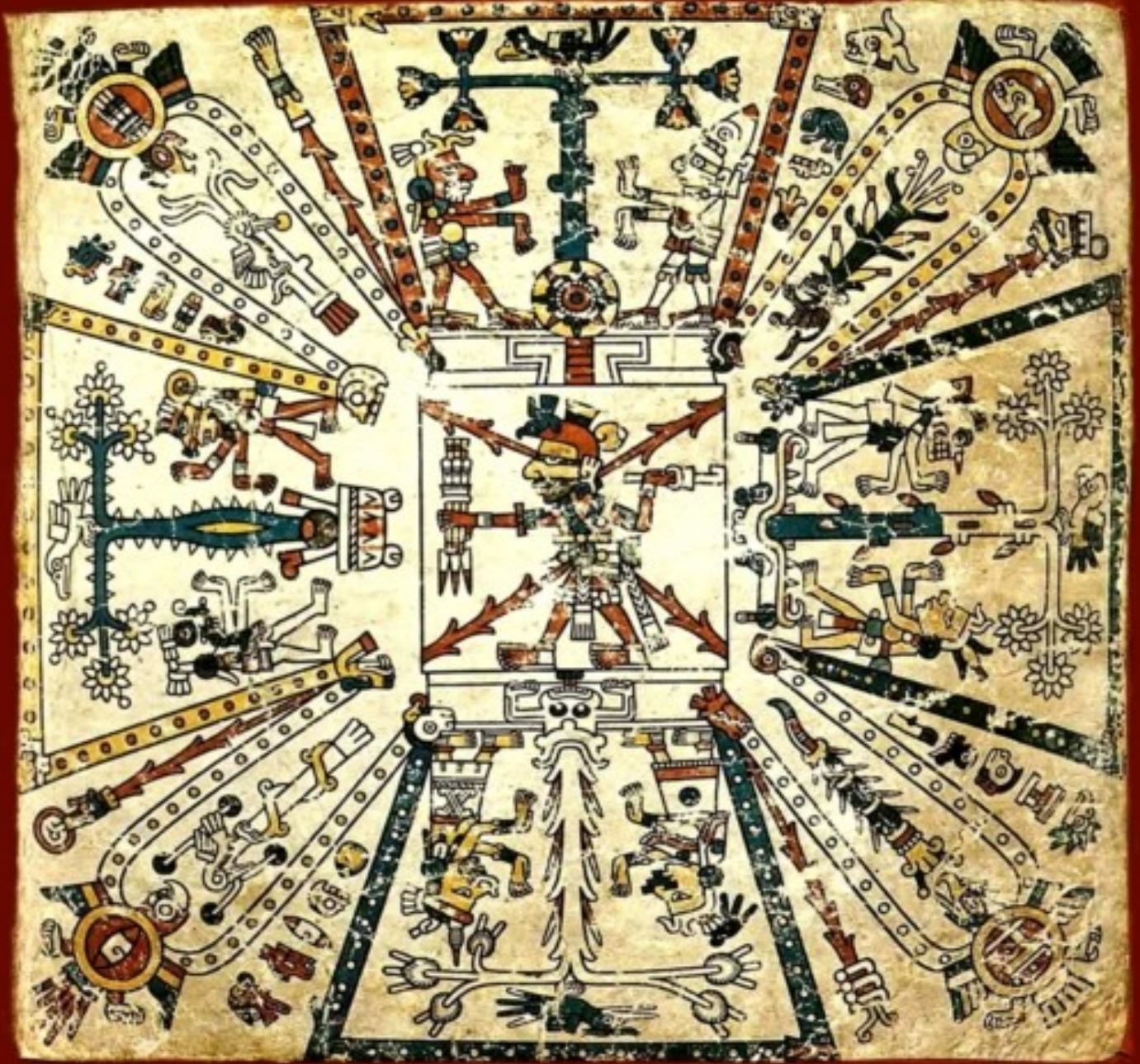
CIFAR
CANADIAN INSTITUTE
for ADVANCED RESEARCH



What is cosmology? Literally "the study of the Universe"
Or an attempt to understand the world we live in, in its
globality

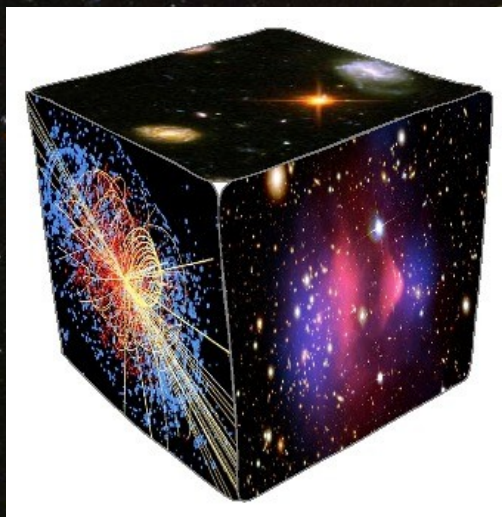
- understand the nature of the Universe
- its past
- its future
- its meaning (ancient civilizations, philosophy, religion,...)

Aztec cosmology



What is modern cosmology?

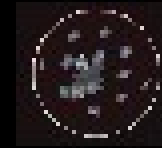
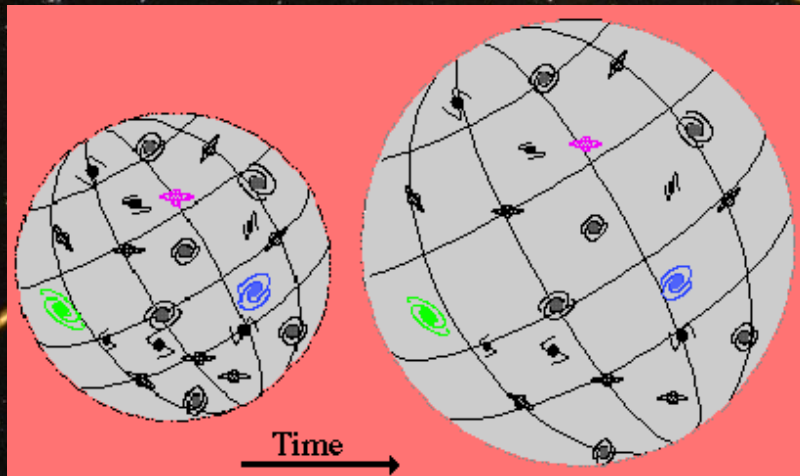
- it is a -very young- science, based on observations
- it makes a deep connection between the large and the small,
That is a real revolution
- we have definitely lost our central position!



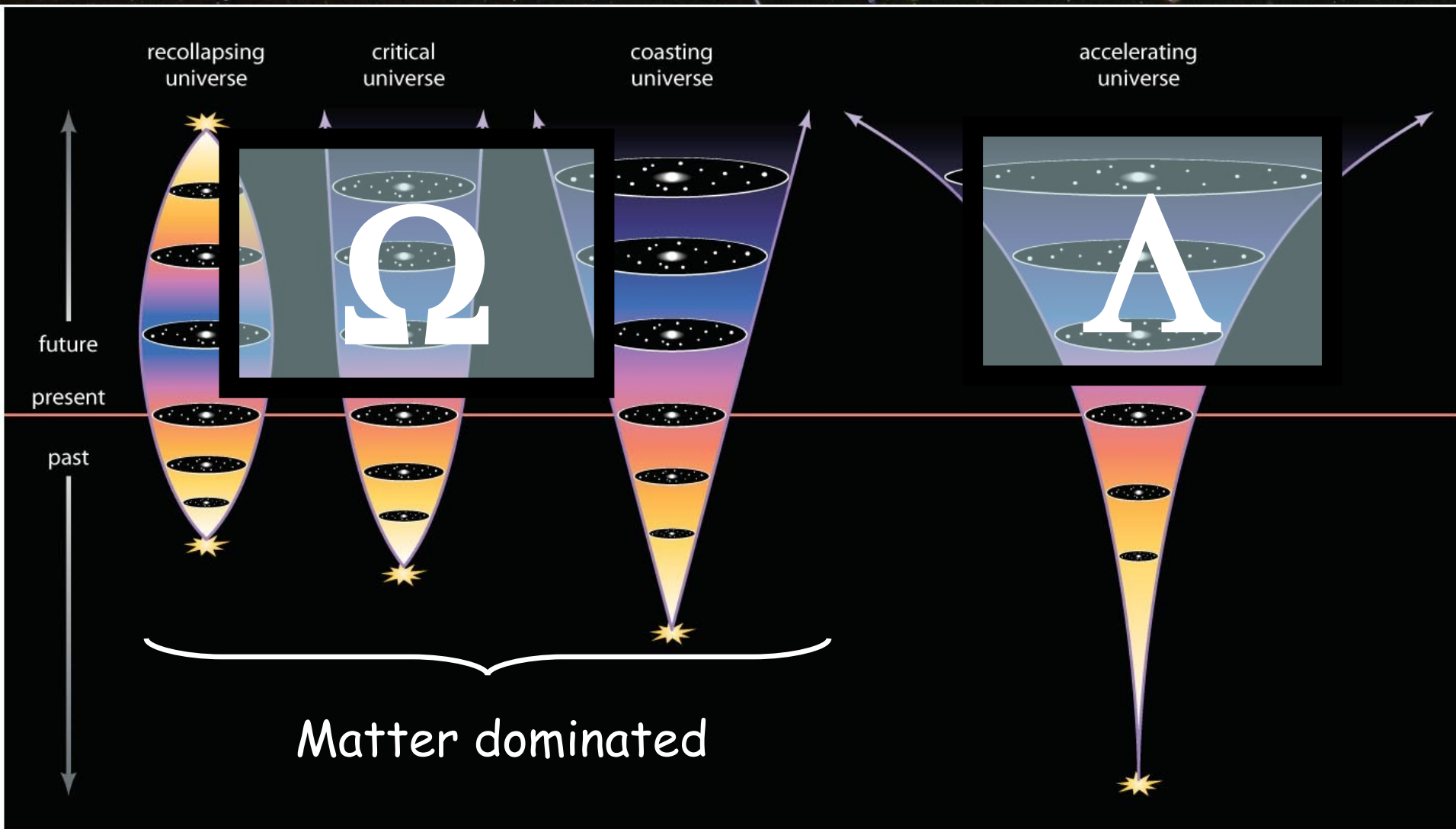
1927: Edwin Hubble discovered the expansion of the Universe!
founded the idea of a **Big Bang**



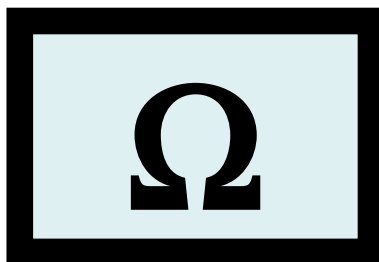
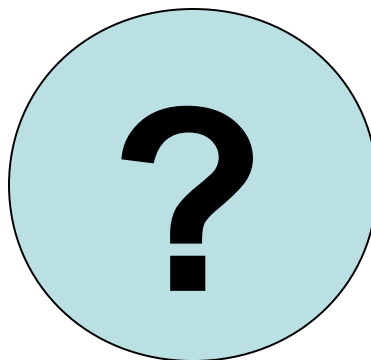
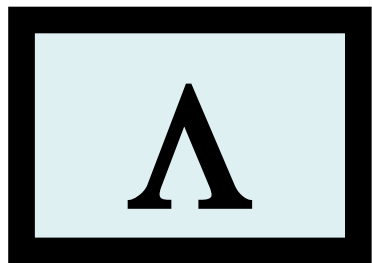
The Universe is expanding

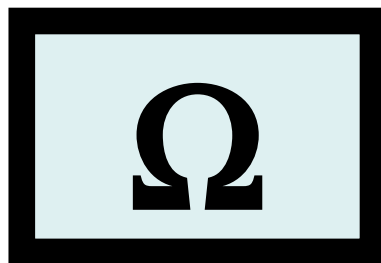
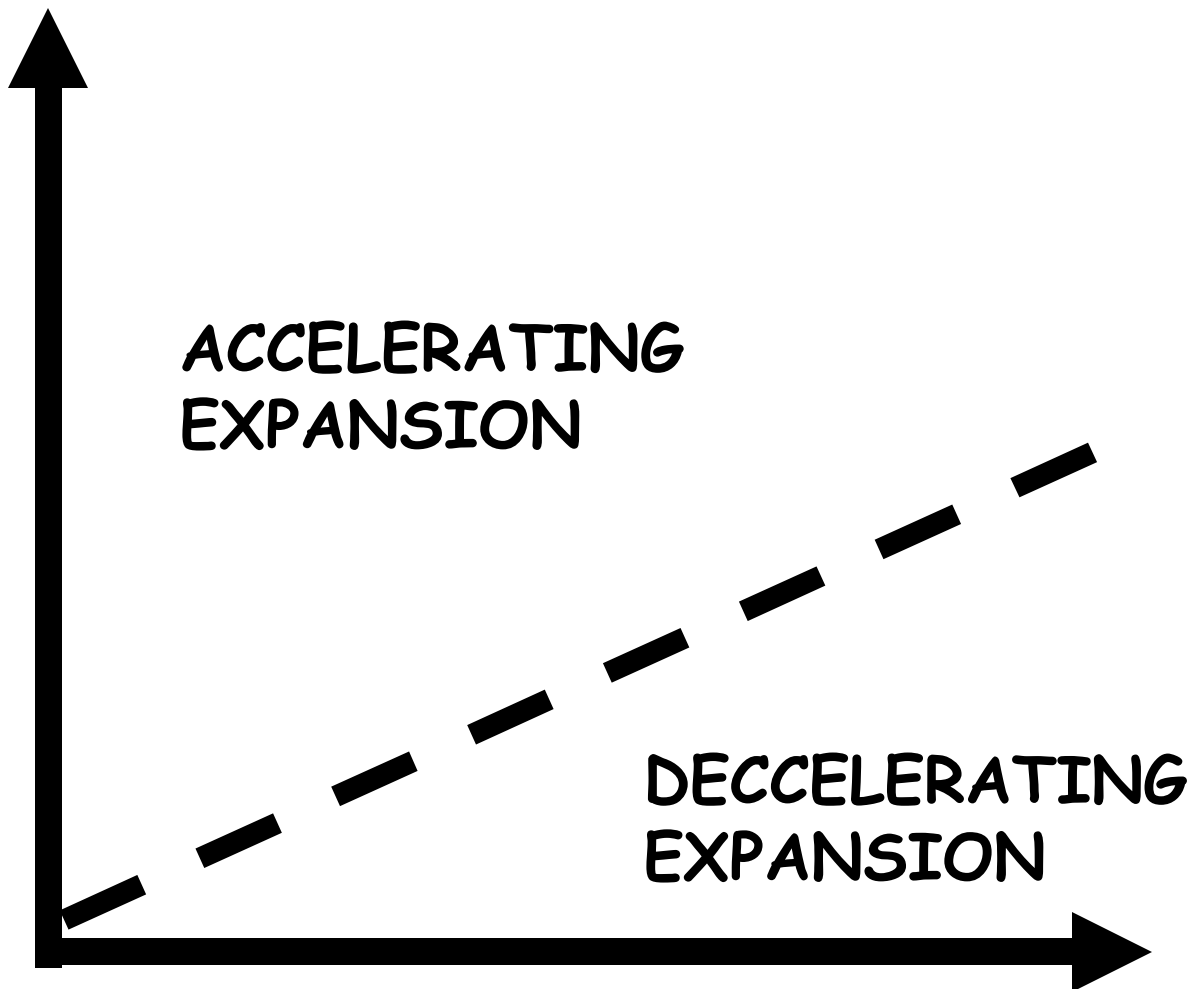
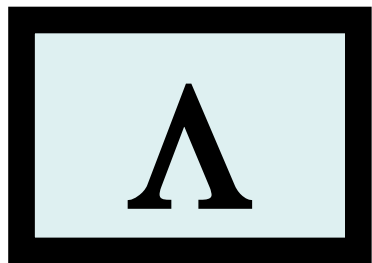


Different possible fates for the Universe



"Anti" gravity? Or cosmological constant



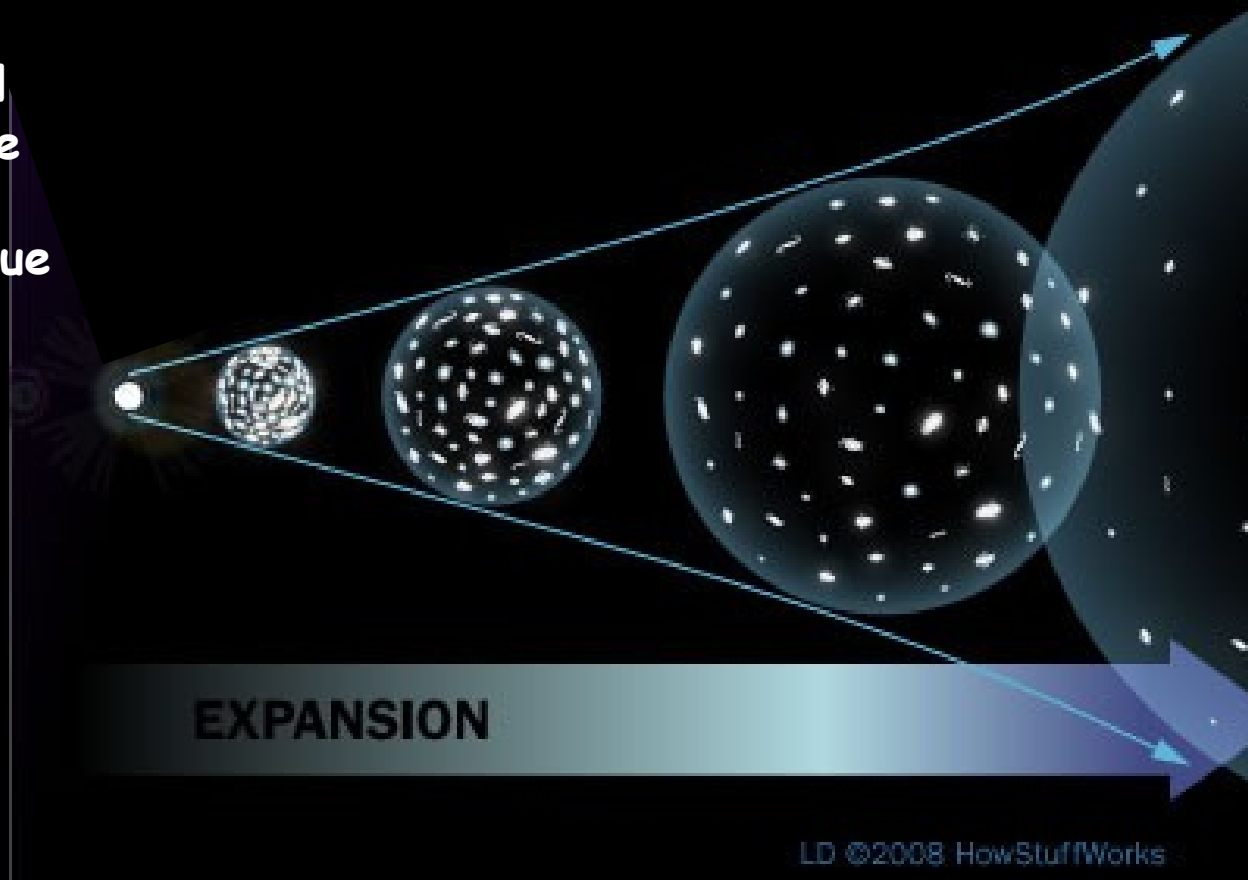


Early Universe was

Small
Dense
Hot
Opaque

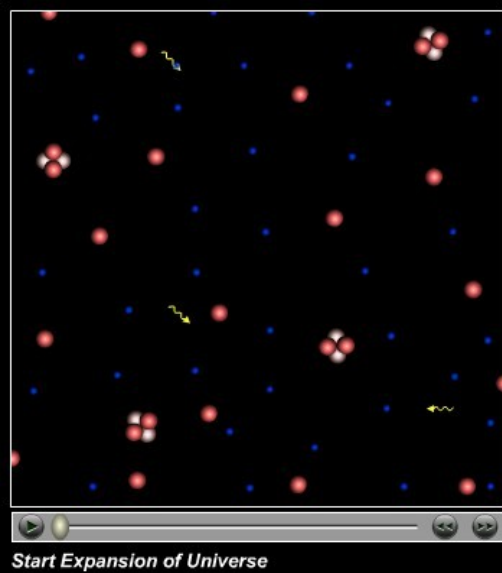
Universe today is

Big
Low density
Cold
Transparent

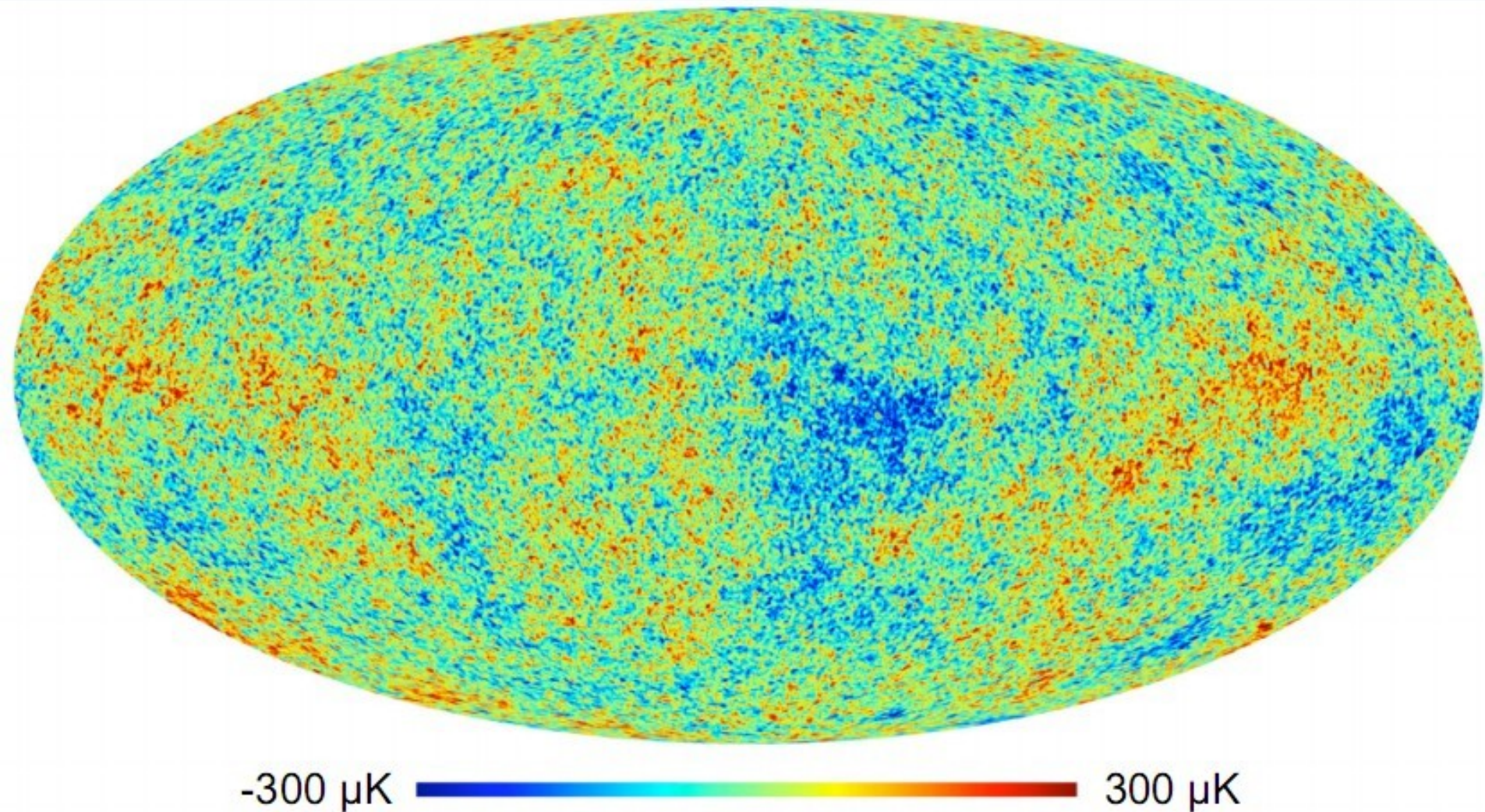


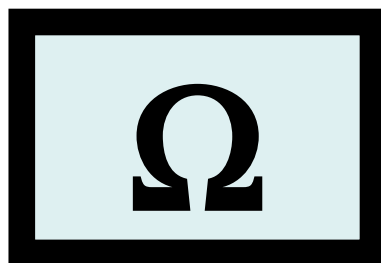
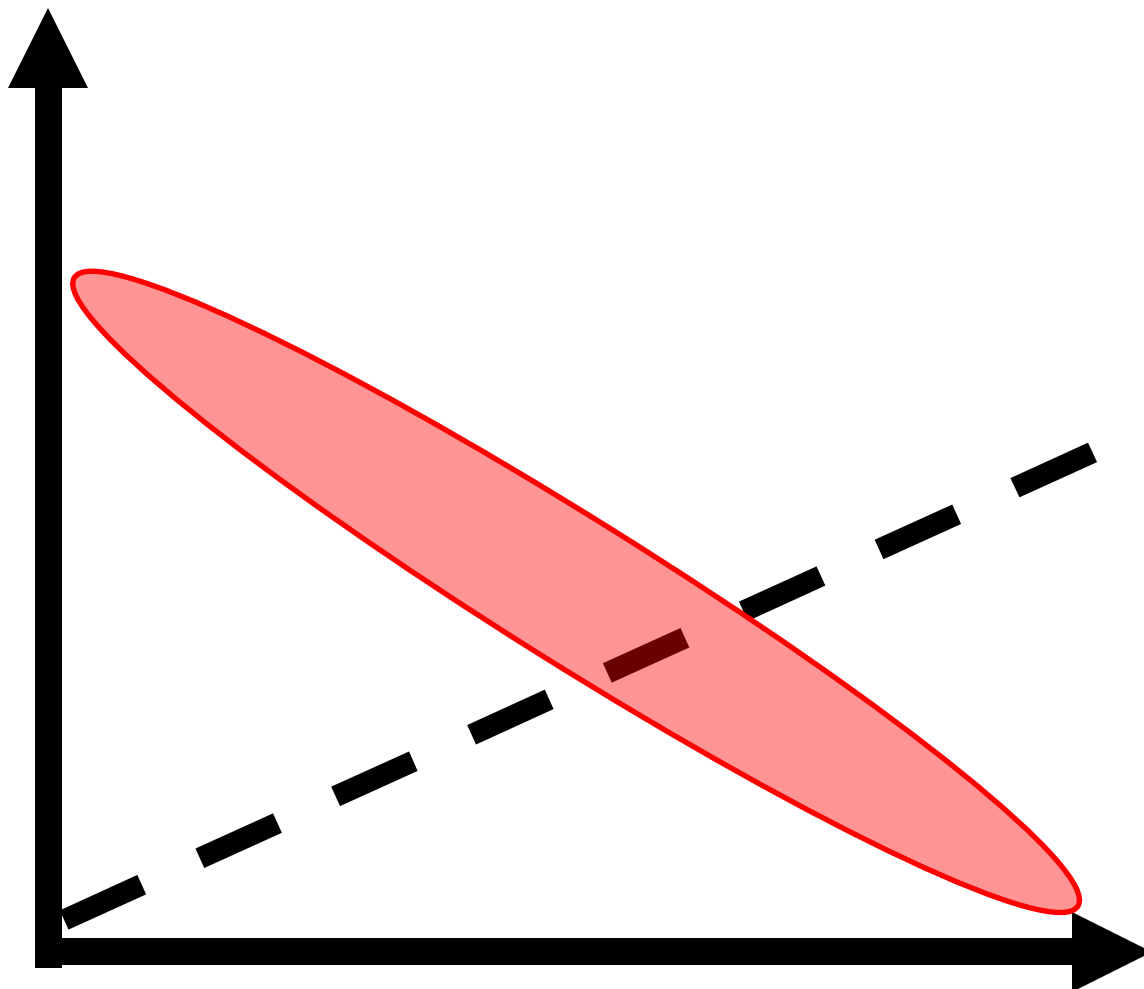
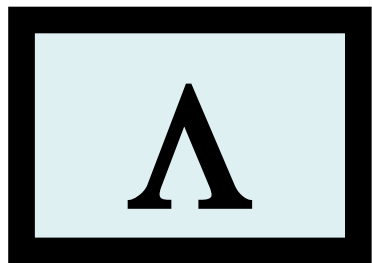
Cosmic Microwave Background:

A picture of the early Universe tells us how "big" things were at that time.



CMB temperature anisotropies

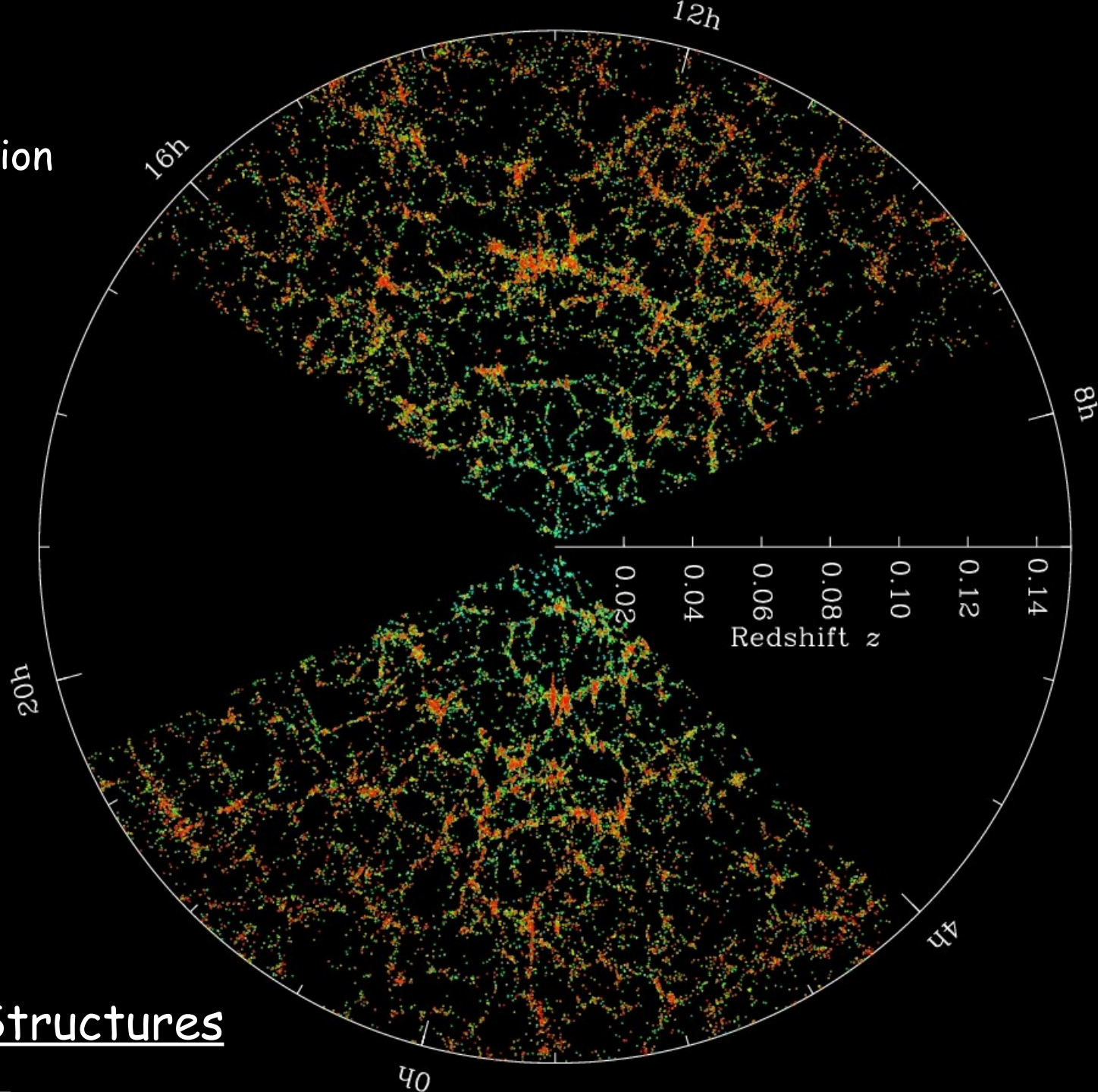




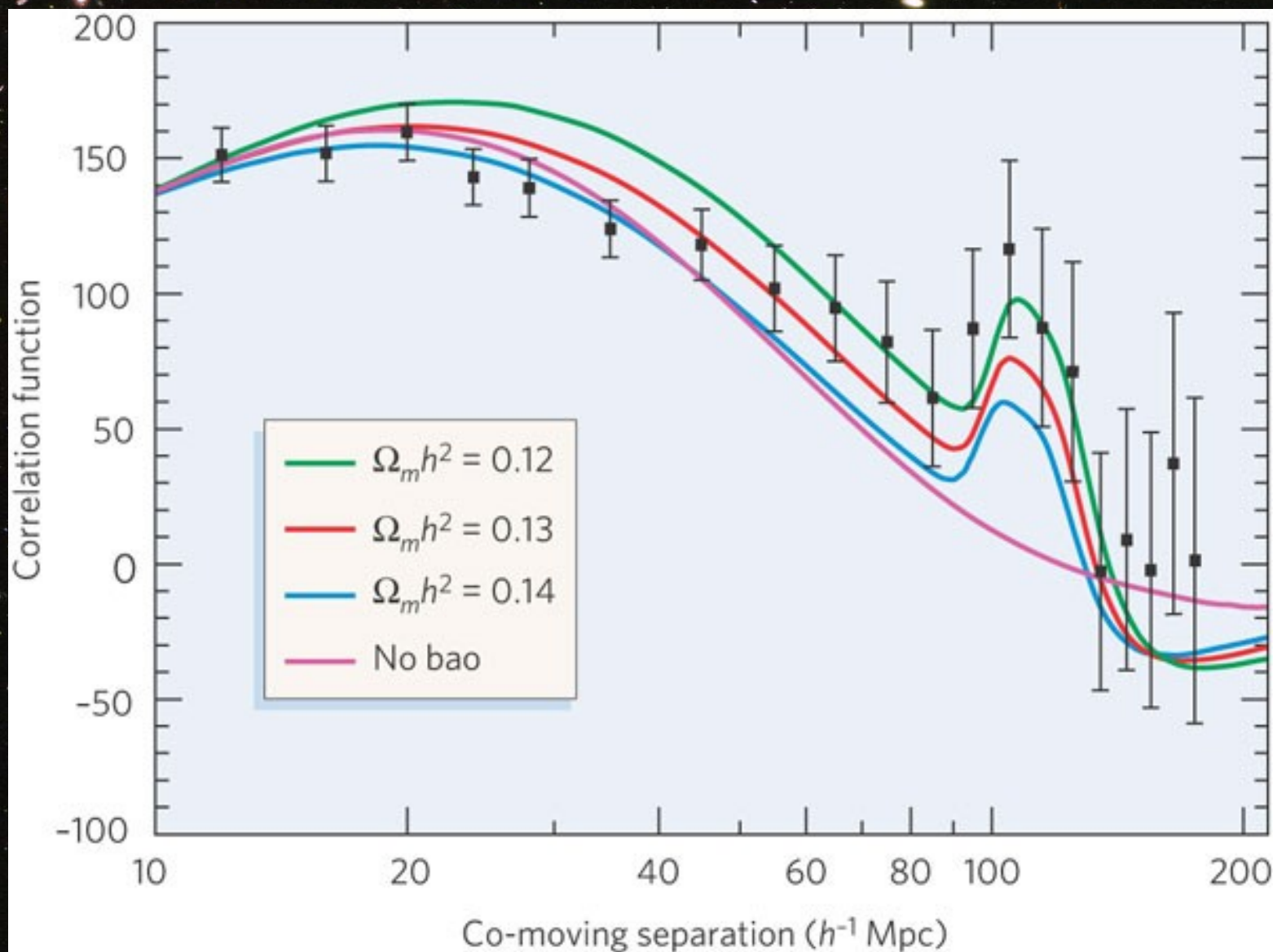


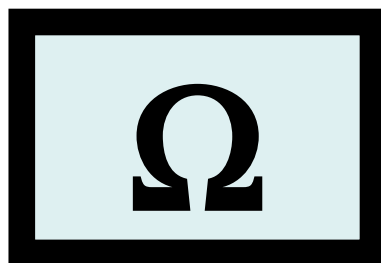
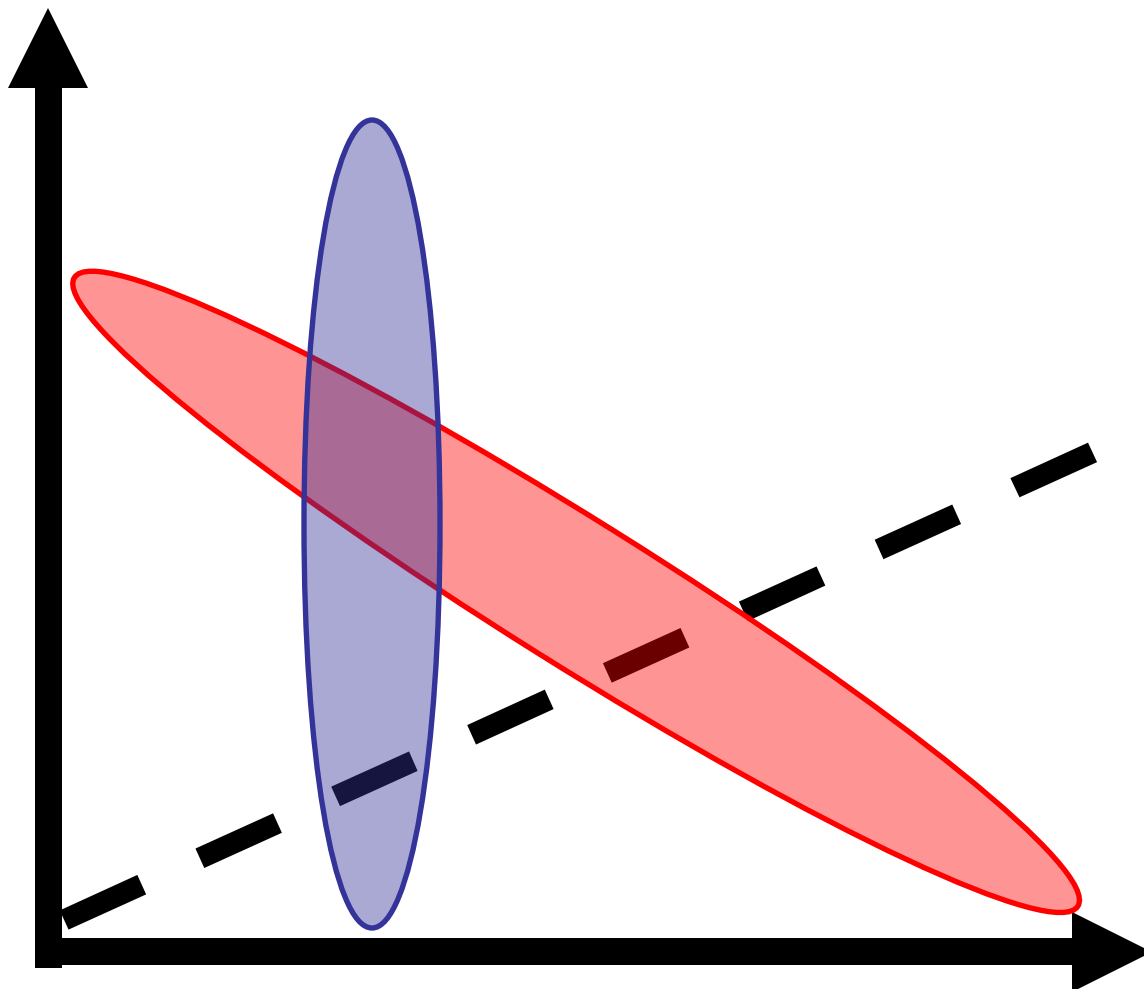
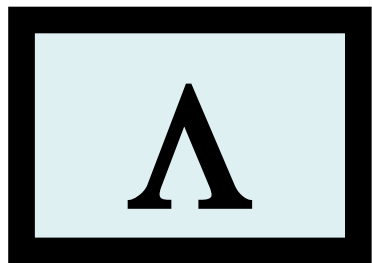
SDSS

Galaxy distribution



Large Scale Structures

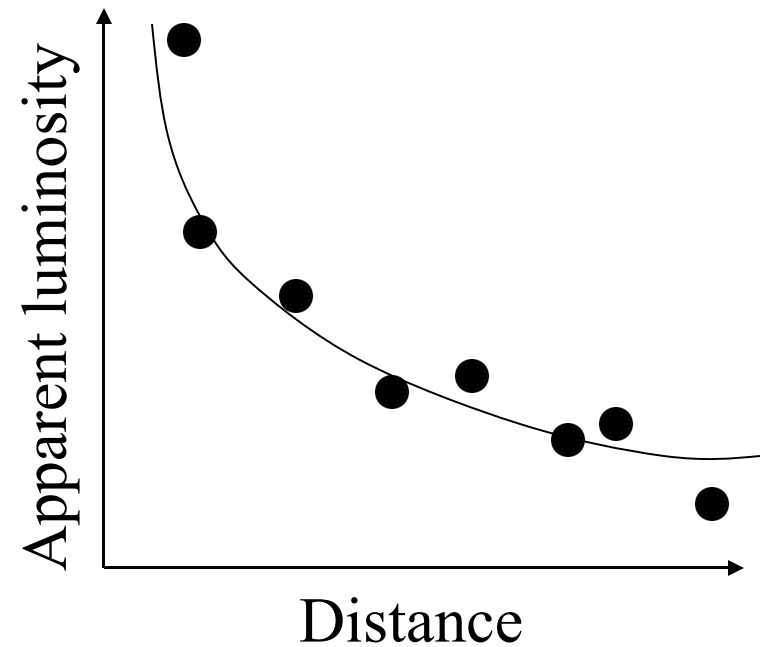


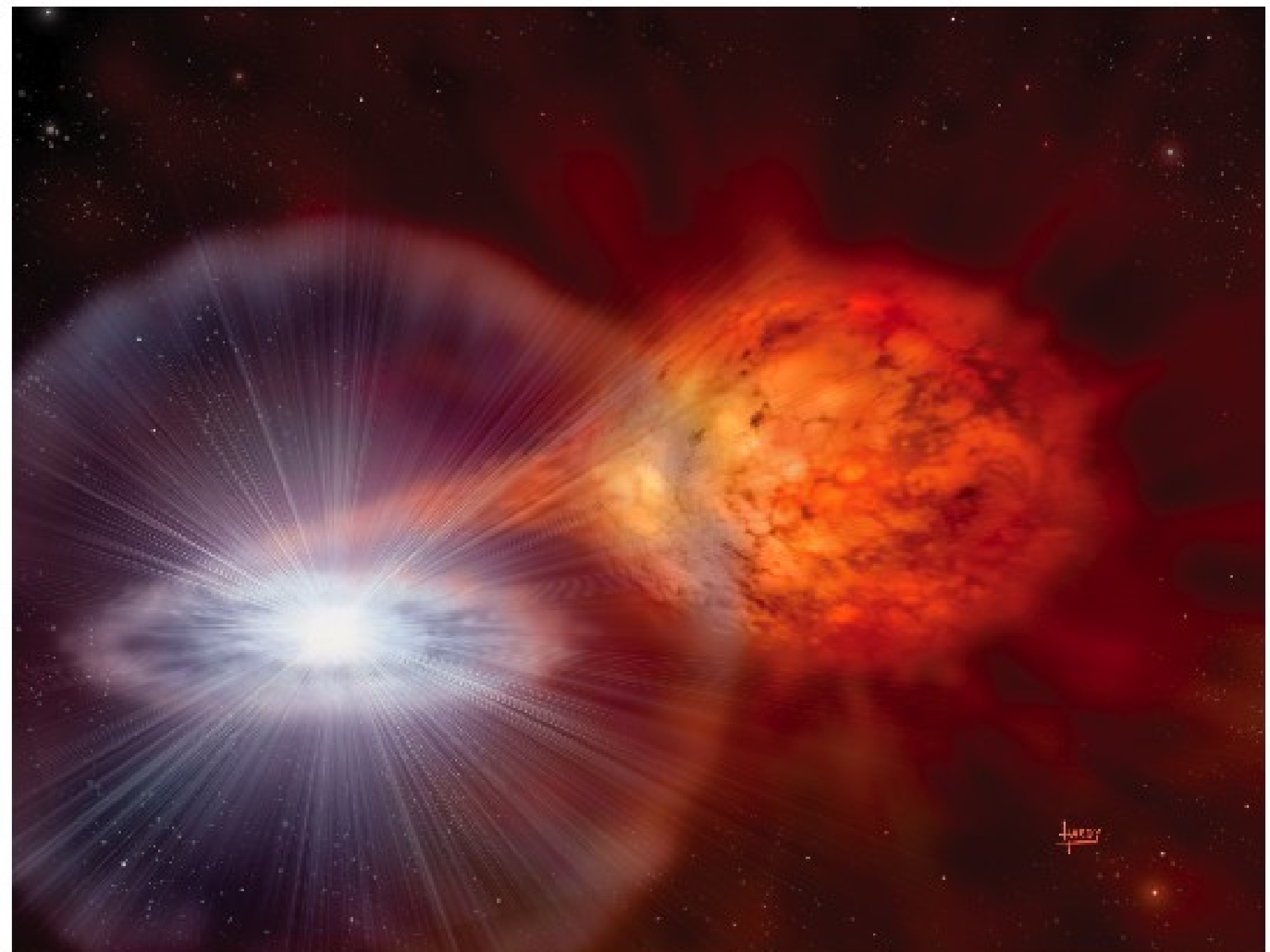


Cosmological candles...

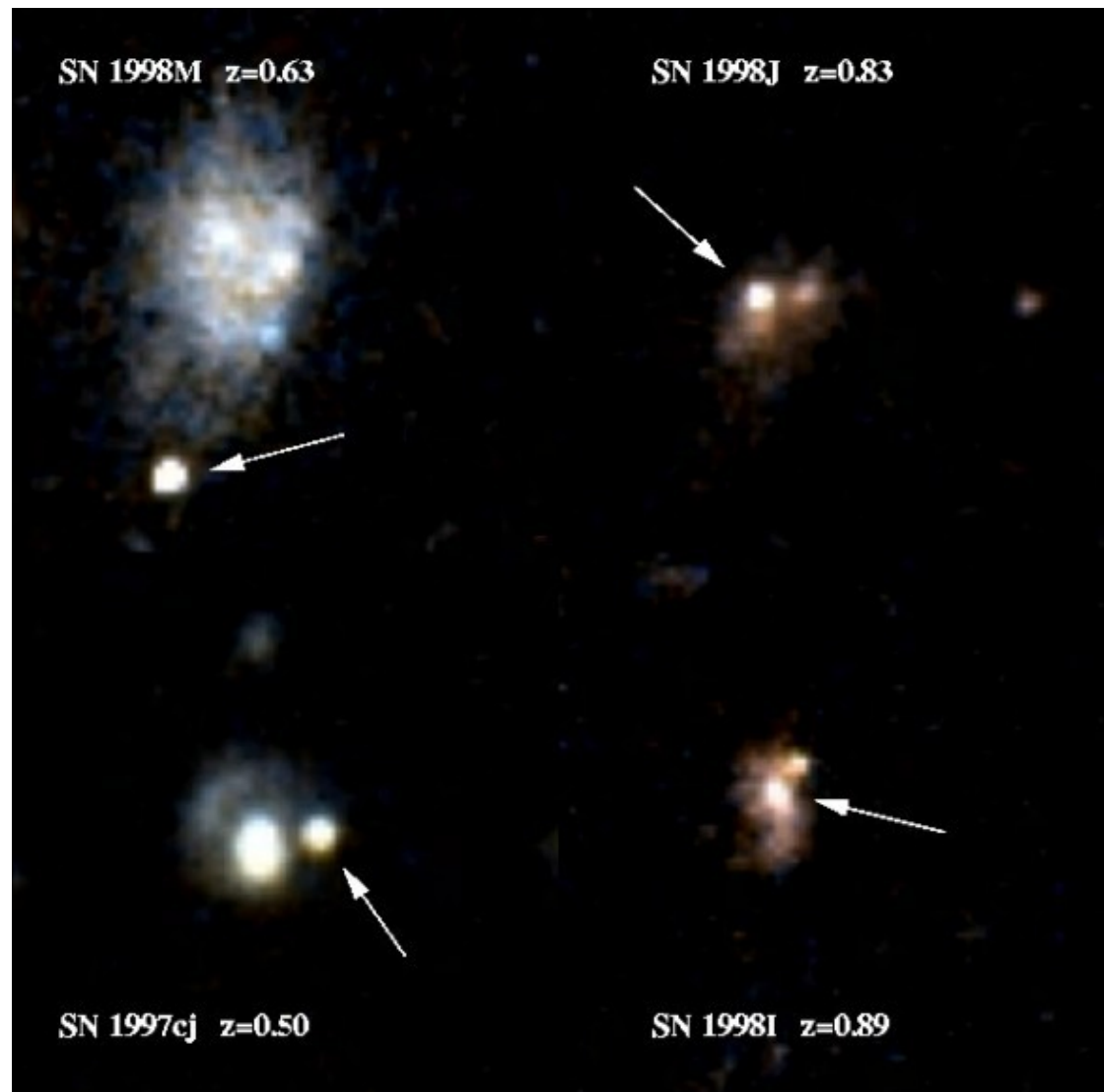
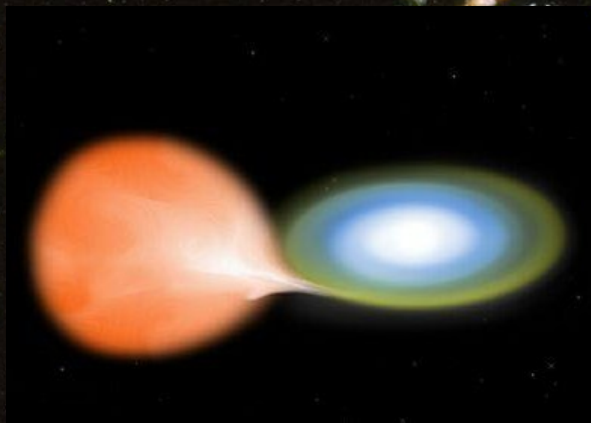


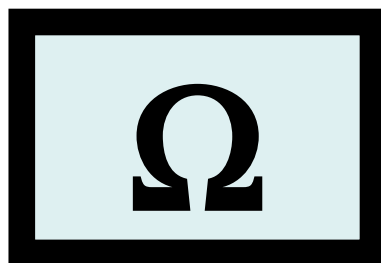
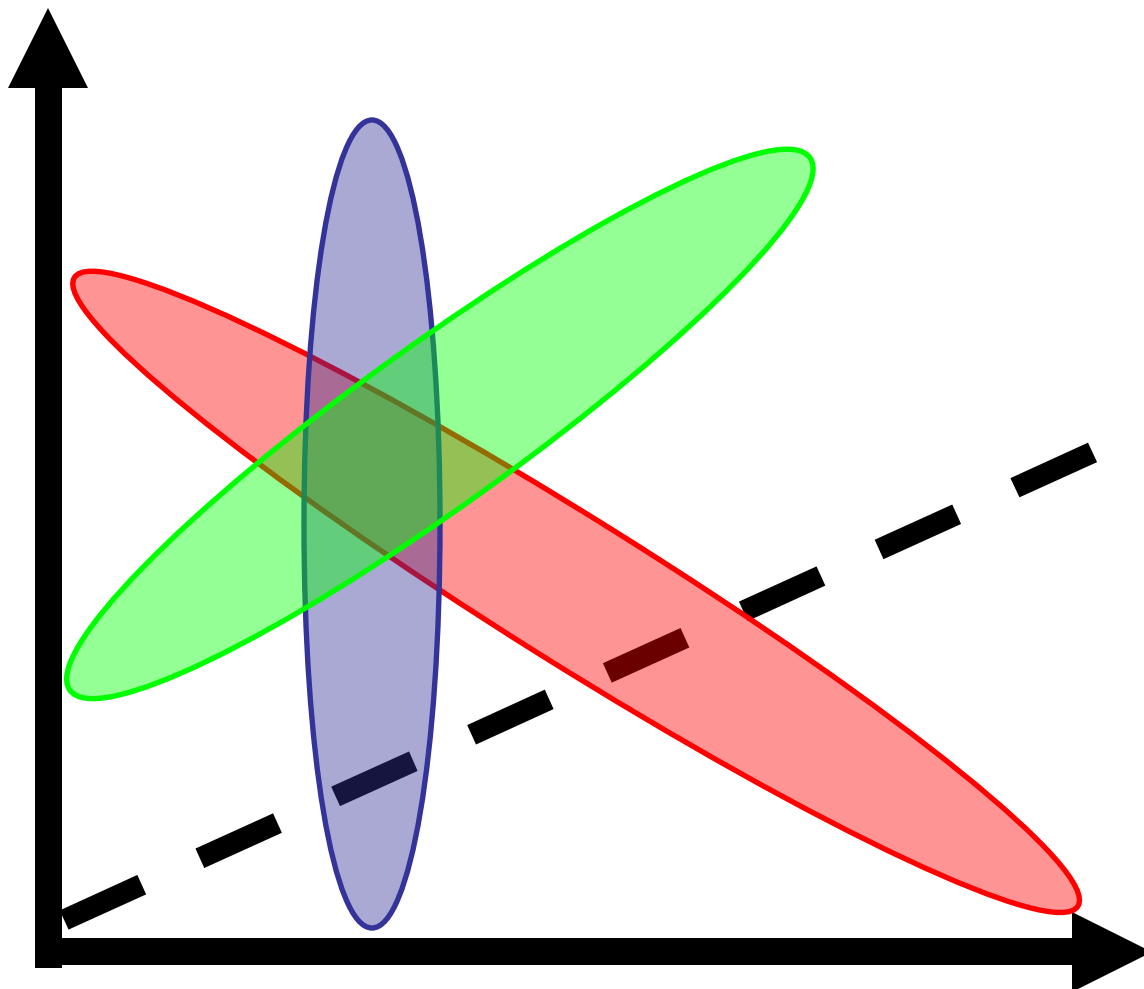
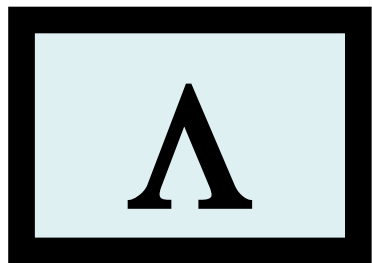
Standard candle





Supernovae of type Ia are "standard candles"



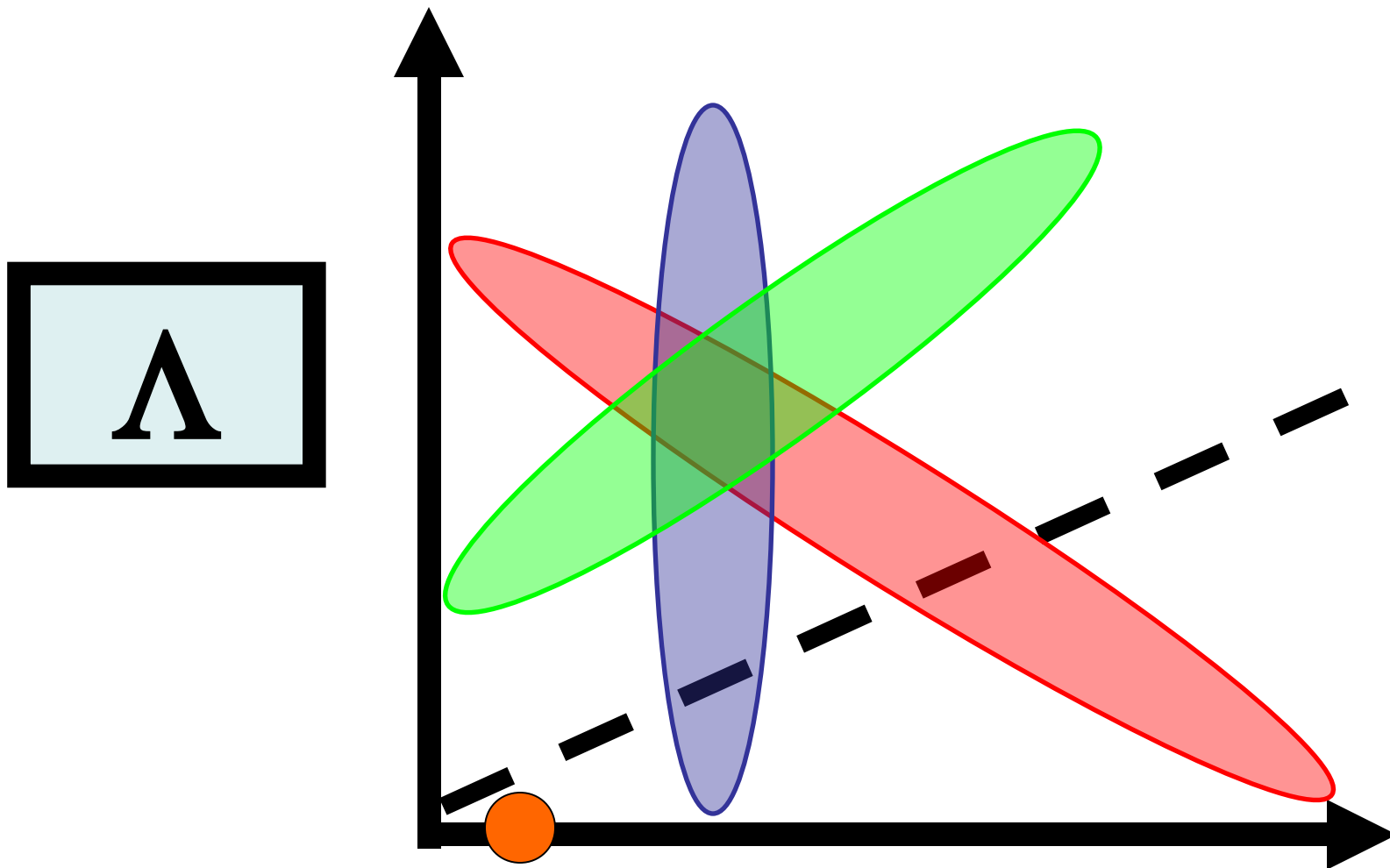


The background of the entire slide is a high-resolution astronomical image, likely from the Hubble Space Telescope, showing a dense field of galaxies. These galaxies vary in shape, size, and color, appearing as bright, colorful spots and streaks against the deep black of space. Some are spiral galaxies with distinct arms, while others are more irregular or elliptical. The distribution is uniform across the frame, creating a sense of vastness and depth.

The expansion of the Universe
is accelerating

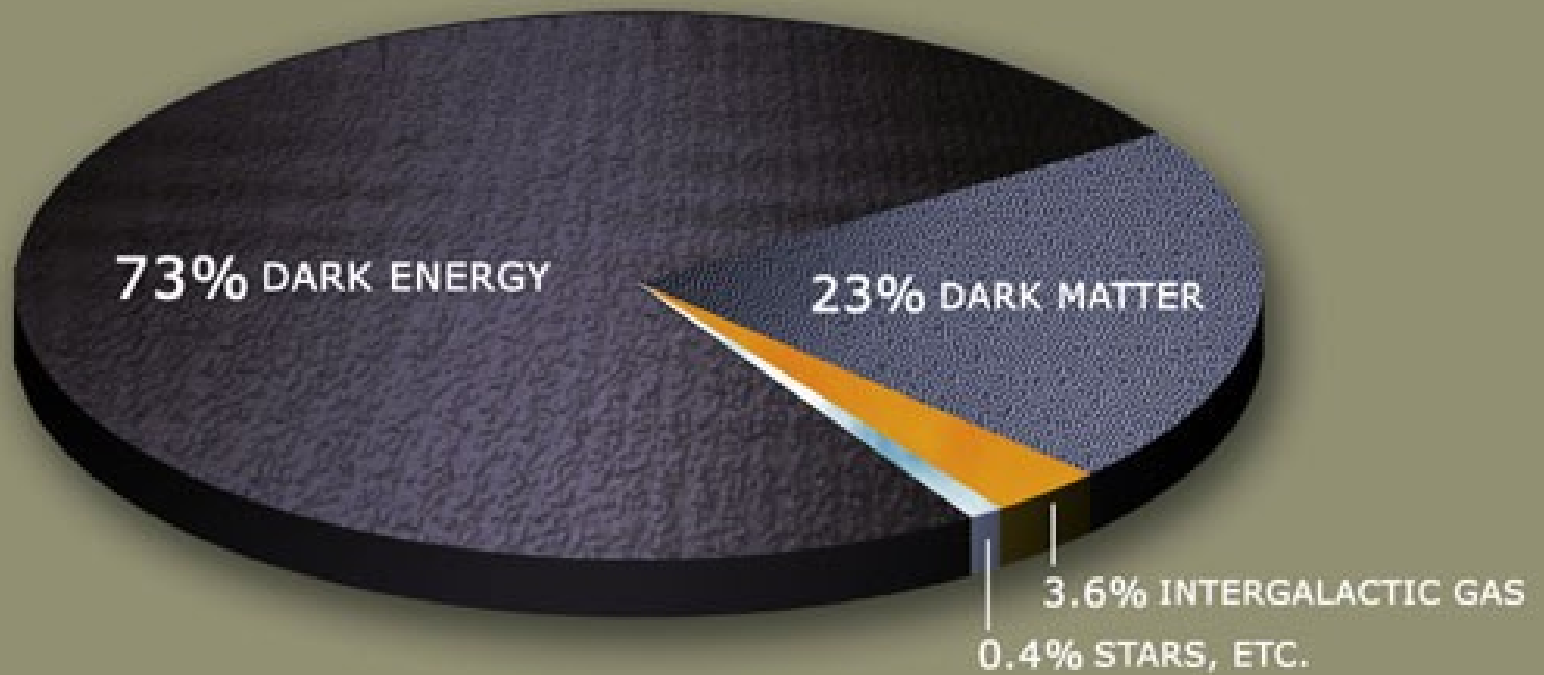
So...what?

We don't understand
the physics behind it!



This is where
we "should" be!

Do we have a problem?



> 95% of the Universe content is of unknown nature!

What is DARK MATTER?



Cornelia Parker
Cold Dark Matter: An Exploded View, 1991

What it is not:

- normal matter e.g. planets, gas, dust, proto-stars

What it could be

- new type massive particle yet to be Discovered

- modified gravity

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National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

NIST SP 966 (September 2003)

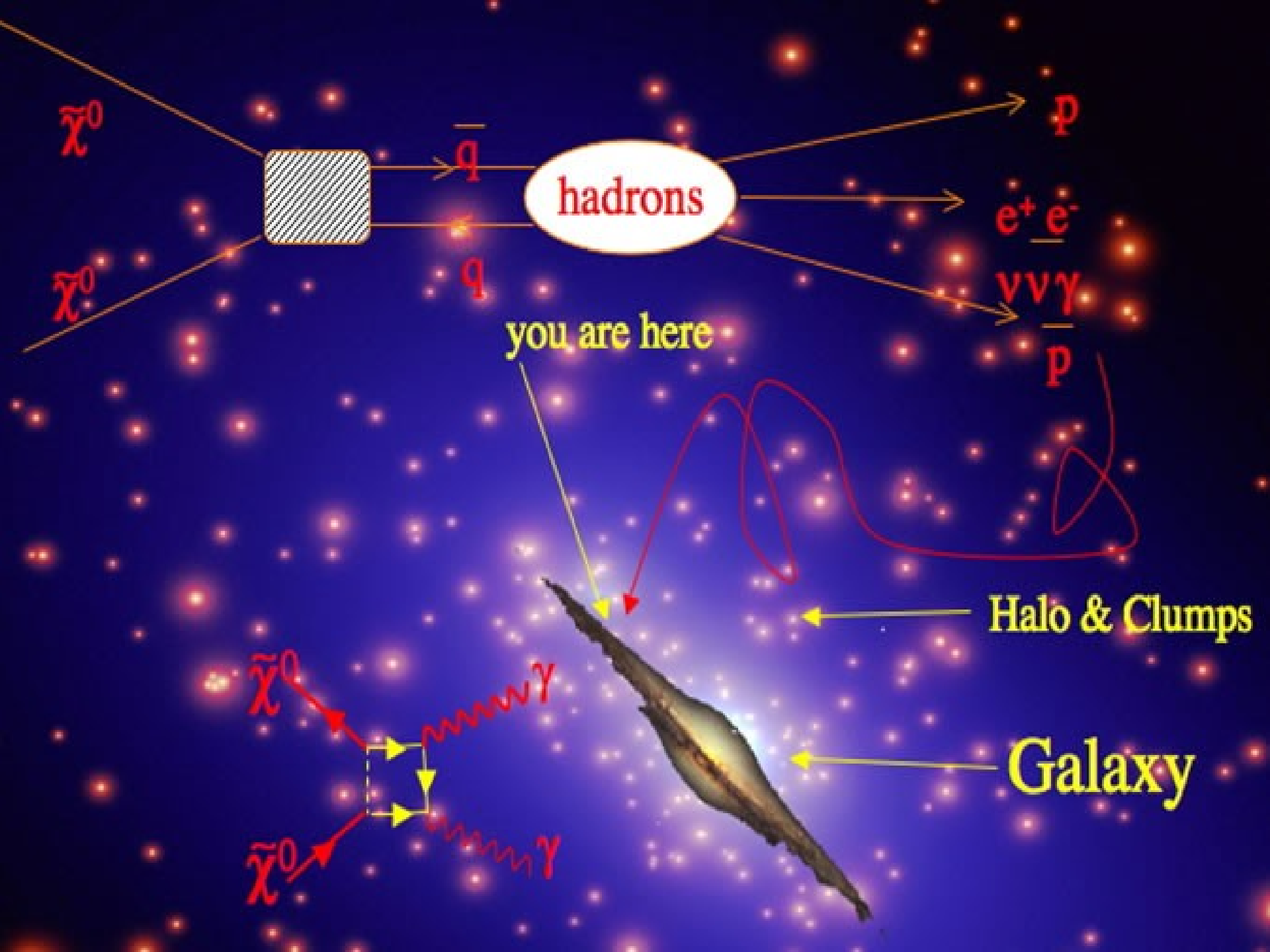
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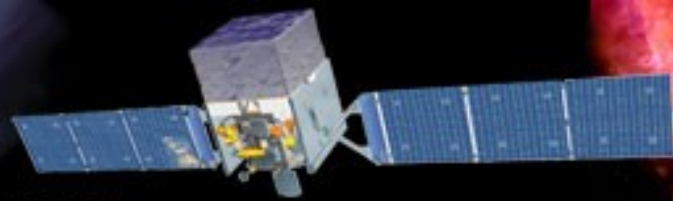
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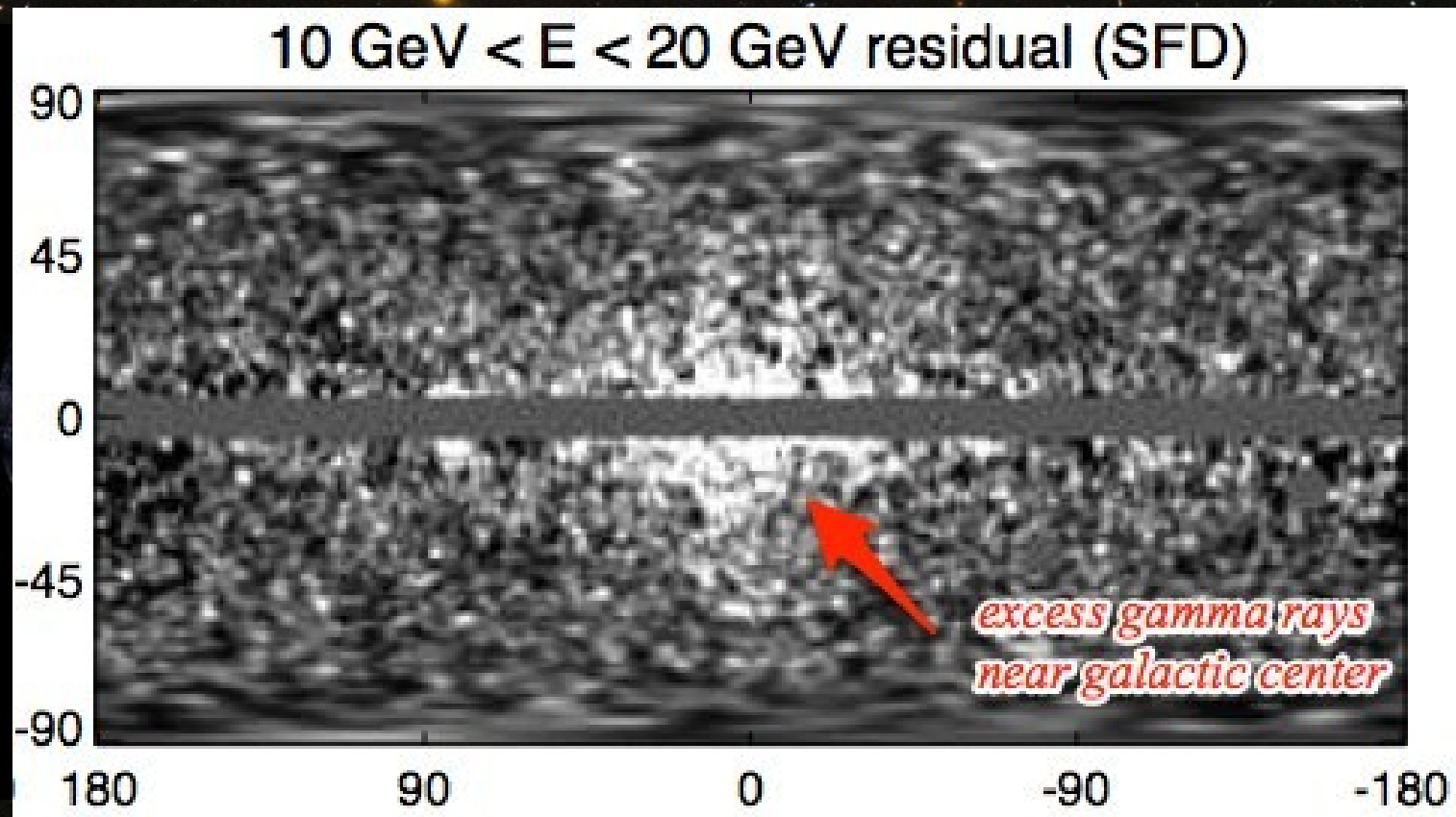


Fermi

Gamma-ray Space Telescope



Launched in June 2008



What it is not:

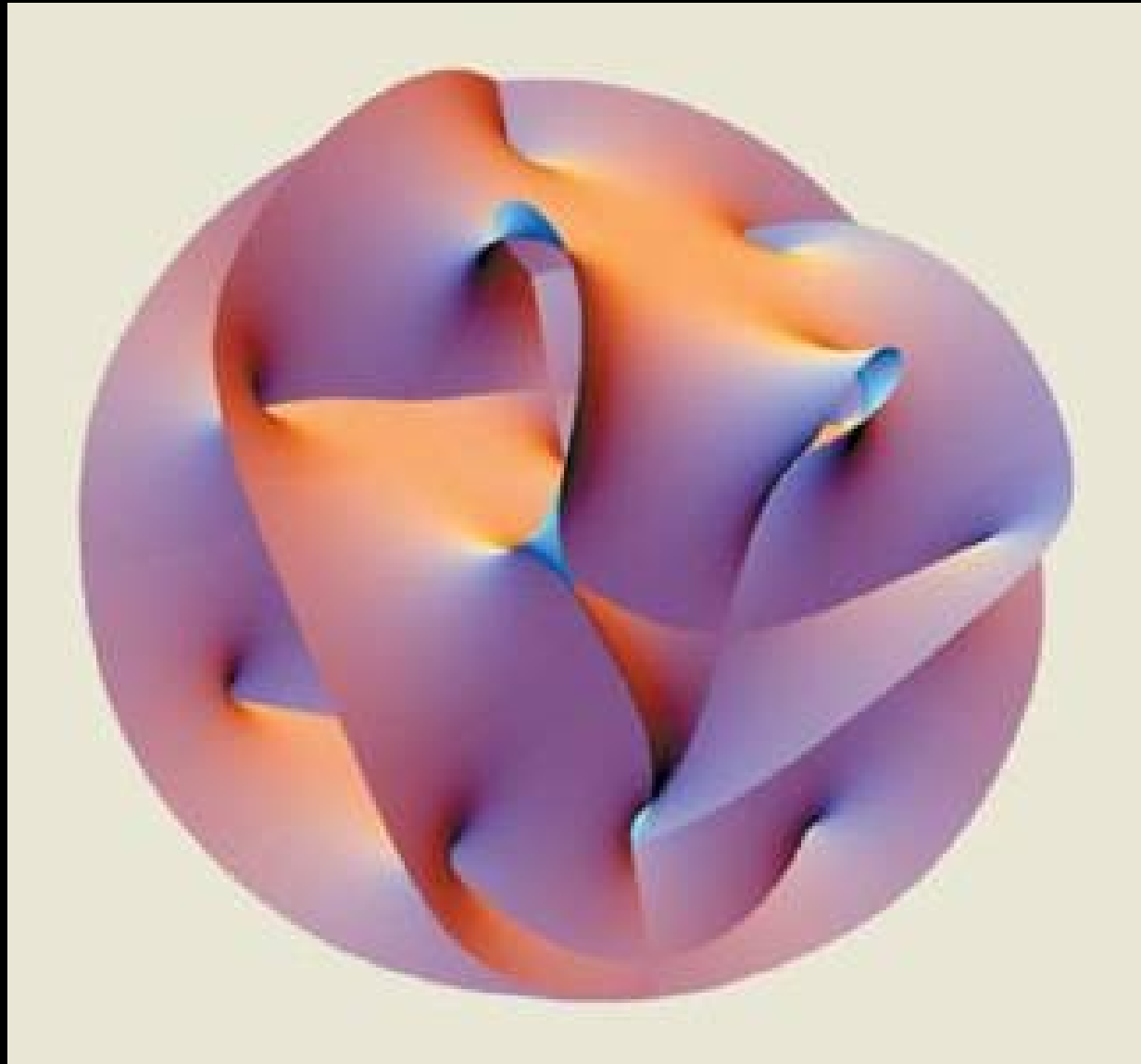
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- modified gravity

Space-time could be wrapped at small scale with many more dimensions than 4!



What is DARK ENERGY?





Dark Energy is a complete mystery but we know that:

- it has negative pressure
(equation of state is completely unlike anything else)

- it is small but not zero
(theory predicts it is either zero or incredibly large)

>100 distinct candidates

SUMMARY

Many independent observations now confirm the existence of dark matter and dark energy

This is an embarrassing result that we don't understand 95% of the Universe!

Everything indicates that their physical nature is linked with Fundamental physics yet to be discovered

Research agencies across the world (e.g. DoE in the US) are designing new generation of detectors capable of probing the physics of DM and DE

The fact the DM and DE have been detected does not necessarily mean they are real (e.g. epicycles?)