

# Victoria University of Wellington

*Te Whare Wānanga o te Ūpoko o te Ika a Maui*



## Cosmology: Dark energy, dark matter, and all that...

Matt Visser

Sunday May 24 2009 — Te Papa

# Abstract:



Modern cosmology is an interesting mixture — some aspects of cosmology are now precision science; other aspects are much more uncertain.

I will discuss dark matter, dark energy, and the accelerating expansion of the universe.



# Basics:

Some parts of cosmology are rock solid:

- ▶ Yes, the universe really is expanding; and had been doing so for about 13,000,000,000 years...
- ▶ Yes, there is something odd about the motion of stars at the fringes of our own and other galaxies (most commonly attributed to **dark matter**).
- ▶ Yes, we really can perform one part in a million measurements on the CMB (cosmic microwave background), aka CBR (cosmic background radiation).

# Basics:

Some parts of the cosmological story are plausible, but we really would like more data...

- ▶ Belief in the accelerating universe (dark energy) depends critically on estimating distances out to the furthest supernovae to about 5% accuracy.  
(The historical record on distance estimates in cosmology is not particularly encouraging.)
- ▶ Retro-dictions back beyond cosmological nucleosynthesis tend to get a little “fuzzy” around the edges...

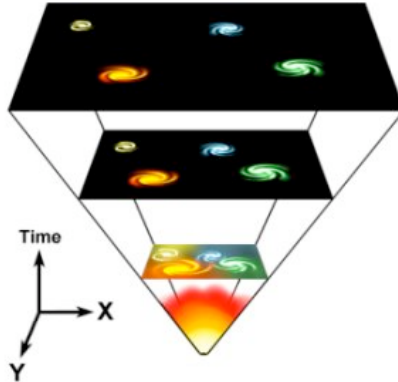


# Basics:

Some parts of the cosmological story are considerably more speculative..

- ▶ If you try to retro-dict too far back (cosmological inflation?), the retro-dictions tend to get extremely “fuzzy”, and not just at the edges.
- ▶ Landscape physics?  
(Consider the “fitness landscape” of all possible universes in the multi-verse...)
- ▶ Swampland physics?  
(Some physicists take an extremely dim view of the “landscape”.)

# The big picture: Expansion



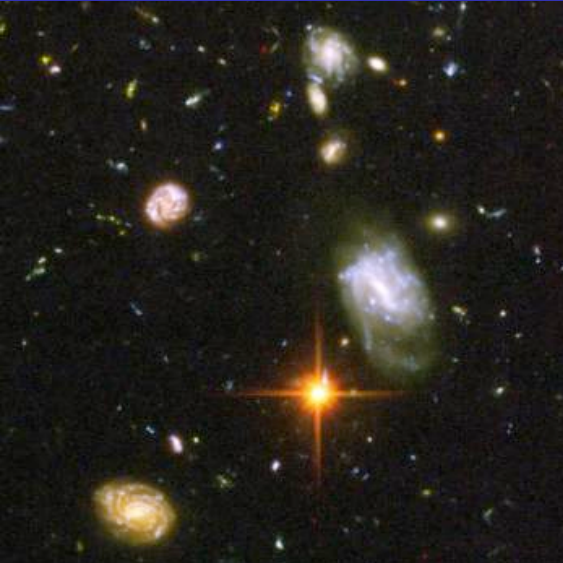
It is the distance between the galaxies that is expanding...

# The big picture: Expansion



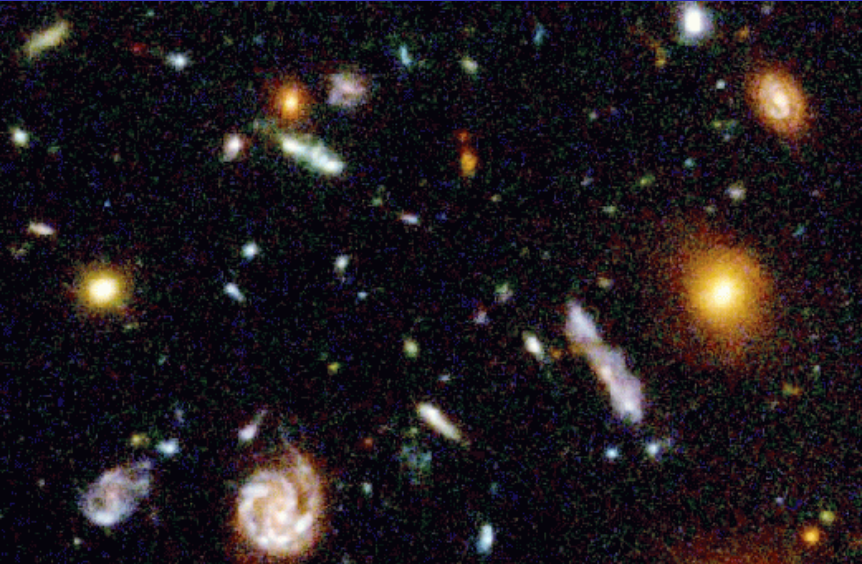
Hubble ultra-deep field

# The big picture: Expansion

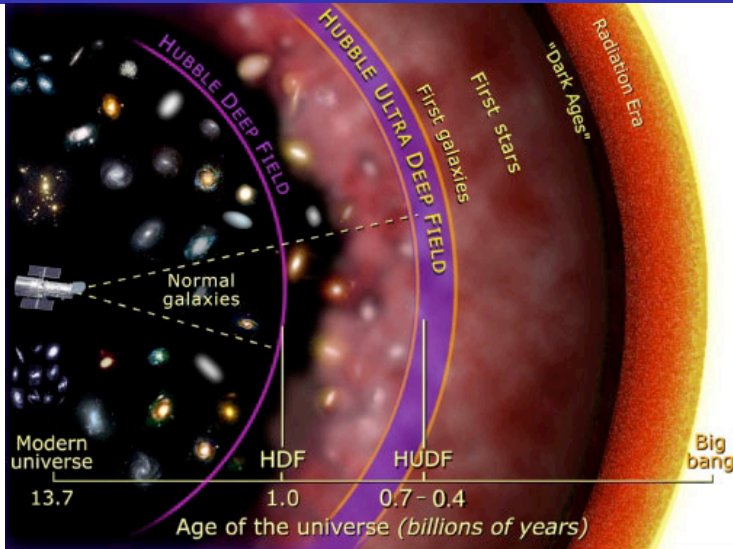


Small section of the  
Hubble ultra-deep field

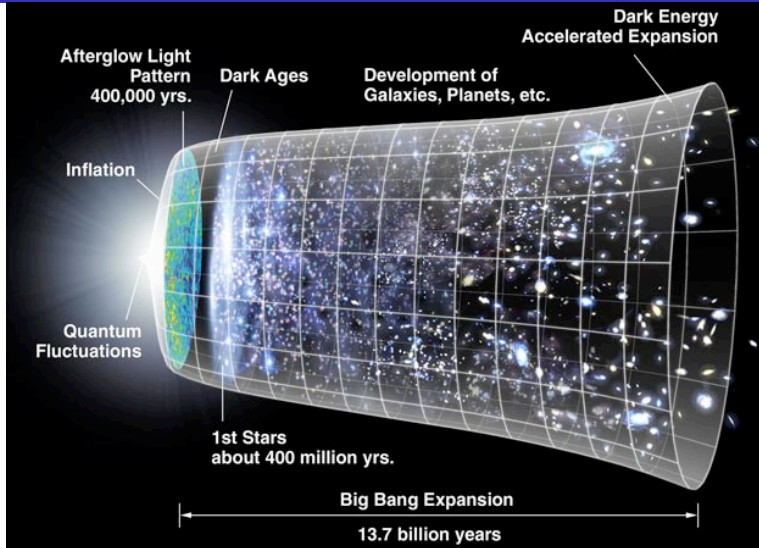
# The big picture: Expansion



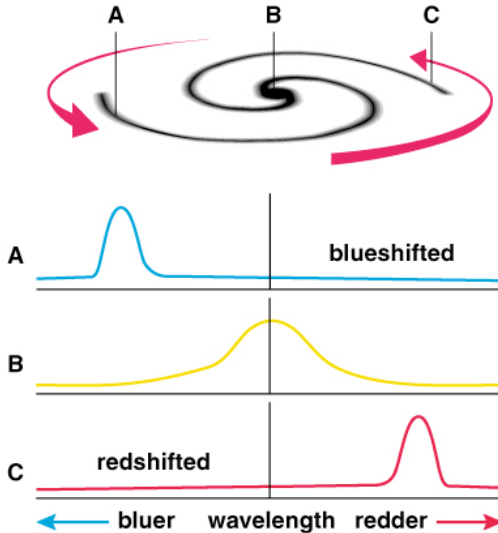
# The big picture: Expansion



# The big picture: Big bang

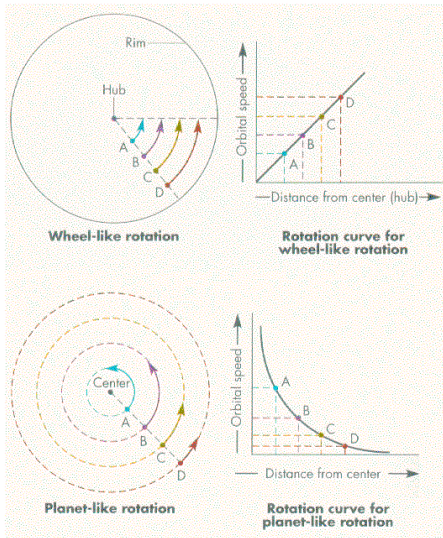


# The big picture: Galactic dynamics

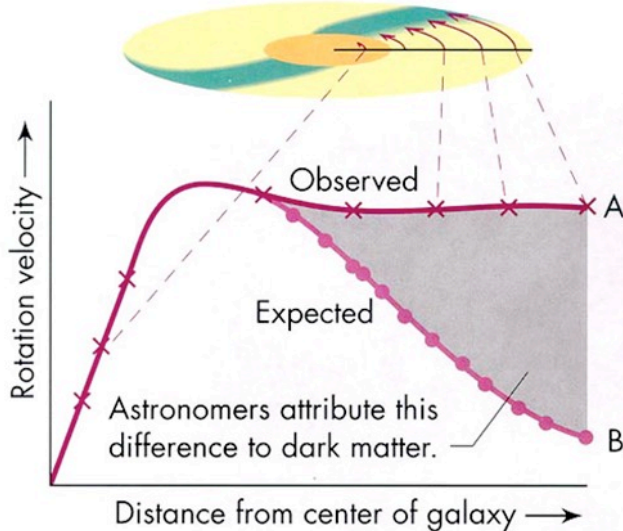




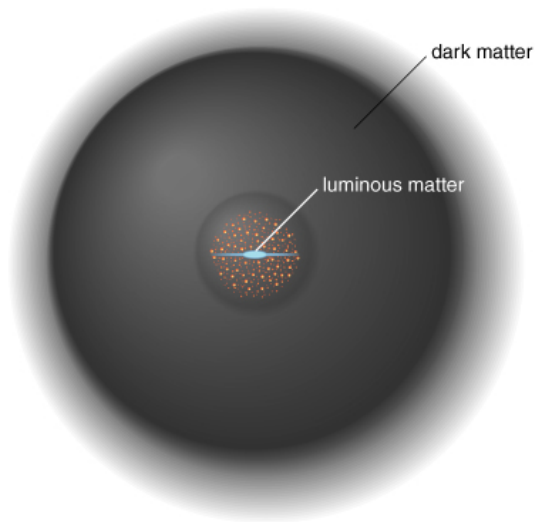
# The big picture: Galactic dynamics



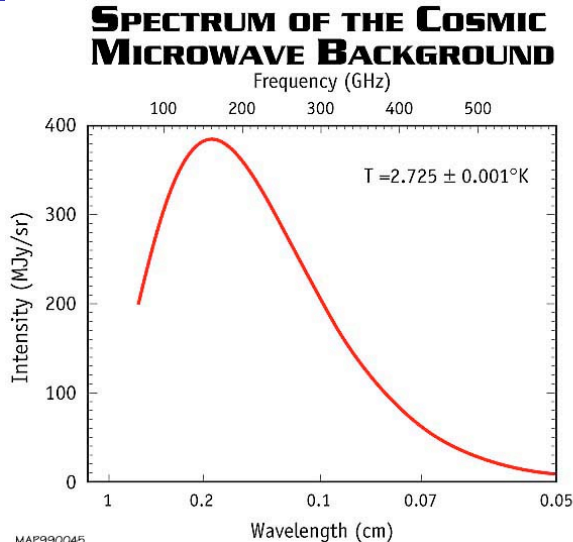
# The big picture: Galactic dynamics



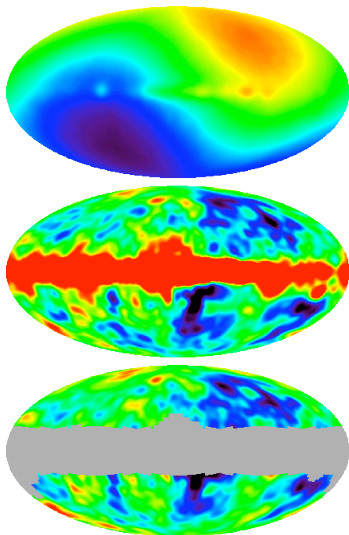
# The big picture: Galactic dynamics



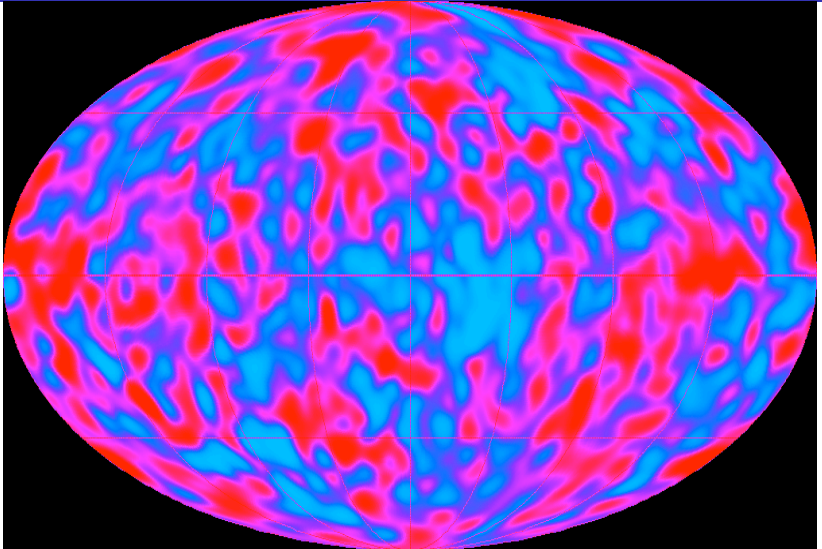
# The big picture: CMB/ CBR



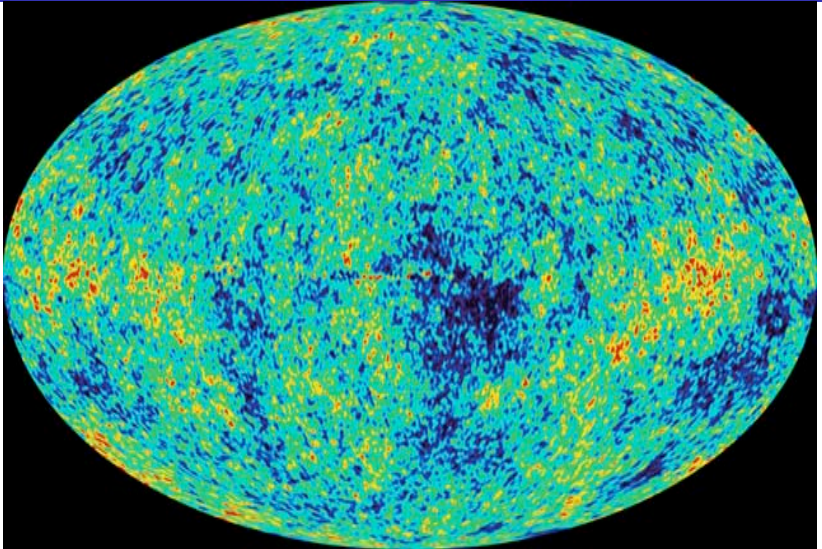
# The big picture: CMB/ CBR



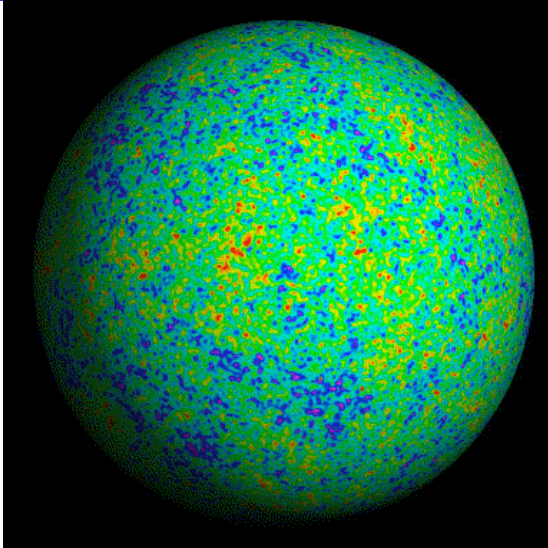
# The big picture: CMB/CBR (COBE)



# The big picture: CMB/ CBR (WMAP)

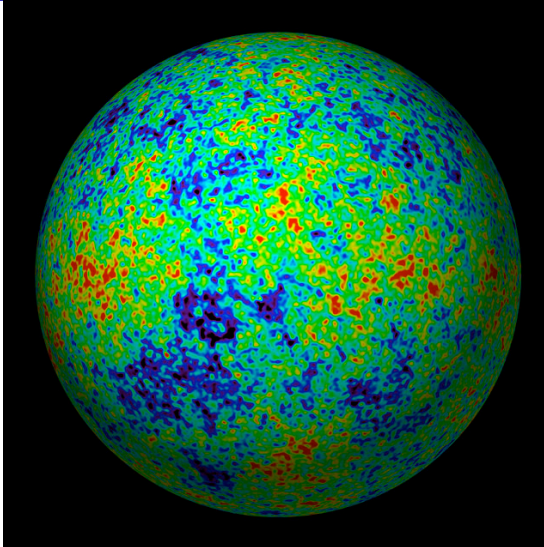


# The big picture: CMB/ CBR

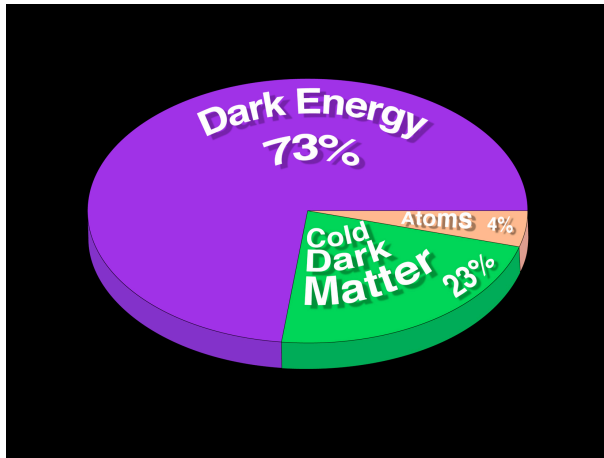




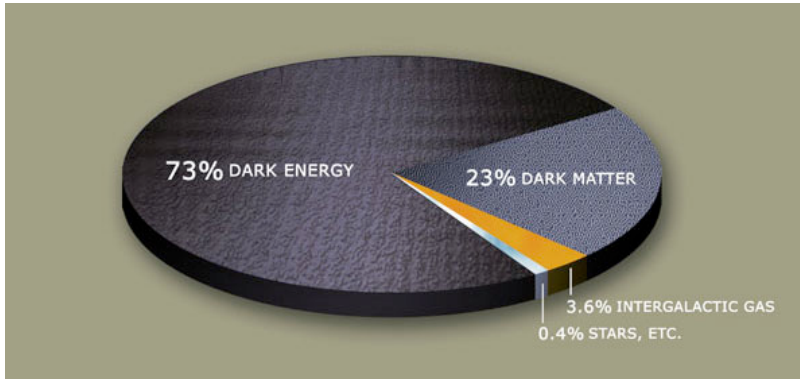
# The big picture: CMB/ CBR



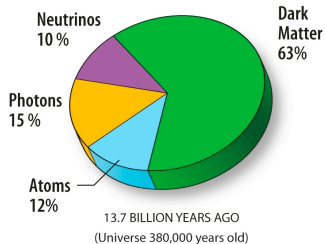
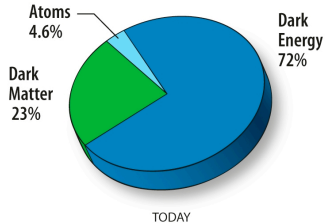
# The big picture: Mass–energy budget



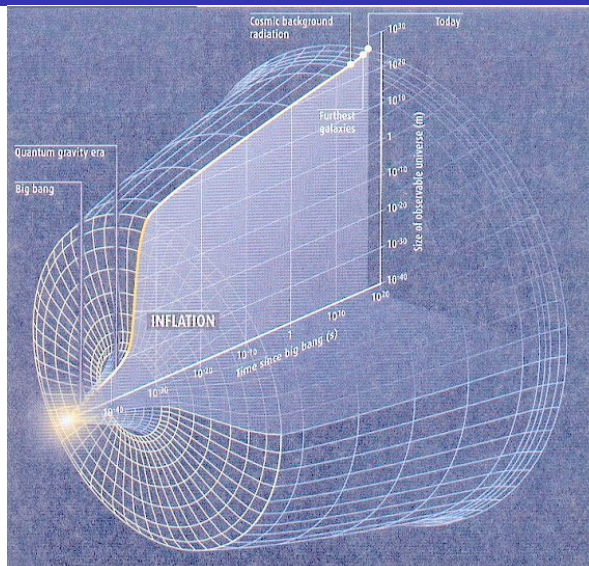
# The big picture: Mass–energy budget



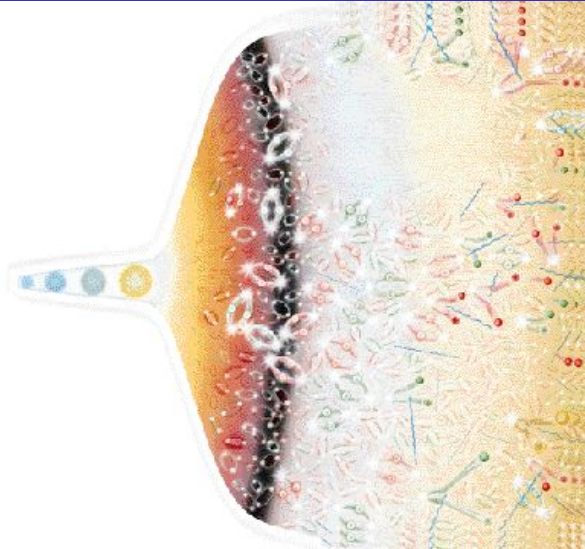
# The big picture: Mass–energy budget



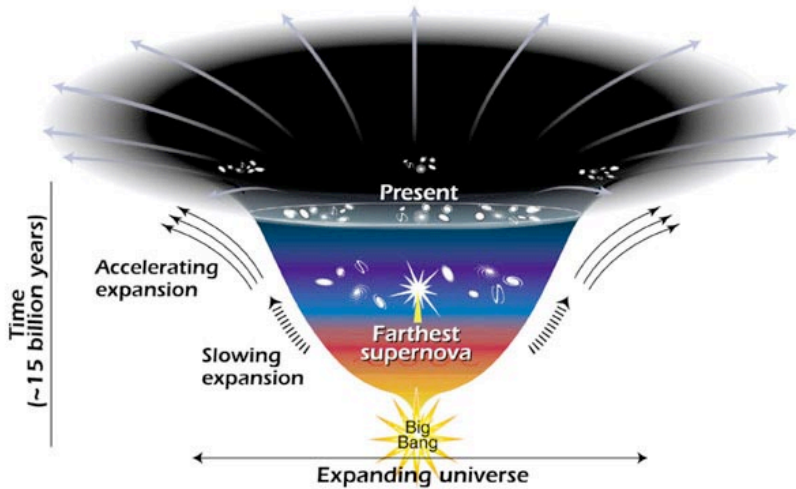
# The big picture: Cosmological inflation



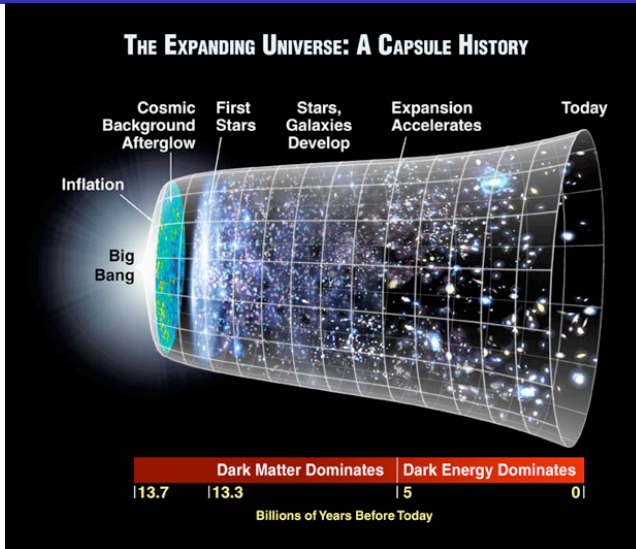
# The big picture: Cosmological inflation



# The big picture: Accelerating expansion

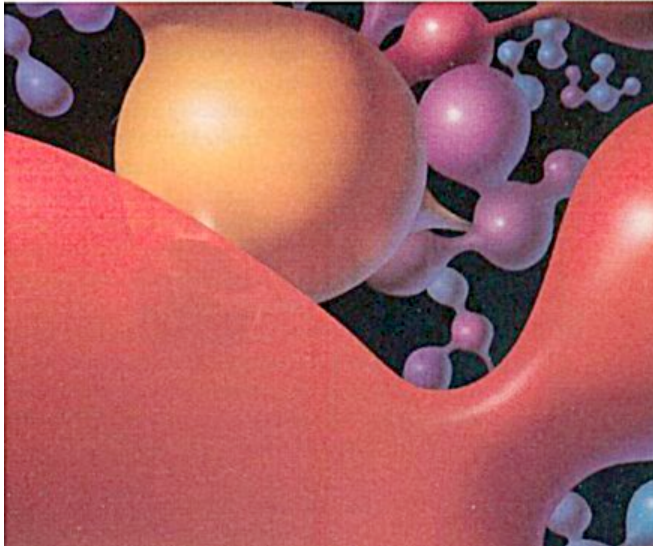


# The big picture: Accelerating expansion

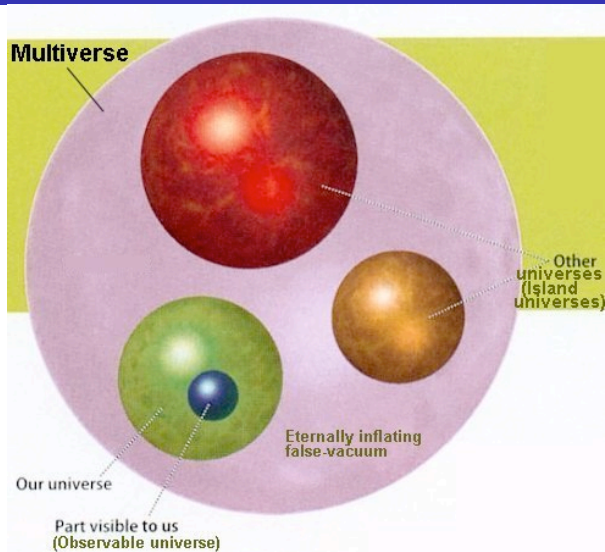




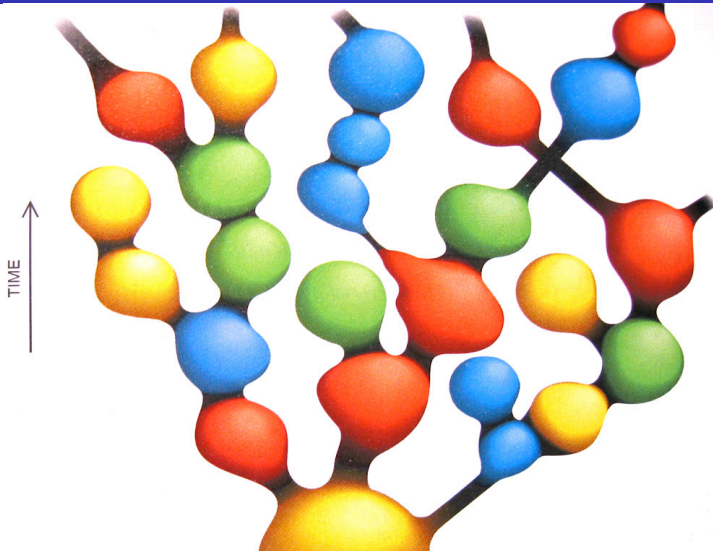
# The big picture: Multi-verse



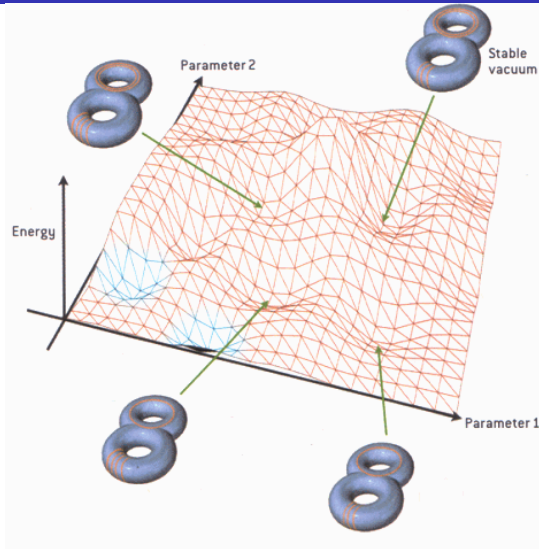
# The big picture: Multi-verse



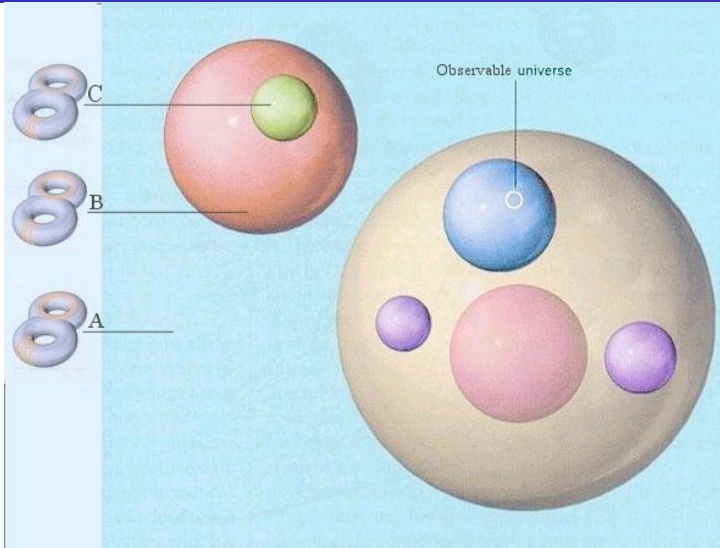
# The big picture: Multi-verse



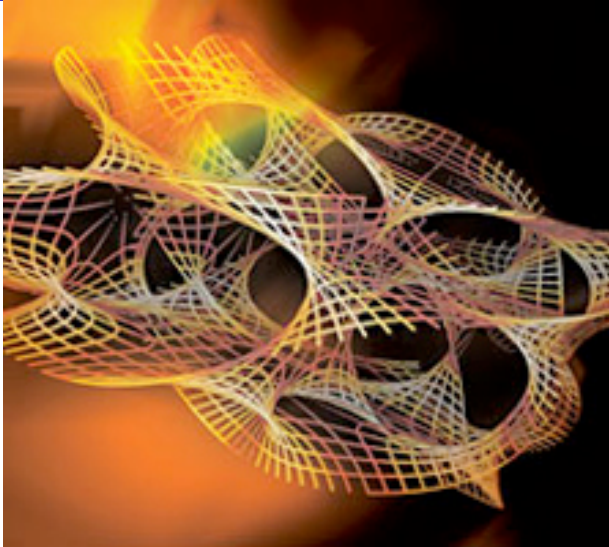
# The big picture: Fitness landscape



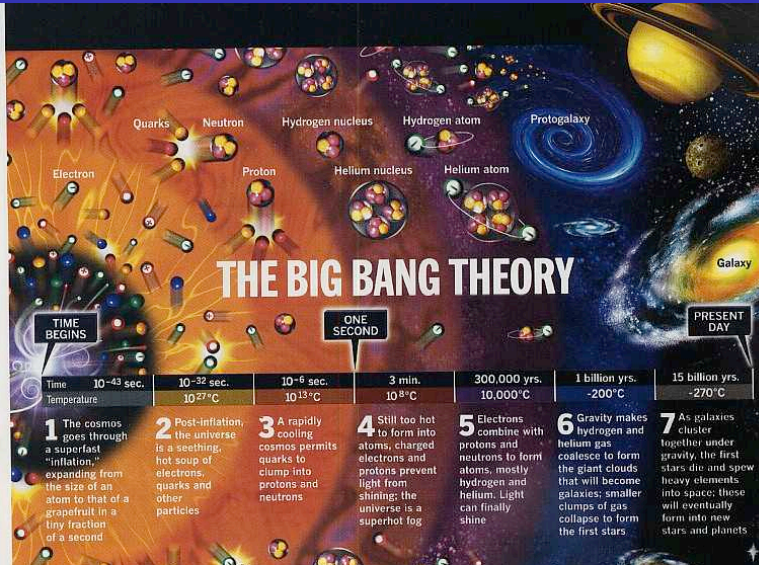
# The big picture: Fitness landscape



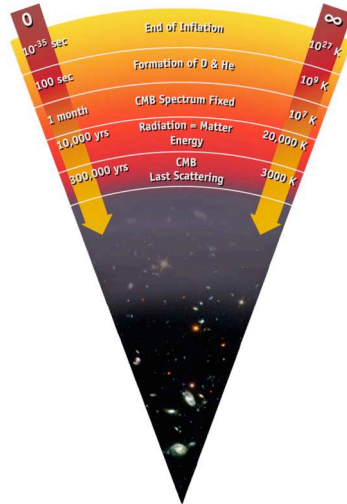
# The big picture: Fitness landscape



# The big picture: Overall history

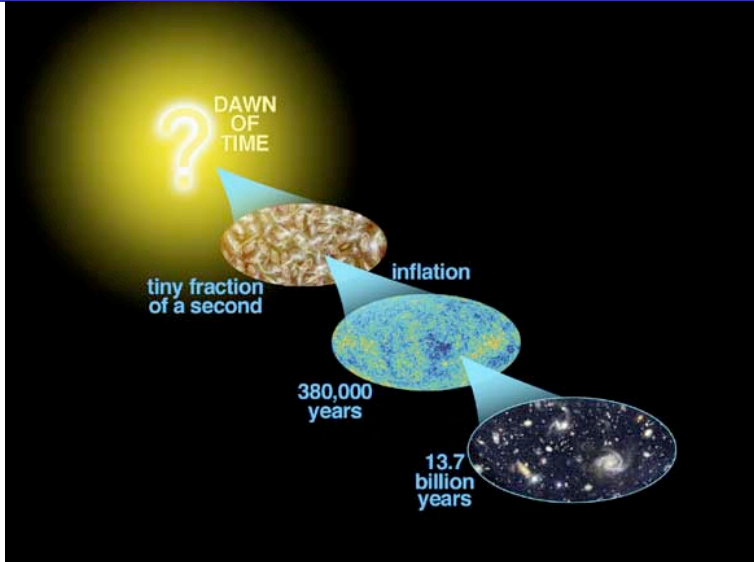


# The big picture: Overall history





# The big picture: Overall history



# Summary:

Some aspects of cosmology are now precision science;  
other aspects are much more uncertain.

The fact that anything to do with cosmology is now precision science is a reflection of the truly remarkable progress being made in this field.

Things really are improving in leaps and bounds.

