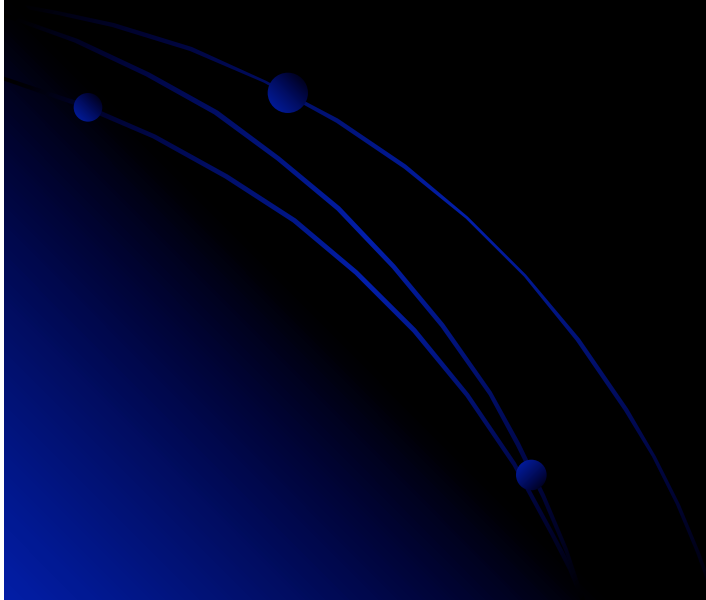


Dark Energy

Jeff Whitney

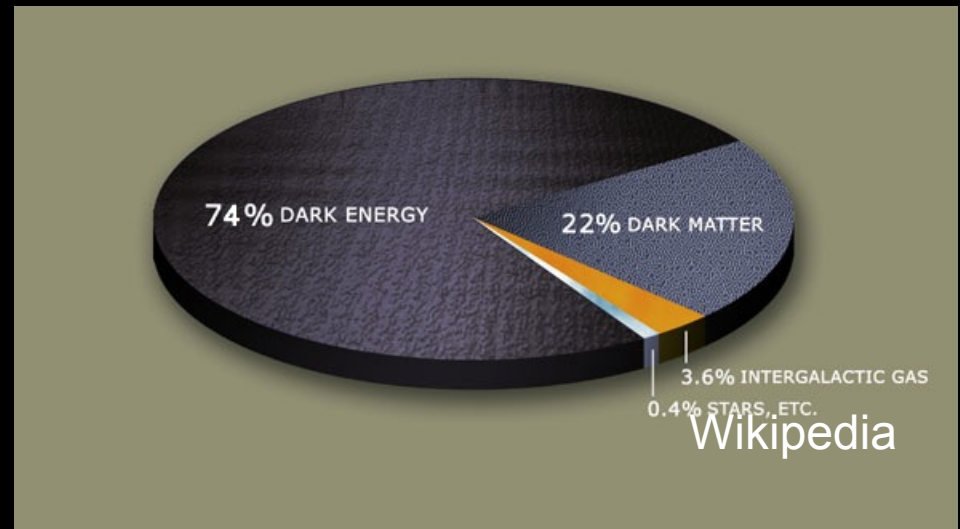


Outline

- What is Dark Energy?
- Evidence
 - Supernova
 - CMB
- Theories
 - Cosmological Constant
 - Quintessence
 - Other
- Finding Dark Energy

What is it?

- Homogeneous
- Cluster mass requires less than 30% necessary for a flat universe
- Accelerating Universe



Evidence

“Uncovering the evidence for dark energy is like finding an elephant on top of a table impeccably set with the finest china and silver – adding the napkin rings no longer seems so important.”

-Evalyn Gates, Einstein's Telescope

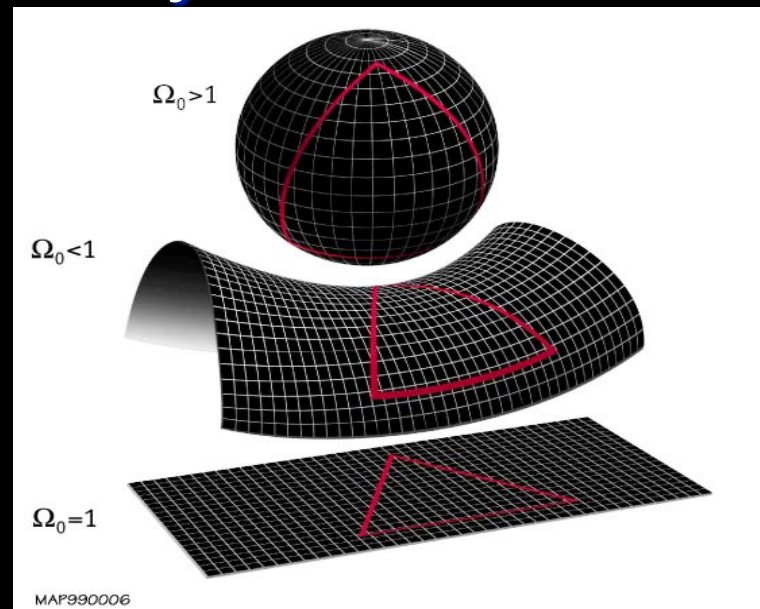


Supernovae

- 1998: Supernova Cosmology Project and High-z Supernova Search Team
- Redshifts determine the speed at which objects are moving away
- Hubble Space Telescope Key Project, 2001
 - Determined that the universe is expanding at 72 kilometers per second per megaparsec

Geometry

- Temperature deviations in the CMB.
- Waves caused by collapse of matter into overdensities.
- Ripples created and limited by distance that the waves could travel.



Theories of Dark Energy

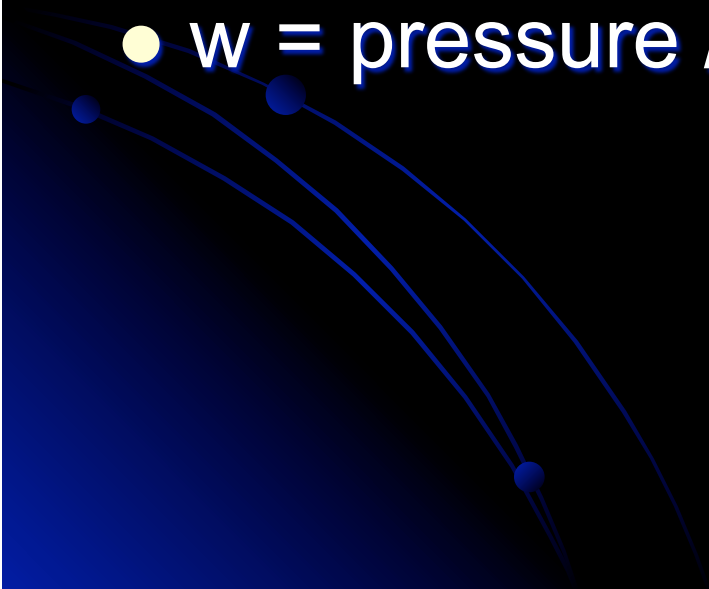
- Cosmological Constant
- Quintessence
- Other

Negative Pressure

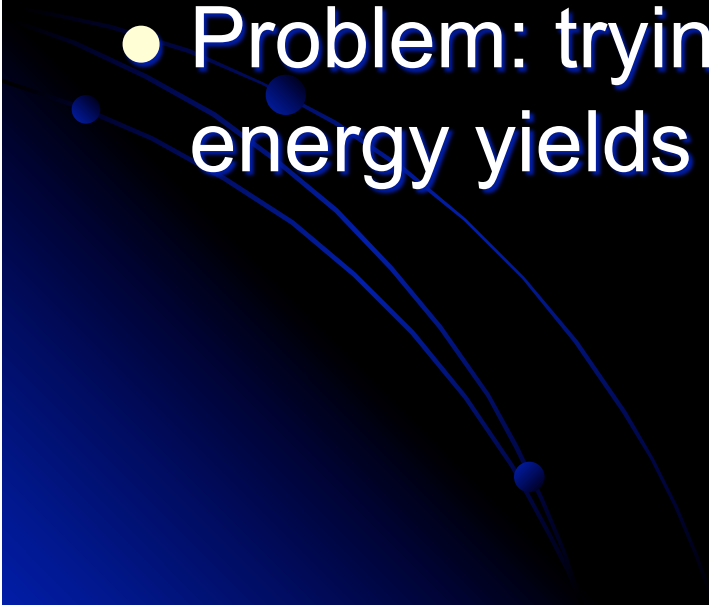
- Normal matter has pressure = 0
- Gas and radiation have pressure > 0
- Dark Energy has pressure < 0 , counters gravity
- $w = \text{pressure} / \text{density}$

Negative Pressure

- Normal matter has pressure = 0
- Gas and radiation have pressure > 0
- Dark Energy has pressure < 0 , counters gravity
- $w = \text{pressure} / \text{density}$

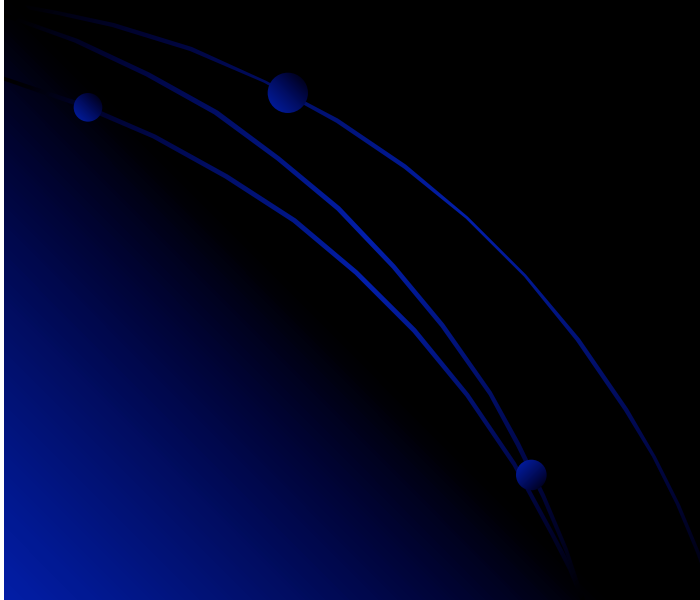


Cosmological Constant

- Constant vacuum energy
 - $w = -1$
 - Constant versus the density of the Universe over time
 - Problem: trying to calculate the vacuum energy yields infinity
- 

Quintessence

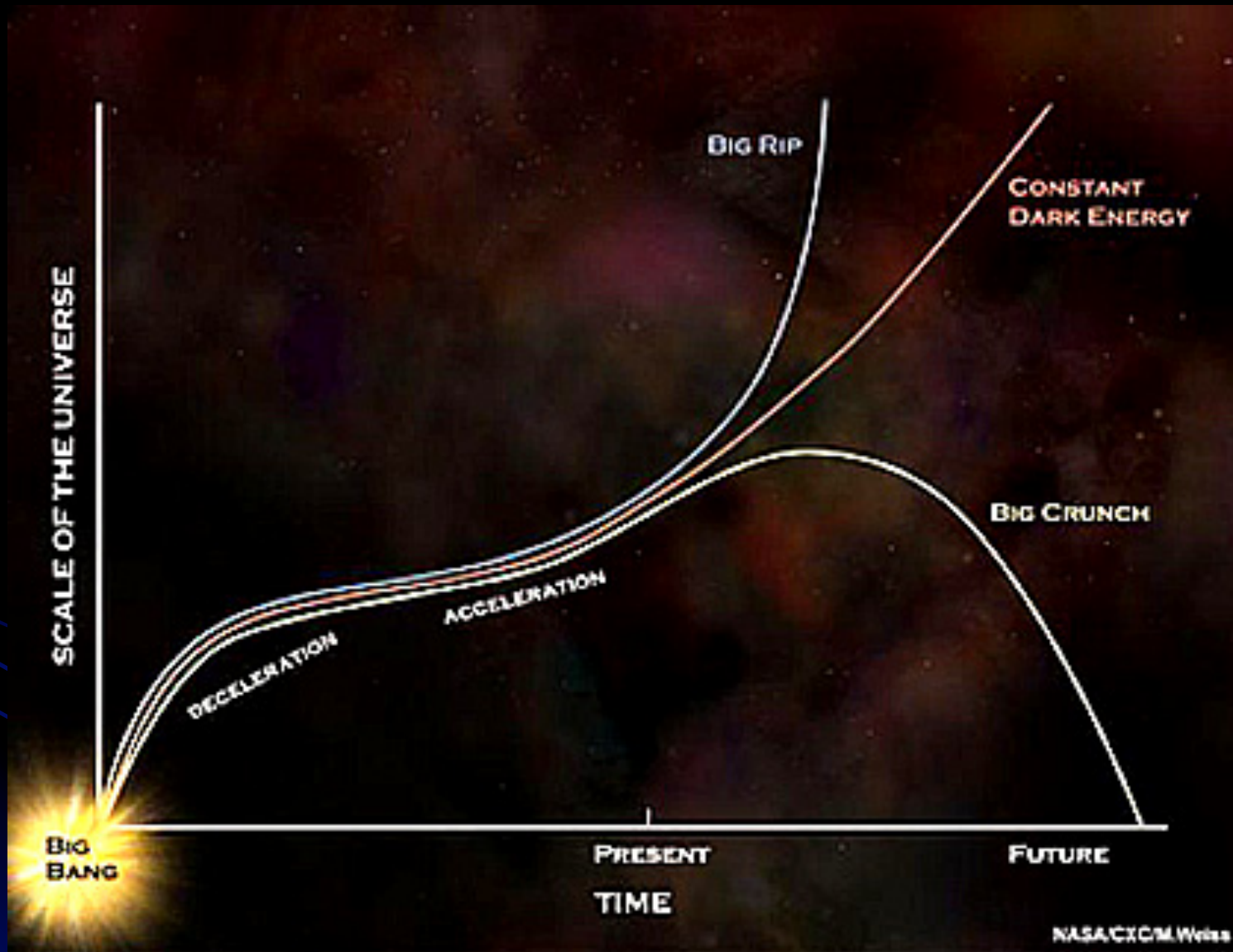
- $w = -1/3$ to -1 and is time dependent
- Energy field that is moving toward its lowest state, w will become less negative
- More consistent with evolution of universe



Other

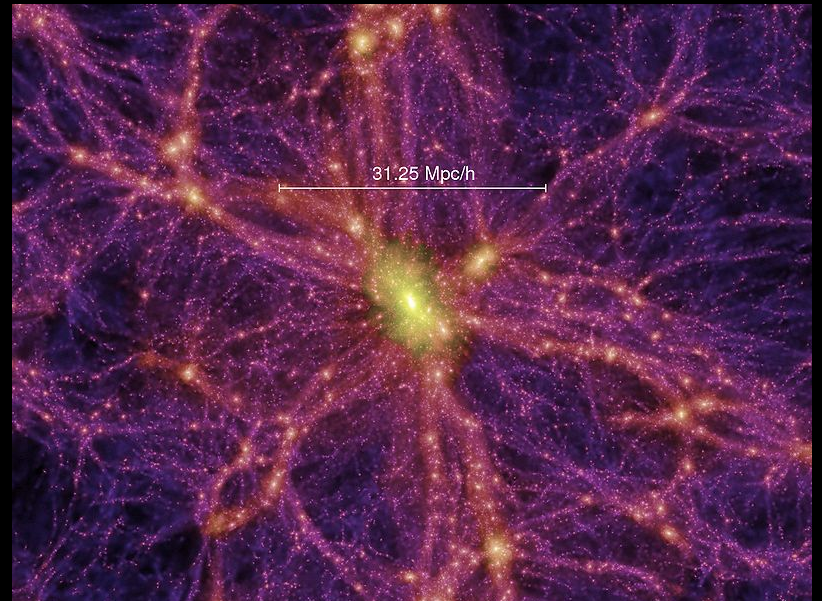
- Combination of Cosmological Constant and Quintessence
 - Negative vacuum energy – Big Crunch
 - $w < 1$, energy density will increase over time
 - Big Rip





Millennium Run

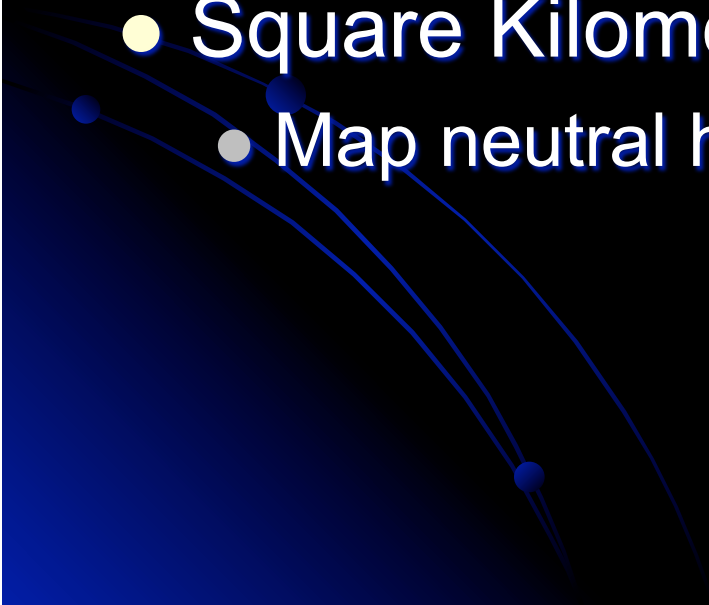
- Virgo Consortium 2005
- Computer Simulation that studied the evolution of the universe
- Kept track of 10 billion bits of dark matter that represented 1.2 solar masses each.



Dark Energy Task Force

- Department of Energy, National Aeronautics and Space Administration, and National Science Foundation, 2005
 - Searching for distant supernovae
 - Mapping the distribution of galaxies
 - Surveying Clusters
 - **Gravitational Lensing**

Future Experiments

- Large Synoptic Survey Telescope (LSST)
 - Google the Universe
 - Joint Dark Energy Mission (JDEM)
 - Measure weak lensing from space
 - Square Kilometer Array (SKM)
 - Map neutral hydrogen in the universe
- 

Thank You

