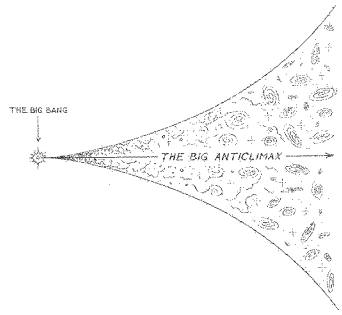
Friday, December 3

The Future of the Universe



Final exam: Tuesday, Dec. 7, 1:30 pm

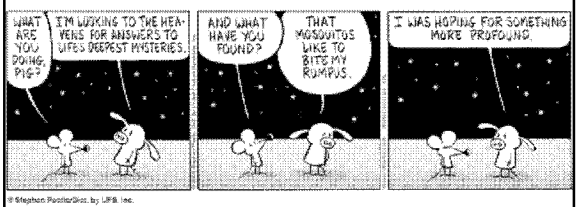
The Future of the Universe
Key Concepts

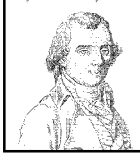
1) We live in an expanding universe that began in a hot dense initial state ("Big Bang").

2) Evidence indicates that the expansion of the universe is speeding up.

3) The universe will end "not with a bang but with a whimper."

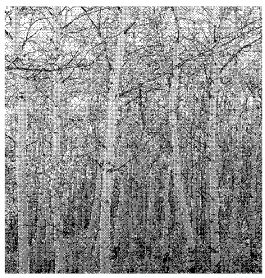
1st observation of modern cosmology:
The night sky is dark.





(This is known as "Olbers' Paradox".)

Why is the darkness of the night sky paradoxical?



In a large enough **universe** every line of sight ends at a **star** .

Implication: The universe can't be static, infinitely large, and infinitely old.

If it were, every line of sight would end at a star's surface, and the sky would be uniformly bright.

2nd observation of modern cosmology: Galaxies have a redshift proportional to distance.

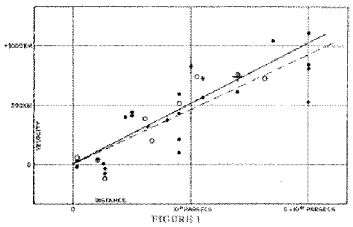
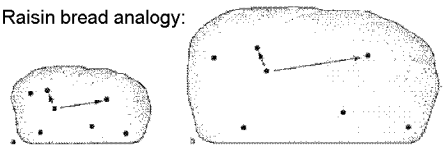


FIGURE 1
Velocity-Distance Relation among Extra-Galactic Nebulae.

(This is known as "Hubble's Law".)

Implication: Galaxies are moving away from each other as space expands.

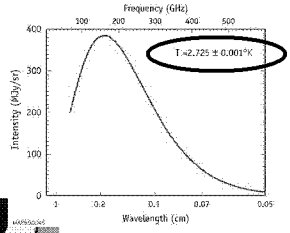
Raisin bread analogy:

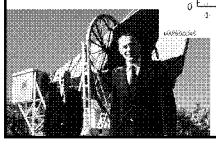


Bread dough = expanding space

Raisins = non-expanding galaxies

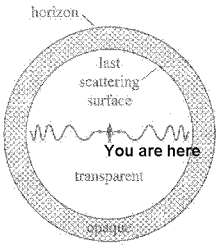
3rd observation of modern cosmology: The universe is filled with a **Cosmic Microwave Background**.





Discovered by Wilson and Penzias, 1965

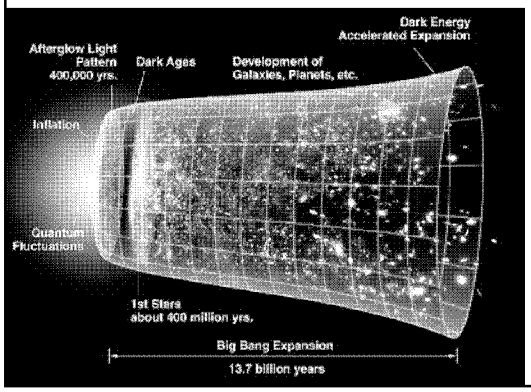
Implication: The entire universe was once hot, dense, and opaque – just like a star!



BIG BANG scenario:

- The universe began in an extremely hot, dense, opaque state a finite time ago (about 13.7 Gyr).
- As the universe expanded, it cooled and became transparent.
- Galaxies formed, containing stars, planets, and (in at least one case) life.

What lies ahead?



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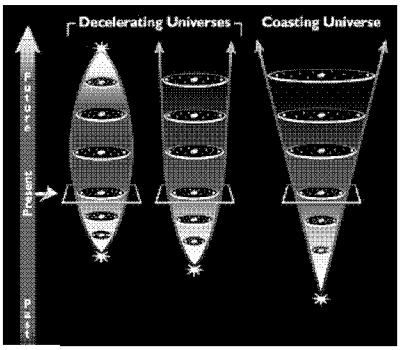
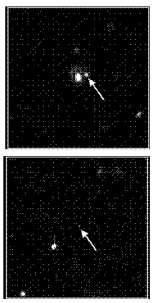
High-density universes will stop expanding, then collapse under their own gravity.



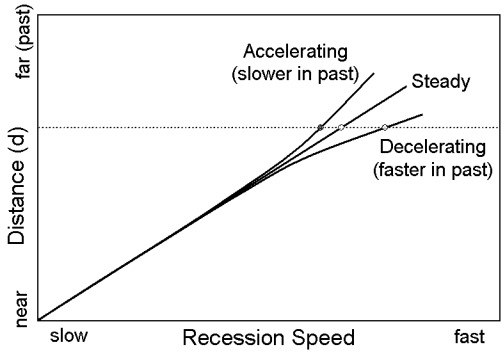
Supernovae are excellent “standard candles” for measuring immense cosmic distances.

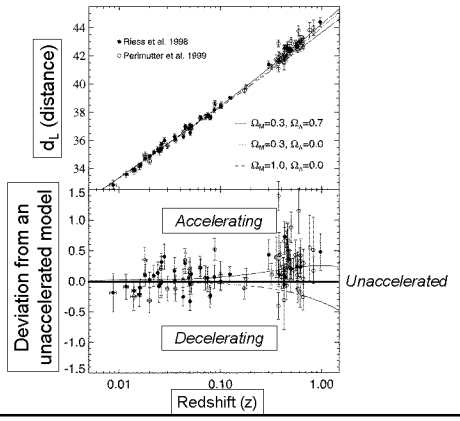
Supernovae are very luminous; we can see them billions of light-years away.

Some types of supernova have characteristic spectra that make them easy to identify.



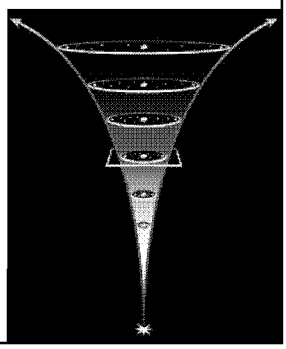
From the distance – redshift relation for supernovae, we can tell how the expansion speed has varied.





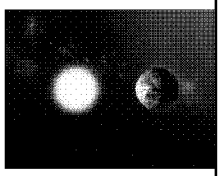
The supernova results show that we live in an **accelerating universe**.

The expansion rate increases with time; the universe cools at an increasing rate.



100 trillion years after the "Big Bang", the last of the nuclear fuel in our galaxy will be used up.

The last red dwarfs will burn out, and become steadily cooling white dwarfs.



"This is the way the world ends
This is the way the world ends
This is the way the world ends
Not with a bang but a whimper."

T.S. Eliot
The Hollow Men (1924)