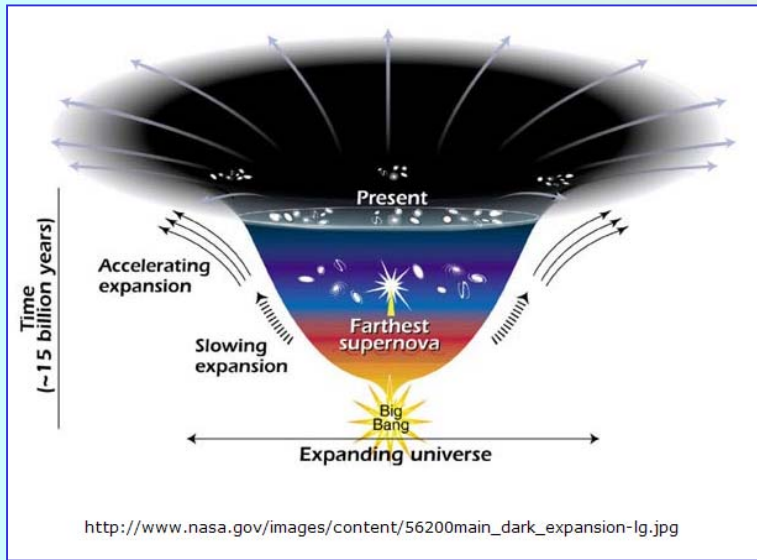


# The Big Bang



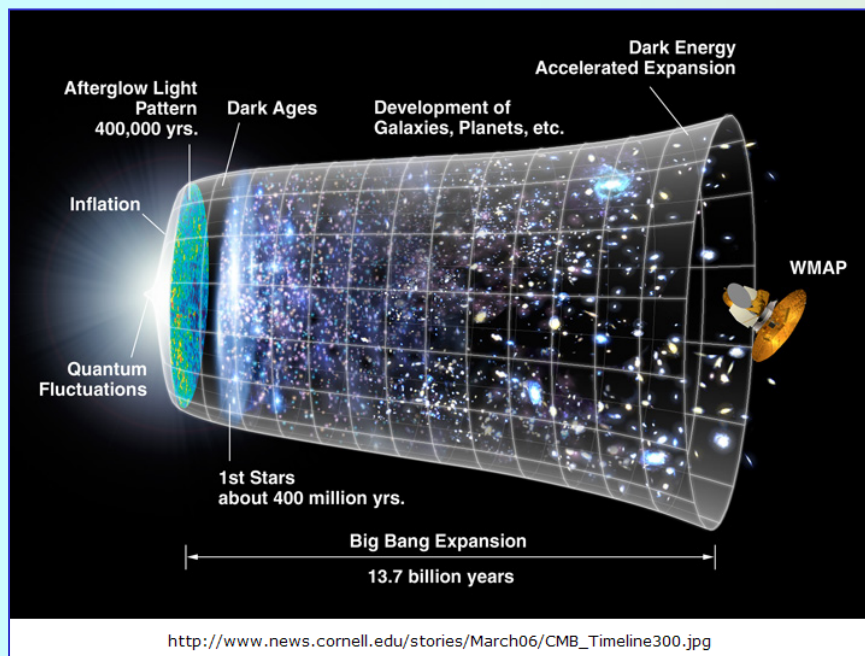
## The Universe is Expanding

Hubble's work showed that the Universe is expanding.

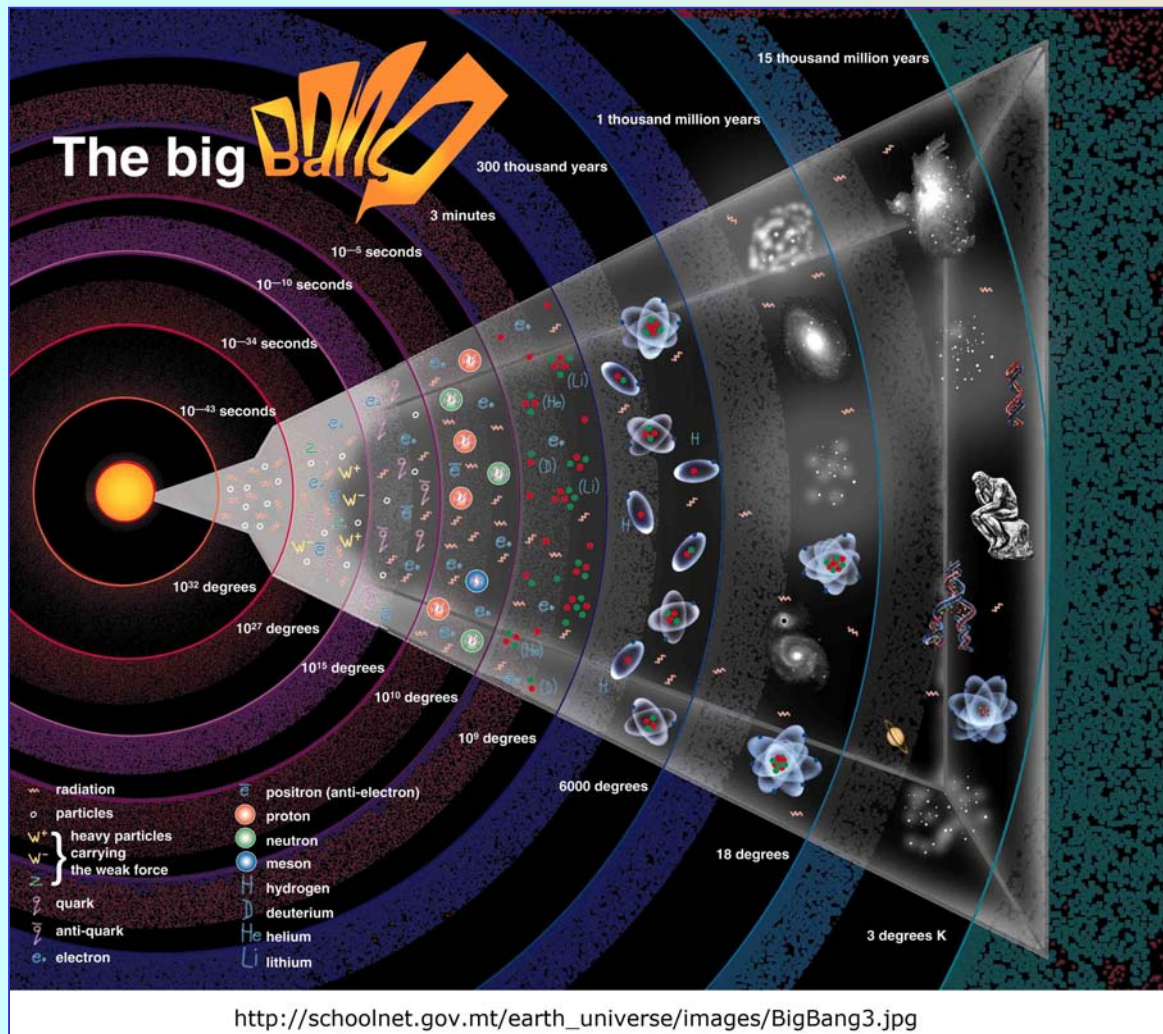
The further a galaxy was, the faster it was moving away from us.

This suggests that the universe began with a big bang.

This cannot be explained using by the normal physical laws: it seems to imply that new matter is being formed all the time as the universe expands



# The Big Bang



## The Theory

The Big Bang is the model of the universe that is best supported by all lines of scientific evidence and observation.

The essential idea is that the universe has expanded from a primordial hot and dense initial condition (singularity) at some finite time in the past and continues to expand to this day

It postulates that 12 to 14 billion years ago, the portion of the universe we can see today was only a few millimeters across.

It has since expanded from this hot dense state into the vast and much cooler cosmos we currently inhabit.

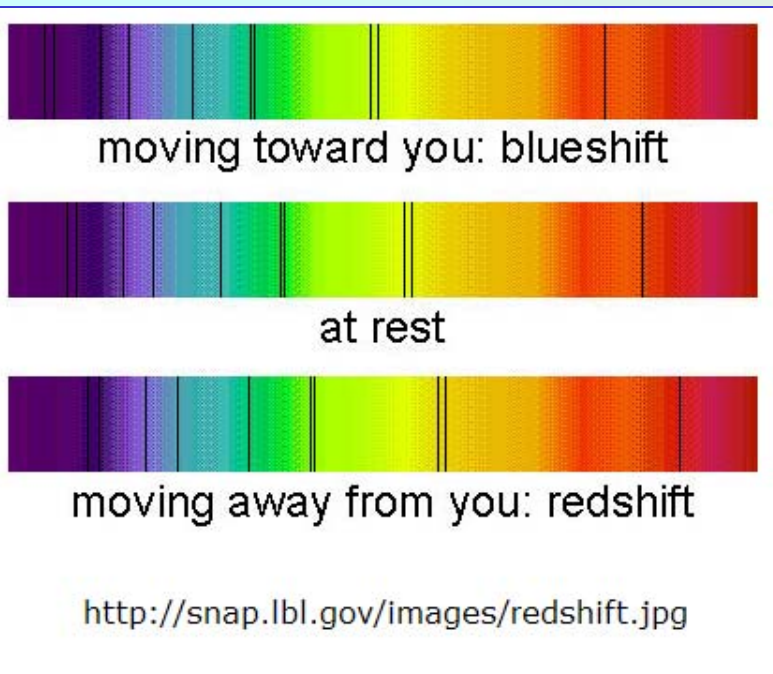
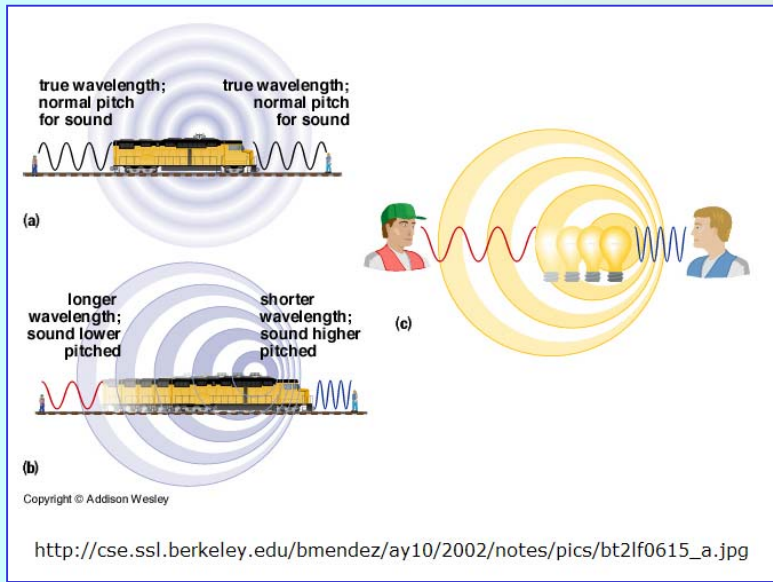
# The Big Bang

## The Doppler Effect. The Red Shift.

We can measure the velocity of an object by analyzing the apparent wavelengths of spectral lines from it.

Objects in motion compress the light waves in front of them making them appear more blue (blue shift), the light waves behind are stretched out and appear more red (red shift).

Amount of shift of wavelength is proportional to the component of velocity along the line of sight.

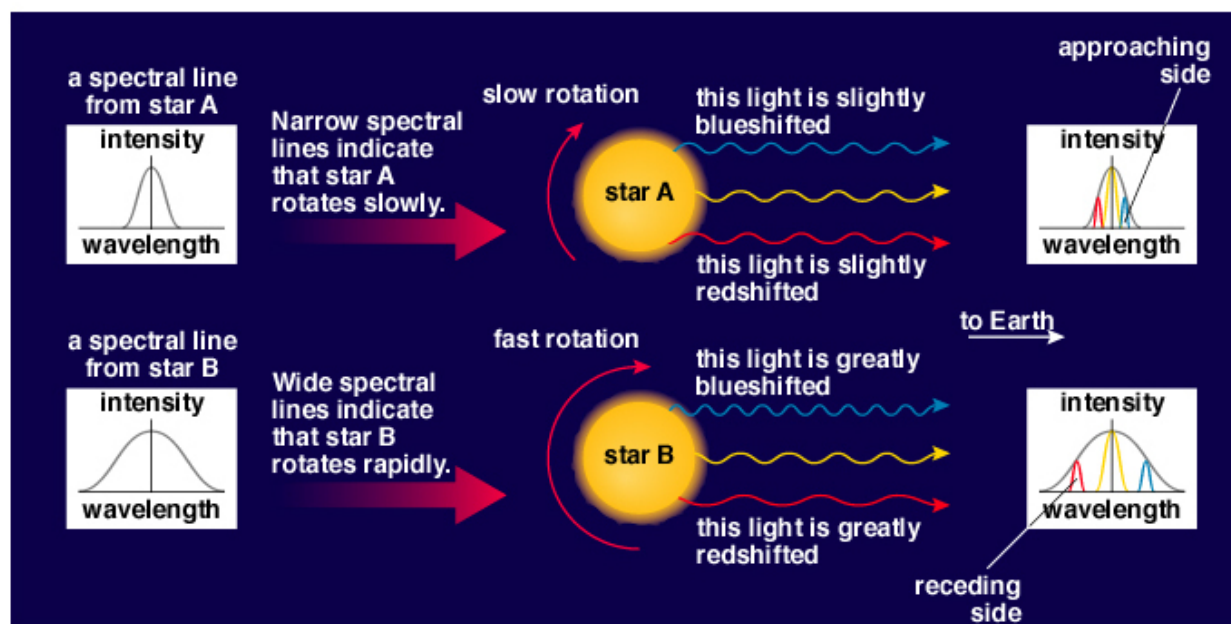


# The Big Bang

## The Doppler Effect. The Red Shift.

This effect (the shift caused by the Doppler Effect) is extremely important in astronomy. Using that data we can:

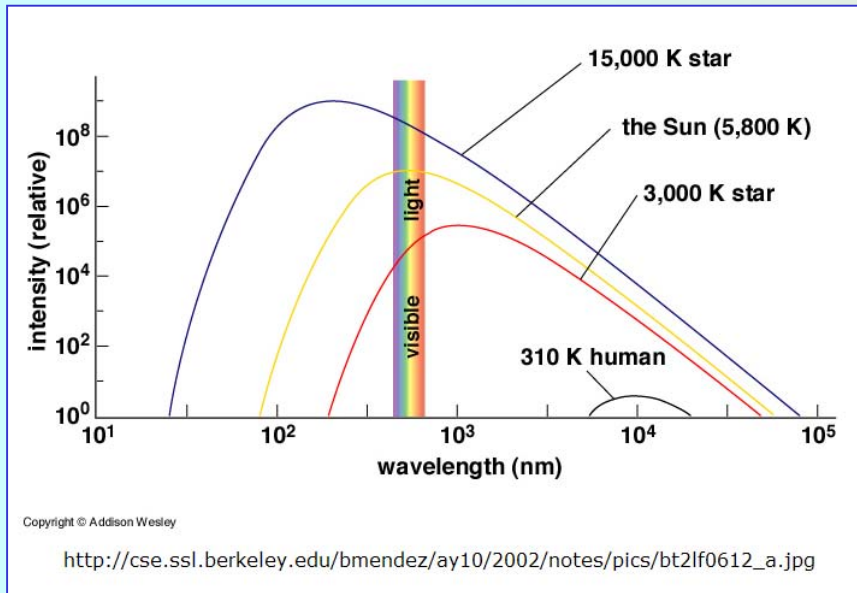
- measure the velocities of stars with respect to us
- measure their rotational velocities.



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[http://cse.ssl.berkeley.edu/bmendez/ay10/2002/notes/pics/bt2lf0617\\_a.jpg](http://cse.ssl.berkeley.edu/bmendez/ay10/2002/notes/pics/bt2lf0617_a.jpg)

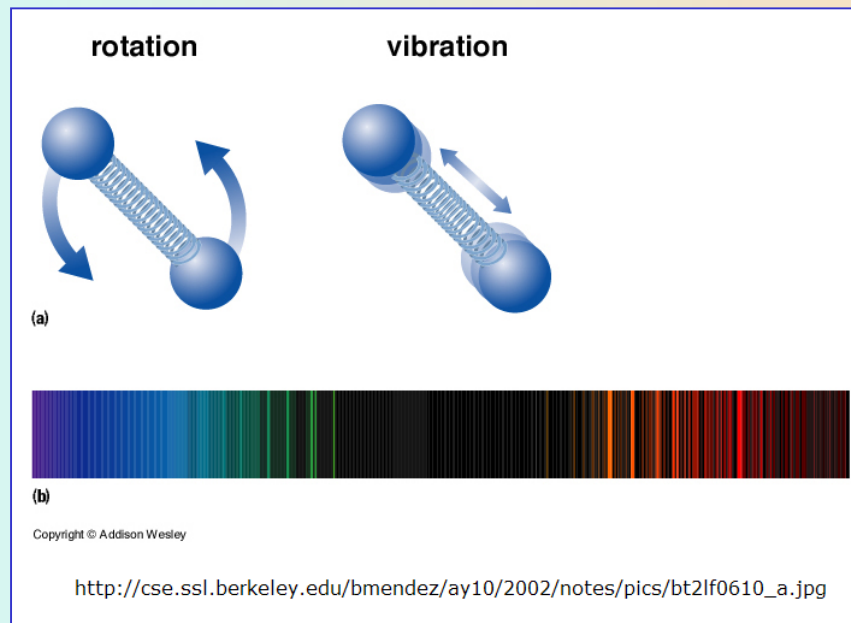
# The Big Bang



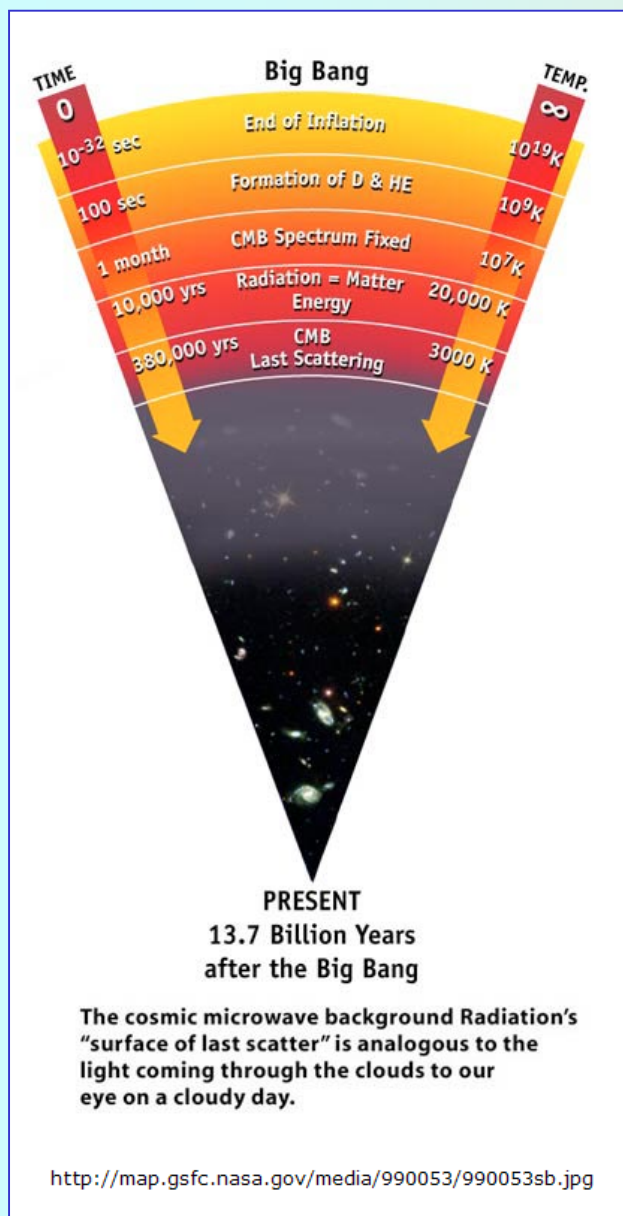
## What can we learn from light?

Breaking light from an object into a spectrum can tell you:

- The Chemical Composition
- The Temperature
- The Velocity along the line of sight



# The Big Bang

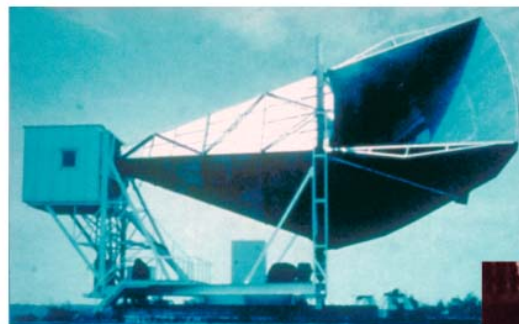


## Evidence Found: The Cosmic Background Radiation

In 1964, two radioastronomers (Robert Wilson and Arno Penzias) discovered that in the universe there was a background microwave radiation corresponding to a temperature of 3 K (-270 °C).

This was considered an evidence of the Big Bang.

### DISCOVERY OF COSMIC BACKGROUND



Microwave Receiver



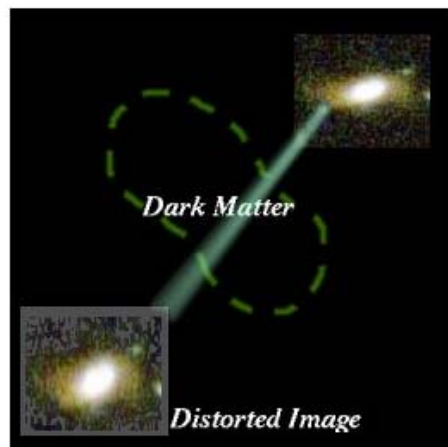
MAP990045

Robert Wilson



Arno Penzias

# The Big Bang



Exaggerated view of gravitational distortion from dark matter affecting the observed shape of a galaxy

<http://plus.maths.org/issue12/news/darkMatter/dark.jpg>

## Unresolved questions: dark matter

The Big Bang theory has left some questions unresolved.

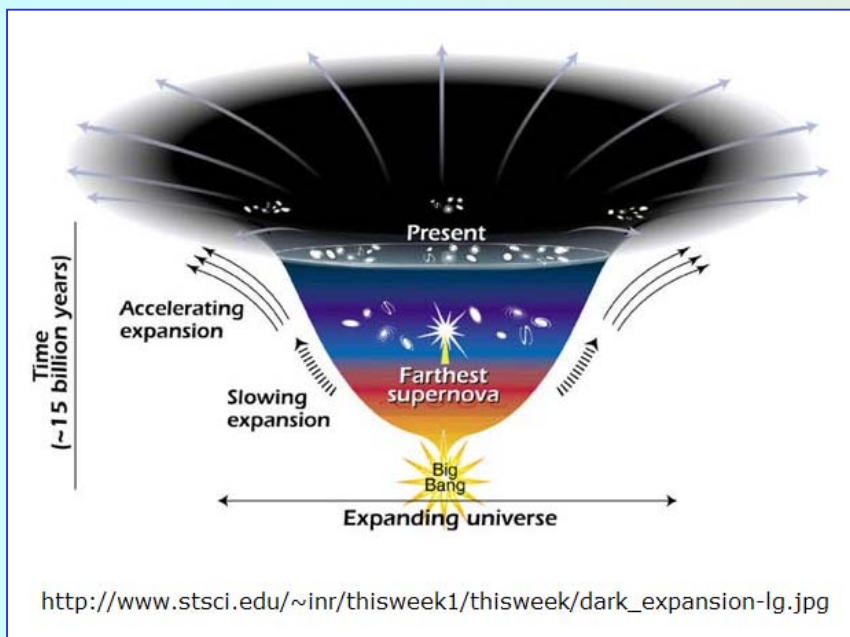
For instance, the motions of galaxies we observe seem to require more mass in the system than we can actually see.

If randomly arranged galaxies are all distorted in the same direction, the resulting bias can be detected



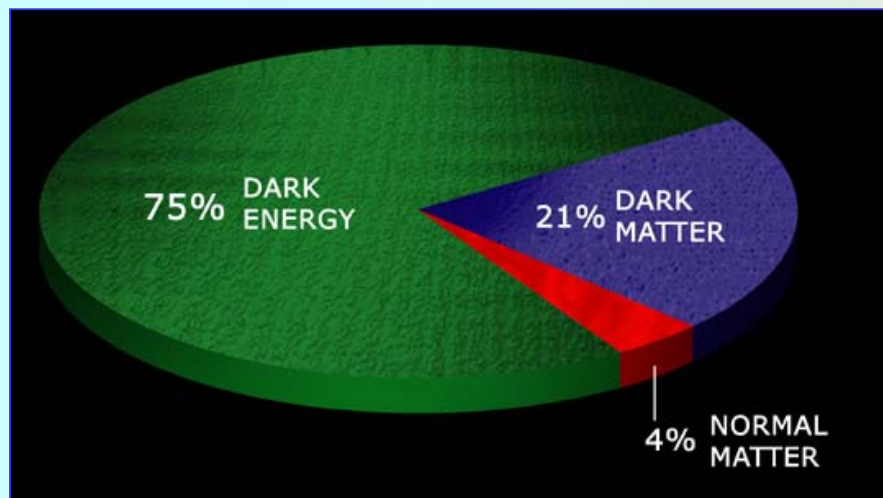
<http://plus.maths.org/issue12/news/darkMatter/snap2.jpg>

# The Big Bang

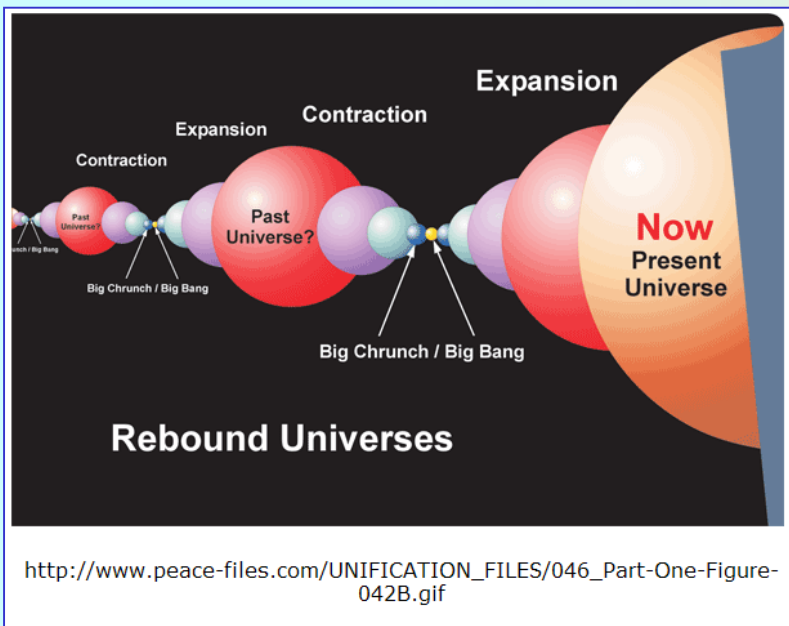


## Unresolved questions: dark energy

A "dark energy" has been postulated to explain the fact that our universe is expanding at increasing speed.



# The Big Bang



## The Top Problems of the Big Bang

The Big Bang theory is our current and widely accepted theory.

But that doesn't mean that there are no problems within that theory.

Here we have some objections to that theory:

- Is a singularity acceptable?
- Is the microwave background's proof strong enough to consider it as a proof of the big bang?
- How are heavy elements formed?