11/10/04

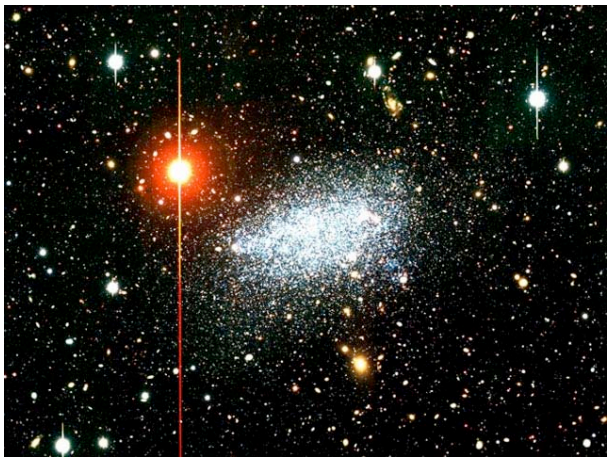
Wheeler away Wed, Fri next week. Film on Wednesday on worm holes and time machines (next topic, not on exam)

4th exam Friday, November 19. Review sheet probably by Monday. Chapters 10, 11.

Review session THURSDAY Nov 18, 5 - 6 PM RLM 15.216B

News? New York Times article on Type Ia supernovae

Pic of the day: Dwarf Irregular Galaxy



Age and Fate of the Universe

Age of Universe ~14 billion years

Fate of the Universe is intimately tied to the shape

Finite age, recollapse ("sphere," high density, high gravity)

Expand forever, $v > 0$ (Pringle, low density, low gravity)

Special Case: expand forever, $v \rightarrow 0$ as reach infinity (flat, very special density, gravity). Only in this case would initially parallel lines stay parallel

In principle, we can figure out the shape and fate of our Universe by doing 3-D geometry in our 3-D Universe

Dark Matter

Previously known surprising result:

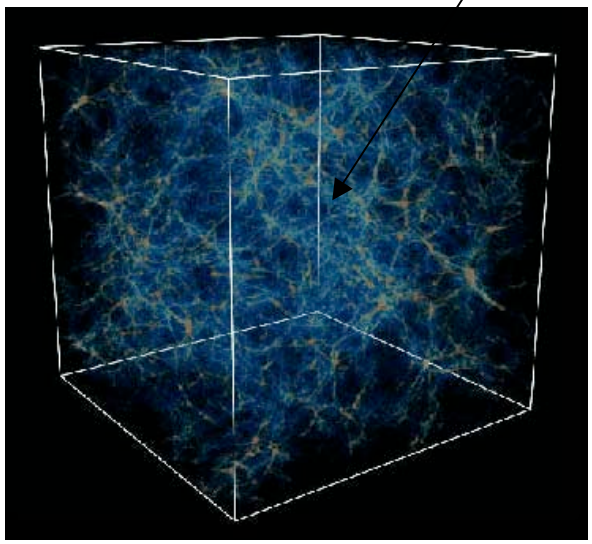
Most ***gravitating*** matter in the Universe is mysterious ***Dark Matter***

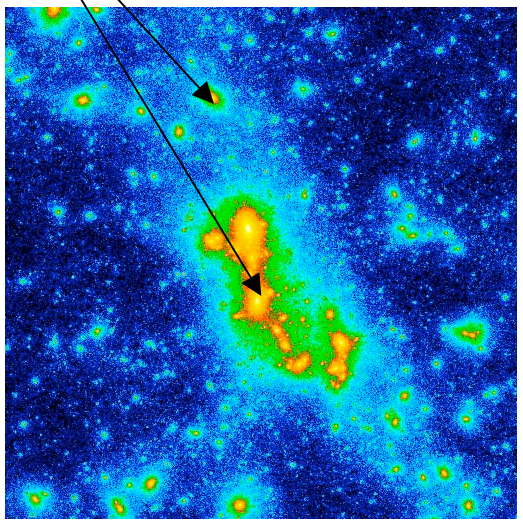
Not composed of p, n, e - the stuff of stars, galaxies, planets, and people

Dark Matter was ***never*** composed of that stuff (or would upset observed mix of hydrogen and helium from the Big Bang), so also not black holes once made from ordinary star stuff.

Some yet undiscovered particles that only interact by gravity and by the weak nuclear force, no electrical force, no strong nuclear force:***100 × more total mass than normal stuff stars, gas, etc.***

Dark Matter





Computer simulations show that from the tiniest wrinkles the Dark Matter agglomerates to form all the ***Large Scale Structure*** of the Universe

Ordinary matter, protons, electrons, settle to center of Dark Matter lumps to form galaxies and clusters of galaxies

Density of Dark Matter is not enough to close the Universe

$\Rightarrow$ Universe is "open?" (3D Pringle)

Nature recently threw us a curve ball

SN were the key!

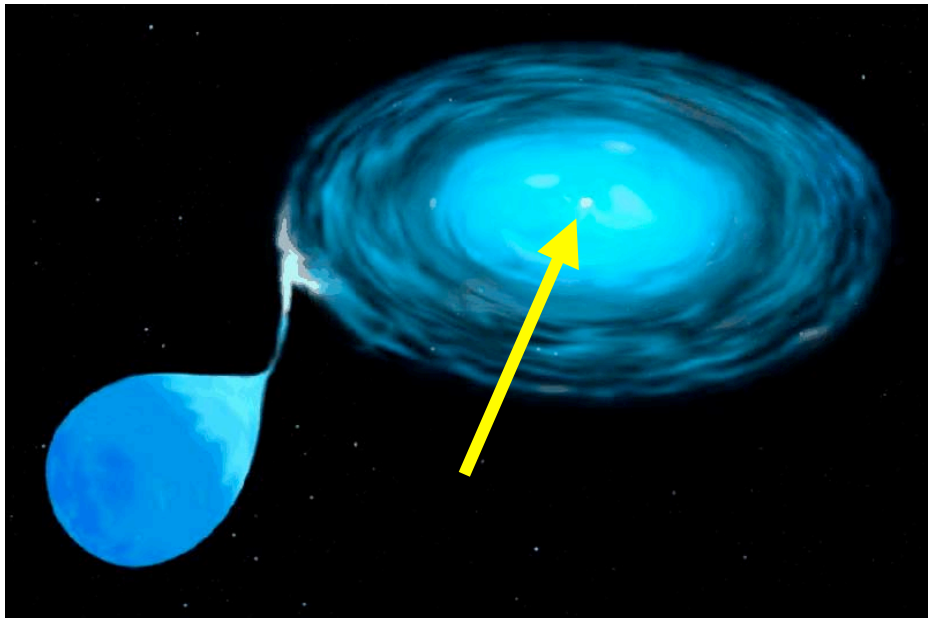
Use Type Ia supernovae (brightest, ~ uniform behavior)

Carefully map ***distances*** (dimmer appearance means further away), ***velocities*** (Doppler red shifts) in all directions

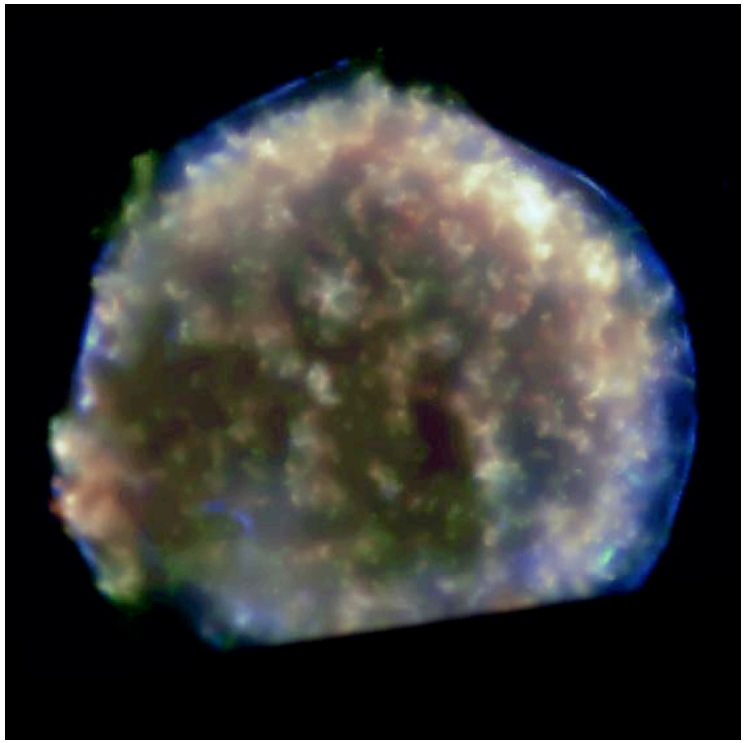
Do geometry - measure curvature - “sphere”, “Pringle”, “flat”
closed, open, flat

More subtle techniques than making parallel lines or drawing triangles, but still amounts to “doing 3D geometry.”

One type of supernovae (Type Ia) is thought to come from a white dwarf that grows to an explosive condition in a binary system.



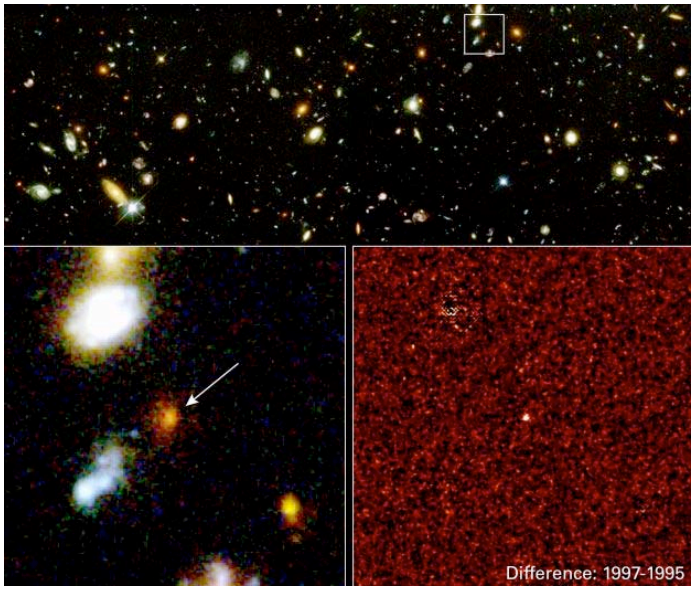
Chandra X-ray Observatory image
Of Tycho's supernova of 1572



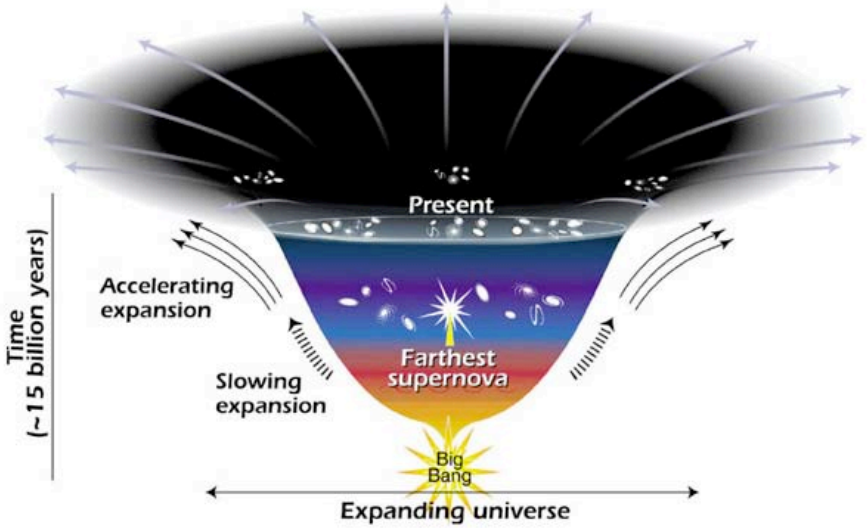
These explode completely, like a stick of dynamite, and leave no compact object (neutron star or black hole) behind.

This type of supernovae is generally the brightest and can be seen at cosmological distances.

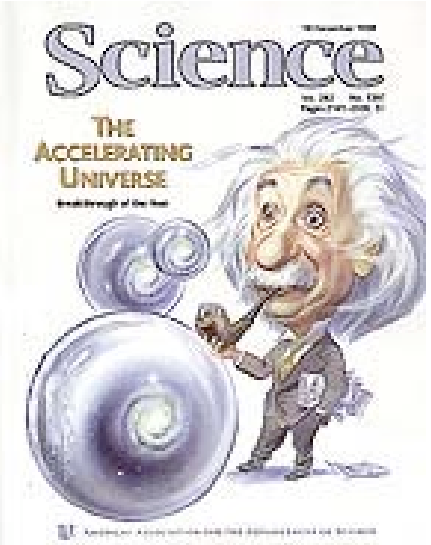
They were used as cosmological probes...



to discover the ***acceleration*** of the Universe...



the Science Magazine scientific Breakthrough of the Year in 1998



The supernovae were found to be a little too dim at given expansion velocity (red shift)

$\Rightarrow$ Further away than expected for a "normal" gravitating Universe

How do you get further away in a given time?

$\Rightarrow$ Universe has been *accelerating*!!

Throw ball

Other arguments, especially careful study of the small irregularities of the temperature of the cosmic background radiation left over from the Big Bang, confirm the evidence from supernovae

=> Accelerating Universe - confirmed by all tests applied so far.

$\Rightarrow$ Universe is filled with an even more mysterious ***Dark Energy***,

The dark energy seems to be some sort of force field (like a magnetic field, only different), that permeates the vacuum, empty space, and that that *pushes*, ***anti-gravitates!***

As space expands there is just more vacuum filled with this force field, so the effect is not diluted by the expansion.

Anti-gravitates: cannot be any particle, normal or dark matter that gravitates.

Dark Energy force field is not accounted for by any currently known physics.

A major challenge to fundamental physics!

The Accelerating Universe

Interim Report of the National Research Council Committee on the Assessment of Options for Extending the life of the Hubble Space Telescope- July 13, 2004:

"The resulting acceleration of universal expansion is a new development in physics, possibly as important as the landmark discoveries of quantum mechanics and general relativity near the beginning of the 20th century."

Pressure Gravitates	Tension Anti-Gravitates
Dark Matter Gravitates	Dark Energy Anti-Gravitates
1/3 of that needed to be flat (3D)	2/3 of that needed to be flat (3D)

Total 1/3 + 2/3 = 1 just the right total mass/energy to be flat (3D)

The stuff that we and the Sun and stars are made of is essentially irrelevant to this argument, there is too little of it in the Universe.

Most of the stuff of which the Universe is composed is substances completely unlike us.

The best current guess is that our real 3D Universe is essentially flat

But accelerating!