11/12/04

Wheeler away Wed, Fri next week. Film on Wednesday on Gamma-Ray Bursts (topic 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?

Pic of the day: aurora

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

But accelerating!

Flat on average

Still have individual stars, neutron stars, black holes, galaxies, that curve the space around them causing the small scale, local effects of gravity.

Nature of Dark Energy

Energy of vacuum - quantum fluctuations, particle/anti-particle (recall role in Hawking radiation) predict an acceleration that is too large by a factor x 10^{120}

"Worst prediction ever in physics," Steve Weinberg (UT Nobel)

Related phase early in Big Bang, when the Universe was a fraction of a second old,

A huge "inflation" by anti-gravitating vacuum force blows the Universe so big that it is essentially flat (like the surface of the Earth appears to us, only moreso!)

Anti-gravitating energy went away - has come back gently.
What is it???

Einstein's theory of the behavior of the Universe contained a "Cosmological Constant," that could be positive, negative, or zero.

Einstein first argued it was positive in order to provide a force to counteract gravity to keep the Universe from expanding or contracting, but then the expansion of the Universe was discovered and he called it a "blunder."

Current results on the expansion are consistent with the Dark Energy being just the value set by Einstein.

Even if true, still need to know if that what it is, physically!

Theories of quantum fields suggest that the Dark Energy could or should vary with time and space.

One theory called “quintessence” (the fifth essence, after the Greek earth, air, fire, and water) would have that property.

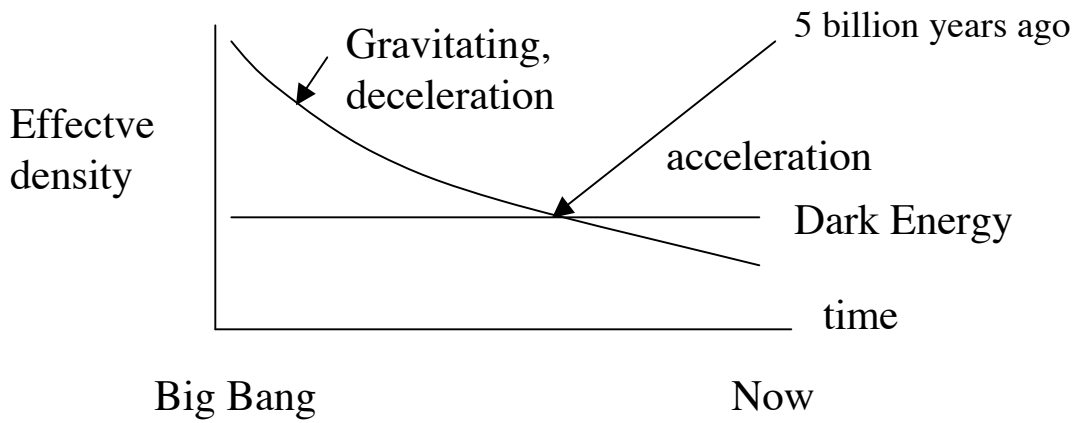
The race is on to determine whether the Dark Energy is constant or not (one of my meetings next week).

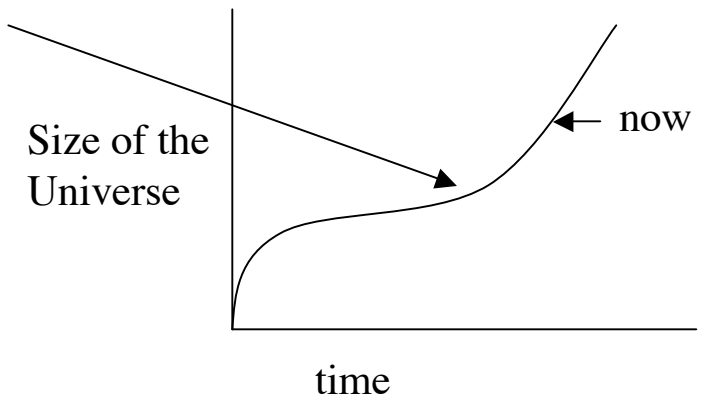
If the Dark Energy is roughly constant, as the Universe expands, the density of gravitating stuff (Dark Matter and normal matter) decreases in a given volume, but the Dark Energy, a property of empty space, stays the same.

The Dark Matter and gravity would be strongest early on, but Dark Energy, anti-gravity and acceleration would come to dominate.

Recent results from the Hubble Space Telescope suggest the Universe switched to acceleration about 5 billion years ago.

Why now?





The Fate of the Universe?

If the acceleration stays constant, the fate is rather dismal: galaxies will be pulled infinitely far apart, then even small mass, long-lived stars age and die, protons, neutrons and electrons will decay to photons, black holes will evaporate by Hawking radiation.

The result would be an empty Universe filled with dilute radiation.

We know so little about the Dark Energy, that it could do other things.

It could get stronger, leading to a ***Big Rip*** with atoms and the very fabric of space being pulled apart (most physicists think this unlikely)

It could reverse sign and gravitate, leading to the recollapse of the Universe in a ***Big Crunch***.

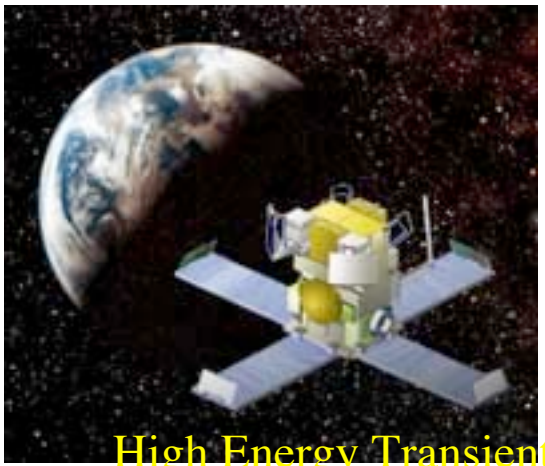
DARK ENERGY

One of the greatest challenges to astrophysics now is to understand the nature of the ***Dark Energy*** that drives the acceleration.

The dark energy is probably a field (like a magnetic field, but different), but it is 120 orders of magnitude smaller than physicists would expect. ***No current theory of physics accounts for it***.

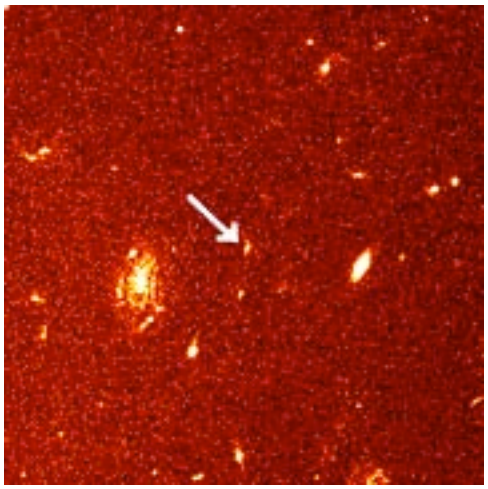
If it stays constant, the Universe will expand to a ***Dark Oblivion***. If it reverses, the Universe could slam shut in a ***Big Crunch*** (in more than 10 billion years).

Gamma-Ray Bursts

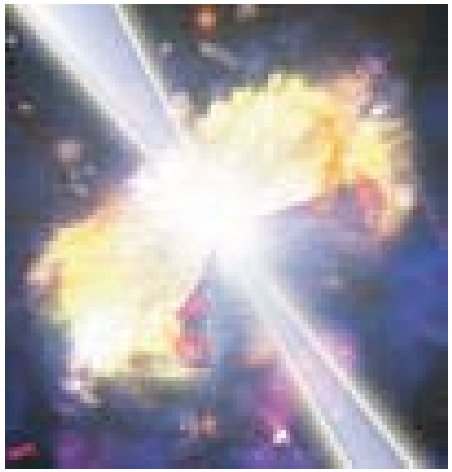


Cosmic explosions, flashes of gamma-rays lasting about 30 seconds, detected by satellites.

Seen across the Universe.



Energy is expelled in narrow jets.
Energy comparable to that of supernovae, but all in gamma-rays, with later ***afterglow*** in X-ray, radio and optical radiation.
Birth of a black hole?

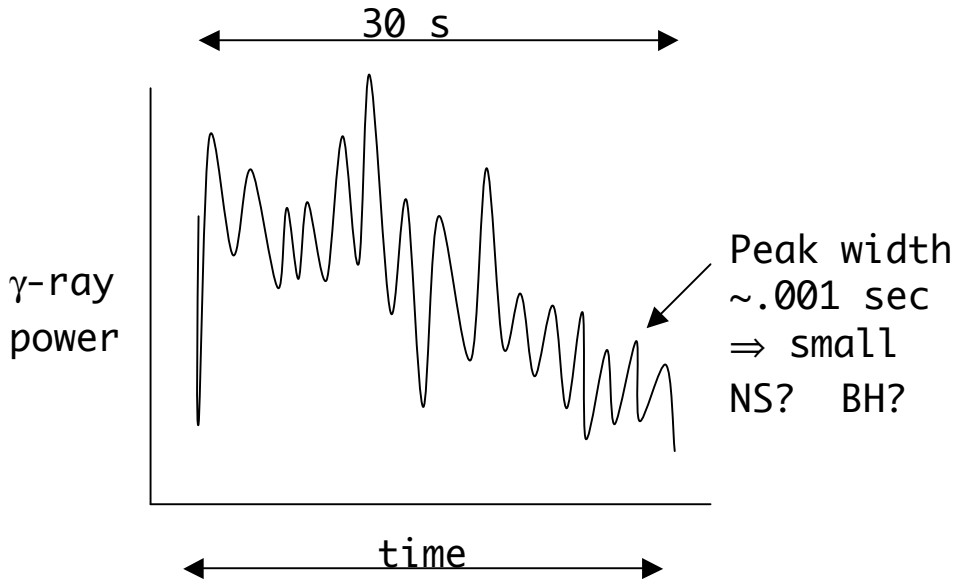


Gamma-Ray Bursts unite ***stars*** and ***cosmology***

Mystery since late 60's - satellites to monitor space nuclear test ban treaty, avoid confusion between astronomical effects, and bombs

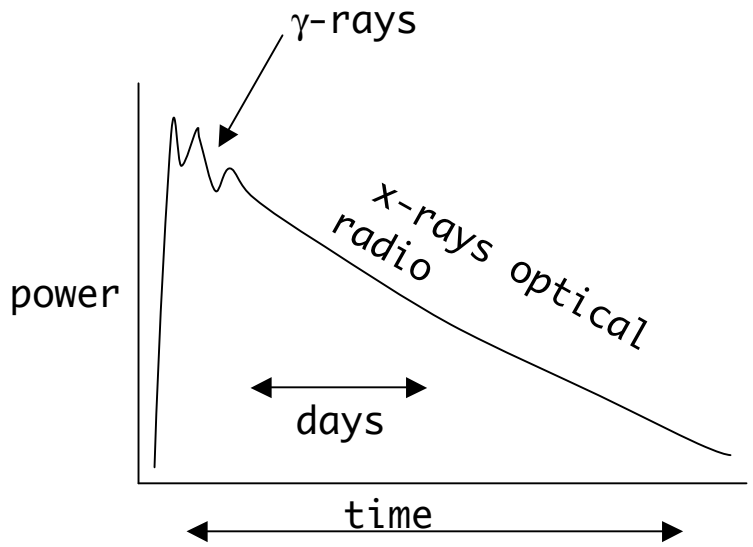
Flare of γ-rays lasts ~ 30 sec

Never Repeat - for 30 years, no optical counterpart,
C*an't focus gamma-rays*.
Did not know which of millions of stars to look at.



Did not know the distance: guesses ranged from within the Solar system to cosmologically distant

Revolution in 1997: 1st detection of "after glow" - optical, radio, X-ray, fading light



Position localized - could bring full armament of modern astronomy to bear on the fading radiation.

⇒Found bursts were in distant galaxies - all at huge, cosmological distances

⇒ Very bright to shine that far

January 23, 1999 optical flash associated with the gamma-ray burst itself (need to discover, swivel telescope, look in 30 seconds!)

9th magnitude - human limit 6th magnitude, could almost see with naked eye, could have seen with good binoculars, but half way across the Universe! ***Brightest optical event ever recorded.***

If gamma-ray bursts shine equally in all directions, the energy released in gamma rays would be $3000 \times$ SN or $30 \times$ core collapse neutrinos.

Comparable to total annihilation of entire star!