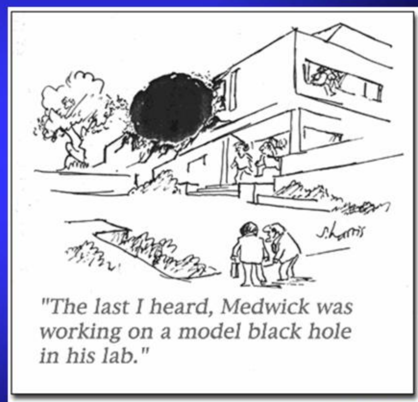
Weird Stuff


"WHAT IT COMES DOWN TO IS THE GOVERNMENT WANTS TO KNOW HOW $\frac{K}{4}\sqrt{3^n}-T$ WILL HELP AMERIKA."


"The last I heard, Medwick was working on a model black hole in his lab."

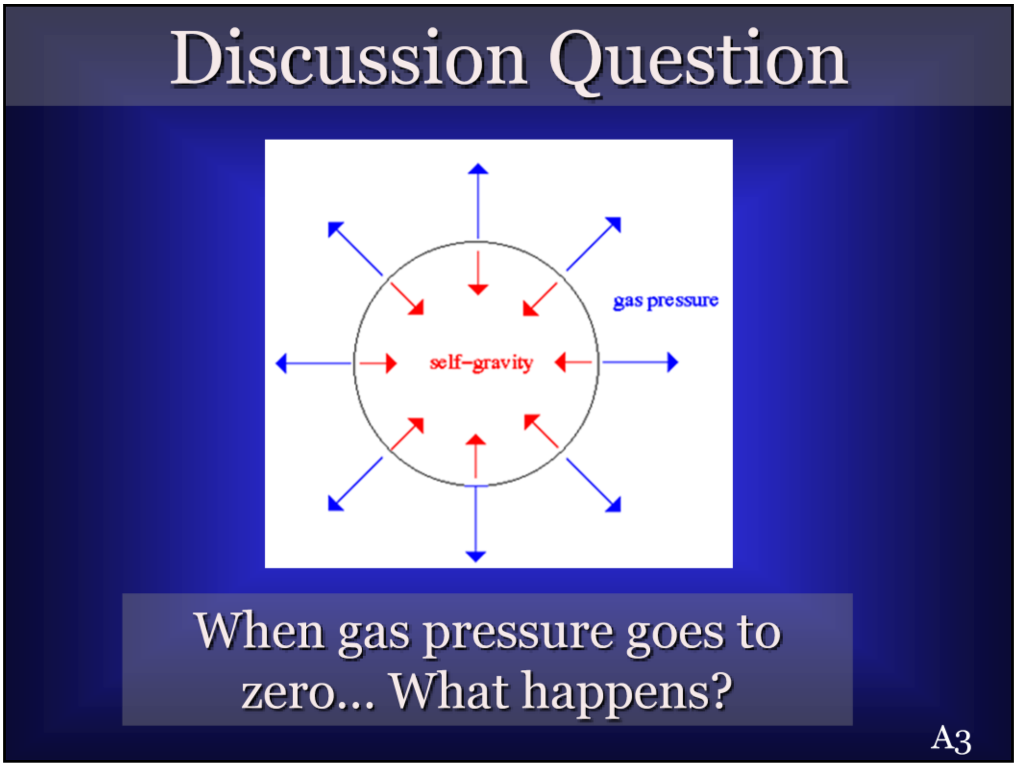
Overview

A. White Dwarf
1. How do they form?
2. What are they made of?
3. What stops them from collapsing?
4. How big are they?
5. What's their size/mass relationship?
6. What is a nova?
7. What is a type I supernova?

Overview

B. Neutron Star
   1. Repeat questions A 1-4
   2. What is a Pulsar?
   3. How where pulsars discovered (and by whom?)

C. Black Holes
   1. What are they?
   2. What is Einstein's gravitation theory?
   3. Why are black holes "black"?
   4. Are black holes eating the universe?
   5. What if I fall into one?
   6. Do they REALLY exist?



What is the “gas” made of?

What determines the size of the ball?

The Pauli exclusion principle states that subatomic particles like electrons, neutrons, and protons may not occupy the same quantum state.

When you try to make them, they start to fight.

If you keep packing people in, they will eventually sit on each others laps. Or get in a fight. Or something…

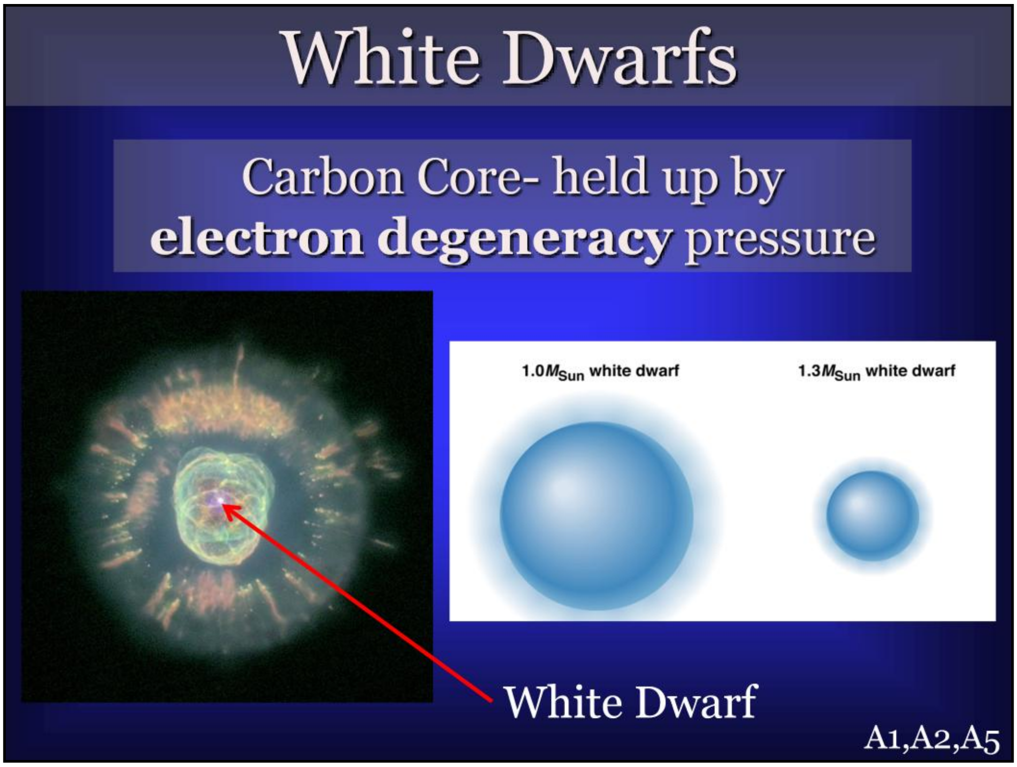
In short, subatomic particles really really hate being next to each other.

The ‘pressure’ in this case is the subatomic particle thrashing around banging into its neighbors.

Pressure no longer depends on temperature. It depends instead on how closely packed the electrons are.

According to the uncertainty principle, if you squish electrons down into a small space, their momentum gets more and more out of control. Thus the ‘pressure’

Degeneracy refers trying to make them occupy the same quantum state. They resist degeneracy.



They are not fusing… only cooling off. Verrrrrrrrrry slowly

Since there is no longer an internal energy source, gravity crushes the material down until it is being held up by electron degeneracy pressure.

Since degeneracy pressure doesn't depend on temperature, white dwarfs never change size once they are created.

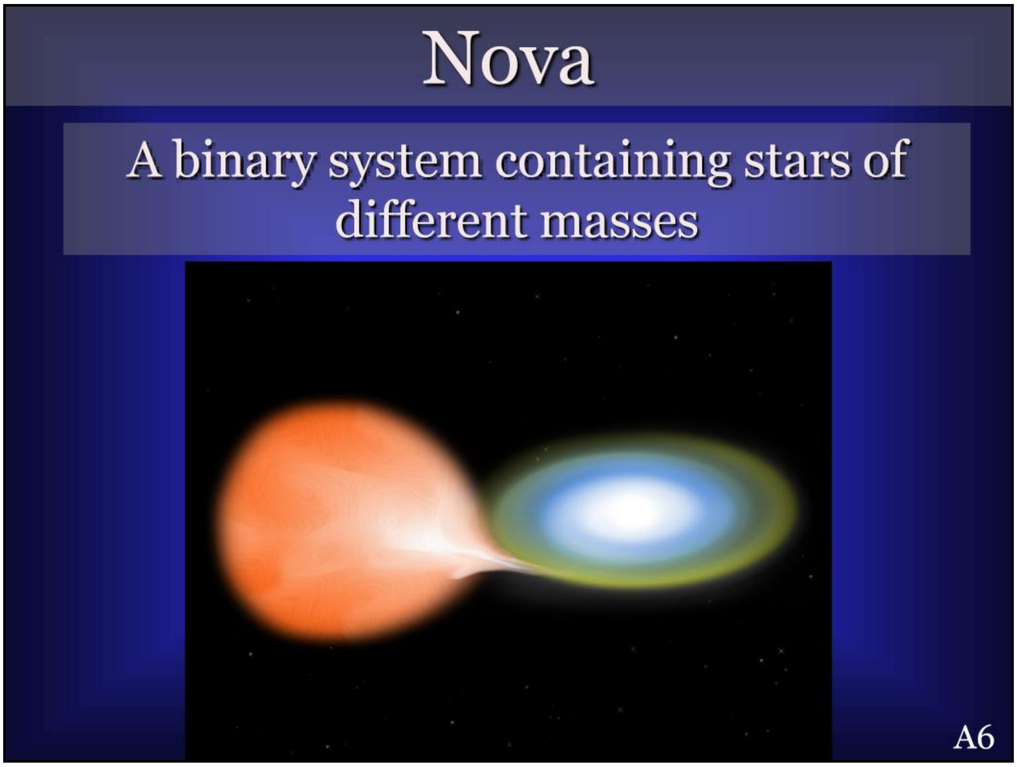
In fact, white dwarfs actually get smaller the more massive they are because degeneracy pressure depends on the distance between particles.

On the HR diagram, they follow a line of constant radius, slowly cooling off and getting dimmer.

Degenerate matter is VERY dense. Approximately 10 tons per cubic inch.

They are dead core of a low mass star. When the star dies (creating a planetary nebula), the nebula eventually disperses leaving behind the white dwarf

Therefore, White dwarfs are made up mostly of carbon nuclei and electrons.



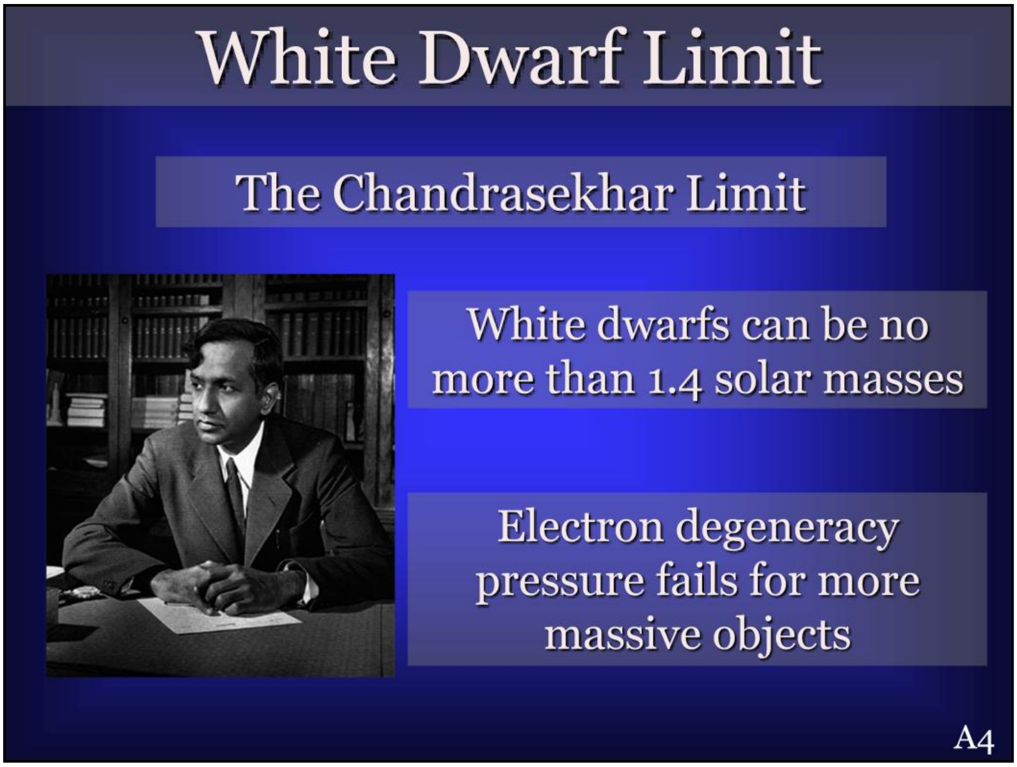
The high mass star evolves more quickly becoming a white dwarf.

Later, the lower mass star becomes a red giant.

Some of the hydrogen from the giant spills onto the surface of the dwarf.

Eventually, enough hydrogen piles up that hydrogen fusion begins resulting in a sudden detonation.

Then the process starts all over again.



Chandrasekhar showed if a white dwarf exceeds 1.4 solar masses, electron degeneracy will fail because the electrons will combine with the protons to make neutrons.

Chandrasekhar did this work between his undergraduate and graduate academic careers.

When he presented the work to the Royal Society, they balked.

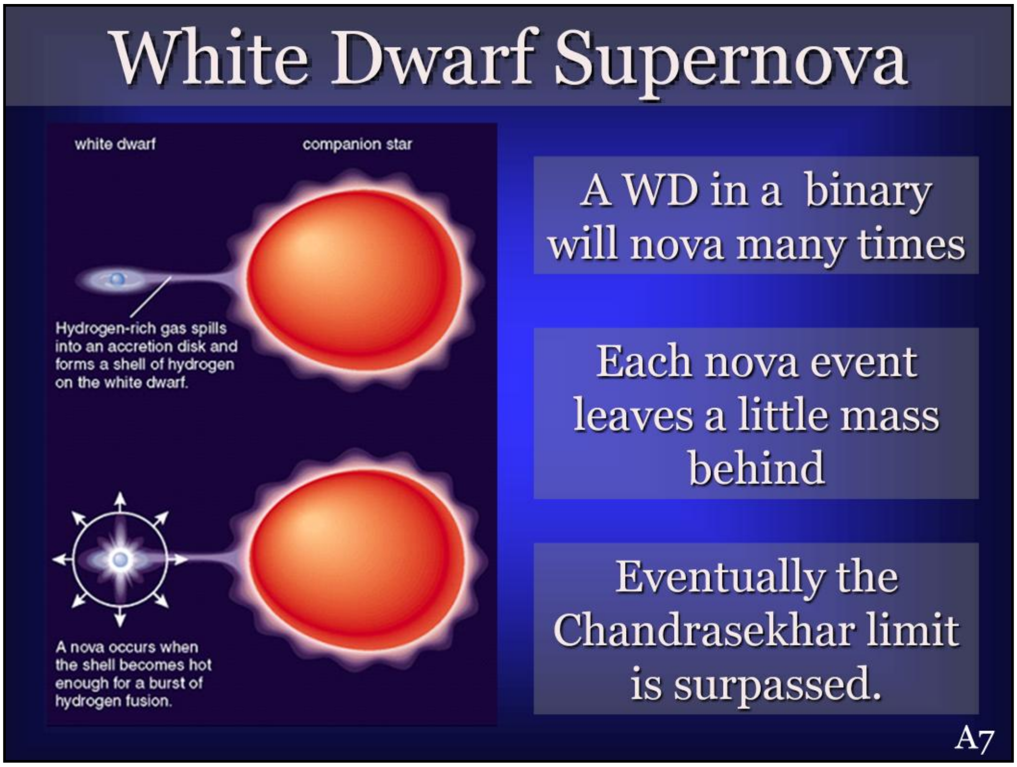
Later he won the Nobel Prize in physics for his work on degeneracy.

So… What happens when a white dwarf exceeds the Chandrasekhar Limit?

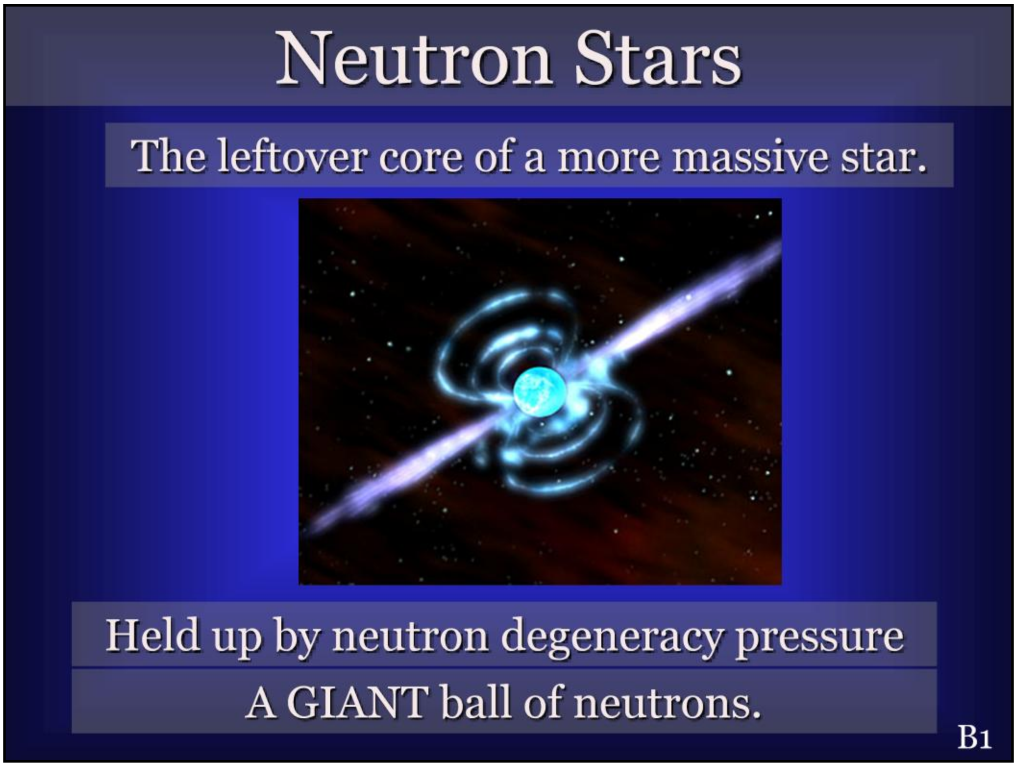
Question

After MANY white dwarf novas, the white dwarf

A. gets more massive and slowly shrinks to a single point
B. uses up the fuel of its red giant companion and becomes a "normal" white dwarf.
C. collapses suddenly and explodes violently
D. The novae keep happening forever

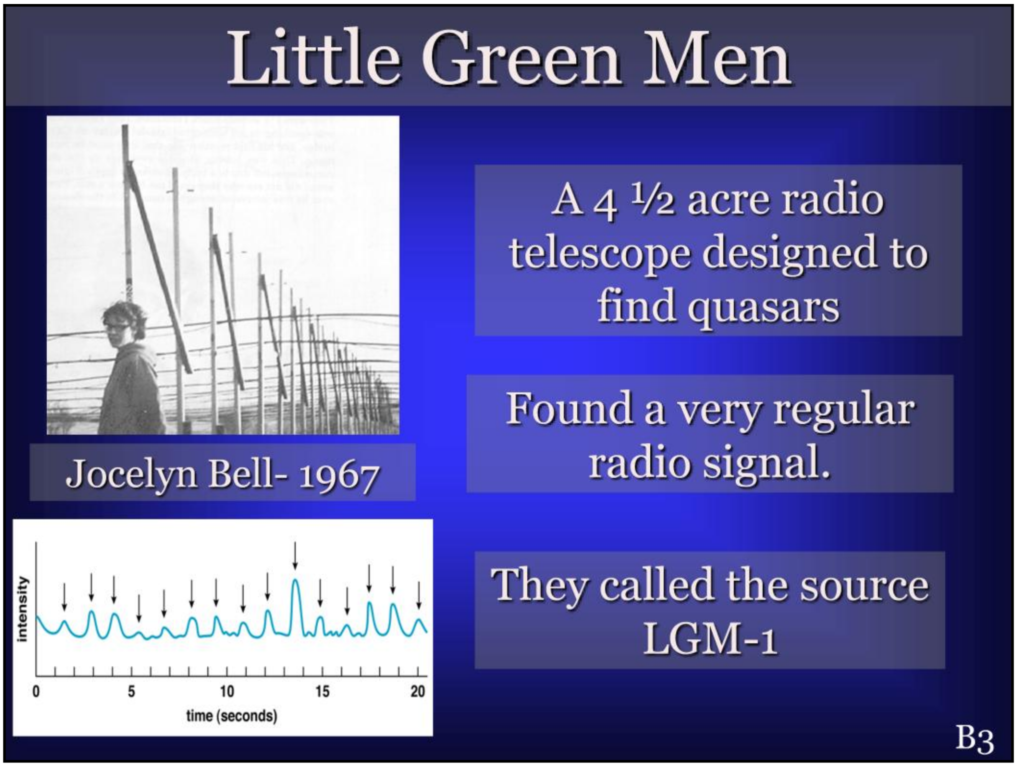


And THEN a big explosion happens.
The WD collapses and detonates.
This is a Type I supernova.

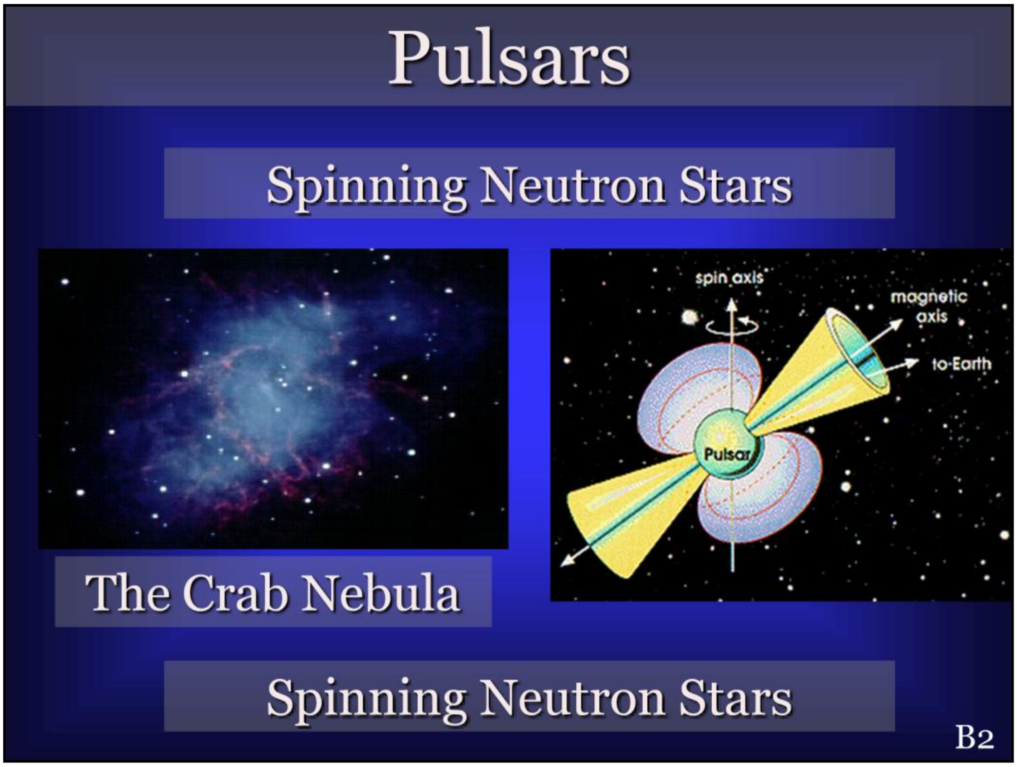


Fits nicely inside the Twin Cities freeway loop but 1-4 times more massive than the Sun.

A cubic inch weighs more than Mt. Everest.



Jocelyn Bell, then a PhD student found the original signal.
Her advisor won a Nobel prize for the discovery.



After a lot of puzzling, they turned out to be spinning neutron stars.

The magnetic field is offset from the axis of rotation.

Light is being beamed out of the poles of the magnet.

When the light sweeps past us, we see a pulse. The period of the pulsation is the rotation period of the neutron star.

All pulsars are neutron stars. The light is from charged particles (electrons) moving very fast around the magnetic fields. The emission is concentrated into a beam that comes out at the magnetic poles.

We only see the pulse if the beam sweeps past us.

A super massive star goes supernova leaving behind a particularly large core.

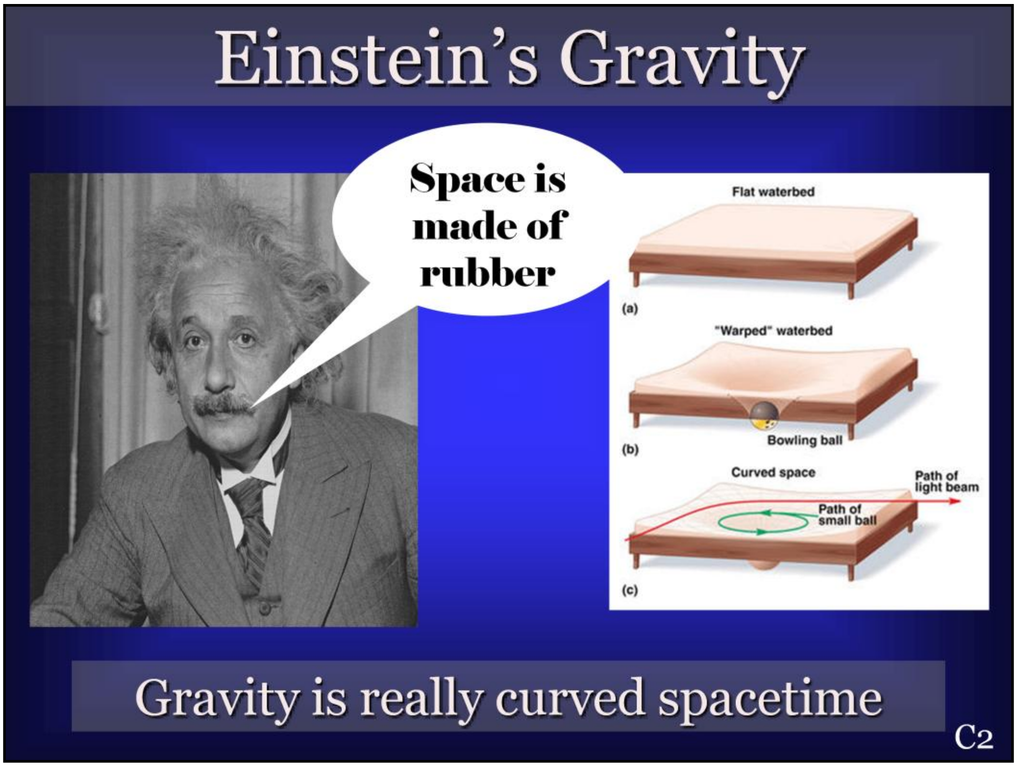
The release of gravitational potential energy that used to halt the collapse further strengthens it.

There is no form of pressure that we know of to stop gravity once neutron degeneracy fails.

The star collapses into oblivion. Gravity finally wins once and for all.

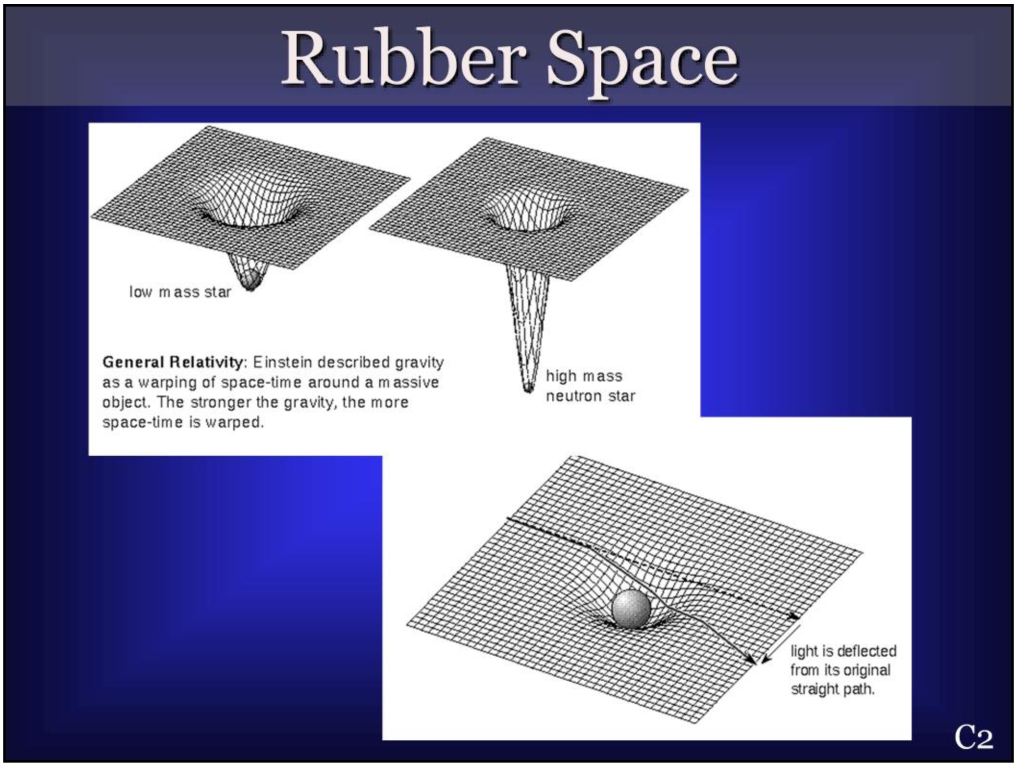
The star becomes infinitely small, reduced to a point that mathematicians call a singularity.

These objects are so compact and have such an immense gravitational field that Newton's gravitational law fails completely and we must turn to Einstein.

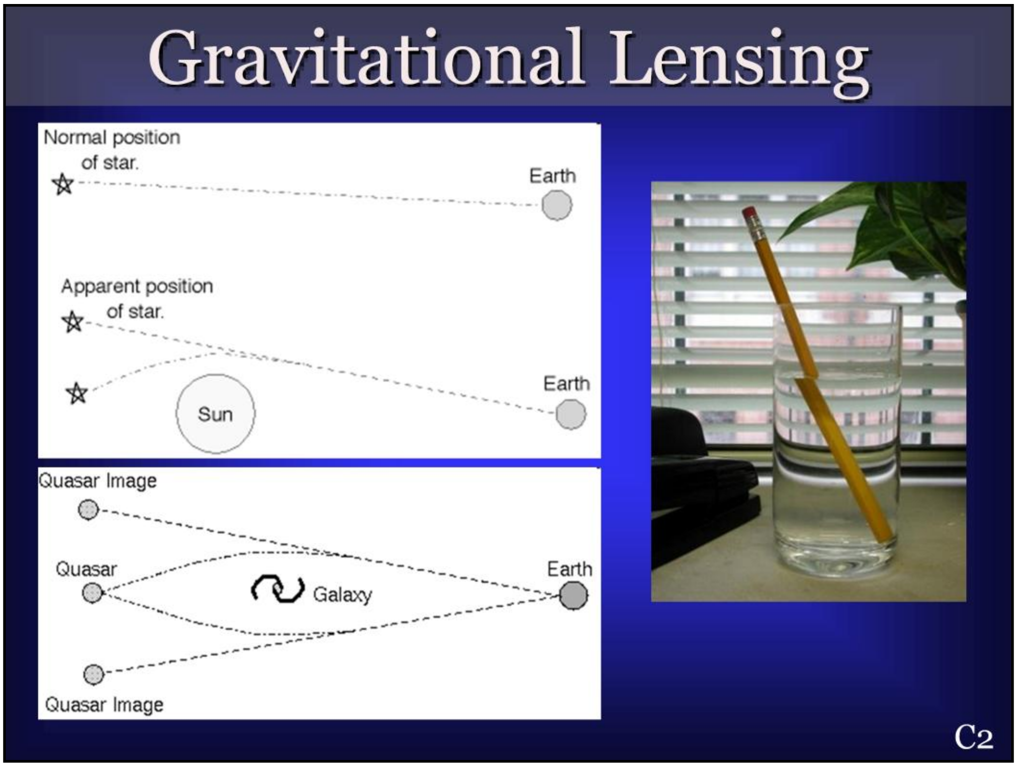


Objects always follow the shortest path through space.
In flat space, the shortest path is a straight line.

Spacetime gets warped by massive objects, so the shortest path is a curved line.
Light follows these curved paths as well. Light is effected by gravity.



Everything is effected by the curvature of space… Even light!



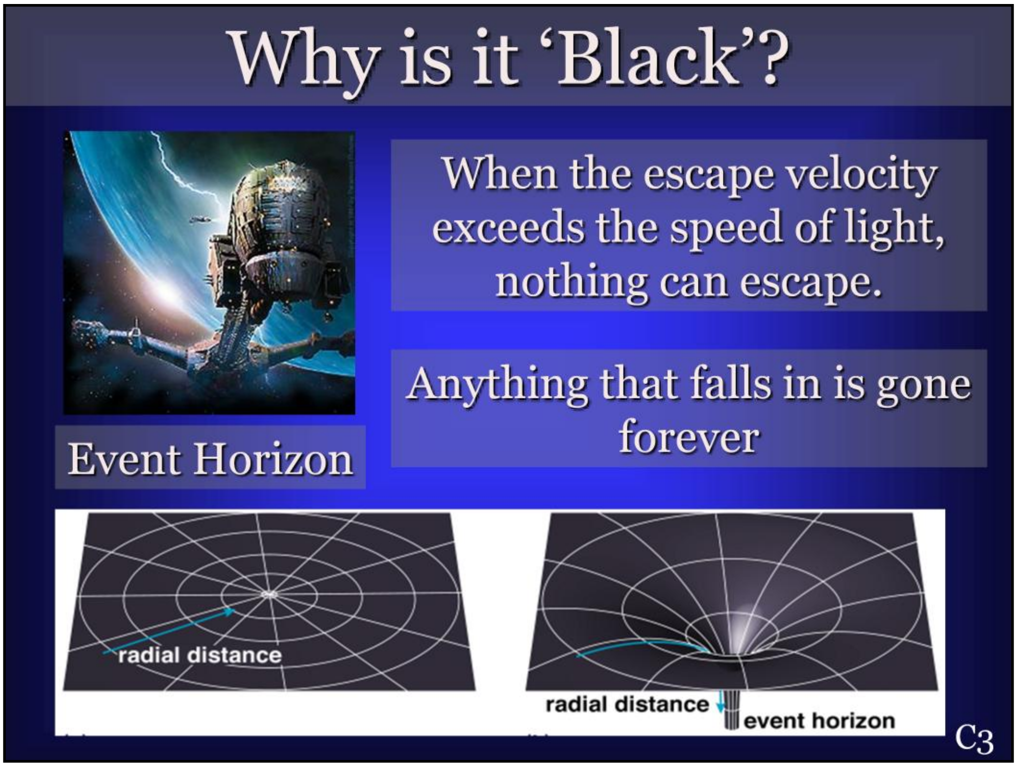
Massive objects bend the light path so that objects apparent position changes.

Just like looking at a pencil in a glass of water, the light bends (refracts) in the water making the pencil appear broken.

Starlight can get bent by the presence of a galaxy or the Sun so that the star appears somewhere else.

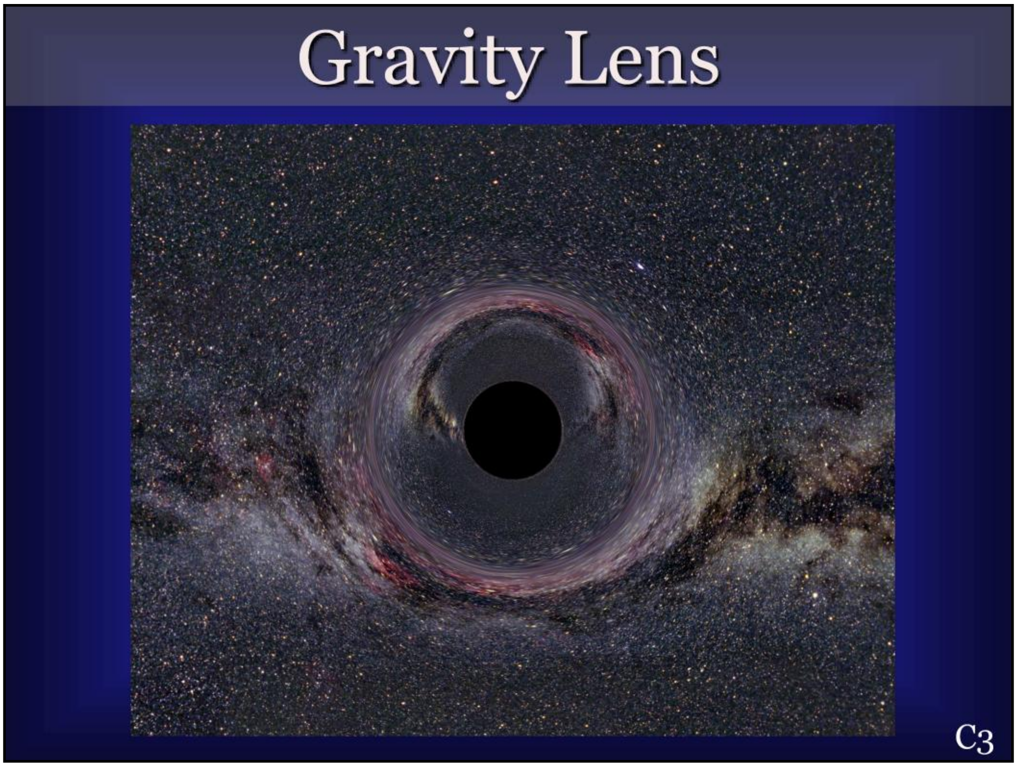
We can even see multiple copies of the same object.

We can see gravitational lensing of background galaxies due to the large cluster of galxies in the foreground.



Light itself actually goes into orbit around the black hole at the event horizon. If you could position yourself there, you could see the back of your own head!

The Schwarzschild radius of the Sun is about 3 kilometers.



Simulated view of a black hole in front of the Milky Way.
The hole has 10 solar masses and is viewed from a distance of 600 km.
An acceleration of about 400 million g is necessary to sustain this distance.

Black Holes

The force of gravity 1 AU from a 10 Solar Mass black hole is:

A. The same as the force gravity from a 10 solar mass star .
B. Greater than the force of gravity from a 10 solar mass star
C. Less than the force of gravity from a 10 solar mass star.
D. Infinite

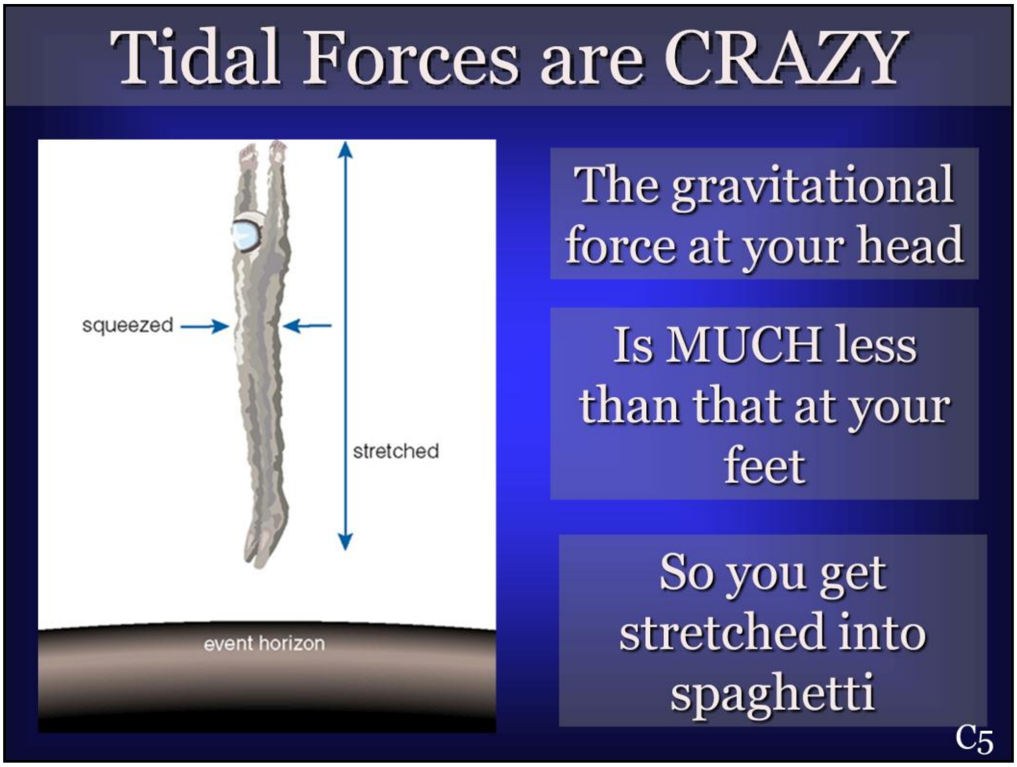
C4

Black Holes

If the Sun were replaced by a 1 Solar Mass black hole:

A. The Earth and all the planets would be sucked in.
B. We would get very cold but our orbit would be unaffected.
C. The inner planets would get sucked in.
D. Everything would be exactly the same as now.

B: Because black holes ***don't suck***!   C4



Gravitational force decreases as you move farther away.

Very close to a black hole, the difference in gravity between your head and your feet is large

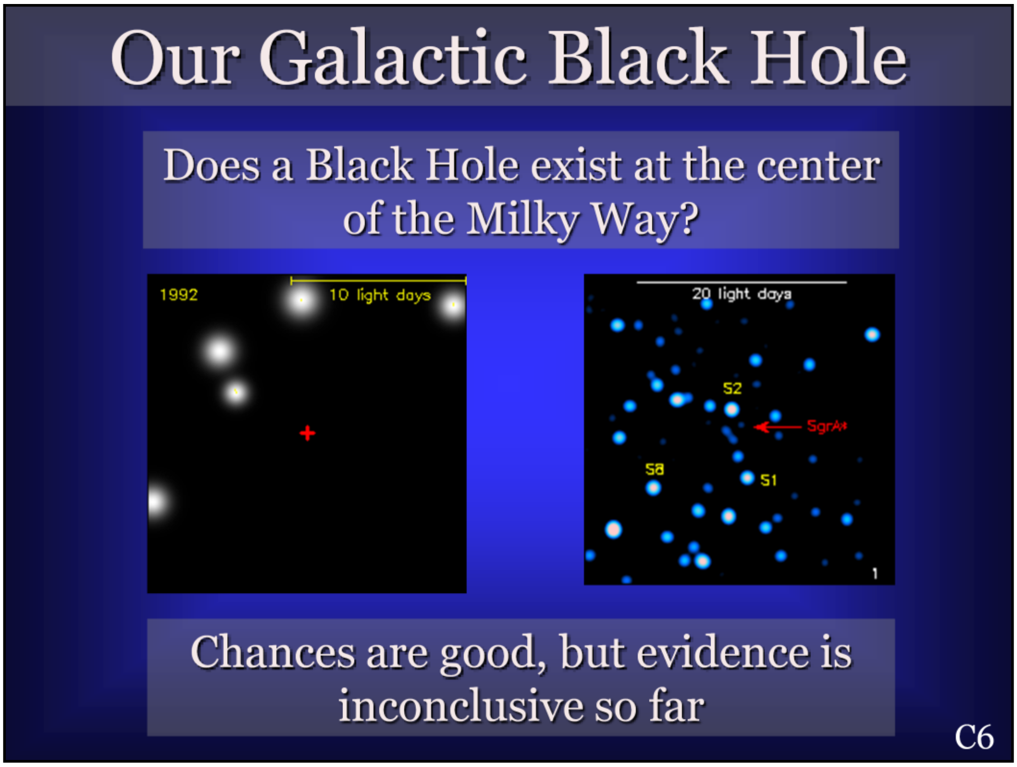
You get ripped apart

At least from our perspective.

Light also red shifts and at the event horizon, the wavelength becomes infinite.

Objects become unobservable to us.

One such effect is an x-ray binary.
Two stars are in a binary, one high mass, one low mass.
The high mass star supernovas and becomes a black hole.
The other star becomes a red giant and begins losing mass to the black hole
An accretion disk forms.
Around a black hole, the accretion disk will be particularly hot and emit in x-ray light.

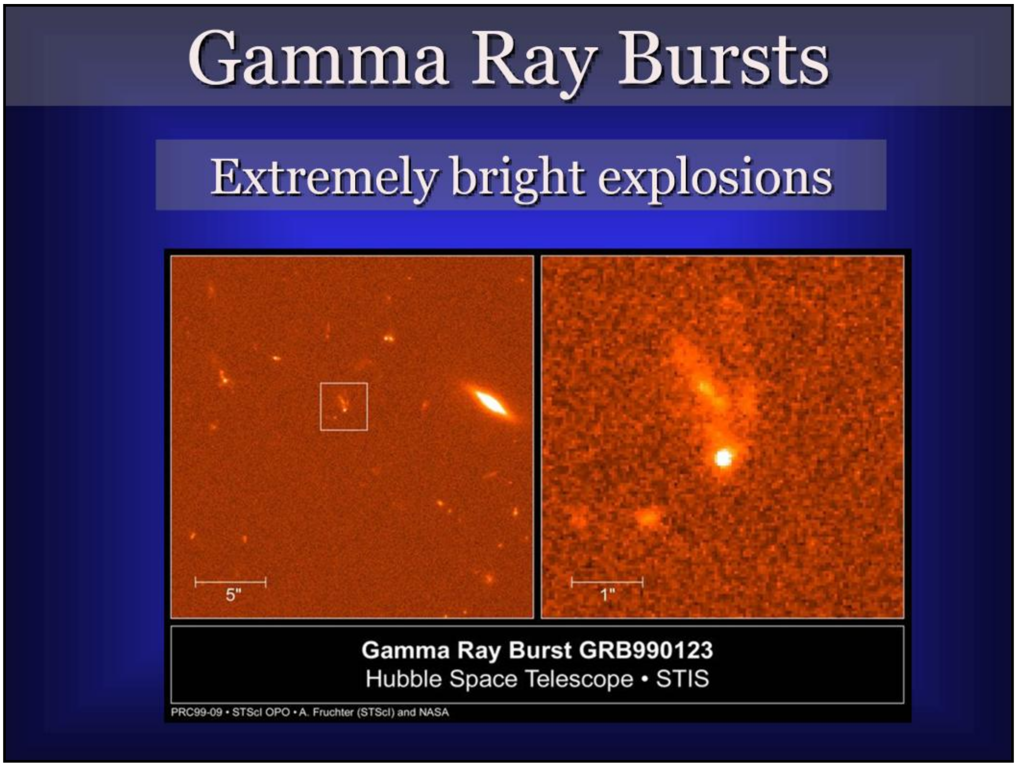


At the center of our galaxy is a 3.6 million solar object that is an excellent candidate for a super massive black hole.

It has been observed in the past as a radio source and named Sagittarius A.

Observations of the positions of several stars in the neighborhood suggest something of the correct mass is there. It could be a dense cluster however.

There was a flare observed in 2003 within 10 Schwarzschild of the location of Sgr A. It is characteristic of a flare from an accretion disk.



In the 1960s, the US put satellites up to watch for gamma rays due to nuclear detonations.

They saw bursts of gamma rays coming from all over the place.

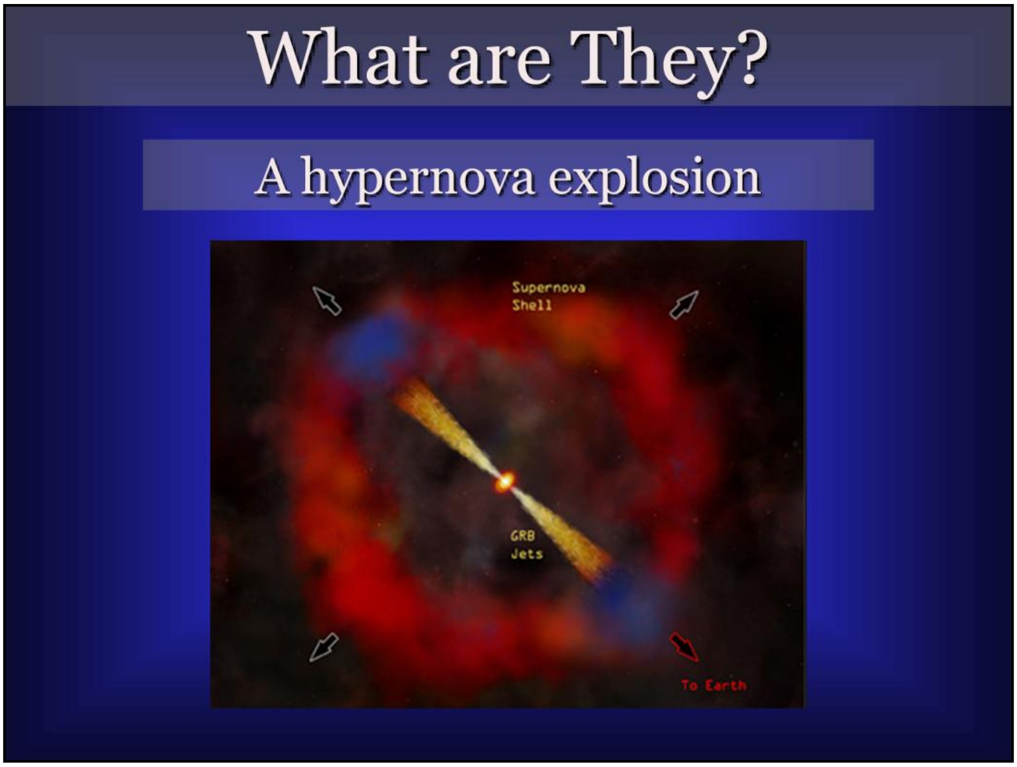
For a long time, we had no idea what or even where they were. We didn't know if they came from within the solar system, within the galaxy, or from distant extra-galactic sources.

GRB lasts a few seconds to a few minutes.

They are hundreds of times brighter than a typical supernova explosion.

Gamma rays are hard to focus, so pinpointing their location is difficult.

One has to look for lower energy counterparts, such as in the optical



They appear to be very far away, some near the edge of the observable universe.

Really big explosions of first or second generation stars.

It is inconceivable, given their distance, that the energy is spherically distributed.

The gamma rays are actually beamed at us. We don't see the burst unless we are in the beam.