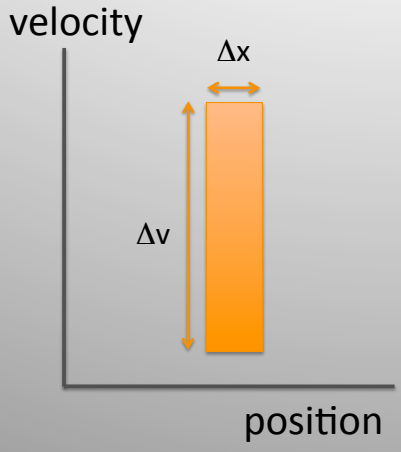
The Chandrasekhar Limit



Pressure (gradient) that supports a white dwarf is a quantum mechanical effect

Pressure increases with the density: electrons are forced into states of higher energy (larger v)

The Chandrasekhar Limit

More massive white dwarf has stronger gravity:

- need larger pressure gradient
- requires higher density
- *so much so* that radius goes **down**!

The Chandrasekhar Limit

Fastest electrons "slow"

Faster

Electrons almost have v = c

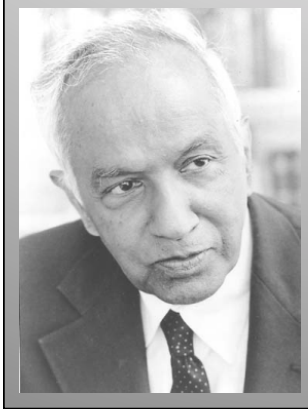
Higher density ⇒ faster electrons ⇒ higher P

But when v ~ c, speeds can't get any higher!
Higher density fails to increase pressure…

The Chandrasekhar Limit

There is a maximum mass of white dwarf that can be held up by electron degeneracy pressure

1.4 Solar masses, called the Chandrasekhar limit



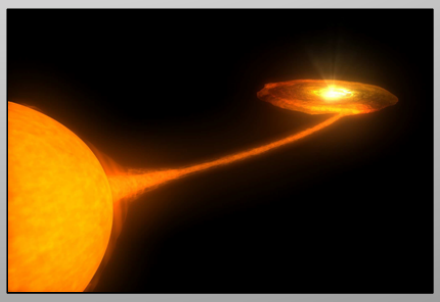
Subrahmanyan Chandrasekhar

The Chandrasekhar Limit

1.4 M_{sun}

No white dwarfs with masses exceeding the limit are known, most are ~0.6 M_{sun}

In mass transfer binaries, gas can be accreted by a white dwarf from a mass losing ordinary star



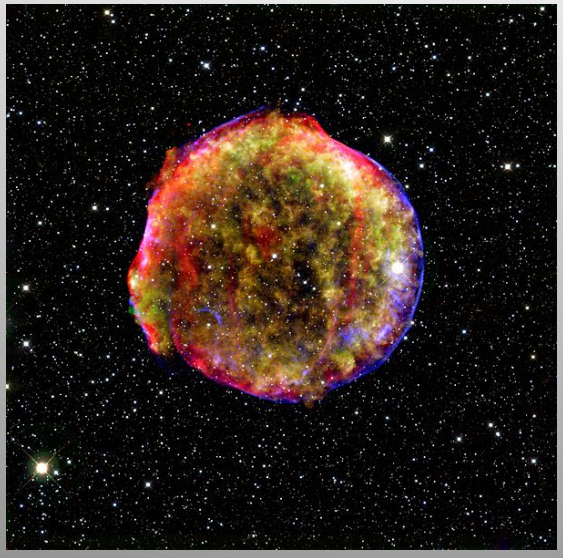
What happens when mass reaches the limit?

A (white dwarf) supernova explosion

"Type 1a" supernova in the Pinwheel galaxy (2011)

All have very similar luminosity

A (white dwarf) supernova explosion



Nothing is left behind…

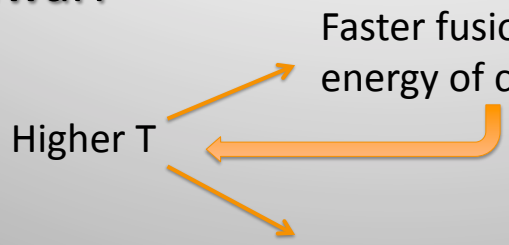
Nuclear fusion "burns" in a normal star

Higher T

- Faster fusion (higher kinetic energy of colliding nuclei)
- Higher pressure → Stellar core expand → Cools off

Stable feedback

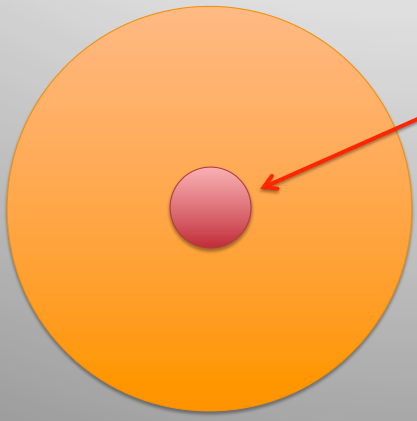
Nuclear fusion "explodes" in a white dwarf



Same quantum mechanical degeneracy pressure

Unstable feedback

Can also approach limiting mass in the core of a massive star



Iron core:

- most stable nucleus
- no energy from further fusion possible

This time no *thermonuclear* explosion: can't get any more energy out of iron from nuclear reactions

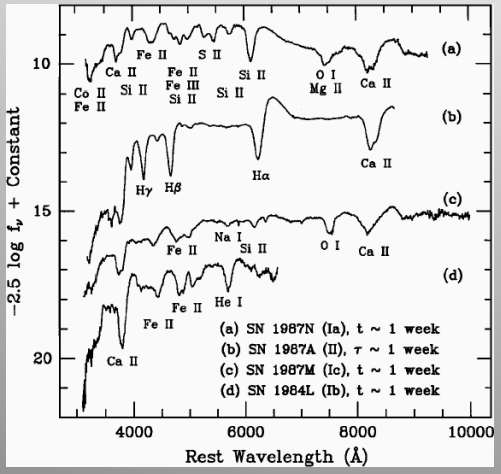
Core collapses

At very high densities protons and electrons combine to form neutrons

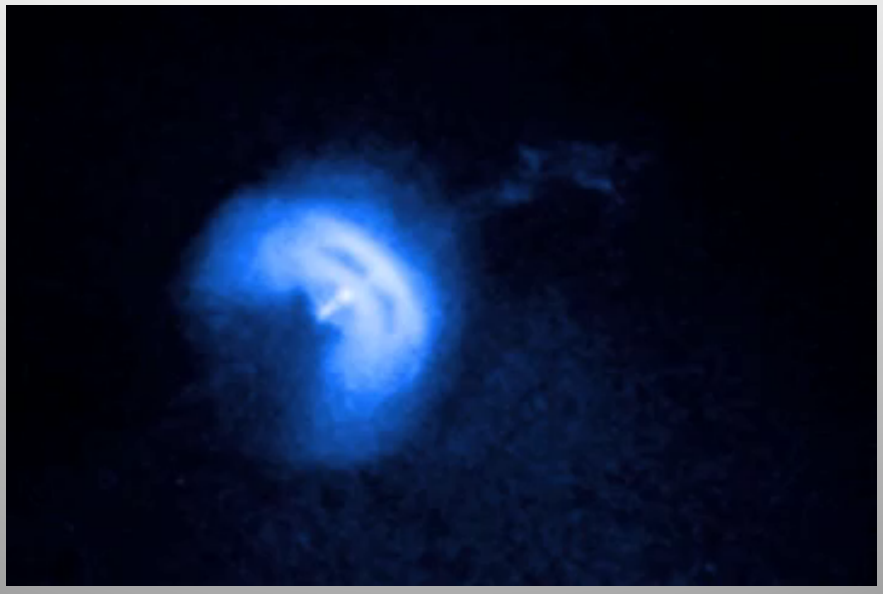
If neutron degeneracy pressure is enough to halt collapse, core bounces and we get an explosion again

How could we tell observationally if a supernova is a white dwarf supernova or a core collapse supernova?

How could we tell observationally if a supernova is a white dwarf supernova or a core collapse supernova?



See spectrum of hydrogen in the core collapse case: outer layers of the star didn't undergo fusion



Core collapse supernova leave something behind: a neutron star (or sometimes a black hole)