Tuesday, September 15, 2009

Wheeler lecture Natural Sciences Week - *Space and You: From Climate Change to the Big Bang*, RLM 4.102, 7 - 8 PM, Tomorrow. IYA extra credit.

Astronomy in the News? Augustine Committee on U. S. Human Space Flight Plans released summary of report to President Obama. Human space exploration to Moon, asteroids, Mars, emperiled without

increase to NASA budget.



Pic of the Day - Crescent Nebula, blown by *winds* of massive star



Space and You: from Climate Change to the Big Bang



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§5.3 Origin of Cataclysmic Variables

Cataclysmic variables often have a *main sequence companion transferring mass* -- how can this be?

The two stars must once have been far apart to allow the originally more massive star to make a red giant with a white dwarf core.

Need room!!

The stars are observed now to be close together with the main sequence star filling its Roche lobe.

The main sequence star has not expanded to become a red giant, how come it is filling its Roche lobe?

Answer: § 3.9 Common Envelope Evolution



One Minute Exam

In most dwarf nova systems, the star transferring mass is a main sequence star. This means:

A The main sequence star was once a red giant, but lost mass

B The main sequence star used to be further away from the white dwarf

C The main sequence star and the star that made the white dwarf were born close together.

D The main sequence star has more mass than the white dwarf



§ 5.4 Final Evolution of Cataclysmic Variables

Some CVs have managed to reach large masses $M_{wd} \sim M_{ch}$ Chandrasekhar mass, 1.4 solar masses, like U Sco

If get close enough to M_{ch} , attain high density, ignite carbon in center Quantum Deregulated \rightarrow violent explosion Supernova (Chapter 6)

What CVs have white dwarfs that reach M_{ch}?

Not classical novae

explosion of surface H shell also rips off a bit of the white dwarf mass - we see excess carbon & oxygen in ejected matter

white dwarf shrinks in mass rather than grows.

Likely outcome in this case - 2nd star finally burns out H, tries to form red giant, likely makes a 2nd common envelope => *Two WDs!*

Quantum Pressure -- just depends on squeezing particles,

electrons for white dwarf, to very high density

- -- depends on density only
- -- *does not* depend on temperature

Important Implication:

- Normal 🖈 Radiate energy, temperature/pressure try to drop, star compresses, gets hotter (and higher pressure)
- White DwarfRadiate energy, temperature does not matter,
pressure remains constant, star gets cooler

Opposite behavior

- Normal Star put in energy *Regulated*
 - put in energy, star expands, cools
 - White Dwarf -
Unregulatedput in energy, hotter, more nuclearUnregulatedburning -- explosion!

Hydrogen transfers from a main sequence star to a white dwarf in a binary system.

Modest rate of transfer, hydrogen has a chance to radiate and cool as it is added to the surface of the white dwarf, ends up cool but dense, supported by the *quantum pressure*. If the hydrogen begins to burn the result is:

Unregulated hydrogen burning, an explosion --> Classical Nova

White dwarf loses mass, cannot grow to Chandrasekhar mass

Second star eventually makes its own white dwarf --> 2 WD



Clearly some systems like recurrent nova U Sco with nearly 1.4 solar mass white dwarf escape this fate - How?

Recent work suggests that transfer of mass at just the right fast rate allows the H layer to stay hot, supported by *thermal pressure, regulated*

H burns to He, He to C and 0 that are added to white dwarf

M_{wd} grows in C/0 mass

Hydrogen transfers from a main sequence star to a white dwarf in a binary system.

Higher rate of transfer, hydrogen does *not* have a chance to radiate and cool as it is added to the surface of the white dwarf, it stays hot and is supported by the *thermal pressure*. If the hydrogen begins to burn the result is:

Regulated burning, bright flash, but no hydrogen explosion --> *Recurrent Nova*

White dwarf gains mass, can grow to near Chandrasekhar mass

Eventually may ignite carbon in the center, quantum deregulated, explode whole star as a *supernova*

Hot hydrogen layer, supported by thermal pressure



C/O white dwarf grows in mass

A binary system could be a classical nova for some time then accrete faster, convert to recurrent nova, grow WD to M_{ch}

Some white dwarfs may be born with larger mass.

Some white dwarfs grow to near the Chandrasekhar mass and explode, some don't.

We still don't fully understand why...

One Minute Exam

We expect classical nova systems to end up making two white dwarfs orbiting one another because:

A The first white dwarf loses mass and hence cannot grow and explode

B The first white dwarf will accrete mass until it reaches the Chandrasekhar limit

C The main sequence star transferring mass must eventually make a white dwarf

D The hydrogen layer is supported by thermal pressure

We do observe 2 white dwarfs in orbit in some cases - is that the end?

No: *gravitational radiation* (§ 3.10) ripples in curved space-time like paddle on surface of pond



remove energy from orbit - acts as drag

If you try to slow down an orbiting object what happens?

Falls inward, speeds up, Get more gravitational radiation, more inspiral

Given enough time (billions of years) 2 white dwarfs must spiral together!

One Minute Exam

Name three situations where we have talked about friction and drag causing orbiting stuff to fall inward and *move faster*.

Flow of gas in accretion disk

Two stars orbiting in a common envelope

Two orbiting white dwarfs losing energy to gravitational radiation

What happens when two white dwarfs spiral together?

Larger mass WD has smaller radius

Which WD has the smaller Roche lobe?

The smaller mass

Which fills its Roche Lobe first?

Must be the smaller mass

Smaller mass, Larger radius Larger mass, Smaller radius

As small mass WD loses mass, its *radius gets larger*, but its *Roche Lobe gets smaller*! Runaway mass transfer.

Small mass WD transfers essentially all its mass to larger mass WD

Could end up with one larger mass WD If larger mass hits $M_{ch} \rightarrow$ could get explosion => Supernova

End of Material for Test 1