Astronomy Bizarre
309N Fall 2001
(46490, 46495)

Wheeler
October 3, 2001

Review for Test #2
ACCRETION DISKS AND WHITE DWARFS

Accretion disk—matter streaming through inner Lagrangian point does not directly strike the tiny, orbiting, companion star, but circles around and forms a flat spiraling disk. The disk has its own life in the system.

Friction—matter at smaller distance from the center of the disk moves more quickly, rubbing against matter just beyond it moving more slowly and against matter interior to it moving more quickly. The result is friction and heat and light generated everywhere in the disk. The friction also drags material inward giving rise to the *accretion* onto the central compact star.

X-rays—the outer parts of disks typically have temperatures comparable to the Sun and shine with optical light. Middle parts are hotter and glow in ultraviolet light. The innermost parts, found only for neutron stars and black holes, are hot enough to emit X-rays.

The friction in accretion disks is thought to be caused by turbulent, chaotic magnetic fields that act like tiny springs to link orbiting blobs of matter. With the drag provided by such a “spring, ” the inner blob will spiral inward uncontrollably.

Disk heating instability — when mass transfer rate is low, material is stored in the disk in a cool state. Eventually heat is trapped, leading to a runaway heating instability which turns the whole disk hot and bright. The disk then thins out and cools and returns to the storage state.

Hot, nearly spherical regions that advect energy inward or convect energy outward may occupy the inner portions of disks, especially around black holes. The matter can be hot enough to form electron-positron pairs and emit gamma-rays. When the matter flows straight in, the condition is called an Advection Dominated Accretion Flow. The most recent theory says that the ball must boil or convect, and that condition is called a Convection Dominated Accretion Flow.

White dwarfs—most are single stars, mass about 0.6 $M_\odot$, cooling time longer than the age of the Universe. Interiors can be probed by “seismology.”

Seismological studies have revealed the masses, compositions and ages of white dwarfs. In particular, common white dwarfs have been shown to be composed of carbon and oxygen and even the ratio of those elements throughout the star have been studied. Current plans call for the use of the white dwarf waves as a “clock” to determine wobbles in any orbit that would indicate planets that have survived the red giant phase.

Cataclysmic variable—system consisting of a white dwarf receiving mass via an accretion disk from a companion, frequently a small mass main sequence star.

Dwarf nova—flares about 10 times brighter every month or so. Probably due to a process in the disk causing mass transferred from the companion star to be stored until a critical density is reached. A wave of heating causes a sudden rise in brightness. The matter then flows rapidly inward toward the white dwarf. A wave of cooling subsequently occurs, the disk returns to a storage mode, and the cycle begins again.

Recurrent Novae—flare 1000 times brighter every 10-100 years. The mechanism is thought to be similar to that of Classical Novae, a thermonuclear explosion of an accreted layer of hydrogen, but on an especially massive white dwarf, where the strong gravity leads to frequent but weaker flashes. Recurrent Novae may grow the white dwarf to the Chandrasekhar mass limit of 1.4 $M_\odot$, at which point the white dwarf would explode.

U Sco—An example of a recurrent nova in the constellation of Scorpius. The white dwarf has been measured to have a mass greater than 1.3 $M_\odot$ and is thought to be headed to a thermonuclear supernova explosion.

Classical Novae—flares 10^4 to 10^5 times brighter, suspected to recur, but no direct evidence. Mechanism is layer of accreted hydrogen supported by the quantum pressure that builds up on the surface of the white dwarf and then ignites, burns unstably and explodes. About 10^{-4} $M_\odot$ is ejected.

Classical Nova explosions show an enrichment in heavy elements suggesting that some matter has been ripped from the white dwarf itself, thus reducing its mass.

Common envelope evolution—when the first star evolves its envelope may surround both its core and the companion star. Core and companion may spiral together. Possible explanation of why cataclysmic variables have main sequence companions.

Stars with mass less than 8 $M_\odot$ on the main sequence will form C/O white dwarfs. Stars with mass between about 8 and 12 $M_\odot$ will burn carbon in a regulated way to neon and magnesium, and the resulting core of O/Ne/Mg will become supported by the quantum pressure and form a white dwarf.

Final evolution of cataclysmic variables—one possibility is that a massive white dwarf may reach mass limit of 1.4 $M_\odot$ and collapse or explode.

White dwarfs nearing 1.4 $M_\odot$ made of C/O will explode completely after igniting carbon under conditions of quantum pressure support. Those made of O/Ne/Mg will have protons absorb electrons and collapse to form a neutron star.

Double white dwarfs—If the first white dwarf does not grow and explode, the second star can evolve to produce a white dwarf, resulting in two orbiting white dwarfs. These will spiral together by gravitational radiation, until smaller mass, larger radius white dwarf fills its Roche lobe. Mass transfer causes small white dwarf to be transferred essentially entirely to the larger one. May get larger white dwarf, thermonuclear explosion or collapse.