Today

- White dwarf supernovae from mass transfer in binary system, but also repeated novae
- Discuss white-dwarf supernovae (binaries)
- Observational properties of such Type Ia supernovae, including being "standard candles"
- Mass transfer also involves neutron stars

- Evening Review tonight 7-9 pm for Second Mid-Term Exam on Mon Mar 15. Reviews sheets still available, so too new HW # 8.
- Overview read S.3 Spacetime & Gravity
- Read Chap 19 Our Galaxy with care
- Planet Finder homework due next Thur Mar 18

“Compact Companions” in Binary Systems

- Mass transfer from red giant companion spirals onto accretion disk
- Inner parts become VERY hot -- glow in UV, X-rays

Mass transfer → accretion disk

With mass transfer, the gas spiral around the massive star heats and radiates brightly

- Makes neutron stars and black holes visible!
White Dwarfs in Binary Systems

- Again, mass transfer from red giant companion spirals onto an accretion disk
- But too much mass can take white dwarf over the edge!

WD snooze ... → pyrotechnics

(in three flavors)

1. Localized accretion flash burning on surface (hydrogen) → "Nova in the making!"
2. Enhanced "fuel" fuel up to ignite surface flash cycle ... explosive dying off (eventually)
   → NOVA ("new", or "vivid" one)
   Recurrence 1 - 20^5 yr or more, then more (can repeat)

NOVA

- Accretion of gas onto white dwarf can lead to H fusion on surface
- Star becomes much brighter → nova (may blow off shell)

NOVA Cygni 1992+2
Recurring Nova T Pyxidis ~ every 20 yrs

White Dwarf SURPRISES...

3. If WD close to 1.4 M_\sun, limit... collapse of WD, explosive fusion burning of "carbon star" – all gone!

Brightest SN: superb beacons for measuring distances

Supernova Light Curves
Bright Candles in Sky to Measure Distance

- Type II – core collapse
- Type Ia – WD
SUPERNOVAE in Other Galaxies

- Bright enough to be seen as sudden, bright point in other galaxies
- Many astronomers monitor nearby galaxies nightly to catch them
- 1 per 100 years per galaxy means that if you monitor 100 galaxies, see ~ 1 SN per year
- If monitor a million galaxies, likely to find 30+ new ones each night!

In Milky Way: Tycho Brahe SNR (1572)

Kepler’s SNR (1604) latest SN in MW

Kepler SNR (1604) Chandra X-ray

“We are made of star stuff”

- Discussion topic
- How has this occurred, what processes in stellar evolution are involved?

White dwarf SN as distance estimators

- “Standard explosion” = fusion of 1.4 solar masses of material
- Nearly the same amount of energy released
**Bright enough to be seen halfway across observable universe**

**Useful for mapping the universe to the largest distances**

**Supernovae in very distant galaxies**

**Practical difficulty: White dwarf SN**

- Need to catch them within a day or two of the explosion
- About 1 per galaxy per century
- Need to monitor thousands of galaxies to catch a few per year → galaxy clusters are useful

**White dwarf supernovae**

- Carbon fusion explosion: mass transfer in binary takes white dwarf "over the edge"
- Roughly same amount of energy released (calibrate)

**Calibrated**

**Since white dwarfs in evolving binary systems come "alive" – what about neutron stars?**

**Neutron Stars in Binary Systems**

- Mass transfer builds very hot accretion disk around neutron star:
  - intense x-ray emission (continuously)
  - explosive helium burning (in bursts) on disk

**Binary WD:**

- Hot accretion disks, novae, supernovae

**Neutron star:**

- Radiation with more vigor, no SN

**MASS TRANSFER**
“X-Ray Bursters”
Accretion flow onto neutron star (overflow or wind) → helium fusion flash burning

Clicker: Where have all the white dwarfs gone ..?
• Imagine two star clusters, one 10 billion years old, and one very young. Which is more likely to have a lot of white dwarfs?
  • A. the old one
  • B. the young one
  • C. can’t tell
  • Hint: what mass stars create white dwarfs?

Old globular cluster – lots of white dwarfs
White dwarfs are mostly made by low-mass stars
Their evolution proceeds slowly, so must wait for cluster to age

Old globular clusters have white dwarfs!

Next: read S.3 “Spacetime & Gravity”
Black Holes plus – courtesy of Albert
• Einstein’s (1911) General Theory of Relativity: gravity is really the warping of spacetime around an object with much mass
• Light travels in “straight lines” – and its bending comes from spacetime being curved by gravity