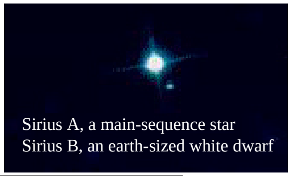
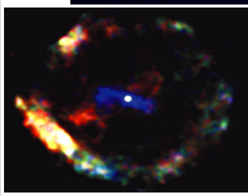
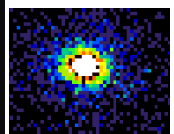
Black Holes–March 25





X-ray source G11.2-03
Supernova 386AD
Neutron star in center



Black hole
Cyg X1

- White dwarfs cannot exist with mass greater than 1.4 $M_{\odot}$. Gravity trumps pressure of degenerate electrons.
- Neutron stars cannot exist with mass greater than 3 $M_{\odot}$. Gravity trumps pressure of degenerate neutrons.
- Nothing can travels faster than light
- Black hole: escape speed exceeds speed of light.

Maximum mass for white dwarf I

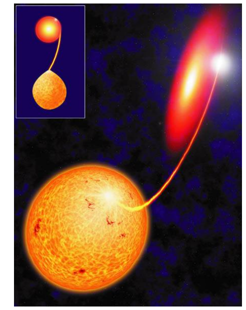
- In white dwarf, degenerate electrons cause pressure.
- Uncertainty relation

  speed × space > Planck's constant
- In normal gas,

  (Speed due to temperature) × (lots of space) > Planck's constant
- In WD,

  (Speed due to temperature) × (little space) < Planck's constant

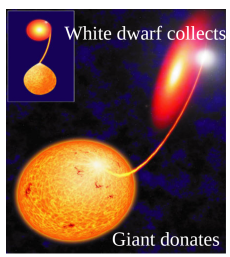
  and quantum mechanical law ⇒ speed must be higher.



Maximum mass for white dwarf II

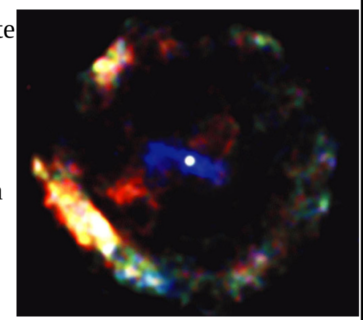
- Uncertainty relation

  speed × space > Planck's constant
- Binary star system with giant & WD.
  - Giant donates mass; WD collects
  - More mass ⇒ less space ⇒ higher speed ⇒ higher pressure to balance higher gravity
- Einstein: Nothing can go faster than light.
- Chandrasekhar: Maximum speed ⇒ maximum mass for white dwarf is 1.4M
- WD collects too much mass, & gravity wins. Star collapses & rebounds as supernova



Maximum mass for neutron star

- Neutron star has degenerate neutrons
  - For same speed, pressure is higher b/c neutrons have more mass than electrons.
- Chandrasekhar: Maximum speed ⇒ maximum mass for neutron star is $3M_{\odot}$
- If mass is greater, gravity wins. Star collapses; nothing stops collapse.



Supernova in 386AD
X-ray image showing remnant & neutron star.
Fig. 13.6

Black hole

- Escape from earth
  - To escape from earth’s gravity, a molecule must go faster than 11 km/s.
- Escape speed depends on mass and radius
  escape speed^2 is proportional to mass/radius
- If mass is big enough or radius is small enough, escape speed is bigger than speed of light.
- If sun were squeezed to 3-km radius, light could not escape from it.
- Schwarzschild radius is boundary between inside & outside.
  - Light can escape if outside Schwarzschild radius.

Black hole

1. A new compact (not MS, not giant) object is discovered in the sky. Clever astronomers measured its mass to be 2.5 $M_{\odot}$. It cannot be a
   a. NS, BH, or WD
   b. NS, BH
   c. WD
   d. BH

Black hole

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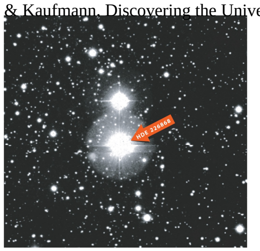
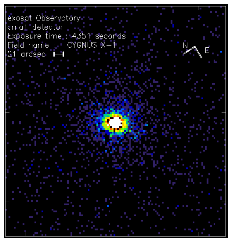
   d. BH <
- How can we detect a black hole if light cannot escape from it?

Comis & Kaufmann, Discovering the Universe

Black hole

- How can we detect a black hole if light cannot escape from it?
  - Look at something that orbits around it
  - Look at the mass that is falling into it.
- A compact star must be a black hole if its mass is greater than 3$M_{\odot}$.
- Cygnus X1
  - Bright source of X rays
  - In visible, star HD226868
  - HD226868 moves around something at 50km/s with 5 day period

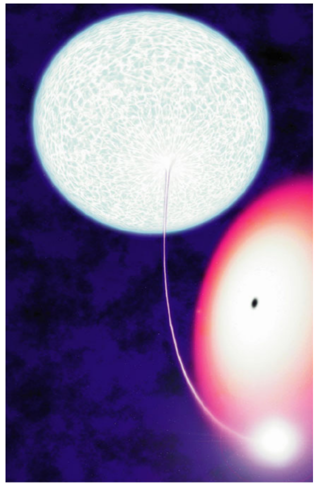




heasarc.gsfc.nasa.gov/ Images/exosat/cygx1.gif

Cygnus X1

- HD226868, a giant, donates mass to BH
  - Mass falls toward BH, moves fast, gets hot.
  - Hot gas emits X rays
- Mass of companion
  - Kepler's 3rd law: Radius & period ⇒ total mass of two stars.
    - P=5da
    - 5da & 50km/s ⇒ R.
  - Speed ⇒ mass of companion
  - Mass of companion is $10M_\odot$.
- Companion is compact
  - A $10\text{-}M_\odot$ star would be seen in visible.



2. A new binary star system is discovered in the constellation Cygnus. One star is a B giant, and the other is an O star. Both have masses greater than 10 $M_\odot$. Could either be a black hole?
   a. Yes
   b. No <

- Study guide is on angel. Announcement:

  Study guide for test 3 is ready. Go to
  http://www.pa.msu.edu/courses/2005spring/ISP205/sec-1/
  and click on "Study Guide" next to Test 3.
- Third test is Monday, 28 March