


AST1002




## ***Stellar Alchemy***

Chapter 15  
The Bizarre Stellar Graveyard

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## ***The Bizarre Stellar Graveyard***

- White Dwarfs
  - End of Low and Medium mass stars
  - Supported by electron degeneracy pressure in core
    - 1-2  $m_{\text{sun}}$  : carbon
    - More than 2  $m_{\text{sun}}$  : carbon or oxygen core
    - Much less than 1  $m_{\text{sun}}$  : helium core
  - Absolute limit on total mass 1.4  $m_{\text{sun}}$  (Chandrasekhar's Limit)

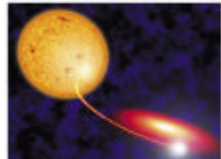
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## ***The Bizarre Stellar Graveyard***

- White dwarf's in close binary systems
  - Mass flows from companion into disk
  - Material from disk falls on white dwarf
  - Outbursts occur
    - Small = Nova
      - H fusion in shell
    - Large = type Ia Supernova
      - Carbon fusion in core



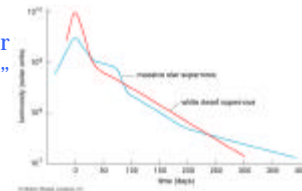
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## ***The Bizarre Stellar Graveyard***

- Type Ia Supernovae in white dwarf close binary stars
  - $10^{10} L_{\text{sun}}$
  - Distance indicator
  - "standard candle"




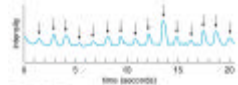
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## ***The Bizarre Stellar Graveyard***

- Pulsars
  - Jocelyn Bell detected 1967
  - Rotating neutron stars
  - Intense magnetic field

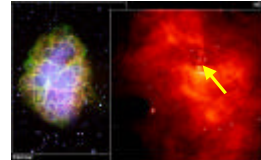
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## ***The Bizarre Stellar Graveyard***

- Pulsar sounds
  - <http://www.jb.man.ac.uk/~pulsar/Education/Sounds/sounds.html>
  - Typical
  - Vela
  - Crab
  - fastest



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### General Relativity Theory

- Gravity and Acceleration are *Equivalent*
- Light rays are bent by Gravity (even though light is a form of *Electromagnetic Radiation* and has no mass)

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### General Relativity Theory

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### General Relativity Theory

- Gravity and Acceleration are *Equivalent*
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### A Review of Geometry

- Triangles
  - sum of the angles is  $180^\circ$
- Parallel Lines
  - meet only at infinity
  - crossed at equal angles by third line

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### A Review of Geometry

- Triangles
  - sum of the angles is  $180^\circ$
- Parallel Lines
  - meet only at infinity
  - crossed at equal angles by third line
- This is *Plane or Euclidean Geometry*

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### A Review of Geometry

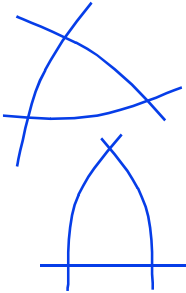
- Triangles
  - sum of the angles is greater than  $180^\circ$
- Parallel Lines
  - meet at the poles
  - crossed at equal angles by third line

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### A Review of Geometry

- Triangles
  - sum of the angles is greater than  $180^\circ$
- Parallel Lines
  - meet at the poles
  - crossed at equal angles by third line
- This is **non-Euclidean Geometry** with **positive curvature**

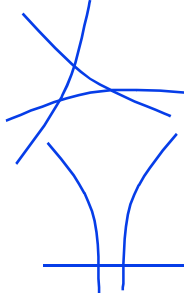


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### A Review of Geometry

- Triangles
  - sum of the angles is less than  $180^\circ$
- Parallel Lines
  - never meet
  - crossed at equal angles by third line

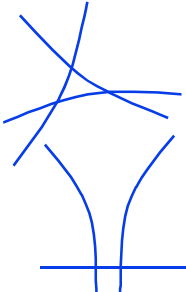


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### A Review of Geometry

- Triangles
  - sum of the angles is less than  $180^\circ$
- Parallel Lines
  - never meet
  - crossed at equal angles by third line
- This is **non-Euclidean Geometry** with **negative curvature**

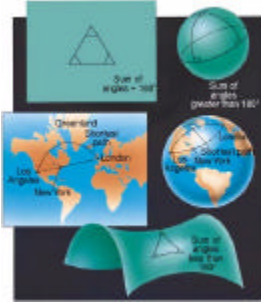


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### Shapes for Space

- flat
- positive
- negative



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### A Review of Geometry

- Define a straight line

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### A Review of Geometry

- Define a straight line
  - A straight line is the shortest distance between two points

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### **A Review of Geometry**

- Define a straight line
  - A straight line is the shortest distance between two points
- Nothing can travel faster than the speed of light

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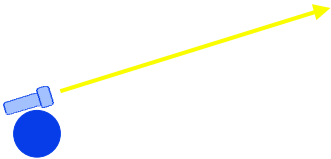
### **A Review of Geometry**

- Define a straight line
  - A straight line is the shortest distance between two points
- Nothing can travel faster than the speed of light
- There is no path between two points that is shorter than the path taken by light between those points

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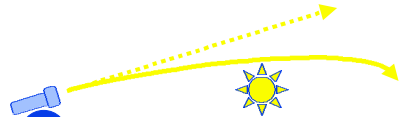
### **Gravity Warps Space**



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### **Gravity Warps Space**

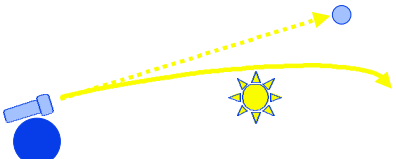


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### **Gravity Warps Space**

- Try to hit Mercury with a light beam

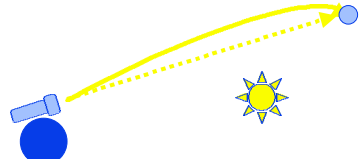


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### **Gravity Warps Space**

- Try to hit Mercury with a light beam
  - need "Tennessee" windage



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### Gravity Warps Space

- Try to hit Mercury with a light beam
  - need "Tennessee" windage
- Now bounce to Venus

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### Gravity Warps Space

- Try to hit Mercury with a light beam
  - need "Tennessee" windage
- Now bounce to Venus
- And complete the triangle

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### Gravity Warps Space

- Try to hit Mercury with a light beam
  - need "Tennessee" windage
- Now bounce to Venus
- And complete the triangle

- the sum of the angles is greater than 180°

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### The Bizarre Stellar Graveyard

- Black Holes and the geometry of Space-Time
  - A 2-dimensional representation of a 3-D reality

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### The Bizarre Stellar Graveyard

- Radiation is red shifted
- Clocks appear to run slow

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### The Bizarre Stellar Graveyard

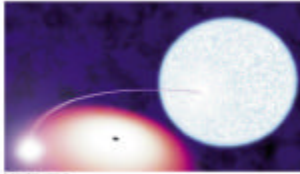
- Tidal forces
  - $F_{\text{gravity}} = G (m_1 \cdot m_2) / r^2$
  - Gravity pulls more strongly on feet than head

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 **The Bizarre Stellar Graveyard**

- “Observations” of Black Holes
  - Material falling into a black hole becomes very compressed and thus very hot
  - Result
    - Gamma rays
    - X-rays




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 **The Bizarre Stellar Graveyard**

- Gamma Ray Bursters
  - Burst of gamma rays lasting a few seconds
  - Seen by military satellites in 1960's
  - Seen in equal numbers in all directions



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**Questions and/or Comments?**

**Let me know at [oliver@astro.ufl.edu](mailto:oliver@astro.ufl.edu)**

**or visit <http://www.astro.ufl.edu/~oliver/>**