Announcements

- Show and tell
  - Constellations are random . . .
  - Human brains detect patterns (even when they are not there!)
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- Problem Set #1 available on line
  - Practice with scientific notation and units
  - Due next Friday
  - Score vs letter grades correct on web site
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  - Constellations are random . . .
  - Human brains detect patterns
    (even when they are not there!)
- Problem Set #1 available on line
  - Practice with scientific notation and units
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- Please read Chapters 1 & 2
  - Note: In class, I will not cover all material in the reading!
Announcements

Last class: Distance in meters (m) over 40 orders of magnitude
Powers of ten

Concept of powers of ten or orders of magnitude is related to the ????????
Powers of ten

Concept of powers of ten or orders of magnitude is related to the logarithm:
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\[ y = 10^x \]

\[ x = \log_{10}(y) \]
Powers of ten

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Examples:
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Examples:

\[ \log_{10}(1000) = 3 \quad \text{or} \quad \log_{10}(10^3) = 3 \]

\[ \log_{10}(3000) = 3.48 = 3 + 0.48 \]

\[ 10^{3.48} = 10^3 \times 10^{0.48} = 1000 \times 3 \]
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\[ \log_{10}(3000) = 3.48 = 3 + 0.48 \]
\[ 10^{3.48} = 10^3 \times 10^{0.48} = 1000 \times 3 \]

\[ \log_{10}(y^3) = \log_{10}(10^{3x}) = 3x \]
\[ \log_{10}(y^n) = n \log_{10}(y) \]
### Sample data

<table>
<thead>
<tr>
<th>Standard notation</th>
<th>Scientific notation</th>
<th>Logarithmic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>Luminosity</td>
<td>Mass</td>
</tr>
<tr>
<td>12.6040</td>
<td>2944.8000</td>
<td>1.260 × 10^1</td>
</tr>
<tr>
<td>0.1985</td>
<td>0.0113</td>
<td>1.985 × 10^-1</td>
</tr>
<tr>
<td>4.8718</td>
<td>113.2200</td>
<td>4.872</td>
</tr>
<tr>
<td>12.0320</td>
<td>1294.5000</td>
<td>1.203 × 10^1</td>
</tr>
<tr>
<td>0.4725</td>
<td>0.0874</td>
<td>4.725 × 10^-1</td>
</tr>
<tr>
<td>0.9354</td>
<td>0.5180</td>
<td>9.354 × 10^-1</td>
</tr>
<tr>
<td>3.5567</td>
<td>47.2800</td>
<td>3.557</td>
</tr>
<tr>
<td>2.7732</td>
<td>23.2680</td>
<td>2.773</td>
</tr>
<tr>
<td>5.2466</td>
<td>129.5900</td>
<td>5.247</td>
</tr>
<tr>
<td>0.1825</td>
<td>0.0080</td>
<td>1.825 × 10^-1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Direct plot of data

- Y-axis: Luminosity ($L_\odot$)
- X-axis: Mass ($M_\odot$)
Logarithmic plot

Luminosity ($L_\odot$) vs. Mass ($M_\odot$)
Logarithmic plot

Logarithmic axes
Location of points in space

- One dimensional
Location of points in space

One dimensional
- Number line
- Mile markers on a highway
Location of points in space

- One dimensional
  - Number line
  - Mile markers on a highway
- Two dimensional
Location of points in space

- One dimensional
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- Two dimensional
  - Battleship game
  - Longitude and latitude
Location of points in space

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- N-dimensional . . .
Location of points in space

- One dimensional
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- Two dimensional
  - *Battleship* game
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- N-dimensional . . .
  - $N = 3$, cubic grid, spherical grid
  - $N = 4$, time and space
  - $N = 10, 11, 26$, string theory
Two-dimensional coordinate systems (1/2)

Rectangular grid

Polar grid
Two-dimensional coordinate systems (2/2)

Projection of sphere onto paper
Astronomical measurement

Measuring distance directly is hard
Astronomical measurement

- Measuring distance directly is hard
- Measuring angles on the sky is easy
Astronomical measurement

- Measuring distance directly is hard
- Measuring angles on the sky is easy
- Strategy: measure angles and infer distance
Geometry of distance (1/4)

\[ \frac{\theta}{2} \]

\[ d \]

\[ \frac{D}{2} \]
$D/2 = d \sin(\theta/2)$
Geometry of distance (1/4)

\[ D/2 = d \sin(\theta/2) \]

\[ D = 2d \sin(\theta/2) \]
When the angle is very small:

\[ \sin(\theta) \approx \theta \]

where the angle \( \theta \) must be expressed in radians

\[ D = 2d \sin(\theta/2) \Rightarrow D = d\theta \]
Surveyor’s transit:
Used to measure terrestrial angles for surveying
Examples: size of Moon, distance to Sun

\[ \theta \]
\[ d \]
\[ D \]
Examples: size of Moon, distance to Sun

\[ D = d\theta \]
\[ d = D/\theta \]
Small angle formula: \( D = d\theta \) where \( \theta \) is in radians.
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$2\pi$ radians is 360 degrees so:

$$D = d \frac{2\pi}{360} \theta$$

where $\theta$ is in degrees.
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\( 2\pi \) radians is 360 degrees so:
\[ D = d \frac{2\pi}{360} \theta \]

where \( \theta \) is in degrees.

A degree is often too large a unit

- Divide one degree into 60 minutes
- Divide one minute into 60 seconds

\[ D = d \frac{2\pi}{360} \frac{1}{60} \frac{1}{60} \theta \]

and doing the arithmetic:
\[ D = \frac{d\theta}{206,265} \]

where \( \theta \) is in seconds of arc.
The Parsec

Earth moves around Sun in nearly a circle
The Parsec

- Earth moves around Sun in nearly a circle
- Diameter of orbit is 1 astronomical unit (1 AU = $1.5 \times 10^{11}$ m)
The Parsec

- Earth moves around Sun in nearly a circle
- Diameter of orbit is 1 astronomical unit (1 AU = $1.5 \times 10^{11}$ m)
- Define a parsec as the distance of an object if angle on the sky changes by one second of arc for a baseline of 1 AU
More distance units

- **Light year**: distance light travels in a year, $9.6 \times 10^{12}$ km
- **Parsec (pc)**: $3.1 \times 10^{13}$ km = 1.3 ly
- **Kilo parsec (kpc)**: 1,000 = $10^3$ pc
- **Mega parsec (Mpc)**: 1,000,000 = $10^6$ pc
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- **Solar system**: 100 AU = 100/206,265 pc = 0.0005 pc
- **Milky Way galaxy**: 40,000 pc = 40 kpc
- **Local group of galaxies**: few Mpc
- **Great wall**: 100 Mpc
- **Observable Universe**: 3,000-6,000 Mpc
Location of Galaxies