


# Chapter 18

## Celestial Distances




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### 18.1 Fundamental Units of Distance

- Imperial (American) system
  - Distance: Foot
  - Volume: Gallon
  - Mass: Pound
- SI system (metric system)
  - Distance: Meter
  - Volume: Liter
  - Mass: Gram
- Bonus question: name all the countries that use the imperial system

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### 18.1 Fundamental Units of Distance

- Astronomical Unit - solar system
  - Earth-to-Sun = 1 AU
  - Measurements confirmed today using radar
  - Signals to/from spacecraft: measure round-trip time and divide by two
  - Cannot measure Sun with radar, but can use distances to other planets and Kepler's laws to determine 1 AU




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## 18.2 Surveying the Stars

- Distance to the stars
  - Units of distance
    - Light year
    - Parsec

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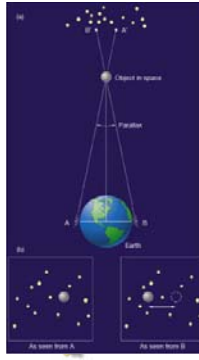
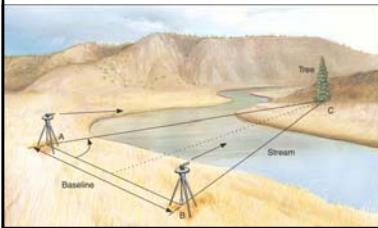
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## 18.2 Surveying the Stars

- Distance to the stars
  - Triangulation: parallax
    - Surveying
    - Astronomy
      - Friedrich Bessel: 1838



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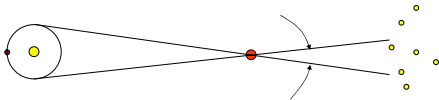
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## 18.2 Surveying the Stars

- Distance to the stars
  - Parsec
    - Term origin: parallax of one arc-second
    - Distance = inverse of parallax  $d = 1/p$
    - 1 parsec = 3.26 LY



- Parallaxes measured for about 10,000 stars from Earth

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## 18.2 Surveying the Stars

- Distance to the stars
  - HIPPARCOS satellite: High Precision Parallax Collection Satellite
    - 100,000 stars in program



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## 18.2 Surveying the Stars

- Naming Stars
  - International Star Registry



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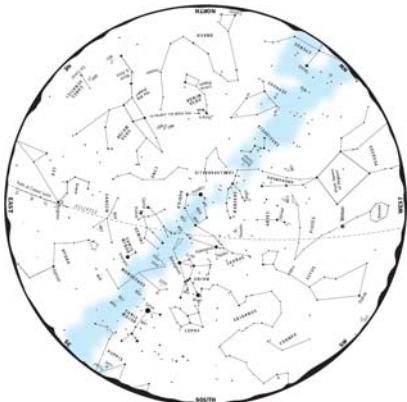
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## 18.2 Surveying the Stars



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## 18.2 Surveying the Stars

- Naming Stars
  - Set by the International Astronomical Union
  - Proper names
    - Arabic translations of Greek and Roman astronomy
    - Examples:
      - Betelgeuse: *The Armpit of the Giant*
      - Rigel: *The Left Leg of the Giant*
      - Aldebaran: *The Follower*
      - Procyon: *Before the Dog*
      - Capella: *The Little She-goat*

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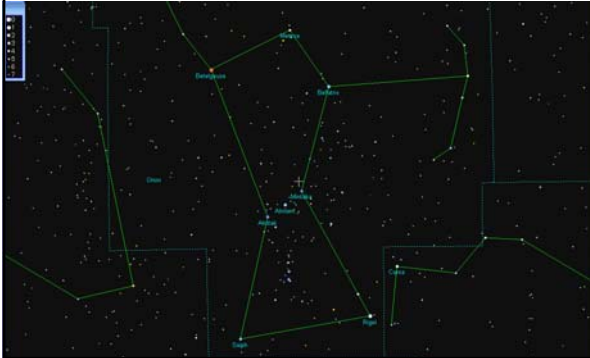
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## 18.2 Surveying the Stars

- Naming Stars: Proper names




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## 18.2 Surveying the Stars

- Naming Stars
  - Johann Bayer: German
    - 1603
    - Greek alphabet
    - Betelgeuse =  $\alpha$  Orion



$\alpha$ alpha	$\iota$ iota	$\rho$ rho
$\beta$ beta	$\kappa$ kappa	$\sigma$ sigma
$\gamma$ gamma	$\lambda$ lambda	$\tau$ tau
$\epsilon$ epsilon	$\mu$ mu	$\upsilon$ upsilon
$\delta$ delta	$\nu$ nu	$\phi$ phi
$\zeta$ zeta	$\xi$ xi	$\chi$ chi
$\eta$ eta	$\omicron$ omicron	$\psi$ psi
$\theta$ theta	$\pi$ pi	$\omega$ omega

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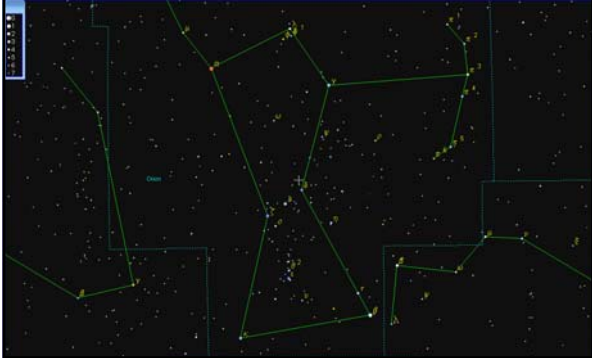
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## 18.2 Surveying the Stars

- Naming Stars: Bayer



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## 18.2 Surveying the Stars

- Naming Stars
  - John Flamsteed: English
    - 1725
    - Numbers from west to east in a given constellation
    - Betelgeuse =  $\alpha$  Orion = 58 Orion
  - Other general catalogs
    - HD: Henry Draper Catalogue
    - SAO: Smithsonian Astrophysical Observatory
    - BD: Bonner Durchmusterung (German)
    - USNO-B1.0: US Naval Observatory
    - HGSC: [Hubble Guide Star Catalog](#)



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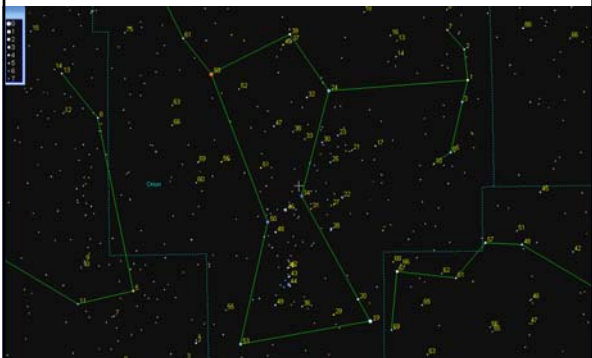
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## 18.2 Surveying the Stars

- Naming Stars: Flamsteed



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## 18.2 Surveying the Stars

- Naming Stars
  - Other general catalogs
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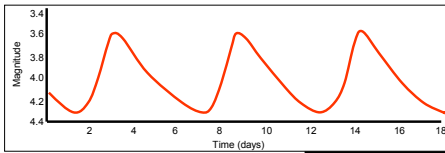
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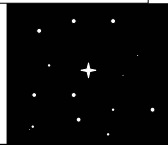
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## 18.3 Variable Stars

- Breakthrough in measuring distances to the stars came from the study of **variable stars**
  - These strange stars actually change in light output



- Three types of variable stars
  - Pulsating variables
  - Erupting variables
  - Eclipsing binaries



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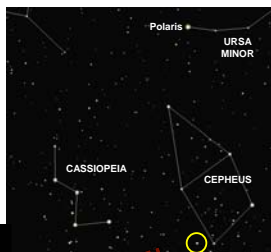
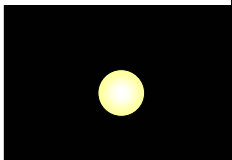
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## 18.3 Variable Stars

- Cepheid variables
  - Named for Delta Cephei
  - Periodically expand and contract: "breathing"
  - Large, yellow stars
  - Periods = 3 to 50 days
  - Luminosities = 1,000 to 10,000 times the Sun



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### 18.3 Variable Stars

- Cepheid variables
  - Period-Luminosity relationship
    - Discovered by [Henrietta Leavitt](#) (1868-1921)
    - Studied stars in Magellanic Clouds
      - Satellite galaxies of Milky Way
      - Stars within considered to be the same distance away
      - Found that the longer its period, the greater the star's luminosity




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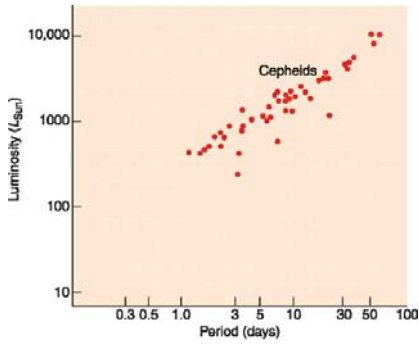
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### 18.3 Variable Stars




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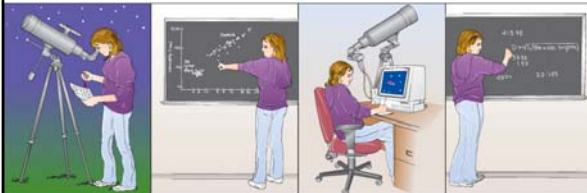
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### 18.3 Variable Stars

- Cepheid variables
  - Period-Luminosity relationship
    - Knowing distances to nearby Cepheids by parallax, astronomers calibrated the system



Find a Cepheid variable star and measure its period      Use the Period-Luminosity Law to calculate the star's luminosity      Measure the star's apparent brightness      Compare the luminosity with the apparent brightness to calculate the distance

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### 18.3 Variable Stars

- RR Lyrae stars
  - Pulsating variables
  - Named for prototype star in constellation Lyra
  - Similar in behavior to Cepheids
    - Period-luminosity relationship
  - Very short periods
    - Always less than one day
  - More common but less luminous
    - Can be detected to 2 million LY
    - Cepheids to 60 million LY

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### 18.3 Variable Stars

- RR Lyrae stars
  - Visible in star clusters
    - All stars within are at the same distance from Earth
    - All RR Lyrae stars in a given cluster shine at same magnitude, so must have same luminosity: like a standard light bulb
    - Once we know magnitude and luminosity, we can calculate distance using the inverse-square law



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### 18.4 H-R Diagram and Cosmic Distances

- So far, we have seen how to measure the distance to a:
  - Nearby stars: parallax
  - Cepheid/RR Lyrae variables: Period-luminosity relationship
  - Cluster stars: Use Cepheids or RR Lyrae
- But what if the star we want to measure is not variable or in a star cluster?

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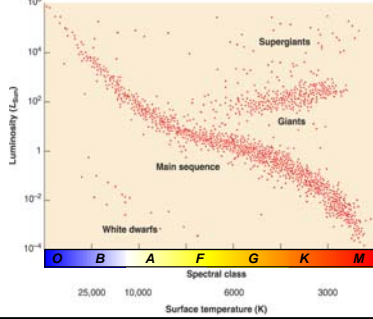
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### 18.4 H-R Diagram and Cosmic Distances

- We can use the H-R Diagram from chapter 17
- What did it show?




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### 18.4 H-R Diagram and Cosmic Distances

- The H-R Diagram classifies stars by spectral type and temperature based on spectral analysis
- Astronomers can also tell:
  - Diameters using differences in pressure
    - Giant stars - lower pressures
    - Dwarf stars - higher pressures
- From this, astronomers created **luminosity classes**

Class	Description	Typical Luminosity (solar luminosities)
Ia	Bright supergiants	500,000
Ib	Supergiants	8,000
II	Bright giants	1,300
III	Giants	100
IV	Subgiants	25
V	Main-sequence stars/dwarfs	Entire range of values

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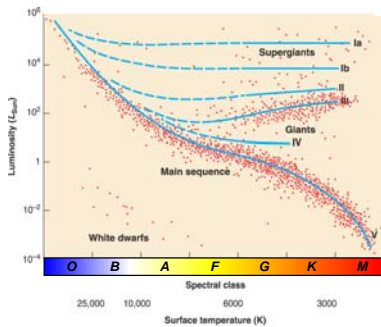
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### 18.4 H-R Diagram and Cosmic Distances

- Luminosity classes




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#### 18.4 H-R Diagram and Cosmic Distances

- Luminosity classes

1. A1 V

2. G2 V

3. M2 Ib

4. B8 Ia

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