Properties of Stars

star - basic building block of universe

What are stars like? intrinsic properties?

problem:

through telescope
only see a point of light

how to find:

energy emitted
surface temperature
diameter
mass

Distance to Stars

most important and most difficult measurement

surveyors use trig.
with length and angles to calculate distance

astronomers need long baseline and good angular resolution

Parallax, \( p \) - apparent change in position due to movement of observer

VERY narrow triangles measure shift in seconds of arc

1 sec = \( 1^\circ / 3600 \)

30 sec = paper thickness at arm’s length

\[ d \text{ (parsec)} = \frac{1}{p} \text{ (sec)} \]

for baseline 1 AU

1 parsec = 3.26 ly

Earth based measurements only accurate to about 0.02 sec
due to atmospheric turbulence
limited to stars within 50 pc (parsec)

European Space Agency - Hipparcos satellite 1989
120,000 stars with parallax to 0.001 sec

Brightness and Distance

brightness = flux of energy

Trifid Nebula - stars born in center of cloud
Luminosity, $L$ total energy emitted per second in all $\lambda$

- $\text{Sun} \Rightarrow 4 \times 10^{26} \text{ J/s}$
- other stars compared with Sun
  - must correct for temperature (color)

**Spectra of Stars**

- absorption spectra
- dark line
  - from hydrogen in atmosphere
- strength of lines
  - how dark depends on $T$
  - by studying strength can determine $T$

**classify stars into spectral types**

- $O$ 40,000 K
- $B$ 20,000 K
- $A$ 10,000 K
- $F$ 7,500 K
- $G$ 5,500 K
- $K$ 4,500 K
- $M$ 3,000 K

Careful spectral analysis and modeling $\Rightarrow$ identify elements complicated by temperature effects

<table>
<thead>
<tr>
<th>element</th>
<th>% atoms</th>
<th>% mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>91.0</td>
<td>70.9</td>
</tr>
<tr>
<td>Helium</td>
<td>8.9</td>
<td>27.4</td>
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<tr>
<td>Oxygen</td>
<td>0.07</td>
<td>0.8</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.03</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Hertzsprung-Russel (H-R) Diagram

How do we measure the diameter of a star, when all (except the Sun) appear as points?

For a given spectral type, luminosity is proportional to area, \( A \), gives diameter, \( D \):

\[
L \propto A \propto D^2
\]

period and separation distance gives the 2 masses
over half of all stars are members of multiple systems

\( \Rightarrow \) binaries common

Visible Binary
both stars can be seen
have long periods
Sirius

- brightest star in sky
- white dwarf companion visible in image from Chandra x-ray satellite
- period $\approx 50$ yr

Spectroscopic Binary

- visible as single point
- spectral line shifts in opposite directions due to Doppler Effect

Eclipsing Binary

- orbit tipped so stars cross in front of each other as seen from Earth
- brightness varies

Algol

- visible to naked eye with spectral lines can give most information

Family of Stars

- finding patterns in Mass, luminosity, Density
add Mass $M/M_{\text{sun}}$ to H-R Diagram

Main sequence ordered!

**Mass-Luminosity relation**
for stars in
Main sequence
normal density $\sim 1 \text{ gm/cc}$

white dwarfs (open circles)
different relation
high density

Giants
low density

**Frequency of Stellar Types**

red dwarfs - lowest mass
main sequence stars
most common

white dwarfs,
also common

highly luminous, rare