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 = \( \frac{1}{3600} \)°

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
Luminosity, $L$ total energy emitted per second in all $\lambda$

Sun $\Rightarrow 4 \times 10^{26}$ 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>
</tr>
<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>
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</tbody>
</table>
How do we measure the diameter of a star, when all (except the Sun) appear as points?

find some pattern or classification that groups objects and allows prediction of unknown quantity

For a given spectral type, luminosity is proportional to area, $A$ gives diameter, $D$: $L \propto A \propto D^2$

**H-R Diagram**

$L/L_{\text{sun}}$ vs $T$

- **Main sequence**
  - 90% of stars

- **Giants**
  - cool
  - large area

- **Supergiants**
  - $10-1000 \times \text{Sun}$

- **White dwarfs**
  - very faint
  - very hot
  - very dense

For a given spectral type, luminosity is proportional to area, $A$
gives diameter, $D$: $L \propto A \propto D^2$

**Binary Stars $\Rightarrow$ Mass**
two close stars
orbit each other about center of mass

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

**Table:**

| Neon | 0.01 | 0.2 |

11/2/2001
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
tip of orbit unknown $\Rightarrow$ only get lower limit to masses

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 $\sim 1$ 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