Why Should We Be Interested in Astronomy At All?

The Ancients:

- **Judging the seasons:**

In Ancient times, astronomical knowledge was important for the prediction of the changing seasons.

Many early calendars were based on the lunar cycle rather than a yearly one.

Different constellations in the sky indicate a different season. "Orion" is a winter constellation.

- **The importance of the moon:**

The changes in the appearance of the moon (its *phases*) should remind you of another excellent reason for the ancients to be interested in astronomical phenomena. Knowing when the moon will be full, for instance, allows one to judge whether it is feasible to go out hunting or to harvest grain late into the evening. The beautiful full moon of late September is still called the "Harvest Moon" for this reason, and (I suppose) benefits farmers just as it always did. The October full moon is known as the "Hunters' Moon."

- **Using the stars for navigation:**

Many ancient civilizations encouraged enthusiastic exploration. In the open sea the stars overhead to keep one oriented.

The best-known application of this is the use of the North Star as a signpost. Since the Earth spins once a day, the whole pattern of stars moves across the sky at night just as the sun does during the day, but the North Star lies almost directly above the Earth's North Pole, so its motion is minimal and it is, to a very good approximation, always in the same place in the sky.

If you ever get lost in the woods and need to walk out to civilization, you need merely find the North Star to figure out your directions. Unfortunately this is not very useful for people who live in the *southern* hemisphere, since there is no single conspicuous star directly above the South Pole of the Earth. But if you learn the southern constellations, you will know how to recognize the patch of sky directly over the South Pole.

- **For timekeeping:**

Just as your modern watch is set to record the passage of one full day in accordance with the regular reappearance of the sun, so too the stars at night, wheeling overhead, mark off the passage of the hours. It is possible, for instance, to develop the ability to tell the time by the stars, using the `handle' of the Big Dipper as the `hand' of a giant clock in the sky. It is interesting to note, by the way, that the first clocks were built to run `clockwise' because that is the direction in which the shadow on a sundial moves (in the Northern hemisphere) as the sun crosses the sky during the day.

- **The religious significance:**

The heavens commonly had religious associations in many civilizations.

In Modern Times:

- **For navigation**:

To know where one is on the Earth, one usually relies on maps which are carefully drawn to meticulous scale, often through the use of images taken by satellites. Fundamentally, all such map-making is with reference to the stars.

- **For timekeeping:**

For centuries, all our timekeeping has been predicated on the fact that the sky provides a great natural clock for us: we see the sun go around us once a day (since we spin) and go across the field of background stars once a year (since we orbit around it and see it in front of different stars at different times). There are now other ways of keeping time, using atomic clocks for instance; but astronomical timekeeping services are still important.

- **To have frontiers to explore:**

Human society is fragile, and there are reasons for thinking that it may be important for our continued stability to have some sense of purpose, some unexplored frontier to investigate. Eventually we will have visited every corner of the Earth, including the deep oceans, and space will then remain, in the words of Star Trek, the *'Final Frontier.'*

- **To appreciate our own insignificance:**

A consideration of our insignificance on the scale of the universe may be important.

- **To appreciate our fragility:**

The Earth has a fragile ecosystem, and most of us are well aware of the dangers of producing uncontrolled amounts of toxic waste. But it is also true that there are dangers from the reaches of space, two of which are or have lately been on dramatic display.

  - The first is the danger of *global warming,* the steady climb in the Earth's atmospheric temperature because of our production of exhaust gases and our depletion of forested areas. The planet Venus provides a clear warning: the greenhouse effect there has made that planet utterly uninhabitable, with a surface hot enough to melt lead.

  - The second threat comes from the fact that we are, in a sense, in a *cosmic shooting gallery,* in a solar system filled with small chunks of rock and ice (asteroids and comets) flying about in all directions. Occasionally, these chunks can hit the Earth, and indeed such an impact is thought to have led to the extinction of the dinosaurs 65 million years ago. This danger was reinforced some years ago when Comet Shoemaker-Levy (found by a team which included David Levy, a Queen's alumnus) ran into Jupiter, with spectacular consequences.

- **To search for nearly inexhaustible supplies of power and resources:**

The Earth has limited resources, and if the human population is to continue to grow (which we might not all think is a good idea!) it will need new sources. There is no reason, for instance, why we might not go out to one of the millions of asteroids to find fresh supplies of easily-extracted metal ore for manufacturing purposes. Similarly, it may be possible to collect from space the energy produced by the sun and stars in a more efficient manner than at present from the ground. We may even, through a study of astronomy, learn to mimic on Earth what only the stars can do so far: contain a controlled nuclear fusion reactor yielding a long-term, reliable source of energy.

- **To search for habitable external worlds:**

A growing population also needs more *room,* and it may be necessary at some stage to provide other habitable locations for the human race. Even if you think that unconstrained growth is unwise, there may be good sociological reasons for providing the prospect of colonization and expansion to other worlds. What if some global catastrophe should fall on the Earth?

- **To search for intelligent extraterrestrial species:**

The question of our uniqueness in the cosmos is a very deep one. We now live at the very special time at which it may be possible to make a first contact with ETs - if they exist! If we were to make contact, the consequences would surely be profound: such a discovery would have a huge impact on our society and psychology. We might hope to learn a great deal from such species and, perhaps, to learn how really insignificant are the differences between ourselves, differences to which people pay far too much attention.

- **On the chance that some really important technical discovery may be made**:

In astronomy, we study the physics of matter in extreme conditions: in intensely strong gravitational fields, the vacuum of space, weightless conditions, or the unimaginably high densities in neutron stars or near black holes. Who can predict what important understanding might result, and where it might lead?

- **Just for the love of knowledge!**

This is the best reason of all for doing astronomy!

<u>**Models of the Solar System**</u>

The observations that you have been making of the Sun, Moon and stars were the same observations made by early scientists. In order to understand the world we live in these scientists came up with models to explain the patterns they saw.

<u>Aristotle</u>

- ________ model
- ________ to imagine
- ______ was a gigantic ______ with the ______ at the ________. On this sphere was attached the ____, _____ and ______.
- ___________ ________ (Earth -Centered Model)

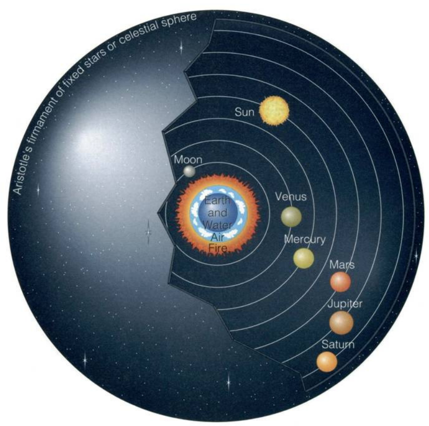


Figure 13.7 Aristotle's Earth-centred model, with its outer celestial sphere and many inner spheres. Since the stars on the celestial sphere were visible from Earth, it was reasoned that the inner spheres had to be "crystalline," or transparent.

This model was accepted by scientists even though it could not explain the ____________ motion of Mars, Jupiter and Saturn.

<u>Nicholas Copernicus</u>

- early 1500s
- Sun was at the ________ of the model and the ________ rotated around the Sun on the same ______ _______
- _____________ _________ (Sun-Centered Model)

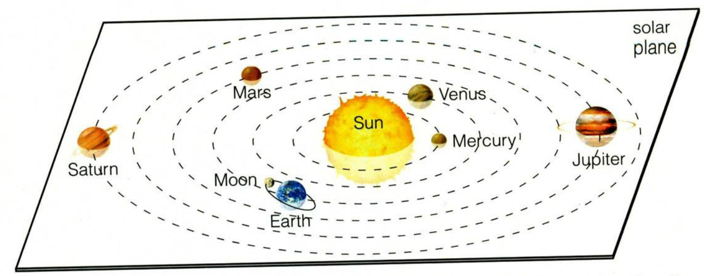


Figure 13.8 The solar plane. Imagine cutting an orange in half and then placing the two halves back together with a large piece of paper between them. All the planets would lie on or near the paper.

<u>Galileo</u>

- used a ___________ and provided evidence that ___________ the Heliocentric Model
- Galileo saw the _______ ___________, rings of _______, four moons of ________ and noted that ________ showed phases like the Moon

This model had some problems predicting planetary motions.

Kepler

- Used _______ and deduced that the orbits were not circles but ____________. (football shaped)
- Along with Sir Isaac Newton's _____ ___ ___________ predictions of _________ _______ were more successful.

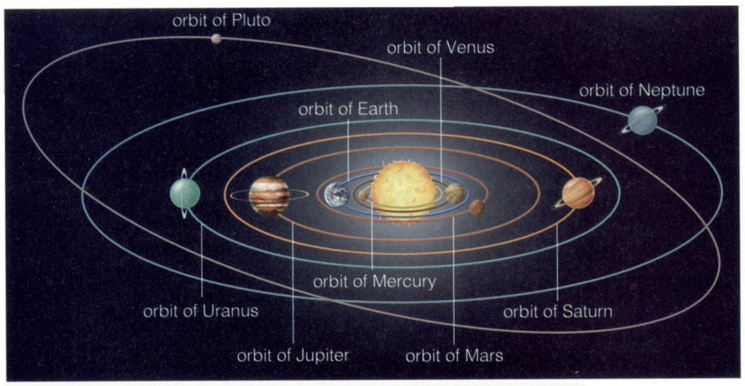


Figure 13.14 Pluto's orbit compared to the orbits of other planets. (Planet sizes are exaggerated.)

In 1781, using the Sun-Centered model and Newton's Laws astronomers predicted the position and orbit of another planet and found ____________.

The Planets

- the planets that orbit our Sun are different from one another but there are similar features
- inner planets (Mercury, Venus, Earth and Mars are called the terrestrial planets because they are rocky in composition
- outer planets (Jupiter, Saturn, Uranus and Neptune) are all gaseous in composition

Pluto is in a category all by itself.

In order to study the planets we need a scale. We use Earth as a standard to establish our scale.

For example:

Diameter of the Earth is 12 750 km = 1 Earth-diameter
∴ Venus which 12 100 km in diameter
=

and Jupiter which is 143 200 km in diameter
=

Similarly we use Earth-mass, Earth-density etc.
For distances we use Astronomical Units (AU) instead of kilometers.

1 AU=

So the Earth is 1 AU from the Sun and Mars (228 000 000 km) is

Other Solar System Bodies

The solar system does not only contain the Sun, planets and moons.
For example:

Asteroids

- between ______ and _________ there is the asteroid belt
- asteroids are known as "_________ _________"
- range in size from ____ metre to hundreds of __________
- largest is _________ (1000 km)
- _________ rich materials
- potential ____________ hazard

Comets

- mainly ______ and _____ (dirty snowball)
- as they orbit the Sun, material _________ forming the tail
- the tail ________ points away from the Sun
- Halley's comet orbits the Sun every ____ years (1986)

Meteors and Meteorites

- Earth is bombarded everyday by _____ and _______ fragments from space
- when one of the objects ________ up generating light to make it visible they are called __________
- any of these fragments that are ________ enough or tough enough to crash on the ________ _________ are known as ______________

The Sun....

is a huge ball of very hot *gas* (71% H, 26% He)

has a mass of 1.99 x 10^{30} kg

(over 330 000 times more massive than Earth)

(contains 99.9% of the mass of the Solar System)

has a diameter of 1.4 million km

(over 110 times the Earth)

is about 150 million kilometres away

(1 AU=*149.599* million km)

has a surface temperature of about 6000^0C

has a core temperature of about 15 000 000^0C

rotates about its axis once every 27-35 days

is always bubbling and churning which causes

Sun Spots (cooler regions that appear dark)

Solar Flares (bursts of particles spewed into space)

Prominences (streams of gas that arch into space)

<u>The Properties of Stars</u>

Remember stars are hot glowing spheres of gas like our Sun.

The light from a star (starlight) tells us about the _________, _________, ___________, ____________, ________ and ______

Light is a form of energy

- only form of energy we can detect with our _____
- other forms of energy that come from stars are:

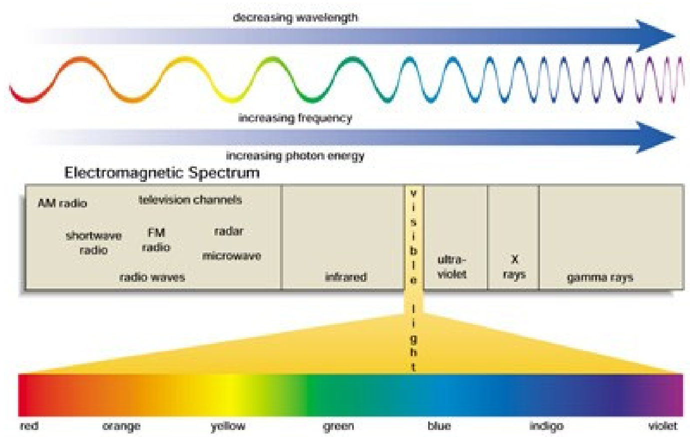


Figure 3.5. This vast range of electromagnetic radiation is emitted naturally in the universe.

radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays and gamma rays

- special instruments can detect these forms of energy

Some stars may seem brighter because:

-

or

-

-

Luminosity is:

- total amount of __________ a star radiates per second
- some stars are ___________ more luminous than the Sun
- some stars are ___________ less luminous than the Sun

Different ____________ of stars represent a different temperature

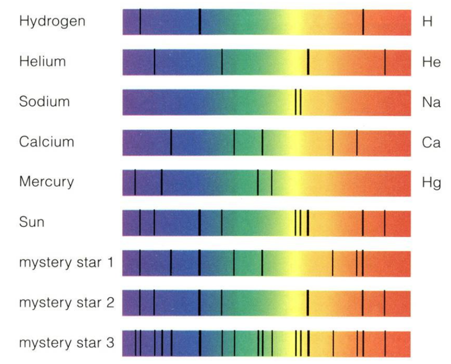
For example:

Red -

Yellow (Sun) -

Blue - to

Astronomers use a spectroscope to analyze the spectrum or colour of a star.
The spectrum of a star tells us the elements that make up a star.



Investigation 14-A (p.465)

Analyze:

1. The Sun's spectrum shows lines for Hydrogen, helium and sodium.
2. Mystery stars 1 and 3 have calcium lines.
3. Mystery star 3 contains sodium.
4. Mystery star 4 contains mercury.
5. Mystery star 3 because it contains the heavy elements missing in the Sun's spectrum.
6. By comparing the pattern of dark lines in a star to each element's spectrum, astronomers can determine the individual elements that make up a star.

Solar mass is used to express the mass of a star.

- One Solar Mass is equal to the ______ ____ ____ ______ (1 Solar mass = 2.0×10^{30} kg)

The Hertzsprung-Russell diagram shows the different types of stars and the relationship between ________, ___________, ___________ and _______.

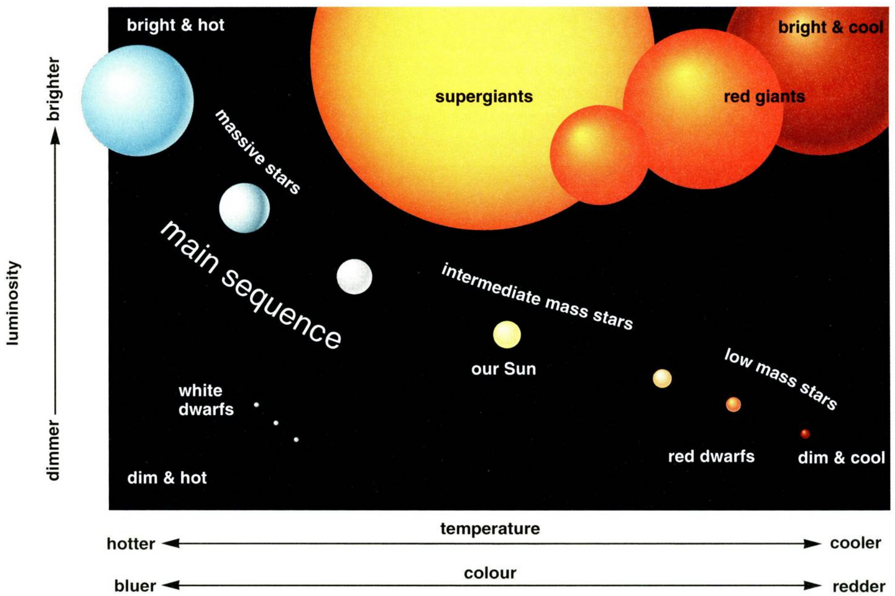
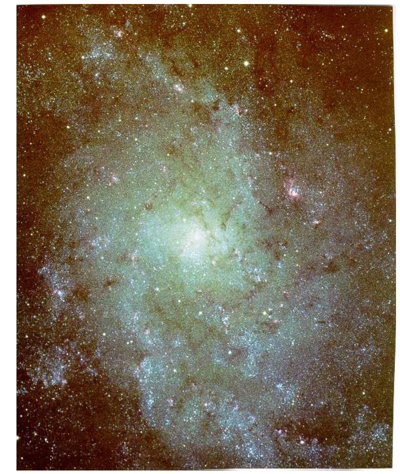


Figure 14.7 This simplified version of the Hertzsprung-Russell diagram is based on data from thousands of stars. It shows that there is a relationship among star colour, temperature, luminosity, and mass. Once astronomers recognized this pattern, they realized that stars were not unchanging and eternal after all. As you will discover in section 14.2, they have a definite, predictable life cycle.

The Life Cycle of a Star

Stars are formed inside massive clouds of dust and gas called a __________.



__________ pulls the dust and gas together into an ever-shrinking ball…

- as the ball of gas (mostly __________) gets smaller it gets __________
- when the temperature hits _______________ nuclear fusion begins and __________ atoms combine to form __________.

The hot material in the core pushes __________, but gravity pulls the material back __________. A star becomes ________ when these two forces are balanced and is defined a _______ __________ ______.

Our Sun is in this state now. The time a star remains in the stable main sequence state is determine by its ______ and its eventual fate of the star is also determined by its _____.

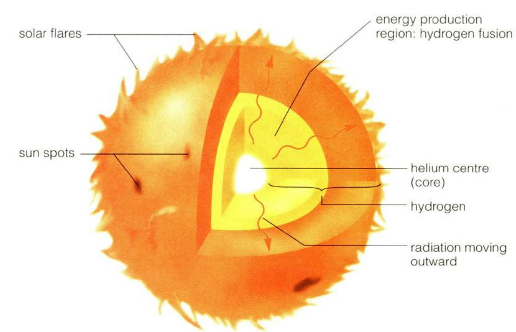


Figure 14.10 Fusion occurs in the core of stars. In the core, the temperature and pressure are high enough to cause hydrogen atoms to fuse and create helium. The high heat makes the hydrogen atoms so energetic that they collide. When they fuse, energy is released and the star shines.

LOW MASS STARS (RED DWARFS)

Low mass means ______ gravitational pressure…

- core does not consume hydrogen very _________
- hot material escapes _________
- after about ____ **billion years** they become ________ _______.

INTERMEDIATE MASS STARS

Stars like the Sun run out of hydrogen after about ____ **billion years**…

- core collapses under _____________ pressure
- core heats up and ________ begins to fuse into other elements (carbon)
- outer surface expands up to _____ times
- huge size mean low temperature… it is now a ______ ________.
- The outer layer of gas gets blown off producing a cloud of gas called a ___________ ______________
- leaving a hot, dense core…it is now a ________ __________.
- the white dwarf eventually cools into a _________ __________.

MASSIVE STARS

Massive stars have much _______ gravitational pressure on the core…

- they consume hydrogen much __________ (7-10 million years)
- the core temperatures are very ________
- the outer surface is very large…a ______________ ________
- when fuel runs out the star collapses and explodes…___________
- small remaining cores collapse into ___________ _______
- larger remaining cores collapse into __________ _________

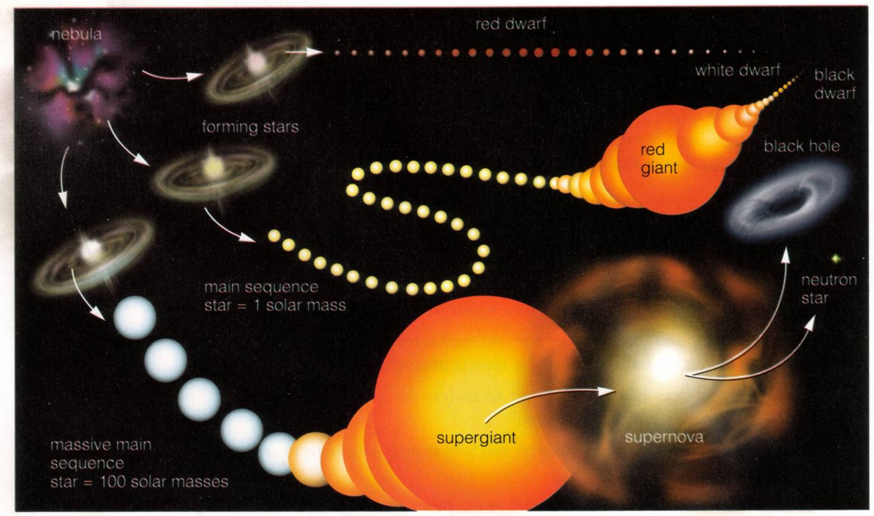
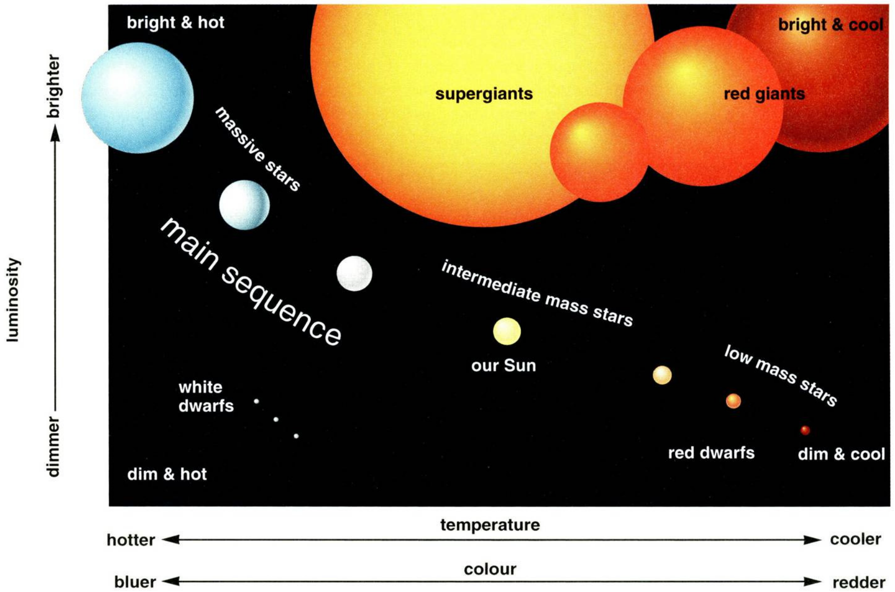


Figure 14.9 The phases in the life of stars



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The Solar System and Sun

- Solar System is made up of the ____ and _____ planets.

________, ________, _________, ________, ________, ________, ________, _________ and _________

The Sun

- huge ball of very ____ ____ (71% H, 26% He)
- mass of ______________
- __________ times more massive than the Earth
- ______ of the mass of the solar system
- diameter of ______________
- 110 times bigger than the __________
- _____ ___________ __________ away (1 AU = 149.599 million kilometres)
- surface temperature _________
- core temperature _____________
- rotates about its axis once every ________ days
- is always bubbling and churning which causes:
  - _________ (cooler regions that appear dark)
  - _________ __________ (bursts of particles spewed out into space)
  - ________________ (streams of gas that arch into space)

The Origin of the Universe - The Big Bang Theory

Scientists believe that at one point in time, all the _____________ in the universe was packed together into one small, extremely dense, hot mass under enormous pressure. The event where this mass began to move apart is called the _____ ________ _____________.

Scientists believe that the Big Bang occurred _____ billion to _____ billion years ago.

Stages of the Big Bang

Stage	Time	Temp (°C)	Description
A	10^{-43} s	10^{32}	
B		Cooler	
C	10^{-4} s	cooler	
D	3 min	10 million	
E	1 h	Cooler	
F	½ million years	3000	
G	1 billion years	Cooler	

Evidence for the Big Bang

- Edwin Hubble studied the ________ _________ of 46 galaxies.
- He discovered all the galaxies were _____-___________. They were moving _________ from us. Galaxies far away were moving ________ than the nearby galaxies. This is known as ___________ ______.
- Scientists (Penzias and Wilson) have detected background _________ in signals from telescope antennas. This static is faint ___________ given off by the original Big Bang.