Textbook: Discovering the Universe

* Look up Textbook website.

Unit 1, ch. 1

Discovering the Night Sky

Scales of the Universe (Major types of Objects in the Universe)

SEE APPENDIX E-10 p. A-16

1 inch = 2.54 cm
1 cm = 0.394 in
1 yd = 0.914 m
1 m = 1.09 yds = 39.37 in
1 mile = 1.61 KM
1 KM = 0.621 mi

Know scientific Notation (Powers of 10)

ex's
Ranges of sizes of objects
- and -
" " " " atomic Particles

~~Patterns~~ Patterns of Stars

On a perfectly clear night, with no interference, you can see 3000 stars ~~at~~ at any one time.

Since only $\frac{1}{2}$ of all stars are above the horizon at a given time, there are 6000 stars which are theoretically visible, otherwise.

horizon - Boundary between Earth and Sky

Patterns of stars are called Asterisms
(informally called Constellations)

Constellations make Locating Stars Easy

You can get an idea of where you are on Earth by looking at the stars.

ex:

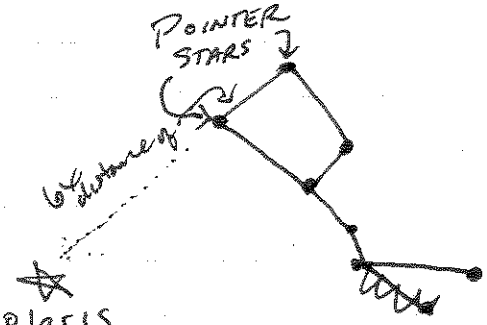
If you live in the Northern Hemisphere, you can use the Big Dipper to find the direction North.

Most often the big dipper is found upside down, but sometimes, not.

How, you ask?

① Locate the Big Dipper, imagine its bowl is resting on a table

(Fig 1-5)



NOT ONE OF THE 20 brightest stars... and still easy to find. (Appendix E-6)

B/c it is almost DIRECTLY over North pole

So...
If you are facing Polaris, you are facing North

LEO

If you grab Big Dipper's handle and slam the "bowl" straight down onto the head of Leo

Leo is the first group of bright stars your dipper encounters.

Regulus - is the brightest star of the group, and is the dot of the backward question mark that Traces the lion's mane.

Dx2!

Follow the arc of the Big Dipper's Handle away from its Bowl. The first bright star you encounter along that arc beyond the handle is **Arcturus** in Boötes (The Herdsman). Follow the same arc farther to the prominent blush star Spica in Virgo (The Virgin). Spotting these stars and remembering their names is easy if you ~~[illegible]~~ remember the saying "Arc to Arcturus and speed on to Spica."

WINTER △

* DIFFERENT CONSTELLATIONS ARE VISIBLE AT NIGHT DURING DIFFERENT TIMES OF THE YEAR *

WINTER (NORTHERN HEMISPHERE)

- SOME OF BRIGHTEST STARS ARE SEEN
- MOST ARE NEAR "WINTER TRIANGLE"

fig 1-6 WINTER TRIANGLE CONNECTS BRIGHT STARS IN THE CONSTELLATIONS OF
- ORION THE HUNTER
- CANIS MAJOR THE LARGER DOG
- CANIS MINOR SMALLER DOG

Sirius is the brightest star, and can be found by continuing the Belt of Orion to the left.

SUMMER △

Fig 1-7

CONNECTS BRIGHT STARS
- VEGA IN LYRA (THE LYRE)
- DENEB IN CYGNUS (THE SWAN)
- ALTAIR IN AQUILA (THE EAGLE)

* A PORTION OF THE MILKY WAY FORMS A BEAUTIFUL BACKGROUND TO THESE CONSTELLATIONS (WHICH ARE NEARLY OVERHEAD IN THE MIDDLE OF SUMMER @ Midnight)

SEE: GUIDED DISCOVERY: The Stars and Constellations

Celestial Sphere - A SKY MAP WITH COORDINATE SYSTEM OF LATITUDE (N-S) & Longitude (E-W)

STARS ARE FIXED ON IT

- HELPS TO LOCATE A STAR QUICKLY, WITH KNOWN COORDINATES

1-3 CELESTIAL SPHERE AIDS IN NAVIGATING THE SKY

ANIMATION 1.1

ARTIFICIAL EARTH BASED VIEWS

- STARS APPEAR TO BE FIXED RELATIVE TO EACH OTHER.
- PATTERNS of STARS (ALL) APPEAR TO RIGIDLY ORBIT EARTH

THIS IS THE PERSPECTIVE WHEN MAKING MAP

CELESTIAL SPHERE
- SHOWS 88 CONSTELLATIONS
- BOUNDARIES OF CONSTELLATIONS ARE ALL STRAIGHT LINES THAT MEET AT RT ∠'s (Fig 1-4b)

The "map" Leads us to think the stars are fixed in distance to the earth, but their distances vary.

Also, they do NOT move relative to each other

Celestial equator - Divides map sky into NORTHERN & SOUTHERN HEMISPHERES.

NORTH CELESTIAL POLE } PROJECTIONS OF N. & S. POLE OUT INTO SPACE
SOUTH CELESTIAL POLE

MAPS VERSION OF LATITUDE = Declination (Decl.)
0°-90° North or South of Celestial Equator

" " " Longitude = RIGHT ASCENSION (R.A.
0h to 24h around Celestial Equator.

INTERACTING EXERCISE 1.1

Fig 1-8

Prime Meridian - ∅ of Longitude on Earth where Greenwich, England is.

THE SUN'S PATH INTERSECTS THE CELESTIAL EQUATOR AT 2 POINTS:

- on the upswing

SUN MOVING NORTHWARD

∠'s of RT ASCENSION ARE MEASURED FROM THIS POINT, CALLED VERNAL EQUINOX

ANGULAR SEPARATION: ~~How~~ On CELESTIAL SPHERE, DISTANCE BETWEEN OBJECT IS MEASURED, IN TERMS OF ∠'S.

EARTHLY CYCLES

3 Celestial Motions

Earth's SPINNING

- CAUSES DAY AND NIGHT
- " APPARENT DAILY MOTION OF CELESTIAL SPHERE & objects on it.

EARTH'S ORBIT AROUND THE SUN

- CREATES SEASONS
- " THE YEAR
- Δ in times that constellations are up @ night.

MOON'S ORBIT AROUND EARTH

- CREATES LUNAR PHASES
- " CYCLE OF TIDES
- SPECTACULAR ECLIPSES.

1-4 EARTH'S ROTATION CREATES THE DAY-NIGHT CYCLE AND ITS REVOLUTION DEFINES A YEAR.

Activity: Reading "Rotation & the Sun"

Rotation - Spinning on Earth's axis

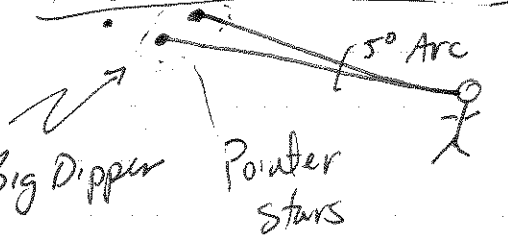
Why do we not feel this rotation?
b/c our planet is so physically large compared to us that Earth's gravitational attraction holds us firmly on its surface.

Rotation causes Stars, ~~the Sun~~ to rise on the eastern horizon, move across the sky, and set on the western horizon. (Day & Night)

This is called a Diurnal motion, or daily motion

P. 14 Observational Measurements Using Angles

Arc Angles
moon diameter is approx $\frac{1}{2}°$



How to estimate?

By knowing distance away, and it's angular diameter, (tan)

you can estimate the objects physical size

width of hand, full distance from eyes, is approx 8°

.. .. Index finger
2° 3° 6°

Sidereal Period: The length of a planet's cycle of motion, with respect to the other stars

Revolution: motion of any astronomical object around another

When ~~Earth~~ Sun is within the boundaries of Virgo (September 18 - Nov 1), the hemisphere containing the Sun and the constellations around Virgo are in daylight (Fig 1-10a)

When the Sun is up, so are Virgo and the surrounding constellations, so we cannot see them. at this time of year, the constellations on the other side of the celestial sphere, centered on the constellation Pisces, are in darkness.

So...

when the sun is in Virgo, Pisces and the constellations around it are high in our sky at night.

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How we know Earth revolves around the Sun, and not over a fixed place on the Sun:

Over a fixed place

Every star would rise and set at the same times all year

Revolving around Sun

Stars rise approximately 4 minutes earlier each day. This affect accumulates, bringing different constellations up at night throughout the year.

Fig 1-10

@ Autumnal equinox

Sun is on the Constellation Virgo
So, from earth, that part of the sky is daylight & we see only the stars on the other half of the sky, centered around Constellation Pisces.

Then... 6 months later...
this side of the sky (Sun is in Pisces). This side, then, becomes bright while the side centered on Virgo is in DARKNESS.

EQUINOXES & SOLSTICES

Fig 1-14
Fig 1-15

ECLIPTIC & CELESTIAL EQUATOR ARE DIFFERENT CIRCLES, TILTED $23\frac{1}{2}°$ FROM EACH OTHER ON THE CELESTIAL SPHERE. & THE EARTH'S ROTATION AXIS IS TILTED $23\frac{1}{2}°$ FROM LINE PERPENDICULAR TO ECLIPTIC.

* THESE 2 PLANES (CIRCLES) INTERSECT AT ONLY 2 POINTS, which are exactly opposite each other. These 2 points are called:

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An equinox → • Autumnal Equinox
• Vernal Equinox
(Latin: Equal Night)

* When the Sun appears @ either point, it is DIRECTLY over the Earth's Equator, resulting in 12h of Daytime & 12h of night time EVERYWHERE ON EARTH THAT DAY.

Polaris is above the NorthPole throughout the year, and is ~~last~~ seen when the Southern hemisphere is pointed toward the sun

Winter Solstice: approx 12-22 (Dec 22) each year
* Sun rises farthest South of East

- Winter in Northern Hemisphere
- Summer in Southern Hemisphere

For Northern Hemisphere people
- Shortest Day of the year
- Sun rises the LEAST

3 months later... (approx March 20)

Sun crosses Celestial equator, heading Northward
This is called
VERNAL EQUINOX
- ONE OF 2 DAYS in the year that Sun rises DUE East and sets DUE WEST

Fig 1.17b

VERNAL EQUINOX IS ALSO THE PRIME MERIDIAN of THE CELESTIAL SPHERE

3 months later (Approx June 21)
Summer Solstice
- Most Daylight
- Sun is highest

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The Seasons

Temperature (~~and Seasons~~) are determined by the duration of daylight at any place and height of the Sun in the sky there

So...

The Sun is lowest in the Northern sky @ Winter Solstice
Beginning of Winter

Midpoint to Summer is Vernal Equinox
Beginning of Spring

Sun is highest in Northern Sky. Longest Day of year
Summer Solstice
Beginning of Summer

Sun Crosses the Autumnal Equinox
Beginning of Fall

Fact

Distance between the Earth & Sun changes by 5 million km (3 million miles) throughout the year (Minor effect on seasons)

More significant effect.

- Southern Hemisphere has much more water areas, and heat & light bounces back into space more so than the Northern Hemisphere when it is closest to the Sun.

The Sun's path across the Sky

During the Summer months, the Sun rises in the NE & Sets in the NW

During Winter months, the sun is at it's lowest, and Sun rises in SE & Sets in SW

~~Earth~~ Latitude matters

Those over 66.5° North Latitude or below 66.5° South Latitude, Sun does not rise at all during parts of their Fall & Winter months

- Spring & Summer for them is almost all daylight

Fig 1-18

The Sun moves along the Ecliptic at approx < 1° per day b/c 365 1/4 days in a cycle

Zodiac Constellations - Those constellations through which the Sun moves throughout the years as it travels along the ecliptic ~~or called the~~

- We can't see these Constellations when the Sun is among them.

Table 1-1 Shows all 13

As of 1930's, there are 12+1 (13) Zodiac Constellations throughout the year.

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- The Sun is NOT always at it's highest at noon

b/c

- Not each day is exactly 24 hours

* BECAUSE EARTH Changes speed during travel around Sun

Astronomical Noon in NYC occurs EARLIER than in Philadelphia.

Before Time Zones, Local Time was based on Astronomical Noon

This led to time zones in Late 19th Century

Time Zones
are based on the time @ 0° Longitude in Greenwich, England. This is the Prime Meridian

Time Zones
Fig 1-19

- Each 15° of Longitude is a new time zone

Solar day vs Sidereal Day
(Length of Time where a star is in one place until it comes again @ same place.

b/c earth not only rotates, but travels (around the Sun) Stars return 4 mins earlier each day, so each Sidereal day is 23h 56min.

Solar Day is 24hr.

B.22

Calendars Based on Equal-Length Years Also Created Scheduling Problems

One day on Earth is 1 axis rotation

One year on Earth is 1 rotation around the Sun
365 ¼ days

When we only observed 365 day years, holidays would occur on wrong days.

So, Julius Caesar ~~~~ implemented a 365 ¼ day year in 45 B.C. This is called the Julian Calendar, and includes a leap year added every 4 years.

Examples/Important Holidays to keep accurate
Beginning of Spring

Problem with Julian Calendar

* A year is not EXACTLY 365 ¼ days long (more like 365.2425)

* Earth's rotation axis ~~~~ ~~~~ doesn't always point toward Polaris (North Star)

So...

1582
Gregorian System was implemented by Pope Gregory XIII's committee
(Still used today)

Gregorian System

* Initial correction, a one time thing
  Oct 5, 1582 became October 15, 1582
  Brought 1st Day of Spring Back

* Modified Caesar's System of Leap years
  b/c adding a day every 4 years results in 3 day ERROR every 4 centuries.

  So, at Century years: (1700, 1800, 1900, & 2000)
  would only get an extra day if divisible by 400. So, ~~1700~~ ~~1800~~ ~~1900~~ 2000 ✓

  1 year (365.2425) = Time from one Vernal equinox to the next

Now: So, the error is only 1 day in 3300 years what ???

P. 23 1-8 Precision is a slow circular motion of Earth's axis of Rotation

- Earth's axis of rotation is Drifting away from Polaris (North star). (Small Δ over lifetimes)
  - b/c of gravitational forces from the moon & Sun pulling on the slight equatorial bulge at Earth's equator created by Earth's rotation

Use football to lead into this

↓

Fig 1-20b

Called Precession

@ Equatore → Diameter Earth = 27 mi greater than from Pole to Pole

without a Moon, Earth would NOT keep a 23.5° tilt. Discovered by simulation in Mid 1990's.

Instead, it would Δ & relative to the ecliptic dramatically over Millions of years.

Key Point: Moon plays a CRUCIAL ROLE in stabilizing EARTH & maintaining Seasons as we know them.

How long does the earth complete a circle of wobble (Precession)?
26,000 years!

(Fig 1.20) "North celestial pole to trace out a complete circle the sky"

Currently, Earth's North axis of rotation points within 1° of Polaris.

IN 3000 B.C., it pointed near star Thuban in constellation DRACO. (The Dragon)

in A.D. 14,000, the pole star will be near Vega in Lyra

2nd Century, B.C. Discovered by Great greek astronomer Hipparchus

So the equatorial plane "wobble" with the precession. The celestial equator and the ecliptic DEFINE the equinoxes, so these Key locations in the sky shift slowly from year to year

This is called:
Precession of the Equinoxes

TODAY, Vernal equinox ~~will move into~~ is located in the constellation ~~Aquarius (The Water Bearer)~~ Pisces

2000 years ago, it was located in Aries (The Ram)

@ approx A.D. 2600 Vernal equinox will move into Aquarius (The Water Bearer)

1-9 The Phases of the Moon originally Inspired the Concept of the Month.

The Moon's phase that we see depends on how much of it's Sunlit hemisphere is facing Earth.

Interactive Exercise 1.2 Animation 1.4

When the moon is CLOSEST to the Sun in the sky ... It's DARK HEMISPHERE FACES EARTH

NEW MOON
A TINY CRESCENT

NEXT 7 DAYS, MORE OF THE MOON'S ILLUMINATED HEMISPHERE BECOMES EXPOSED TO OUR VIEW, RESULTING IN A PHASE CALLED:

WAXING CRESCENT Moon
(1ST QTR MOON)

We see: ½ of the illuminated hemisphere and half of the dark hemisphere. "Quarter moon" refers to how far Moon has gone in cycle.

Next 7 days: More illuminated hemisphere can be seen from Earth, giving us:
→ Waxing Gibbous Moon

Means: Rounded on Both sides

- When the moon arrives on the OPPOSITE SIDE of Earth from the Sun, we see virtually ALL of the Fully Illuminated Hemisphere.

KNOWN AS
FULL MOON

Next 2 weeks, we see less & less of the illuminated hemisphere
- Waning gibbous Moon
- 3RD QTR moon
- Waning CRESCENT Moon

Moon's cycle is 29 ½ days

"Far Side" vs "Dark Side"
(of the moon)

Side of the moon facing AWAY from Earth

Side of moon which is Not Shining.

Fig 1-21

SAME physical side of the Moon faces Earth ALL THE TIME.
(we always see the same craters)

* The ½ that NEVER FACES EARTH IS CALLED THE FAR SIDE.

(BUT THE FAR SIDE IS NOT ALWAYS THE DARK SIDE!)

WE SEE PART OF THE DARKSIDE WHEN WE DON'T HAVE A FULL MOON

Sun's orientation to Moon:

Waxing Moon - Sun is on Rt (west).

Waning Moon - Sun is on LT (EAST)

THE TERMINATOR: Boundary of Moon that is BETWEEN BRIGHT AND DARK REGIONS

Fig 1-21 Shows TIMELINE, IN 1 DAY of Moon to EARTH

KEY POINTS

@ 1ST Quarter: Moon is 90° East of the Sun
(Highest Point, at Sunset)

@ full Moon: Moon is OPPOSITE THE SUN IN THE SKY
(Highest Point @ Midnight)
* Visible in Daytime

Fig 1-22

How is reading the Moon helpful (many years ago) for people?

THE NEED FOR TIMEKEEPING!

When would the Nile Flood? (Ancient Egyptians)

When to plant crops (farmers)

When would weather change? (Migratory Tribes)

When to observe religious holidays? (Religious Leaders)

In accordance to celestial Events →

Key Point

Astronomers have been traditionally responsible for Telling Time.

- Time is Determined by the position of the Moon, Sun[2], or stars[3], or by today's standards... atomic clock

A MONTH WAS INVENTED TO COINCIDE WITH ONE MOON CYCLE AROUND EARTH

2 TYPES OF MONTHS

① MOON'S MOTION TO STARS

SIDEREAL MONTH
Cycle around Earth

Fig 1-23 →

Begins and ends @ same place to celestial Sphere
≈ 27.3 days

② MOON'S MOTION TO SUN

Synodic month (or Lunar Month)

Time to complete phases from Sun

Fig 1-23

SYNODIC MONTH IS LONGER THAN SIDEREAL MONTH b/c EARTH IS ORBITING THE SUN WHILE THE MOON GOES THROUGH ITS PHASES.

Key Point:
The MOON ENDS UP TRAVELING MORE THAN 360° ALONG ITS ORBIT TO COMPLETE A CYCLE OF PHASES

ex:
FROM ONE NEW MOON TO NEXT, 2.2 DAYS LONGER THAN SIDEREAL MONTH

B/C of gravitational pull of the Sun on the moon, affecting speed as it orbits earth

SIDEREAL MONTH may vary as much as 7 hours

SYNODIC MONTH may vary as much as 12 hours

OTHER USE FOR TERMS

Synodic Period of a planet = time between Consecutive Straight alignments of the Sun, Earth, and that planet

Earth's sidereal year is 365.2564 days

From year to year, our sidereal year differs from the time between vernal equinoxes, known as tropical year. Primarily due to

P.27

Eclipses

Lunar Eclipses -
Full moon darkens to a deep red.

Moon passes through Earth's shadow

Sun - Earth - & Moon are in straight line @ full moon

Solar Eclipse
when sun seems to be blotted from the sky.

INTERACTIVE EXERCISE 1.3

Moon's shadow moves across Earth's surface

As seen from Earth, the moon moves in front of the Sun - A new moon

> Eclipses Don't occur during EVERY new or full phase
> 1-10

Fig 1.24

You would think otherwise, but the Moon's orbit is tilted 5° from the Ecliptic plane

Usually, the new moon and full moon occur when the moon is above or below the plane of Earth's orbit. So alignment for eclipse is not possible

The moon crosses the ecliptic at the LINE OF NODES
When the moon crosses the plane of the ecliptic during it's

new or full ~~moon~~ phase, an eclipse takes place

2-5 eclipses happen each year

3 TYPES OF LUNAR ECLIPSES
1-11

Umbra: the part of the shadow where all direct sunlight is blocked by Earth

Penumbra where Earth blocks only part of the sunlight

Penumbral Eclipse: when the moon passes through the Earth's penumbra

- Moon still looks full, just slightly dimmer than usual and reddish, sometimes.

Partial eclipse: when just part of the lunar surface passes through the umbra. (A bite seems to be taken out of the Moon)

Total Eclipse when the moon travels completely into the umbra

Total, partial, & Annular

3 Types of Solar Eclipses

1-12

When moon completely covers the Sun, this is a TOTAL SOLAR ECLIPSE

Total eclipses are brief... ~7.5 mins

only at total eclipse, a Solar Corona is observed, where only hot gases are visible, surrounding the Sun.

Fig 1-26

When the moon is far enough from the earth that it does not cover the sun completely, there is NO total eclipse.

Fig 1-29

Annular Eclipse { A thin ring, known as an annulus of light is seen around the edge of the moon Mid-eclipse

* Annular Solar Eclipses are more common than Total Solar Eclipses

1-13 Frontiers yet to be discovered

(SKIP...)

P. 32-33 Summary of KEY IDEAS

Use "Starry Night" resource online