Sky, Celestial Sphere and Constellations
Last lecture

- Galaxies are the main building blocks of the universe.
  - Consists of few billions to hundreds of billions of stars, gas clouds (nebulae), star clusters, debris from dead stars ...
  - Few hundreds of thousands of light years in size
  - Shapes spiral, elliptic, irregular
- Our galaxy: Milky way a spiral galaxy 100,000 LY in size, 100 billion stars with many satellite galaxies.
- Galaxies group together, local clusters, clusters, super clusters of galaxies
- Largest scale they from a filamentary/wall like structure: cosmic web
  - Largest scales universe homogeneous, isotropic
- Universe is 13.8 years old, first stars/galaxies formed 400M years after that.
- So oldest galaxies 13.4 billion years old, at a distance 13.4 billion LY away.
- Regions beyond that are not visible to us, light from those regions has not reached us yet.
The side of the Earth facing sun at a given time gets sunlight and it is daytime.
The other side facing away from the sun is experiencing nighttime.

During the day, sky looks blue, at night sky is dark and we can see stars and other celestial objects in the sky.

At a given time and a given location only half of the sky is visible.

On a typical moonless clear night about 3000 stars are visible.
During the day we can not see stars due to glare of the atmosphere (from sunlight).

- When light fall on air molecules (particles) some of the light get scattered (i.e., deflected) in all directions.
- White light is a combination of different colors, blue light in it is more likely to scatter.
- We see this scattered light in the atmosphere during the day. Since most of it is blue, we see a lot of blue light in the atmosphere in all directions.
- So sky looks blue during the day, in fact what we see is the atmosphere illuminated by sunlight.
- Light from stars are much less intense (weaker) than the scattered sun light from atmosphere, so we do not see them (unless a star happen to be very bright)
- Away from the atmosphere (in space, on moon...) one can to see stars during the day.
At sunrise and sunset, Sun is close to the horizon, light has to travel a longer distance in the atmosphere to reach earth surface.

By the time sun light reached the Earth surface, most of the blue light has scattered away. Only red light remains.

So Sun and the sky in that direction looks redder.
Twinkling of Stars (stellar scintillation)

- When star light travels through the atmosphere light gets slightly refracted (changes direction) as it go from one air layer to another of different densities.
- When there is turbulence in the atmosphere refraction is not uniform or steady, changes from moment to moment, changing the direction of light slightly all the time.
- Stars are so far away that, their angular diameters are extremely small, typically 1/100th of an arc second or less.
- So even a tiny change in the direction is noticeable, and the result is “twinkling” of stars.
- When a star is low in the sky since light has to travel a longer distance through the atmosphere we see more twinkling.
- Planets have larger angular diameters, few to tens of arc seconds. So a very small changes of direction is not so notable, so they twinkle less.
- Moon is so big in the sky we do not see the Moon twinkling.
- This is one way to distinguish a planet from a star (sometimes!)
- Twinkling is not good for astronomy, for astronomical observations, a steady atmosphere with good “seeing” is needed.
On a clear dark night one can see about 3000 stars.

We see only one half of the sky at a given time. What is above the horizon?

Zenith: the point directly overhead in the sky at a given time and location.

Nadir: direction pointing directly below,
Celestial Sphere

- To a casual observer sky looks like a giant dome or a hollow sphere, surrounding the earth.

- All stars and other celestial objects (sun, moon, planets...) seemed to be located on this sphere, which rotates around earth.

- We know this is an illusion, (different celestial objects are at different distances from us, and it is the earth that rotates)

- But, to consider sky as a sphere centered at earth is a useful geometrical concept for observational purposes and to locate celestial objects and to follow their movements.
  - To observe an object we should be able to tell its location the sky.
In this context we consider sky as a giant hollow sphere where all celestial objects are located, the “Celestial Sphere”
Celestial Sphere

- Stars appear to move from East to West on circular path around the axis.
- Stars at the poles of the sphere do not move, they appear stationary.
- Consider what the observer $O$ sees.
• Consider what the observer O sees

• North pole of the celestial sphere at an altitude equal to the latitude of the observer O.

• Stars in the circle between horizon and the pole never sets, they circle around the pole.

• They are known as **circumpolar stars**
Locating objects in the Sky – sky coordinates

- Simplest way to give the location of a celestial object in the sky is to give its apparent position in the sky
  - **Altitude**: vertical angular position above the horizon
  - **Azimuth**: angular distance (angle) along the horizon to the location of the object, measured from north towards the east along the horizon
- But the apparent position of a celestial object changes with time and location.
- Not the best way to identify an object.
• Position of an object on the celestial sphere can be specified, similar to a location of a place on earth given by longitude and latitude.
• We can just project longitude and latitude to the sky (celestial sphere)
• **Declination**: angular distance to the object from the equator of the celestial sphere.
• **Right ascension**: angle between the celestial meridian through the object and a reference median.
• This is a good, but need a way to identify the reference median
• The position of sun at the spring equinox is taken as that reference
• As the Earth moves around the sun we see the Sun in different directions in the sky, and against different stars, constellations.

• Sun’s apparent position in the sky over the year traces a path in the sky, called Ecliptic (when eclipses occur moon is located on it, hence the name).

• Axis of earth’s rotation is tilted by an angle 23.5° to the axis of earth’s orbit (in other words earth’s equatorial plane is at an angle 23.5° to the orbital plane), so ecliptic is also tilted by the same angle to equatorial plane.
• Stars are fixed on the celestial sphere
• But the location of Sun (and moon, planets...) is not fixed on the celestial sphere.
• Sun seems to move on the celestial sphere along the ecliptic annually.
• Ecliptic is tilted by the same angle as the earth axis to orbital axis (23.5°). They intersect at two points: Location of the Sun at Spring equinox and Autumn equinox
• We use the Spring equinox (ie. meridian through it) as the reference point to measure right ascension
• This evening southern sky from Oxford MS 8.30 PM,
  – Stars, moon, Mars, Saturn, Milky way
• Ancestors imagined groups of brighter stars as patterns, called constellations.
• related to mythological characters; heroes, animals, royalty whatever important or fascinated them.
Today we use them as an easy way to remember and identify the sky.
Stars in a constellation have no physical relation with each other, just happen to be in the same direction as seen from earth.
• For example, stars in the Big Dipper are at distances 63 to 210 light years in various directions. When we look at them from the position of Earth, we see the shape of the dipper, no other relation between them.
Stars do actually move in the sky, but at a very slow rate, not noticeable to eye in a life time or even over a few centuries. However over many thousands of years, there could be obvious changes.
- Constellation figures
Examples of few constellation figures

- All above constellations are of the Zodiac – the narrow band in the sky where sun, moon and planets seem to move.
• Orion (the hunter): a conspicuous, constellation with bright stars, known since antiquity in many cultures.

• Ursa Major (larger bear): another prominent constellation known since the antiquity. Part of it consisting of 7 stars (an asterisms) is known as big dipper, or plough.

• Asterism: A distinctive pattern of stars, but often not an official constellation. examples: big dipper, summer triangle, coat hanger, tea pot, belt of Orion, Pleiades, Delphinus
Few Asterisms

Sickle (in Leo)

Delphinus

Coat hanger (binocular)

W in Cassiopeia

Orion’s belt
• Many constellations we use today descends from classical Greek and Roman times
• But origin of constellations dates back to much earlier times
• Greeks adopted them from the Babylonians, whose origins in turn may well be from Sumerians 3,000 years before. Constellations like Scorpion, Orion, Taurus (the bull) and Leo (the Lion) considered to be first originated in those civilizations in the western world.

• All ancient civilizations and cultures had their own constellations and star lore.

• More on Chinese astronomy:
http://idp.bl.uk/education/astronomy/sky.html
Ancient star maps were vividly decorated with constellation figures.}

- Albrecht Dürer, 1515, Germany
- Uranographia, Johann Bode (1801)
- Ancient star maps were vividly decorated with constellation figures
Antique star atlases

- Ignace Gaston Pardies sky maps 17th Century

- By Alexander Jamieson sky atlas early 19th Century
• Today we use them as *mnemonics*, an easy way to remember and identify the sky.
• Today we use 88 constellation which divide the sky in to 88 divisions.
• 48 of them have ancient roots descending from ancient Greek times, with their mythological stories, which were in turn adopted from even older Babylonian constellations.
• Southern constellation (32) were formed in the 19th century.