Sky Coordinate System

- The sky, then, appears to rotate like a sphere about an axis running through it from the *north celestial pole* to the *south celestial pole*.
- This rotation produces a constant relative motion between the lines of longitude and RA.
- noon on the first day of spring (approximately March 21) as the moment in time when the 0°-line of RA aligns with the 0°-line of longitude.
- Dec is, in fact, given in units of degrees. RA, though, has units of time
- since there are 24 h of RA around the sky and 360 degrees around a full circle, at the equator, 1 h of RA = 15° of arc, and so 1 minute of RA = 15 min of arc and 1 s of RA = 15 s of arc *at the equator*

Observer-Centered Definitions

- *Horizon*: This defines the limit of what parts of the sky you can see at any particular moment
- *Zenith*: This is the point in the sky directly overhead
- *Altitude or elevation*:The angular height of an object above your horizon at any given moment.
- *Azimuth*: This is the angular position perpendicular to the altitude, and is defined as the angular position of an object along the horizon relative to due north.
- *Meridian*: This is the line of RA that runs through your zenith. This RA is called the *Local sidereal time (LST)*
- All stars, regardless of their Dec, will be highest in the sky during the moment when they cross your meridian.
- *Hour angle (HA)*: An object's HA is the amount of time (in hours) since the object transited.
- *HA = LST - RA*

BASIC STRUCTURE OF A TRADITIONAL RADIO TELESCOPE

- An equatorial mount is really just an alt-az mount that is tilted, so that the azimuth axis of the telescope points toward the Celestial Pole rather than toward the zenith.
- The dish reflects radio light from the sky to its focus where specially designed antennas called *feeds* convert the EM waves in free space into confined EM waves in transmission lines, which carry the signal to *receivers*.
- This minimum size is of order the wavelength of the radiation, so for longer radio wavelengths, the feeds must be fairly large

- Luminosity, though, is not directly measurable because we do not detect *all* the radiation that was emitted by the source in any given second.

Intensity

- But in this case, the signal is not isotropic, so the radiation is *not* spread out over the whole area $4pd^2$, so the normal equation for flux, $F = L/4pd^2$, is not true

Blackbody

- In the Planck function given, written as Bv(T), the subscript v indicates that the spectral measure is per unit frequency and B represents the intensity, or brightness, of the blackbody radiation and has units of intensity
- Blackbody emission is a continuous spectrum that reaches zero at v = 0 (owing to the v^3 term), increases to some peak value as v increases, and then decreases and reaches zero again at v = ∞
- the Planck function depends only on the body's temperature and the frequency of the radiation. the intensity of radiation that a blackbody emits at any given frequency depends only on its temperature.
- The total flux of radiation (W m^{-2}) emitted by the body can be obtained by integration of the Planck function over frequency and solid angle. The result (graph) shows that the total flux is proportional to the fourth power of the body's temperature
- a hotter body produces more energy at every frequency.
- at any given frequency, any particular value of inten- sity corresponds to exactly one temperature. Note that the blackbody curves for different temperatures never cross

Wein Displ Law

- The peaks of these curves for the same temperature might not even occur in the same spectral band.

Brightness Temp

- intensity is a measure of the radiation emitted, while temperature refers to a physical condition of the source

Coherent Radiation

- all these wave chains with random phases together, the interference term averages to zero, at all times and at all locations. The total beam will then have an intensity proportional to *N* times the intensity of an individual wave chain.

- the *intensities* of the coherent and incoherent beams differ, but their total *energies* are the same.
- when the two intensities are integrated over frequency and solid angle, they yield the same flux, or the same rate of energy flow.

Polarisation

- If the magnitudes of oscillation of the electric field in the *x*- and y-directions are equal and the phase difference between them is exactly $\pm\pi/2$ radians, then the total electric field vector will be constant in magnitude but will rotate around the *z*-axis, tracing out a circle (as will the magnetic field vector). This case is called *circular polarization.*
- by allowing the magnitudes of the component electric fields to vary, as well as the phase difference between them, the total electric field vector can also trace out an ellipse. This situation is called *ellip- tical polarization*.
- When the phase difference is zero or 180°, the total electric field vector will oscillate in a fixed direction in the *xy*-plane, a case that is called *linear polarization*.
- *right* circularly polarized wave obeys the *right*-hand rule in that when the thumb points in the direction of propagation, the curl of the fingers indicates the direction that the electric field turns.
- Stokes
  - *I, is equal to the total intensity of all the radiation*
  - *Q*, is equal to the difference in the intensities of the two linear polarizations, so
  - *U*, is very similar to the second, but involves a rotation of the *x*- and *y*-axes by 45
  - *V*, is equal to the difference in the intensities of the left and right circular polarizations. *V*, alone, is a measure of the amount of net circular polarization.

Beam Pattern

- the circular solid angle with a diameter equal to the FWHM of the main beam is considered to be the range over which the telescope can detect radio emission; that is, we can detect off-axis objects anywhere within this solid angle, albeit with reduced sensitivity, if they are located close to or inside the half-power points
- two sources with an angular separation less than the main beam FWHM (full width at half maximum)cannot be distinguished from one another; they appear as a single (and brighter) source.
- The radius of the Airy disk, in fact, is larger than the FWHM of its central peak, which is equal to 1.02 λ/D.
- Usually a small angular resolution is desirable, as it means that astronomical sources close together in angle on the sky can be distinguished or that fine angular detail can be discerned within a source. Since the FWHM of the main lobe is inversely proportional to the diameter of the reflector, we have that *large diameter telescopes not only collect more power from an astronomical source, but also provide better angular resolution*.

- radio telescopes generally have *diffraction-limited resolution*, which depends only on the optics of the telescope and the wavelength being observed. At shorter wavelengths, the atmosphere can affect even radio waves, while at longer wavelengths, the ionosphere has a significant impact.

Feed

- For smaller telescopes operating at longer wavelengths, such as the Haystack Small Radio Telescope (SRT), only one feed will fit it the focal plane, and hence the power can be measured at only one position for each pointing of the telescope. In larger telescopes, operating at millimeter and submillimeter wavelengths, an array of feeds can often be used, permitting many positions to be observed simultaneously in a single pointing.
- Each feed and receiver work well only for a certain range of frequencies. If observations involving a number of different frequency ranges are needed, then different feed horns and receivers must be employed for each frequency band.
- Using the reciprocity theorem, we can model the feed horn's sensitivity to the incident radiation in terms of its own beam pattern
- Edge Taper
    - The ratio of the effective collecting area considering all effect to the physical area is called the *illumination efficiency*.
    - Some of the feed's beam pattern misses the reflector, and so the signal entering the feed is diluted by its sensitivity to area beyond the physical reflector. The illumination of the feed beyond the reflector is called *spillover.*
    - The edge taper that maximizes the collecting area of the telescope is one in which the power per unit area transmitted to the center of the reflector is 10 times larger than that at the edge; this is called a *10-dB edge taper*.
    - with the optimum (10-dB) edge taper, the angular resolution is $\theta_{FWHM} = 1.15\lambda\ D$
    - for this optimum edge taper, *the first sidelobe level is approximately 0.4% of the peak,* and *the maximum collecting area of the telescope is about 82% of the reflector's physical area*

the total path difference is twice the deviation, 2dz; therefore, these deviations produce *rms* phase errors of $4\pi\ dz/\lambda$.

The RF amplifier, the first device the radiation enters into immediately after the feed, therefore, is *the most critical* in determining the total noise temperature. Since RF amplifiers usually have gains of at least a factor of 100 (or 20 dB), the contributions to the noise temperature of all other elements in the receiver and detector are reduced by *at least* a factor of 100. It is, therefore, extremely important that the RF amplifier has as much gain and as little noise as possible.

. Note that the magnitude of n is less than 1 when hv > kT and greater than 1 when hv < kT. Therefore, at higher frequencies, the first term in Equation 3.11 dominates and the uncertainty is proportional to the square root of the number of photons per mode, that is,

$\sigma \propto \mathrm{sqrt}(n)$

while at lower frequencies, the second term dominates and the uncertainty is proportional

to the number of photons per mode,

$\sigma \propto n$