PHY 300 Problem Set #2
Due Monday 2-Mar-2015, start of class

1. A radio receiver is connected to a Radio Telescope via a microwave horn, fed from the dish.
The receiver consists of a calibration noise source, injected via a directional coupler, a low noise RF amplifier with a noise temperature of 50K, and gain of 10 dB, followed by a room temperature mixer with a loss of 0.1dB feeding an intermediate frequency (IF) amplifier with a gain of 20 dB and a detector.

What is the system noise temperature, T, of the complete receiver?

Derive the equation $\Delta T/T = 1/(B\tau)$ and hence determine the minimum source noise level, ΔT, (in Kelvins), which can be detected in an integration time of 30 minutes.

2. What is the resolution of the 100m telescope in Effelsberg at a frequency of 1420 MHz?
How does this compare with an interferometer with a baseline of length:
a) 1 km
b) 200 km

3. MeerKAT, in its first receiver complement, will have a highest frequency of 14.5 GHz. What would be the highest red-shift at which it could detect the 2.6 mm line of carbon monoxide?

Nb $z = (\lambda_{obs} - \lambda_{em})/\lambda_{em}$ or $1+z = (\lambda_{obs}/\lambda_{em}) = (\nu_{em}/\nu_{obs})$

4.The Seyfert galaxy NGC 4258 has a water maser spectrum and a maser spot distribution shown in the attached diagram, (Global VLBI measurements). The data lends itself to an interpretation of an edge on disc with central solid body rotation and with a very precise Keplerian fall-off at the higher velocities. It has a peak rotation velocity of 1080 km/s at an angular radius of 4.5 mas. The spectral features are not stationary and show evidence for acceleration at 9.5 km/s per year. Determine the mass of the central object and its distance.
The number of seconds in a year is 3.156×10^7 seconds (6)

1.You want to measure the temperature of Mars with an rms uncertainty of about 1% by observing at an RF frequency of 10 GHz. The angular diameter of Mars is θ_M=18" and its 10 GHz flux density is 4.2 Jy. Your antenna has a parabolic reflector with a diameter of 25m and aperture efficiency η_A= 0.7.
The single channel total power receiver is connected to a feed sensitive to right circular polarization and its bandwidth is 100 MHz. The receiver noise temperature is T_{RX}= 18K, the atmosphere adds about 3.5K, the microwave background 3K, and spillover pickup is about 11K.

a) show that Mars is a point source for your observations, that is, $\theta_M << \theta_{FWHM}$, the telescope beam-width between half power points.
b) What antenna contribution T_A do you expect from Mars?
c) What is the system noise temperature, T_{sys} when the telescope is pointing at Mars?
d) If the receiver has perfect gain stability, how long must you point the telescope at Mars?

2. Define the spin-flip hydrogen line transition in radio astronomy and discuss its importance as a diagnostic of Galactic structure

Why is molecular hydrogen not so useful and why is carbon monoxide an excellent substitute?

The GBT has sensitive receivers covering the frequency ranges 18 – 26.5 and 26 – 40 GHz. Show that this frequency coverage is sufficient to detect CO emission from galaxies at any red-shift from z=1.9 to at least z=10, the estimated red-shift at which stars produce significant amounts of interstellar CO.

3. Describe and discuss the properties of radio galaxies and quasars.
Discuss the 'unified model' of an active galactic nucleus, describing its various components in relation to the central black hole and the viewing angle of the observations.
How was the presence of a black hole in such objects confirmed through the detection and subsequent observations of water masers in the galaxy NGC 4258?

4. Describe ONE of the two major astronomical projects of the present epoch, 2014: ALMA or the SKA with reference to their main scientific objectives.
Consider:
i) the site in relation to the scientific goals
ii) the importance of those scientific goals
iii) the synergy between the two projects