# Astro Techniques II

**Assignment-1; Given - 6 April, 2016; Due on - 13 April, 2016**

1. The Ooty Radio Telescope (ORT) is the world's largest steerable telescope. It is a parabolic cylinder of size $530 \times 30\ m$. It is currently undergoing an upgrade where its observing bandwidth is being increased from 4 to 40 MHz. What is the minimum detectable flux density and brightness temperature by the old and the new system using the full bandwidth and an observing time of 1 hour. Assume a system temperature of 150 $K$ for both the old and the new system and an aperture efficiency ($\eta$) of 70%.

2. A household mircowave oven typically has an output of 1 $kW$. Assume that this power is radiated over a bandwidth of 1 $MHz$ in an isotropic manner.

   (a) What would be strength, in $Jy$, of this radio source at a distance of 1 $km$?

   (b) What is the farthest distance at which the ORT be able to detect this mircowave oven for an observing duration of one hour?

3. In a recent analysis of archival GMRT observations of Venus, it was found to have a flux density of $56.0 \pm 1.5\ mJy$ at an observing frequency of 606 MHz. The angular diameter of Venus during these observations was 22.72" and the size of the synthesised beam was 9.9" × 7.7". What would be its average brightness temperature ($T_B$). More observations are planned when Venus is closer to the Earth and subtends an angular diameter of 56". What would be expected values of flux density and average brightness temperature for these planned observations? Assume the same synthesised beam for the planned observations and that the radio emission from Venus does not vary in time.

4. Using the standard relationship between the complex visibility, $V(u, v)$, measured by an interferometer and the brightness distribution, $B(l, m)$, calculate the radial profile, $V(r)$ (where $r = \sqrt{u^2 + v^2}$), for the following circularly symmetric models for $B(\sigma)$ (where $\sigma = \sqrt{l^2 + m^2}$). All the models are centered at the origin of the $(l, m)$ coordinate system. Assume the primary beam response, $A(l, m)$, to be unity over the extent of the models.

   (a) $B(\sigma) = \frac{1}{\eta\sqrt{2\pi}} e^{-\frac{\sigma^2}{2\eta^2}}$. Use a Gaussian corresponding to a full width at half maximum (FWHM) of 5".

   (b) $B(\sigma) = 4/(\pi a^2)$, if $r \leq a/2$, and 0 otherwise. Use $a = 5$".

   (c) $B(\sigma) = 0$, if $r \leq a/2$,
   $= C$, if $a/2 < r \leq b/2$, and 0 otherwise. Use $a = 5$" and $b = 8$".

   Plot $V(r)$ for these models.

5. List and justify the assumption made to arrive at the perfect 2D Fourier transform relationship between the sky brightness distribution $B(l, m)$ and the visibility $V(u, v)$ (the van Cittert Zernike theorem). What is the phase error incurred under this assumption? For a given interferometer, what is the maximum size of the field-of-view which one could map if one wanted to restrict these errors to a maximum of $5°$?

6. Obtain the relationship between the physical antenna coordinates and $u$, $v$ and $w$, the direction cosines of the baseline vector. Use the conventional Cartesian right-handed coordinate system, to set up the problem and arrive at the result.

7. Show that the locus of the projected antenna spacing components $u$ and $v$ for a given baseline trace out an ellipse as the interferometer tracks a source from rise to set.

   (a) Obtain the expressions for semi-major and semi-minor axes of this ellipse.

   (b) What are the coordinates of the centre of this ellipse?

   (c) When will this ellipse become a perfect circle?

   (d) What conditions need to be satisfied for this ellipse to reduce to a line ?

8. Define the term *fringe frequency* and derive an expression for it. When tracking a source from rise to set, when does the *fringe frequency* attain its largest value?

9. The Murchison Widefield Array (MWA) is one of the SKA pre-cursors. It is situated at the site chosen for the SKA in Western Australia ($116°42'$E and $-26°32'$) and comprises 128 elements. Each of these elements is a collection of $4 \times 4$ dipoles and is referred to as a *tile*. The coordinates of these 128 tiles antennas are provided in MWA-antenna-coordinates.txt.

   (a) Use the International Terrestrial Reference Frame (ITRF) coordinates of the tiles to plot the instantaneous $u$-$v$ coverage of this array towards the direction of local zenith at a frequency of 150 MHz for a single spectral channel of bandwidth 4 kHz.

   (b) The MWA observes over a bandwidth of 30 MHz, which is split into a large number of spectral channels. Plot the $u$-$v$ coverage for the same situation as above, only this time for the entire bandwidth. Assume that the bandwidth is split into 48 spectral channels.