Extragalactic Astrophysics: Question Sheet 8

1. **Superluminal motion.** In certain active galaxies, changes in the position of substructures may be detected over intervals as short as a year. For the quasar 3C 273 at a redshift of z=0.158, one component is seen to move away from the nucleus with an apparent angular velocity of 2.2×10^{-3} arcseconds/yr.
(i) What is the corresponding apparent, projected linear velocity of this component using for the distance (You can use the angular diameter distance in the cosmology calculator http://www.astro.ucla.edu/%7Ewright/CosmoCalc.html)?
(ii) Assuming that the phenomenon of superluminal motion is due to matter moving with a relativistic velocity v close to the line of sight, and that θ is the angle between the line of sight and the direction of ejected mater, what value of θ would produce the largest apparent velocity of the ejected component?
(iii) What is the minimum matter ejection velocity required in order to produce the apparent superluminal speed observed in (i)?

2. **Gravitational lensing I.** A faint galaxy is observed at 1' from the centre of a galaxy cluster. The redshift of this object indicates that it is a distant background object, gravitationally lensed by the mass of the foreground cluster. The cluster is located at an angular size distance of 200 Mpc and the galaxy at 500 Mpc. Assuming the cluster mass to be spherically symmetrically distributed, and that the mass inside 1' from the centre amounts to $10^{14} M_{\odot}$, at what angle from the centre of the cluster would the galaxy be observed in the absence of the gravitational bending of light?

3. **Gravitational lensing I.** Consider the gravitationally lensed quasar QO957+561. The two images are located at $\theta_{+} = 5.35''$ and $\theta_{-} = -0.80''$. The redshift of the quasar and the lens are $z_S = 1.41$ and $z_L = 0.36$. These redshifts translate into angular diameter distances of $D_S = 1693$ Mpc, $D_L = 1011$ Mpc, and $D_{LS} = 1123$ Mpc. Estimate the mass M of the lens.

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