ASTRONOMY 8400 – Spring 2024
Homework Set 1 – "Answers"

1. a) $1+z=\sqrt{\frac{1+\beta}{1-\beta}} \quad \rightarrow \quad (1+z)^2 = \frac{1+\beta}{1-\beta}$

$$(1+\beta)=(1+z)^2(1-\beta)=(1+z)^2-(1+z)^2\beta$$
$$\beta+\beta(1+z)^2=(1+z)^2-1$$
$$\beta=\frac{(1+z)^2-1}{(1+z)^2+1}$$

b) You can solve this algebraically or graphically. For a 1% error:

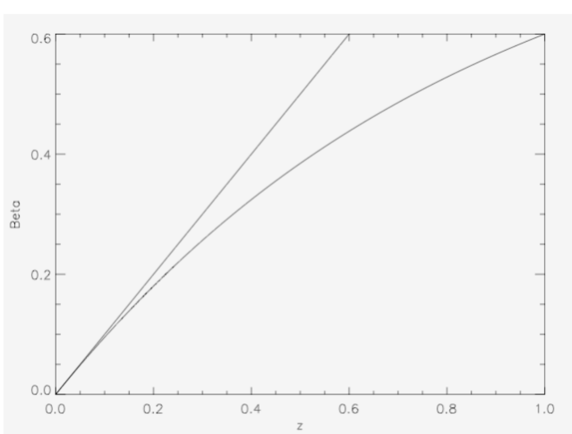
$$\frac{z-\beta}{z}=0.01 \quad \text{so} \quad \frac{\beta}{z}=0.99$$
$$\frac{1}{z}\frac{(1+z)^2-1}{(1+z)^2+1}=0.99$$
$$\frac{z^2+2z}{z^2+2z+2}=0.99z$$
$$0.99z^3+2(0.99)z^2+(2)(0.99)z=z^2+2z$$
$$0.99z^2+1.98z+1.98=z+2$$
$$0.99z^2+0.98z-0.02=0$$

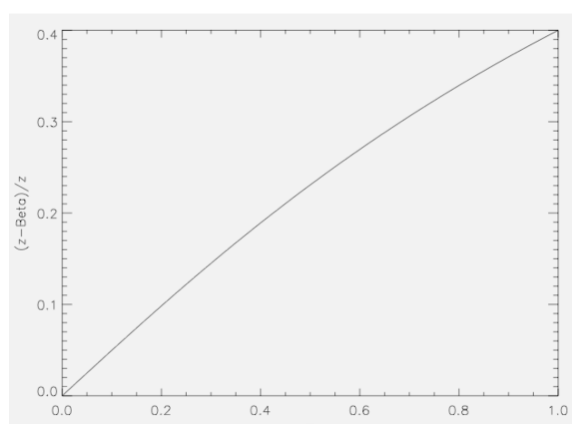
Using the quadratic equation:

$$z=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

$z=0.02$ (the other solution is -1.01, which is not valid)

For a 10% error, use the same formalism to get:
$z = 0.2$ (the other solution is -1.09, which is not valid)





c) The Hubble flow velocity would have to be ~6000 km s^{-1}.
$z = v/c = 0.02$, Galaxies with $z < 0.02$ are affected most severely.

2. a) NGC 4151: RA = 12h10m32.6s +39d24m21s (J2000)
- from "Optical Positions of Seyfert Galaxies", Clements, E.D. 1981, MNRAS, 197, 829.

b) z =0.003319, cz = 995 km/s (heliocentric)
- from H I 21-cm emission from host galaxy, Third Reference Catalog of Bright Galaxies (RC3), deVaucouleurs et al. (1991)

c) Distance from z: $D = cz/H_0 = 13.6$ Mpc, where $H_0 = 73$ km/sec/Mpc
Corrected z to CMB frame: D = 17.0 Mpc
Distance from other techniques (average) = 14.1 Mpc
- huge variation depending on technique!

d) R'SAB(rs)ab – Spiral galaxy with weak bar, outer pseudo-ring, inner ring/spiral, early type (deVaucouleurs et al. 1991)
Seyfert 1.5

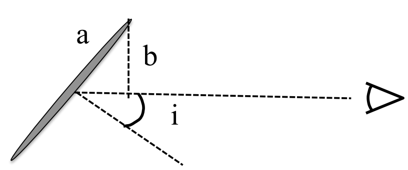
e)
$$\theta = \frac{r}{D} = \frac{1\ \text{kpc}}{13.6\times10^{3}\ \text{kpc}} = 7.35\times10^{-5}\ \text{rad}\left(\frac{206{,}265\ \text{arcsec}}{1\ \text{rad}}\right) = 15\ \text{arcsec}$$

Scale = 15 arcsec/kpc

From NED: Scale = 12 arcsec/kpc (using CMB correction)

f) Major, minor axes = 6.3 x 4.5 arcmin, 31 x 22 kpc (from POSS)

g) Inc = $\cos^{-1}(a/b) = 44°$



b = a cos(i)

h) E(B-V) = 0.028 mag (from Schlegel et al. maps of IR emission from Galactic dust)

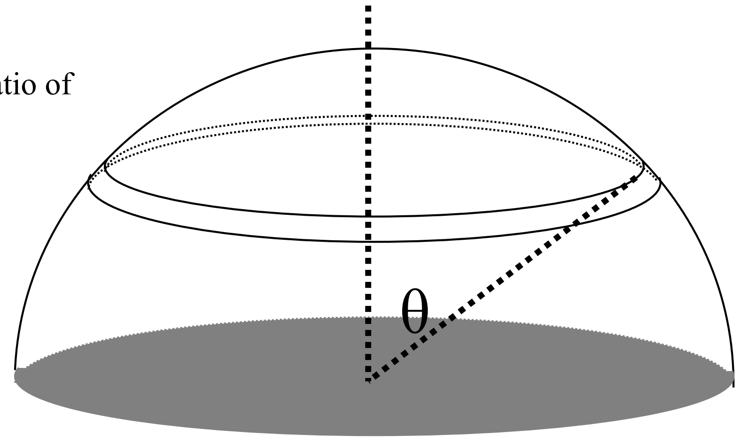
3. a) Assume you are looking at a torus from different inclination angles along a hemisphere. At a given distance (r), the probability of viewing at angle θ is proportional to the solid angle determined by an annulus perpendicular to the disk with width dθ. So:
$dP(\theta) = \sin(\theta)d\theta$ (probability increases with increasing θ)

The probability of observing between angles θ_1 and θ_2 is:

$$P = \int_{\theta_1}^{\theta_2} \sin\theta\, d\theta \Big/ \int_0^{\pi/2} \sin\theta\, d\theta$$

$$P = \cos(\theta_1) - \cos(\theta_2)$$

The probability of observing a certain ratio of Seyfert 2s to Seyfert 1s is:



$$x = \frac{\text{\# Seyfert 2s}}{\text{\# Seyfert 1}s} = \frac{N_2}{N_1}$$

$$P = \frac{N_2}{N_1 + N_2} \rightarrow P = \frac{x}{x+1}$$

$$P = \cos(\theta_{\min}) - \cos(90) = \cos(\theta_{\min})$$

$$\theta_{\min} = \cos^{-1}(P) = \cos^{-1}\left(\frac{x}{x+1}\right)$$

For x = 1, $\theta_{\min} = 60^{\circ}$

For x = 2, $\theta_{\min} = 48^{\circ}$

For x = 3, $\theta_{\min} = 41^{\circ}$