GA 2

1. Briefly describe what is the 'surface brightness' of a galaxy. Provide an equation for surface brightness and describe all factors that appear. Demonstrate that surface brightness is independent of distance. [4 marks]

   Answer:
   Surface brightness SB, is defined as SB$=dF/d\Omega$, where dF is the flux (measured from an extended source) per solid angle $d\Omega$.[1 mark]
   Let dL/dS be the luminosity surface density of a galaxy - the total luminosity dL emitted (by all stars) per unit area dS. Let the galaxy be at distance R (and take R much larger than the size of the galaxy, so that each surface area dS is at approximately the same distance R from the observer). The surface area dS extends under the solid angle $d\Omega$, as seen by the observer.
   The surface of the galaxy within the solid angle is $dS = R^2\,\mathrm{d}\Omega$[1 mark]
   the luminosity emitted is $(dL/dS) \times dS = (dL/dS) \times R^2\,\mathrm{d}\Omega$ [1 mark]
   The flux received within the solid angle $d\Omega$, is therefore

   $$dF = \frac{dL}{4\pi R^2} = \frac{(dL/dS)\,dS}{4\pi R^2} = \frac{(dL/dS)R^2 d\Omega}{4\pi R^2} = \frac{(dL/dS)d\Omega}{4\pi} \quad (1)$$

   so that the surface brightness is $dF/d\Omega = (dL/dS)/(4\pi)$, which is independent of R. [1 mark]
   Note: the reason this cancellation occurs is as follows. Suppose you contrast the surface brightness from a galaxy at distance R, to that of the *same* galaxy now placed at a distance of $2R$. The flux detected from a *given* star will of course be smaller in the second case, by a factor of 4, since $F \propto 1/R^2$. However, when the galaxy is further away, the surface area that corresponds to a given solid angle will be *larger* by a factor of 4, since $dS \propto R^2$ (a larger fraction of the galaxy is seen for a given value of $d\Omega$.) These two factors cancel exactly, making the SB distance independent. Amusingly this is no longer true on *very* large (cosmological) scales, because the flux from a given star decreases as the square of the *luminosity distance*, $F \propto d_L^2$, whereas the surface area increases with the square of the angular size distance, $dS \propto d_A^2$. These distances are not the same, because of cosmological red shifting and the curvature of the Universe. Obviously, this more detailed calculation falls outside of the scope of this L2 course, and for the galaxies we study here it holds true that the SB is constant. See my cosmology course notes if you're interested.

2. Describe two effects that intervening dust can have on the flux detected from stars. How does the magnitude of these effects depend on (1) the amount of dust, (2) the size of the dust grains. [2 marks]

   Answer:
   Intervening dust can absorb light from a distant source making it appear *fainter*. The amount of absorption depends on wavelength, so dust can change the observed *colour*. [1 mark]
   The amount of dust affects the amount of absorption. The size of the dust grains compared to the wavelength of light determine how much light is absorbed as well, and so sets the level of reddening. [1 mark]

3. The Sun is on an a circular orbit with radius $R = 8.0$ kpc around the centre of the galaxy, moving at speed $v = 220$ km s^{-1}. Calculate the period of its orbit in years. [2 marks]
   To measure the speed of another galaxy relative to the Milky Way, observers need to take v and the direction of the Sun's motion into account. Compare v with the speed of Earth around the Sun: which one is bigger? Is the motion of the Sun rather than that of Earth around the Sun always the dominant factor to take into account? [2 marks]

   Answer:
   Period $P = 2\pi R/v = 2.2 \times 10^8$ yrs. [2 marks]
   Full marks require answer in years, with correct rounding.
   The distance Earth-Sun is 1 AU=150×10^6 km (see GA1), its period is 1 year, and hence its speed is $v_E = 30.0$ km s^{-1} which is smaller than v.[1 mark]
   The ecliptic is not in the plane of the Milky Way disk that contains the Sun's orbit. So which of v_E or v is dominant depends on the direction to the galaxy.[1 mark]