AST 613 Example Problem: Observing event horizons

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The Event Horizon Telescope Collaboration has taken two ‘photos’ of supermassive black hole event horizons—first the central supermassive black hole in M87 and later the Milky Way’s own supermassive black hole, Sgr A*.

1. What angular resolution would a telescope need to have to resolve the event horizon of Sgr A*?
   a. First, we need the size of the event horizon we’ll be resolving. We can estimate the size of its event horizon by calculating the Schwarzschild radius: $R_S = \frac{2GM_{BH}}{c^2}$

      Sgr A* is a 4 million $M_\odot$ black hole $\rightarrow 4E6M_\odot(\frac{1.989E30kg}{1M_\odot}) \rightarrow R_S = \frac{2G(8E36M_\odot)}{c^2}$

      $R_s = 1.19E10m$ → This could fit within the orbit of Mercury in our solar system! And technically we’d only need to resolve the size of the diameter, so we can up that by a factor of 2: $2R_S = 2.38E10m$

      To find the angular resolution necessary to resolve this linear size: $\theta = \frac{s}{d}$

      Sgr A* is at the center of the Milky Way, about 7kpc away. 7kpc=2.16E20m

      $\theta = \frac{2.38E10m}{2.16E20m} = 1.1E - 10rad(206265) = 2.3E - 5as = 23\mu as$
2. The Event Horizon telescope used Very Long Baseline Interferometry at a wavelength of 1.3mm to observe this. What distance apart would the farthest Event Horizon Telescope elements need to be to get this resolution?
   a. $\theta = \frac{\lambda}{L} \rightarrow 1.1E - 11rad = \frac{1.3E-3m}{L}$

      $L = \frac{1.3E-3m}{1.1E-10} = 1.18E7m = 1.18E4km$

(Check: Not too far off from the EHT’s 2019 longest baseline of 1.1E4km!)