Year 2: Observing the Universe

Case Study: Observing time calculation for high redshift elliptical galaxies.

You are interested in studying high redshift elliptical galaxies, and trying to understand how their properties compare with the ellipticals that we see in the local universe. The immediate science goal is to detect a sample of $N = 1000$ candidate elliptical galaxies at $z = 1$, as the basis for detailed further study.

Previous research suggests that ellipticals at $z = 1$ are 20th magnitude – i.e. your observations should reach at least a limiting magnitude of $m_{\text{lim}} = 20$ – and that their number density on the sky is $\phi = 700\text{degree}^{-2}$.

To help achieve your science goal you have built an imaging device that contains CCD detectors that have an area of $A = 100\text{mm}^2$. You now need to choose which of two telescopes to use for your observations, and have decided to simply base your decision on which telescope requires the least amount of observing time to accomplish your goal.

1. Before considering the details of the two telescopes in question, your first step is to understand the calculation that you will form the basis of your decision. For this purpose we define the apparent magnitude of an object that you can detect in a 1 second observation with your camera and an arbitrary telescope as m_1.

   Show that the amount of observing time required to achieve your science goal can be written in terms of $m_{\text{lim}}, m_1, A, N, \phi$, and the focal length of the telescope, f, as follows:

   $$\text{Total observing time} = \frac{N}{A\phi} \left(\frac{\pi f}{180}\right)^2 10^{0.4(m_{\text{lim}} - m_1)}$$

   State any assumptions that you make.

2. You consider mounting your camera at the f/12.2 Cassegrain focus of the Subaru 8.2-m diameter telescope, for which $m_1 = 18.5$. Calculate how much observing time is required on Subaru to achieve your science goal. State any assumptions that you make.

3. You also consider mounting your camera at f/3.3 Prime focus of the Hale 200inch diameter telescope on Mount Palomar. Calculate how much observing time is required on the Hale to achieve your science goal. State any assumptions that you make.

4. Which telescope do you want to mount your camera on?

5. Discuss qualitatively how your answers to parts 2 and 3 would change if your assumptions were more realistic?