OPTICAL INTERFEROMETRY: THE SIM PLANETQUEST PROJECT

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Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 6, Problem 6.15.

Interferometry can be used with optical as well as radio telescopes. The angular resolution $\Delta\theta$ between two neighbouring sources is given in terms of the observation angle θ, the wavelength of the light λ and the baseline distance d between the telescopes by

$$\Delta\theta=\frac{\lambda}{d\cos\theta} \tag{0.1}$$

For observations near the zenith $\theta\approx0$ and $\cos\theta\approx1$ so the resolution is

$$\Delta\theta=\frac{\lambda}{d} \tag{0.2}$$

For radio telescopes, d needs to be quite large (kilometres, typically) since radio wavelengths are in the centimetre to metre range. Optical wavelength are much shorter, so we can get good resolution with the two telescopes much closer together.

This principle is being used in the SIM PlanetQuest space telescope which is, at the time of writing (August 2015) still under construction. It is planned to have a resolution of $4\times10^{-6\,\prime\prime}$.

Example 1. To get a feel for how good this resolution is, suppose we could use SIM to watch grass grow from a distance of 10 km. At that distance, SIM could resolve a distance of

$$\begin{aligned} D &= \left(10^{4}\text{ m}\right)\times\frac{\pi\left(4\times10^{-6}\right)}{180\times3600}\text{ rad} && (0.3)\\ &= 1.94\times10^{-7}\text{ m} && (0.4)\end{aligned}$$

If grass grows at 2 cm per week, this is 3.31×10^{-8} m s^{-1} so SIM could detect a change in the length of the grass after around 6 seconds.

Example 2. Now suppose we use SIM for parallax measurements, with a baseline of the diameter of Earth's orbit. In this case, the distance to the object is given in parsecs if the parallax angle is measured in arc-seconds:

$$d = \frac{1}{p} \text{ pc} \tag{0.5}$$

The parallax angle is half the measured change in angular position from one end of the orbit to the other, so with SIM's resolution, the smallest parallax angle is 2×10^{-6}, giving a maximum distance of

$$d_{max} = 5 \times 10^5 \text{ pc} \tag{0.6}$$

Given that the Sun is around 8000 pc from the centre of the Milky Way, SIM should be able to measure parallax angles for any object in the galaxy, provided it's bright enough to be visible to SIM's telescopes. However, it can't quite detect parallax for the Andromeda galaxy, as it is around 7.8×10^5 pc away.

Example 3. Given that SIM can detect stars down to apparent magnitude 20, could it actually see the Sun from a distance d_{max}? The Sun's absolute magnitude is $M = +4.74$ so its apparent magnitude at d_{max} is

$$\begin{aligned} m &= M + 5(\log d_{max} - 1) & (0.7) \\ &= +28.2 & (0.8) \end{aligned}$$

Sadly, the Sun wouldn't be visible to SIM from that distance.

How about an intrinsically bright star like Betelgeuse, with $M = -5.14$? The maximum distance at which it could be seen by SIM is

$$\begin{aligned} \log d &= \frac{m - M}{5} + 1 & (0.9) \\ &= \frac{20 - (-5.14)}{5} + 1 & (0.10) \\ &= 6.028 & (0.11) \\ d &= 1.07 \times 10^6 \text{ pc} & (0.12) \end{aligned}$$

Thus if Betelgeuse were at a distance d_{max}, SIM could see it and measure its parallax.