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AST10: Week 7b

Homework

(1) Which of the ground-based telescopes that we discussed in class might not have its observations affected by the earth's rotation?

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Answer(s)

(1) BICEP2 at the South Pole. (Why?)

(2) How smooth does the surface of the Arecibo telescope seem compared to the surface of the Subaru? (See class notes for pictures.) If the smoothnesses seem different, why might it be OK to have different degrees of smoothness in the two cases? For a radio telescope that's distinctly not smooth, see the picture on the right of a radio telescope at Stanford University. Why might it work as a reflector?

The imperfections have to be under $\lambda/4$.

A telescope aimed at visible light ($\lambda \approx 5 \times 10^{-7}$ m — about half a millionth of a meter) must have imperfections smaller than $1/4$ that.

A radio telescope aimed at wavelengths, say, of 4 m, needs to have imperfections only smaller than a meter. Imperfections (holes. bumps, etc.) of about 0.5 m would be OK.

(3) If a telescope with focal length $30\,\text{cm}$ "sees" an object taking up 2° of its view, how big is the image in the telescope?

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Answer(s)

(3) The size is

$$s = \frac{\theta}{180^\circ}\pi f = \frac{2^\circ}{180^\circ}\pi \cdot 30 \approx 1.05\,\text{cm}.$$

(4) If an object makes an image that's 0.5 mm on your retina, how many degrees of your view does it occupy?

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Answer(s)

(4) We have

$$0.5\,\text{mm} = \frac{\theta}{180^\circ}\pi \cdot 17\,\text{mm} \approx (0.3)(\theta).$$

So, $\theta = 0.5/0.3 \approx 1.7^\circ$.

(5) When you zoom into an object optically with your camera (not electronic zoom), does the lens extend or contract? Why?

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Answer(s)

(5) Extend. The effective focal length of the lens system is increasing.

(6) Why is a ground-based x-ray telescope not a great idea?

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Answer(s)

(6) Few x-rays get through the atmosphere.

(7) What is the resolution in seconds of telescope with a 0.5 m diameter lens at visible light?

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Answer(s)

(7) The resolution is

$$\theta_{\mathsf{res}} = 1.22\frac{180}{\pi}\frac{\lambda}{D} = 1.22\frac{180}{\pi}\frac{5\times 10^{-7}}{0.5}$$
$$\approx 70\frac{5\times 10^{-7}}{0.5} = \left(700\cdot 10^{-7}\right)^{\circ}$$
$$= \left(7\cdot 10^{-5}\right)^{\circ} = \left(3600\cdot 7\cdot 10^{-5}\right)'' \approx 0.25''.$$

(8) We've seen in class that some telescopes are dual-purpose: they detect visible light and infra-red. Were the telescope in the question above capable of this, would it have higher resolution in infra-red or lower (compared to visible light)?

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Answer(s)

(8) Infra-red has longer wavelength, therefore a bigger θ_{res}, therefore *lower* resolution.

(**9**) What diameter lens do you need on a telescope that can resolve up to a thousandth of a second?

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Answer(s)

(**9**) First convert $\left(10^{-3}\right)''$ to degrees: $10^{-3}/3600 = \left(2.8 \times 10^{-7}\right)^{\circ}$. So

$$2.8 \times 10^{-7} = 1.22 \frac{180}{\pi} \left(\frac{5 \times 10^{-7}\text{m}}{D} \right)$$

So,

$$2.8 \times 10^{-7} \approx \frac{70 \times 5}{D} \times 10^{-7}.$$

Or,

$$2.8 \approx \frac{350}{D}.$$

$$D \approx \frac{350}{2.8} = 125\,\mathrm{m}.$$