

# Lensing & Fermat's Principle

## Cosmology Crash Course

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- A) Optics review: What are the shapes of (optical) converging lenses (which focus light) and diverging lenses (which spread light out)?
- B) Use Fermat's Principle of Least Time to explain why converging lenses focus light and optical lenses spread light out.
- C) When viewing an object through a converging lens, will it appear brighter or dimmer? Explain.
- D) When viewing an object through a diverging lens, will it appear brighter or dimmer? Explain.
- E) Given gravitational time dilation and Fermat's principle of least time, will a massive object act as a converging or diverging lens? Explain.
- F) Will a massive gravitational lens make background galaxies look brighter or dimmer?
- G) (Bonus) "Surface brightness" or "specific intensity" is defined as the flux (energy per second per unit area) per unit solid angle (that is, pointed into unit solid angle. Surface brightness is said to be constant along a light ray. By considering two differential areas  $dA_1$  and  $dA_2$  separated by a distance  $r$ , and considering the rays that pass through both of them, show that the surface brightness is the same at both  $dA_1$  and  $dA_2$ .