

## Diagrams and Equations

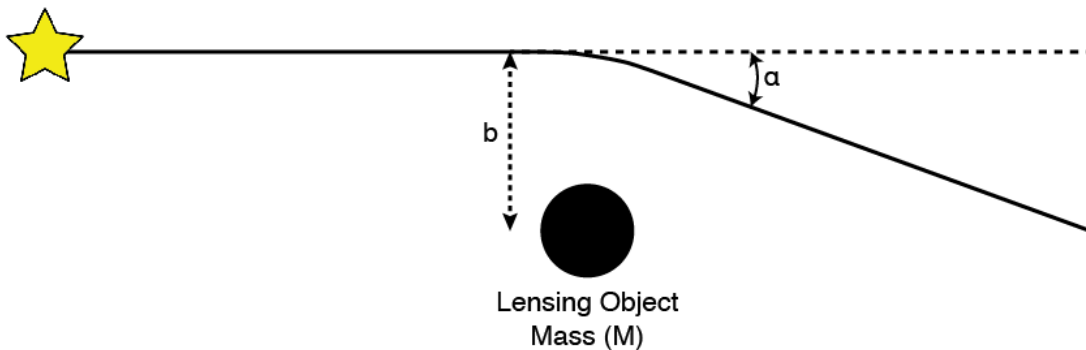
### Constants

$M$  = the (unknown) mass of the black hole

$$G = 6.67 \times 10^{-11} \frac{m^3}{kg s^2} \text{ (gravitational constant)}$$

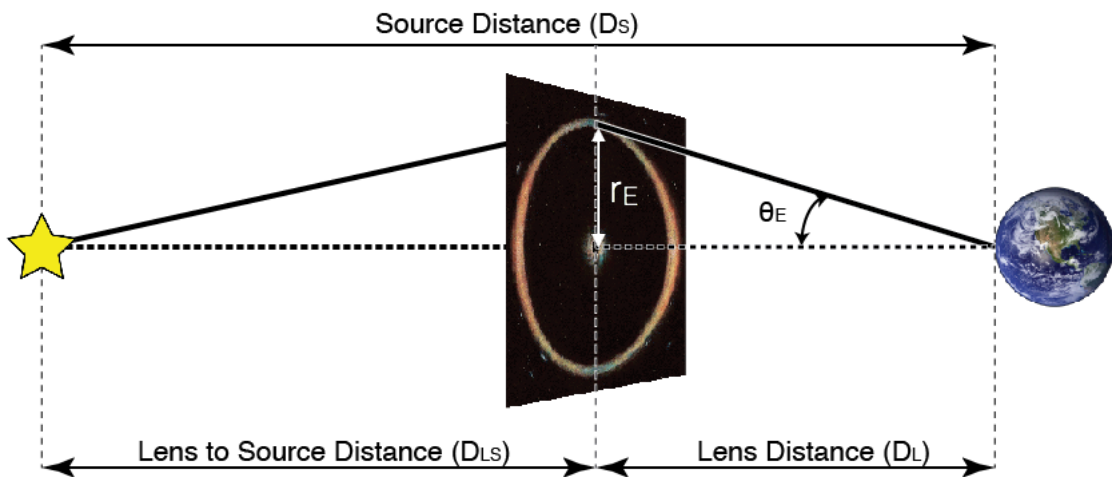
$$c = 3.00 \times 10^8 \frac{m}{s} \text{ (speed of light in empty space)}$$

1) **Deflection Angle:** A ray is bent while passing near a massive object



$$\alpha = \frac{4GM}{bc^2}$$

2) **Einstein Ring:** The light from a distant object appears as a ring around a massive object according to someone on Earth.



$$\theta_E^2 = \frac{4GM}{c^2} \frac{D_{LS}}{D_L D_S}$$

$$r_E^2 = \frac{4GM}{c^2} \frac{D_{LS} D_L}{D_S}$$

### Degrees and Radians

Angles are commonly measured in two different units; degrees and radians. The angles that appear in the equations in this handout must be measured in radians. You can convert from degrees to radians by multiplying by  $\pi/180$ :

$$\theta(\text{radians}) = \frac{\pi}{180} \theta(\text{degrees})$$