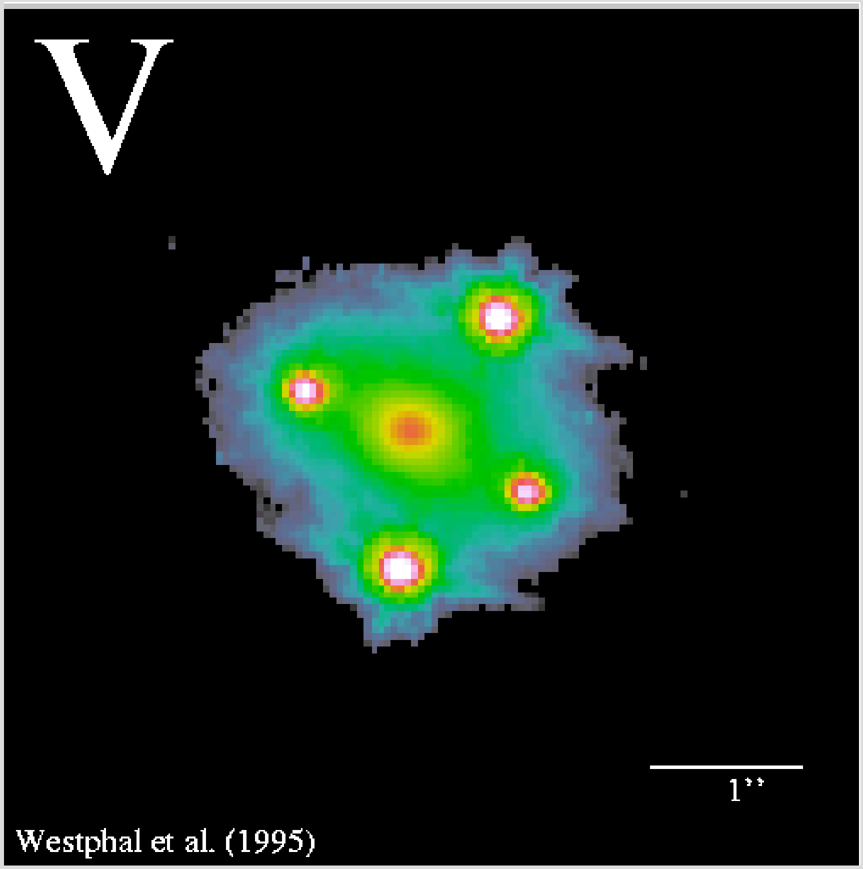
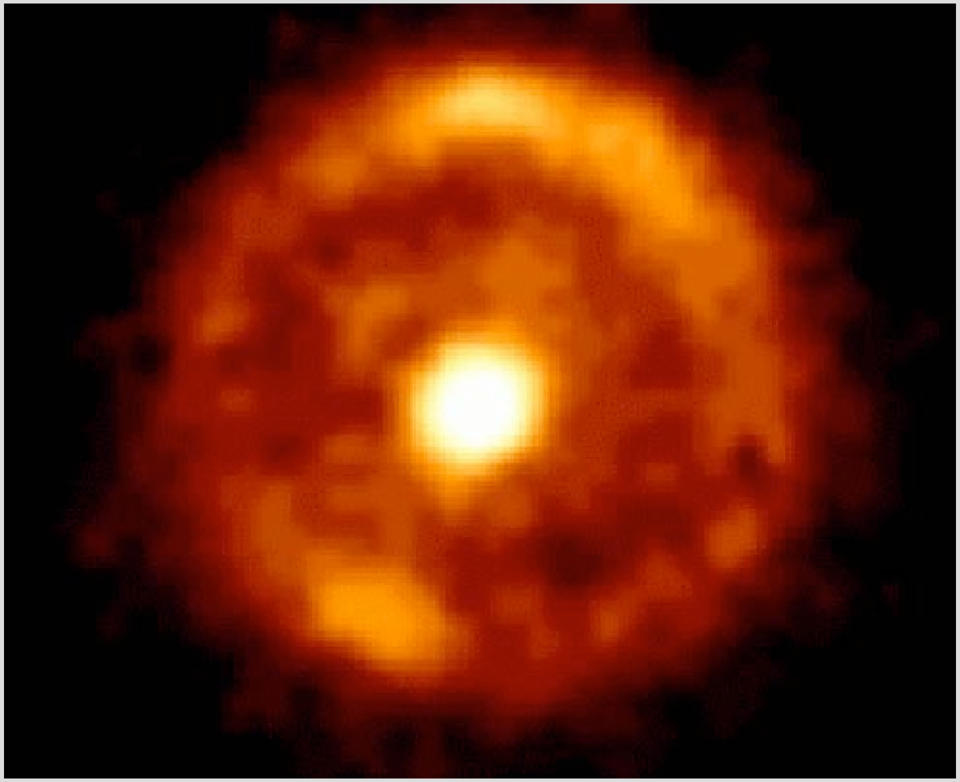
Different lensing regimes

Conceptually simplest situation for gravitational lensing is when the lens is massive enough to produce a `large' angle of deflection. Case where we can resolve multiple images of the background source is called **strong lensing**:





Near perfect Einstein ring!

Strong lensing normally requires galaxy mass lenses, which are extended objects (i.e. slightly more complicated than the point mass case we considered).

Consider instead a Solar mass star half way between us and the Galactic Bulge:

$$d_S = 8 \text{ kpc}$$

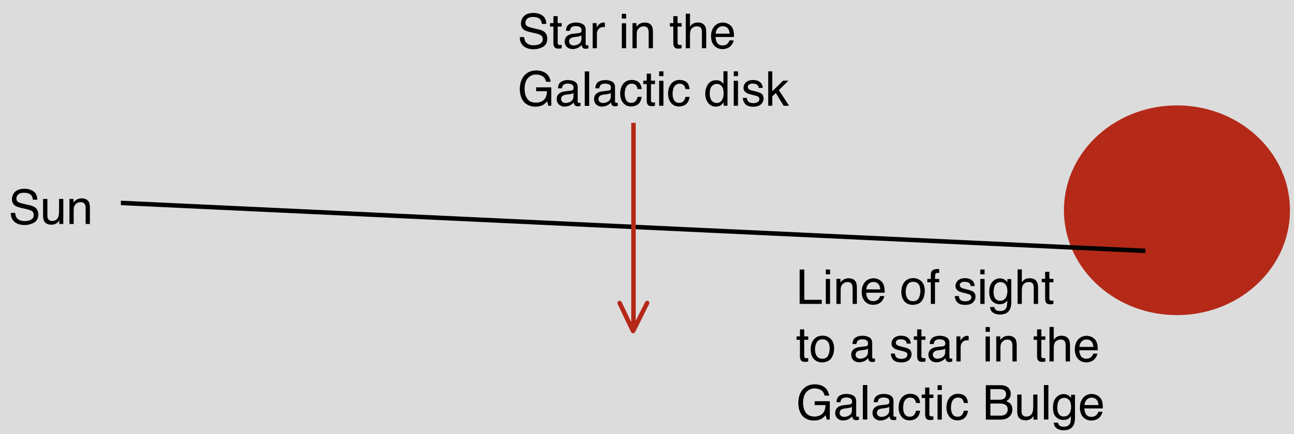
$$d_L = d_{LS} = 4 \text{ kpc}$$

$$\theta_E = \frac{2}{c}\sqrt{\frac{GMd_{LS}}{d_L d_S}} = 5 \times 10^{-9} \text{ radians} = 10^{-3} \text{ arcsec}$$

Warning: lots of possibilities for getting the units wrong here. Need M in g; distances in cm; c in cm s^{-1}. Answer is in radians.

Can't resolve the multiple images - the separation is only 1 milliarcsecond…

All is not lost if there is relative motion between the lens and the background source. **Brightness** of the unresolved source changes as the lens passes in front of the source:



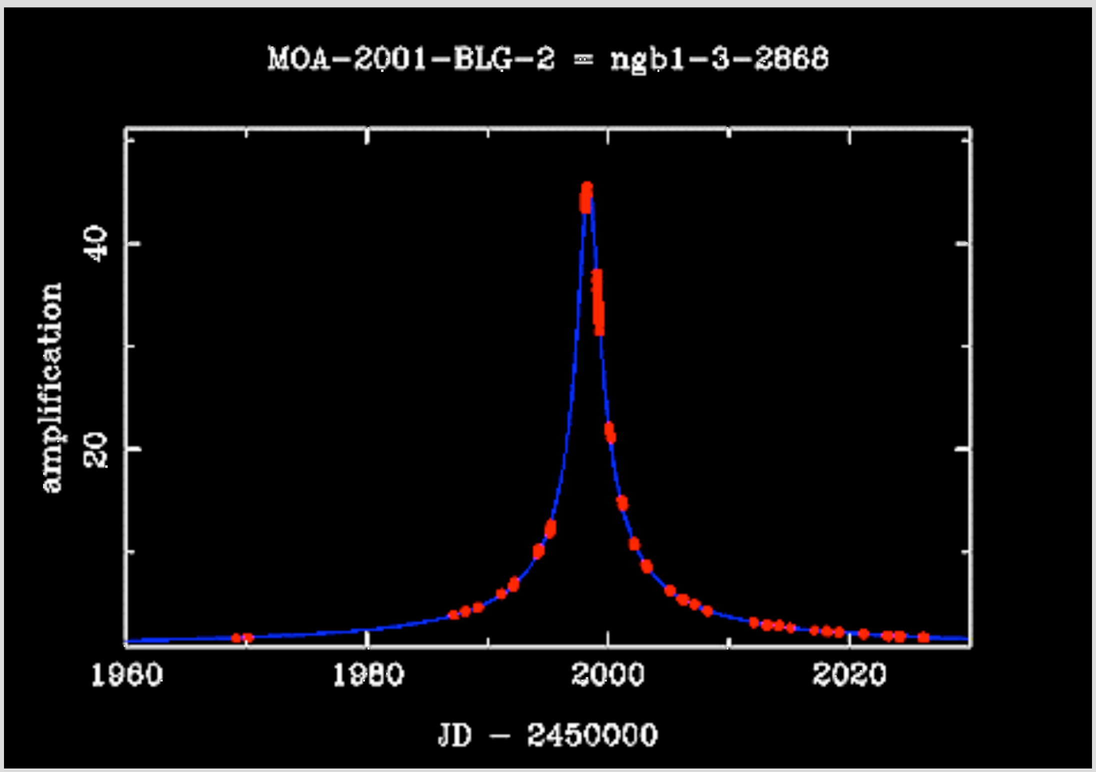
Lensing event occurs as the disk star passes within an angular distance θ_E of the bulge star:

- bulge star initially brightens
- eventually fades as the alignment is lost

This unresolved lensing regime: **microlensing**.

Physics: lensing *conserves surface brightness*. Lensed images are bigger, so source appears magnified.

- Strong effect for impact parameters $\square < \square_E$ - source can be magnified by a factor of 10 (2.5 magnitudes) or more
- But very rare - probability of a given star in the Bulge being lensed at any instant is ~few x 10^{-6}

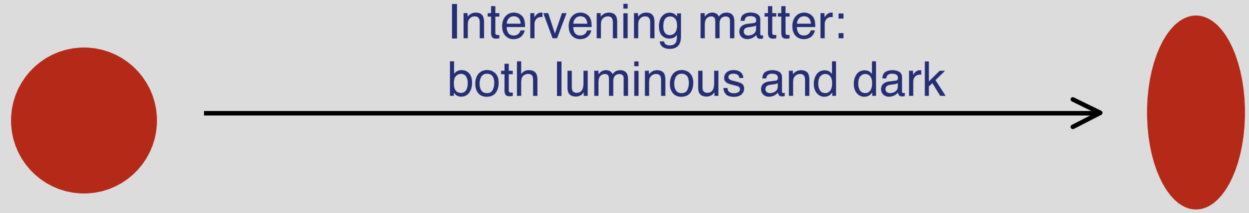


Now routinely observed, example light curve of a lensed star.

Final regime is **weak lensing**:

- no multiple images
- deflection causes only a distortion in the **shape** of extended sources

e.g. a distant spherical galaxy may appear as an ellipse rather than a circle due to weak lensing by all the matter along the line of sight.



Subtle and hard to measure effect - distortion is only a few % at most. But an important probe of the dark matter distribution on very large scales.