MACHOS AND BROWN DWARF STARS

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Reference: Moore, Thomas A., *A General Relativity Workbook*, University Science Books (2013) - Chapter 13; Problem P13.5.

We saw in the graph of the brightness of a background source when lensed by a MACHO that the main brightening occurs for times such that $-0.5 < t/t_E < +0.5$, so the MACHO moves about the radius of the Einstein ring, θ_E:

$$\theta_E \equiv \sqrt{D_{LS}\frac{4GM}{D_L D_S}} \tag{1}$$

If we consider a solar mass MACHO, then $GM = 1.477$ km $= 1.56 \times 10^{-13}$ ly. If we take the distance of the MACHO as 30,000 light years and the distance of the source as twice that, then $D_L = D_{LS} = 3 \times 10^4$ ly and $D_S = 6 \times 10^4$ ly. The angle is then

$$\theta_E = 3.226 \times 10^{-9} \text{ radians} \tag{2}$$

At a distance of D_L, this corresponds to an actual distance of

$$d_E = 9.15 \times 10^8 \text{ km} \tag{3}$$

If the MACHO has a transverse speed of 200 km/s it will take it about 53 days to move this distance.

The MACHO in Moore's Fig. 13.6 takes about 10 days to travel an angle of θ_{E0} so if the distances and speed are the same as in this example, the mass M_0 of the MACHO is found from

$$\frac{\theta_{E0}}{\theta_E} = \frac{10}{53} = \sqrt{\frac{M_0}{M}} \tag{4}$$

This gives the MACHO a mass of around 0.04 solar masses, which could fit if the MACHO is a brown dwarf star, as some are believed to be.