The Effect of Galaxy Peculiar Motion on the Calculation of Time Delay between Gravitationally Lensed Images

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Introduction

Gravitational Lensing

Gravitational lensing is one of the more prominent ideas predicted in the theory of general relativity by Albert Einstein.

Today its one of the fundamental tools that we are using to identify the mass distribution of the universe.

In a nutshell gravitational lensing is the bending of photons(light) near a massive mass distribution due to the curvature of space time.

Introduction

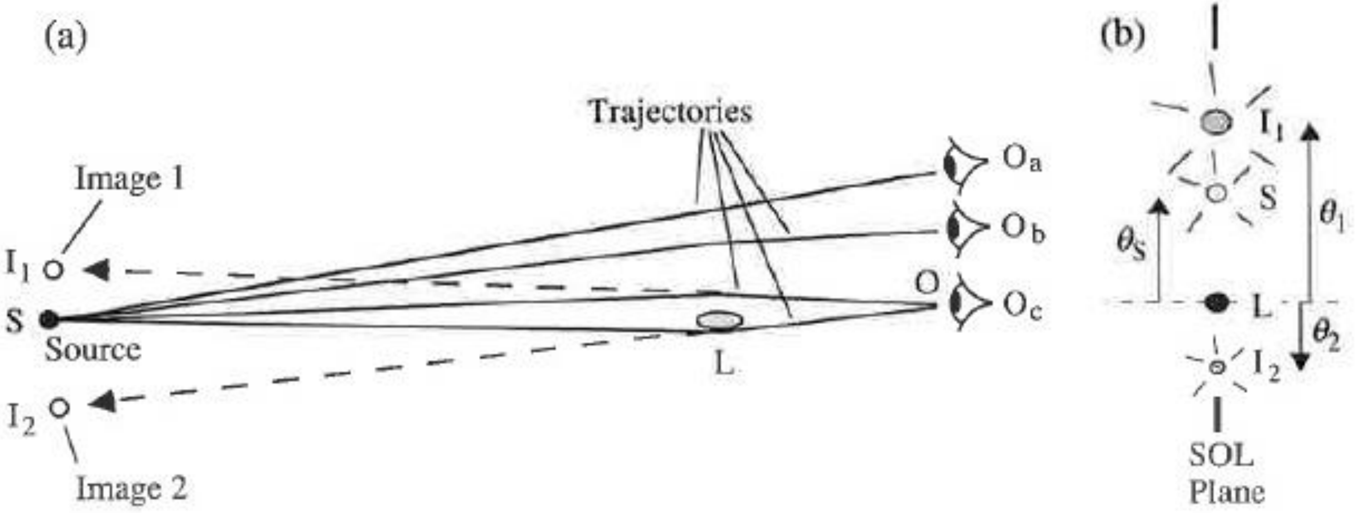


Fig 1. Gravitational lensing diagram

Introduction

Peculiar Speeds of the Galaxies

The Universe is having an accelerated expansion due to the Dark Energy, therefore at any given time the bulk motion of the Universe is this expansion. [1][2].

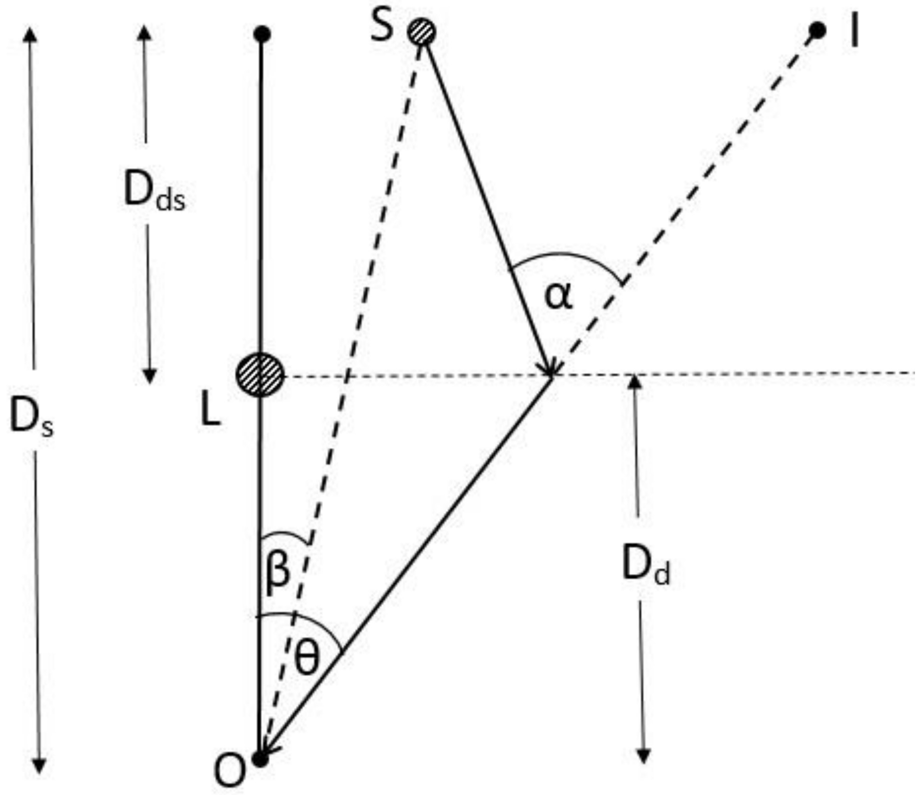
But the Galaxies themselves are having random motions in any given direction which is called the peculiar motion of the Galaxies.

At the moment when the gravitation lensing calculations are carried out these peculiar motions of the Galaxies are neglected.

In this research we are measuring the effect of this Galaxy peculiar motion on the Gravitational lensing time delays and whether it is significant.

Introduction

Fig 2. Gravitational lensing Schematic Diagram



Introduction

Lensing Time Delay for a Point Mass

There will be two images formed when the light rays are travelling around the lens (Fig. 1 and Fig. 2). Assuming there is no peculiar motion, the time delay will be given by the following equation [3]

$$\Delta\tau = \frac{D_f}{c}(1 + z_d)\left[\frac{1}{2}(\theta_1^2 - \theta_2^2) + |\theta_1\theta_2| ln\left|\frac{\theta_1}{\theta_2}\right|\right] \qquad (1)$$

Where

$$D_f = \frac{H_0}{c}\frac{D_d D_s}{D_{ds}} \qquad (2)$$

Methodology

The angular diameter distance D of a source *having no peculiar motion* at a redshift z is given by [4][5]

$$D(z) = \frac{c}{H_0}\frac{1}{1+z}\int_{\frac{1}{1+z}}^{1}\frac{dx}{\sqrt{\mathrm{x}\,\Omega_{m,0}+\Omega_{r,0}+\mathrm{x}^4\,\Omega_{\Lambda,0}}} \qquad (3)$$

Where $\Omega_{i,0}$ is the density parameter of the substance *i* measured at the present time. We assume a flat universe (k=0) for which [6]

$$\Omega_m + \Omega_r + \Omega_\Lambda = 1 \qquad (4)$$

Methodology

The redshift of z_{ds} of S as seen by L is given by,

$$1 + z_s = (1 + z_d)(1 + z_{ds}) \tag{5}$$

Thus, from the equations (3), (4) and (5) we can derive the value of D_{ds}, the angular diameter distance of the source as seen by an observer on the lens is,

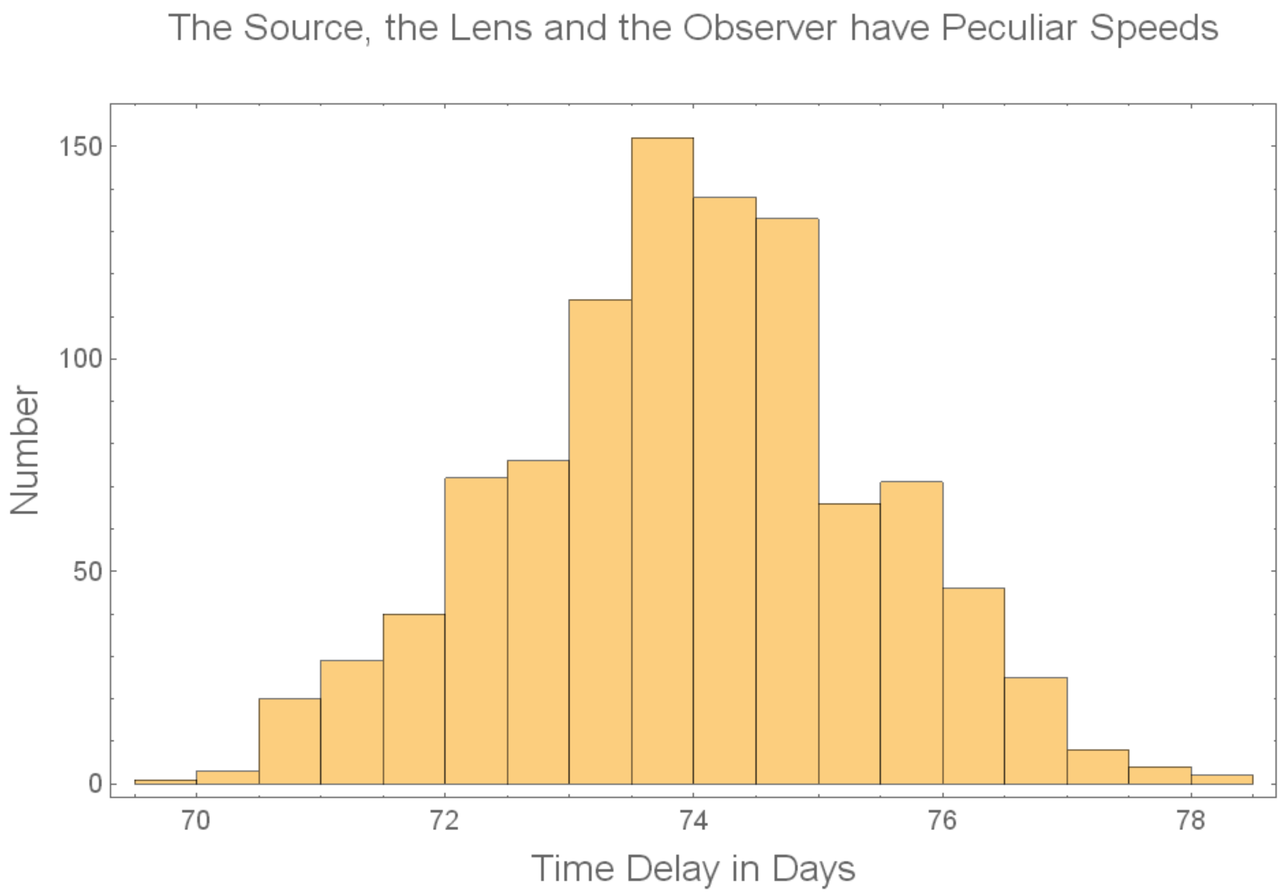
$$D_{ds} = \frac{c}{H_0} \frac{1}{\sqrt{\Omega_{\Lambda,0}}} \frac{1+z_d}{1+z_s} \int_{\frac{1+z_d}{1+z_s}}^{1} \frac{dx}{\sqrt{x^4 + x\left(\frac{1}{\Omega_{\Lambda,0}} - 1\right)(1+z_d)^3}} \tag{6}$$

Results and Discussion

The following diagrams illustrate our results for the lensing system for which $z_d = 0.42$, $z_s = 1.59$, $\theta_1 = 1''.14$, $\theta_2 = 0''.25$, $\beta = 0.01$ for L and S, for peculiar motions oriented randomly. Without these peculiar motions, the delay is about 74 days.

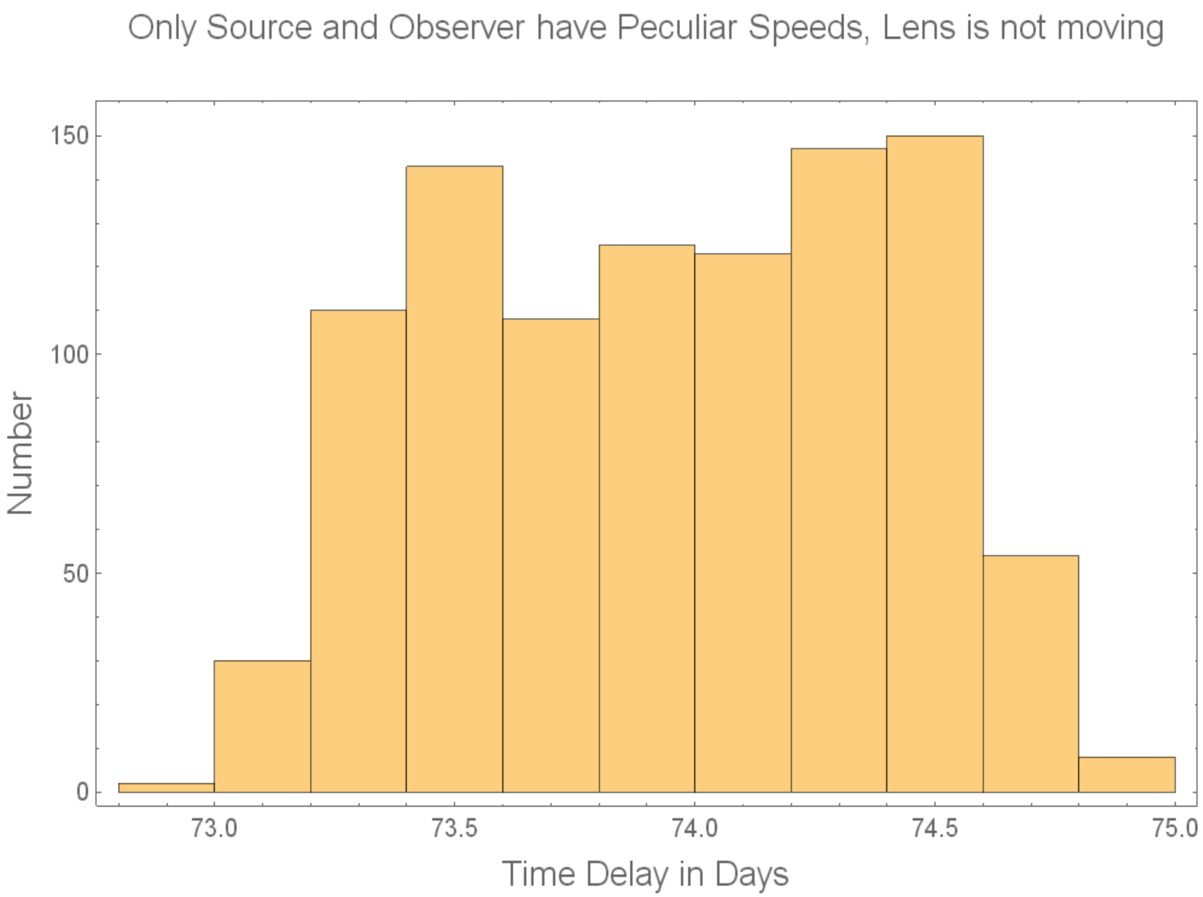
Results and Discussion

Fig 3. **The source, the lens and the observer having peculiar speeds.**



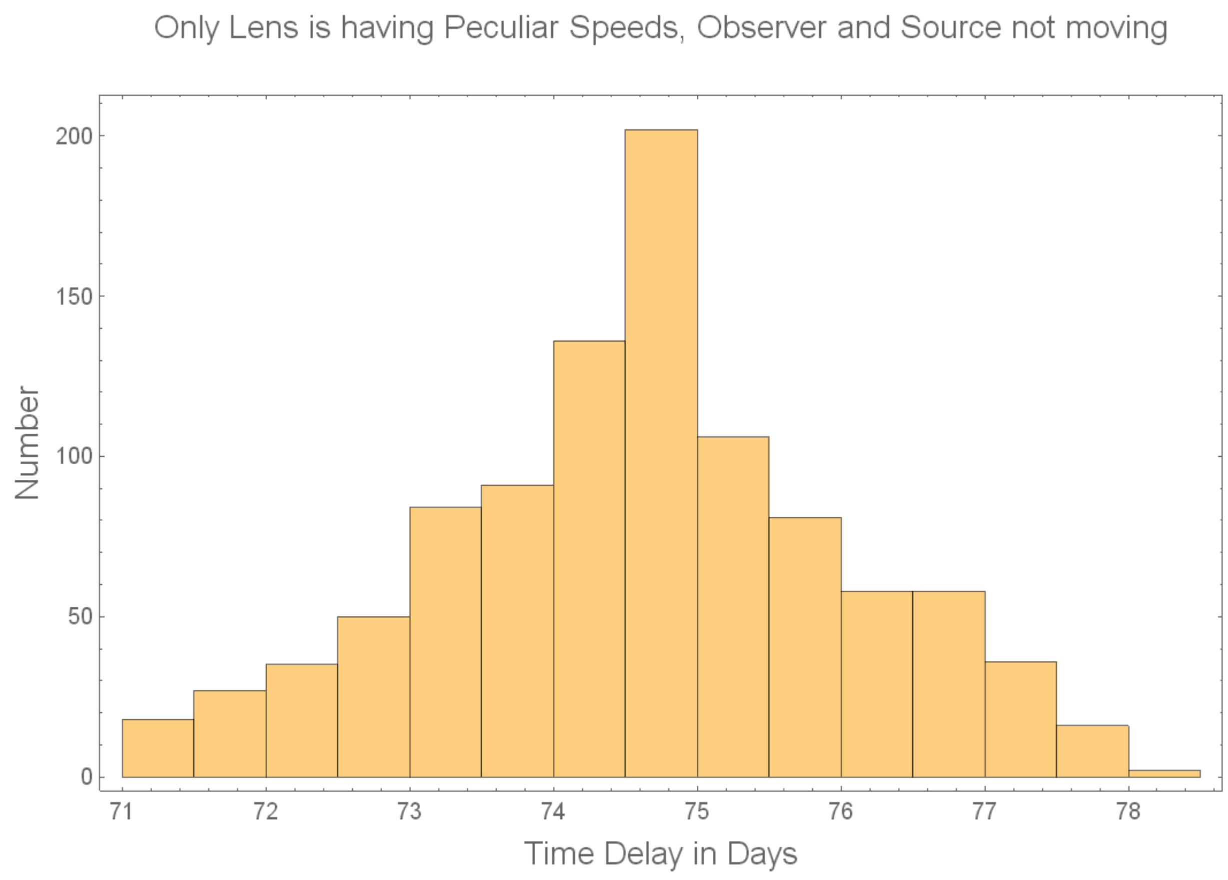
Results and Discussion

Fig 4. The source and the Observer only having peculiar speeds.



Results and Discussion

Fig 5. Only the lens is having a peculiar motion



Conclusion

We investigated the problem of gravitational lensing when the lens, source and observer are in motion.

Our main aim was to find out if there is any significant modification to the time delay between images.

We have found out that in fact there is a significant measurable time delay difference arising from the peculiar speeds of lenses.

In that the motion of the lens is very significant and the motion of the source and the observer is insignificant in the gravitational lesing time delay

References

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Thank you

Questions?