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GRAVITATIONAL LENSING EFFECTS ON IMAGE OF DISTANT OBJECT

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Abstract

This paper present studying the effect of gravitational lensing on magnification factor and the location of image for distant object (quasar).We assume the lens to be point mass lens. The cosmological parameters are represent by mathematical equations and programmed by mat lab language to compute these parameters .The results show the mass lens a great effect on the image position magnification and agreement with other models.

Introductions

The deflection of light by massive bodies, and the phenomena, resulting there form, are now referred to as Gravitational Lensing. It is an important astrophysical tool because it directly probes mass distribution and it brightens the images of distant sources. The necessary parts of a Gravitational Lens are

1. A luminous object called the source (S).
2. A massive object called the lens (L).

When light from the background source passes by the foreground lens, it will be defected and sometimes magnified. These effects result in an object which appears to be a different shape or brighter than it would ordinary appear (1).

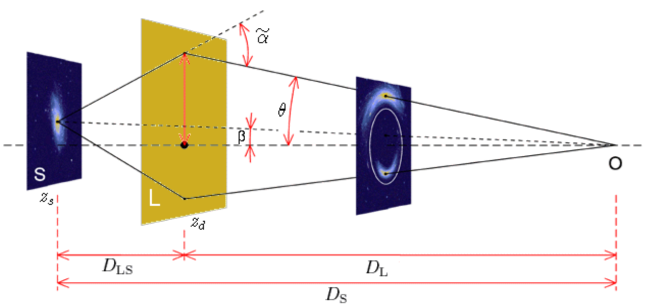


Fig.(1) : If the source, lens and the observer located on the same optical axis, the image seen as a (ring) which called (Einstein ring).

Lensing geometry and lens equation

The geometry of a typical gravitational lens system is shown in Fig. (1).

A light ray from a source S is deflected by the angle $\hat{\alpha}$ at the lens and reaches an observer O. The angle between the (arbitrarily chosen) optic axis and the true source position is β, and the angle between the optic axis and the image I is θ. The (angular diameter) distances between observer and lens, lens and source, and observer and source are D_L, D_{LS}, and D_S, respectively.

The angular separations of the source and the image from the optic axis as seen by the observer are β and θ, respectively. The actual deflection angle $\hat{\alpha}$ is related as follow [2]:

$$\hat{\alpha} = \frac{D_{LS}}{D_S}\vec{\alpha} \quad \text{...(1)}$$

The position of the source and the image are related through the simple equation

$$\vec{\beta} = \vec{\theta} - \vec{\alpha}(\vec{\theta}) \quad \text{...(2)}$$

The above equation is called the lens equation, It is nonlinear in the general case, and so it is possible to have multiple images θ corresponding to a single source position β.[3]

Einsten Radius

For a point mass lens M the lens equation is given by

$$\beta = \theta - \frac{D_{LS}}{D_L D_S}\frac{4GM(\theta)}{C^2\theta} \quad \text{.................................(3)}$$

For a special case in which the source lies exactly behind the lens ($\beta = 0$), due to the symmetry a ring-like image occurs whose angular radius is called Einstein radius θ_E : [4]

$$\theta_E = \sqrt{\frac{4GM(\theta)}{c^2}\frac{D_{LS}}{D_L D_S}} \quad ....(4)$$

Where G=6.67*10^-8
dyne.cm.g^-2
and c=3*10^10 cm/s

Image positions and magnifications

The lens equation (2) can be re-formulated in the case of a single point lens [4]:

$$\beta = \theta - \frac{\theta_E{}^2}{\theta} \quad ....(5)$$

in this paper we will assume that the source position is one half the Einstein radius

$$\beta = \frac{\theta_E}{2} \quad ....(6)$$

Solving this for the image positions θ one finds that an isolated point source always produces two images of a background source. . Any source is imaged twice by appoint mass lens. The two images are on either side of the source, with one image inside the Einstein rings and the other outside, as the source moves away from the lens (i.e. as β increases), one of the images approaches the lens and becomes very faint, while the other image approaches closer and closer to the true position f the source and ends towards a magnification of unity as the Fig. (2).The positions of the images are given by the two solutions [5]

$$\theta_{\pm} = \frac{1}{2}\left(\beta \pm \sqrt{\beta^2 + 4\theta_E{}^2}\right) \quad ....(7)$$

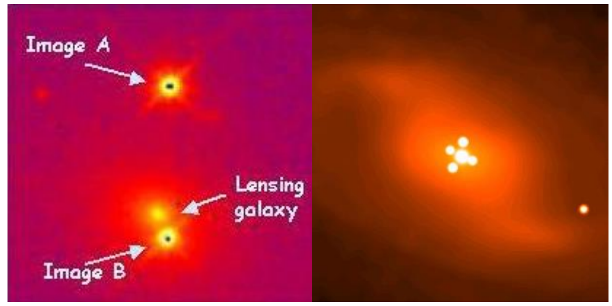


Fig.(2): (A) The gravitational lensing system Q0957+561 as observed with Hubble Space Telescope in the H band. The two quasar images A and B are seen through the lensing galaxy.
(B) The gravitational lensing system Q2237+0305 four images are seeing through the lensing spiral galaxy. These pictures were made available online by the CASTLES Survey [6].

The magnification of an image is defined by the ratio between the solid angles of the image and the source, since the surface brightness is conserved. For circularity symmetric lens, the magnification factor μ is given by[7]:

$$\mu = \frac{\theta}{\beta}\frac{d\theta}{d\beta} \quad ....(8)$$

In the symmetric case above, the magnification of the images is given by the ratio of the surface elements as in the last equation (by using the lens equation). For a point mass lens, which is a special case of circularity system lens, we can substitute for β using lens equation (2) to obtain the magnification factor of two images.[8]

$$\mu_{\pm} = \left[1 - \left(\frac{\theta_E}{\theta_{\pm}}\right)^4\right]^{-1} \quad ....(9)$$

Results and discussion

1- Table (1) Show the results of location of image source, and magnification factories for different values of lens mass (M).
2- Table (2) Show the result of images position of the source using different value of angular diameter distance of source D_S.

3- Table (3) Shown in the result of images position of the source using different value of angular diameter distance of lens D_L.

4- Fig (1-a) illustrates the relation between the lens mass (M) and image of position (Θ_1, $\Theta 2$).

5. Fig (1-b): illustrates the relation between the lens mass (M) and magnification factor

6. Fig (2-a): illustrates the relation of angular diameter distance of the source D_S and image position (Θ_1, $\Theta 2$) with M=5*10^45gm and D_L=1500cm.

7. Fig (2-b): illustrates the relation of different values of angular diameter distance of the source D_S and the magnification factor with M=5*10^45gm and D_L=1500 Mpc.

8. Fig (3-a): show the relation between different values of angular diameter distance of the lens D_L and magnification factor with M=5*10^45gm and D_S=2000 Mpc.

9. Fig (3-b) show the relation between different values of angular diameter distance of the lens D_L and image position (Θ_1,Θ_2) with M=5*10^45gm and D_S=2000 Mpc.

From the results any source is imaged twice by a point mass lens, the two images are on either side of the source. Further, we obtained two values of magnification, first is negative this means is very faint and located inside the Einstein rings and other values is positive and it is very clear and located outside the Einstein rings. Finally the magnification factor depends strongly on the mass lens .

References

[1] J. A.Tyson, R. A.Wenk, F. Valdes, 1990, "Detection of systematic gravitational lens galaxy image alignments - Mapping dark matter in galaxy clusters", Ap. J. lett. 349.

[2] N. Jackson, 1998, "Lensing galaxies: light or dark?", Astron. Atrophies. 334, L33.

[3] M. Bartelmann, P. Schneider, 1999, "Weak Gravitational Lensing", to be submitted to Physics Reports, preprint: astro-ph/9912508.

[4] W. S. Robert, 2000, "Cosmological applications of gravitational lensing", Ph. D thesis, Potsdam university. London, Britania..

[5] N. Ramesh, B. Matthias, 2001, "Lectures on Gravitational Lensing", Preprint astro-ph/ 9606001.

[6] CASTLES Survey Web site: fawww.harvard.edu/castles/.

[7] J.Wambsganss, 2001,"Gravitational Lensing in Astronomy", Max-Planck Institute for Gravitational Physics, Albert Einstein Institute, Potsdam, Germany.

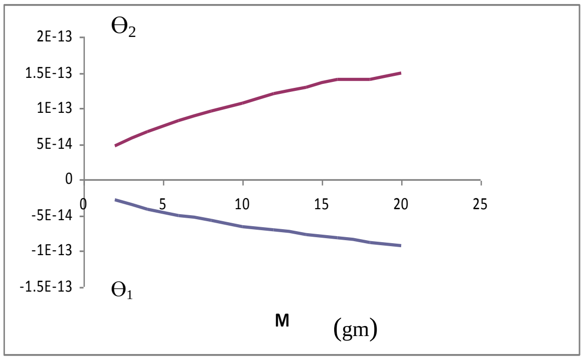
[8] S. D. Rex, 2002, "A Brief Introduction to Gravitational Lensing”. S.D.Rex.htm.

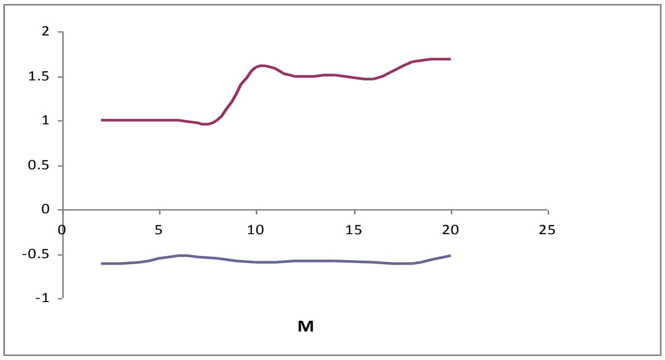
الخلاصة

تم في هذا البحث دراسة تاثير ظاهرة التعدس الجذبي على موقع الصورة و مقدار التكبير لجسم بعيد (كويزر) وقد تم فرض موديل عدسة ذات كتلة نقطية ،تم تمثيل كافة المتغييرات الكونية على شكل معادلات رياضية وتم برمجتها بلغة (mat lab), ومن النتائج تبينت ان للكتلة اثر كبير في مواقع الصورة ونسبة التكبيرو توافقها مع الموديلات الاخرى.

Table (1)
A analytical study for the image magnification and image location for values of lens mass

D_S(Mpc)	θ_1	θ_2	µ1	µ2
3500	-5.4E-14	8.9E-14	-0.58	1.62
4000	-3.9E-14	6.43E-14	-0.59	1.61
5000	-3.4E-14	5.6E-14	-0.6	1.54
10000	-1.6E-14	2.6E-14	-0.57	1.55
15000	-1E-14	1.66E-14	-0.63	1.57
25000	-5.9E-15	9.8E-15	-0.6	1
50000	-2.9E-15	4.8E-15	-0.59	1.59
100000	-1.5E-15	2.4E-15	-0.51	1.67
200000	-7.2E-16	9.3E-16	-0.58	1.58
250000	-5.7E-16	9.5E-16	-0.57	1.61
500000	-2.9E-16	4.7E-16	-0.58	1.57
10*10^6	-1.4E-17	2.4E-17	-0.46	1.69
15*10^6	-9.6E-18	1.6E-17	-0.62	1.56
25*10^6	-5.8E-18	9.5E-18	-0.61	0.61
5*10^7	-2.9E-18	4.7E-18	-0.54	1.57
10*10^7	-1.4E-18	2.36E-18	-0.58	1.62

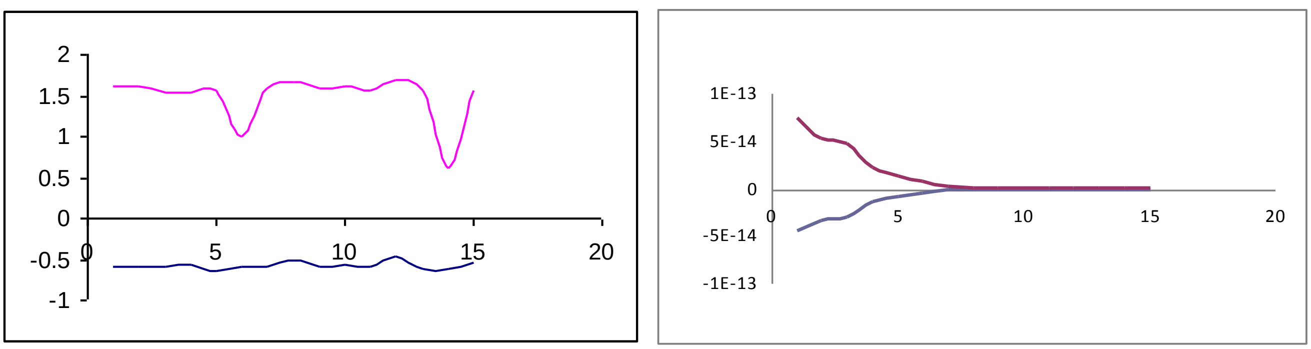




Fig(1) a)The relation between lens mass and the image positions of source.
b) The relation between lens mass and Magnification factor.

Table (2)
A analytical study for the image location of the source using different values of angular diameter distance of source DS

M *10^45(gm)	Θ1	θ2	μ1	μ2
2	-2.9E-14	4.80E-14	-0.6061	1
4	-4.11E-14	6.70E-14	-0.5943	1
6	-5.04E-14	8.27E-14	-0.5153	1
8	-5.8E-14	9.50E-14	-0.5568	1
10	-6.5E-14	1.06E-13	-0.6029	1.6023
12	-7.1E-14	1.20E-13	-0.5887	1.4941
14	-7.7E-14	1.30E-13	-0.5772	1.5068
16	-8.2E-14	1.40E-13	-0.5923	1.4629
18	-8.7E-14	1.40E-13	-0.6061	1.6533
20	-9.2E-14	1.50E-13	-0.5278	1.6938

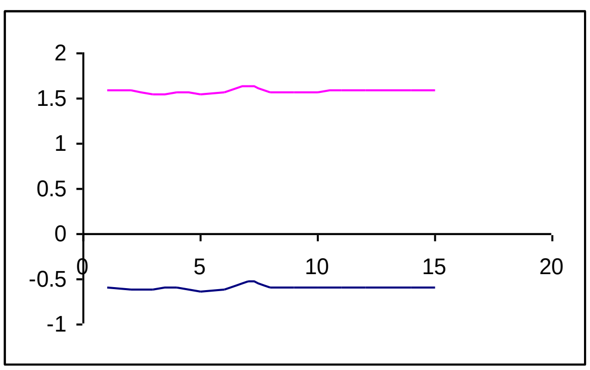


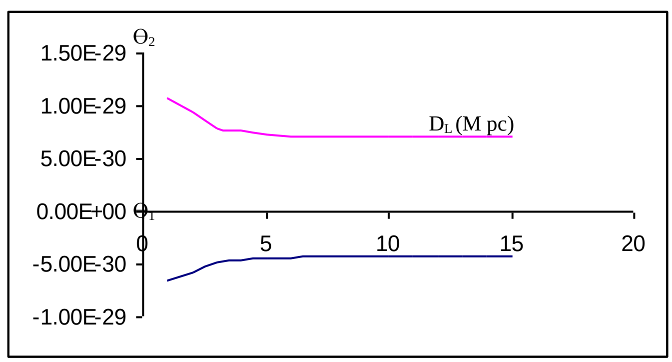
(a) *(b)*

Fig (2):a) The relation between the angular diameter distance of source D_S and image position b) The relation between the angular diameter distance of source D_S and Magnification factor.

Table (3)
A analytical study for the image location of the source using different values of angular diameter distance of lens D_L

D_L(Mpc)	θ_1	θ_2	μ1	μ2
3500	-6.60E-30	1.07E-29	-0.59	1.59
4000	-5.80E-30	9.50E-30	-0.6061	1.58
5000	-4.80E-30	7.90E-30	-0.6218	1.55
10000	-4.60E-30	7.60E-30	-0.5861	1.57
15000	-4.50E-30	7.40E-30	-0.635	1.54
25000	-4.40E-30	7.20E-30	-0.6158	1.57
100000	-4.30E-30	7.10E-30	-0.532	1.63
200000	-4.30E-30	7.09E-30	-0.59	1.56
250000	-4.30E-30	7.08E-30	-0.59	1.57
500000	-4.30E-30	7.07E-30	-0.59	1.57
10*10^6	-4.30E-30	7.06E-30	-0.59	1.58
15*10^6	-4.30E-30	7.06E-30	-0.59	1.5831
25*10^6	-4.30E-30	7.06E-30	-0.59	1.5831
5*10^7	-4.30E-30	7.06E-30	-0.59	1.5831
10*10^7	-4.30E-30	7.06E-30	-0.59	1.5831





(a) (b)

Fig (3):a) The relation between the angular diameter distance of lens D_L and Magnification factor. b) The relation between the angular diameter distance of lens D_L and image position