Gravitational Lensing an Observational Evidence for Dark Matter Search

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Abstract: The question as to how this universe came into being and as to how it has evolved to its present stage, is an old question. The answer to this question unfolds many secrets regarding fundamental particles and forces between them. The most important ingredient of this whole creation namely 'Dark Matter' was for the first time identified by Fritz Zwicky of California Institute of Technology (Caltech) in 1933[1,2].A gravitational lens is formed when the light from a very distant, bright source (such as a quasar) is "bent" around a massive object (such as a cluster of galaxies) between the source object and the observer. The process is known as gravitational lensing. Gravitational lenses are considered as direct evidence of the presence of dark matter in the universe. The gravitational lensing has become an observational science. Today lensing is a booming part of astrophysics.Orest Chwolson is credited as being the first to discuss the effect of gravitational lensing in print , the effect is more usually associated with Einstein, who published a more famous article on the subject in 1936. Fritz Zwicky predicted in 1937 that the effect could allow galaxy clusters to act as gravitational lenses. It was not until 1979 that gravitational lensing was confirmed by observation of the so-called "Twin QSO" SBS 0957+561. In this paper a study of gravitational lenses in the context of dark matter is presented.

Keywords : **Dark Matter, Gravitational Lense**

I. INTRODUCTION

Gravitational lensing, now taken as an important astrophysical consequence of the general theory of relativity, was found even before this theory was formulated but was discarded as a speculative idea without any chance of empirical confirmation[1]. Gravitational lensing - the attraction of light by matter - displays a number of attractive features as an academic discipline. Its principles are very easy to understand and to explain due to its being a geometrical effect. Its ability to produce optical illusions is fascinating to scientists and laypeople alike. And - most importantly of course - its usefulness for a number of astrophysical problems makes it an attractive tool in many branches of astronomy.

II. CLASSES OF GRAVITATIONAL LENSING

Strong lensing:
Where there are easily visible distortions such as the formation of Einstein rings, arcs, and multiple images.

Weak lensing:
Where the distortions of background sources are much smaller and can only be detected by analyzing a large number of sources to find coherent distortions of only a few percent. The lensing shows up statistically as a preferred stretching of the background objects perpendicular to the direction to the center of the lens.Since galaxies are intrinsically elliptical and the weak gravitational lensing signal is small, a very large number of galaxies must be used in these surveys. The results of these surveys help in cosmological parameters estimation, and in the improvement of ΛCDM model.These studies can be used also in providing consistency check on other cosmological observations

III. MICROLENSING

Where no distortion in shape can be seen but the amount of light received from a background object changes in time. The background source and the lens may be stars in the Milky Way in one typical case, and stars in a remote galaxy and an even more distant quasar in another case.

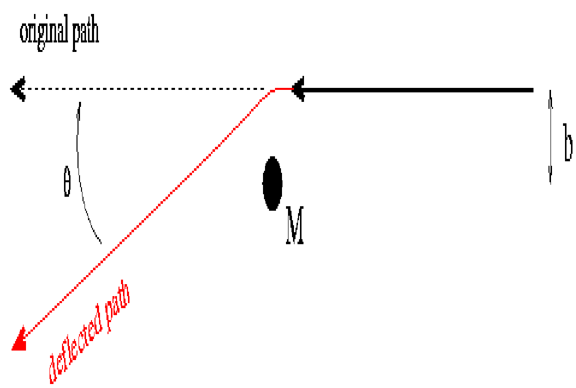

Fig:2Bending of light by the gravitational field of a massive object.

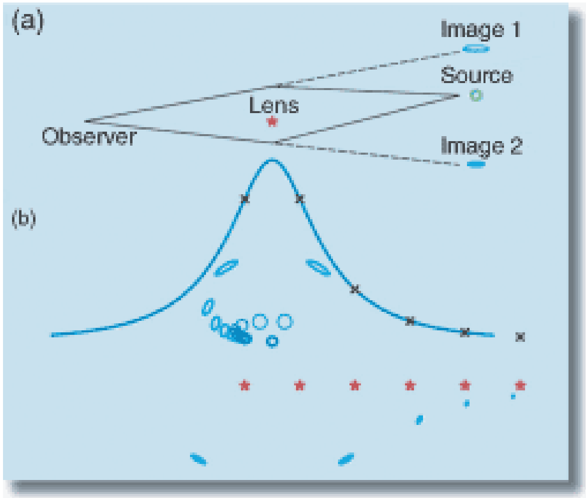

Fig:1A step-by-step guide to gravitational microlensing. (a) Light from the source star (green) is deflected by the lens (red), creating two enlarged and distorted images (blue). (b) As the lens passes in front of the source, the pair of images becomes first larger and then smaller, so that the observed light flux (blue curve) becomes brighter and then fainter.

IV. GRAVITY AND FORMATION OF GRAVITATIONAL LENSING

The strong gravity from a massive object can warp space-time, bending everything in it - including the paths followed by light rays from a bright background source. This alters the time taken for the light to reach an observer, and can both magnify and distort the apparent image of the background source. Unlike an optical lens, maximum 'bending' occurs closest to, and minimum 'bending' furthest from, the center of a gravitational lens. Consequently, a gravitational lens has no single focal point, but a focal line instead. If the source, massive lensing object, and observer lie in a straight line, the source will appear as a ring behind the massive object.For example black hole, after all, is simply an object with a gravitational field so strong that even photons are unable to escape from its vicinity. Any light ray which attempts to fly outwards from a black hole is stopped, and turned back into the black hole. That's an extreme case of "bending."

There are more modest situations, in which the photon is not stopped, but merely pushed a bit so that its direction (and energy) changes slightly. For example, if we place a very massive object near the path of an incoming light ray:

The angle θ by which the light ray is deflected depends on two factors: its closest approach to the massive object (called the *impact parameter*, and denoted by **b** in the diagram), and the mass of the lensing object, **M**. As is guessed, it takes both a very massive lens, and a very close approach, to cause any significant deflection. If an intervening mass lines up *perfectly* with a background source, it can bend the light from the source which would otherwise go far above us to come to us; and bend the light which would otherwise go far below us to come to us.

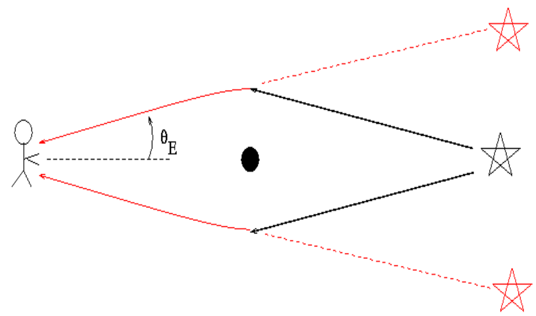

Fig: 3 Double image of a star is obtained due to gravitational lens of a galaxy or other massive object

To us, it looks like there is light coming from an angle above the actual source, and from an angle below the actual source, and, in fact, from an angle to the left, and then to the right, and everywhere in between. The result is that we see a ring of light surrounding the actual position of the source:

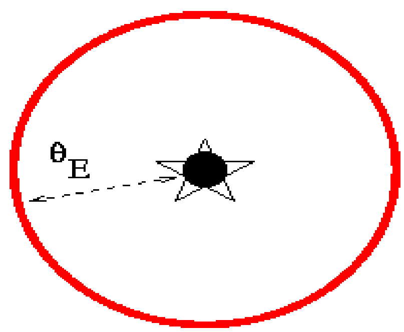

Fig:4 Einstein ring radius.

The angle θ_E is called the **Einstein ring radius**, because Albert Einstein was the first to figure out that -- in the very unlikely event that a faint, massive object lined up exactly in front of a bright, background source -- we might see a bright ring of deflected light.The Einstein ring radius depends on the mass of the lensing object: the more massive it is, the larger the Einstein ring radius. It also depends on the distance between us, the lensing object, and the background source. Gravitational lensing is most effective (meaning the ring radius is largest) when the lensing object is half way between us and background source. In that event, the Einstein ring radius is given by this equation:

$$\theta_E = \{4GM/Dc^2\}^{1/2}$$

where

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G = 6.67 x 10^(-11)  N*kg^2/m^2
M =mass of lensing object,in kg
D =distance from us to lens
   (and lens to source), in m
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c = 3 x 10^8 m/s
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This turns out to be pretty darn small.

Table2.1

Calculation of the Einstien ring radius for some standard value of masses of stars/galaxy/galaxy clusters

Mass of Lensing Object (Solar Mass)	Distances (Parsecs)	Einstein Ring Radius Degrees	Arc Seconds
Lensed by a Star 1	100 1000 10000	0.0000025 0.00000078 0.00000025	0.0089 0.0028 0.00089
Lensed by a Galaxy 1 x 10^12	100 Mpc 1000 Mpc 10000 Mpc	0.0025 0.00078 0.00025	8.9 2.9 0.89
Lensed by a Galaxy Cluster 1 x 10^15	1000 Mpc 10000 Mpc 100000 Mpc	0.025 0.0078 0.0025	89 28 8.9

V. LENSING AS A TOOL TO UNDERSTAND DISTRIBUTION OF DARK MATTER

Keeton [2] indicated that gravitational lensing is the best tool to understand the distribution of dark matter in the galaxy. Using the number and sizes of observed gravitational lenses, he derives upper limits on the dark matter content of elliptical galaxies. On the average, dark matter can account for not more than 33% of the total mass within one effective radius (R_e) of elliptical galaxies, or 40% of the mass within $2R_e$ (95%confidence upper limits). he shows that galaxies built from Cold Dark Matter (CDM) mass distributions are too concentrated to comfortably satisfy these limits; a high-density ($\Omega_M = 1$) CDM cosmology is ruled out at better than 95% confidence, while a low-density, flat cosmology is only marginally consistent with the lens data. Thus, lensing adds to the evidence from spiral galaxy dynamics that CDM mass distributions are too concentrated on kiloparsec scales to agree with real galaxies, and extends the argument to elliptical galaxies [3].

VI. MICROLENSING EXPERIMENTS IN INDIA

Gravitational microlensing is a new technique that allows low-mass exoplanets to be detected at large distances of ~7kpc. At early stage it was well thought-out that telescope of 1m will detect the microlensing but G.Christie briefly outlines the principles of the method and describes the observational techniques. It shows that small (e.g. 0.35m) telescopes with a CCD camera can make unexpectedly useful observations of these events[9].

In India ARIES(Aryabhatt Research Institute of observational SciencES) Nainital, Girawali Observatory Pune, Indian Astronomical Observatory Leh, Kodaikanal Solar Observatory Kodaikanal, Mount Abu Observatory, and Vainu Bappu Observatory Vellore are working in the field few of them observed microlensing effect also.

The M.P. Council of Science and Technology (MPCST), Bhopal has initiated a project to establishing an astronomical observatory at Dongla Ujjain. This place is situated exactly on the tropic of cancer

(longitude 75°45' 45.5"E and longitude 23°26'43.2"N), and was center of ancient Indian astronomy over several hundreds of years. The place is relatively dark, having moderate seeing and found to have large number of clear nights during September-April months. The proposed observatory will have mid size robotic Optical Telescope equipped with large format CCD imaging camera. The science driver for the observatory is to continuously monitor variety of variables stars and the transient objects. It is expected that the observatory can also note the microlensing effect when it comes in running condition.

VII. ACKNOWLEDGEMENT

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VIII. REFERENCES:

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