Subfile Example

Team Learn ShareLaTeX

1 Introduction

This is chapter introduction.

ACRONYMS

CDM	Cold Dark Matter
CMB	Cosmic Microwave Background
DE	Dark Energy
DM	Dark Matter
FWHM	Full Width Half Maximum
GR	General Relativity
HST	Hubble Space Telescope
IMCAT	Image and Catalogue Manipulation Software
LSS	Large Scale Structure
LSST	Large Synoptic Survey Telescope
PSF	Point Spread Function
SED	Spectral Energy Distribution
WFIRST	Wide-Field Infra-red Survey Telescope

2 Second section

3 Introduction

Gravitational Lensing provides us a way to see how dark matter along with visible matter is distributed in a galaxy or galaxy cluster. This is supported by Einstein's general theory of relativity which predicts the deflection of light in a gravitational field produced by a massive object. Refer to [**?**]

3.1 Formulation of Gravitational Lensing

I have to write here.

3.1.1 Einstein's Deflection Angle

3.1.2 Lens equation

Figure 1: Simple sketch to gravitational lensing. (Bartelmann and Schneider 2001)

General Relativity predicts that when the beam of light passes through near the massive objects, the rays of light undergo deflection from their original path. This angle of deflection was predicted by Einsteins's theory of General Relativity. According to this theory if the massive object of mass M is located at a perpendicular distance ξ (called **impact parameter**) from the line of sight of source and the observer then the deflection caused by that mass is given by [**?**]

$$\hat{\alpha} = \frac{4GM}{c^2 \xi}. \tag{1}$$

This equation (1) is valid only when the angle $\hat{\alpha} << 1$. In case of gravitational lensing, the product of mass of the deflector and the Gravitational Constant is always the much smaller than the squared of velocity of light, thus making the deflection angle very small.

For quantitative purpose, we can calcuate the value of deflection angle for distant stars appearing near to the solar limb by setting the mass $M = M_\odot$ and radius $R = R_\odot$ in the above equation to obtain the angle of deflection $\hat{\alpha} = 1.74''$. This value was tested in famous solar eclipse experiment in May 29, 1991 which was concived by Sir Frank Watson Dyson, Astronomer Royal of Britain in 1917 and led by Sir Arthur Stanley Eddington two years later in 1919. [**?**]. The experiment was designed to test following hypohteses:

- The light path is uninfluenced by gravitations.
- The law of gravitation will follow Newtonian law and will produce 0".87 apparant displacement

- The course of ray of light will follow Einsteins generalized relativity and lead to apparent displacement of 1".75

The experiment concluded that the results were close to the Einsteins predicted delectioin angle and thus supporting the gravitational lensing theory.

We can also define the two dimensional vector α as:

$$\hat{\alpha}(\xi) = \frac{4G}{c^2} \int d^2\xi\prime \; \Sigma \; \xi\prime \; \frac{\xi - \xi\prime}{|\xi - \xi\prime|^2} \tag{2}$$

Here, the surface mass density is defined as,

$$\Sigma(\xi) \equiv dr_3 \; \rho(\xi_1, \xi_2, r_3) \tag{3}$$

which is the mass density projected onto the lens plane, perpendiculary to the light ray, and r_3 is the coordiante along the line of sight, and ξ_1, ξ_2 the other two perpendicular coordinates. We consider a simplistic lensing model in which lens and the source objects are point objects. The observer observes the rays of light from the source at a distance D_s which pass through the gravitational influence field of a massive object of mass M and distance D_d located perpendicularly ξ distance away from line of sight (also called impact parameter).

Let η denotes the true, two-dimensional position of the source in the source plane and β is the true angular position of the source. This means in absence of light deflection we would have,

$$\beta = \frac{\eta}{D_s} \tag{4}$$

The relation between position ξ and θ is given by,

$$\theta = \frac{\xi}{D_d} \tag{5}$$

This means θ is the observed position of the source on the sphere relative to the position of center of the lens which is the origin of the coordinate system with $\xi = 0$. D_ds is the distance of the source plane from the lens plane.

Here we adopt the relation,

$$D_{ds} = D_s - D_d. \tag{6}$$

This relation holds true as long as the relevant distances are much smaller than the radius of the universe (c/H_0) and this is always the case for distances within our Galaxy and in Local Group. However, this relation no longer holds true for cosmological distances between source and lenses.