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## **Gravitational Lensing: Determining the Mass of a Lensing Source**

Abstract:

The study of gravitational lensing is the deflection of light by gravity. The study has increased over the past half century with the development of new technology and the discovery of the first doubly imaged quasar. The evolution of the study of lensed objects has been rapid and it is now an essential part of astrophysics. Because the science is relatively new, scientists are still finding new applications of lensing such as calculating the mass of galaxy clusters and determining the amount of dark matter in a galaxy halo. Massive catalogues have been created listing all the known lensed objects in the universe. These catalogues give a few characteristics about the lensed images such as the red shift as well as the luminosity, but they don't have the distance to the source, the mass of the source, or the density of the object. These calculations are useful in order to determine whether or not the lensed object is a black hole.

Introduction:

The topic of gravitational lensing is a growing part of modern astrophysics. The concept of lensing is when a massive object deflects light due to its immense gravitational pull. They have been studied more in the past few decades but were originally predicted at the beginning of the 20<sup>th</sup> century. There have been many catalogues made which list the known lensed images and their basic characteristics. There are also many subtopics that have evolved from lensing such as microlensing and the study of Einstein Rings.

## Method:

The archival data for all the known lensed objects had basic information on each object, and in order for us to calculate the mass, density, and distance of the source, we had to pick objects with certain luminosity in order to obtain a proper image of the source. The criteria was simple, the luminosity had to be greater than 1 Jansky. Then we had to take the given data and use it to run in Pixelens, a program used for determining the mass distribution of lensed objects. All the information required to run the Pixelens program was not given by the catalogue. Pixelens needed the location of the lensed images in relationship to the source in order to show the mass distribution. We had to import the radio images of the lenses into Photoshop and measure out the separation of the source and the lenses with a ruler tool. Once we had all the required data to run the program, we were able to see the mass distribution of the 3 objects we chose. Then we had all the required information to begin calculations about each object. We were then able to prove that the sources were not black holes by plugging in the calculated mass back into the Schwarzschild radius equation of black holes. We were successful in determining the mass, density, and distance of all three lenses, but we were hoping to prove that they were black holes.

## Results:

The results were mainly our computations towards proving the lenses weren't black holes

Object B0218

Red Shift : 0.255 + 0.052

$$\sum_{Crit} 1.67 \times 10^{22} \times M_o \left( \frac{1}{D} \right)$$

$$1 \div D = 24.157 \text{ arc sec}$$

$$\sum_{Crit} 4.034 \times 10^{13} M_o$$

Size between objects = 0.307 arcsec

$$= 1.488 \times 10^{-6} \text{ radians} = A$$

$$d = r \times A$$

$$r = \frac{V}{H_o}$$

$$r = \frac{0.052 \times c}{50} = 310.96$$

$$d = 4.628 \times 10^{-4} \text{ MPC}$$

Schwarzschild Radius :

$$R = \frac{2GM}{c^2}$$

$$R = 1.806 \times 10^{20} \text{ m}$$

$$R = 5.863 \times 10^{-3} \text{ MPC}$$

$$D = \frac{M}{V}$$

$$D = 9.716 \times 10^{22} \frac{M_o}{\text{MPC}^3}$$

Object PKS1830-211

Red Shift : 0.96 + 2.64

$$\sum_{\text{Crit}} 1.67 \times 10^{22} \times M_o \left( \frac{1}{D} \right)$$

$$1 \div D = 1.637 \text{ arc sec}$$

$$\sum_{\text{Crit}} 2.734 \times 10^{12} M_o$$

Size between objects = 2.51 arcsec

$$= 1.217 \times 10^{-5} \text{ radians} = A$$

$$d = r \times A$$

$$r = \frac{V}{H_o}$$

$$r = \frac{0.96 \times c}{50} = 5083$$

$$d = 6.185 \times 10^{-2} \text{ MPC}$$

Schwarzschild Radius :

$$R = \frac{2GM}{c^2}$$

$$R = 1.233 \times 10^{19} \text{ m}$$

$$R = 3.973 \times 10^{-4} \text{ MPC}$$

$$D = \frac{M}{V}$$

$$D = 2.758 \times 10^{15} \frac{M_o}{\text{MPC}^3}$$

Object MG0414+5334

Red Shift : 0.96 + 2.64

$$\sum_{\text{Crit}} 1.67 \times 10^{22} \times M_o \left( \frac{1}{D} \right)$$

$$1 \div D = 1.637 \text{ arc sec}$$

$$\sum_{\text{Crit}} 2.734 \times 10^{12} M_o$$

Size between objects = 2.51 arcsec

$$= 1.217 \times 10^{-5} \text{ radians} = A$$

$$d = r \times A$$

$$r = \frac{V}{H_o}$$

$$r = \frac{0.96 \times c}{50} = 5083$$

$$d = 6.185 \times 10^{-2} \text{ MPC}$$

Schwarzschild Radius :

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$$D = 2.758 \times 10^{15} \frac{M_o}{\text{MPC}^3}$$

The results as shown in each case prove that the object was not a black hole because they would have to be equal to the Schwarzschild radius.

Discussion:

The calculations were fairly straight forward and they led us to prove we were not observing black holes. If the calculated radius had matched the theoretical radius, then the lenses would have been black holes.

Citations:

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