
The recent discovery of the double quasar, 0957 + 561 A and B and the subsequent explanation of this phenomenon in terms of the gravitational "lens" associated with a galaxy, succinctly expounded by Chaffee in a recent article, prompted the development of the following classroom demonstration for Astronomy undergraduates. The solid plastic (methyl methacrylate or Lucite) cone shown in the photograph in figure 1 had been machined previously to a $1/r$ hyperbola of revolution to simulate Rutherford scattering of particles by atomic nuclei by the rolling of steel balls.

Fig. 1—Photographs of the solid plastic cone used as the gravitational lens analogue in classroom demonstrations, originally machined by the author for a Rutherford nuclear particle scattering demonstration.

across it at varying distances from the cone centre\textsuperscript{2,3}. The optical performance of a cone of this shape for light moving parallel to its axis of revolution is approximately that expected from the gravitational field of a massive astronomical object, in that deflection of light becomes much higher the closer the light beam approaches the axis, in contrast to a normal lens. Icke\textsuperscript{4}, in a recent article, derived the shape that a lens would need in order to approximately simulate a black hole, for which the lens thickness $T$ was required to vary with distance $r$ from the axis of symmetry in the form $T = \frac{2R}{(n - 1)} \log(r_0/r)$, where $R$ is the Schwarzschild radius of the black hole being imitated, $n$ is the refractive index of the lens material, and $r_0$ is the maximum possible radius of the lens. The present lens approximated this shape, and the optical arrangement used in the demonstration is shown in the sketch in figure 2. A zirconium arc served as the point source of light (the “quasar”) while a 35-mm camera replaced the observer in order to record the resultant images. The cone (“gravitational lens”) was mounted about half-way between the source and observer and could be moved perpendicular to the optical axis.

The images of the point source when viewed through this “lens” were somewhat unexpected and counter-intuitive, the most striking feature being that they were most often double images, with little or no extension compared to the undeflected image. The simple derivation by Icke\textsuperscript{4} for the case of a black hole resulted in solutions for position angles of deviated rays with plus and minus signs, indicating a double-image situation in this case. Only when the axis of the cone approached the optical axis did the images
Fig. 3—Sequence of photographs of twin images of the point source produced with the "lens" at different distances from the optical axis between camera and source. The circular haloes are produced when the cone axis almost coincides with the optical axis. It was found in practice that a large depth of focus was necessary in the camera lens in order to record small undistorted images.
begin to elongate along annular rings, and a full circular image was seen when these axes coincided. The sequence of photographs in figure 3 shows these changes, and demonstrates that this somewhat impromptu optical analogue reproduces reasonably well the "twin-quasar" phenomenon, in showing that the most probable result of the intervention of this general form of lens between point source and observer is a double image unless the centre of the lens lies close to the line of sight. This is an unlikely event in practice, compared to the off-axis alignment. In any case, the material within the massive object in anything other than a highly consolidated body such as a black hole would probably obscure the halo image. It is interesting to speculate on the relationship of this optical effect to the appearance of ring-type and other peculiar galaxies which are known to exist in the universe.

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