Gravitational Lensing by a Wine Glass

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The formation of multiple images of a distant quasar by the gravitational lensing effect of a foreground galaxy may be very simply, and faithfully, accounted for by a wine glass experiment.

Use as the quasar light source a candle or a bright compact light source as shown in Figure 1. This source is set at a typical distance of several meters, and somewhat higher, from a table on which a glass of wine is placed. Like a gravitational lens, the wine glass distorts the

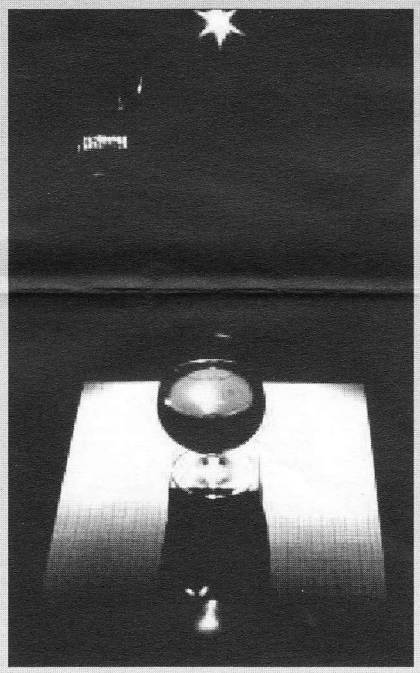

Figure 1. In the wine glass experiment, a bright compact light source (at the top of the photo) serves as a distantquasar. The wine glass on the table distorts the light rays from the "quasar" and produces a caustic having with a triangular shape (see enlargement in Figure 3). Photo courtesy of author.

background field. This space distortion is very well seen through the glass in Figure 2. Because of the presence of the wine glass, the distribution of light on the table is no longer uniform (see Figure 1). Just behind the glass, higher concentrations of light may be seen at some locations in the form of a caustic (i.e., the intersection of a three-dimensional caustic with the plane of the table). The latter is, in the present case, approximately triangular. The three sides and summits of this triangular caustic are named folds and cusps, respectively.

A blow-up of this caustic is shown in Figure 3. The folds result from the envelope of pairs of tangent light rays from the candle. As a result, an observer setting his or her eye on a fold will see a pair of merging images from the distant quasar. Three merging images will be seen at the location of a cusp.

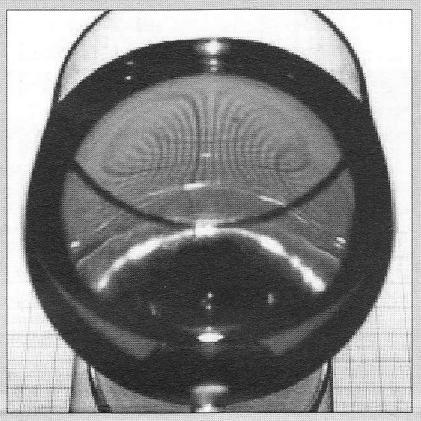

Figure 2. When looking through the wine glass, one sees very conspicuous distortion of the background field — millimetric paper in this case. Photo courtesy of author.

To be able to put your eye at various locations with respect to the caustic, I recommend that you place the glass at the very edge of the table. You may then also observe that the total number of images increases by two when your eye crosses a fold from outside to inside the caustic. Figure 4 shows a photograph made with a camera set up at the caustic's center. As an exercise, draw various diagrams showing the multiple image configurations of the background light source for different positions of your eye with respect to the caustic (folds and cusps) and compare them with the multiple image configurations observed for the known cases of multiply imaged quasars (visit *vela.astro.ulg.ac.be/grav_lens/*).

The formation of caustics of light is a generic feature in nature. It arises whenever a foreground object (the wine glass in this experiment, a galaxy acting as a gravitational lens, etc.) distorts the propagation of light rays from a distant light source. For instance, for each pair of quasars and galaxies that exist in the Universe, a more or less complex three dimensional caustic is formed behind each galaxy. Whenever an observer lies close to such a caustic, the former sees multiple images of the distant quasar. Due to the relative motion between the quasar, the lensing galaxy, and the observer, this phenomenon does not last forever. It can be shown that the typical lifetime of a cosmic mirage involving a quasar and a lensing galaxy is of the order of twenty million years.

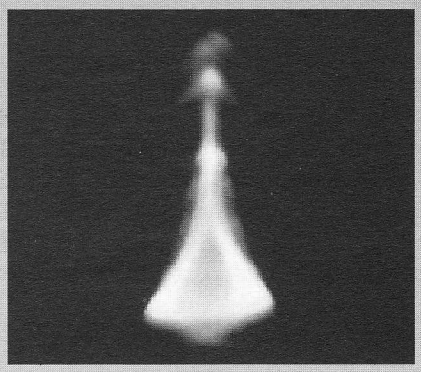

Figure 3. An enlargement of the triangular caustic visible in Figure 1. The caustic results from redistribution by the wine glass of light rays emitted from the "quasar." Photo courtesy of author.

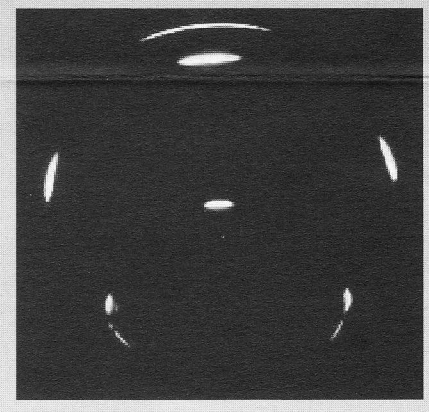

Figure 4. Multiple images of the "quasar" are visible to a camera placed inside the caustic. Photo courtesy of author.

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