Aperture Diffraction Patterns

Images of bright point sources taken with reflecting telescopes are surrounded by diffraction spikes. Astronomers and the public have got used to the effect and many NASA images are thought to be more attractive because of the spikes. There is even software available to add diffraction patterns to images taken with refracting telescopes that do not show the effect. The spikes are not of course real, but are caused by the struts of the spider that holds the central mirror in place. The symmetry of the diffraction pattern is the symmetry of the spider.

Fig 1 – diffraction spikes due to the four perpendicular supports of the central mirror in the Hubble Space Telescope surround the brightest images. Credit: ESA/Hubble & NASA.

Camera images show diffraction spikes due to the aperture: a regular polygon with typically five or more sides.

Fig 2 – diffraction points surround lights at night in this digital camera image taken with a square aperture placed in front of the lens (inset).

The diffraction points that surround the foreground lights in figure 2 are double. The doubling has nothing to do with the aperture. Each light holder has two bulbs in a horizontal line: except for the light second right, which has two bulbs displaced on the diagonal.

Apertures constructed with razor blades having 3, 4, 5 and 6 sides respectively are shown in figure 3. To make the images below each aperture was placed in turn at night over the lens of a digital camera to photograph a white LED at 30 metres. The aperture of the camera itself was in each case larger than the addition.

Fig 3 – apertures constructed with razor blades.

The triangular aperture produced a six pointed diffraction pattern (three streaks of light centered on the overexposed central image, perpendicular to side of side of the triangle.

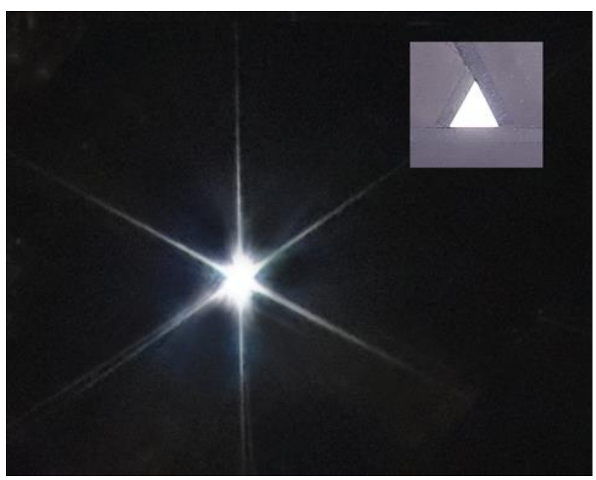

Fig 4 – diffraction by a triangular aperture.

Triangular apertures are not found on any commercial cameras. The pattern has been included for completeness.

Diffraction by four, five, and six sided apertures are shown below.

Fig 5 – diffraction produced by 4, 5 and 6 sided apertures.

The square aperture in the upper image of figure 5 is regular and the sides are perpendicular. The diffraction points are the same size and perpendicular. Digital camera images with four perpendicular spikes are unusual but can be found occasionally in photographs taken with webcams.

Pentagonal apertures are more common. In the example in the central image of figure 5 the pentagonal aperture is deliberately irregular. In particular the vertical side is short and the horizontal spikes perpendicular to this side are correspondingly weak, both in apparent length and brightness. The two longest sides are associated with the brighter more upright pairs of spikes.

The hexagonal aperture in the lower image of figure 5 is also irregular but each pair of spikes in the diffraction pattern is associated with two opposite parallel edges. The sums of the lengths of opposite edges are similar and consequently the spikes are uniform in length and intensity, or nearly so.

Camera apertures are always regular polygons with five or more sides. Odd numbers of sides give patterns with twice the number of spikes. Occasional images of street lights on the web have 18 points from nine-sided apertures.

The image below was taken with a 0.5 mm parallel sided slit in front of a hexagonal camera aperture. The diffraction patterns surrounding the lights have two prominent horizontal spikes. The small white light in the distance is a better approximation to a point source and careful inspection shows interference fringes. These fringes are not seen in the spikes surrounding extended sources.

Fig 6 – diffraction produced when a vertical 0.5 mm slit was placed in front of the camera lens.

The ends of the slit were closed by the internal aperture of the camera. Small additional features at 60 degree intervals indicate that the combined aperture is a hexagon with two much longer vertical sides.