Scattered Light Echoes from SN 1998bu
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Abstract
Scattered light echoes offer one of the most effective means to study the structure and make-up of circumstellar and interstellar dust and gas. These light echoes not only provide exact three-dimensional positions of scattering dust, but they can also be used to determine the dust's composition, size, and number density. However, they are very rare and have only been unambiguously resolved around a handful of sources. Here, we present new data and analyses of echoes previously discovered around SN 1998bu. Like SN 1991T (see poster by Thormann & Sugerman), this supernova was a type Ia and has illuminated an hourglass-shaped circumstellar nebula up to 30 lt-yr in size. However SN 1998bu has also illuminated a plane of interstellar material 300-700 lt-yr in front of the supernova. We interpret this plane as a 100 lt-yr thick dust lane in the host-galaxy’s (M96) disk.

Space Geometry
Scattered light echoes offer one of the most effective means to probe circumstellar and interstellar structure. A light echo occurs when a light pulse, e.g. from a supernova (SN), is scattered into the line of sight by dust.

M96 & SN 1998bu
SN 1998bu is a type Ia (accreting white dwarf) located in the spiral galaxy M96 (left), roughly 11.2 Mpc away. Cappellaro et al. (2001) reported that SN 1998bu showed the same photometric decline and spectral features as SN1991T (see poster by Thormann & Sugerman #412.07), which has been known to have an echo since the mid-1990’s. From the data shown below, Cappellaro et al. concluded their observations were caused by a light echo from dust about 230 lt-yr in front of the SN. HST imaging in 2000 revealed a ring of radius 0.3–0.76 centered around the SN, as expected.

Hubble Space Telescope Observations
SN 1998bu was observed by HST with WFCPC2 in 2000 and 2002, and has been subsequently been imaged with ACS in 2003 and 2006. After examination of these images (below) it is apparent that in addition to seeing the echo predicted by Cappellaro et al., the central source is itself an echo, just resolved in 2003 with a radius of roughly 0.12 arcsec.

The echoes can then be visualized by plotting the 3-D distribution of points from any orientation.

Inner Ring Analysis
The inner echoes were an unexpected surprise to find as previously there had only been information and speculation about the outer echoes. Their positions from 2002-2006 in the plane of the sky are shown at right. Viewed from the side, we see that this material is up to 30 lt-yr in front of the SN. The available data are reasonably well fit by an hourglass shape with either a circular or elliptical cross-section, both of which are slightly offset from the SN position. These hourglasses represent the best fit from a few common geometric shapes, but do not represent exhaustive series of fits. More observations will be needed to determine, for example, is there is a “cap” to this structure, and if it is indeed hourglass in shape.

Hourglass formation
We suspect that the hourglass seen above may come from the interacting winds of the binary system during its lifetime. Due to the gravitational pull of the white dwarf on its main-sequence companion there would be a natural equatorial buildup on the companion. This would, in turn, cause for an almost bipolar outflow of the companion’s stellar wind. If the inner echo is in fact the remnant of bipolar winds, it will be exciting to have imaged a fossil nebula so late after its formation.

References