Infrared Observations of "Middle-Aged" Supernovae Filling the Gap between Supernovae and Supernova Remnants

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Observational studies of supernovae can be divided into two categories: (1) young supernovae (within a few years after the explosion) in external galaxies, and (2) supernova remnants in our Galaxy (older than a few hundred years old). Extragalactic supernovae can be observed only for a few years since they get fainter. On the other hand, probability to have a young supernova in our Galaxy is extremely low (about once in a century). Therefore, we don't have any observational example in the gap of these two phases, except for SN 1987A in the Large Magellanic Cloud. Thus, it was basically impossible to observationally study the long-term evolution from supernova to supernova remnant.

In order to detect supernovae in this gap, so called "middle-aged" supernovae, we searched supernovae in the images of nearby galaxies taken with AKARI satellite. As a result, we discover infrared emission from SN 1978K in NGC 1313 [1] (Figure 1). This is the emission at 28 years after the explosion, and the second example of middle-aged supernovae after SN 1987A.

The spectral energy distribution (SED) is quite intriguing. It is similar to the SED of Galactic supernova remnant Cassiopeia A (about 300 years old). In addition, from the analysis of the SED and model calculations, we found that (1) SN 1978K is associated with 1×10^{-3} $M_\odot$ of silicate dust, and (2) the emission is caused by the circumstellar dust heated by the shock wave of the supernova. These results indicate that at least this supernova already radiates by the interaction between supernova ejecta and surrounding medium as in supernova remnants. This observation provides a unique example to understand the long-term evolution from supernova to supernova remnant.

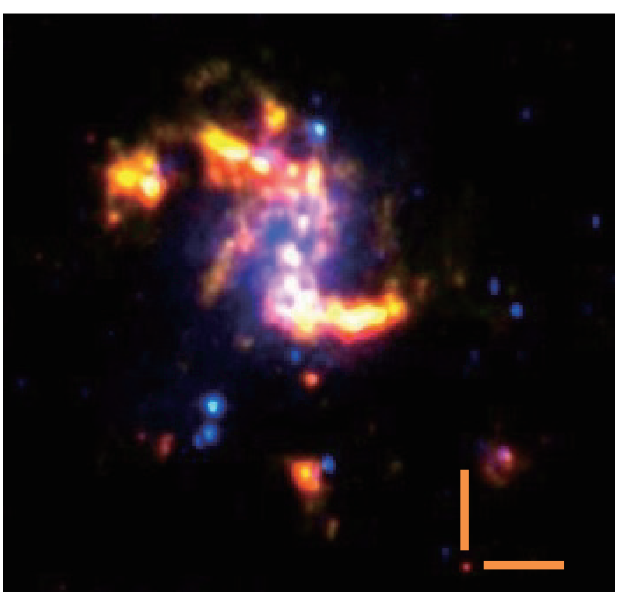

Figure 1: Infrared image of SN 1978K in NGC 1313 at 28 yr after the explosion (the position of the supernova is pointed by the lines).

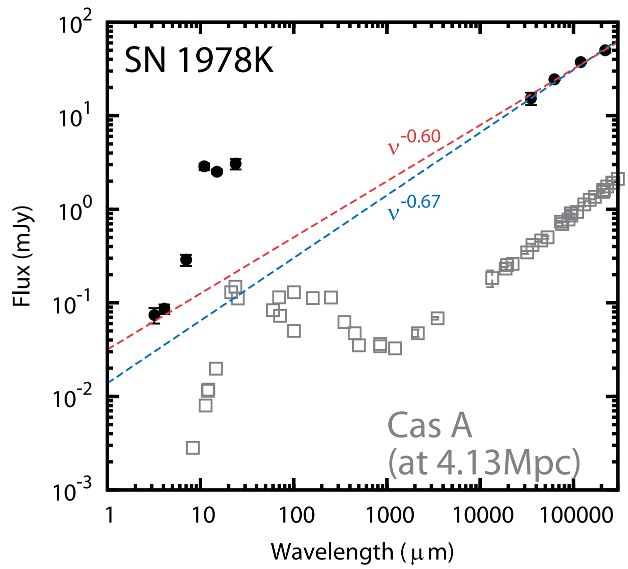

Figure 2: Infrared-to-radio SED of SN 1978K (black), compared with that of Cassiopeia A (gray). Both objects show synchrotron emission at radio wavelengths and infrared excess by the dust emission. The infrared emission from SN 1978K is reproduced by 1×10^{-3} $M_\odot$ of silicate dust.

Reference

[1] Tanaka, M., et al.: 2012, *ApJ*, **749**, 173.