Four Decades of the Type IIn Supernova 1978K

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SN 1978K in NGC 1313 is the oldest, and one of the closest of the class of Type IIn supernovae that explode into an unusually dense circumstellar medium. Since its serendipitous discovery in 1992 we have been following its evolution at X-ray, optical, infrared, and radio wavelengths. Recent VLBI measurements confirm significant deceleration of the ejecta. SN 1978K is only the third evolved extragalactic supernova to be detected with ALMA, yielding important clues about dust formation and destruction in core-collapse supernovae.

SN 1978K in NGC 1313

At just 4.6 Mpc away, SN 1978K in the late-type barred spiral galaxy NGC 1313 is the second-closest example (after SN 1996cr in the Circinus Galaxy) of a Type IIn supernova, in which the Balmer optical emission lines show a narrow (few hundred km s^{-1}) emission peak atop a broader (several thousand km s^{-1}) profile. These characteristics are thought to be associated with a dense circumstellar medium (CSM) arising from significant mass-loss by the progenitor star prior to explosion. This is consistent with our VLBI observations at 8.4 GHz in 2015, that showed the diameter of the remnant of SN 1978K to be <5 milli-arcsec (0.1 pc), giving a past average expansion velocity <1500 km s^{-1}, and thus the ejecta has been significantly slowed down as it plows through the dense CSM. SN 1978K was the only one of 6 nearby supernovae in the "transitional" phase (age 10–100 years) from SN to SN remnant to be detected at ~4 µm with the *Akari* satellite (Tanaka+ 2012), suggestive of emission from warm dust. Our continuing and archival observations with *Spitzer* (Fig. 1) show the infrared flux to be fading as $t^{-2.45}$. Such rapid, consistent fading cannot be due to expansion or cooling, but rather implies either destruction of dust or the presence of an infrared echo.

SN 1978K at submillimeter wavelengths

SN 1978K was observed with the Atacama Large Millimeter/submillimeter Array (ALMA) in 2016 in Bands 3, 4, 6, and 7 (covering 90–350 GHz). SN 1978K is only the third evolved extragalactic supernova (after SN 1987A and SN 1996cr) to be detected at these frequencies, *but is >400× brighter than SN 1987A!*

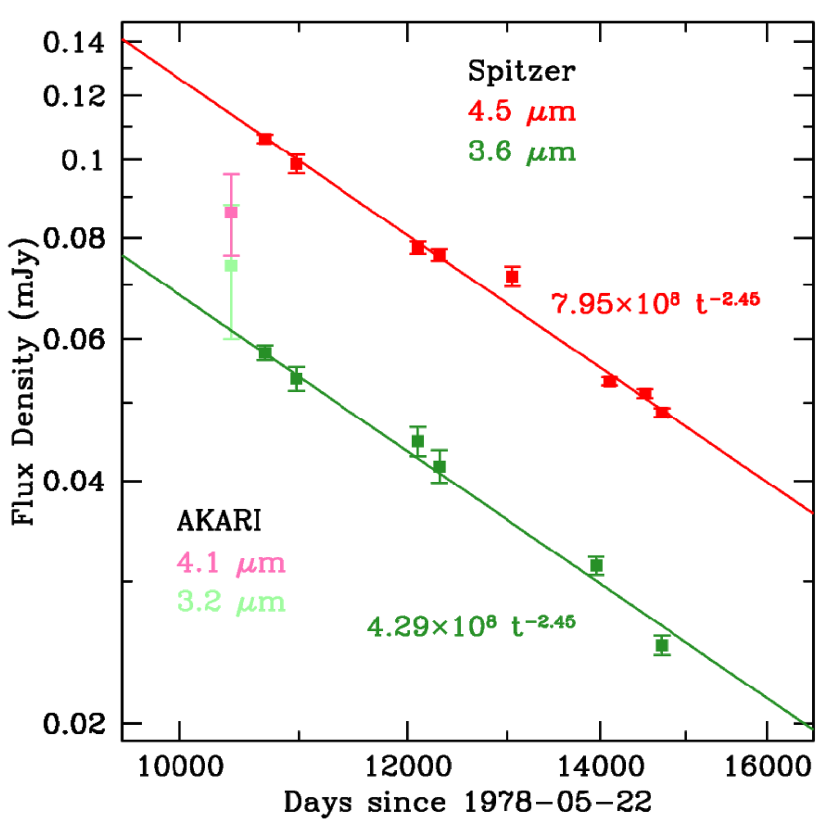

Fig. 1: Infrared light curves for SN 1978K from *Akari* (2006) and *Spitzer* IRAC (2007–2018).

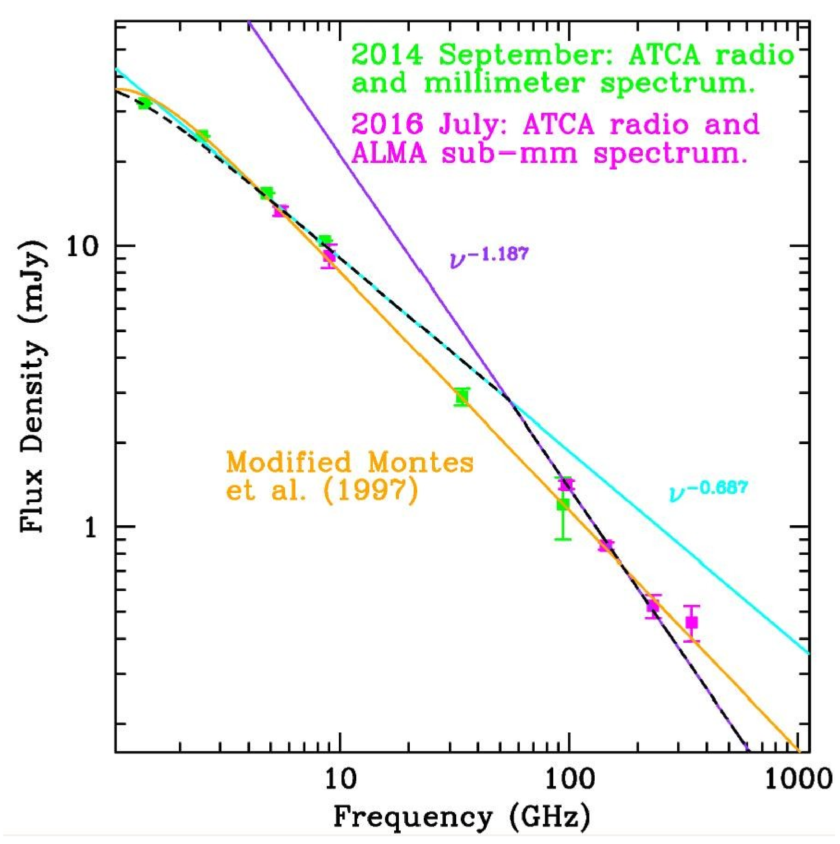

Fig. 2: Composite radio spectrum of SN 1978K. The orange curve is a modified version of the Montes+ 1997 model for a SN shock. The black dashed curve shows the broken power law result from an ultra-relativistic fireball model.

Fig. 2 shows the combined 1–350 GHz spectrum for SN 1978K from ATCA + ALMA. The Montes+ 1997 model for a SN shock interacting with a dense ionized CSM provides a good fit, with the exception of the ALMA Band 3 (100 GHz) flux. A broken power law fireball model akin to that used to explain GRB afterglows, with a wind scaling for the external medium, provides a better fit to ALMA Bands 3, 4, and 6, with the hint of an upturn in Band 7 that could be due to an additional cold dust component. However further observations in ALMA Bands 8–10 are needed to confirm this.

Full details of the results presented here can be found in Ryder et al. 2016, A&A, 595, L9; and Smith et al. 2019, ApJ, 870:59.

Acknowledgements

SR and RK acknowledge support from the Royal Society International Exchange scheme. The Australia Telescope Compact Array and Long Baseline Array are part of the Australia Telescope National Facility which is funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO. ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada), MOST and ASIAA (Taiwan), and KASI (Republic of Korea), in cooperation with the Republic of Chile.