Late-Time Spectral Observations of PTF11kx and Other Type Ia Supernovae Strongly Interacting with Circumstellar Media

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PTF11kx

PTF11kx (Dilday, et al. 2012, Science, 337, 942) is a type Ia supernova (SN Ia) that showed evidence for strong interaction with circumstellar material (CSM). It was interpreted as having a symbiotic nova progenitor, i.e. a white dwarf (WD) in a binary system with a red giant. PTF11kx was somewhat overluminous with initially extremely deep Ca II H&K absorption. This evolved into narrow emission and at the same time narrow Hα emission appeared (see below).

SN Ia Interactors

PTF11kx is a SN Ia and almost certainly came from the thermonuclear explosion of a WD. However, it also resembles a type IIn SN which is a core-collapse SN from a massive star where the ejecta interacts strongly with CSM, giving rise to narrow emission lines. There are other objects, like PTF11kx, that appear to be a cross between a SN Ia and a SN IIn. In earlier work these have been called SN Ia interactors, Ian, IIna, hybrid SNe, and Ia-csm (which is our preferred name). Previously, it was not clear if these objects were actually SNe Ia coming from a WD or some kind of strange core-collapse SN. However, PTF11kx links the Ia-csm objects directly to SNe Ia and WD.

“Finding” Ia-csm

To date, only a handful of SNe have been classified as Ia-csm objects and only a few have been well-studied:

• SN 1999E (Rigon, et al. 2003)
• SN 2005gj (Aldering, et al. 2006; Prieto, et al. 2007)
• SN 2008J (Taddia, et al. 2012)
• SN 2008cg, SN 2011jb, CSS120327:110520-015205 (only un refereed CBETs)

Using the first 4 Ia-csm objects above, along with normal SNe Ia and SNe IIn, we used a cross-correlation code (SNID) to look for other objects that were spectroscopically similar to the known Ia-csm objects. We inspected 310 spectra of 163 SNe "IIn" in the UC Berkeley SN dataset, and blindly "rediscovered" the latter 4 objects above. In addition, we performed this search on nearly 3 years of Palomar Transient Factory (PTF) data and discovered 7 more Ia-csm objects out of 63 SNe "IIn".

Characteristics of Ia-csm

• Slow LCs (20 - 40 d rise times) & luminous (-21 ≤ M_R,peak ≤ -19; see below for M_R,peak of all PTF SNe "IIn"; arrows are non-PTF Ia-csm, star is PTF11k, black are PTF Ia-csm, and gray is the typical SN Ia range)

• Strong Hα and Ca II near-IR triplet emission (like PTF11kx, e.g. bottom-left)

• Weak Hβ, He I, and O I emission (like PTF11kx, e.g. bottom-left)

• Large Balmer decrement, statistically larger than SNe IIn, which may indicate collisionally excited H from ejecta running into CSM

• Hα luminosities of about (2-9)x10^{40} erg/s, implying mass loss rates of about (2-120)x10^{-4} M_☉/yr (from previously published models)

• Decreasing flux in the red wing of Hα seen after ~90 d past maximum (see below; spectra are labeled by epoch), often attributed to newly formed dust

• Strong, early-time UV emission

• No early-time XR or radio emission

• Strong, late-time IR emission

• Strong Na I D absorption from host-galaxy ISM

• Late-type host galaxies

Data through 100 d past maximum brightness was presented in Dilday, et al. We present later data through 440 d past maximum. There is little spectral evolution during these epochs. All spectra show strong Hα emission (width ~ 2000 km/s) and strong, broad (~10,000 km/s) Ca II near-IR triplet emission. On the other hand, there is only weak Hβ, He I, and O I emission (see below; spectra are labeled by epoch). Hα emission increases with time and narrow (~100 km/s) CSM emission from multiple features varies with time in unison (see below, right).

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