Highly Luminous SNe Associated With GRBs

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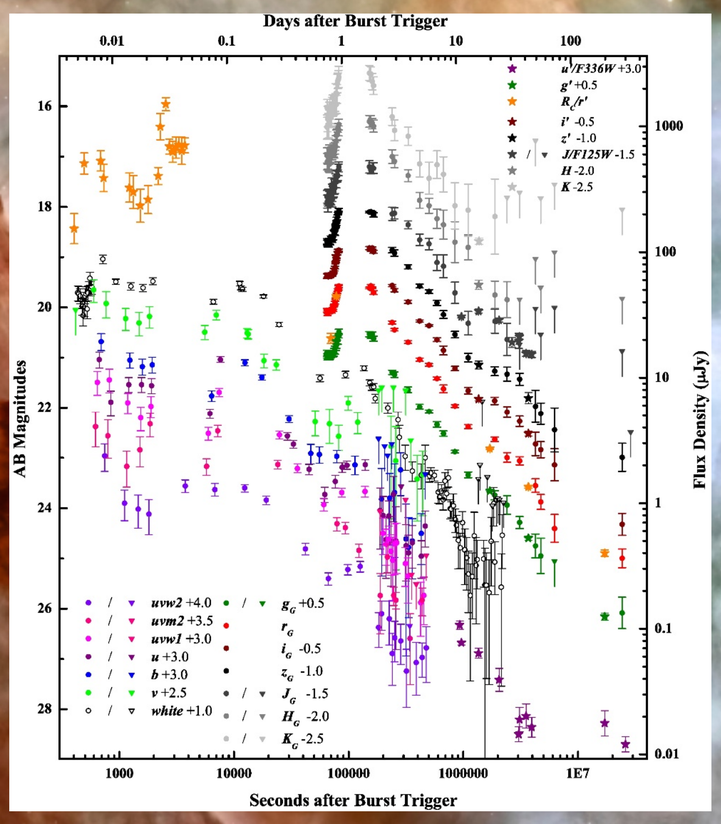
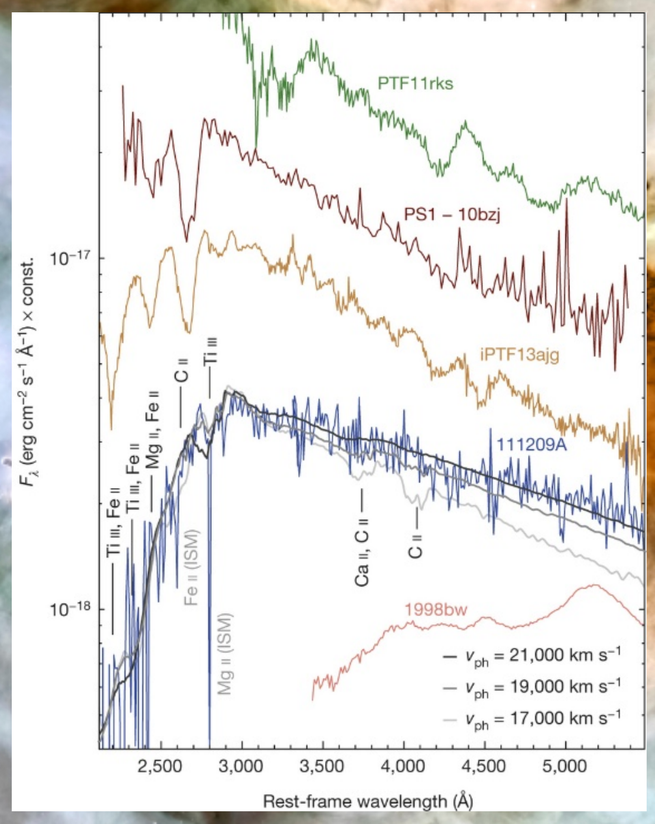
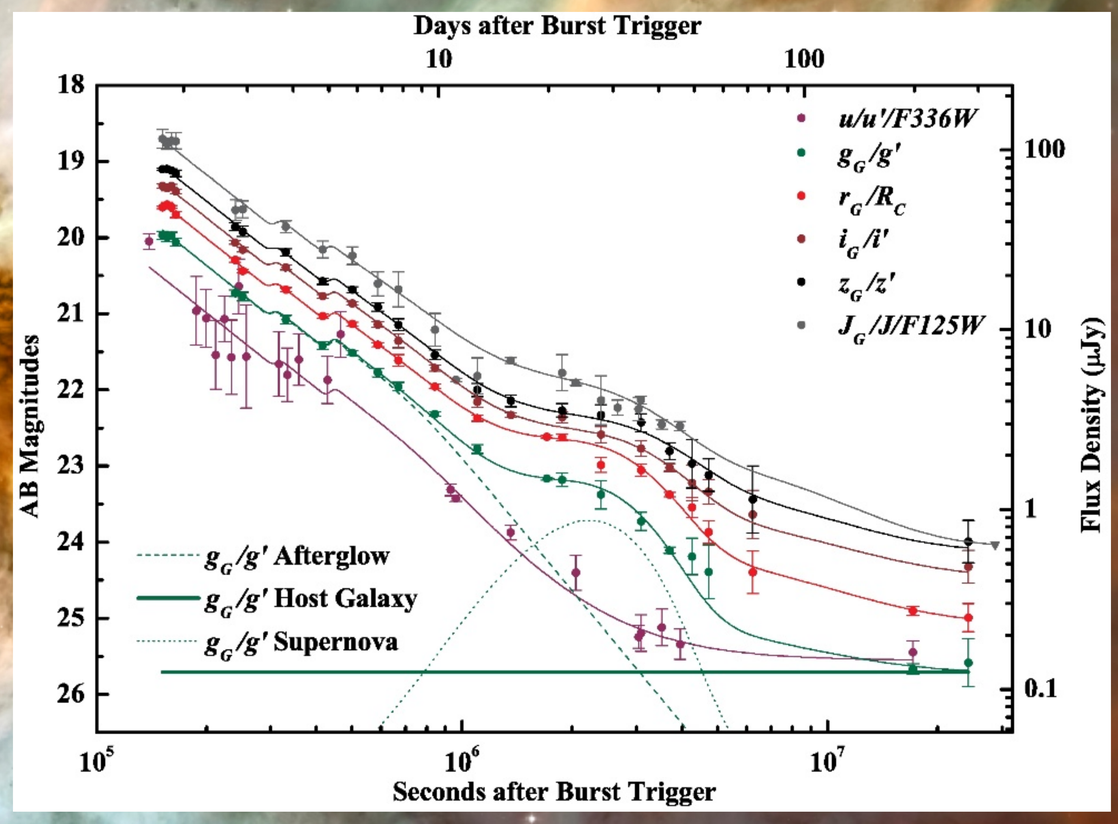
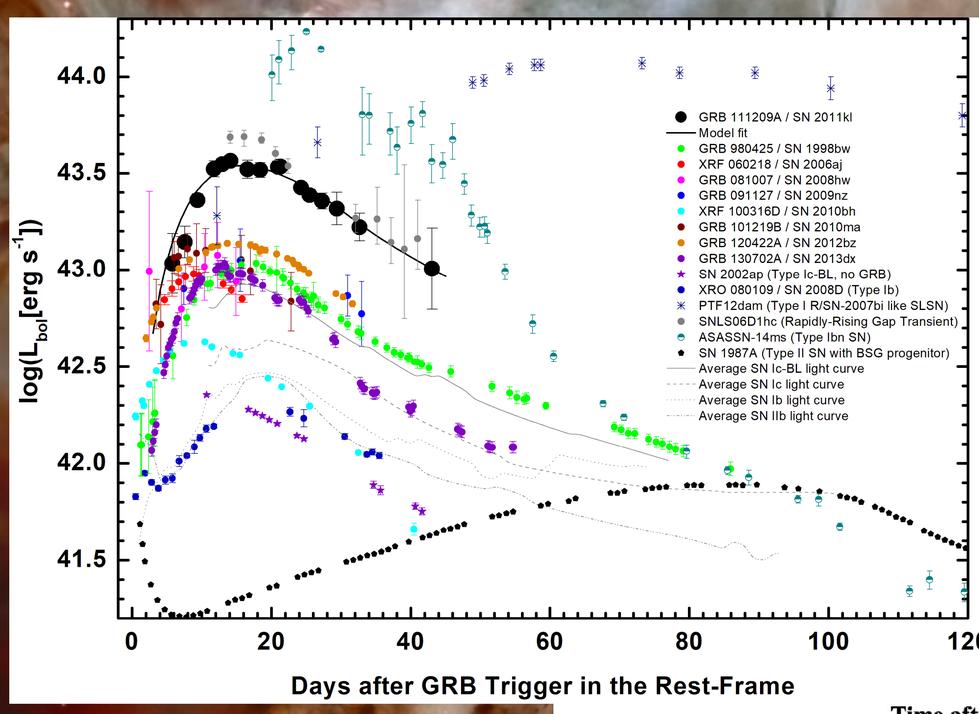
The broad-lined Type Ic Supernovae (SNe) associated with Gamma-Ray Bursts (GRBs) were long considered the most luminous class as a whole among core-collapse SNe, until the discovery of Superluminous SNe (SLSNe) over the last decade. There are many differences between the two classes, but in recent years, events have been discovered which form a link between the two. Associated with GRBs but more luminous and hotter, and in one case clearly spectrally dissimilar to any other known GRB-SNe, these sources point the way toward common mechanisms underlying GRBs and SLSNe.

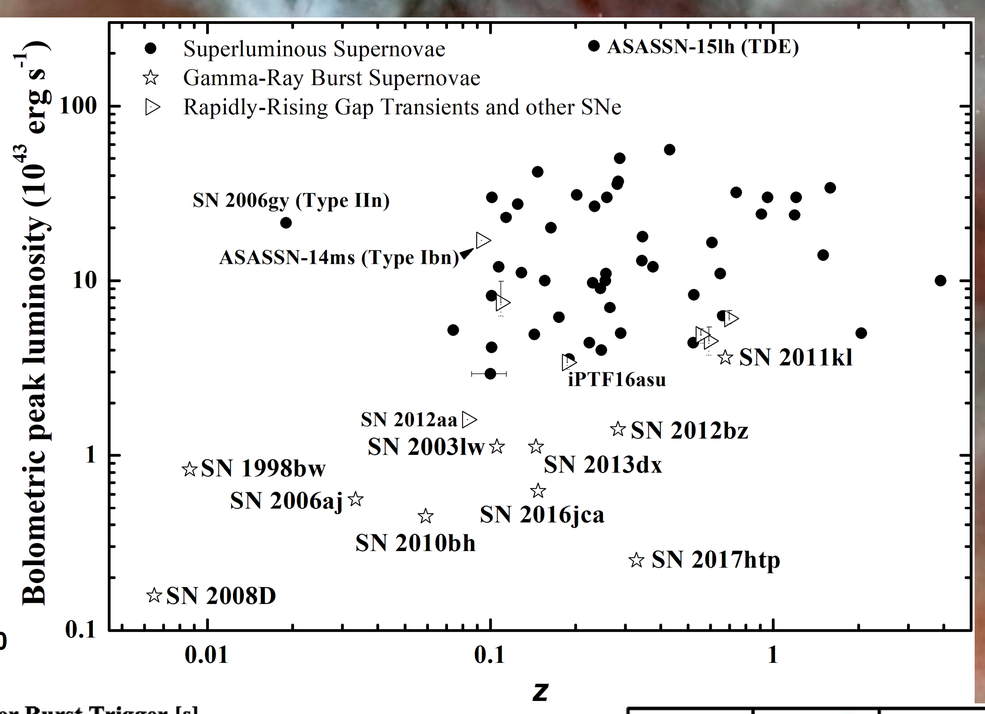






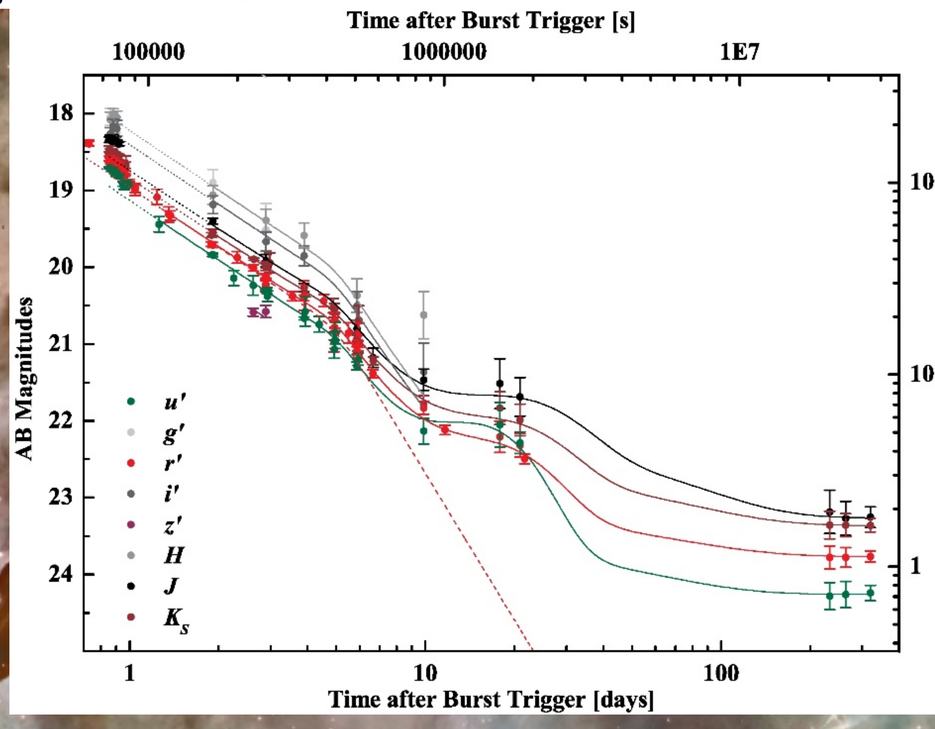
Left: The highly complex light curve of the ultra-long GRB 111209A. The early light curve shows strong, rapid variability over a roughly constant emission level. At about 20 ks, contemporaneous with the end of the prompt emission, the light curve begins to decay before experiencing a chromatic rebrightening well-covered by our GROND data. The late light curve shows several achromatic rebrightenings before going over into the blue SN 2011kl. **Middle:** Spectral comparison between the X-shooter spectrum of SN 2011kl near peak, the spectra of several SLSNe, and SN 1998bw, the archetype GRB-SN. Possible absorption lines are marked. Clearly, SN 2011kl resembles SLSNe more than usual GRB-SNe. **Right:** Despite the spectral dissemblance, the SN 1998bw light curve template fits SN 2011kl well. Here we assume no contribution in the *u* band, which shows a break in the GRB afterglow. The three components are shown for the *g´* light curve.

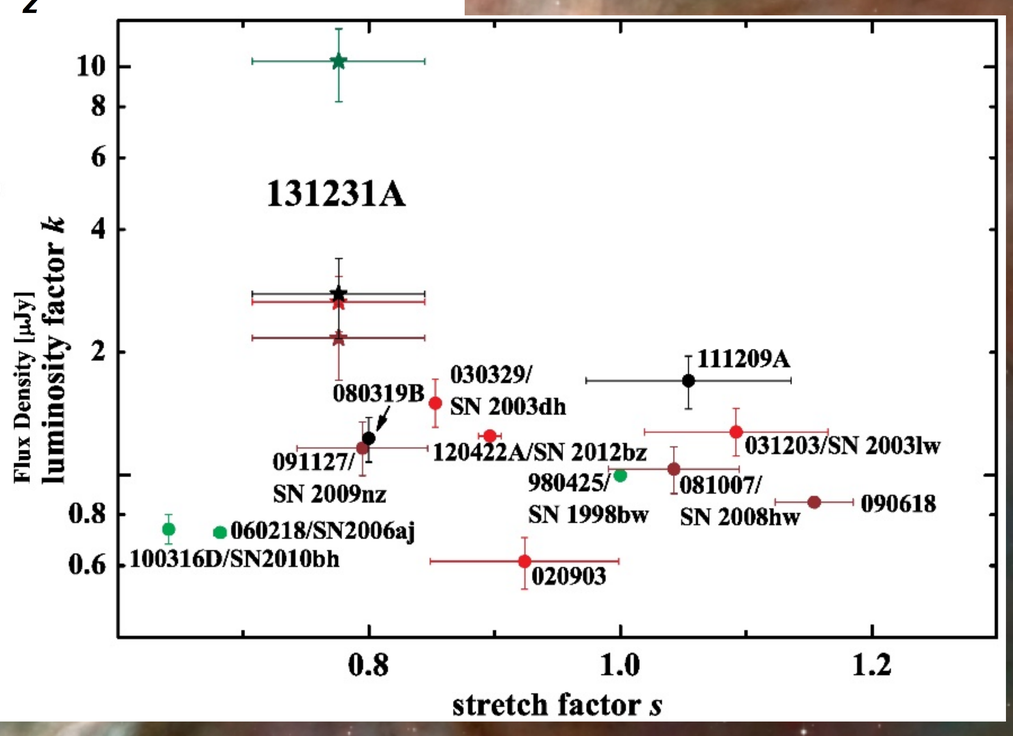




Left: Bolometric light curve of SN 2011kl as well as a purely ^{56}Ni-powered fit. The fit is good but has unphysical parameters. A multitude of other SNe are shown for comparison. **Right:** The bolometric peak luminosity of SN 2011kl, other GRB-SNe, SLSNe as well as further special SNe. SN 2011kl is the most luminous GRB-SN shown here, and comparable to the least luminous SLSNe as well as several so-called gap transients. Also shown is ASASSN-15lh, now known to be an extreme Tidal Disruption Event.

Left: The light curve of the ordinary GRB 131231A. Following a steep decay (not shown), a typical decay and break set in, going over into a plateau with a very strong color change. The SN is actually more luminous in *g´* than in *r´* which is completely unprecedented. **Right:** The SN of GRB 131231A in the *k*, *s* context. *k* is the luminosity compared to that of SN 1998bw (at peak) whereas *s* describes the time stretch compared to SN 1998bw. For other GRB-SNe, we show *k*, *s* for a filter comparable to rest-frame *V*. The GRB 131231A SN is more luminous than any other, extremely blue, and does not follow the trend of more luminous SNe also being slower.





These results show that the luminosity range of GRB-SNe is larger than expected, and that some GRB-SNe show significantly bluer emission than usual. SN 2011kl is spectroscopically similar to SLSNe and was associated with an extraordinary ultra-long GRB, but GRB 131231A was completely ordinary, whereas its associated SN (which was not observed spectroscopically) is even more luminous and likely hotter than SN 2011kl. Clearly, many unanswered questions remain on GRB-SNe, SLSNe and the possible link between them.

For more information, see: Greiner, Mazzali, Kann et al. 2015, Nature, 523, 189; Kann et al. 2017a, A&A, submitted (arXiv1606.06791v2); Kann et al. 2017b, A&A, submitted (arXiv:1706.00601). GRB 131231A is Kann et al. 2018, in preparation.