Two New Ca-rich Gap Transients in Group and Cluster Environments

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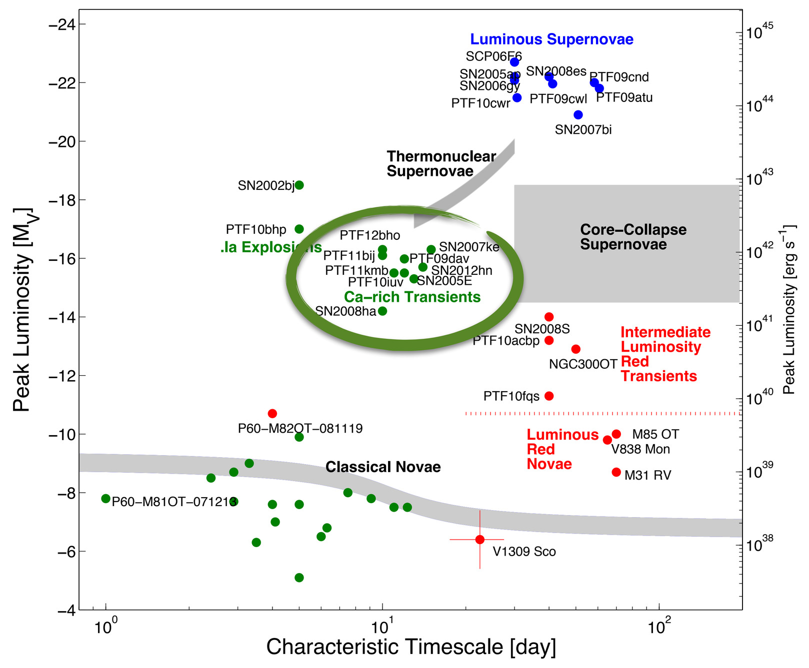
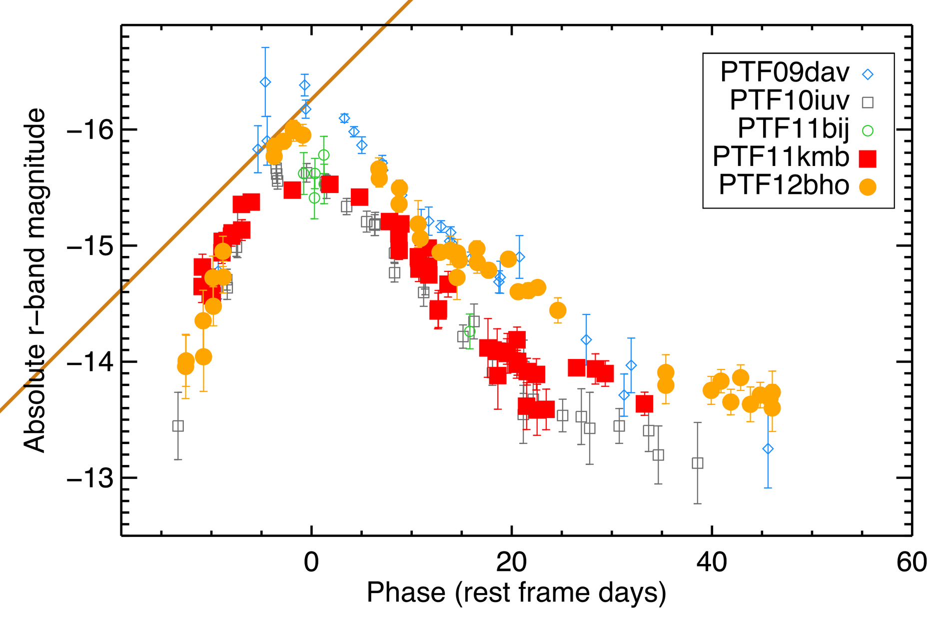
PTF11kmb and PTF12bho: Two new Ca-rich Gap Transients

Context



The Ca-rich gap transients are characterized by **shorter timescales** and **lower luminosities** than typical supernovae, and a nebular spectrum with **strong [Ca II] emission** compared to [O I] [1,2]. Their **physical origin and progenitor system are not well understood** — candidates include a helium white dwarf (WD) being disrupted by a neutron star (NS) [3,4], or the merger of a He WD with a carbon-oxygen WD [1,5,6].

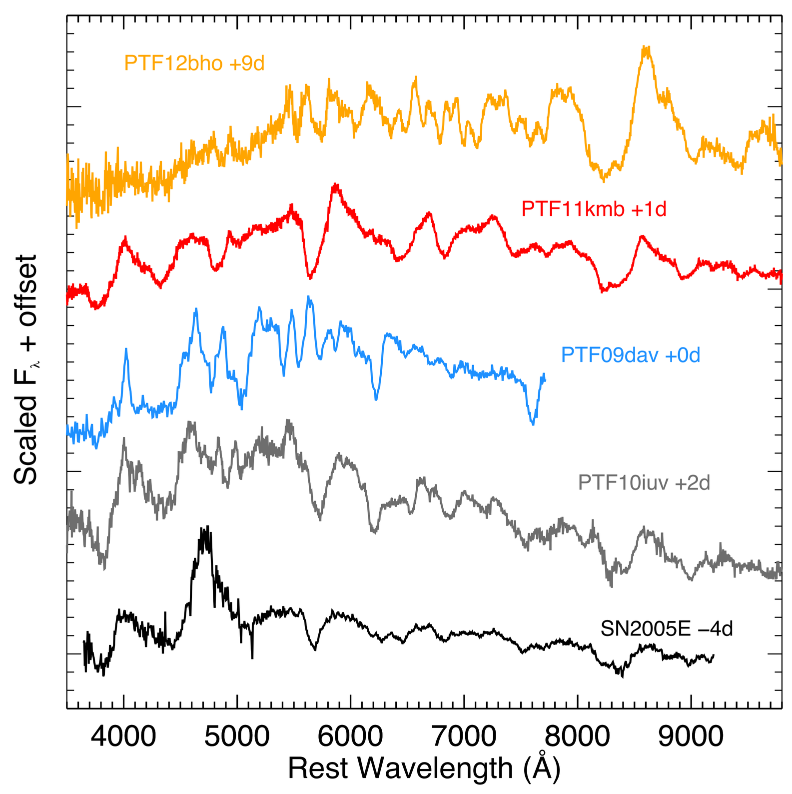
Light Curves



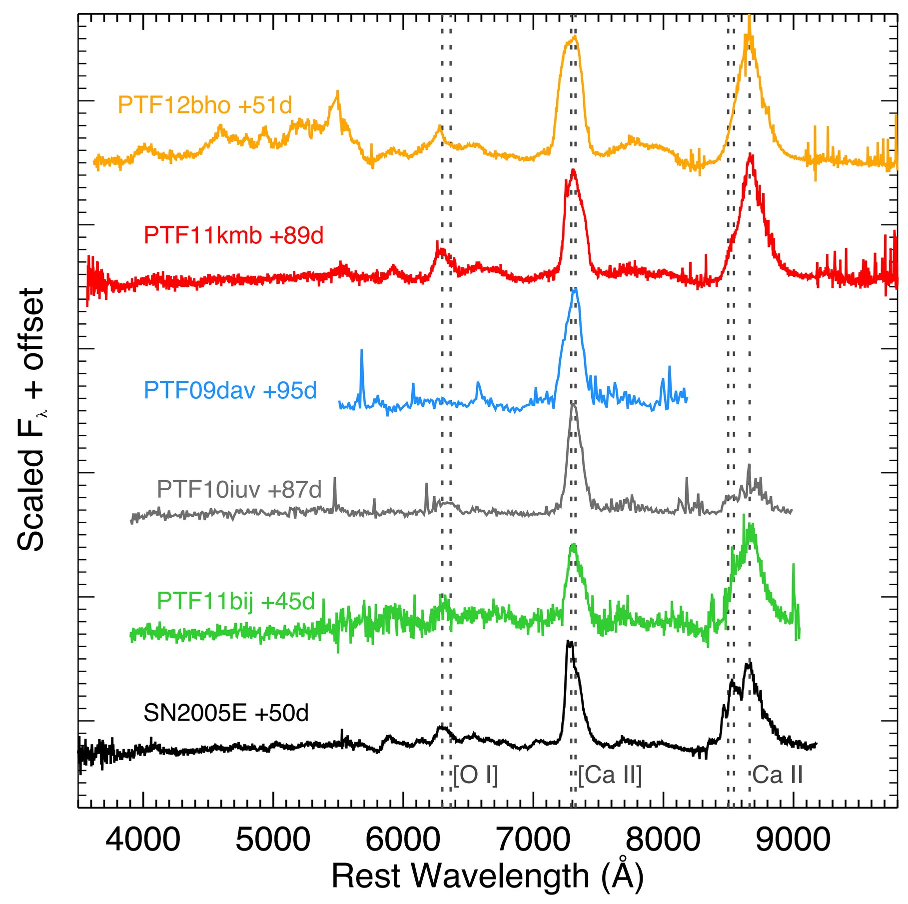
Light curves (*r*-band) of PTF11kmb and PTF12bho, compared to other Ca-rich gap transients from PTF [2]. Like previous objects, they show fast evolution and low peak luminosities, indicating a **low ejecta mass**.

PTF11kmb (at z=0.017) and PTF12bho (at z=0.023) were both discovered by the Palomar Transient Factory (PTF). Photometry from Palomar 48-in, Palomar 60-in, and LCOGT.
Spectra from Palomar 200-in (DBSP), Keck I (LRIS) and Keck II (DEIMOS).

Spectra



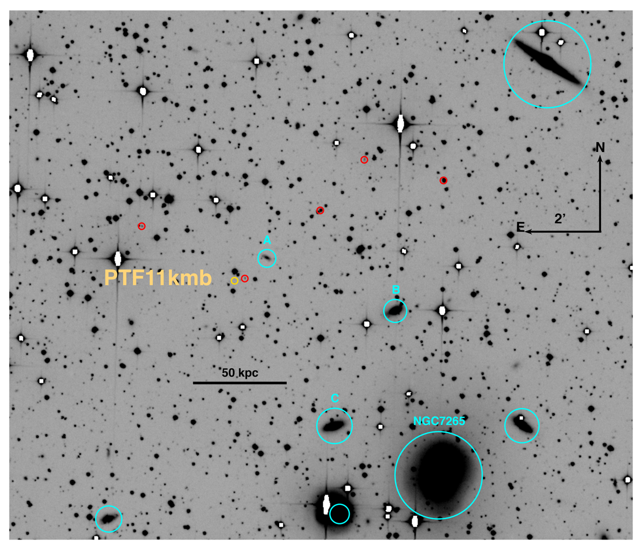
Photospheric-phase spectra, compared to other Ca-rich gap transients [1,2]. PTF11kmb shows **strong He lines**, similar to SN2005E. In contrast, the spectrum of PTF12bho is very complicated with narrower lines — we securely identify Ca II, O I, Fe II, Mg II and He I.



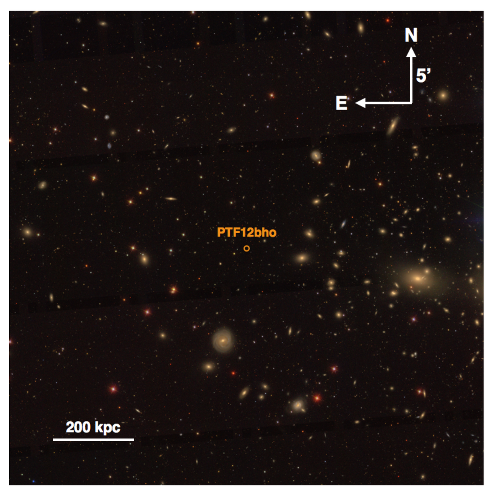
Nebular-phase spectra, compared to other Ca-rich gap transients [1,2]. Note the **high ratio of [Ca II] to [O I],** characteristic of this class of transients.

Host Galaxy Environments: Old, Massive and Remote

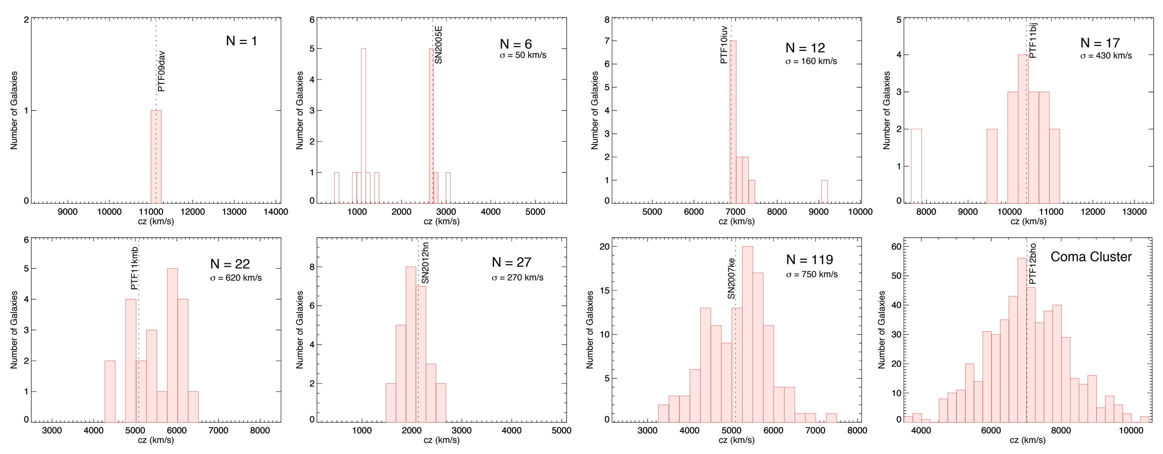
Large-Scale Environments: Groups and Clusters



Above: PTF R-band reference of field around PTF11kmb. Cyan circles mark members of the galaxy group.
Below: SDSS gri composite image of the Coma Cluster. Location of PTF12bho is marked.

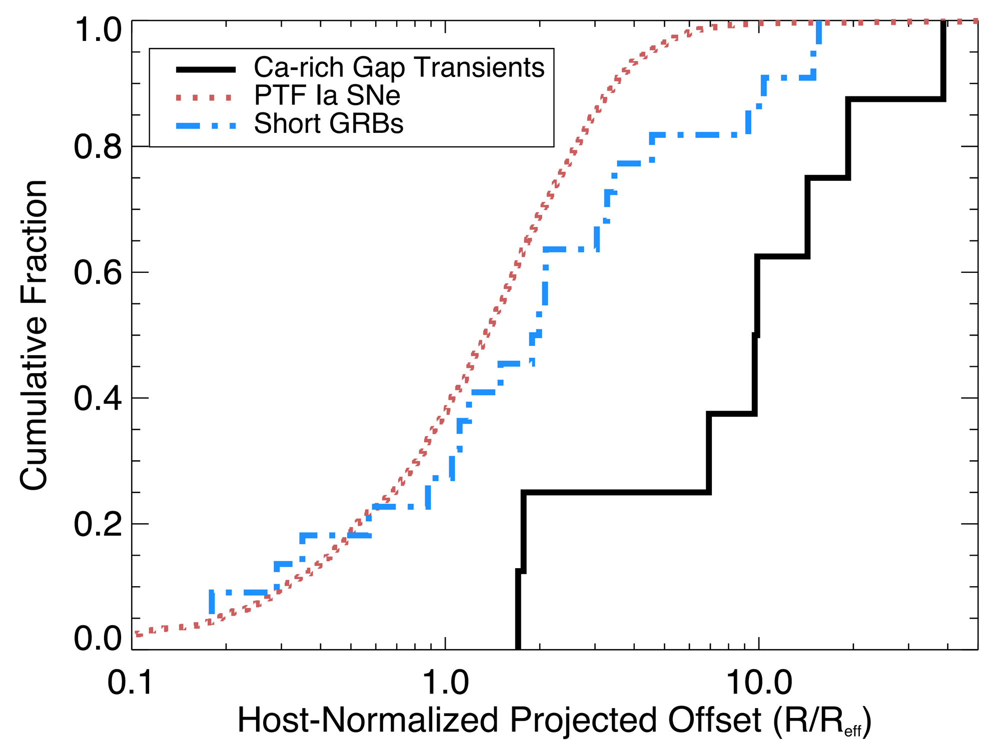


- PTF12bho is an **intra-cluster** transient in the Coma Cluster.
- PTF11kmb is located in a galaxy group, ~150 kpc from the most likely host, NGC7265.
- The majority of Ca-rich gap transients found to date are in **galaxy groups or clusters**, often near the central elliptical galaxy and near the velocity center of the group.
- This suggests that Ca-rich gap transients come from an **old stellar population**, and that galaxy-galaxy interactions and intracluster light may also play a role in explaining their remote locations.



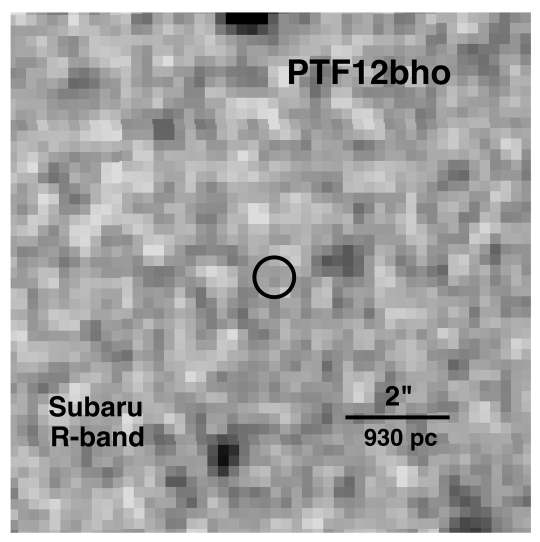
Above: Velocity histograms of galaxies within 1 Mpc and 3000 km/s for the sample of Ca-rich gap transients. Group member galaxies are colored. Only one known Ca-rich gap transient to date is in an isolated galaxy, and 2/8 are in rich clusters.

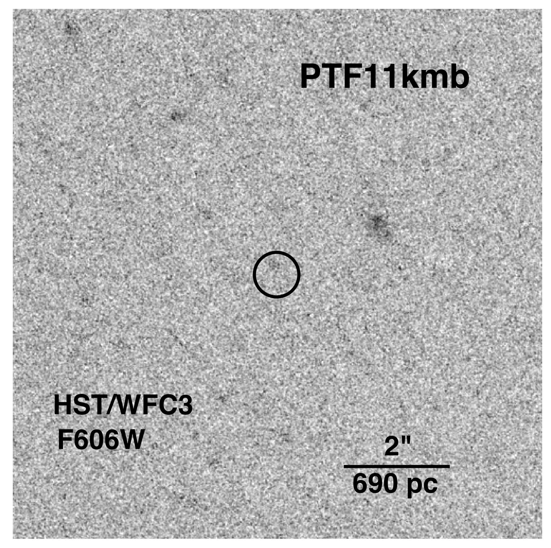
Host Galaxy Offsets



- The **offset distribution** of Ca-rich gap transients is significantly more **extreme** than that of SN Ia and short-hard gamma ray bursts [7,8].
- If offsets result from a supernova kick (NS-WD merger scenario) either the kick velocities or the merger times need to be significantly larger/longer than for short GRBs (NS-NS mergers).
- This is **not a selection effect** — PTF is capable of finding such transients in high surface brightness regions.

Limits on In-Situ Formation





- Deep Subaru imaging of the Coma Cluster (*left*; [9]) puts a limit $M_R > -8.0$ mag for any underlying source at the location of PTF12bho.
- *Hubble Space Telescope* imaging of the field of PTF11kmb (*right*) finds a marginal source within the 5σ error radius.
  - This could be an artifact or a background galaxy (~10% chance coincidence).
  - If the source is real and at the redshift of PTF11kmb, the absolute magnitude would be $M_{606W} \simeq -6.0$ mag, consistent with a globular cluster.

References: [1] Perets et al., 2010, Nature, 465, 322; [2] Kasliwal et al., 2012, ApJ, 755, 161; [3] Metzger, 2012, MNRAS, 419, 827; [4] Sell et al. 2015, MNRAS, 450, 4098;
[5] Waldman et al., 2011, ApJ, 738, 21; [6] Sim et al., 2012, MNRAS, 420, 3003; [7] Fong et al., 2010, ApJ, 708, 9; [8] Fong & Berger, 2013, ApJ, 769, 56; [9] Yagi et al., 2016, ApJS, 225, 11.