Short gamma-ray bursts and gap transients

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Overview

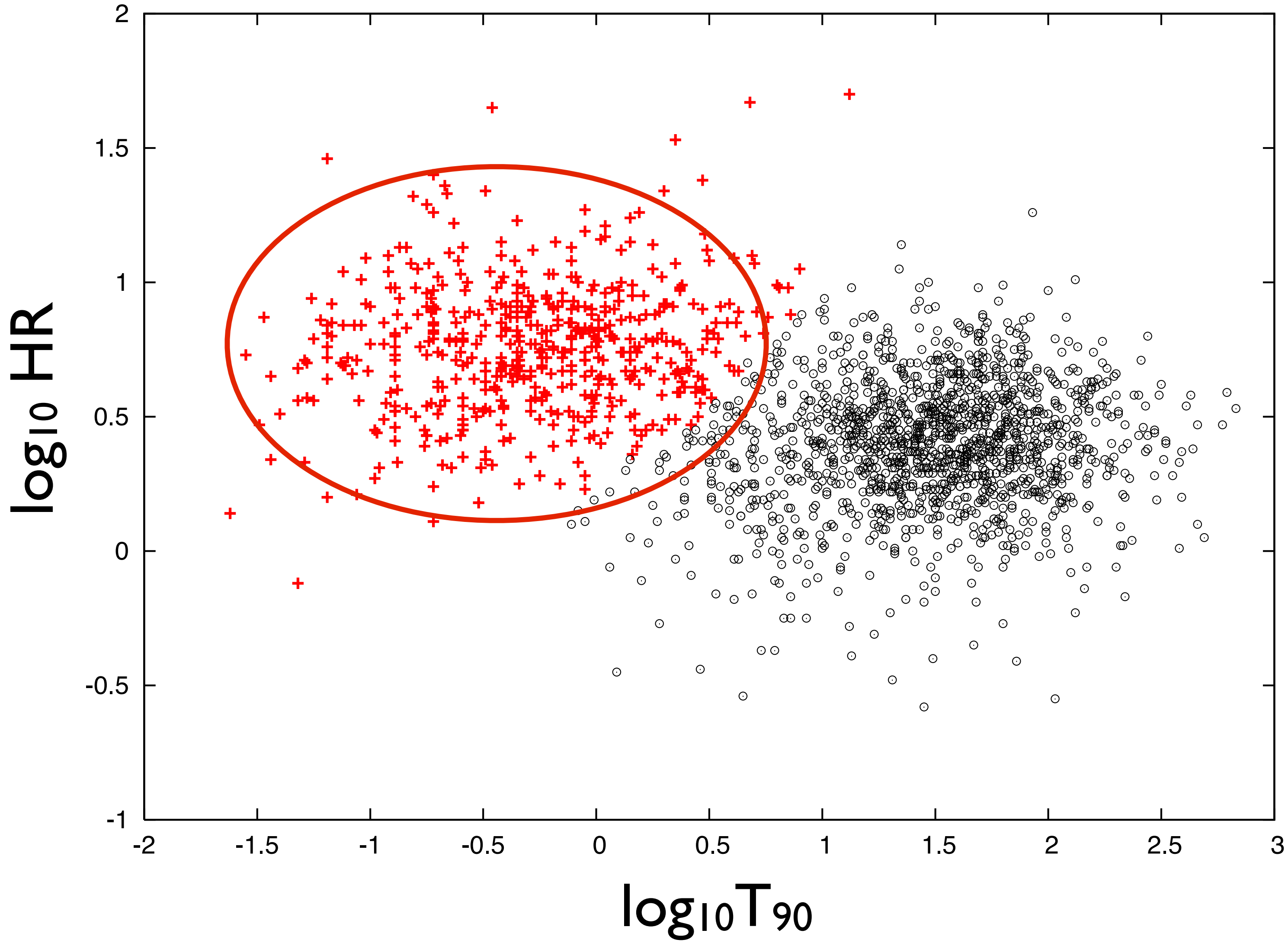
Short gamma-ray burst observations

Gap transient observations

Compact binary formation and properties

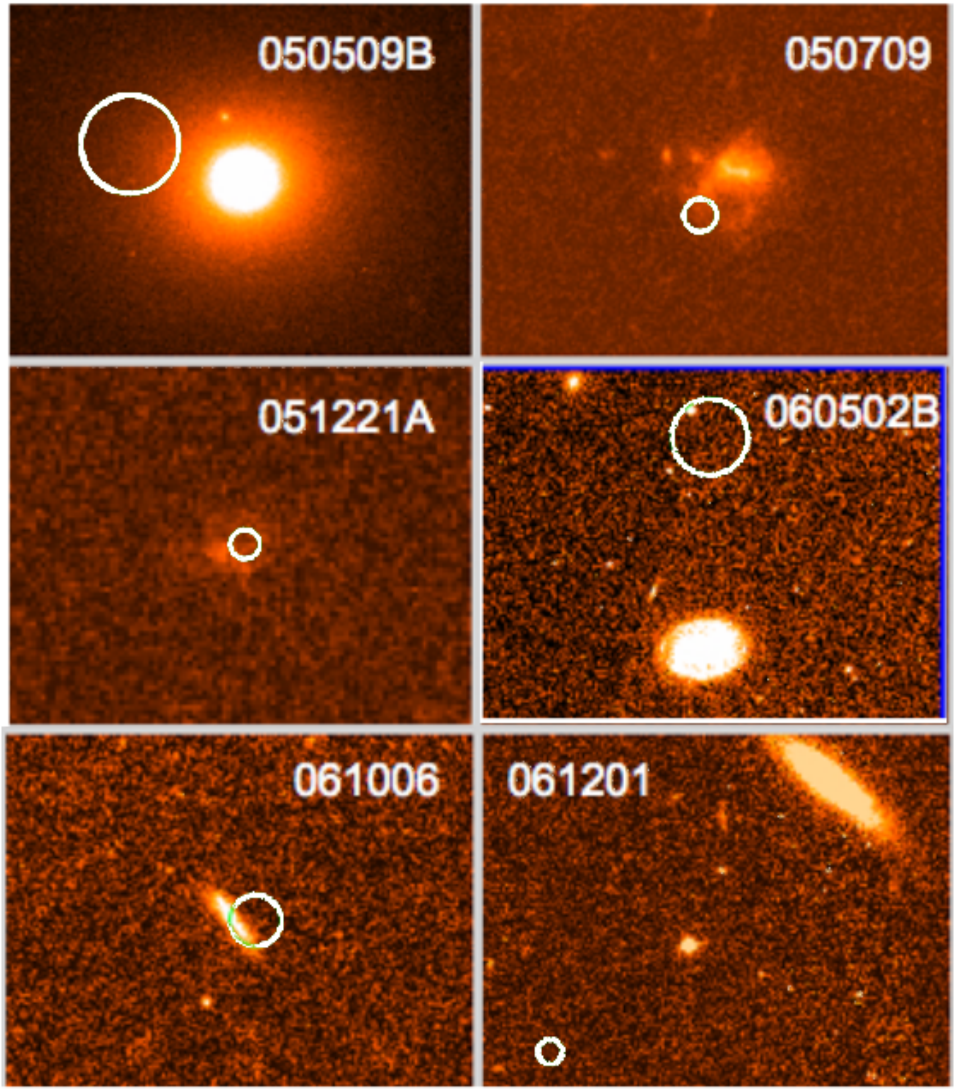
Offset predictions

Short vs. long bursts



(Kouveliotou et al. 1993; figure adapted from Horváth et al. 2006)

Short gamma-ray burst environments



Localisations from Swift

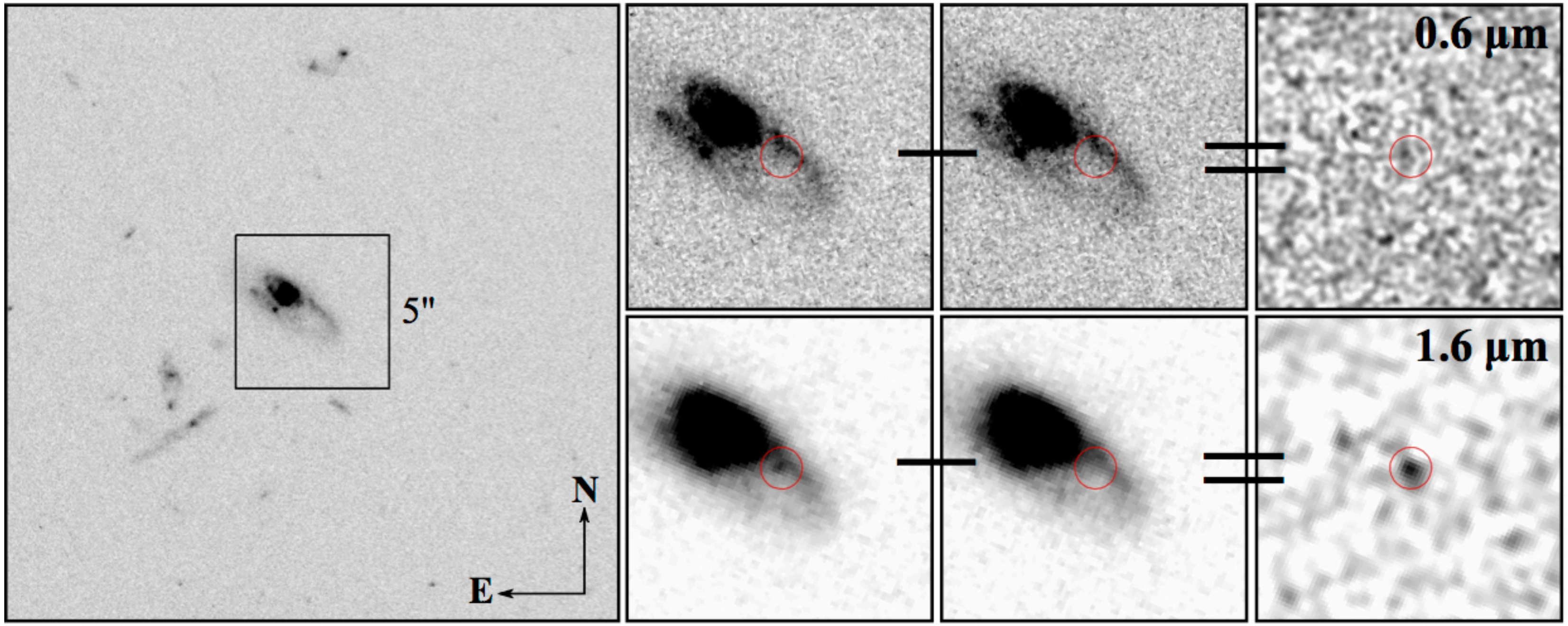
All galaxy types represented

Burst offset from host galaxies by up to ~100 kpc

See Fong et al. (2013) for a recent compilation

Kilonova

Emission from radioactive decay of *r*-process rich material



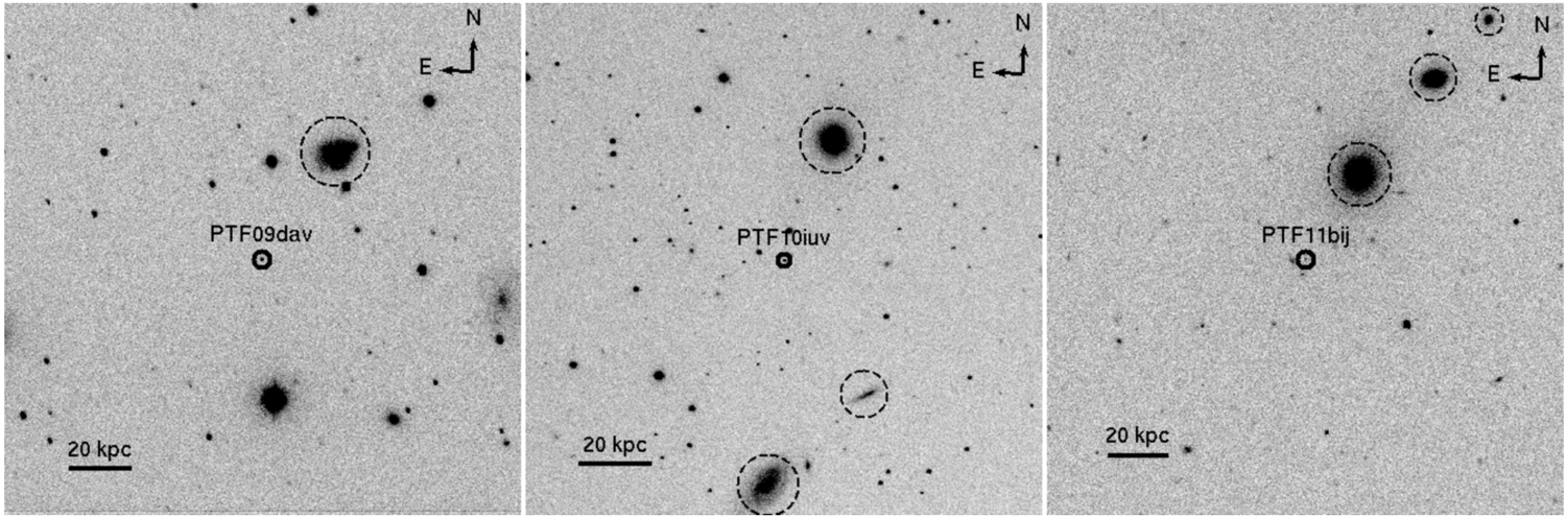
Near-IR brightening observed for GRB 130603B consistent with kilonova.

Tanvir et al. (2014) *Nature* **500** 547

Inferred mass ejection consistent with compact binary merger.

Piran et al., arXiv1401.2166

Calcium-rich "gap" transients



$$M_{R,\mathrm{peak}} = -15.5 \text{ to } -16.5$$

$$t_{\mathrm{rise}} = 12 - 15\,\mathrm{days}$$

Nebular spectra dominated by calcium.

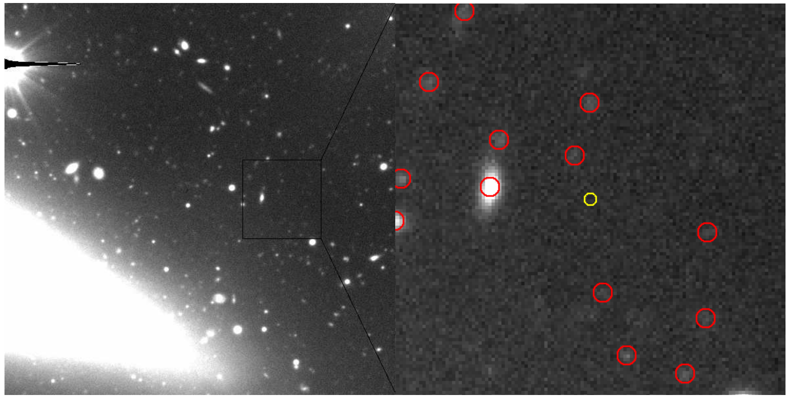
Offset from host galaxies.

Kasliwal et al. (2012) *ApJ* **755** 161

Gap transient background limits

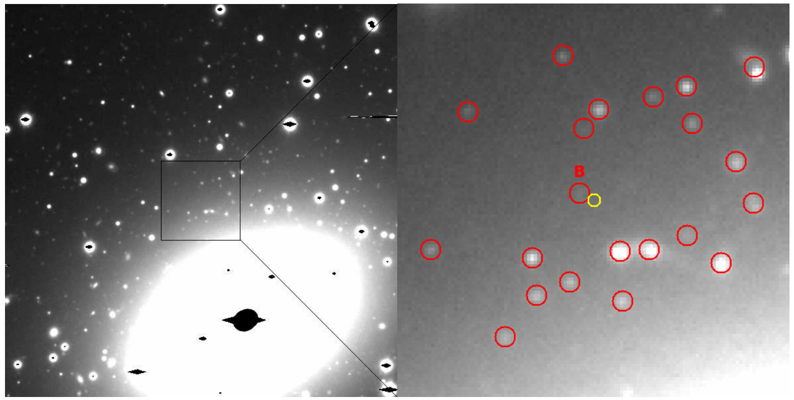
FORS2/VLT late-time imaging of gap transient locations.

SN 2005E



$$M_R > -5.26$$

SN 2012hn



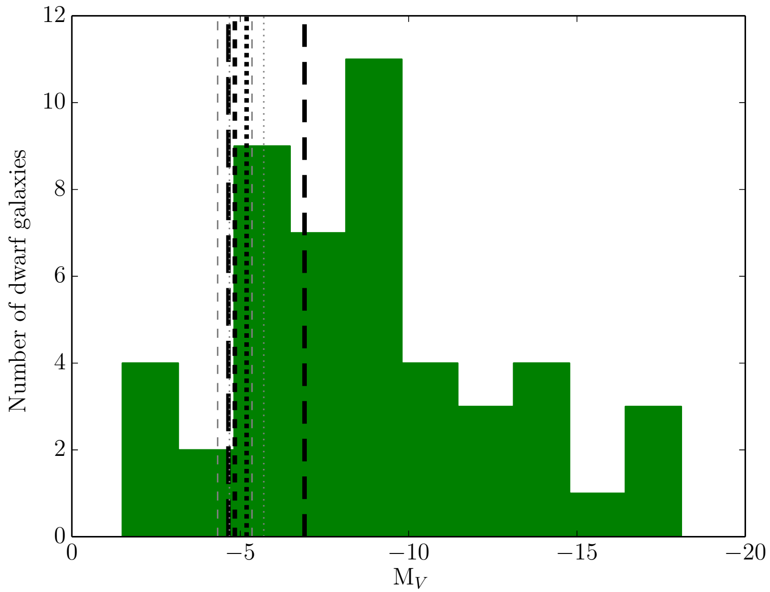
$$M_R > -5.48$$

$$M_B > -4.68$$

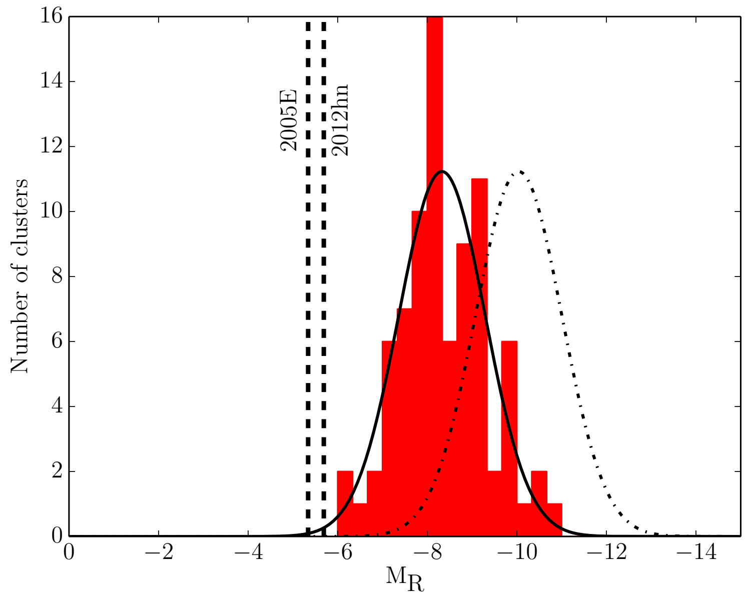
Lyman, Levan, Davies, RC & Tanvir, submitted to MNRAS

Gap transient background limits

Dwarf galaxies



Globular clusters



Limit excludes massive stars, globular clusters and almost all dwarf galaxies.

Implies that the progenitor was not born in location.

Lyman, Levan, Davies, RC & Tanvir, submitted to MNRAS

Possible gap transient progenitor

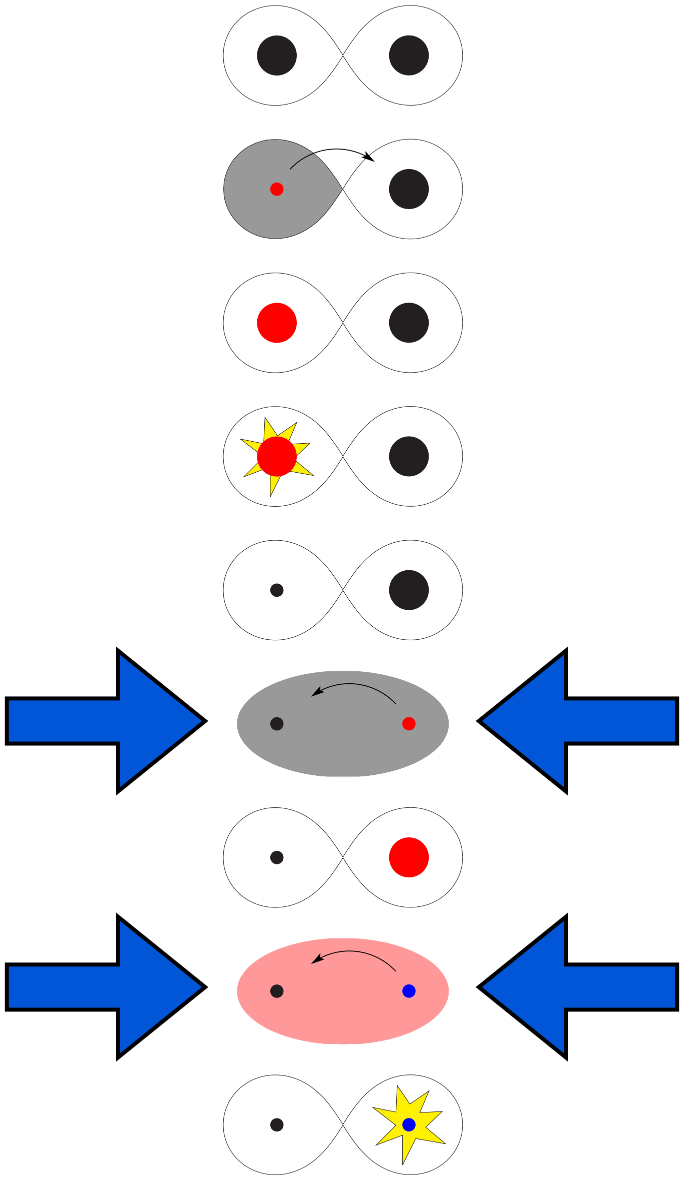
Binaries containing a white dwarf and a neutron star merge due to gravitational wave emission.

If the mass transfer is unstable, the white dwarf will be tidally disrupted into an accretion disc.

Nuclear burning in the accretion disc can produce the observed calcium. (Metzger 2012, *MNRAS* **419** 827)

These binaries contain a neutron star. Hence the supernova kick could be responsible for the offset.

Evolutionary pathway to compact binaries



Initial main sequence–main sequence binary

Stable mass transfer from primary

Helium star–main sequence star binary

First supernova

Black hole–main sequence star binary

Common envelope evolution

Close black hole–helium star binary

Common envelope evolution (round 2)

Final supernova

Evolutionary pathway to WD-NS binaries

Stars initially of similar mass

White dwarf forms from initially more massive star

Late-time mass transfer shrinks the orbit

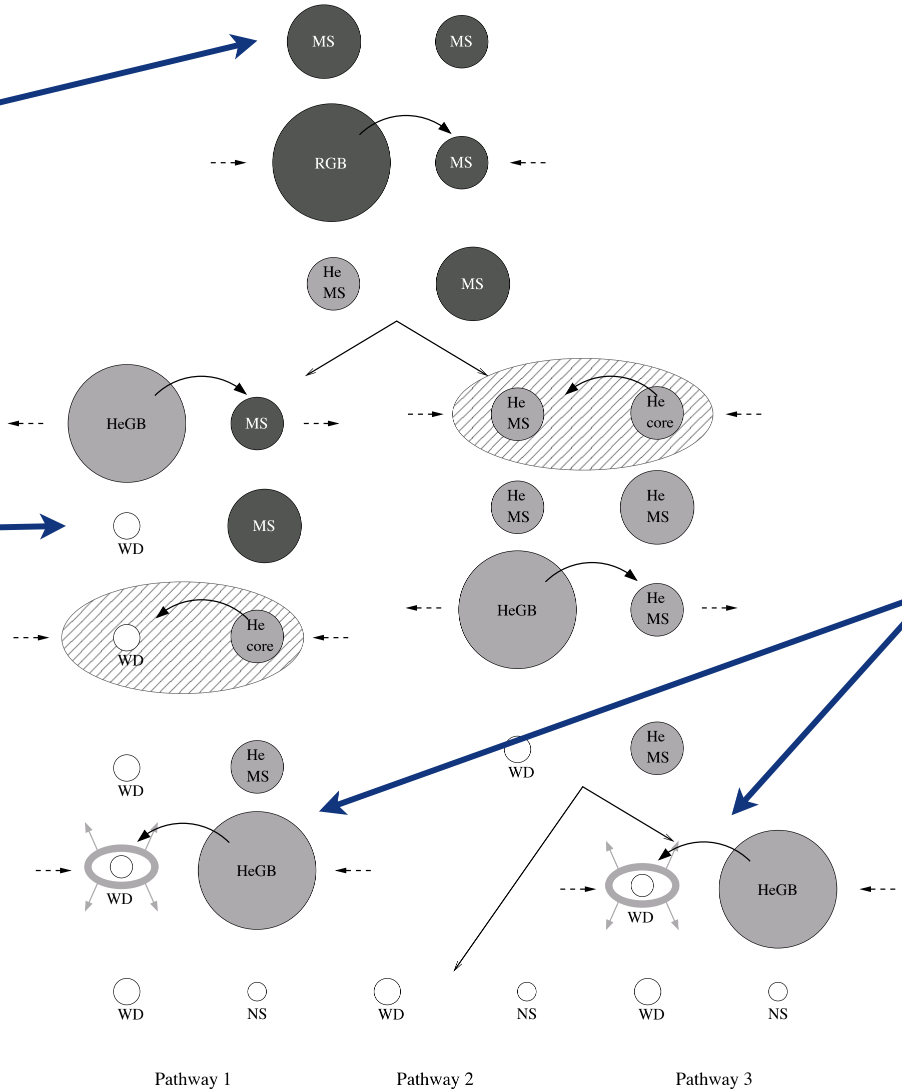
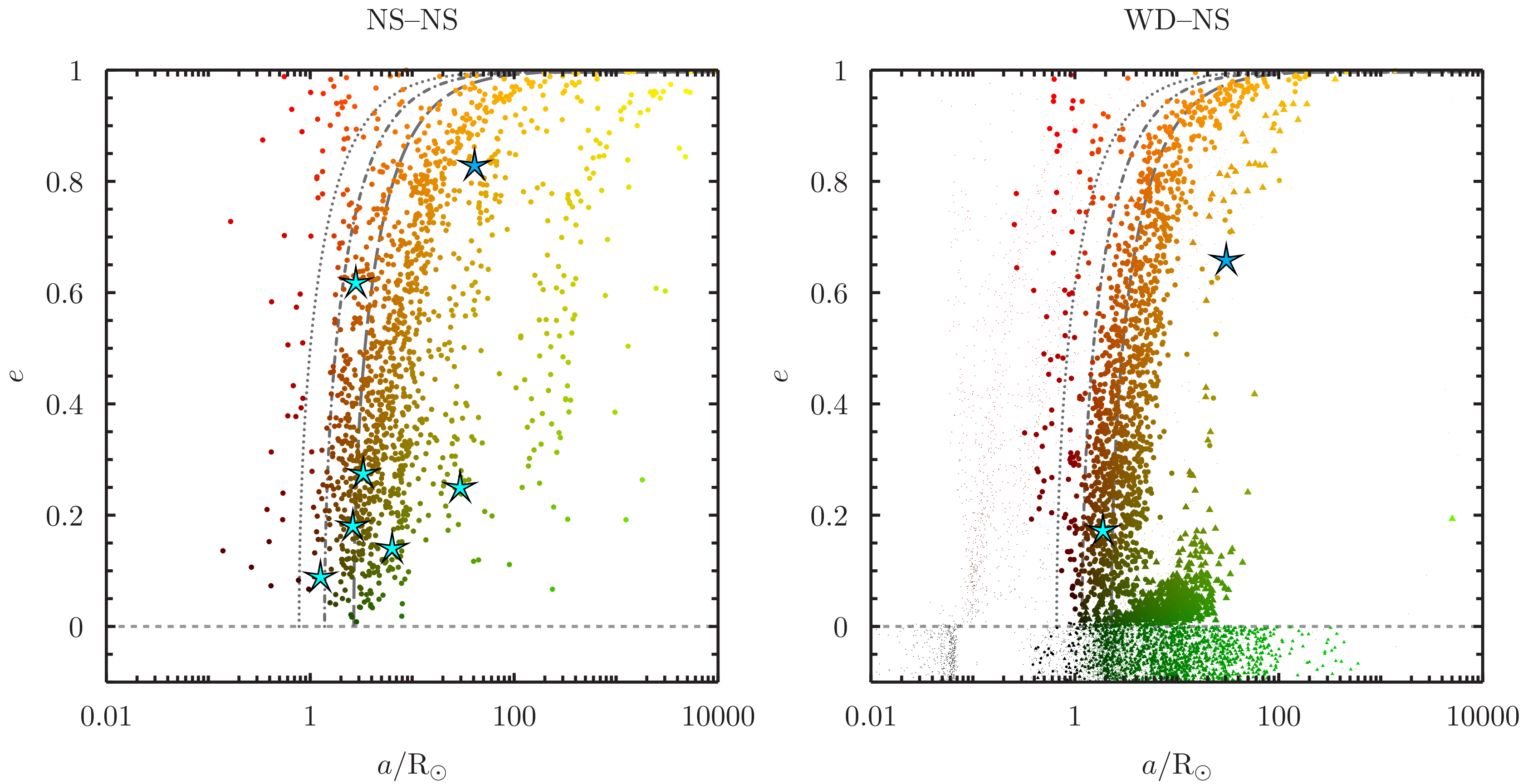


Figure from RC et al. (2006) *MNRAS* **372** 715; see also Davies et al. (2002)

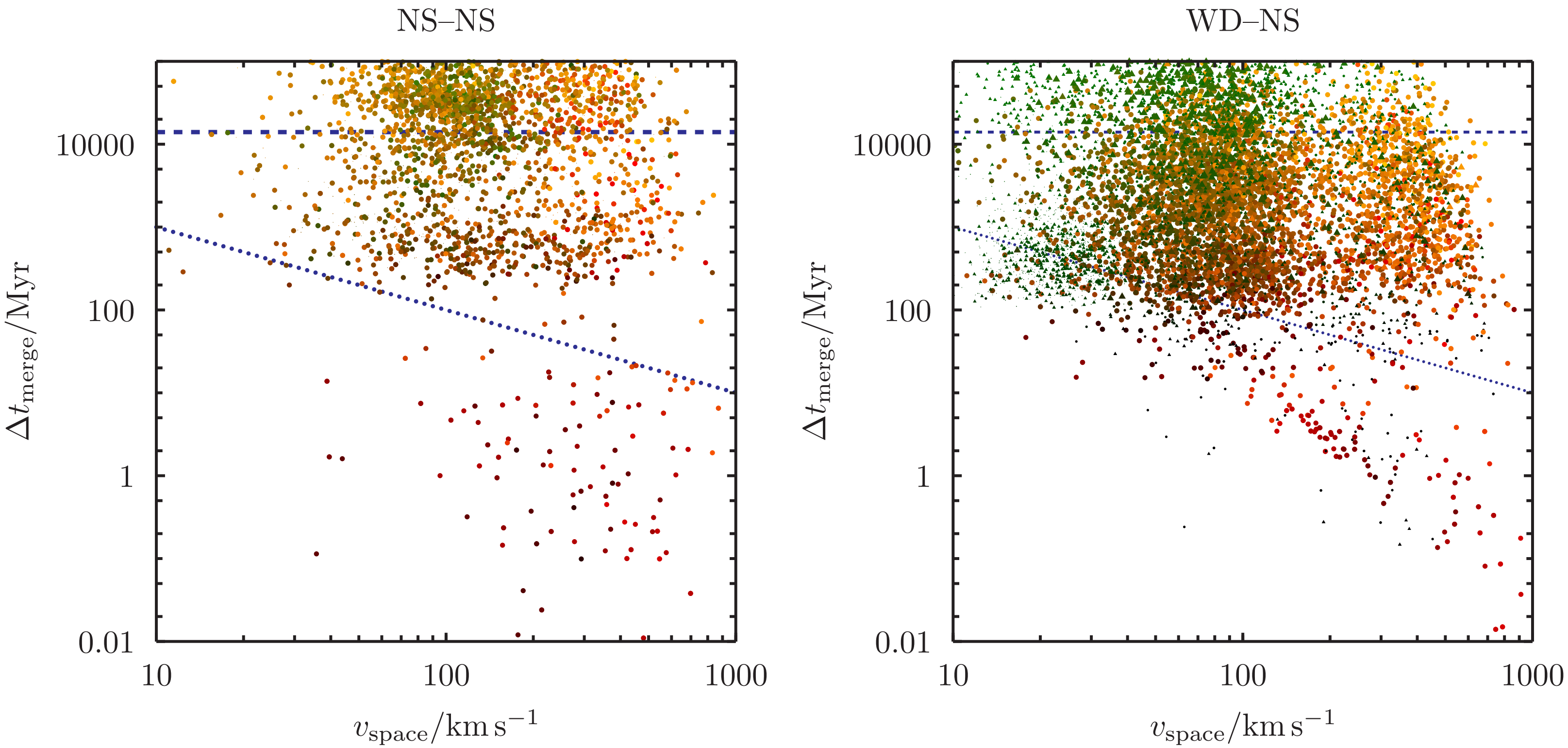
Population synthesis



Population synthesis including stellar evolution reproduces all Galactic NS-NS and WD-NS binaries.

RC et al. (2011) *MNRAS* **413** 204; RC et al. in prep.

Space velocities and merger times



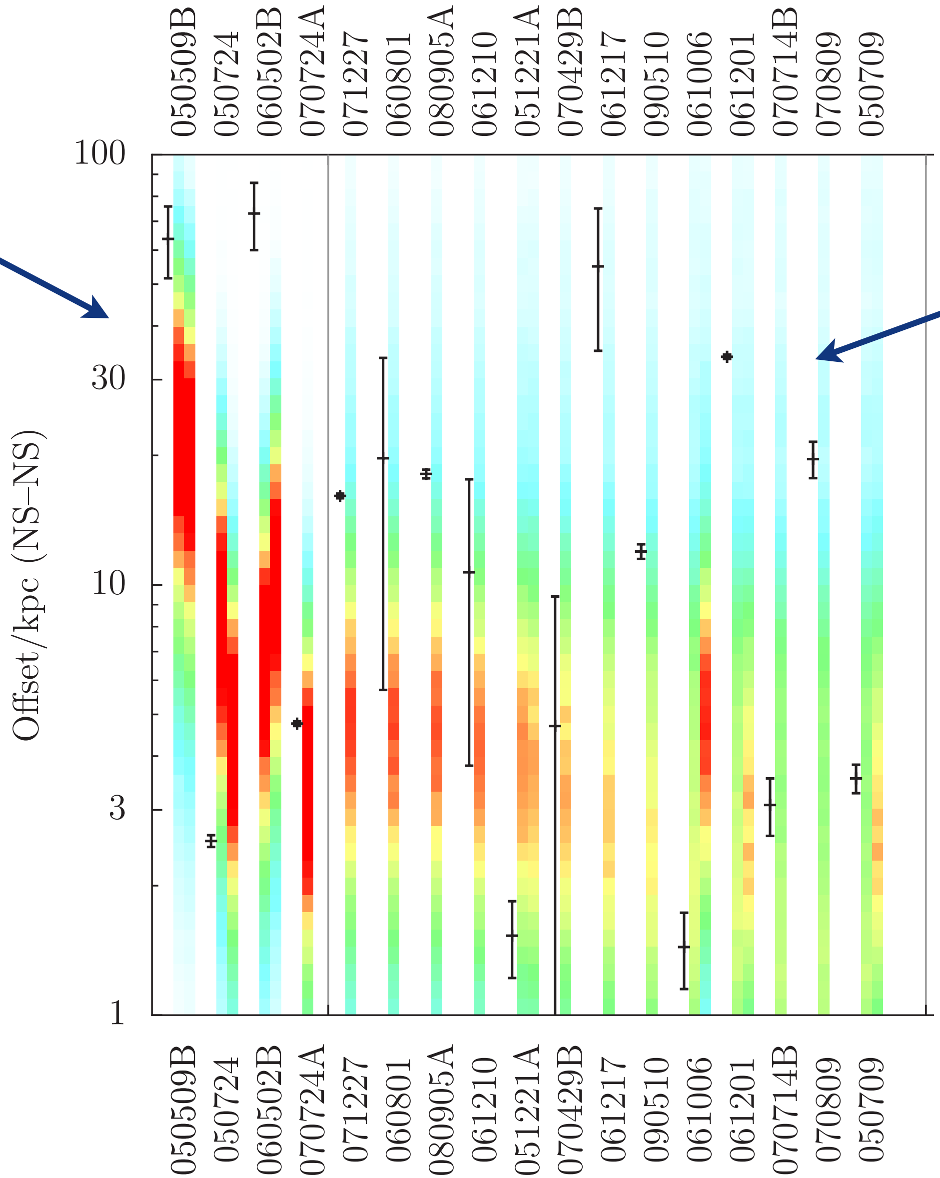
Systems between the blue lines may be able to travel over 10 kpc, depending on the host galaxy's potential.

RC et al. (2011) *MNRAS* **413** 204; RC et al. in prep.

SGRB host offsets

Elliptical hosts

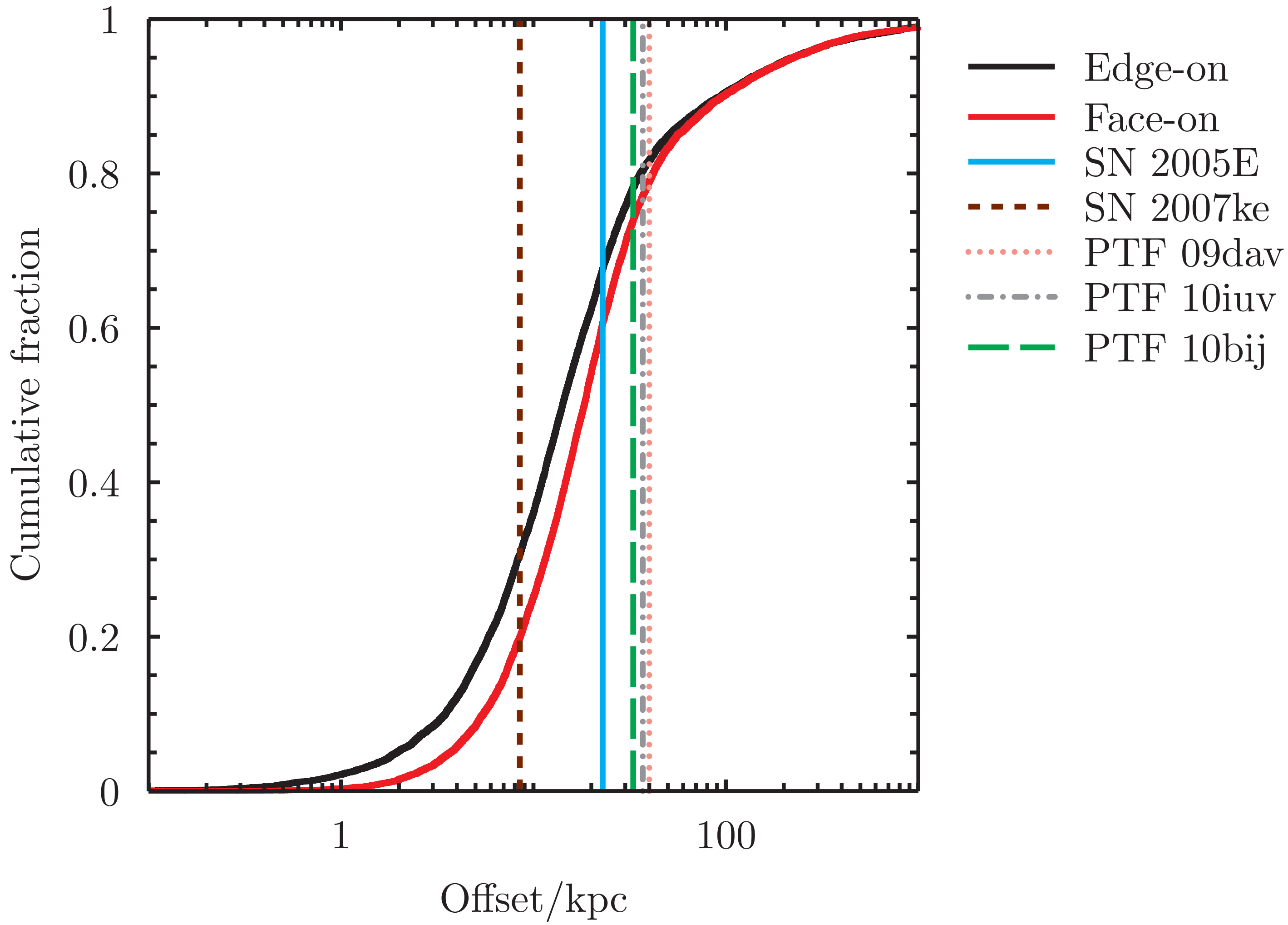
Spiral/irregular hosts



Peak probability densities in red

RC et al. (2011)

Gap transient host offsets



RC et al. in prep.

Uncertainties in offset prediction

Possible origins of under-predicted offsets for merging compact binaries include:

Binaries formed dynamically in globular clusters.

Host misidentification.

Supernova kick uncertainties.

Over-estimated host gravitational potential well.

Evolution of host galaxies.

Conclusions

Both short gamma-ray bursts and calcium-rich "gap" transients are systematically offset from their host galaxies.

For nearby gap transient hosts formation in situ can be excluded.

For both classes of system this favours an origin in merging compact binaries.