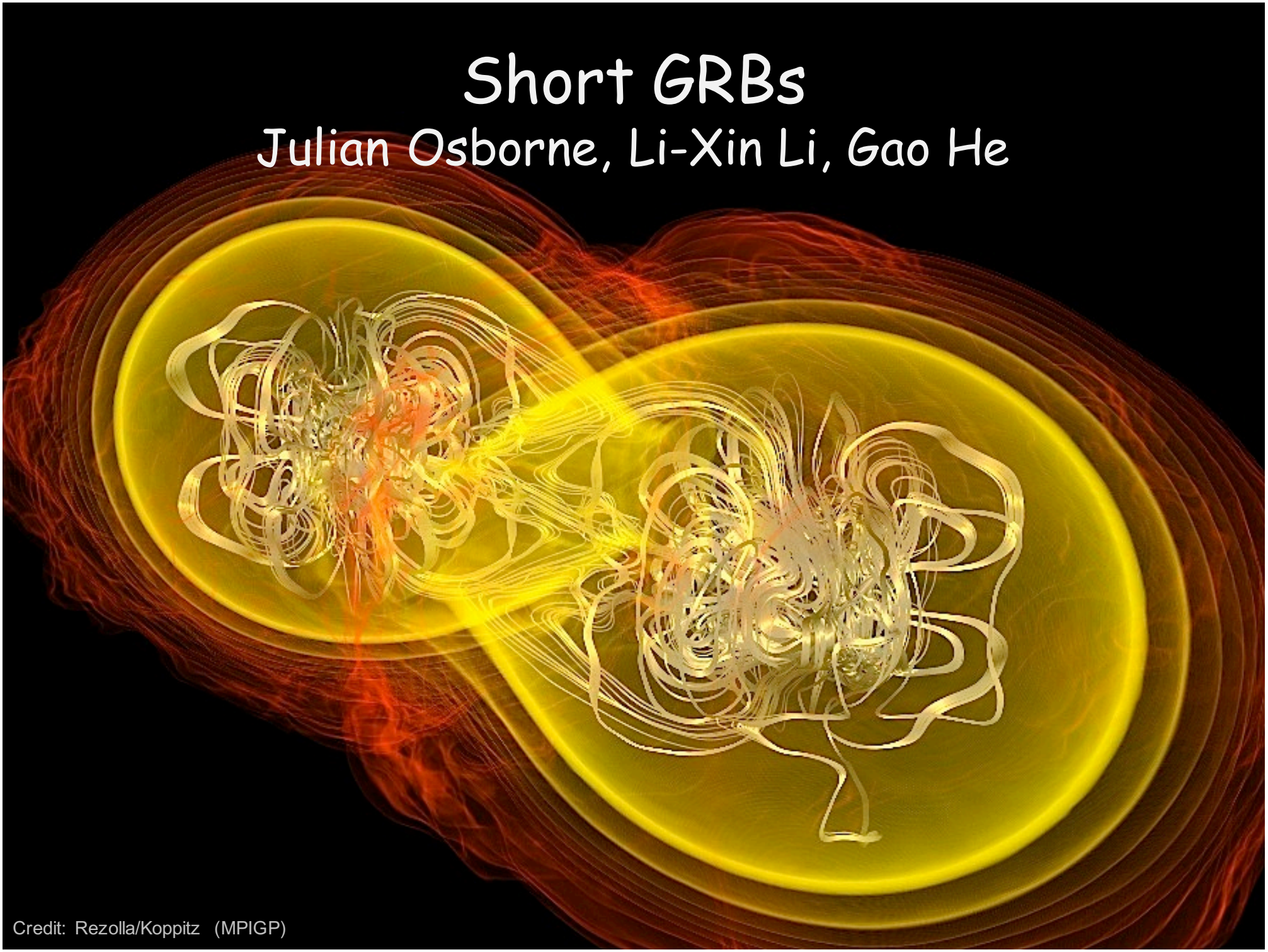
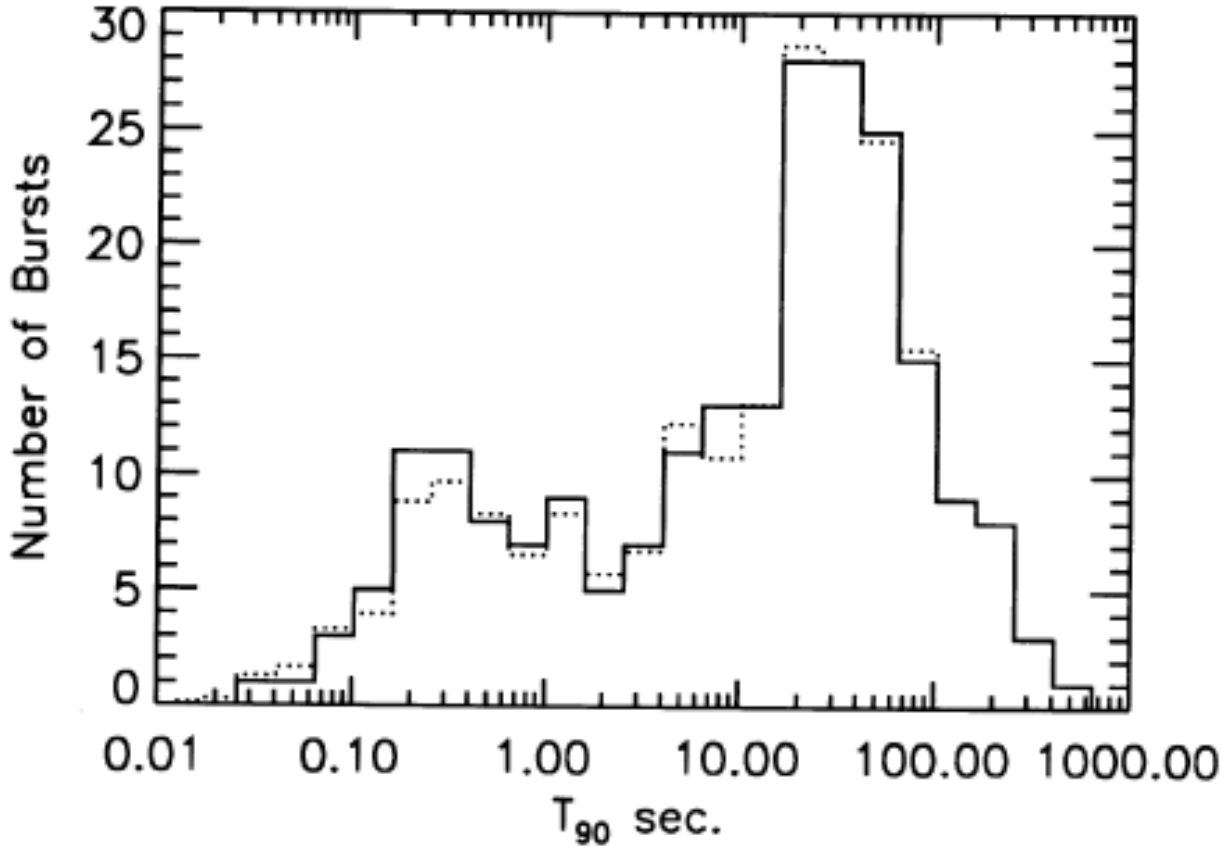
Short GRBs

Julian Osborne, Li-Xin Li, Gao He



Credit: Rezolla/Koppitz (MPIGP)

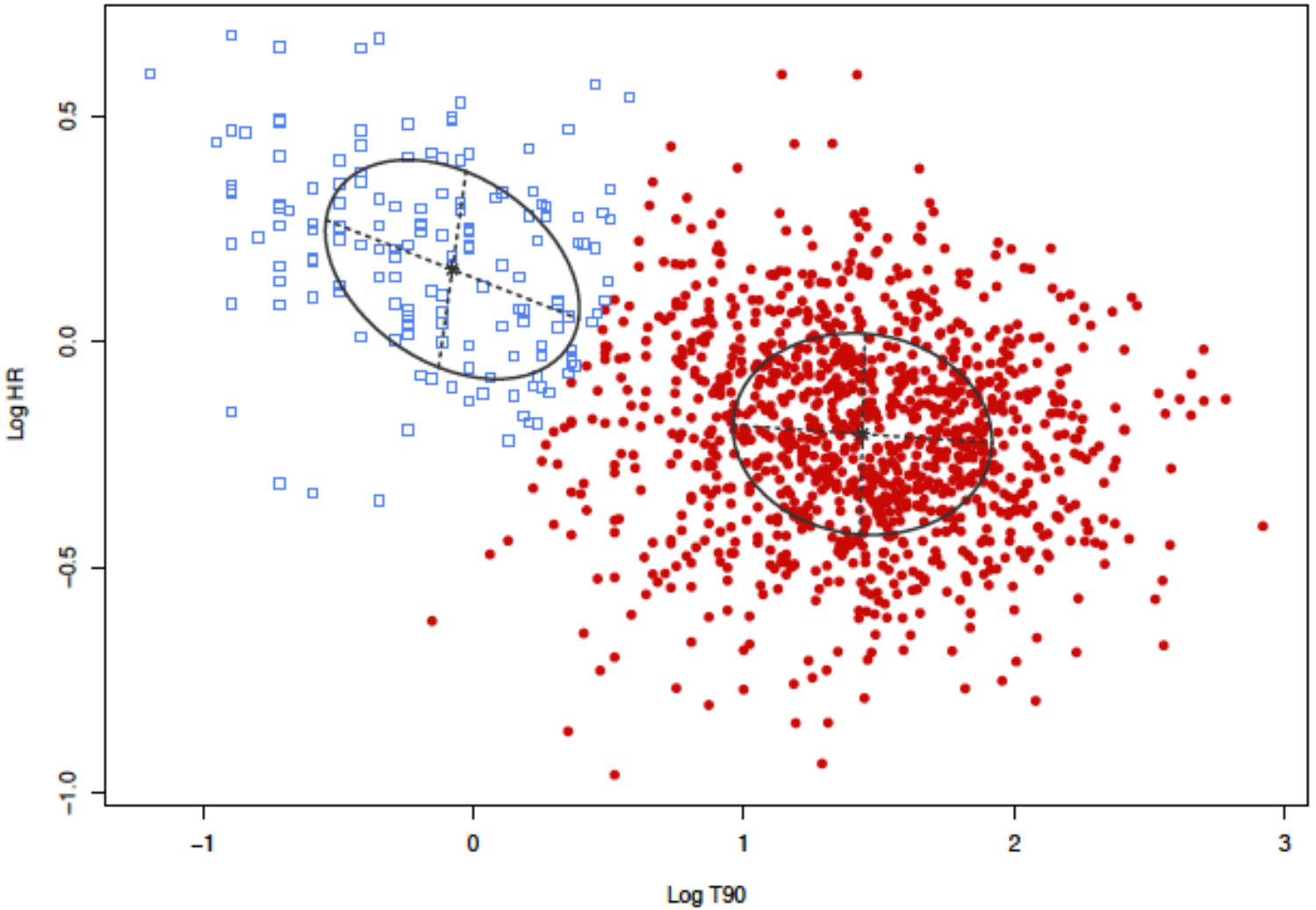
GRB durations



Kouveliotou et al. (1993) ApJ 413 L104

spectral-temporal distinction

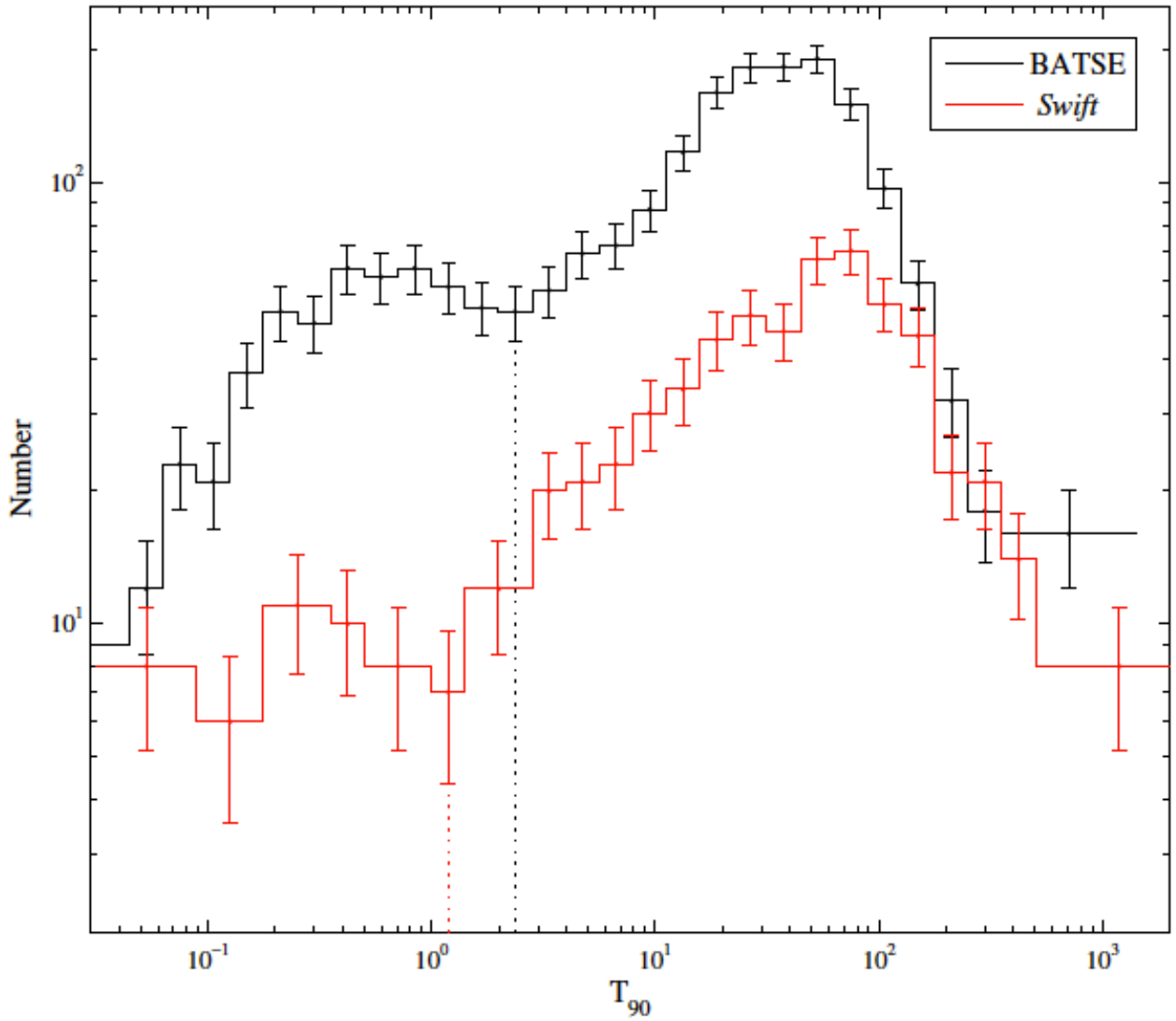
3rd GBM catalogue



2 populations strongly preferred over 3

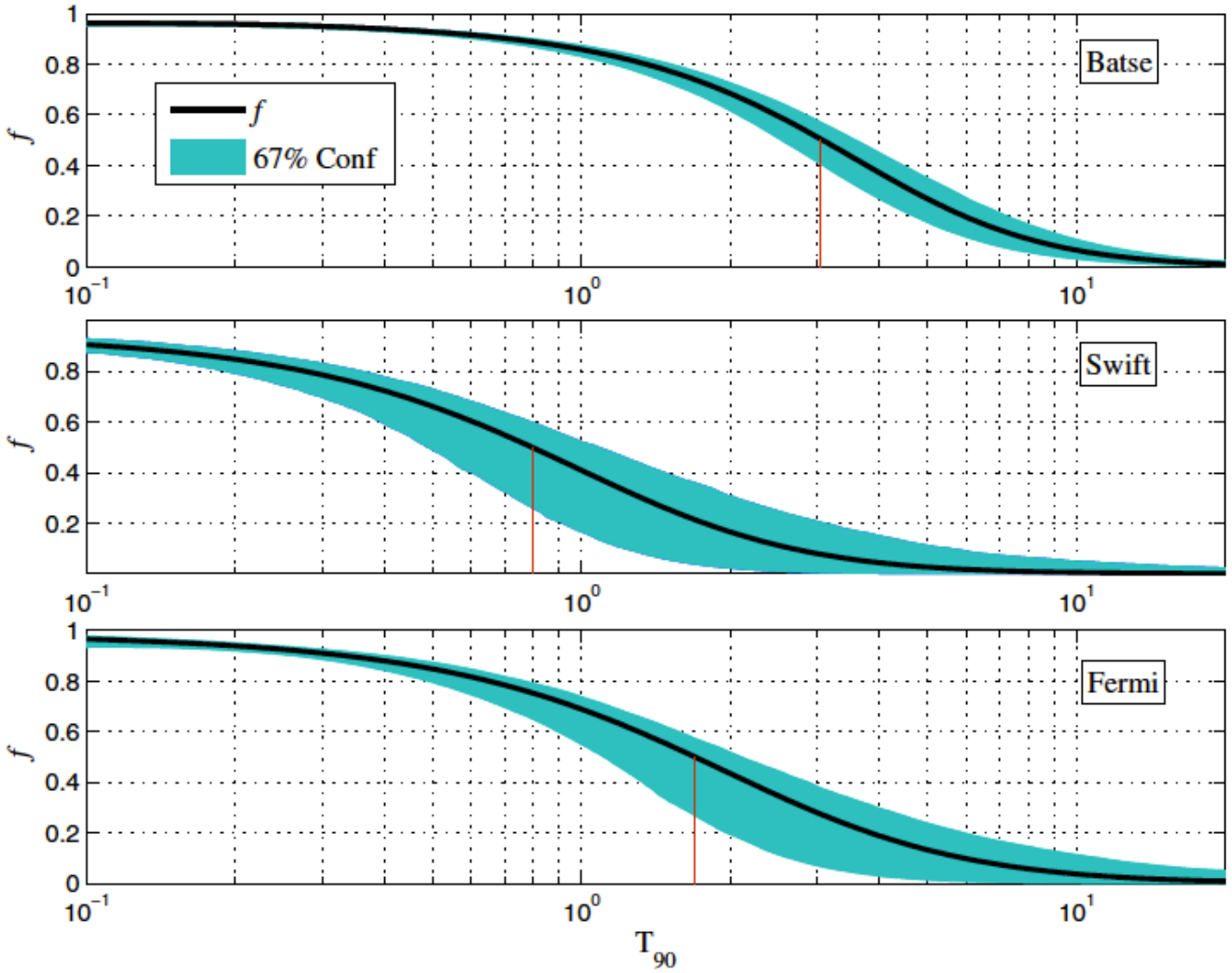
Bhat et al. arXiv:1603.07612

Short GRB difficulties



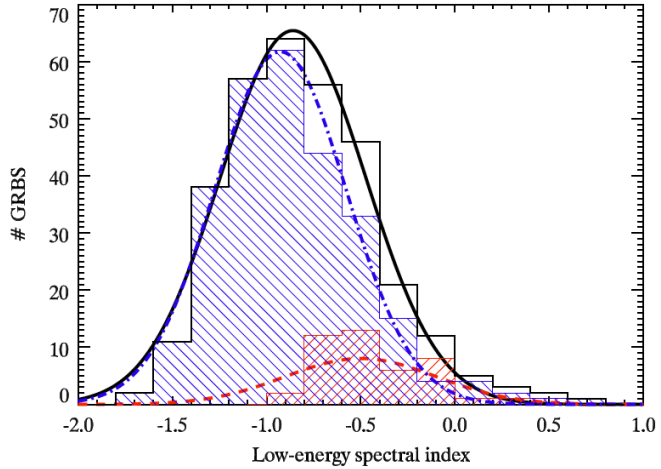
Bromberg et al. (2013) ApJ 764 179

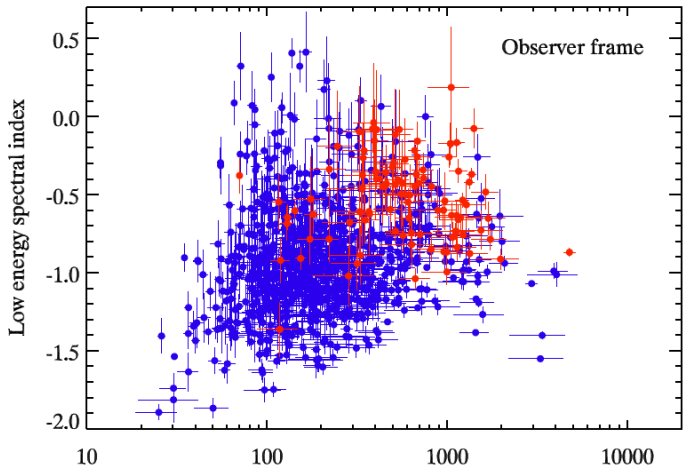
Threshold duration is a f(E)

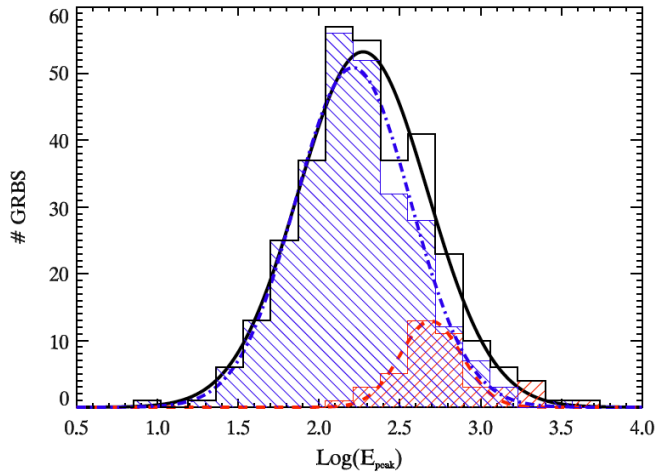


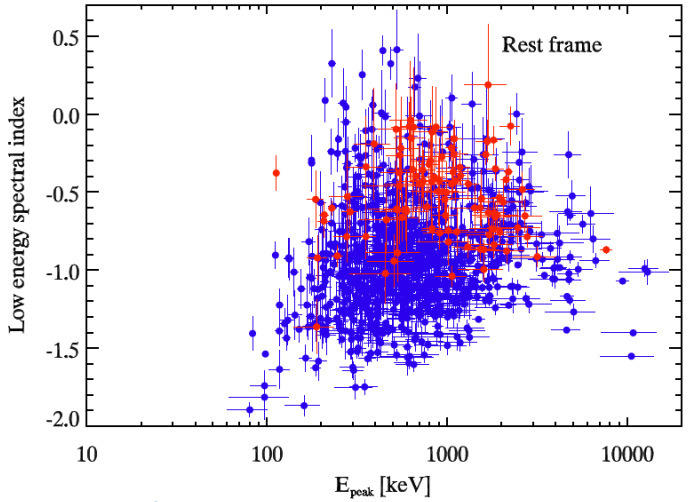
Bromberg et al. (2013) ApJ 764 179

sGRB vs lGRB spectra





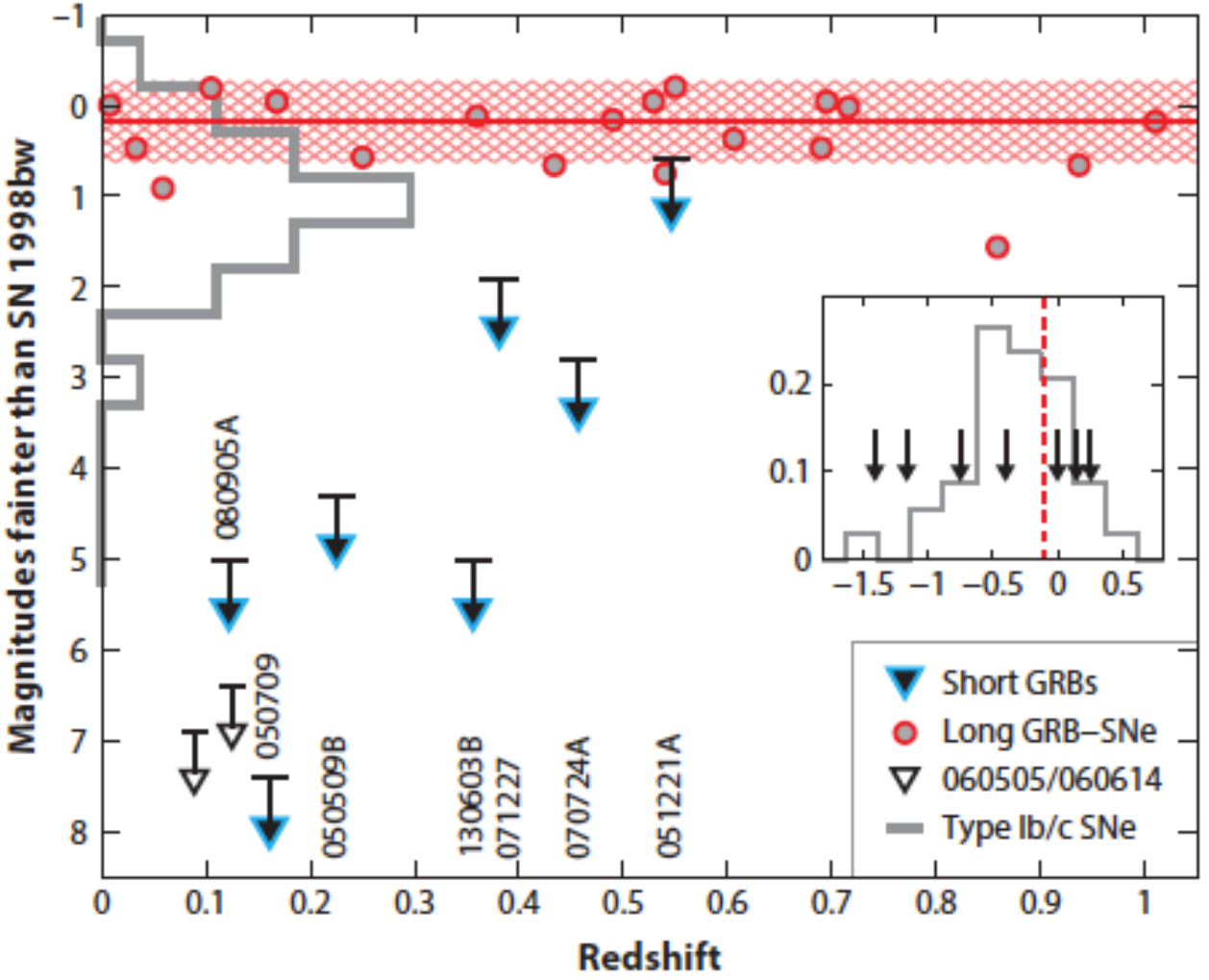




Short GRBs have flatter low-energy slope, but same rest-frame Epeak

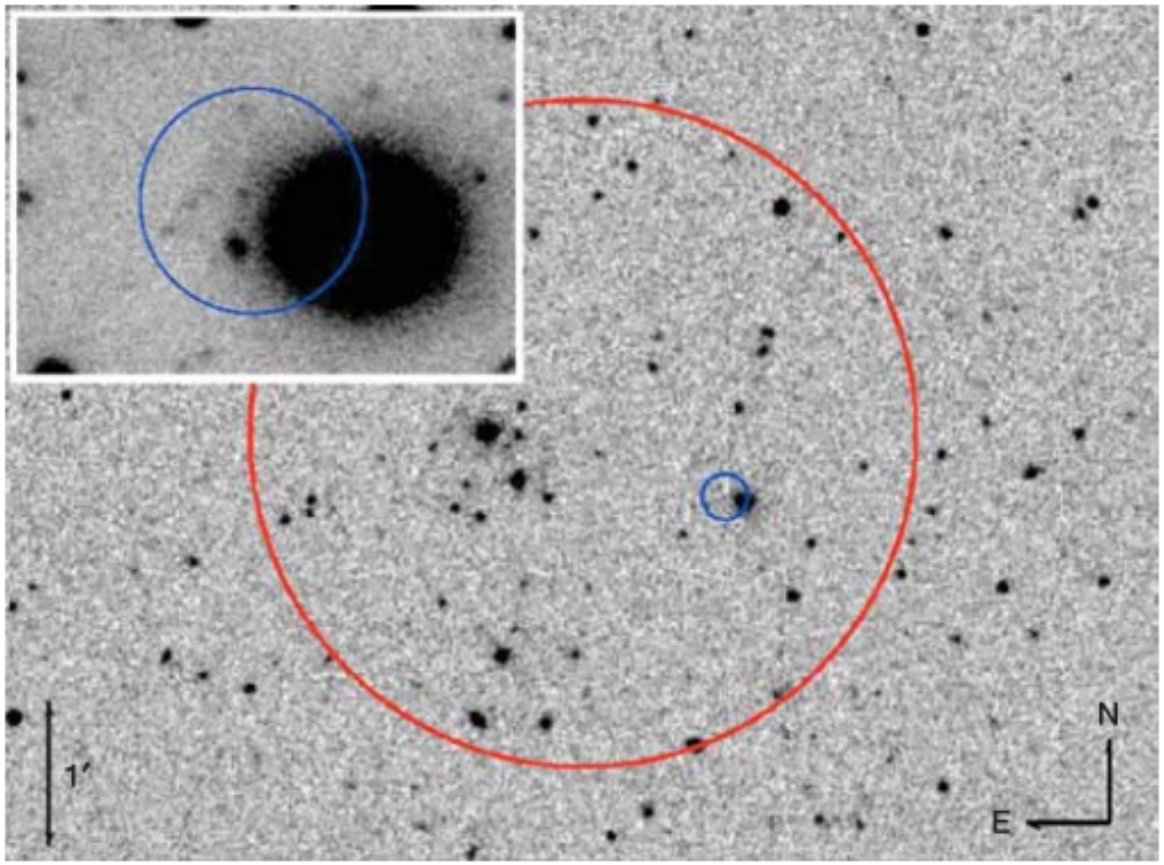
Ghirlanda et al. (2015) JHEAP 7 81

Short GRBS have no SNe



Berger (2014) ARA&A 52 43

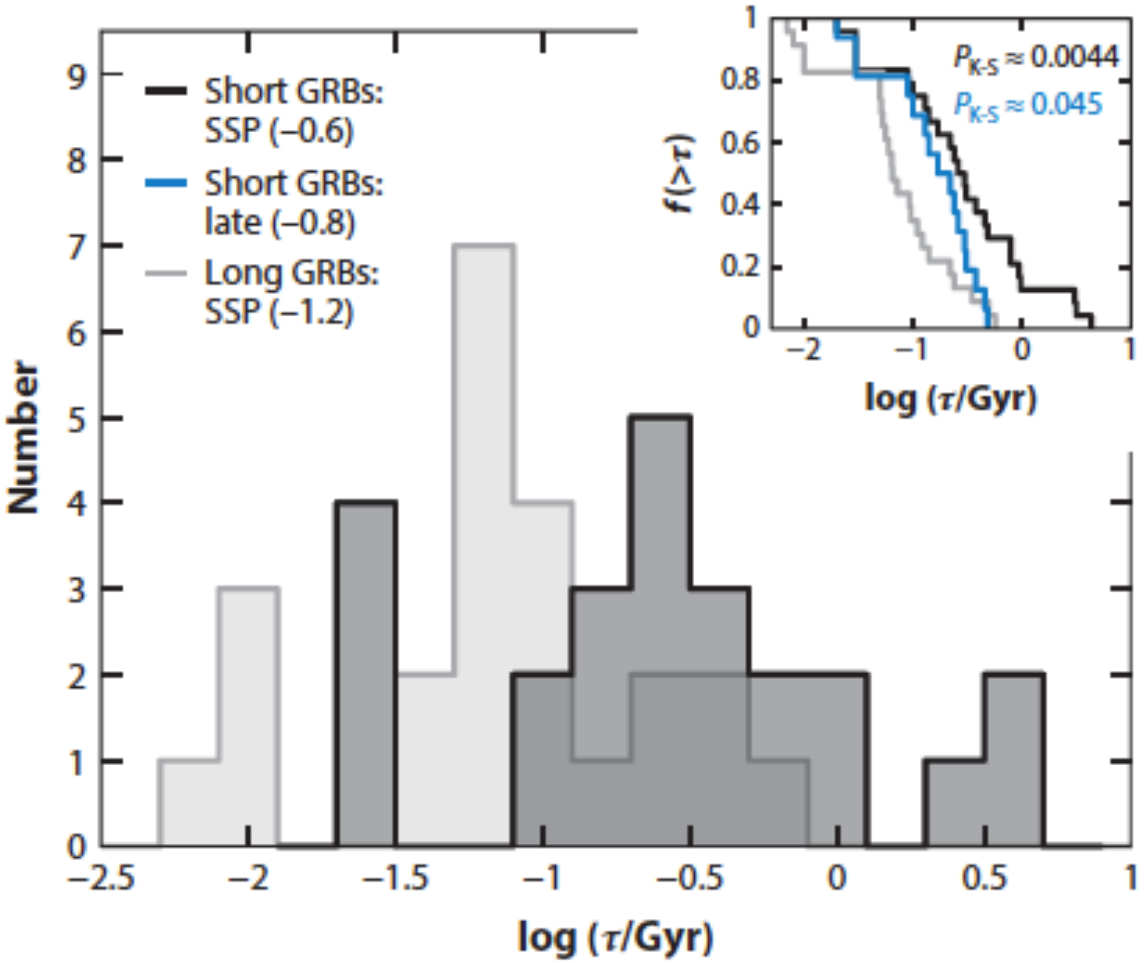
GRB 050509B



First short GRB AG associated with an elliptical galaxy

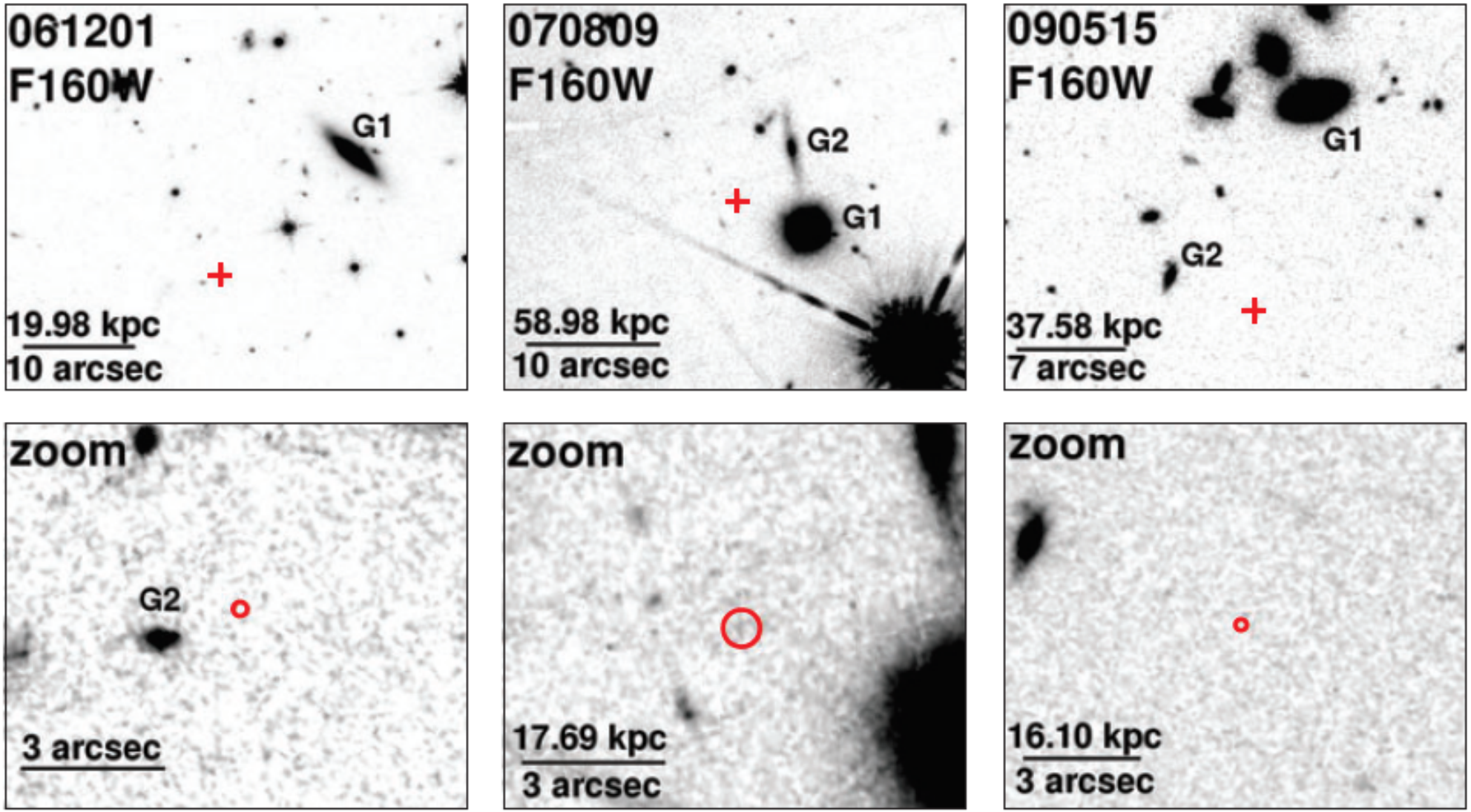
Gehrels et al (2005) Nature 437 851

sGRBs are in old populations



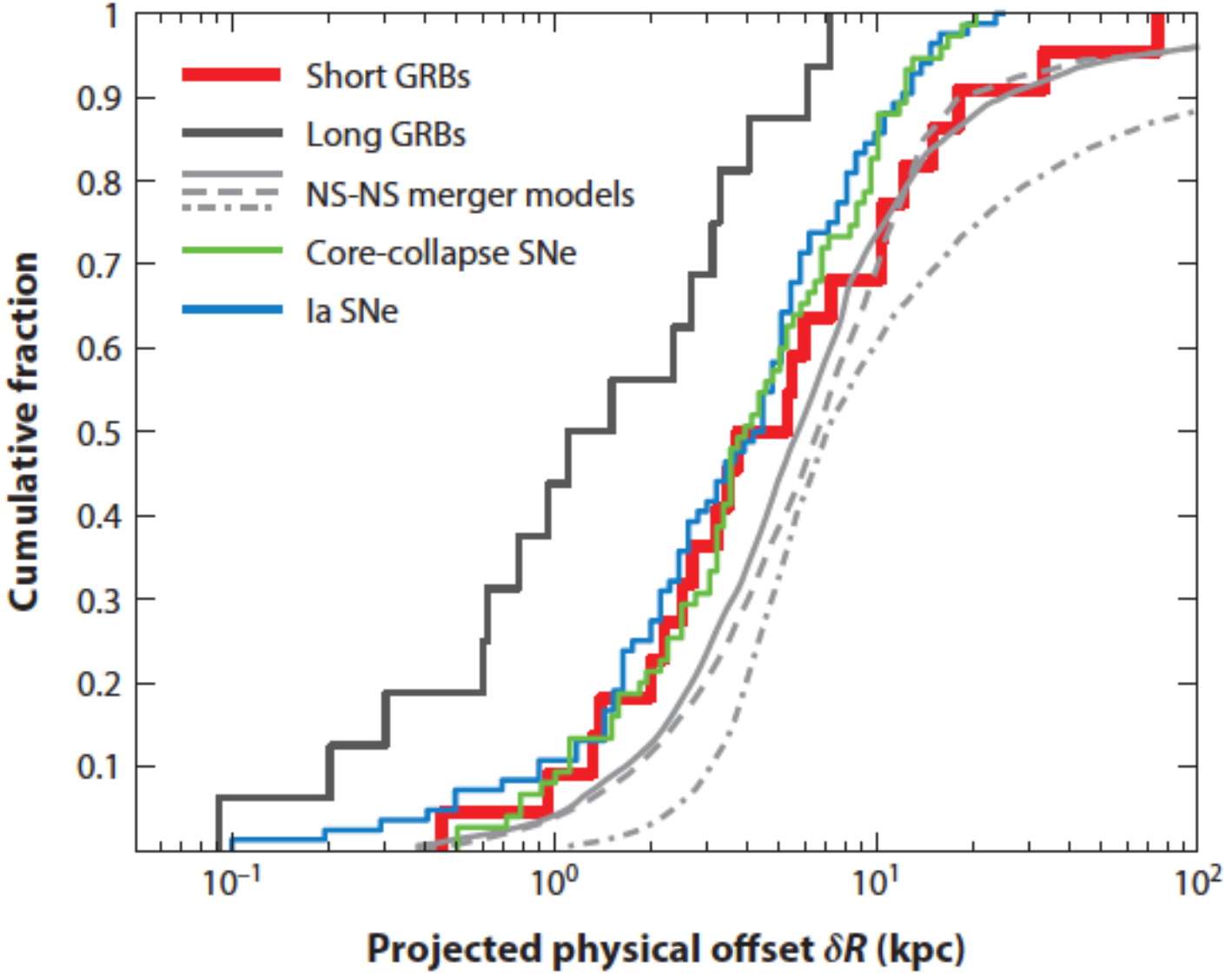
Berger (2014) ARA&A 52 43

sGRBs have been kicked out



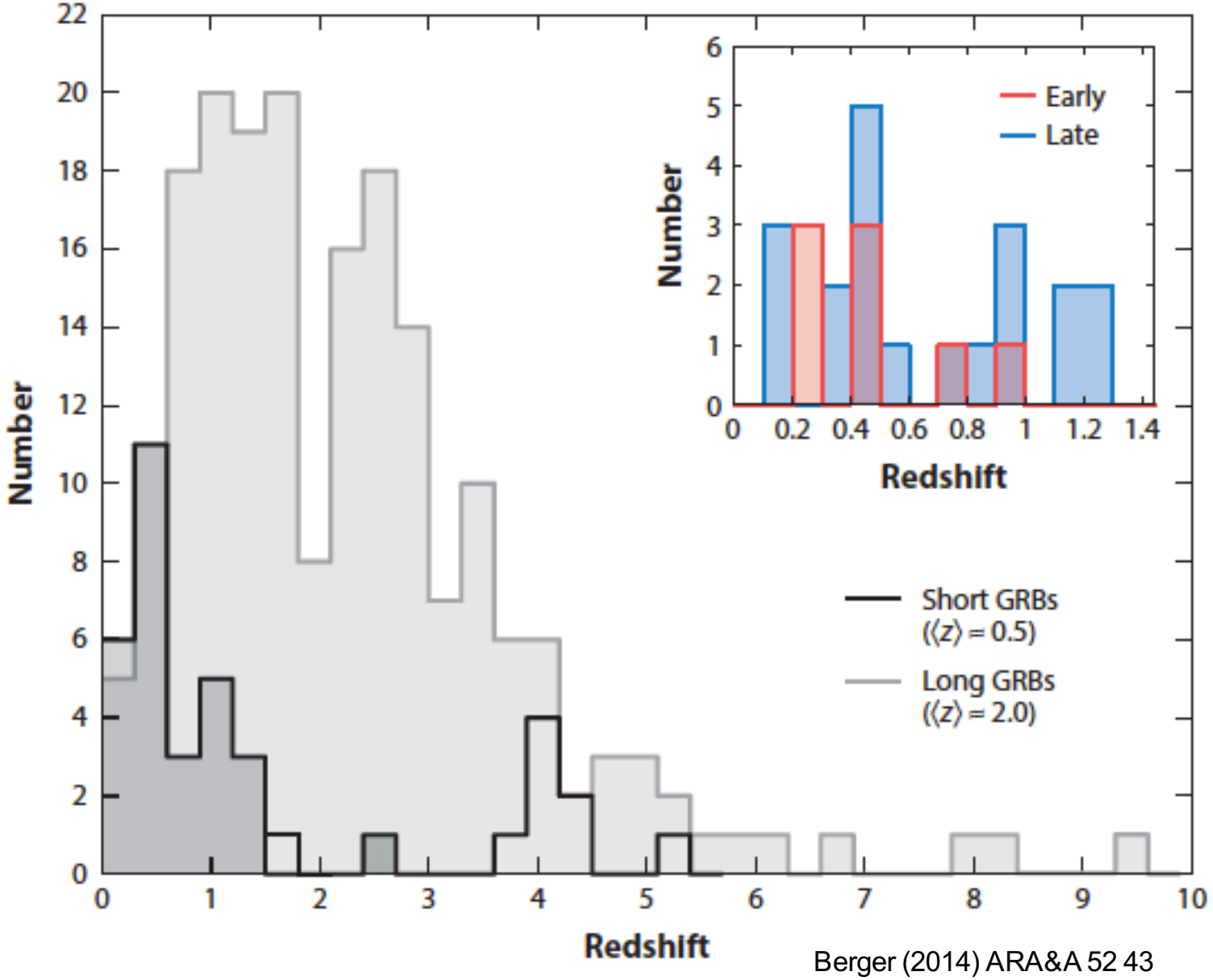
Berger (2014) ARA&A 52 43

sGRBs have been kicked out



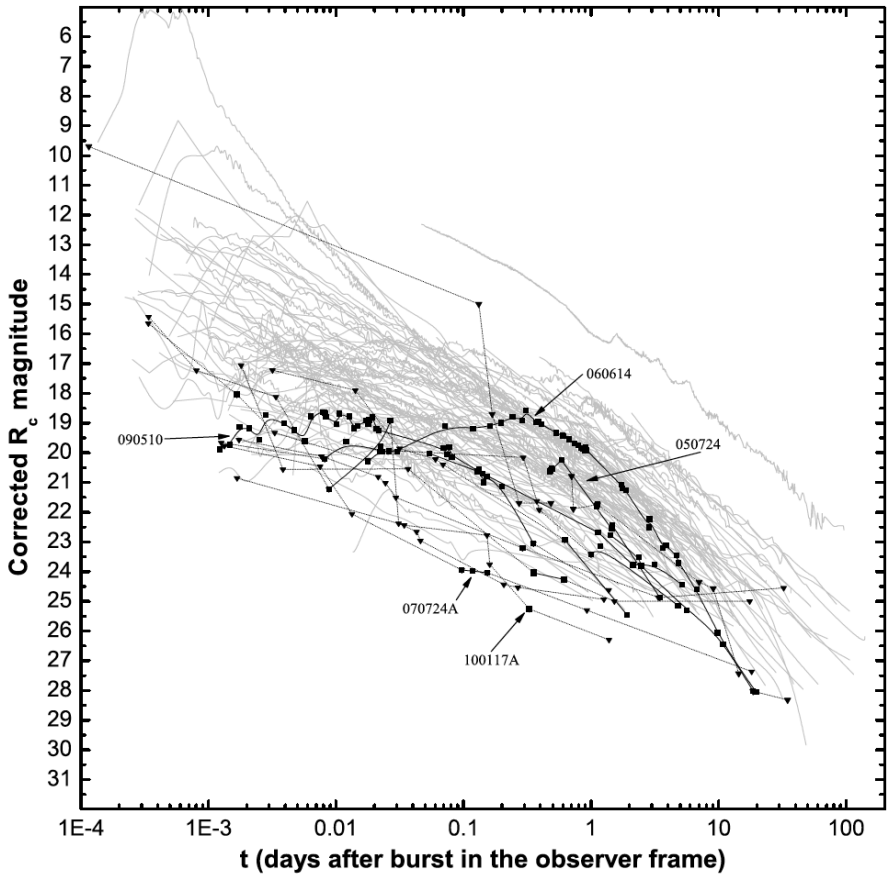
Berger (2014) ARA&A 52 43

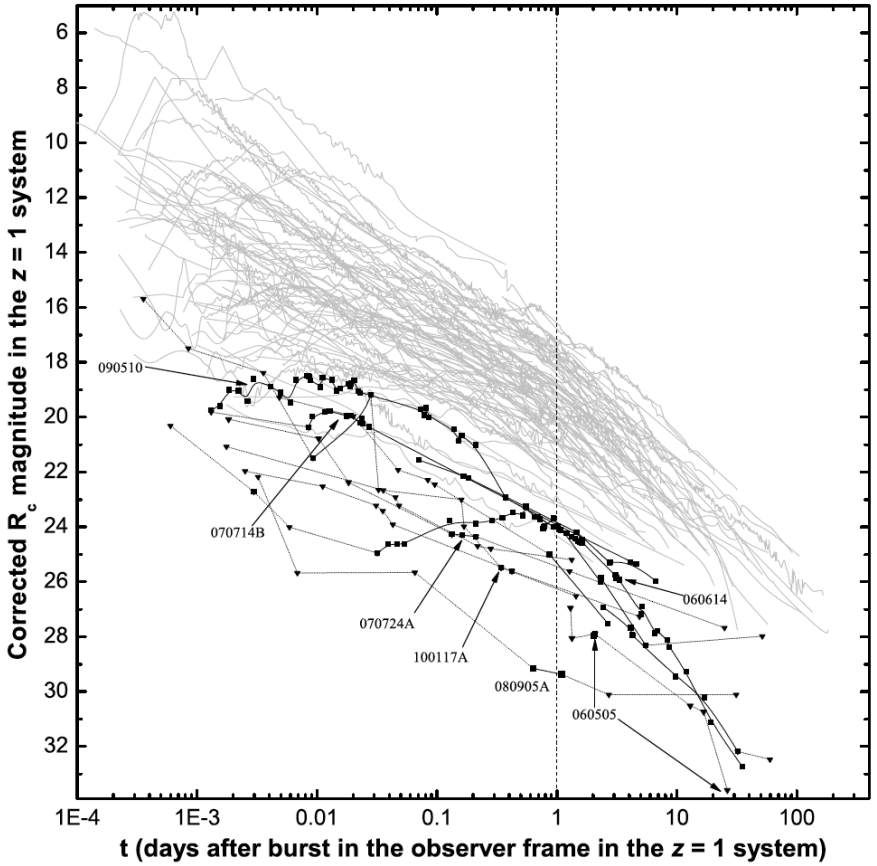
sGRB are nearer than lGRBs



Berger (2014) ARA&A 52 43

merger AGs vs collapsar AGs

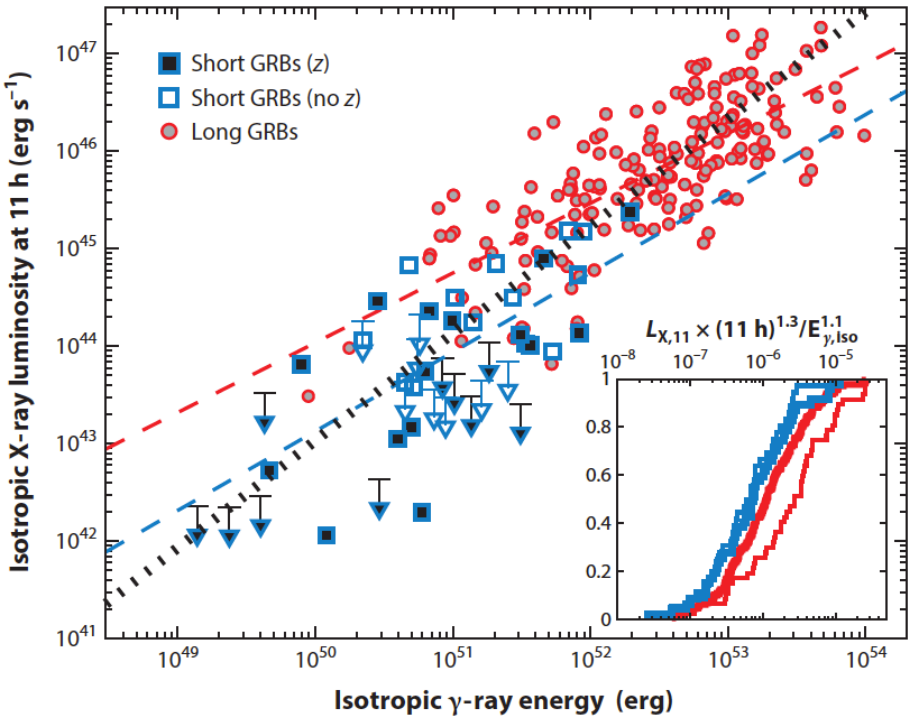


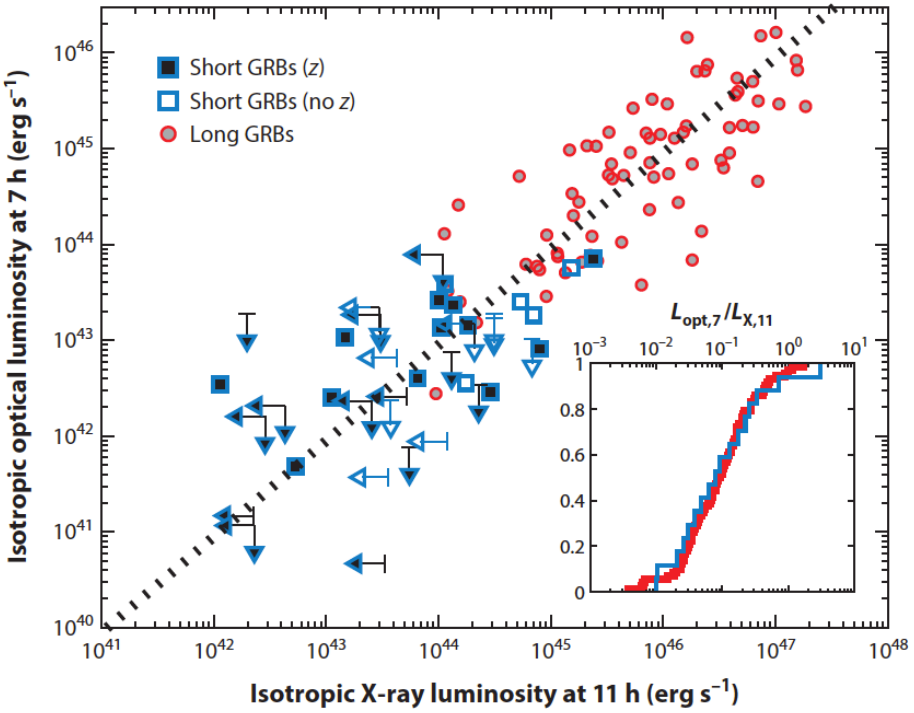


The best sample: others are fainter

Kann et al. (2011) ApJ 734 96

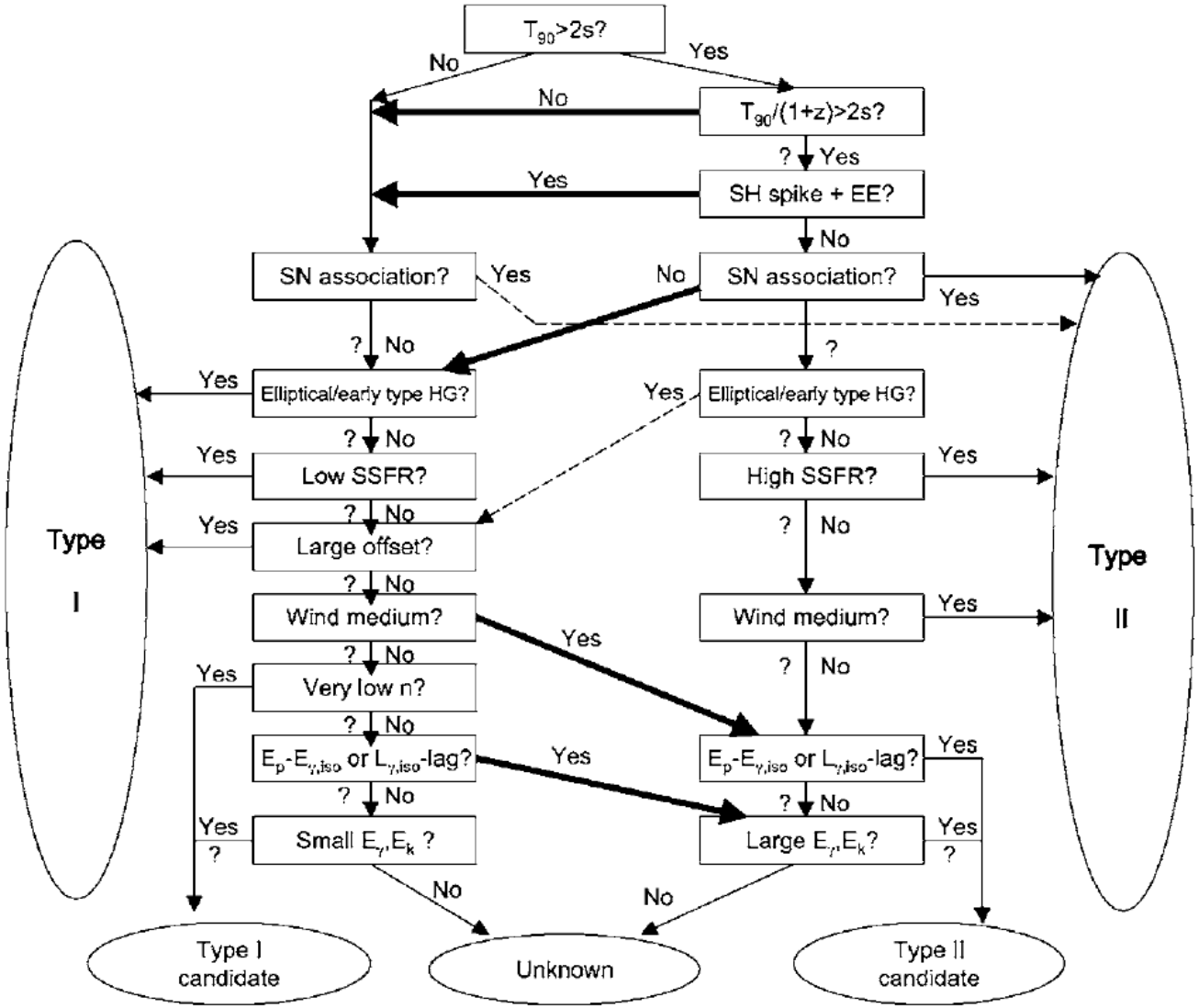
Short GRBs are fainter





Berger (2014) ARA&A 52 43

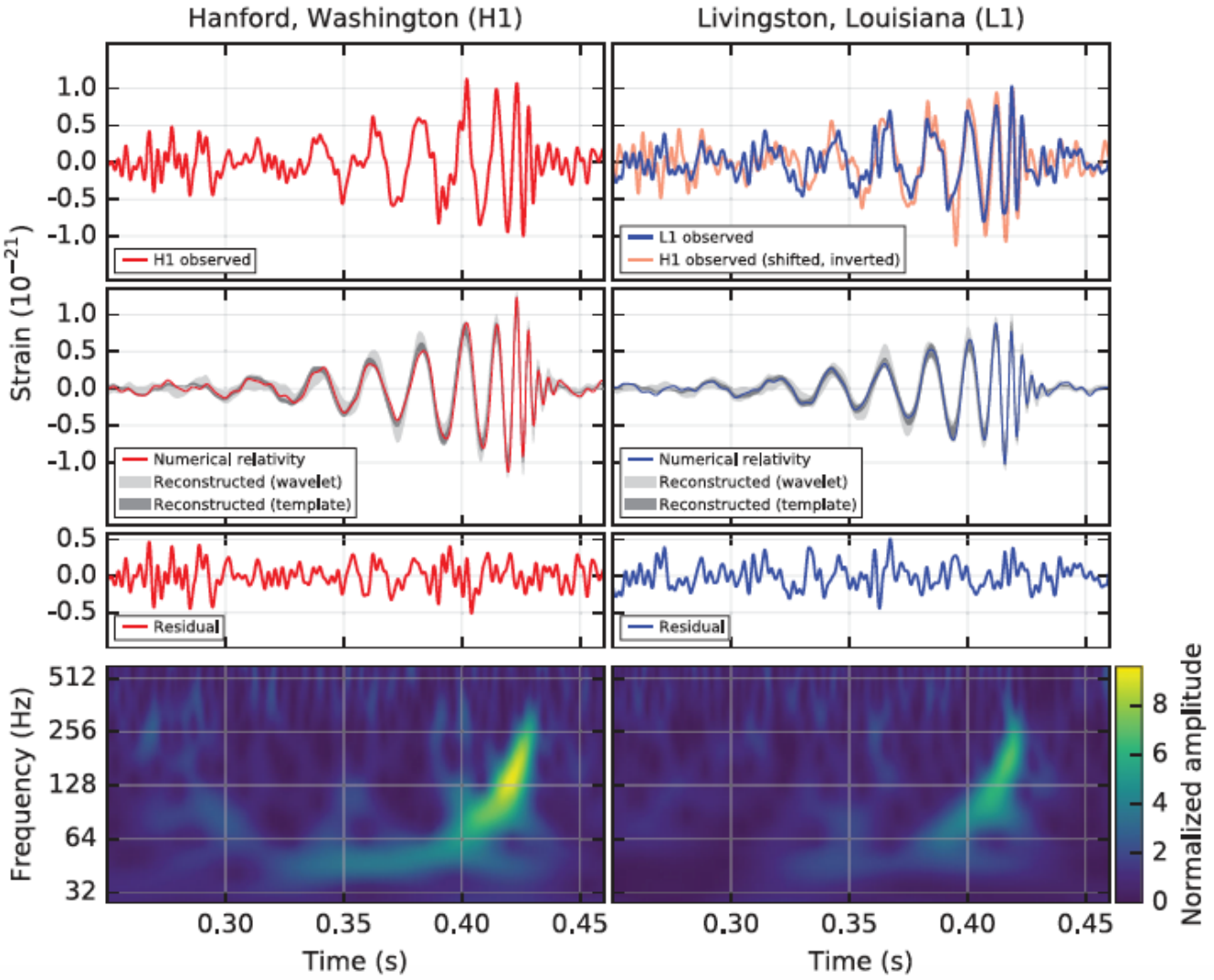
Classifying GRBs



Zhang et al. (2009) ApJ 703 1696

GW150914

ALIGO: 1st gravitational wave detection!



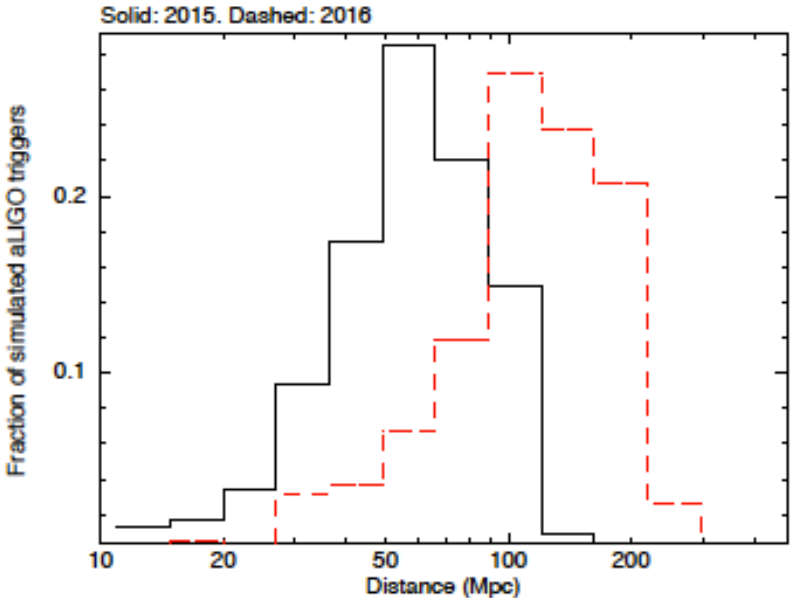
Abbott+16 PRL

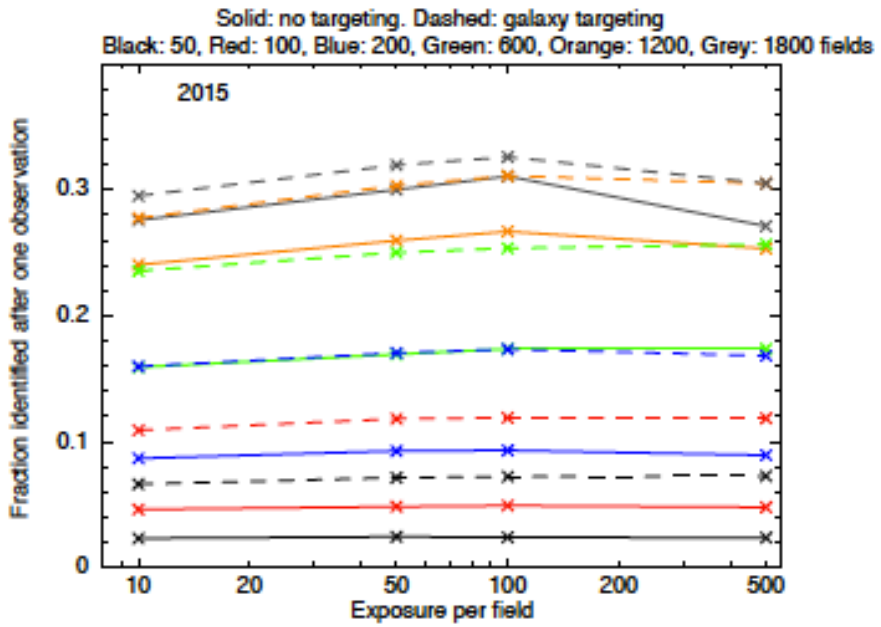
GW150914

- GW event @ 14 Sept 09:50
- Alert @ 16 Sept 06:39
  - Initial FAR 1 in 2.7 yrs, then 1 in 400 yrs, finally 1 in 203,000 yrs
  - Initially 750 sq degrees, finally 600 sq degrees (90% confidence)
- Alert occurred in an engineering run
  - before ALIGO alert system and Swift automated response were ready
- Swift obsns @ 16 Sept 15:19 to 17 Sept 20:12
  - 5 top probability fields @ 1ksec each + LMC

GW150914

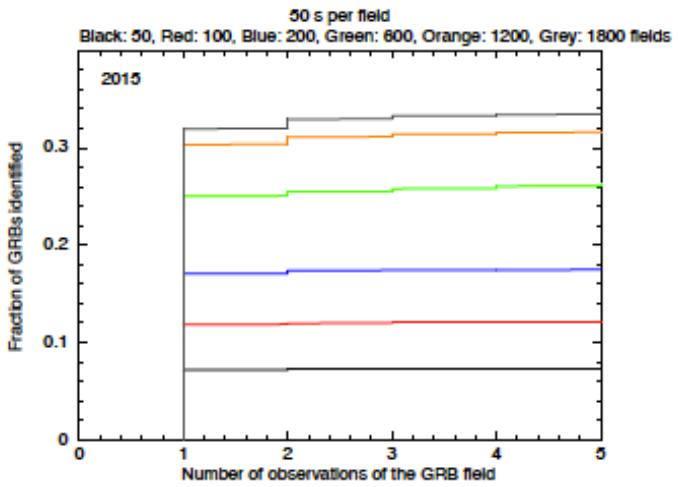
- Swift ALIGO follow-up plan described by Evans+16 MNRAS & Gehrels+16 ApJ
- ALIGO O1 run sensitivity limits NS+NS distance to ~100 Mpc
- Use product of ALIGO probability map and GGWC local galaxy catalogue (White+11 CQG) to cut down area to be observed
  - Add 100kpc halo to each galaxy
  - Weight galaxies by luminosity



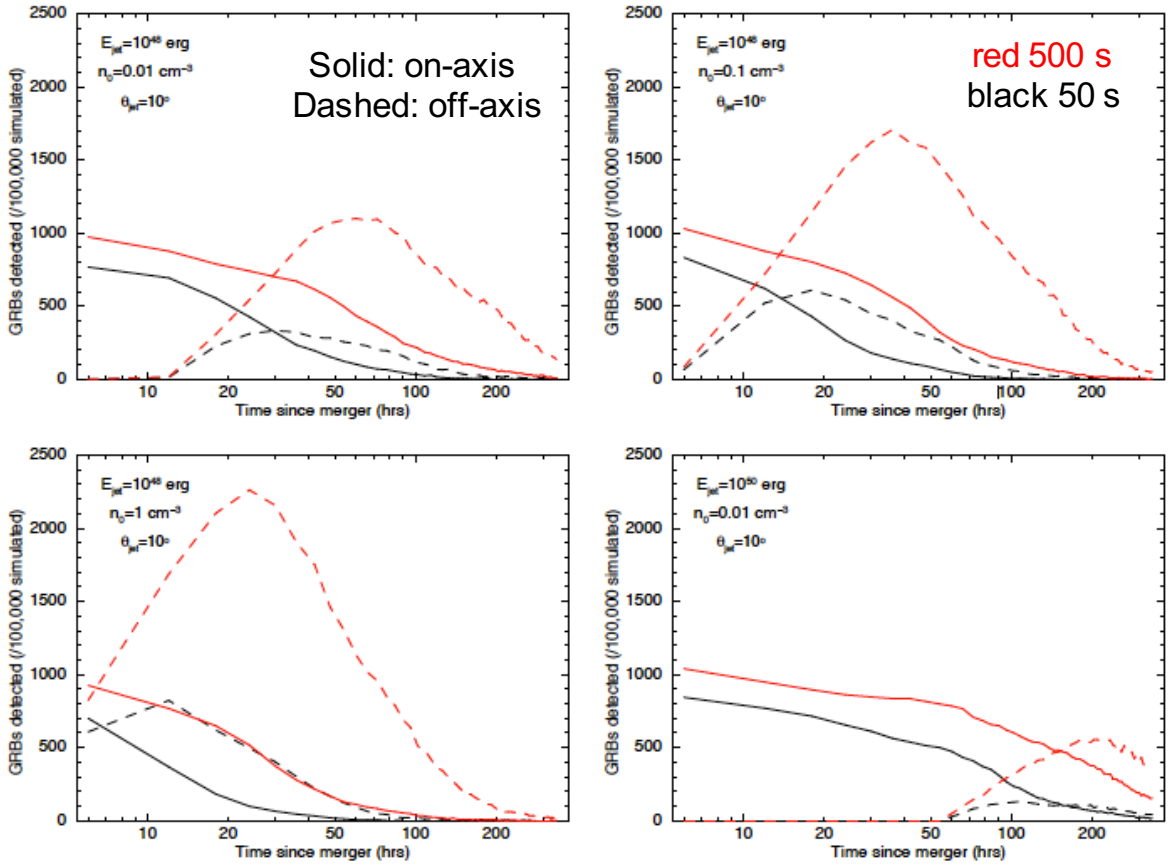


Evans+16 MNRAS

GW150914



Assume sGRBs are as the observed population

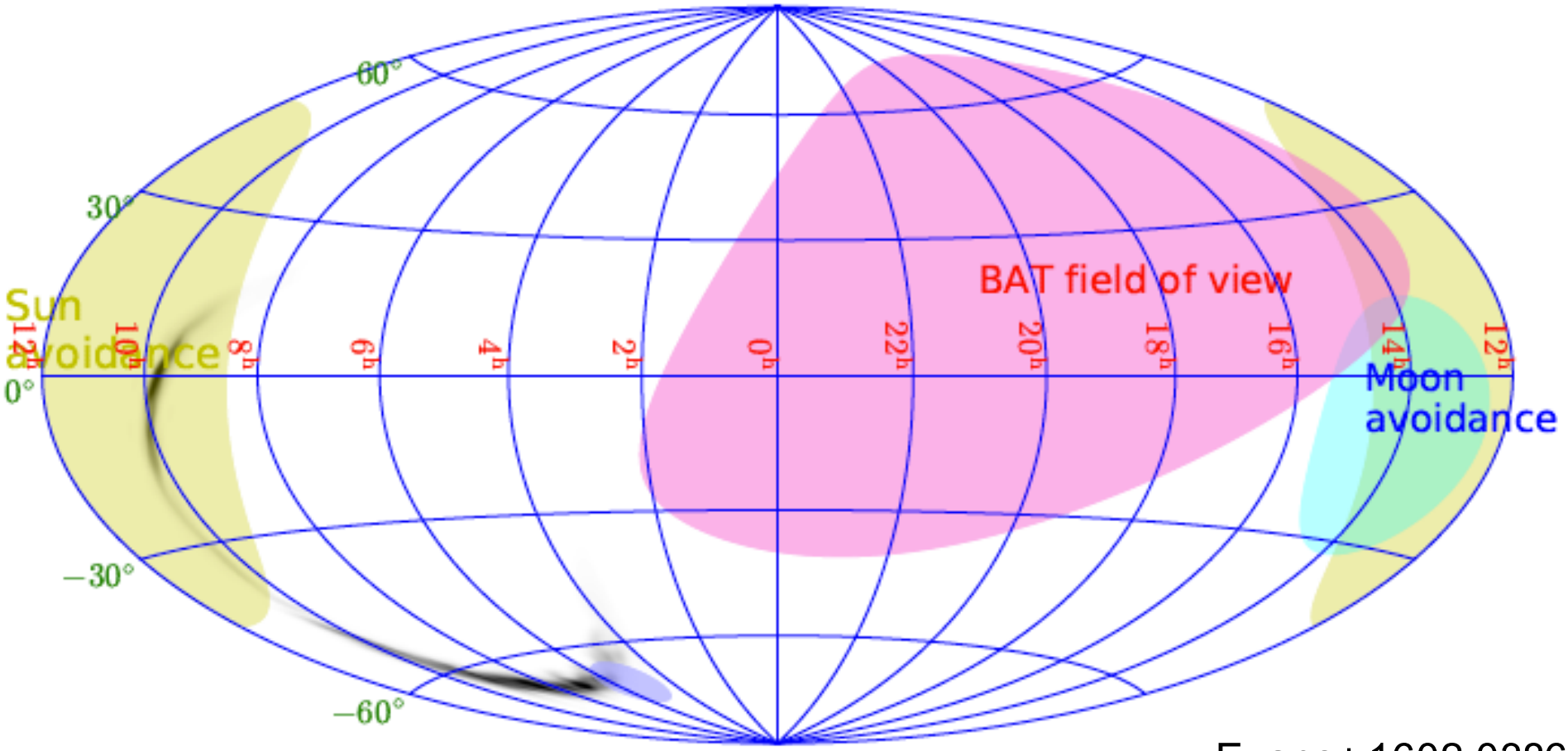


Plan calls for 2 days of single 50 sec exposure/field ASAP to look for on-axis emission, then 4 days of 500 sec exposure/field to look for off-axis emission

Evans+16 MNRAS

GW150914

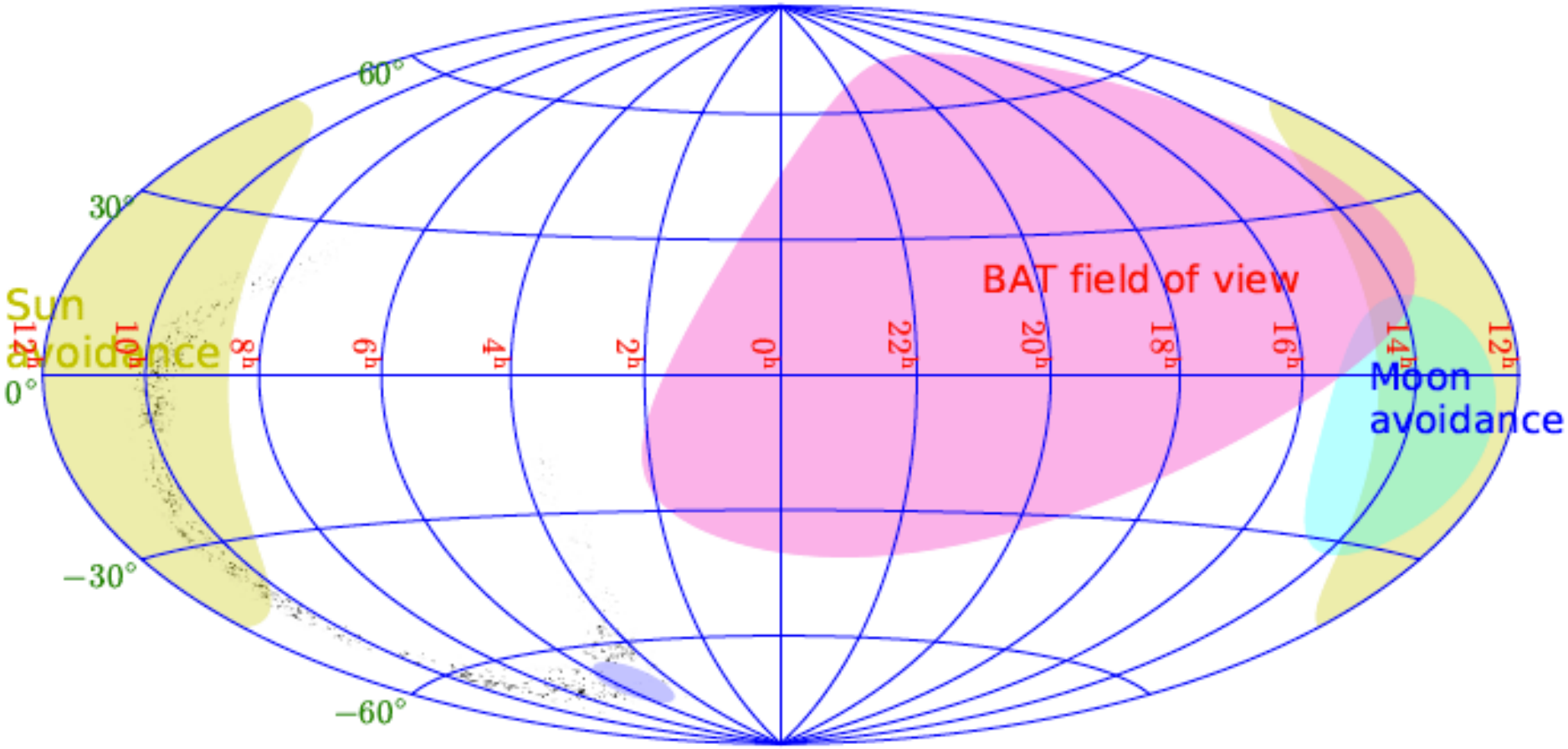
Swift constraints and BAT FOV



Evans+ 1602.03868

GW150914

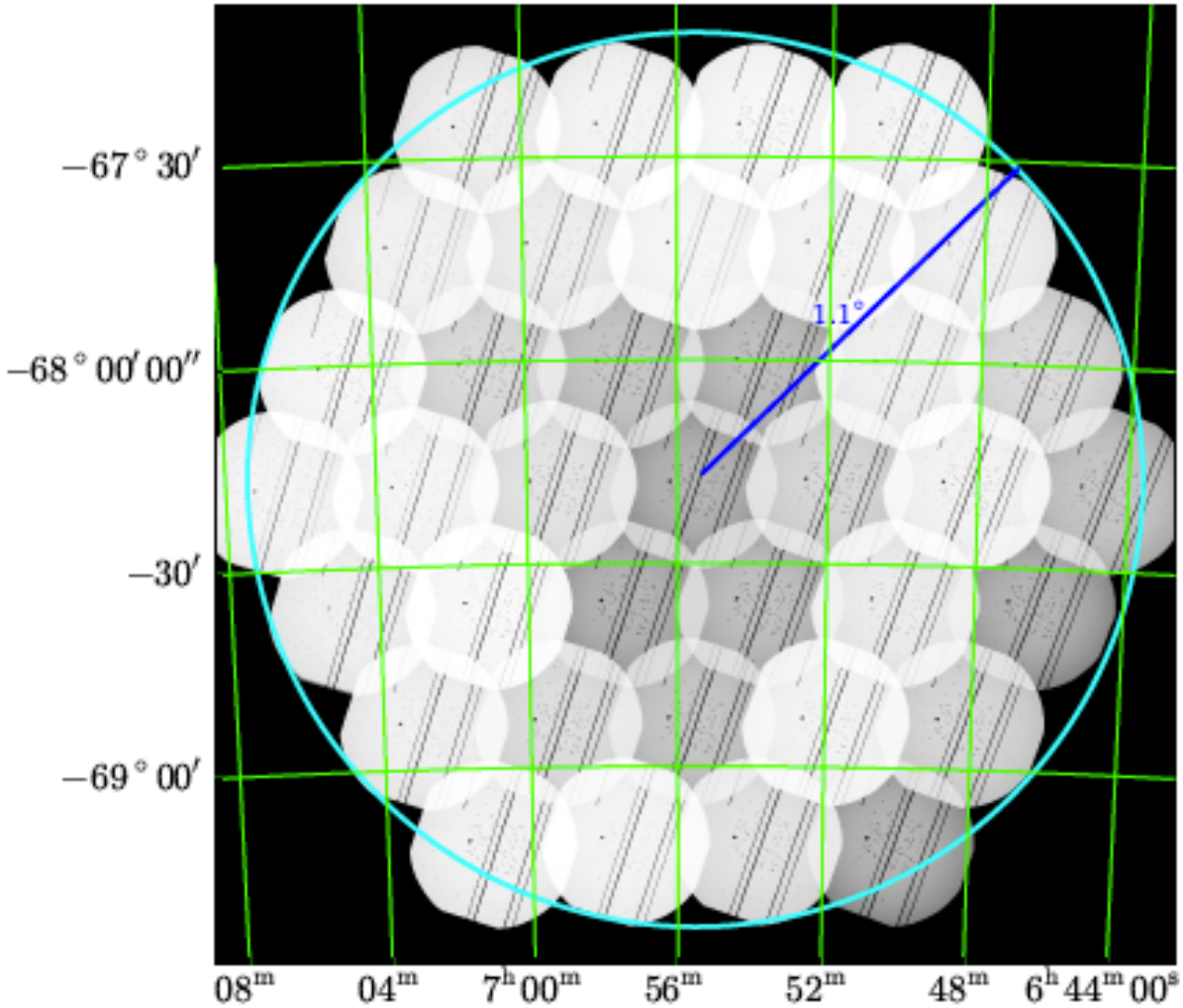
GWGC galaxies



Evans+ 1602.03868

GW150914

XRT LMC mosaic; 37 pointings @ 20-77 sec



Evans+ 1602.03868

GW150914

XRT sources detected all had flux consistent with catalogued values – discounted as possible GW counterpart

Table 2. Sources detected by *Swift* follow-up of GW150914

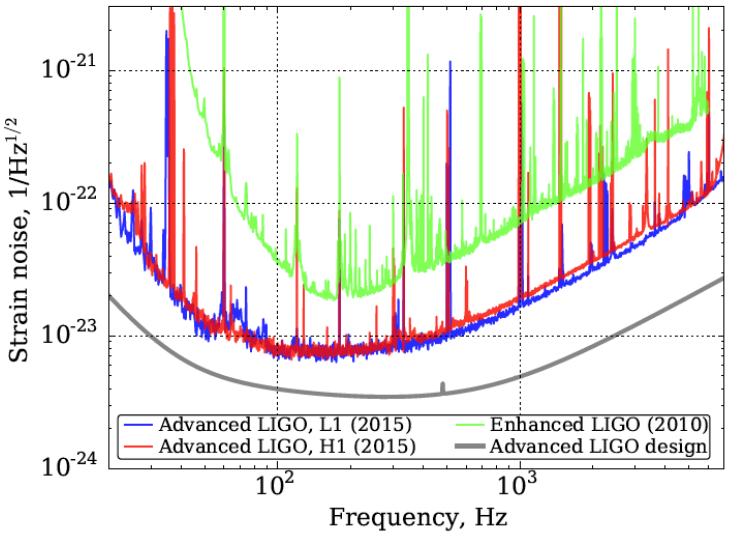
Evans+ 1602.03868

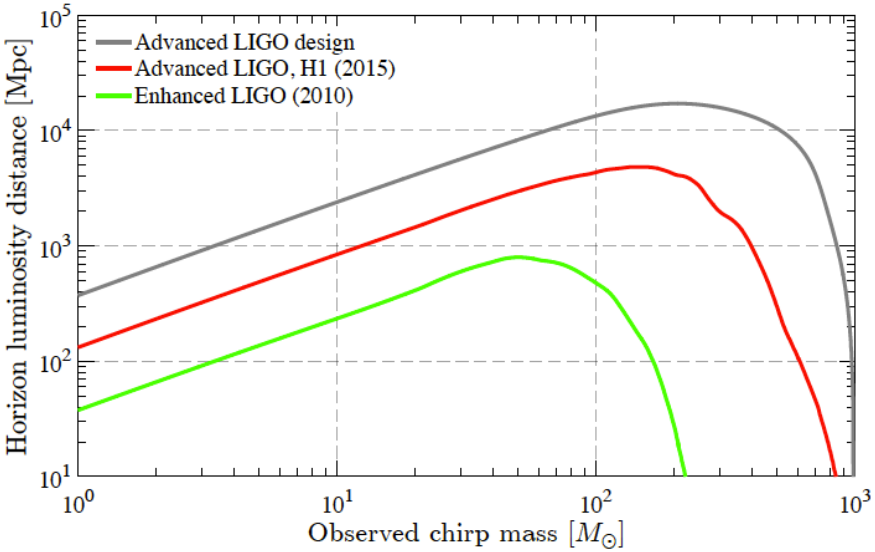
RA (J2000)	Dec (J2000)	Error 90% conf.	Flux 0.3–10 keV, erg cm^{-2} s^{-1}	Magnitude AB mag	Catalogued name
09h 14m 06.54s	-60°32′ 07.7″	4.8″	$(1.9 \pm 0.5) \times 10^{-12}$	N/A	XMMSL1 J091406.5-603212
09h 13m 30.24s	-60°47′ 18.1″	6.1″	$(5.3 \pm 2.0) \times 10^{-13}$	15.44±0.02[a]	ESO 126-2 = 1RXS J091330.1-604707
08h 17m 60.62s	-67°44′ 03.9″	4.7″	$(8.9 \pm 2.4) \times 10^{-13}$	17.53±0.05	1RXS J081731.6-674414

XRT observations covered 4.7 sq degrees, 2% of the final GW error region (8% of GWGC x GW)

Abbott+16: GW due to 29+36 $M_\odot$ BH+BH binary @ 410 Mpc
➔ no electromagnetic signal expected (and source is beyond GWGC horizon)

aLIGO development

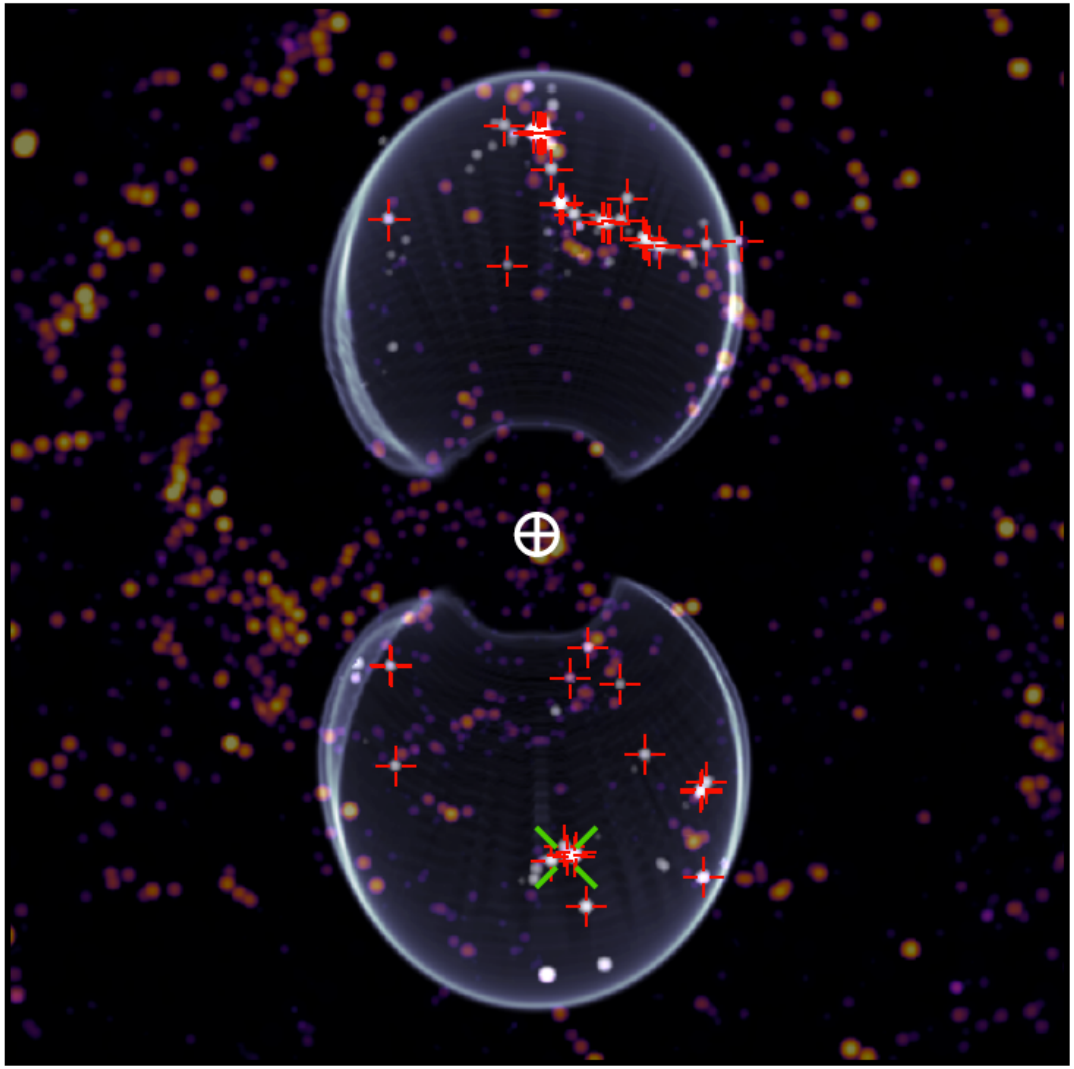


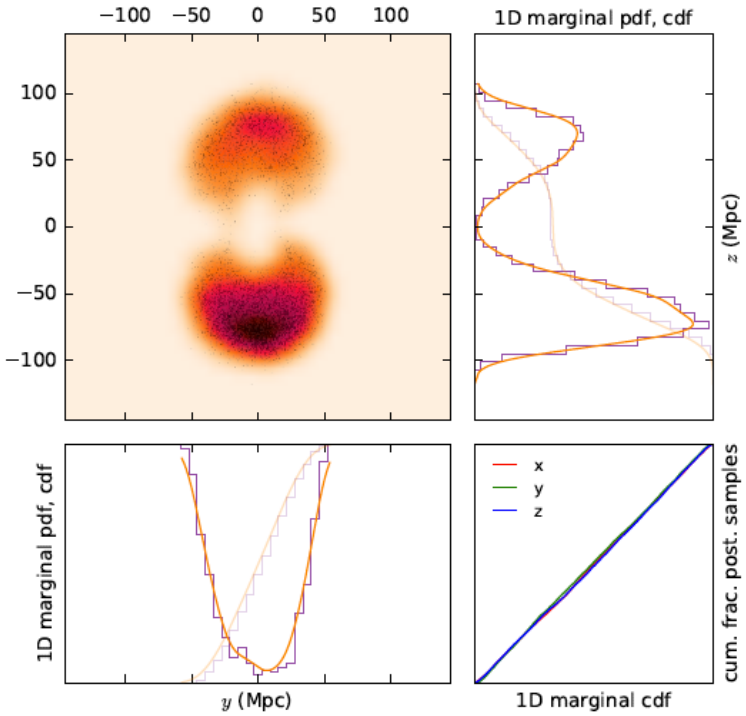


- GW sensitivity improvement is on track
- NS-NS max distance ~ 1000 Mpc
- NS-BH max distance ~ 3000 Mpc?

Martynov et al. (2016) arXiv:1604.00439

Rapid GW distance promised

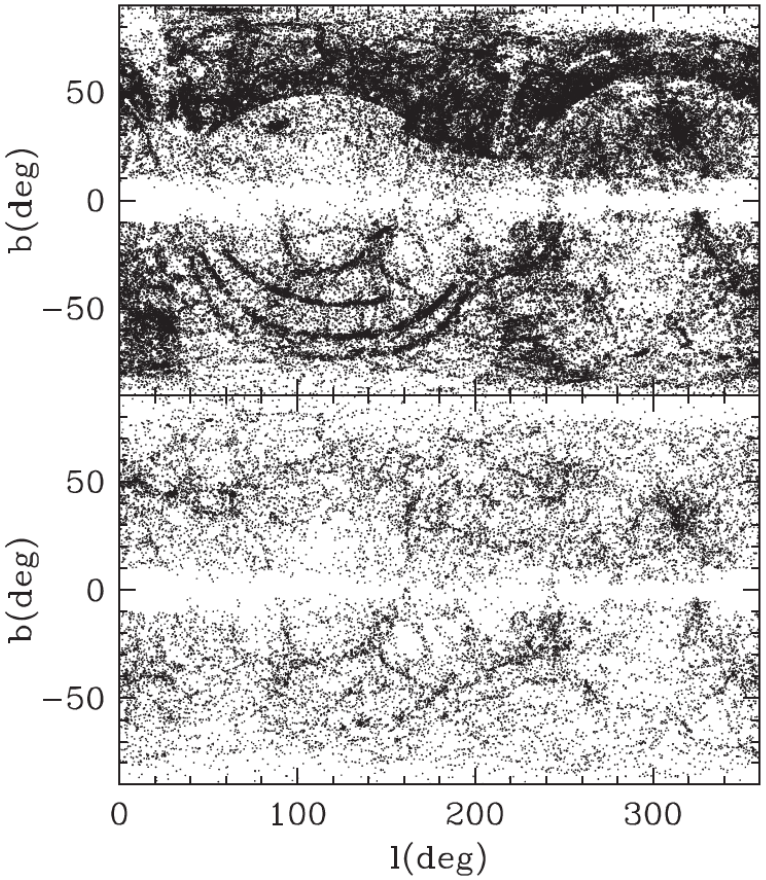




GW location probability distribution to have distance probability distribution at each pixel in ~ 1 min

Singer et al. (2016) arXiv:1603.07333

Catalogue of the local universe



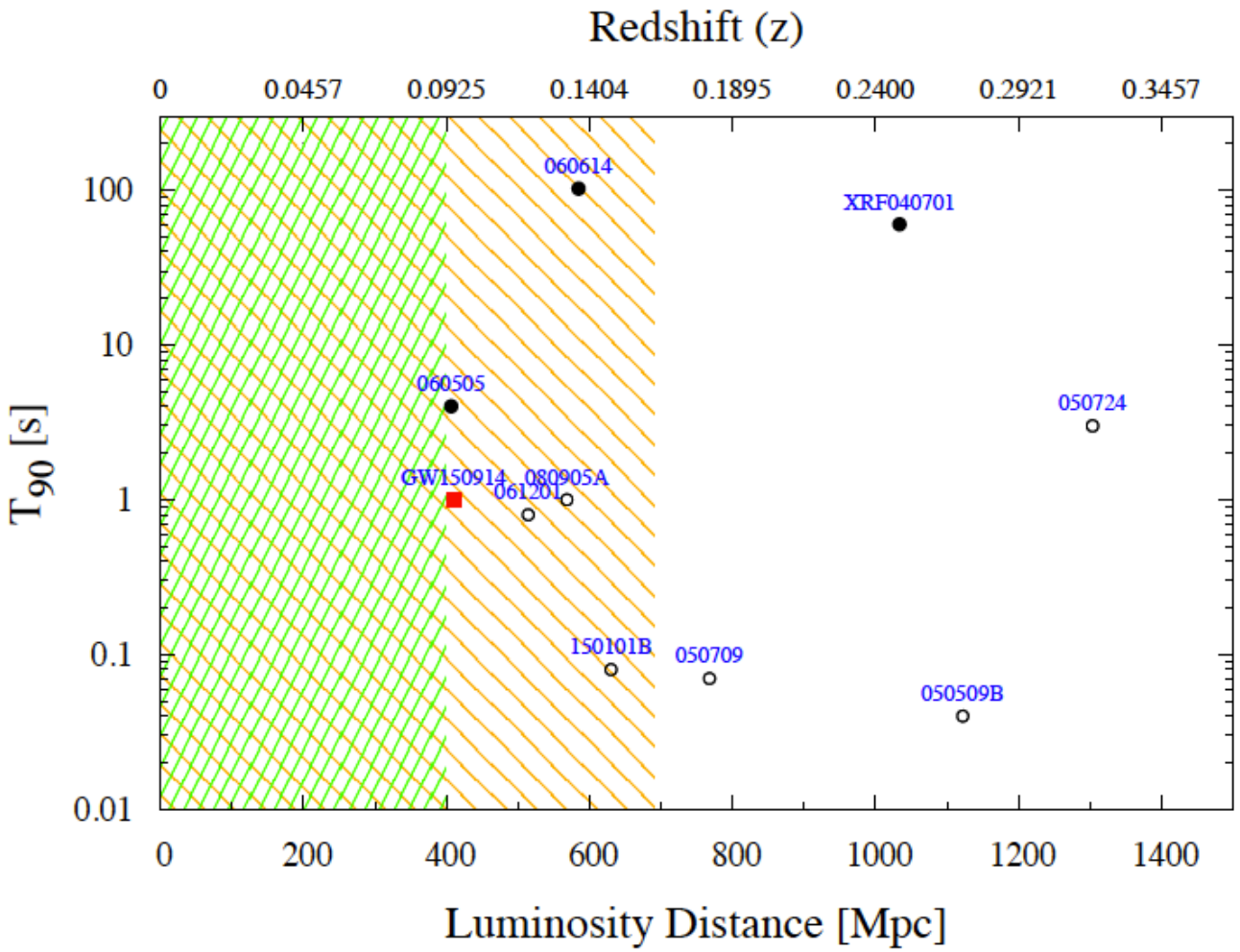
all 144k galaxies

27.5k galaxies with $L > L_B^*$

Urgent need for all-sky complete galaxy redshift catalogue to maximum aLIGO distance

Gehrels et al. (2016) ApJ 820 136

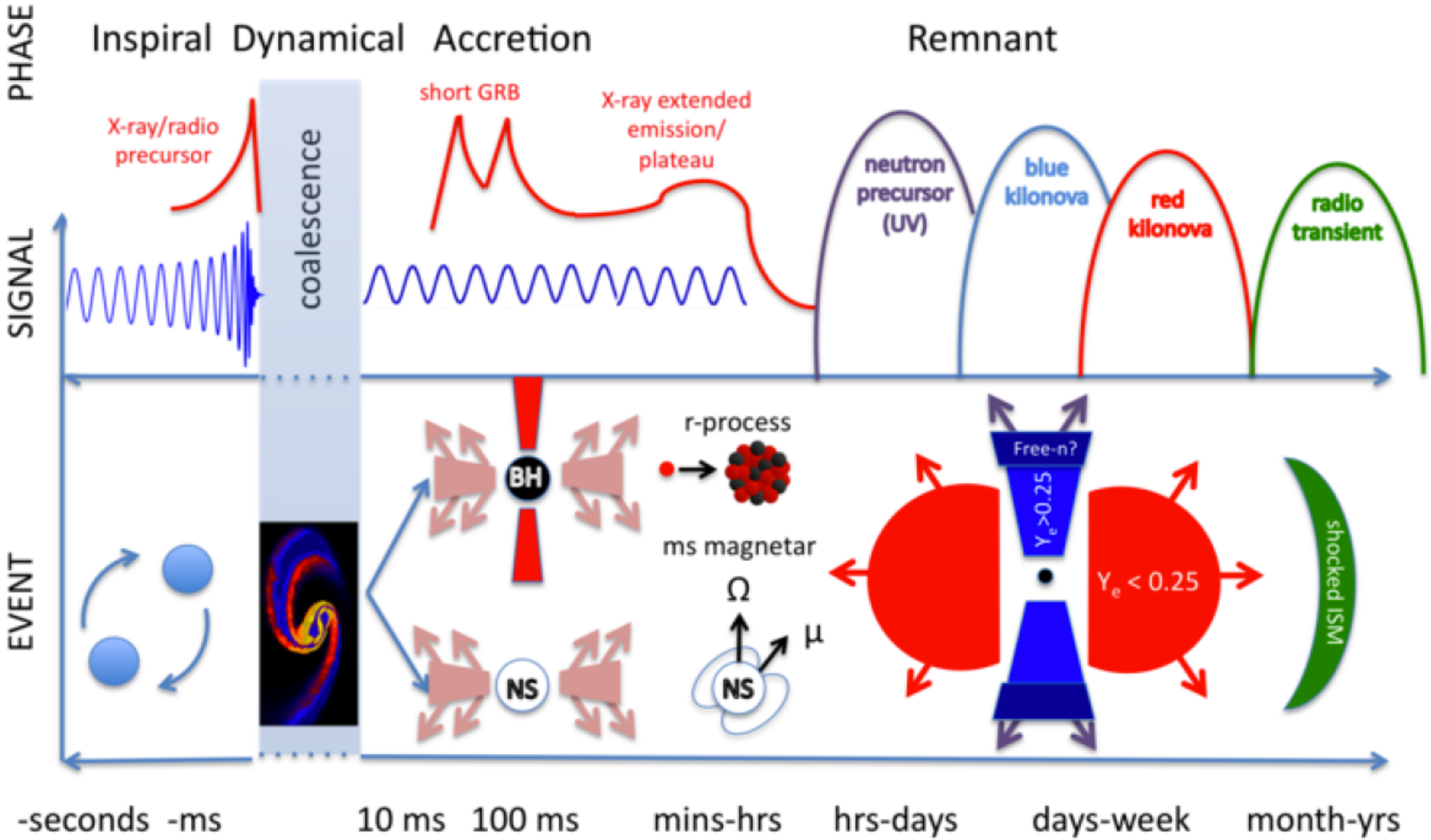
Some SN-less GRBs in range



NS-NS NS-BH

X Li et al. (2016) arXiv:1601.00180

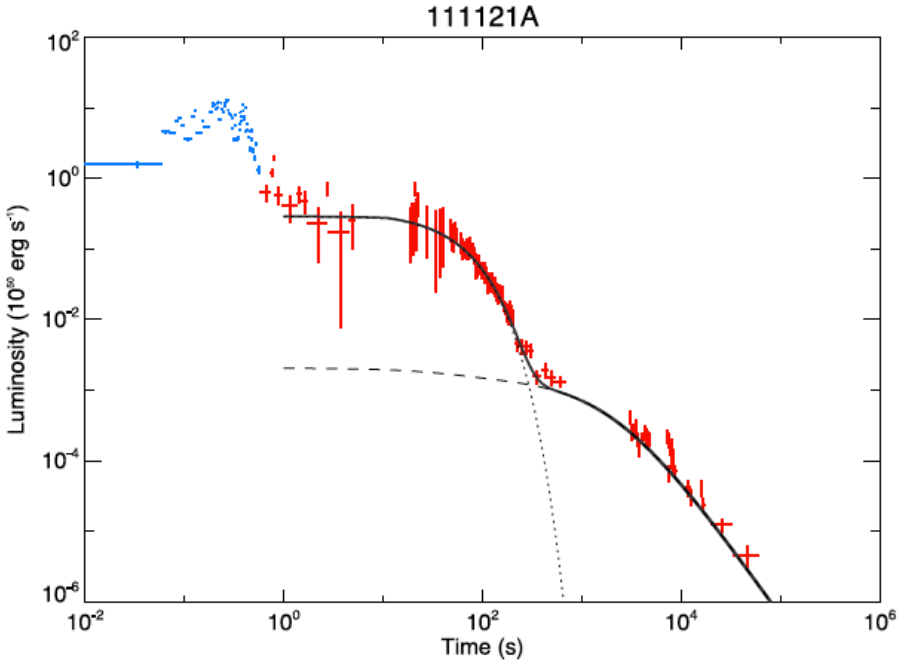
binary merger phases

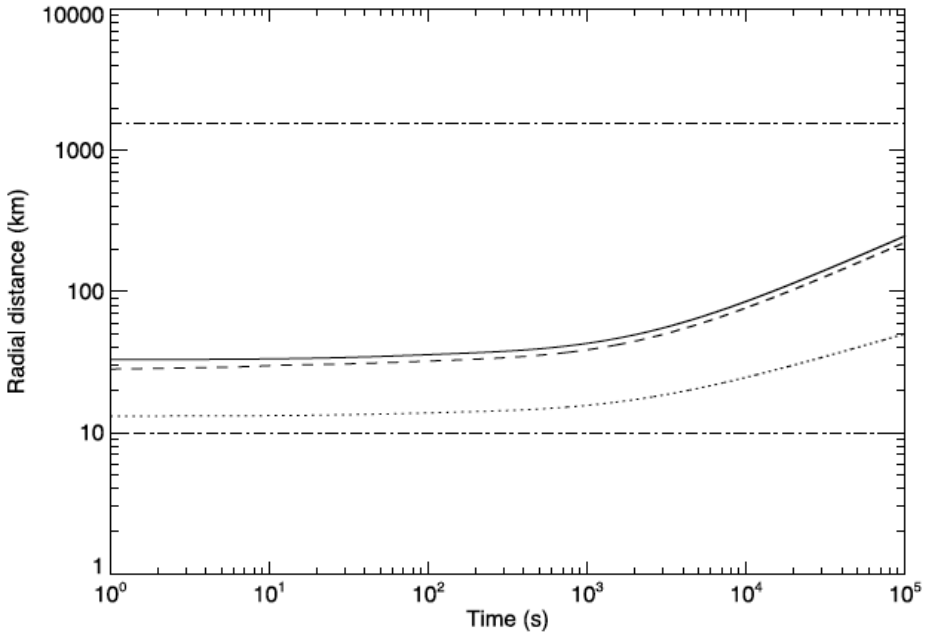


Fernández & Metzger(2016) ARNPS 66 1

Magnetar-powered sGRBs:

EE phase due to large mass ratio?



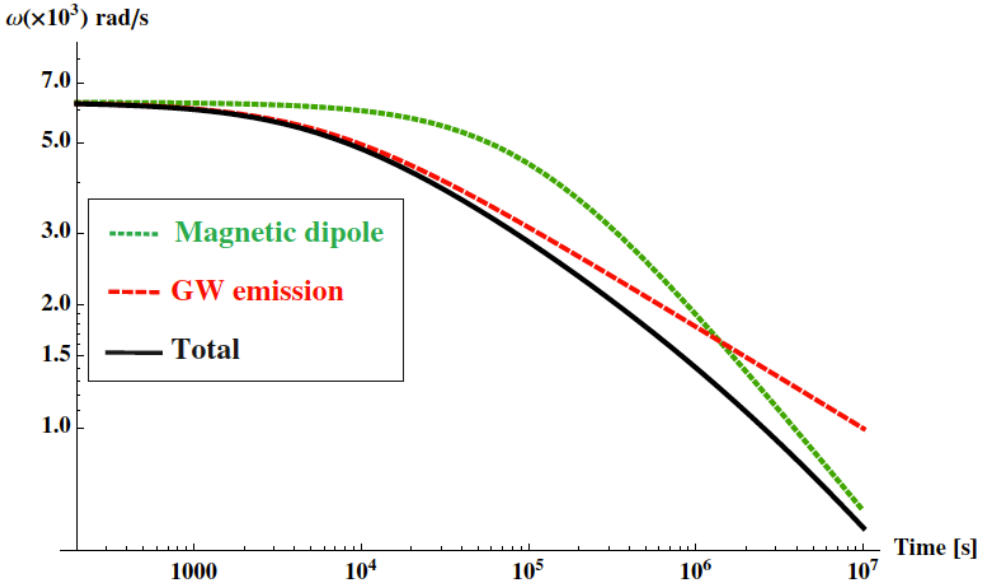


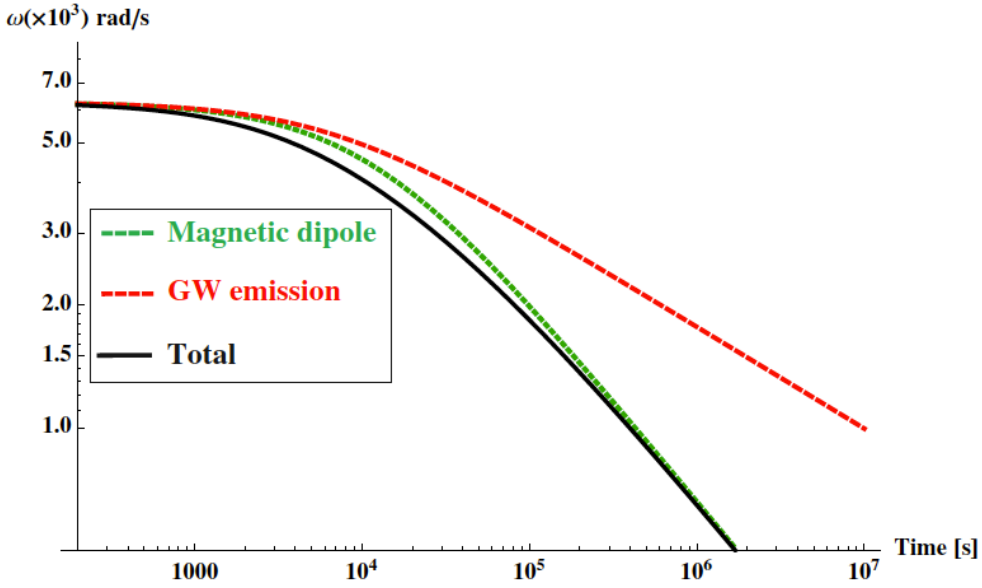
Dotted:
Propeller luminosity – EE phase
Dashed:
Dipole luminosity – plateau phase

Outer disk radius
Light cylinder radius
Alfvén radius
Co-rotation radius
Magnetar radius

Gompertz et al. (2014) MNRAS 438 240

Magnetar spin-down emission





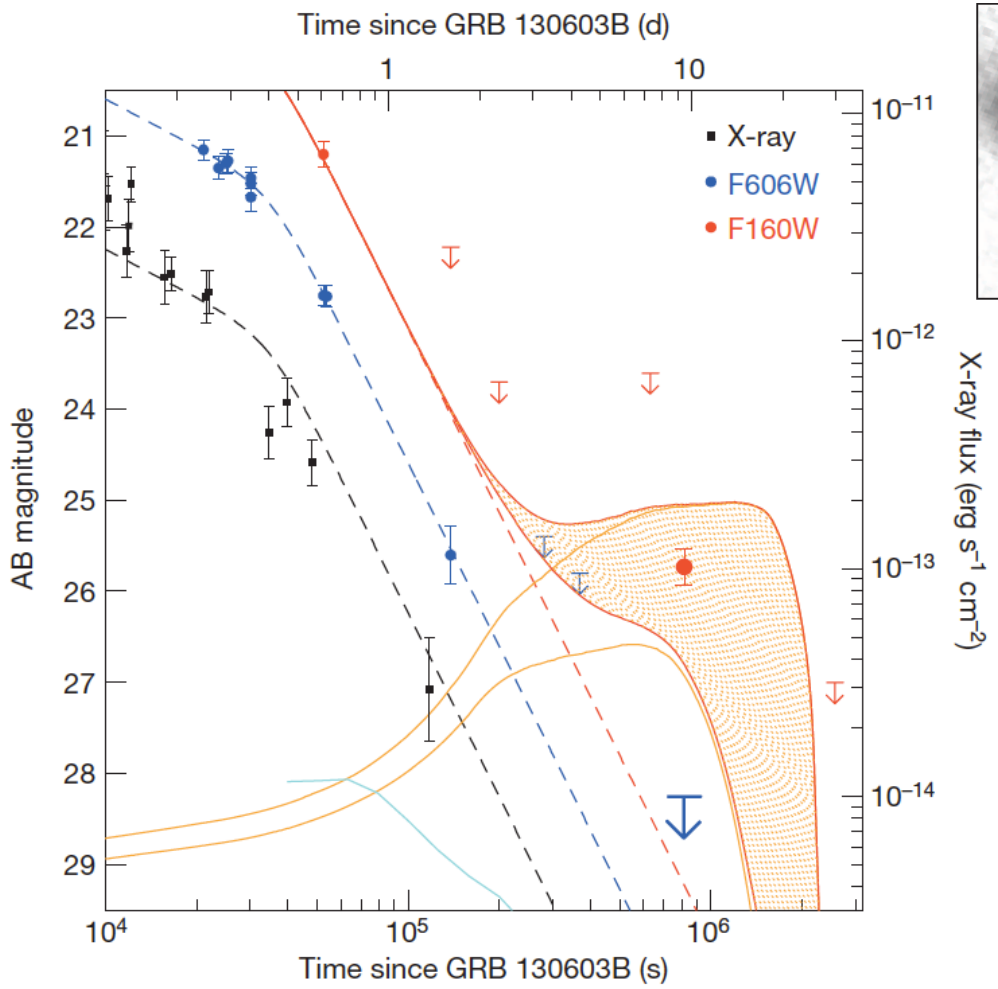
Two cases of post-merger NS spin-down:

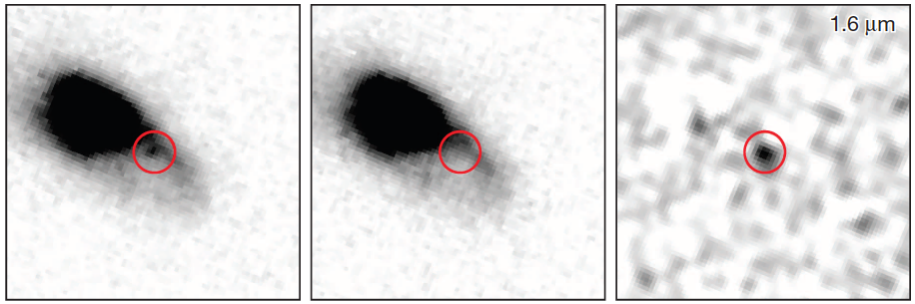
Left – GW emission initially dominates, EM emission determined by GW losses
Right – GW emission is sub-dominant, a bright dipole-powered EM source

Case depends on EOS and ratio of internal magnetic energy to external dipole field

Dall'Osso et al. (2015) ApJ 798 25

A kilonova ! (?)

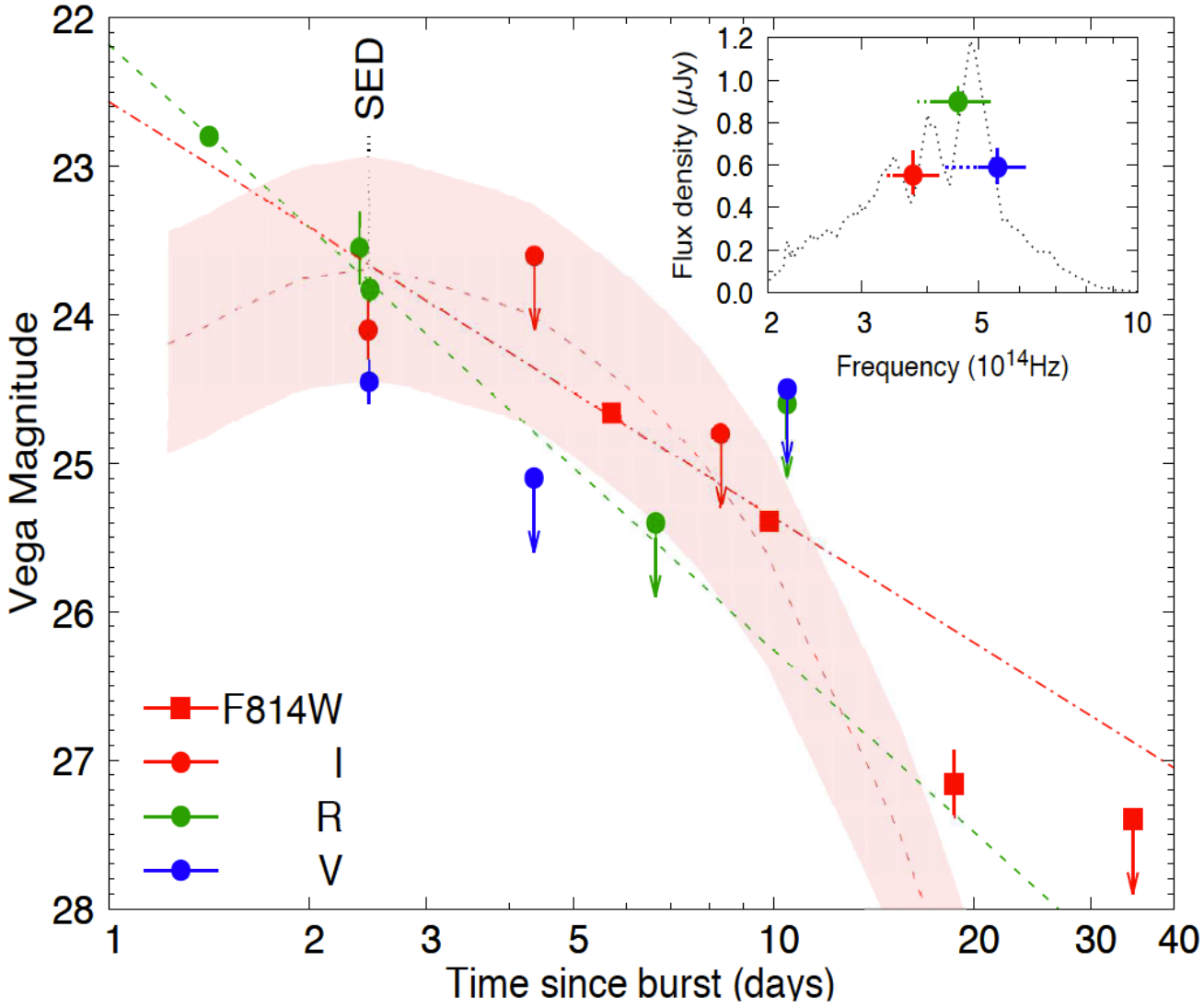




BAT T_{90} = 0.18 sec

Tanvir et al. (2013) Nature 500 547

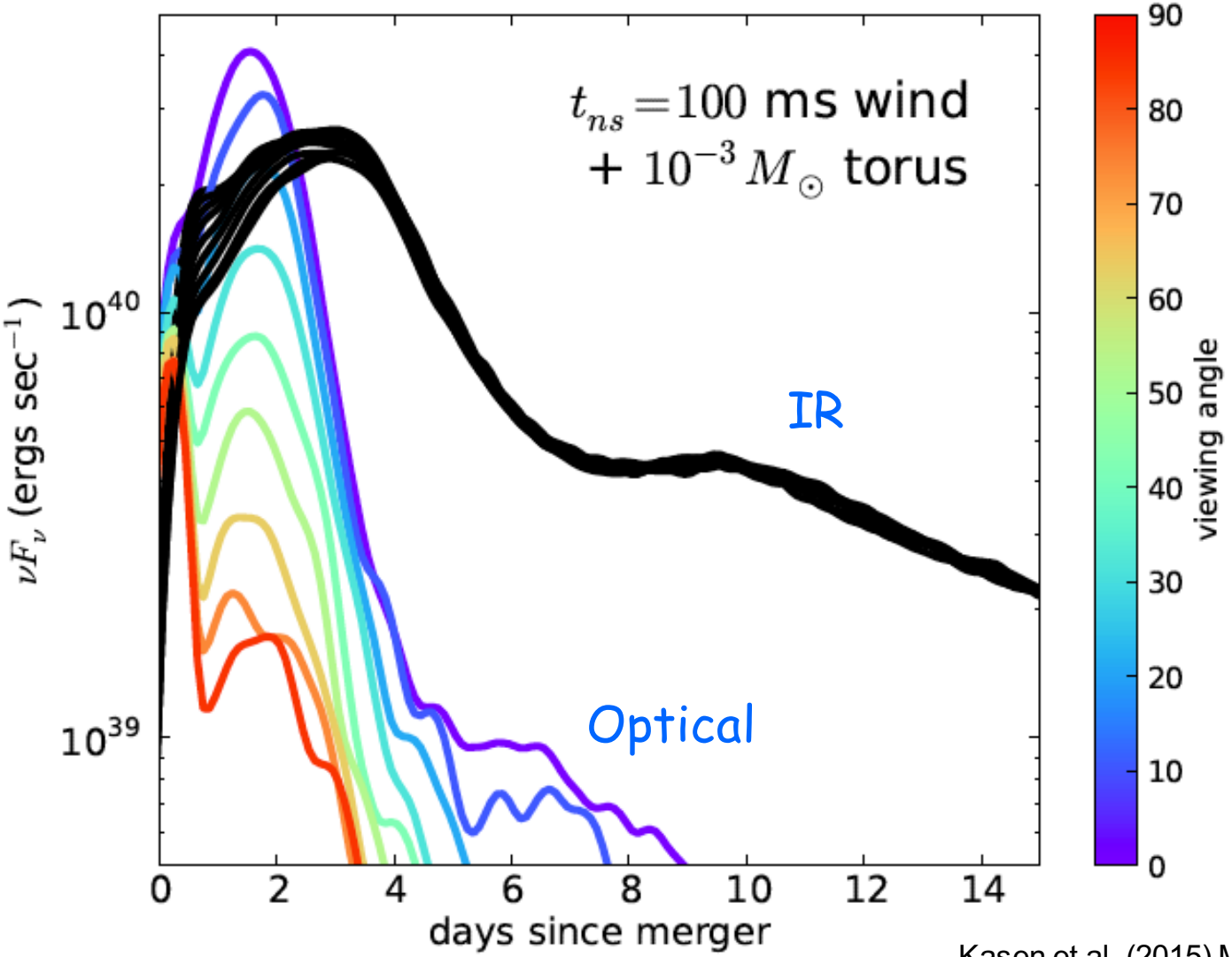
Hint of a KN in 050709??



I/F814W shows non-PL excess at ~ 5-10 d compared to R-band decline

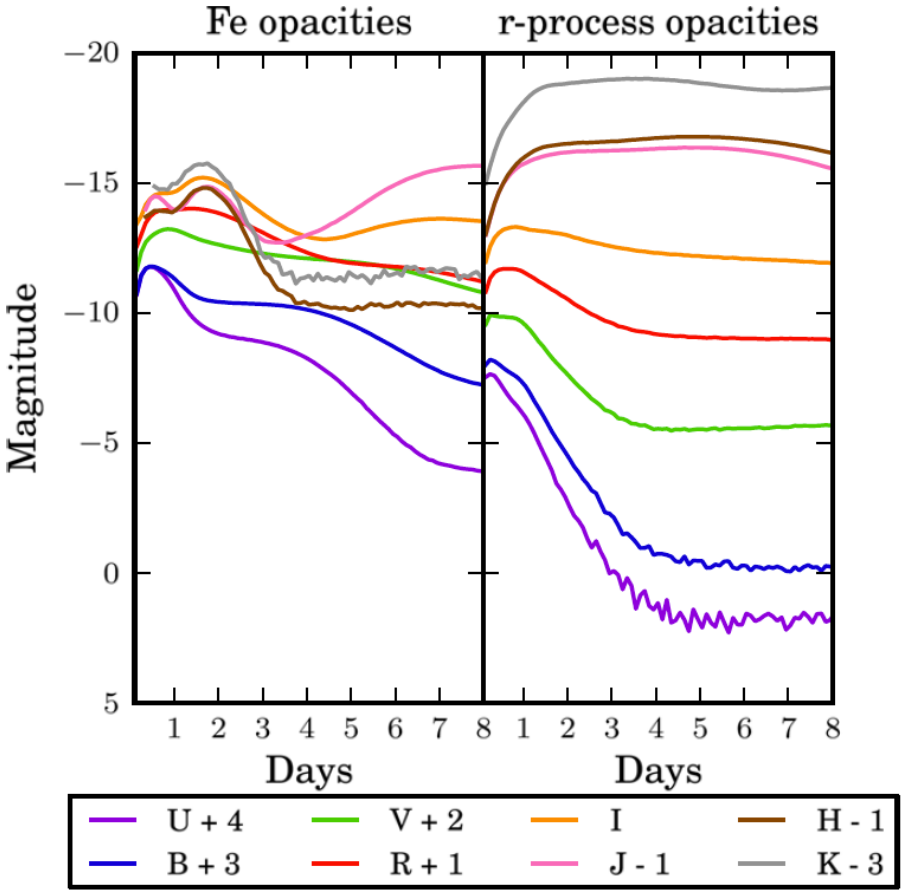
Jin et al. (2016) arXiv:1603.07869

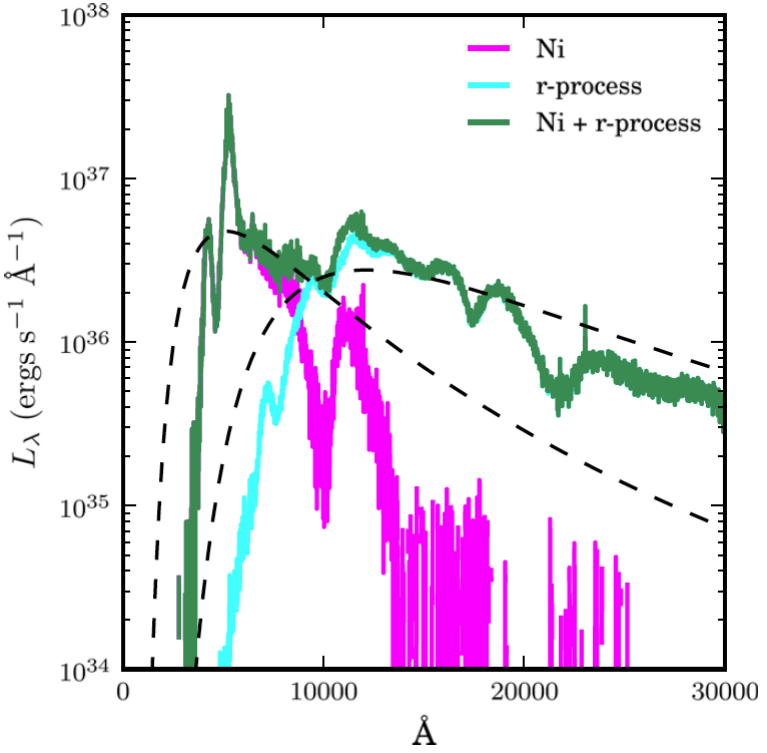
Opt & IR kilonova emission



Kasen et al. (2015) MNRAS 450 1777

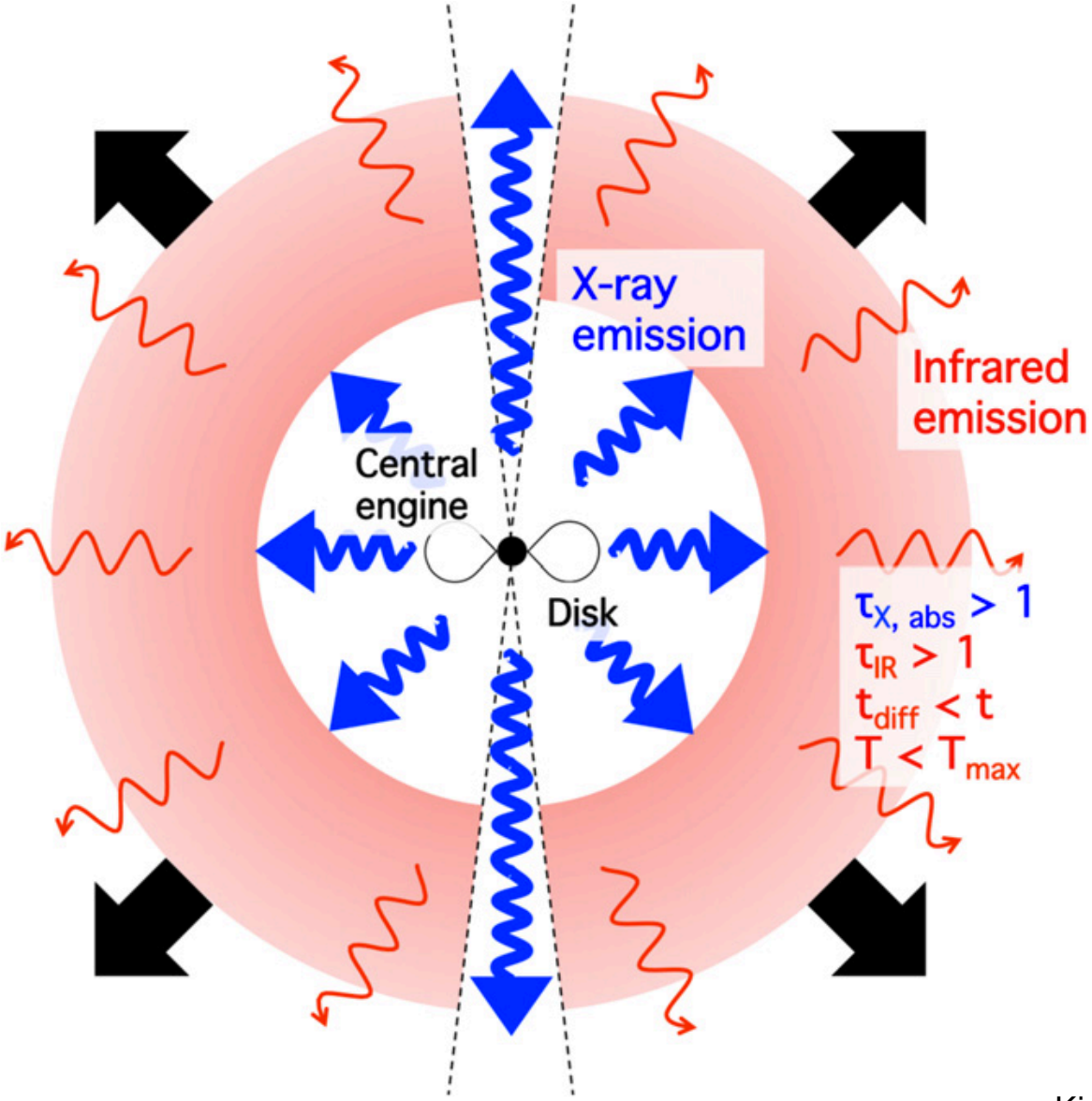
Kilonova emission





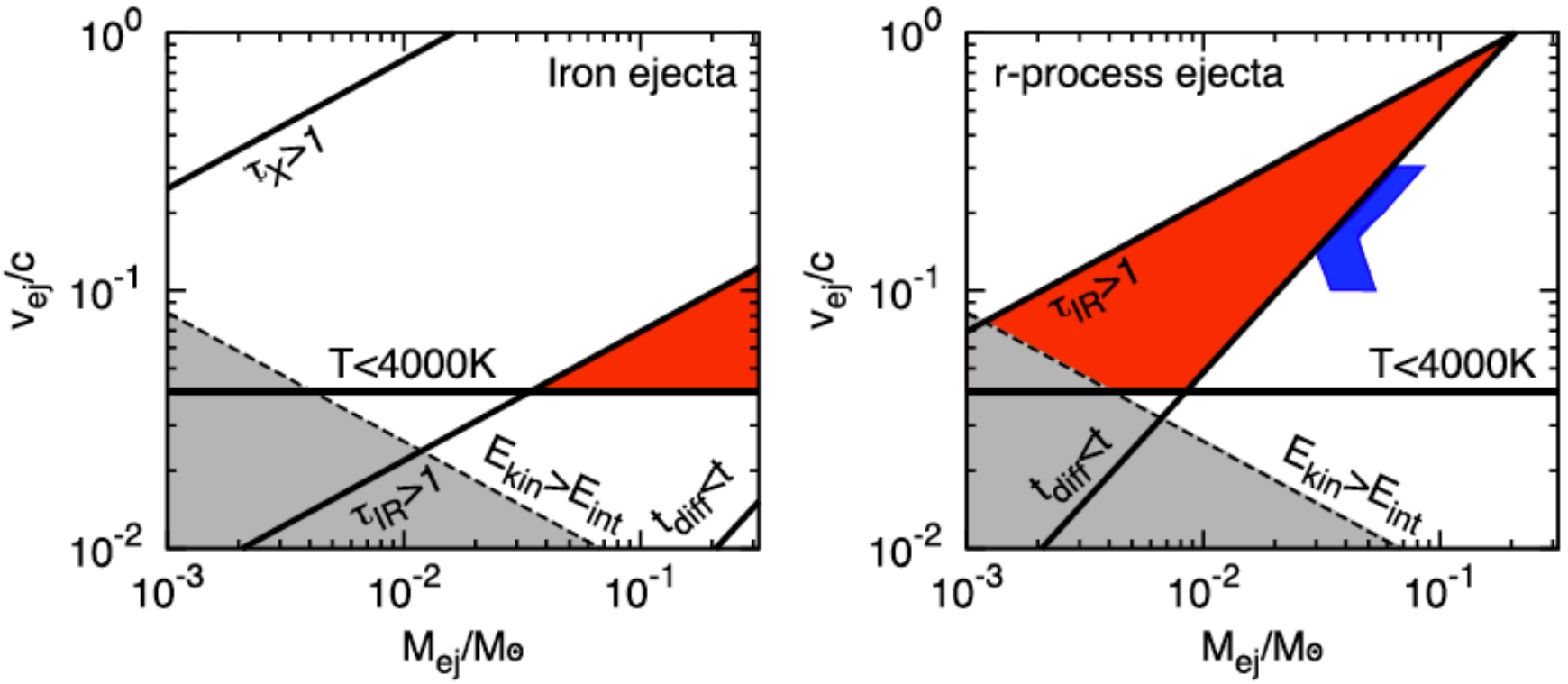
Barnes & Kasen (2013) ApJ 775 18

X-ray powered macronona?



Kisaka et al. (2016) ApJ 818 104

X-ray powered macronova?



Able to produce emission with much lower ejecta mass than r-process radioactive decay

Kisaka et al. (2016) ApJ 818 104

SVOM potential for sGRBs

- Good measurement of Band low energy slope with ECLAIRs & GRM
  - distinguishes short GRBs
- Good sensitivity to extended emission with ECLAIRs & MXT
  - constrains magnetar & precursor properties
- Good broad-band sensitivity with VT
  - measure kilonova Fe & r-process phases?
- Good high-energy grasp with ECLAIRs and MXT
  - well-suited to GW counterpart search
- Good lifetime in aLIGO era
  - large sample of joint GW-EM measurements