

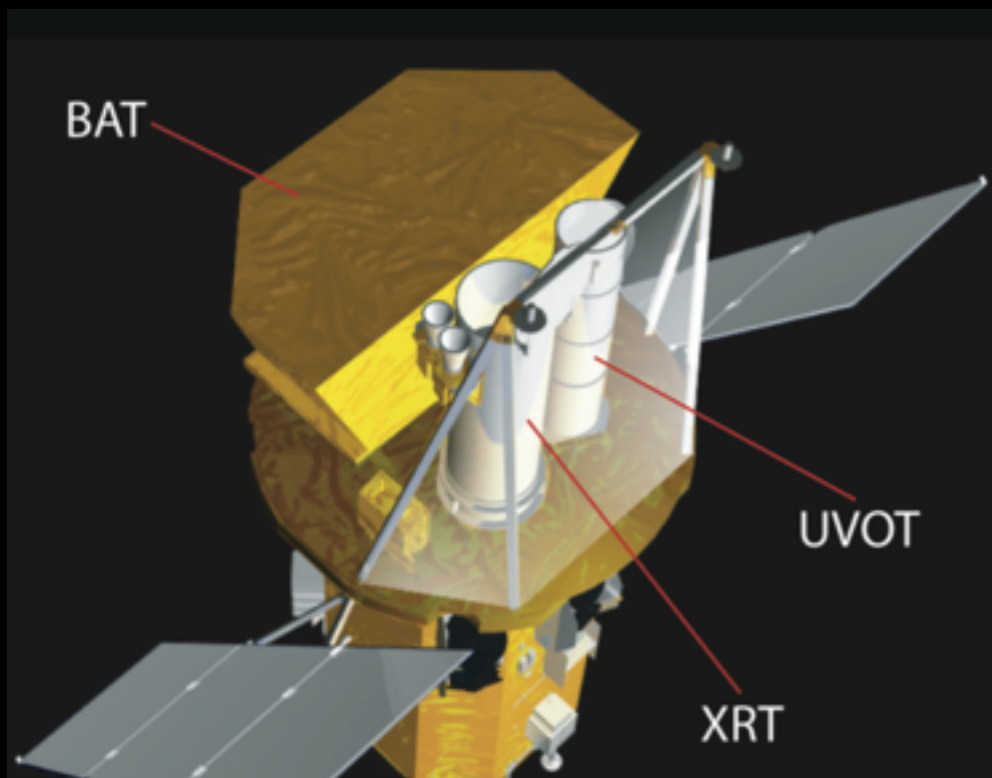
SERGIO CAMPANA



SWIFT FOLLOW UP OF GW150914



WHAT IS SWIFT



BURST ALERT TELESCOPE

Aperture	Coded Mask
Detecting Area	5200 cm ²
Detector	CdZnTe
Detector Operation	Photon Counting
Field of View	2.0 sr (partially coded)
Detection Elements	256 modules of 128 elements
Detector Size	4mm x 4mm x 2mm
Telescope PSF	17 arcminutes
Location Accuracy	1 - 4 arcminutes
Energy Range	15 - 150 keV
Burst Detection Rate	>100 bursts/year

X-RAY TELESCOPE

Telescope	Wolter I
Detector	XMM EPIC CCD
Effective Area	135 cm ² @ 1.5 keV
Detector Operation	Photon Counting, Integrated Imaging, & Rapid Timing
Field of View	23.6 x 23.6 arcminutes
Detection Element	600 x 600 pixels
Pixel Scale	2.36 arcsec/pixel
Telescope PSF	18 arcsec HPD @ 1.5 keV
Location Accuracy	3 - 5 arcseconds
Energy Range	0.2 - 10 keV
Sensitivity	2×10^{-14} ergs cm ⁻² s ⁻¹ in 10 ⁴ sec

ULTRAVIOLET/OPTICAL TELESCOPE

Telescope	Modified Ritchey-Chrétien
Aperture	30 cm diameter
F-number	12.7
Detector	Intensified CCD
Detector Operation	Photon Counting
Field of View	17 x 17 arcminutes
Detection Element	2048 x 2048 pixels
Telescope PSF	0.9 arcsec @ 350 nm
Location Accuracy	0.3 arcseconds
Wavelength Range	170 nm - 650 nm
Colors	6
Spectral Resolution (Grisms)	$\lambda/\Delta\lambda \sim 200$ @ 400 nm
Sensitivity	B = 24 in white light in 1000 sec
Pixel Scale	0.48 arcseconds
Bright Limit	m _v = 7 mag

Swift
Catching Gamma-Ray Burst on the Fly

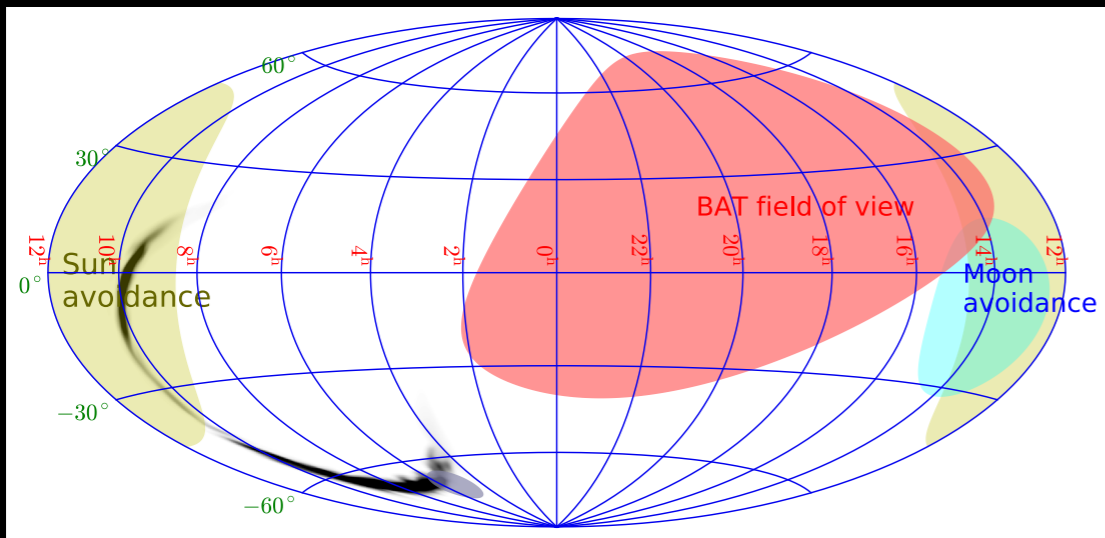


GW150914 WITH SWIFT

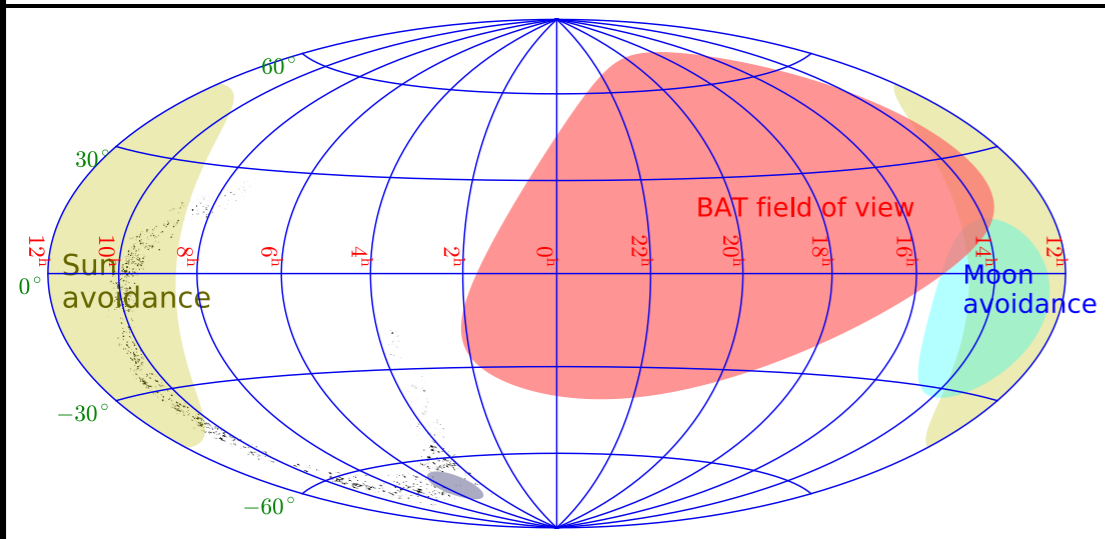
Swift follow-up of the Gravitational Wave source GW150914

P.A. Evans^{1*}, J.A. Kennea², S.D. Barthelmy³, A.P. Beardmore¹, D. N. Burrows², S. Campana⁴, S.B. Cenko^{3,5}, N. Gehrels³, P. Giommi⁶, C. Gronwall^{2,7}, F. E. Marshall³, D. Malesani⁸, C.B. Markwardt^{3,9}, B. Mingo¹, J. A. Nousek², P. T. O'Brien¹, J. P. Osborne¹, C. Pagani¹, K.L. Page¹, D.M. Palmer¹⁰, M. Perri^{6,11}, J. L. Racusin³, M.H. Siegel², B. Sbarufatti^{2,4}, G. Tagliaferri⁴

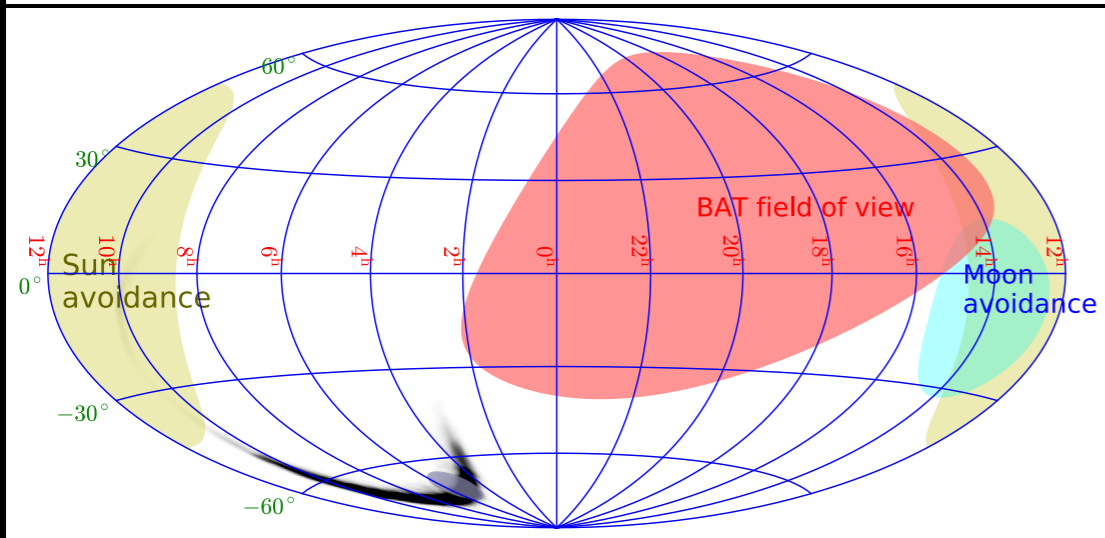
Evans et al. 2016



LIB skymap

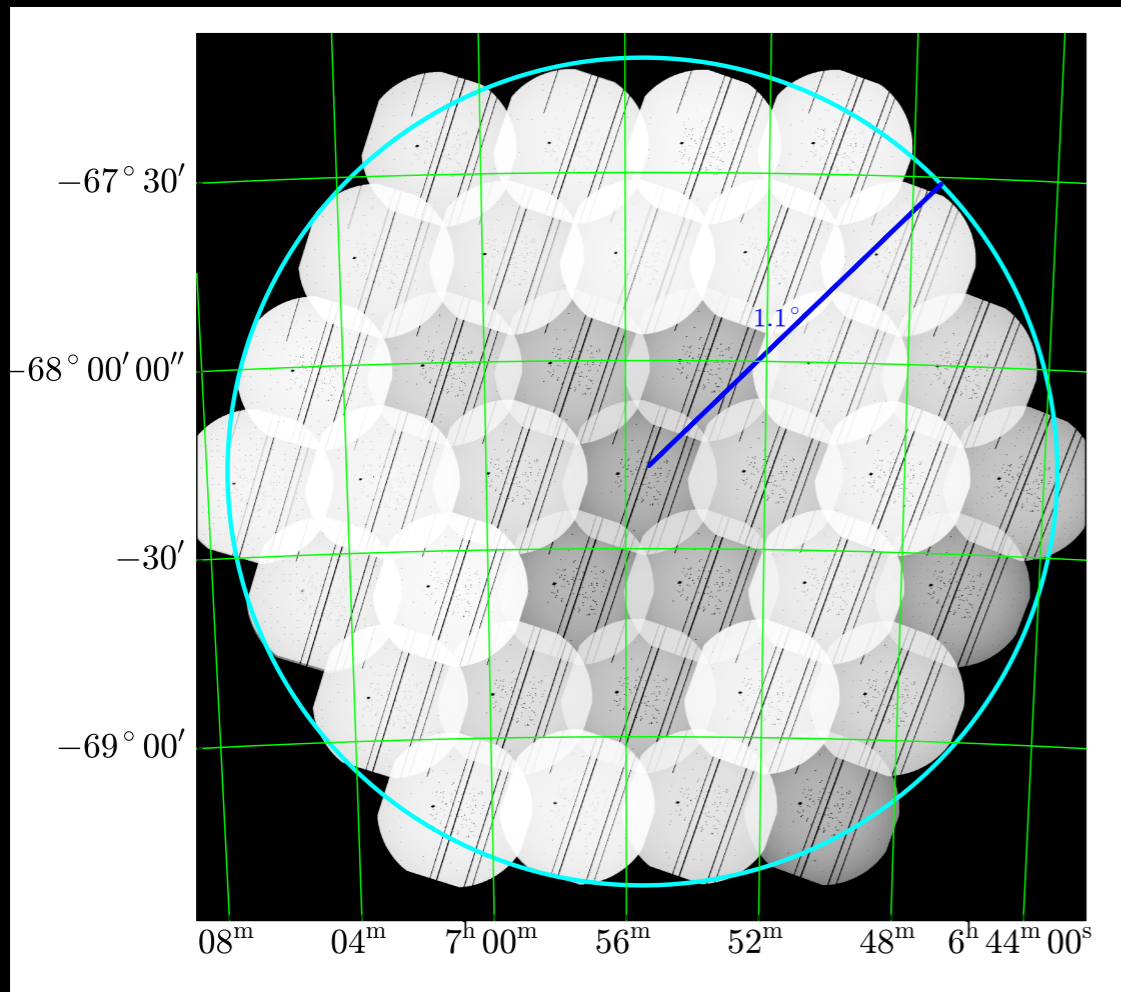


LIB convolved with galaxies
Swift probability map



LAL inference

TWO POINTING MODES



5 pointings on
high probability
regions
~1,000 s exposure
Sep 16

37-tile automatic
1.1° radius
20-75 s exposure
Sep 17

2% of LIB

RESULTS

5 initial pointings: $<1.5 \times 10^{-2} \text{ ct s}^{-1}$,
 $<6.5 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$

LMC tiling: $<1.6 \times 10^{-1} \text{ ct s}^{-1}$,
 $<6.9 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$
 $<2.0 \times 10^{36} \text{ erg s}^{-1} @ \text{ LMC}$

Observation in u-band
No transient brighter than
- 5 pointings $u_{\text{AB}} < 19.8$
- LMC $u_{\text{AB}} < 18.8$

XRT

UVOT

Table 2. Sources detected by *Swift*-XRT in follow-up of GW150914, with *u*-band magnitudes from UVOT.

RA (J2000)	Dec (J2000)	Error 90% conf.	Flux 0.3–10 keV, $\text{erg cm}^{-2} \text{ s}^{-1}$	<i>u</i> 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

SWIFT STRATEGY

Motivated by short GRBs

Convolve LIB with GWGC galaxy catalog

- **ASAP**

search for an on-axis short GRB afterglow

short 50-100 s observations

- **days after**

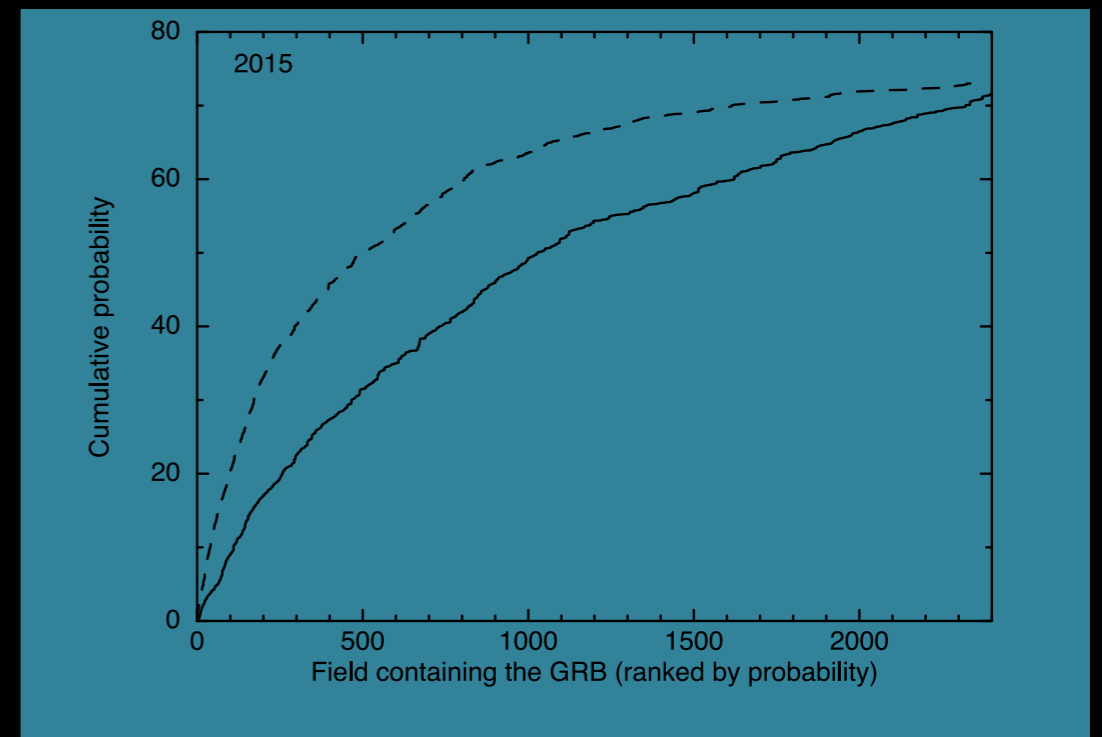
search for an off-axis orphan

longer 500 s observations

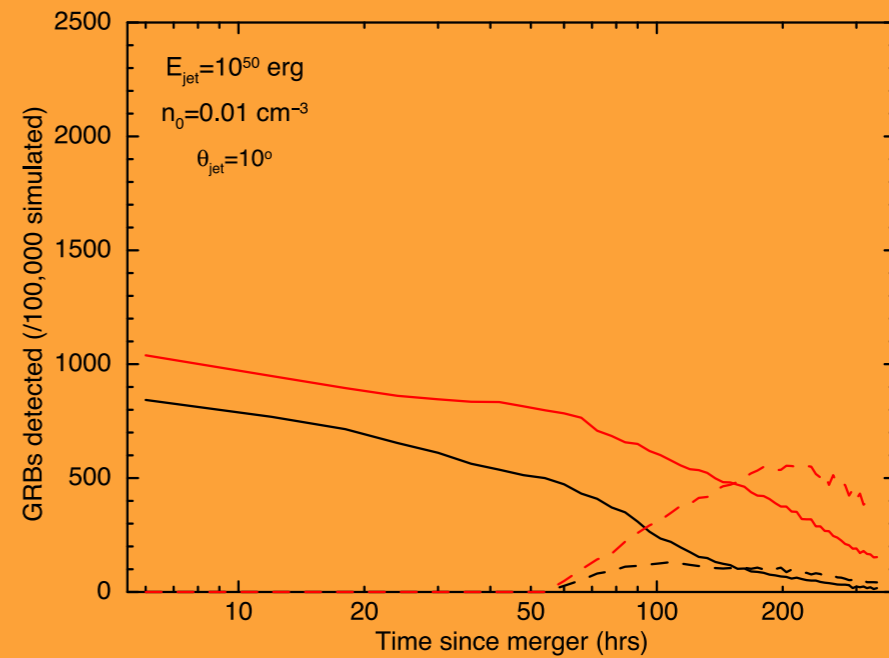
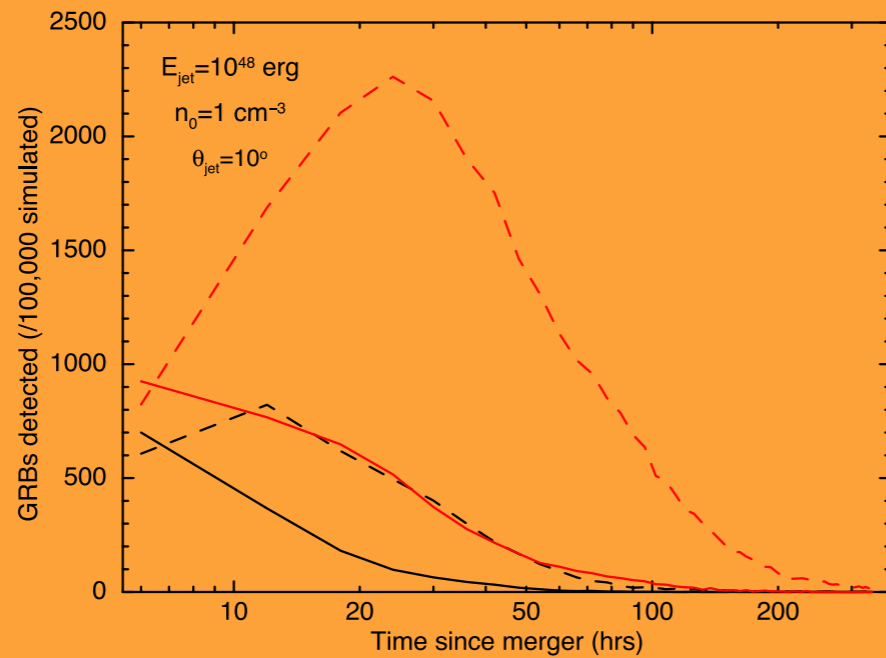
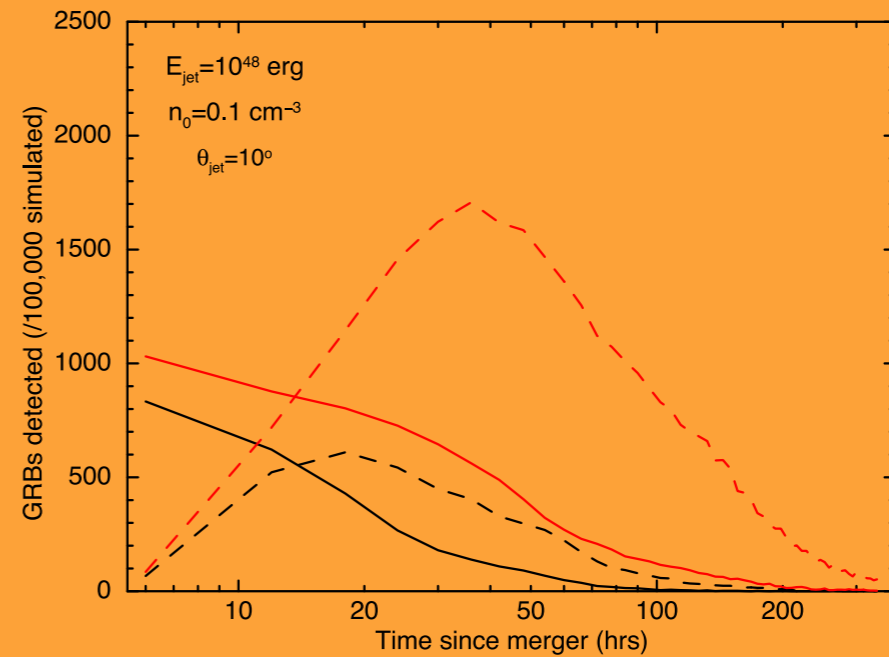
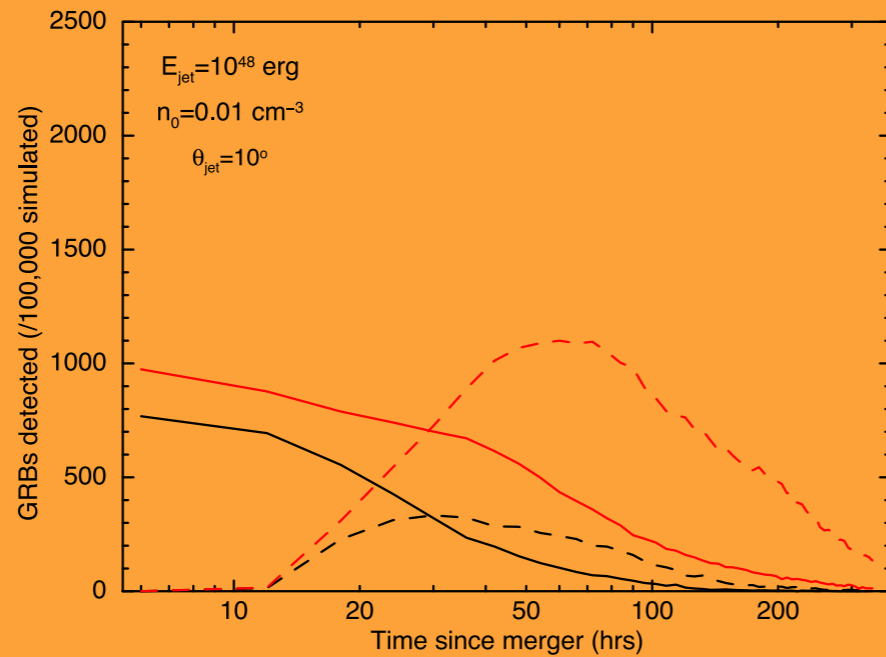
Table 1. Completeness of the GWGC, based on fig. 5 of White et al. (2011).

Distance (Mpc)	Completeness (per cent)
<40	100
50	70
60	65
70	65
80	60
90	58
100	55
>100	0 ^a

Note. ^aThe GWGC only includes galaxies within 100 Mpc, hence the sudden cut-off.



DETECTABILITY



10 deg opening angle

CONCLUSIONS

- Swift is the **only** sensitive soft X-ray and UV facility able to search for a GW counterpart (as well as a large FOV hard X-ray detector, BAT)
- Immediate search with short 50-100 s exposures looking for a short GRB afterglow (ALV+galaxy)
- Late time search (days) with long 1,000 s exposures looking for an orphan GRB afterglow (ALV+galaxy)
- Italian involvement: Swift team members & connections with GRAWITA