HOW NEIL GERHELS CHANGED THE FIELD OF TRANSIENT ASTRONOMY

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University of Leicester

(with thanks to the Swift team)

Neil Gehrels
1952-2017

NEIL GEHRELS

Music major (1972), climber, cyclist, volunteer and above all a great friend...

Neil worked on many projects, e.g. Voyager, balloon flights, CGRO, Integral, Swift, Fermi, WFIRST and more yet to come...

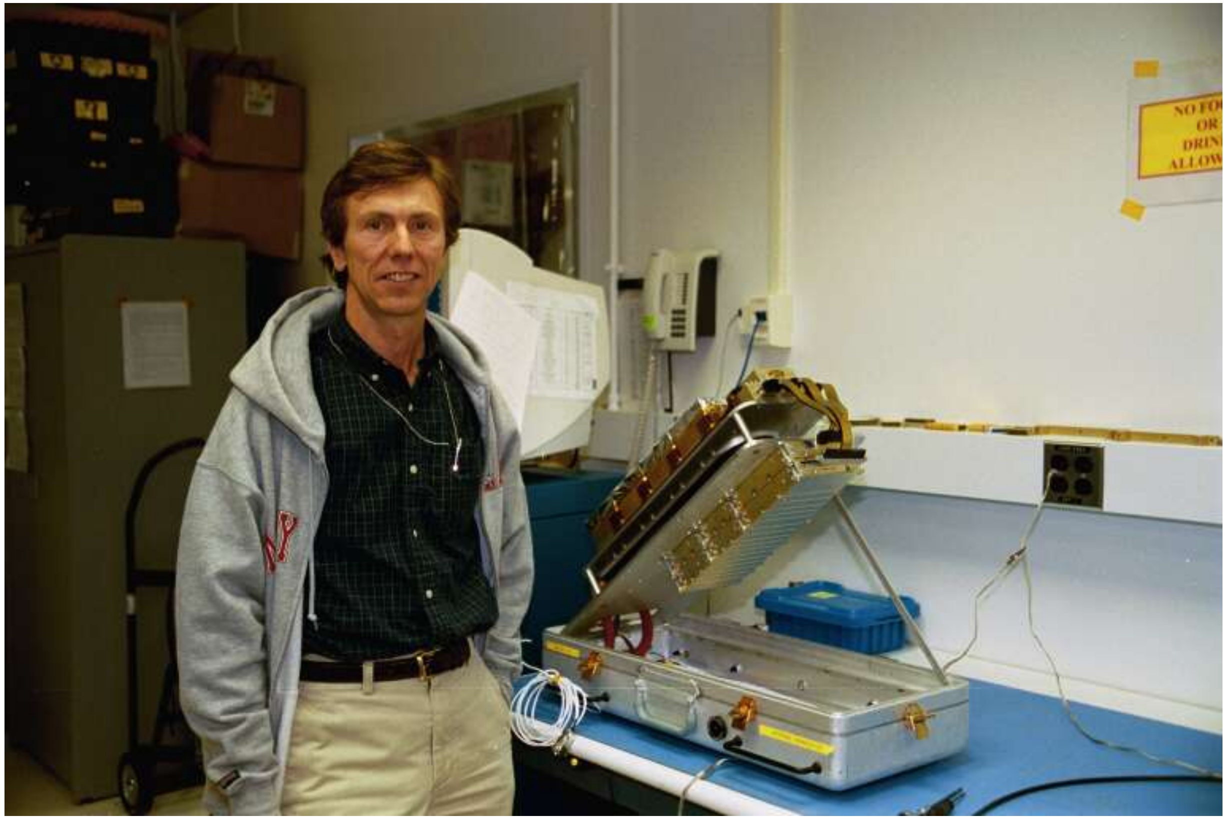
THE BAND

Adventures

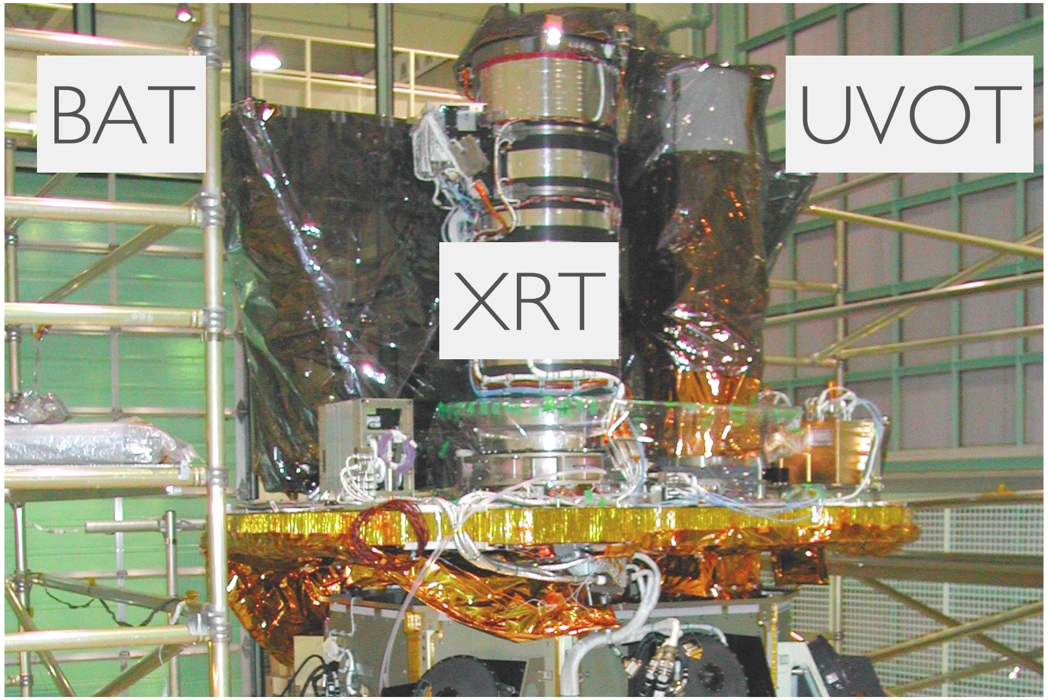
Bicycle to Panama

Hitchhike Round the World

So, what did we learn from Neil?



LESSON 1: PICK YOUR MOMENT



Swift: the right technology at the right time, with the right PI

Swift

LESSON 1B: DON'T GIVE UP

November 2002

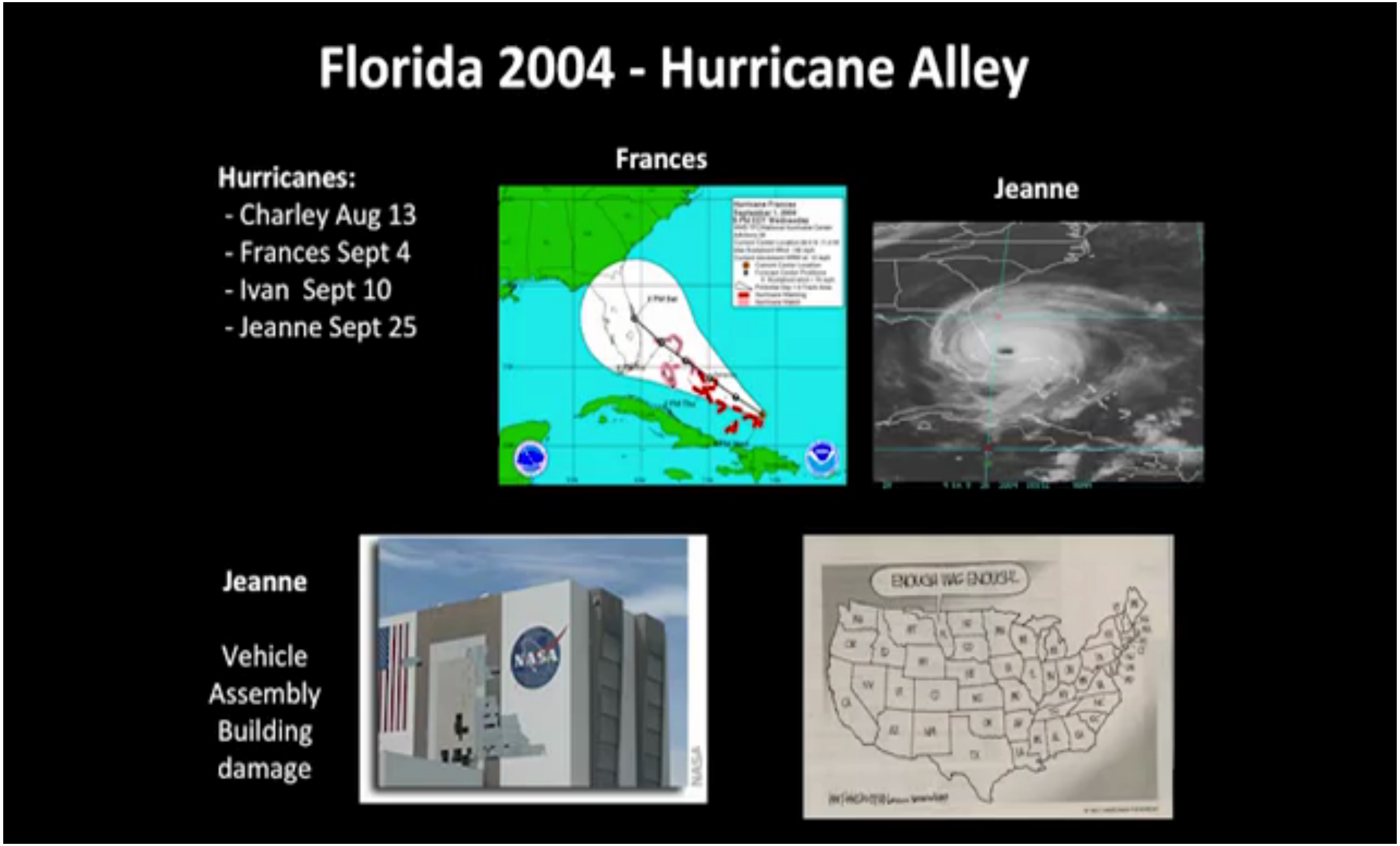
NASA Cancellation Review

Swift late and >20% over budget

Neil's approach: be honest, explain and have a plan

Result: extra funding and continue to launch

WAITING, WAITING…

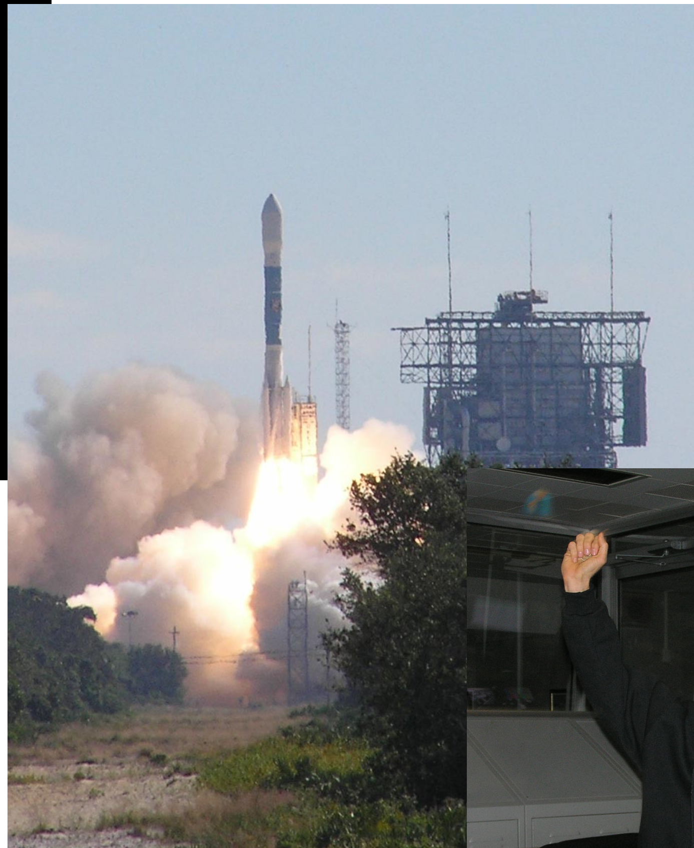


HURRICANE FRANCES (SEPT 5)

It's ok, the backup system worked

DON'T DO THIS…

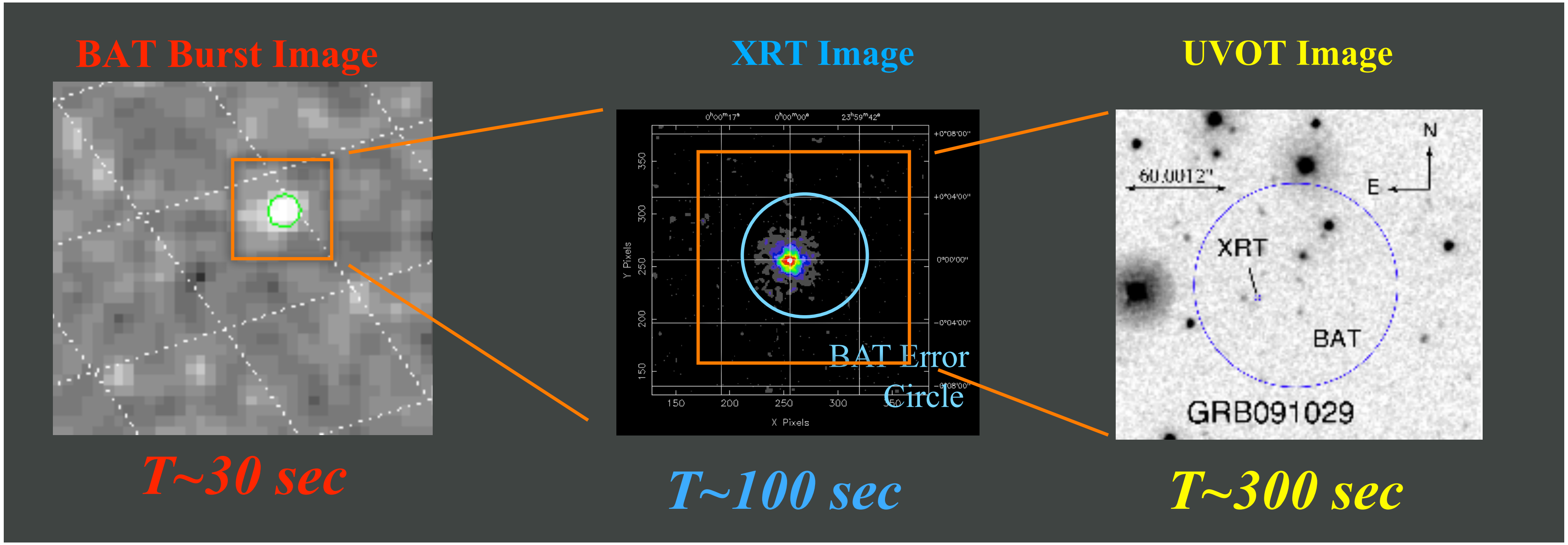
DO THIS



20 November 2004

LESSON 2: USE AUTOMATION

1. Burst Alert Telescope triggers on 'automated target', calculates position to ~ 1- 3 arc-minutes, transmits to ground via TDRSS and distributed by GCN.
2. Spacecraft autonomously slews to position in 1-2 minutes
3. X-ray Telescope: ~ 5 arcsec prompt, ~2 arcsec delayed position (distributed via GCN ASAP)
4. UV/Optical Telescope images field, transmits finding chart to ground
5. The Swift team analyzes the data in real time and sends out notice in ~5 - 20 minutes.



GRB PRIORITY 1: SHORT GRBS

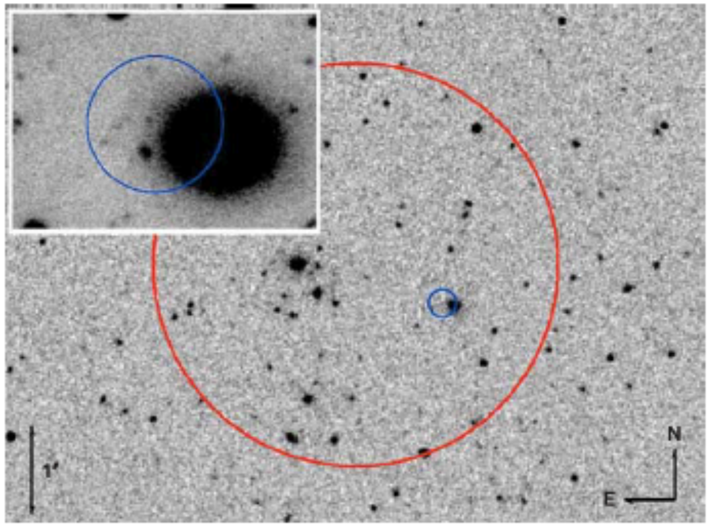
Vol 437 | 6 October 2005 | doi:10.1038/nature04142 nature

LETTERS

A short γ-ray burst apparently associated with an elliptical galaxy at redshift $z = 0.225$

N. Gehrels[1], C. L. Sarazin[2], P. T. O'Brien[3], B. Zhang[4], L. Barbier[1], S. D. Barthelmy[1], A. Blustin[5], D. N. Burrows[6], J. Cannizzo[1,7], J. R. Cummings[1,8], M. Goad[3], S. T. Holland[1,9], C. P. Hurkett[3], J. A. Kennea[6], A. Levan[3], C. B. Markwardt[1,10], K. O. Mason[5], P. Meszaros[6], M. Page[5], D. M. Palmer[11], E. Rol[3], T. Sakamoto[1,8], R. Willingale[3], L. Angelini[1,7], A. Beardmore[3], P. T. Boyd[1,7], A. Breeveld[5], S. Campana[12], M. M. Chester[6], G. Chincarini[12,13], L. R. Cominsky[14], G. Cusumano[15], M. de Pasquale[5], E. E. Fenimore[11], P. Giommi[16], C. Gronwall[6], D. Grupe[6], J. E. Hill[6], D. Hinshaw[1,17], J. Hjorth[18], D. Hullinger[1,10], K. C. Hurley[19], S. Klose[20], S. Kobayashi[6], C. Kouveliotou[21], H. A. Krimm[1,9], V. Mangano[12], F. E. Marshall[1], K. McGowan[5], A. Moretti[12], R. F. Mushotzky[1], K. Nakazawa[22], J. P. Norris[1], J. A. Nousek[6], J. P. Osborne[3], K. Page[3], A. M. Parsons[1], S. Patel[23], M. Perri[16], T. Poole[5], P. Romano[12], P. W. A. Roming[6], S. Rosen[5], G. Sato[22], P. Schady[5], A. P. Smale[24], J. Sollerman[25], R. Starling[26], M. Still[1,9], M. Suzuki[27], G. Tagliaferri[12], T. Takahashi[22], M. Tashiro[27], J. Tueller[1], A. A. Wells[3], N. E. White[1] & R. A. M. J. Wijers[26]

Gamma-ray bursts (GRBs) come in two classes[1]: long (>2 s), soft-spectrum bursts and short, hard events. Most progress has been made on understanding the long GRBs, which are typically observed at high redshift ($z \approx 1$) and found in subluminous star-forming host galaxies. They are likely to be produced in core-collapse explosions of massive stars[2]. In contrast, no short GRB had been accurately (<10″) and rapidly (minutes) located. Here we report the detection of the X-ray afterglow from—and the localization of—the short burst GRB 050509B. Its position on the sky is near a luminous, non-star-forming elliptical galaxy at a redshift of 0.225, which is the location one would expect[3,4] if the origin of this GRB is through the merger of neutron-star or black-hole binaries. The X-ray afterglow was weak and faded below the detection limit within a few hours; no optical afterglow was detected to stringent limits, explaining the past difficulty in localizing short GRBs.

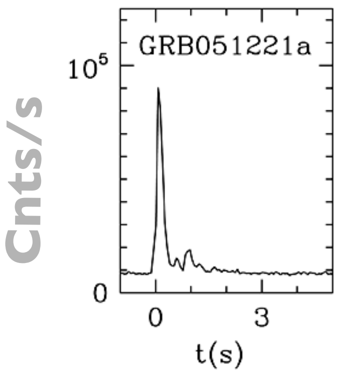


Clues for the merger origin of short GRBs:

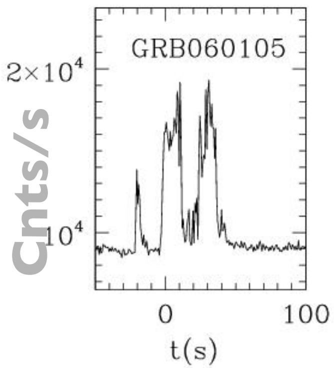
- Early afterglow detections. None has a SN signature.
- In different types of host galaxies, including a few in elliptical/early-type galaxies, and most in star-forming galaxies
- Do not follow bright sights of hosts
- In regions of low star formation in star-forming galaxies
- Redshift distribution (a good fraction of low-z).
- Theoretical expectation should be "short"

Short vs Long GRBs

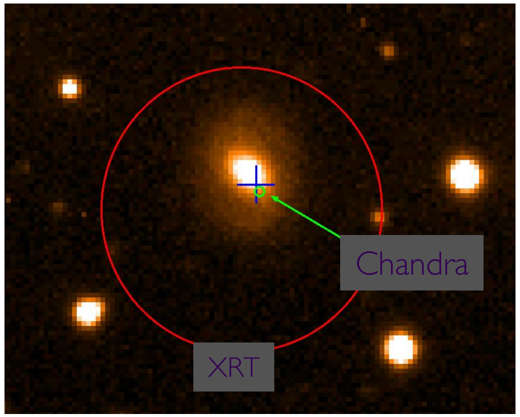
Short GRB



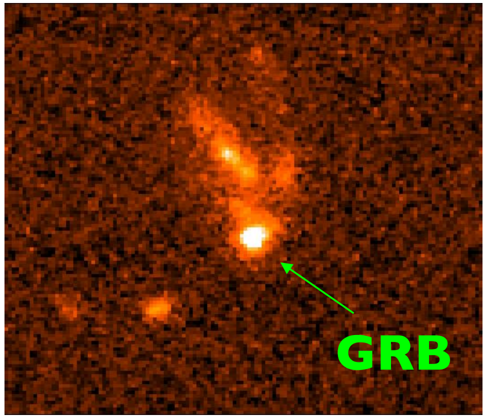
Long GRB



GRB 050724 - *Swift*
elliptical host



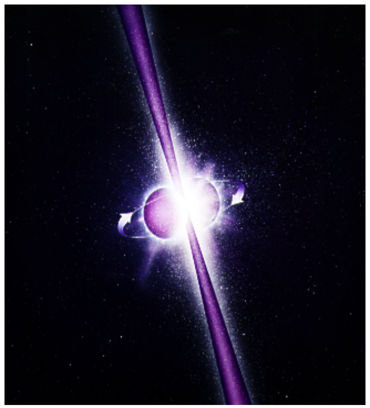
GRB 990123 - *SAX*
SF dwarf host

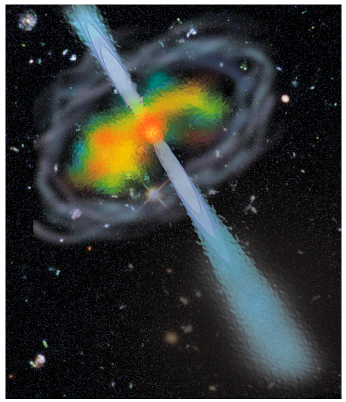


In non-SF
and SF galaxies

No SNe detected

Possible **merger** model – but what?





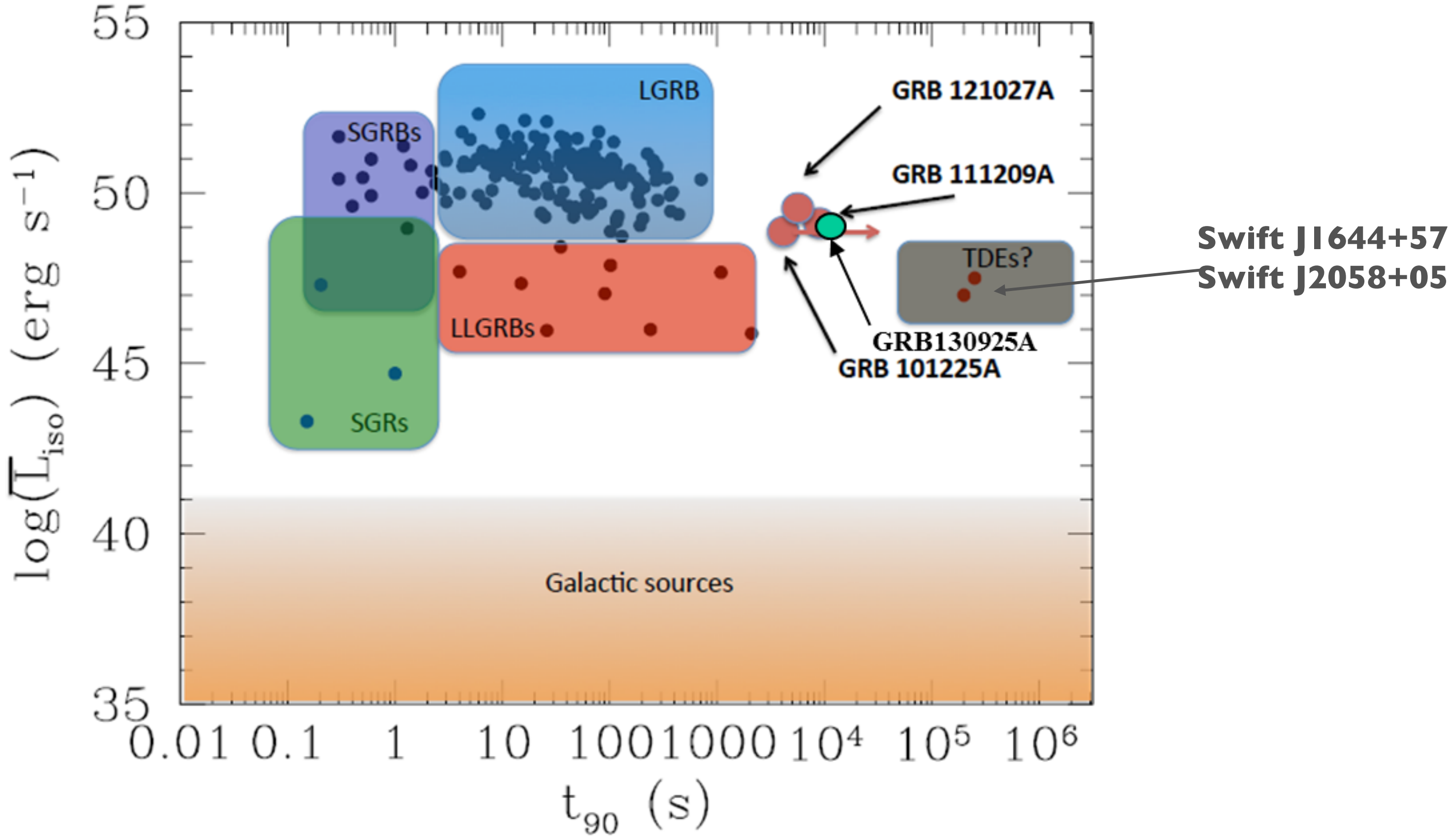
In SF
galaxies

Accompanied by SNe

Collapsar model well supported

THE TRANSIENT ZOO: NEW ANIMALS?

(LEVAN ET AL., 2014; EVANS ET AL. 2014)



Swift has found a small number of "ultra long" transients/GRBs, with T_{90} >2000s

LESSON 3: COMMUNITY INVOLVEMENT = NEW PRIORITIES

- Swift has a GI programme and a TOO web page which scientists use to submit requests for observations.
- For some programs (Neutrino, Fermi LAT GRB, LIGO/Virgo GW triggers), we have a 'backdoor' system that allows auto generated TOOs.

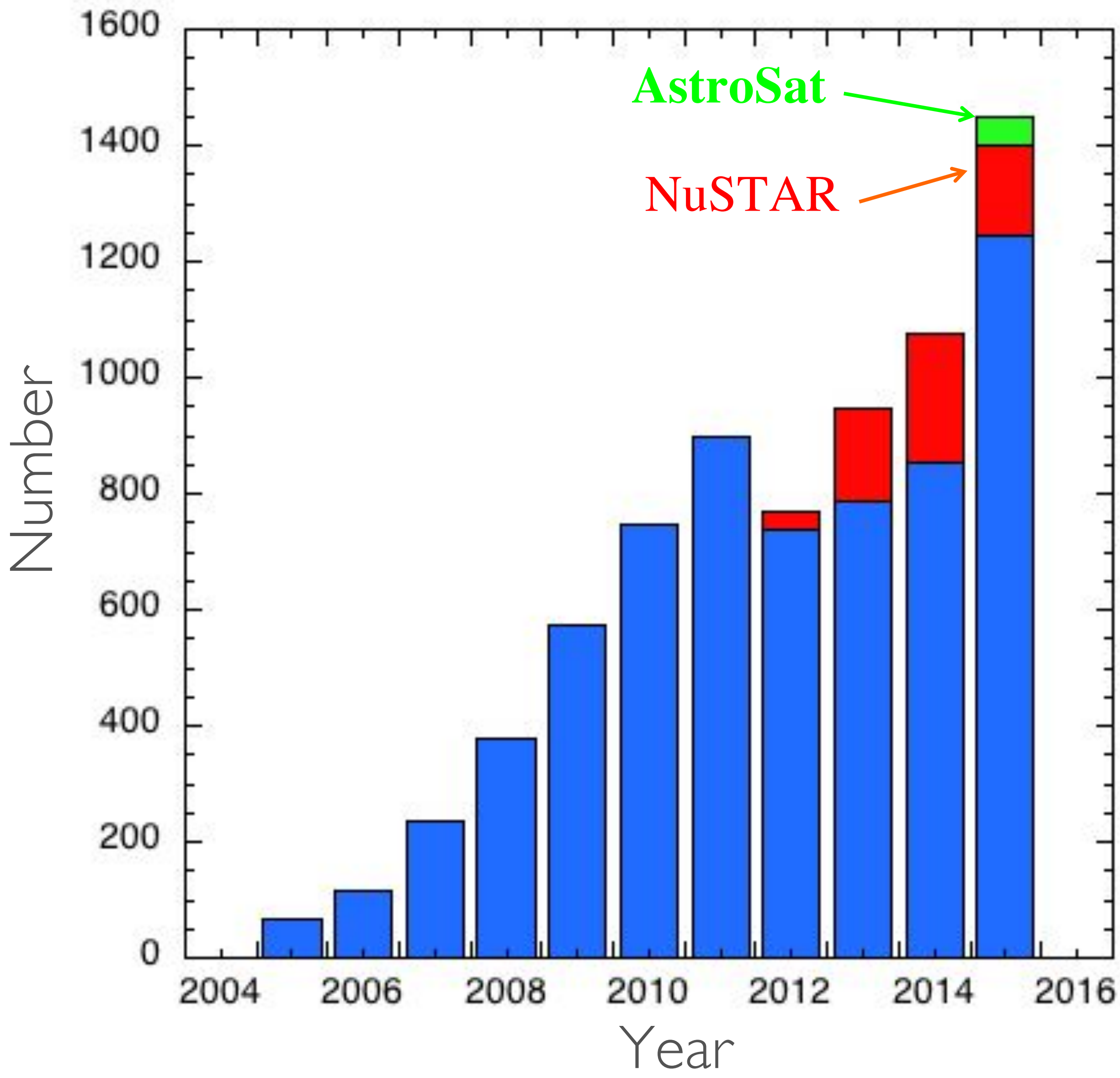
http://www.swift.psu.edu

Game-Changing Discoveries Every Year

- 2005: Short burst mystery solution. NS-NS mergers
- 2005: Flares & bright afterglows in GRBs
- 2008: Discovery of a SN shock break-out X-ray flash
- 2008: Naked-eye GRB from reverse shock jet physics
- 2009: Discovery of 2 GRBs with z>8
- 2005-2011: SFR and metallicity evolution to z>5
- 2010: Many galaxy mergers in hosts of absorbed AGN
- 2011: Tidal disruption super-flare of star eaten by BH
- 2012: Discovery of very young (2500 year old) SNR
- 2013: Anti-glitch *spin down* in magnetar 11E 2259+586
- 2013: Evidence for kilonova emission in a short GRB
- 2015: Extreme glitch in pulsar B0540-69
- 2015: V404 Cyg bright outburst for a micro-blazar
- 2015: Magnetar powered SN with ultra-long GRB
- 2015: ASASSN 14li tidal disruption event
- 2015: UV pulse in iPTF SN Ia, single degenerate explosion
- 2016: Starspots on Proxima Centauri
- 2017: NGC4151 monitoring changes disk reprocessing model

Continuous break-throughs with *Swift*:
many not GRB related

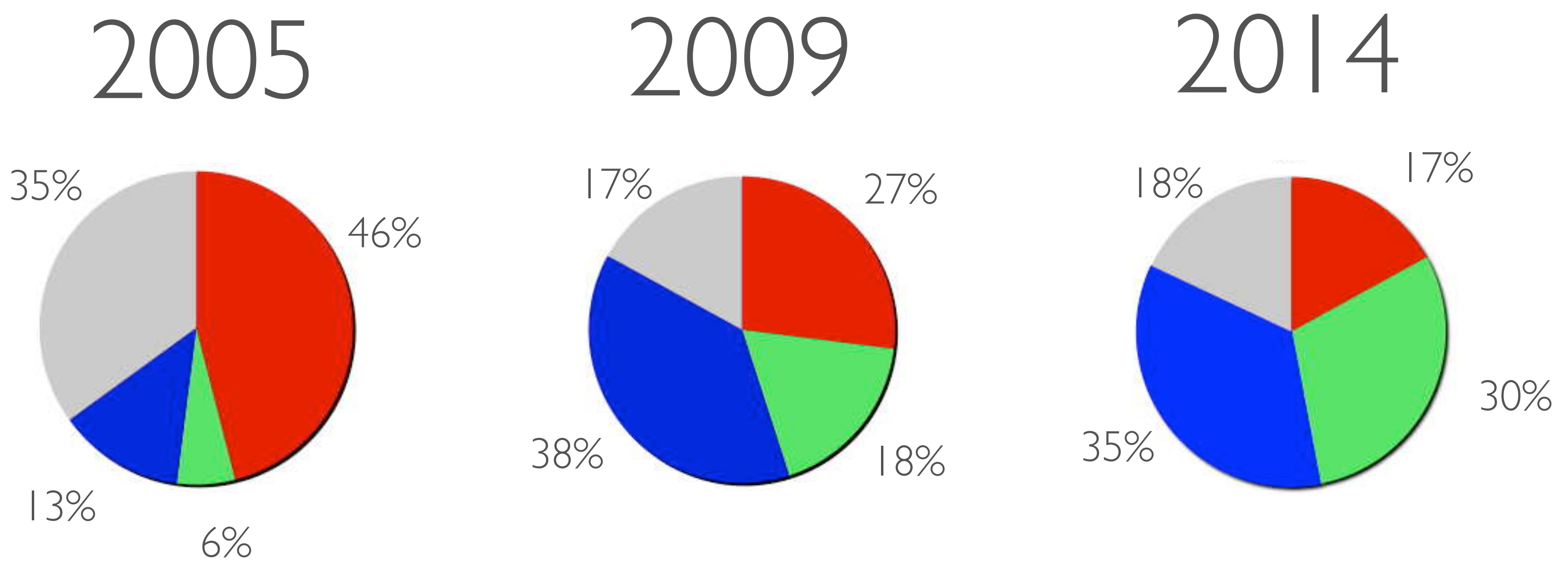
TOO requests increasing



~1300 in 2016
>500 requests so far in 2017

In the past 28 days, Swift has received 105 Target of Opportunity requests (3.8 per day), from 60 members of the community, for 82 different celestial objects. In that time Swift observed 76 targets in 130 separate observations on average per day. Swift was observing for 73% of the time, the rest of the time spent slewing or passing through the South Atlantic Anomaly.

Swift Operations & Science are Evolving

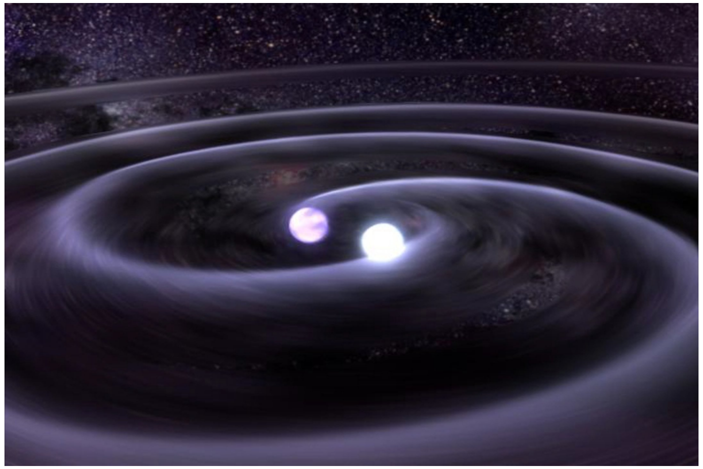


- GRBs
- TOOs
- GI obs & Fill-ins
- SAA & Calibration

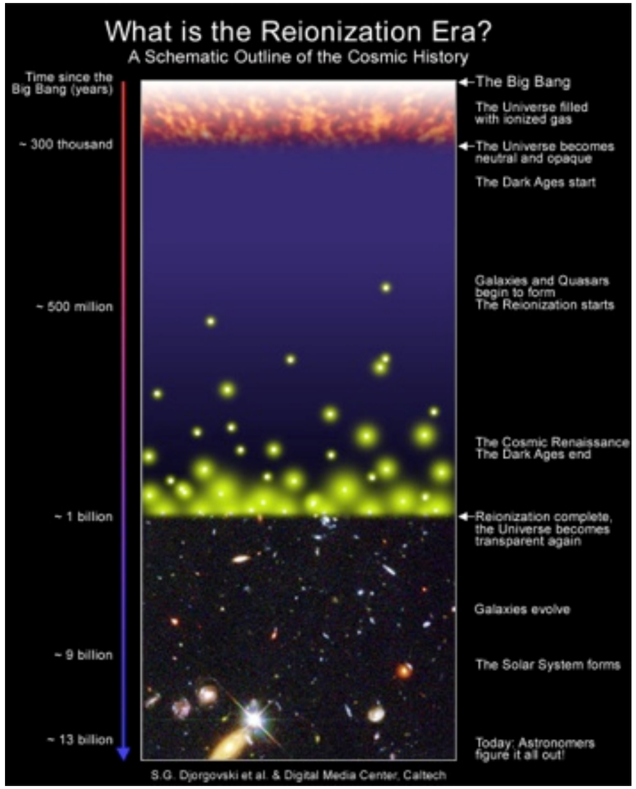
Some TOOs in GI

Fermi, NuSTAR, MAXI, INTEGRAL
Spitzer, Kepler, Planck,
Chandra, XMM, AstroSat
VERITAS, MAGIC, HESS, HAWC,
IceCube, ANTARES
ALIGO-Virgo
70 ground telescopes

Current Prioritized Mission Objectives



- **Short burst progenitors**
  - Counterpart of ALIGO-Virgo detection
  - r-process kilonova emission
- **Epoch of reionization**
  - High signal-to-noise spectra of $z > 7$ event
- **Supernovae & Cosmology**
  - UV light curves of SNe Ia in Hubble flow
- **Time-domain discovery**
  - New mission initiatives
  - Wide-field optical and radio surveys



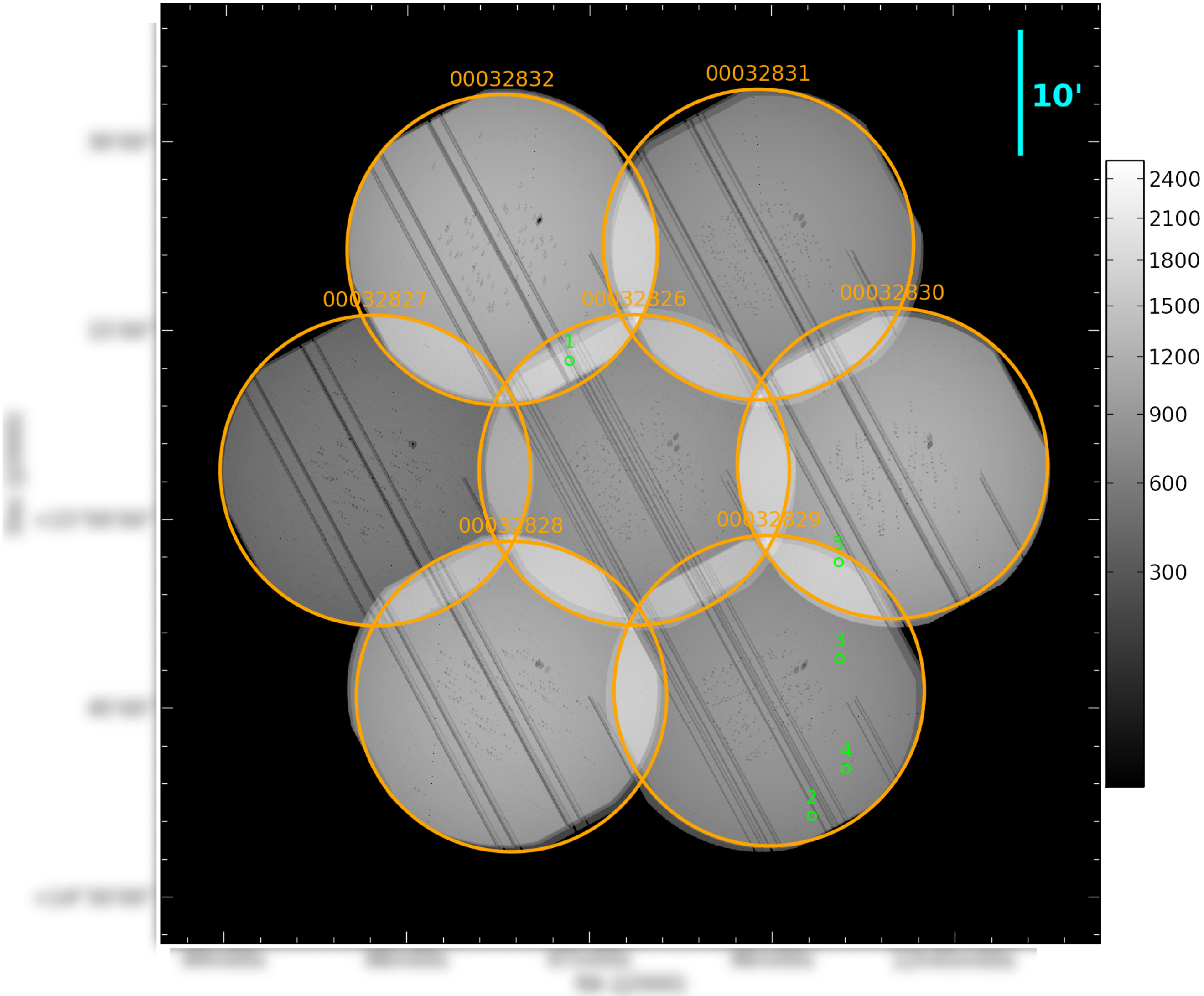
NASA SR proposal 2014: Swift came top, again

TILING: EXAMPLE FOR ICECUBE

Swift response to a neutrino doublet from IceCube.

7-point tiling needed to cover the error region.

Multiple sources detected, but…

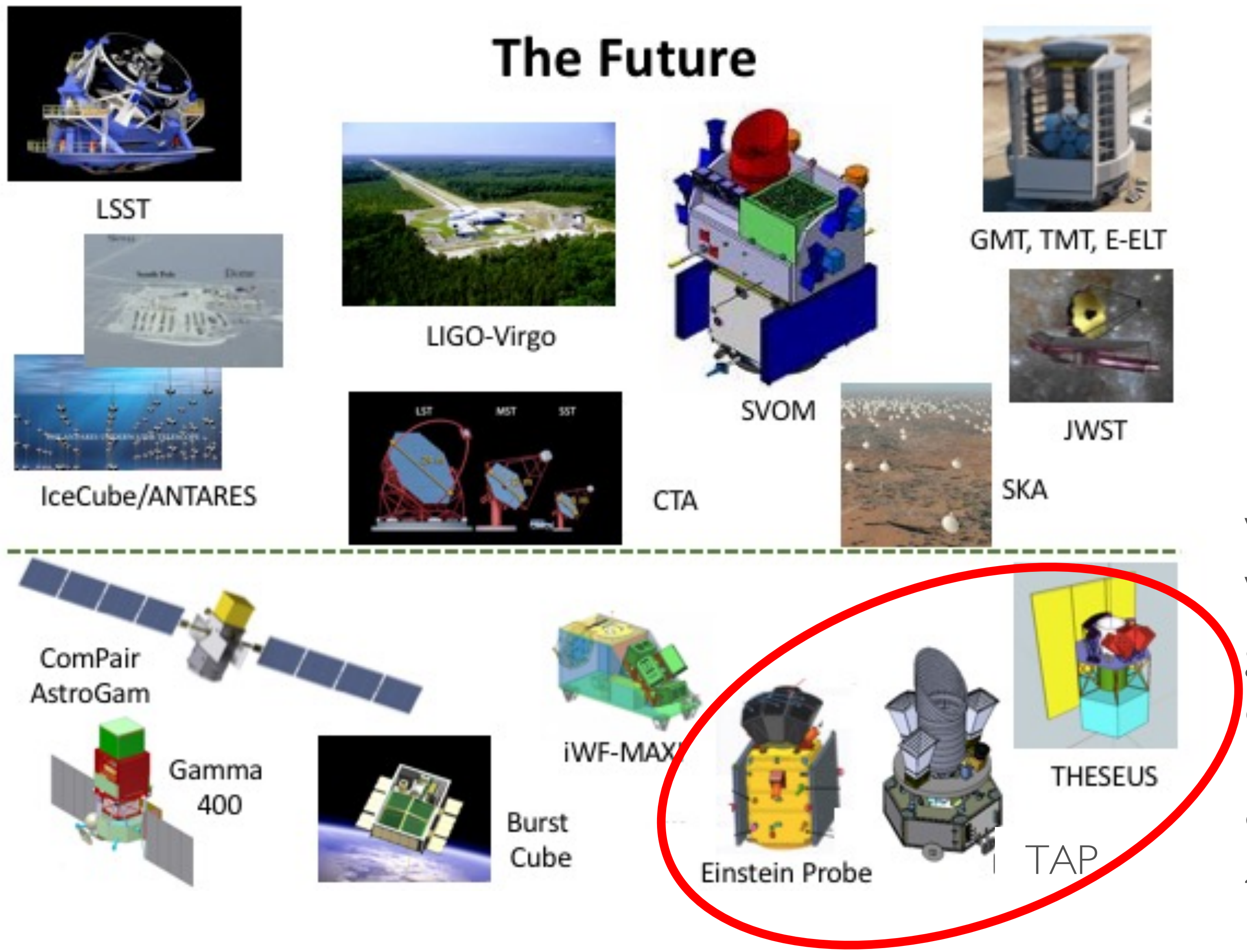


Coordinates redacted…

OBSERVING LIGO/VIRGO TRIGGERS

- Trigger on compact binary coalescent events.
- Take BAYESTAR error region, convolve with Galaxy Catalog to target nearby galaxies.
- Upload PPST containing as many 60s exposures of the LIGO error regions for 48 hours to look for prompt emission.
- For following three days take as many 500s exposures of these galaxies again, in order to look for off-axis afterglows.
- Process validated and in use

LESSON 4: THE NEXT MISSION



Want:
Wide sky coverage,
good localisation,
on-board redshift

'Lobster' X-ray technology

Neil's vision for the future (Huntsville, Nov. 2016)

WE MISS YOU NEIL

Neil Gehrels, 1952-2017