INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

La partecipazione italiana alla missione Swift

Swift

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Why Swift?

Discovered in the `sixties GRBs remained enigmatic sources for decades

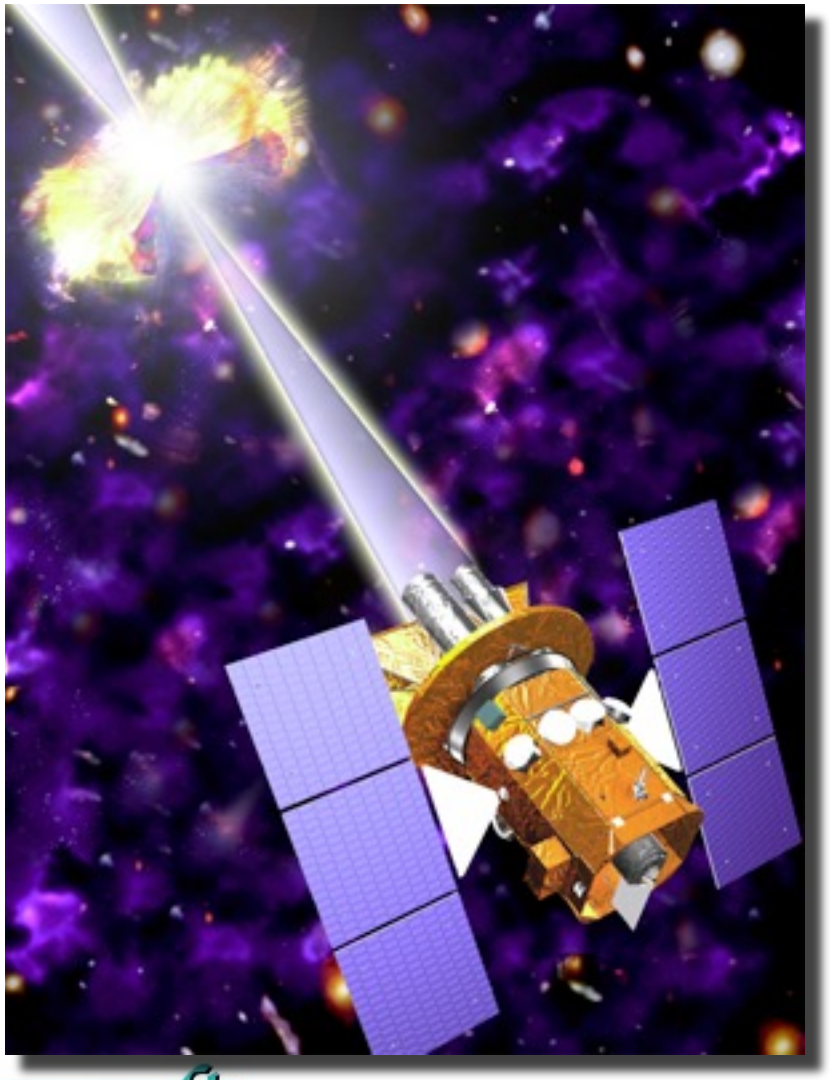
The real breaktrough came in the late `nineties thanks to BeppoSAX discoveries!

Swift has been thought, proposed and realised following the BeppoSAX discoveries!

Swift

Swift Overview

Catching Gamma Ray Bursts on the Fly



Selected by NASA on October 1999
launched on November 2004

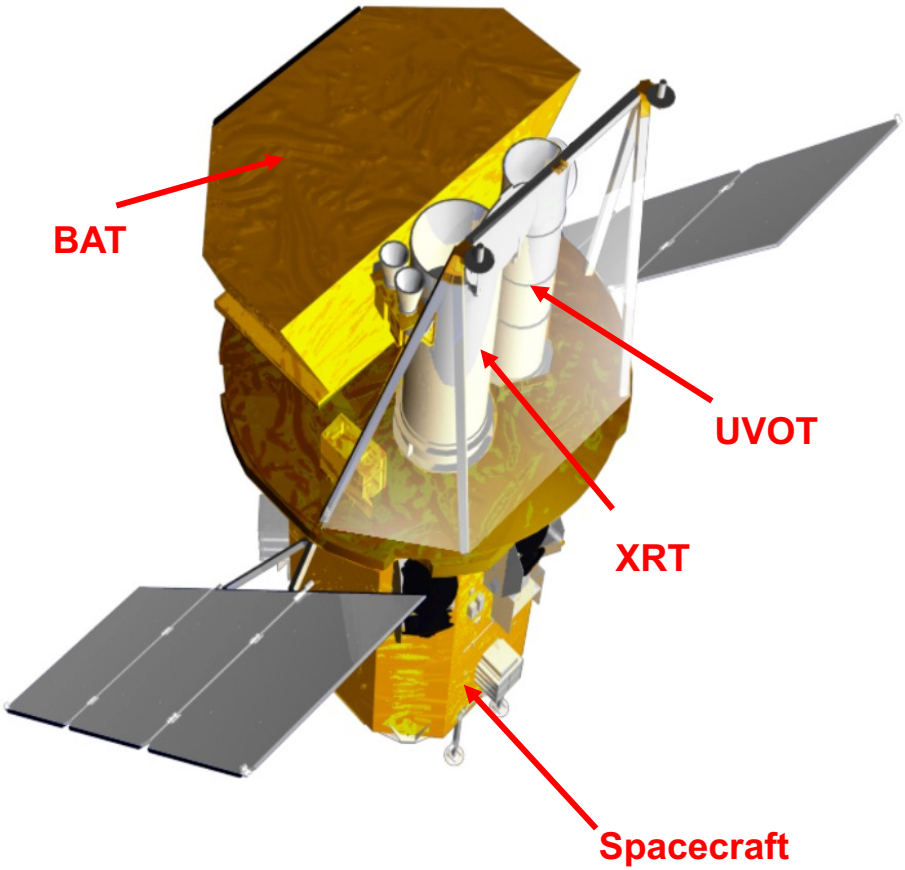
- Objectives
  - Determine origin of GRBs
  - Determine the difference between short and long GRBs
  - Use GRBs to probe the early Universe
  - Perform hard X-ray survey
- International collaboration:
  - GSFC: lead institution
  - PSU: lead university partner
  - UK & Italy: key hardware collaborators
  - Spectrum Astro: spacecraft provider

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Swift Instruments

Instruments

- Burst Alert Telescope (BAT)
  - **New CdZnTe detectors**
  - **Detect >100 GRBs per year depending on logN-logS**
  - **Most sensitive gamma-ray imager ever**
- X-Ray Telescope (XRT)
  - **Arcsecond GRB positions**
  - **CCD spectroscopy**
  - **Photometry in the range 10^{-7}-10^{-15} erg cm^{-2} s^{-1}**
- (UVOT) UV/Optical Telescope
  - **Sub-arcsec imaging**
  - **Grism spectroscopy**
  - **24th mag sensitivity (1000 sec)**
  - **Finding chart for other observers**



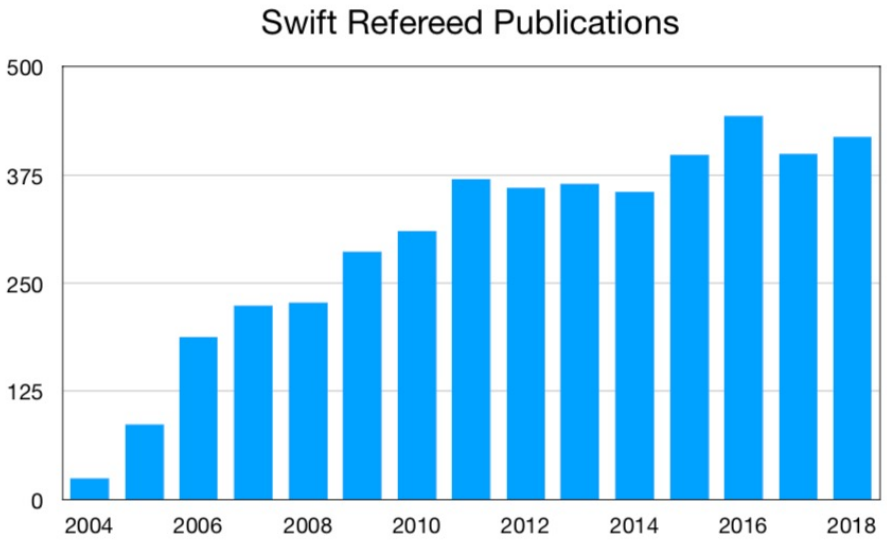
Spacecraft

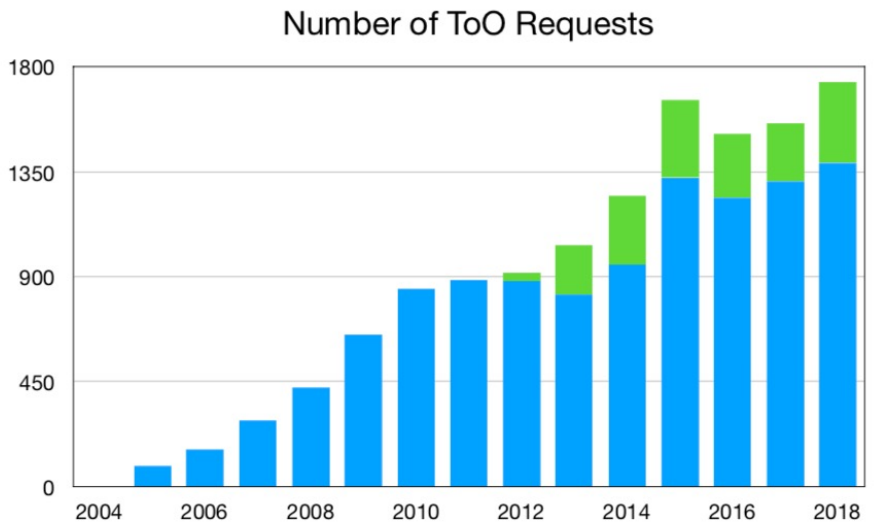
- Autonomous re-pointing, 20 - 100 sec
- Onboard and ground triggers

>1450 GRB discovered with arcmin position, >80% with arcsec position, >70% repointed in <300 s, 396 with redshift

Swift continues to be a highly productive mission

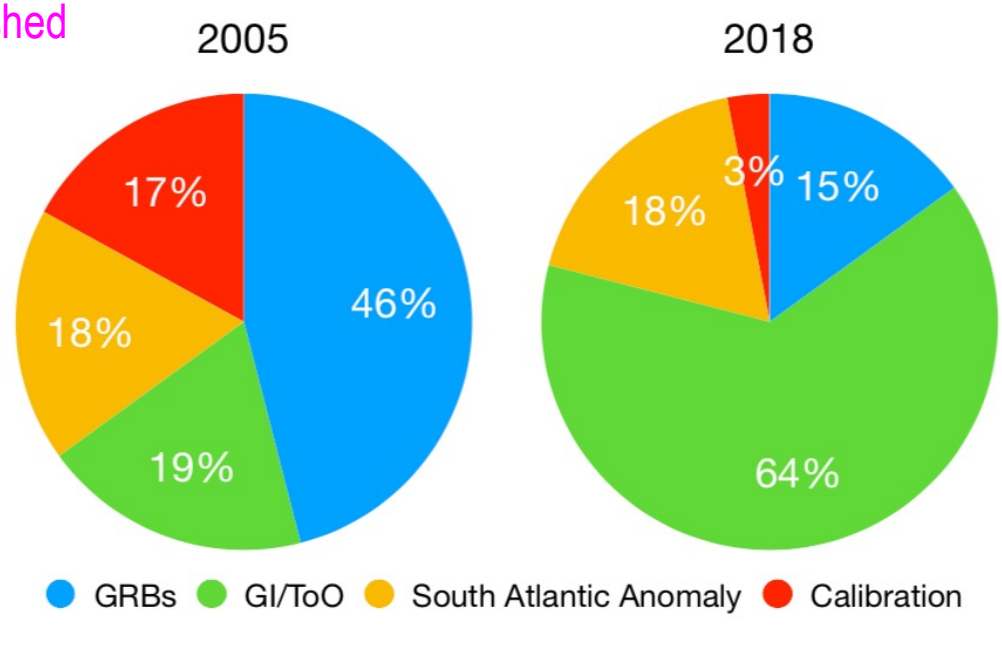
INAF
ISTITUTO NAZIONALE
DI ASTROFISICA





Several tens of Swift papers published on **Nature** & **Science** journals

Swift spends no time Earth occulted. 23 Ms of good time per year



INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Swift unique Time Domain Astronomy sampling and wavelength coverage

- Conceived as a mission for rapid follow-up of GRBs, Swift has also proven to be highly flexible and responsive allowing for observations of nearly every type of astronomical object

- ToOs response (on average ~ 4.8 every day) in as little as ten minutes, or samplings over periods of time ranging from minutes to hours, days or months, ~25 observations per day (Swift has now passed **550.000** slews!)

Swift

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

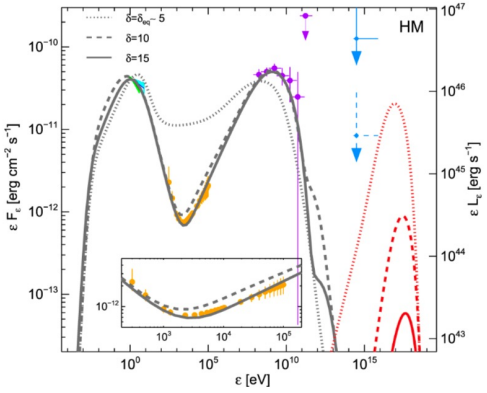
Synergies with Other Missions

- Fermi & AGILE: Follow-up of GRBs, blazars, unidentified sources, etc.
- NuSTAR & ASTROSAT: co-pointing with Swift to enlarge energy band
- INTEGRAL, MAXI, NICER: Follow-up of transients, GRBs, etc.
- XMM-Newton and Chandra: synergy in TOO programs
- EVLA, LOFAR, MWA, MeerKAT, CHIME: triggers for GRB and FRB searches
- TeV observatories: Joint observations of blazars, triggers for GRB searches
- LIGO/VIRGO: search for counterpart of GW events
- IceCube: follow-up of transients, triggers for GRB searches
- ZTF, ATLAS, ASASSN, Vera Rubin Observatory: follow-up of transients

Swift

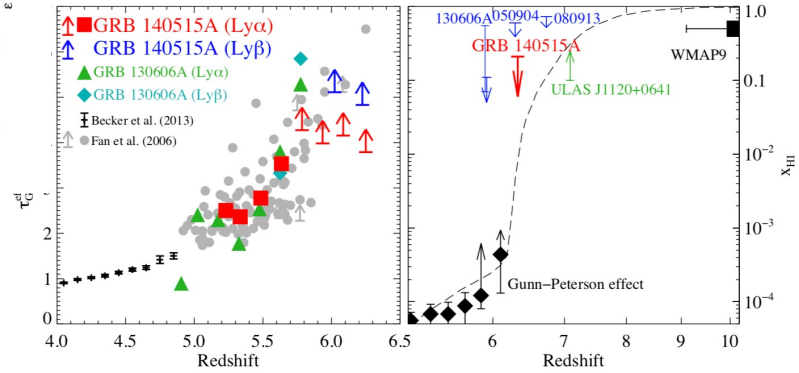
Most important goals for the next years

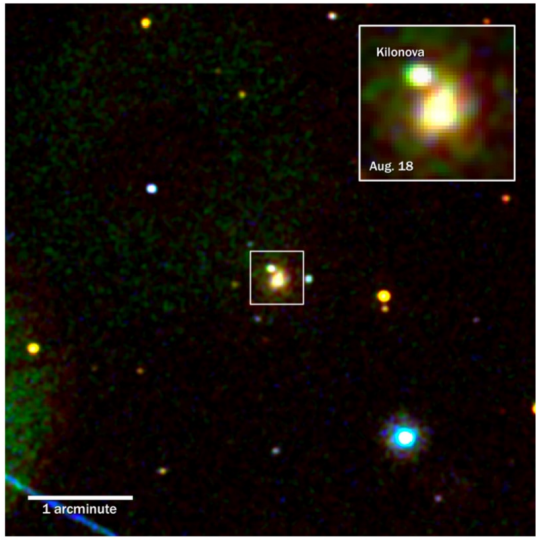
- Multi-messenger astronomy
- Leading the Time-Domain Revolution (+Vera Rubin Observatory)
- Probing the Epoch of Reionisation
- Providing multiwavelength coverage (optical, UV, soft- and hard-X-ray)
- …..



SED of TXS 0506+056 at the time of neutrino emission

High-z GRB





NS-NS mergers detectability

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

After >16 years is Swift still relevant?

Every two years, now every three, all NASA missions are going through an evaluation process called Senior Review. An independent panel of expert is ranking all missions, recommending:

- either the continuation of a mission, including a recommendation on the budget to be allocated
- or the termination of a project

In the last four evaluation processes Swift was ranked first in 3 of them (2012-2014-2016) and second in the other one (2019, TESS first) and with an increase of the allocated budget.

Swift

After >16 years is Swift still relevant?

Strong support and request from the community as proven by the:

- very high number of ToO requested (a lot of which from Italian scientist)
- The high oversubscription of the GI program

Unique capabilities:

- Fast autonomous repointing
- Capability to repoint any urgent ToO in <1hr
- UV imaging & fast timing
- Sensitive MW coverage (from optical up to hard-X)

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Swift: Italian Contribution & Responsibility

Our group has been (and it is) involved in all phases of this mission:

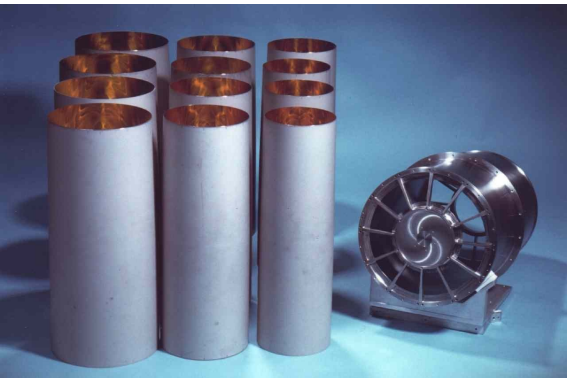
- from the preparation of the proposal submitted to the three agencies
- to the realisation of the satellite
- to the management of the operations
- to the scientific exploitation of the data

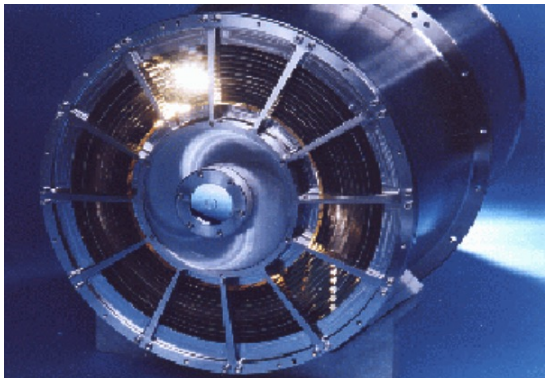
Swift

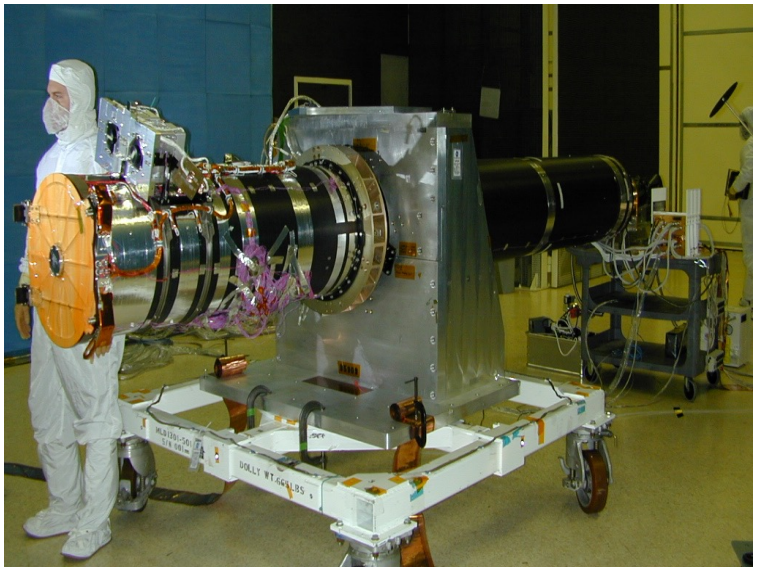
INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Swift: Italian Contribution & Responsibility

1. Mirror Module of the XRT Telescope
2. Malindi Ground Station
3. XRT Analysis software & Italian Swift archive
4. XRT calibration, BA+XBS responsibility (2 weeks every 5) & operation support
5. Scientific exploitation







Swift: Italian Contribution & Responsibility

Nel periodo dicembre 2019 – Febbraio 2021:

- Il team Swift ha partecipato alla pubblicazione di centinaia di articoli con referee di cui 37 a guida di membri dello Swift team italiano o scienziati o studenti ad esso collegati nel periodo 12/2019 – 2/2021
- Sono state scritte più di 10.000 GCN/Atel, 225 nel periodo 12/2019-2/2021 di cui 83 a primo nome italiano
- Partecipazione/preparazione di varie press release

- Responsabilità per 48 GRB come XBS e di 20 come BA
- Responsabilità aggiornamento calibrazioni XRT e software XRT (2 XRT team meeting in teleconf)
- Supporto alle attività del MOC

Swift: Italian Contribution & Responsibility

Several tens of publications led by the Italian team, here are some of the most relevant ones

Tagliaferri et al. 2005, **Nature**, Studio delle prime fasi delle curve di luce X dei GRB
Tagliaferri et al. 2005, A&A, Studio dell'emissione ottico/NIR di un GRB a z=6.3
Campana et al. 2006, **Nature**, Associazione di un GRB con una SN con scoperta dello Shock break-out
Cusumano et al. 2006, **Nature**, Scoperta di un GRB a z=6.3
Molinari et al. 2007, A&A, Scoperta dell'onset di due afterglow e determinazione del fattore di Lorentz iniziale
Salvaterra et al. 2009, **Nature**, Scoperta di un GRB a z~8.1, spettro al TNG con NICS e il prisma di Amici
Cusumano et al. 2010, A&A, Survey di Swift-BAT ottenuta dopo 54 mesi di osservazioni
Campana et al. 2011, **Nature**, Un GRB atipico spiegato come un asteroide che cade su una stella di neutroni
Salvaterra et al. 2012, A&A, Selezione di un campione di GRB lunghi completo in redshift ottenuto con Swift
Maselli et al. 2014, **Science**, Studio di un GRB vicinissimo e brillantissimo
Melandri et al. 2014, A&A, Confronto dell'energetica nei long-GRB con le proprietà della SN associata
Burrows, Kennea, Ghisellini et al. 2011, **Nature**, Onset di un jet relativistico dovuto ad un TDE attorno ad un SMBH
D'Avanzo et al. 2014, MNRAS, Selezione di un campione completo di GRB-short ottenuto con Swift
Covino et al. 2017, **Nature Astr**., Studio della polarizzazione nella macronova associata a GW170817

INAF institutes and people involved

OABrera, IASF-PA, OARm, IASF-Mi + SSDC

M.G Bernardini, S. Campana, S. Covino, G. Ghisellini, P. D'Avanzo, A. Melandri, P. Romano, T. Sbarrato
E. Ambrosi, A. Compagnino, M. Capalbi, G. Cusumano, A. D'Ai', V. La Parola
P. Caraveo, A. De Luca, M. Marelli, R. Mignani, R. Salvaterra
M. Perri, S. Piranomonte, L. Stella
V. D'Elia

22 INAF, 1 associate; many more involved with the science exploitation …

Overall INAF FTE 1999-2021: 180 (95 TI, 90 TD)

Current FTE/yr involvement: 5 (3 TI, 2(3) TD)

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Criticality

According to the MOU, we need to guarantee rapid response assistance 24/24 hr, 7/7 days for 2 weeks every 5.

There are people that do this since more than 10 years and this is getting burdensome.

In the first 6-7 years of operation we had up to 8 people on soft money, now we have only 2 (3 for the next 3 years). It is true that many activities are now fully automatised reducing the effort required, still one need to be always ready in case of unexpected event/situation.

Swift

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Back-up slides

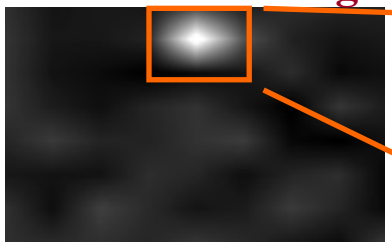
Swift

Observing Scenario

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

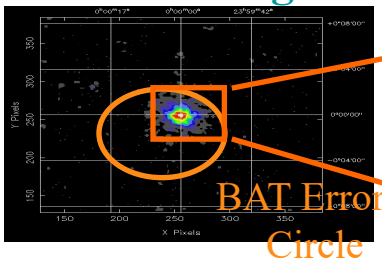
1. Burst Alert Telescope triggers on GRB, calculates position to < 4 arcmin
2. Spacecraft autonomously slews to GRB position in 20-100 s
3. X-ray Telescope determines position to < 5 arcseconds
4. UV/Optical Telescope images field, transmits finding chart to ground

BAT Burst Image



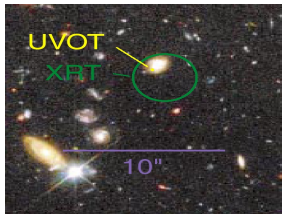
T<10 sec
θ < 4'

XRT Image



T<100 sec
θ < 5''

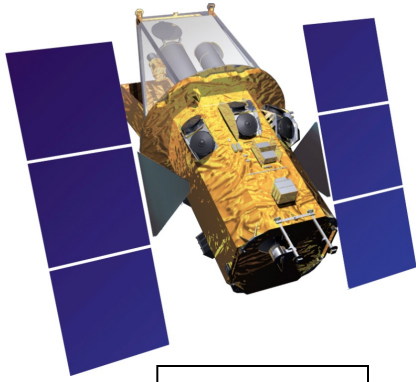
UVOT Image



T<300 sec

Swift

Swift Mission communication flow

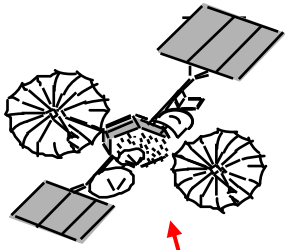


Spacecraft

Spectrum Astro
Rapid Autonomous Slews

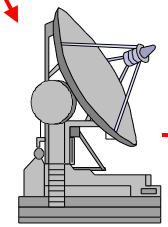
Payload

BAT
XRT
UVOT



TDRSS

Malindi



Mission Operations Center (MOC)

PSU

Science Center

GSFC

GCN & Web

HEASARC
UK
Italian
Archives

User Community

Swift continues to be a highly productive mission

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Swift payload

Instr.	Bandpass	FOV	Localization
BAT	15–350 keV	2 sr	~ 3′
XRT	0.3–10 keV	24′ diameter	~ 2″
UVOT	160–800 nm	17′ × 17′	~ 0.5″

Autonomous repointing typically in the range 50-150 seconds

Swift By the Numbers

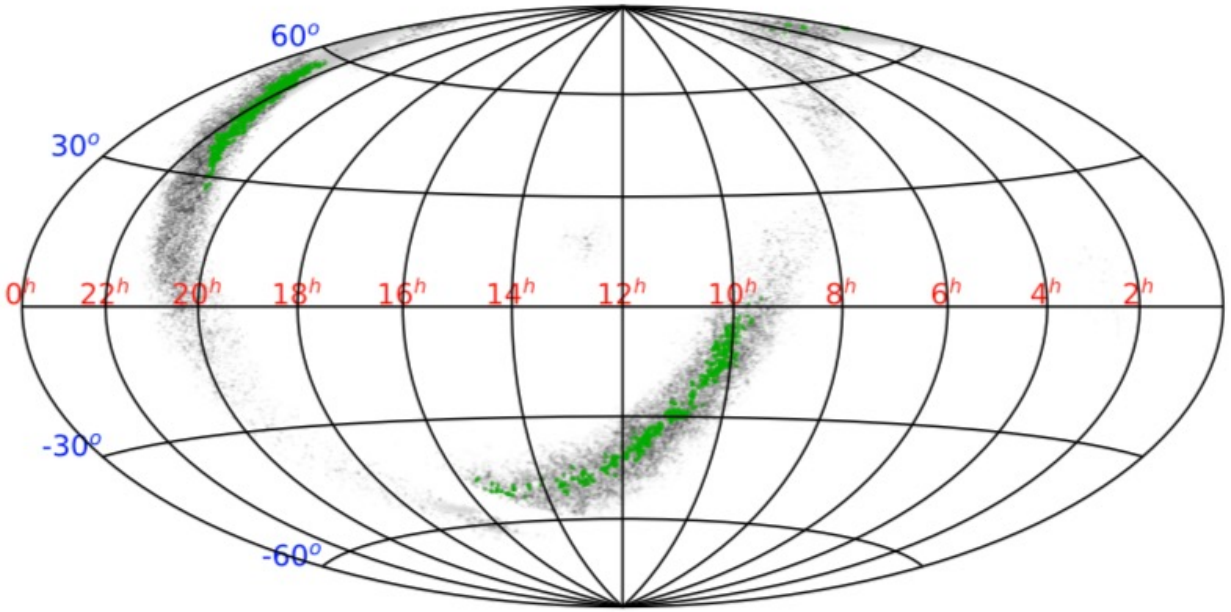
A wide-field hard X-ray monitor and sensitive focusing X-ray and UV/optical telescopes on a rapidly slewing spacecraft.

De-Orbit Date (median)	2033
Yearly Cost (NASA)	$5.5M
Refereed papers	> 4400
Refereed citations	> 100,000
Science/Nature papers (2016–2018)	24
Online ToO Requests (2018)	1752
Successful GI Proposers	1050
PhDs based on *Swift*	242

Updated up to 2019

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Capability to rapidly tile large area of the sky



In this example Swift carried out over 1400 observations covering 191 deg^2 in 48 hours to tile a candidate GW localization

Swift

Satellite with BAT, XRT & UVOT Installed

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA