ALERTS FROM GAMMA-RAY BURSTS

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PLAN OF THE PRESENTATION

1. Gamma-Ray Bursts Phenomenon
2. What and When, i.e. what is the critical information and how it is used
    i. *The example of GRB 171205A*
3. Conclusions and Perspectives

GAMMA-RAY BURSTS AND TIME DOMAIN ASTROPHYSICS

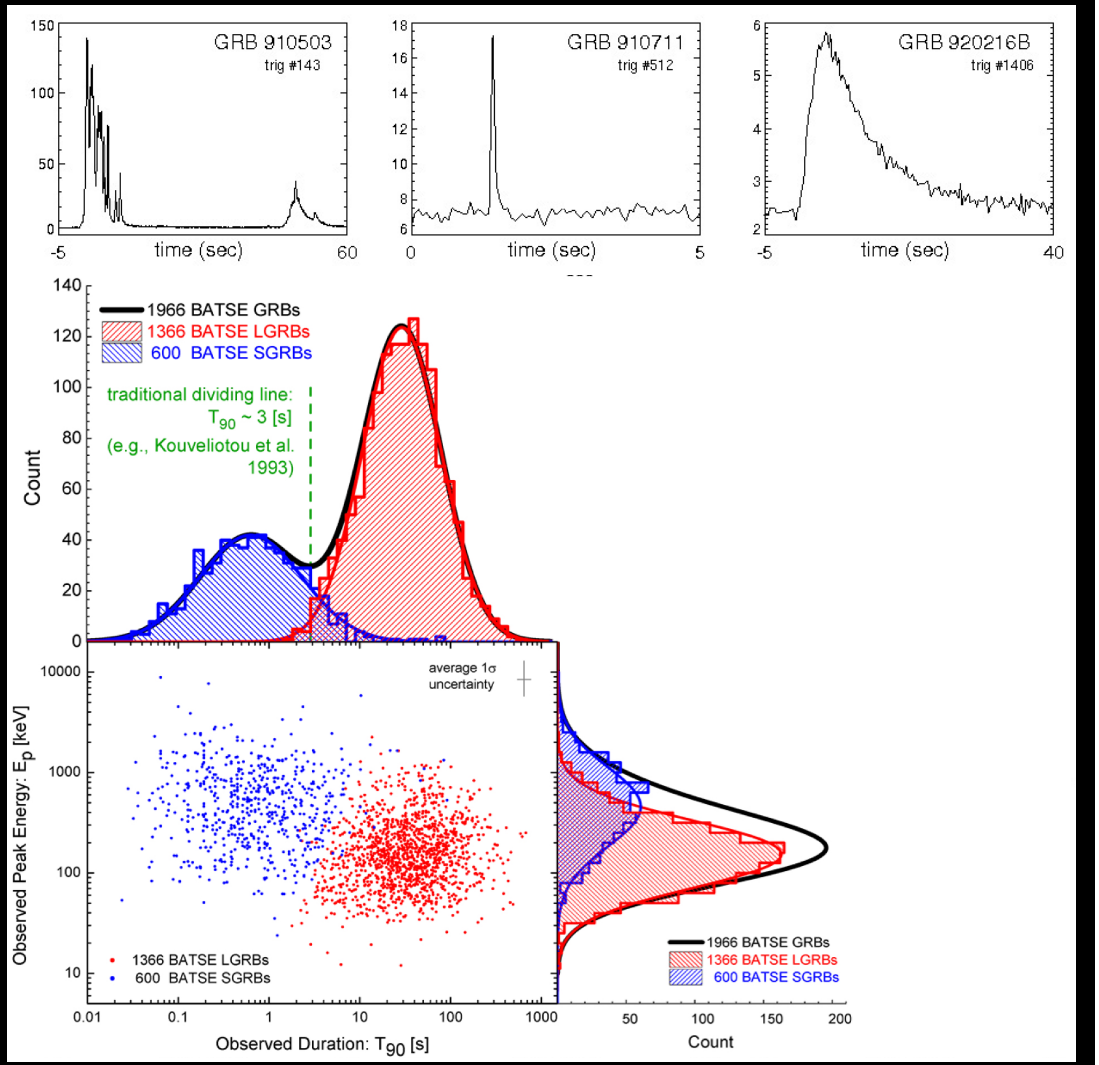
- The study of the time variation of sources is a common practice in astronomy and especially in the X- and gamma-ray domain since the first satellite experiments, but it was made « by hand »

- What we understand today under TDA is the use of modern computational techniques in order to detect characterise transient and variable sources in near real-time and inform on the shortest delays the astronomical community at large in order to organise an efficient follow-up with other instruments

GAMMA-RAY BURSTS

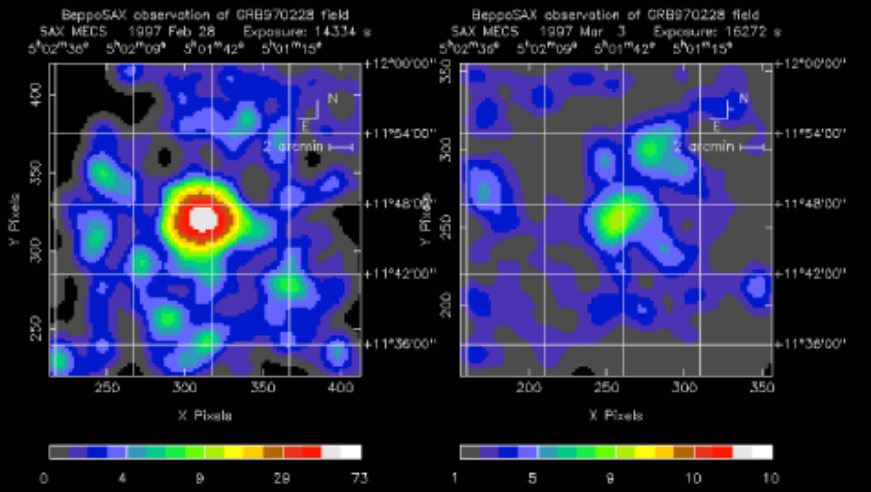
GAMMA-RAY BURSTS

- GRB are short flashes of gamma-ray radiation with a by-modal time distribution
- They appear randomly over the entire sky
- They spectra are mainly-non thermal
- The variability and the spectra imply a relativistic compact object origin

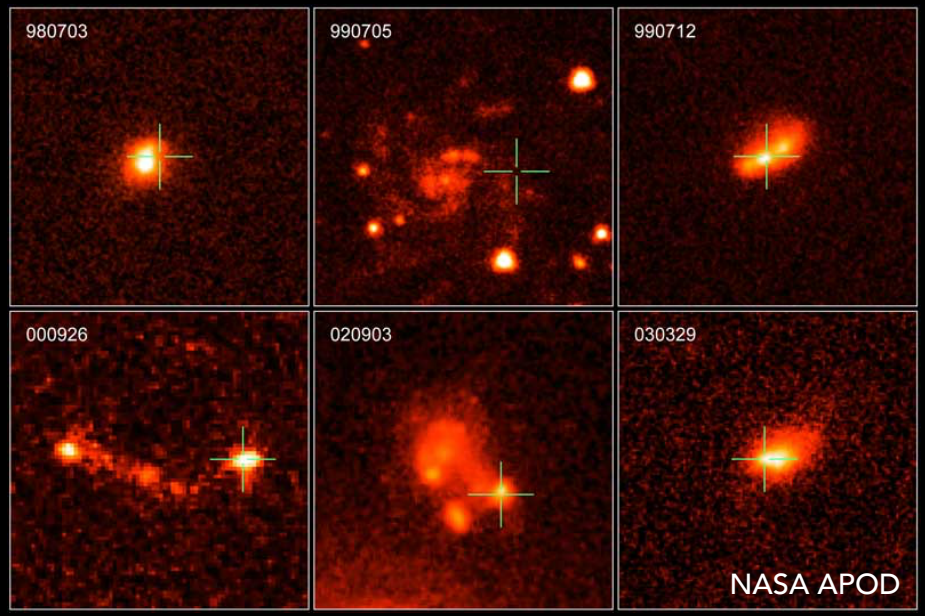


GAMMA-RAY BURSTS AFTERGLOWS

- Major discovery (GRB 970228) by the Italian-Dutch BeppoSAX satellite: GRBs are followed by long term declining X-ray emission; well localized
- This led to the discovery of optical afterglows and finally of GRB host galaxies
- Measured (spectroscopic and photometric) redshifts between ~0.1 and ~9.4
- E_{ISO}~10^{50}-10^{54} erg
- GRBs are powerful cosmic explosions

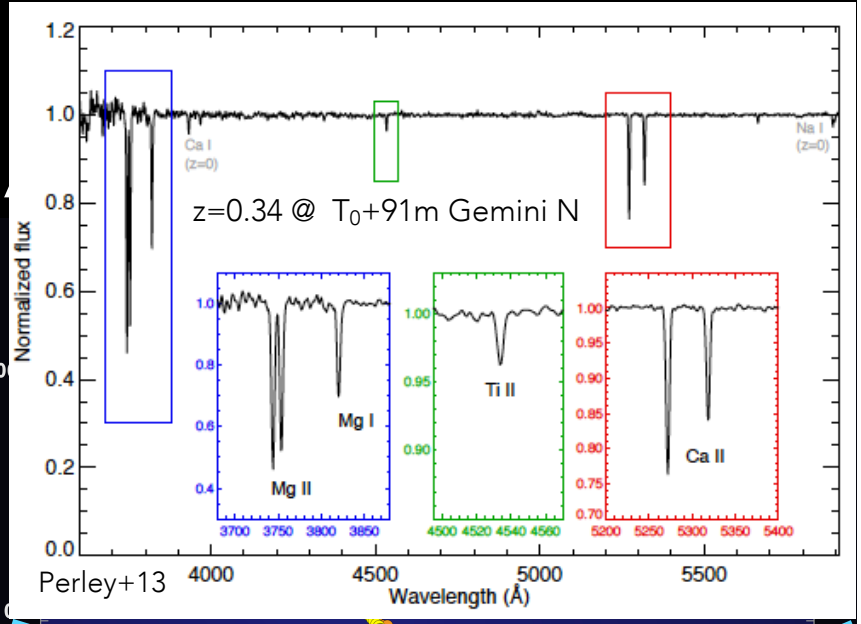


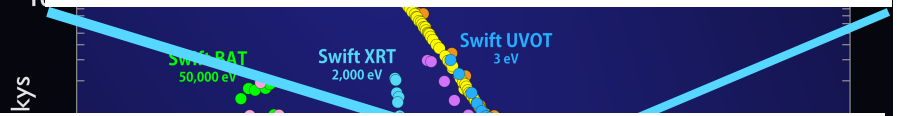
Costa+97

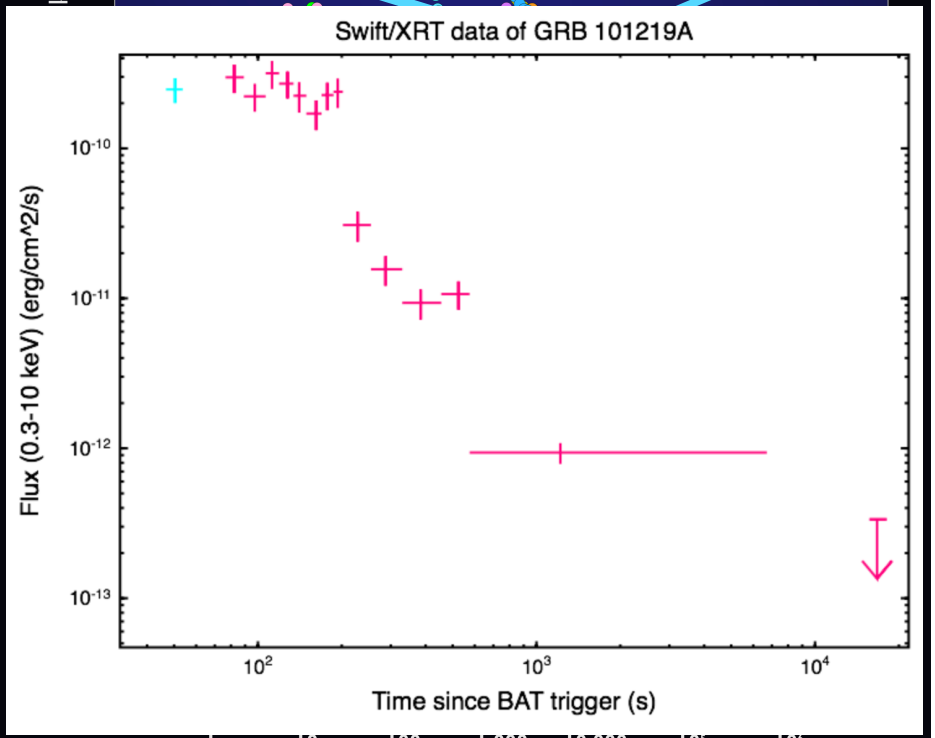


GAMMA-RAY BURSTS

- GRB afterglows are panchromatic events
- They are detected from radio to GeV
- They show fast decline and variability
- Fast reaction is the key!
- Today mainly discovered and localized by Swift, Fermi, and INTEGRAL

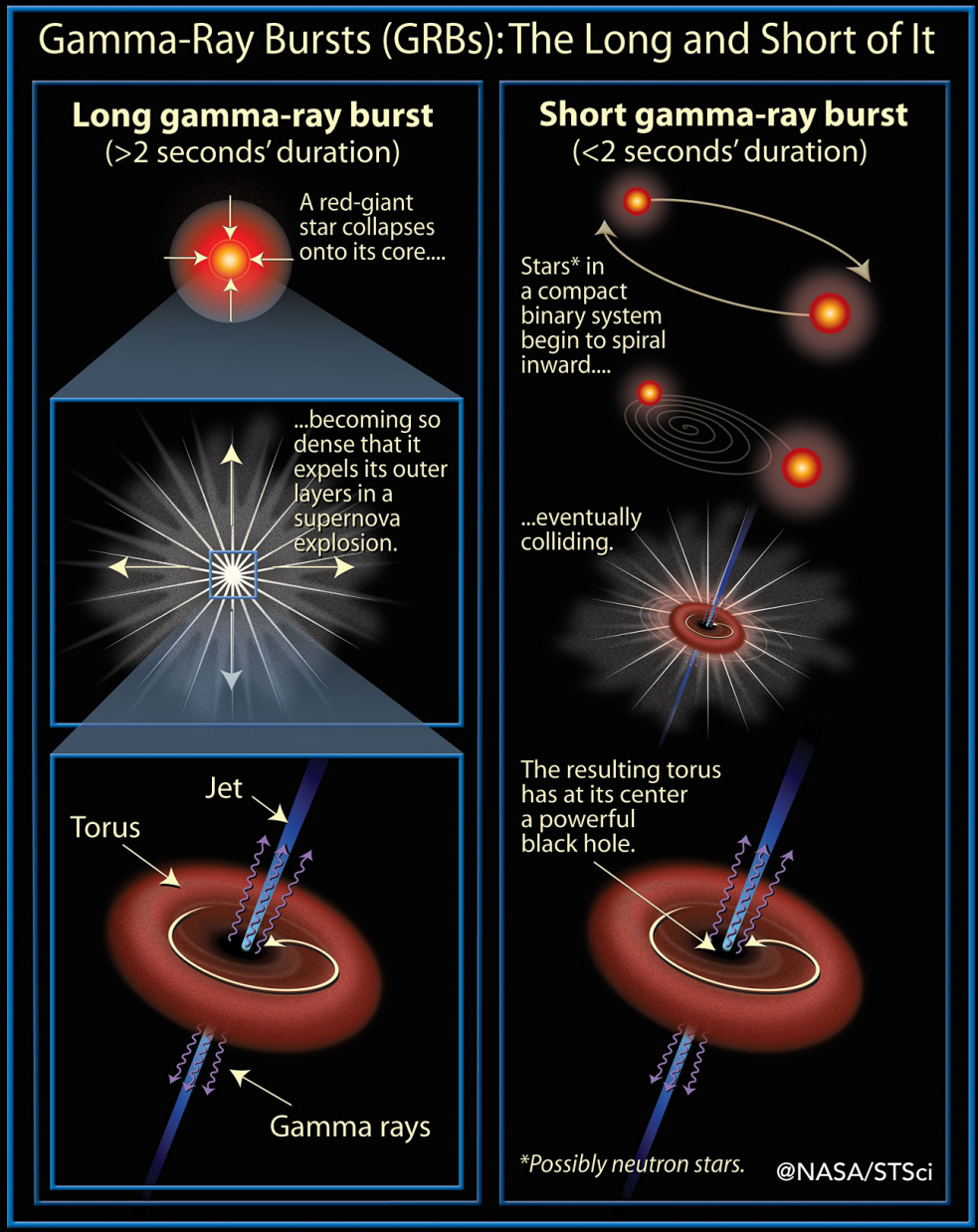




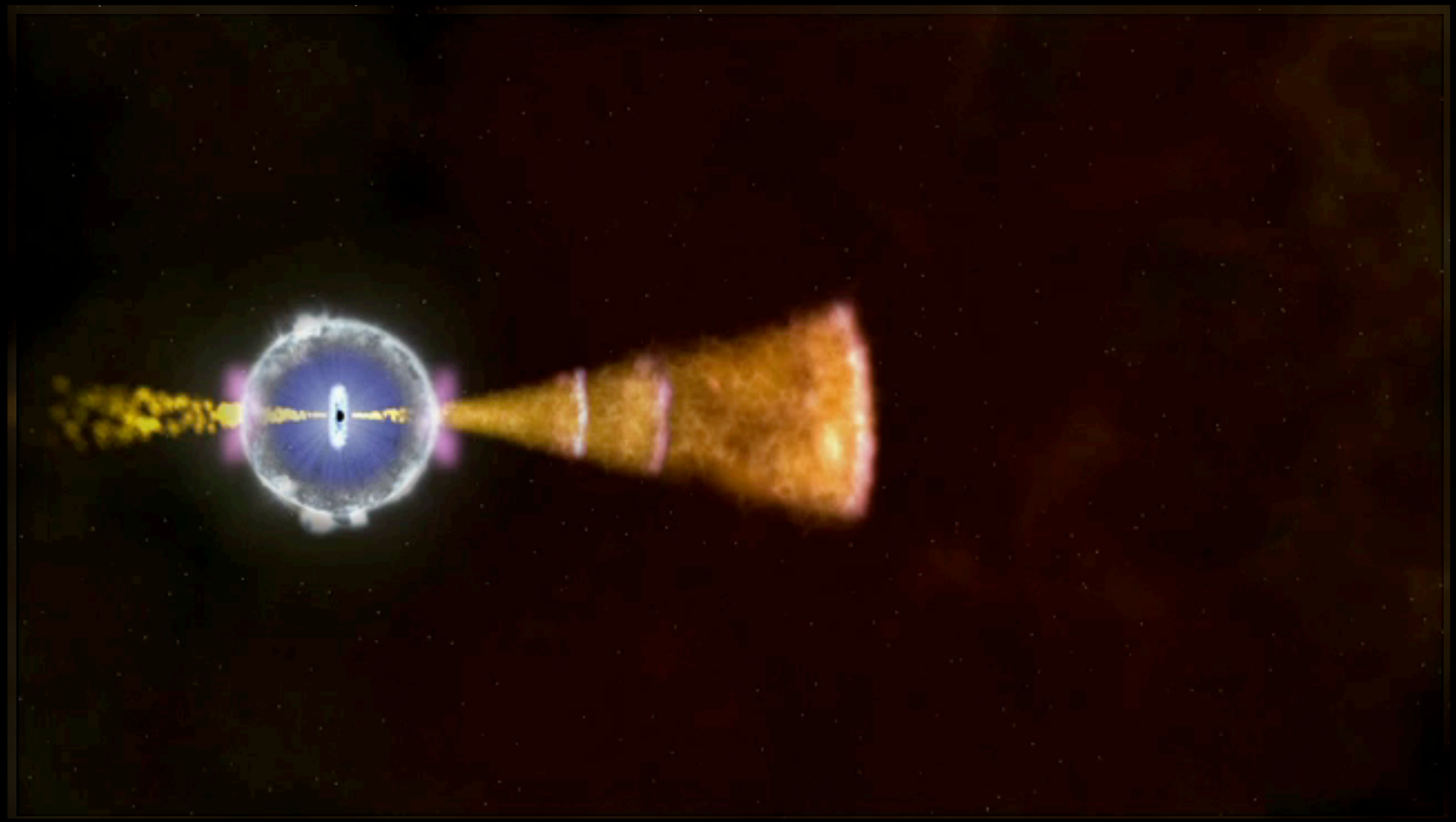


GAMMA-RAY BURSTS MODELS

- Two distinct progenitors for the two classes
- Long GRBs are the endpoint of very massive (binary?) stars
  - Association to SN Ib/c for some GRBs confirms this scenario
- Short GRBs are associated with the merger of two compact objects: NS-NS, NS-BH,…
- The production of a relativistic jet is a common feature
- There is no consensus on the central engine: BH or Magnetar?

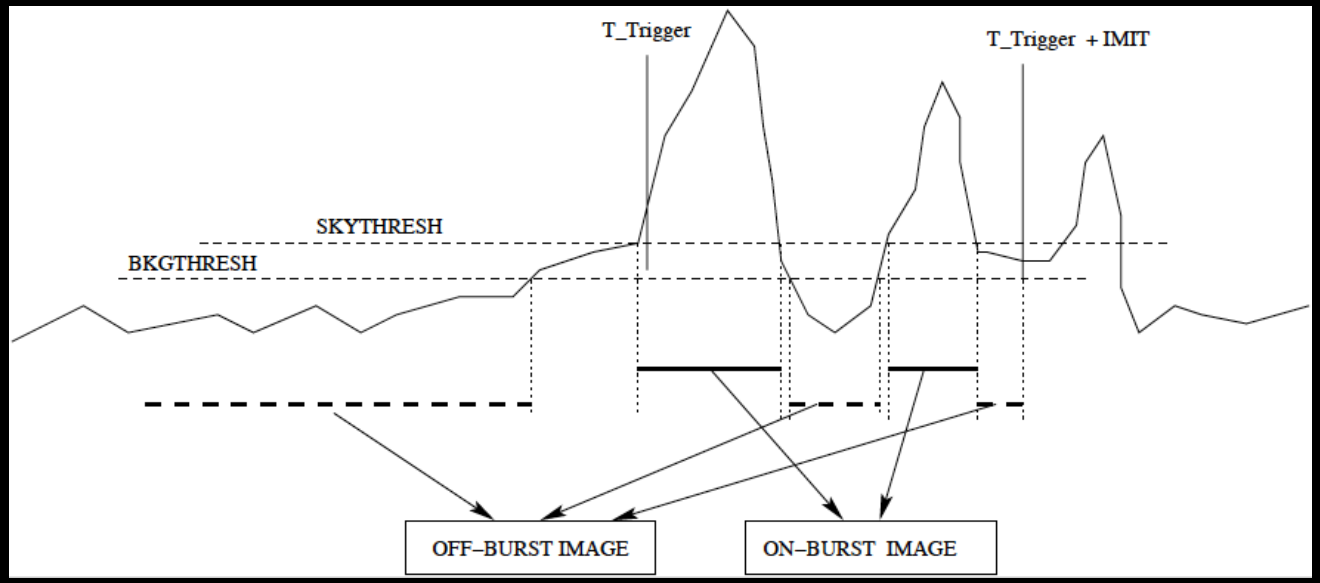


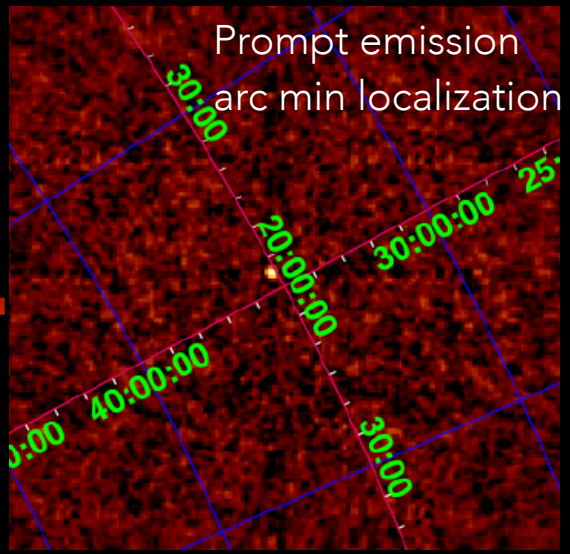
GAMMA-RAY BURSTS MODELS



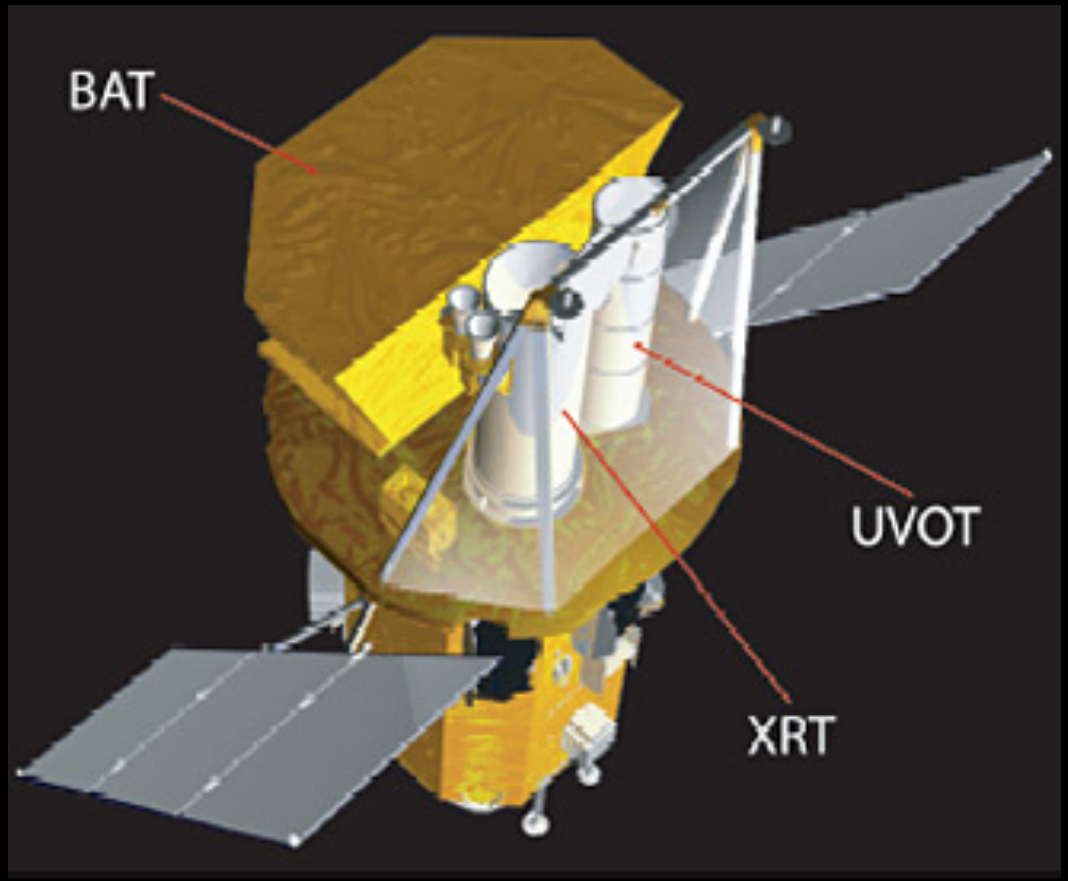
@NASA/GSFC

REAL-TIME FLOW





THE NASA SWIFT SATELLITE



Burst Alert Telescope
wide FOV (~2 sr)
15-150 keV coded mask telescope

X-Ray Telescope
small FOV (23.6x23.6 arc min)
0.2-10 keV Wolter-I focussing telescope

UVOT
UV-Optical Telescope
17x17 arc min
170-600 nm

SHARING INFORMATION

- Today the information is mostly exchanged through the (public!) Gamma-ray Coordinate Network (GCN) (https://gcn.gsfc.nasa.gov), either in form of notices or circulars
- notices are automatically generated short and mostly intended to be read by machines. They contain the vary basic information about the event. The most important ones are the GRB position, time and flux.
- circulars are longer text messages written by a human being and intended to be read by humans. They contain more detailed information, intended to stimulate and facilitate the follow-up observation by other facilities (redshift, links to finding charts,…).

A SPECIFIC EXAMPLE: GRB171205A

- Swift/BAT trigger number 794972
- Emitted about 30 s after the GRB start at 07:26:19 UT
- Contains
  - GRB RA, DEC, error (3 arc min)
  - GRB Time
  - GRB SNR
  - Trigger time scale (here it is an imaging trigger)

```
////////////////////////////////////////////////////////////////////////
TITLE:          GCN/SWIFT NOTICE
NOTICE_DATE:    Tue 05 Dec 17 07:26:19 UT
NOTICE_TYPE:    Swift-BAT GRB Position
TRIGGER_NUM:    794972,   Seg_Num: 0
GRB_RA:         167.447d {+11h 09m 47s} (J2000),
                167.672d {+11h 10m 41s} (current),
                166.820d {+11h 07m 17s} (1950)
GRB_DEC:        -12.604d {-12d 36' 12"} (J2000),
                -12.701d {-12d 42' 03"} (current),
                -12.332d {-12d 19' 55"} (1950)
GRB_ERROR:      3.00 [arcmin radius, statistical only]
GRB_INTEN:      0 [cnts]    Image_Peak=1321 [image_cnts]
TRIGGER_DUR:    64.000 [sec]
TRIGGER_INDEX:  20000     E_range: 15-50 keV
BKG_INTEN:      0 [cnts]
BKG_TIME:       0.00 SOD {00:00:00.00} UT
BKG_DUR:        0 [sec]
GRB_DATE:       18092 TJD;   339 DOY;   17/12/05
GRB_TIME:       26443.89 SOD {07:20:43.89} UT
GRB_PHI:         -2.22 [deg]
GRB_THETA:       44.44 [deg]
SOLN_STATUS:    0x13
RATE_SIGNIF:    0.00 [sigma]
IMAGE_SIGNIF:   9.46 [sigma]
MERIT_PARAMS:    +1  +0  +0  +6  +1  +0  +0  +0 -17  +0
SUN_POSTN:      251.95d {+16h 47m 47s}  -22.40d {-22d 23' 55"}
SUN_DIST:        79.99 [deg]   Sun_angle= 5.6 [hr] (West of Sun)
MOON_POSTN:      96.94d {+06h 27m 45s}  +19.94d {+19d 56' 26"}
MOON_DIST:       76.85 [deg]
MOON_ILLUM:     96 [%]
GAL_COORDS:     267.84, 43.24 [deg] galactic lon,lat of the burst (or transient)
ECL_COORDS:     173.54,-16.53 [deg] ecliptic lon,lat of the burst (or transient)
COMMENTS:       SWIFT-BAT GRB Coordinates.
COMMENTS:       This Notice was delayed by more than 60 sec past the end of the trigger integration interval;
COMMENTS:       probably due to it occurring during a Malindi downlink session.
COMMENTS:       This is an image trigger.  (The RATE_SIGNIF & BKG_{INTEN, TIME, DUR} are undefined.)
COMMENTS:       A point_source was found.
COMMENTS:       This does not match any source in the on-board catalog.
COMMENTS:       This does not match any source in the ground catalog.
COMMENTS:       This is a GRB.
COMMENTS:       This trigger occurred at longitude,latitude = 11.57,1.84 [deg].
```

Followed by the « Swift will observe notice » at 07:26:33 UT and the « Swift will slew notice » at 07:26:41 UT

A SPECIFIC EXAMPLE: GRB171205A

- XRT starts observing and reports automatically about the improved GRB position at 07:26:51 UT (only about 30 s after the first notice, small slew)
- The error shrieked to 5 arc sec
- The position is compatible with the BAT one

```
//////////////////////////////////////////////////////////////////////
TITLE:           GCN/SWIFT NOTICE
NOTICE_DATE:     Tue 05 Dec 17 07:26:51 UT
NOTICE_TYPE:     Swift-XRT Position
TRIGGER_NUM:     794972,   Seg_Num: 0
GRB_RA:          167.4144d {+11h 09m 39.45s} (J2000),
                 167.6393d {+11h 10m 33.42s} (current),
                 166.7876d {+11h 07m 09.02s} (1950)
GRB_DEC:         -12.5857d {-12d 35' 08.5"} (J2000),
                 -12.6831d {-12d 40' 59.3"} (current),
                 -12.3143d {-12d 18' 51.5"} (1950)
GRB_ERROR:       5.0 [arcsec radius, statistical plus systematic, 90% containment]
GRB_INTEN:       2.81e-09 [erg/cm2/sec]
GRB_SIGNIF:      9.69 [sigma]
IMG_START_DATE:  18092 TJD;   339 DOY;   17/12/05
IMG_START_TIME:  26588.59 SOD {07:23:08.59} UT,   144.7 [sec] since BAT Trigger Time
TAM[0-3]:        327.65 237.21 261.53 243.38
AMPLIFIER:       2
WAVEFORM:        134
SUN_POSTN:       251.95d {+16h 47m 47s}  -22.40d {-22d 23' 55"}
SUN_DIST:         80.03 [deg]   Sun_angle= 5.6 [hr] (West of Sun)
MOON_POSTN:       96.94d {+06h 27m 46s}  +19.94d {+19d 56' 27"}
MOON_DIST:        76.80 [deg]
MOON_ILLUM:      96 [%]
GAL_COORDS:      267.79, 43.23 [deg] galactic lon,lat of the burst
ECL_COORDS:      173.51,-16.53 [deg] ecliptic lon,lat of the burst
COMMENTS:        SWIFT-XRT Coordinates.
COMMENTS:        The XRT position is 2.18 arcmin from the BAT position.
```

The following notices alerts about the availability of TDRSS products (light curves, images, spectra).
The last notices are used to announce Swift revisits.

A SPECIFIC EXAMPLE: GRB171205A

- The first Swift circulars are semi-automatic. They need just to be checked by humans that update a few values. Sent at 07:48:19 UT (22 min after the first notice).
- The first GRB duration value (T_{90}) is contained in the BAT one.

```
////////////////////////////////////////////////////////////////////////
TITLE:   GCN CIRCULAR
NUMBER:  22177
SUBJECT: GRB 171205A: Swift detection of a burst
DATE:    17/12/05 07:48:19 GMT
FROM:    Boris Sbarufatti at PSU  <bxs60@psu.edu>

V. D'Elia (ASDC), A. D'Ai (INAF-IASFPA), A. Y. Lien (GSFC/UMBC) and
B. Sbarufatti (PSU) report on behalf of the Swift Team:

At 07:20:43 UT, the Swift Burst Alert Telescope (BAT) triggered and
located GRB 171205A (trigger=794972).  Swift slewed immediately to the burst.
The BAT on-board calculated location is
RA, Dec 167.447, -12.604 which is
   RA(J2000) = 11h 09m 47s
   Dec(J2000) = -12d 36' 12"
with an uncertainty of 3 arcmin (radius, 90% containment, including
systematic uncertainty). As is usual with an image trigger, the available
BAT light curve shows no significant structure.

The XRT began observing the field at 07:23:08.5 UT, 144.7 seconds after
the BAT trigger. XRT found a bright, uncatalogued X-ray source located
at RA, Dec 167.4144, -12.5857 which is equivalent to:
   RA(J2000)  = +11h 09m 39.46s
   Dec(J2000) = -12d 35' 08.5"
with an uncertainty of 5.0 arcseconds (radius, 90% containment). This
location is 132 arcseconds from the BAT onboard position, within the
BAT error circle. No event data are yet available to determine the
column density using X-ray spectroscopy.

UVOT took a finding chart exposure of 150 seconds with the White filter
starting 153 seconds after the BAT trigger. No credible afterglow candidate has
been found in the initial data products. The 2.7'x2.7' sub-image covers 100% of
the XRT error circle. The typical 3-sigma upper limit has been about 19.6 mag.
The 8'x8' region for the list of sources generated on-board covers 100% of the
XRT error circle. The list of sources is typically complete to about 18 mag. No
correction has been made for the expected extinction corresponding to E(B-V) of
0.05.

Burst Advocate for this burst is V. D'Elia (delia AT asdc.asi.it).
Please contact the BA by email if you require additional information
regarding Swift followup of this burst. In extremely urgent cases, after
trying the Burst Advocate, you can contact the Swift PI by phone (see
Swift TOO web site for information: http://www.swift.psu.edu/too.html.)
```

A SPECIFIC EXAMPLE: GRB171205A

- At 08:38:42 UT the first independent (i.e. non-Swift) circular
- The GRB is likely to be very close, but no UVOT detection has been reported.
- ??? Interesting ???

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////////////////////////////////////////////////////////////////////////
TITLE:   GCN CIRCULAR
NUMBER:  22178
SUBJECT: GRB 171205A: Likely association with low-z spiral galaxy
DATE:    17/12/05 08:38:42 GMT
FROM:    Alexander Kann at TLS Tautenburg  <kann@tls-tautenburg.de>

L. Izzo, D. A. Kann (both HETH/IAA-CSIC), J. P. U. Fynbo (DARK), A. J.
Levan (U. Warwick), and N. R. Tanvir (U. Leicester) note on behalf of the
Stargate Consortium:

The XRT position of GRB 171205A (V. D'Elia et al. GCN #22177) contains a
bright spiral galaxy 2MASX J11093966-1235116 which lies at z = 0.037
according to SIMBAD (6df Galaxy Catalog).

The combination of a BAT image trigger, a bright XRT afterglow and lack of
a bright optical afterglow may indicate a source similar to XRFs 060218
and 100316D.

Multiwavelength follow-up is encouraged.
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At 10:32:58 UT (GCN 22179), the enhanced XRT postion is published, 2.3 arc sec error radius.

A SPECIFIC EXAMPLE: GRB171205A

- VLT/X-shooter results announced at 11:01:51 UT (3.5 hours after the first notice)
- Observations done at 08:56 UT (i.e. using the first XRT position)
- There is a bright (16 mag) R band counterpart
- The redshift is announced: indeed a very nearby GRB at z=0.0368, strengthening the association with the putative HG

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////////////////////////////////////////////////////////////////////////
TITLE:   GCN CIRCULAR
NUMBER:  22180
SUBJECT: GRB 171205A: VLT/X-shooter optical counterpart and spectroscopic
observations
DATE:    17/12/05 11:01:51 GMT
FROM:    Jonatan Selsing at DARK/NBI  <jselsing@dark-cosmology.dk>

L. Izzo (HETH/IAA-CSIC), J. Selsing (DARK), J. Japelj (API, Univ. Amsterdam),
B.
Milvang-Jensen, J. P. U. Fynbo (both DARK), D. Xu (NAOC), D. A. Kann
(HETH/IAA-CSIC), N. R. Tanvir, R. Starling (both U. Leicester), A. J. Levan, K.
Wiersema (both U. Warwick), G. Pugliese (API, Univ. Amsterdam), V. D'Elia
(ASI-SSDC), and S. Campana (INAF-Brera) report on behalf of the Stargate
Consortium:

We observed the optical afterglow of GRB 171205A (V. D'Elia et al. GCN #22177)
with the ESO VLT/X-shooter spectrograph, covering the wavelength range
3500-20000 AA. Spectroscopy started at 08:56:18 UT on 2017-12-05 (i.e., 1.5 hr
after the GRB) and consisted of 1 exposure of 600 s taken in twilight.

From the acquisition image prior to the spectroscopy, a new optical transient
is clearly detected in the outskirts of the putative host galaxy (L. Izzo et
al. GCN #22178) at the following coordinates:

RA(J2000) = 11h 09m 39.573s Dec.(J2000) = -12d 35' 17.37"

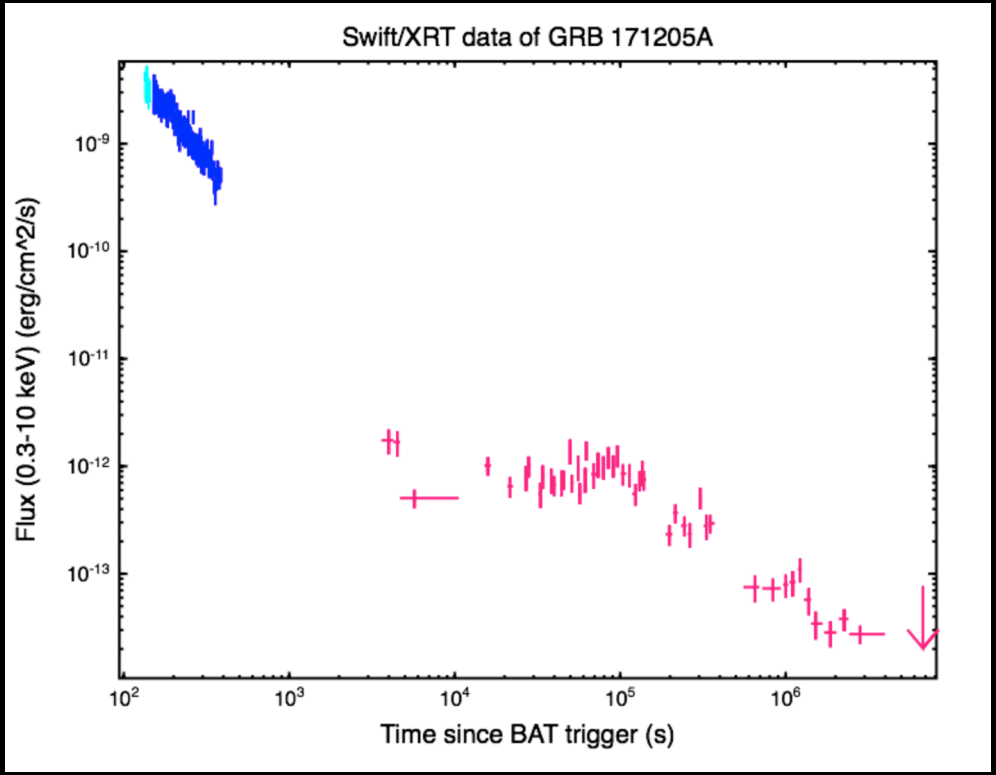
This source is inside the error box reported by (J.P. Osborne et al. GCN
#22179). From the acquisition image we measure this source to have m(r)~16.0
mag, calibrated with a nearby Pan-STARRS star.

The source continuum is well detected across the entire spectral coverage and
clear emission lines are superposed on it identified as Halpha, [N II] 6584,
and [S II] 6717/32 located at z = 0.0368, suggesting an association with the
nearby galaxy. Additionally, a tentative detection of absorption lines
identified as NaI 5891/5897 in the continuum further supports z = 0.0368 as the
redshift of the GRB.

We acknowledge the excellent support from the ESO staff, particularly Jose
Velasquez and Zahed Wahhaj in obtaining these observations.
```

A SPECIFIC EXAMPLE: GRB171205A

- Marginal evidence (galaxy contamination!) of a source in the white filter of the UVOT data is reported at 13:45 UT (GCN 2281). The position is consistent with the VLT one.
- At 15:10 UT (GCN 22182) RATIR reports an r, i, Z, Y band source observed between 2.5 and 5.3 hr after trigger
- At 16:08 UT Swift-XRT refined analysis is published. The source is bright and decaying fast. Nothing really unusual.
- At 17:49 UT Swift-BAT refined analysis. Refined T_{90} (189 s). The spectrum is not unusual. The flux is high, but the Energy (E_{ISO}) is low! 5e49 erg! A low luminosity burst!



Assuming z = 0.0368 (Izzo et al., GCN Circ. 22180) and a standard cosmology model with H_0 = 70.5 km/s/Mpc, Omega_M = 0.274, Omega_\Lambda = 0.726 (Spergel et al. 2007), the isotropic energy release Eiso (in the observed 15-150 keV band) is 5.72e+49 erg. This Eiso is similar to other low-luminosity GRBs. For example, the Eiso (in the observed 15-150 keV band) for GRB060218 is 2.57e+49 erg (assuming T90 = 2100 s based on Campana et al. 2006) and GRB100316D has Eiso >= 3.70e+49 erg (assuming T90 >= 1300 s based on Starling et al. 2011).

A SPECIFIC EXAMPLE: GRB171205A

- Several optical and NIR detection announcements follow
- The source is bright in the mm band (second brightest GRB ever)
- At 17:31 UT on the 6th a detailed analysis of XRT data reports the presence of a possible thermal component in the spectrum

```
TITLE:   GCN CIRCULAR
NUMBER:  22187
SUBJECT: GRB 171205A: NOEMA detection of a bright mm afterglow
DATE:    17/12/06 10:26:44 GMT
FROM:    Antonio de Ugarte Postigo at IAA-CSIC  <deugarte@iaa.es>

A. de Ugarte Postigo (HETH/IAA-CSIC, DARK/NBI),
S. Schulze (Weizmann), M. Bremer, M. Krips (IRAM),
C.C. Thoene, L. Izzo, D.A. Kann, Z. Cano, K. Bensch
(HETH/IAA-CSIC), S. Martin Ruiz, I. de Gregorio (ALMA),
S. Kim (PUC), R. SÃ¡nchez-Ramirez (INAF-IAPS),
D. Malesani (DARK/NBI) report:

We observed the afterglow of GRB 171205A with
NOEMA at 150GHz and 90GHz starting at 3:30 UT on the
6th of December (20.2 hrs after the GRB onset). We
detect a bright afterglow in 150GHz with a preliminary
flux density estimate of 35-40 mJy. The coordinates
of the detected source are (J2000 +/- 0.05"):

R.A.: 11:09:39.52
Dec.: -12:35:18.34

We note that if the flux density is confirmed, it would be
the second brightest GRB ever detected in mm/submm
wavelengths, after GRB 030329 (for a review on
mm/submm data of GRBs see de Ugarte Postigo et al.
2012).

Further follow-up observations are encouraged.
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A SPECIFIC EXAMPLE: GRB171205A

- At 21:55 UT on the 6th the photometric properties of the host galaxy are published, suggesting a SN nature of the optical counterpart.
- At the emergence of a Supernova component is reported on the 7th.
- On the 9th a VLA detection is reported (4.5-16 GHz)
- …

```
TITLE:   GCN CIRCULAR
NUMBER:  22204
SUBJECT: GRB 171205A: Detection of the emerging SN
DATE:    17/12/07 18:13:58 GMT
FROM:    Antonio de Ugarte Postigo at IAA-CSIC  <deugarte@iaa.es>

A. de Ugarte Postigo (HETH/IAA-CSIC, DARK/NBI), L. Izzo (HETH/IAA-CSIC),
D.A. Kann (HETH/IAA-CSIC), C.C. Thoene (HETH/IAA-CSIC), P. Pesev (GTC),
R. Scarpa (GTC), D. Perez (GTC) report on behalf of a larger collaboration:

We have been monitoring the counterpart of GRB 171205A (D'Elia et al.
GCN22177; Izzo et al., GCN 22180) photometrically and spectroscopically
with OSIRIS at the 10.4m GTC telescope. Our latest observation consisted of
3x600s exposure using the R1000B grism, which covers the spectral range
between 3700 and 7880 Angstrom. On the combined spectrum, with epoch on
the 7th of December at 6:05 UT, we detect broad undulating spectral
features, which are prominent between 4000 and 6000 Angstrom, superposed to
the afterglow continuum, which seem to indicate the emergence of an
underlying supernova component. The features include a double bump in this
range, similar to what was seen for the very early spectra of SN 1998bw
(Patat et al. 2001), indicating that this is probably also a broad line Ic
supernova.

Further information will be provided through the TNS.
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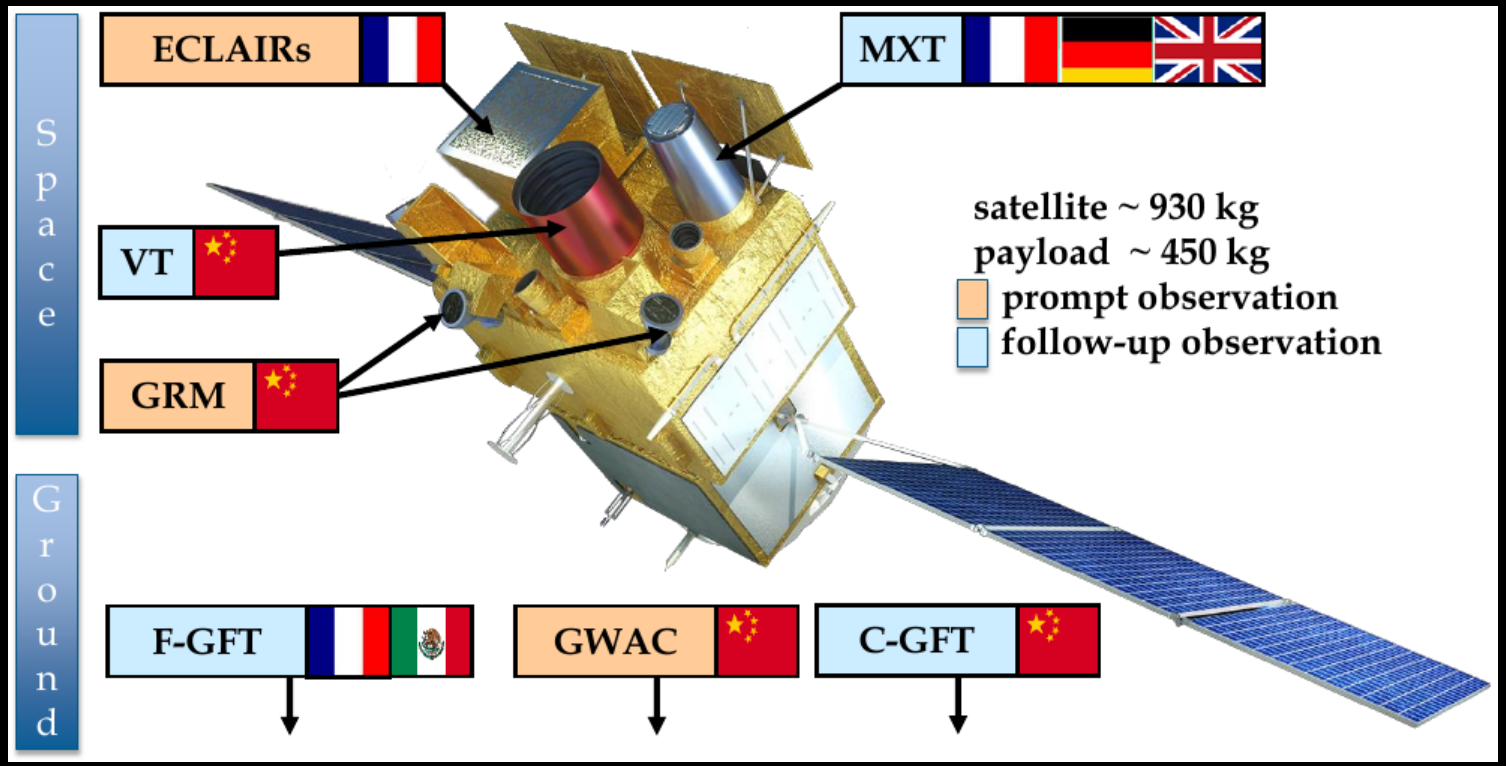
IN SUMMARY

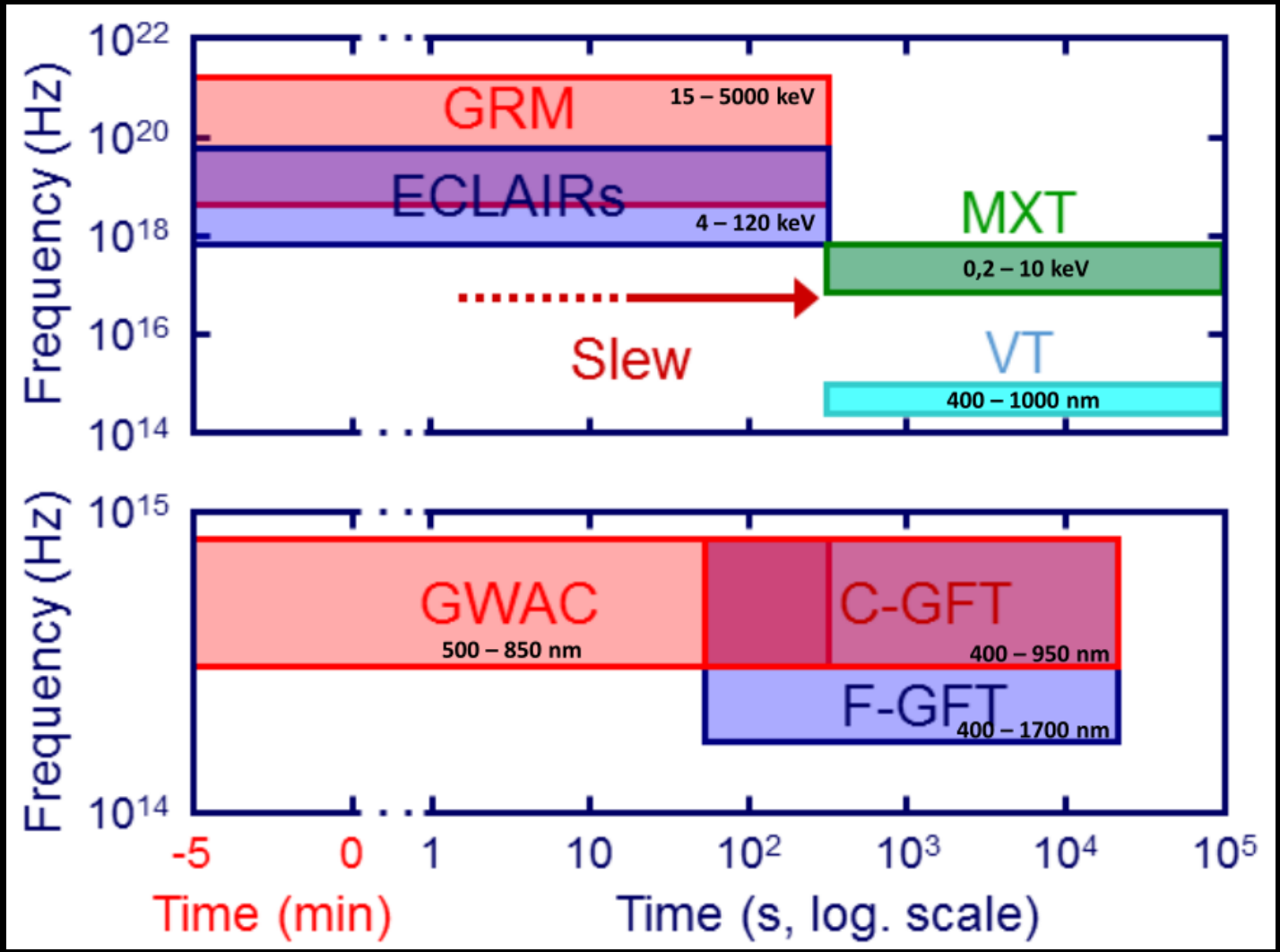
- In the Swift era many crucial informations are exchanged efficiently on the GCN circulars
- Key information is reported promptly in order to stimulate the community for the follow-up. There is no gain in « hiding » detections
- Position, time and flux are the first informations to be used (*robotic telescopes are not needed for localization in the Swift era!*)
- Spectral informations are less critical in the first hours, but are very important after, in order to make choices about continuing/stopping the follow-up, triggering large facilities (i.e. « consuming » precious AO time)
- Even ideas/suggestions and theoretical interpretation can sometimes be useful

THE SVOM MISSION CHALLENGES

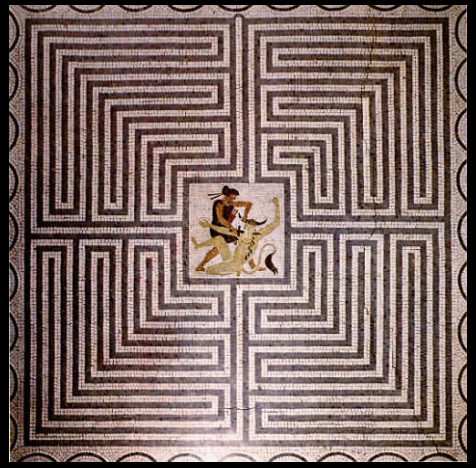
- ECLAIRs and MXT are less sensitive and precise than BAT and XRT
  - *Robotic telescopes will play a key role in the SVOM era*
- VHF data may not be critical (like TDRSS ones), except for crude flux and duration estimation. But are useful internal diagnostic tools.
  - *Waiting for X-band data may probably be appropriate (TBD)*



SVOM MULTI-WAVELENGTH COVERAGE

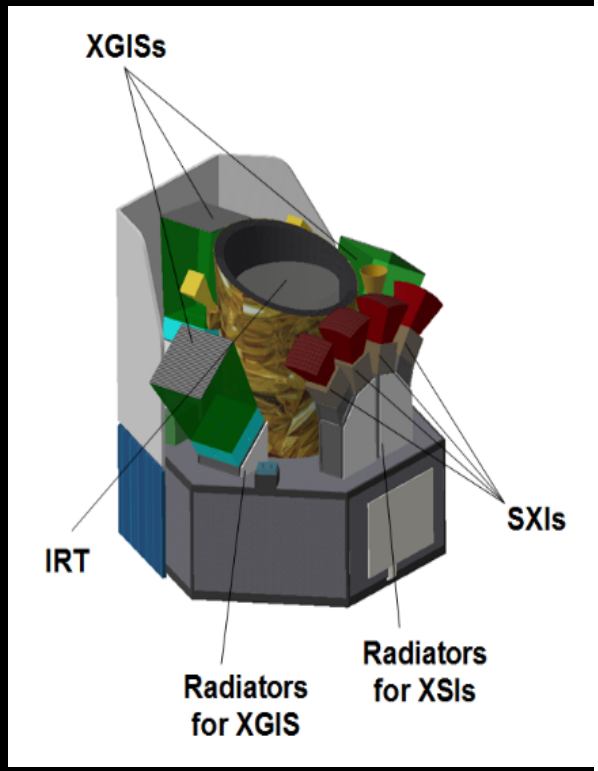


BEYOND SVOM: THESEUS



An M5 project, selected for competitive (3 candidates) phase 0/A study, lead by L. Amati (INAF Bologna); launch date 2029-2030

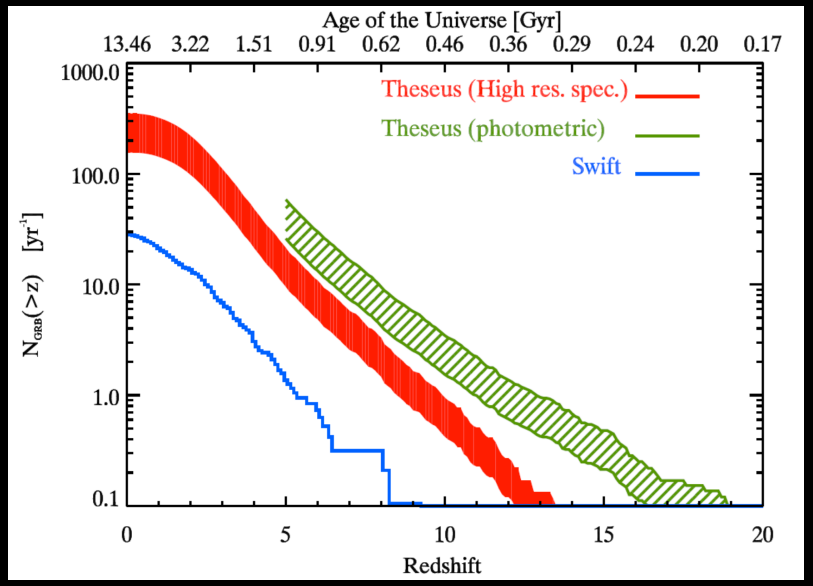
- **Soft X-ray Imager (SXI):** a set of four sensitive lobster-eye telescopes observing in 0.3 - 5 keV band, total FOV of ~1 sr with source location accuracy < 1-2'; **UK lead**
- **X-Gamma rays Imaging Spectrometer (XGIS)**: 3 coded-mask X-gamma ray cameras using bars of Silicon diodes coupled with CsI crystal scintillators observing in 2 keV – 10 MeV band, a FOV of ~1sr, overlapping the SXI, with ~5' source location accuracy;. **Italy lead**
- **InfraRed Telescope (IRT)**: a 0.7m class IR telescope observing in the 0.7 – 1.8 μm band, providing a 10'x10' FOV, with both imaging and moderate resolution spectroscopy capabilities; **France lead (CEA, LAM, IRAP, GEPI, …?)**

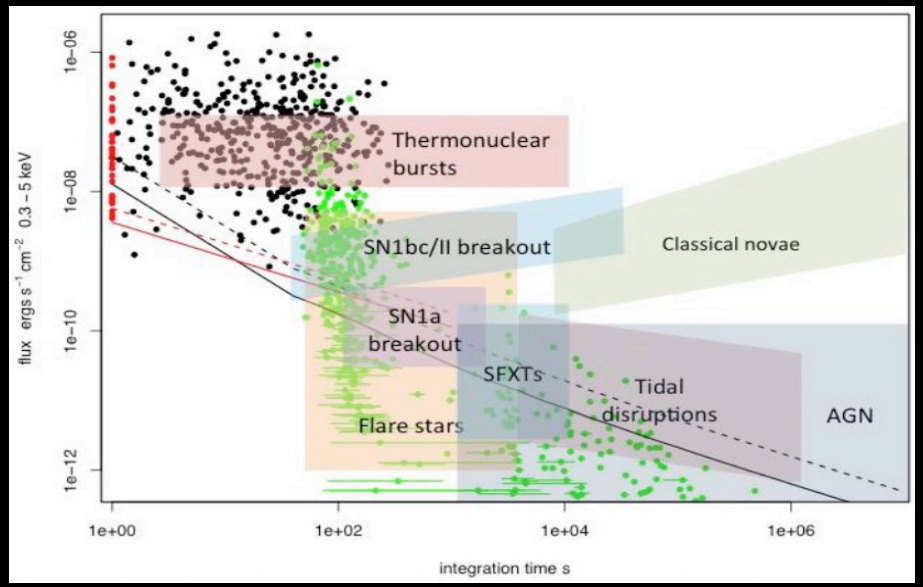


- LEO (< 5°, ~600 km)
- Rapid slewing bus
- Prompt downlink

THESEUS: THE ULTIMATE GRB MACHINE

THESEUS GRB#/yr	All	z > 5	z > 8	z > 10
Detections	387 - 870	25 – 60	4 – 10	2 - 4
Photometric z		25 – 60	4 – 10	2 - 4
Spectroscopic z	156 - 350	10 - 20	1 - 3	0.5 - 1





Transient type	SXI Rate
GW sources	0.03-33 yr^{-1}
Magnetars	40 day^{-1}
SN shock breakout	4 yr^{-1}
TDE	50 yr^{-1}
AGN+Blazars	350 day^{-1}
Thermonuclear bursts	35 day^{-1}
Novae	250 yr^{-1}
Dwarf novae	30 day^{-1}
SFXTs	1000 yr^{-1}
Stellar flares	400 yr^{-1}
Stellar super flares	200 yr^{-1}

Theseus aims at being independent from short time ground based follow-up