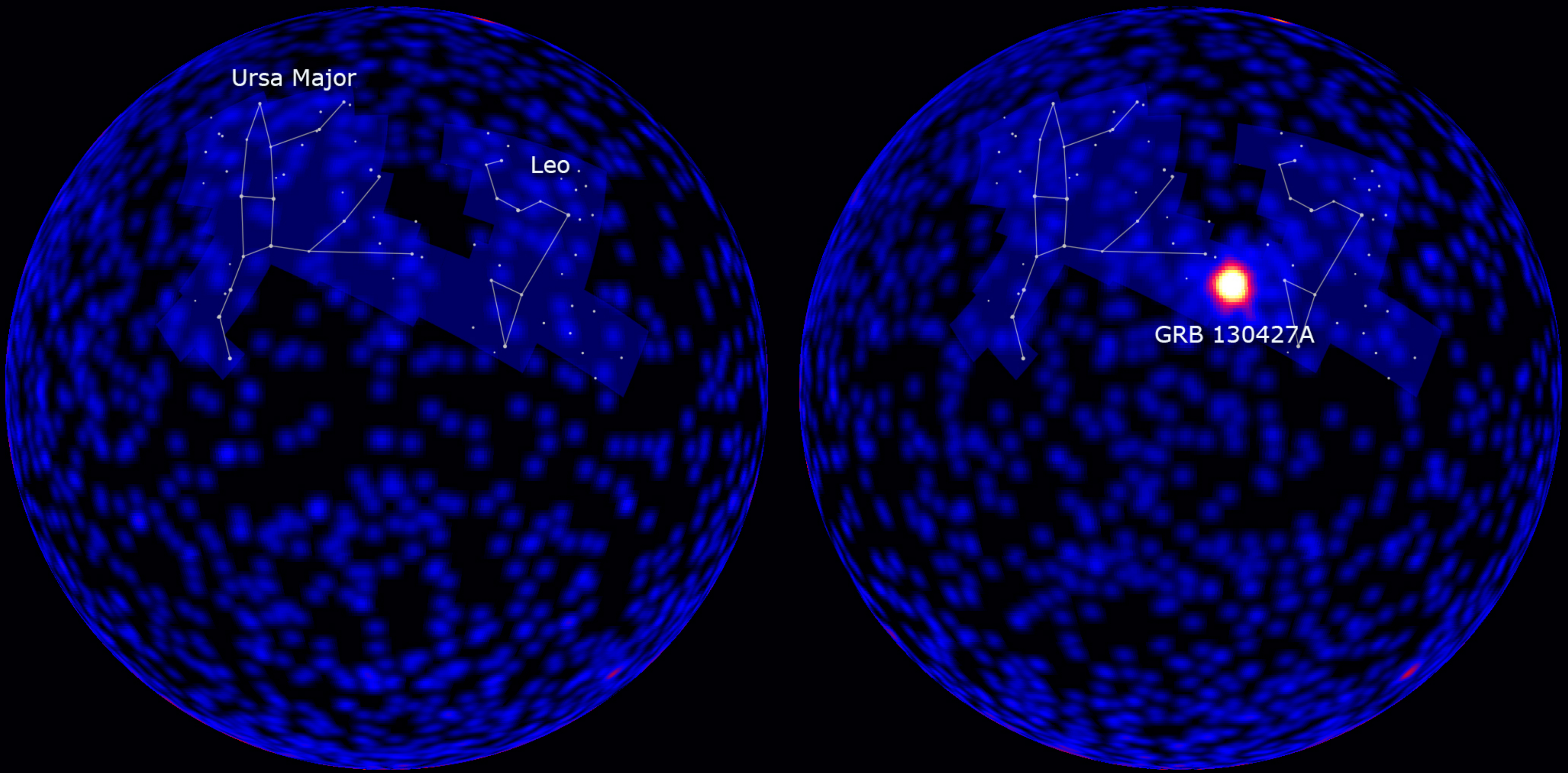
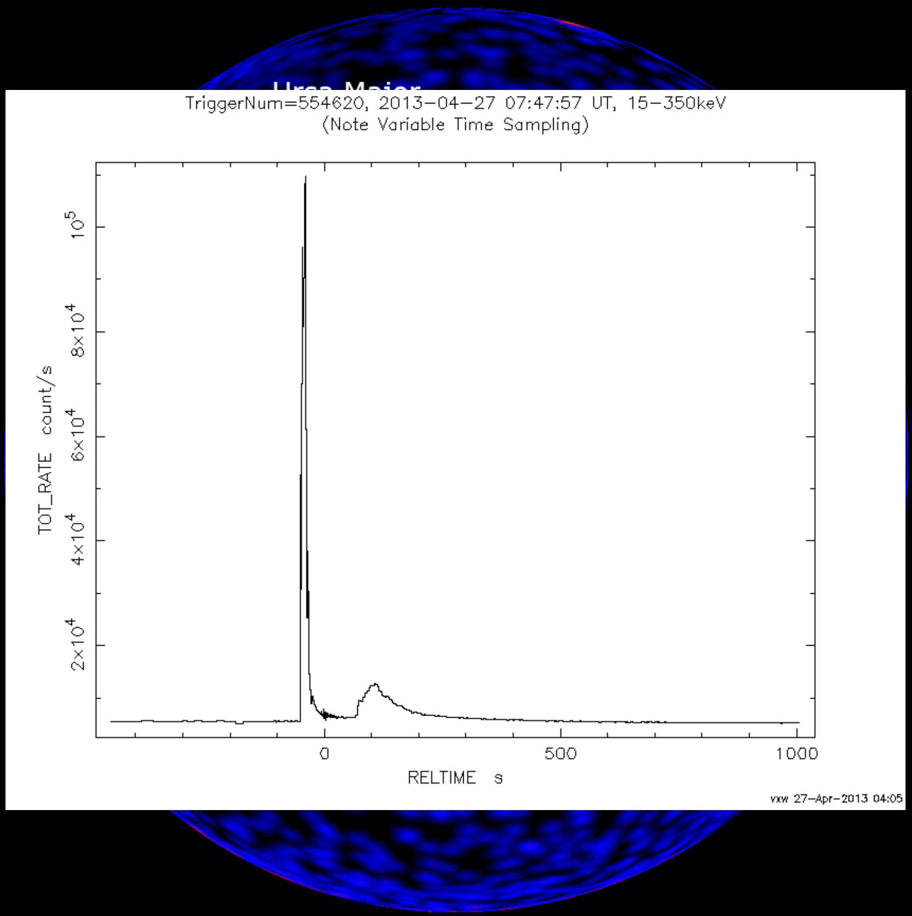
I 10 anni del satellite Swift: il rondone che sonda l' Universo violento

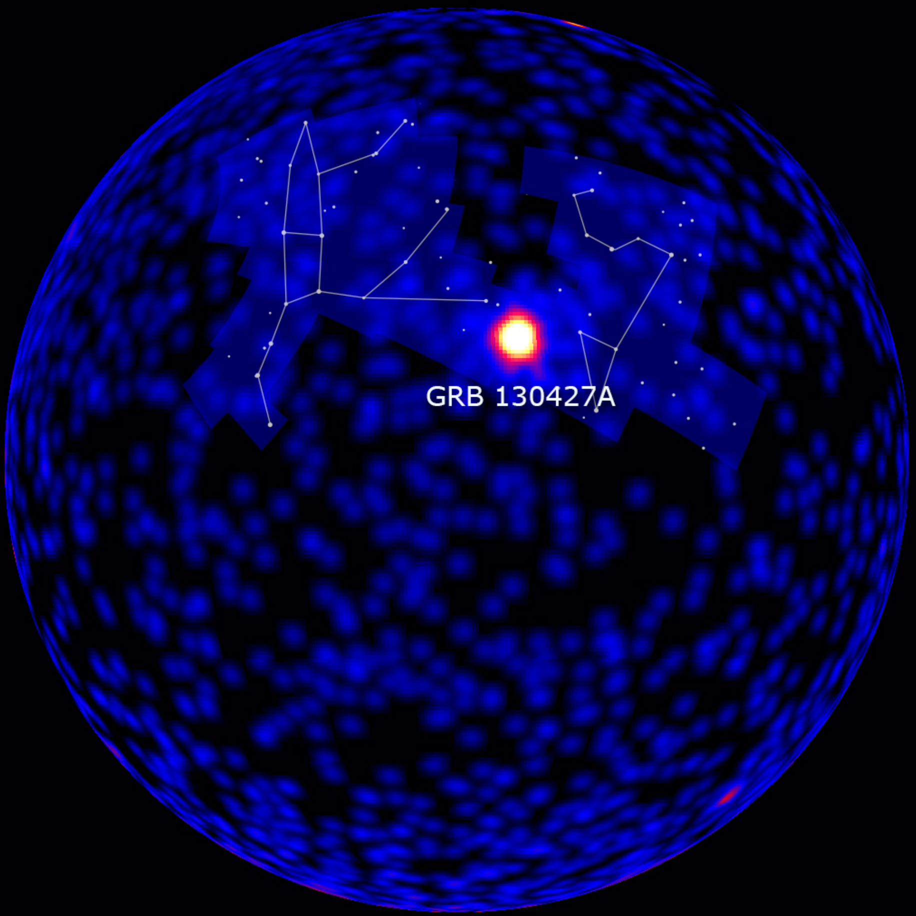
Paolo D'Avanzo

INAF / Osservatorio Astronomico di Brera

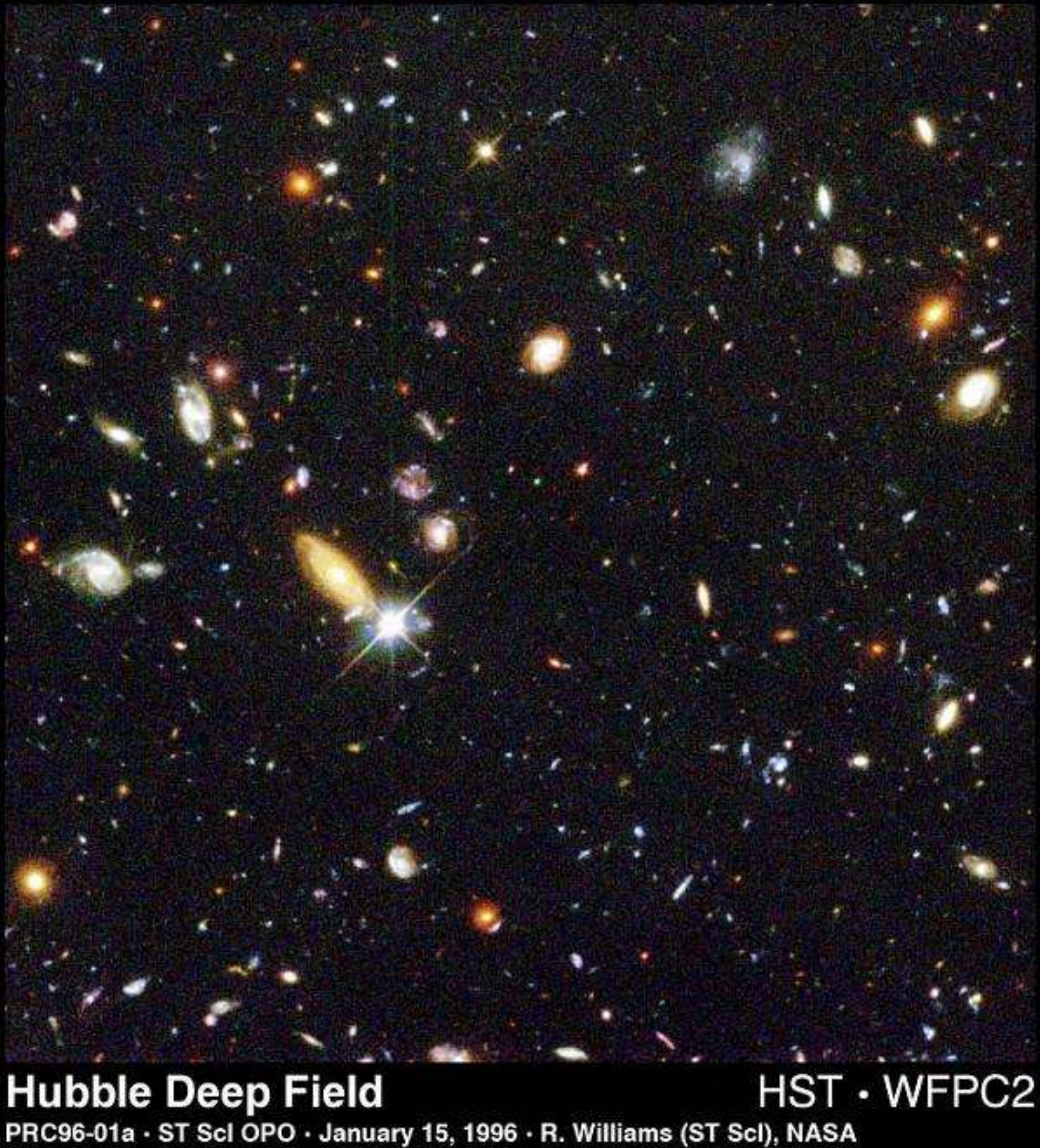


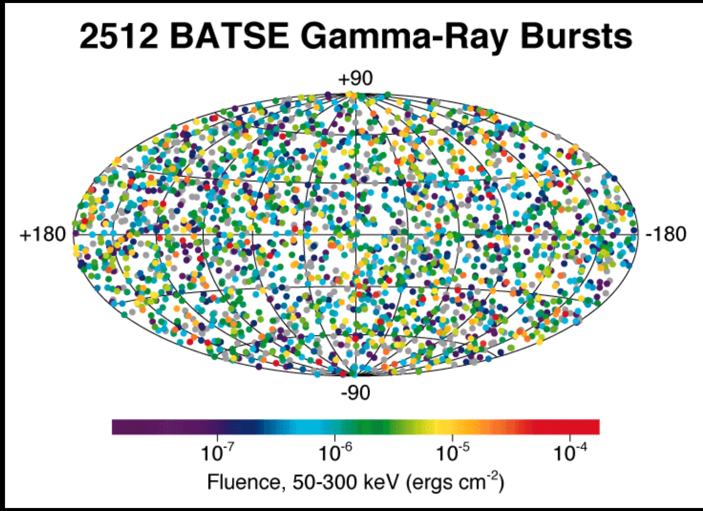
Before and after Fermi LAT views of GRB 130427A, centered on the north galactic pole





Before and after Fermi LAT views of GRB 130427A, centered on the north galactic pole


Hubble Deep Field
HST • WFPC2
PRC96-01a • ST ScI OPO • January 15, 1996 • R. Williams (ST ScI), NASA

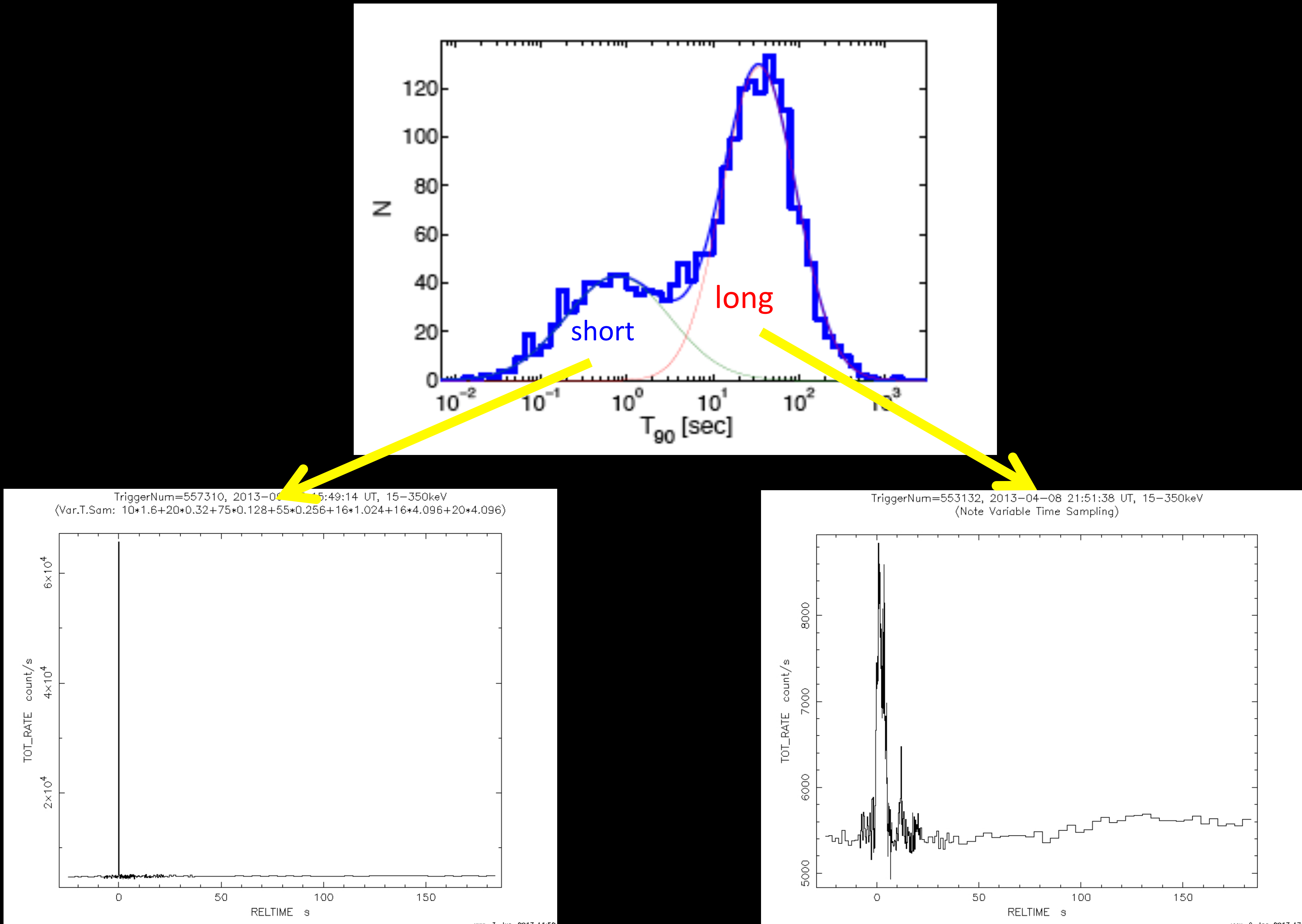

2512 BATSE Gamma-Ray Bursts
+90
+180
-180
-90
10-7
10-6
10-5
10-4
Fluence, 50-300 keV (ergs cm-2)

I GRB sono tra le sorgenti piu` distanti che conosciamo

La loro energia e` quindi enorme: 10^{53} erg:

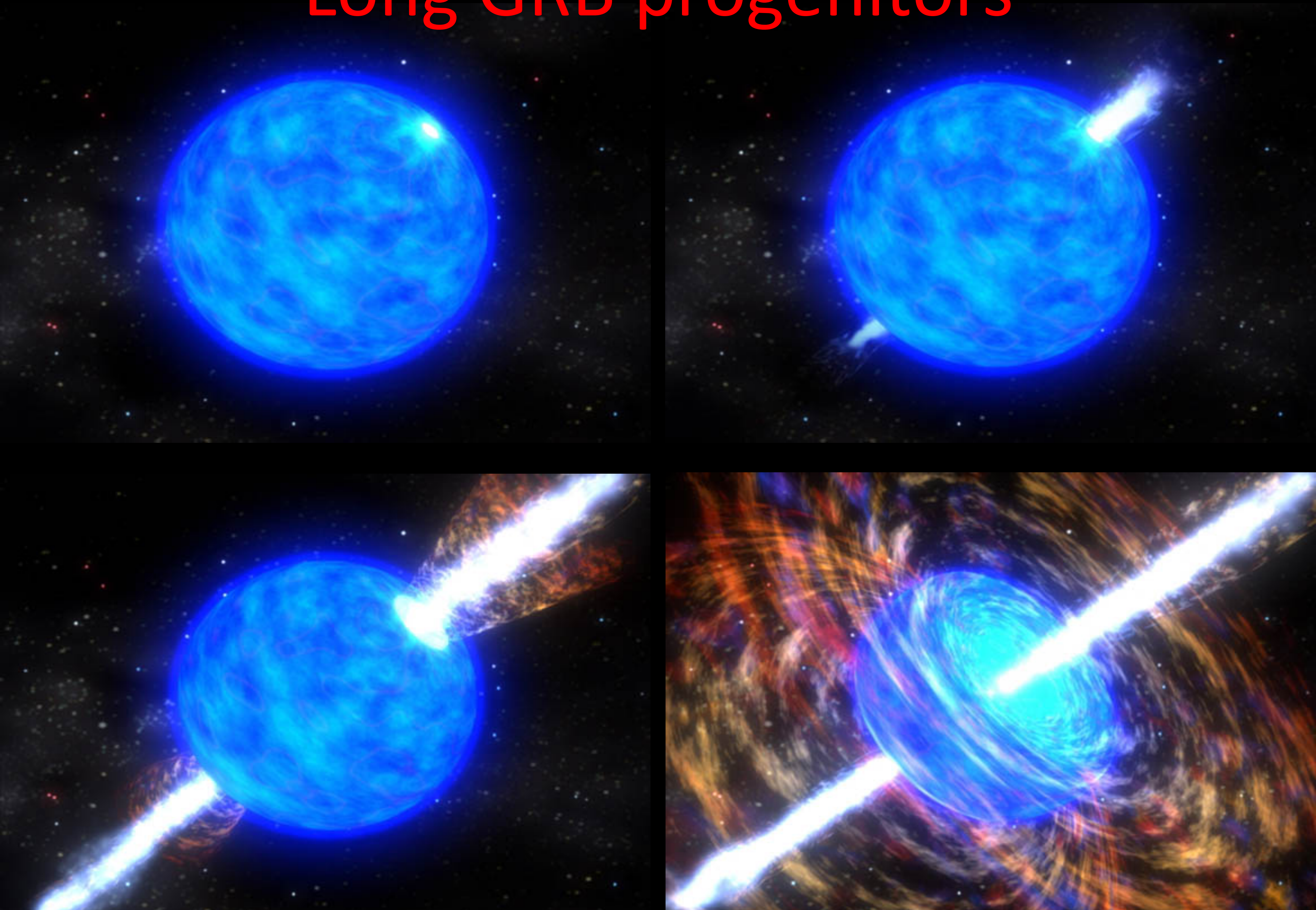
- Come 100 Supernovae
- Come il Sole per 3000 miliardi di anni
- Come tutta la nostra Galassia per 100 anni

E tutto cio` in pochi secondi….

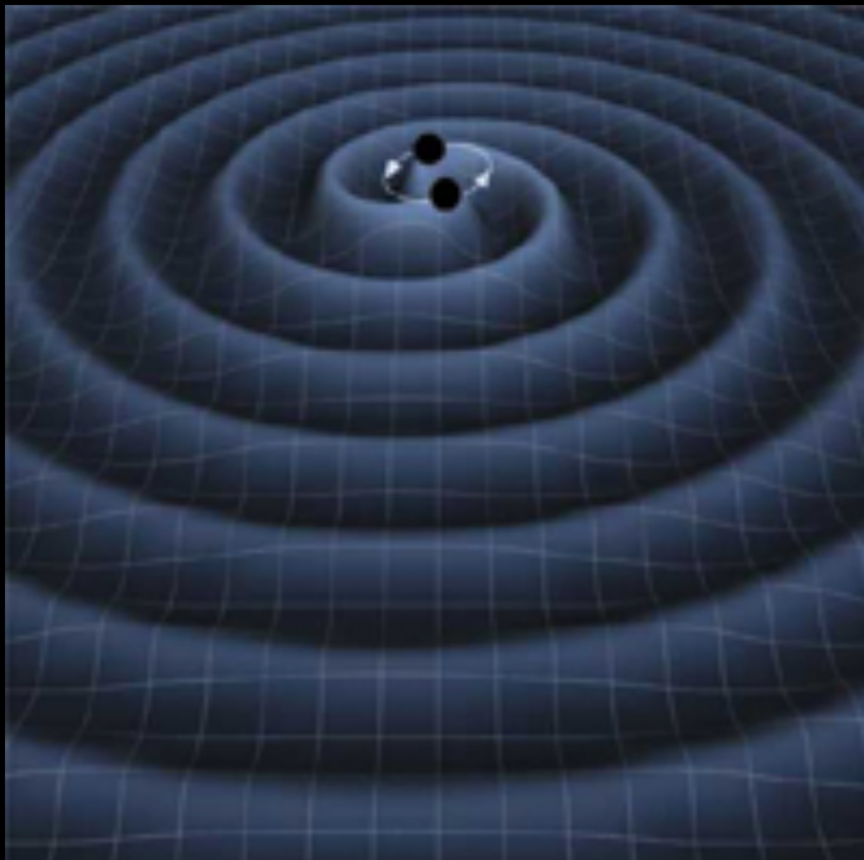


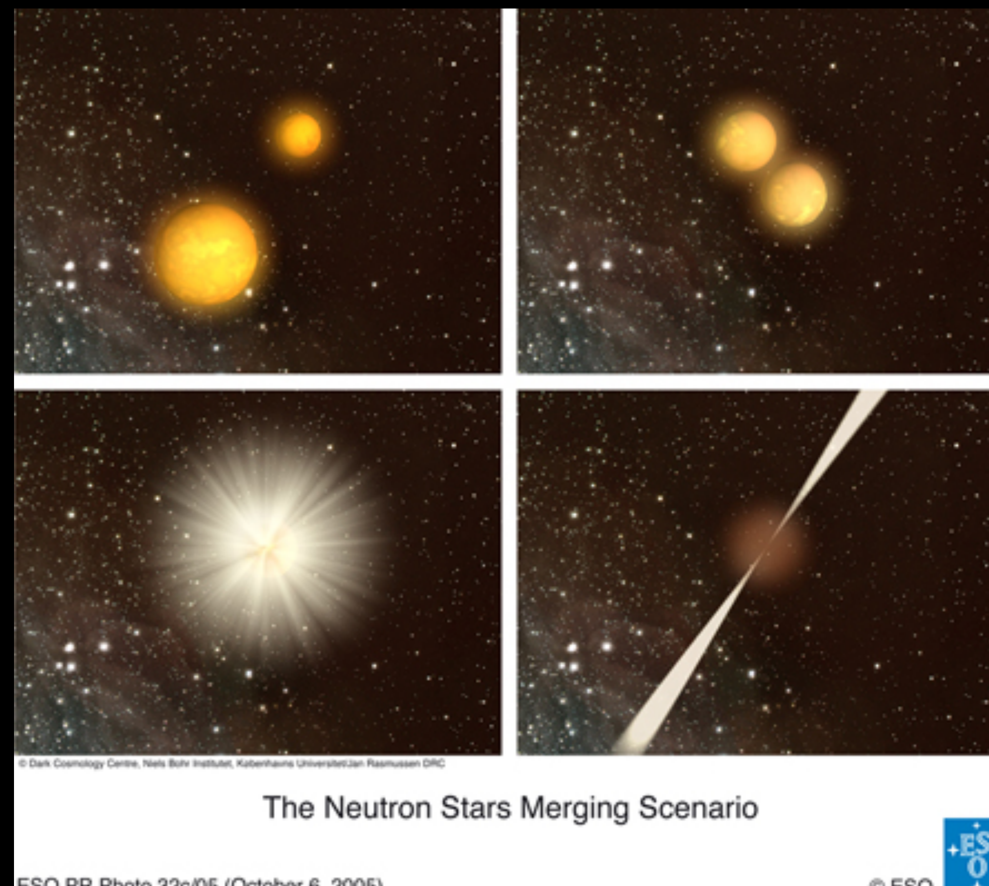
N
T90 [sec]
short
long
TriggerNum=557310, 2013-0
5:49:14 UT, 15–350keV
(Var.T.Sam: 10*1.6+20*0.32+75*0.128+55*0.256+16*1.024+16*4.096+20*4.096)
TOT_RATE count/s
RELTIME s
vxw 3-Jun-2013 11:52
TriggerNum=553132, 2013–04–08 21:51:38 UT, 15–350keV
(Note Variable Time Sampling)
TOT_RATE count/s
RELTIME s
vxw 8-Apr-2013 17:59

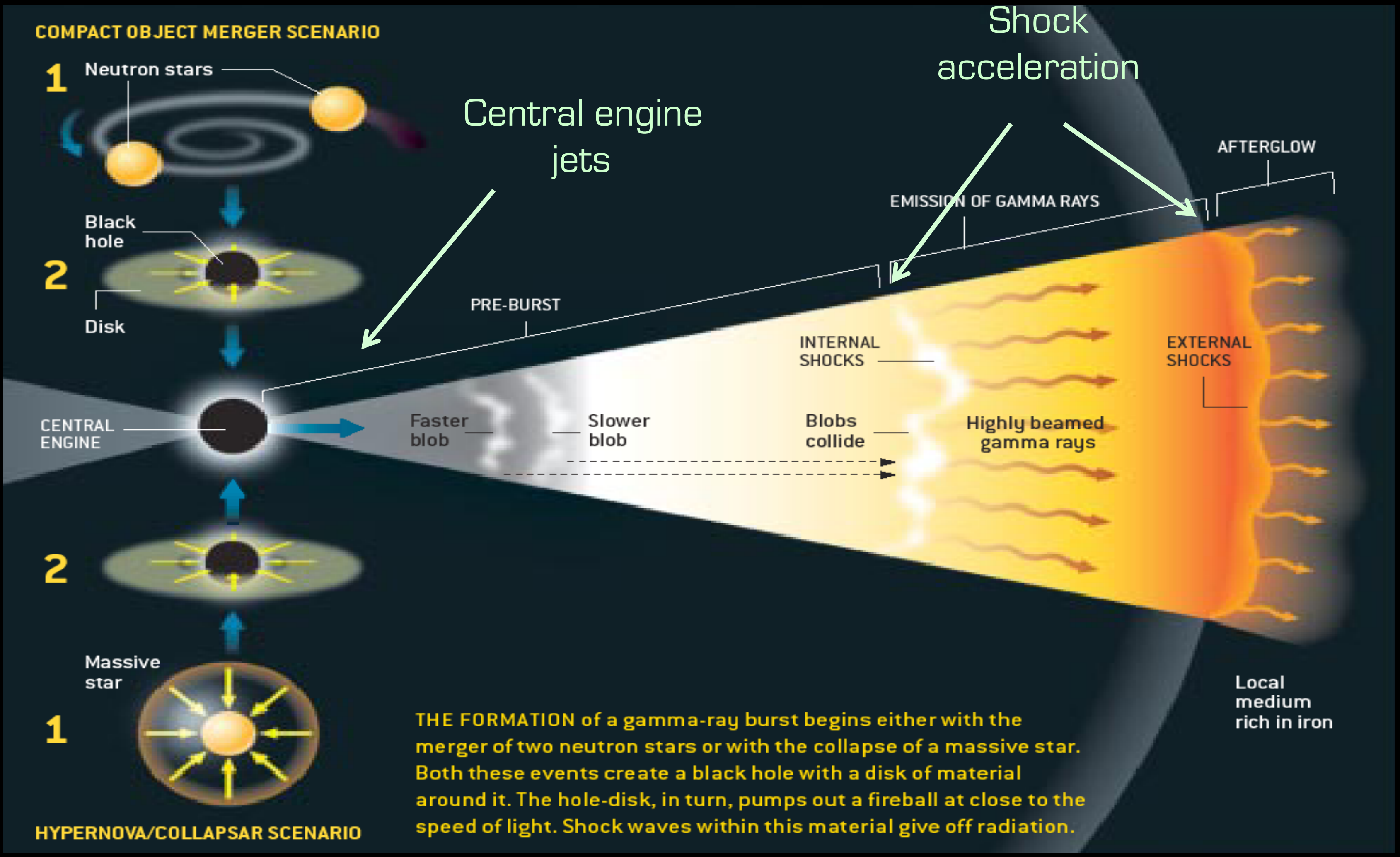
Long GRB progenitors

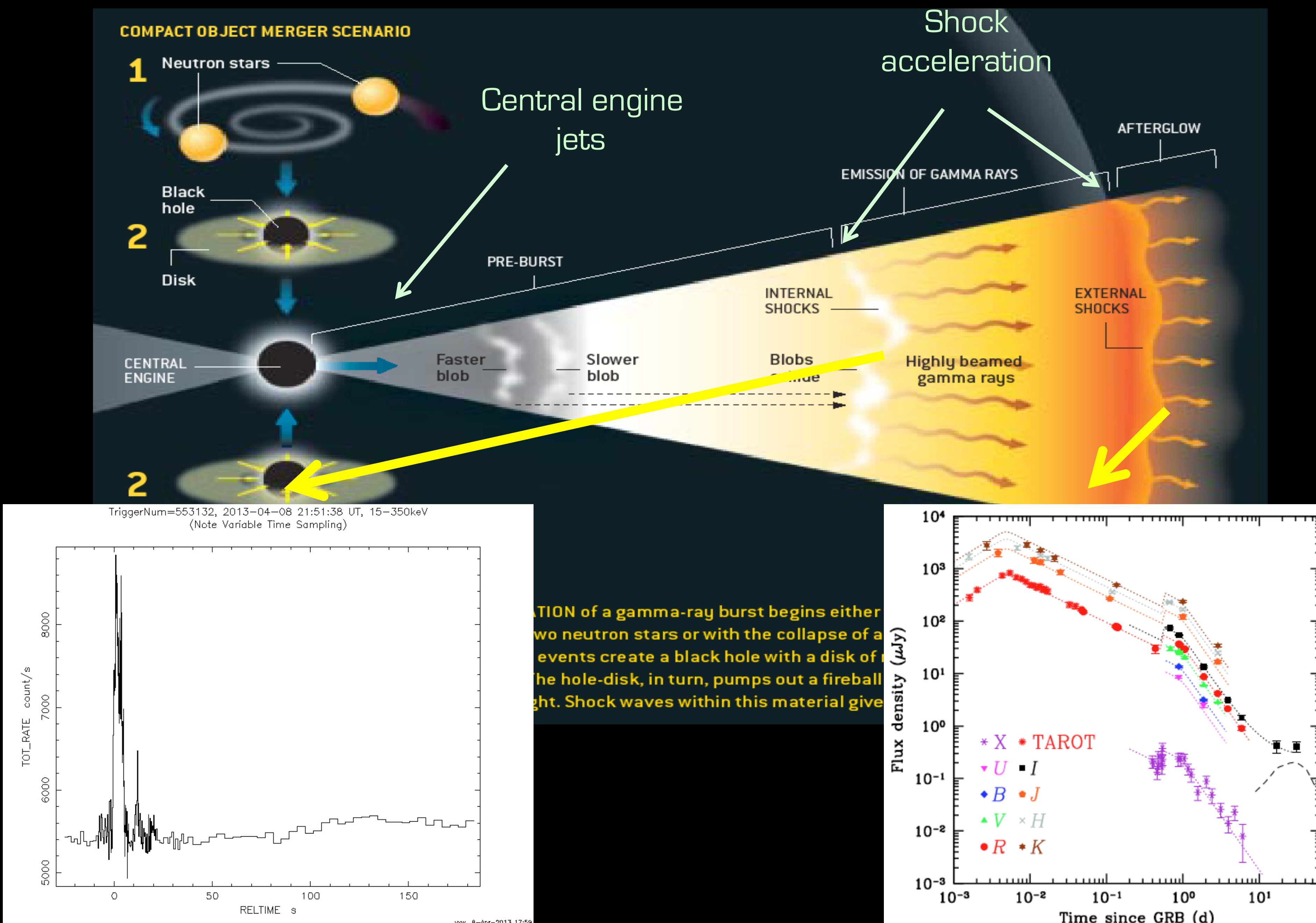


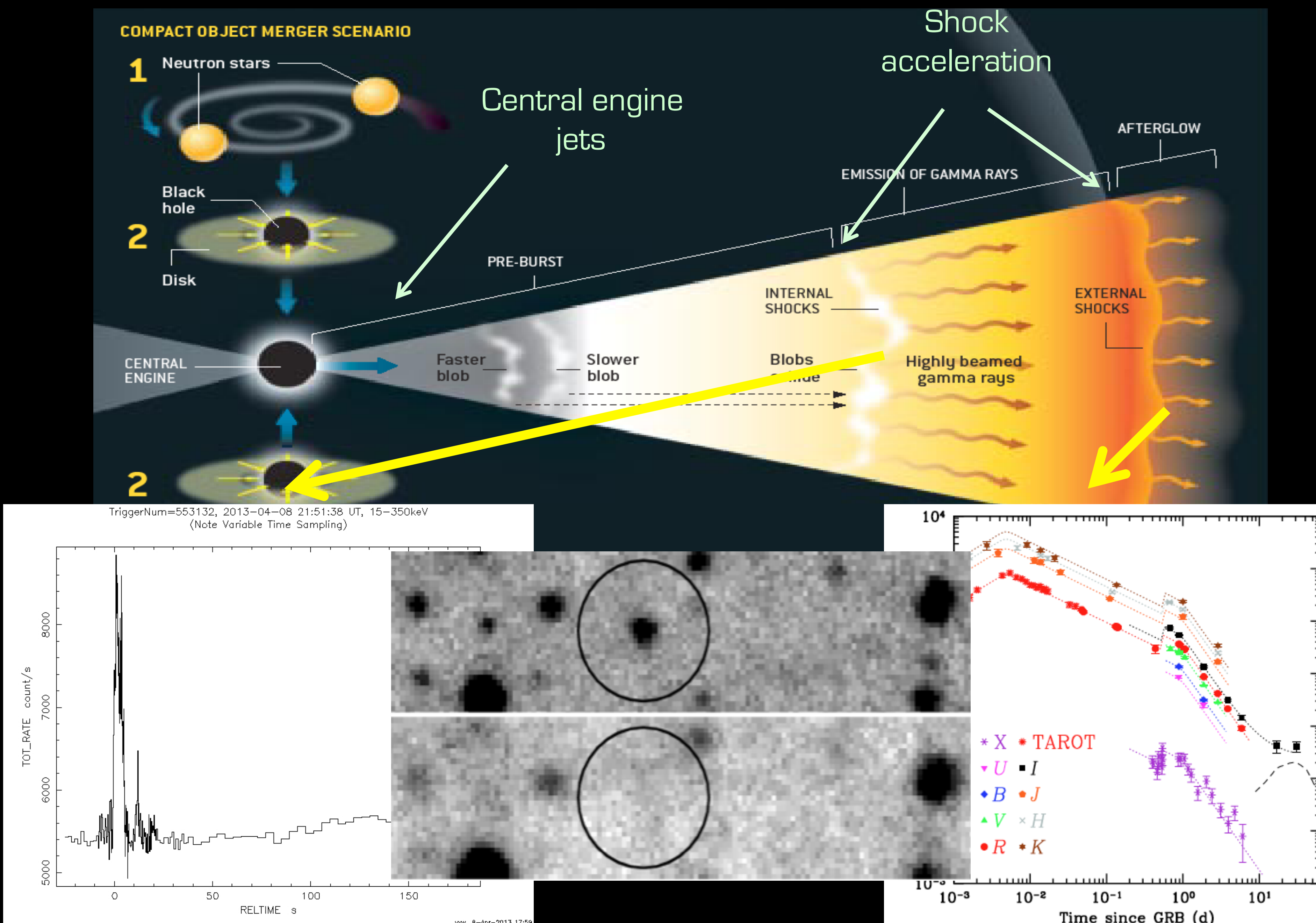
Short GRB progenitors





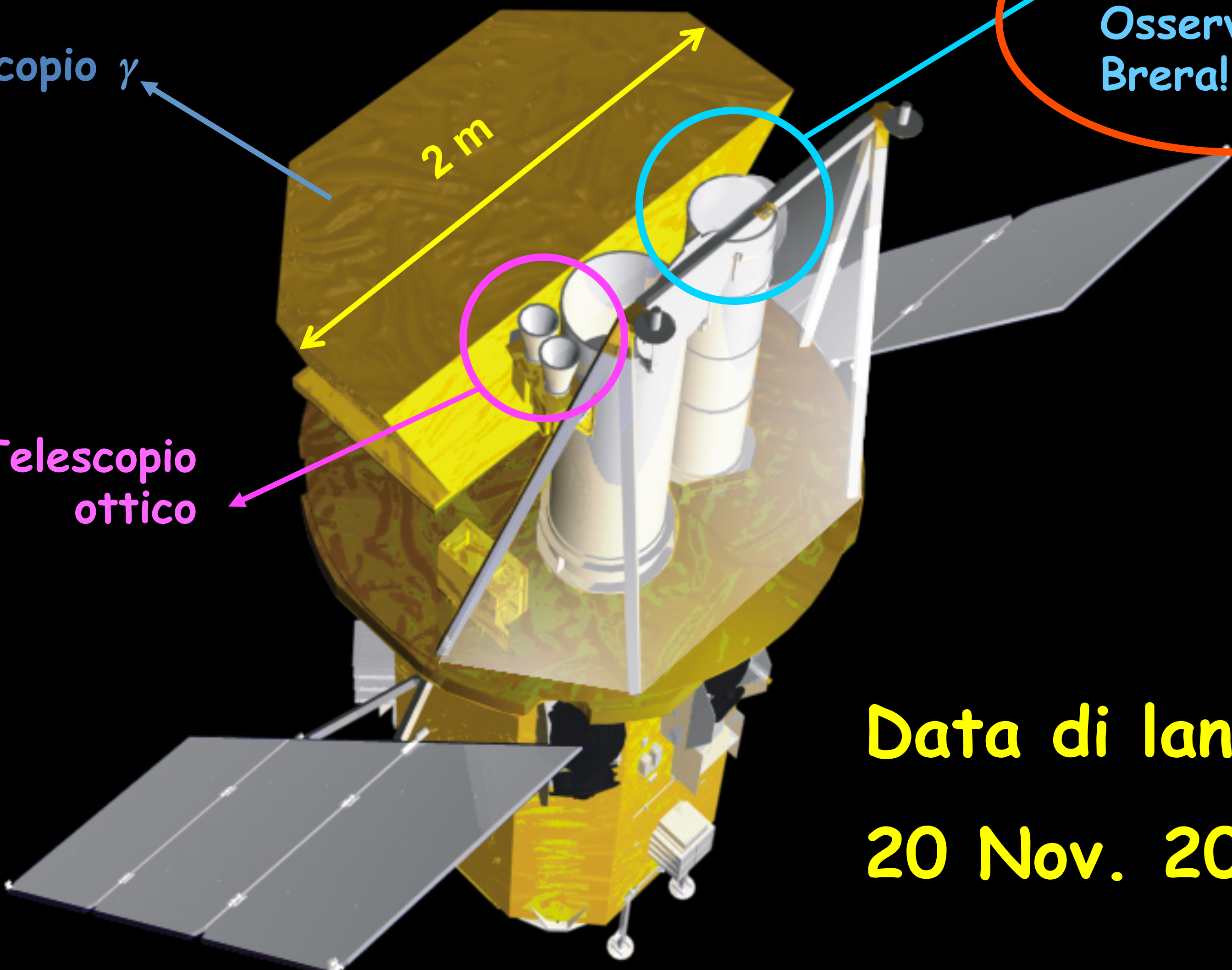

Shock
acceleration
Central engine
jets
COMPACT OBJECT MERGER SCENARIO
1
Neutron stars
Black
hole
2
Disk
CENTRAL
ENGINE
2
Massive
star
1
HYPERNOVA/COLLAPSAR SCENARIO
PRE-BURST
EMISSION OF GAMMA RAYS
AFTERGLOW
INTERNAL
SHOCKS
EXTERNAL
SHOCKS
Faster
blob
Slower
blob
Blobs
collide
Highly beamed
gamma rays
Local
medium
rich in iron
THE FORMATION of a gamma-ray burst begins either with the merger of two neutron stars or with the collapse of a massive star. Both these events create a black hole with a disk of material around it. The hole-disk, in turn, pumps out a fireball at close to the speed of light. Shock waves within this material give off radiation.


COMPACT OBJECT MERGER SCENARIO
1
Neutron stars
Black hole
2
Disk
2
CENTRAL ENGINE
Central engine jets
Shock acceleration
PRE-BURST
EMISSION OF GAMMA RAYS
AFTERGLOW
INTERNAL SHOCKS
EXTERNAL SHOCKS
Faster blob
Slower blob
Blobs
Highly beamed gamma rays
TION of a gamma-ray burst begins either
wo neutron stars or with the collapse of a
events create a black hole with a disk of
he hole-disk, in turn, pumps out a fireball
ght. Shock waves within this material give
TriggerNum=553132, 2013-04-08 21:51:38 UT, 15-350keV
(Note Variable Time Sampling)
TOT_RATE count/s
RELTIME s
vxw 8-Apr-2013 17:59
Flux density (μJy)
Time since GRB (d)
X
TAROT
U
I
B
J
V
H
R
K



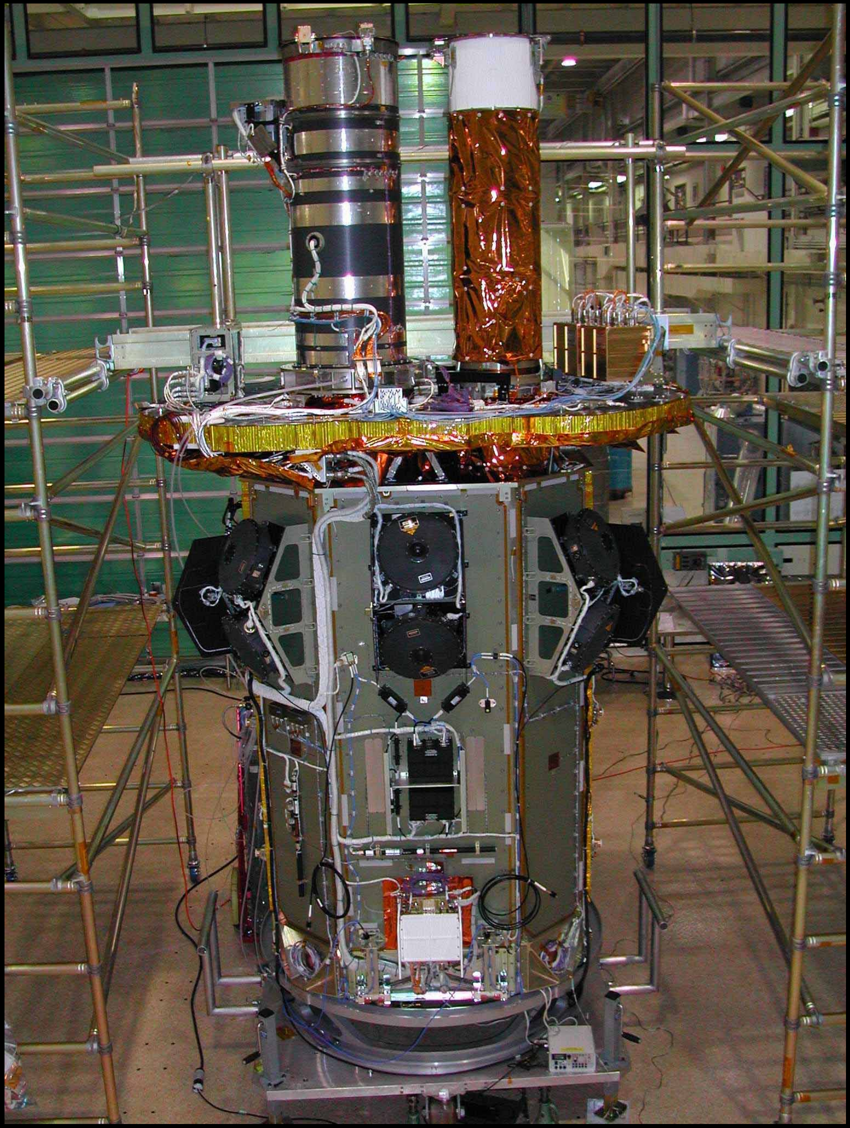
COMPACT OBJECT MERGER SCENARIO
1
Neutron stars
Black hole
2
Disk
CENTRAL ENGINE
2
Central engine jets
Shock acceleration
PRE-BURST
EMISSION OF GAMMA RAYS
AFTERGLOW
Faster blob
Slower blob
Blobs
INTERNAL SHOCKS
Highly beamed gamma rays
EXTERNAL SHOCKS
TriggerNum=553132, 2013-04-08 21:51:38 UT, 15-350keV
(Note Variable Time Sampling)
TOT_RATE count/s
5000
6000
7000
8000
0
50
100
150
RELTIME s
vxw 8-Apr-2013 17:59
10⁴
X
TAROT
U
I
B
J
V
H
R
K
10⁻³
10⁻²
10⁻¹
10⁰
10¹
Time since GRB (d)

Swift



Data di lancio:

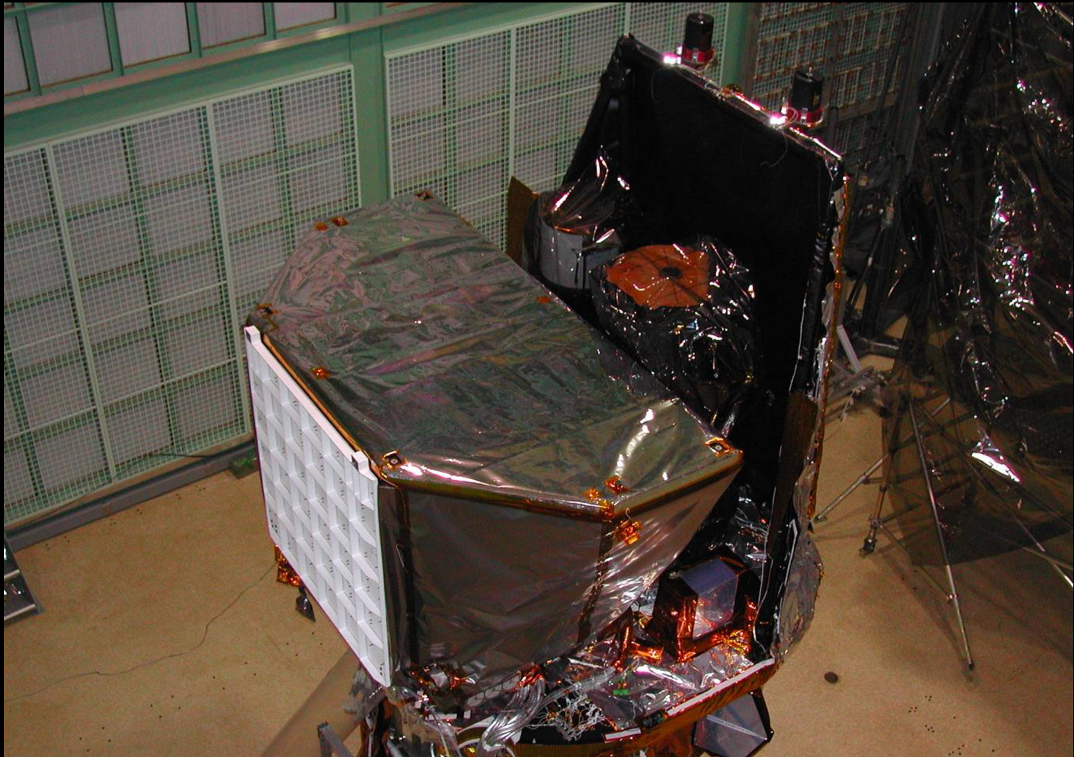
20 Nov. 2004



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Swift

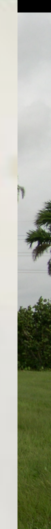
CATCHING GAMMA-RAY BURSTS ON THE FLY




MONSTER EDGE


AE





Swift

OSSERVATORIO ASTRONOMICO DI BRERA

NASA

GSFC

PENNSTATE
1855

University of Leicester

UCL
MSSL

eV PRODUCTS

agenzia spaziale italiana

SwRI

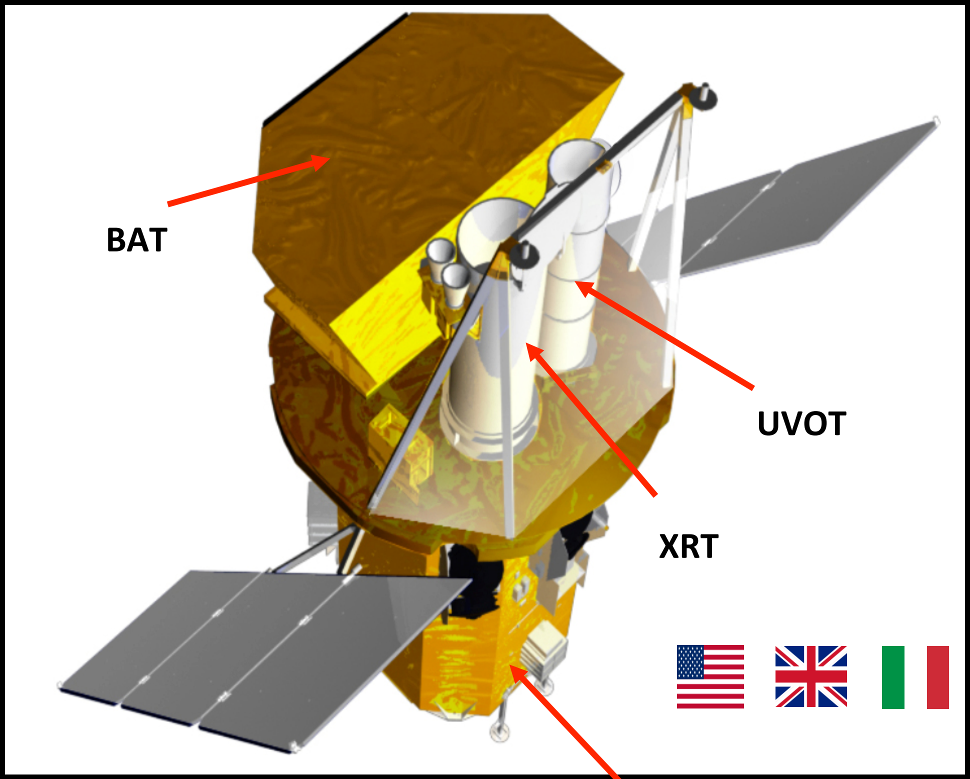
SPECTRUMASTRO

SWALES AEROSPACE

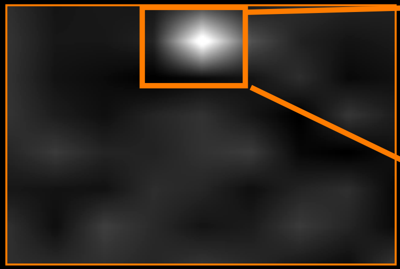
OMITRON Inc.

Los Alamos NATIONAL LABORATORY

- **Burst Alert Telescope (BAT)**
  - 15-150 keV
  - FOV: 2 steradiants
  - Centroid accuracy: 1' - 4'
- **X-Ray Telescope (XRT)**
  - 0.2-10.0 keV
  - FOV: 23.6' x 23.6'
  - Centroid accuracy: 5"
- **UV/Optical Telescope (UVOT)**
  - 30 cm telescope
  - 6 filters (170 nm – 600 nm)
  - FOV: 17' x 17'
  - 24^{th} mag sensitivity (1000 sec)
  - Centroid accuracy: 0.5"

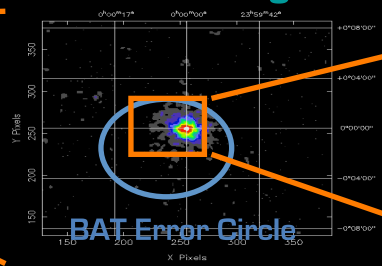


BAT Burst Image



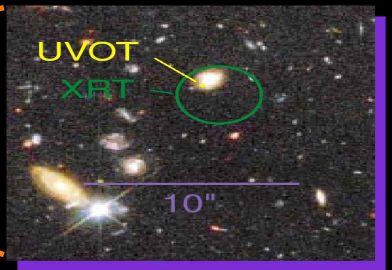
T<10 s; θ < 4'

XRT Image



T<100 s; θ < 5''

UVOT Image

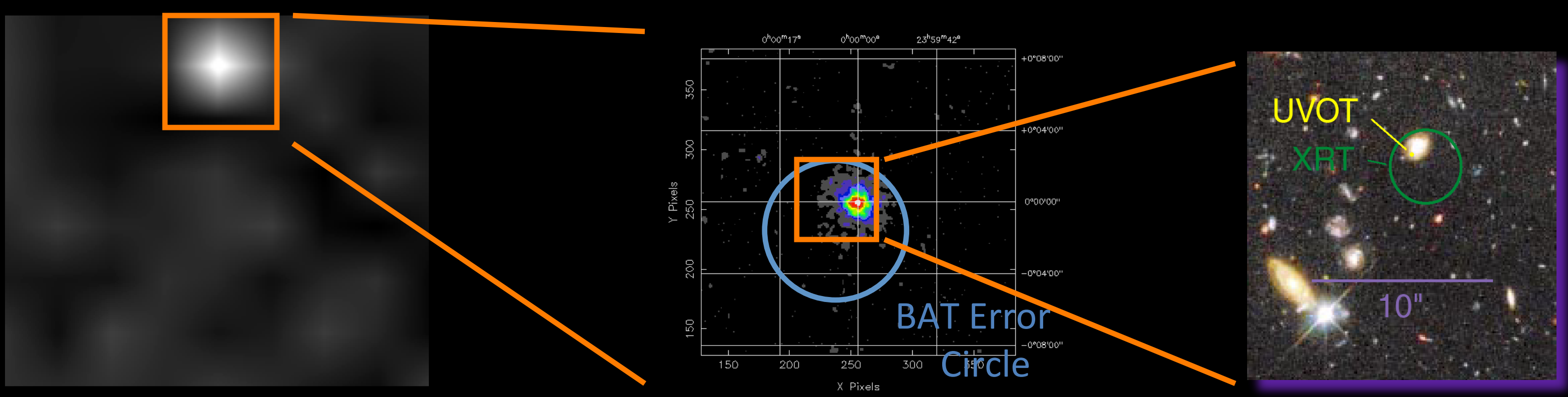


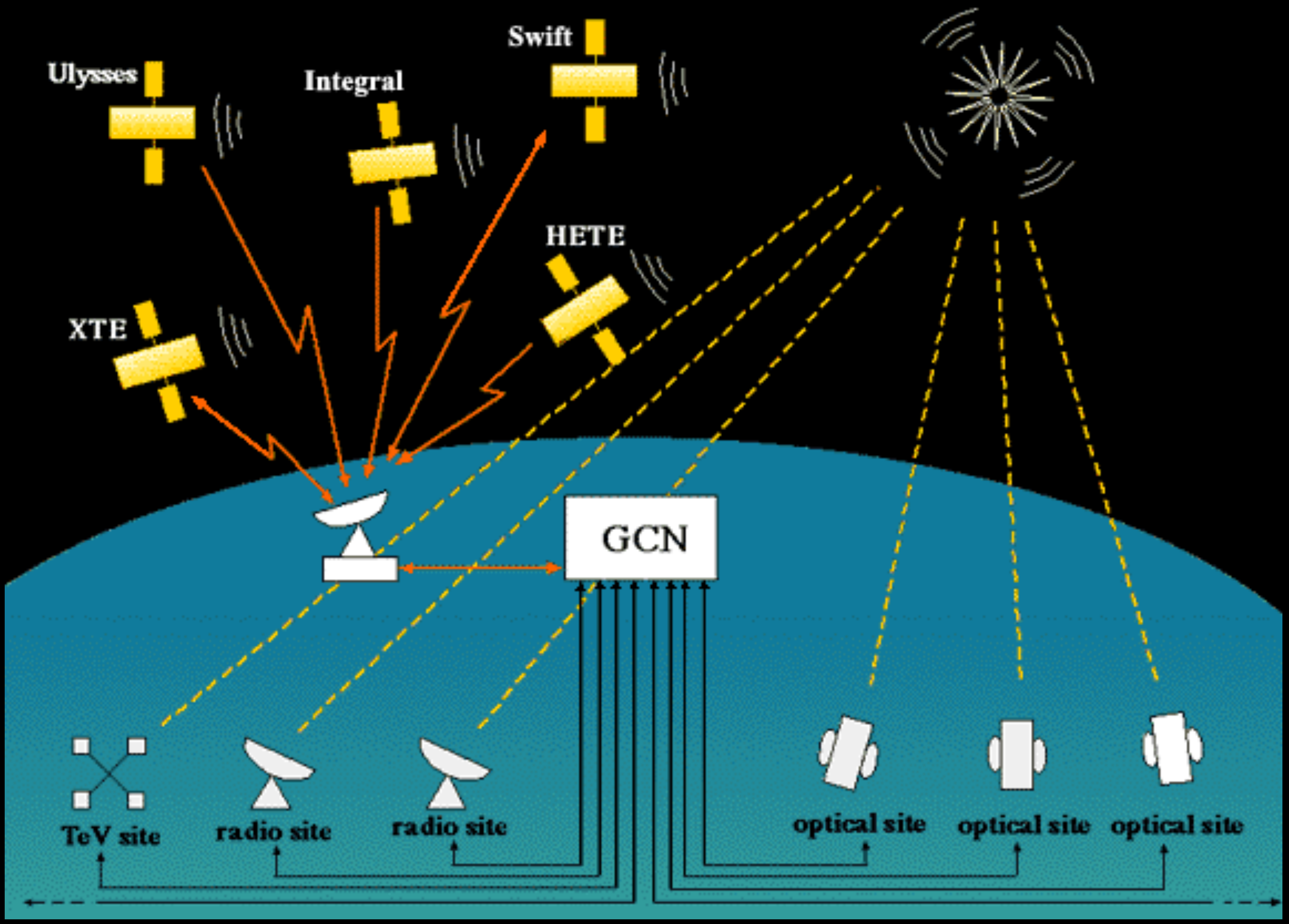
T<300 s; θ < 0.5''

Lo Scenario Osservativo

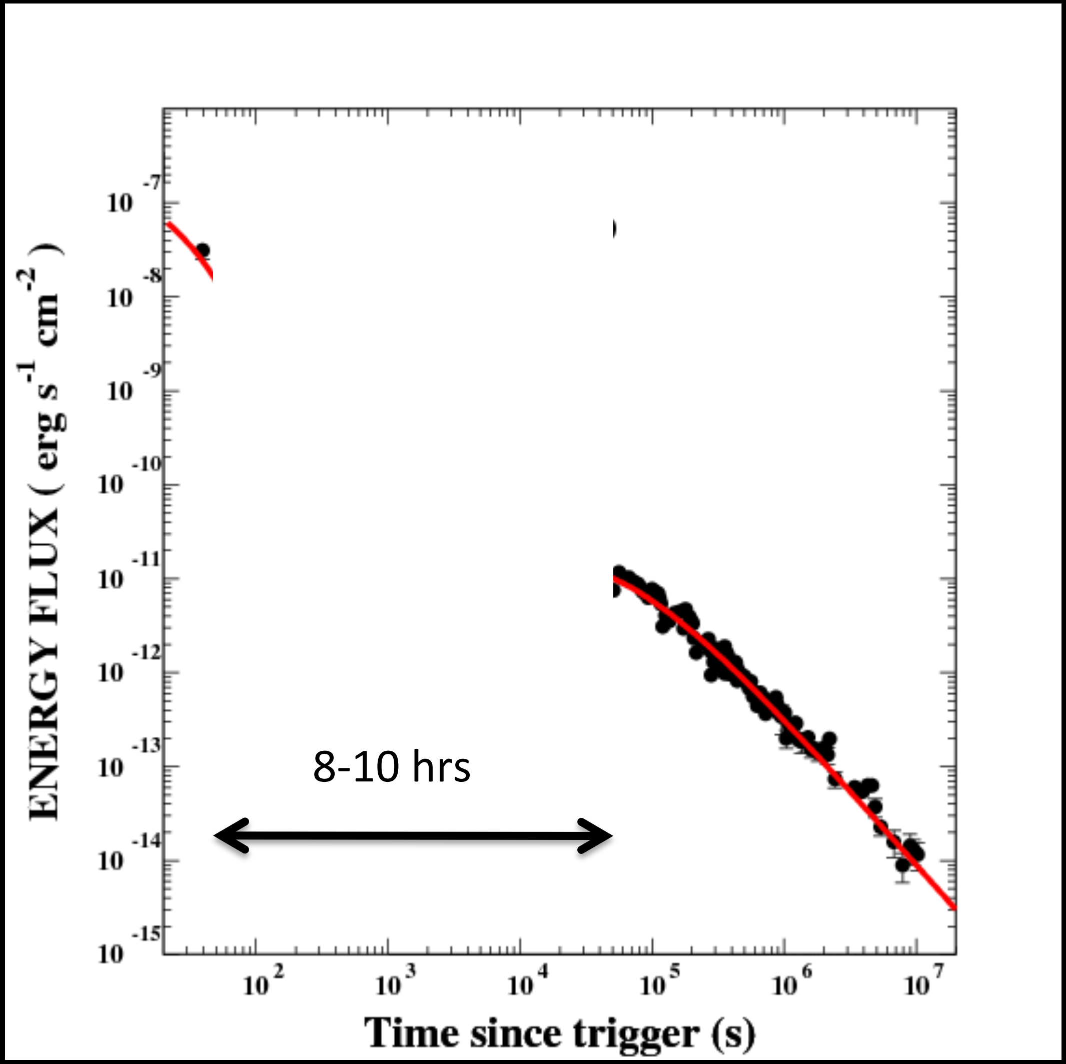
1. BAT localizza il GRB, e calcola la posizione a meno di ~ 3 arcmin
2. La navicella autonomamente punta il GRB in ~70 s
3. Il telescopio X trova la posizione a meno di ~ 5 arcseconds
4. Il telescopio ottico/UV trasmette immagini a terra

BAT **XRT** **UVOT**

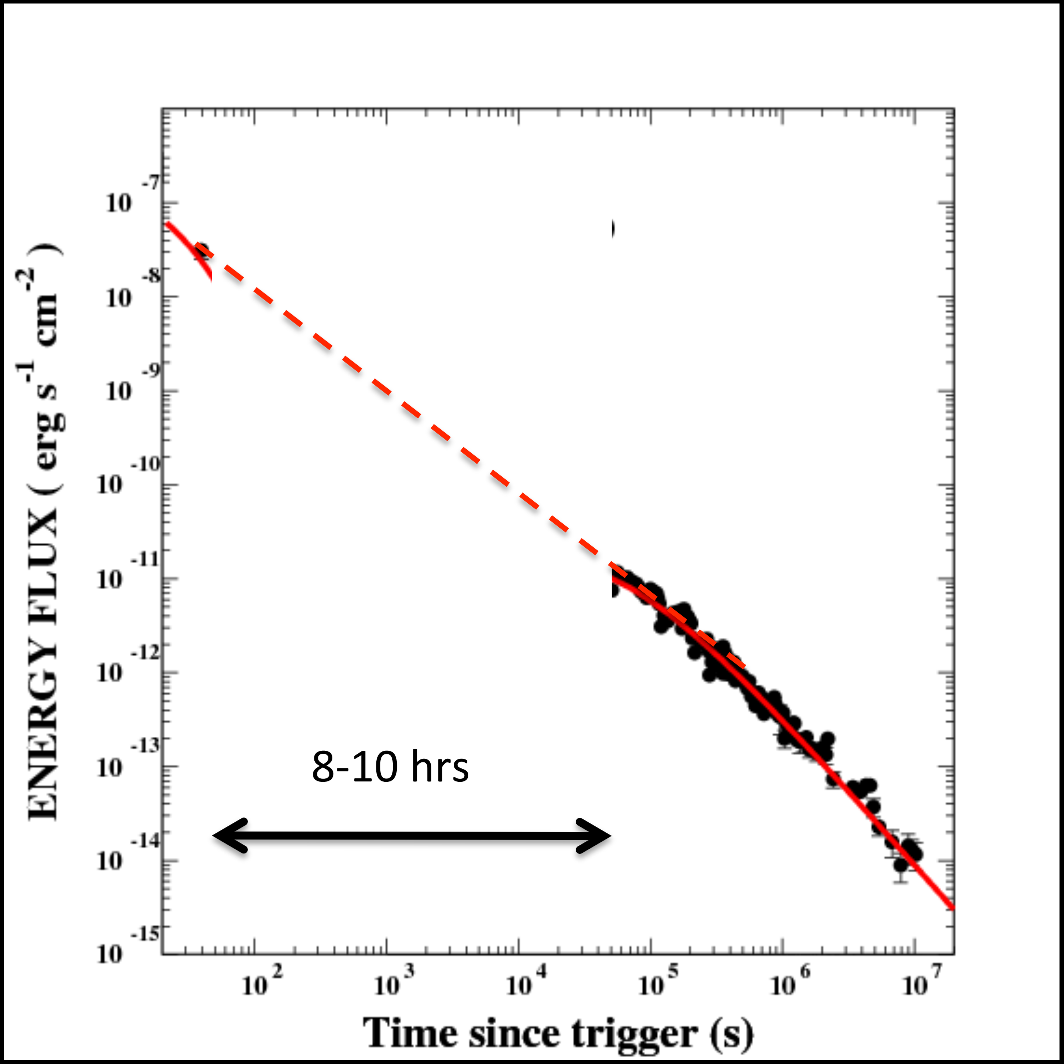



Ulysses
Integral
Swift
HETE
XTE
GCN
TeV site
radio site
radio site
optical site
optical site
optical site

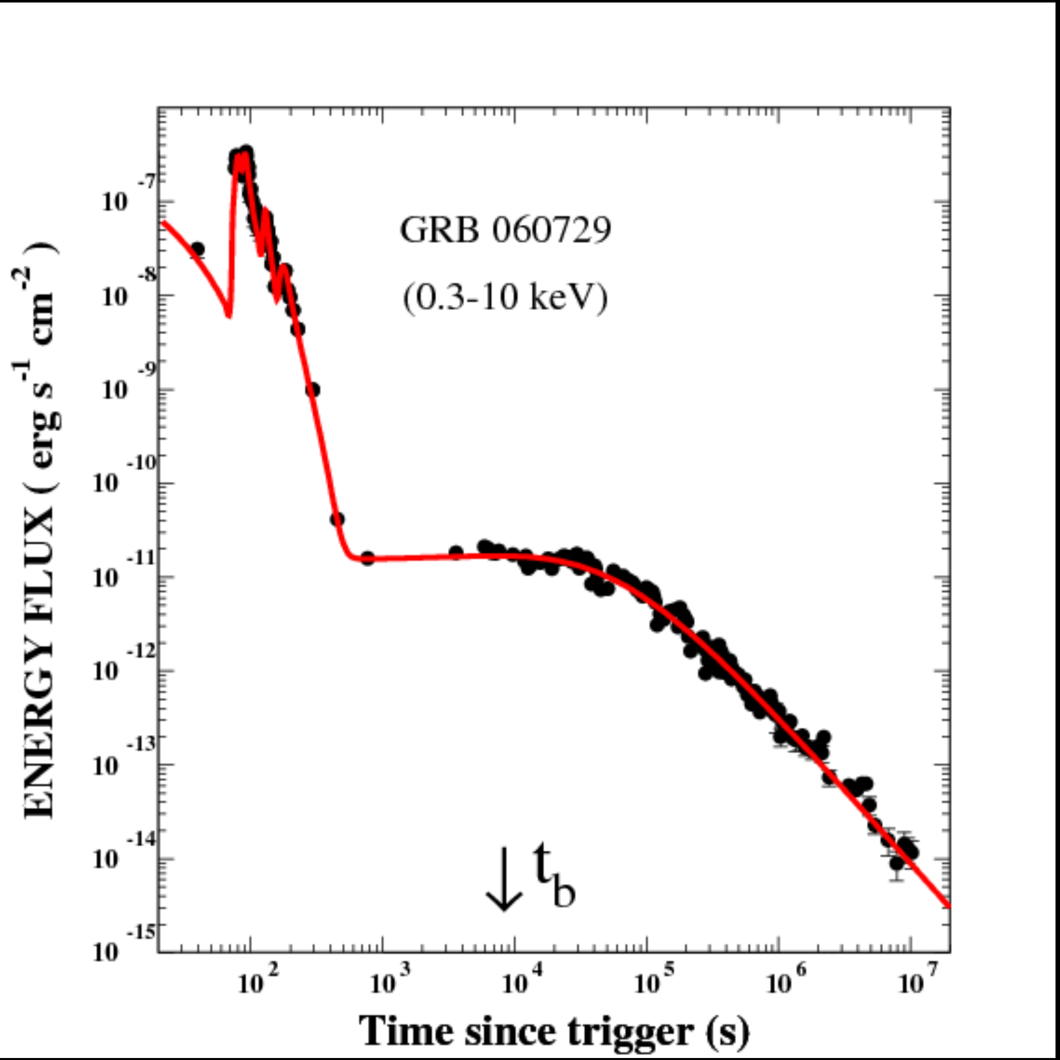
pre-Swift afterglow light curves



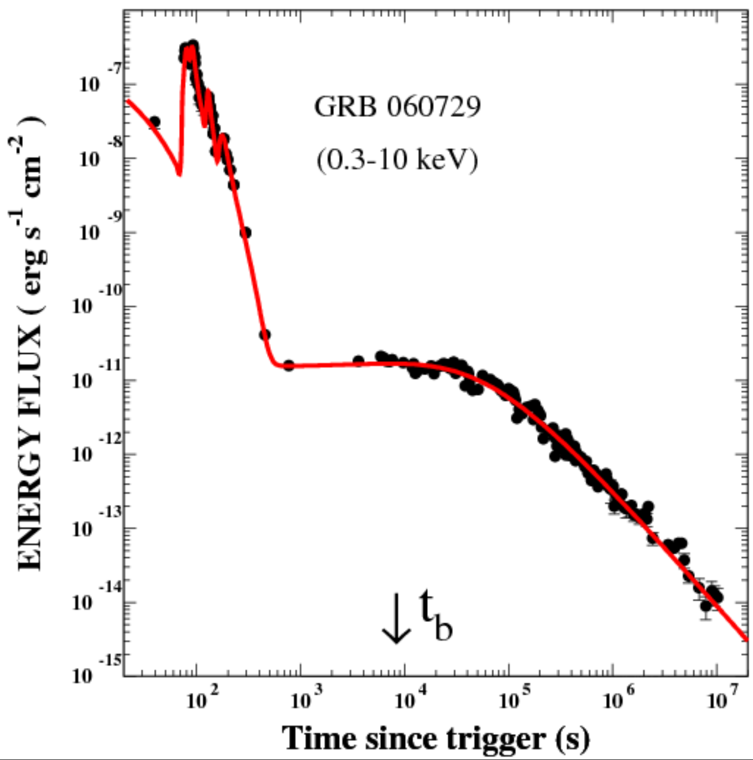
pre-Swift afterglow light curves

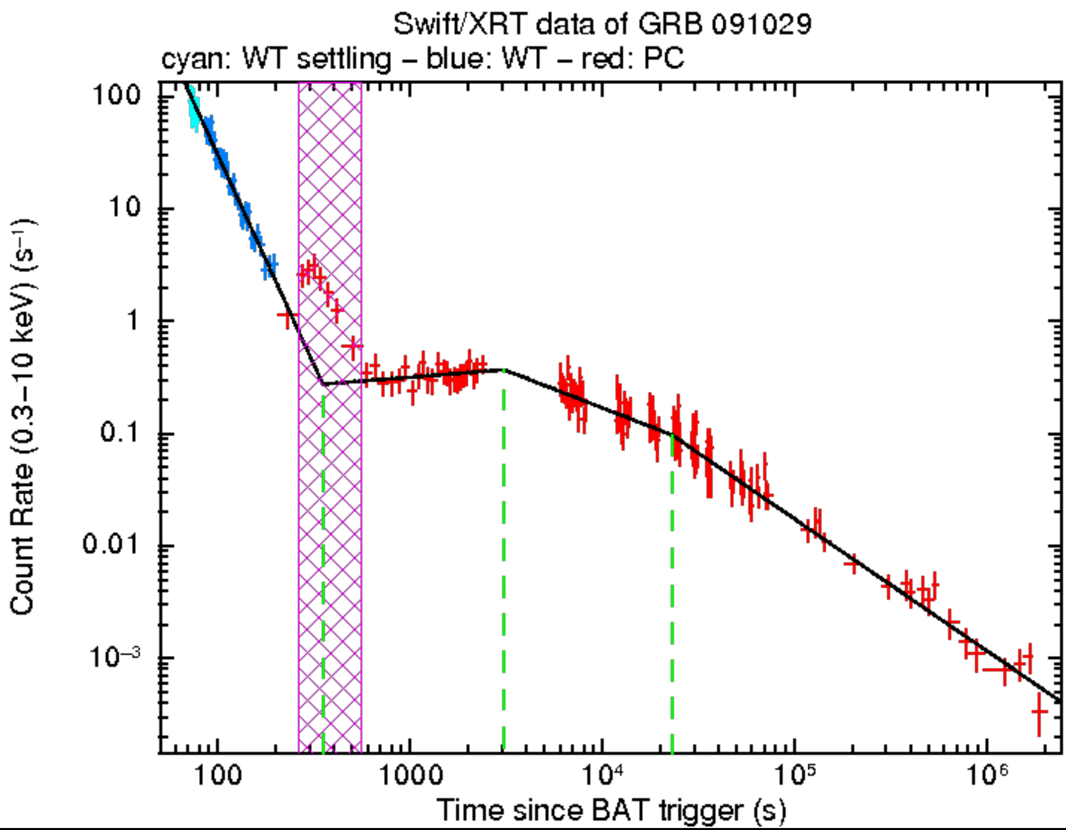


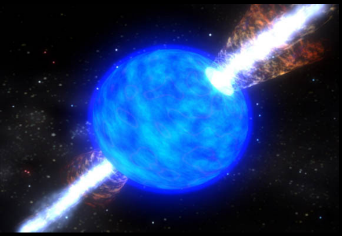
Swift afterglow light curves



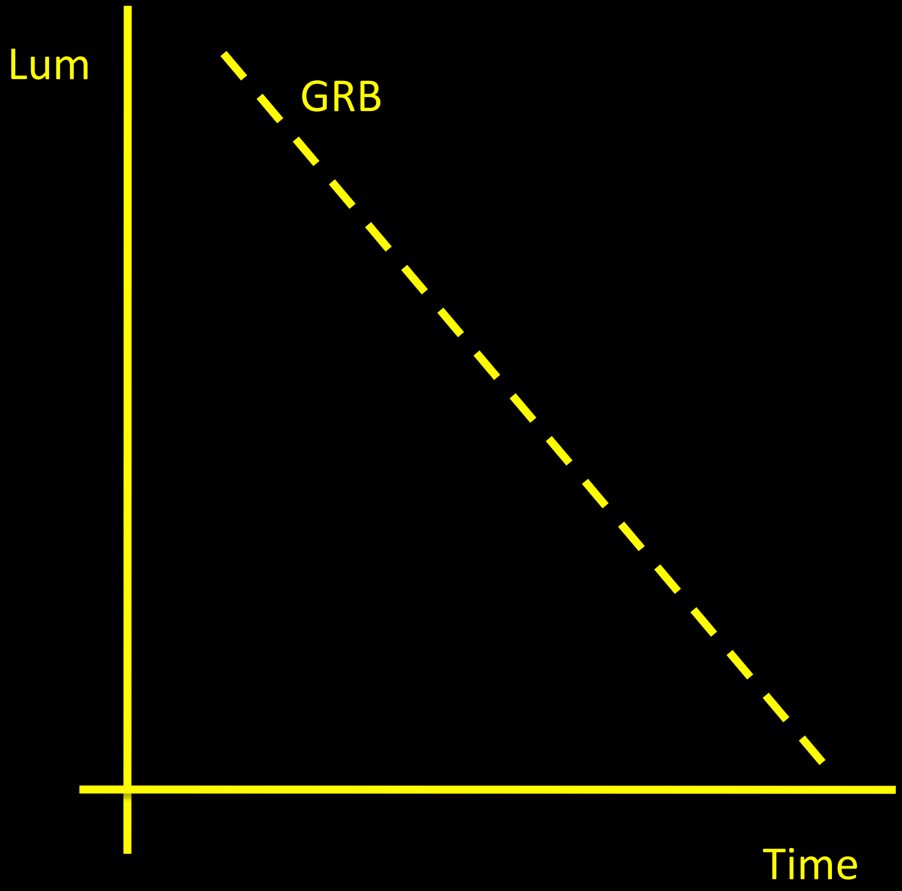
Swift afterglow light curves

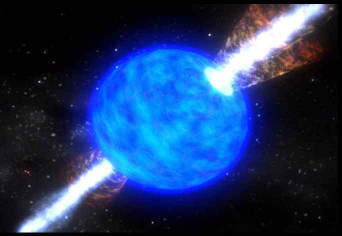




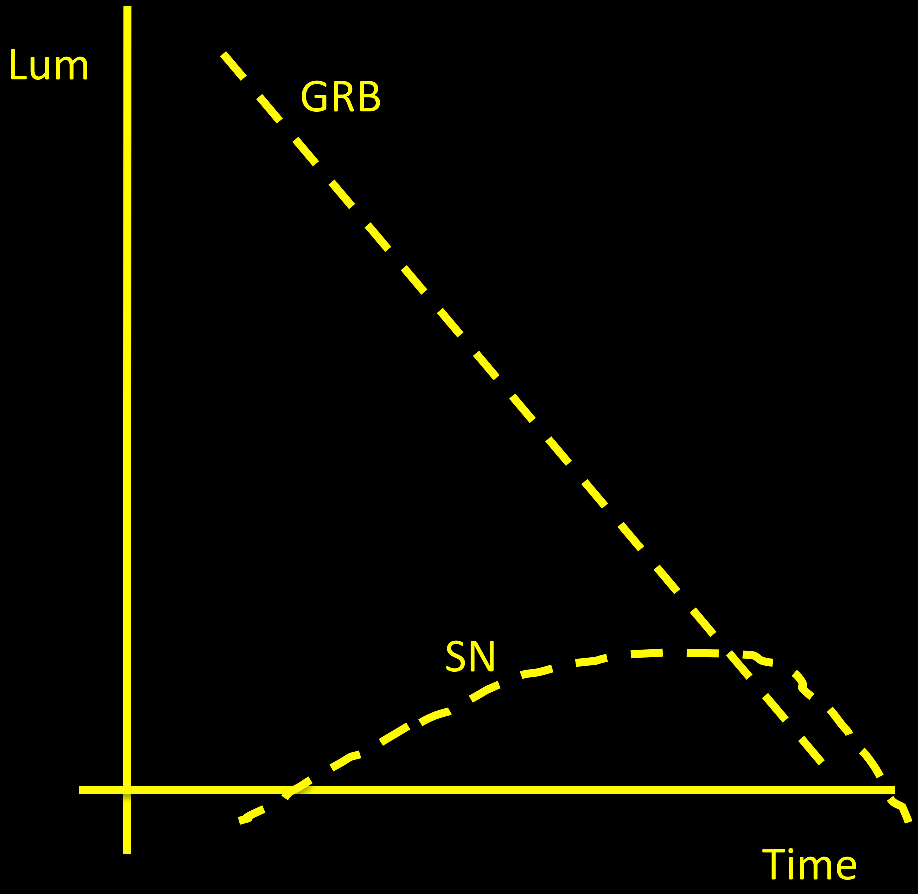


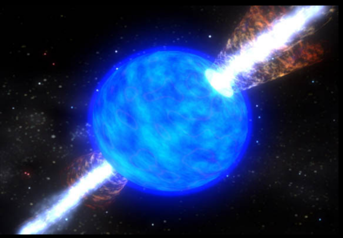
Long GRB & Supernovae



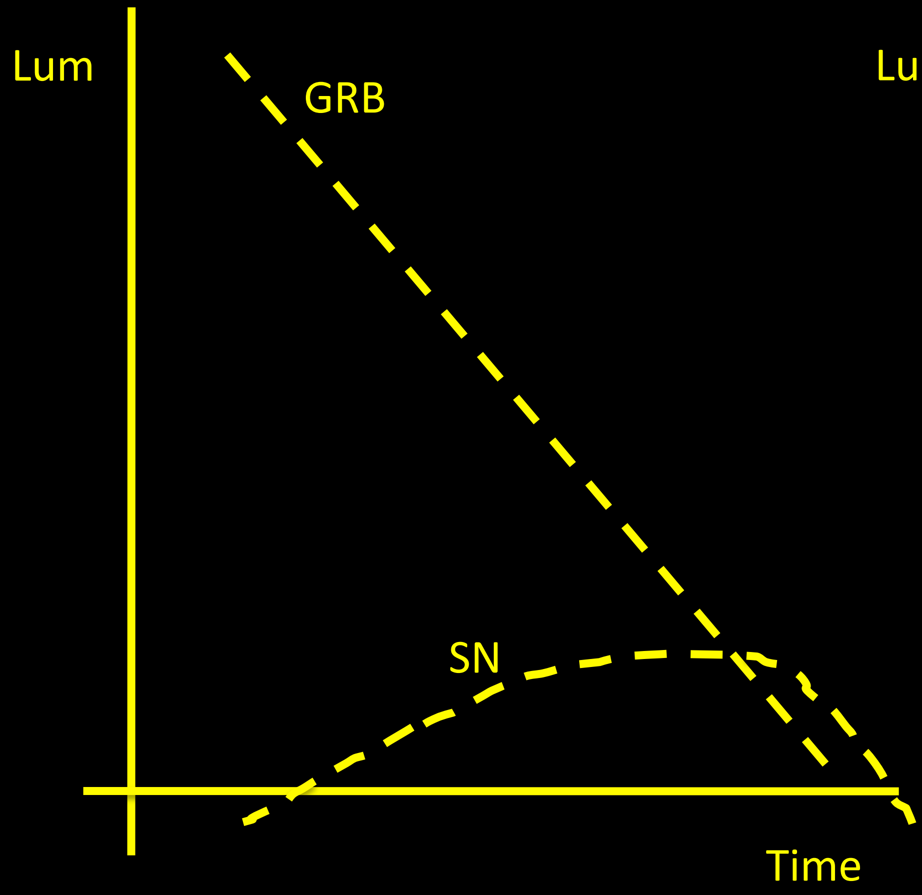


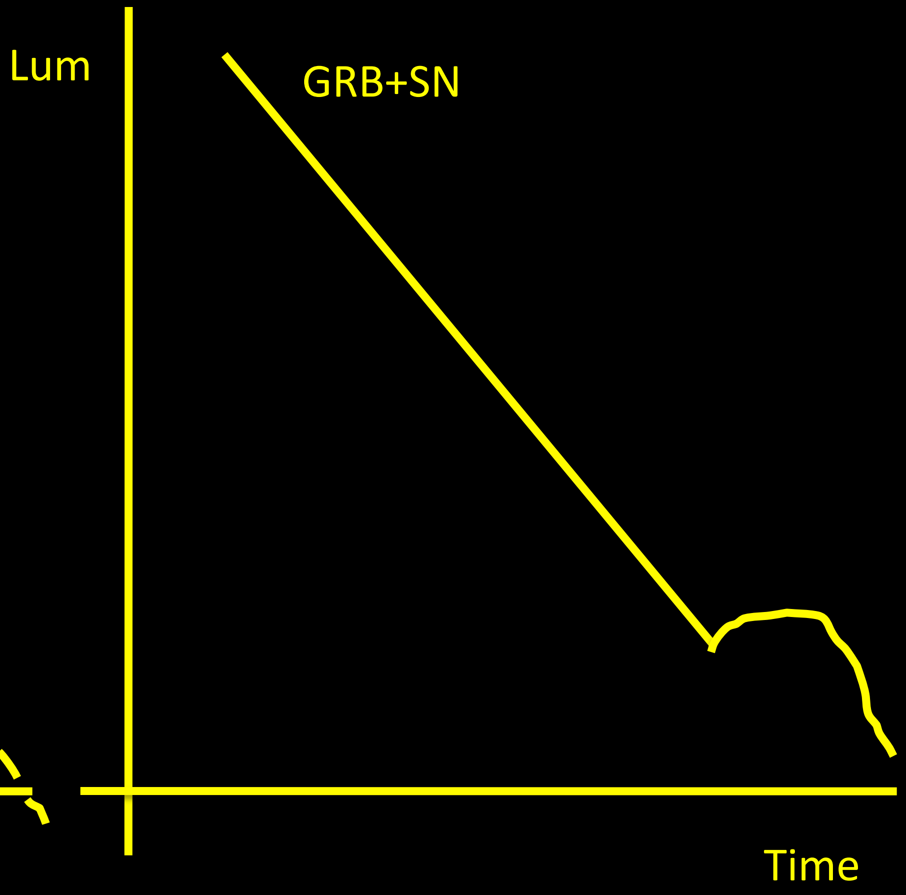
Long GRB & Supernovae

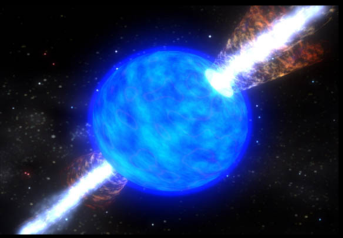




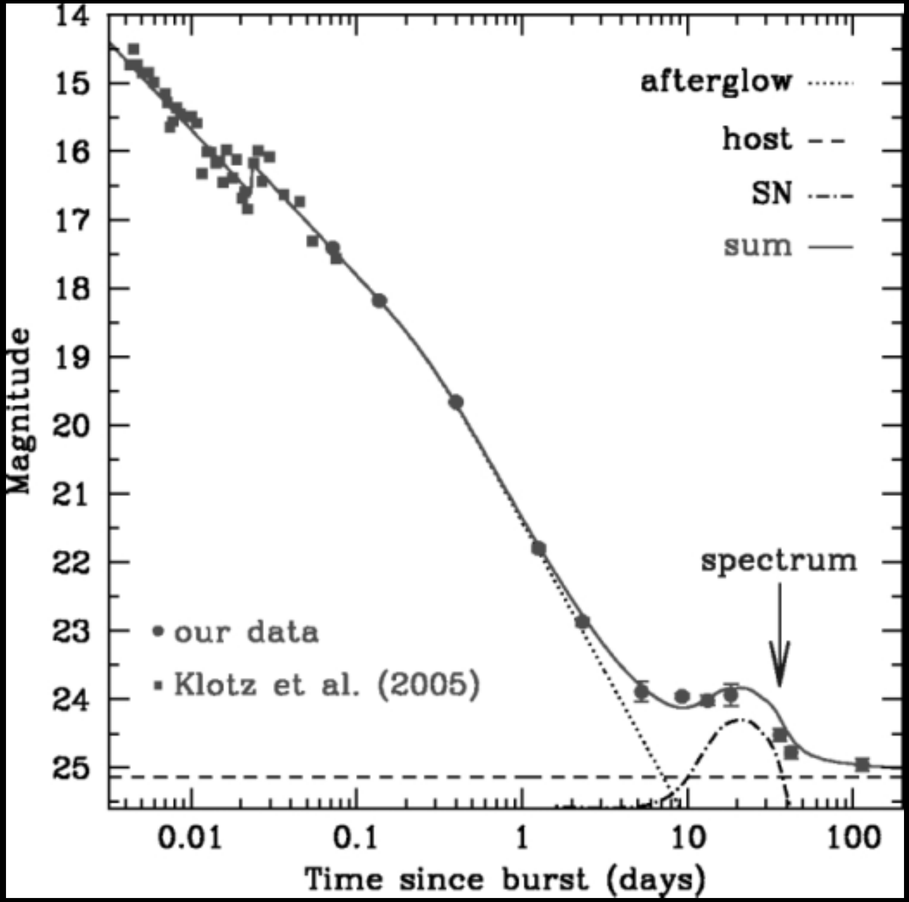
Long GRB & Supernovae

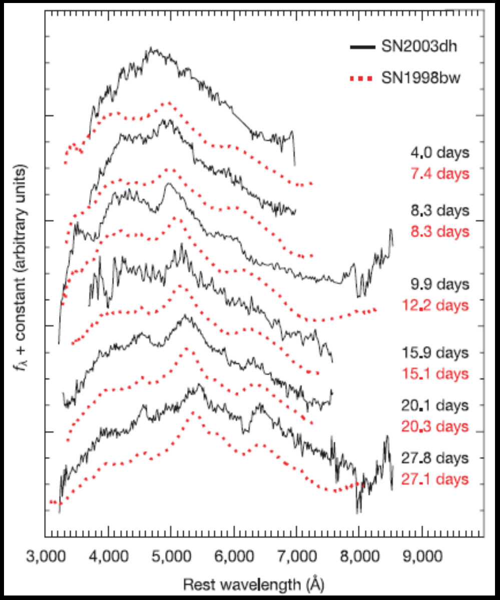


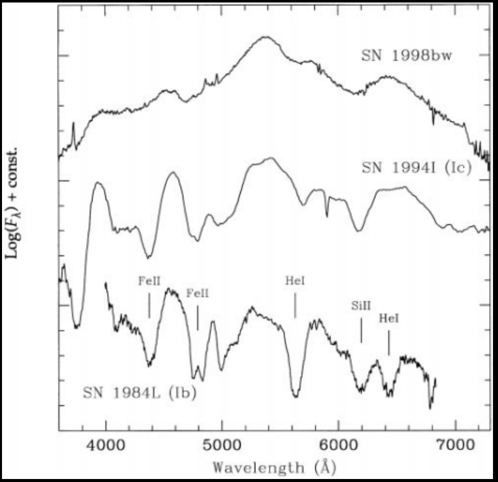




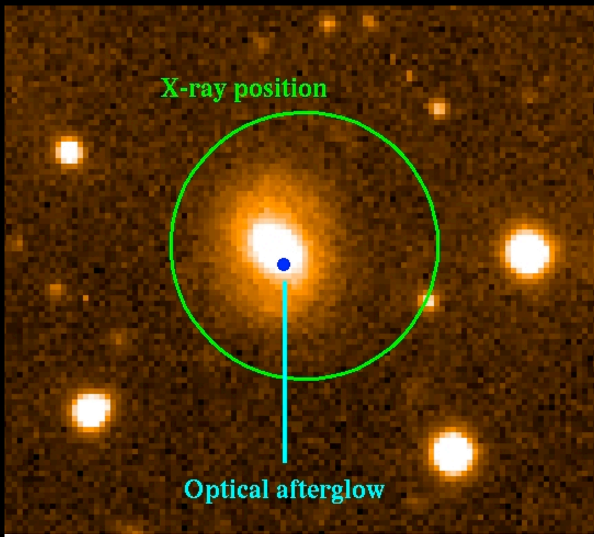
Long GRB & Supernovae

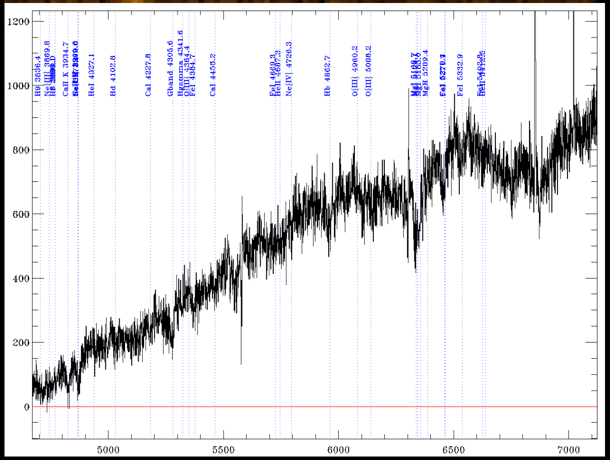


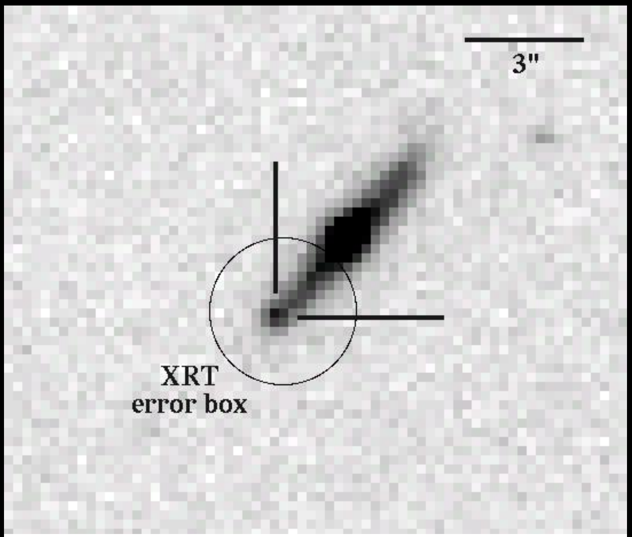


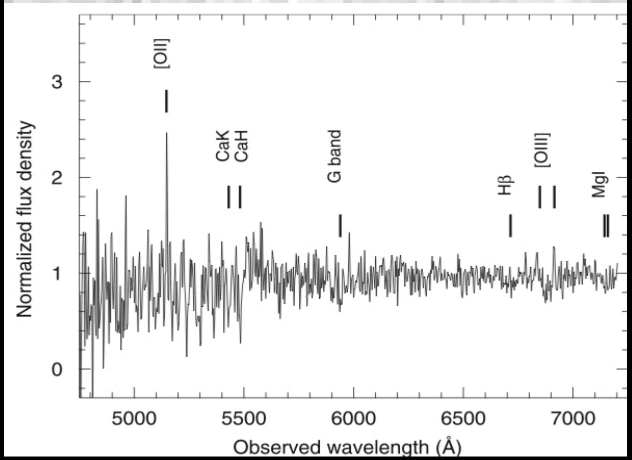


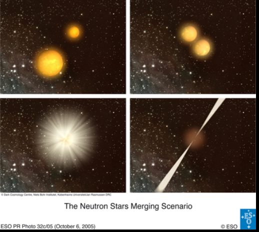
Short GRB afterglows, galaxies and redshift





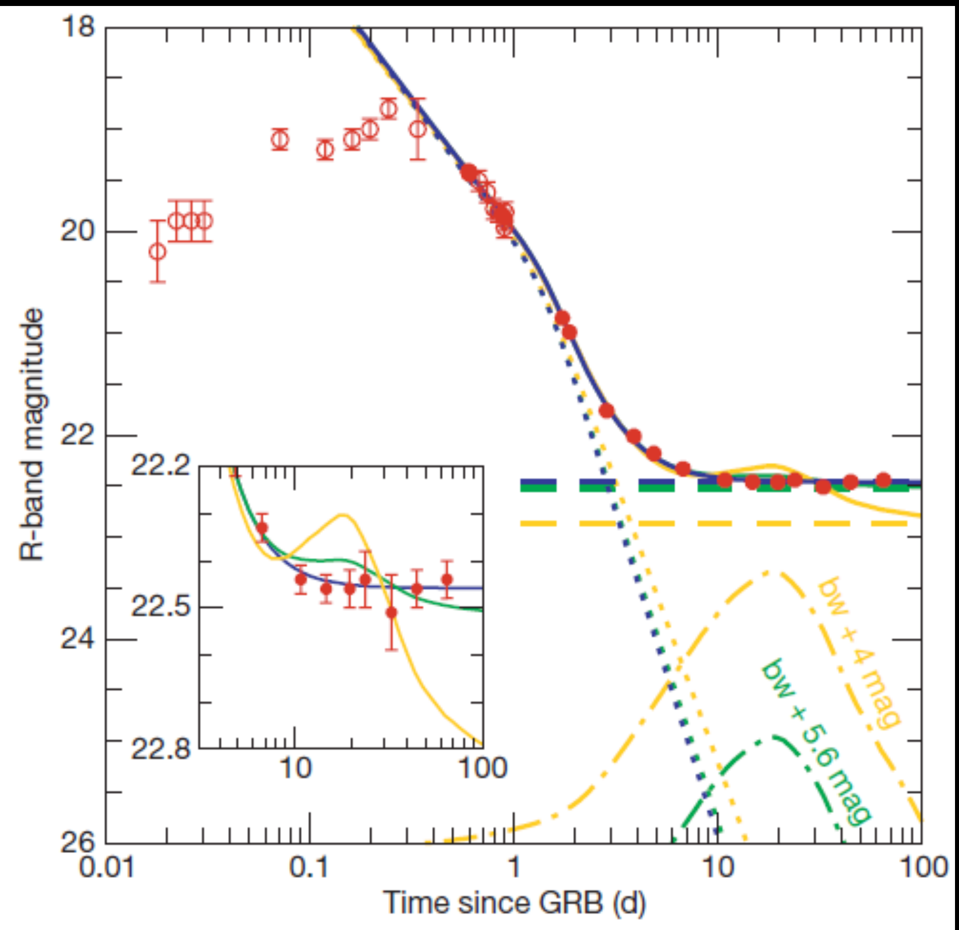




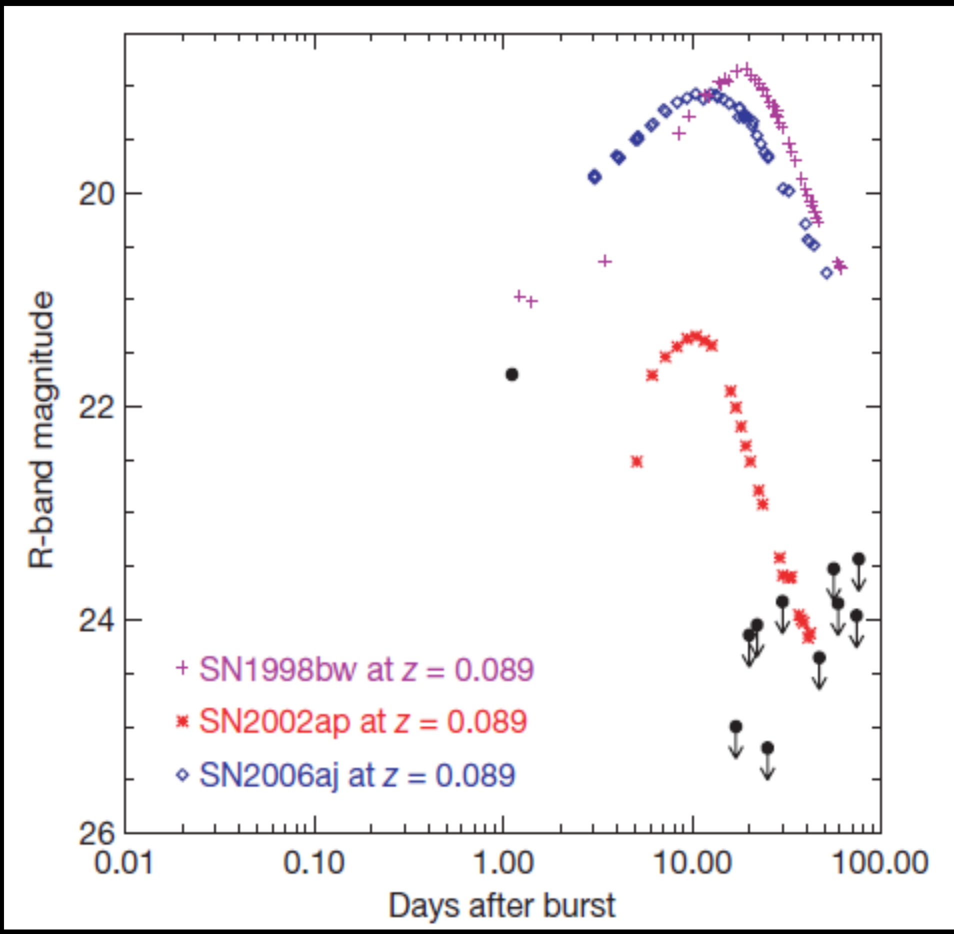


Short GRB & NO Supernovae

GRB 060614



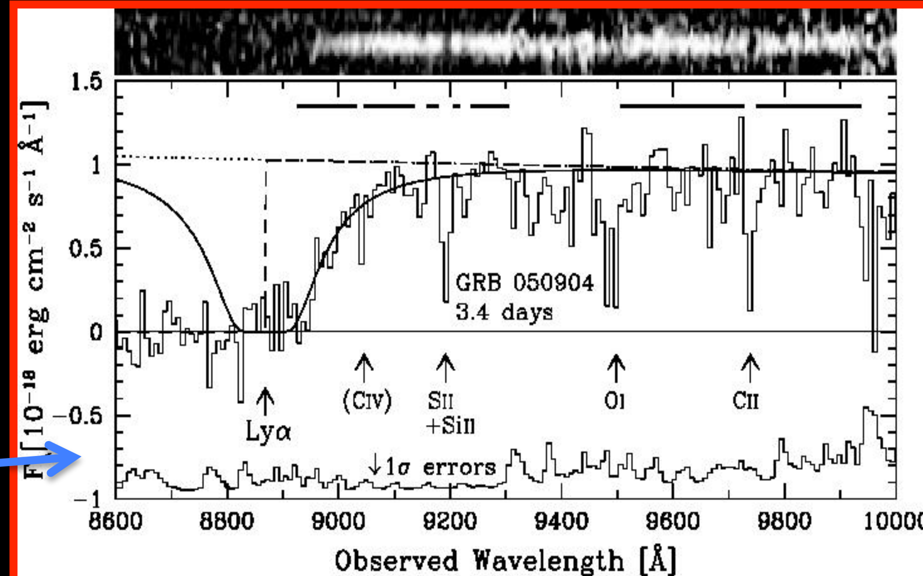
GRB 060505

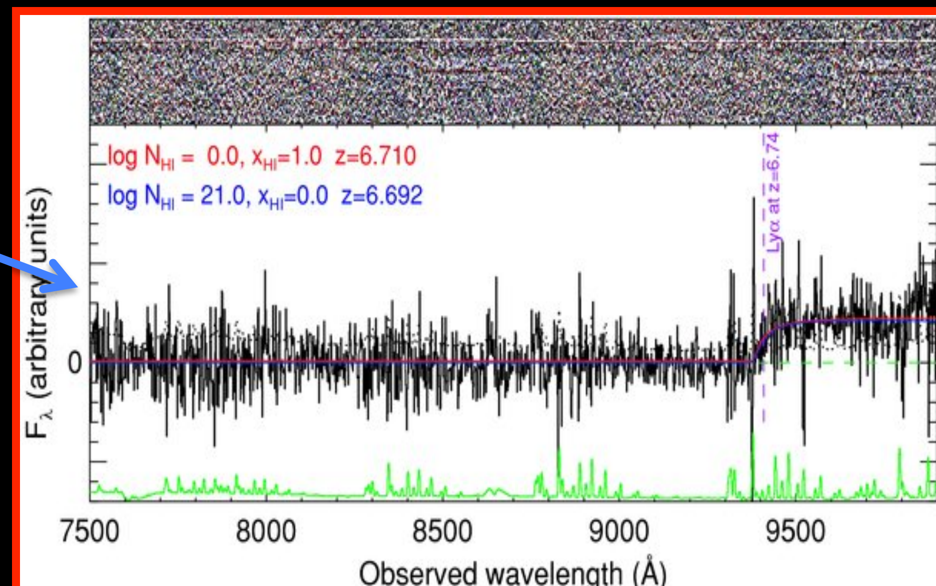


High-redshift GRBs

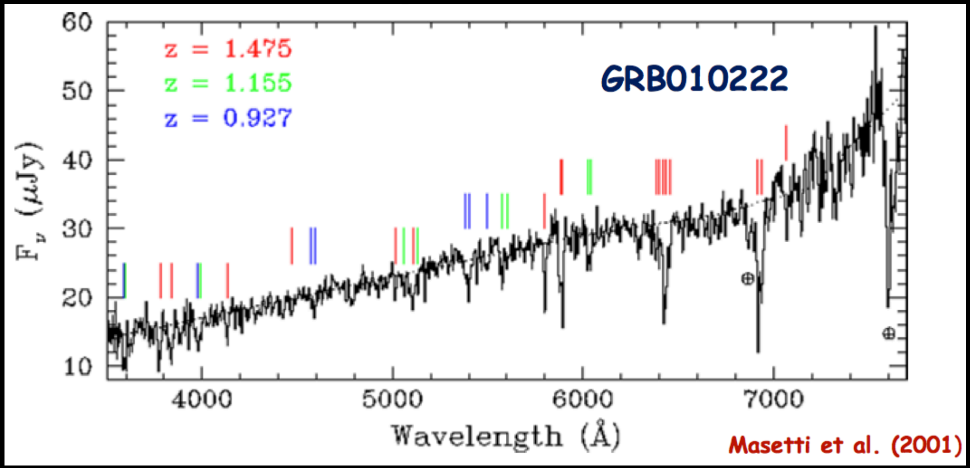
9 events with $z > 5$

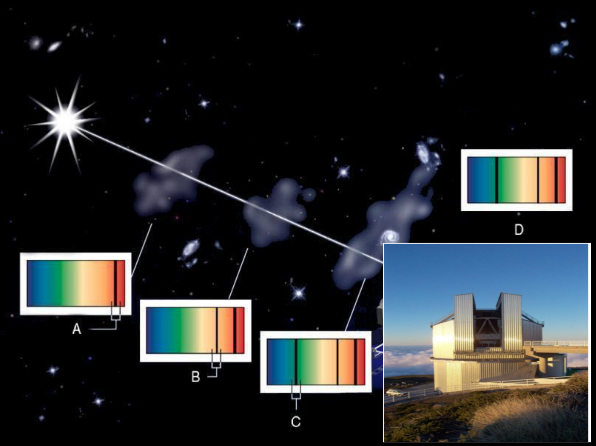
GRB	z	*Time (Gyr)*
050814	(5.3 ph)	12.6
050904	(6.3)	12.8
060522	(5.1)	12.5
060927	(5.6)	12.6
080913	(6.7)	12.8
090423	(8.2)	13.0
090429B	(9.4 ph)	13.1
100905A	(7.5)	13.0
120521C	(8.2)	12.6





GRB redshift and environment





Spectroscopic observations of GRB afterglows reveal a lot about the composition of the circumburst and the host galaxy environment and of the structures possibly present along the GRB line of sight.

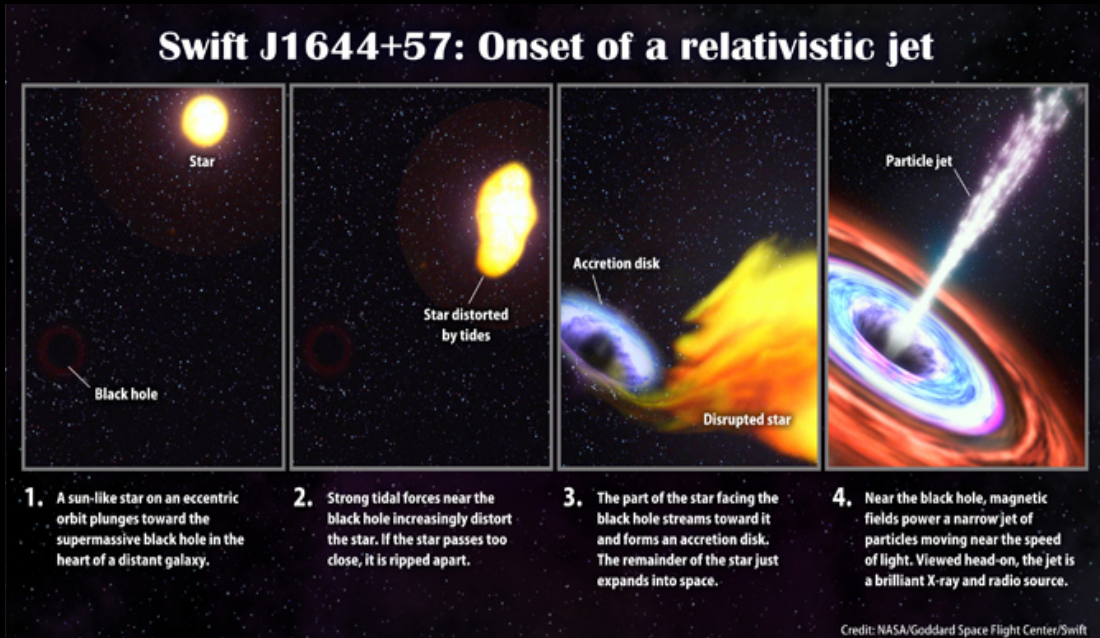
GRBs as probes

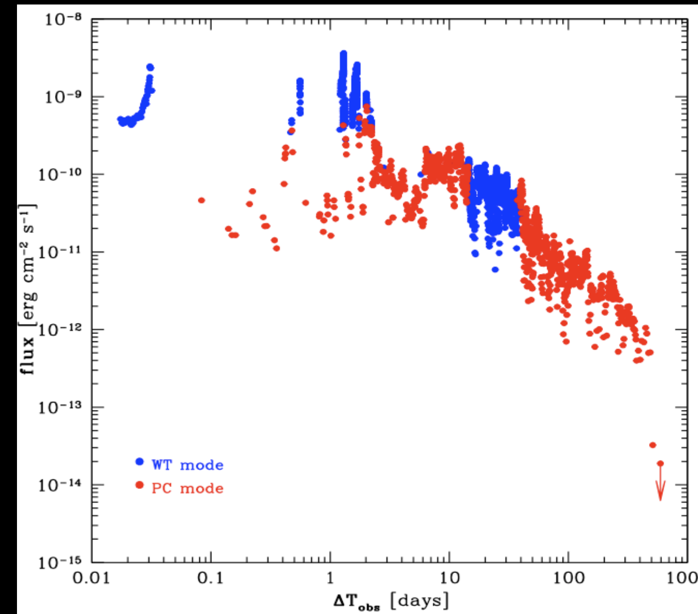
Thanks to their brightness, GRBs are detectable from the local Universe to very high redshift. A unique tool to study:

- cosmic star formation history
- metallicity & dust evolution
- the properties of faint galaxies that would be missed by 'traditional' surveys

non-GRB science

Unexpected Transients: Tidal Disruption Events



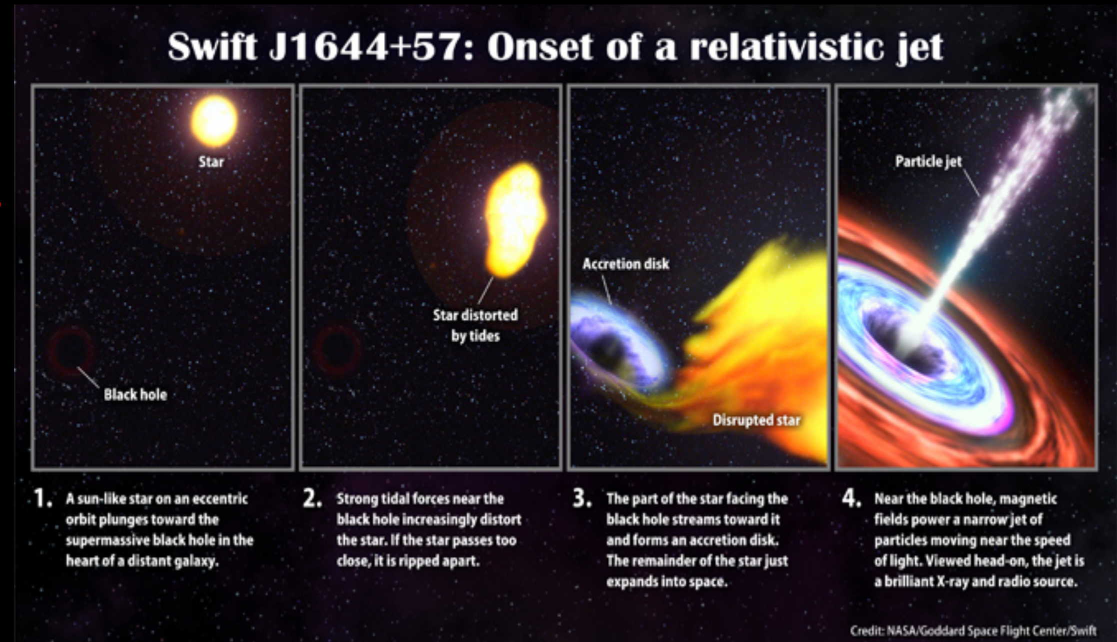


Swift Science

- BAT discovery of bright transient Mar '11
- Located at center of non-AGN galaxy
- Emission due to relativistic jet from star torn apart by ~$10^{6\text{-}7}$ M_o black hole
- TDEs long predicted but never seen so clearly. Jet not predicted

Unexpected Transients: Tidal Disruption Events

GRB 110328A/Swift J1644+57
a tidal disruption event on a
distant galactic nucleus



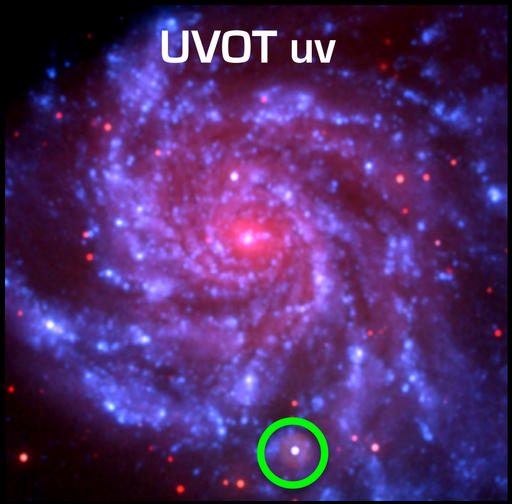
LETTER

doi:10.1038/nature10374

Relativistic jet activity from the tidal disruption of a star by a massive black hole

D. N. Burrows[1], J. A. Kennea[1], G. Ghisellini[2], V. Mangano[3], B. Zhang[4], K. L. Page[5], M. Eracleous[1], P. Romano[3], T. Sakamoto[6,7,8], A. D. Falcone[1], J. P. Osborne[5], S. Campana[2], A. P. Beardmore[5], A. A. Breeveld[9], M. M. Chester[1], R. Corbet[6,7,8], S. Covino[2], J. R. Cummings[6,7,8], P. D'Avanzo[2], V. D'Elia[10], P. Esposito[11], P. A. Evans[5], D. Fugazza[2], J. M. Gelbord[1], K. Hiroi[12], S. T. Holland[6,7,13], K. Y. Huang[14], M. Im[15], G. Israel[16], Y. Jeon[15], Y.-B. Jeon[17], H. D. Jun[15], N. Kawai[18,19], J. H. Kim[15], H. A. Krimm[6,7,13], F. E. Marshall[7], P. Mészáros[1], H. Negoro[20], N. Omodei[21,22], W.-K. Park[15], J. S. Perkins[6,7,8], M. Sugizaki[19], H.-I. Sung[17], G. Tagliaferri[2], E. Troja[7], Y. Ueda[12], Y. Urata[23], R. Usui[18], L. A. Antonelli[10,16], S. D. Barthelmy[7], G. Cusumano[3], P. Giommi[10], A. Melandri[2], M. Perri[10], J. L. Racusin[7], B. Sbarufatti[3], M. H. Siegel[1] & N. Gehrels[7]

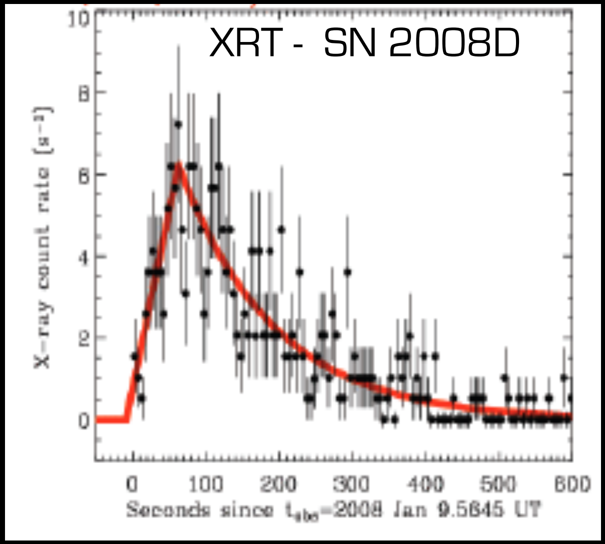
Supernovae

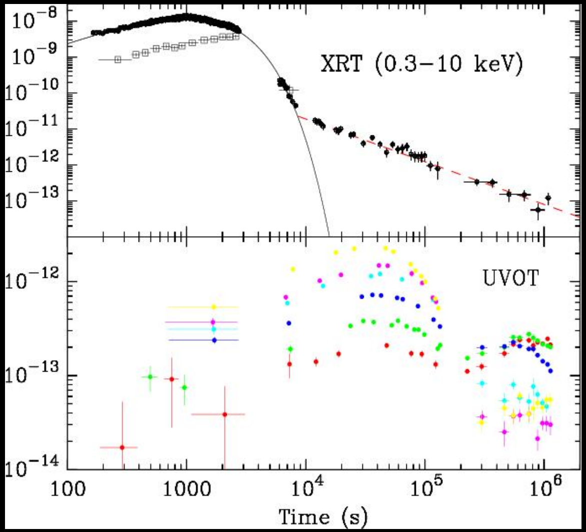


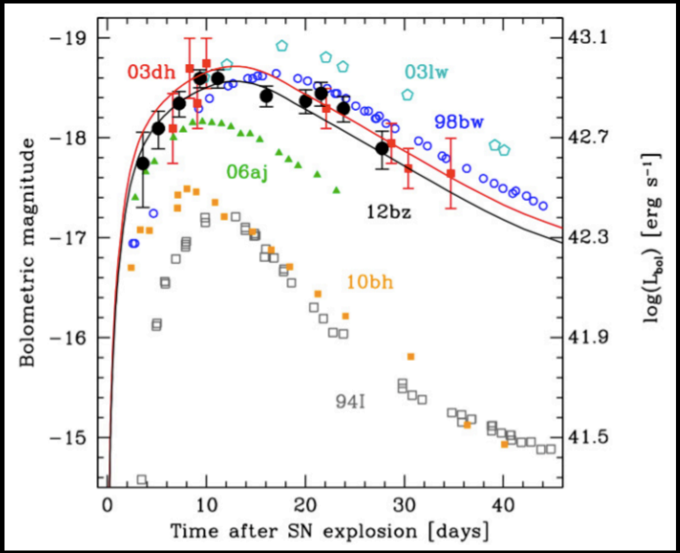
SN 2011ef (Ia)

***Swift* Science**

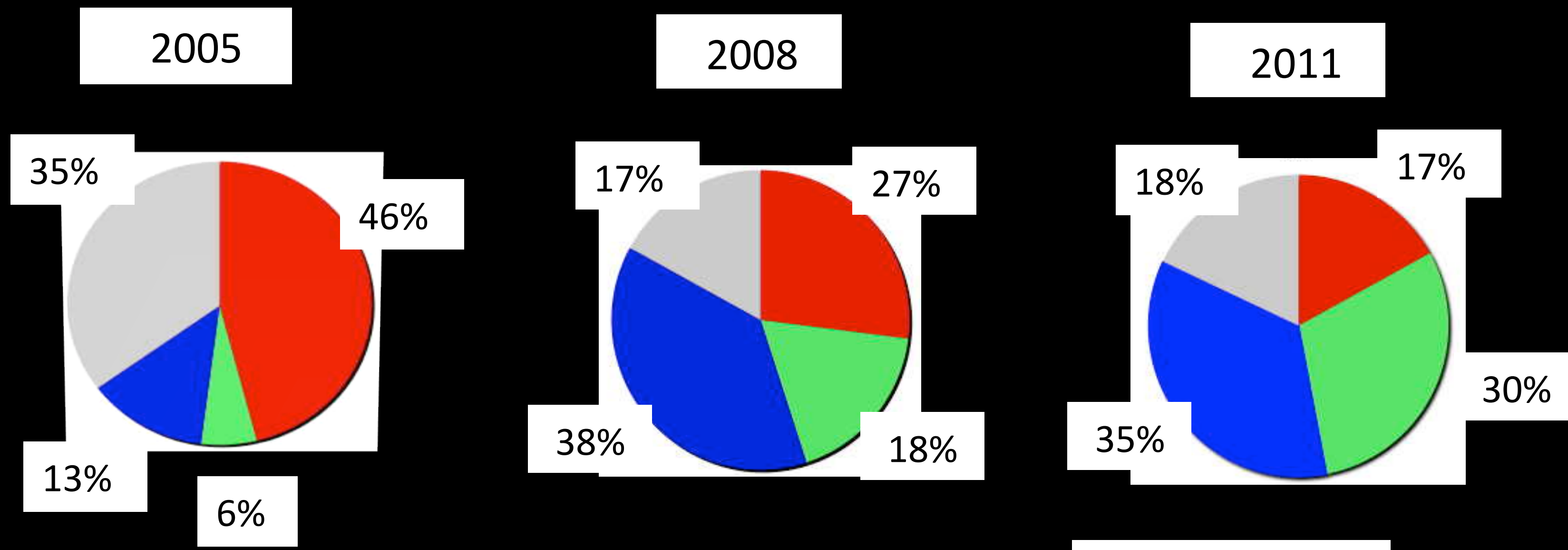
- SN shock breakout discovered by *Swift*/XRT
- *Swift* is accumulating best UV data set on Type Ia SNe.
- *Swift* has detected far more SNe in X-rays and UV than any other mission



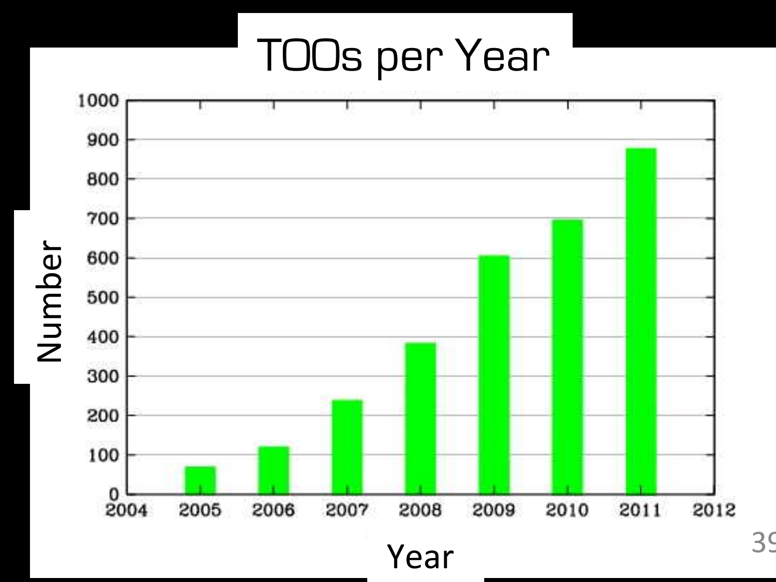




Evolving Observing Time: change of strategy for GRBs observations

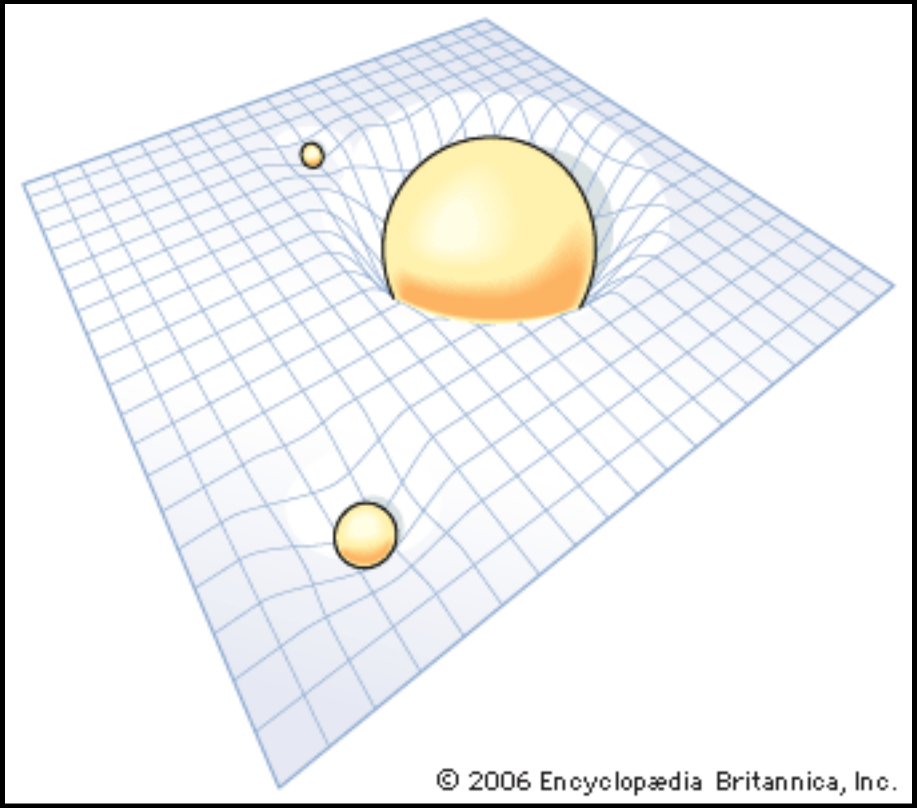


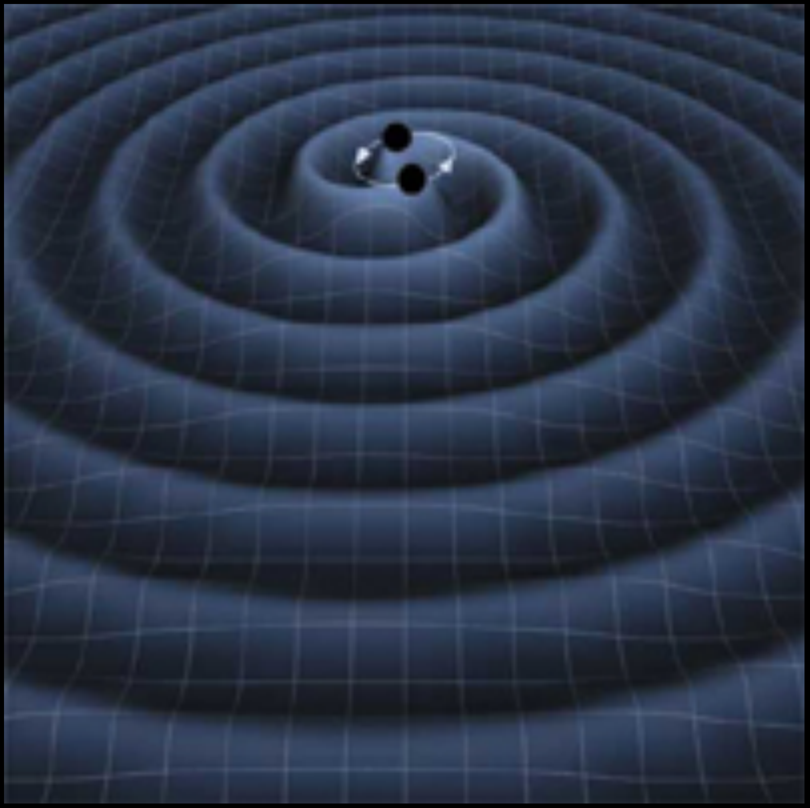
- GRBs
- Target of Opportunities (TOOs)
- Guest Investigator targets / Fill-ins
- SAA & Calibration



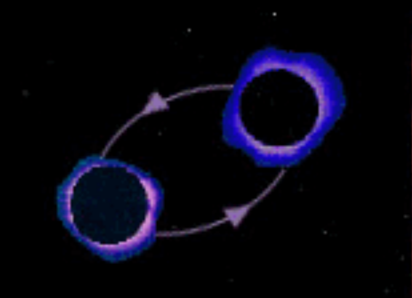
The Future

Oltre lo spettro EM: le onde gravitazionali

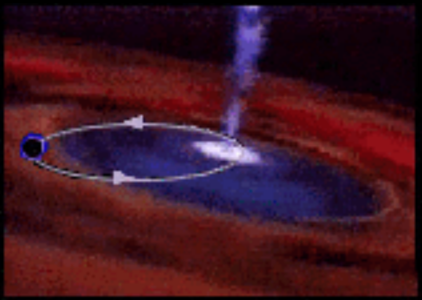




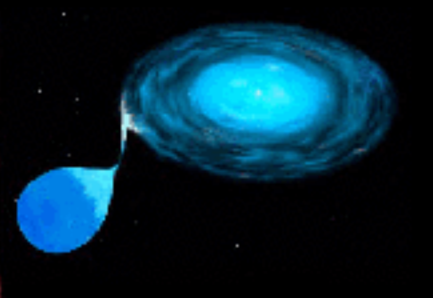
Sorgenti di onde gravitazionali



Coalescence of massive black holes during collisions between galaxies, perhaps in formation of massive black holes, probing the central engines powering quasars.



Black holes orbiting massive black holes, providing precision tests of gravitational theory in the high-field limit.



Hundreds of galactic binary star systems, many containing neutron stars or black holes, including several known binary systems.

Supernovae

Rivelatori di onde gravitazionali

LIGO

Laser Interferometer Gravitational-Wave Observatory

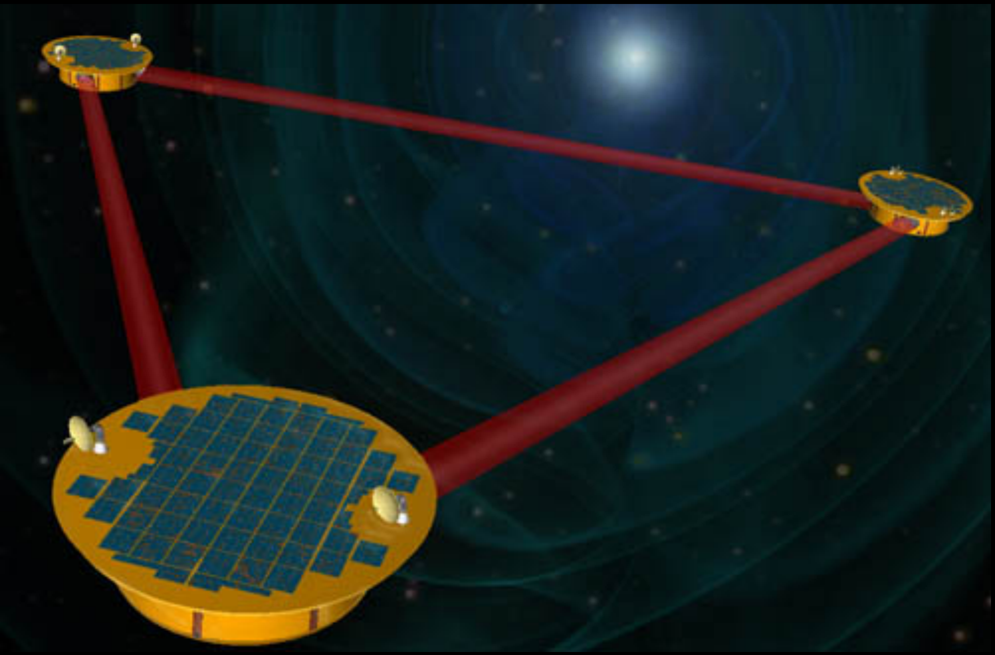
VIRGO

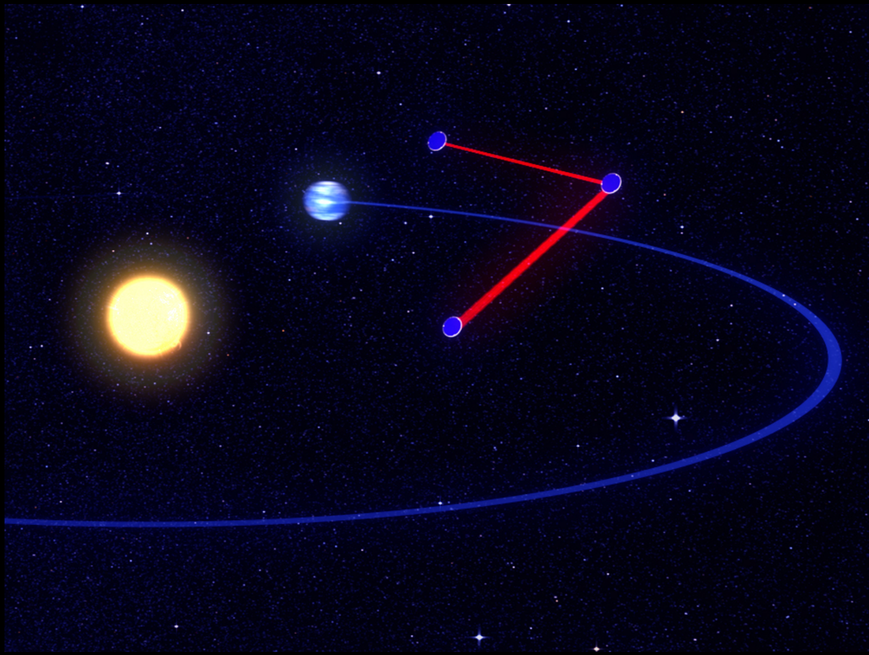
Ciascun braccio dell' interferometro e` lungo circa 3-4 km

Distorsione prevista: 10^{-18} m

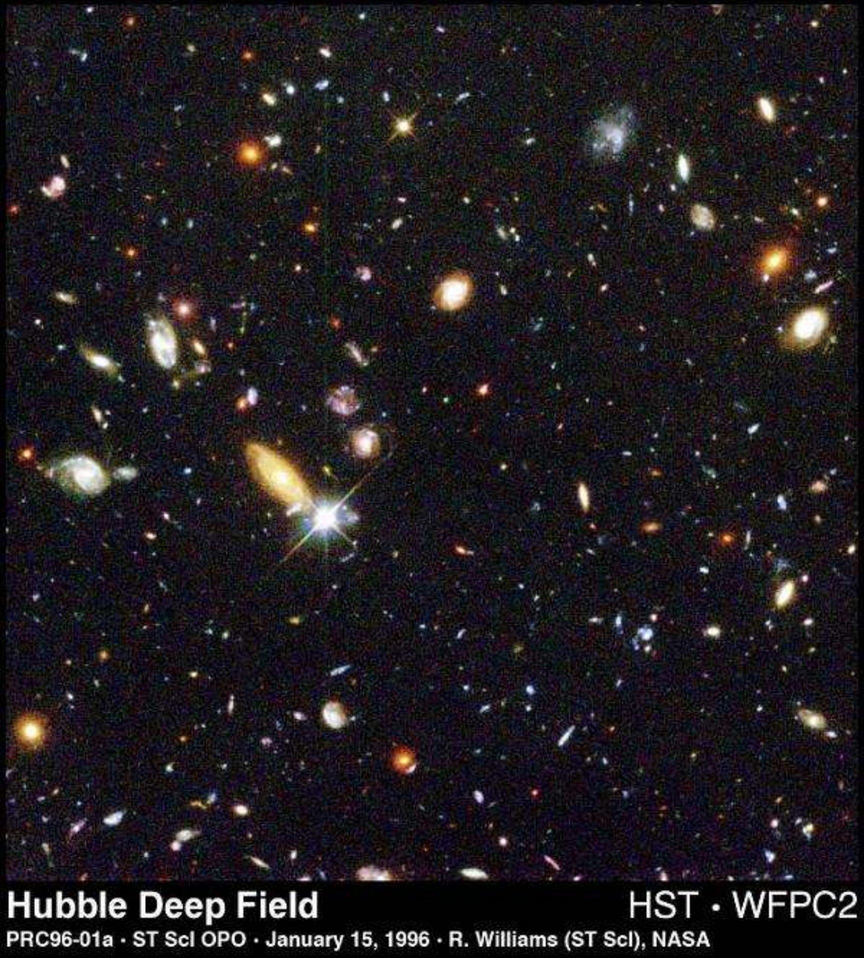
Rivelatori di onde gravitazionali il futuro

eLISA/NGO (202?)

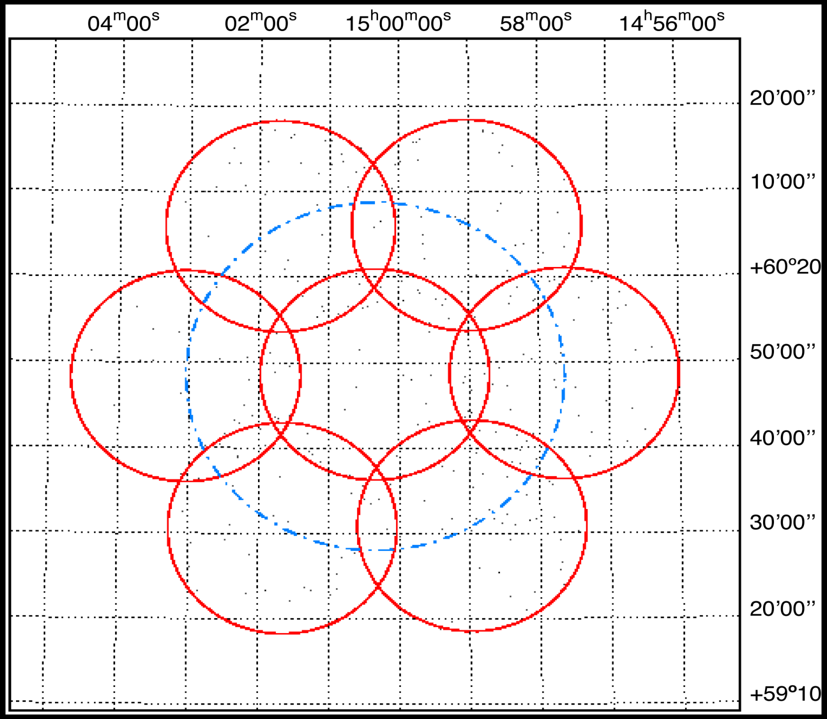




Searching for GW counterparts

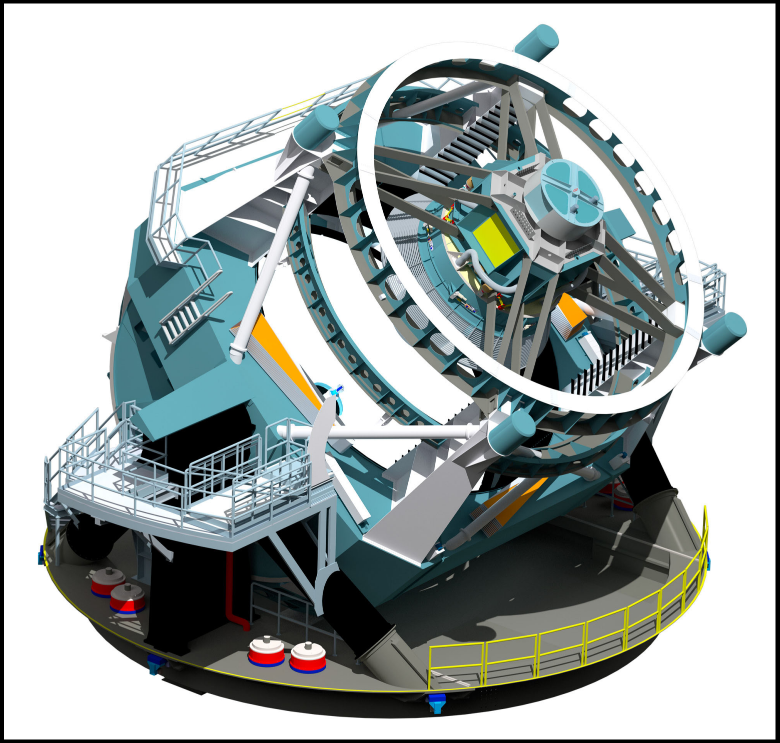


Auto Sky Tiling



Survey del futuro: LSST

Large Synoptic Survey Telescope (2020)

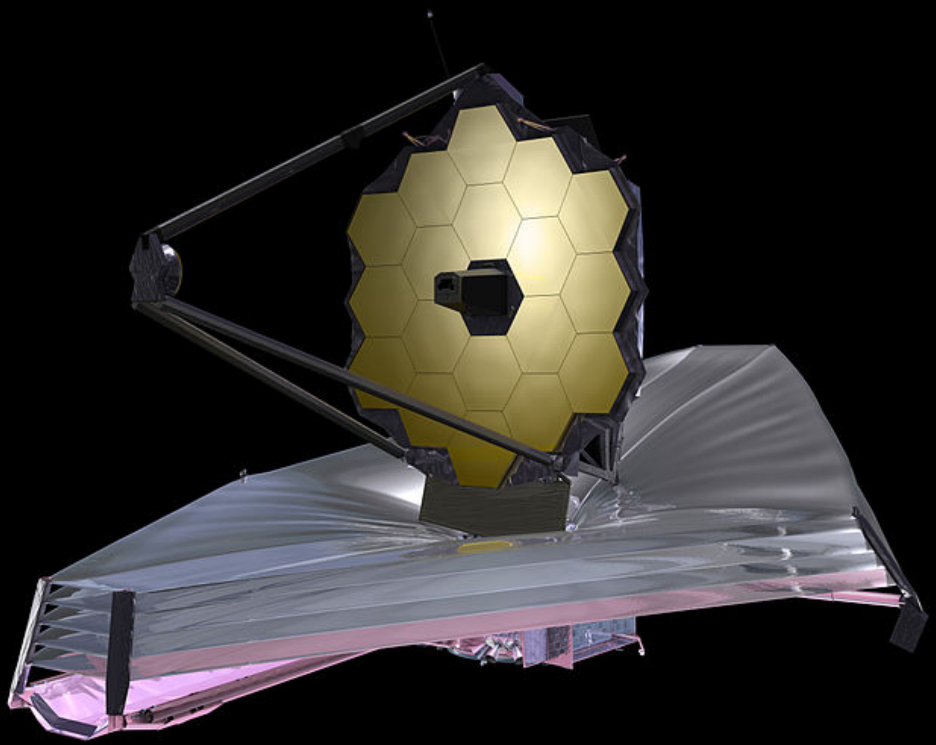


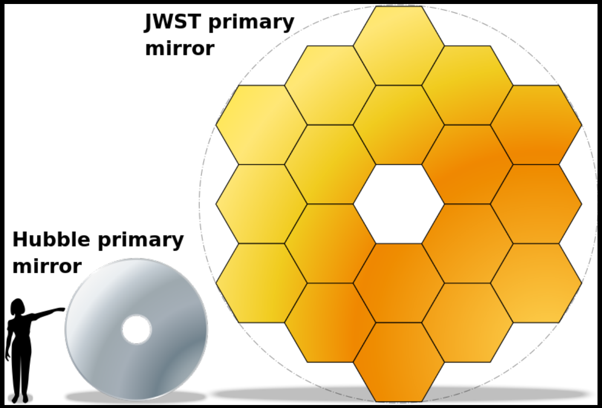
- 18000 gradi quadri ogni 3-4 notti (50% del cielo)
- sorgenti variabili
- 15 Tbyte (1000 Gb) di dati ogni notte per 10 anni
- 8.4 metri di apertura

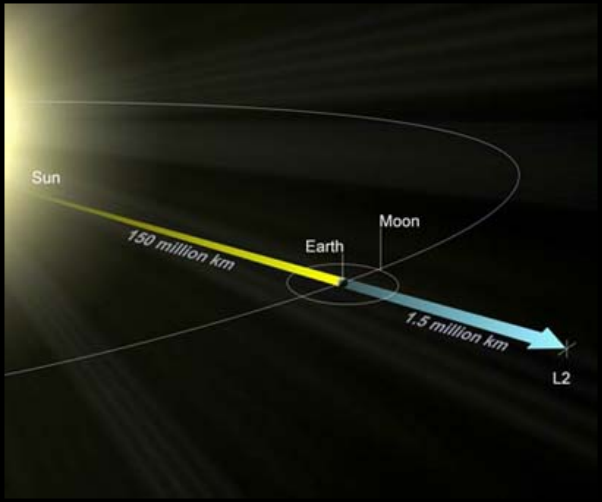
Legacy

I telescopi del futuro: JWST

James Webb Space Telescope (2018)

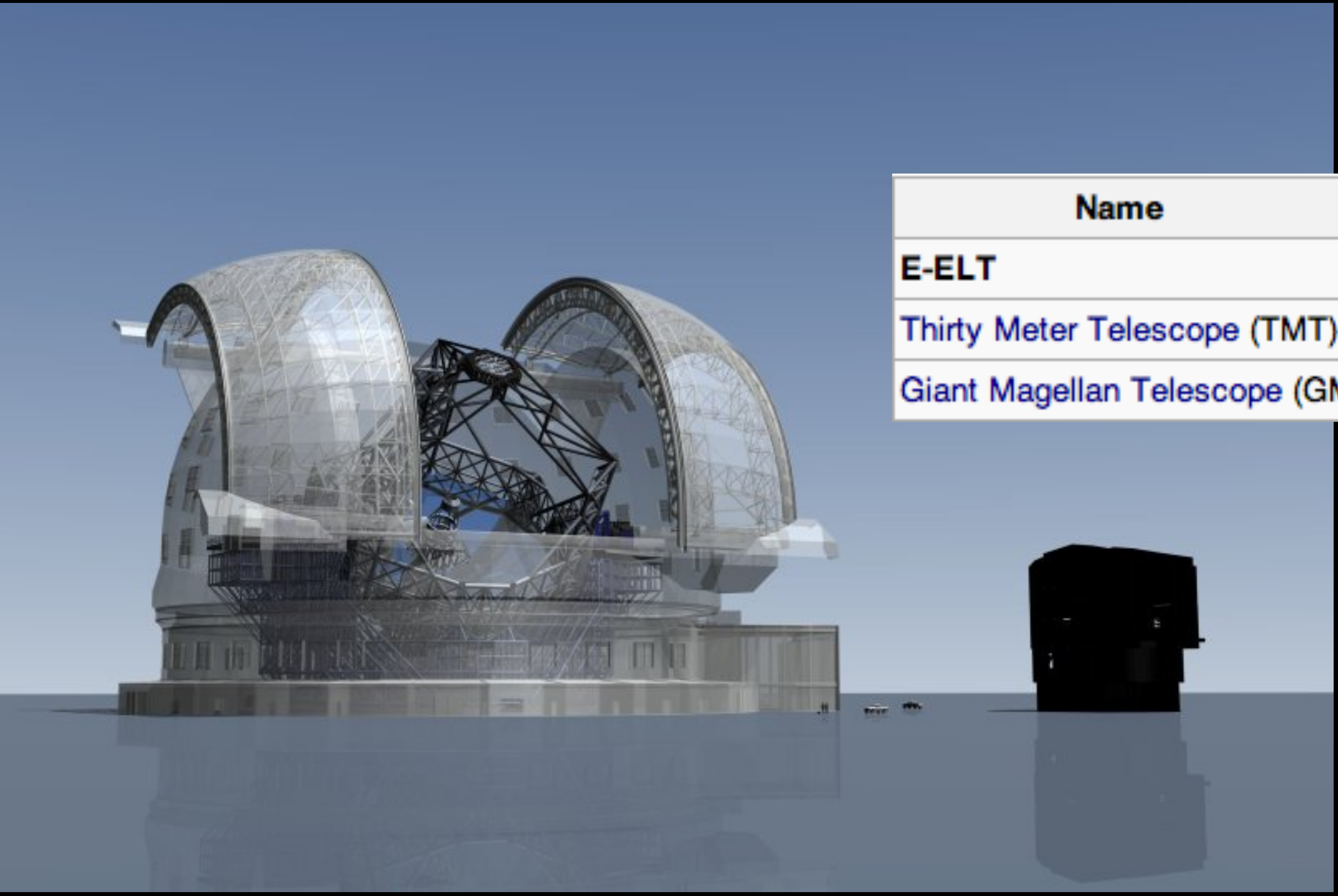






I telescopi del futuro: E-ELT

European Extremely Large Telescope (2020)
Diametro: 39 m

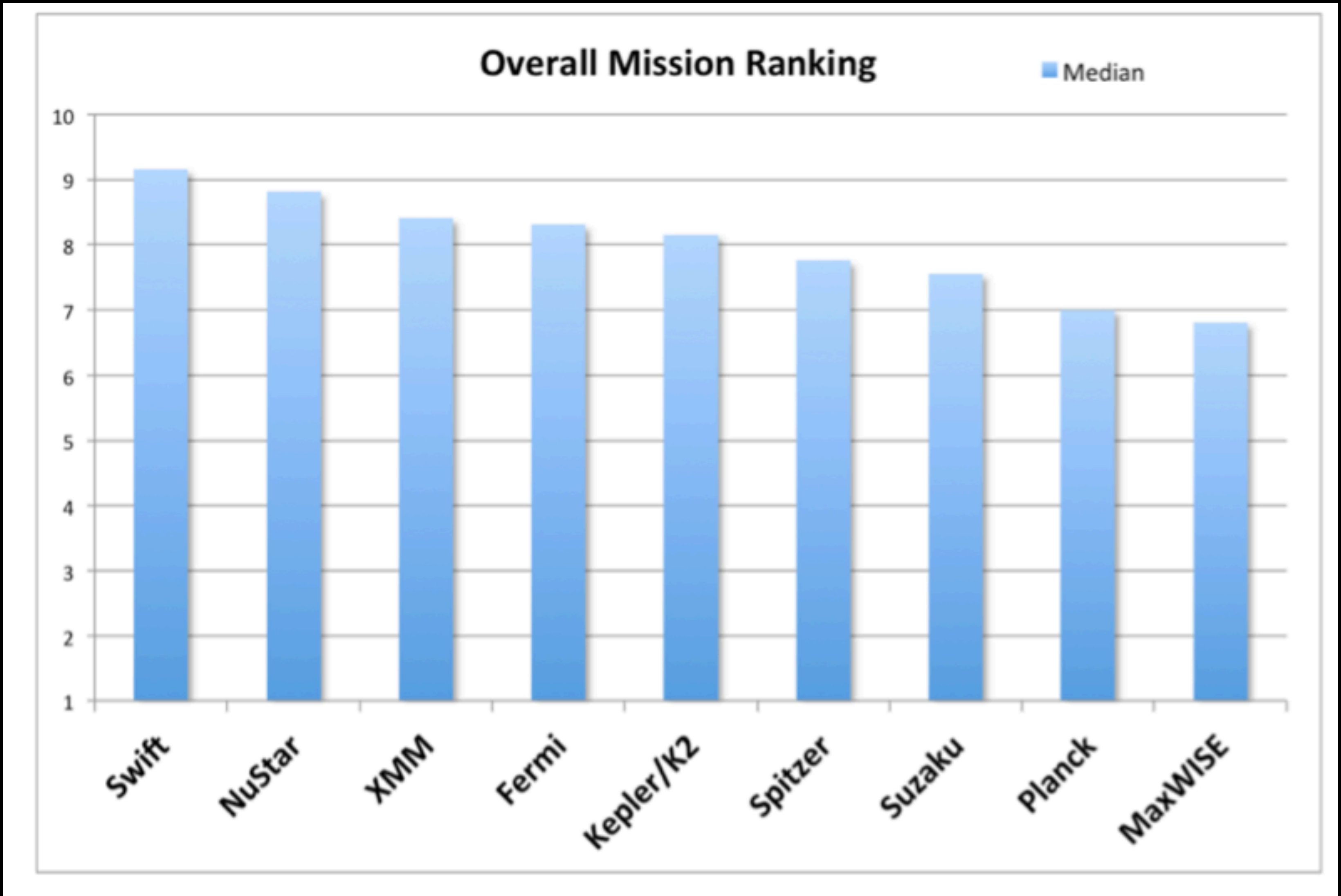


Name	Aperture diameter (m)
E-ELT	39.3
Thirty Meter Telescope (TMT)	30
Giant Magellan Telescope (GMT)	24.5

Numbers

- 939 GRB (10% short)
- 711 Active Galactic Nuclei
- 334 Supernovae
- 186 X-ray Binaries
- 42 magnetar outbursts
- 20 Pulsars
- 2 Tidal disruption events
- Up to 75 target per day
- > 1800 scientific papers (>28000 citations)

NASA 2014 senior review



Happy Birthday, Swift!

Summary

- World's premier GRB observatory: outstanding science results on GRBs (X-ray light curve, high-z GRBs, GRB-SN connection, short GRBs)
- Rate of publications remains high and includes game-changing papers
- GI program (5 Ms/year) making discoveries on a broad range of topics
- Unique Time Domain sampling and wavelength coverage
  - Up to 75 target per day; >1000 observing program per year
  - Autonomous response (s to min): GRBs, SGRs, flare stars, X-ray transients
  - ToO response in periods from minutes up to hours and/or days
  - Now: spending most of its observing time on non-GRBs source
- *Swift* has improved capabilities and exciting new opportunities:
  - Automated tiling of large error regions to identify high-value events
  - Augmented on-board catalog to find transients in nearby galaxies
  - Improved ground-based instruments to identify high-z GRBs
  - Future collaboration to find & identify gravitational wave event
- Detected for the first time the onset of an extragalactic jet (+1) result of a TDE by SMBH