Gamma-Ray Bursts at OAS

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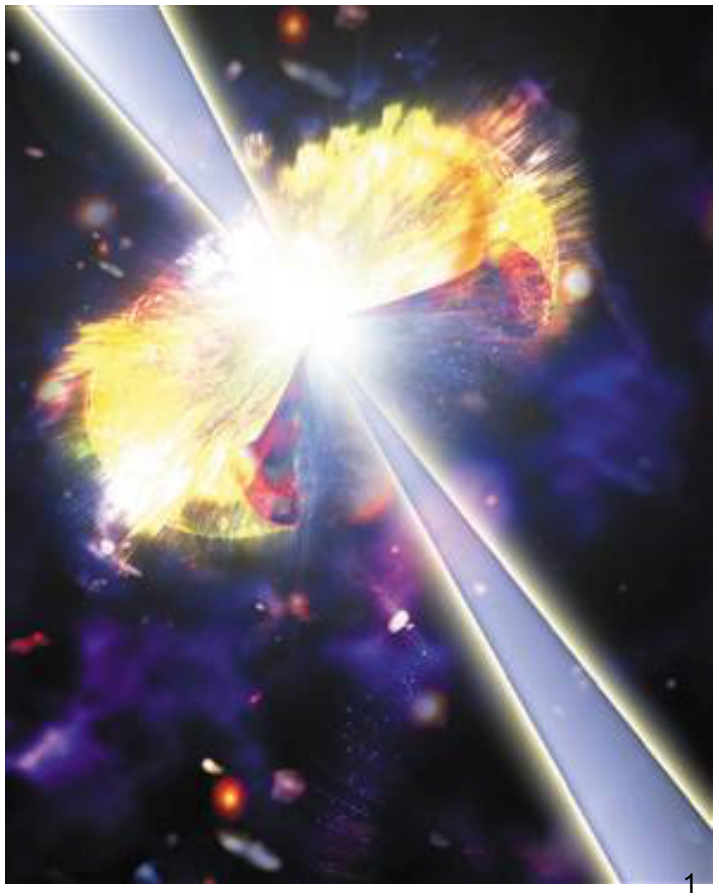
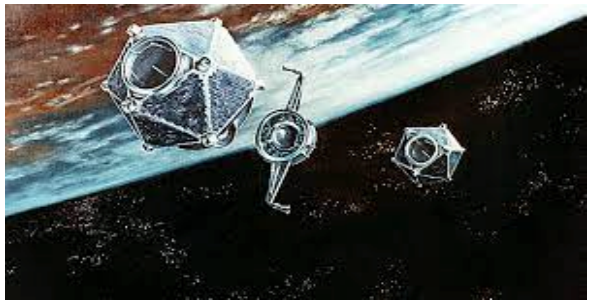


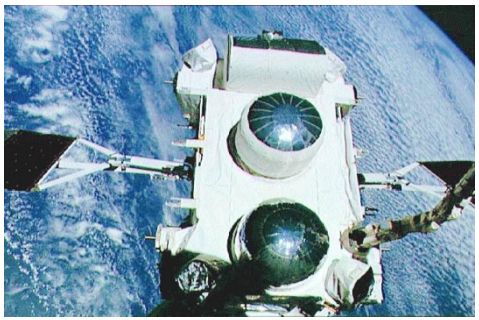
Gamma Ray Bursts (GRBs)

GRBs are sudden, unpredictable, short lived, extremely bright γ-ray sources:

- ➢ random locations in the sky
- ➢ duration 10^{-3} - 10^{4} seconds
- ➢ isotropic equivalent γ-ray energy: $\sim 10^{48}$ - 10^{55} erg
- ➢ emitting photons of energy ~10 keV - 2 MeV
- ➢ cosmological sources, redshifts ~ 0.01 - 9
- ➢ measured rate: ~1 /day

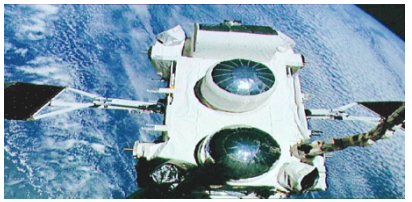


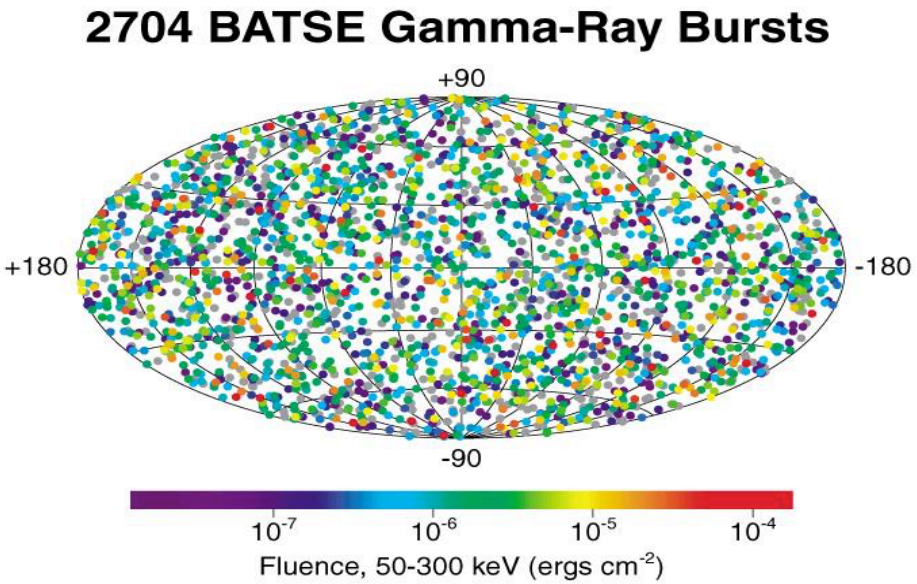
Serendipitously discovered in the late '60s by US military satellites VELA (Klebesadel et al. 1973)

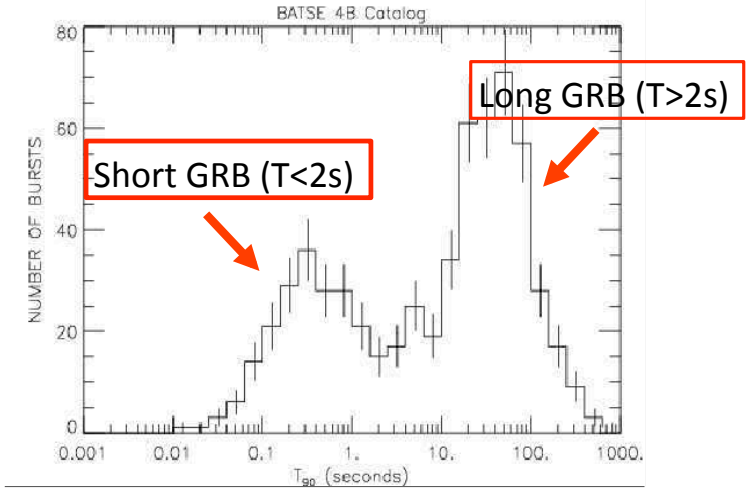


BATSE instrument on board CGRO (1991-2000)

GRBs - The BATSE era (1991-2000)





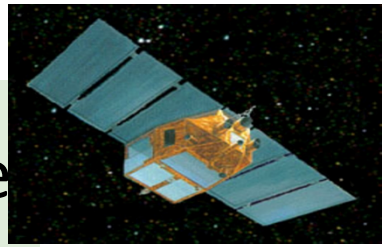


Bimodal distribution of burst durations
—> **two classes of GRBs**

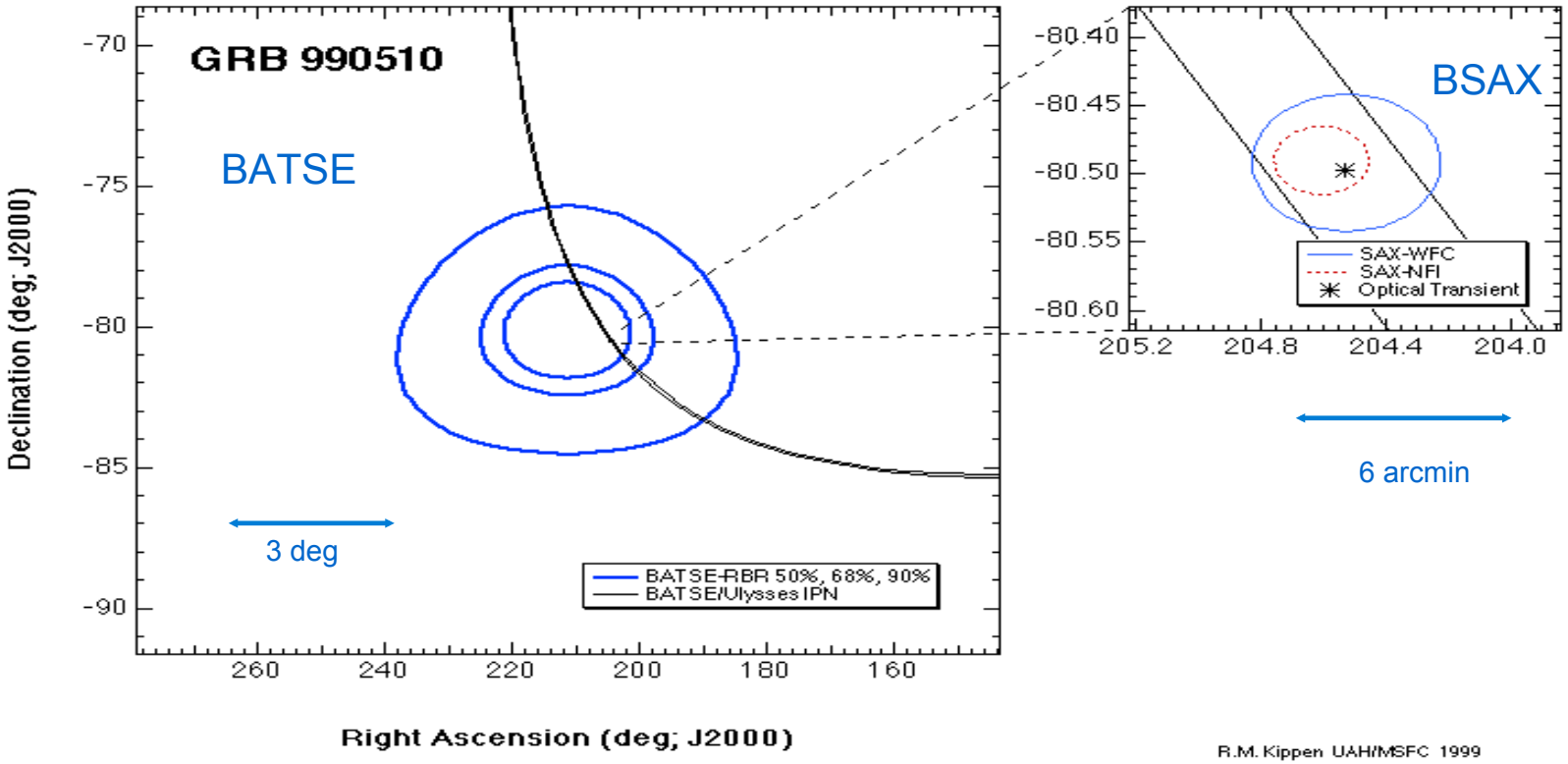
Kouveliotou et al. 1993

GRBs - The *BeppoSAX* era (1996-2002)

The importance of accurate localization (~arcminute

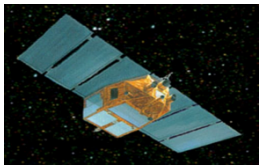


The BeppoSAX satellite

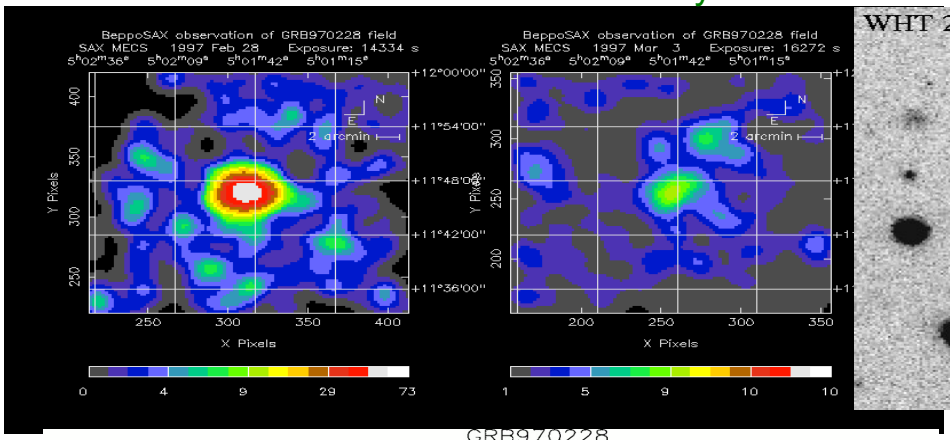


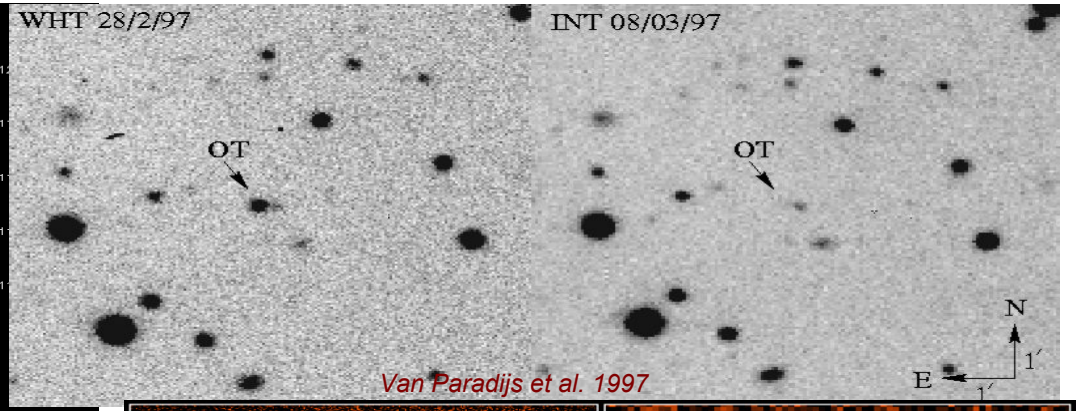
R.M. Kippen UAH/MSFC 1999

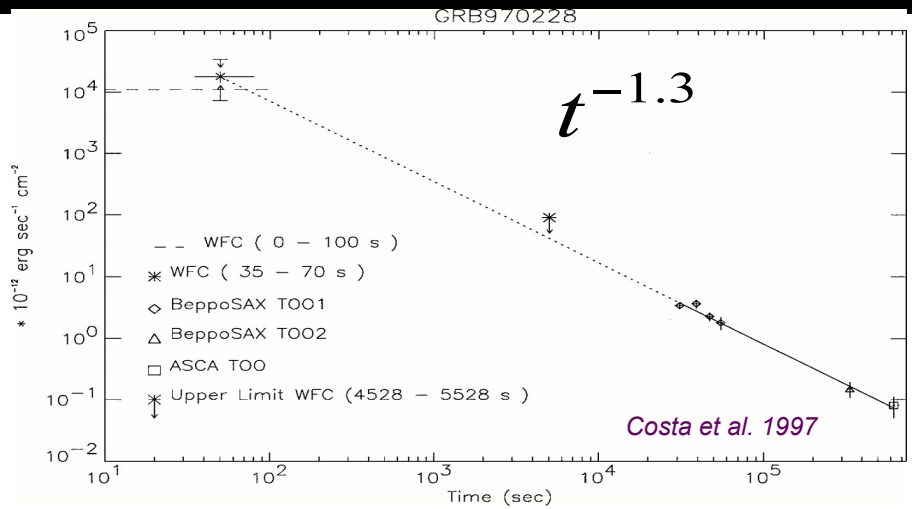
GRB970228: first detection of X-ray and optical afterglow

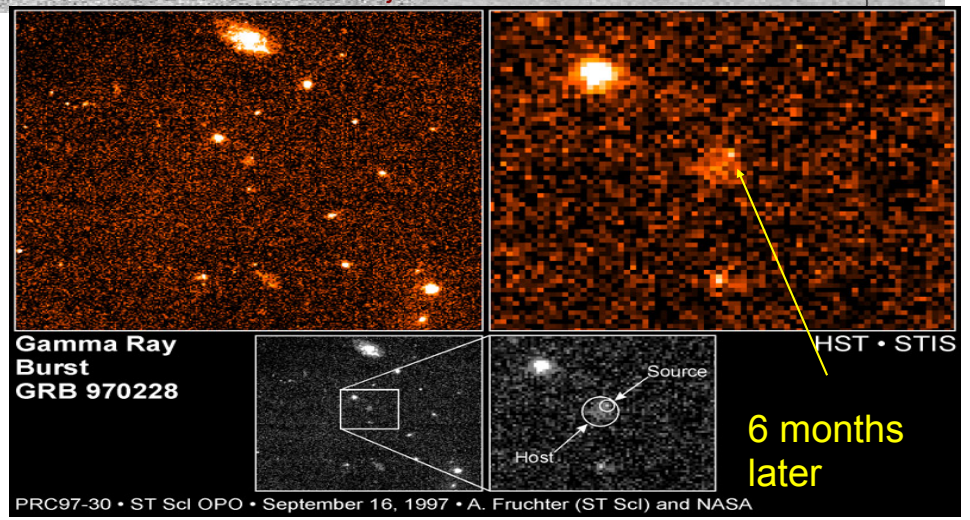


8 hours 3 days

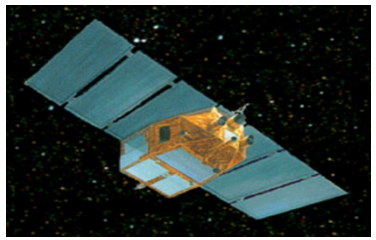


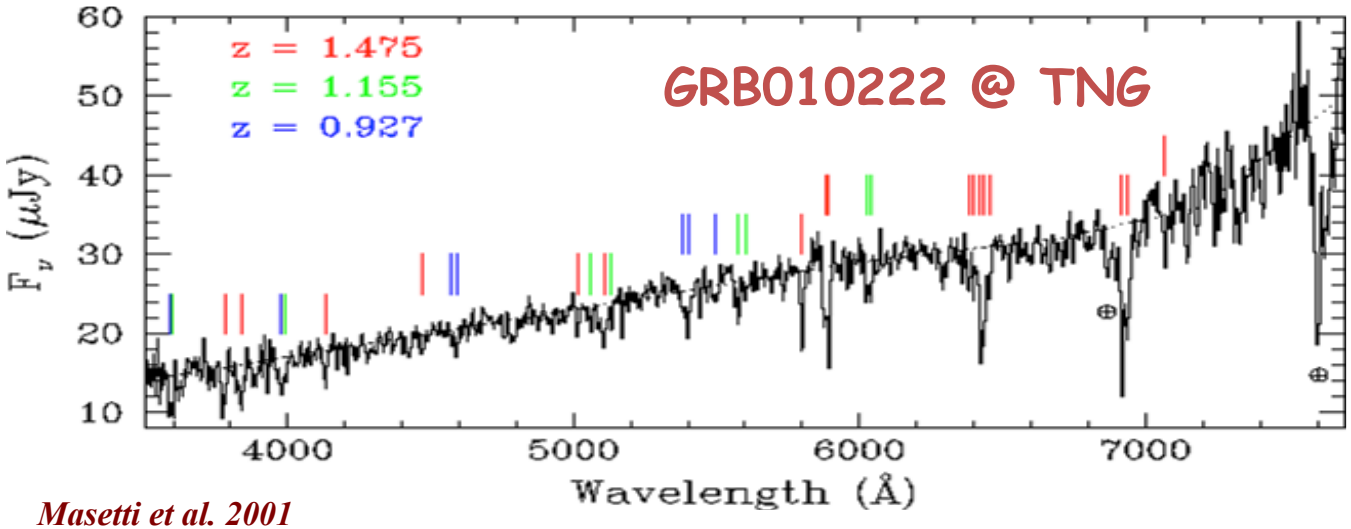




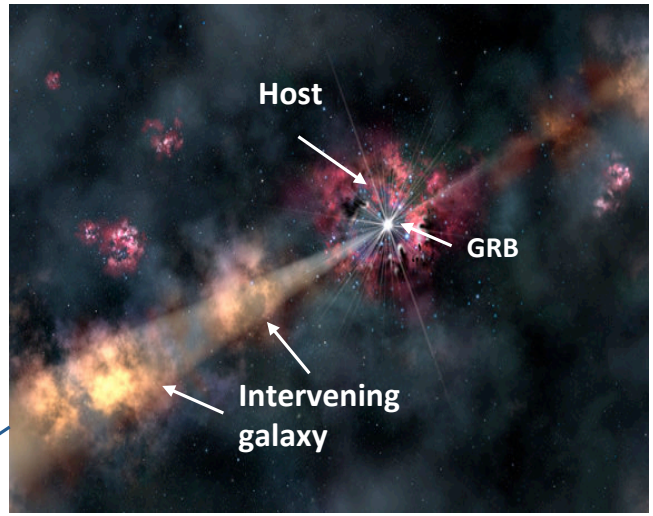


LGRBs - Redshift measurement





Masetti et al. 2001

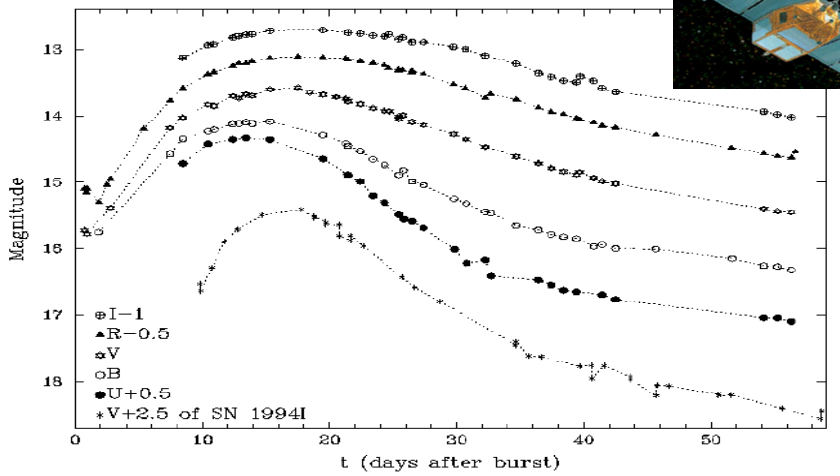


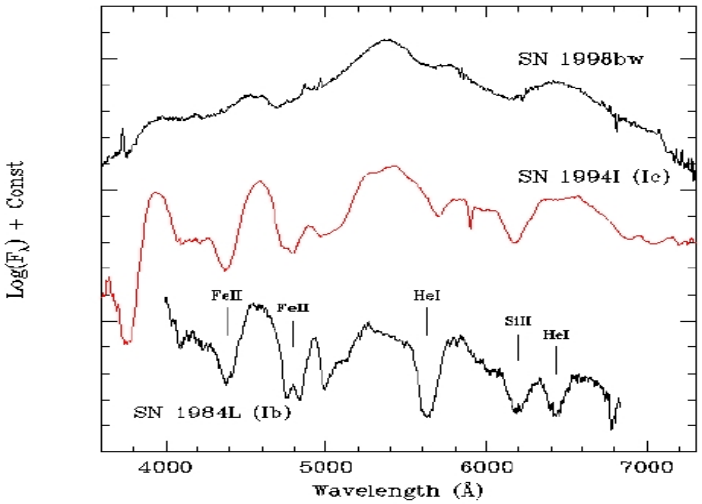
GRB980425
Supernova 1998bw (Type Ic)

SN 1998bw in Spiral Galaxy ESO184-G82

z = 0.0085

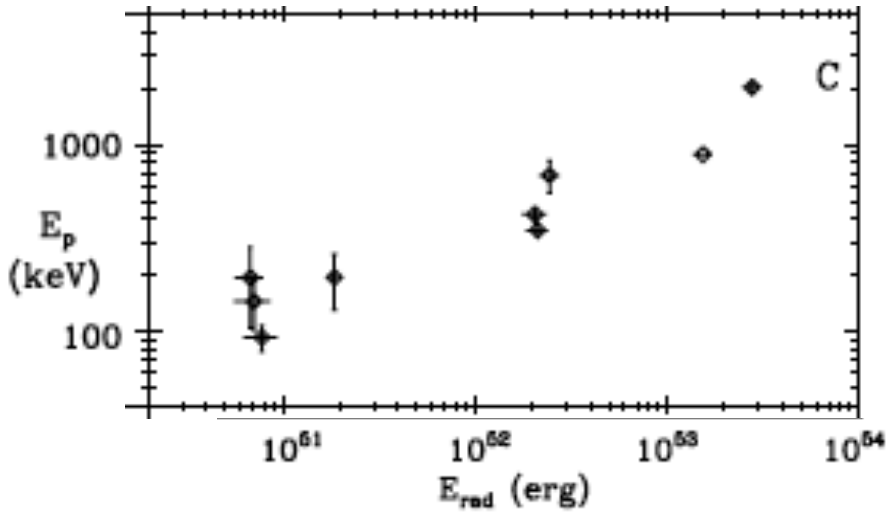
ESO PR Photo 39a/98 (15 October 1998)



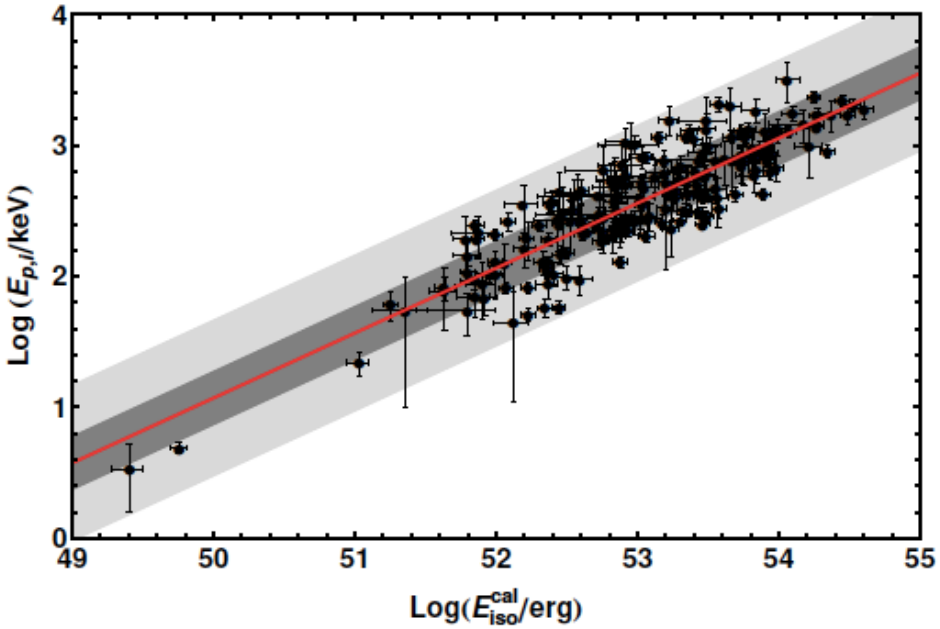


Galama, BSAX Dutch and Italian ESO Collaboration et al. 1998

Amati relationship between Ep and Eiso of long GRBs

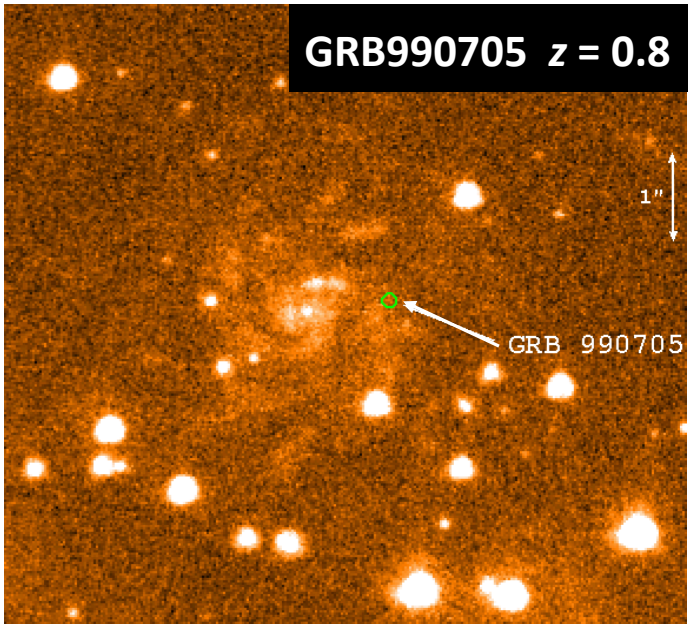


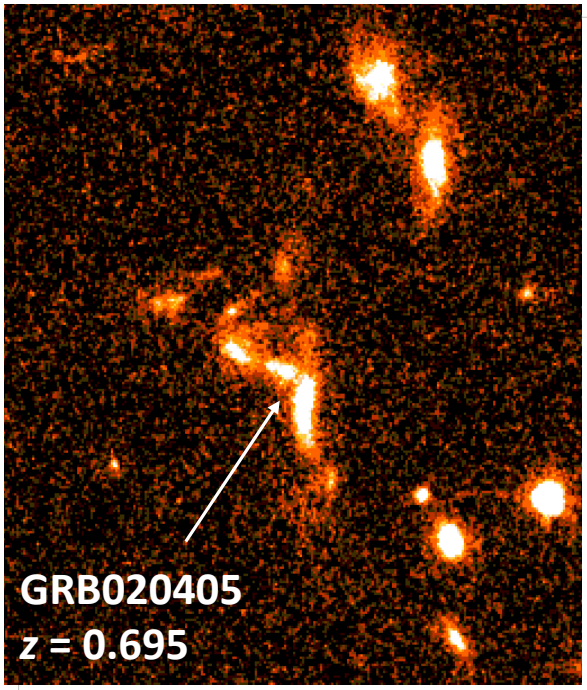
Amati et al. 2002

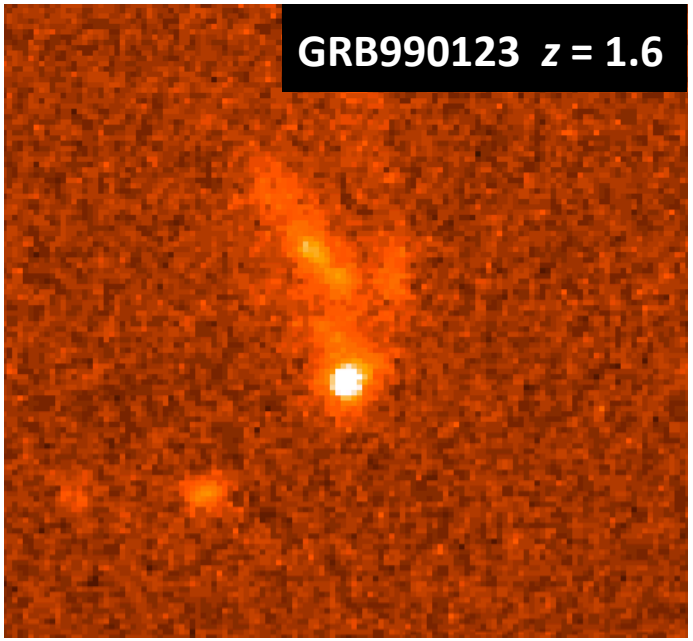


Amati et al. 2019

LGRB hosts: probes to the distant Universe



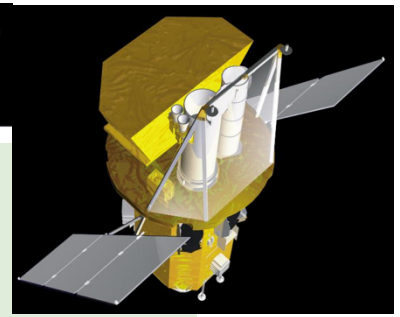




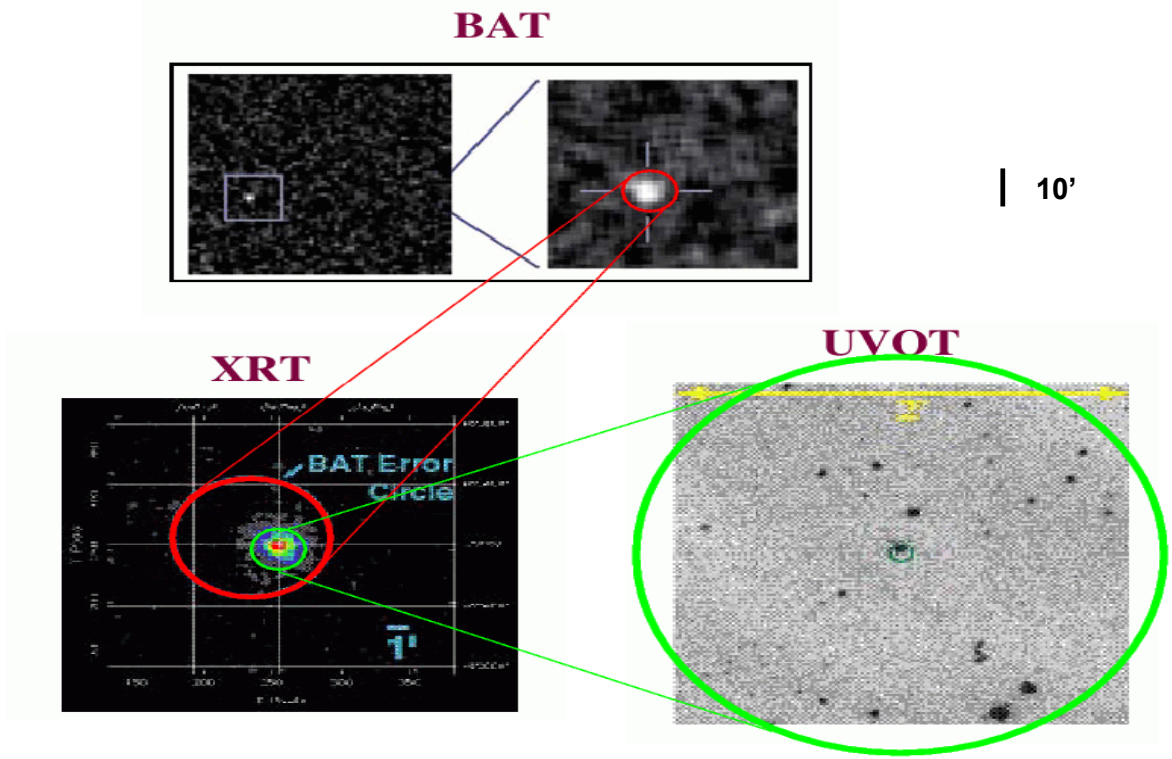
LGRB hosts: irregular **blue dwarf** hosts with **low metallicity**, **intense star formation** and mostly **young stellar population**

Consistent with **young massive star (> 30 M_{sun}) progenitors for LGRBs**

GRBs - The *Swift* era (2004-....)



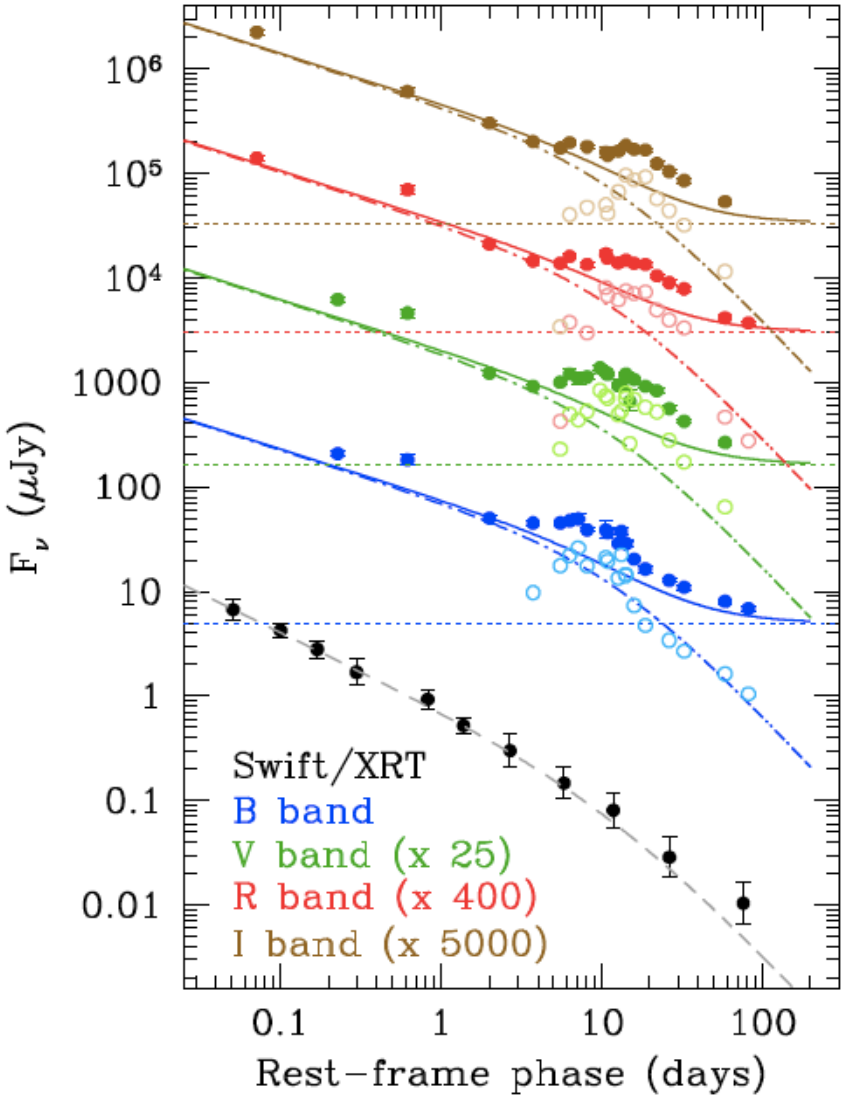
The importance of accurate localization
(~arcseconds) and fast repointing (few minutes)



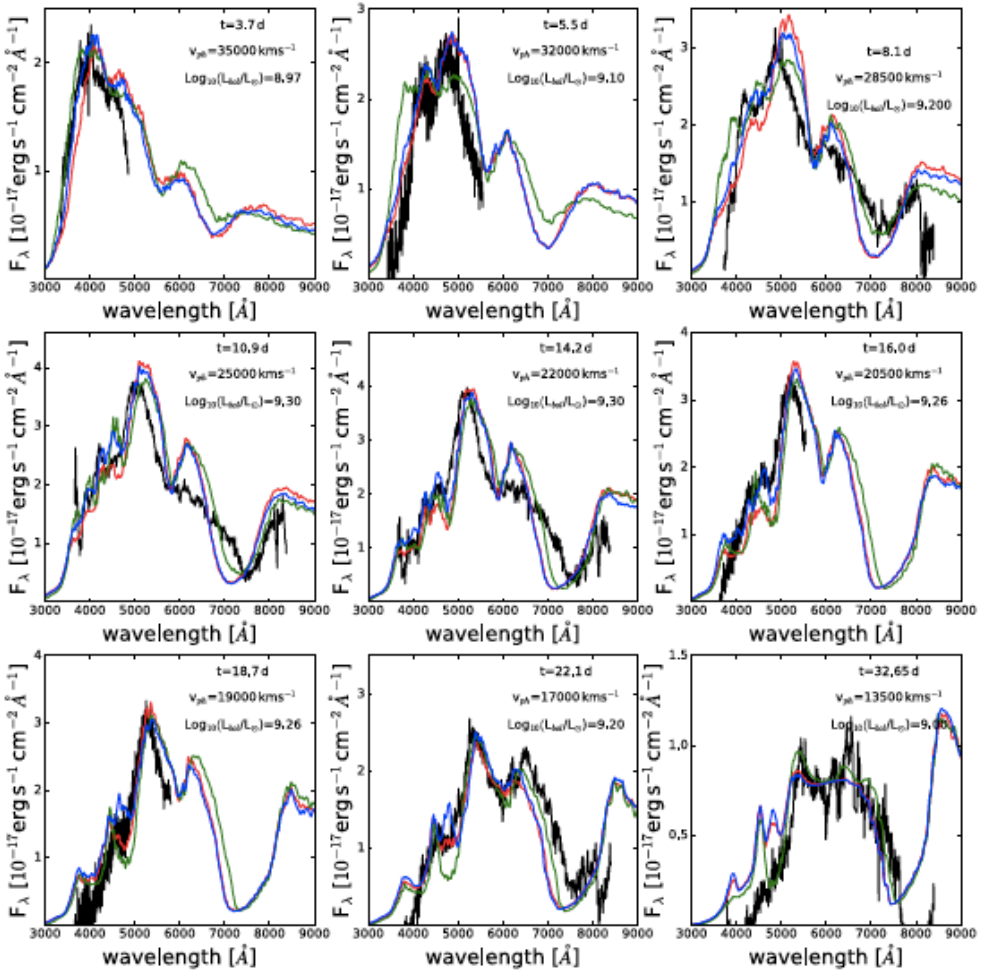
>2000 GRBs
(both long and short)

>1500 X-ray afterglows

~600 GRBs with redshift

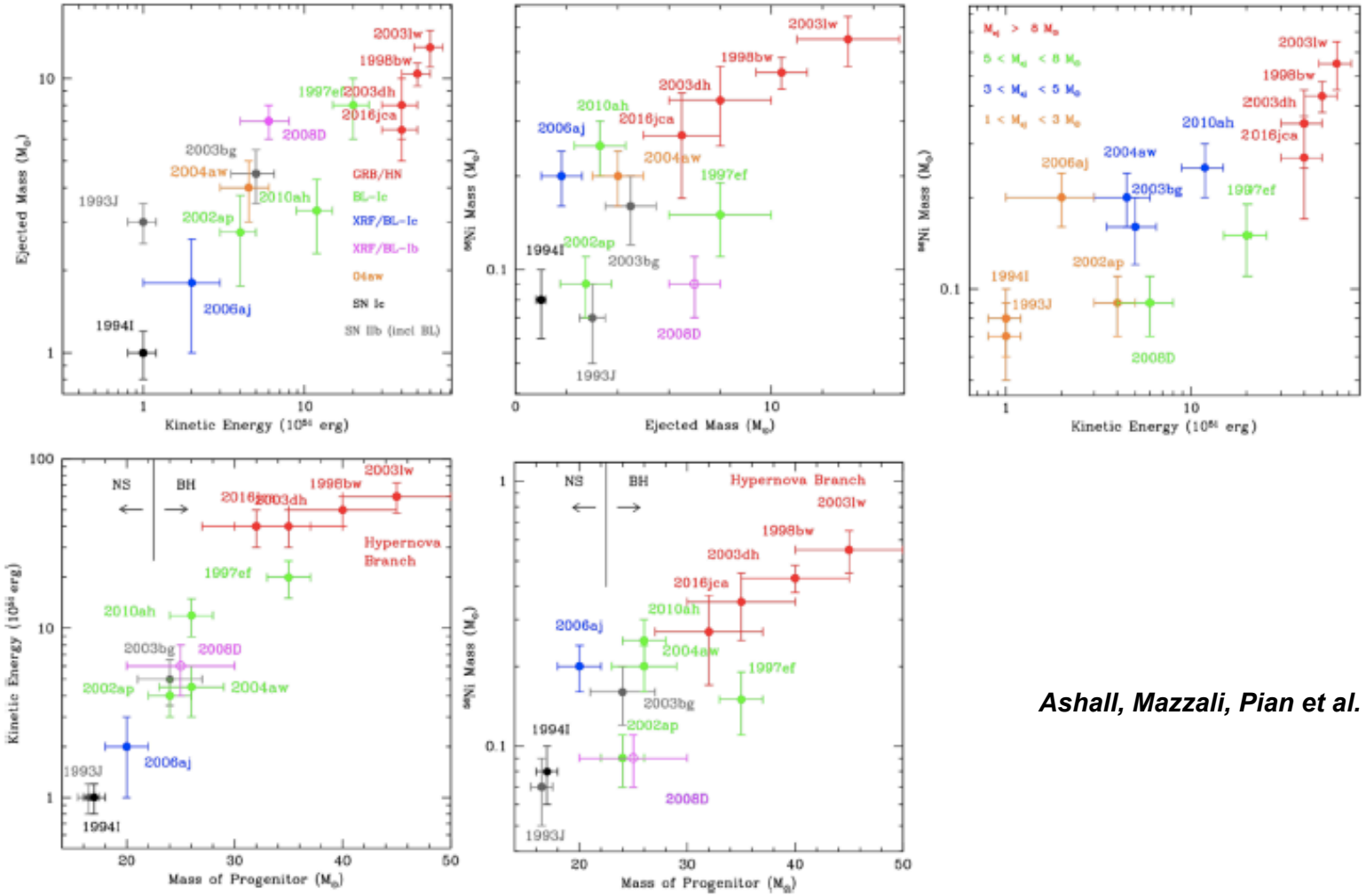


GRB161219B/SN2016jca (z = 0.1475)



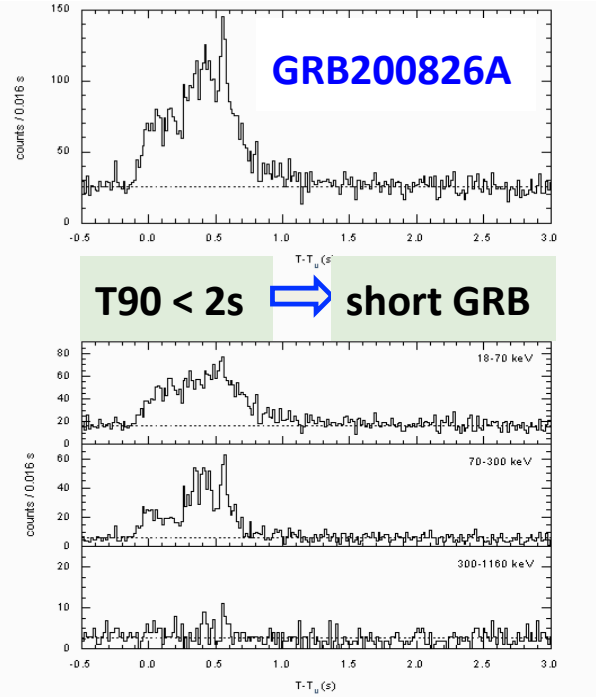
Ashall, Mazzali, Pian et al. 2019

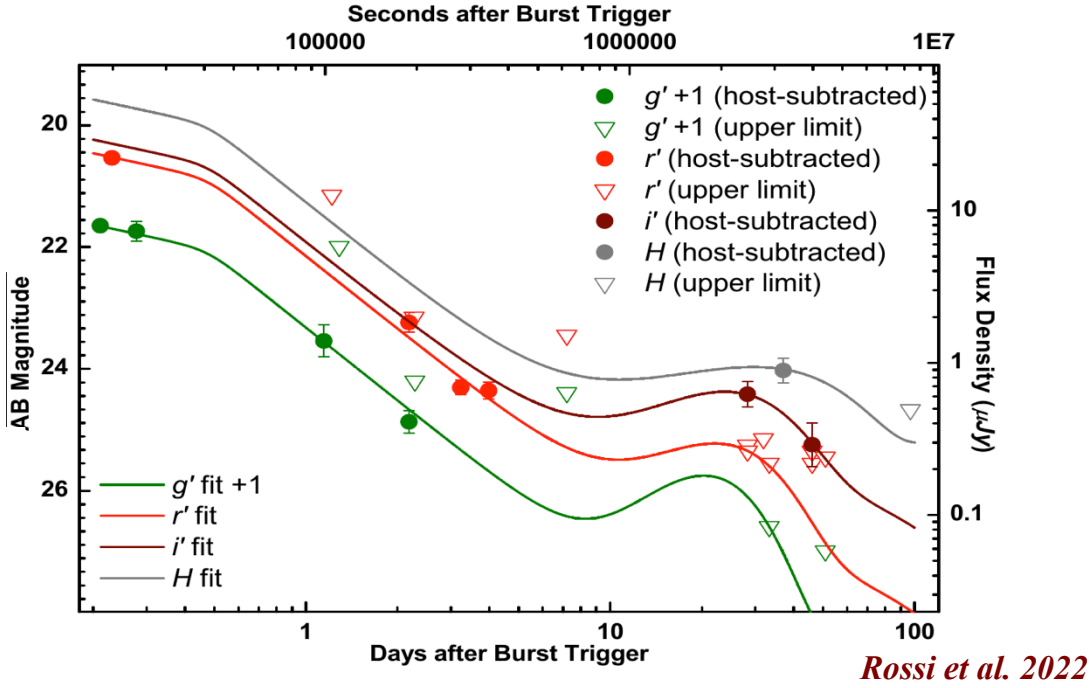
Physical properties of GRB/Supernovae)



Ashall, Mazzali, Pian et al. 2019

Long GRBs - SN Connection but….



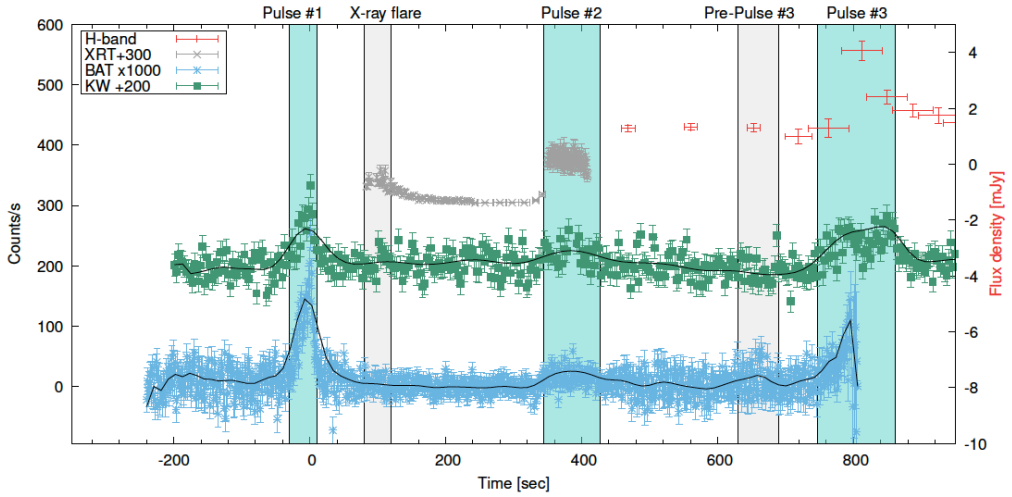


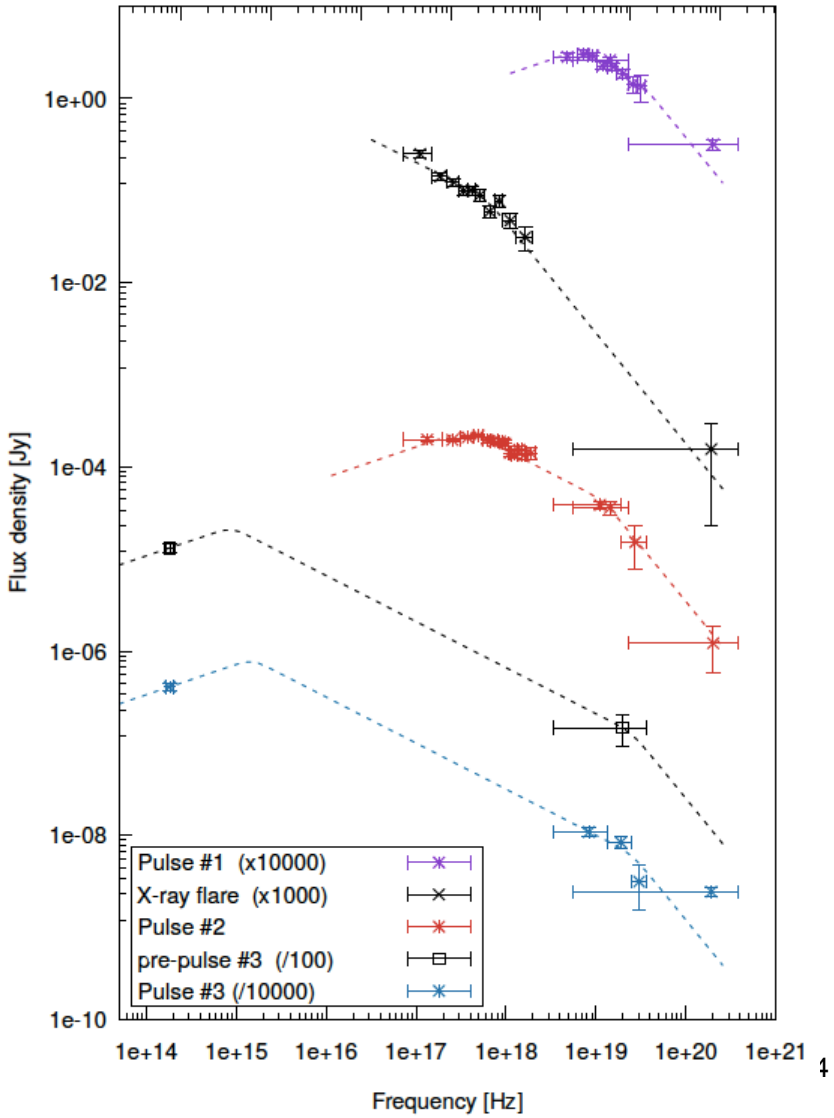
GRB 200826A is a temporally **short GRB** at z = 0.748577 but **duration alone is not an efficient discriminator for the progenitor class of a GRB**

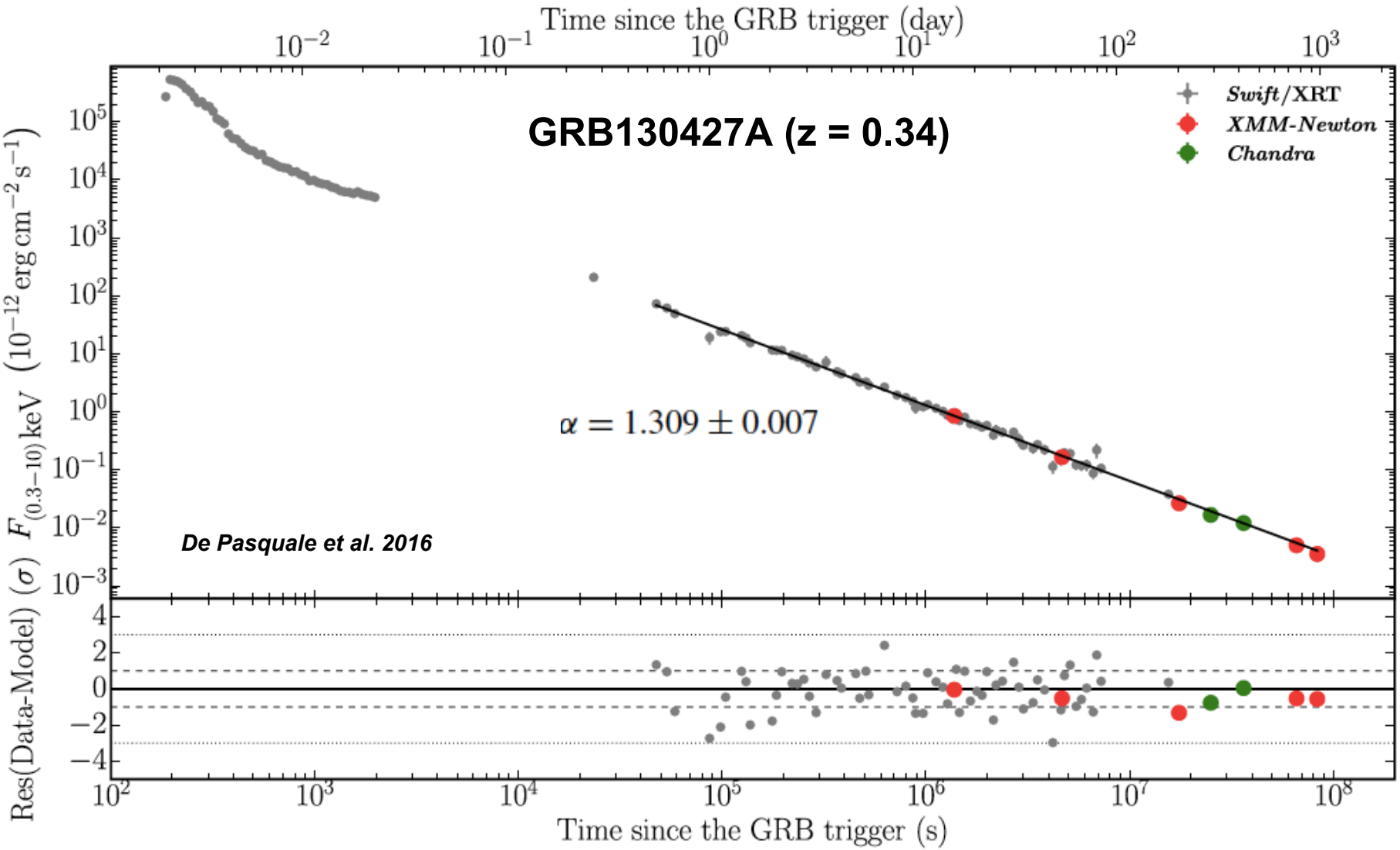
GRB210905 (z = 6.3)

Time-resolved gamma-ray to infrared spectral indicate single Emission component

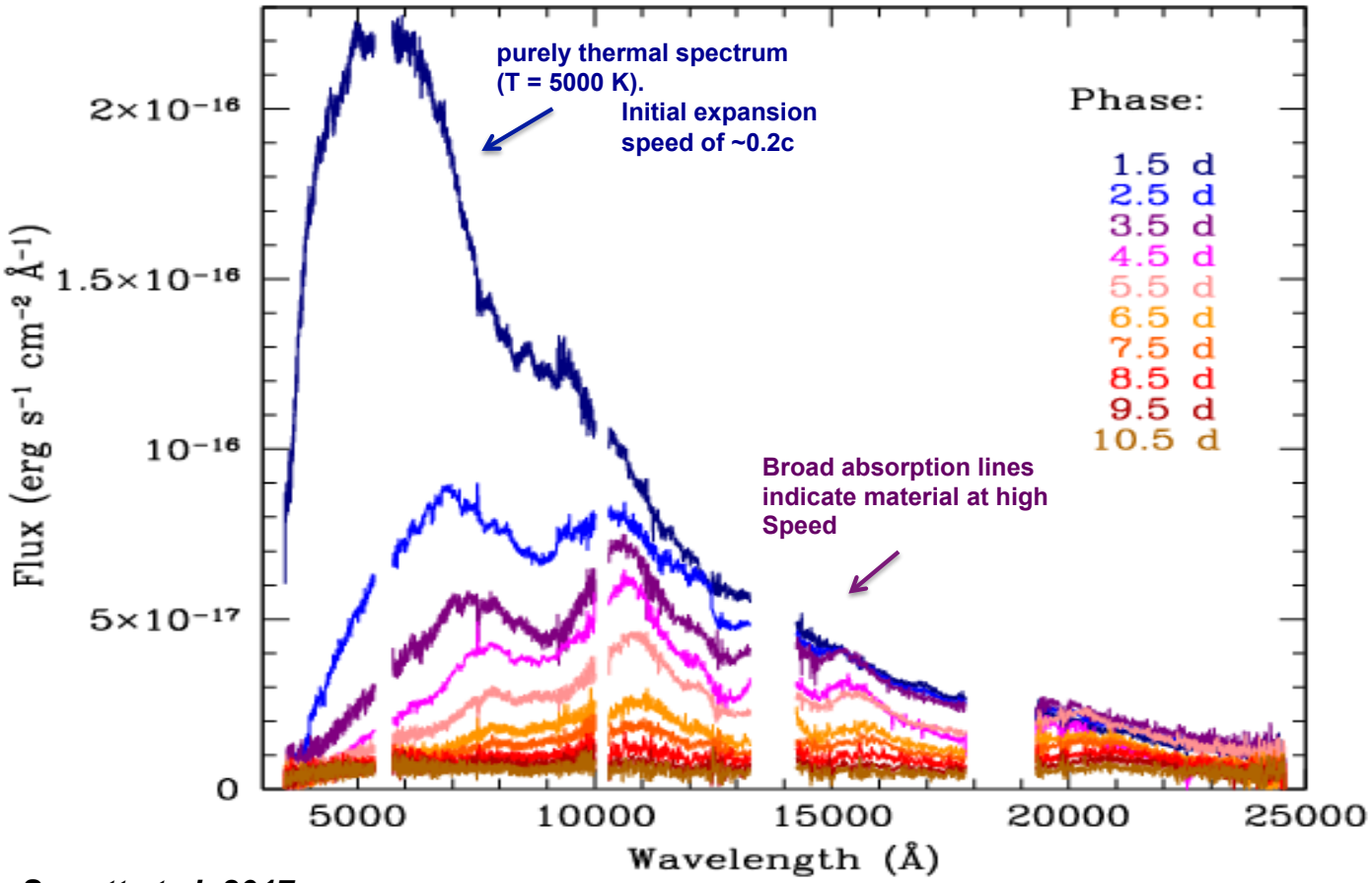
Rossi et al. 2022






Time since the GRB trigger (day)
GRB130427A (z = 0.34)
Swift/XRT
XMM-Newton
Chandra
$\alpha = 1.309 \pm 0.007$
De Pasquale et al. 2016
$F_{(0.3-10)\,\mathrm{keV}}$ $(10^{-12}\,\mathrm{erg\,cm^{-2}\,s^{-1}})$
Res(Data-Model) (σ)
Time since the GRB trigger (s)

ESO VLT X-Shooter spectral sequence of kilonova associated with GW170817 and short GRB170817A (40 Mpc)



Pian et al. 2017; Smartt et al. 2017

Open problems in GRB science

1) Nature of GRB engine: black hole or magnetar

2) Can a magnetar produce and sustain a Lorentz factor of 100-1000?

3) What is the dominant energy extraction and transport mechanism in GRBs: matter-dominated or Poynting flux? And what is the efficiency?

4) What drives the Amati relationship?

5) How are GRB jets related to the asymmetries of the explosions and progenitors: anisotropies in supernovae and kilonovae geometry and nucleosynthesis

6) What is the physics and geometry of the jet: are afterglow time-breaks tracers of jet geometry? Does uniform or structured jet prevail (see GRB170817A)?

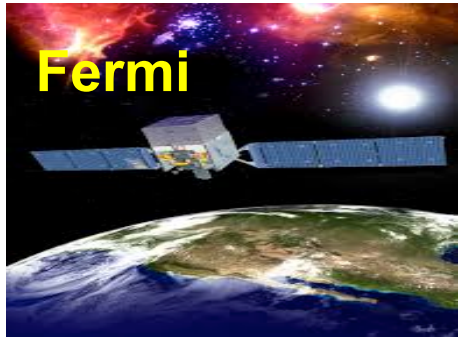
7) How do the local (circumburst medium) and large scale (host galaxies) environments influence GRB production?

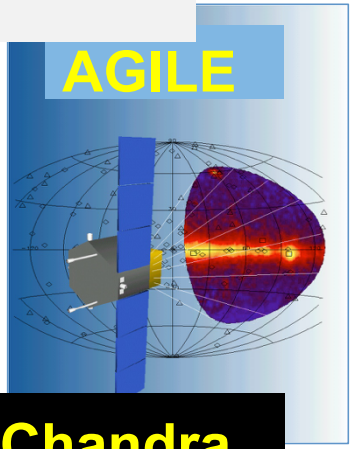
8) Can GRB trace binary massive stellar evolution? To which redshift?

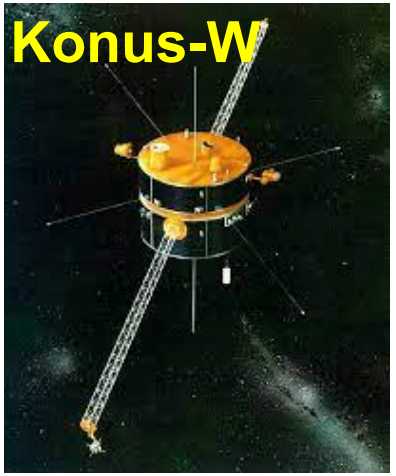
9) Can very high-z GRB map the history of star formation? Can they guide us to primordial star formation (Pop III)?

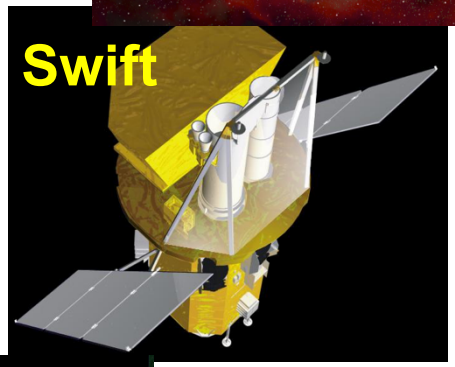
10) Do GRBs have a role in cosmic-ray acceleration? Can they be neutrino emitters?

Orbiting satellites for GRBs and soon-to-be launched SVOM

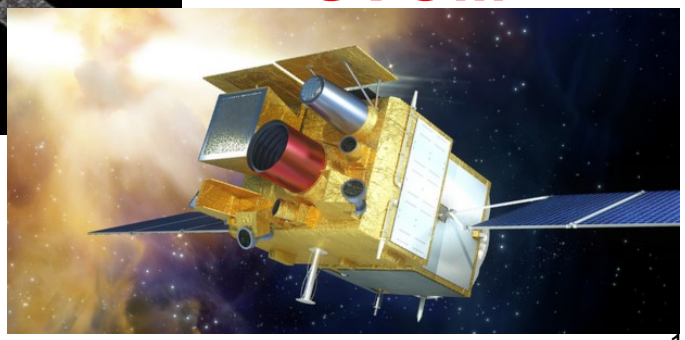




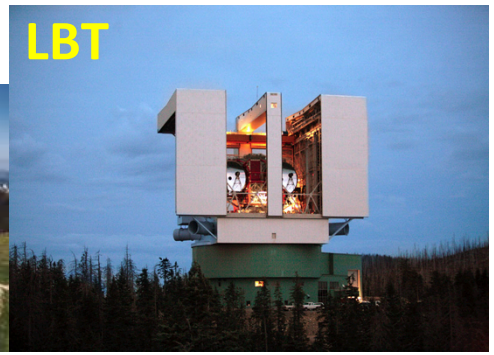


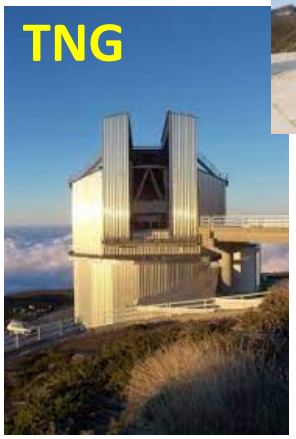


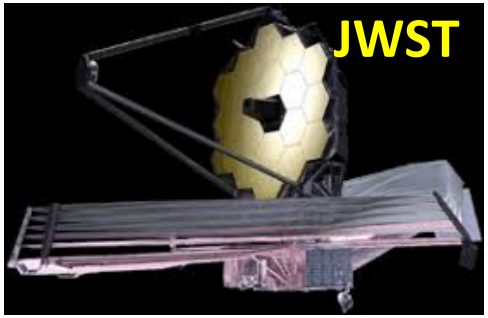
SVOM



MWL telescopes for GRBs follow-ups .....just to name a few....







Future Perspectives and Plans

Observational expertise:
X-rays (Swift, XMM, CXO, HXMT, Nustar, Fermi, INTEGRAL)
Optical (LBT, TNG, REM, VLT, NTT, Stargate Consortium at ESO-VLT)
Millimetric (ALMA)

Technological development:
THESEUS, Gamow Explorer → see ESA proposal PI-ed by L.Amati and his dedicated scheda
Laue lenses for hard X-ray focussing (F.Frontera)
Optical/IR/radio follow-up → package led by E.Pian in PNRR project on Cherenkov Telescope Array
E-ELT first-generation instrument MAORY (E. Maiorano)

Critical upgrades:
Acquisition of at least a student or PDRA on each of above 2 areas