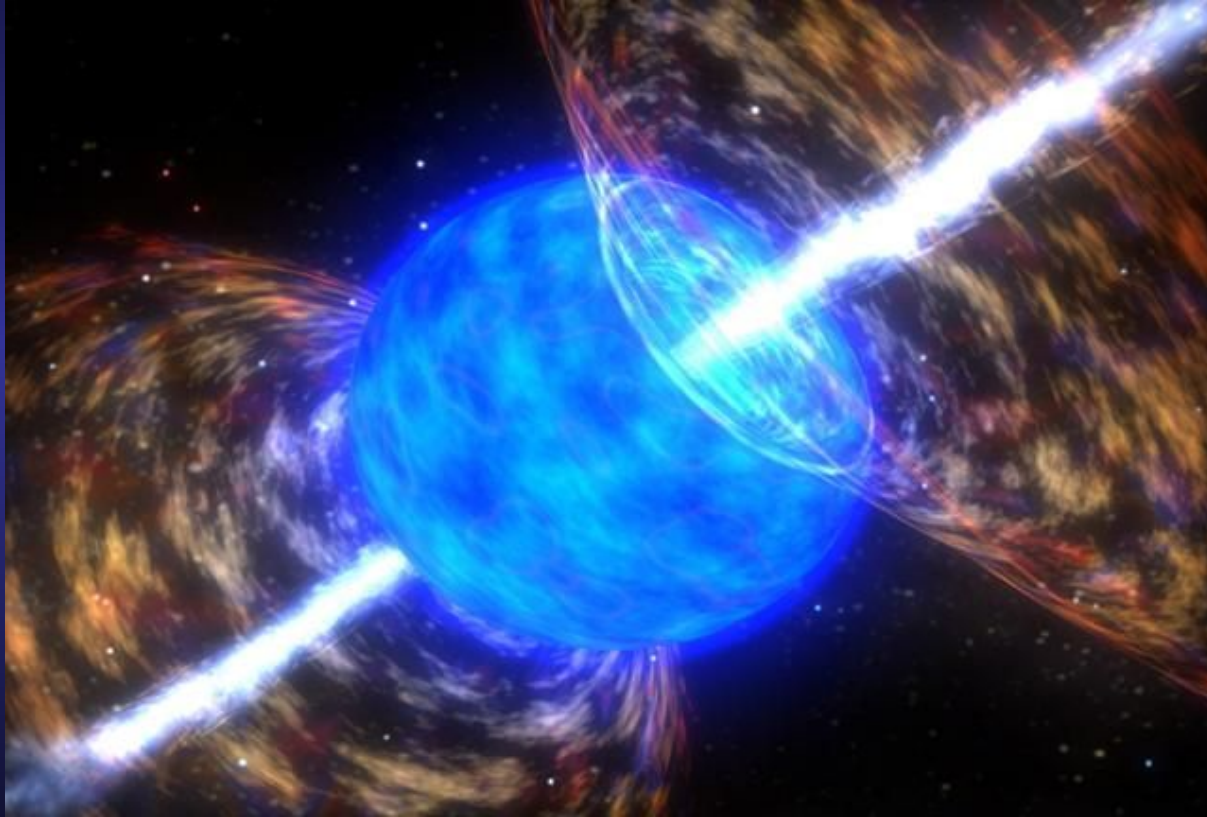


GRB

FROM GAMMA TO RADIO



R. Marcinkowski & G.Wrochna

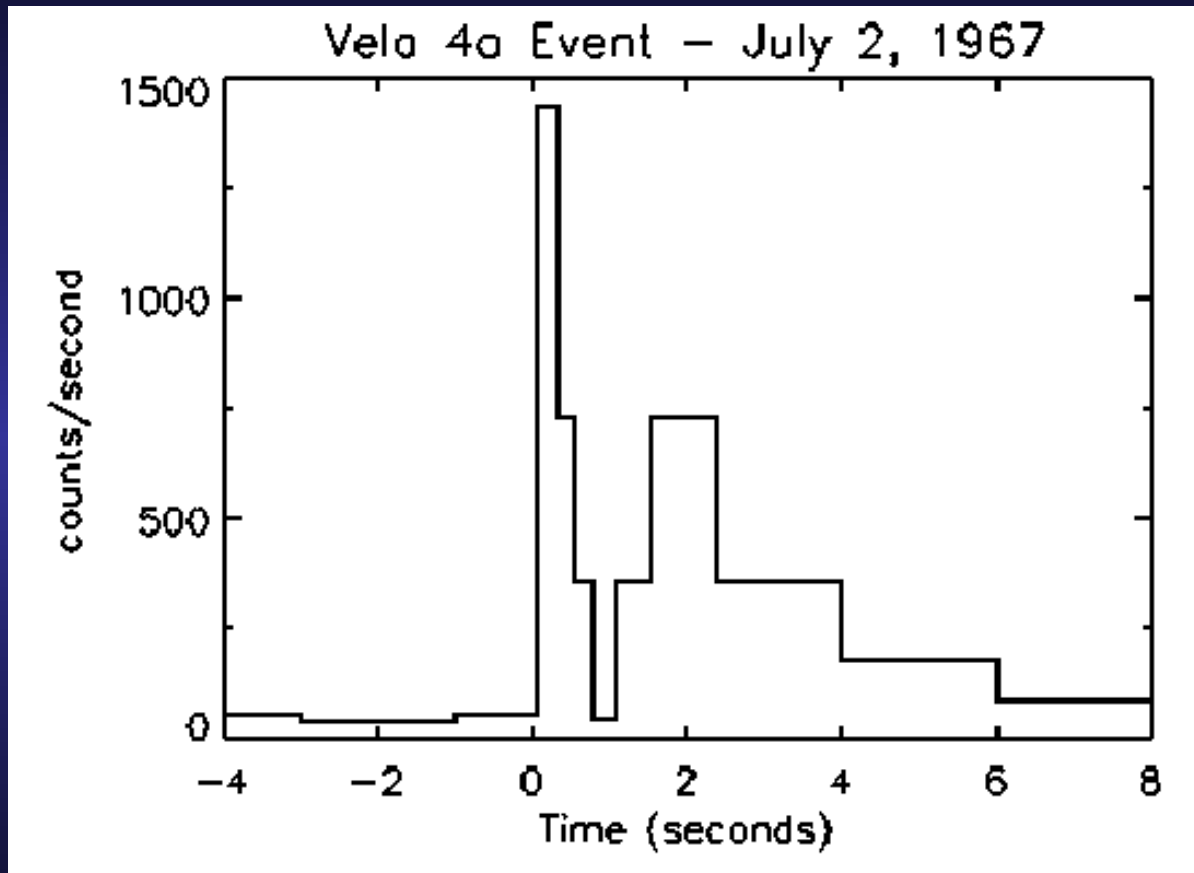
IPJ Świerk/Warsaw POLAND

GRB?

Gamma-ray bursts (GRBs) are, by definition, electromagnetic signals in the gamma-ray band (in the spectral domain) with short duration (in the temporal domain). They are, however, unusual in having most of their electromagnetic output in gamma-rays, typically at sub-MeV energies, and having most of it concentrated into a brief episode, typically lasting tens of seconds.

(Bing Zhang & Peter Mészáros, X.2003)

The first (detected) GRB

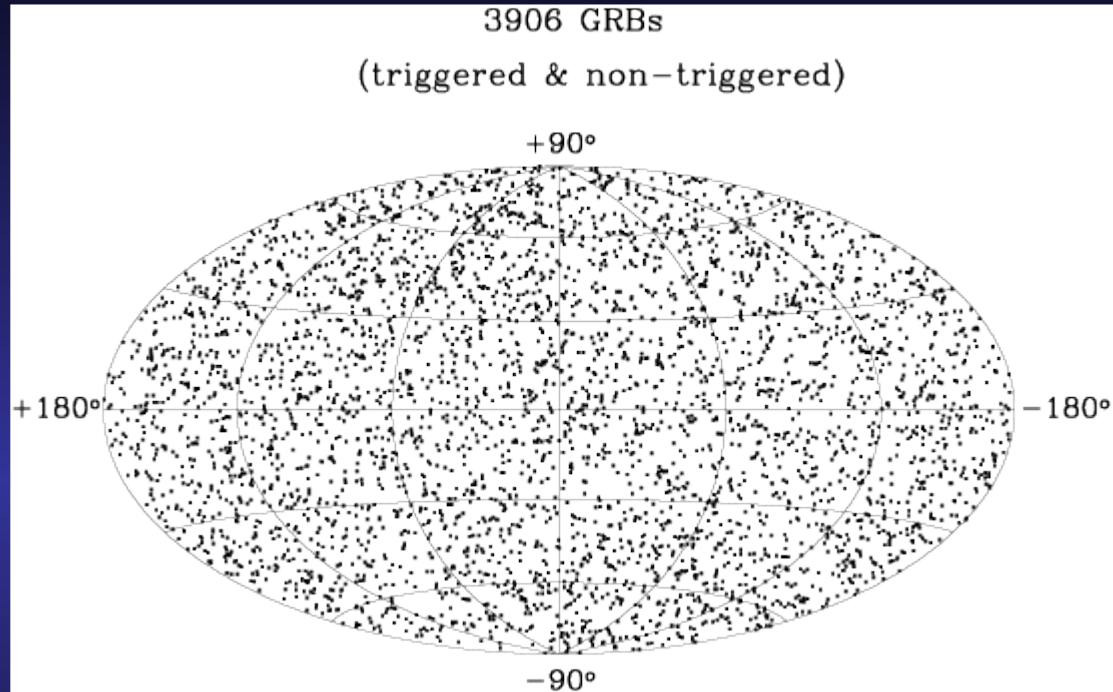


GRB 670702

Up to ~1995

- What is GRB?
- Where!?
- What (and how) produces energy?
- Only gamma?

BATSE (1991-2000): isotropic distribution on the Sky

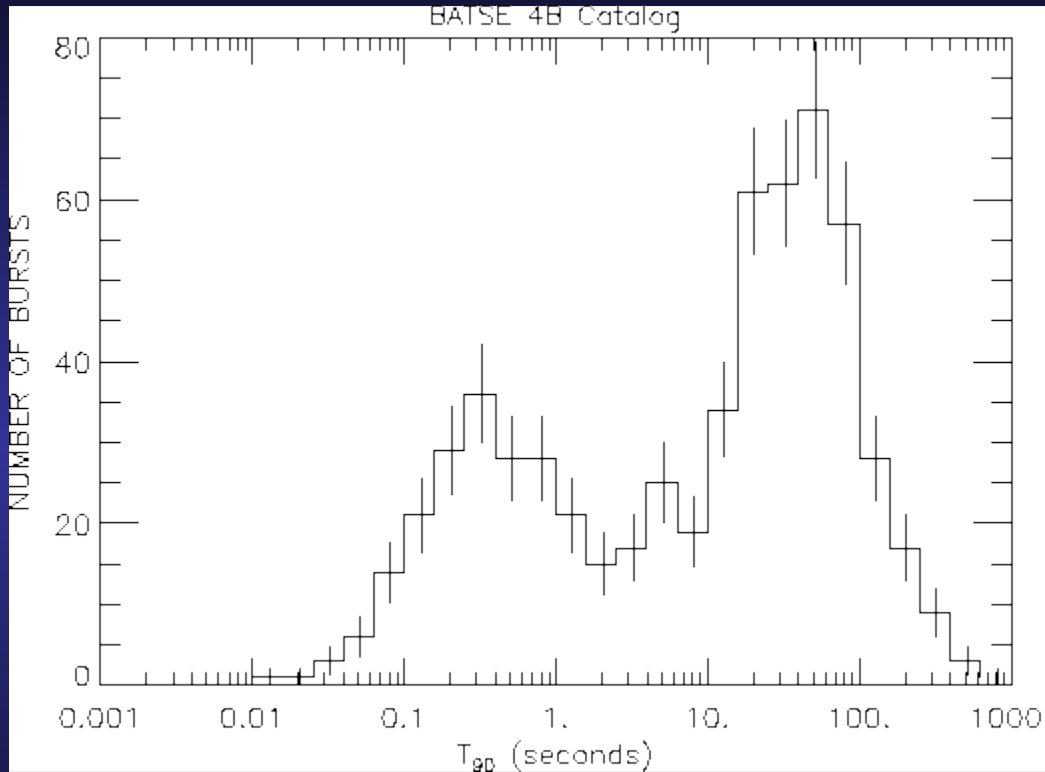


A.D. 1995

B. Paczyński: *GRBs are at cosmological distances!*

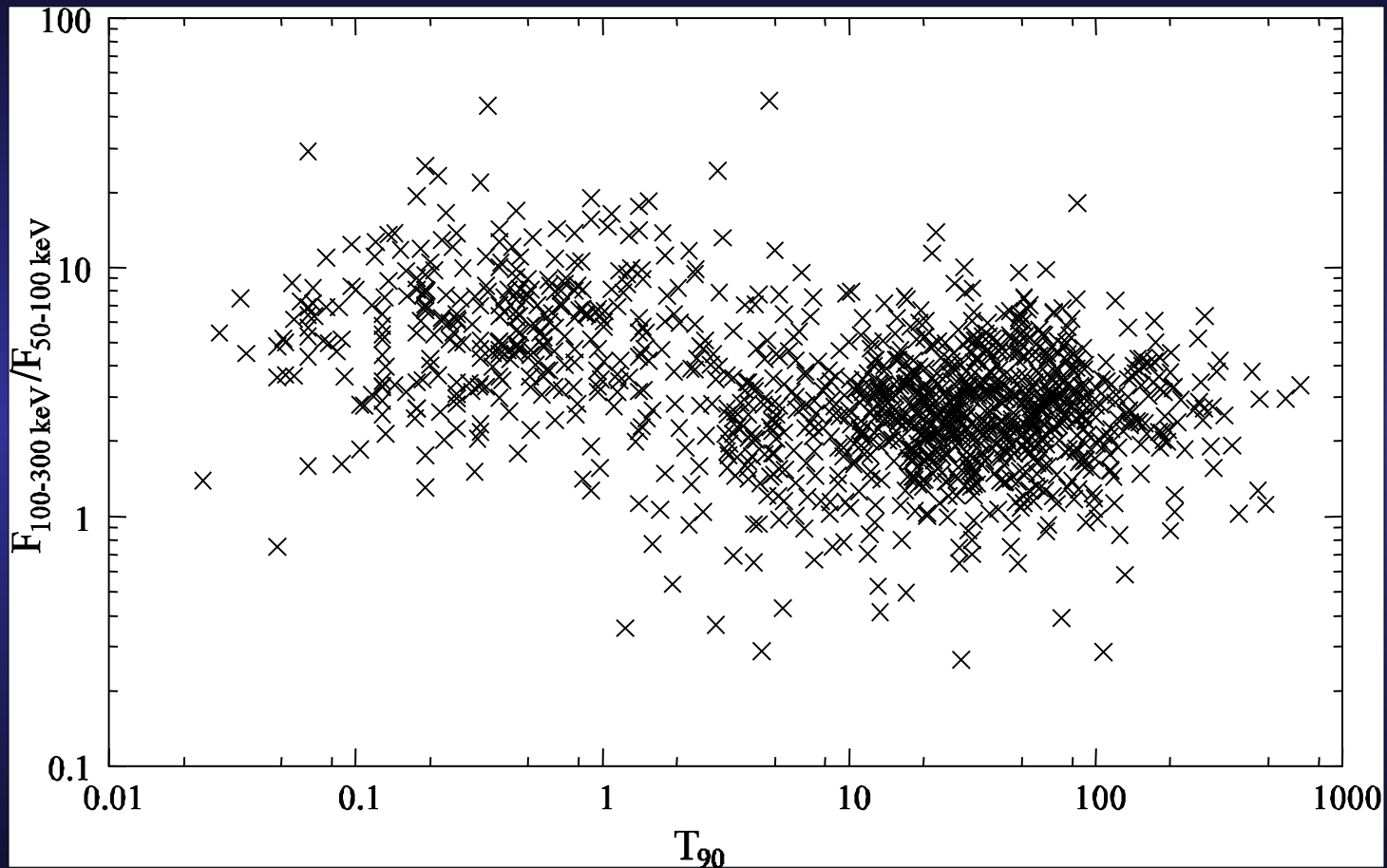
D. Lamb: *No! They are in halo of our Galaxy!*

BATSE (1991-2000): short and long bursts

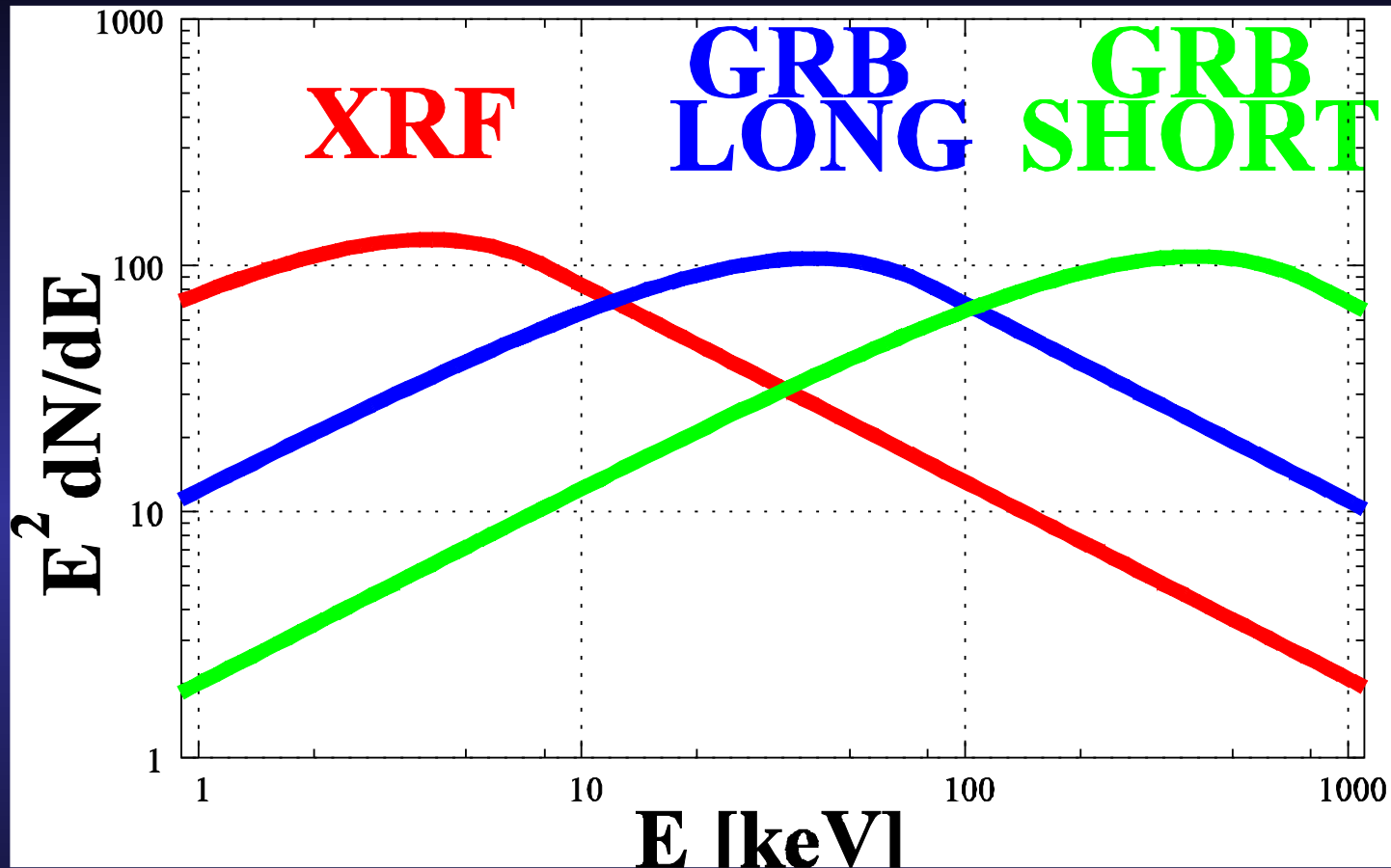


~25% shorter and ~75% longer than 2 seconds

BATSE (1991-2000): short-hard & long-soft

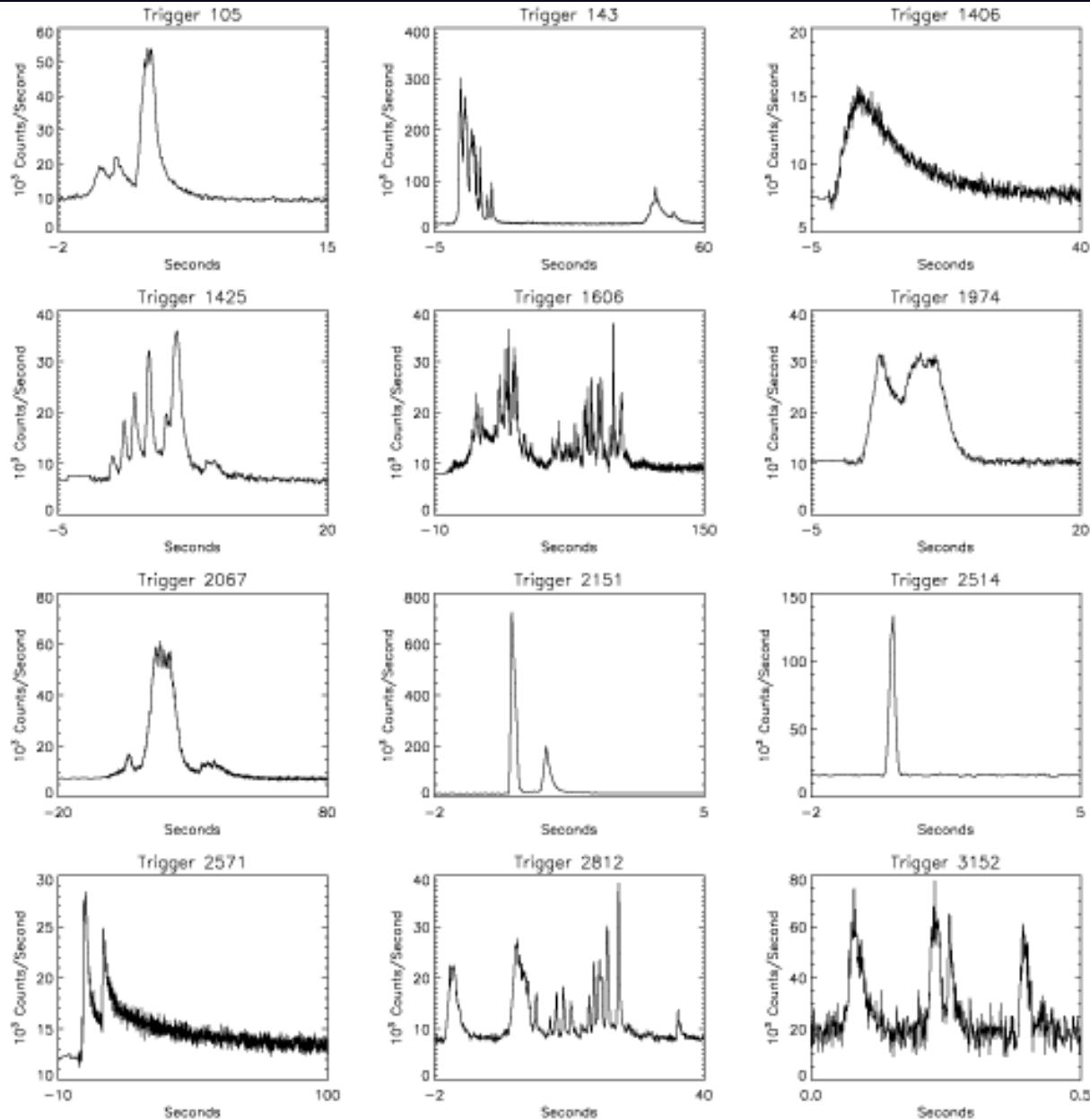


GRB spectrum

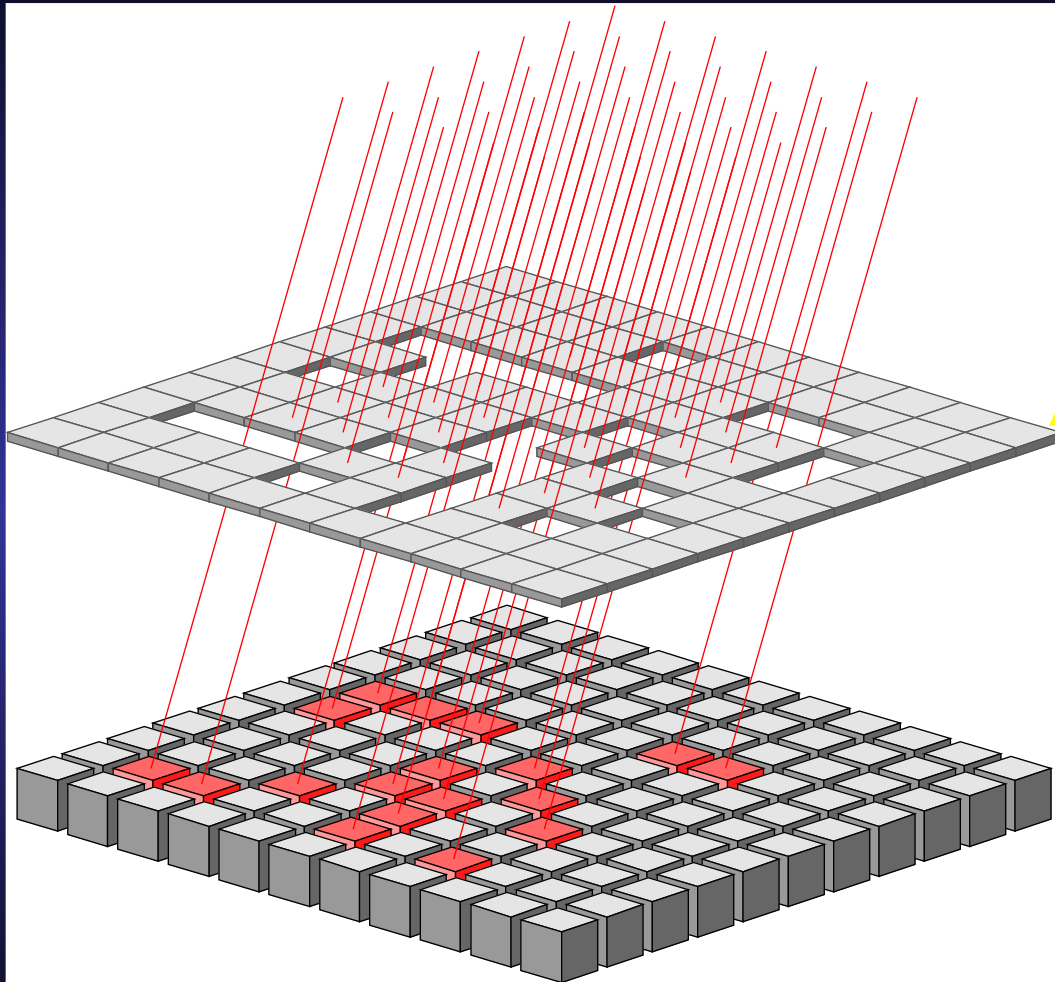


Smooth broken power-law \leftrightarrow Band function

Lightcurves



Gamma-ray detection in Space



coded mask (passive)

detection array
(usually 0.01-10 MeV)

Post-BATSE instruments and methods:

GCN: optical & radio

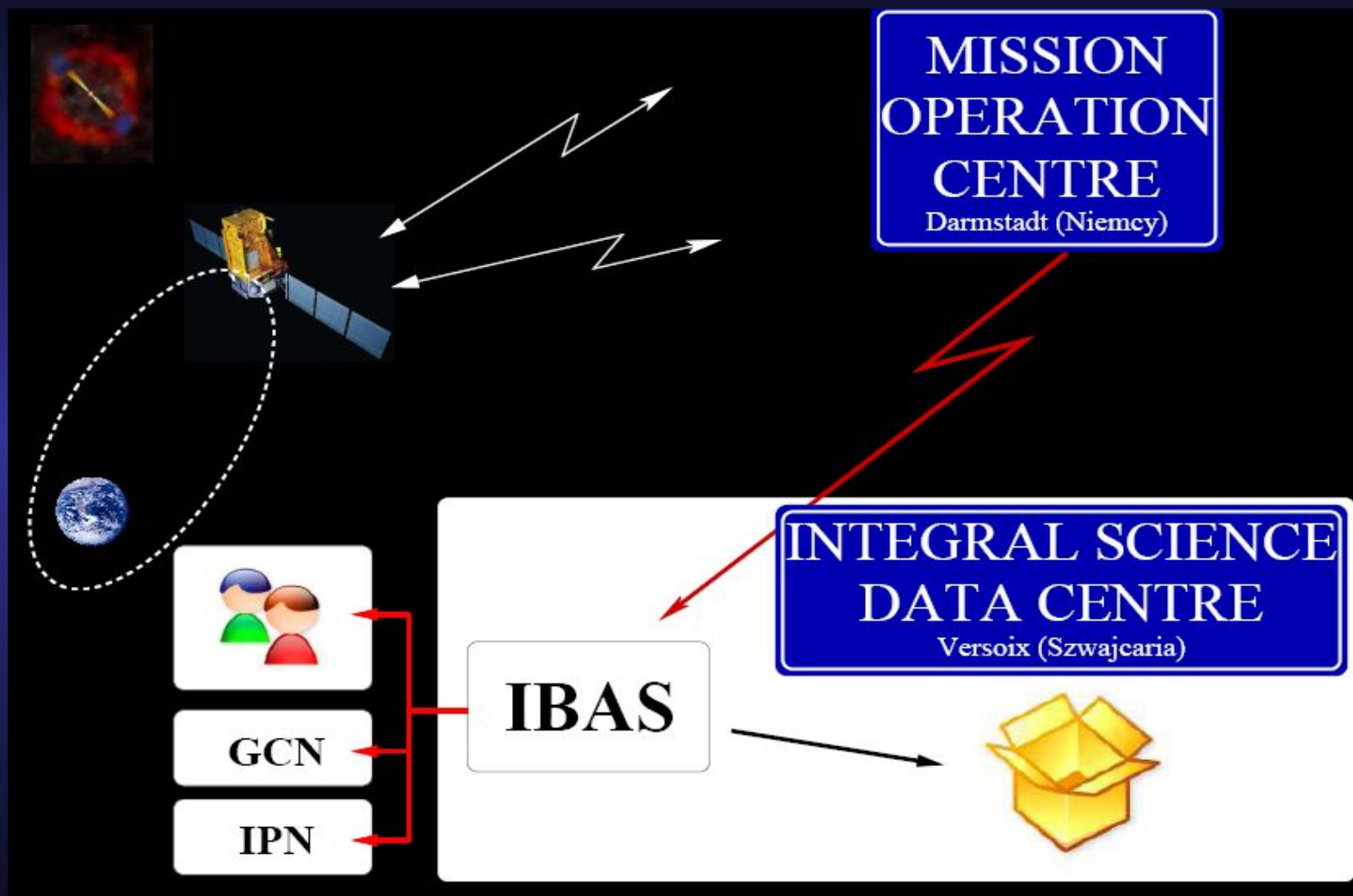
Beppo-SAX: X-ray afterglow (1997)

HETE-2: XRF, short burst host galaxy (2005)

Swift: X-ray and OT since the prompt gamma

Konus, INTEGRAL, RHESSI etc. – gamma-ray missions

GCN



GCN: π of the Sky



π (in ASAS dome), Las Campanas (Chile)

GCN

PROMPT: 5 x 41cm telescopes (Chile)

ROTSE: 4 x 45cm telescopes (Namibia, US, Turkey & Australia: Sun never rises over ROTSE Empire!)

BOOTES: 2 telescopes (Spain)

MASTER: 35cm & 20cm (Russia)

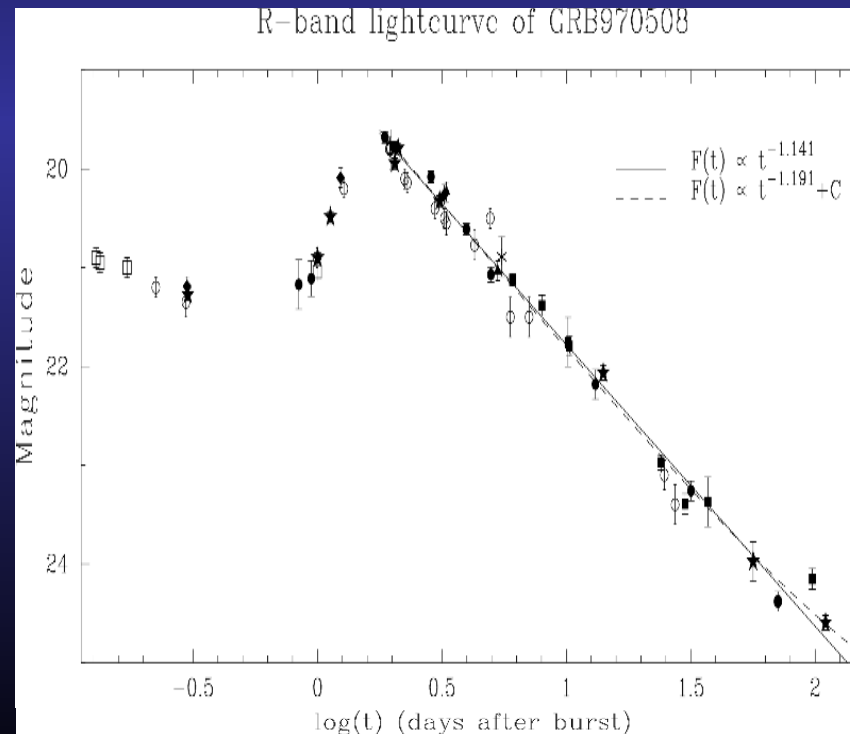
and many, many others

Afterglow: other (than gamma) electromagnetic emission

by BeppoSAX

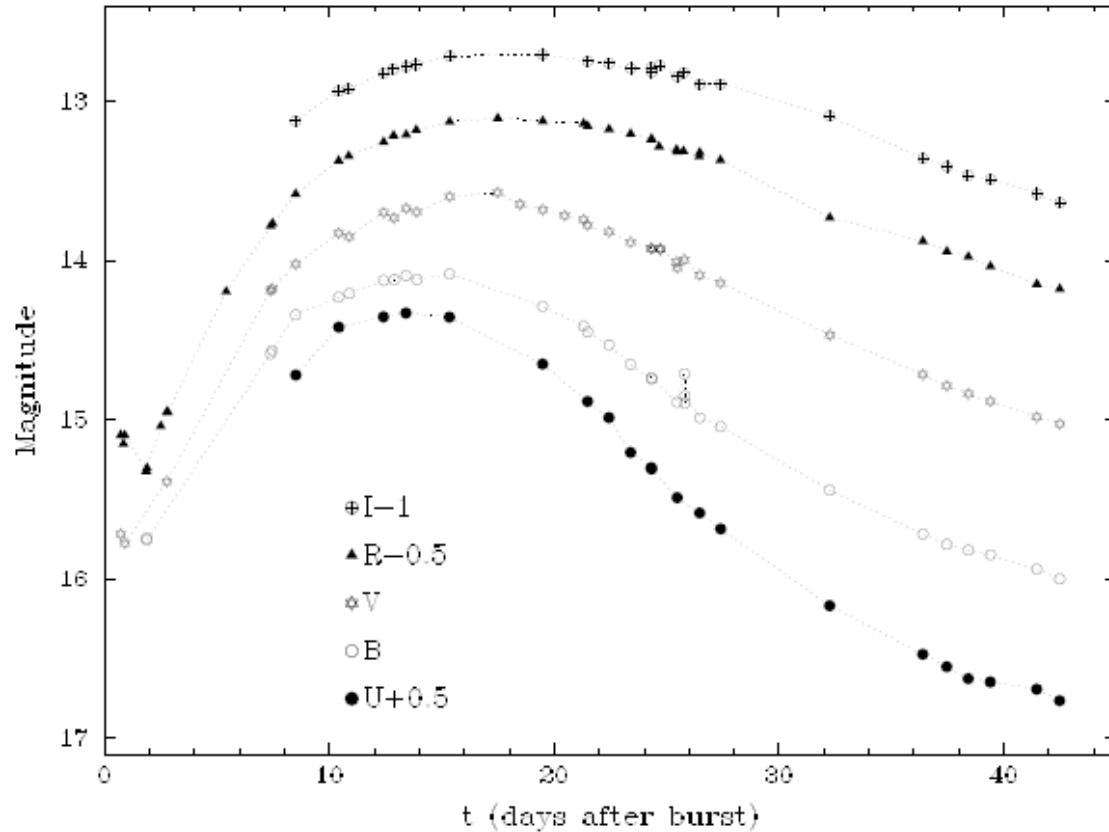
- 970228: X-ray afterglow with associated faint galaxy (van Paradijs et al., 1997)
- 970508: optical redshift $z=0.835$ (Metzger et al., 1997) & radio afterglow

GRBs are at cosmological distances!



(Galama et al., 1998)

GRB – supernova connection

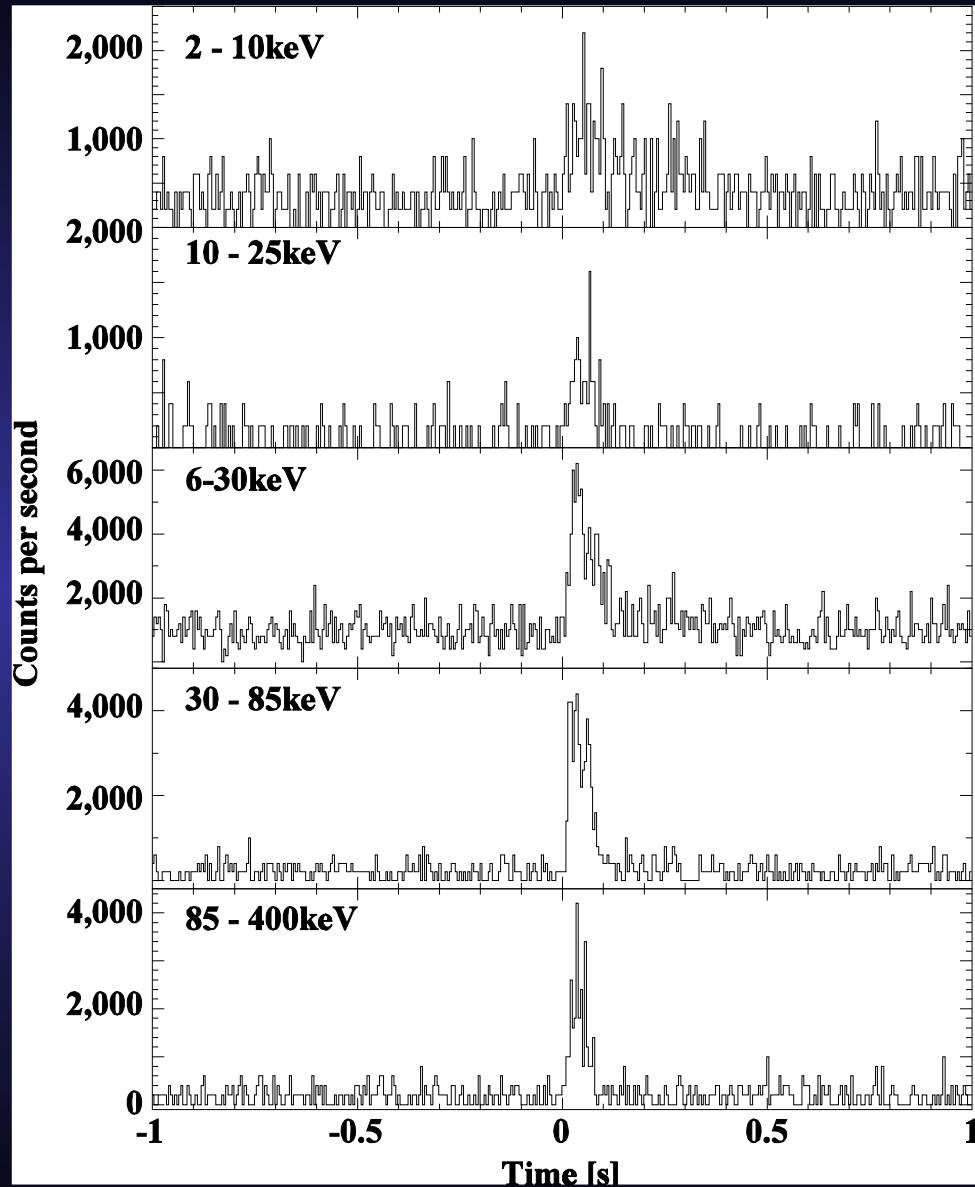


~5 known GRB-SN
connections
but:
~5 known GRB w/o SN

GRB980425 = SN1998bw

(Galama et al., 1998)

HETE-2 short bursts

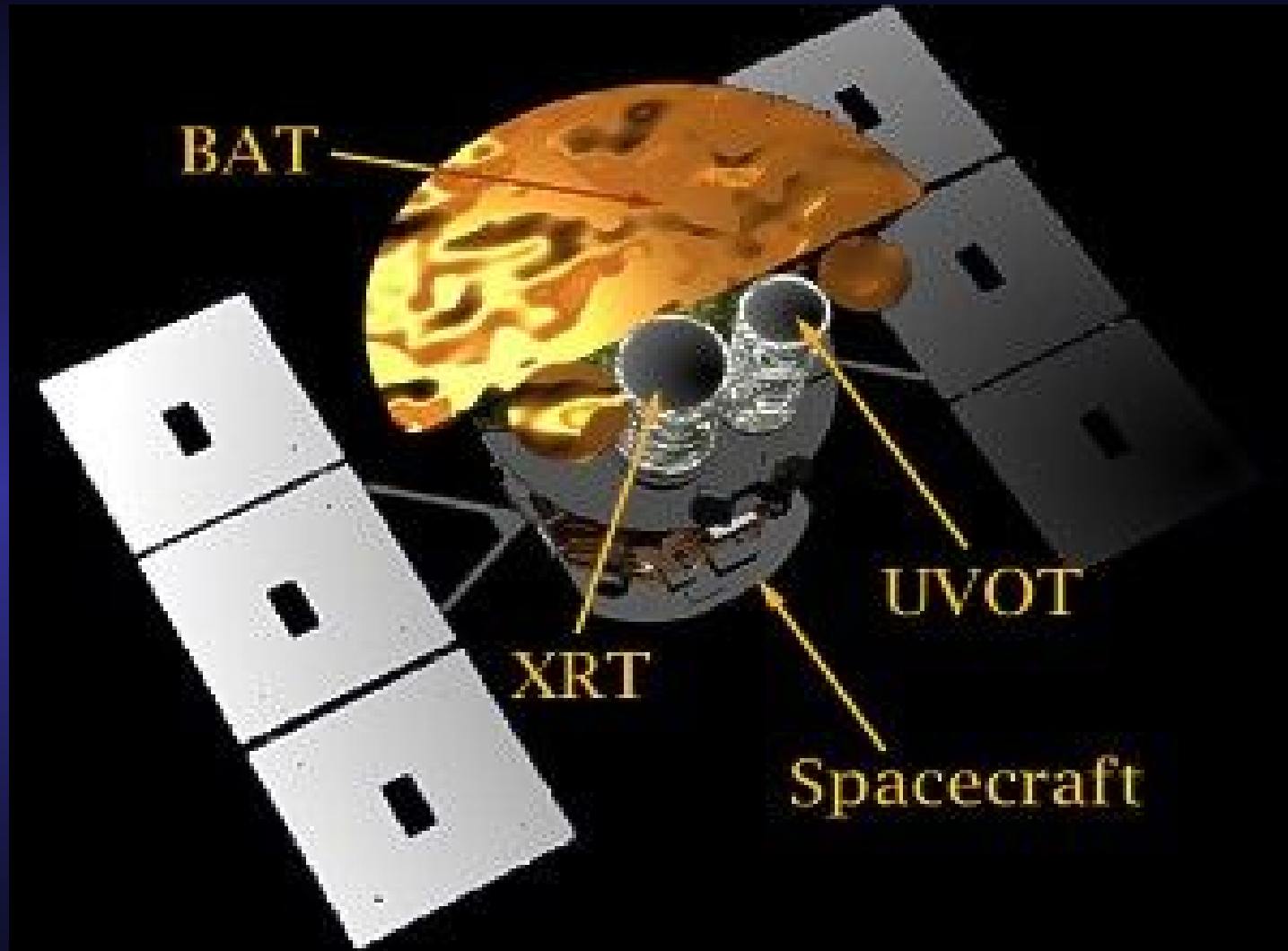


GRB050709

$z=0.16$

(Villasenor, Lamb et al., 2005)

Swift



Properties of the GRB

Gamma-ray prompt duration: 10^{-3} - 10^3 s

Median redshift:

- long: 2.5
- short: 0.25

Isotropic gamma-ray energy:

- long: 10^{52} - 10^{54} ergs (Sun mass in gamma-rays!)
- short: 10^{49} - 10^{51} ergs

Typical Lorenz factor Γ in jets:

- long: 100
- short: 30

Properties of the GRB

Host galaxies:

- long: young, high SFR, in arms of spiral galaxies
- short: older, elliptic, lower SFR

Gamma-ray νF_ν spectrum with peak in 0.01-10 MeV

Optical afterglows:

- $t^\alpha \nu^\beta$ where: $\alpha \sim -1$ $\beta \sim -0.7$
- $\sim 10^{\text{mag}}$ in maximum
- breaks in lightcurve (jet breaks)

X-ray afterglows:

- $t^\alpha \nu^\beta$ where: $\alpha \sim -1$ $\beta \sim -1.4$

Radio afterglows:

- sometimes active years after GRB

GRB - theory

(Ultra) Relativistic hydrodynamics of leptons and hadrons, taking into account:

- magnetic field,
- stellar wind (long bursts),
- ISM,
- rotation of progenitor,
- neutrino physics,
- cosmology (high z)

GRB standard fireball model

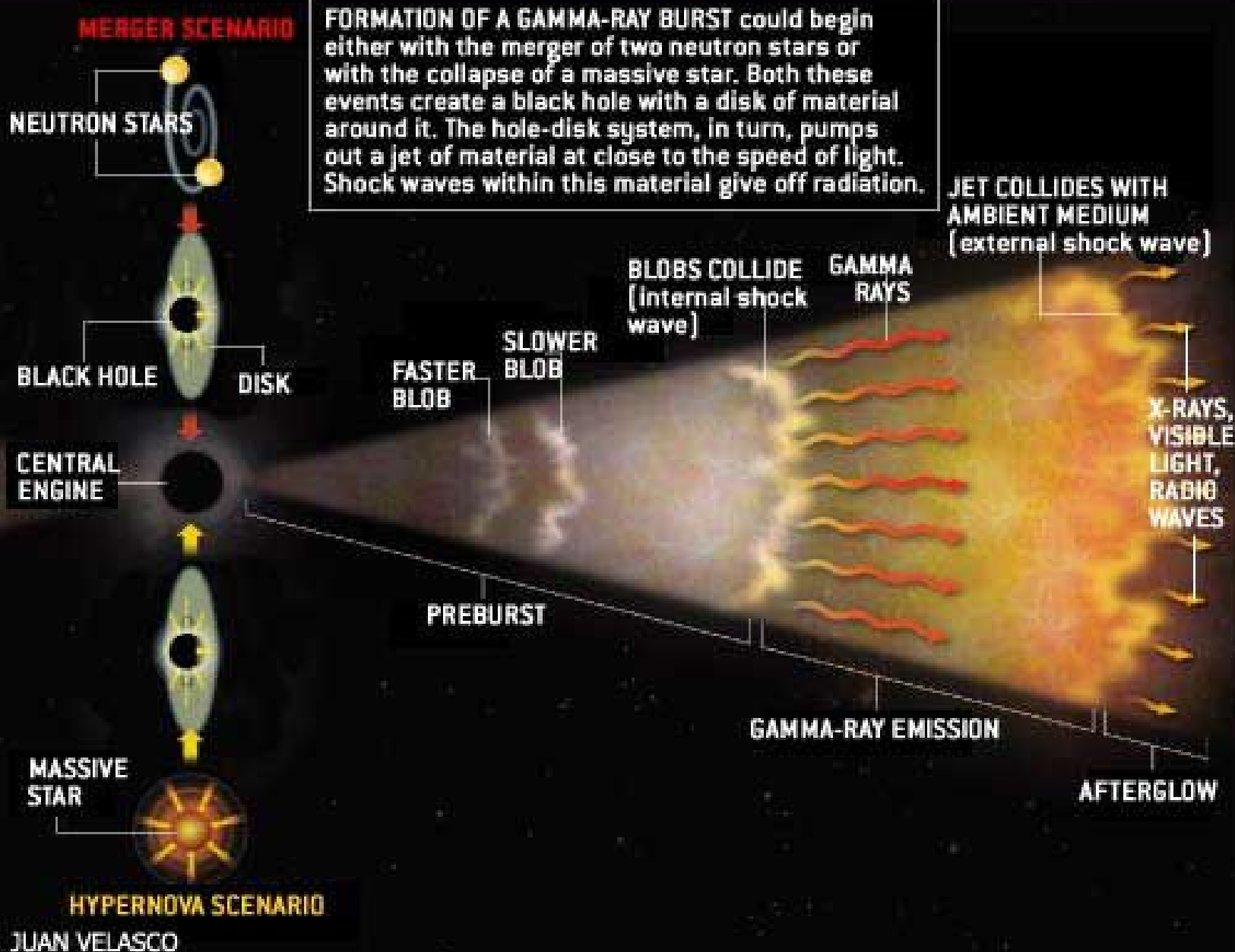
Progenitor:

- long: collapsar/hypernova; massive, rotating star,
- short: merger; coalescence of compact objects (NS+NS)

Gamma-rays produced in synchrotron process (internal shocks)

Afterglows produced with interaction of ISM (external shocks)

BURSTING OUT



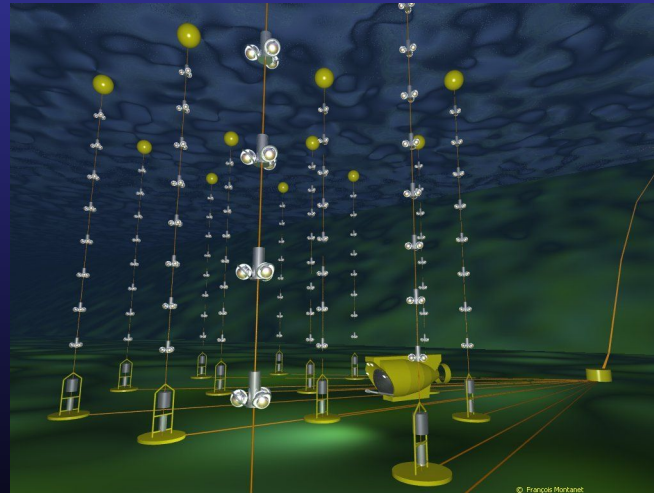
Other: EM polarization, GW, neutrino

Known papers about 100% polarized gamma-rays from GRB (skeptic!)

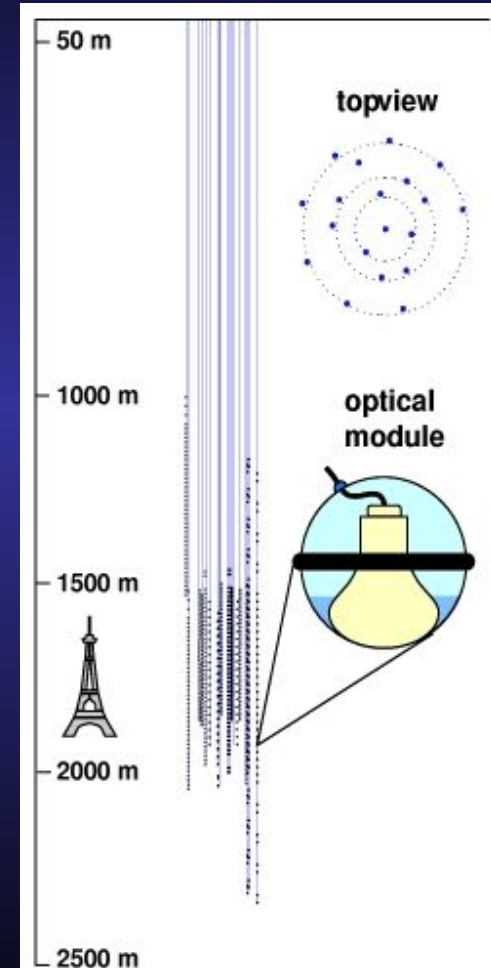


LIGO (US)

Only upper limits
for ν from GRB

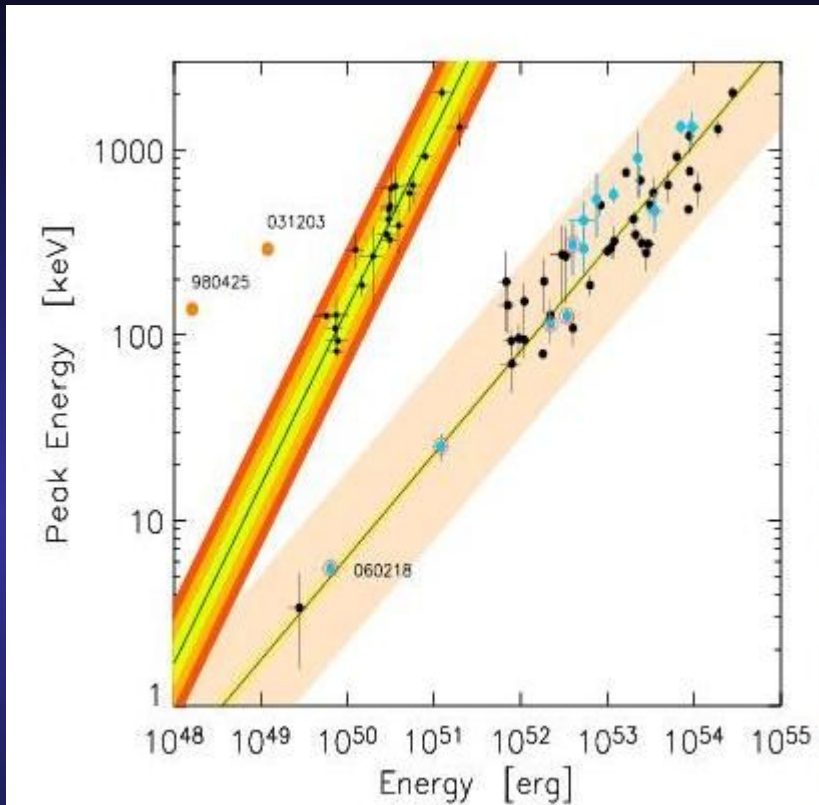


Antares (Mediterranean Sea)

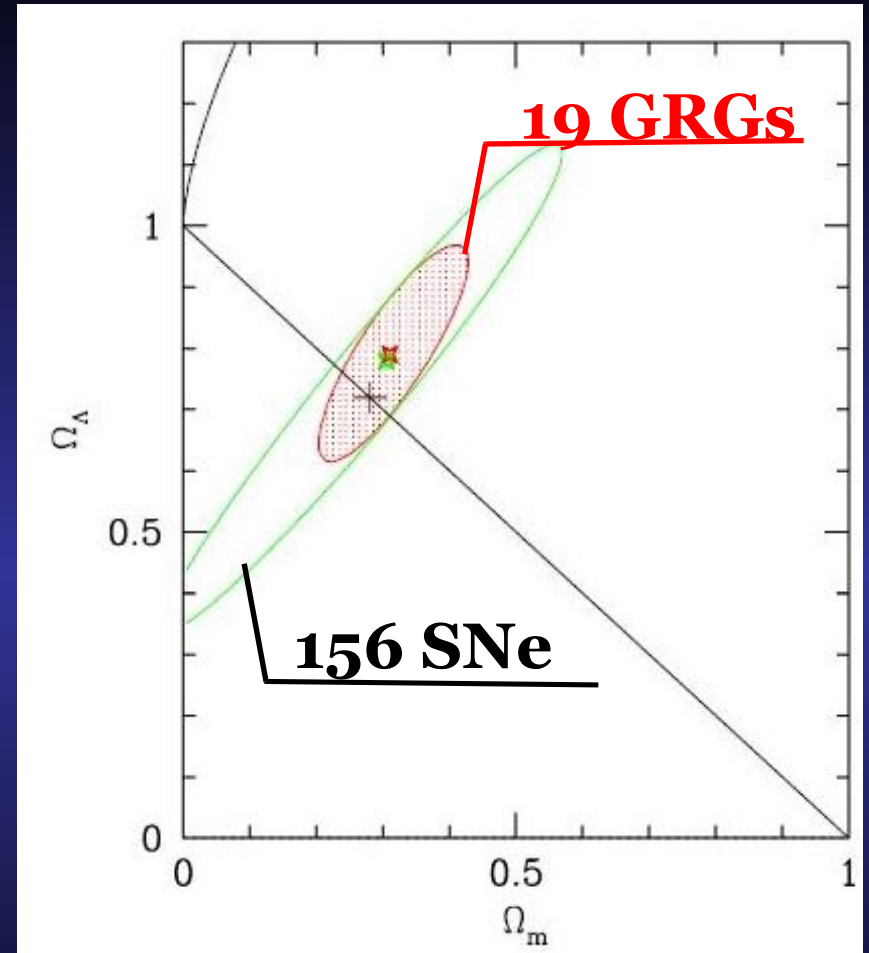


Amanda (South Pole)

Cosmology



Amati & Ghirlanda
empirical relations
(calibrated candles?)



(Ghirlanda, 2006)

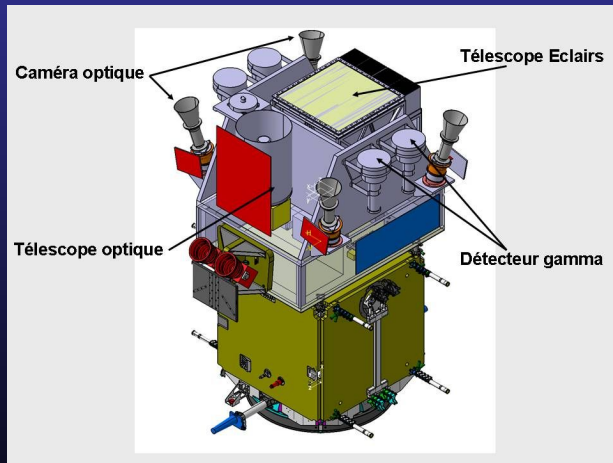
Future



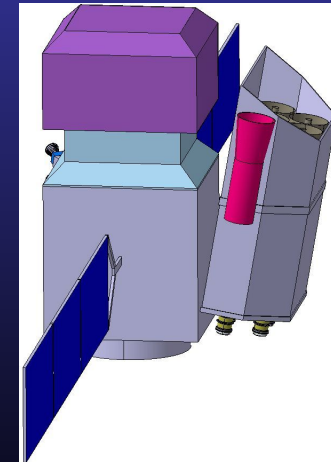
AGILE (IT, 23.04.2007), 10 GeV region



GLAST (US, 2007), $\sim 10^2$ GeV



Eclairs (FR, 2011)



GRIPS (EU, 2015) for GRB with $z > 15$

Summary

GRBs:

- are active from radio to gamma in EM,
- seem to emit neutrinos,
- seem to emit GW,
- probe ends of Universe ($z_{\text{max}} = 6.5$),
- probe cosmological parameters,
- **still wait for full theoretical understanding!**