

Astroteilchenphysik II: Gamma-Astronomie Vorlesung II

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Gamma-Strahlen-Blitze (GRBs)

Eigenschaften von Gamma-Strahlen-Blitzen

- Entdeckung und erste Beobachtungen
- Energiespektren und Zeitvariabilität
- Verteilung im Universum
- Luminositätsabschätzungen

Interpretation und Physik von Gamma-Strahlen-Blitzen

- allgemeine Deutung der Beobachtungen
- Modell des relativistischen Feuerballs
- Plasmastrahlen und relativistische Effekte

Vorlesung: Termine

Dienstag		Donnerstag	
		23.04.2020	Vorlesung
		30.04.2020	Vorlesung
		07.05.2020	Vorlesung
12.05.2020	Übung	14.05.2020	Vorlesung
		-	Feiertag
		28.05.2020	Vorlesung
		04.06.2020	Vorlesung
09.06.2020	Übung	-	Feiertag
		18.06.2020	Vorlesung
23.06.2020	Übung	25.06.2020	Ausgefallen
		02.07.2020	Vorlesung
07.07.2020	Übung	09.07.2020	Vorlesung
		16.07.2020	Vorlesung
21.07.2020	Übung	23.07.2020	Vorlesung

Gamma-Strahlen-Blitze (GRBs): Historisches

- 1967 Entdeckung (Vela-Satelliten)

• $E_\gamma > 10 \text{ keV}$ $\langle E_\gamma \rangle = 500 \text{ keV} - 1 \text{ MeV}$ $\Delta t = 10 \text{ ms}, \dots, 1 \text{ s}$

- 1991 Compton Gamma Ray Observatory (CGRO), BATSE-Detektor

$1/\text{Tag}$, isotrope Verteilung \rightarrow extragalaktisch!

- 1997 Beppo-SAX-Satellit, anschließend HETE-2

• Entdeckung des Nachleuchtens (Röntgen)

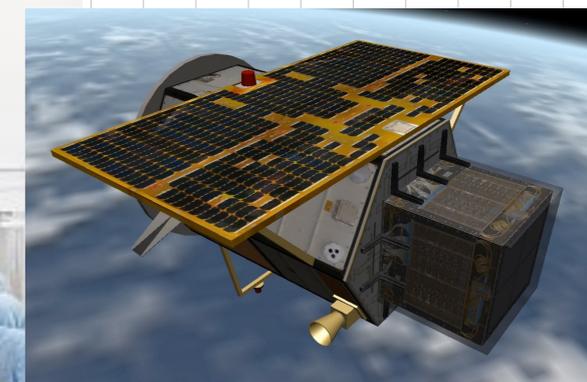
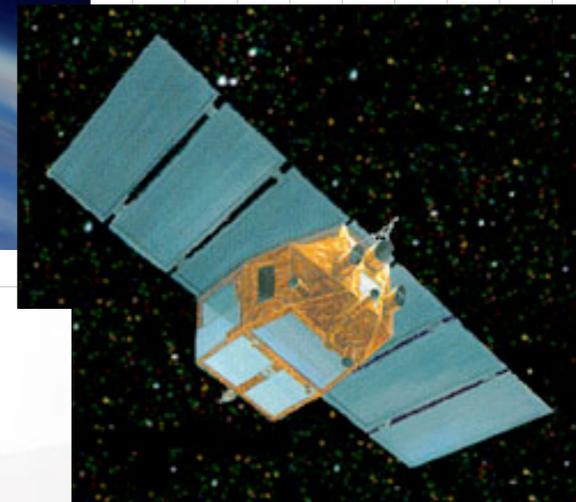
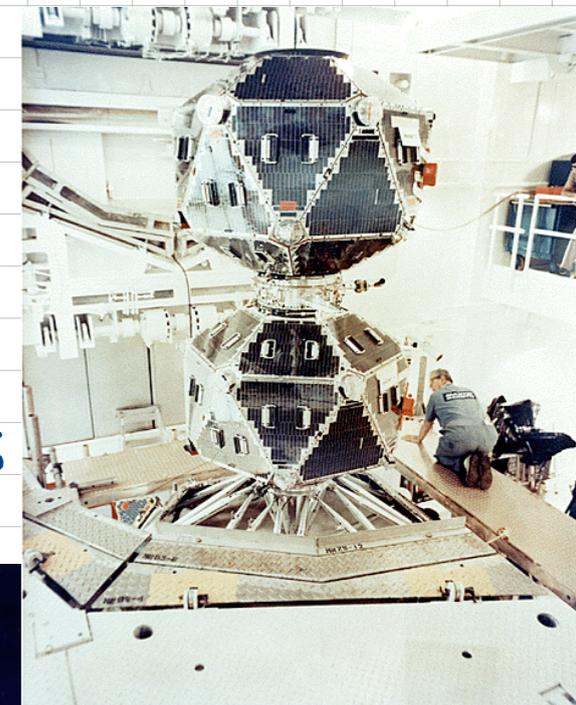
- 2004 Swift-Satellit

Zeitnahe Beobachtung und Positionsbestimmung
Korrelation mit SN-Explosionen

- AGILE-Satellit

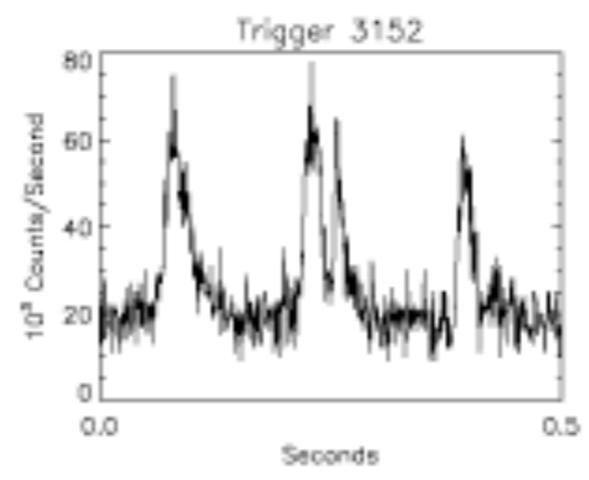
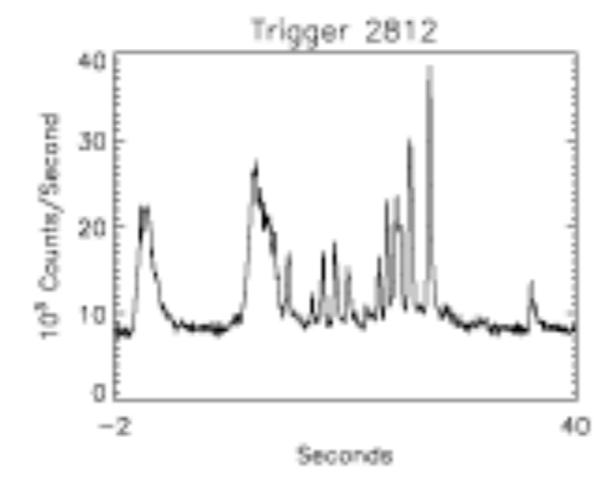
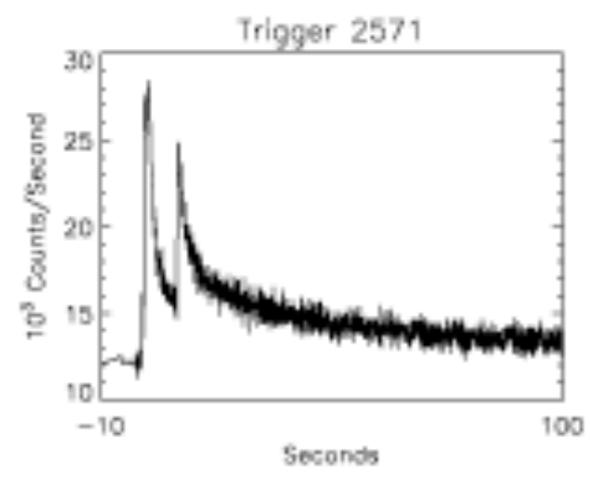
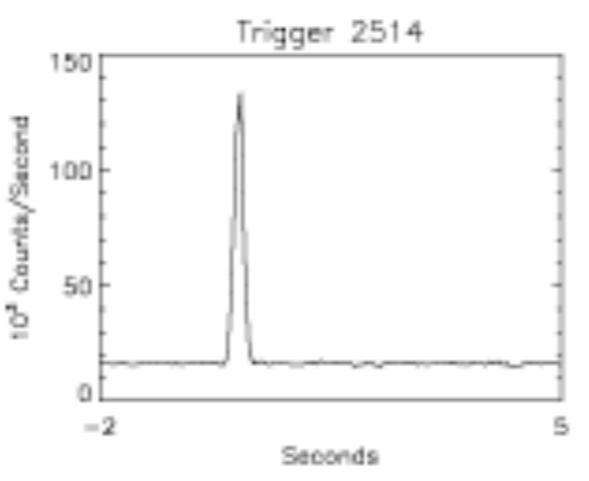
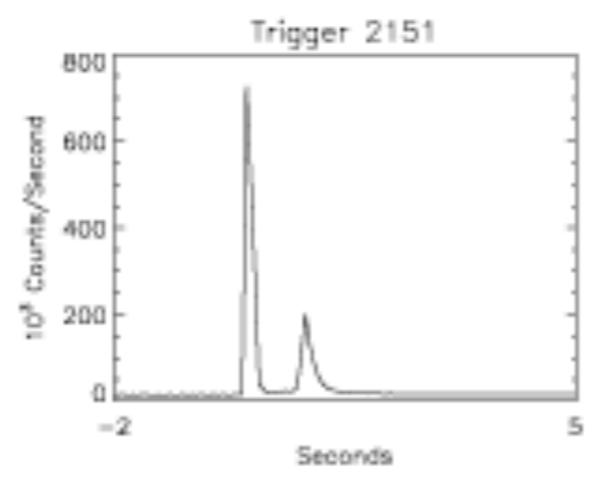
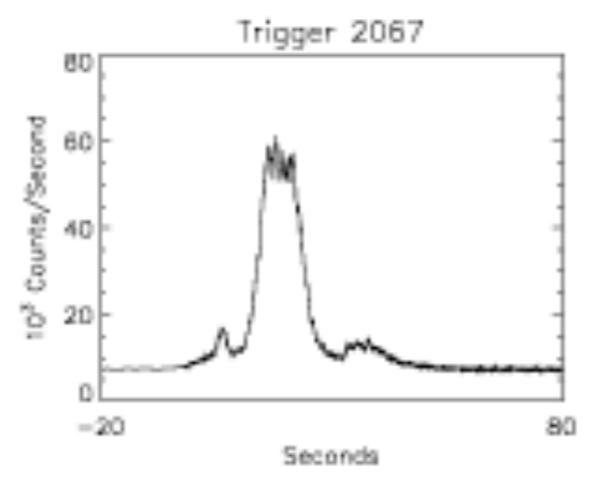
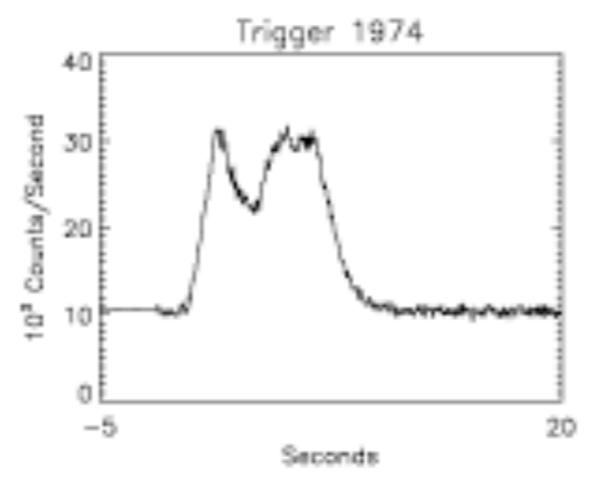
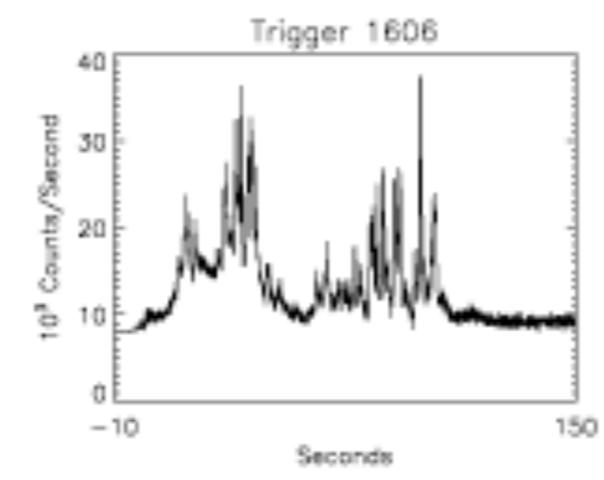
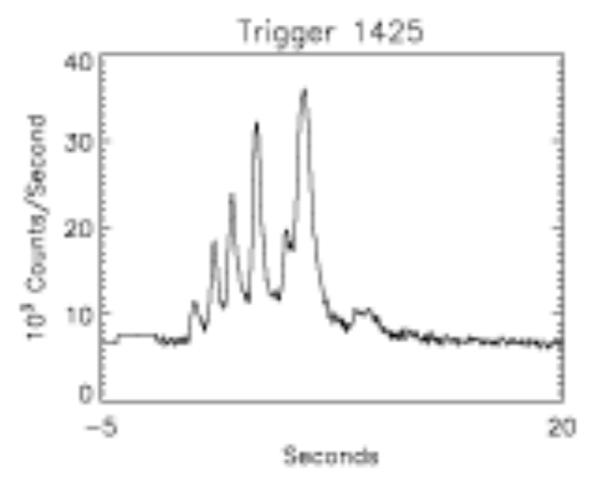
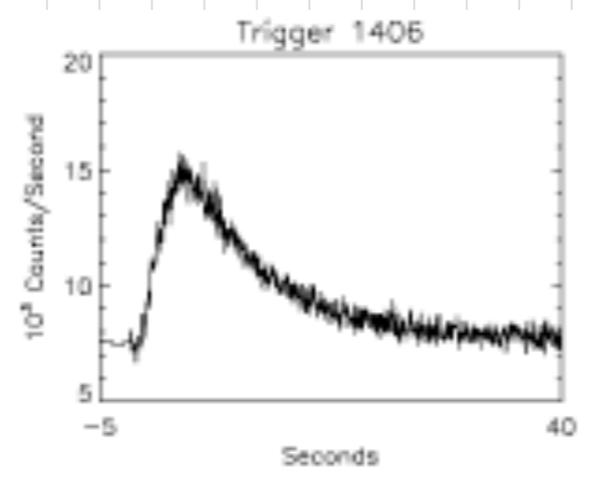
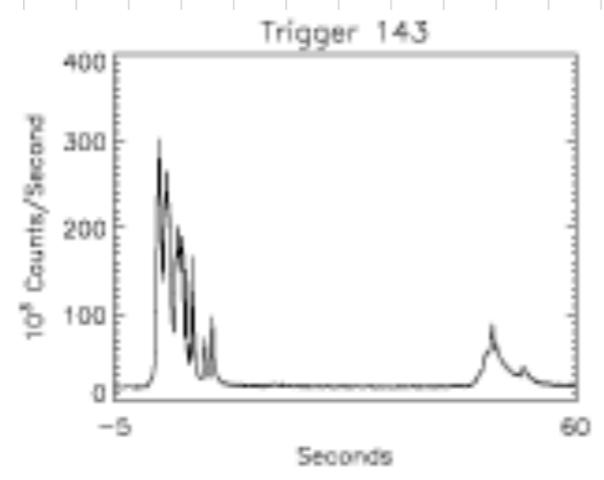
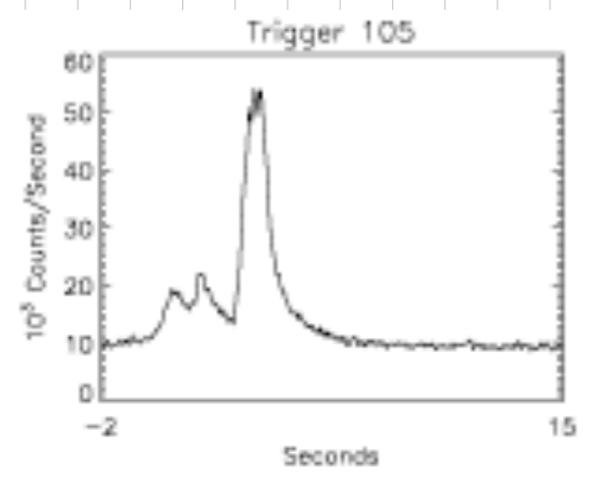
Fermi-Satellit (GLAST)

MAGIC (HESS, VERITAS, ...)

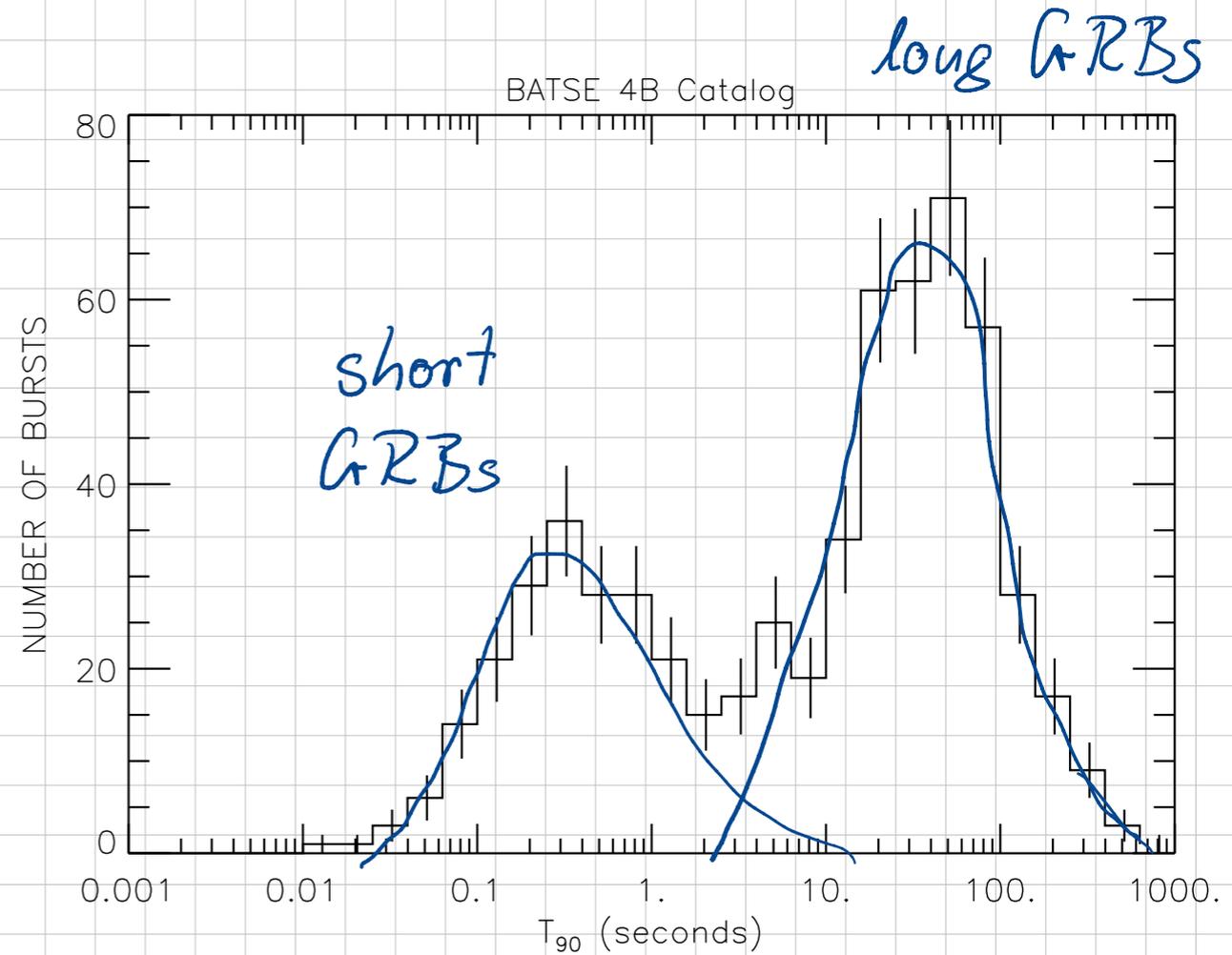
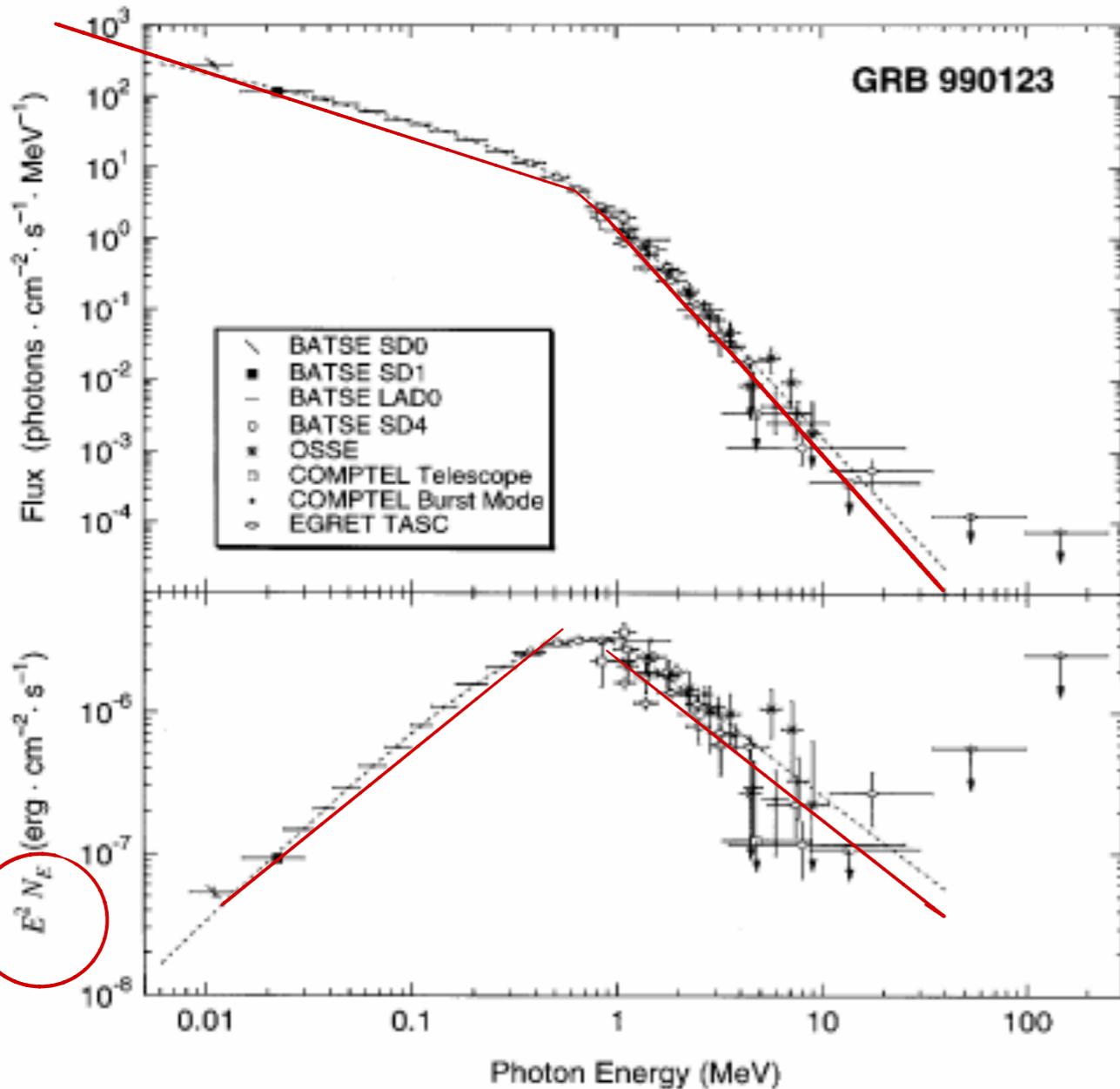


GRB-Eigenschaften

- Irreguläre Zeitabläufe
- sehr verschiedene Zeitskalen
- kaum Regelmäßigkeiten vorhanden
- Klassifizierung sehr schwierig



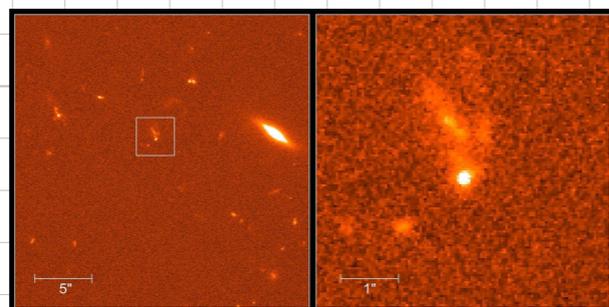
Energiespektrum und Ausbruchsdauer



Energiespektrum: gebrochenes
Potenzgesetz

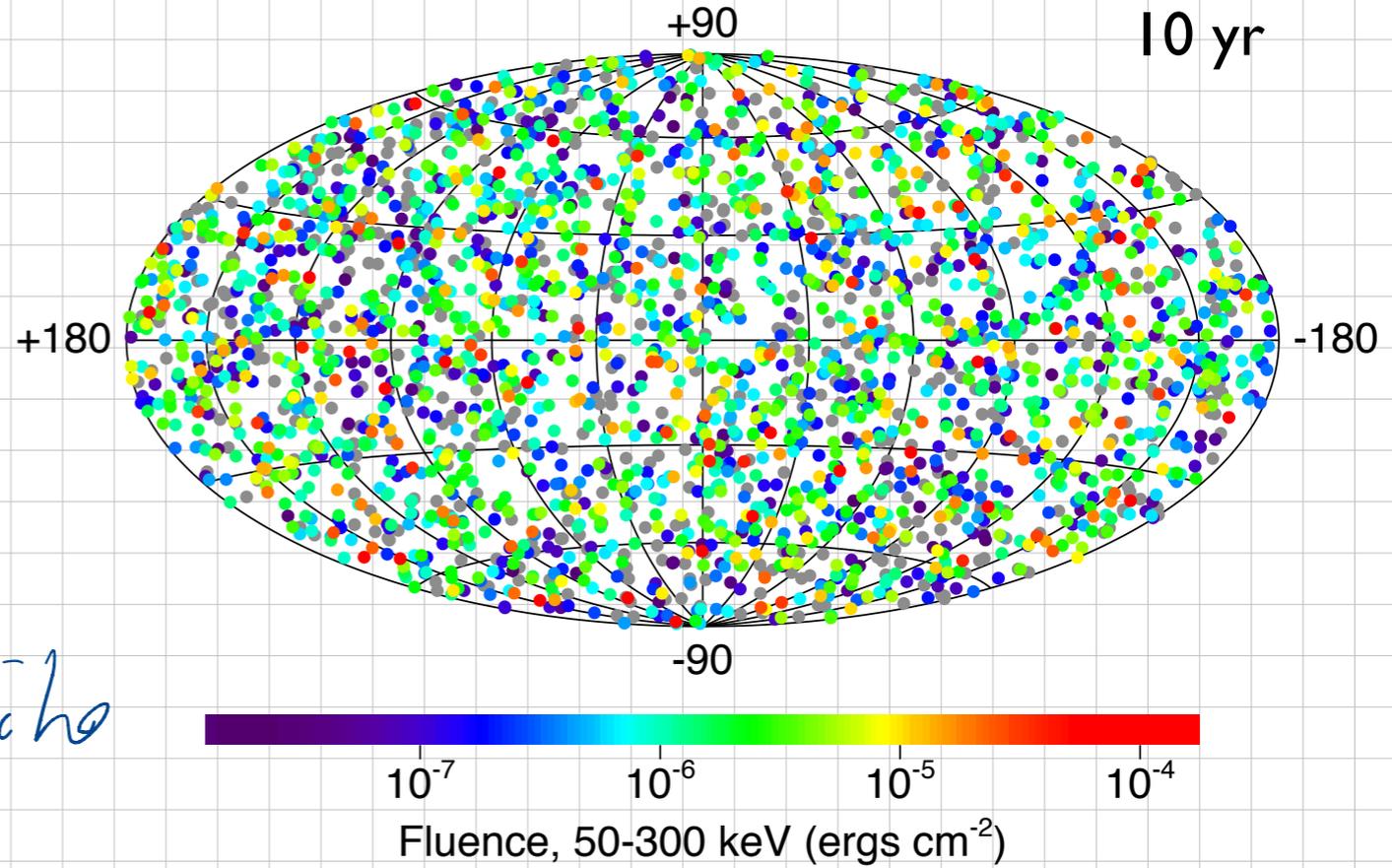
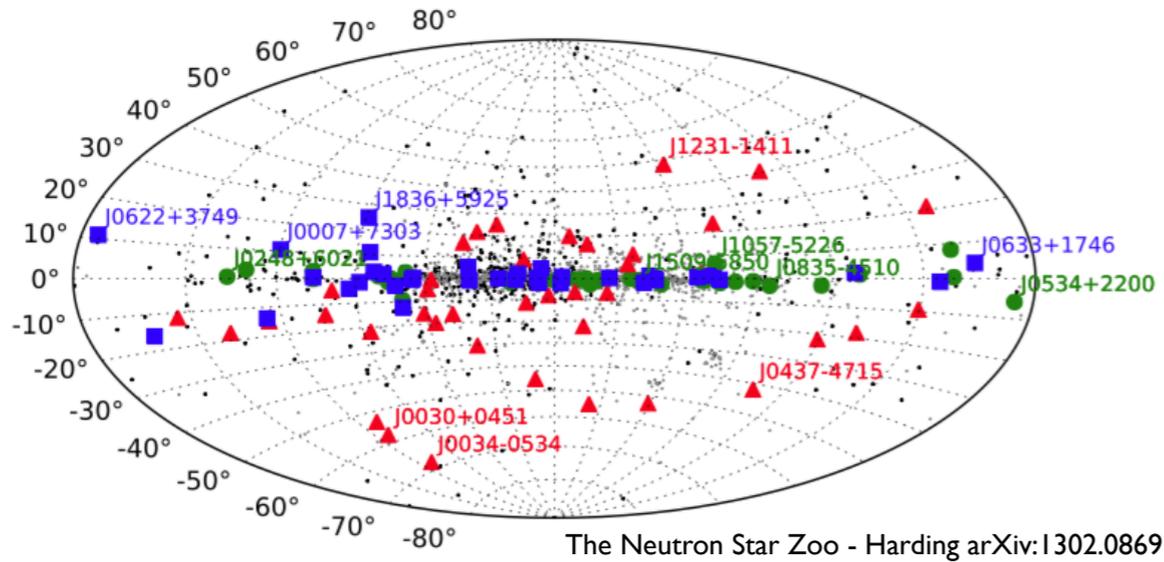
↳ vermutlich nicht-thermische
Quelle

First detected in
gamma-ray, x-ray, radio
and optical spectrums



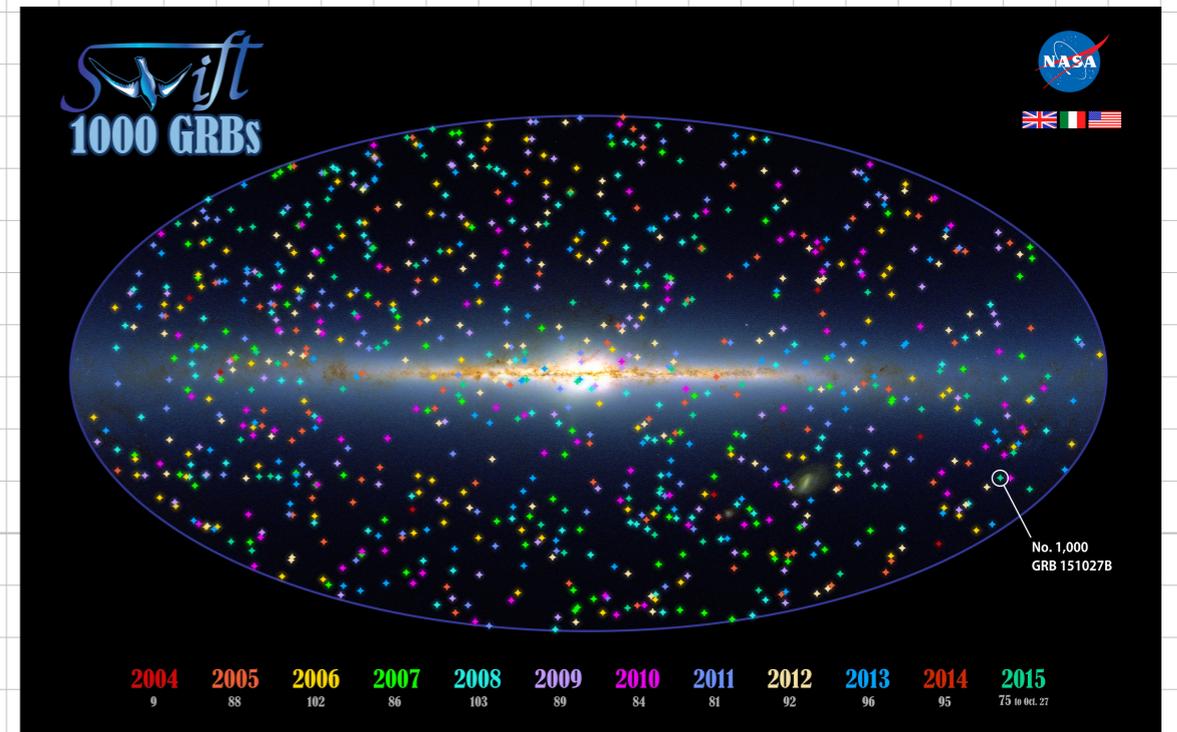
Richtungsverteilung

2704 BATSE Gamma-Ray Bursts



• Kosmologische, extragalaktische Verteilung der Quellen

• gal. Halo: 10-20% Anisotropie erwartet



Erwartete Verteilung der GRBs

Annahme: Konstante Dichte n von Quellen gleicher L_0
 Es gibt $\Delta N = 4\pi r^2 \Delta r \cdot n$ Quellen in Schale mit Dicke Δr

Beobachteter Fluss in Schale $S = \frac{L_0}{4\pi r^2}$ pro Quell

$$\Delta S = \frac{dS}{dr} \cdot \Delta r = -2 \frac{L_0}{4\pi r^3} \Delta r$$

$$\Delta r = \frac{4\pi r^3}{-2L_0} \Delta S$$

$$\Delta N = 4\pi r^2 \Delta r \cdot n = 4\pi \frac{L_0}{4\pi S} \cdot \frac{4\pi \left(\frac{L_0}{4\pi S}\right)^{3/2}}{-2L_0} \cdot n \cdot \Delta S$$

$$= \frac{(4\pi)^2}{L_0} \cdot n \cdot \left(-\frac{1}{2}\right) \left(\frac{L_0}{4\pi S}\right)^{5/2} \cdot \Delta S$$

$$\frac{\Delta N}{\Delta S} \propto S^{-5/2}$$

$$N(S_0) = \int_{S_0}^{\infty} \frac{\Delta N}{\Delta S} dS \propto \int_{S_0}^{\infty} S^{-5/2} dS \propto \frac{S_0^{-3/2}}{S_0} = S_0^{-5/2}$$

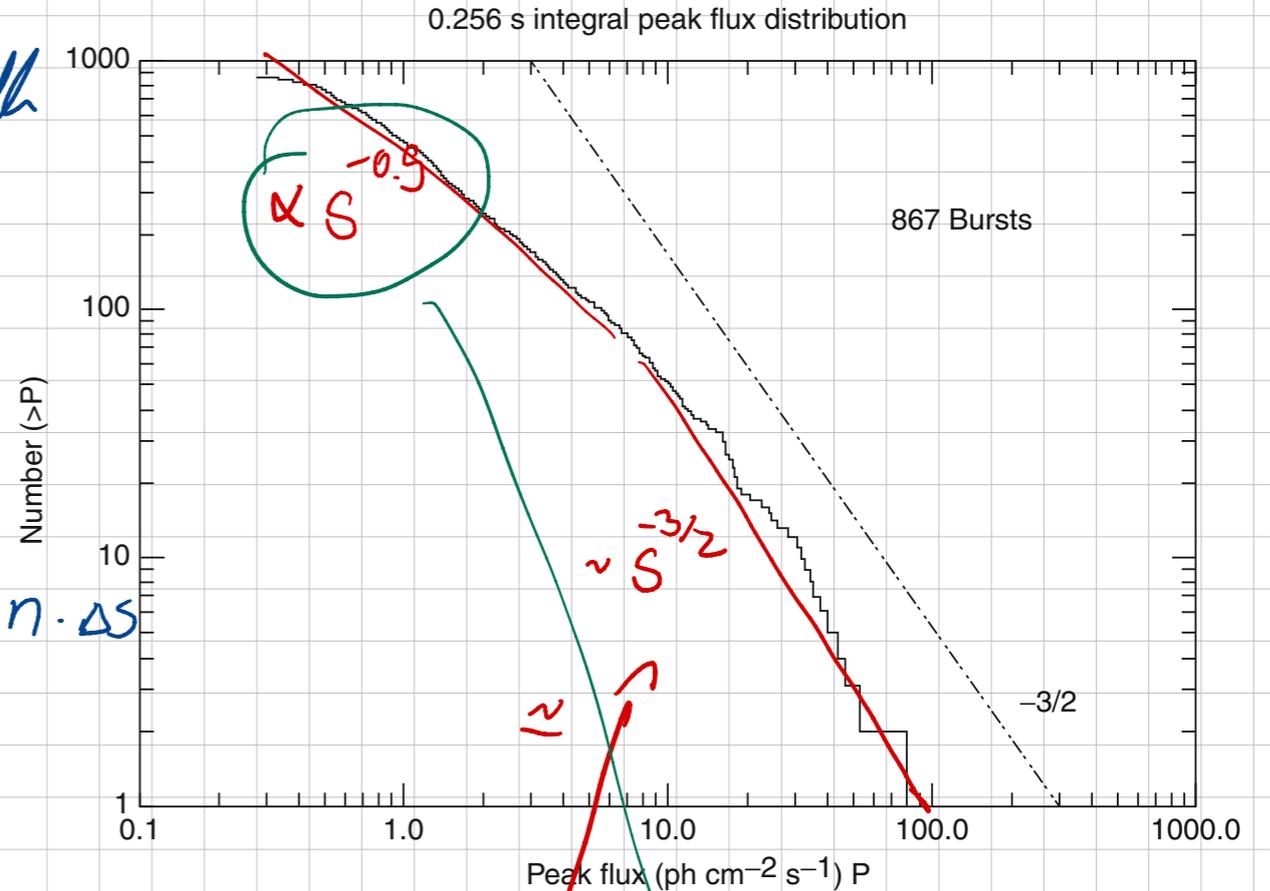
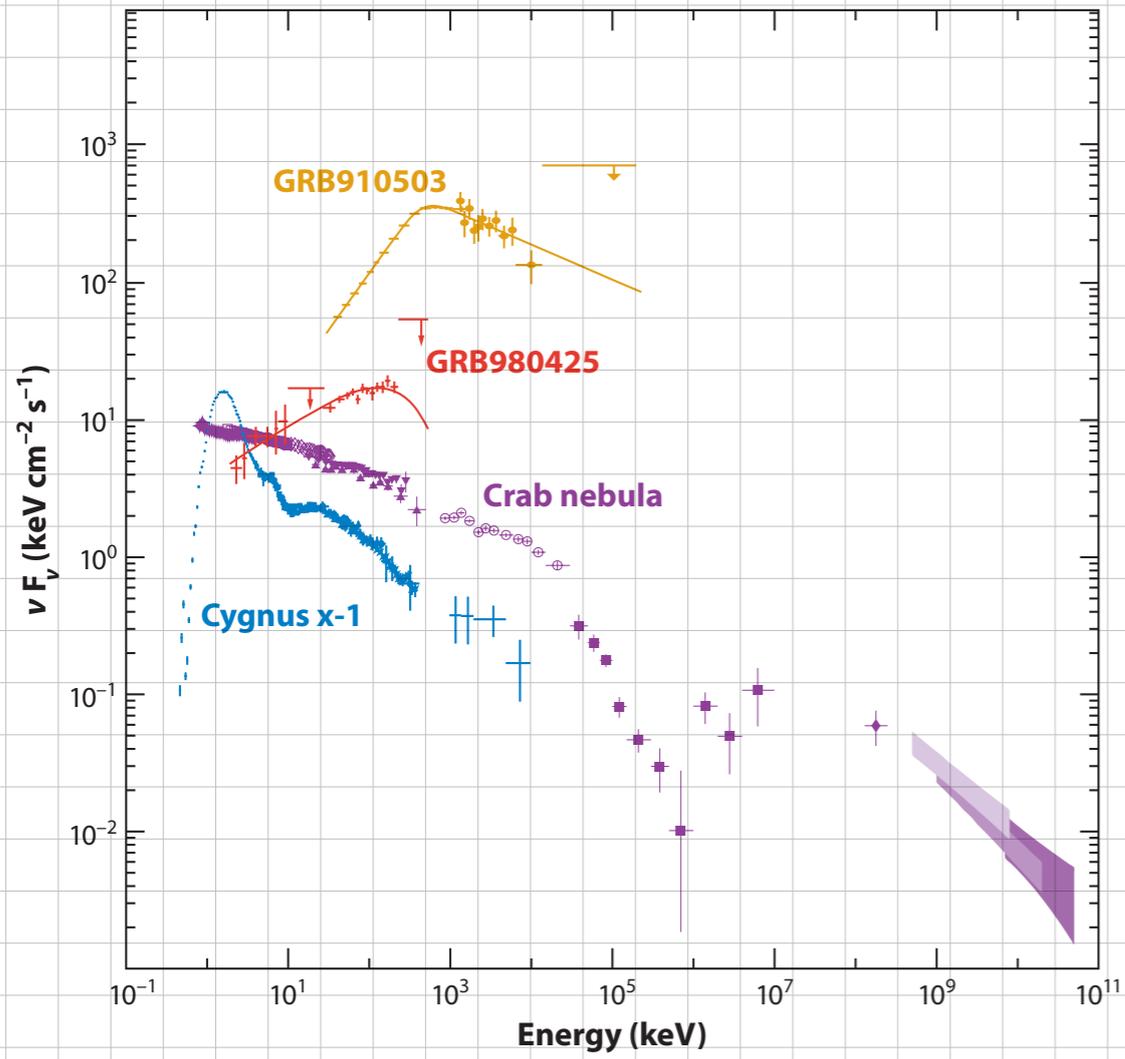


Fig. 19.4 The number of GRBs whose peak flux is brighter than flux P . A homogeneous distribution of bursts in space would imply a slope of $-3/2$ (see text) (Data from BATSE, figure from P. Meszaros (<http://www2.astro.psu.edu/users/nmp/cosm.html>))

$S_0 = f(z)$?
 Maximale Rotverschiebung erreicht

Luminositätsabschätzung



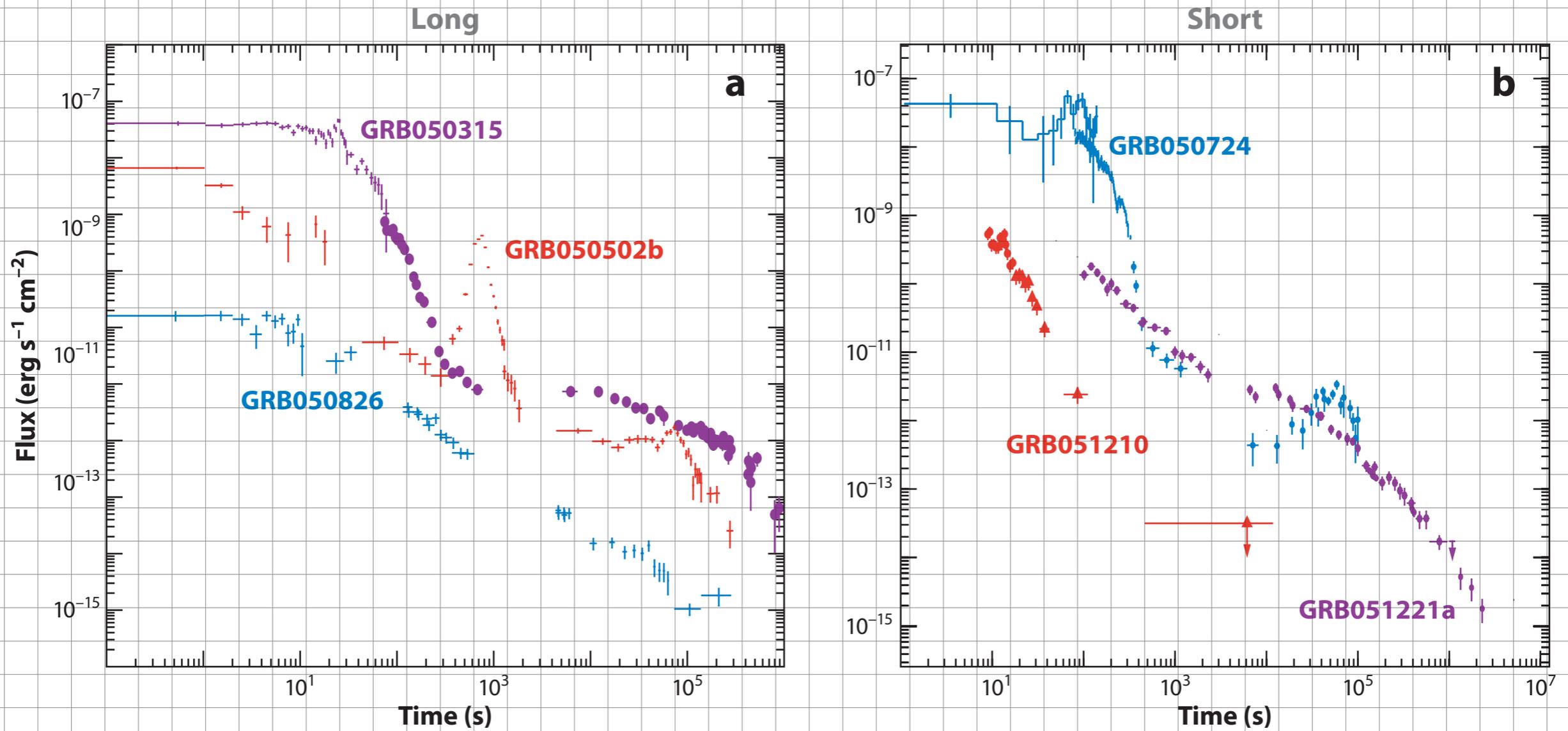
Problem der optischen Dichte

Dichteproblem

Optische Dichte

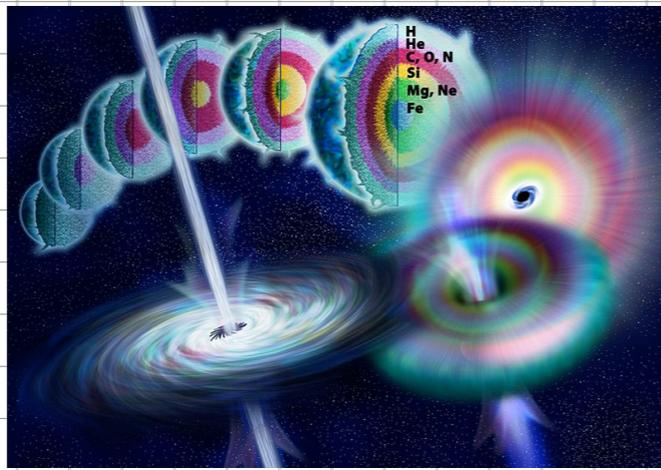
Optische Dichte mit Korrekturen

Nachleuchten (Afterglow)



Representative examples of X-ray afterglows of (a) long and (b) short *Swift* events with steep-to-shallow transitions (GRB050315, 050724), large X-ray flares (GRB050502B, 050724), and rapidly declining (GRB051210) and gradually declining (GRB051221a, 050826; flux scale divided by 100 for clarity) afterglows.

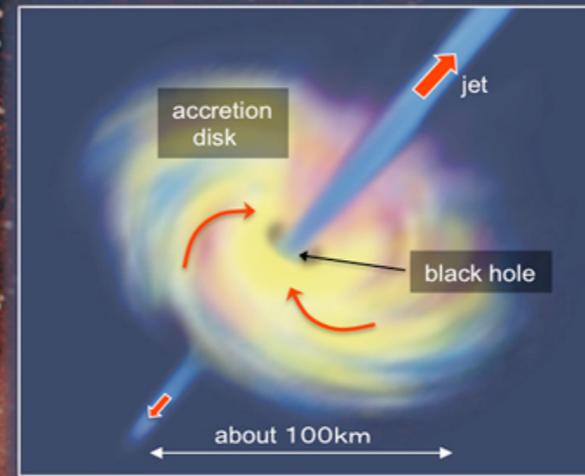
Modell- vorstellungen



Gamma-Ray Bursts (Imaginary Picture)

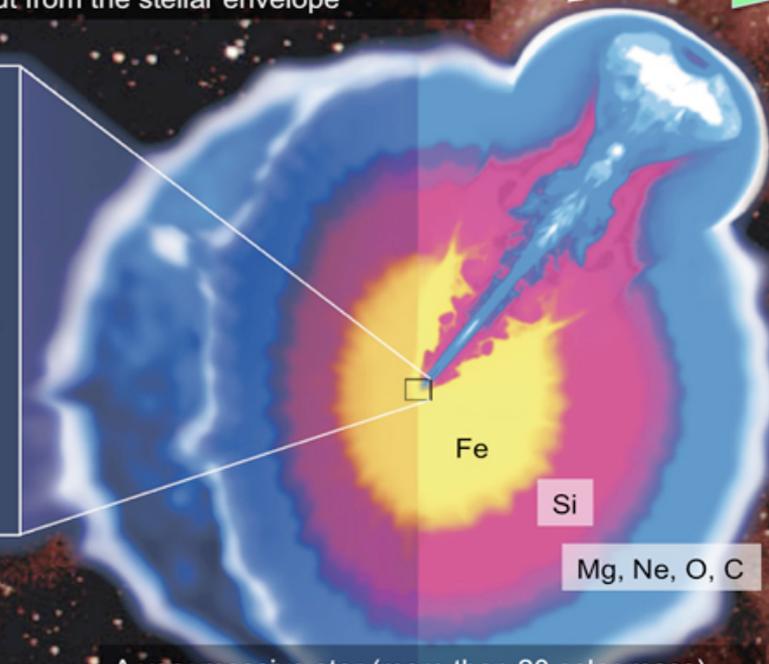
gamma-rays are produced when the jet (close to the light speed) breaks out from the stellar envelope

Observer



A black hole, accretion disk and jet are formed by the gravitational collapse of the stellar core

Kyoto University, T. TOTANI



A very massive star (more than 20 solar mass), whose outer envelope (hydrogen and helium) has been removed

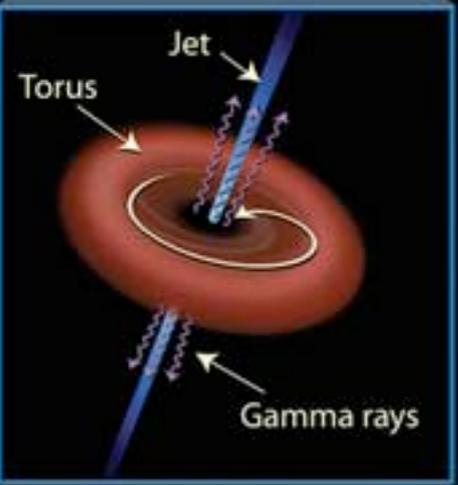
Gamma-Ray Bursts (GRBs): The Long and Short of It

Long gamma-ray burst (>2 seconds' duration)



A red-giant star collapses onto its core....

...becoming so dense that it expels its outer layers in a supernova explosion.

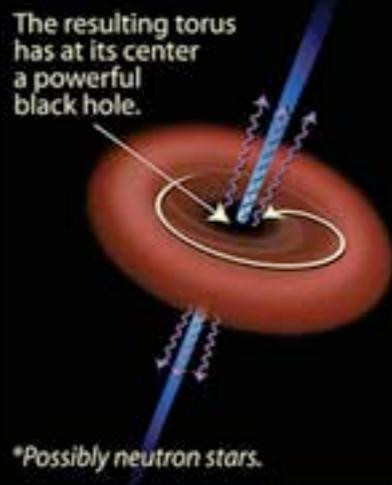


Short gamma-ray burst (<2 seconds' duration)



Stars* in a compact binary system begin to spiral inward....

...eventually colliding.



The resulting torus has at its center a powerful black hole.

*Possibly neutron stars.

Kurze Gamma-Strahlen-Blitze:
Vereinigung von kompakten
Objekten

Lange Gamma-Strahlen-Blitze:
Hypernova-Explosionen

Größe der Quellen

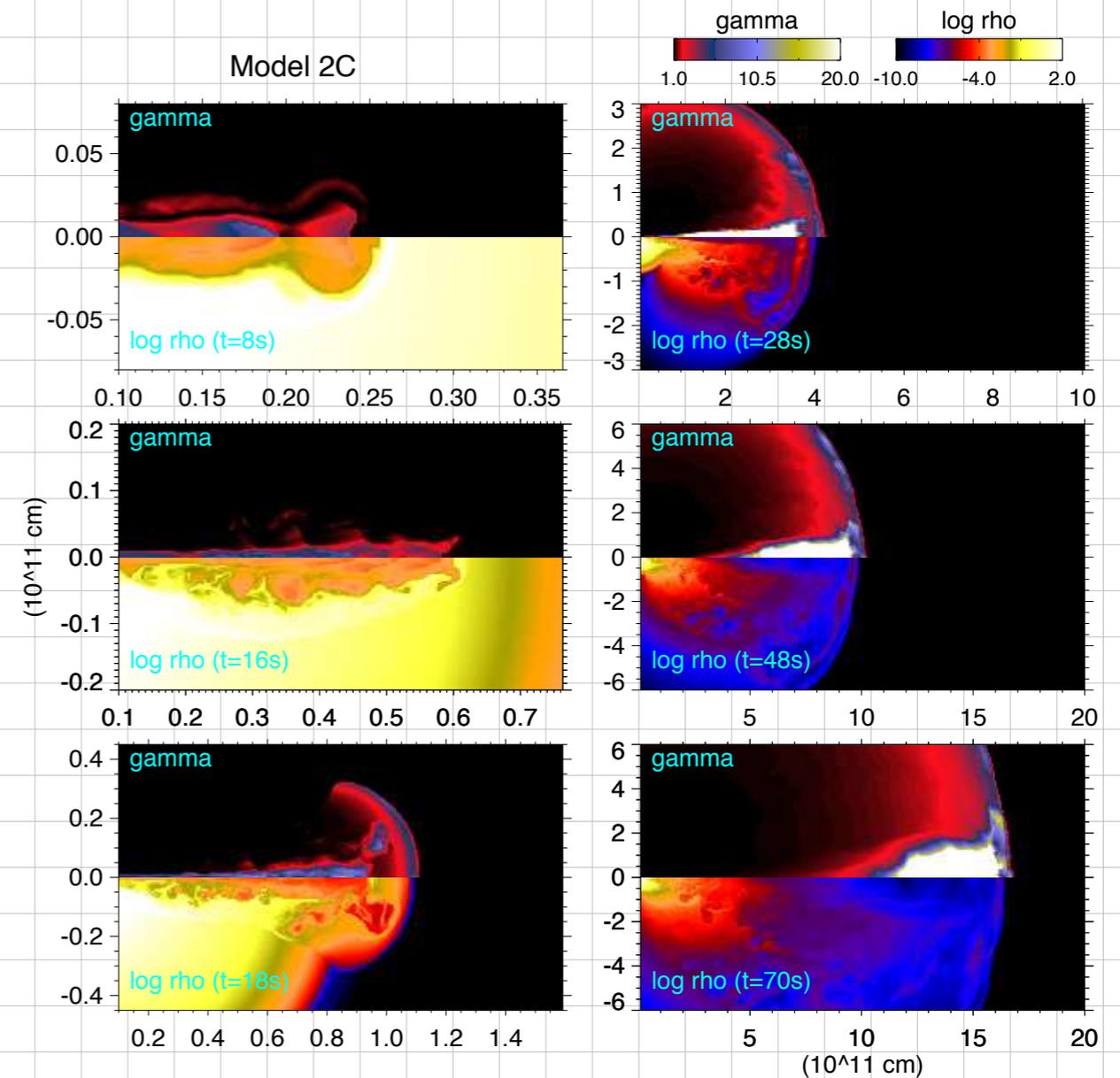
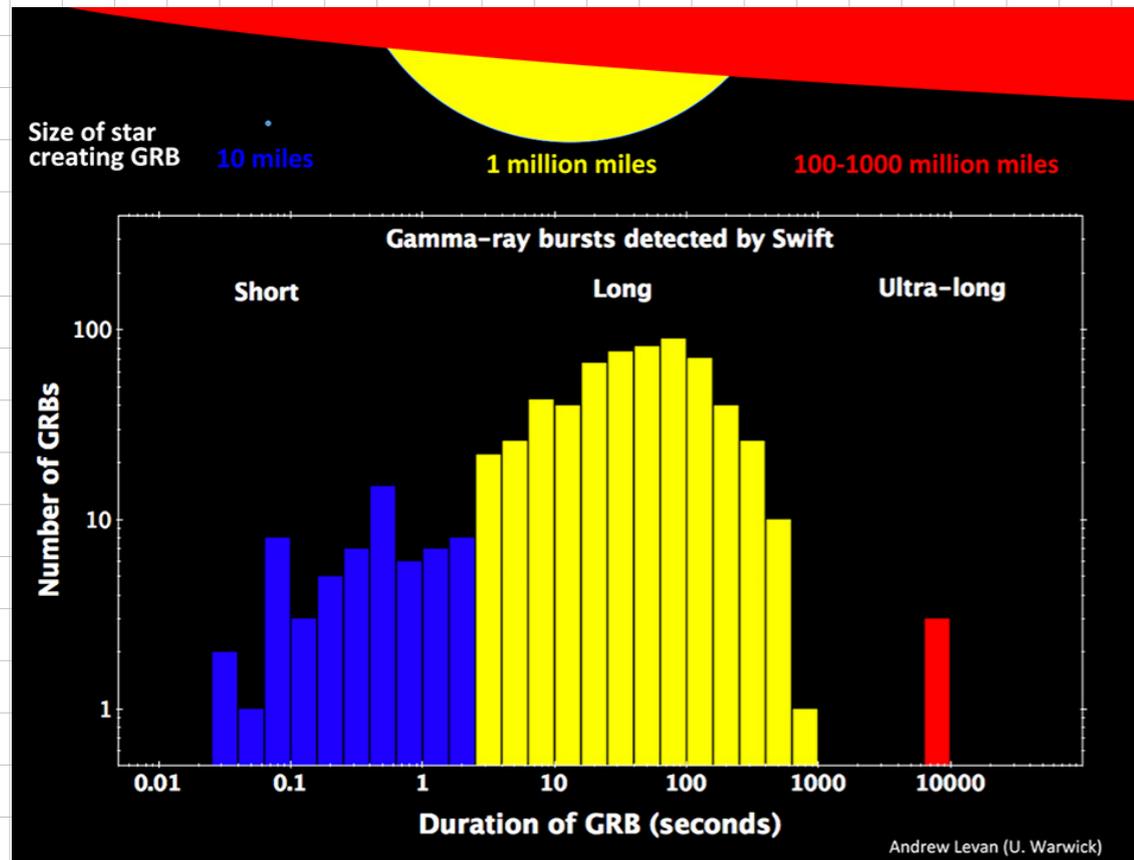
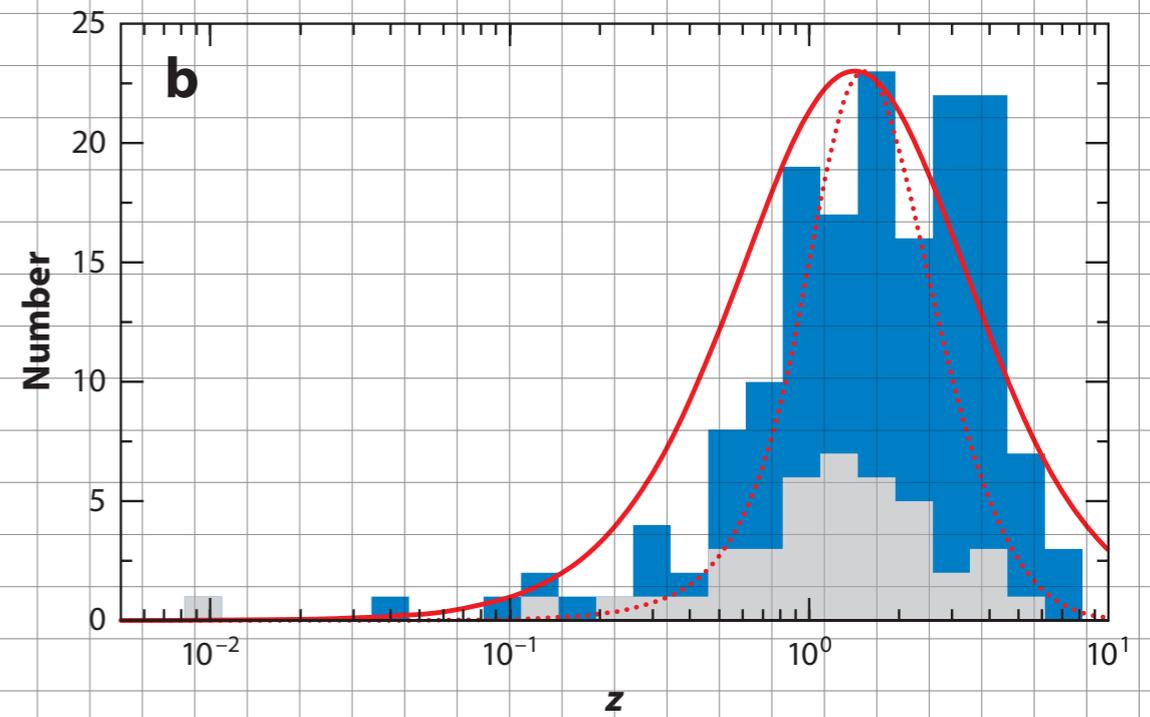
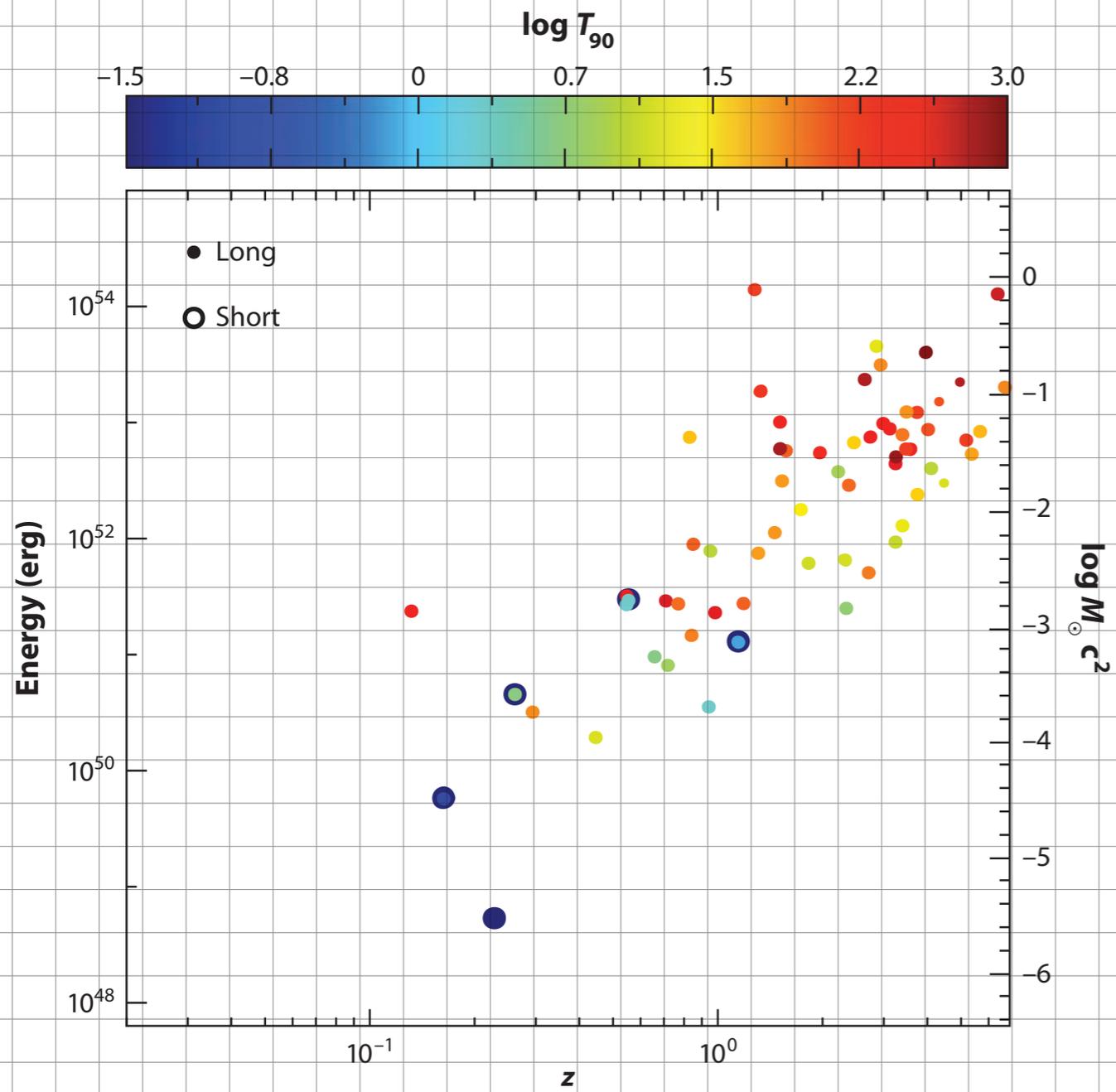
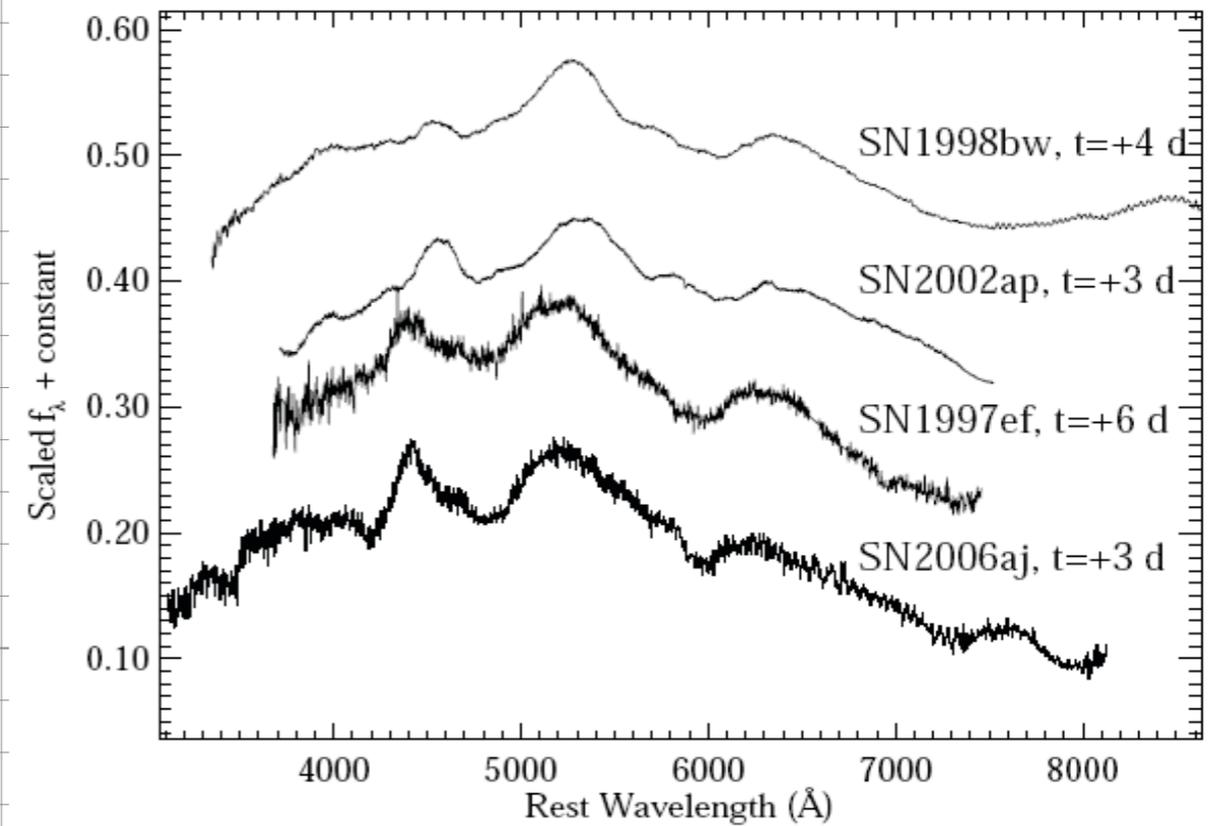
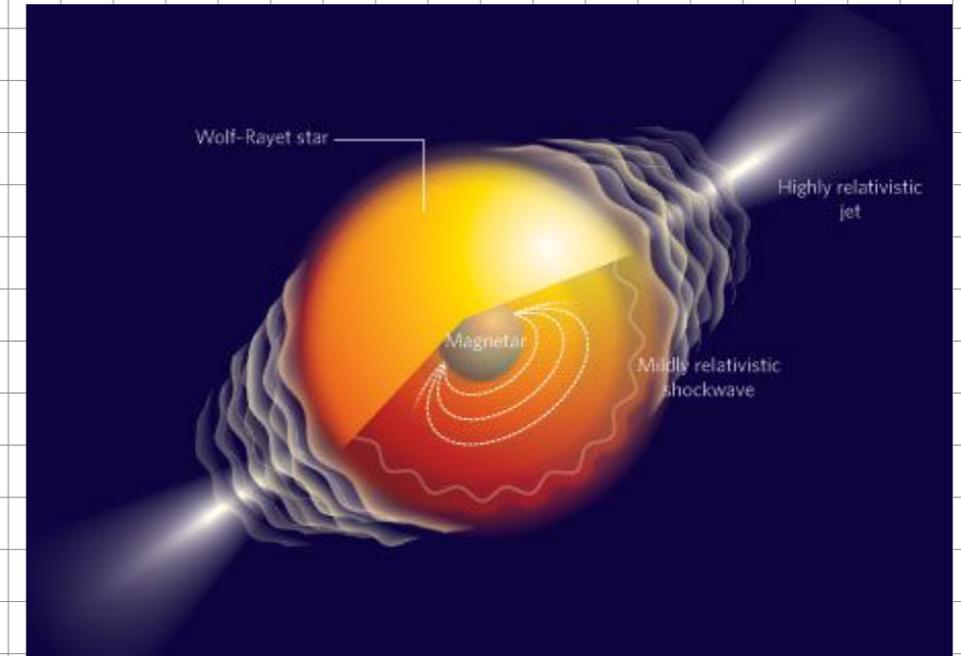
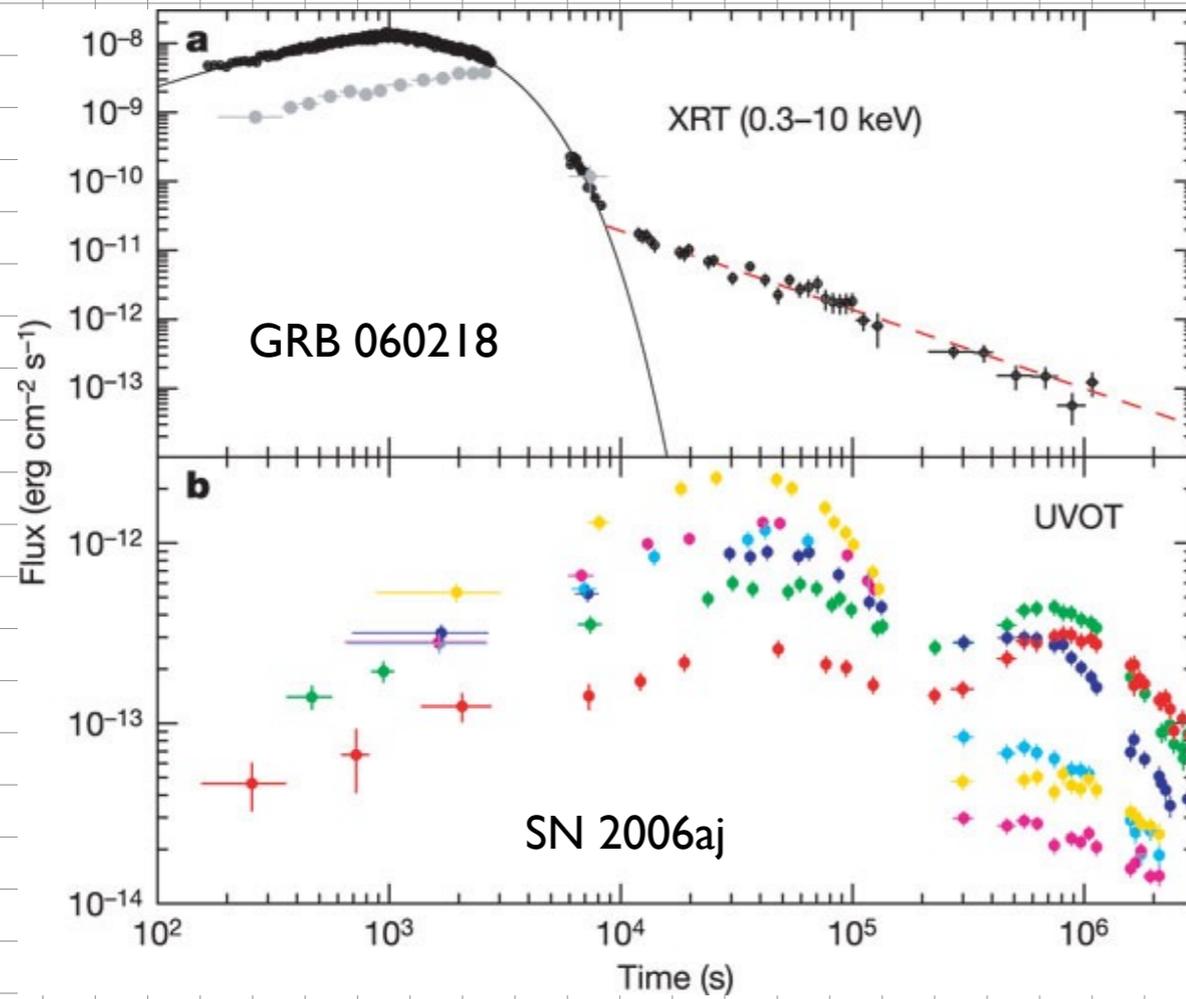


Fig. 4.— Time evolution of the density (bottom of each frame) and Lorentz factor (top of each frame) in the jet and its environs for Model 2C. The density is on a logarithmic scale, the Lorentz factor is on a linear scale, both color coded. Quantities are given 8, 16, 18, 28, 48, and 70 s after the initiation of the jet at 0.1×10^{11} cm. See also Fig. 2. Model 2C is a less energetic jet and takes longer to reach the surface.

Entfernungsverteilung

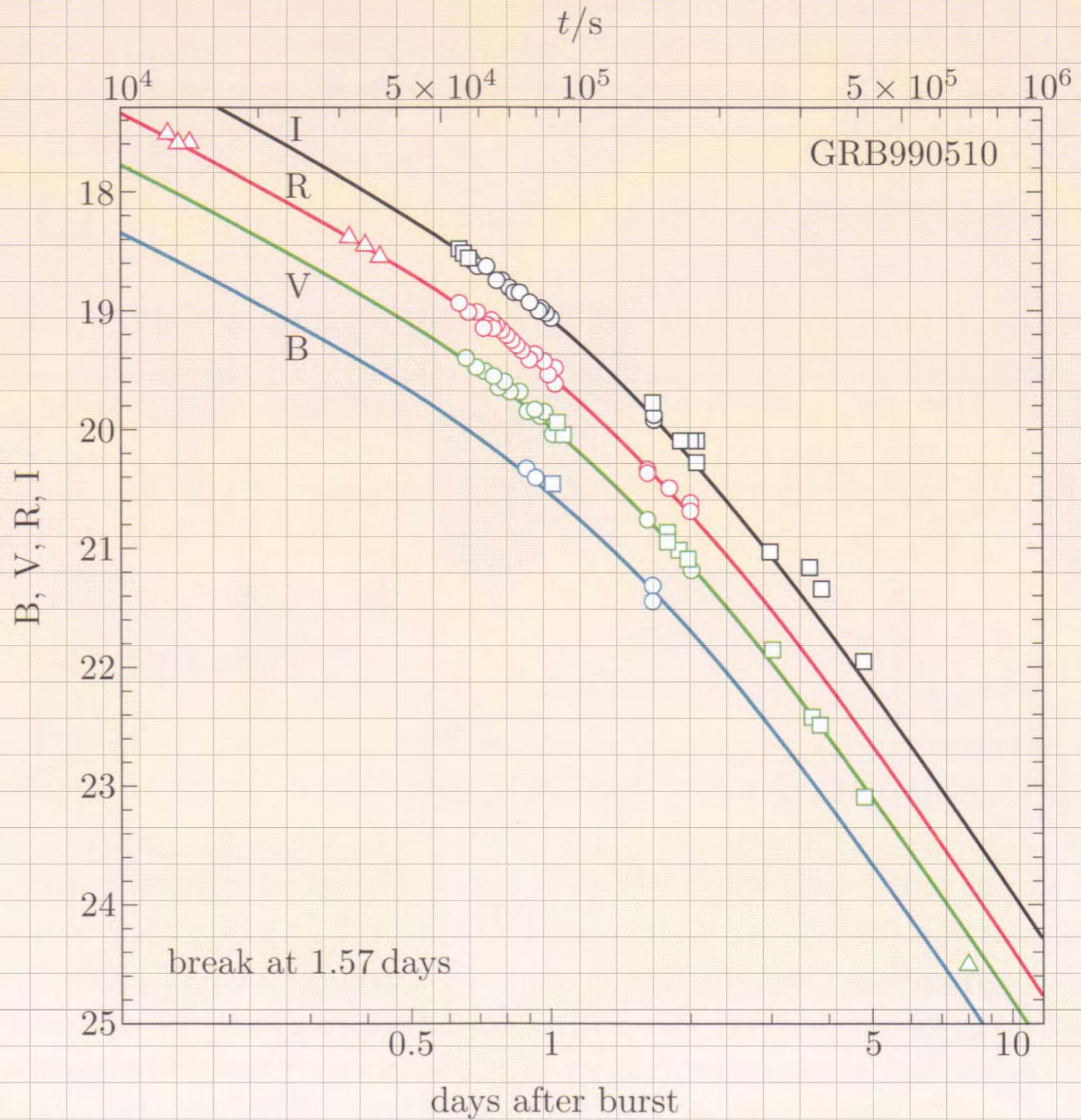


Beobachtung einer Supernova nach GRB (GRB 060218)

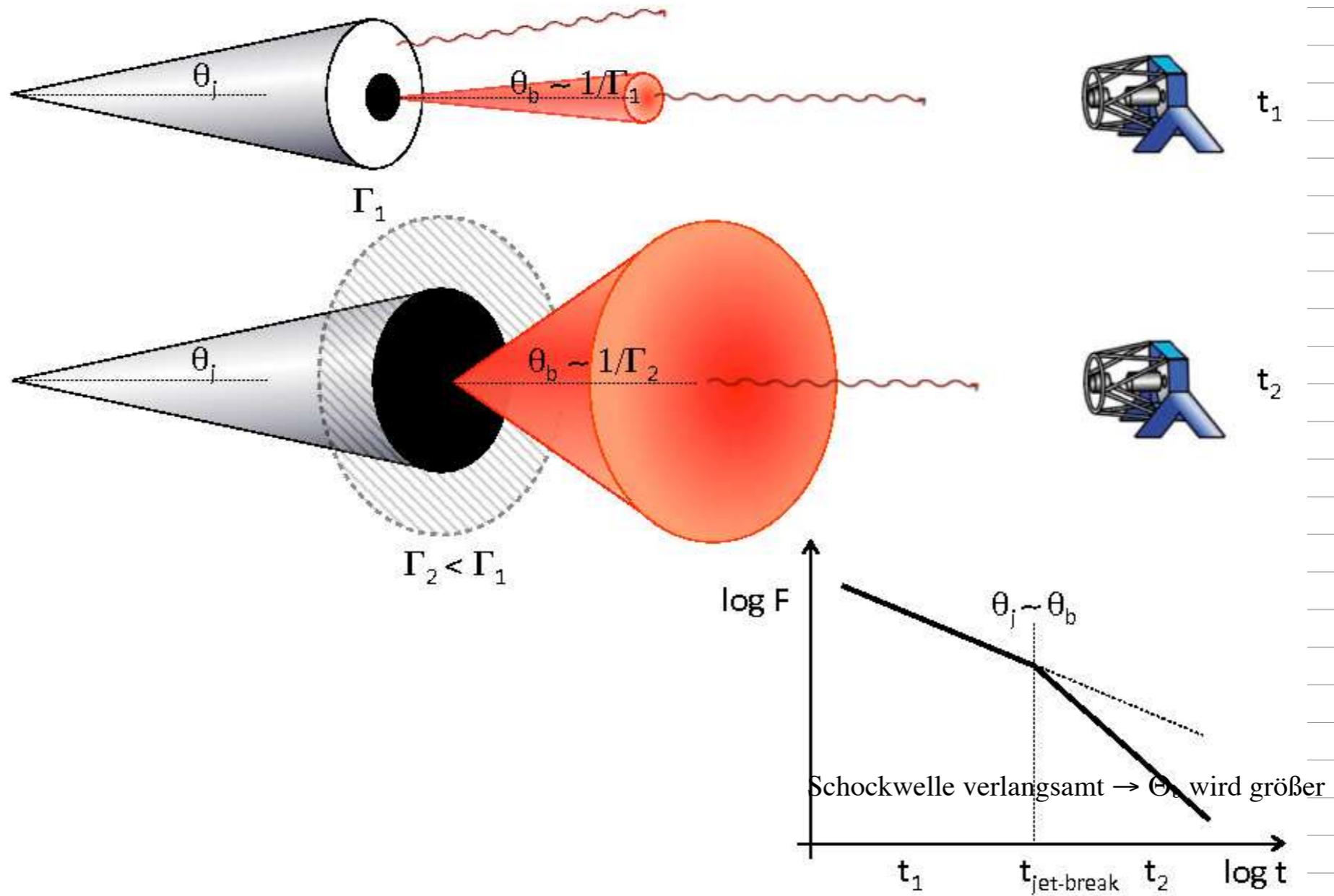


(Campana et al. Nature 2006, 442)

Nachweis relativistischer Plasmastrahlen



Plasmastrahlen als Emissionsquelle



Relativistische Bewegung als Lösung

GRB FIREBALL MODEL

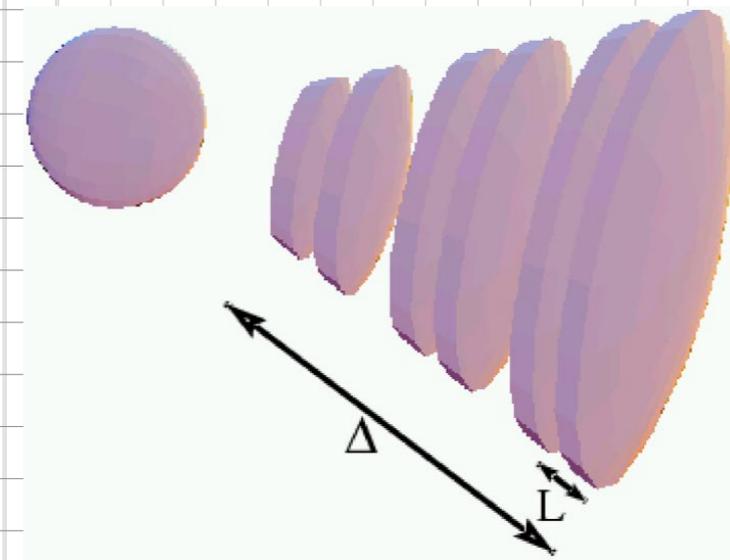
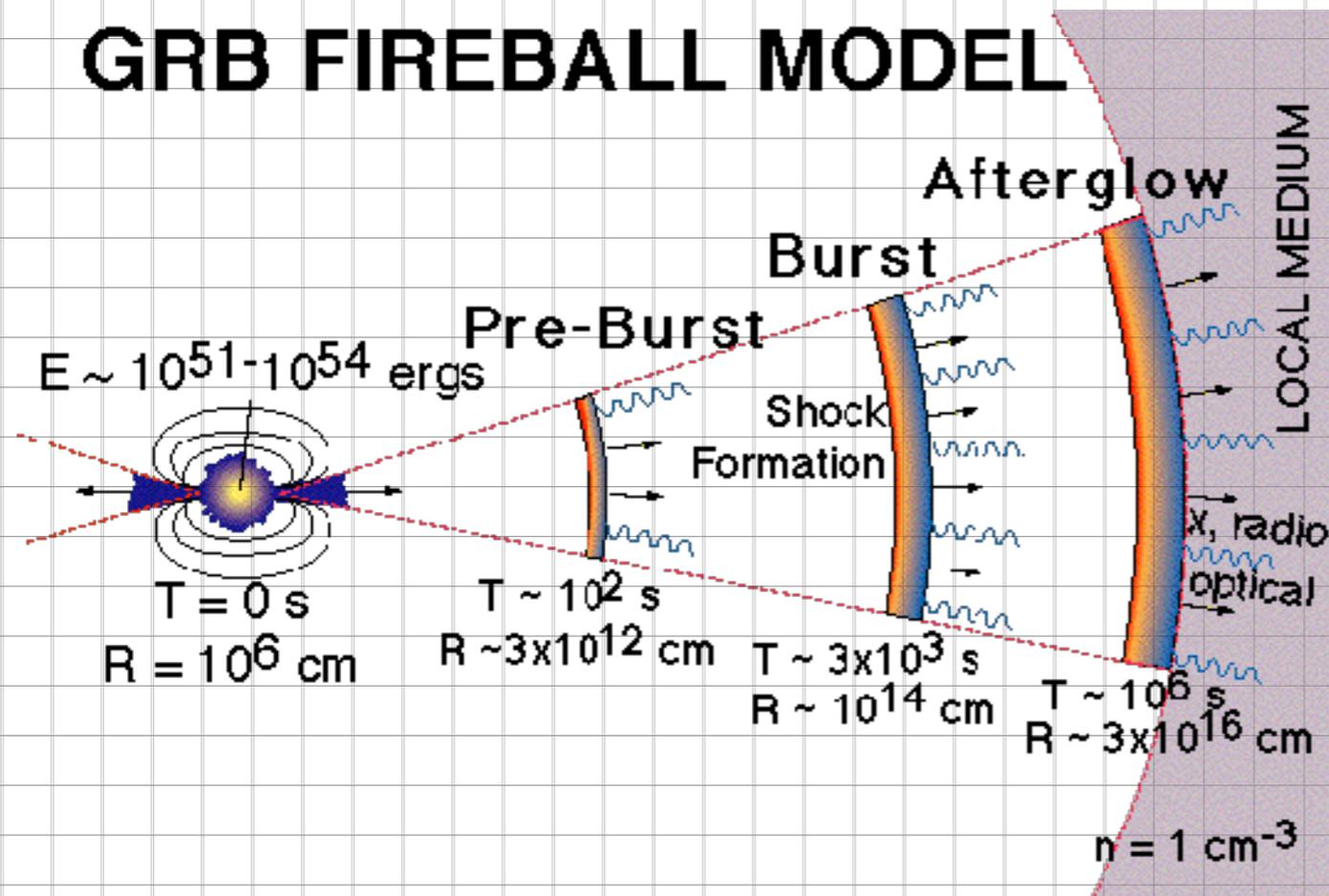
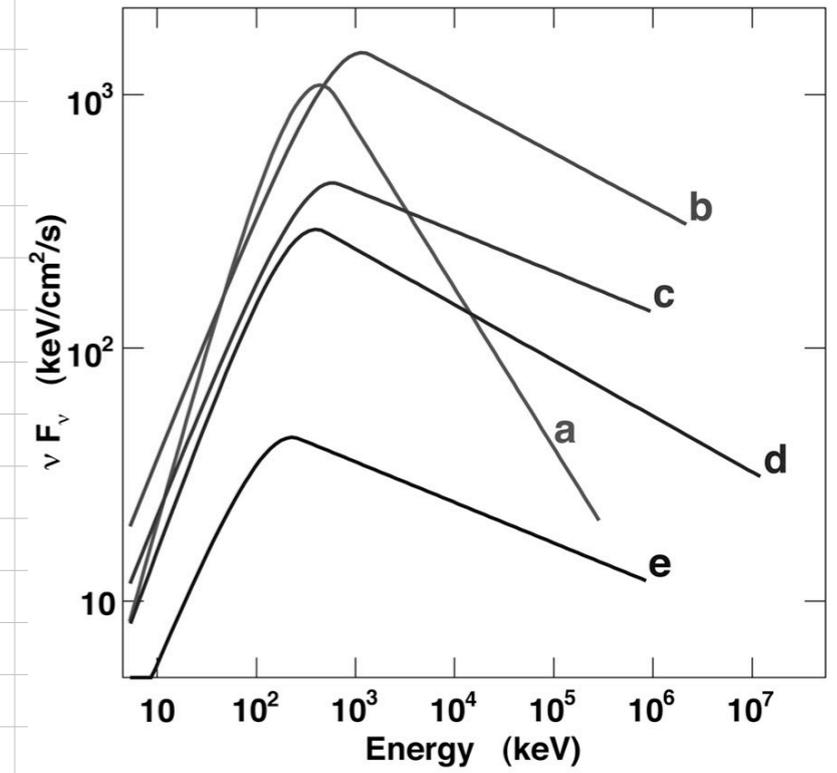
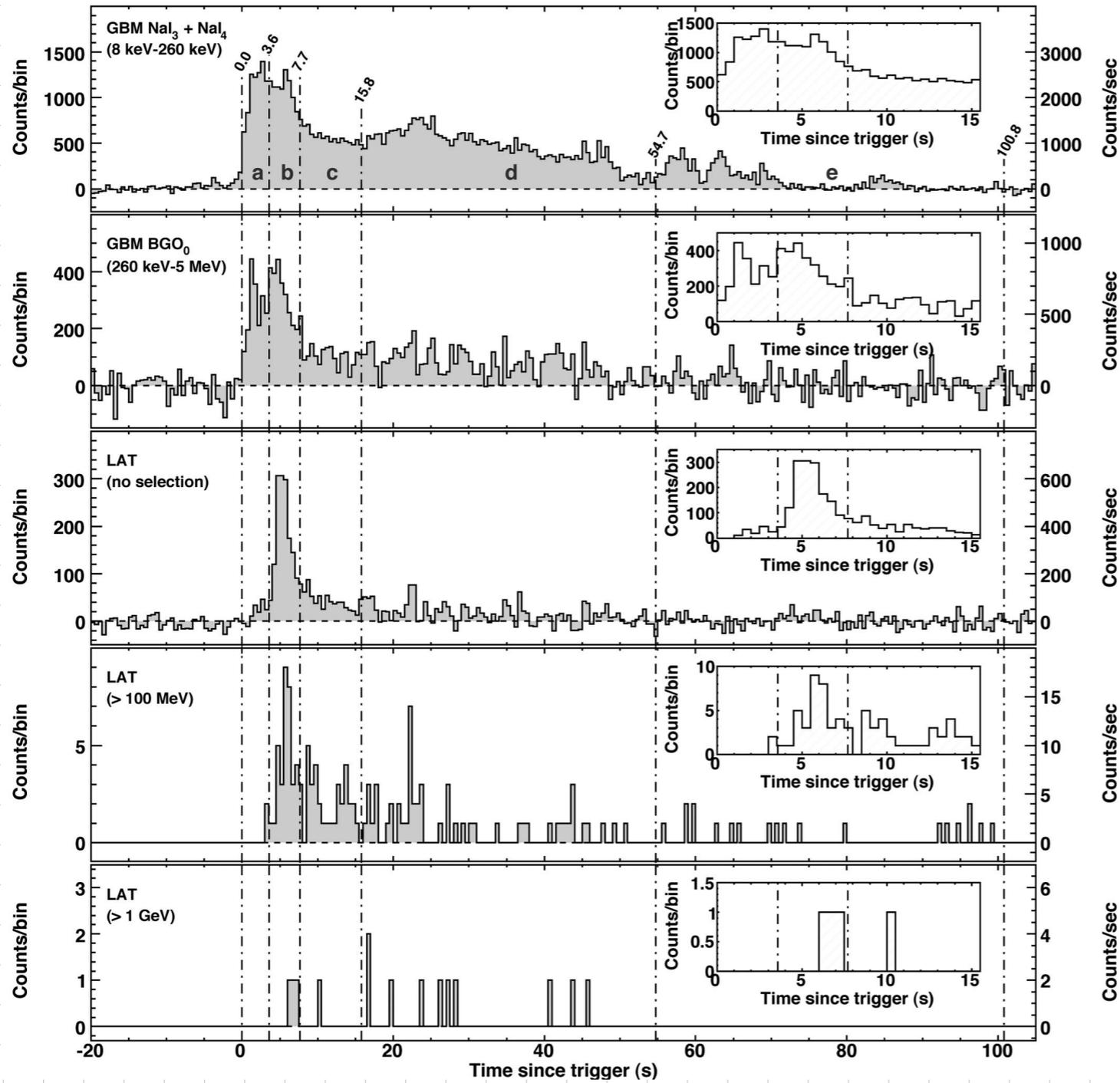


FIG. 21. (Color in online edition) The internal shocks model (from Sari, 1999a). Faster shells collide with slower ones and produce the observed γ rays. The variability time scale is L/c , while the total duration of the burst is Δ/c . From Sari, 1999a.

Hinweis auf Emissionsprozess



Multi-messenger Observations of a Binary Neutron Star Merger

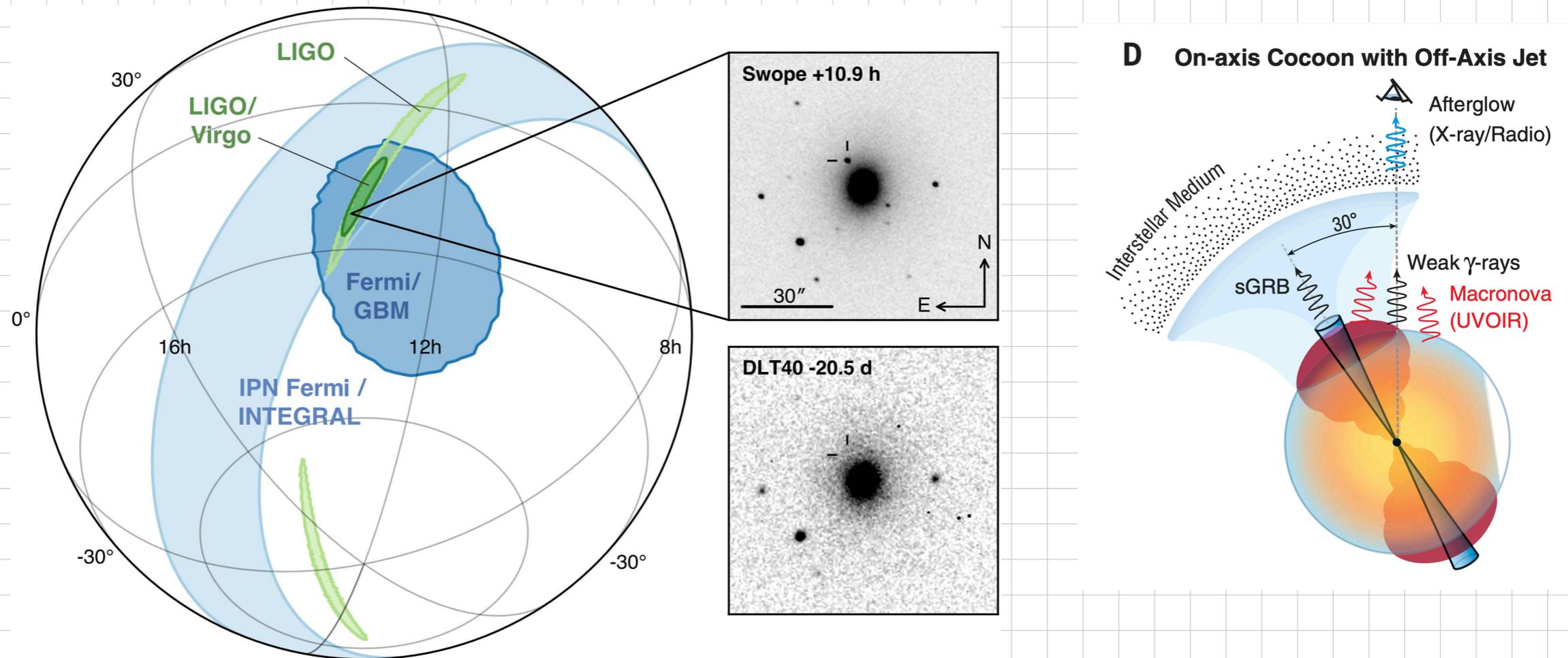
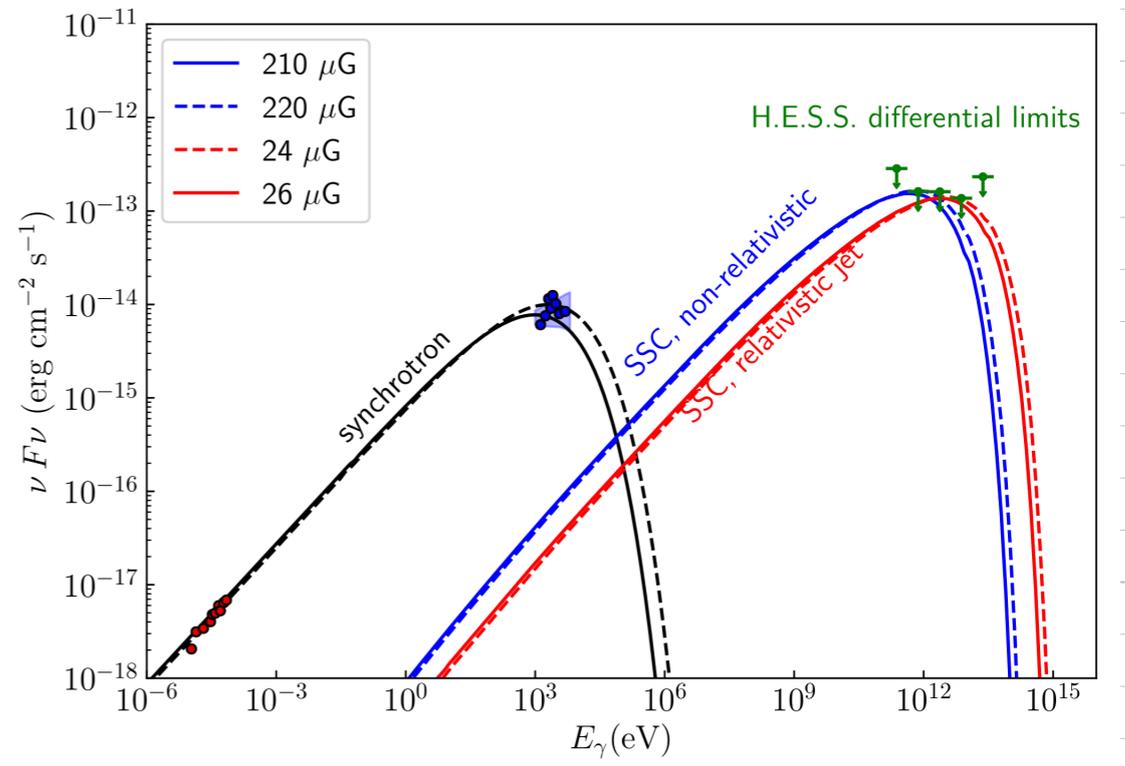
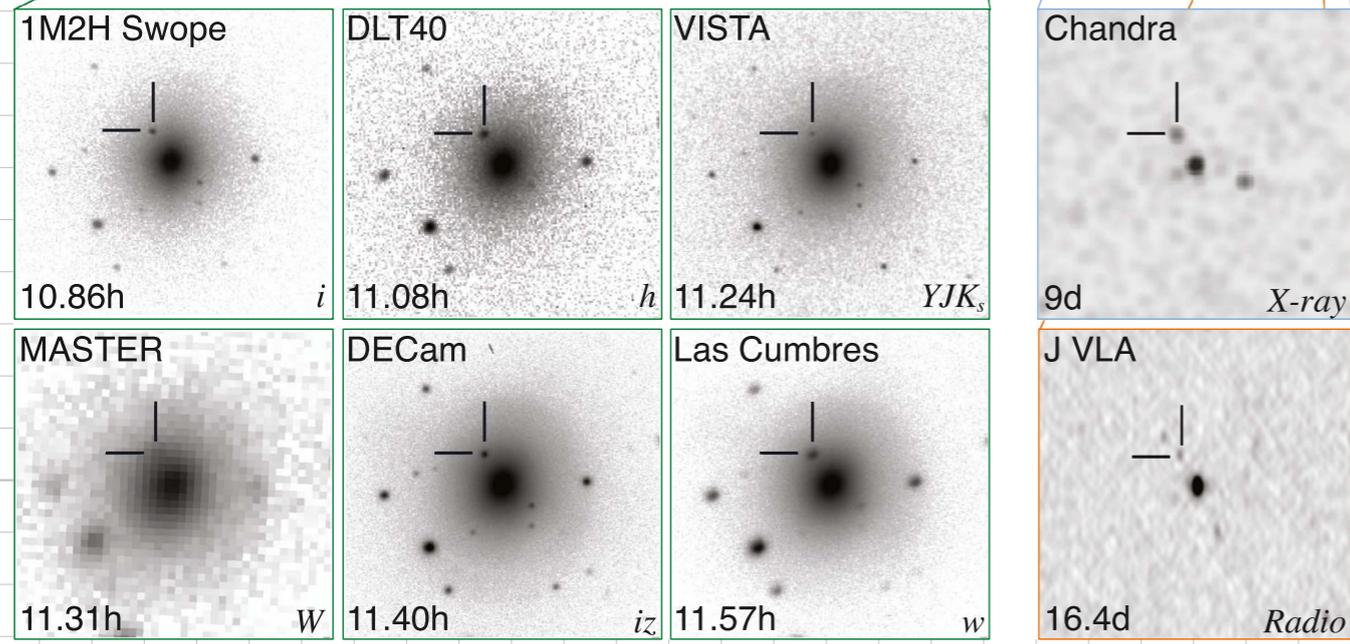
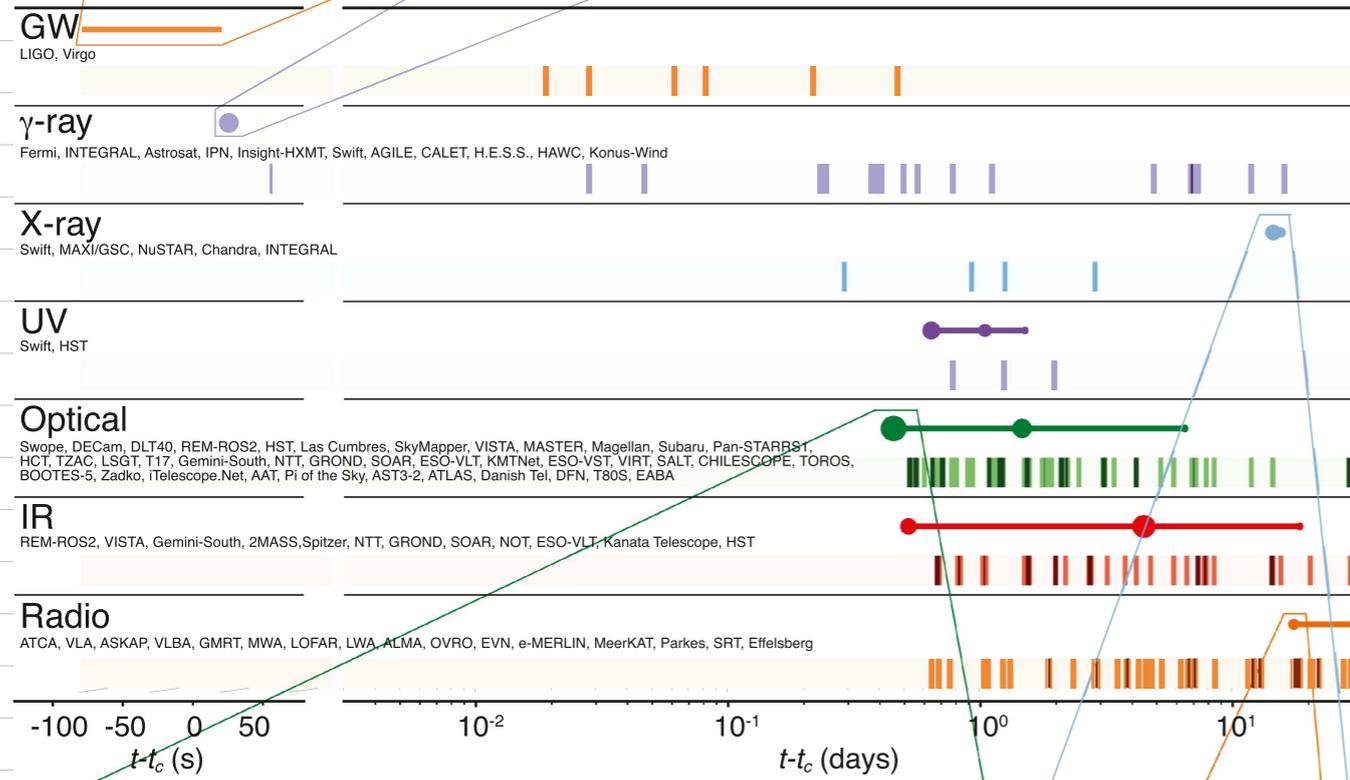
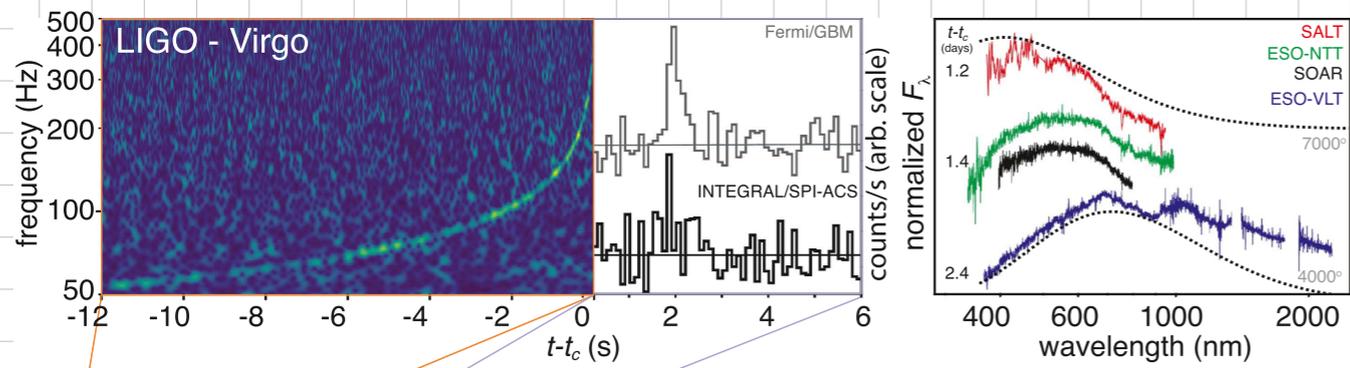


Figure 1. Localization of the gravitational-wave, gamma-ray, and optical signals. The left panel shows an orthographic projection of the 90% credible regions from LIGO (190 deg^2 ; light green), the initial LIGO-Virgo localization (31 deg^2 ; dark green), IPN triangulation from the time delay between *Fermi* and *INTEGRAL* (light blue), and *Fermi*-GBM (dark blue). The inset shows the location of the apparent host galaxy NGC 4993 in the Swope optical discovery image at 10.9 hr after the merger (top right) and the DLT40 pre-discovery image from 20.5 days prior to merger (bottom right). The reticle marks the position of the transient in both images.



Rotverschiebung der GRBs

