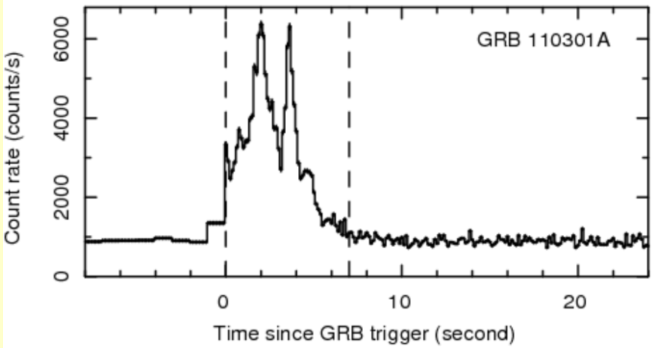
Signs of the Blandford & Znajek mechanism in GRB afterglow lightcurves

Antonios Nathanail
ITP Frankfurt, University of Athens

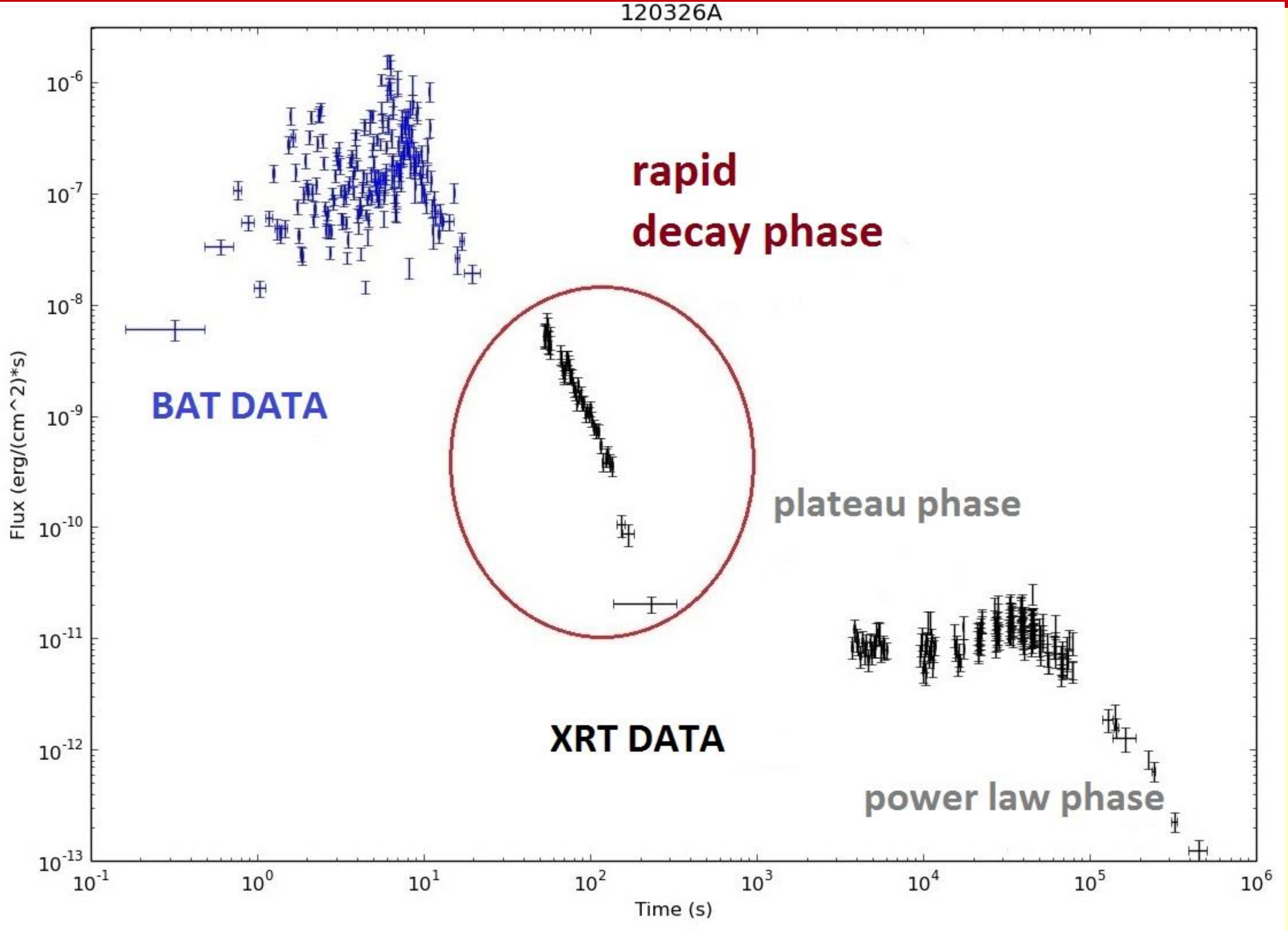
European Union
European Social Fund
OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION, LIFELONG LEARNING AND RELIGIOUS AFFAIRS
MANAGING AUTHORITY
Co- financed by Greece and the European Union
NSRF 2007-2013
EUROPEAN SOCIAL FUND

Geneva 2015



We want to argue that the rapid decay phase of the afterglow (X-rays), is nicely described as the spin down of a slowly rotating black hole (Blandford-Znajek mechanism)

ANATOMY OF A BURST



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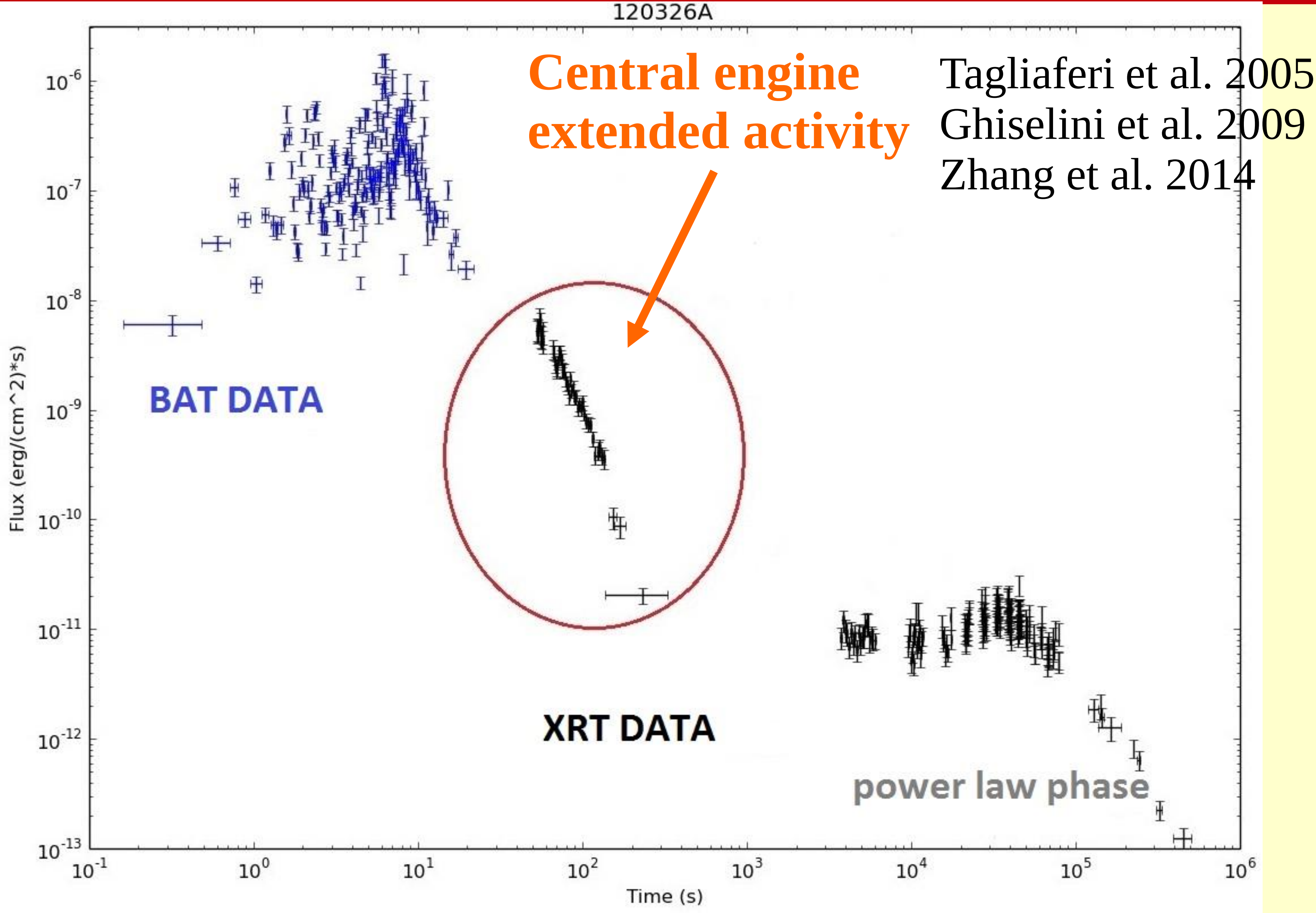

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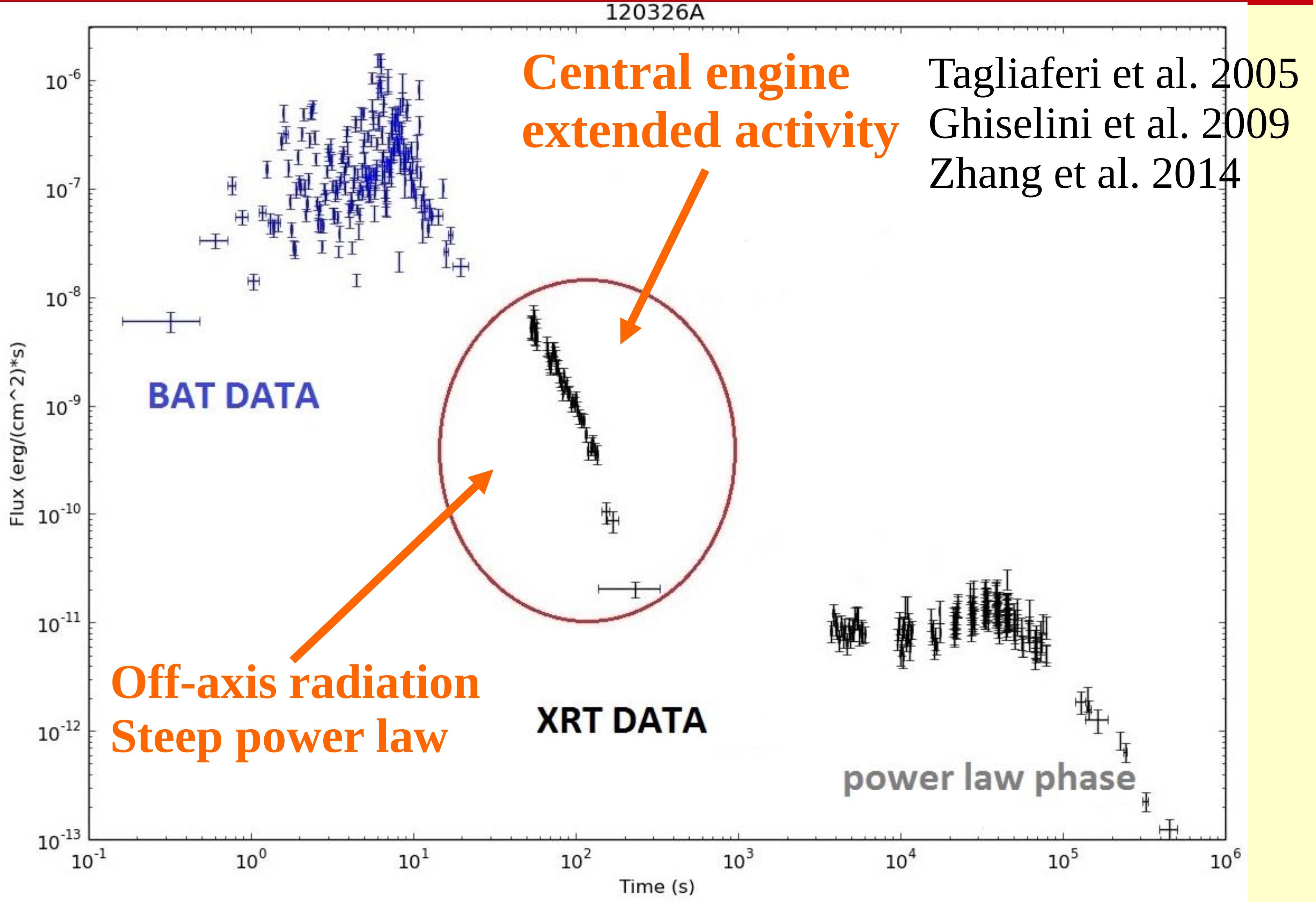
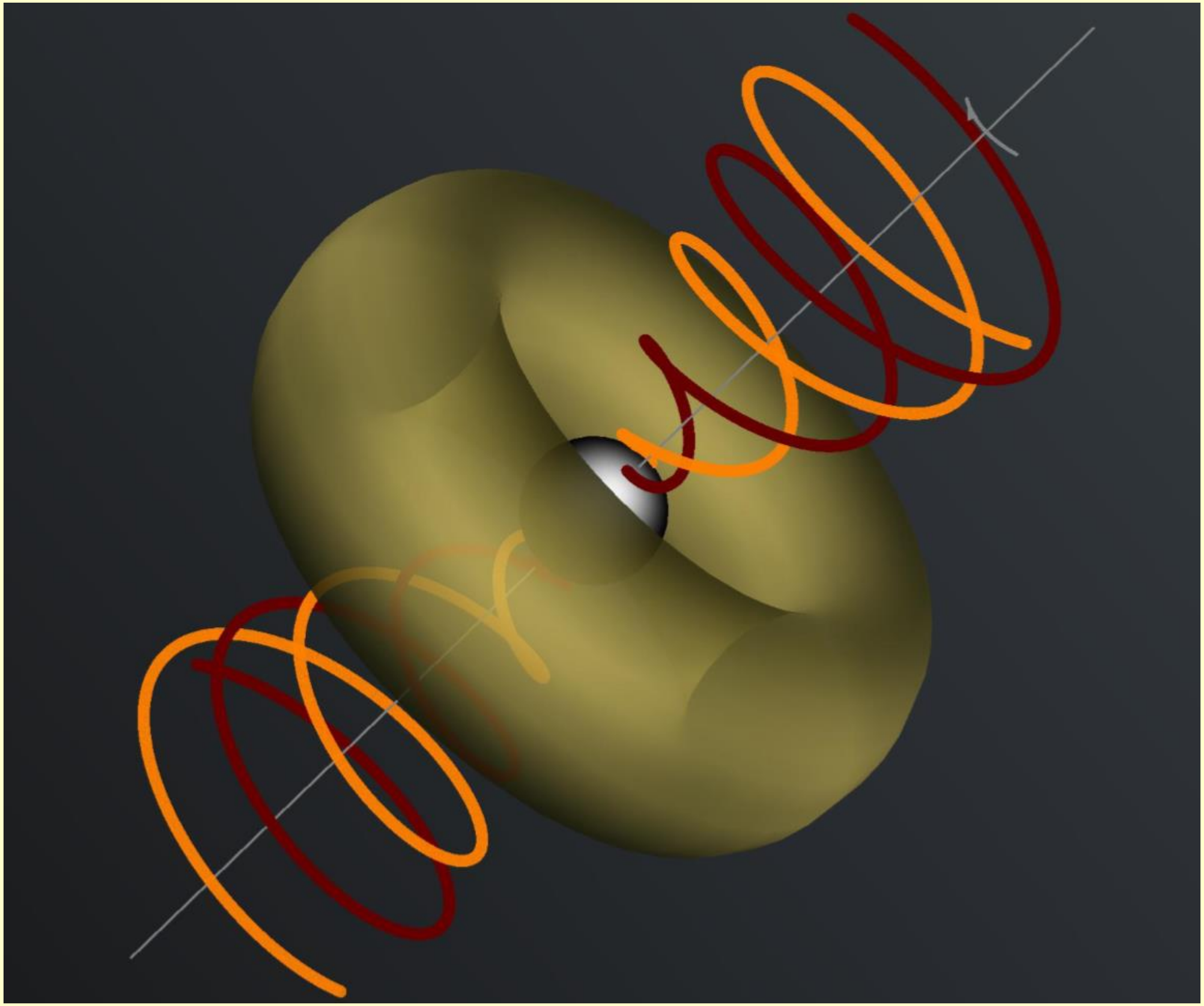


Small Break for theory



Small Break for theory

The Astrophysical Journal, 637:914–921, 2006 February 1

THE PROGENITOR STARS OF GAMMA-RAY BURSTS

S. E. Woosley[1] and A. Heger[1,2]

Received 2005 August 6; accepted 2005 October 3

Spin of BH

TABLE 2

Presupernova Models for Rapidly Rotating Stars

Mass/Model	J_{init}[a] (10^{52} ergs s^{-1})	v_{rot}[b] (km s^{-1})	Pre-SN Type[c]	$\dot{M}$ WR[d]	Magnetic Field[e]	M_{final}[f] ($M_\odot$)	Fe core[g] ($M_\odot$)	$J_{Fe\ core}$[h] (10^{47} ergs s^{-1})	Period[i] (ms)	a_{BH}[j] (3 $M_\odot$)
16OE	2.5	255	RSG		no	15.57	1.84	523	0.20	(1.8)
16OF	3.3	325	WR	1.0	no	8.97	1.35	318	0.18	(1.1)
16OG	2.5	255	RSG		yes	15.66	1.50	9.6	7.0	0.05
16OH	3.3	325	WR	1.0	yes	9.18	1.45	9.8	7.9	0.03
16OI	3.3	325	WR	0.3	yes	12.21	1.65	55.3	1.5	0.26
16OJ	4.1	400	WR	0.1	no	14.20	1.56	1290	0.06	(5.0)
16OK	4.1	400	WR	1.0	no	8.58	1.52	399	0.21	(1.4)
16OL	4.1	400	WR	1.0	yes	8.68	1.52	14.9	5.6	0.05
16OM	4.1	400	WR	0.3	yes	11.94	1.55	53.3	1.4	0.25
16ON	4.1	400	WR	0.1	yes	14.17	1.78	121	0.85	0.43

...

Why not a slowly rotating black hole

Small Break for theory

- Stellar mass black hole slowly rotating

$$E_{\mathrm{rot}} \approx \frac{1}{8} M c^2 \left(\frac{\Omega}{\Omega_{\mathrm{max}}} \right)^2$$

Ω angular velocity

- Strong magnetic fields expected

Loosing Energy as …….

Small Break for theory

- Stellar mass black hole slowly rotating $(\alpha = 0.1)$

$E_{\mathrm{rot}} > 10^{52}$ erg

$$E_{\mathrm{rot}} \approx \frac{1}{8} M c^2 \left(\frac{\Omega}{\Omega_{\mathrm{max}}} \right)^2$$

Ω angular velocity

- Strong magnetic fields expected

Loosing Energy as …….

Small Break for theory

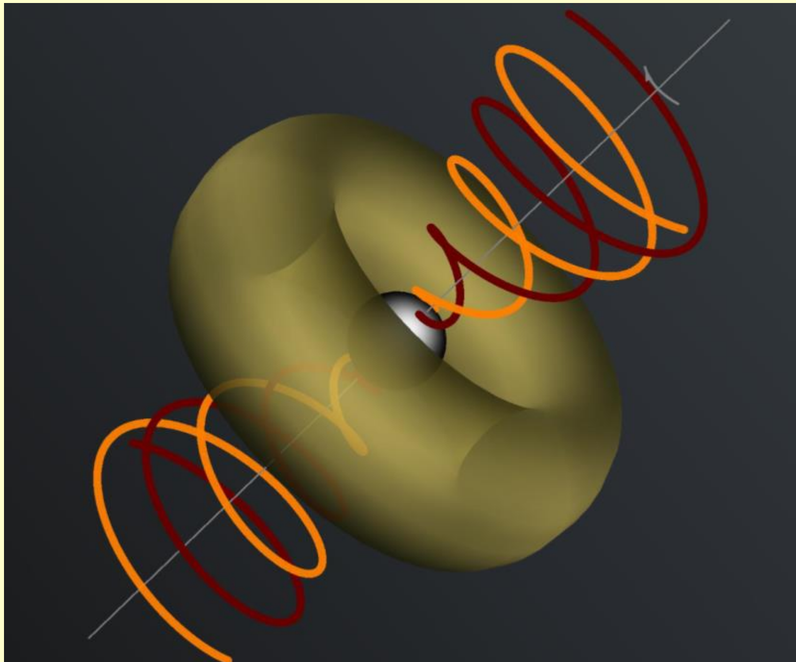
Loosing Energy as …….

$$\dot{E} \approx -\frac{1}{6\pi^2 c}\Psi_m^2\Omega^2$$

Blanford & Znajek 1977

………..

Ψ_m magnetic flux



Small Break for theory

Loosing Energy as …

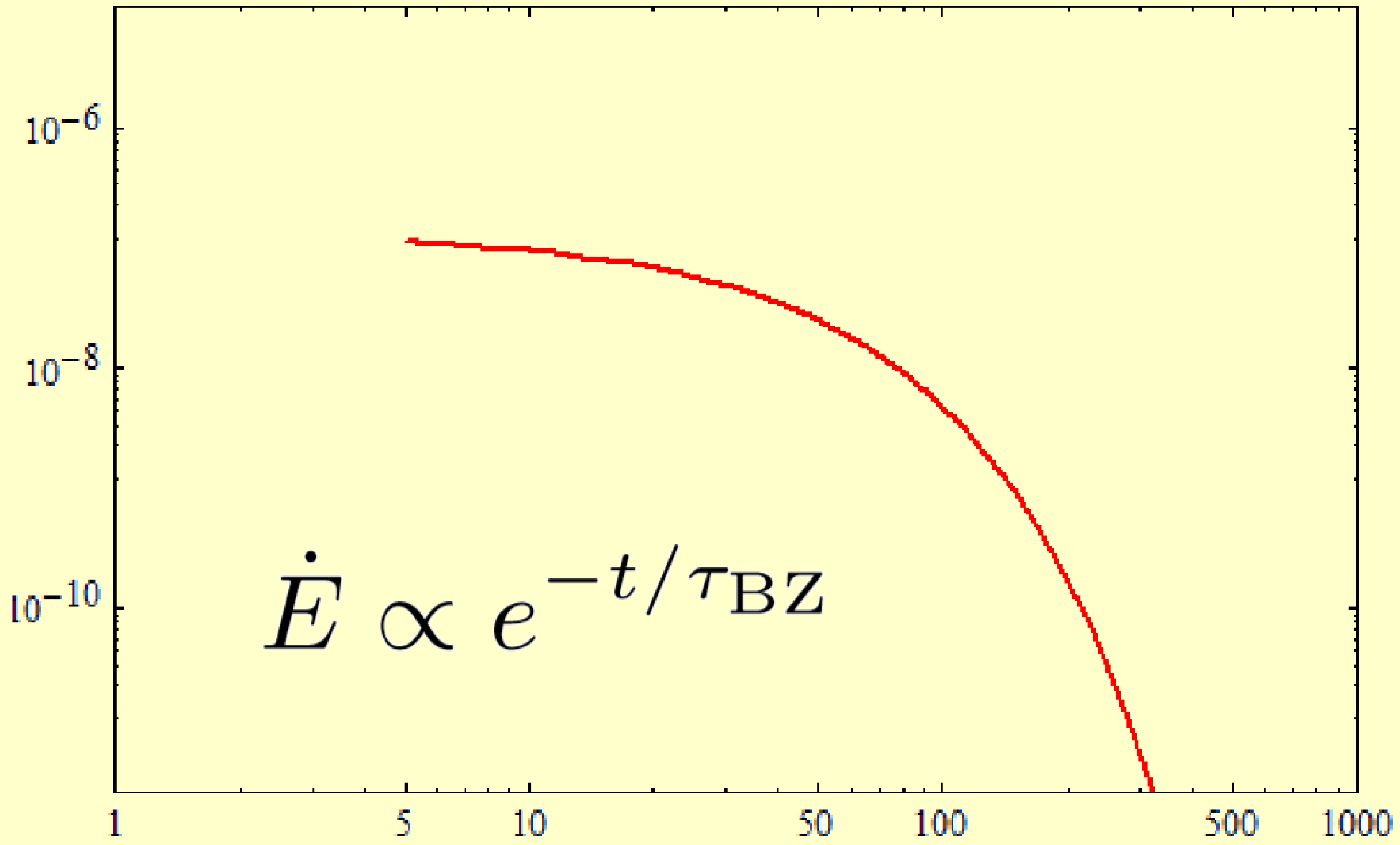
$$\dot{E} \propto e^{-t/\tau_{\rm BZ}}$$

$$\tau_{\rm BZ} \equiv 50 \left(\frac{B}{10^{15}\ {\rm G}} \right)^{-2} \left(\frac{M}{10 M_\odot} \right)^{-1} {\rm sec}$$

Nathanail & Contopoulos 2015

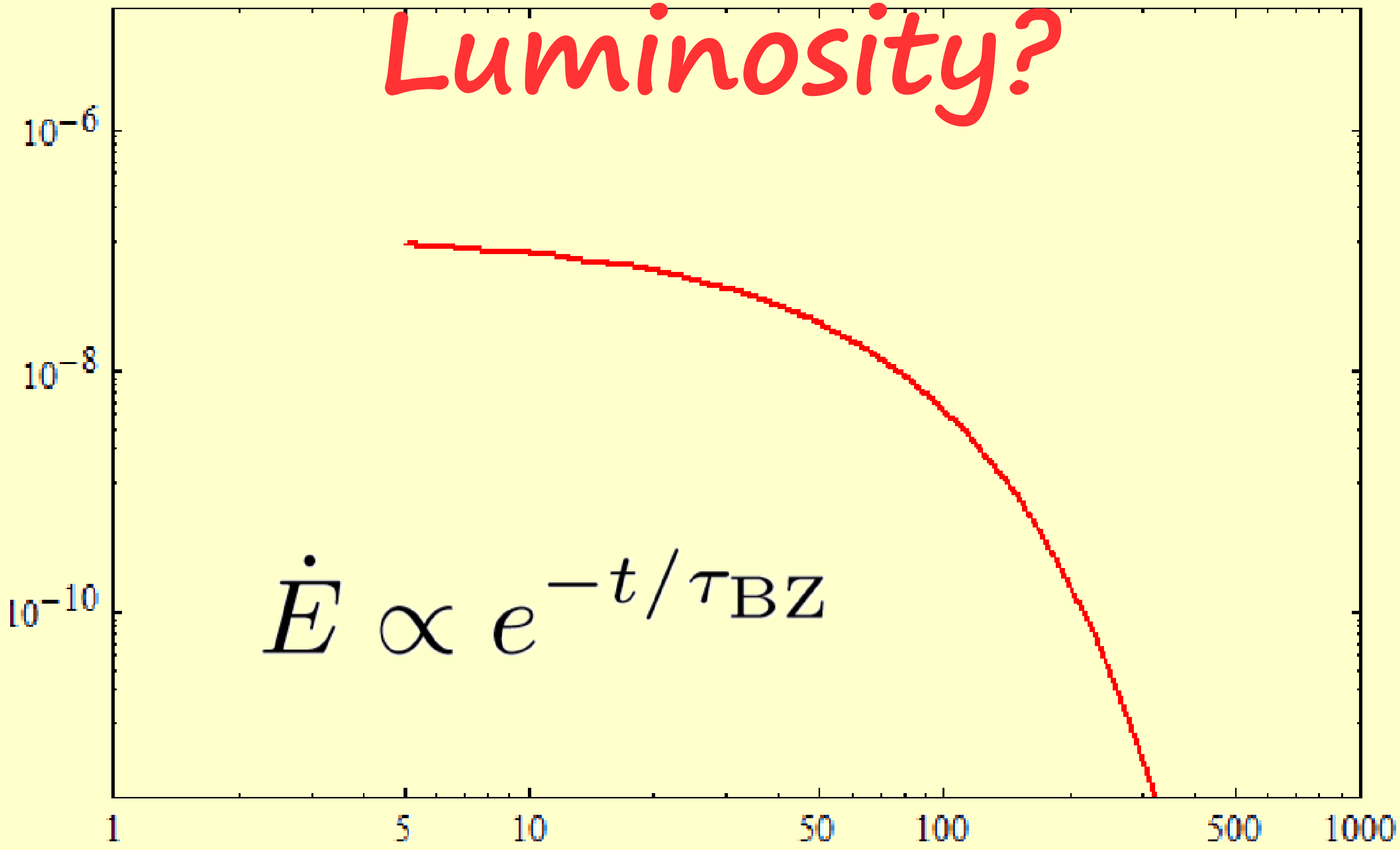
Nathanail, Strantzalis & Contopoulos 2015

Small Break for theory



$$\tau_{\rm BZ} \equiv 50 \left(\frac{B}{10^{15}\ {\rm G}} \right)^{-2} \left(\frac{M}{10 M_\odot} \right)^{-1} {\rm sec}$$

Can This Be observed Luminosity?



$$\dot{E} \propto e^{-t/\tau_{\rm BZ}}$$

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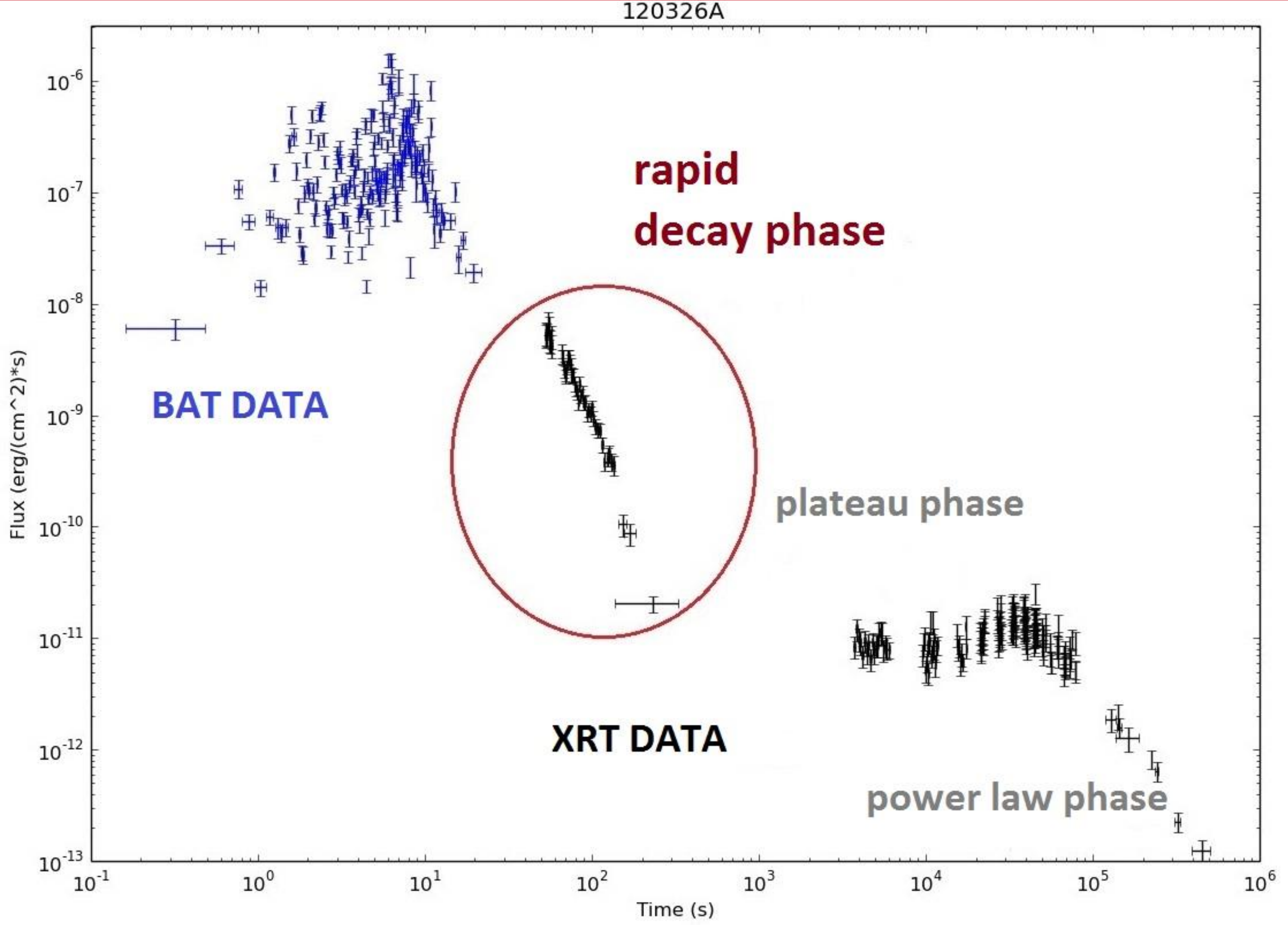
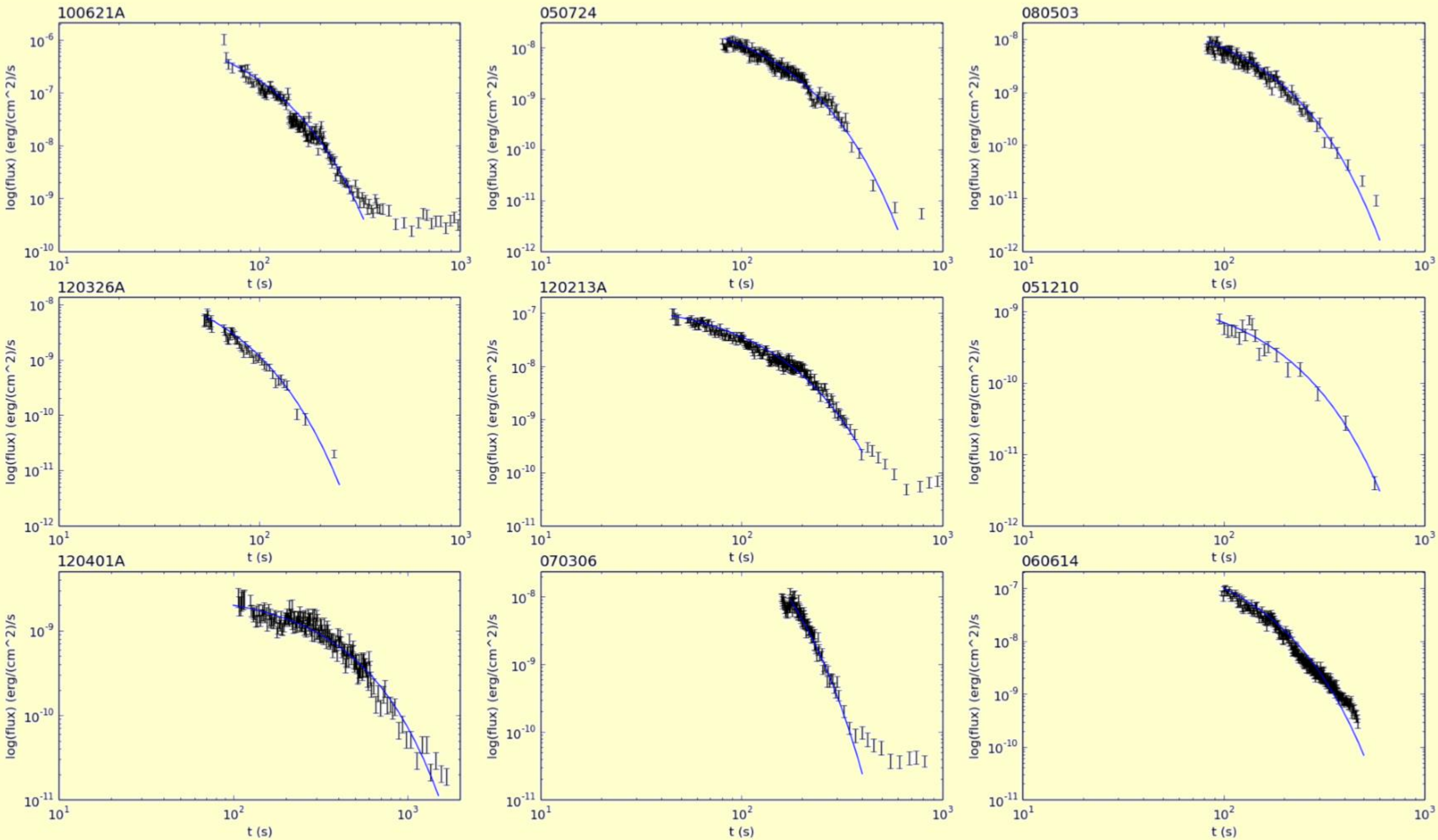
ANATOMY OF A BURST



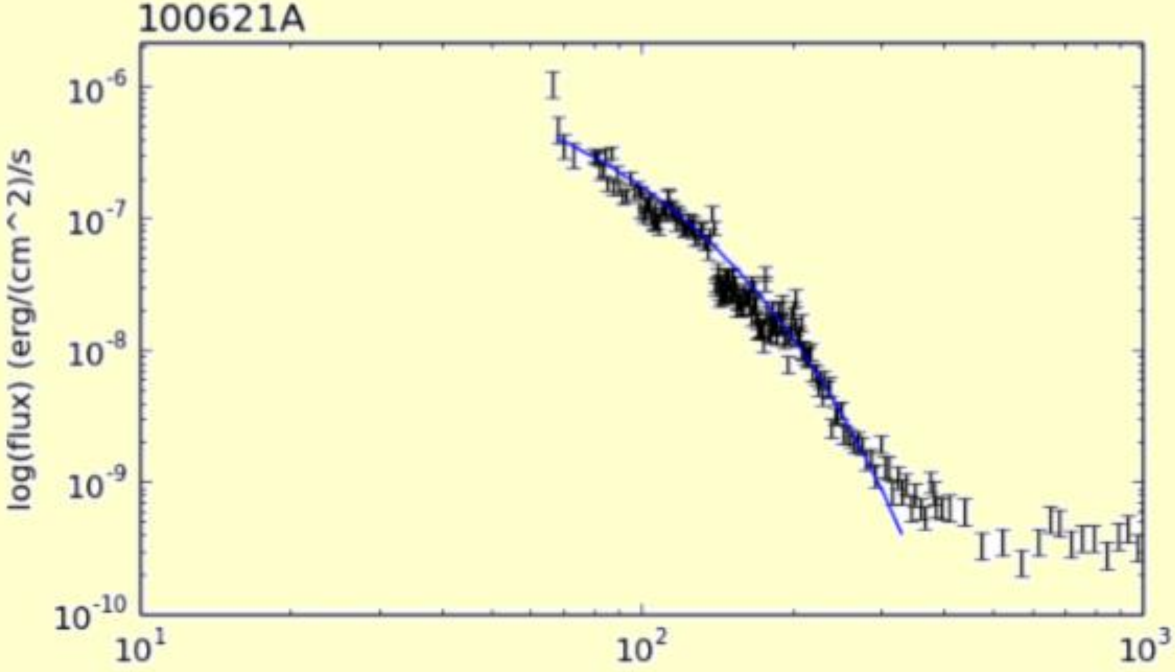
Zoom in the rapid decay phase



Nathanail, Strantzalis & Contopoulos 2015

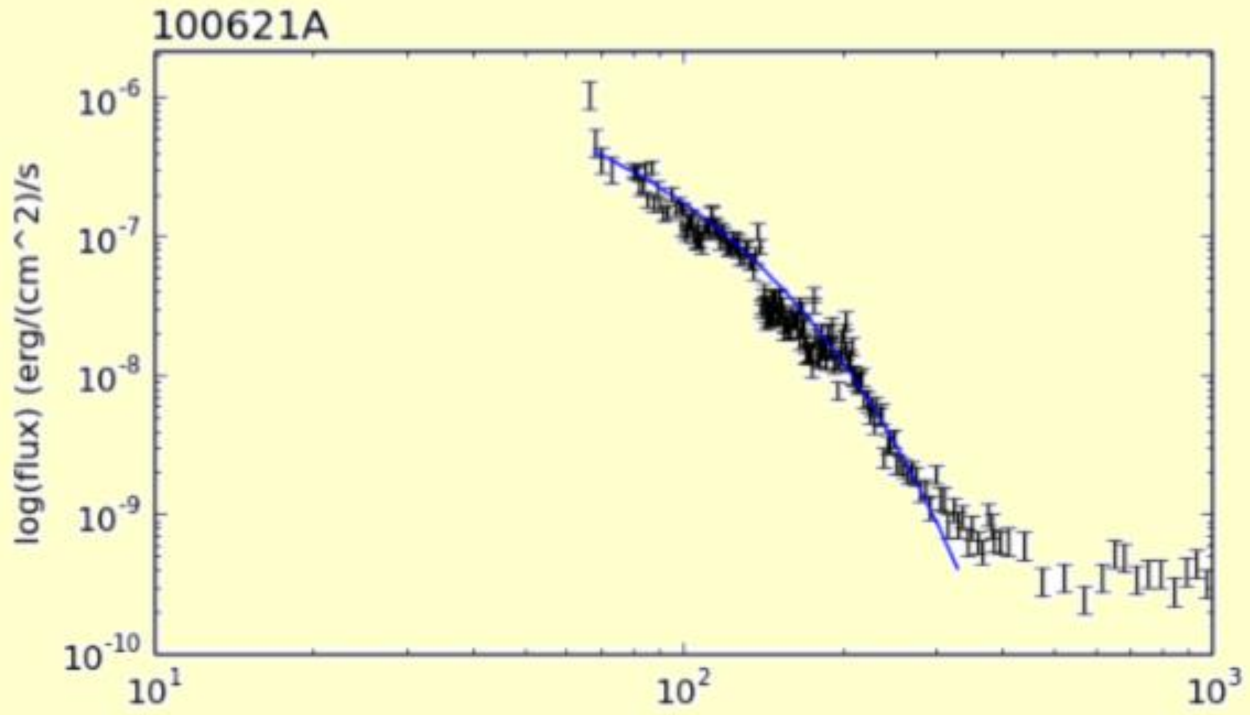
From 343 Long GRBs

30% had this sign



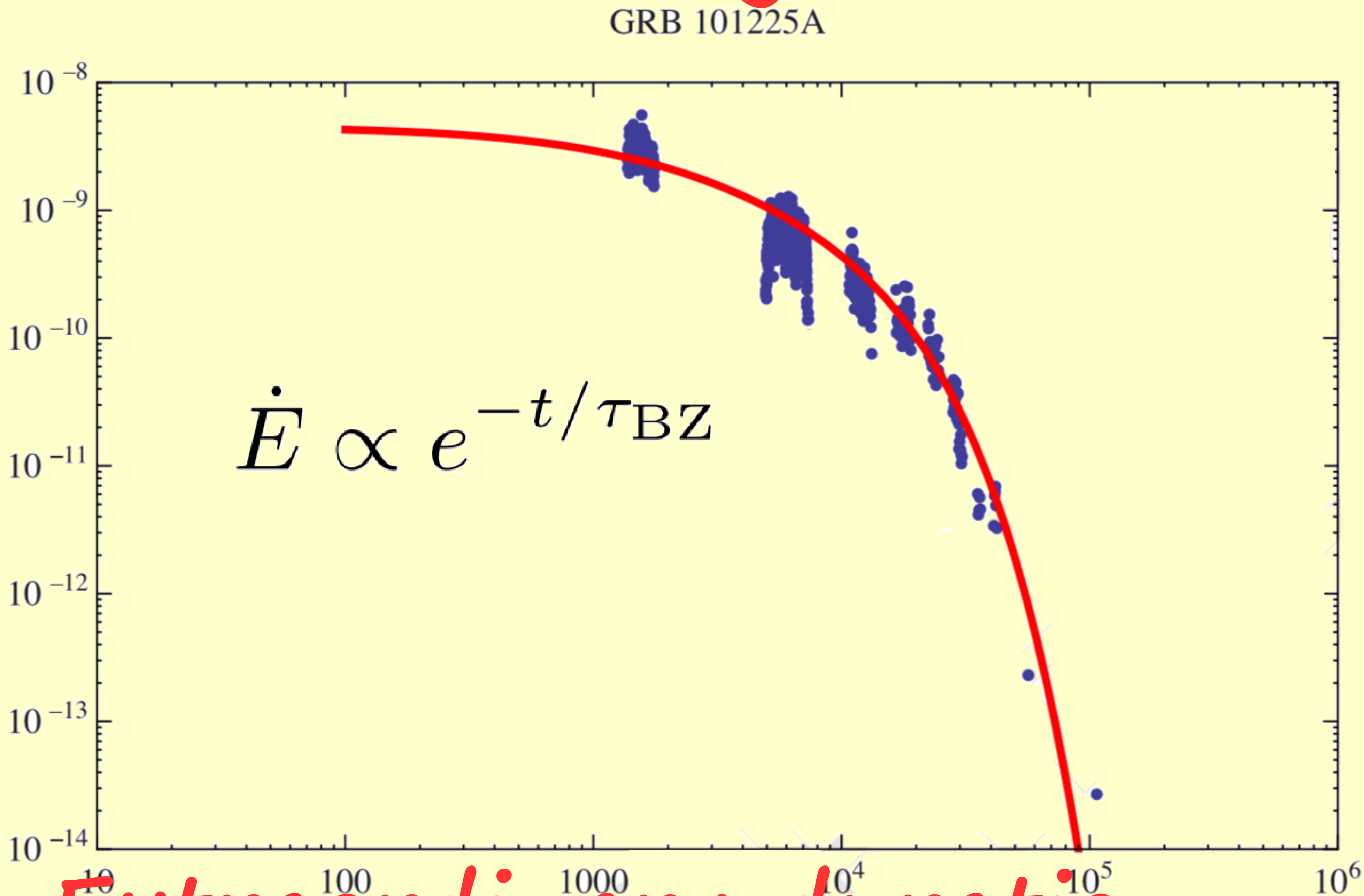
Nathanail, Strantzalis & Contopoulos 2015

Duration of a GRB depends on the magnetic field strength



Nathanail, Strantzalis & Contopoulos 2015

Easy to explain Ultra Long GRBs



Extraordinary duration ...

Nathanail & Contopoulos 2015

From the timescale we can estimate the magnetic field strength at the black hole

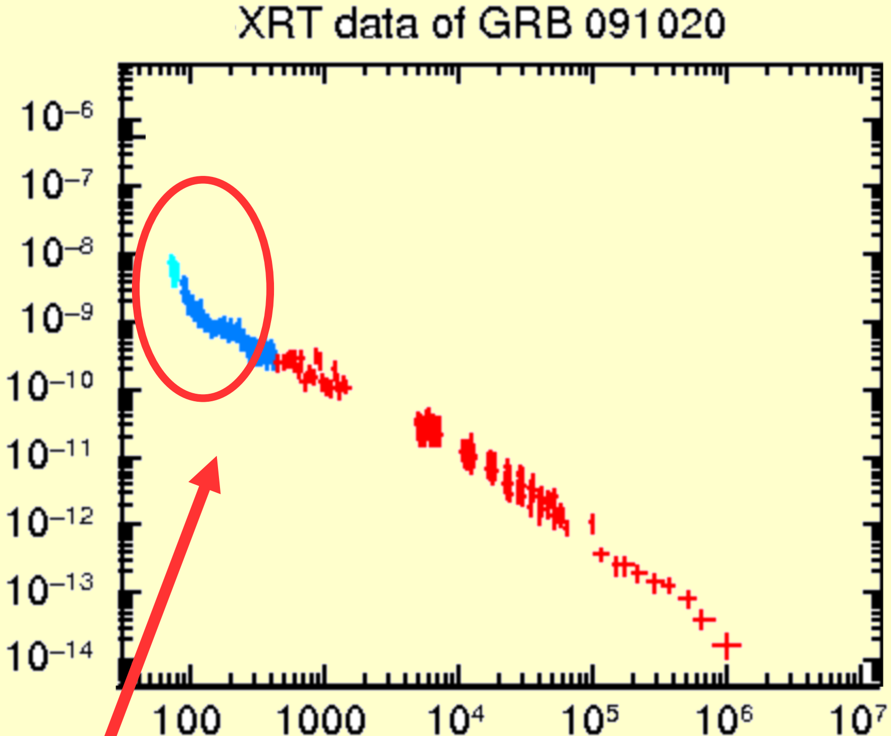
$$\dot{E} \propto e^{-t/\tau_{\rm BZ}}$$

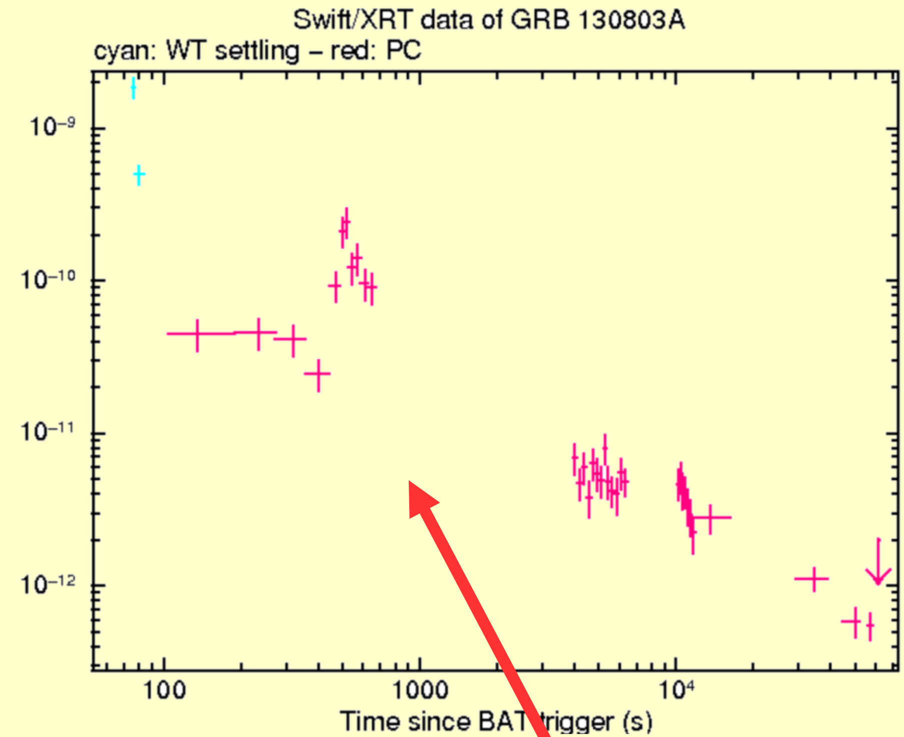
$$\tau_{\rm BZ} \equiv 50 \left(\frac{B}{10^{15}\ {\rm G}} \right)^{-2} \left(\frac{M}{10 M_\odot} \right)^{-1} {\rm sec}$$

Nathanail & Contopoulos 2015

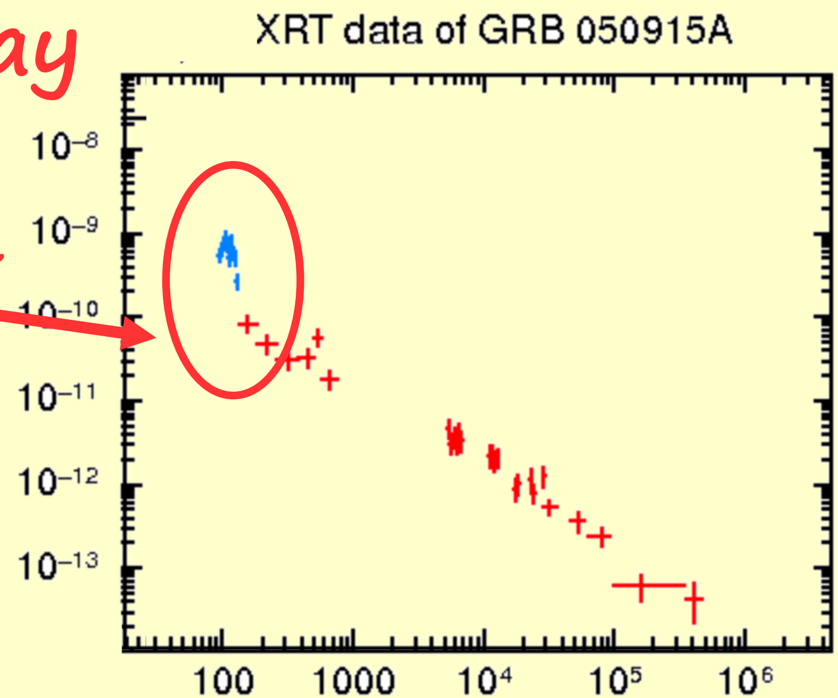
Nathanail, Strantzalis & Contopoulos 2015

The Rest 70%



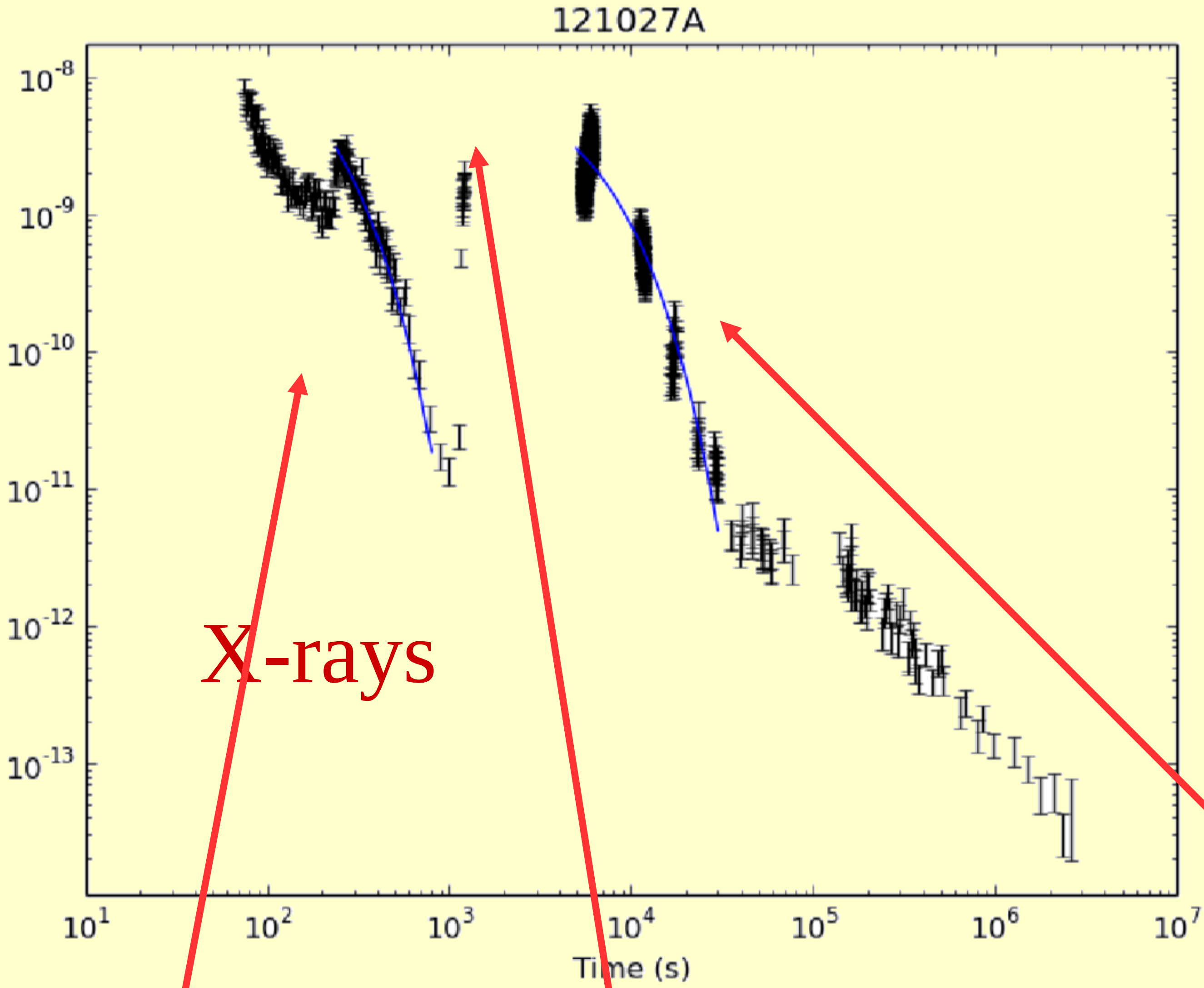


The rapid decay phase is not entirely seen



sparse data

Mass infall-Flaring Activity



Proga & Zhang 2006

magnetic barrier

spin down (spin up)

mass infall

again spin down

in preparation . . .

Summary

30% of Long GRBs show signs
of
Black Hole Spin Down

Duration of a GRB depends on
the magnetic field strength