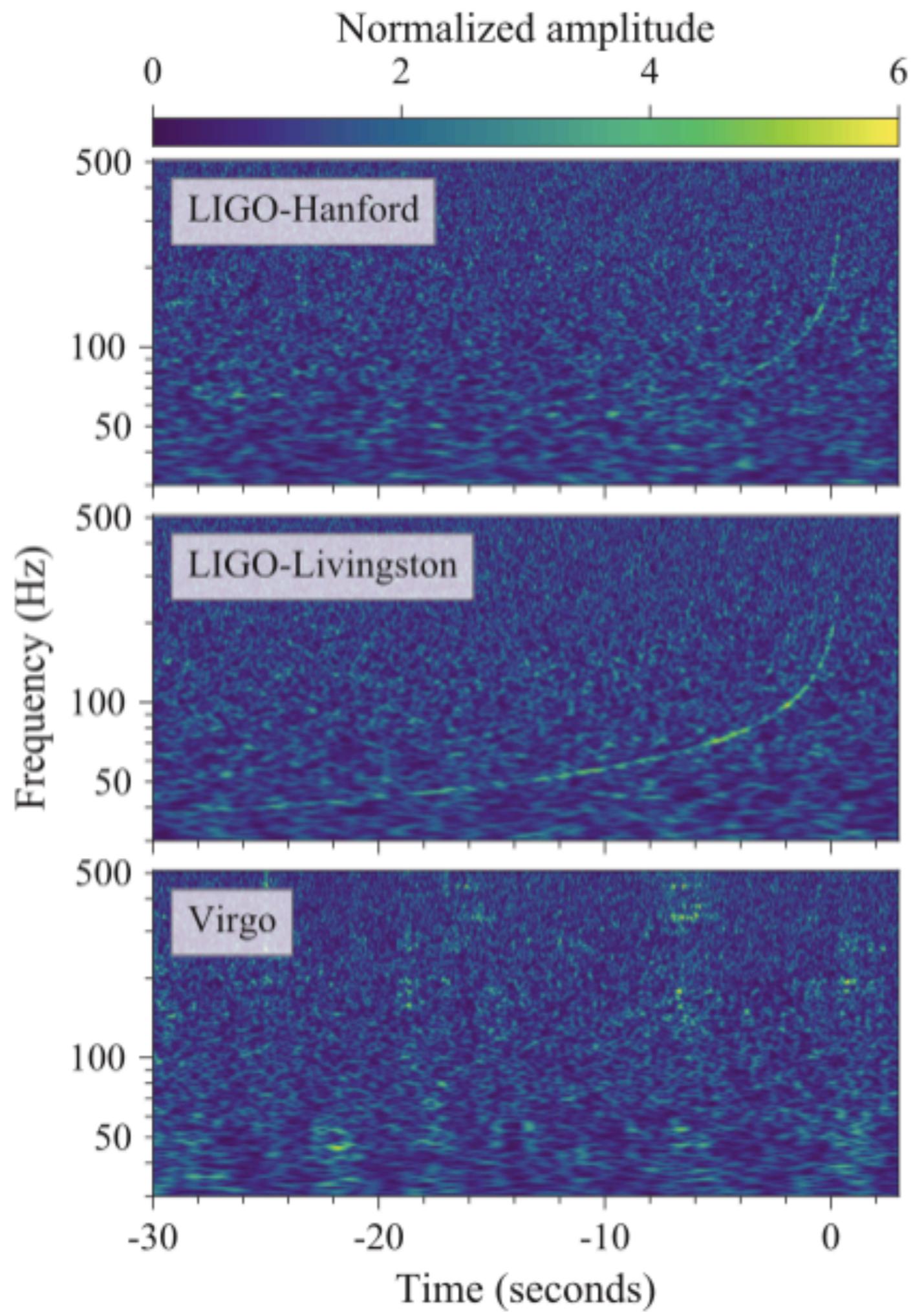


GW170817/SHB170817A

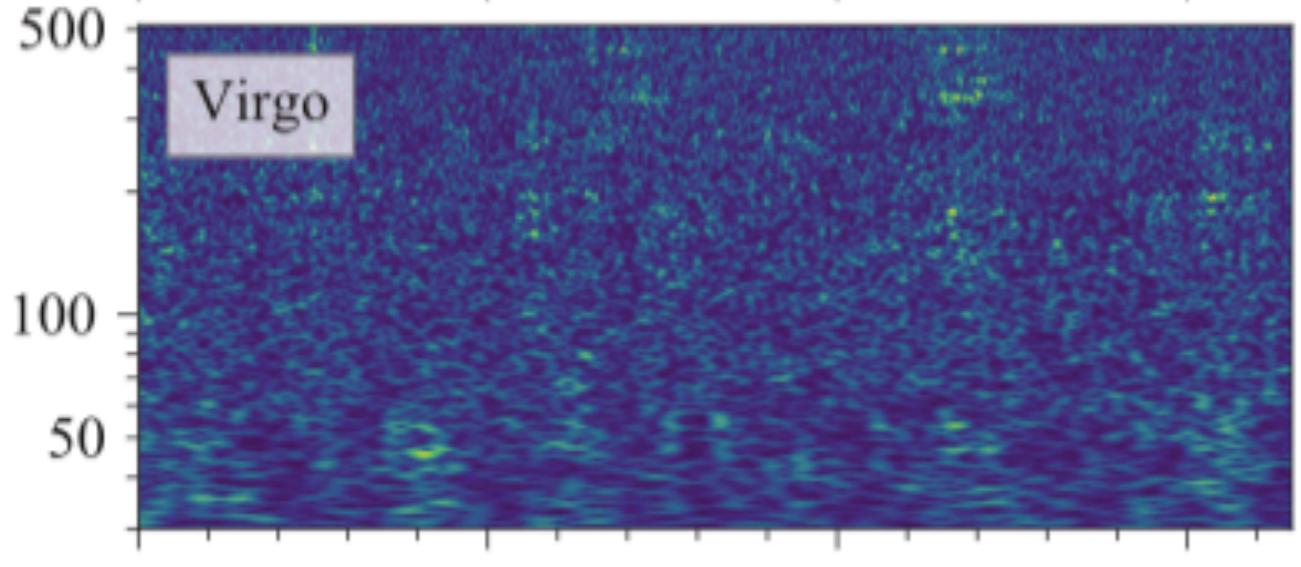
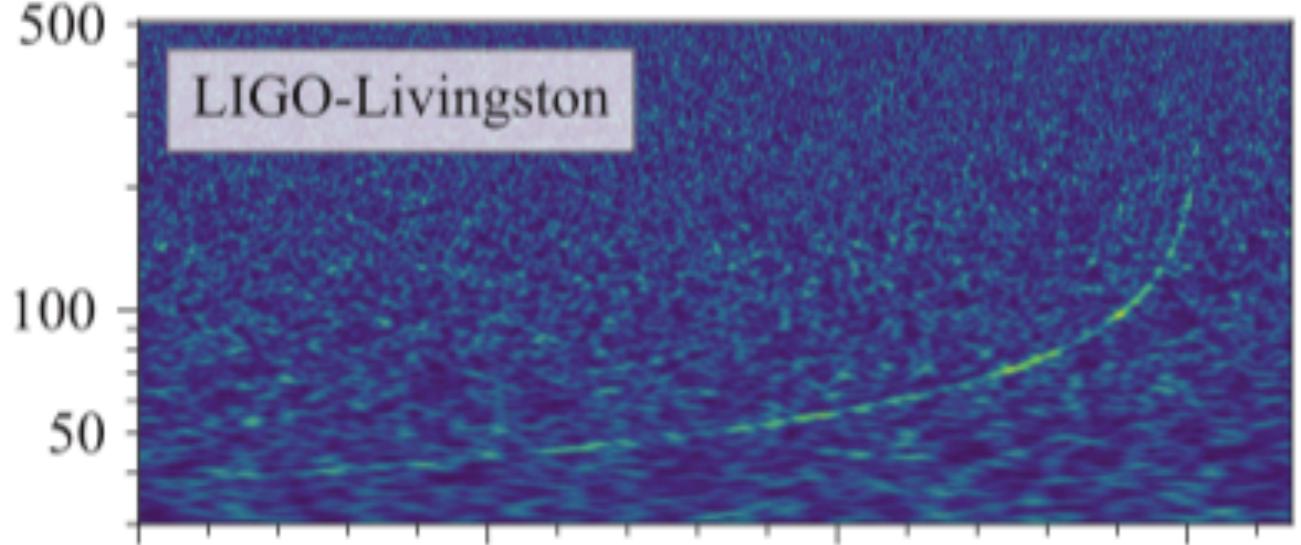
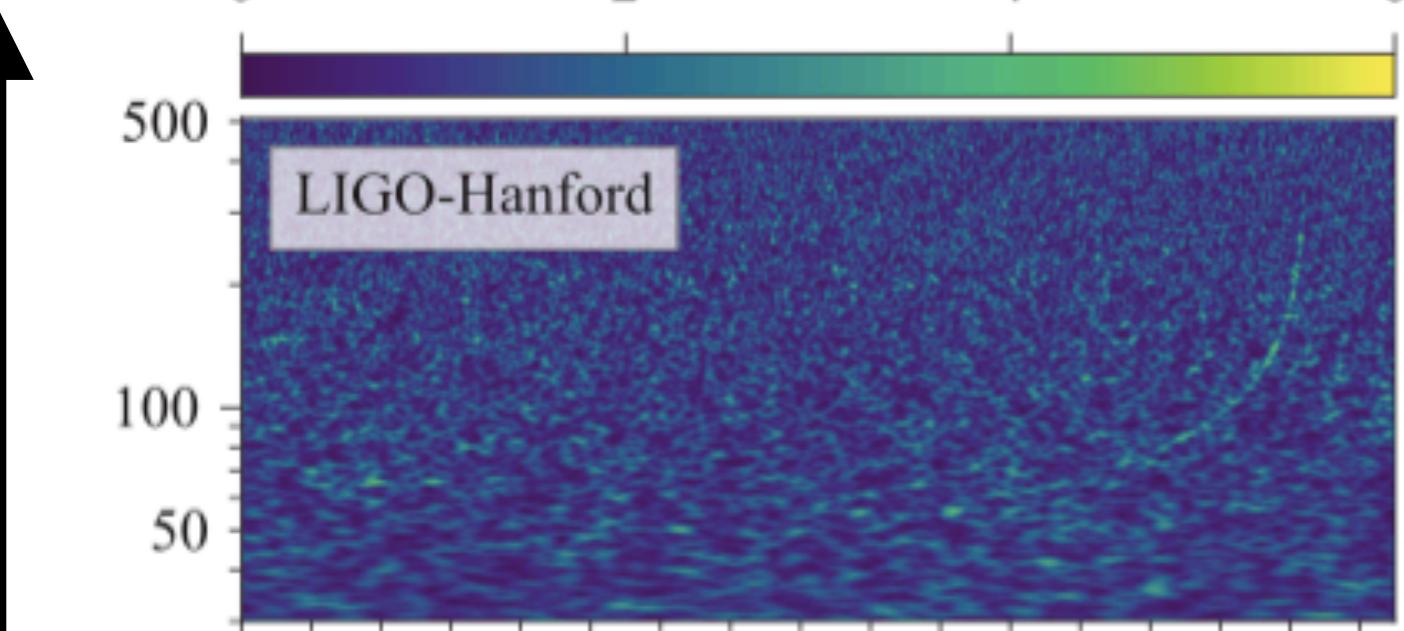
A binary neutron-star merger

The dawn of an era;

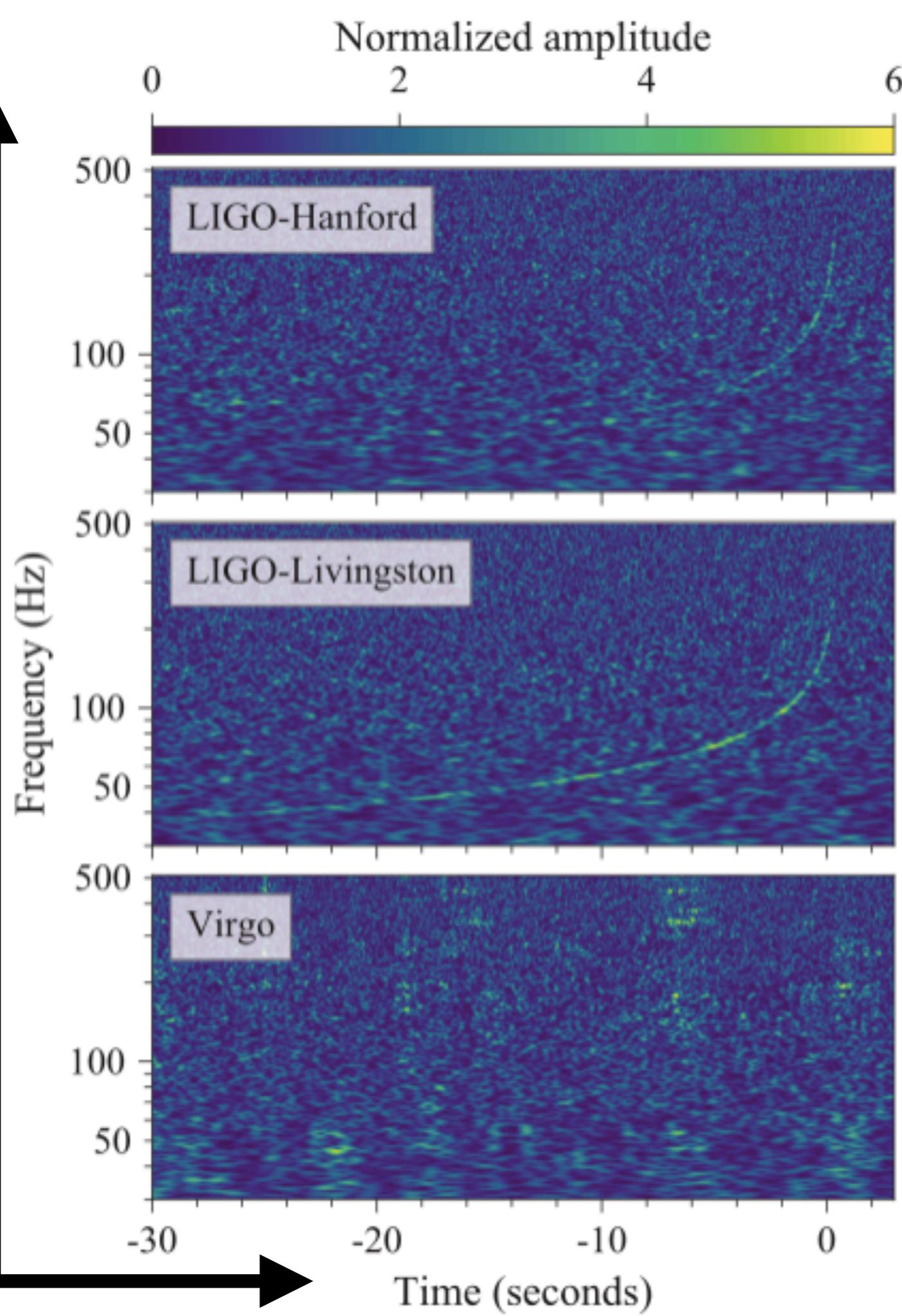
*Or the sunset
of another one?*



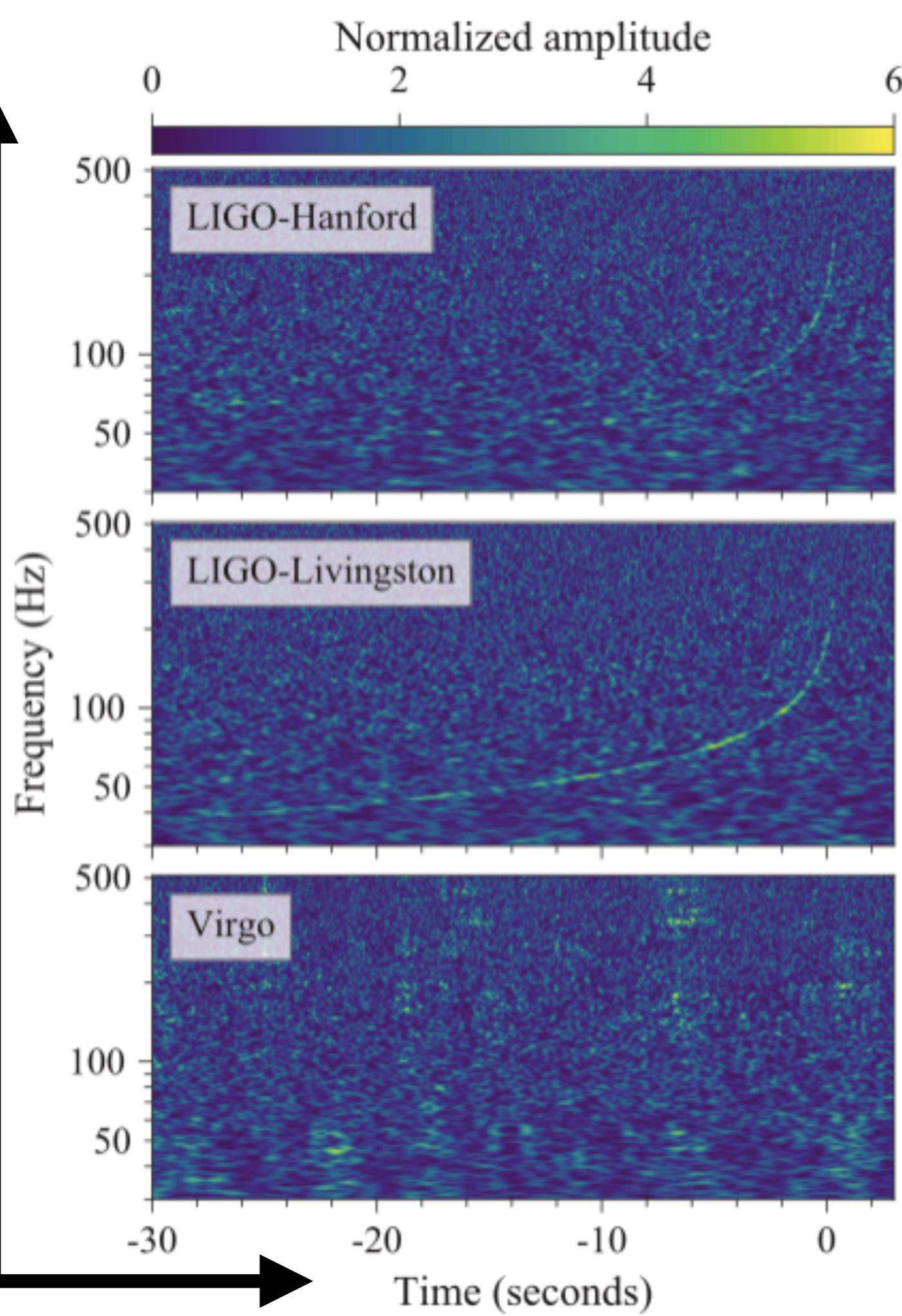
Normalized amplitude



Time (seconds)

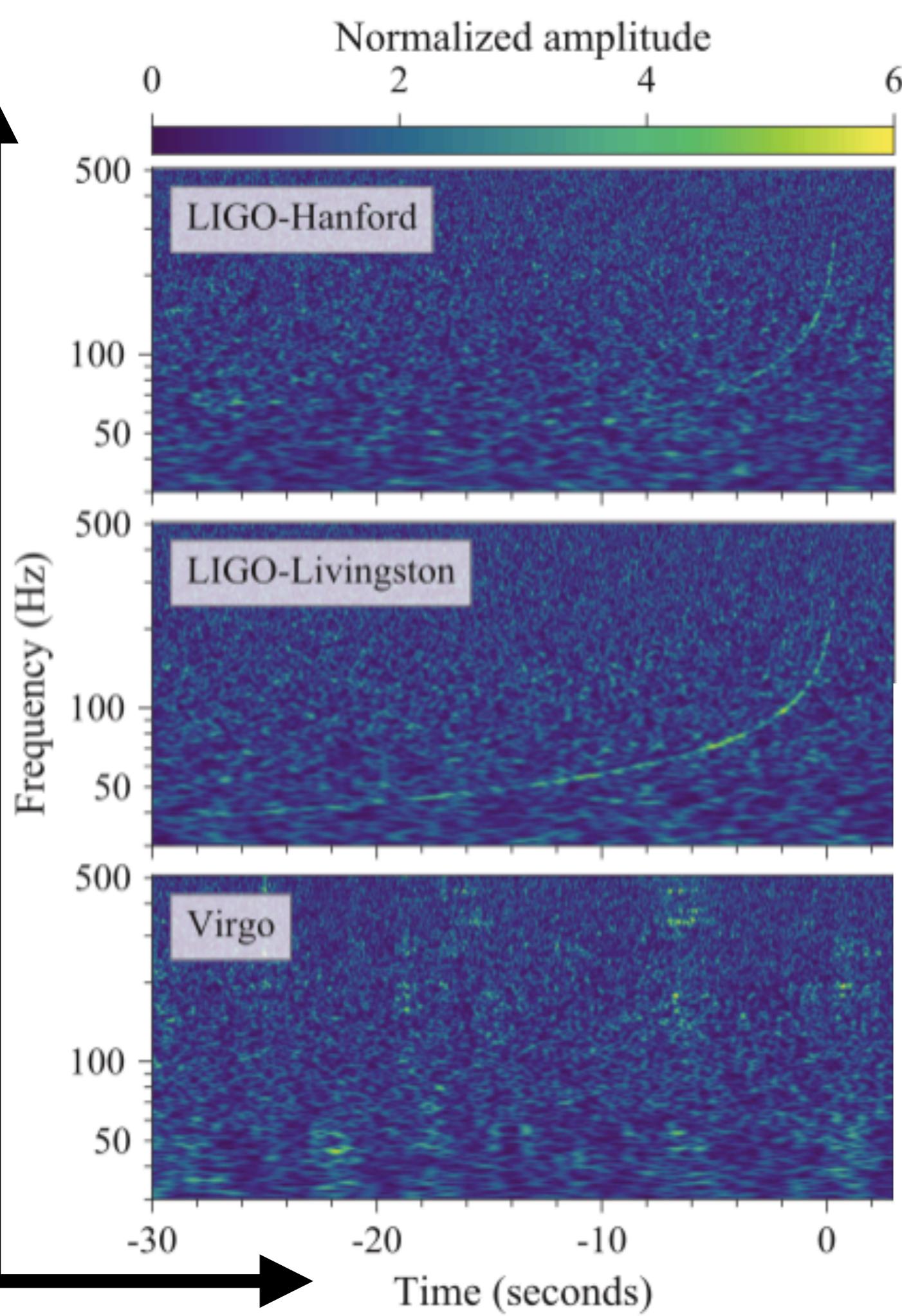


Total mass **2.73 to 3.29 M_⊙**.
Individual mass **0.86 to 2.26 M_⊙**



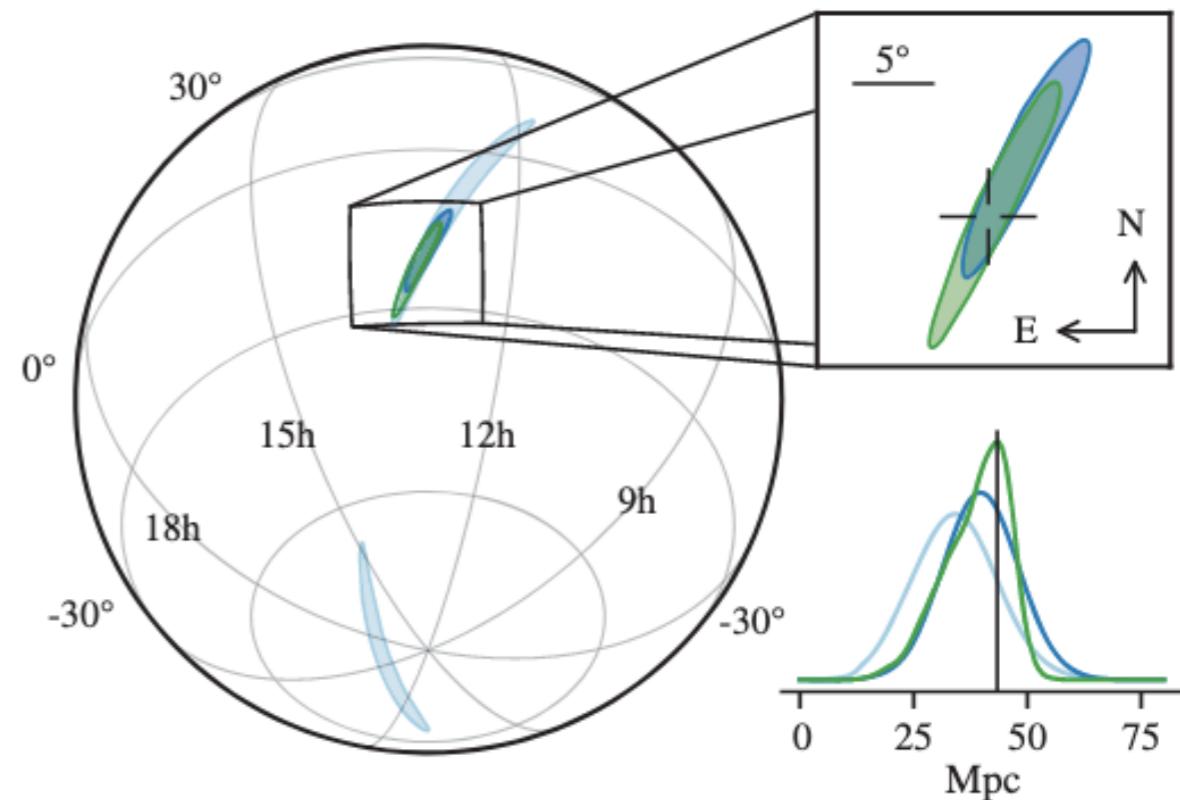
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NS/BH system is not ruled out, but inconsistency with masses of known BHs in binary systems → NS/NS



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[9] L. Blanchet, Thibault Damour, Bala R. Iyer, Clifford M. Will, and Alan G. Wiseman, Phys. Rev. Lett. 74, 3515 (1995).

[10] A. Buonanno and T. Damour, Phys. Rev. D 59, 084006 (1999). **BH**

[11] T. Damour, P. Jaranowski, and G. Schäfer, Phys. Lett. B 513, 147 (2001). **+**

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+ Numerical General Relativity

**Observation of
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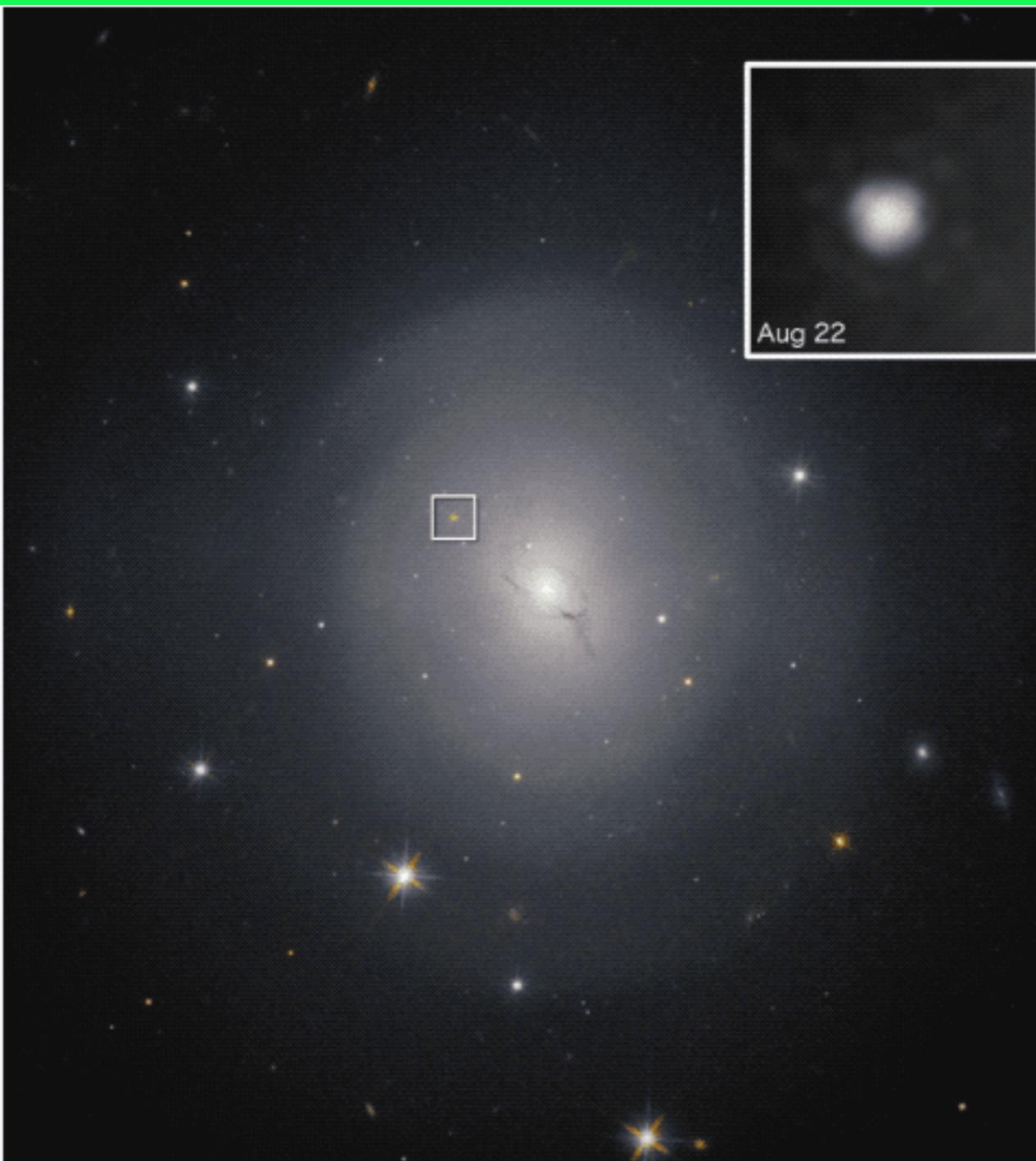
An optical transient, the
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Lenticular Galaxy NG 4993

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NGC 4993 and GRB 170817A afterglow as
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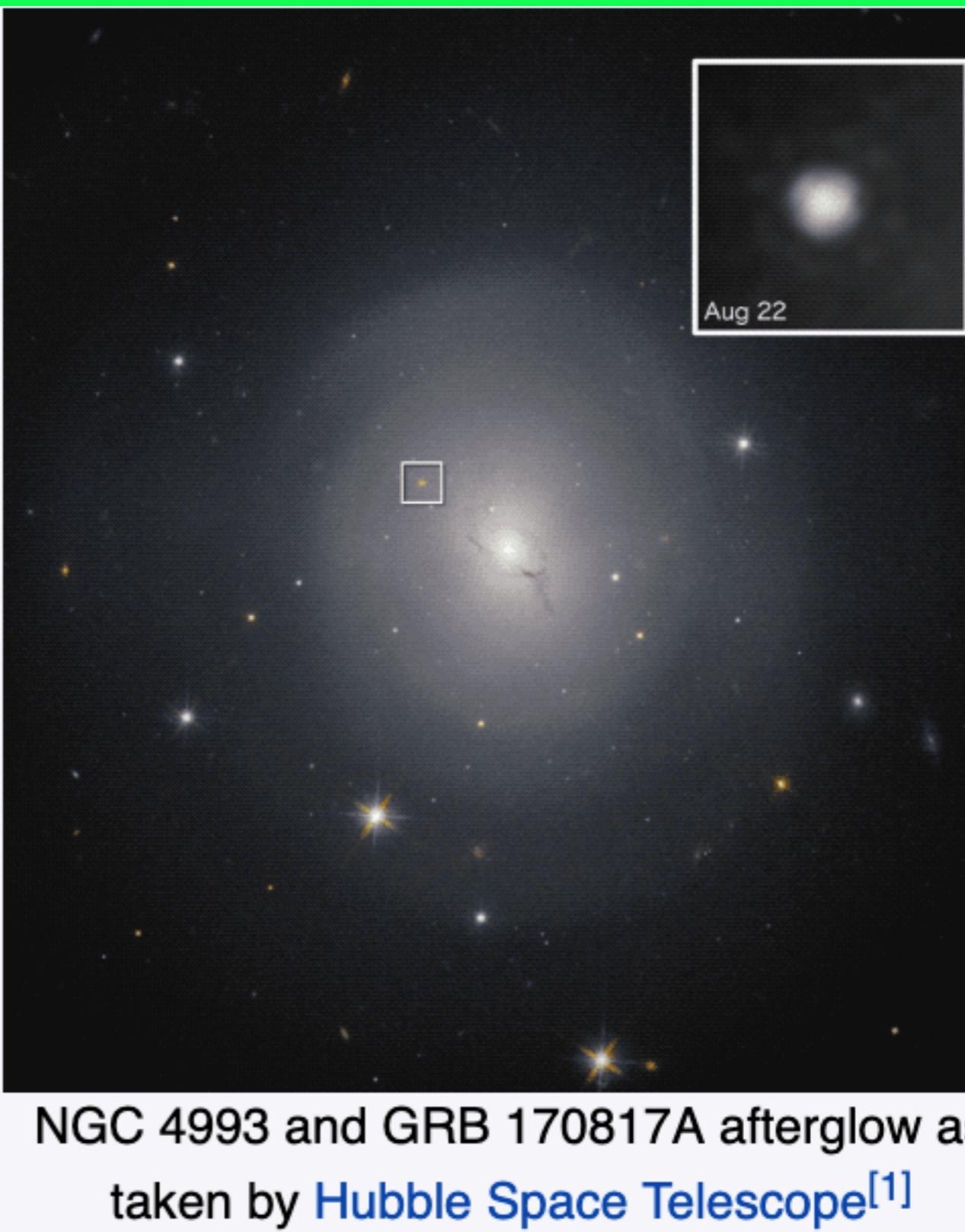
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140 million light-years away

$z = 0.009783$



NGC 4993 and GRB 170817A afterglow as
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arXiv:1710.05858

Spectroscopic identification of r-process
nucleosynthesis in a double neutron star
merger E. Pian & 88 others

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Spectroscopic identification of r-process nucleosynthesis in a double neutron star merger E. Pian & 88 others

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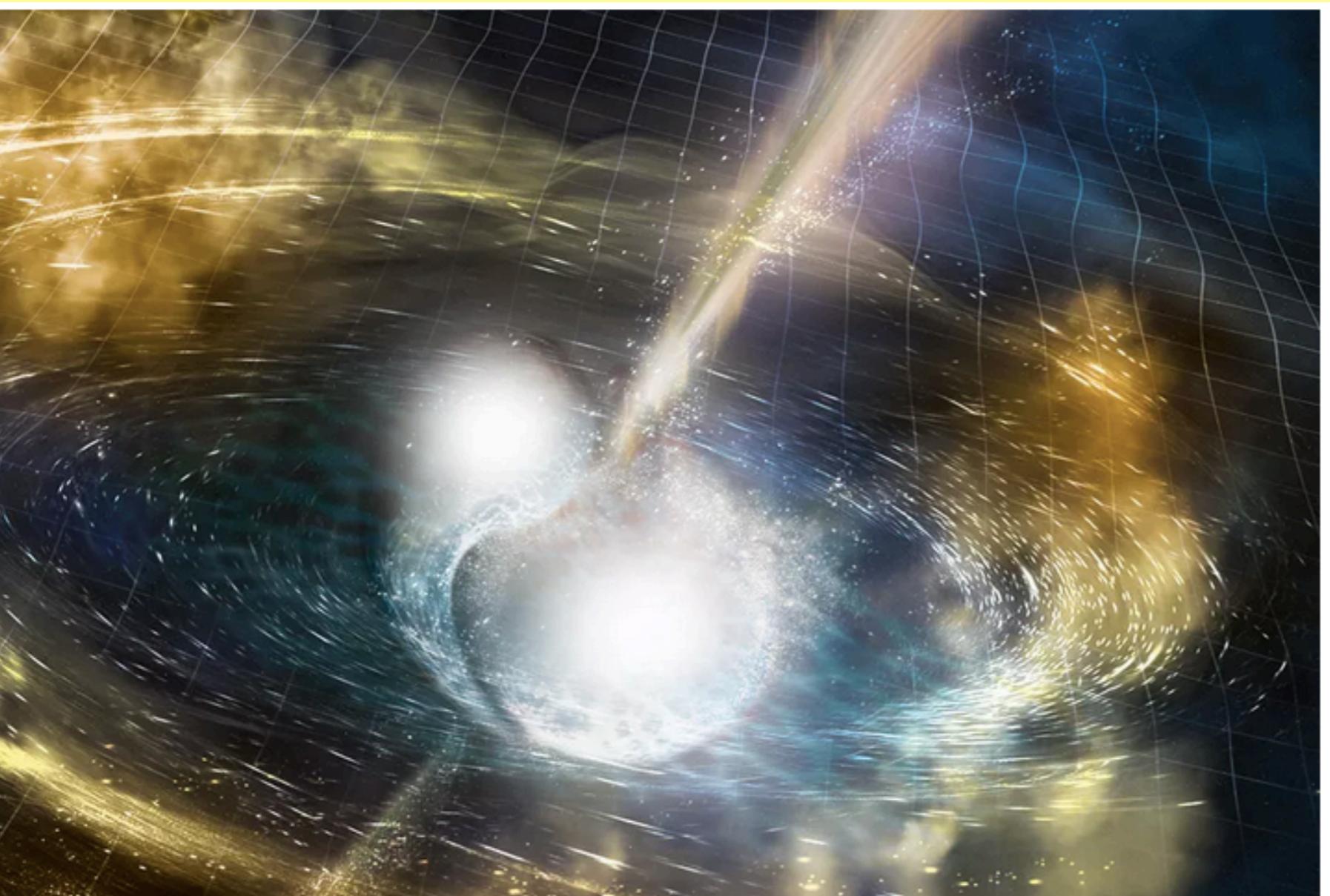
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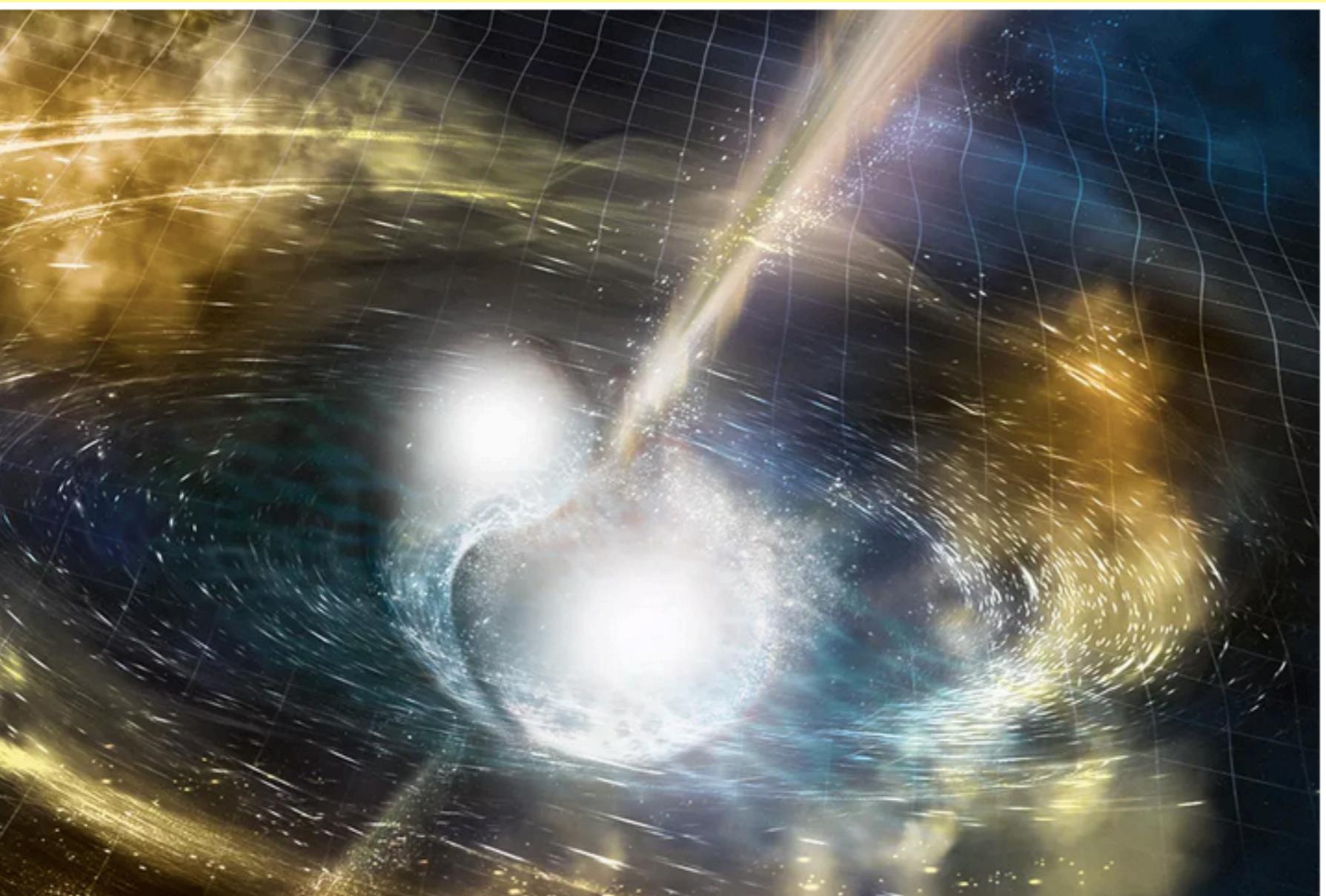
Huge amounts of gold, platinum, uranium and other heavy elements were created in the collision of these compact stellar remnants, and were pumped out into the universe – unlocking the mystery of how gold on wedding rings and jewellery is originally formed.



An illustration of two merging neutron stars. This stellar collision created heavy elements such as platinum, uranium and gold. (Image credit: National Science Foundation/LIGO/Sonoma State University/A. Simonnet)

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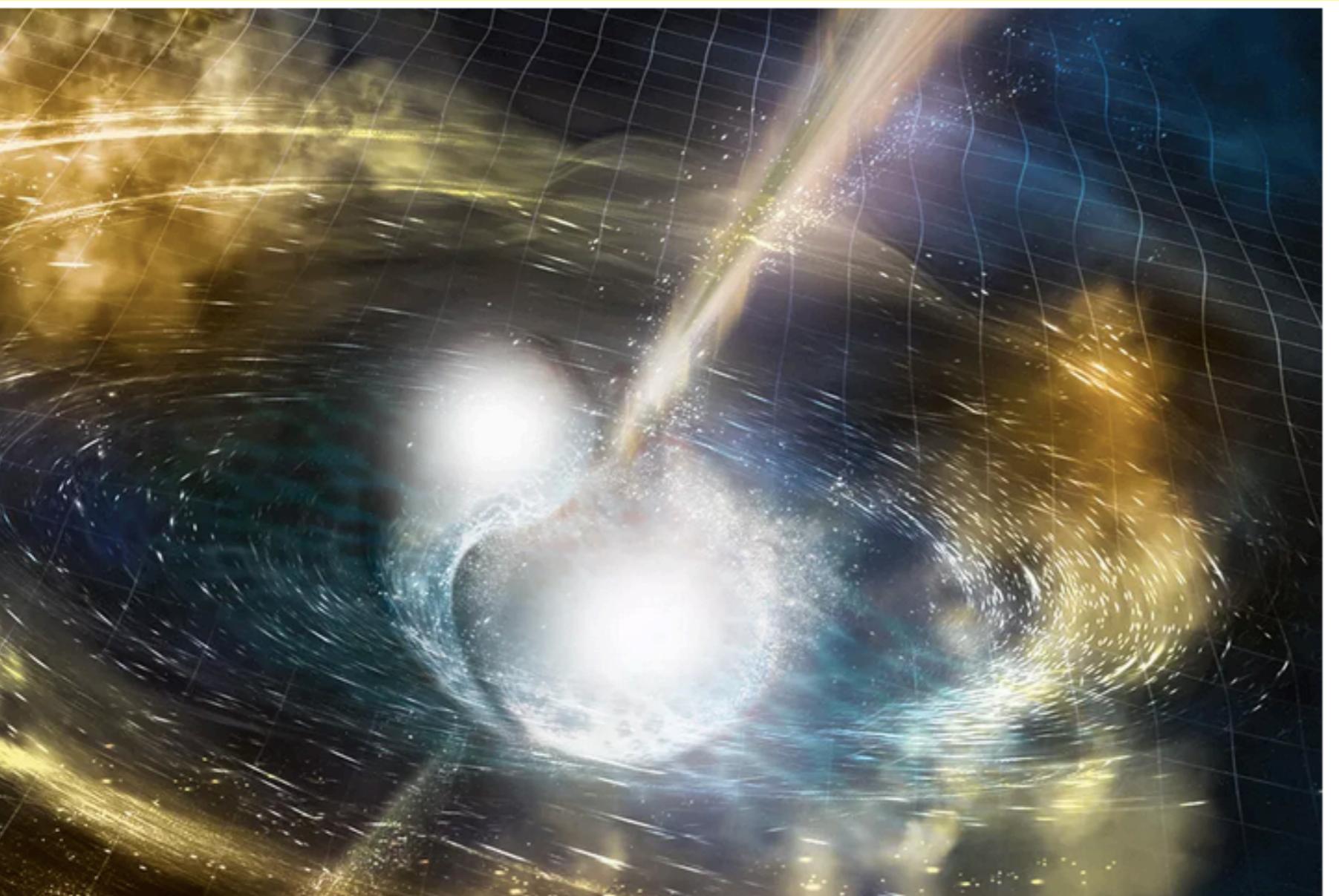
"There's about 10 times the Earth's mass in gold and platinum alone," he said.



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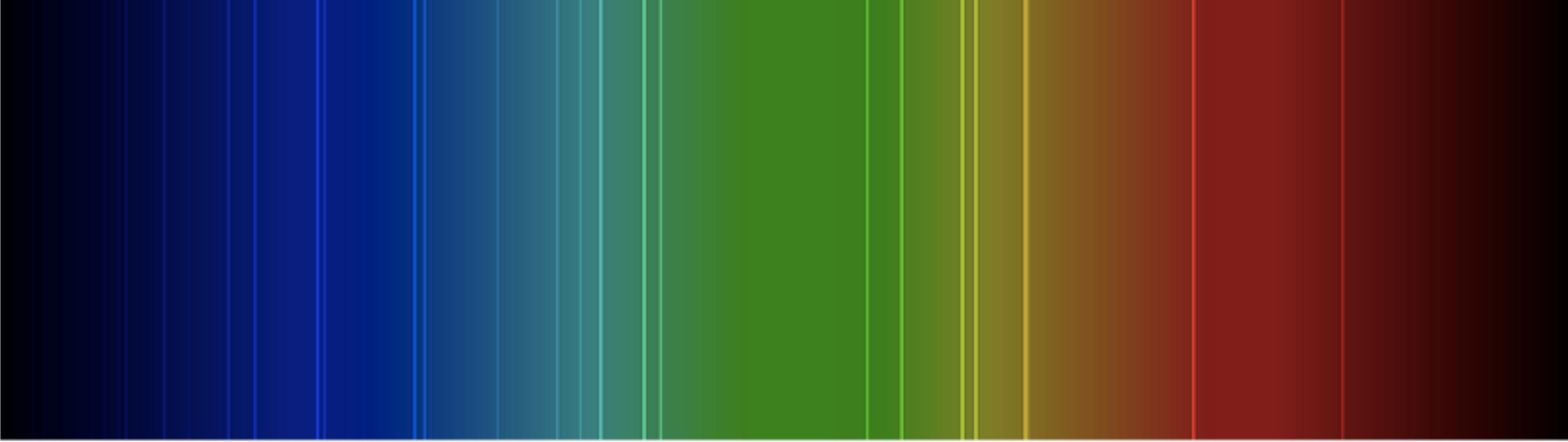
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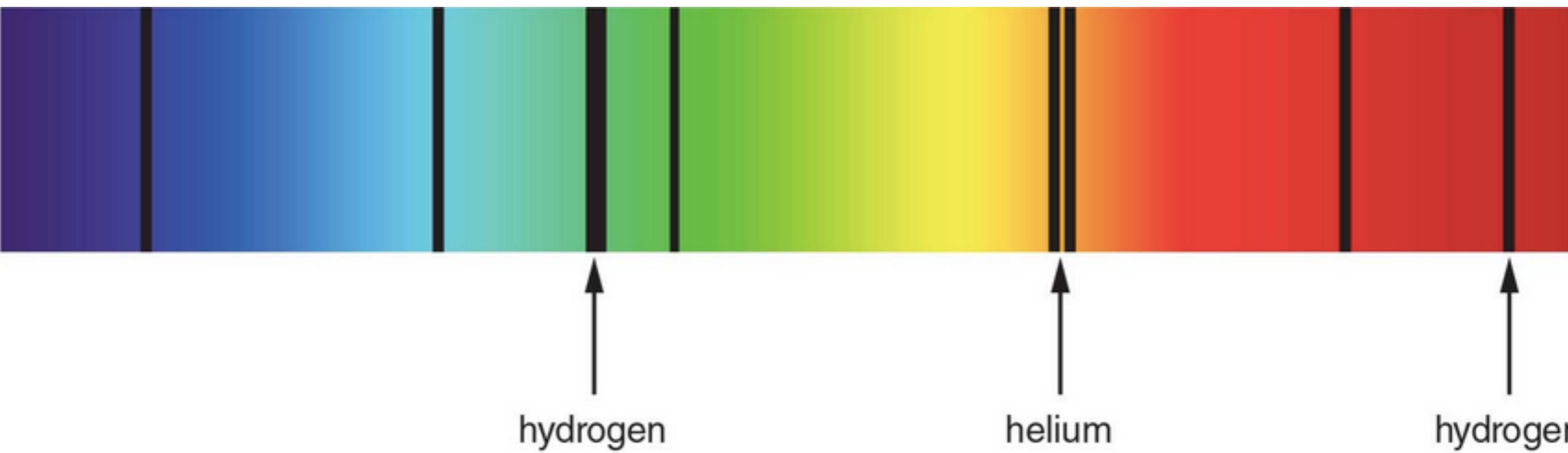
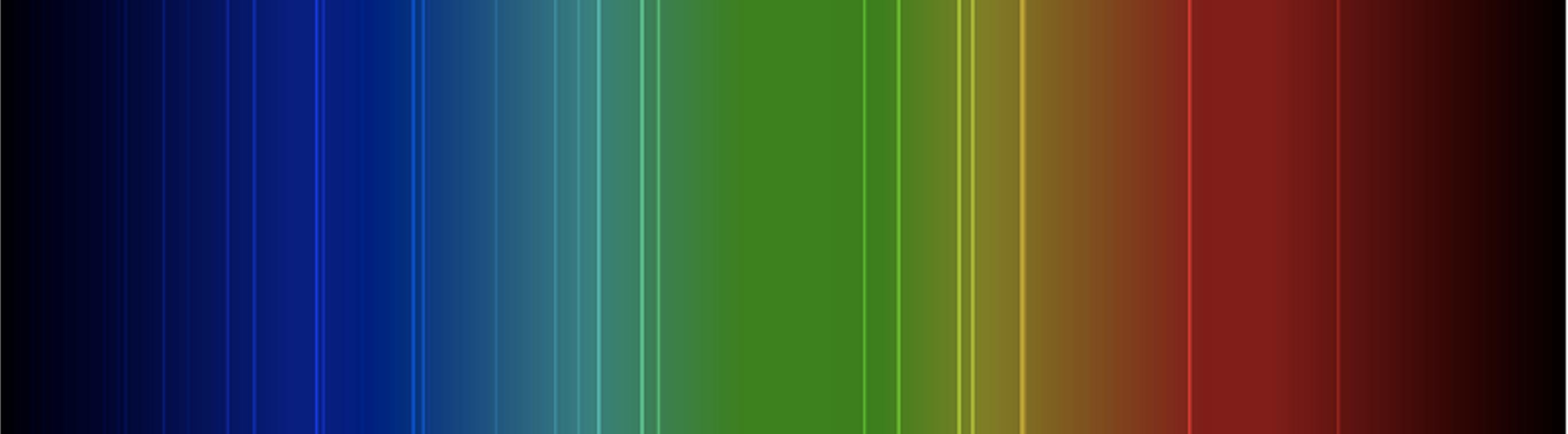


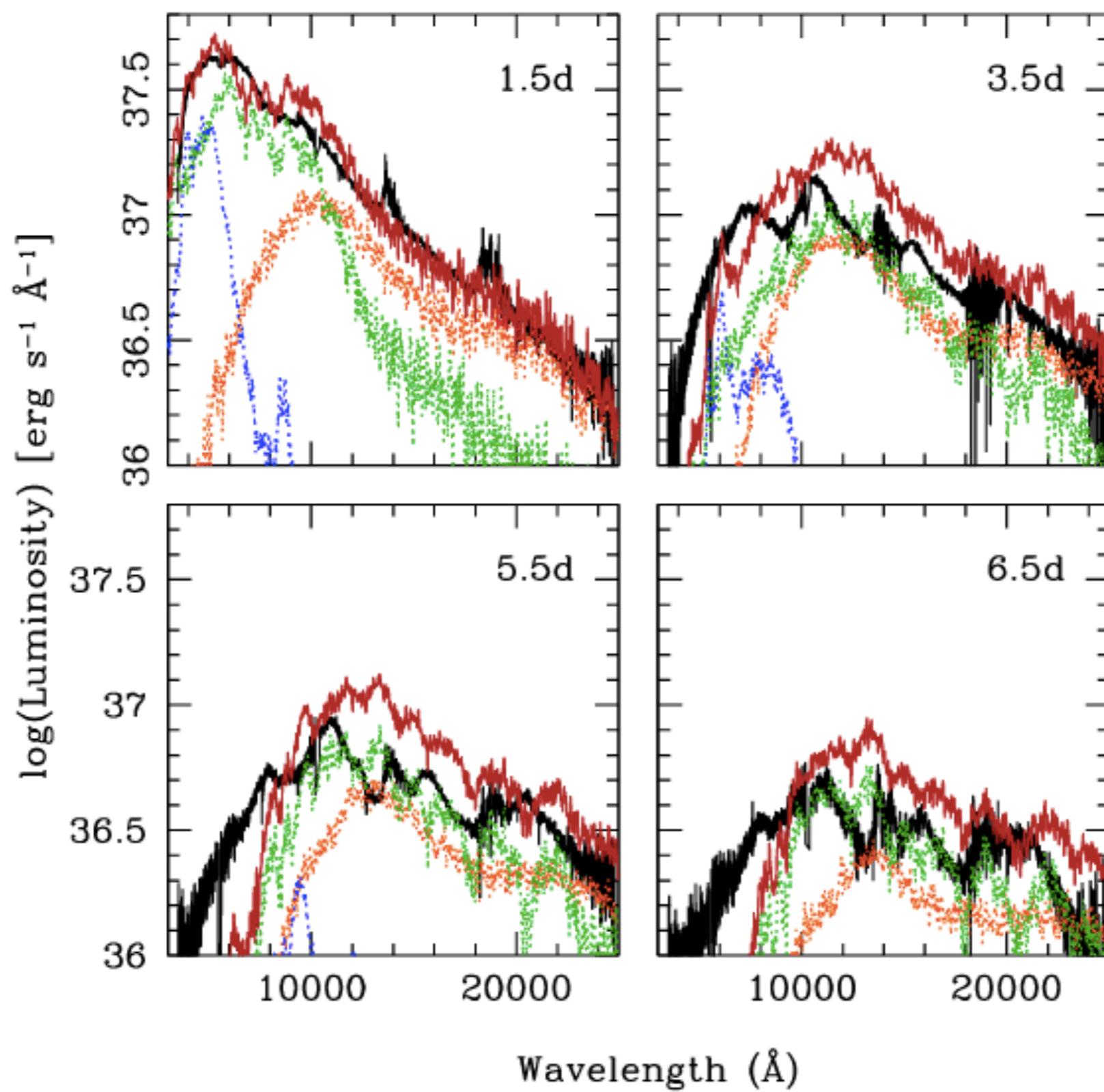
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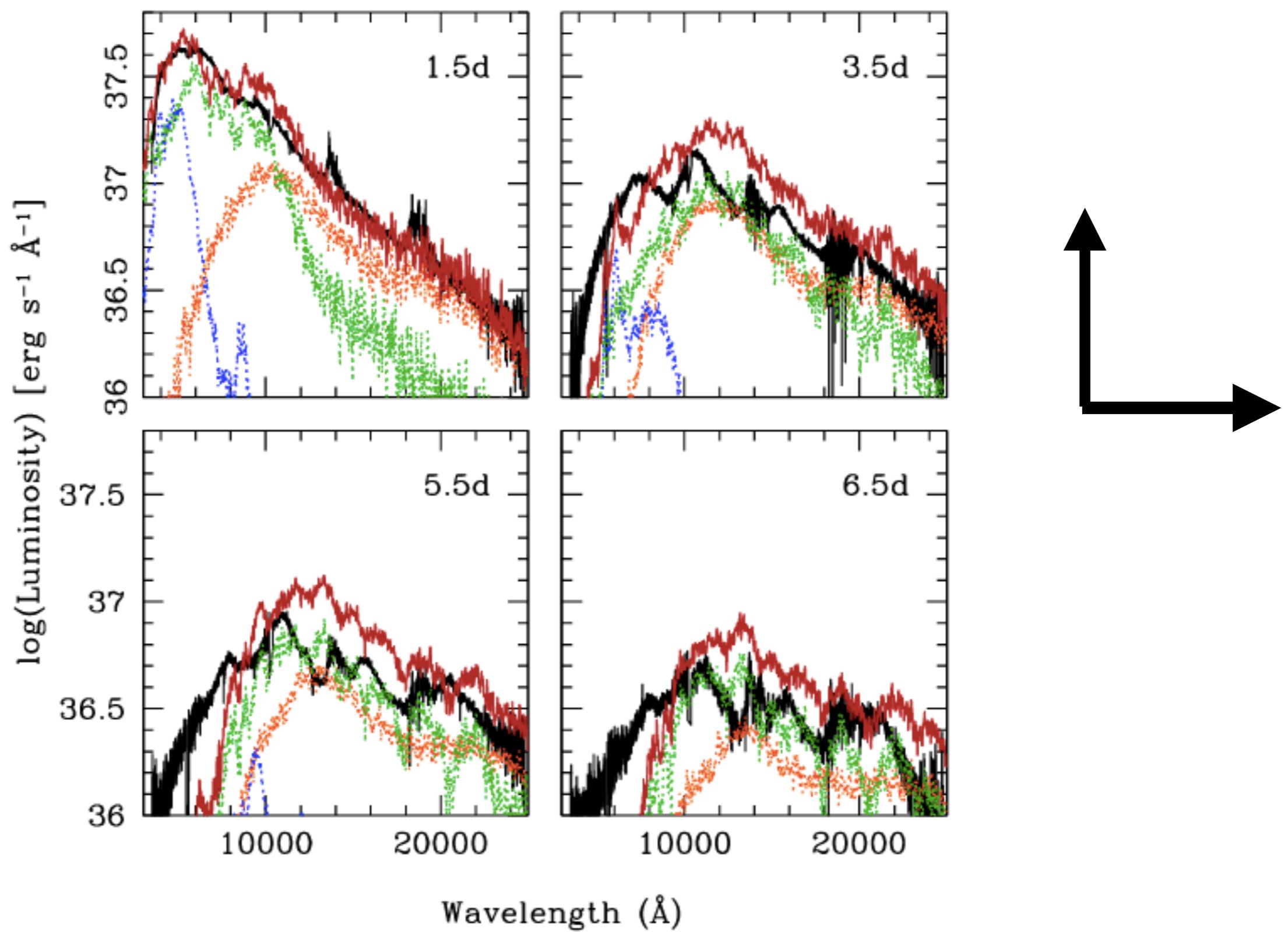
The collision produced as much gold as the mass of the Earth

1.8×10^{49} atoms









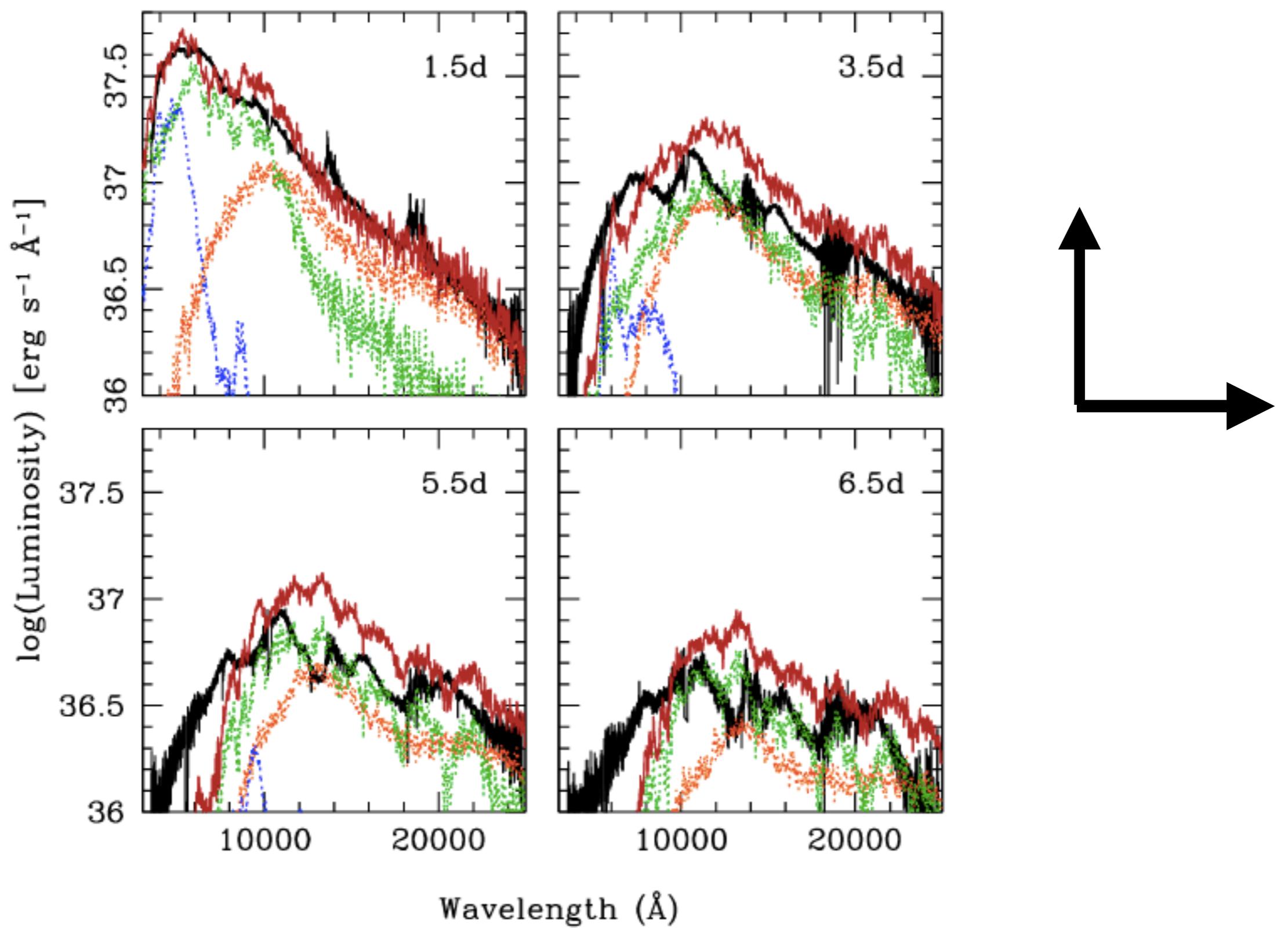


Figure 3: Kilonova model compared to the AT 2017gfo spectra. X-shooter spectra (black line) at **the first four epochs and kilonova models:** dynamical ejecta ($Y_e = 0.1$ – -0.4 , orange), wind region with proton fraction $Y_e = 0.3$ (blue) and $Y_e = 0.25$ (green). The red curve represents the sum of the three model components.



CARL BARKS

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FAKE
NEWS

COMMERCIALS

COMMERCIALS

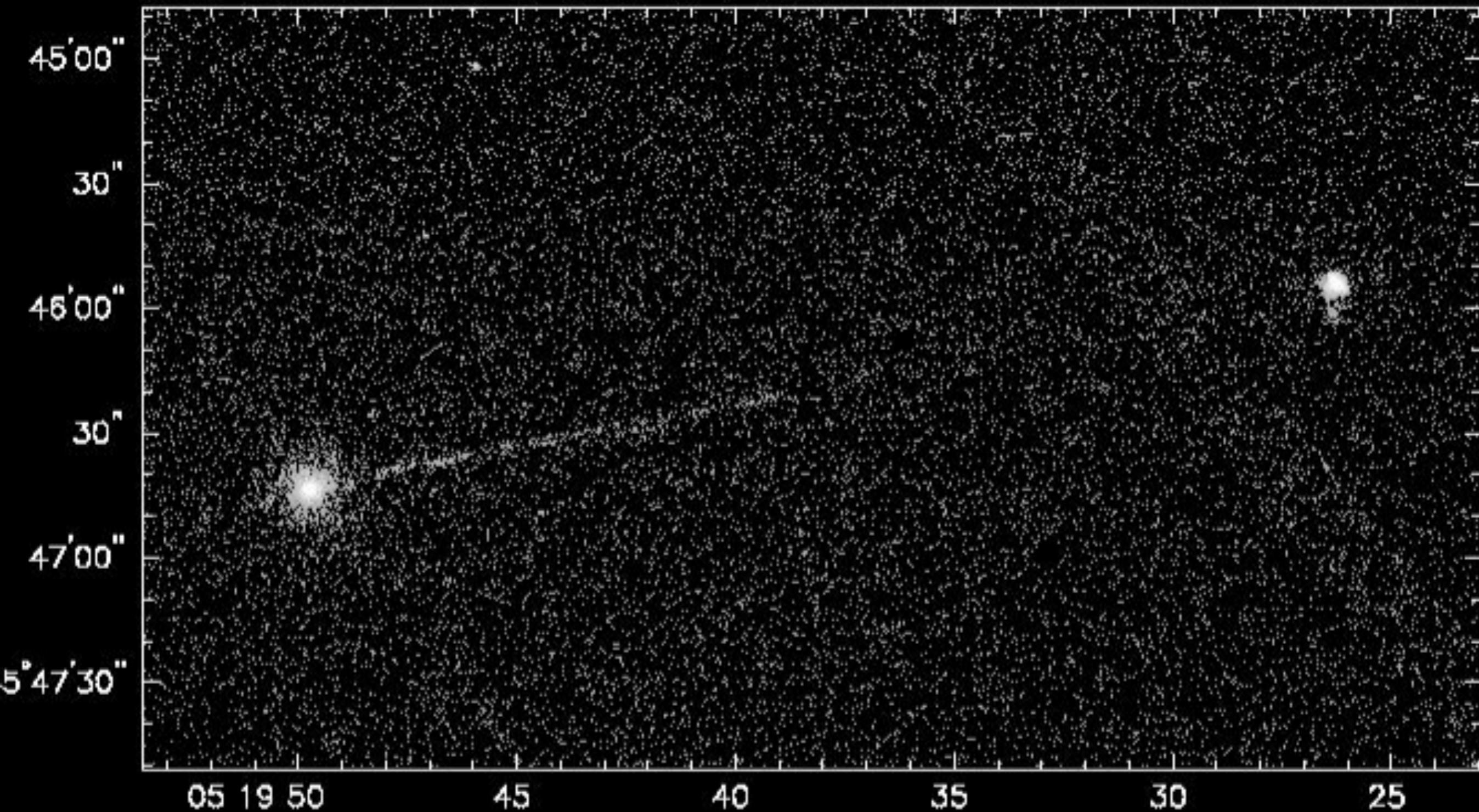
TRUE TALK

WILL START IN

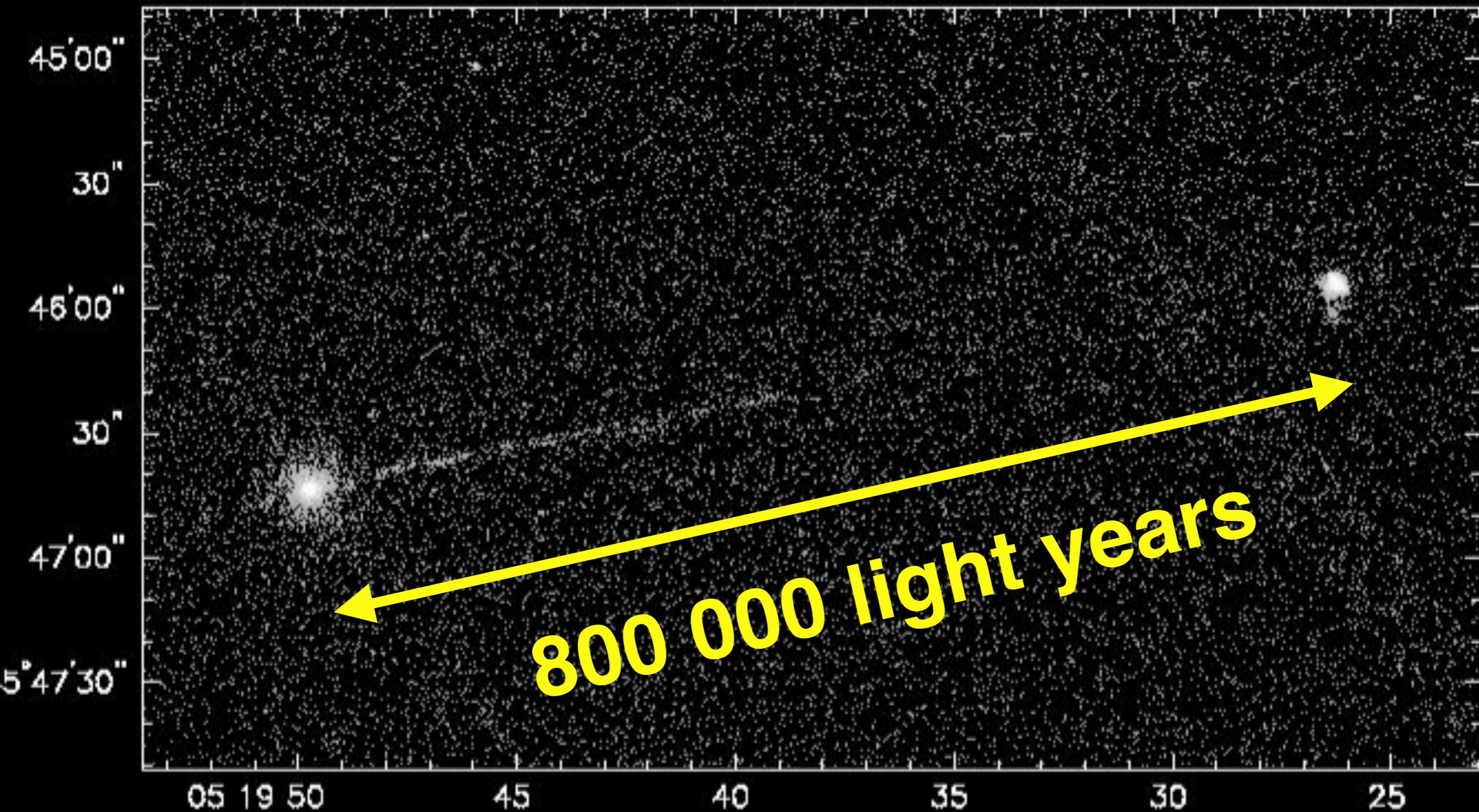
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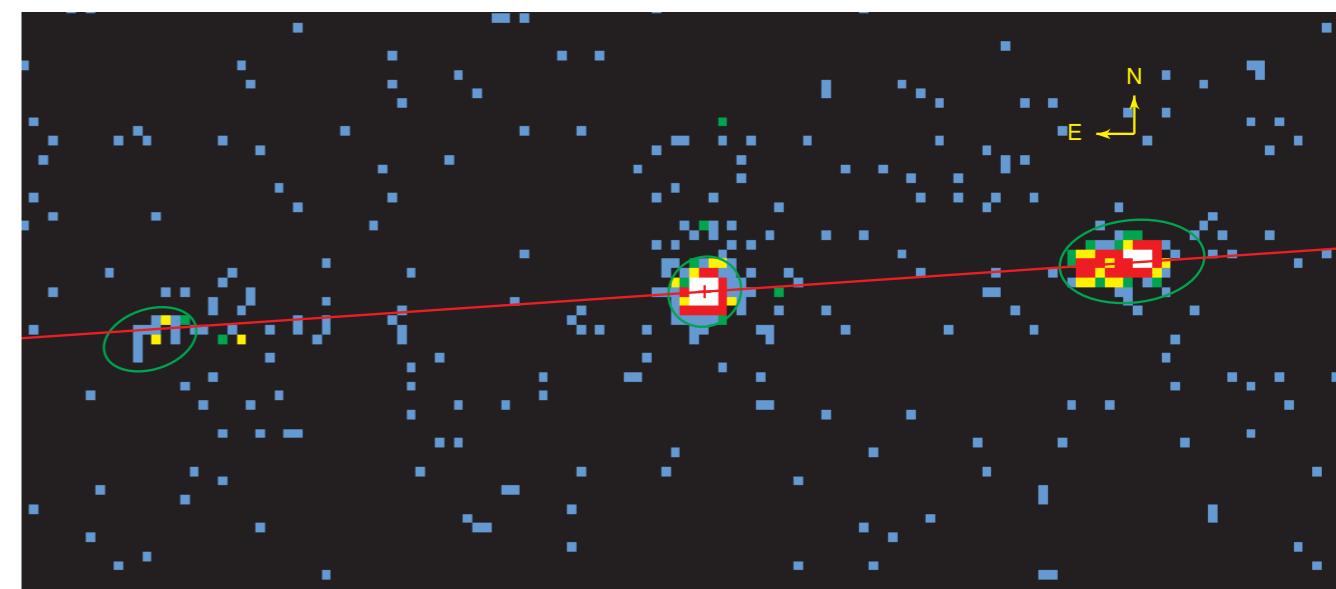
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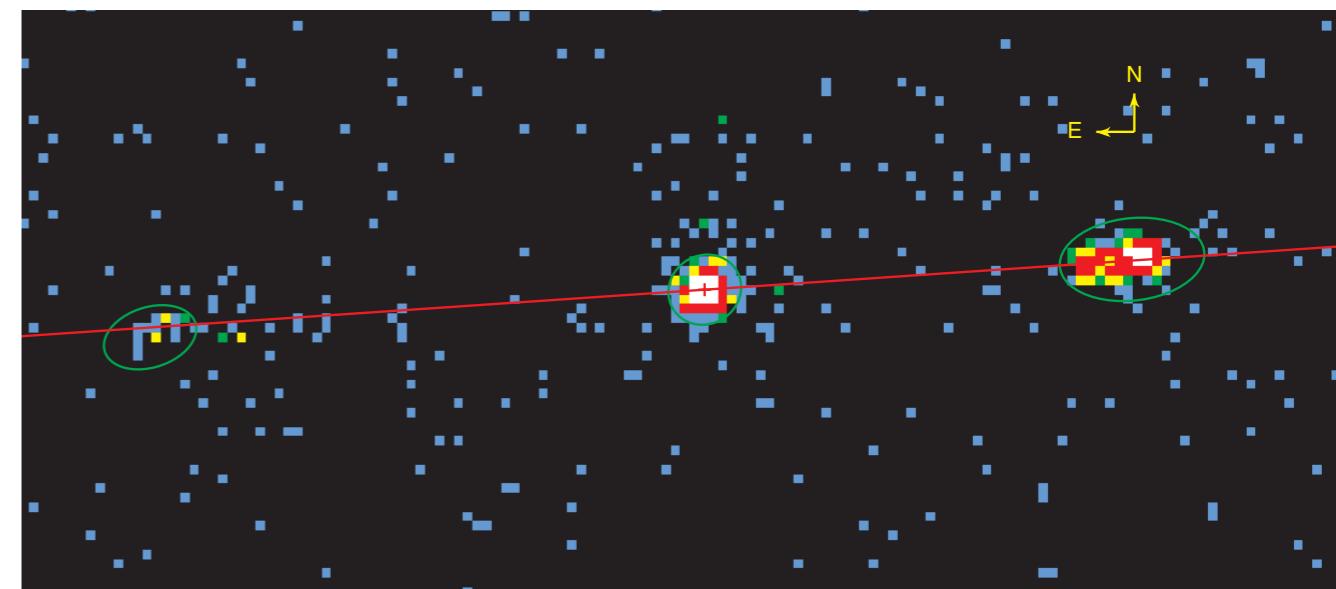


Pictor(ius) A quasar

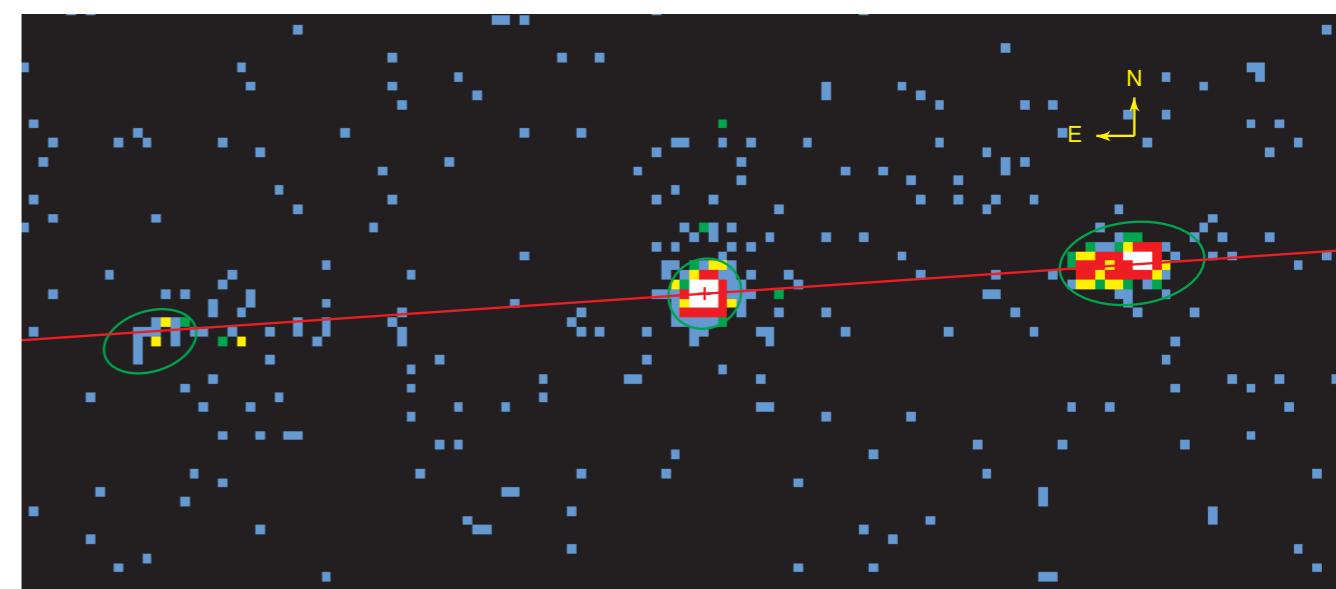
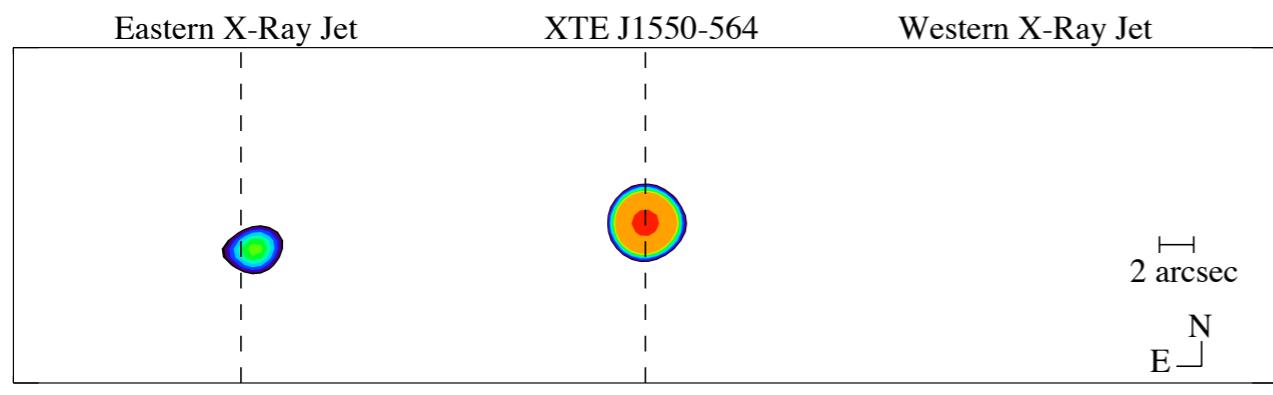


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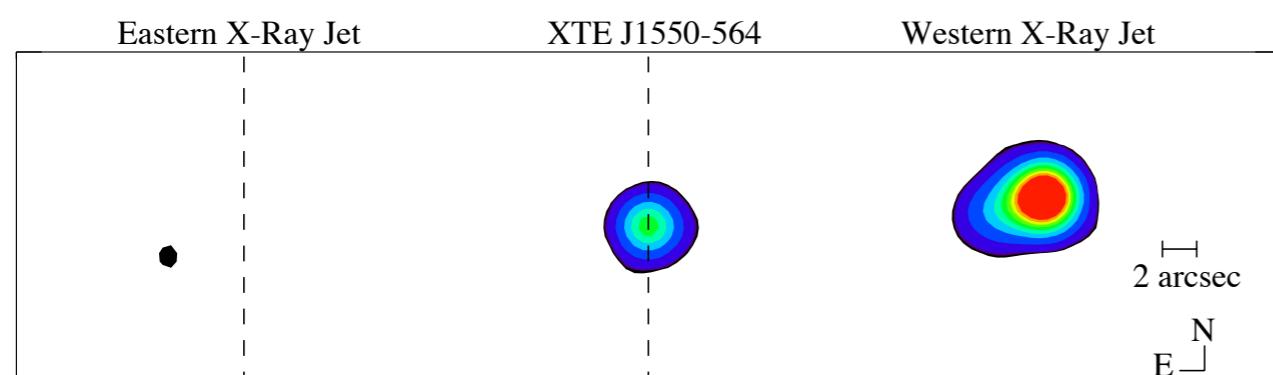
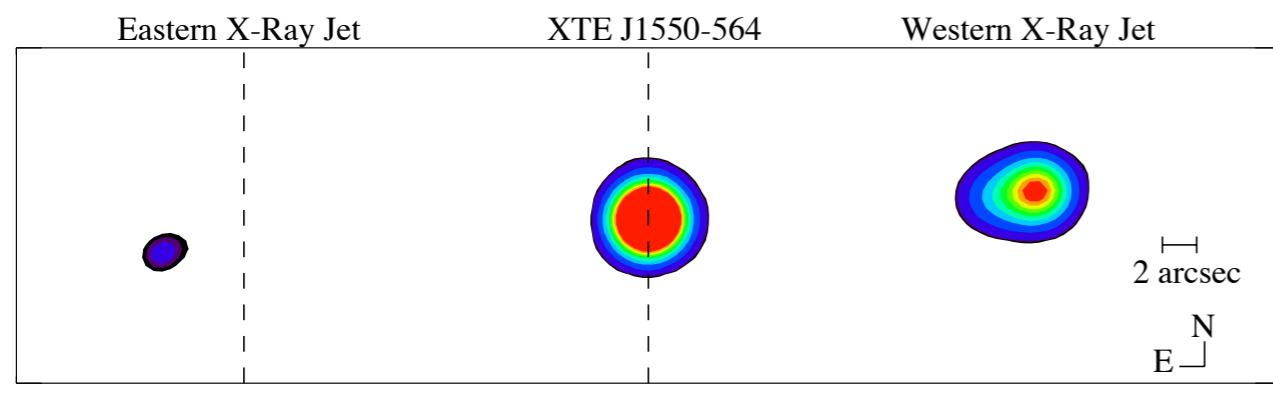
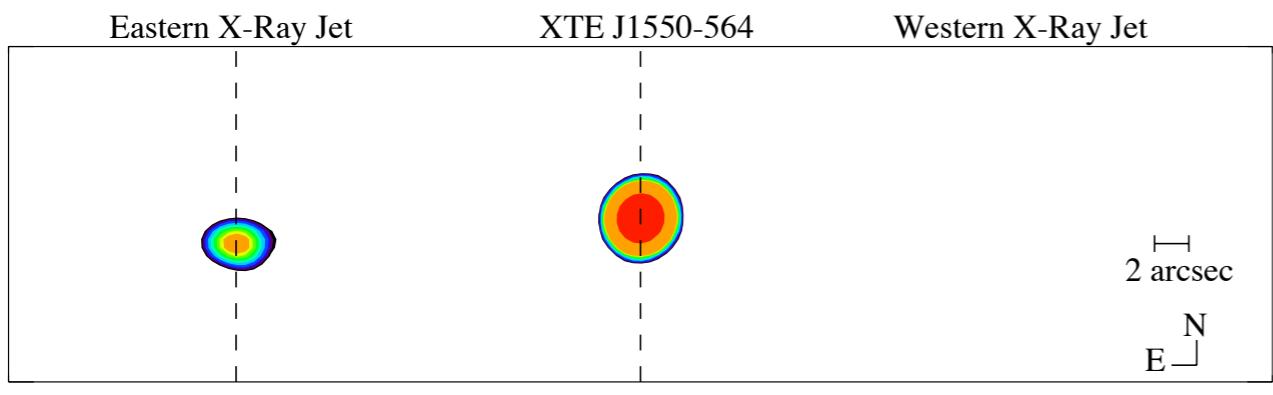


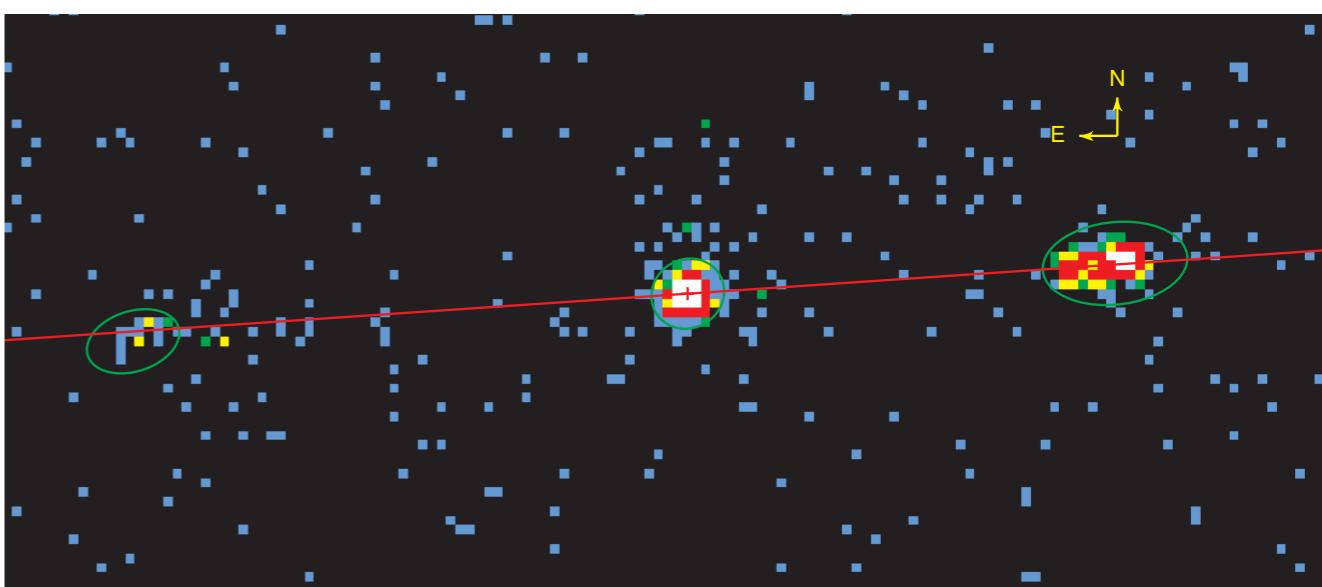
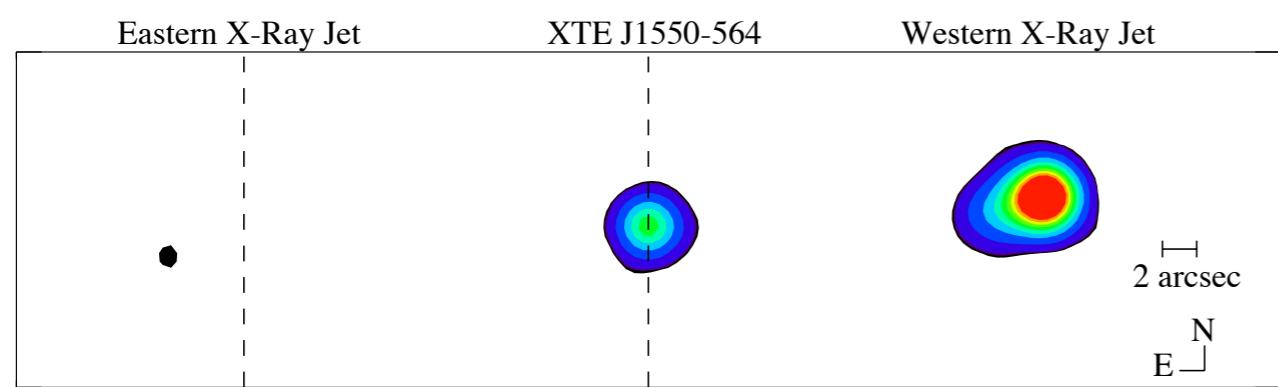
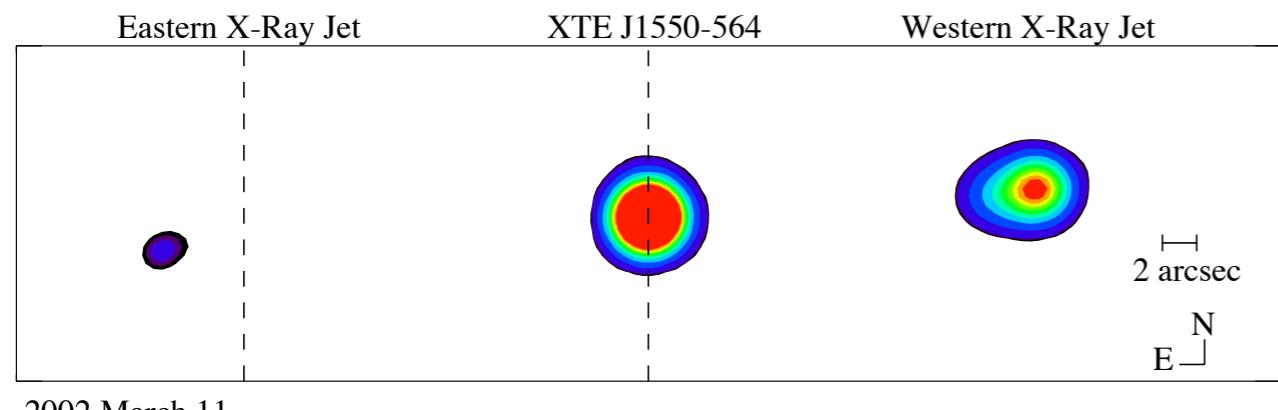
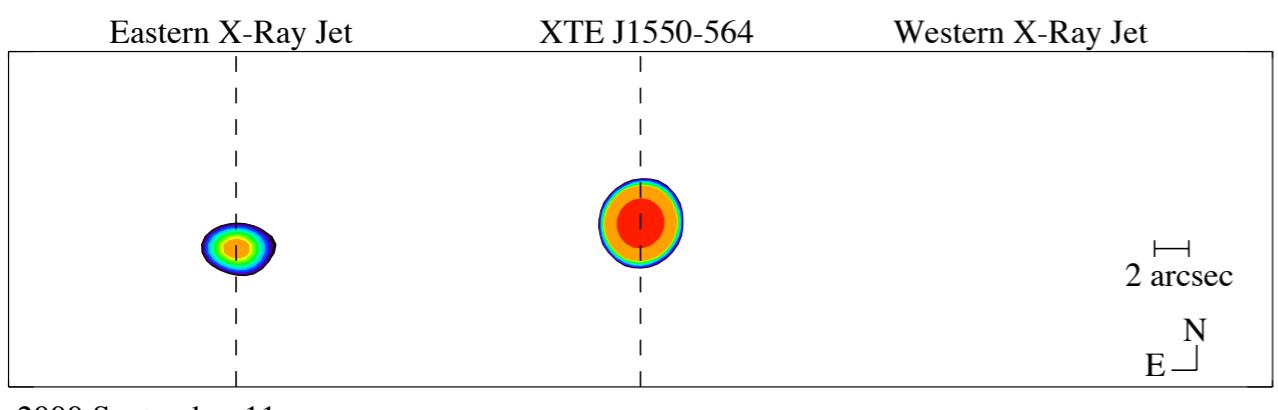
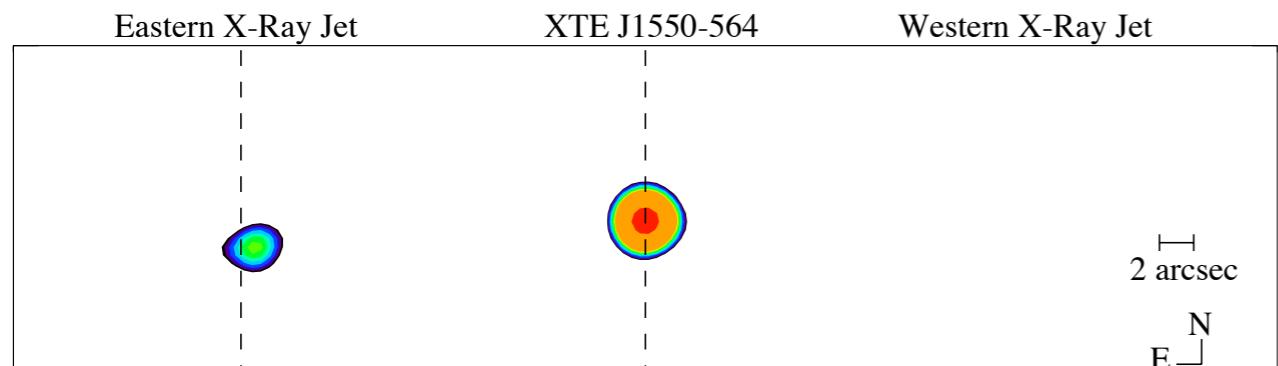


Micro-quasar XTE J1550-564

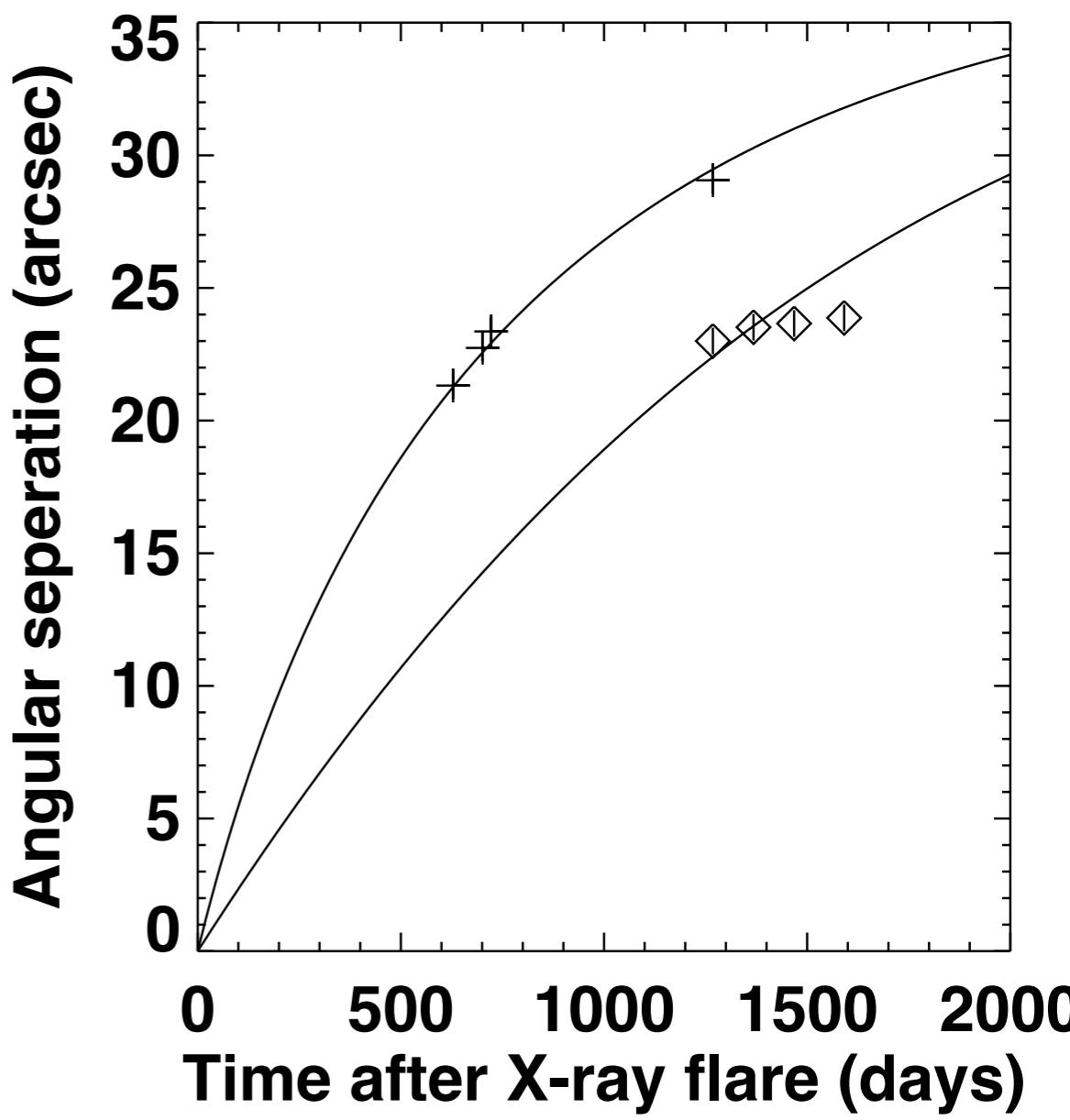


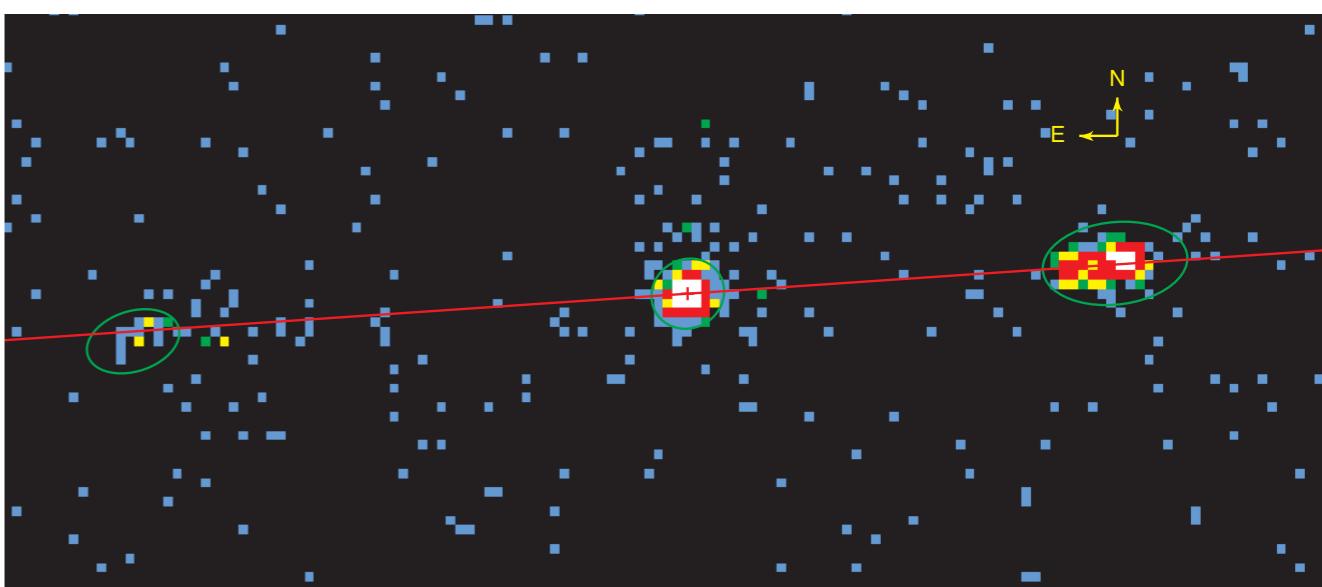
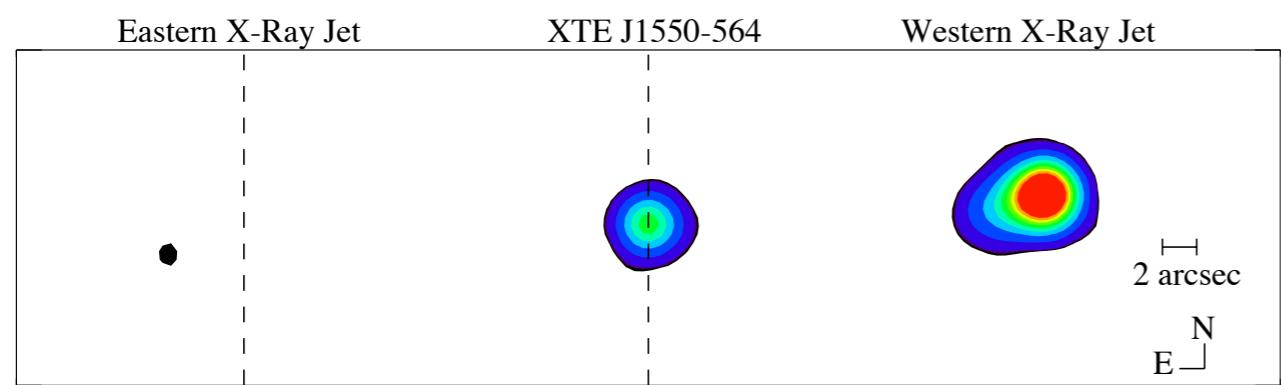
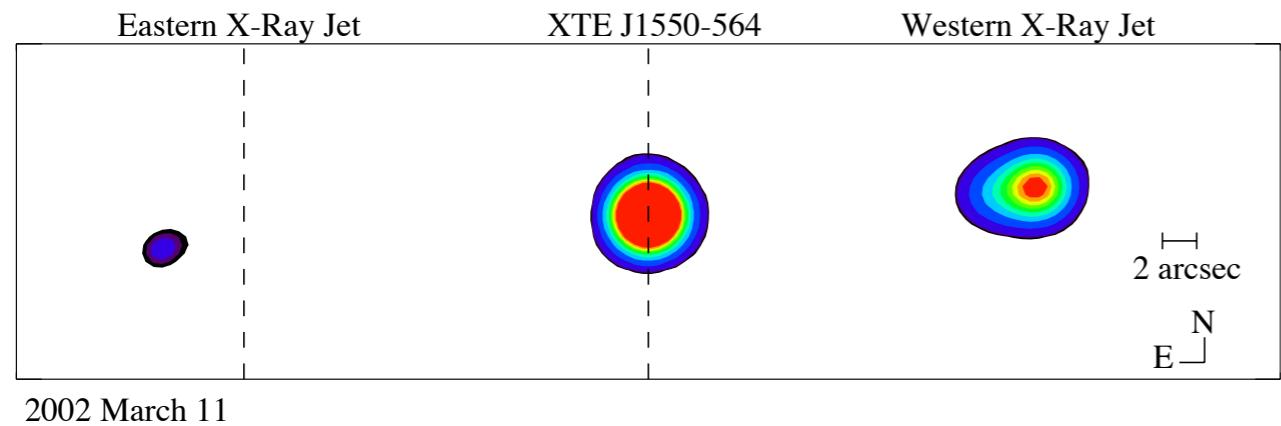
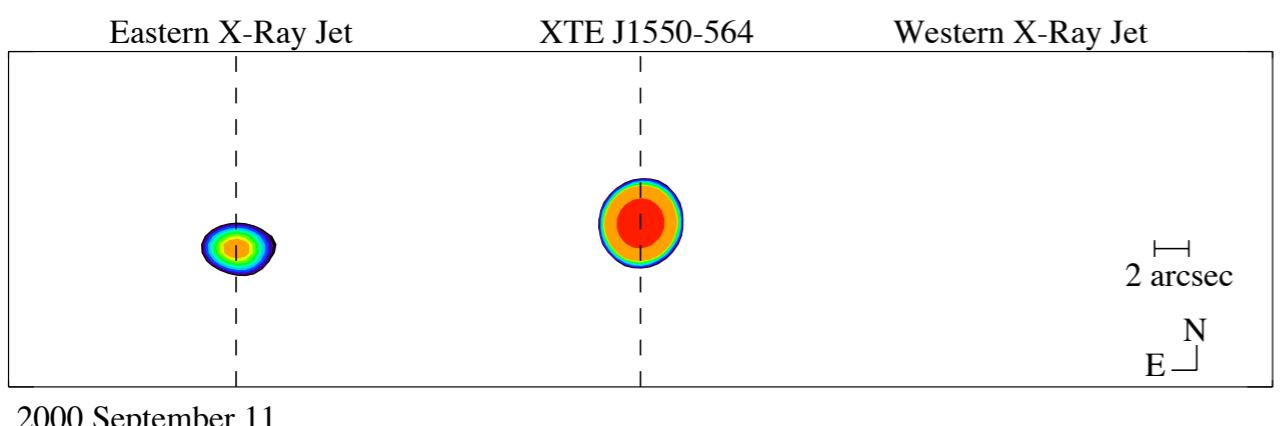
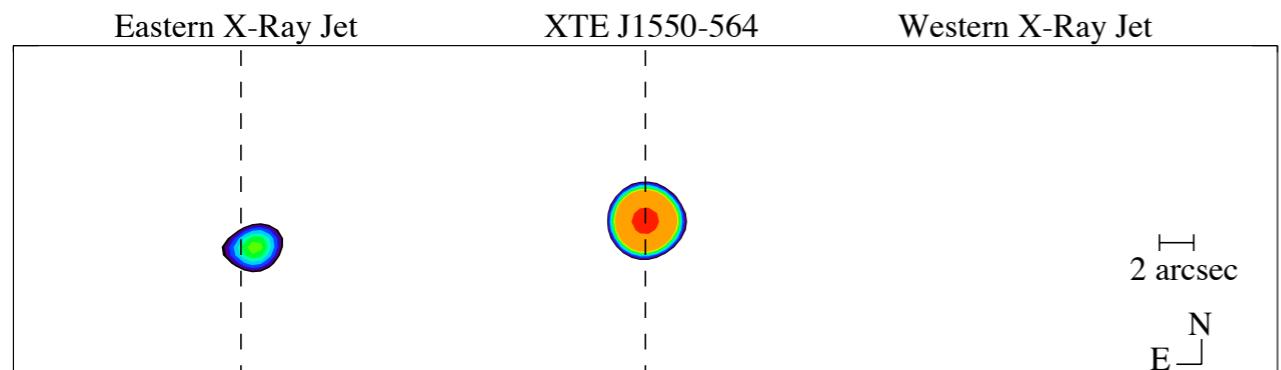
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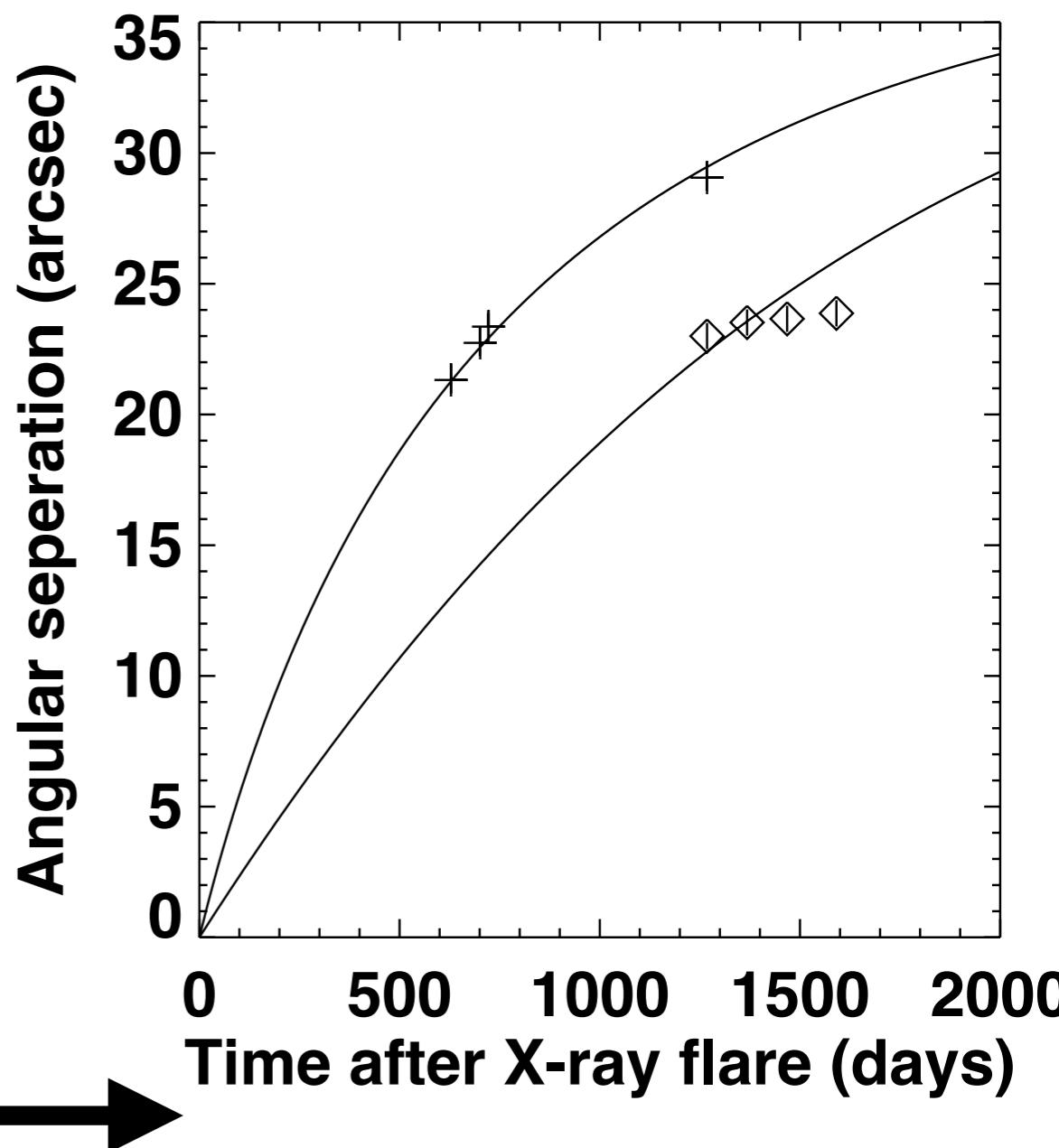


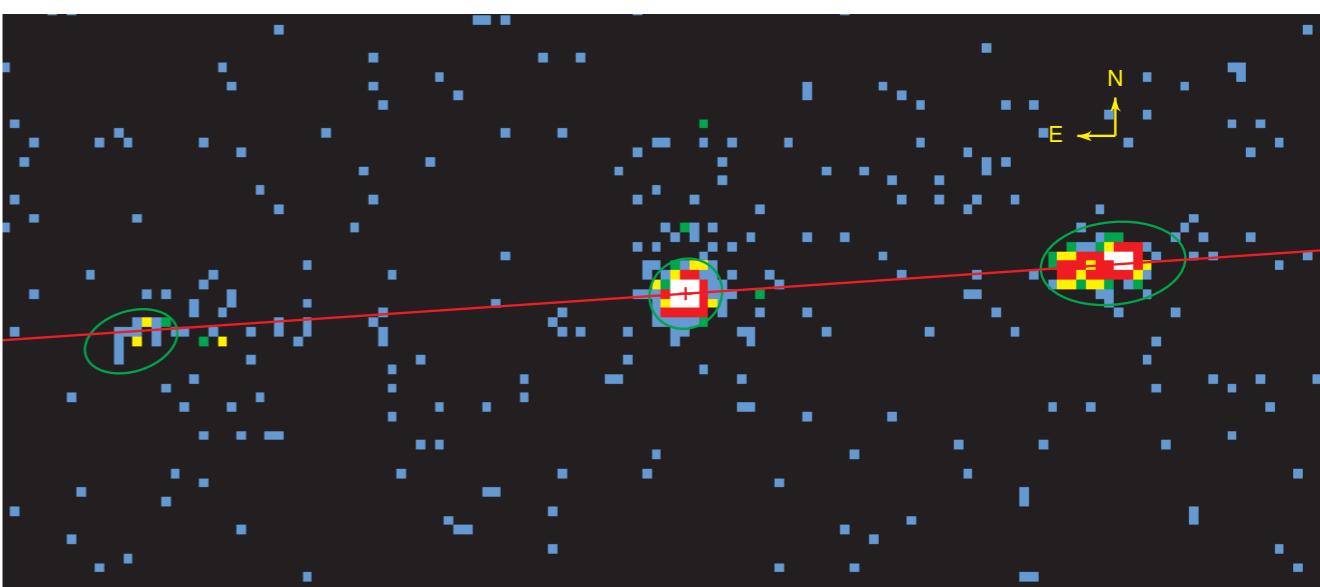
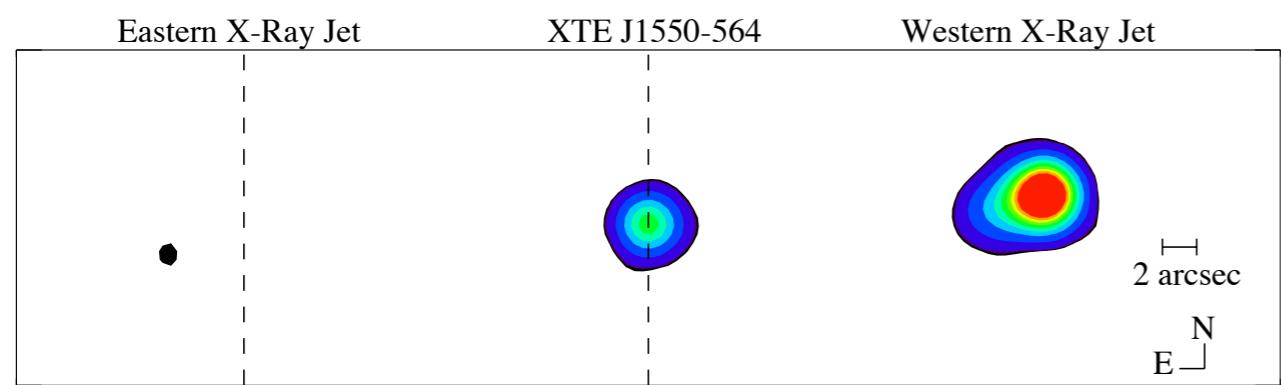
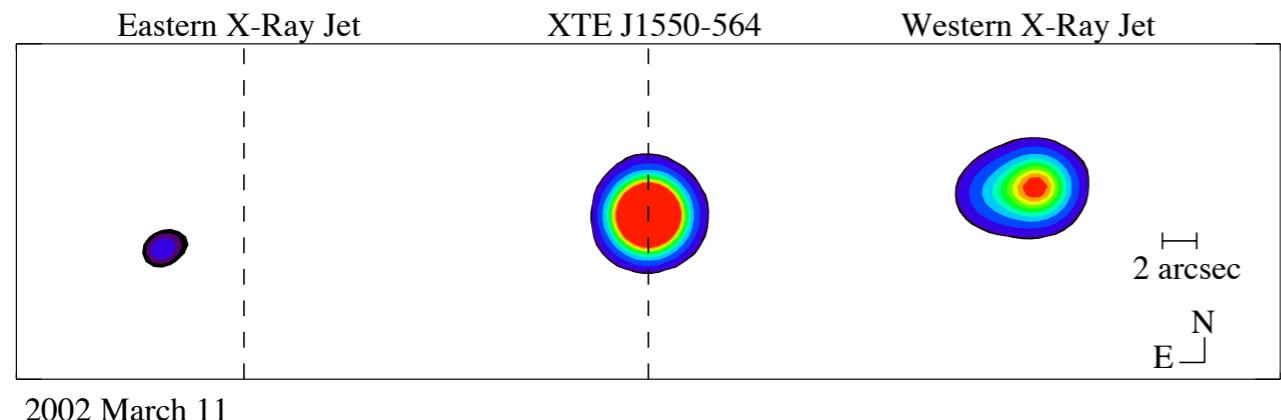
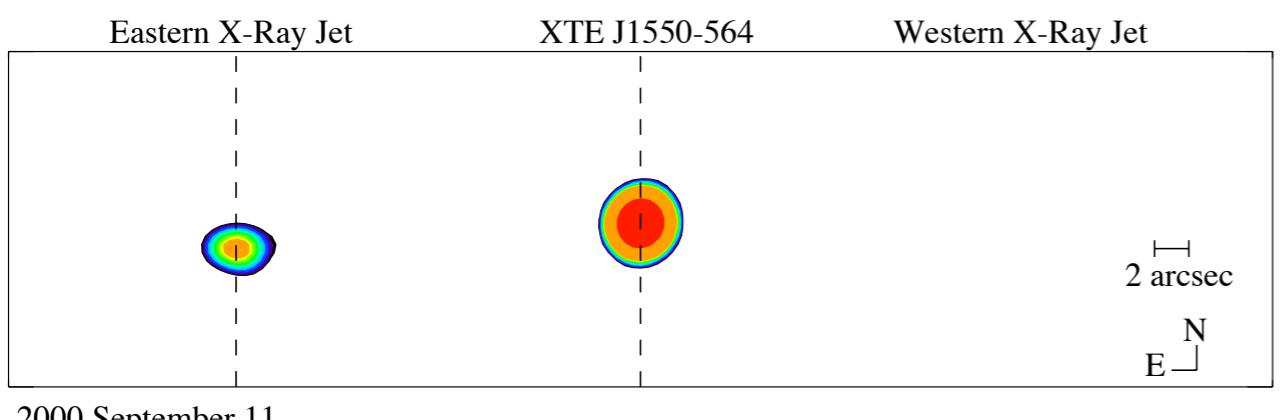
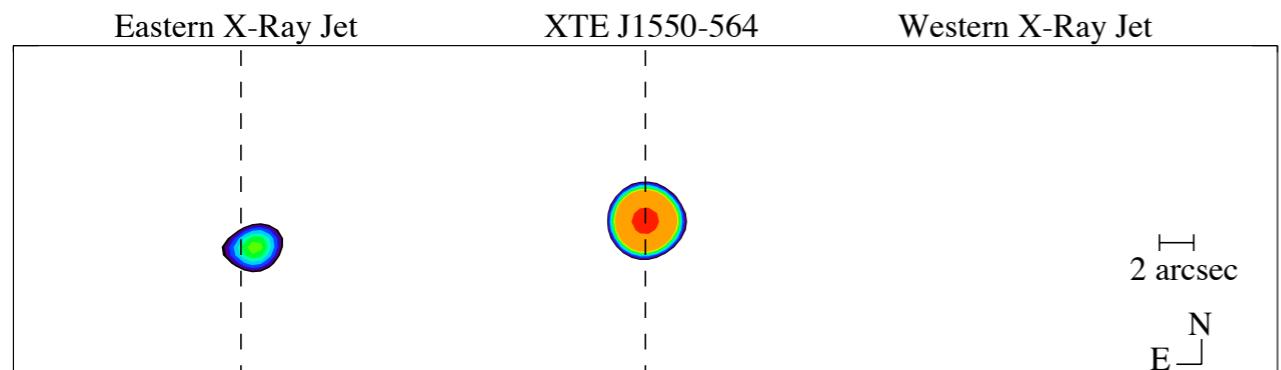
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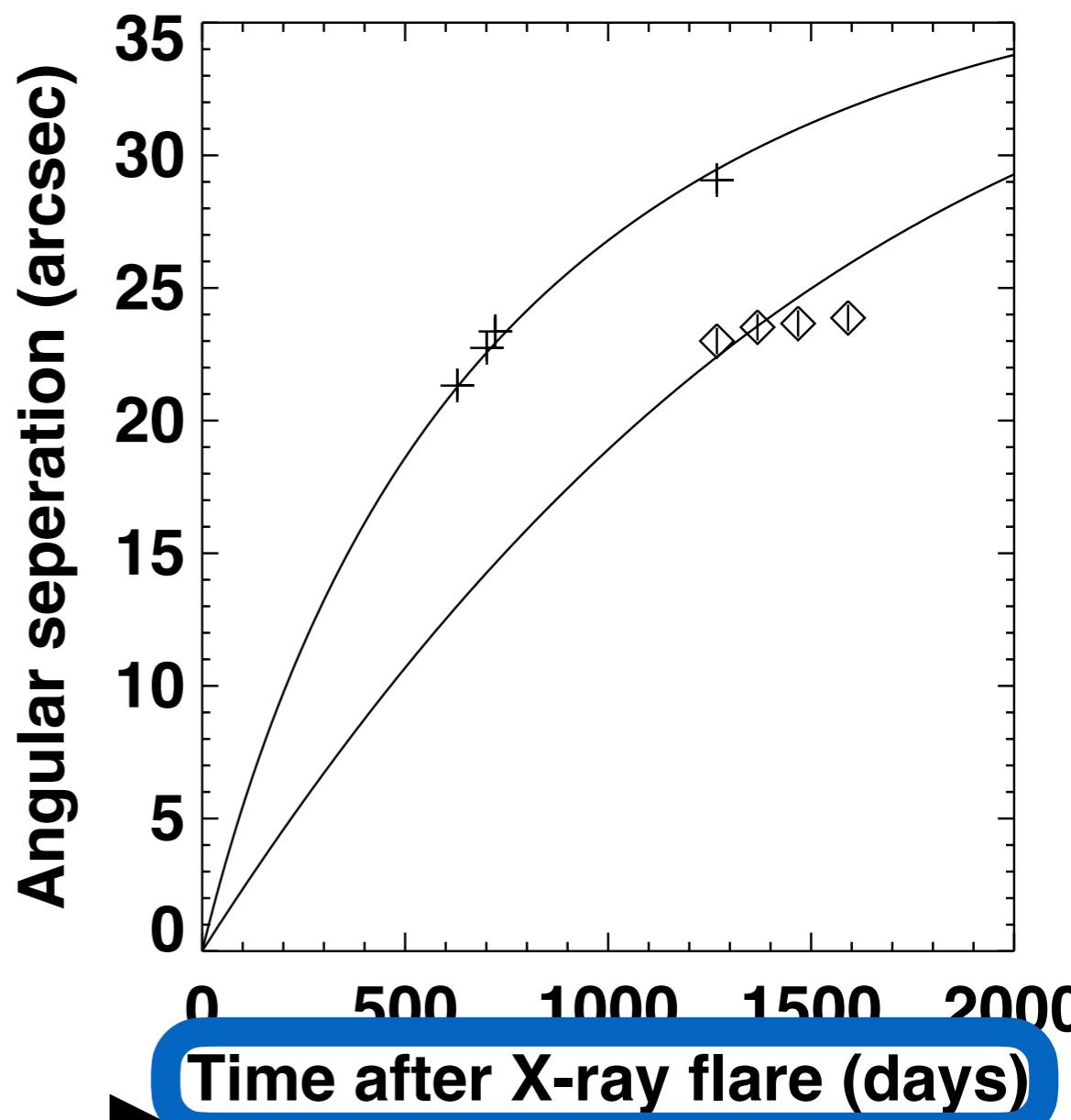


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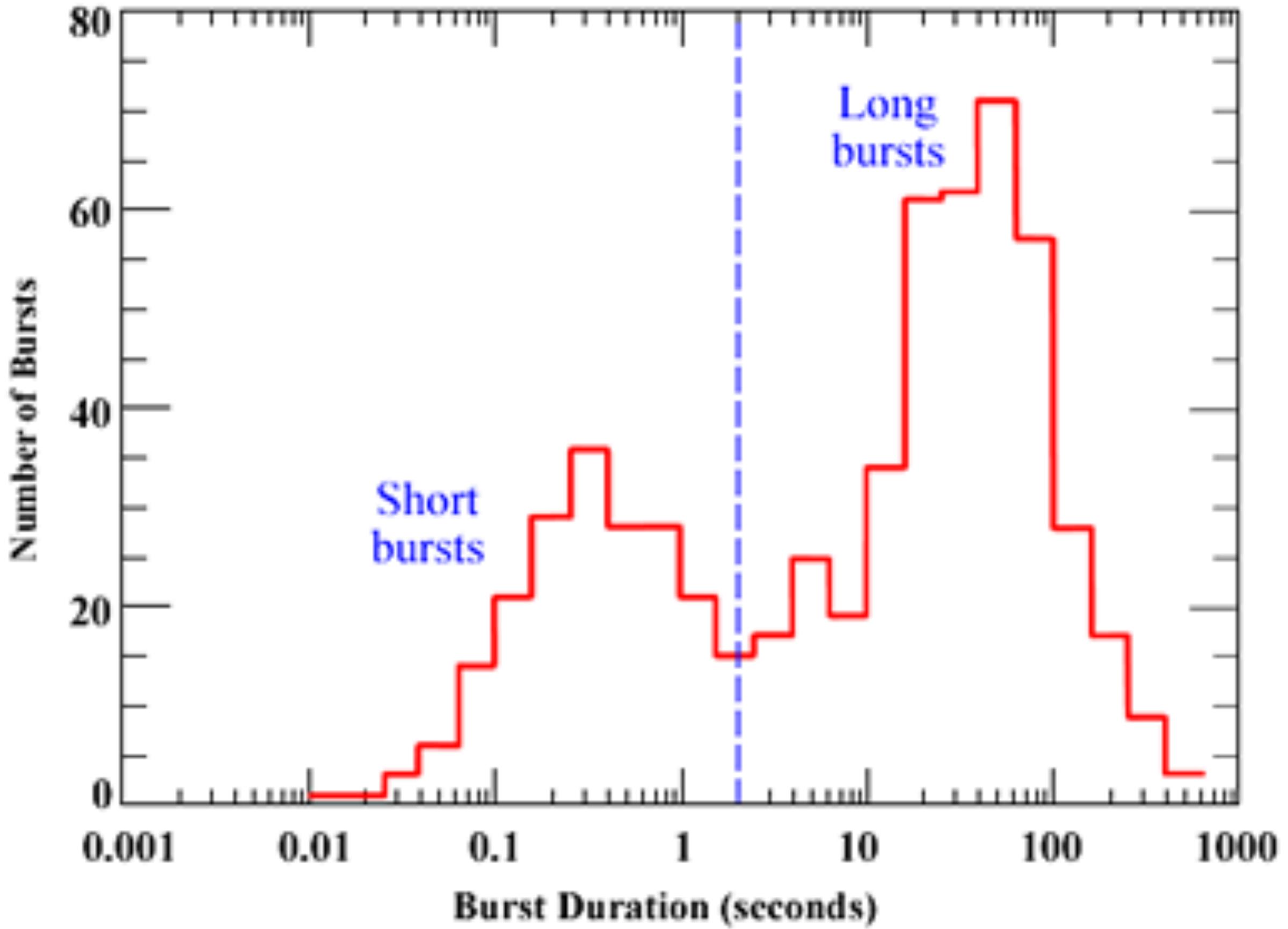


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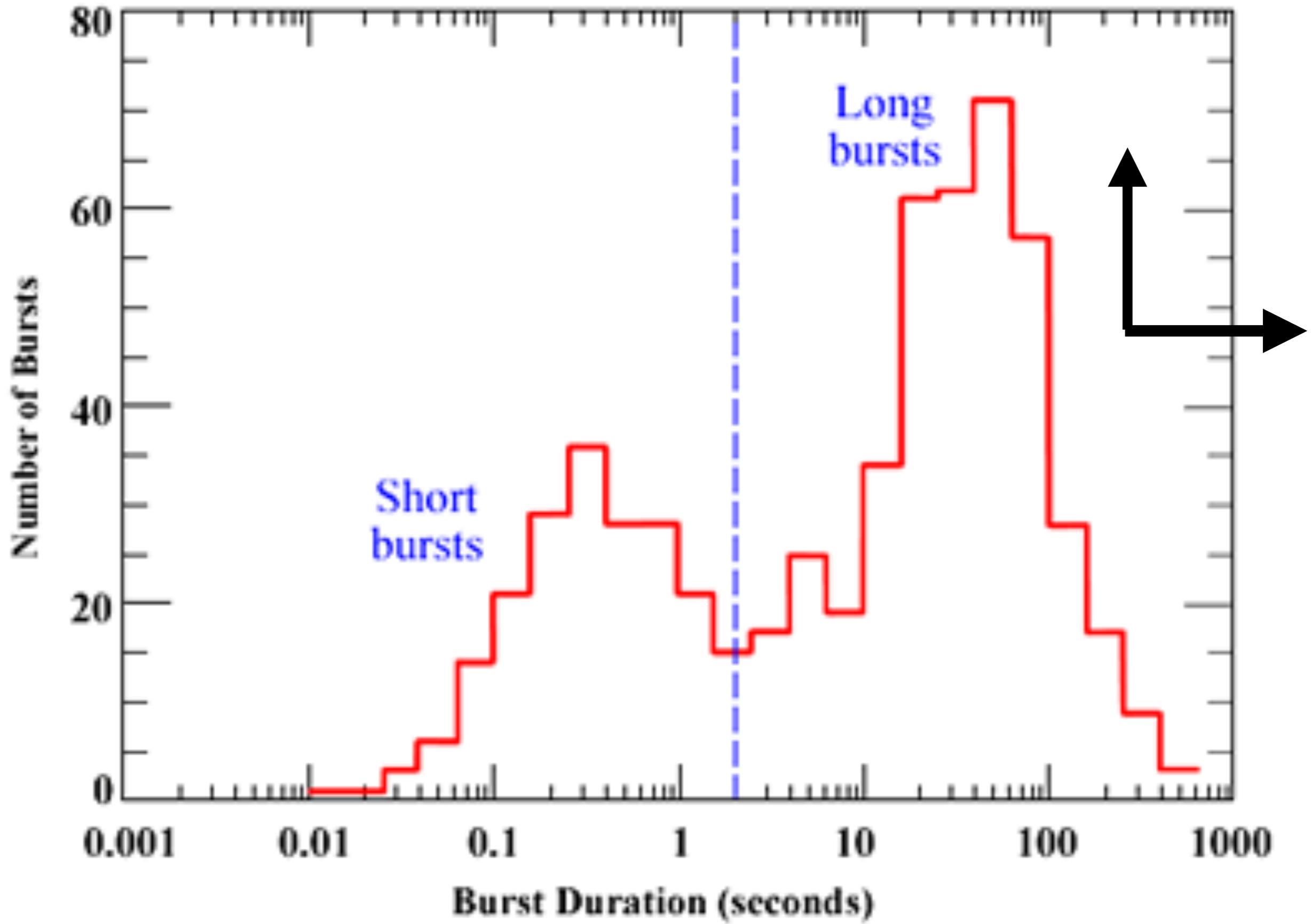


**END
OF
COMMERCIALS**

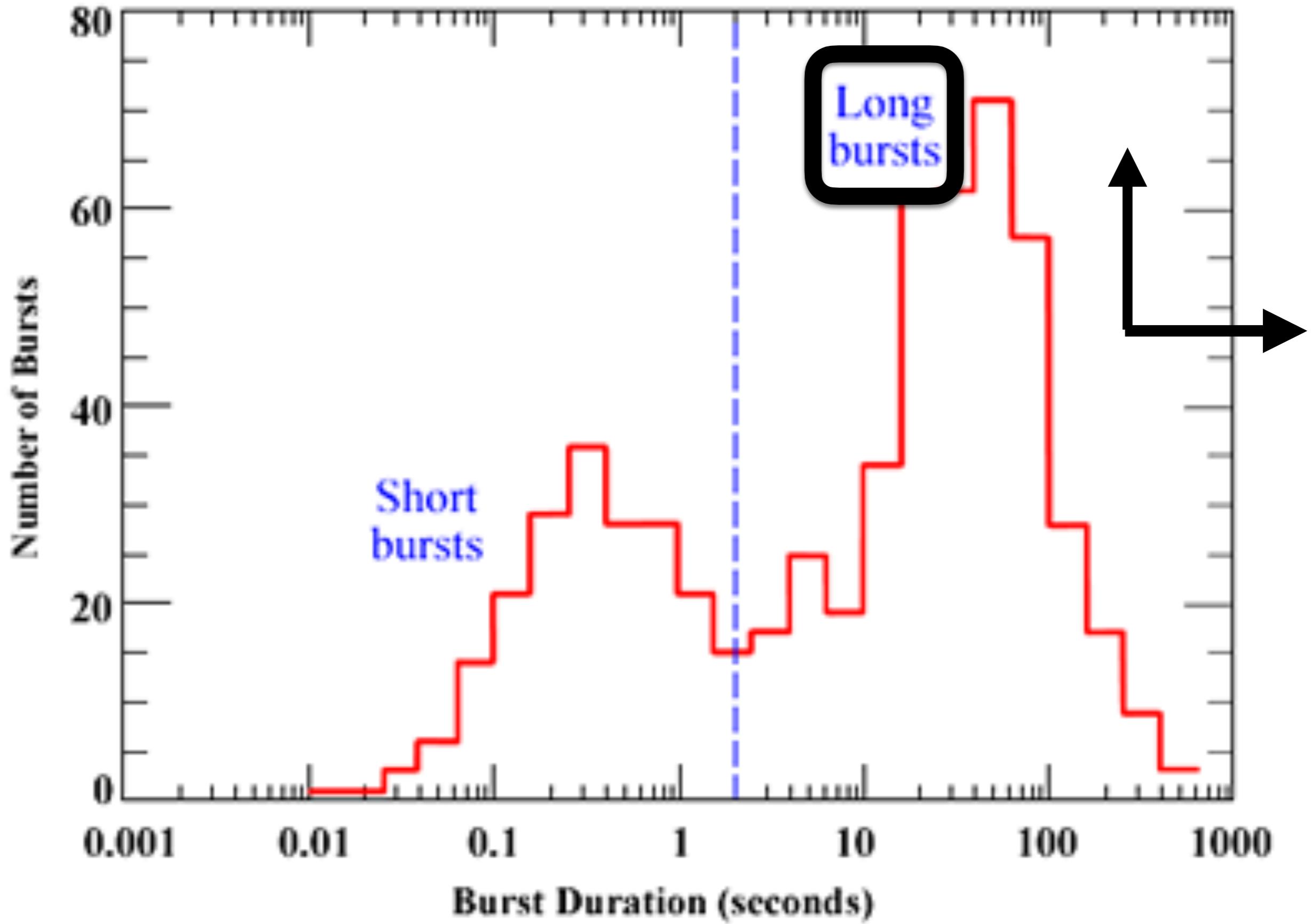
Duration of gamma-ray BURSTS



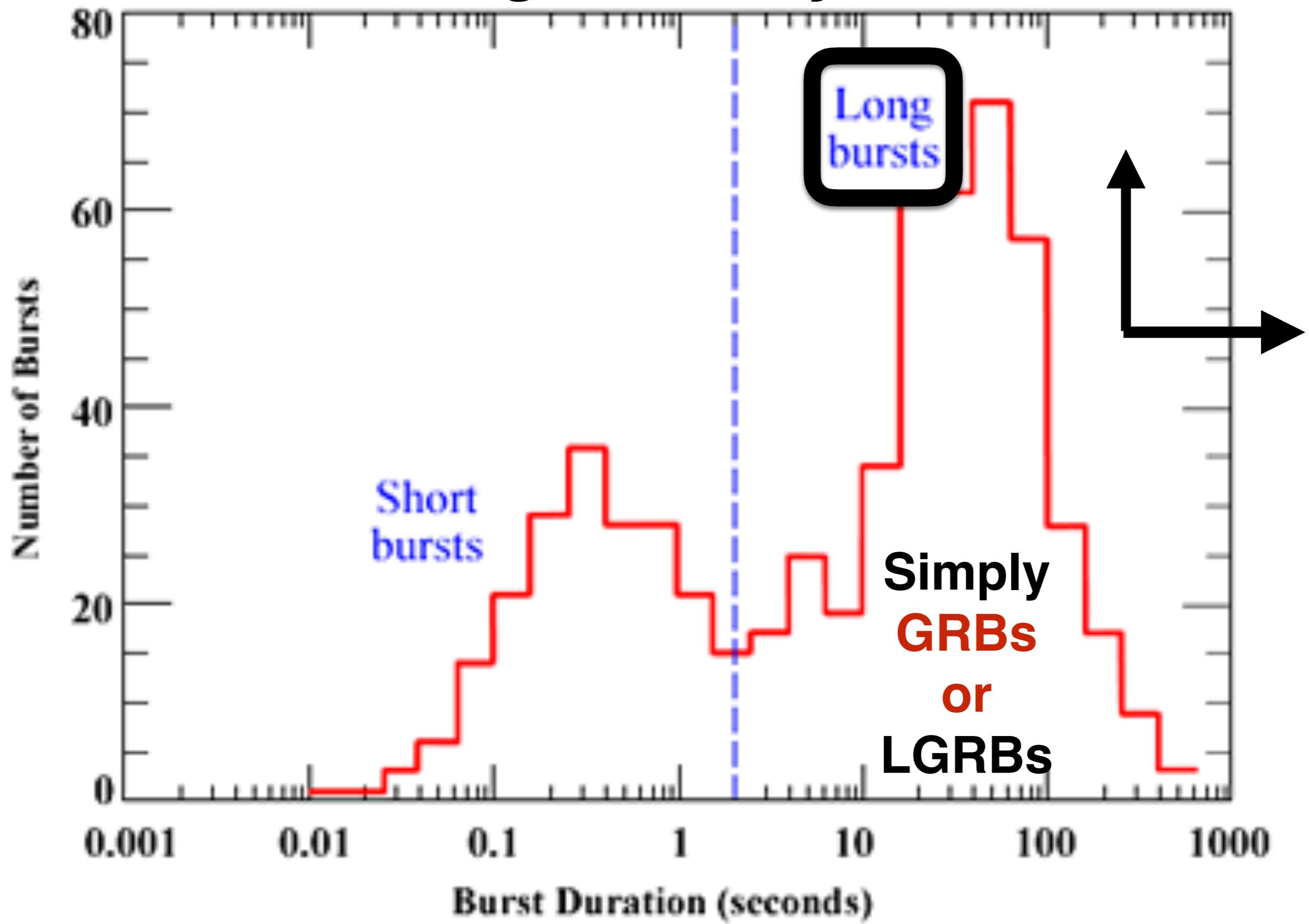
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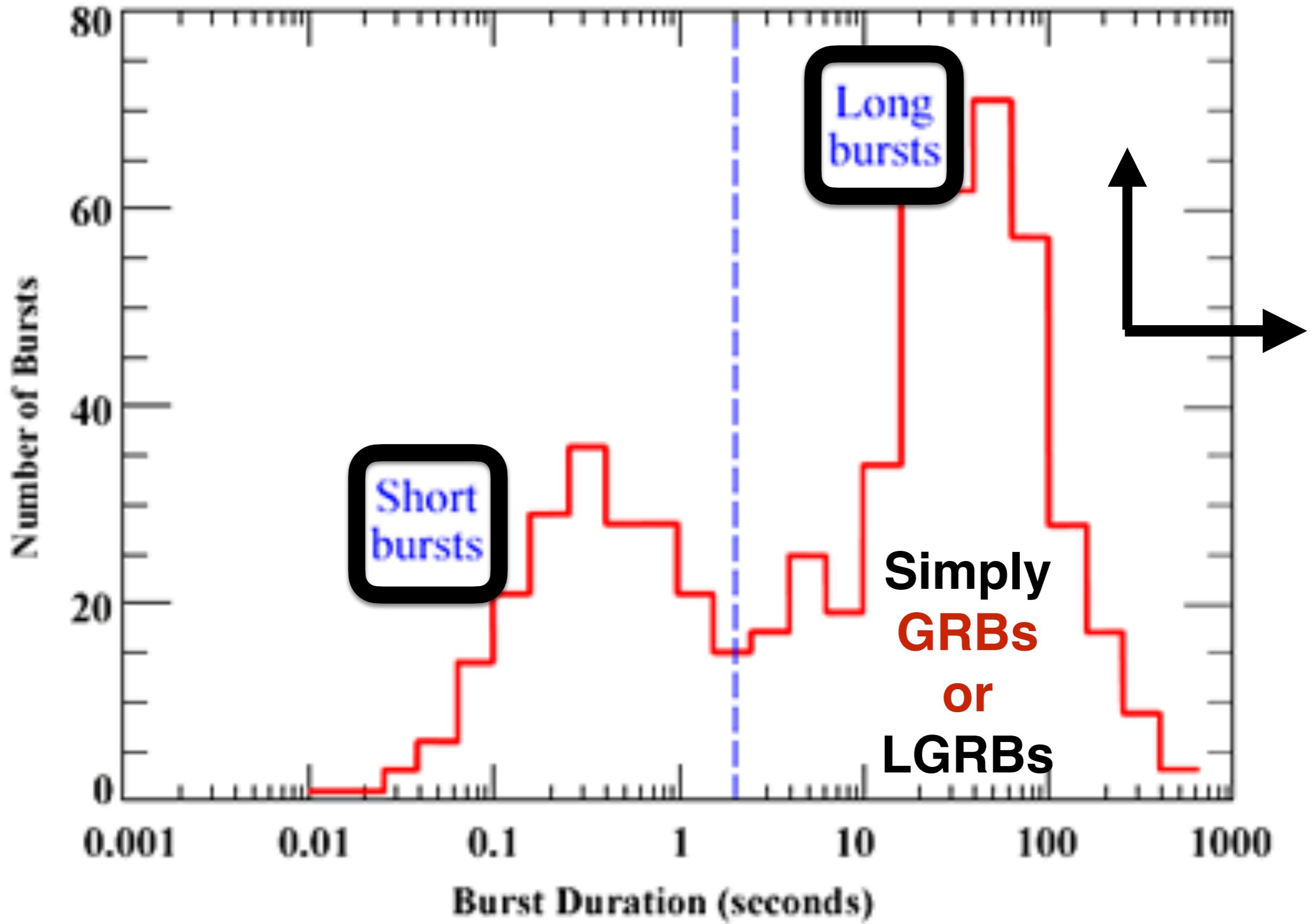
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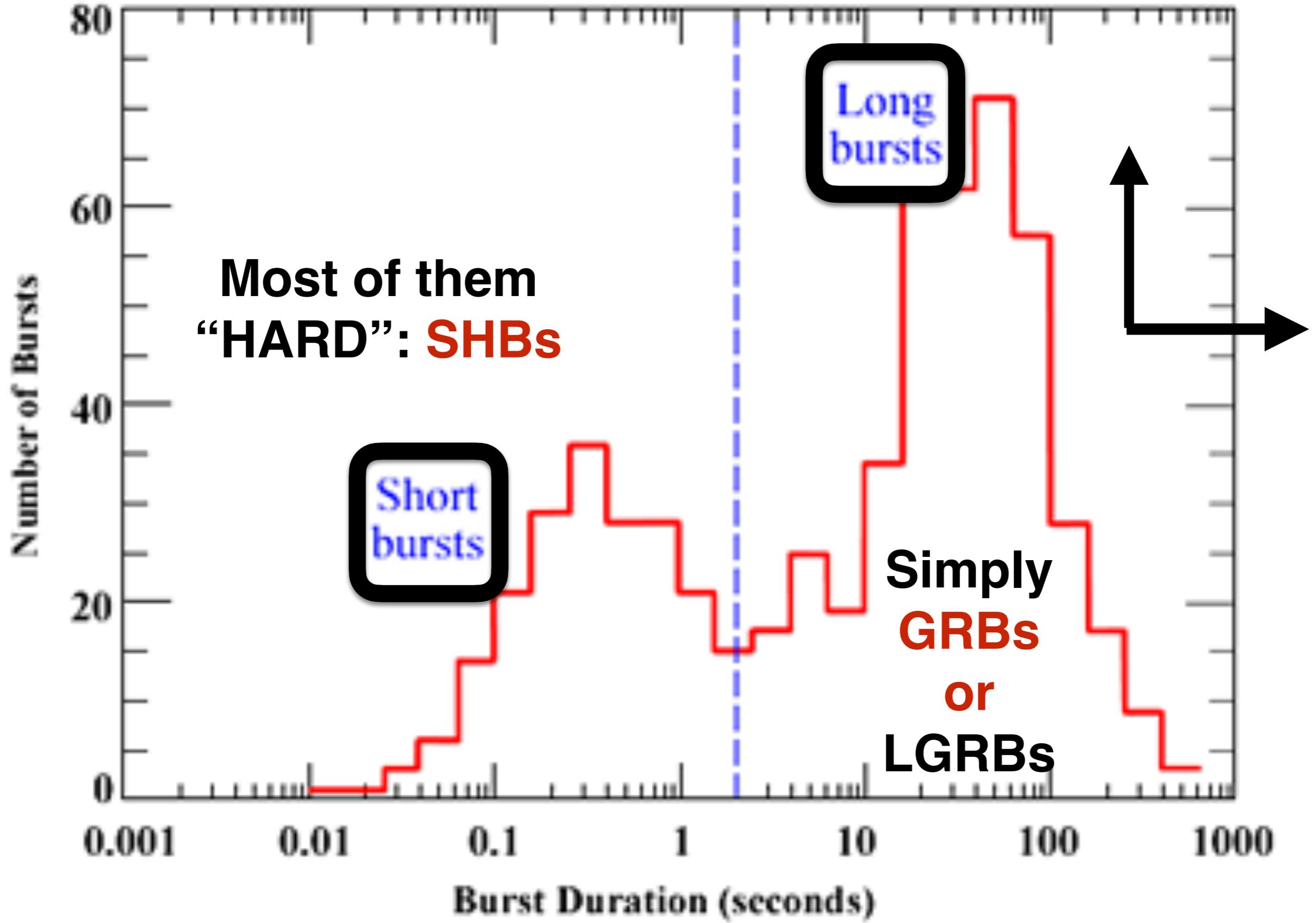
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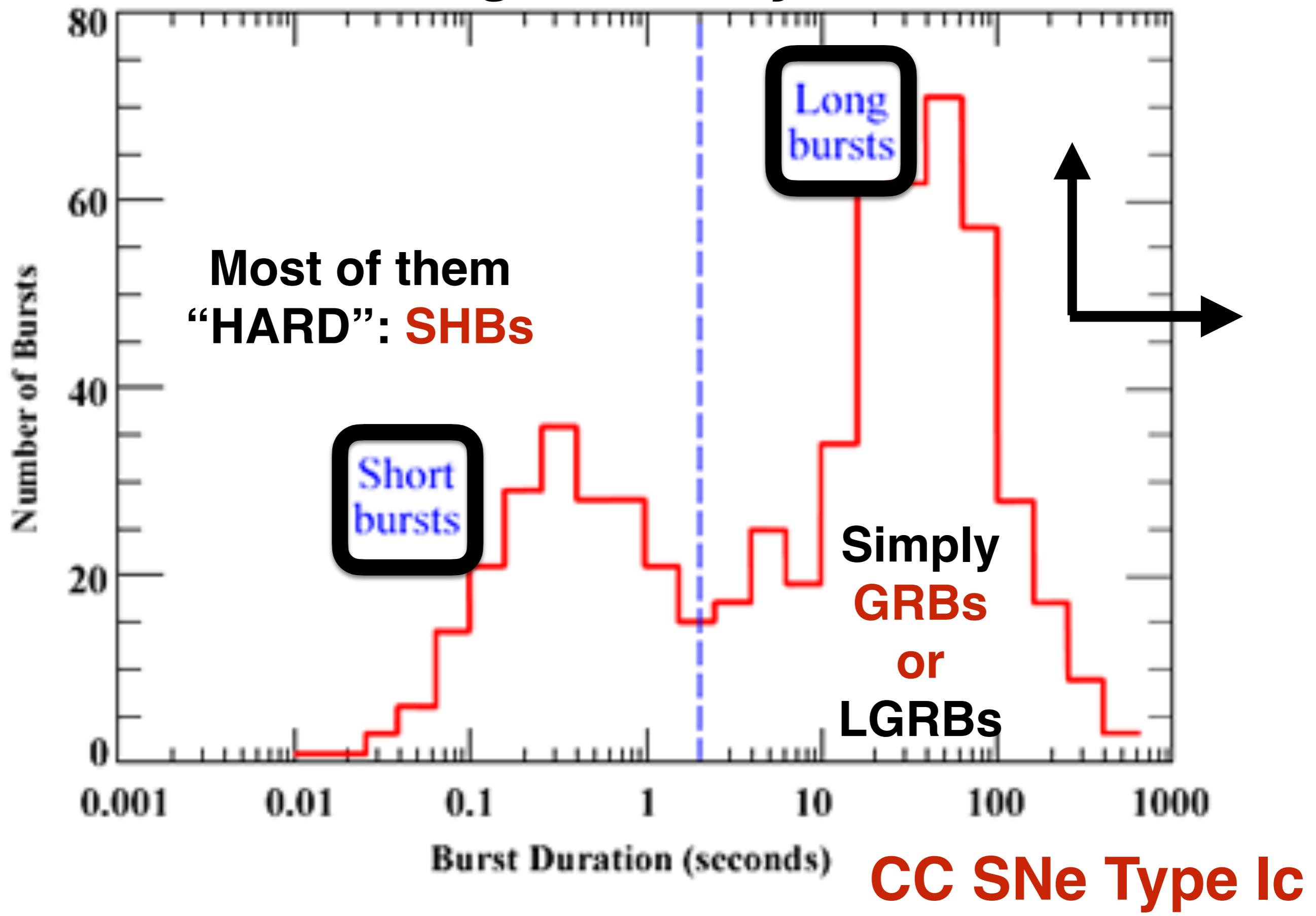
Duration of gamma-ray BURSTS



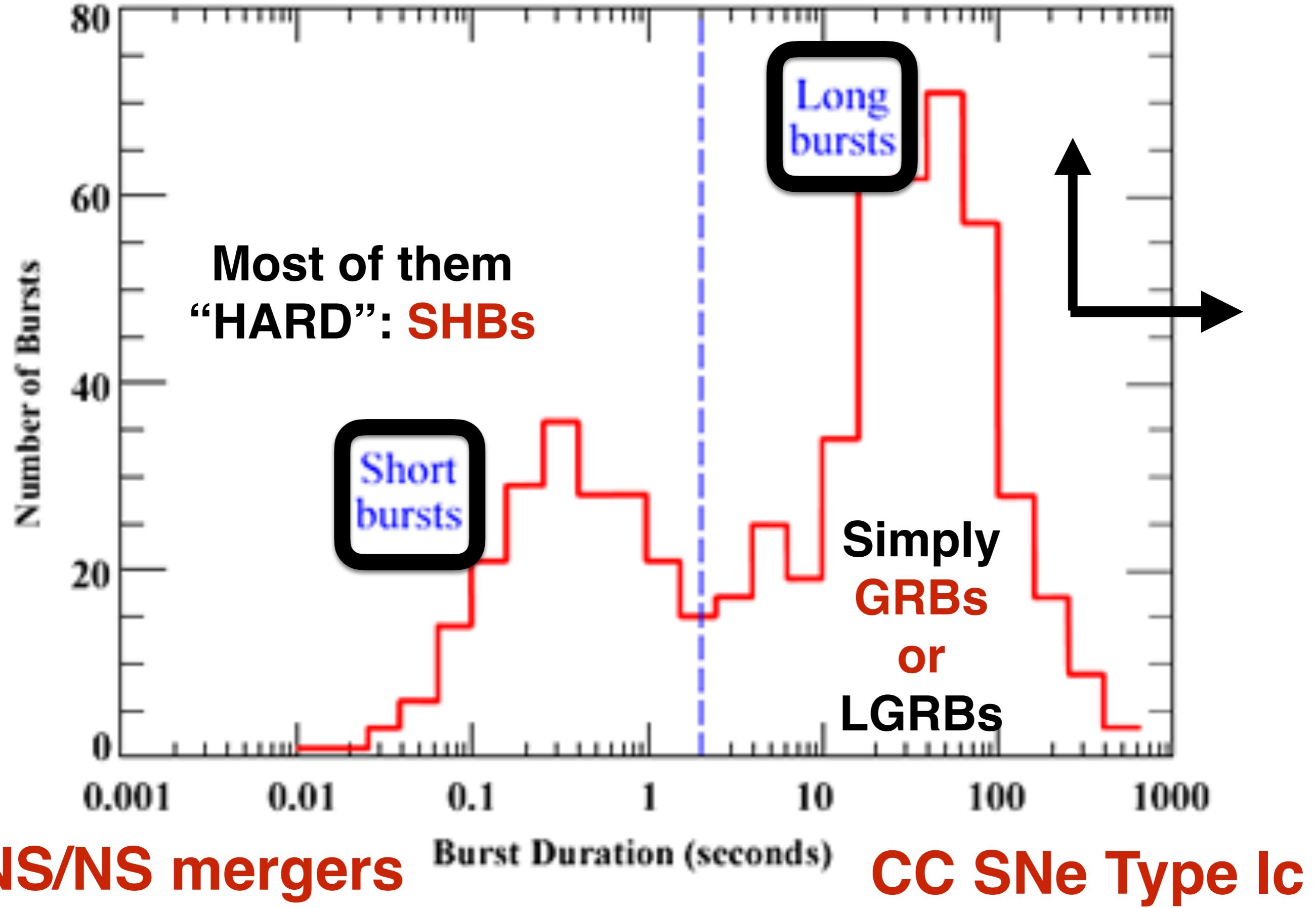
Duration of gamma-ray BURSTS



Duration of gamma-ray BURSTs



Duration of gamma-ray BURSTs



Goodman, Dar and Nussinov (1987)

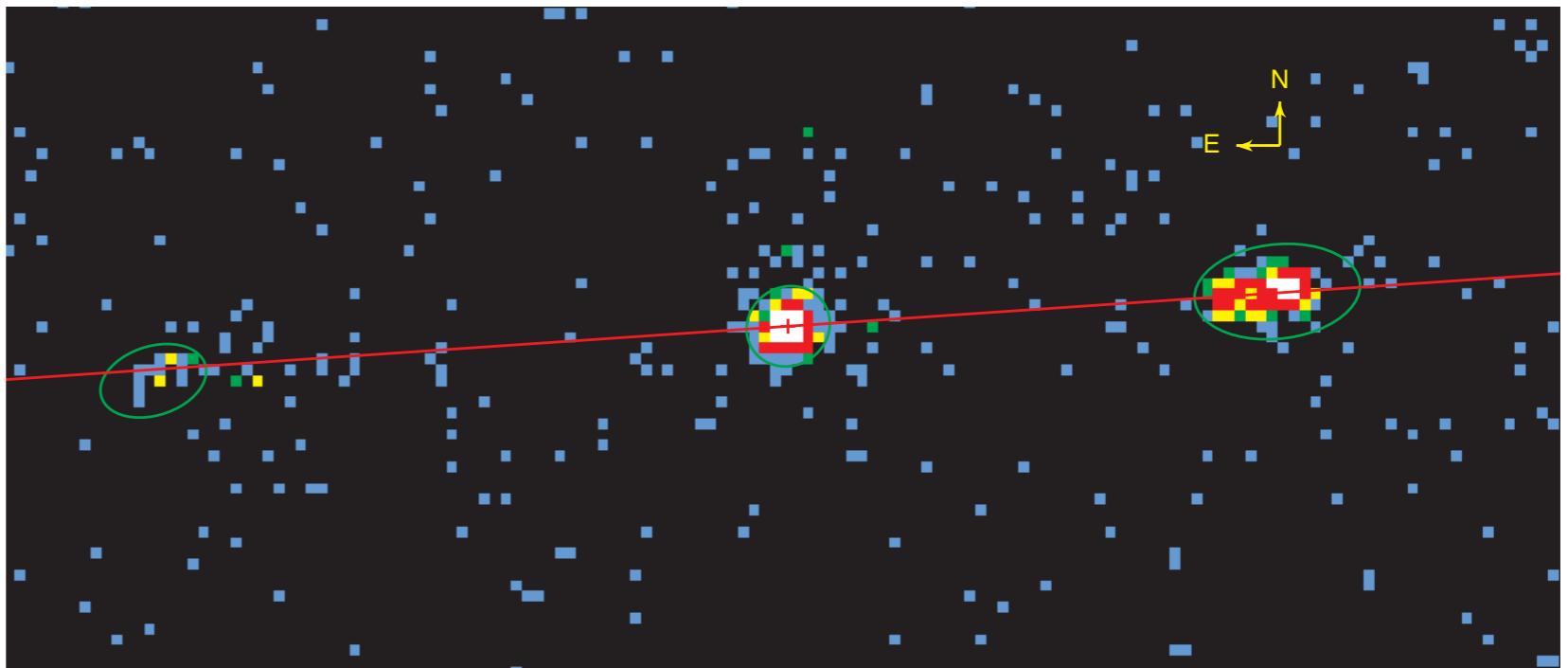
Arnon Dar and collaborators

Systematically: **Shlomo Dado**

Occasionally: ADR

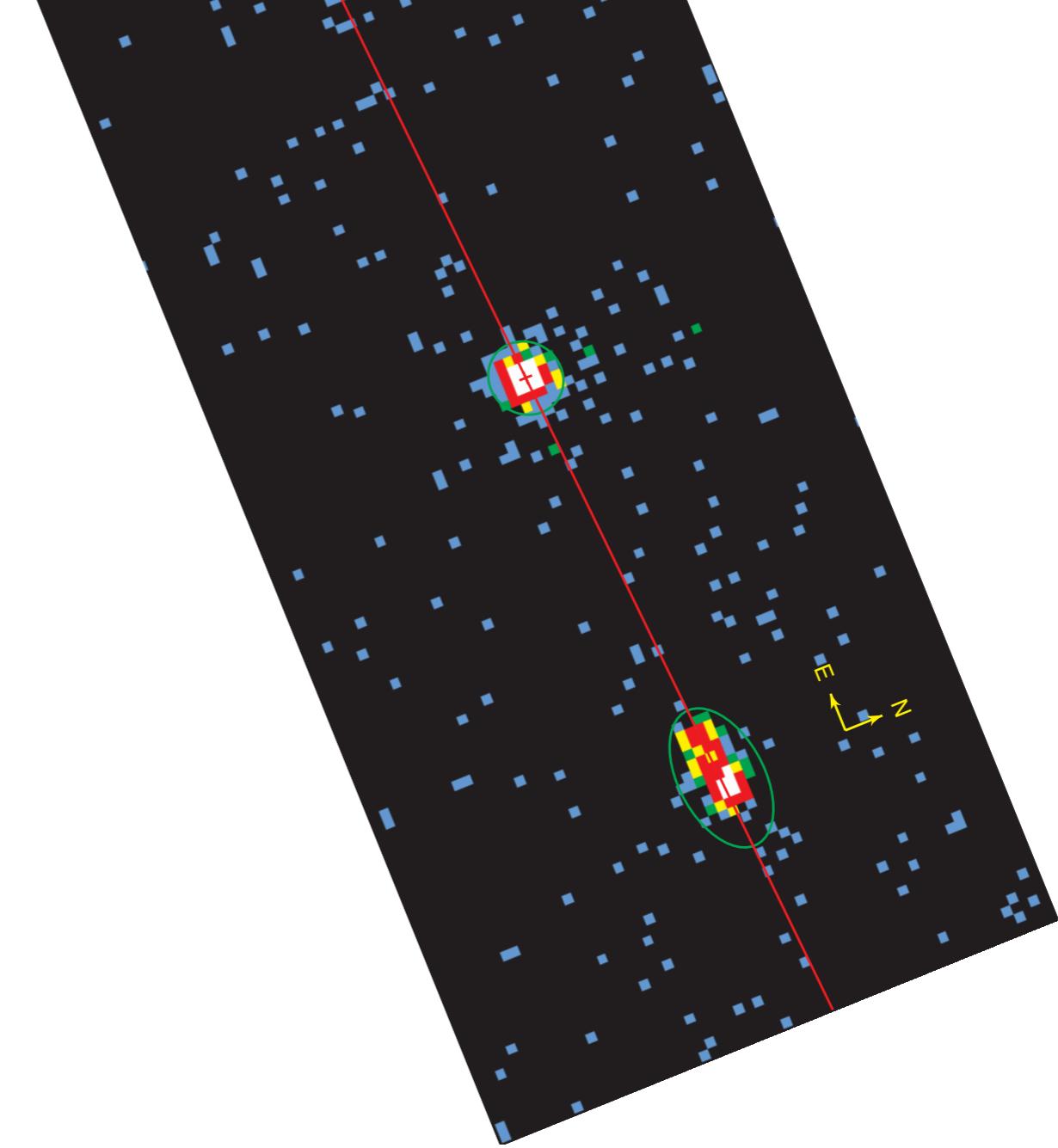
μ -QUASAR

XTE J1550-564



μ -QUASAR

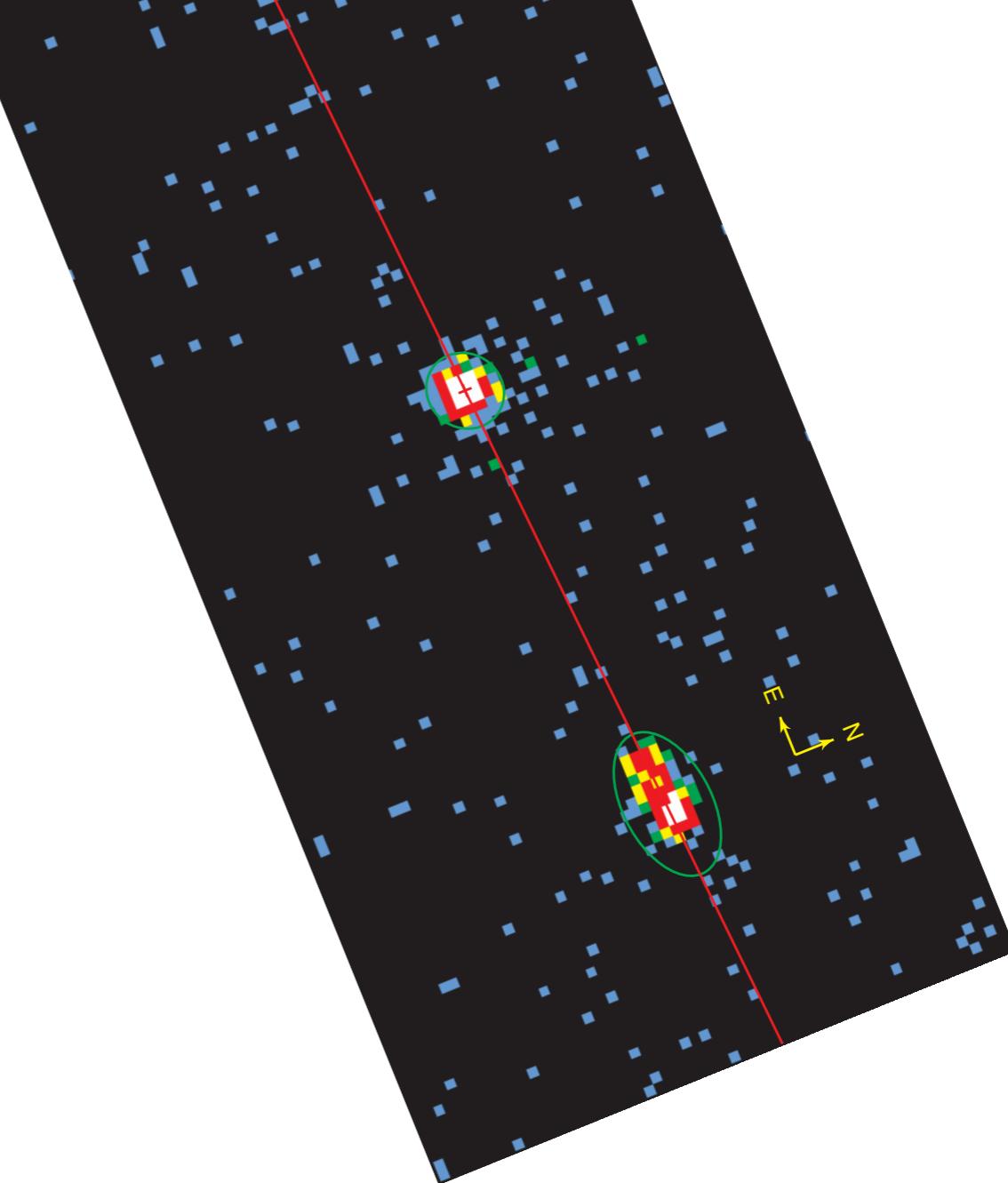
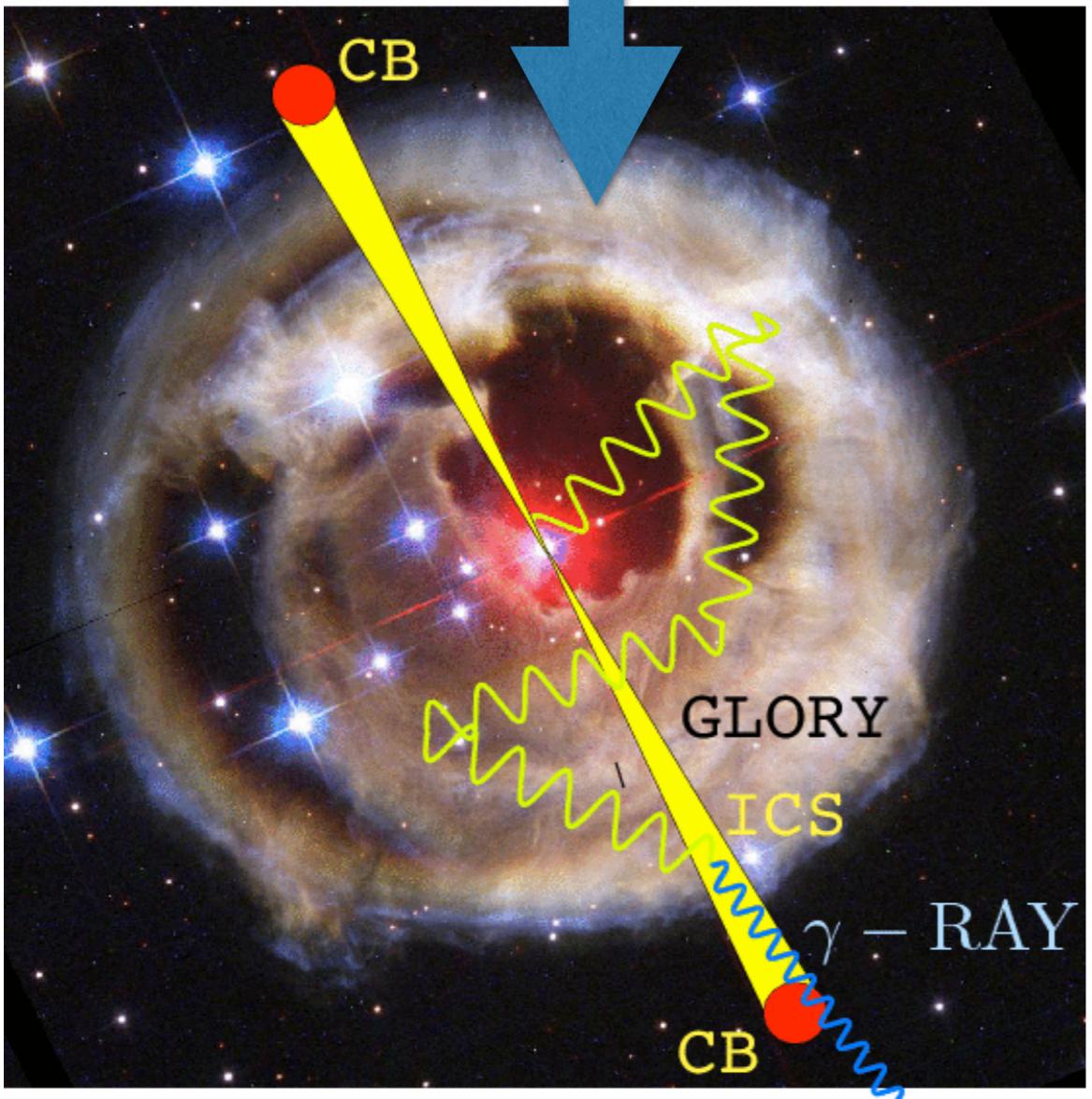
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μ -QUASAR

XTE J1550-564

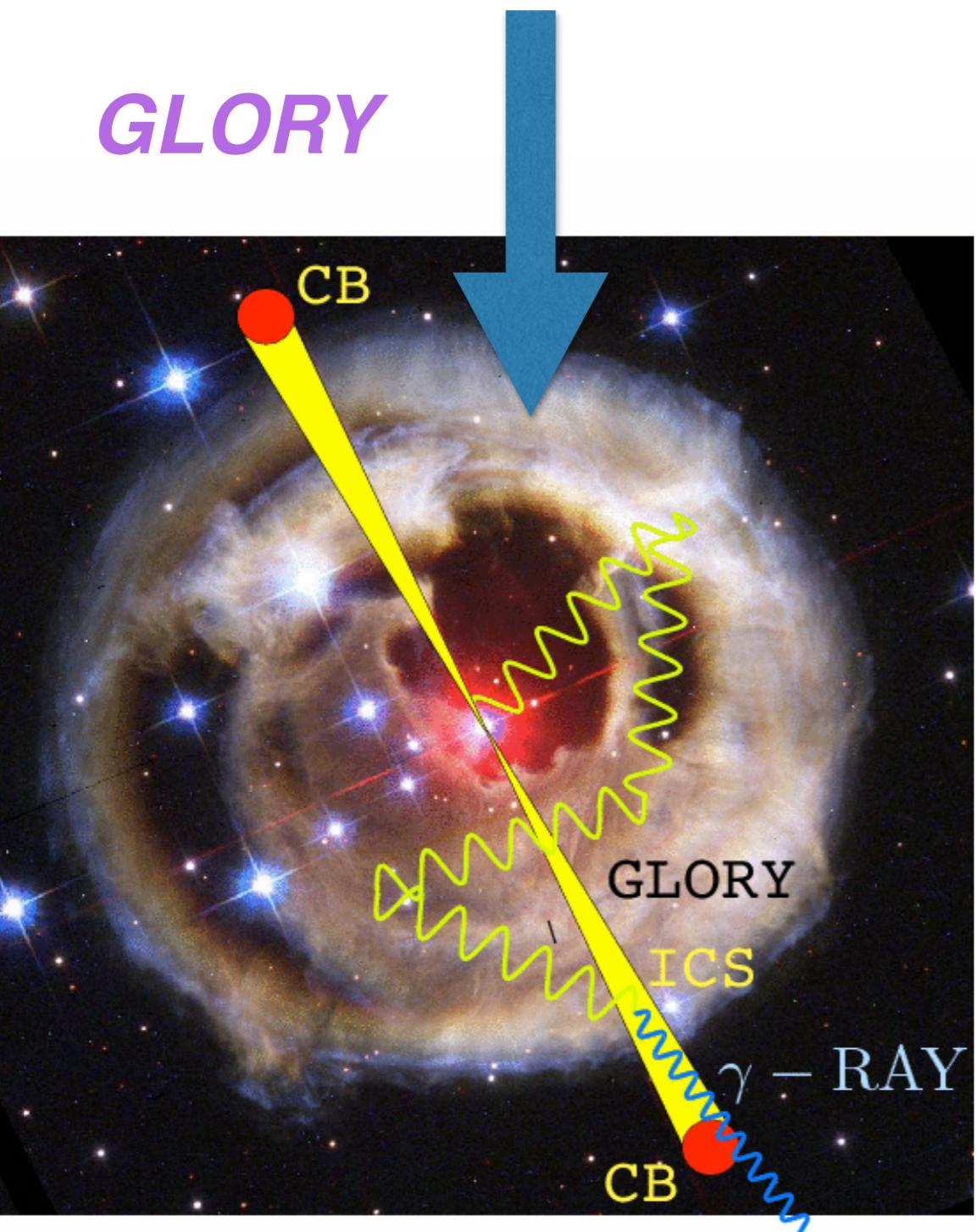
GLORY



μ -QUASAR

XTE J1550-564

GLORY



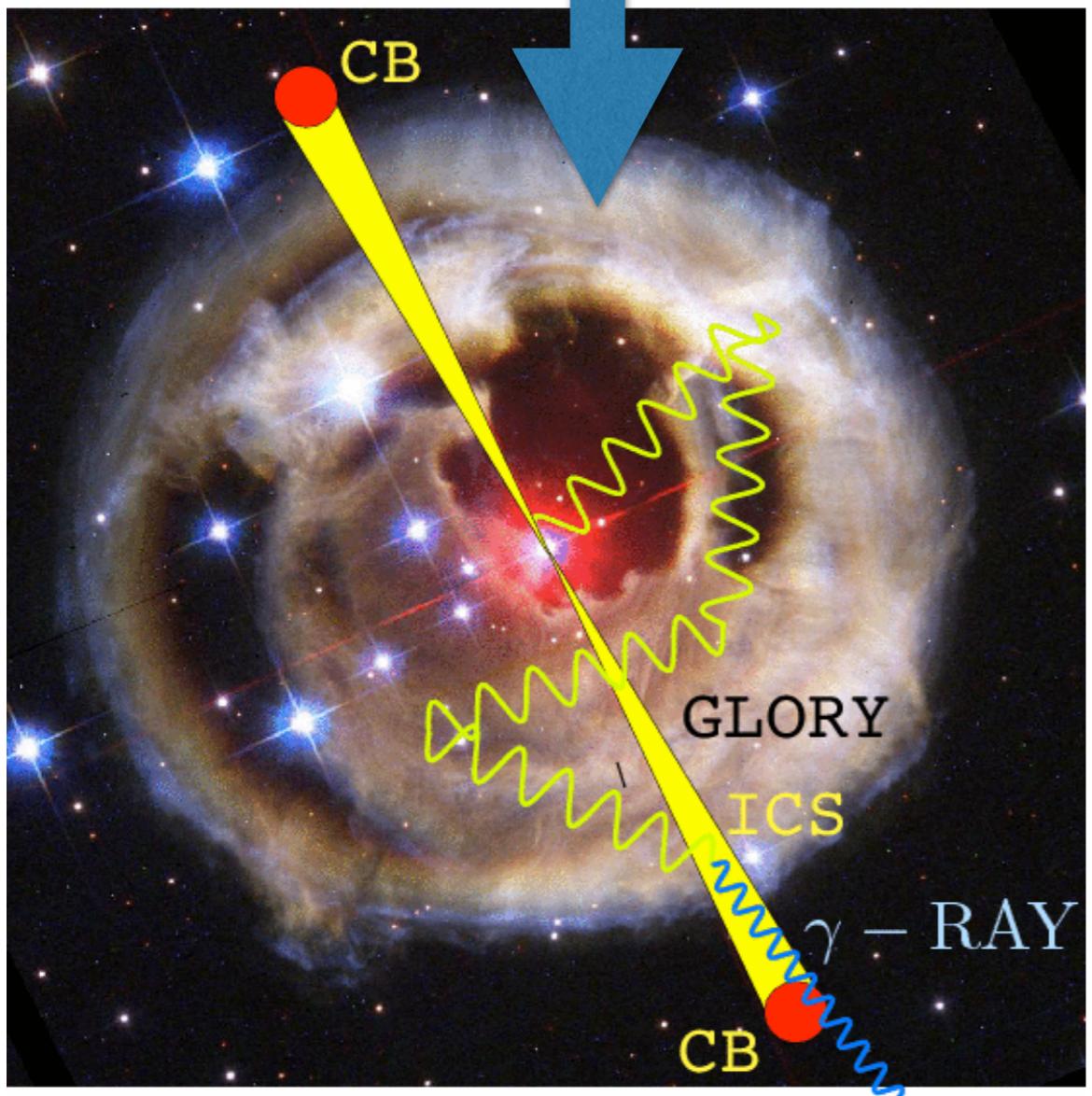
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GLORY



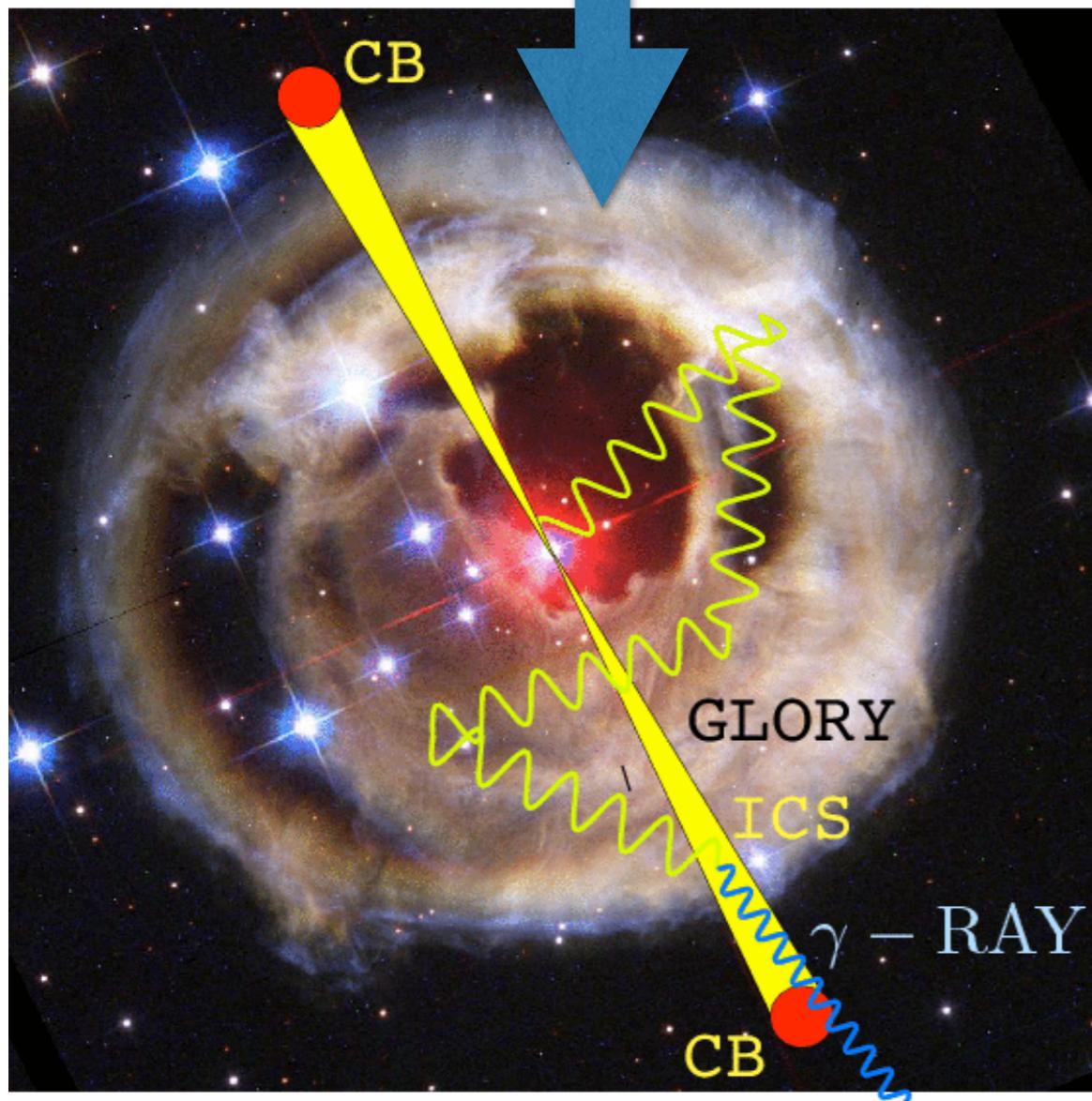
GRB



μ -QUASAR

XTE J1550-564

GLORY



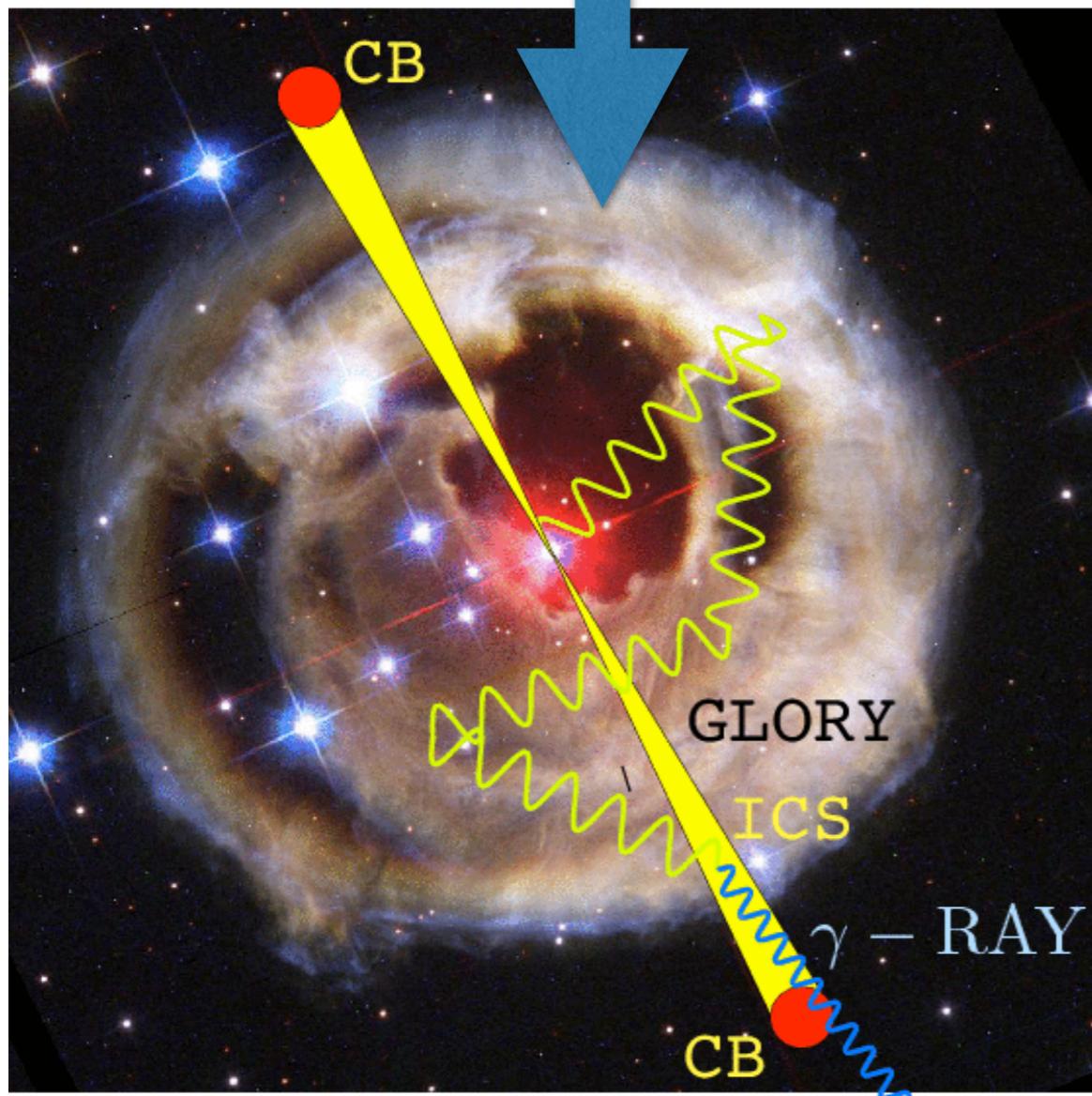
GRB

Type Ic **CORE-COLLAPSE SUPERNOVA**
axially emits
relativistic
Ord.-matter
CANNONBALLS

μ -QUASAR

XTE J1550-564

GLORY



GRB

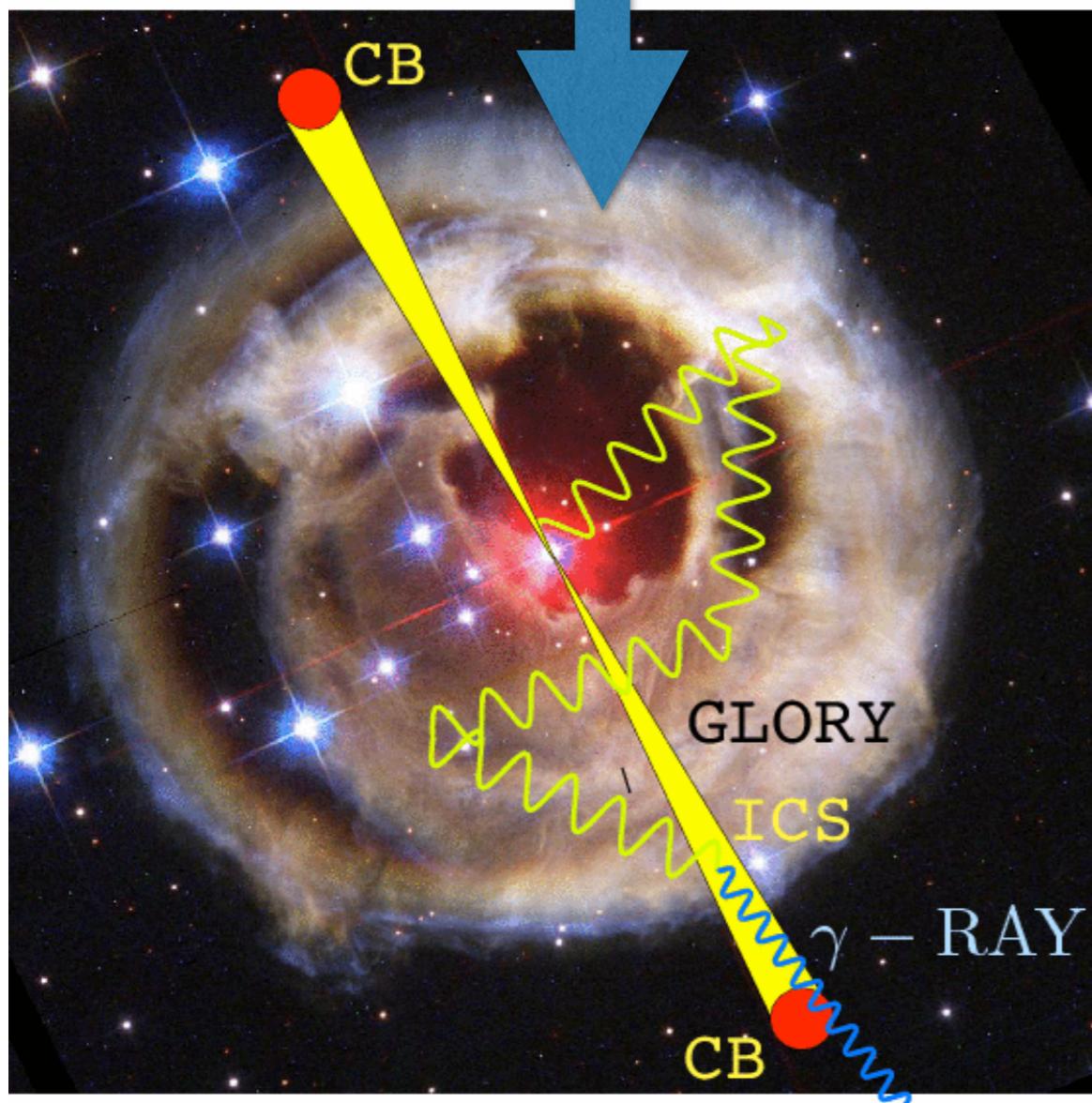
Type Ic **CORE-COLLAPSE SUPERNOVA**
axially emits
relativistic
Ord.-matter
CANNONBALLS

Glory's light
is **INVERSE COMPTON SCATTERED**
by the CB's
electrons

μ -QUASAR

XTE J1550-564

GLORY



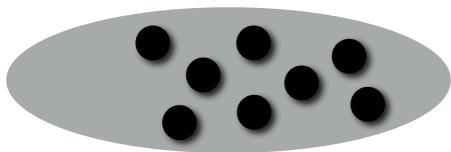
GRB

Type Ic **CORE-COLLAPSE SUPERNOVA**
axially emits relativistic Ord.-matter **CANNONBALLS**
ONE CB \rightarrow a **NARROW GRB PULSE** of γ -RAYS

Glory's light
is **INVERSE COMPTON SCATTERED**
by the CB's electrons

Gamma-Ray Emission Mechanism

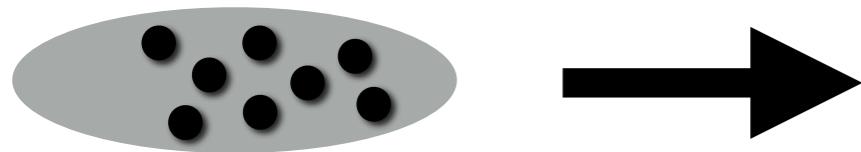
CB Model



Gamma-Ray Emission Mechanism

CB Model

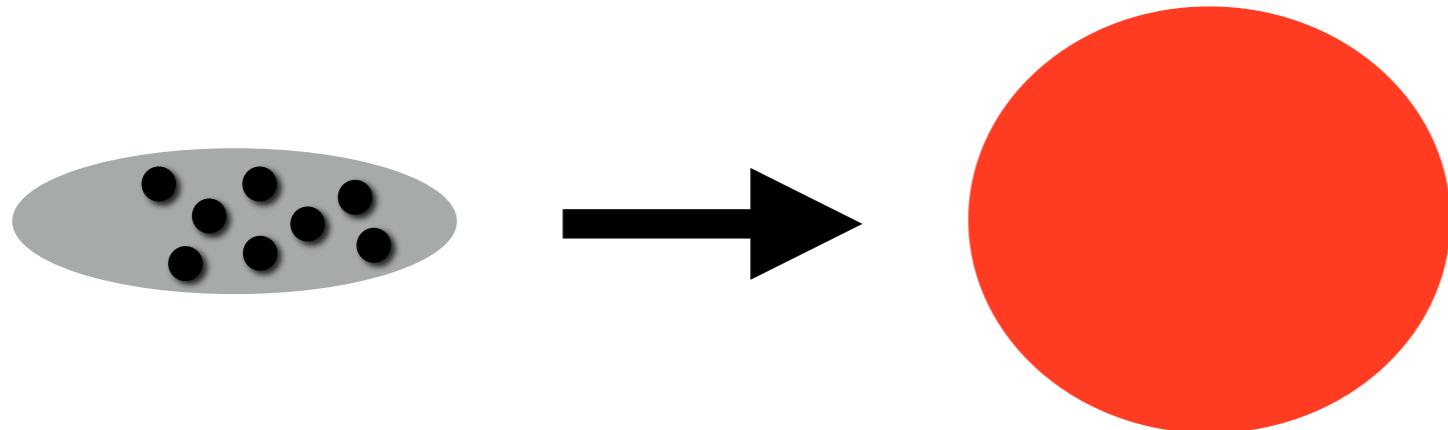
$$\gamma_0 = E_e / (m_e c^2)$$



Gamma-Ray Emission Mechanism

CB Model

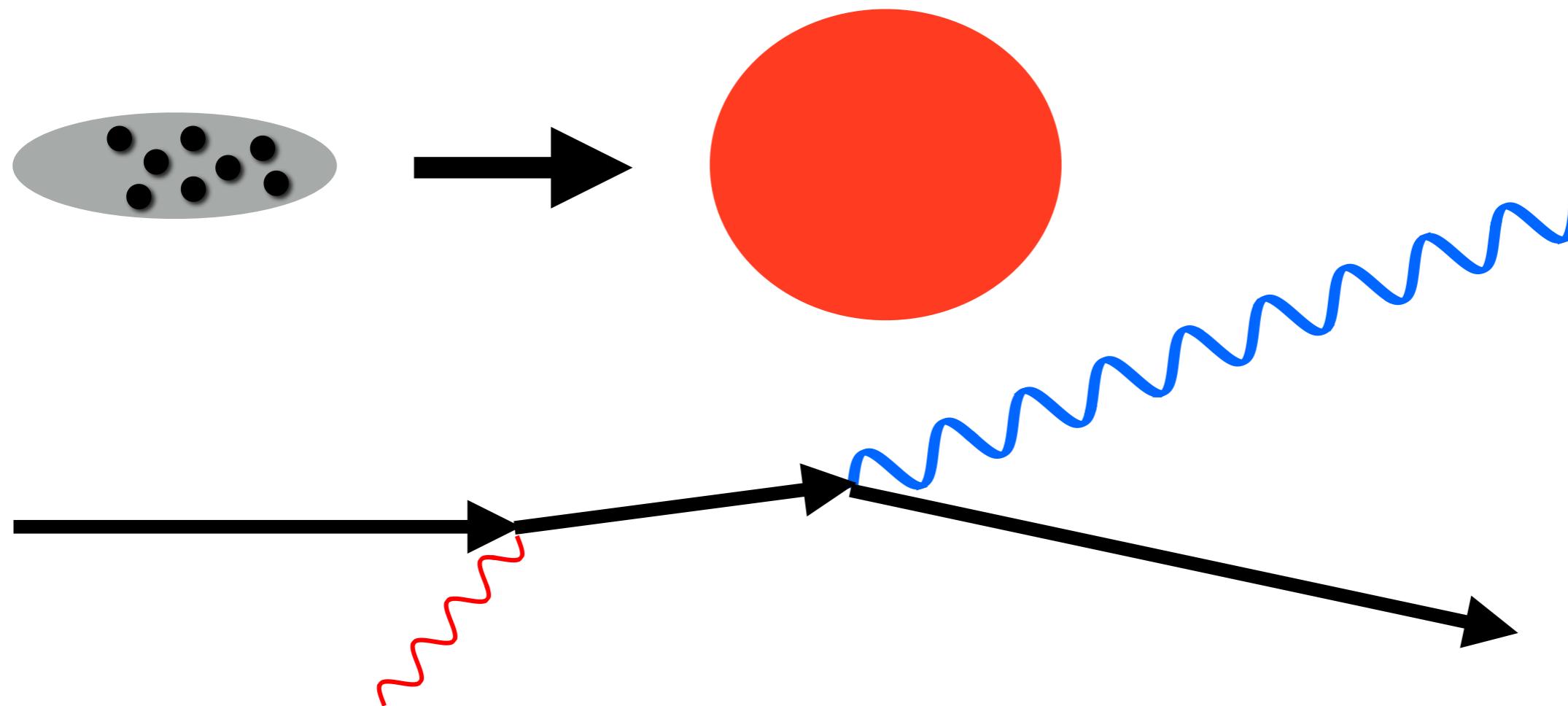
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Gamma-Ray Emission Mechanism

CB Model

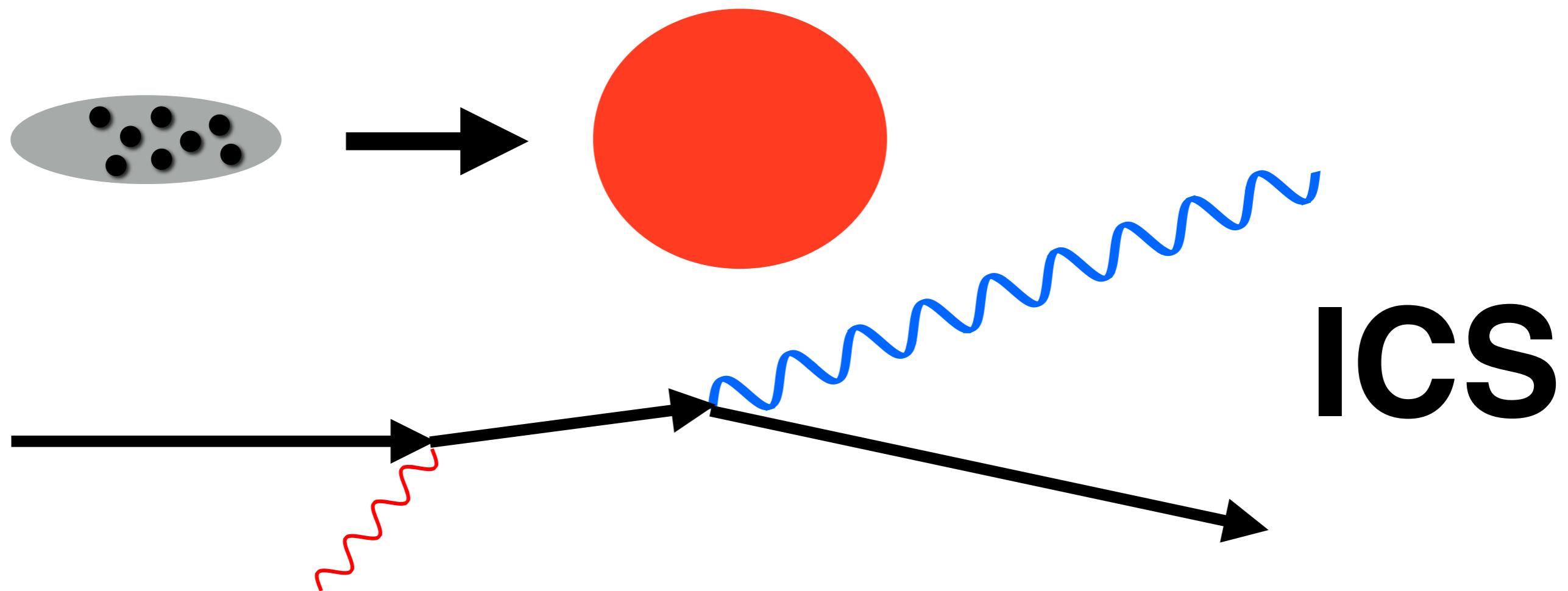
$$\gamma_0 = E_e / (m_e c^2)$$



Gamma-Ray Emission Mechanism

CB Model

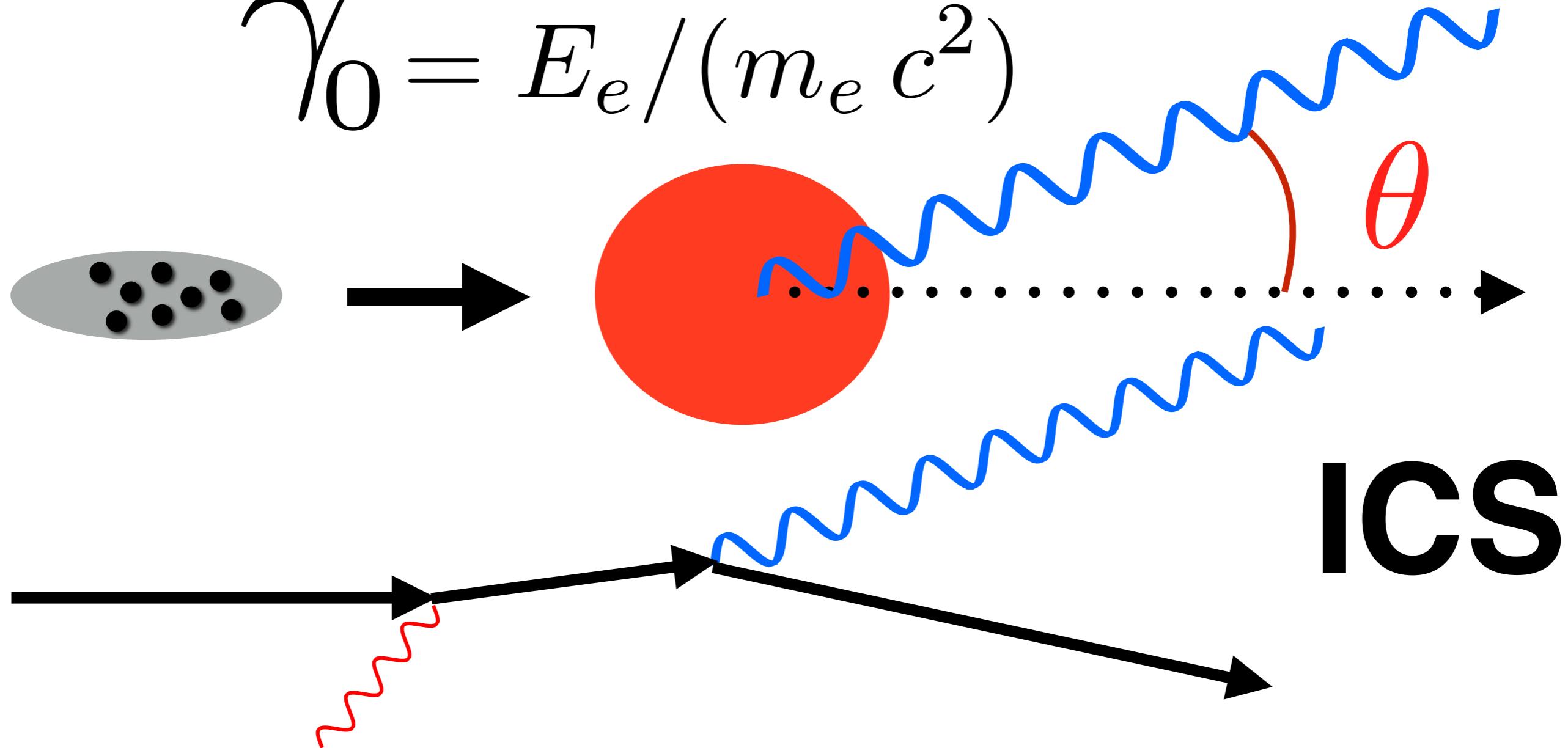
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Gamma-Ray Emission Mechanism

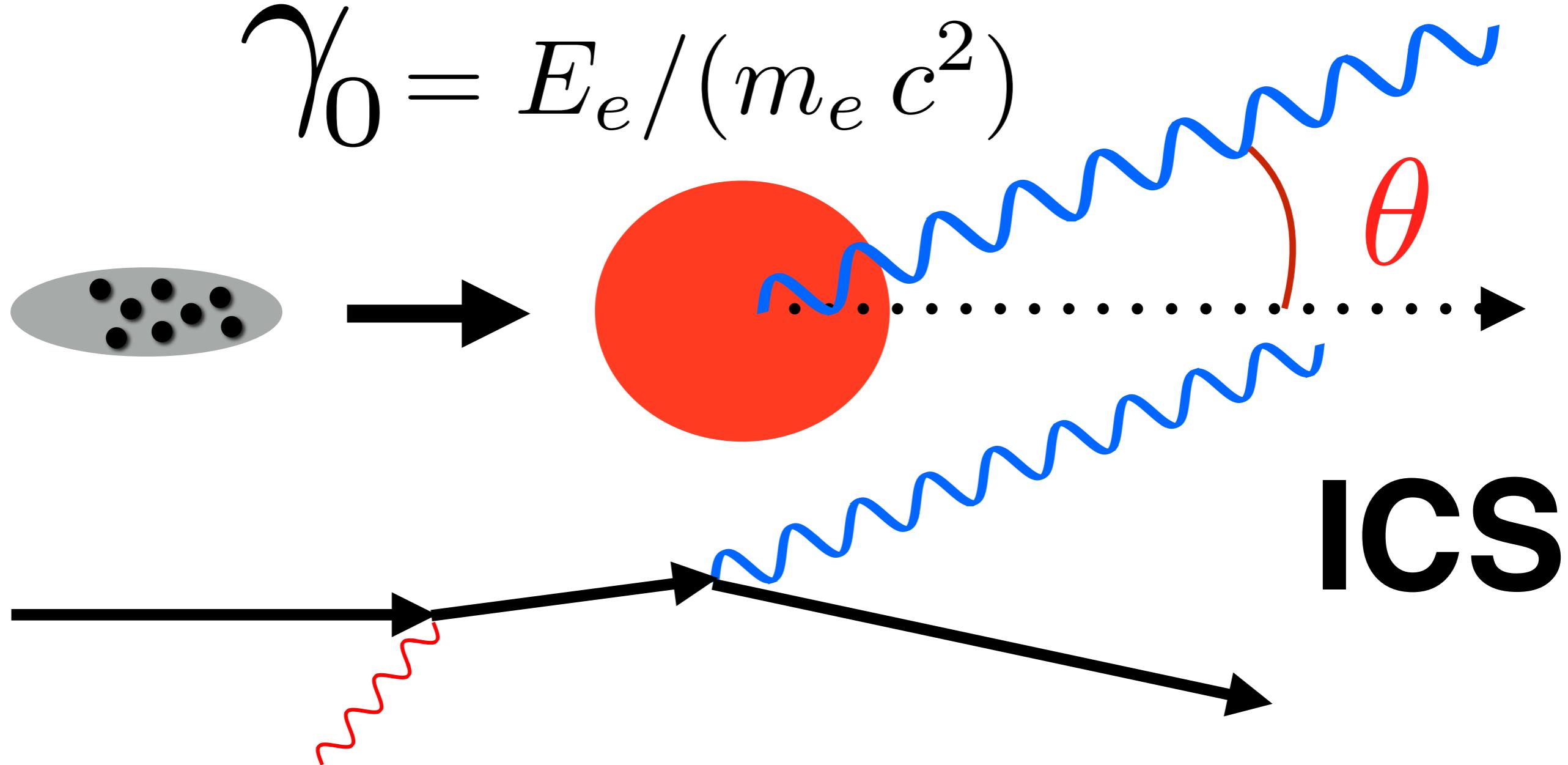
CB Model

$$\gamma_0 = E_e / (m_e c^2)$$



Gamma-Ray Emission Mechanism

CB Model



*Very forward photon beam of
precisely calculable properties*

Pulse shape

Thin thermal brems

$$dn_g/d\epsilon \propto \epsilon^{-\alpha} \exp[-\epsilon/\epsilon_p] \quad n_g(r) \propto 1/r^2$$

$$E \frac{d^2 N_\gamma}{dE dt} \propto \frac{t^2}{(t^2 + \Delta^2)^2} E^{1-\alpha} \exp\left[-\frac{E}{\mathcal{E}_p(t)}\right]$$

$$\mathcal{E}_p(t) \approx E_p \left[1 - \frac{t}{\sqrt{t^2 + \tau^2}} \right]$$

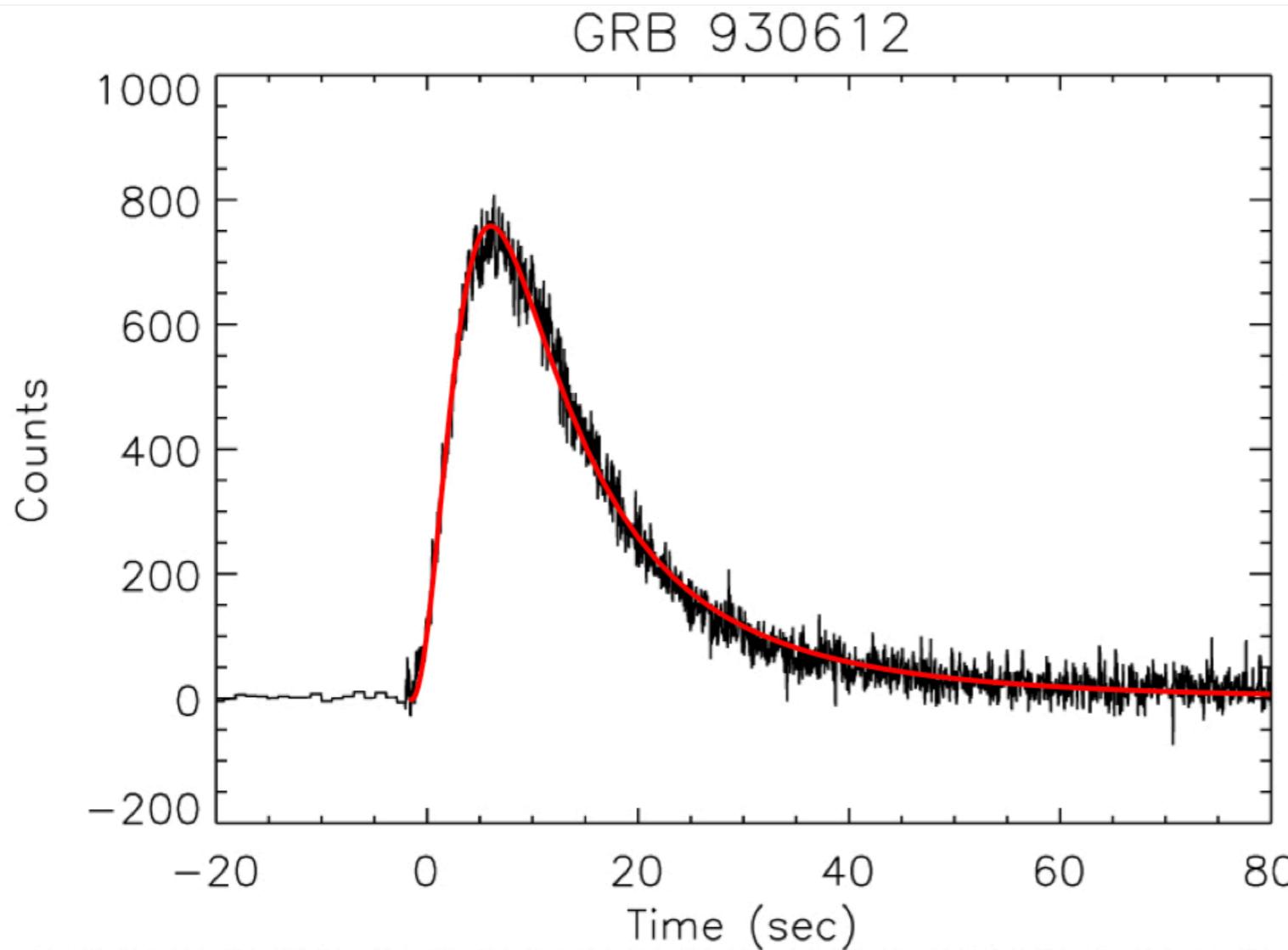
$$\tau = R_g \frac{(1+z)}{\gamma \delta c}$$

Pulse shape

Thin thermal brems

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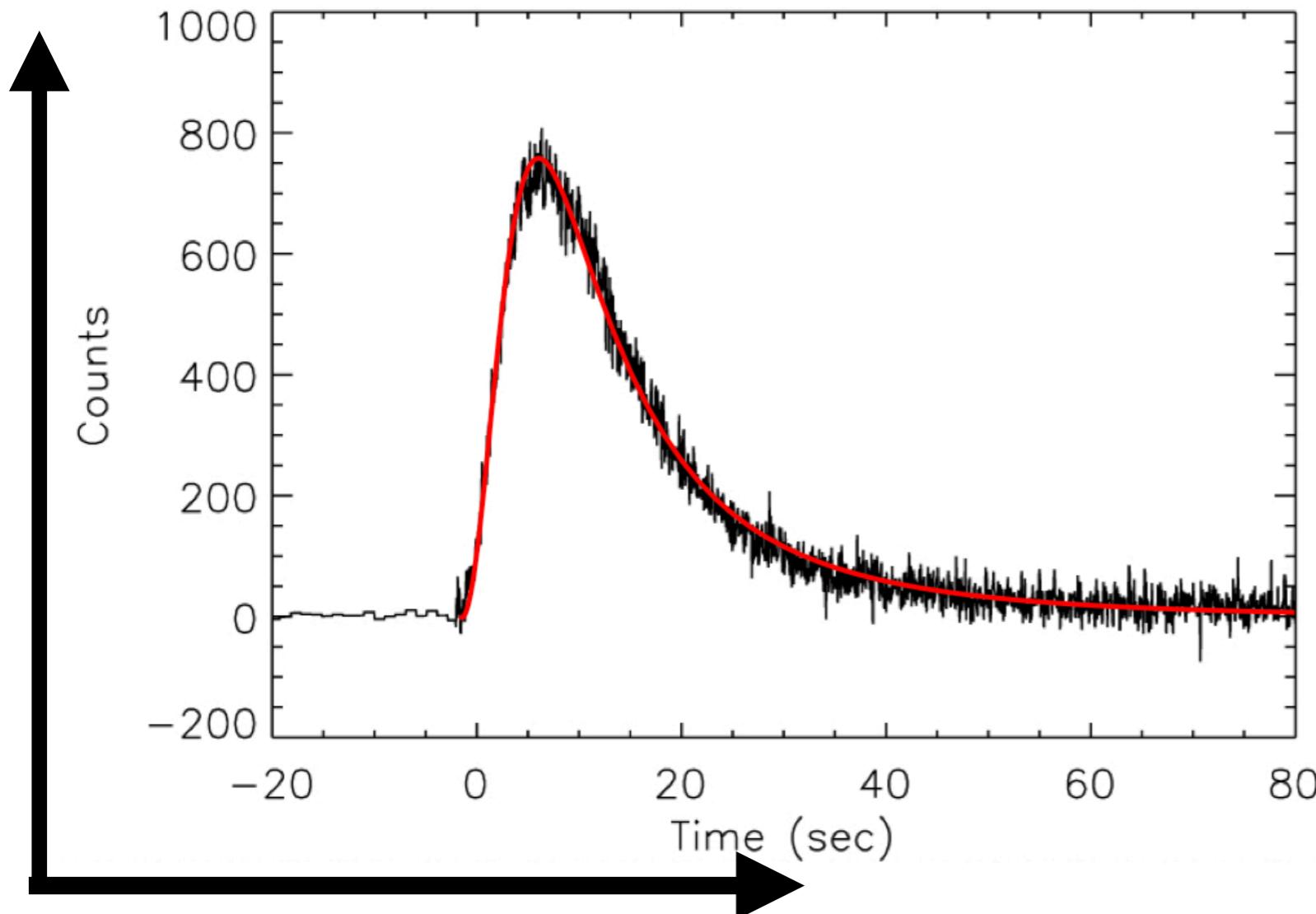
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GRB 930612



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$$\tau = R_g \frac{(1+z)}{\gamma \delta c}$$

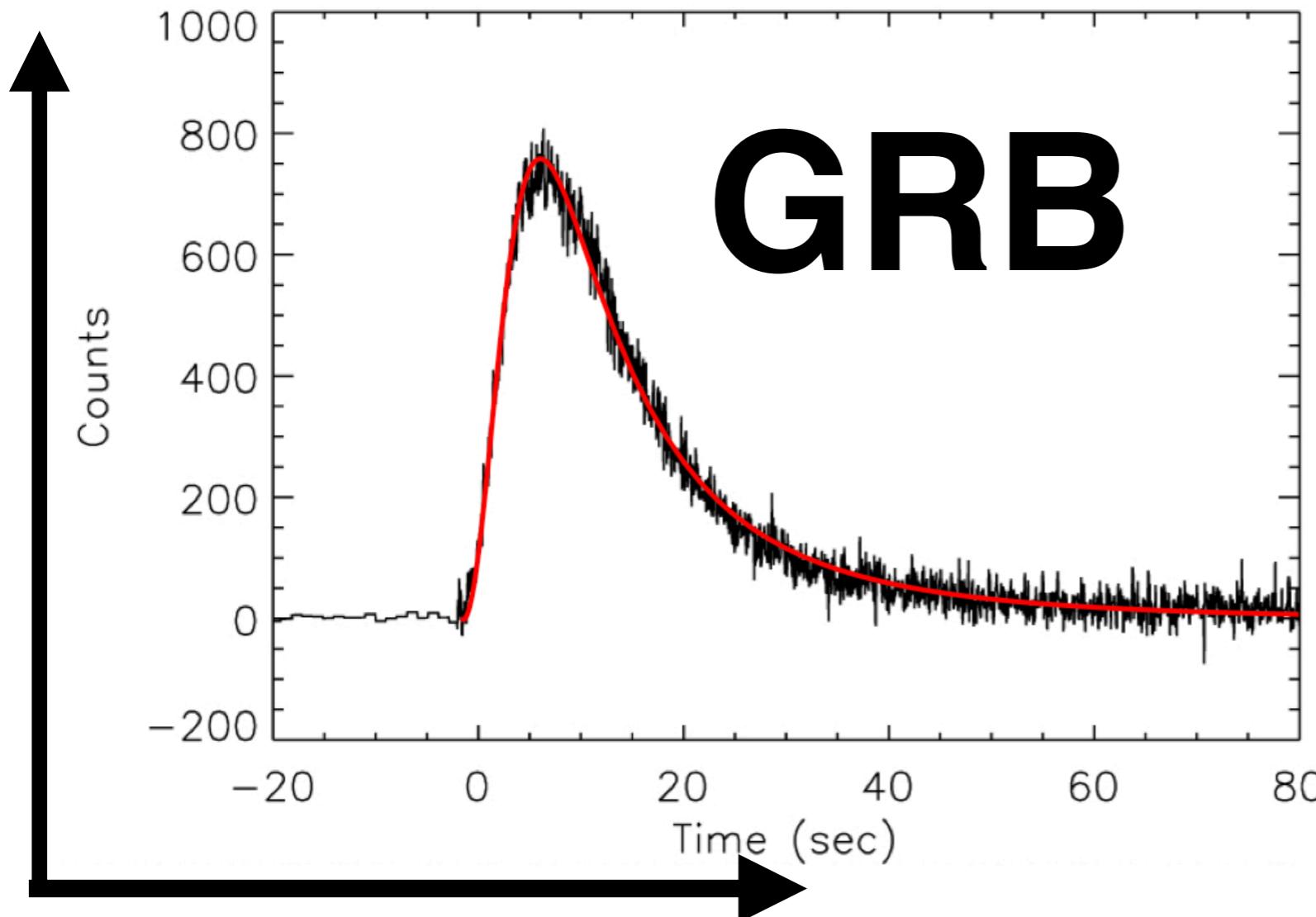
Pulse shape

Thin thermal brems

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GRB 930612

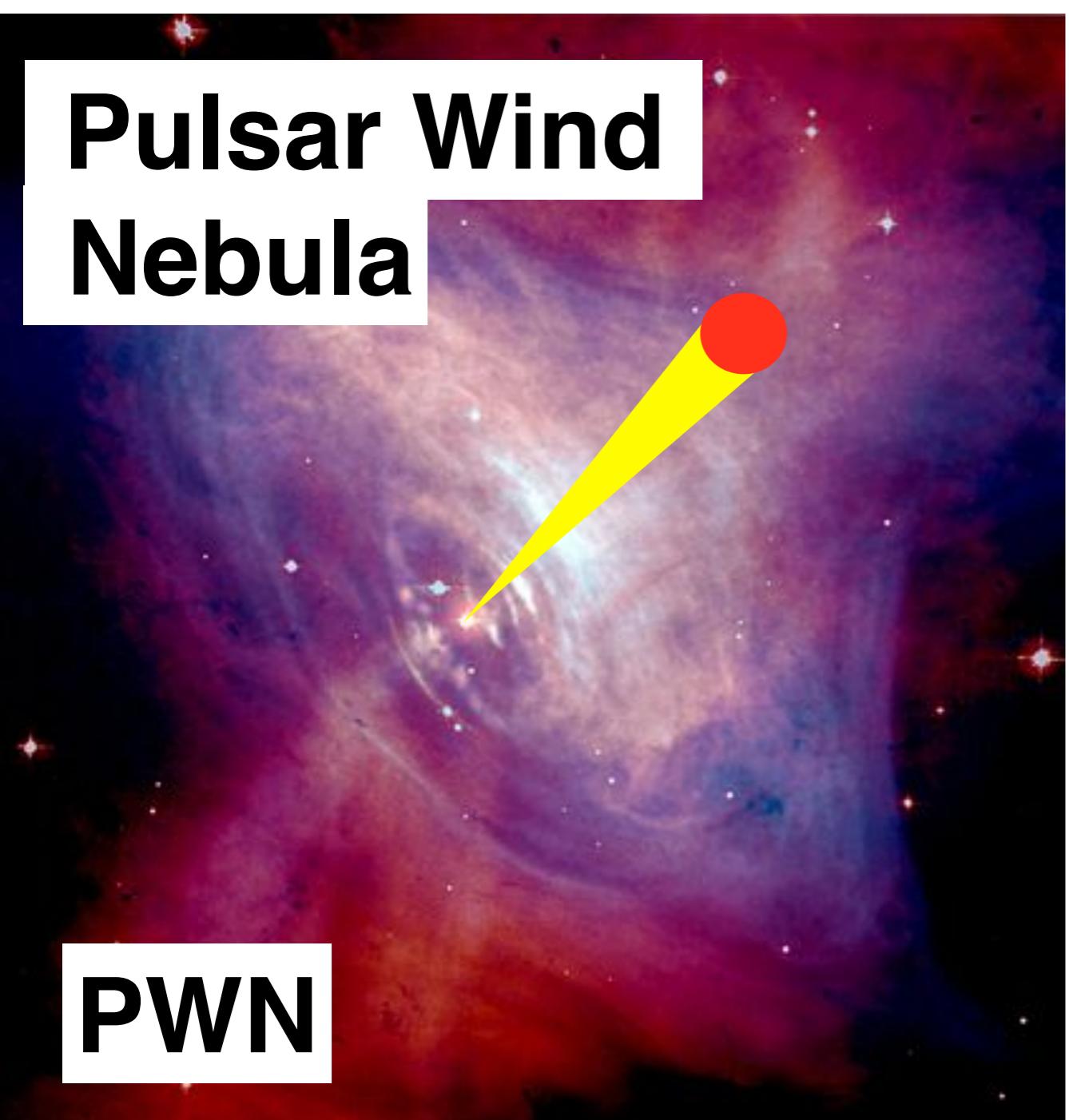


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Pulsar Wind Nebula

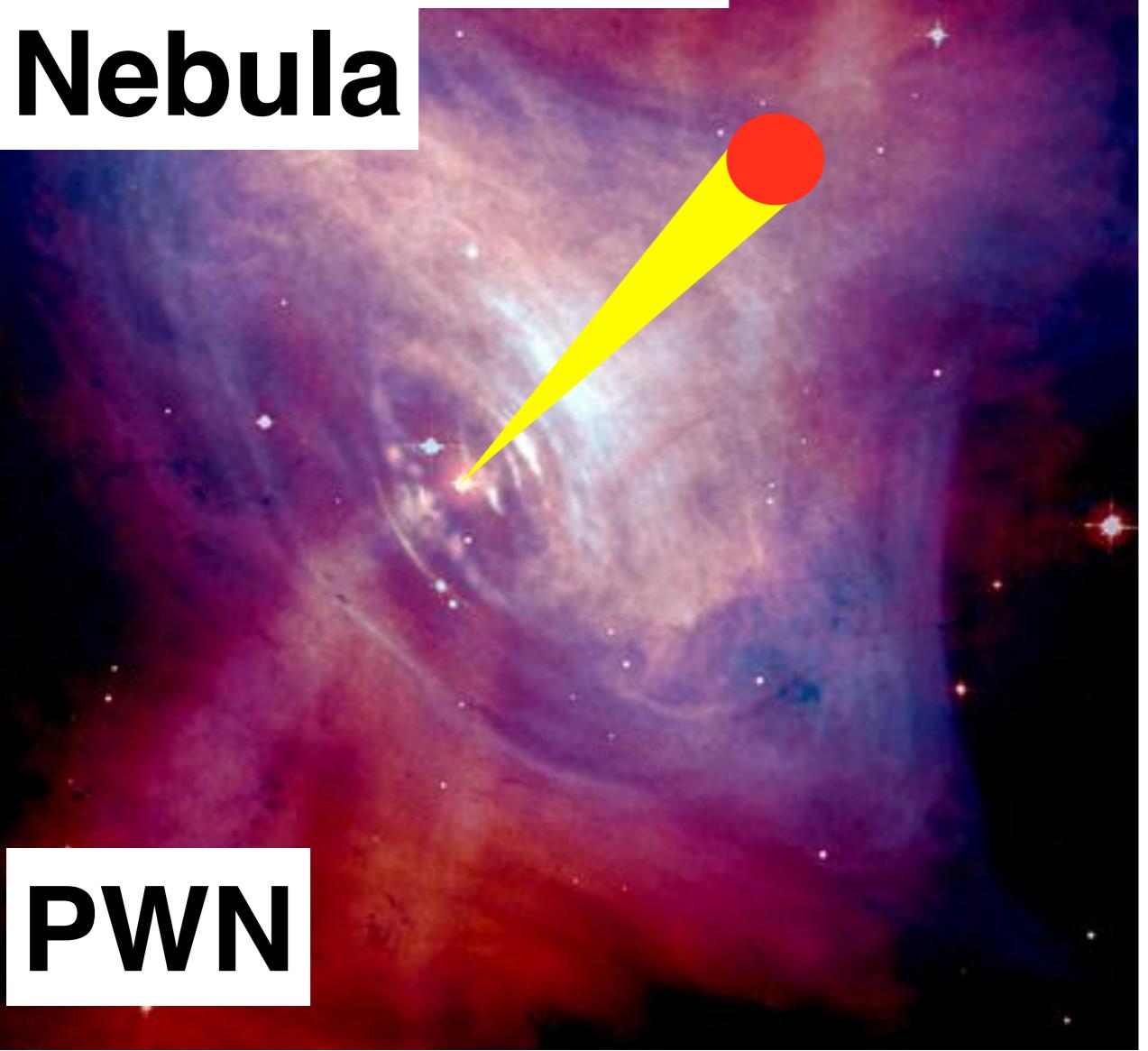
PWN



The inner [Crab Nebula](#). Central part:
the pulsar wind nebula (PWN);
red star in the centre is [Crab Pulsar](#).
Optical data [Hubble](#) (red) and [X-ray](#)
[Chandra](#) (in blue).

Pulsar Wind Nebula

SHB



PWN

The inner [Crab Nebula](#). Central part:
the pulsar wind nebula (PWN);
red star in the centre is [Crab Pulsar](#).
Optical data [Hubble](#) (red) and [X-ray](#)
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Pulsar Wind Nebula



PWN

SHB
NS NS Fusion

The inner [Crab Nebula](#). Central part:
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Pulsar Wind Nebula



PWN

SHB
NS NS Fusion
detected in GWs

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Pulsar Wind Nebula



PWN

The inner [Crab Nebula](#). Central part: the pulsar wind nebula (PWN); red star in the centre is [Crab Pulsar](#). Optical data [Hubble](#) (red) and [X-ray Chandra](#) (in blue).

SHB
NS NS Fusion
detected in GWs

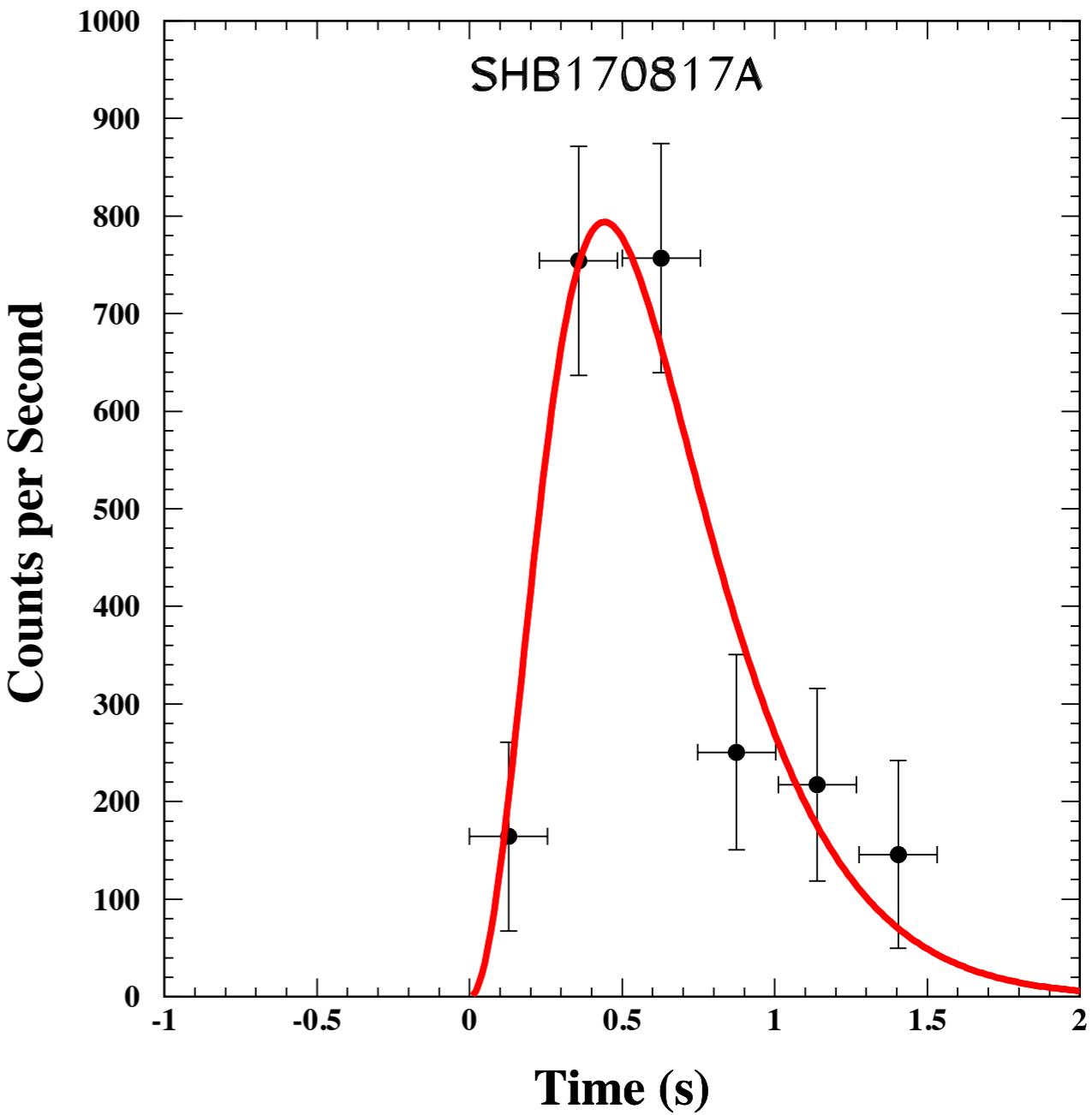


Table 1. GRBs with measured γ -ray polarization during the prompt emission.

GRB	Polarization(%)	CL	Reference [41]	Polarimetry
930131	$> 35,$	90%	Willis et al. 2005	BATSE (Albedo)
960924	> 50	90%	Willis et al. 2005	BATSE (Albedo)
021206	80 ± 20	???	Coburn & Boggs 2003	RHESSI
041219A	98 ± 33	68%	Kalemci et al. 2007	INTEGRAL-SPI
100826A	27 ± 11	99%	Yonetoku et al. 2011	IKARUS-GAP
110301A	70 ± 22	68%	Yonetoku et al. 2012	IKARUS-GAP
110721	$84 +16 / -28$	68%	Yonetoku et al. 2012	IKARUS-GAP
061122	> 60	68%	Gotz et al. 2013	INTEGRAL-IBIS
140206A	> 48	68%	Gotz et al. 2014	INTEGRAL-IBIS
160821A	$66 +27 / -26$	99%	Sharma et al. 2019	AstroSat-CZTI
190530A	55.4 ± 21.3	99%	Gupta et al. 2022	AstroSat-CZTI

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First of > 13 decisive tests

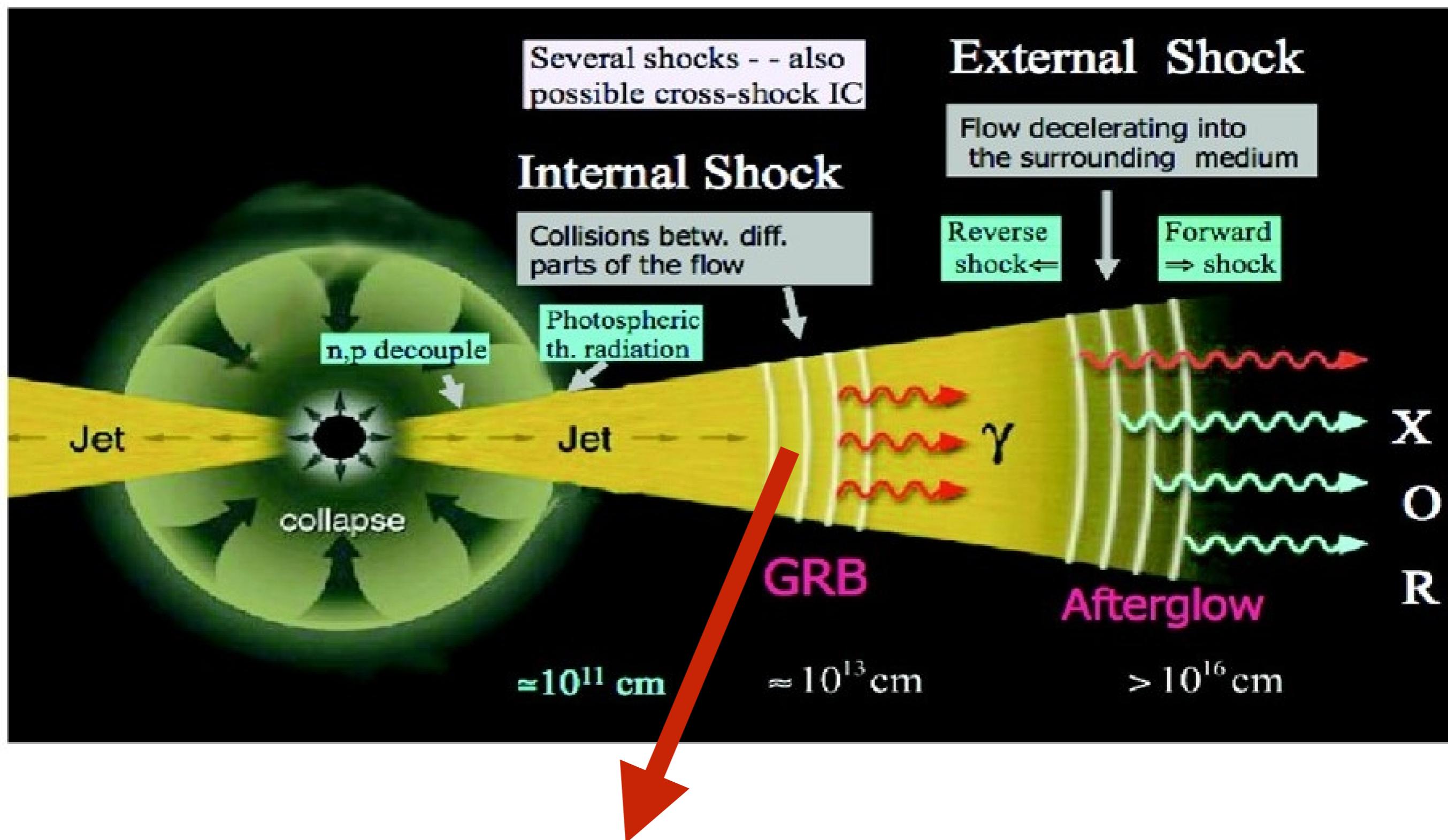
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First of > 13 decisive tests

... because ...

Gamma-Ray Emission Mechanism in FB Model



Electrons in turbulent shocks emit (unpolarized) SR

P. Meszaros,
M. J. Rees,
arXiv:1401.3012

Several shocks - - also
possible cross-shock IC

External Shock

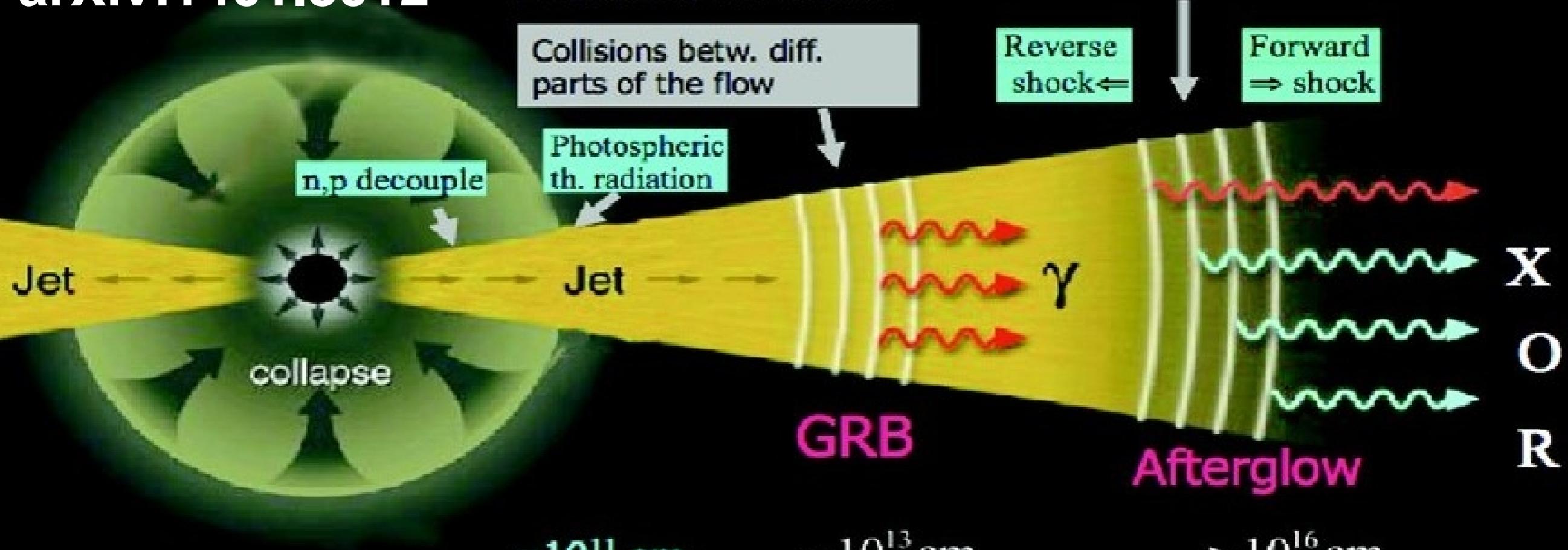
Flow decelerating into
the surrounding medium

Internal Shock

Collisions betw. diff.
parts of the flow

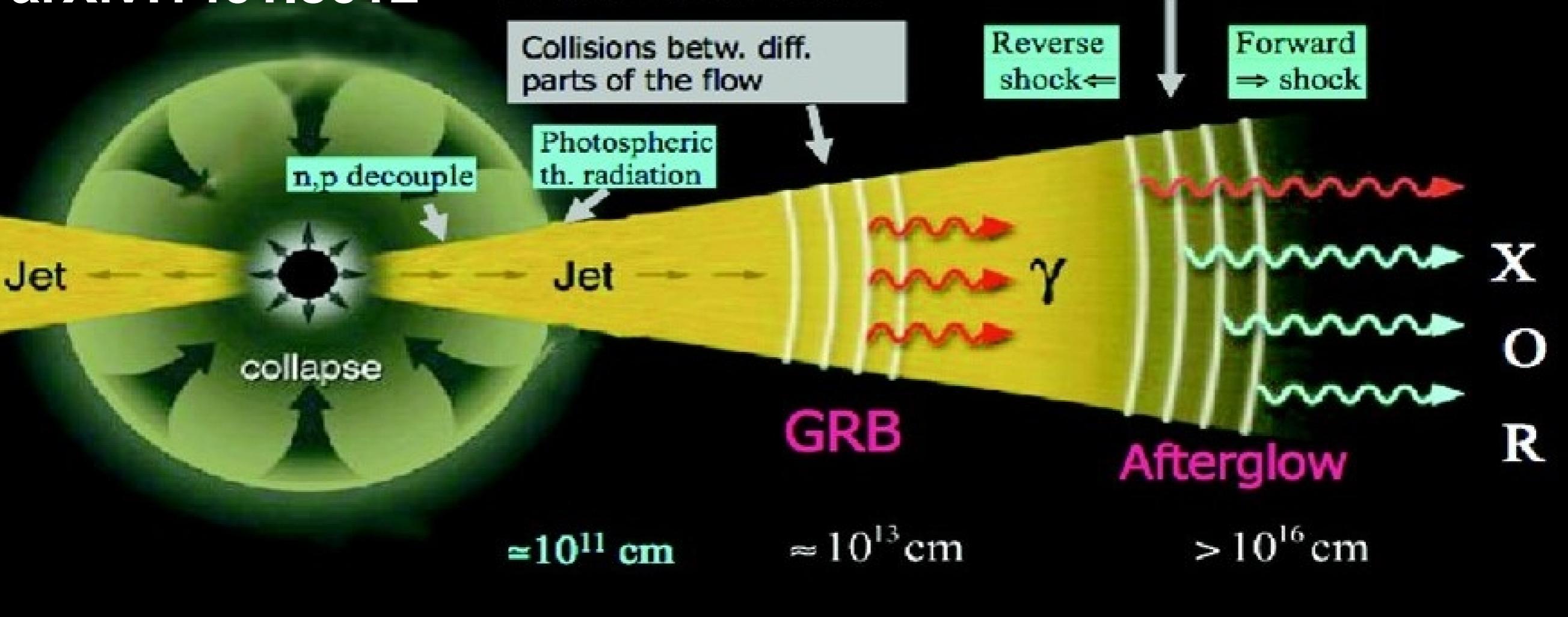
Reverse
shock \Leftarrow

Forward
 \Rightarrow shock



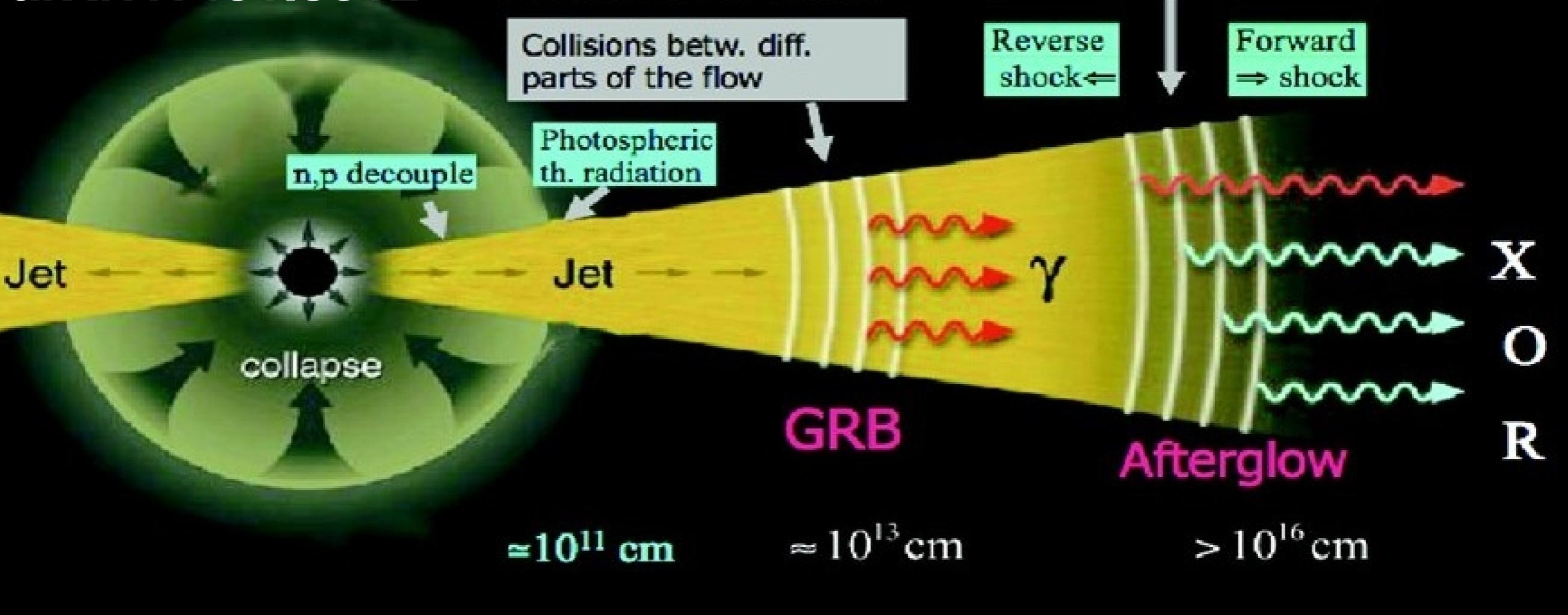
“Standard” Fireball Model of GRBs

P. Meszaros,
M. J. Rees,
arXiv:1401.3012



“Standard” Fireball Model of GRBs
Progenitor:

P. Meszaros,
M. J. Rees,
arXiv:1401.3012



“Standard” Fireball Model of GRBs
Progenitor: Failed SN

P. Meszaros,
M. J. Rees,
arXiv:1401.3012

Several shocks - - also
possible cross-shock IC

External Shock

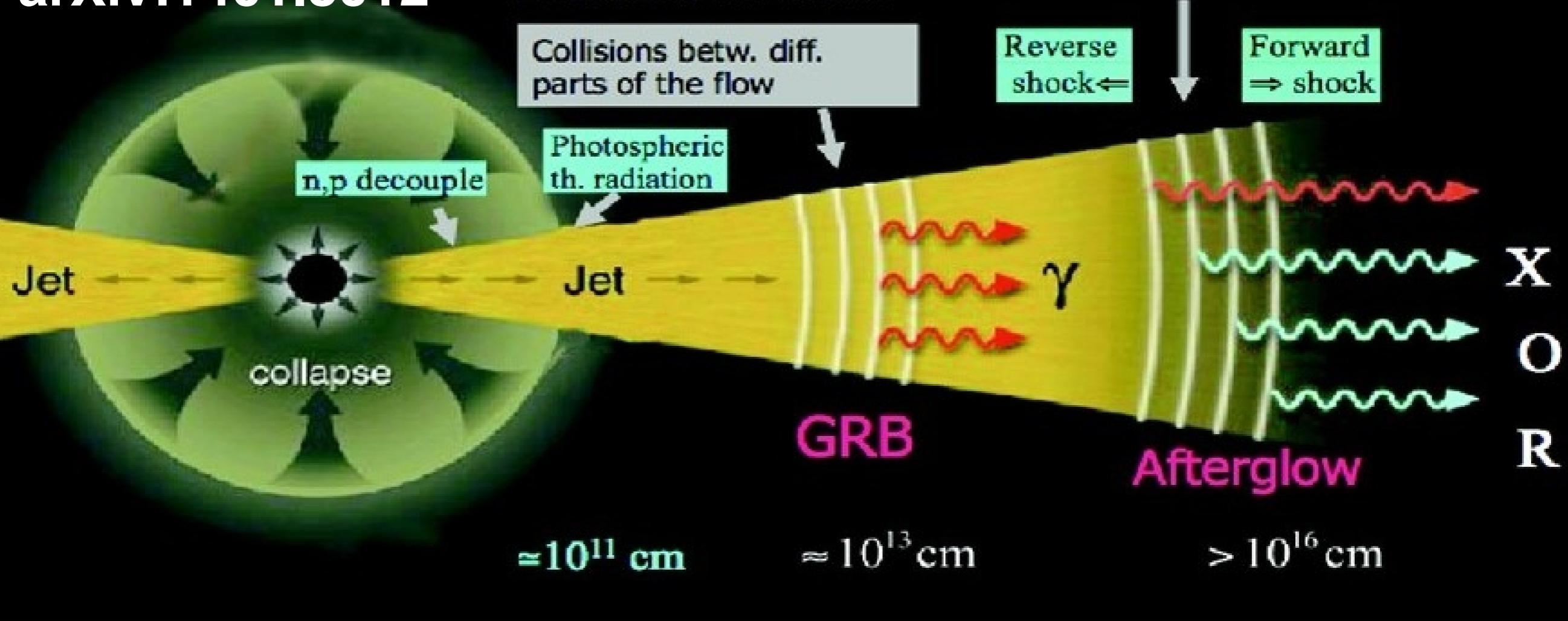
Flow decelerating into
the surrounding medium

Internal Shock

Collisions betw. diff.
parts of the flow

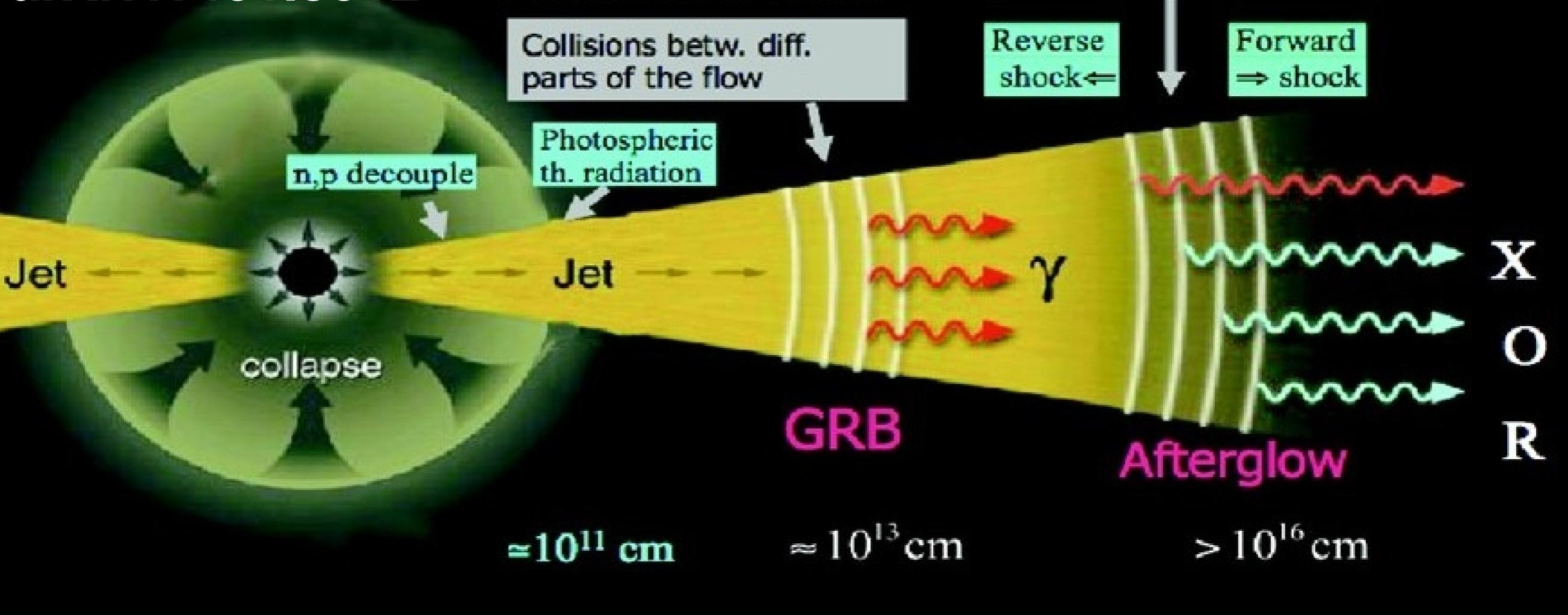
Reverse
shock \Leftarrow

Forward
 \Rightarrow shock



“Standard” Fireball Model of GRBs
Progenitor: Failed SN Hypernova

P. Meszaros,
M. J. Rees,
arXiv:1401.3012



“Standard” Fireball Model of GRBs
Progenitor: Failed SN Hypernova Macronova

P. Meszaros,
M. J. Rees,
arXiv:1401.3012

Several shocks - - also
possible cross-shock IC

External Shock

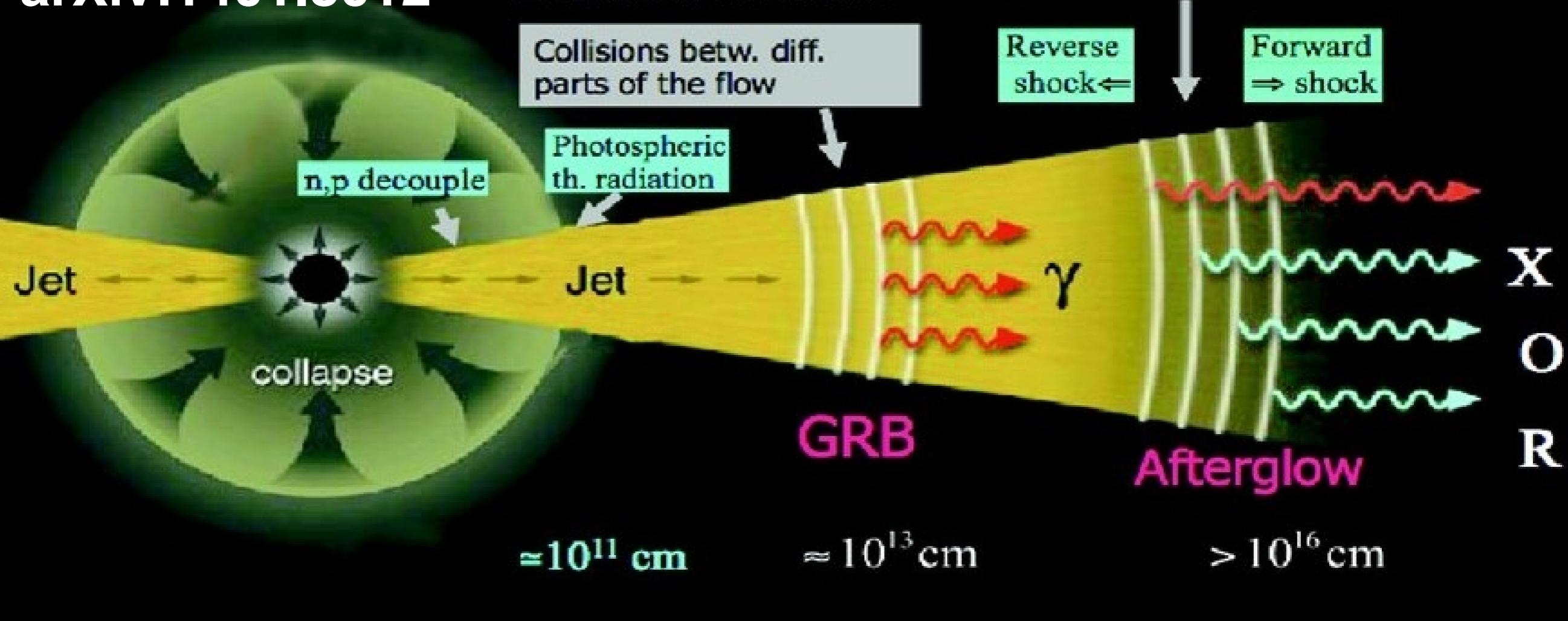
Flow decelerating into
the surrounding medium

Internal Shock

Collisions betw. diff.
parts of the flow

Reverse
shock \Leftarrow

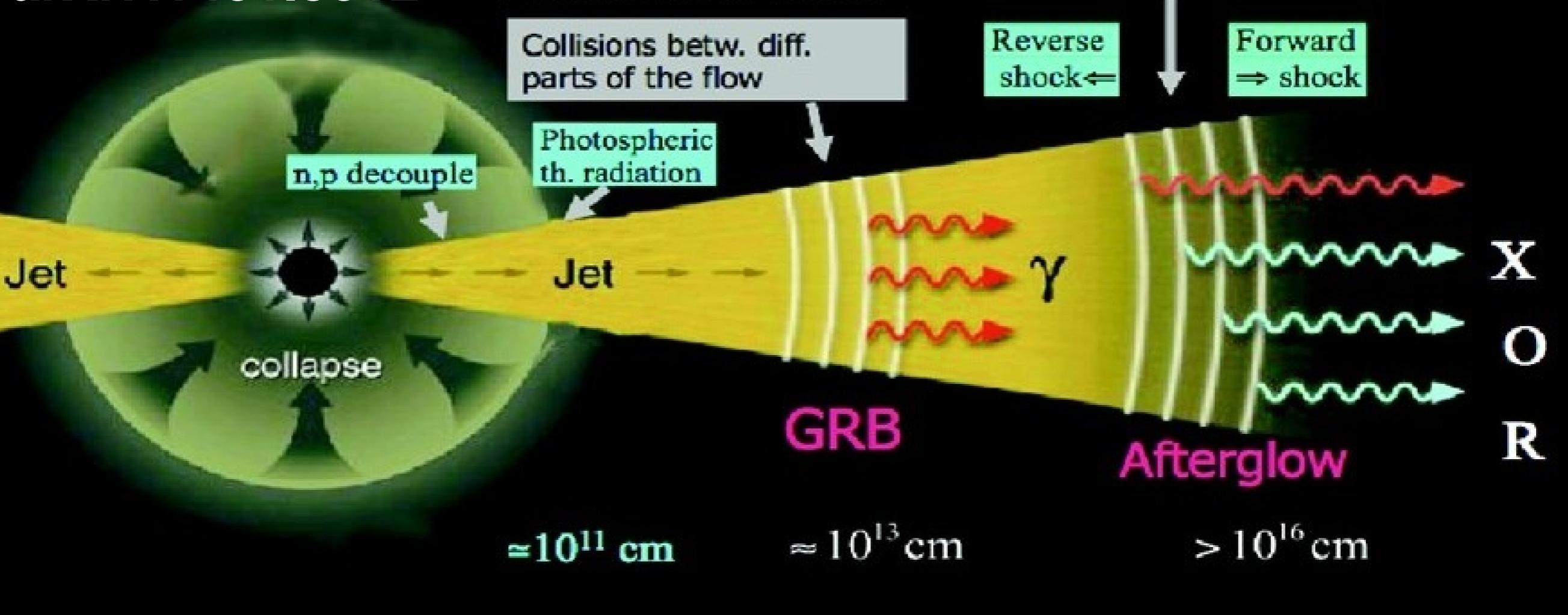
Forward
 \Rightarrow shock



“Standard” Fireball Model of GRBs

Progenitor: Failed SN Hypernova Macronova ✗

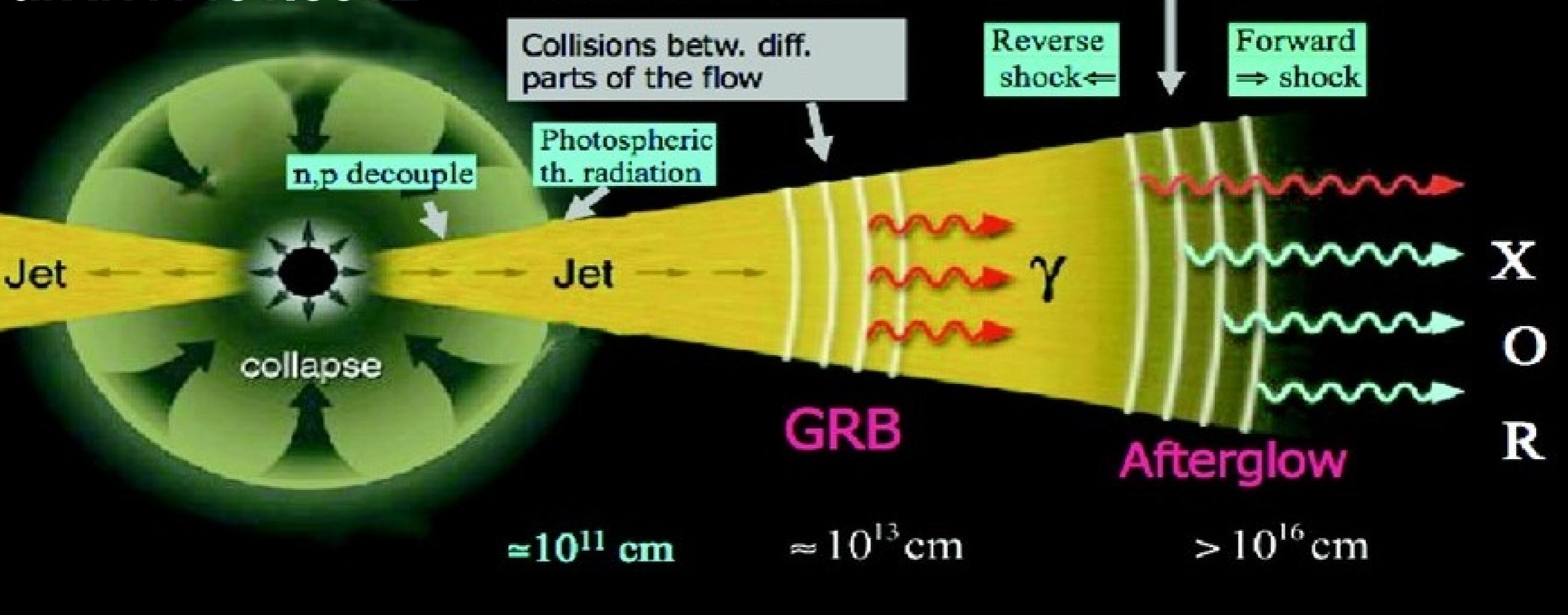
P. Meszaros,
M. J. Rees,
arXiv:1401.3012



“Standard” Fireball Model of GRBs

Progenitor: Failed SN Hypernova Macronova ✗
Geometry:

P. Meszaros,
M. J. Rees,
arXiv:1401.3012

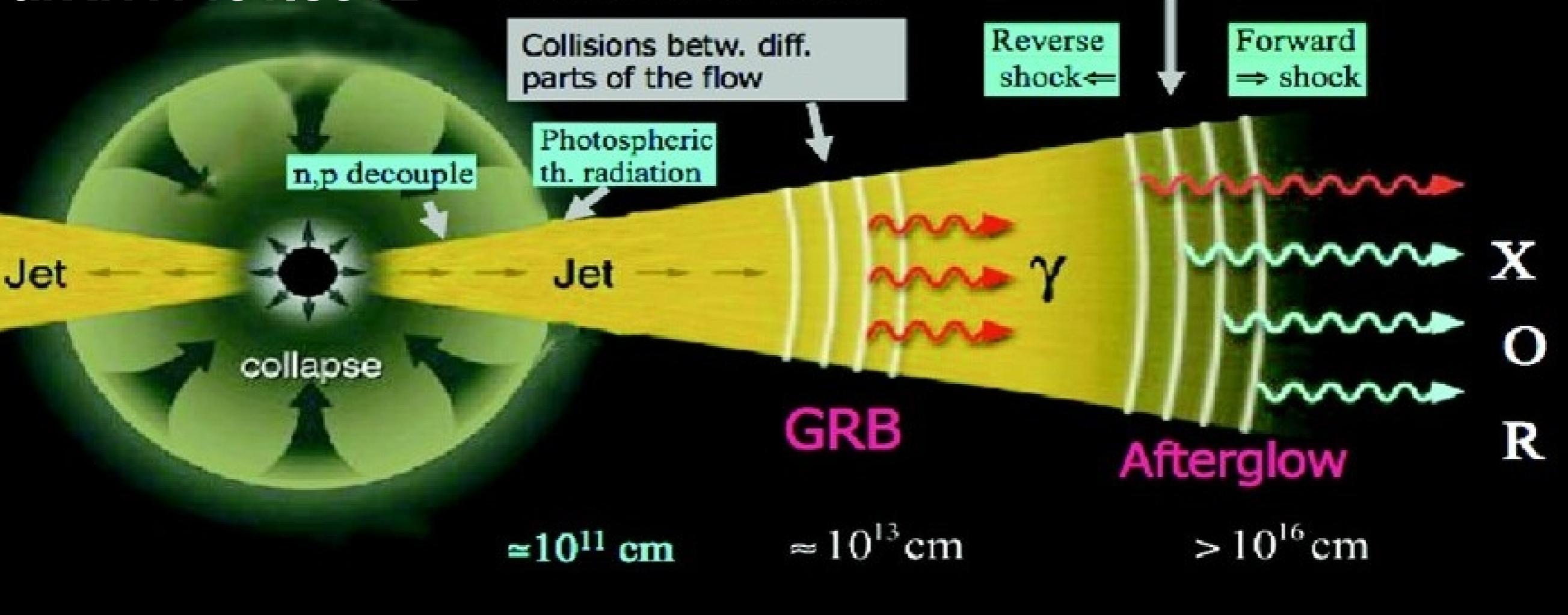


"Standard" Fireball Model of GRBs

Progenitor: Failed SN Hypernova Macronova ✗

Geometry: Spherical

P. Meszaros,
M. J. Rees,
arXiv:1401.3012



"Standard" Fireball Model of GRBs

Progenitor: Failed SN Hypernova Macronova ✗

Geometry: Spherical Funneled

P. Meszaros,
M. J. Rees,
arXiv:1401.3012

Several shocks - - also
possible cross-shock IC

External Shock

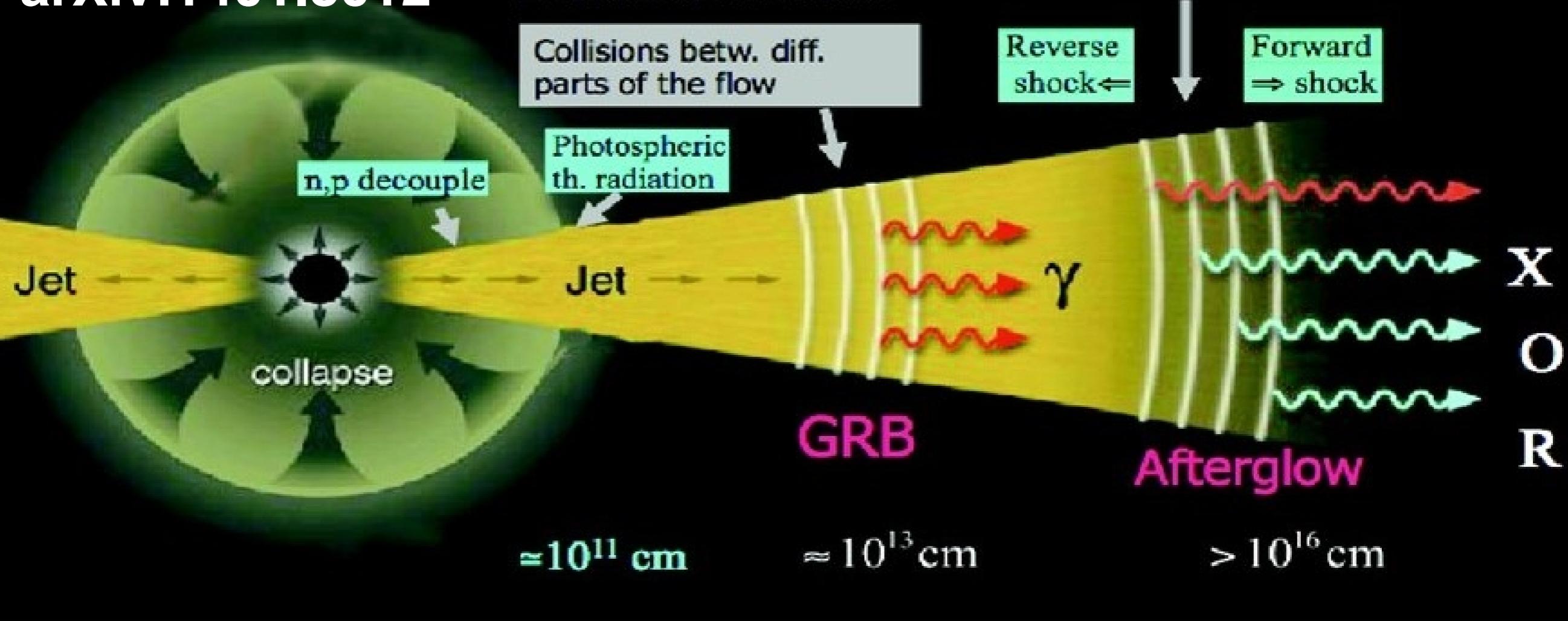
Flow decelerating into
the surrounding medium

Internal Shock

Collisions betw. diff.
parts of the flow

Reverse
shock \Leftarrow

Forward
 \Rightarrow shock



"Standard" Fireball Model of GRBs

Progenitor: Failed SN Hypernova Macronova ✗

Geometry: Spherical Funneled Narrower Cone

P. Meszaros,
M. J. Rees,
arXiv:1401.3012

Several shocks - - also
possible cross-shock IC

External Shock

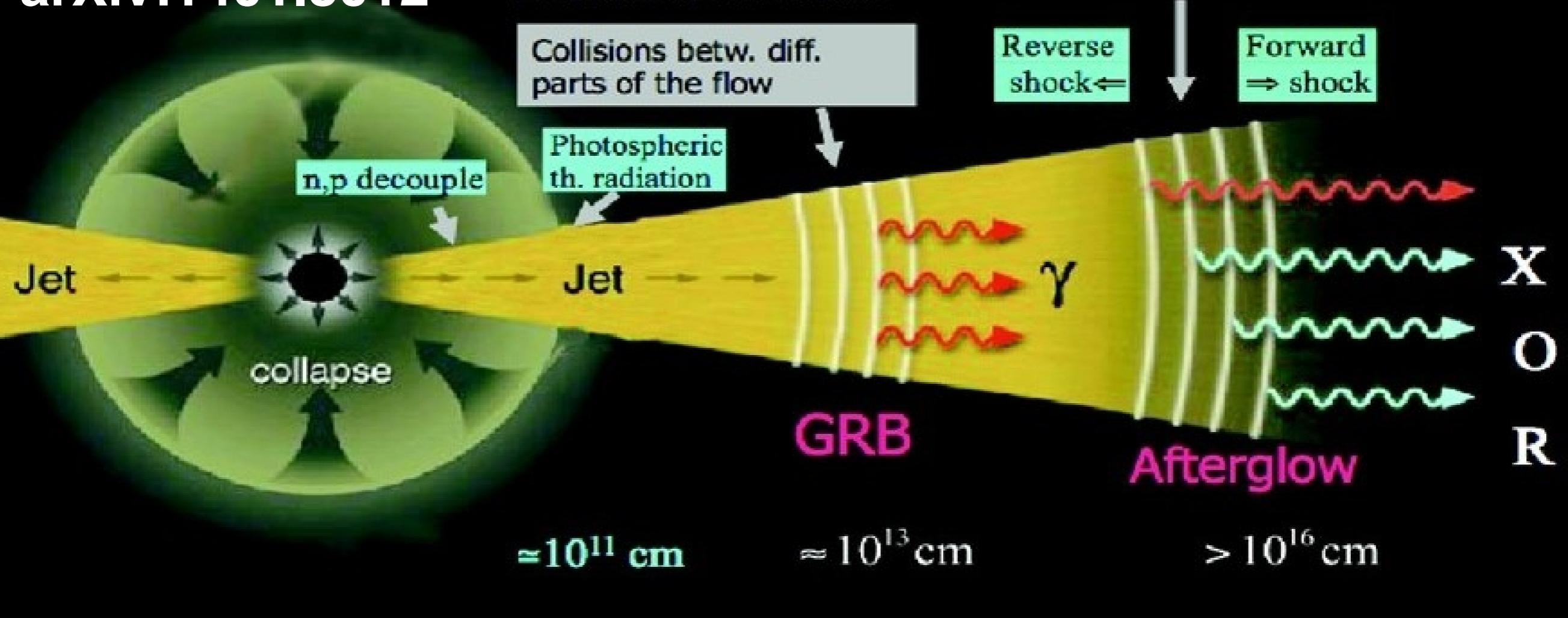
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Internal Shock

Collisions betw. diff.
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Reverse
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Forward
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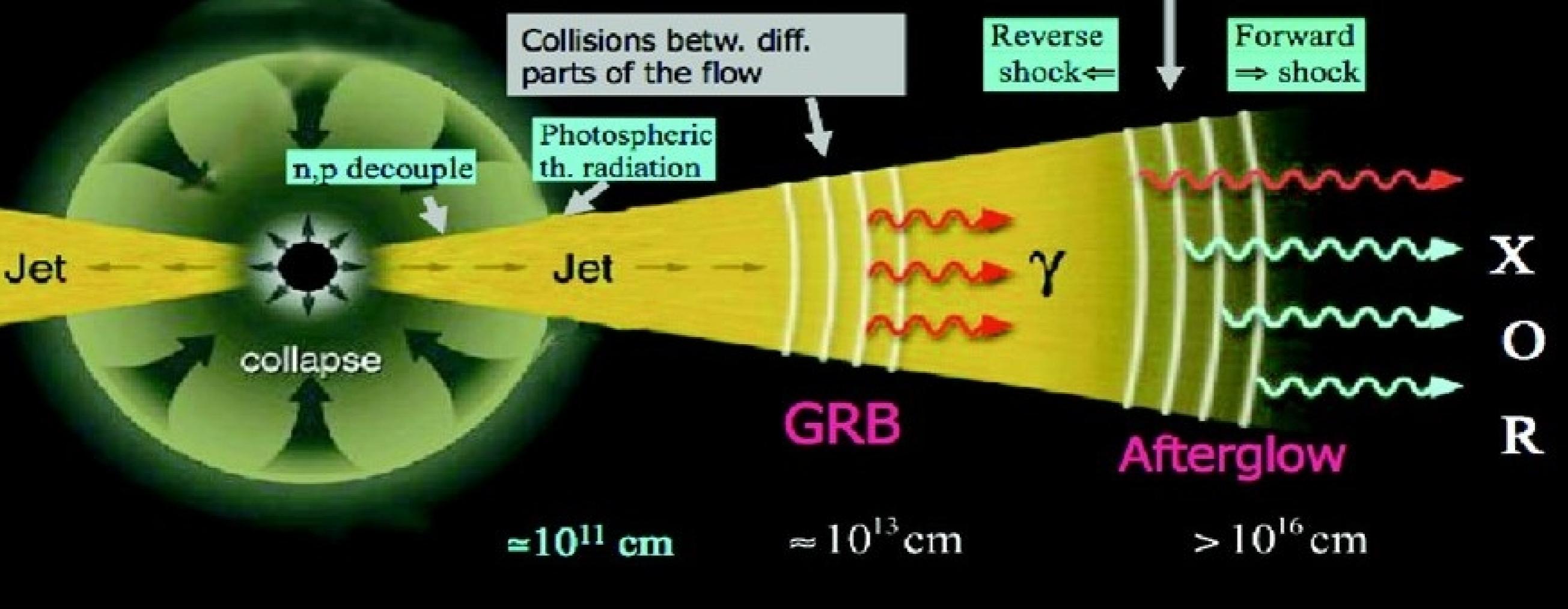


"Standard" Fireball Model of GRBs

Progenitor: Failed SN Hypernova Macronova \exists

Geometry: Spherical Funneled Narrower Cone $\theta \sim 0$

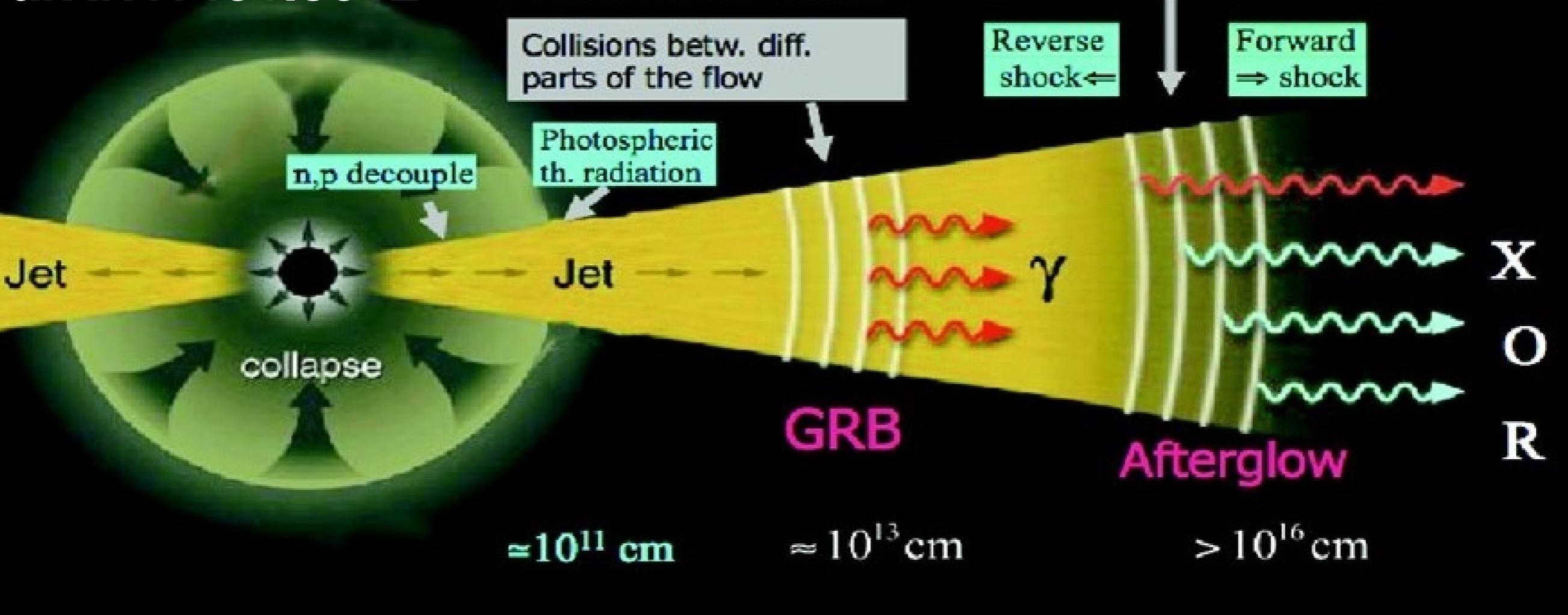
P. Meszaros,
M. J. Rees,
arXiv:1401.3012



"Standard" Fireball Model of GRBs

- Progenitor:* Failed SN Hypernova Macronova \exists
- Geometry:* Spherical Funneled Narrower Cone $\theta \sim 0$
- Radiation:*

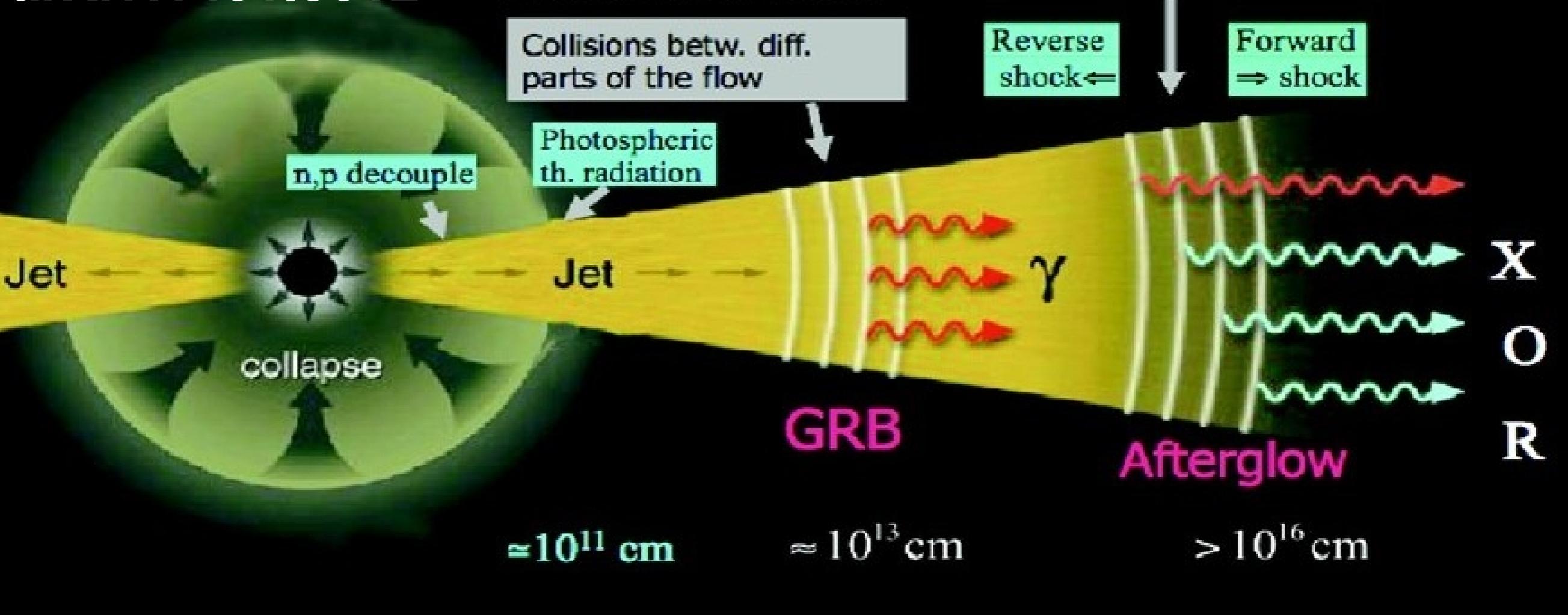
P. Meszaros,
M. J. Rees,
arXiv:1401.3012



"Standard" Fireball Model of GRBs

- Progenitor:* Failed SN Hypernova Macronova \exists
- Geometry:* Spherical Funneled Narrower Cone $\theta \sim 0$
- Radiation:* SR from shocks

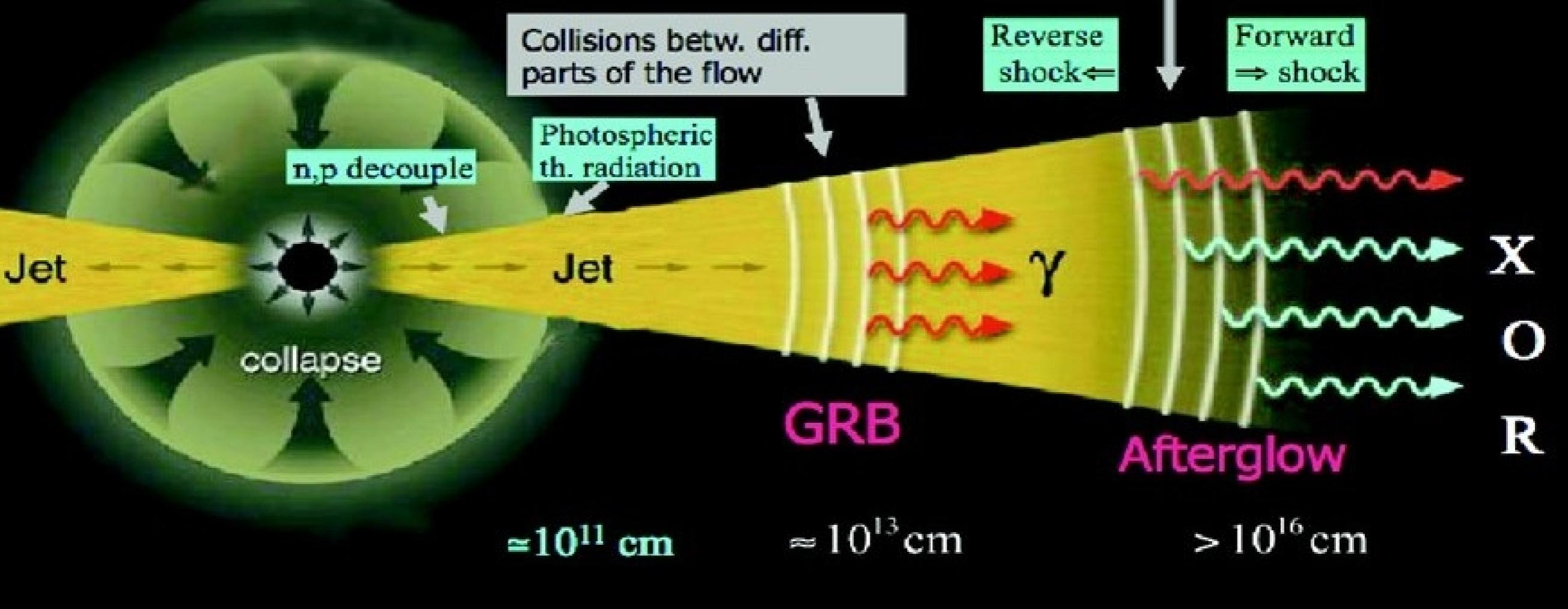
P. Meszaros,
M. J. Rees,
arXiv:1401.3012



"Standard" Fireball Model of GRBs

- Progenitor:* Failed SN Hypernova Macronova \exists
- Geometry:* Spherical Funneled Narrower Cone $\theta \sim 0$
- Radiation:* SR from shocks $e^+ e^- \gamma$

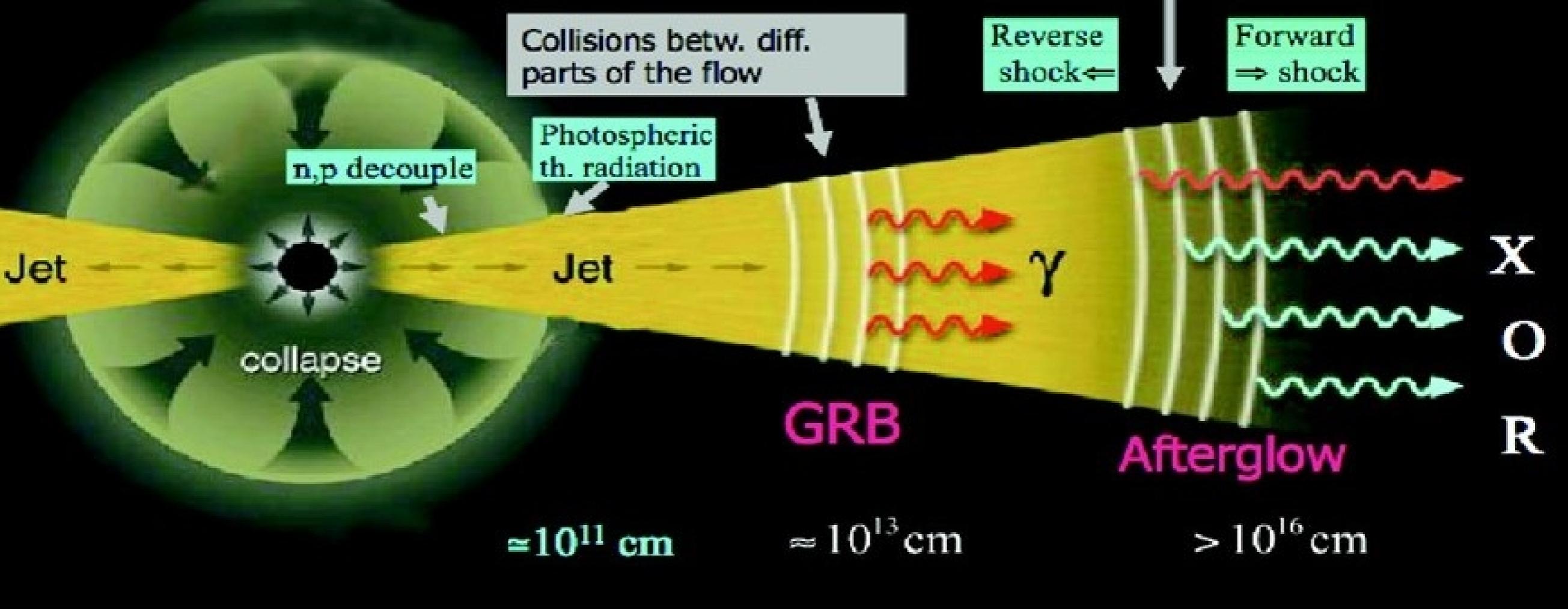
P. Meszaros,
M. J. Rees,
arXiv:1401.3012



"Standard" Fireball Model of GRBs

- Progenitor:* Failed SN Hypernova Macronova \exists
- Geometry:* Spherical Funneled Narrower Cone $\theta \sim 0$
- Radiation:* SR from shocks $e^+ e^- \gamma$ B-loaded

P. Meszaros,
M. J. Rees,
arXiv:1401.3012



"Standard" Fireball Model of GRBs

Progenitor: Failed SN Hypernova Macronova \exists

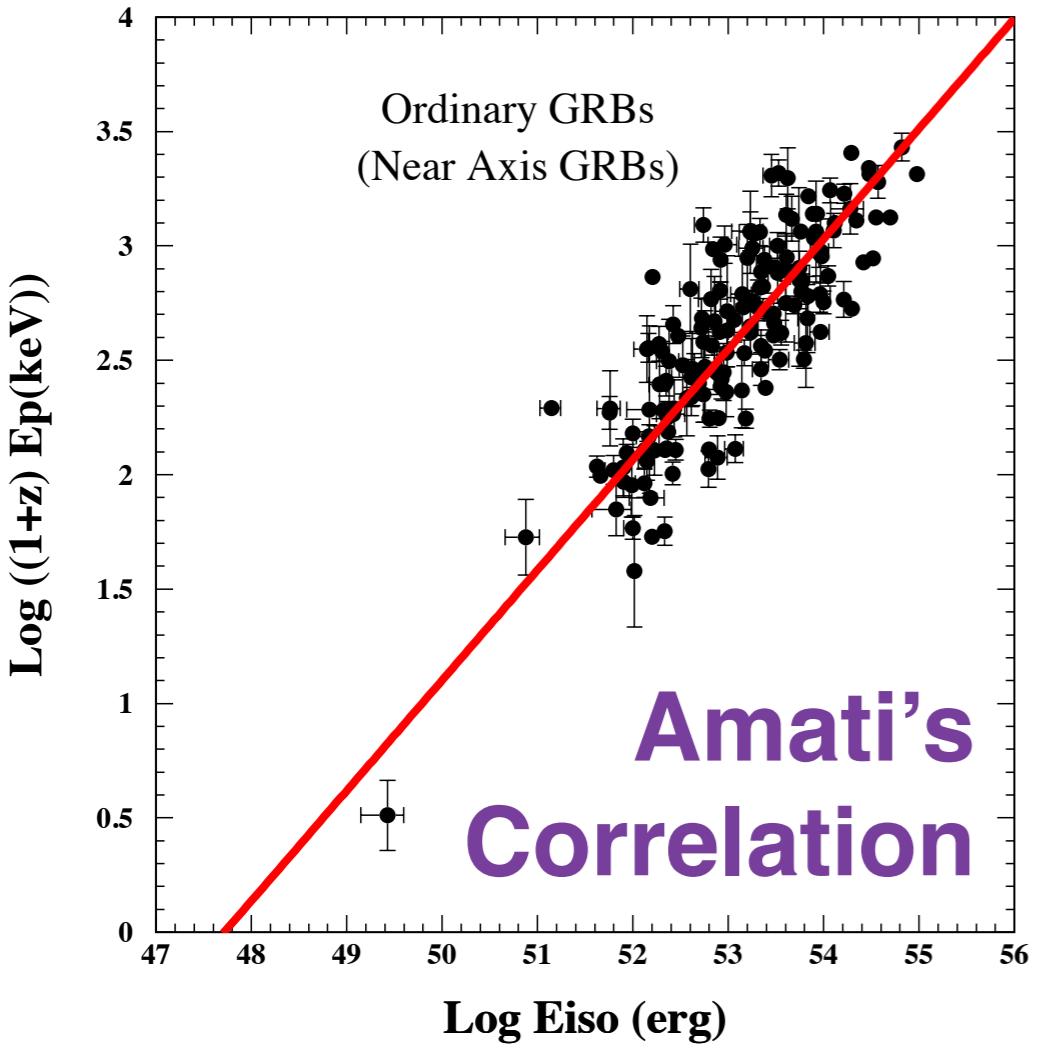
Geometry: Spherical Funneled Narrower Cone $\theta \sim 0$

Radiation: SR from shocks $e^+ e^- \gamma$ B-loaded Ord-matter

CB-model CORRELATIONS
(as if all GRB properties
were fairly “standard
candle”-like but for
THE VIEWING ANGLE)

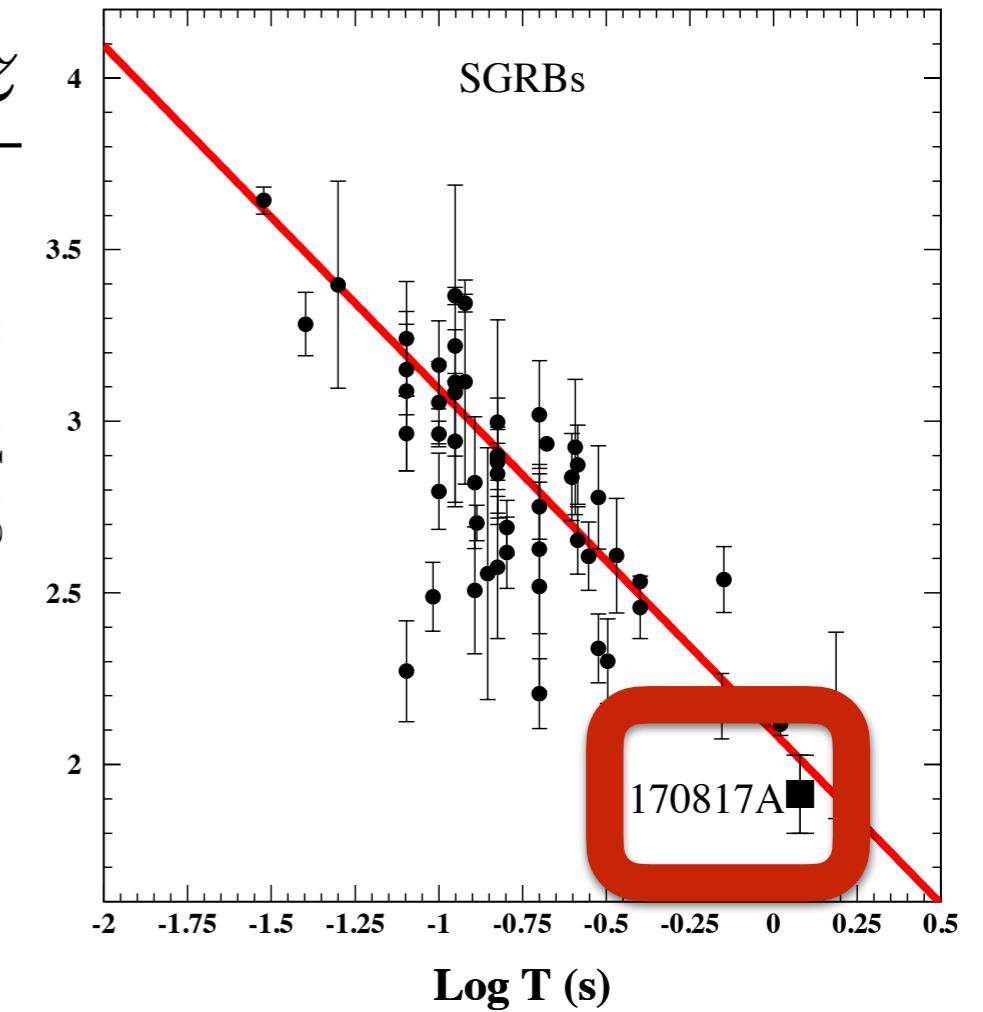
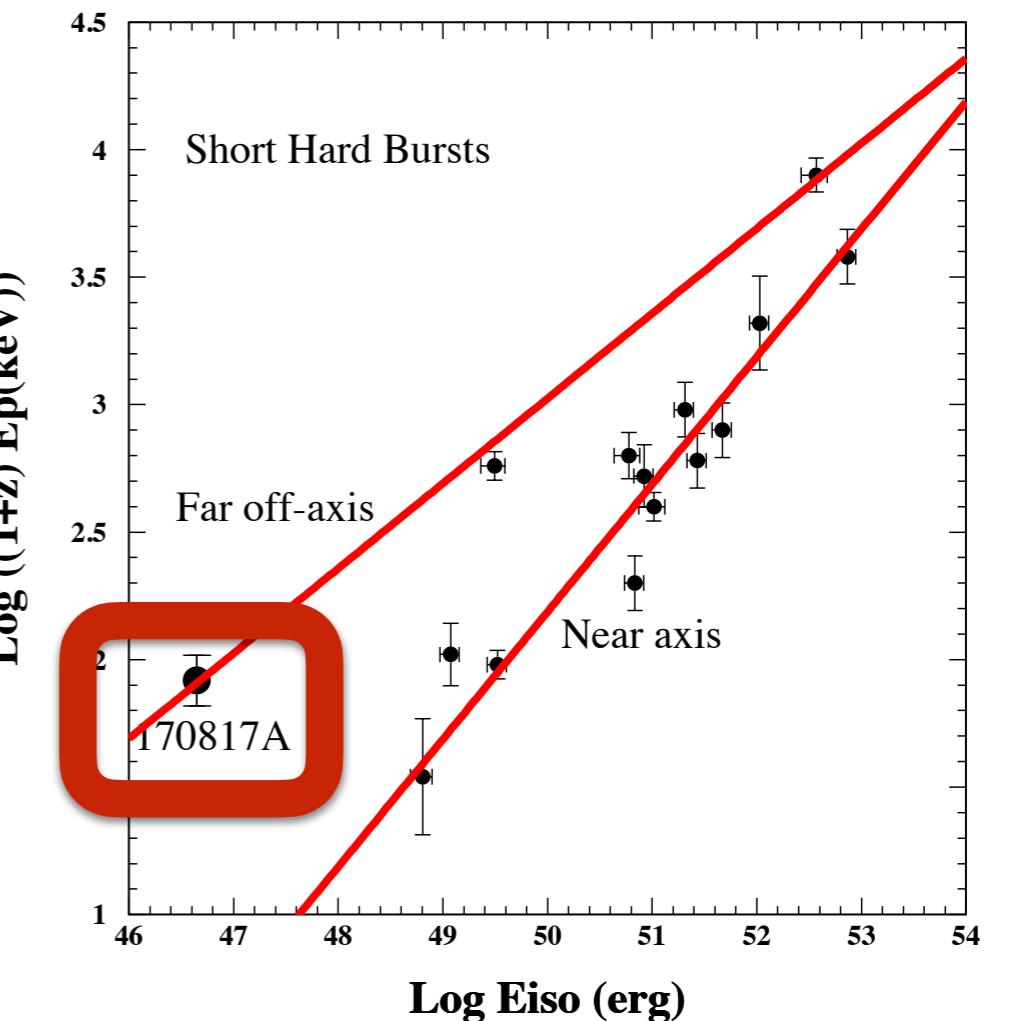
Relativistic-kinematics

$$E_p \approx \frac{\gamma \delta \langle \epsilon \rangle}{1+z}$$



$$T \propto \frac{1+z}{\gamma \delta}$$

$$E_p \propto \frac{1}{T}$$

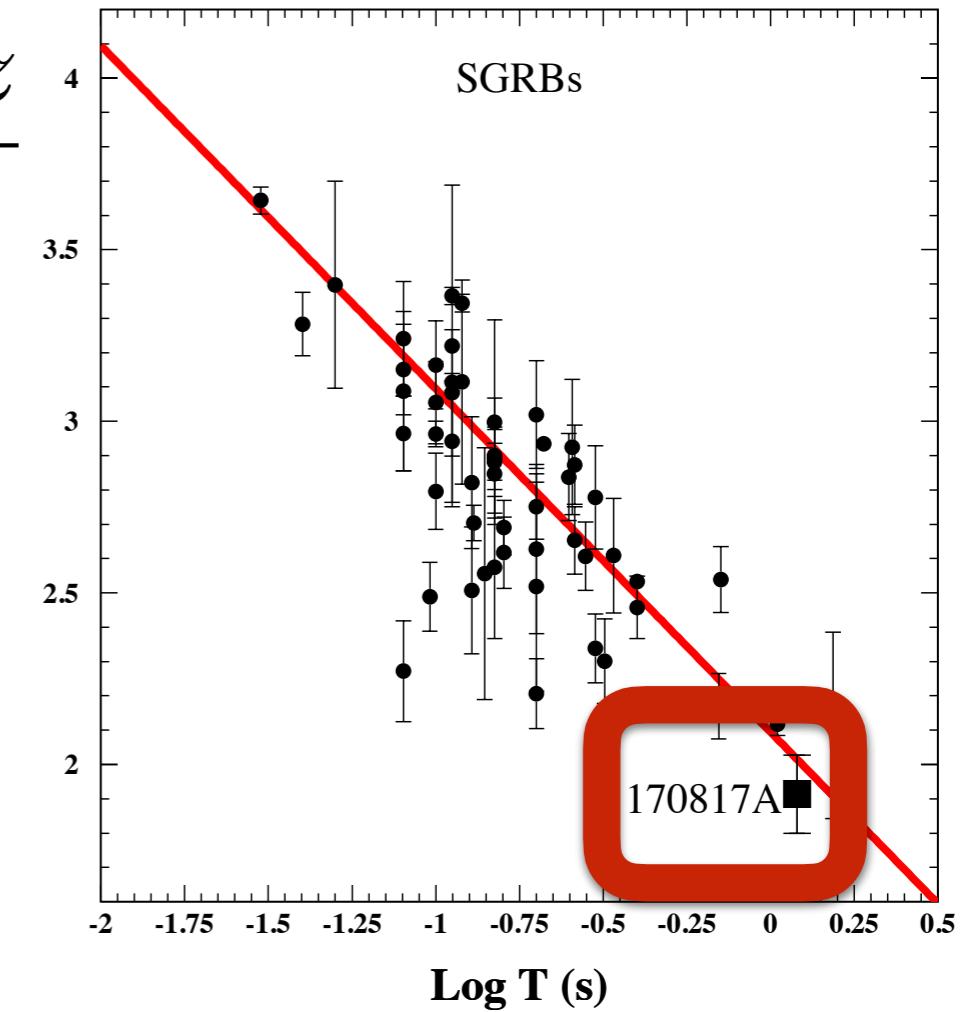
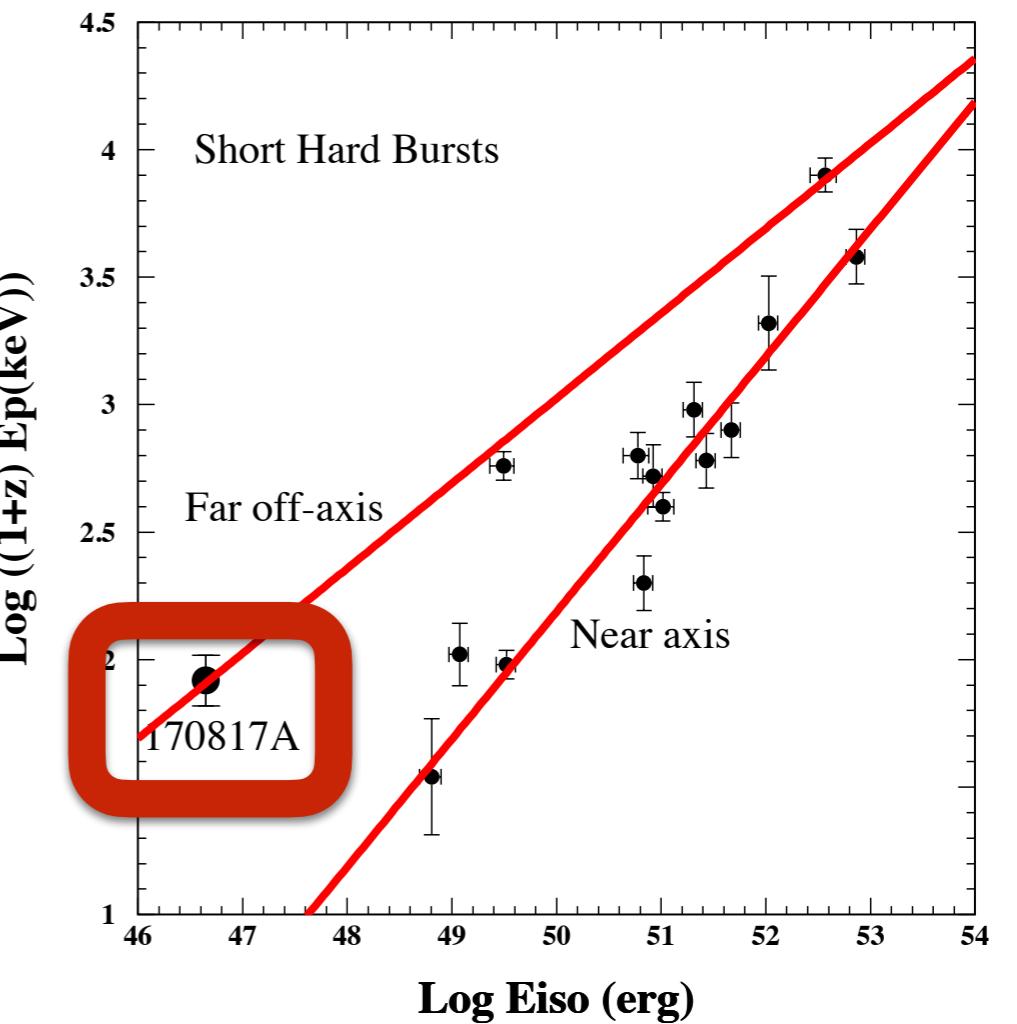
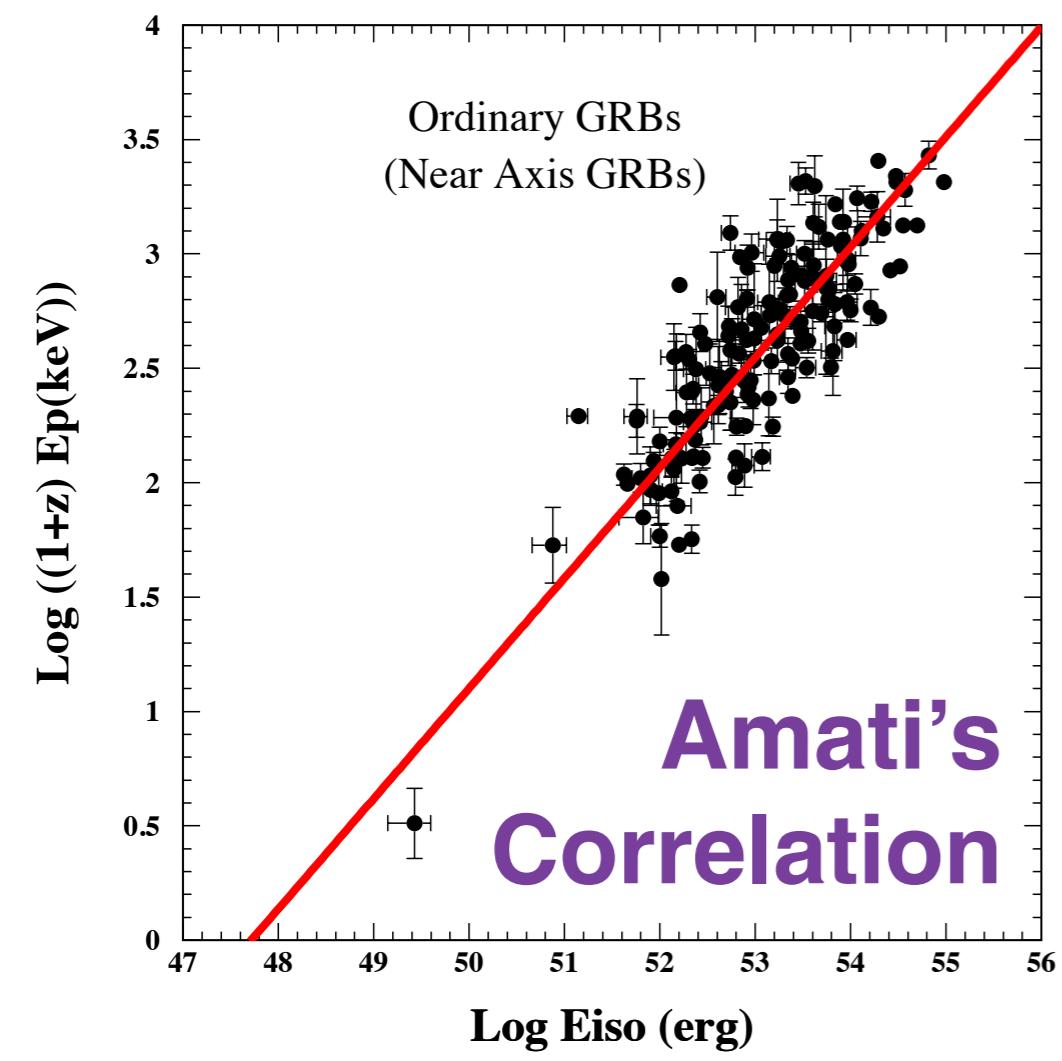


$$E_p \approx \frac{\gamma \delta \langle \epsilon \rangle}{1+z}$$

$$E_{\text{ISO}} \propto \gamma \delta^3$$

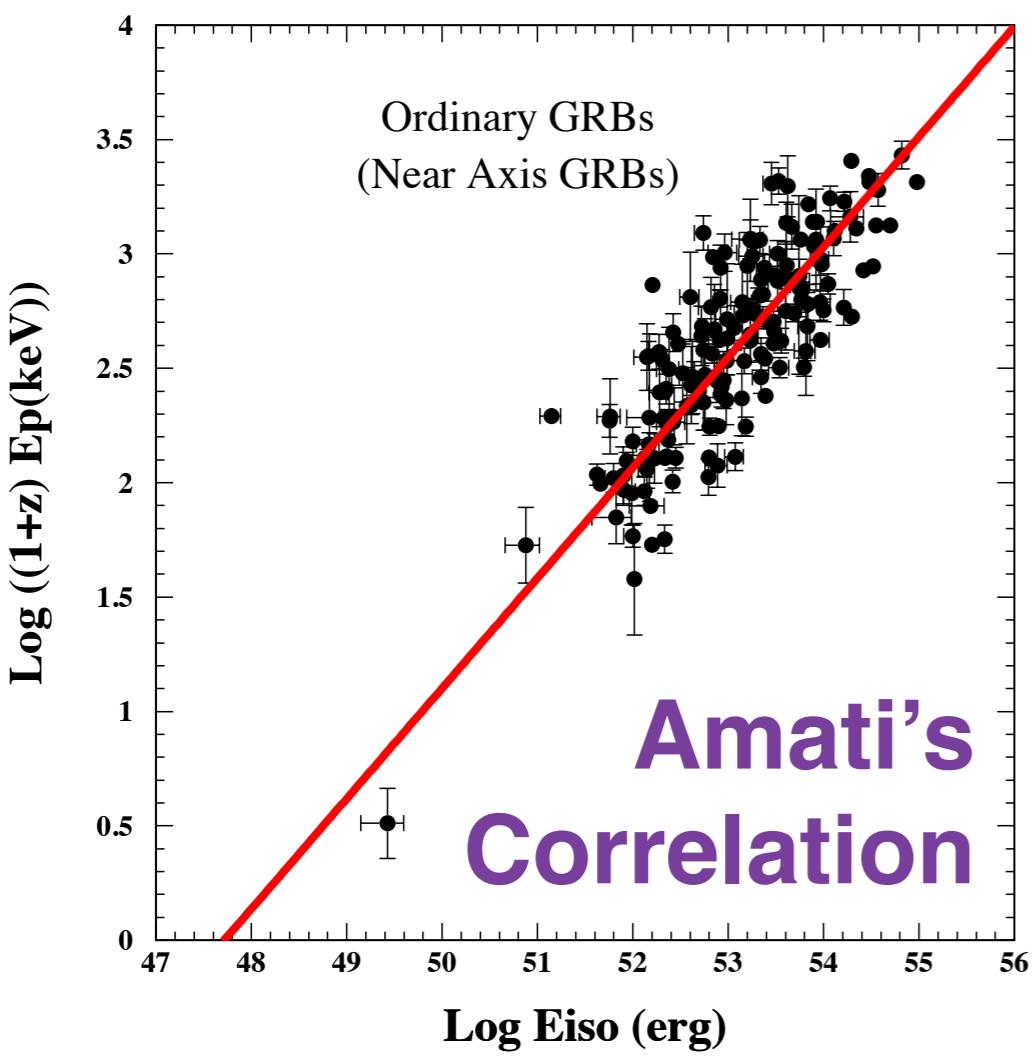
$$T \propto \frac{1+z}{\gamma \delta}$$

$$E_p \propto \frac{1}{T}$$



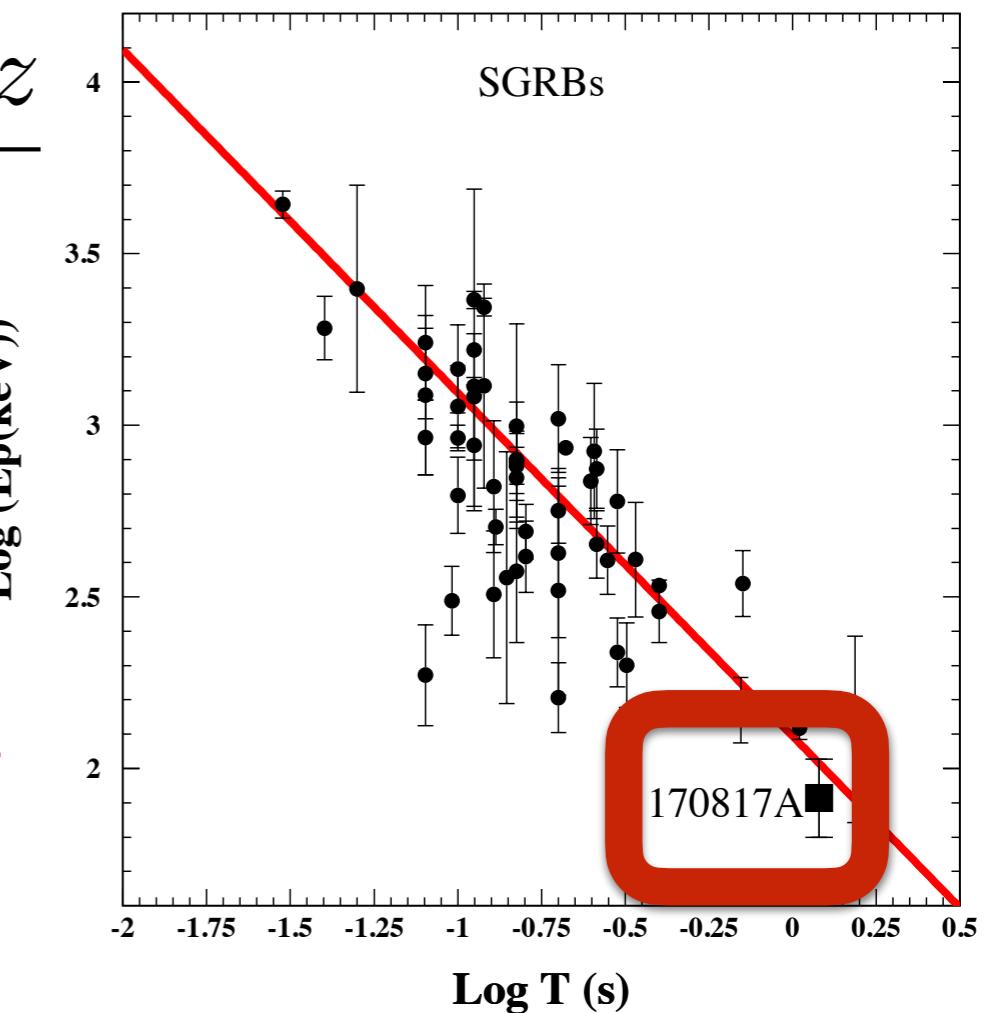
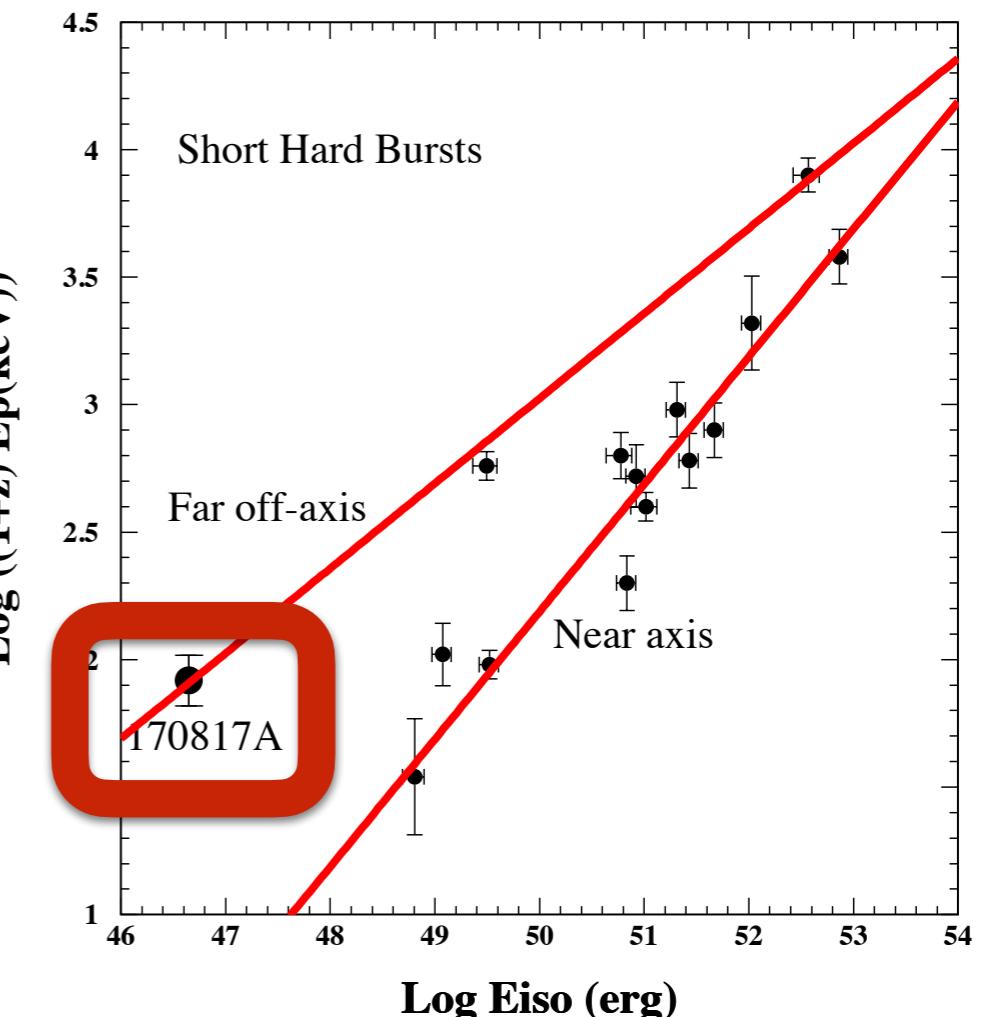
$$E_p \approx \frac{\gamma \delta \langle \epsilon \rangle}{1+z} \quad E_{\text{ISO}} \propto \gamma \delta^3$$

$\theta \sim 1/\gamma$ most probable



$$T \propto \frac{1+z}{\gamma \delta}$$

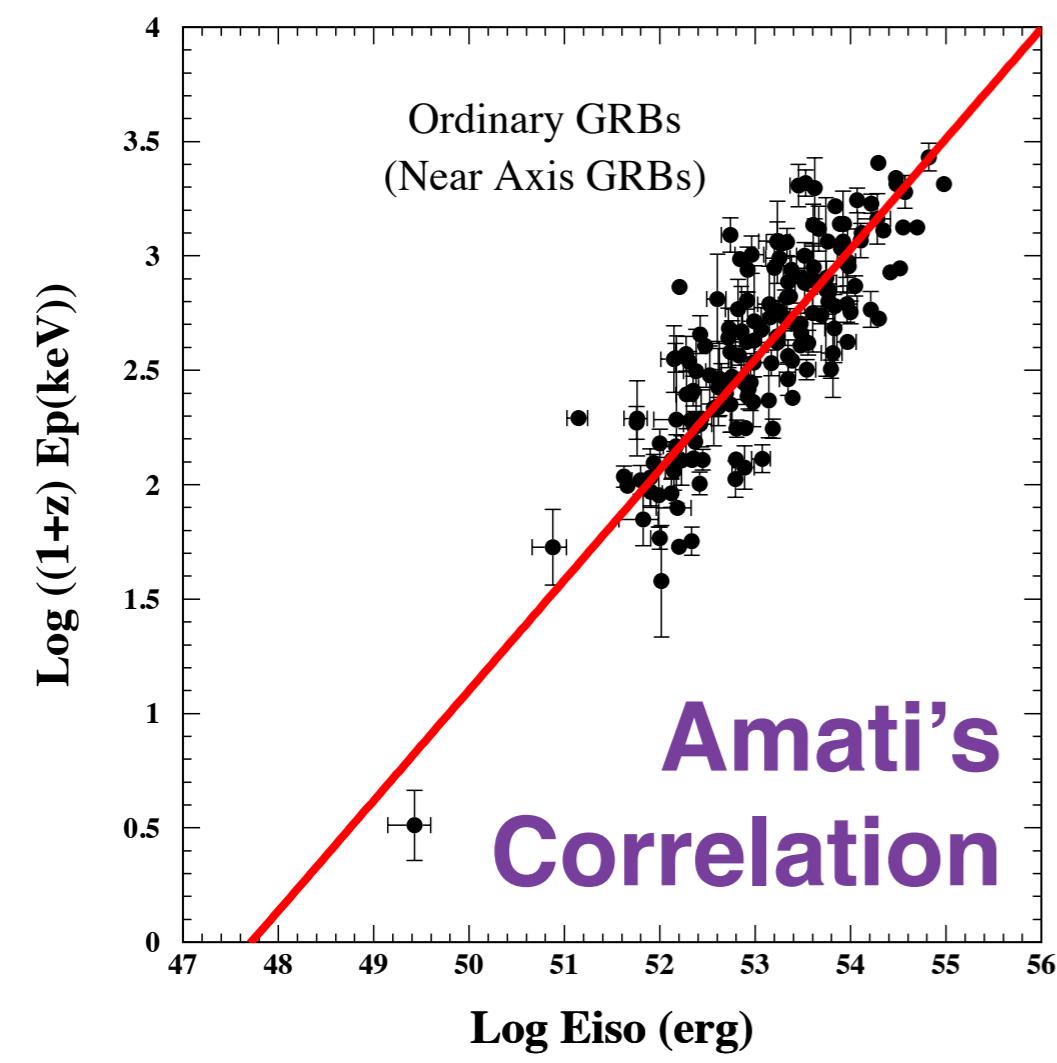
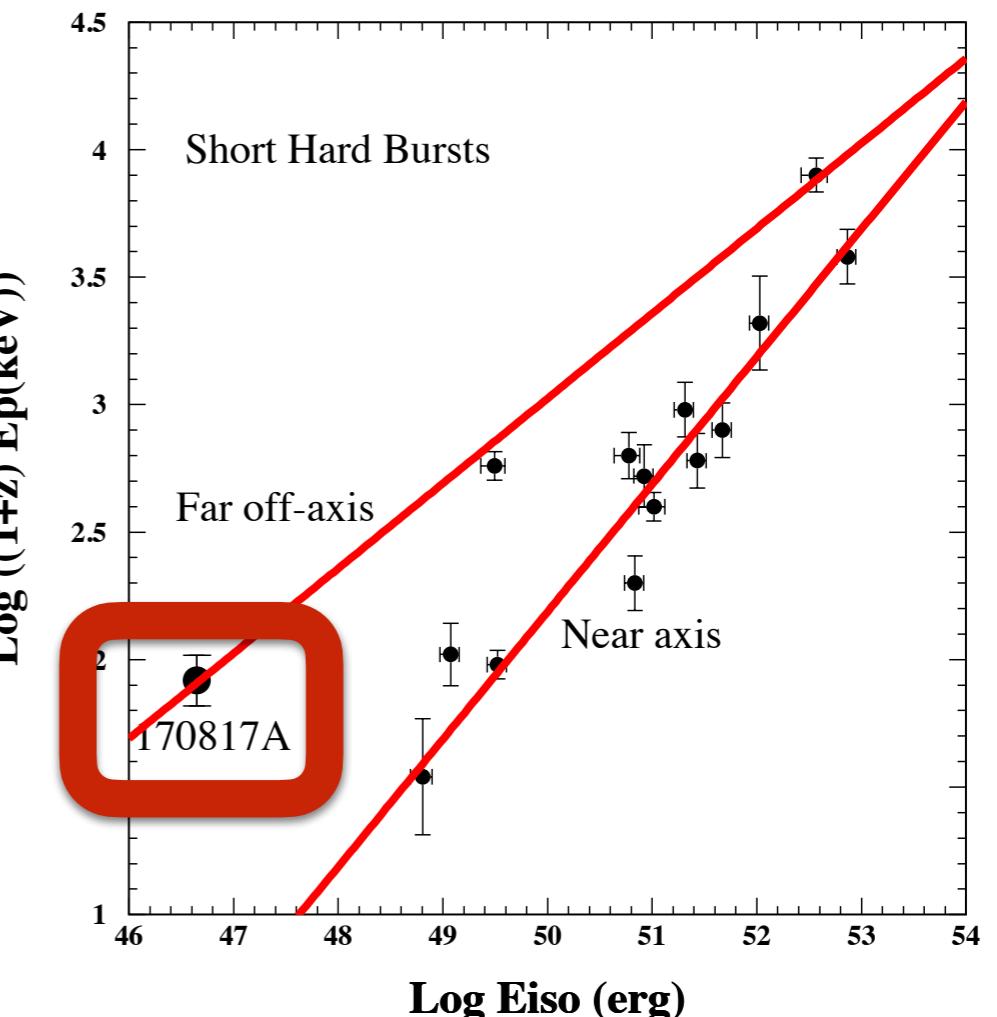
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$$E_p \approx \frac{\gamma \delta \langle \epsilon \rangle}{1+z} \quad E_{\text{ISO}} \propto \gamma \delta^3$$

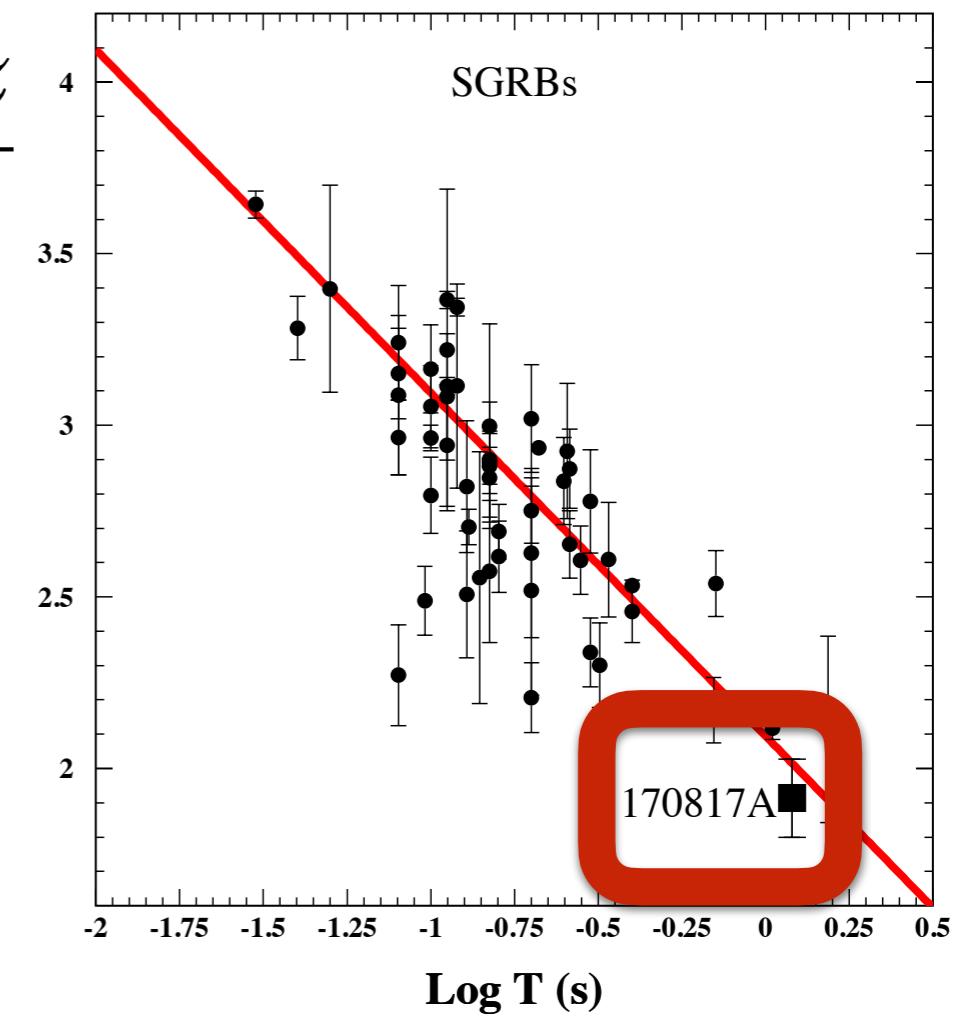
$\theta \sim 1/\gamma$ most probable

$$(1+z) E_p \propto E_{\text{ISO}}^{1/2}$$



$$T \propto \frac{1+z}{\gamma \delta}$$

$$E_p \propto \frac{1}{T}$$

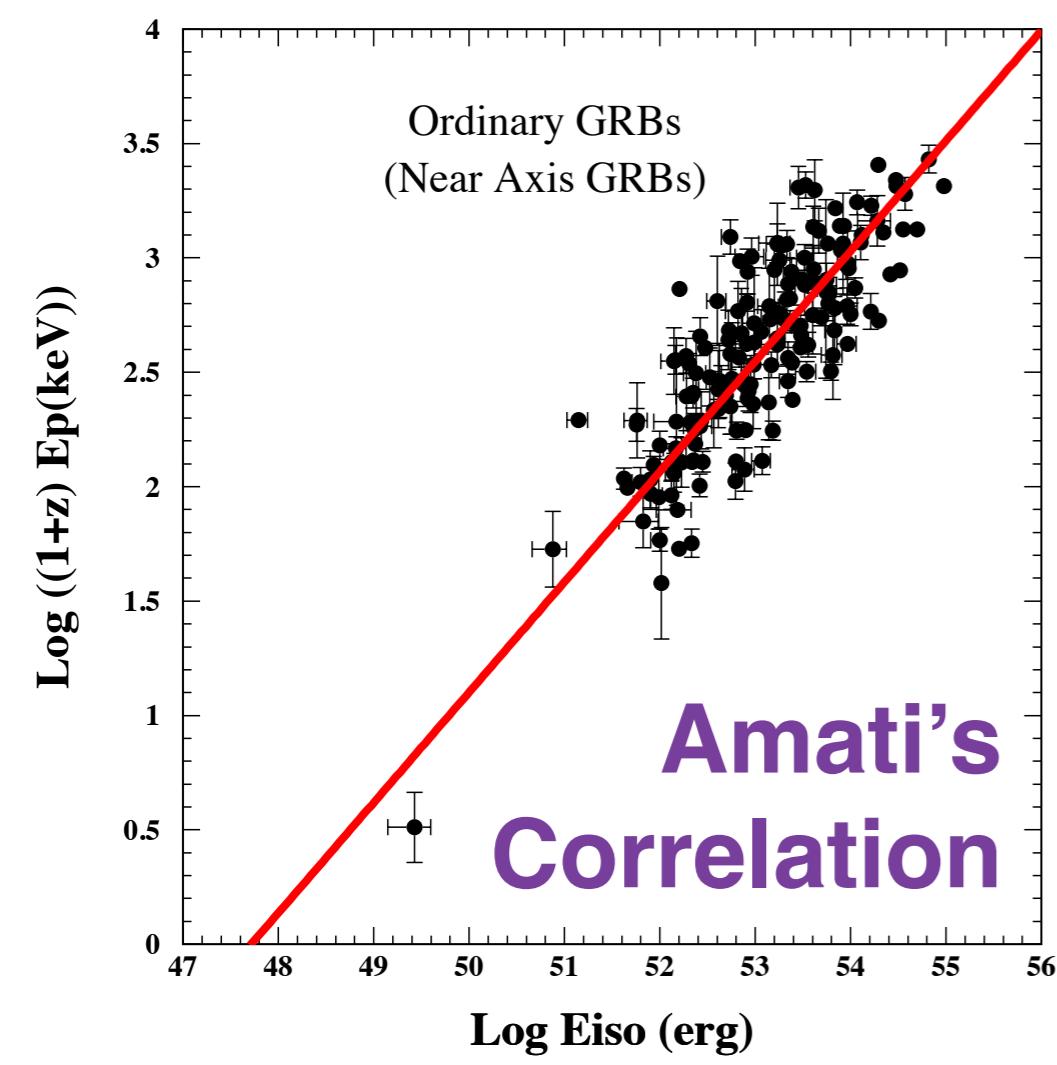
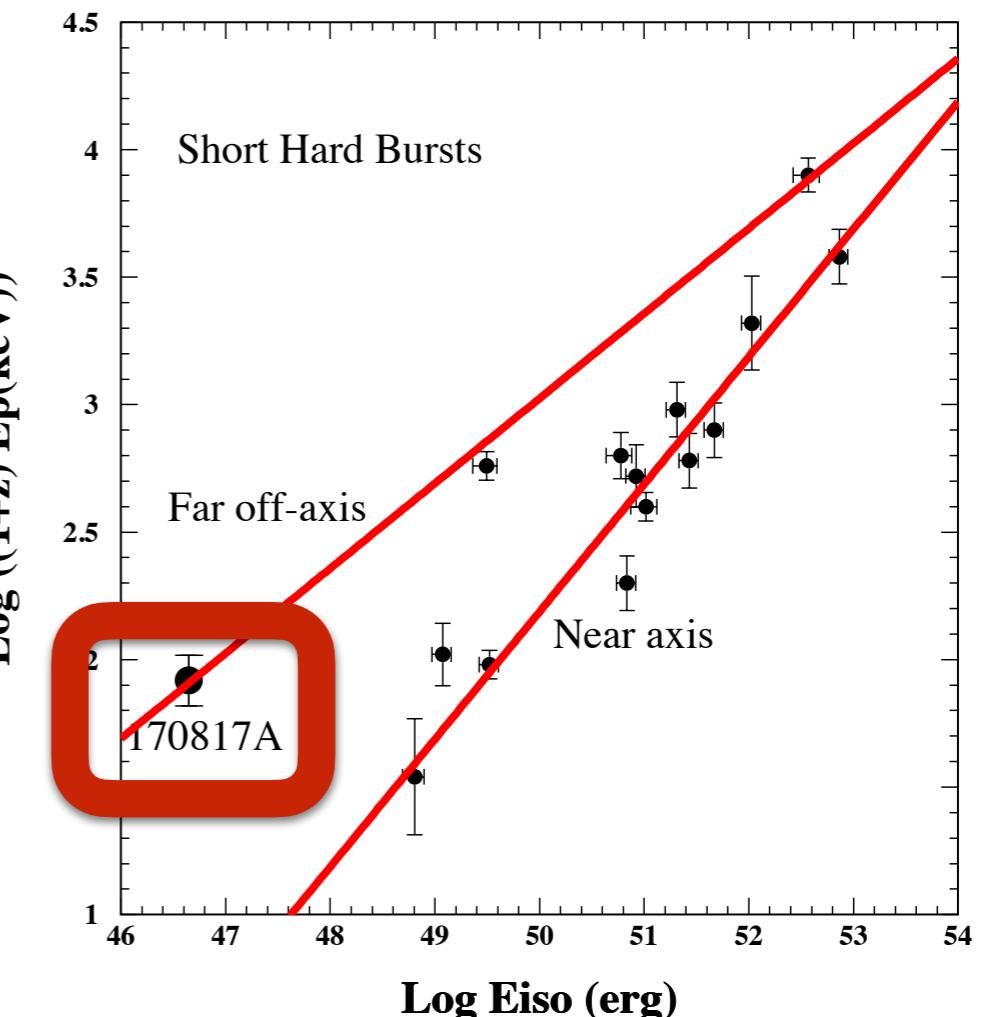


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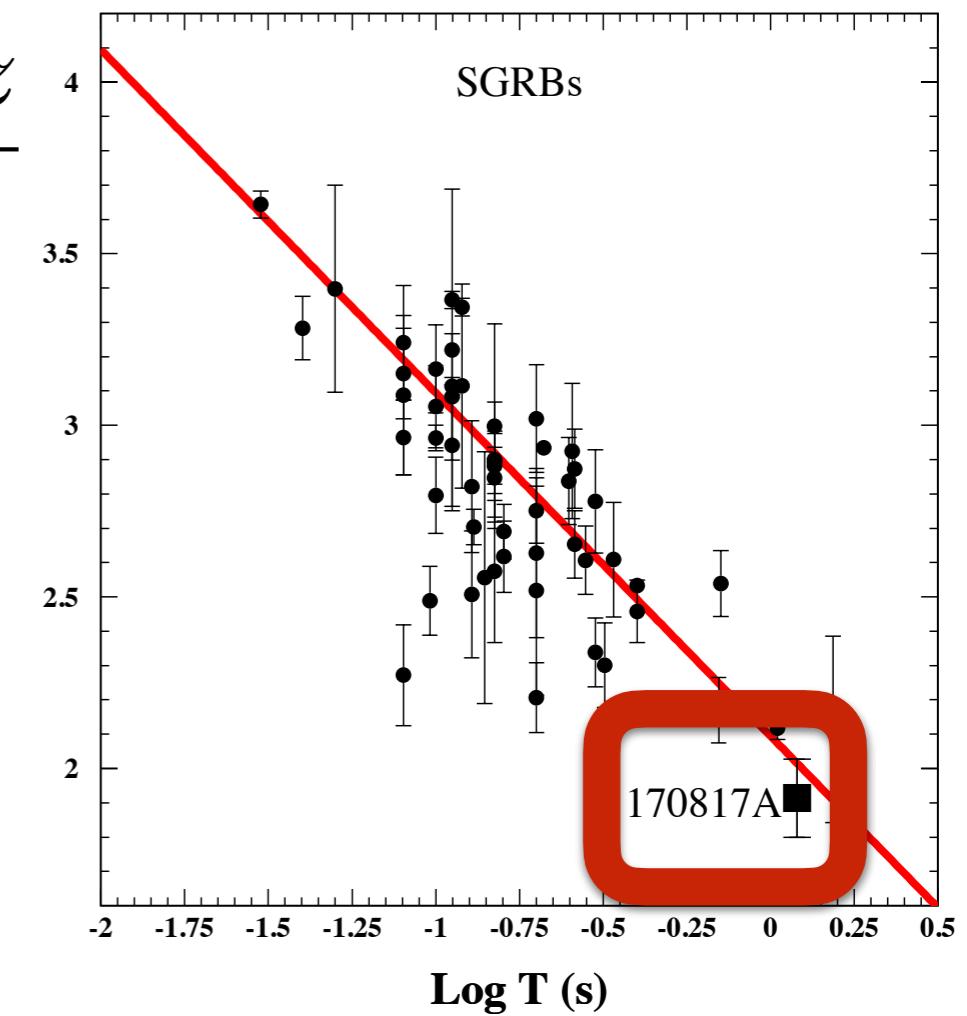
$$(1+z) E_p \propto E_{\text{ISO}}^{1/2}$$

$\theta \gg 1/\gamma$ “far” off-axis



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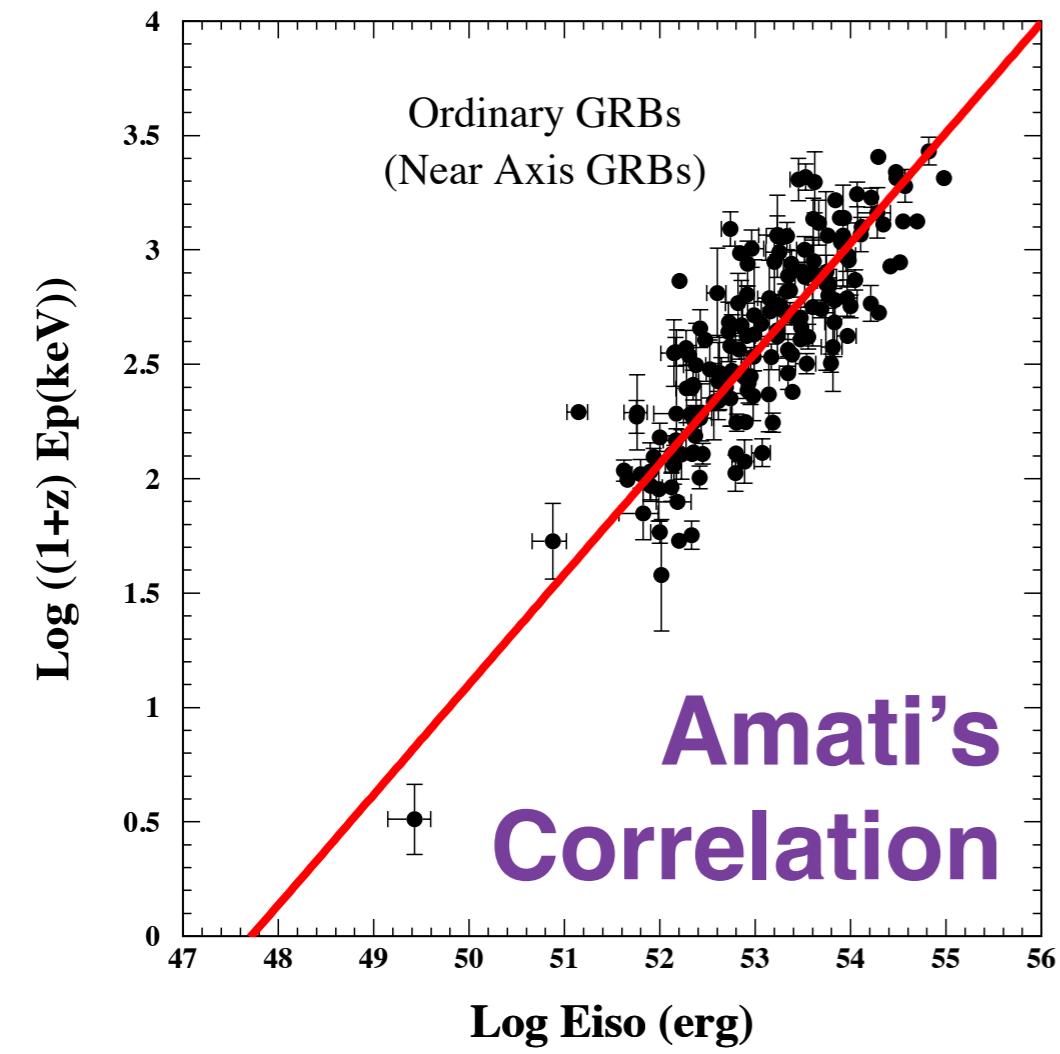
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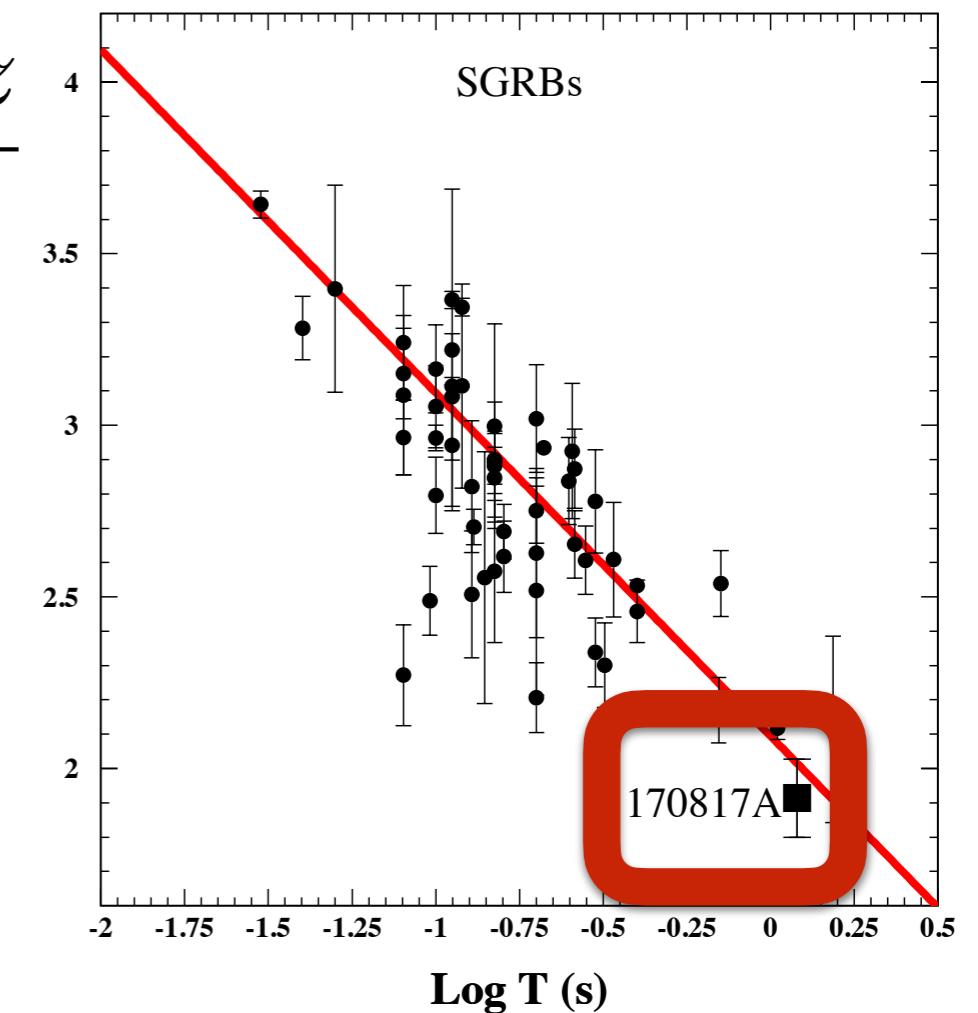
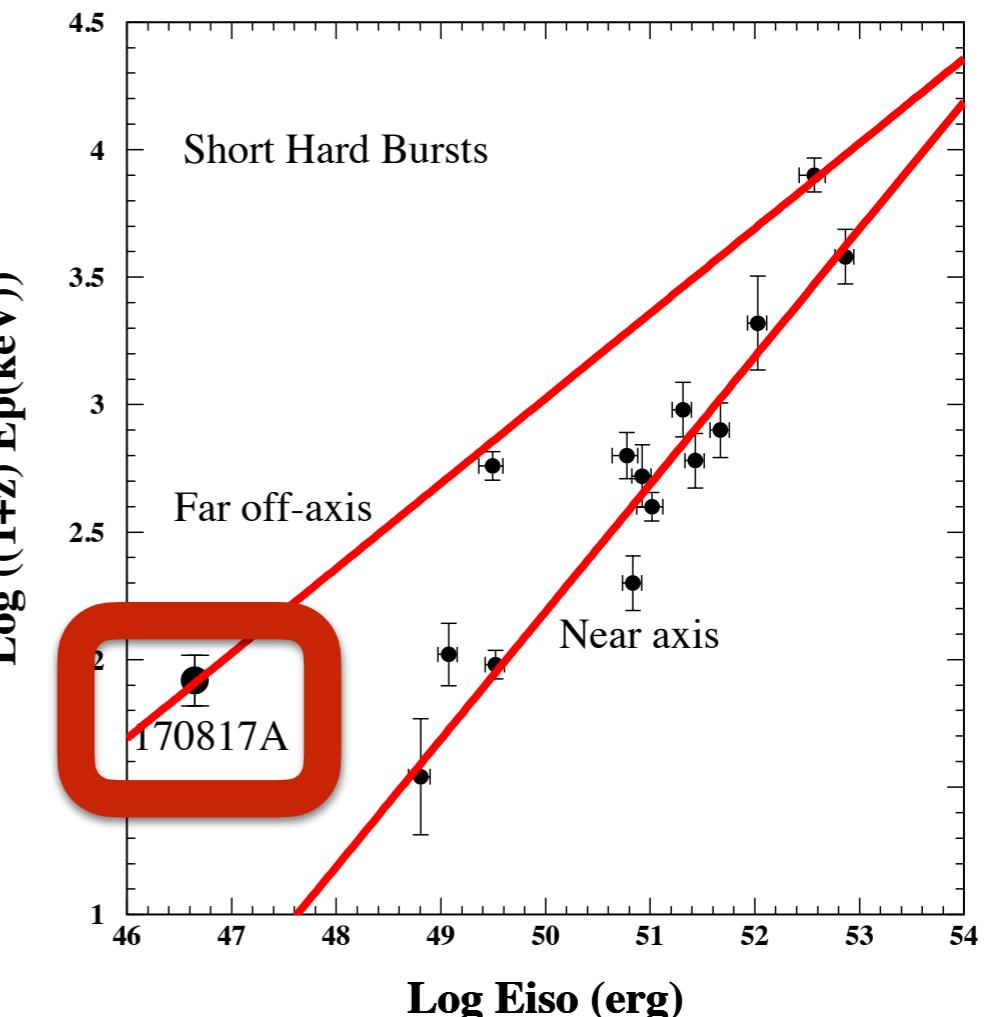
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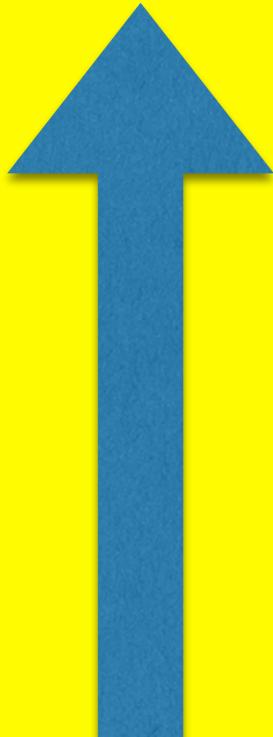
$$(1+z) E_p \propto E_{\text{ISO}}^{1/3}$$



$$T \propto \frac{1+z}{\gamma \delta}$$

$$E_p \propto \frac{1}{T}$$





The Gamma Rays of “long duration” GRBs and Short Hard Bursts



The Gamma Rays of “long duration” GRBs and Short Hard Bursts

Their (longer wavelength)

“AfterGlows”



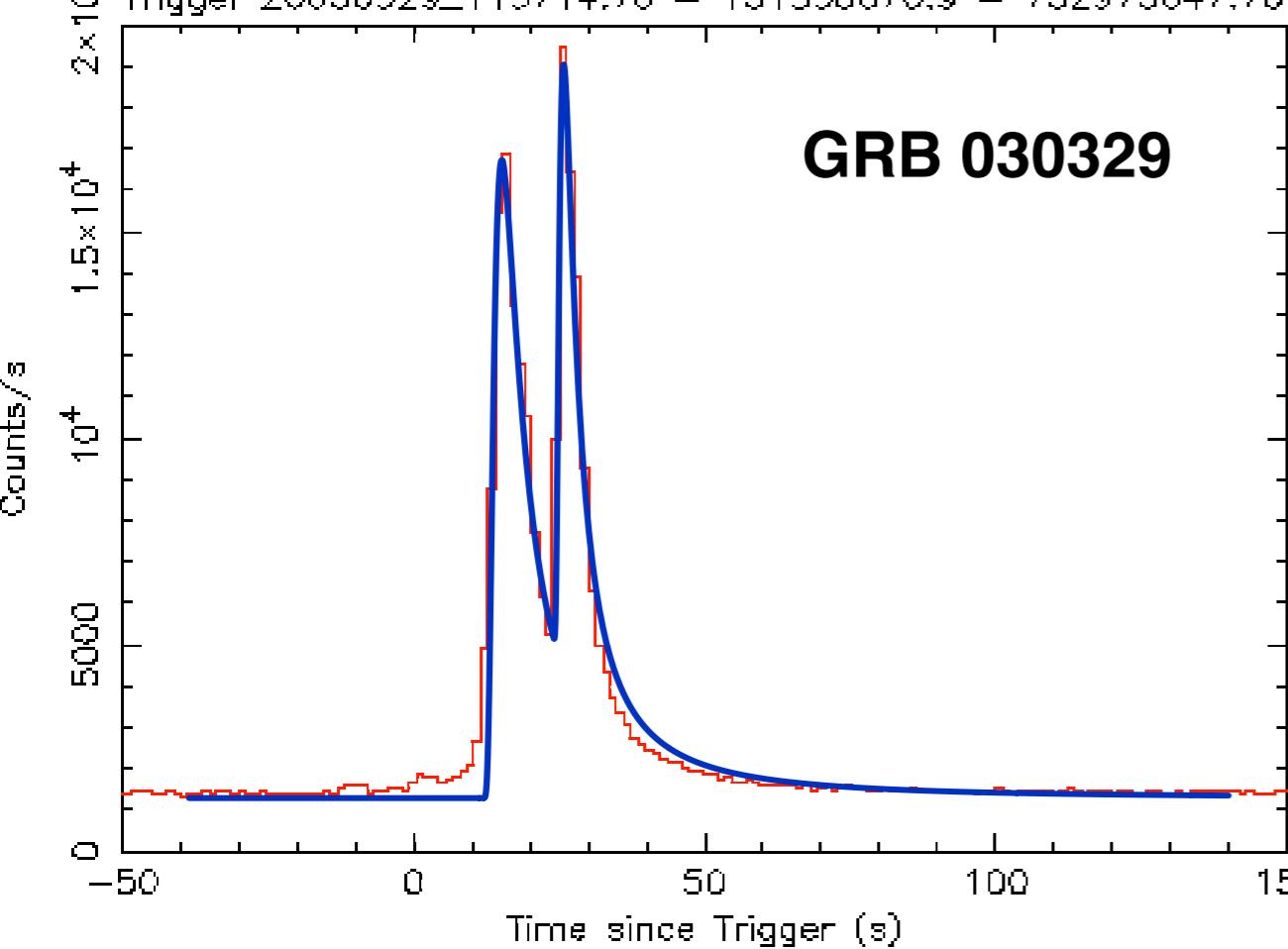
The SN-LGRB association: a CB-model prediction

The SN-LGRB association: a CB-model prediction

CB's AG: $F_\nu(t, \nu) \propto$

$$\gamma(t)^{2.3} \delta(t)^{4.1} \nu^{-1.1}$$

$$\rightarrow t^{1.6} \nu^{-1.1}$$

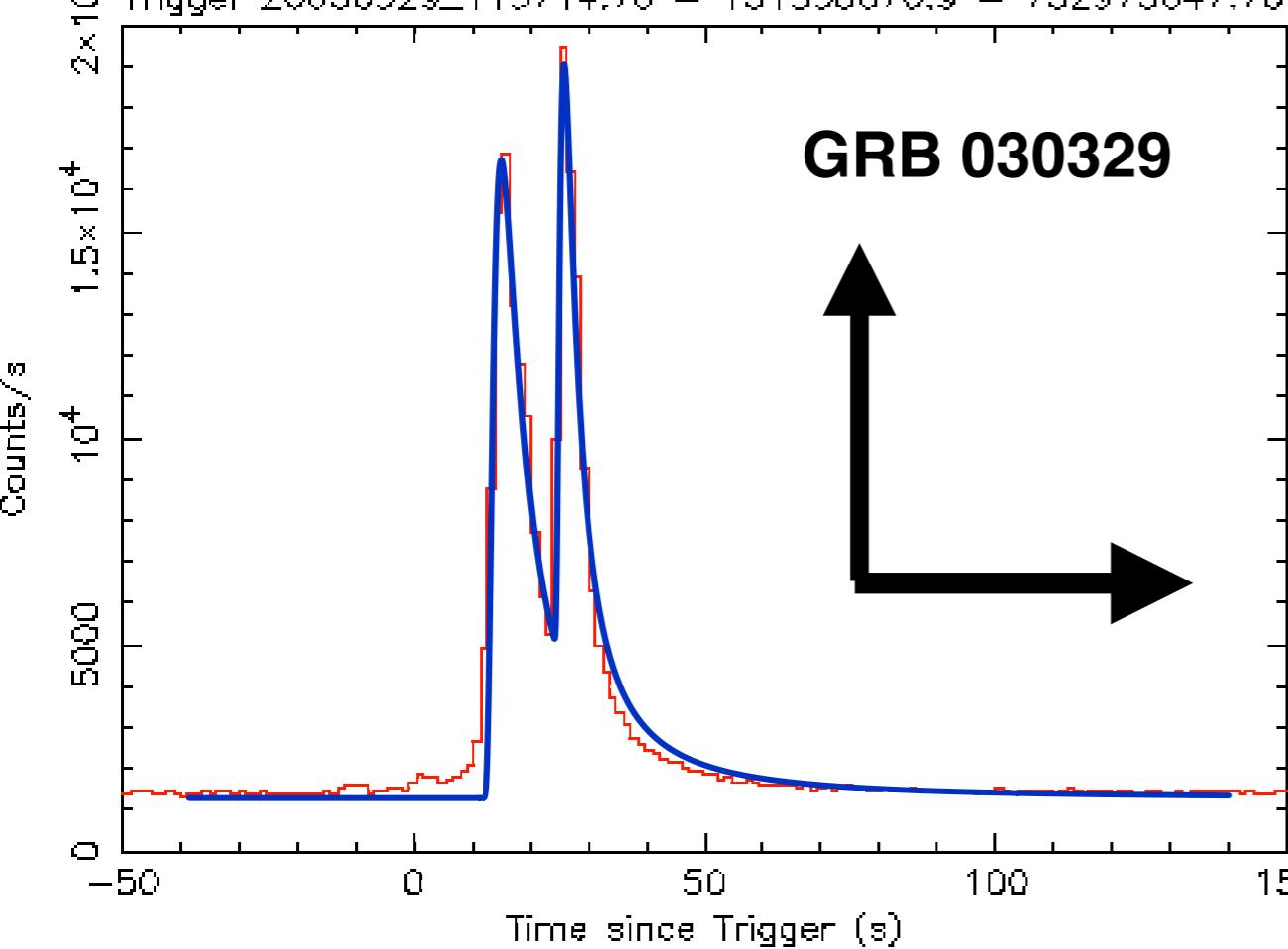


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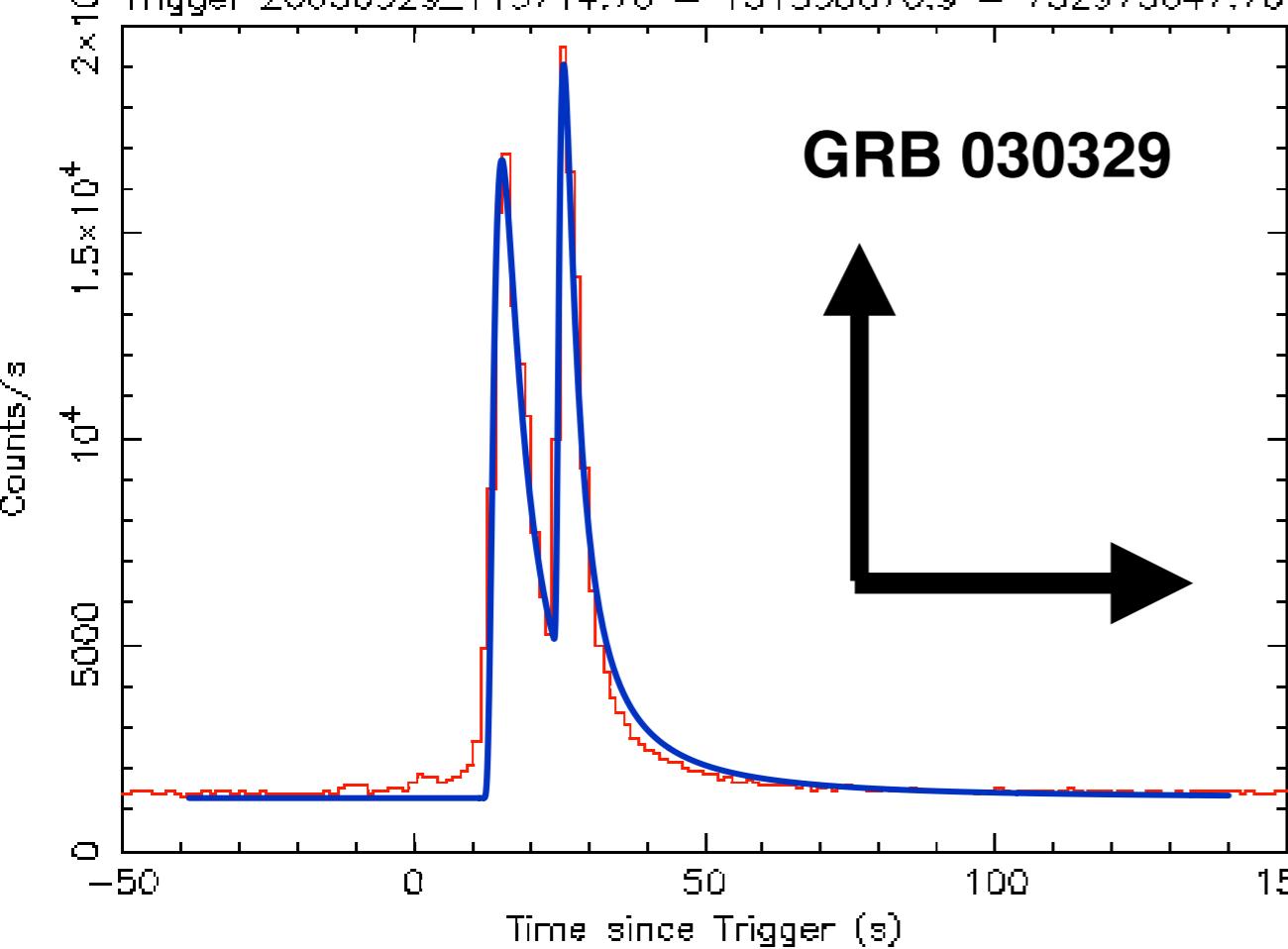
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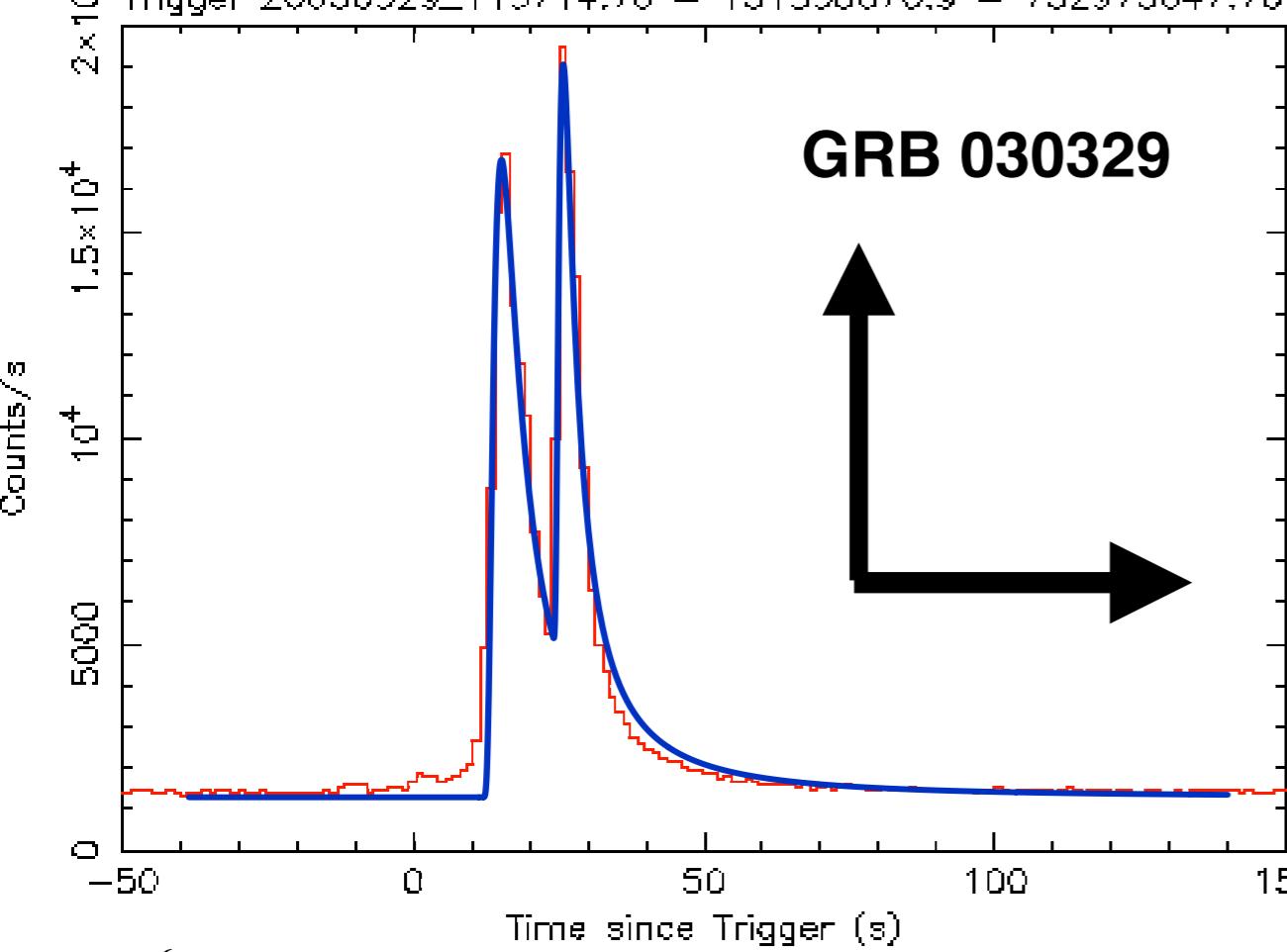


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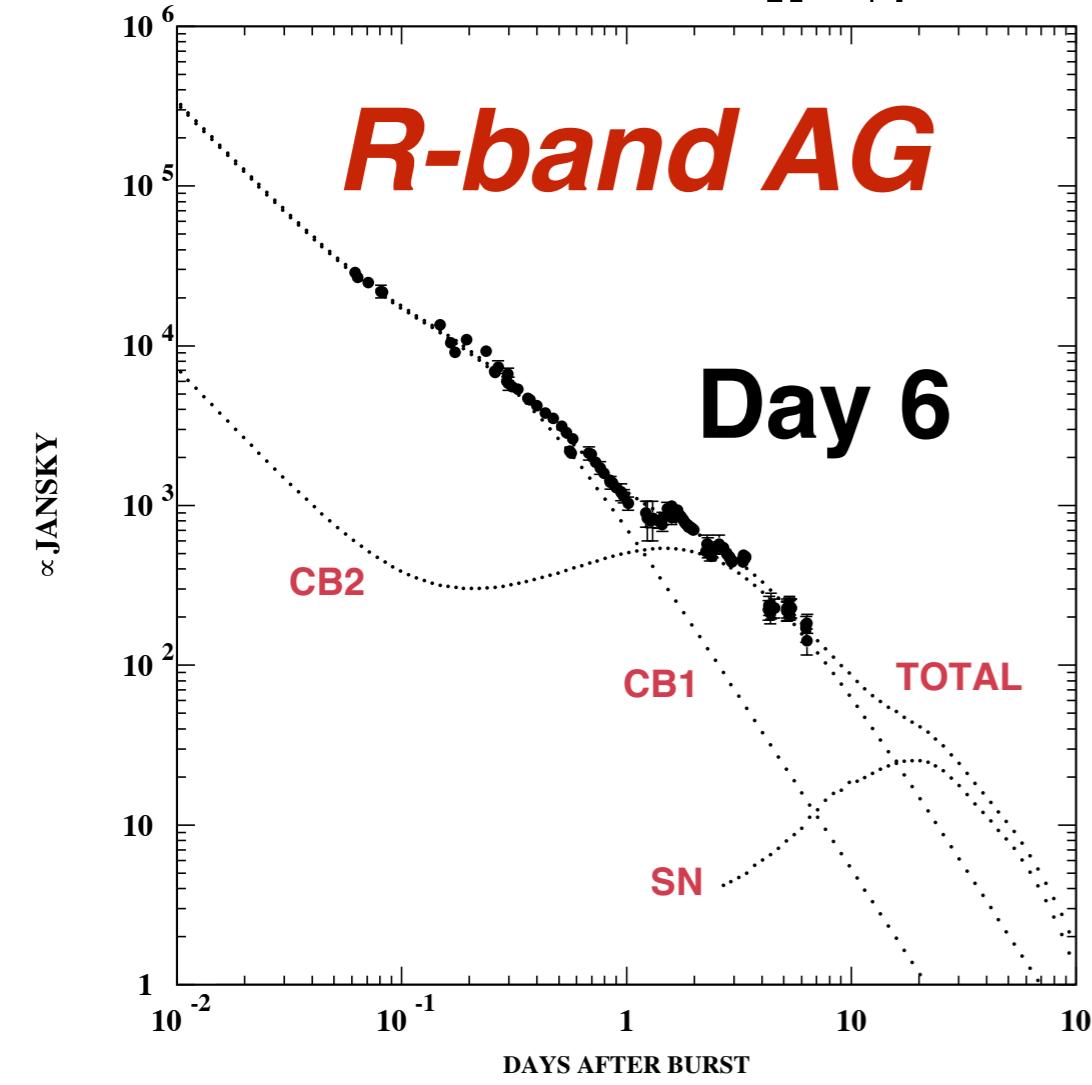
R-band AG

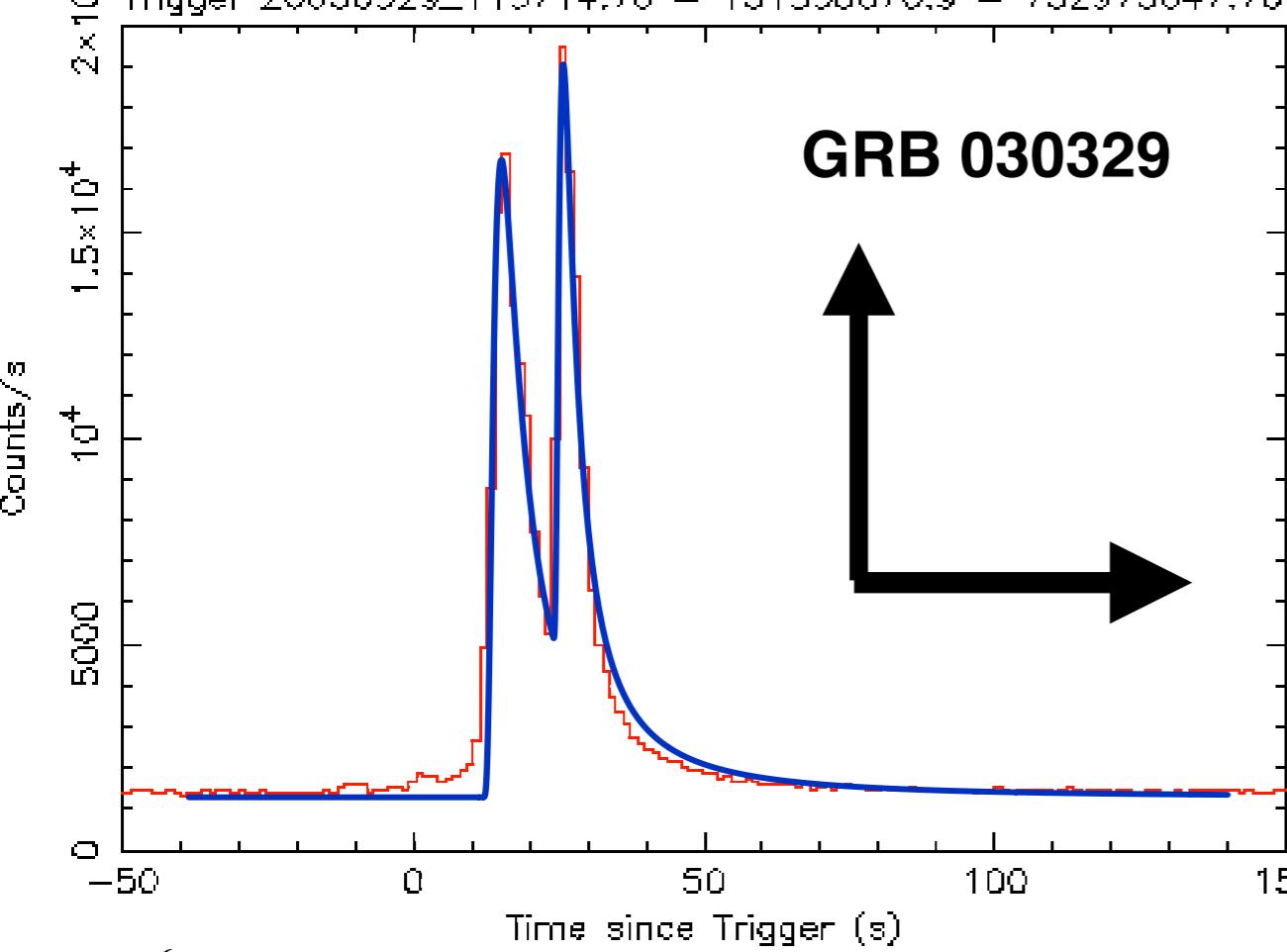


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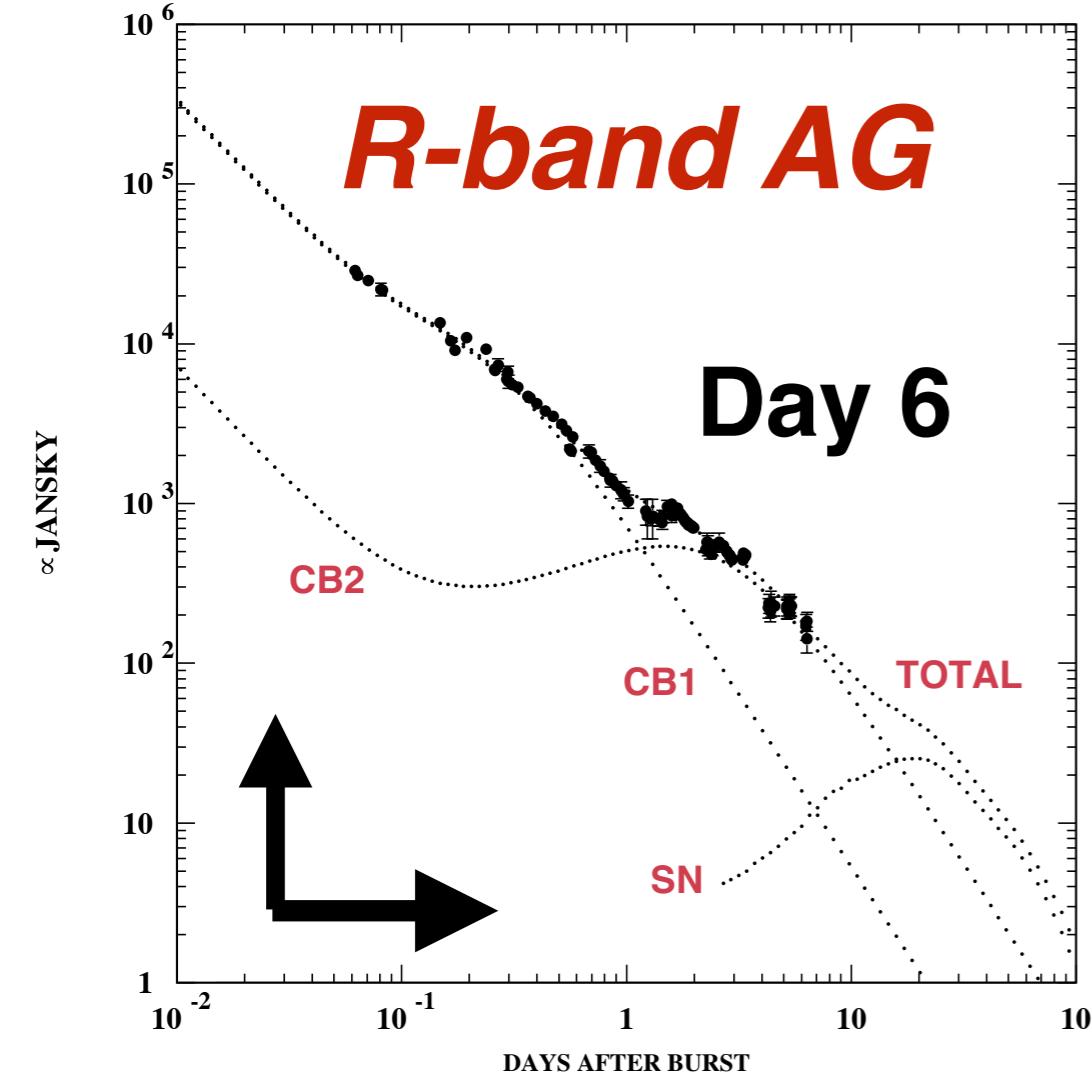


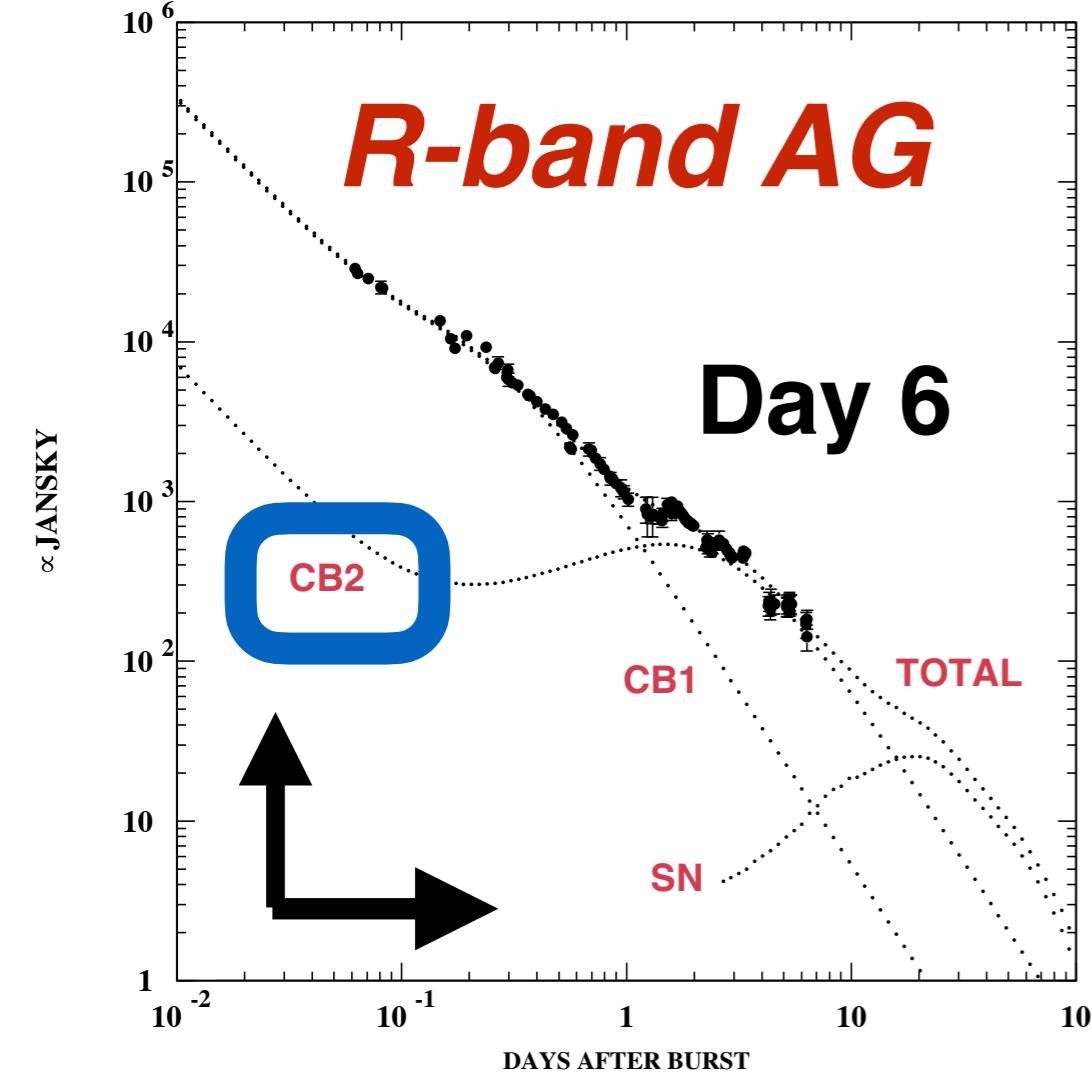
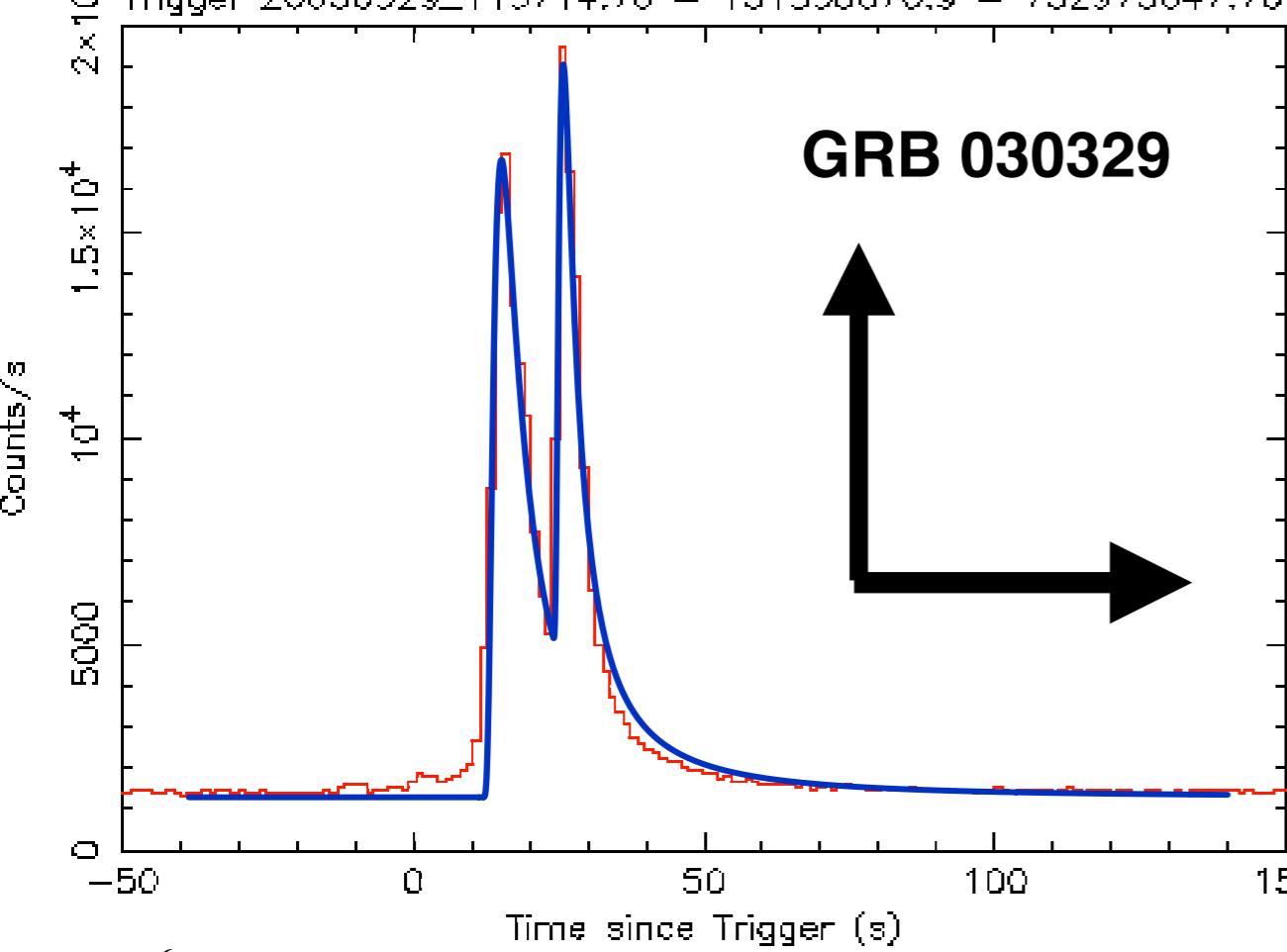


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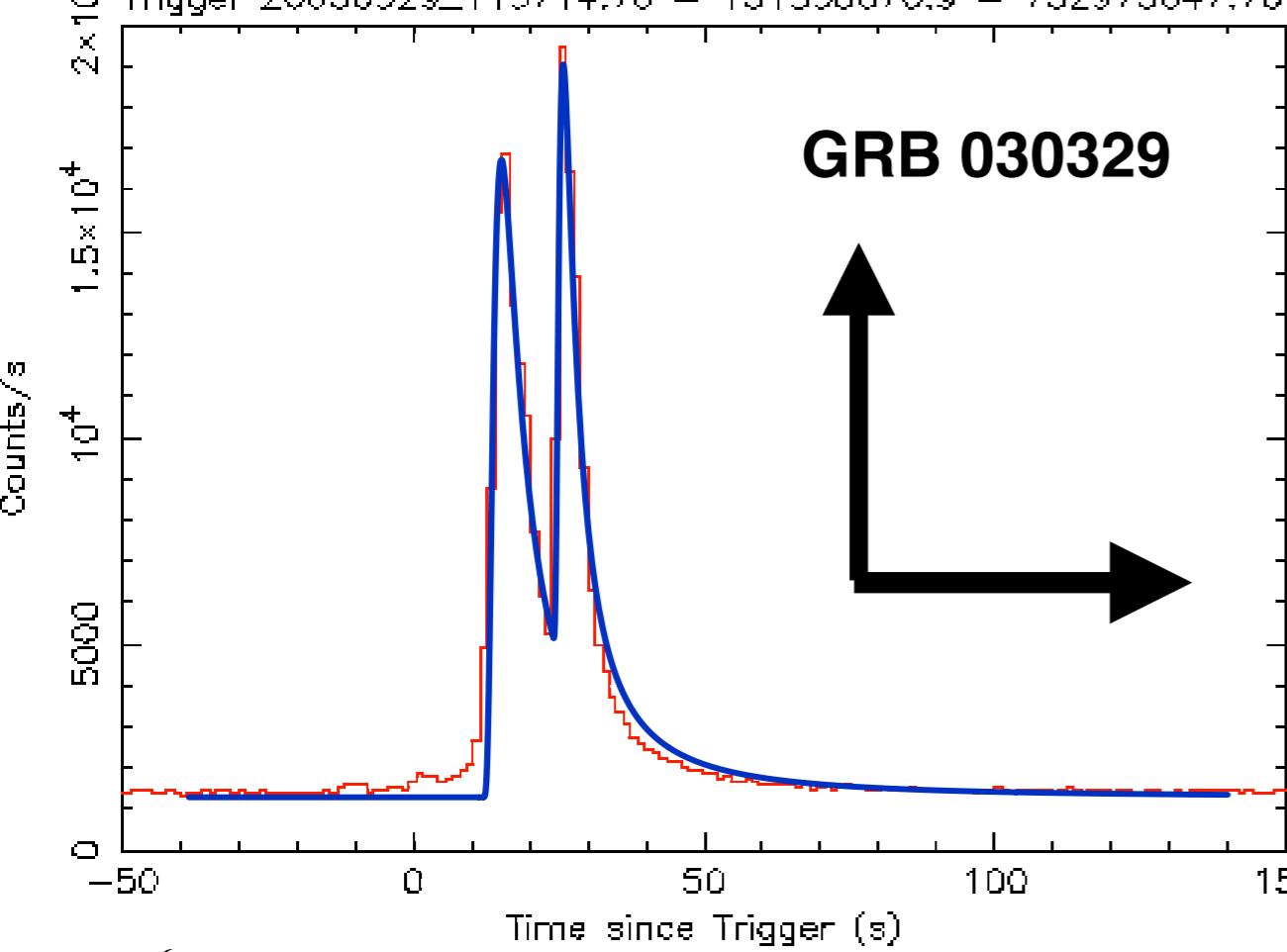
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The SN-LGRB association: a CB-model prediction

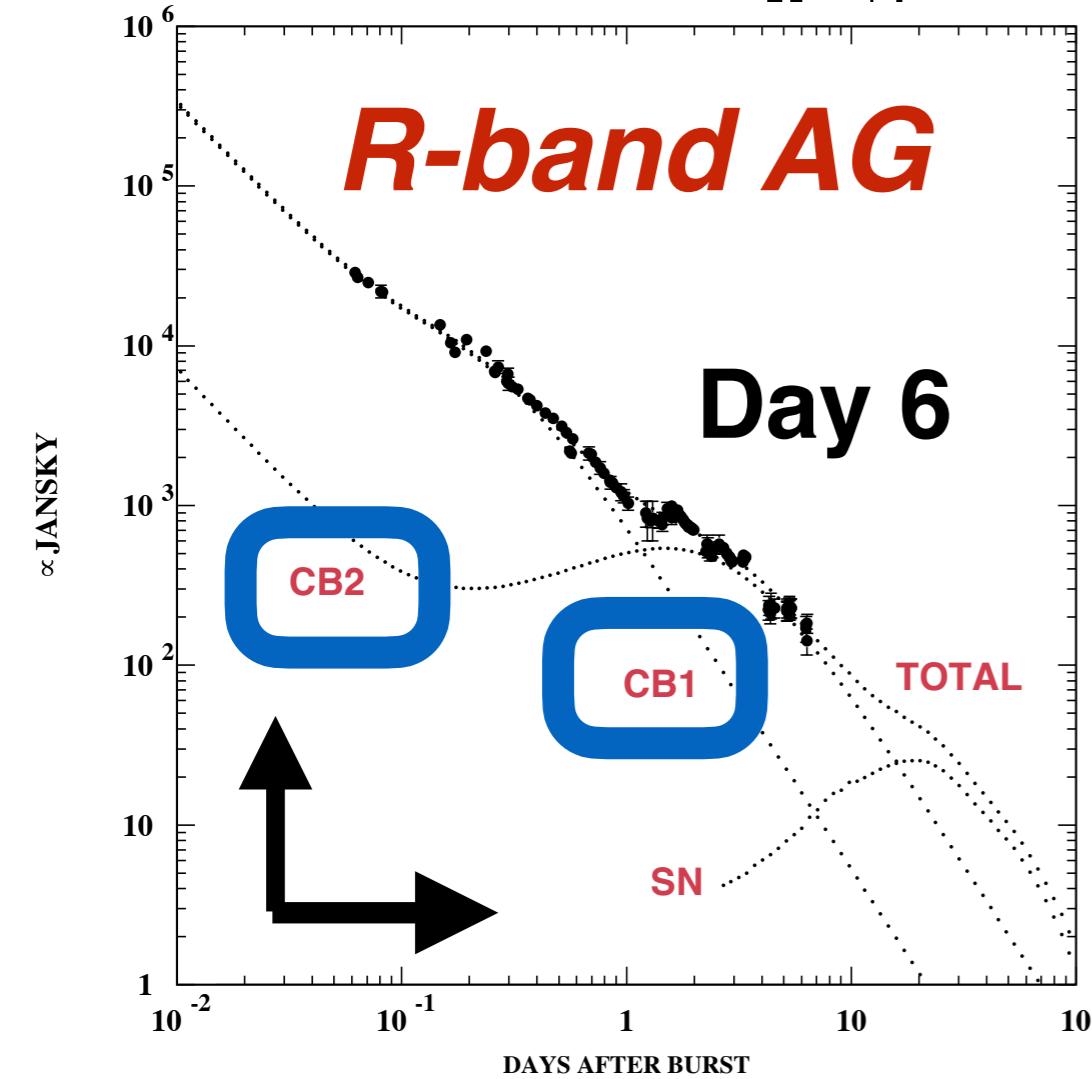
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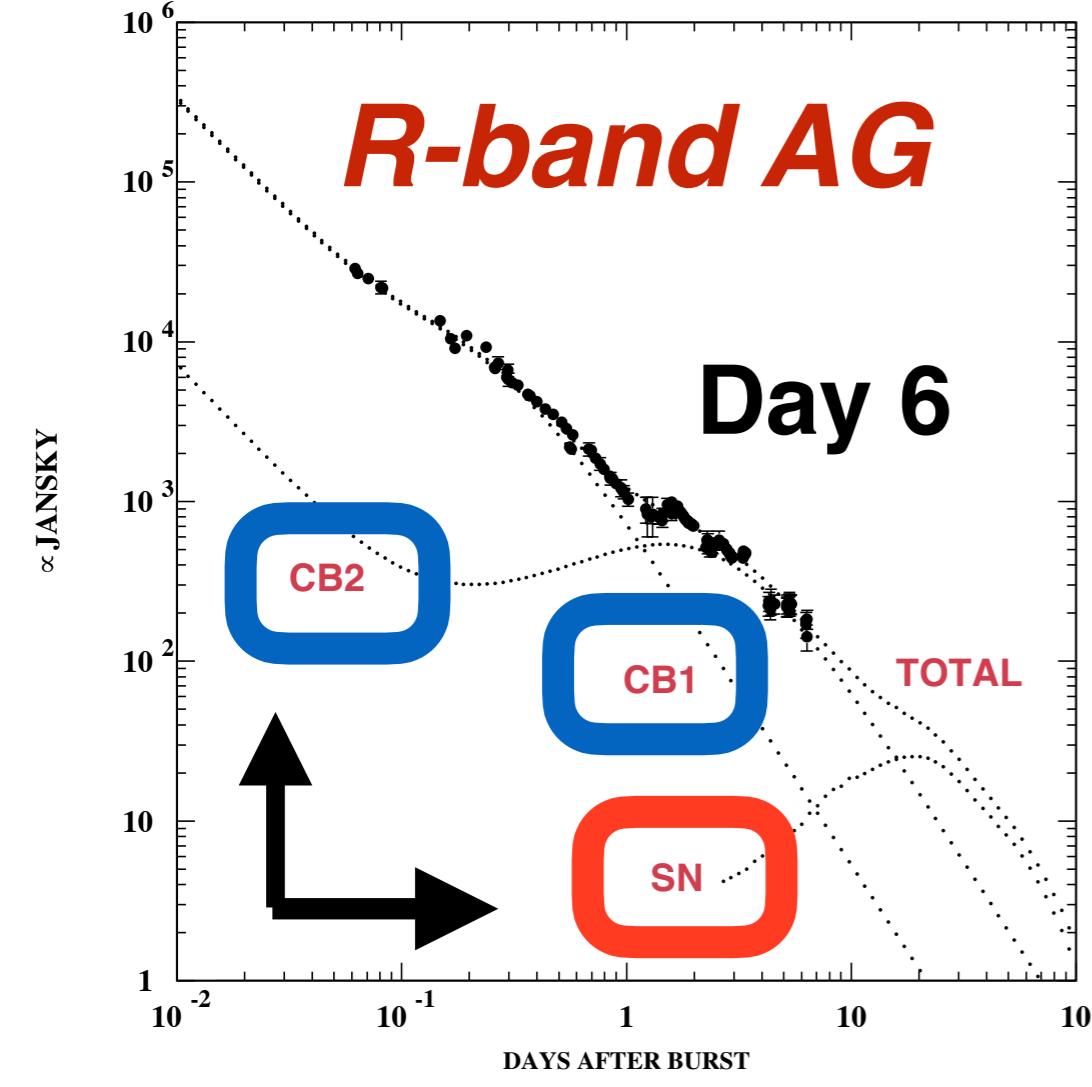
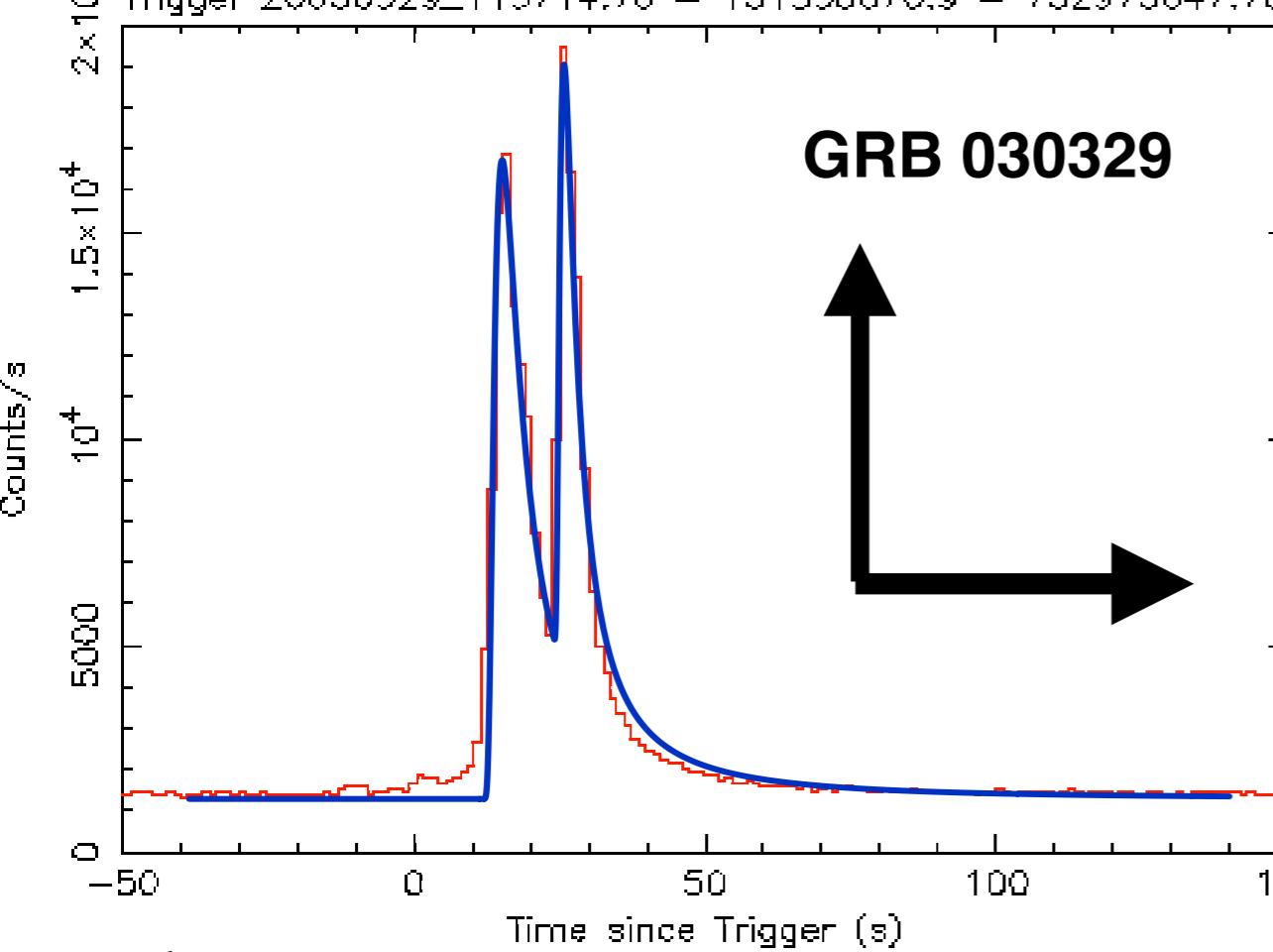


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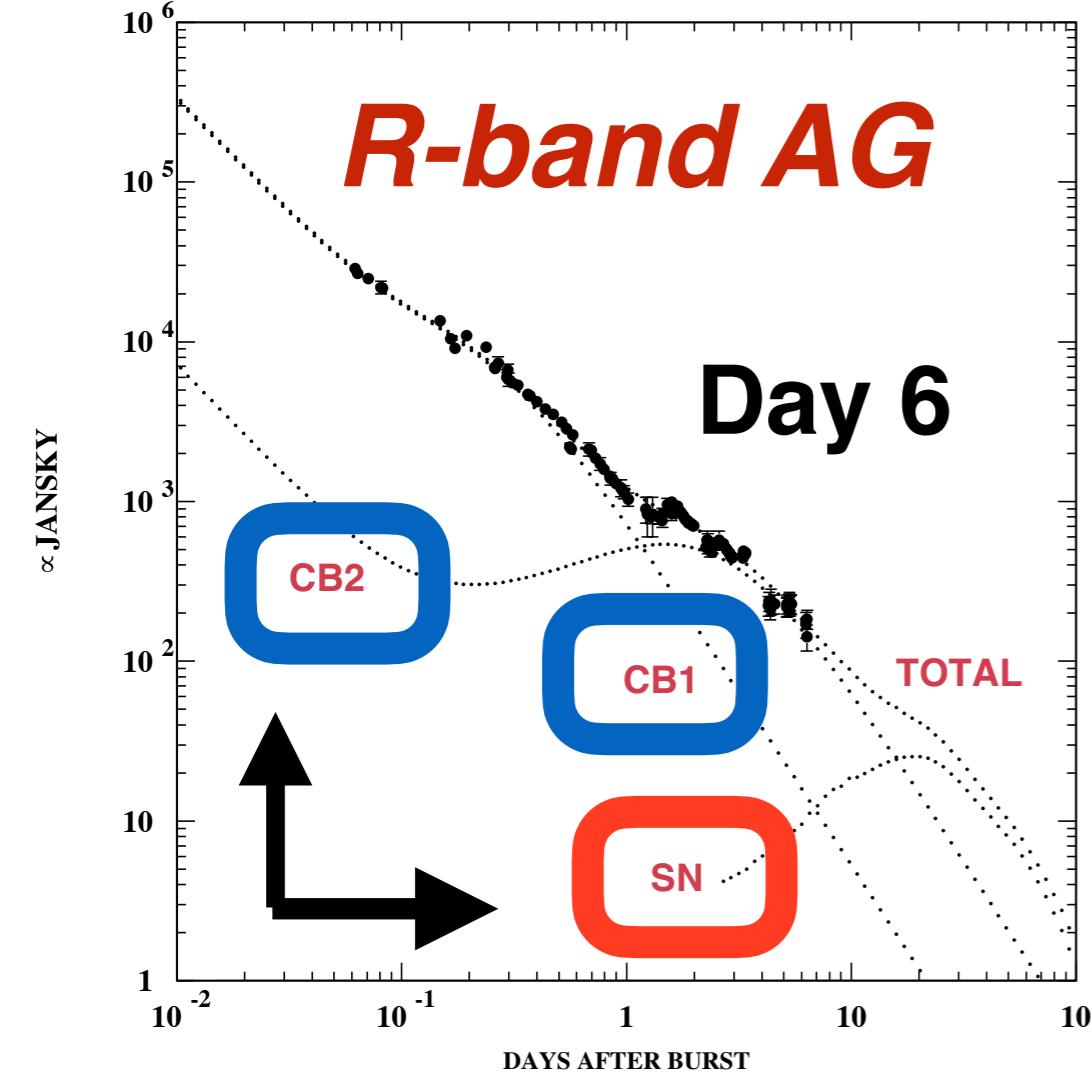
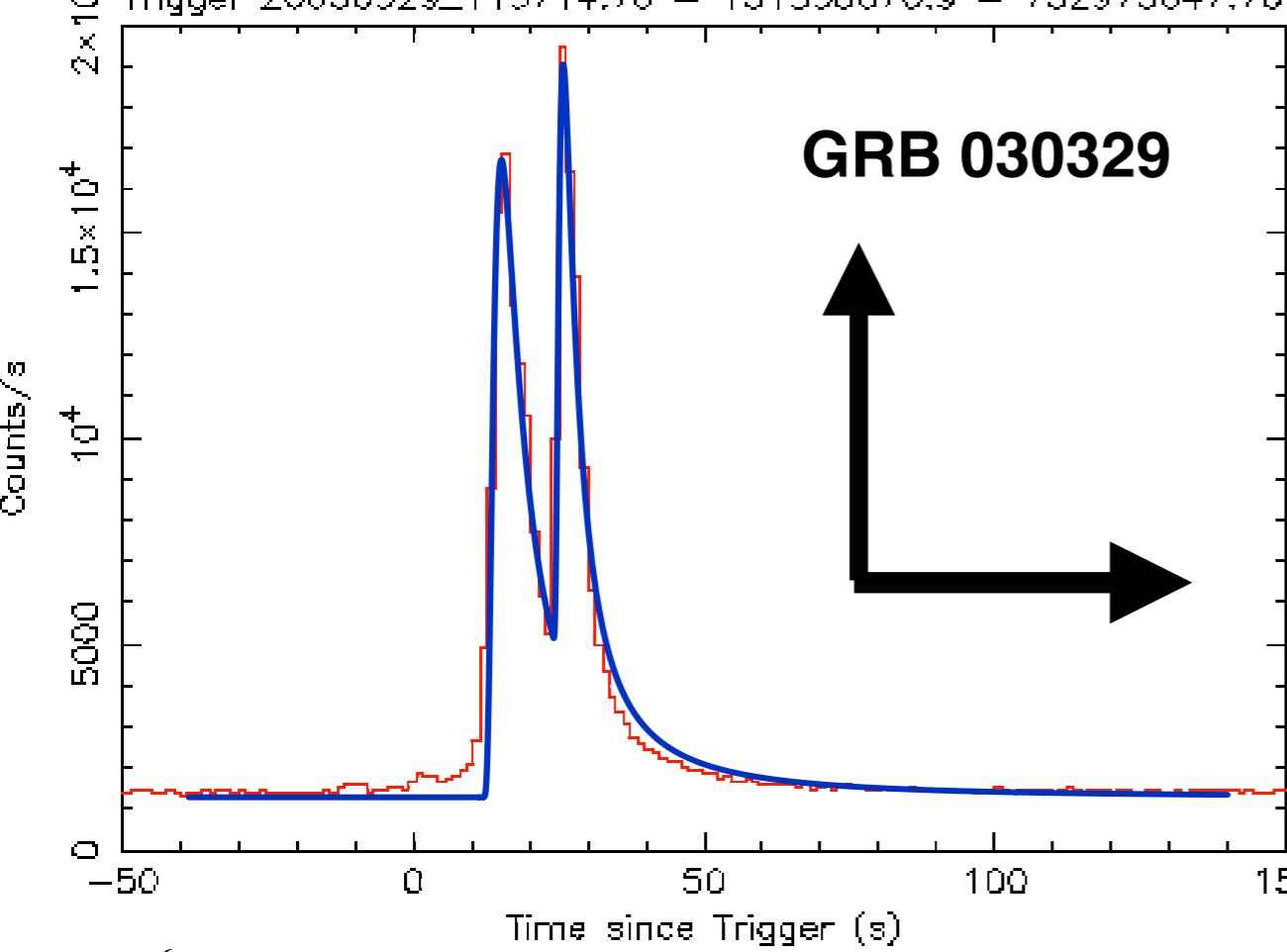
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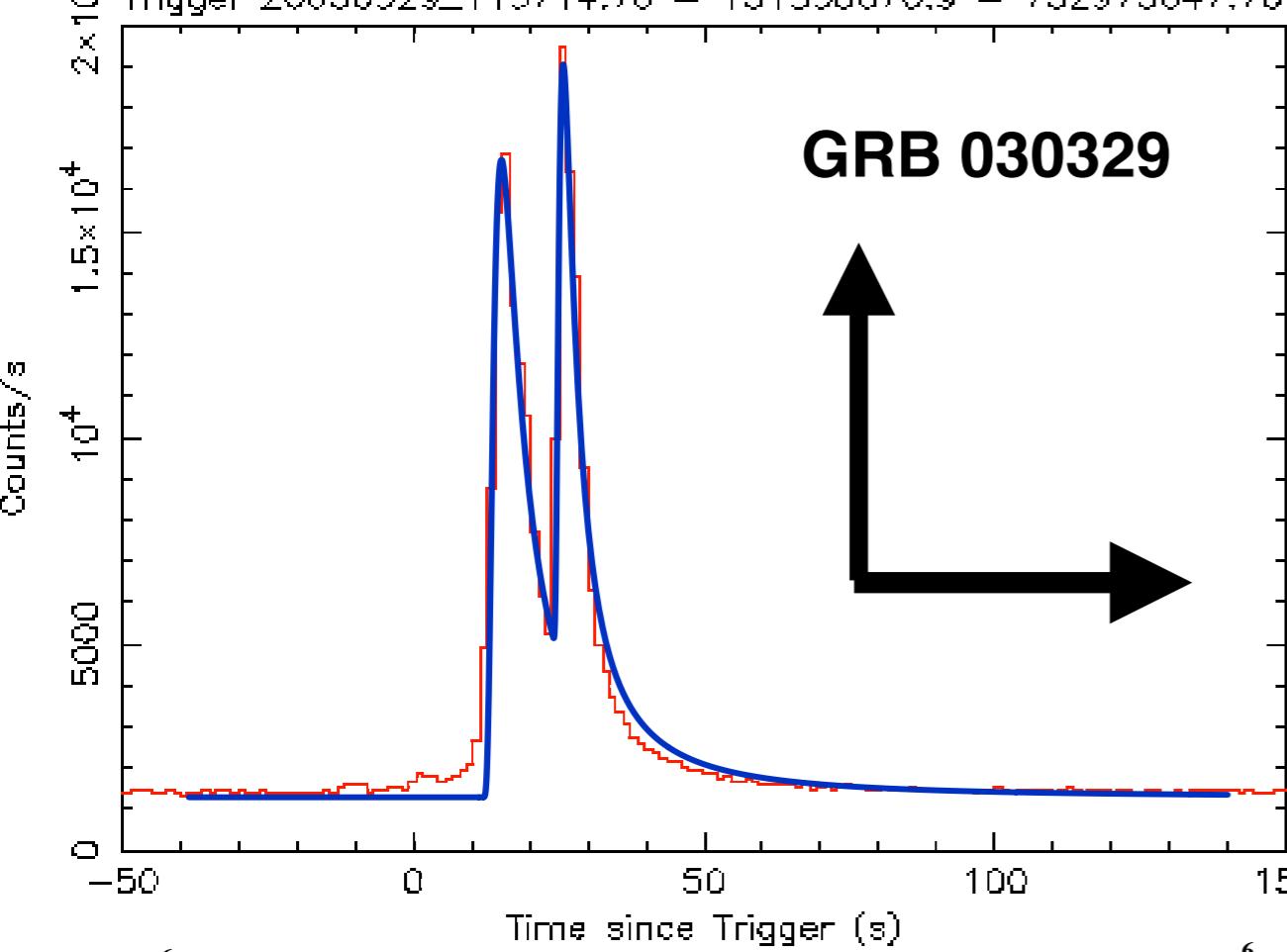


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Predicted
Supernova
discovery
date $d=10$

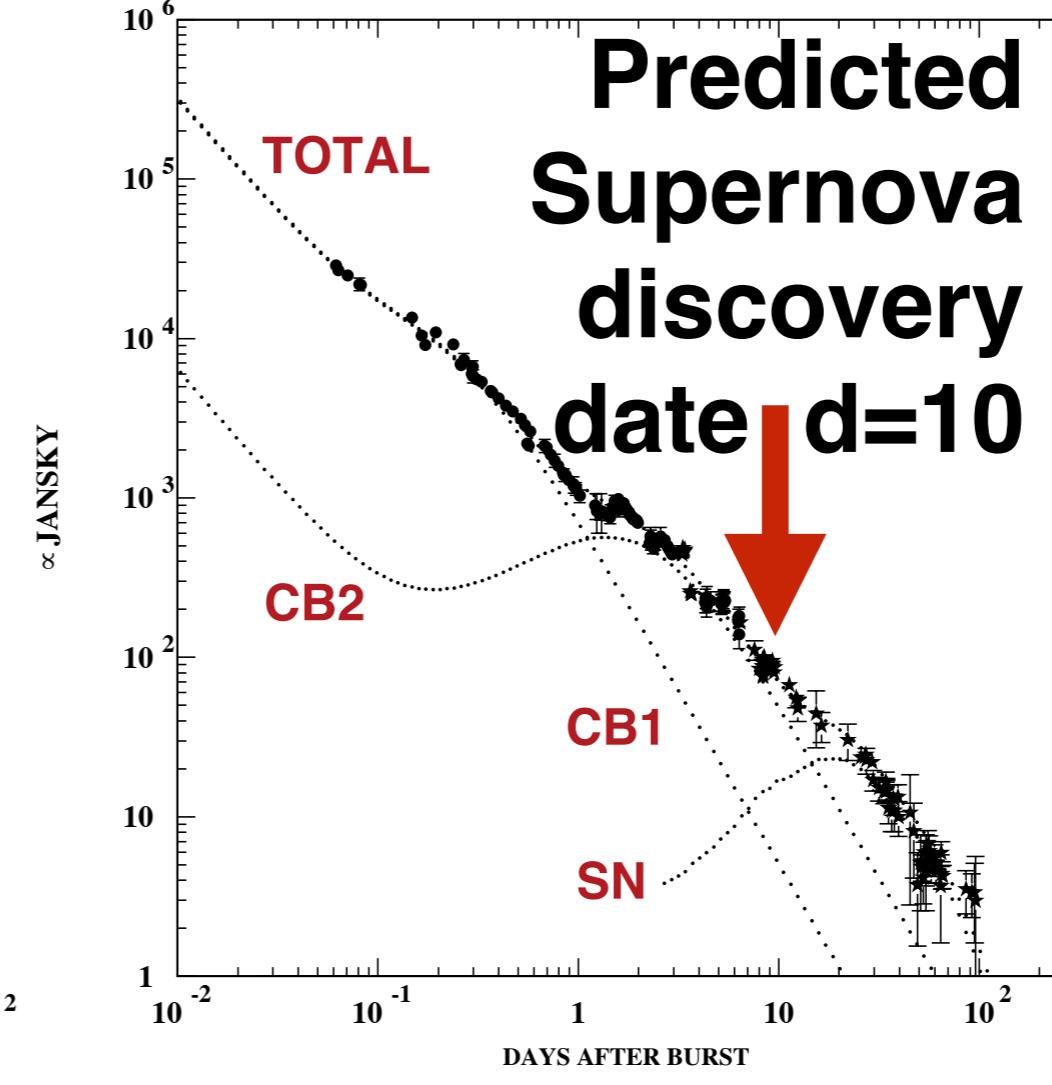
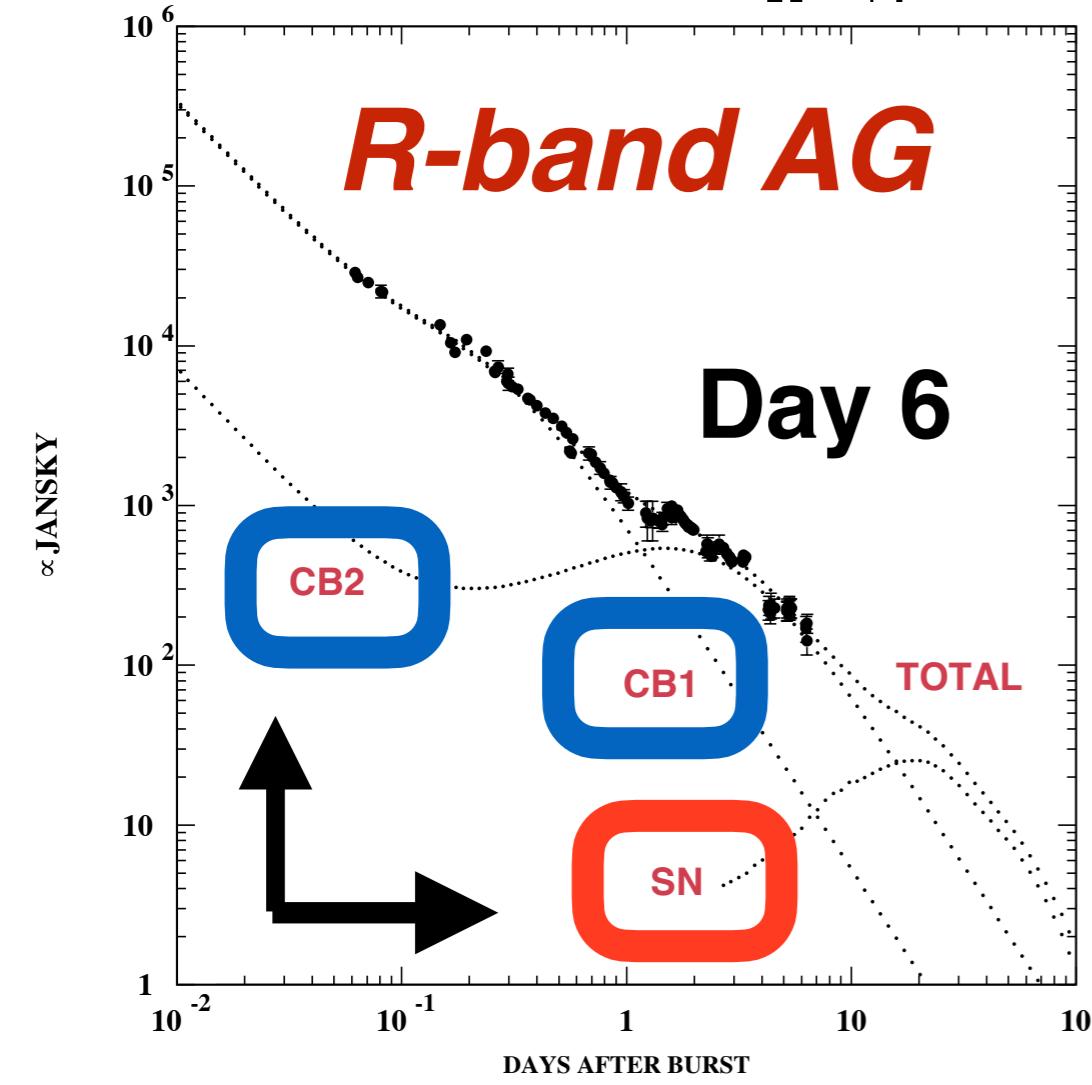
A red arrow points downwards from the text to the 'SN' component in the SED plot.

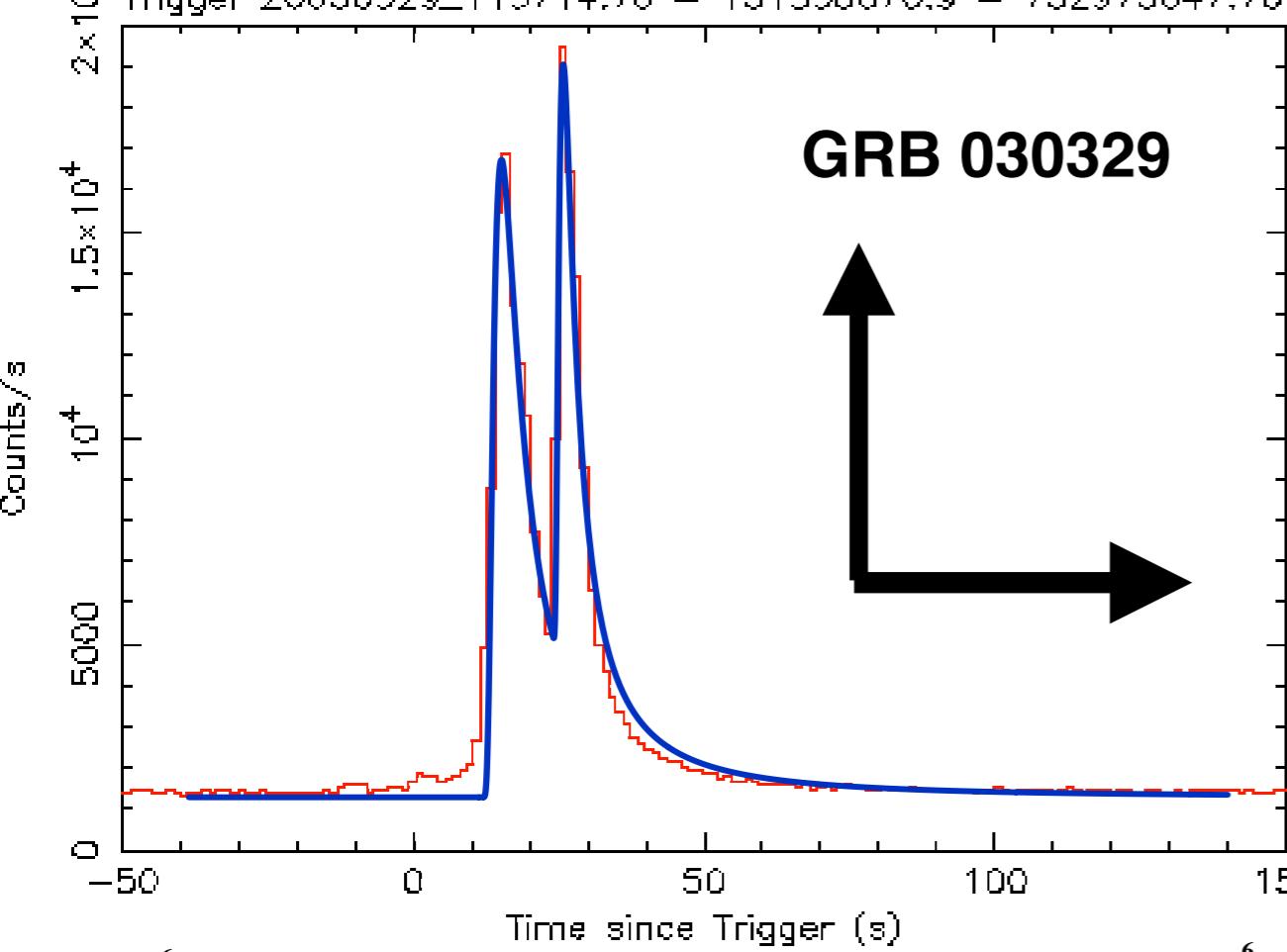


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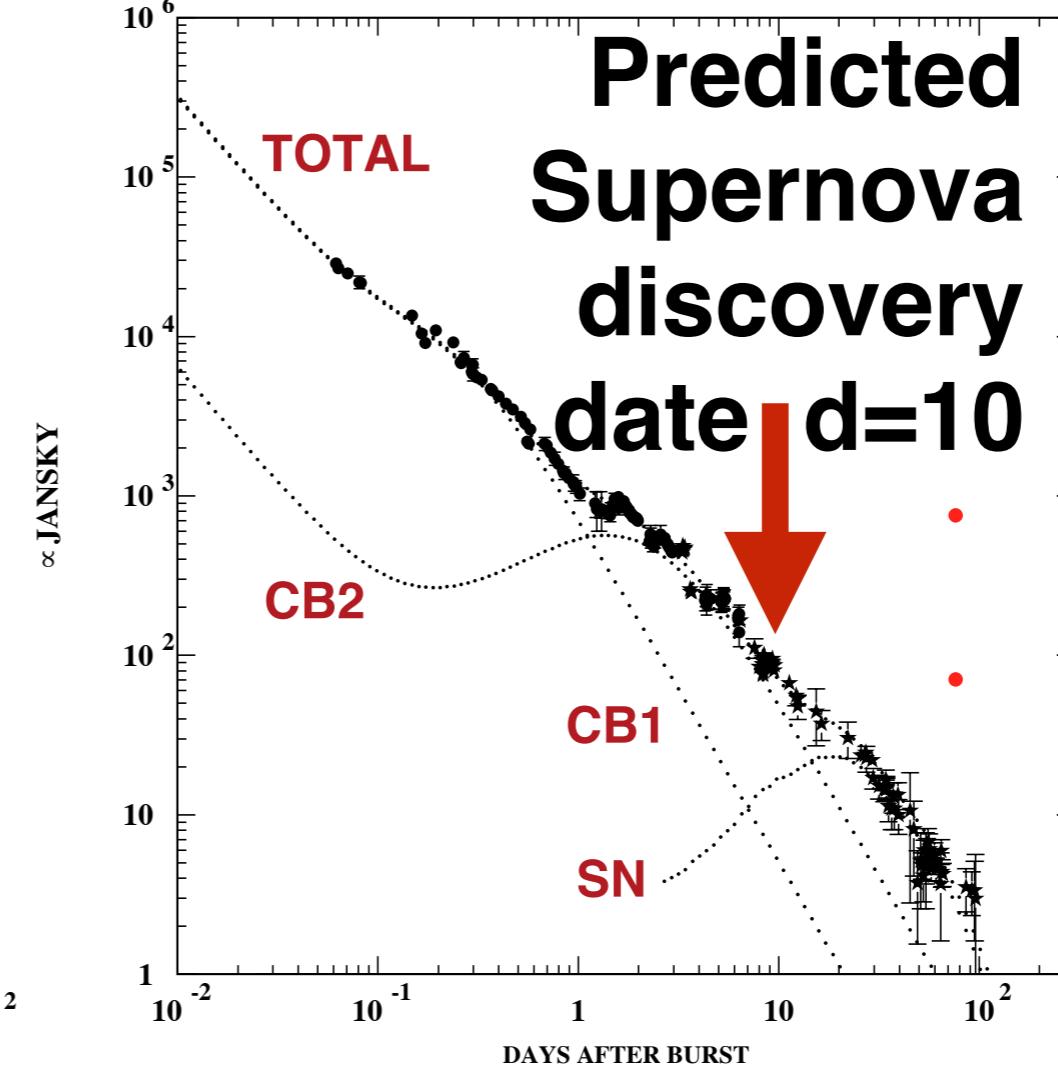
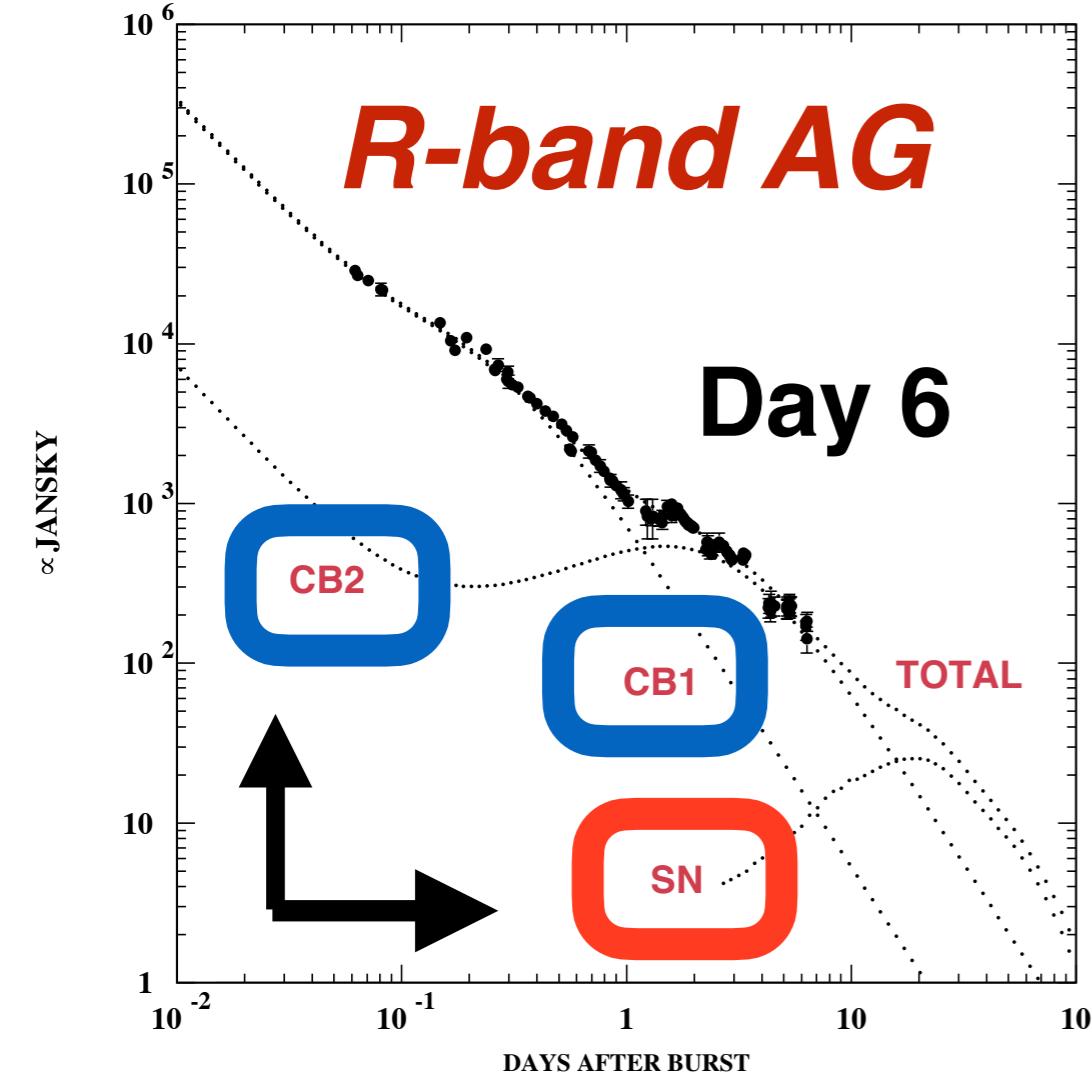




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$$F_\nu[SN] \neq F_\nu[CB]$$

FB before GRB 030329

FB before GRB 030329

Progenitor:

FB before GRB 030329

Progenitor: Failed SN

FB before GRB 030329

Progenitor: Failed SN Hypernova

FB before GRB 030329

Progenitor: Failed SN Hypernova Macronova

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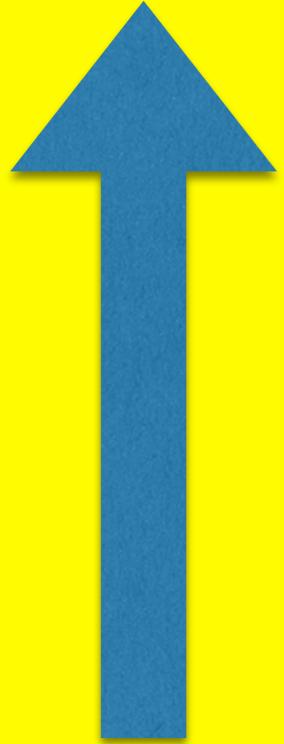
FB after

FB before GRB 030329

Progenitor: Failed SN Hypernova Macronova

FB after

*Progenitor: Everybody always
knew it was core-collapse SNe*



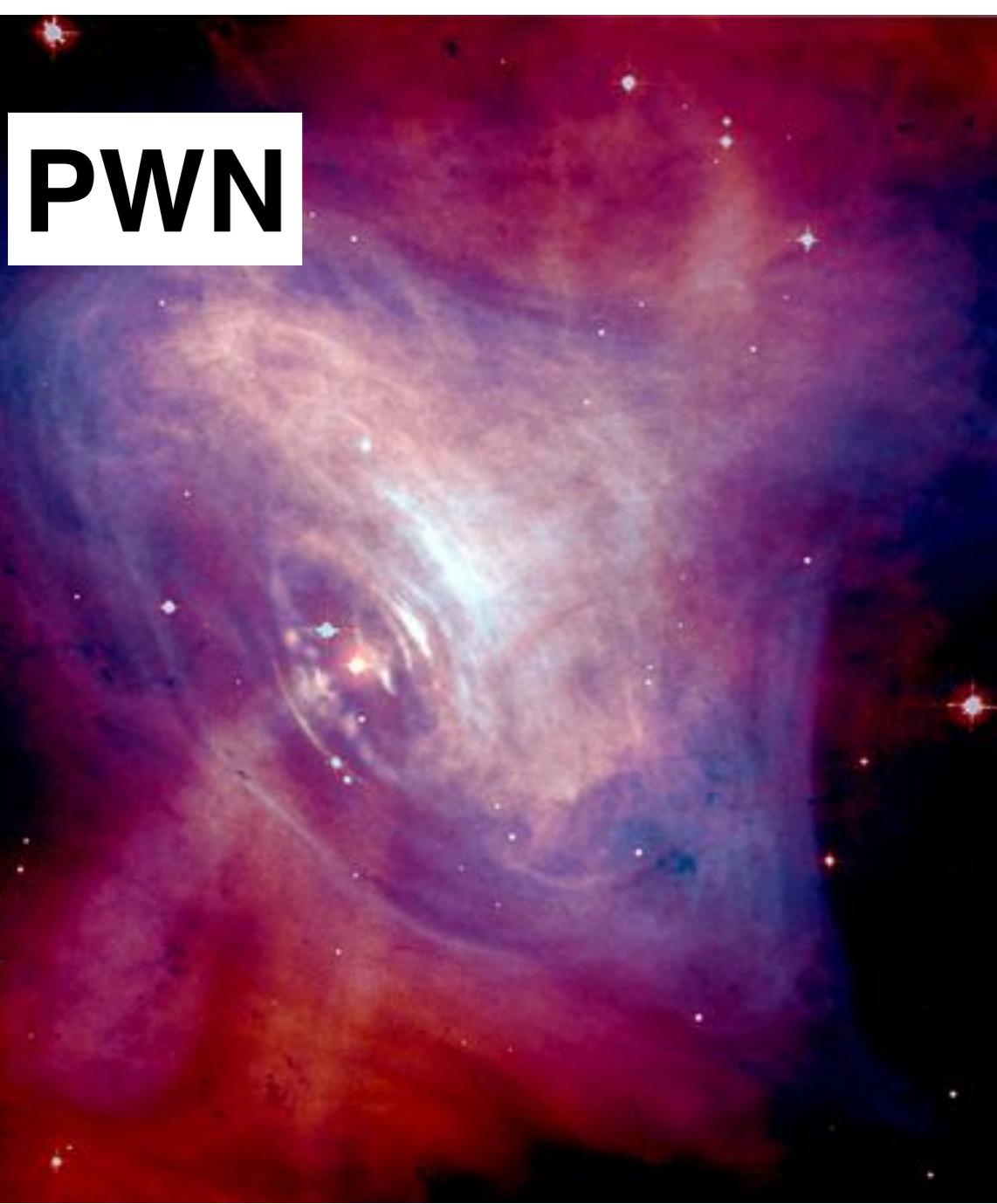
The AfterGlows of Long GRBs

**The AfterGlows
of SHBs**



CB-Model'S SHB AfterGlows

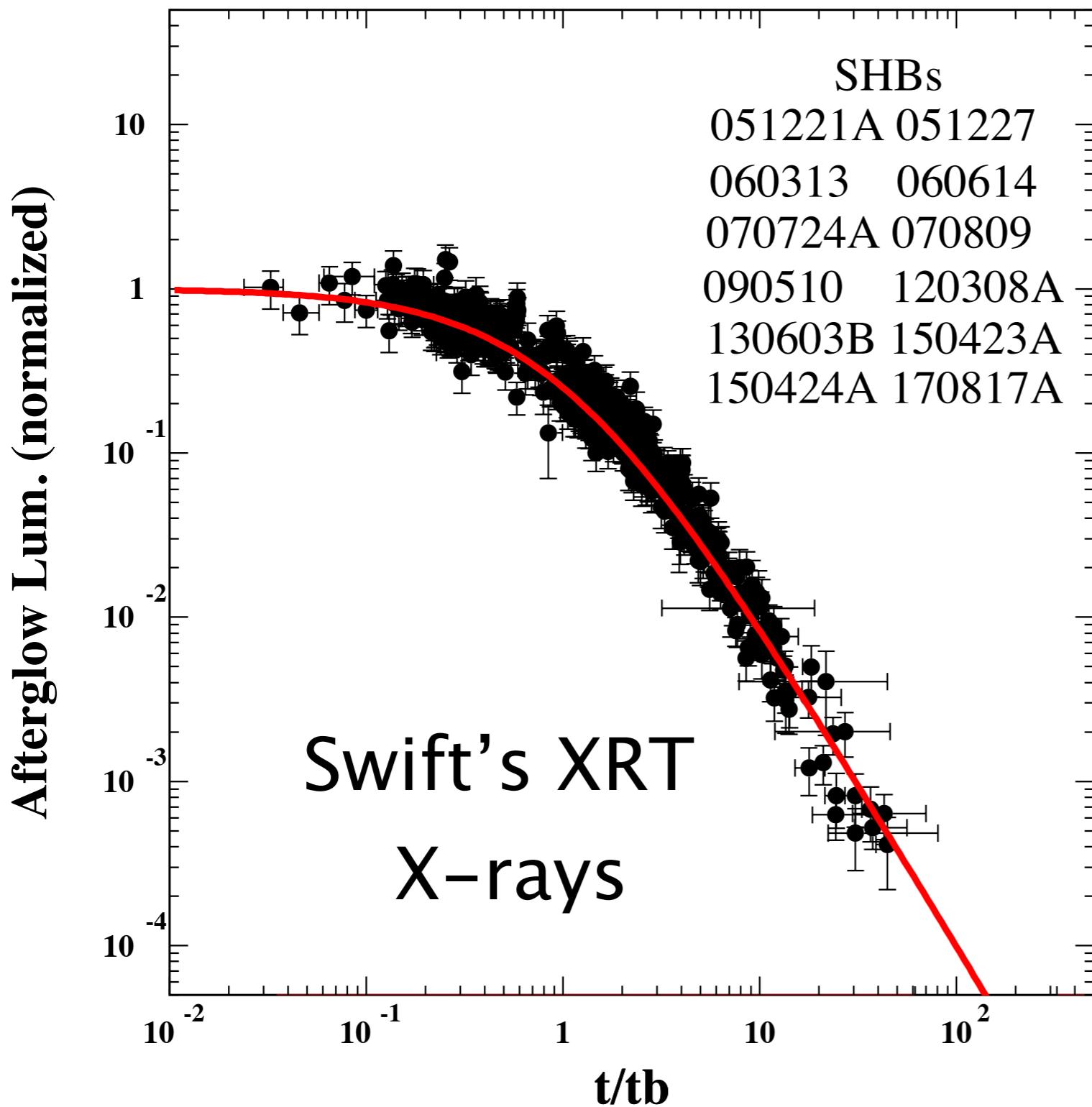
Pulsar losing rotational energy
by magnetic dipole radiation



Constant fraction of this
energy absorbed and
re-emitted by PWN as
electromagnetic radiation
(Pacini, 1967,
Dado, Dar 2018)

$$\frac{L(t, t_b)}{L(t = 0)} = \frac{1}{(1 + t/t_b)^2}$$

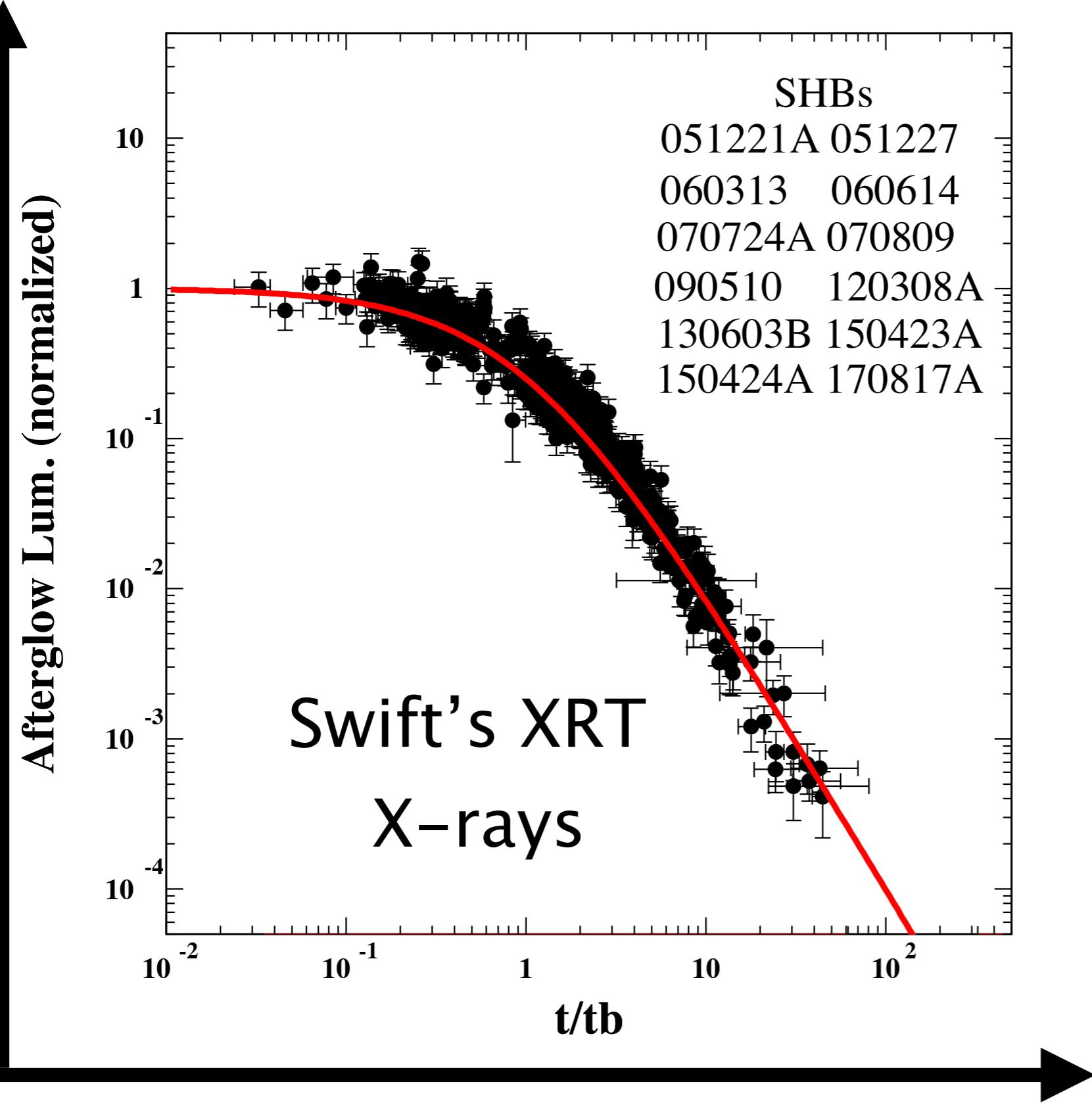
$$t_b = \frac{P(0)}{2 \dot{P}(0)}$$



“Universal Light-Curve”

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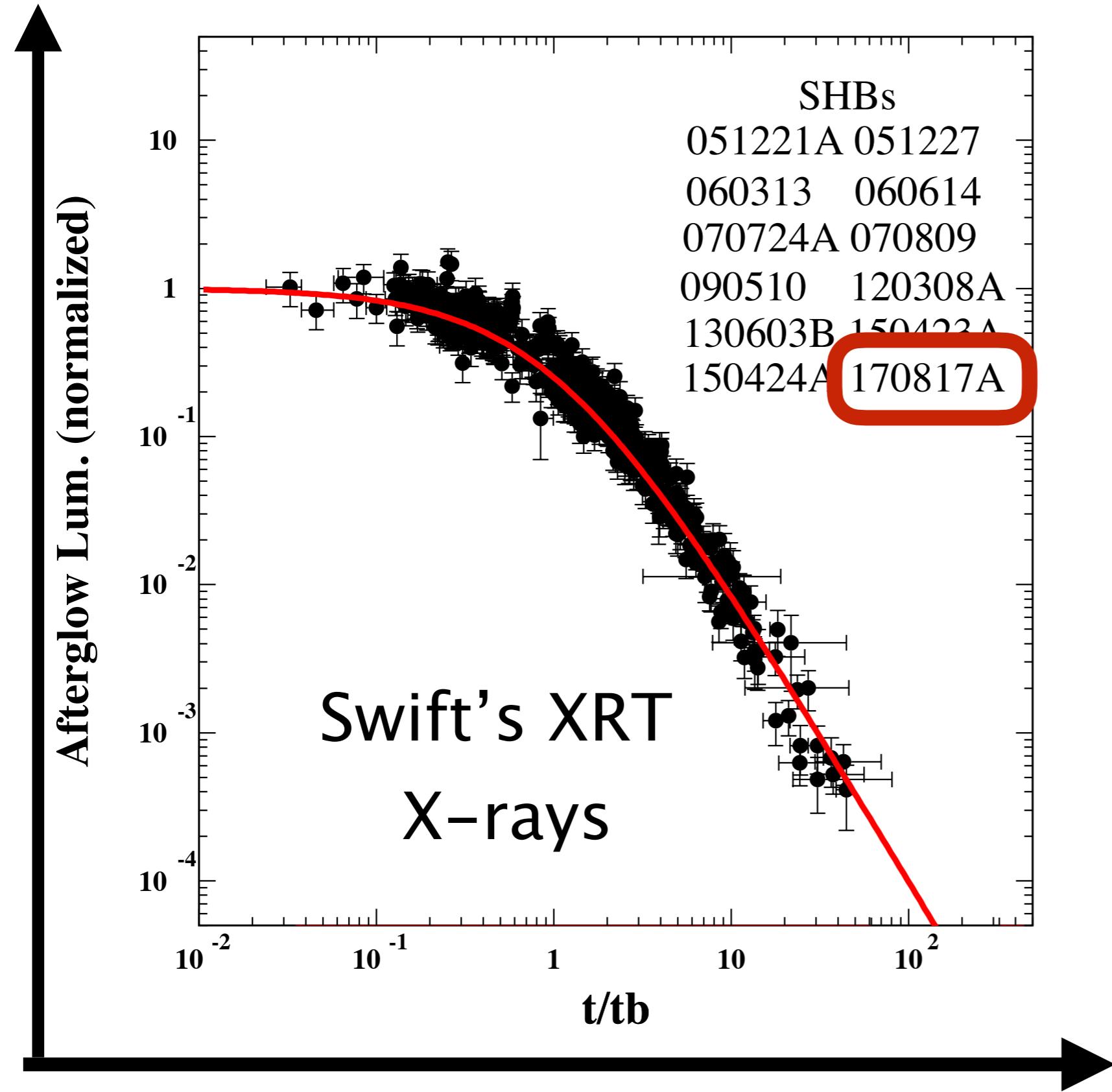
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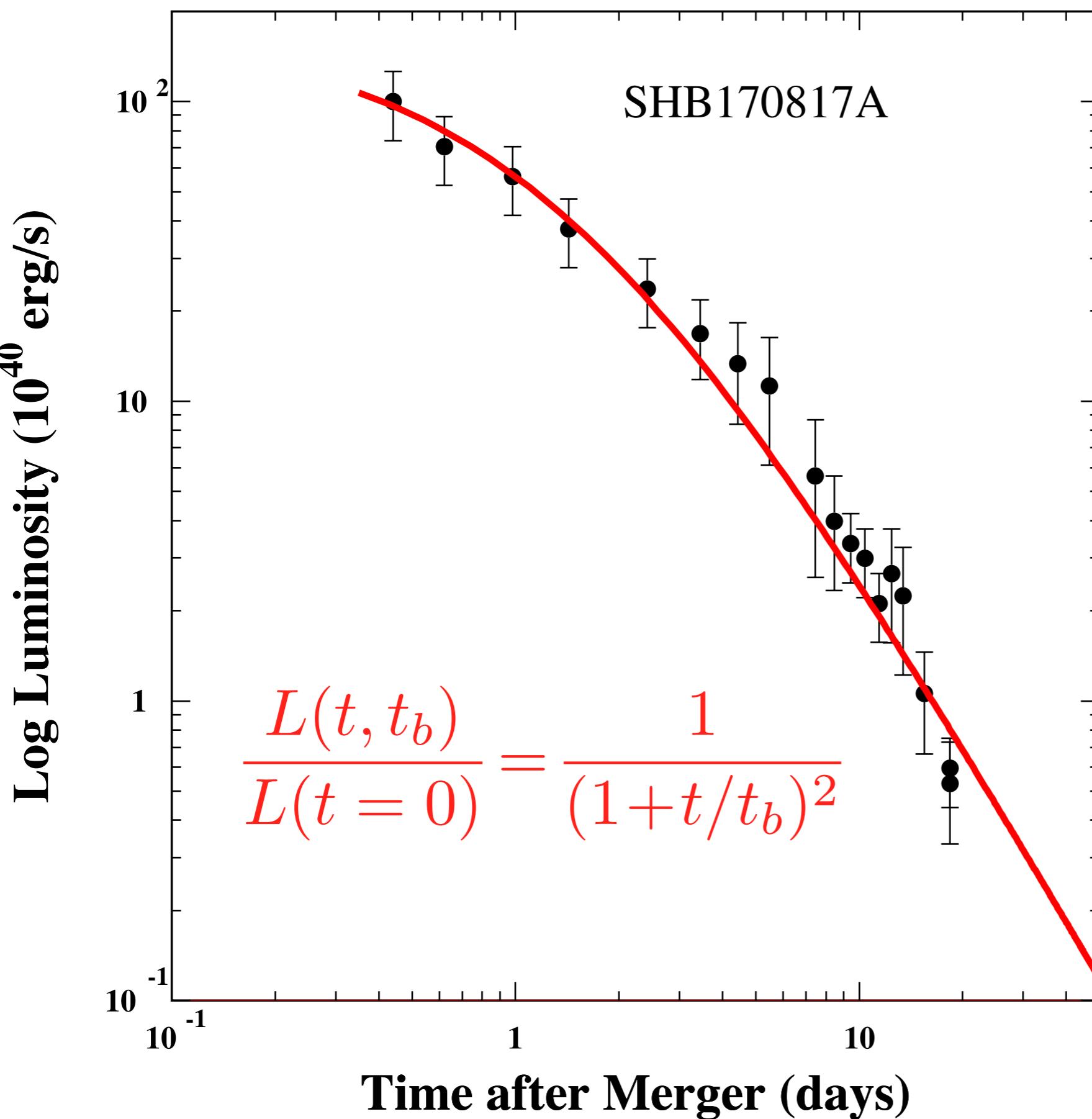
$$L(0) = 2.27 \times 10^{42}$$

erg/s.

$$t_b = 1.15 \text{ d},$$

$$\chi^2 / \text{dof} = 1.04.$$

$$t_b = \frac{P(0)}{2 \dot{P}(0)}$$



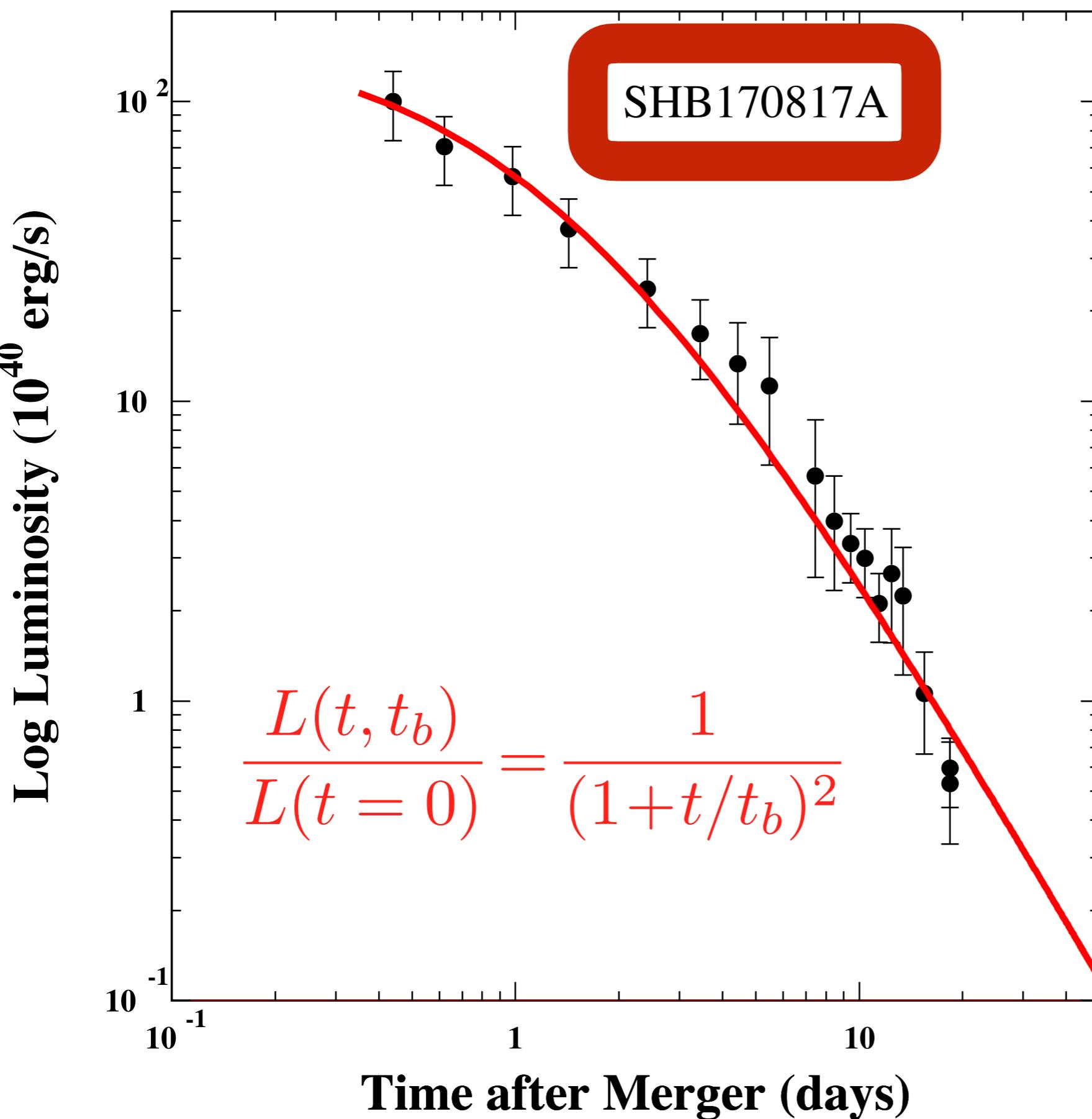
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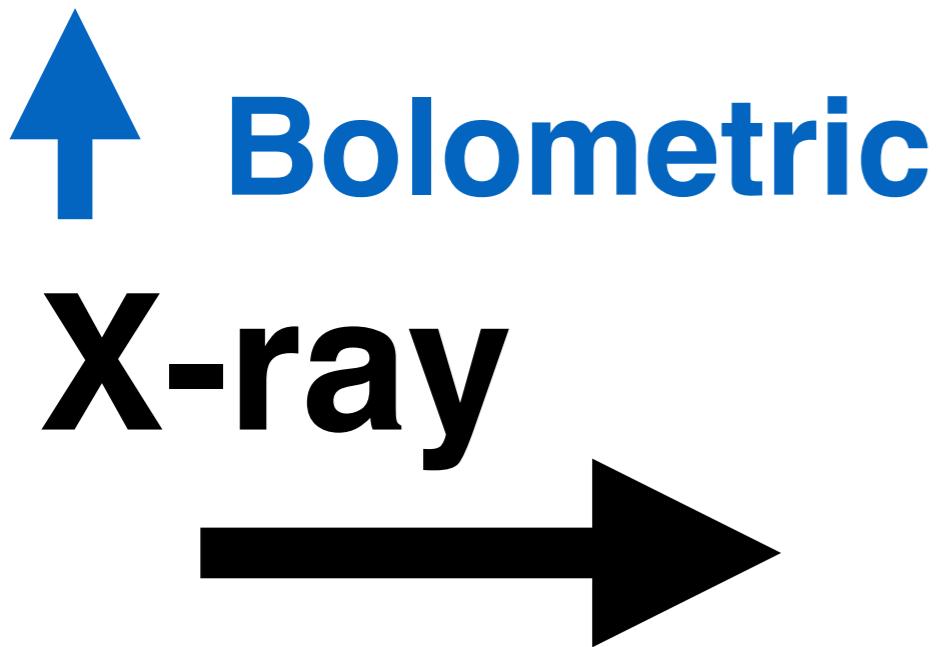
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$$F \propto t^{-\alpha} \nu^{-\beta}$$

CB-Model
Prediction

$$\alpha_x = \beta_x + 1/2$$

$$\beta_x [\text{Obs.}] = 1.17 \pm 0.04$$

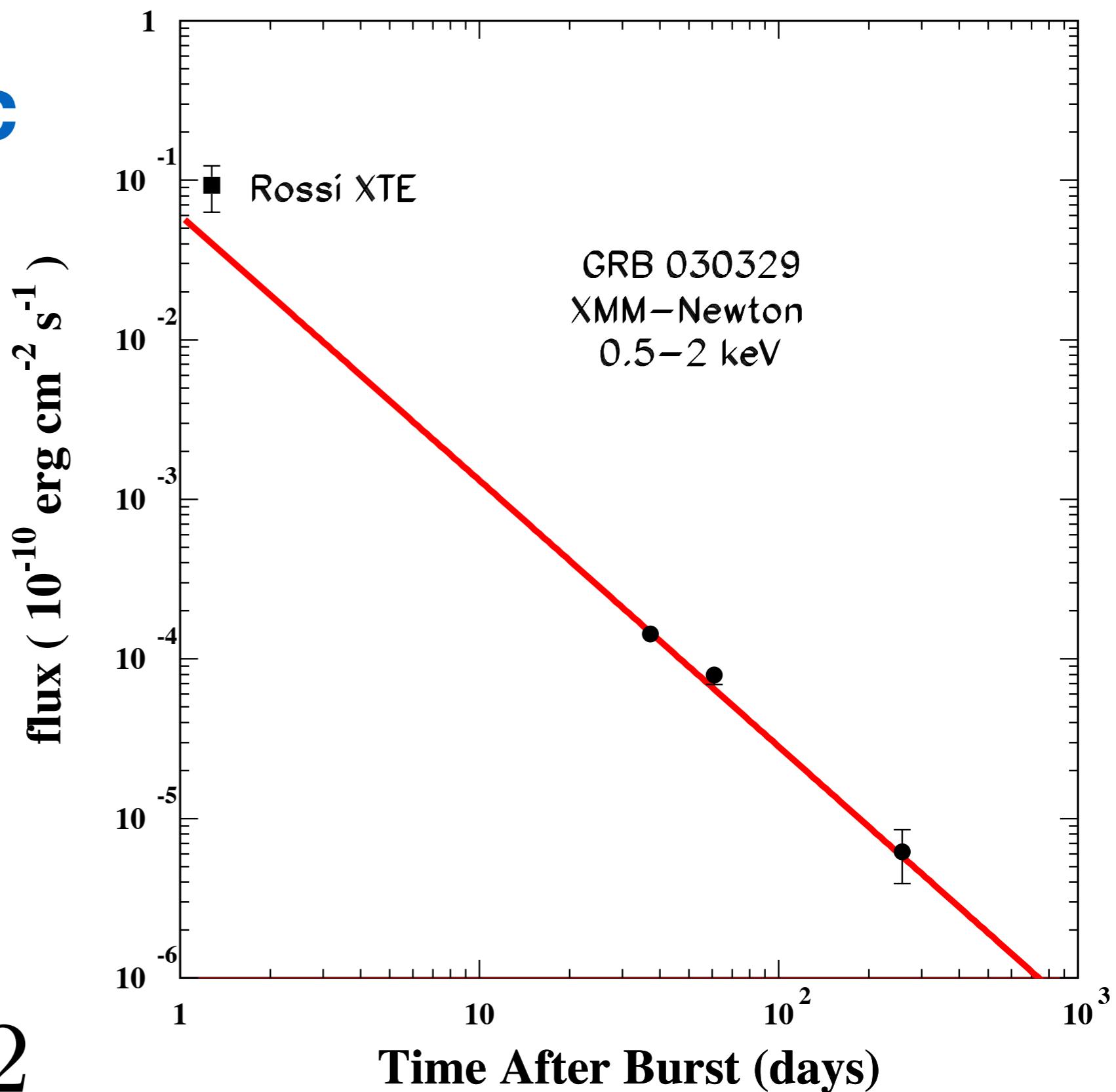
Bolometric
X-ray

$$F \propto t^{-\alpha} \nu^{-\beta}$$

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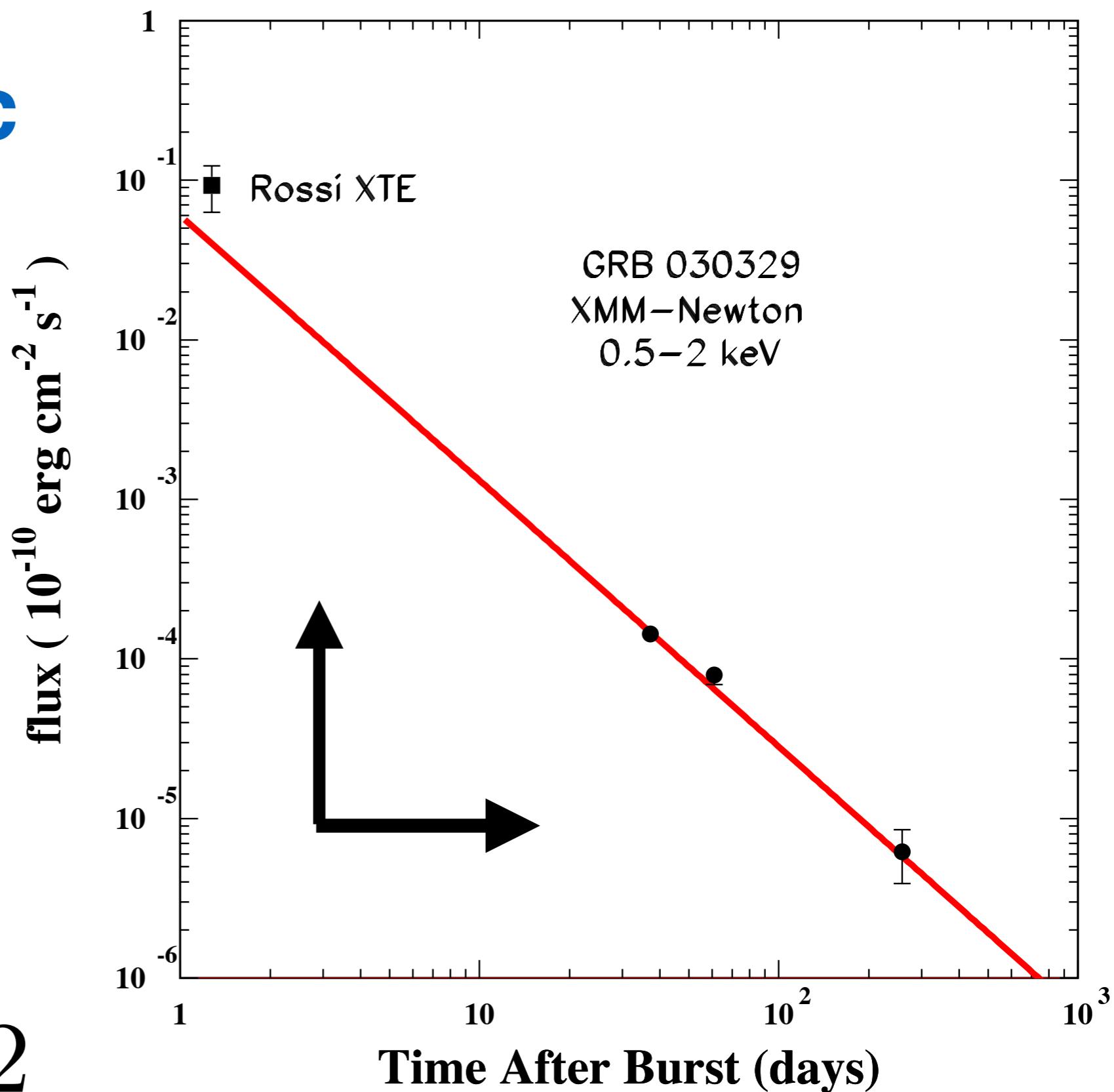
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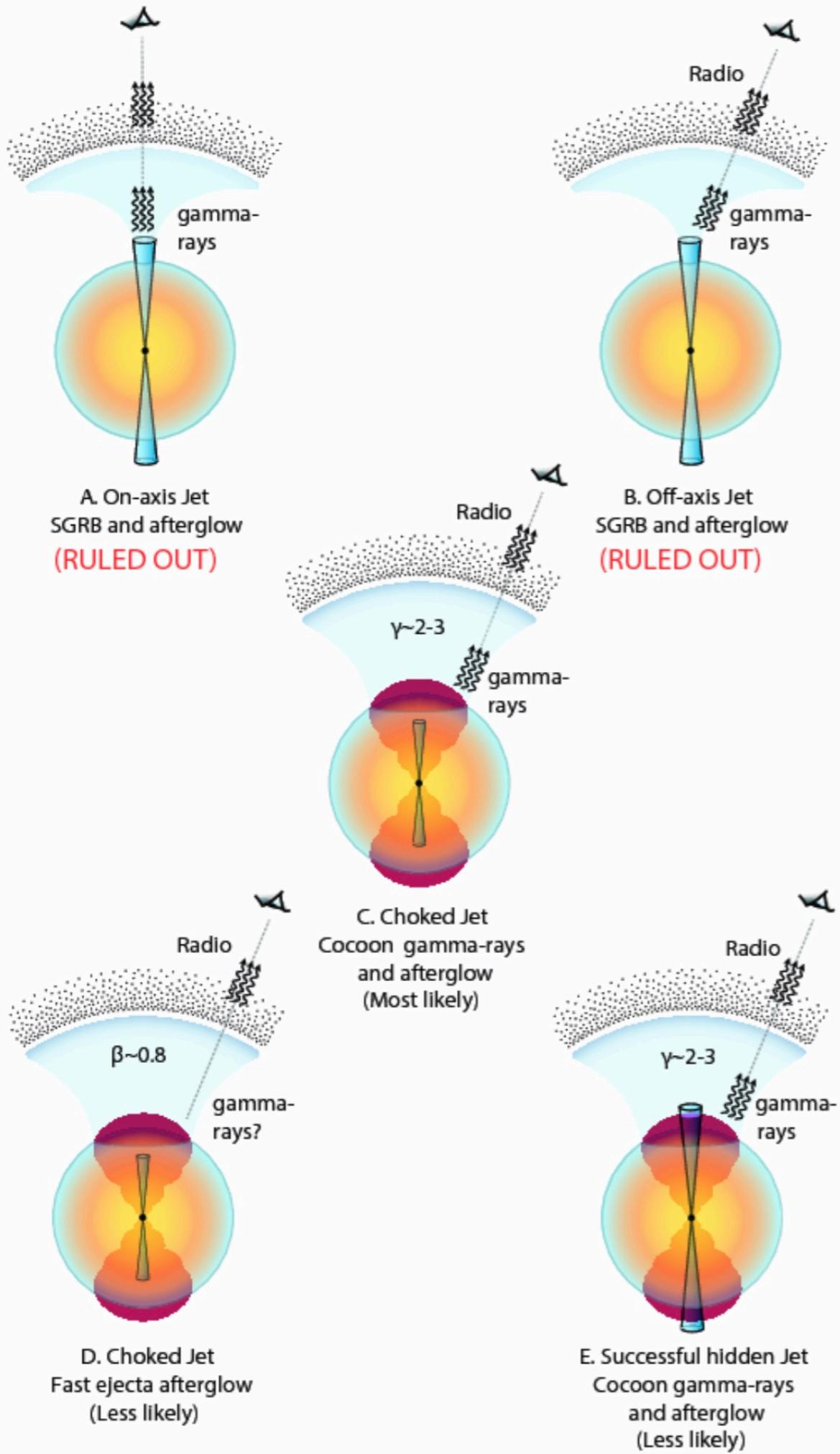
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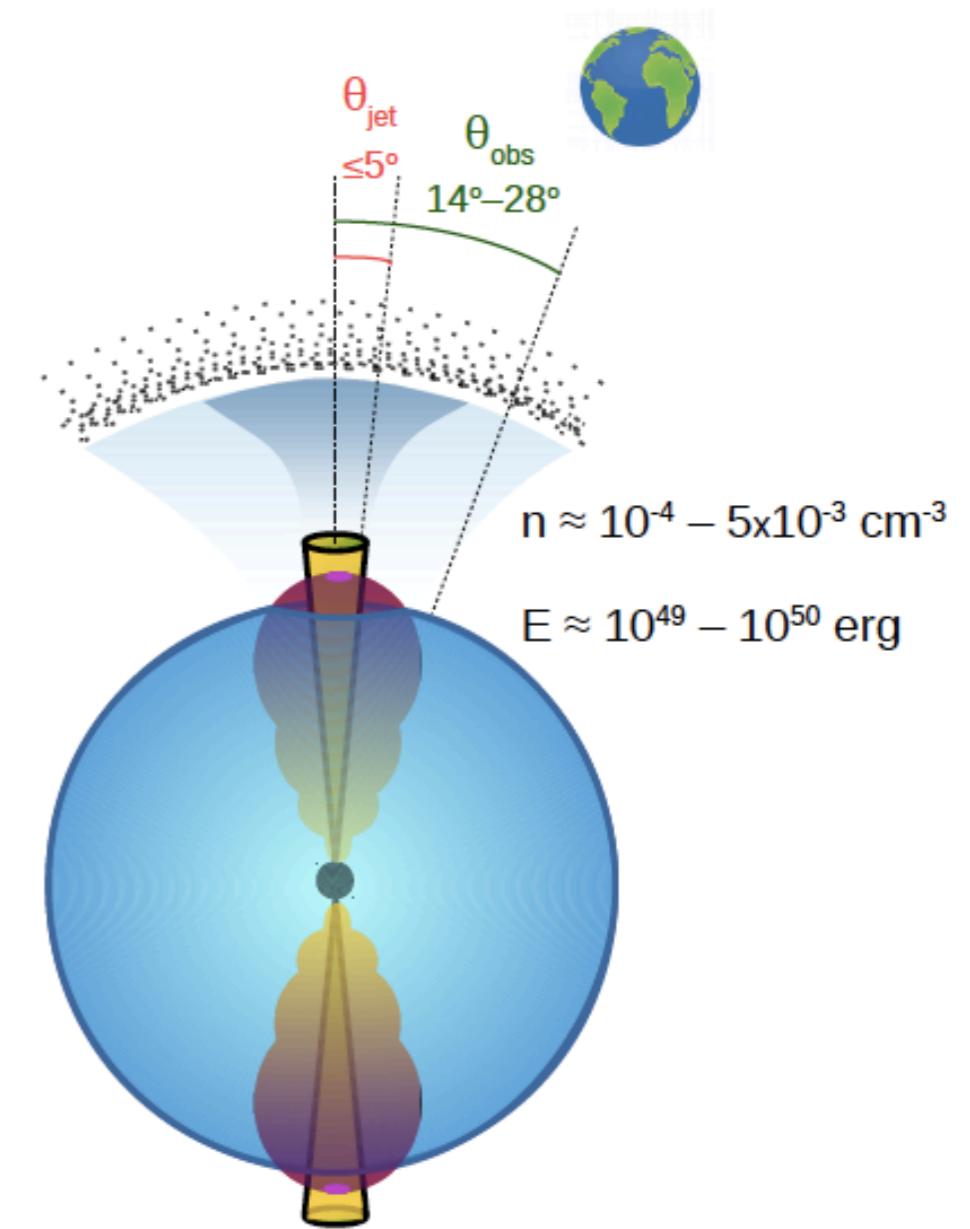
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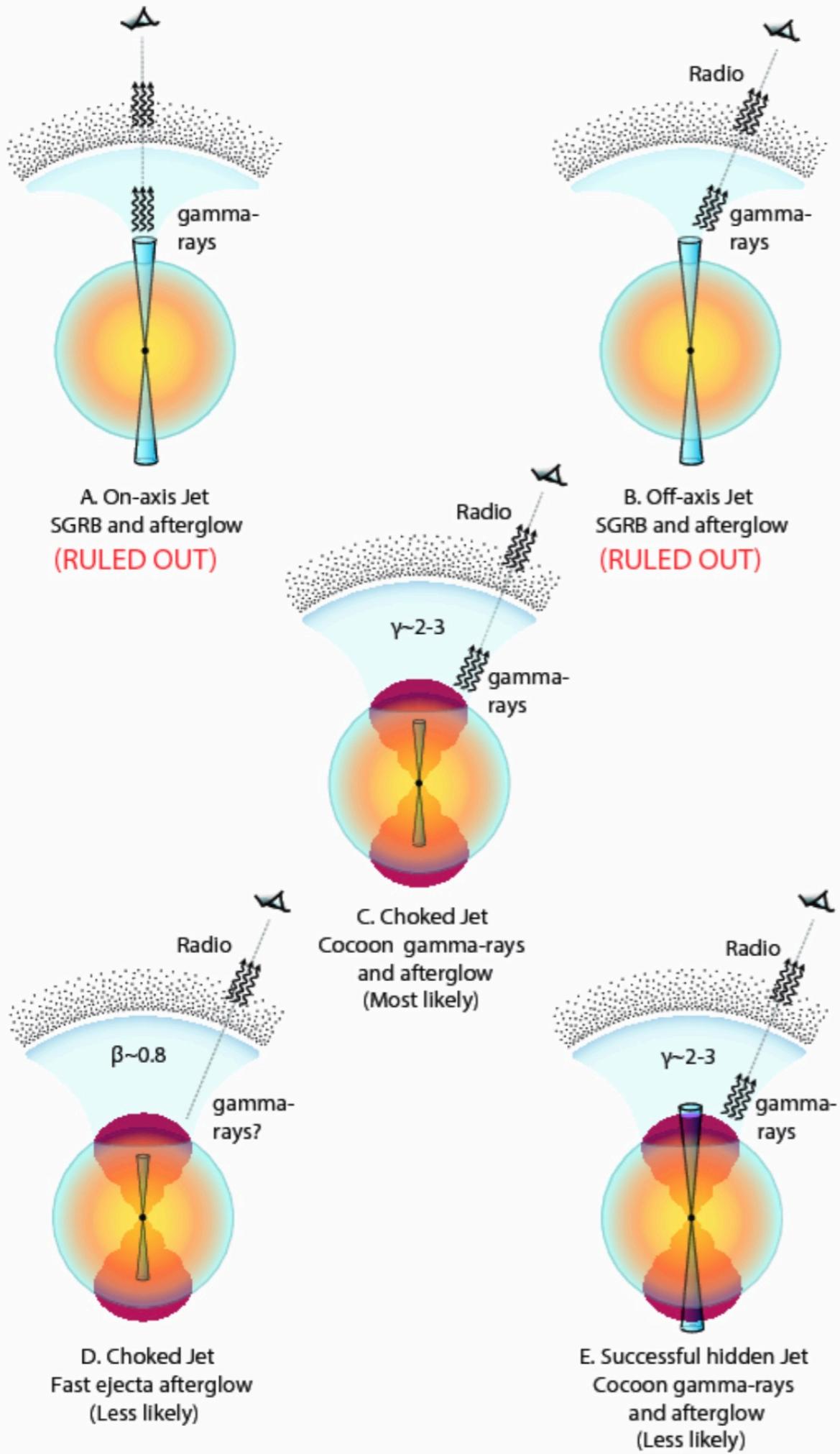




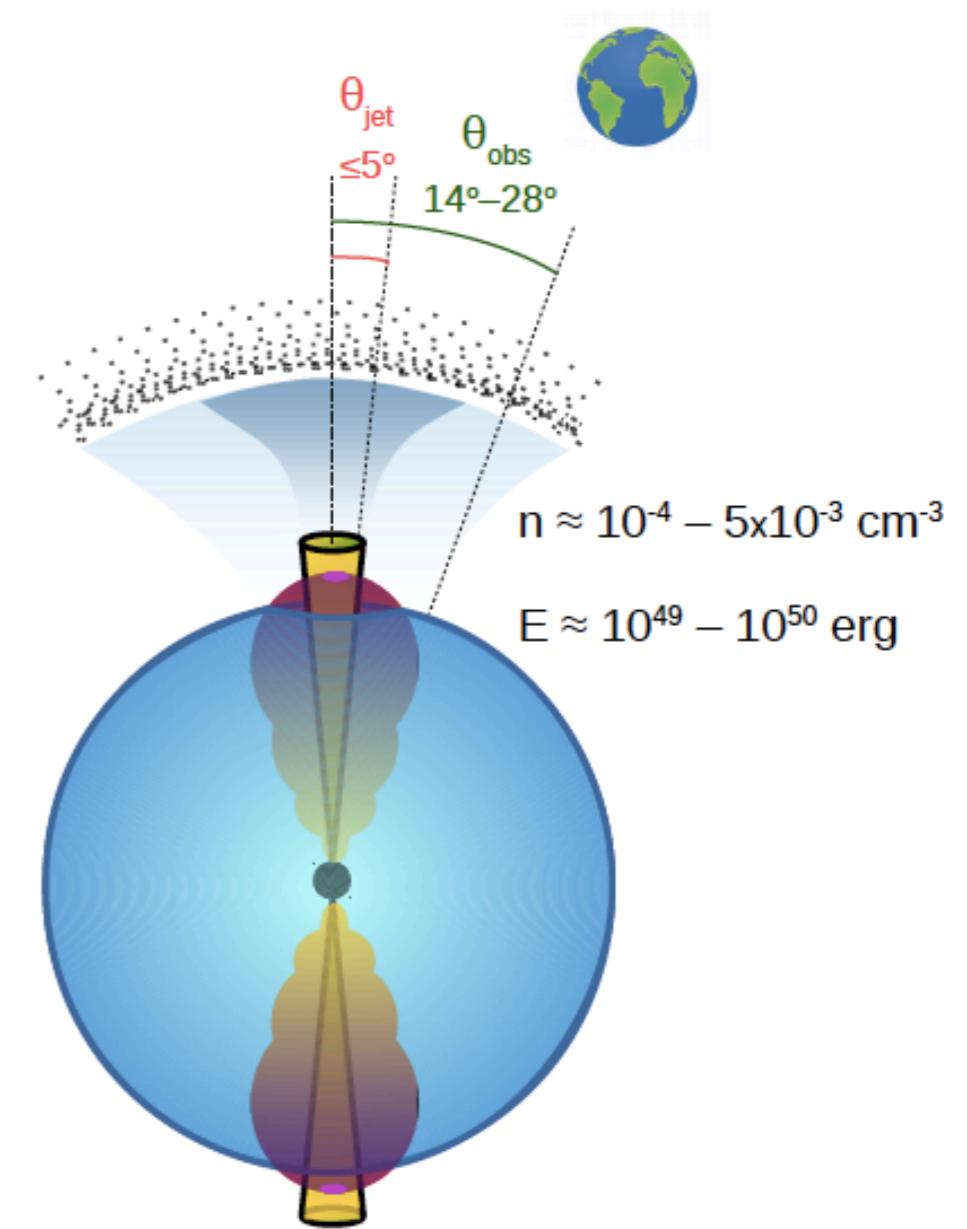
K. P. Mooley, et al.,
Nature, 554, 207 (2018)
[arXiv:1711.11573].



GW170817 has a successful jet (yellow) that drives a cocoon (red) through interaction with the dynamical ejecta (blue).



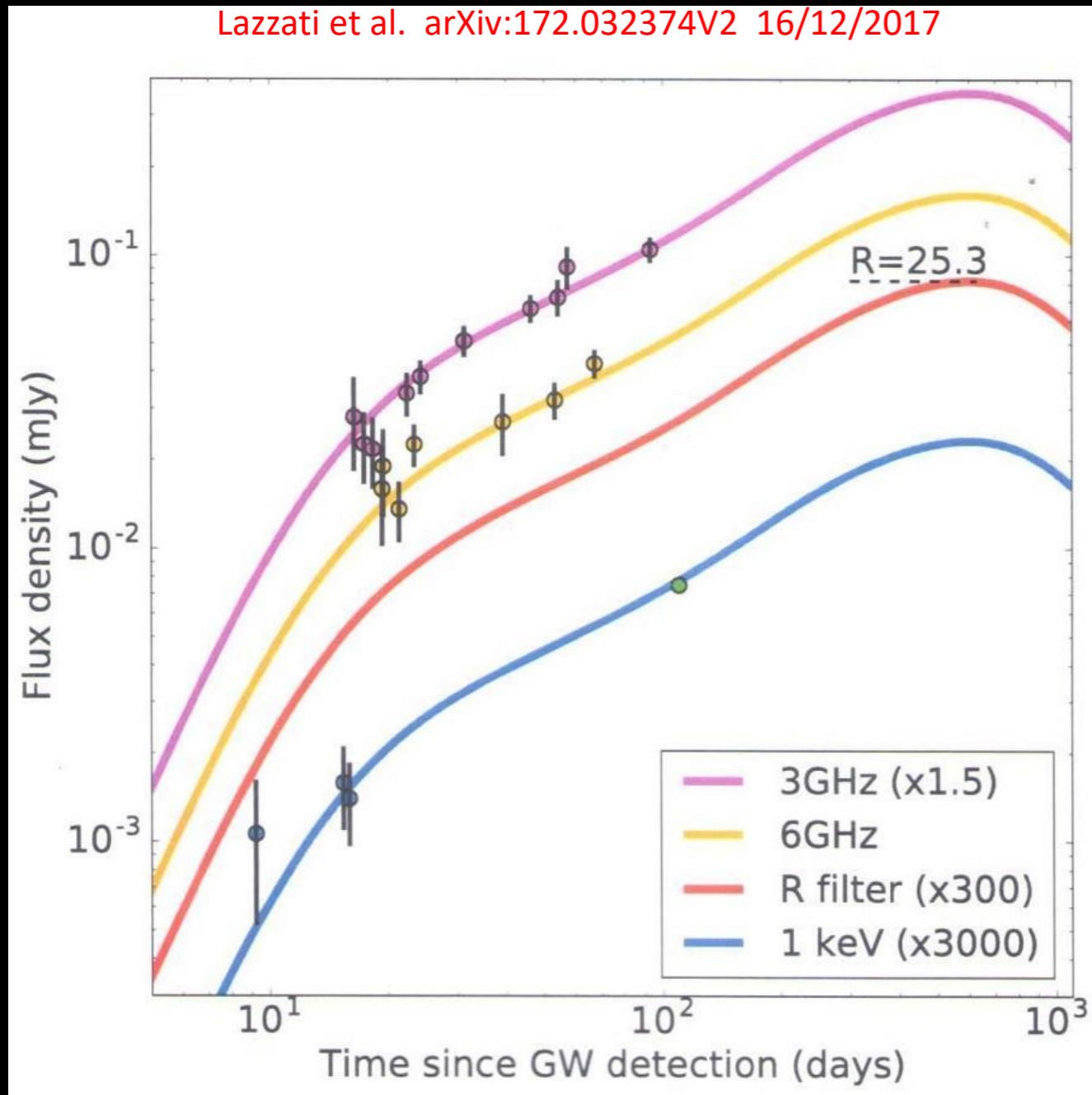
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In FB model

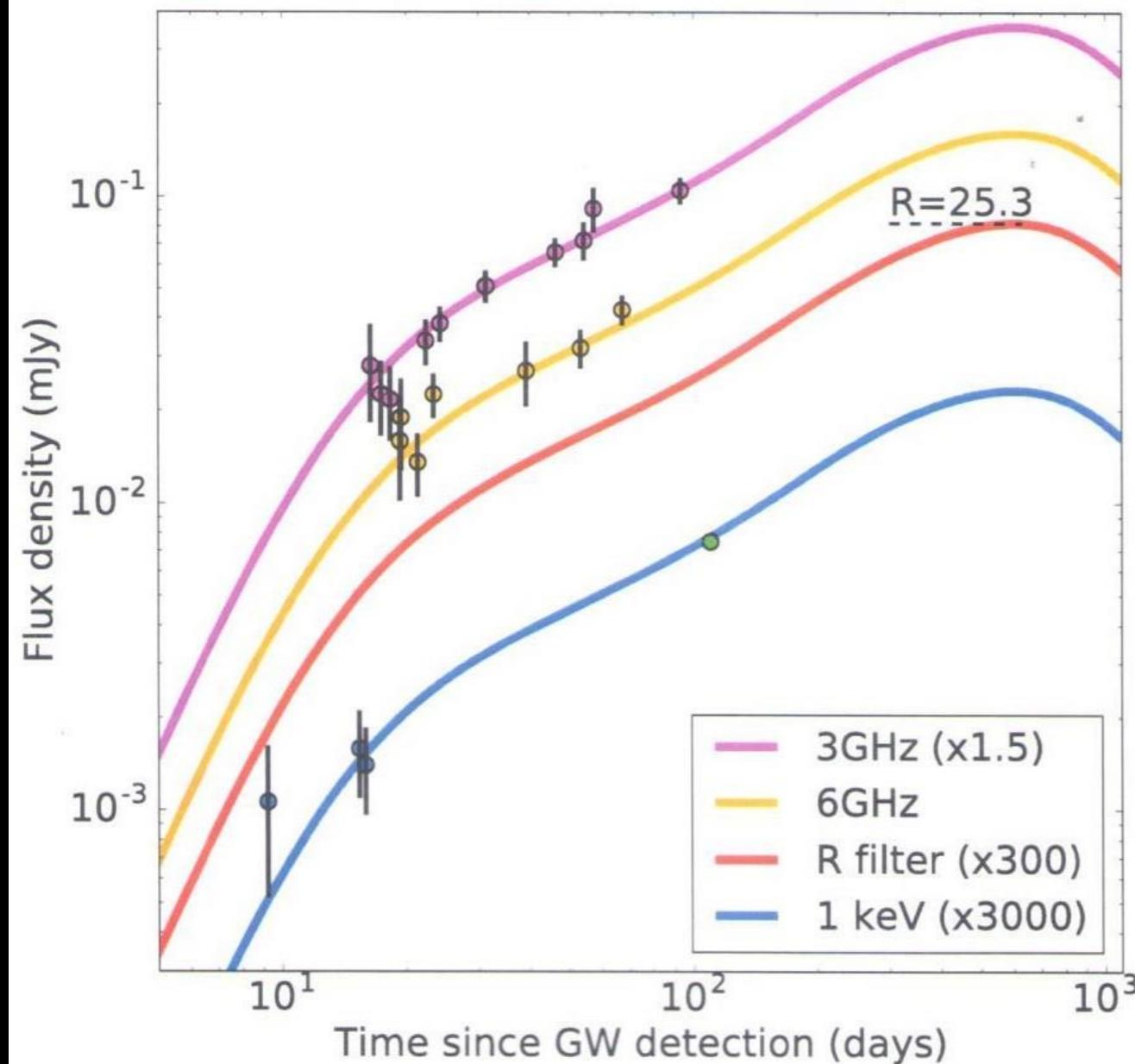
Lazzati et al. arXiv:172.032374v2 16/12/2017



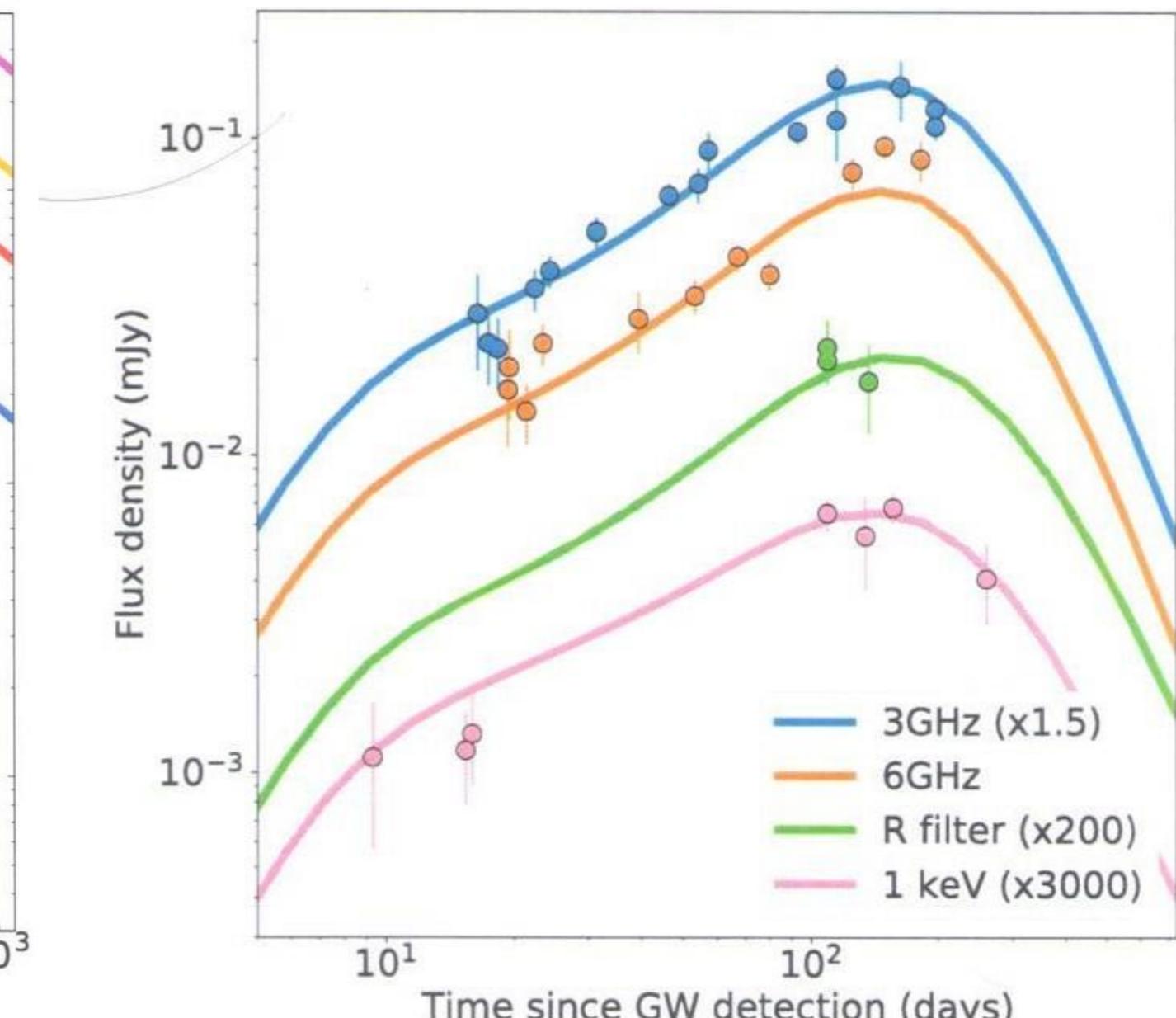
“STRUCTURED JET” MODEL

In FB model

Lazzati et al. arXiv:172.032374V2 16/12/2017



Lazzati et al. arXiv:172.032374V4 11/05/2018



“STRUCTURED JET” MODEL



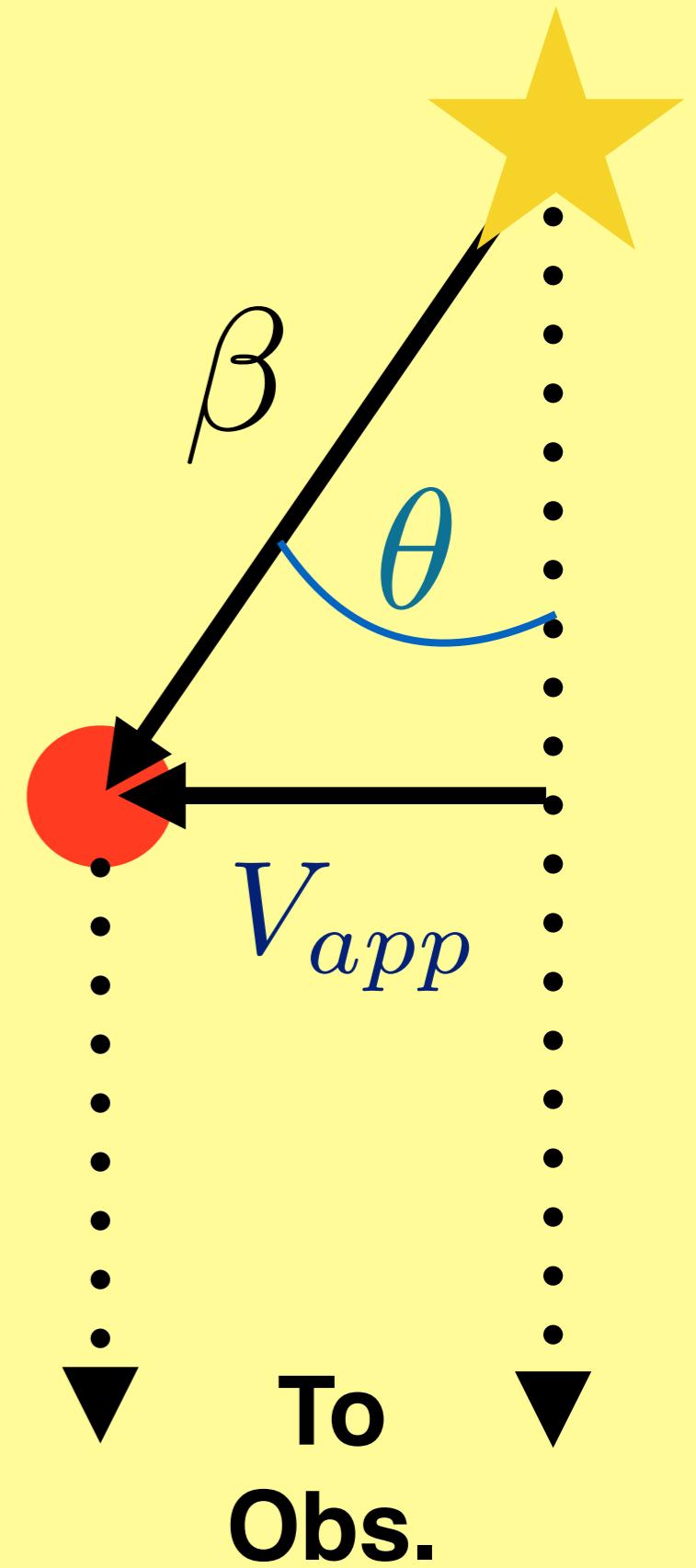
(App) *SuperLuminal* \mathcal{V}

(App) SuperLuminal \mathcal{V}

P. Courdec (1939)

(App) SuperLuminal \mathcal{V}

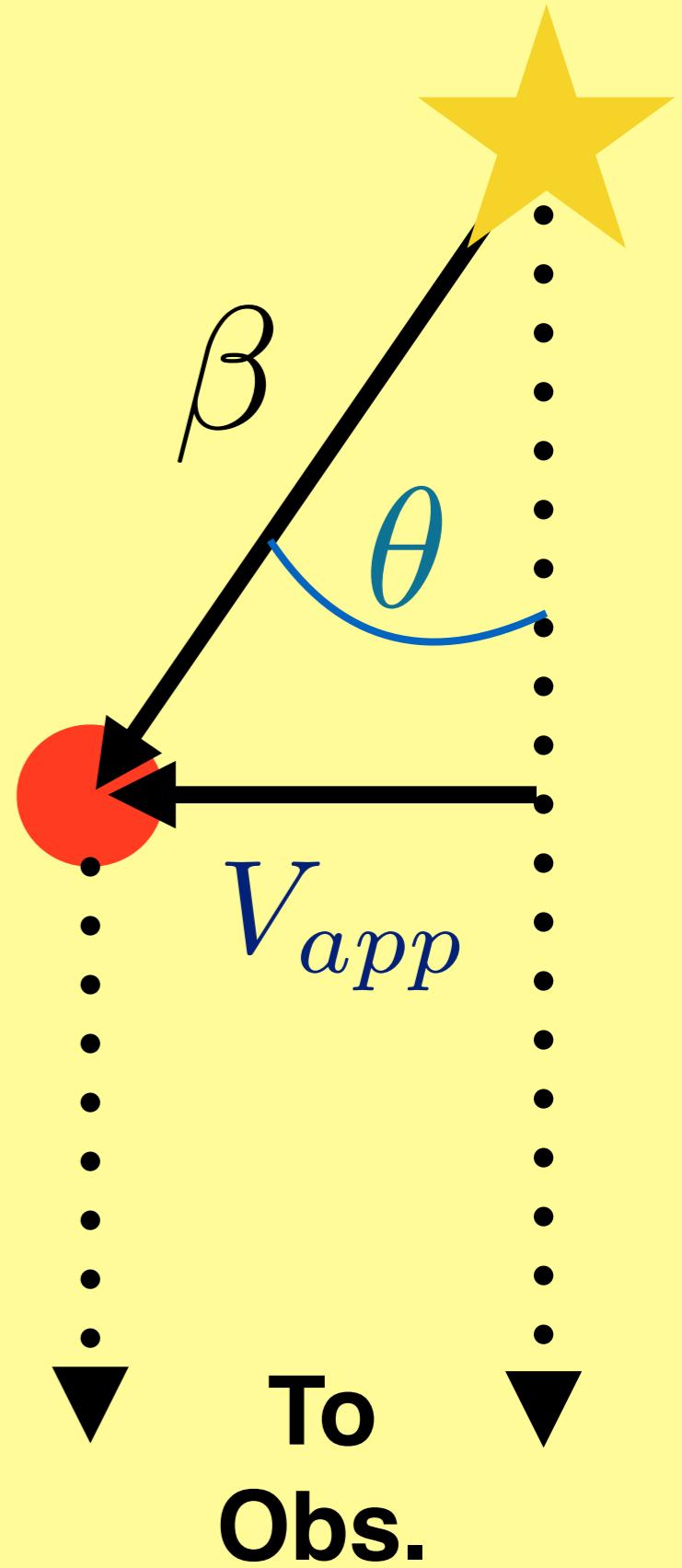
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(App) SuperLuminal \mathcal{V}

P. Courdec (1939)

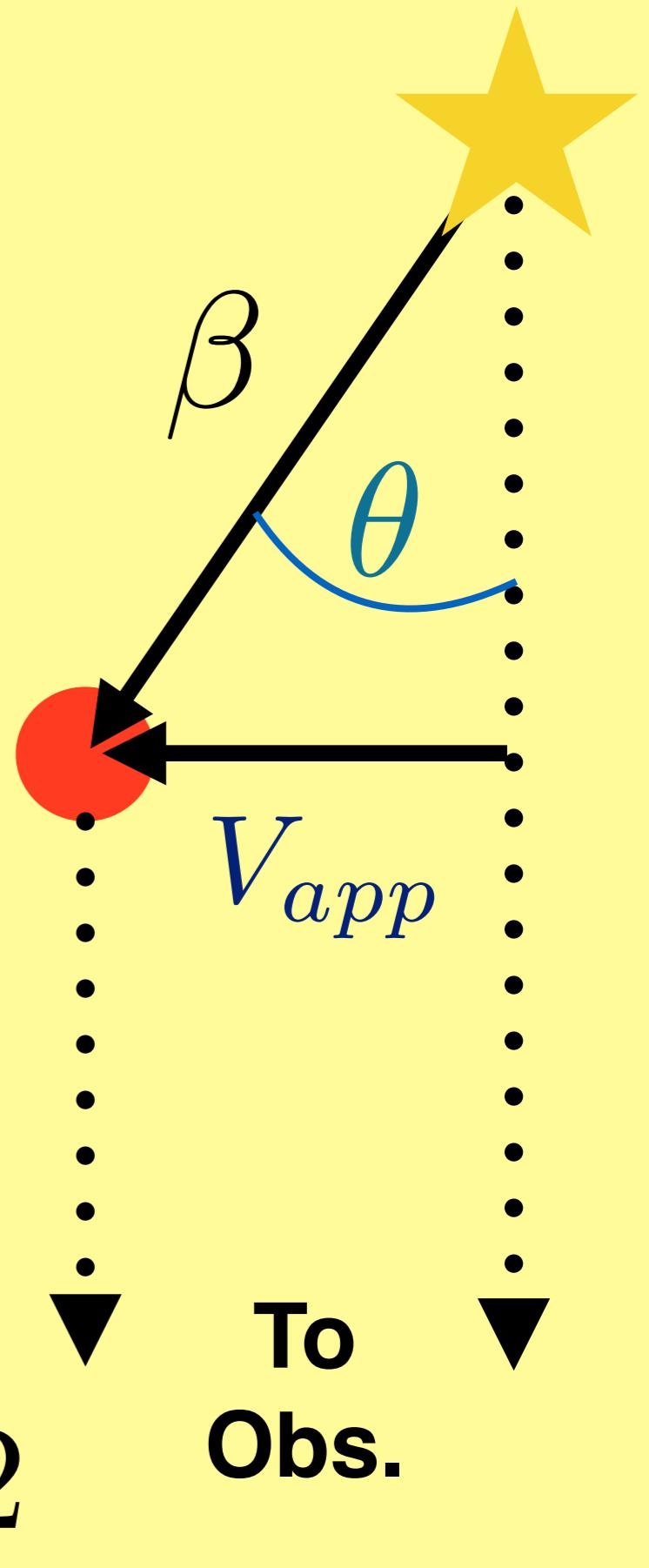
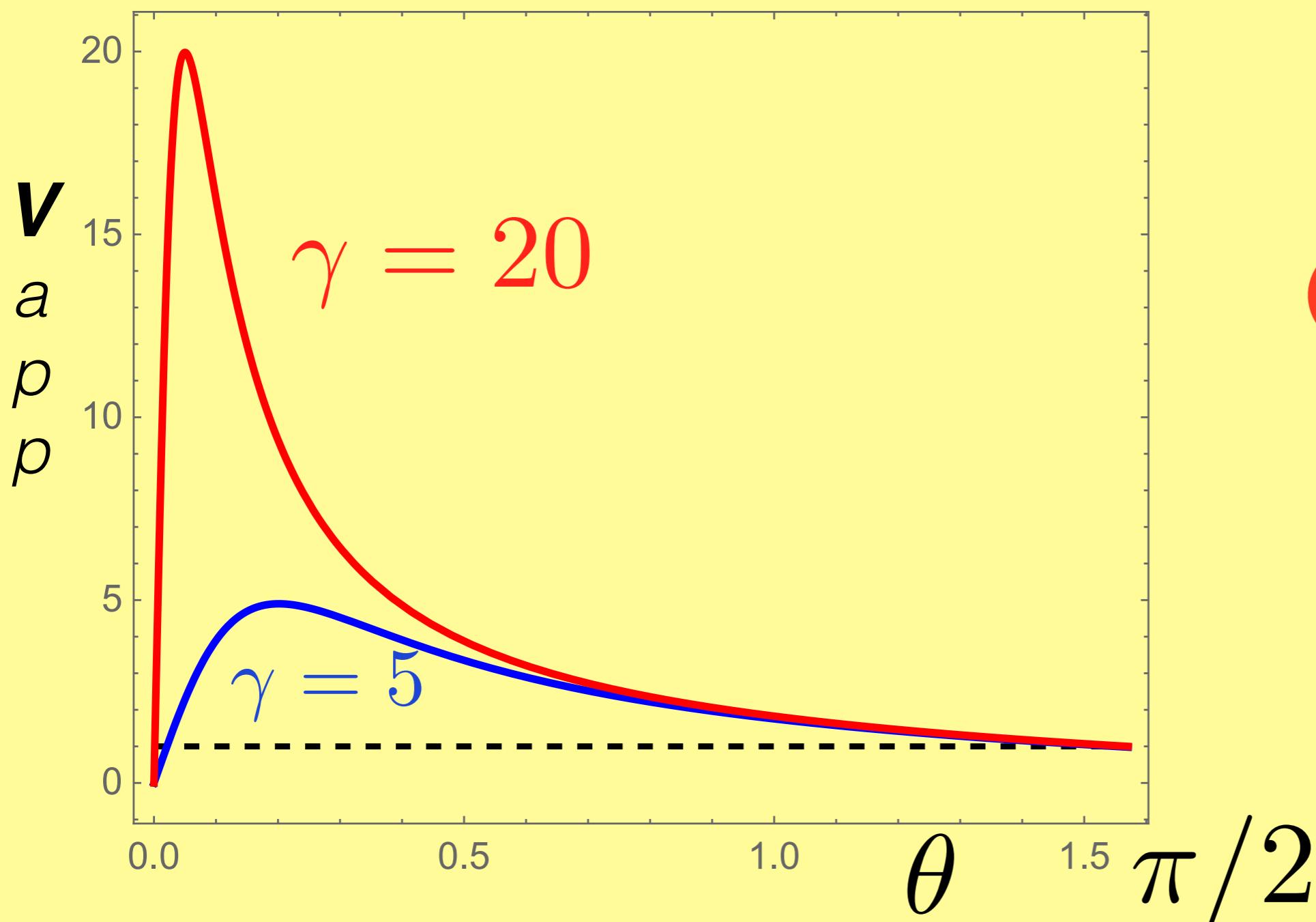
$$V_{app} = \frac{\beta c \sin \theta}{(1+z)(1-\beta \cos \theta)} = \frac{\beta \gamma \delta \sin \theta}{(1+z)}$$



(App) SuperLuminal \mathcal{V}

P. Courdec (1939)

$$V_{app} = \frac{\beta c \sin \theta}{(1+z)(1-\beta \cos \theta)} = \frac{\beta \gamma \delta \sin \theta}{(1+z)}$$



$$\beta\!\equiv\!v/c\!\approx\!1$$

(1)

$$V_{app} \approx \frac{c \sin \theta}{(1+z) (1-\cos \theta)} \approx \frac{D_A \Delta \theta_s}{(1+z) \Delta t}$$

$$\beta \equiv v/c \approx 1$$

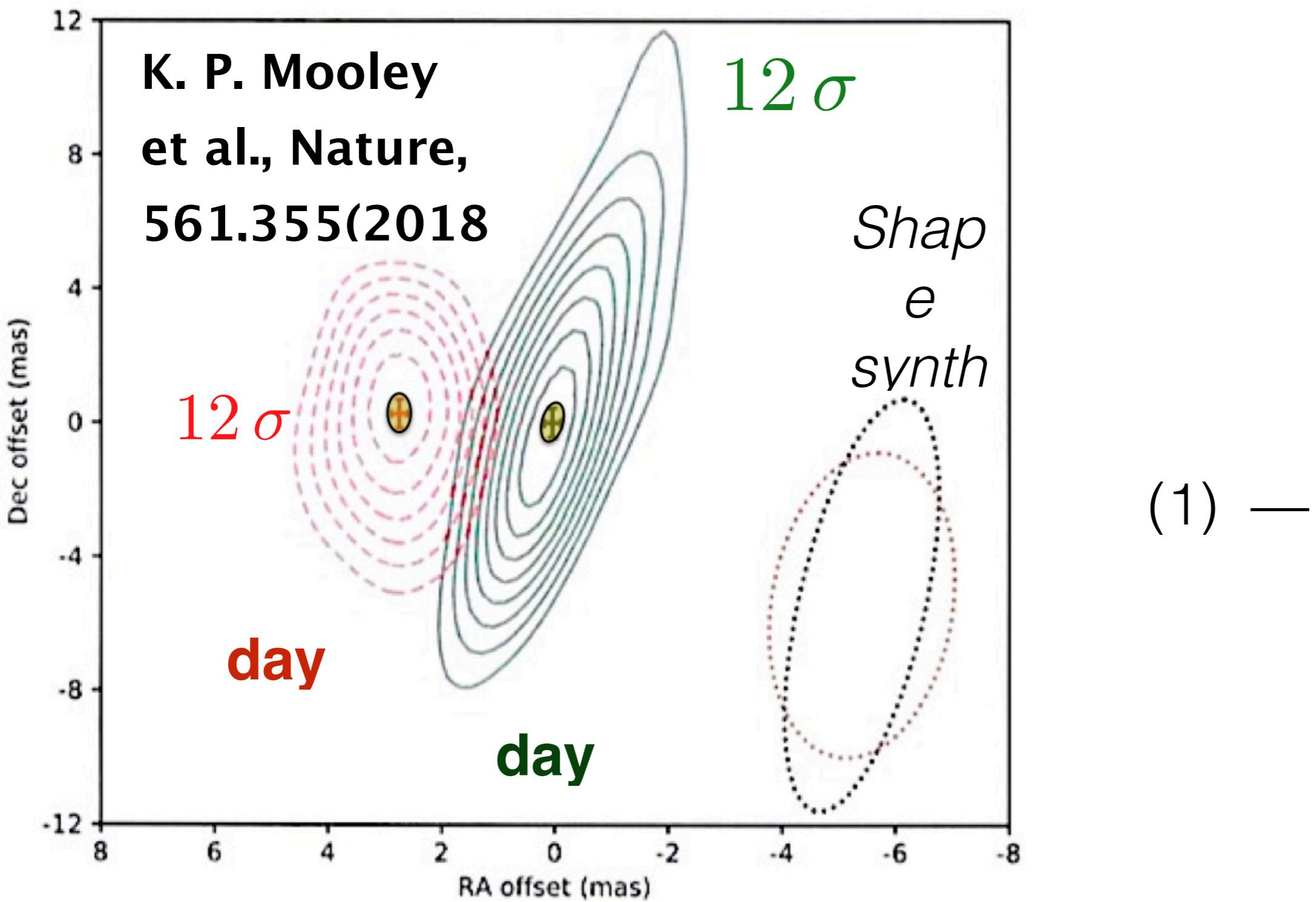
$$V_{app} \approx \frac{c \sin \theta}{(1+z)(1-\cos \theta)} \quad (1)$$

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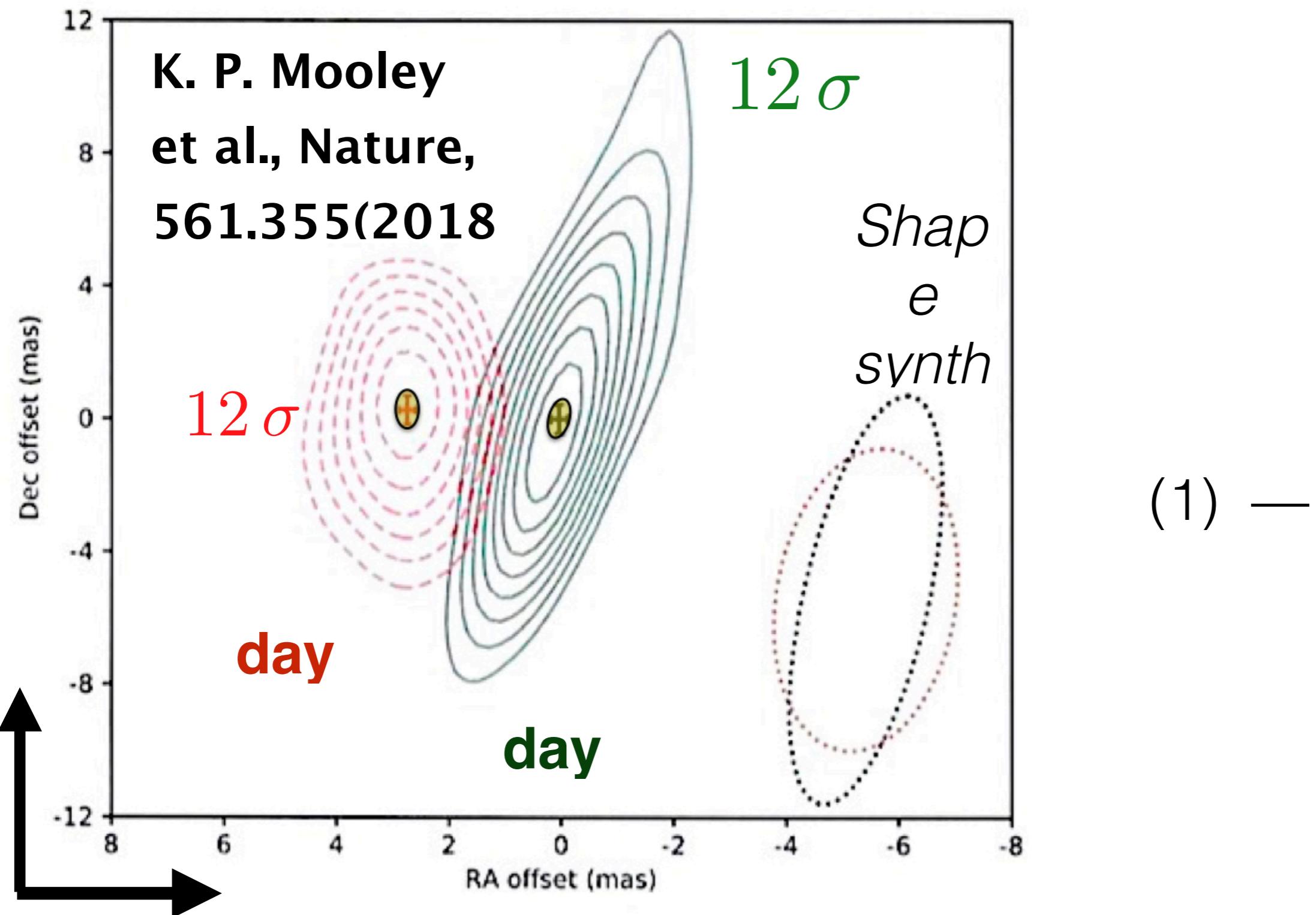
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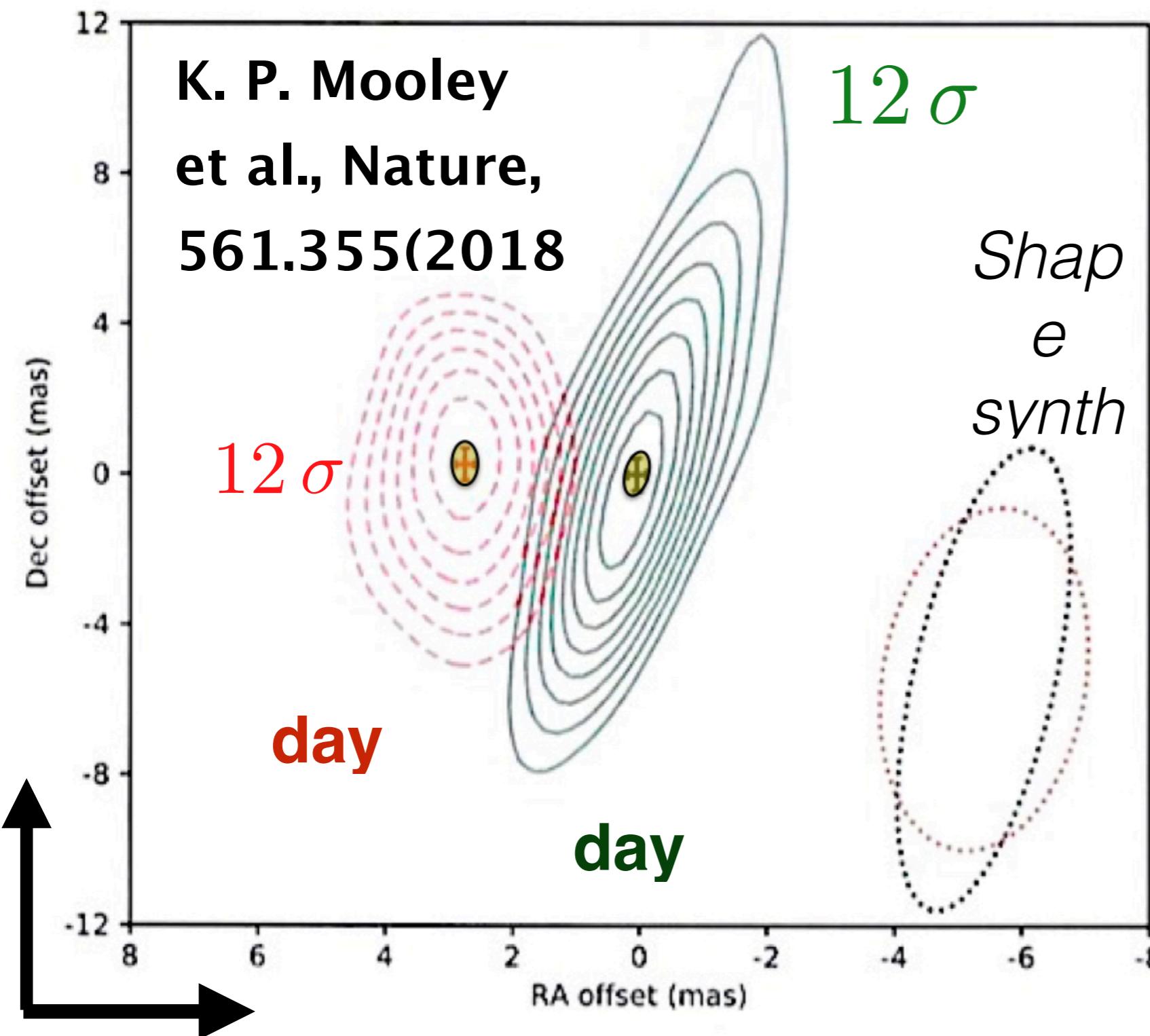


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$$z = 0.009783$$



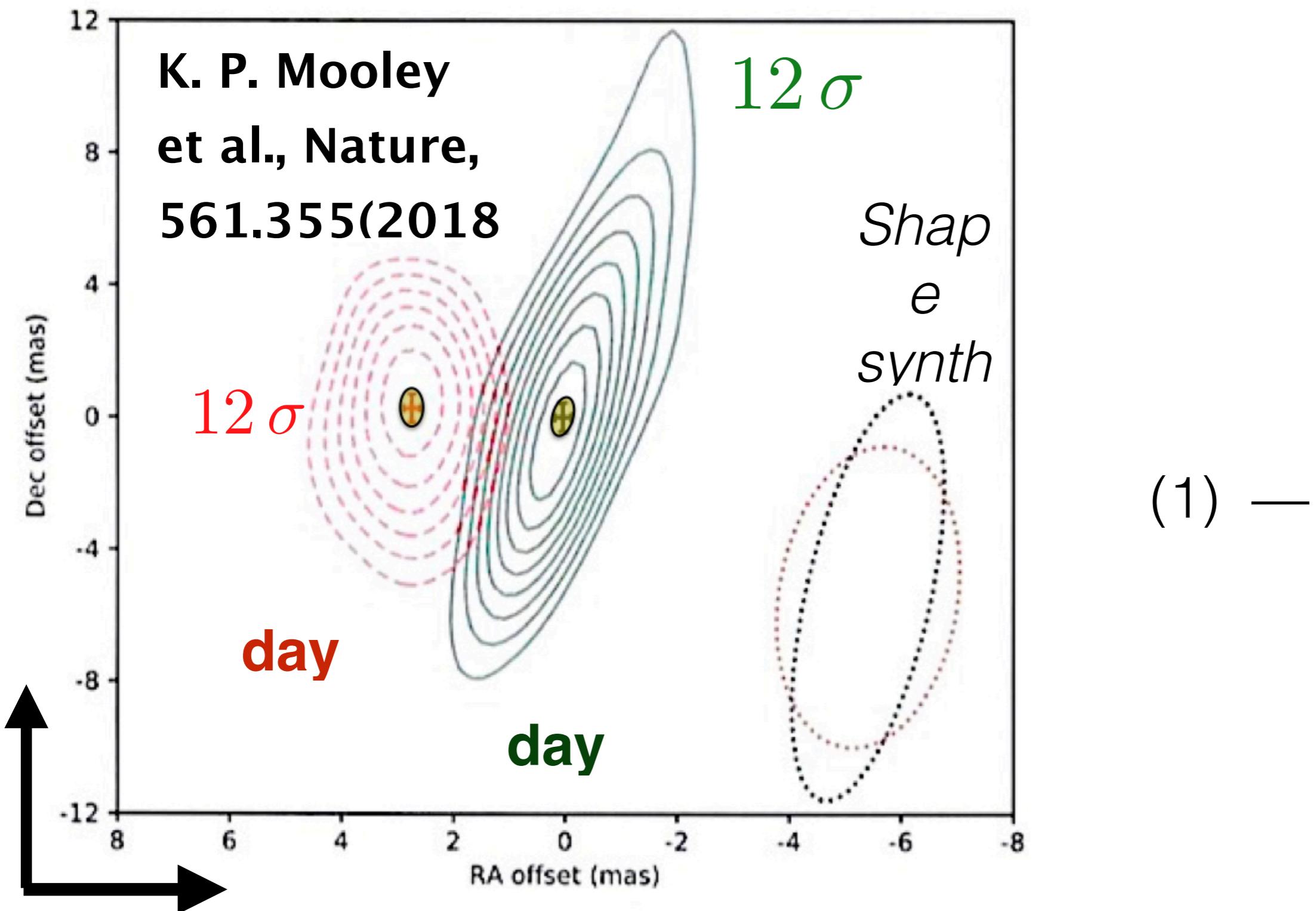
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$$D_A = 39.6 \text{ Mpc}$$



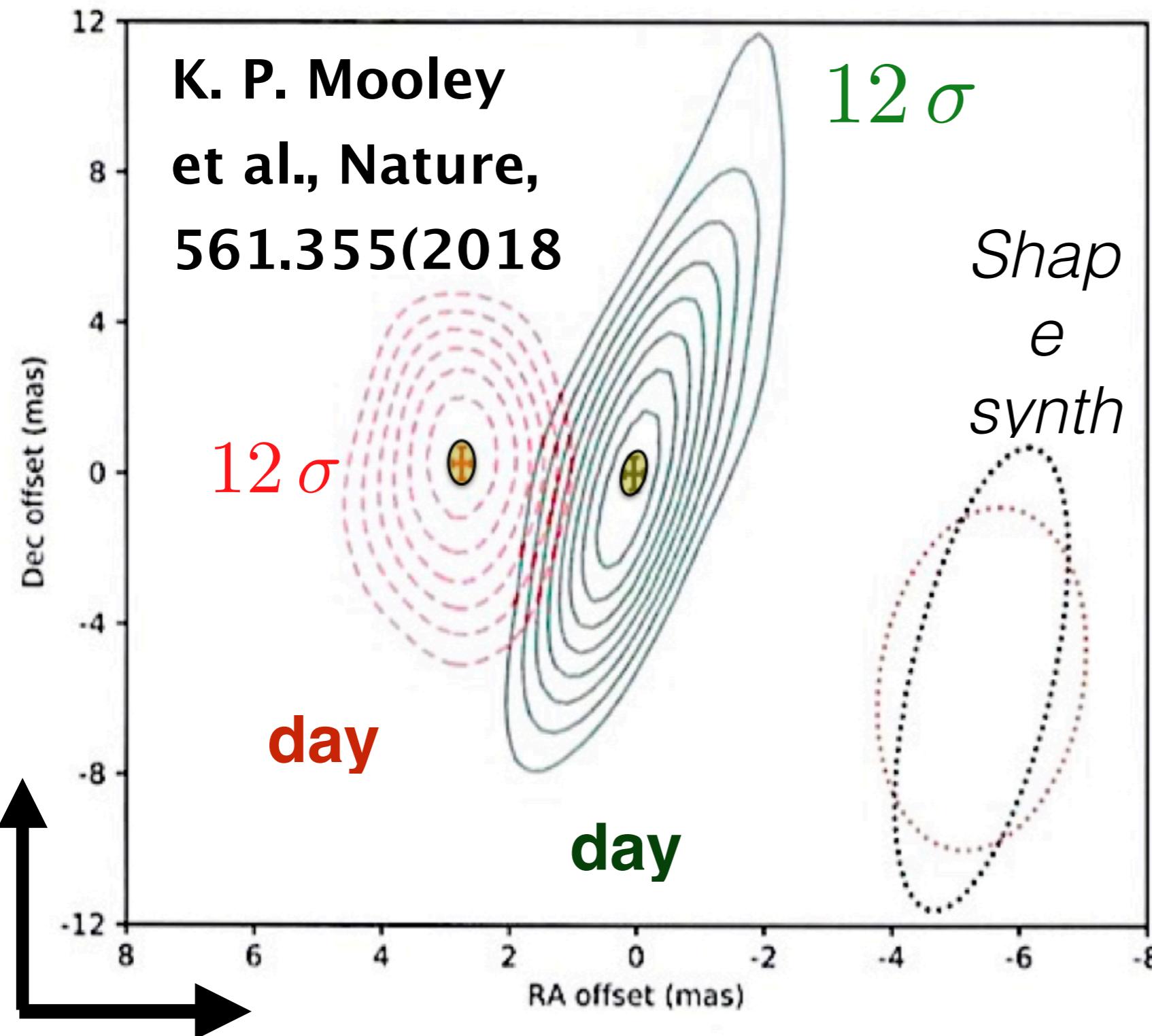
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$$\Delta\theta_s = 2.70 \pm 0.3 \text{ mas}$$

$$\Delta t = 155 \text{ d}$$

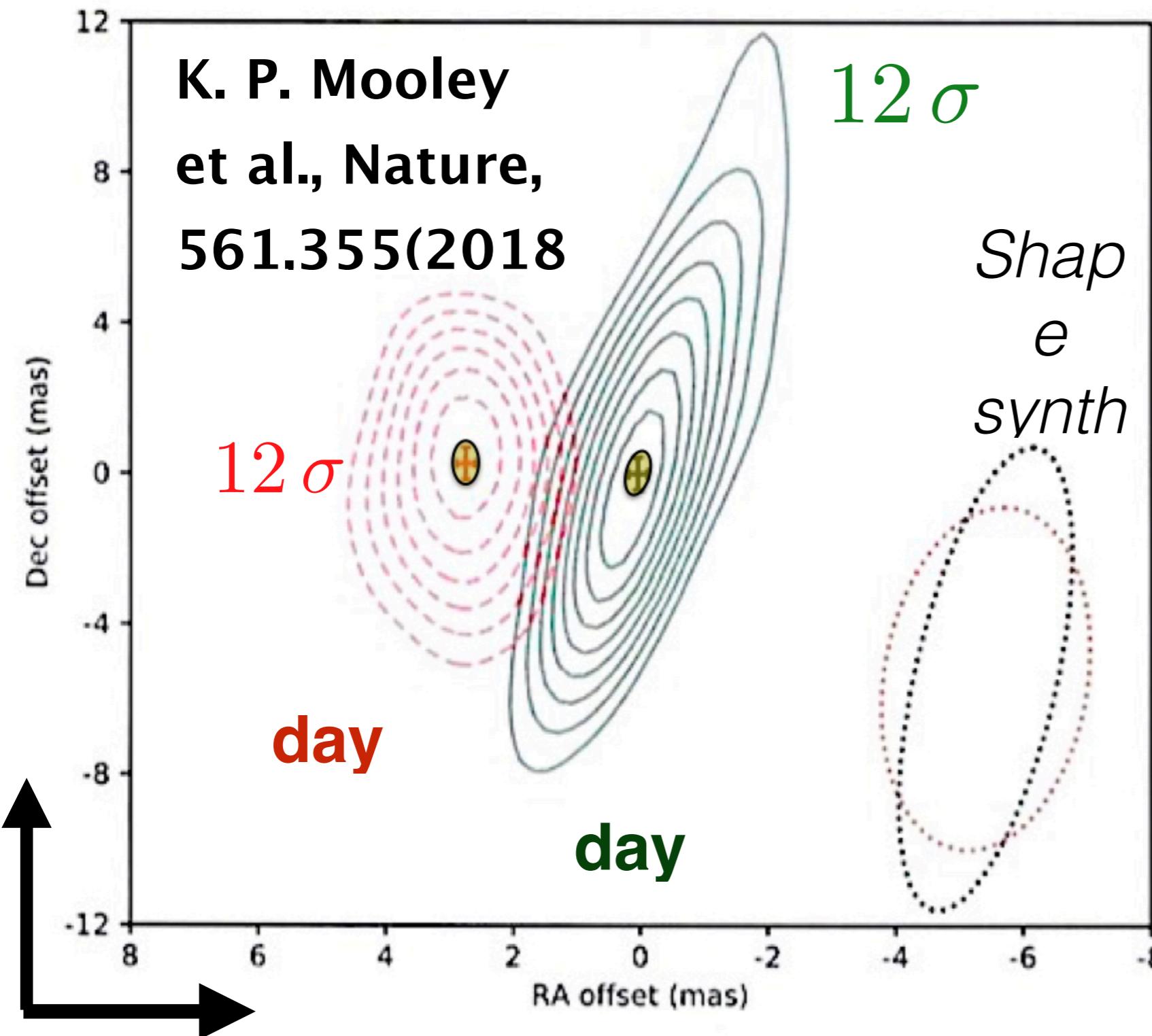
$$\beta \equiv v/c \approx 1$$

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$$\Delta\theta_s = 2.70 \pm 0.3 \text{ mas}$$

$$\Delta t = 155 \text{ d}$$

$$V_{app} \approx (4.0 \pm 0.4) c$$

(1) —

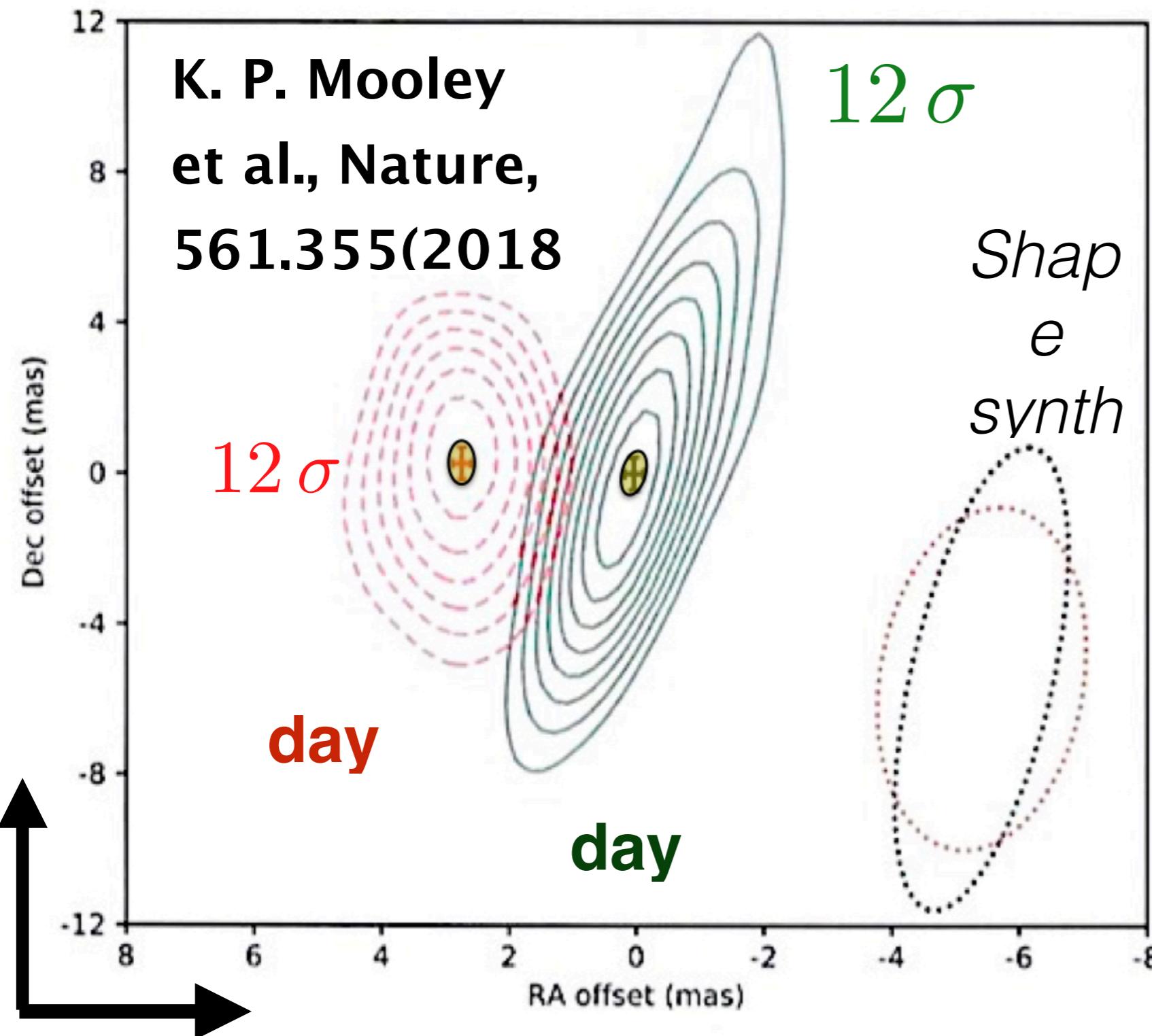
$$\beta \equiv v/c \approx 1$$

$$V_{app} \approx \frac{c \sin \theta}{(1+z)(1-\cos \theta)} \quad (1)$$

$$\approx \frac{D_A \Delta\theta_s}{(1+z)\Delta t}$$

$$z = 0.009783$$

$$D_A = 39.6 \text{ Mpc}$$



$$\Delta\theta_s = 2.70 \pm 0.3 \text{ mas}$$

$$\Delta t = 155 \text{ d}$$

$$V_{app} \approx (4.0 \pm 0.4) c$$

(1) — {CB model}

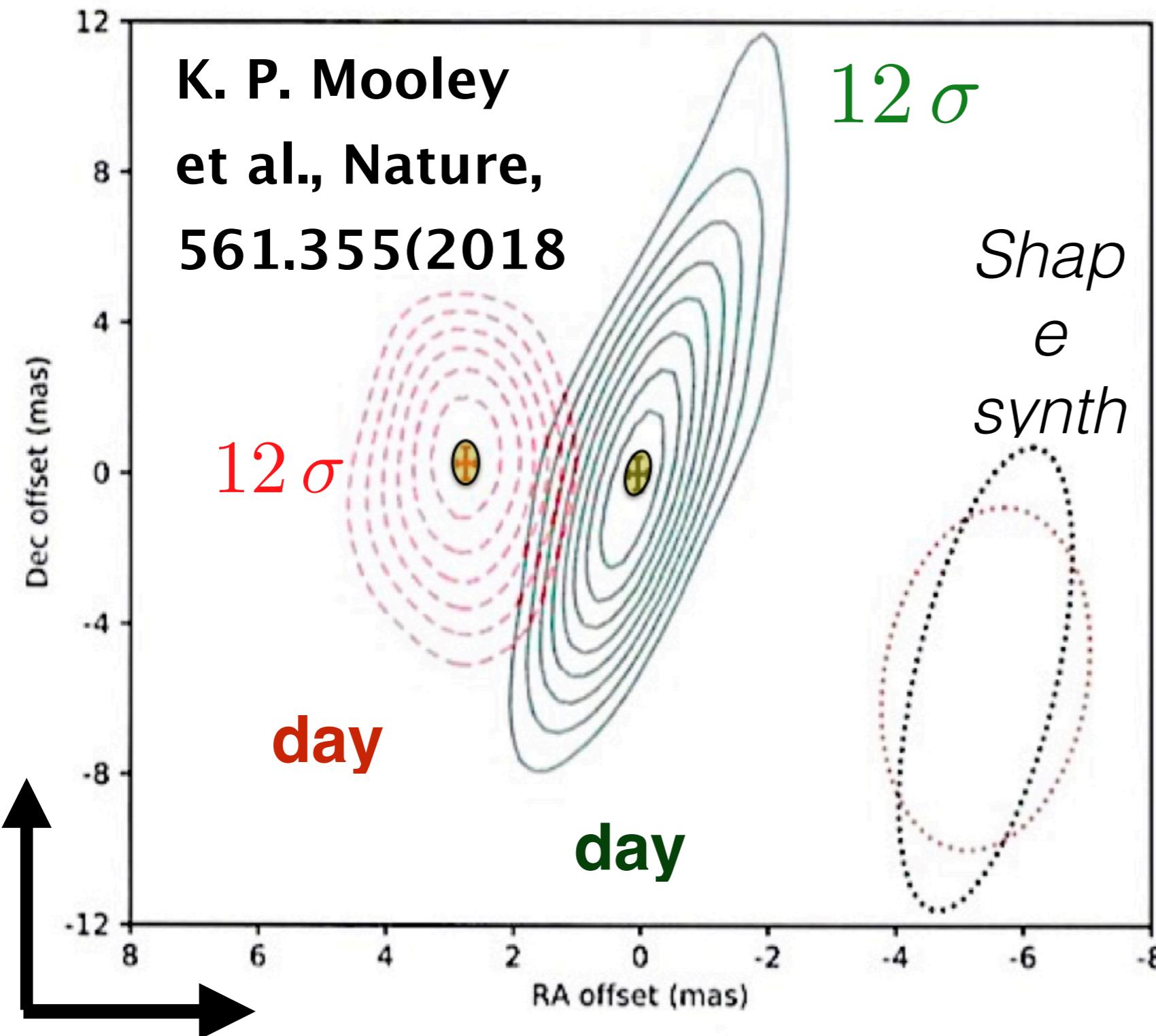
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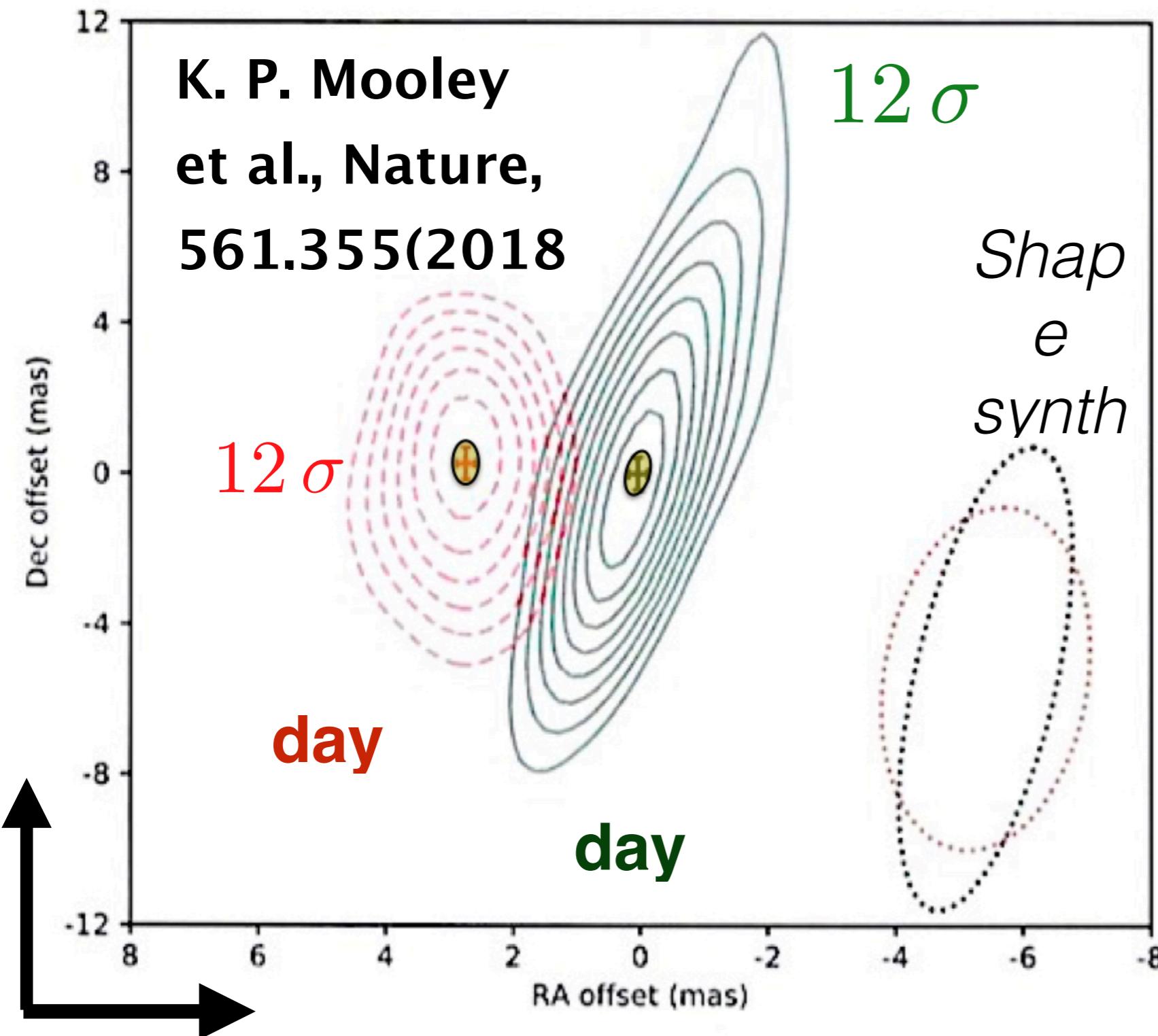
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$$\theta = 27.8 \pm 4 \text{ deg}$$

GW observ.:
If CB along \vec{L}_{Bin}

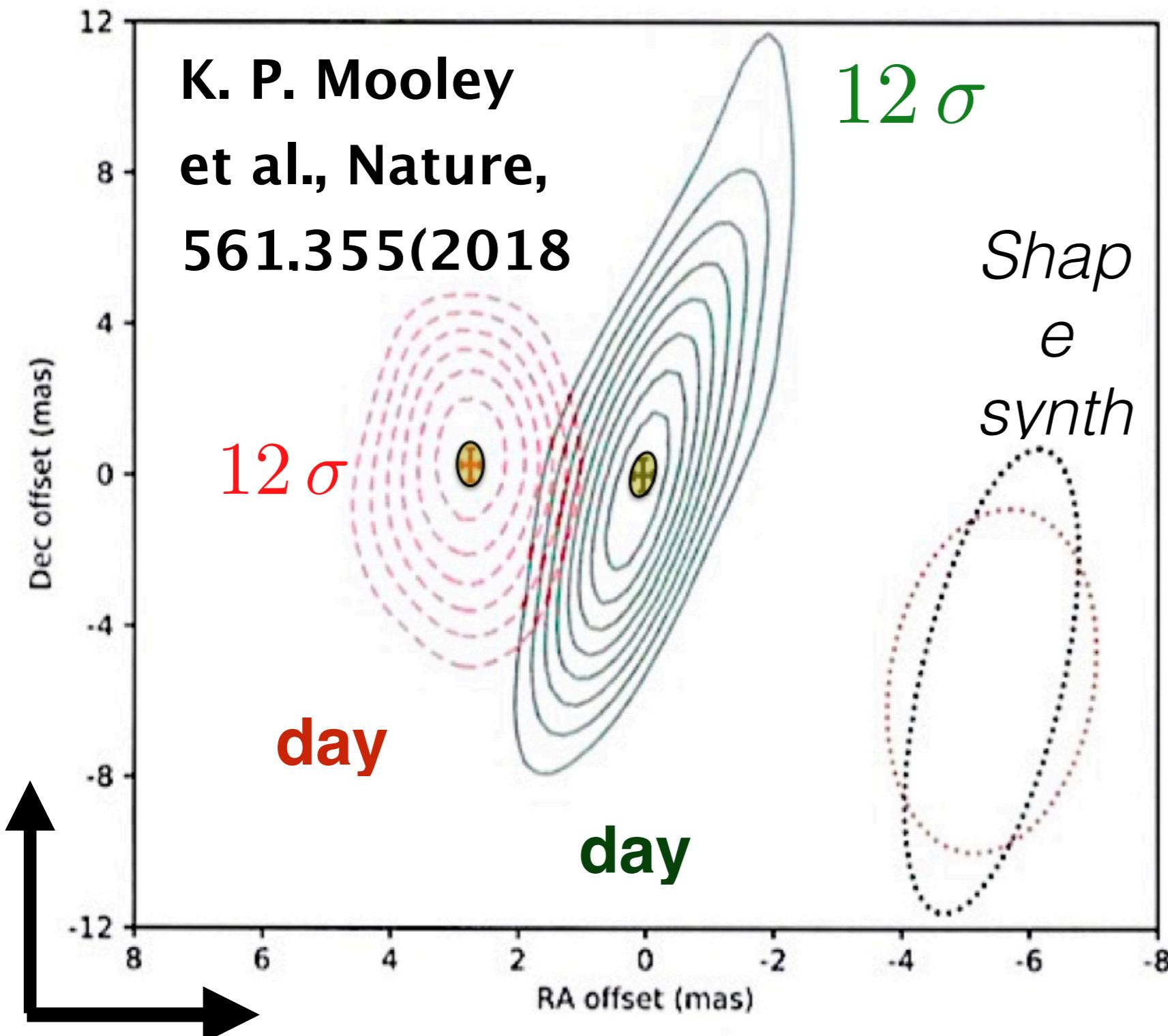
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$$\theta = 27.8 \pm 4 \text{ deg}$$

GW observ.:
If CB along \vec{L}_{Bin}

$$\theta_{\text{Obs}} = 28 \pm 2 \text{ deg}$$

One should never
trust an observation

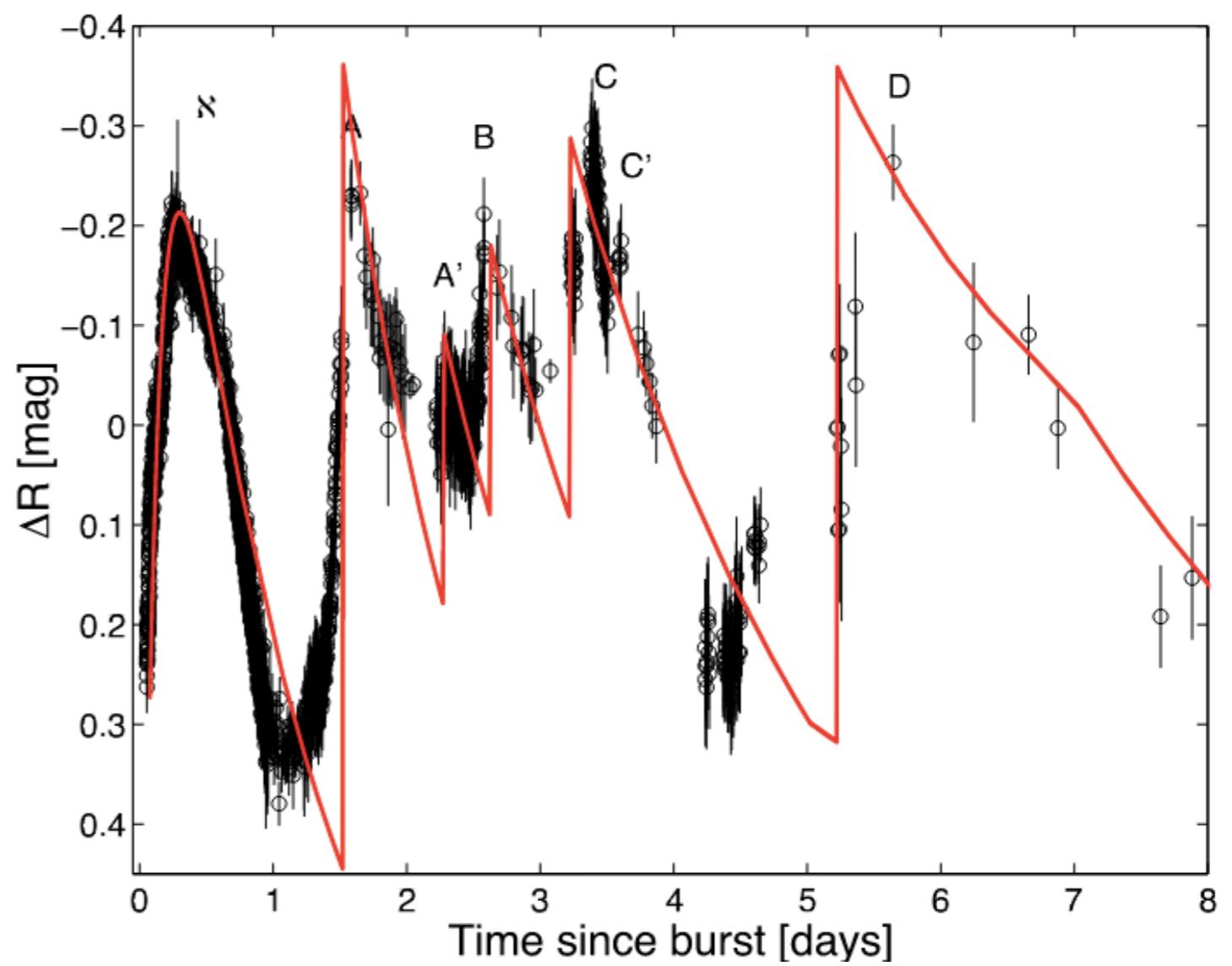
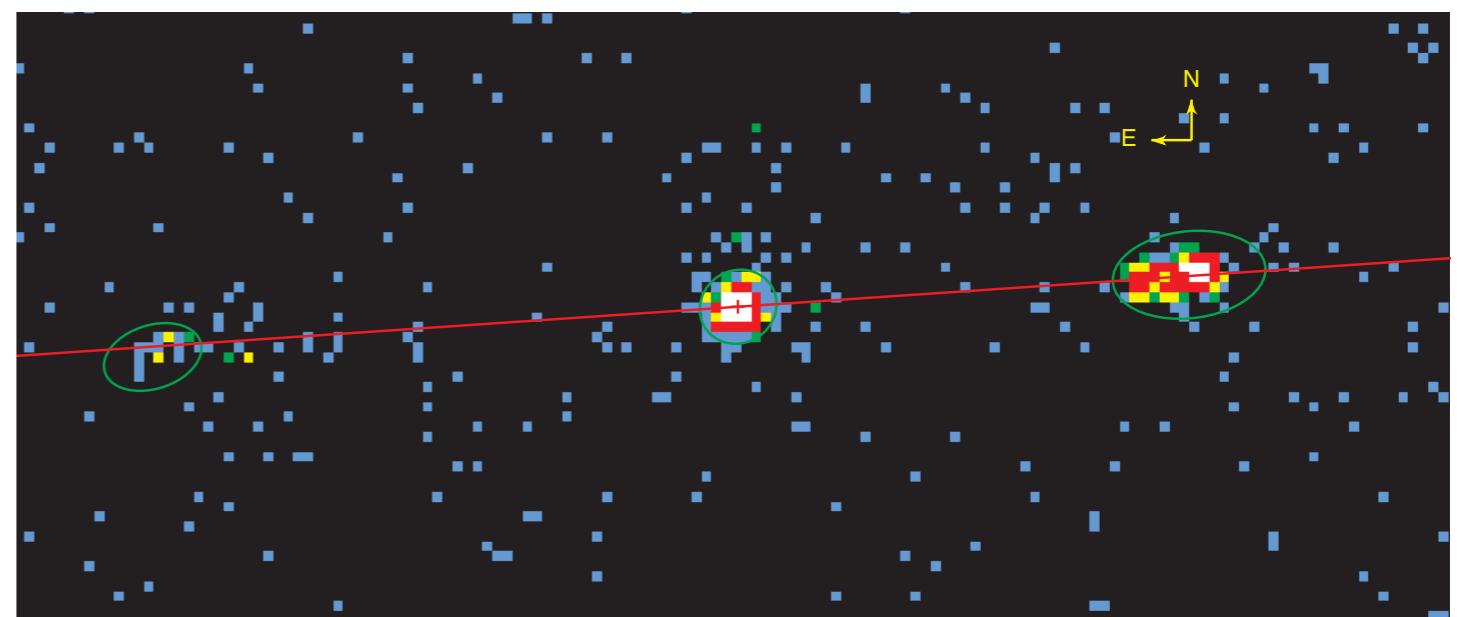
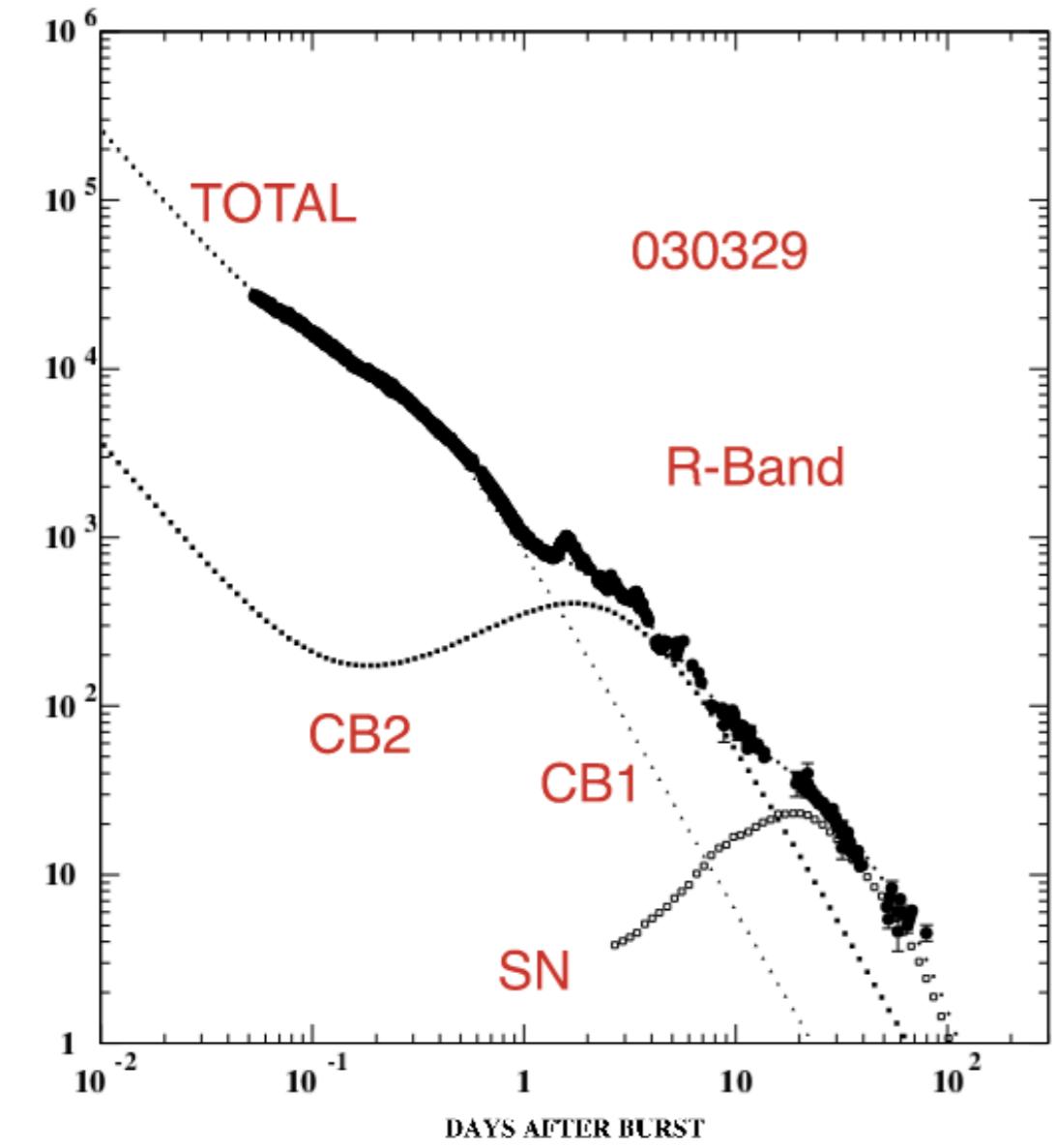
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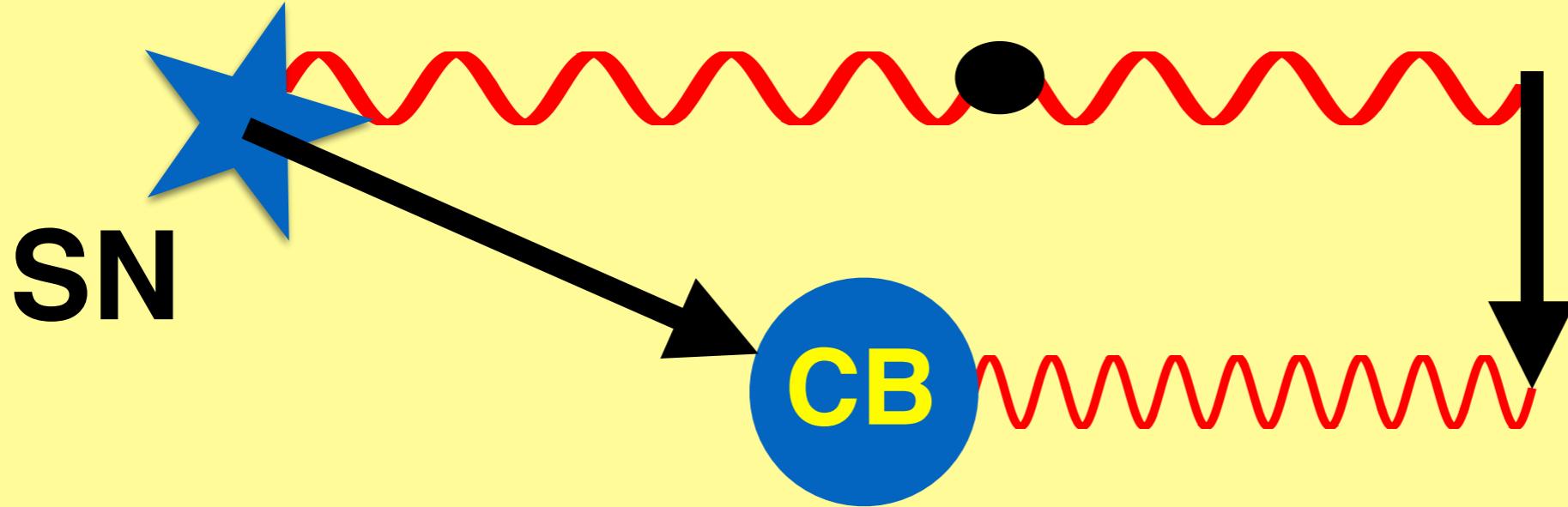
Until it is
corroborated
by theory

One should never
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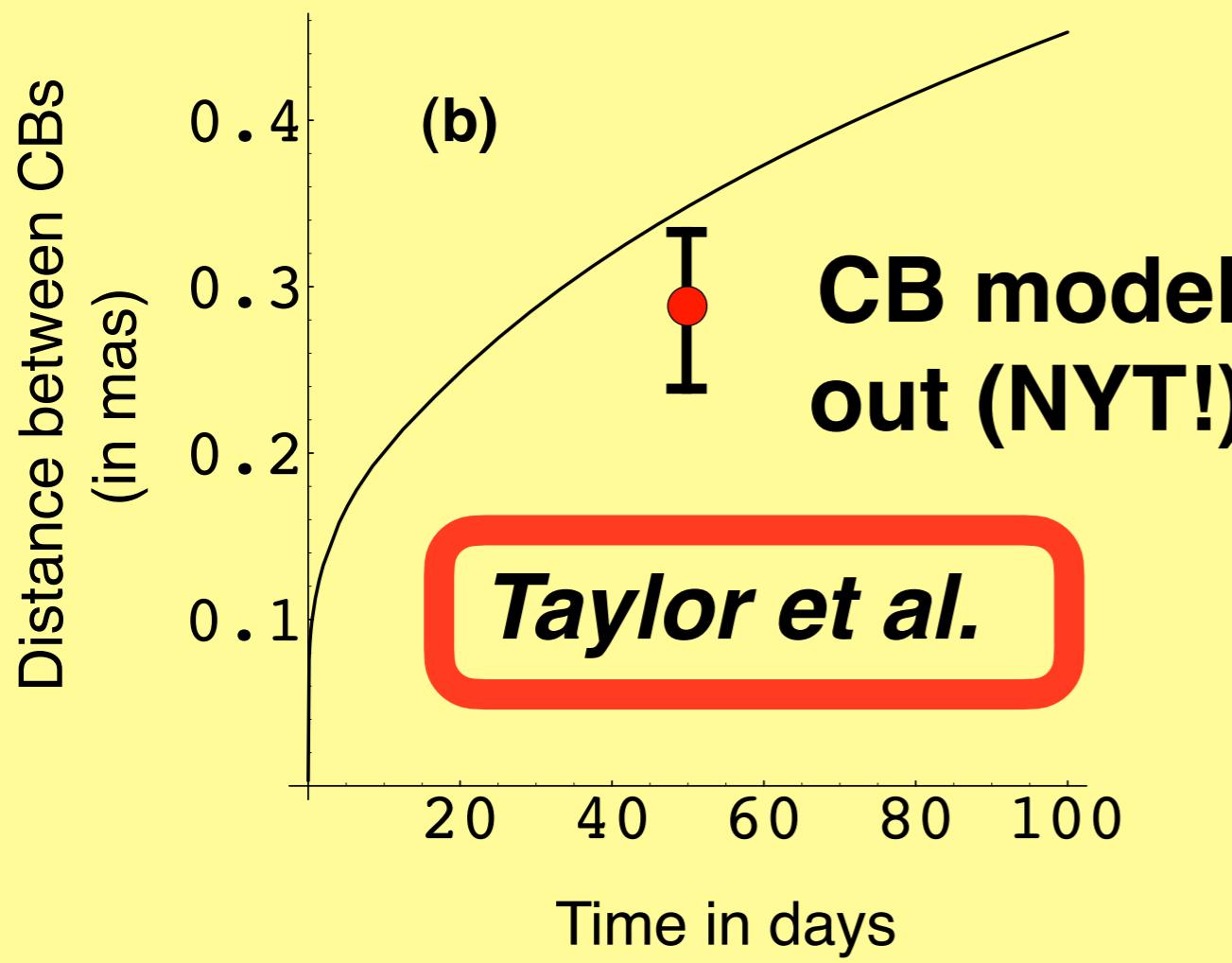
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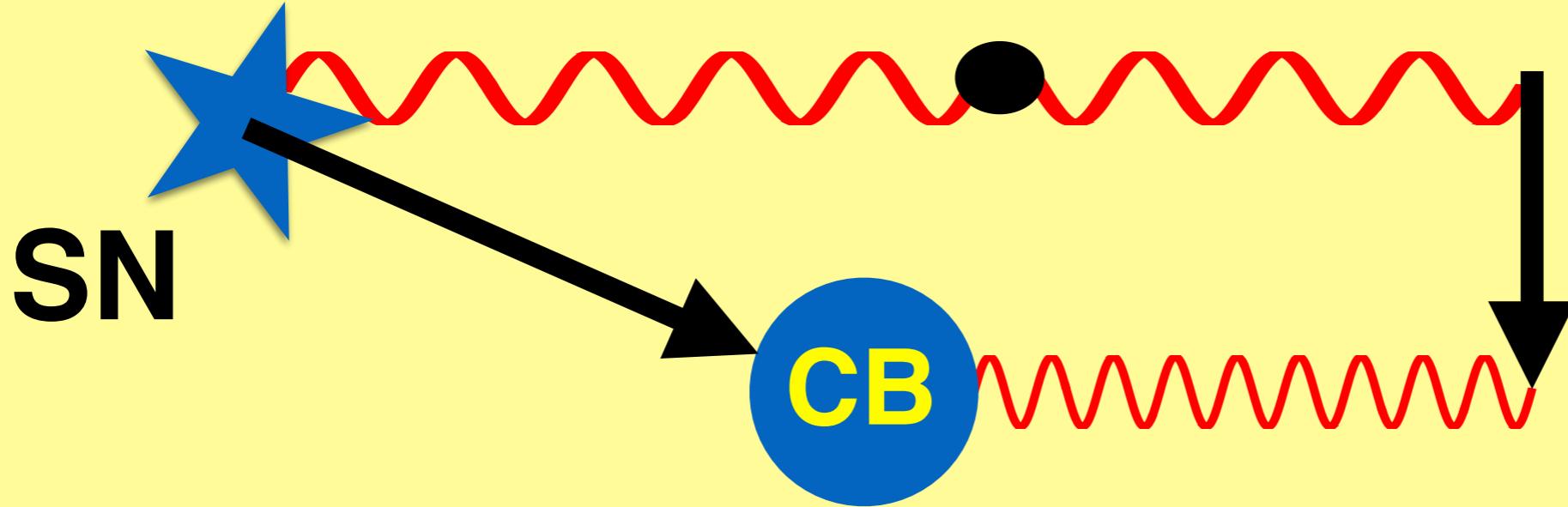
WHOSE THEORY ??



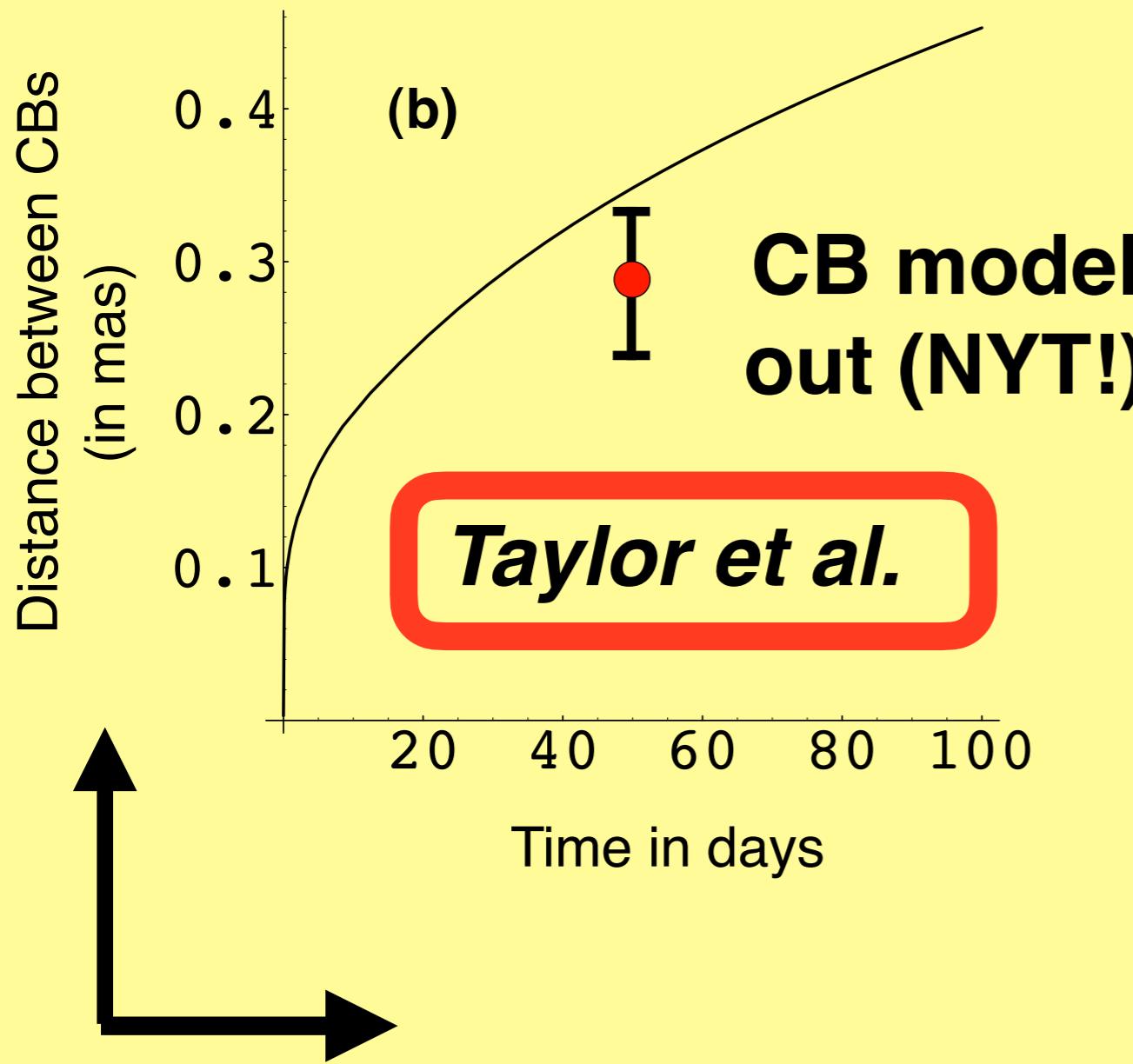


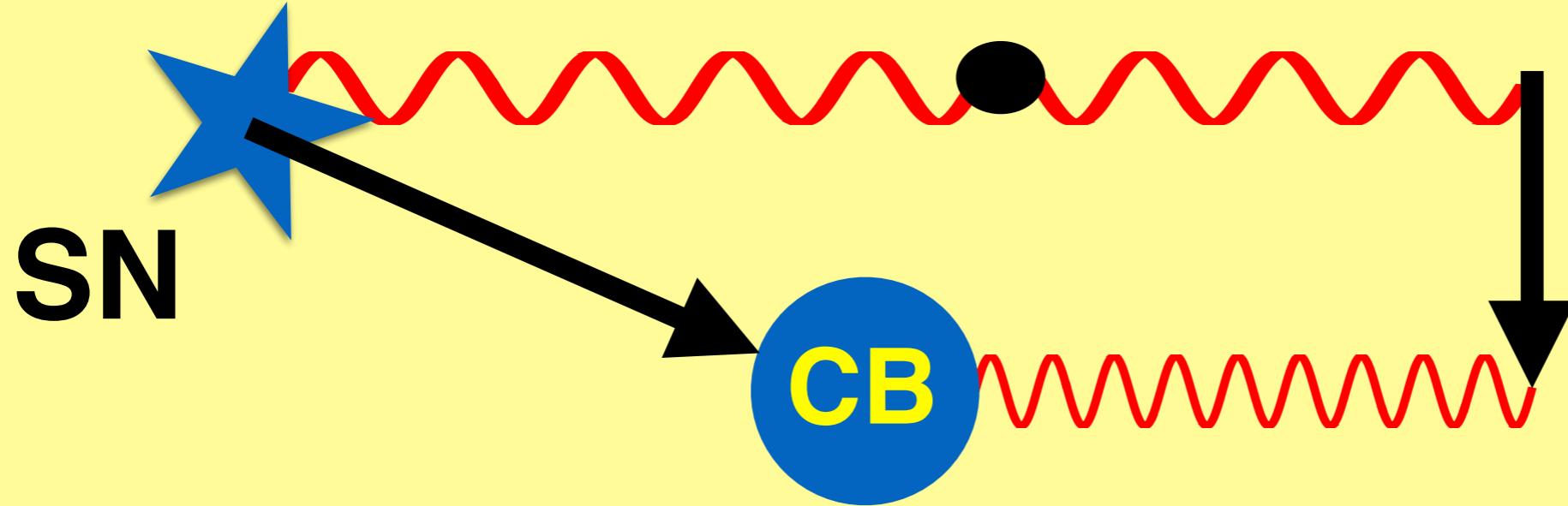
*Apparently
superluminal
velocity*



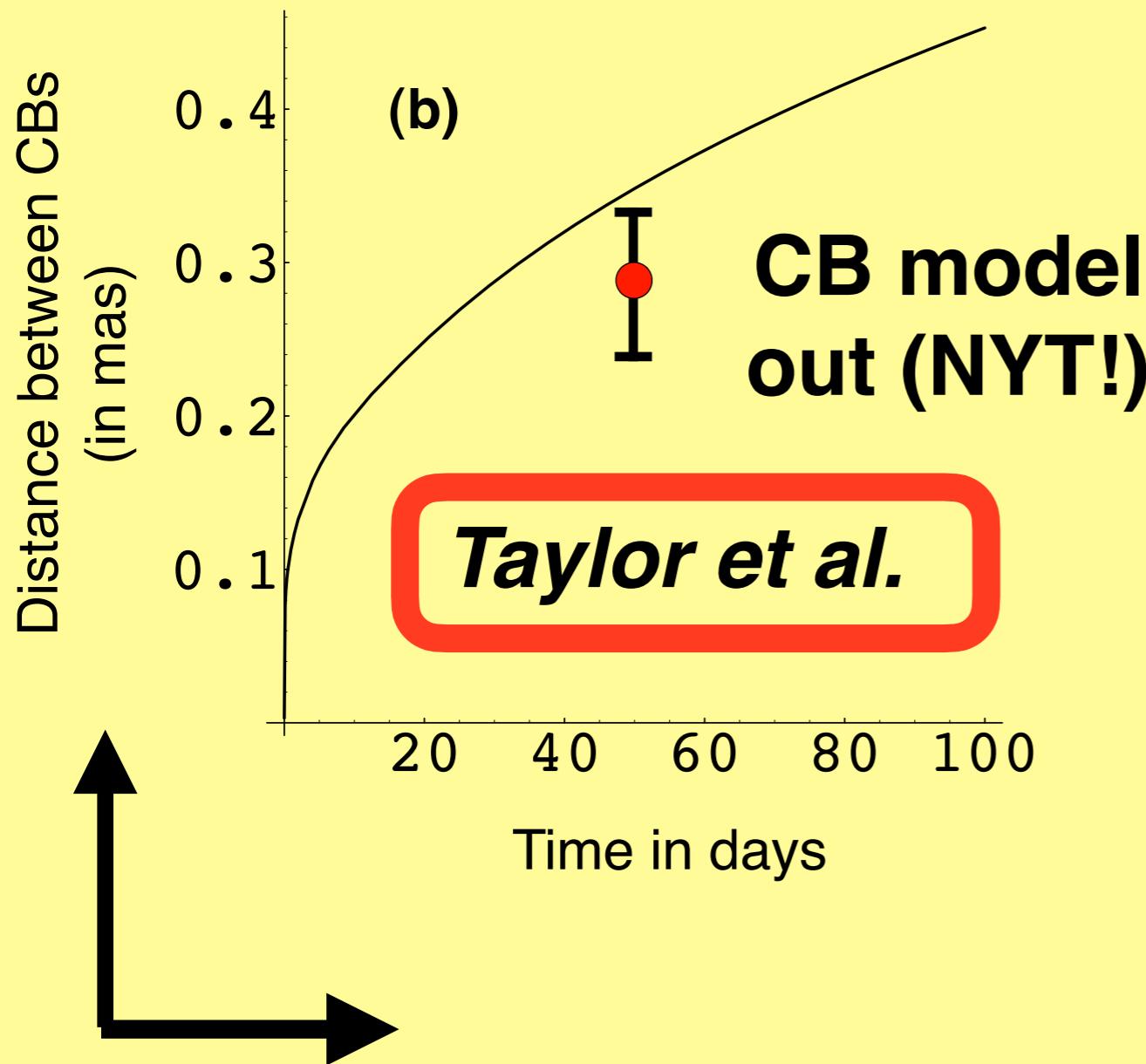


*Apparently
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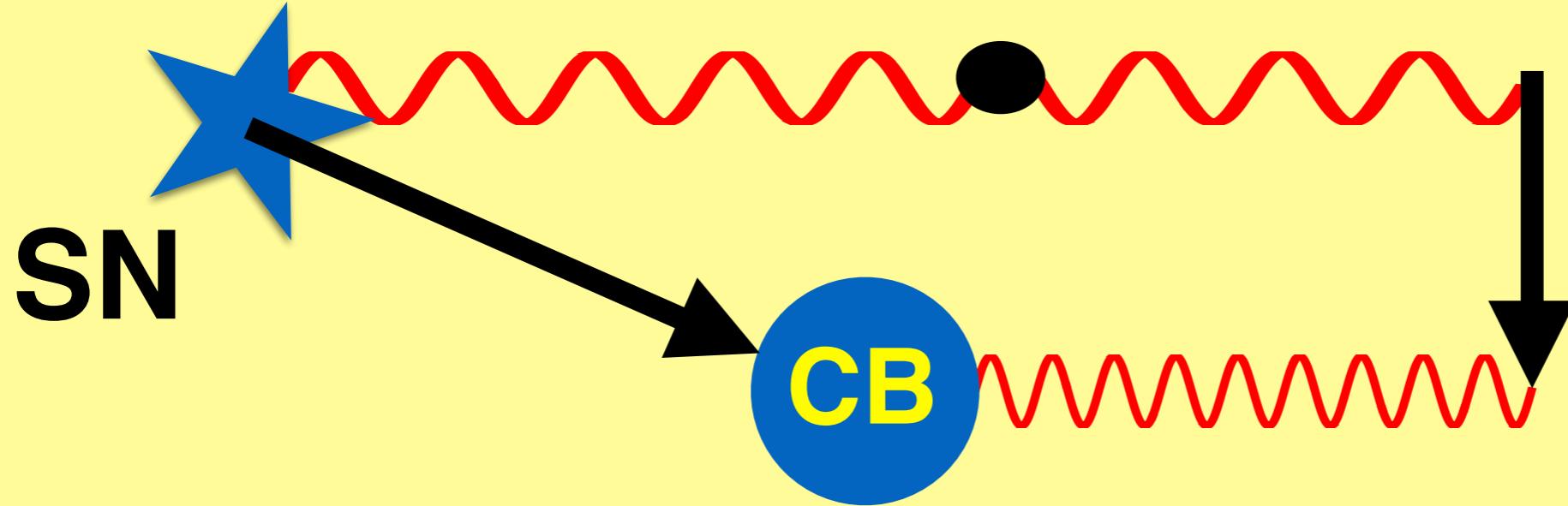




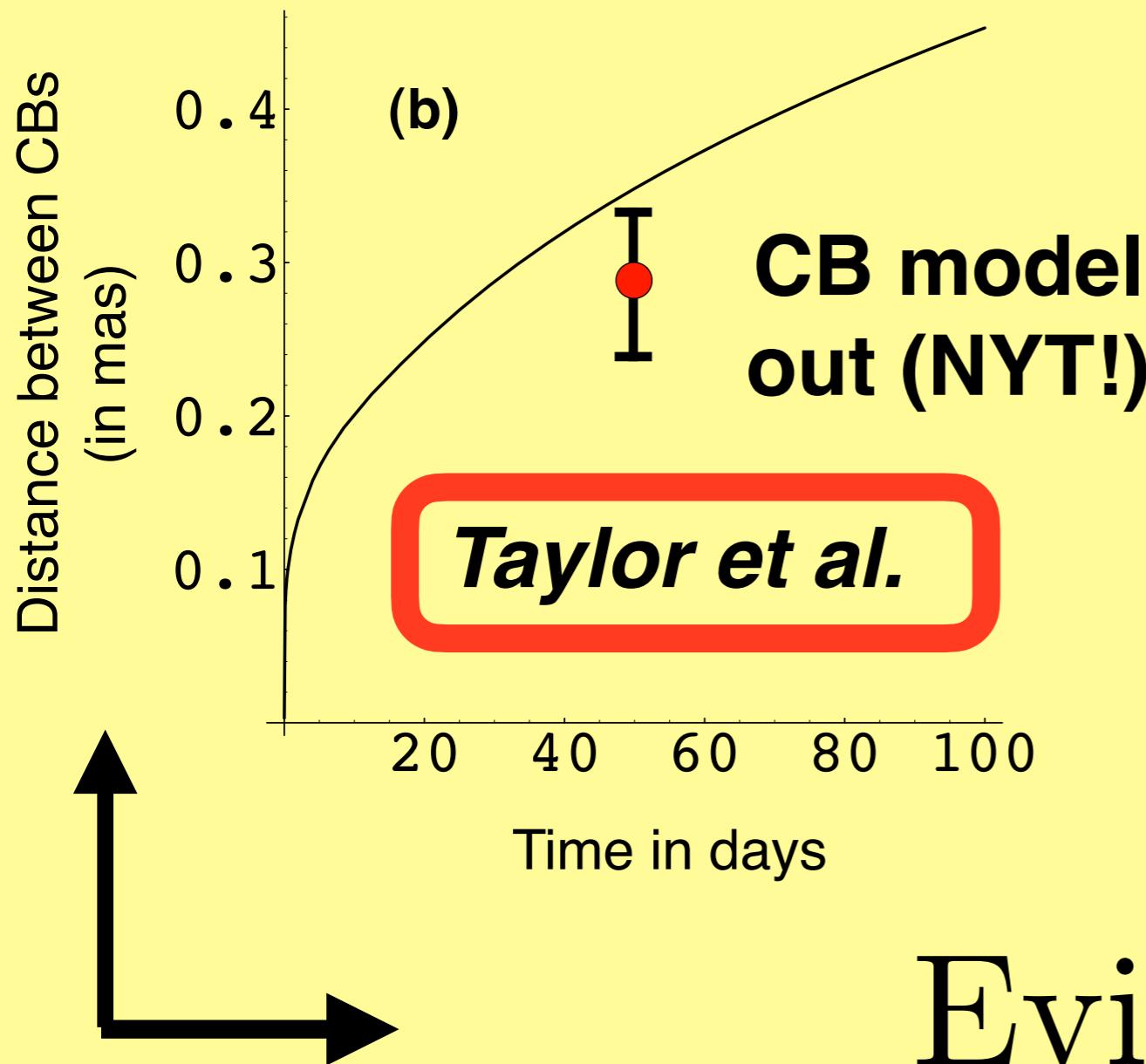
**Apparently
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**Much less easy to explain
is the single observation 52
days after the burst of an
additional radio component
0.28 mas northeast of the
main AG. This component
requires a high average
velocity of 19c and cannot
be readily explained by any
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*Apparently
superluminal
velocity*



Much less easy to explain is the single observation 52 days after the burst of an additional radio component 0.28 mas northeast of the main AG. This component requires a high average velocity of 19c and cannot be readily explained by any of the standard models.

Evidence : 20σ

SEEING IS BELIEVING

ONLINE LEARNING

Owing to Discrepancy

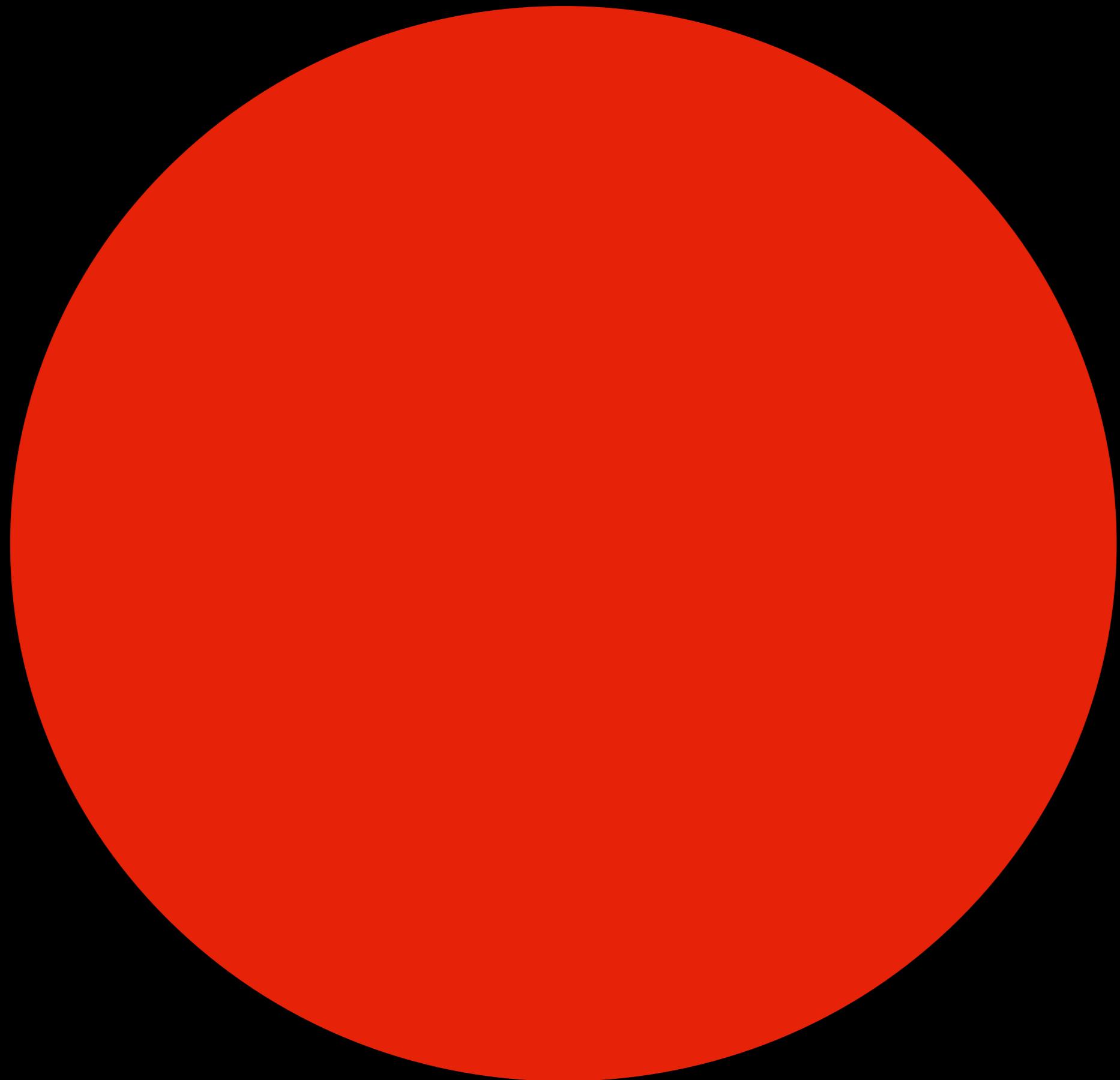
Regarding the search for a superluminal motion, we learned by reading the e-version of NYT 030529 (the New York Times of that date, in GRB's parlance) that, according to Dale Frail “[Our observations] are sufficient to rule out predictions of the cannonball model”. We have shown that, indeed, the observations of complicated features in the optical AG of GRB 030329 imply that our earlier results (Dar & De Rújula 2003b) —which ignored the presence of these features— constituted an overestimate of the predicted superluminal displacement. In this sense, Frail was right in stating that the observations ruled out the *predictions*, as opposed to the model itself.

\cite{Taylor2004}

In a setting more scientific than the NYT, Bloom et al. (2003) state: “*Owing to the proximity and bright radio emission, high-resolution (~ 1 pc) Very Long Baseline Array imaging of the compact afterglow was used by Frail (2003) to unequivocally disprove the cannonball model for the origin of GRBs.*” The emphasis is ours. We have seen that these news of the death of the CB model may have been premature. Even though Mark Twain eventually died for sure, the CB model —though probably not immortal— is still in an excellent shape. Yet, trying to disprove the best available model(s), or even the proof of a

*In Astrophysics standard
theories never die, only the
proponents of*

“non-standard views” Do





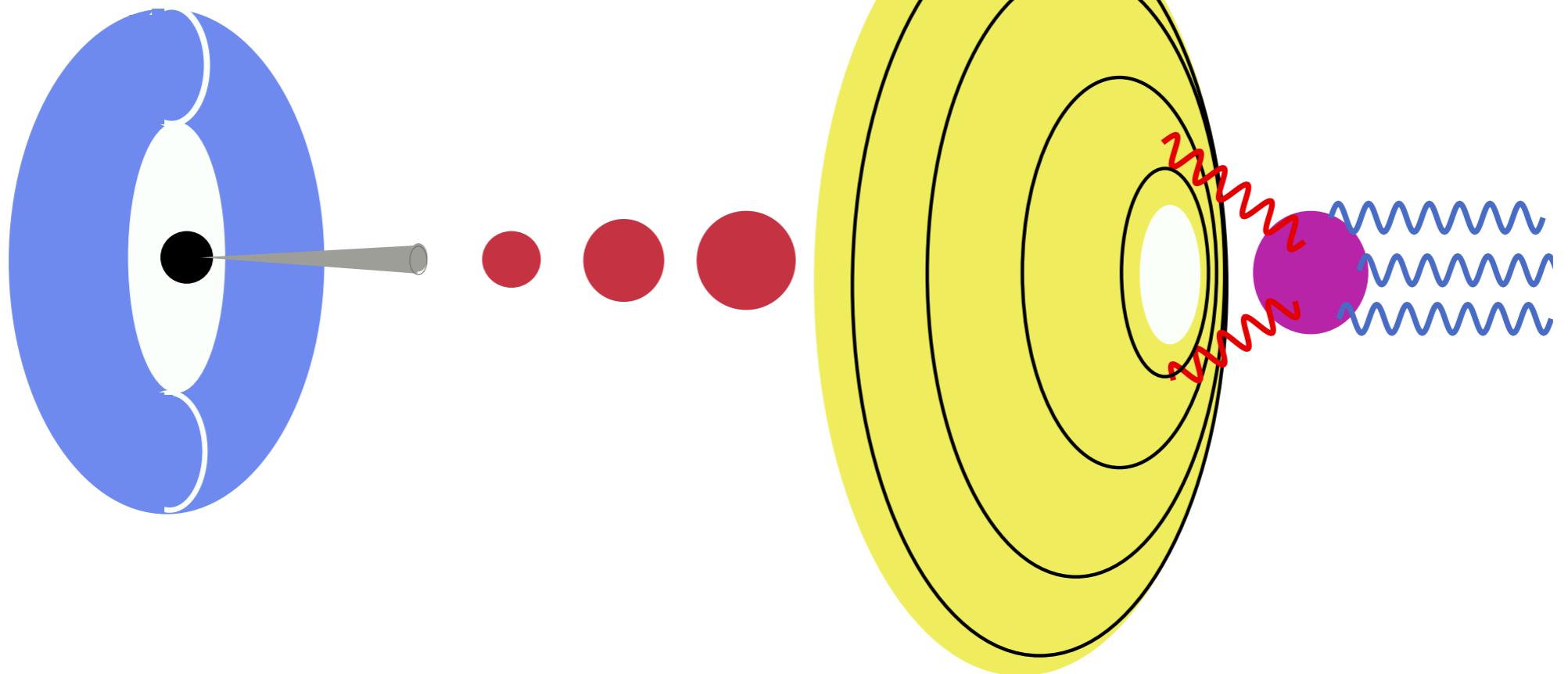
STOP

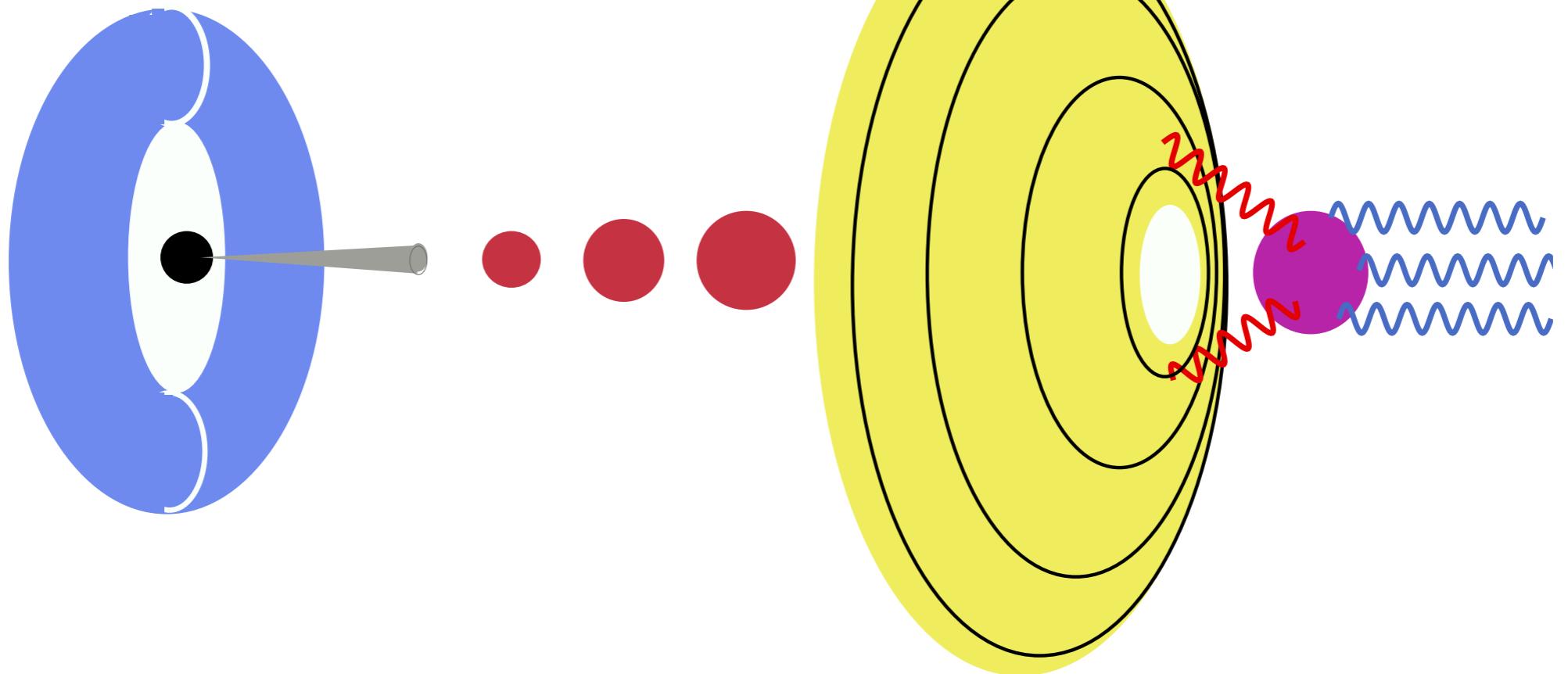
Table 3. Critical Tests of The Cannonball and Fireball models of GRBs and SHBs

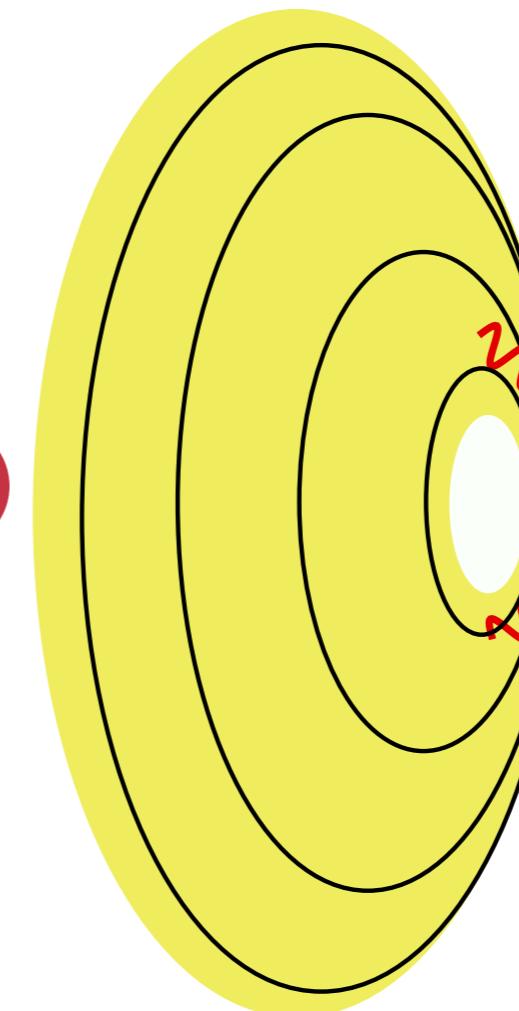
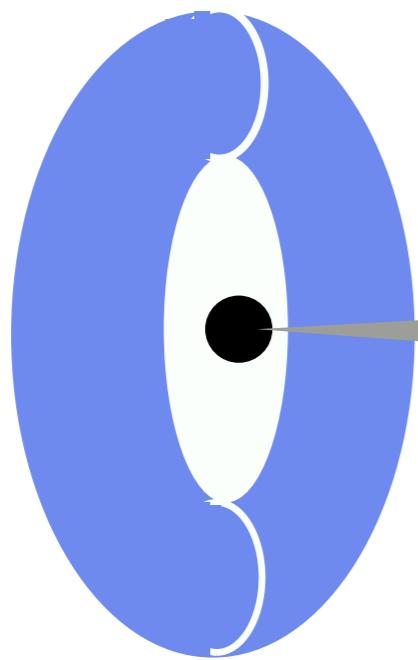
Test	Cannonball Model		Fireball Model	
Test 1	Large GRB linear polarization	✓	Small GRB polarization	X
Test 2	Prompt emission correlations	✓	Frail relation	X
Test 3	Inverse Compton GRB pulses	✓	Curvature-shaped pulses	X
Test 4	SN-GRBs: Canonical afterglow	✓	Canonical AG not expected	X
Test 5	AG's break correlations	✓	AG's Break correlations	X
Test 6	Post-break closure relation	✓	Post-break closure relation	X
Test 7	Missing breaks (too early)	✓	Missing breaks (too late)	X
Test 8	Chromatic afterglow	✓	Achromatic afterglow	X
Test 9	MSP-powered AG of SN-less GRB	✓	Magnetar jet re-energization	X
Test 10	GRB rate \propto SFR	✓	GRB rate not \propto SFR	X
Test 11	LL GRBs = far off-axis GRBs	✓	LL GRBs = Different GRB class	X
Test 12	Super-luminal CBs	✓	Superluminal fireball	X
Test 13	SHBs optical AG powered by NS	?	SHBs + macronova	?
Test 14	XRFs = Far off-axis LGRBs	✓	Different class of LGRBs	X
Test 15	XRTs = NS-powered AGs	✓	AGs of Far-off-axis GRBs	X
Test 16	Radio image of SHB170817A: a CB	✓	A complex structured jet	X

Table 4. Majority and minority views on GRBs preceding decisive observations

Key property	Majority view		Minority view	
Location:	Galactic	X	Extragalactic	✓
Produced by	Relativistic $e^+e^- \gamma$ fireball	X	Highly relativistic plasmoids	✓
Production mechanism	Collisions of e^+e^- shells	X	ICS of light by plasmoids (CBs)	✓
Prompt Emission	Synchrotron radiation (SR)	X	Inverse Compton scattering	✓
GRB geometry	Isotropic	X	Very narrowly beamed	✓
LGRBs origin	Stellar collapse to BH	X	Stripped-envelope SN	✓
Afterglows' origin	SR from shocked ISM	X	Synchrotron from CBs	✓
Afterglows' geometry	Isotropic	X	Narrowly beamed	✓
SN1998bw/GRB980425	Rare SN/Rare GRB	X	SNIc-GRB viewed far off-axis	✓
LL GRBs	Different class of GRBs	X	Normal GRBs seen far off-axis	✓
SN-Less LGRBs	Stellar Collapse to BH	?	Phase Transition in HMXRBs	?
AG plateau origin	Jet re-energization	X	Early time jet deceleration	✓
AG break origin	Deceleration of conical jet	X	Deceleration of CBs	✓
Missing jet breaks	Too late to be seen	X	Too early to be seen	✓
Observed rate of GRBs	\propto SFR + evolution	X	\propto SFR, modified by beaming	✓
Geometry	Spherical \rightarrow Conical shells	X	Succession of cannonballs	✓



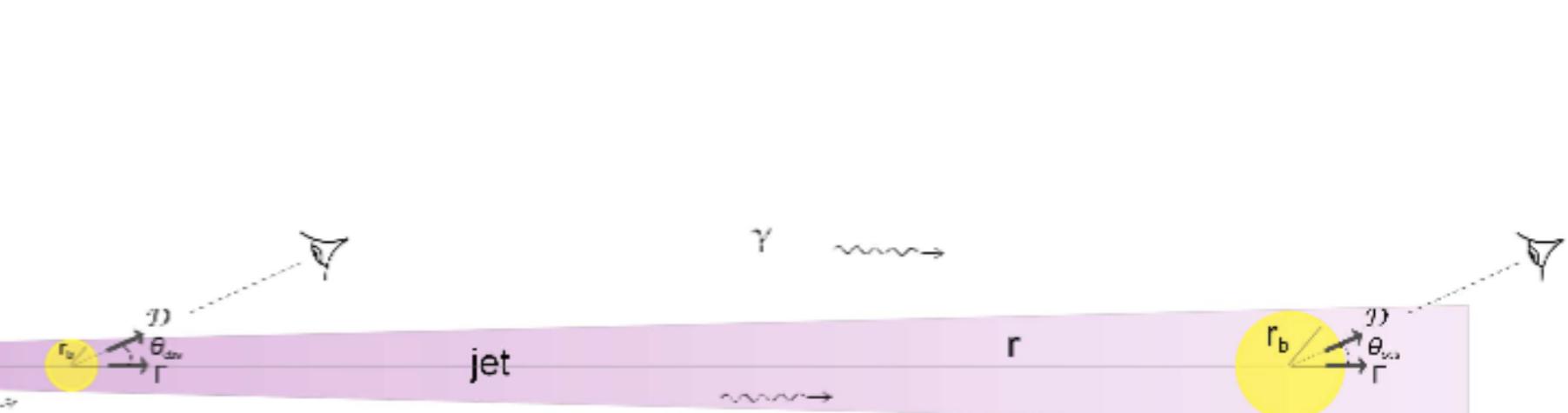
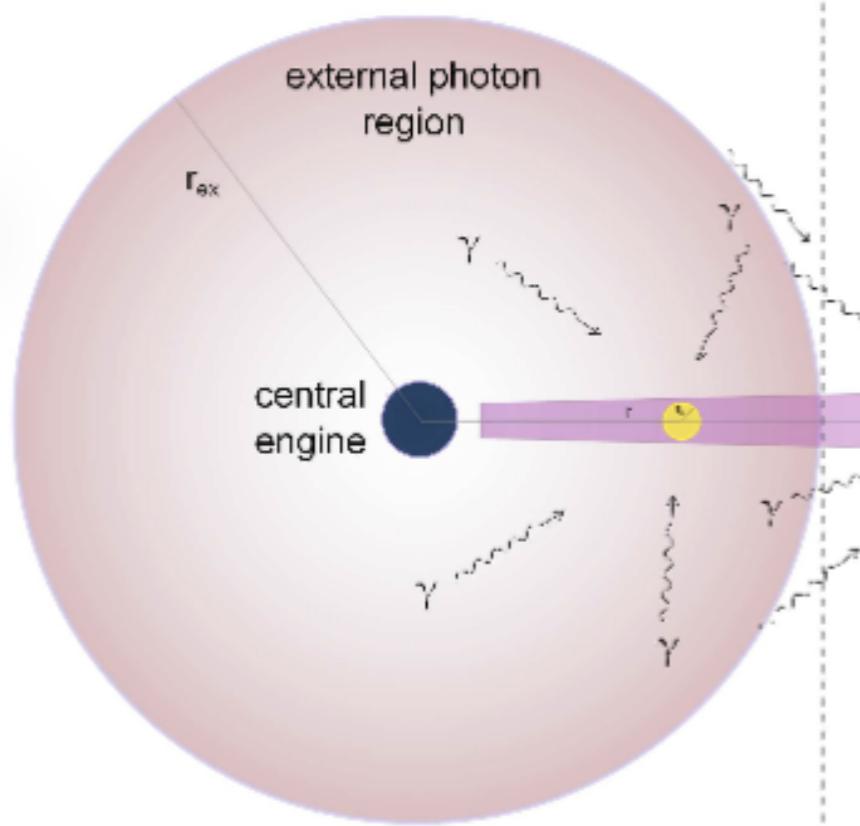




emission region inside
external photon region

emission region outside
external photon region

emission region far outside
external photon region



emission
region

CB Model objects

GRB or LLGRB gamma rays, $T_{90} > 2$ s

Produced by Type Ic SNe

AG Produced by SR from CB

SGRBs. Short. $T_{90} < 2$ s. Hardest of them: SHBs

Produced by NS/NS mergers

AG produced by Pulsar Wind Nebula, with universal shape

SN-less GRBs are a “Glow” with PWN universal shape

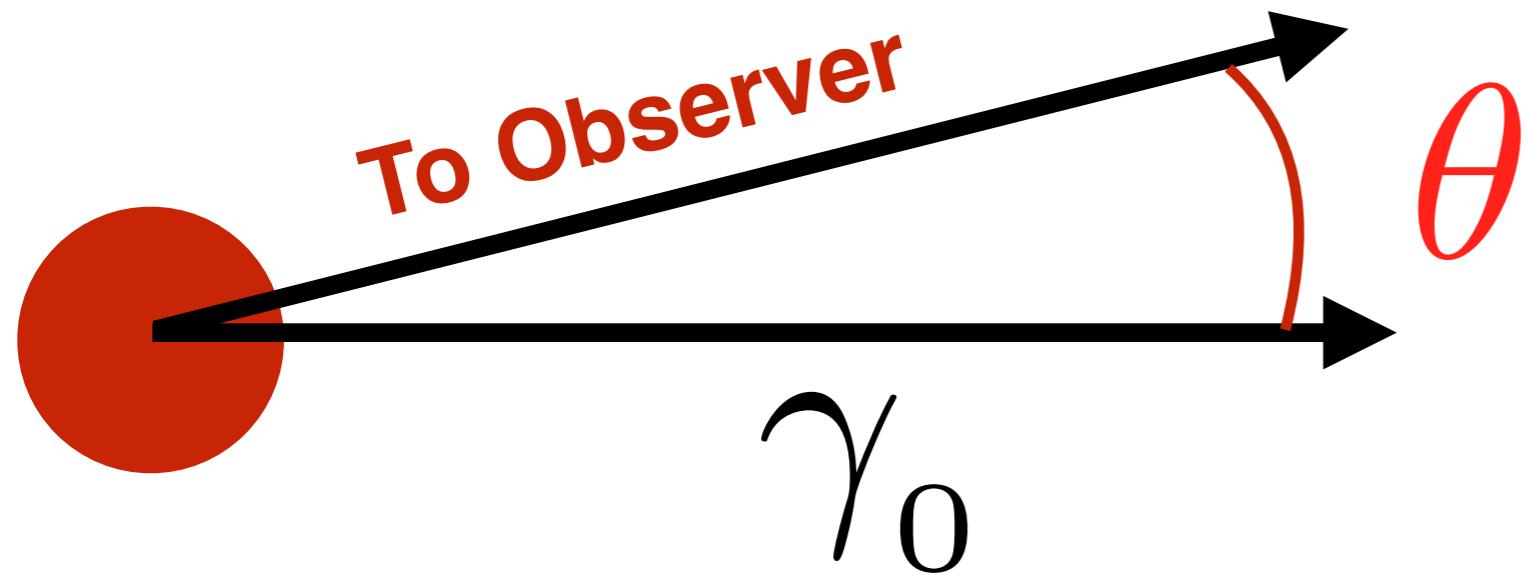
Accreting NS -> quark star?

XRF is a GRB seen at large angle

LL GRBs, high energy but off-axis Low Luminosity

O GRBs, closer to axis

In the CB model GRBs produce two main types of extragalactic X-ray transients: X-ray flashes , which are narrowly beamed LGRBs viewed far off axis [130], and fast X-ray transients (XRTs) which are emissions from a wind nebula powered by a newly-born millisecond pulsar in a binary neutron-star merger (are these not SHBs?) and in SN-less LGRBs [130].

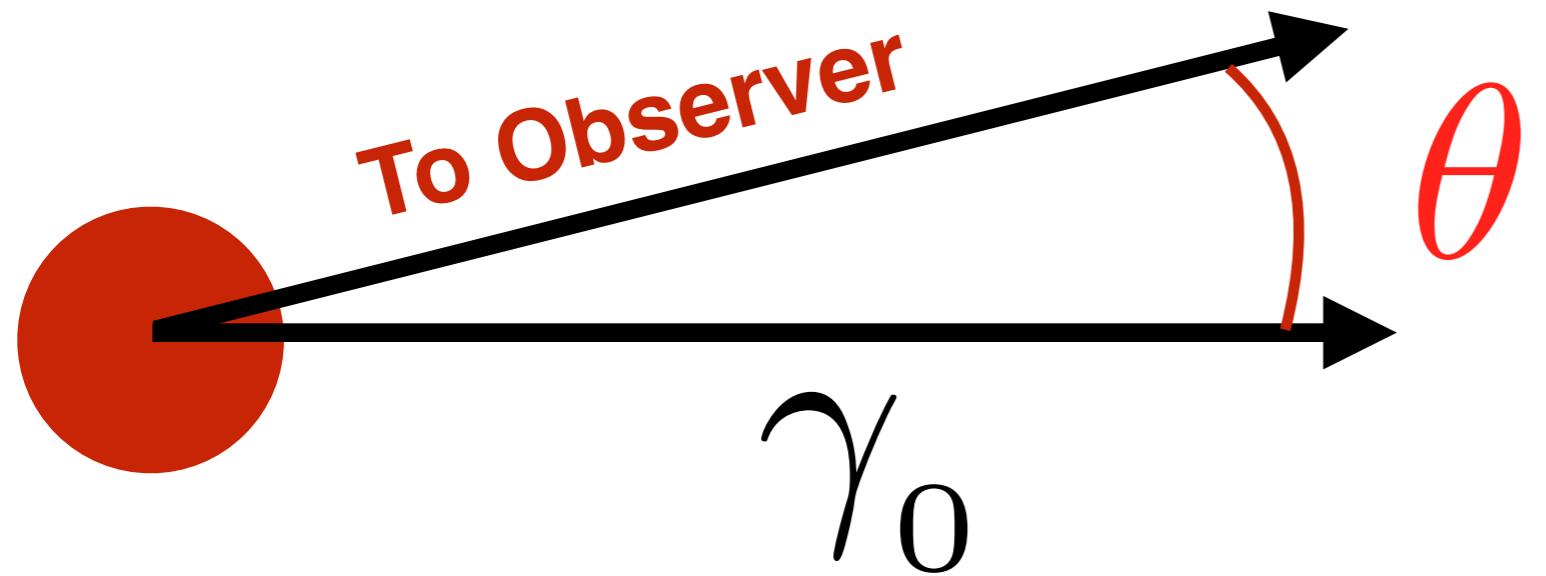


Doppler

$$\delta = \frac{1}{\gamma(1 - \beta \cos[\theta])}$$

$$E_{\text{Obs}}^\gamma = \delta E_{\text{CB}}^\gamma / (1 + z)$$

$$dx_{\text{SN}} = \frac{\gamma \delta}{1 + z} c dt_{\text{Obs}}$$

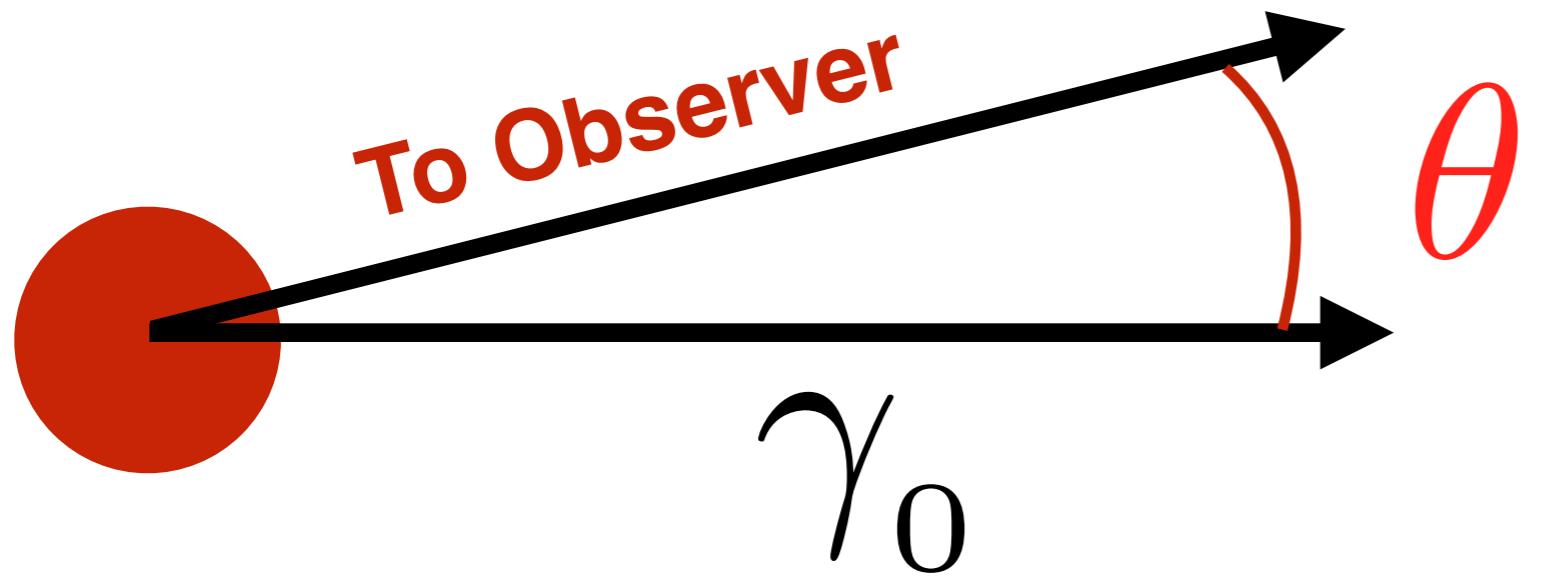


$$\textbf{\textit{Doppler}} \quad \gamma_0 \gg 1$$

$$\frac{\delta =_1}{\gamma(1 - \beta \cos[\theta])} \quad \theta \ll 1$$

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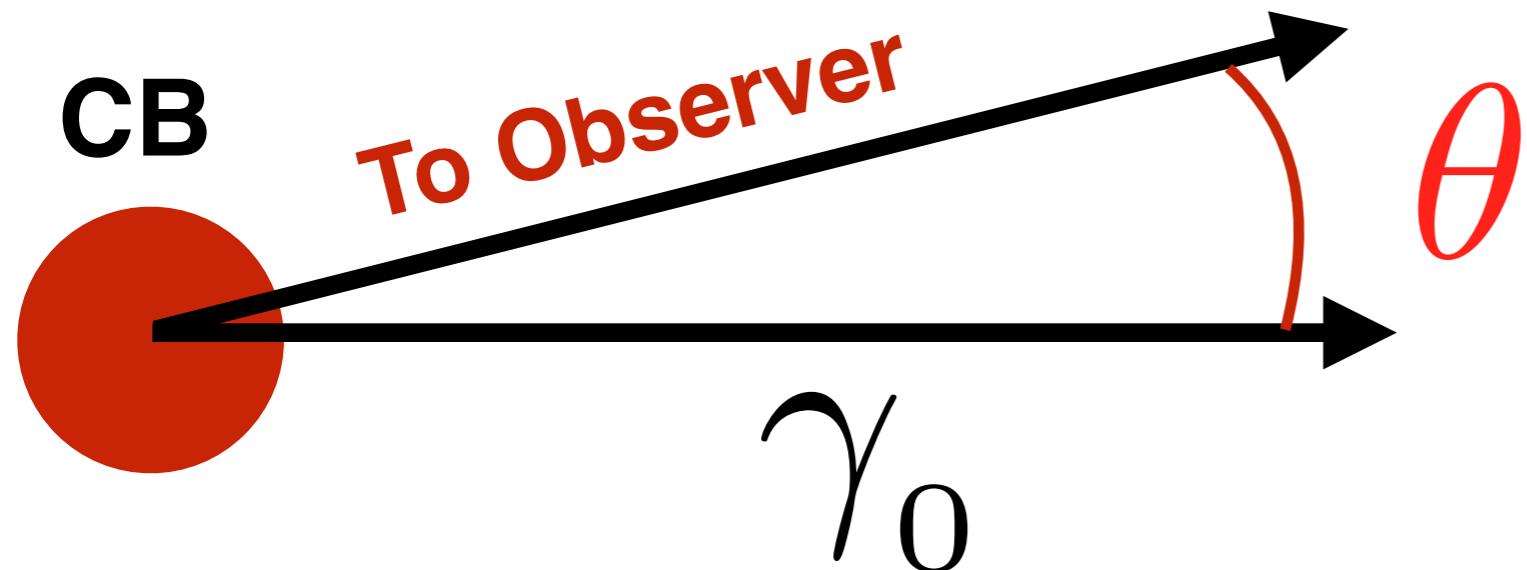
$$\frac{dn}{d\Omega_{\text{OBS}}} = \delta^2 \frac{dn}{d\Omega_{\text{CB}}}$$

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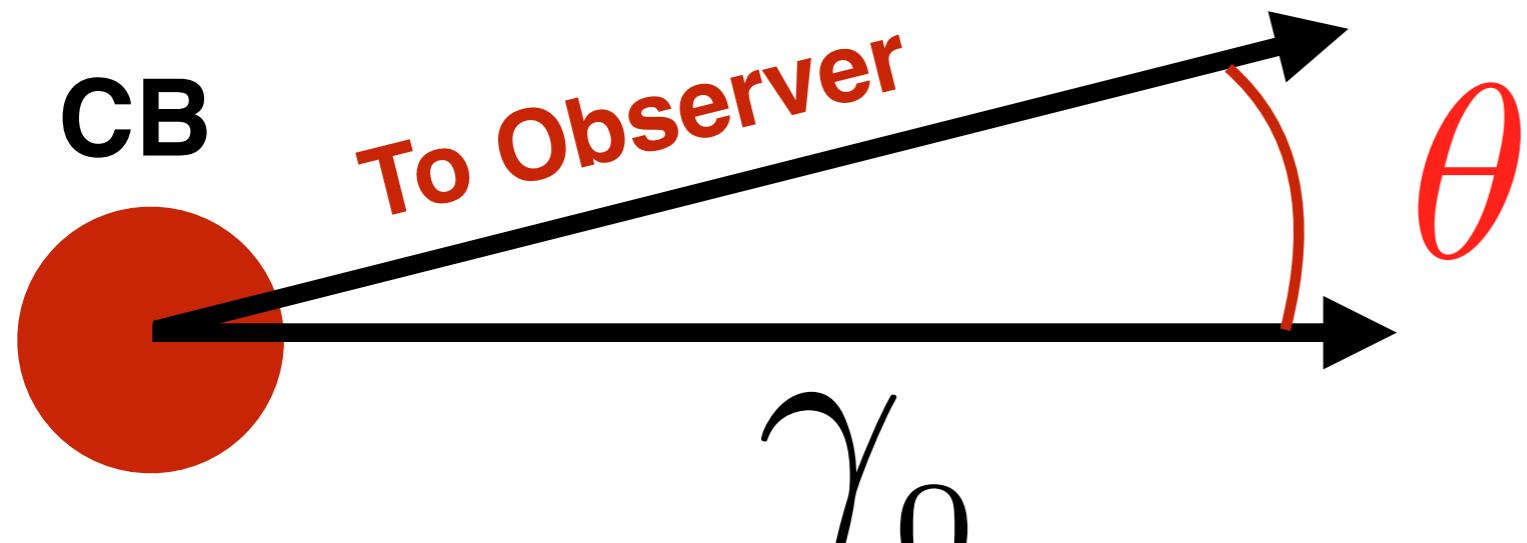
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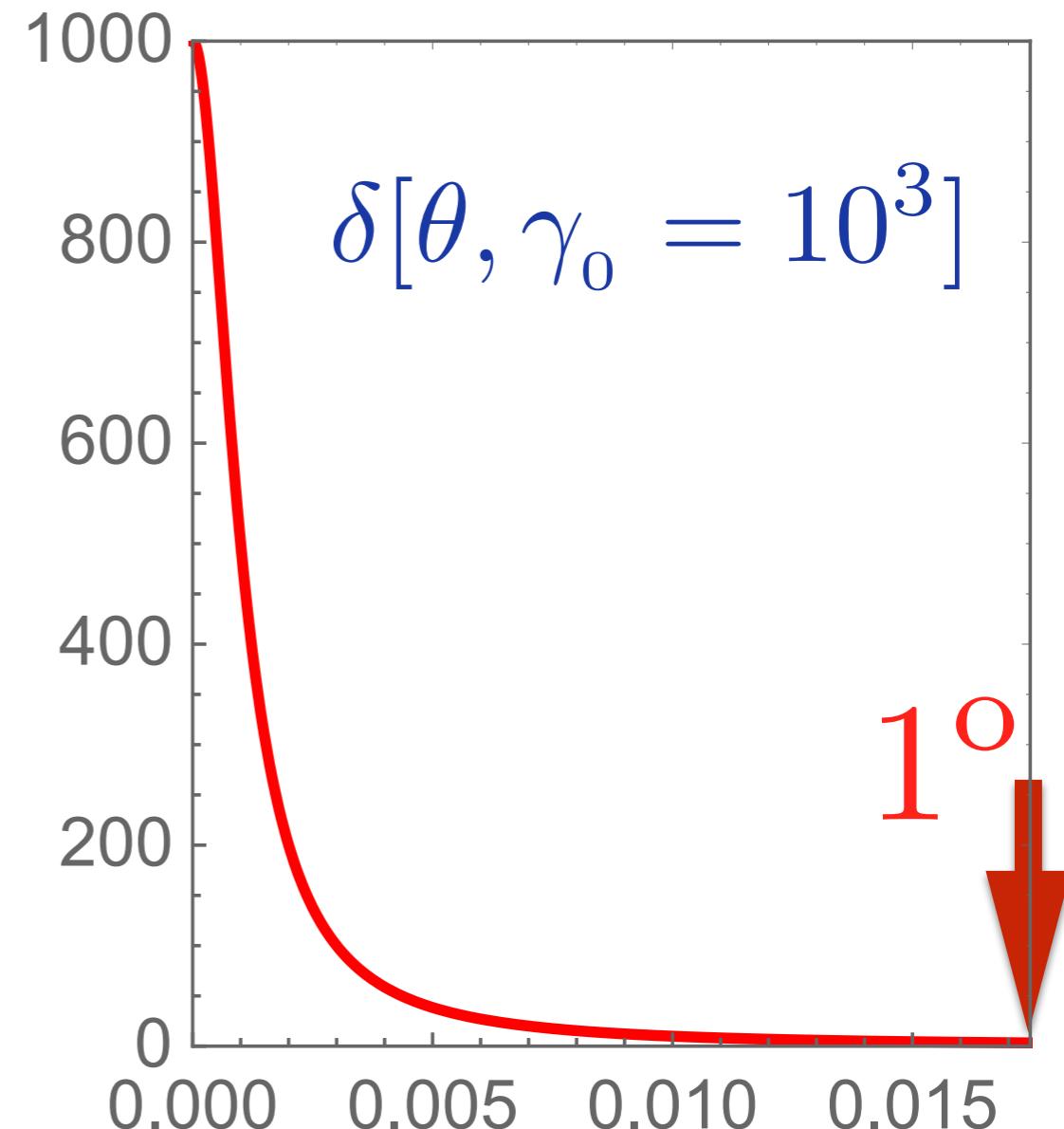
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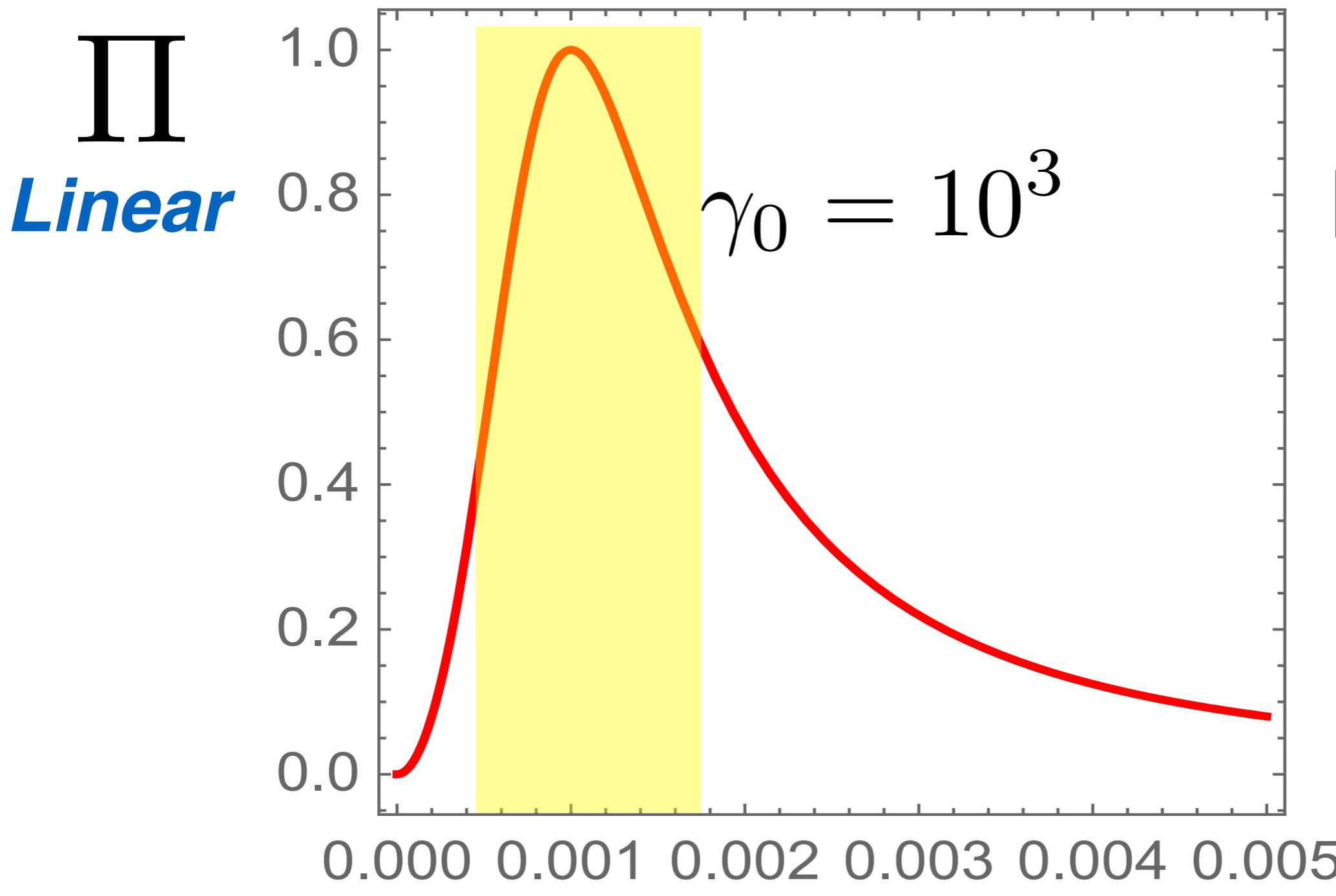


POLARIZATION

N. J. Shaviv, A. Dar,
ApJ, 447, 863 (1995)

$$\Pi = \frac{2\gamma_0^2 \theta^2}{(1 + \gamma_0^4 \theta^4)}$$

$$\text{Max } \Pi = \Pi[\theta = 1/\gamma_0] = 1$$



Most
probable
viewing
angle

$$\theta \sim 1/\gamma$$

$$\theta$$

Table 1. GRBs with measured γ -ray polarization during prompt emission

GRB	Polarization(%)	CL	Reference [38]	Polarimetry
930131	> 35,	90%	Willis et al. 2005	BATSE (Albedo)
960924	> 50	90%	Willis et al. 2005	BATSE (ALbedo)
021206	80 +/- 20	???	Coburn & Boggs 2003	RHESSI
041219A	98 +/- 33	68%	Kalemci et al. 2007	INTEGRAL-SPI
100826A	27 +/- 11	99%	Yonetoku et al. 2011	IKARUS-GAP
110301A	70 +/- 22	68%	Yonetoku et al. 2012	IKARUS-GAP
110721	84 +16/-28	68%	Yonetoku et al. 2012	IKARUS-GAP
061122	> 60	68%	Gotz et al. 2013	INTEGRAL-IBIS
140206A	> 48	68%	Gotz et al. 2014	INTEGRAL-IBIS
160821A	66 +27/-26	99%	Sharma et al. 2019	AstroSat-CZTI

First of > 12 decisive tests

... because ...

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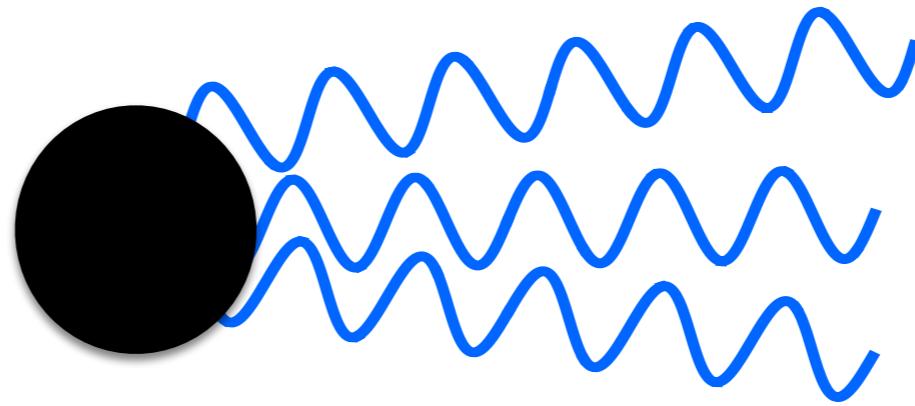
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First of > 12 decisive tests

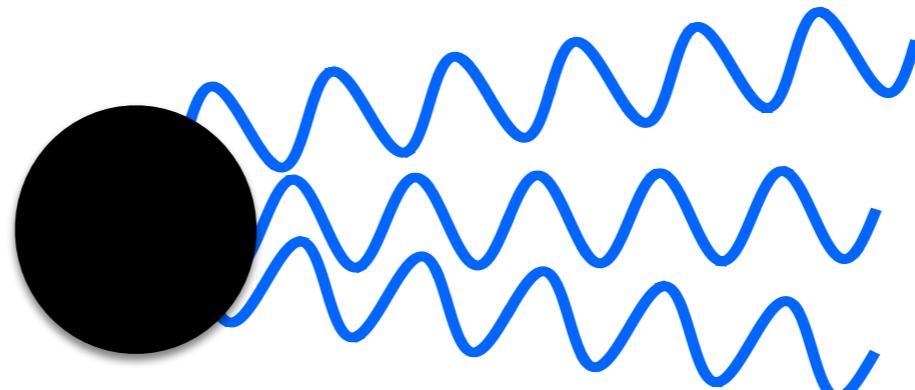
... because ...

**CB in motion
in a galaxy**

**CB in motion
in a galaxy**

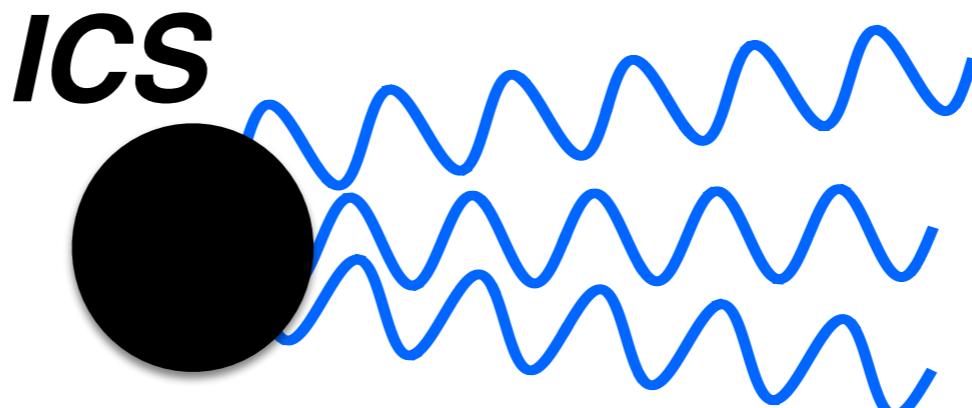


CB in motion in a galaxy



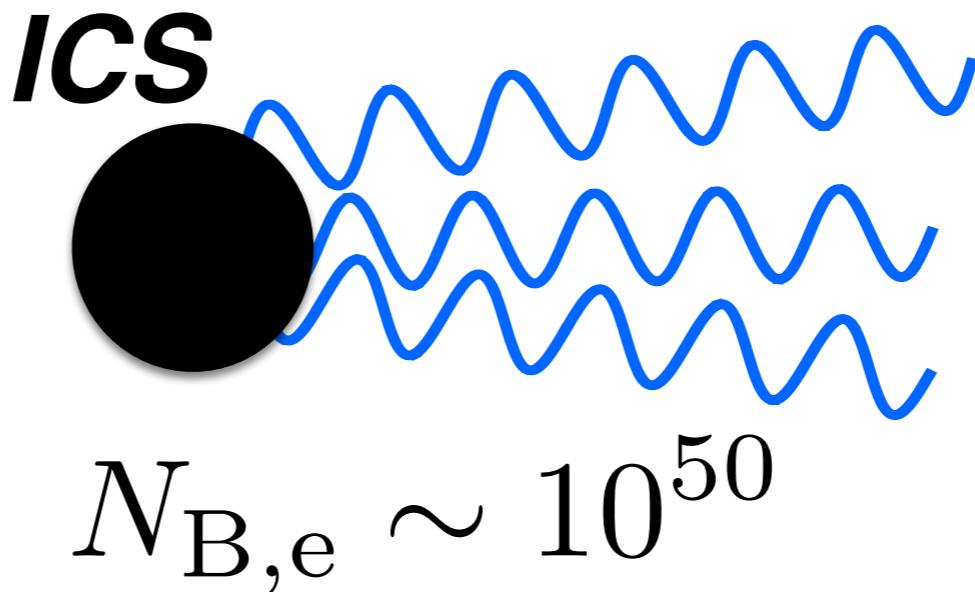
$$N_{\text{B,e}} \sim 10^{50}$$

CB in motion in a galaxy



$$N_{B,e} \sim 10^{50}$$

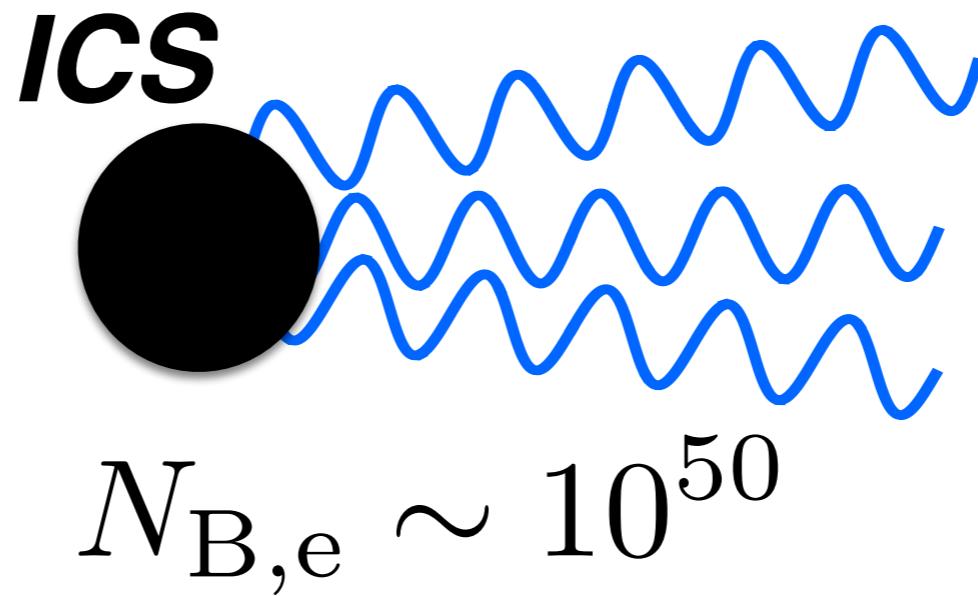
**CB in motion
in a galaxy**



**GRB
ionizes
ISM**

**CB in motion
in a galaxy**

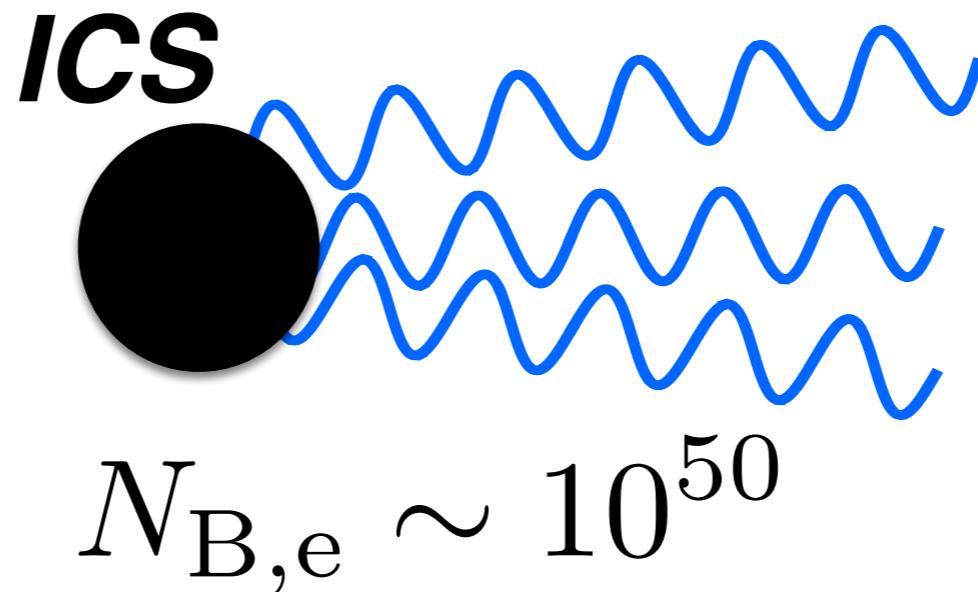
**CB in its
rest system**



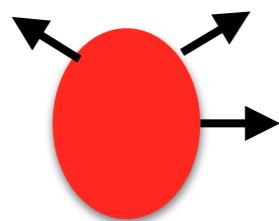
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ISM**

**CB in motion
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rest system**



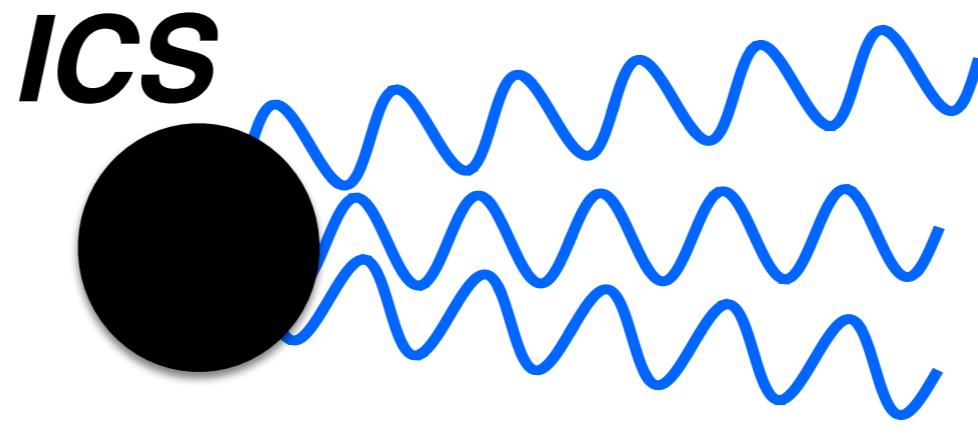
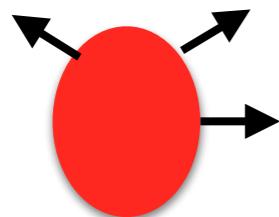
**GRB
ionizes
ISM**



**CB in motion
in a galaxy**

**CB in its
rest system**

$$v_{\text{exp}} \sim c/\sqrt{3}$$



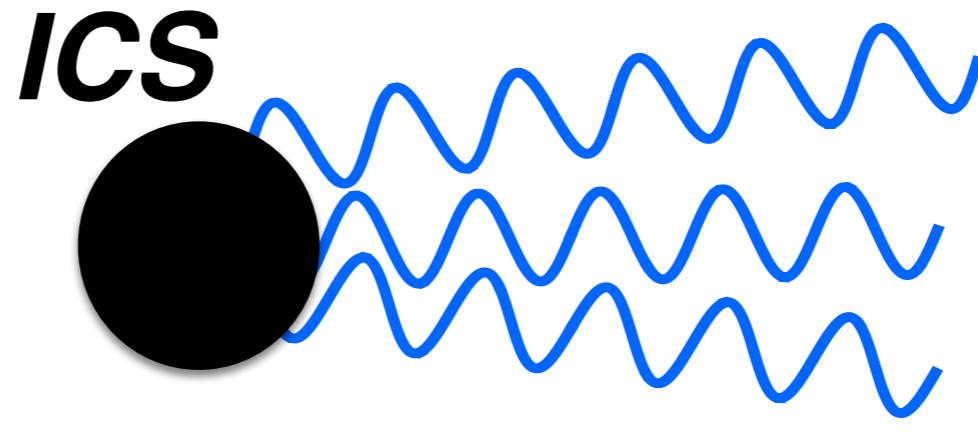
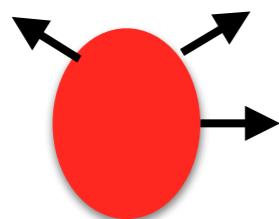
$$N_{\text{B,e}} \sim 10^{50}$$

**GRB
ionizes
ISM**

**CB in motion
in a galaxy**

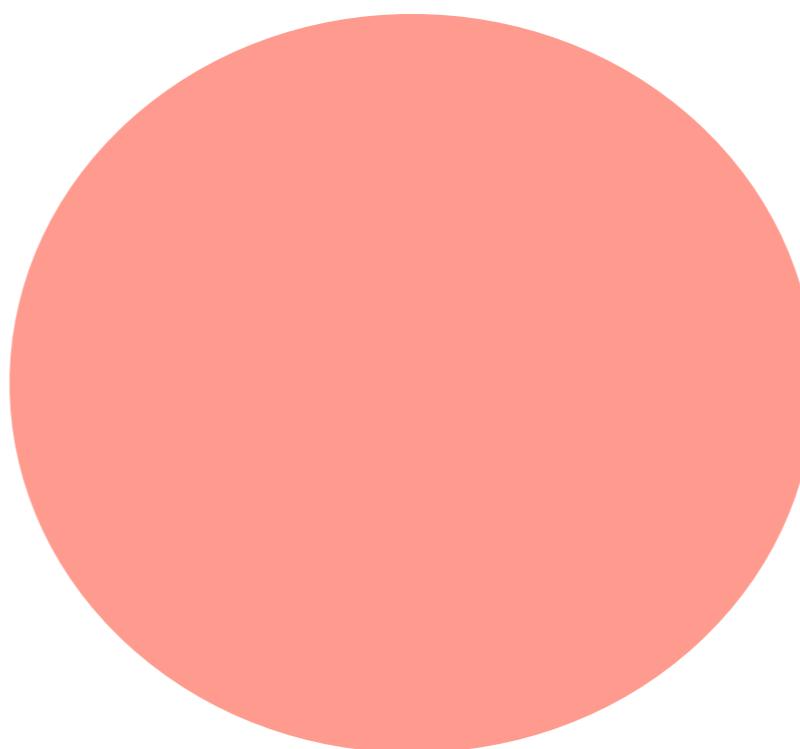
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$$N_{\text{B,e}} \sim 10^{50}$$

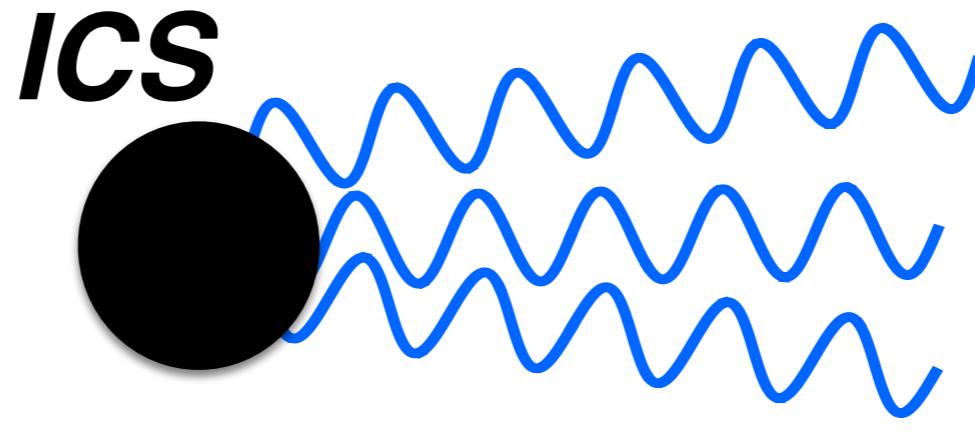
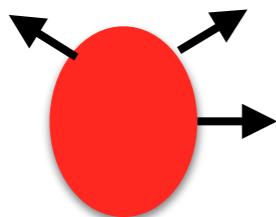
**GRB
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ISM**



**CB in motion
in a galaxy**

**CB in its
rest system**

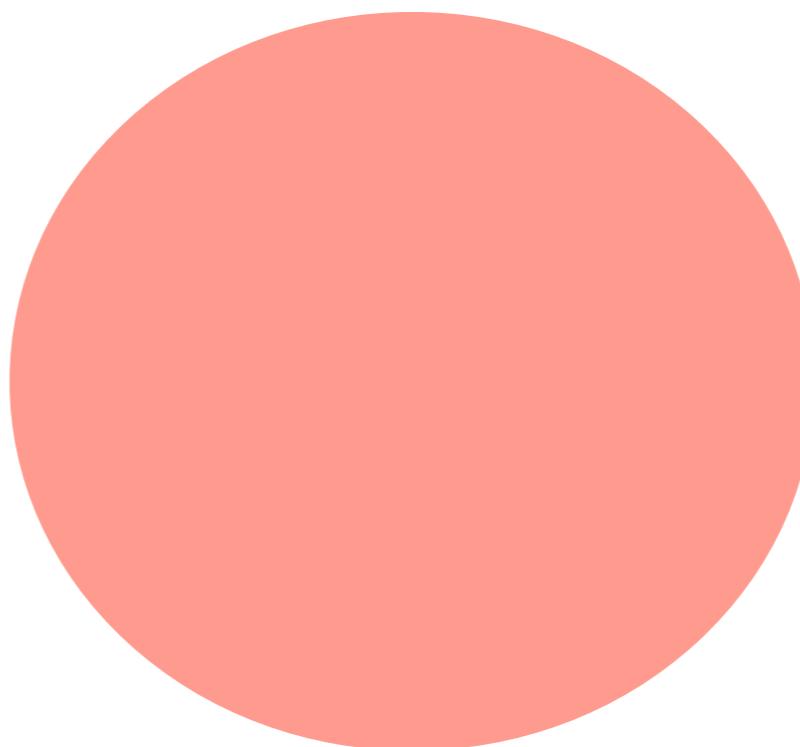
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**GRB
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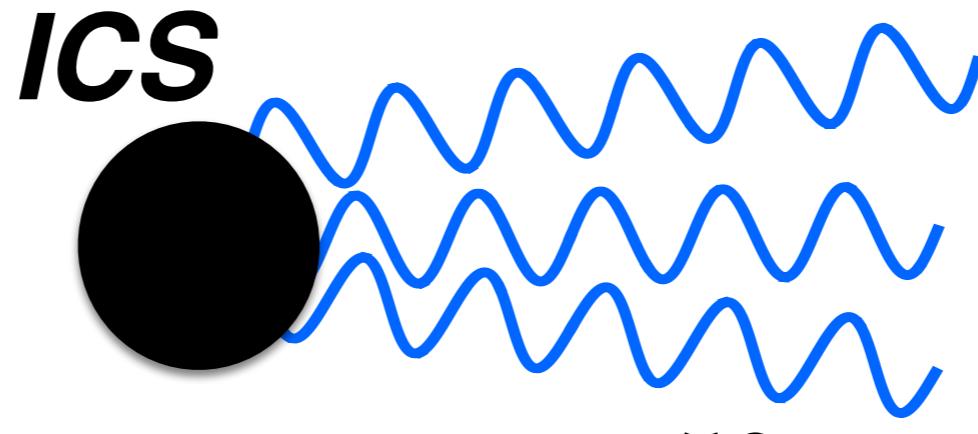
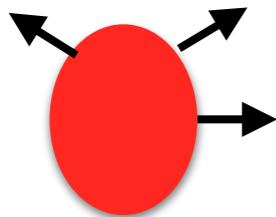
Collisionless



**CB in motion
in a galaxy**

**CB in its
rest system**

$$v_{\text{exp}} \sim c/\sqrt{3}$$

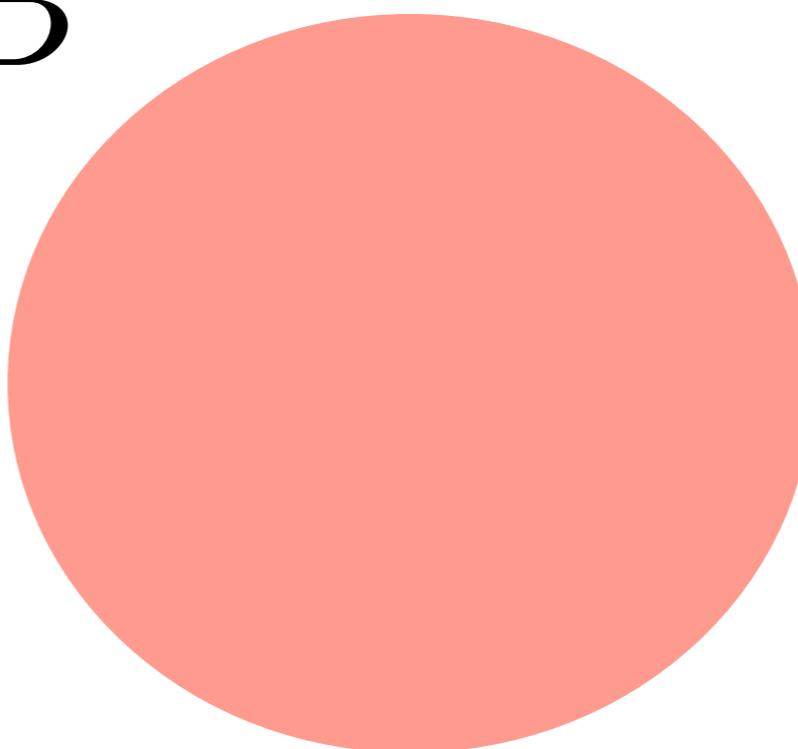


$$N_{B,e} \sim 10^{50}$$

**GRB
ionizes
ISM**

Collisionless

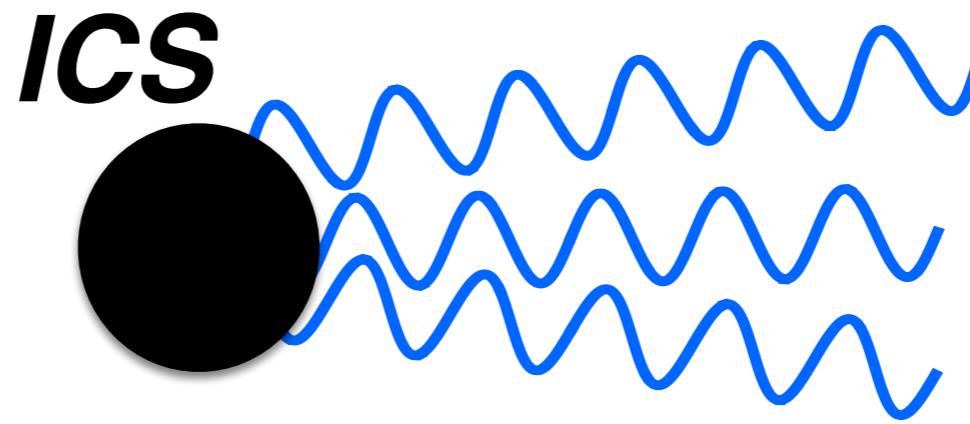
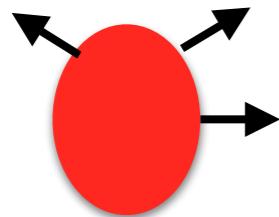
$$\vec{B}$$



**CB in motion
in a galaxy**

**CB in its
rest system**

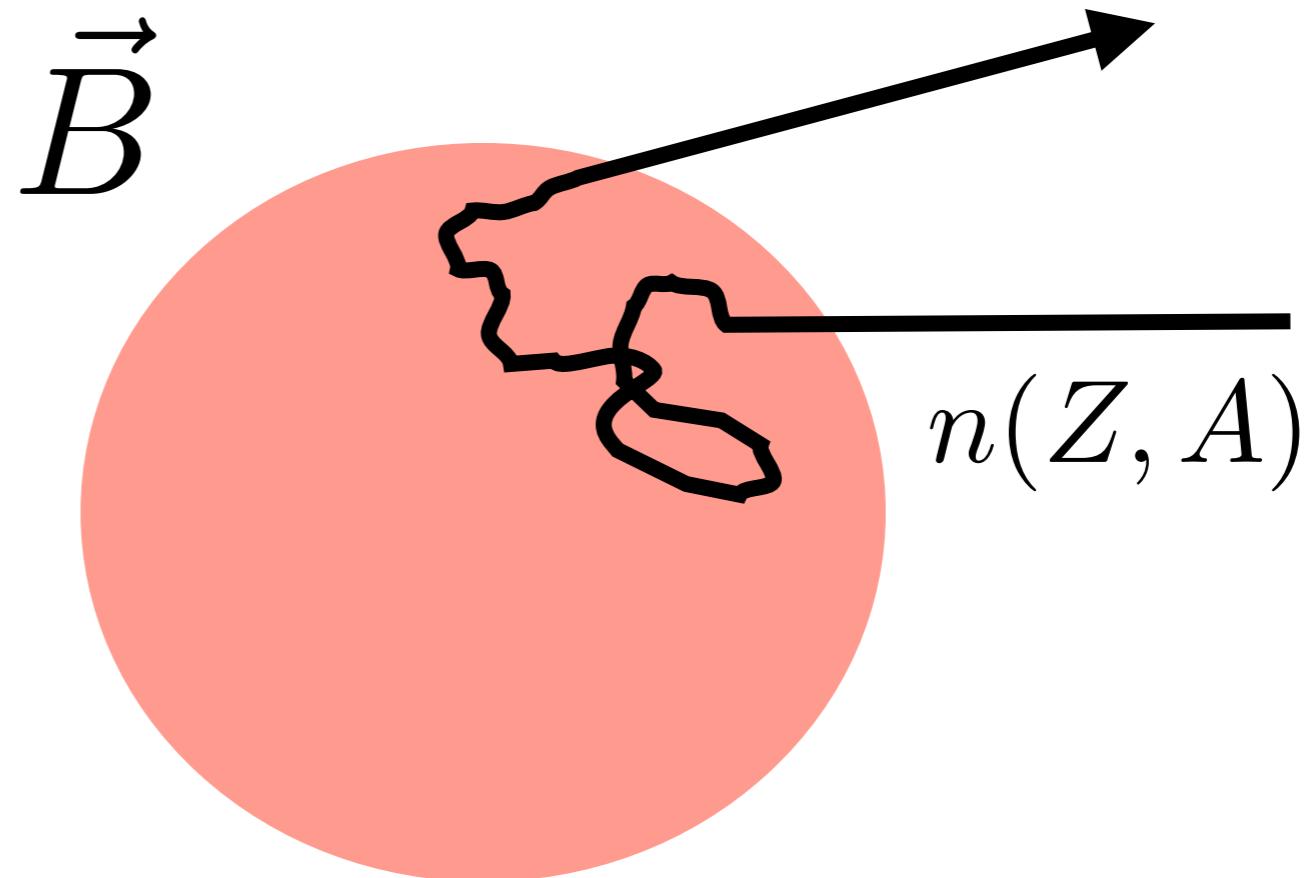
$$v_{\text{exp}} \sim c/\sqrt{3}$$



$$N_{B,e} \sim 10^{50}$$

**GRB
ionizes
ISM**

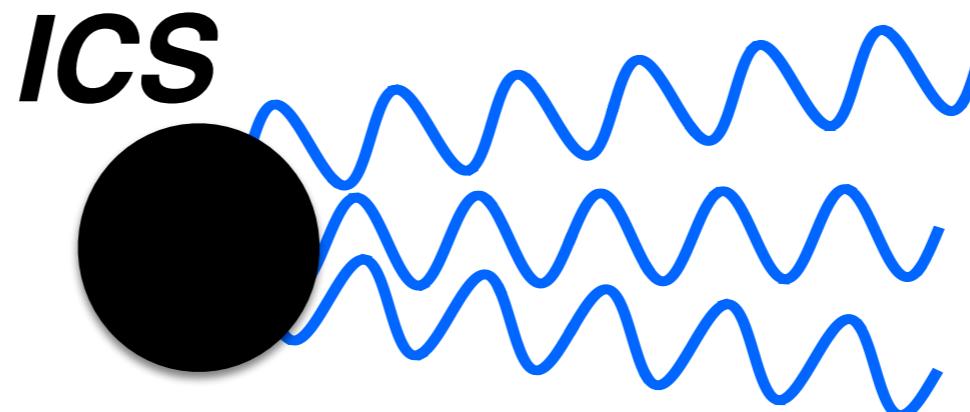
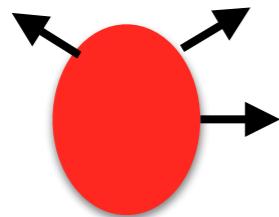
Collisionless



**CB in motion
in a galaxy**

**CB in its
rest system**

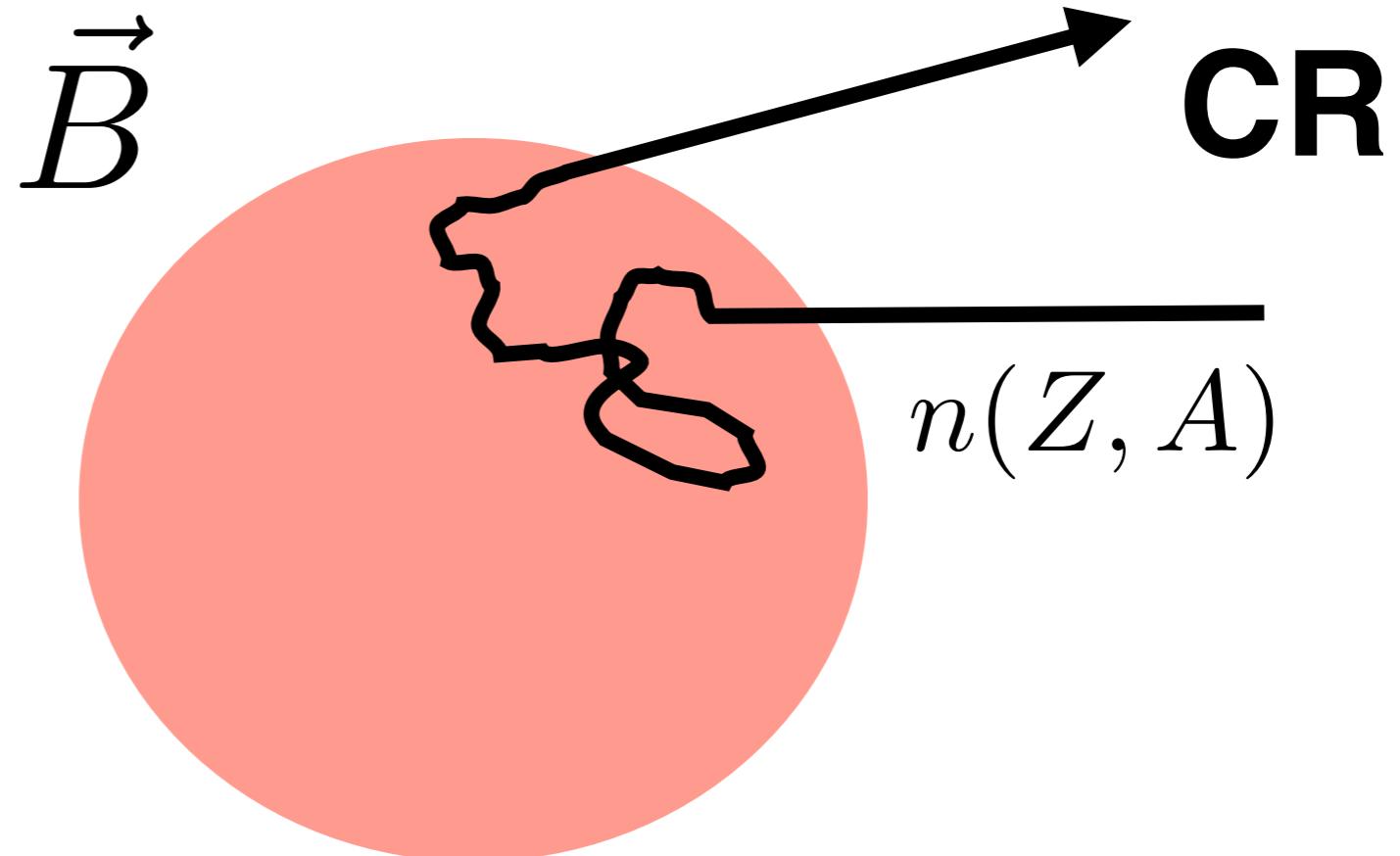
$$v_{\text{exp}} \sim c/\sqrt{3}$$



$$N_{B,e} \sim 10^{50}$$

**GRB
ionizes
ISM**

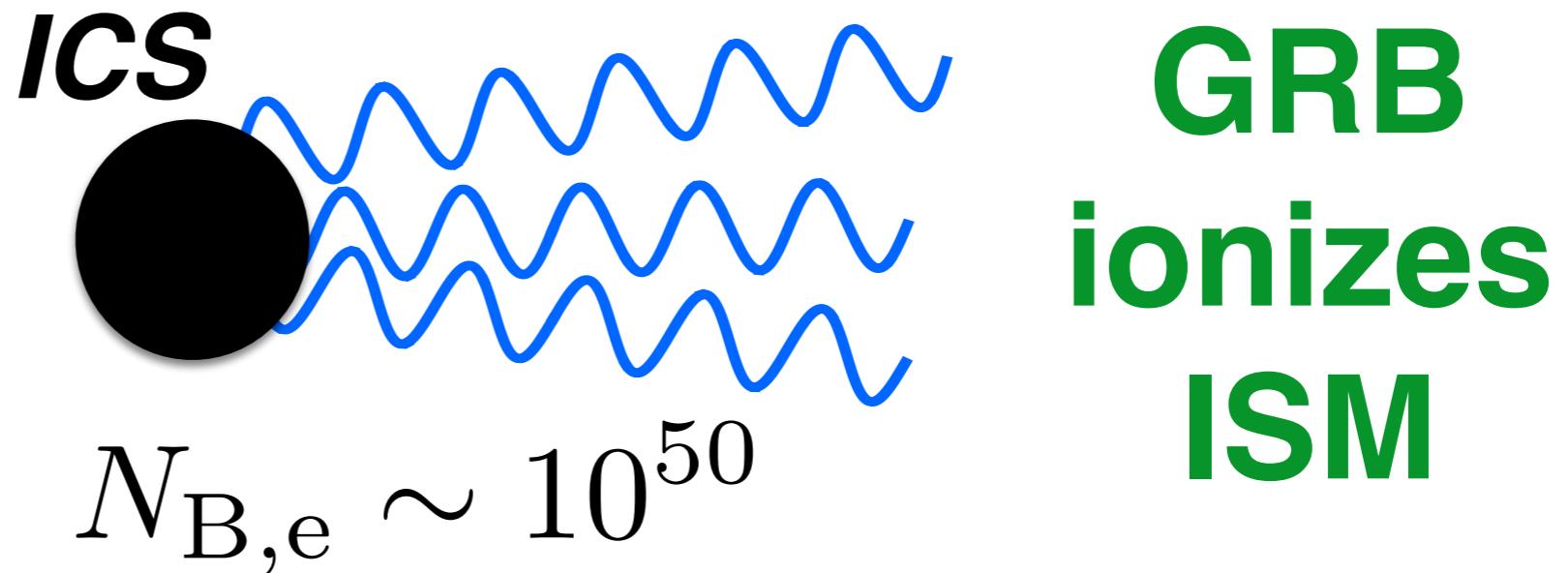
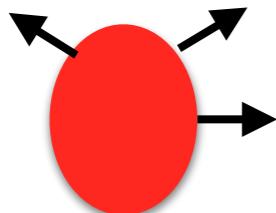
Collisionless



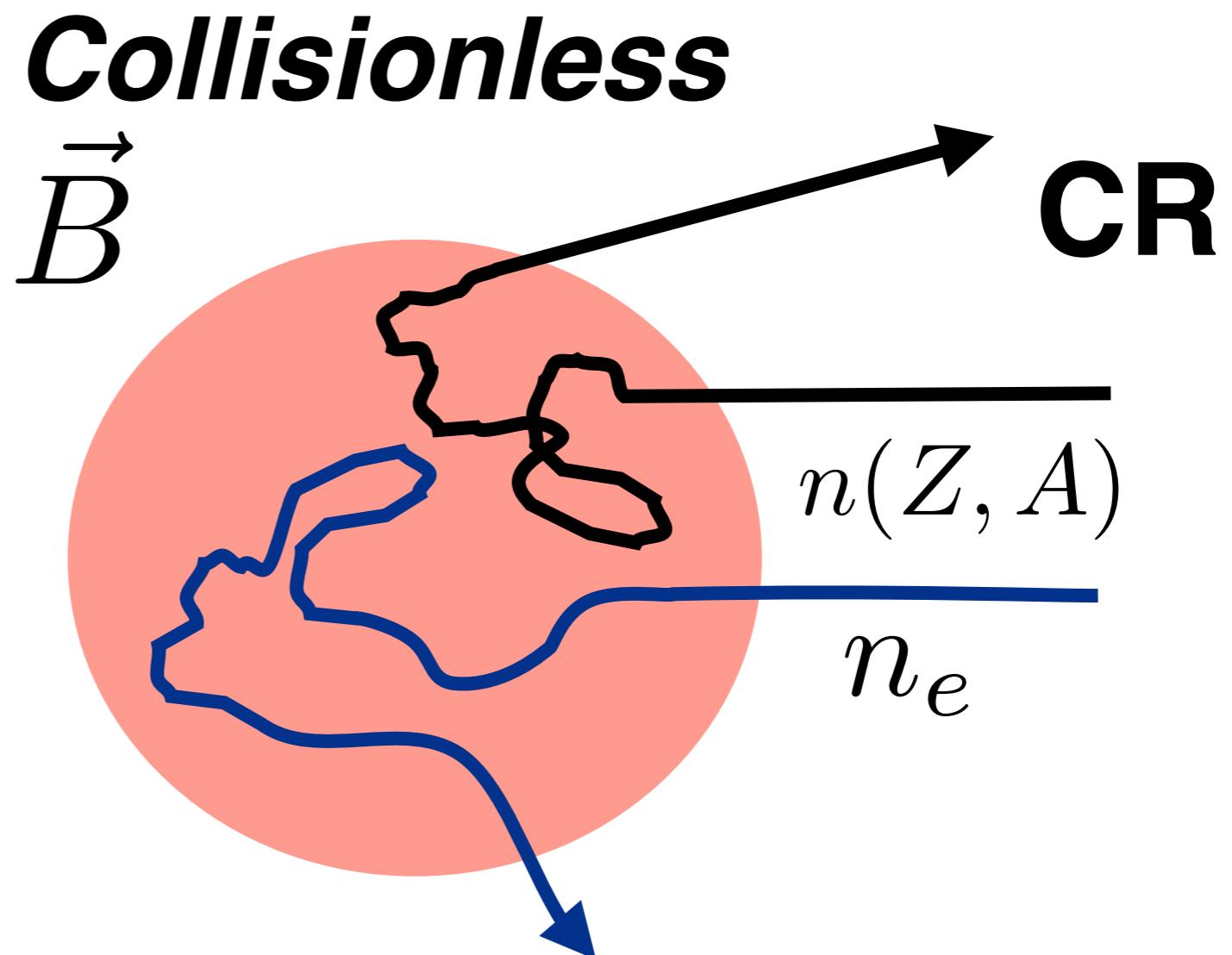
**CB in motion
in a galaxy**

**CB in its
rest system**

$$v_{\text{exp}} \sim c/\sqrt{3}$$



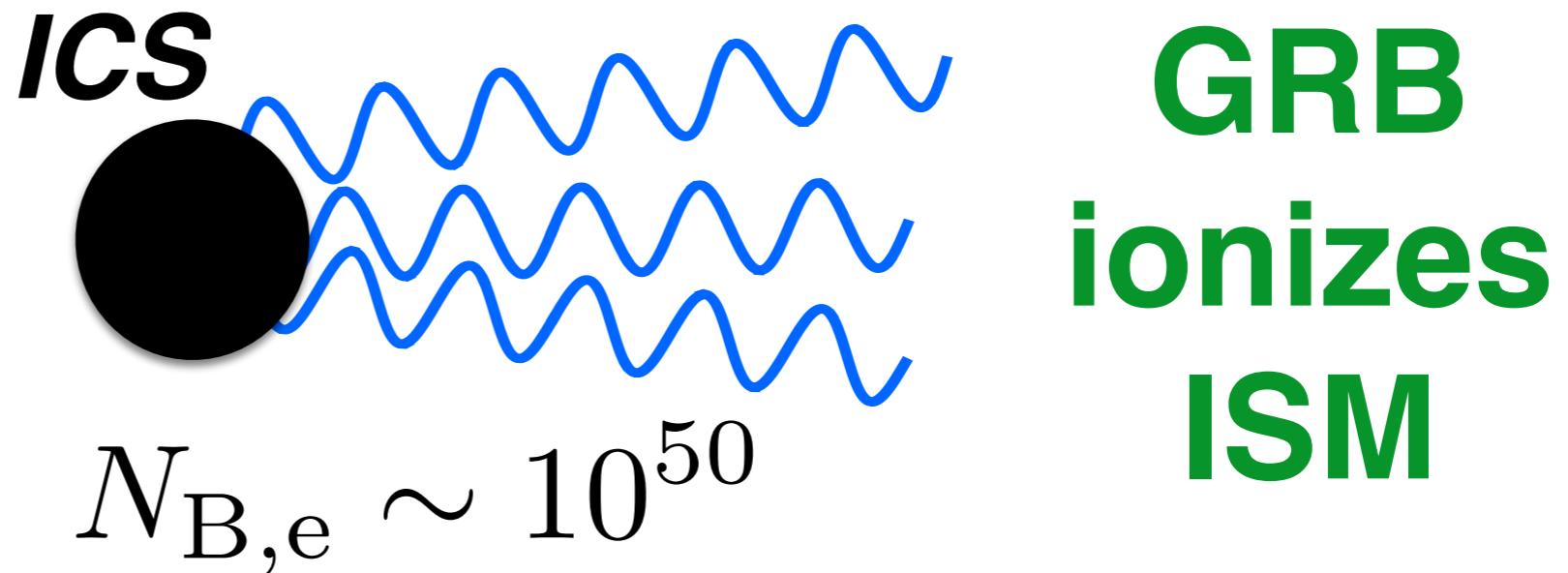
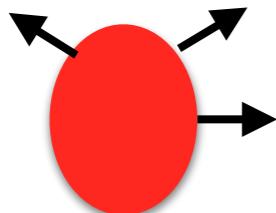
**GRB
ionizes
ISM**



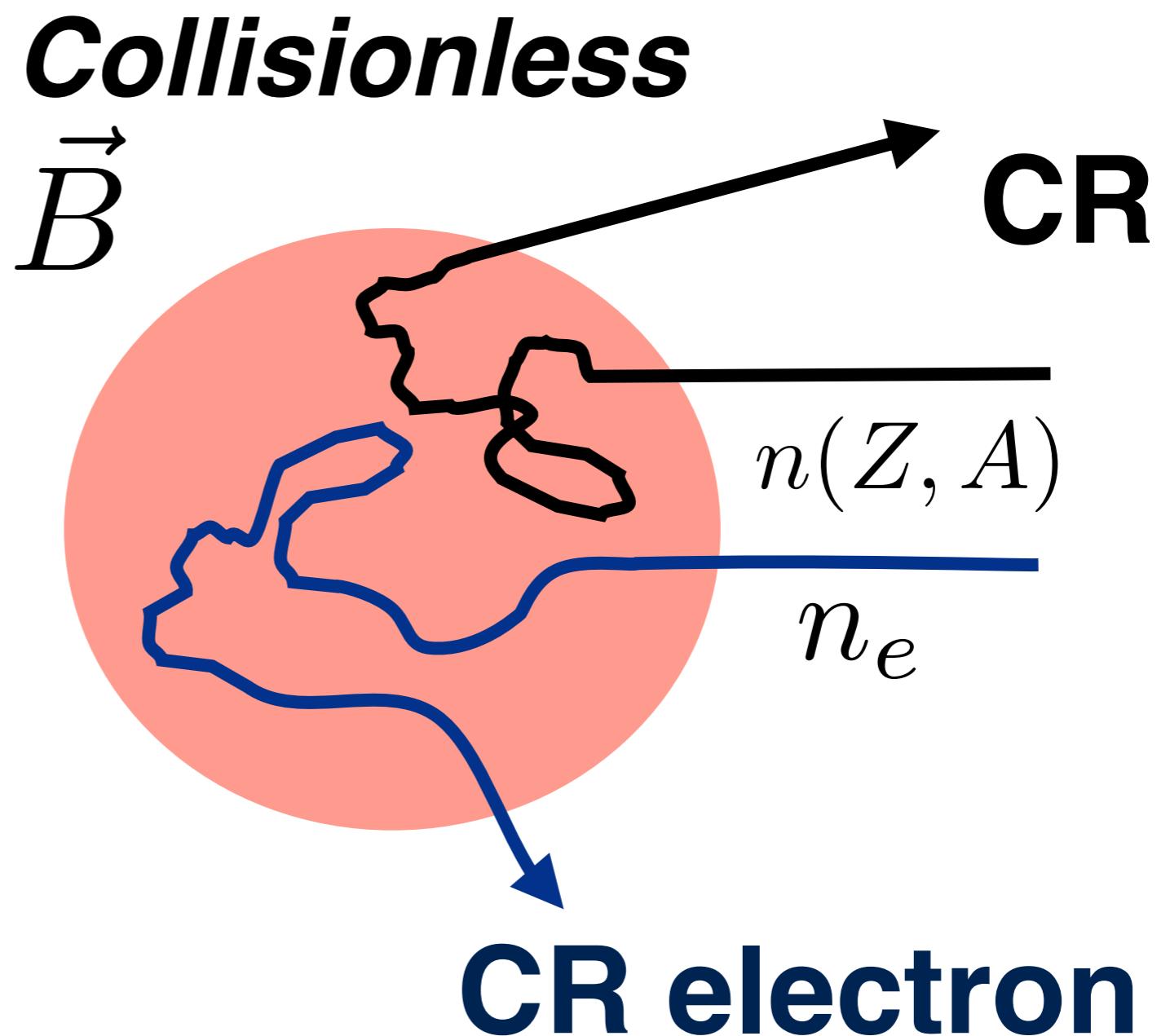
**CB in motion
in a galaxy**

**CB in its
rest system**

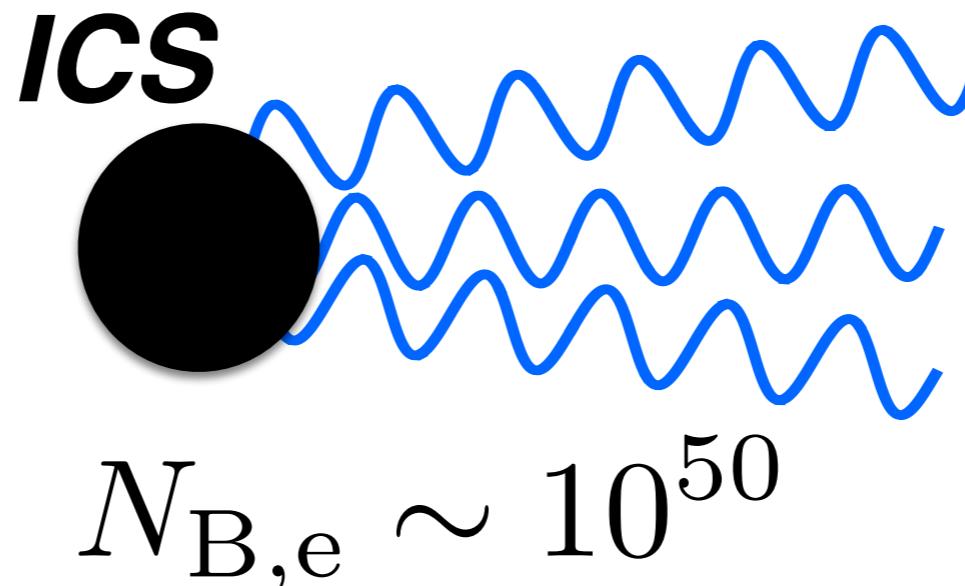
$$v_{\text{exp}} \sim c/\sqrt{3}$$



**GRB
ionizes
ISM**



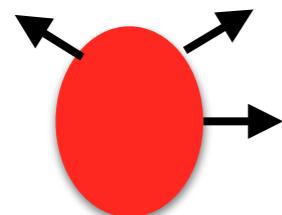
**CB in motion
in a galaxy**



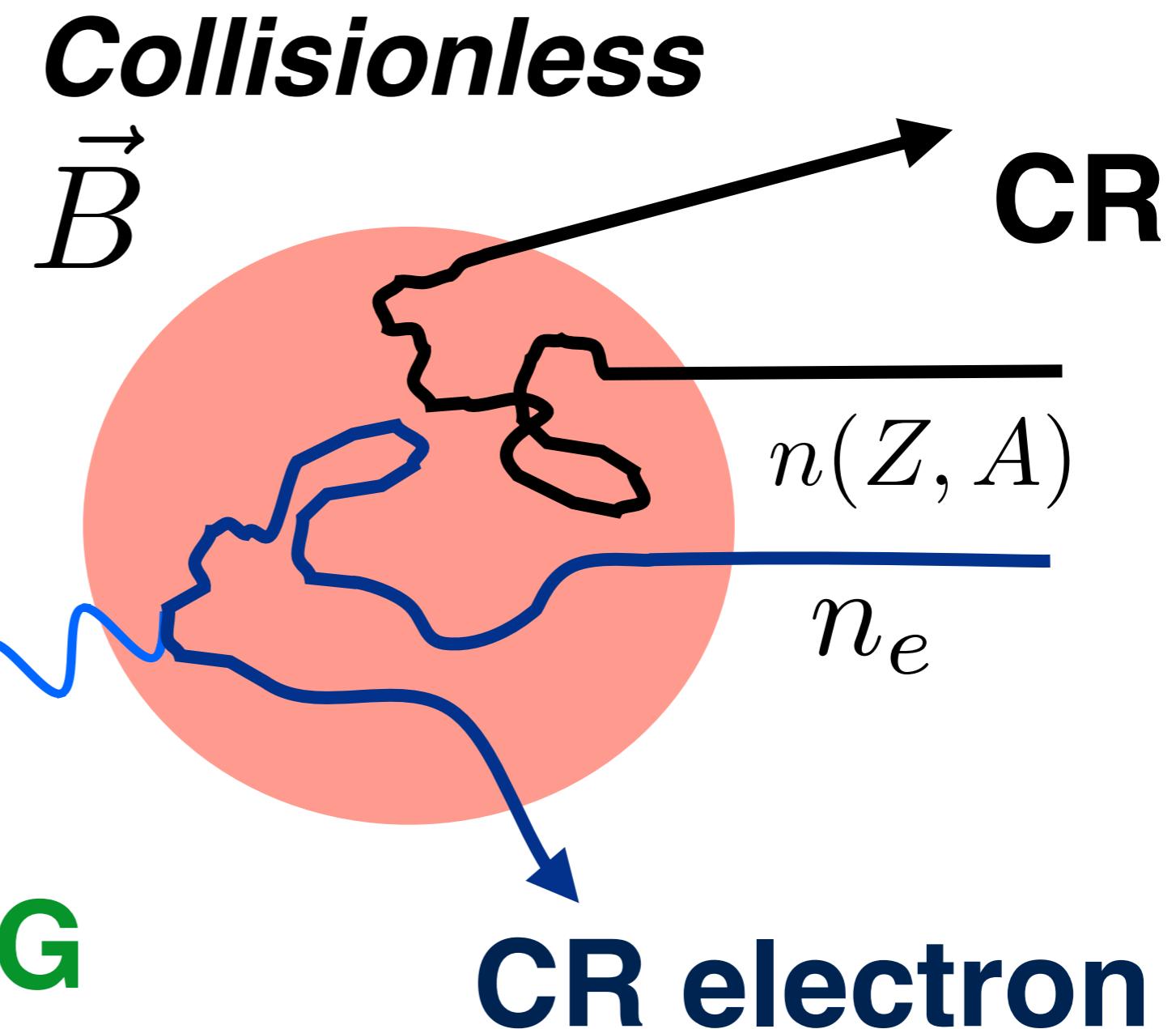
**GRB
ionizes
ISM**

**CB in its
rest system**

$$v_{\text{exp}} \sim c/\sqrt{3}$$



**GRB's
synchrotron AG**



X-ray AG Flux

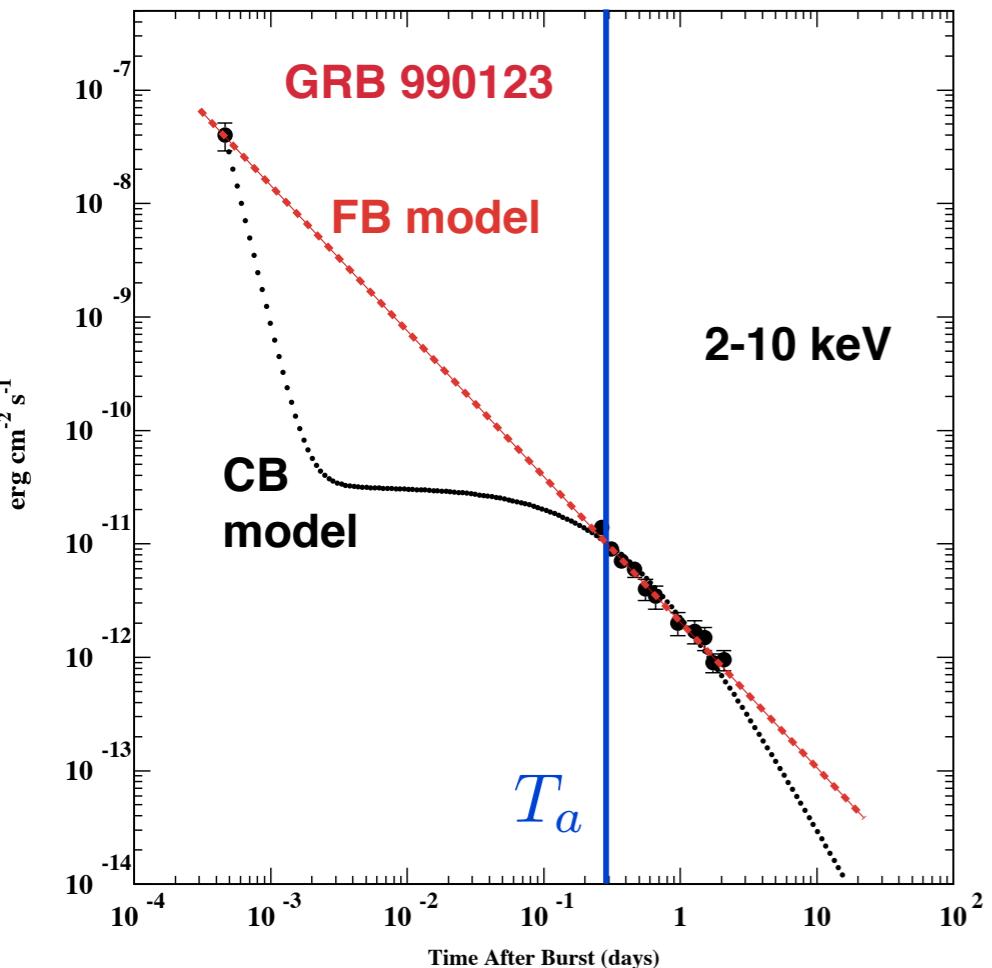
$$F_\nu(t) = \nu dN_\nu/d\nu$$

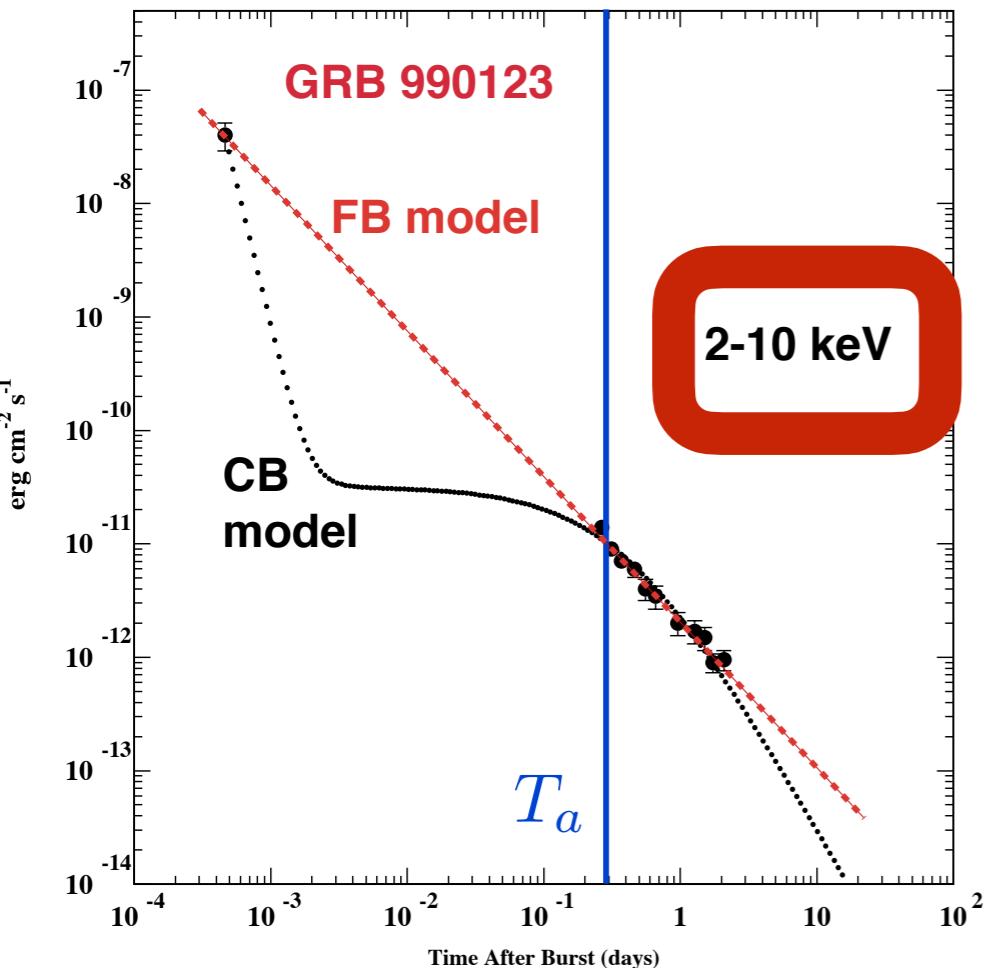
$$\propto n(r[t])^{(\beta_x+1)/2} [\gamma(t)]^{3\beta_x-1} [\delta(t)]^{\beta_x+3} \nu^{-\beta_x}$$

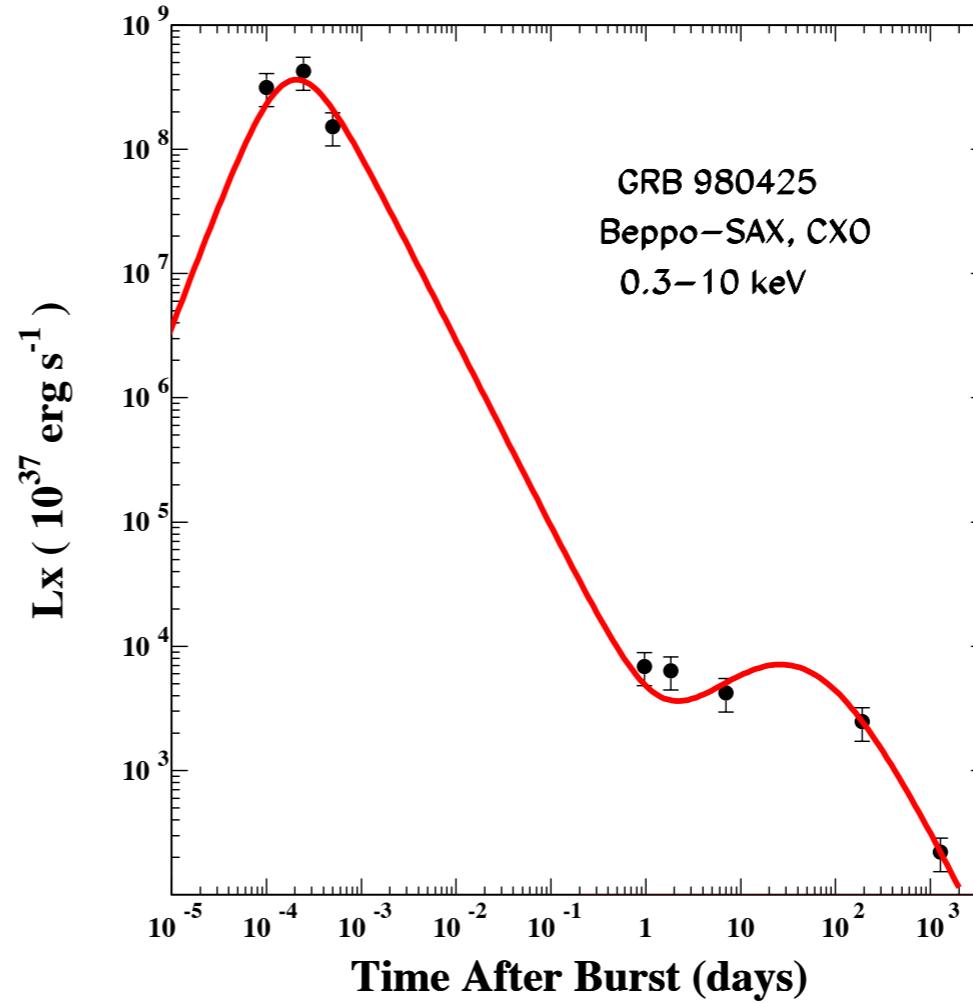
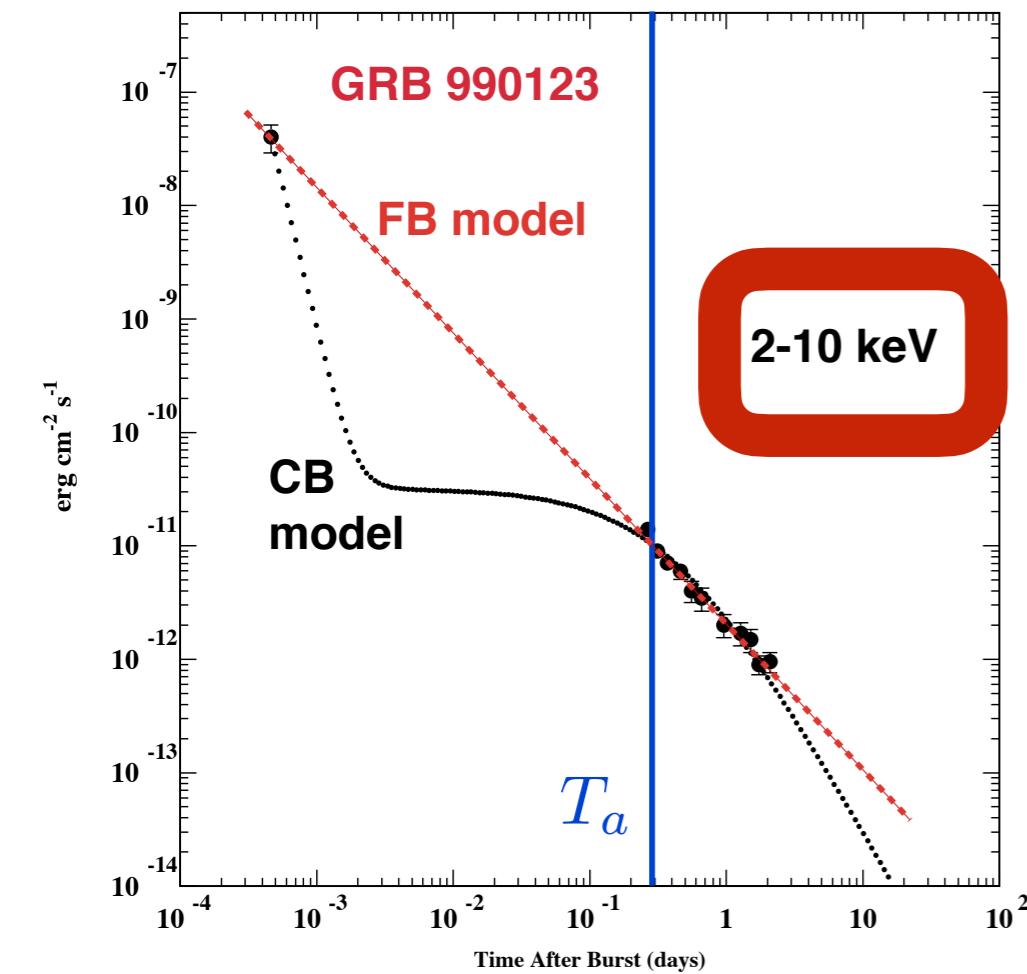
For constant ISM density $n(r)$

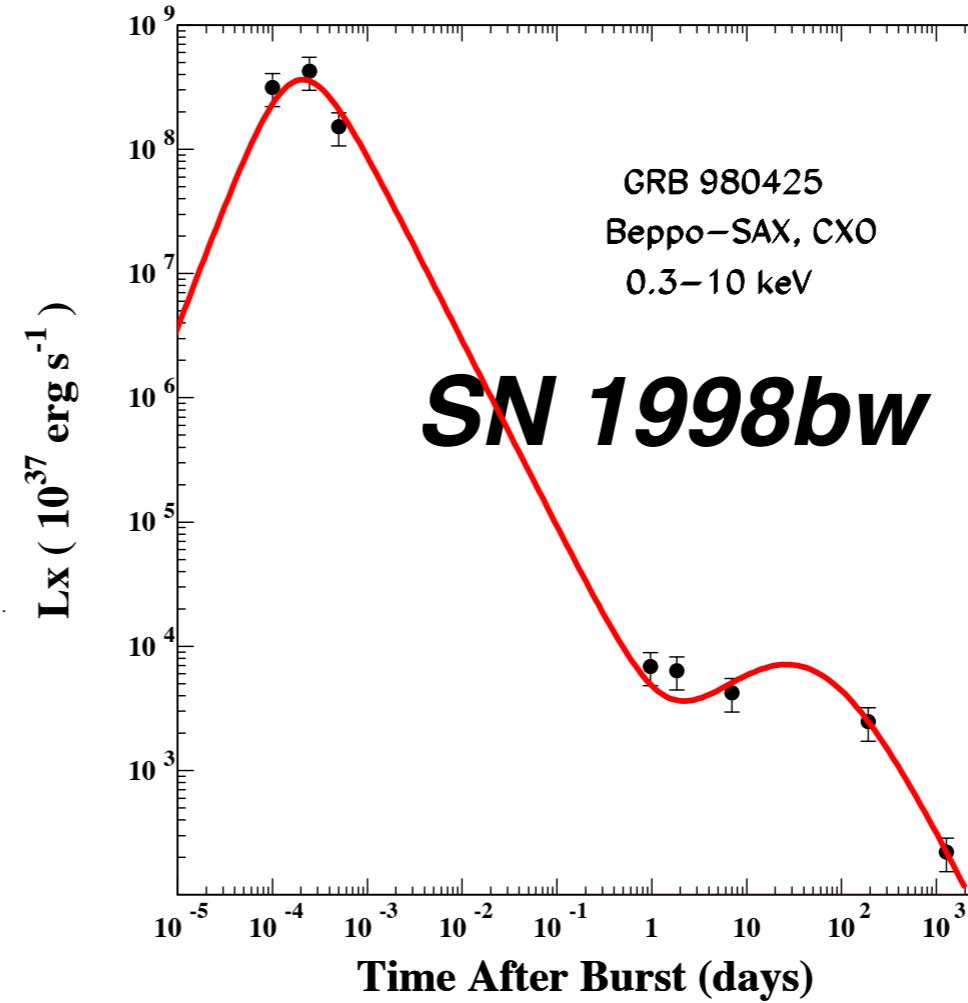
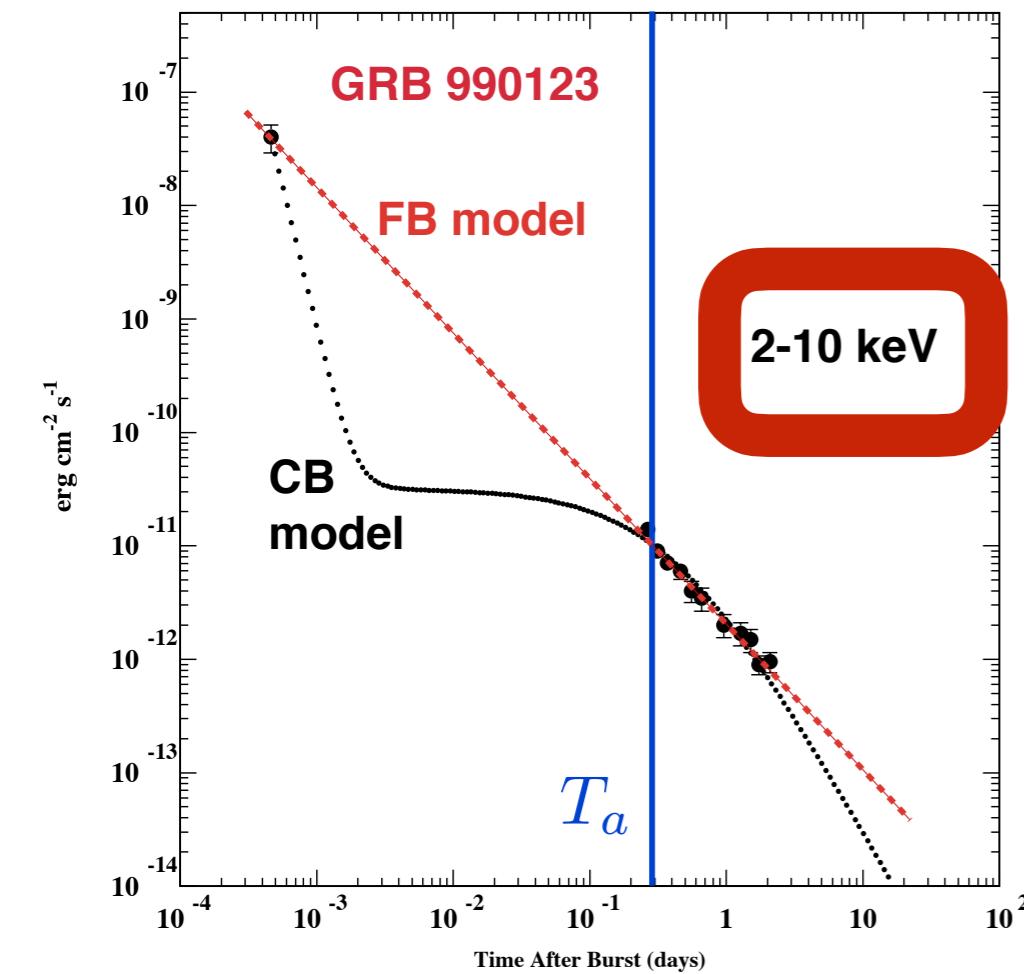
$$\gamma(t) = \frac{\gamma_0}{\left[\sqrt{(1 + \theta^2 \gamma_0^2)^2 + t/t_d} - \theta^2 \gamma_0^2 \right]^{1/2}}$$

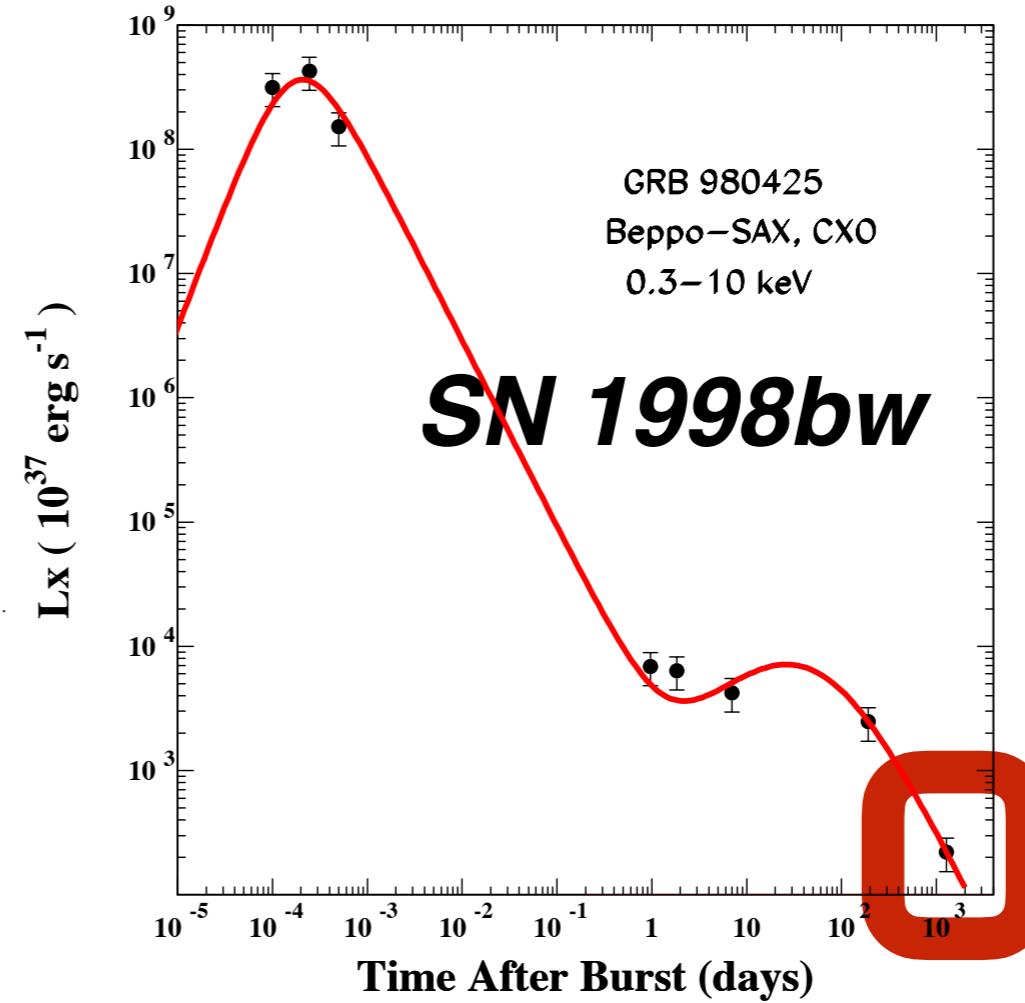
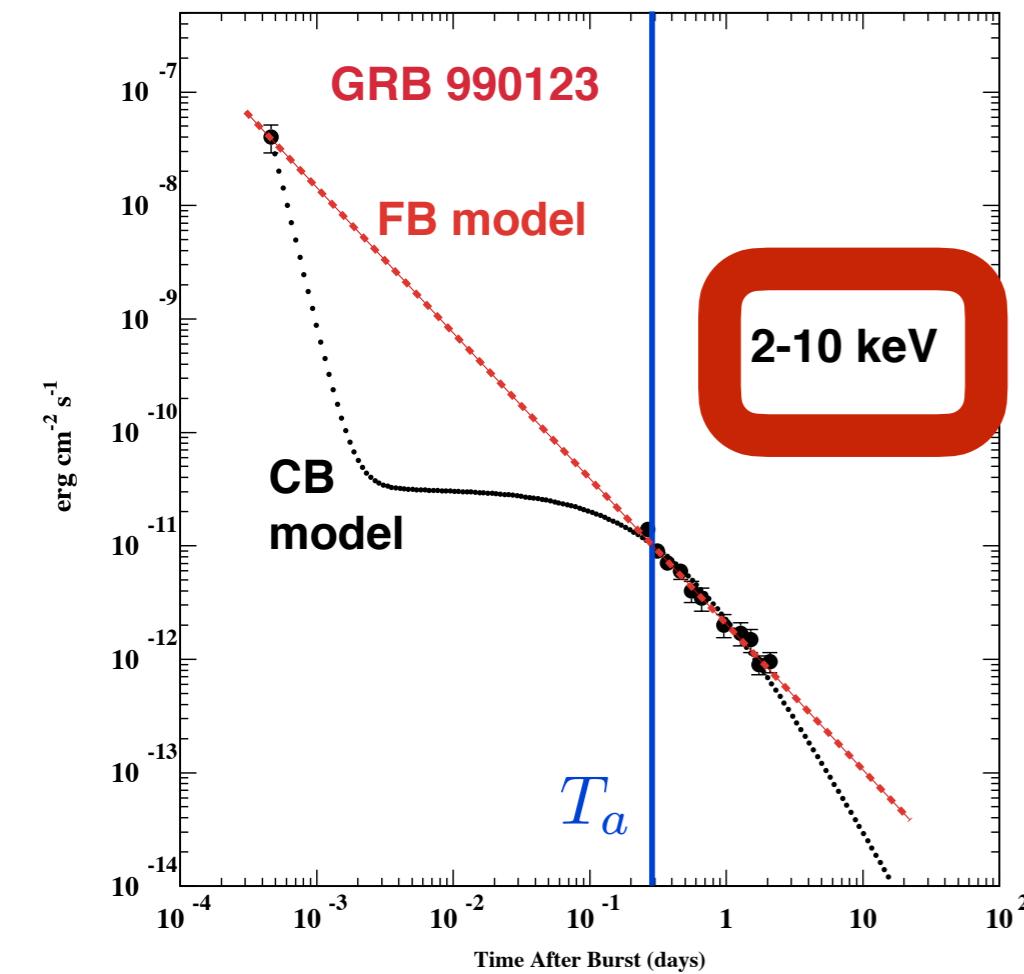
$$t_d = (1+z) N_B / (8 c n \pi R^2 \gamma_0^3)$$

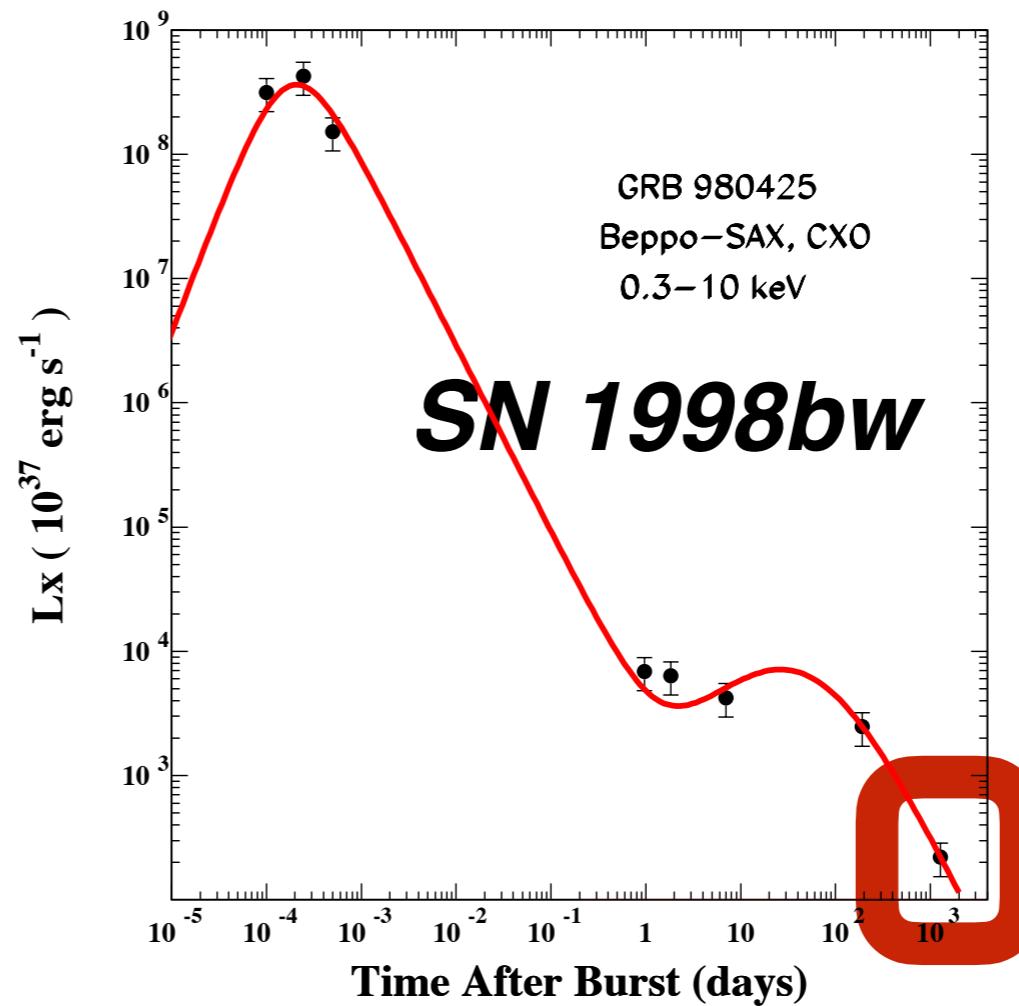
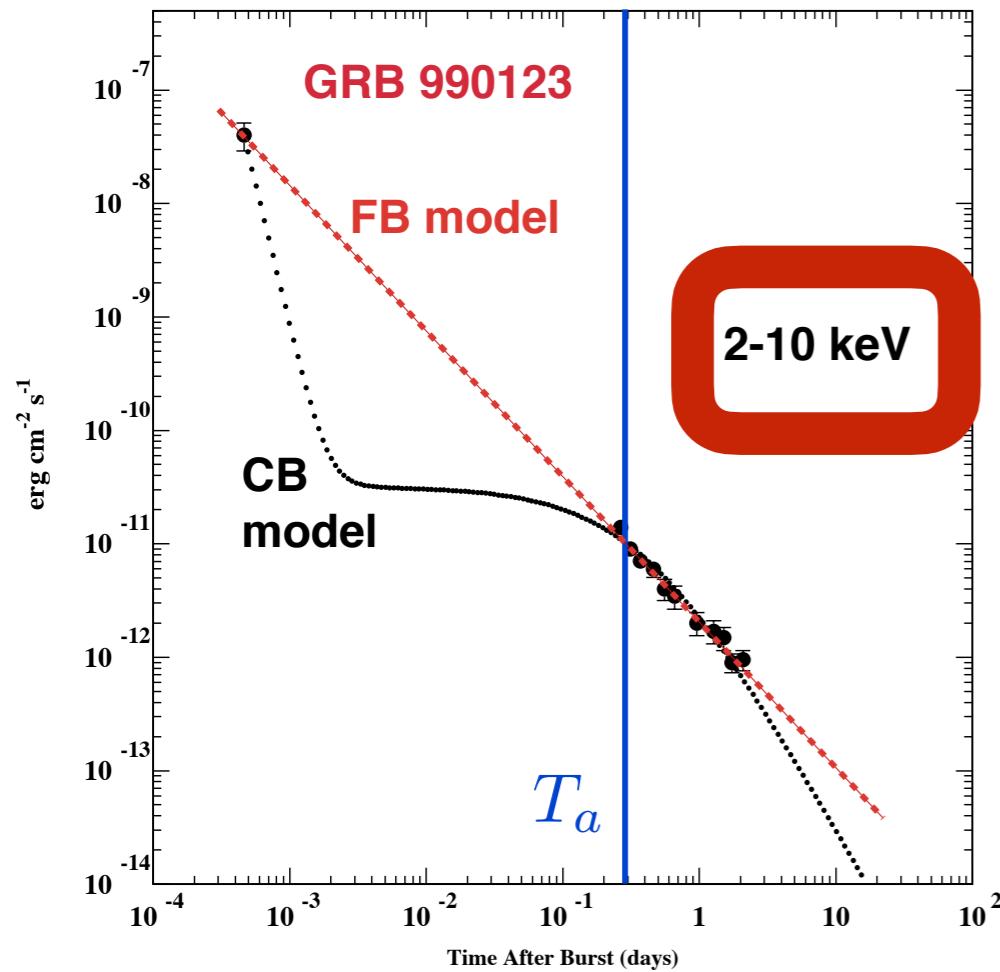




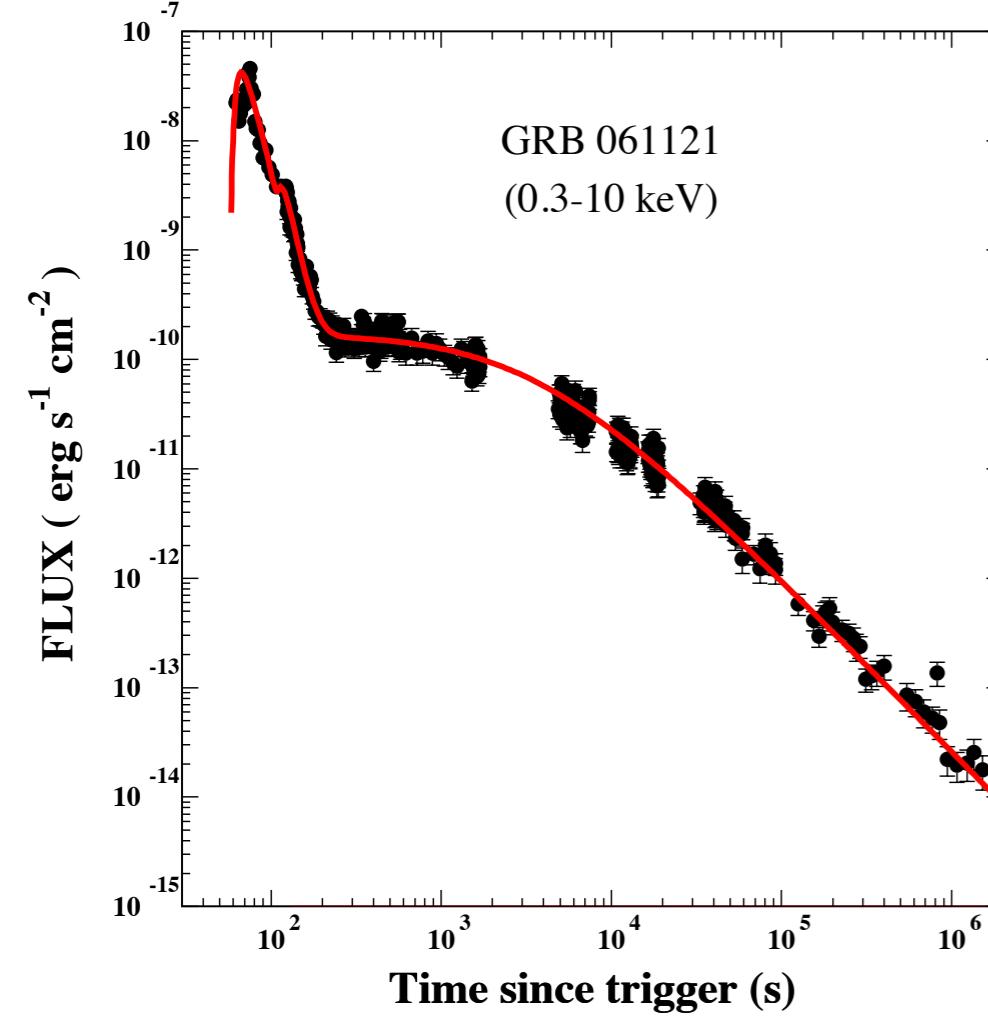
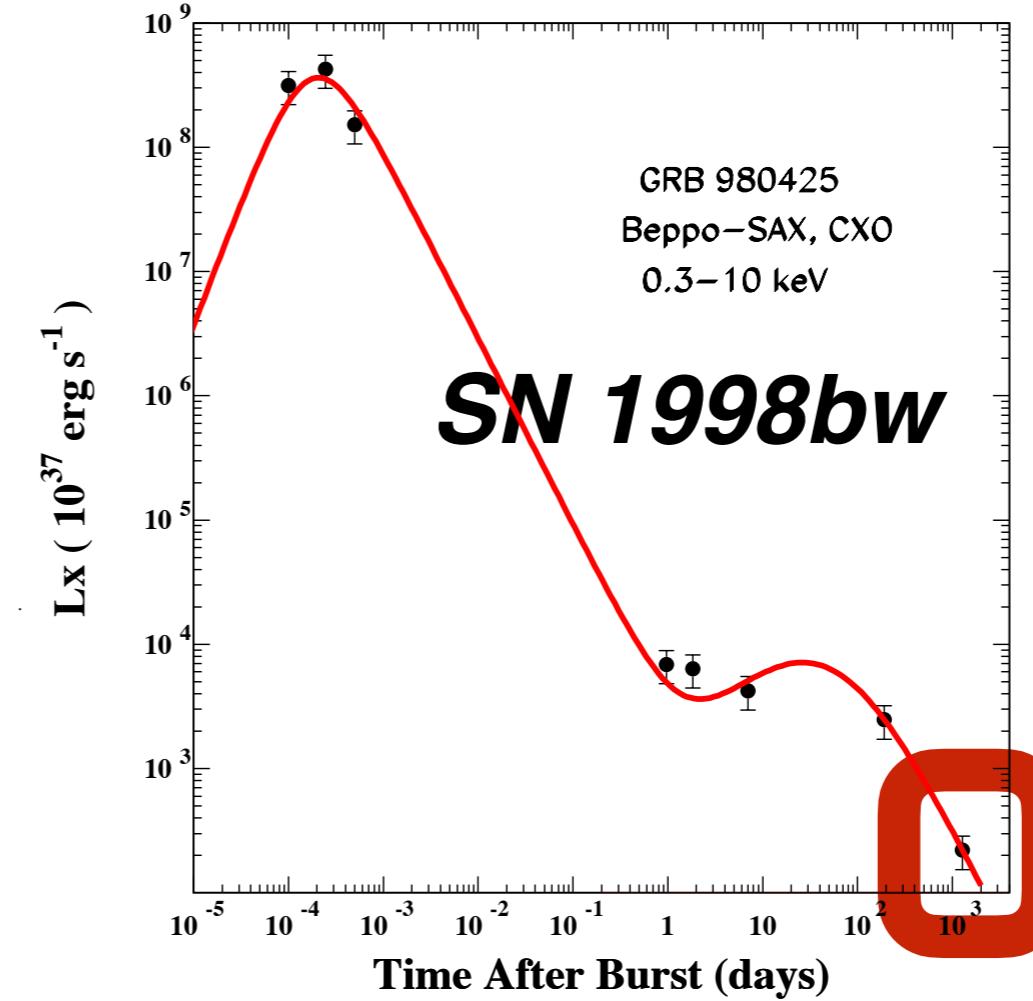
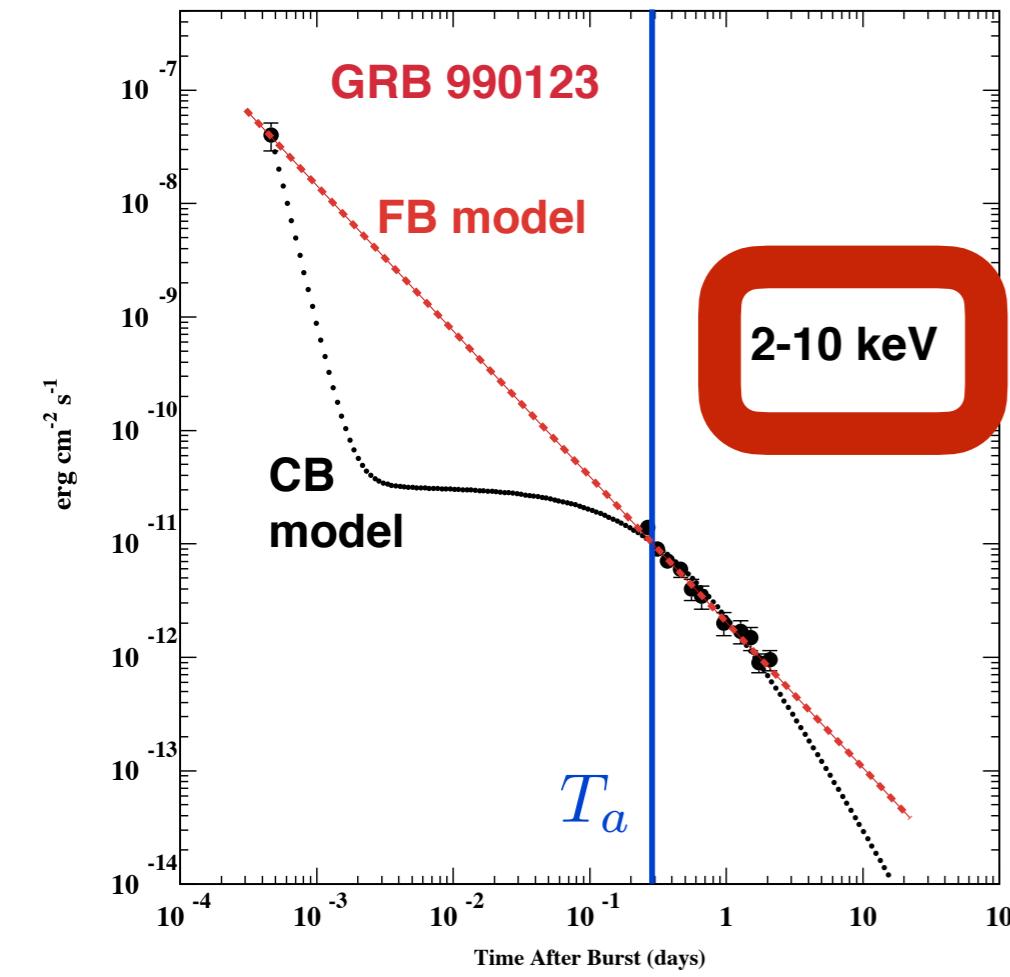






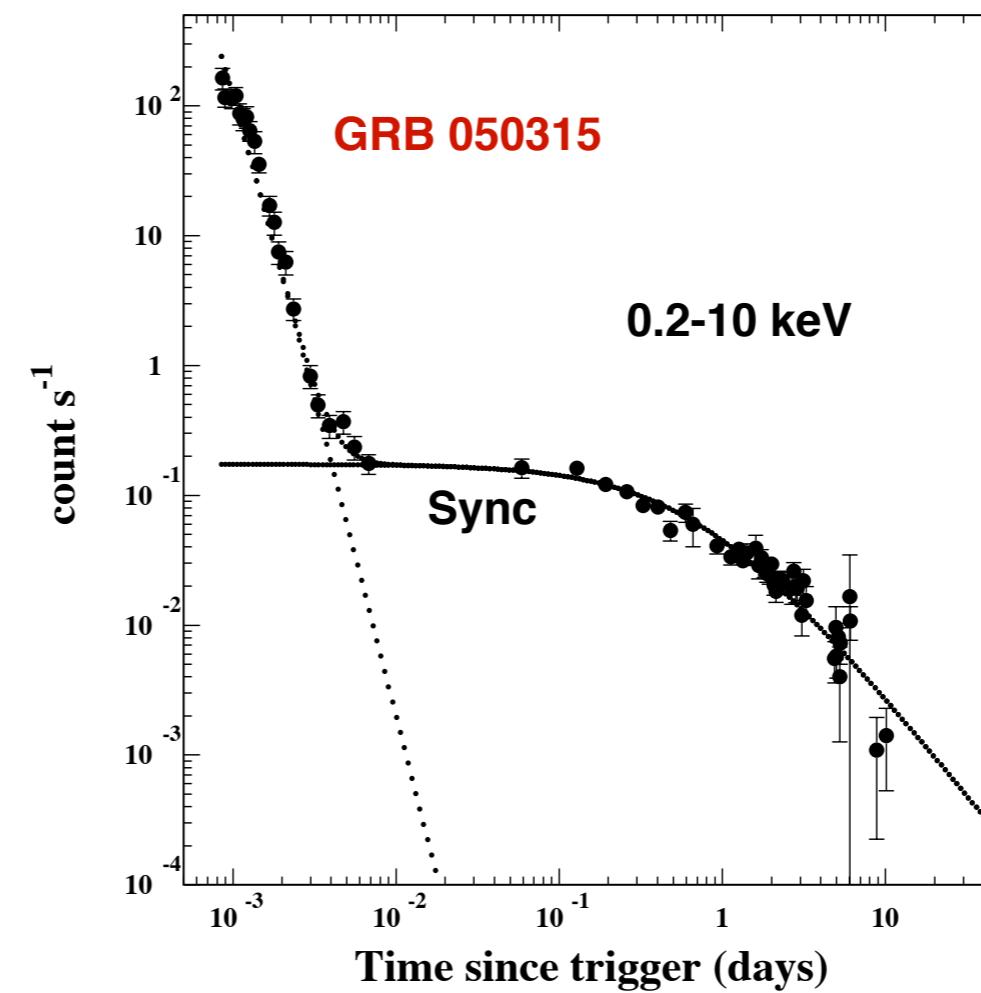
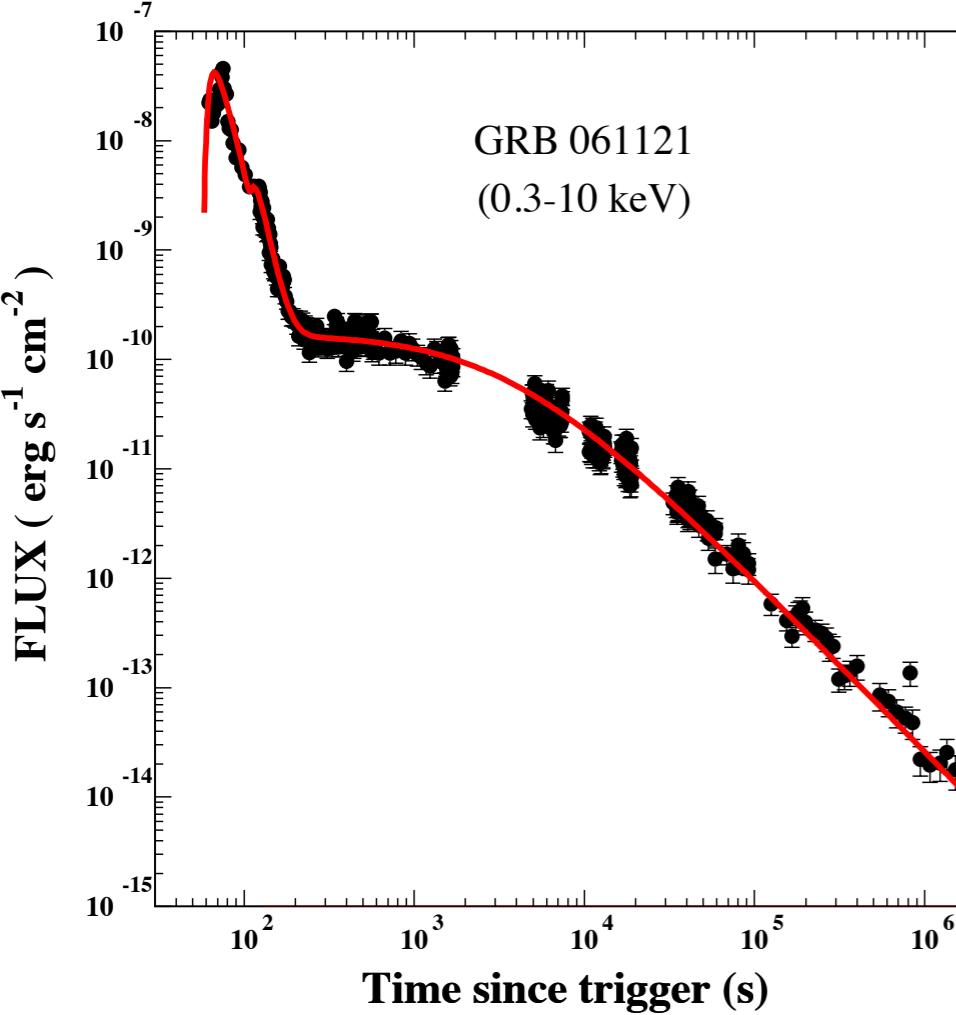
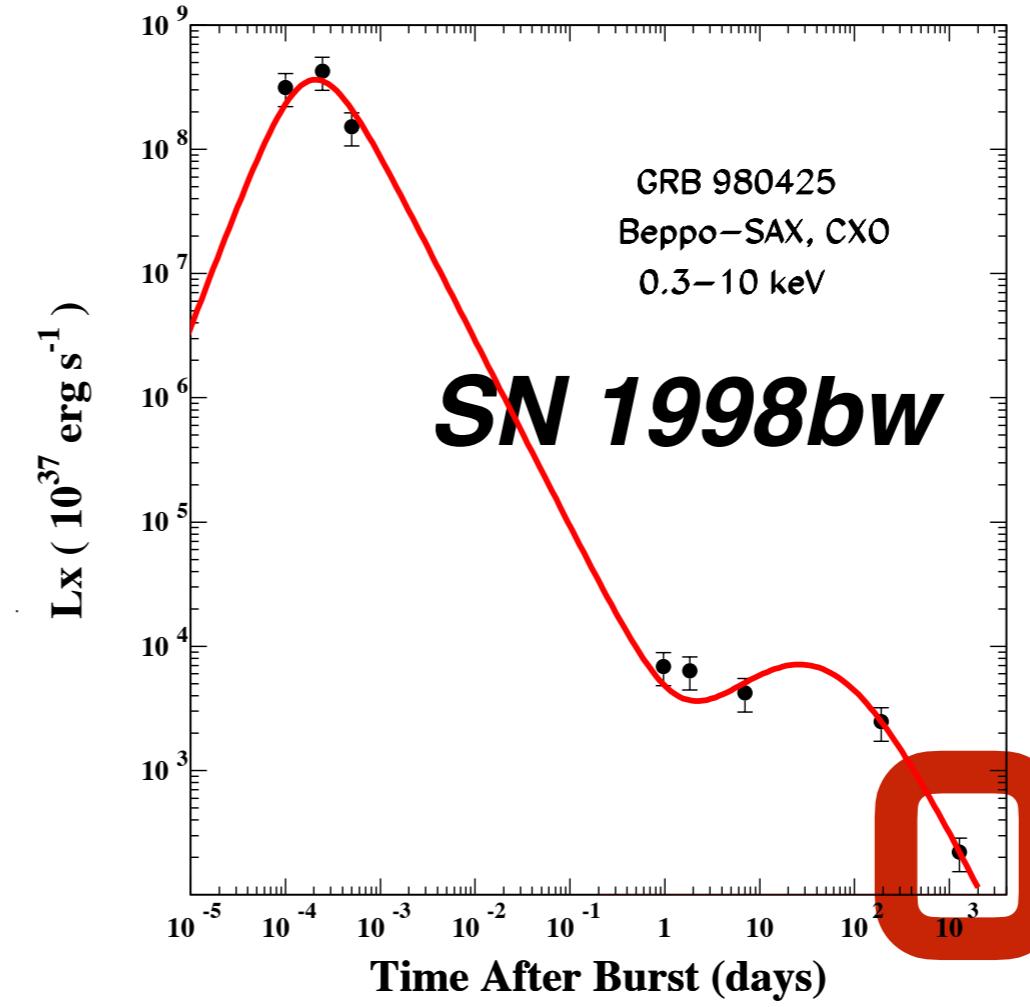
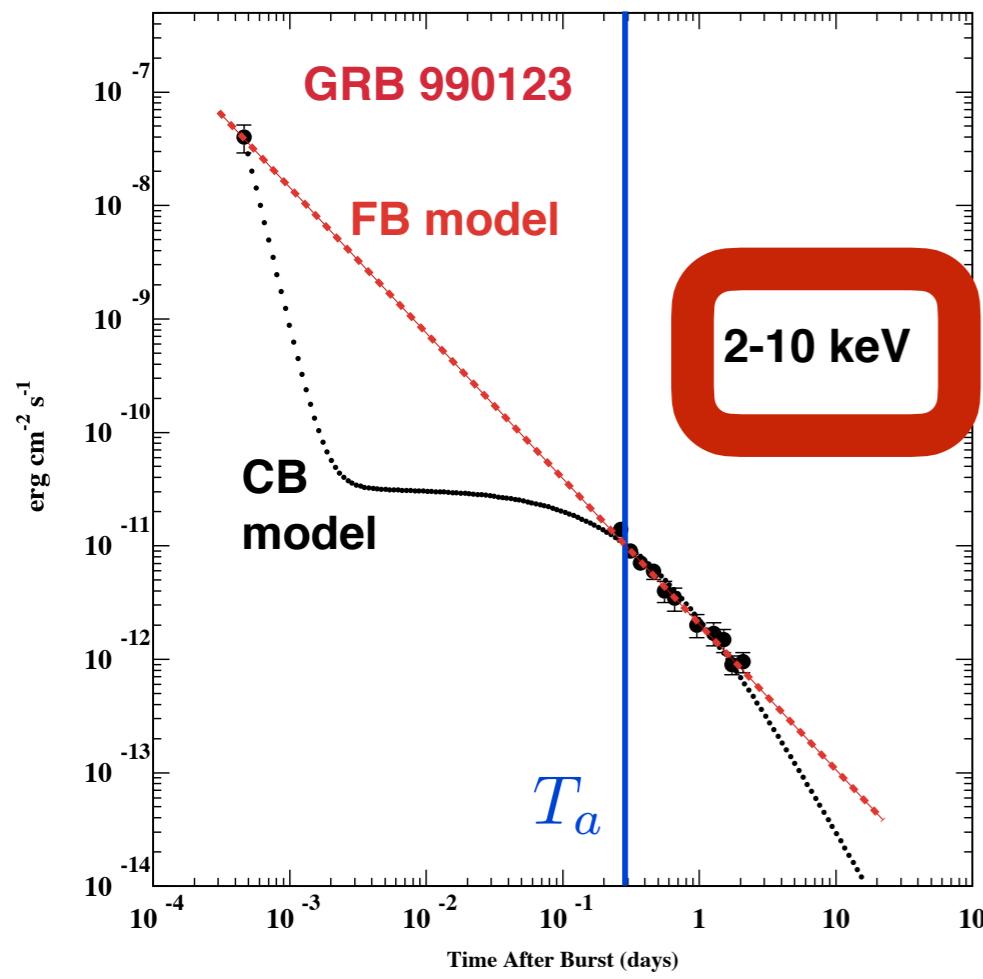


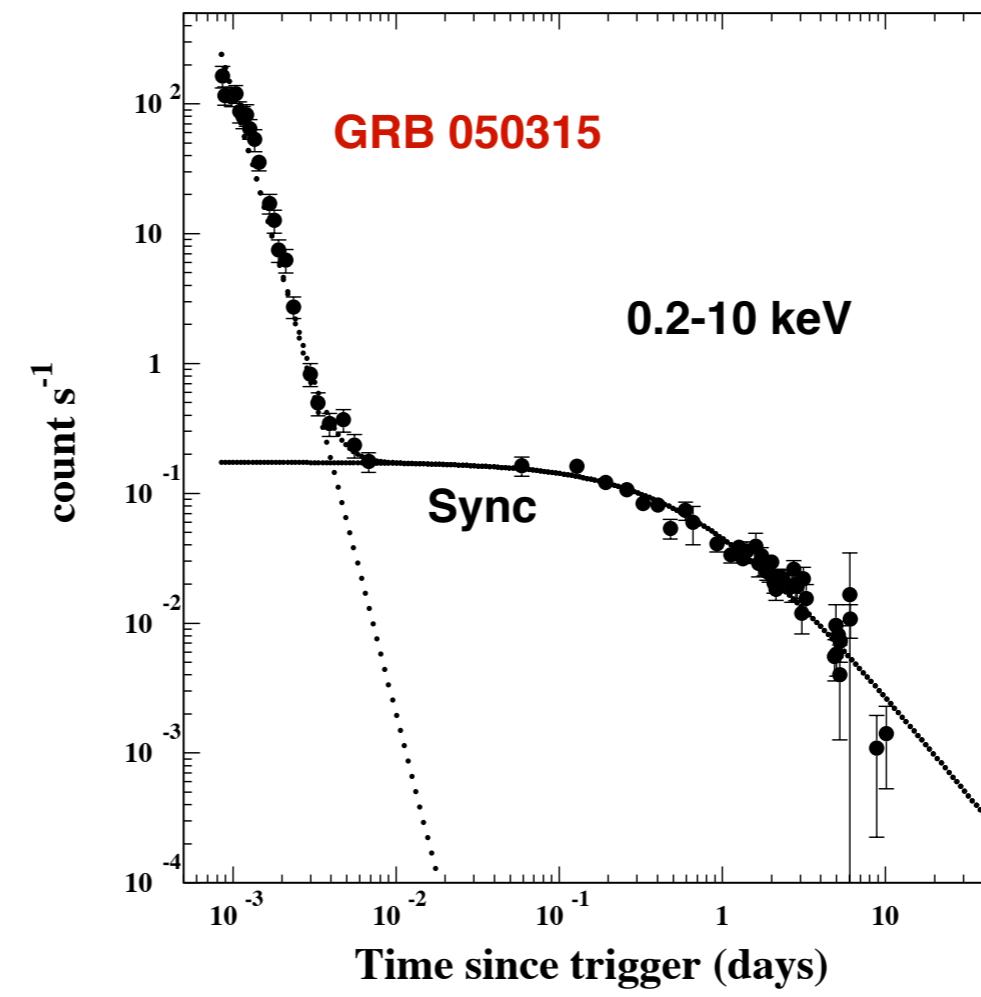
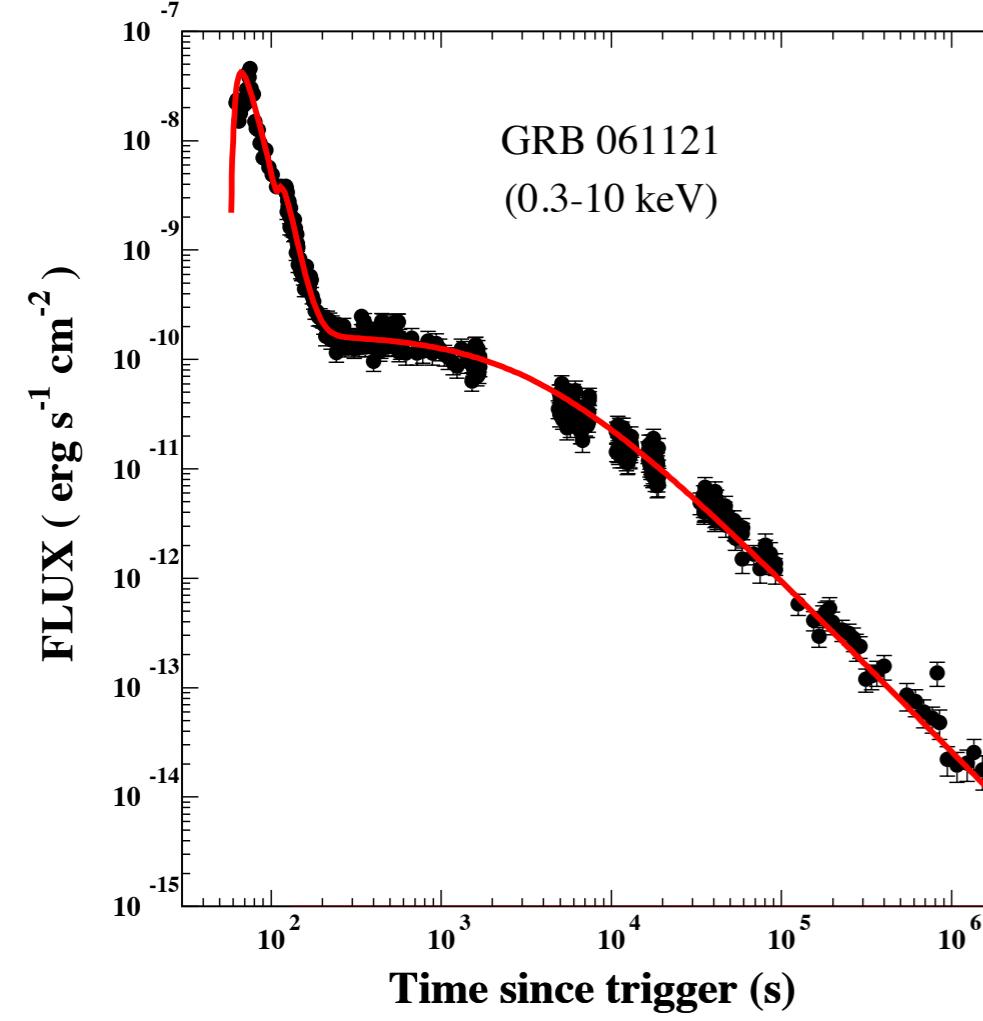
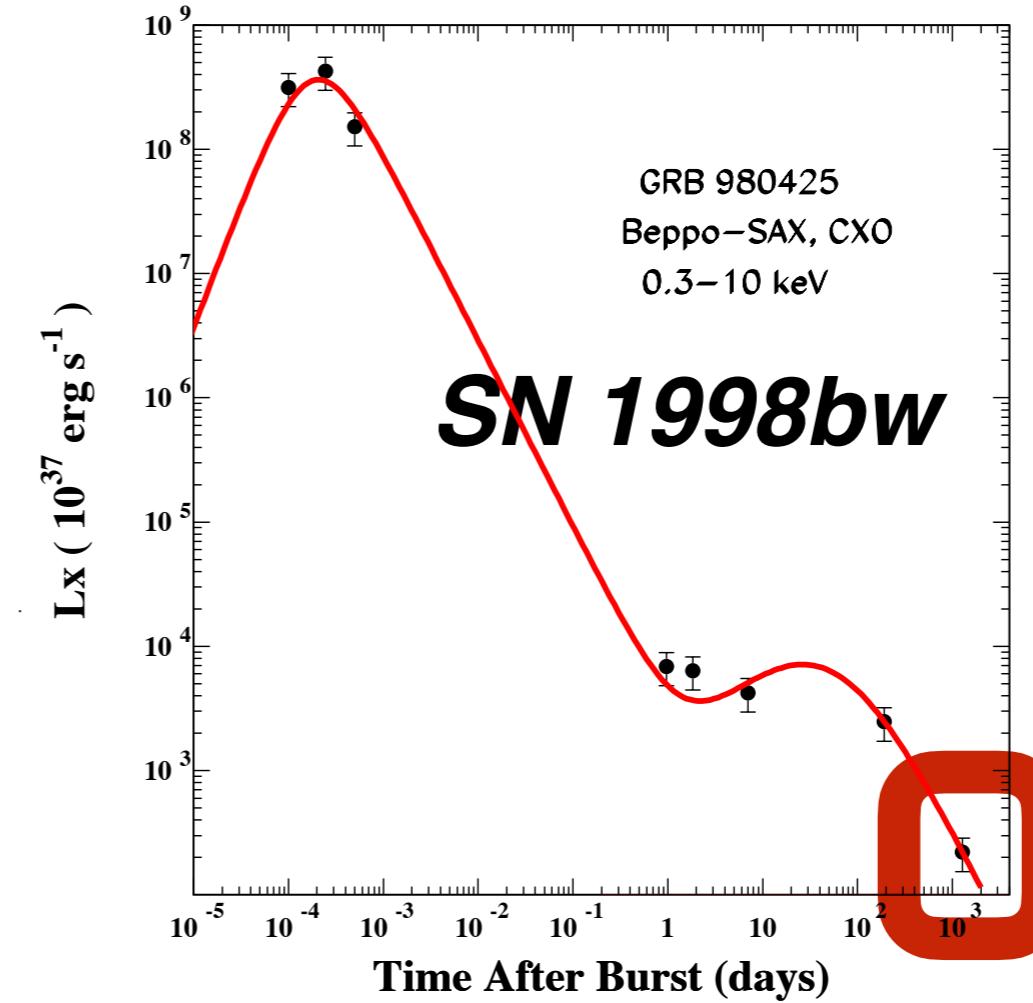
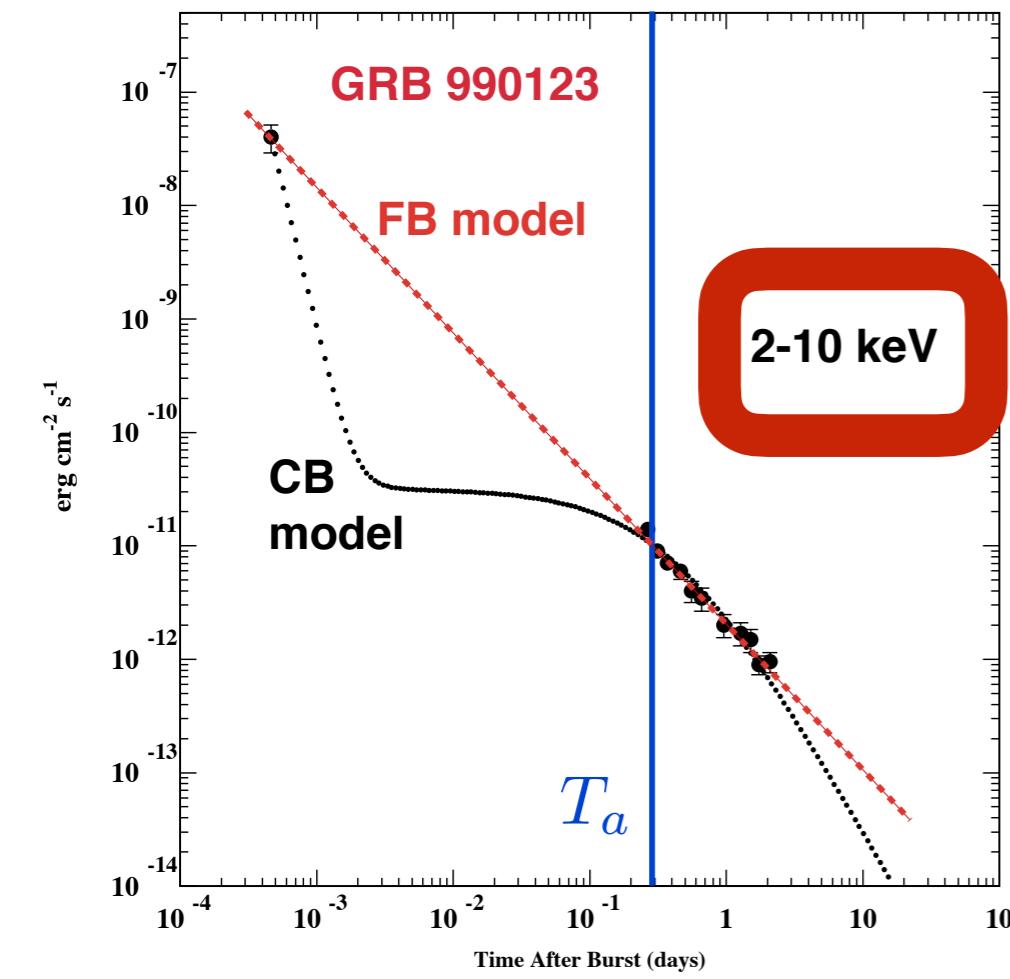
***Then
Swift
“disco-
vered”
Can-
onical
X-ray
AGs***



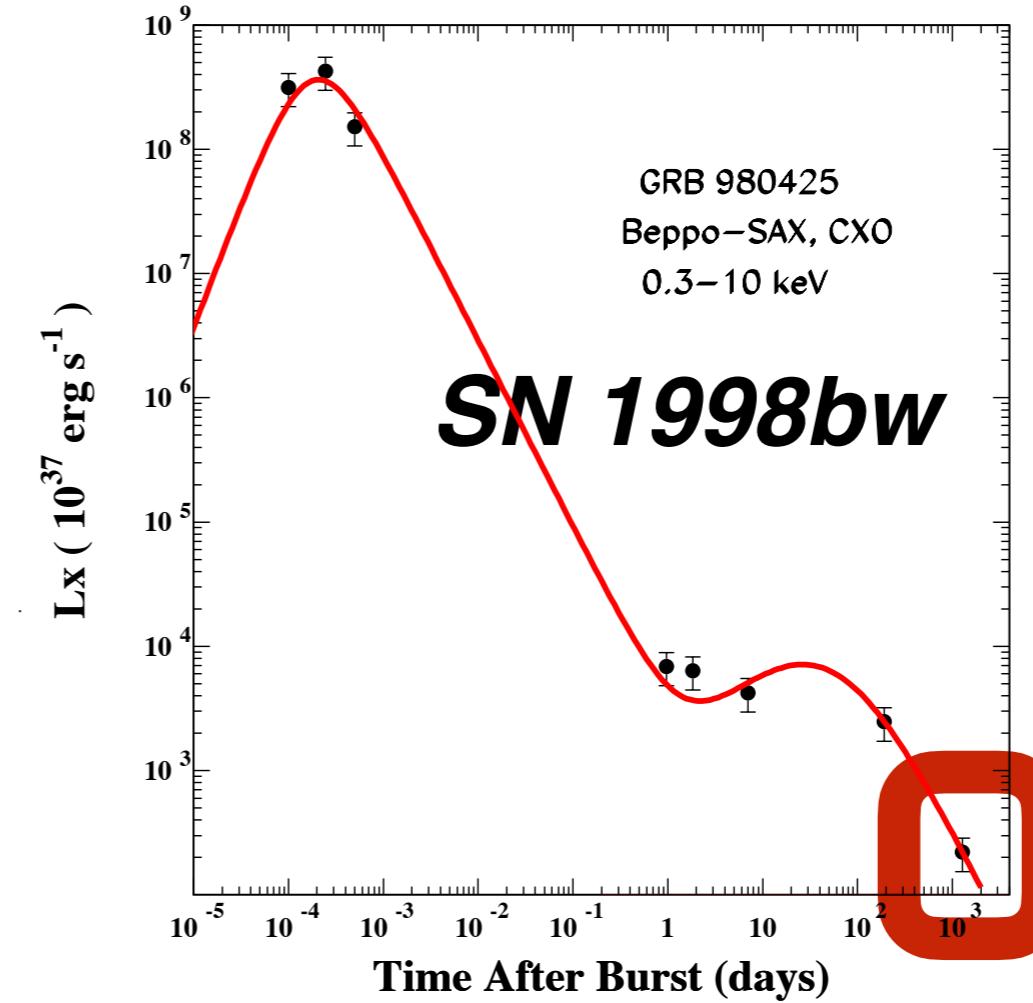
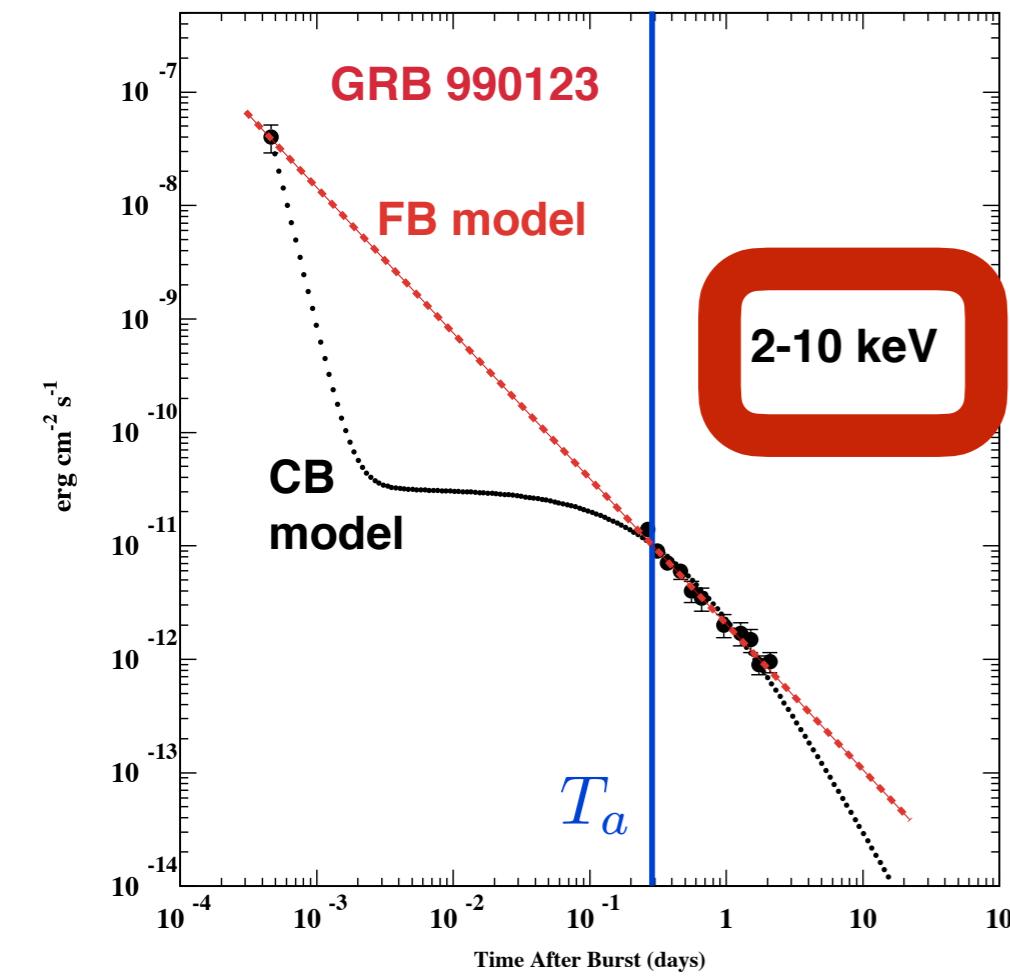
***Then
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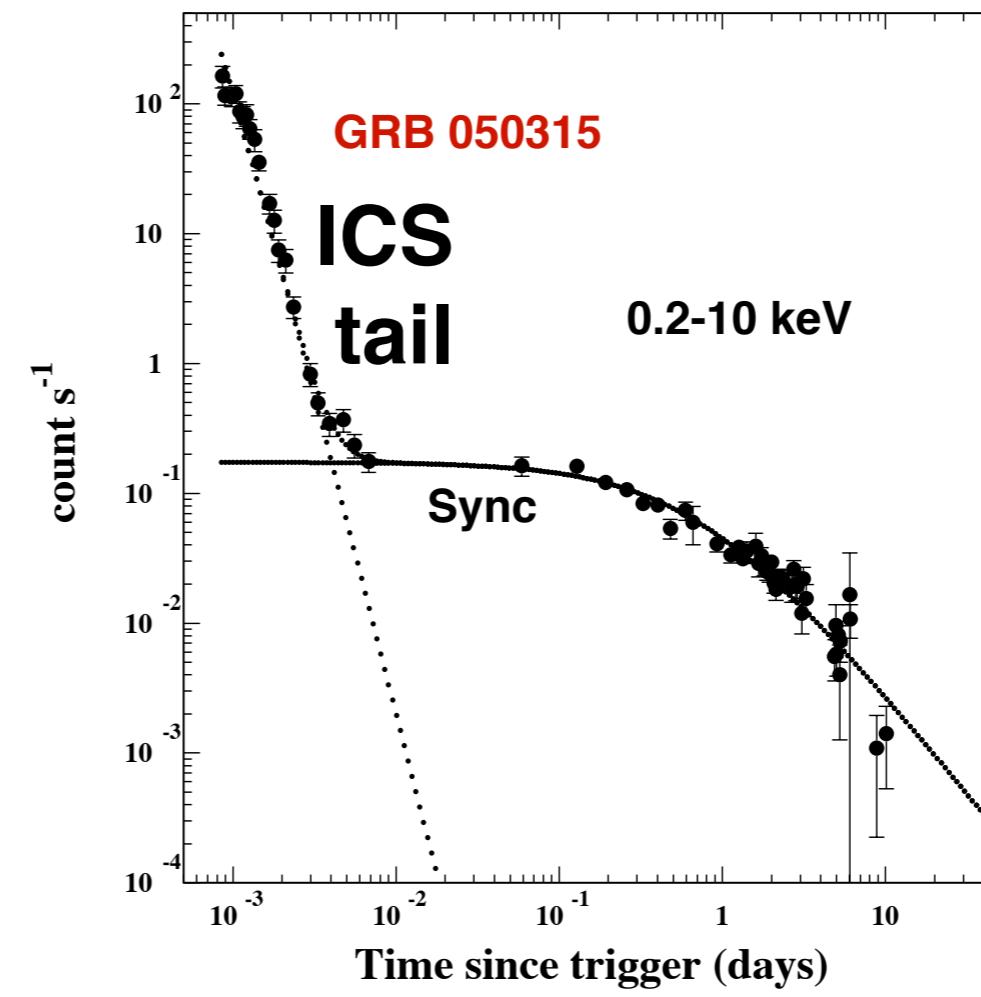
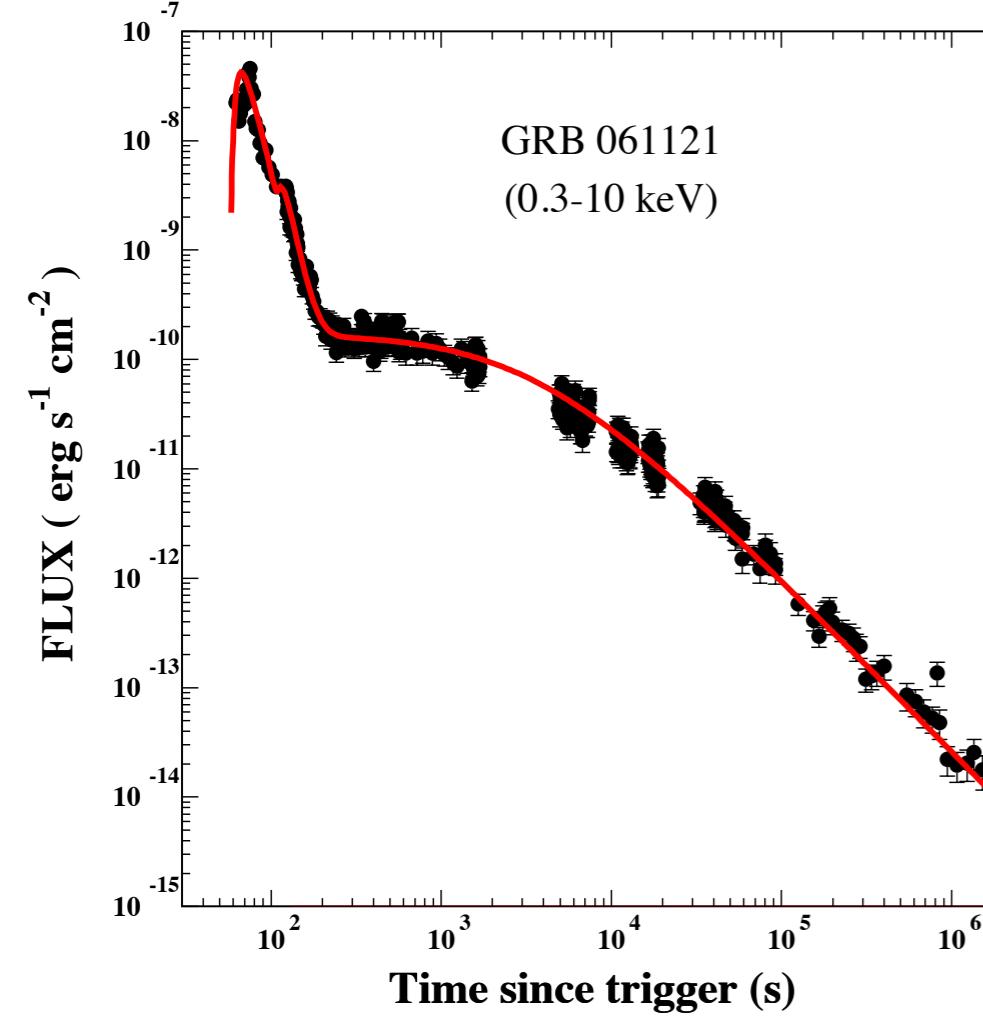


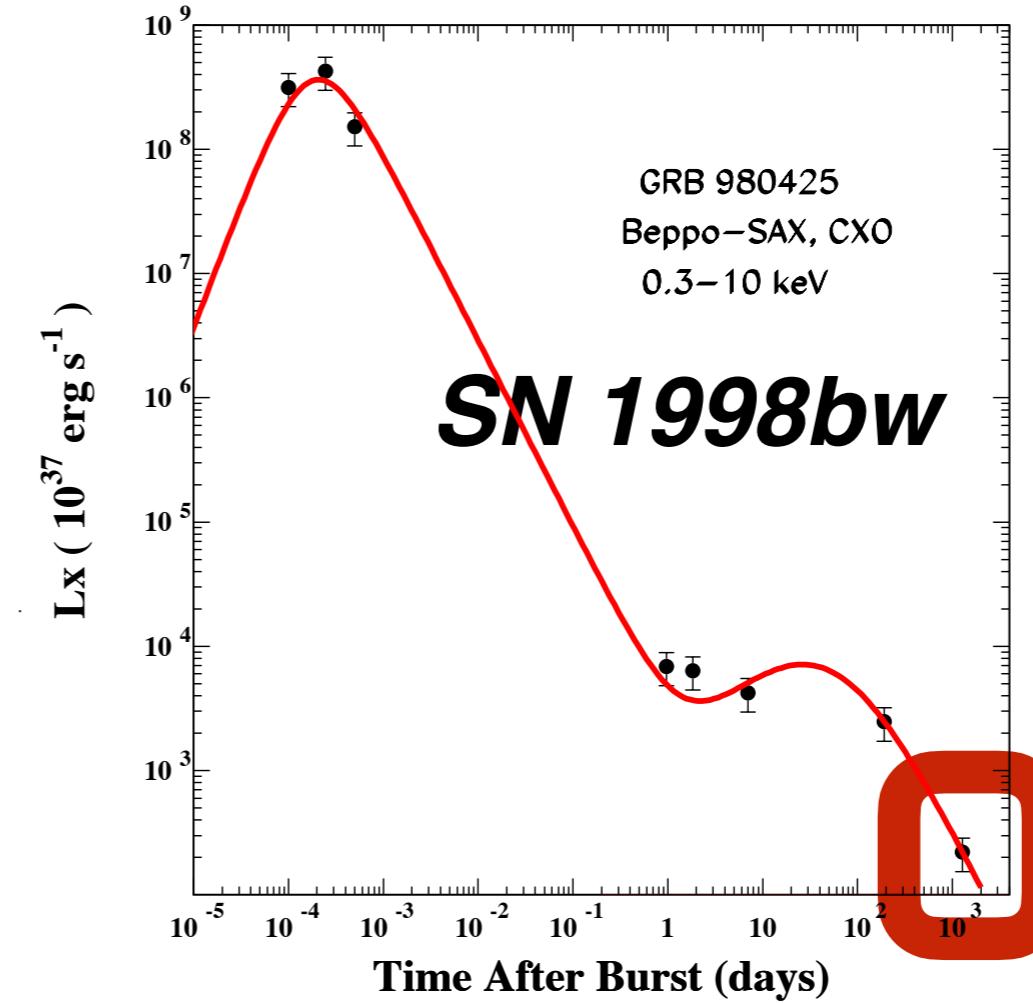
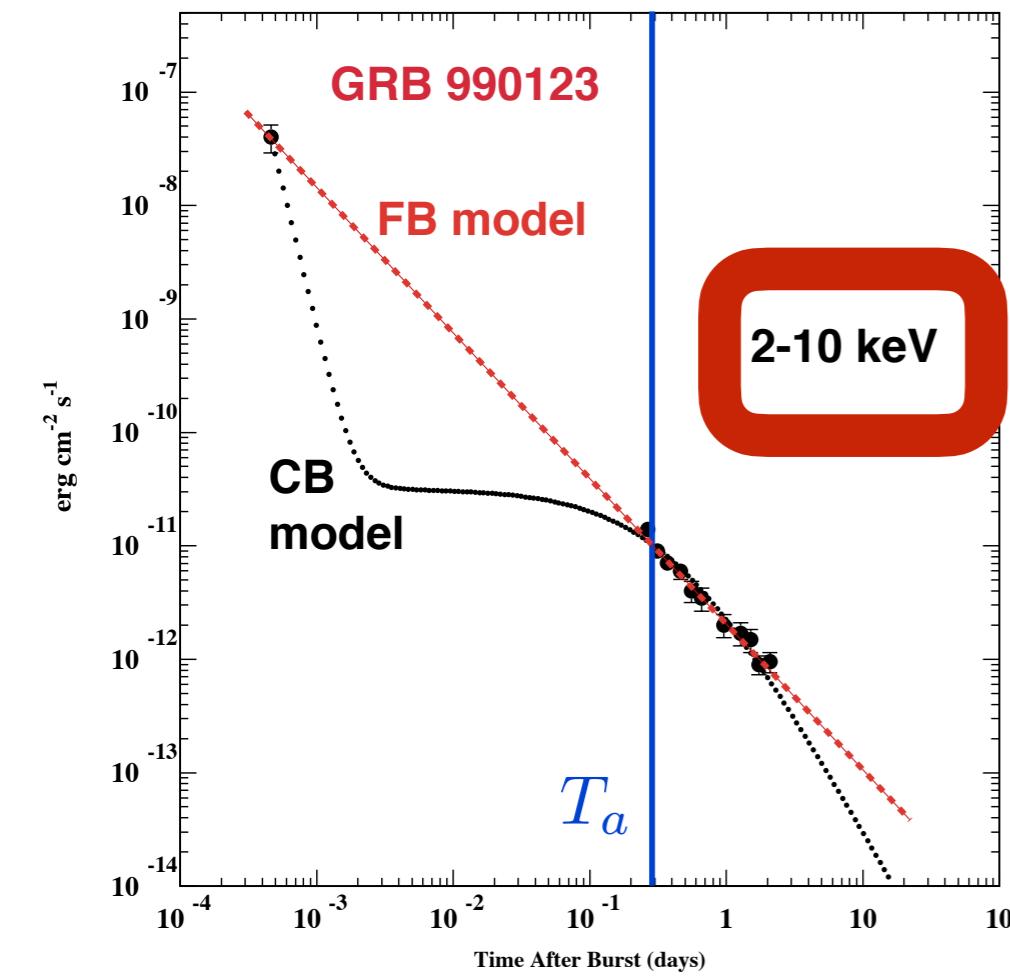
**Then
Swift
“disco-
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Can-
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X-ray
AGs**



Then
Swift
“disco-
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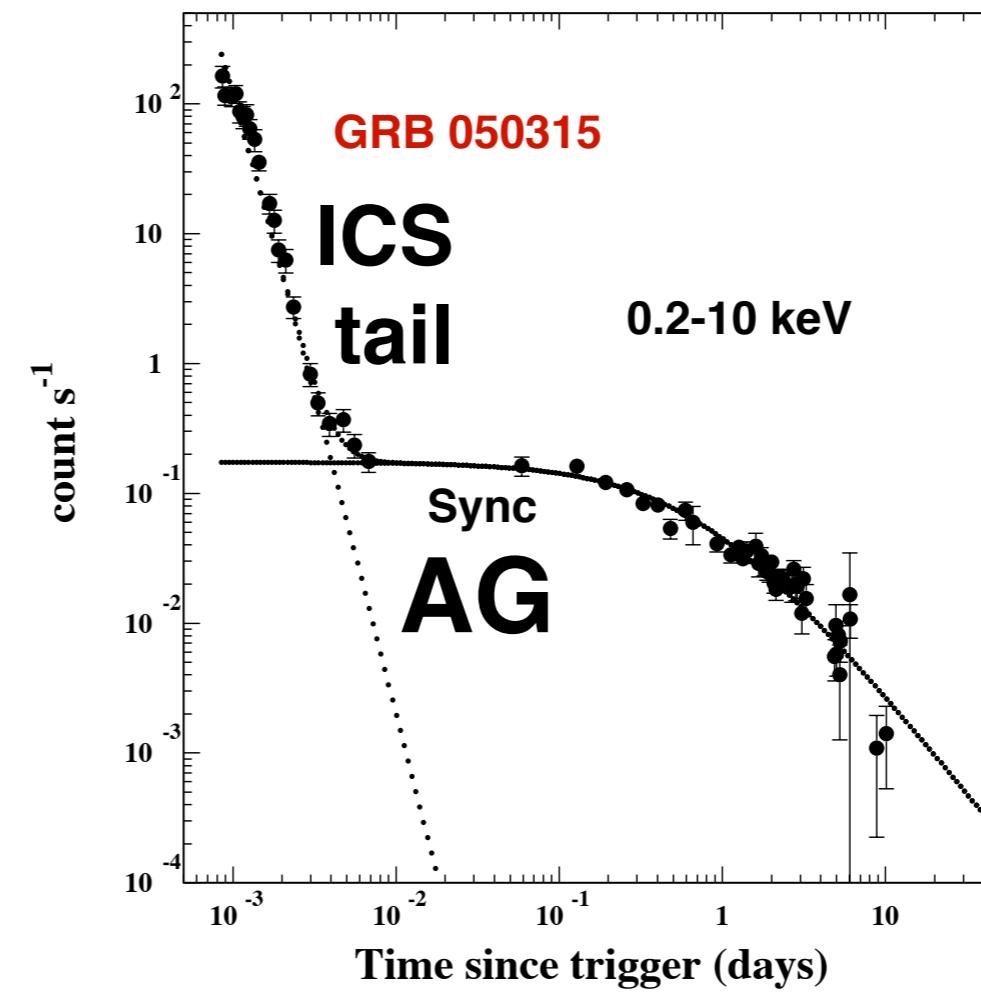
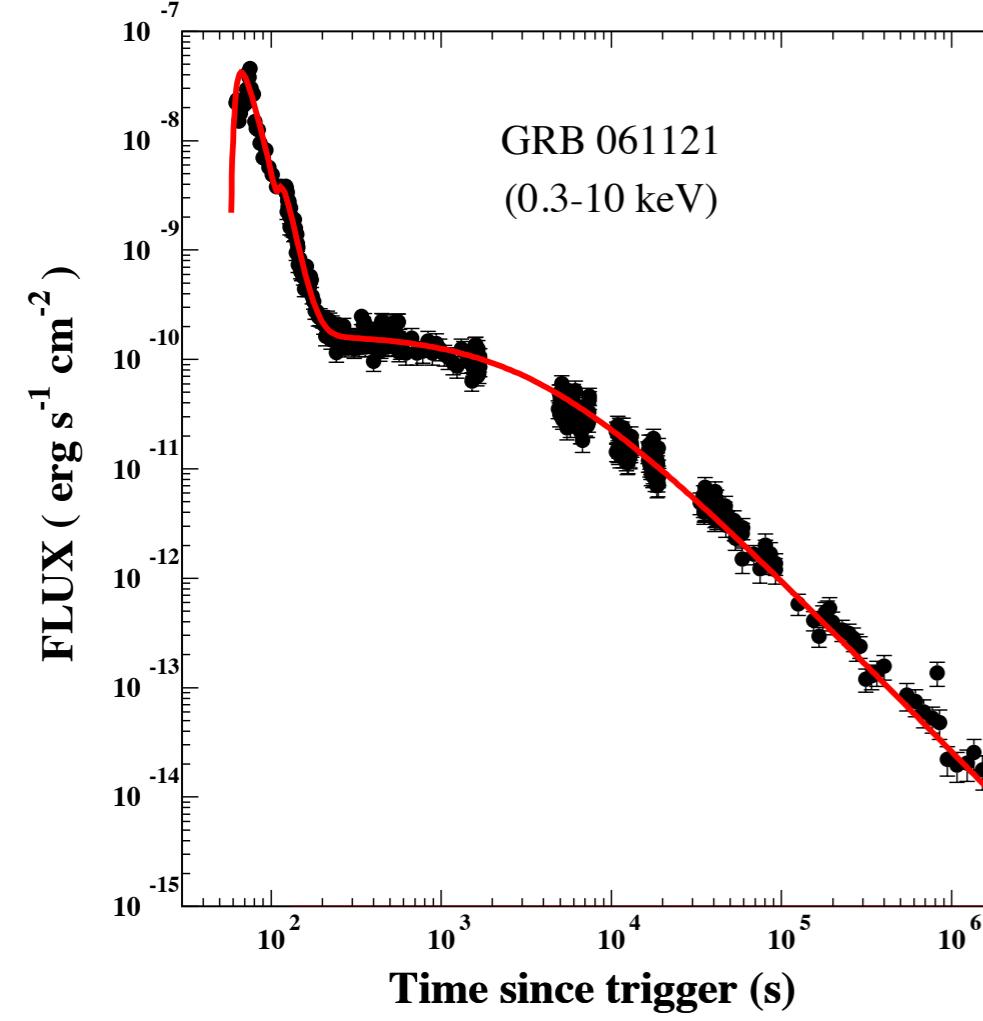
Can-
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X-ray
AGs

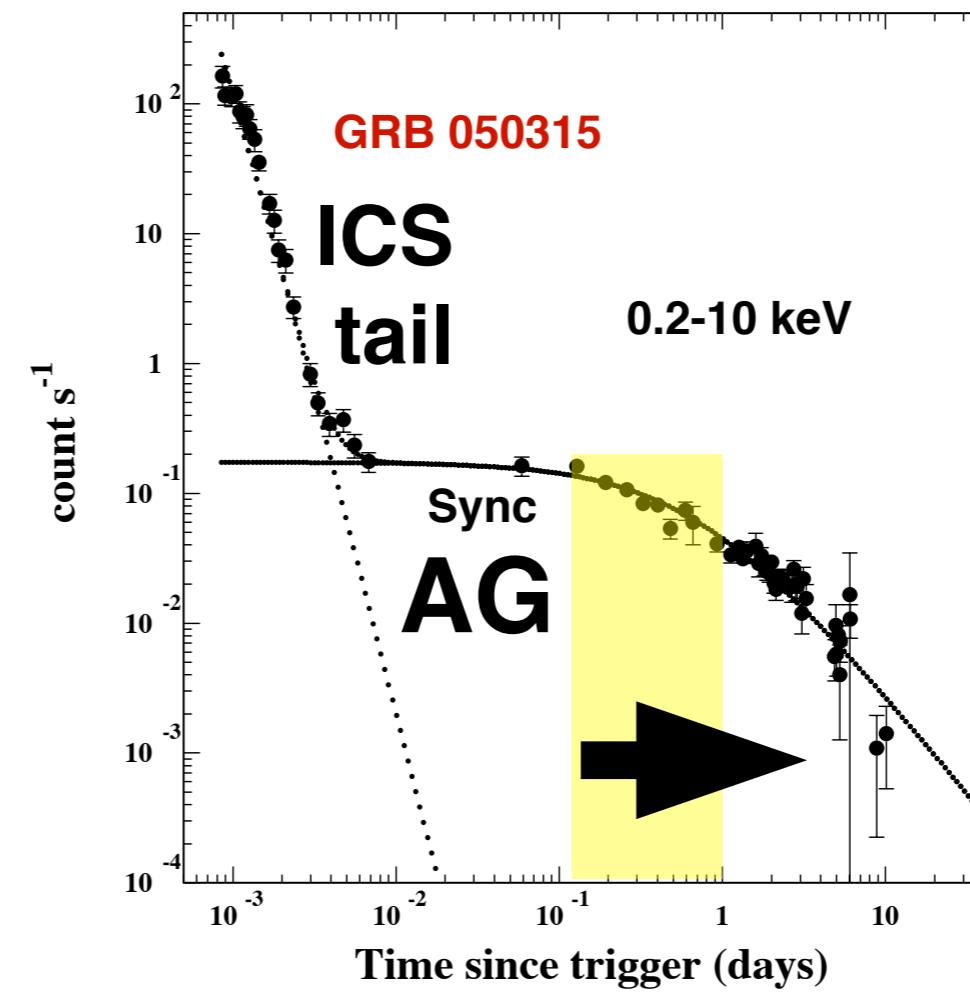
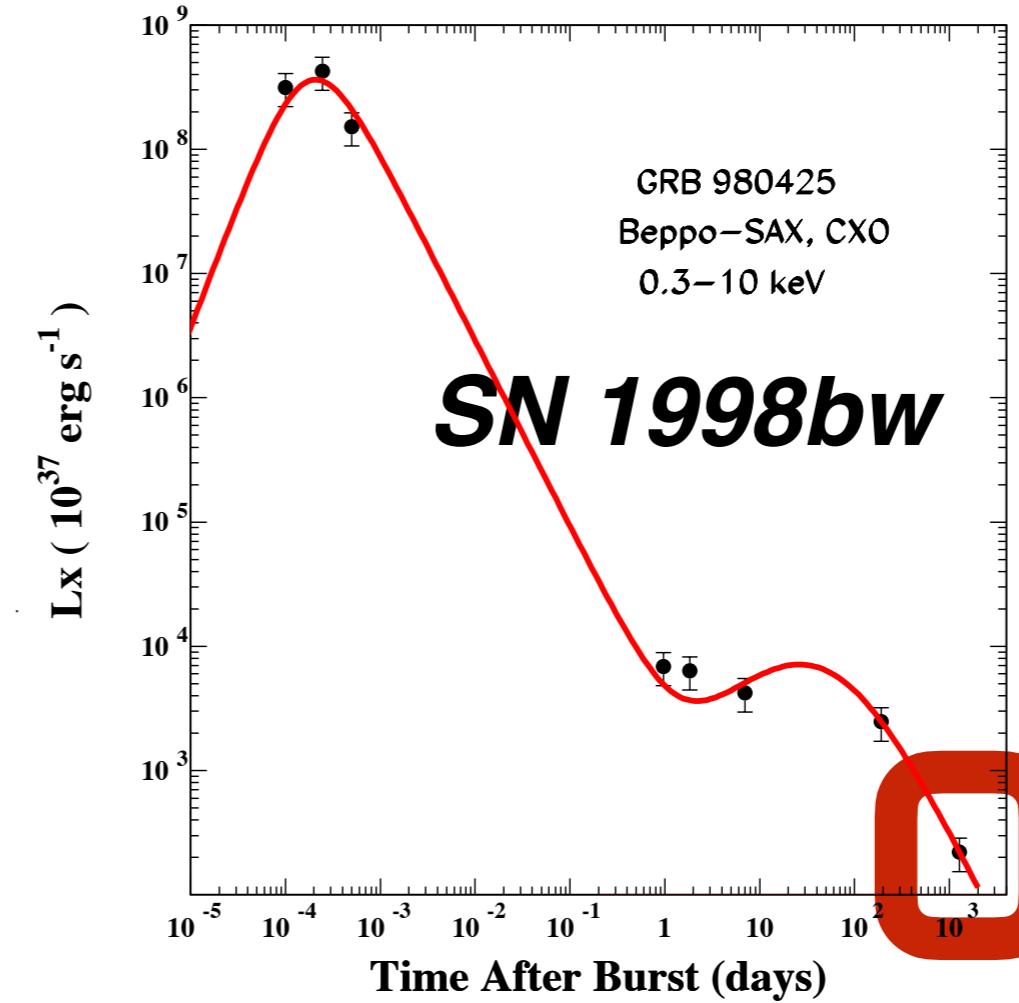
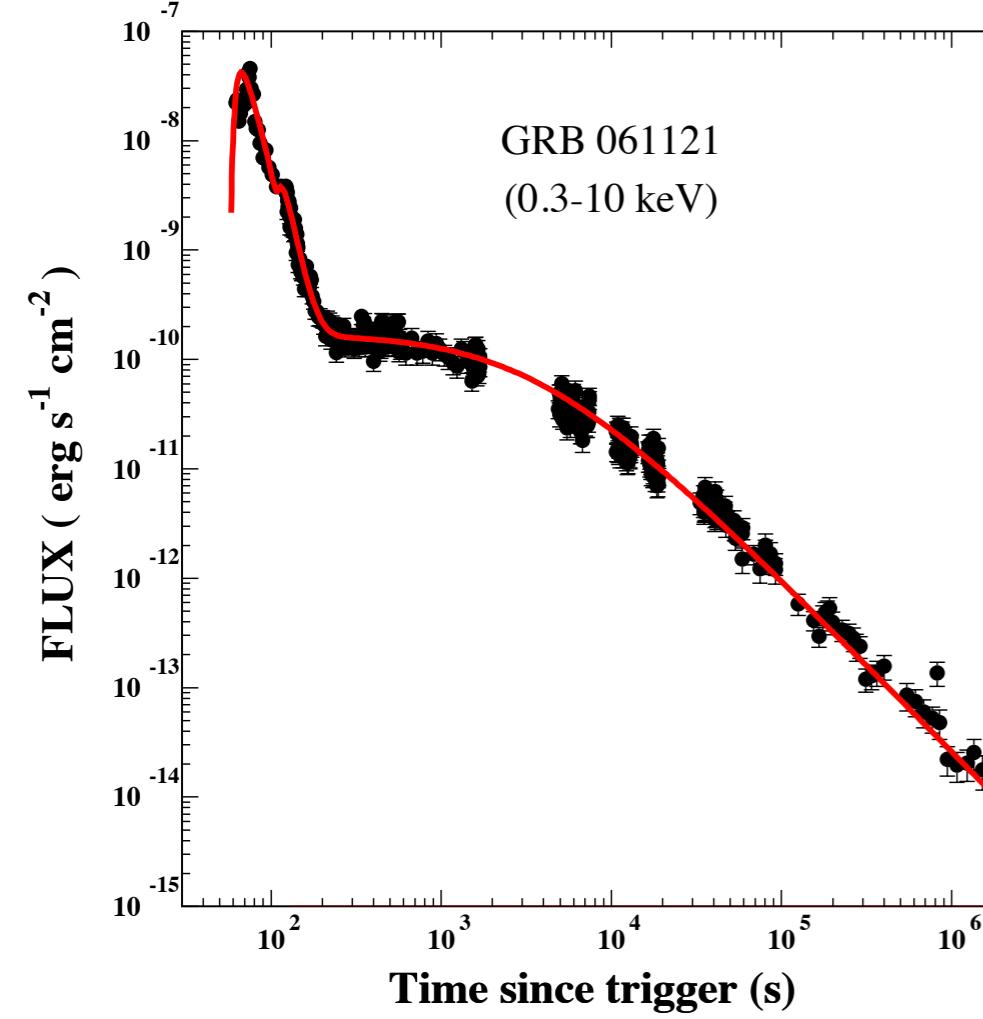
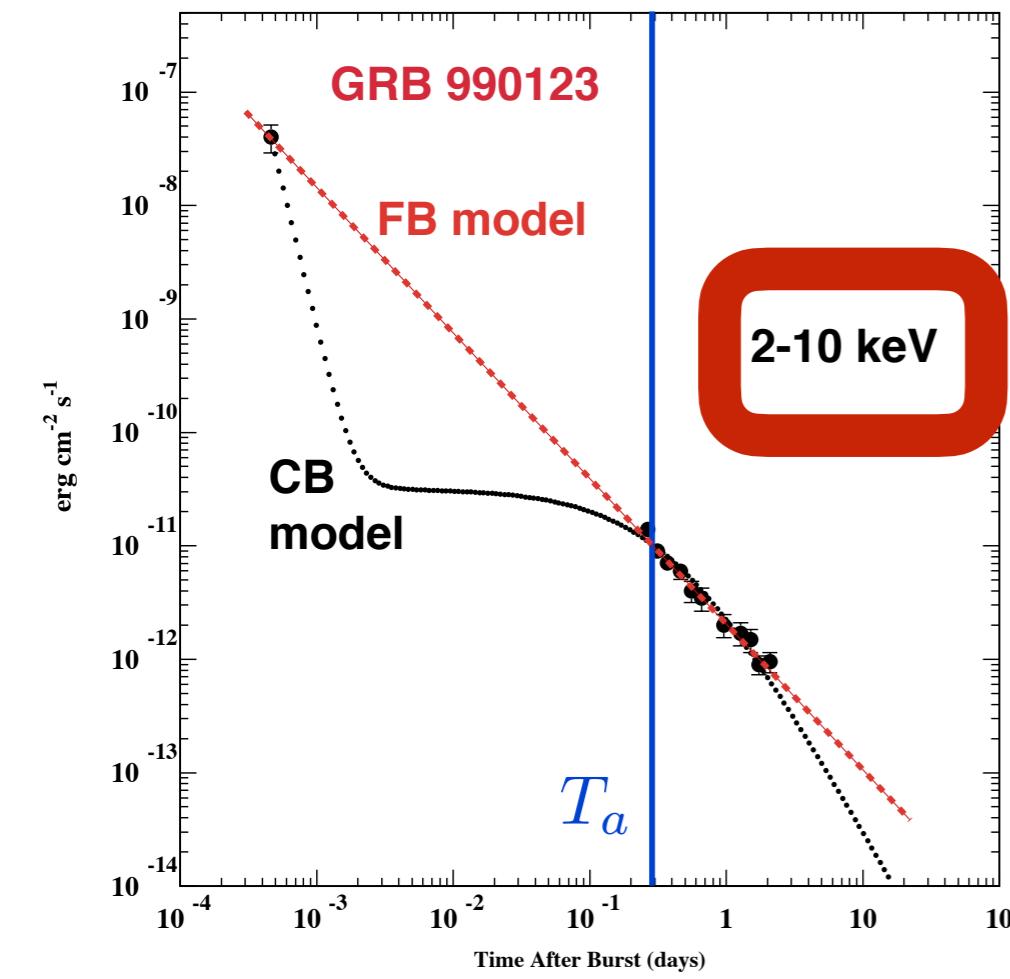




Then
Swift
“disco-
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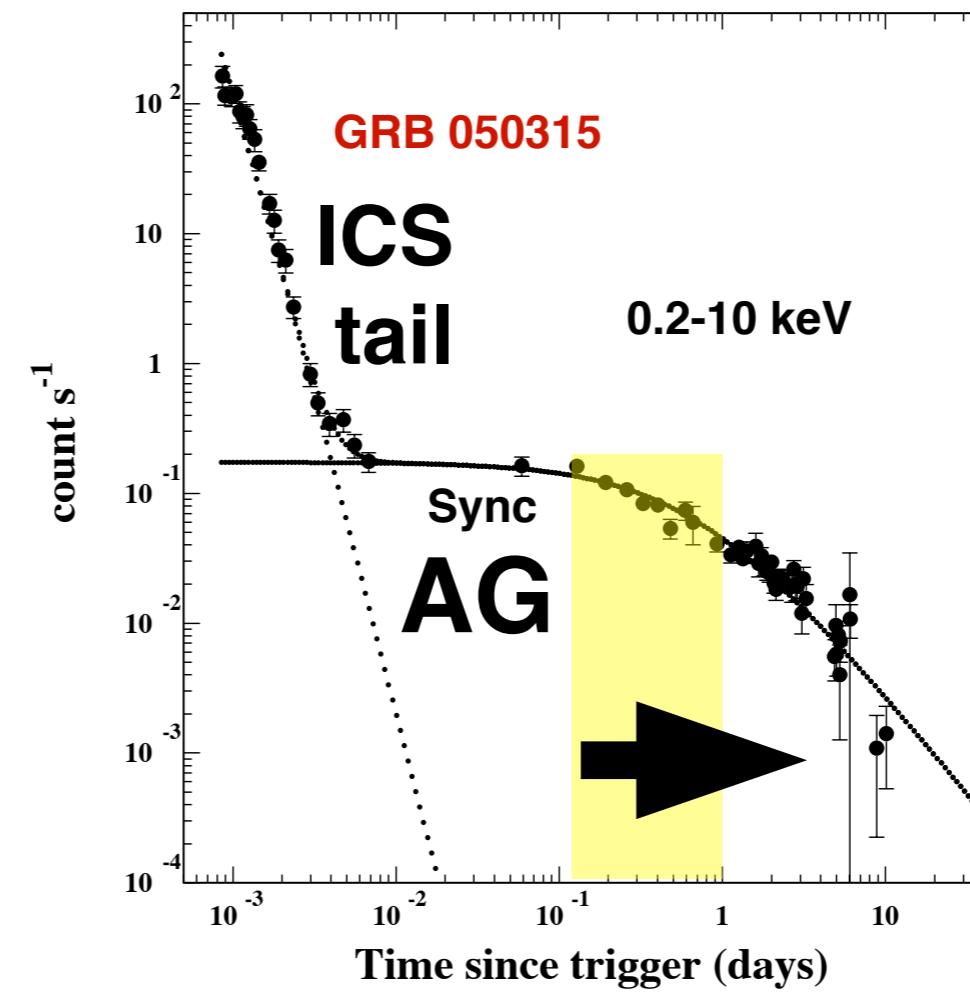
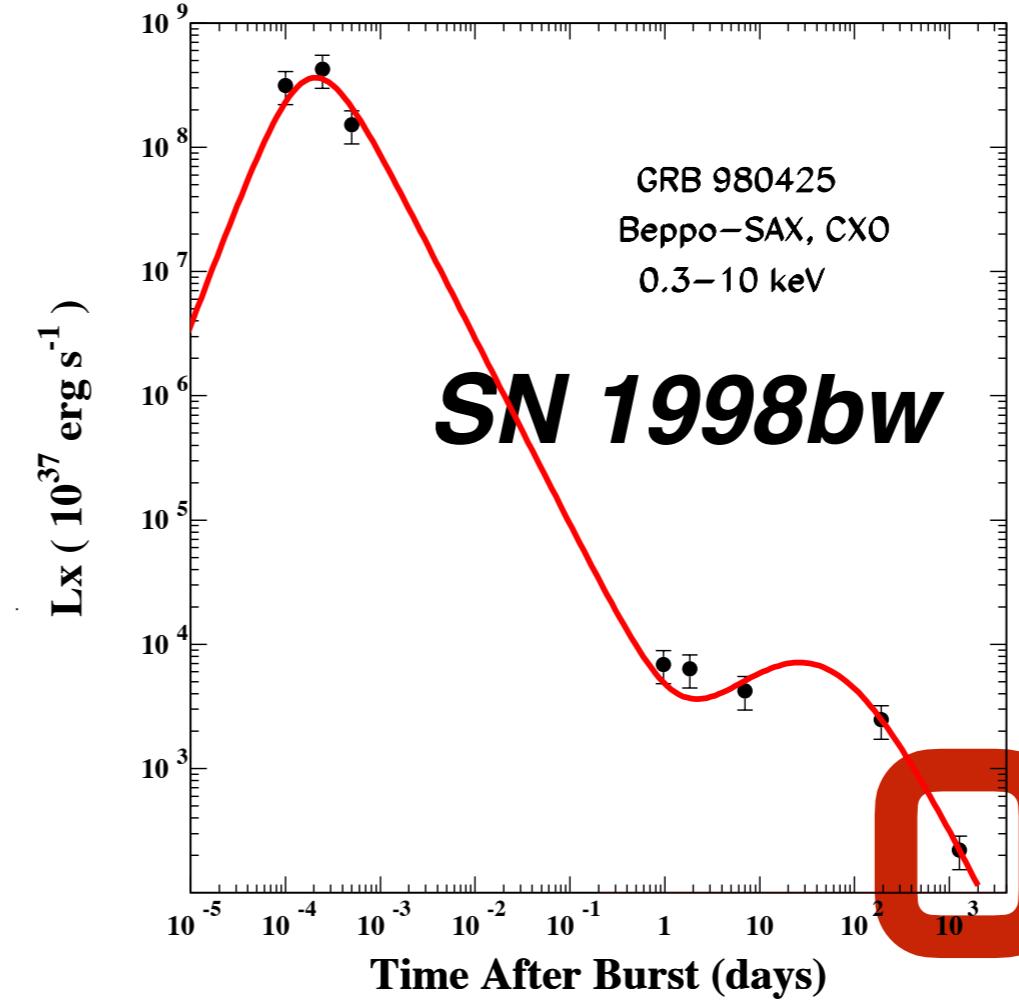
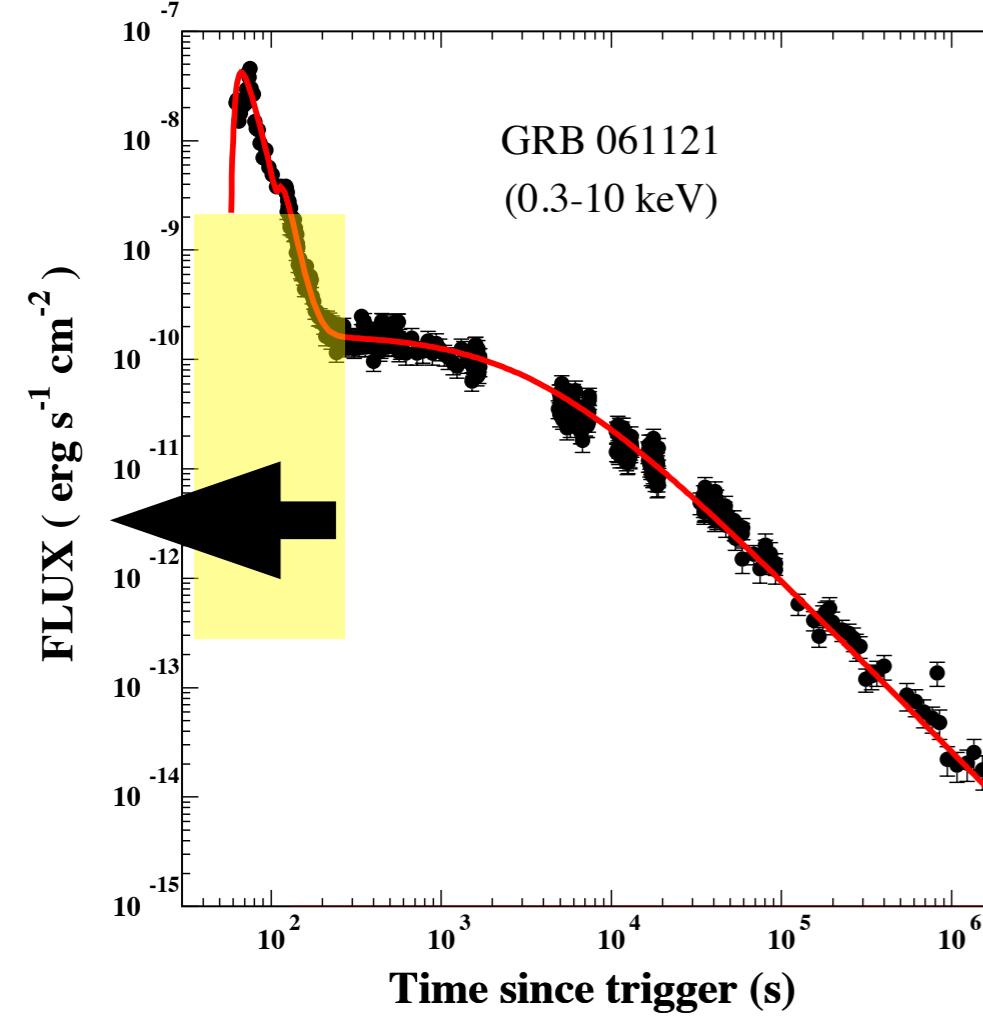
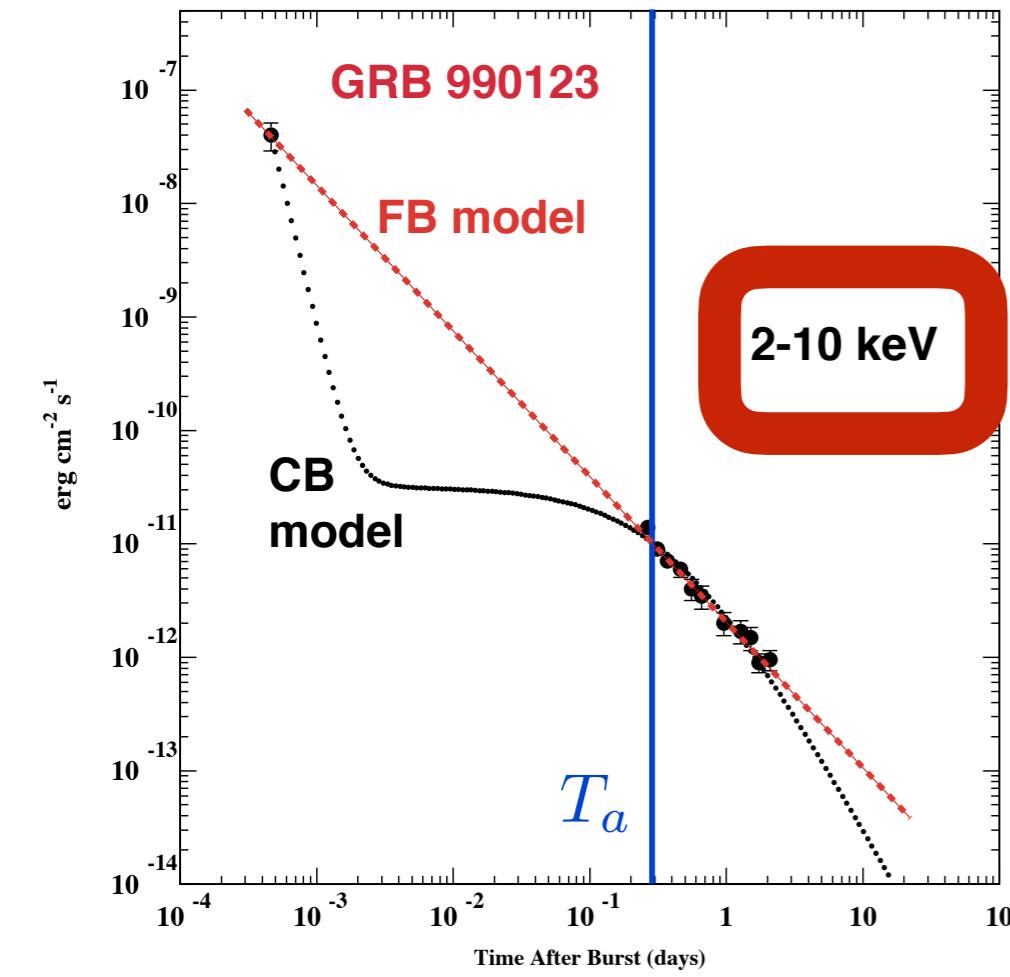
Can-
nical
X-ray
AGs





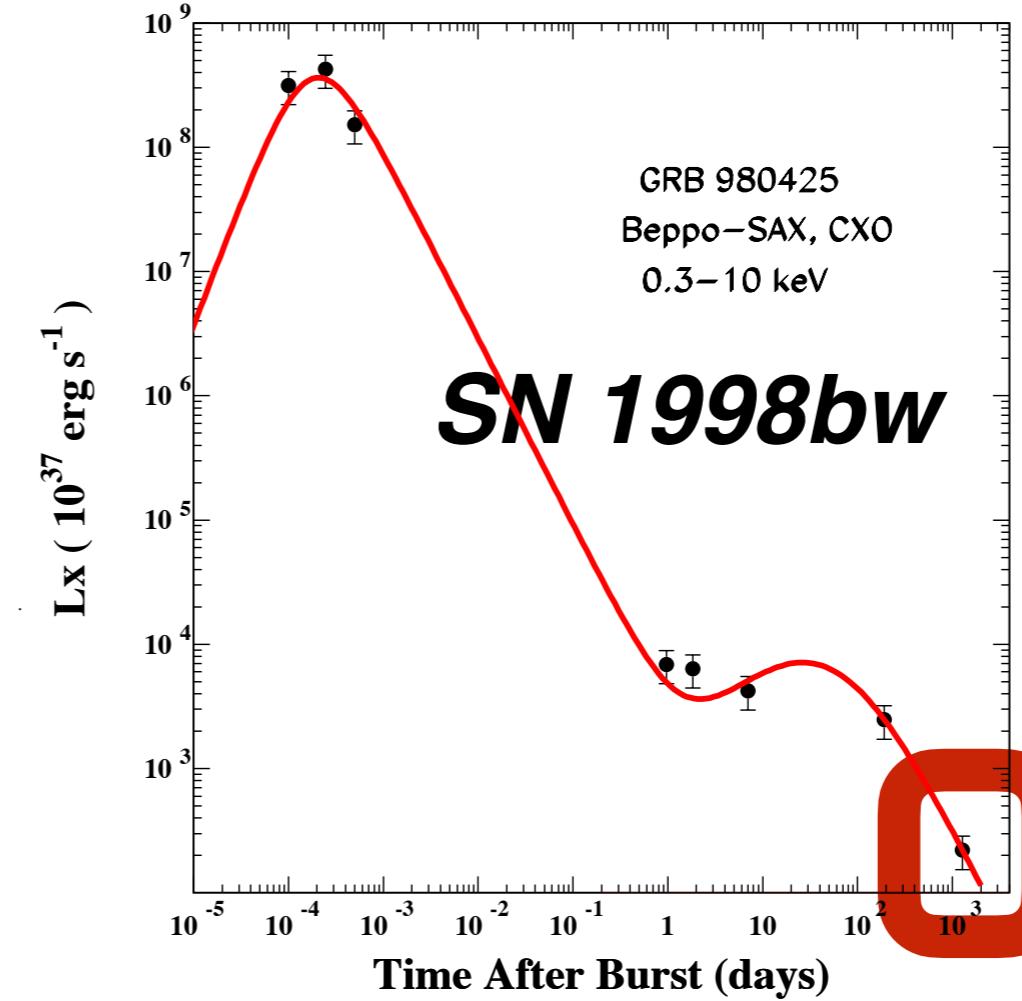
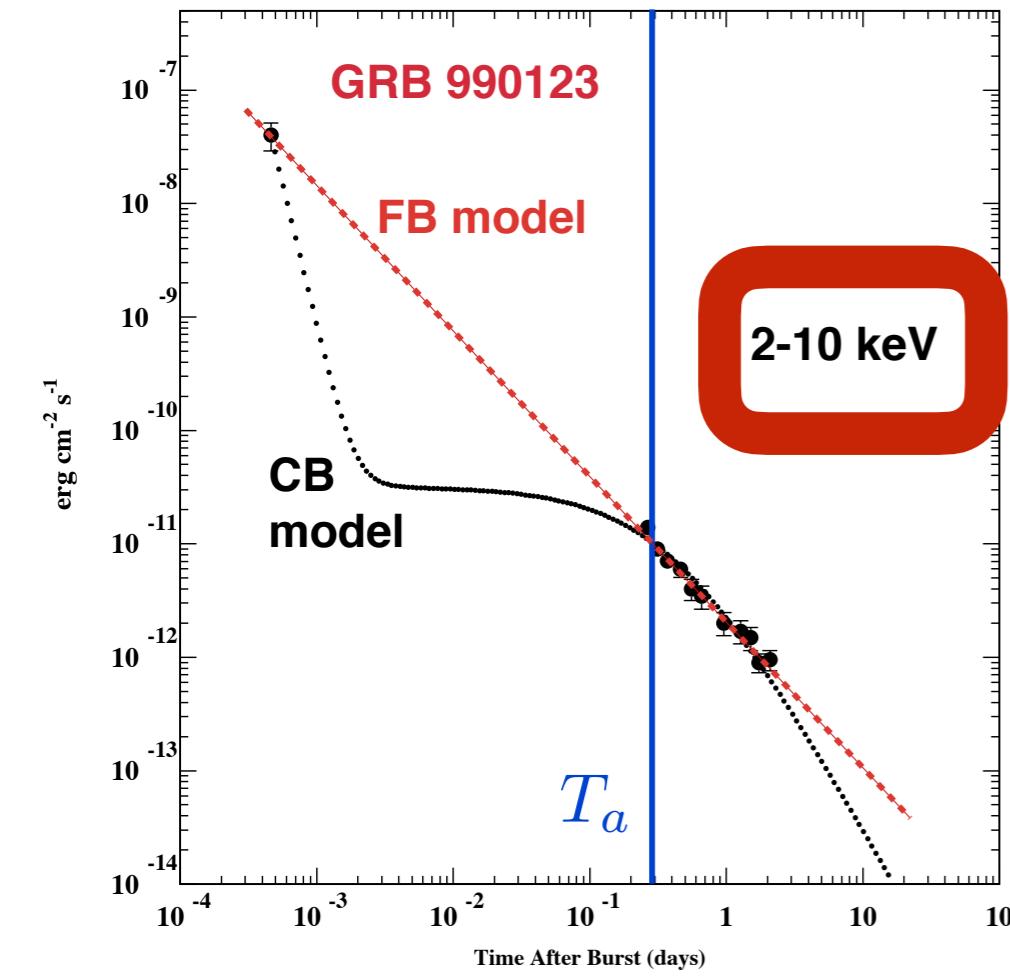
Then
Swift
“disco-
vered”

Can-
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X-ray
AGs



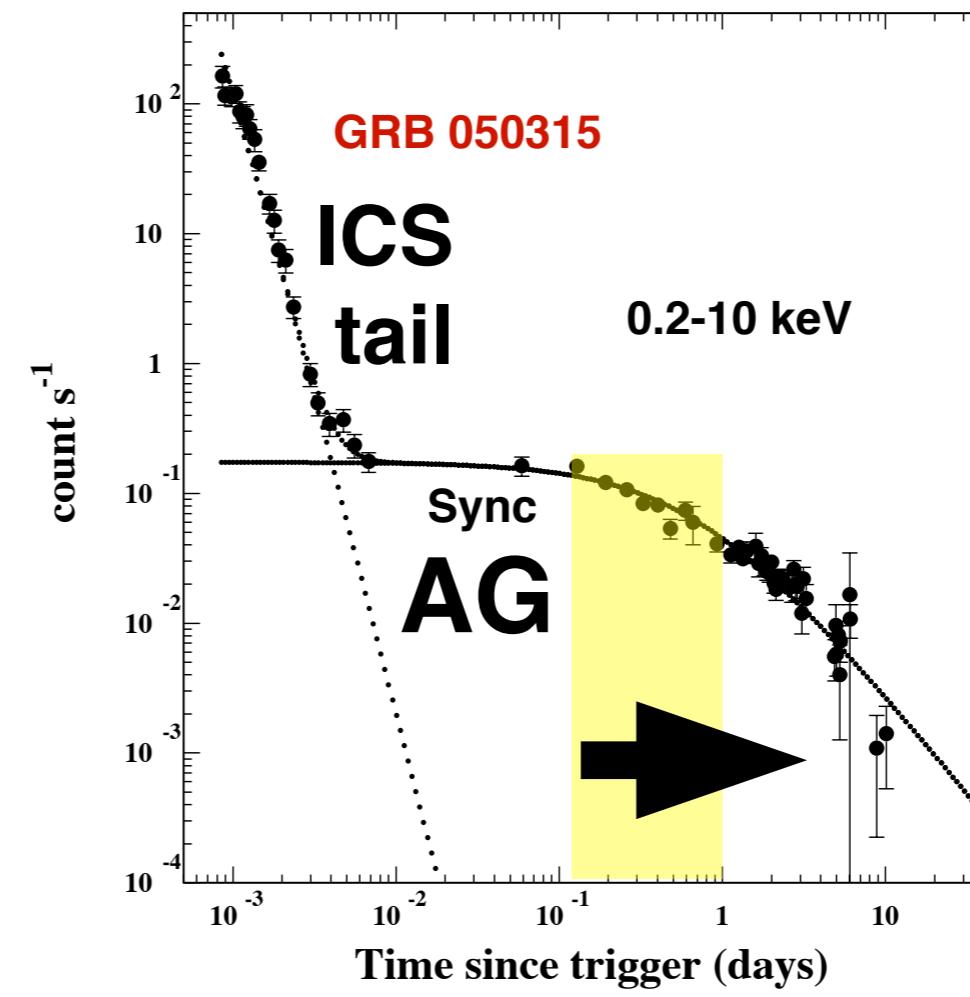
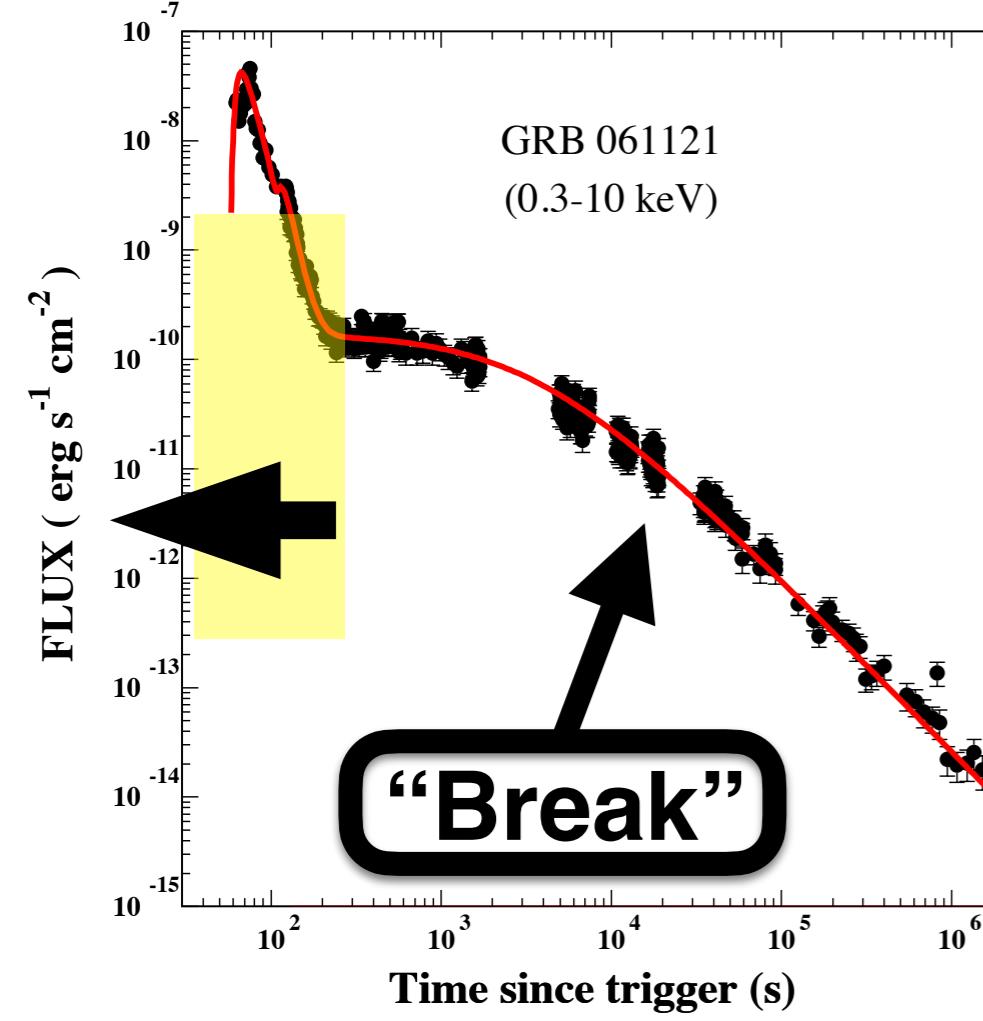
Then
Swift
“disco-
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Can-
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X-ray
AGs

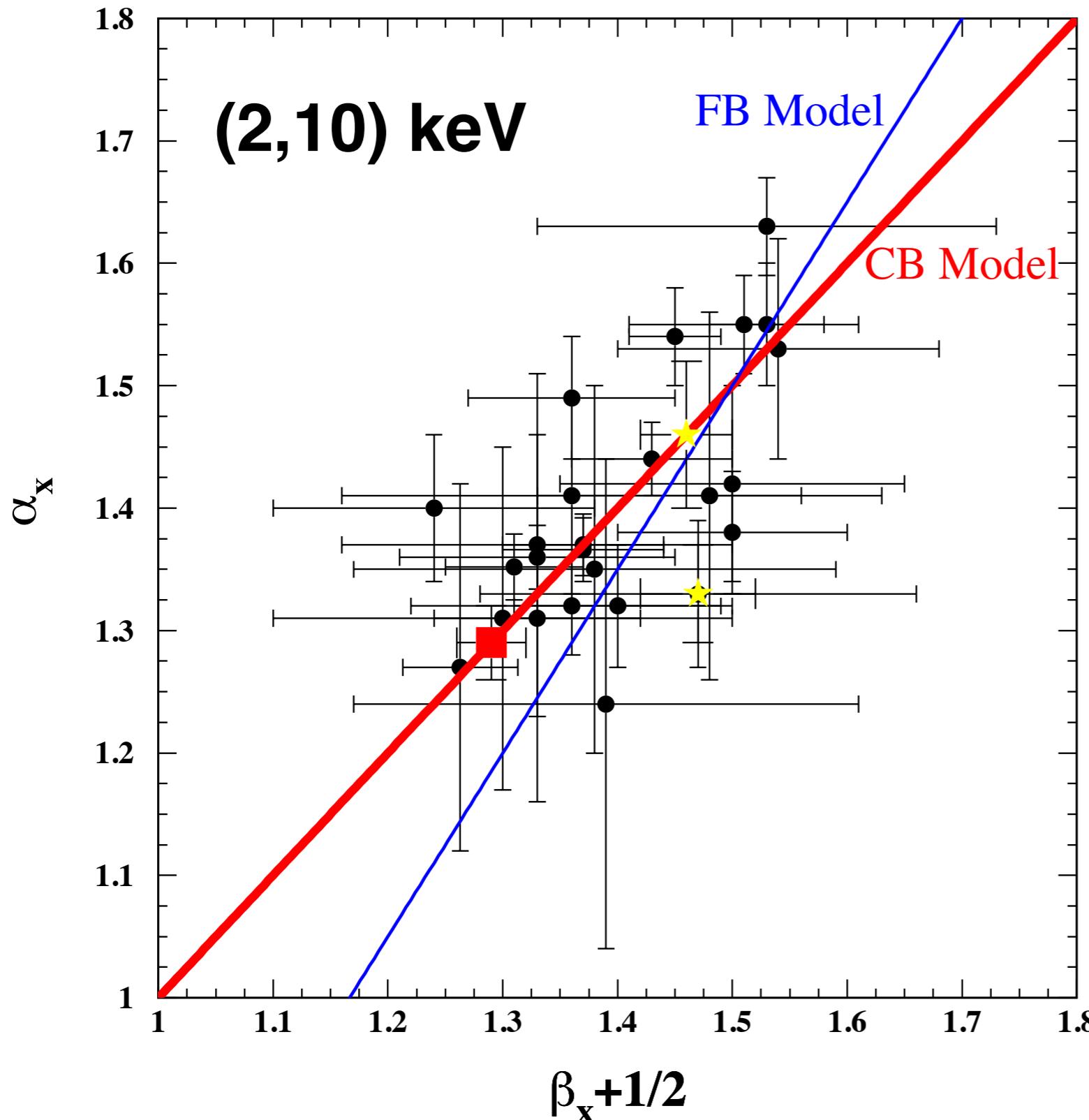


Then
Swift
“disco-
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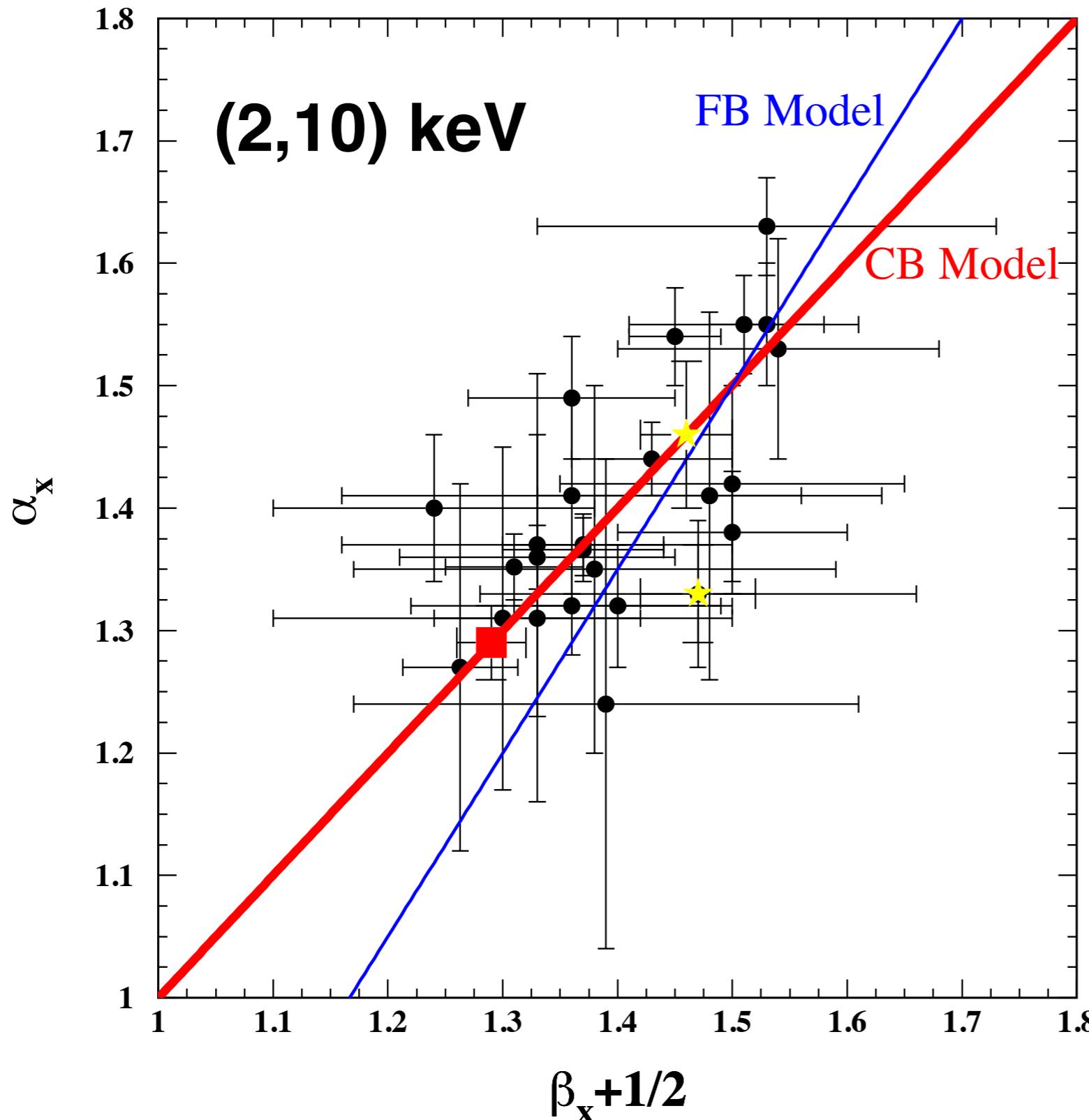
Can-
nical
X-ray
AGs



$$F_\nu(t \gg t_b) \propto t^{-\alpha_\nu} E^{-\beta_\nu} \quad \alpha_\nu = \beta_\nu + 1/2$$



$$F_\nu(t \gg t_b) \propto t^{-\alpha_\nu} E^{-\beta_\nu} \quad \alpha_\nu = \beta_\nu + 1/2$$



***FB
model
almost
right
;-)***

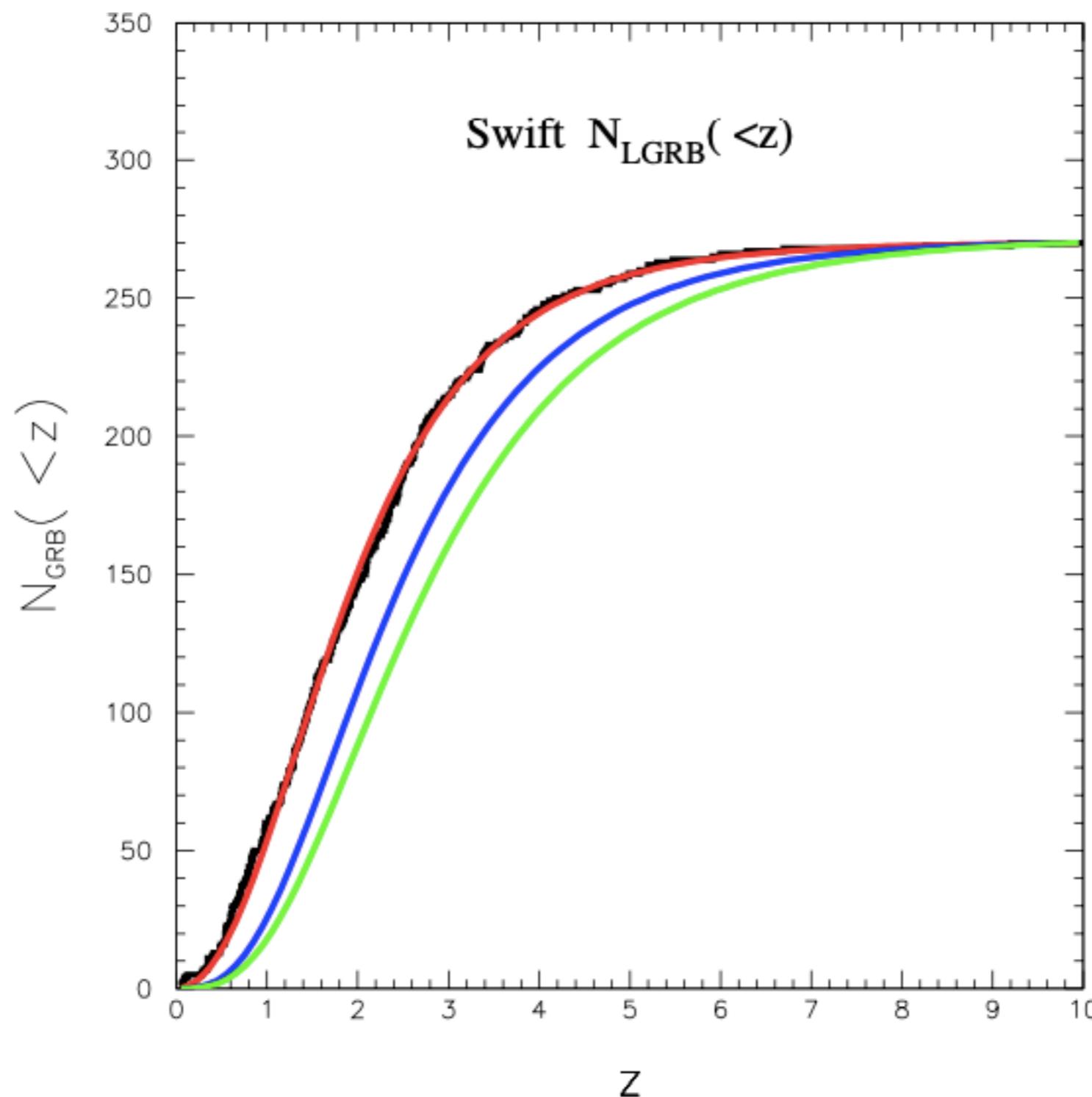
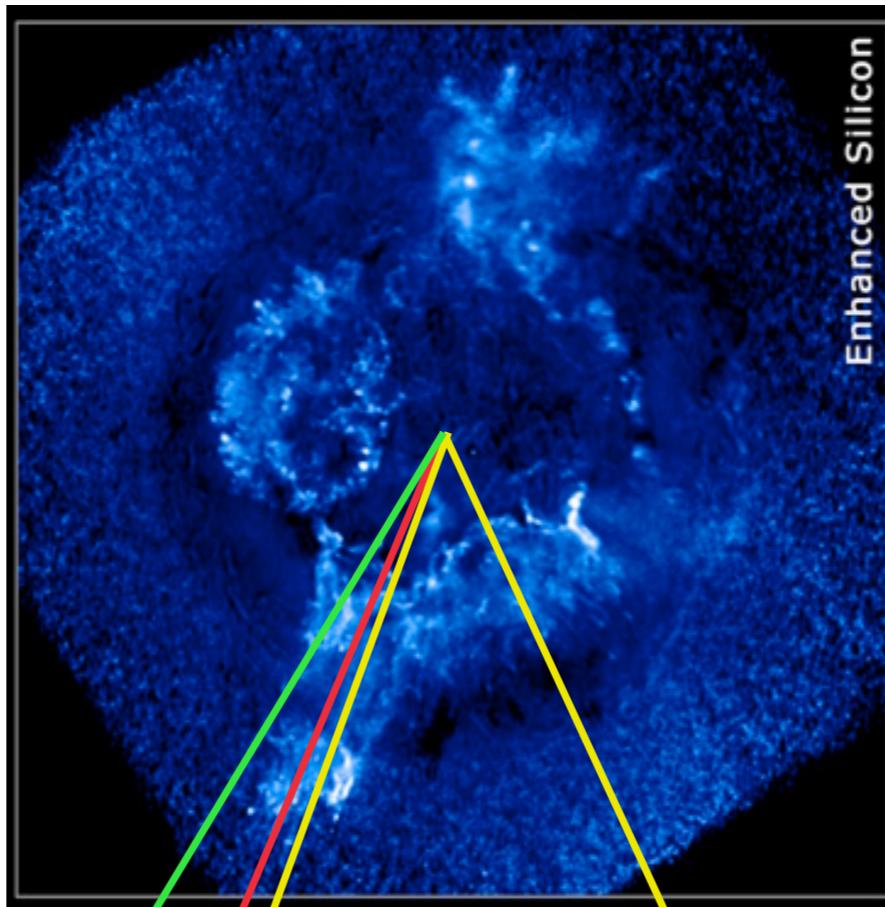


Figure 23. Comparison between the cumulative distribution function, $N(<z)$, of the 262 LGRBs with known redshift (histogram) detected by Swift before 2014 and the $N(<z)$ expected in the CB model (left curve) for long GRBs, whose rate is assumed to trace the SFR. Also shown are the distributions expected in FB models with no evolution (rightmost curve) and with it (middle curve) [77].

A core-collapse SN



XRF
Smallish θ
Axis
of CBs

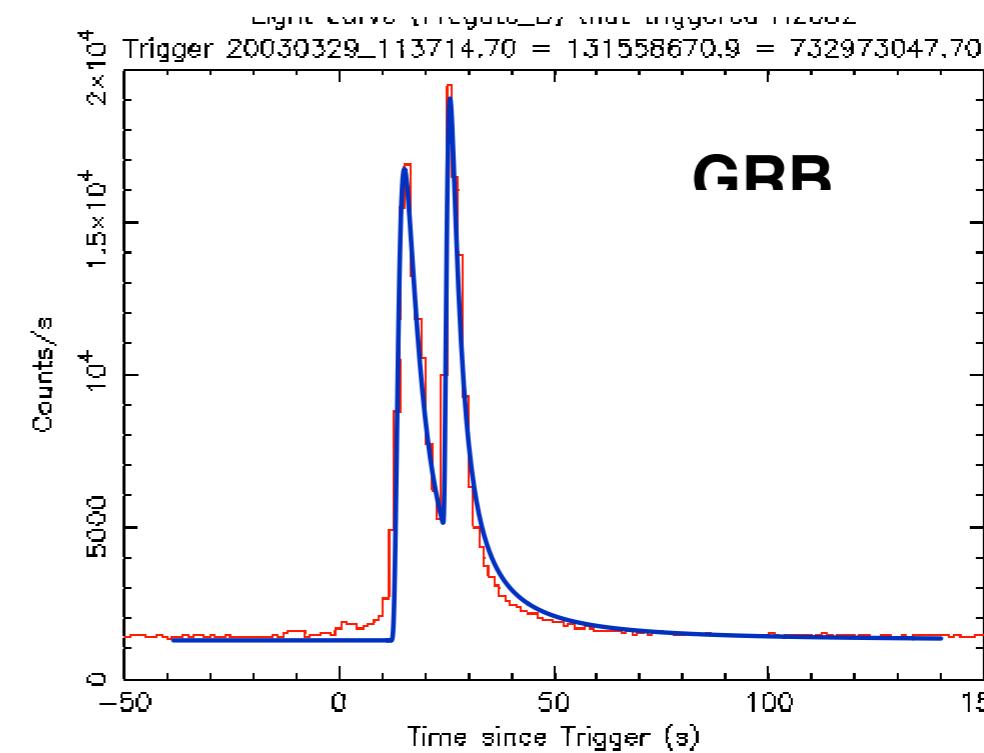
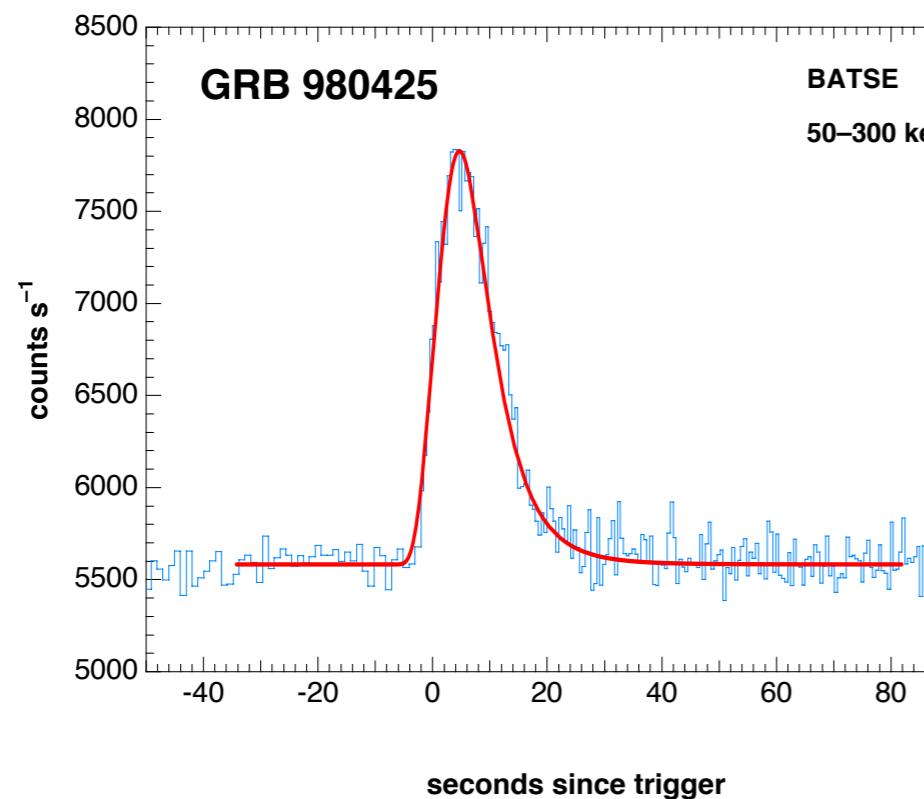
Very
Small
 θ

Observer
sees an
ordinary
Supernova
not a GRB

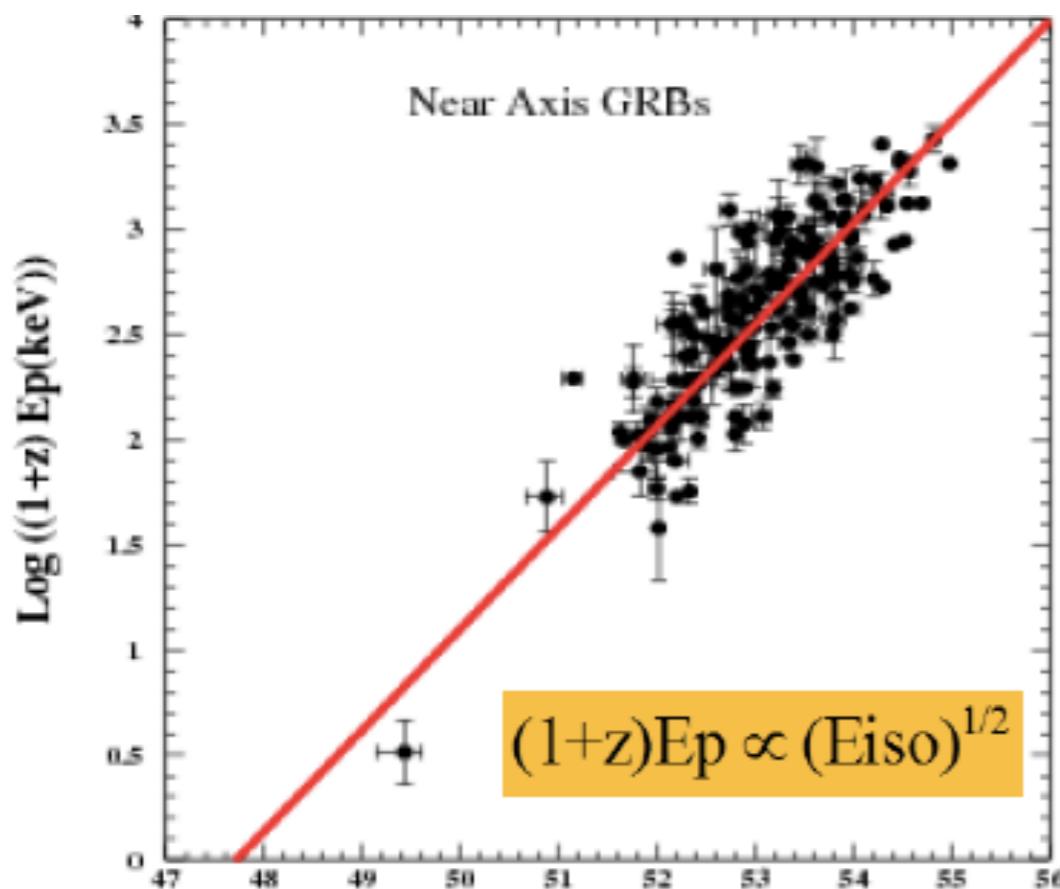
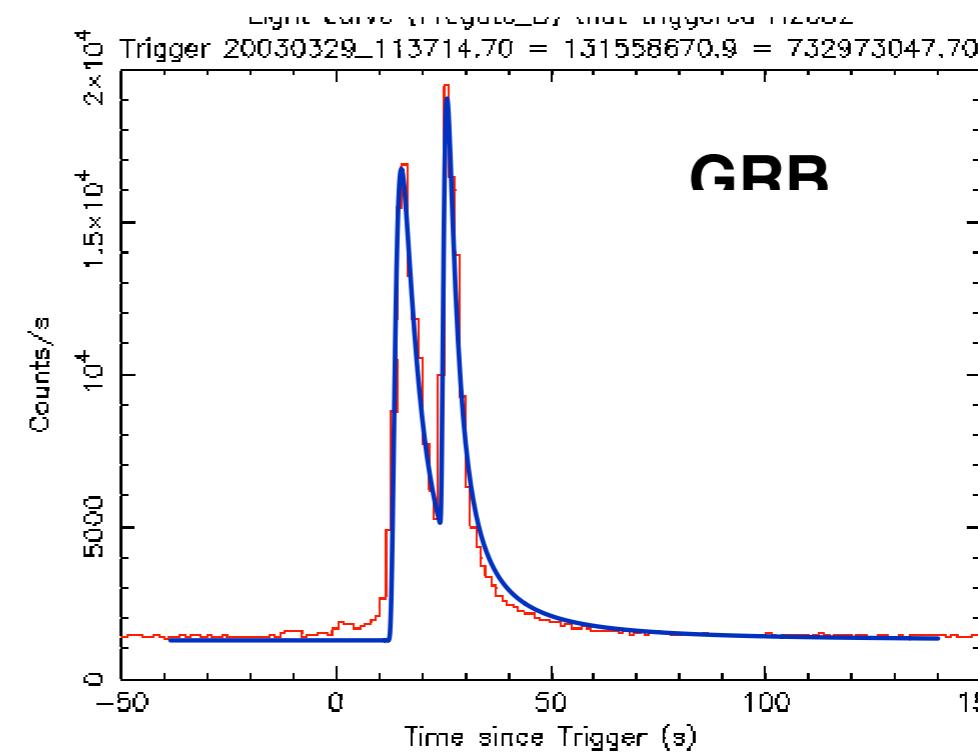
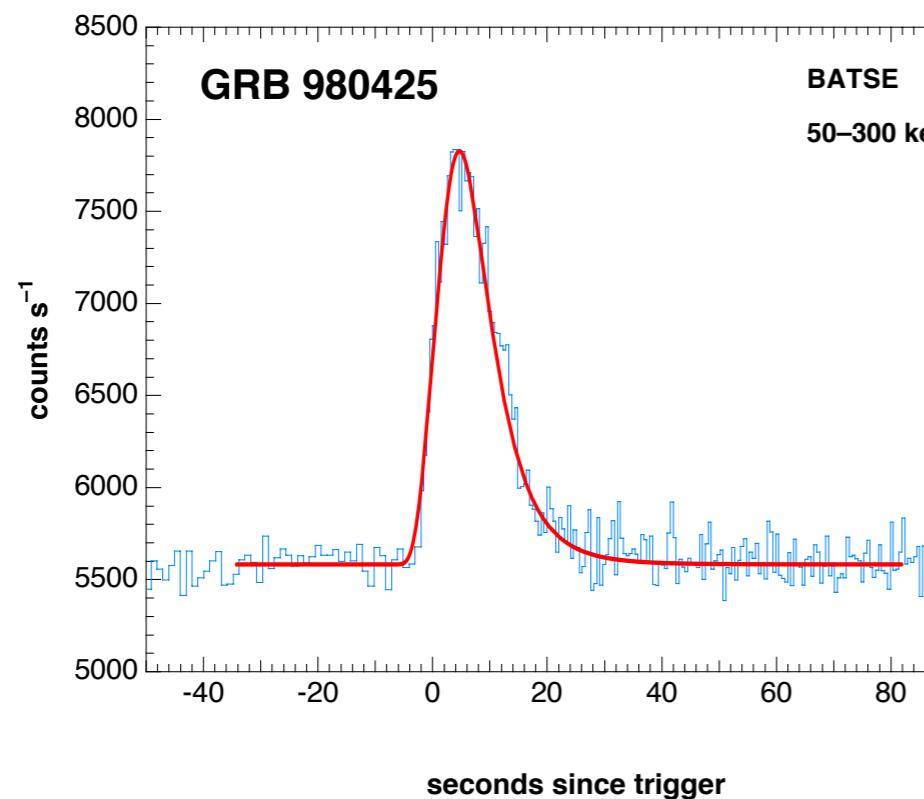
Observer sees a GRB
and fast SN ejecta
Calls it a “Hypernova”

Successful Th of GRBs

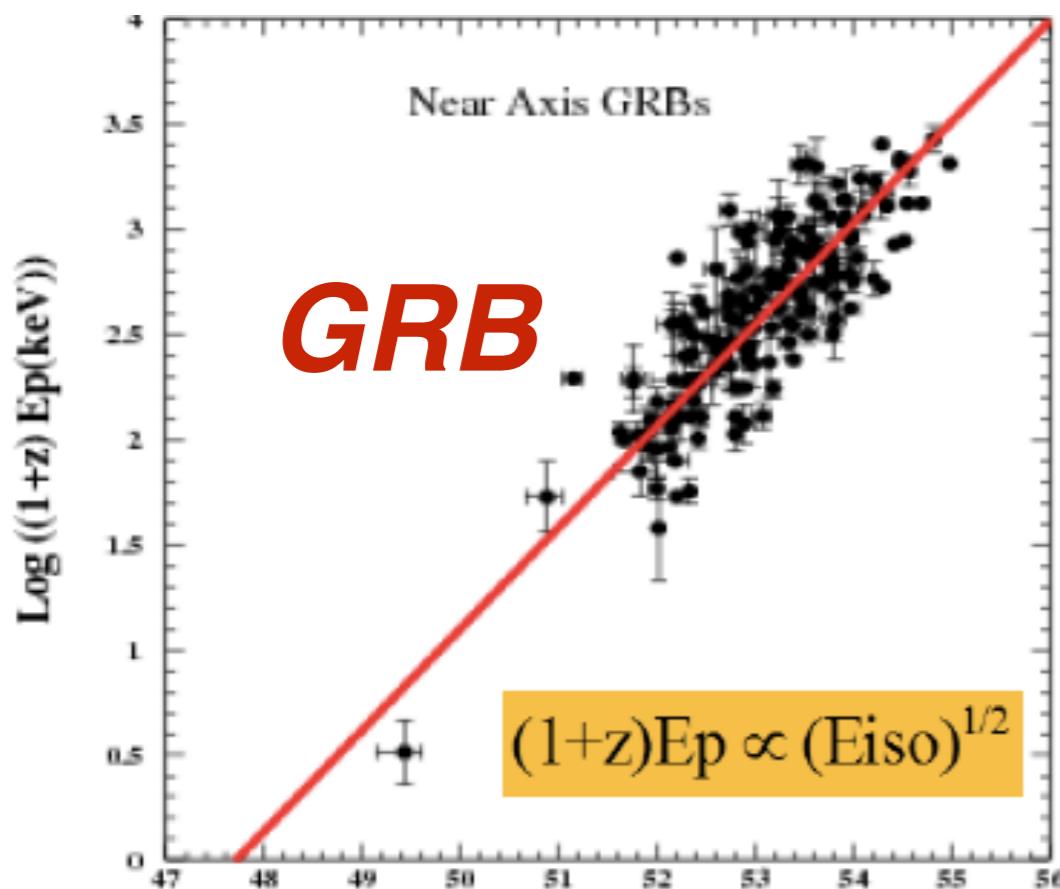
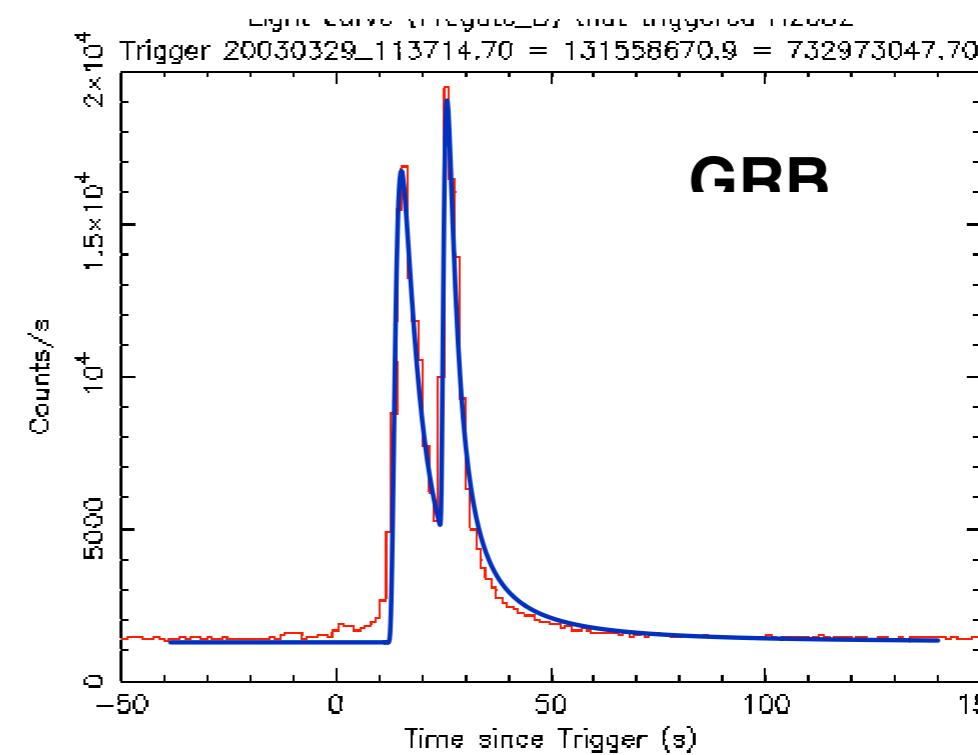
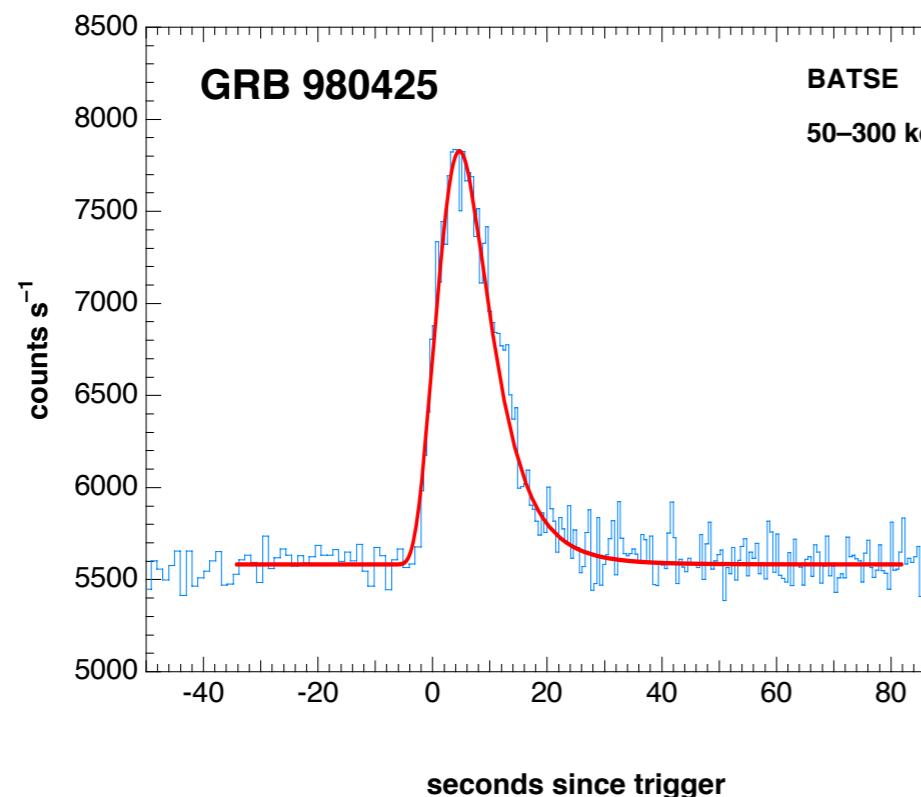
Successful Th of GRBs



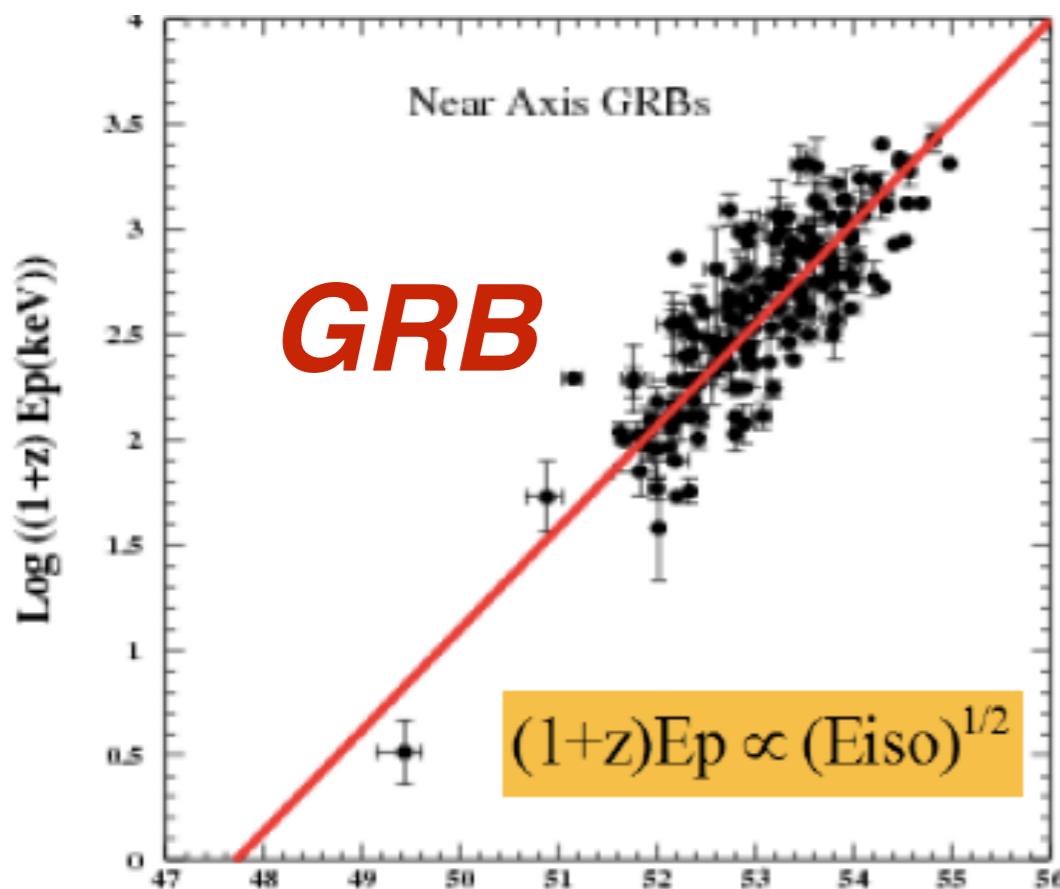
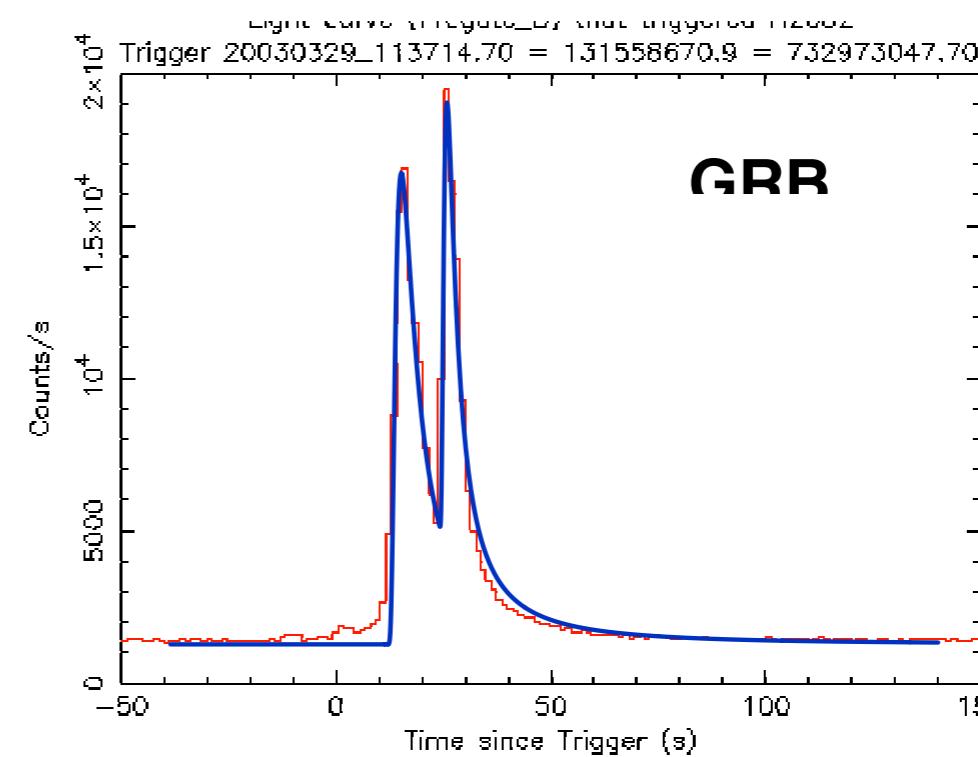
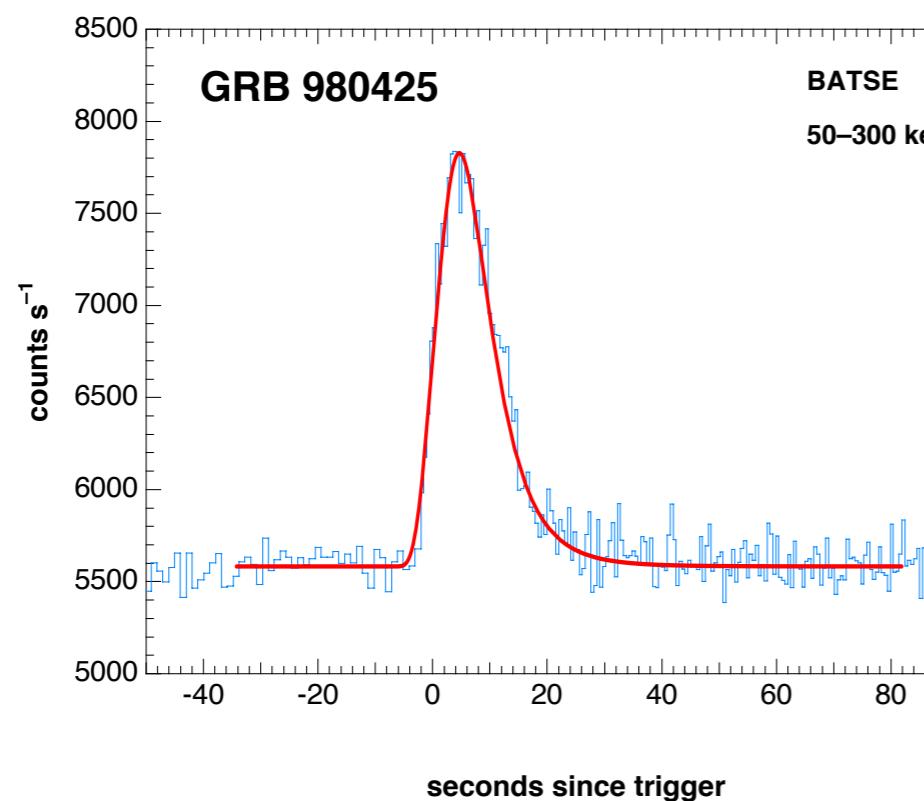
Successful Th of GRBs



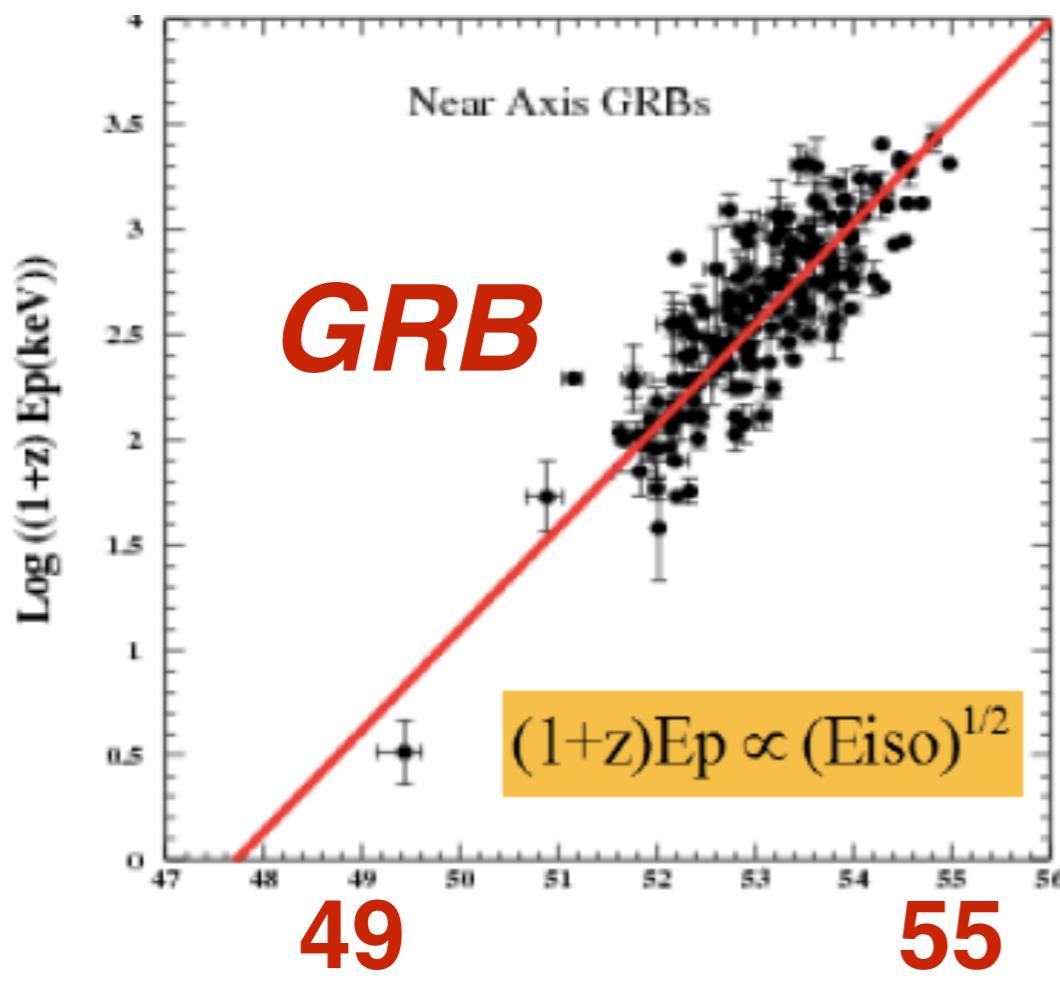
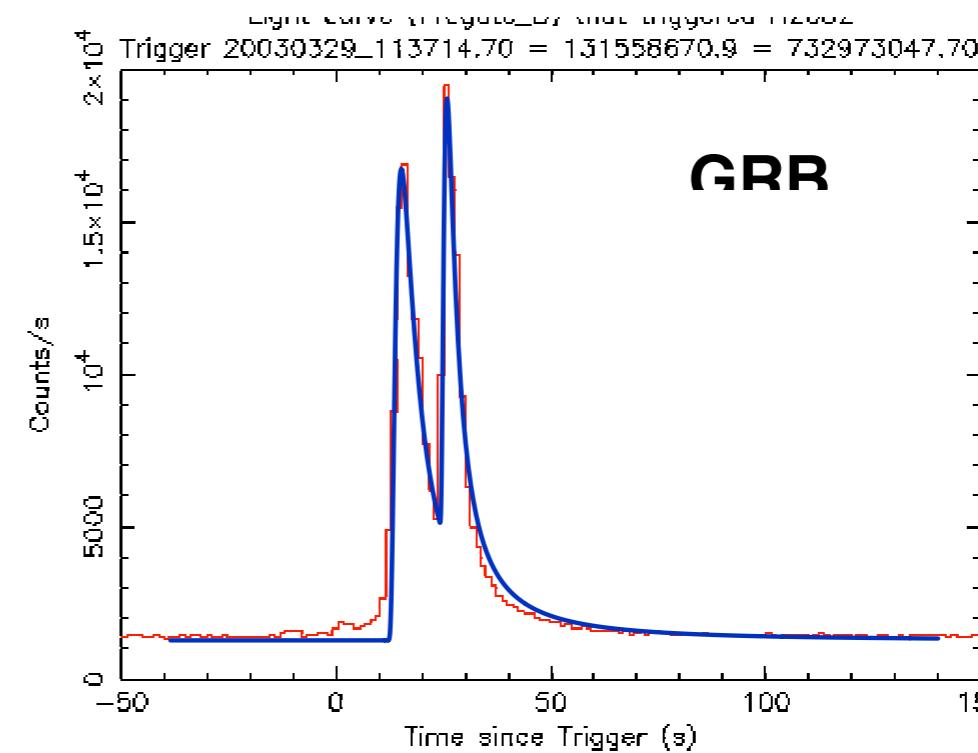
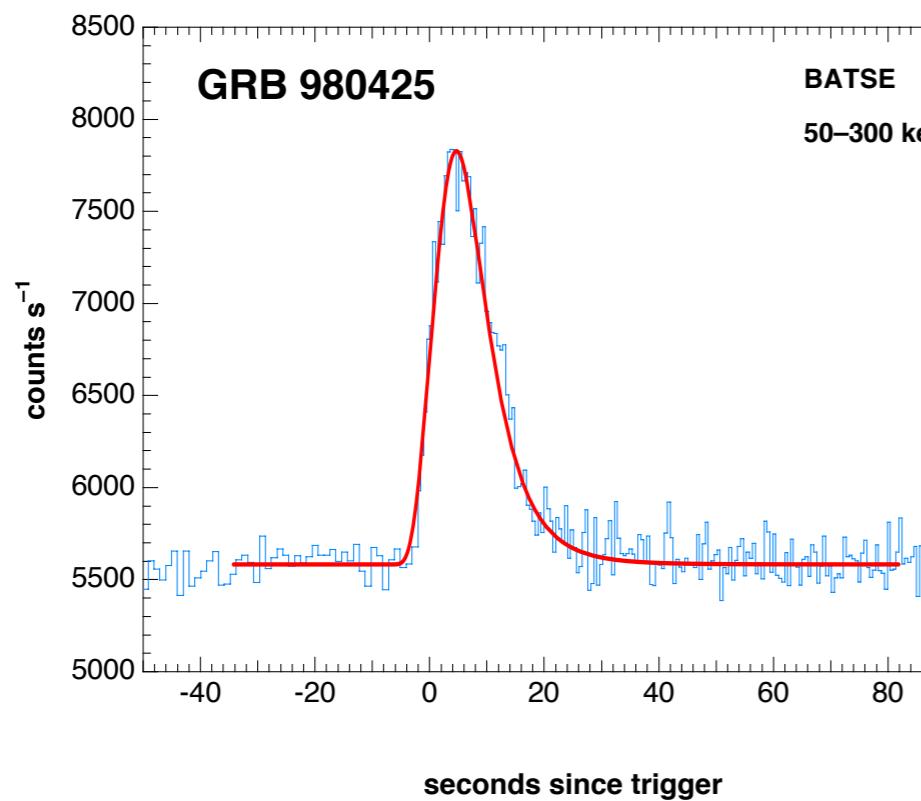
Successful Th of GRBs



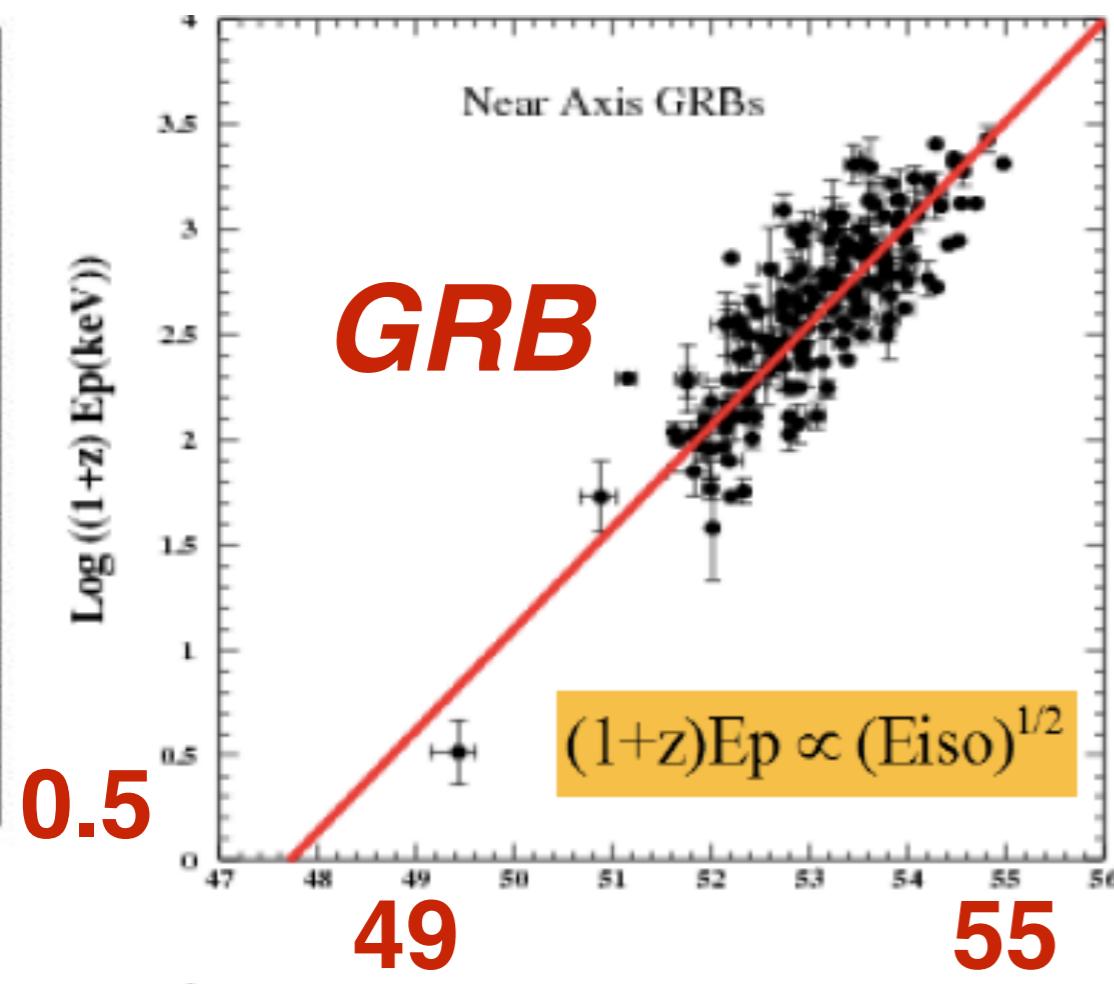
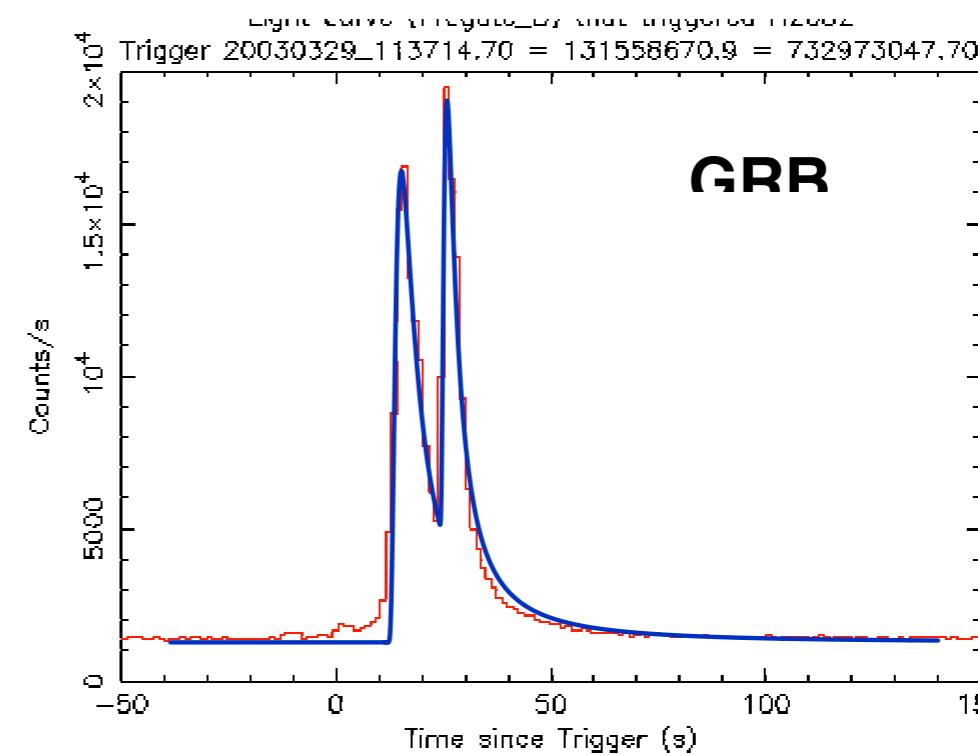
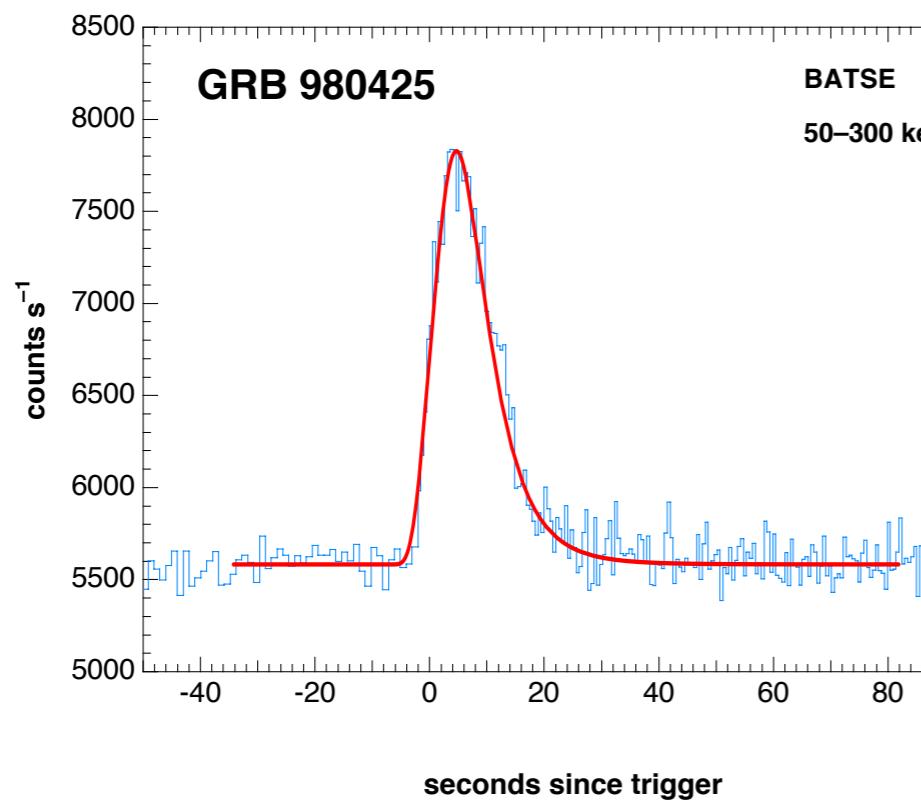
Successful Th of GRBs



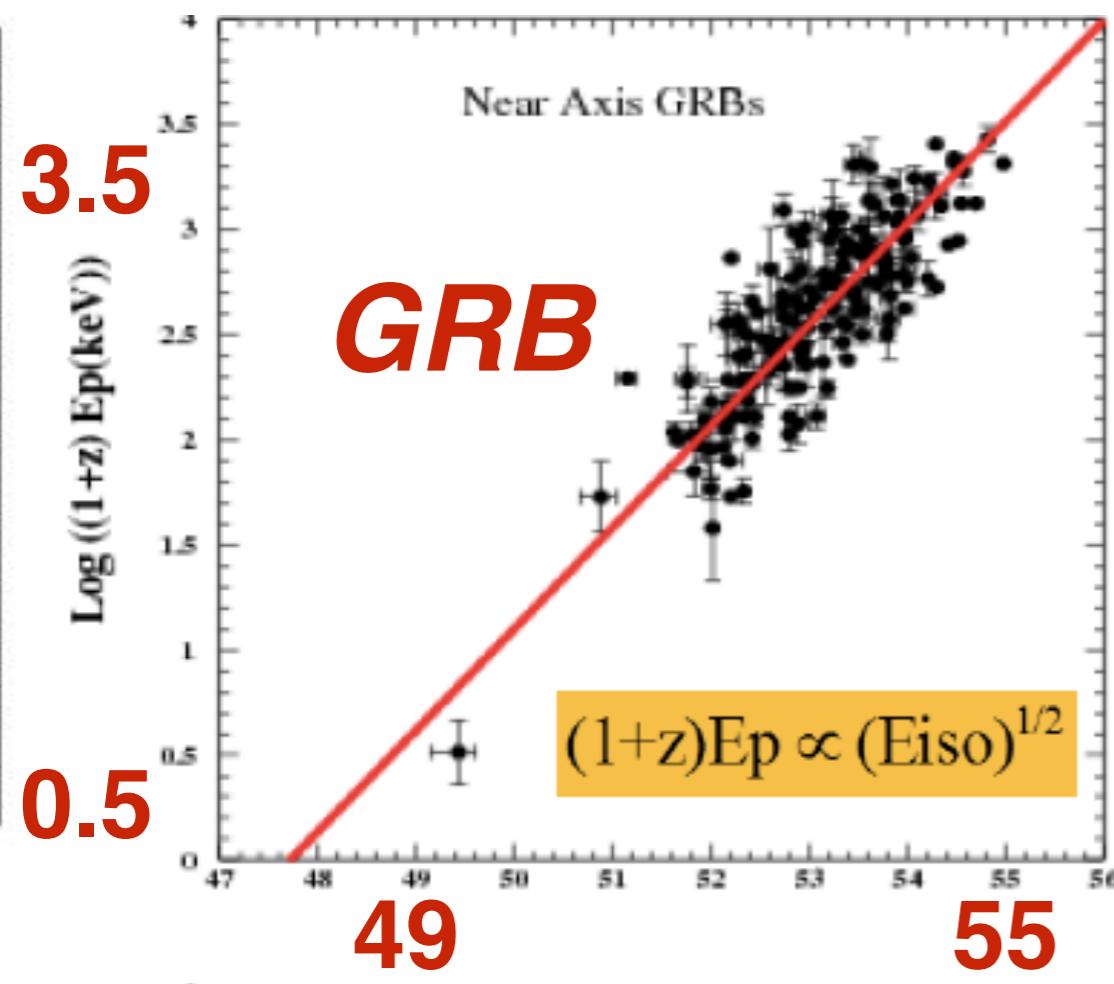
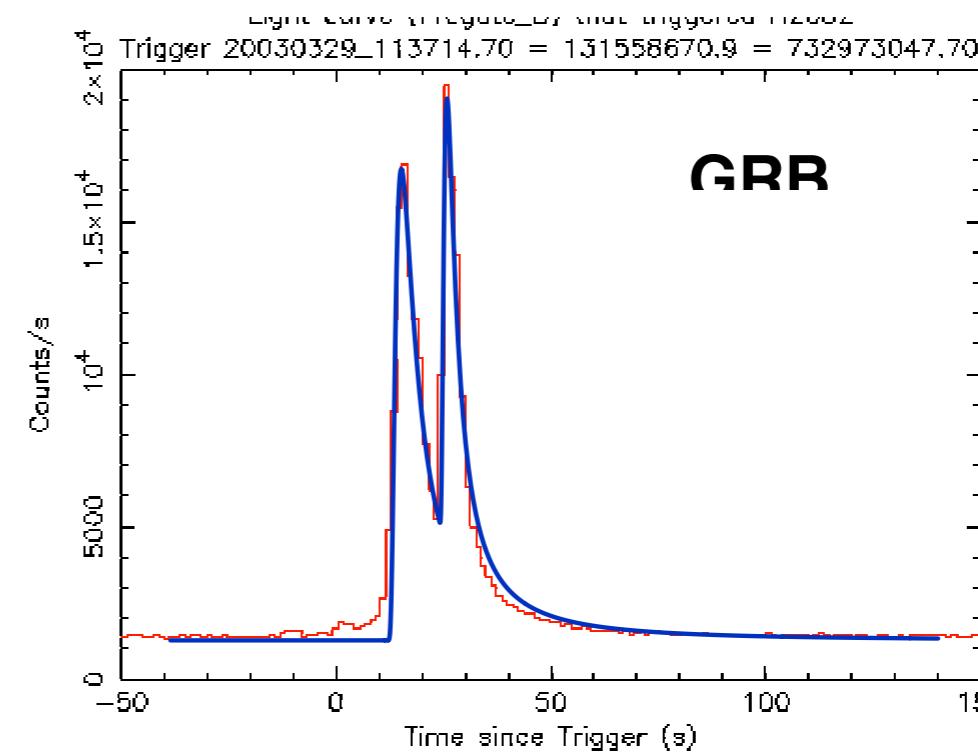
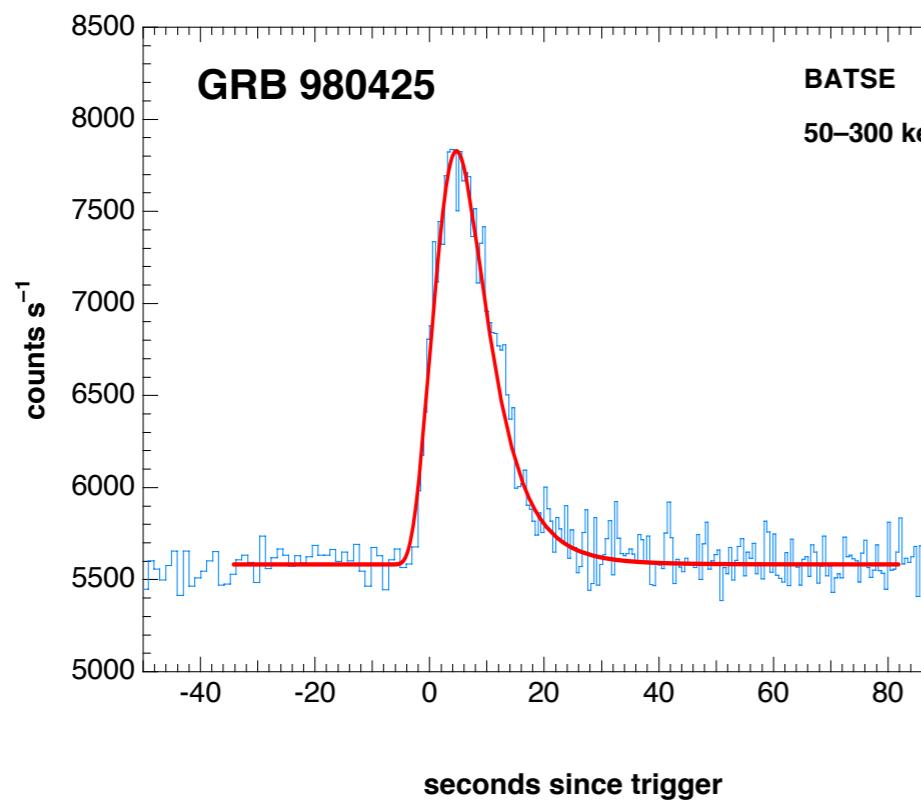
Successful Th of GRBs



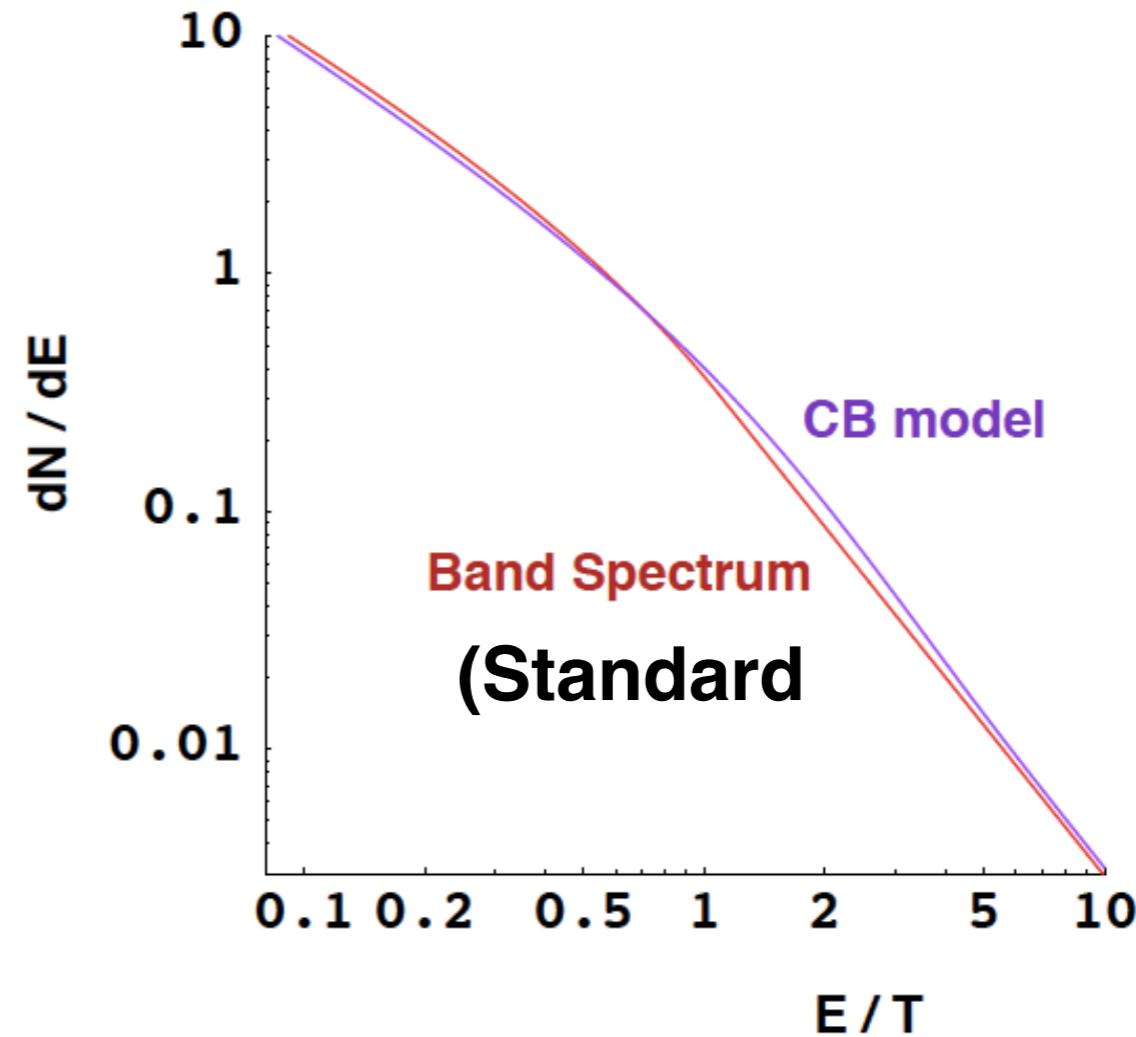
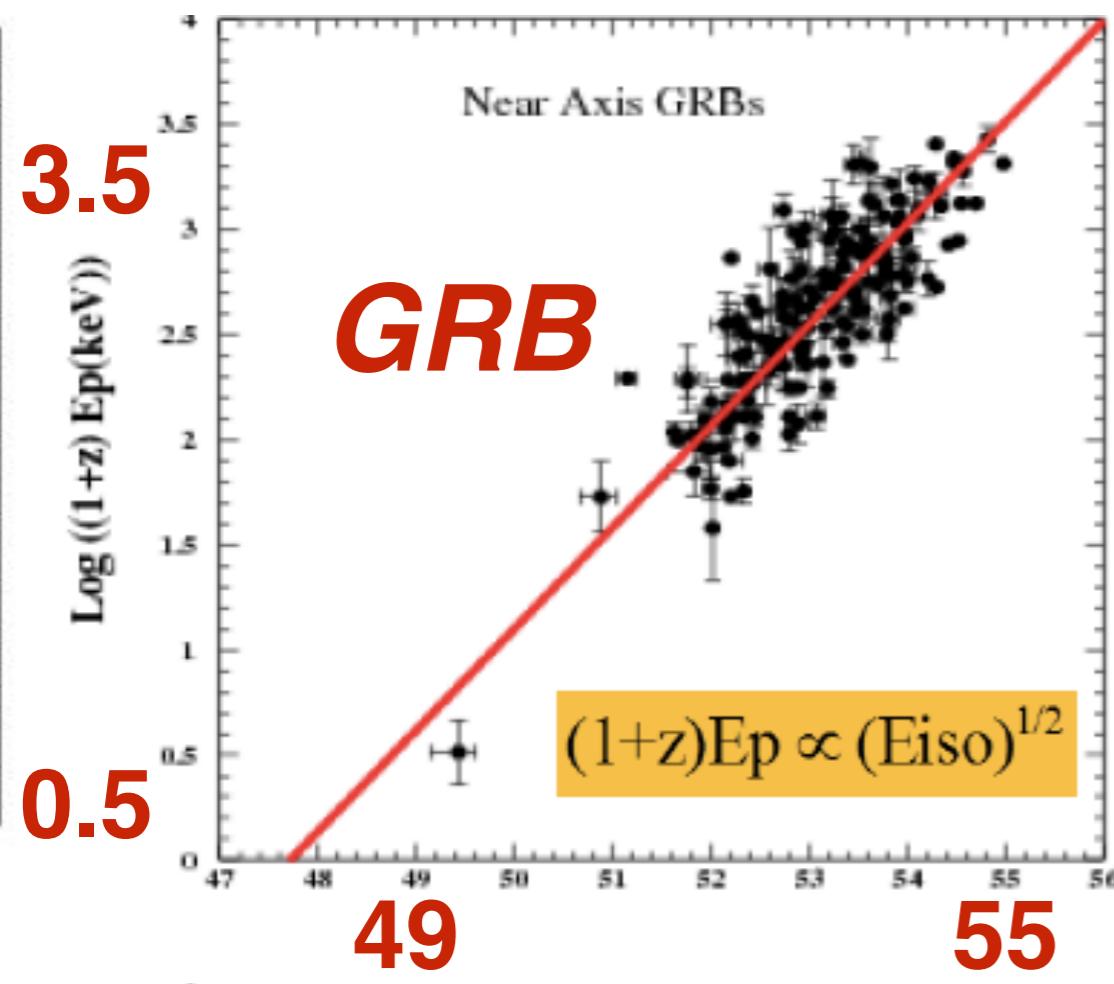
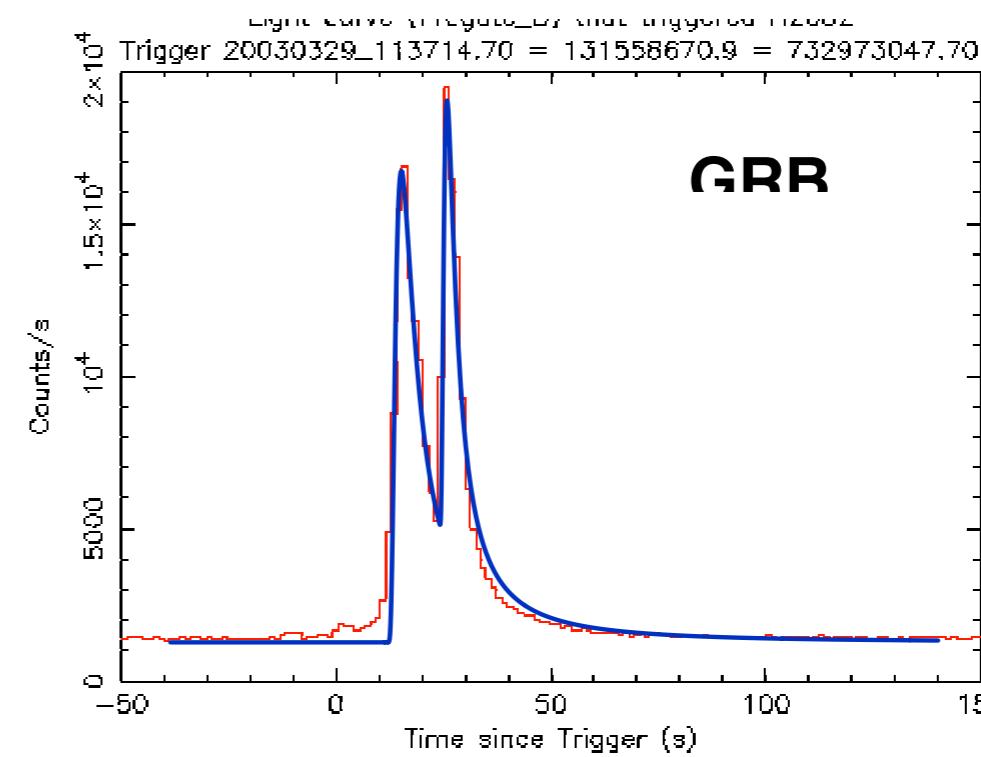
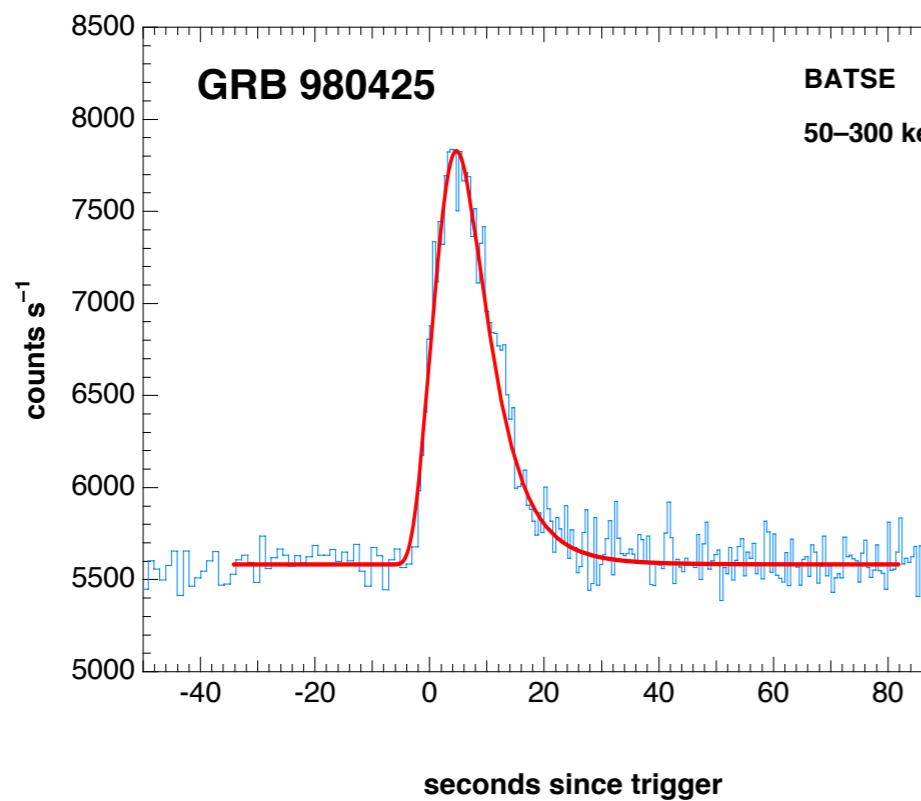
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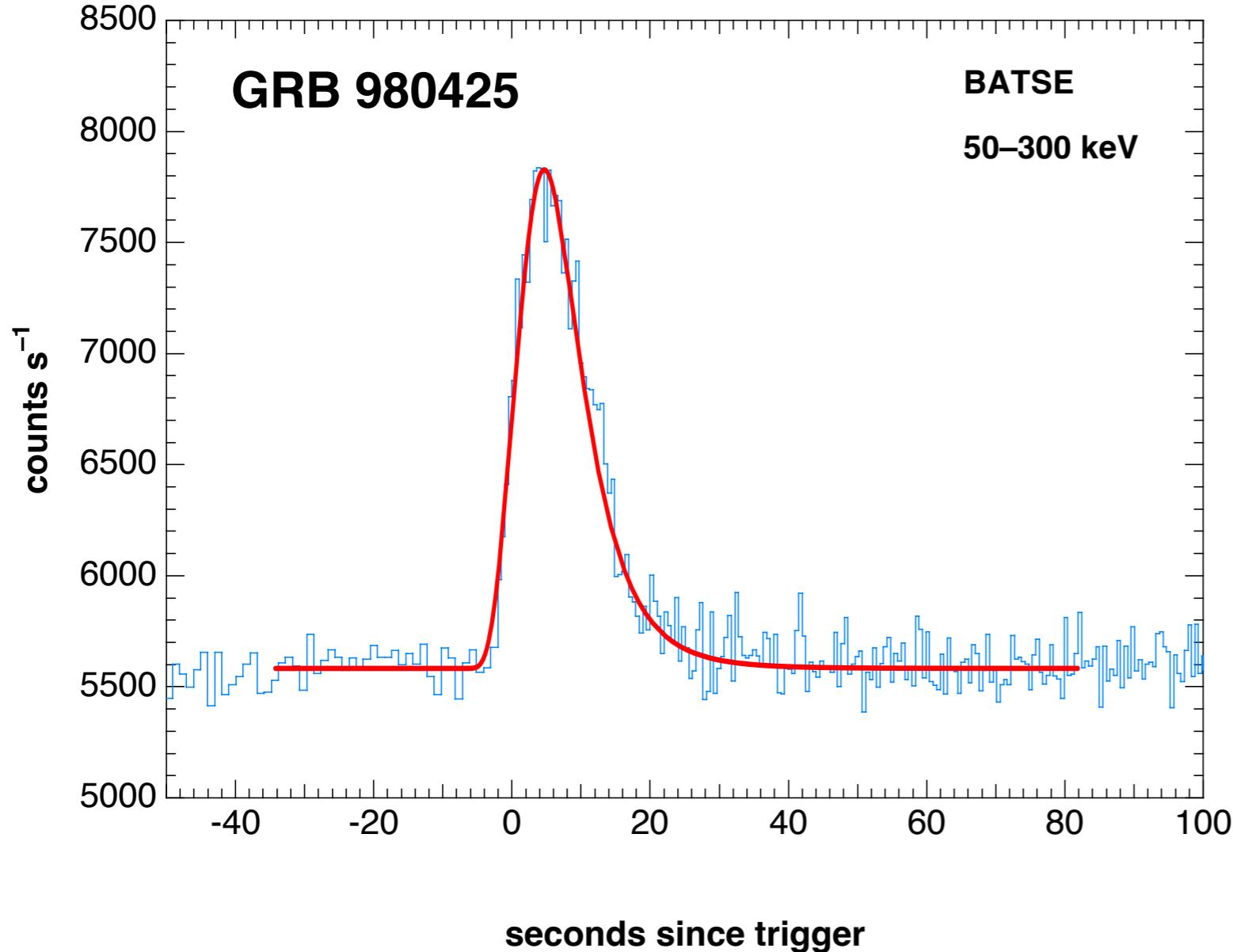


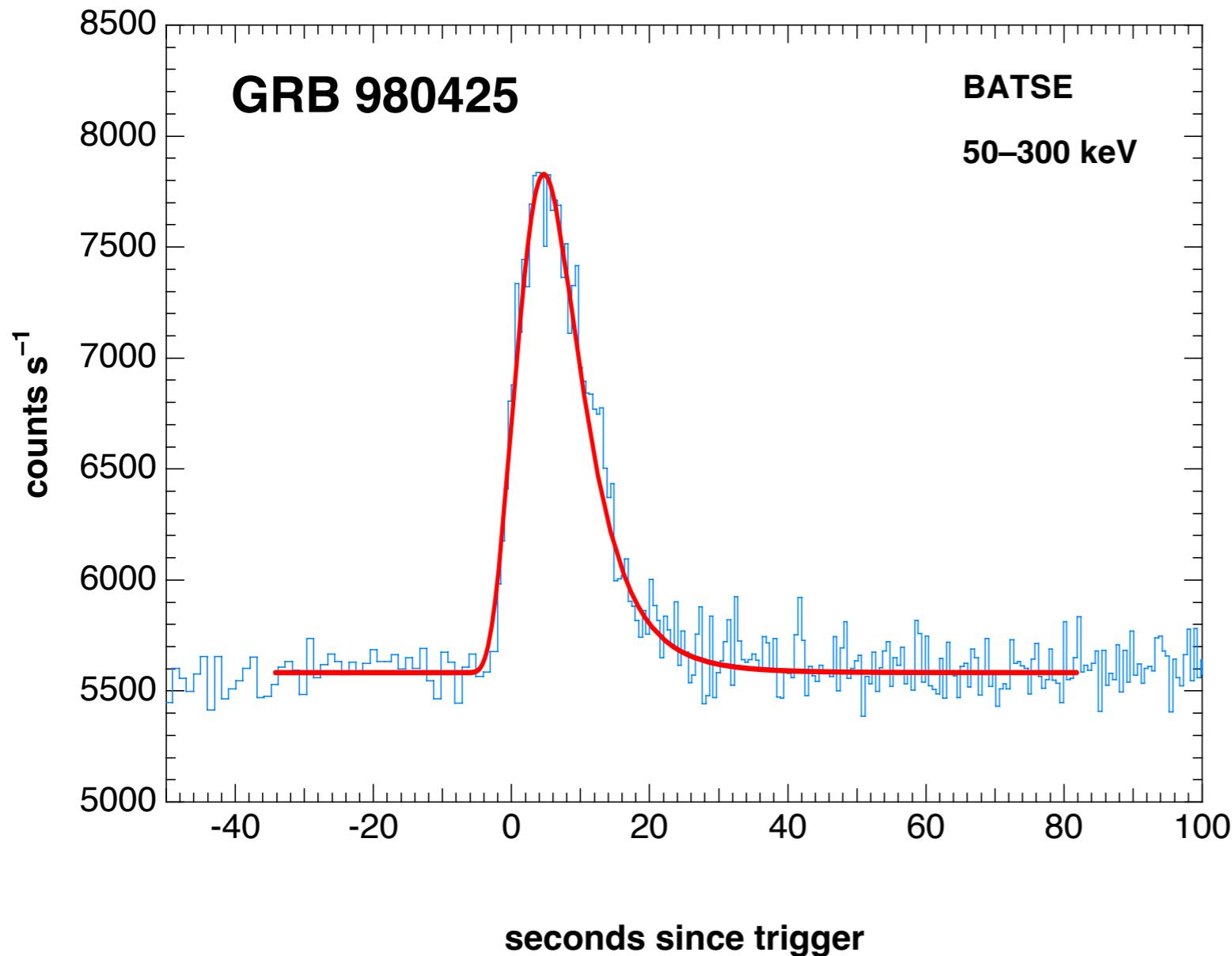
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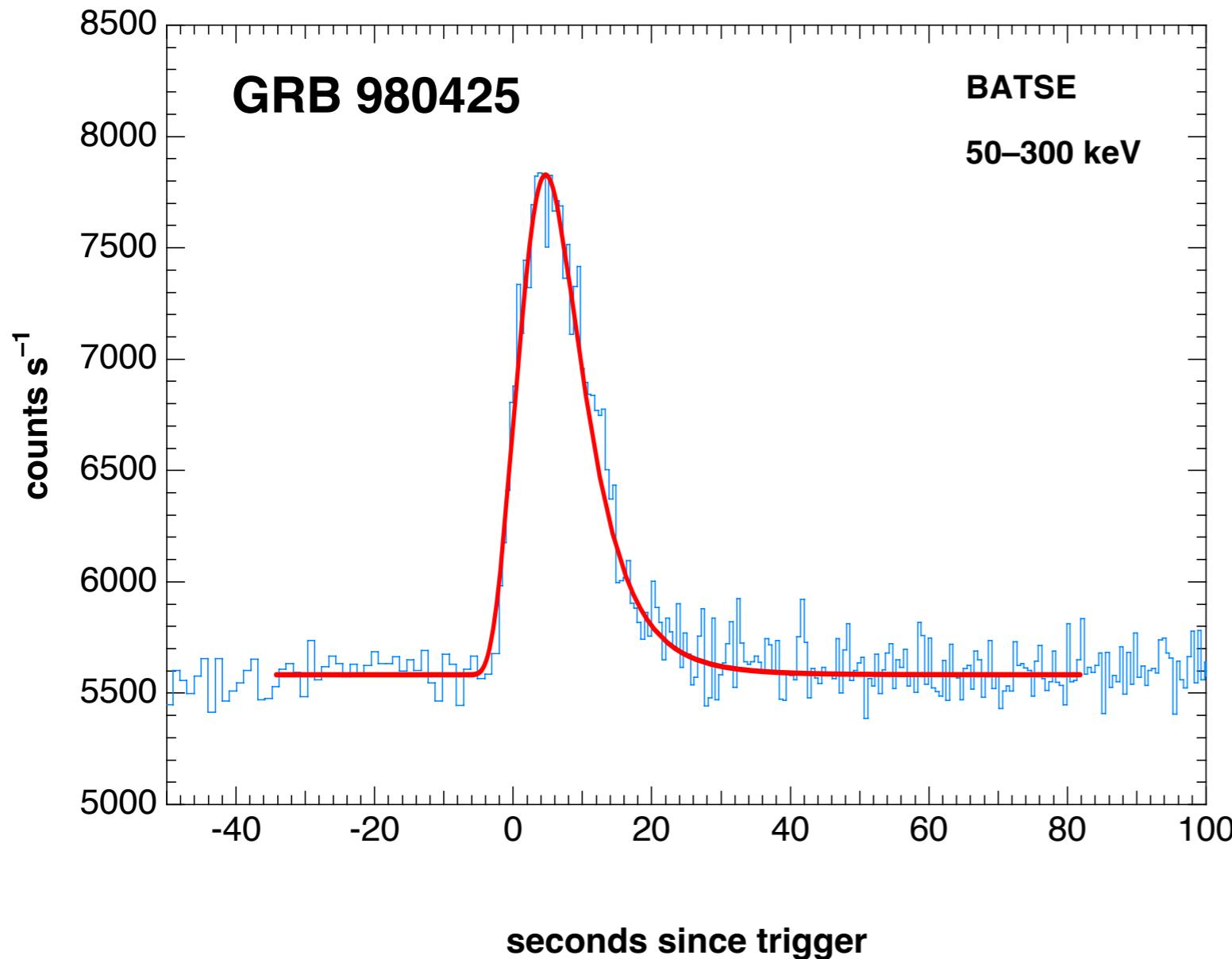
GRB 980425

BATSE
50–300 keV

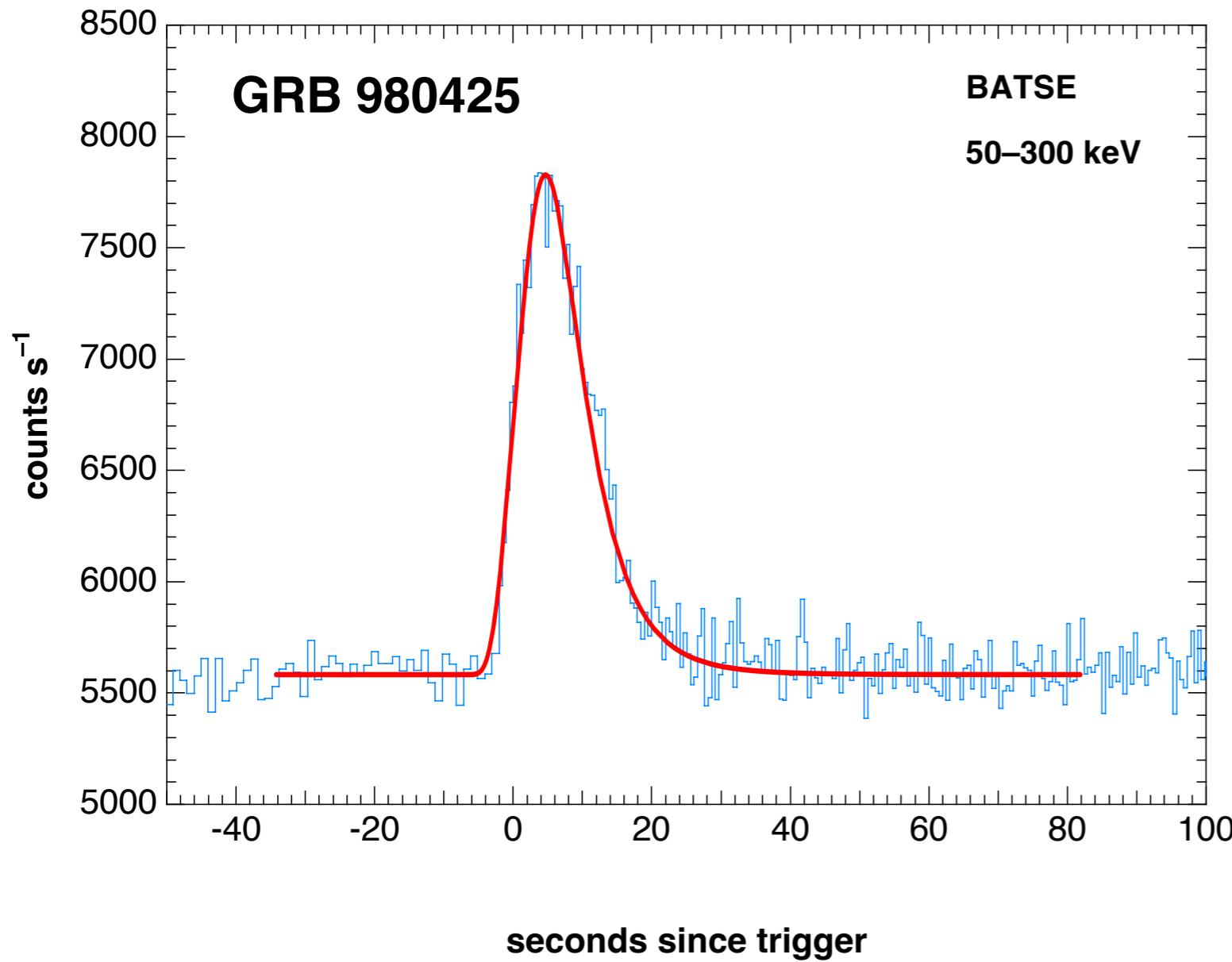




$$E_{\gamma} \sim 250 \text{ MeV}$$



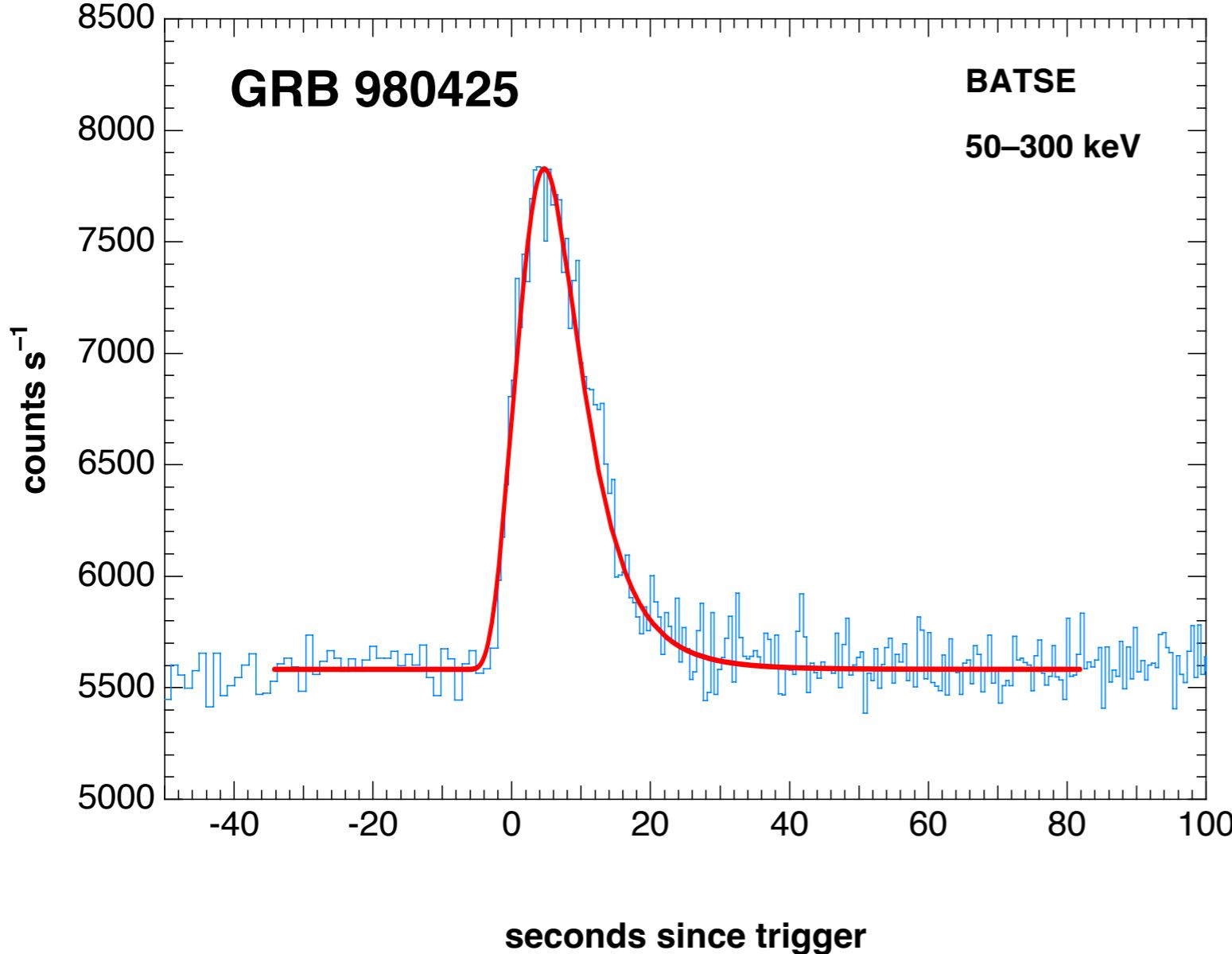
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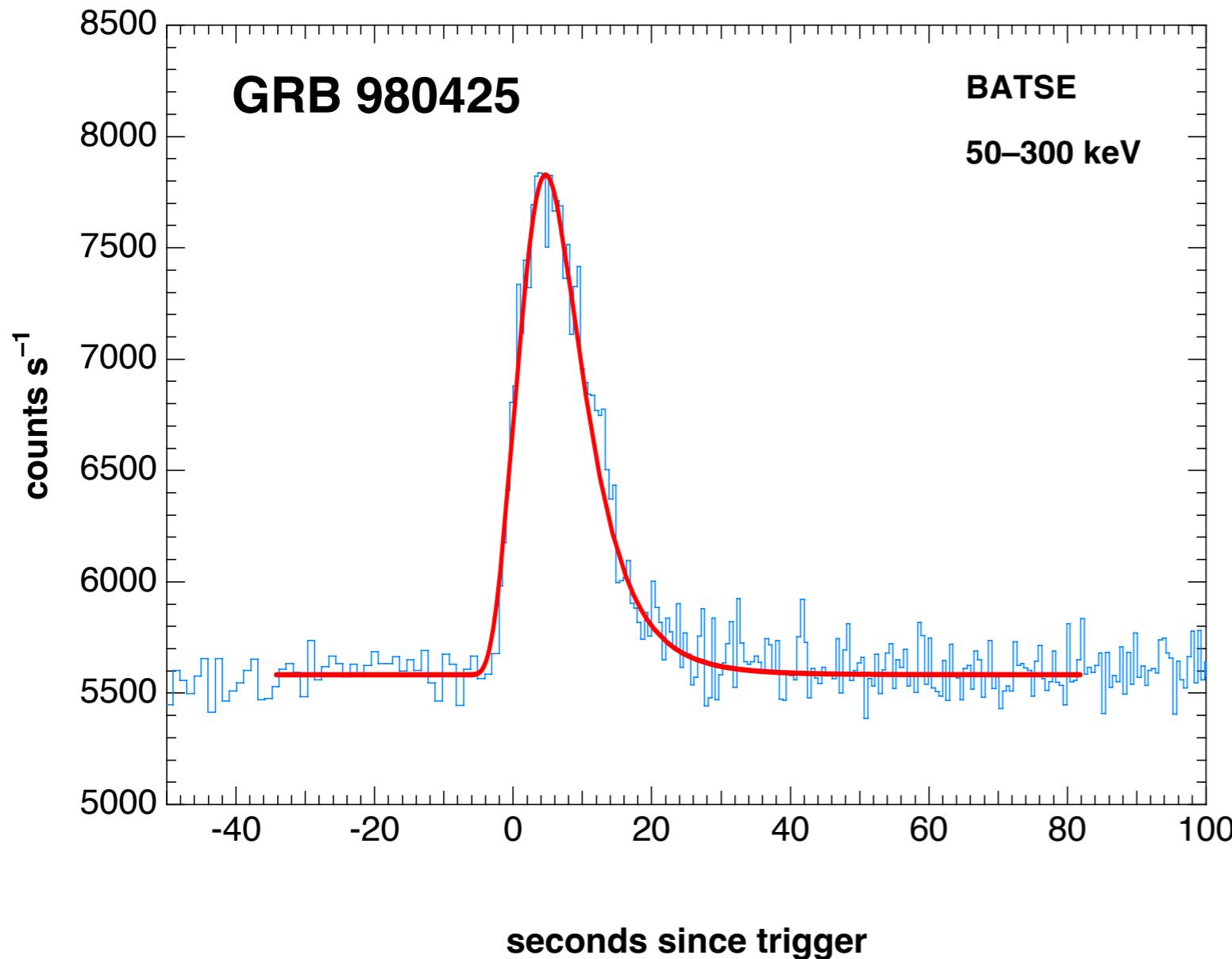


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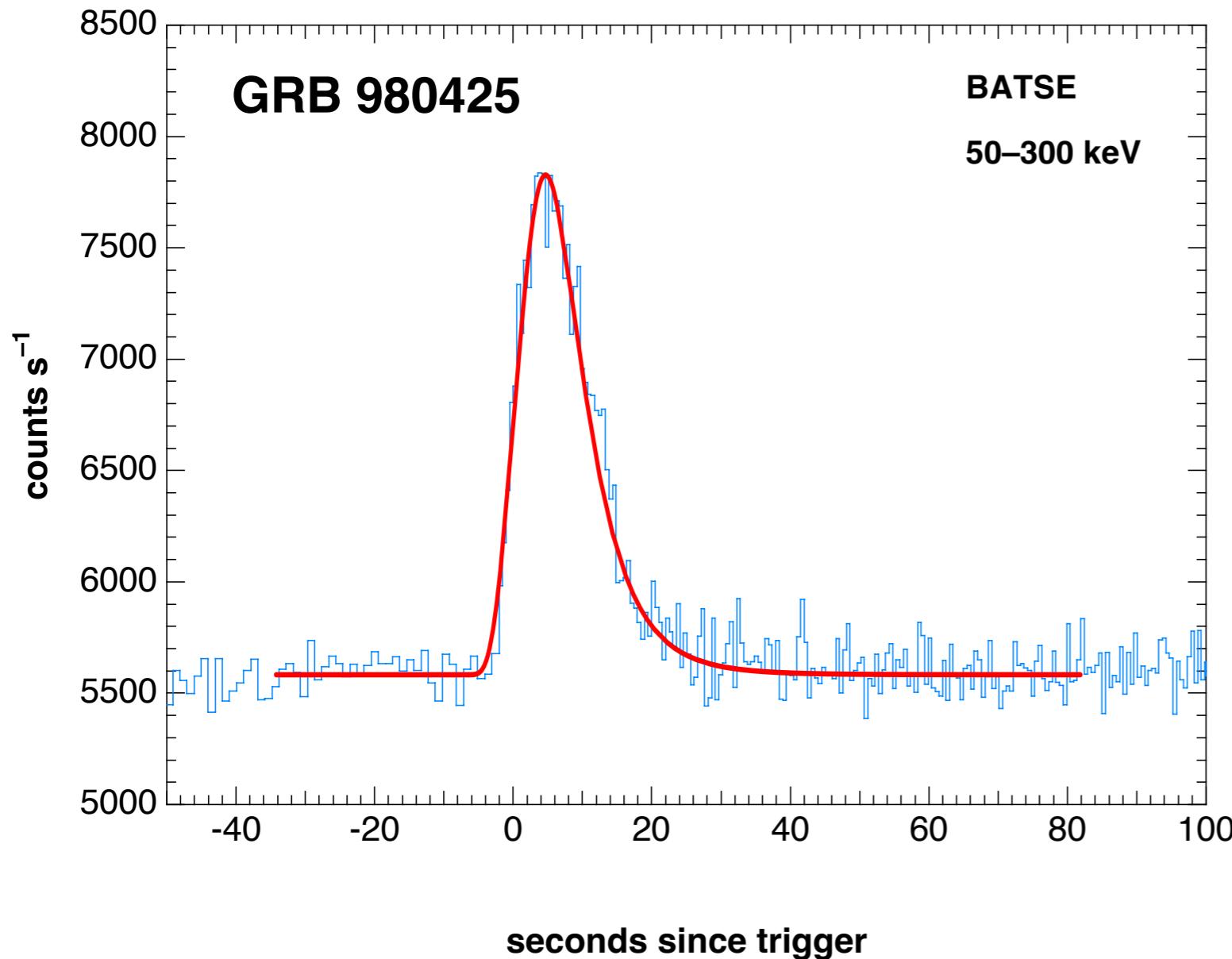


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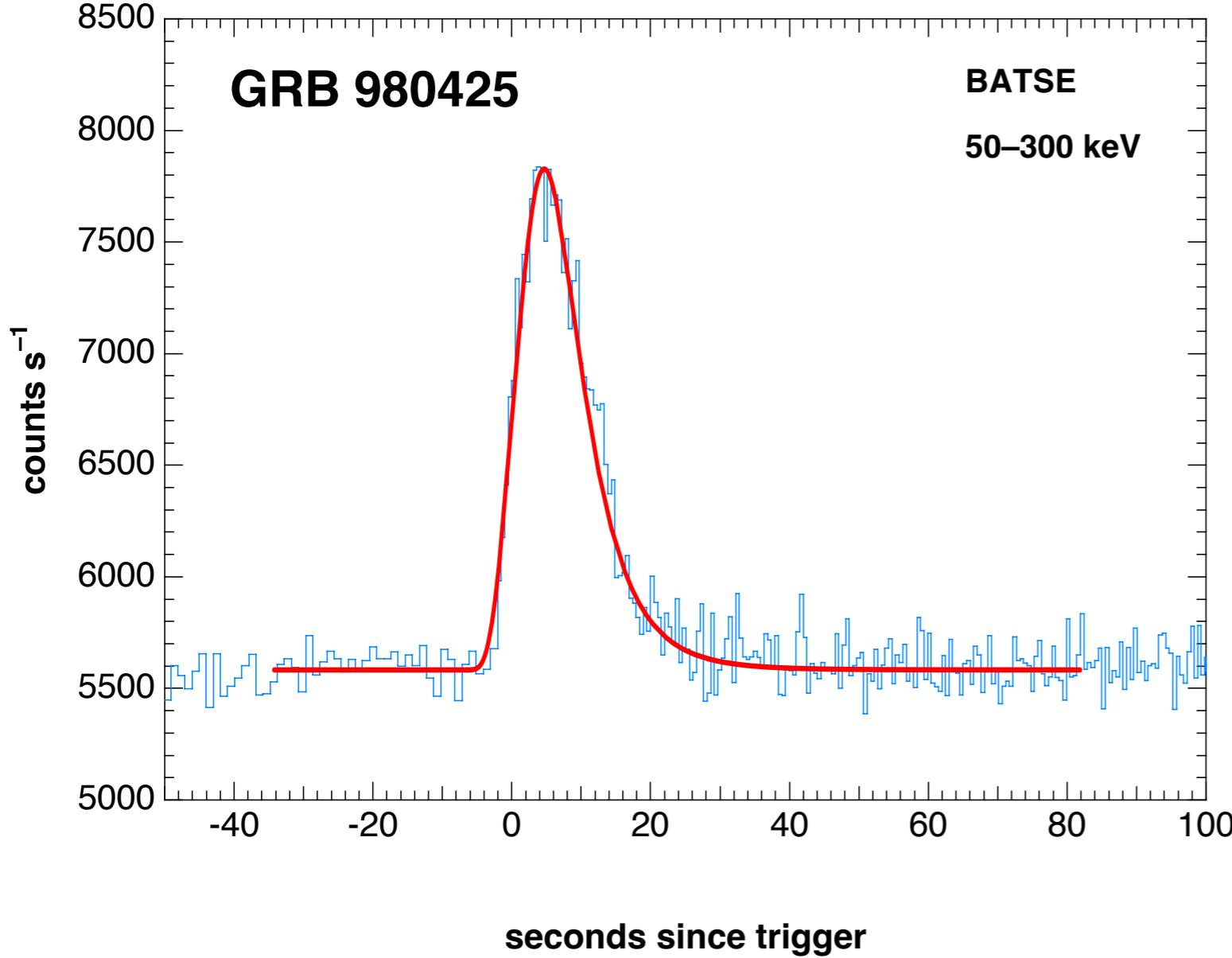


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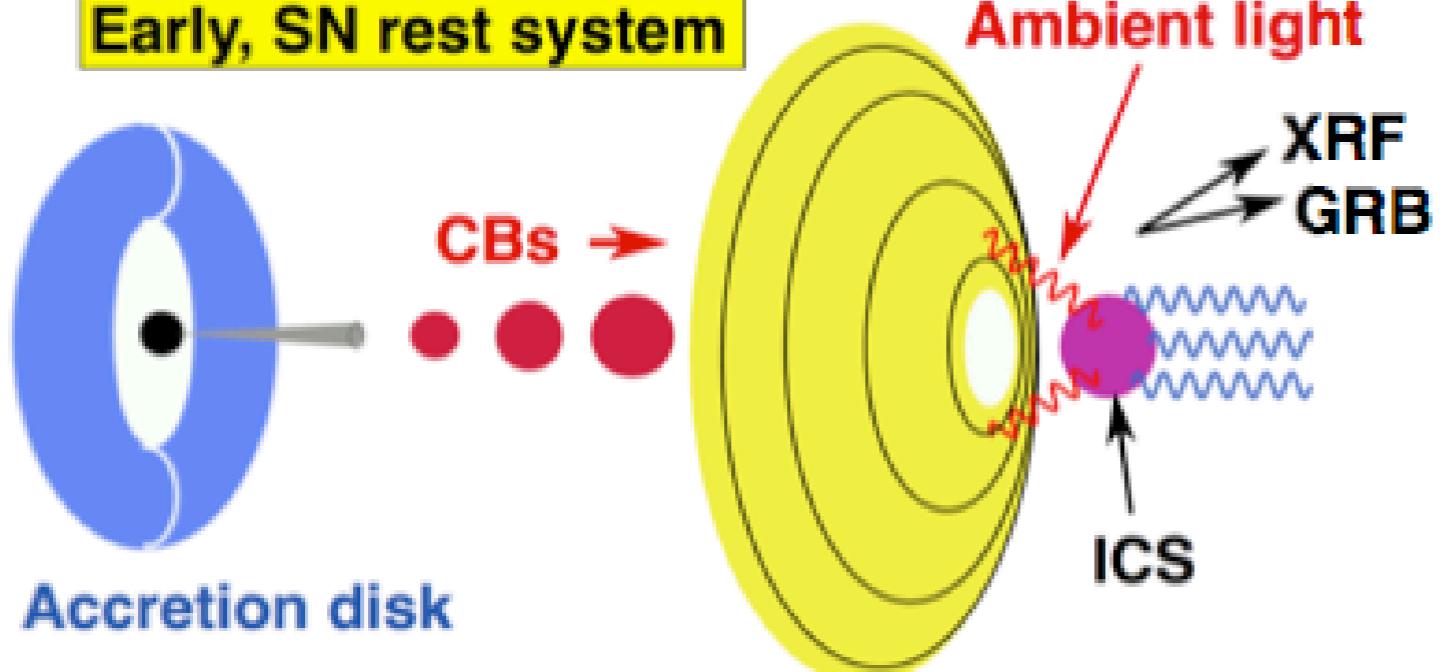
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Cannot be isotropic

Early, SN rest system



Accretion disk

Ambient light

**XRF
GRB**

Late, CB rest system

CR nucleus

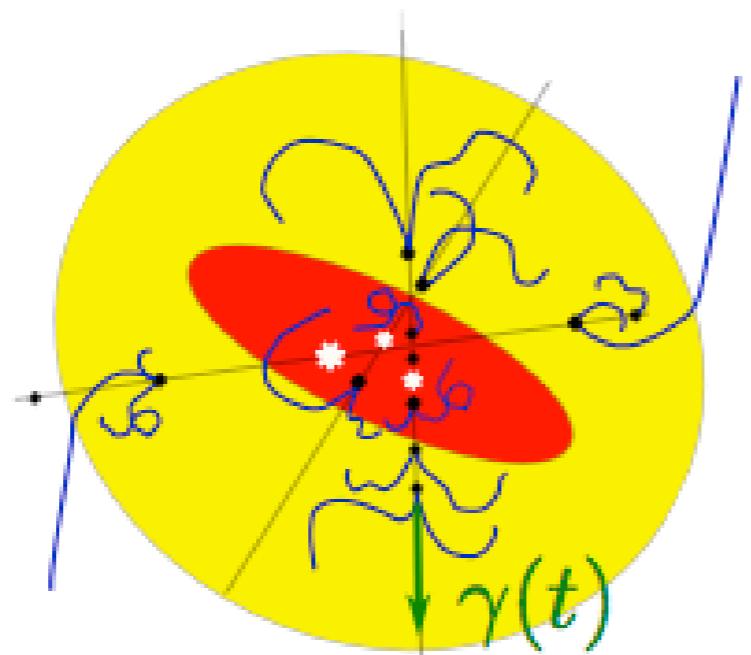
**Synchrotron
Afterglow**

CR electron

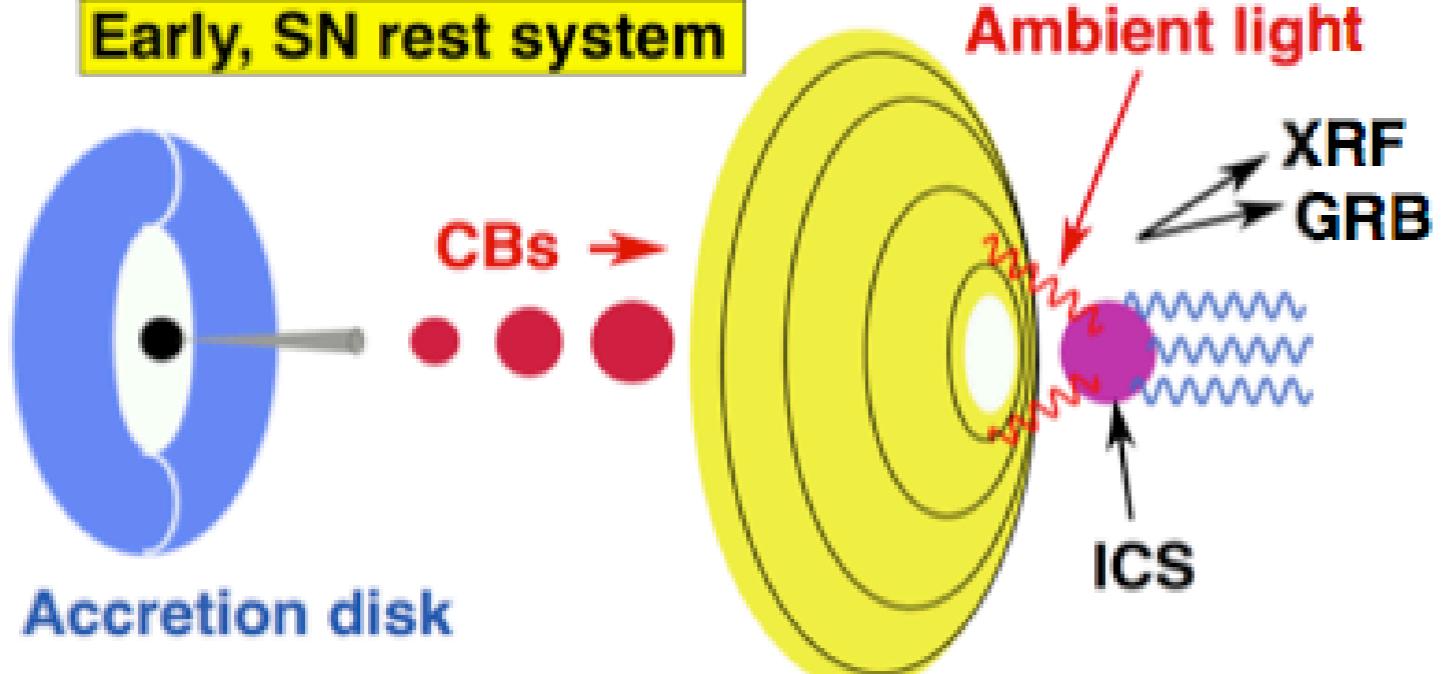
ISM electron

ISM nucleus

**Late, SN
rest-system**



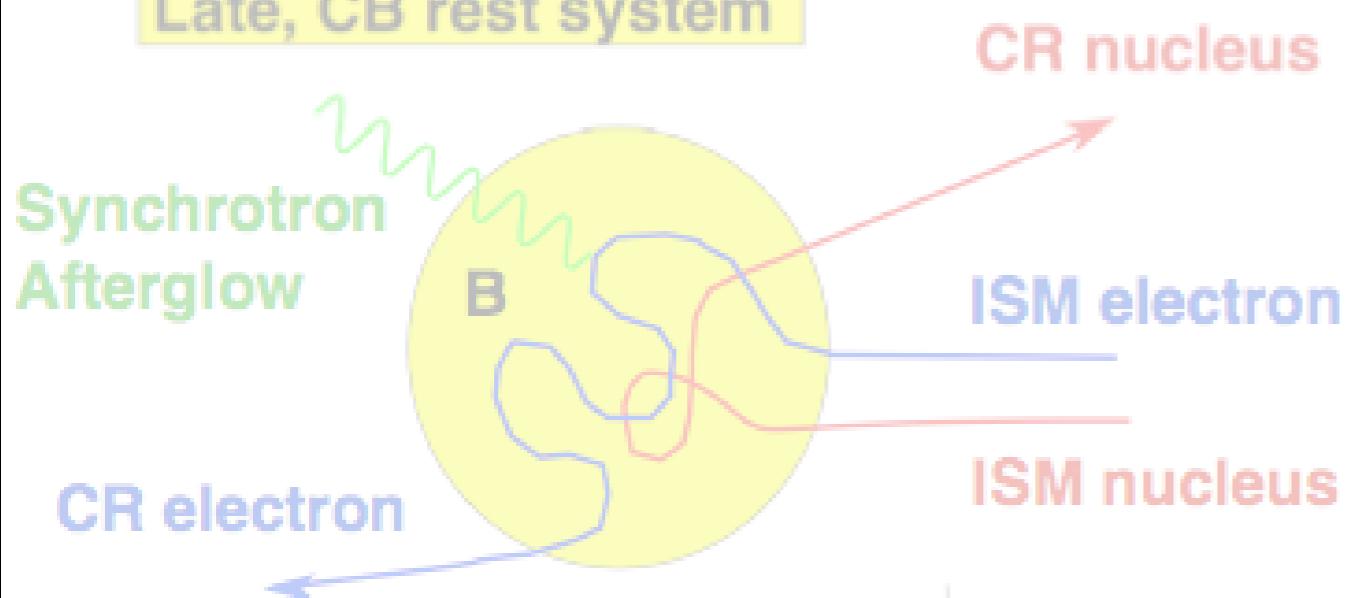
Early, SN rest system



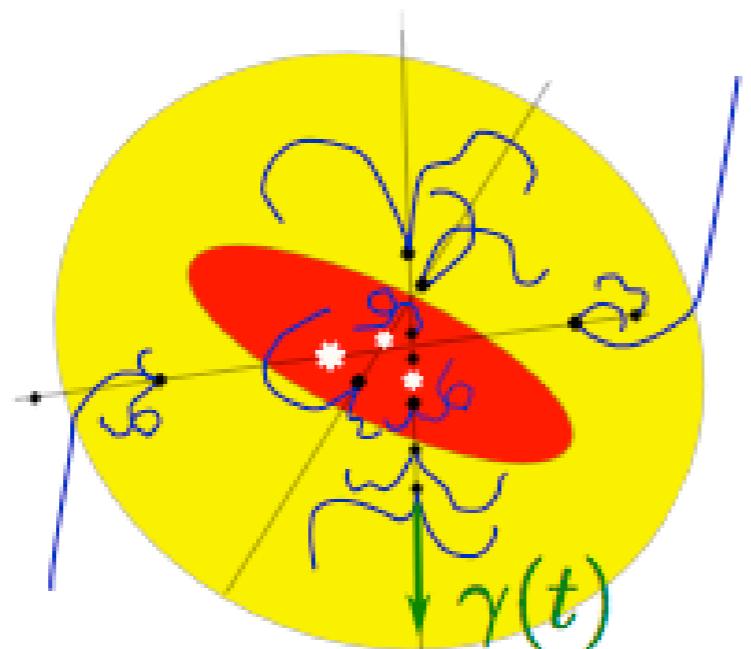
Accretion disk

GRBs and XRFs are emitted by core-collapse SNe (Type Ia)

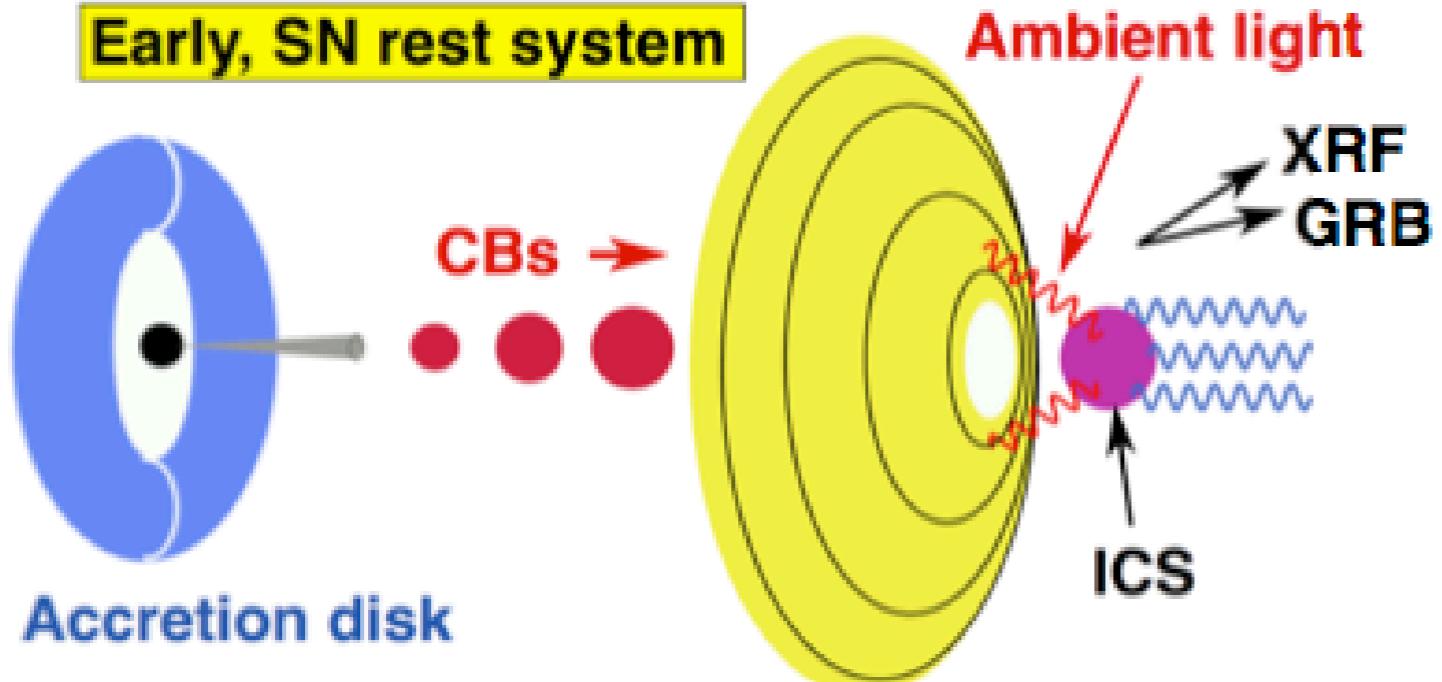
Late, CB rest system



Late, SN
rest-system



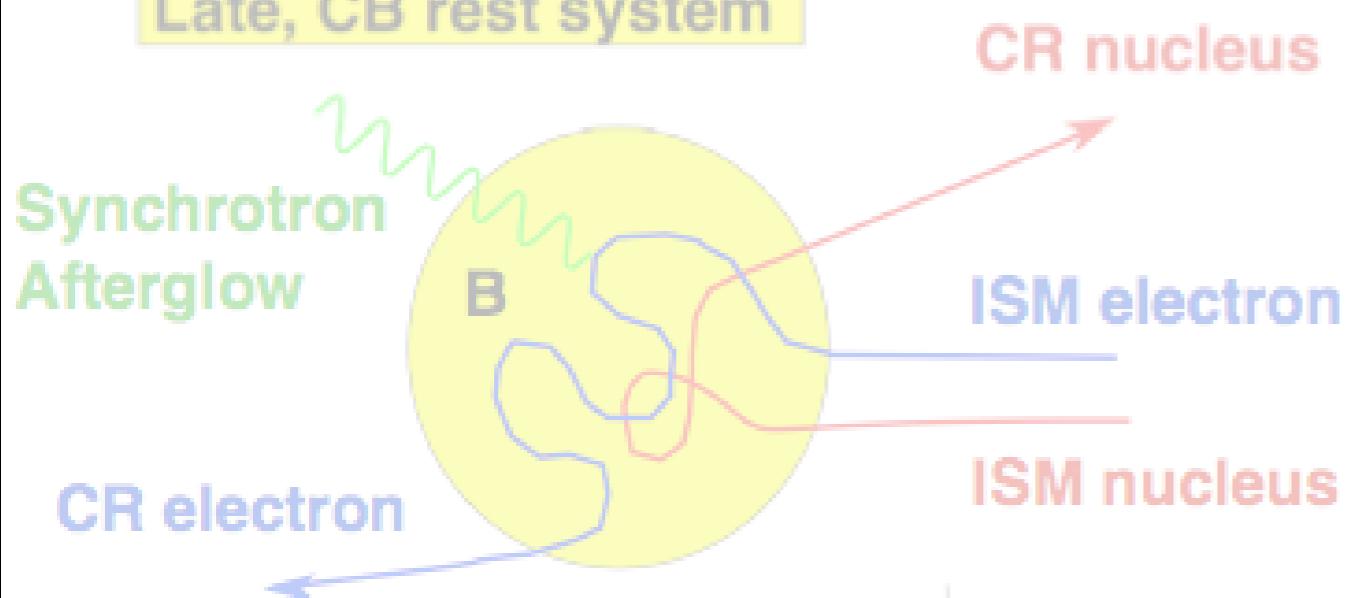
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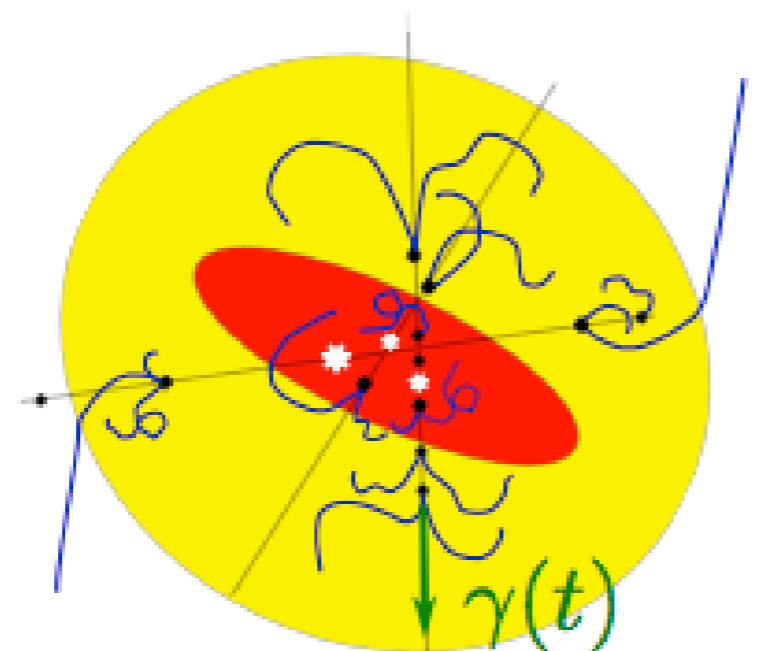
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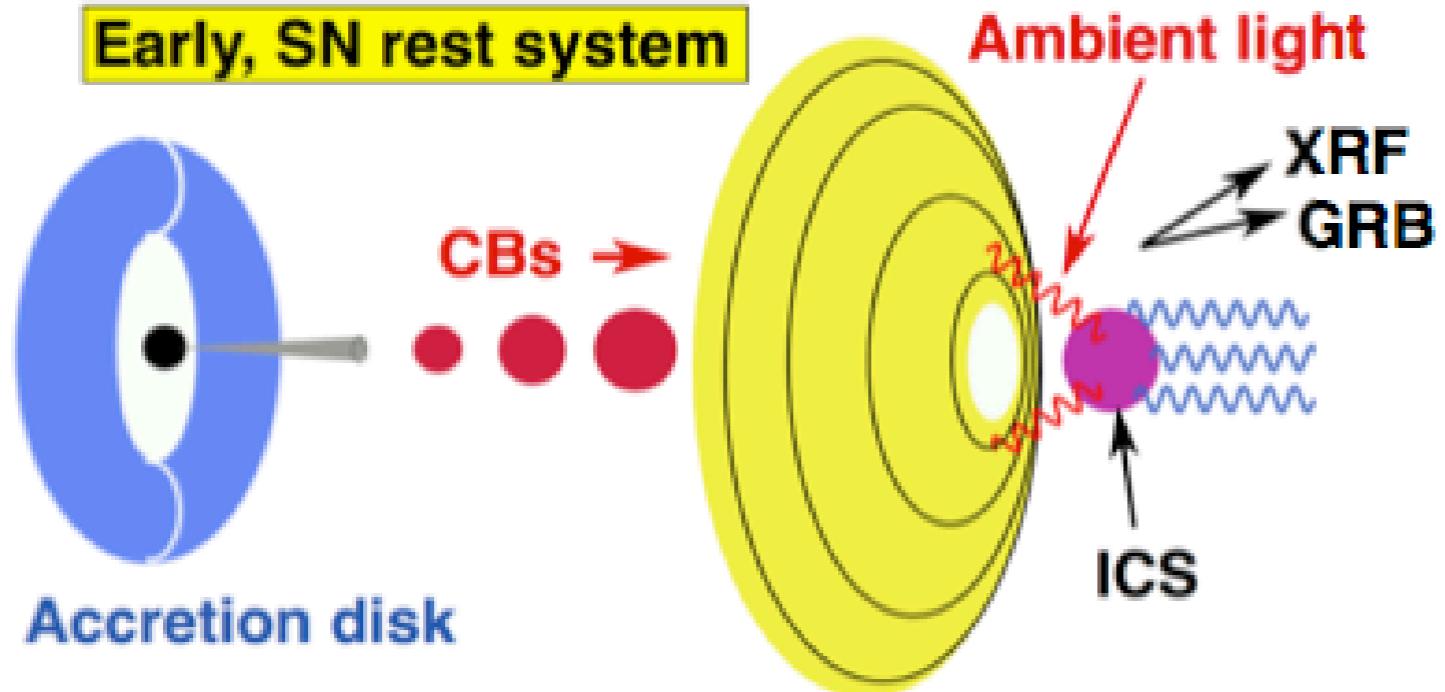


Late, SN
rest-system



CBs decelerate as they travel in galaxy & halo

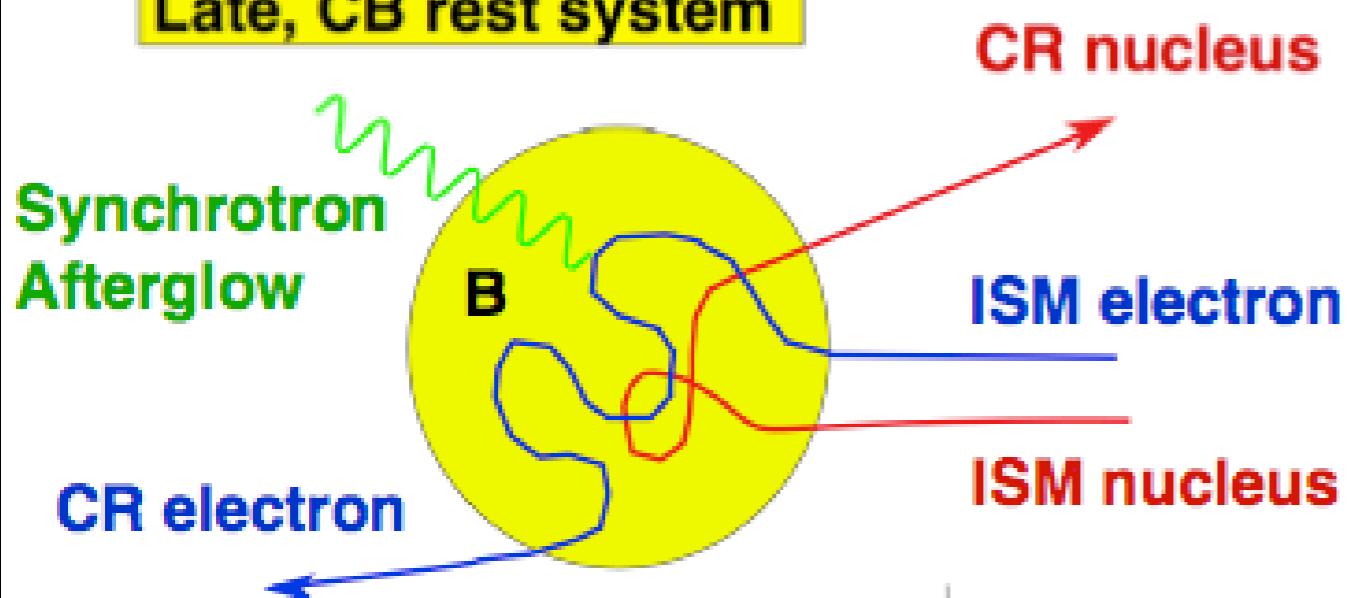
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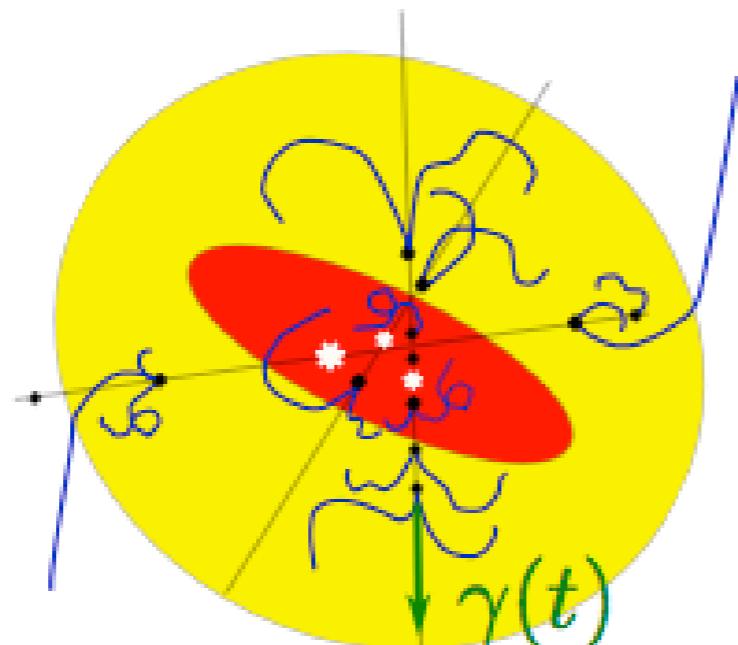
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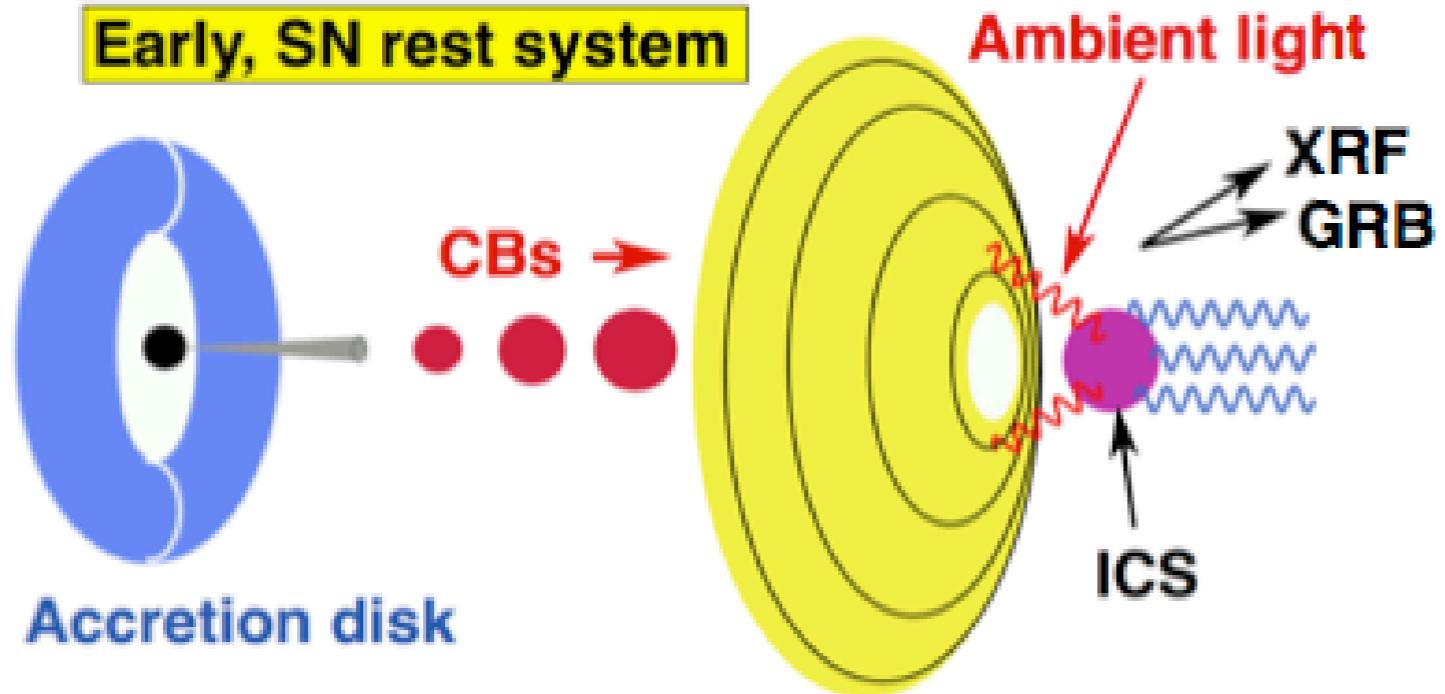


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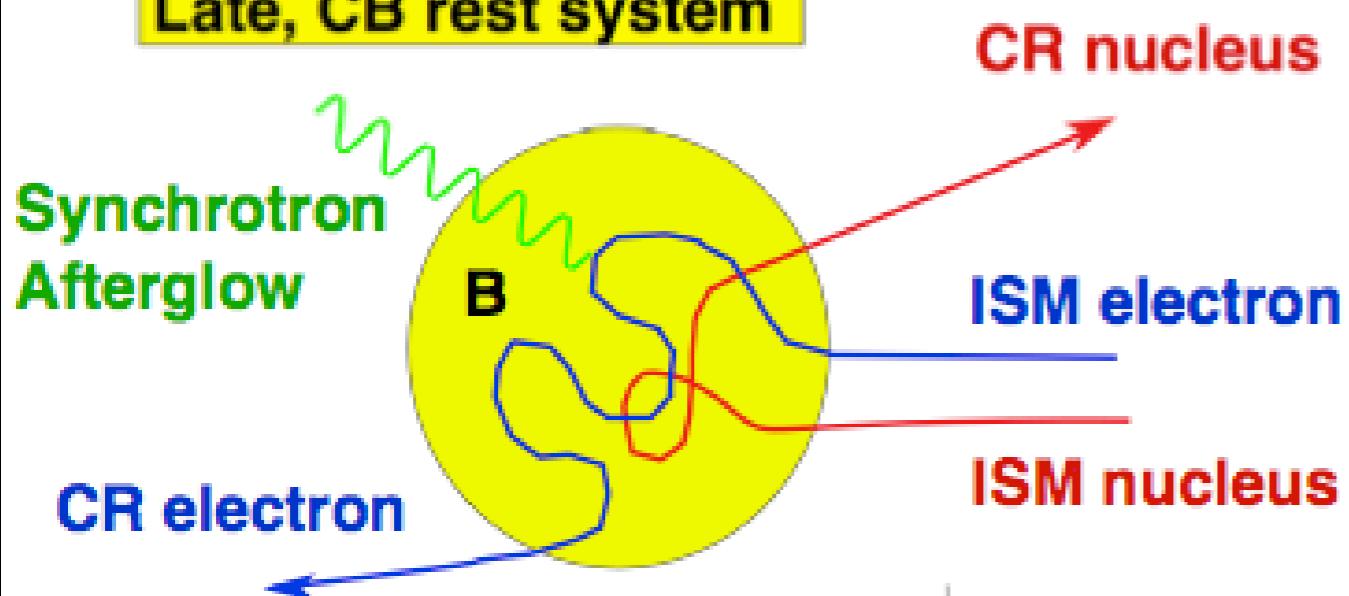


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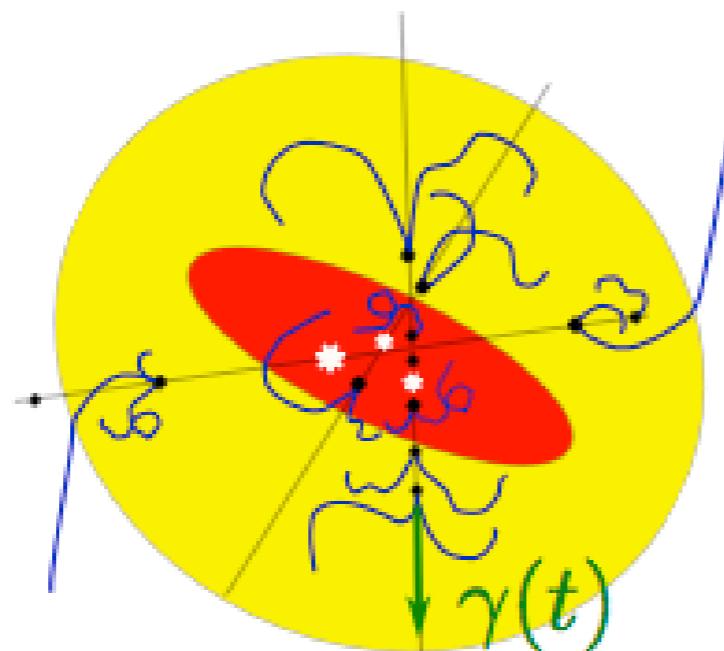
CBs (made of ionized

ordinary matter)
scatter ISM ions & electrons → CRs

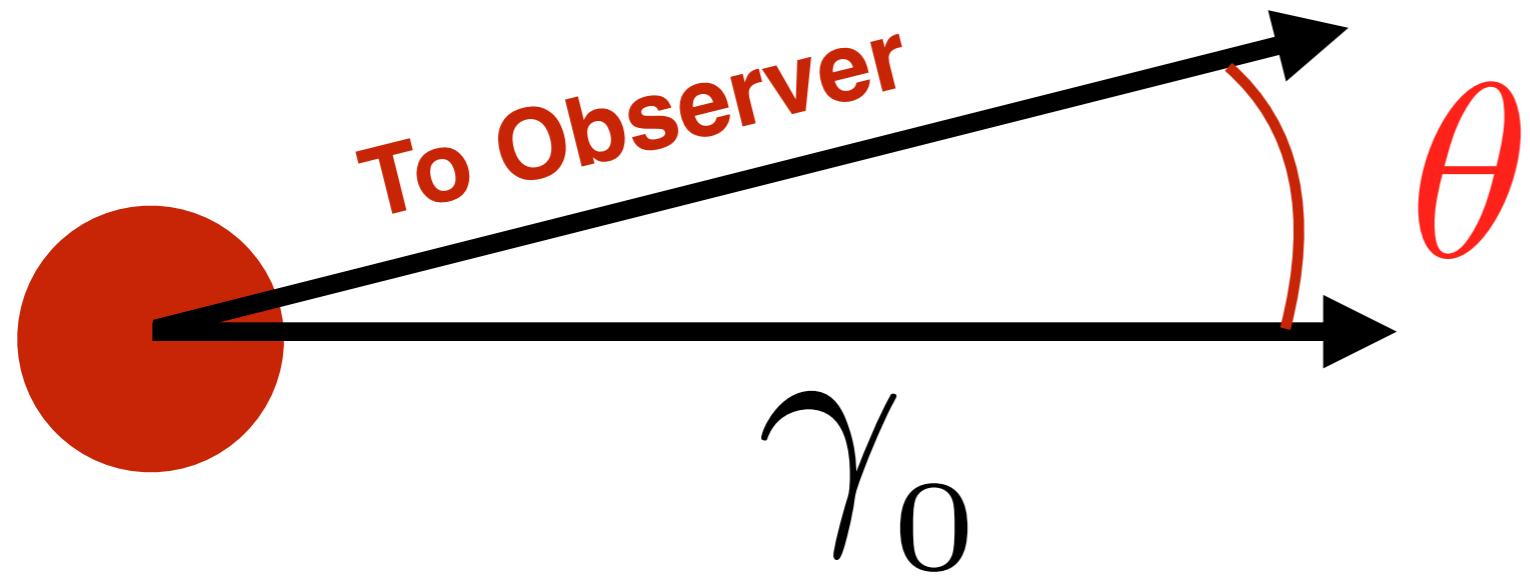
Late, CB rest system



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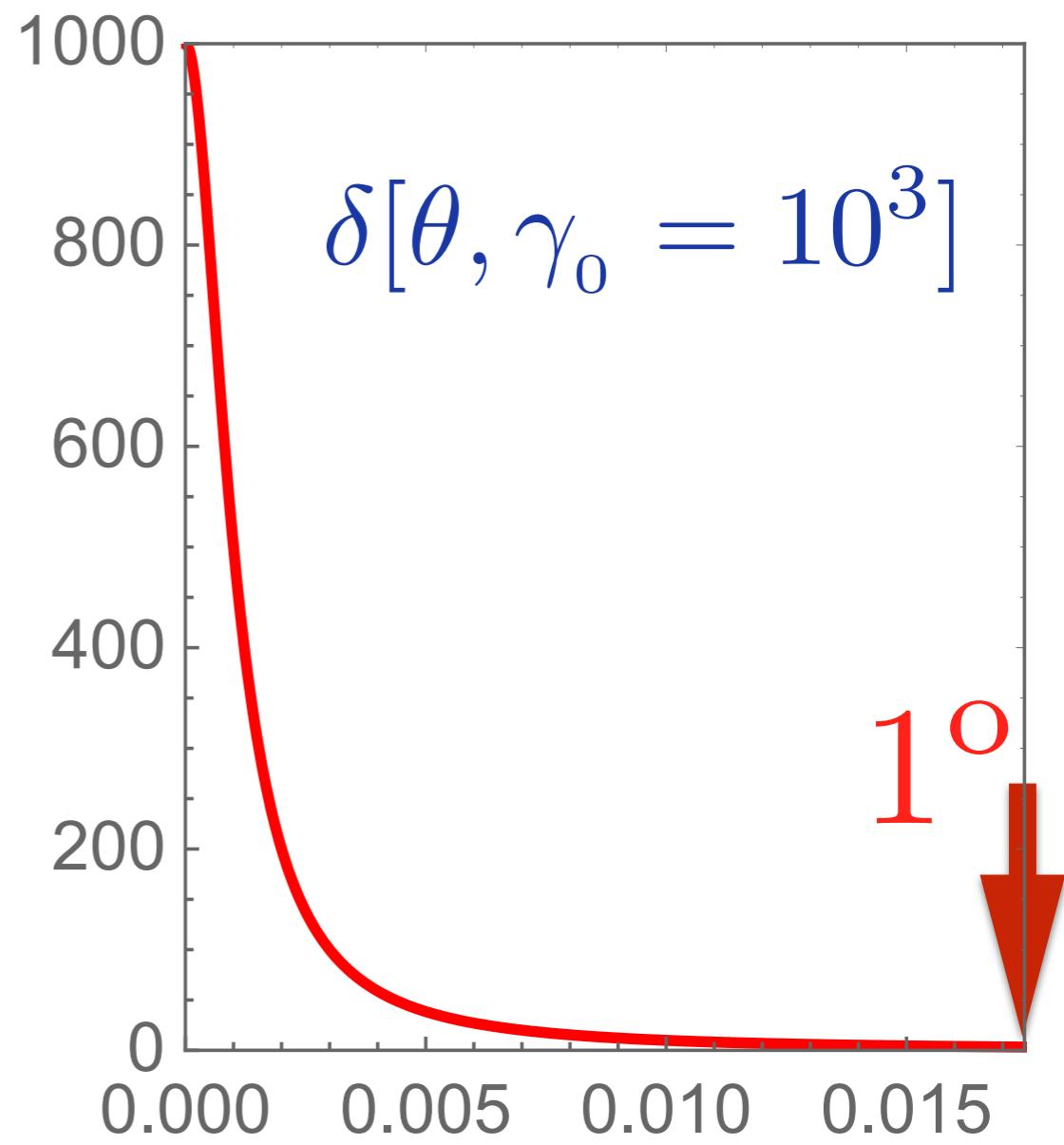


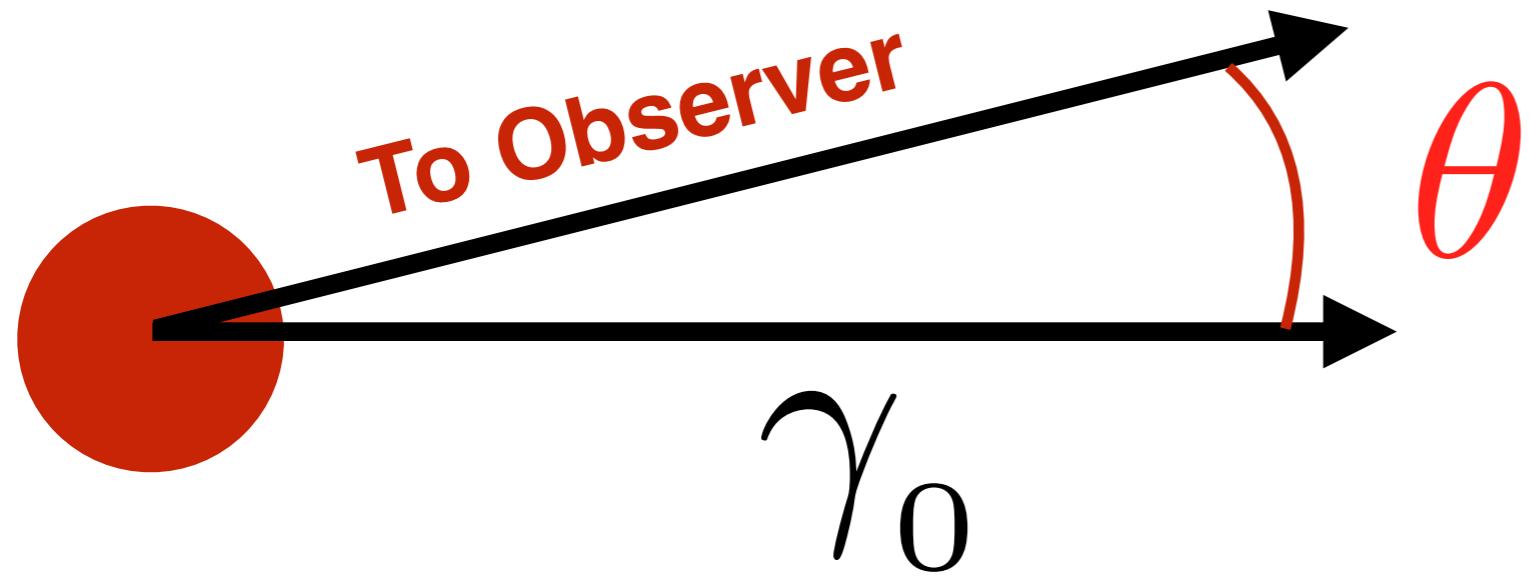
$$\gamma_0 \gg 1$$

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$$\delta \approx \frac{2\gamma}{1 + \gamma_0^2 \theta^2}$$

$$\frac{dn}{d\Omega_{\text{OBS}}} = \delta^2 \frac{dn}{d\Omega_{\text{CB}}}$$



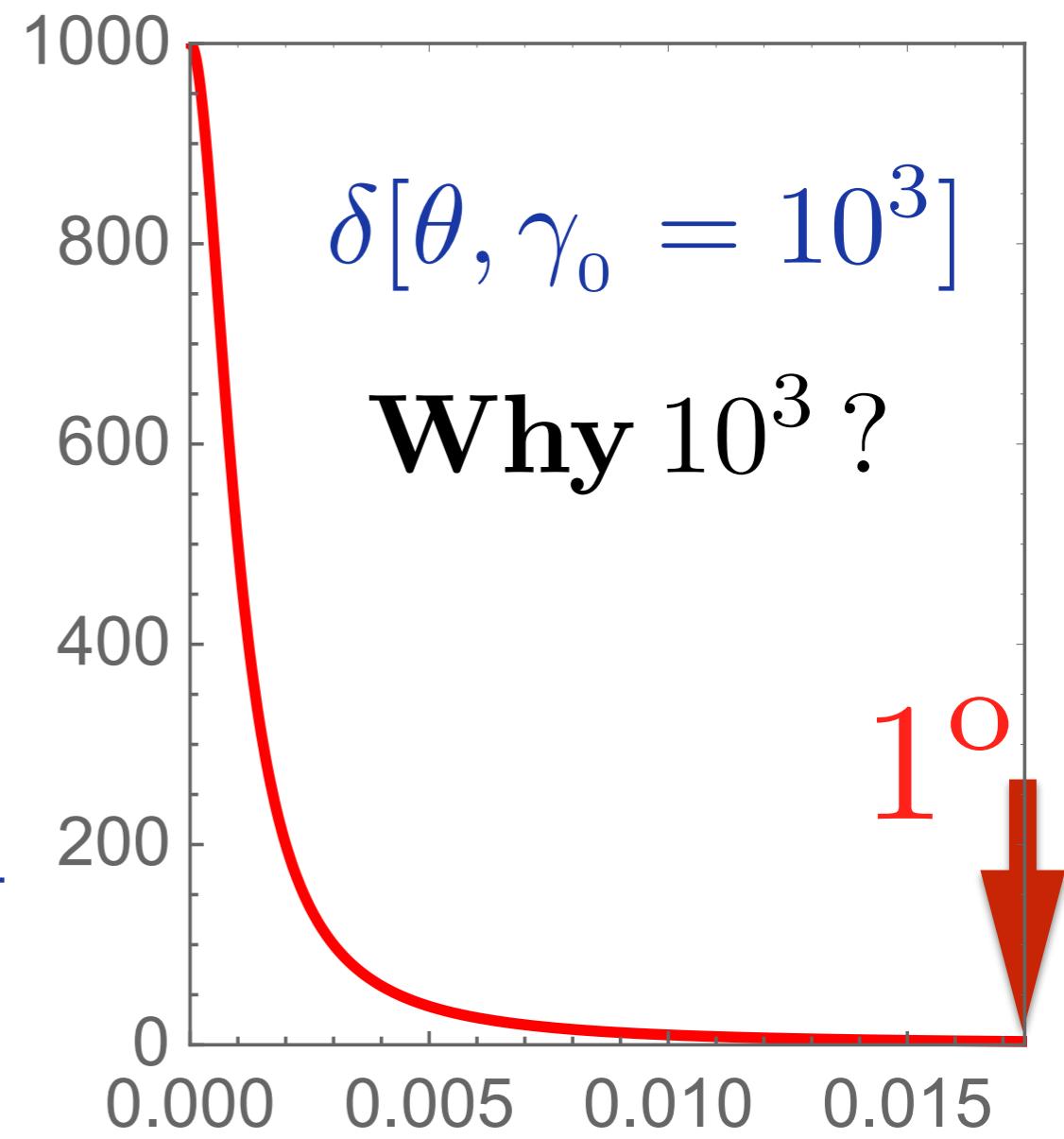


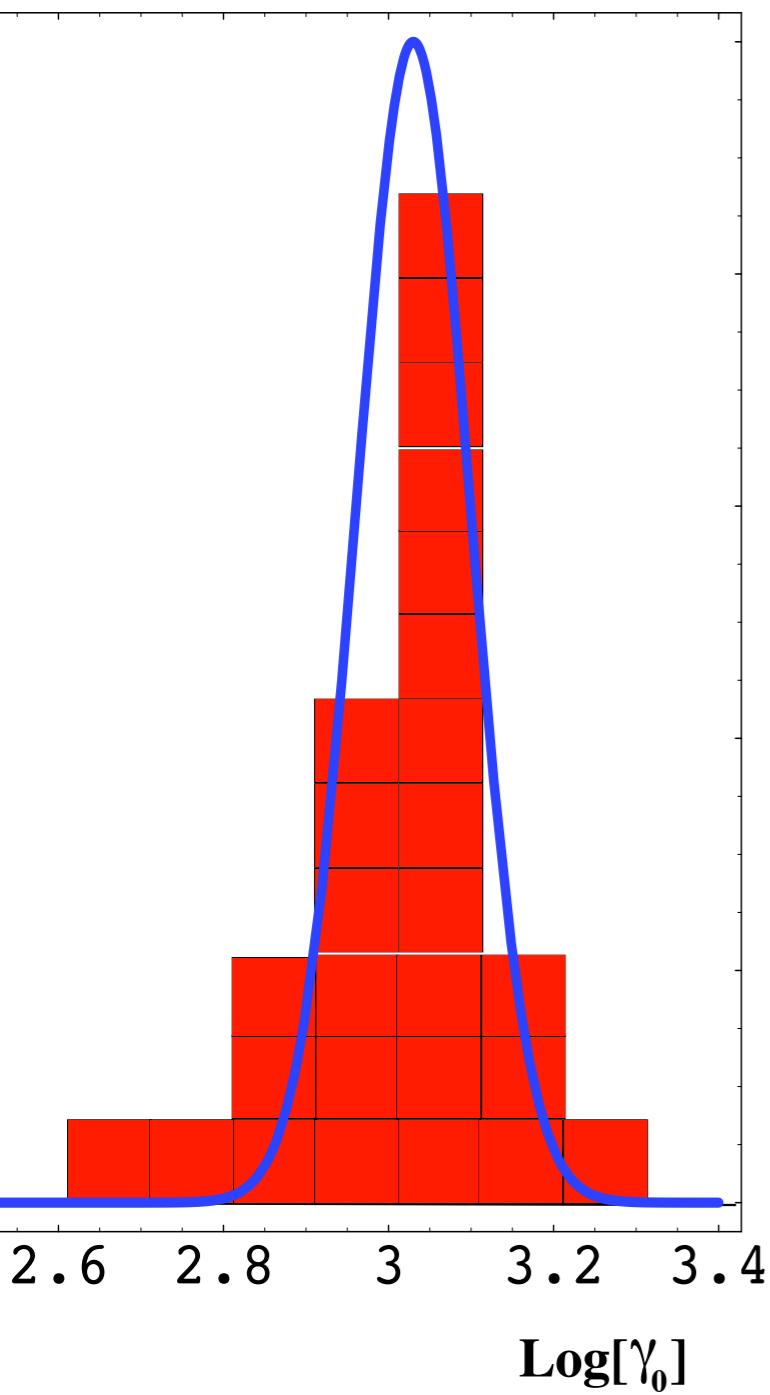
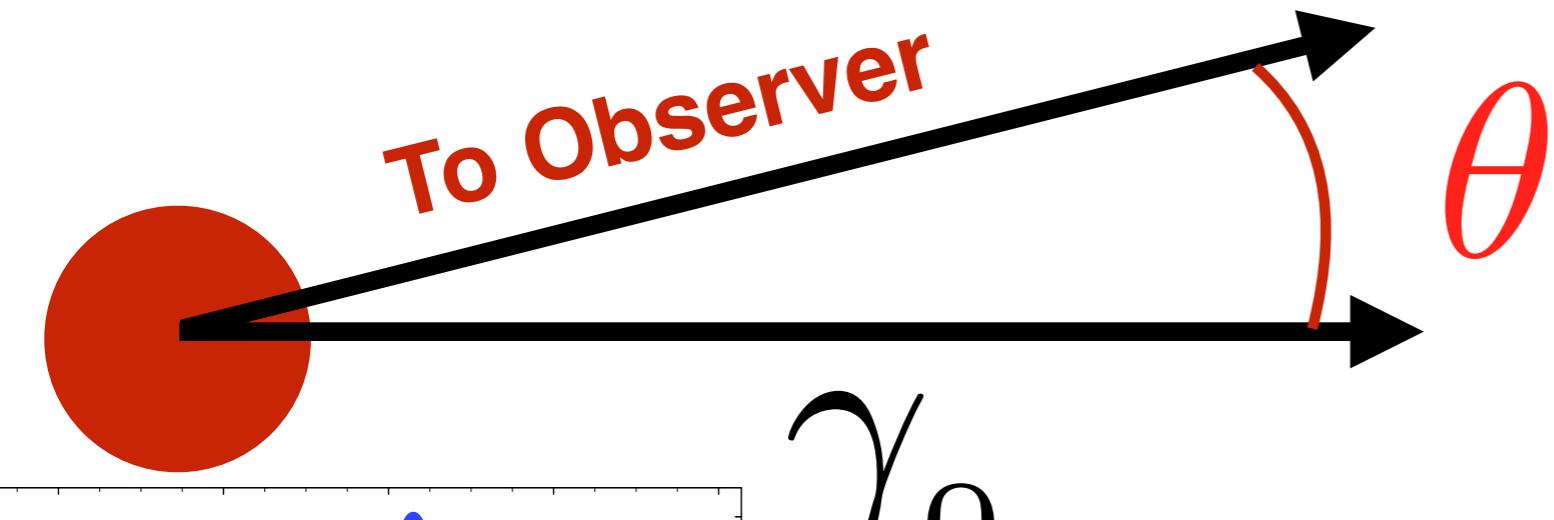
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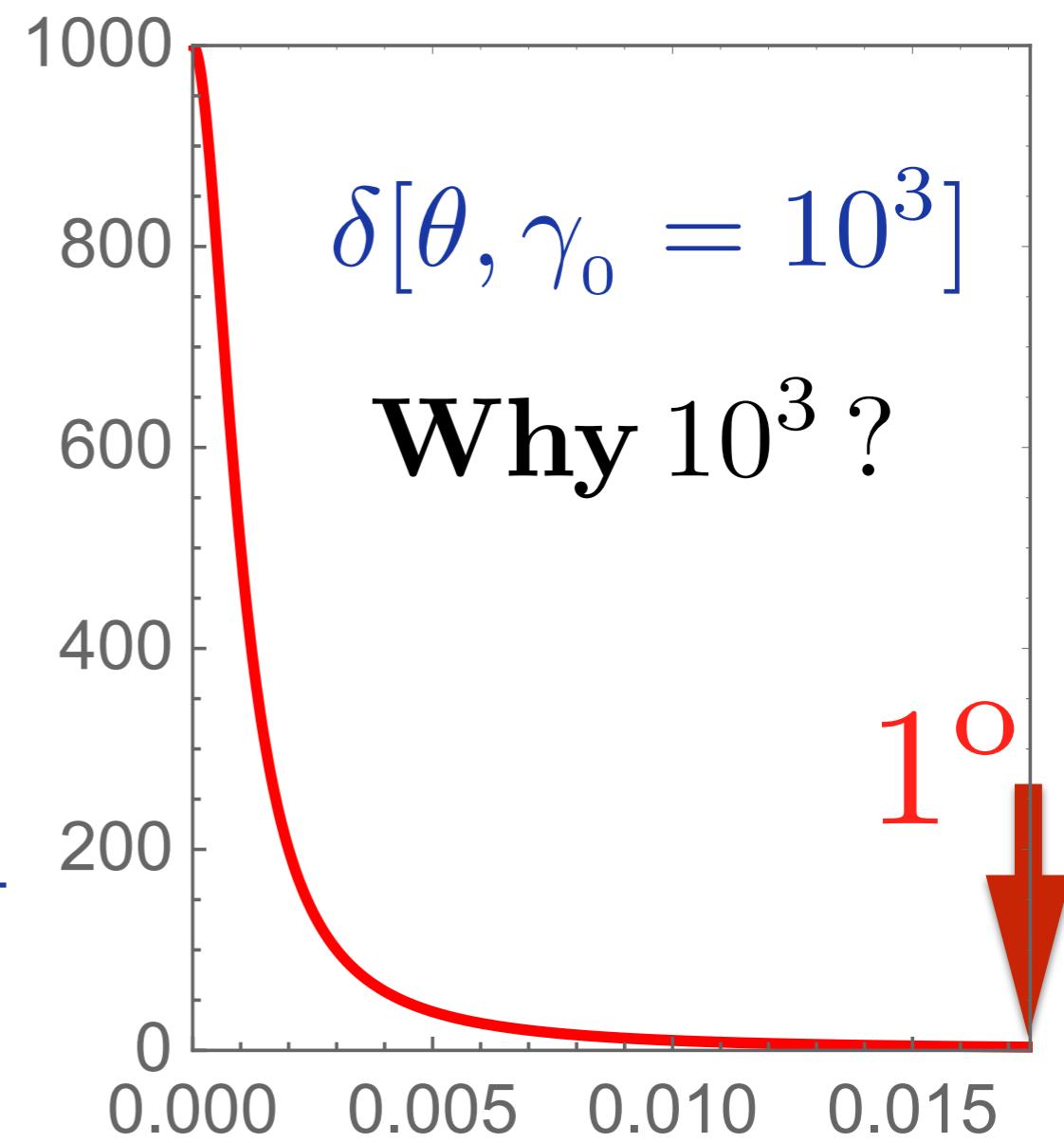
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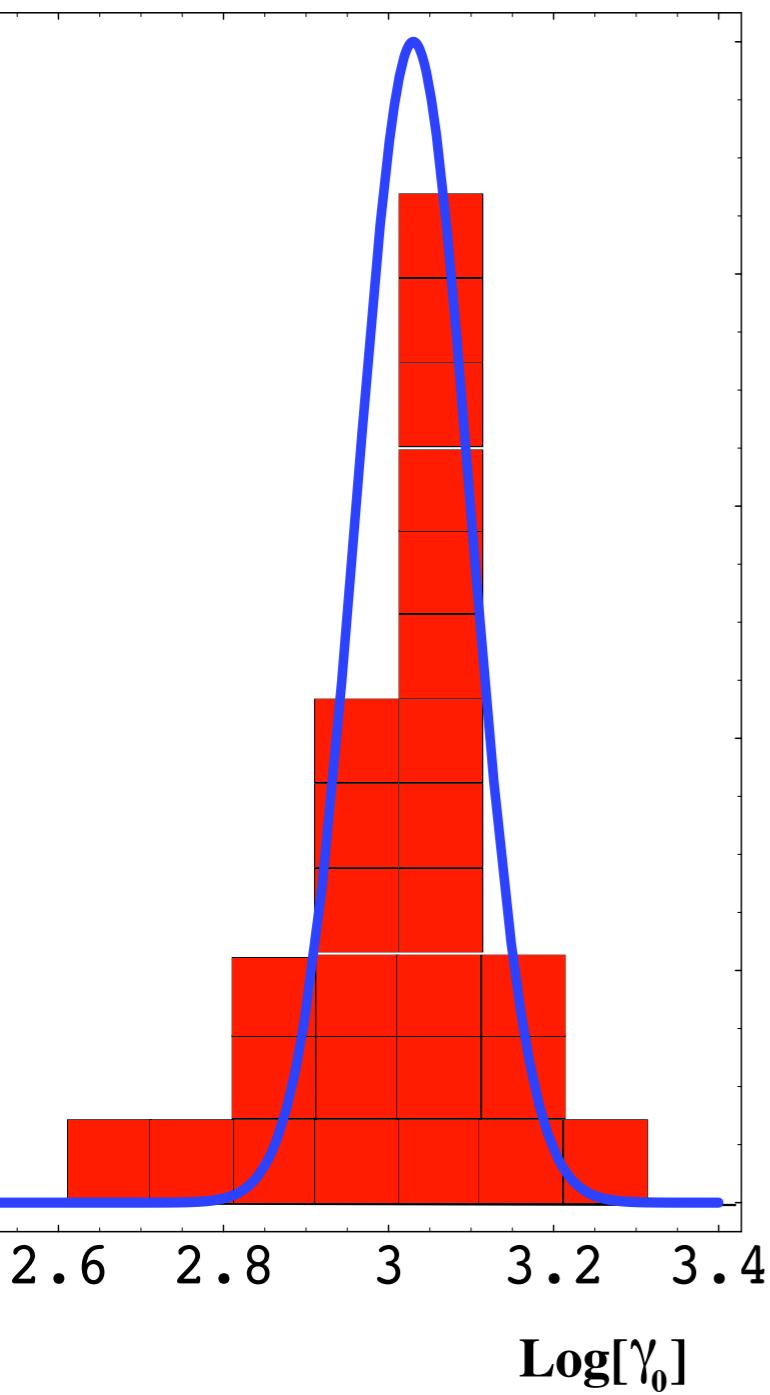
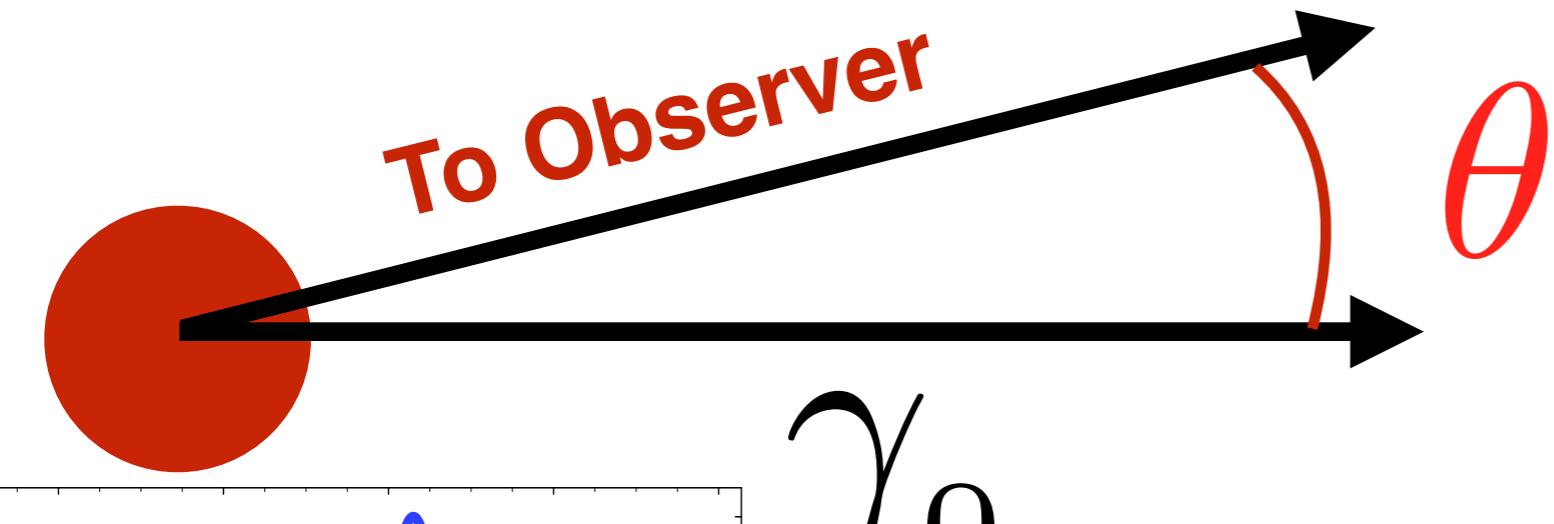
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$\text{Log}[\gamma_0]$



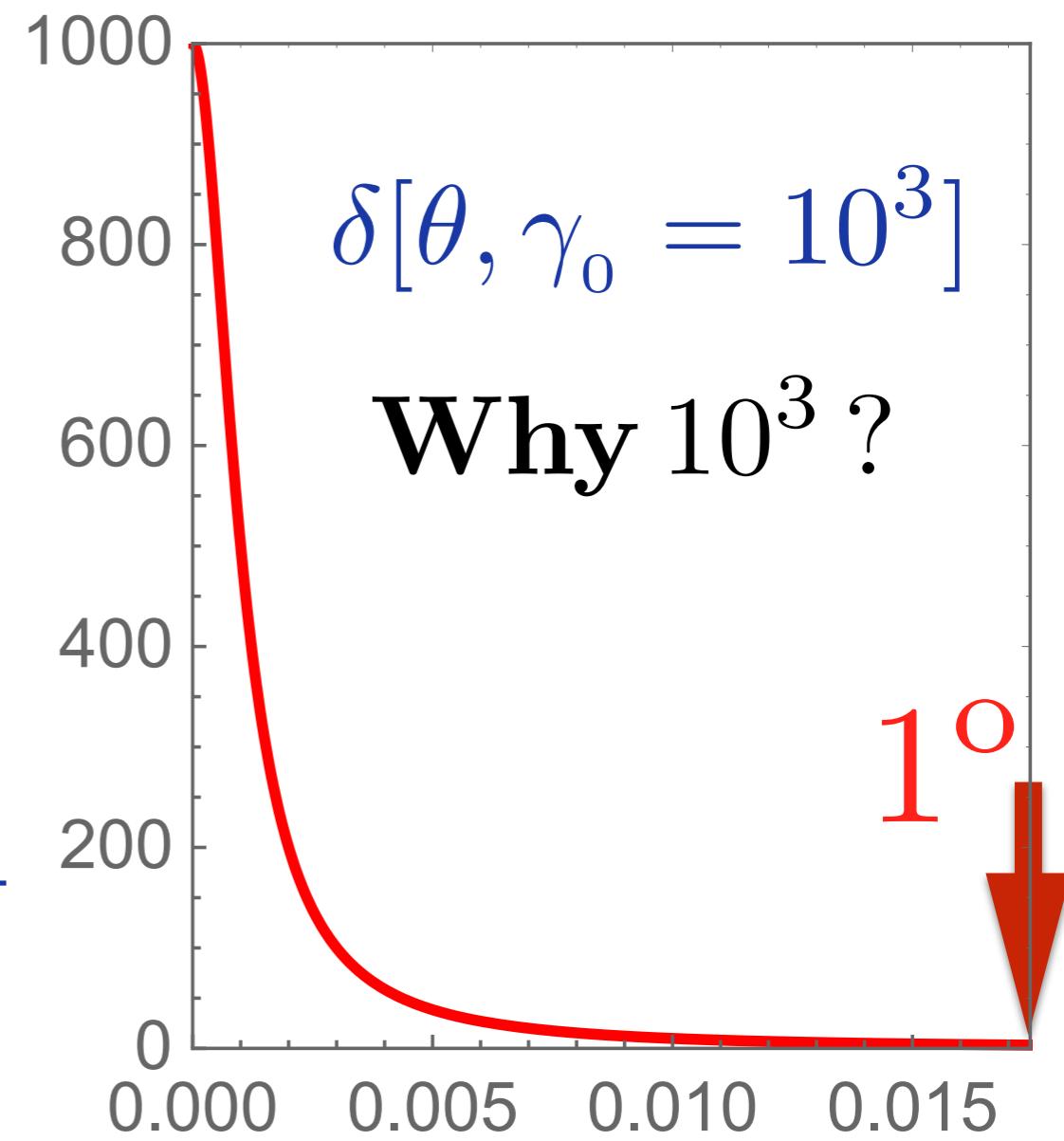
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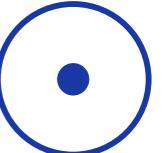
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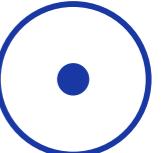
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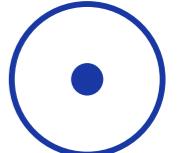
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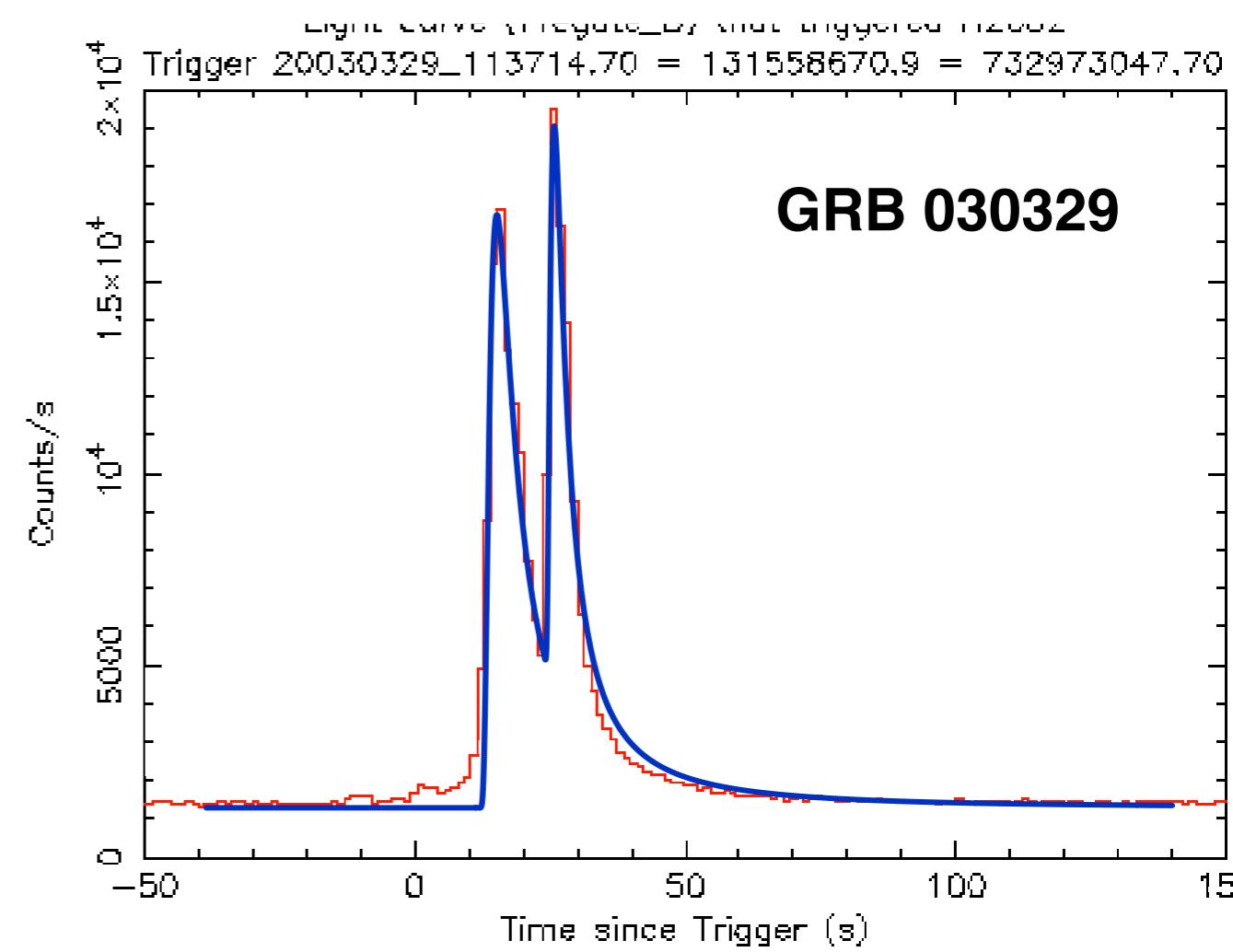
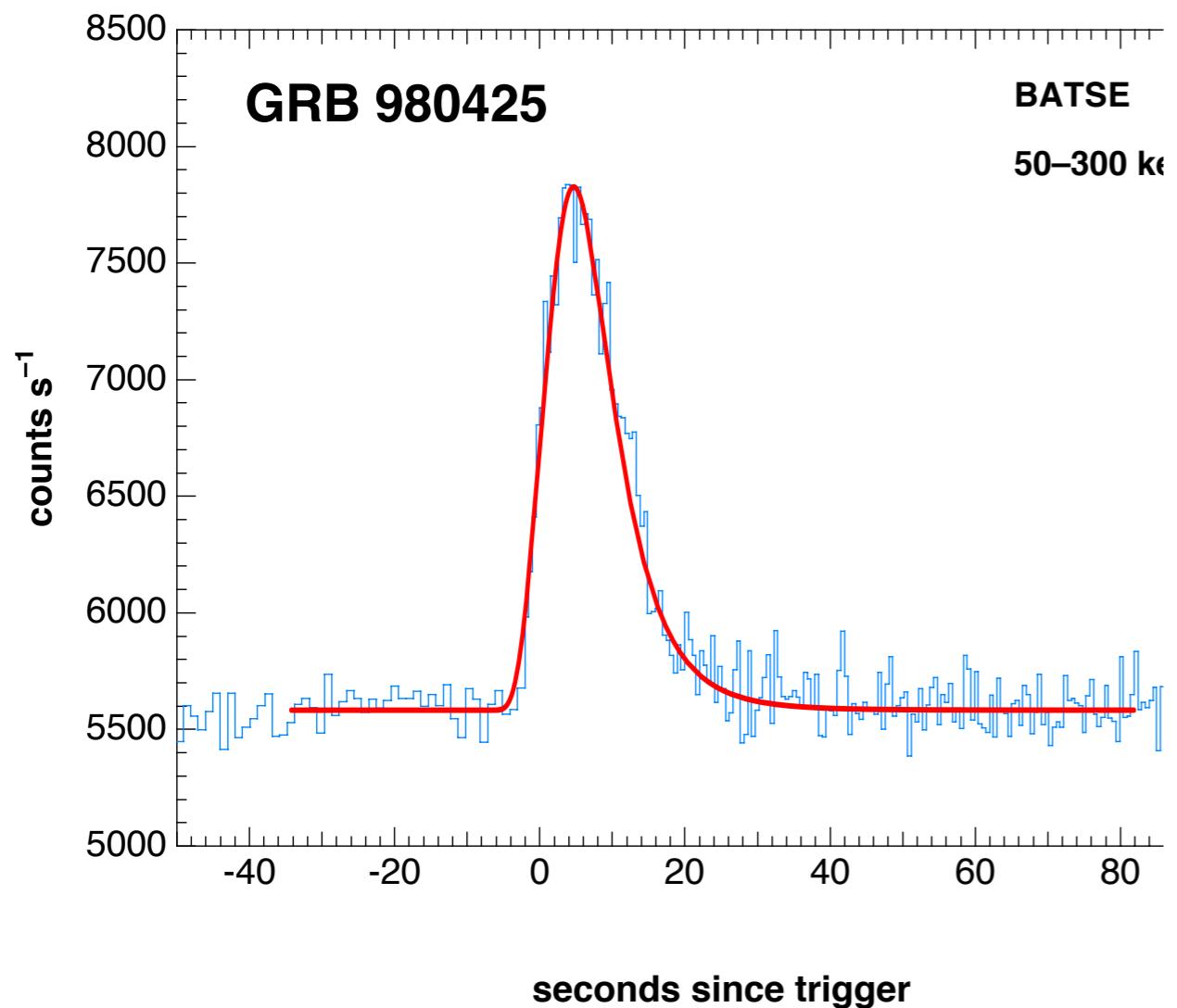
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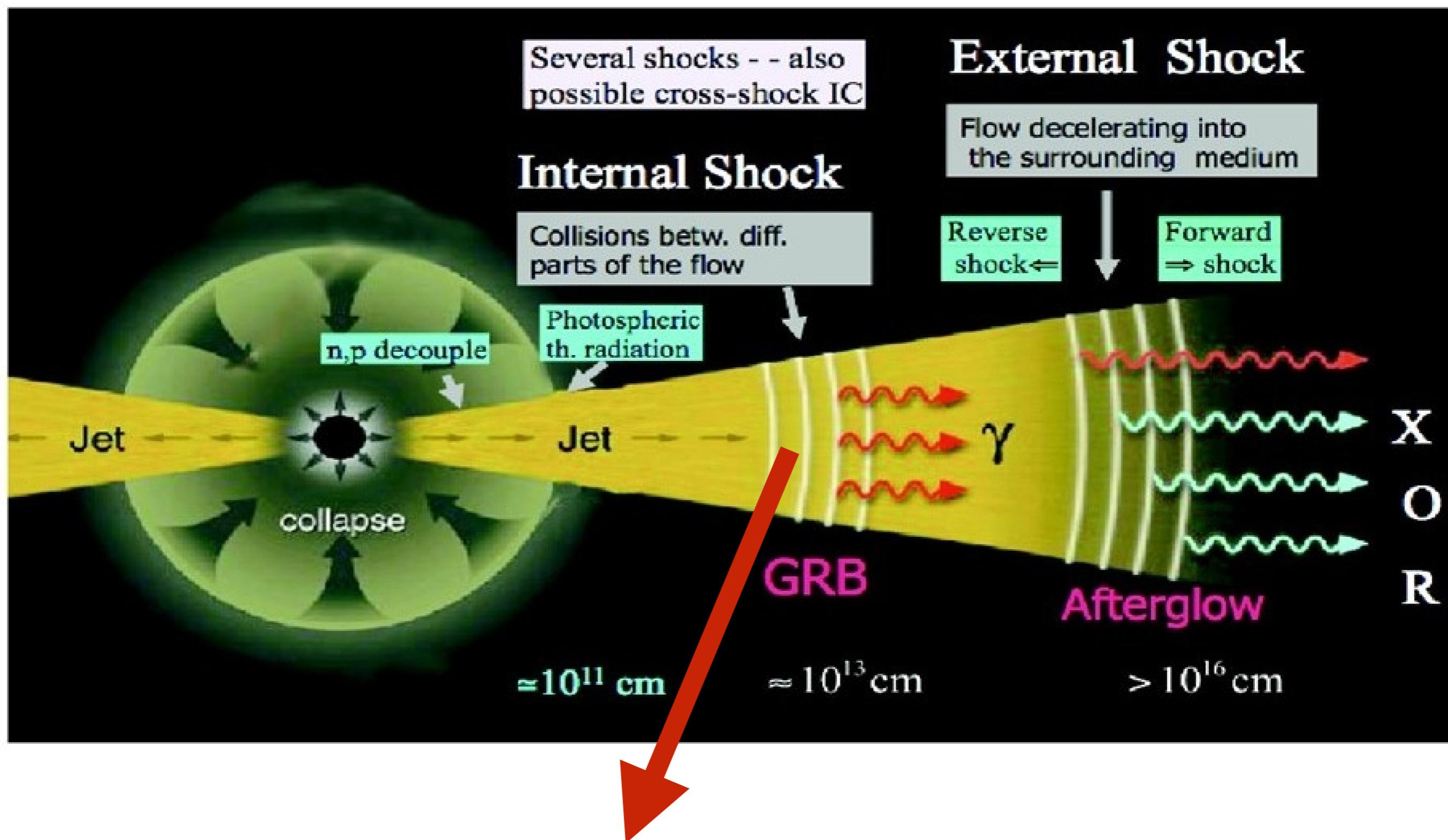
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G. Cocconi (1956)

P. Morrison (1957)

Gamma-Ray Emission Mechanism in FB Model



Electrons in turbulent shocks emit (unpolarized) SR

*C.B Theory
of
Cosmic Rays*

CB Theory of Cosmic Rays

- Flux Normalization
- Spectral Features
(knees, ankle, endpoint)
- Spectral Slopes
- “Chemical” Abundances
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- Confinement volume, time

All Predicted
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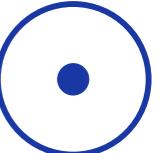
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ONE Parameter (freely chosen today)
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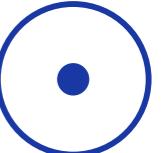
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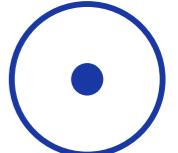
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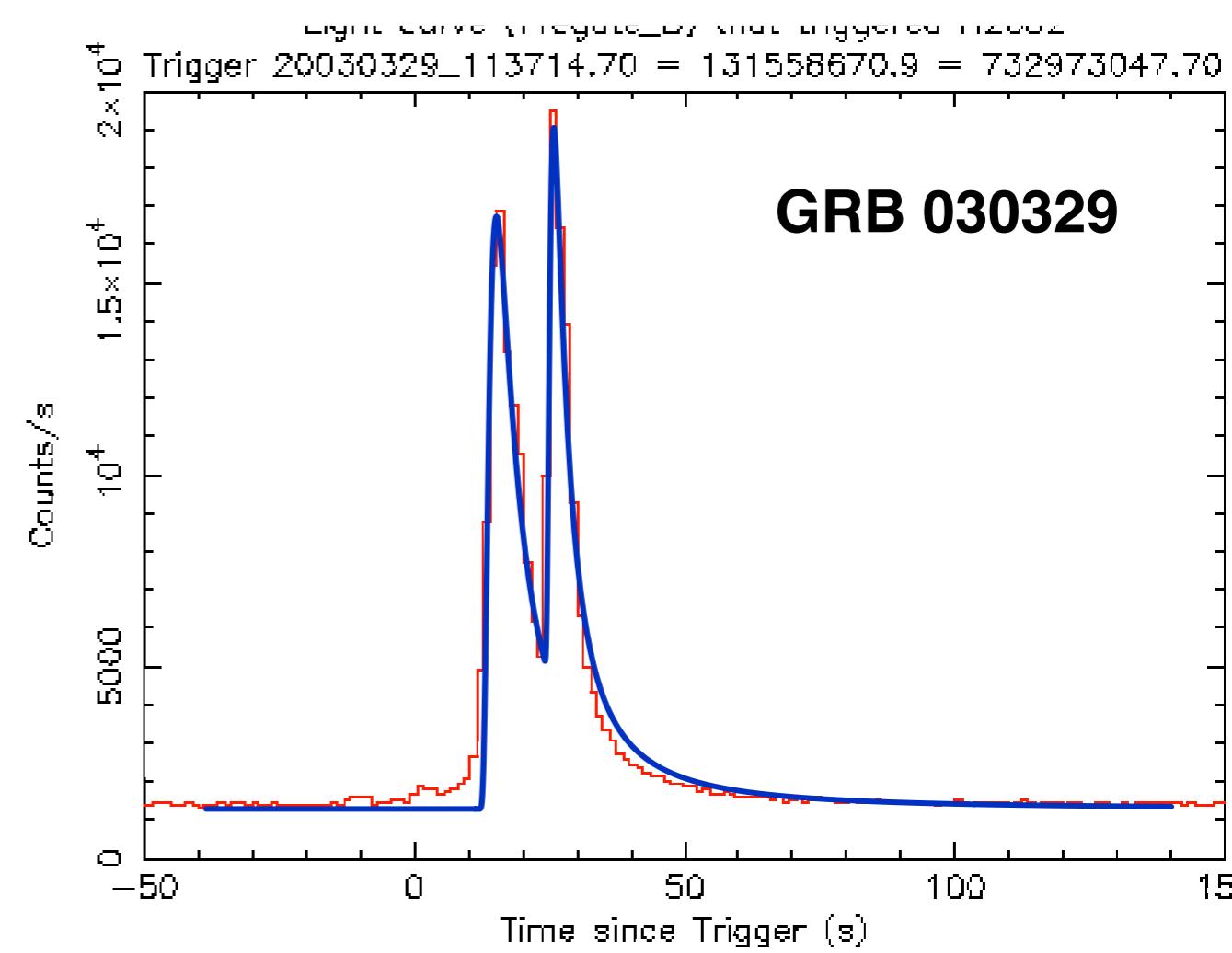
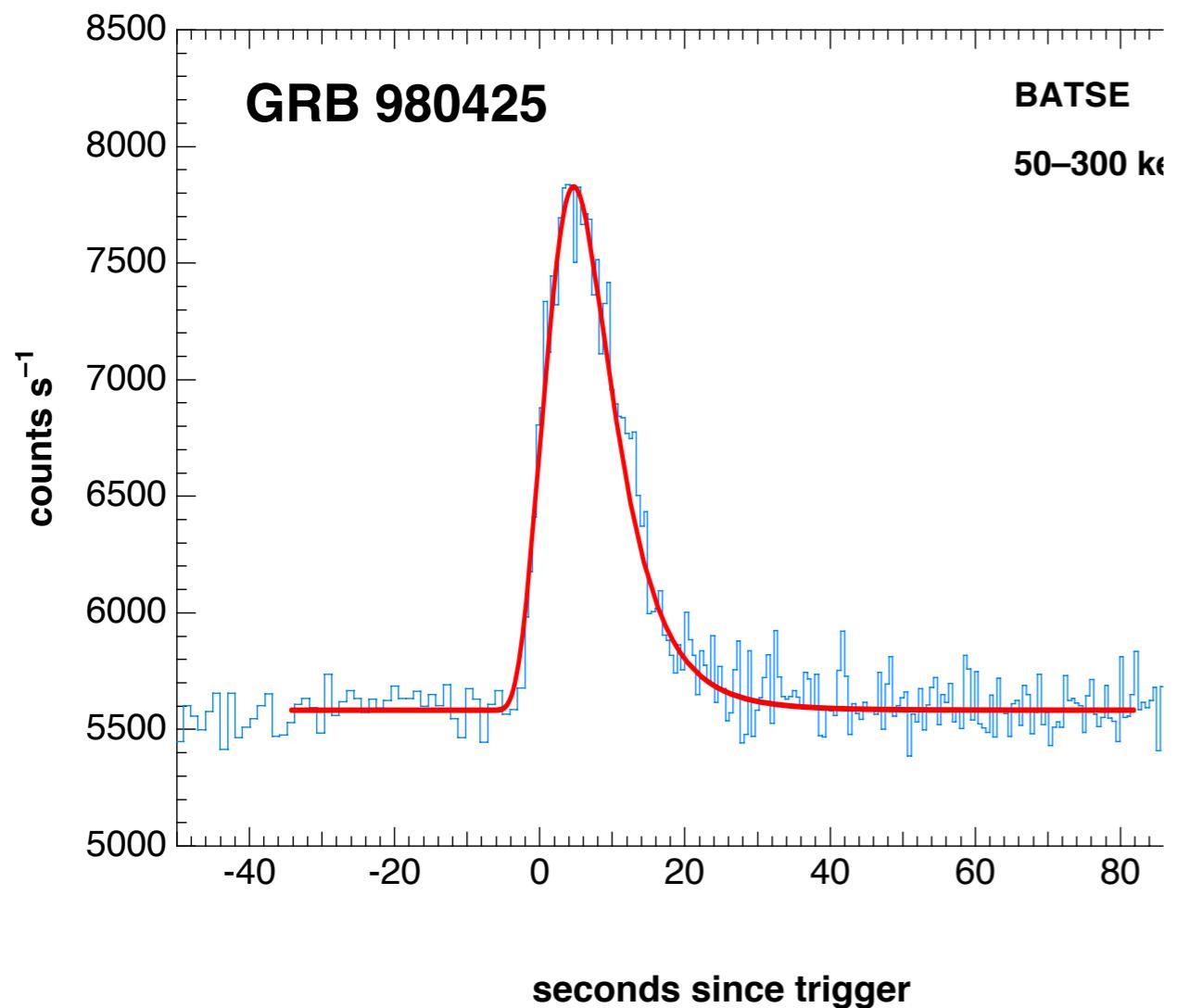
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**CBs ejected by core-collapse
Supernovae & acting on the
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Relativistic Rackets explain
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all properties of (non-solar)
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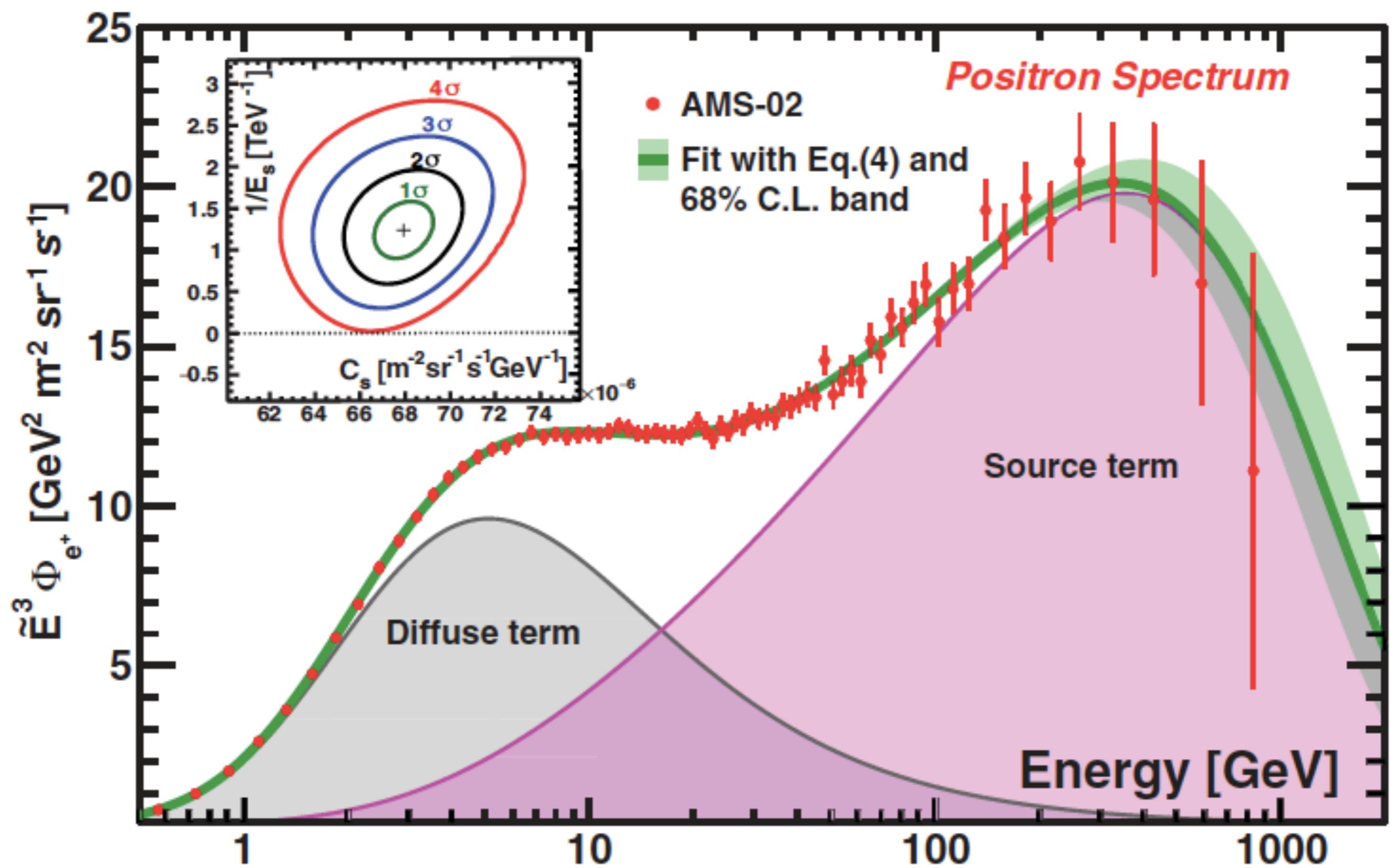
Should YOU care ???

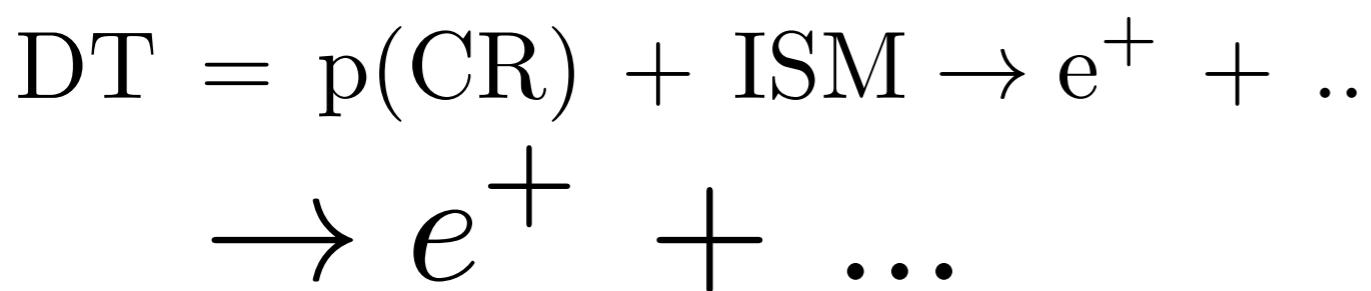
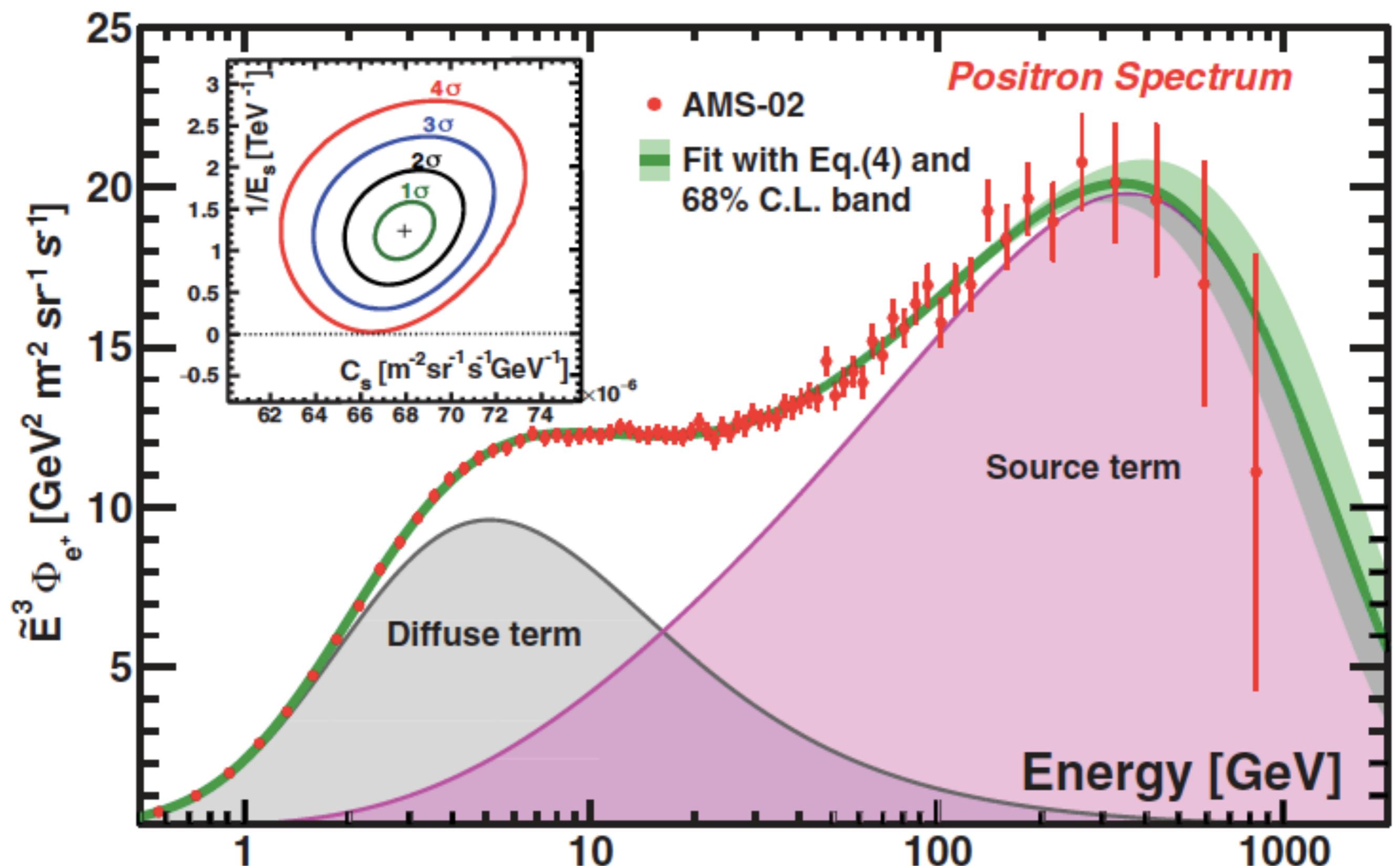
**Is the positron
flux of AMS a
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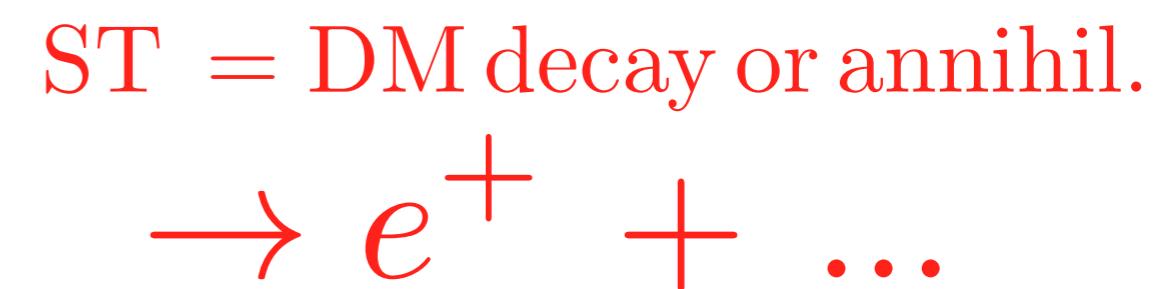
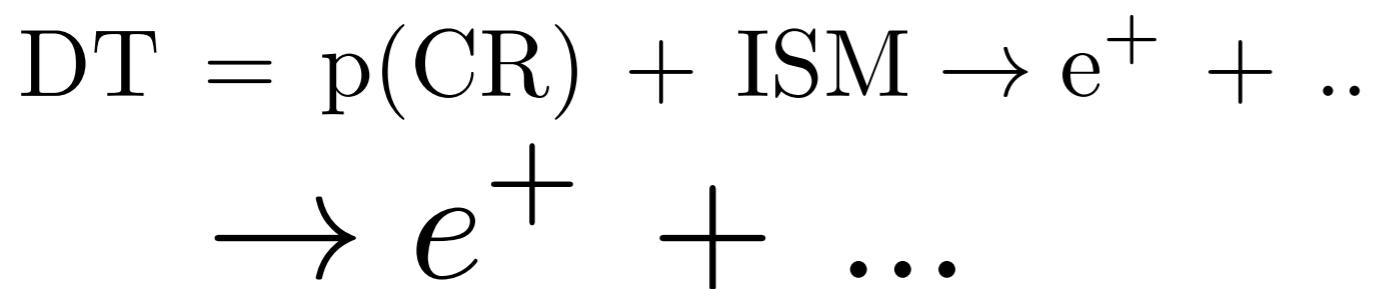
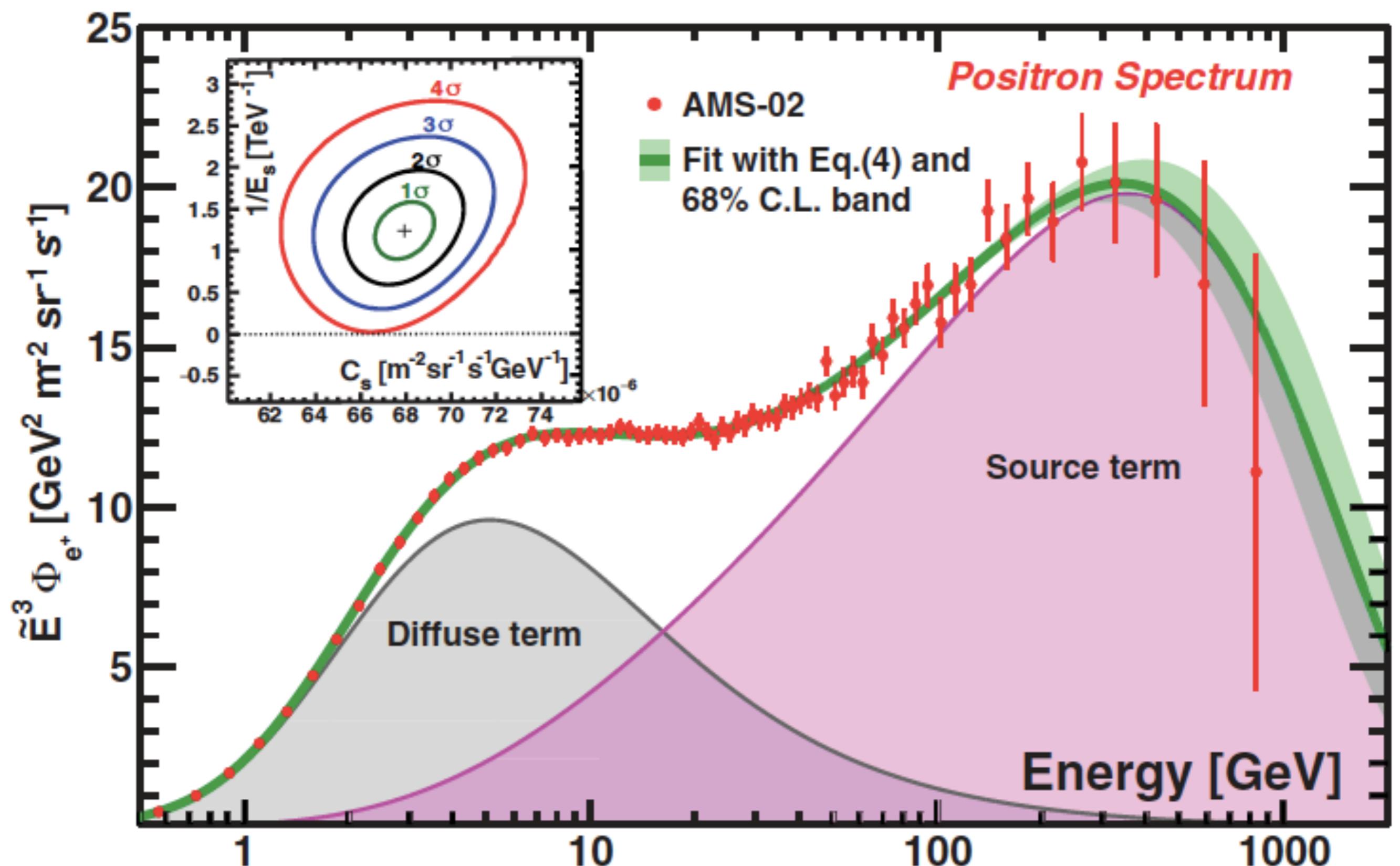
???

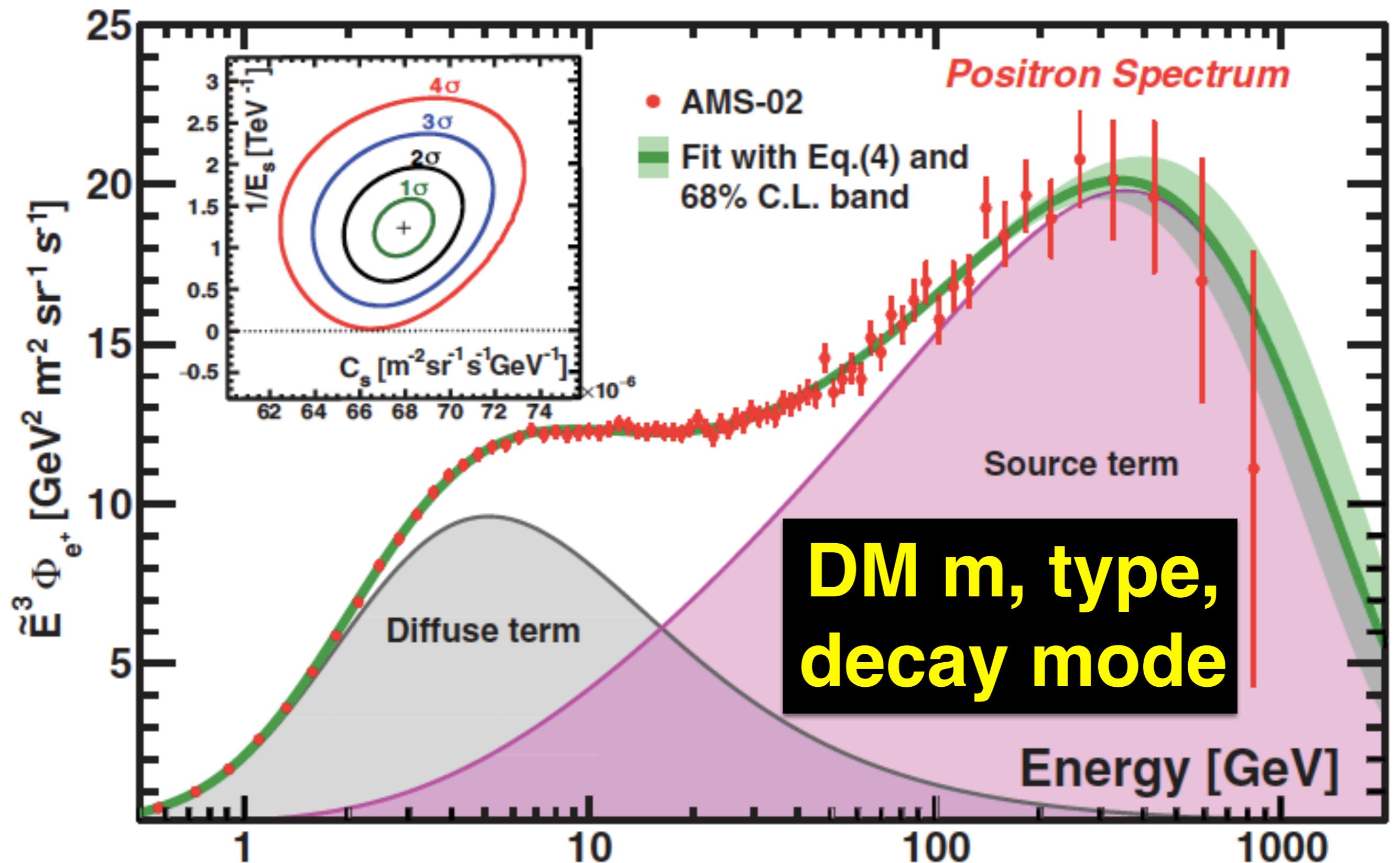
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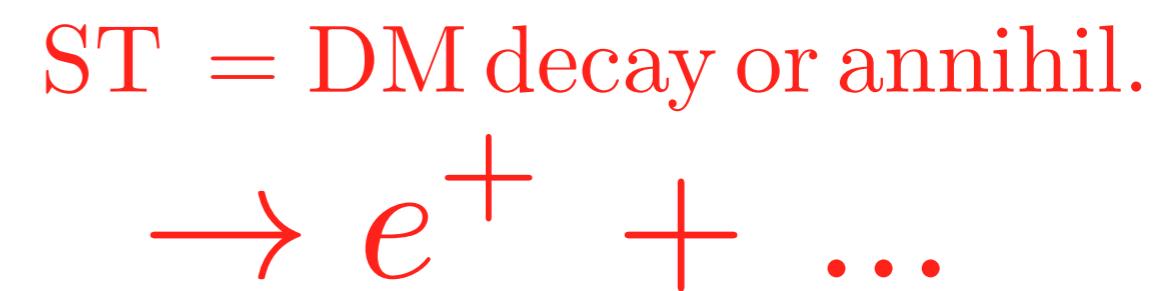
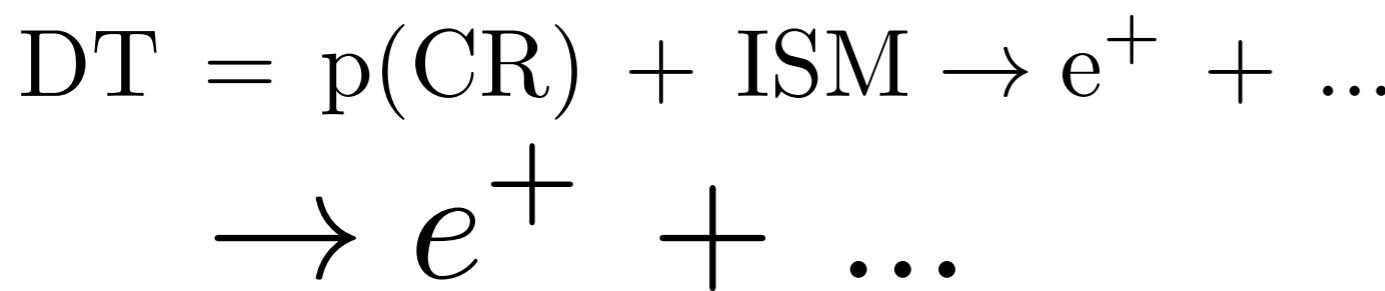


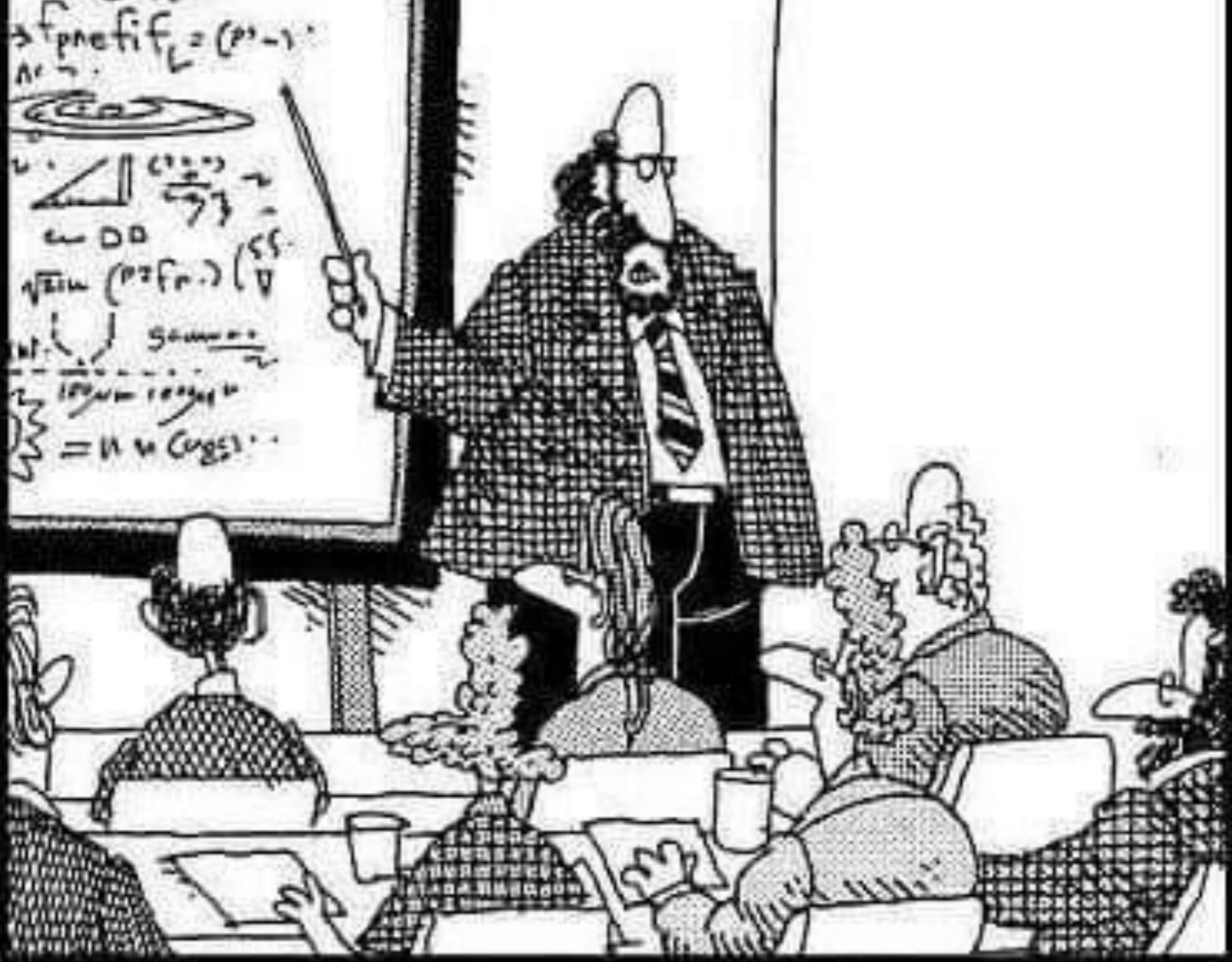




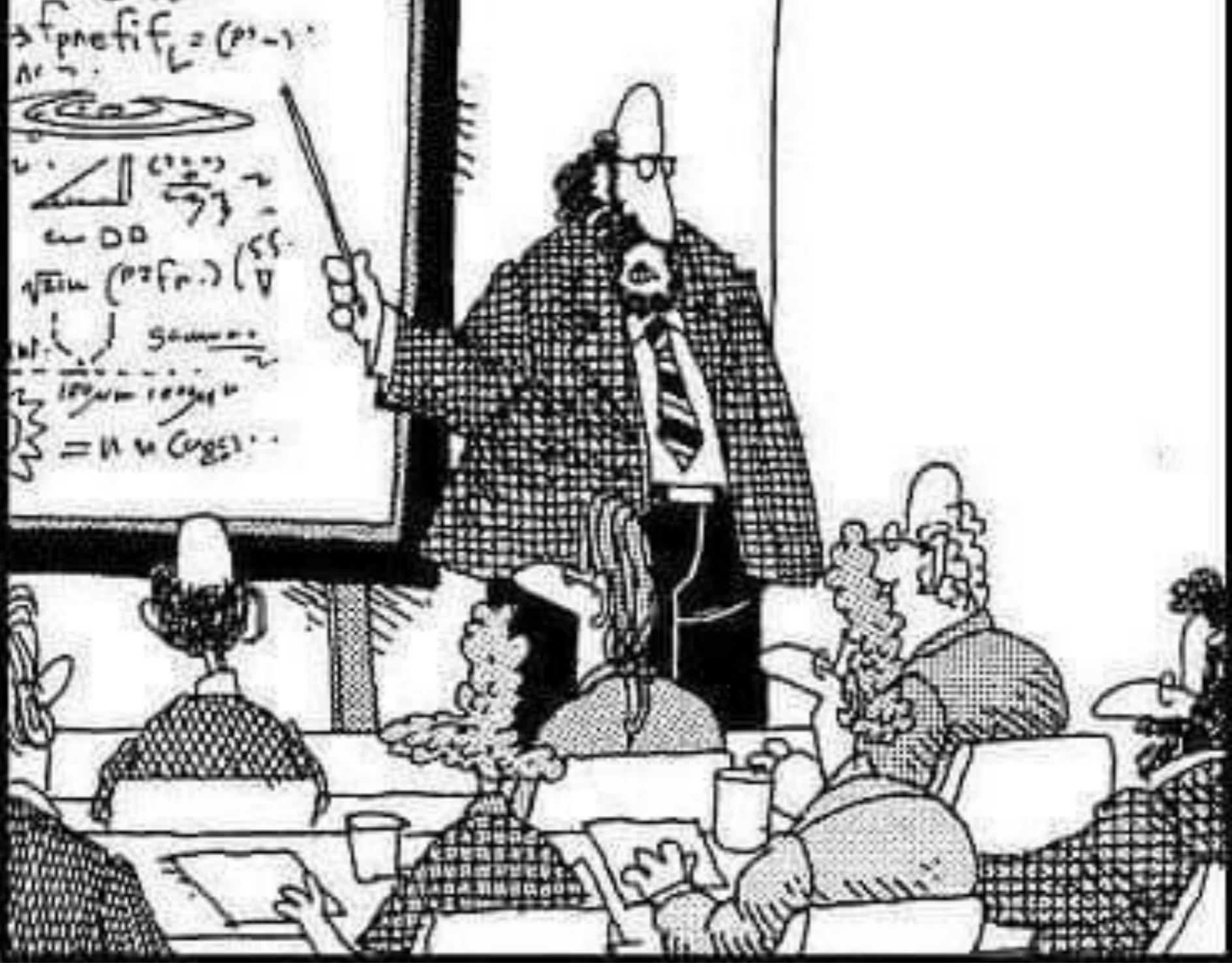


**DM m, type,
decay mode**

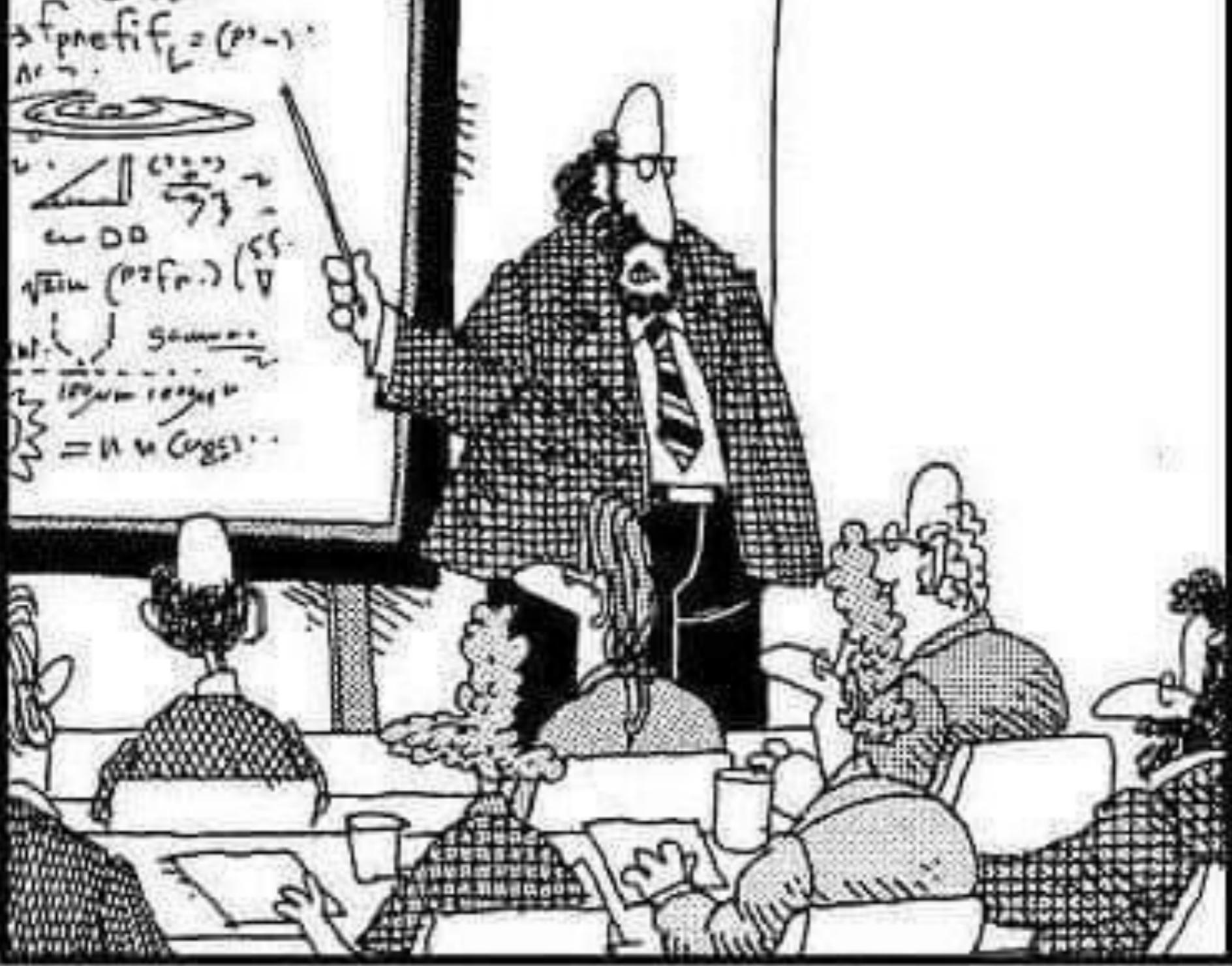




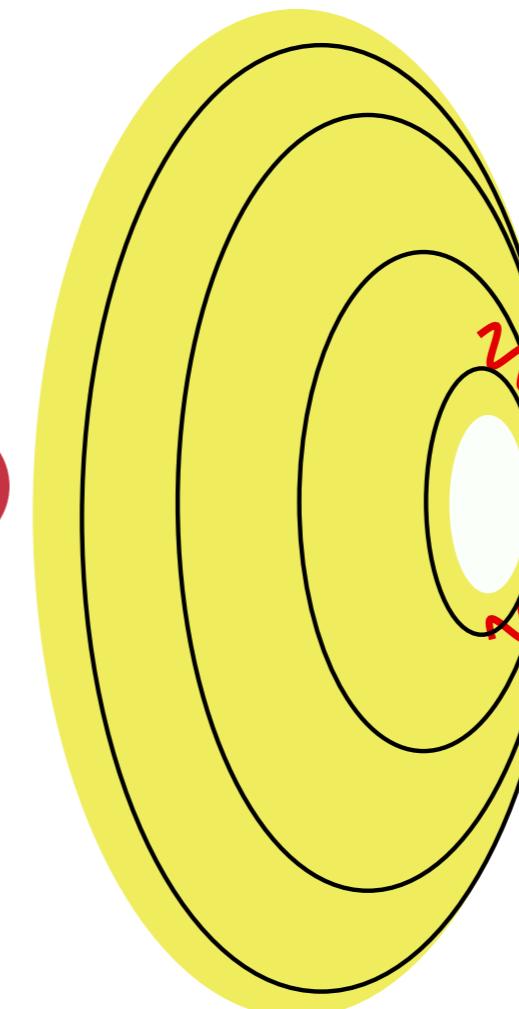
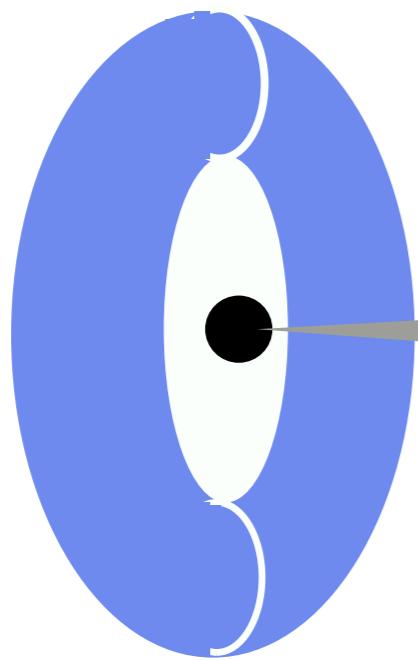
"Along with 'Antimatter,' and 'Dark Matter,' we've recently discovered the existence of



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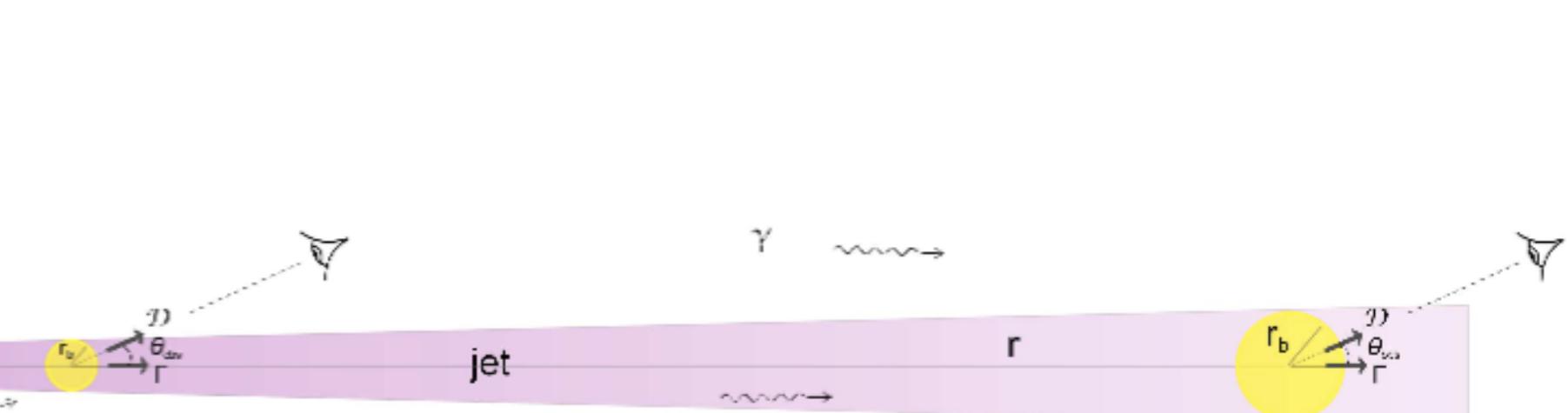
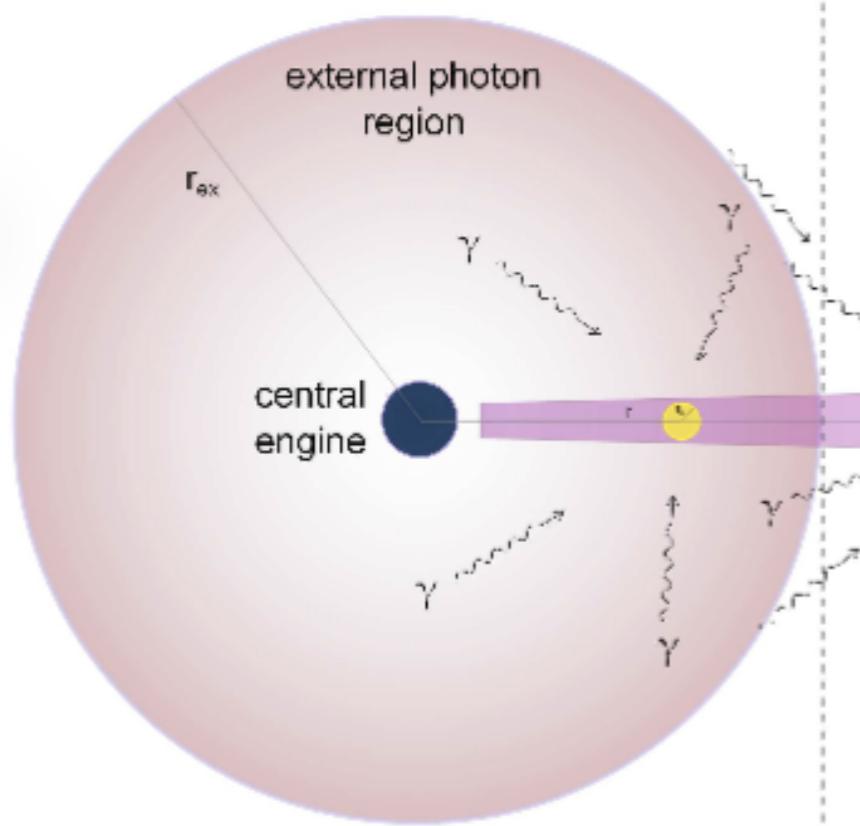
"Along with 'Antimatter,' and 'Dark Matter,' we've recently discovered the existence of 'Doesn't Matter,' which appears to have no effect on the universe whatsoever."



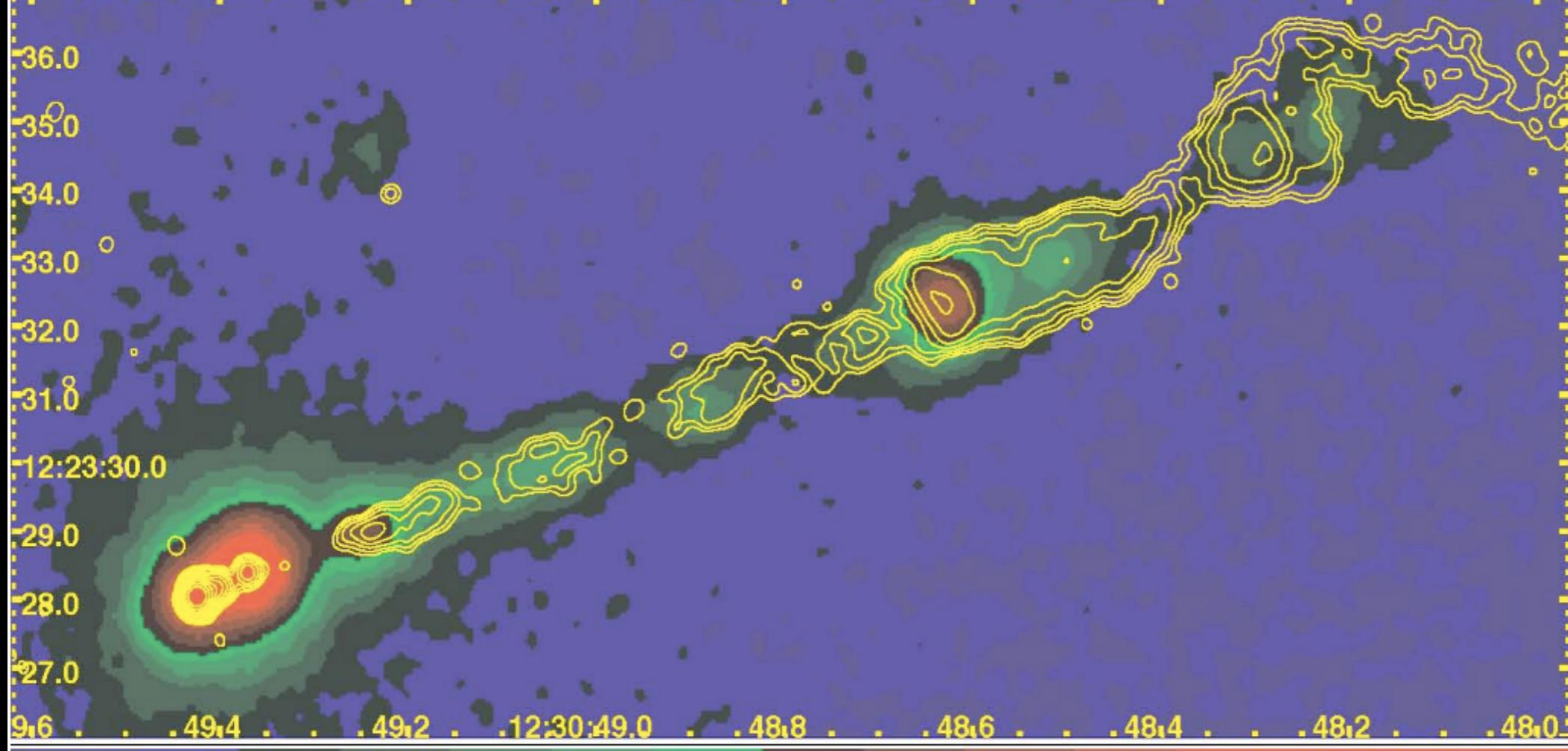
emission region inside
external photon region

emission region outside
external photon region

emission region far outside
external photon region

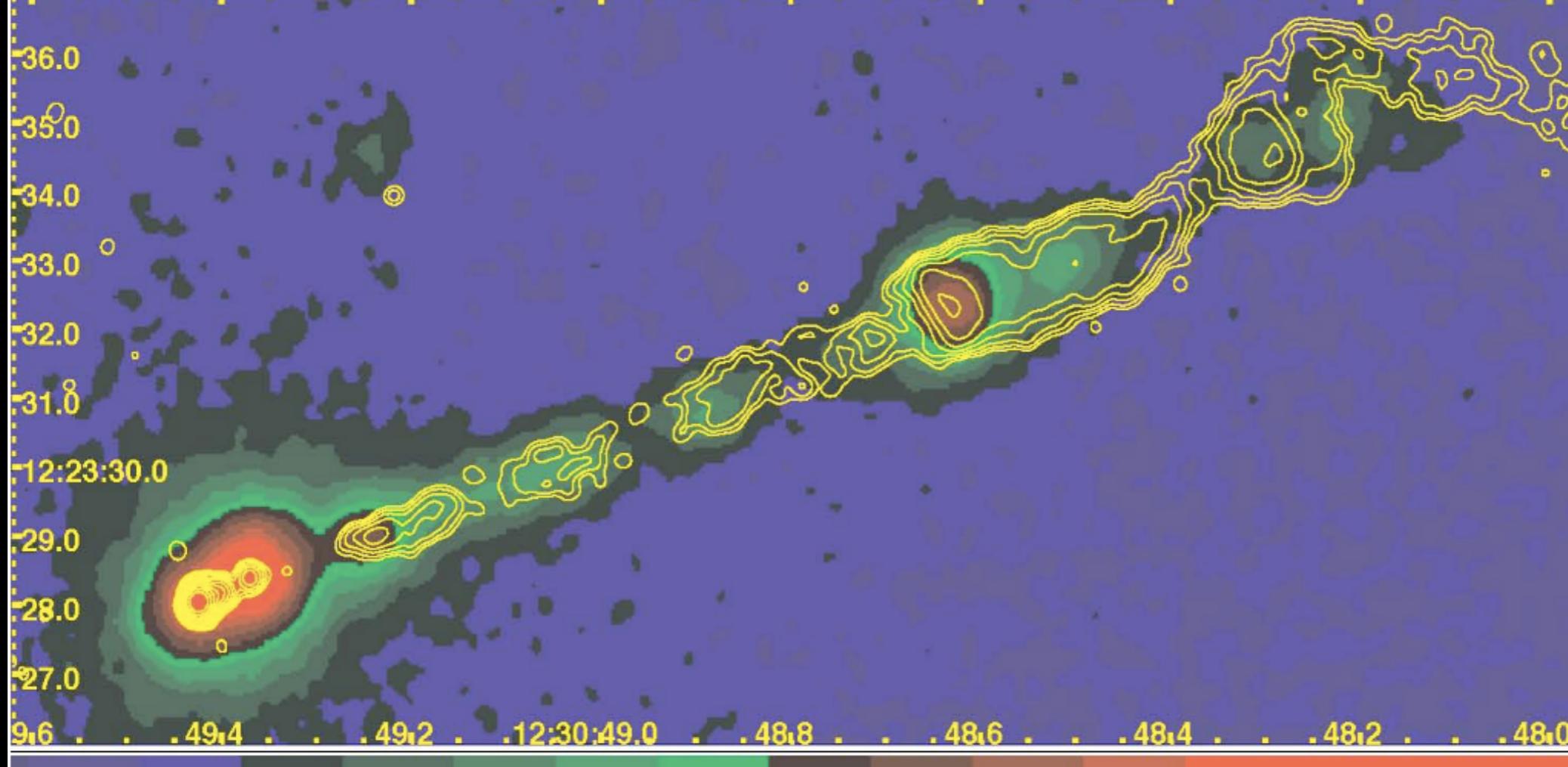


emission
region



M87

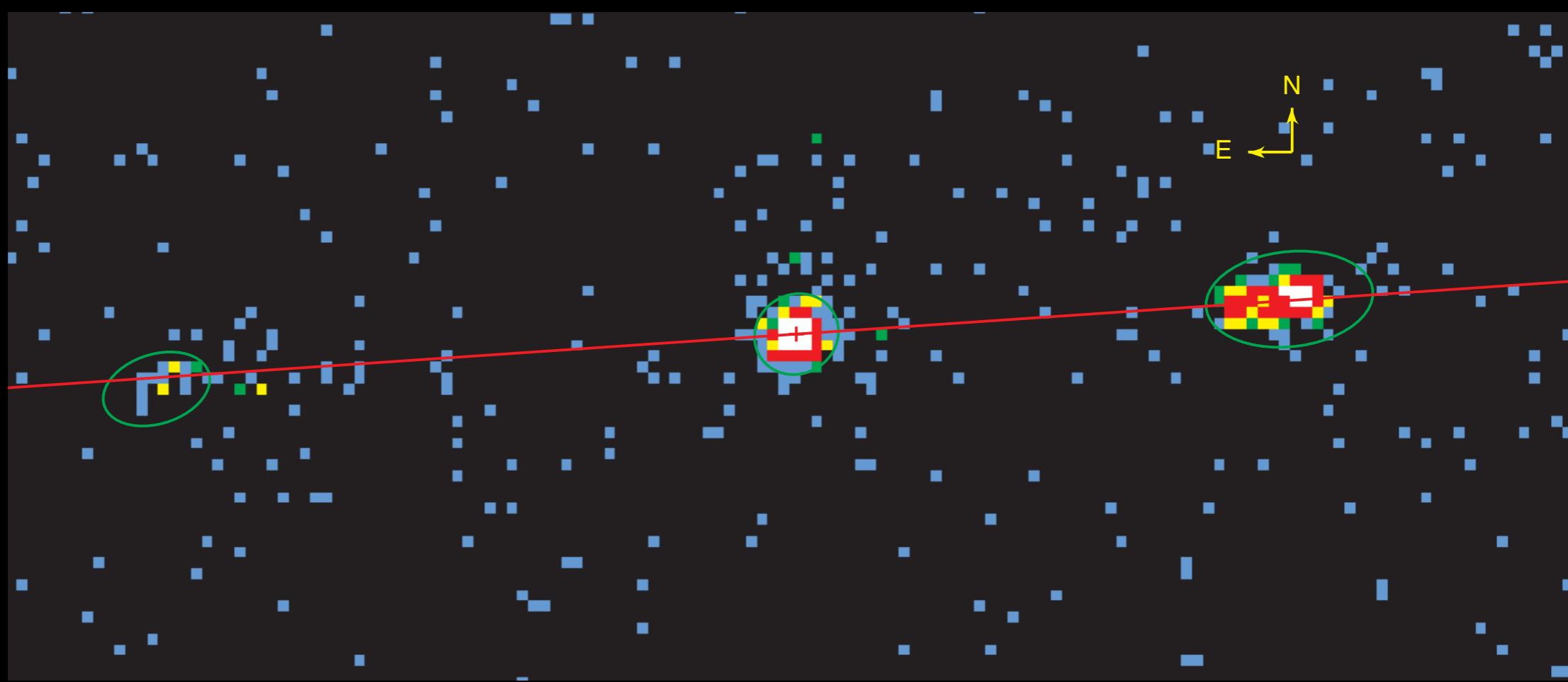
FIGURE 3: A Chandra image of the M87 jet, with radio contours overlaid. This image was co

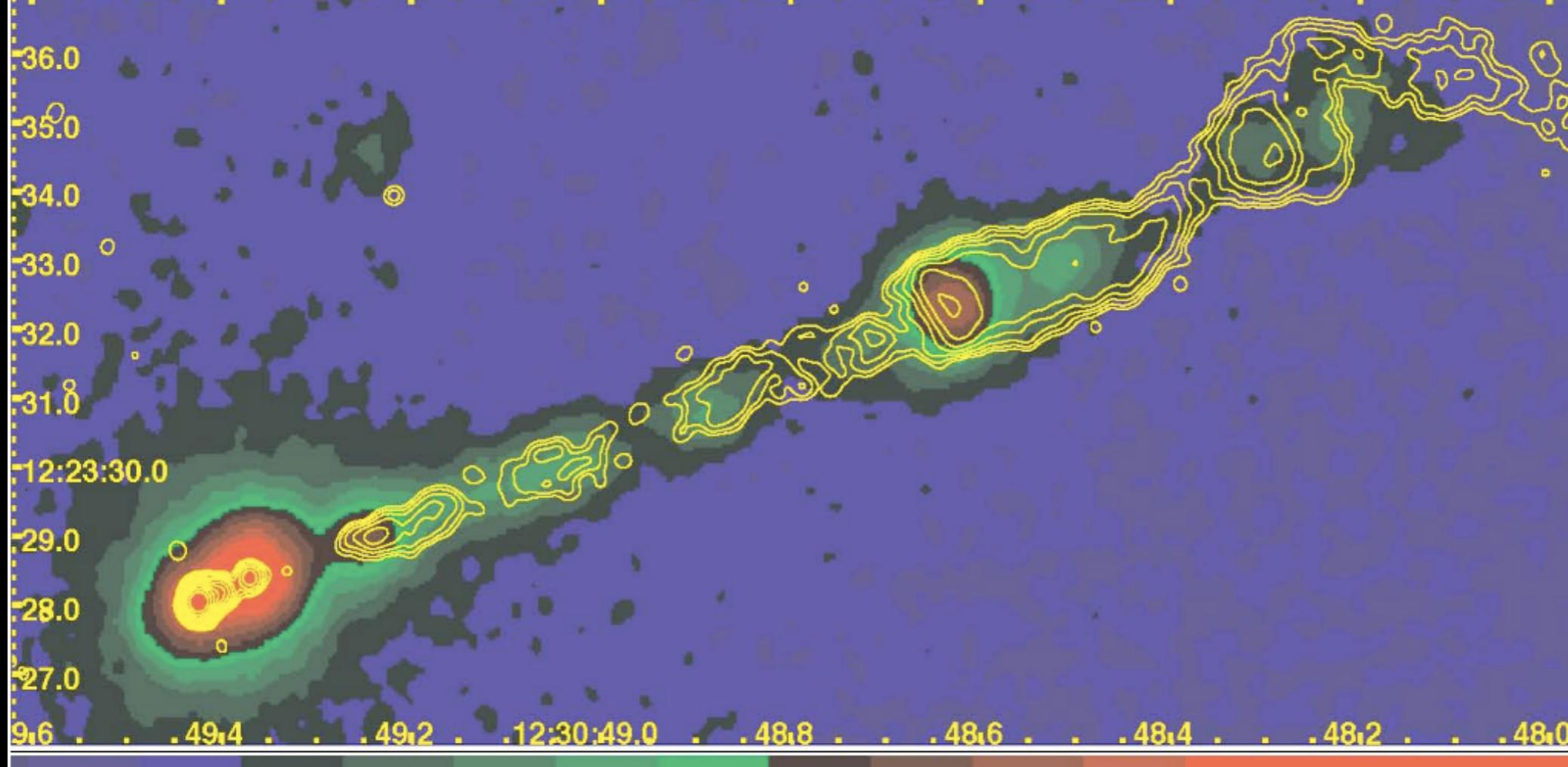


M87

FIGURE 3: A Chandra image of the M87 jet, with radio contours overlaid. This image was co

XTE
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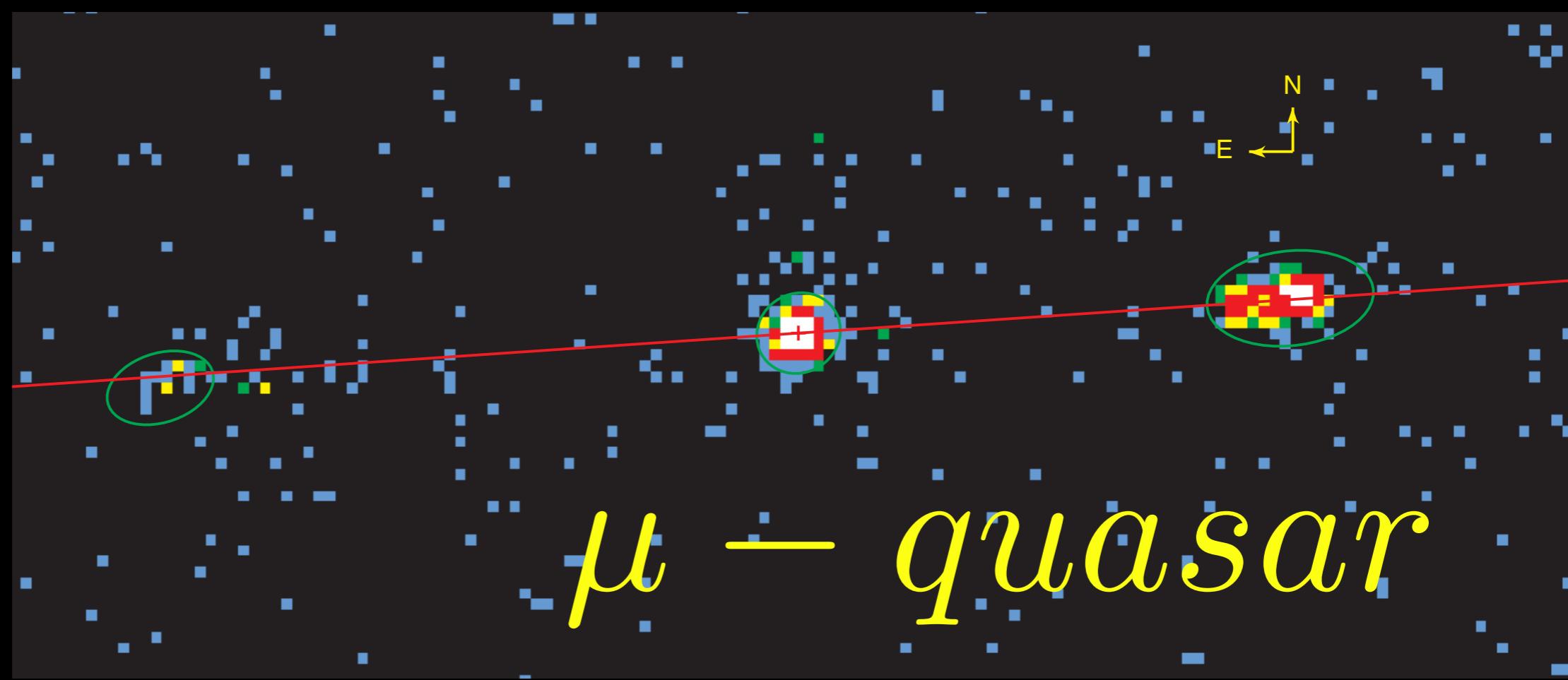




M87

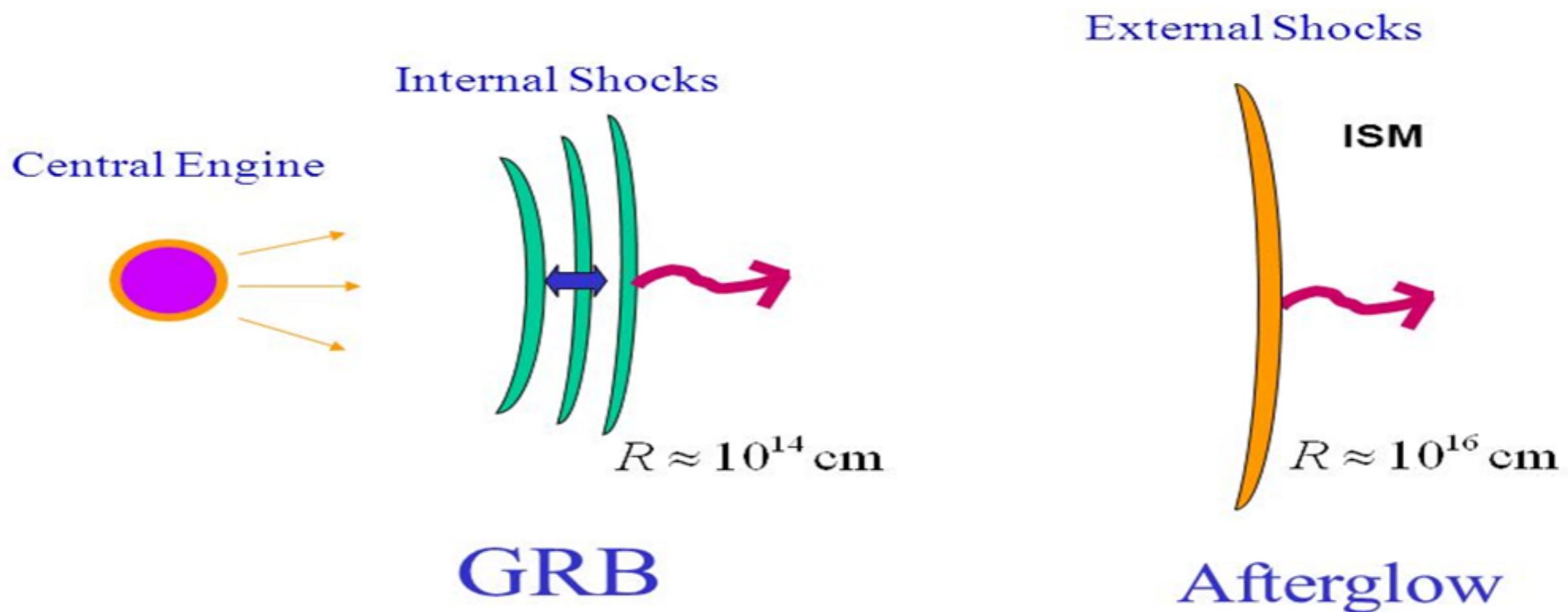
FIGURE 3: A Chandra image of the M87 jet, with radio contours overlaid. This image was co

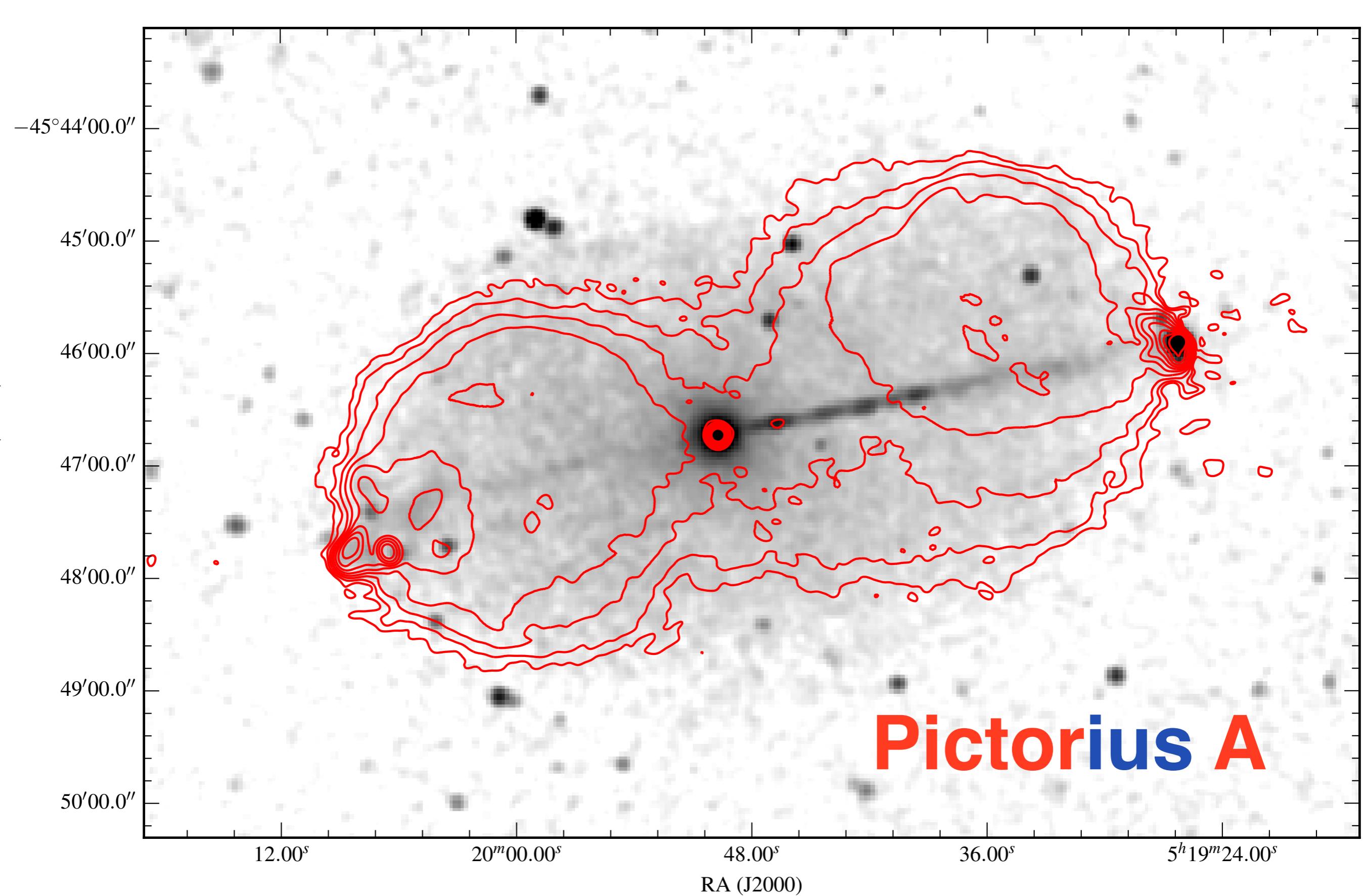
XTE
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μ — quasar

Internal-External Shock Model





M. J. Hardcastle et al. arXiv:1510.08392v1