A Decade of Short-duration Gamma-ray Burst Afterglows

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University of Arizona

in collaboration with:
Raffaella Margutti, Edo Berger, B. Ashley Zauderer

Einstein Fellows Symposium, 10.28.2014

Motivation

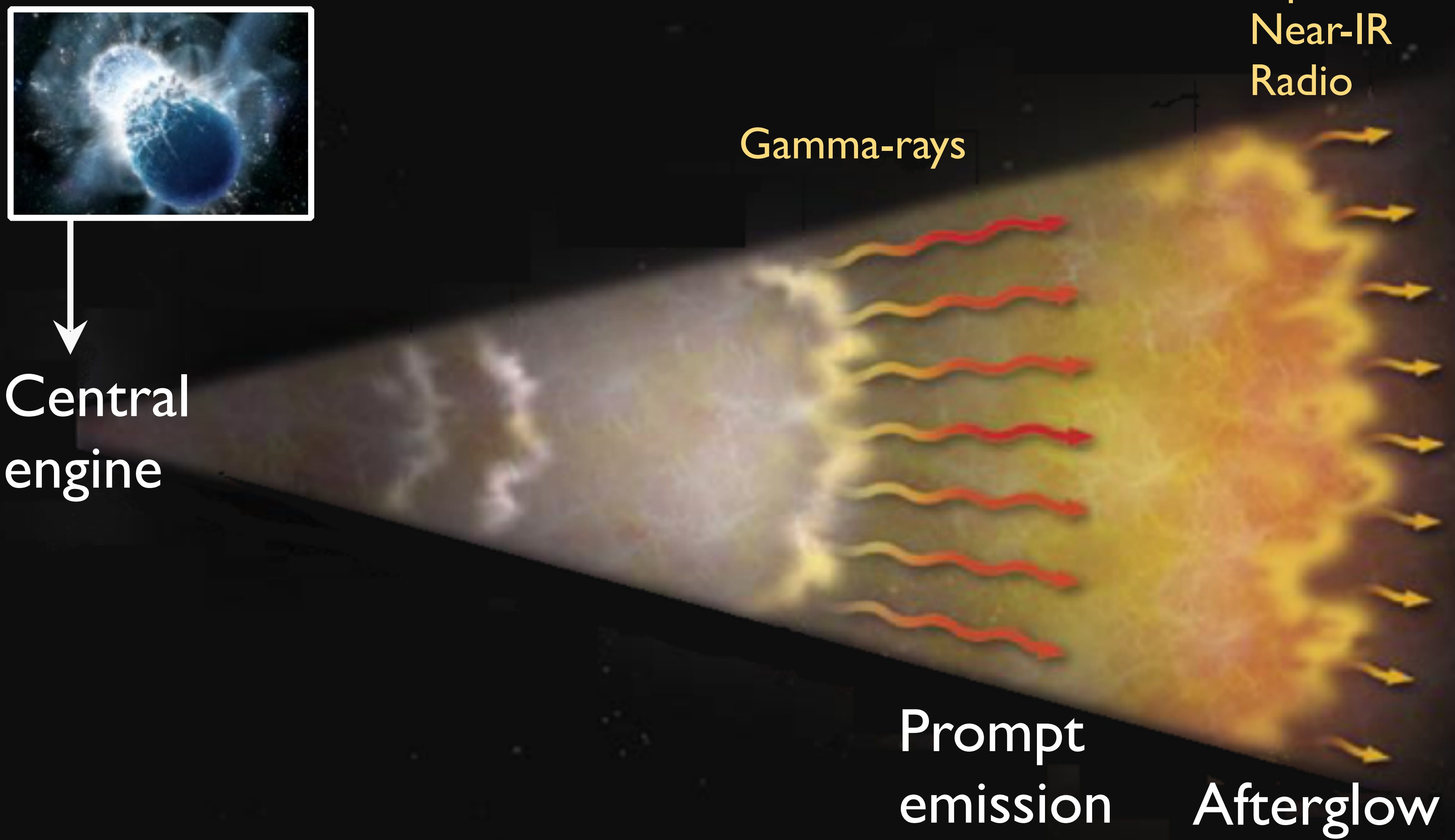

Figure adapted from Gehrels et al. 2007

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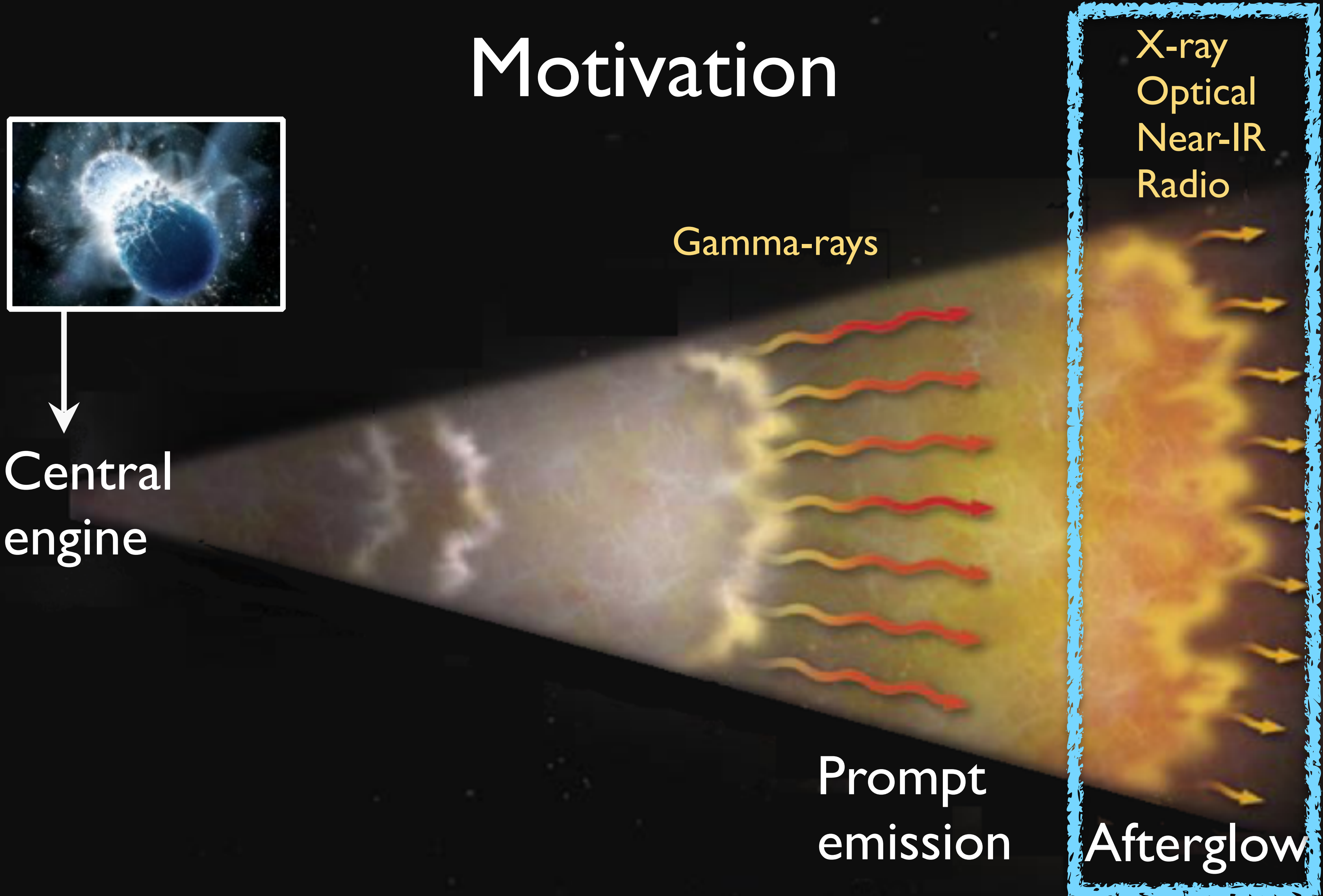

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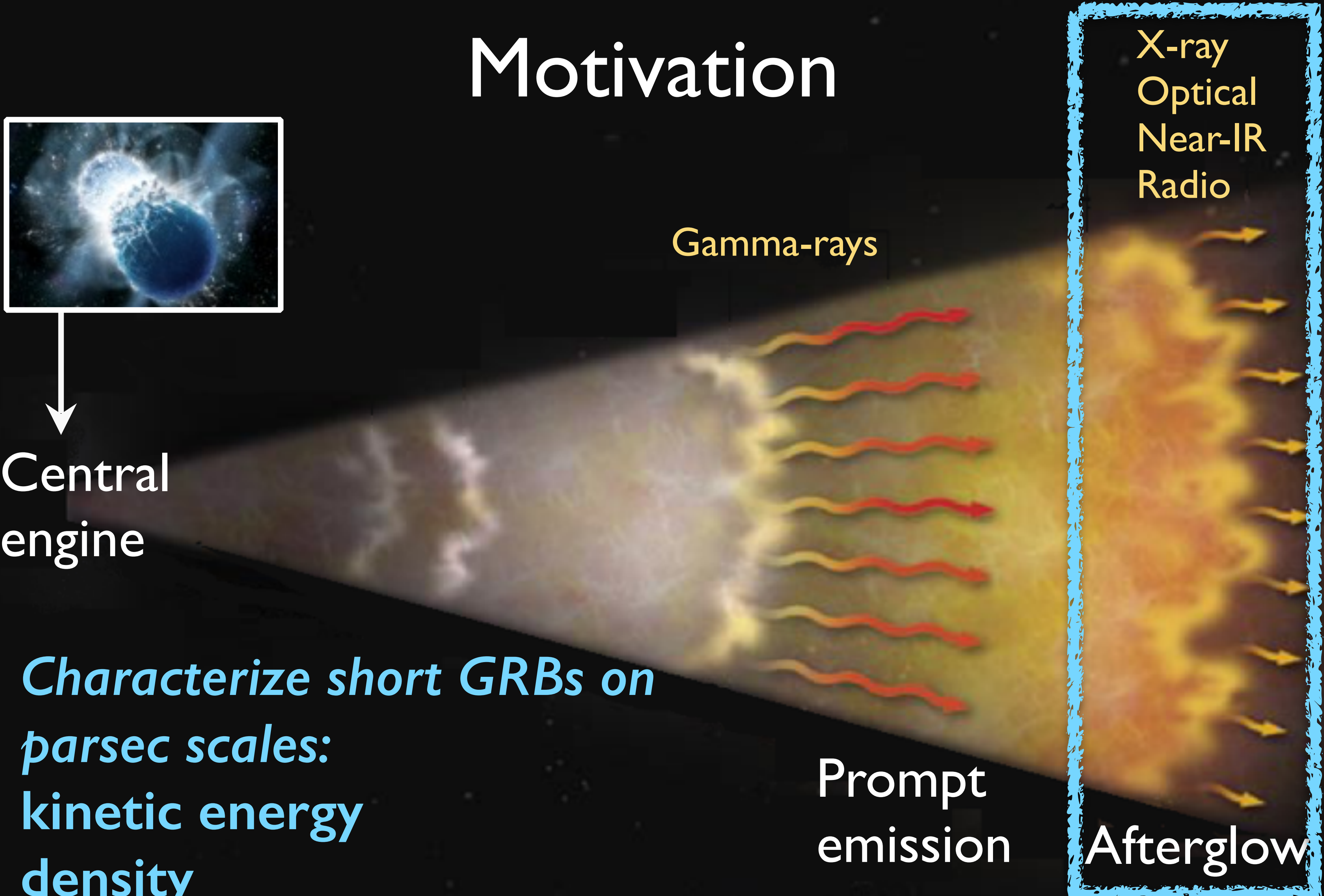


Characterize short GRBs on parsec scales:

kinetic energy

density

opening angle

Figure adapted from Gehrels et al. 2007

Outline

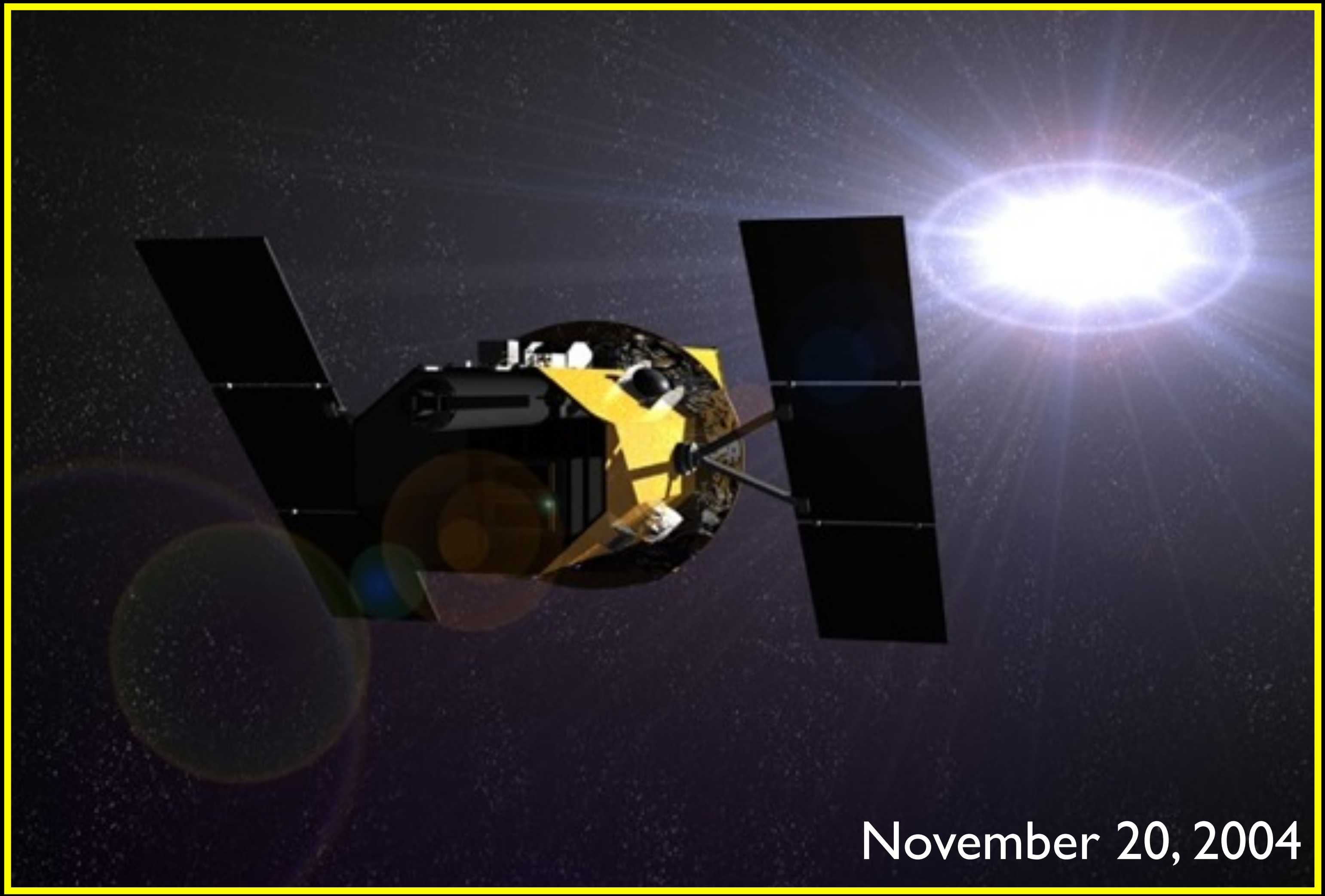
Background

Afterglow census

Explosion properties

Application to gravitational waves

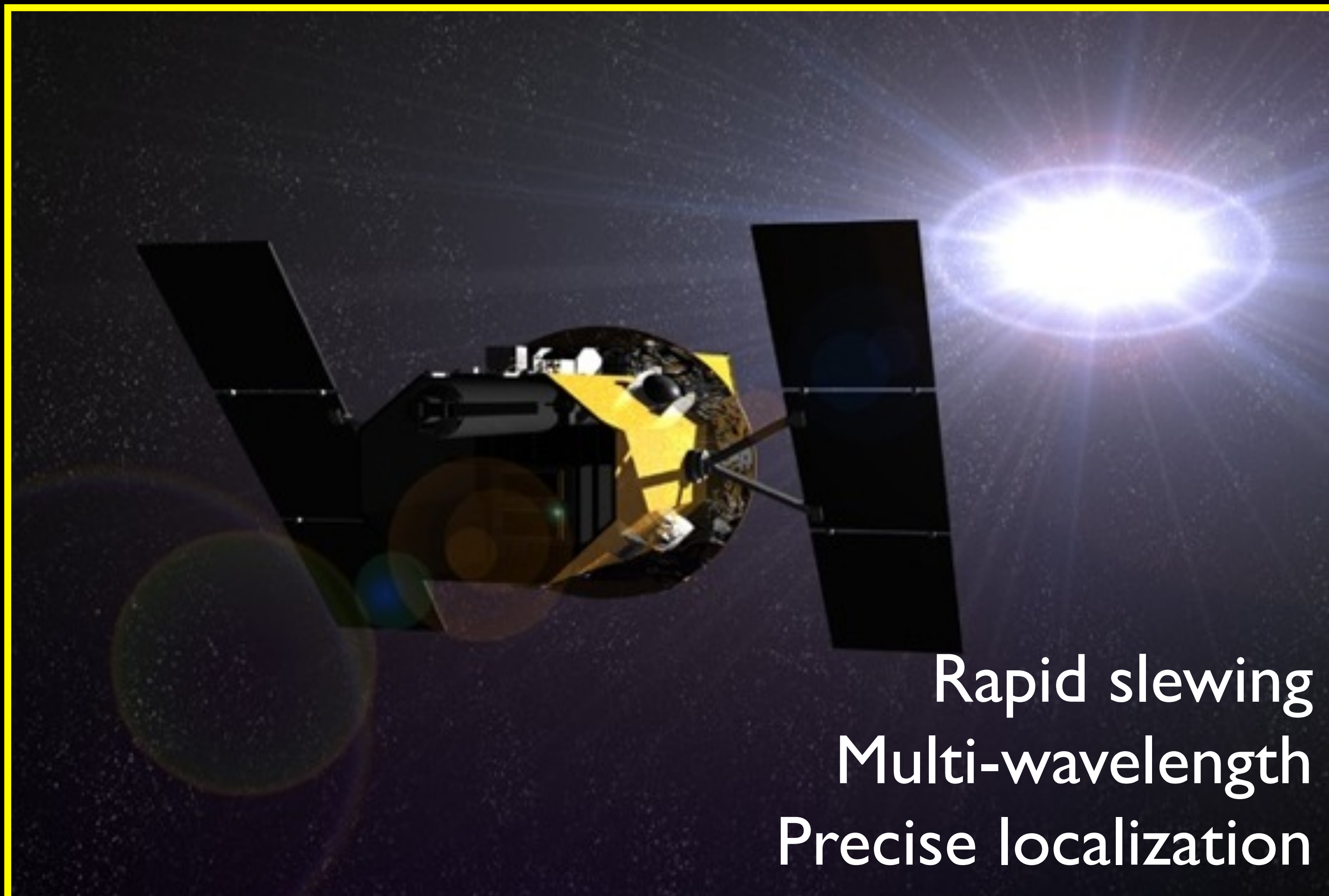
One decade ago…



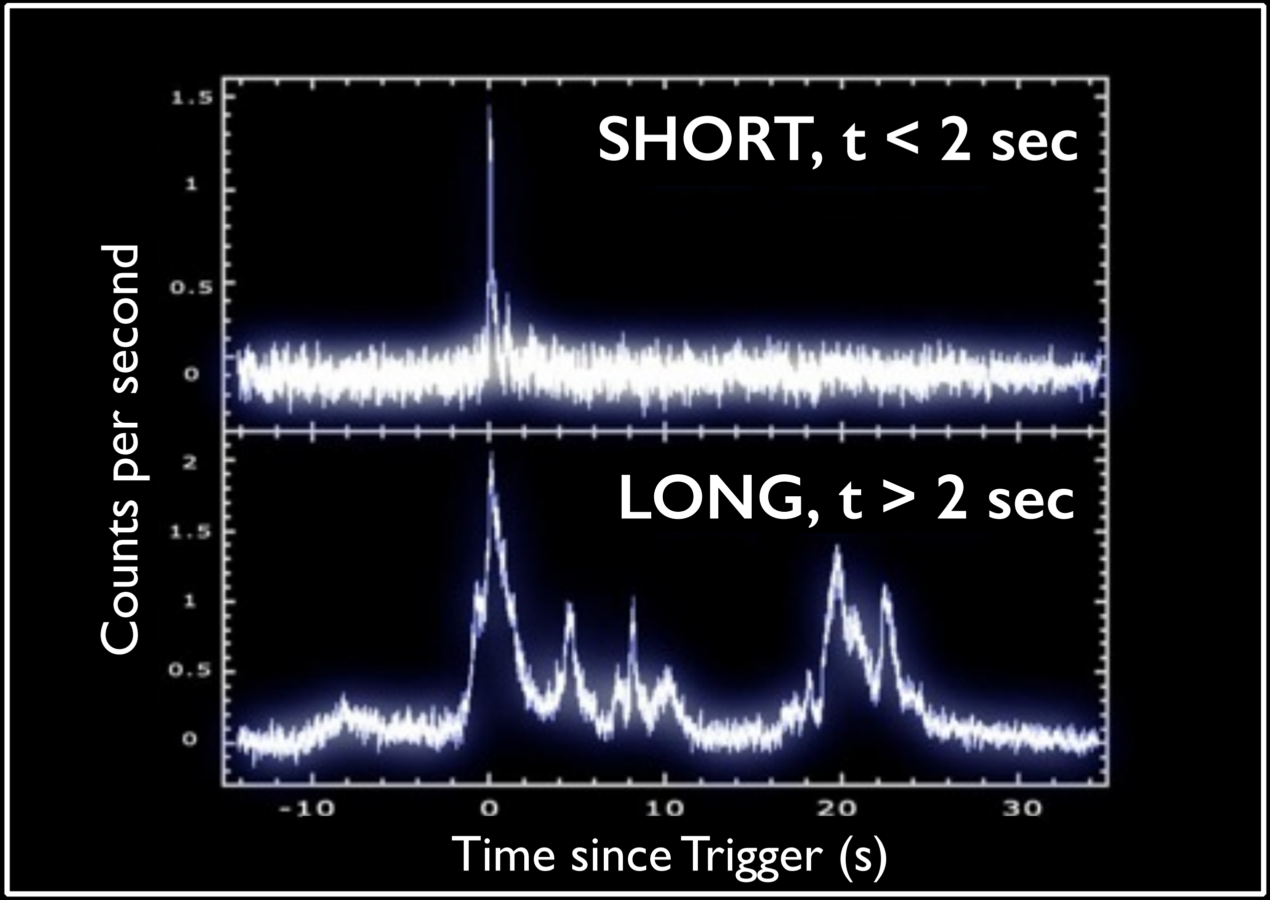
One decade ago…

October 27, 2004

One decade ago…

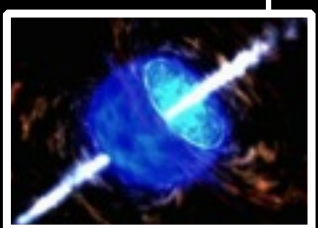


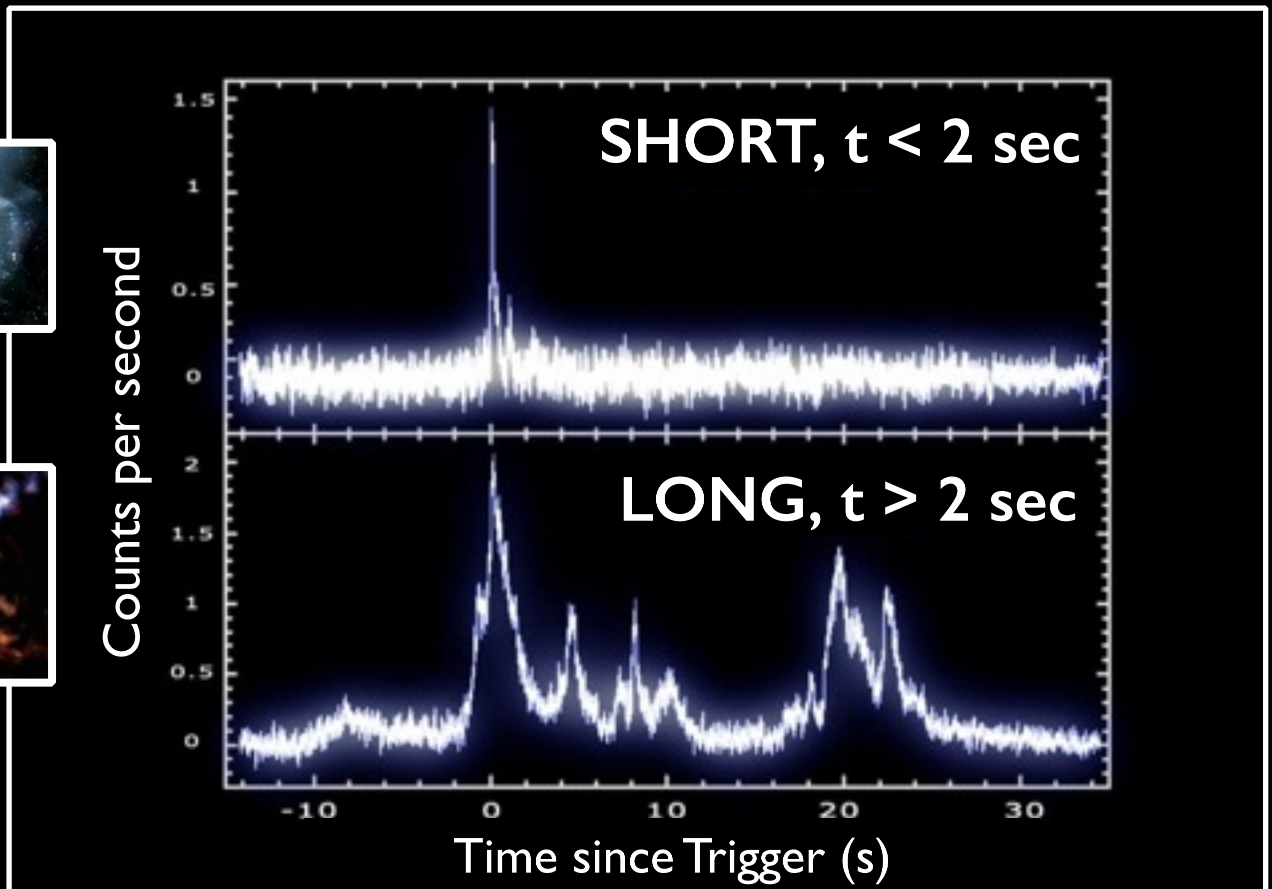
Two populations of bursts



Credit: NASA

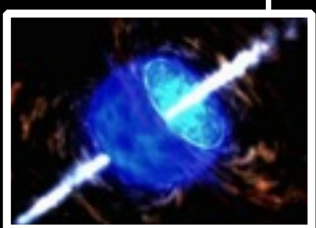
Two populations of bursts

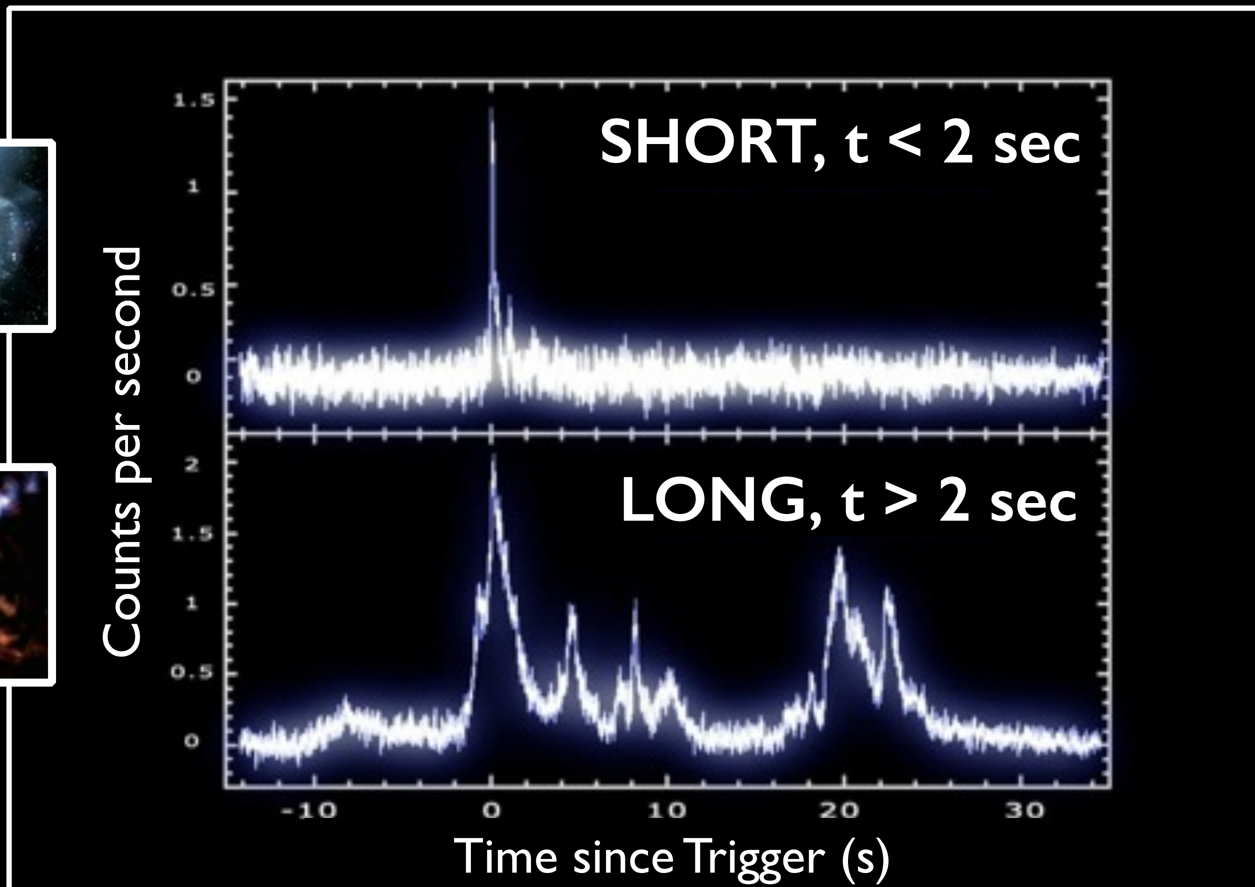




Credit: NASA

Two populations of bursts





10%

90%

Credit: NASA

The first short GRB afterglows

Fox et al. 2005

Hubble Space Telescope

ΔT < 48 hours

The first short GRB afterglows

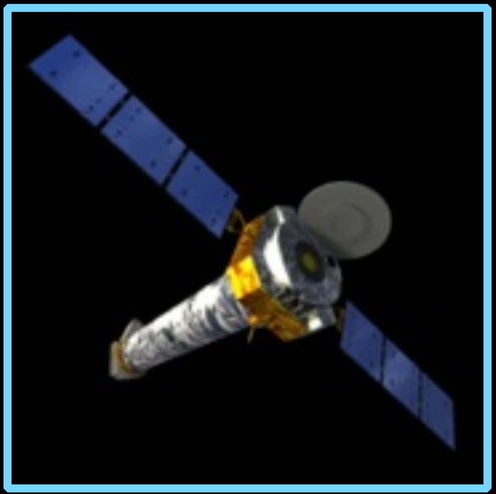
Fox et al. 2005

Hubble Space Telescope

ΔT < 48 hours

~23 mag @ 10 hr after burst discovery

The multi-wavelength Target-of-Opportunity afterglow chase



Chandra

XMM-Newton

The multi-wavelength Target-of-Opportunity afterglow chase

Chandra

Magellan (Chile)

MMTO (Arizona)

LBT (Arizona)

XMM-Newton

The multi-wavelength Target-of-Opportunity afterglow chase

Chandra

Magellan (Chile)

MMTO (Arizona)

LBT (Arizona)

XMM-Newton

UKIRT (Hawaii)

The multi-wavelength Target-of-Opportunity afterglow chase

Chandra

Magellan (Chile)

MMTO (Arizona)

LBT (Arizona)

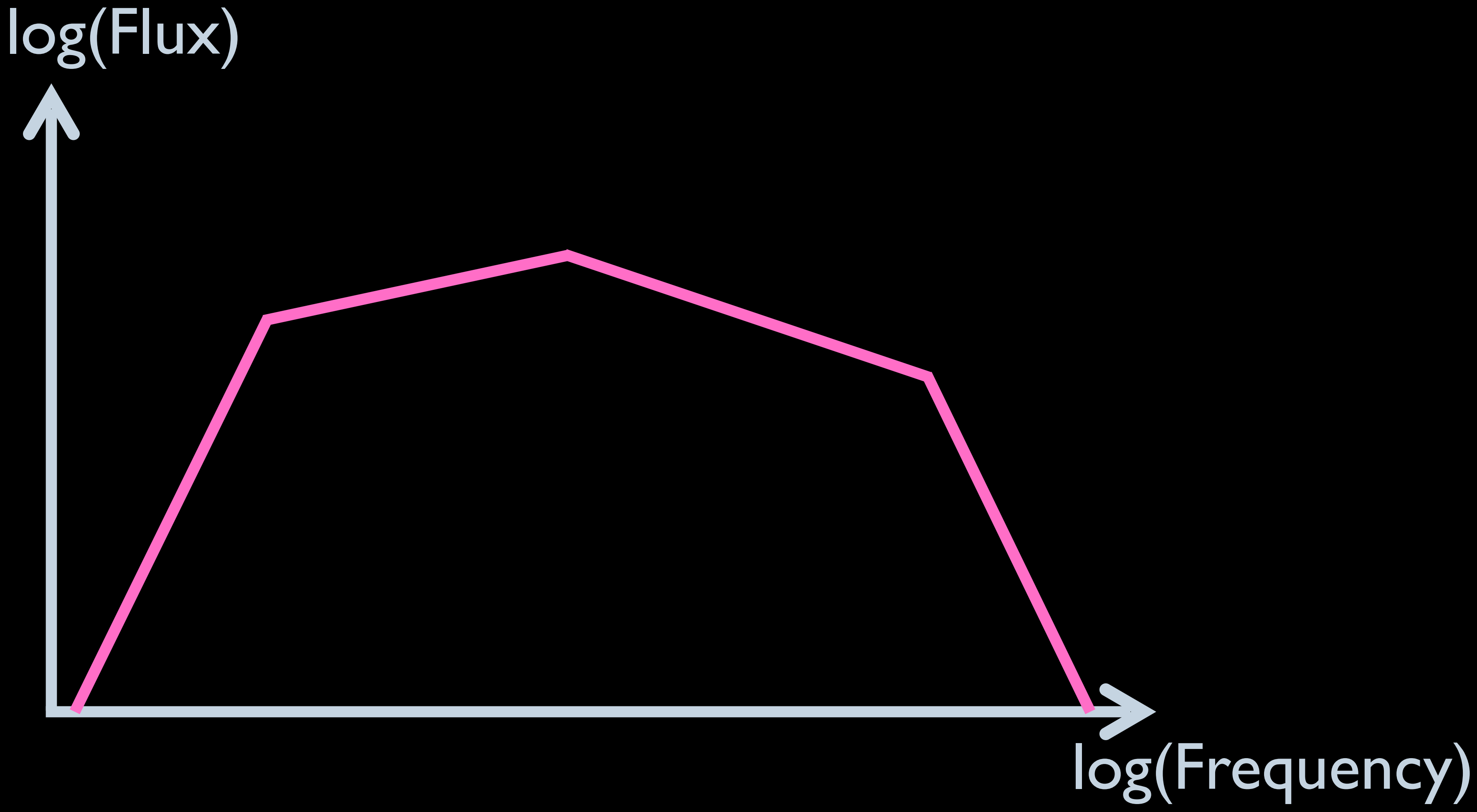
XMM-Newton

UKIRT (Hawaii)

VLA (New Mexico)

Afterglow census

Why do we need multi-wavelength?



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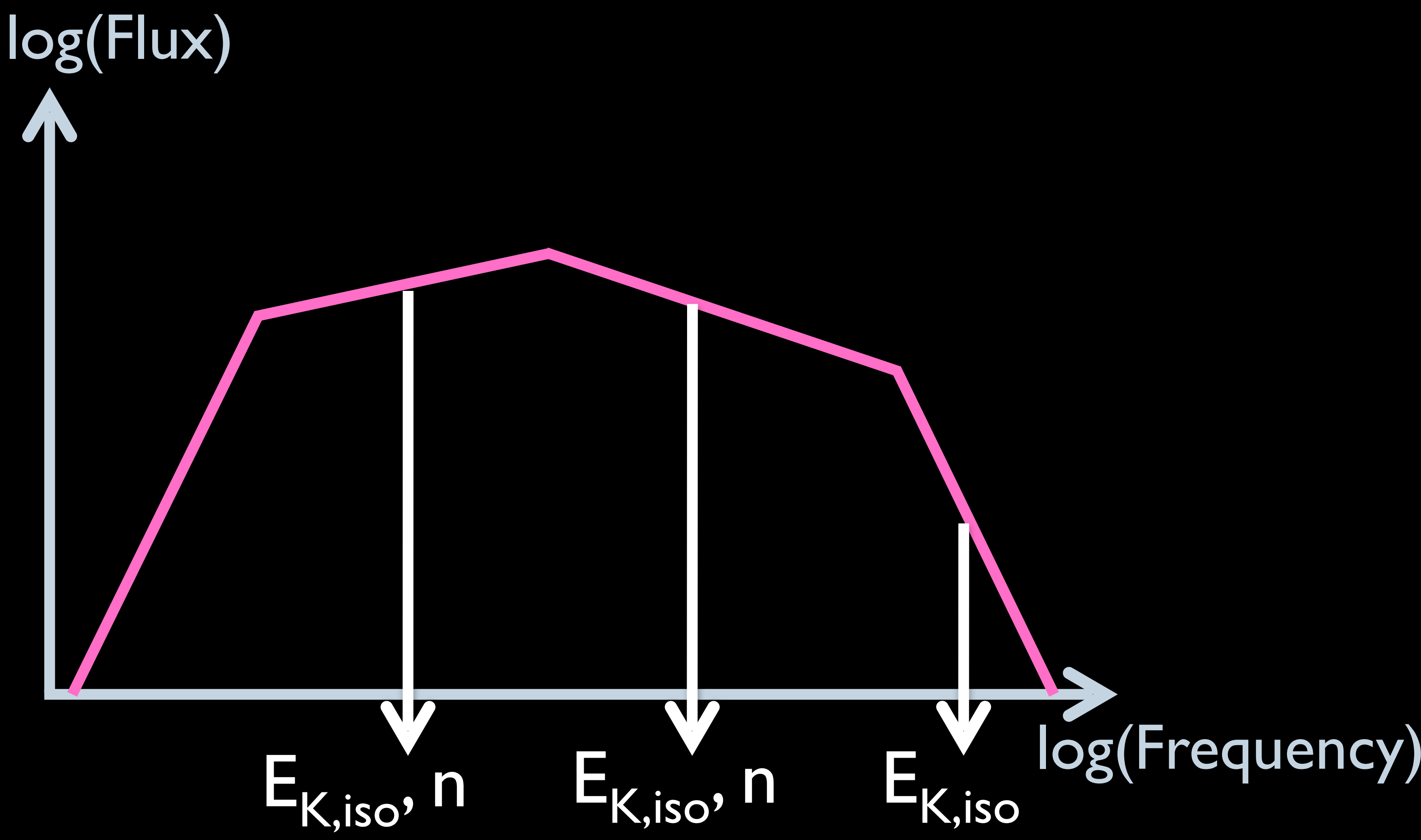
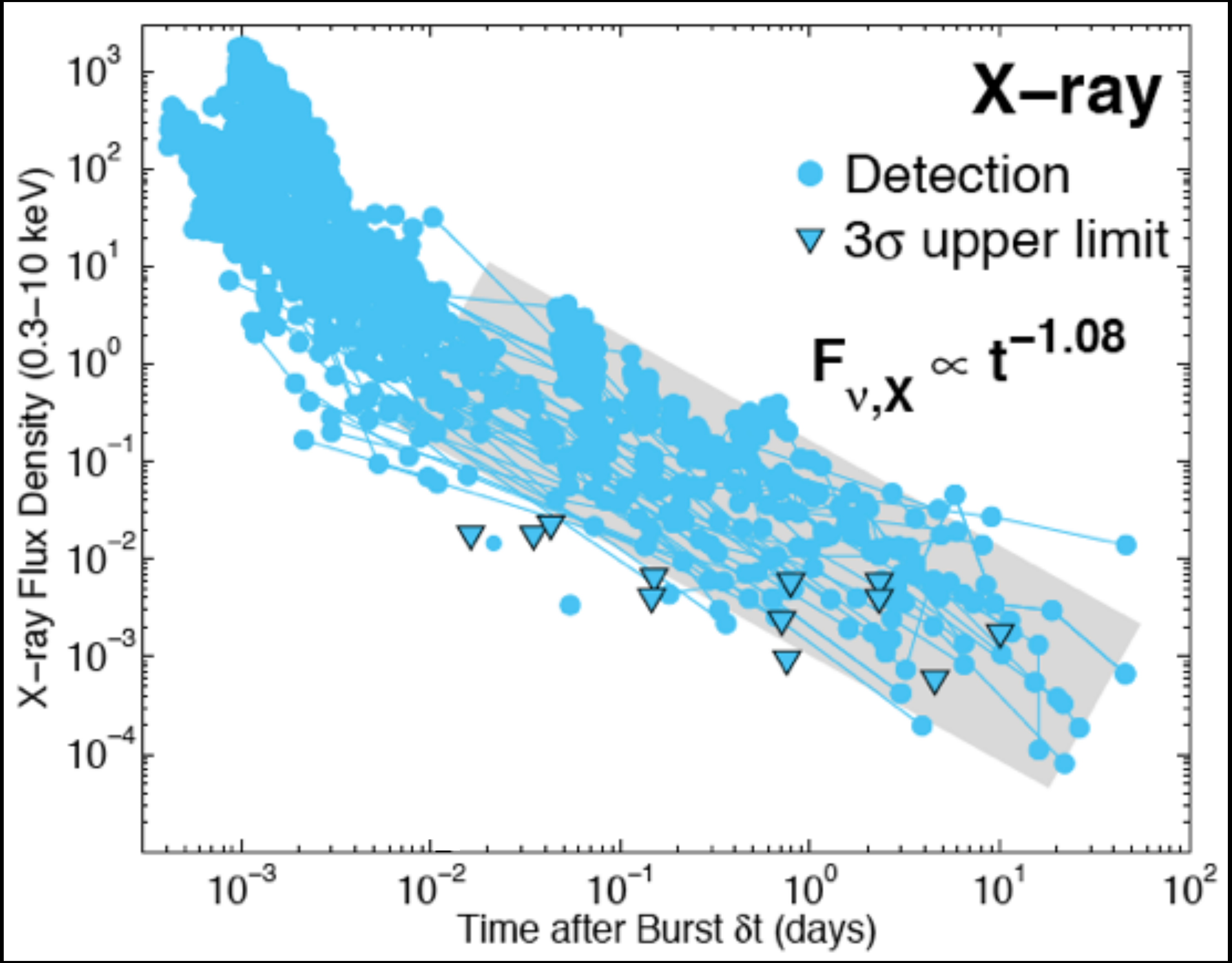


Short GRB X-ray afterglows



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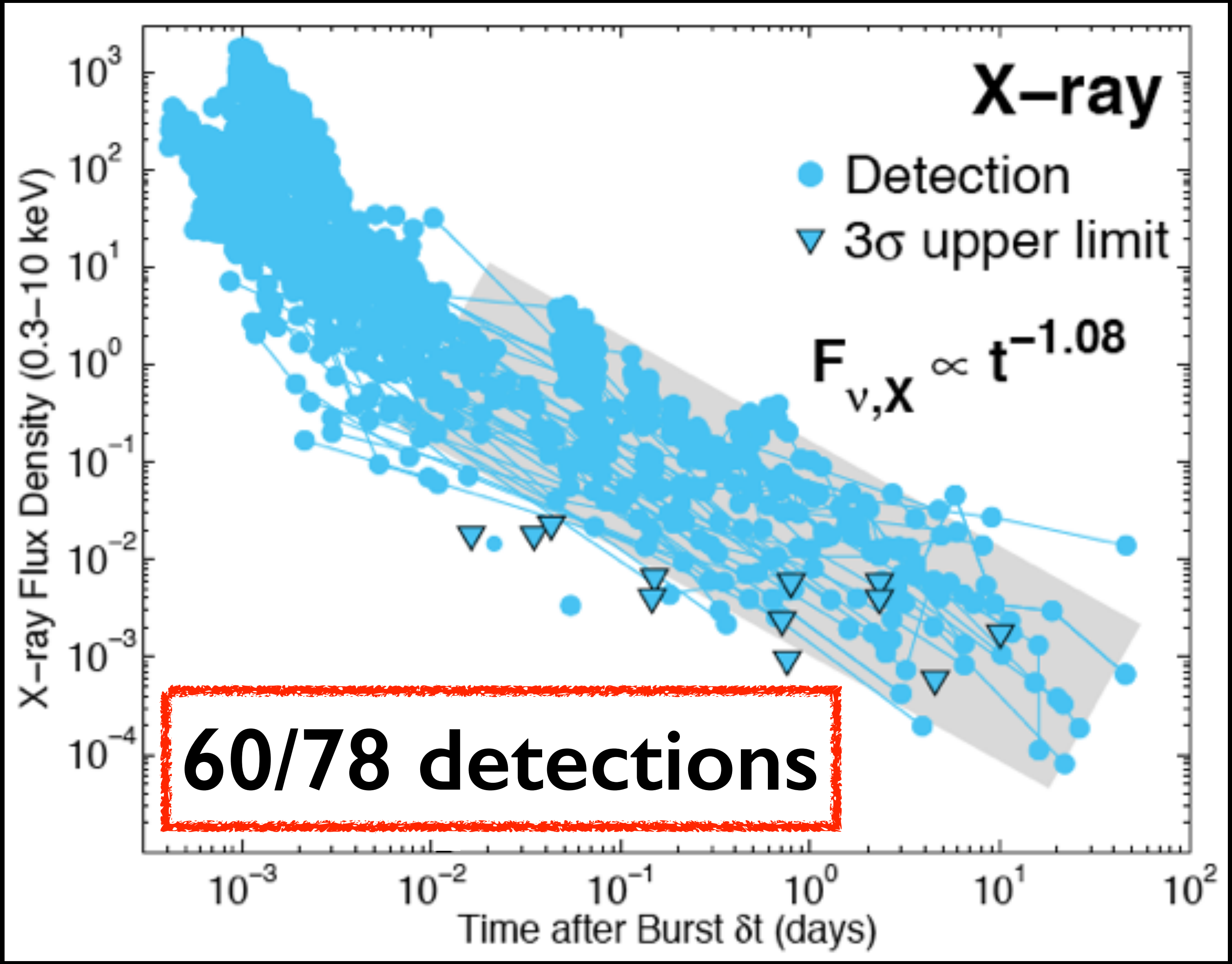
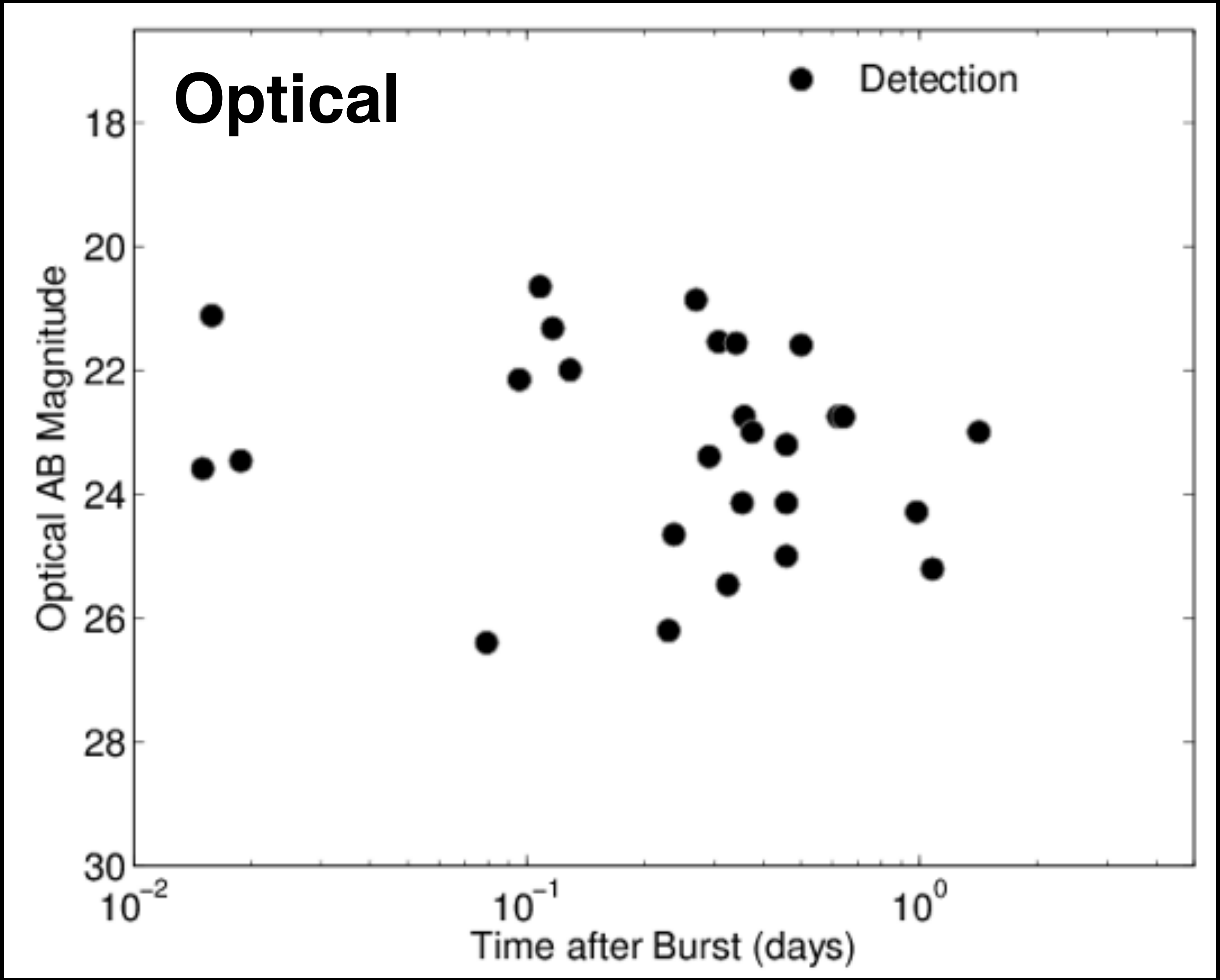
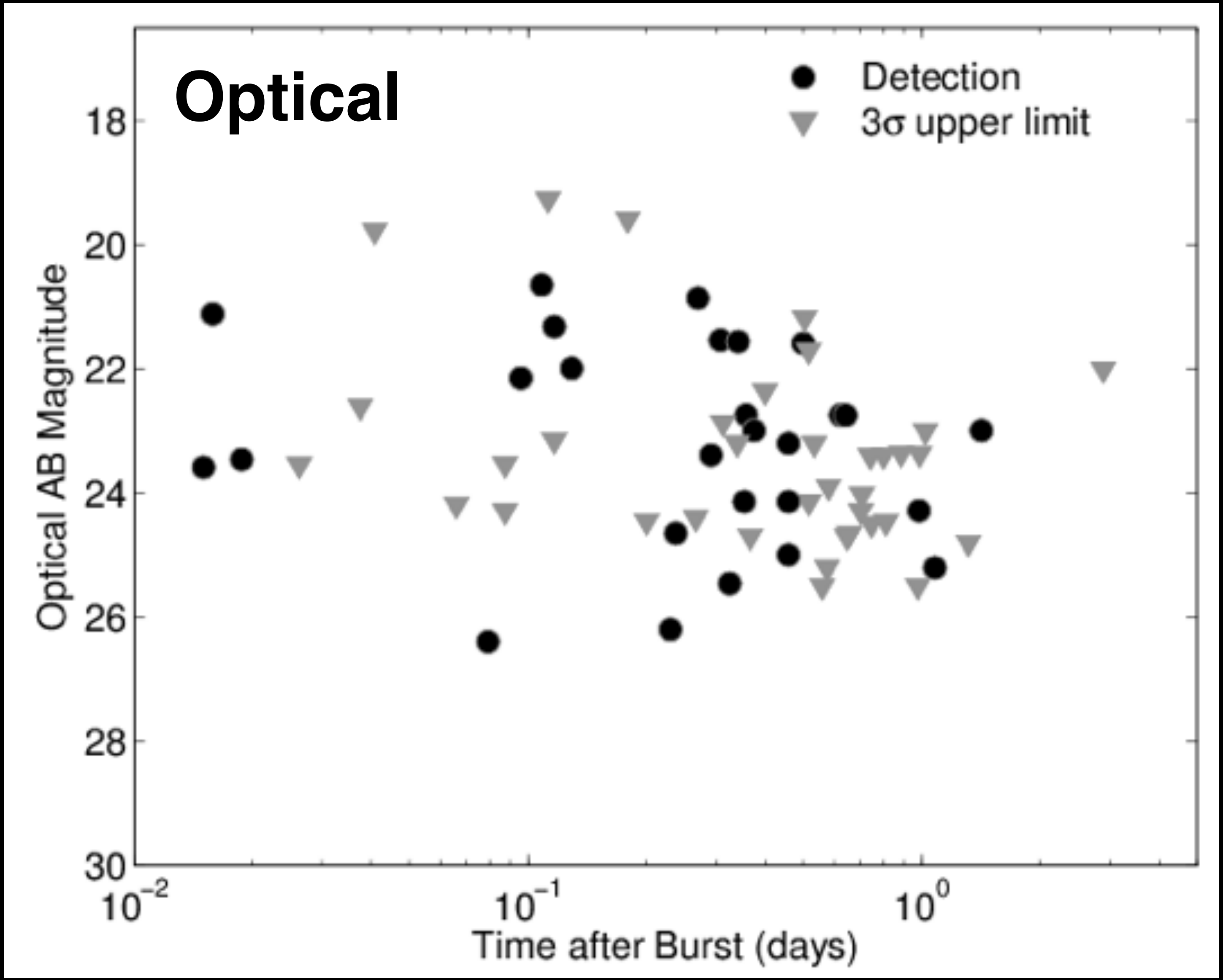


Short GRB optical afterglows



Short GRB optical afterglows



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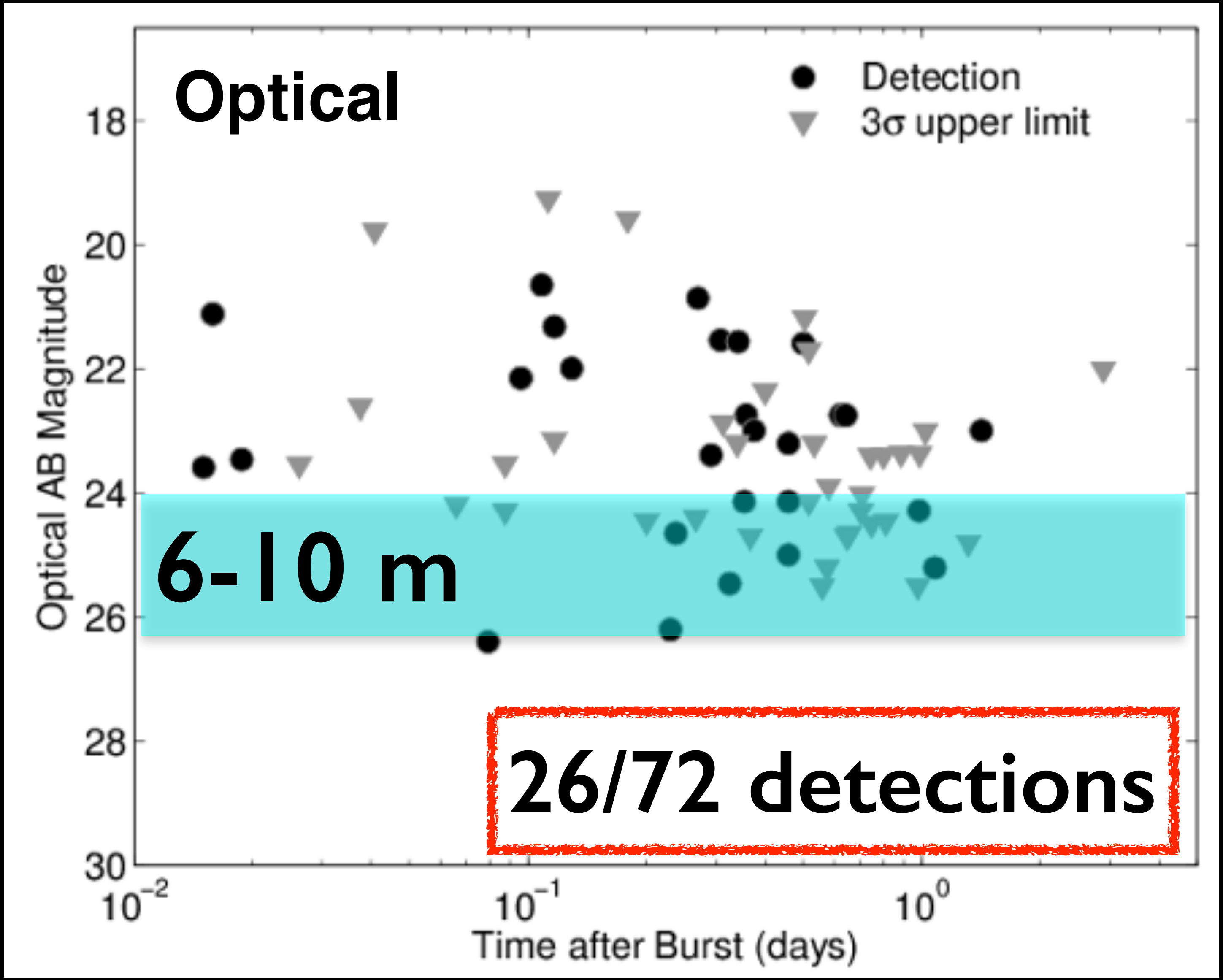
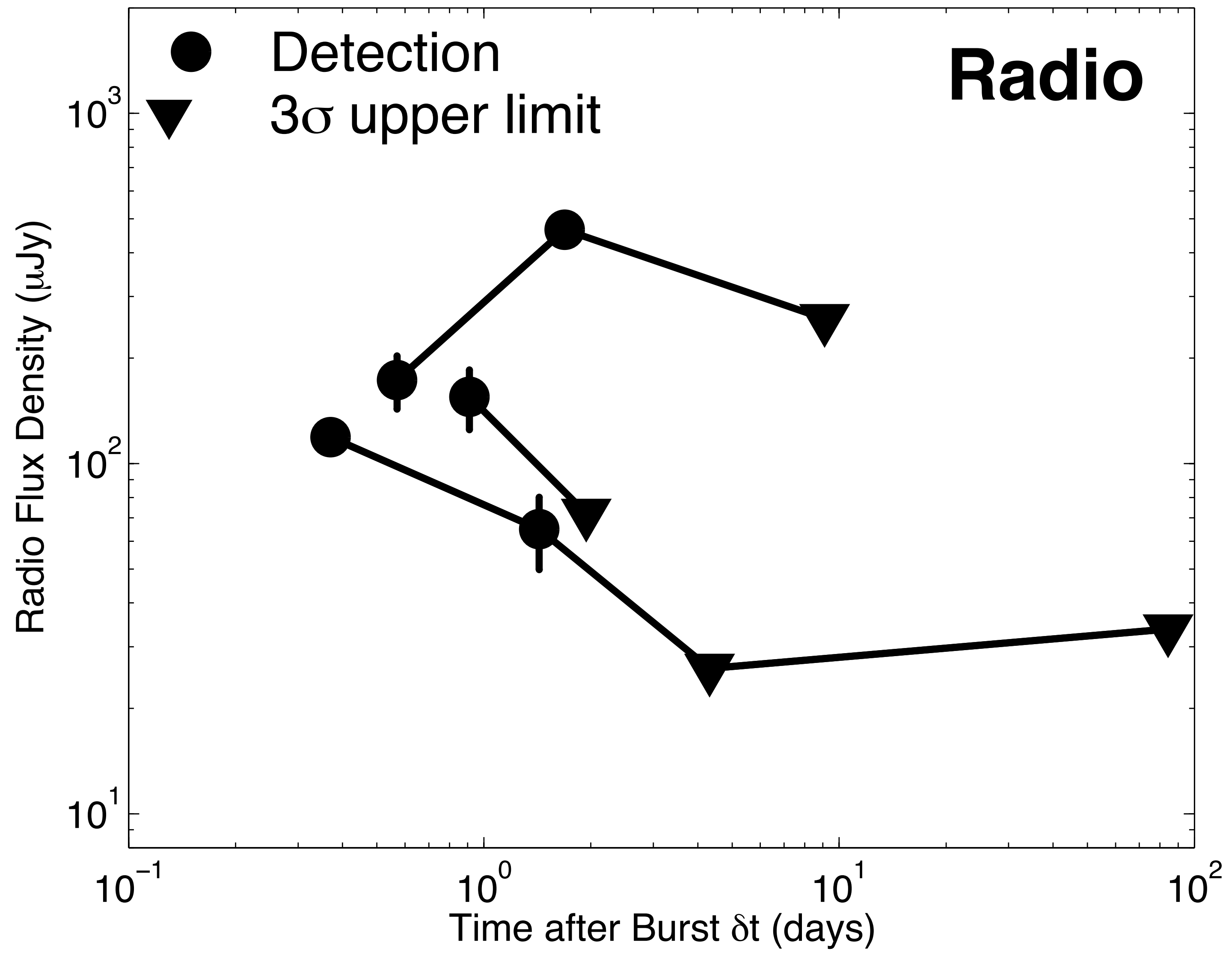
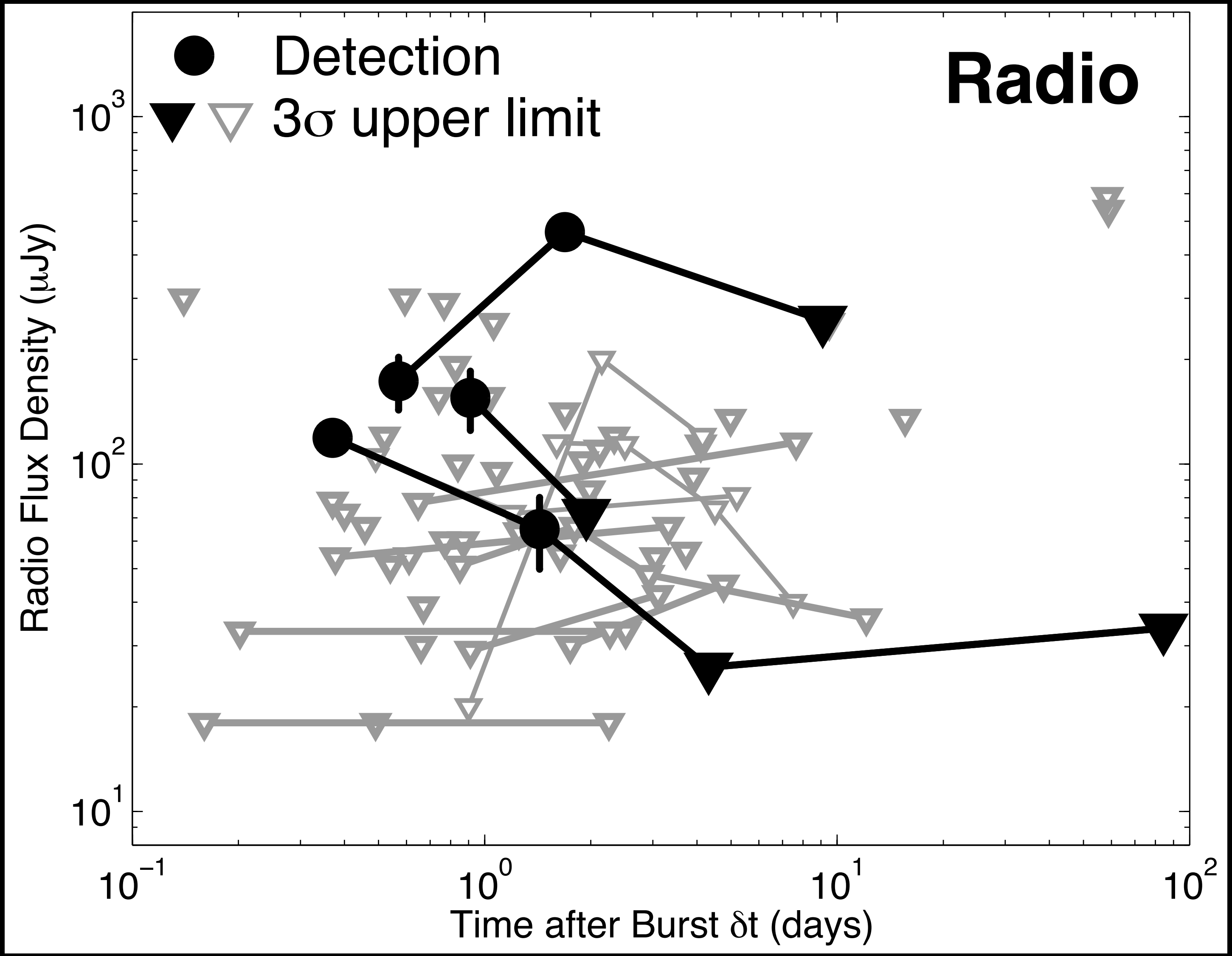


Short GRB radio afterglows



Short GRB radio afterglows



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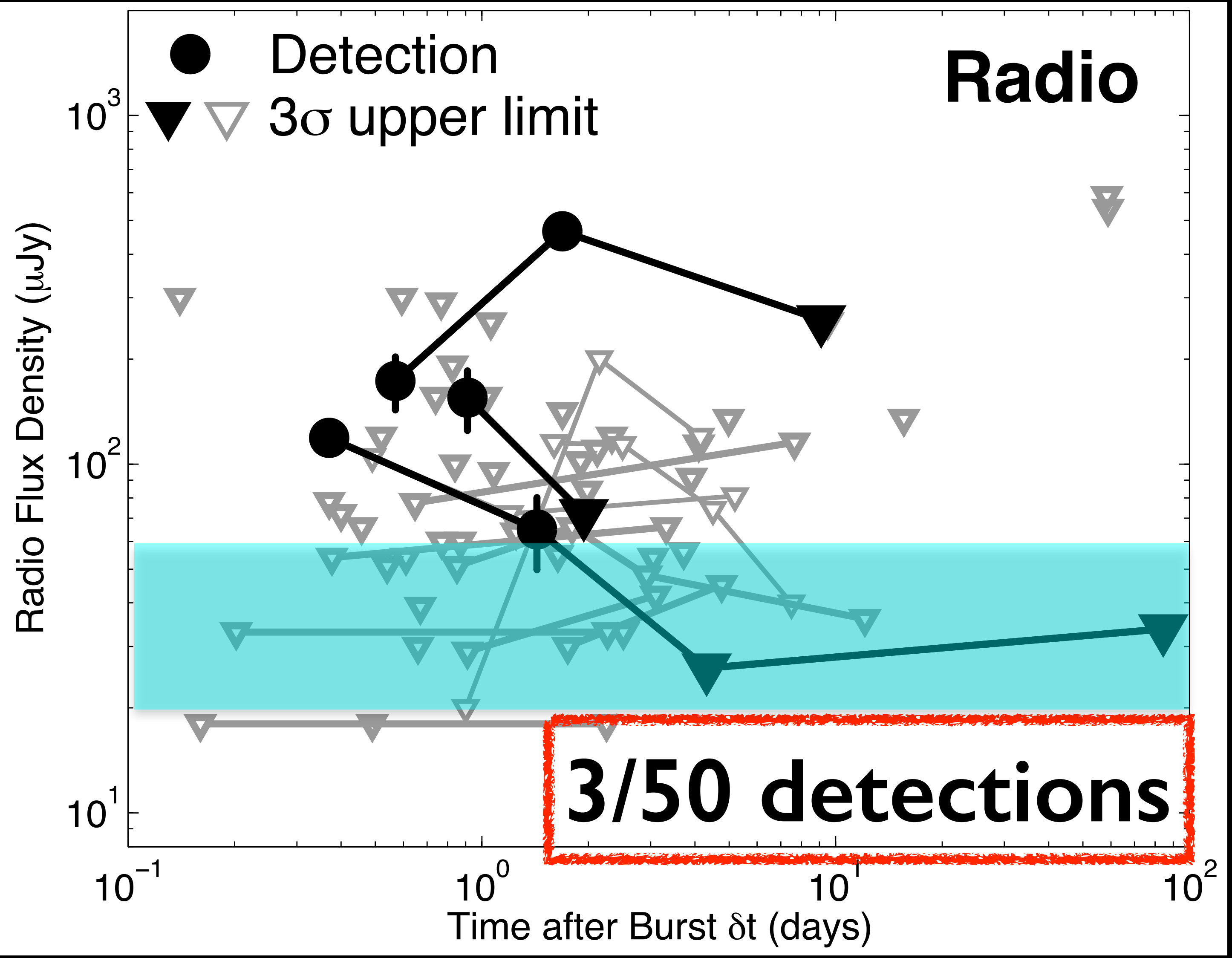
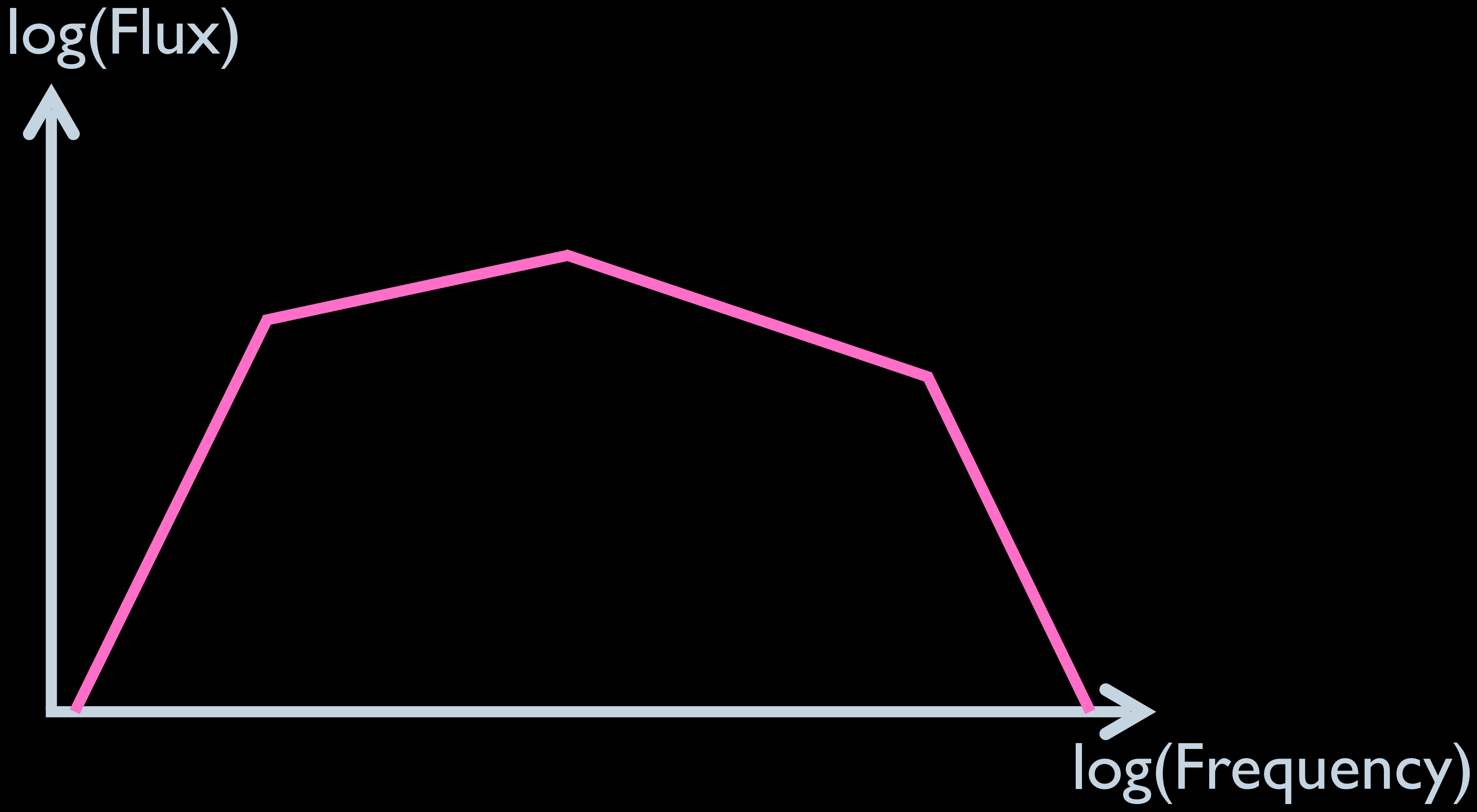
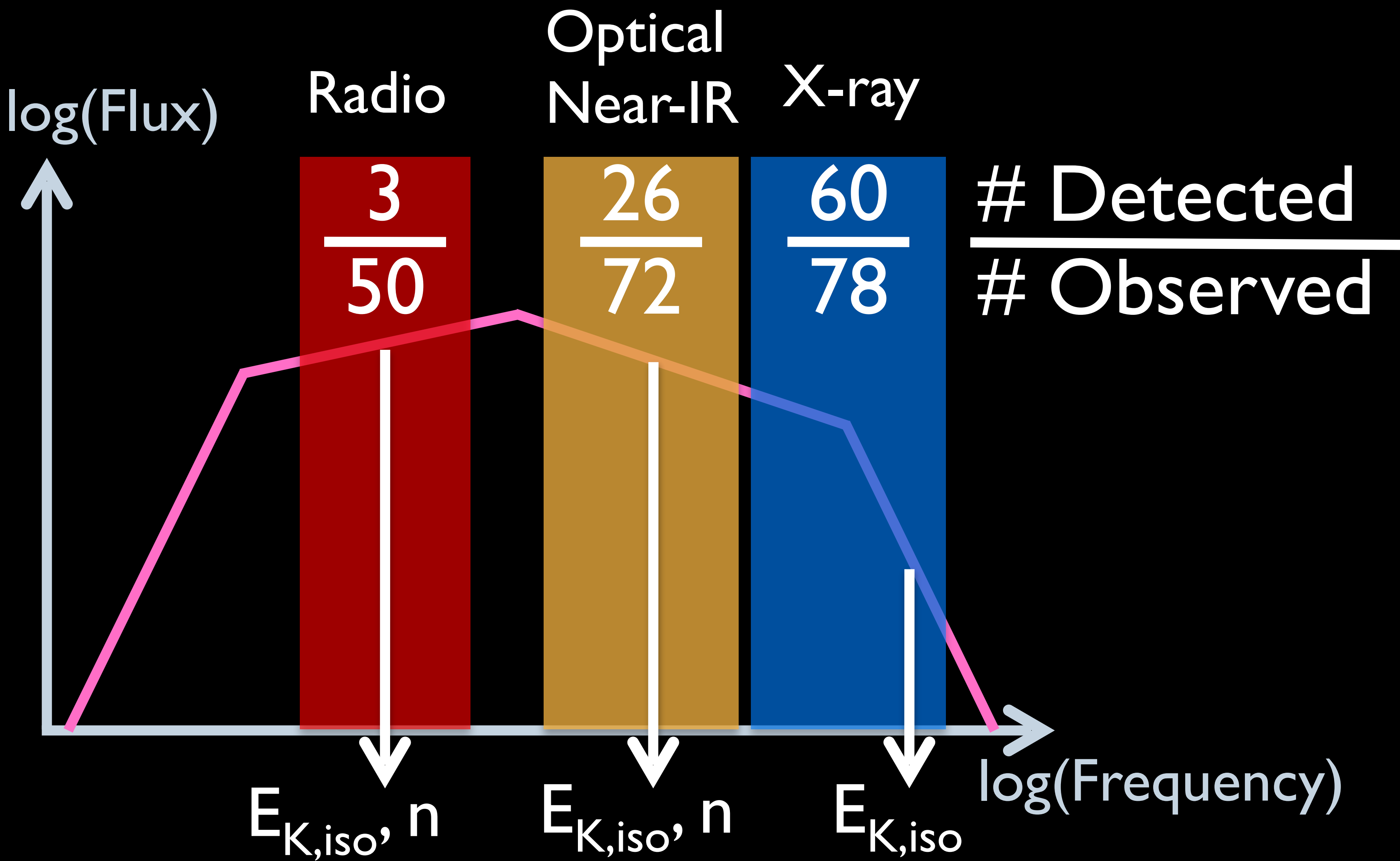


Afterglow census



Afterglow census

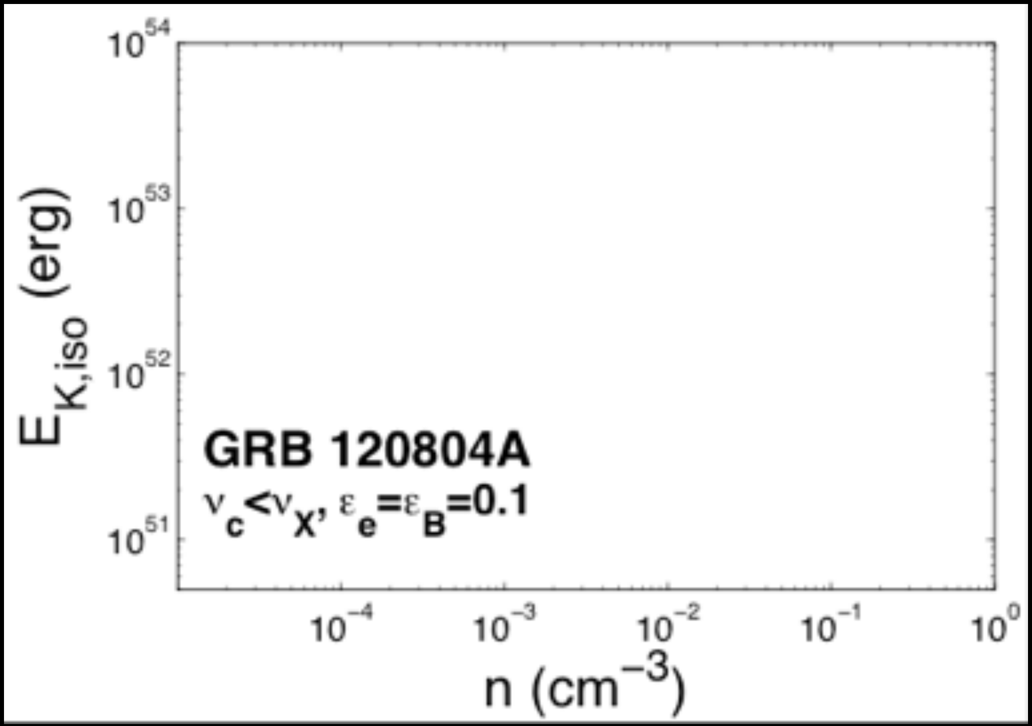


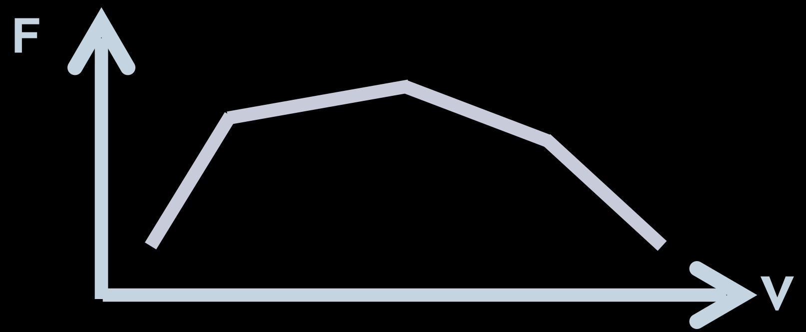
Explosion Properties

What can the lack of afterglow detections tell us about their Explosion Properties?

An example: GRB 120804A

X-ray and optical afterglows, radio non-detection





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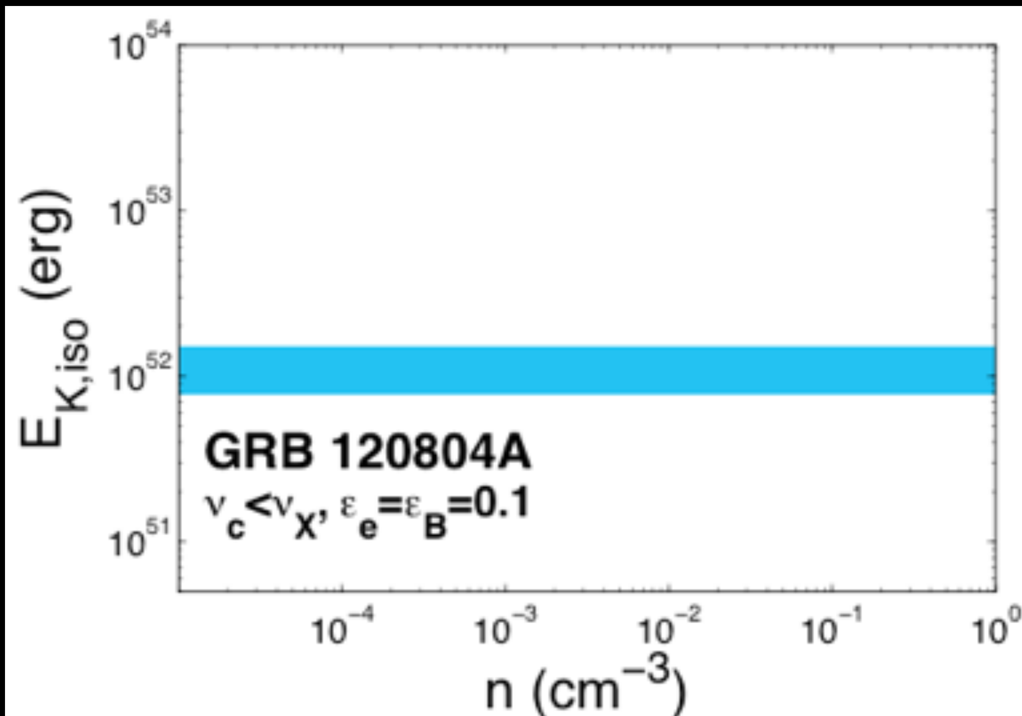

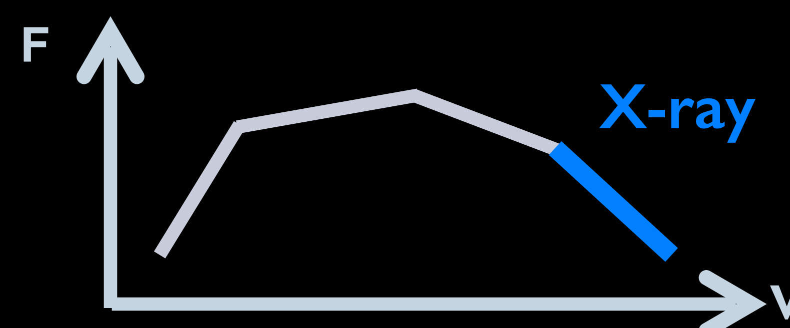

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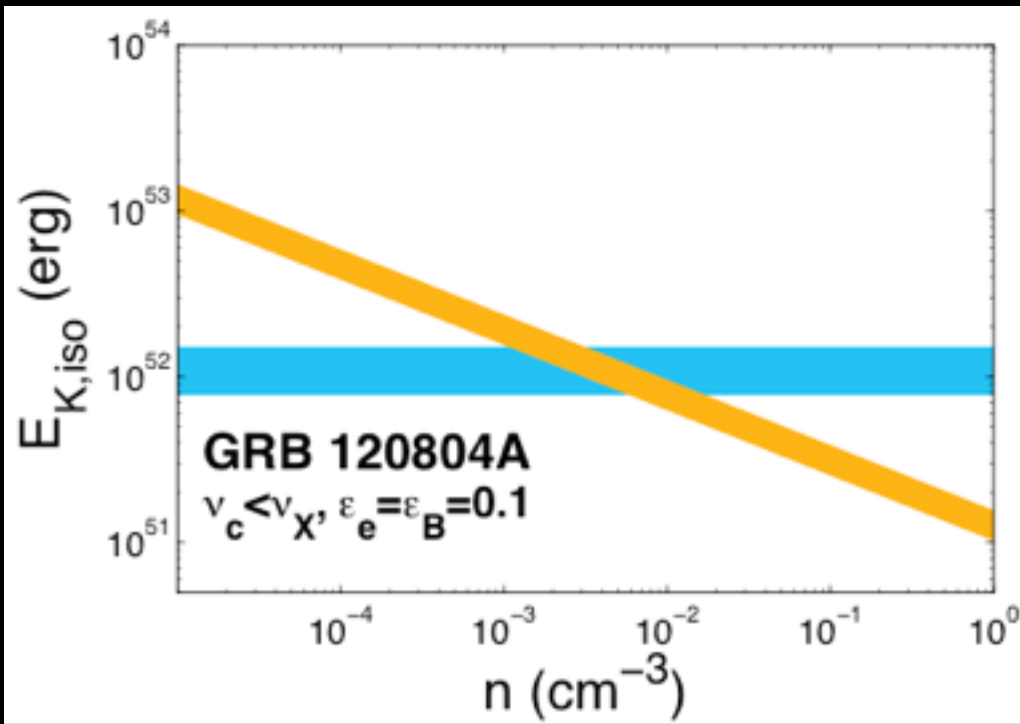

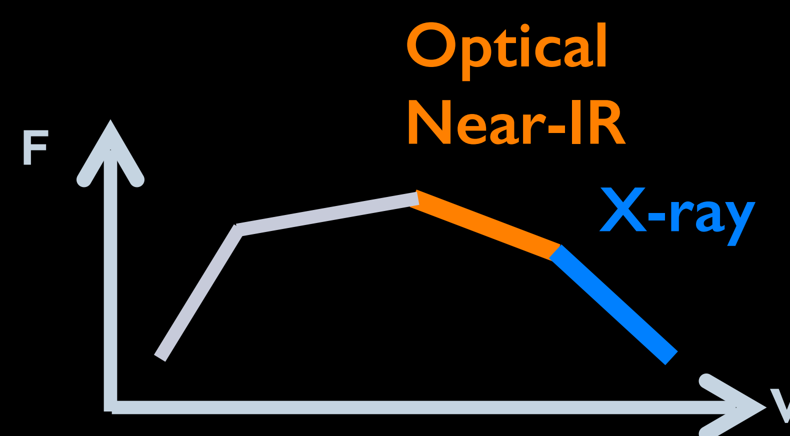

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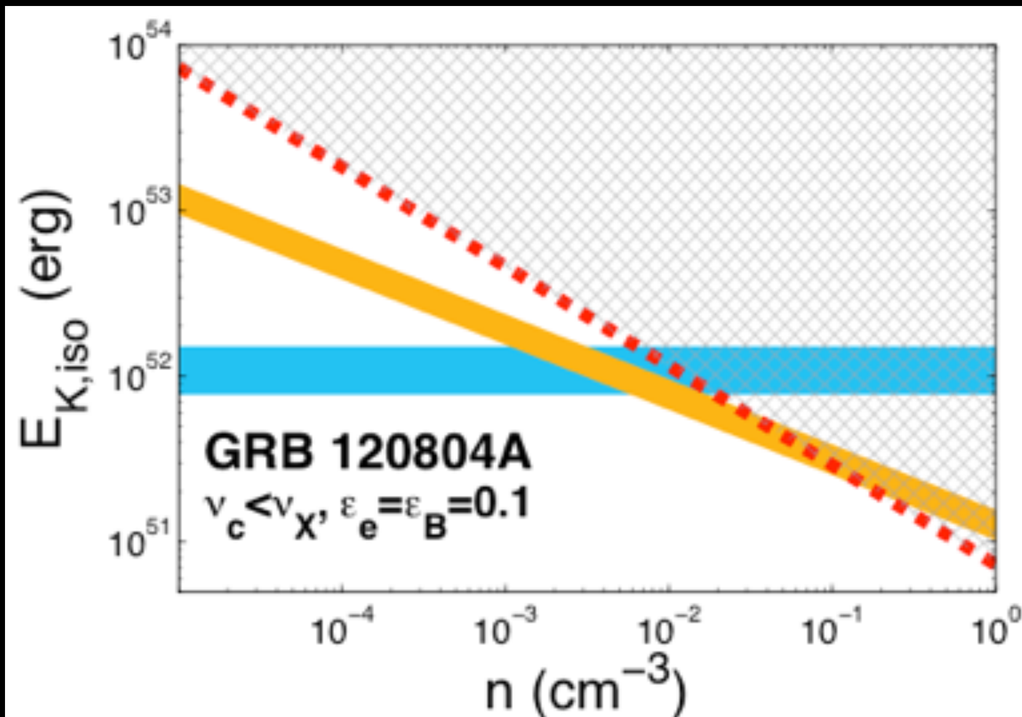

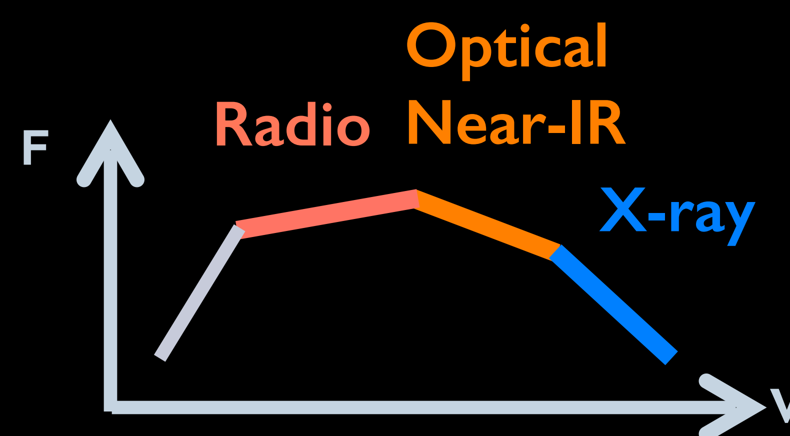

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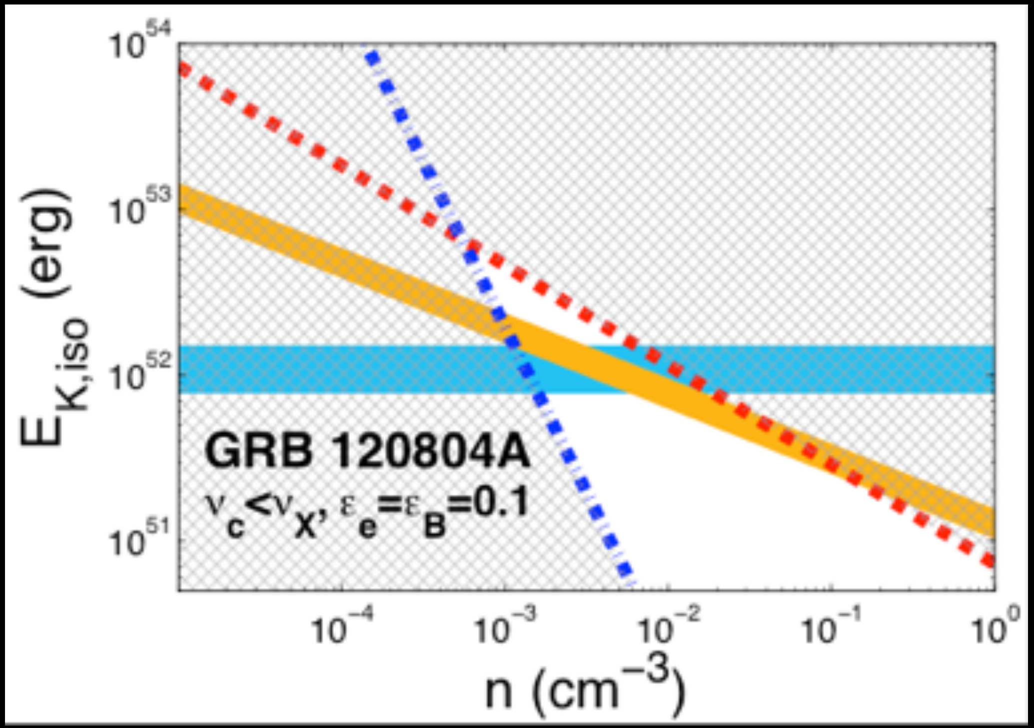

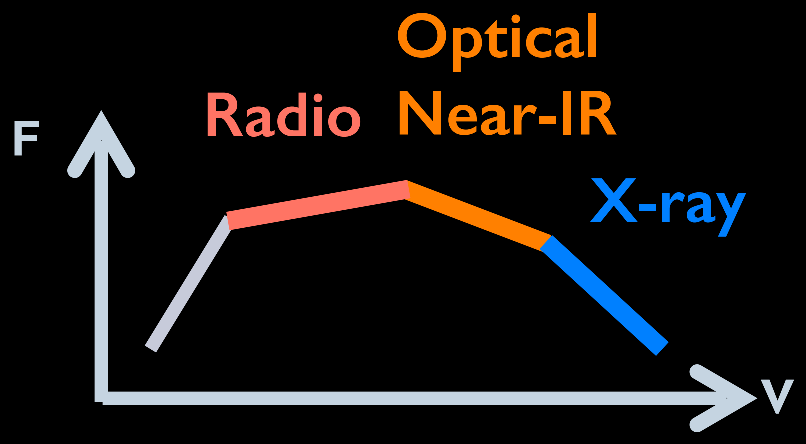

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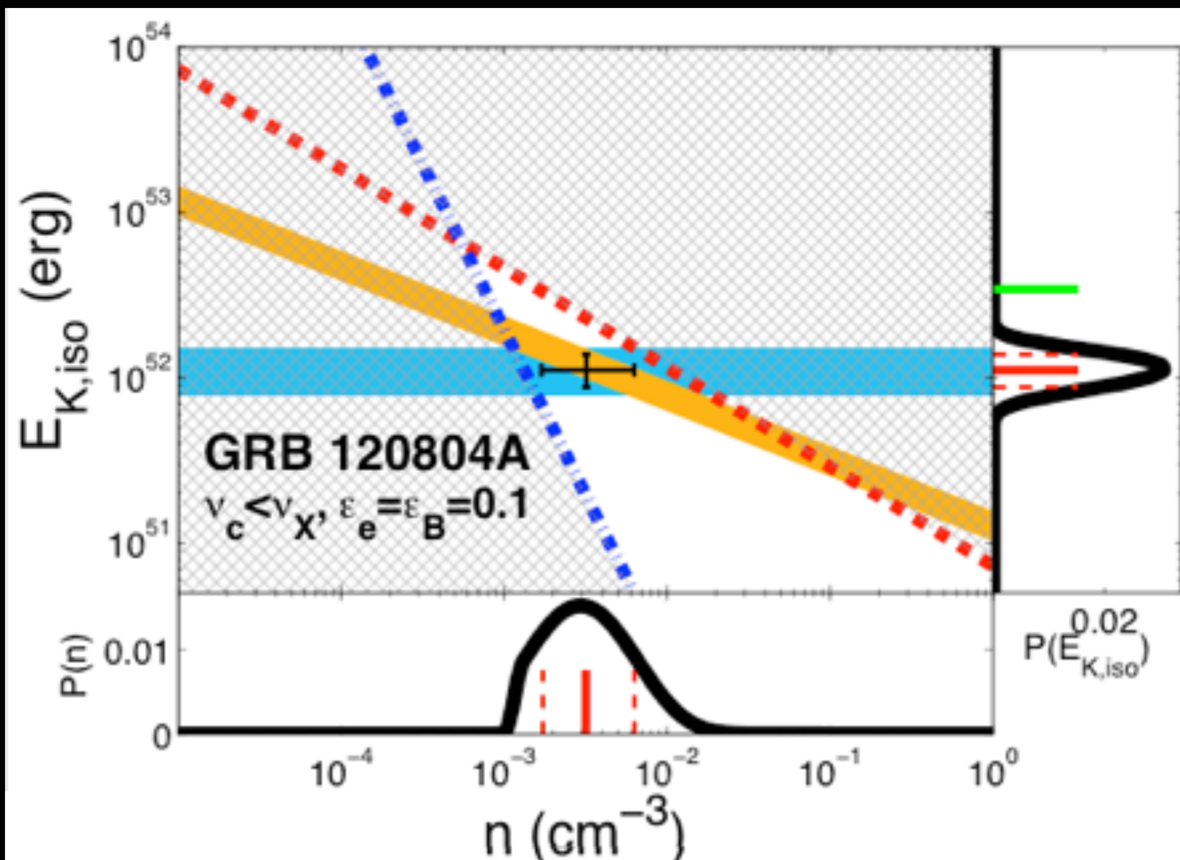
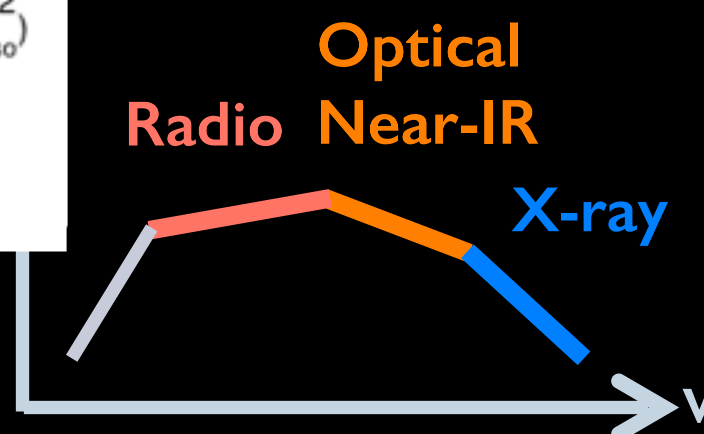
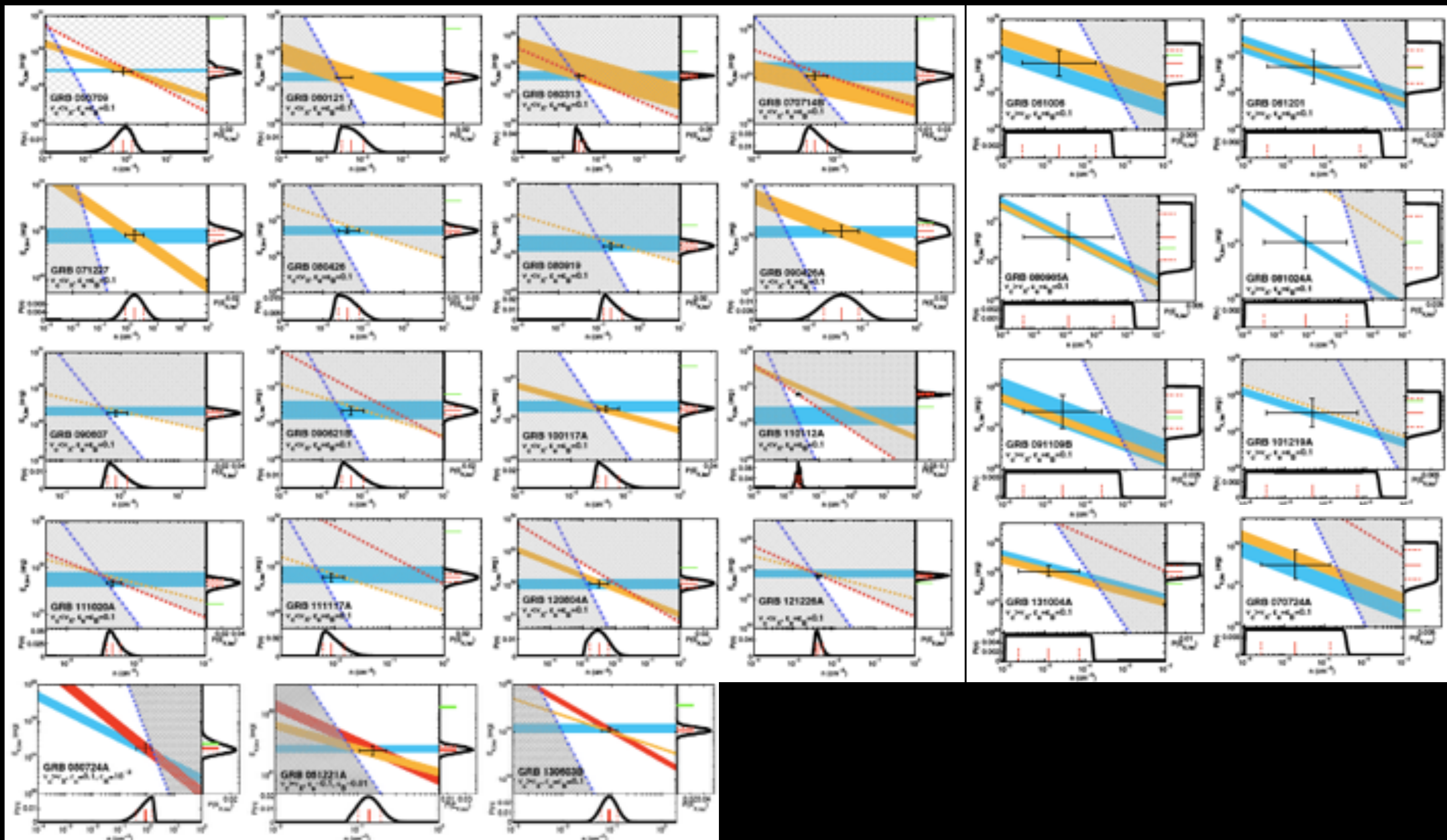


$E_{K,iso} = 1.1^{+0.3}_{-0.2} \times 10^{52}$ erg

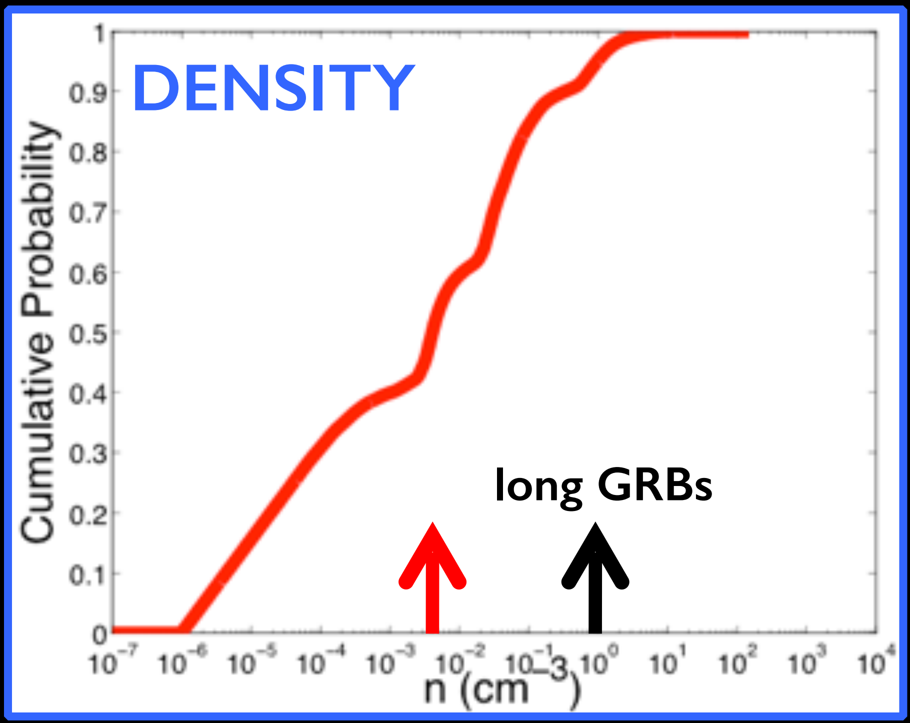
$n = 3.2^{+3.1}_{-1.5} \times 10^{-3}$ cm^{-3}





Each burst has its own story...

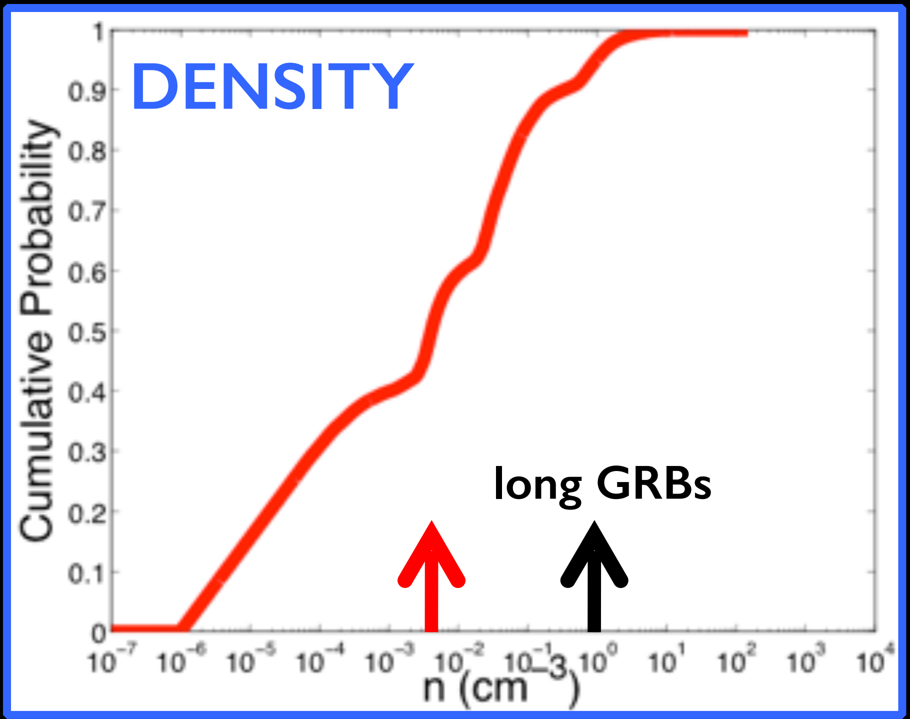
Population explosion properties

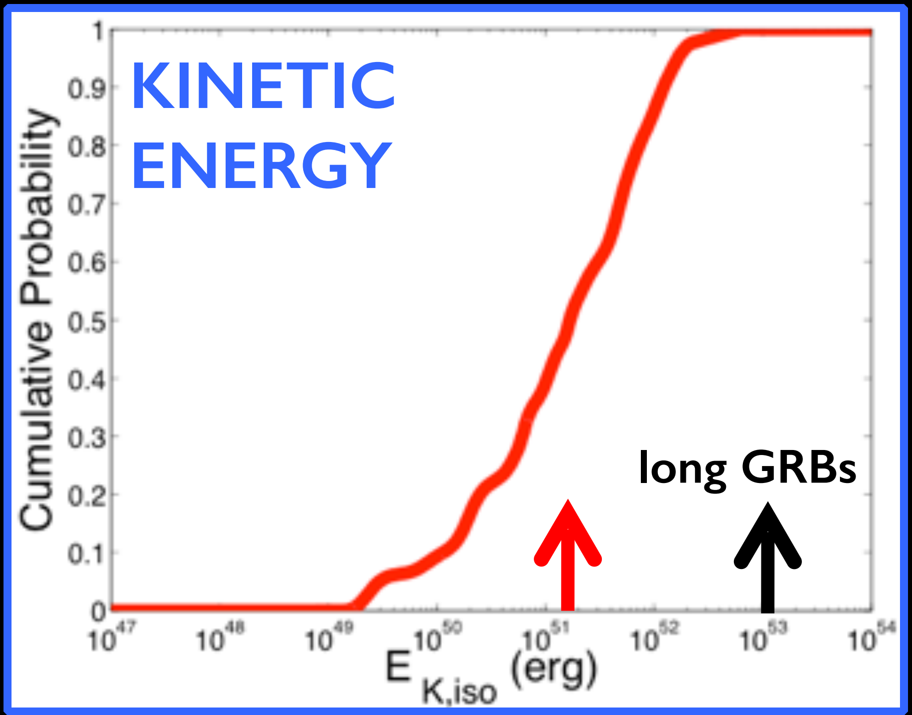


$\langle n \rangle = 4.1 \times 10^{-3}$ cm^{-3}

95% is <1 cm^{-3}

Population explosion properties





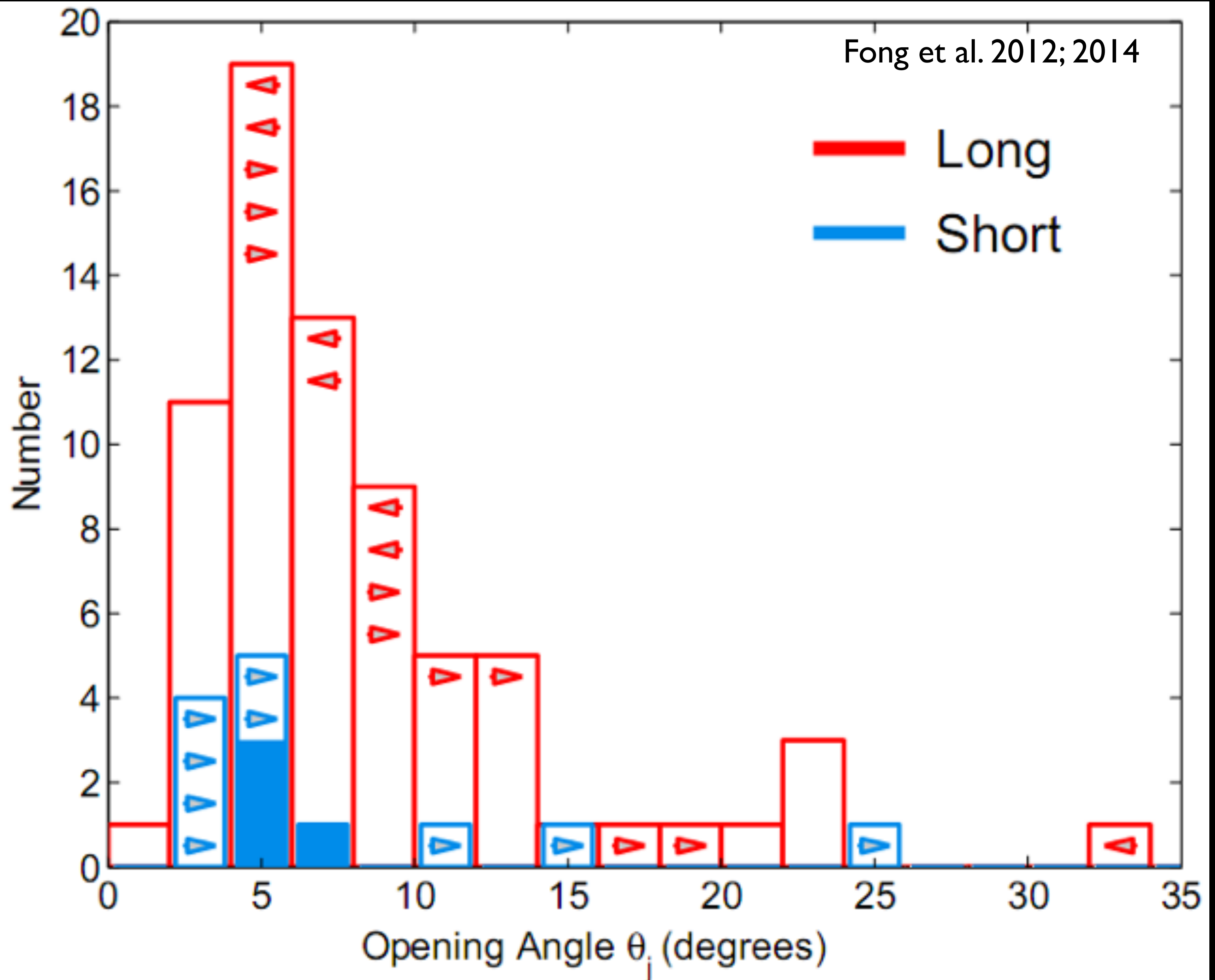
$\langle n \rangle = 4.1 \times 10^{-3}$ cm^{-3}
95% is <1 cm^{-3}

$\langle E_{K,iso} \rangle = 1.7 \times 10^{51}$ erg

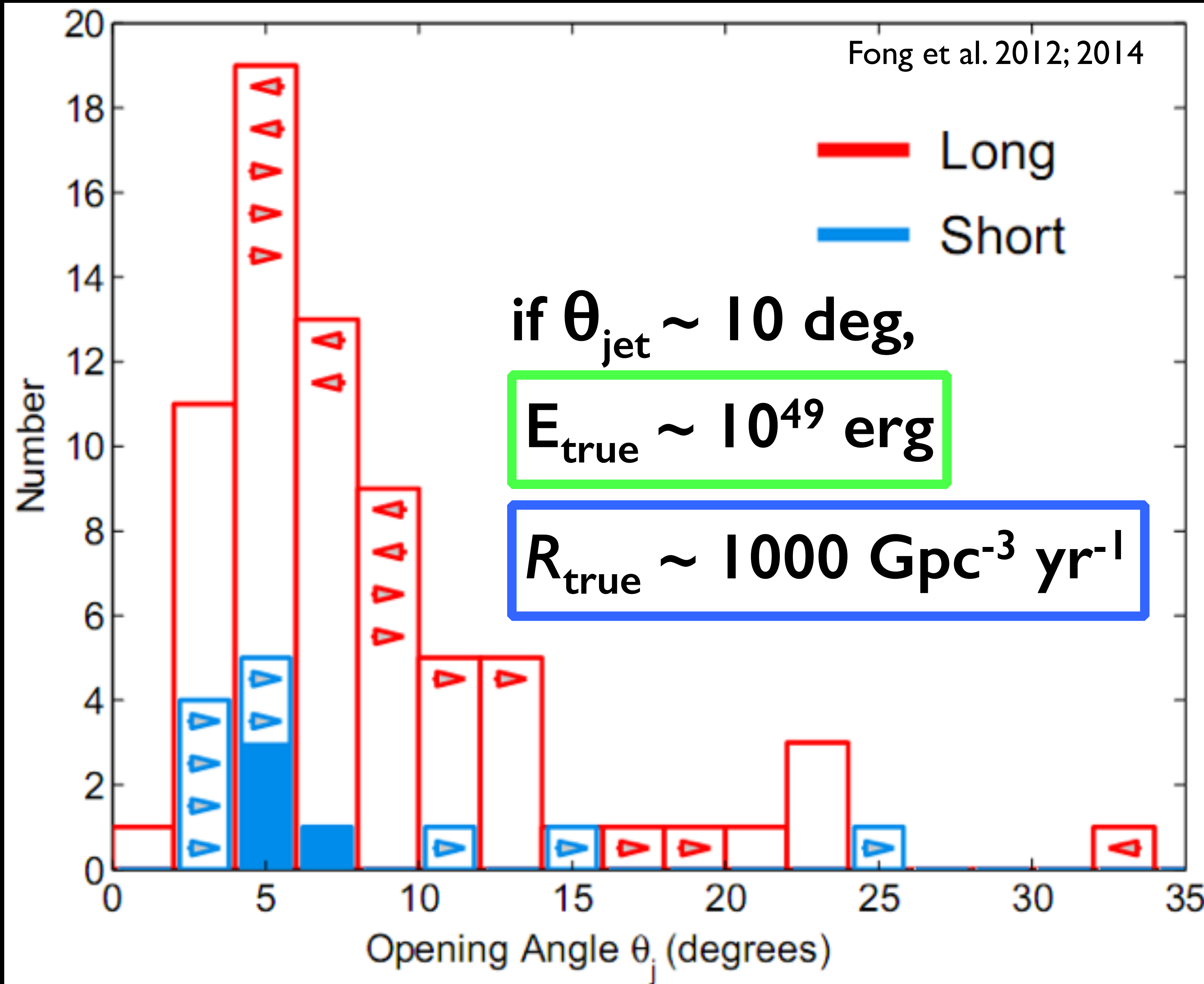
No trend with elliptical vs. star-forming host

highly collimated

spherical

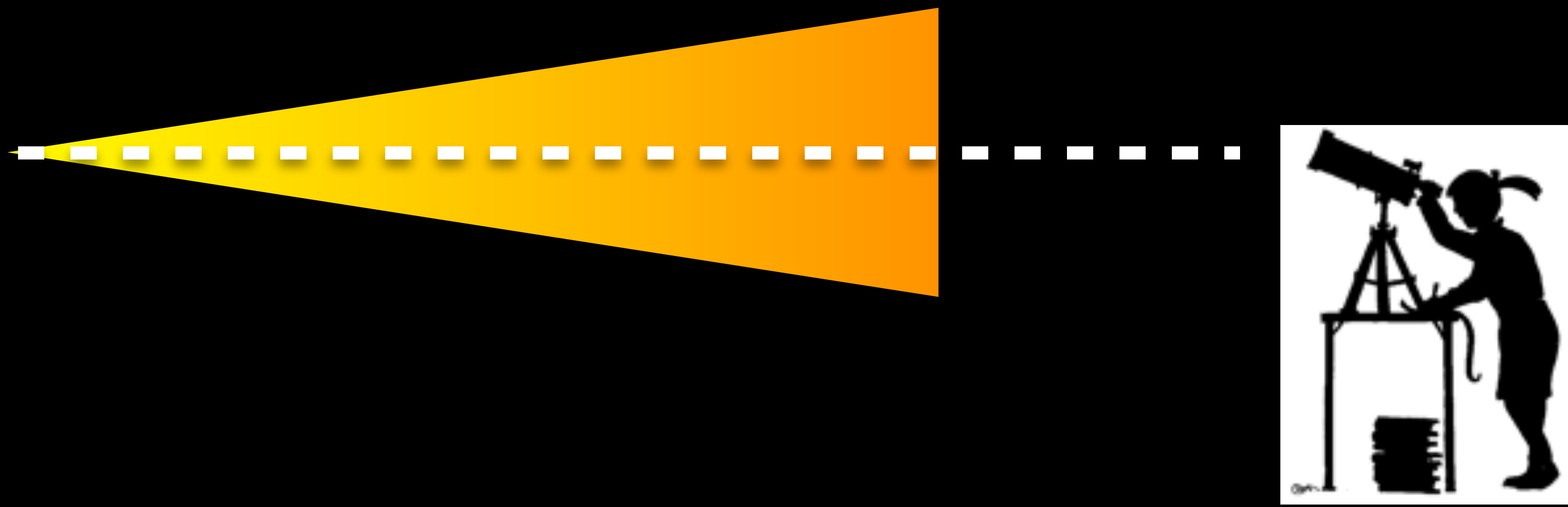


Fong et al. 2012; 2014
Long
Short
Number
Opening Angle θ_j (degrees)
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12
14
16
18
20

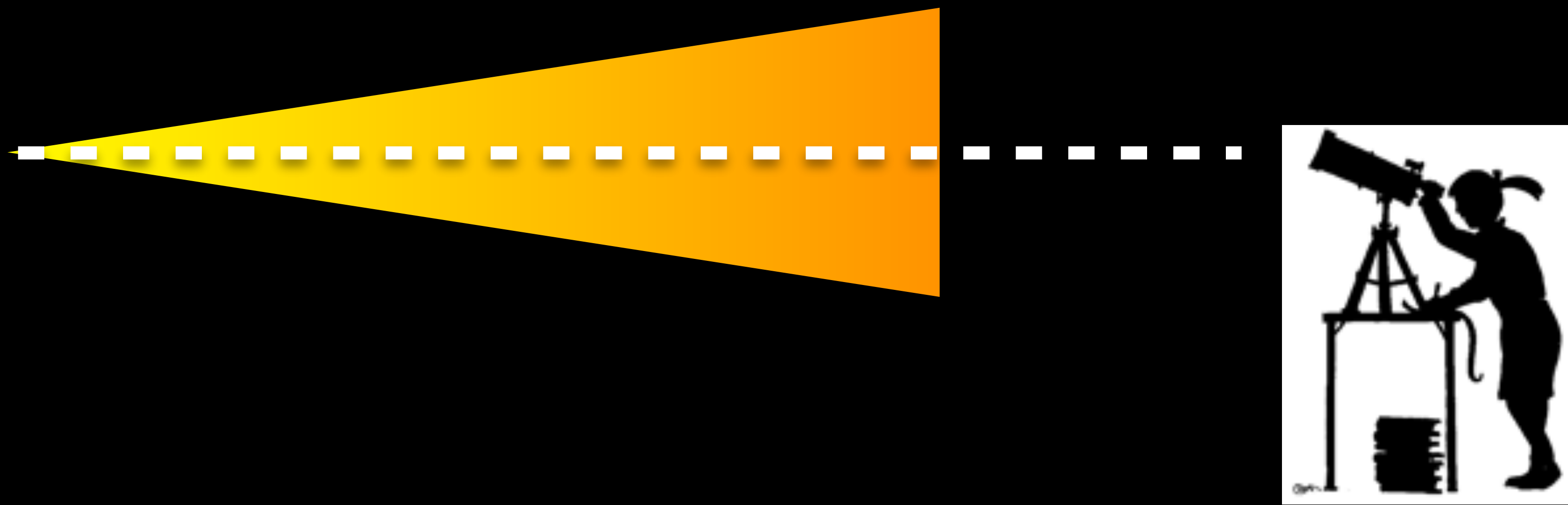


Fong et al. 2012; 2014
Long
Short
if θjet ~ 10 deg,
Etrue ~ 10^49 erg
Rtrue ~ 1000 Gpc^-3 yr^-1
Number
Opening Angle θj (degrees)
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30
35

Application to gravitational wave counterparts



For a compact object merger at 200 Mpc…



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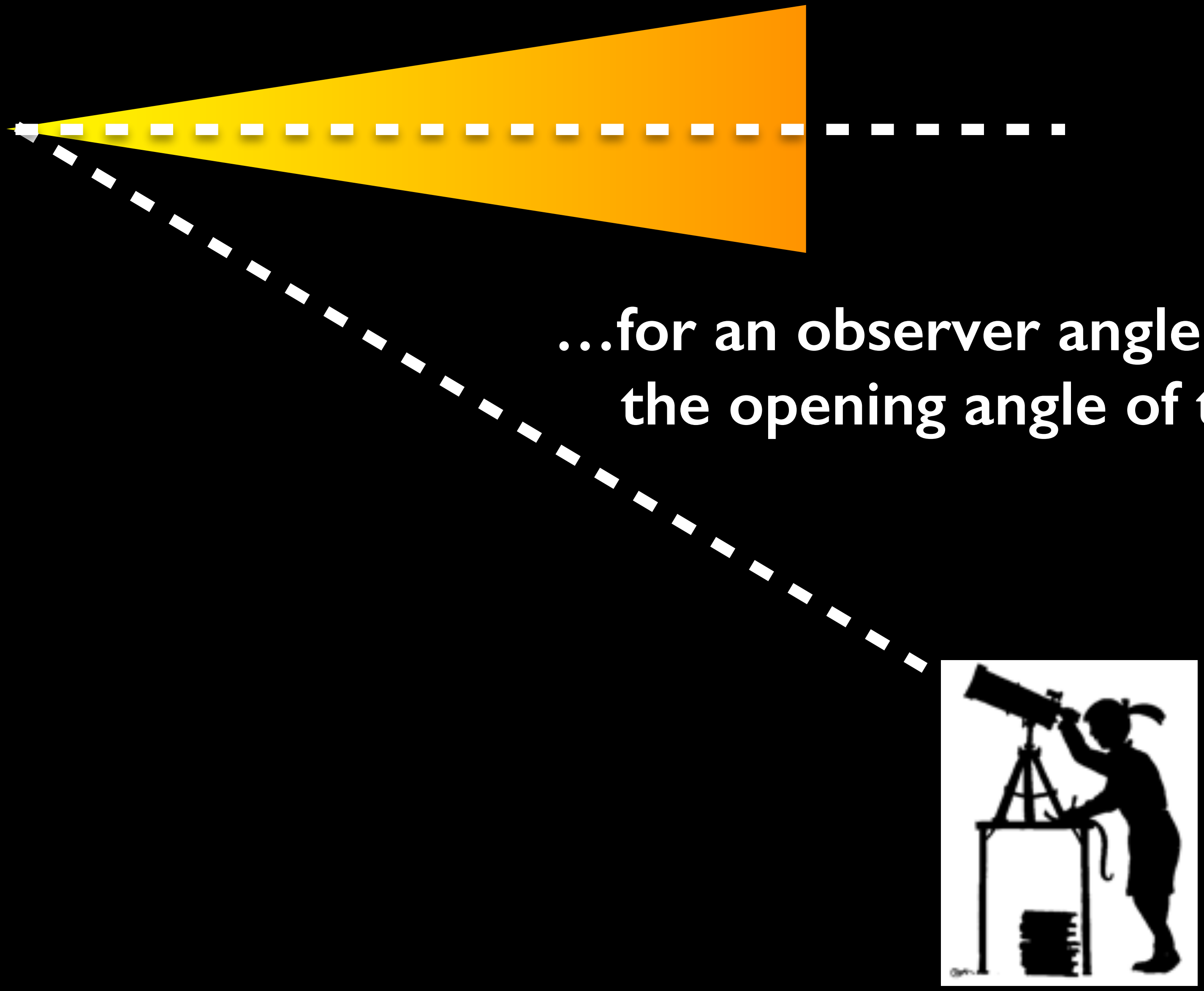

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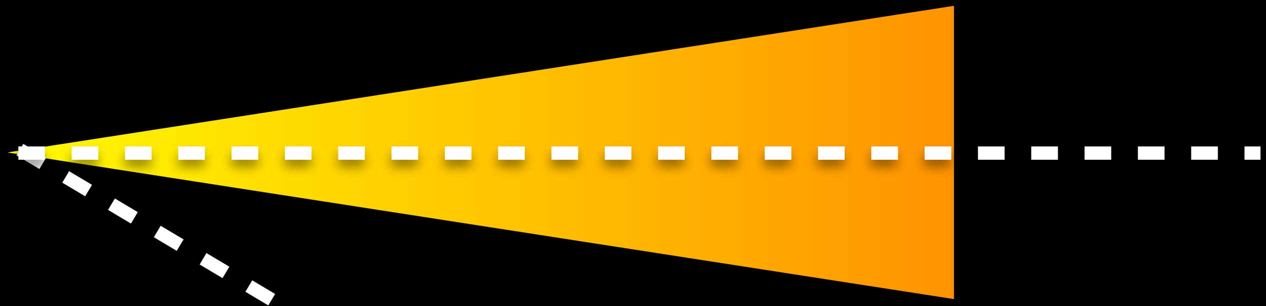
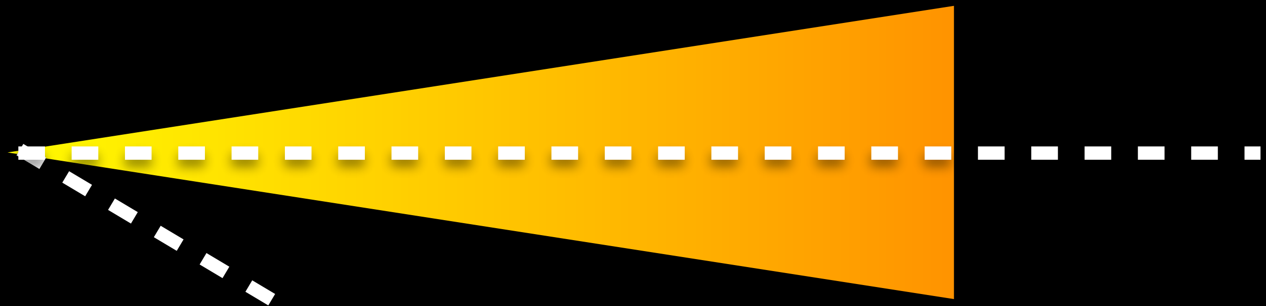


…for an observer angle of twice the opening angle of the jet…

…with typical inputs from observed short GRBs…

$n \sim 10^{-3}\ \mathrm{cm}^{-3}$, $E \sim 10^{49}\ \mathrm{erg}$

For a compact object merger at 200 Mpc…



…for an observer angle of twice the opening angle of the jet…

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$n \sim 10^{-3}\ \mathrm{cm}^{-3}$, $E \sim 10^{49}$ erg

…the optical light curve will peak at 24.5 mag (10^{40} erg s^{-1}).

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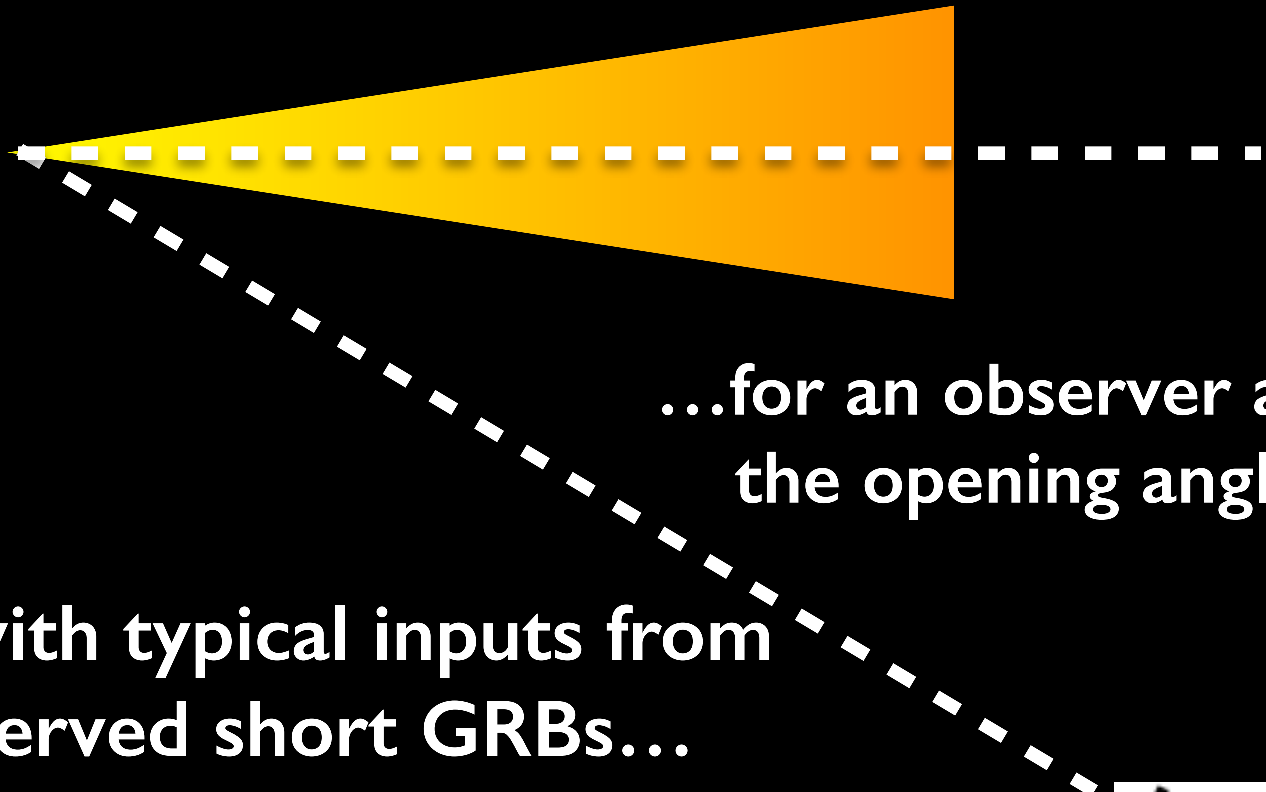


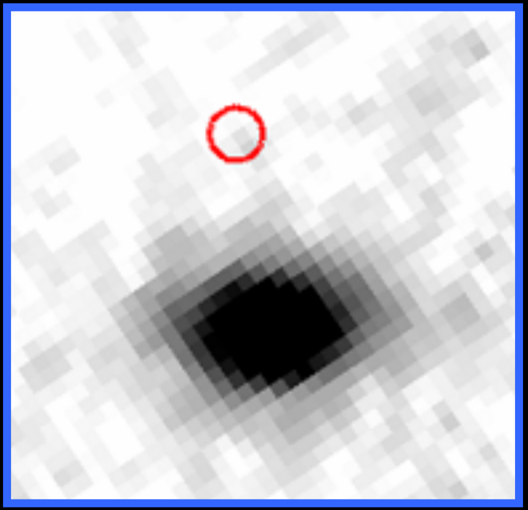
…for an observer angle of twice the opening angle of the jet…

…with typical inputs from observed short GRBs…

$n \sim 10^{-3}\ cm^{-3},\ E \sim 10^{49}\ erg$

…the optical light curve will peak at 24.5 mag (10^{40} erg s^{-1}). *Yikes.*

Trends with host properties?



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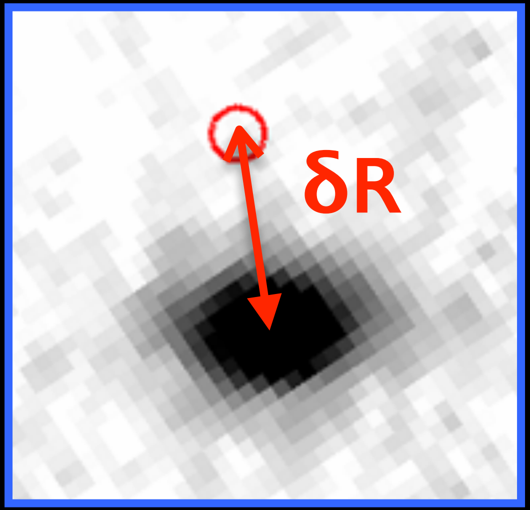

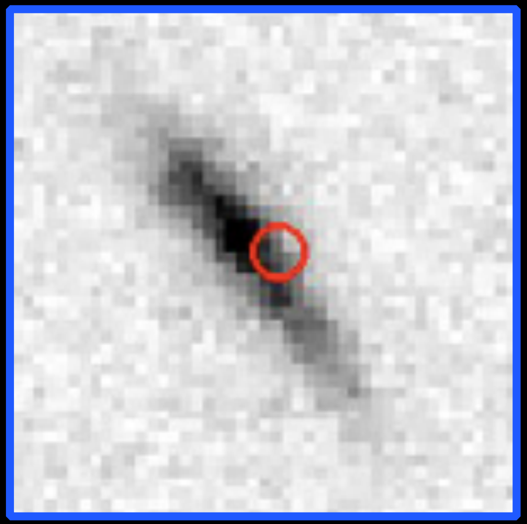

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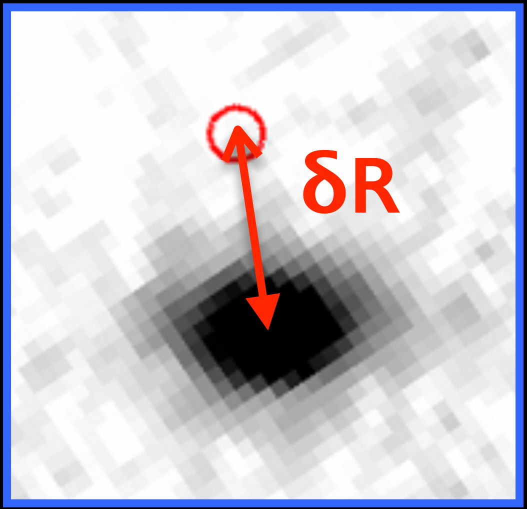

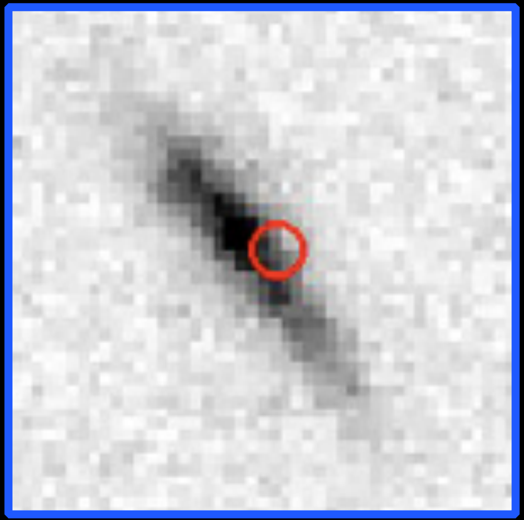

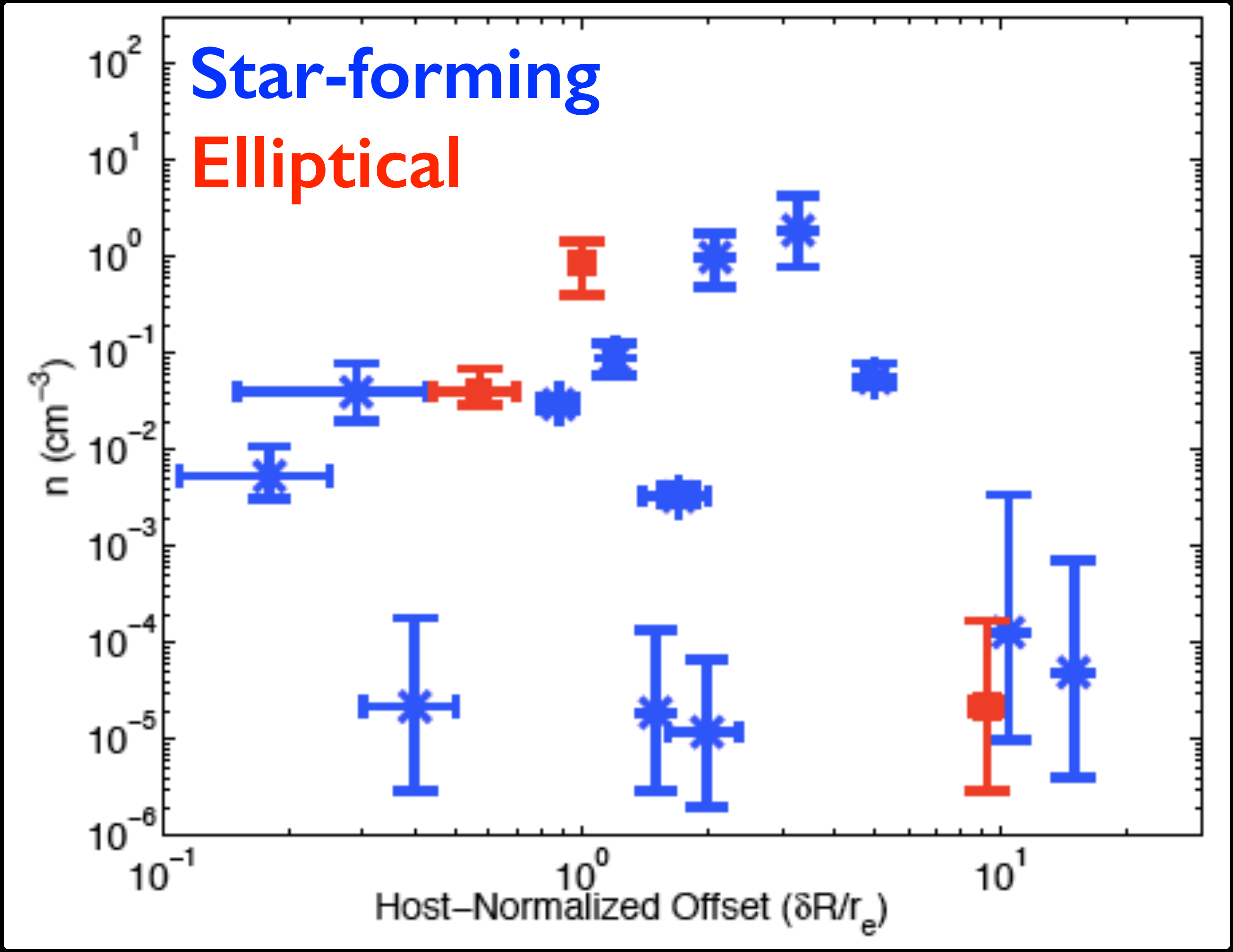

Trends with host properties?