



# Observation of the LIGO/Virgo GW190425 by SPI-ACS/INTEGRAL

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# Instrumentation

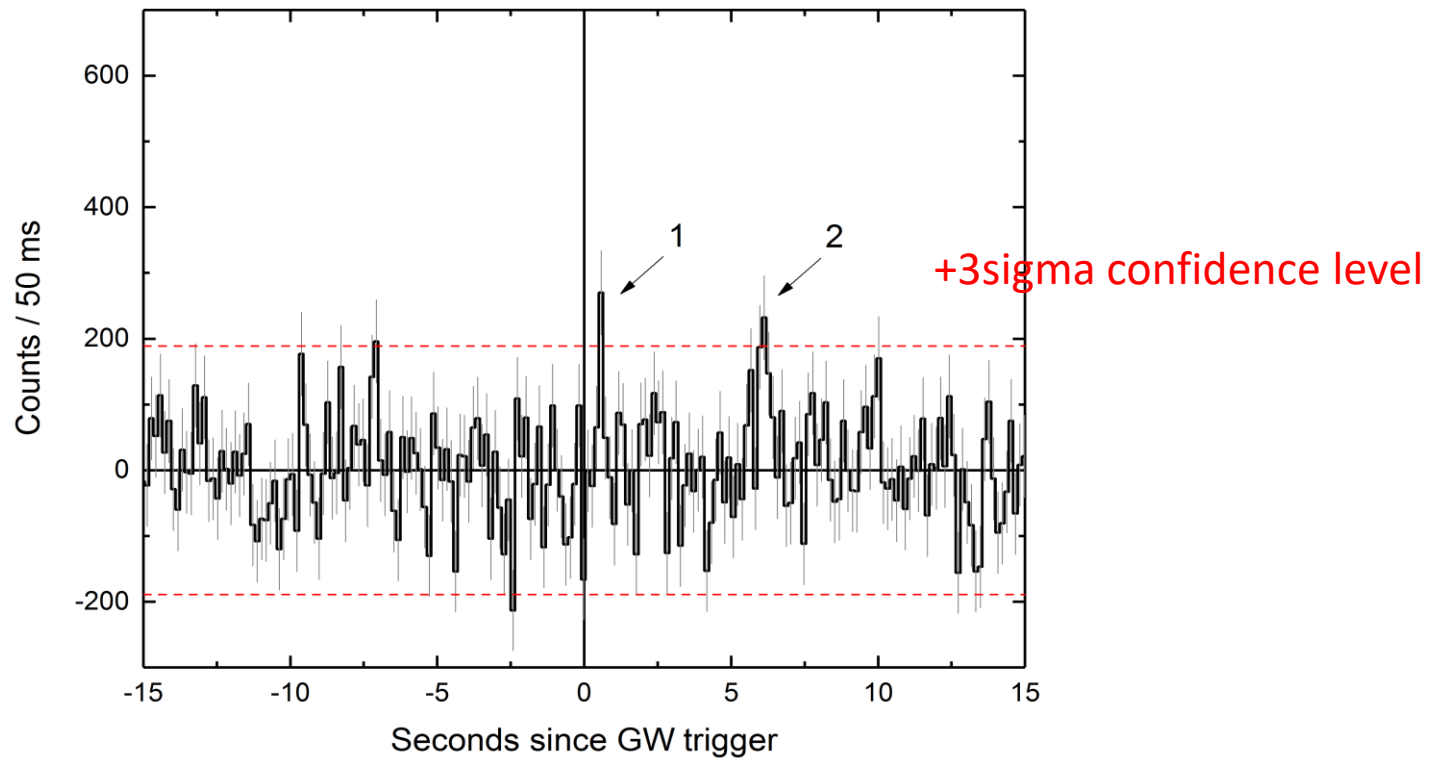
- SPI-ACS onboard INTEGRAL observatory
- The SPI-ACS (AntiCoincidence Shield) consists of a 91 BGO scintillators, effective area for GRB detection  $\sim 0.7\text{m}^2$ , omnidirectional
- Time resolution 50 ms, continuous recording
- Single energy channel  $\sim 80\text{ keV} - 10\text{ MeV}$  (no spectral capabilities)

# Observations

- No reported triggered GRB at the moment of GW190415
- Search for possible GRB in SPI-ACS/INTEGRAL data after data downlink in a public directory.
- Our GCN report issued soon about enhancement detection at 0.4 sec after GW190415 (Minaev+ GCN Circ. 24170)

# GW190425

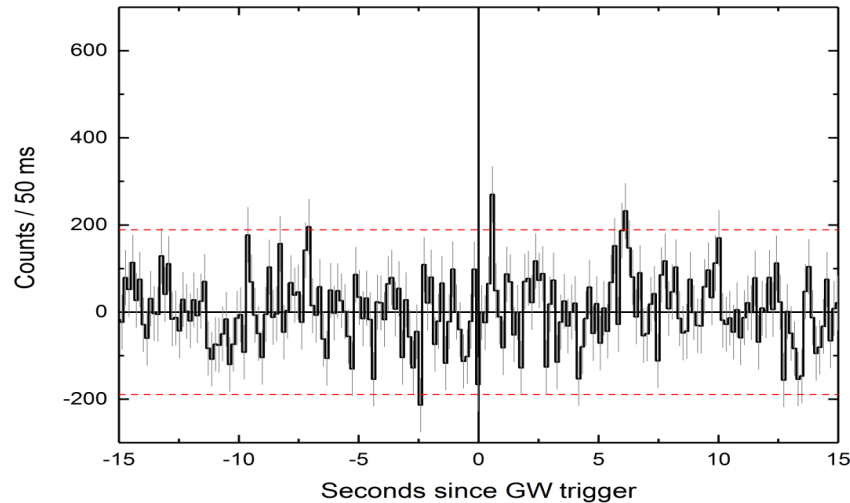
## SPI-ACS data investigation



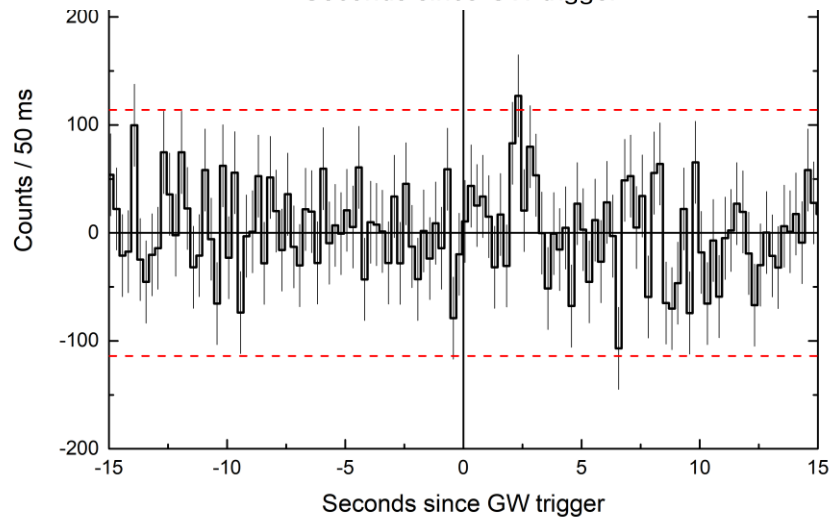
# GW190425 (=GRB 190425) SPI-ACS data investigation

- Background model subtraction
- Proper accounting background variance
- S/N of the pulses depends on binning and background model
- Considering both pulses as a signal from GRB
- False Alarm Rate (FAR) estimating (using whole orbit of about 3 days and search the same GRB pattern).
- Combined probability estimating (i.e. FAR and time duration from GW trigger, see Blackburn+2015; Connaughton+2016) using our search +/- interval of  $T_{\text{max}}=30$  s and binning combination of 0.1 s)

# Comparison of SPI-ACS time profiles after GW190425 and GW170817



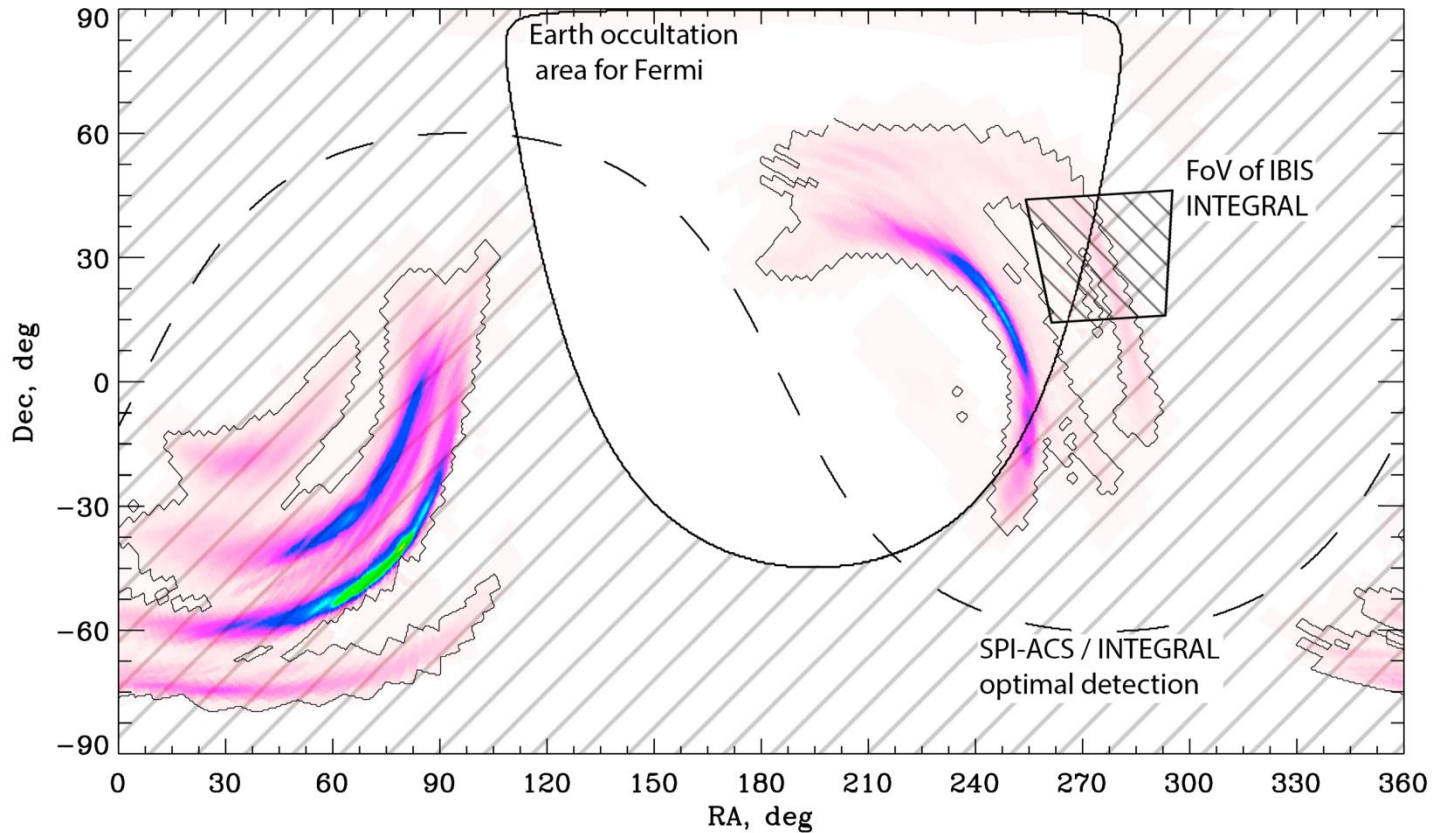
GRB 190425/  
GW190425



GRB 170817A

# No GBM detection?

GW 190425 LIGO/Virgo localization,  
GBM/Fermi Earth occultation



# Parameters of GRB 190425 as detected by SPI-ACS/INTEGRAL

LIGO/Virgo event	S190425z
Trigger time $T_0^a$	2019-04-25 08:18:05
Distance to the source, Mpc	$156 \pm 41$
Localization area (90%) <sup>b</sup> , sq. deg.	7461
Angle to the axis of the SPI-ACS detector	$26^\circ - 60^\circ$
Gamma-ray burst	GRB 190425
Pulse in the GRB profile	first+second
Experiment	SPI-ACS
Beginning of the event <sup>d</sup> , s	0.44
Total duration <sup>d</sup> , s	6.0
Integral number of counts	$2300 \pm 420$
Significance (ratio $S/N$ ), $\sigma$	5.5
Probability <sup>e</sup>	$1.9 \times 10^{-8}$
FAR <sup>f</sup> , events/s	$6.4 \times 10^{-5}$
Combined probability <sup>g</sup>	$1.6 \times 10^{-4}$
Fluence $F^h$ , erg cm <sup>-2</sup>	$8.0 \times 10^{-8} - 2.4 \times 10^{-6}$
Energy release $E_{\text{iso}}^i$ , erg	$2.2 \times 10^{47} - 6.7 \times 10^{48}$



# Comparison of GRB 190425 and GRB 170817A detected by SPI-ACS/INTEGRAL and GBM/Fermi

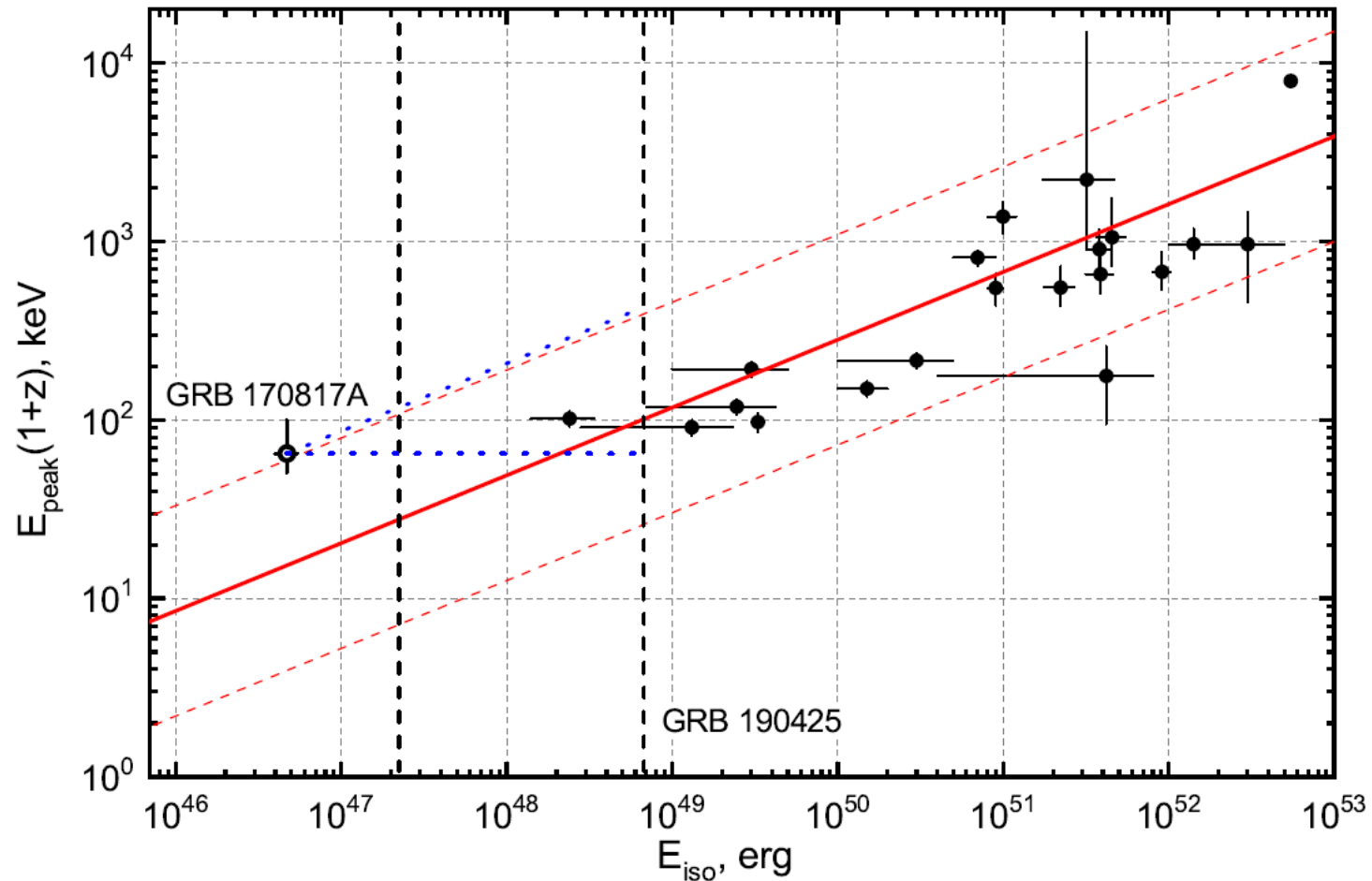
LIGO/Virgo event	S190425z	GW 170817	
Trigger time $T_0^a$	2019-04-25 08:18:05	2017-08-17 12:41:04	
Distance to the source, Mpc	$156 \pm 41$	$40 \pm 8$	
Localization area (90%) <sup>b</sup> , sq. deg.	7461	16	
Angle to the axis of the SPI-ACS detector	$26^\circ - 60^\circ$	$105^\circ$	
Gamma-ray burst	GRB 190425	GRB 170817A	
Pulse in the GRB profile	first+second	first	first+second
Experiment	SPI-ACS	SPI-ACS	<i>Fermi</i> /GBM <sup>c</sup>
Beginning of the event <sup>d</sup> , s	0.44	2.0	1.7
Total duration <sup>d</sup> , s	6.0	0.1	4.1
Integral number of counts	$2300 \pm 420$	$570 \pm 120$	—
Significance (ratio $S/N$ ), $\sigma$	5.5	4.6	8.7
Probability <sup>e</sup>	$1.9 \times 10^{-8}$	$2.1 \times 10^{-6}$	$1.7 \times 10^{-18}$
FAR <sup>f</sup> , events/s	$6.4 \times 10^{-5}$	$4.2 \times 10^{-4}$	—
Combined probability <sup>g</sup>	$1.6 \times 10^{-4}$	$4.8 \times 10^{-3}$	—
Fluence $F^h$ , erg cm <sup>-2</sup>	$8.0 \times 10^{-8} - 2.4 \times 10^{-6}$	$1.7 \times 10^{-8} - 5.2 \times 10^{-7}$	$(2.1 \pm 0.3) \times 10^{-7}$
Energy release $E_{\text{iso}}^i$ , erg	$2.2 \times 10^{47} - 6.7 \times 10^{48}$	$3.8 \times 10^{45} - 1.2 \times 10^{47}$	$(4.7 \pm 0.7) \times 10^{46}$

# Conclusions

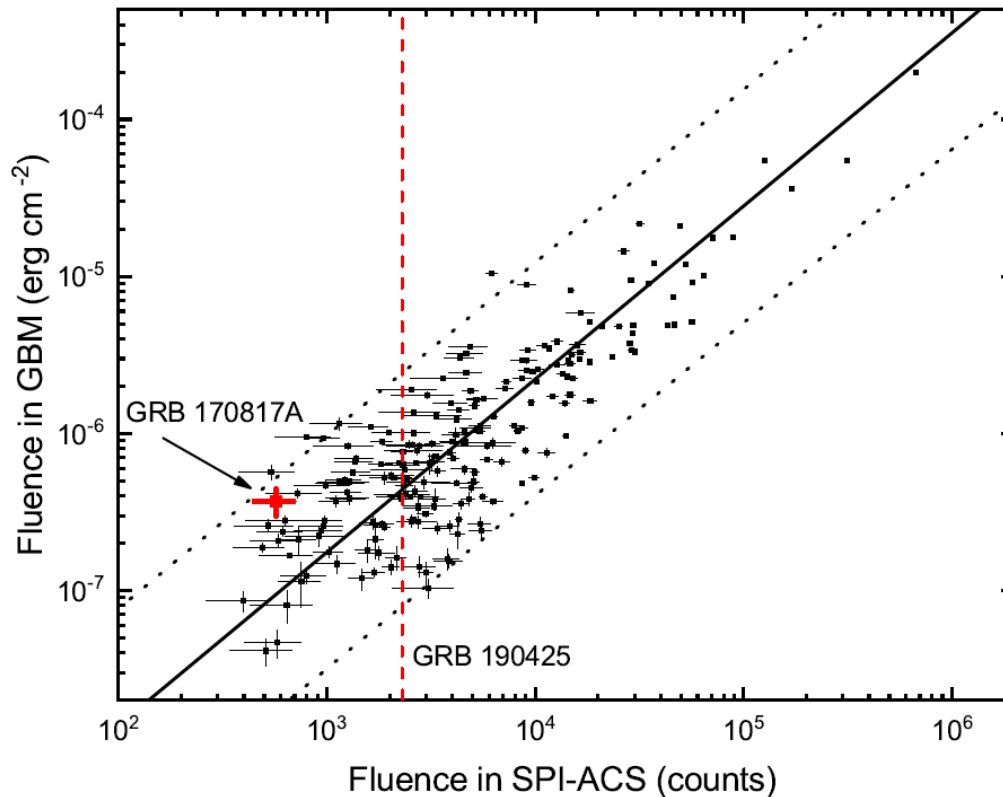
- We detected GRB 190425 in SPI-ACS/INTEGRAL  $\sim 0.4$  s later the GW190425 LIGO/Virgo trigger.
- The GRB 190425 consist of two pulses of 0.25 s and 0.85 s separated by 5 s. The total duration of the burst is 6 s.
- The GRB 190425 was not detected by GBM/Fermi due to Earth occultation ant the moment of the burst.
- Combined probability of the GRB 190425 being a chance counterpart of GW190425 is  $1.6e-5$  (cf. the combined probability of chance coincidence GRB 170817A if detected only by SPI-ACS/INTEGRAL  $4.8e-3$ ).
- We believe GRB 190425 is a gamma-ray counterpart of GW190425.
- We can estimate GRB 190425 energy release ( $E_{iso}$ ) =  $[2e47 - 6.7e48]$  ergs which is larger than GRB 170817A  $E_{iso} = 4.7e46$  (as deduced from GBM/Fermi).
- Based on  $E_{iso}$  and crude spectral parameter  $E_p$  estimating we can speculate, that off-axis cone emission in GRB 190425 is less than off-axis cone emission in GRB 170817A
- A region of a sky localization of GRB 190435/GRB190425 can be reduce down to northern part of final LVC localization.

# Additional slides

GRB190425 in Amati diagram  $E_p - E_{iso}$ . If we suggest that actual energy release in both GRB 170817 and GRB 190425 are the same, and the diagram is a result only off-axis observations, then we conclude the GRB 190425 has less of-axis angle.

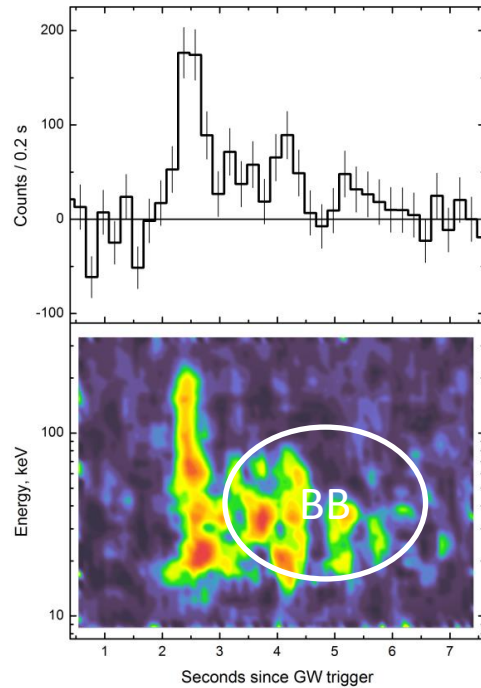


# SPI-ACS/calibrations against simultaneously detected GRB at GBM/Fermi

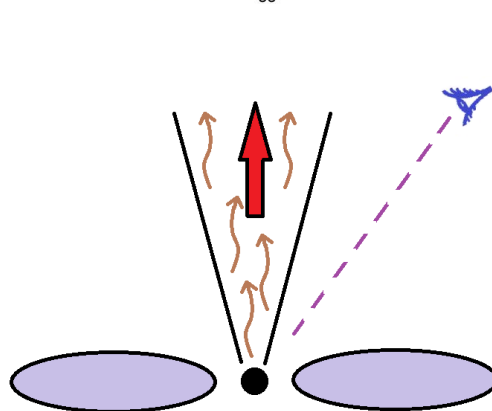
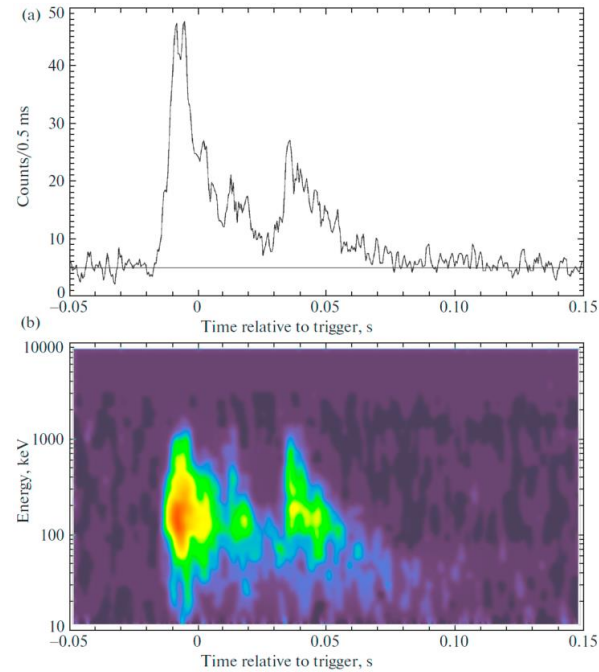


# GW 170817/ GRB 170817A off-axis emission

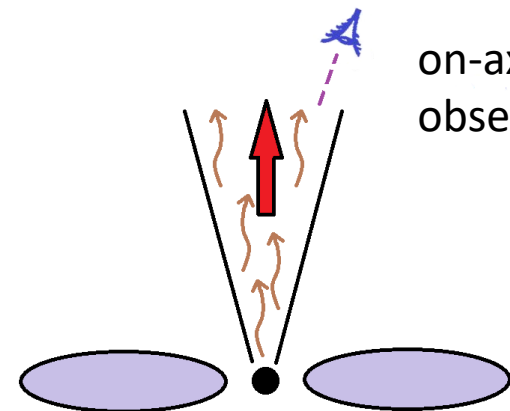
## GRB170817/GW170817



## “typical” short GRB



off-axis of  
cone solid  
angle of  $\Omega$



on-axis  
observer

GRB 190425/GW190425 SPI-ACS/INTEGRAL,  
FAR =  $6.4 \times 10^{-5}$ , joint chance probability =  $1.6 \times 10^{-4}$

