

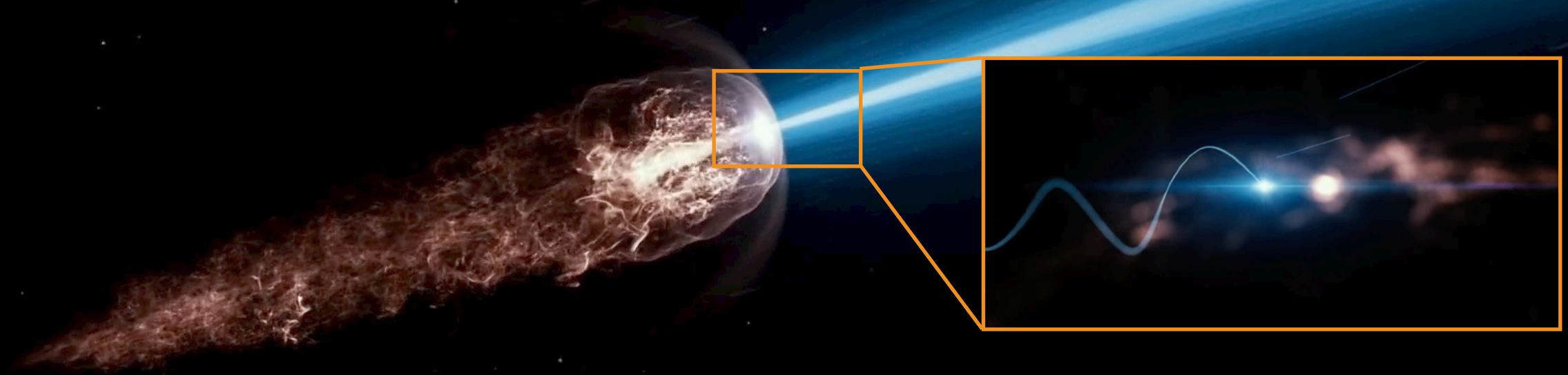
# Gamma-ray burst observations at Very High Energies with IACTs

Sylvia J. Zhu (DESY)

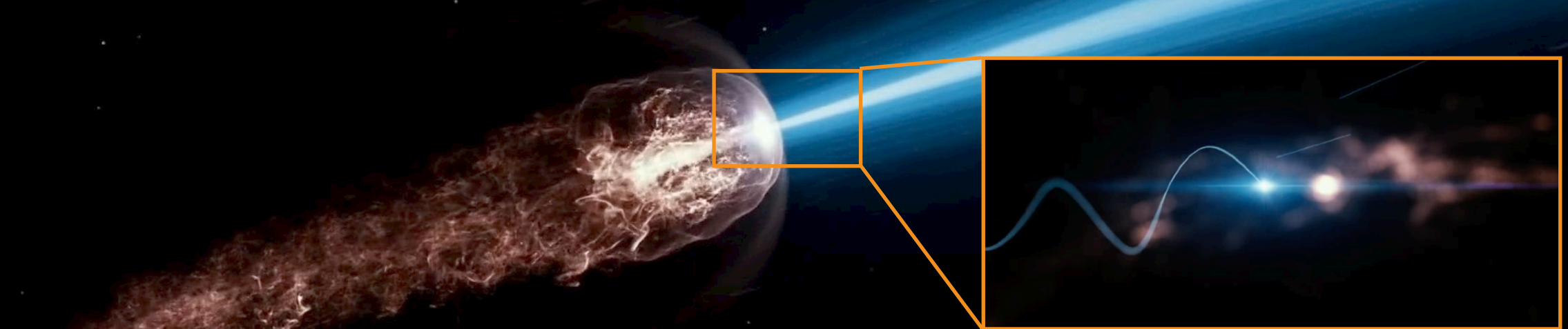
thanks to Alessio and Marcos for providing info



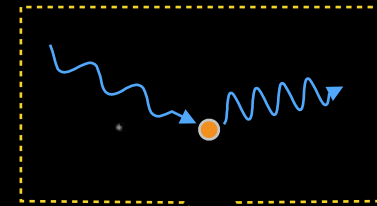
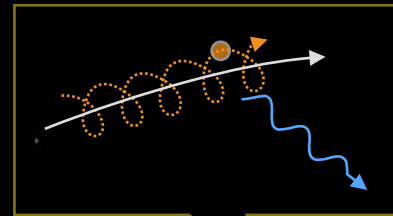
# so what the heck is a gamma-ray burst



# so what the heck is a gamma-ray burst



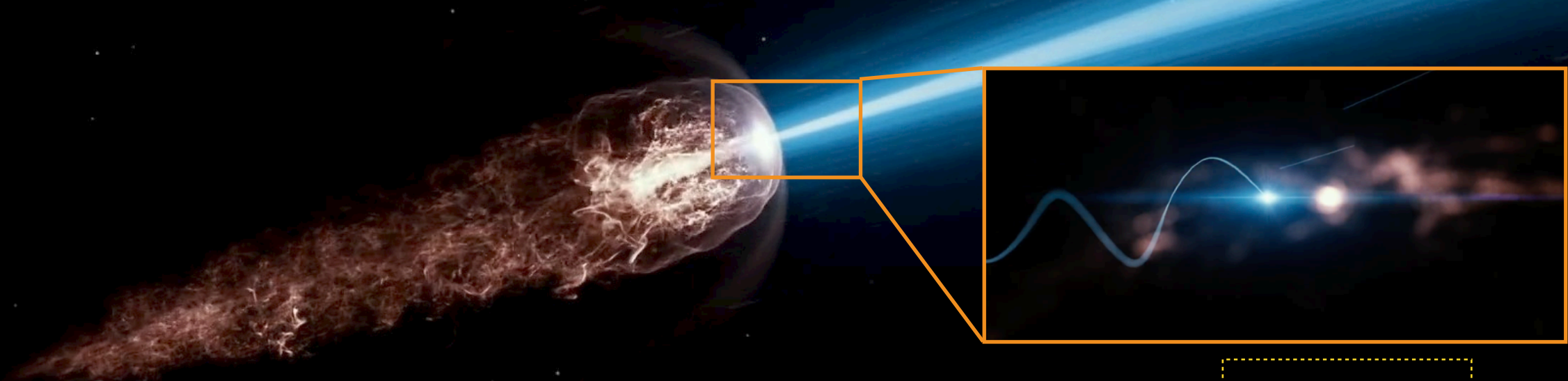
DESY, Science Communication Lab



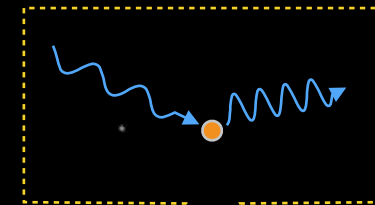
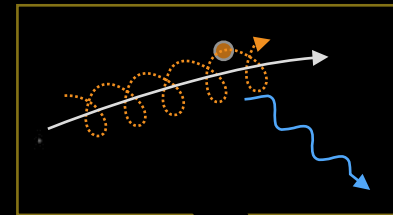
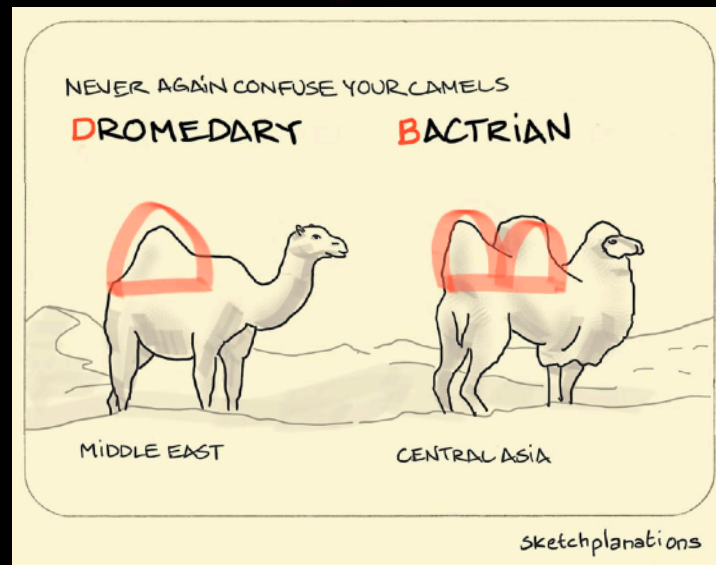
synchrotron

synchrotron  
self-Compton

# so what the heck is a gamma-ray burst



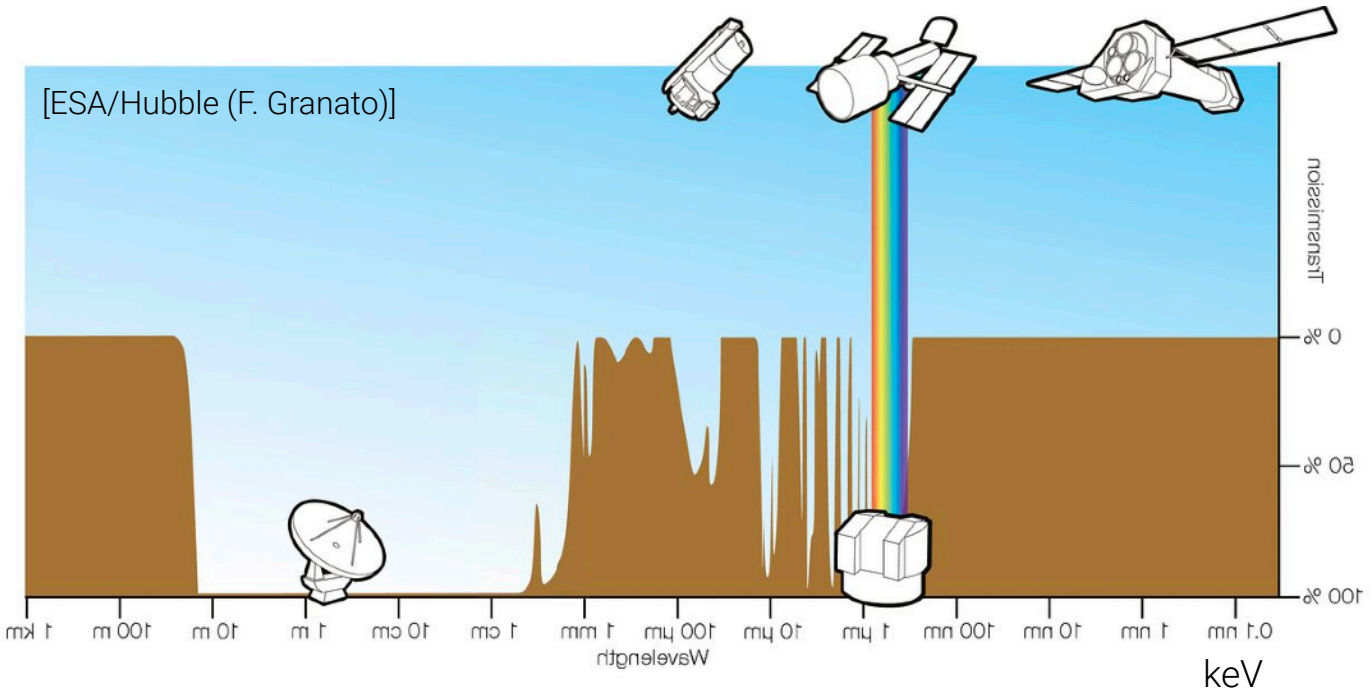
DESY, Science Communication Lab



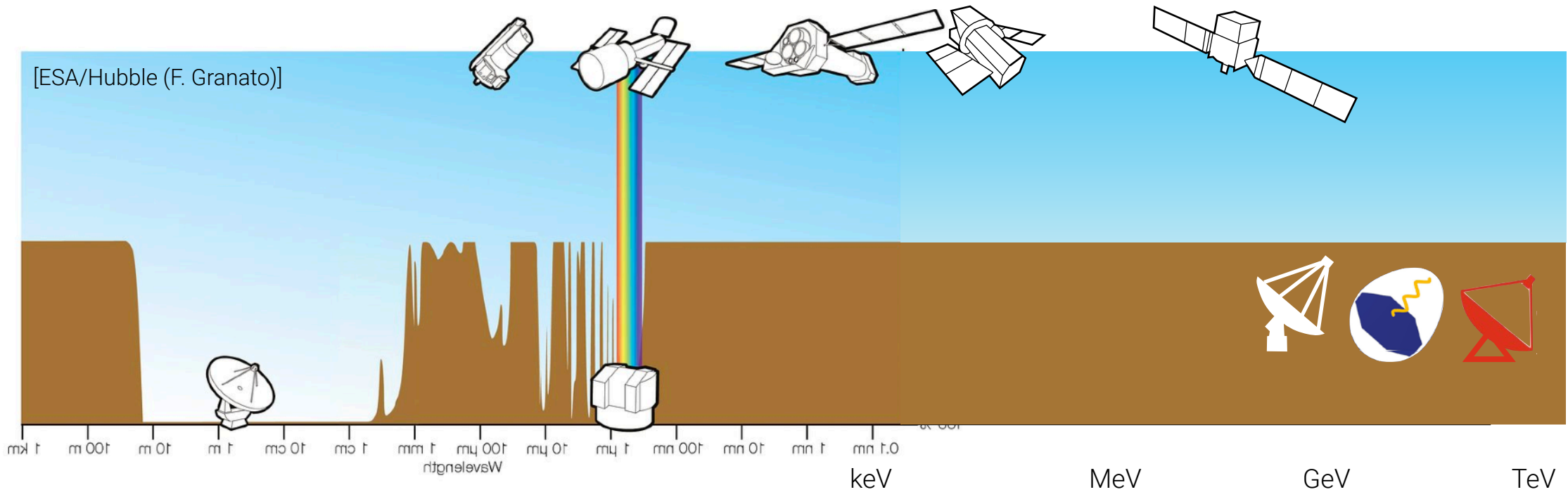
synchrotron

synchrotron  
self-Compton

# Detecting very-high-energy gamma rays (VHE, >100 GeV)



# Detecting very-high-energy gamma rays (VHE, >100 GeV)



# Imaging Atmospheric Cherenkov Telescopes (IACTs)

Derek Strom, Giovanni Ceribella and the MAGIC Collaboration

Otger Ballester (IFAE)

**MAGIC** 

3.5° field of view  
can slew 180° in 25 s  
>50 GeV  
two 17m



**LST-1** 

4.5° field of view  
can slew 380° in 25 s  
>20 GeV  
23m




**VERITAS** 


3.5° field of view  
can slew 1°/sec  
>85 GeV  
four 12m



[http://veritas.uchicago.edu/images/veritas\\_6-12.jpg](http://veritas.uchicago.edu/images/veritas_6-12.jpg)

**H.E.S.S.** 

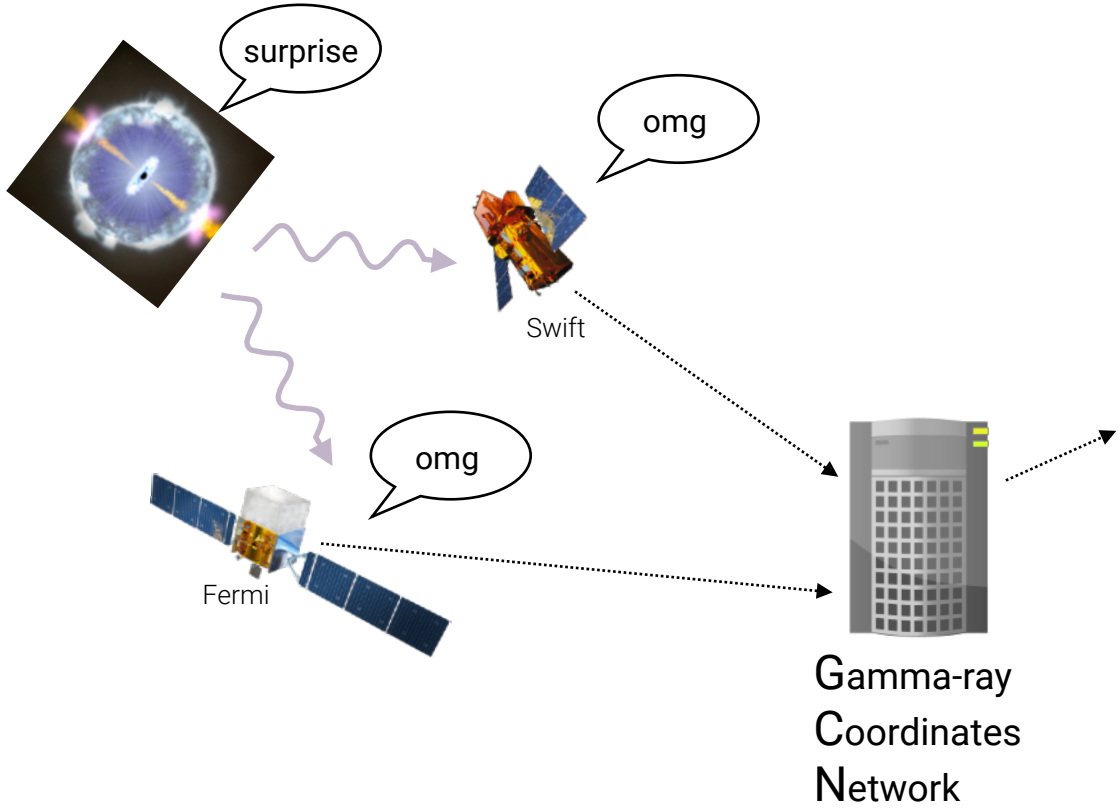
3° field of view at 50 GeV  
can slew 100°/min  
>50 GeV  
28m + four 12m



H.E.S.S., MPIK/Christian Foehr

Wikimedia Commons

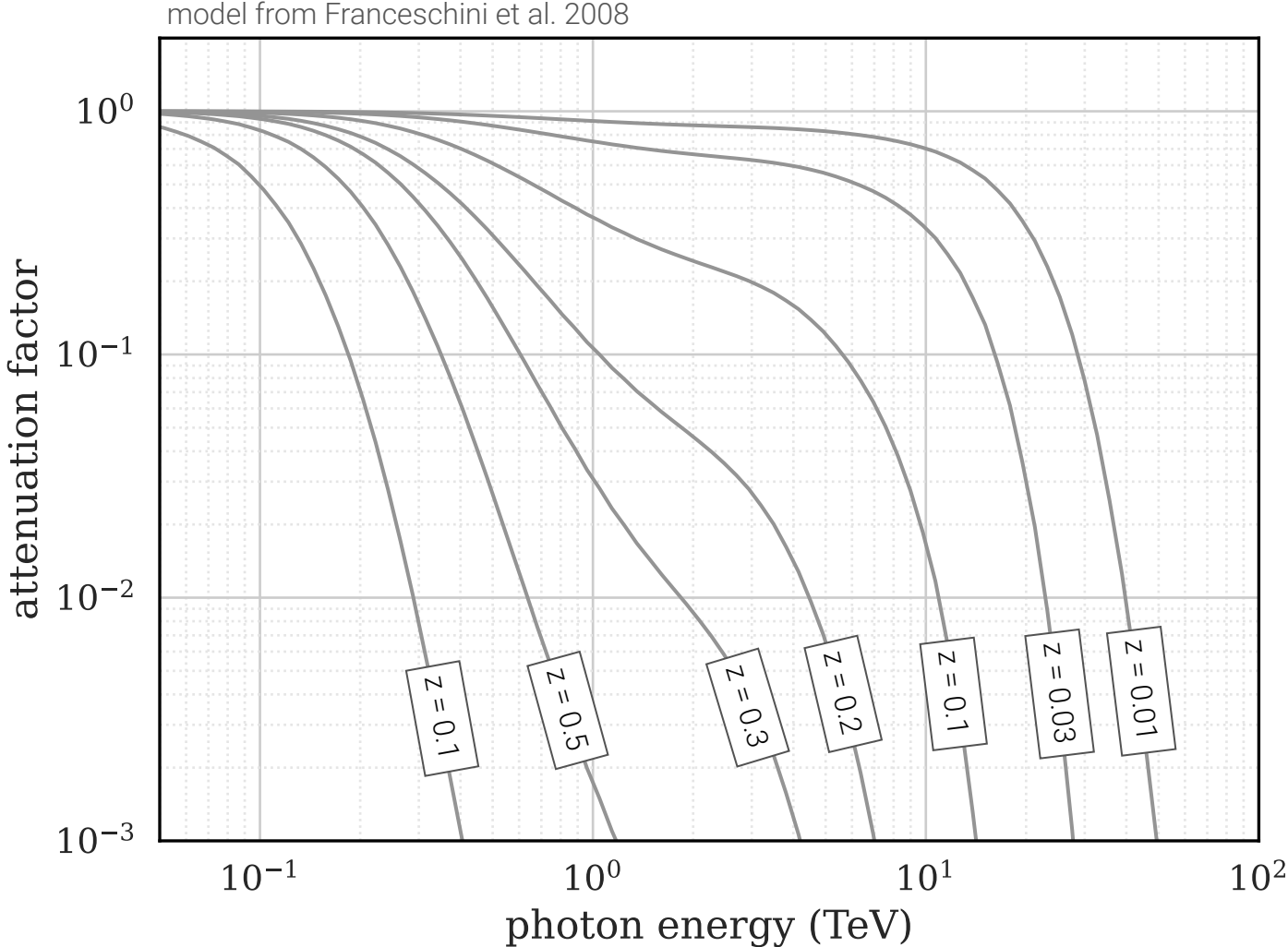
# Observations by IACTs



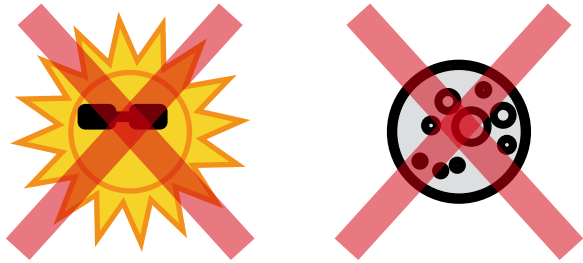
When will it be visible?  
For how long will it be visible?  
How well do we know where it is?  
Do we know how far away it is?



# Extragalactic Background Light (EBL) attenuation



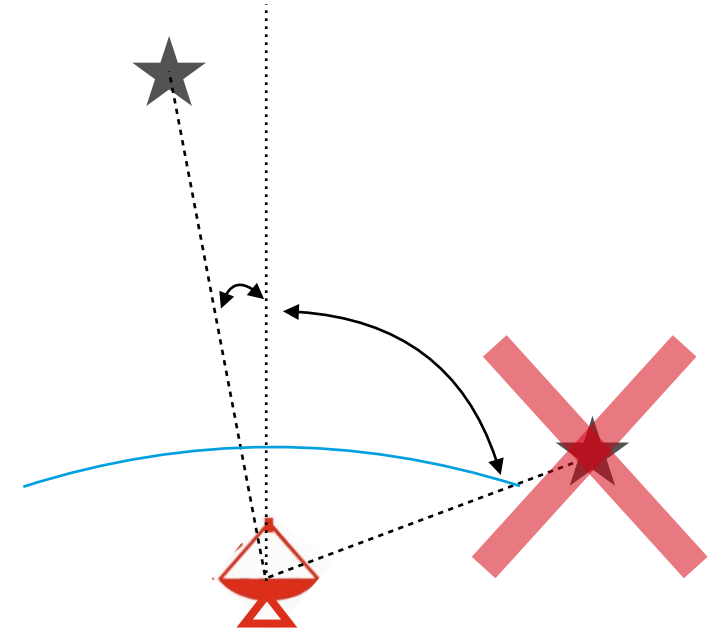
# Observational constraints



Too much ambient light is bad for your cameras



Cloudy nights mean fewer photons get through



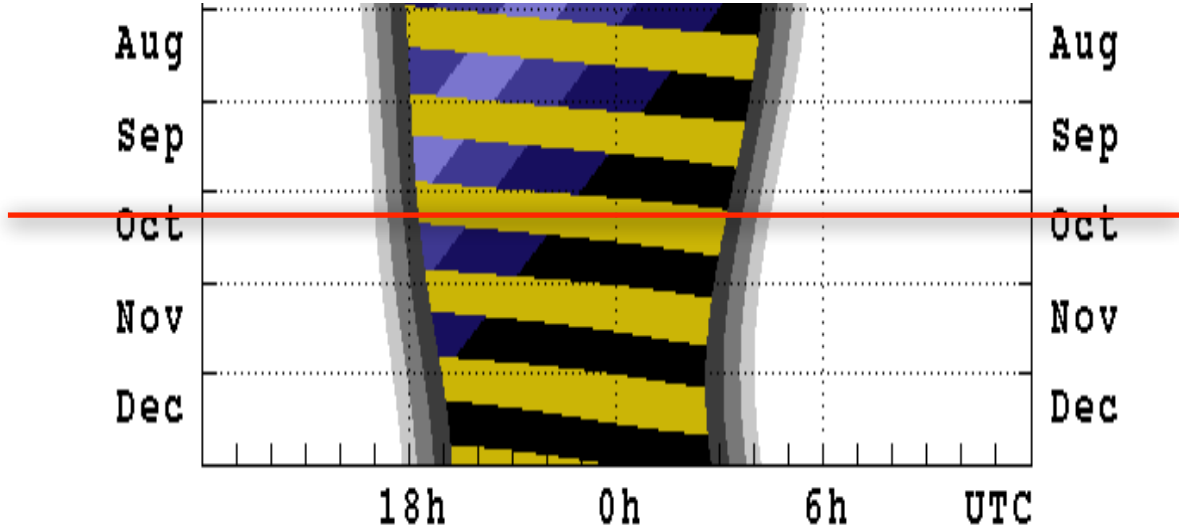
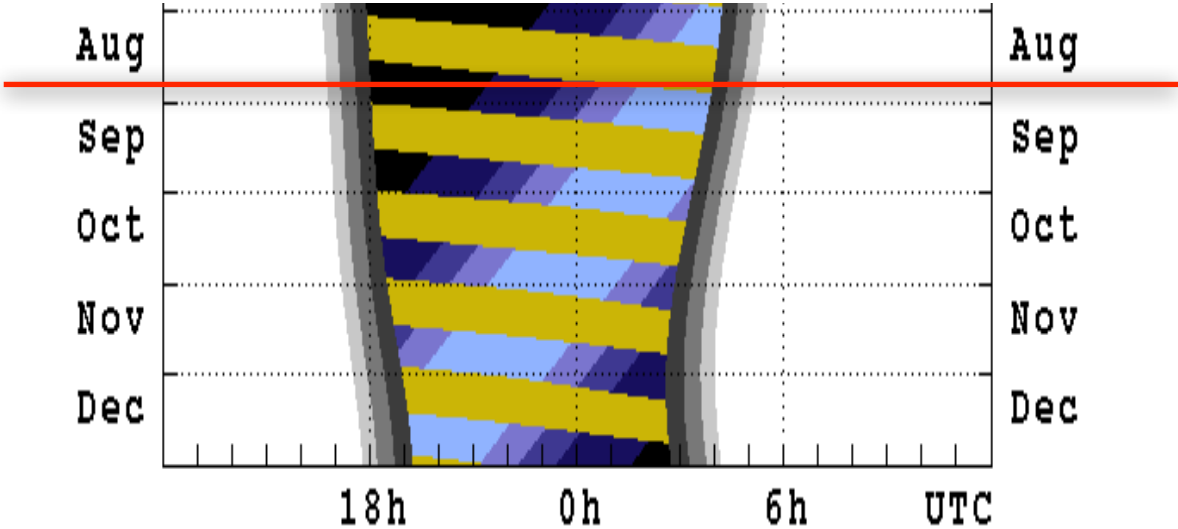
Large zenith angles result in poorer statistics, and you lose low energy photons

# Putting it all together

GRB 190829A's visibility at the H.E.S.S. site

vs

GRB 221009A's visibility at the H.E.S.S. site



moon :(
   
 nope.

great!! :D (zenith angle < 30)
   
 good :) (zenith angle < 45)
   
 ok :/ (zenith angle < 60)

<https://www.mpi-hd.mpg.de/hfm/HESS/public/Visibility.html>

# IACT GRB programs



triggering  
instruments

*Fermi*/GBM, /LAT,  
*Swift*/BAT, INTEGRAL,  
MAXI

*Fermi*/GBM, /LAT,  
*Swift*/BAT, INTEGRAL,  
MAXI

*Fermi*/GBM, /LAT,  
*Swift*/BAT, INTEGRAL,  
MAXI

*Fermi*/GBM, /LAT,  
*Swift*/BAT

reaction type(s)

autonomous, manual

autonomous, manual

autonomous?, manual

manual (for now)

obs type(s)

pointed

pointed, tiled

pointed

pointed

obs duration  
(default)

up to 4h

rest of the night

rest of the night

max delay  
(default)

no fixed rule

24h

3h

whatever they want

zenith angle cut

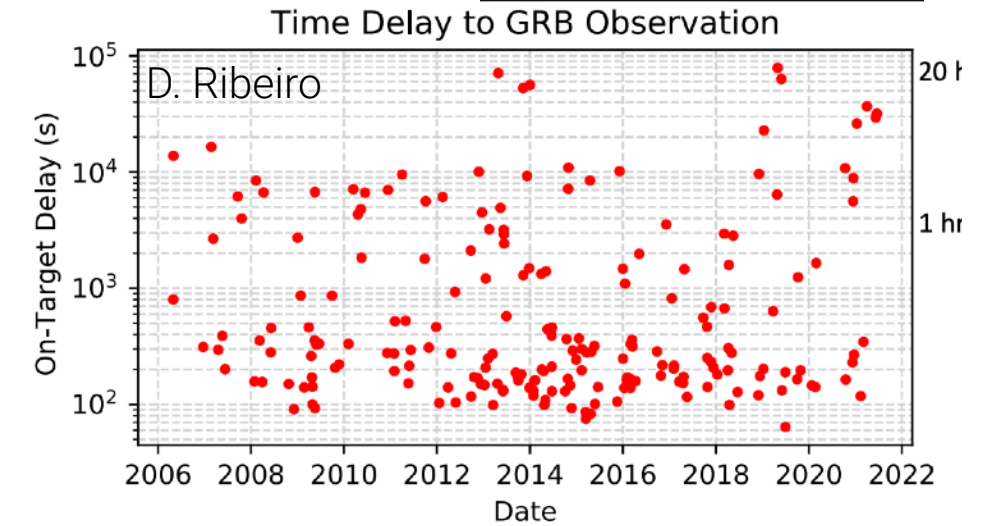
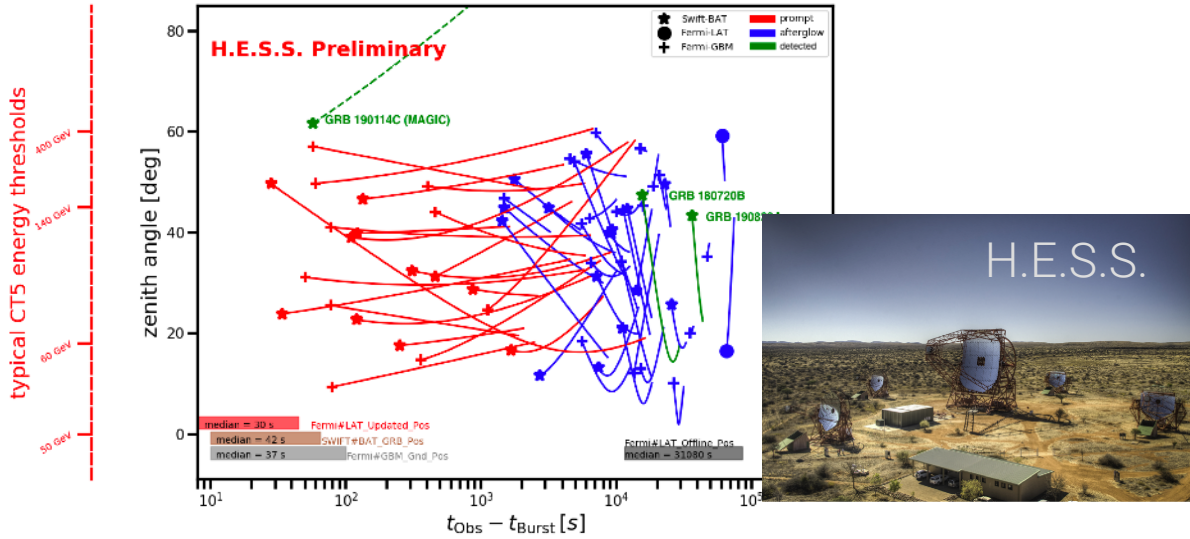
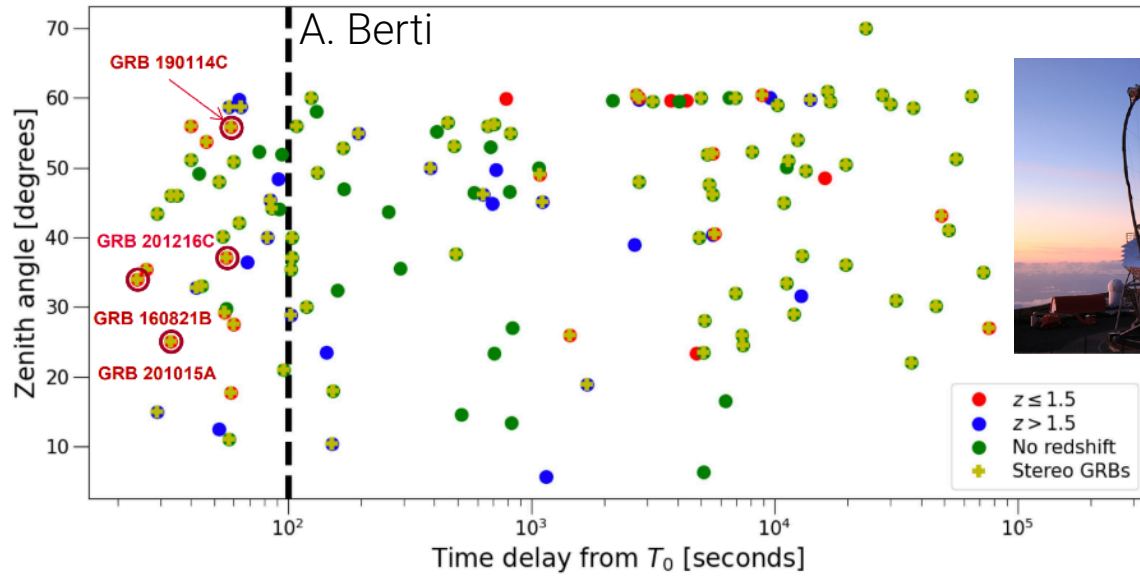
zenith angle < 60 deg

zenith angle < 60 deg

zenith angle < 70 deg

zenith angle < 70 deg

# GRB observations by IACTs

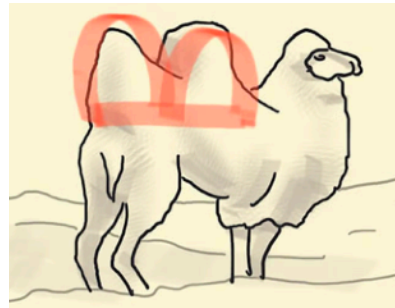


# VHE detections of GRBs so far

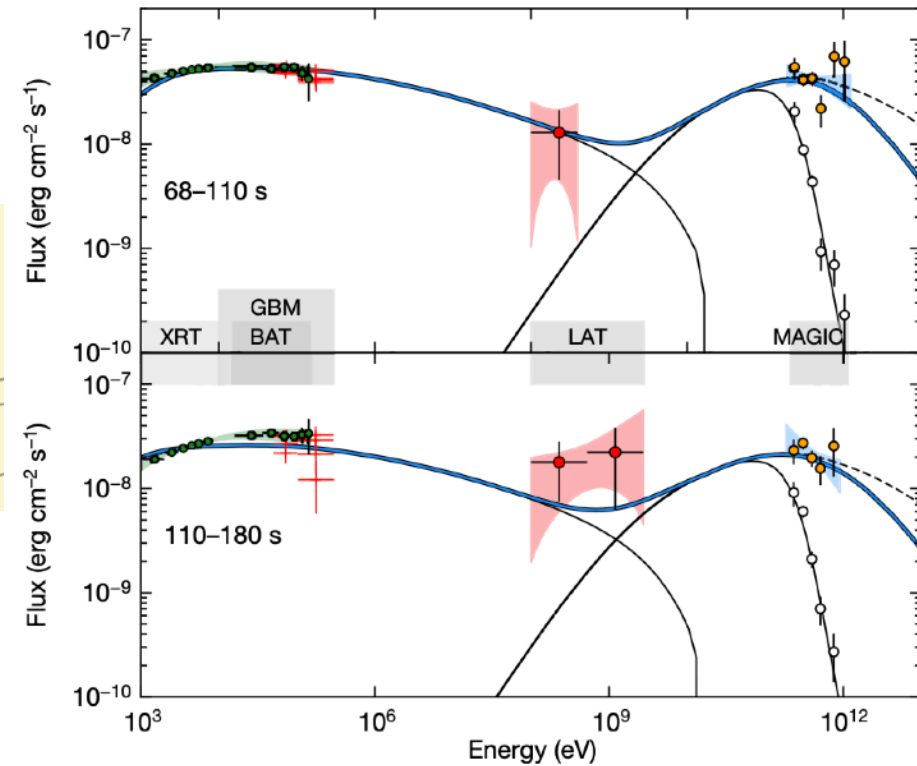
(GRB 130427A	<i>Fermi</i> -LAT)	<i>almost</i> a VHE GRB (highest energy photon = 95 GeV observed)
(GRB 160821B	MAGIC)	$\sim 3\sigma$ excess, the only <i>short</i> GRB
GRB 180720B	H.E.S.S.	$5\sigma$ detection, 8 hrs after onset; X-ray and VHE fluxes at similar level
GRB 190114C	MAGIC	
GRB 190829A	H.E.S.S.	
GRB 201015A	MAGIC	$\sim 3\sigma$ excess
GRB 201216C	MAGIC	$>5\sigma$ detection, paper expected shortly

# VHE detections of GRBs so far

(GRB 130427A	<i>Fermi</i> -LAT)
(GRB 160821B	MAGIC)
GRB 180720B	H.E.S.S.
<b>GRB 190114C</b>	<b>MAGIC</b>
GRB 190829A	H.E.S.S.
GRB 201015A	MAGIC
GRB 201216C	MAGIC

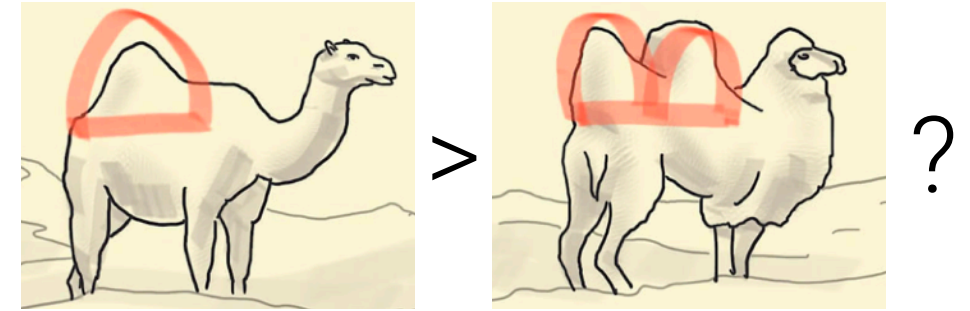


Acciari et al., Nature 575, p. 459 (2019)



VHE emission interpreted as a separate SSC component

# VHE detections of GRBs so far



(GRB 130427A    *Fermi*-LAT)

(GRB 160821B    MAGIC)

GRB 180720B    H.E.S.S.

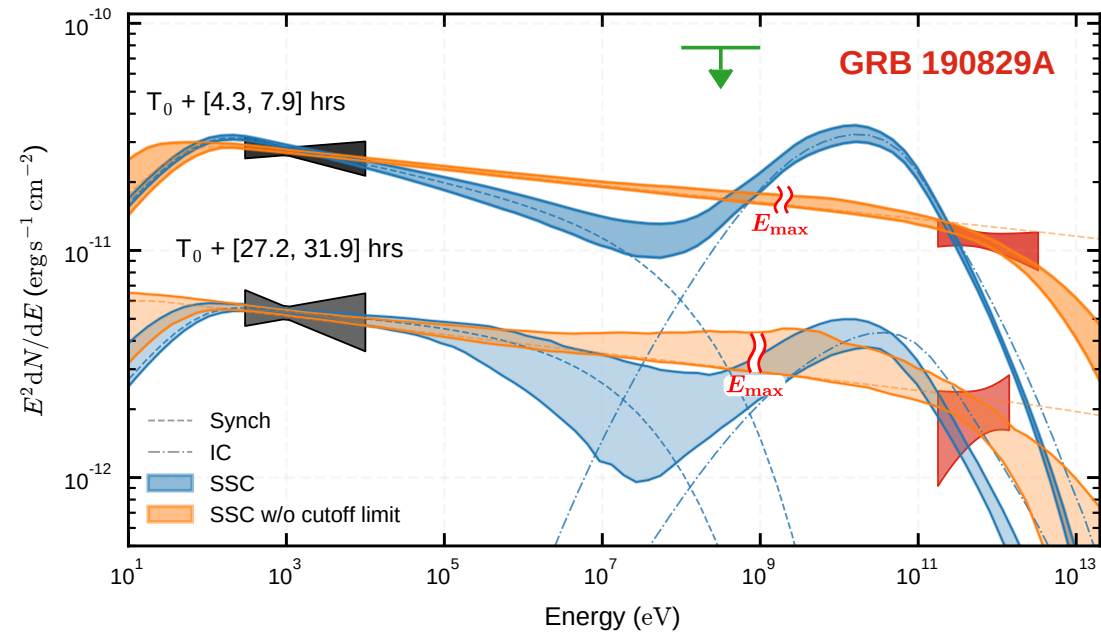
GRB 190114C    MAGIC

**GRB 190829A    H.E.S.S.**

GRB 201015A    MAGIC

GRB 201216C    MAGIC

Abdalla et al., *Science* 372 (2021)



VHE emission more consistent with an extension of the X-ray emission ( $>5\sigma$ )



# VHE detections of GRBs so far

(GRB 130427A *Fermi*-LAT)

(GRB 160821B MAGIC)

GRB 180720B H.E.S.S.

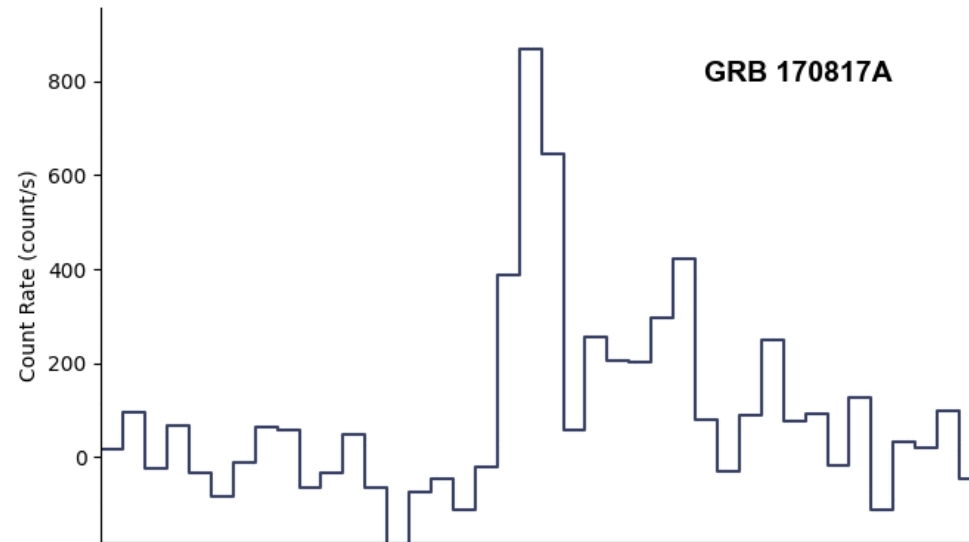
GRB 190114C MAGIC

GRB 190829A H.E.S.S.

GRB 201015A MAGIC

GRB 201216C MAGIC

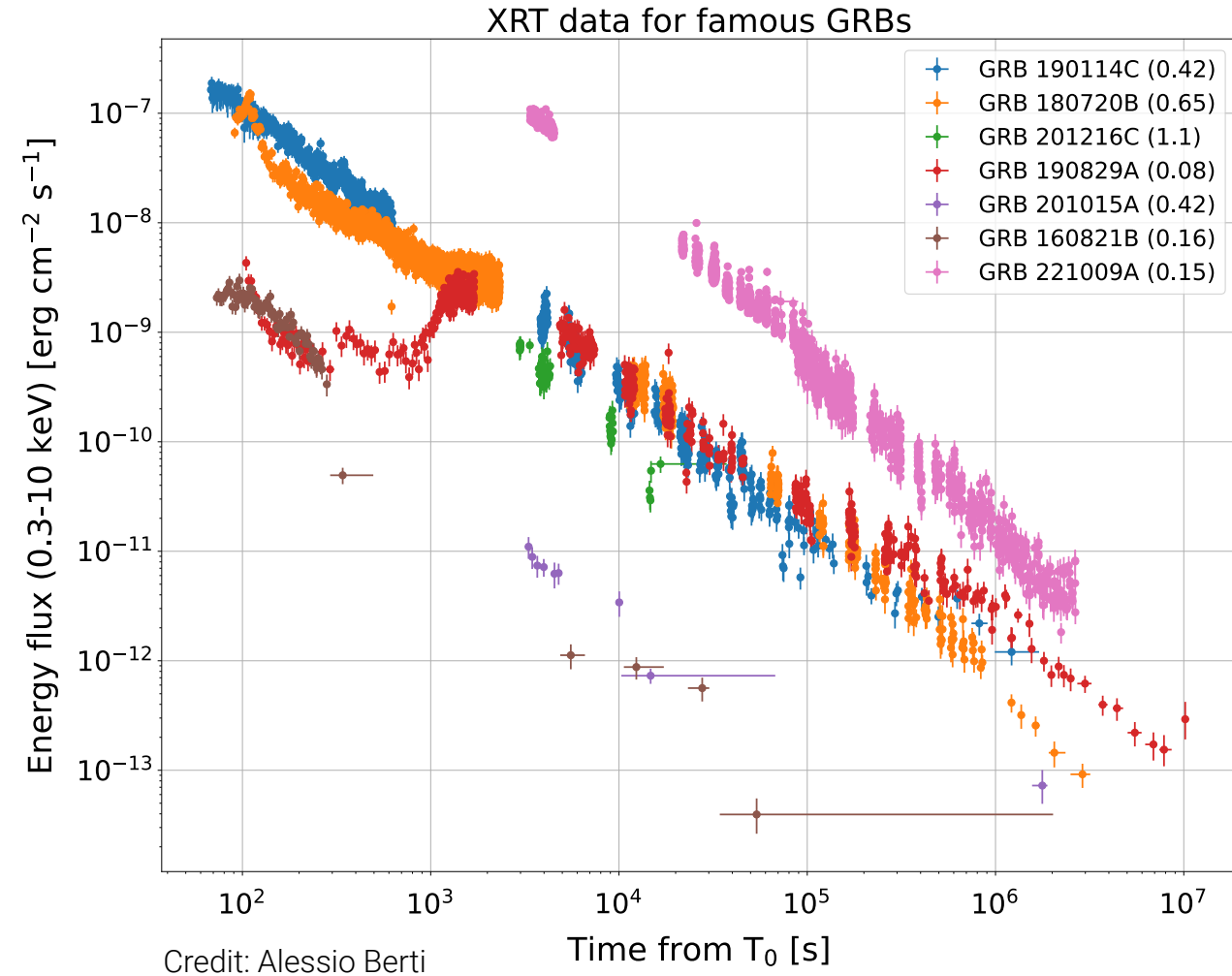
**GRB 221009A LHAASO**



Credit: Adam Goldstein

# VHE detections of GRBs so far

(GRB 130427A	<i>Fermi</i> -LAT)
(GRB 160821B	MAGIC)
GRB 180720B	H.E.S.S.
GRB 190114C	MAGIC
GRB 190829A	H.E.S.S.
GRB 201015A	MAGIC
GRB 201216C	MAGIC
<b>GRB 221009A</b>	<b>LHAASO</b>



# VHE detections of GRBs so far

(GRB 130427A    *Fermi*-LAT)

(GRB 160821B    MAGIC)

GRB 180720B    H.E.S.S.

GRB 190114C    MAGIC

GRB 190829A    H.E.S.S.

GRB 201015A    MAGIC

GRB 201216C    MAGIC

**GRB 221009A    LHAASO**

LHAASO



“GRB 221009A is detected by LHAASO-WCDA at energy **above 500 GeV** ... **within 2000 seconds** after T<sub>0</sub>, with the significance **above 100 s.d.**, and is observed as well by LHAASO-KM2A with the significance about 10 s.d., where the **energy of the highest photon reaches 18 TeV.**” [GCN 32677]

# VHE detections of GRBs so far



(GRB 130427A *Fermi-LAT*)

D. Green

**IACS:**  
MOON IS  
TOO BRIGHT :[

**LHAASO:**  
5000 PHOTONS  
18 TEV  
AXIONS = CONFIRMED

**CARPET-2:**  
250 TEV PHOTON-LIKE EVENT  
4.2 DEG PSF  
1.8 DEG AWAY

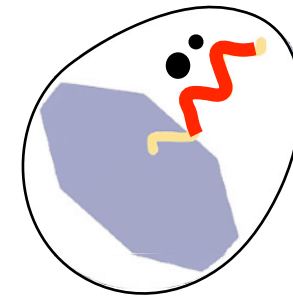
GRB 221009A LHAASO

**LHAASO**

18 TeV  
100 sigma  
5000 photons

**IACS**

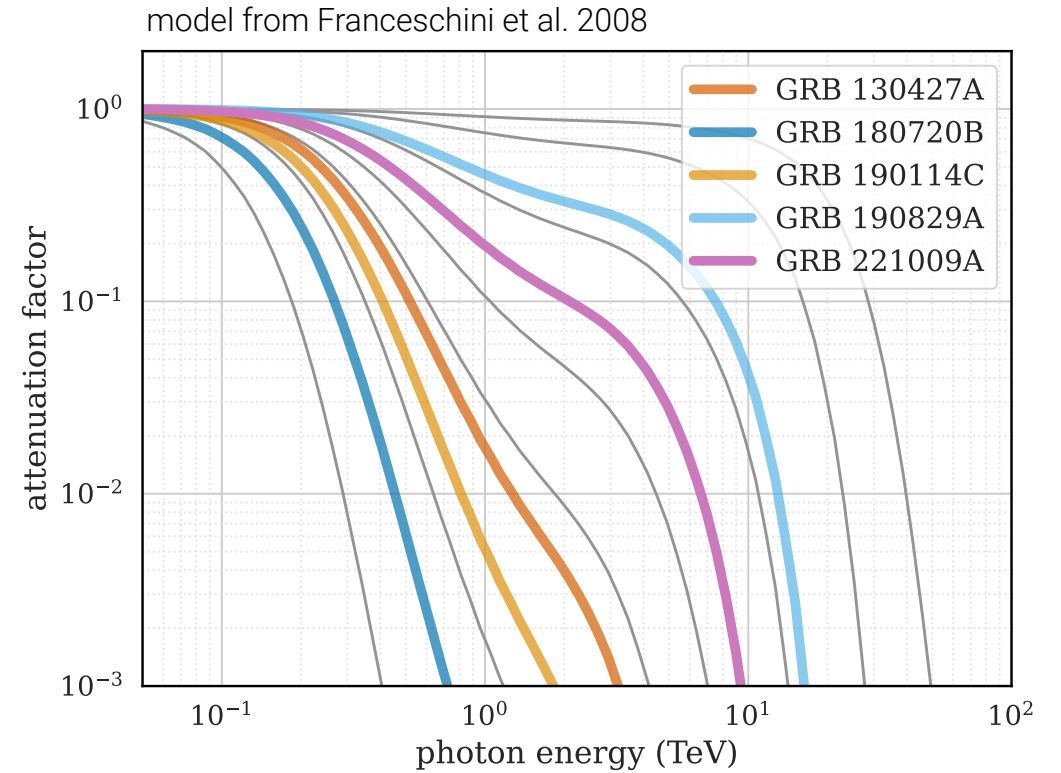
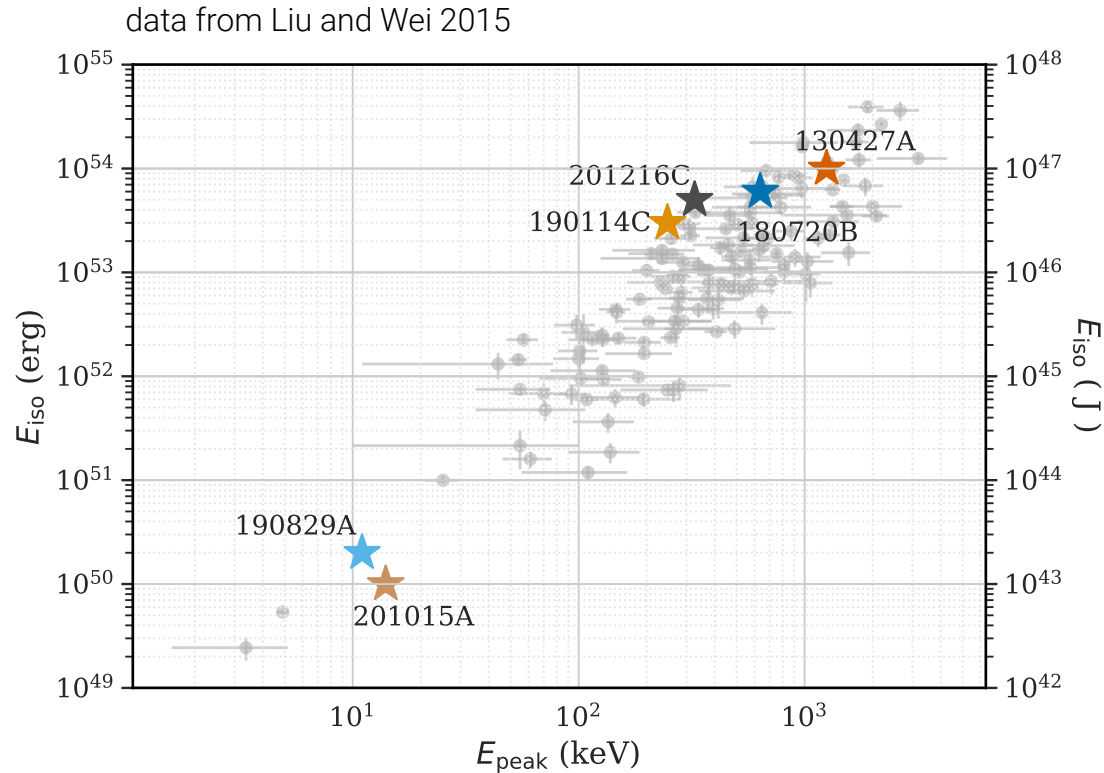
the moooooon  
is too briiiiiight



(meanwhile, at IACTs)

# VHE GRBs as a 'population' ( $N < 10$ )

VHE GRBs span the entire range of GRB properties



# Where do we go from here (IMO)

We need to be more open and work together

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We need to be more open and work together

H.E.S.S. will (soon) publicize our GRB observation schedule for both **completed** and *planned* observations

GRB ID	Triggering instrument	Alert time (T0)	GRB RA (J2000)	GRB Dec (J2000)	H.E.S.S. window start	H.E.S.S. window end	Obs mode	Reaction	Contact
11102329	SWIFT-BAT	2022-04-12 17:06:48 UTC	320.7943 deg (21h23m10.632s)	-0.2232 deg (-00d13'23.52")	2022-04-13 03:06:10 UTC (T0 + 9.99 h)	2022-04-13 03:59:12 UTC (T0 + 10.87 h)	Pointed	Manual	
GRB220503B (610219118)	FERMI-GBM	2020-05-03 17:18:33 UTC	249.900 deg (16h39m36.000s)	-19.788049 deg (-19d47'16.980")	2020-05-04 01:52:58 UTC (T0 + 4.15 h)	2020-05-04 04:05:50 UTC (T0 + 6.19 h)	Tiled	Manual	Halim Ashkar
GRB190829A	FERMI-LAT	2019-08-29 21:00:01 UTC	150.529 deg (10h02m07.129s)	-2.933333 deg (-02d56'00")	2019-08-29 21:03:01 UTC (T0 + 0.20 h)	2019-08-29 03:00:01 UTC (T0 + 6.00h)	Pointed	Automatic	Edna Ruiz Velasco

for completed observations, the table will list when we took observations

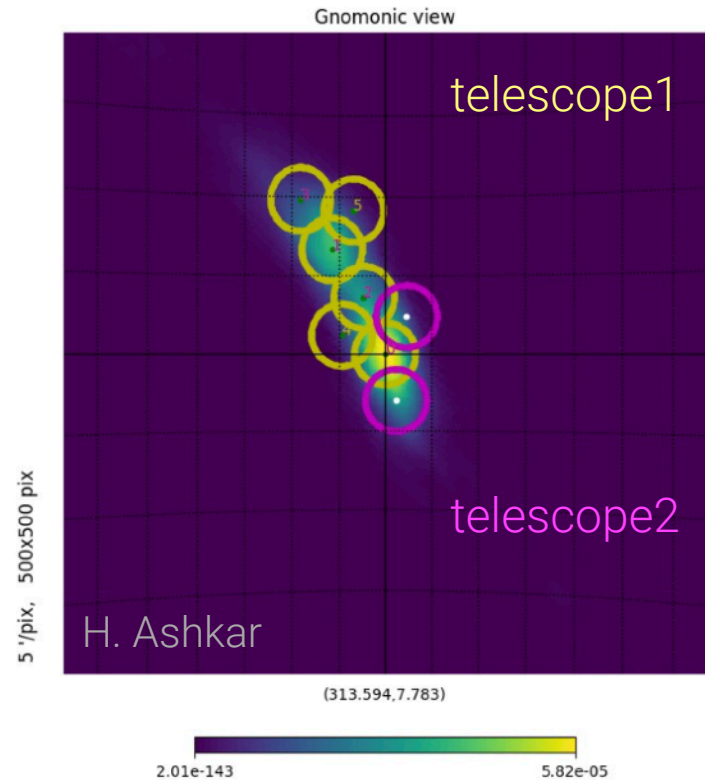
for planned observations, the table will list when we can take observations

# Where do we go from here (IMO)

We need to be more open and work together

H.E.S.S. will (soon) publicize our GRB observation schedule for both **completed** and *planned* observations

Can we (IACTs) coordinate our observing plans? e.g., for GBM-type localizations:





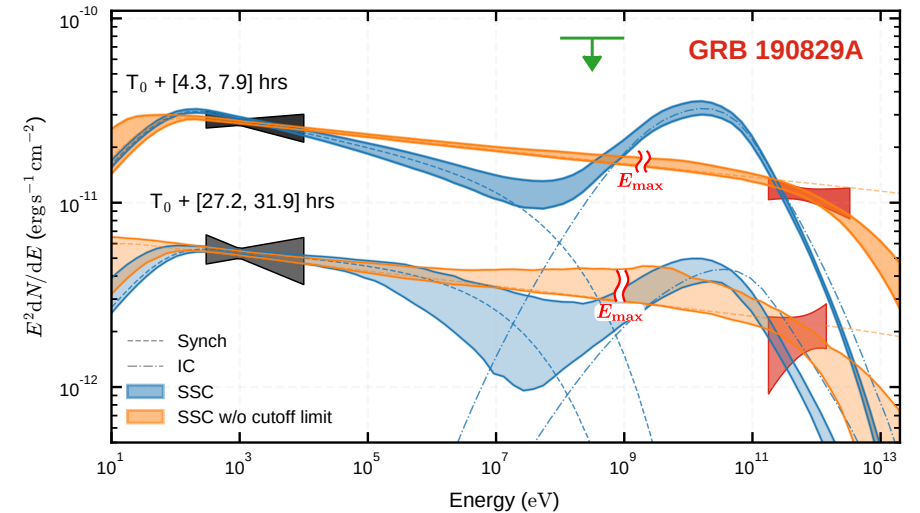
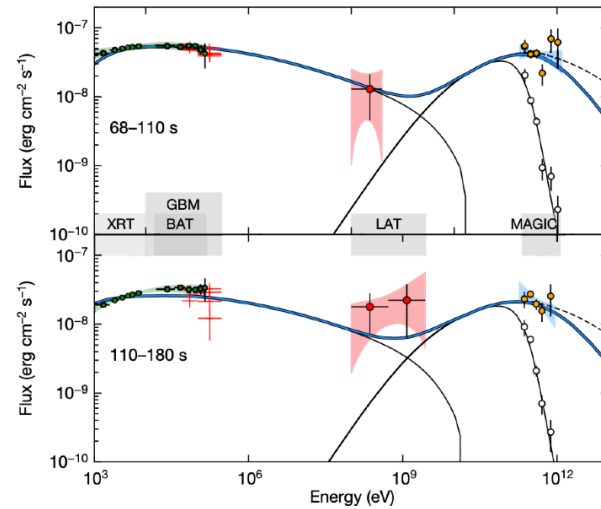
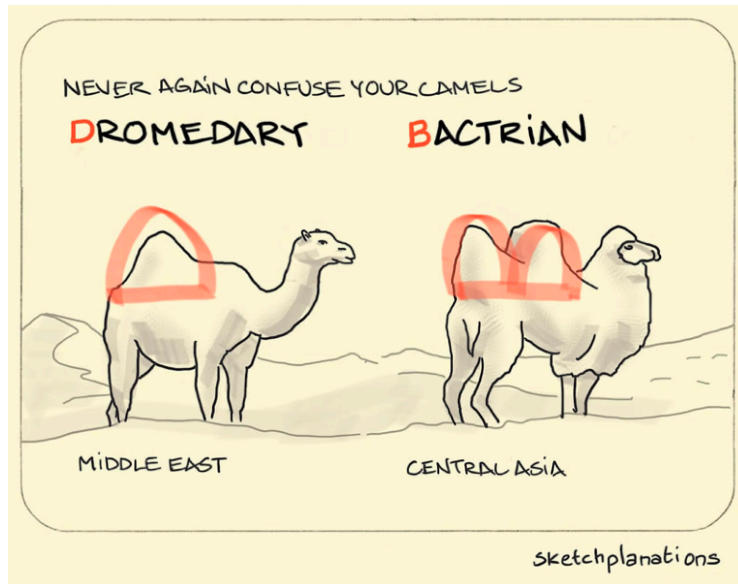
# Where do we go from here (IMO)

We need to be more open and work together

H.E.S.S. will (soon) publicize our GRB observation schedule for both *completed* and *planned* observations

Can we (IACTs) coordinate our observing plans?

How do we resolve the camels???





# VHE observations of GRBs so far

(GRB 130427A *Fermi*-LAT)

(GRB 160821B MAGIC)

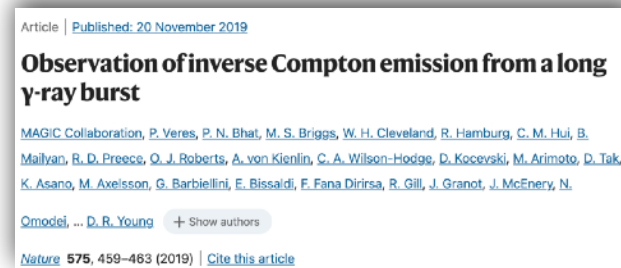
GRB 180720B H.E.S.S.

**GRB 190114C** **MAGIC**

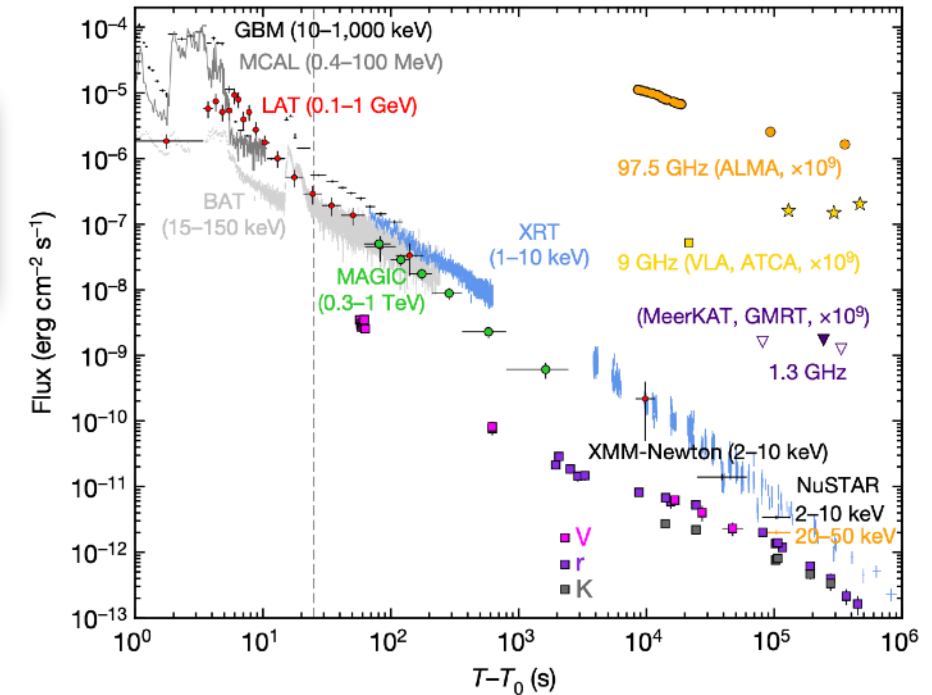
GRB 190829A H.E.S.S.

GRB 201015A MAGIC

GRB 201216C MAGIC

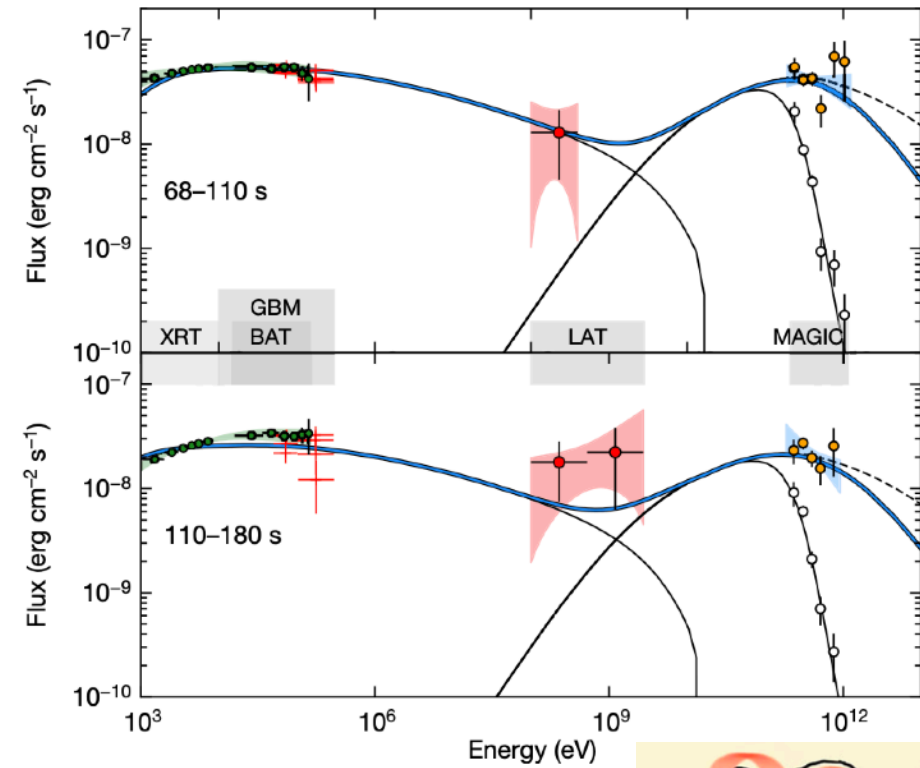
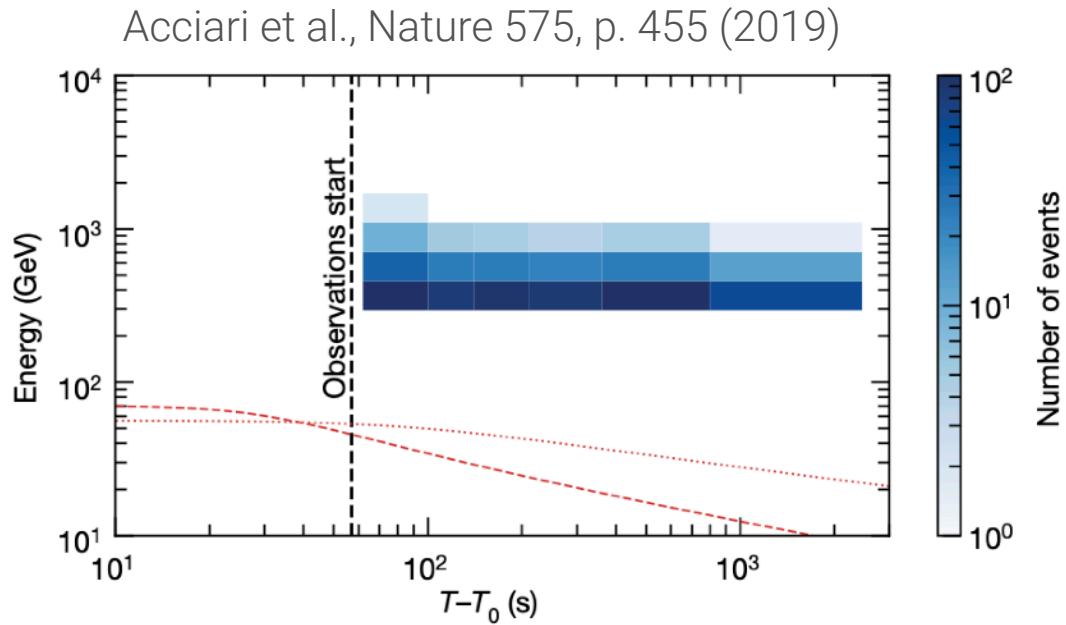


Acciari et al., Nature 575, p. 459 (2019)

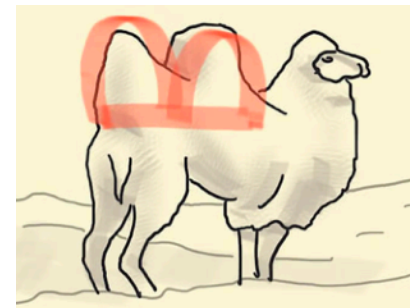


# VHE observations of GRBs so far

Acciari et al., Nature 575, p. 459 (2019)



VHE emission interpreted as a separate SSC component



# VHE observations of GRBs so far

(GRB 130427A *Fermi*-LAT)

(GRB 160821B MAGIC)

GRB 180720B H.E.S.S.

GRB 190114C MAGIC

**GRB 190829A H.E.S.S.**

GRB 201015A MAGIC

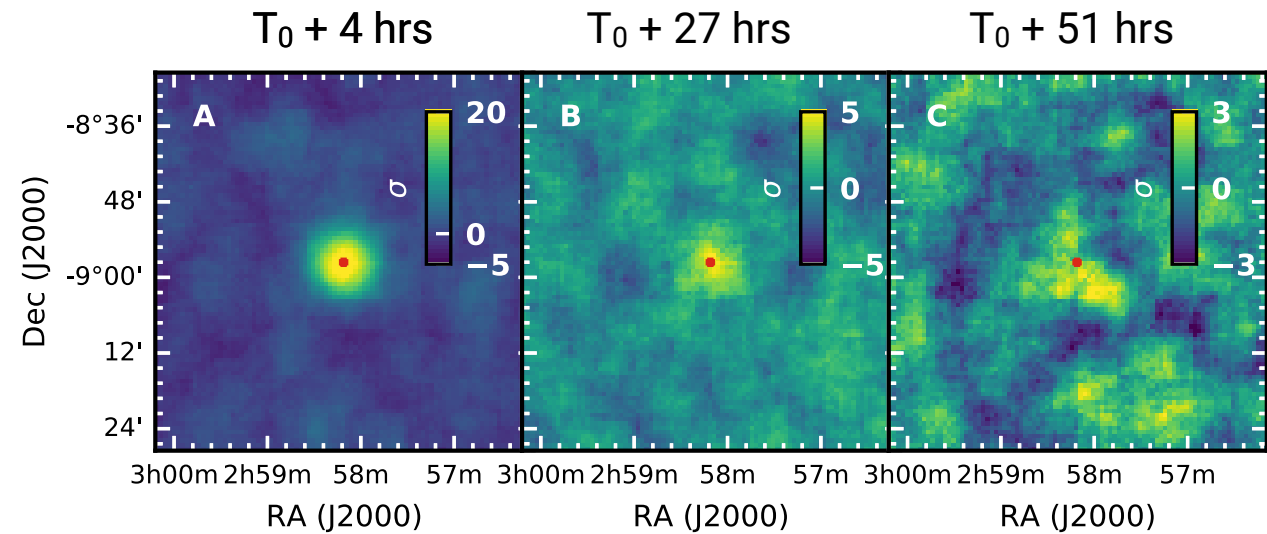
GRB 201216C MAGIC

## Revealing x-ray and gamma ray temporal and spectral similarities in the GRB 190829A afterglow

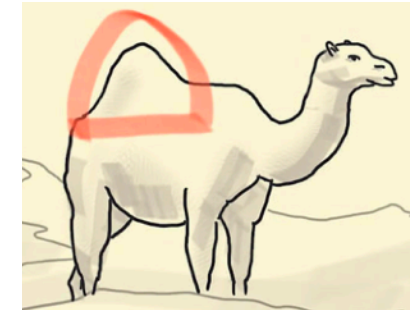
H.E.S.S. COLLABORATION, H. ABDALLA, F. AHARONIAN , F. AIT BENKHALI, E. O. ANGÜNER, C. ARCARO, C. ARMAND, T. ARMSTRONG, H. ASHKAR, [...] K. PAGE

+230 authors [Authors info & Affiliations](#)

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# VHE observations of GRBs so far



**(GRB 130427A *Fermi*-LAT)**

(GRB 160821B MAGIC)

GRB 180720B H.E.S.S.

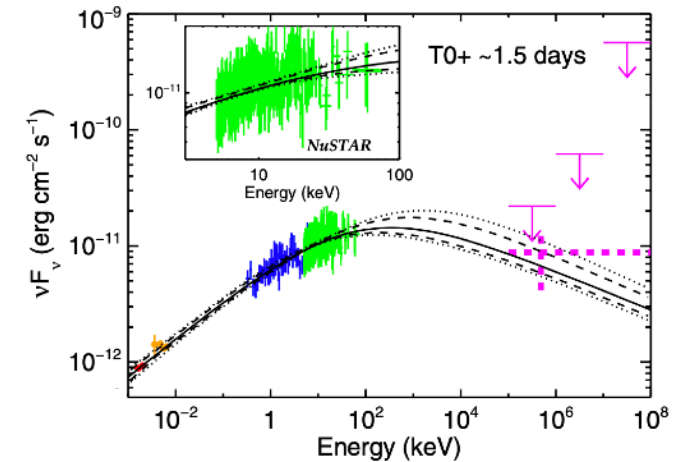
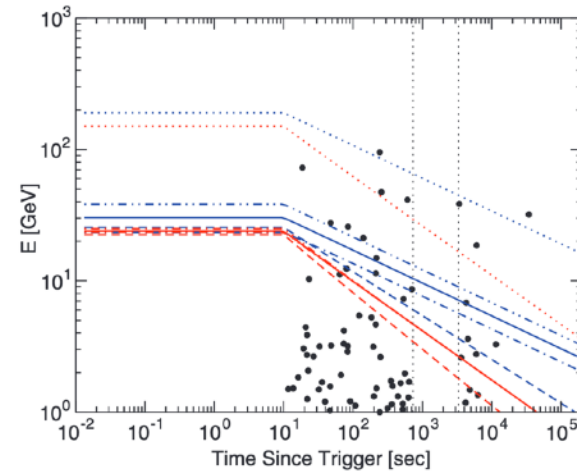
GRB 190114C MAGIC

GRB 190829A H.E.S.S.

GRB 201015A MAGIC

GRB 201216C MAGIC

Ackermann et al., Science 343 (2013)



Highest-energy photons difficult to explain as synchrotron  
in the single-zone scenario  
But, no indication of extra component between X-rays and GeV

# VHE observations of GRBs so far

(GRB 130427A *Fermi*-LAT)

**(GRB 160821B MAGIC)**

GRB 180720B H.E.S.S.

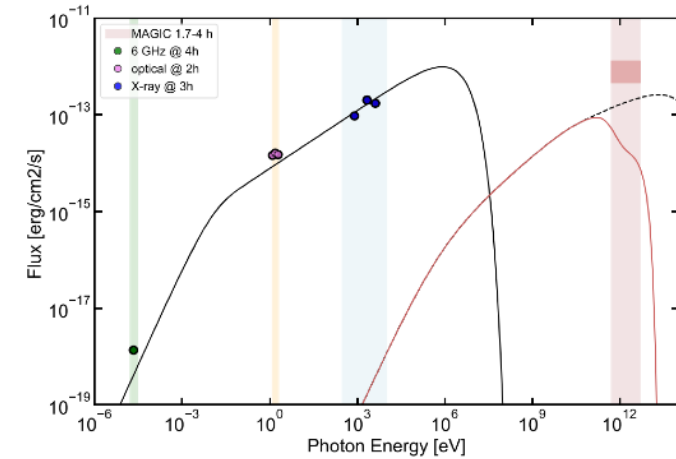
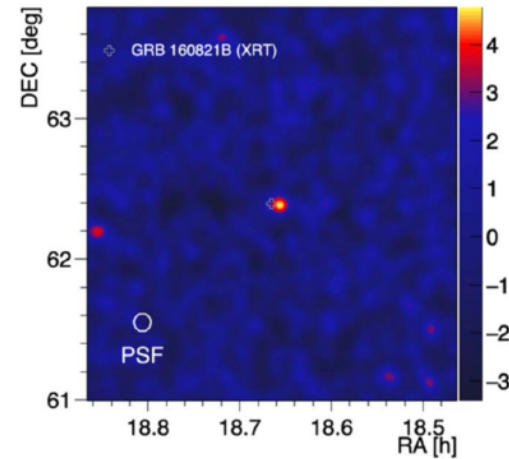
GRB 190114C MAGIC

GRB 190829A H.E.S.S.

GRB 201015A MAGIC

GRB 201216C MAGIC

Acciari et al., ApJ 908 (2021)



$3\sigma$  signal from a **short** GRB at  $z = 0.16$

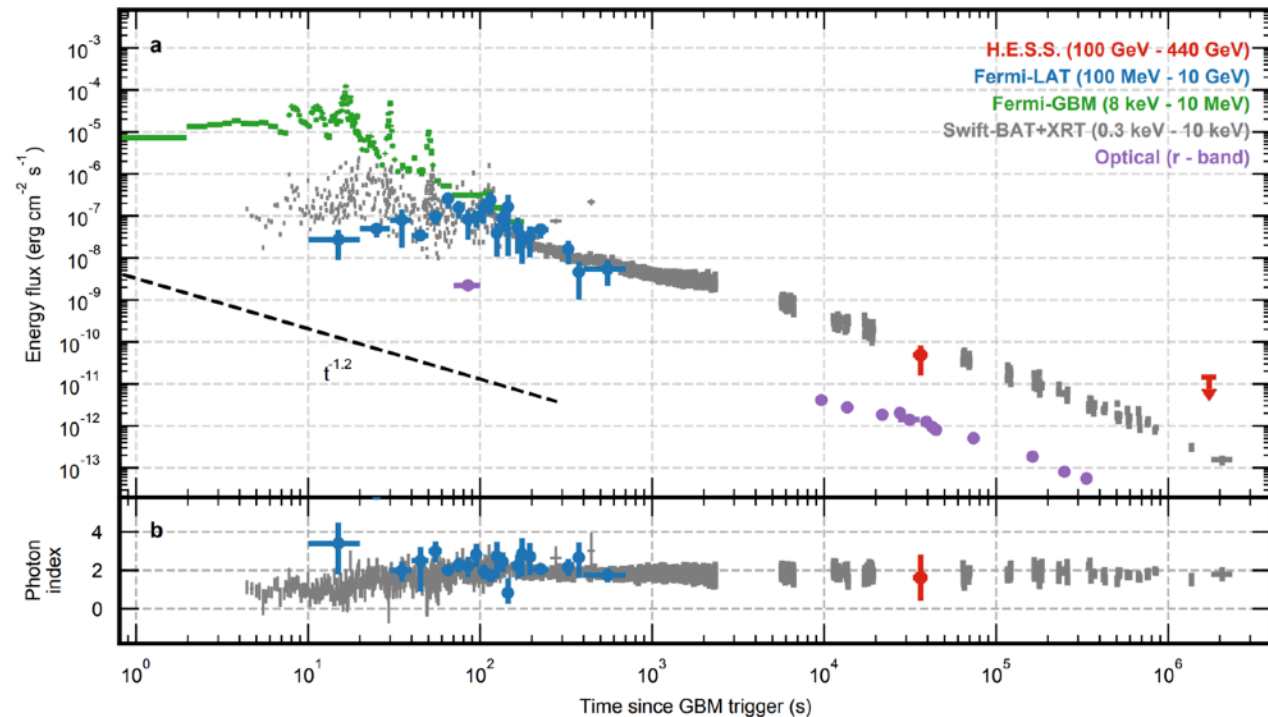
“Simplest emission model (synchrotron + SSC at external forward shock) is in tension with the TeV predicted flux”

- A. Berti’s presentation (pdf)

# VHE detections of GRBs so far

Abdalla et al., Nature 575 (2019)

(GRB 130427A	<i>Fermi</i> -LAT)
(GRB 160821B	MAGIC)
<b>GRB 180720B</b>	<b>H.E.S.S.</b>
GRB 190114C	MAGIC)
GRB 190829A	H.E.S.S.
GRB 201015A	MAGIC)
GRB 201216C	MAGIC)



5 $\sigma$  detection 8 hours after the GRB onset

The VHE and X-ray energy fluxes at this time are around the same level



# VHE observations of GRBs so far

(GRB 130427A *Fermi*-LAT)

(GRB 160821B MAGIC)

GRB 180720B H.E.S.S.

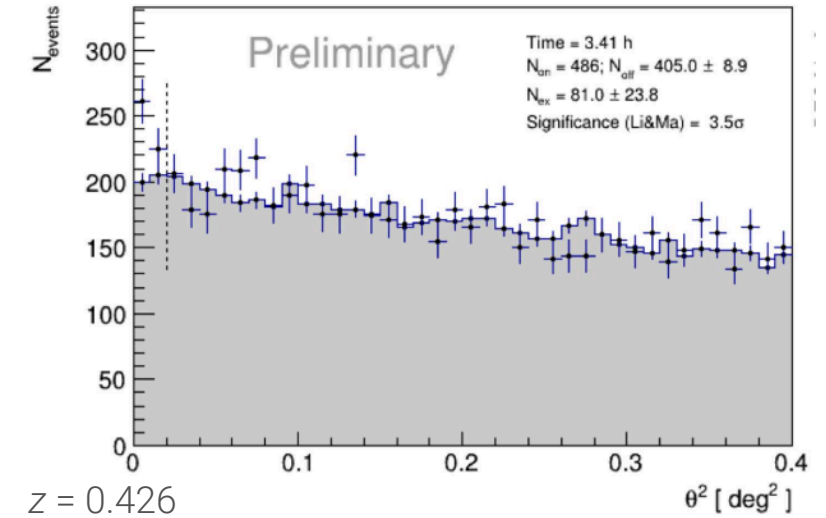
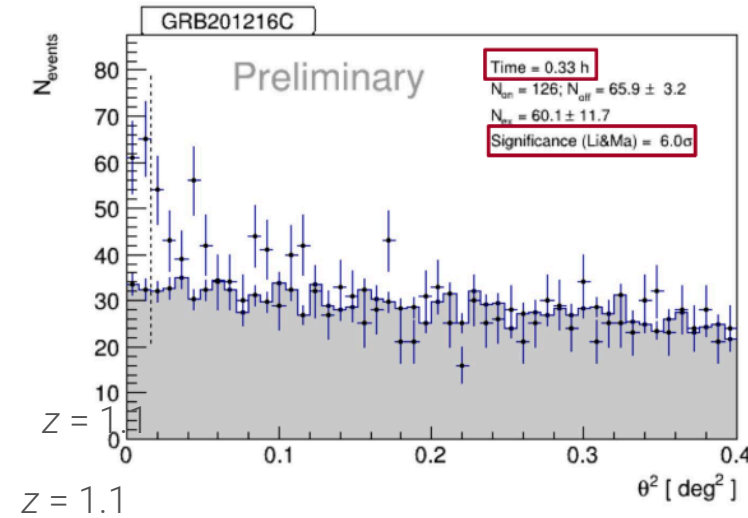
GRB 190114C MAGIC

GRB 190829A H.E.S.S.

**GRB 201015A MAGIC**

**GRB 201216C MAGIC**

From A. Berti's presentation at TeVPA 2022 (pdf)



Two as-yet unpublished but interesting GRBs  
Paper on 201216C by MAGIC collaboration expected soon