Gamma-Ray Burst modeling in a multi-messenger context

Annika Rudolph, DESY Zeuthen

APC public talk, 10.11.2020

HELMHOLTZ WEIZMANN RESEARCH SCHOOL MULTIMESSENGER ASTRONOMY

DESY.

erc European Research Council Established by the European Commission

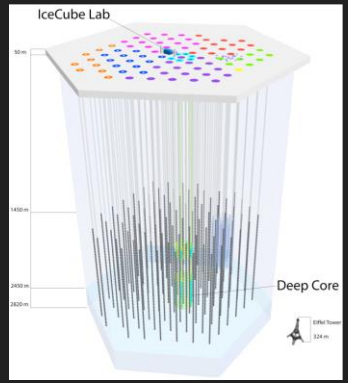
More than a century of cosmic-ray physics

We might have better instruments ...

Alexander Pokusay

Auger coll.

H.E.S.S. coll.



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… but we still haven‘t identified the sources!

More than a century of cosmic-ray physics

We might have better instruments ...

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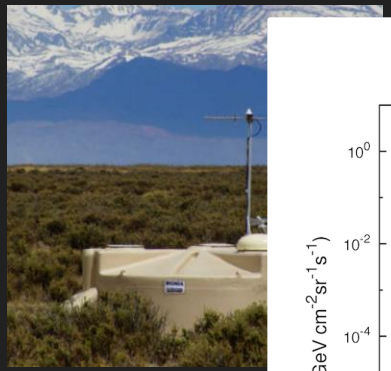

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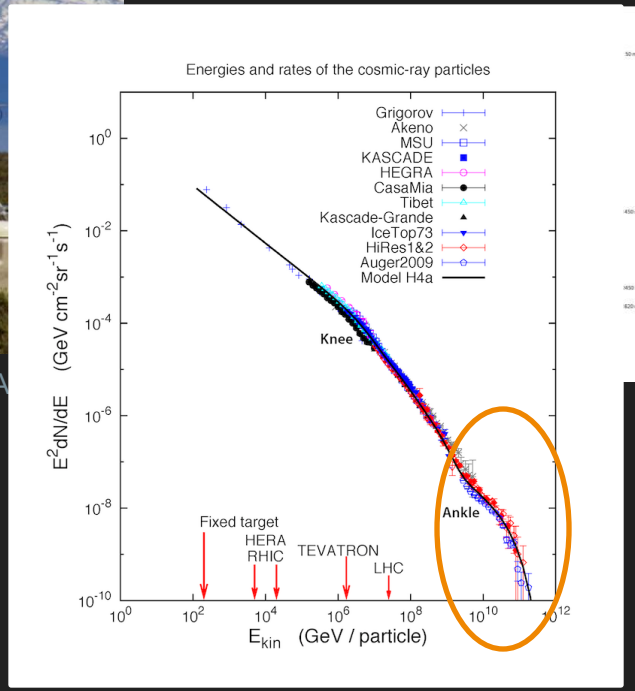

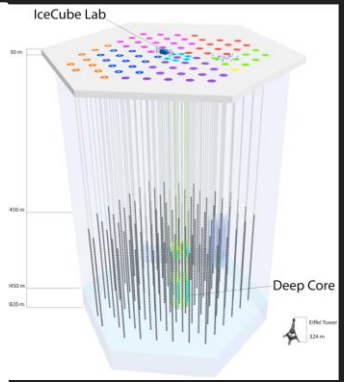

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OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

RAY W. KLEBESADEL, IAN B. STRONG, AND ROY A. OLSON

University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico

Received 1973 March 16; revised 1973 April 2

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Cosmological gamma ray bursts and the highest energy cosmic rays

Eli Waxman

Institute for Advanced Study, Princeton, NJ 08540; E-mail: waxman@guinness.ias.edu

(Phys. Rev. Lett. in press; Received: March 22, 1995; Accepted: May 17, 1995)

Gravitational Waves and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A

B. P. Abbott[3], R. Abbott[3], T. D. Abbott[4], F. Acernese[5,6], K. Ackley[7,8], C. Adams[9], T. Adams[10], P. Addesso[11], R. X. Adhikari[3], V. B. Adya[12] +Show full author list

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The Astrophysical Journal Letters, Volume 848, Number 2

Article | Published: 20 November 2019

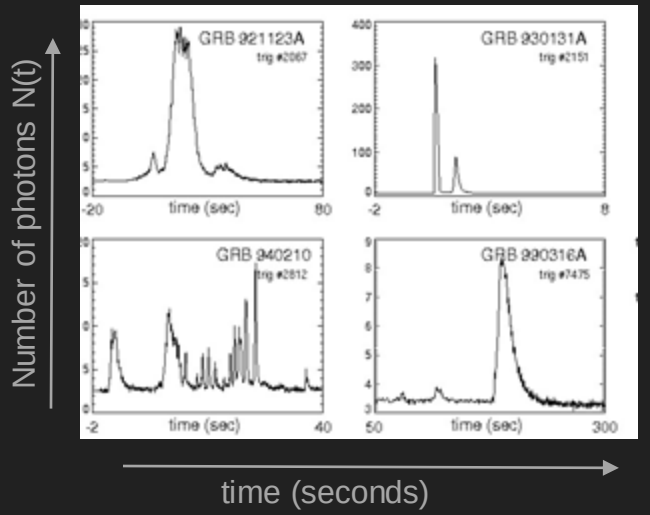
Teraelectronvolt emission from the γ-ray burst GRB 190114C

MAGIC Collaboration

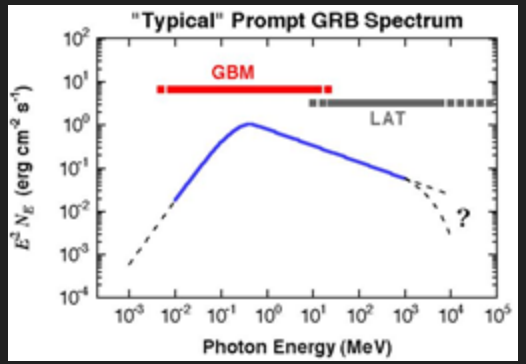
Nature **575**, 455–458(2019) | Cite this article

Gamma-Ray… what?

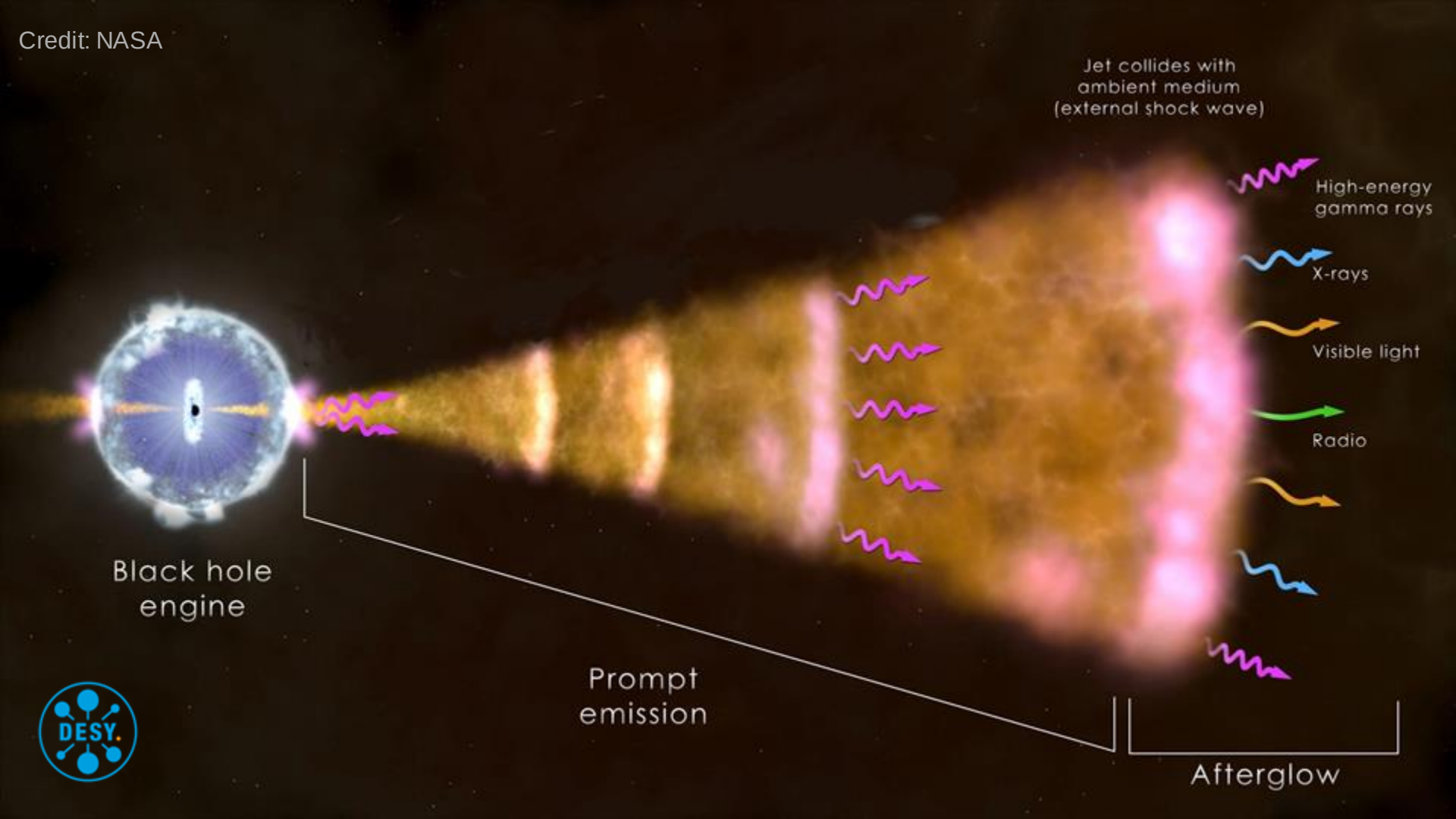
- short, energetic outbursts
  Duration: 0.1 - 100 s
  Energy: 10^{49} - 10^{52} ergs
- emission divided in prompt phase and afterglow
- 2 classes:
  long GRBs → collapse of massive object
  short GRBs → compact object merger
- Outflow with high Lorentz factor, collimated in jet

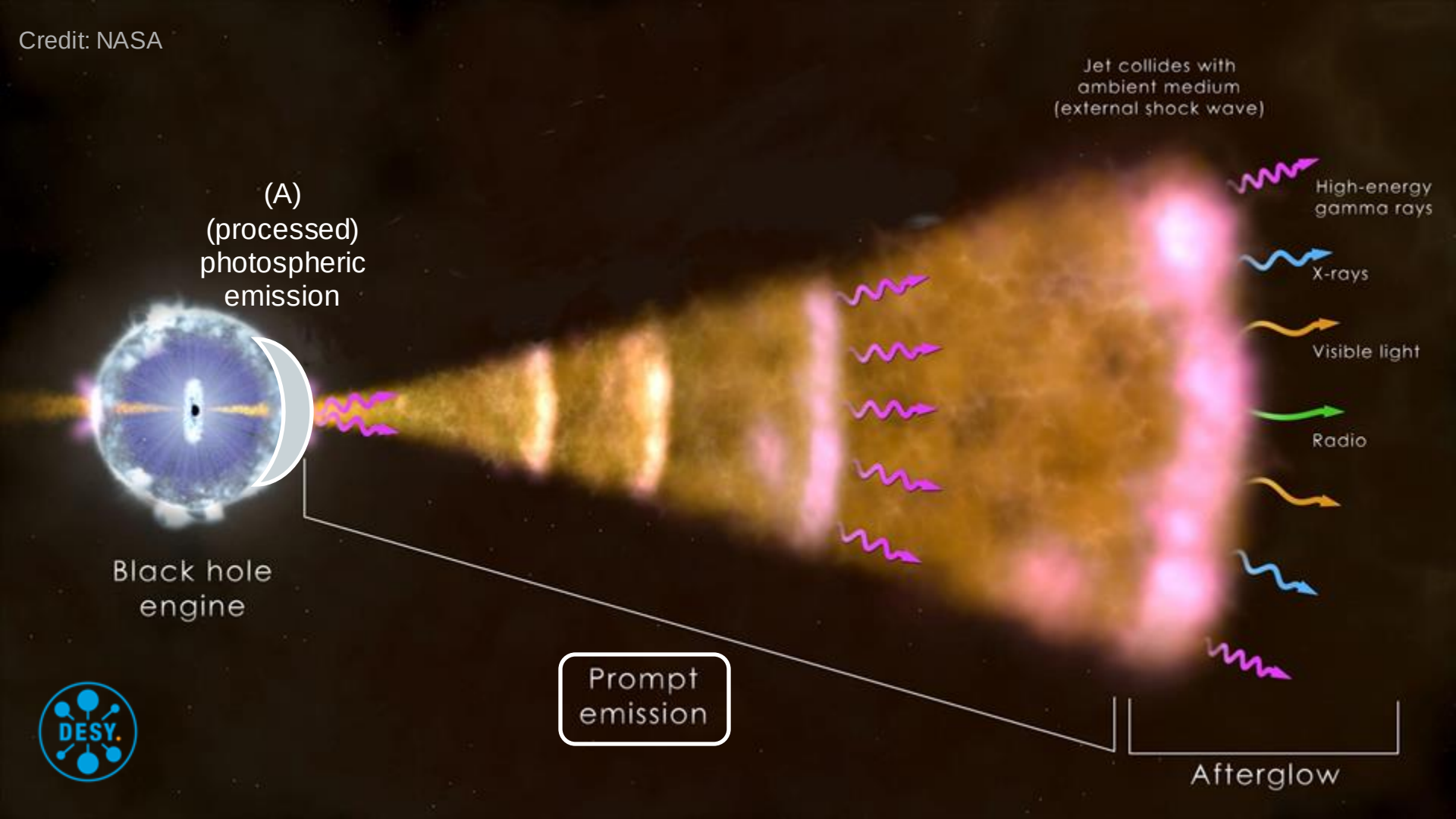


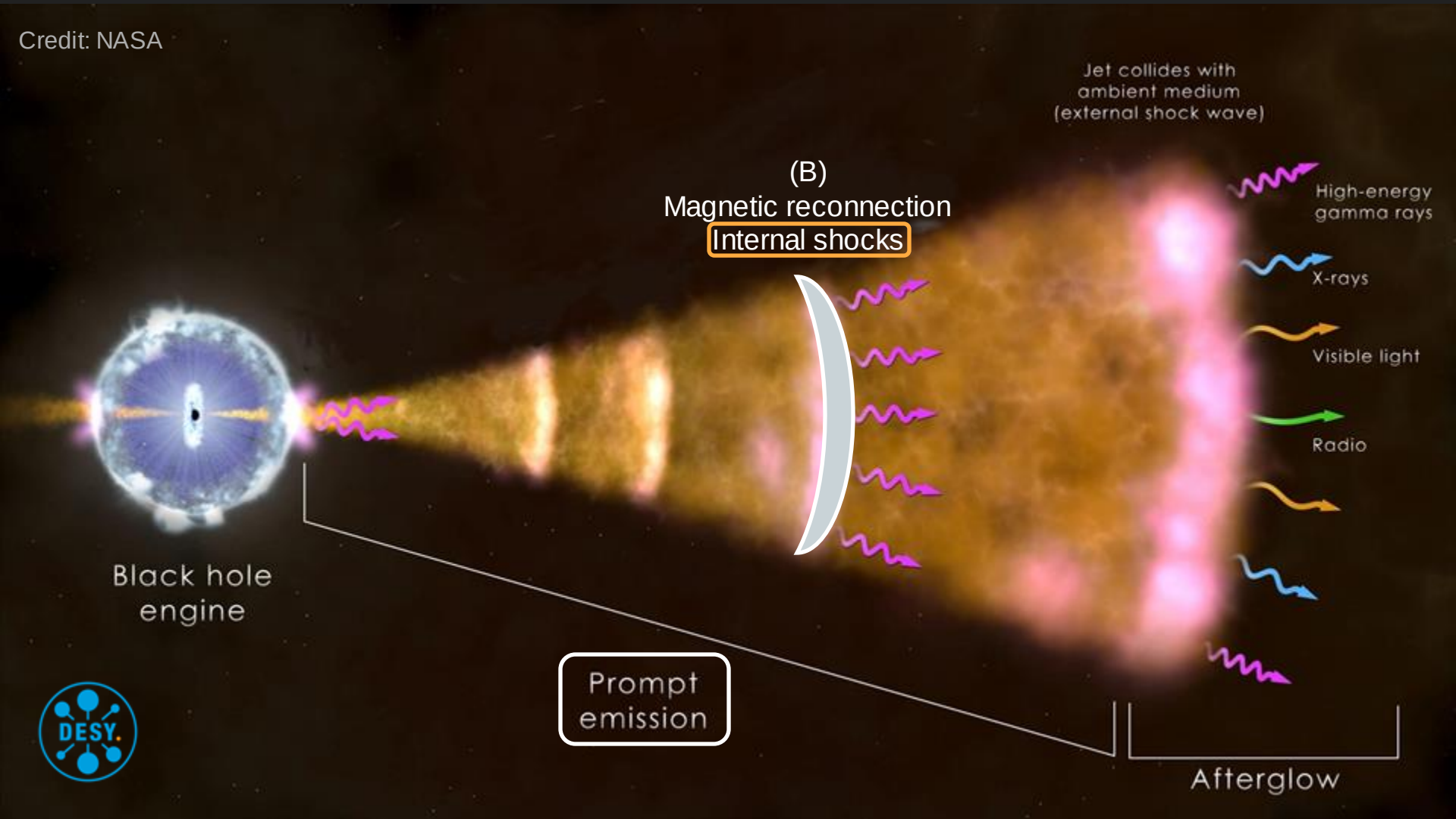
Daniel Perley



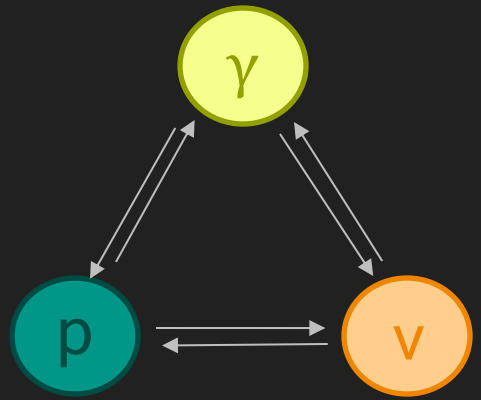
Fermi Coll.


Credit: NASA
Jet collides with ambient medium (external shock wave)
High-energy gamma rays
X-rays
Visible light
Radio
Black hole engine
Prompt emission
Afterglow
DESY.


Credit: NASA
Jet collides with ambient medium (external shock wave)
(A) (processed) photospheric emission
High-energy gamma rays
X-rays
Visible light
Radio
Black hole engine
Prompt emission
Afterglow
DESY.

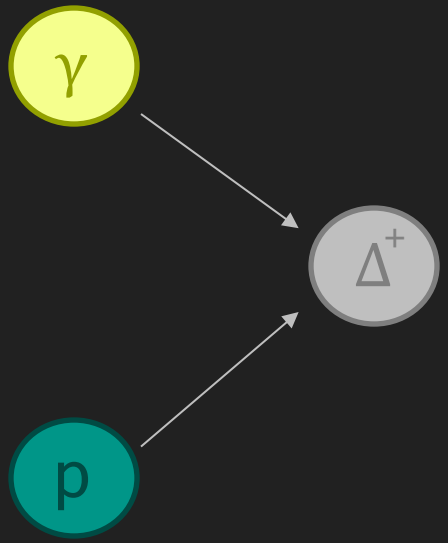

Credit: NASA
Jet collides with ambient medium (external shock wave)
(B)
Magnetic reconnection
Internal shocks
High-energy gamma rays
X-rays
Visible light
Radio
Black hole engine
Prompt emission
Afterglow
DESY.

The multi-messenger picture

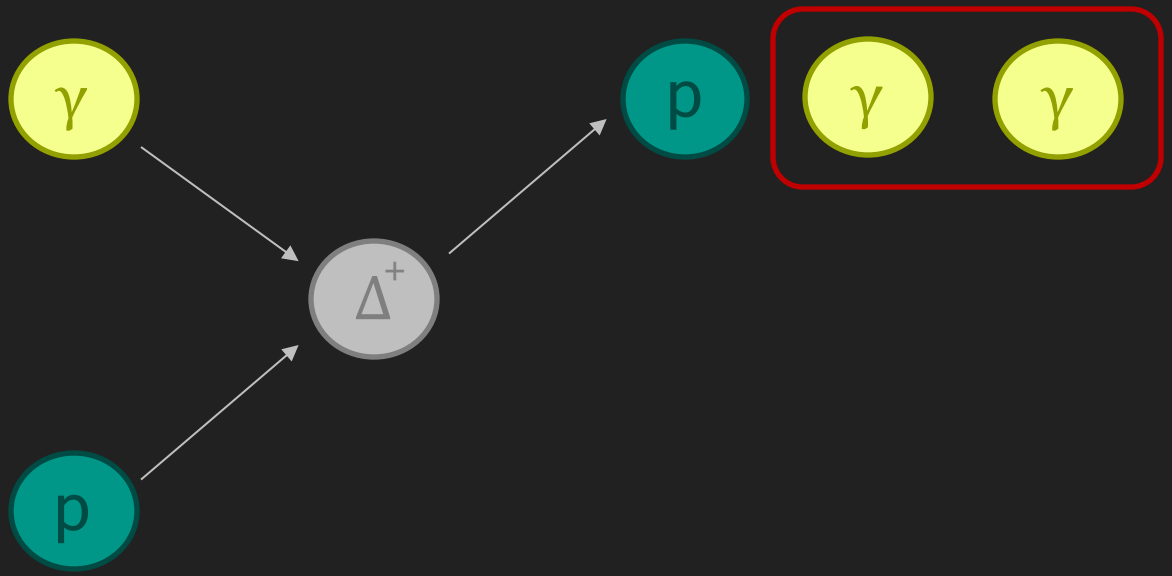


GW

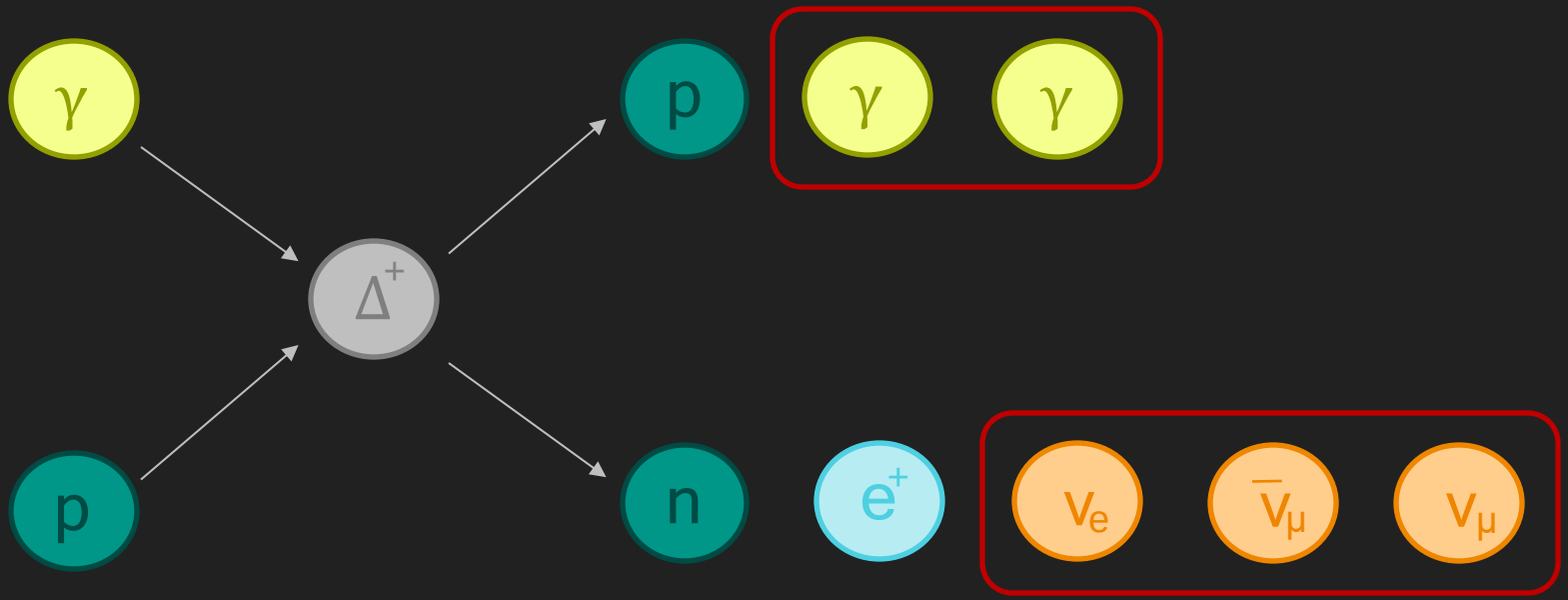
The multi-messenger picture



The multi-messenger picture

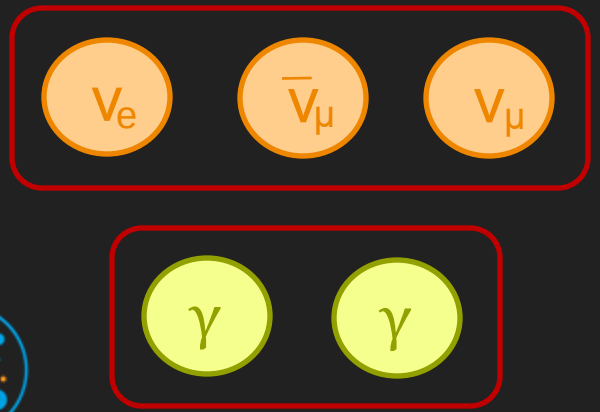


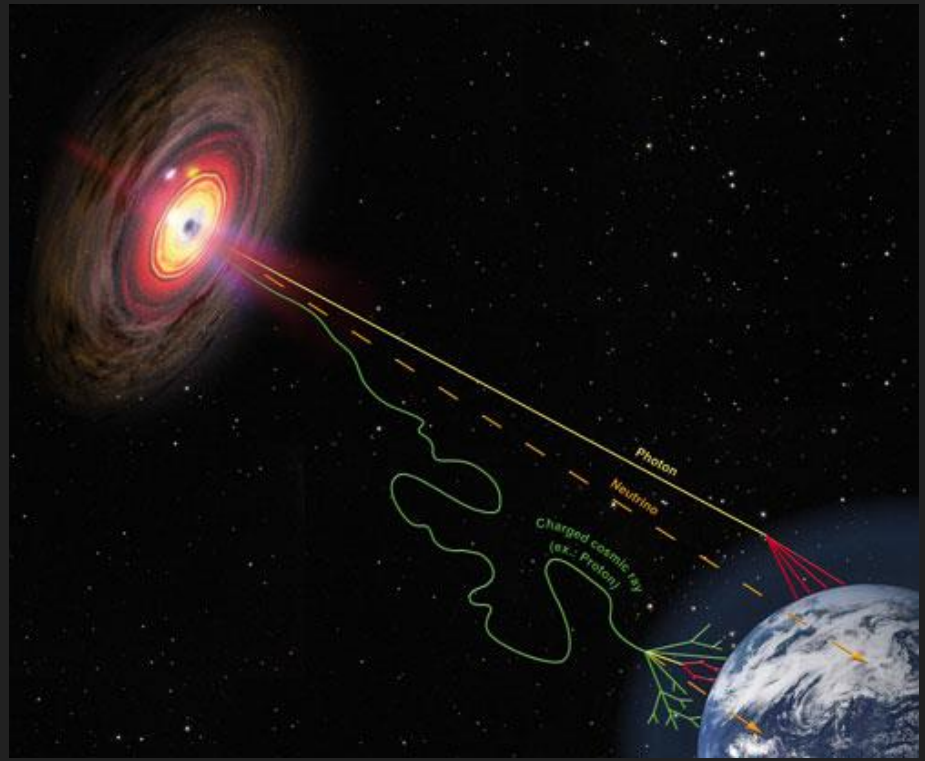
The multi-messenger picture



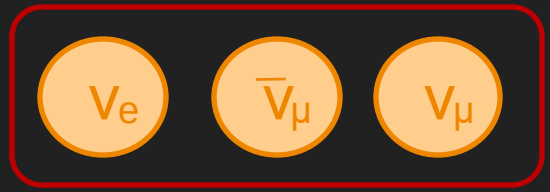
The multi-messenger picture (propagation)

Cosmic rays get deflected and absorbed during propagation, have to use other signatures!

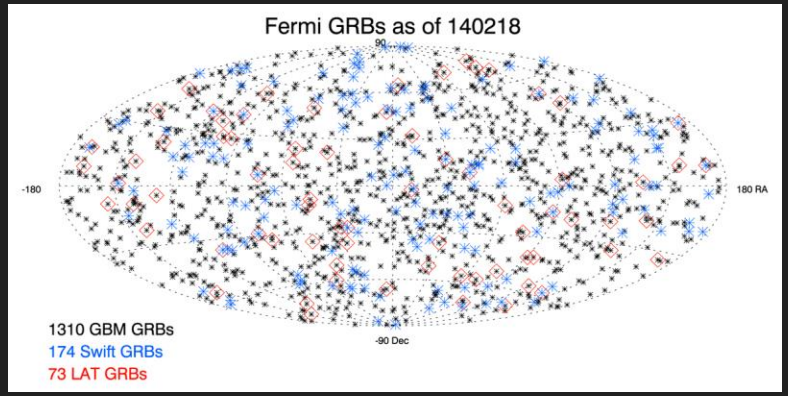


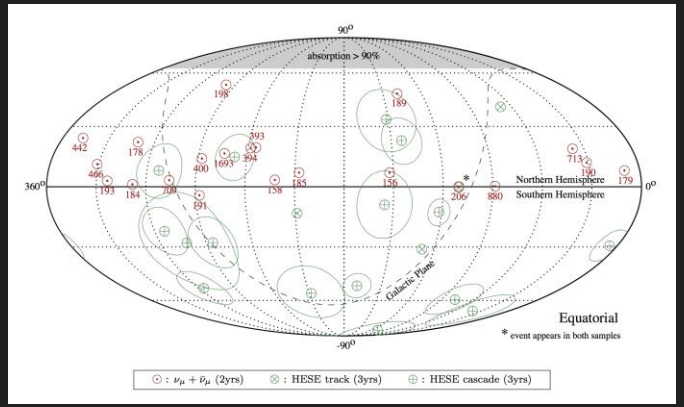


Searching for cosmic-ray signatures



Fermi LAT + GBM coll.

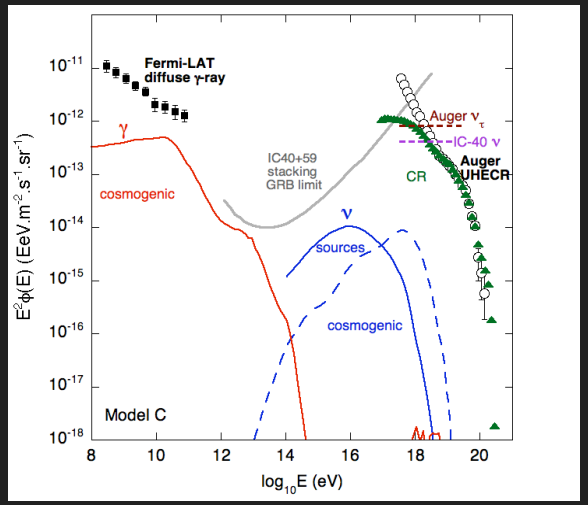




IceCube coll.

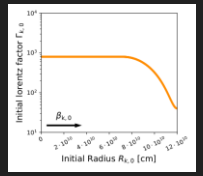
So, GRBs can't be cosmic-ray sources?

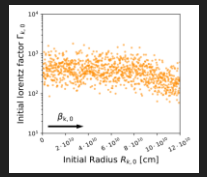
Yes, but need to consider refined models to not violate neutrino limits …



Globus et al 2014,
Bustamante et al 2016

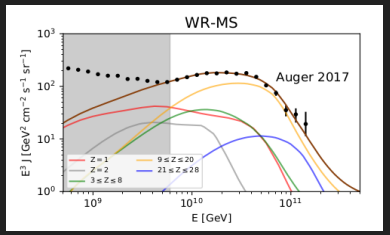
Towards a systematic study



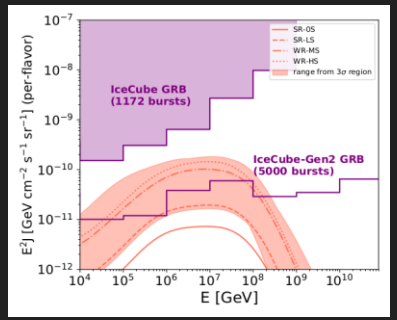


For different engines...

… perform a fit to UHECR data...



… and compare to neutrino limits

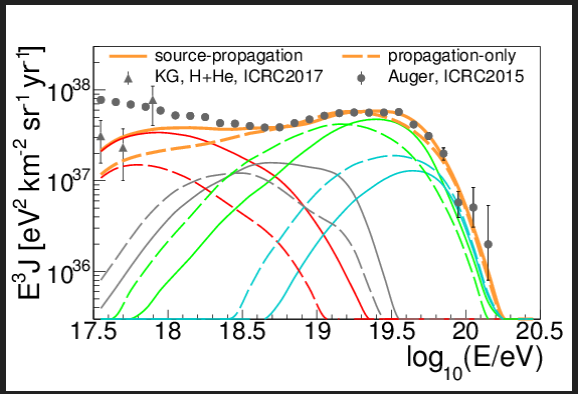


Heinze et al 2020

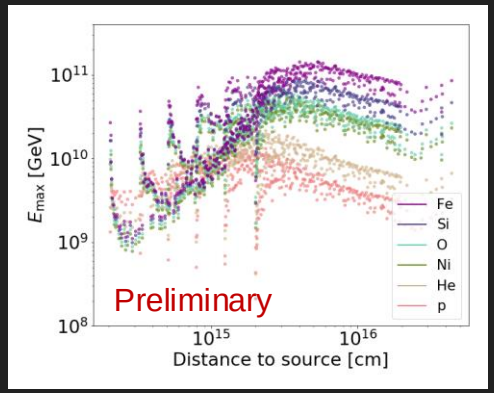
So, GRBs can't be cosmic-ray sources?

… or look at different population!

Low-luminosity GRBs

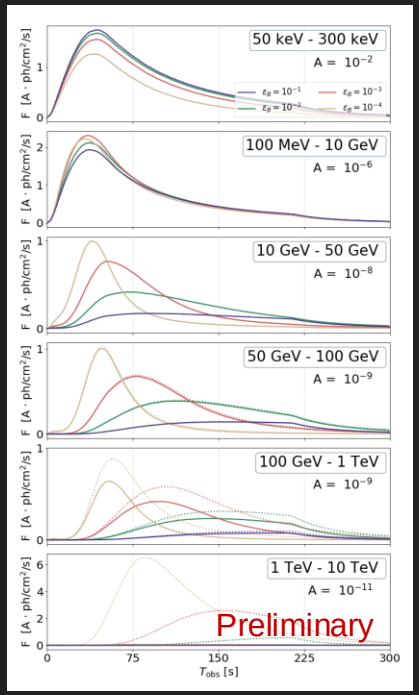


Boncioli et al 2018
Also Murase et al 2006, Zhang et al 2017, Samuelsson et al 2019 & 2020



Can cosmic rays reach ultra-high energies in the source?

Could we detect more LL GRBs with future instruments (CTA)?



AR, Z. Bosnjak, I. Sadeh, A. Palladino, W.Winter

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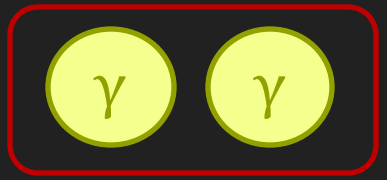

A Decade of Gamma-Ray Bursts Observed by Fermi-LAT: The Second GRB Catalog

M. Ajello (Clemson U.), M. Arimoto (Kanazawa U.), M. Axelsson (Stockholm U., OKC & Royal Inst. Tech., Stockholm), L. Baldini (INFN, Pisa & Pisa U.), G. Barbiellini (INFN, Trieste & Trieste U.), D. Bastieri (INFN, Padua & Padua U.), R. Bellazzini (INFN, Pisa), P.N. Bhat (Alabama U., Huntsville), E. Bissaldi (Bari Polytechnic & INFN, Bari), R.D. Blandford (KIPAC, Menlo Park & SLAC) *et al.* Show all 123 authors

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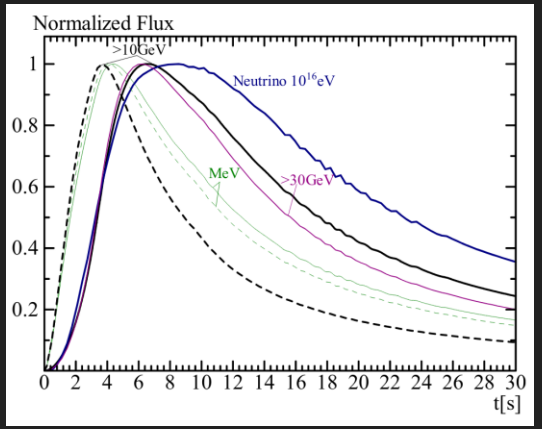

What produces the high-energy emission?

- prompt emission/ afterglow
- cosmic rays / electrons

Asano et al 2012, also Asano et al 2009, Petropoulou et al 2014, Wang et al 2019, ...

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