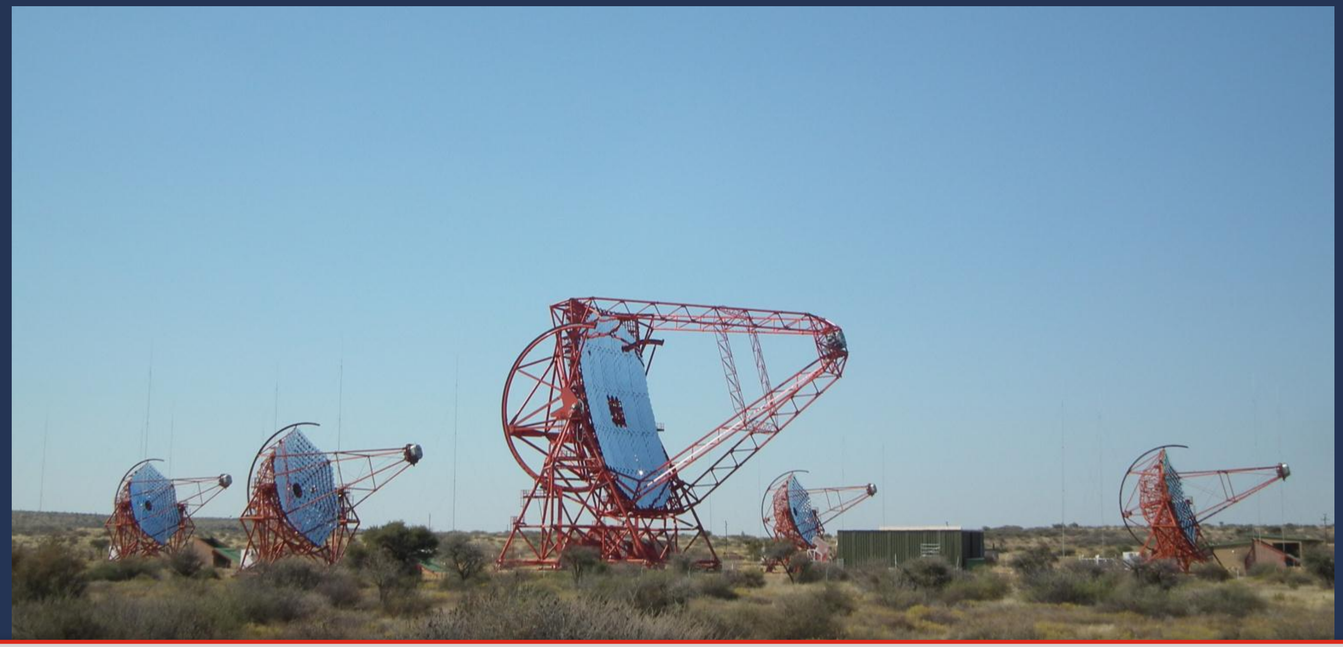
Energetic photons from big explosions: Very-High-Energy observations of gamma-ray bursts

Sylvia J. Zhu, DESY Zeuthen

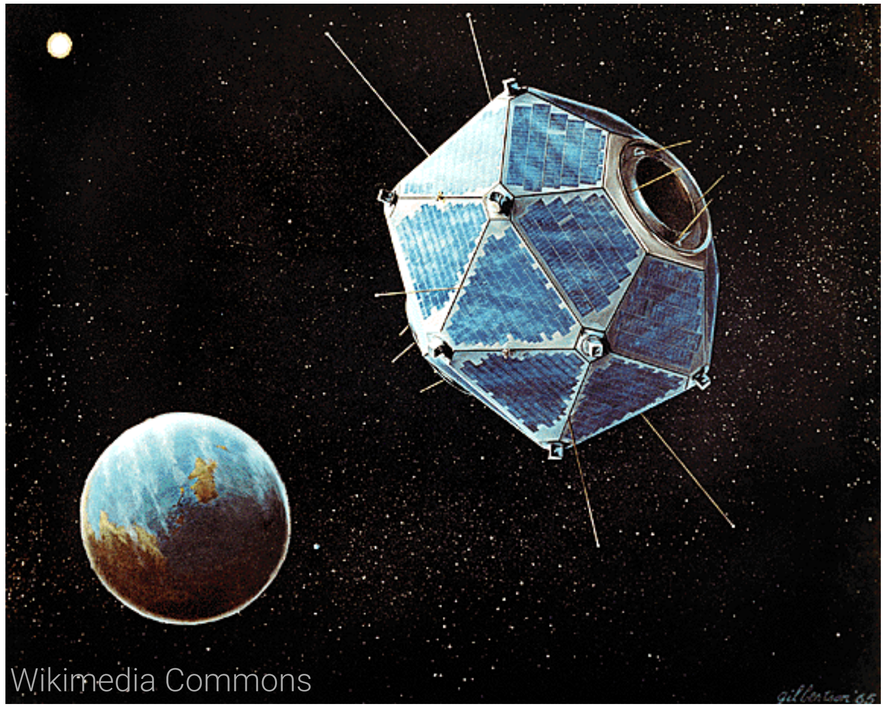


H.E.S.S.


The optical sky in Namibia
© Fabio Acero


The optical sky in Namibia
+ some Very High Energy gamma-ray sources
(c) F. Acero, H. Gast, H.E.S.S. Collaboration

Gamma-ray bursts: An accidental discovery in 1969

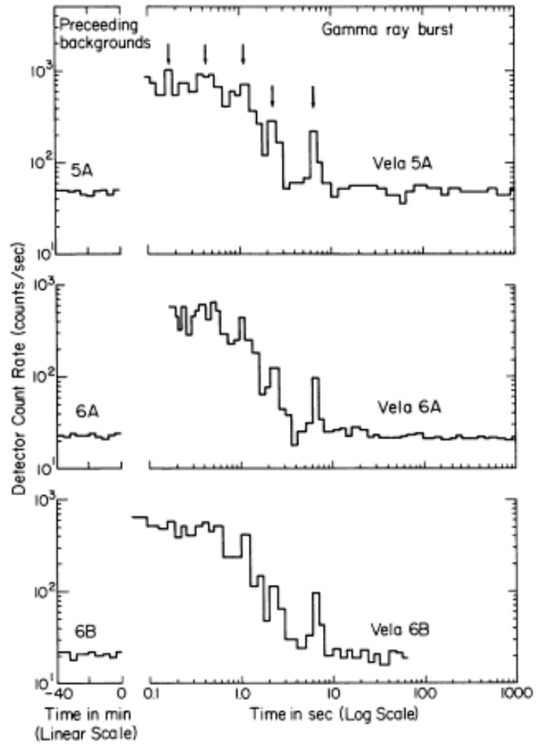


OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

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

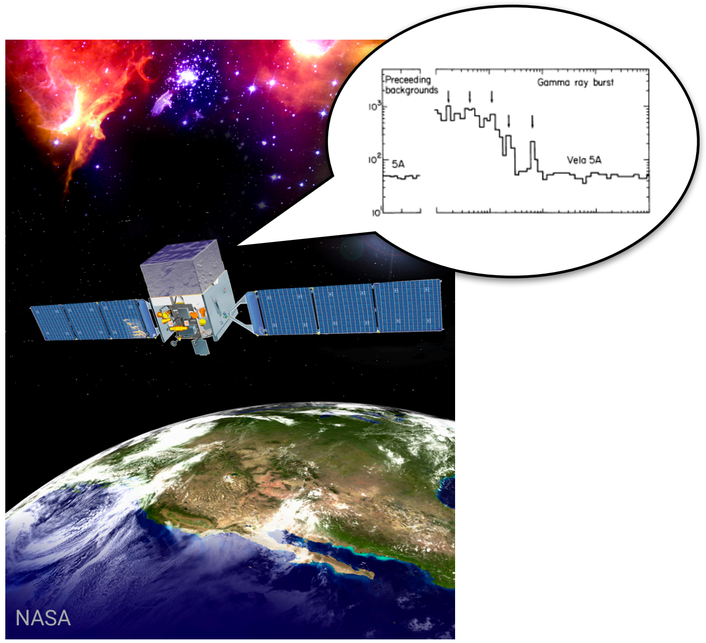
University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico

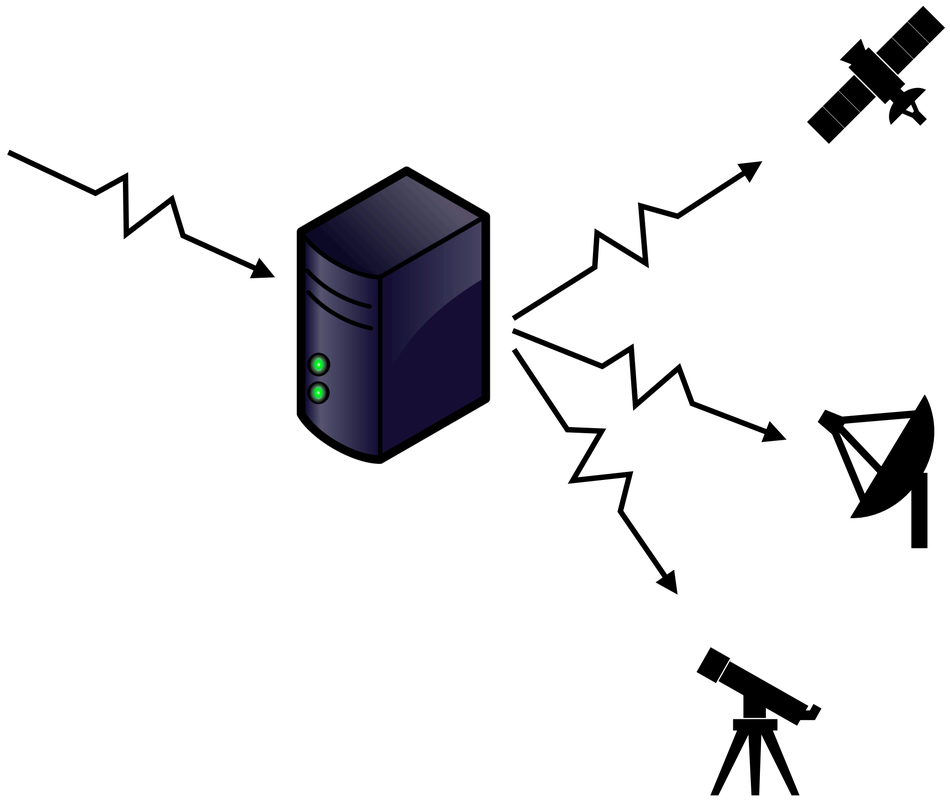
Received 1973 March 16; revised 1973 April 2



Klebesedal, Strong, & Olson (1973)

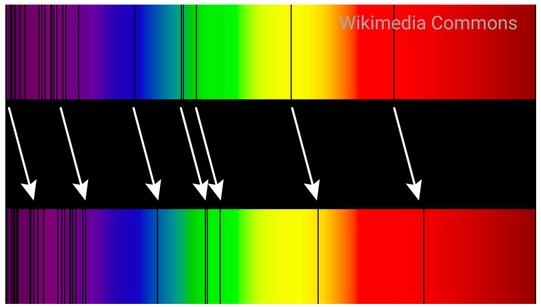
How do we observe GRBs?

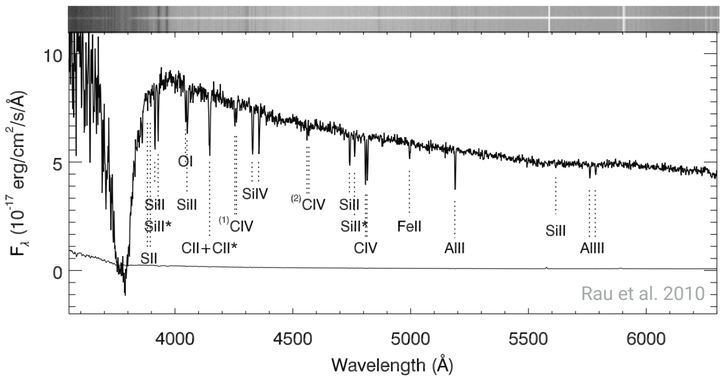




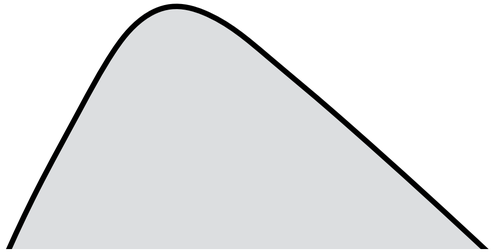
Satellites with large fields of view detect the bright flash of gamma rays (“prompt emission”)

What kinds of information do we get?

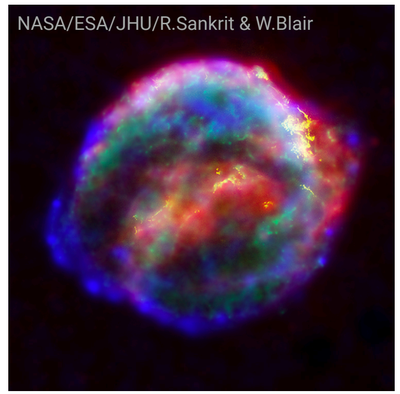




distances
(redshifts)



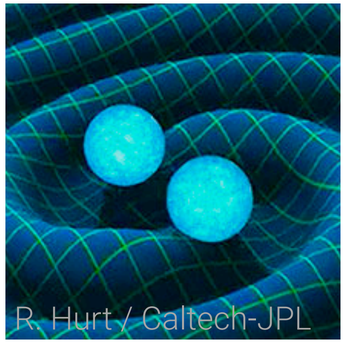
energetics
(energy spectrum)



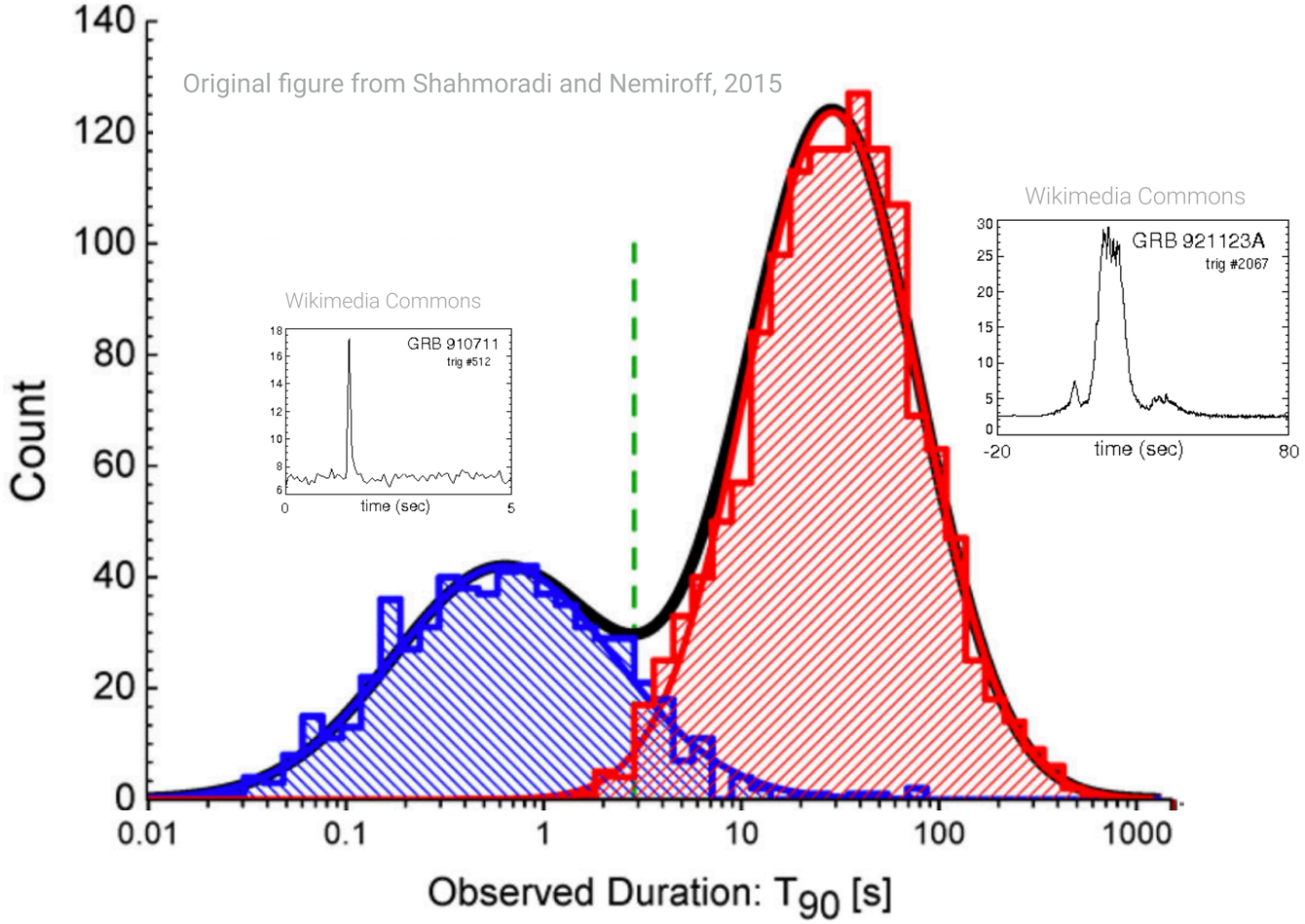
accompanying phenomena

Two types of gamma-ray bursts

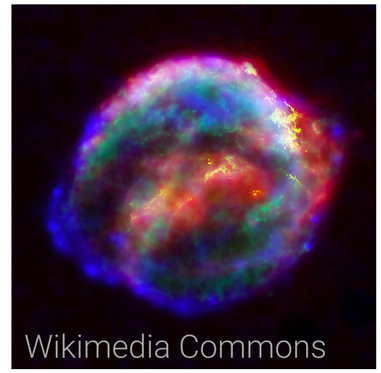
short GRBs

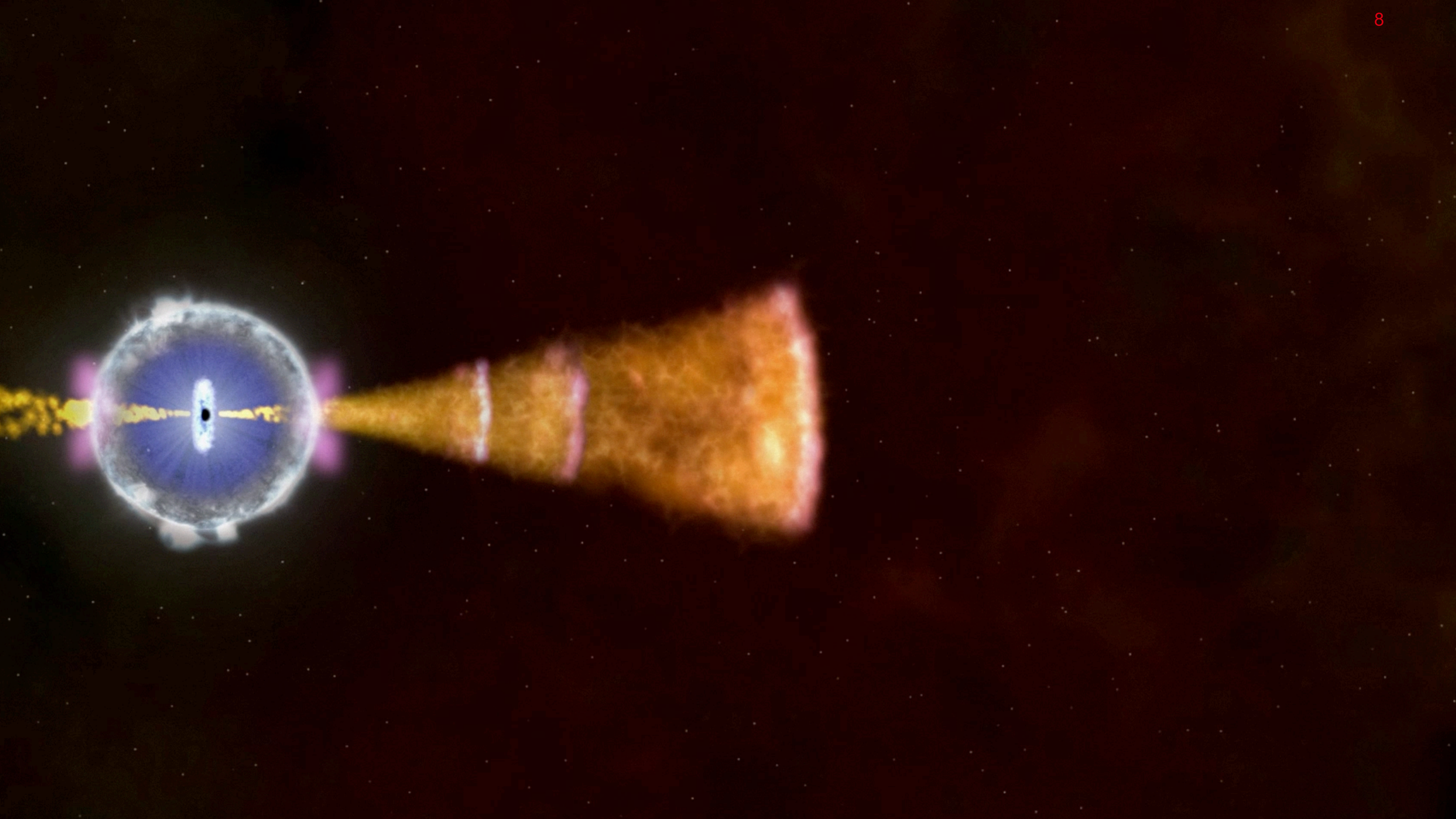


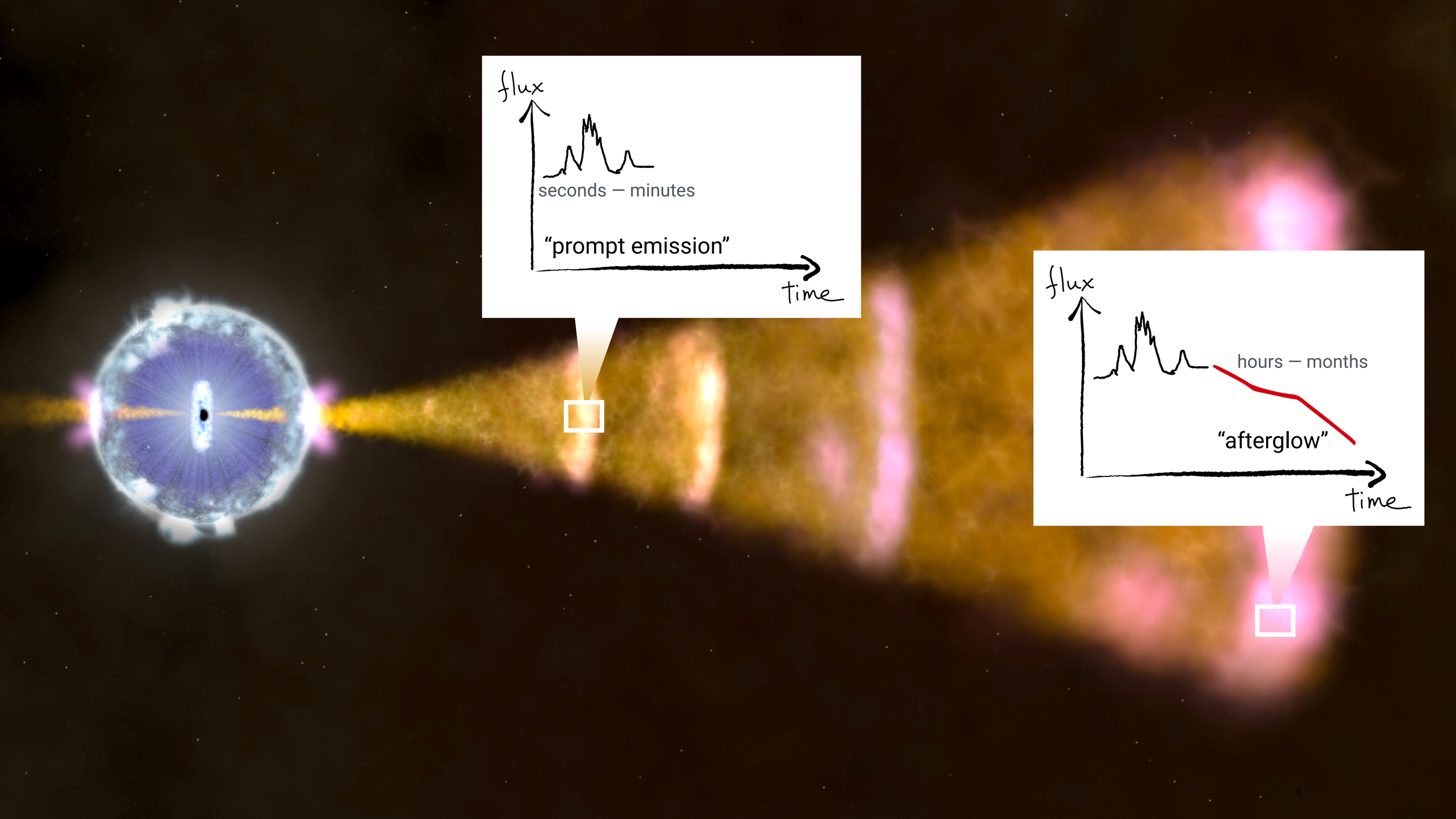
Original figure from Shahmoradi and Nemiroff, 2015

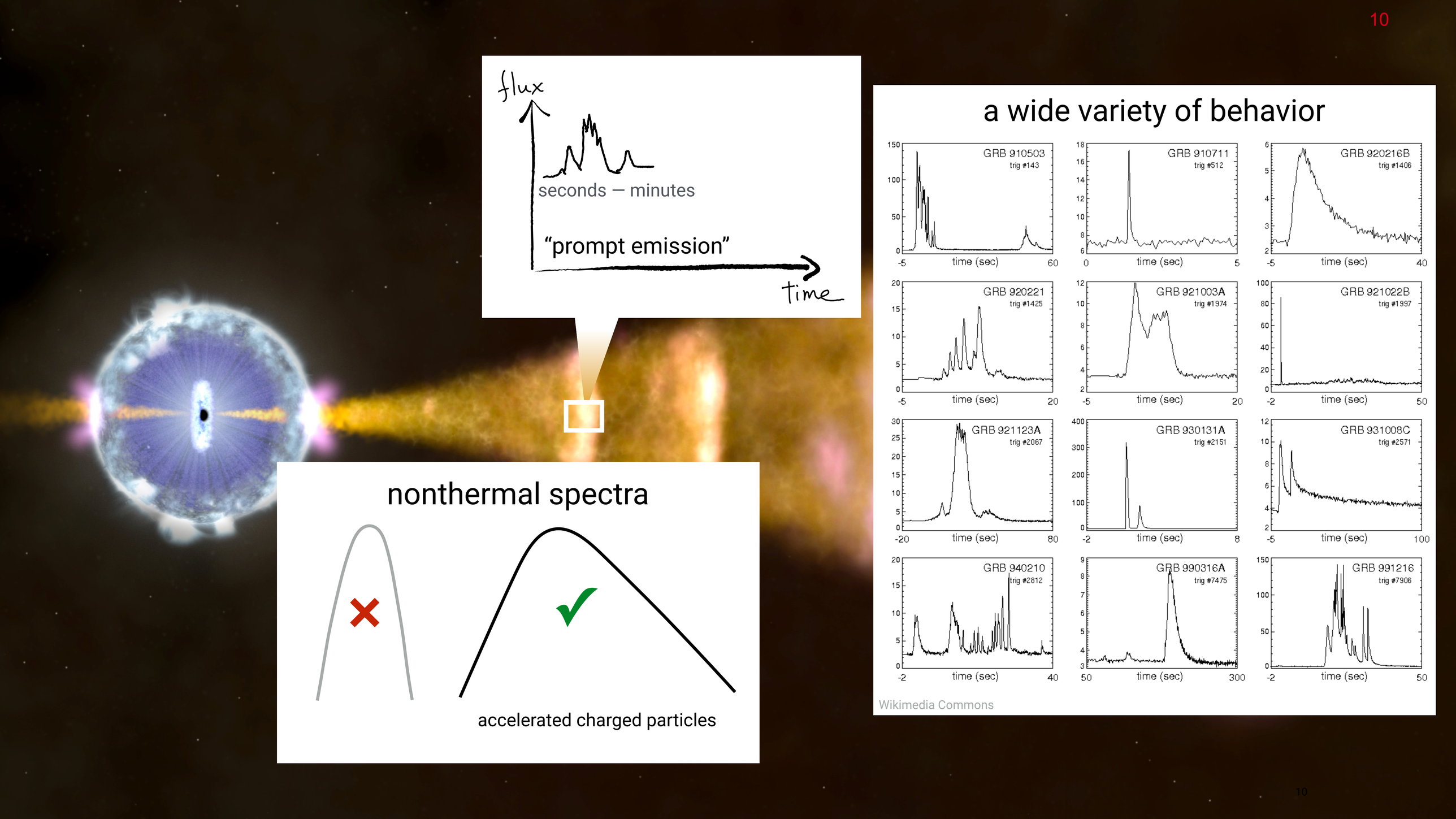


long GRBs






flux
seconds — minutes
“prompt emission”
time
flux
hours — months
“afterglow”
time

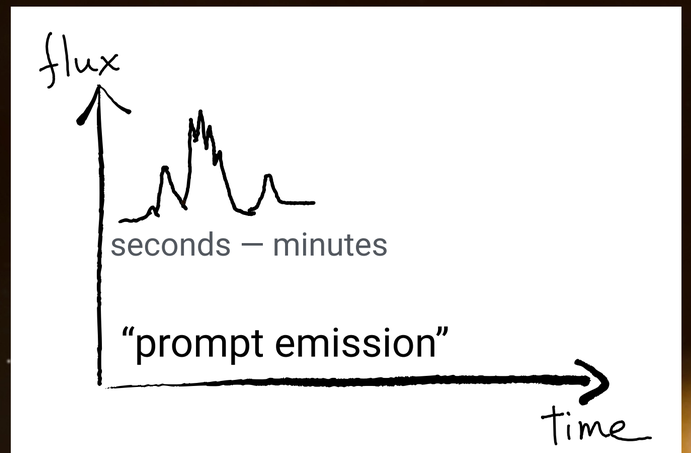


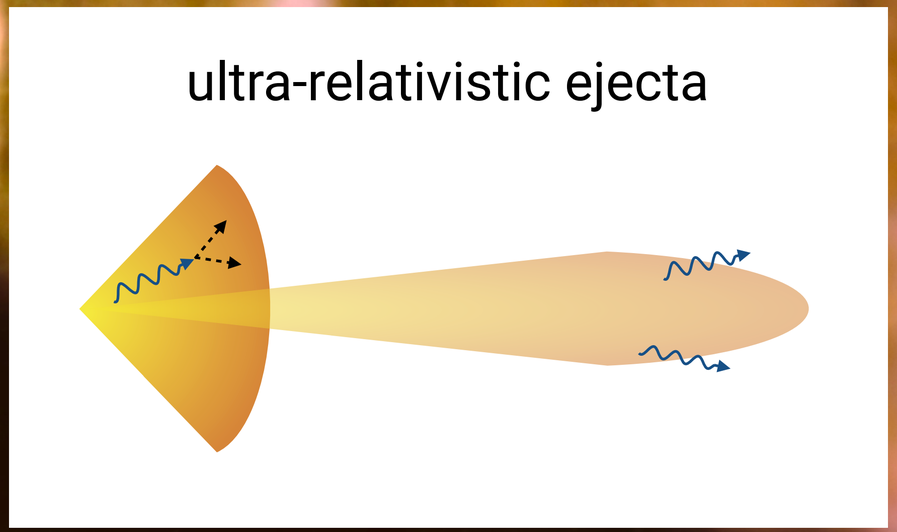
nonthermal spectra

accelerated charged particles

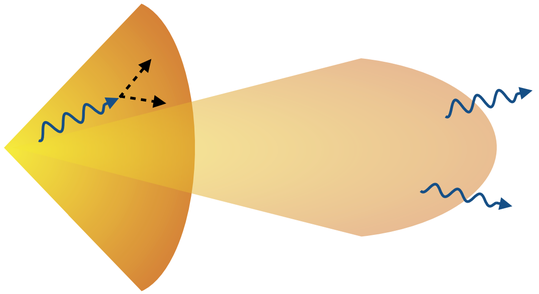
a wide variety of behavior

Wikimedia Commons

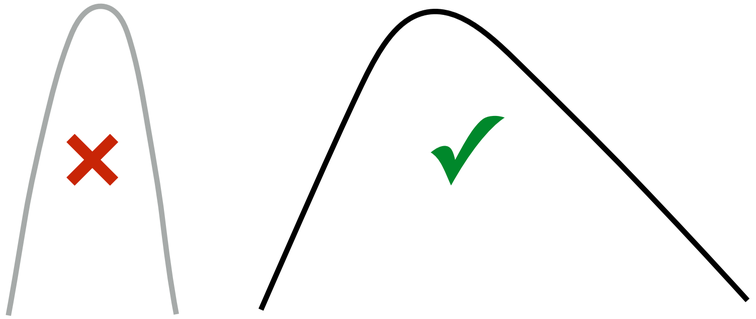

flux
seconds — minutes
“prompt emission”
time


ultra-relativistic ejecta

mildly relativistic ejecta

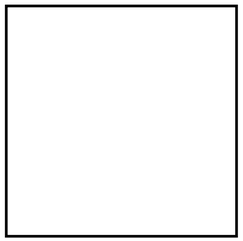


nonthermal spectra

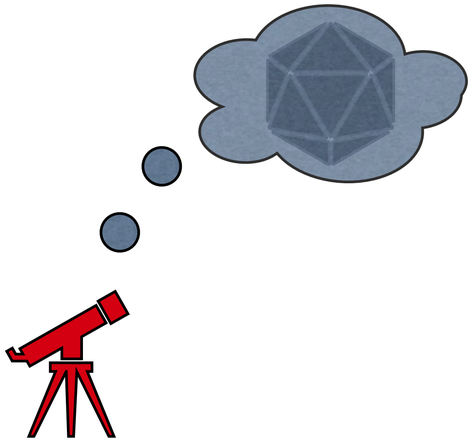


accelerated charged particles

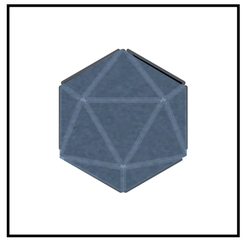
How do we know what we know?



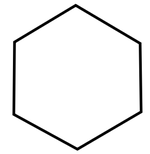
Start with a simple model



Take observations

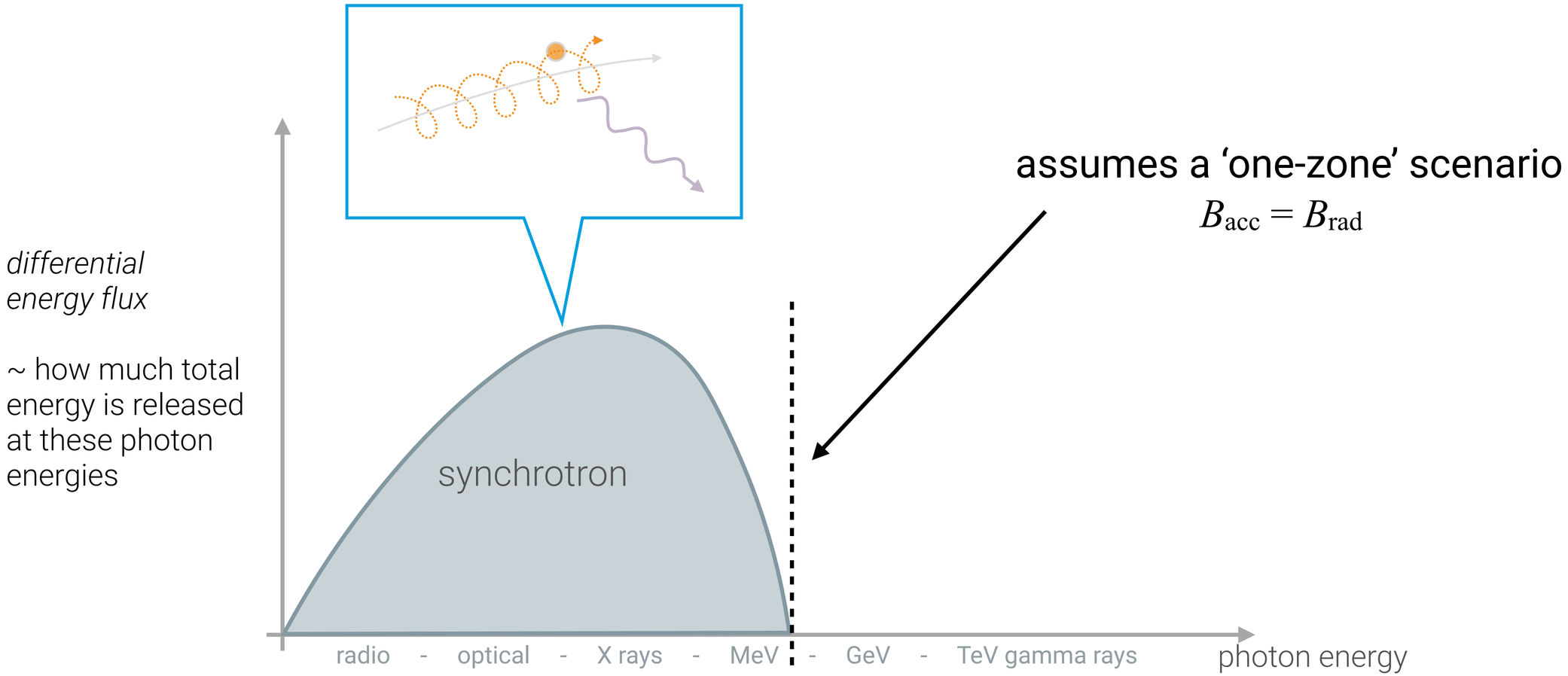


Compare



Update model

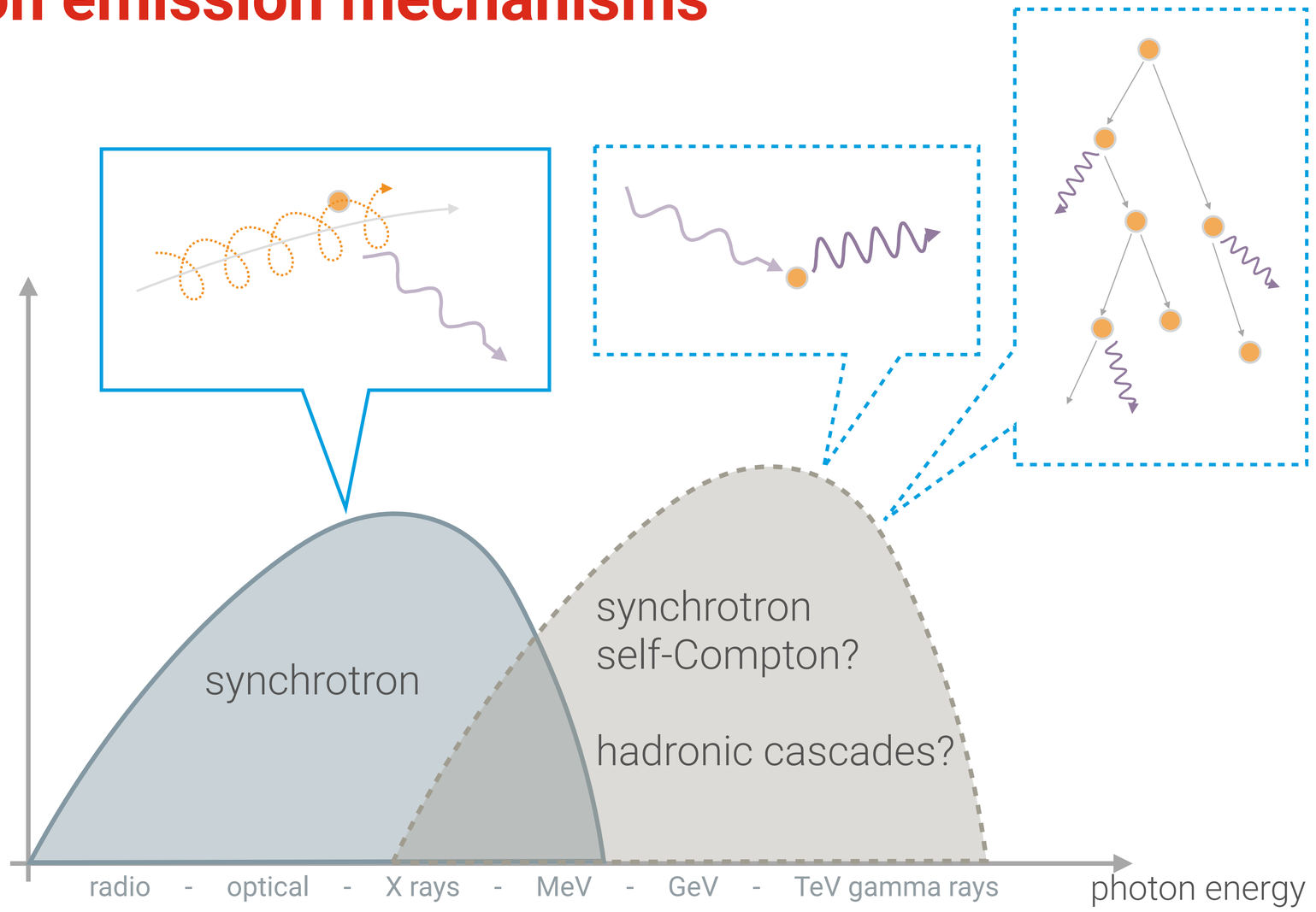
Afterglow photon emission mechanisms



Afterglow photon emission mechanisms

differential energy flux

~ how much total energy is released at these photon energies



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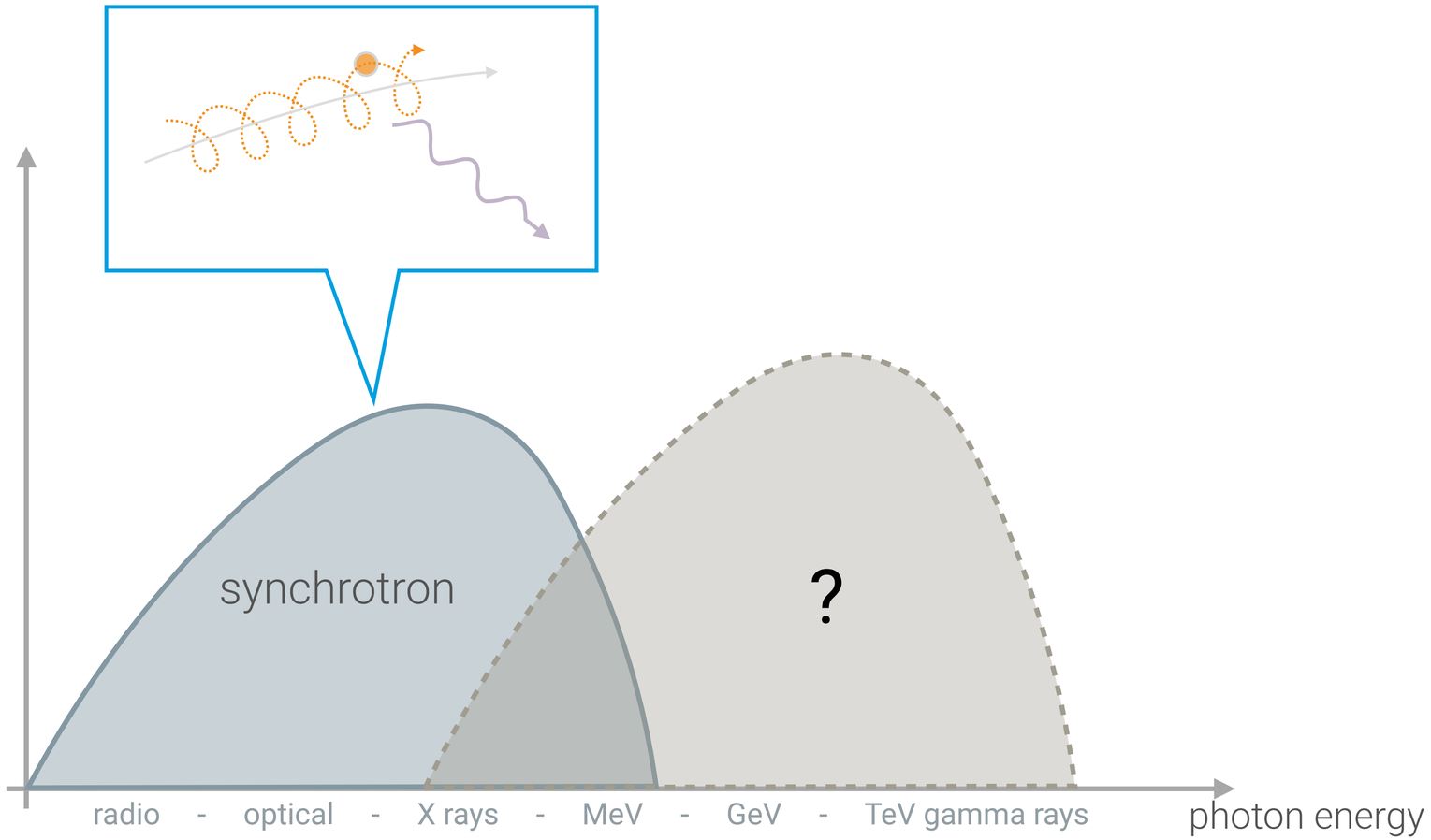

Afterglow photon emission mechanisms

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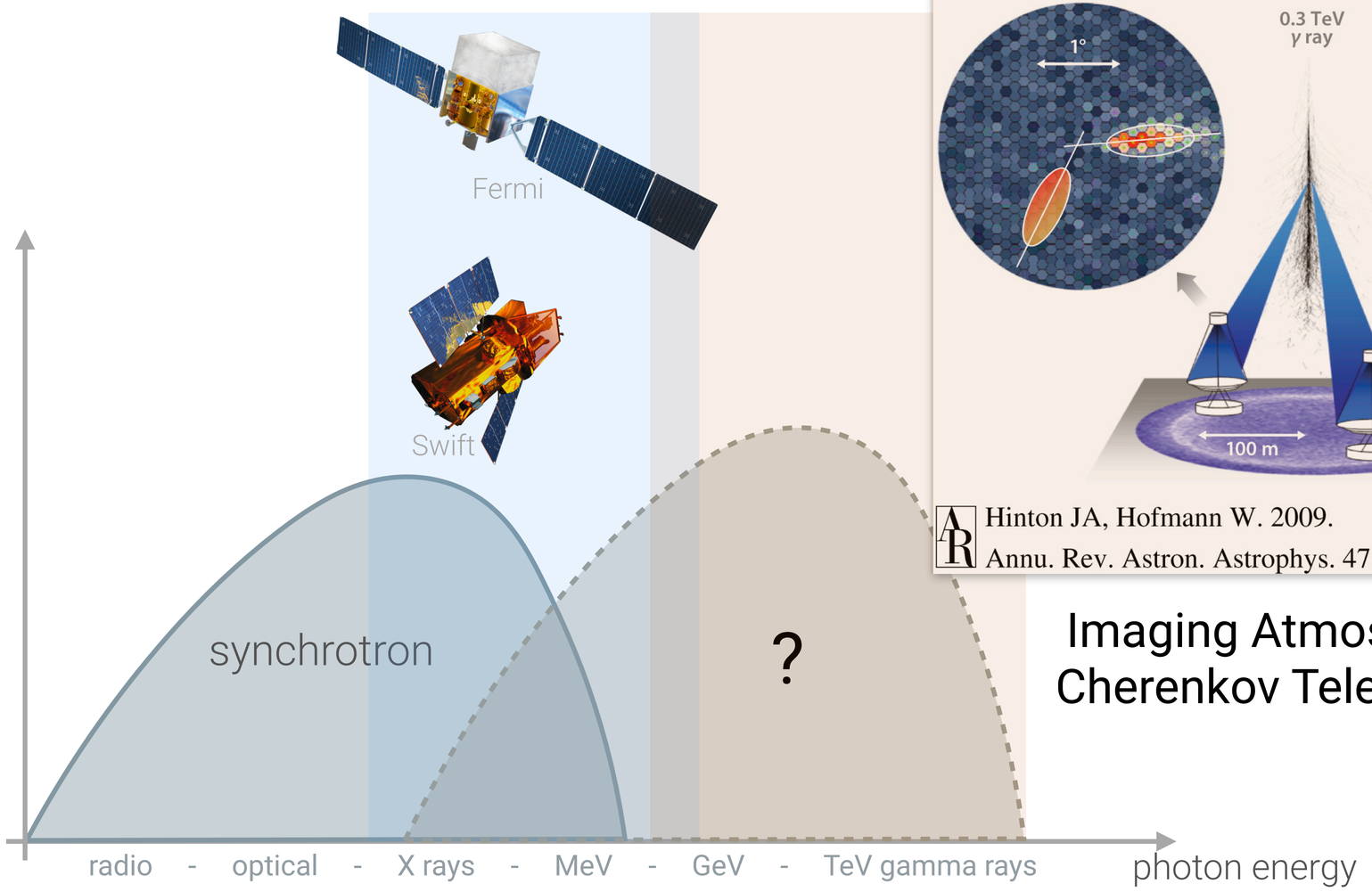


Imaging Atmospheric Cherenkov Telescopes

High Energy Stereoscopic System (H.E.S.S.)

High Energy Stereoscopic System (H.E.S.S.)

3/5 of the H.E.S.S. telescopes, Helmholtz Alliance for Astroparticle Physics

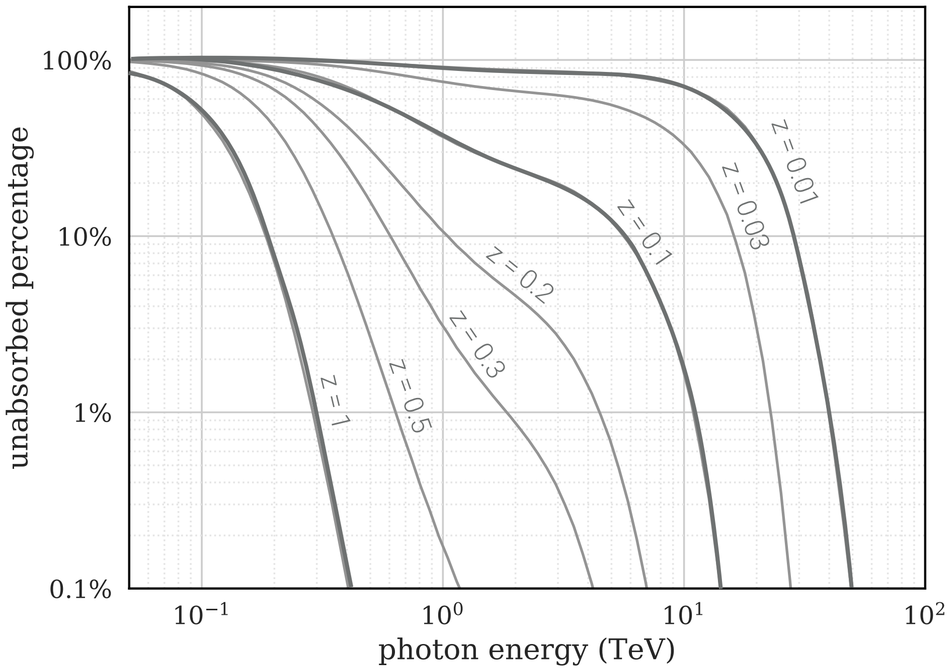
H.E.S.S., MPIK/Christian Foehr

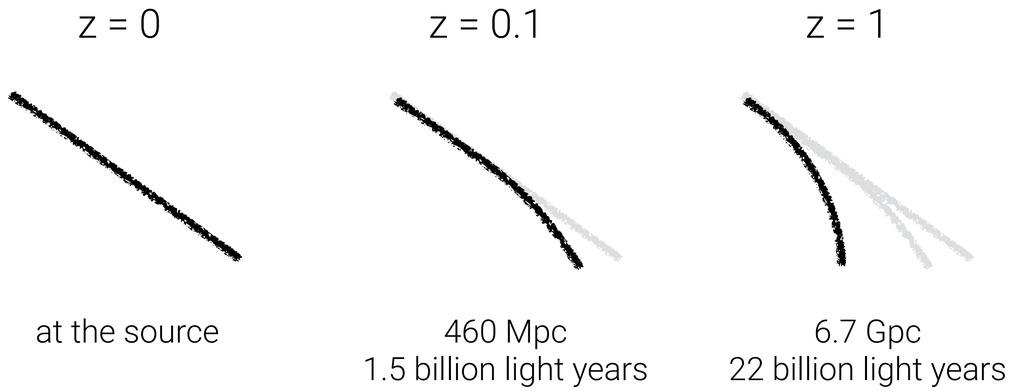
H.E.S.S.

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

Why is it particularly difficult to detect very-high-energy photons?

Extragalactic Background light absorption





Finally we detected GRBs at Very High Energies!! (> 100 GeV)

Article | Published: 20 November 2019

A very-high-energy component deep in the γ-ray burst afterglow

H. Abdalla, R. Adam, [...] O. J. Roberts

Nature **575**, 464–467(2019) | Cite this article

Article | Published: 20 November 2019

Teraelectronvolt emission from the γ-ray burst GRB 190114C

MAGIC Collaboration

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

The most spectacular GRB so far: GRB 190829A

REPORT

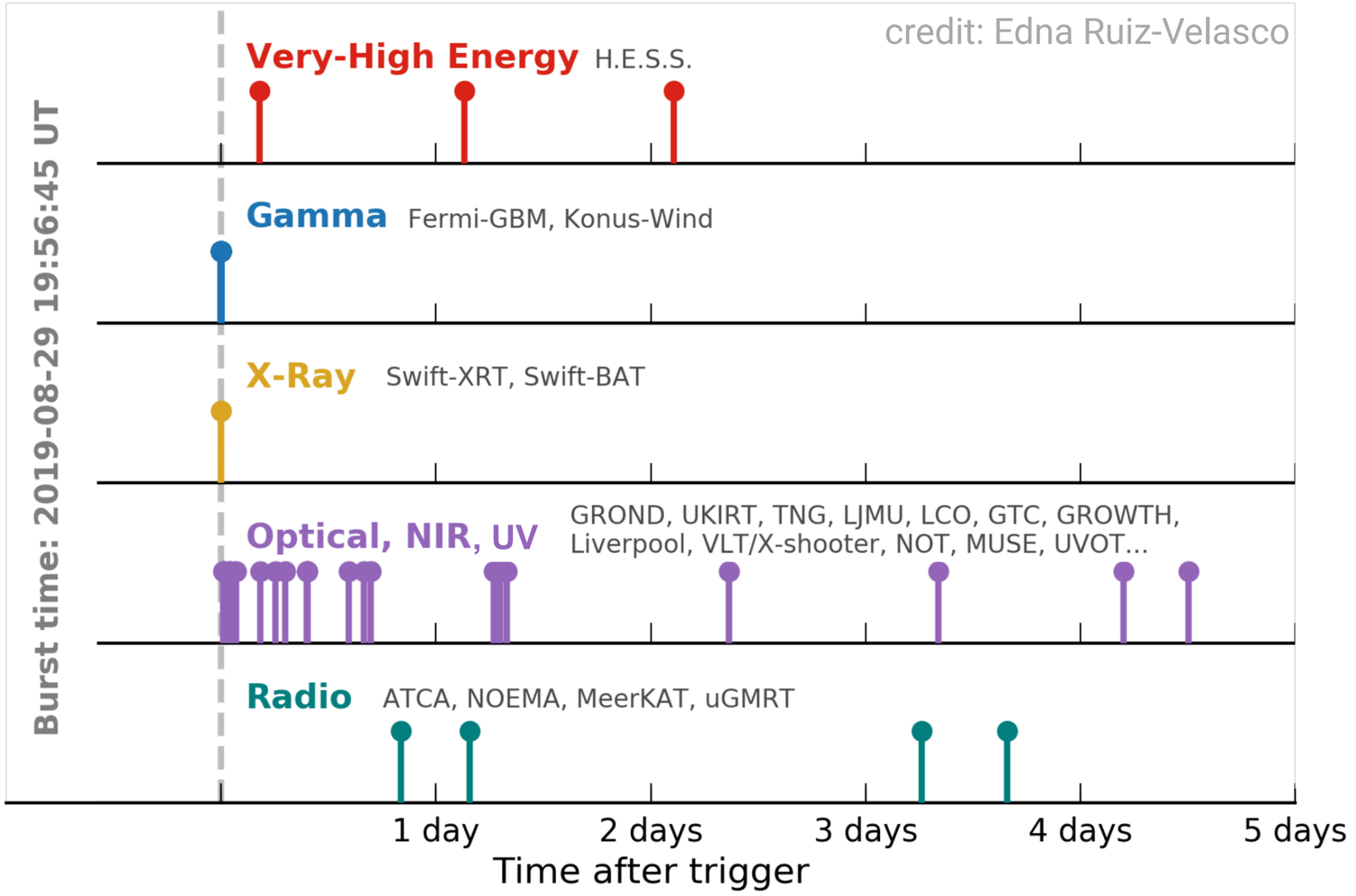
Revealing x-ray and gamma ray temporal and spectral similarities in the GRB 190829A afterglow

H.E.S.S. Collaboration[†,*], H. Abdalla[1], F. Aharonian[2,3,4], F. Ait Benkhali[3], E. O. Angüner[5], C. Arcaro[6], C. Armand[7], T. Armstro…

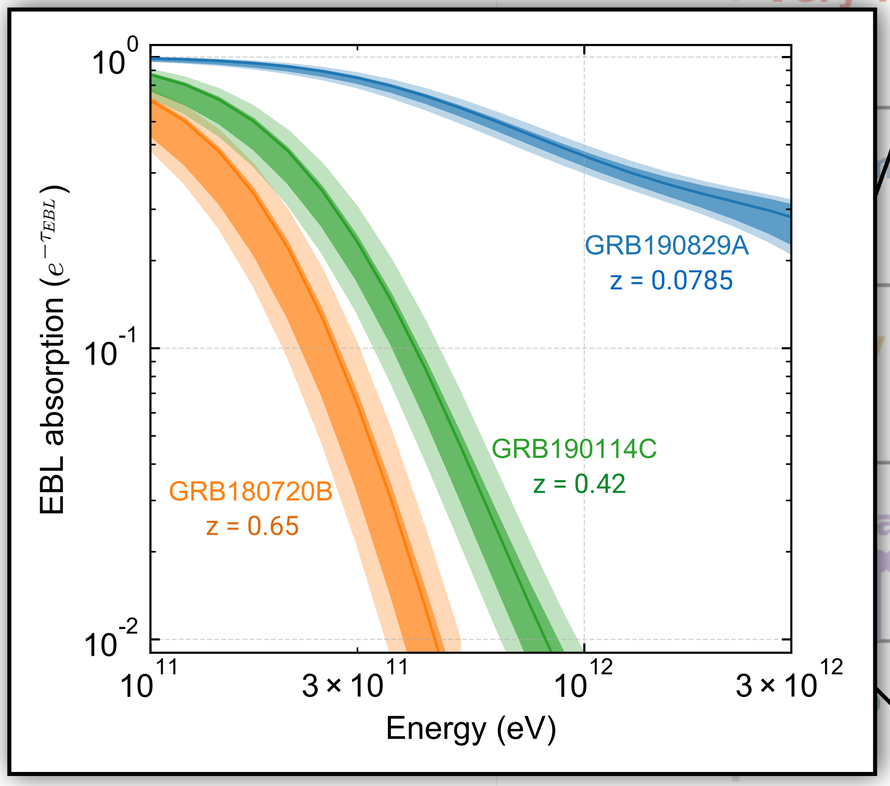
+ See all authors and affiliations

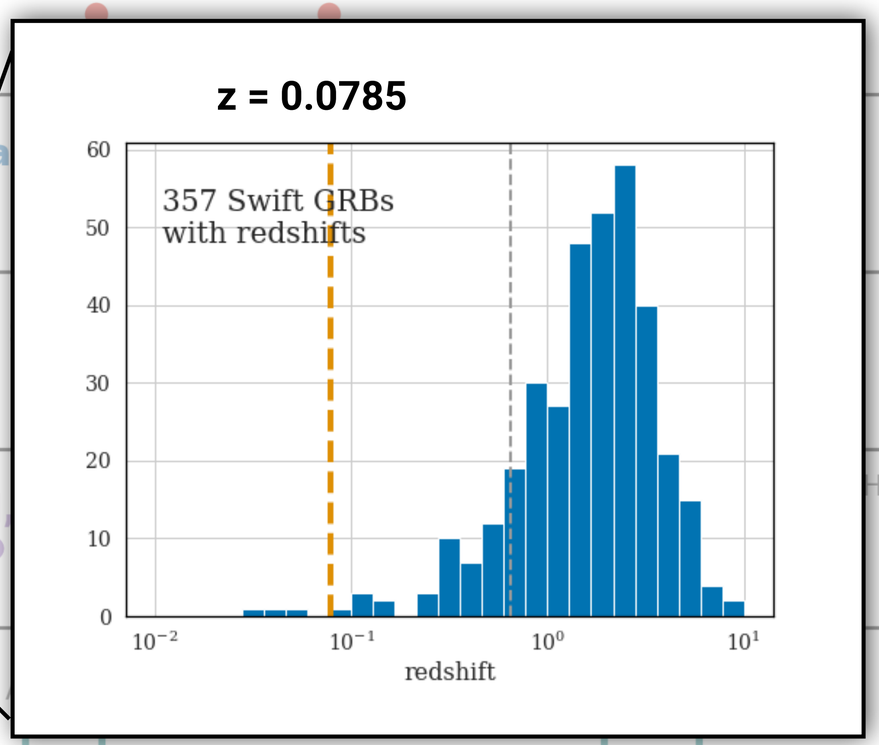
Science 04 Jun 2021:
Vol. 372, Issue 6546, pp. 1081-1085
DOI: 10.1126/science.abe8560

A timeline of events

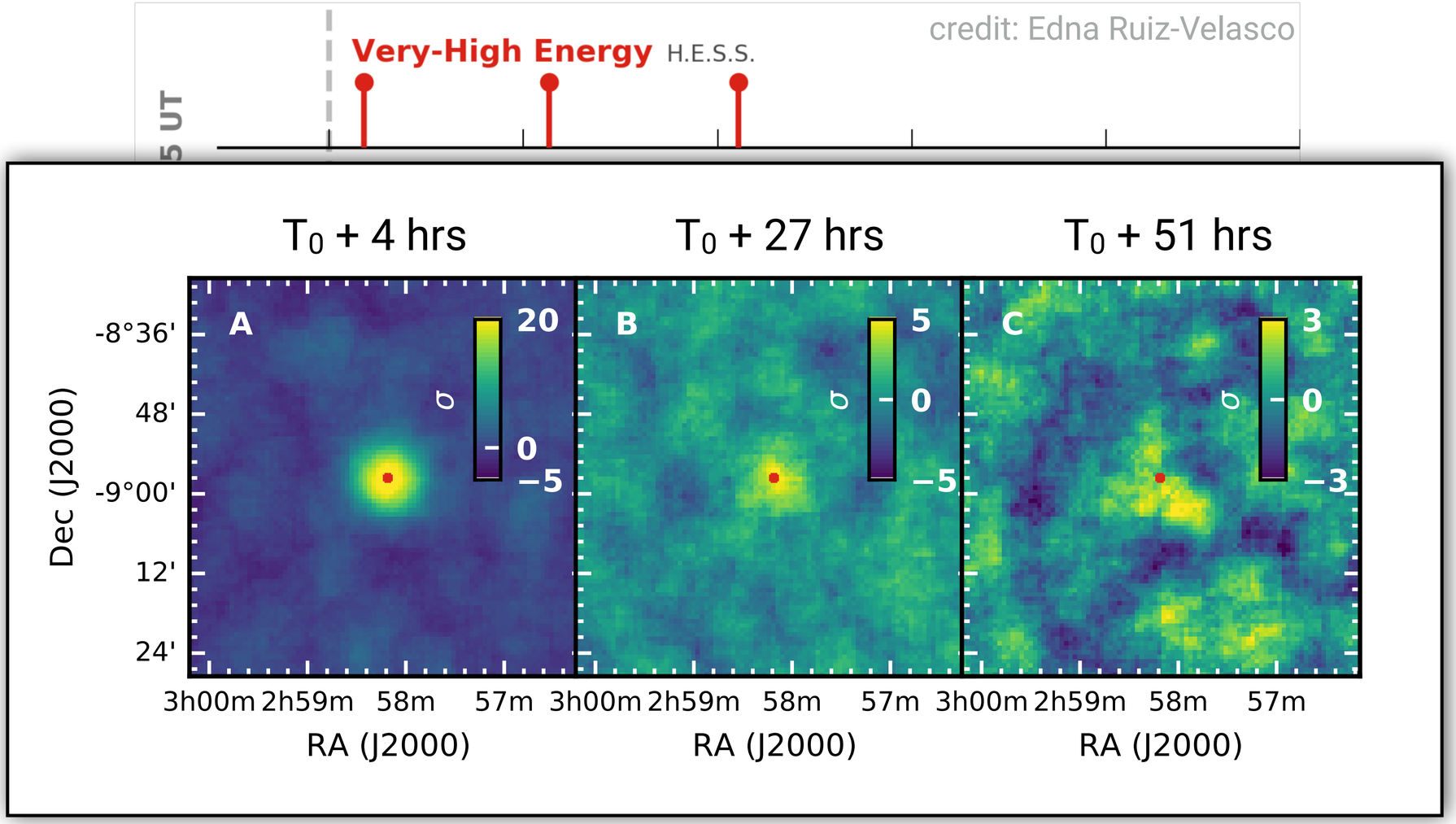


GRB 190829A was very close

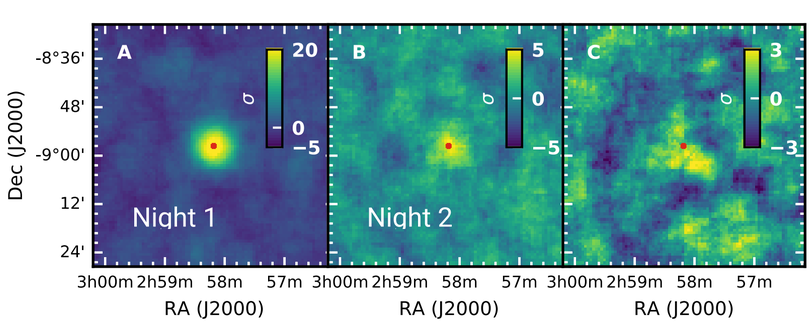




GRB 190829A was detected by H.E.S.S. over three nights



From measurement to intrinsic spectrum



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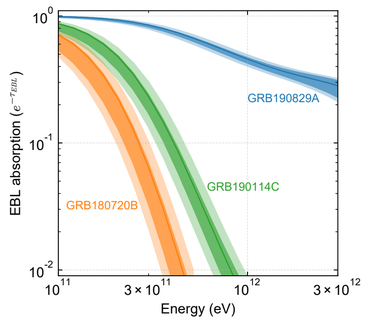
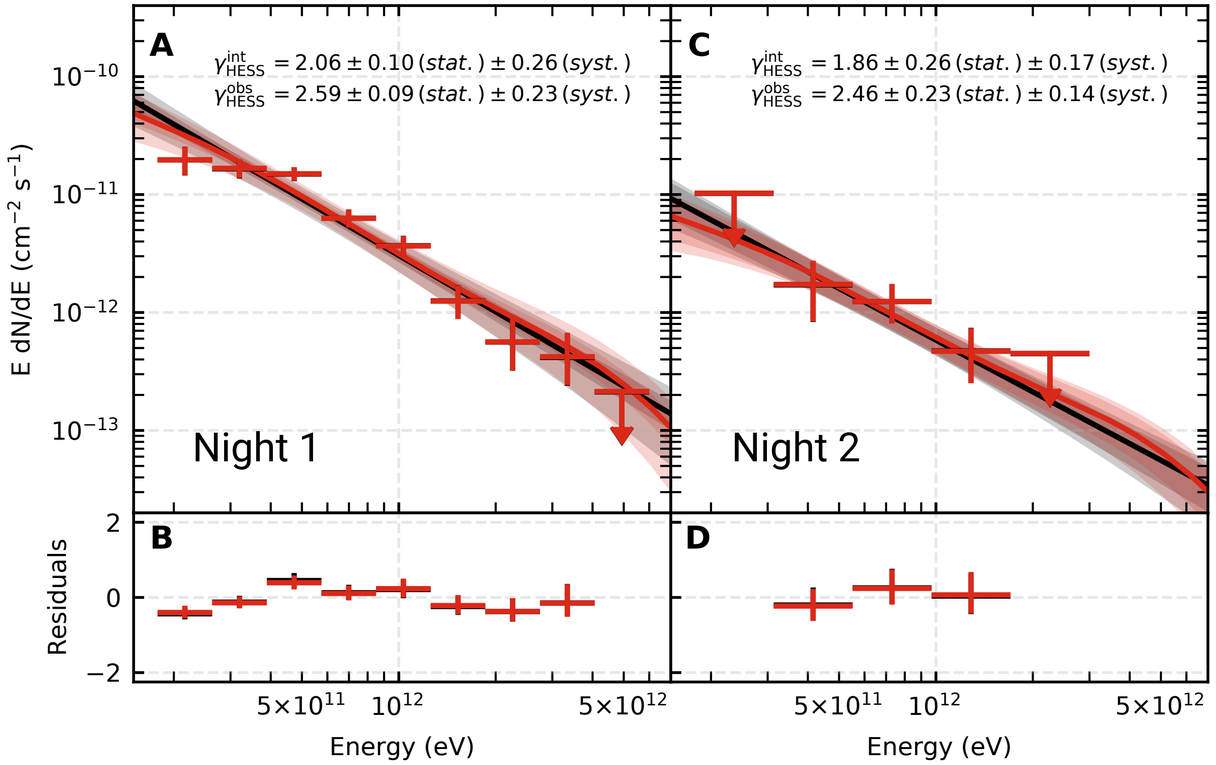
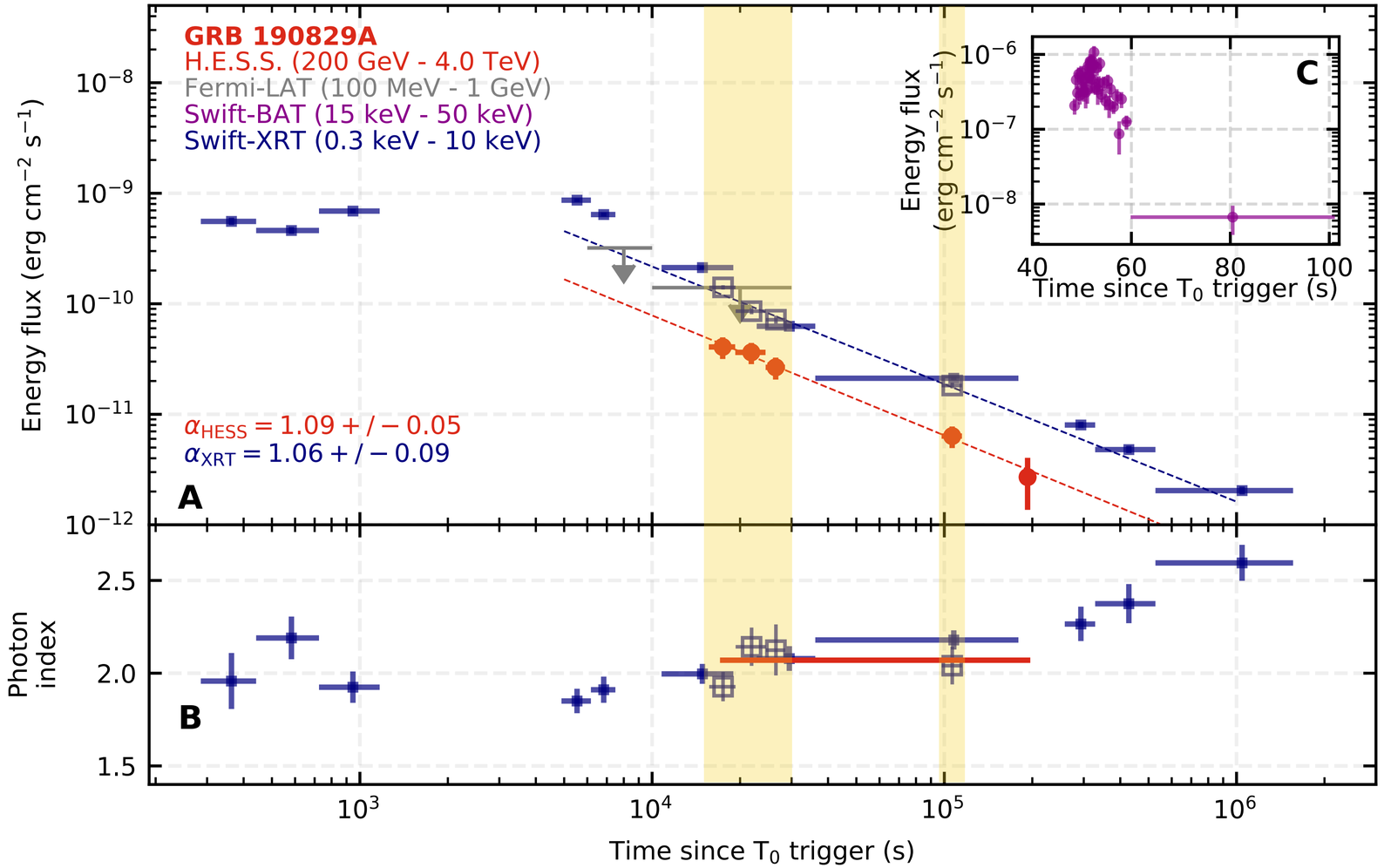




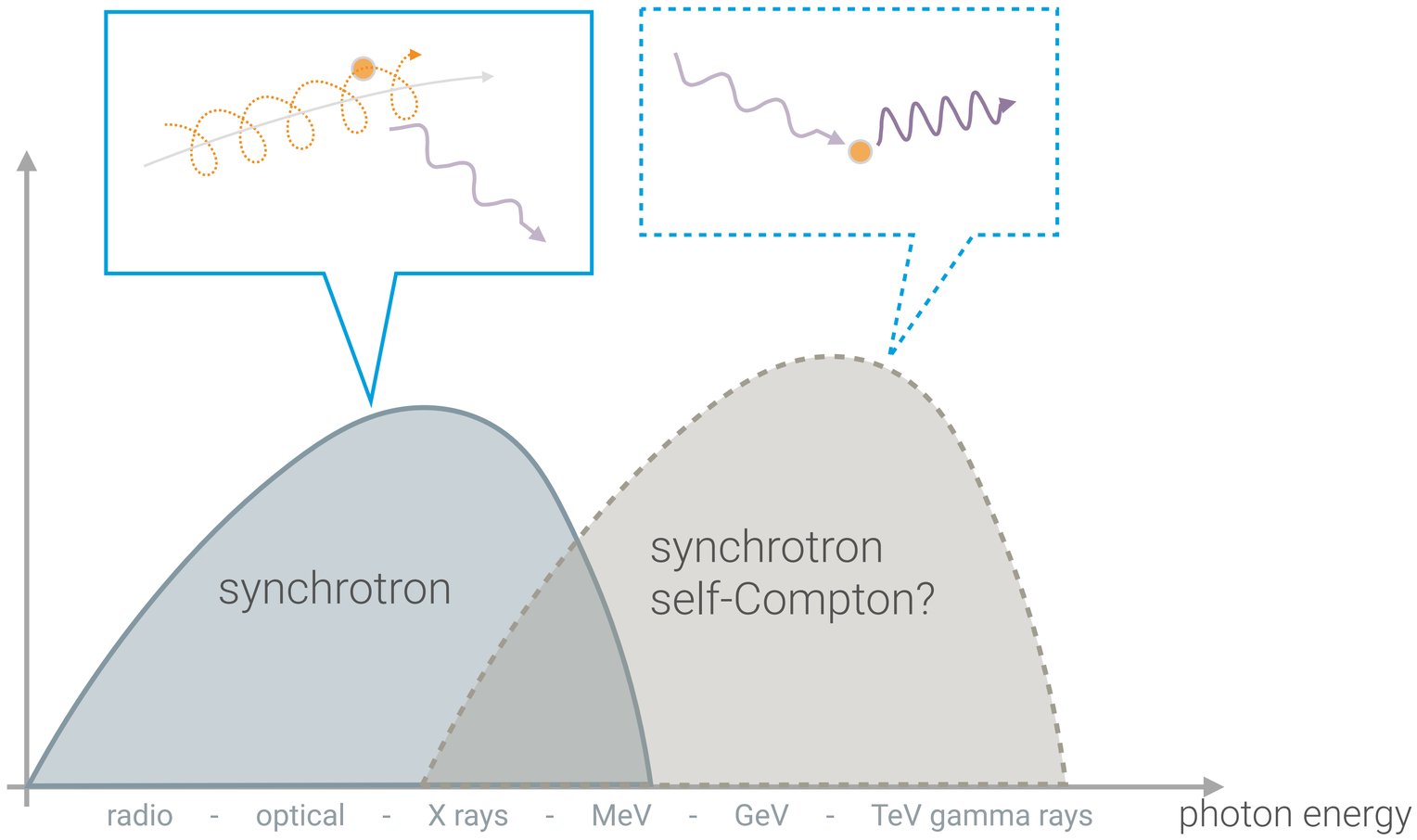
Combining multiwavelength information



Where do the VHE photons come from?

differential energy flux

~ how much total energy is released at these photon energies



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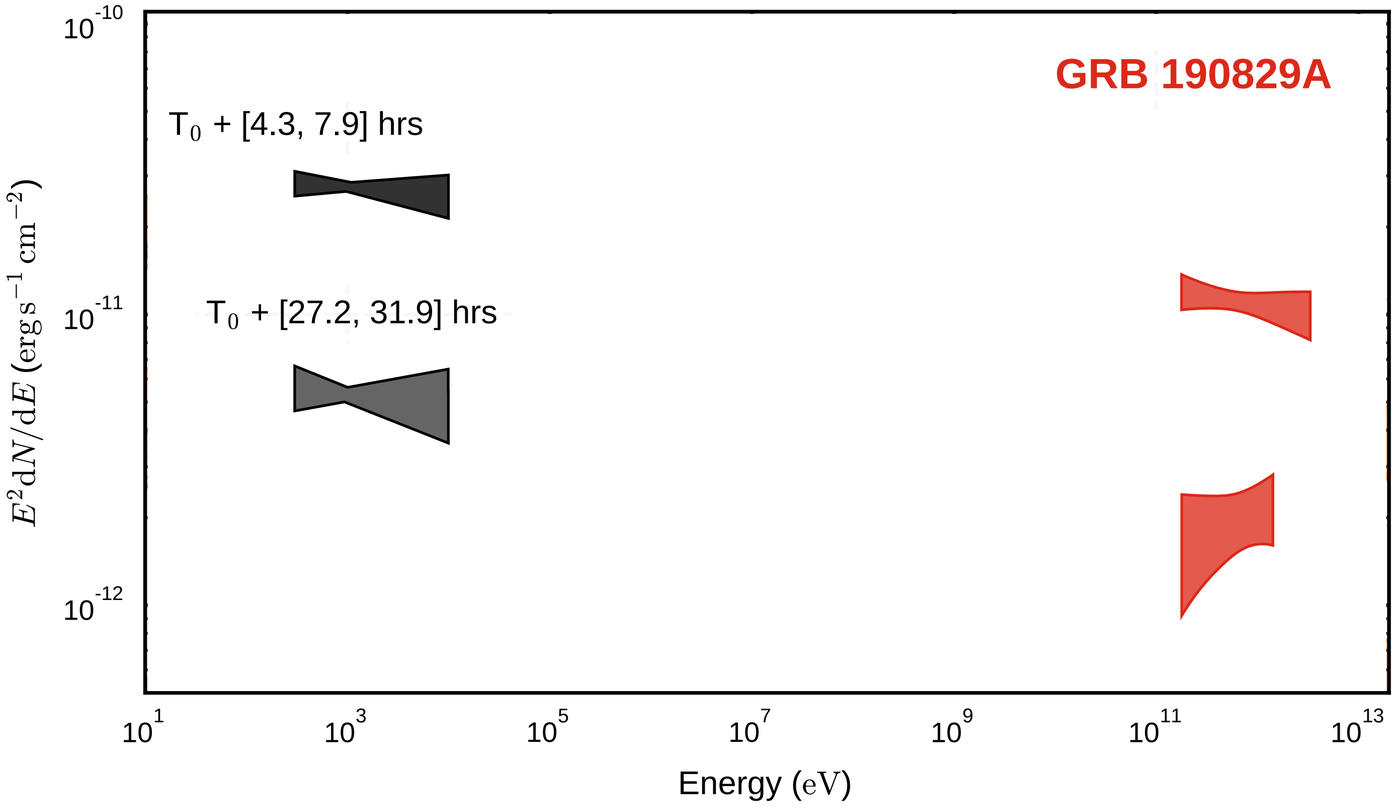

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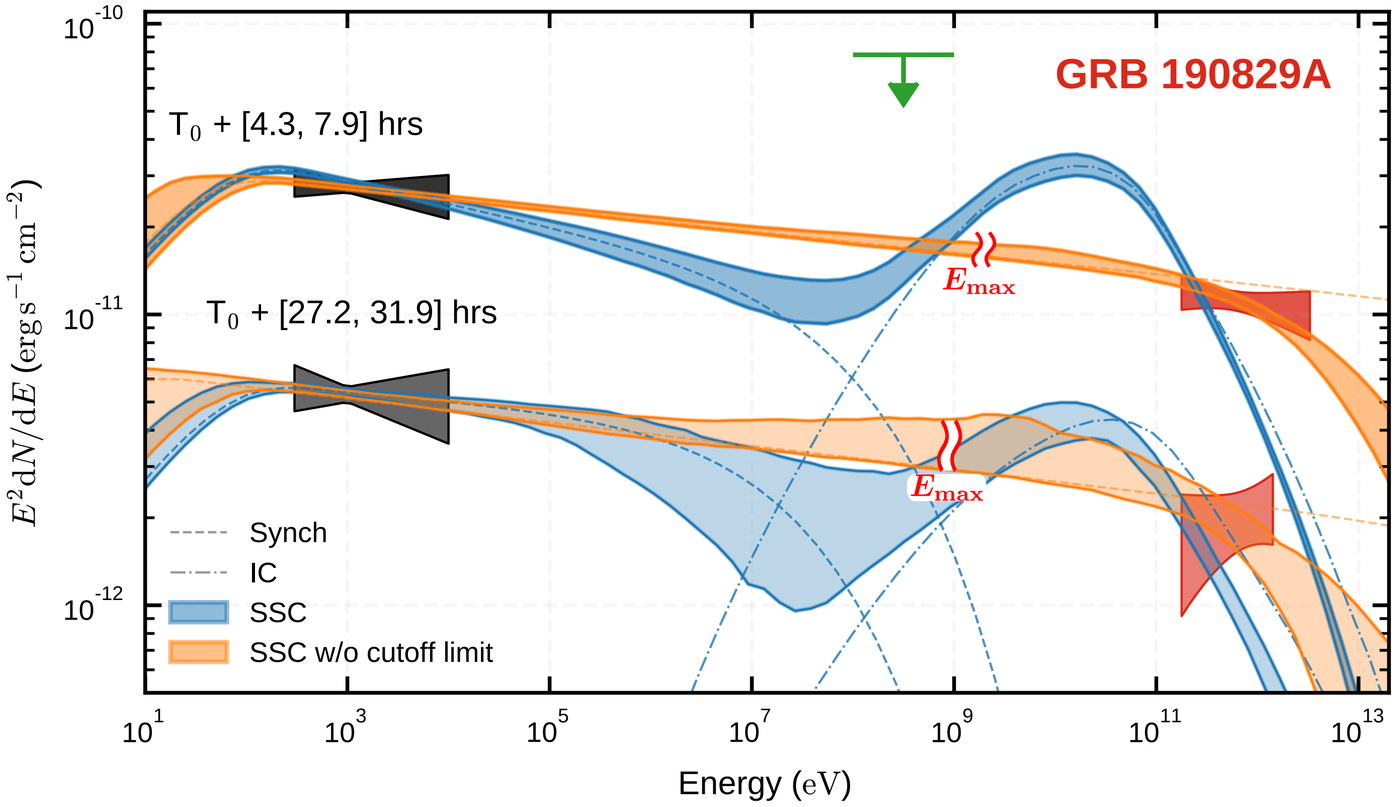
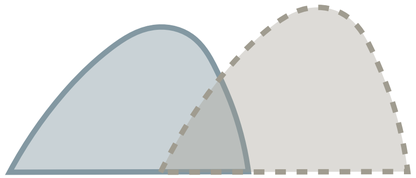


Synchrotron + SSC:
easier to motivate
but poor fit to data

Synchrotron w/o max photon energy:
much better fit to data (>5σ improvement)
but more difficult to explain

*More precisely: The data is good enough that we can/must now include more complexity in the models

How do we know what we know?



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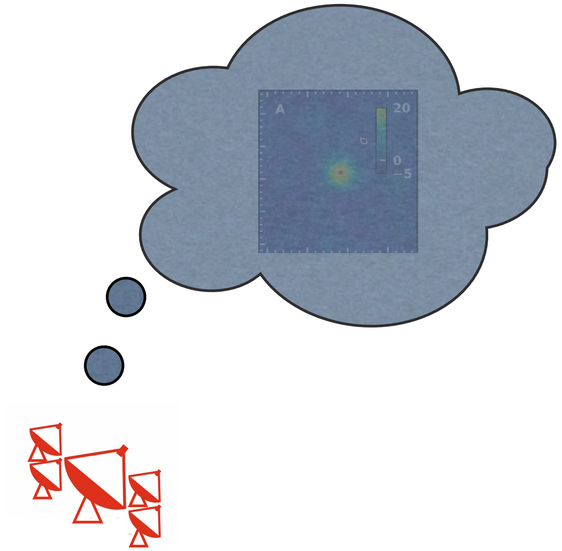
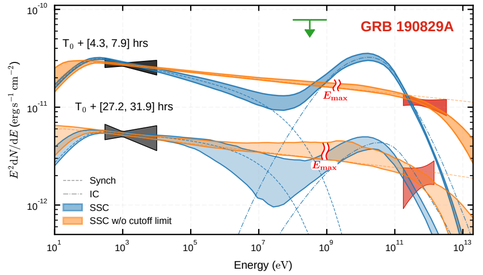


Take observations



Compare

Update model

Thanks!