# GRB and AGN flares observations with MAGIC

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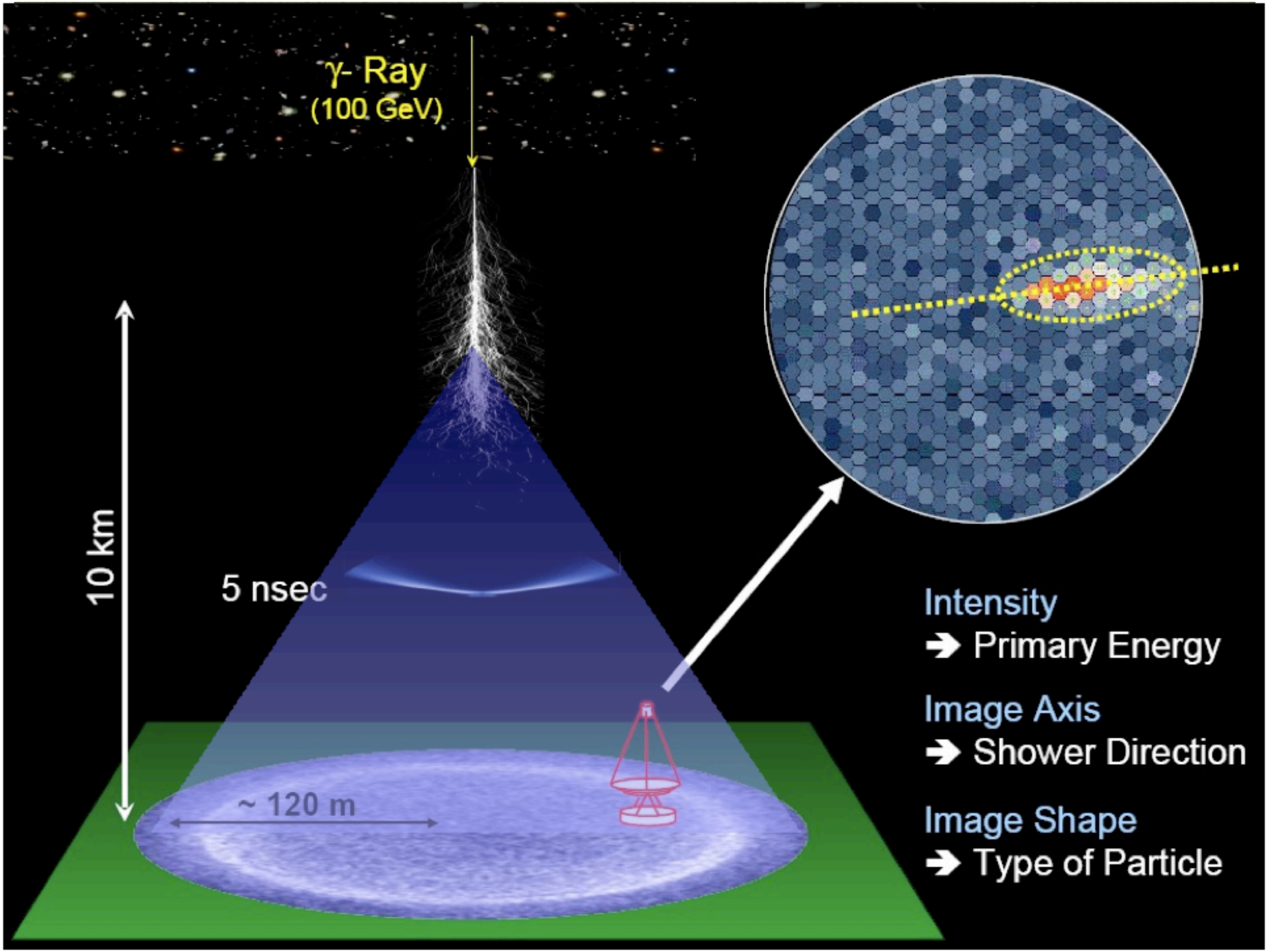
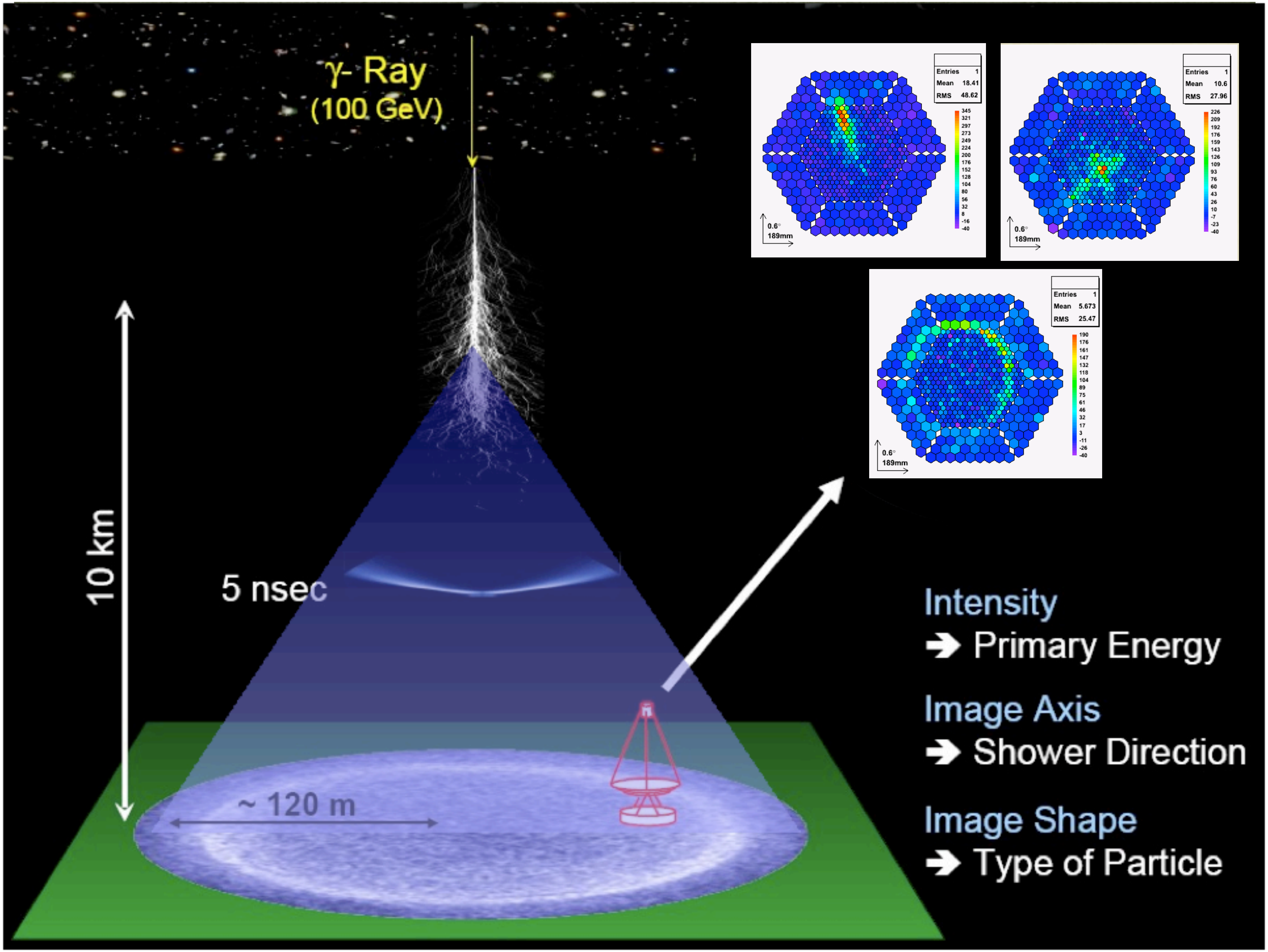
University of Hamburg & Instituto de Astrofísica de Canarias

# Outlook

- Cherenkov technique
- MAGIC telescopes
- GRB observations
  - Observation procedure
  - What can we expect at Very High Energy?
  - MAGIC results
- Other fast trigger:
  - The tidal disruption Sw1644
  - AGN flares
- Summary


γ- Ray
(100 GeV)
10 km
5 nsec
~ 120 m
Intensity
➔ Primary Energy
Image Axis
➔ Shower Direction
Image Shape
➔ Type of Particle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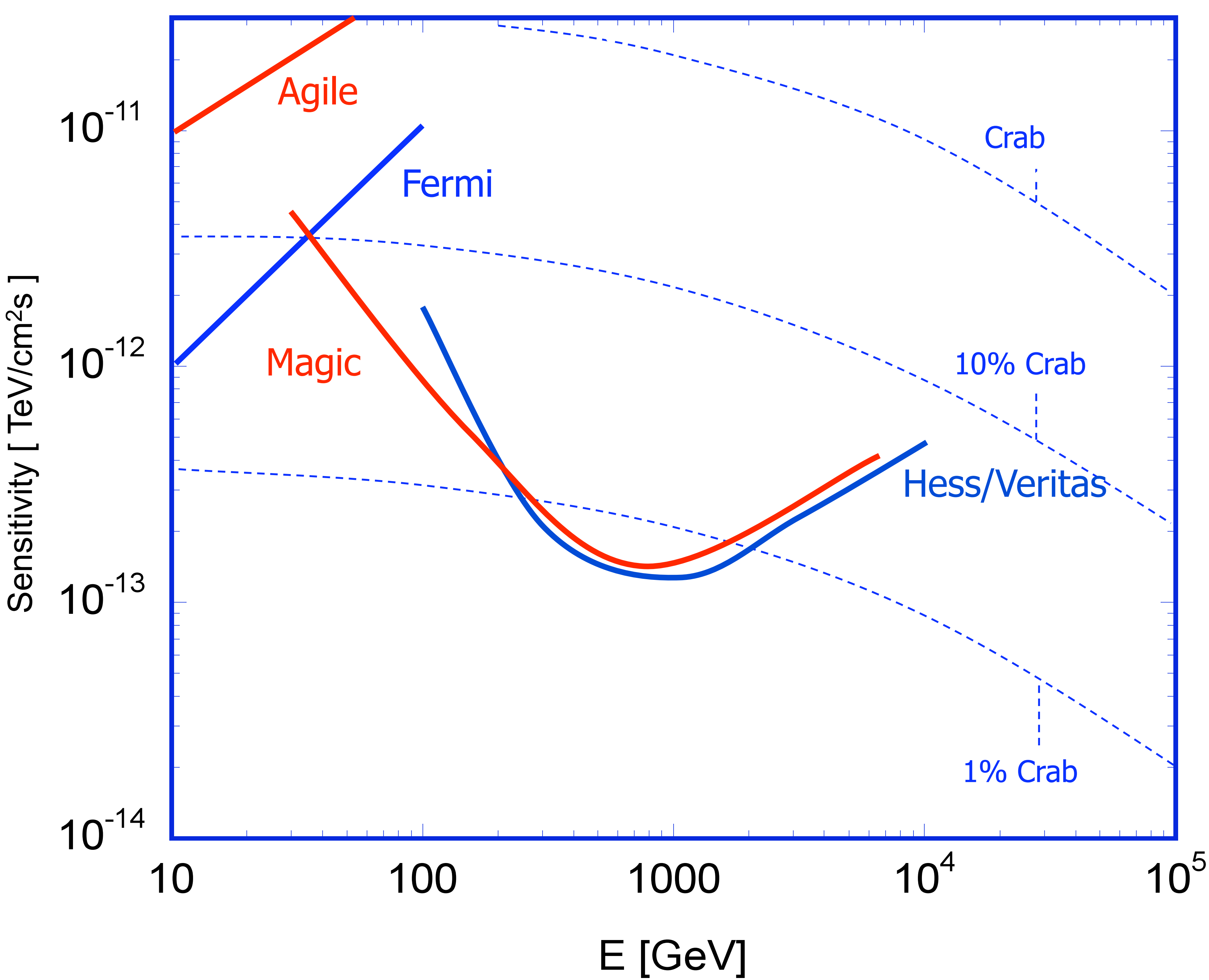
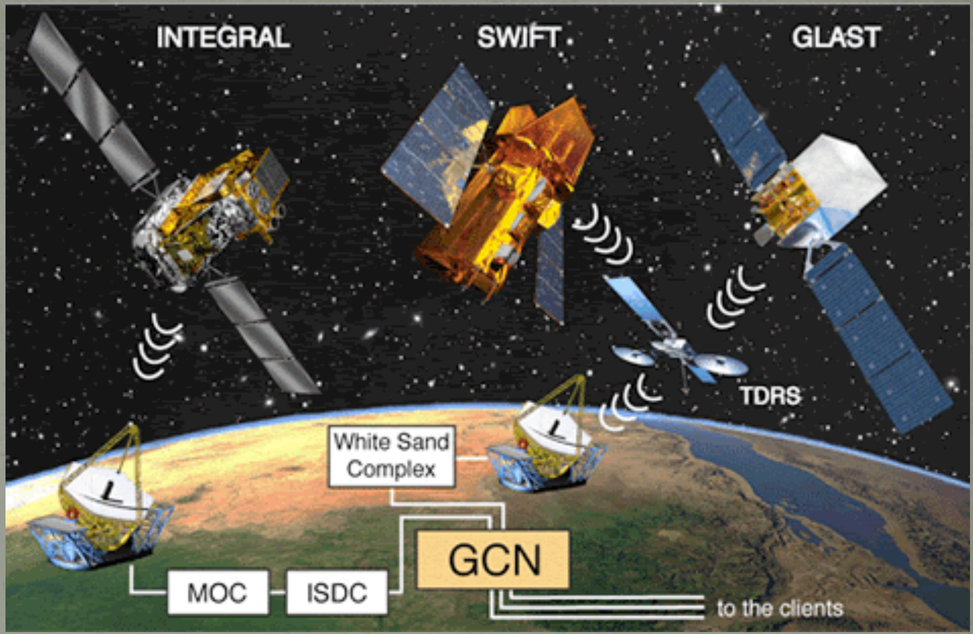
# MAGIC telescopes

• Located at Observatorio del Roque de los Muchachos(La Palma Canary Island) @ 2.200 m altitude
• Working in stereo since 2009
• 17 m mirror dish
• PMT camera
• Lightweight carbon fibre frame → fast repositioning (<30 s)
• FoV ~3.5º
• Energy range: 50 GeV - few tens of TeV (25 GeV Sum Trigger)
• Sensitivity ~0.8% Crab Nebula flux (50 h)
• Energy resolution ~15% (>300 GeV)
• Angular Resolution ~0.1º (100 GeV) - 0.07º (>300 GeV)

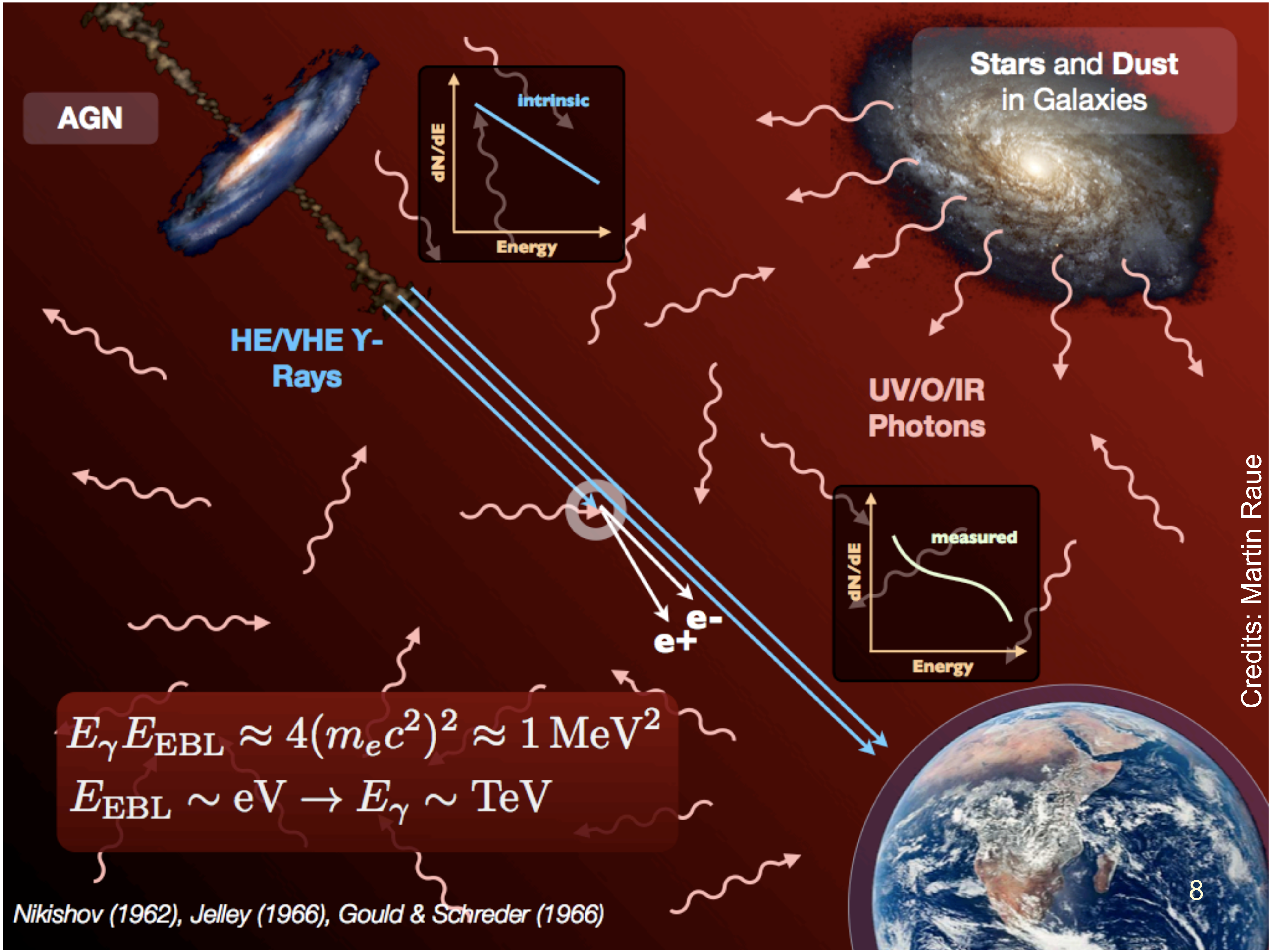



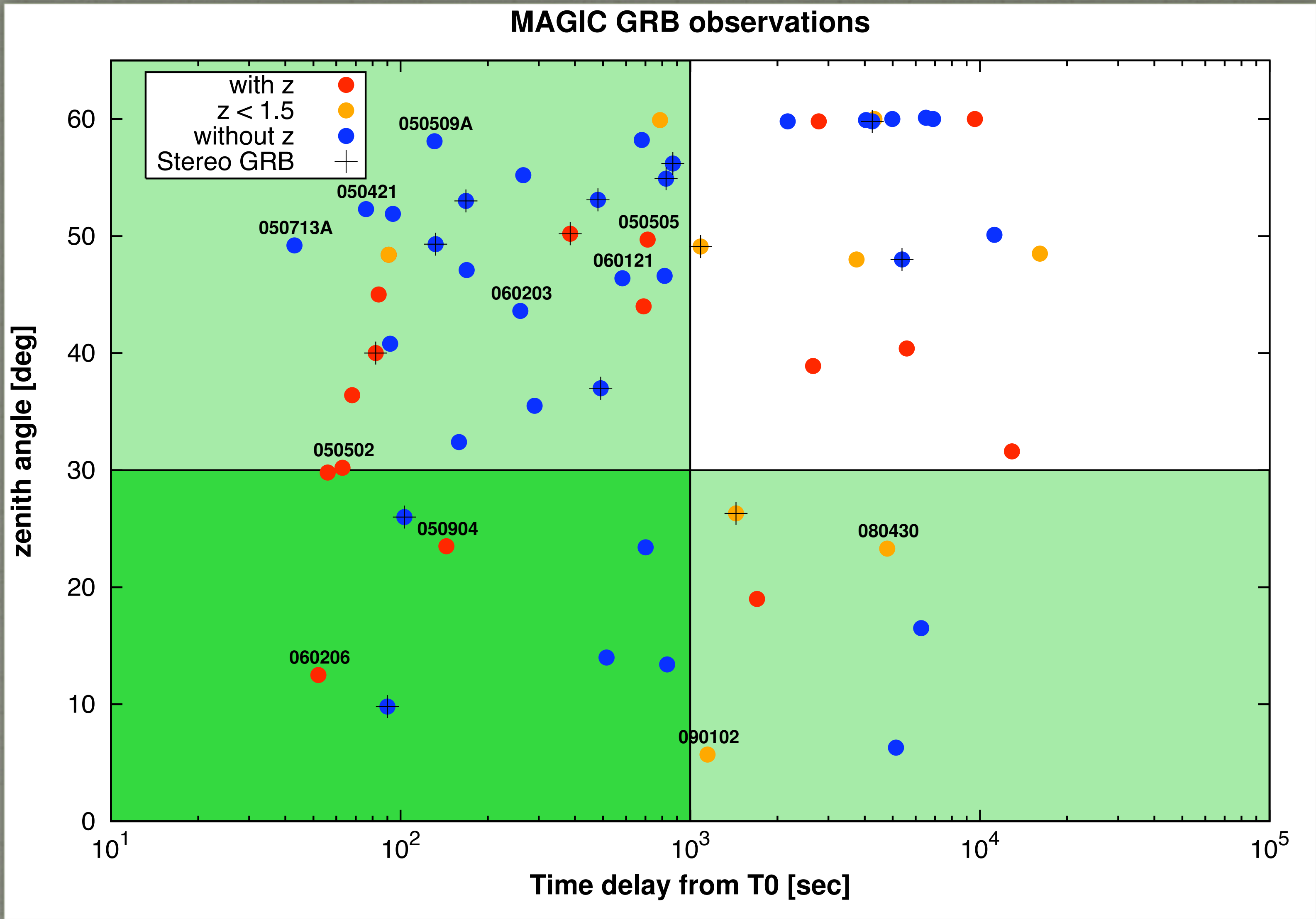
Agile
Fermi
Magic
Hess/Veritas
Crab
10% Crab
1% Crab
Sensitivity [ TeV/cm2s ]
$10^{-11}$
$10^{-12}$
$10^{-13}$
$10^{-14}$
10
100
1000
$10^4$
$10^5$
E [GeV]

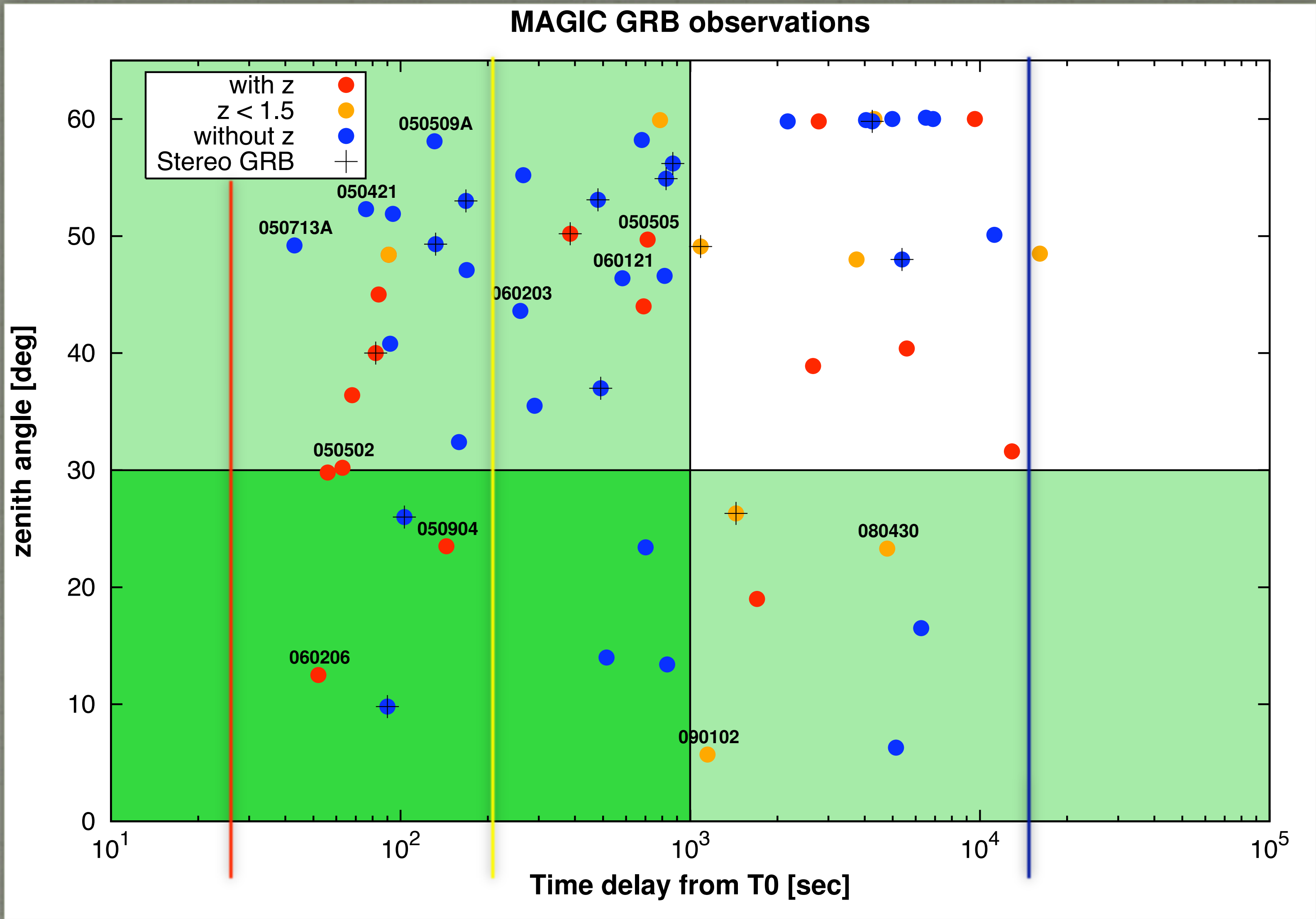
# GRBs procedure




- GCN Alert is received and the trigger criteria are checked automatically
- Trigger criteria:
  - Zenith angle, moon distance, delay to T0, coordinates errors
- If trigger criteria full fill automatic procedure start:
  - Fast repositioning ~30 s
  - Observations are taken automatically without human interaction
  - 4 hours observations (+ special cases)
  - Flare advocate system (check evolution, redshift measurements)


AGN
Stars and Dust in Galaxies
intrinsic
dN/dE
Energy
HE/VHE γ-Rays
UV/O/IR Photons
e-
e+
measured
dN/dE
Energy
$E_\gamma E_{\rm EBL} \approx 4(m_e c^2)^2 \approx 1\,{\rm MeV}^2$
$E_{\rm EBL} \sim {\rm eV} \rightarrow E_\gamma \sim {\rm TeV}$
Nikishov (1962), Jelley (1966), Gould & Schreder (1966)
Credits: Martin Raue


MAGIC GRB observations
with z
z < 1.5
without z
Stereo GRB
050509A
050421
050713A
050505
060121
060203
050502
050904
080430
060206
090102
zenith angle [deg]
Time delay from T0 [sec]
0
10
20
30
40
50
60
$10^1$
$10^2$
$10^3$
$10^4$
$10^5$

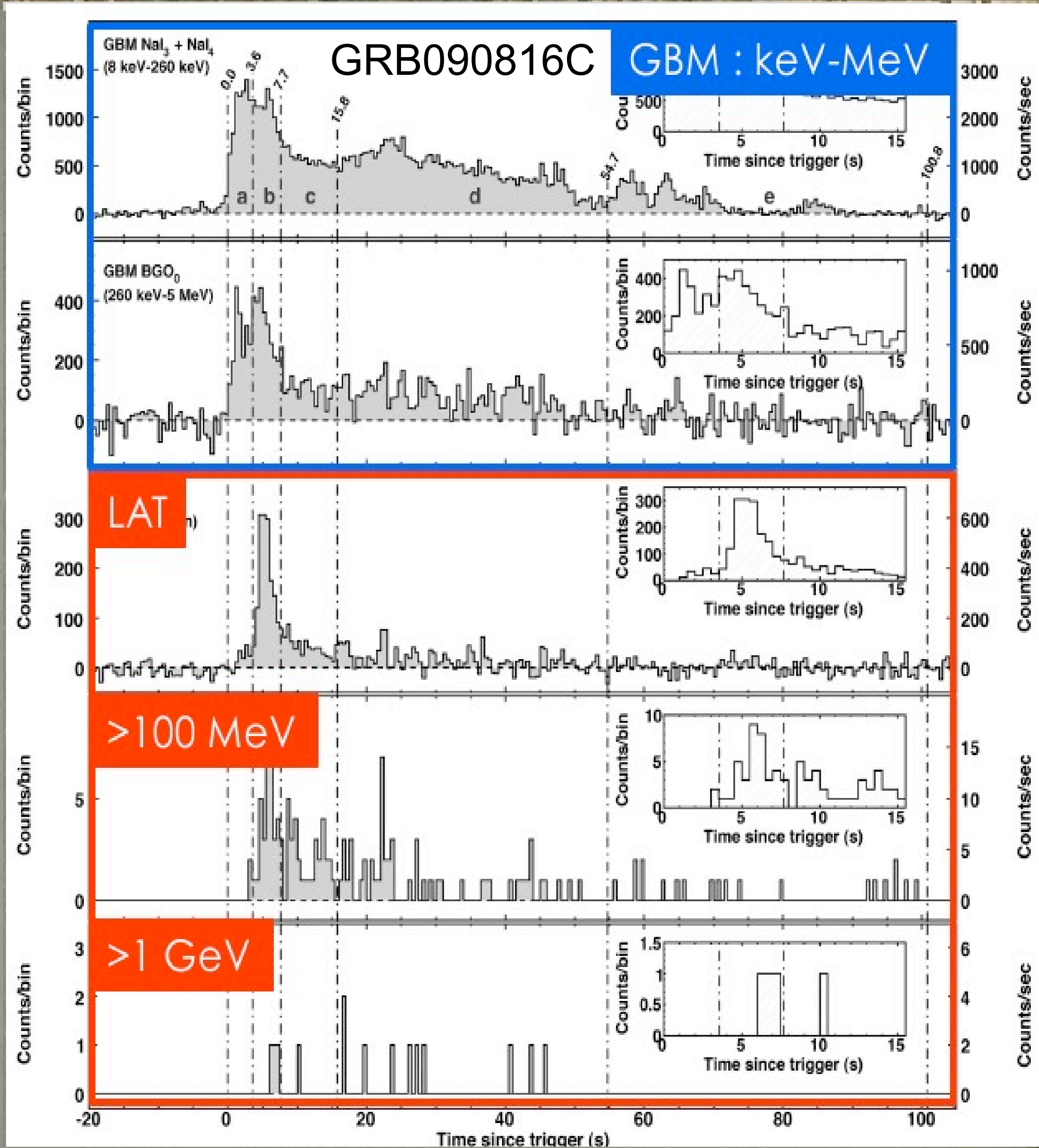



*GCN* *VERITAS* *HESS*

• Highest photon energy detected by Fermi/LAT: E=30 GeV

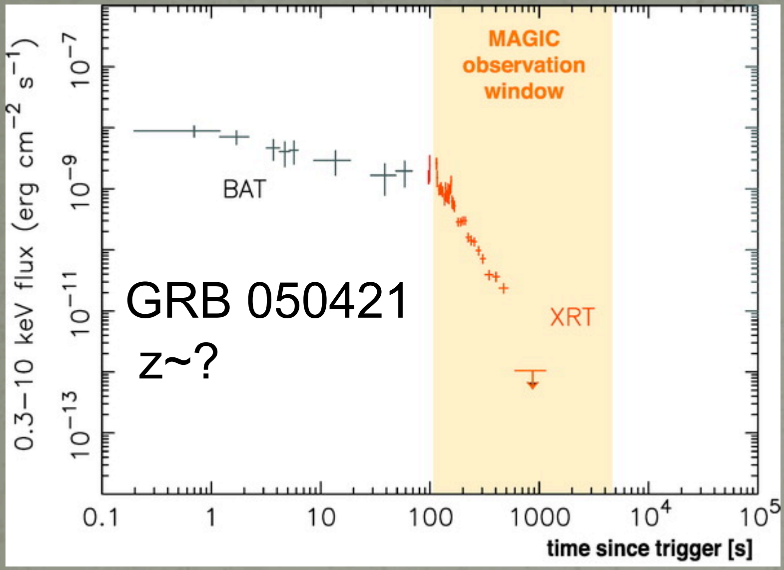
• Evidence for delayed onset of GeV LAT emission with respect to lower energies

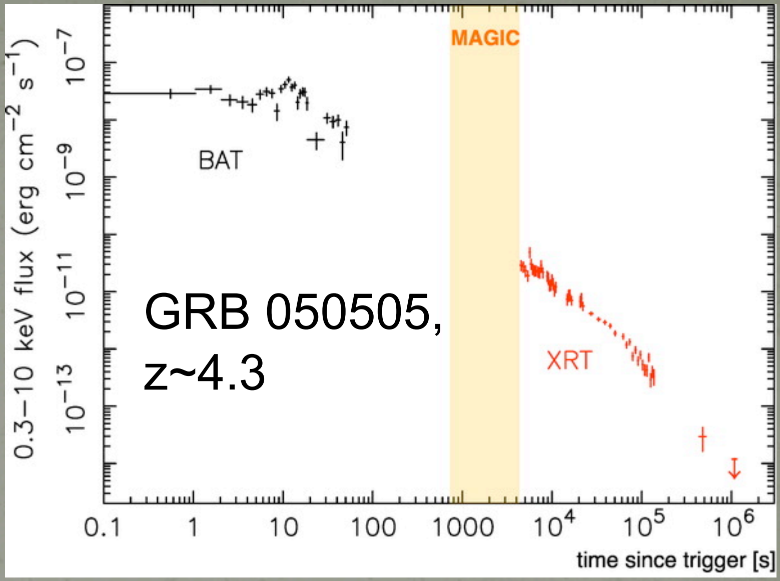
• VHE gamma-ray emission also delayed?

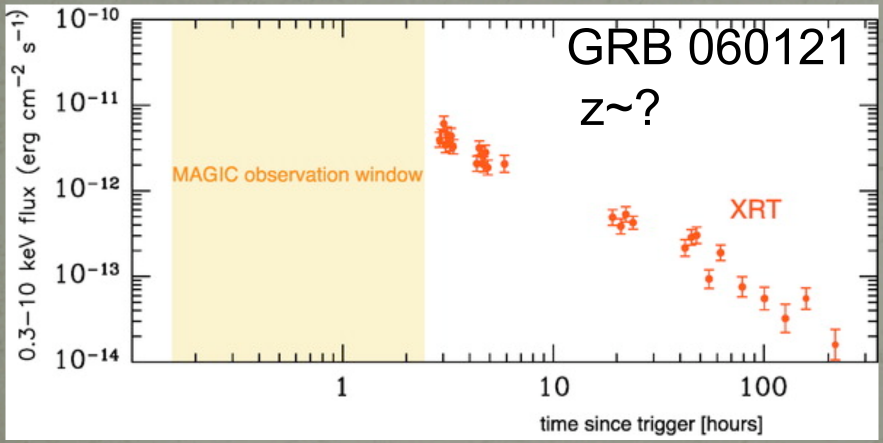


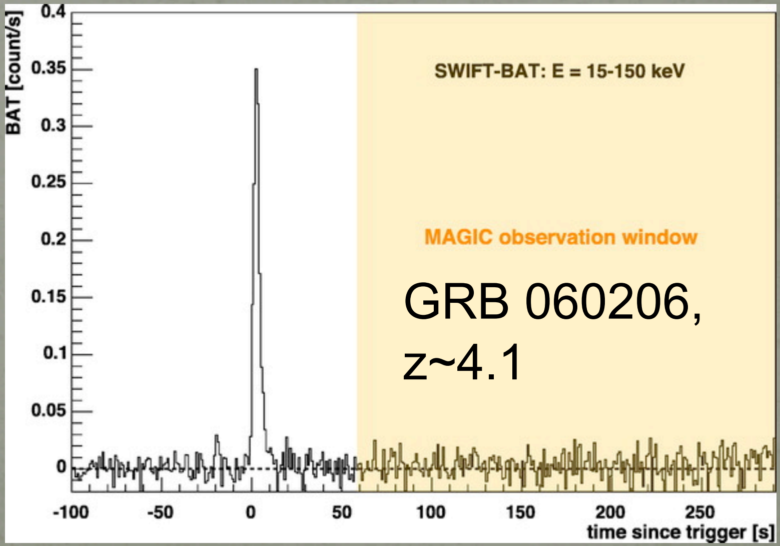

Gehrels&Cannizzo 2010

# GRB observations with MAGIC

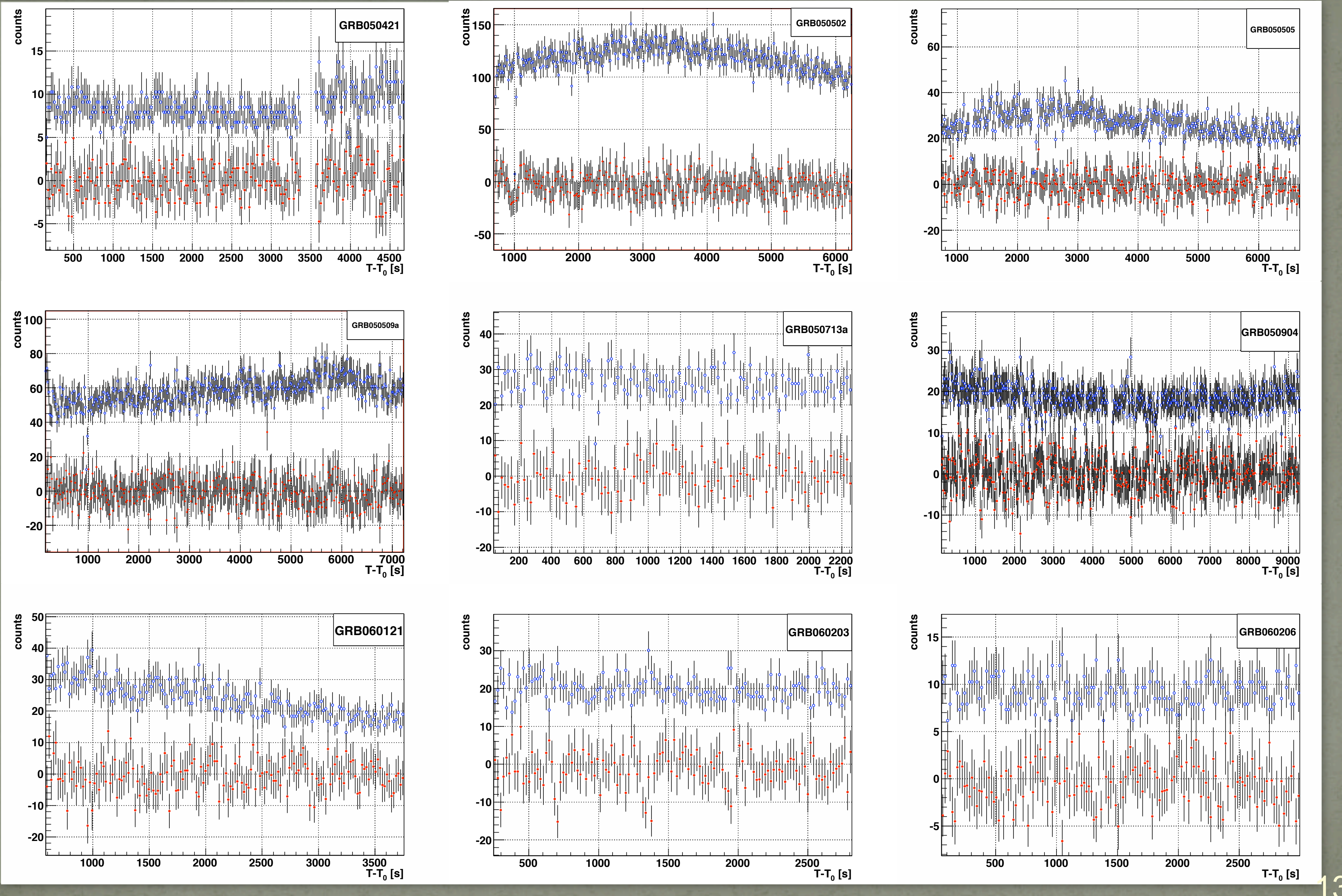


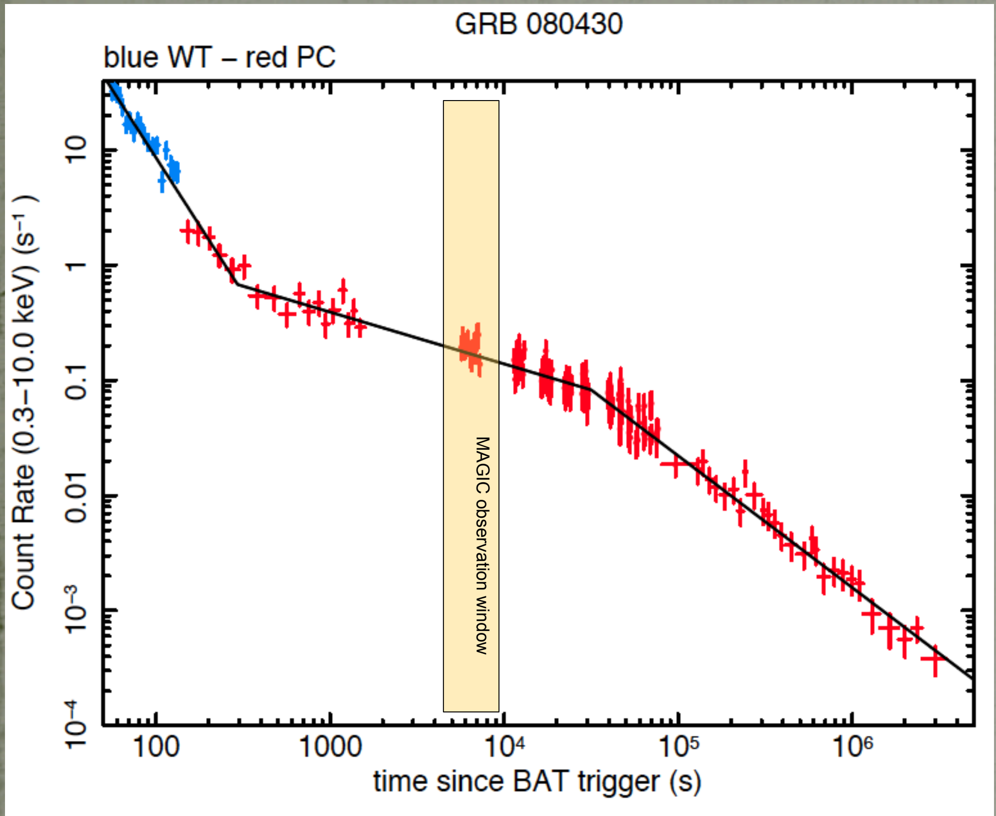



# Search for peaked emission



# GRB080430 afterglow




*GCN-report 139.1*

- SWIFT BAT trigger, $T_{90}$=16 s
- Redshift z=0.758
- Only MAGIC-I mono, no sum-trigger
- MAGIC observation start at $T_0$+4763s (trigger during daytime)
- Observation time = 9616 s
- Low zenith angle: 23º < Zd < 35º
- Energy threshold 90 GeV

## Afterglow modeling:

- Band function:
  - $E_{peak}$=39 ± 12 kev, estimated from BAT data (best fit of Amati relation)
  - $E_{iso}$ = (3 ± 0.9) x $10^{51}$ erg
- Only SSC considered:
  - $F_{90GeV,8ks}$ = 2.6 x $10^{-13}$ erg $cm^{-2}$ $s^{-1}$
  - $F_{MAGIC\ UL}$ = 5.5 x $10^{-11}$ erg $cm^{-2}$ $s^{-1}$
- Different EBL absorption models

Aleksic et al. 2010 (MAGIC Coll.)

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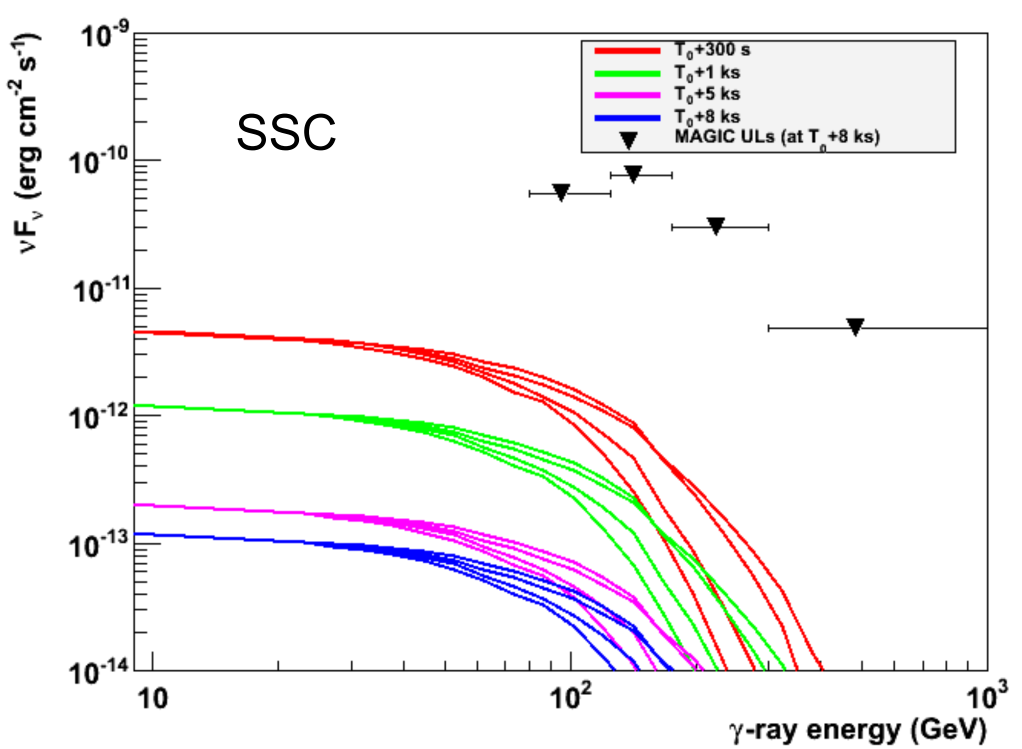


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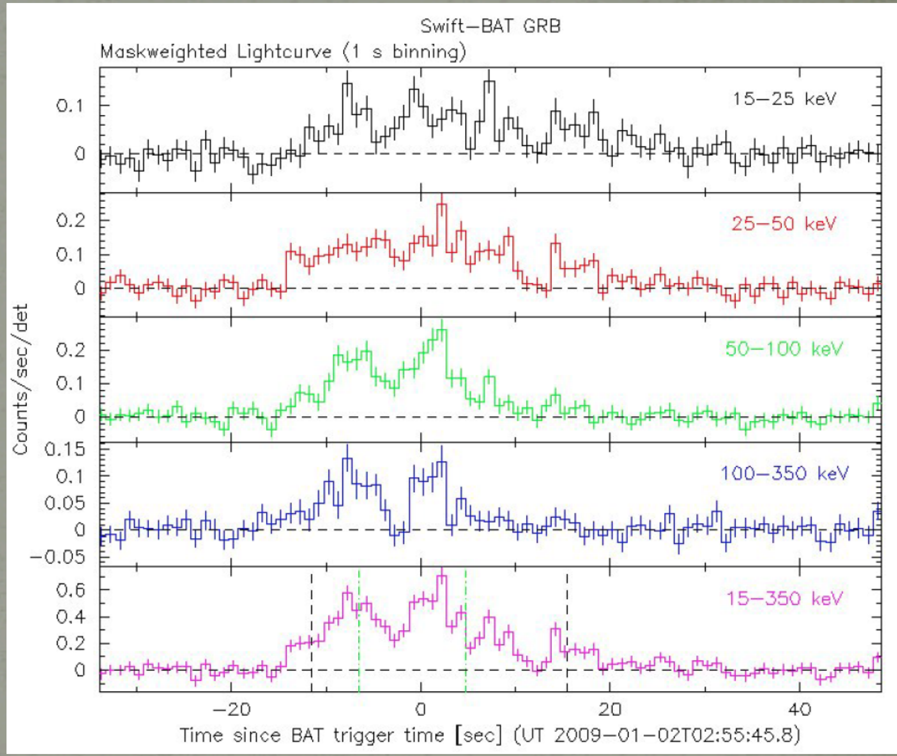
Aleksic et al. 2010 (MAGIC Coll.)

# GRB090102

- SWIFT BAT trigger, $T_{90}$=27 s
- Very good reconstruction of the prompt emission parameters: SWIFT, Konus Wind and INTEGRAL simultaneous observations
- Band function parameters:
  - $E_{peak}=451^{+73}_{-58}$ keV
  - $F_{20keV-2MeV}=3.09^{+0.29}_{-0.25} \times 10^{5}$ erg cm$^{-2}$
- Redshift (NOT) z=1.547
- Optical afterglow detected by various telescopes
- No signal with LAT



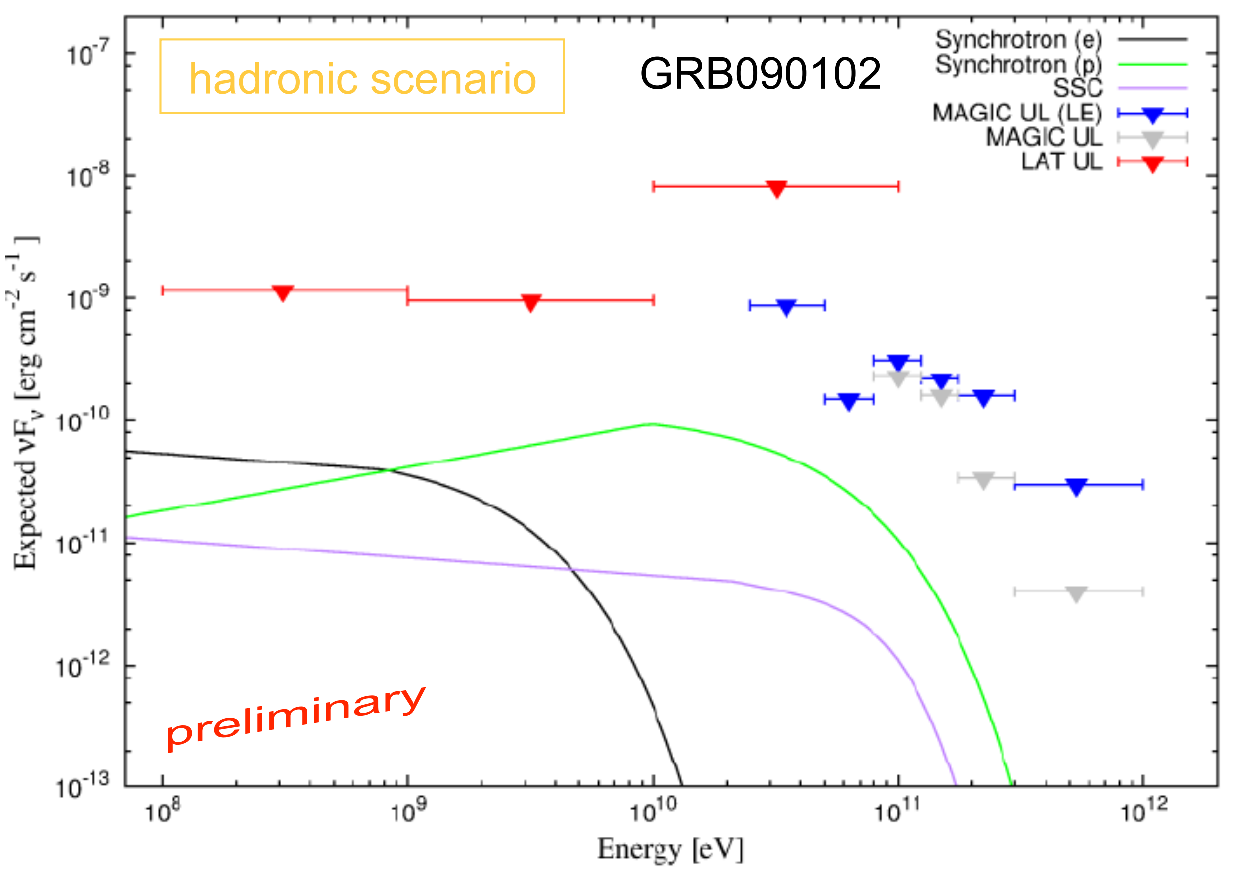

GCN-report 192.1

## MAGIC observations

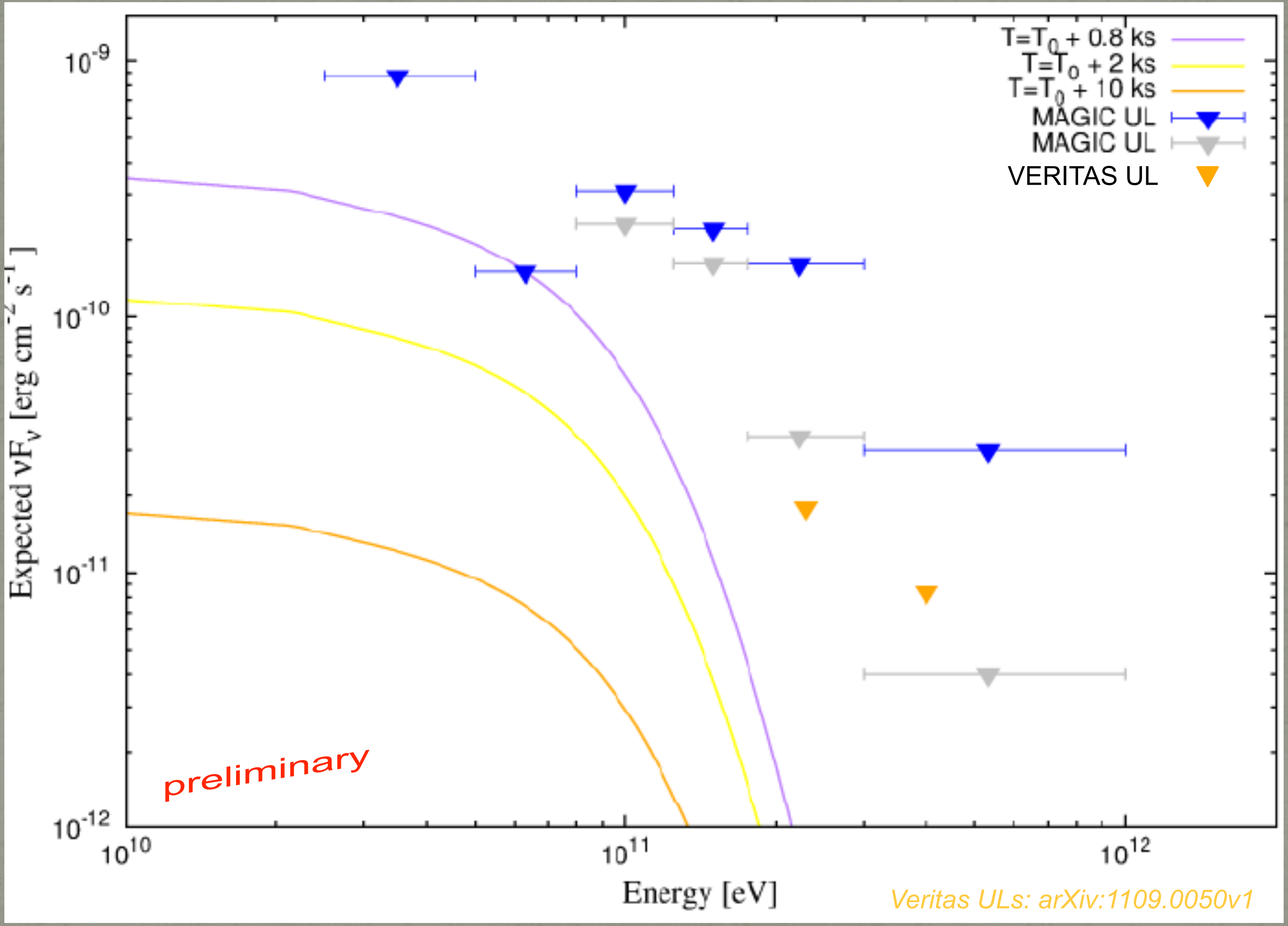
- MAGIC observation started at $T_0$+1161 s (technical problems)
- Zenit: 5º-52º
- Total obs. time : 13149 s (only first 5919 used for analysis z<25º)
- MAGIC-I + sum-trigger

# Standard fireball model scenario

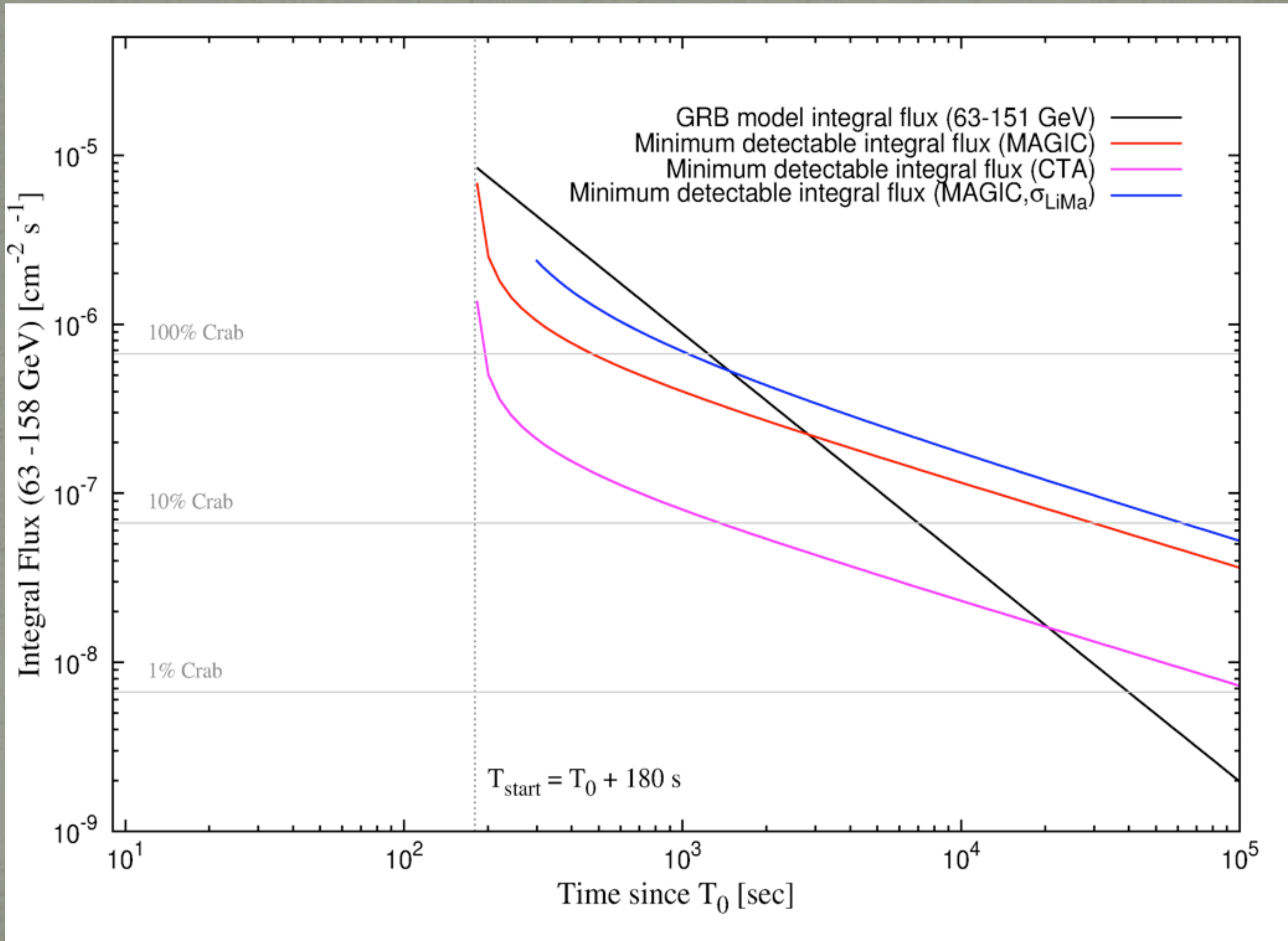
• First simultaneous GRB observation by MAGIC & Fermi/LAT
• VHE photons produced by SSC
• Hadronic component can exceed the electron component at MAGIC energies



# GRB090102 expected SSC emission

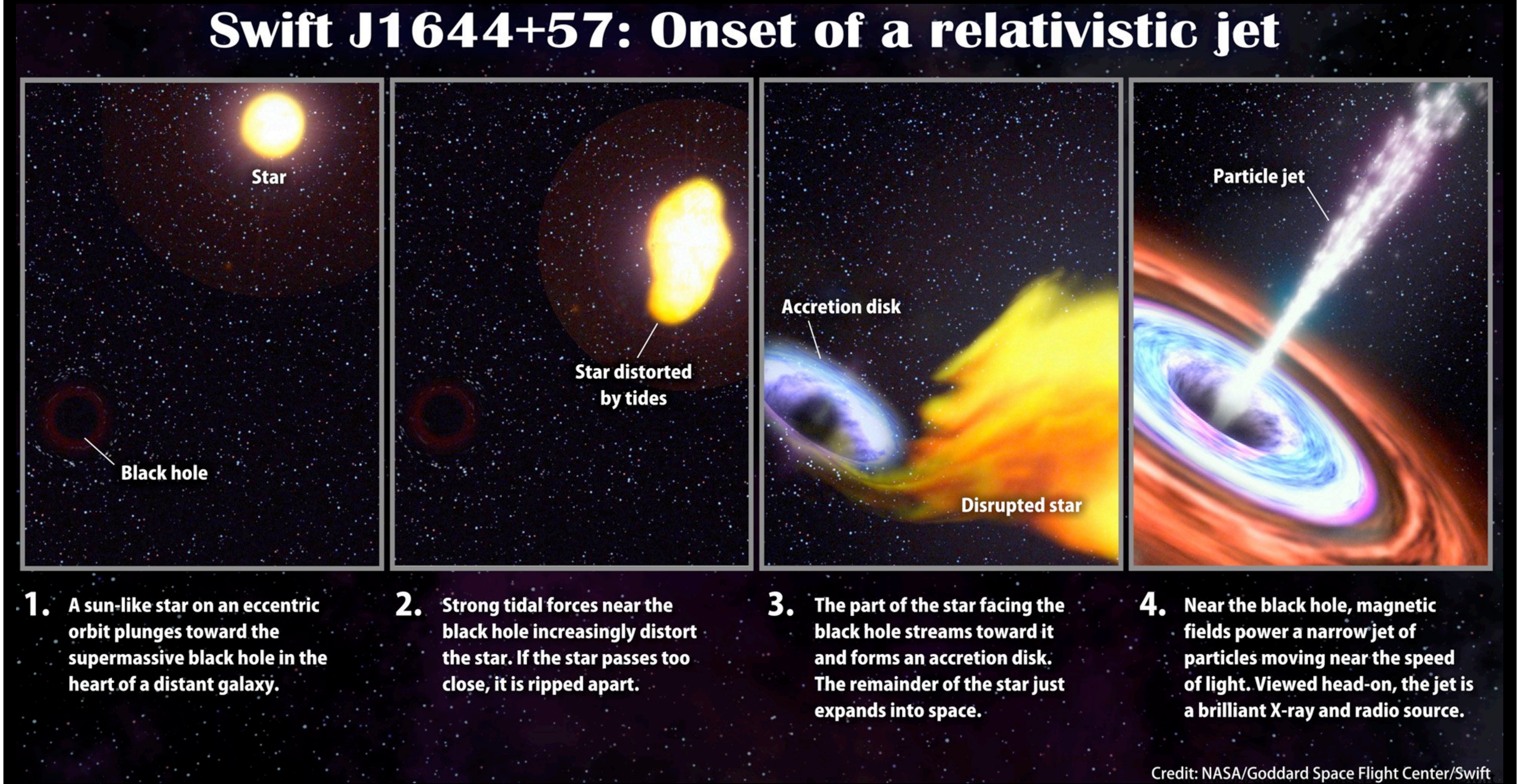


# GRBs with MAGIC, general considerations

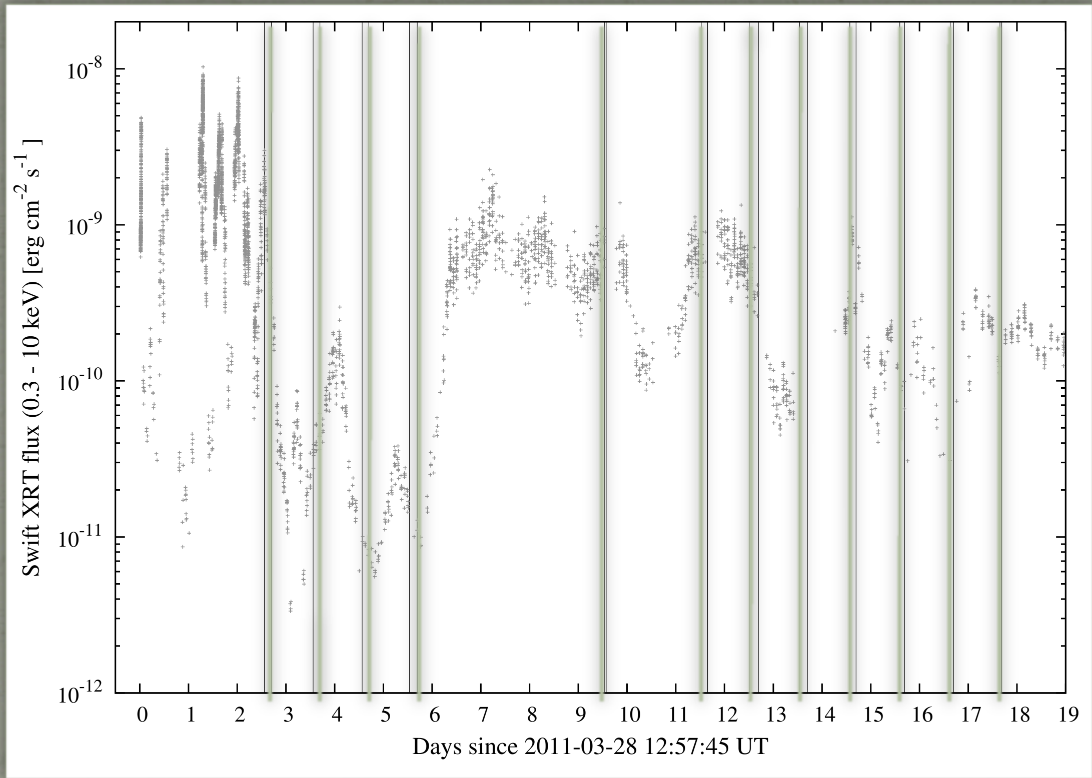


# The tidal disruption Sw1644+57

- Originally predicted by Ress+ in the 80s
- TDFs can ignite activity in dormant central BHs
- Early observational evidences from optical flares from previously inactive galaxies (Komossa 2002)
- Intense signature expected on X-rays from accretion disk emission
- Sw 1644 was the first TDE followed from its early developments, showing signature of accretion onto BH and of a jet formation

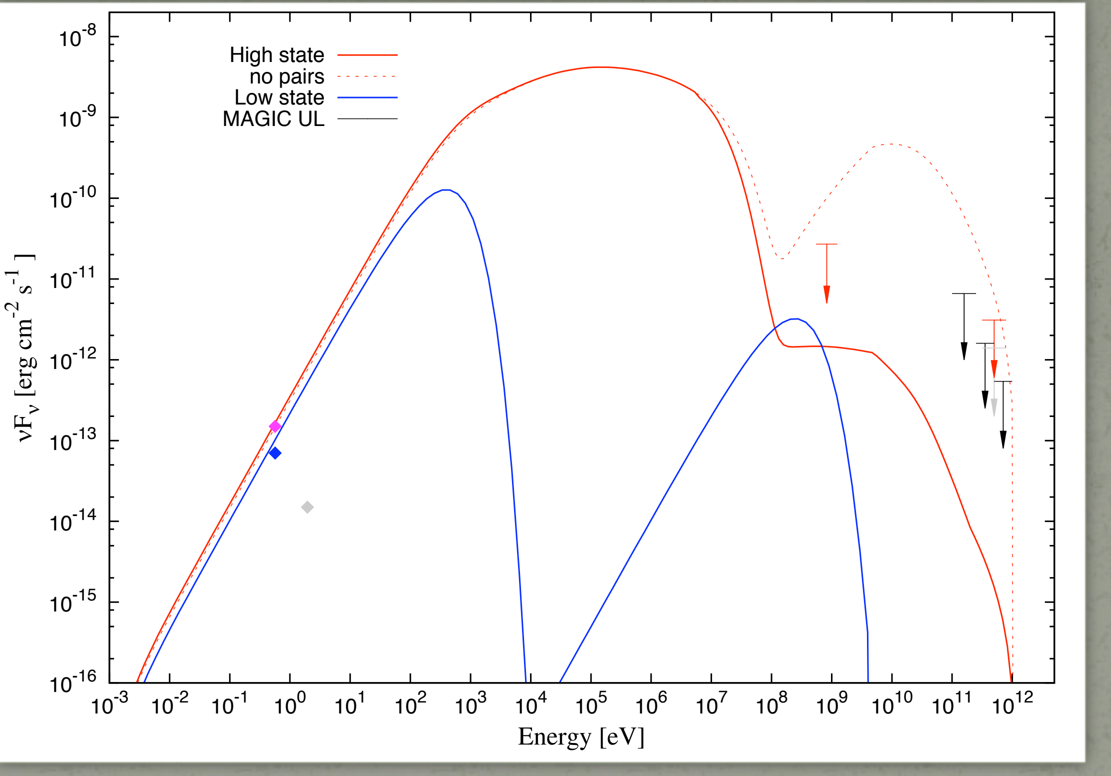

Swift J1644+57: Onset of a relativistic jet
Star
Black hole
Star distorted by tides
Accretion disk
Disrupted star
Particle jet
1. A sun-like star on an eccentric orbit plunges toward the supermassive black hole in the heart of a distant galaxy.
2. Strong tidal forces near the black hole increasingly distort the star. If the star passes too close, it is ripped apart.
3. The part of the star facing the black hole streams toward it and forms an accretion disk. The remainder of the star just expands into space.
4. Near the black hole, magnetic fields power a narrow jet of particles moving near the speed of light. Viewed head-on, the jet is a brilliant X-ray and radio source.
Credit: NASA/Goddard Space Flight Center/Swift

# The tidal disruption Sw1644+57




- MAGIC observed the source for 27 hours from 31 March to 15 April 2011
- Energy threshold 100 GeV
- Analysis with sum-cleaning (Lombardi et al. 2011) gives higher suppression of night sky background and lower energy threshold

# The tidal disruption Sw1644+57



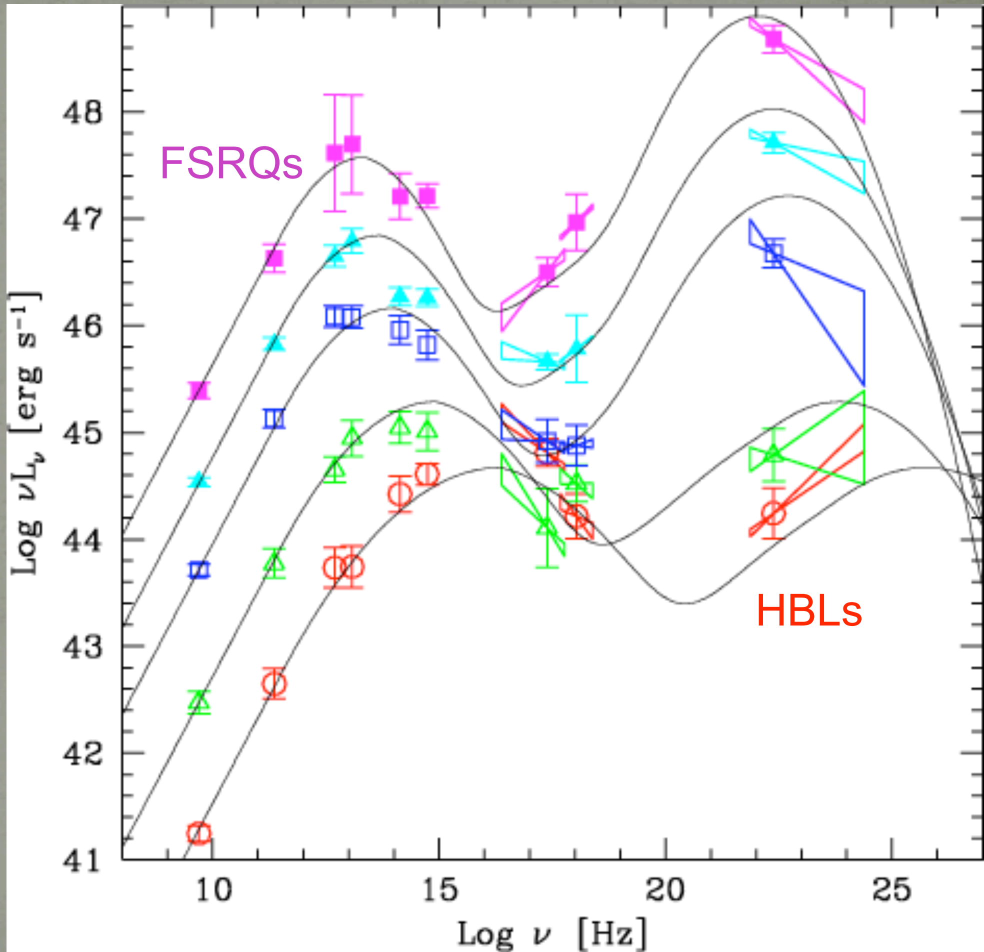

- Upper limits constrain the 100 GeV range by a factor x2 with respect to Fermi/LAT
- MAGIC results supports model for jet emission with an IC component suppressed by pp.
- Confirms constraints to Γ<20 from Burrows et al. 2011

# GRB observation summary

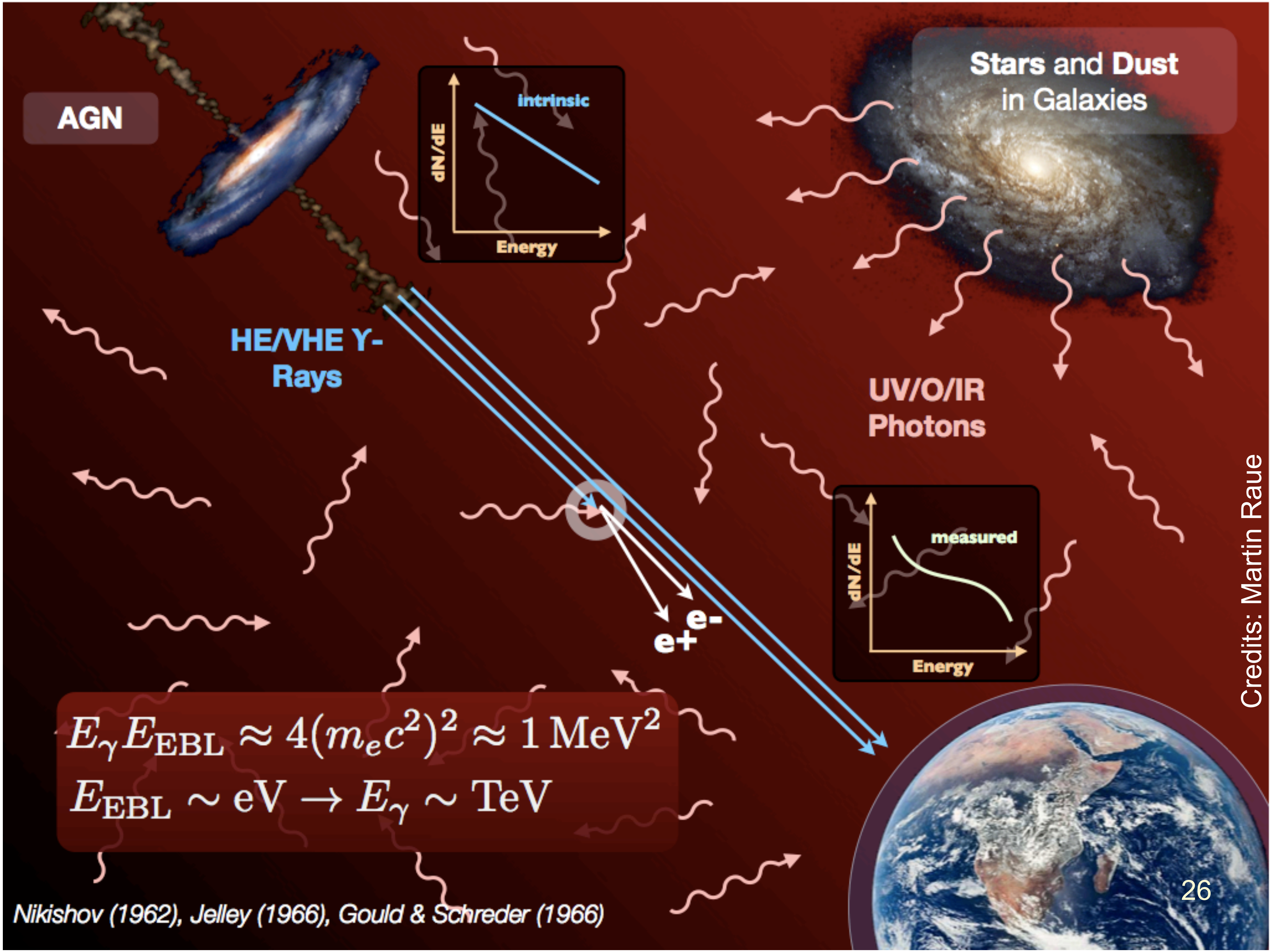
- 62 GRBs follow-up observations by MAGIC since 2004
- Several GBM follow-up's with large coordinate error
- Most MAGIC observations without MWL coverage
- To date, only UL's on VHE gamma-ray emission
- Redshift information is crucial to interpret VHE observations
- Big advantage of simultaneous LAT and MAGIC observatoins
- Low energy threshold and fast repositioning makes MAGIC the best Cherenkov telescope to detect GRBs
- Until now no good candidates were observed with MAGIC (delays, initial failures, high redshifts)
- Low redshift and short delays are essential
- MI telescope upgrade is finished ready to received alerts.
- For the future CTA will improve the chances for GRB detection with a larger field of view and higher sensitivity.

# Testing relativistic jets emission models

- *Jets' origin, composition, acceleration processes under still debate*
- *Blazar emission dominated by high (HE, E>100 MeV) and very high (VHE, E>100 GeV) energy bands*
- *Multi-wavelength simultaneous observations are crucial to understand acceleration processes*




Fossati et. al. 1998



Stars and Dust in Galaxies
AGN
intrinsic
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Energy
HE/VHE γ-Rays
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Energy
e-
e+
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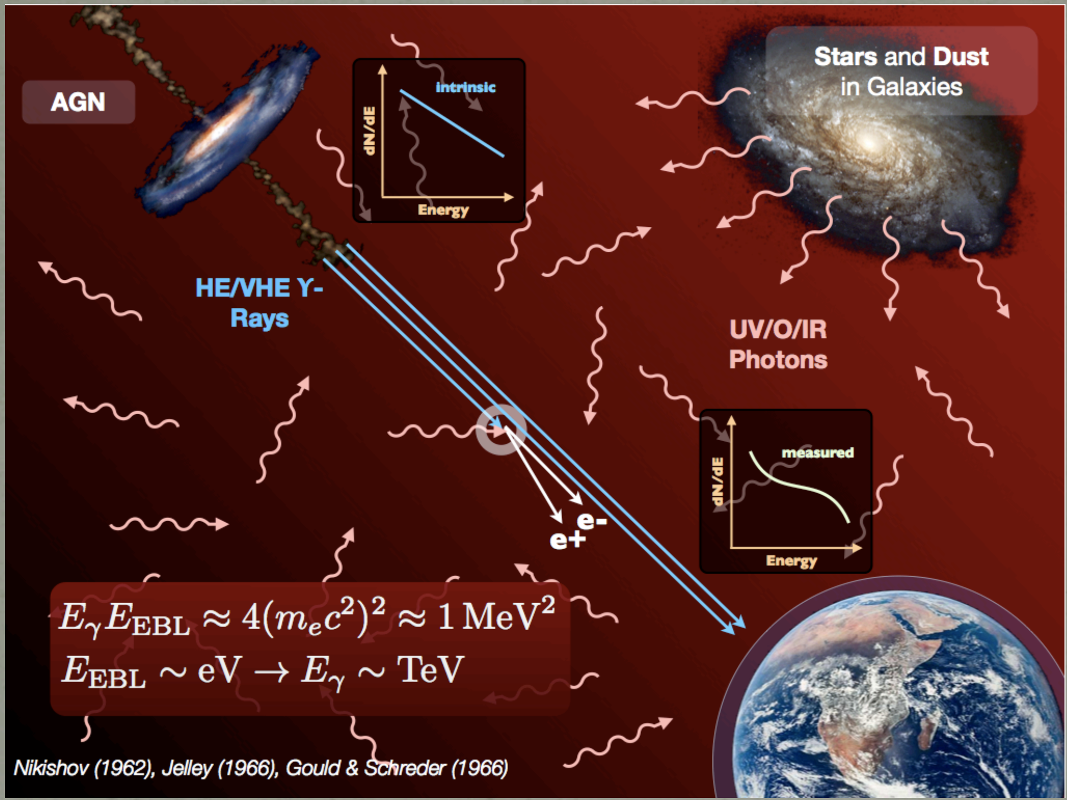
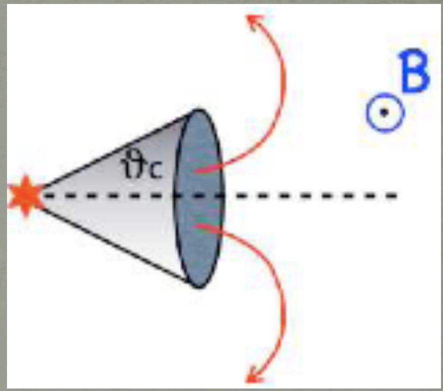
$E_{\mathrm{EBL}} \sim \mathrm{eV} \rightarrow E_\gamma \sim \mathrm{TeV}$
Nikishov (1962), Jelley (1966), Gould & Schreder (1966)
Credits: Martin Raue
26

# Intergalactic magnetic field (IGMF)




- *VHE gamma-ray + EBL photons --> e-e+ pairs*
- *e-e+ can interact CMB photons --> reprocessed emission in the HE gamma-ray regime*
    - *Pair echos: time delay*
    - *Pair halos: extended emission*

# AGN flares alerts

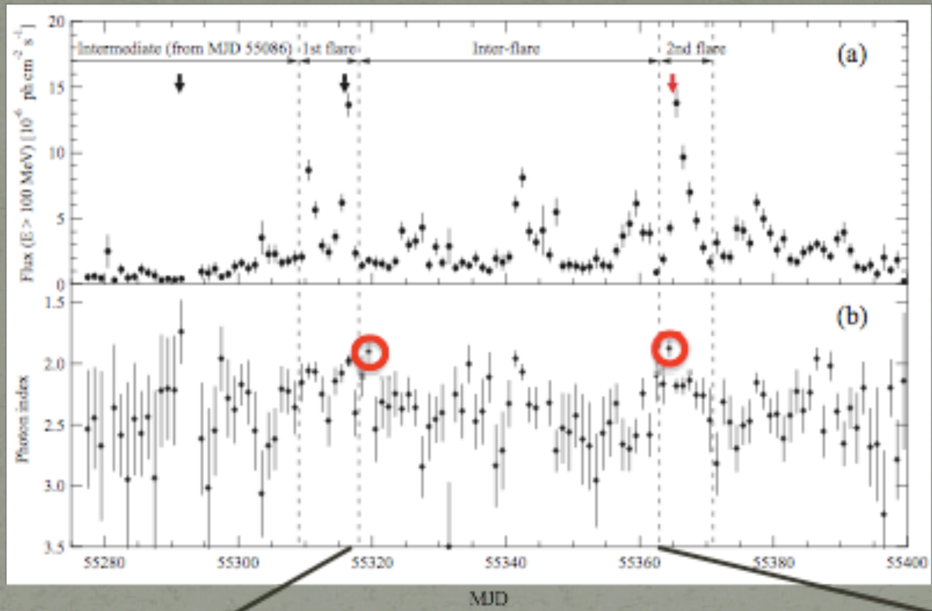
- Optical triggers from Tuorla monitoring program
- X-ray alerts from Swift (GCN/Atels) and MAXI
- Fermi/LAT triggers
- MAGIC/HESS/VERITAS agreement for strong flares
- Neutrino alerts from IceCube
- FACT (triggers strong flares at E>700 GeV)

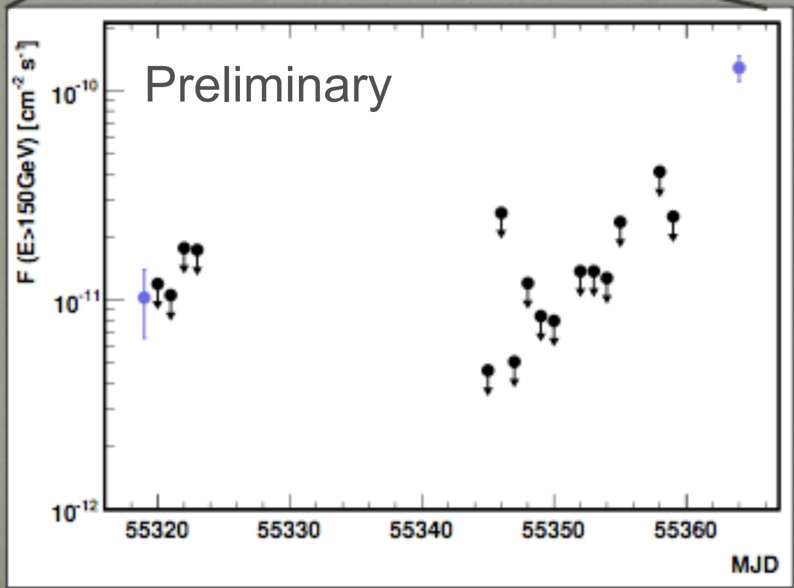
- Fast alerts are essential for FSRQs detections.

# Discovery of the FSRQ PKS1222+21

Fermi light curve

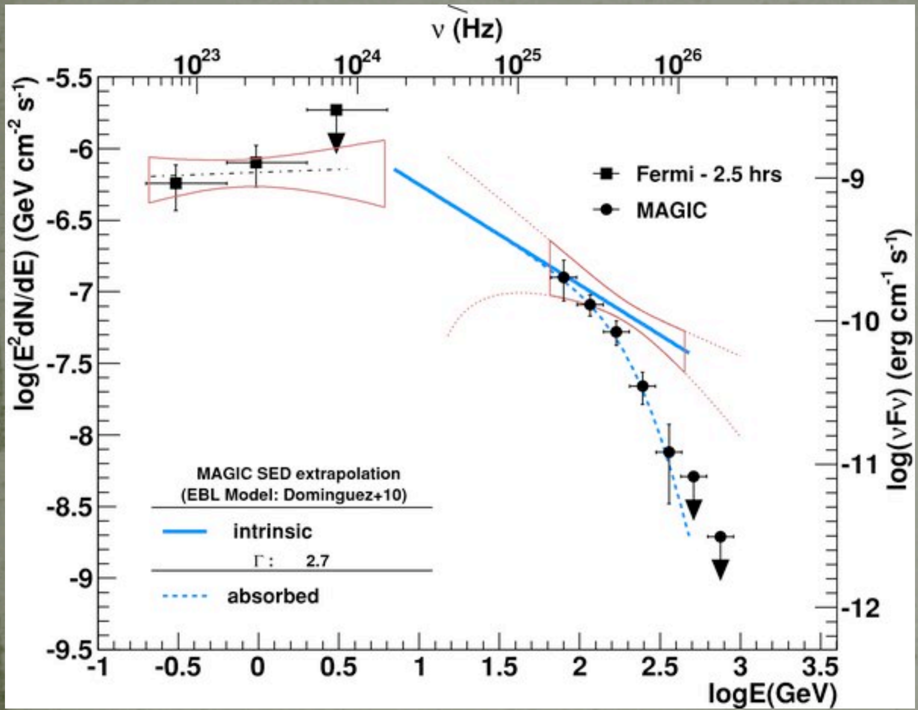
Fermi spectral index

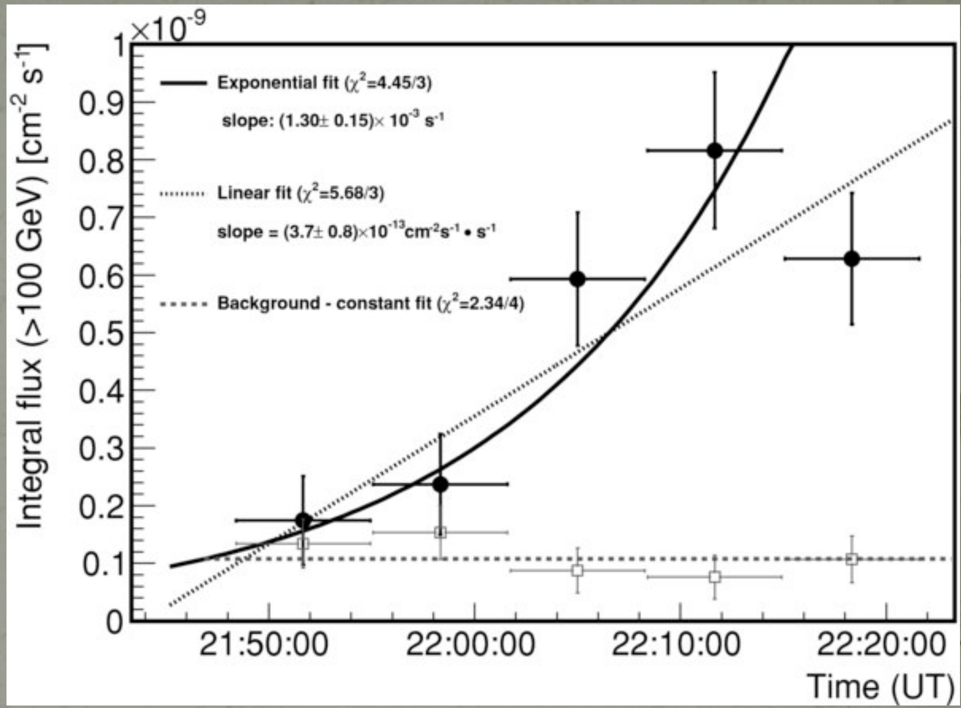



- Only 3 FSRQs has been detected in the VHE band until know
- 2$^{nd}$ most distant source (z=0.43)
- Flare state
- 2010 May 3, first hint of detection: 4.63 σ
- MAGIC detection 17th June 2010

# Discovery of the FSRQ PKS1222+21




- The observed and EBL-corrected spectrum is compatible with a simple power law:
  - Observed: $\Gamma$=3.75±0.29
  - EBL-corrected: $\Gamma$=2.72±0.34 (Dominguez et al., 2011)
- ***Cut-off excluded for E<130 GeV***
- Constant flux hypothesis can be rejected with high confidence ($P \sim 10^{-5}$)
- ***Doubling flux in $8.9^{+1.3}_{-0.8}$ minutes*** ($t_{var}$=ln2/slope)
- Fastest flux variation ever observed in a FSRQ in the VHE range

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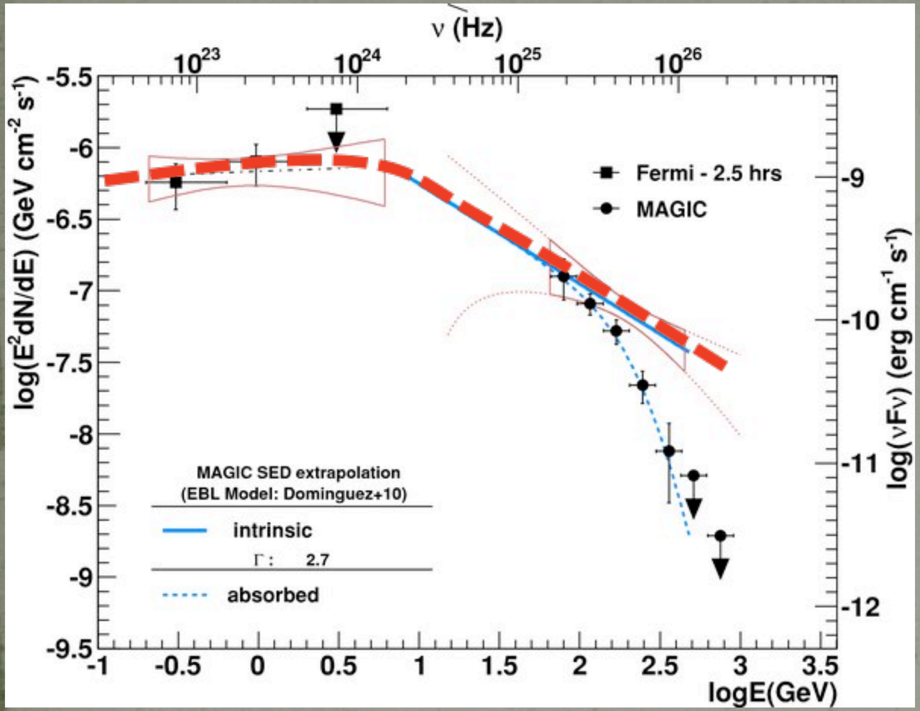


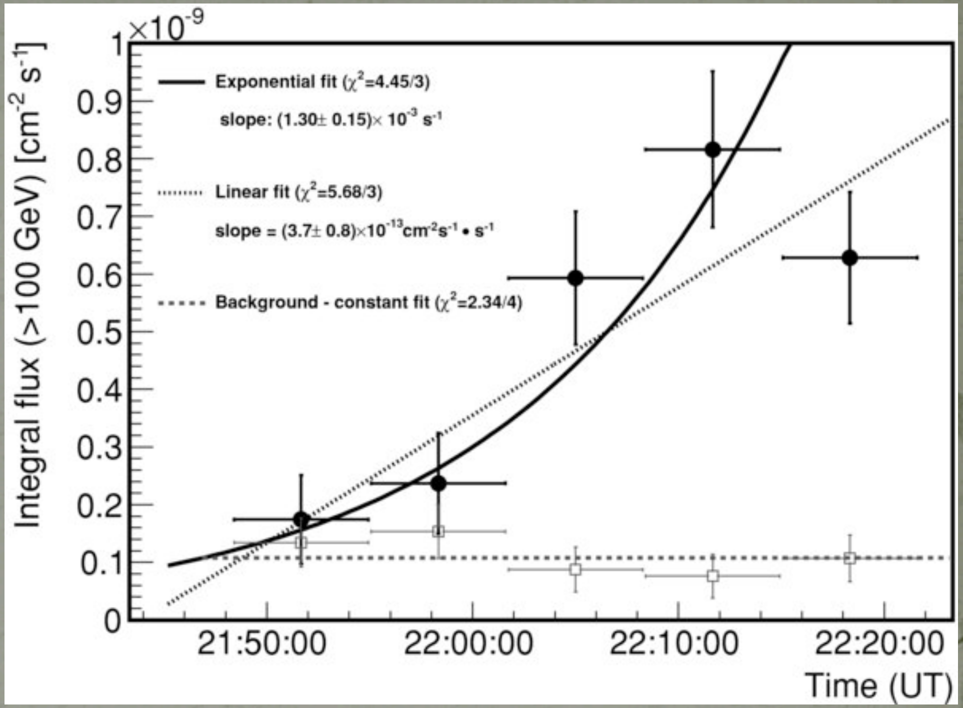


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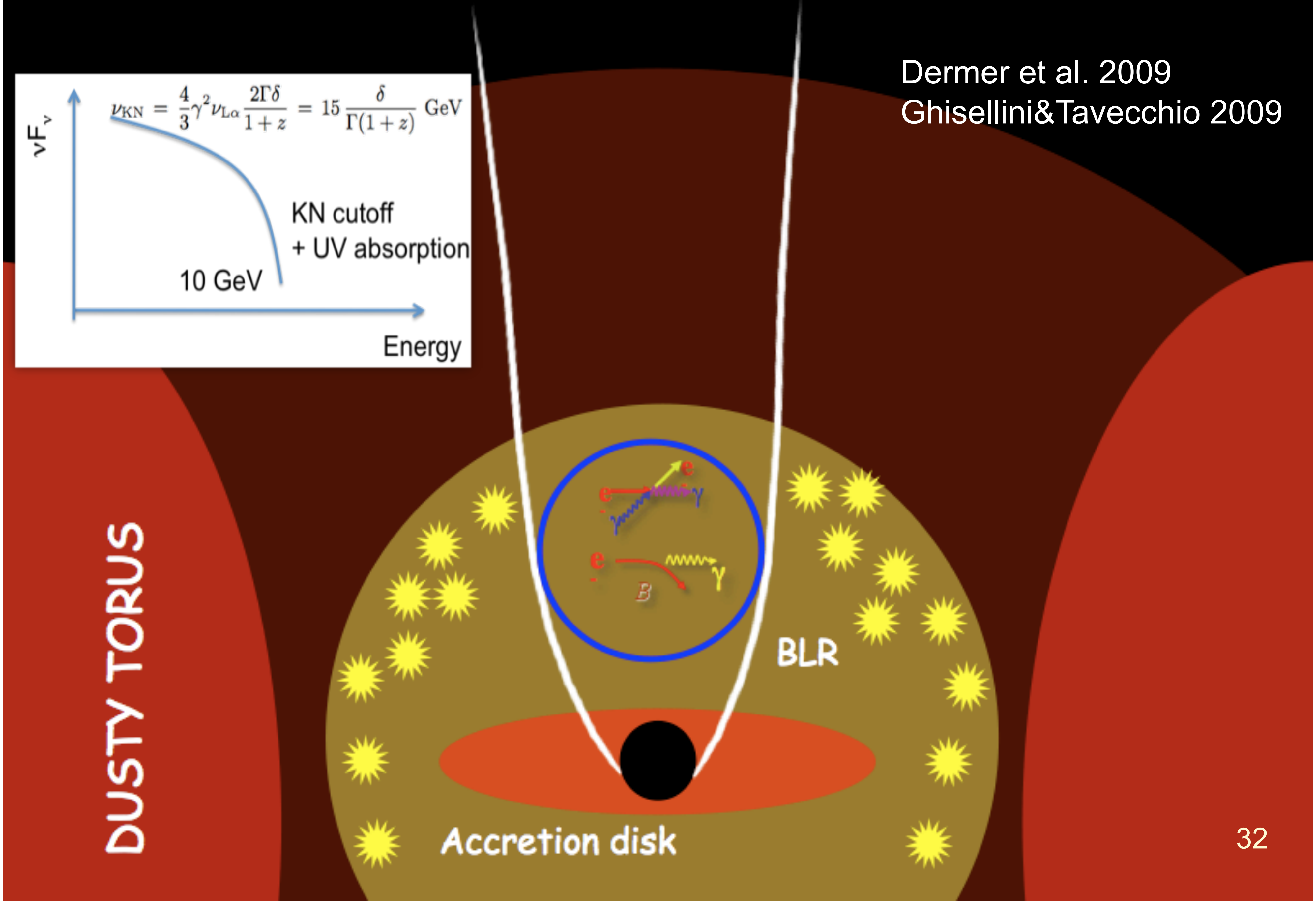
# FSRQs: the "canonical" scenario

Dermer et al. 2009
Ghisellini&Tavecchio 2009



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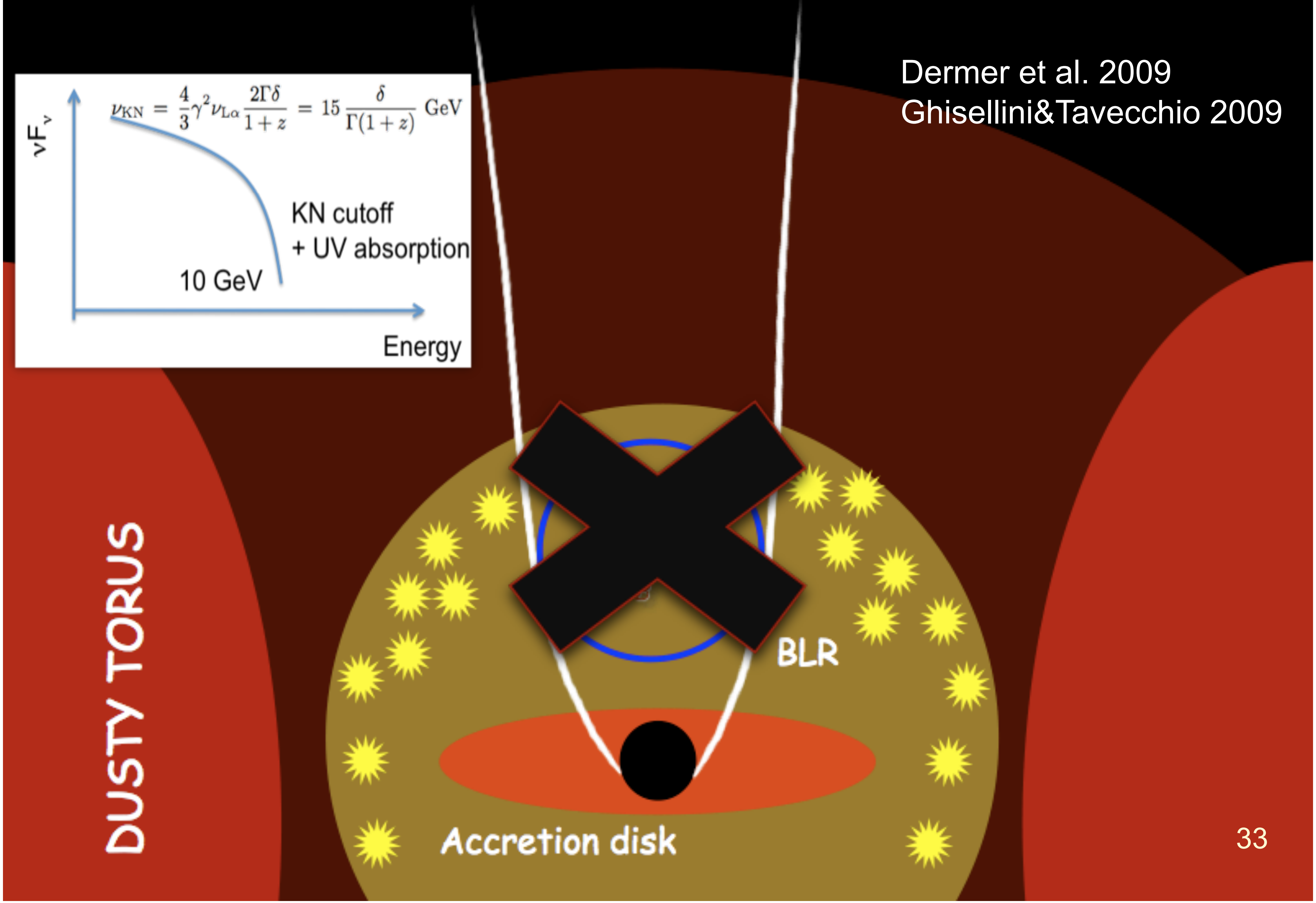
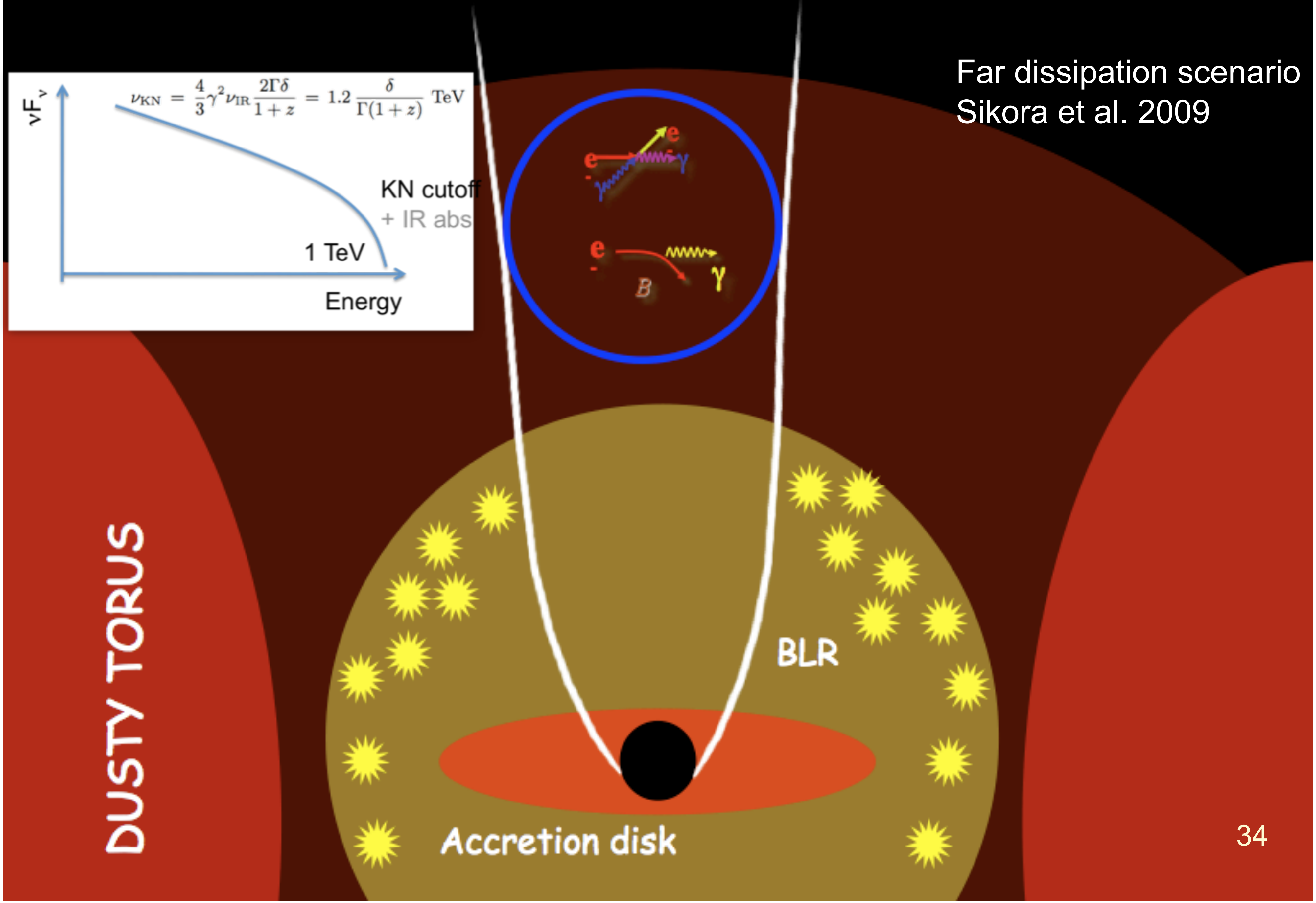


# FSRQs: the "canonical" scenario

Far dissipation scenario
Sikora et al. 2009



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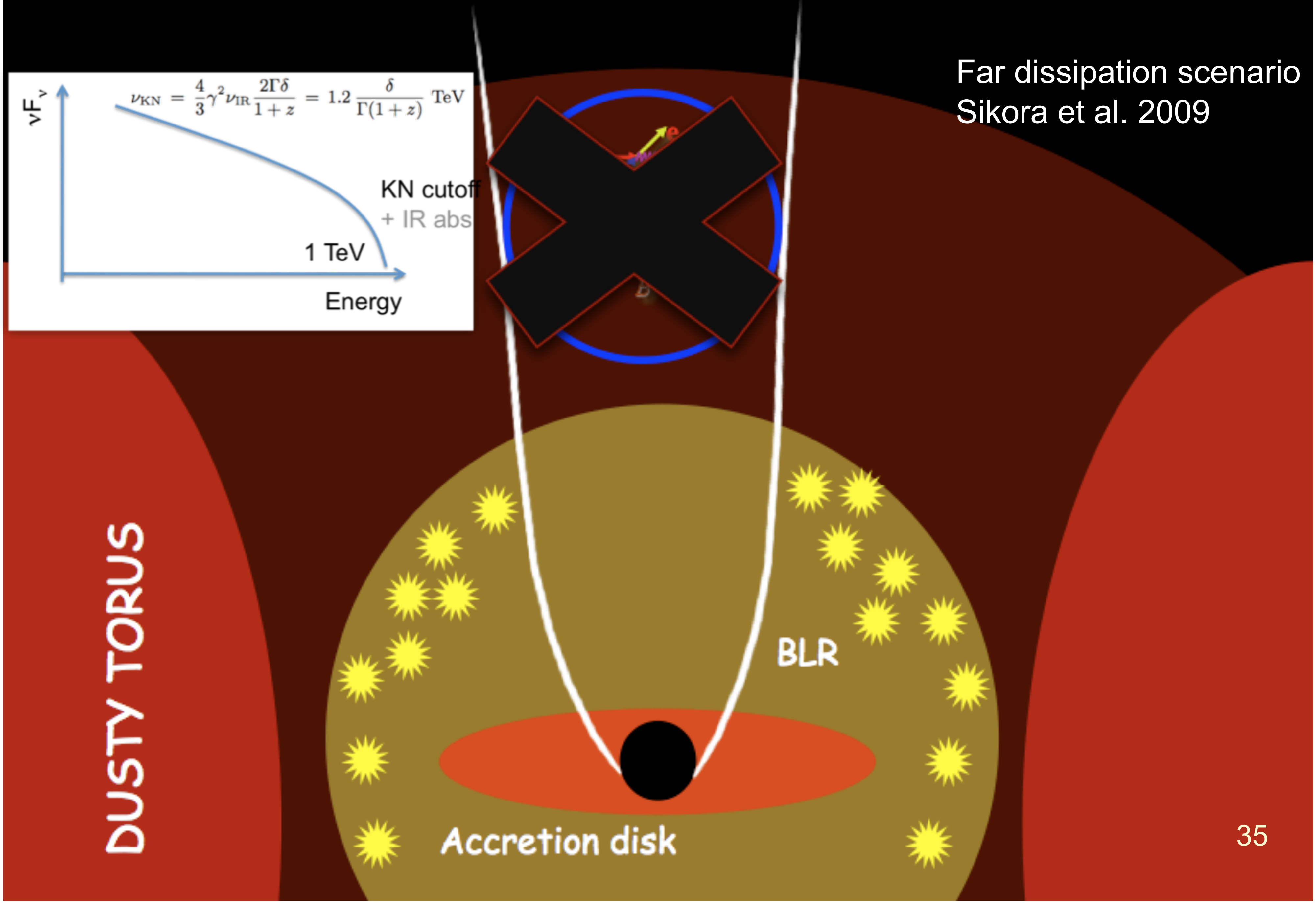
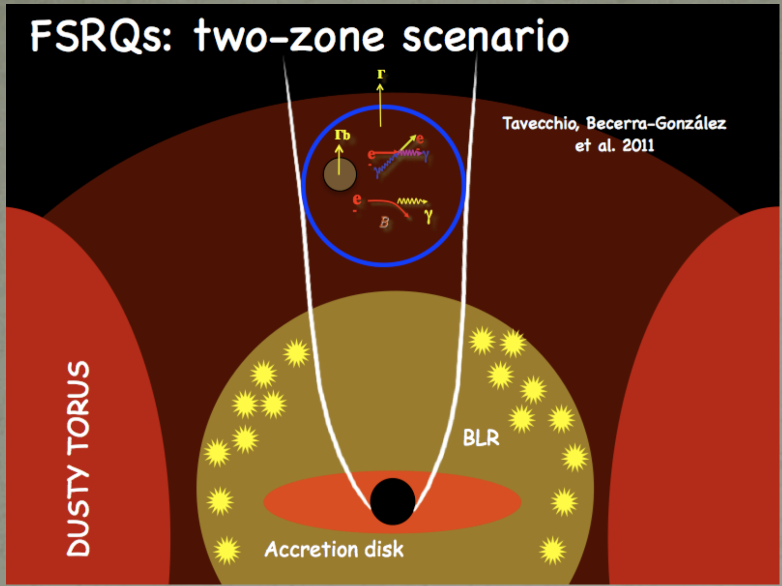
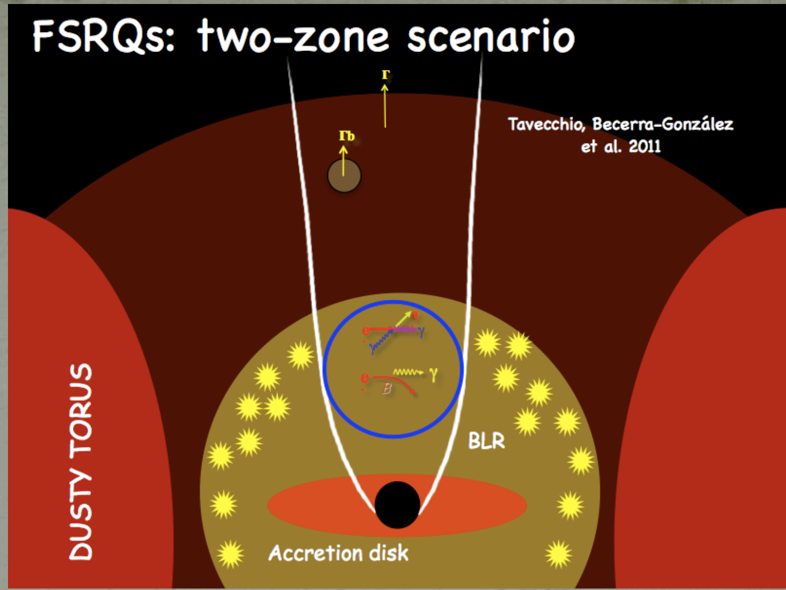
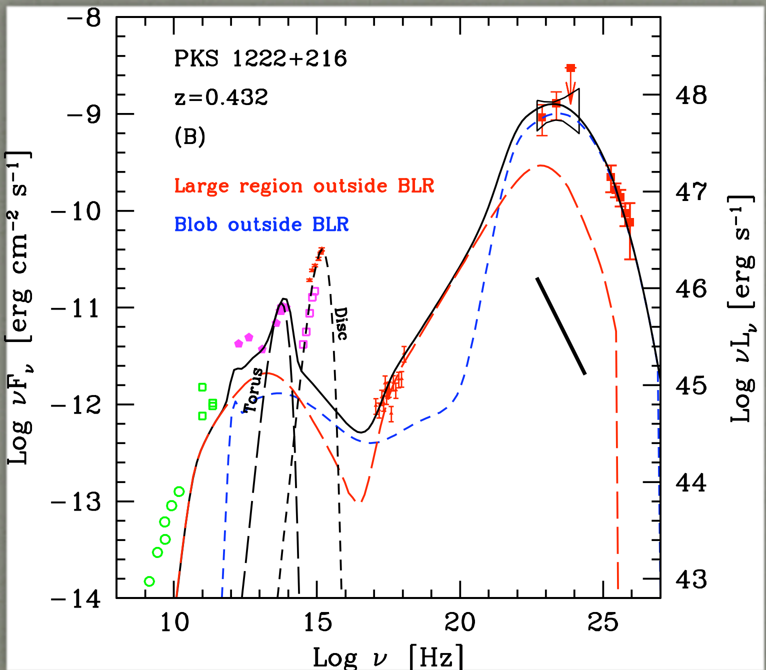
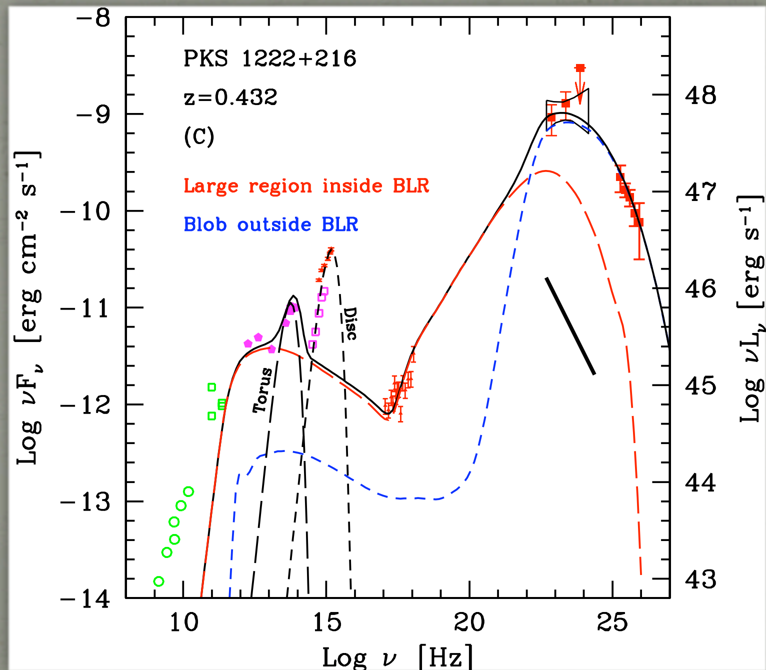





Tavecchio, Becerra-González et al. 2011

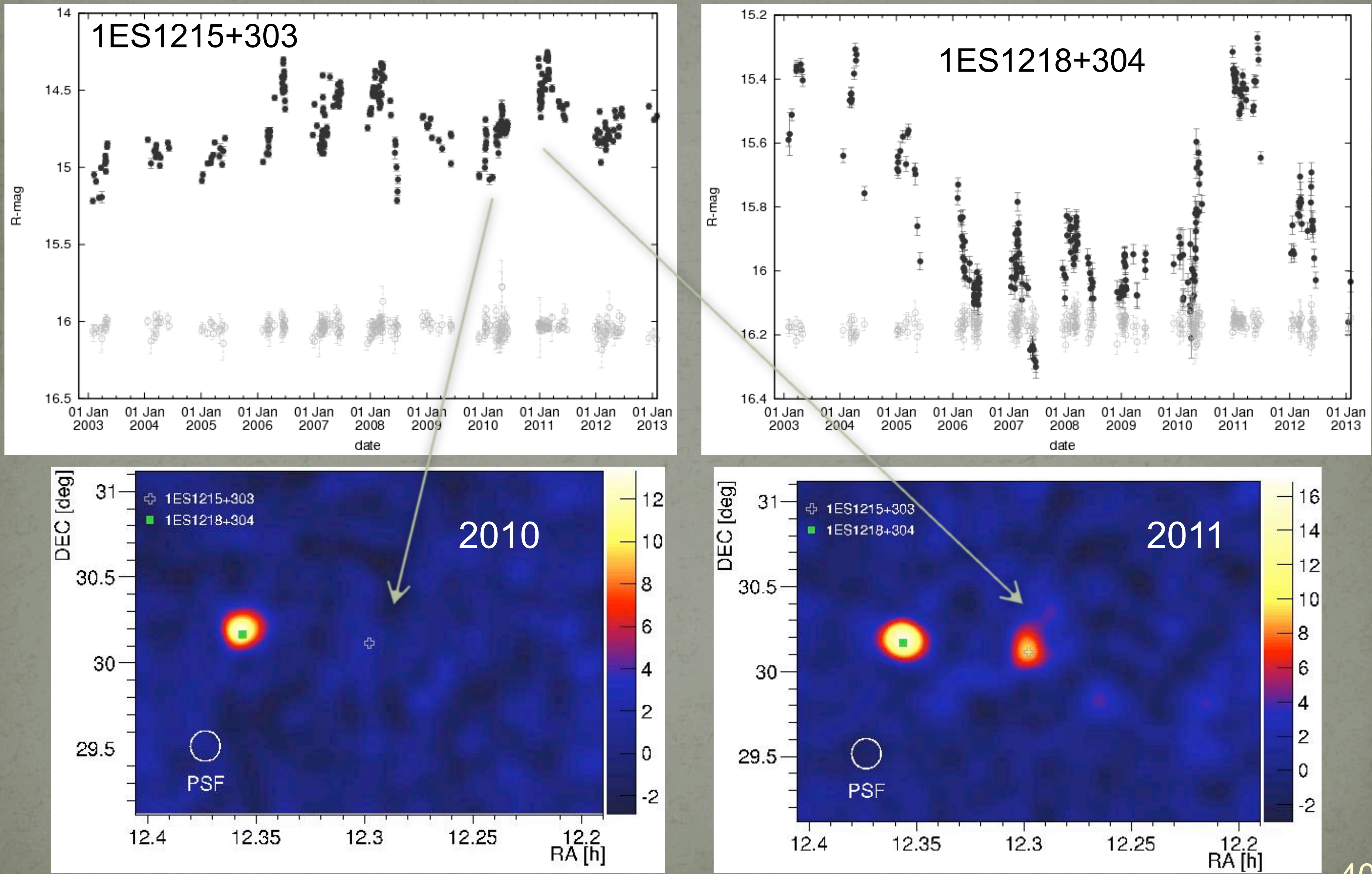
# Conclusions

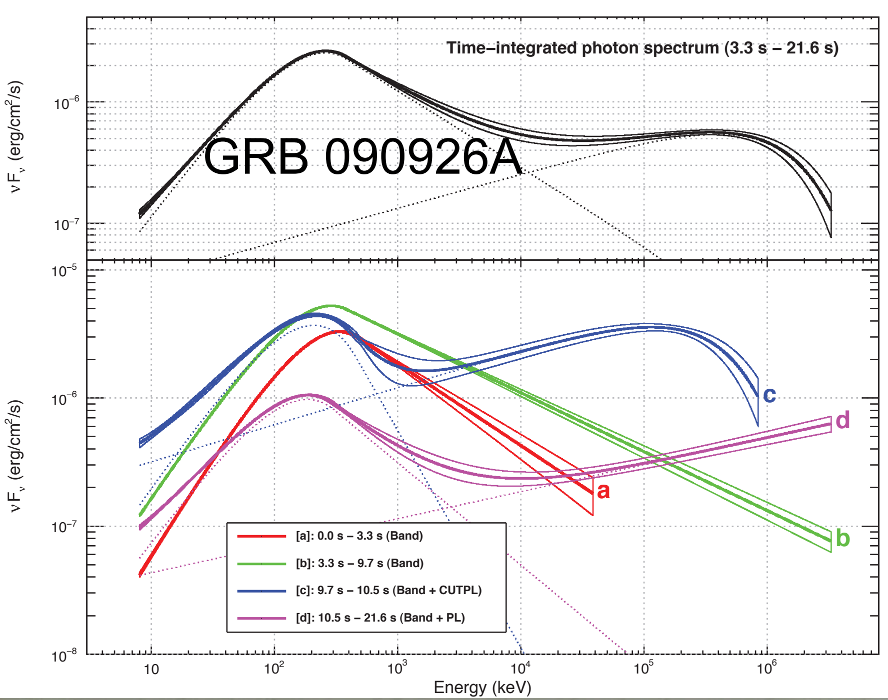
- Coordinates multi-wavelength campaigns are the only way to understand the physics processes
- Flares alerts need to be deliver fast. Now mainly throw Atels which in most of the cases are sent with long delays >1-2 days.
- Specially alerts from strong flares could be sent within 1 hours (or less)
- Alert from satellites (specially Fermi from the whole sky monitoring) should be implemented automatically
- A network similar to GCN is needed for strong flares.

# Thanks!

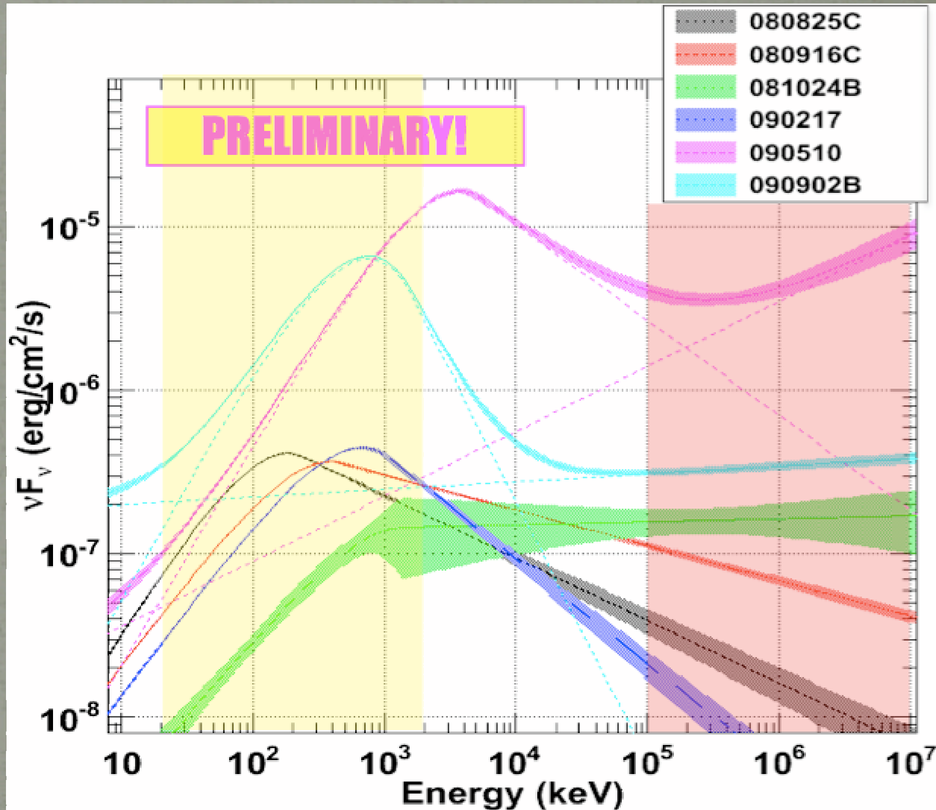
# Backup

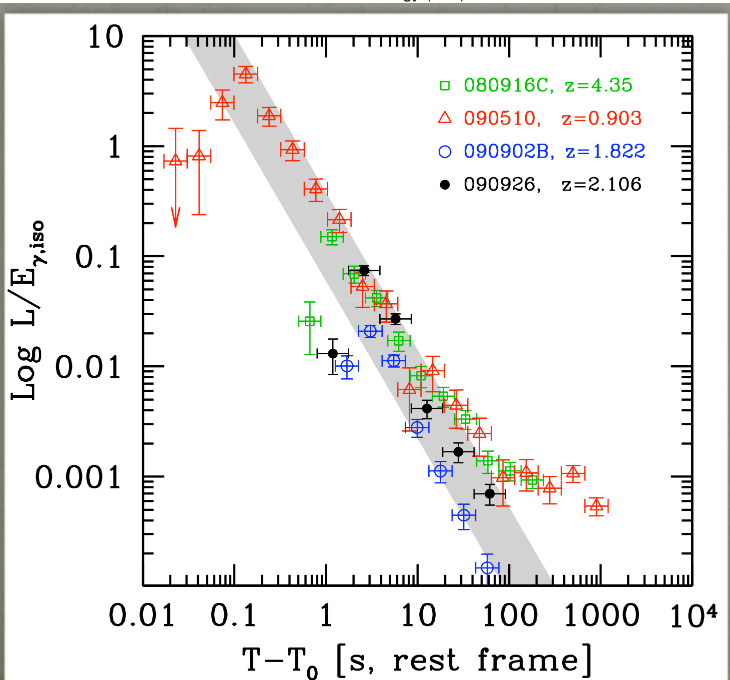
# Discovery of the blazar 1ES1215+303






Granot et al. 2010




Ackermann et al., 2011

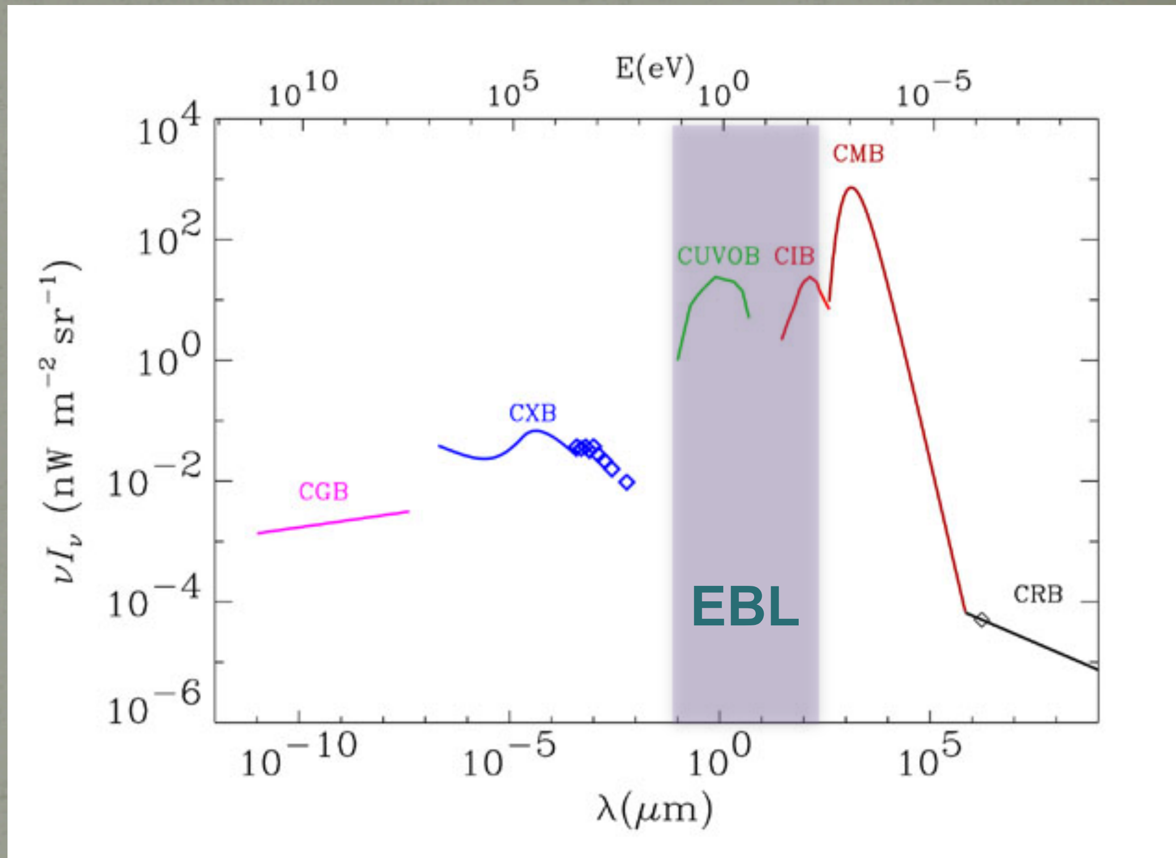
Ghisellini, et al., 2010

# Cosmic radiation background

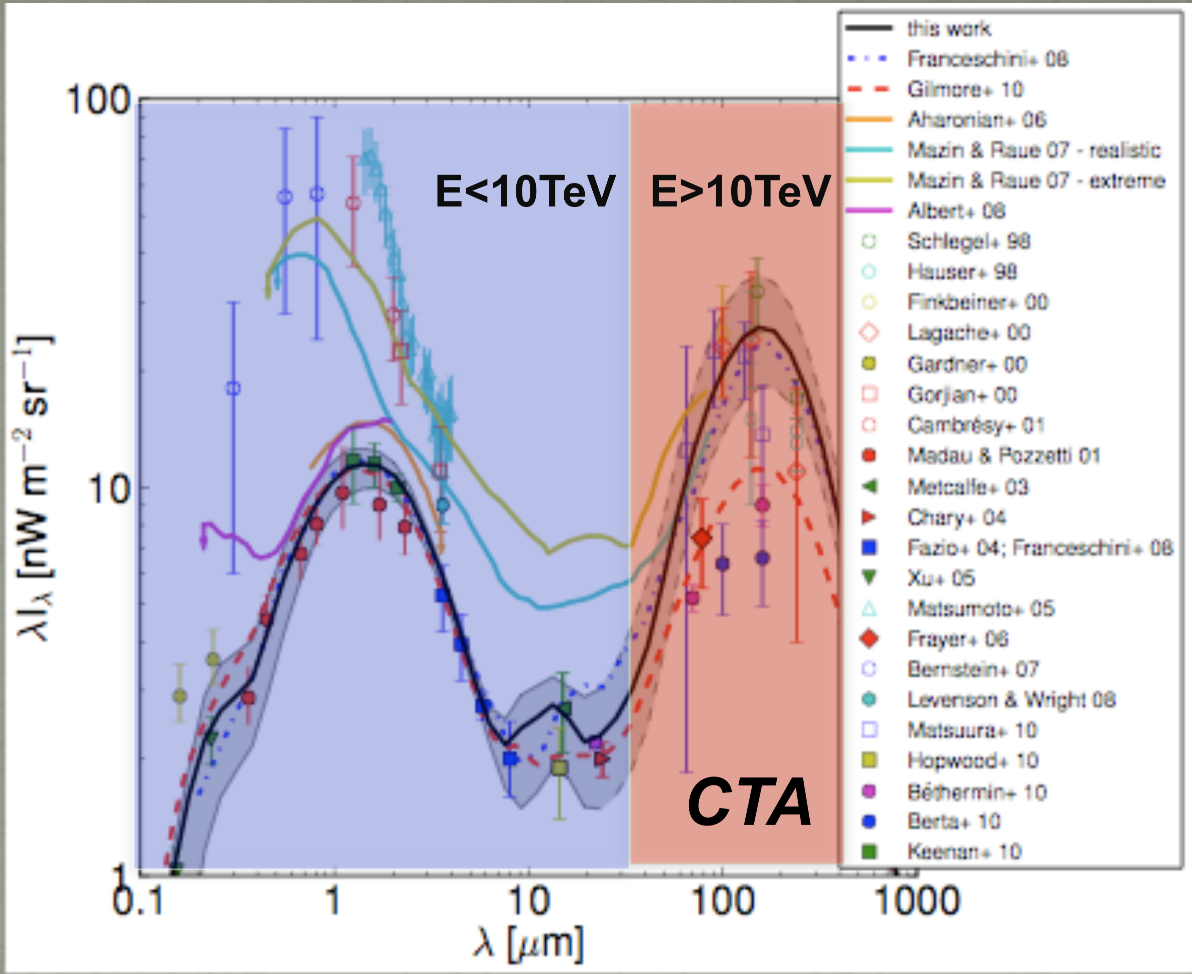
- Universe filled of background photons (from radio to gamma-rays)

- Photons IR-Opt-UV are called Extragalactic Background Light (EBL)

- EBL has cosmological implications since it is the integrated record of the galaxies' emission over cosmic time




Hauser and Dwek et. al. 2001




Dominguez et. al. 2011

- Attenuation effect important for E>100 GeV (λmax[μm]=1.24 Eγ[TeV])
- Effect depends strongly on redshift and energy
- Distortion effect on the spectra