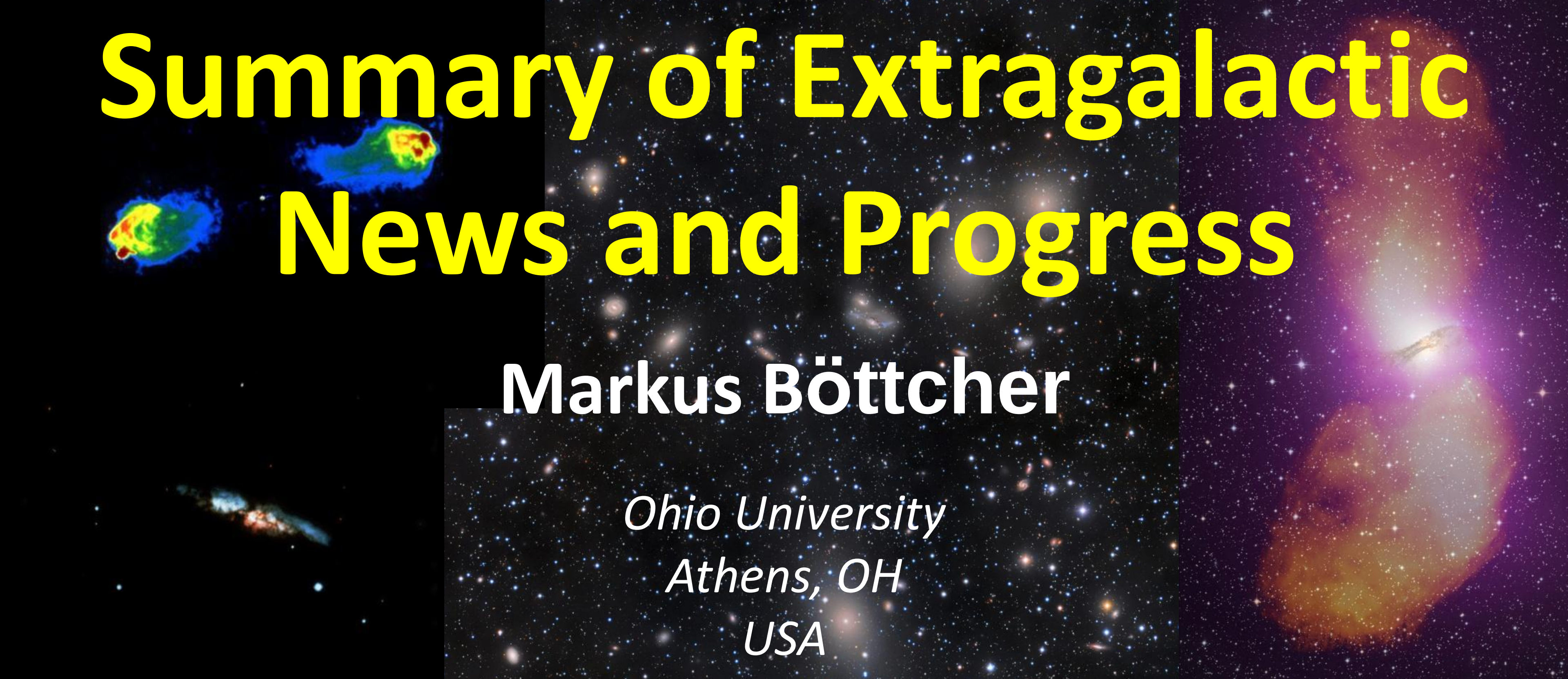


Summary of Extragalactic News and Progress

Markus Böttcher

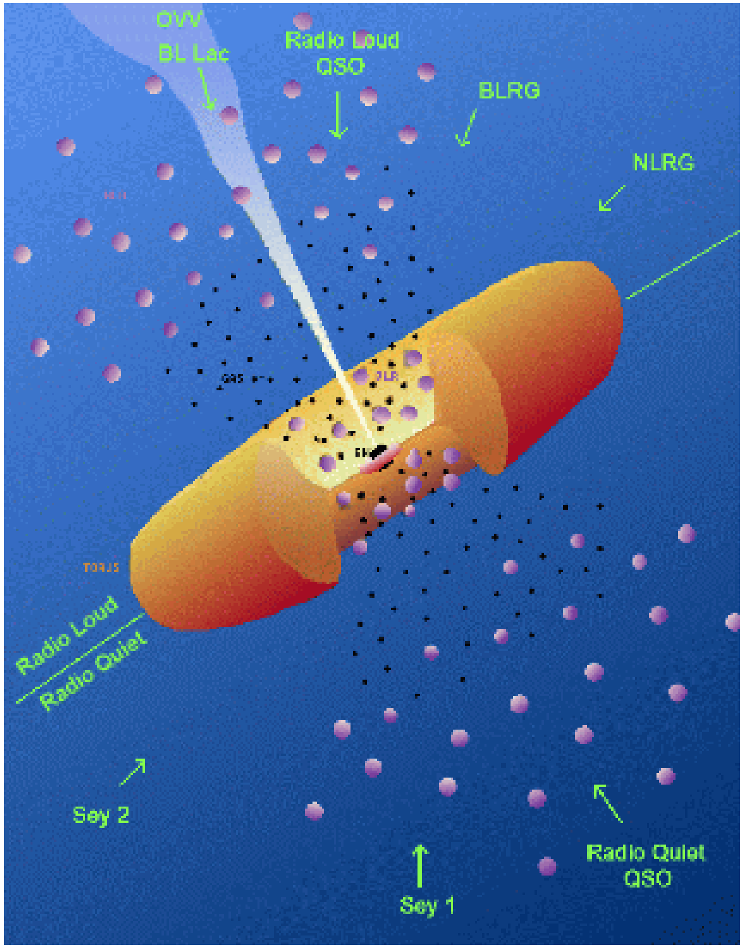
Ohio University
Athens, OH
USA

Outline

1. AGN
   a. Blazars
   b. Non-Blazar AGN
2. Other sources
3. EBL and EGMF

Apologies…

90 extragalactic contributions
40 minutes
=> 26.7 sec/contrib.



AGN : Two main categories

1. *Dominated by (mostly) thermal emission from accretion disk -*

   Radio quiet AGN (>~90 %)

1. *Dominated by Non-Thermal radiation –*

   Jet dominated AGN (< 10%)

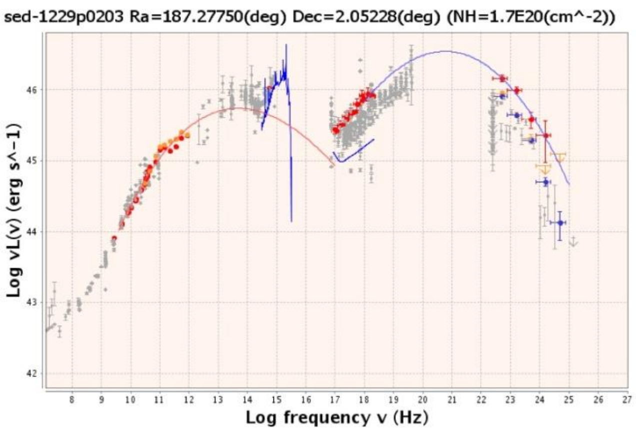
When $\Theta < \theta_{blazar}$ → **Blazar**

(P. Giommi)

Most (over 1000) extragalactic Fermi sources are blazars;
over 50 VHE gamma-ray blazars detected.

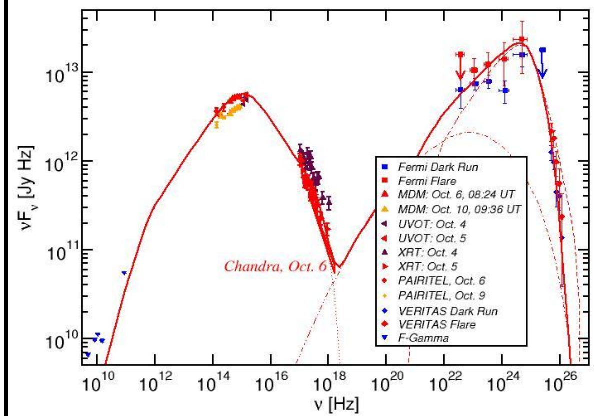
Blazar Classification

3C273



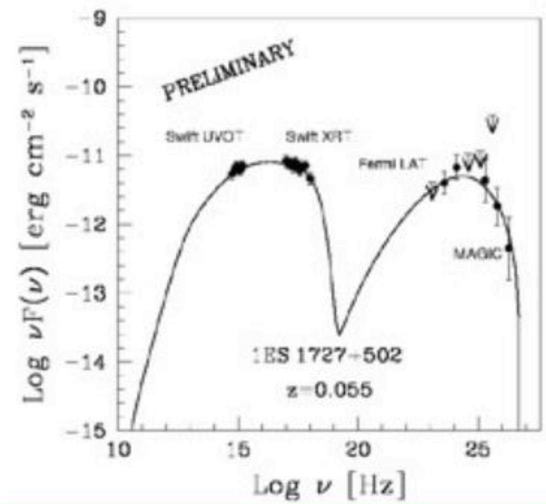
(P. Giommi)

3C66A



(Abdo et al. 2011)

1ES 1727+502



(de Caneva et al.)

Quasars:

Low-frequency component from radio to optical/UV,

$\nu_{sy} \leq 10^{14}$ Hz

High-frequency component from X-rays to γ-rays, often dominating total power

Low-frequency peaked / Intermediate BL Lacs (LBLs/IBLs):

Peak frequencies at IR/Optical and GeV gamma-rays,

10^{14} Hz $< \nu_{sy} \leq 10^{15}$ Hz

Intermediate overall luminosity

Sometimes γ-ray dominated

High-frequency peaked BL Lacs (HBLs):

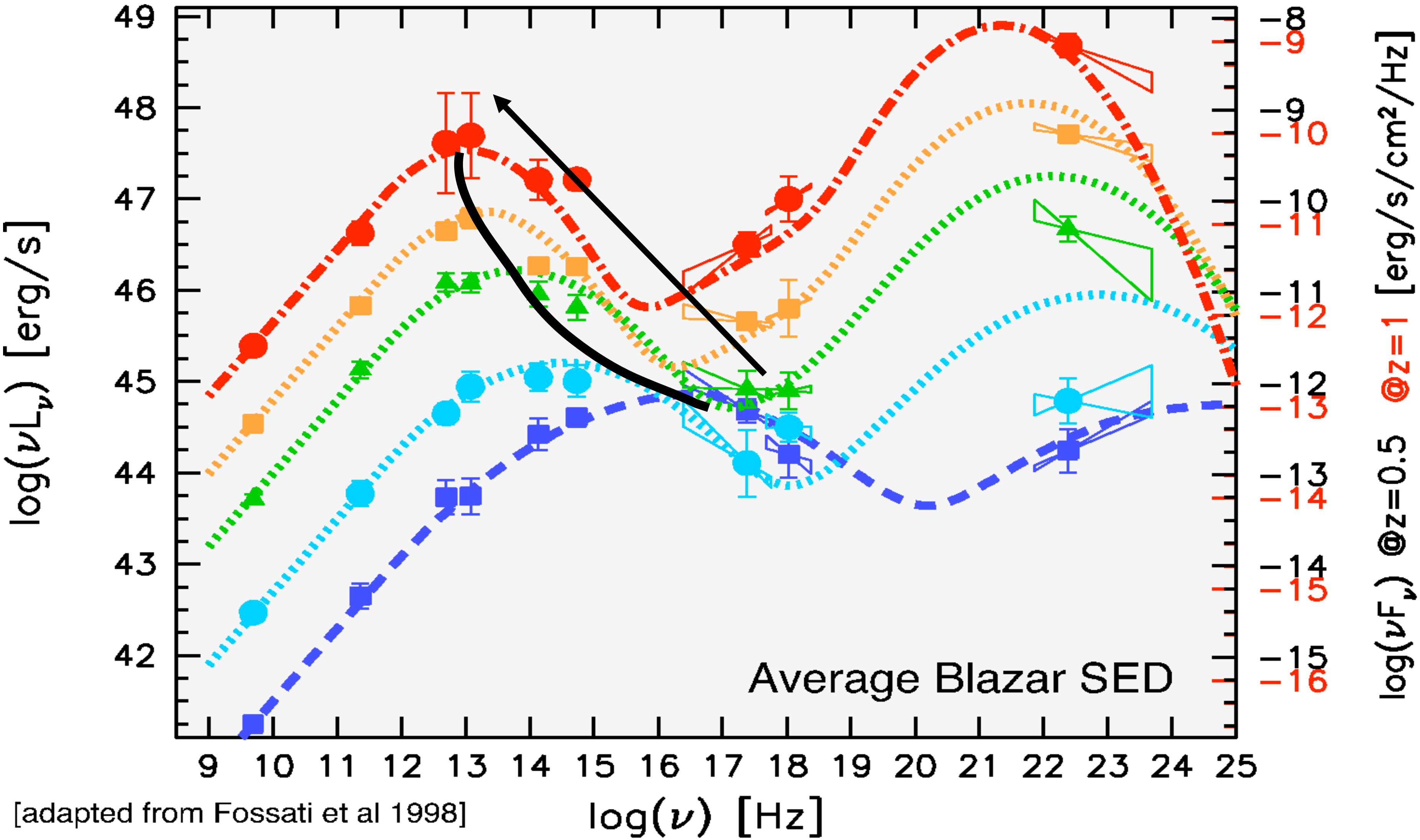
Low-frequency component from radio to UV/X-rays,

$\nu_{sy} > 10^{15}$ Hz

often dominating the total power

High-frequency component from hard X-rays to high-energy gamma-rays

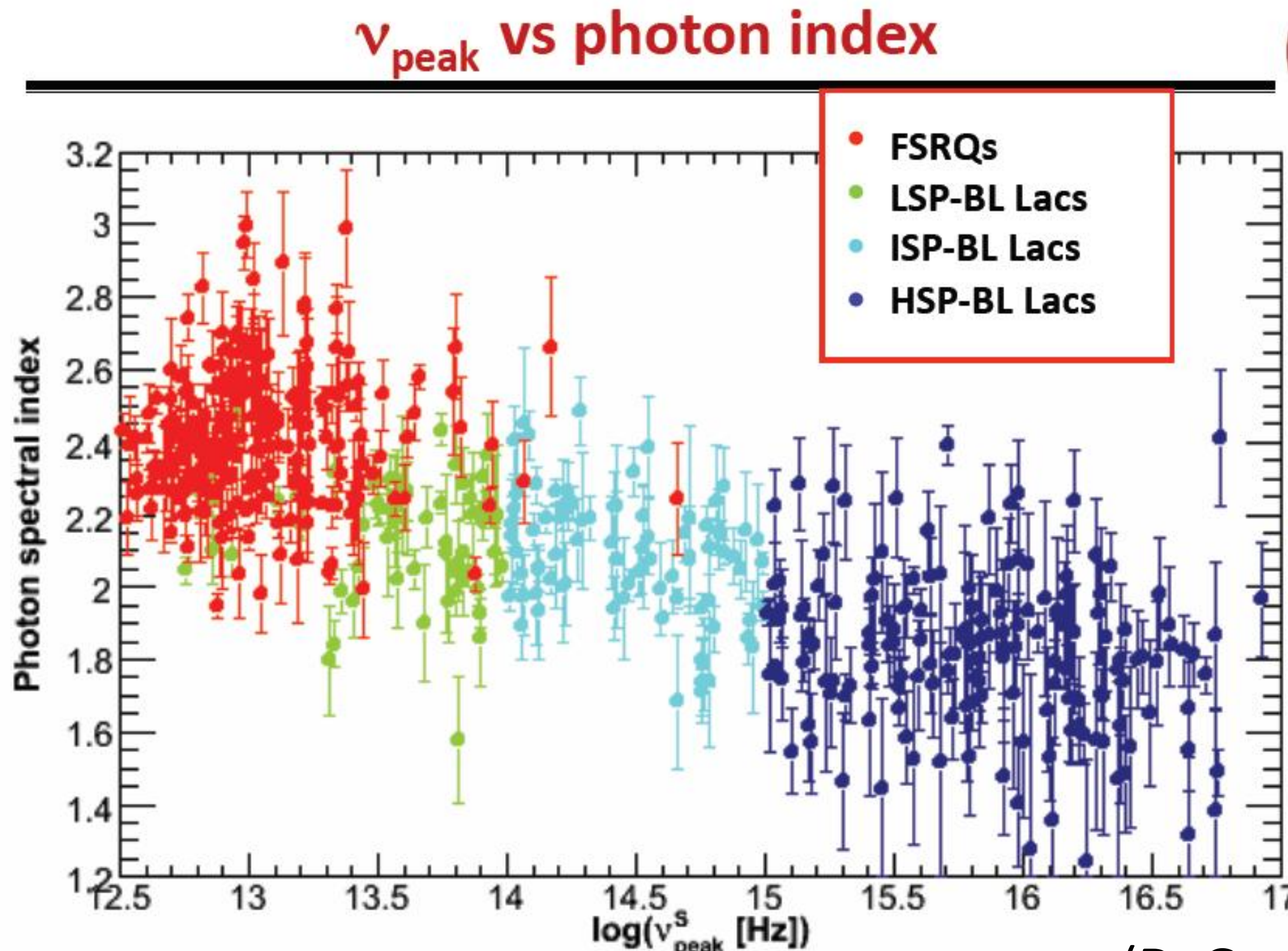
The Blazar Sequence (?)



[adapted from Fossati et al 1998]

(E. Meyer)

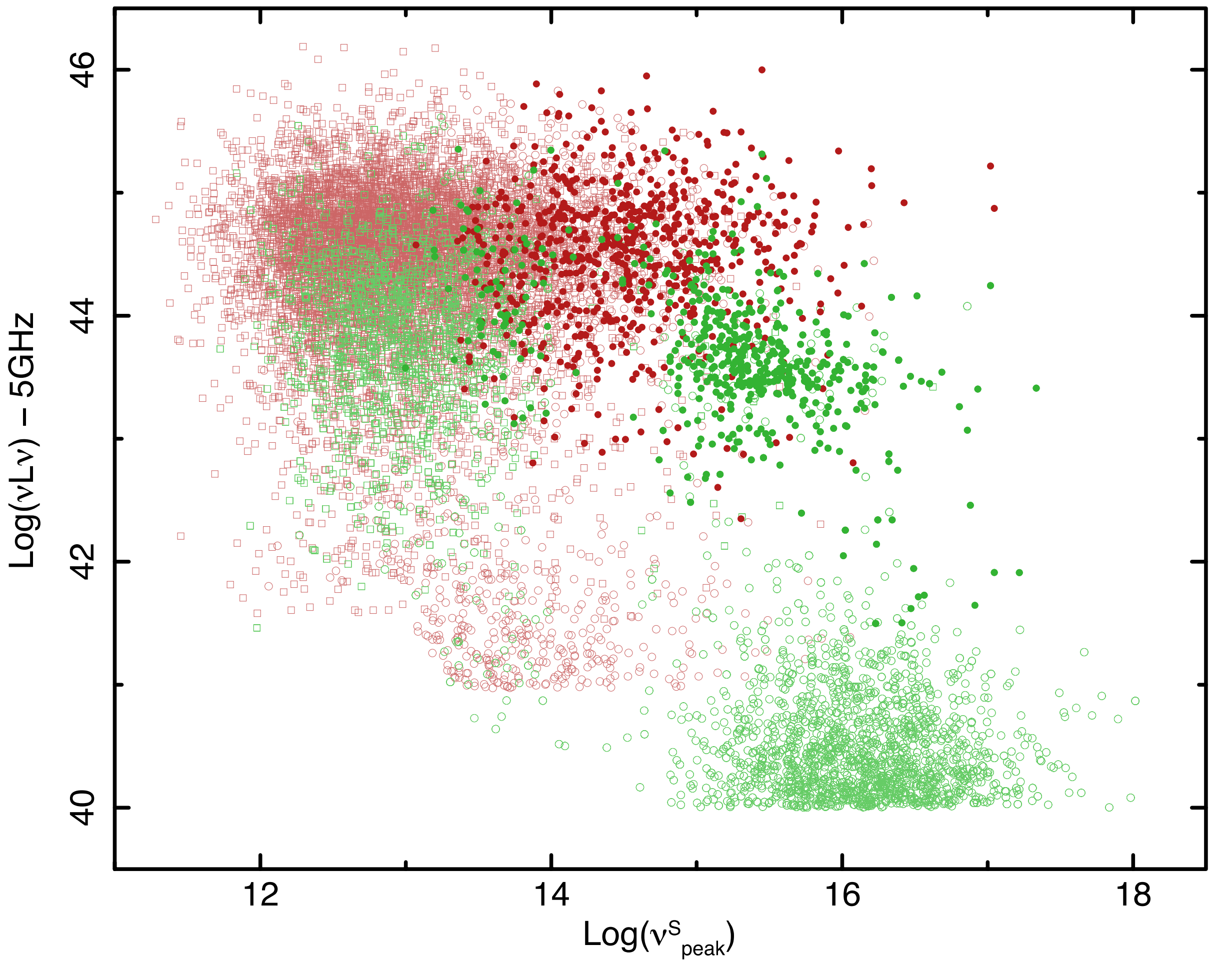
The Blazar Sequence (?)



(D. Gasparrini)

The Blazar Sequence (?)

Mostly Selection Effects (+ missing redshifts of powerful high-z blazars)



(P. Giommi)

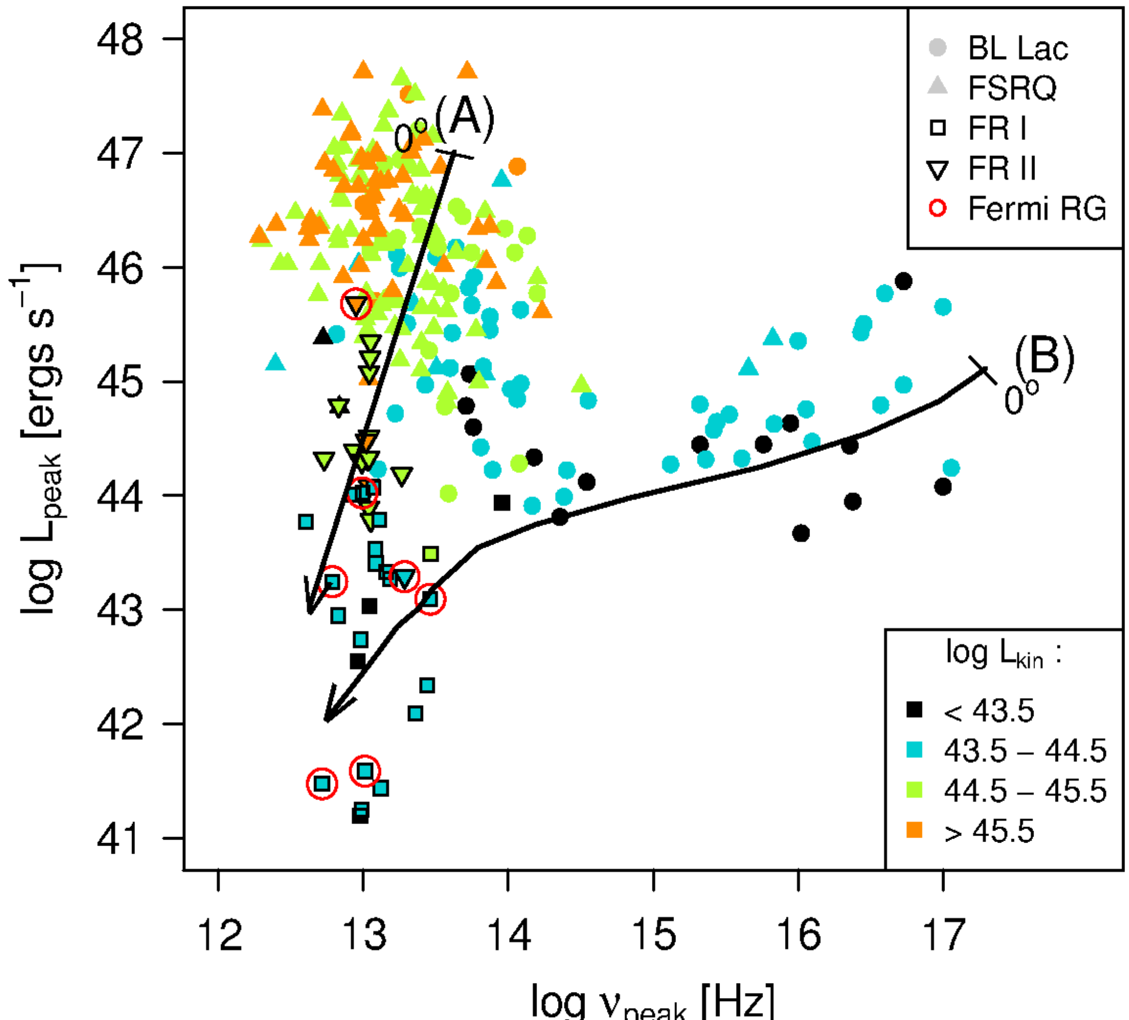
The Blazar Sequence (?)

- Two Branches:

(A) Strong (not decelerating) jets

(B) Weak (decelerating) jets

(E. Meyer)



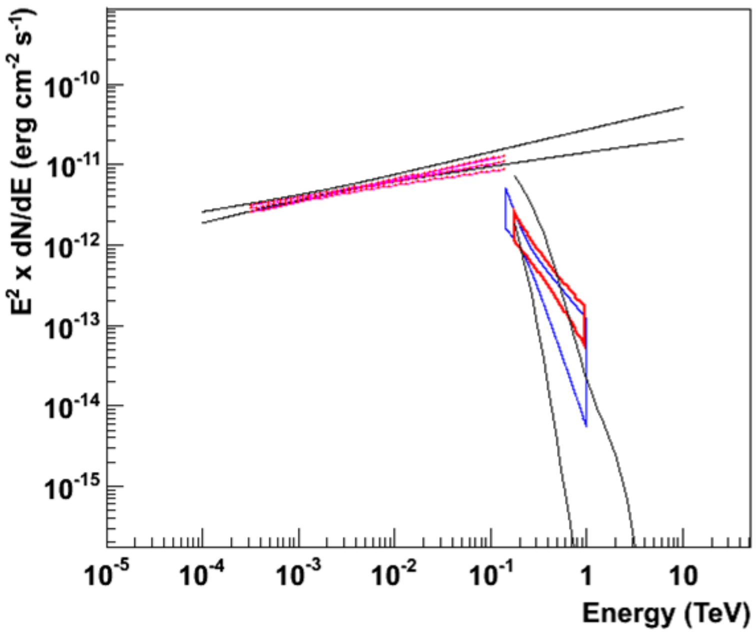
Newly/Recently Discovered VHE Blazars

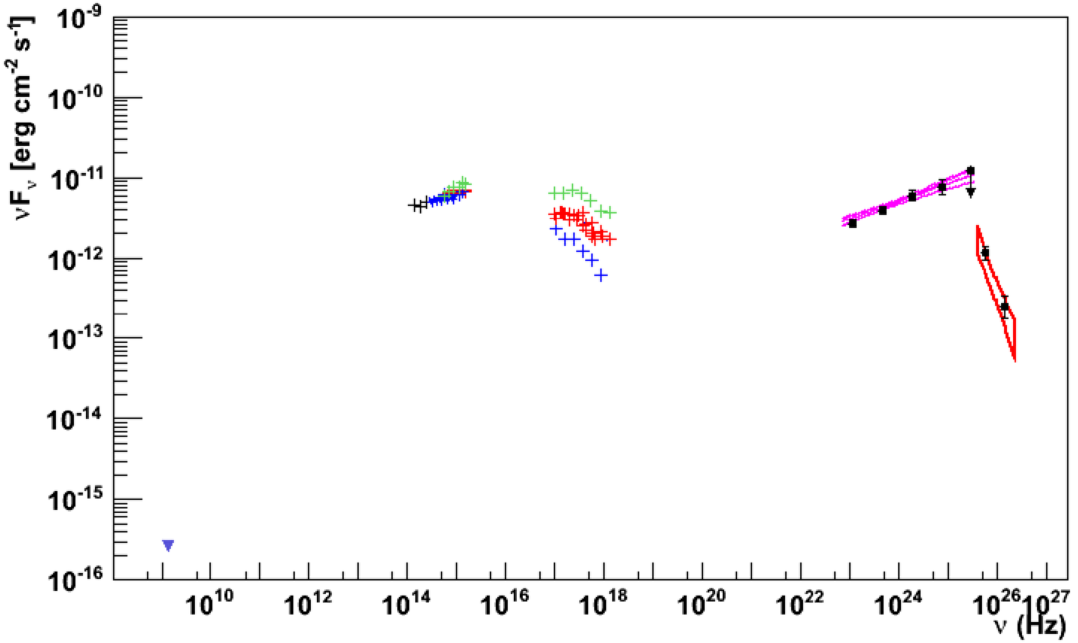
Object Name	Instrum.	Type	Redshift	Model	Author
1ES 0033+595	MAGIC	HBL	???	SSC	Uellenbeck
RGB J0521.8+2112	VERITAS	HBL	???	SSC	Galante
1ES 0502+576	VERITAS	HBL	???	SSC	Galante
1ES 1727+502	MAGIC	HBL	0.055	SSC	De Caneva
SHBL J001355.9-185406	H.E.S.S.	HBL	0.095	SSC	Sanchez
1ES 1312-423	H.E.S.S.	HBL	0.105	SSC	Biteau
1ES 1215+303	MAGIC	HBL	0.130	SSC	Sitarek
RX J0648.7+1516	VERITAS	HBL	0.179	SSC+EC / hadr.	Benbow
RBS 0413	VERITAS	HBL?	0.190	SSC+EC / hadr.	Benbow
PKS 0301-243	MAGIC	HBL	0.26	?	Wouters
RGB J0136+3905	MAGIC	HBL	>0.4	?	Mazin
KUV 00311-1938	H.E.S.S.	HBL	> 0.51 (0.61?)	?	Becherini

Most distant VHE BL Lac object (even most distant VHE blazar?) ever detected!

KUV 00311-1938

HBL at z > 0.51 (possibly z = 0.61).
Most distant VHE BL Lac object ever detected



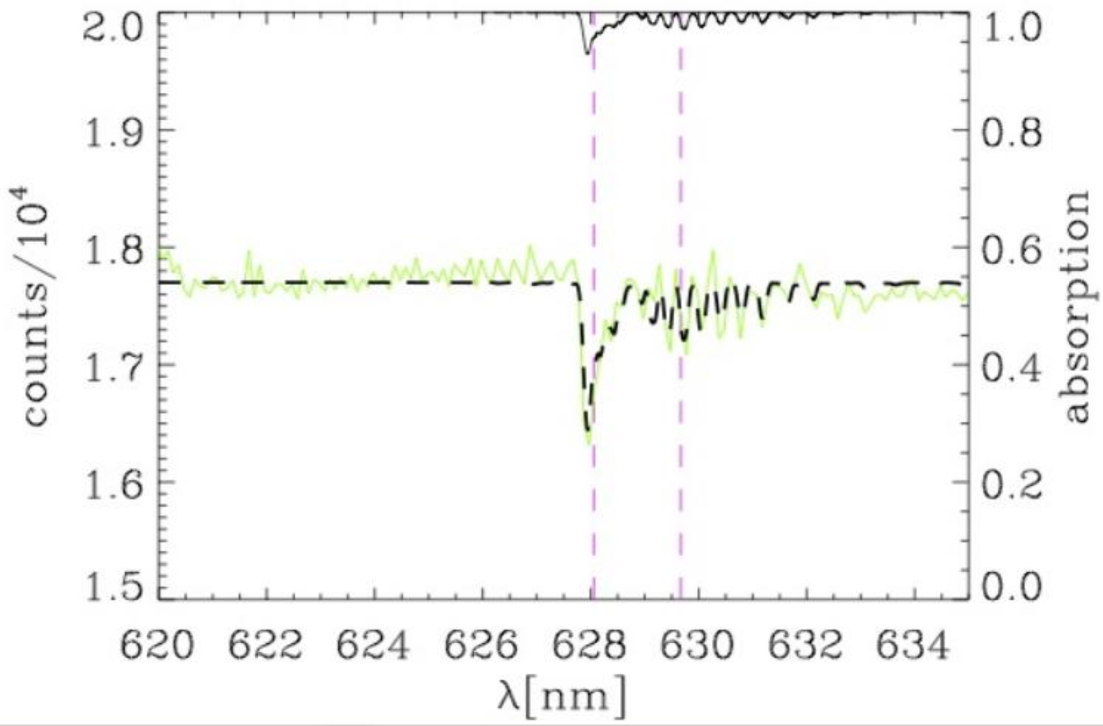


Extrapolation of Fermi spectrum after EBL absorption
consistent with H.E.S.S. spectrum for z = 0.61.

(Y. Becherini)

PKS 0447-439

Claimed redshift of z > 1.246 incorrect!

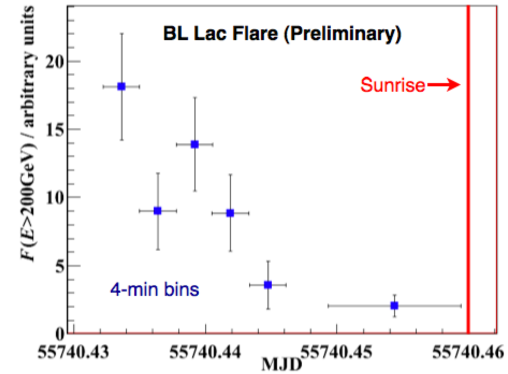


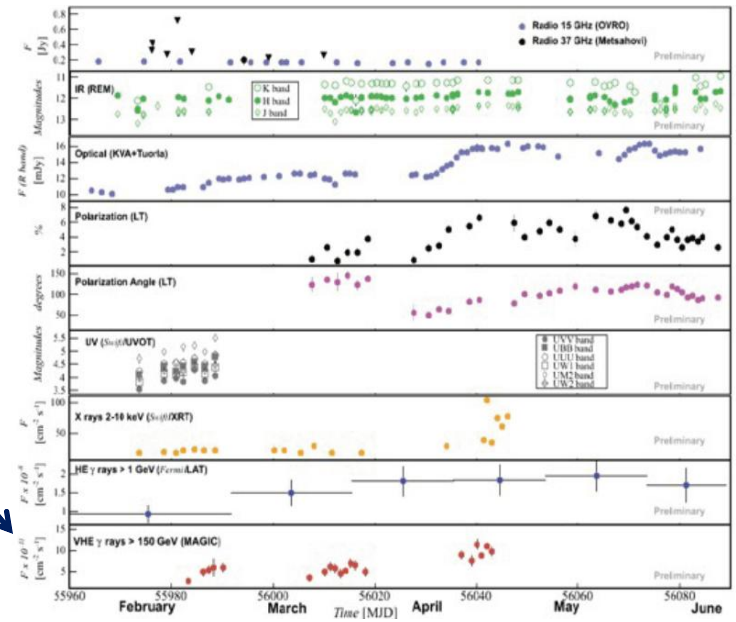
Ca II H&K and Na I D lines indicate z = 0.273.

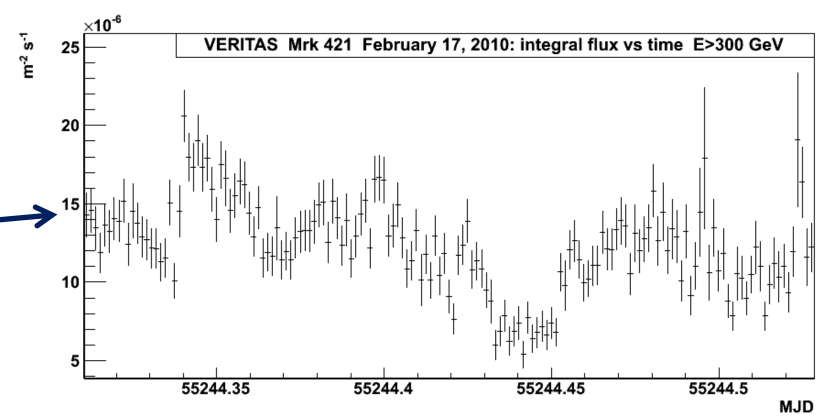
(Pita et al.)

News on Known VHE Blazars

- VHE + GeV Flare of BL Lacertae (Galante)
- Variability seen in 1ES 0806+524 (Schultz)
- High State of PG 1553+113 (Becerra-Gonzalez)
- MAGIC detects PKS 1510-089, no re-detection of 3C279 (de Caneva)
- IBLs (3C66A, W Comae) detected in low state (Fortson)
- VERITAS detects 1ES 1215+303 (Prokoph)
- Minute-scale variability in Mrk 421 (Galante)







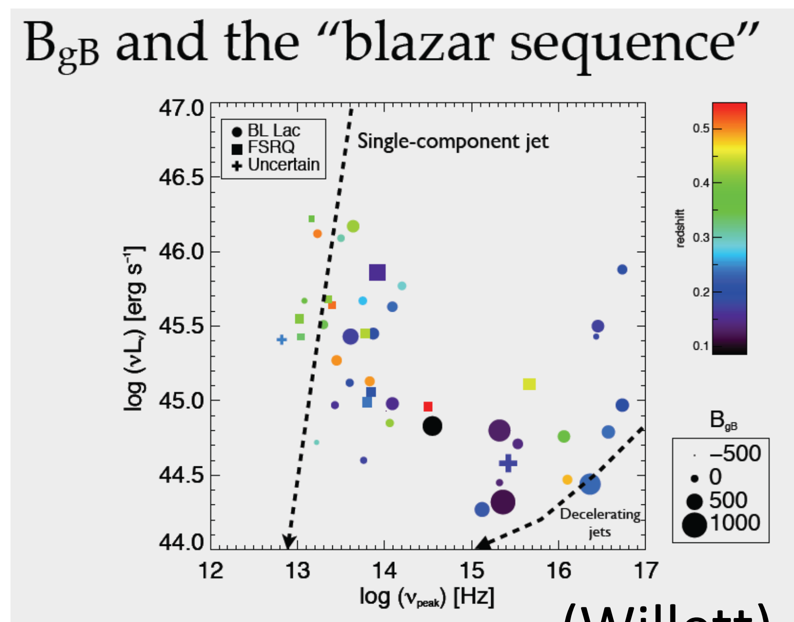
News on AGN Population Studies

- Comparing BL Lac beaming statistics to the FRI population -> Complex jet structure is required (Gerard)

- Fermi FSRQs have systematically smaller M_{BH} ⇔ higher L/L_{Edd} than optically selected quasars (Shaw)

- Fermi spectral break in many FSRQs variable in time (magnitude and break energy!) -> not consistent with double-absorber model (Harris)

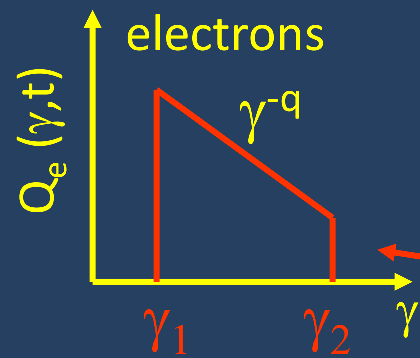
- "Weak jets" seem to prefer rich cluster environments (Willett)



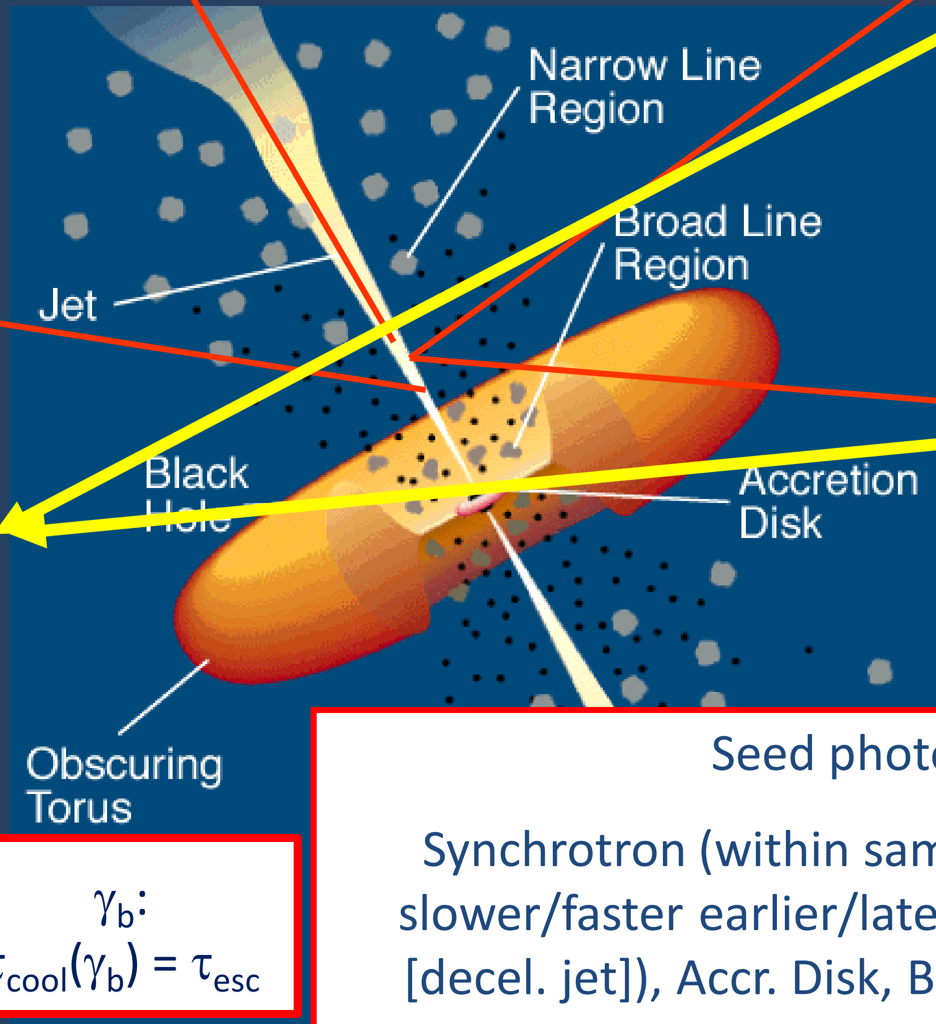
(Willett)

Leptonic Blazar Models

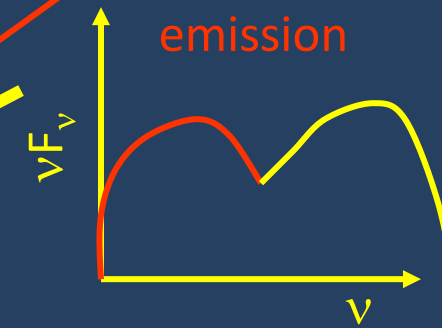
Injection, acceleration of ultrarelativistic electrons



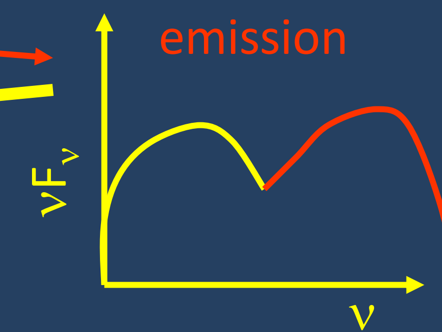
Relativistic jet outflow with $\Gamma \approx 10$



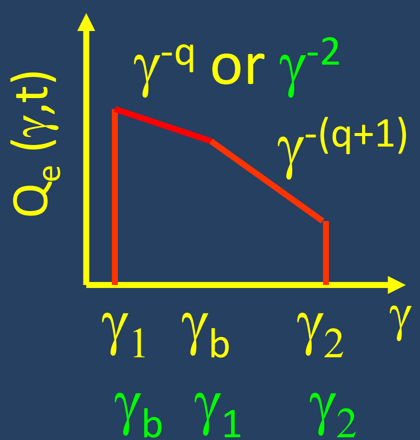
Synchrotron emission



Compton emission



Radiative cooling ↔ escape =>



γ_b:
$\tau_{cool}(\gamma_b) = \tau_{esc}$

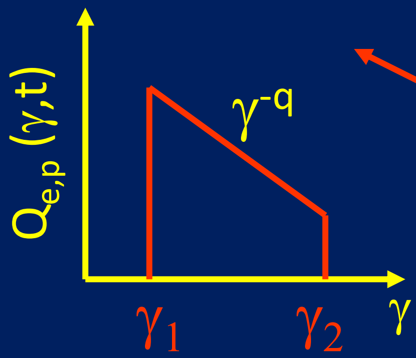
Seed photons:

Synchrotron (within same region [SSC] or slower/faster earlier/later emission regions [decel. jet]), Accr. Disk, BLR, dust torus (EC)

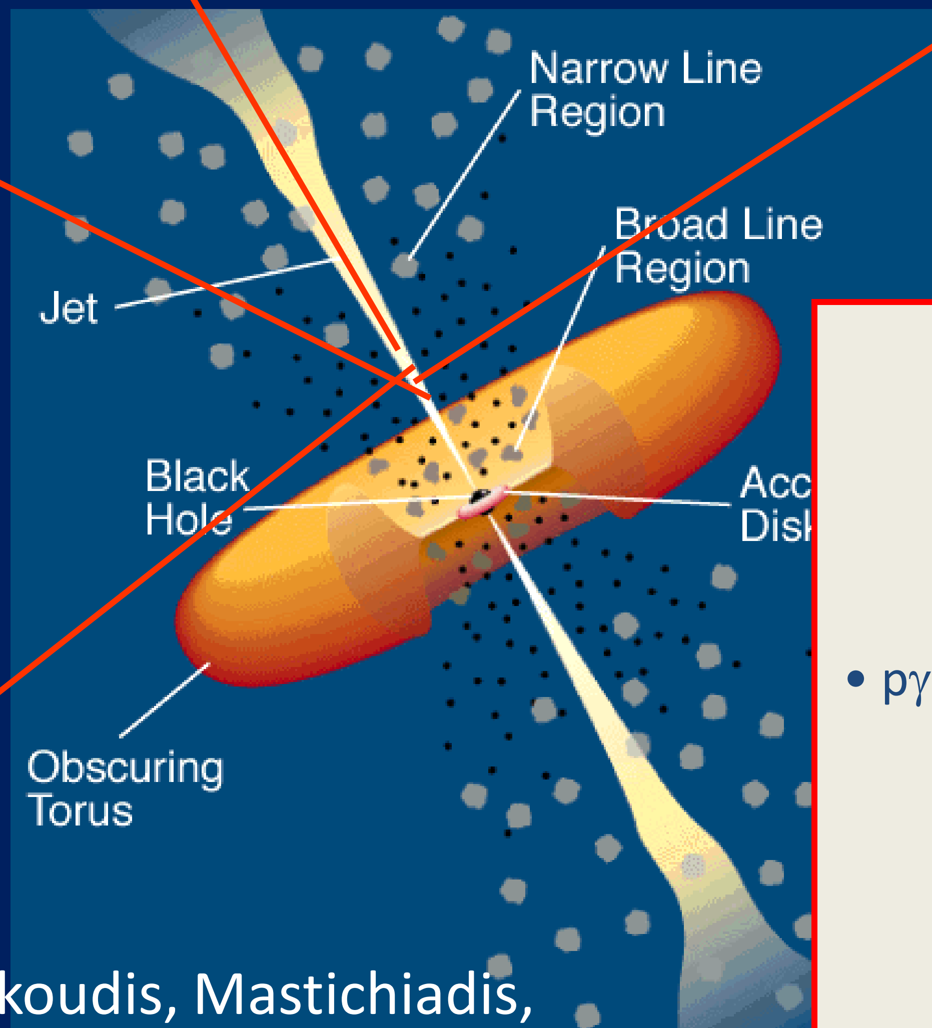
(Fossati, Georganopoulos, Lefa, Menzler, Prandini, Sun, Tammi, Tramacere, Villaume, Zacharias)

Hadronic Blazar Models

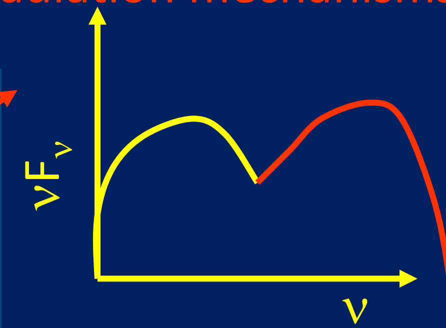
Injection, acceleration of ultrarelativistic electrons and protons



Relativistic jet outflow with $\Gamma \approx 10$

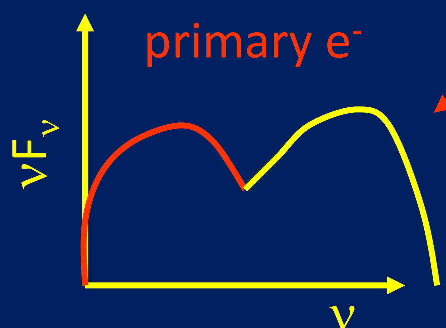


Proton-induced radiation mechanisms:



- Proton synchrotron
- $p\gamma \rightarrow p\pi^0$
  $\pi^0 \rightarrow 2\gamma$
- $p\gamma \rightarrow n\pi^+ ; \quad \pi^+ \rightarrow \mu^+\nu_\mu$
  $\mu^+ \rightarrow e^+\nu_e\overline{\nu_\mu}$
  $\rightarrow$ secondary μ-, e-synchrotron
- Cascades …

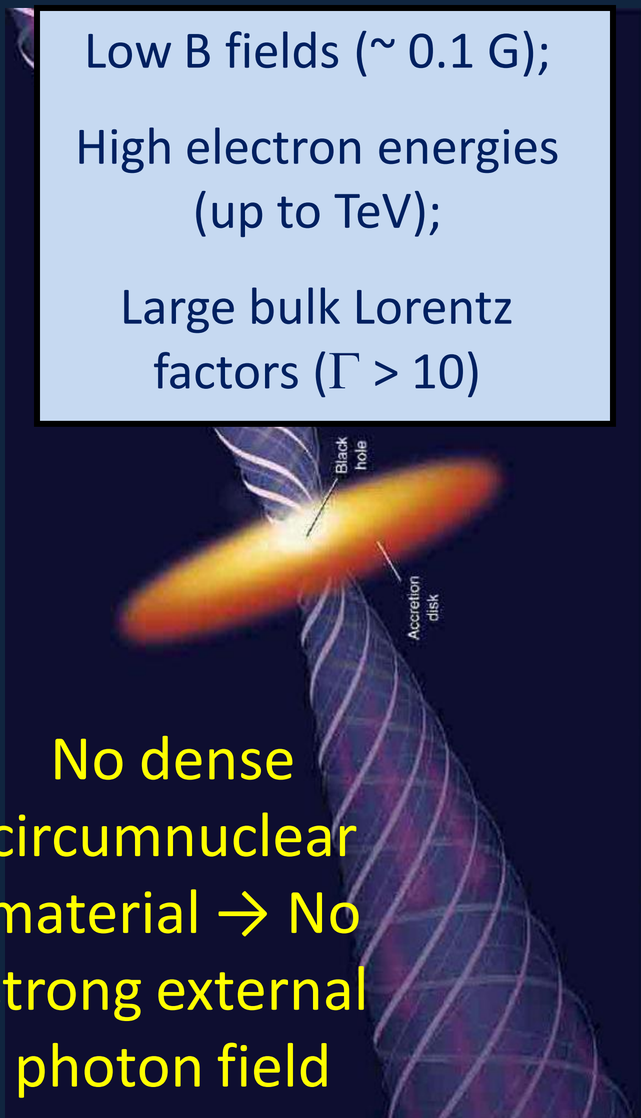
Synchrotron emission of primary e^-



(Cerutti, Dimitrakoudis, Mastichiadis, Petropoulou, Reimer)

Spectral modeling results along the Blazar Sequence: Leptonic Models

High-frequency peaked BL Lac (HBL):



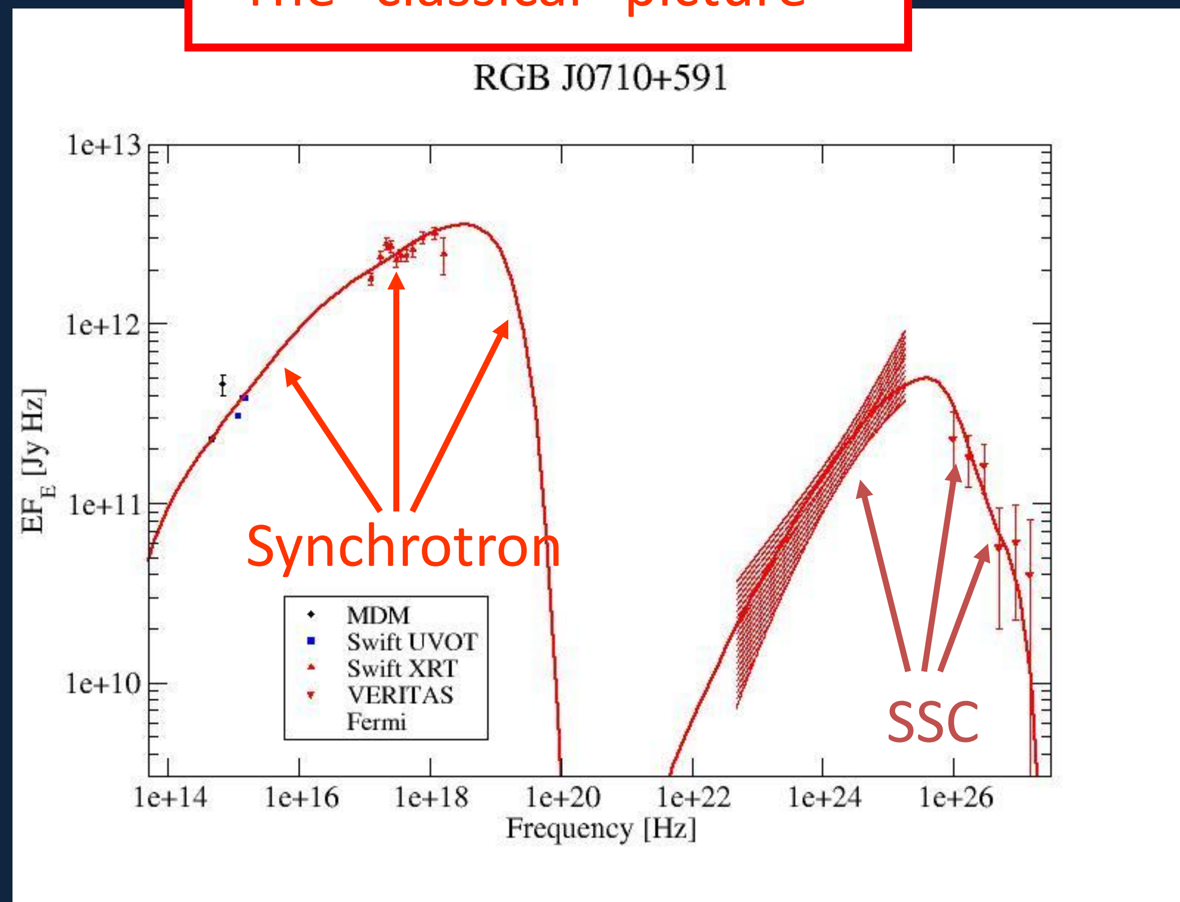
Low B fields (~ 0.1 G);

High electron energies (up to TeV);

Large bulk Lorentz factors (Γ > 10)

No dense circumnuclear material → No strong external photon field

The "classical" picture



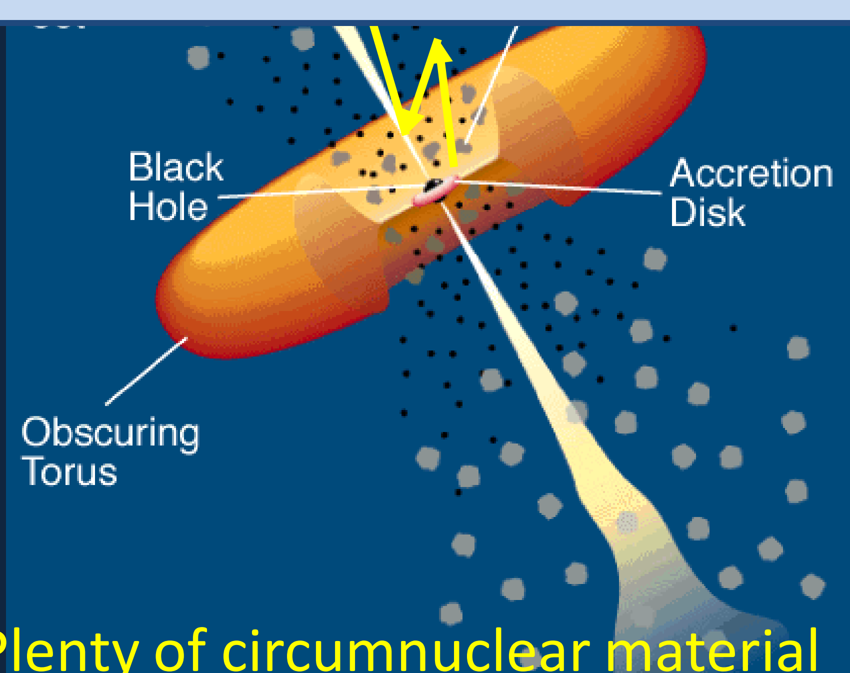
Spectral modeling results along the Blazar Sequence: Leptonic Models

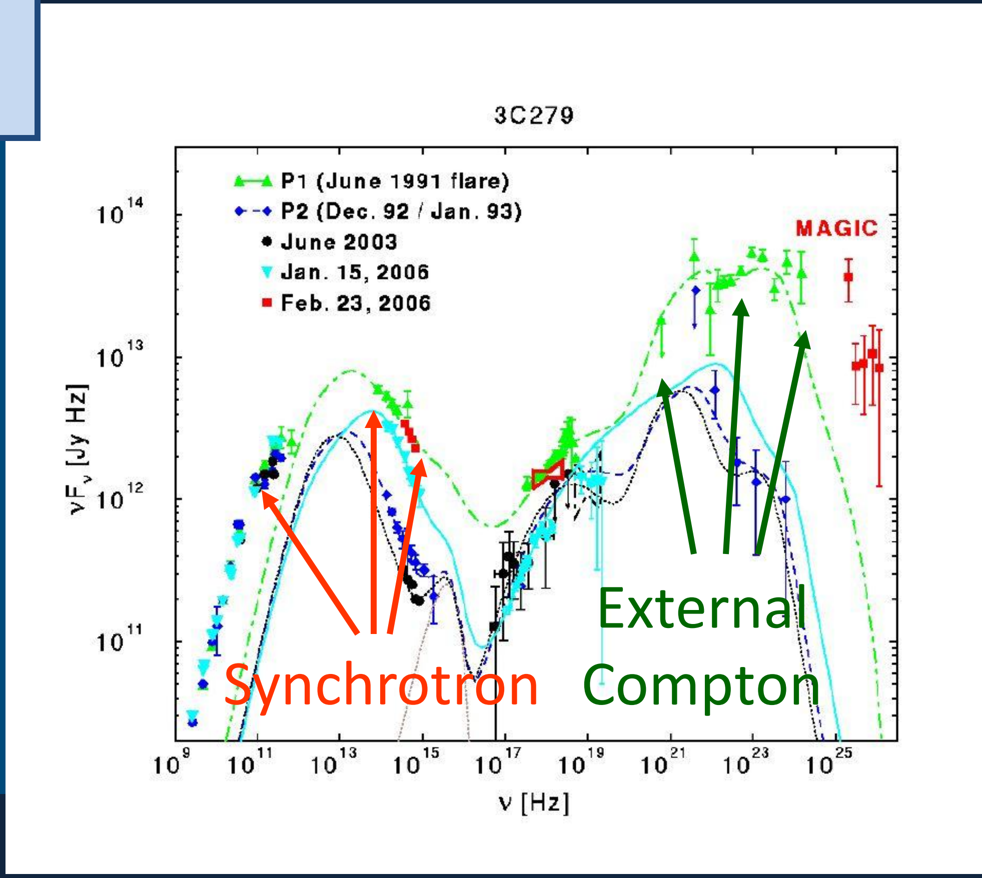
High magnetic fields (~ a few G);

Lower electron energies (up to GeV);

Lower bulk Lorentz factors (Γ ~ 10)

Radio Quasar (FSRQ)





Plenty of circumnuclear material

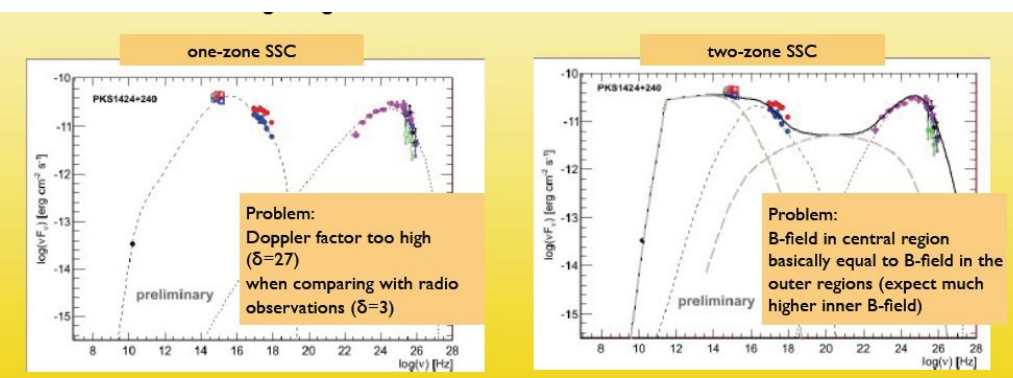
→ Strong external photon field

Challenges to One-Zone Models

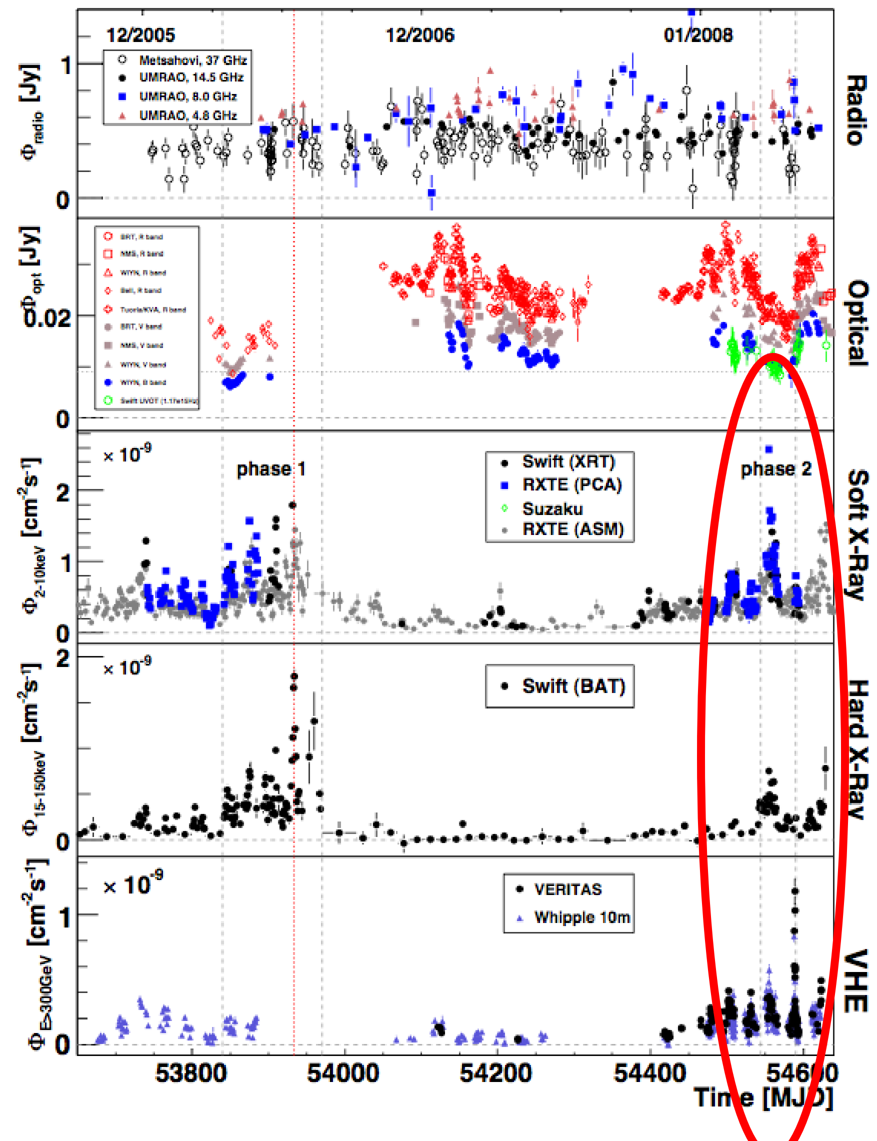
- Uncorrelated X-ray / γ-ray variability
  - Mrk 421: Fortson
  - Mrk 501: Nowak – VHE high state correlated with optical polarization

- 1ES 1959+650: Two-component GeV – TeV spectrum: not well fit by SSC + EC or hadronic or γγ-absorption (Backes)

- Modeling of PKS 1424+240 not consistent with one-zone models (Prandini)



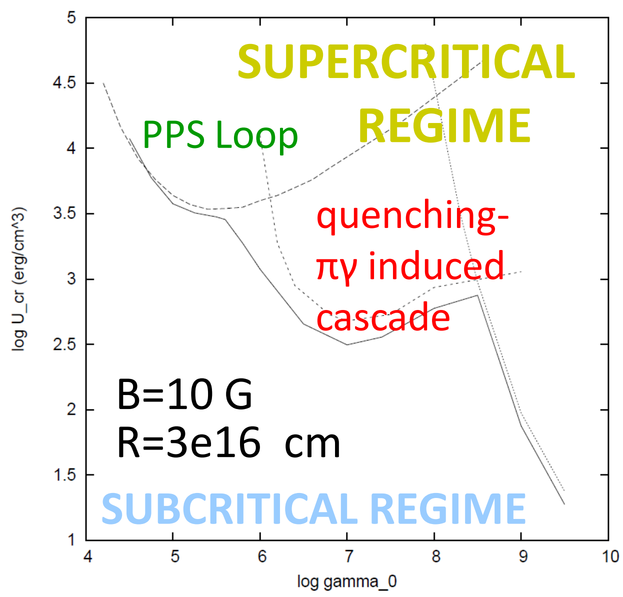
Mrk 421 (L. Fortson)



New Model Ideas and Developments

- Hadronic models: Need to include self-consistent proton cooling on sedoncary-particle synchrotron emission! (Mastichiadis)
- Beware of photon quenching by $\gamma\gamma$-absorption in hadronic models (Petropolou)

  -> Lower limit on Doppler factor δ ~ 20 for 3C279.



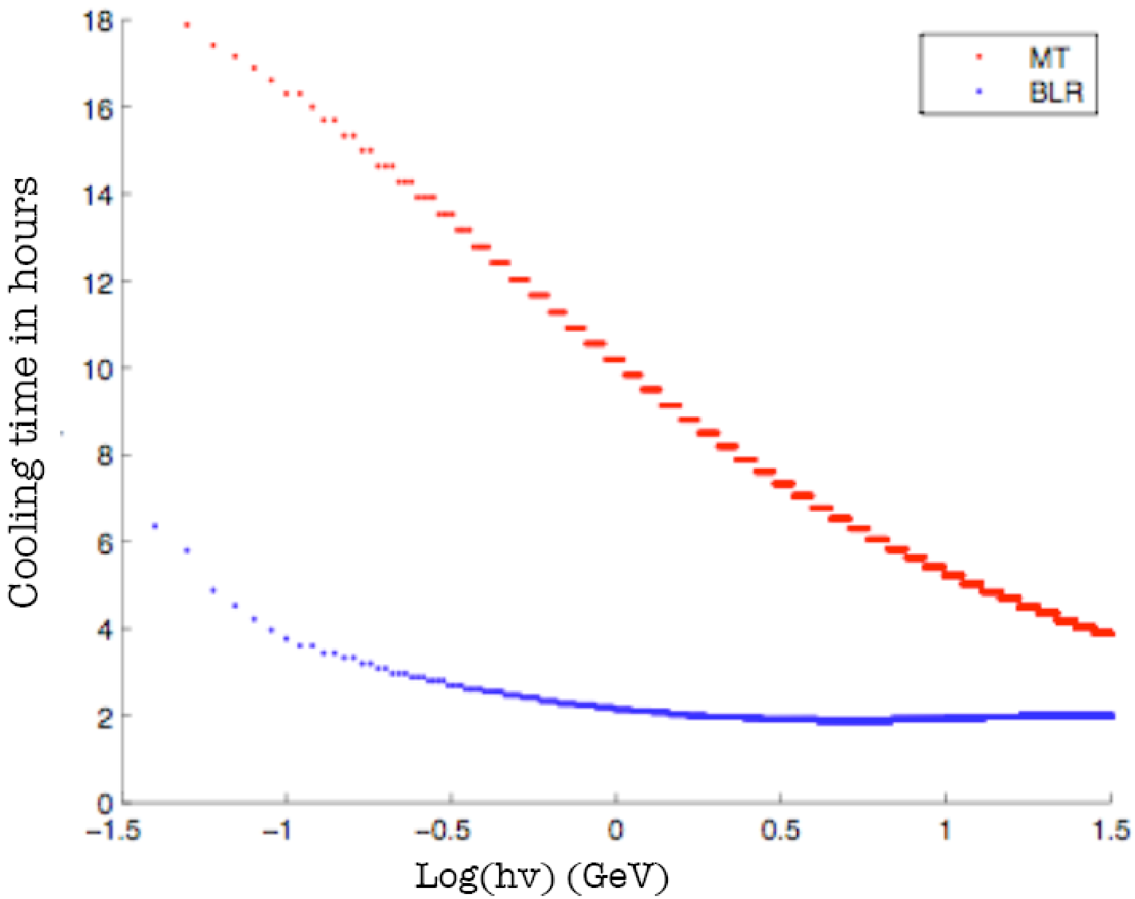
- Hadronic Models become time-dependent (Dimitrakondis, Reimer)

  -> Uncorrelated X-ray / γ-ray variability possible!

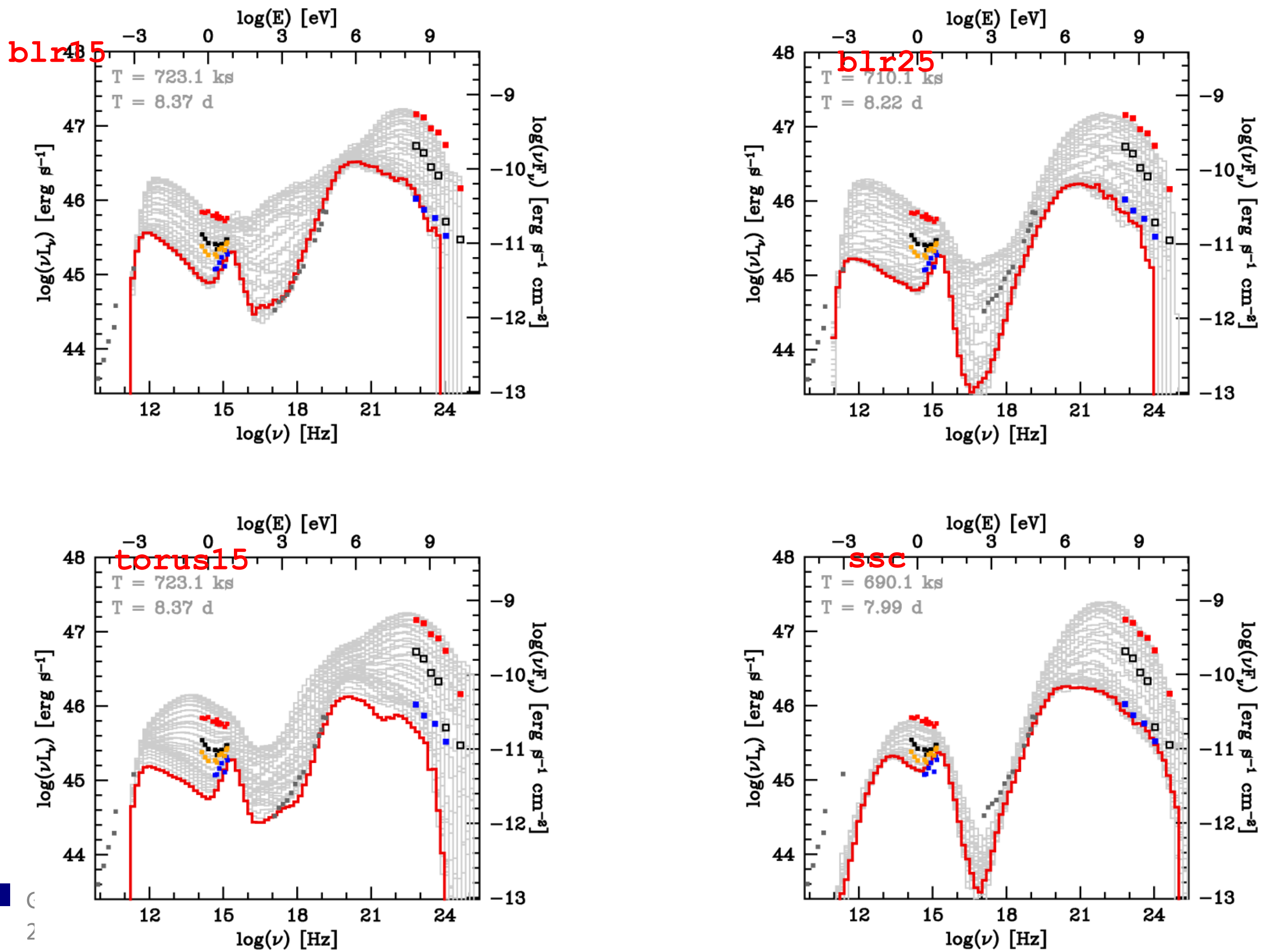
New Model Ideas and Developments

- From beaming: Powerful jets are EC dominated;

  From energy depencence of cooling times: Distinguish between EC on IR (torus) and optical/UV lines (BLR) (Georganopoulos)



Time-dependent SSC + EC Monte-Carlo simulations: PKS 1510-089 (Fossati, Chen)



New Model Ideas and Developments

- High-energy emission and variability from jet-star interactions.
  - 3C454.3 flare reproduced with $L_j \sim 10^{49}$ erg/s; $\delta \sim 60$ (Barkov).
  - Jet-stellar wind interaction produces double bow shock (Araudo)

- Log-parabolic spectra are the natural result of stochastic particle acceleration: Curvature related to momentum diffusion coefficient (Tramacere).

  -> Quasi-Maxwellian electron distrituion -> Hard VHE γ-ray spectra in several VHE blazars (Lefa)

- SSC-dominated compact emission regions can produce FSRQ-like blazar SEDs <-> non-linear electron cooling (Zacharias)

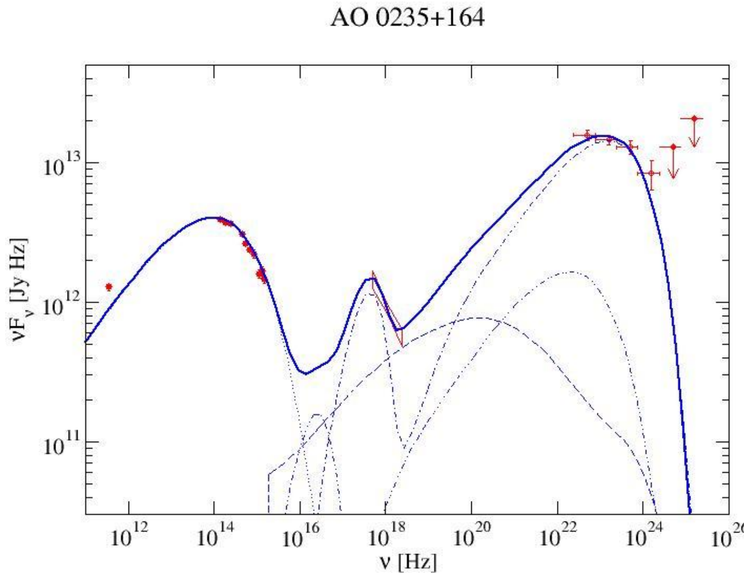
- Consider high-energy (X-/γ-ray) polarization in blazar models (Menzler).

- Magnetic reconnection (Cerutti) or shear flows (MB, Liang) may produce anisotropic particle distributions, ordered magnetic fields -> overcome Doppler factor crisis.

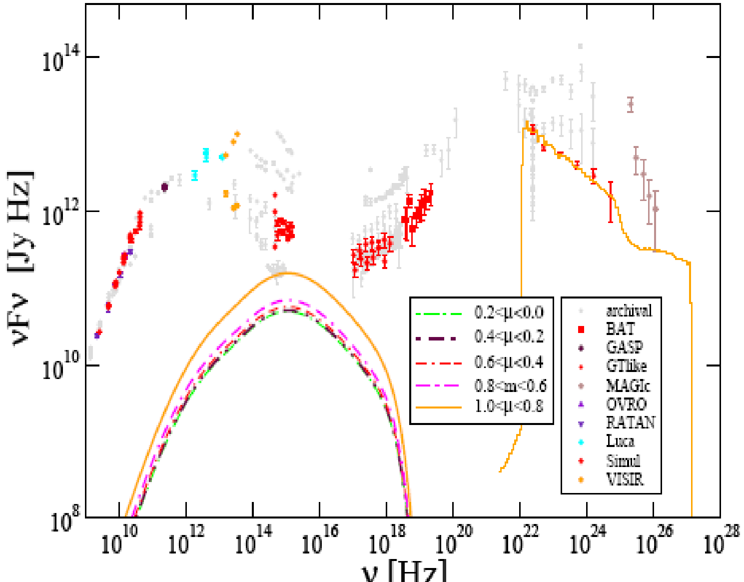
New Model Ideas and Developments

The Big Blue Bump:

- Bulk Compton? Self-consistent shock-acceleration simulations to find thermal vs. non-thermal populations. (MB, M. Baring)



- Synchrotron emission from VHE γ-ray induced pair cascades? (P. Roustazadeh)



Non-Blazar AGN

Radio Galaxies

Name	Type	Distance	MeV/GeV detection	VHE	Notes
Cen A	FR I	3.7 Mpc	EGRET, LAT 2010	✔	Fermi: Core/lobes
M87	FR I	16 Mpc	LAT 2009	✔	TeV 1d-variability
Fornax A	FR I	18 Mpc	LAT 2011		
Cen B	FR I	56 Mpc	LAT 2011		
NGC 1275	FR I	75 Mpc	LAT 2009	✔	**; jet precession; LAT days-variability***
IC 310	FR1 head-tail	80 Mpc	LAT 2010	✔	Neronov+2010; VHE yr-variability
NGC 6251	FR I	106 Mpc	EGRET, LAT 2010		
3C 78	FR I	124 Mpc	LAT 2010*		
3C 120	FR I	142 Mpc	LAT 2010*		BLRG
3C 111	FR 2	213 Mpc	EGRET, LAT 2010*		BLRG
PKS 0943-76	FR 2	1360 Mpc	LAT 2010		
......					

(Rieger)

Non-Blazar AGN
Radio Galaxies

M 87

Extensive MWL campaign over several years:

VHE: VERITAS, MAGIC, HESS

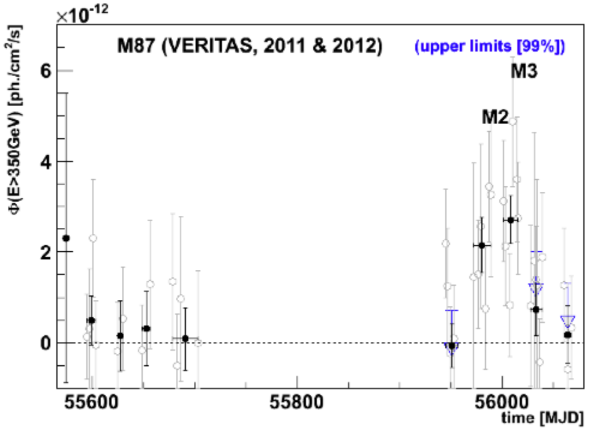
HE: Fermi

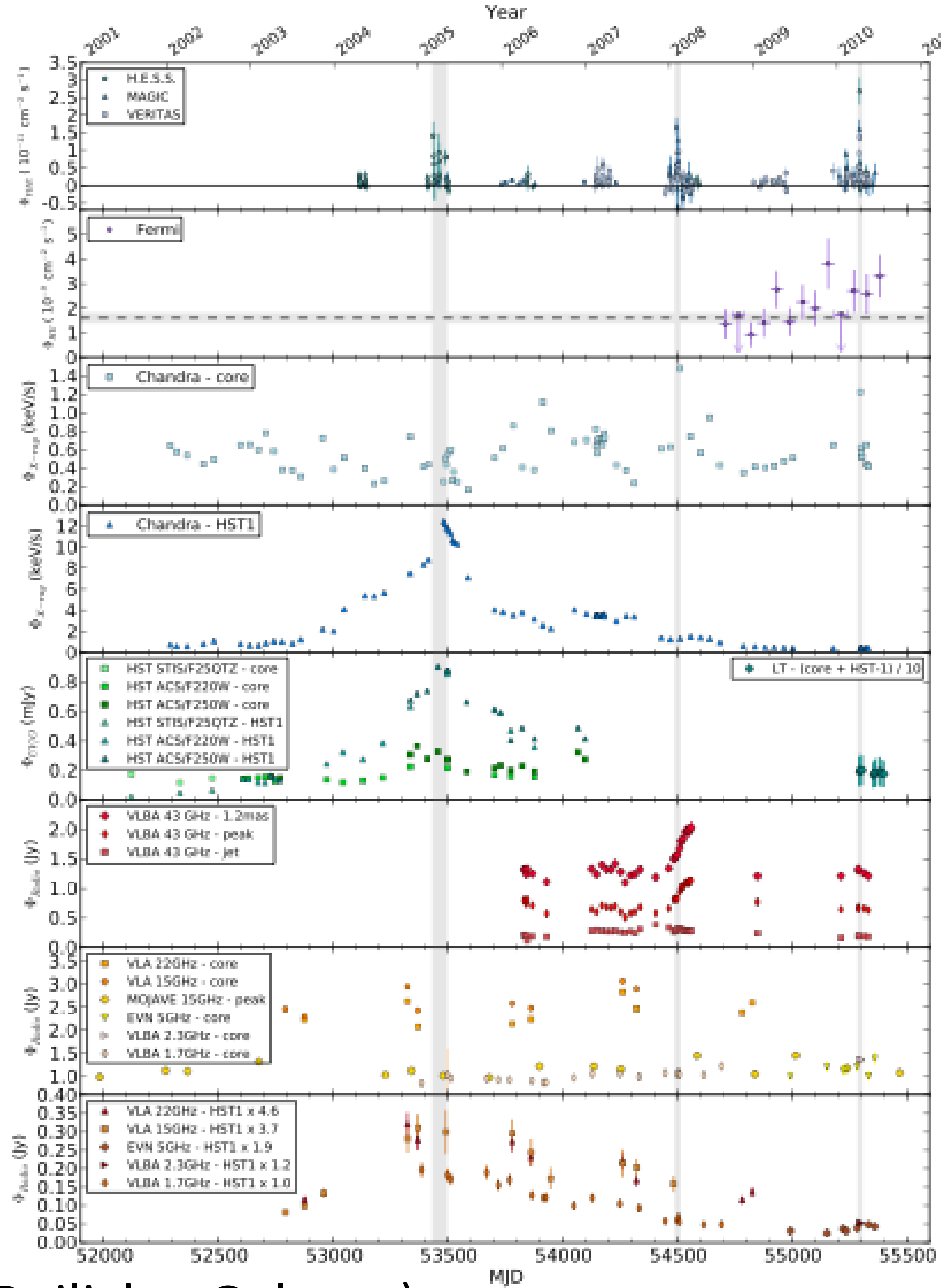
X-ray: Chandra

Optical: HST, Liverpool Telescope

Radio: VLBA,VLA, EVN, Mojave (VLBA)

3 flaring episodes (maybe 4)



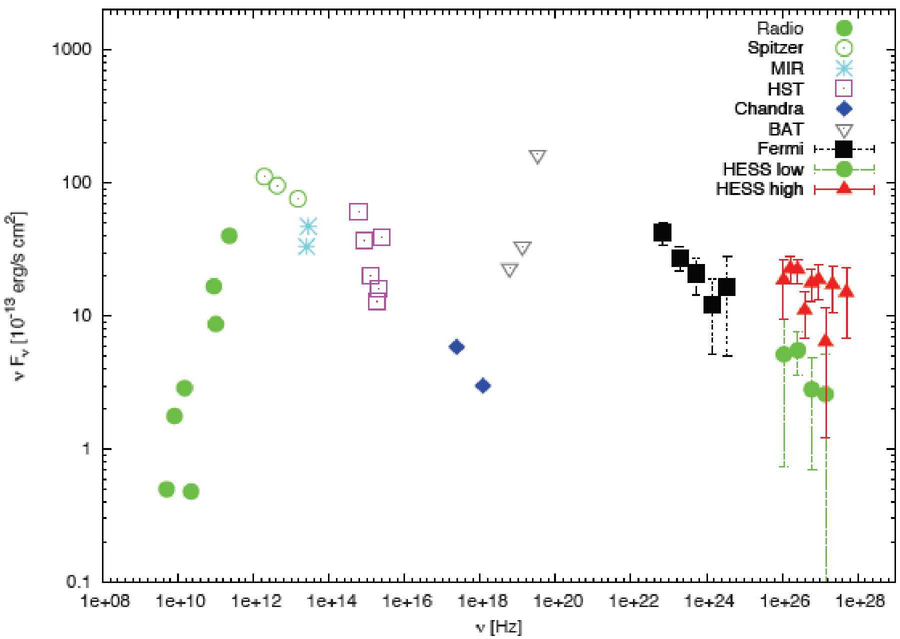


(Beilicke, Galante)

Radio Galaxies

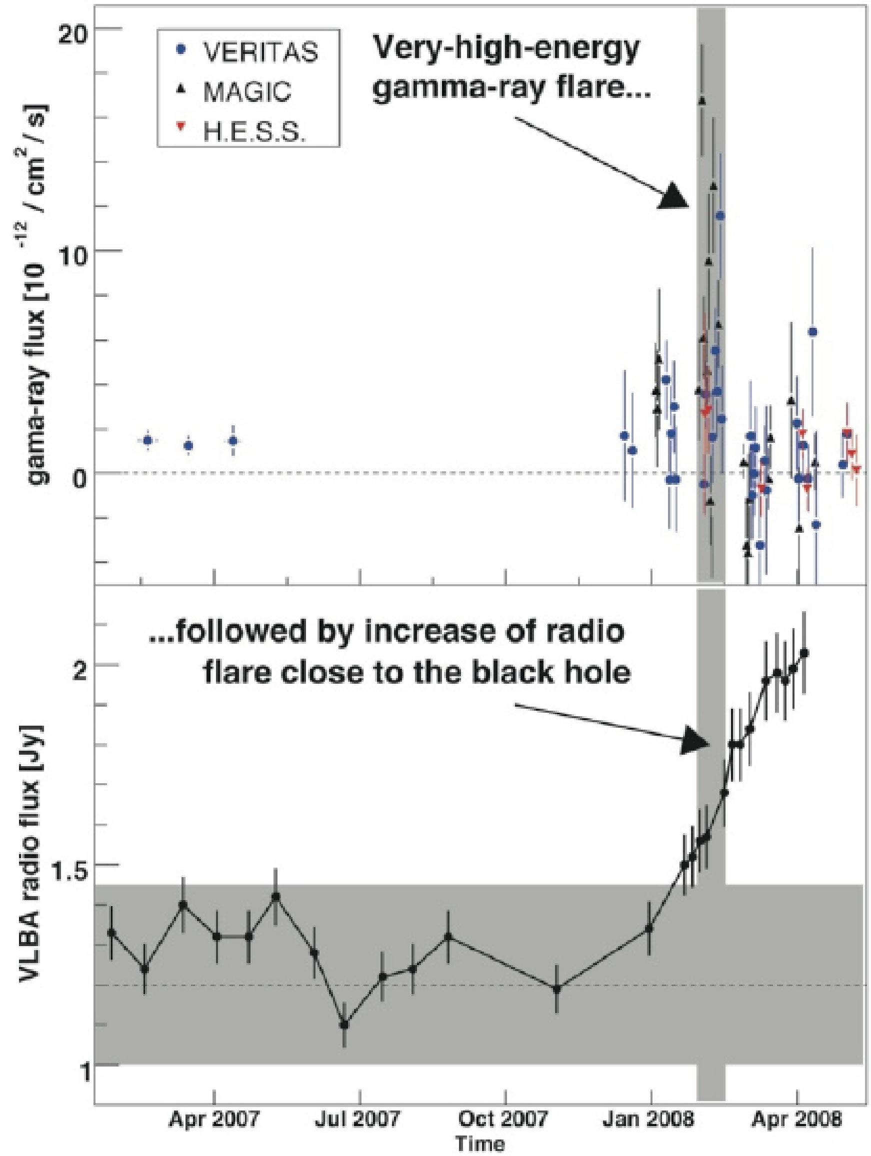
M 87

TeV-only flare poses challenges to one-zone (SSC) models



Possible models:

- Magnetic reconnection
- Jet-Star interaction
- BH Magnetospheric acceleration



Acciari+ 09, Science 325

(Rieger)

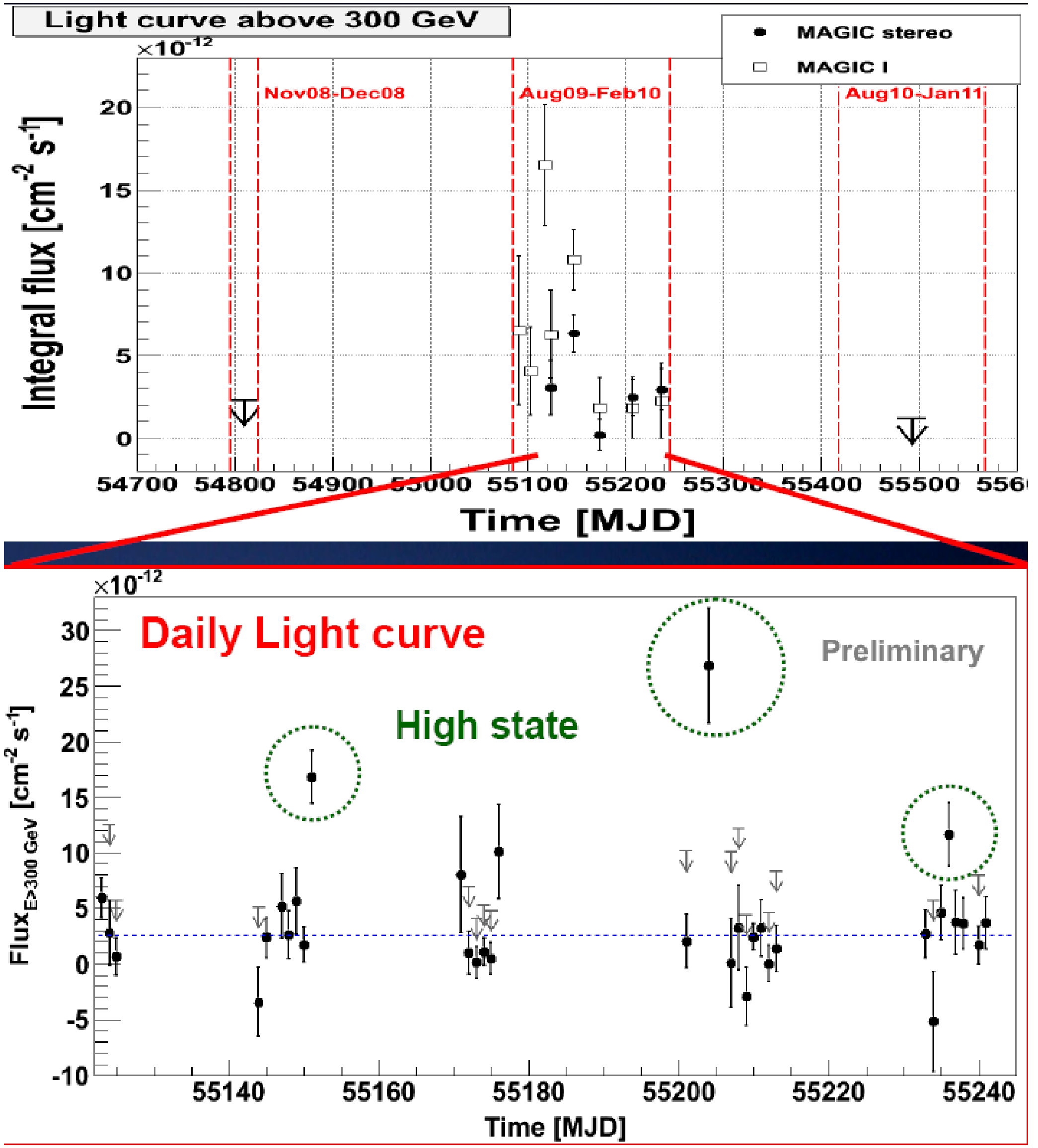
Radio Galaxies

IC 310

Originally classified as head-tail radio galaxy.

Rapid variability + VLBA structure suggest blazar-like properties!

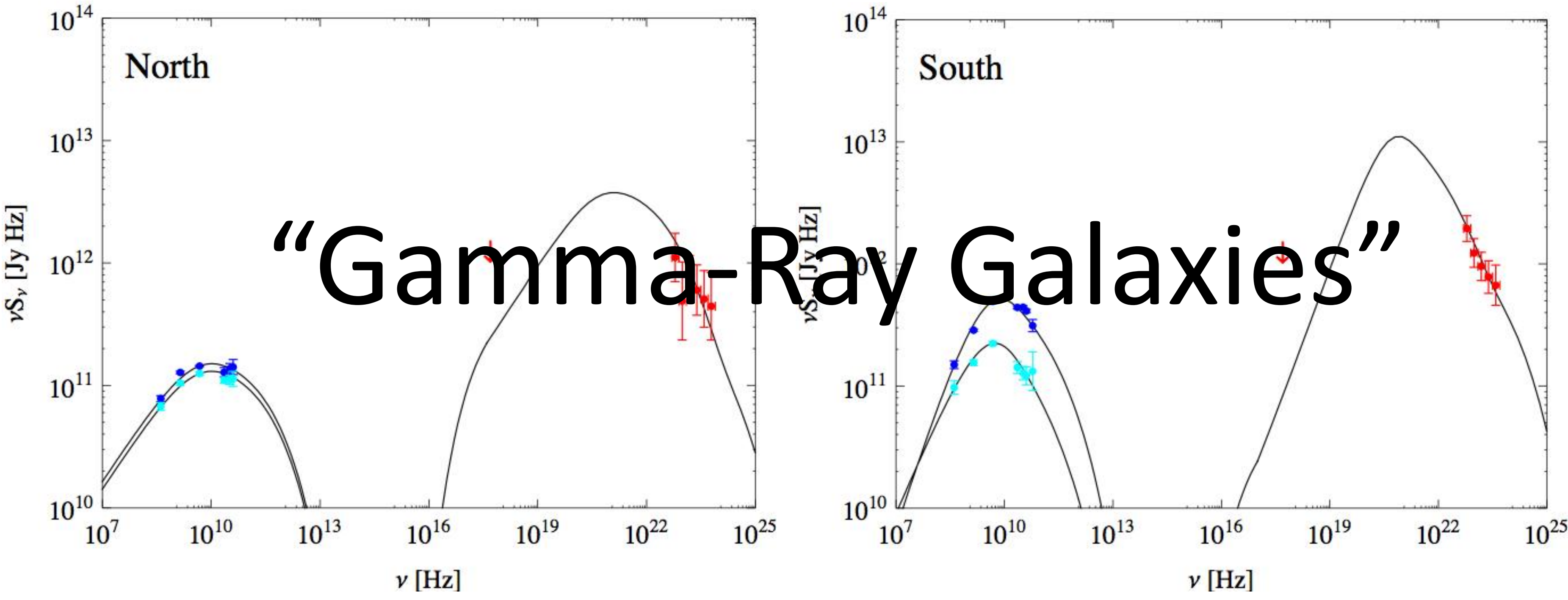
(D. Eisenacher, P. Colin)



Radio Galaxies

Cen A

γ-ray emission from IC on CMB, EBL and galaxy light =>
Good fits with B ~ 0.1 nT; giant lobes close to equipartition!



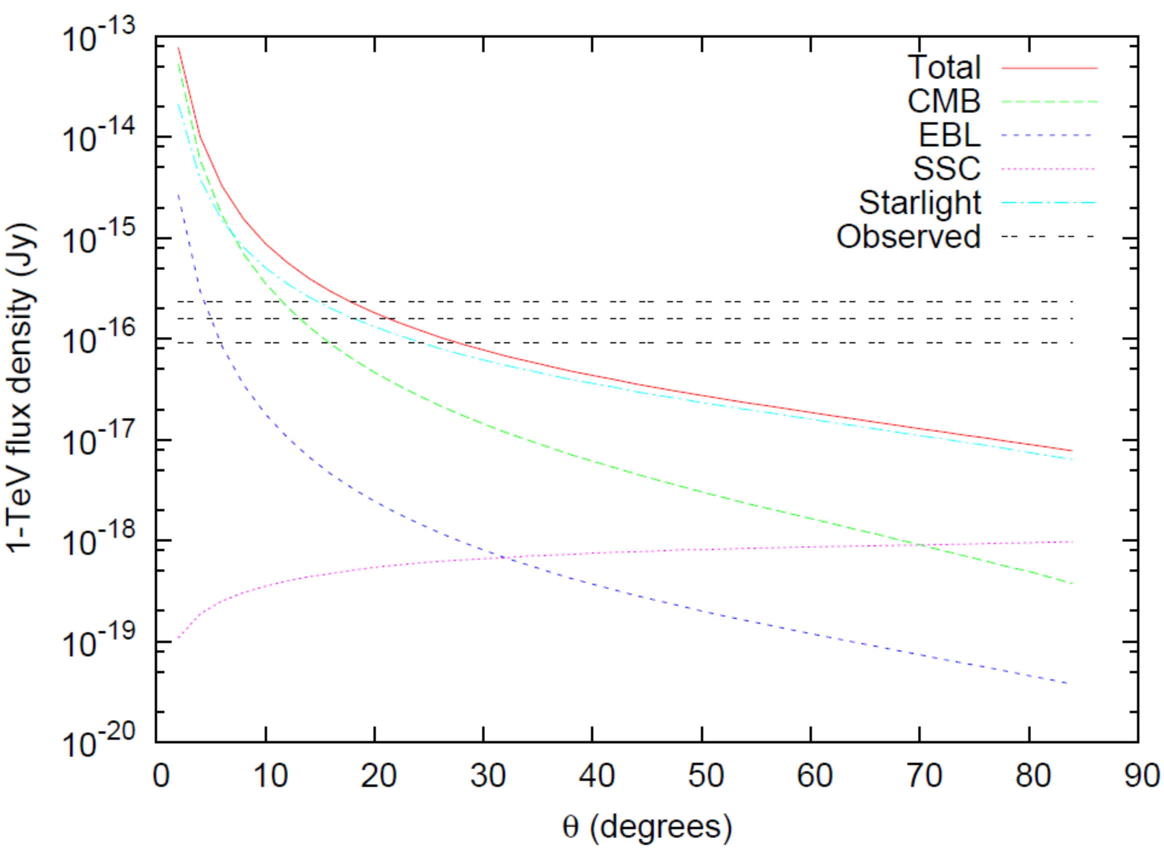
“Gamma-Ray Galaxies”

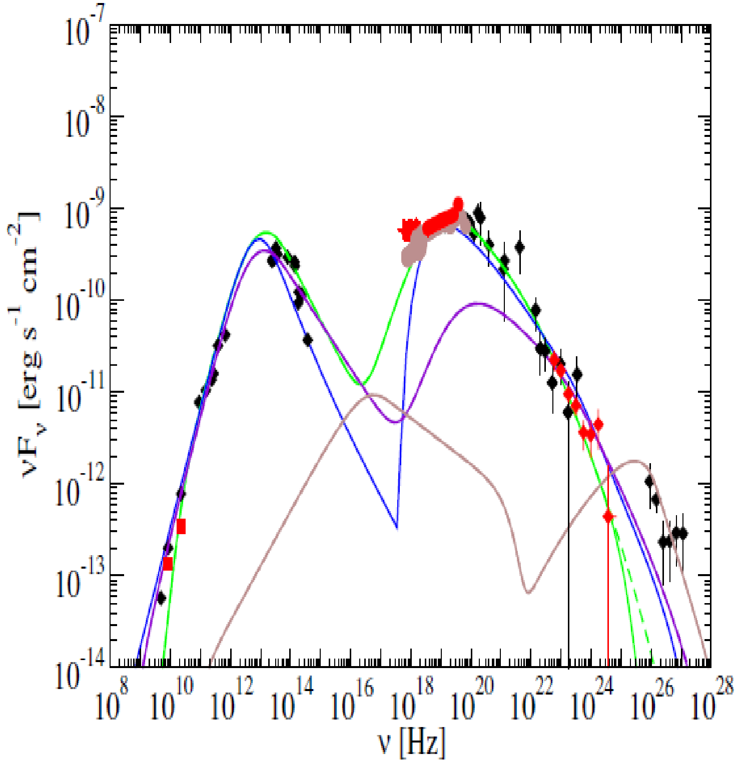
(Hardcastle)

Radio Galaxies

Cen A

Model constraints on viewing angle



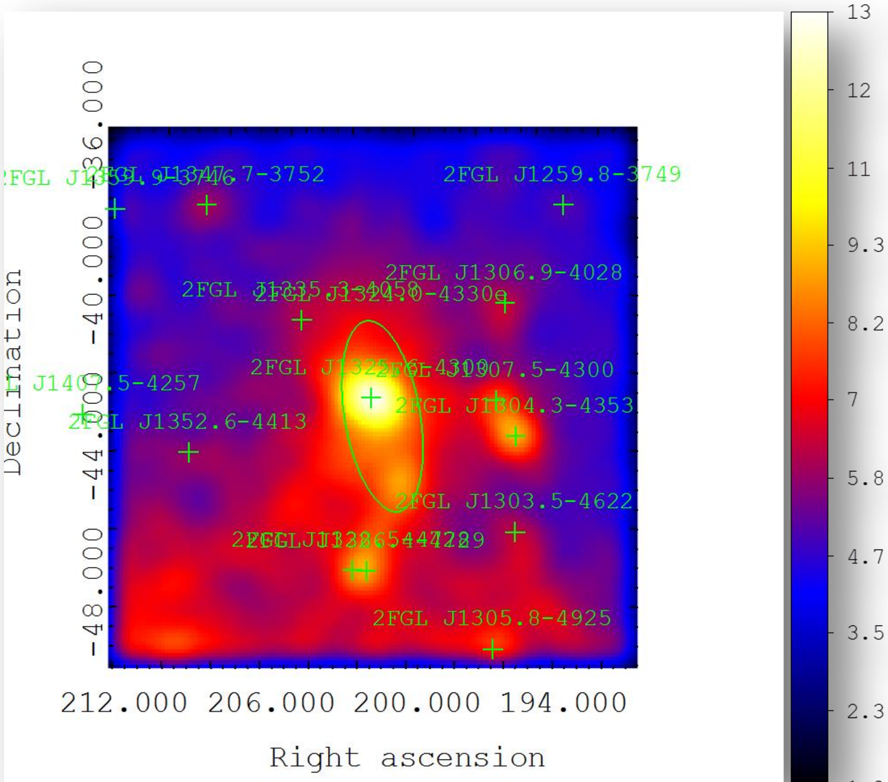


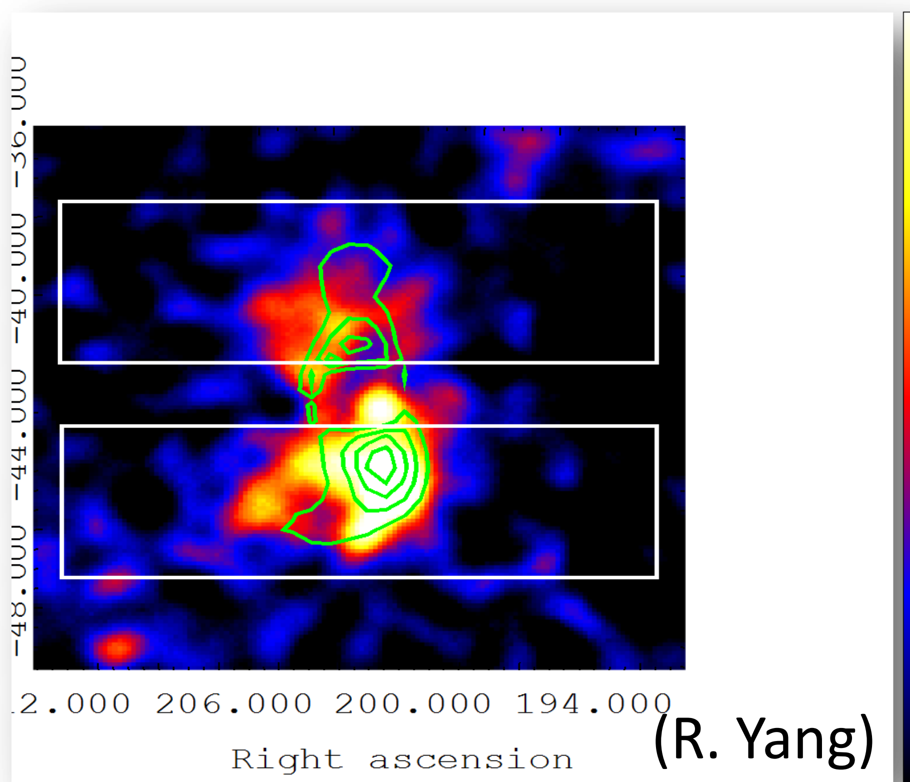
(Hardcastle)

Radio Galaxies

Cen A

Fermi Lobes are 3 times larger than radio lobes!



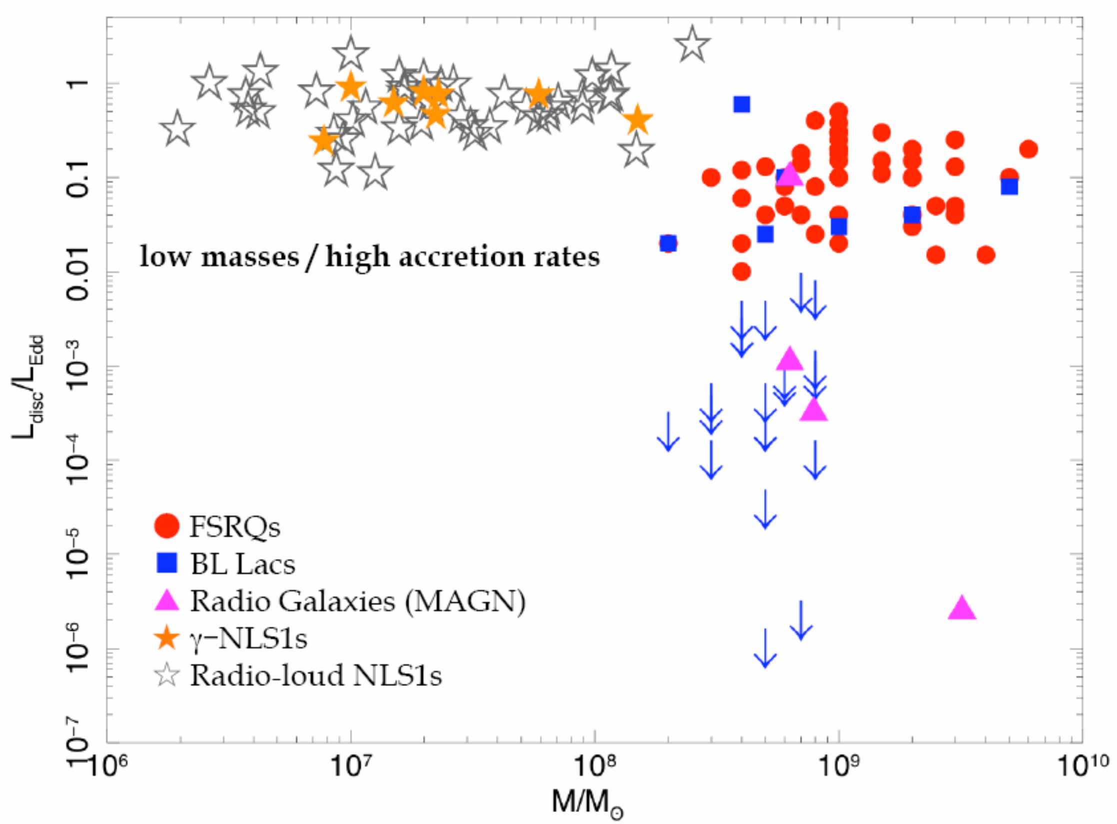


(R. Yang)

NLSy1

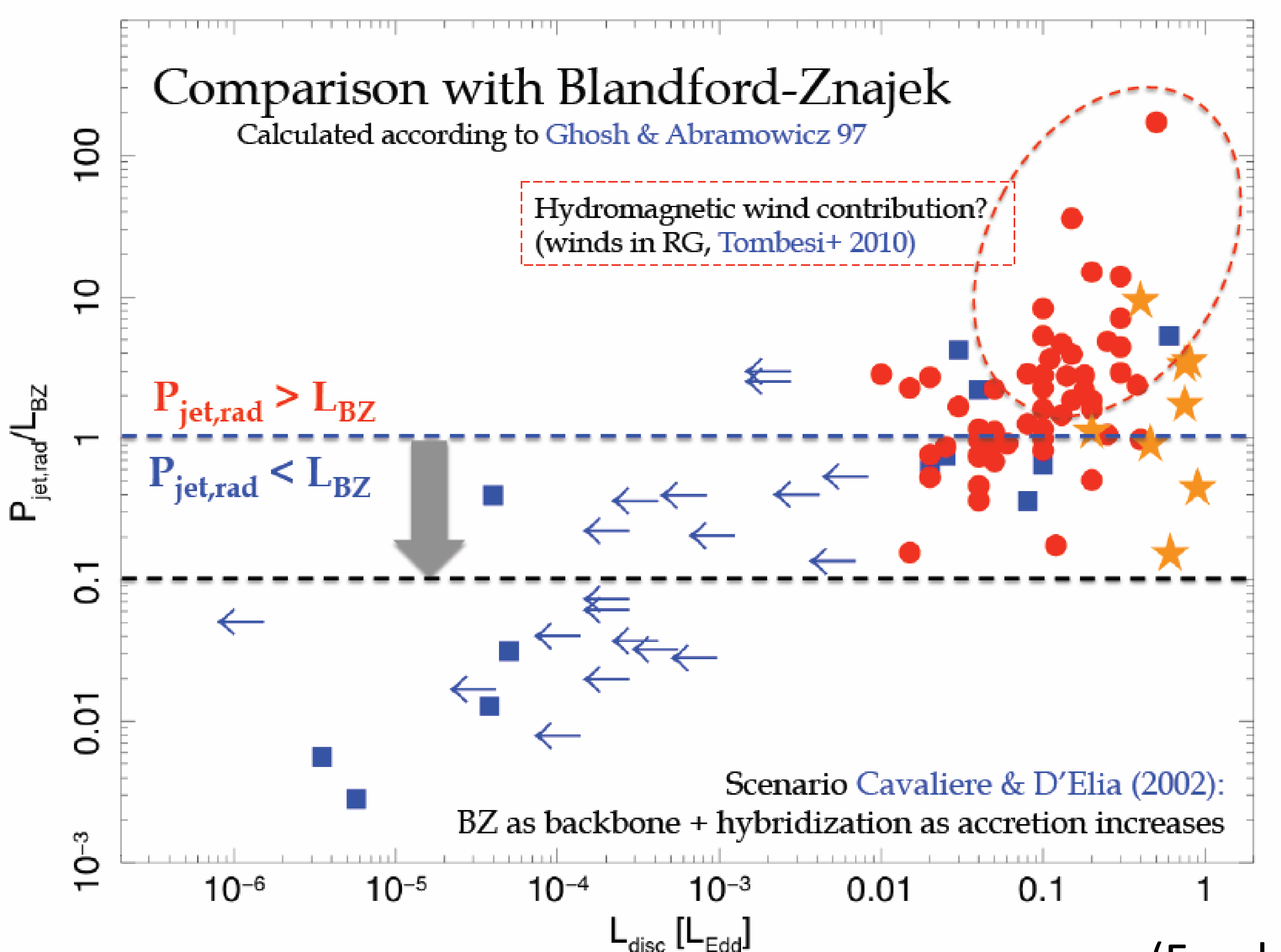
- 5 high-confidence (+ 3 low-confidence) Fermi detections

  Also: LINER/Sy1 @ z = 0.12 PMN J0710-3850 identified as the counterpart of EGRET UID 3EG J0706-3837 (Meintjes).
- PMN 0948+0022 shows radio polarization swings simultaneous with γ-ray flare



(Foschini)

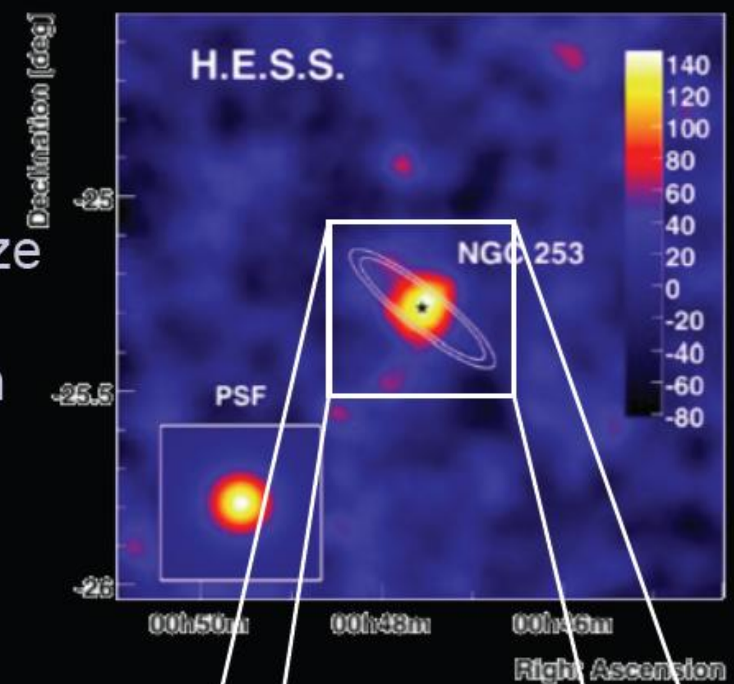
NLSy1



(Foschini)

Starburst Galaxies

Acero et al., 2009

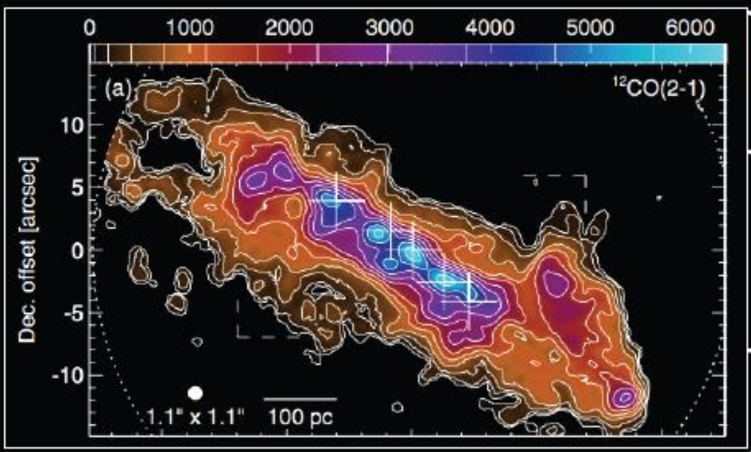


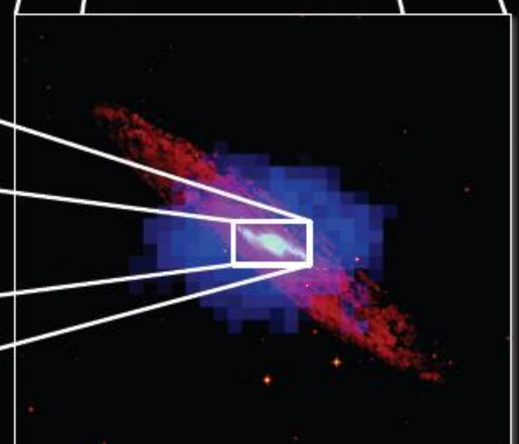
VHE γ-ray emission

- Point-like emission, coincident with the SB nuclei
- Limit on extension (3σ, 2.4’) comparable to size of ^{12}CO emission (0.5’ x 1.0’) for NGC 253
- supports picture of CRs interacting with gas in the SB nucleus, producing VHE γ rays
- HE γ-ray emission?

(S. Ohm)

Sakamoto et al. 2011

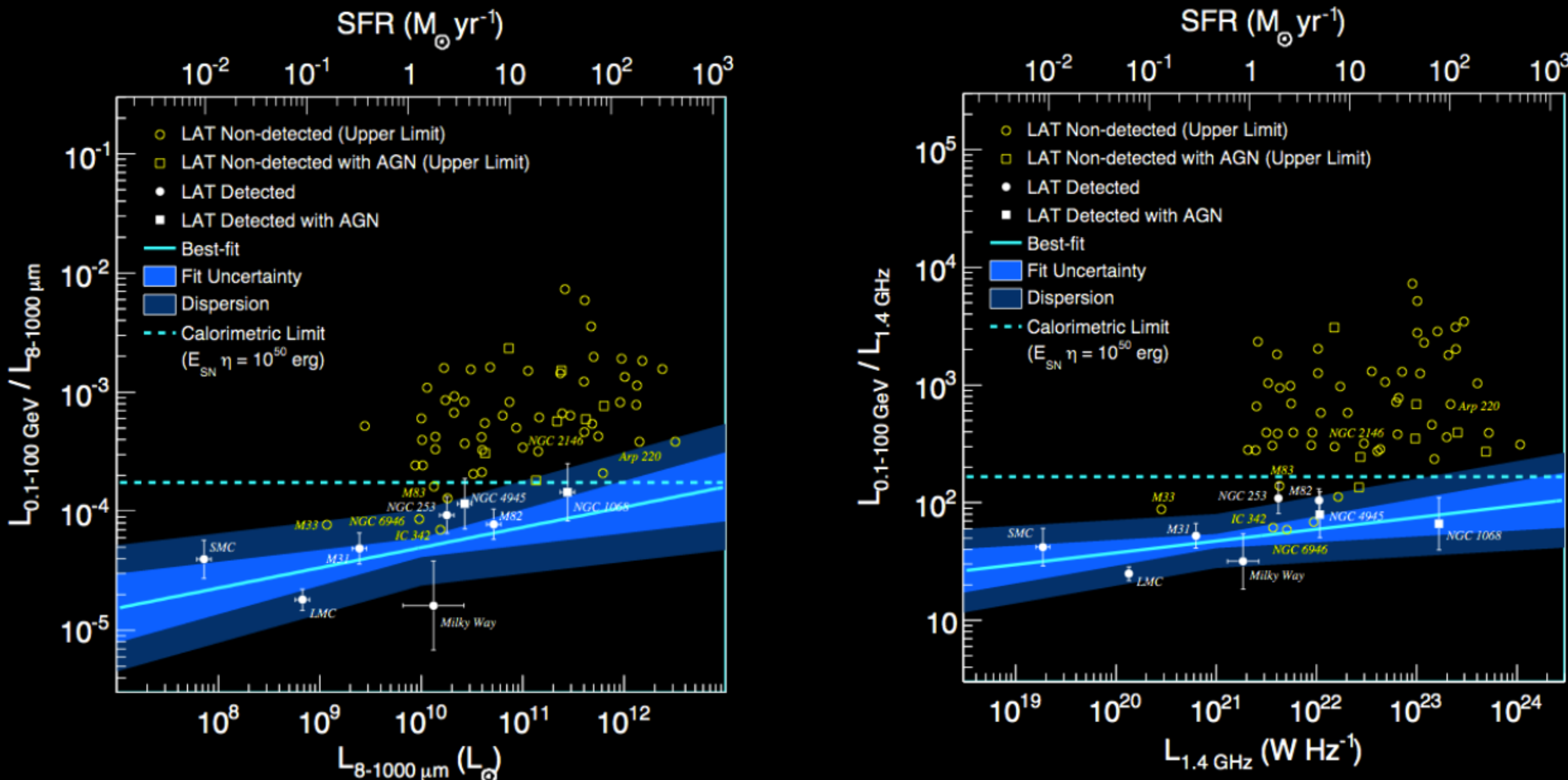




Starburst Galaxies

Sample of γ-ray galaxies is increasing:

- NGC 4945 & 1068 (γ-rays from AGN?)
- Hint for emission from NGC 2146 & M83



Up to 10 galaxies in 10 years of Fermi (?) (S. Ohm)

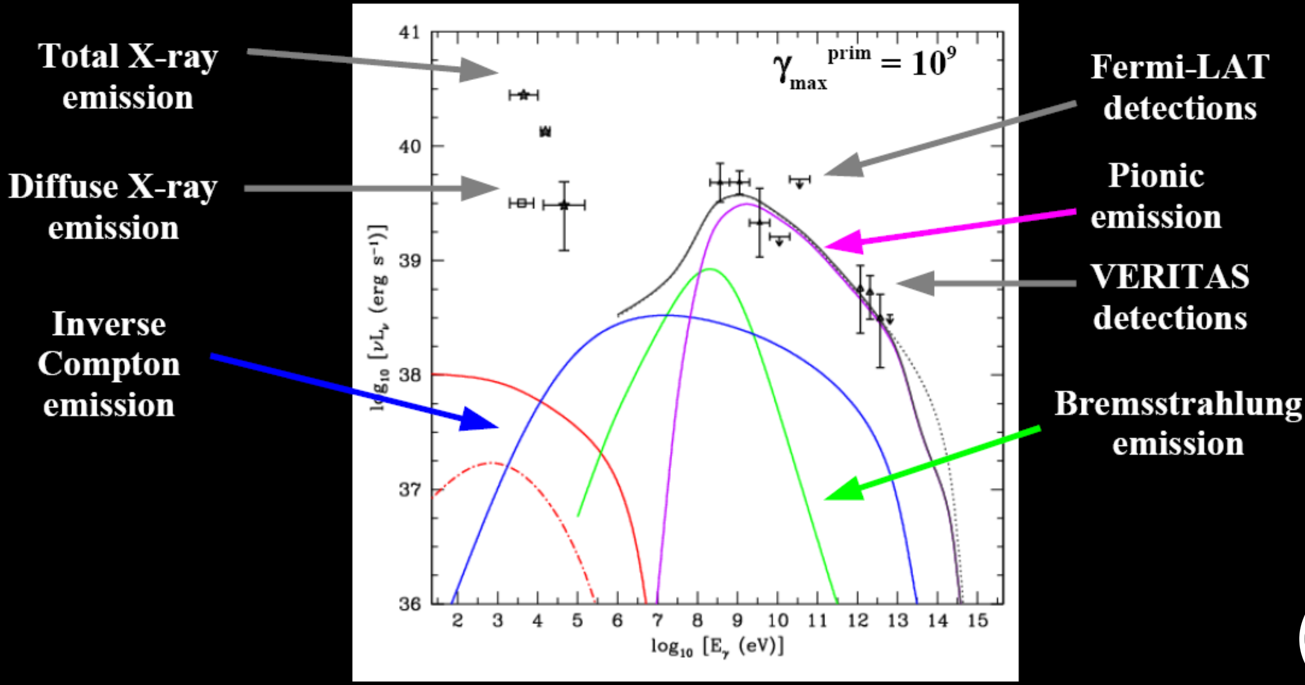
Starburst Galaxies

- Gamma-ray dominance

$\Rightarrow$ Evidence for CR-induced π-production and decay (neutrino fluxes probably too low for detection)

- $u_{CR} \sim u_B \sim u_{FIR}$
- Lack of IC emission -> Limit on B-field

150 μG model for M82

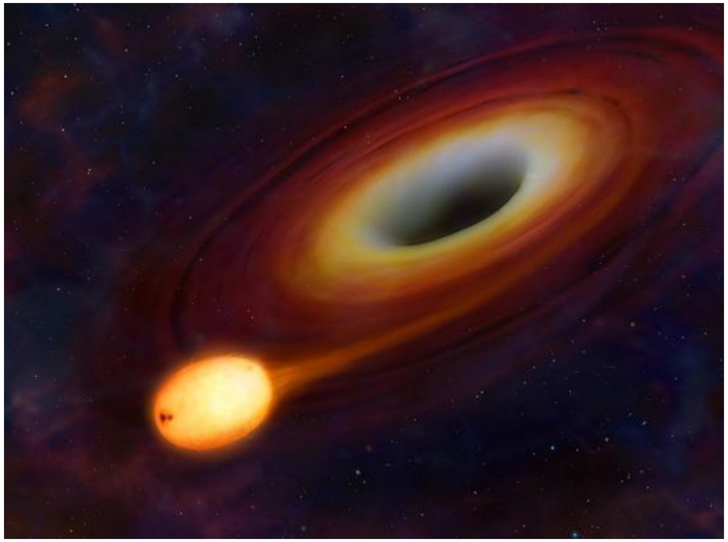


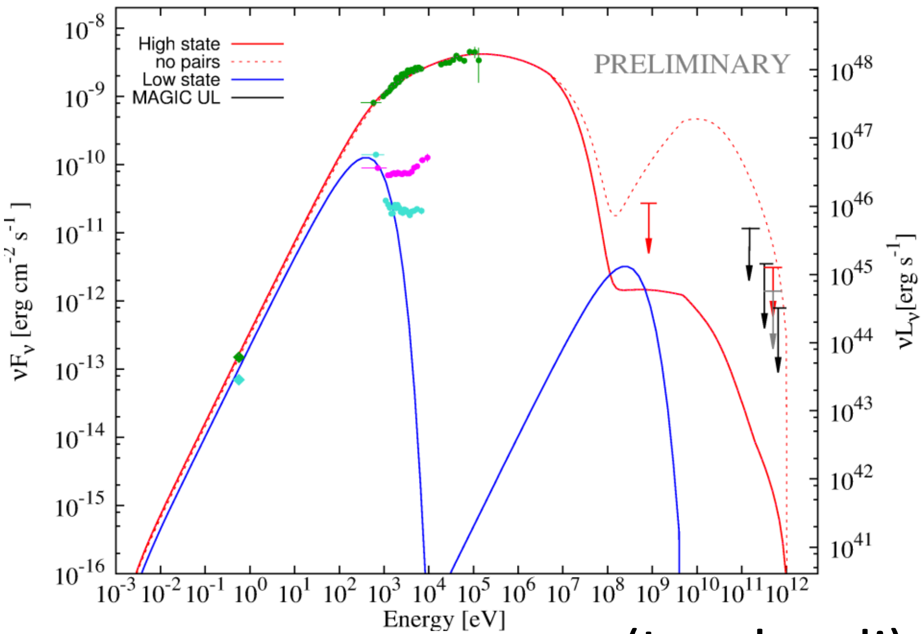
(B. Lacki)

Newly Still-Not-Detected

Swift 1644+57

- Triggered BAT multiple times
- Extended X-ray afterglow without significant decay
- Stringent historical X-ray flux upper limits
- z=0.354, source in the center of galaxy
- Minimum variability ~ 100 s
- Suggested to be the tidal disruption of a star by a 10^6 $M_\odot$ black hole





(Lombardi)

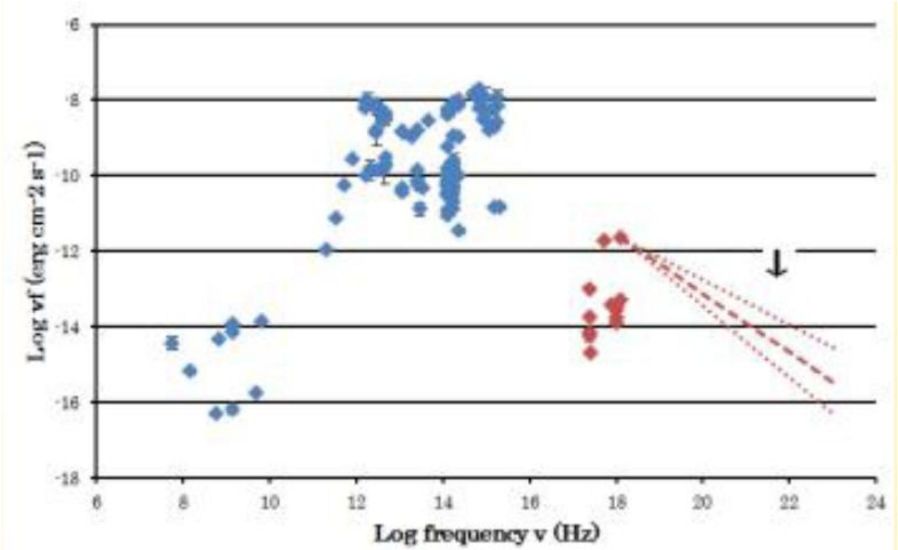
Lack of gamma-ray detection (Fermi, VERITAS) - now confirmed by MAGIC (Lombardi) - possibly due to $\gamma\gamma$ absorption.

Newly Still-Not-Detected

ULXs

Search for GeV emission (Fermi) from ULX in 18 nearby galaxies – no detection.

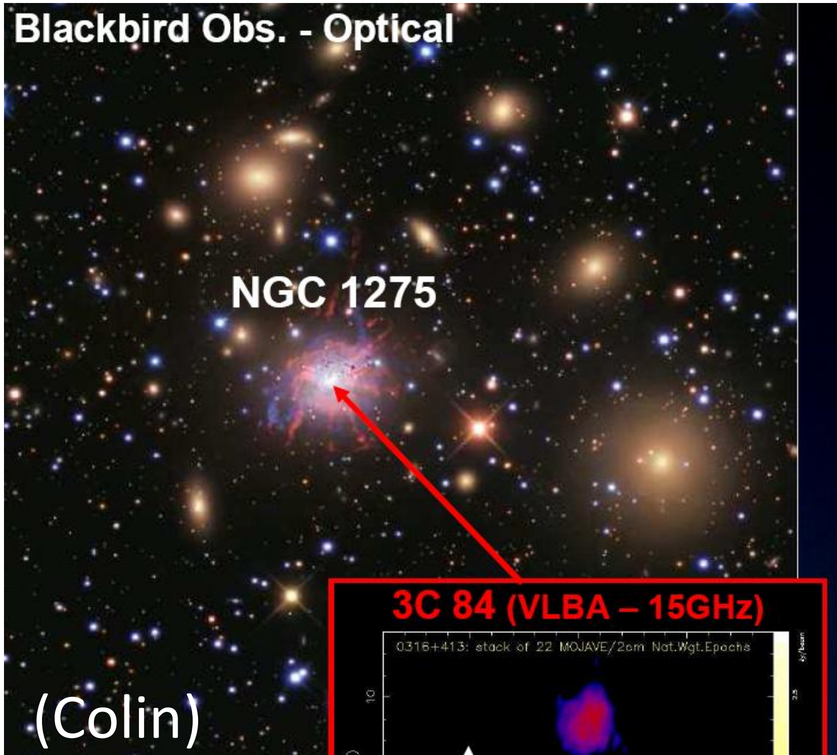
Upper limits consistent with extrapolation from X-rays.



(Lombardi)

Galaxy Clusters

- Still no GeV – TeV emission from clusters of galaxies, but detection of several BCGs (NGC 1275, …)



(Colin)

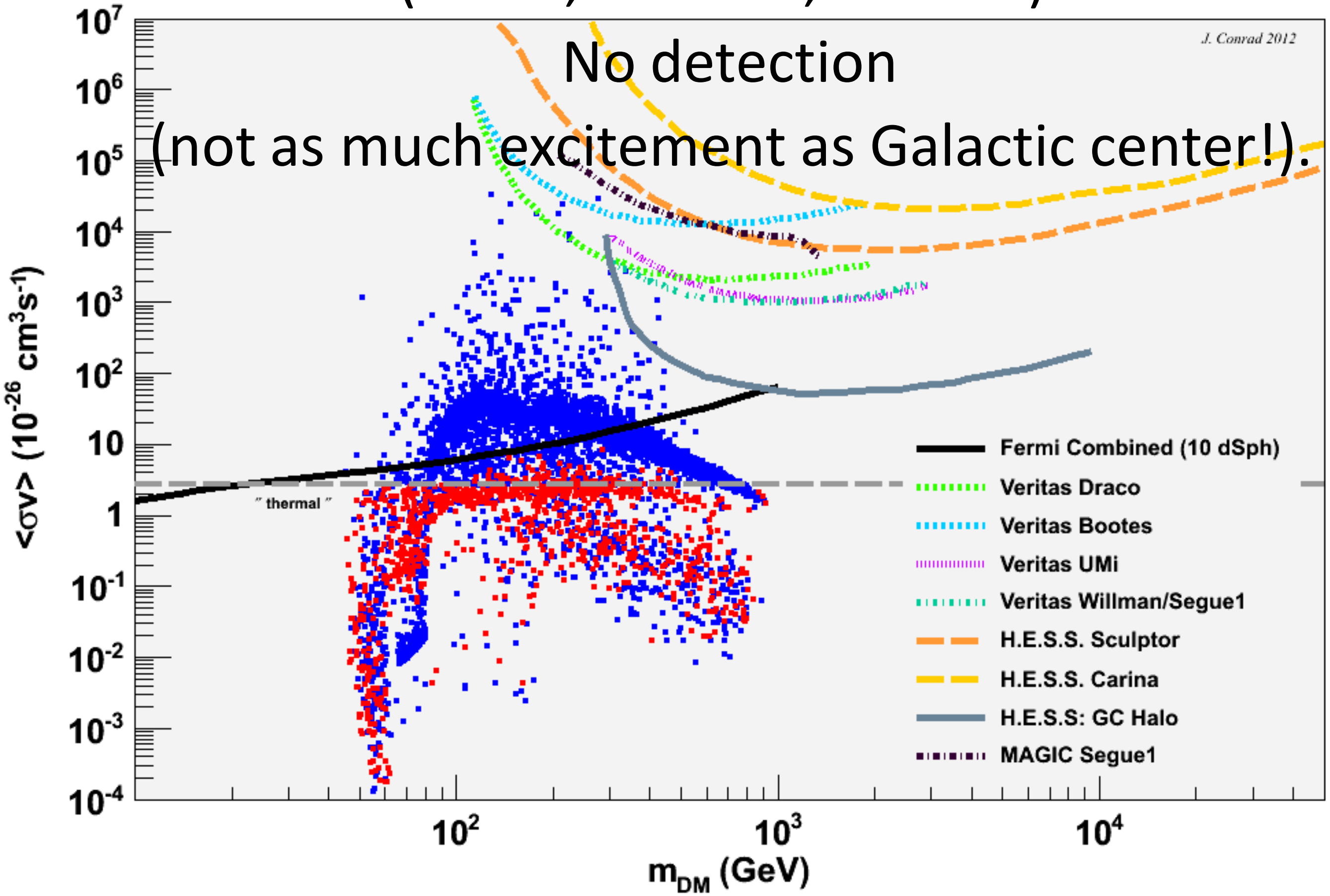
Newly Still-Not-Detected

Dark-Matter Annihilation Signatures from Dwarf Spheroidals and Galaxy Clusters

(Fermi, VERITAS, H.E.S.S.):

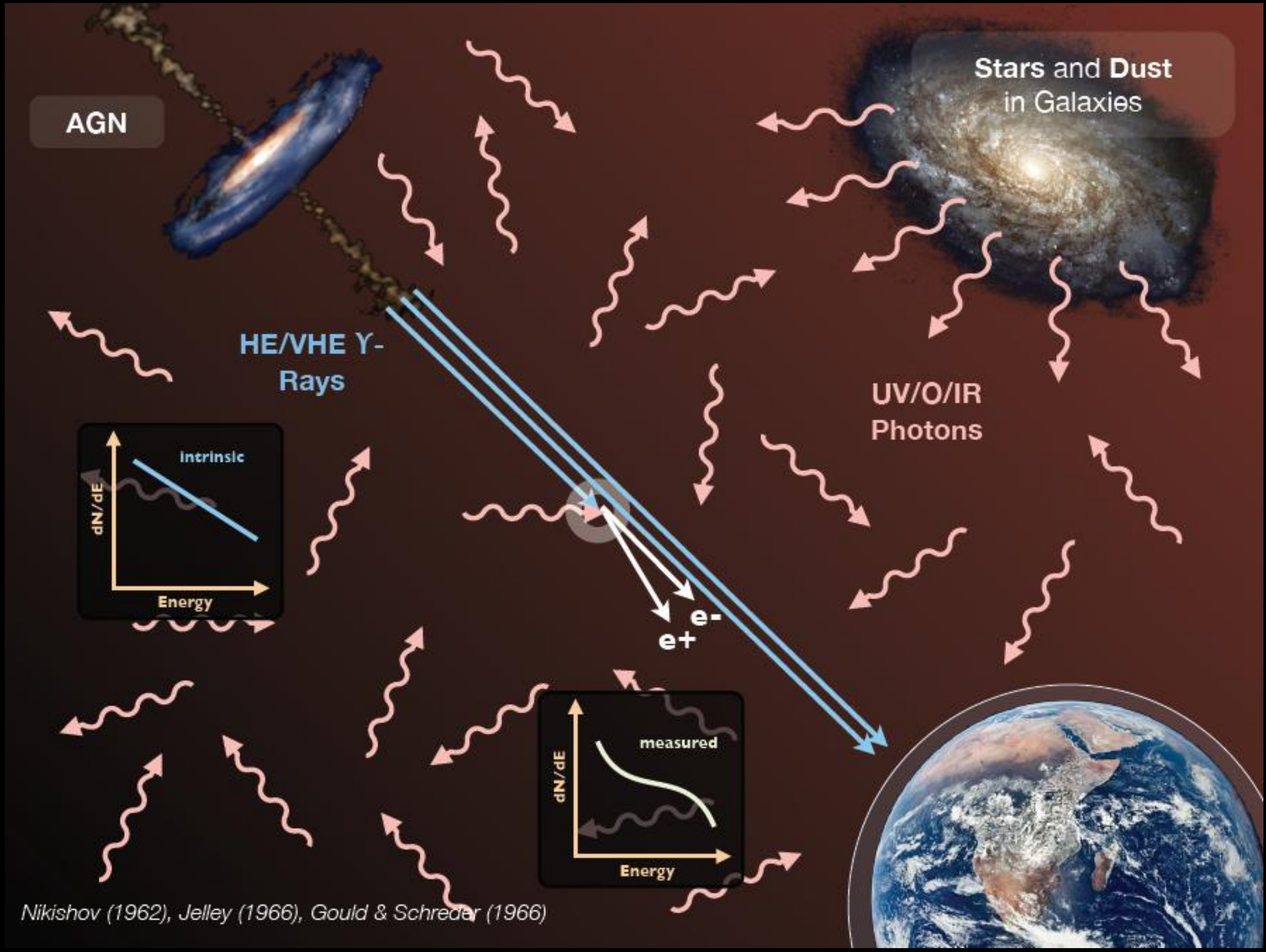
No detection

(not as much excitement as Galactic center!).



(Cholis, Conrad, Galante, Grube, van Eldik)

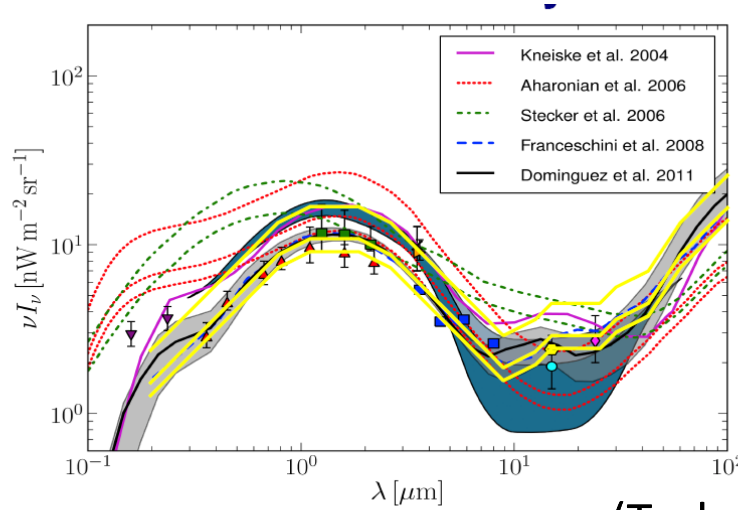
EBL and Extragalactic Magnetic Fields



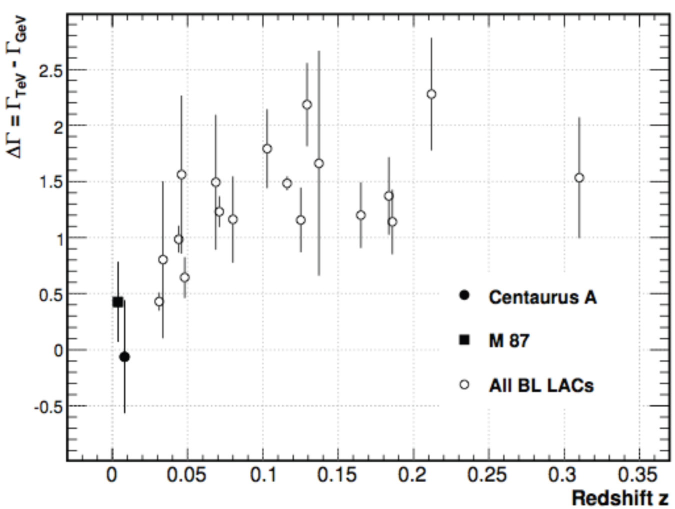
(Raue)

The EBL

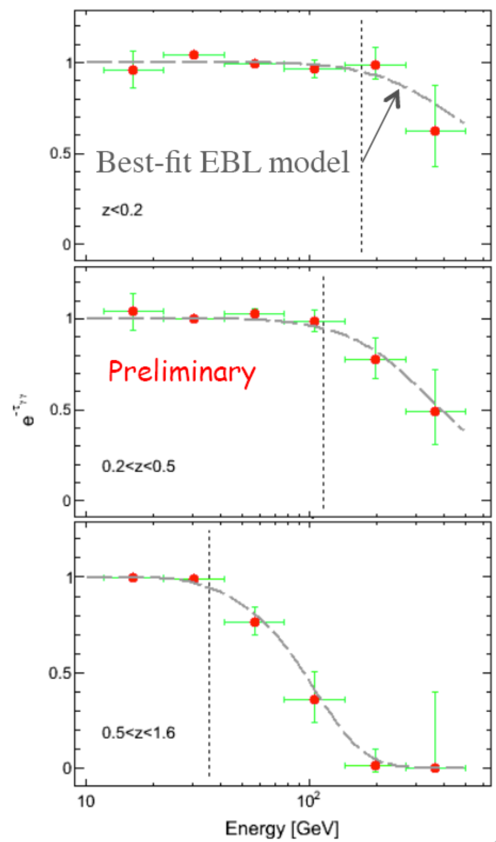
- EBL constrained to be within ~ factor 2 of lower limits from galaxy counts (Meyer) – α = 1.27 (Biteau)
- Can be used to constrain star-formation history (Raue)



(Taylor)

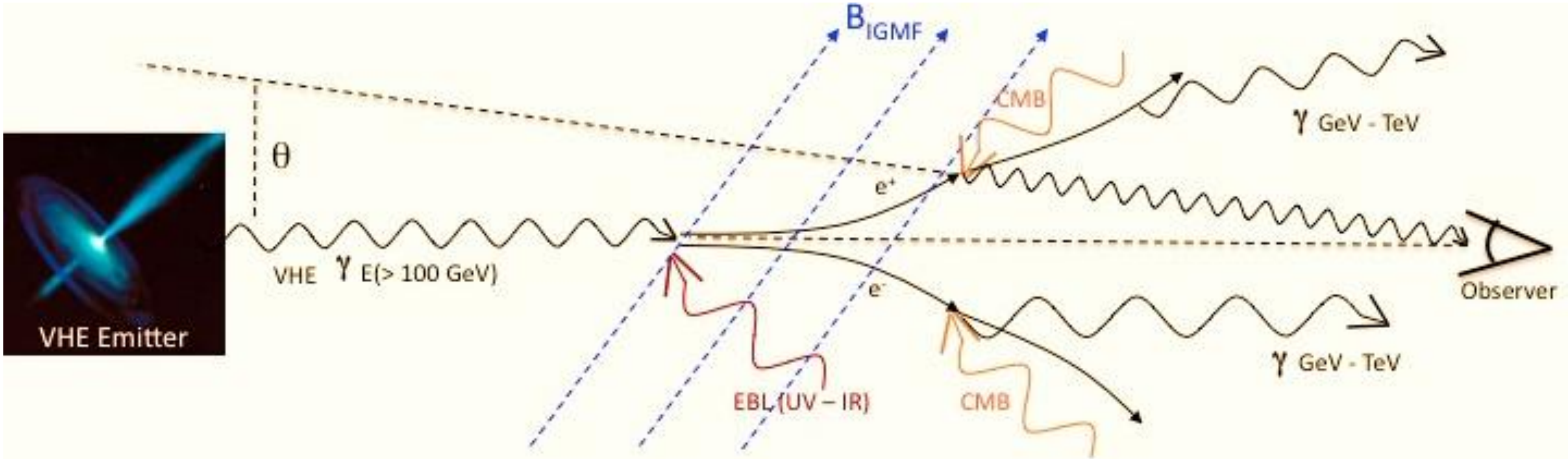


EBL absorption effect clearly reflected in GeV – TeV breaks (Sanchez; Biteau; Gasparrini)



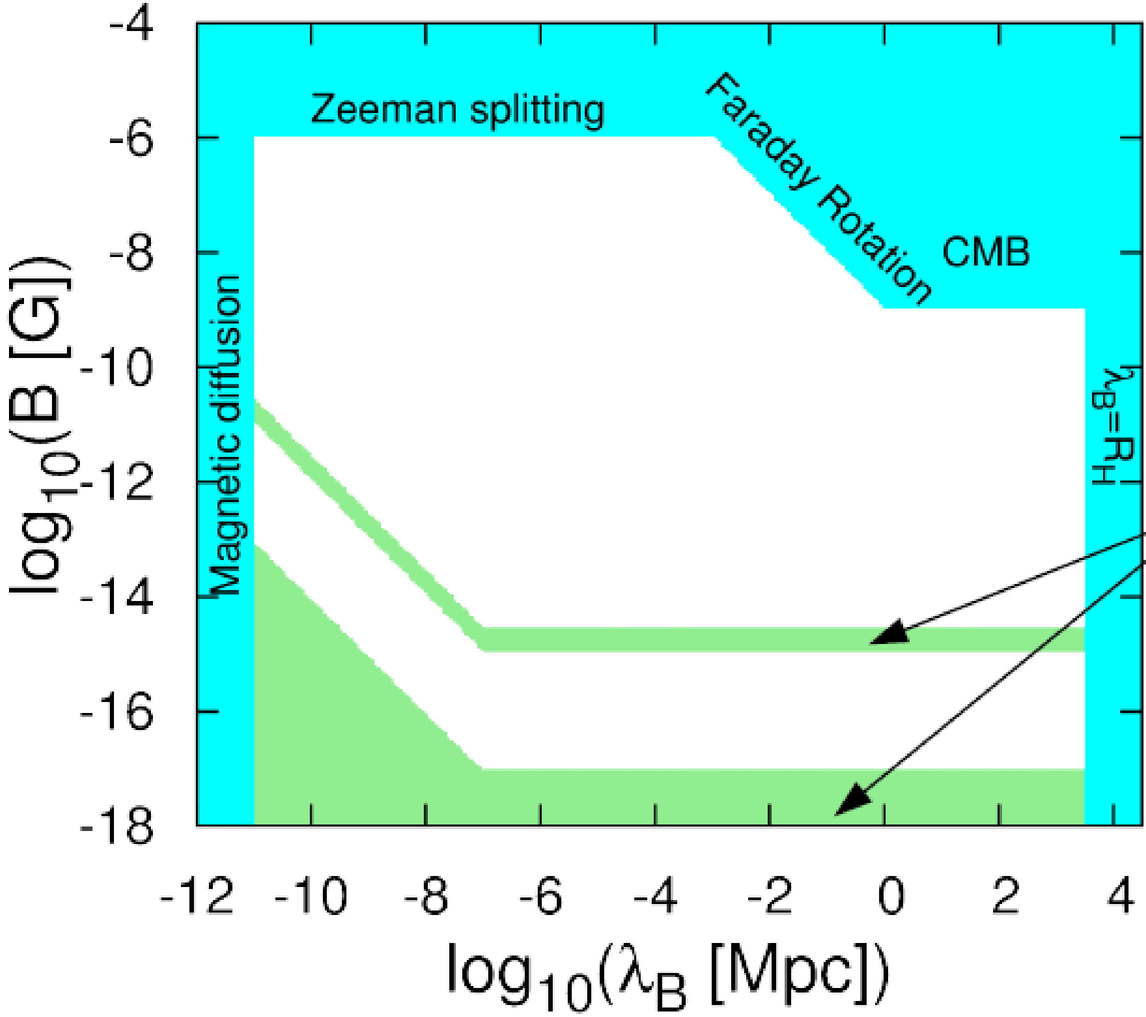
EBL absorption effect seen in Fermi blazar spectra (Ajello)

Intergalactic Cascading and Magnetic Fields



- (Deflected) IC cascades may fill in GeV emission, lead to extended halos -> Limits on B-field

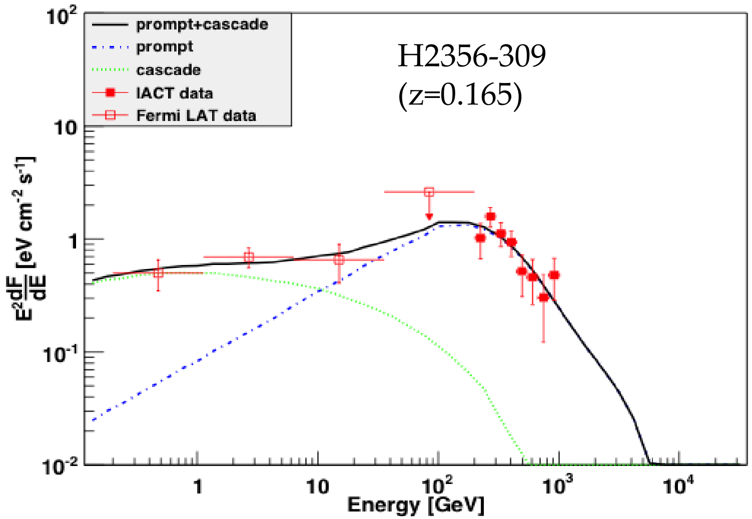
Intergalactic Cascading and Magnetic Fields



New exclusion regions from Blazar measurements

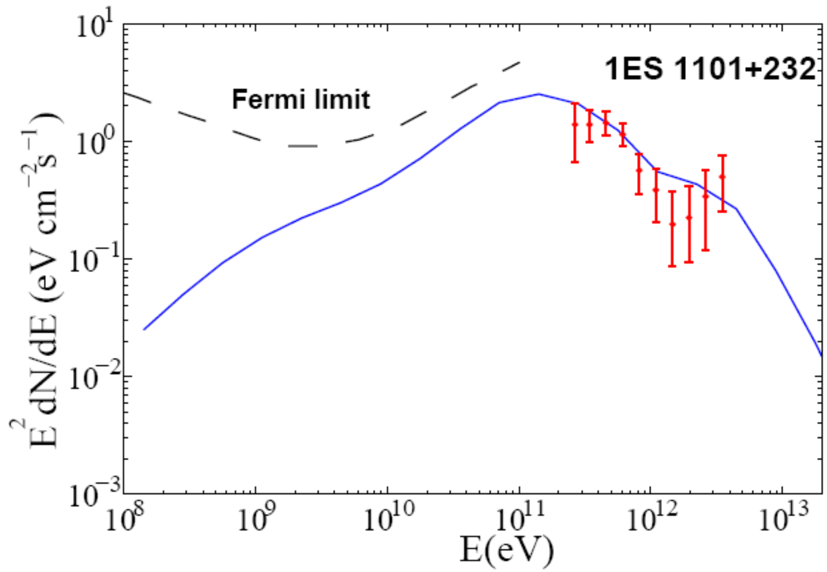
Andrew Taylor

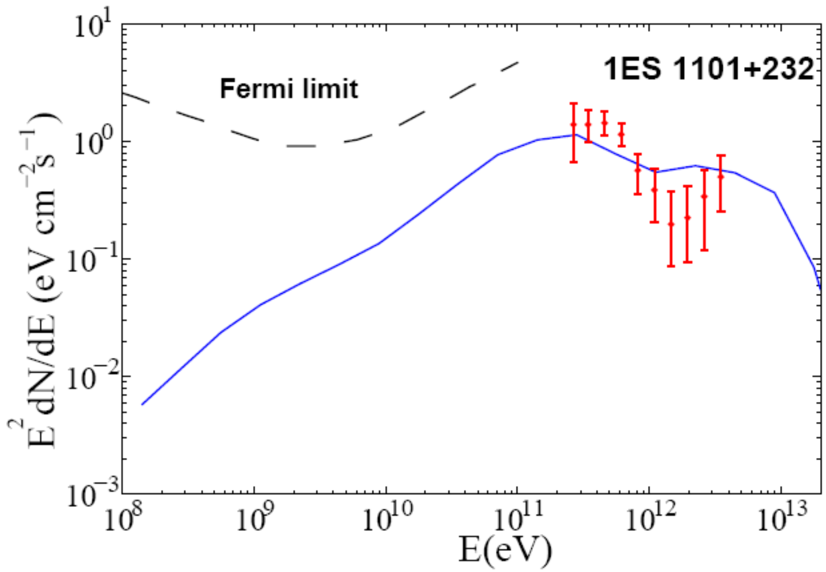
Intergalactic Cascading and Magnetic Fields



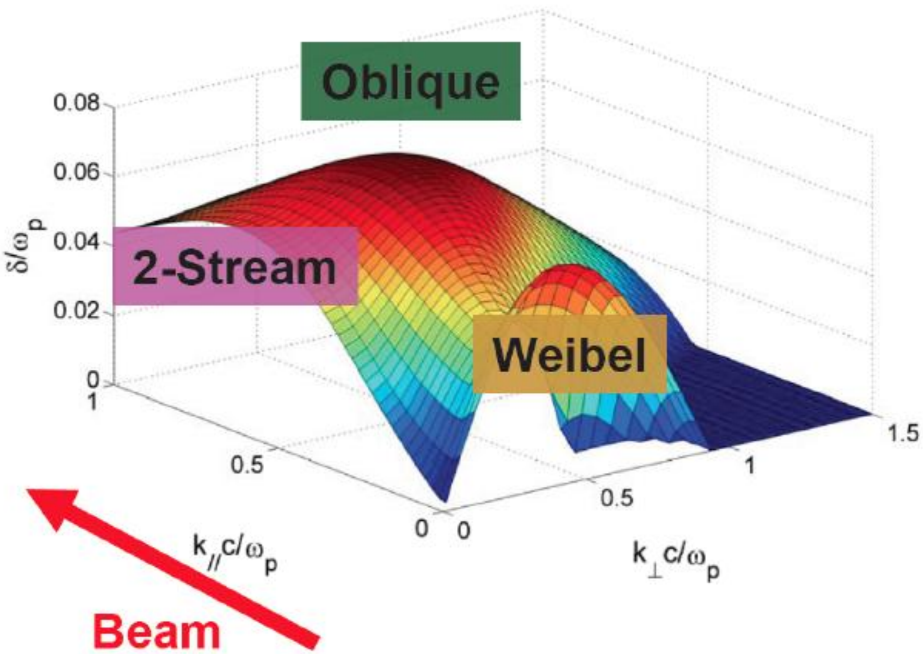
T. Arlen: B = 0 can NOT be exluded!

A. Kusenko: Cosmic-Ray Induced γ-rays produce universal VHE γ-ray spectra, almost independent of EBL!





Intergalactic Cascading and Magnetic Fields



Secondary pairs may lose energy in plasma instabilities

$\Rightarrow$ No B-fields needed!

$\Rightarrow$ Substantial influence on thermal history of the IGM.

$\Rightarrow$ Substantial influende on cosmological structure formation.

(C. Pfrommer)

Central Problems

- Origin of high-energy emission in blazars (leptonic/hadronic – location of the emission region)
- Origin of the blazar sequence (if real)
- Composition of jets and lobes – pressure balance?
- Origin of γ-ray emission in radio galaxies
- Connection between star formation activity and gamma-ray emission (-> CRs)
- EBL absorption relevant? Signatures of IGMF?

A Word from the Shameless-Commerce Department