

Summary of Extragalactic News and Progress



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γ 2012
Heidelberg
International Symposium
on High Energy Gamma-Ray Astronomy

Outline

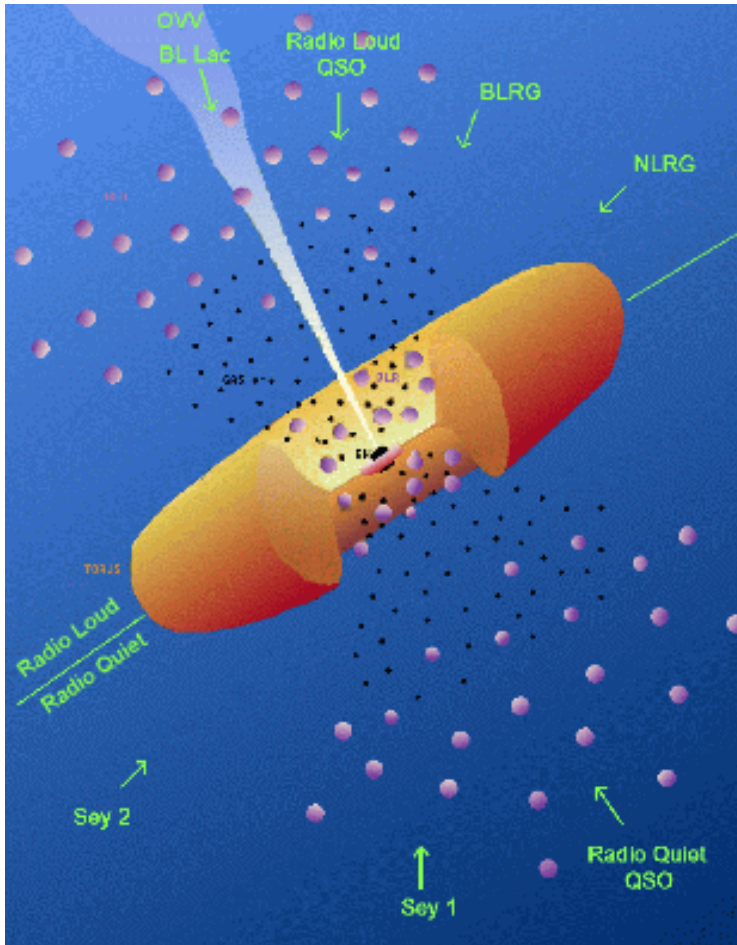
1. AGN
 - a. Blazars
 - b. Non-Blazar AGN
2. Other sources
3. EBL and EGMF



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%)

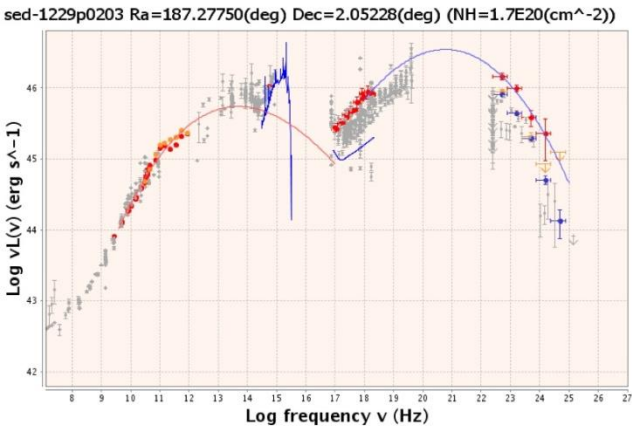
When $\Theta < \theta_{\text{blazar}}$ \longrightarrow Blazar

(P. Giommi)

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

Blazar Classification

3C273



(P. Giommi)

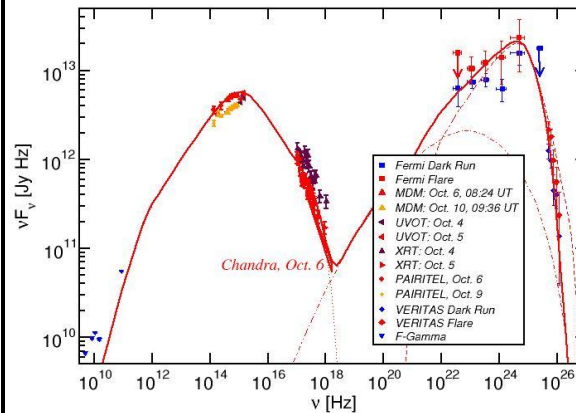
Quasars:

Low-frequency component
from radio to optical/UV,

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

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

3C66A



(Abdo et al. 2011)

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

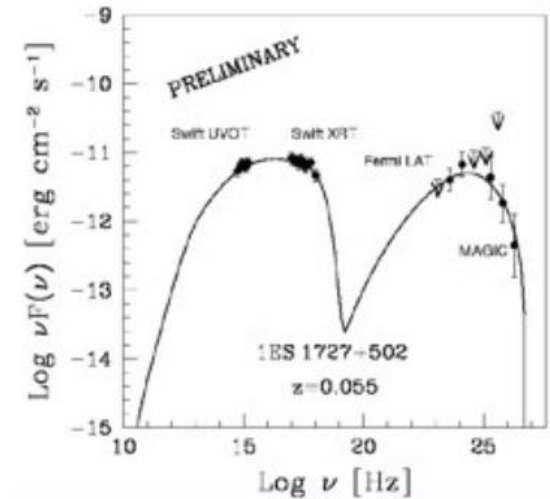
Peak frequencies at IR/Optical
and GeV gamma-rays,

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

Intermediate overall luminosity

Sometimes γ -ray dominated

1ES 1727+502



(de Caneva et al.)

High-frequency peaked BL Lacs (HBLs):

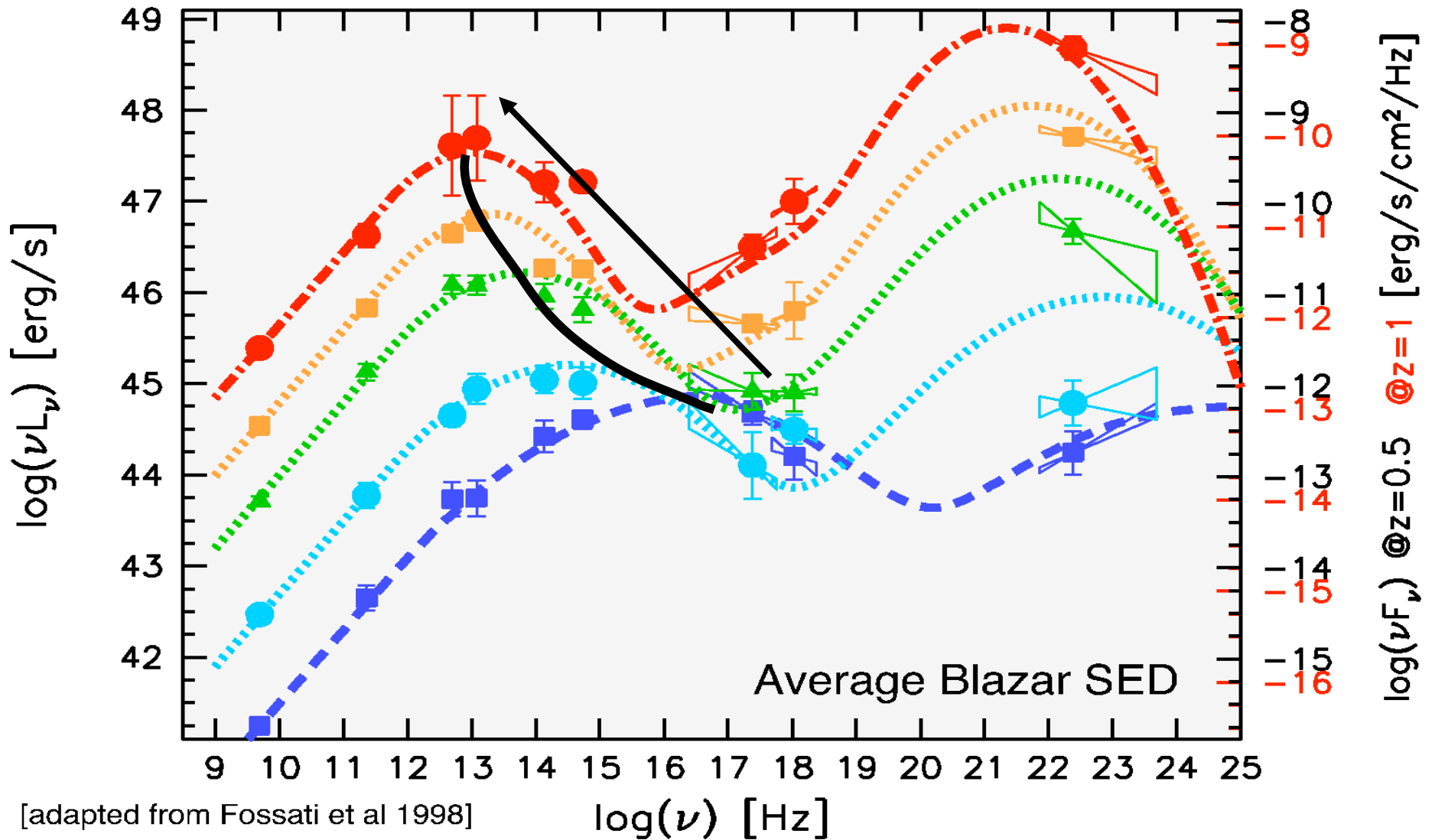
Low-frequency component from
radio to UV/X-rays,

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

often dominating the total power

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

The Blazar Sequence (?)

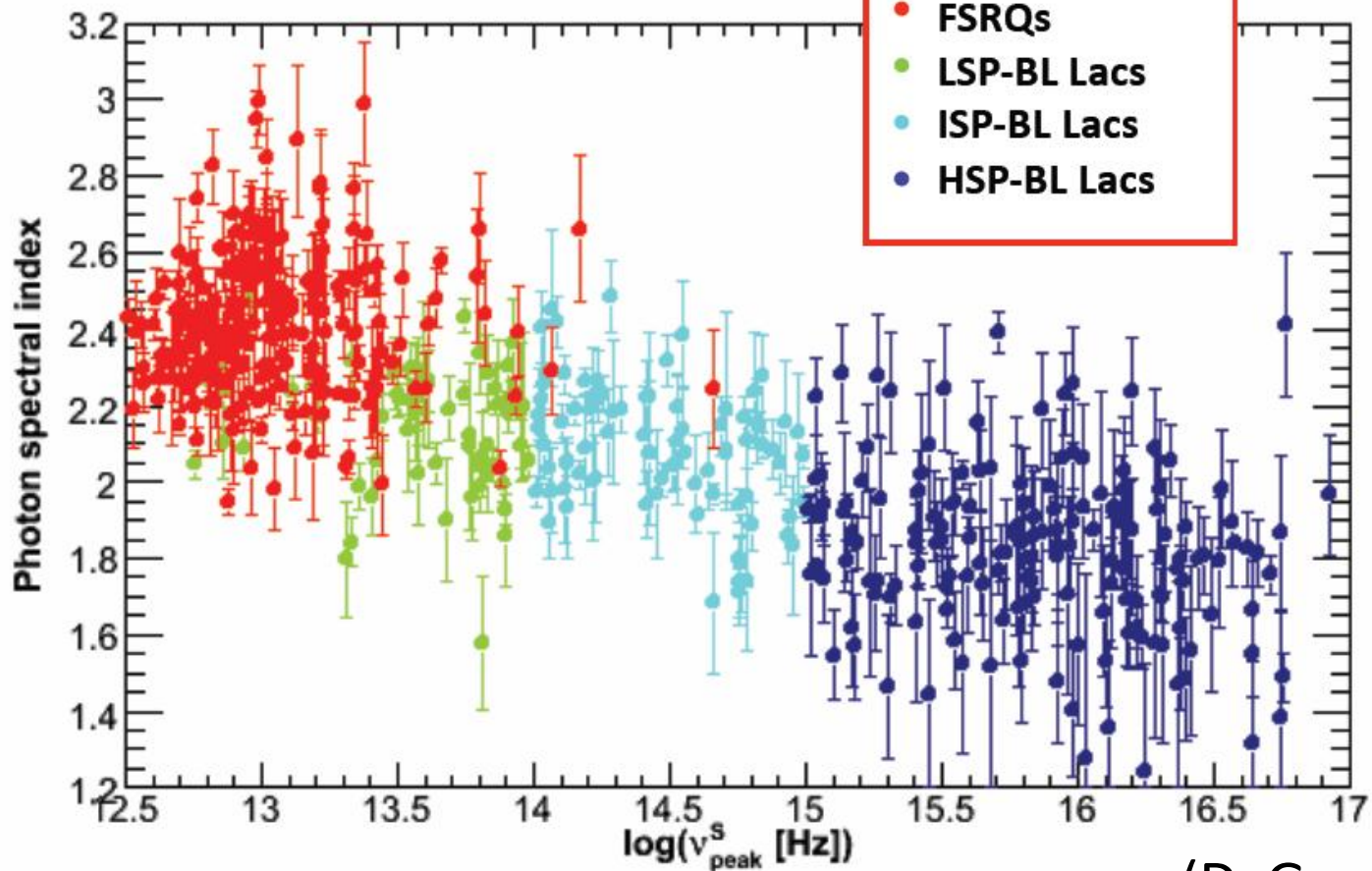


(E. Meyer)

The Blazar Sequence (?)



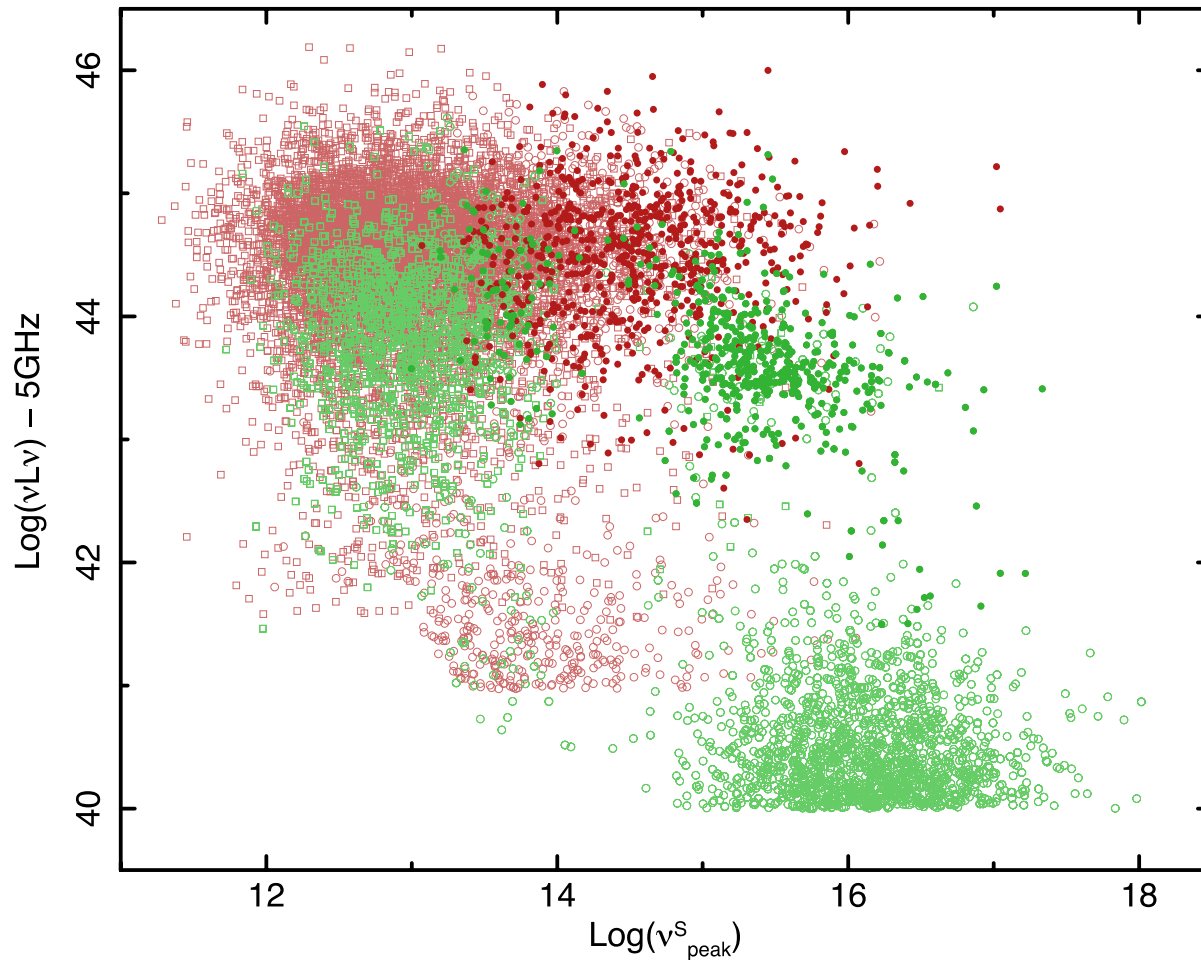
ν_{peak} vs photon index



(D. Gasparri)

The Blazar Sequence (?)

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



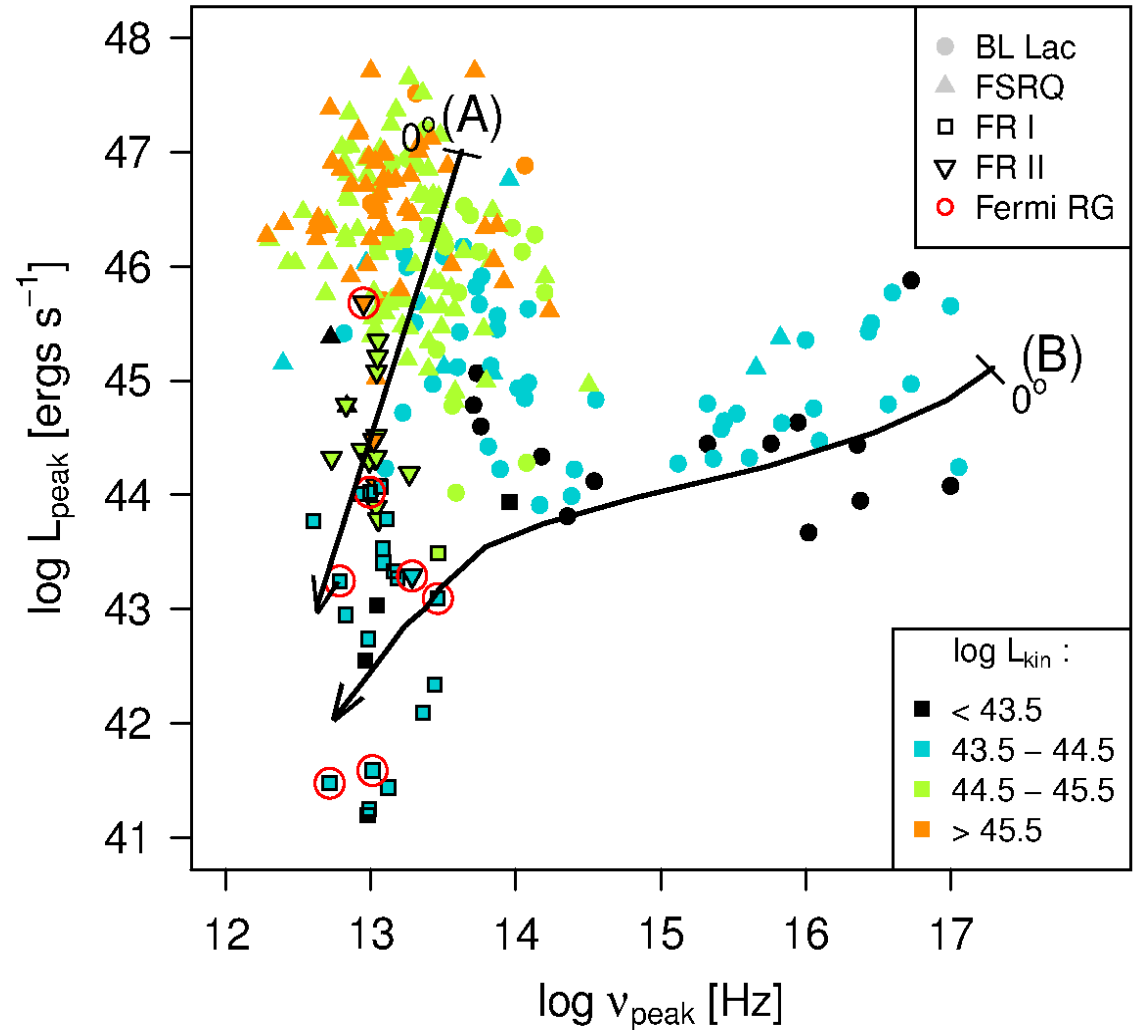
(P. Giommi)

The Blazar Sequence (?)

- Two Branches:
(A) Strong (not decelerating) jets

- (B) Weak (decelerating) jets

(E. Meyer)



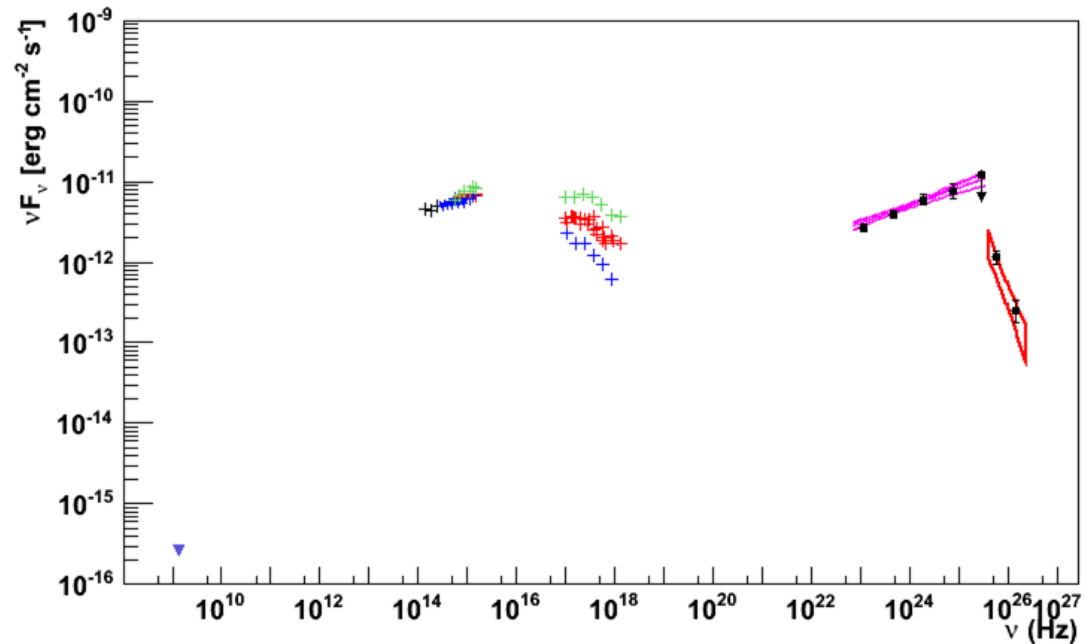
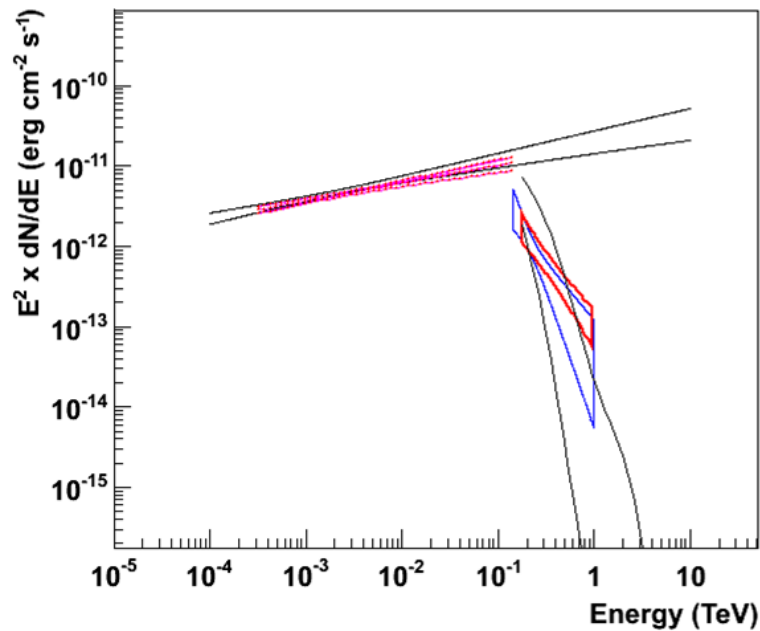
Newly/Recently Discovered VHE Blazars

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

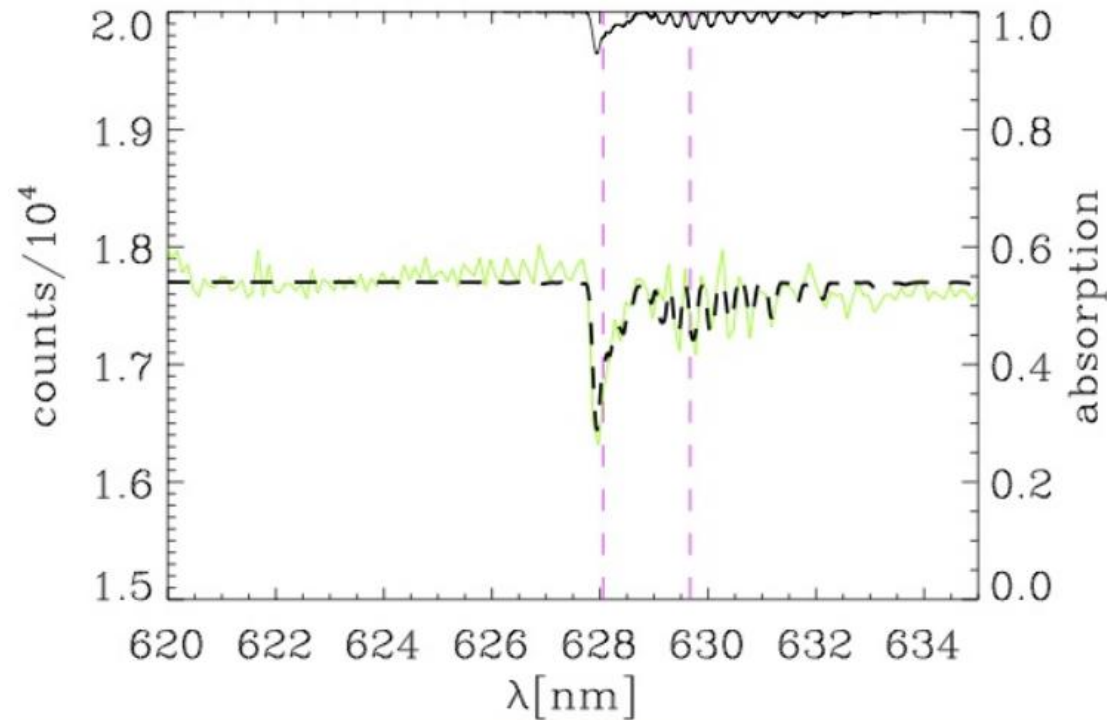


Extrapolation of Fermi spectrum after EBL absorption
consistent with H.E.S.S. spectrum for $z = 0.61$.

(Y. Becherini)

PKS 0447-439

Claimed redshift of $z > 1.246$ incorrect!

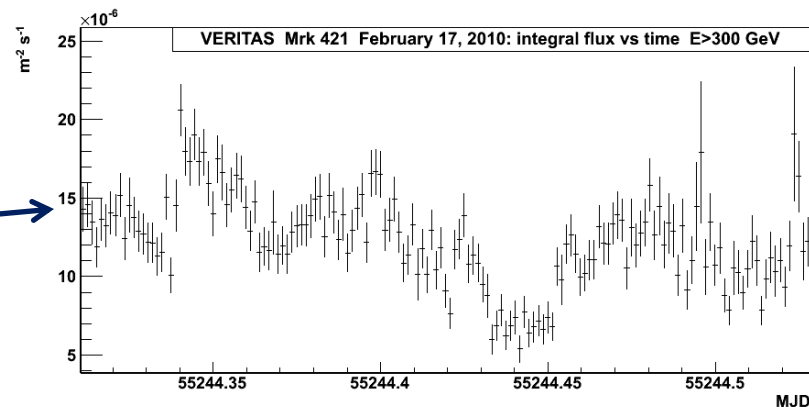
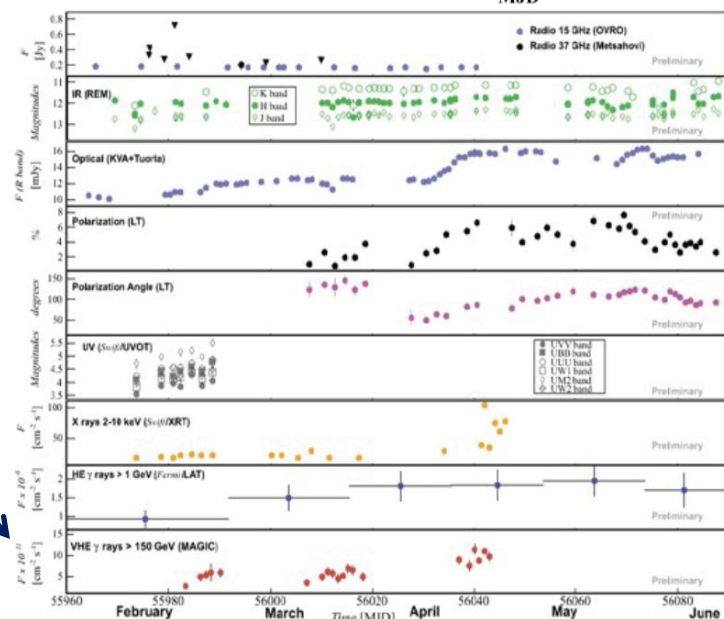
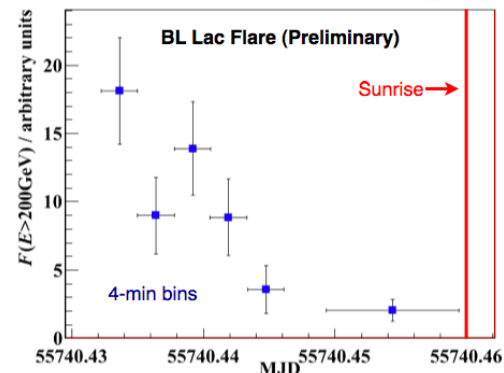


Ca II H&K and Na I D lines indicate $z = 0.273$.

(Pita et al.)

News on Known VHE Blazars

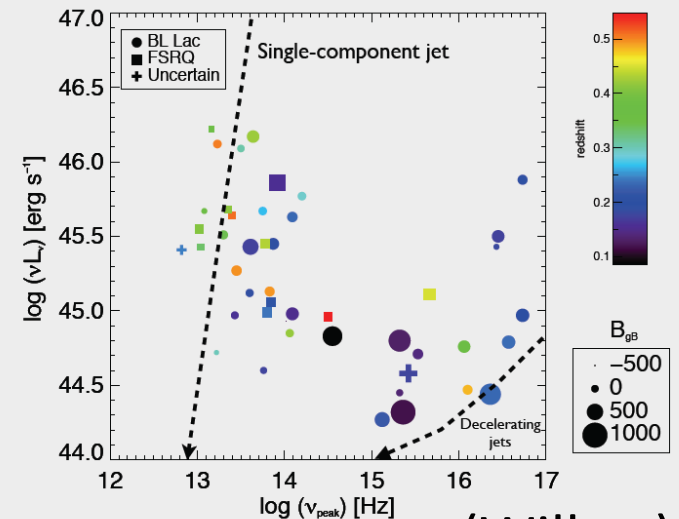
- VHE + GeV Flare of BL Lacertae (Galante)
- Variability seen in 1ES 0806+524 (Schultz)
- High State of PG 1553+113 (Becerra-Gonzalez)
- MAGIC detects PKS 1510-089, no re-detection of 3C279 (de Caneva)
- IBLs (3C66A, W Comae) detected in low state (Fortson)
- VERITAS detects 1ES 1215+303 (Prokoph)
- 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 $M_{\text{BH}} \Leftrightarrow$ 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)

B_{GB} and the “blazar sequence”

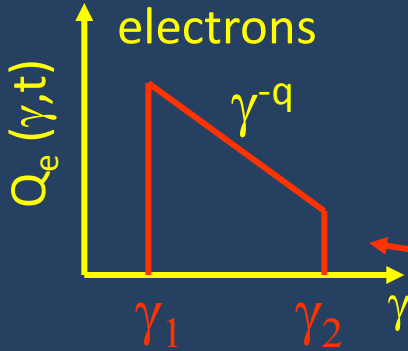


(Willett)

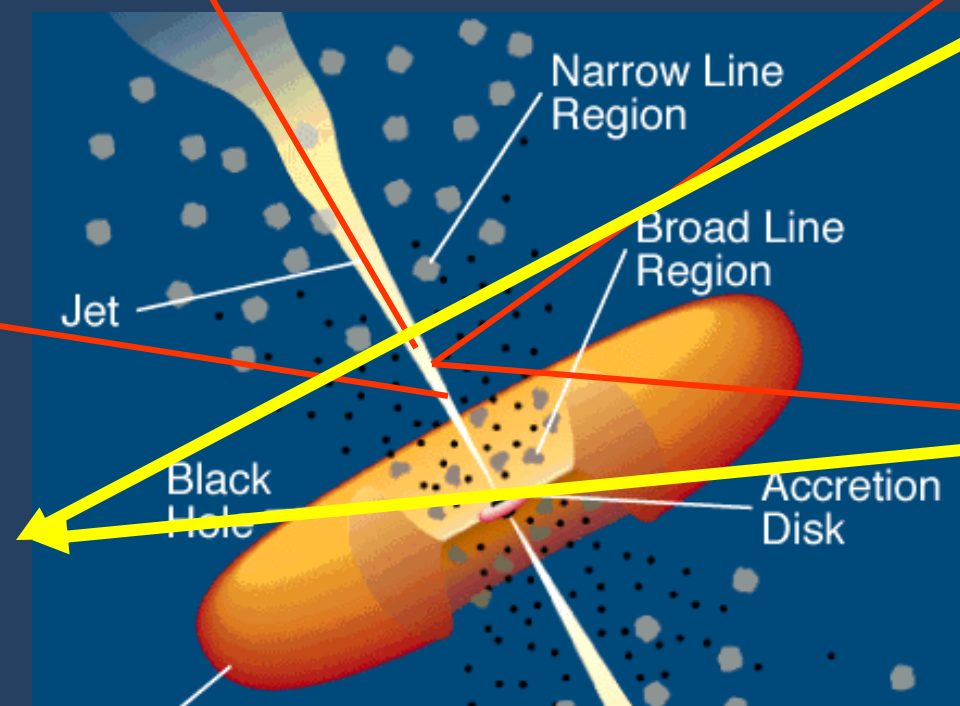
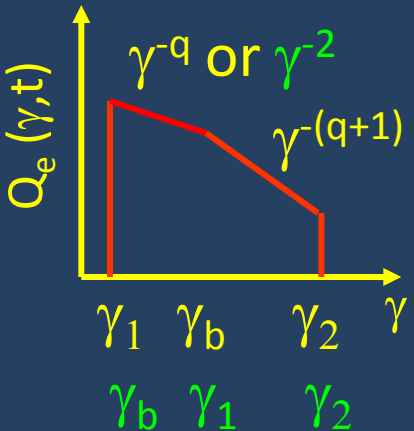
Leptonic Blazar Models

Relativistic jet outflow with $\Gamma \approx 10$

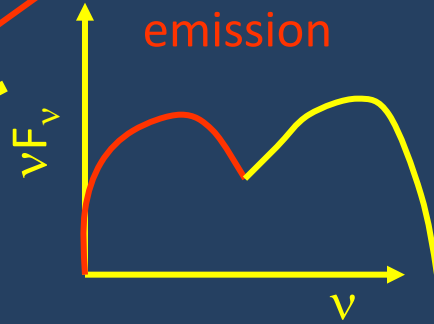
Injection, acceleration of ultrarelativistic electrons



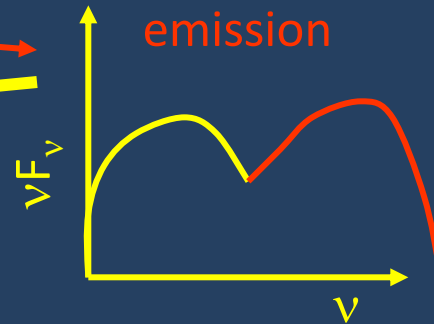
Radiative cooling ↔ escape =>



Synchrotron emission



Compton emission



Seed photons:

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

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

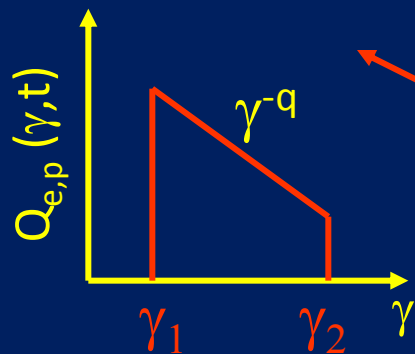
(Fossati, Georganopoulos, Lefa, Menzler, Prandini, Sun, Tammi, Tramacere, Villaume, Zacharias)

Hadronic Blazar Models

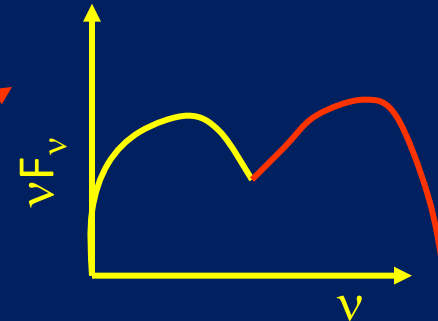
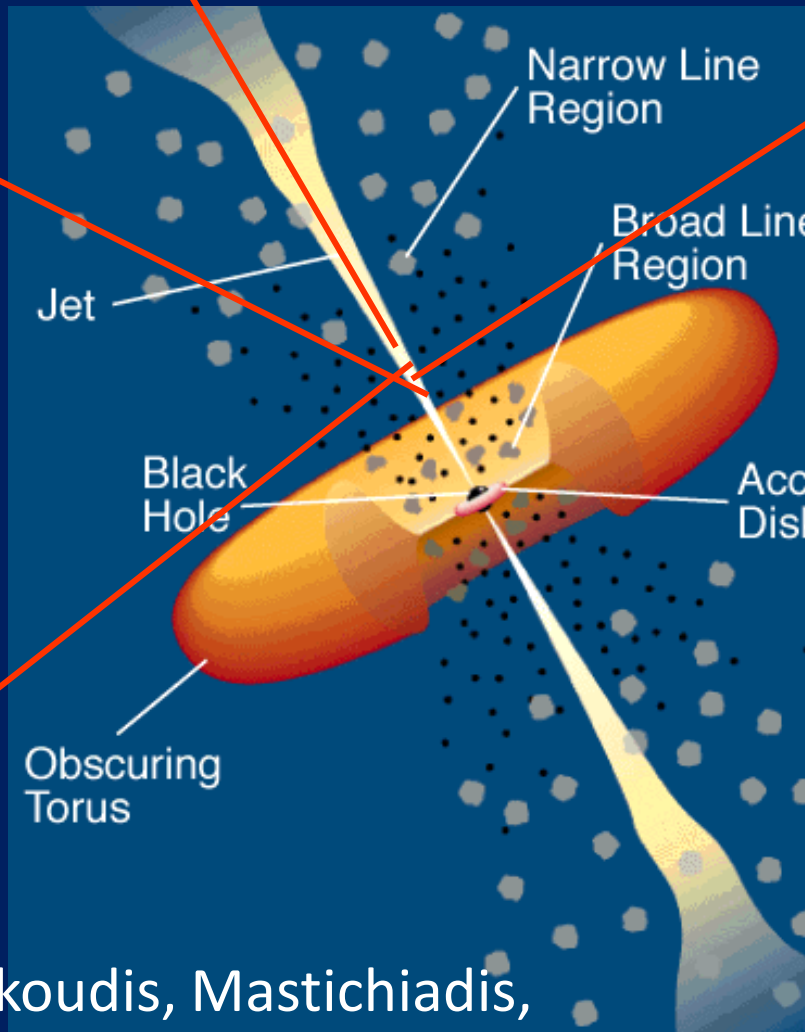
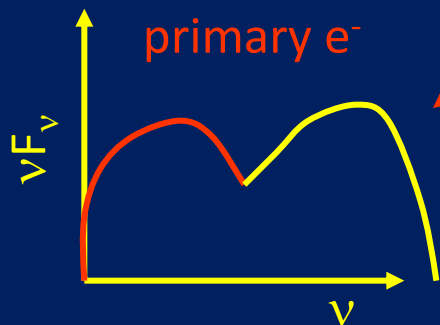
Injection, acceleration of ultrarelativistic electrons and protons

Relativistic jet outflow with $\Gamma \approx 10$

Proton-induced radiation mechanisms:



Synchrotron emission of primary e^-



- Proton synchrotron
- $p\gamma \rightarrow p\pi^0$
 $\pi^0 \rightarrow 2\gamma$
- $p\gamma \rightarrow n\pi^+$; $\pi^+ \rightarrow \mu^+\nu_\mu$
 $\mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$
→ secondary μ^- , e-synchrotron
- Cascades ...

(Cerutti, Dimitrakoudis, Mastichiadis, Petropoulou, Reimer)

Spectral modeling results along the Blazar Sequence: Leptonic Models

Sequence: Leptonic Models

High-frequency peaked BL
Lac (HBL):

The “classical” picture

Low B fields (~ 0.1 G);

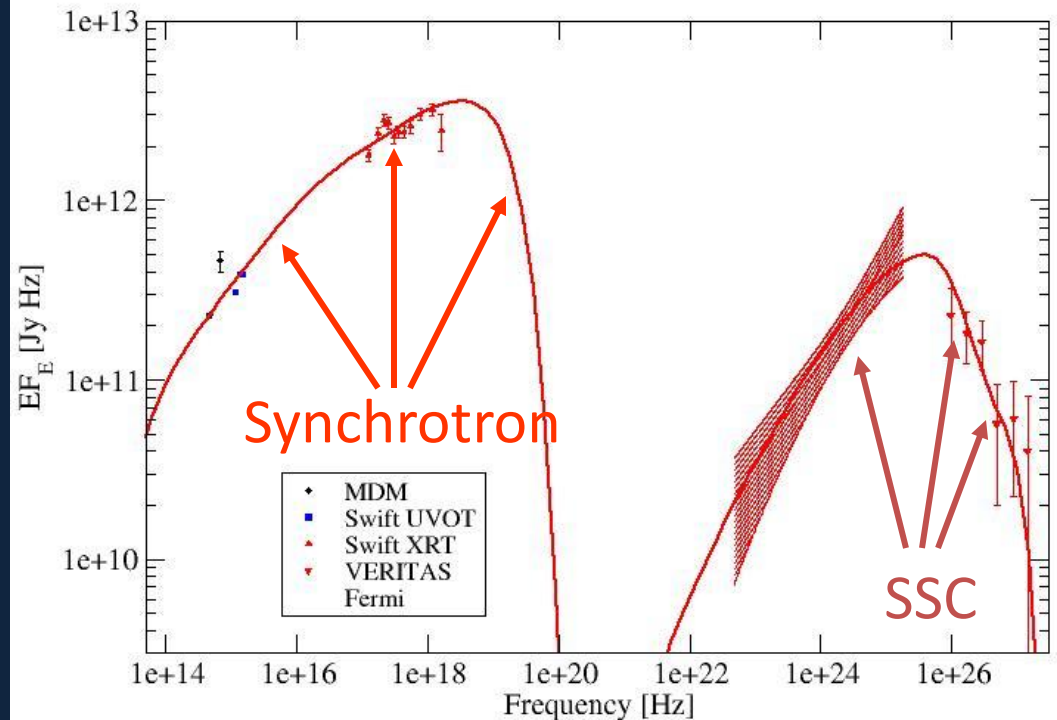
High electron energies
(up to TeV);

Large bulk Lorentz
factors ($\Gamma > 10$)



No dense
circumnuclear
material \rightarrow No
strong external
photon field

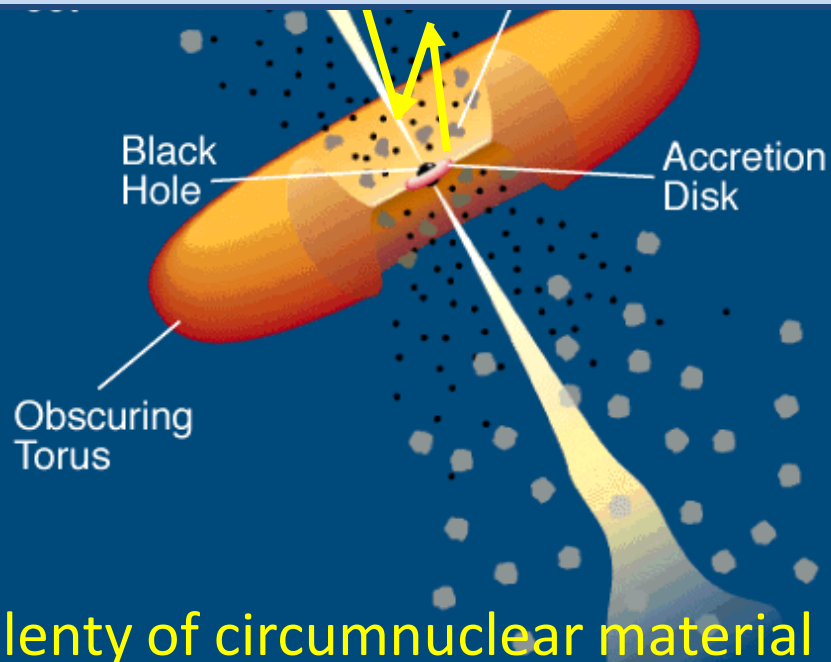
RGB J0710+591



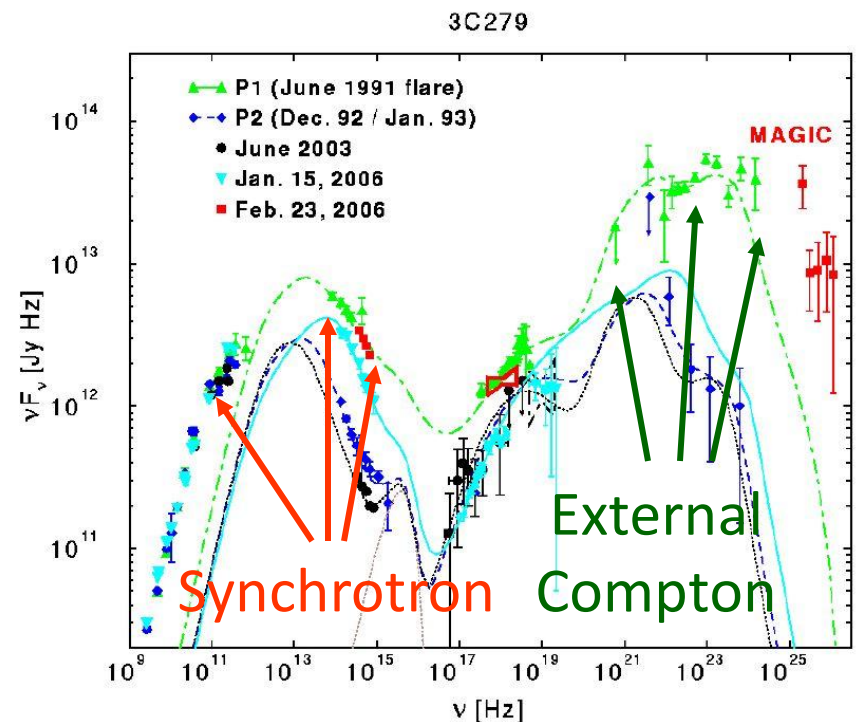
Spectral modeling results along the Blazar Sequence: Leptonic Models

Radio Quasar (FSRQ)

High magnetic fields (\sim a few G);
Lower electron energies (up to GeV);
Lower bulk Lorentz factors ($\Gamma \sim 10$)



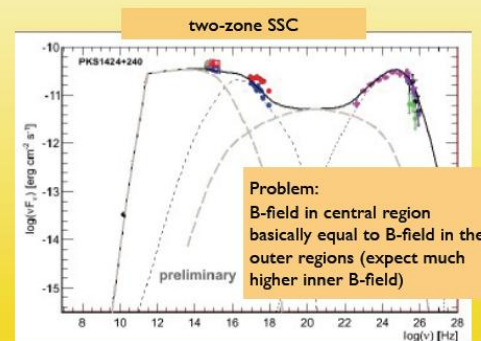
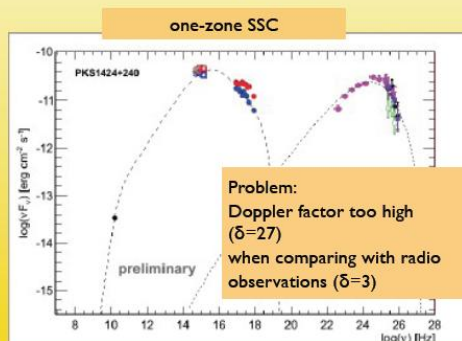
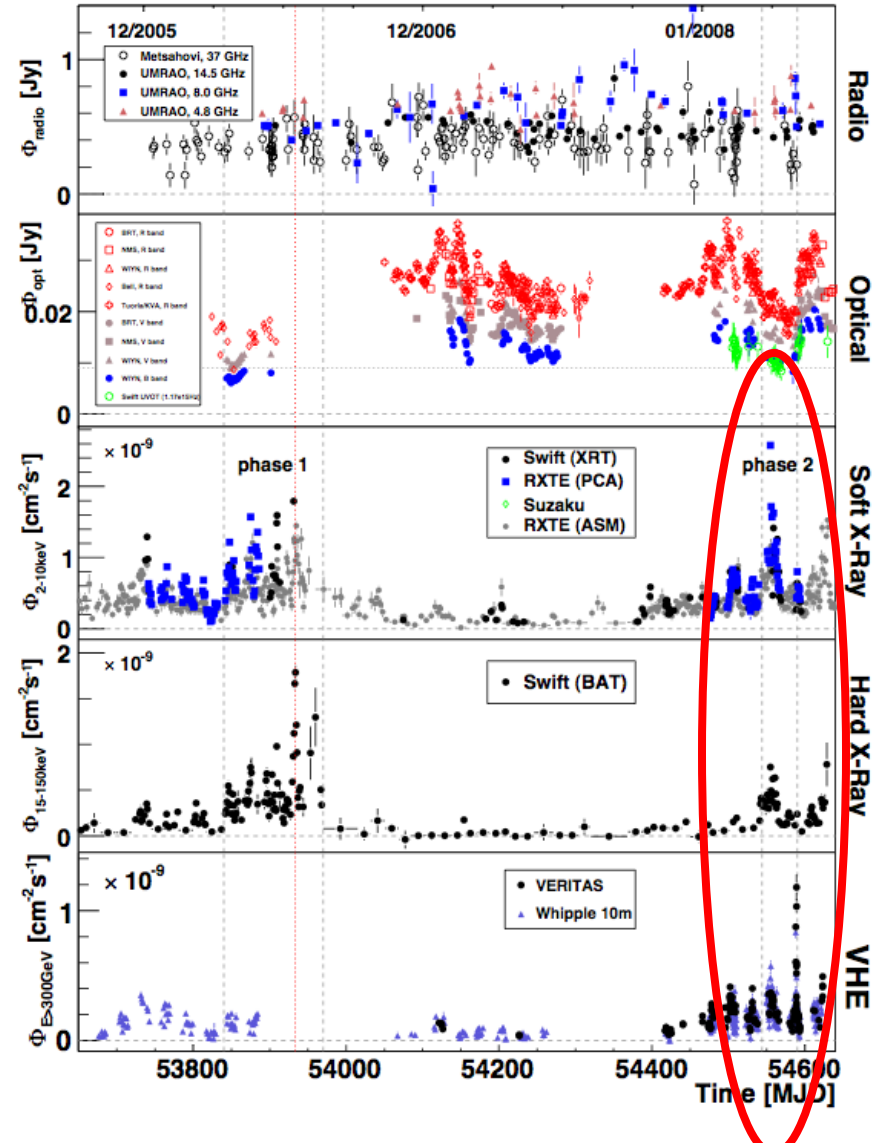
Plenty of circumnuclear material
→ Strong external photon field



Challenges to One-Zone Models

Mrk 421 (L. Fortson)

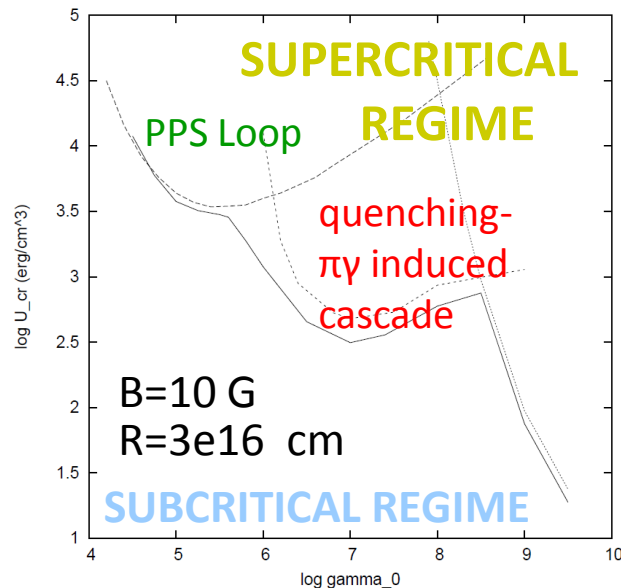
- Uncorrelated X-ray / γ -ray variability
 - Mrk 421: Fortson
 - Mrk 501: Nowak – VHE high state correlated with optical polarization
- 1ES 1959+650: Two-component GeV – TeV spectrum: not well fit by SSC + EC or hadronic or $\gamma\gamma$ -absorption (Backes)
- Modeling of PKS 1424+240 not consistent with one-zone models (Prandini)



New Model Ideas and Developments

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

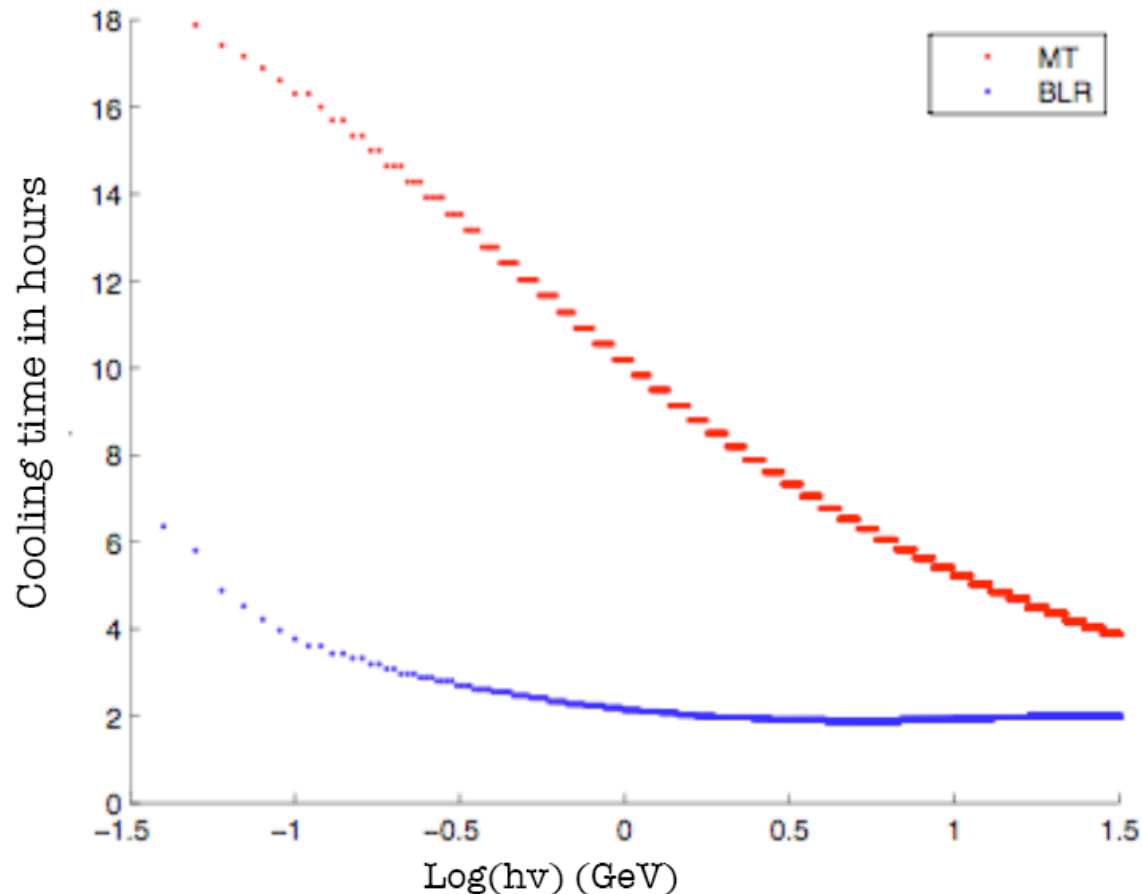
-> Lower limit on Doppler factor $\delta \sim 20$ for 3C279.



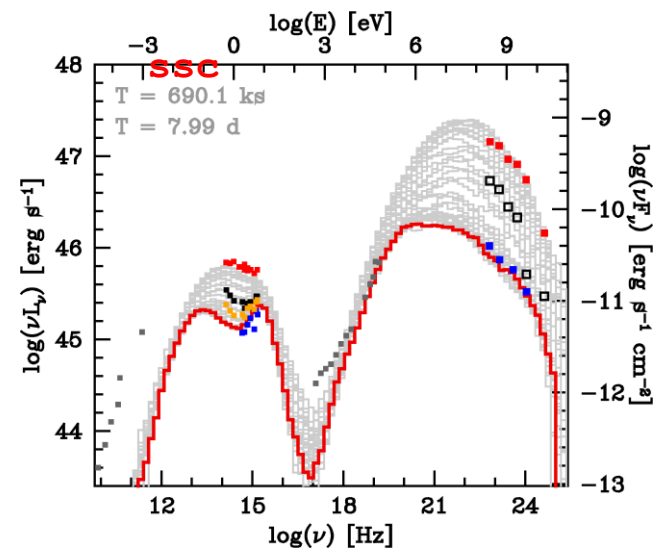
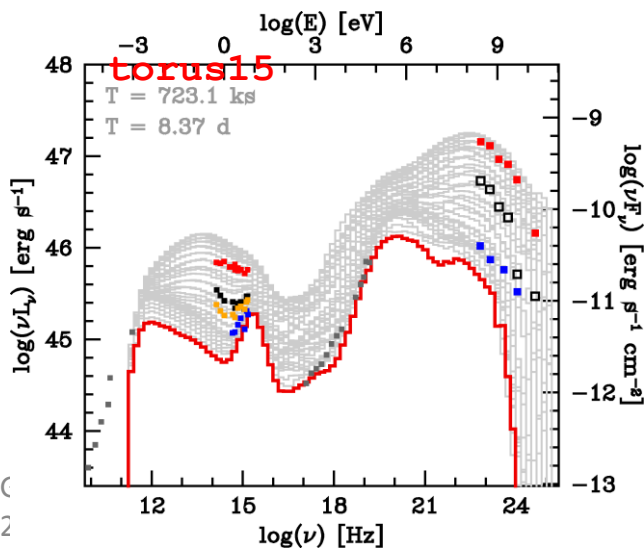
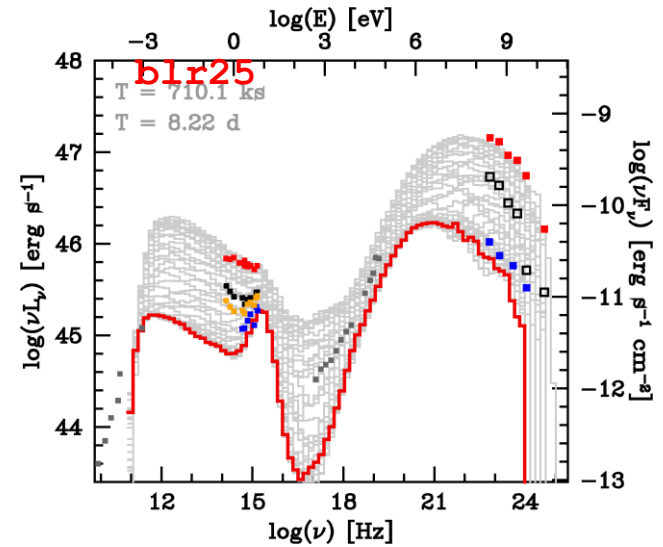
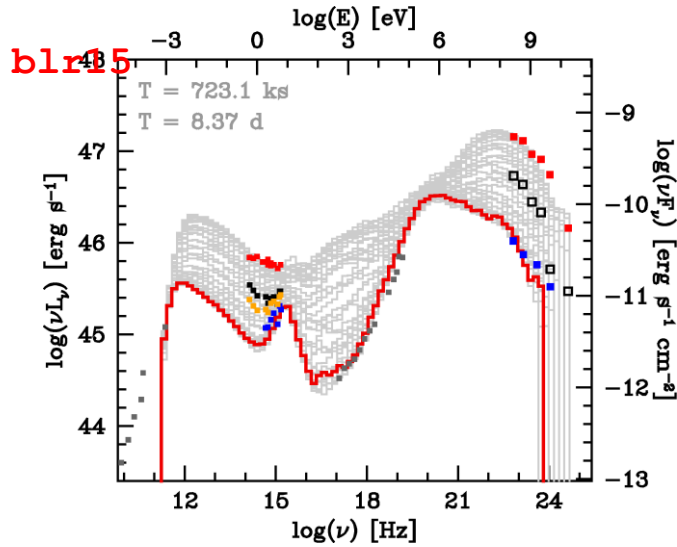
- Hadronic Models become time-dependent (Dimitrakondis, Reimer)
 - > Uncorrelated X-ray / γ -ray variability possible!

New Model Ideas and Developments

- From beaming: Powerful jets are EC dominated;
From energy dependence 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

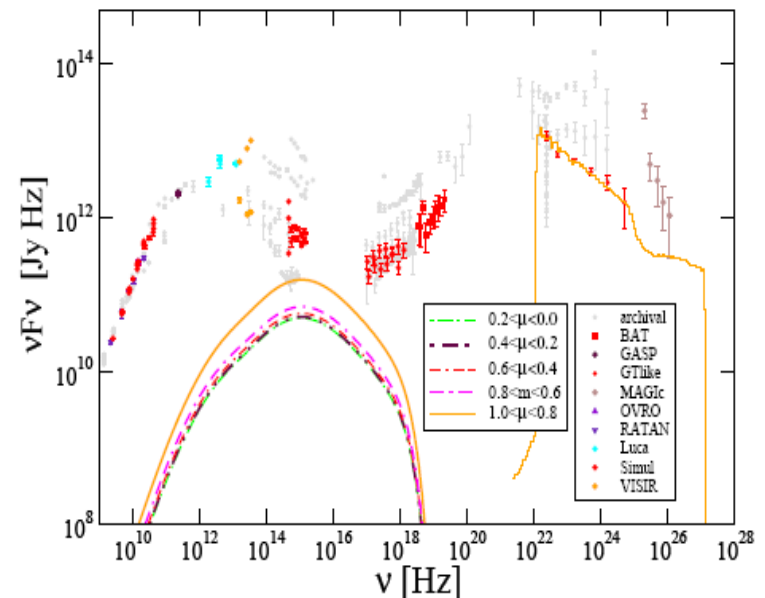
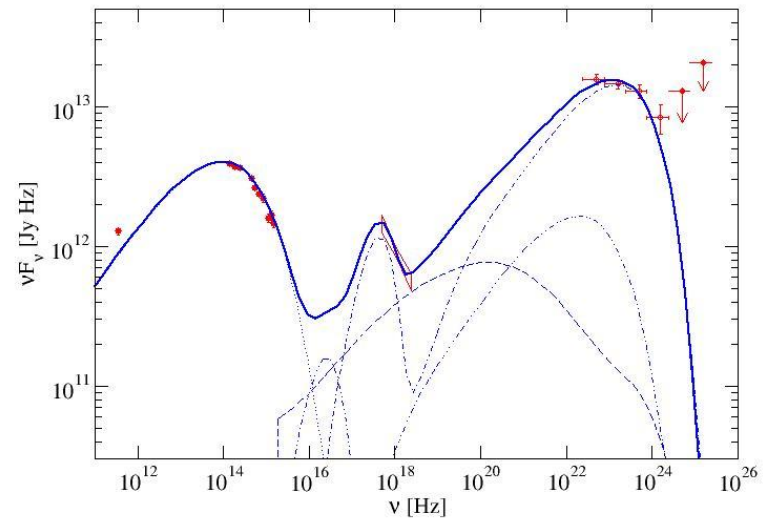
- High-energy emission and variability from jet-star interactions.
 - 3C454.3 flare reproduced with $L_j \sim 10^{49}$ erg/s; $\delta \sim 60$ (Barkov).
 - Jet-stellar wind interaction produces double bow shock (Araudo)
- Log-parabolic spectra are the natural result of stochastic particle acceleration: Curvature related to momentum diffusion coefficient (Tramacere).
 - > Quasi-Maxwellian electron distribution -> 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)

AO 0235+164



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 Id-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	FR I 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

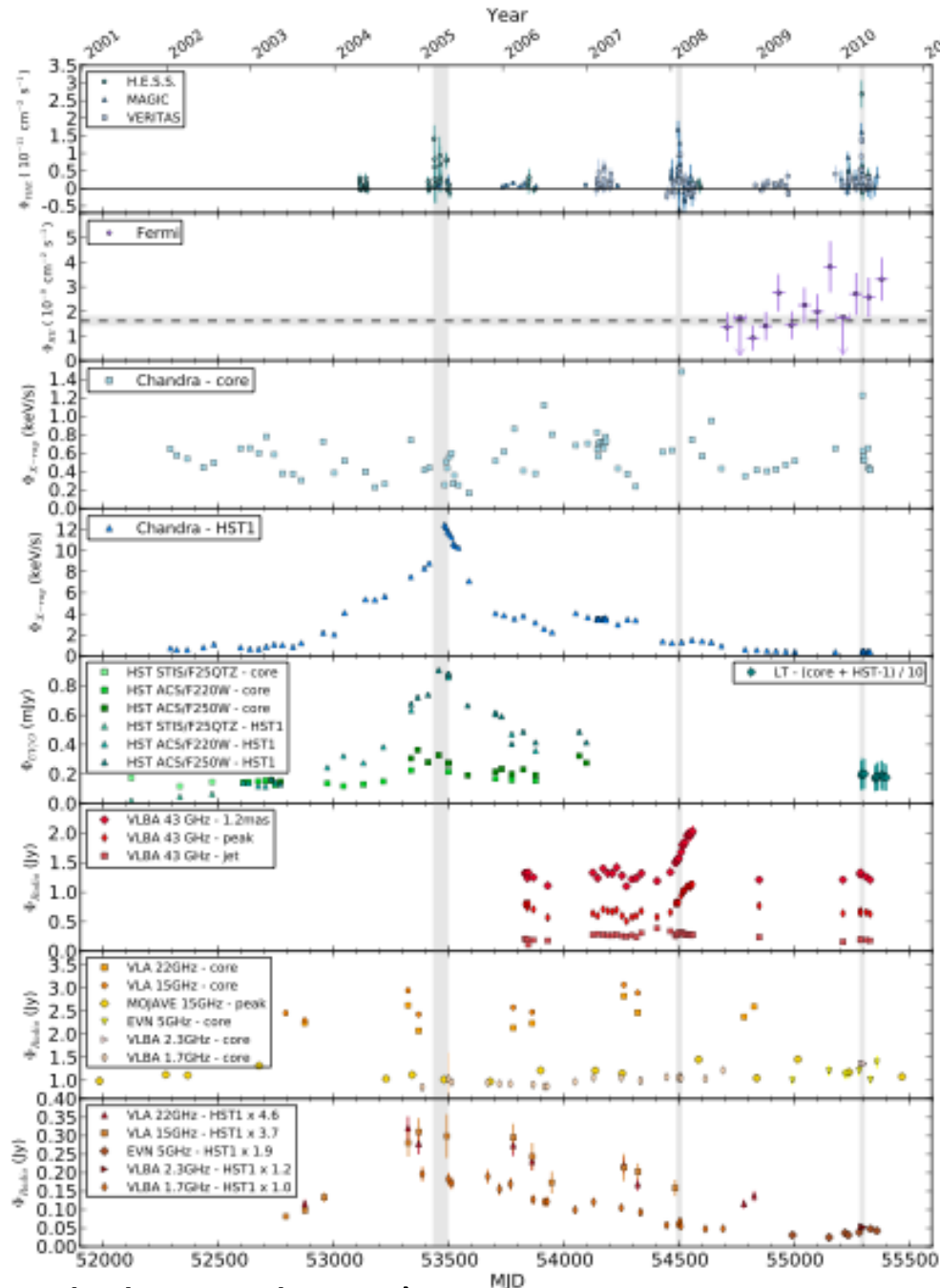
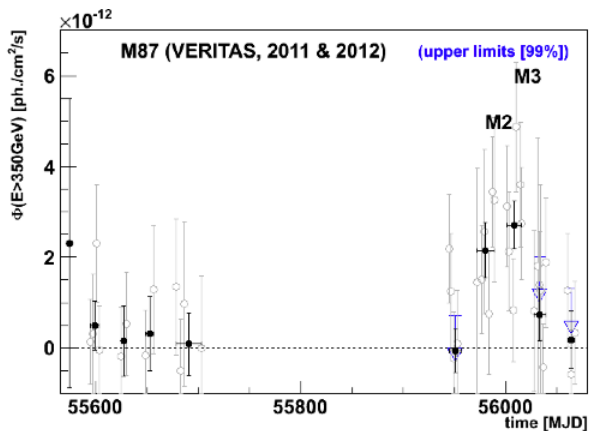
HE: Fermi

X-ray: Chandra

Optical: HST, Liverpool Telescope

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

3 flaring episodes (maybe 4)

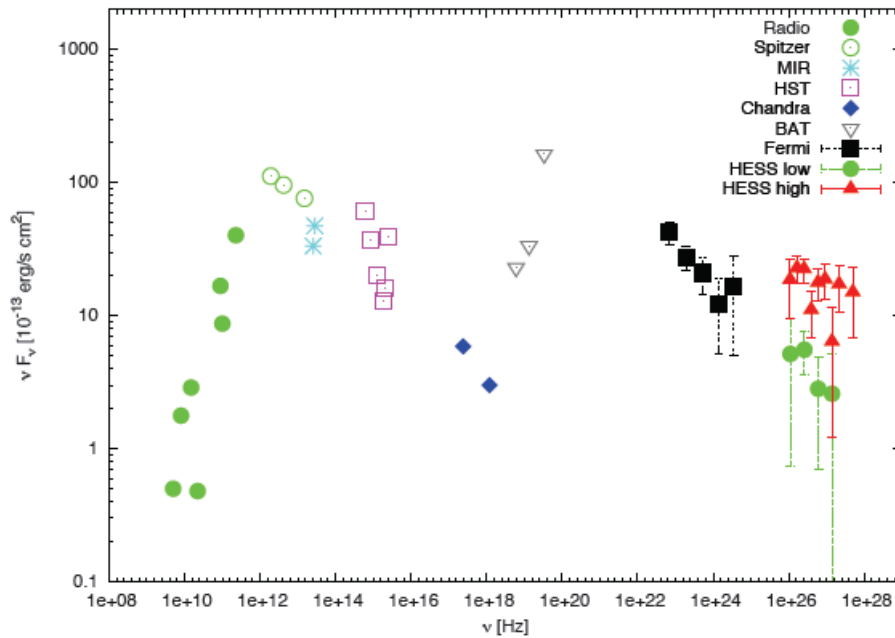


(Beilicke, Galante)

Radio Galaxies

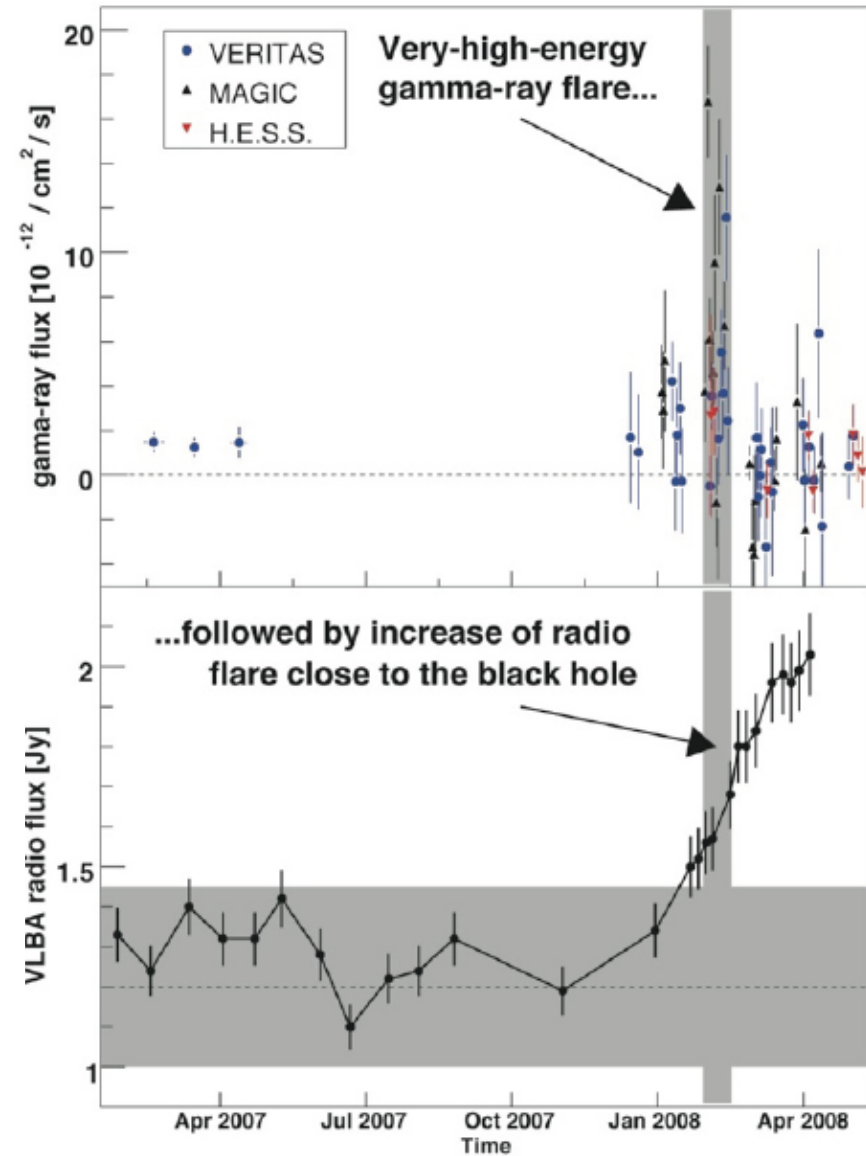
M 87

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)

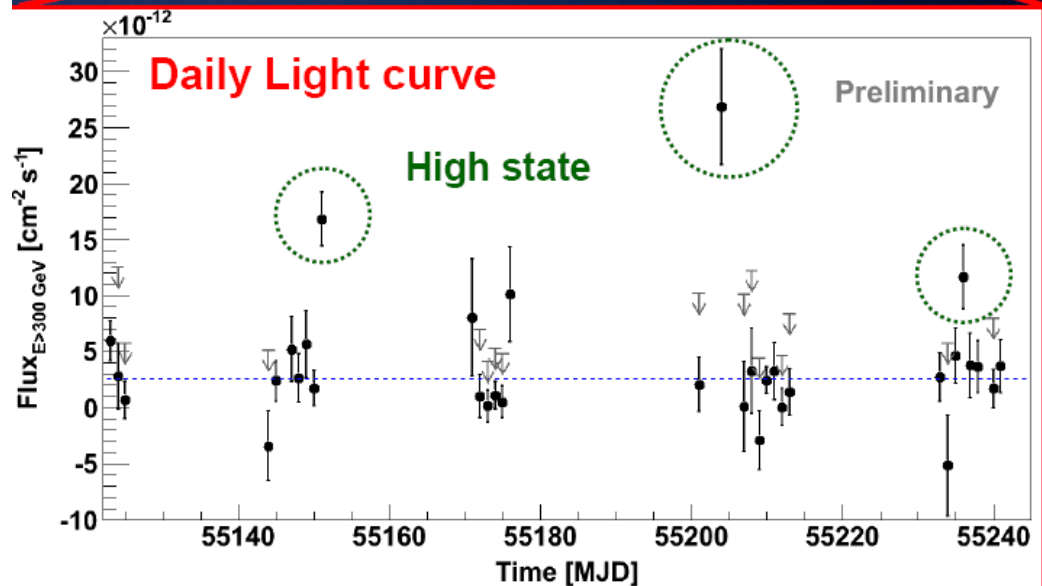
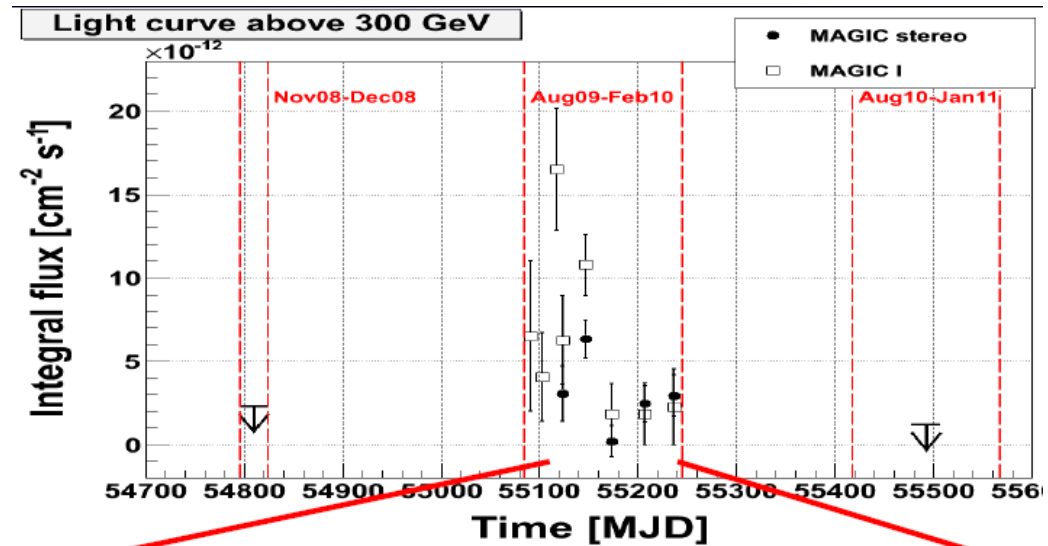
Radio Galaxies

IC 310

Originally classified as head-tail radio galaxy.

Rapid variability + VLBA structure suggest blazar-like properties!

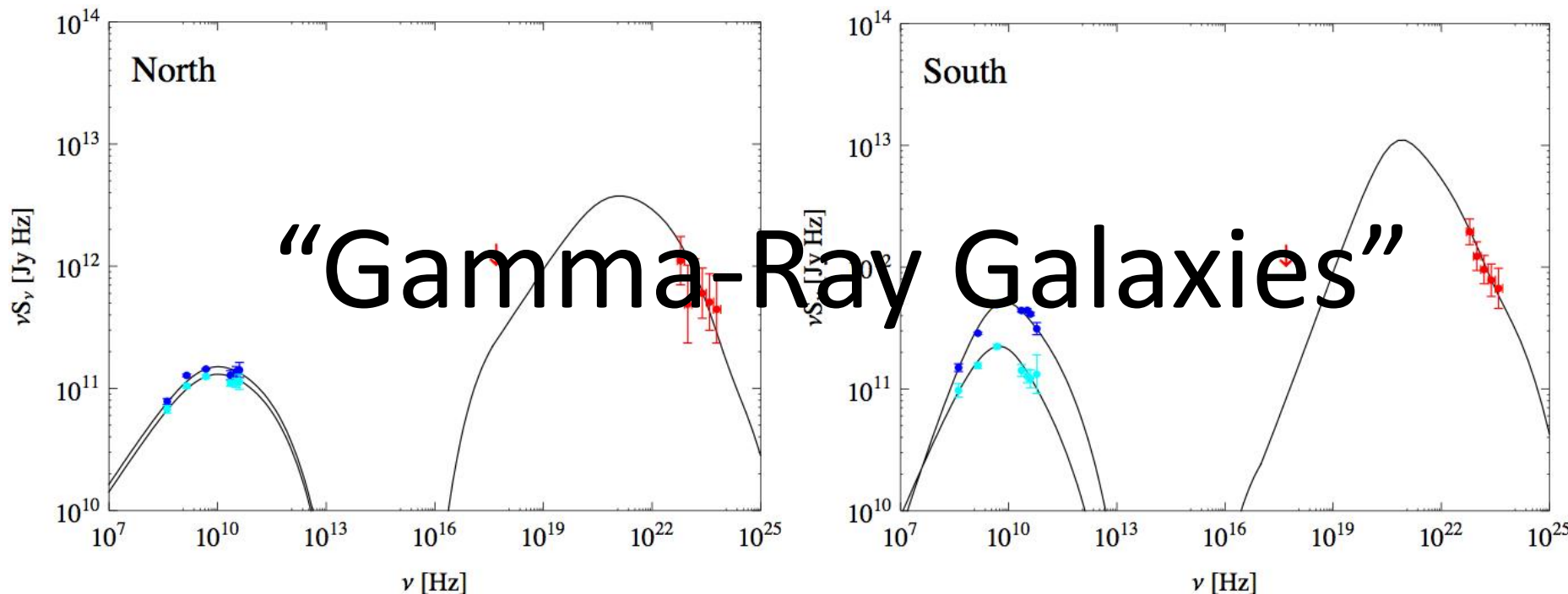
(D. Eisenacher,
P. Colin)



Radio Galaxies

Cen A

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



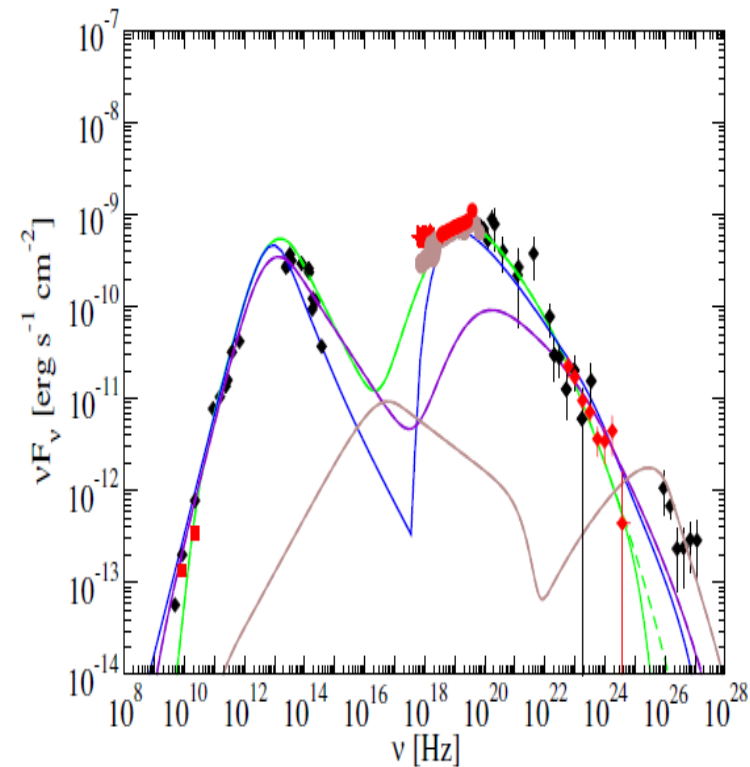
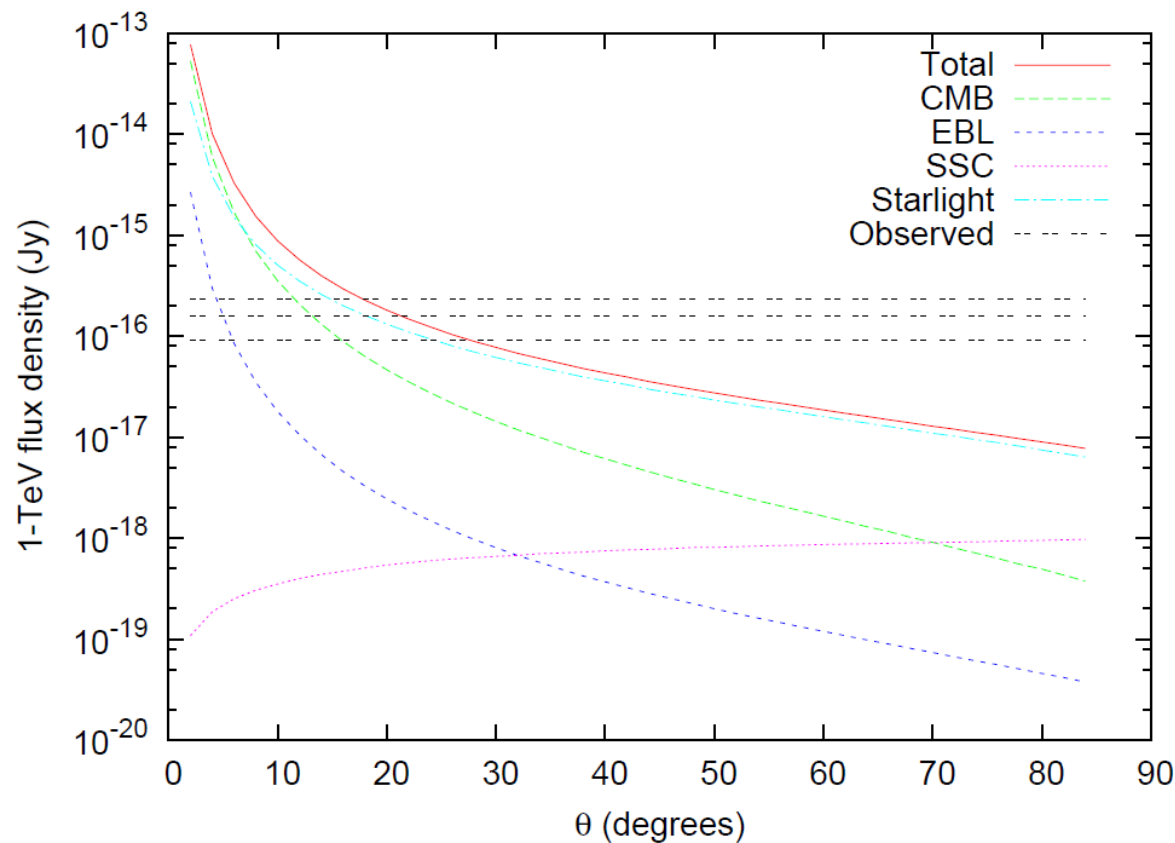
“Gamma-Ray Galaxies”

(Hardcastle)

Radio Galaxies

Cen A

Model constraints on viewing angle

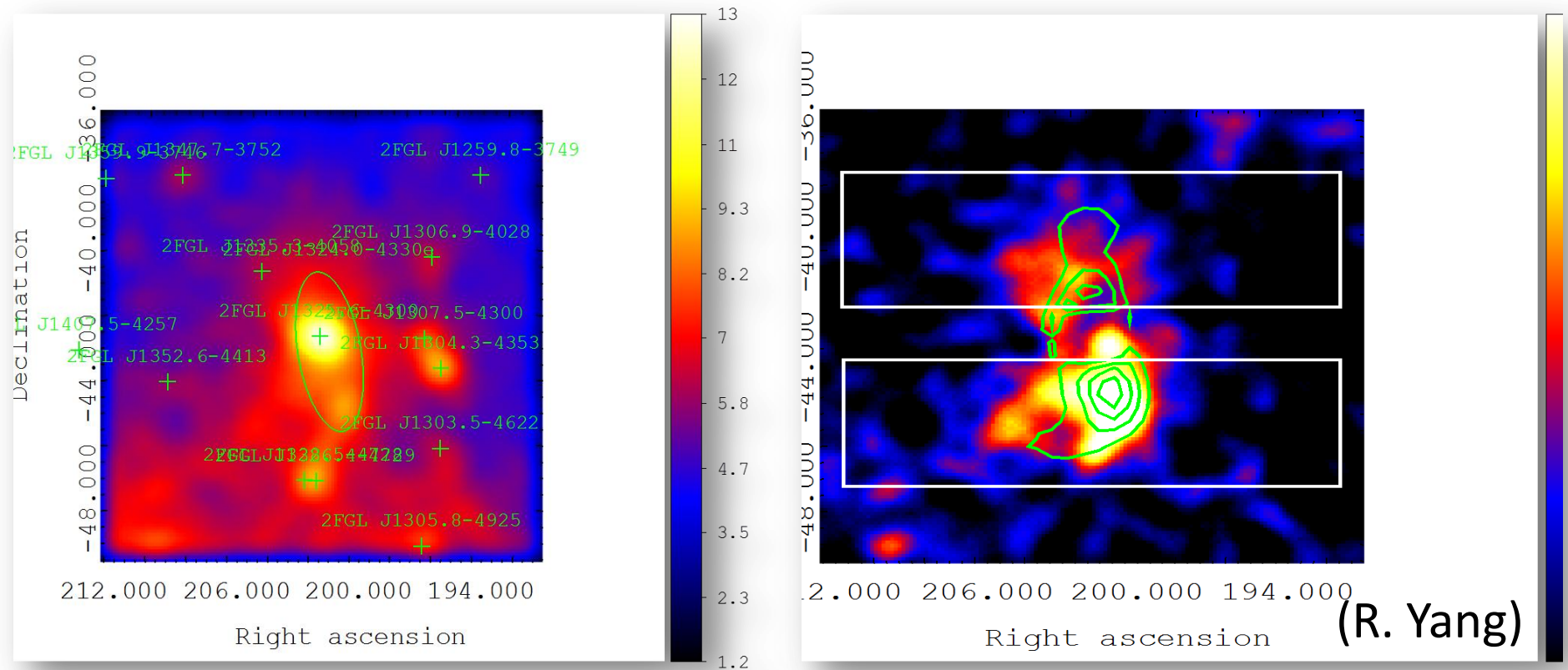


(Hardcastle)

Radio Galaxies

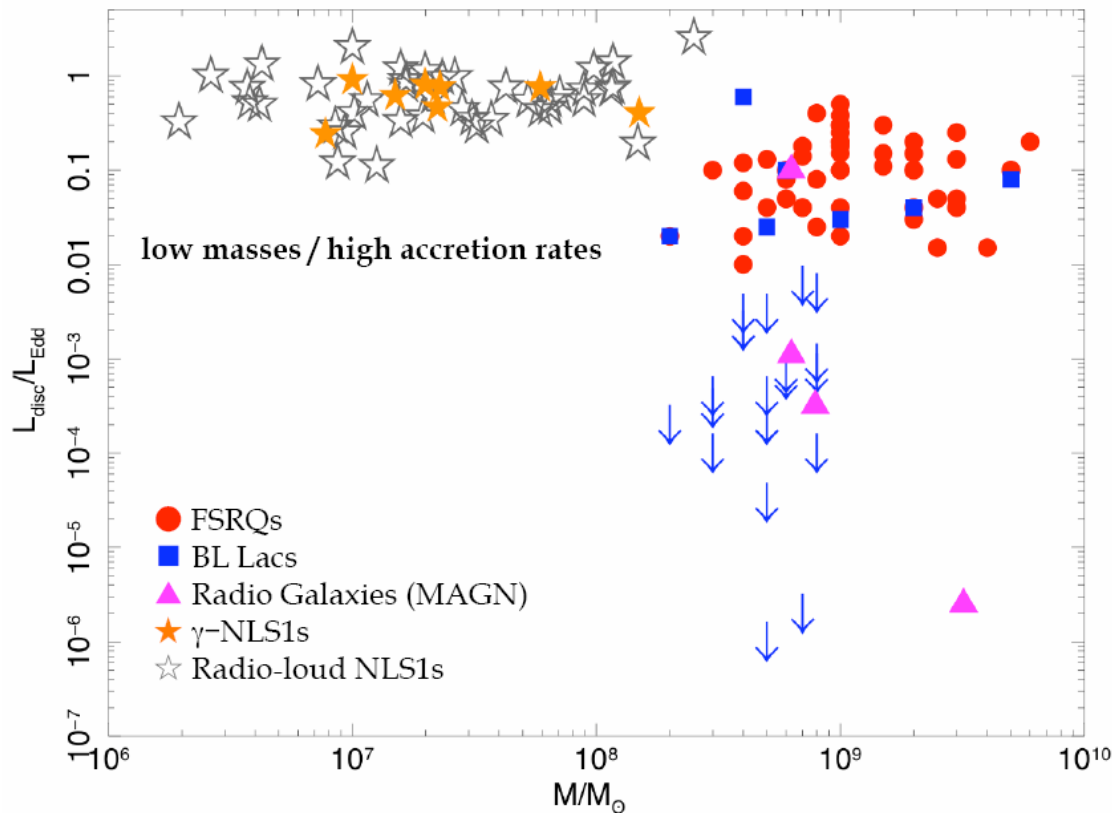
Cen A

Fermi Lobes are 3 times larger than radio lobes!



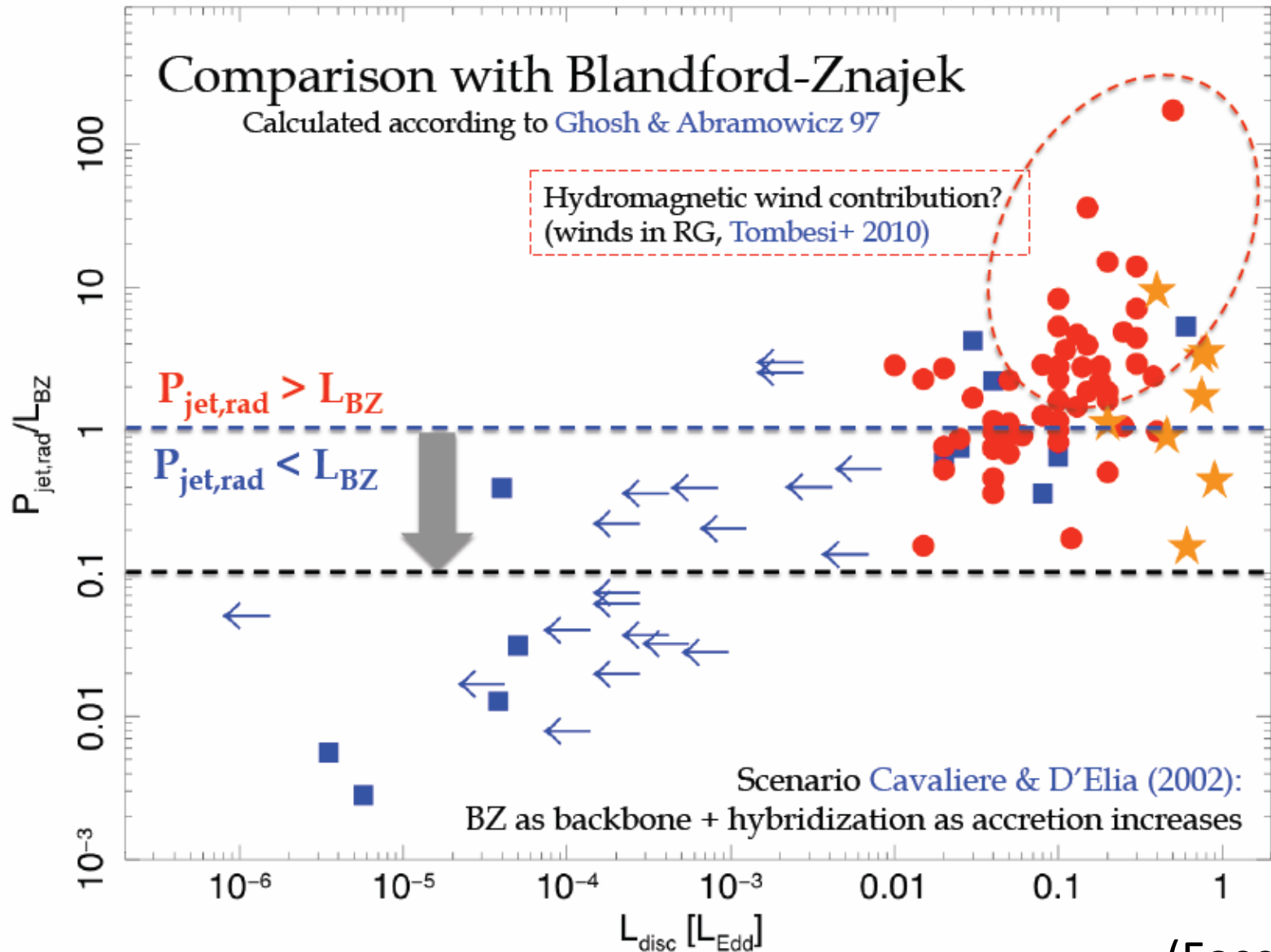
NLSy1

- 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)

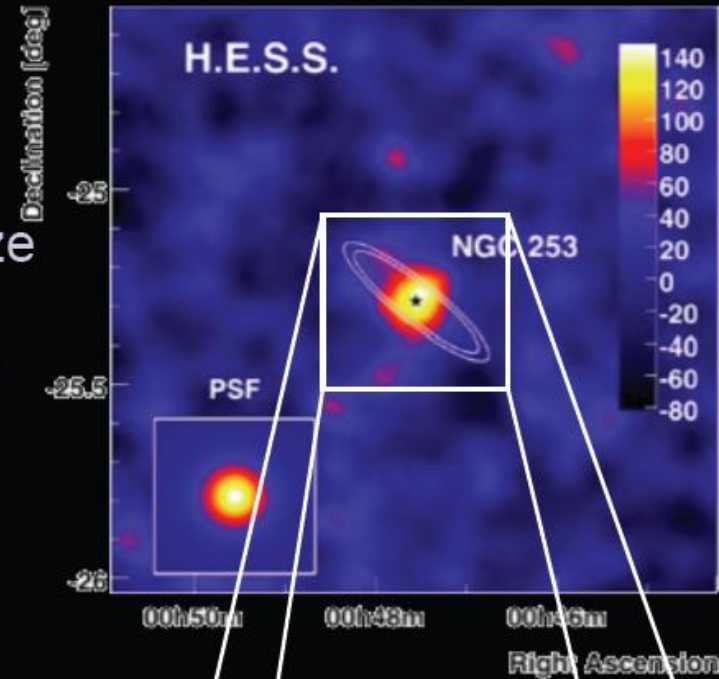
Starburst Galaxies

Acero et al., 2009

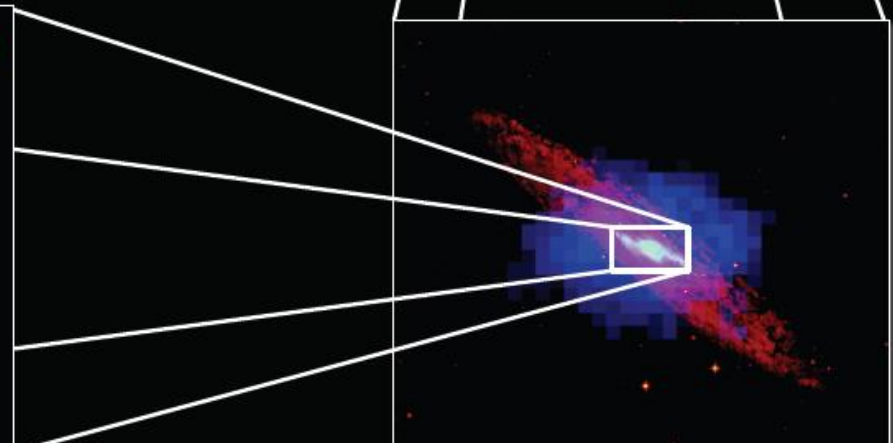
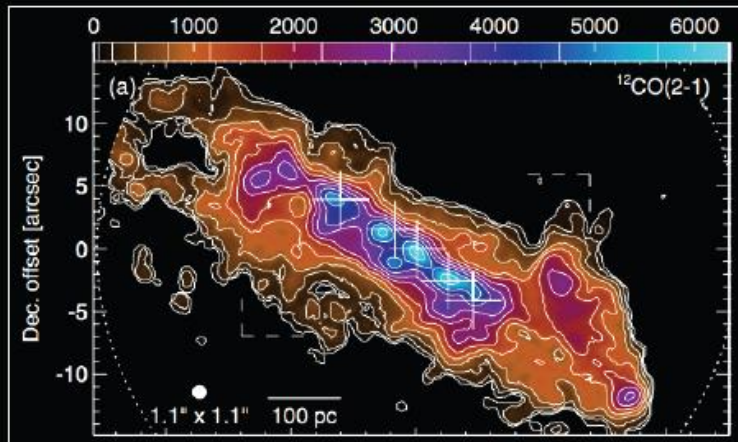
VHE γ -ray emission

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

(S. Ohm)



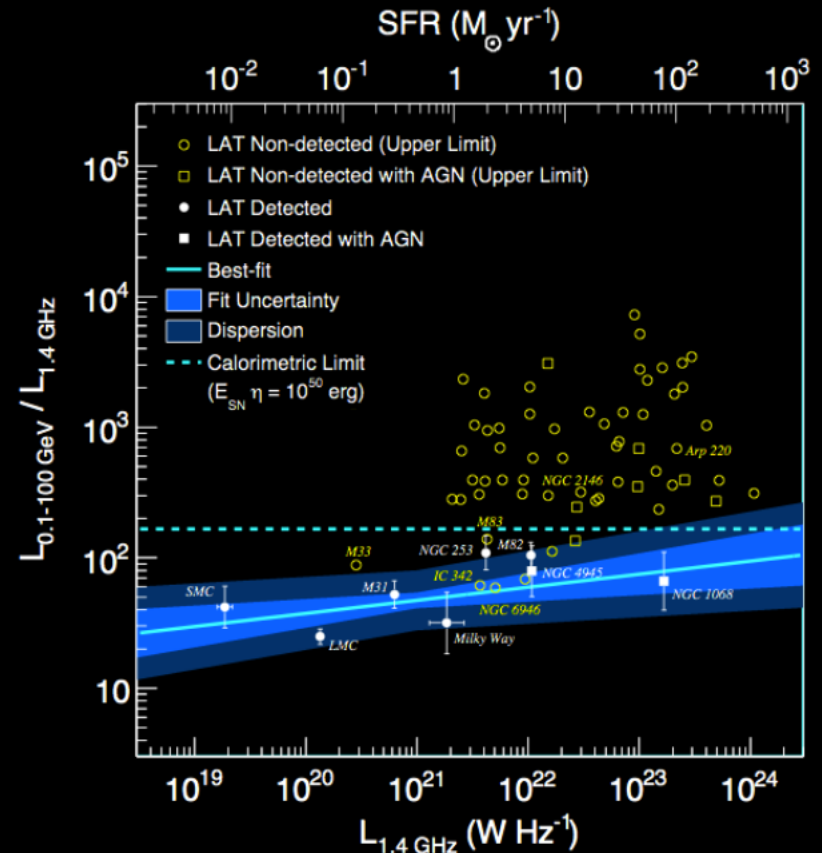
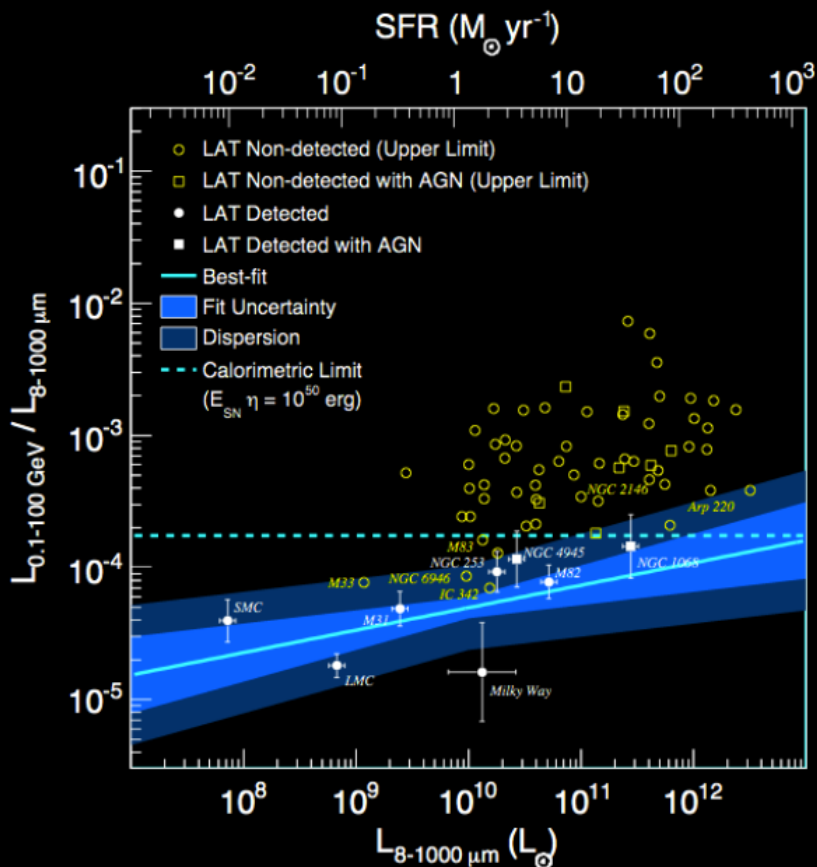
Sakamoto et al. 2011



Starburst Galaxies

Sample of γ -ray galaxies is increasing:

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



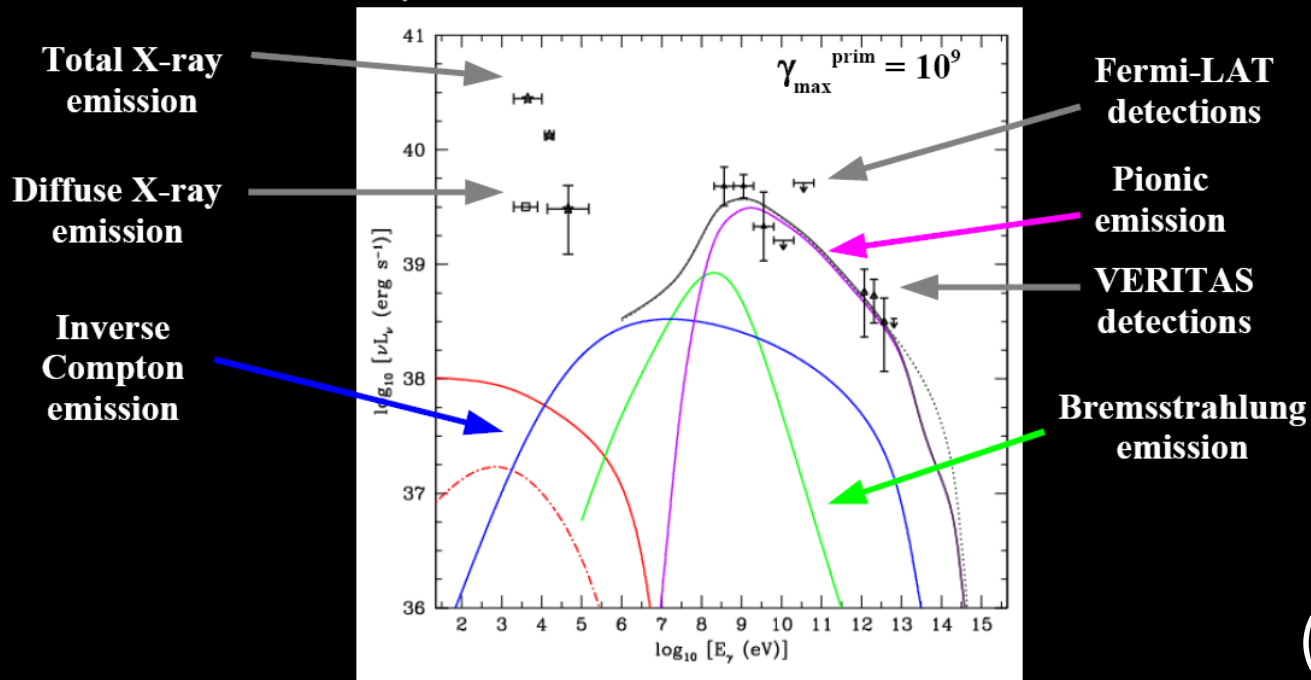
Up to 10 galaxies in 10 years of Fermi (?)

(S. Ohm)

Starburst Galaxies

- Gamma-ray dominance
⇒ Evidence for CR-induced π -production and decay
(neutrino fluxes probably too low for detection)
- $u_{\text{CR}} \sim u_{\text{B}} \sim u_{\text{FIR}}$
- Lack of IC emission -> Limit on B-field

150 μG model for M82

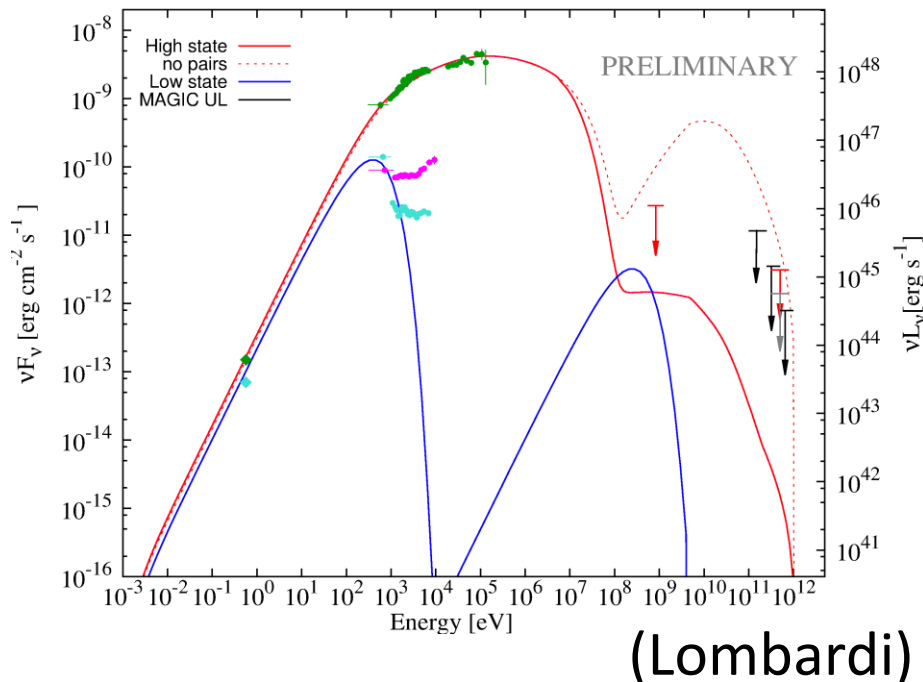
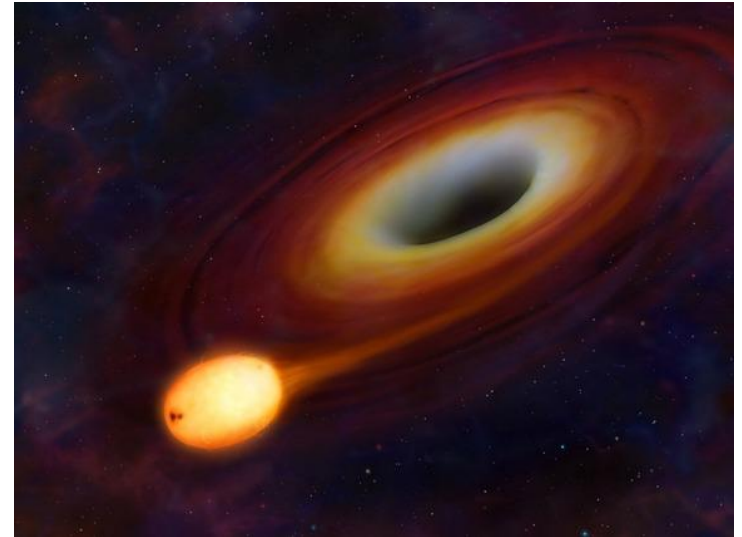


(B. Lacki)

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)

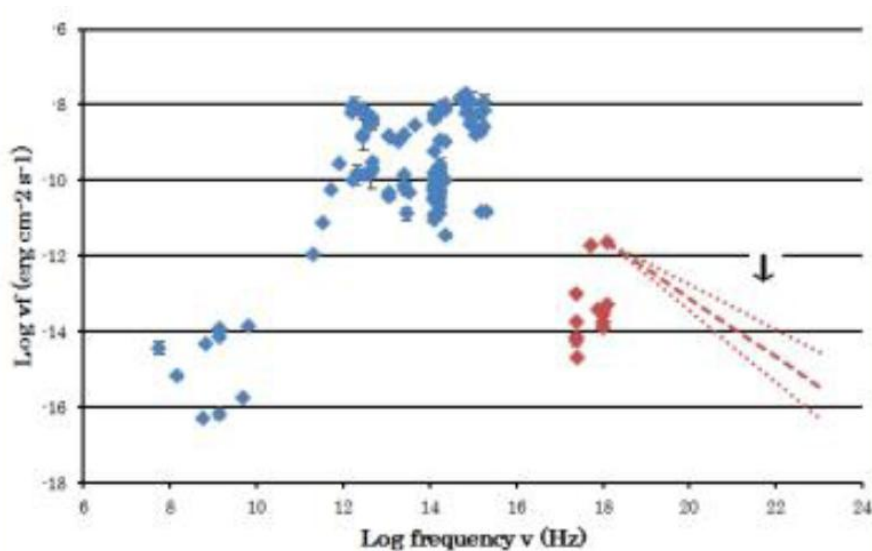
Lack of gamma-ray detection (Fermi, VERITAS) - now confirmed by MAGIC (Lombardi) - possibly due to $\gamma\gamma$ absorption.

Newly Still-Not-Detected

ULXs

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

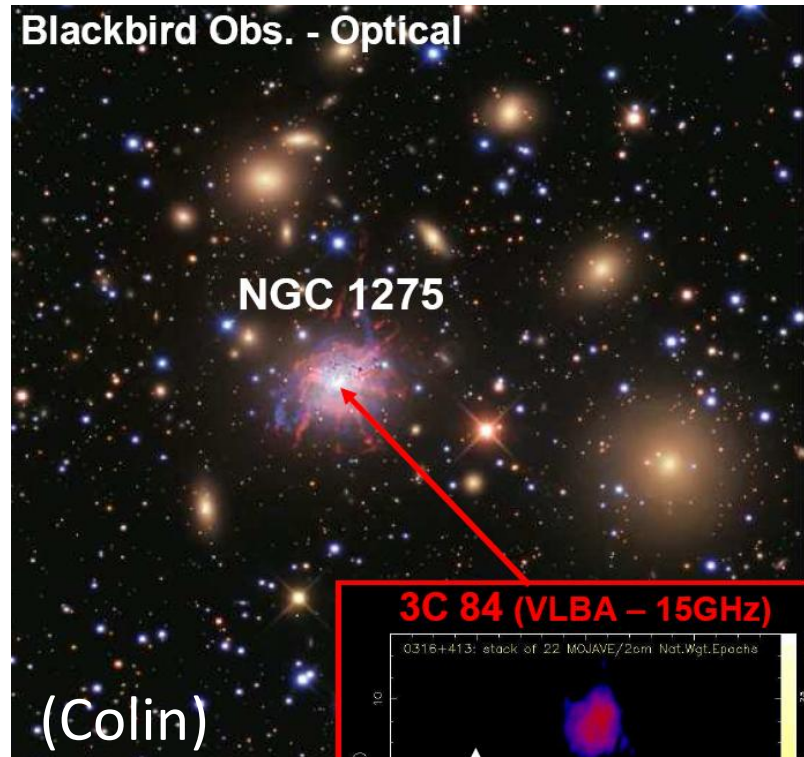
Upper limits consistent with extrapolation from X-rays.



(Lombardi)

Galaxy Clusters

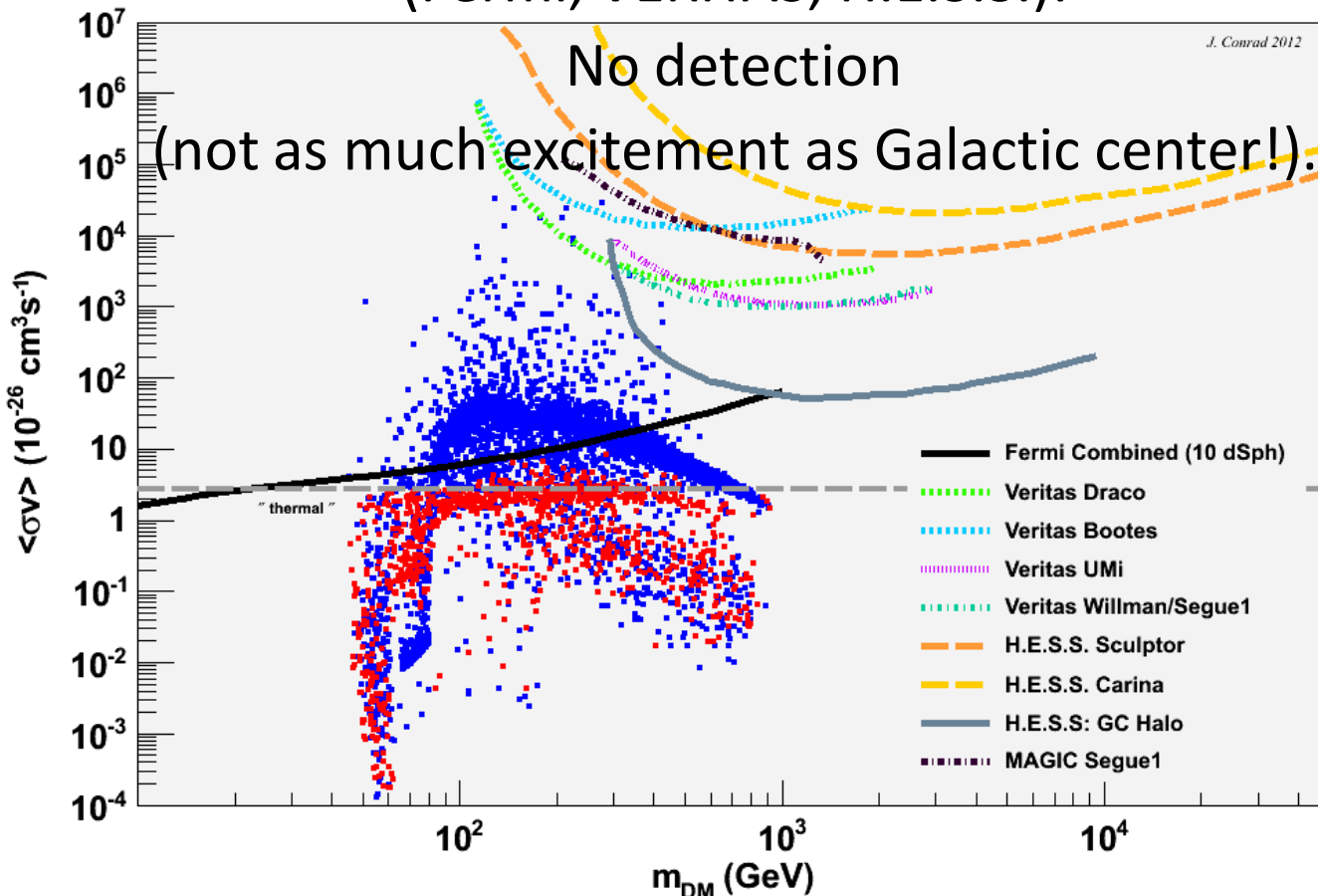
- Still no GeV – TeV emission from clusters of galaxies, but detection of several BCGs (NGC 1275, ...)



(Colin)

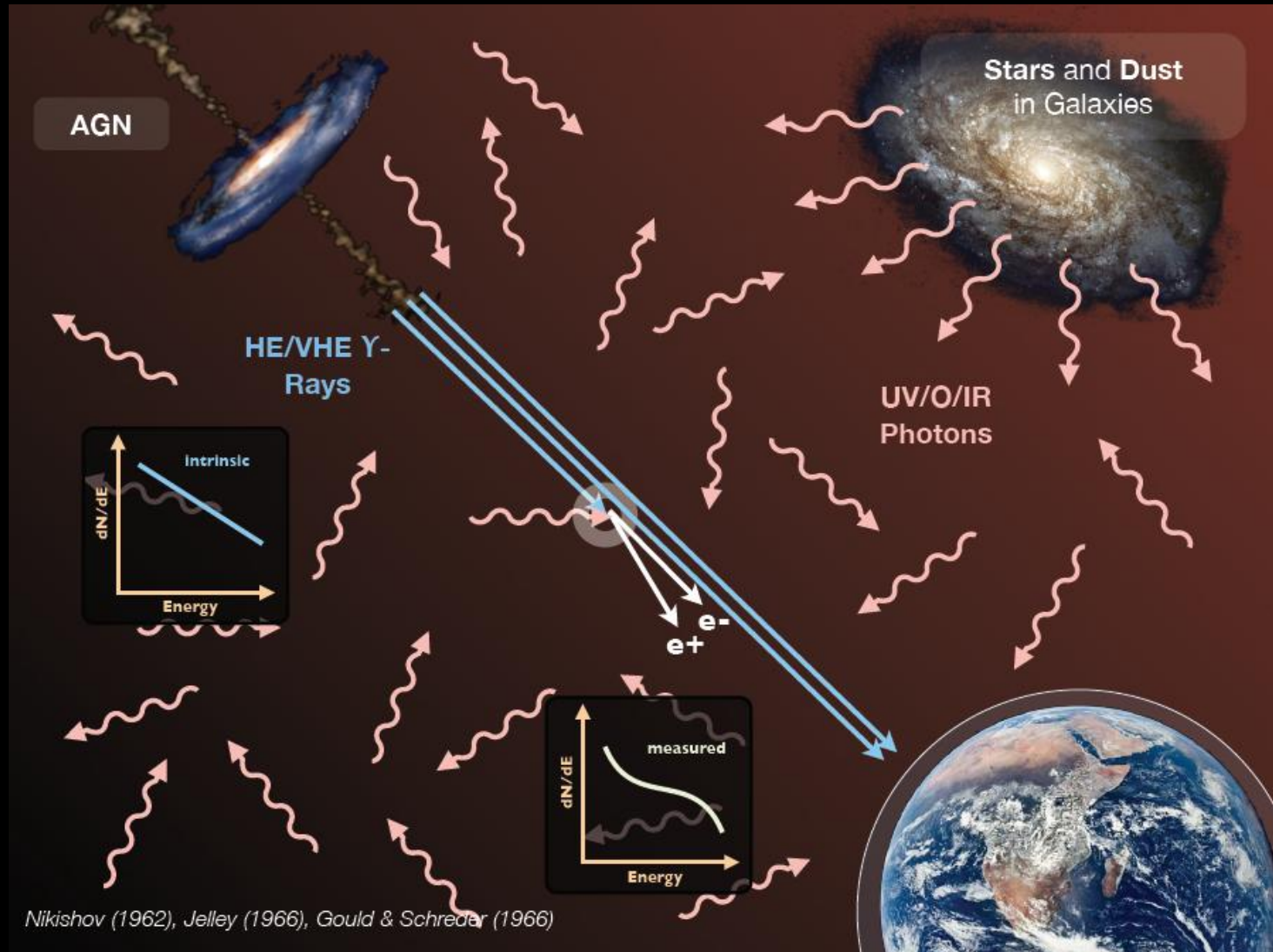
Newly Still-Not-Detected Dark-Matter Annihilation Signatures from Dwarf Spheroidals and Galaxy Clusters

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



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

EBL and Extragalactic Magnetic Fields

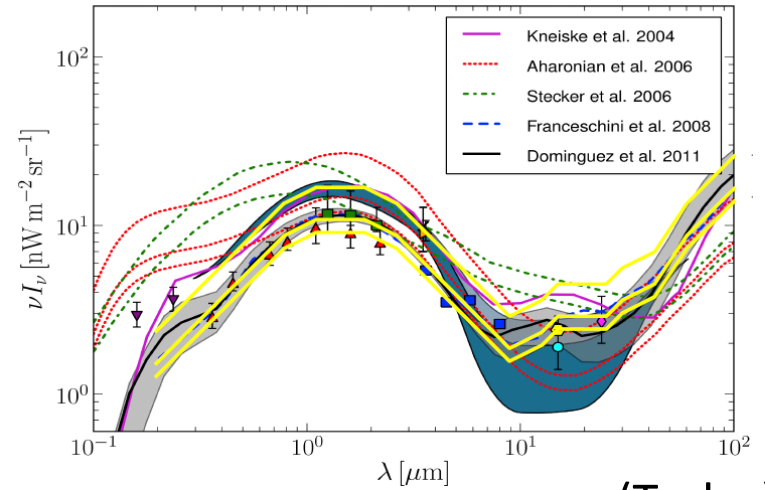


(Raue)

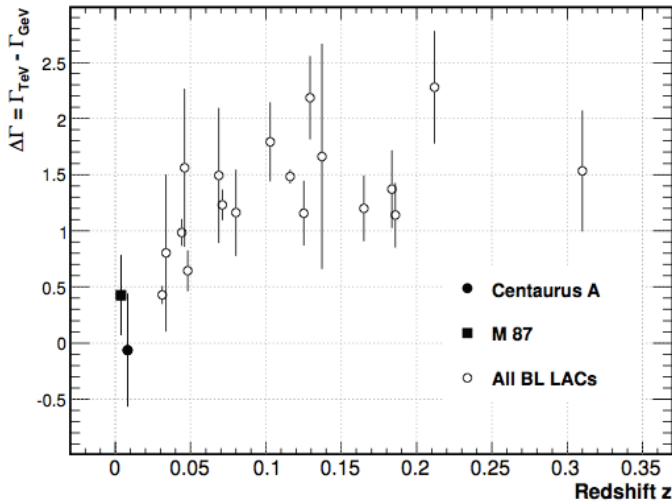
Nikishov (1962), Jelley (1966), Gould & Schredar (1966)

The EBL

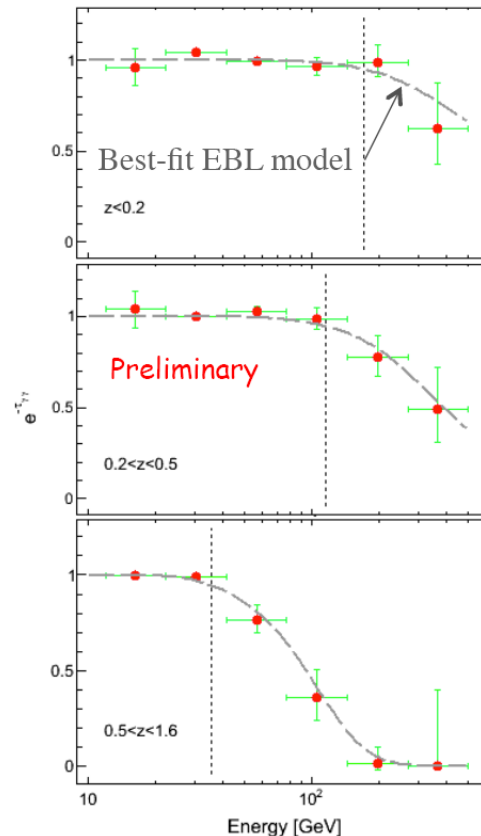
- EBL constrained to be within \sim factor 2 of lower limits from galaxy counts (Meyer) – $\alpha = 1.27$ (Biteau)
- Can be used to constrain star-formation history (Raue)



(Taylor)

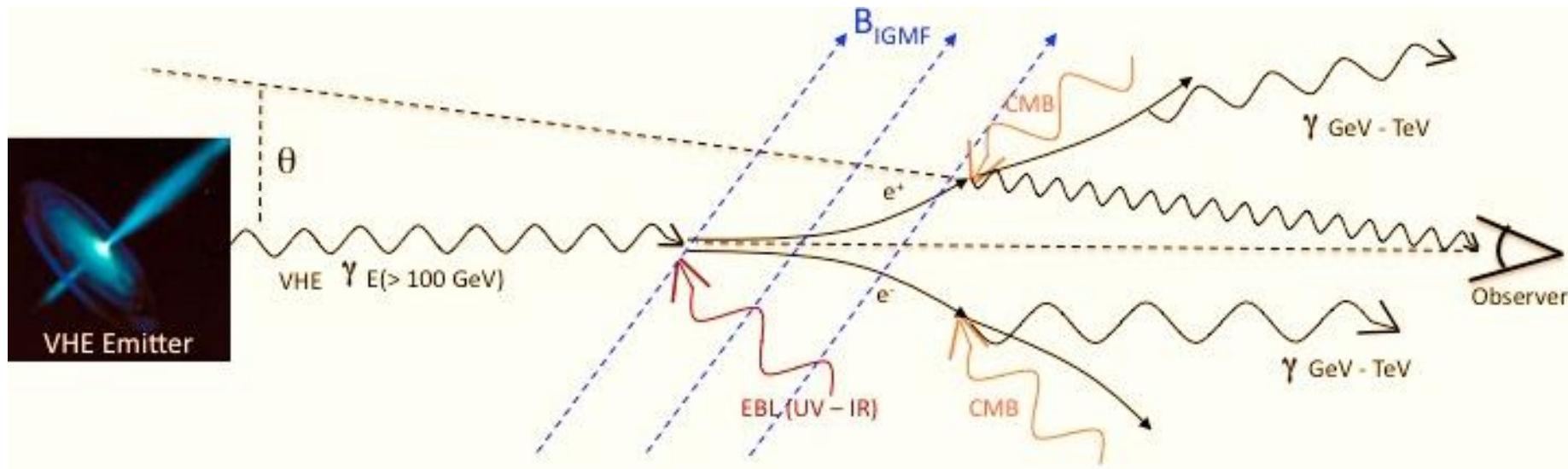


EBL absorption effect clearly reflected in GeV – TeV breaks (Sanchez; Biteau; Gasparrini)



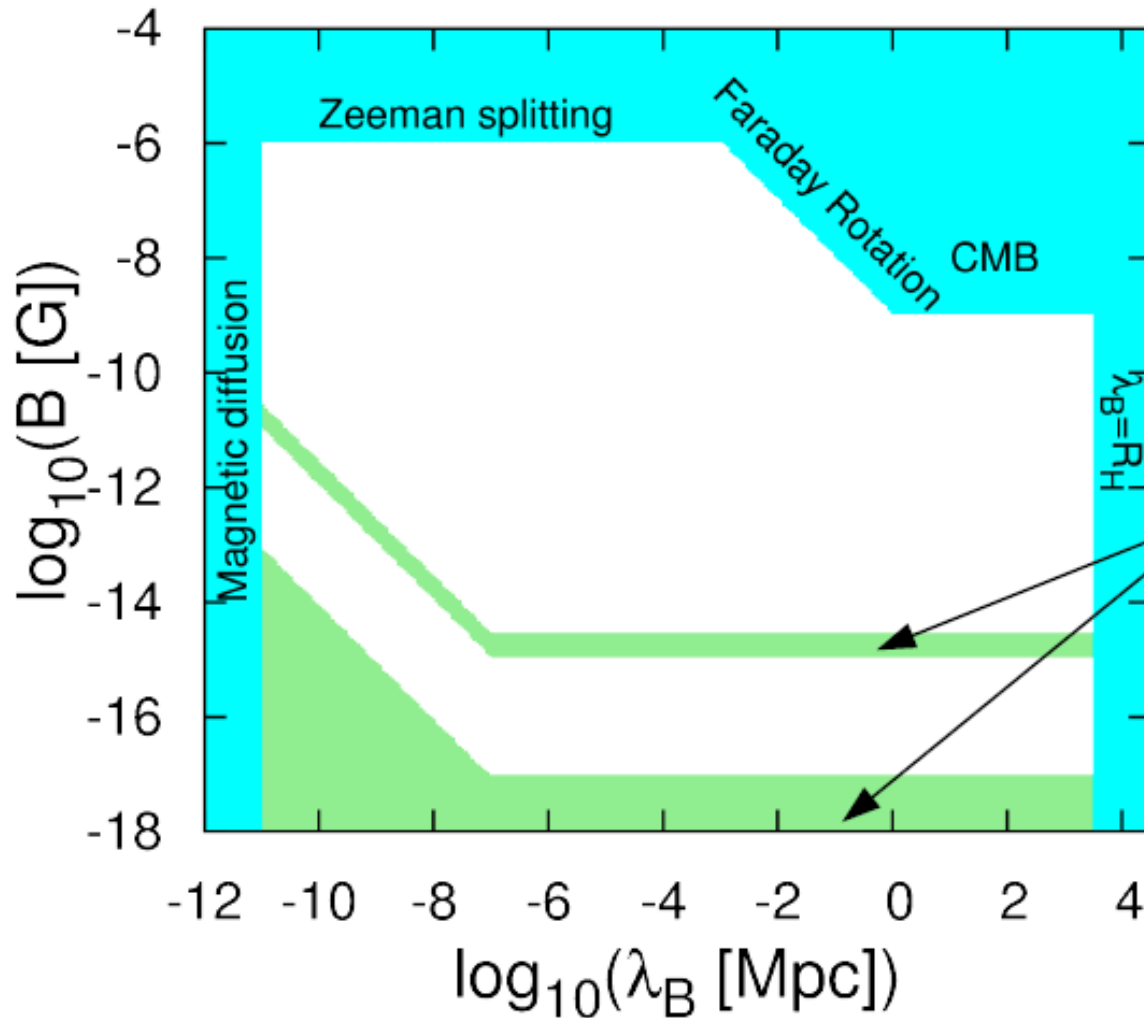
EBL absorption effect seen in Fermi blazar spectra (Ajello)

Intergalactic Cascading and Magnetic Fields



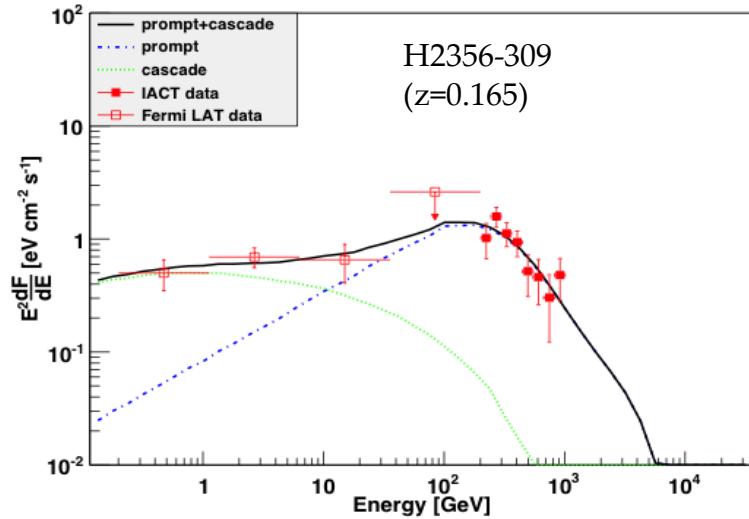
- (Deflected) IC cascades may fill in GeV emission, lead to extended halos -> Limits on B-field

Intergalactic Cascading and Magnetic Fields



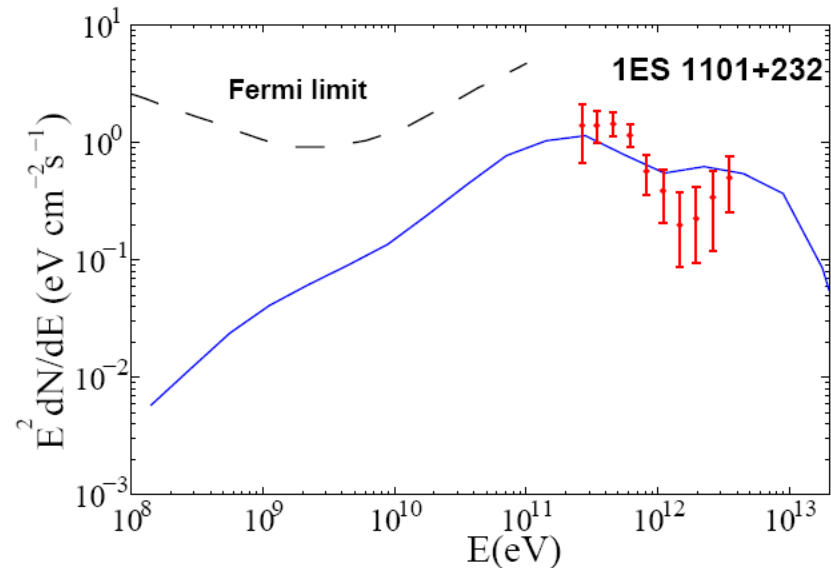
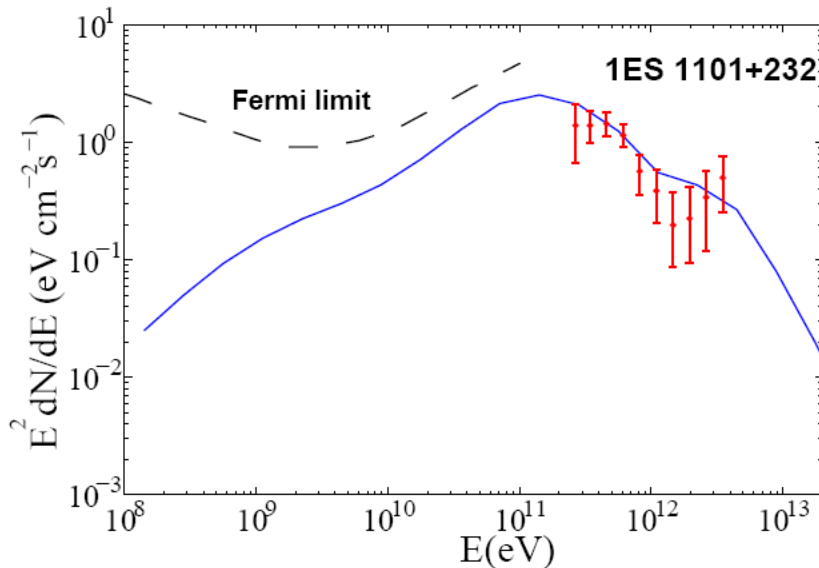
New exclusion
regions from
Blazar
measurements

Intergalactic Cascading and Magnetic Fields

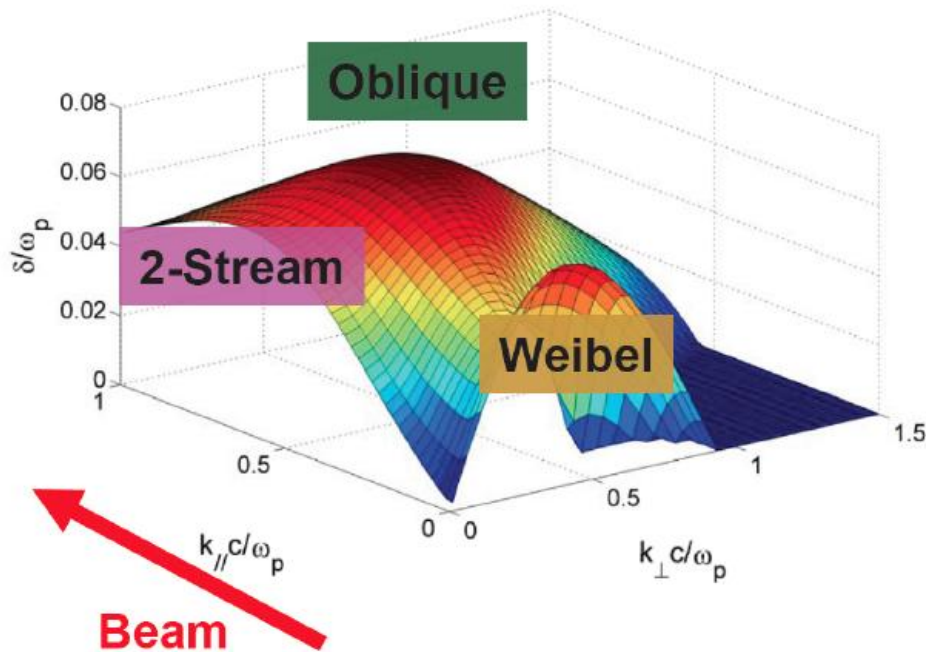


T. Arlen: $B = 0$ can NOT be excluded!

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 influence 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



Written by a carefully selected consortium of researchers working in the field, this book provides an up-to-date summary of the current observational and theoretical understanding of relativistic jets, focusing on jets from active galactic nuclei. As such, this monograph includes a history and theory refresher, an overview of observational results from all wavelengths, from radio to gamma-rays, analytical and numerical theoretical results, and a description of current research topics.

From the contents:

- Introduction and Historical Perspective
- Special Relativity of Jets
- Radiation Processes
- Central Engines, Acceleration, Collimation and Confinement of Jets
- Observational Details: Radio
- Optical, Infrared and UV Observations
- Observational Details: X-rays
- Unresolved Emission from the Core: Observations and Models
- Particle Acceleration in Turbulent Magnetohydrodynamic Shocks
- Simulations of Jets from Active Galactic Nuclei and Gamma-ray bursts
- Jet Structure, Collimation and Stability – Recent Results from Analytical Methods and Simulations
- Jets and AGN Feedback



Markus Boettcher obtained his PhD at the University of Bonn and the Max Planck Institute for Radio Astronomy in Bonn, Germany. Postdoctoral positions included stays at Rice University, Houston, TX, and with the U.S. Naval Research Lab. in Washington, DC. Since 2002 he is holding a professorship at Ohio University. His Research interests are active galactic nuclei, galactic black-hole candidates and gamma-ray bursts.



D. E. Harris received his PhD from the California Institute of Technology in 1961. For the following twenty years he held research positions at a number of radio observatories in Europe, Canada, Puerto Rico, and South America. Since 1980 he has been with the High Energy Division of the Center for Astrophysics, Cambridge, Massachusetts. His field of investigation is non-thermal processes in extragalactic sources, involving radio and X-ray analyses of galaxies and quasars.



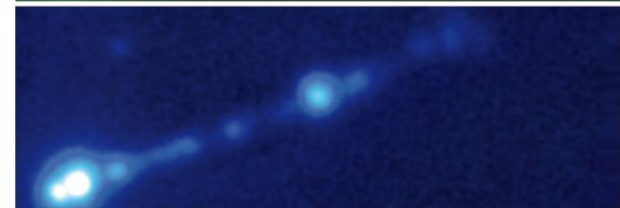
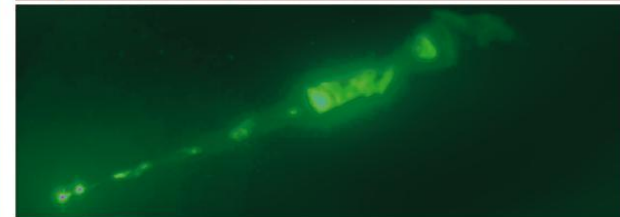
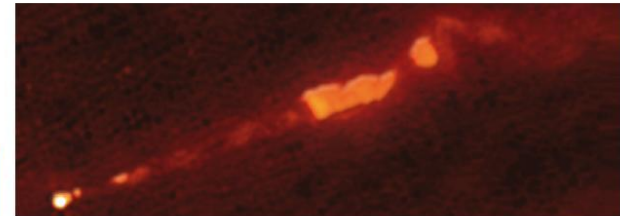
Henric Krawczynski is a Physics professor at Washington University in St. Louis. He obtained his PhD at the University of Hamburg, Germany, and worked at the Max-Planck-Institute for Nuclear Physics and at Yale University as post-doctoral researcher before joining Washington University in 2002. His research includes the development of X-ray and γ -ray telescopes and the analysis and interpretation of X-ray and γ -ray observations of galactic and extragalactic black holes, galaxies and galaxy clusters.

Boettcher · Harris
Krawczynski (Eds.)

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