High energy phenomena in AGN
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Thanks to: G. Ghisellini, L. Maraschi, L. Foschini, G. Ghirlanda, G. Bonnoli et al.
The gamma-ray extragalactic sky: **blazars** and **radiogalaxies**

**Blazars:** the sequence confirmed;
- the general view;
- jet-disk connection;
- the location of the emitting region.

**Radio-galaxies:** structured jets... also in blazars!
The extragalactic $\gamma$-ray sky

MeV-GeV
(11 months LAT AGN catalogue):

671 AGNs (mostly blazars)
radiogalaxies (... NGC 1275, Cen A, M87)
4 NLSy1 New!
The extragalactic $\gamma$-ray sky

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(11 months LAT AGN catalogue):

671 AGNs (mostly blazars)
radiogalaxies (... NGC 1275, Cen A, M87)
4 NLSy1 New!

32 BL Lacertae
4 radiogalaxies (M87, Cen A, IC 310, 3C66B)
2 QSO (3C279, 1510-089)

Extragalactic VHE $\gamma$-ray sources
($E > 100$ GeV)
AGN in gamma rays

Blazars
RL AGNs with jet pointing towards the observer
Observed emission is dominated by the jet

Radio galaxies
Misaligned jet
AGN in gamma rays

Blazars
- RL AGNs with jet pointing towards the observer
- Observed emission is dominated by the jet

Radio galaxies
- Misaligned jet

Also NLSy1 fit this general scenario but ...
Blazars

SED dominated by the relativistically boosted non-thermal continuum emission of the jet.

Two broad bumps:
Synchrotron and IC in leptonic models.
Also hadronic scenarios has been considered (e.g. Mannheim, Boettcher, Reimer).
The "blazar sequence"

FSRQs

BL Lacs

Fossati et al. 1998; Donato et al. 2001
The "blazar sequence"

FSRQs

BL Lacs

Swift

AGILE

Fermi

CT

Fossati et al. 1998; Donato et al. 2001
Strengthening the sequence with $\gamma$ rays

Bright AGN list, Abdo et al. 09
57 FSRQs
30 BL Lacs (with $z$)
1 unc.

Ghisellini, Maraschi, FT 2009

Log $\nu L_{\nu}$ [erg s$^{-1}$] vs. $L_{\gamma}$ [erg s$^{-1}$]

FSRQs

BL Lacs
Still valid with the 11 months catalogue!

“Radiogalaxies”
Caveat: power law model not always excellent

Absorption? KN?  
Intrinsic electron break?  
(e.g. Abdo et al. 2009, Finke & Dermer 2010, Bonnoli et al. 2010 Poutanen & Stern 2010)
FSRQs: the general scenario

Accretion disk
FSRQs: the general scenario

X-ray corona
FSRQs: the general scenario
FSRQs: the general scenario
FSRQs: the "canonical" scenario

Dermer et al. 2009
Ghisellini, FT 2009
Sikora et al. 2009

Accretion disk
X-ray corona
BLR
DUSTY TORUS
BL Lacs: “clean” jets

Inefficient accretion flow (ADAF–ADIOS)*

*but see Raiteri et al. 2009
Capetti et al. 2010 for BL Lac itself
From data to physics

![Graph showing data and physics relationships](image)

- Log $vF_v$ [Hz]
- Log $\nu L_\nu$ [erg s$^{-1}$]
- 0836+710
- $z=2.172$
- SAX/PDS
- SAX
- BAT
- XRT
- EGRET
- UVOT

Log $vF_v$ [Hz]
The physical sequence

Ghisellini, FT et al. 2010
The "cooling" paradigm

Energy of electrons emitting at the peak

Total en. density $\approx$ cooling rate
The “cooling” paradigm

FSRQs: strong cooling \rightarrow \text{low el. energy}

Energy of electrons emitting at the peak

Total en. density \approx \text{cooling rate}

Ghisellini et al. 2010
The “cooling” paradigm

FSRQs: strong cooling \rightarrow low el. energy

BL Lacs: weak cooling \rightarrow high el. energy

Energy of electrons emitting at the peak

Total en. density $\approx$ cooling rate

Ghisellini et al. 2010
Accretion power!
Jet power vs accretion

Jet power

Disk Lum.

Ghisellini, FT et al. 2010
Jet power vs accretion

Sequence of accretion rate

Ghisellini, FT et al. 2010
Jet power vs accretion

Ghisellini, FT et al. 2010

$P_{\text{jet}} > L_d$ !!!!

Acceleration/collimation mechanism? B&Z able to produce enough power?

Ghisellini, FT et al. 2010
Localizing the emission region

Usually believed to be at distances $< 0.1$ pc
Localizing the emission region

Usually believed to be at distances < 0.1 pc

But:

Sikora et al. 2009
Marscher et al. 2009, 2010

~10–20 pc!
Rapid gamma-ray variability!

LAT lightcurve

FT et al. 2010
Rapid gamma-ray variability!

LAT lightcurve

FT et al. 2010
Rapid gamma-ray variability!

LAT lightcurves

\[ R \leq c t_{\text{var}} \left( \frac{\delta}{1+z} \right) \simeq 4 \times 10^{15} \left( \frac{\delta}{10} \right) \text{ cm} \]
TeV emission from FSRQs?

3C 279

Albert et al. 2008

see also Wagner 2010 for 1510-089 (HESS)
TeV emission from FSRQs? Difficult inside BLR!

Strong absorption
(E>30 GeV within BLR, E>1 TeV outside)
(e.g. Liu et al. 2008, Reimer 2007, FT & Mazin 2009)

Decline of the scattering efficiency
(e.g. Albert et al. 2008, FT & Ghisellini 2008)
Gamma rays from radiogalaxies

Unification scheme $\rightarrow$ de-beamed gamma-ray (GeV/TeV) emission
The case of M87

Aharonian et al. 2006
Emission region?

Large scale jet
Stawarz et al. 2003

Knot HST-1 (60 pc proj.)
Stawarz et al. 2006
Cheung et al. 2007

Misaligned (20 deg) blazar
Georganopoulos et al. 2005
Lenain et al. 2007
FT and GG 2008

BH horizon
Neronov & Aharonian 2007
Rieger & Aharonian 2008
Emission region?

Misaligned (20 deg) blazar
Georganopoulos et al. 2005
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BH horizon
Neronov & Aharonian 2007
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Large scale jet
Stawarz et al. 2003

Variability
Knot HST-1 (60 pc proj.)
Stawarz et al. 2006
Cheung et al. 2007

Credit: Frazier Oven (NRAO), John Sh collateral, and colleagues.
The VERITAS Collaboration, the VLBA 43 GHz M87 Monitoring Team, the H.E.S.S. Collaboration, the MAGIC Collaboration 2009
Gamma rays from radiogalaxies

Unification scheme → de-beamed gamma-ray (GeV/TeV) emission

But if $\Gamma = 10-20$ debeamng too strong
Structured jets (in FRI)?

Inefficient accretion flow (ADAF-ADIOS)

\[ \Gamma = 15-20 \]

\[ \Gamma = 3-5 \]
Structured jets (in FRI)?

$\Gamma = 15-20$

$\Gamma = 3-5$

$\Theta \sim 20$ deg for M87

Inefficient accretion flow (ADAF-ADIOS)
Clues for (radially) structured small scale jets

Direct radio imaging (e.g. Giroletti et al. 2004; Kovalev et al. 2007)

FRI/BL Lacs unification (e.g. Chiaberge et al. 2000)

Modelling of TeV BL Lacs (Ghisellini et al. 2005)

Simulations (e.g. Aloy et al. 2000; Mc Kinney 2006)
\[ \Gamma_{\text{rel}} = \Gamma_{\text{layer}} \Gamma_{\text{spine}} (1 - \beta_{\text{layer}} \beta_{\text{spine}}) \]

**The spine** sees an enhanced \( U_{\text{rad}} \) coming from the **layer**

**Also the layer** sees an enhanced \( U_{\text{rad}} \) coming from the **spine**

The **IC emission is enhanced wrt to the standard SSC model**

*Originally Developed for TeV blazars*
Spectral Energy Distribution

FT&GG 2008
The spine is also boosted!
What about FRII?

No FRII in TeV

A handful of FRII in LAT: jet (spine/layer) or lobes/hotspots?
What about FRII?

No FRII in TeV

A handful of FRII in LAT: jet (spine/layer) or lobes/hotspots?

Sambruna et al. 2004
Brunetti et al. 2001
IC 310: a different beast?

LAT 100–300 GeV

Neronov et al. 2010
MAGIC Coll. 2010
IC 310: a different beast?

LAT 100–300 GeV

Head-tail radio galaxy

Neronov et al. 2010
MAGIC Coll. 2010
IC 310: a different beast?

LAT 100–300 GeV

Head-tail radio galaxy

Shock induced emission?

Neronov et al. 2010
MAGIC Coll. 2010
Summary

“Blazar sequence” healthy

Sequence of cooling/accretion rate

Jet power and accretion: a critical point?

Gamma-rays from FRI RG: spine/layer

FRII? Different environment/jet properties?
Grazie!