THE EXTRAGALACTIC γ -RAY BACKGROUND: CONTRIBUTION FROM HSP BLAZARS

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OUTLINE



- SED Background Radiation
- γ-ray component FermiLAT
- Extragal. Iso./Diffuse γ-Component
- Improvements: Identification of New γ-ray sources (Fermi-LAT & 2WHSP catalog)
- HSP dominance in the VHE domain (E>100GeV)

COSMIC BACKGROUND RADIATION



- Most fundamental observables (integral over cosmic time)
- CXB: Accretion process in AGNs
- EGB: Origin still on debate; MeV-GeV
- Blazars + ... CR, DM?

BLAZARS: HSP



- HSP: V_{Sync-peak} > 10¹⁵Hz
- 0.1-100GeV band:



- HESS, Magic, Veritas: $\approx 150 \text{ VHE}_{\text{src}}$
- Most of Extragal.VHE_{src} are HSPs
- Still many blazars are not detected in γ-rays ...

EGB MEASURED BY FERMI-LAT



Fig. 8.— Comparison of the total EGB intensities for different foreground models. The total EGB intensity is obtained by summing the IGRB intensity and the cumulative intensity from resolved *Fermi* LAT sources at latitudes $|b| > 20^{\circ}$ (gray band). See Figure 7 for legend.

- Fermi-LAT: Sky-Survey 0.1-500GeV
- EGB: Total Extragalactic γ-ray component: [All γ we see] -[Galactic Component] (Model Dependent)
- Yellow strip: EGB
- Gray strip: Resolved Sources
- EGB Resolved = Isotropic γ-ray background (IGRB)

IGRB: ISOTROPIC γ -RAY BACK



Fig. 7.— Comparison of the derived IGRB intensities for different foreground (FG) models. The

IGRB: Extragalactic and Isotropic Component

PwLw Γ=2.38, Ecut~270 GeV

"Diffuse": True Diffuse + Unresolved point-like sources

True Diffuse: Chocks, CR, DM?

Unresolved: Blazars? AGNs?

PREDICTIONS: SIMULATION

A simplified view of blazars: contribution to the X-ray and γ -ray cosmic backgrounds 5



Figure 3. The blazar contribution to the X-ray and γ -ray extragalactic backgrounds. All Fermi data are from Ackermann et al. (2015). The dark grey, green and red bands represent the predictions of the blazar simplified view for all blazar types, FSRQs and BL Lacs, respectively. The uncertainty bands come from different assumptions on the radio luminosity function near the low luminosity end. The light grey area with question marks represents a guess of the possible contribution of blazars between 50 keV and 100 MeV: in this region the SED of blazars is not known sufficiently well to allow a quantitative estimation. From Simulations: "Simplified view" model for blazars

Integral emission from Blazars may dominate HE domain

Blazars are Expected to explain most of the HE IGRB (~100%)

....Still, point-like sources are not resolved



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2WHSP: A multi-frequency selected catalog of VHE γ -ray blazars and blazar candidates

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ABSTRACT

Aims. High Synchrotron Peaked blazars (HSPs) dominate the TeV and VHE sky; however, there are only \approx 1000 cataloged HSPs now. HSPs are extremely important to VHE astrophysics, thus in this paper we present the 2WHSP catalog, the most complete list of HSPs to date. 2WHSP is an extension of the 1WHSP sample of γ -ray source candidates

Yu-Ling Chang, B. Arsioli, P. Giommi; P. Padovani; 2016

only ~440 with γ -ray counterpart (from 1/2/3FGL catalogs)

2WHSP

~1692 HSP blazars

GAMMA-RAY DETECTION



Most of Synchrotron-bright HSPs have been γ -ray detected.

Intermediate region with γ -ray detections and non-detections

Those are promising γ -ray candidates

DIRECT SEARCH FOR γ -RAY SIGNATURES



We select ~400 brightest sources not yet observed in gamma-rays

Direct search within raw-data
from Fermi-LAT (7 yrs - Pass 8)

Goal: Evaluate potencial of direct source-search based on samples with promising γ -ray candidates

Goal: Potential for solving the IGRB (Diffuse => Point-Like)

COMPLEMENTARY APPROACH



- Currently Fermi-LAT catalogs are based on γ-ray data only.
- Meaning: Gamma-ray data alone has to trigger the detection

- Complementary: Trigger the γ-ray detection based on the position from HSP blazars .
- Likelihood analysis: Test Point-like source is compatible with observed counts.

RESULTS



- I 50 new γ-ray signatures significance >3 sigma (TS>I0)
- TS map: Source emerge as pointlike signature: not an artefact
- γ-ray signal has high significance and coincide with HSP position (within the 68% confinement radius for TS peak)

SED PARAMETERS



- Model as PowerLaw: 0.3-500 GeV band
- $dN/dE = N_0 (E / E_0)^{-\Gamma}$
- 85 high-significance:TS>25
- 65 low-significance: 10<TS<25</p>

- Resolving the IGRB (diffuse) into pointlike sources
- Unveiling candidates for VHE observations

LOW-SIGNIFICANCE SIGNATURES



- Few examples TS maps for lowsignificance γ-ray signatures
- Emerge as point-source
- Not an artefact from overestimate background in the input model.

LIKELIHOOD OF DETECTION



 FOM = brightness of synchrotron peak (UV to X-ray range)

 Direct source search to improve de description of the γ-ray sky

 MESSAGE: γ-ray Detections
Driven by multi-frequency data [Radio to X-ray]

Complementary Method

LOWER FLUX THRESHOLD



- Red: flux-limit from 3FGL cat.
- Blue: improved flux-limit
- Intersection: where methods complement each other
- We go down to lower flux threshold
- Improve ability to unveil faint γ-ray sources....
- better use of data we already have on hands

SIMILAR SED PROPERTIES



- Comparing Photon Index distribution: New vs. FGL detections
- New γ-ray HSPs: similar Photon Index distribution as FGL-HSPs

TOTAL EGB



The γ -ray LogN-LogS: I-100 GeV

- Extrapolate to lower measured fluxes 6E-11 ph/cm^2/s
- ~9% of total extragalactic γ-ray content (EGB) in I-100 GeV band is due to HSP blazars

A Lower Limit...

MEASURED FLUXES



- 3FGL sources (red)
- New γ-ray detections (indigo)

 If we consider now only the 150 new γ-ray detections...

E_{bin} (GeV)	I_{EGB}	I_{IGRB}	$I_{new-detc}$	%-EGB	Solved _{IGRB}
1.1-13	4.5×10^{-7}	2.7×10^{-7}	1.96×10^{-9}	0.43%	0.73%
13 - 36	1.4×10^{-8}	8.2×10^{-9}	1.25×10^{-10}	0.90%	1.5%
36-51	1.8×10^{-9}	1.1×10^{-9}	2.33×10^{-11}	1.3%	2.1%
51 - 72	1.1×10^{-9}	6.3×10^{-10}	1.74×10^{-11}	1.6%	2.7%
72-100	6.2×10^{-10}	3.6×10^{-10}	1.27×10^{-11}	2.0%	3.5%
100-140	3.1×10^{-10}	1.5×10^{-10}	1.01×10^{-11}	3.2%	6.7%
140-200	1.9×10^{-10}	9.8×10^{-11}	8.27×10^{-12}	4.3%	8.4%

% OF IGRB SOLVED

Dependence on Energy : Dominance of HSP blazars Increase with Energy.

The order of impact from direct source-search to resolve the IGRB.

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Searching for γ -ray signature of WHSP blazars:

Fermi-LAT detection of 150 excess signal in the 0.3-500 GeV band

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ABSTRACT

Aims. A direct search of γ -ray emission centred on multi-frequency selected candidates is a valuable complementary approach to the blind search adopted in all current γ -ray Fermi-LAT catalogs. Our sources are part of the **1WHSP** and **2WHSP** samples, which were assembled with the aim of providing targets for Imaging Atmospheric Cherenkov Telescopes (IACT). A likelihood analysis based on their position allowed us to detect 150 γ -ray excess signal not yet reported in previous γ -ray catalogs (1FGL, 2FGL, 3FGL). By identifying new sources, we could solve a fraction of the extragalactic isotropic γ -ray background (IGRB) composition, improving the description of the γ -ray sky.

Methods. We perform data reduction with the Fermi Science Tools using positions from 400 high synchrotron peaked (HSP) blazars as seeds of tentative γ -ray sources; none of them have counterparts from previous 1FGL, 2FGL and 3FGL catalogs. Our candidates are part of the 1WHSP and 2WHSP samples (currently the largest sets of HSP blazars). We focus on HSPs characterised by bright synchrotron component $\nu f_{(\nu)} \geq 10^{-12.1}$ ergs/cm²/s, testing the hypothesis of having a γ -ray source in correspondence to the WHSP positions. Our likelihood analysis considers the 0.3-500 GeV energy band, integrating over 7.2 yrs of Fermi-LAT observation and making use of Pass 8 data release.

Results. From the 400 candidates tested a total of 150 WHSPs showed excess γ -ray signature: 85 highsignificance detections with TS>25, and 65 low-significance detections with TS in between 10 to 25. We

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PERSPECTIVES: 2WHSP & FERMI



- Successful approach: 400 2WHSPs leading to 150 γ-ray
- We are now searching γ-ray counterparts for all the 2WHSP sources.
- Preliminary results: ~200 extra γray source.
- 440 2WHSP-FGL => +350 sources characterised in γ-rays (+80%)

IMPACTS



 440 2WHSP-FGL + 350 New sources characterised in γ-rays.

IMPACTS

- Better description of γ-ray sky Resolving Diffuse component into point-like sources
- Constrain models DM annihilation / decay
- New Elements in framework of CTA ; Enriching expectations for TeV-sky

THANKYOU!









FERMI: PASS7 / PASS8



- Fermi new data release:
- Improved PSF
- Number of Photon Events:
- 2.30 x at Low Energy (100MeV)
- I.25 x at High Energy (I0GeV)

BLAZARS



AGN

- Energetic: Powered SMBH
- Jets
- jets pointing to us : rare Blazars
- 5BZB \approx 3560 objects



SENSITIVITY: FERMI & CTA

faint for Fermi, but still well within reach of the CTA



LOOKING FOR HSP BLAZARS: EXPLORING THE VHE DOMAIN (E>100GEV)

we can rely on the synchrotron component parameter to select VHE targets

HOW TO FIND HSP BLAZARS?



HSP BLAZARS

... in the vast oceans of data

MULTI-FREQUENCY DATA

- Radio: NVSS FIRST SUMMS (2.9 Mi detections)
- InfraRed: WISE (750 M objects)
- X-ray: Rosat Swift IPC XMM Chandra etc... (900k detections)

IWHSP

B. Arsioli, B. Fraga, P. Giommi, P. Padovani, P. M. Marrese A&A, 2015, 579, 34 DOI: 10.1051/0004-6361/201424148



IR COLORS

Data from ALLWISE catalog: \approx 750 Million Color-Color Selection: Subsample 5 Mi





IWHSP

bright sources in red (potentially detectable by current IACT) \approx 110 Total of 982 HSP/Candidates Blazars

2WHSP

YL. Chang, B. Arsioli, P. Giommi, P. Padovani Expanding the IWHSP sample

2WHSP



- Expanding IWHSP
- Lower Gal. Lat. |b|>10°
- Radio: NVSS, FIRST, SUMSS (updated)
- X-ray: ROSAT B/F
- IPC & IPC Slew (7.000)
- **3XMM DR4 & XMM Slew DR6** (570.000)
- ISWXRT & XRT Deep (94.000)
- WGACAT2, BMWcat (88.000, 30.000)
- Chandra (100.000)

