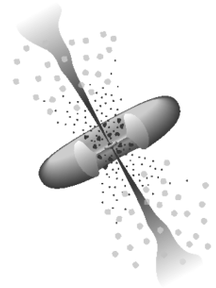
EXTREME BLAZARS AS COUNTERPARTS OF EXTREME MESSENGERS

ELISA RESCONI (TUM)

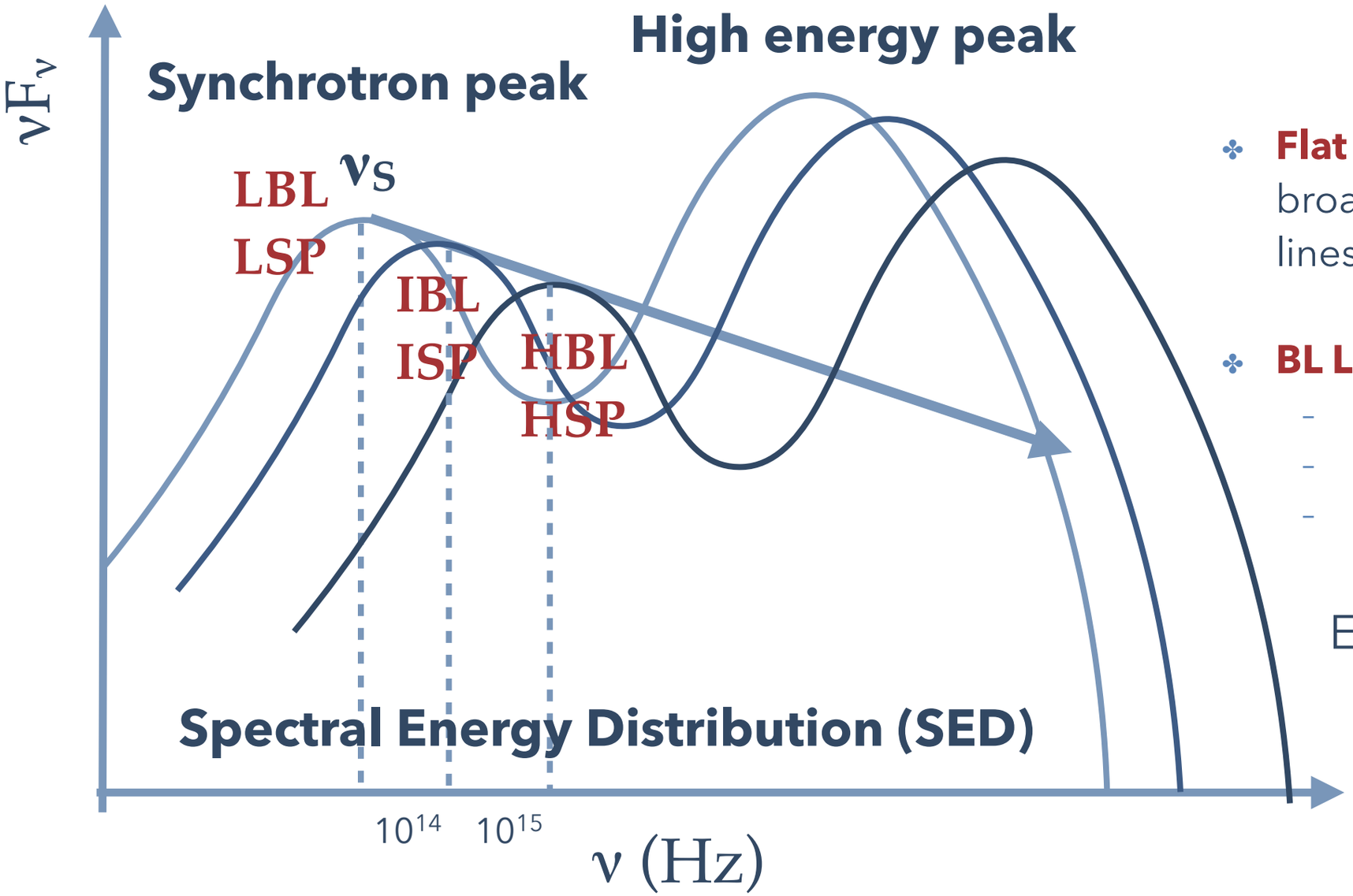
in collaboration with P. Padovani, P. Giommi, A. Turcati, S. Coenders, L. Caccianiga, and M. Petropoulou, B. Arsioli, Y.L. Chang.

SFB 1258 Neutrinos Dark Matter Messengers

BLAZARS: THE GENERAL PICTURE



Jet dominated AGN. The radiation output is mostly due to non-thermal radiation from a relativistic jet, ~ few% of all AGN



- **Flat Spectrum Radio Quasars**: broad emission features (emission lines) in the optical spectrum

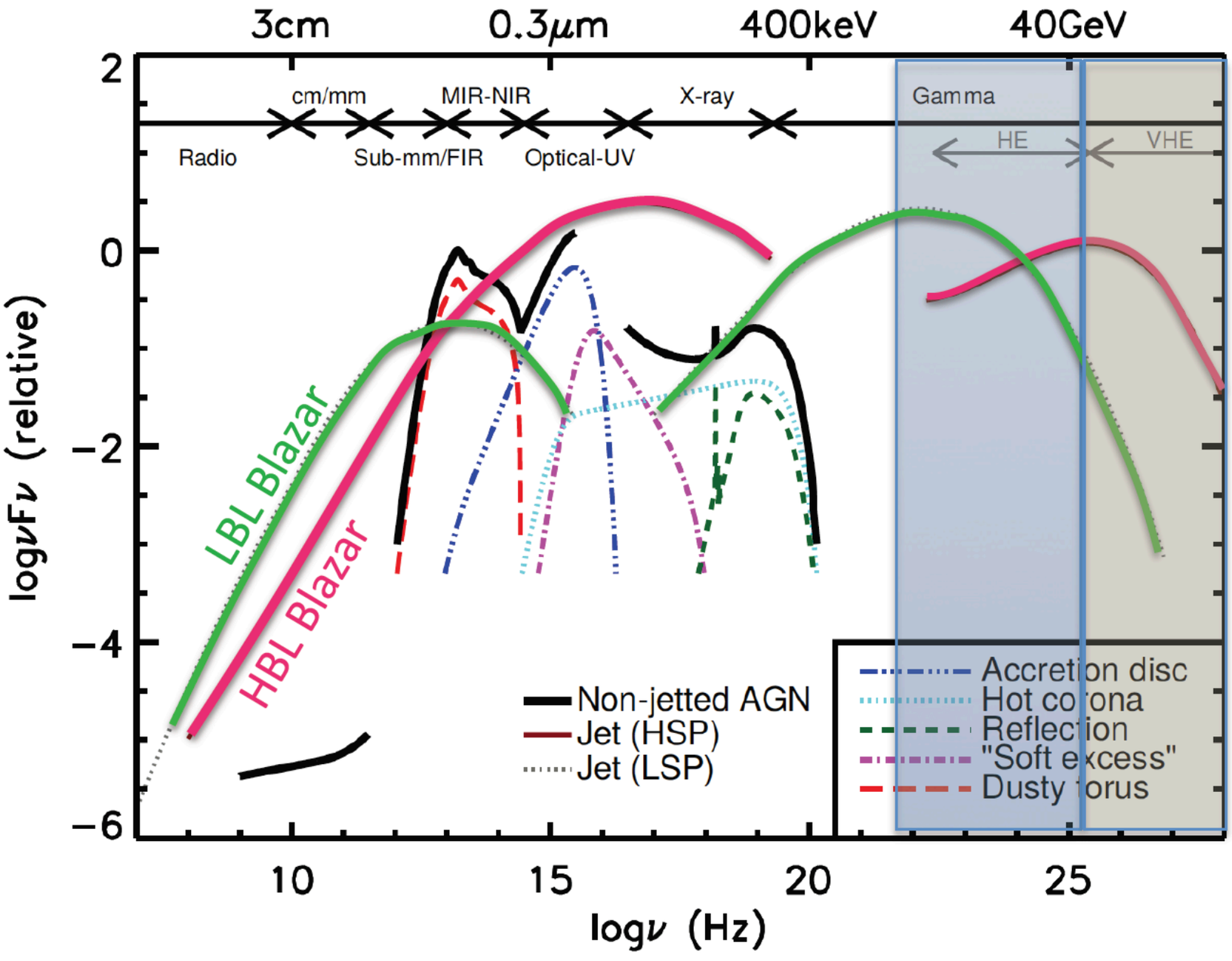
- **BL Lacs**: no broad emission lines.
  - **LBL/LSP**, $\nu_S < 10^{14}$ Hz,
  - **IBL/ISP**, 10^{14} Hz$<\nu_S<10^{15}$
  - **HBL/HSP**, $\nu_S > 10^{15}$ Hz

$E_{em}(\text{FSRQ}) < E_{em}(\text{BL Lacs})$

[Padovani, Giommi, '95]

BLAZARS: A REALISTIC PICTURE

[Y. L. Chang et al., A&A (2017)]



Active Galactic Nuclei: what's in a name?

arXiv:1707.07134

P. Padovani · D. M. Alexander · R. J. Assef · B. De Marco · P. Giommi · R. C. Hickox · G. T. Richards · V. Smolčić · E. Hatziminaoglou · V. Mainieri · M. Salvato

~ 90 pages review submitted to The Astronomy and Astrophysics Review 2017 -

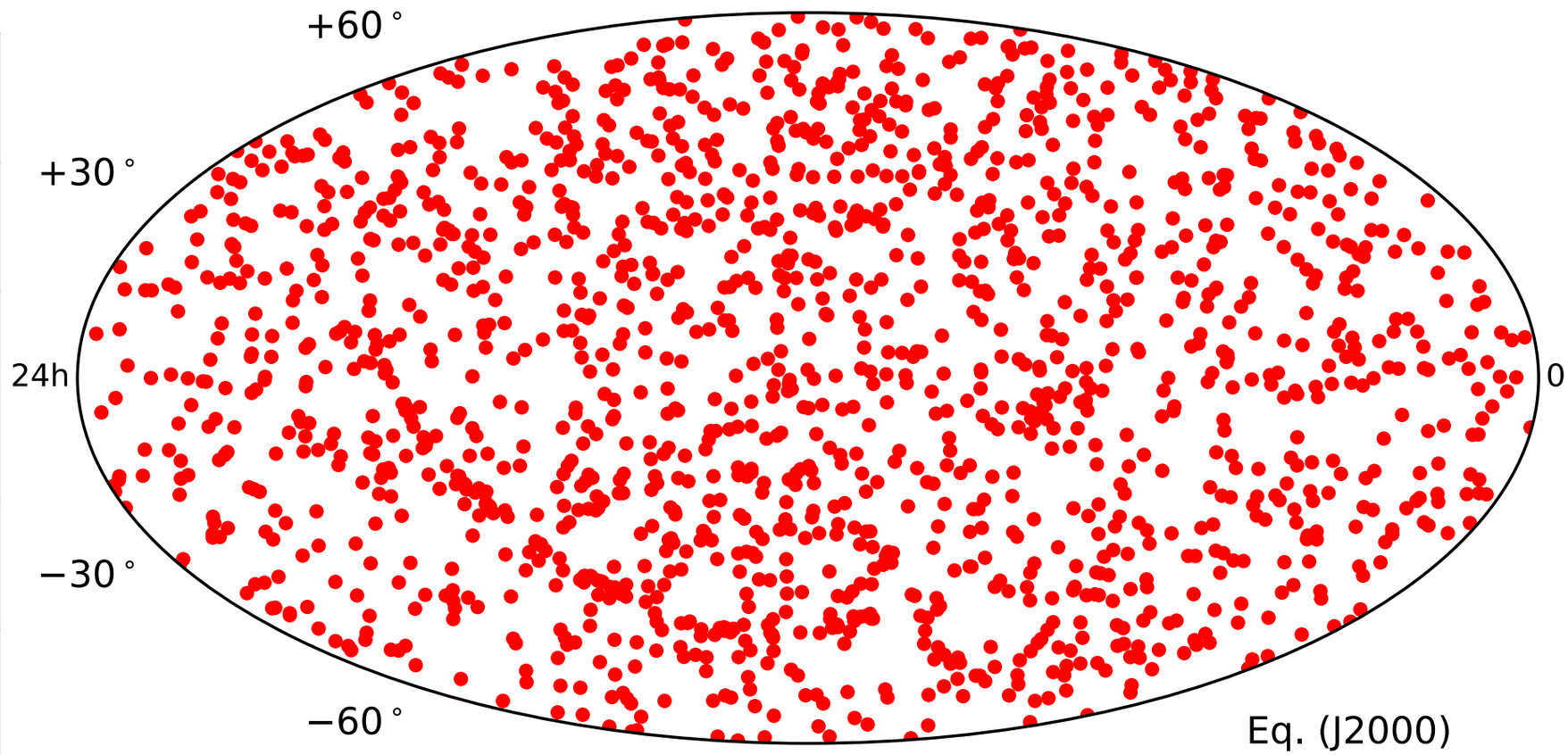
THE CATALOGUES: AT HIGH ENERGY DOMINATED BY BL LACS / HSP

Bzcat5; 2WHSP; 2FHL; 3FHL [10GeV– 2TeV]

[Massaro et al. (2015); Y. L. Chang et al., A&A (2017); Fermi Collaboration, arXiv:1702.00664]

3FHL: 1556 objects

BL Lac	712
FSRQ	141
blazar candidate	309
SFR, SBG	1, 4
SNR	17
PWN	8



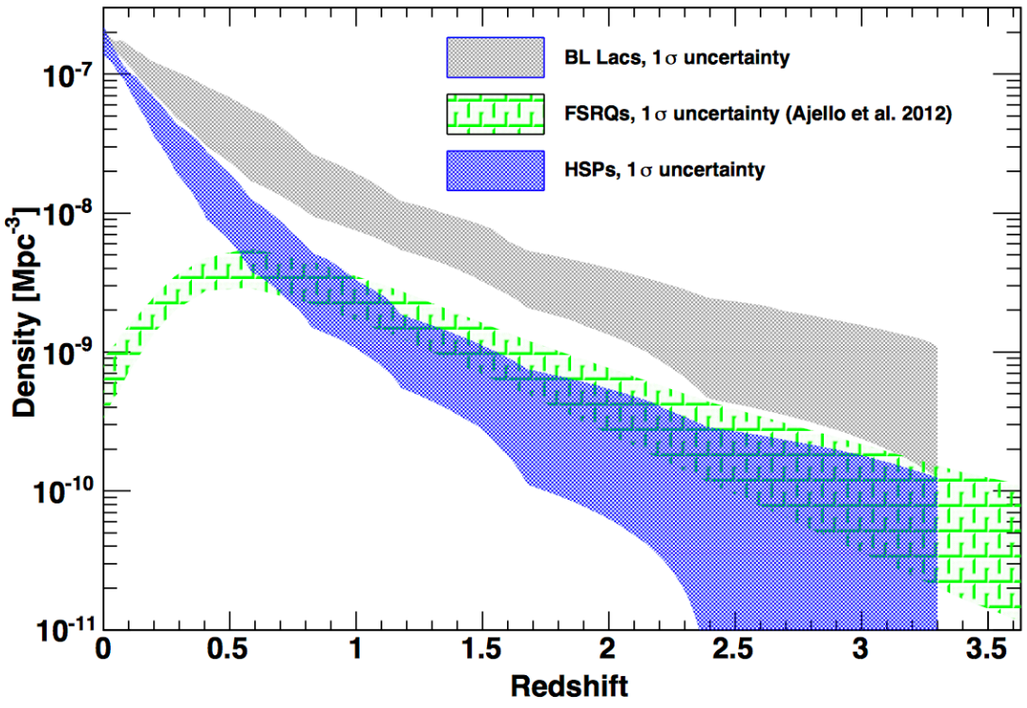
As of today, well over 4,000 blazars are known. This number is increasing rapidly but it remains a small percentage of the over one million AGN known

THE POPULATION

(space number density as a function of luminosity and redshift)

Cosmic evolution is different for HSP

[M. Ajello 2013, P. Giommi et al. 1999; V. Beckmann et al. 2003]



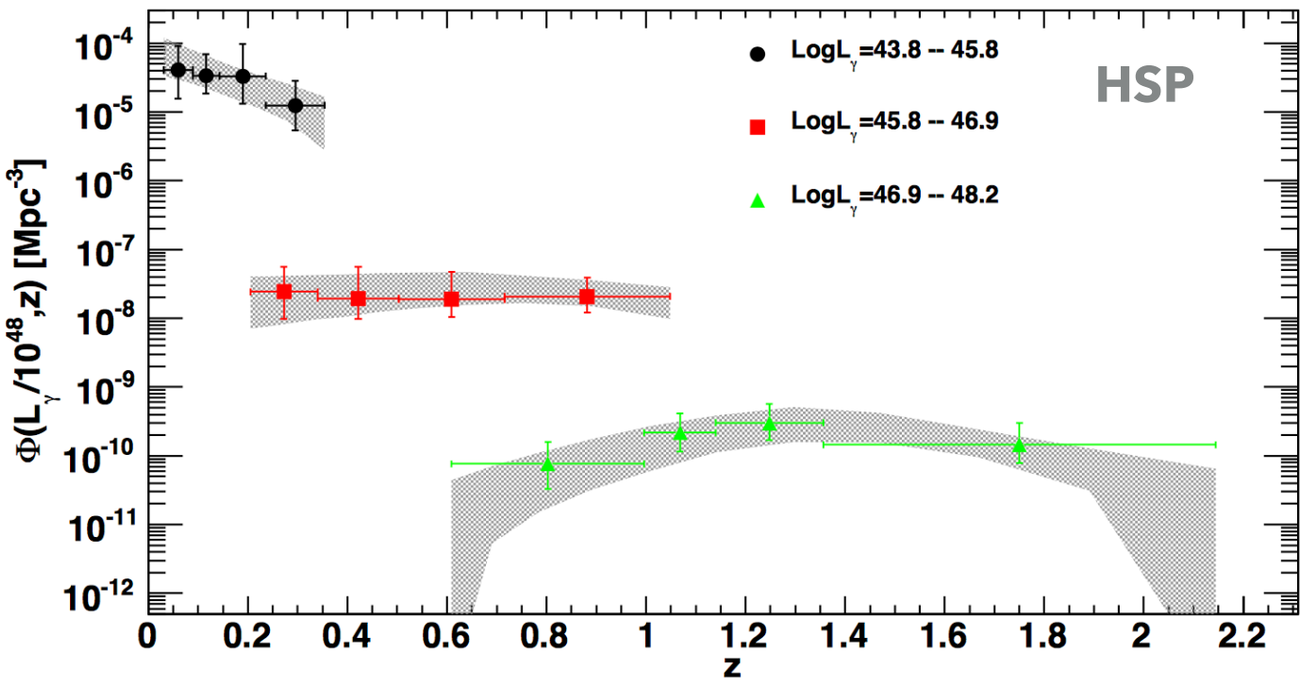


Fig. 10.— Number density (per unit co-moving volume) of BL Lacs, FSRQs and HSPs.

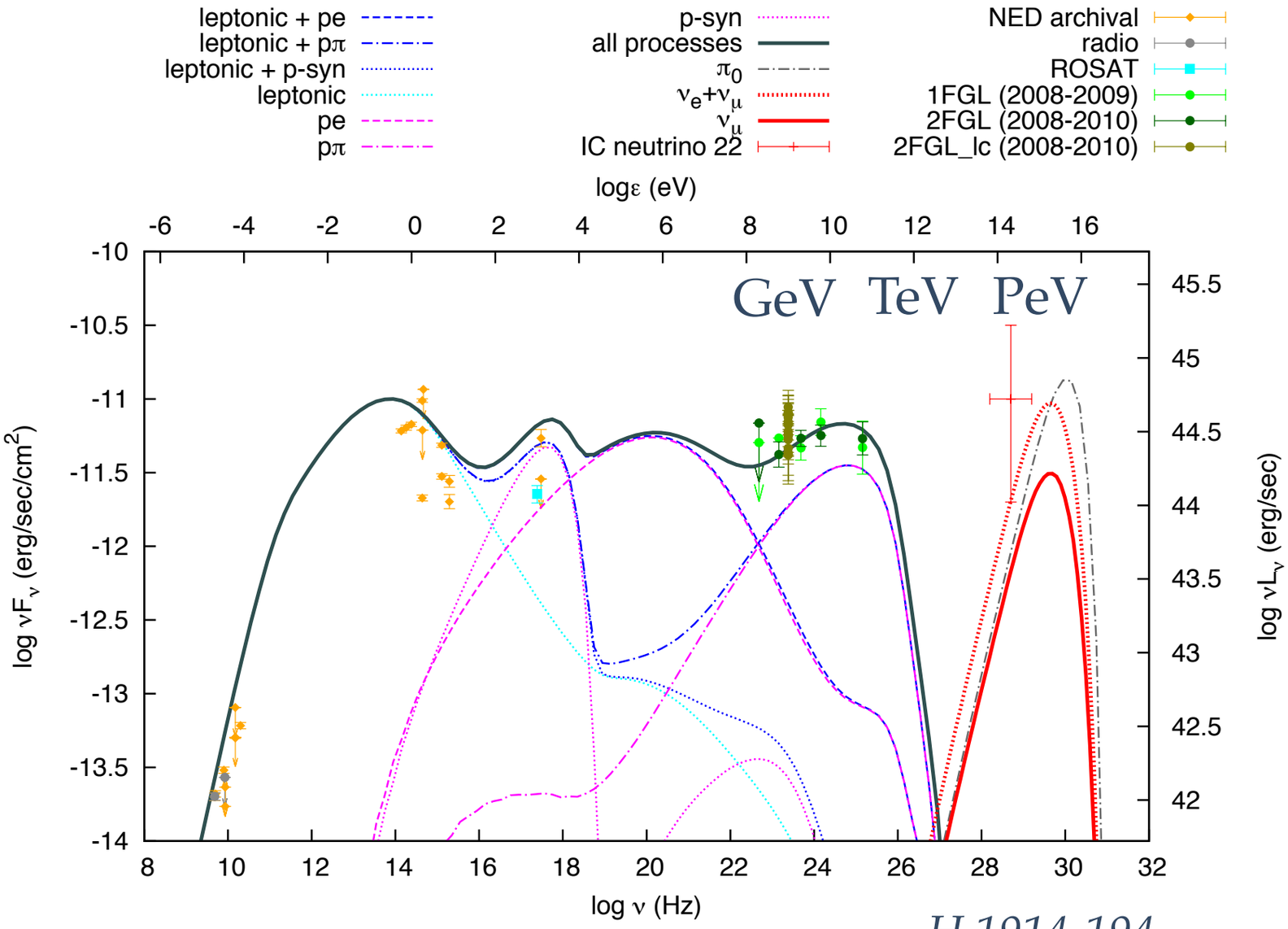
… the evolution of BL Lacs slows down with luminosity, becoming negative for objects with Lγ ≤$10^{45.5}$ erg s^{-1}[…] Subdividing the sample in HSP, ISP and LSP objects we find that the **negative evolution is in fact isolated to the HSP population**, while the ISP and LSP evolve positively from the lowest luminosities.

EXTREME BLAZARS: NEUTRINO CONNECTION?

γ ∝ ν for HSP

[M. Petropoulou, S. Dimitrakoudis, P. Padovani, A. Mastichiadis, E.R., MNRAS (2015)]

z	0,137
B(G)	5
R(cm)	3×10^{15}
δ	18
$\ell_{(e,inj)}$	6×10^{-5}
$\ell_{(p,inj)}$	10^{-2}
$\Upsilon_{\nu\gamma}$	2,0



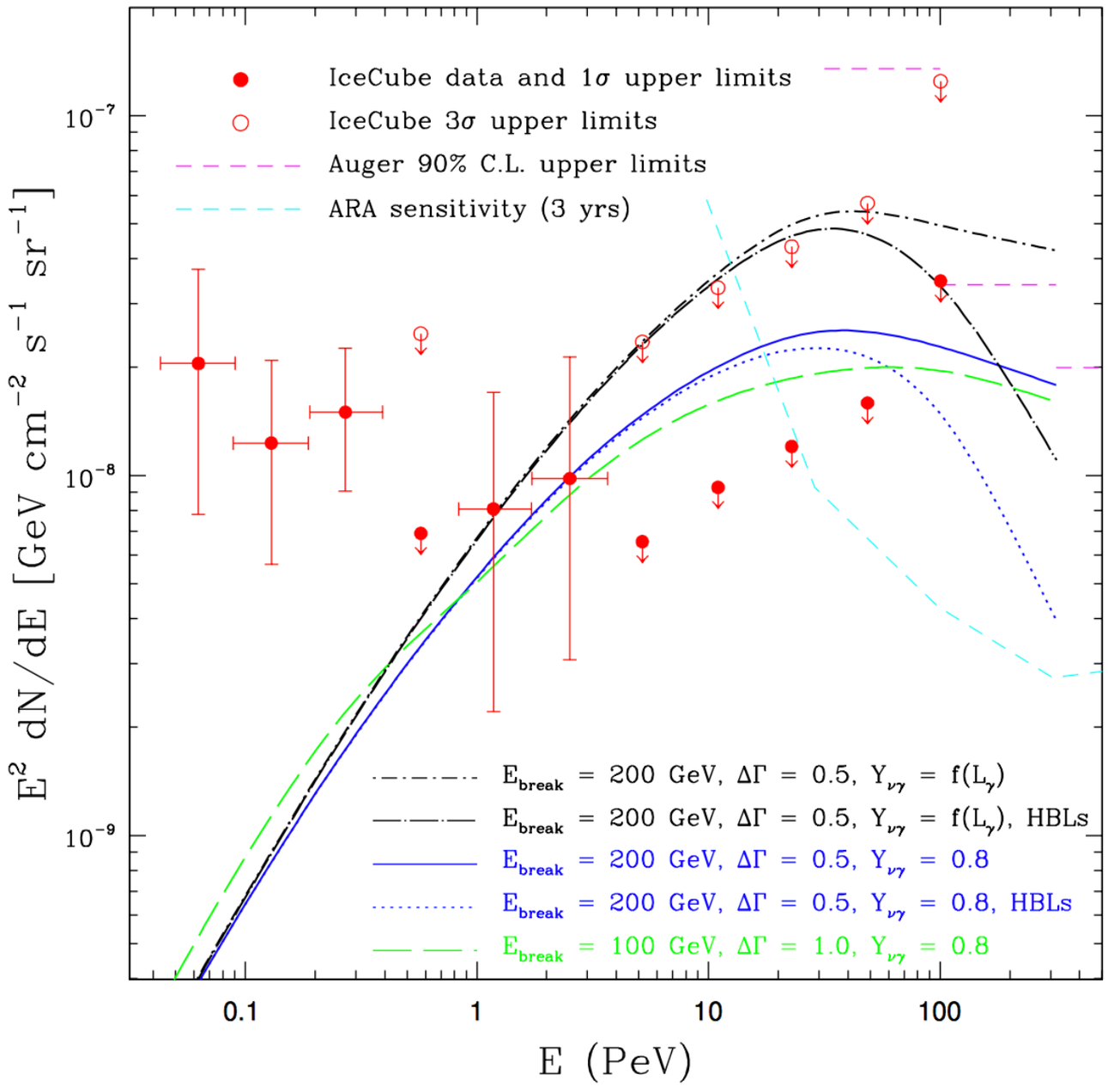
BL LACS AS A CLASS: THE HYPOTHETICAL NEUTRINO BACKGROUND

[P. Padovani, M. Petropoulou, P. Giommi, E. R., MNRAS(2015)]

- Based on Monte Carlo simulations - *blazar simplified view* (BSV)
- BSV - reproduces X-ray, γ-ray blazar surveys, extragalactic γ-ray background > 10 GeV
- the neutrino background is derived by summing up at a given energy the fluxes of each BL Lac in the simulation, all characterised by their own redshift, synchrotron peak energy, γ-ray flux, etc
- hadronic component “calibrated” on few candidates (over-predicting by construction)

BL LACS AS A CLASS: THE HYPOTHETICAL NEUTRINO BACKGROUND

[P. Padovani, M. Petropoulou, P. Giommi, E. R., MNRAS(2015)]



THE SEARCHES: EXTREME BLAZARS FOR EXTREME MESSENGERS?

(Gamma) Photons

↳Secondaries

↳Not charged

↳Interact, limited horizon

Reconstruction:

↳excellent angular resolution

↳excellent energy resolution

(HE) Neutrinos

↳Secondaries

↳Not charged

↳Three flavours

↳Interact weakly, nearly unlimited horizon

Reconstruction:

↳poor angular resolution in shower, good in tracks

↳poor energy resolution in tracks, good in showers

(UHE) Cosmic Rays

↳Primaries

↳Charged

↳Composition

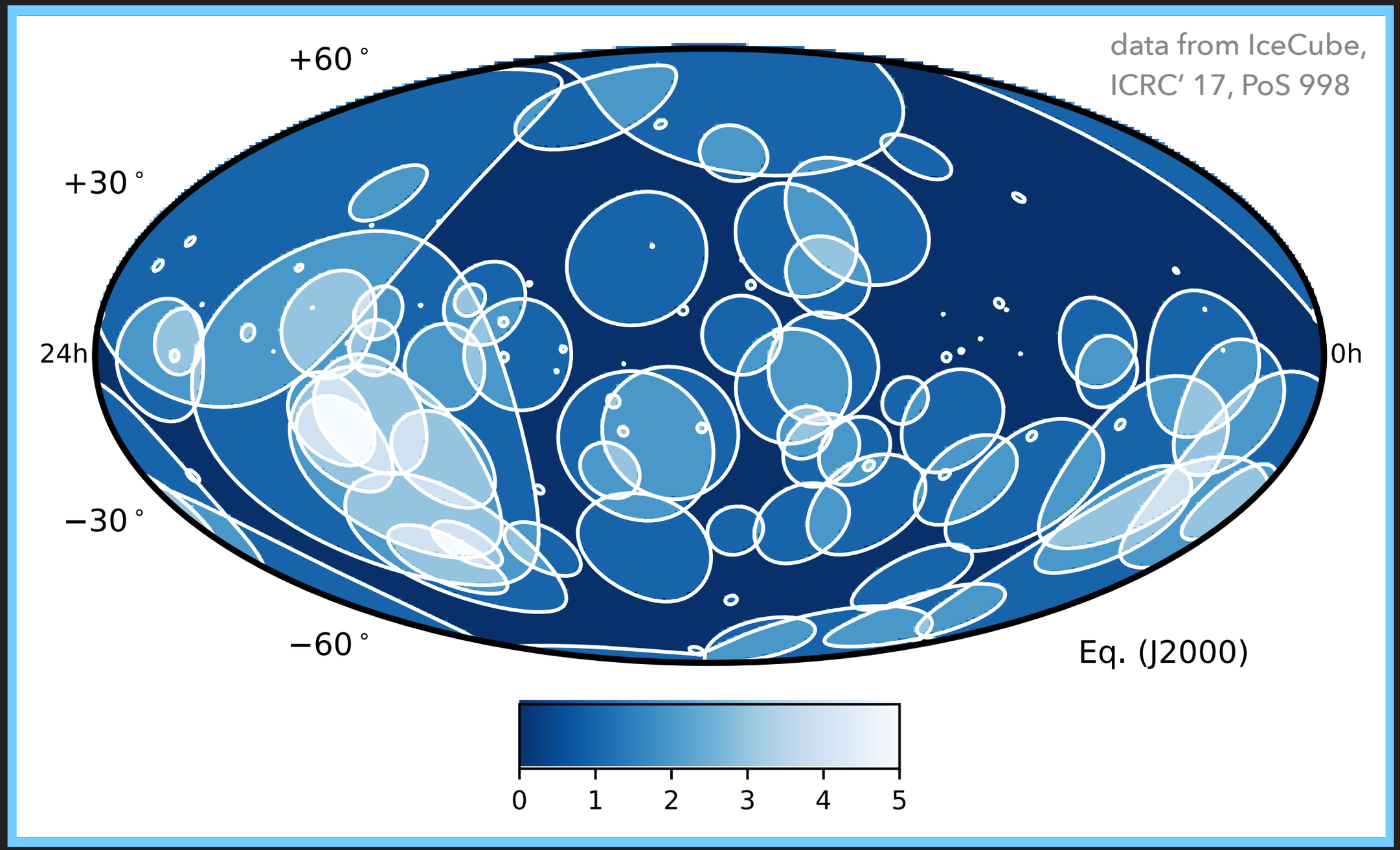
↳Interact, limited horizon

Reconstruction:

↳good angular resolution, bending

↳good energy resolution

ICECUBE: 10^{12}–10^{15} EV SKY IN NEUTRINOS

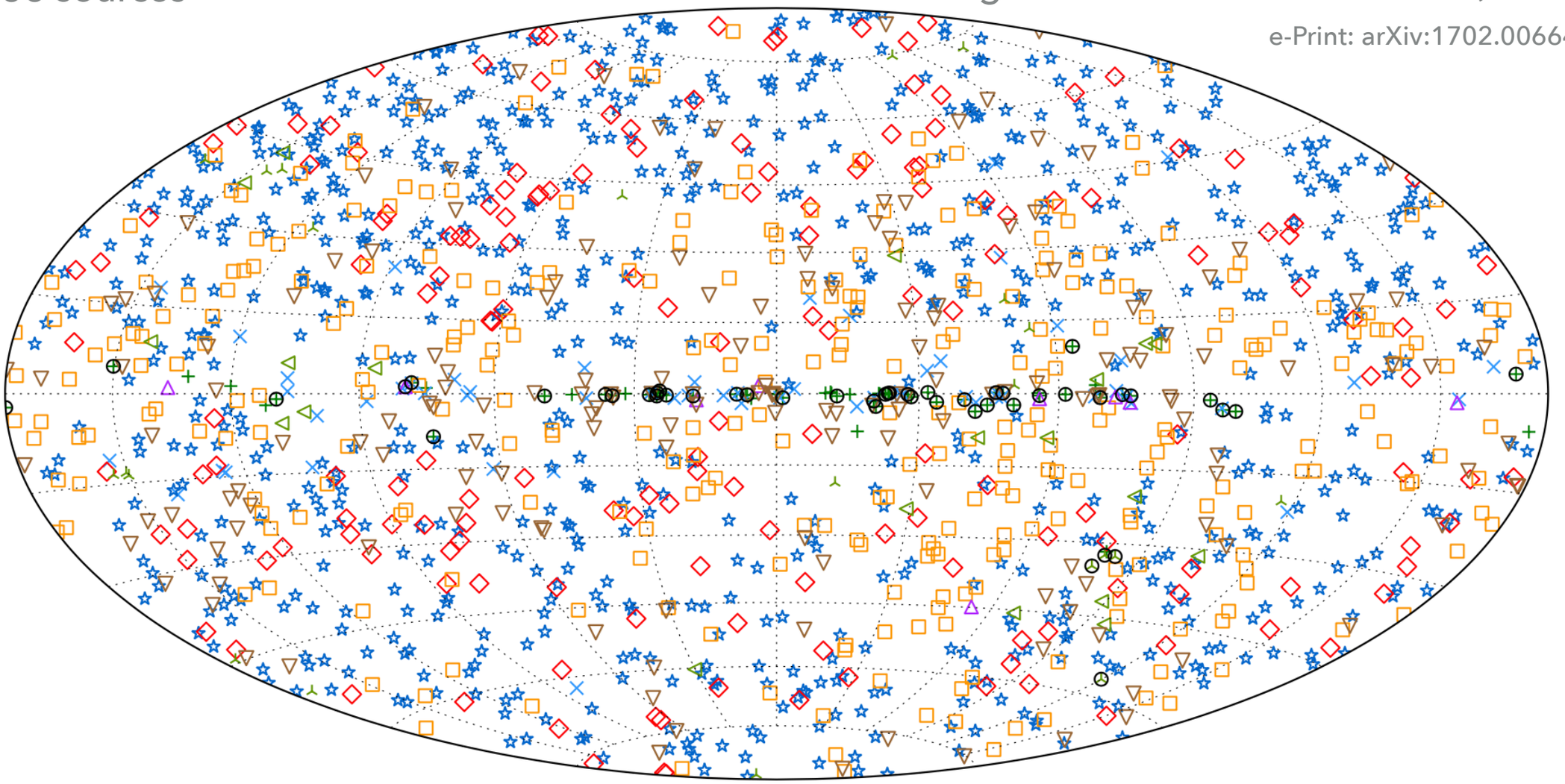


FERMI: 10^{10}–10^{12} eV SKY IN PHOTONS

1556 sources

Third Catalog of Hard Fermi-LAT Sources (3FHL)

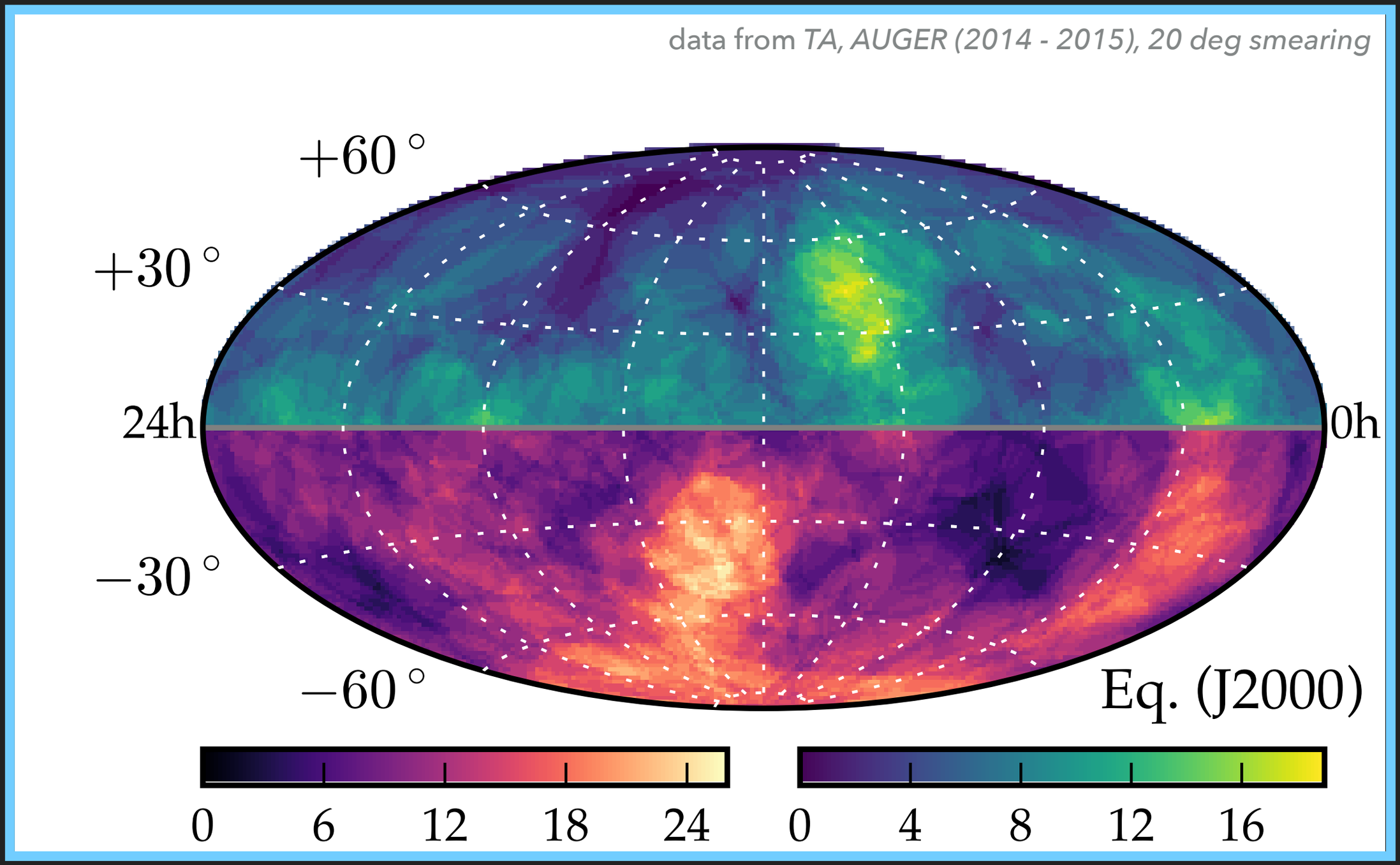
e-Print: arXiv:1702.00664



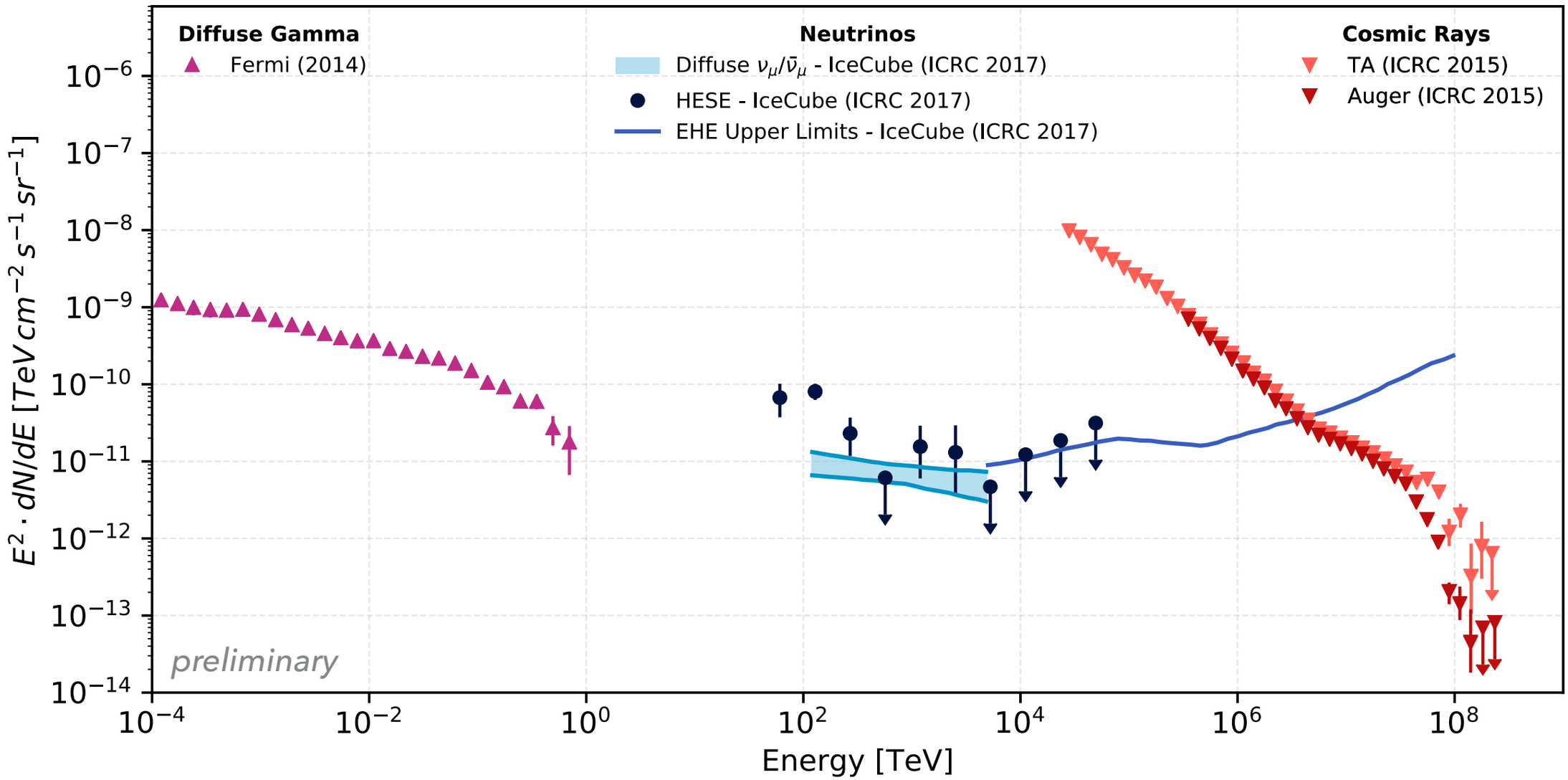
+ SNRs and PWNe	★ BL Lacs	□ Unc. Blazars	△ Other GAL	▽ Unassociated
× Pulsars	◇ FSRQs	Y Other EGAL	◁ Unknown	○ Extended

Galactic Coordinates

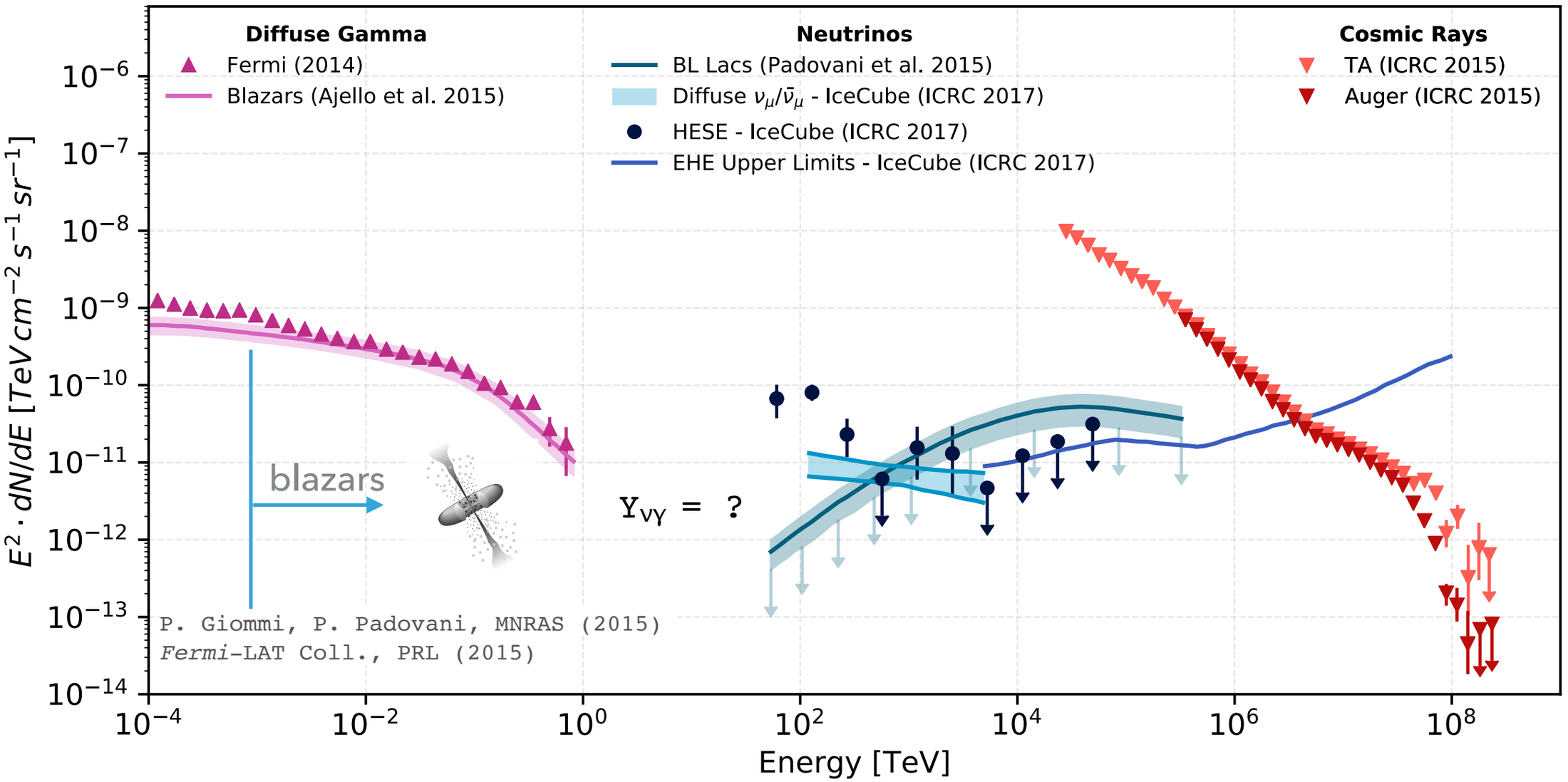
AUGER, TA: 10^{18}–10^{20} eV SKY IN COSMIC RAYS



HYBRID SPECTRAL ENERGY DISTRIBUTION



HYBRID SPECTRAL ENERGY DISTRIBUTION

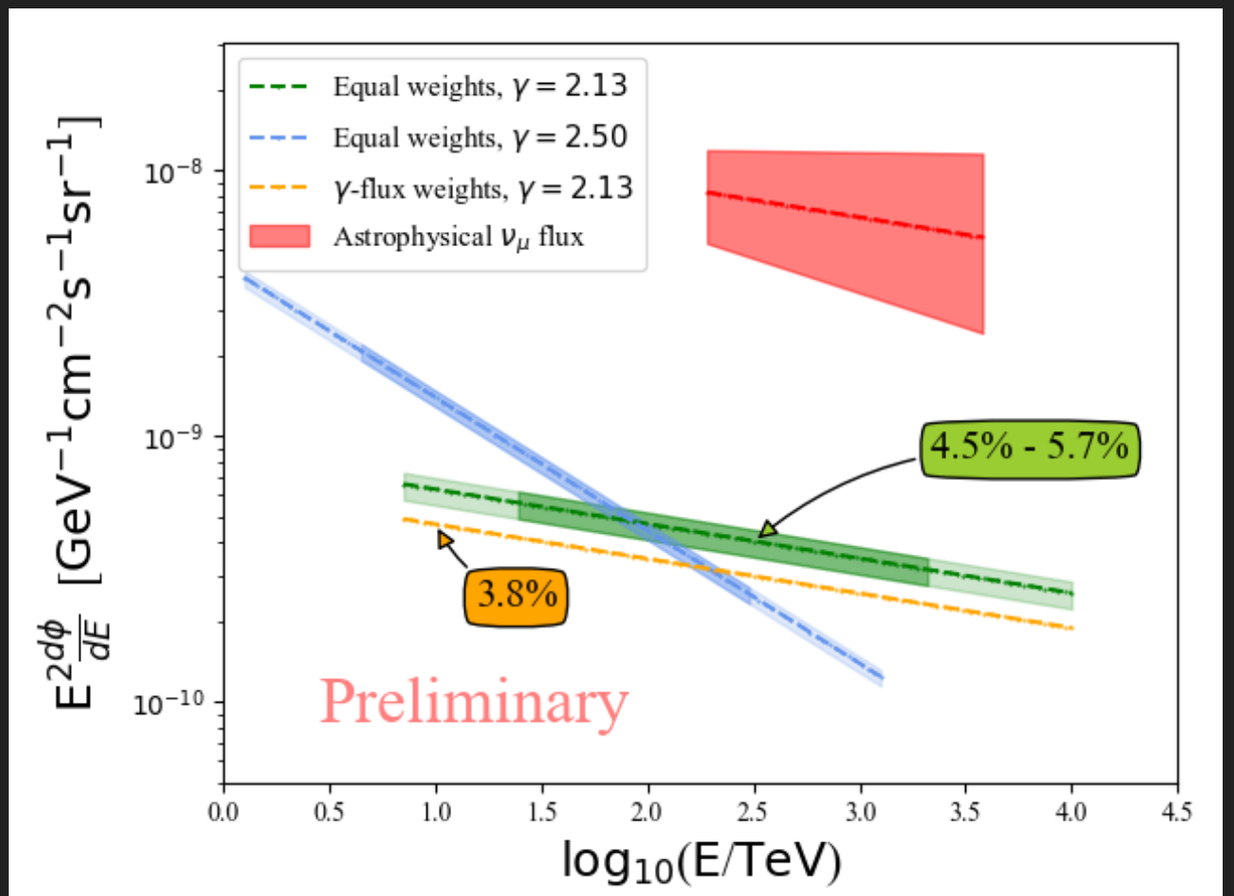


THE SEARCHES

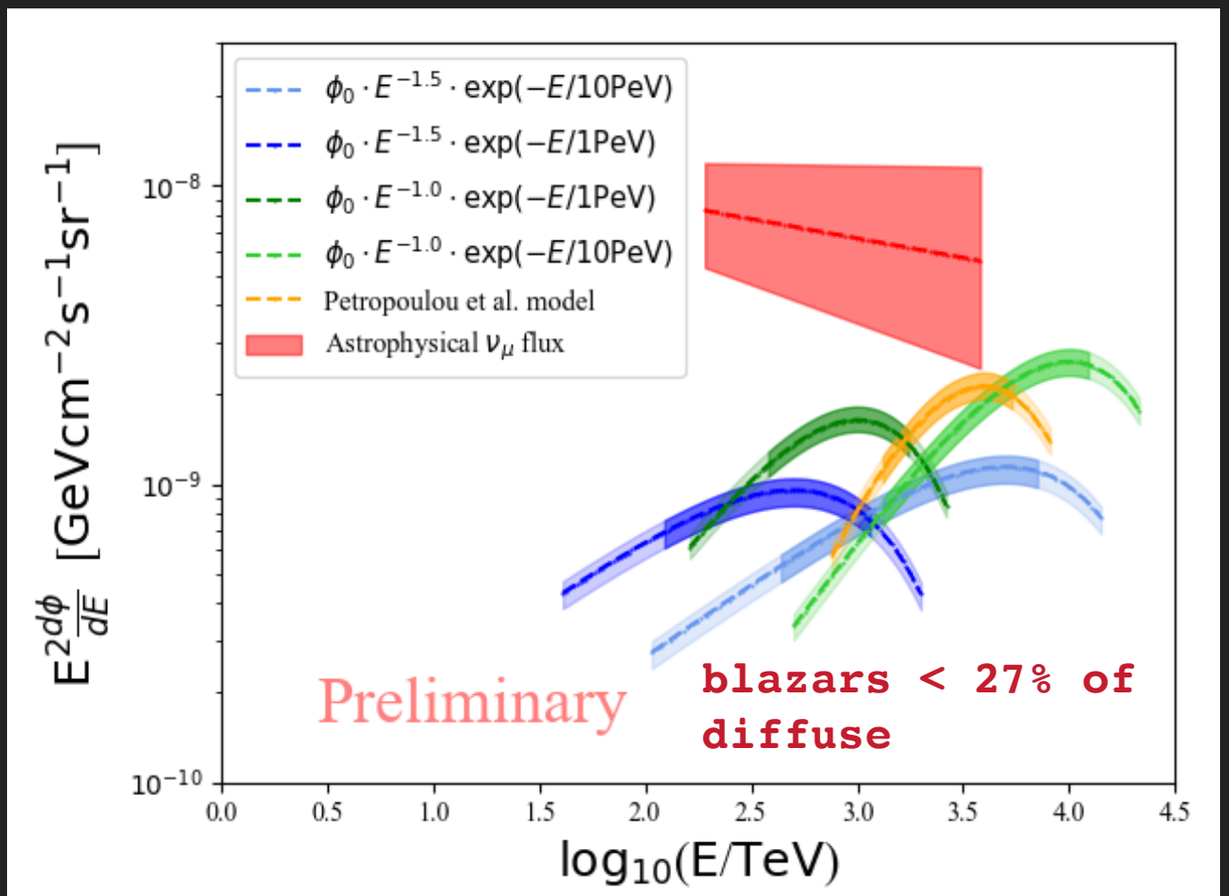
1- Blazars: interpreting upper limits

[IceCube, PoS(ICRC2017)994]

Stacking based on 7 years through going muon sample and 2FHL, 2WHSP, 3LAC catalogues



Unbroken power law assumption



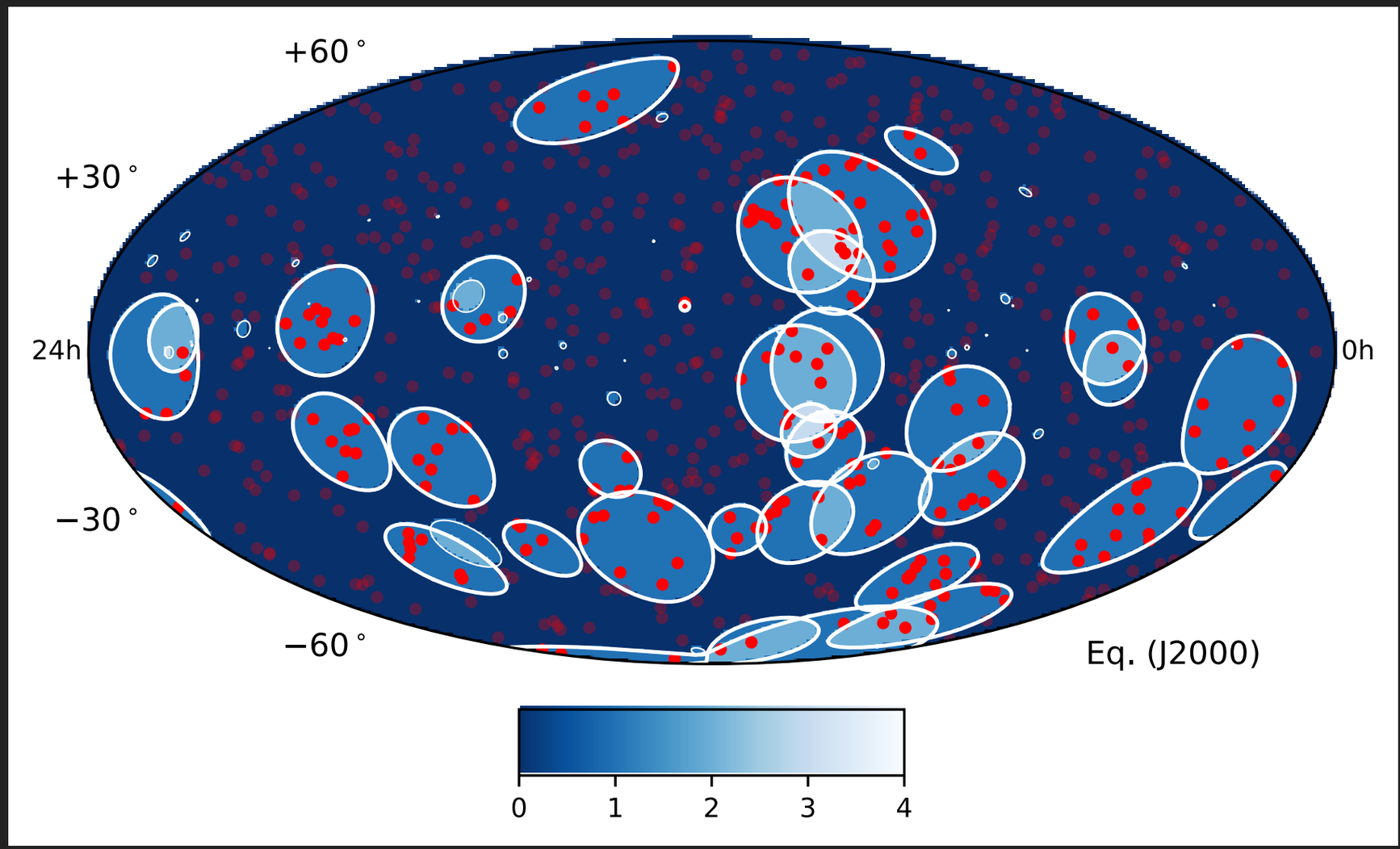
Model dependent assumption

THE SEARCHES

2- Blazars: the neutrino filter

[P. Padovani et al., MNRAS (2016); E.R. et al., MNRAS (2017); E.R. et al., PoS(ICRC2017)1016]

Neutrinos filter (2FHL, 2WHSP, 3LAT)

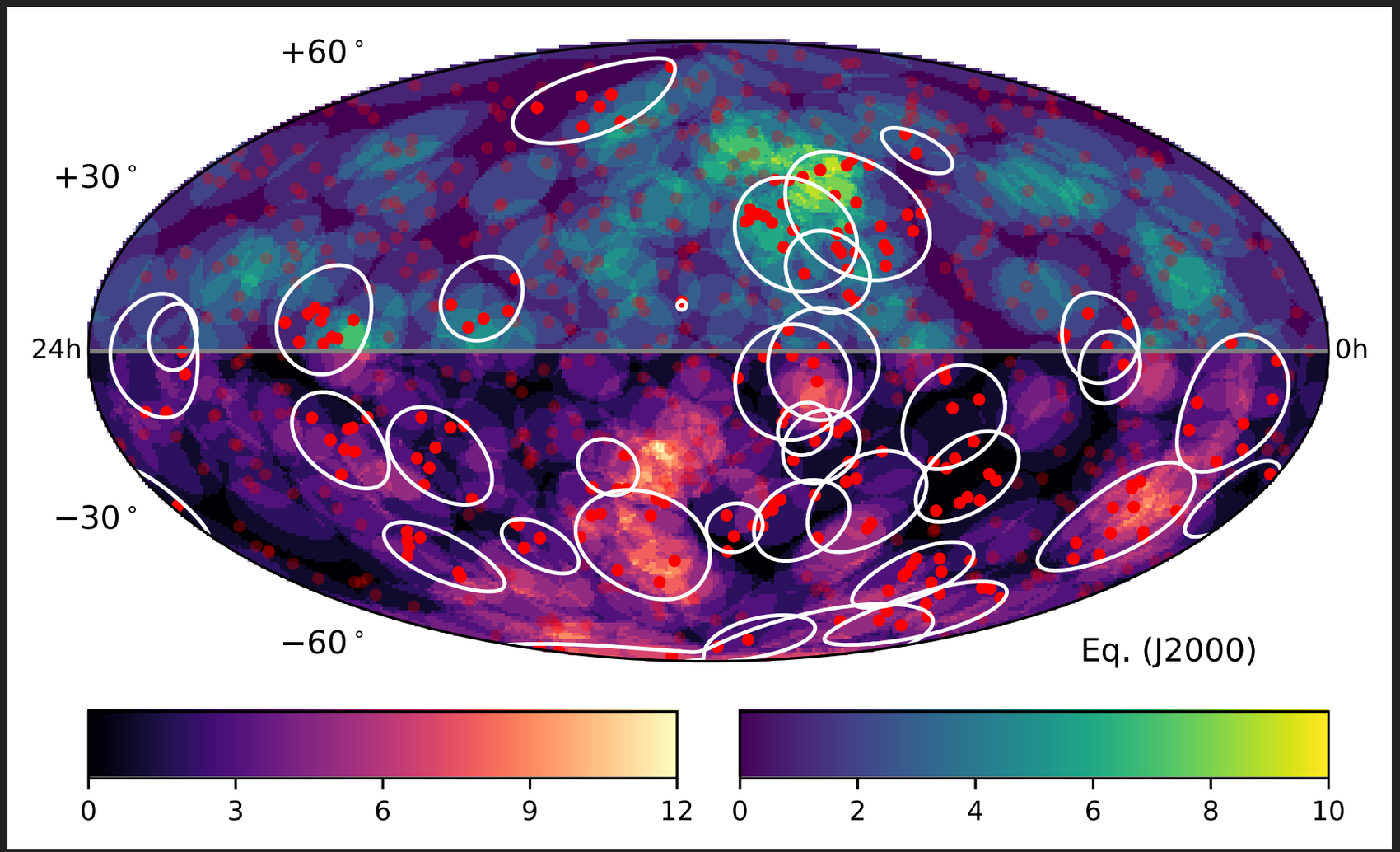


THE SEARCHES

2- Blazars: the neutrino filter

[P. Padovani et al., MNRAS (2016); E.R. et al., MNRAS (2017); E.R. et al., PoS(ICRC2017)1016]

Neutrinos filter updated to 3FHL, 6 years IceCube HESE

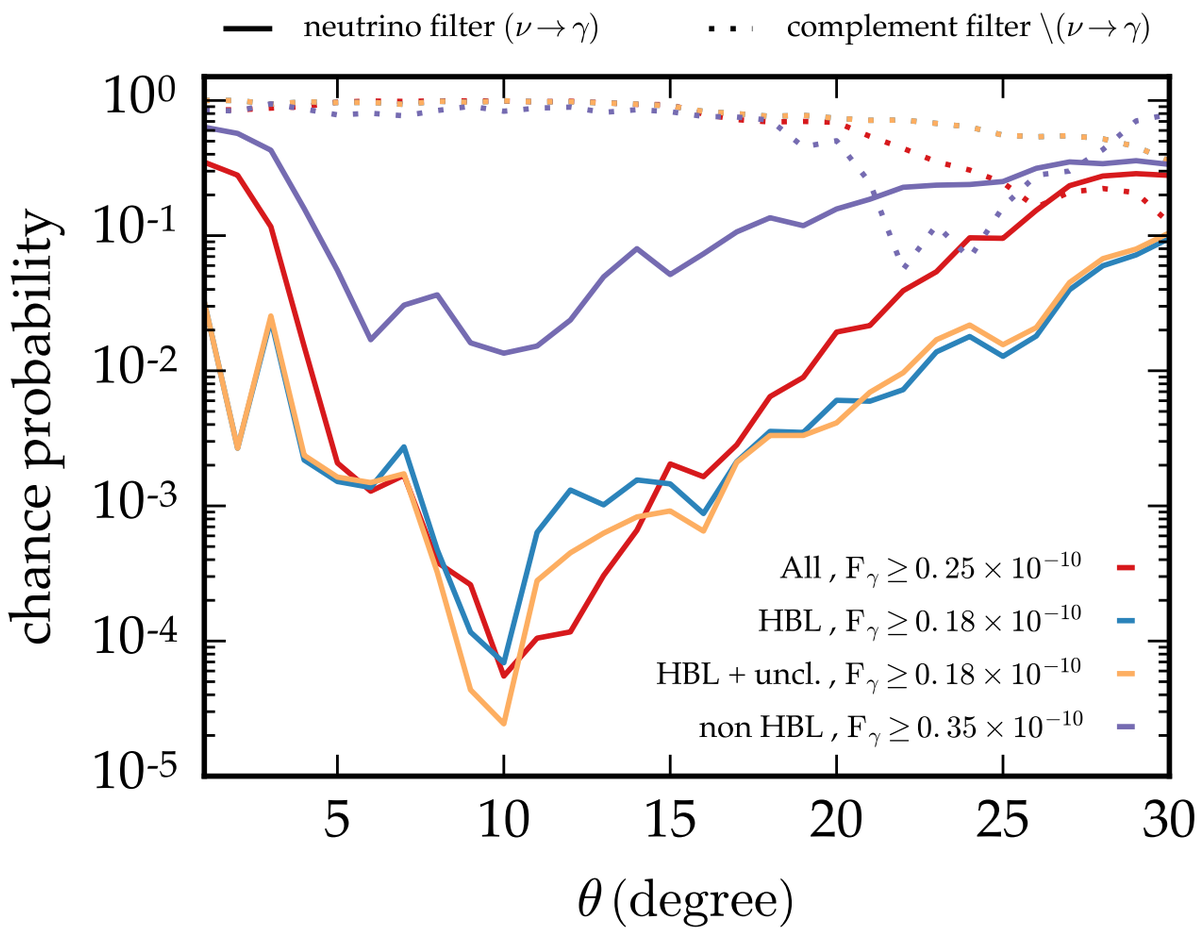


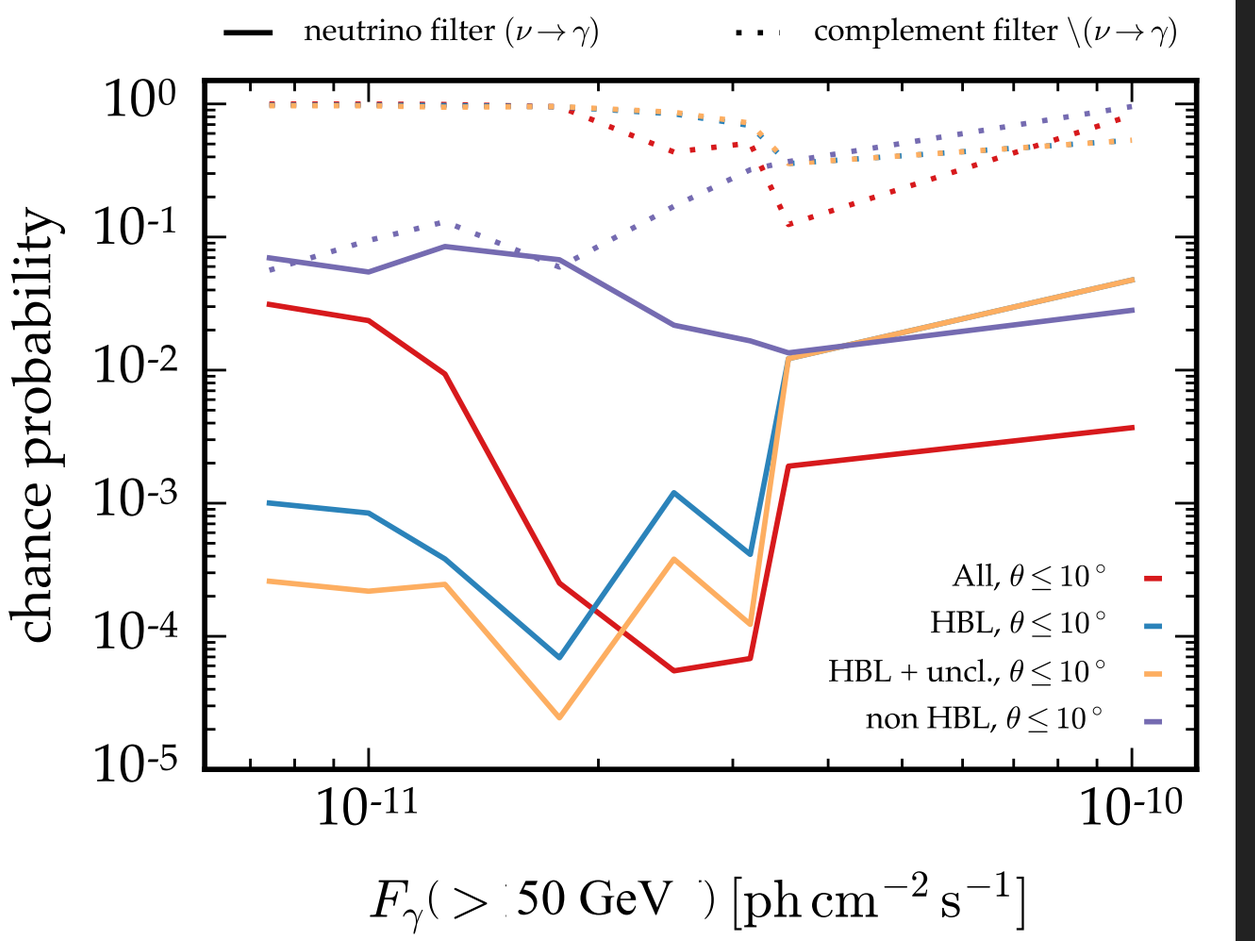
THE SEARCHES

2- Blazars: the neutrino filter

[P. Padovani et al., MNRAS (2016); E.R. et al., MNRAS (2017); E.R. et al., PoS(ICRC2017)1016]

2FHL, 4 years HESE, 2.9 σ (trial corrected)



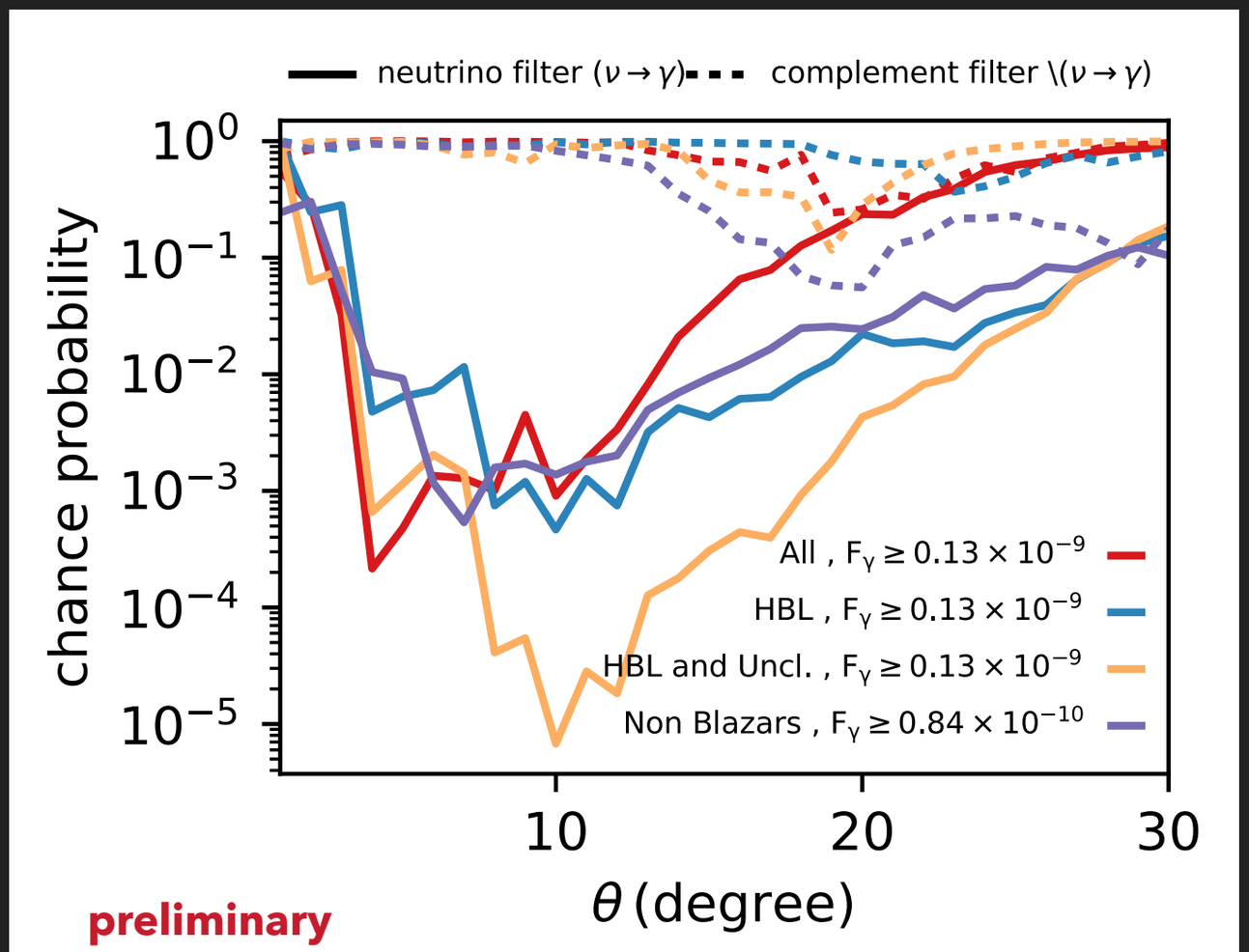


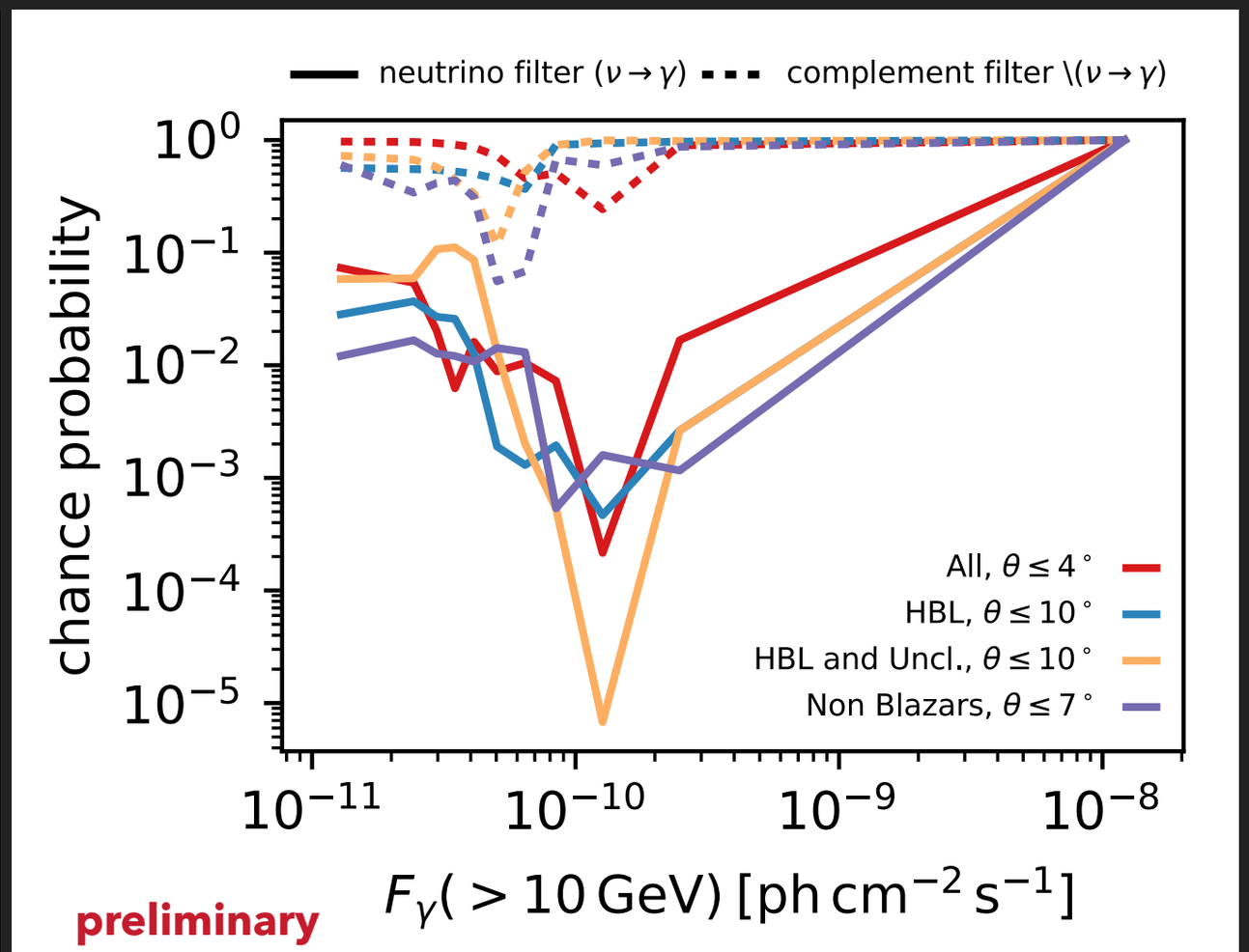
THE SEARCHES

2- Blazars: the neutrino filter

[P. Padovani et al., MNRAS (2016); E.R. et al., MNRAS (2017); E.R. et al., PoS(ICRC2017)1016]

3FHL, 4 years HESE, 3.35 σ (trial corrected)



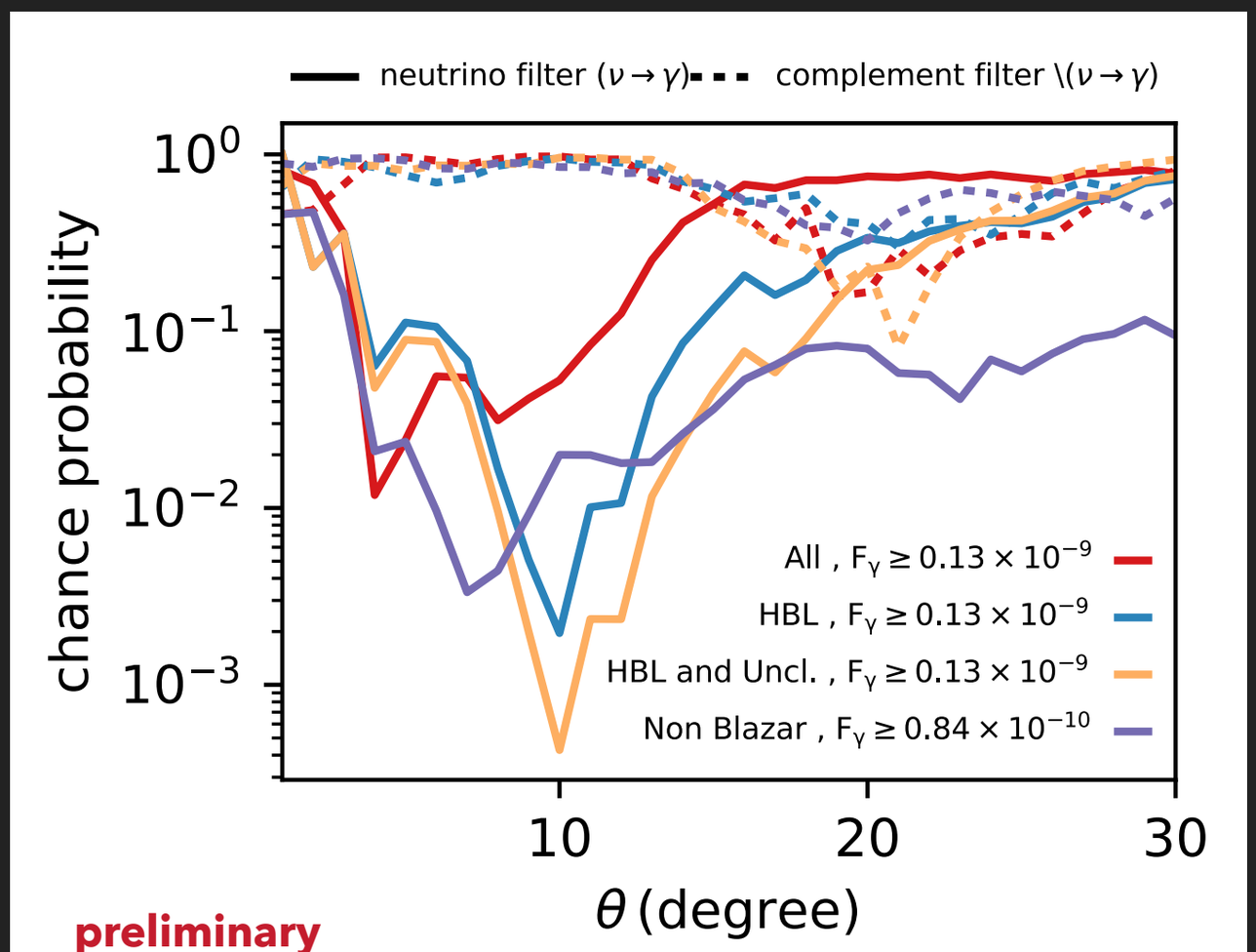


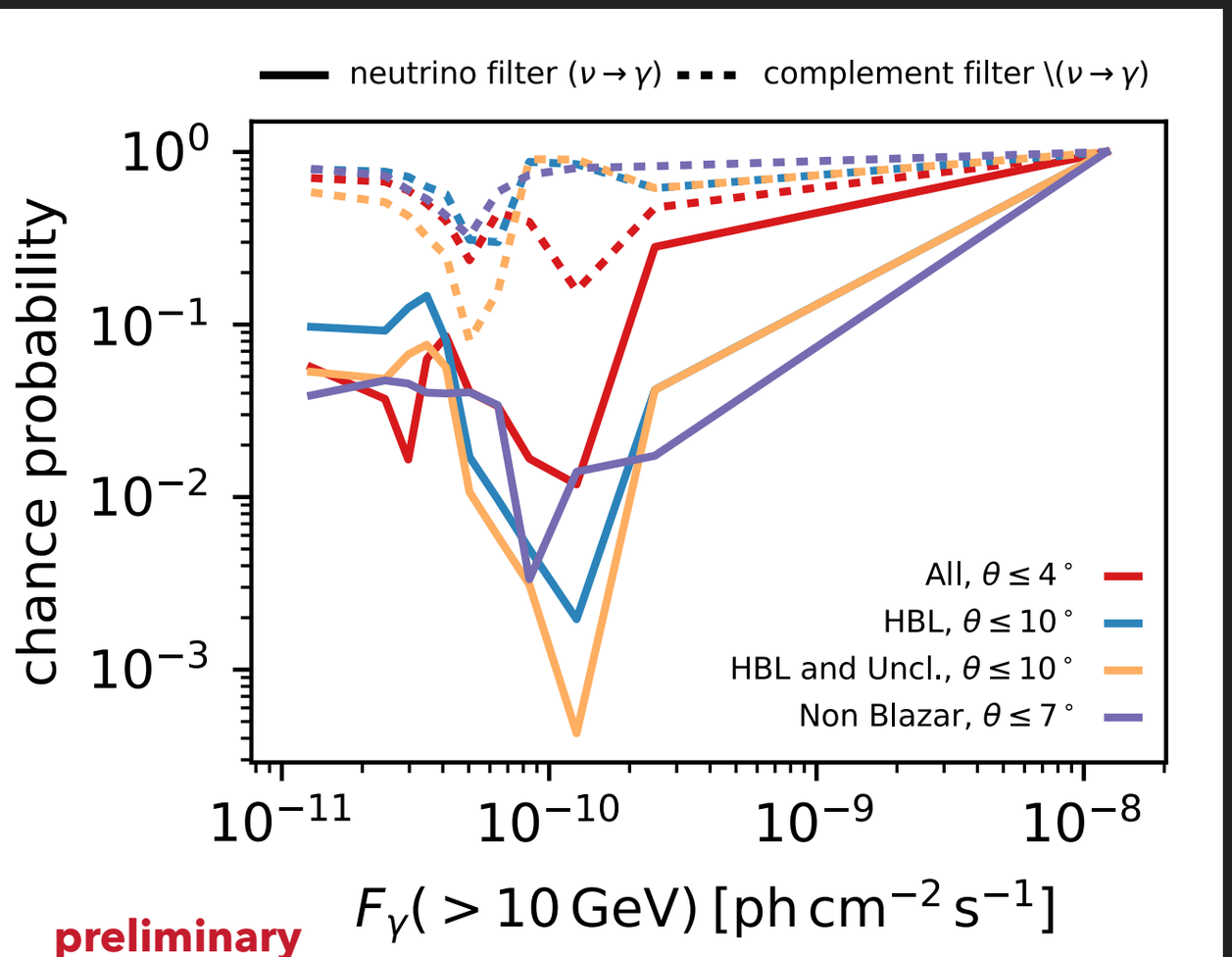
THE SEARCHES

2- Blazars: the neutrino filter

[P. Padovani et al., MNRAS (2016); E.R et al., MNRAS (2017); E.R. et al., PoS(ICRC2017)1016]

3FHL, 6 years HESE, 2.3 σ (trial corrected)

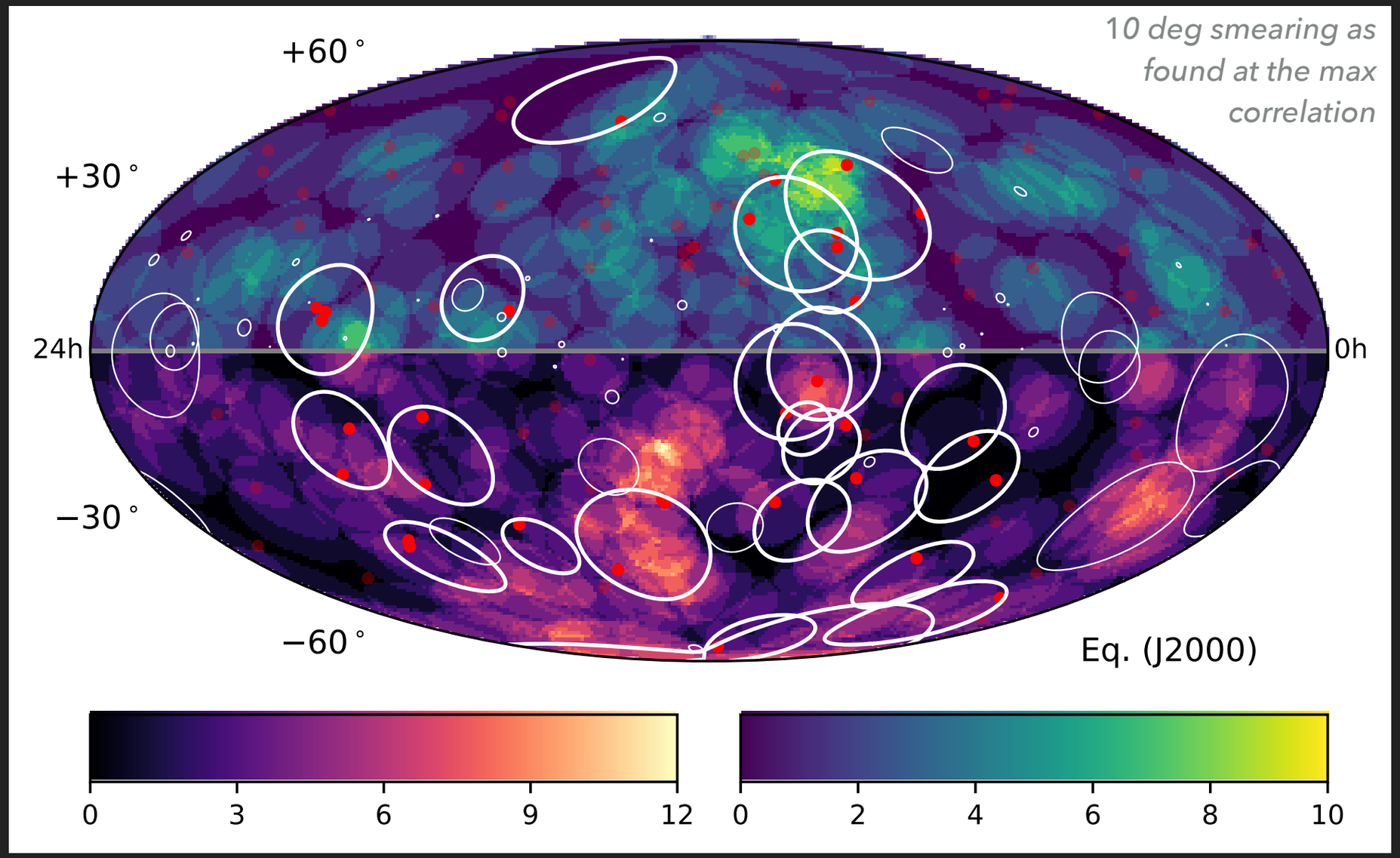




THE SEARCHES

2- Blazars: the neutrino filter

[P. Padovani et al., MNRAS (2016); E.R. et al., MNRAS (2017); E.R. et al., PoS(ICRC2017)1016]



FINAL REMARKS

- Extreme Blazars (HBL/HSP) plausible scenario as multi messenger sources
- Rich set of observations in all messengers: best time ever for multi-messenger astronomy
- Results to be updated soon with new Auger data (Science'17)
- We need more / larger neutrino telescopes
  - GVD, KM3NeT, IceCube-Gen2 and more ideas!

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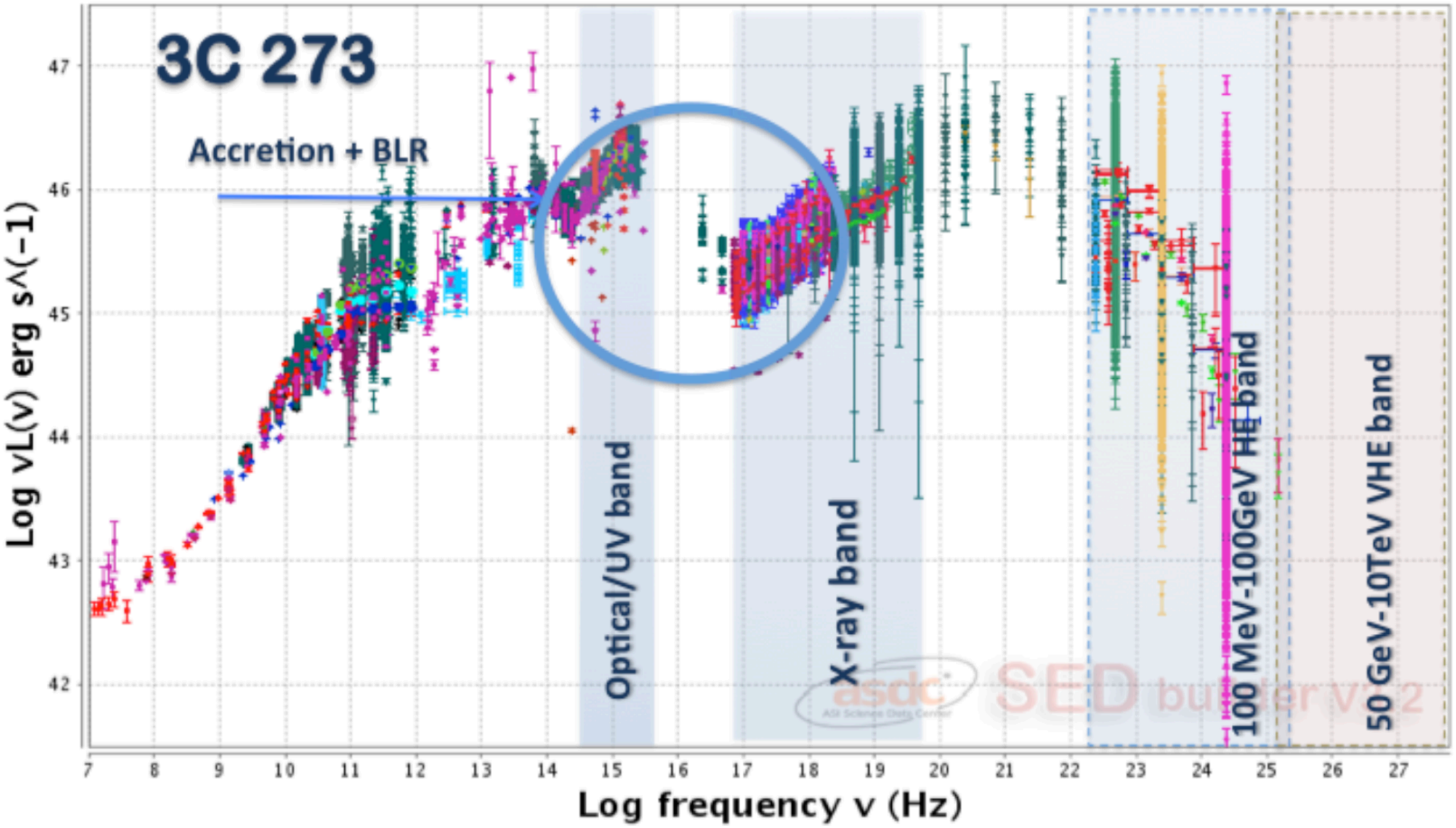

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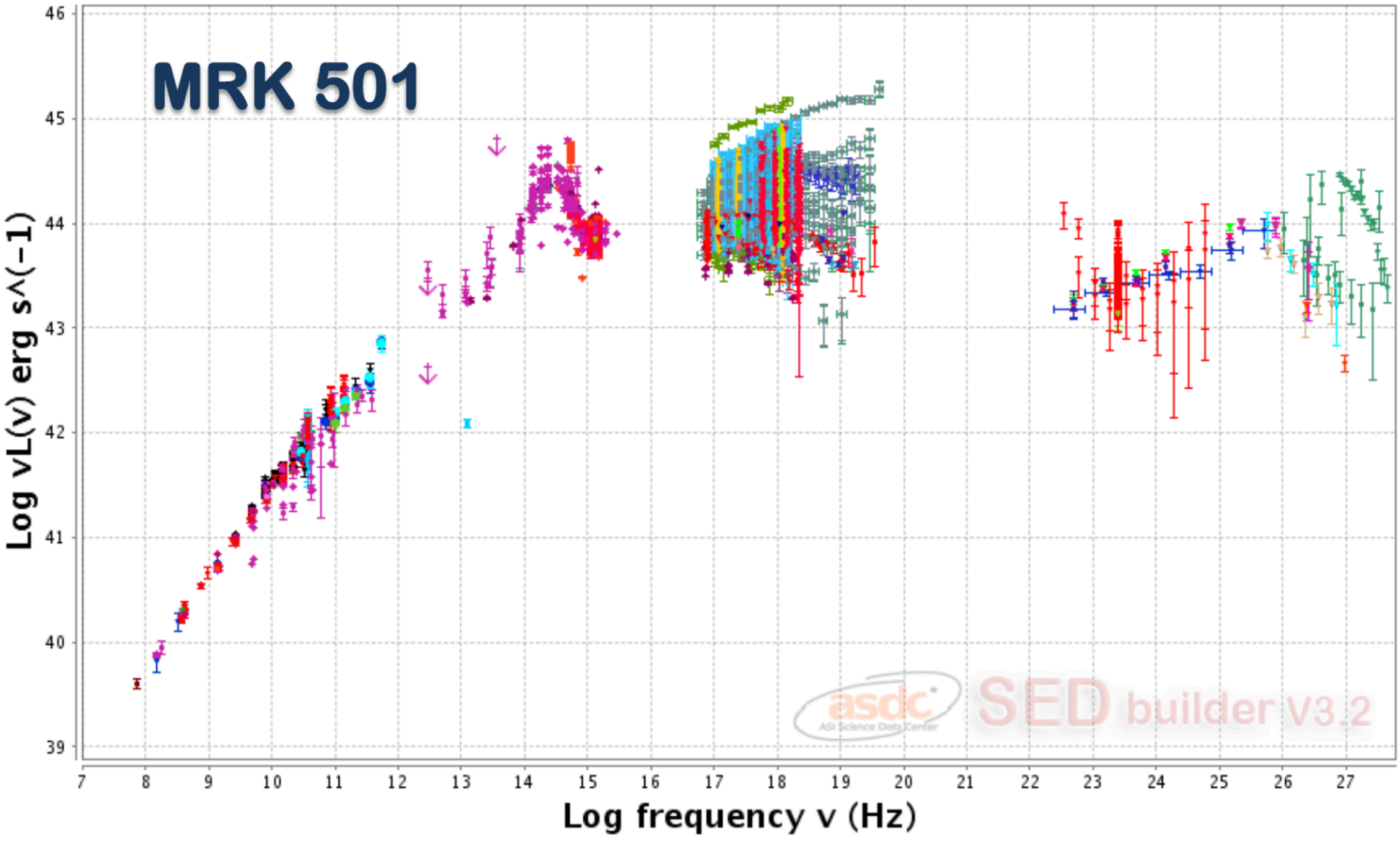

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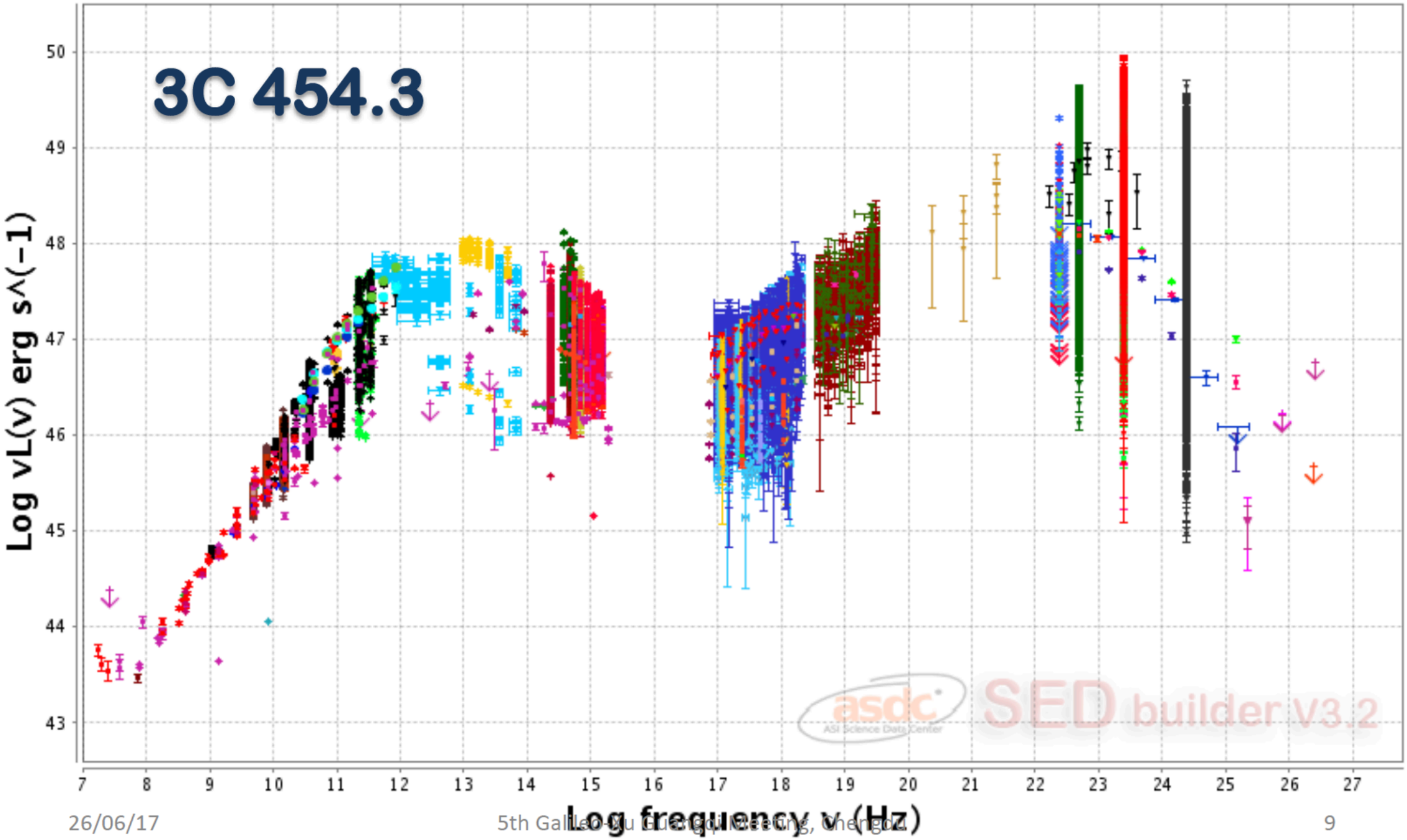

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