Multi-messenger constraints on UHECR sources

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Pure-proton UHECR models strongly constrained by Fermi-LAT

Only narrow range of parameter space remains viable*

*and fit to UHECR spectrum and composition is poor

Model parameters | ***Fraction of Fermi-LAT upper-limits*** | ***Galactic foreground model***

γ_g	m	$z_{\max}$	η_γ ($\tilde{\eta}_\gamma$)	A	η_γ ($\tilde{\eta}_\gamma$)	B	η_γ ($\tilde{\eta}_\gamma$)	C	$\bar{N}_\nu$
2.6	1	5	1.40 (0.59)		0.94 (0.50)		1.11 (0.57)		0.78
2.6	1	1	1.38 (0.46)		0.93 (0.39)		1.10 (0.44)		0.31
2.5	2	5	1.60 (0.87)		1.07 (0.74)		1.26 (0.84)		2.24
2.5	2	1	1.57 (0.60)		1.05 (0.51)		1.24 (0.58)		0.48
2.4	SFR	5	1.88 (1.20)		1.26 (1.03)		1.49 (1.16)		2.28
2.3	5	1	2.23 (1.38)		1.49 (1.18)		1.76 (1.33)		1.72
2.2	6	1	2.52 (1.86)		1.69 (1.59)		2.00 (1.79)		2.88
2.2	5	0.7	2.15 (0.83)		1.44 (0.71)		1.70 (0.80)		0.99
2.2	6	0.7	2.31 (0.99)		1.55 (0.85)		1.83 (0.95)		1.19

LAT compatible models

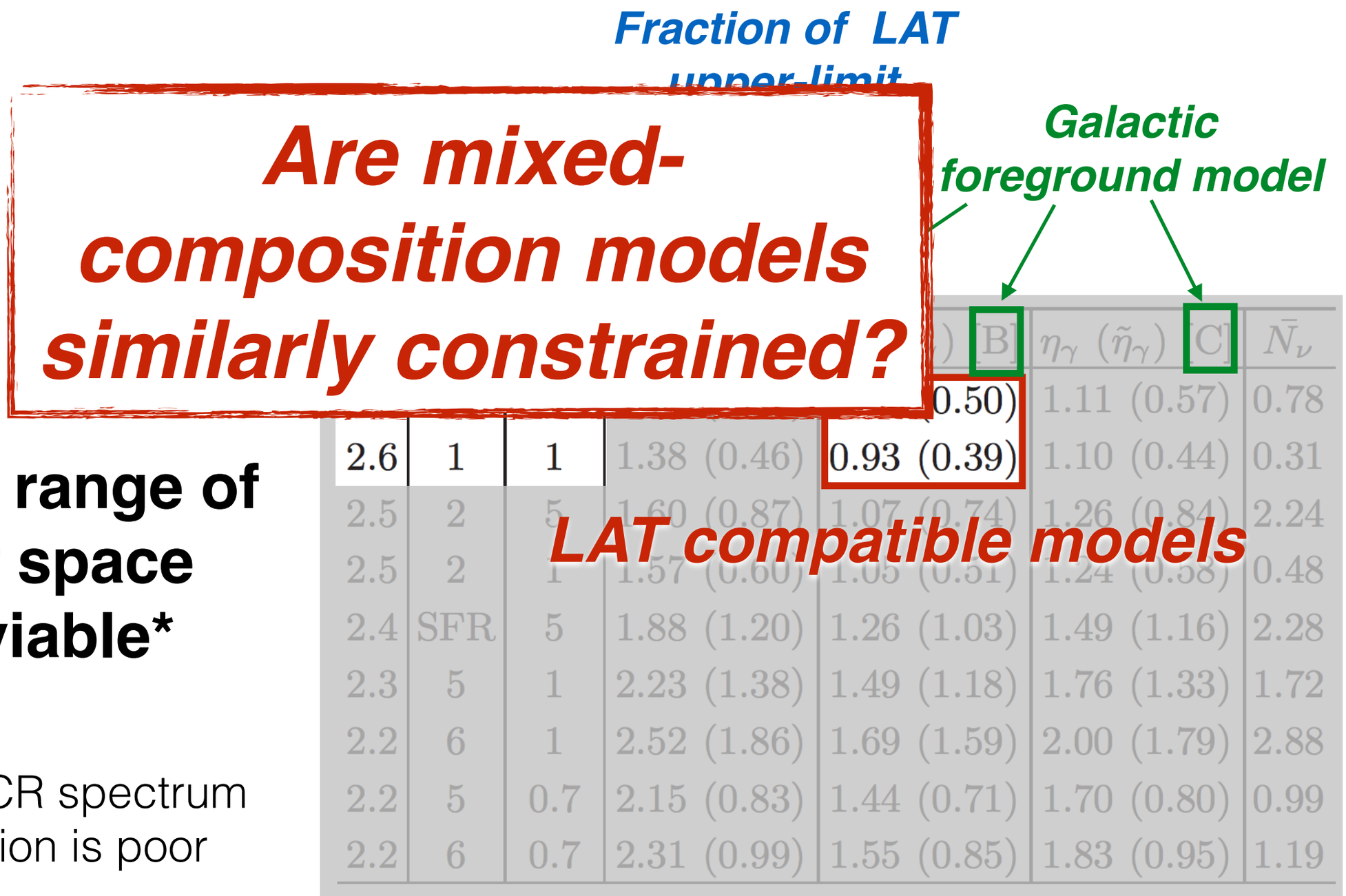
V. Berezinsky et al. Astropart. Phys., 84, 5261 (2016), arXiv:1606.09293.

Pure-proton UHECR models strongly constrained by Fermi-LAT

Are mixed-composition models similarly constrained?

Only narrow range of parameter space remains viable*

*and fit to UHECR spectrum and composition is poor



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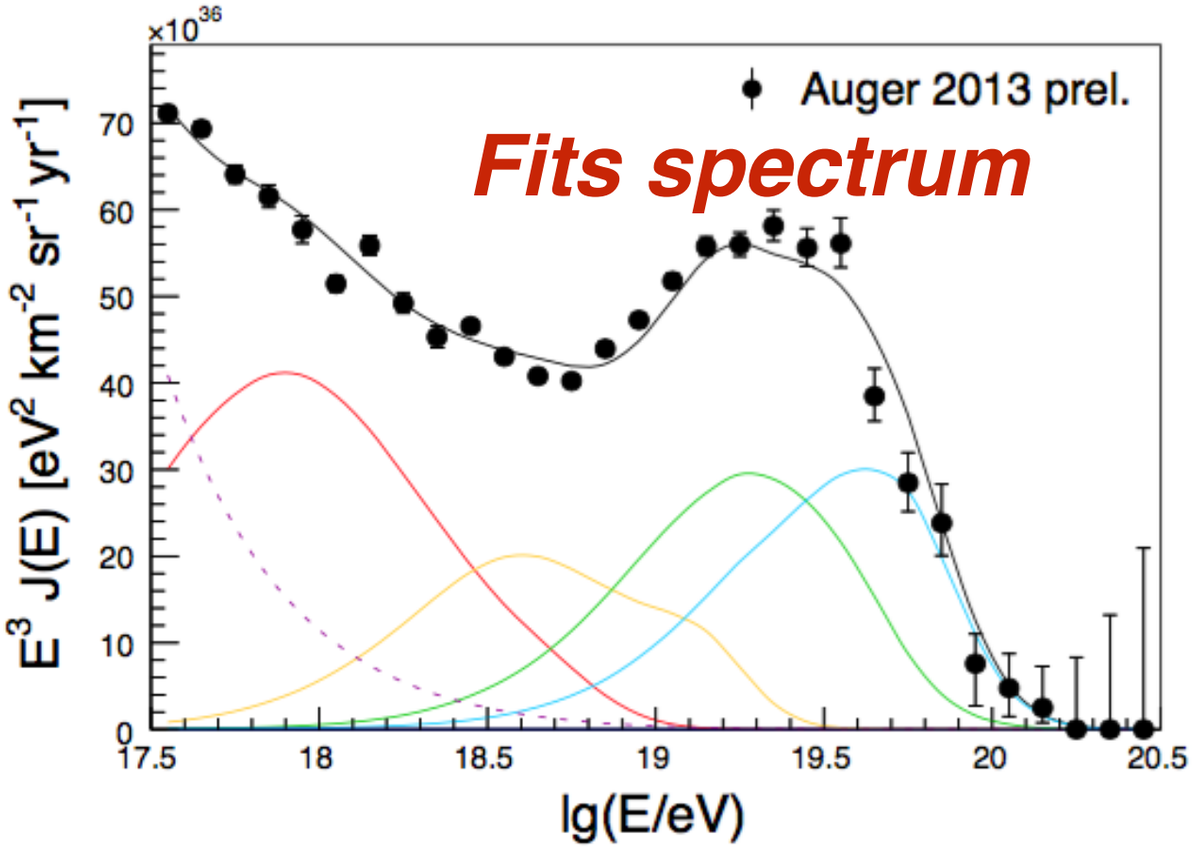
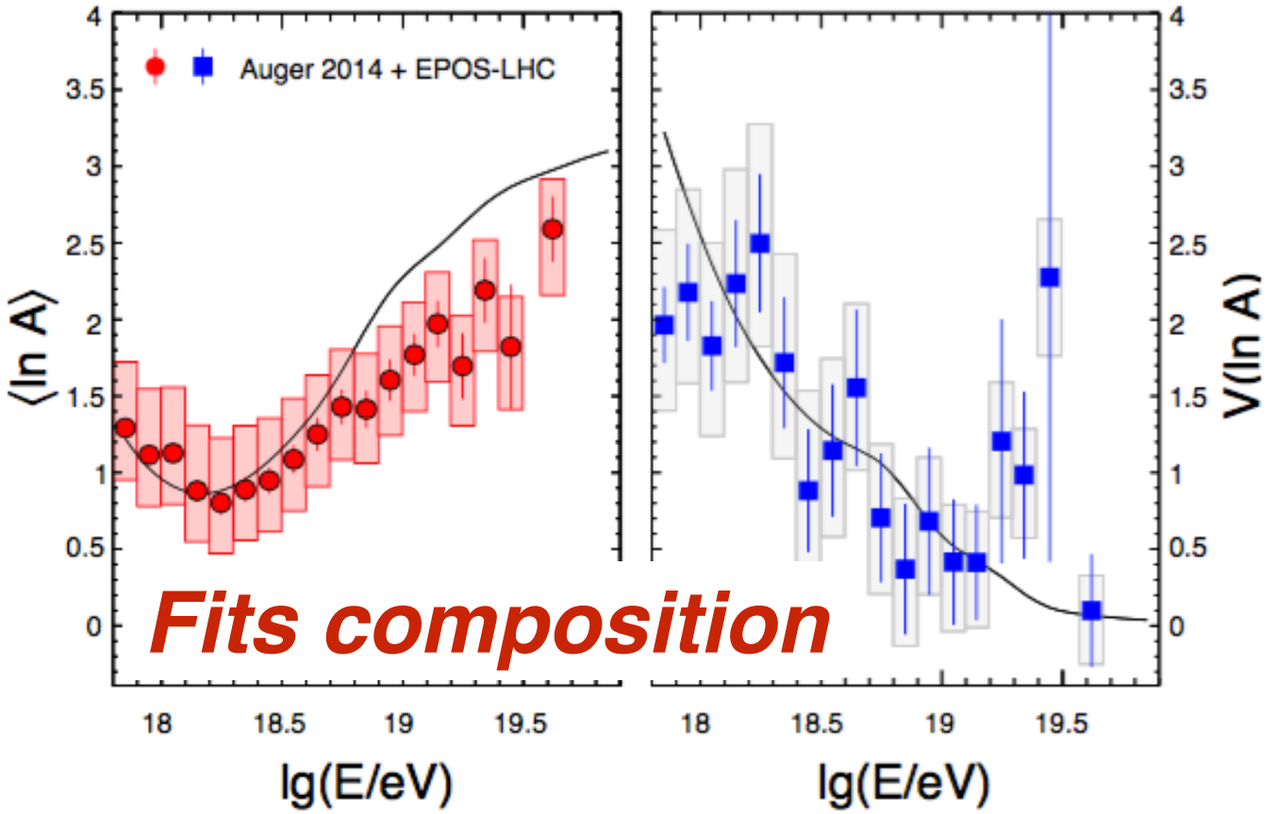
The UFA Source Model

M. Unger, G.R. Farrar & L.A. Anchordoqui, Phys. Rev. D **92** (2015) 123001, arXiv:1505.02153

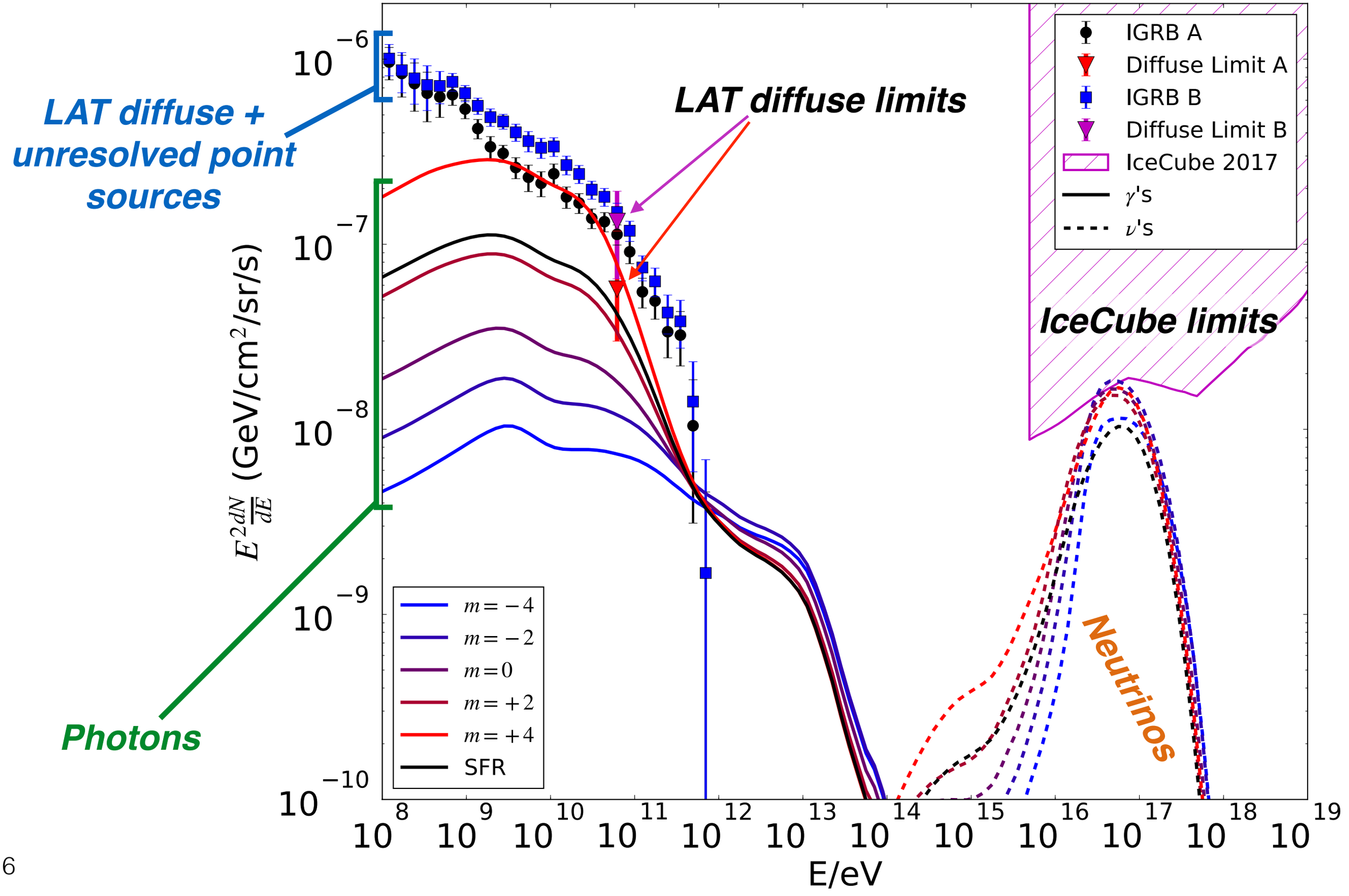




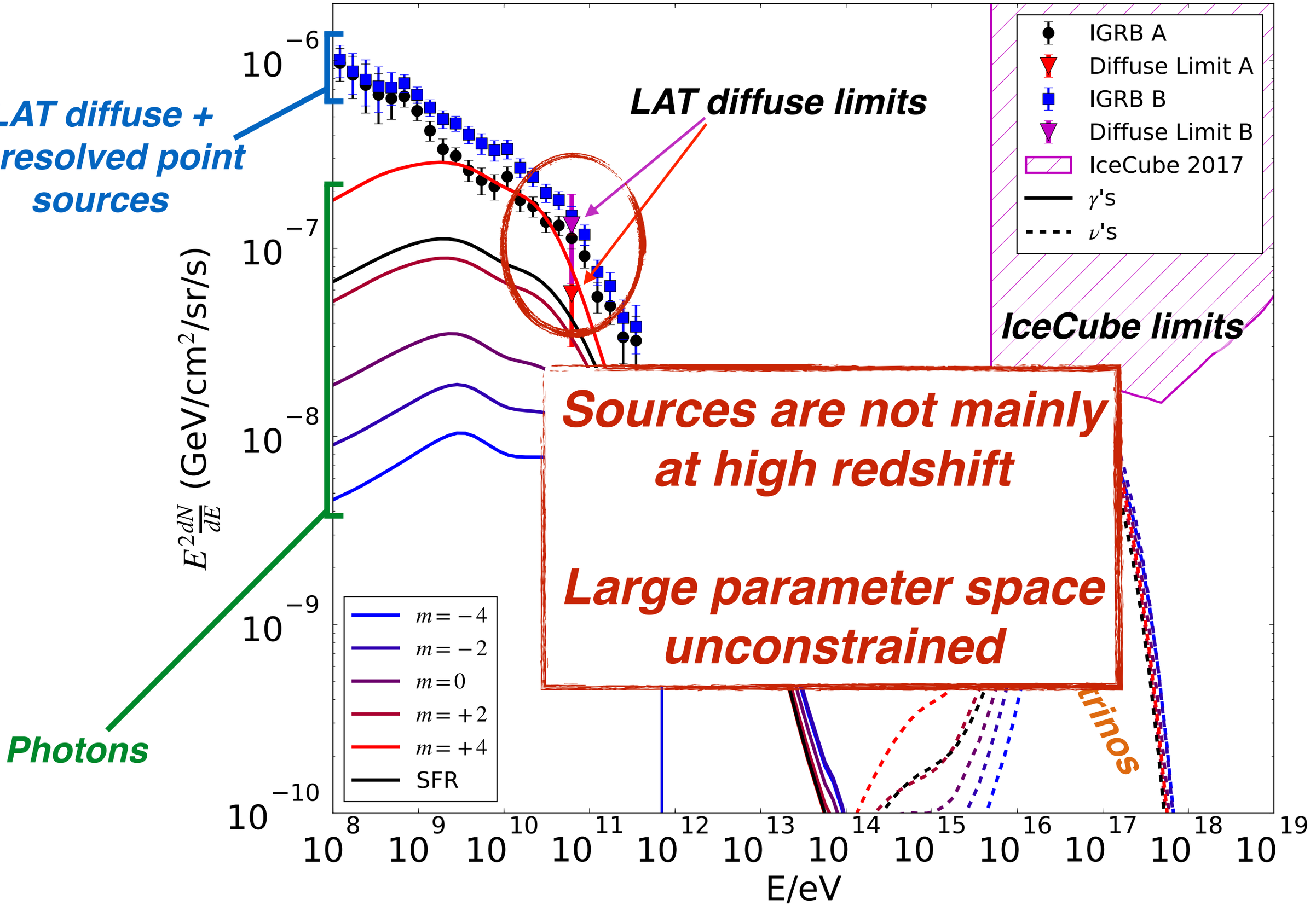
- Allows for injected nuclei to undergo photonuclear disintegration in the source environment
- Explains the origin of ankle and light composition at EeV energies
- Beautifully fits Auger spectrum and composition using escaping mixed-composition

Constraining UFA Source Evolution and Properties with Fermi-LAT and IceCube

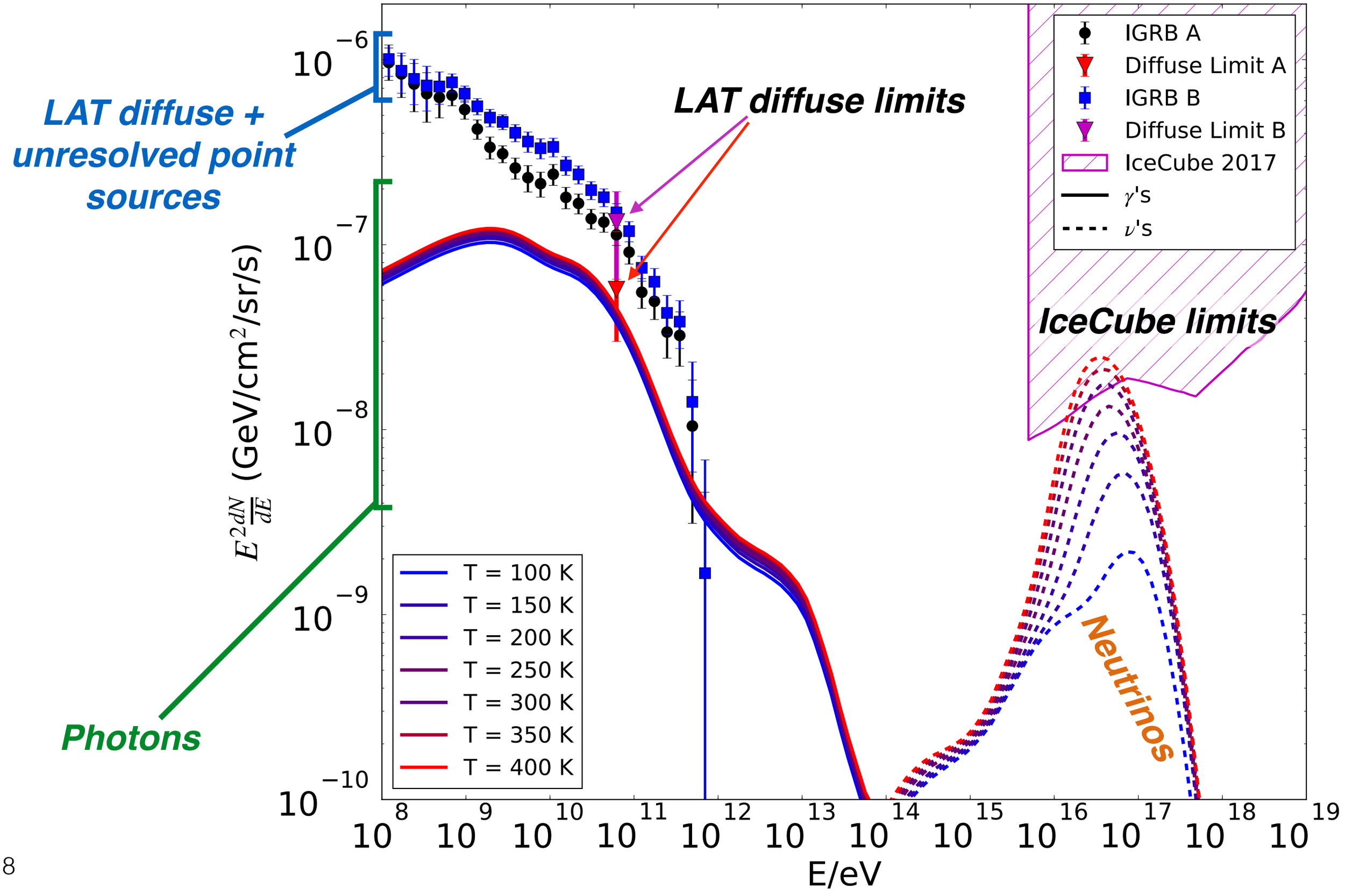
Constraints on Source Evolution



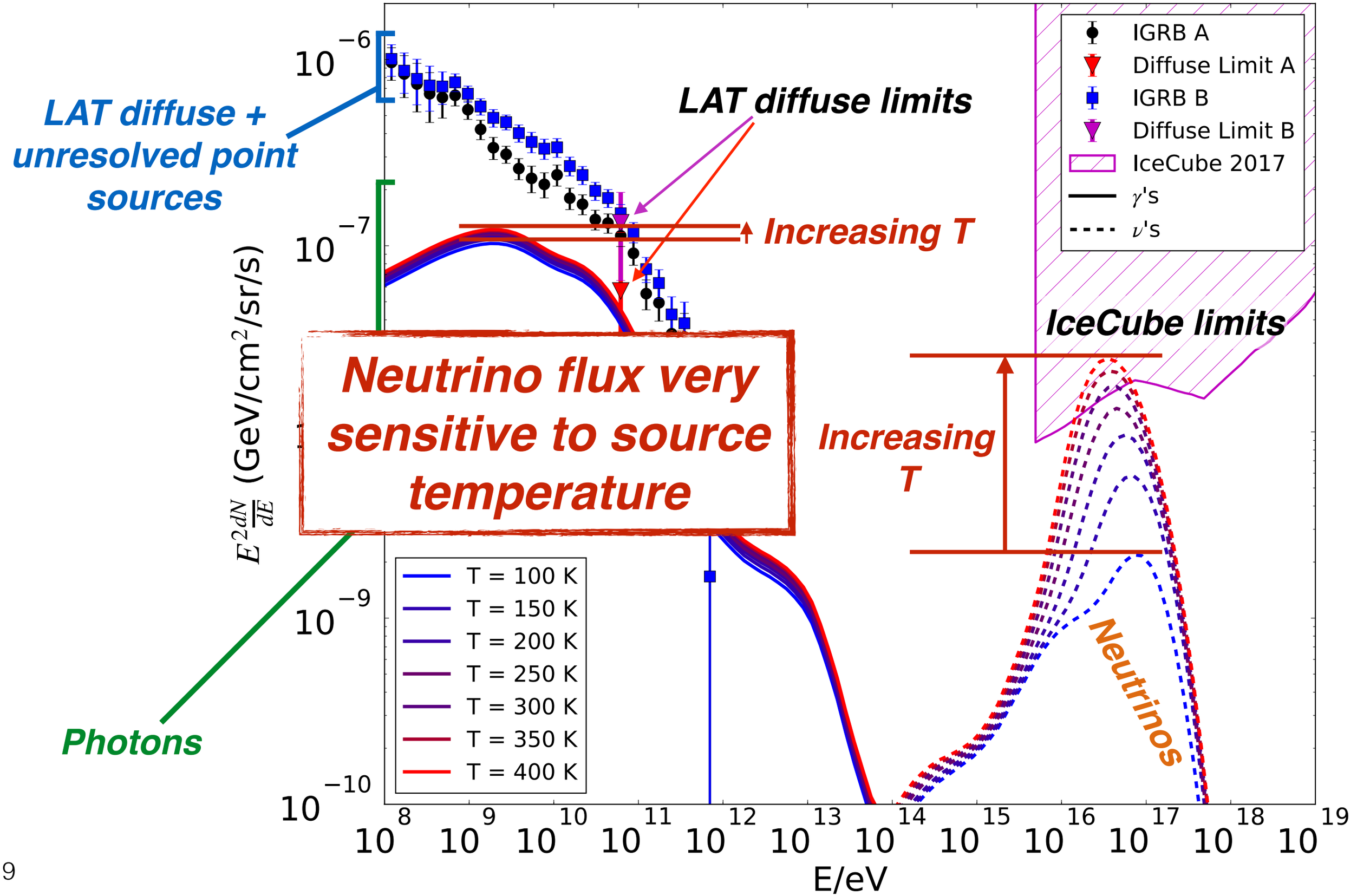
Constraints on Source Evolution



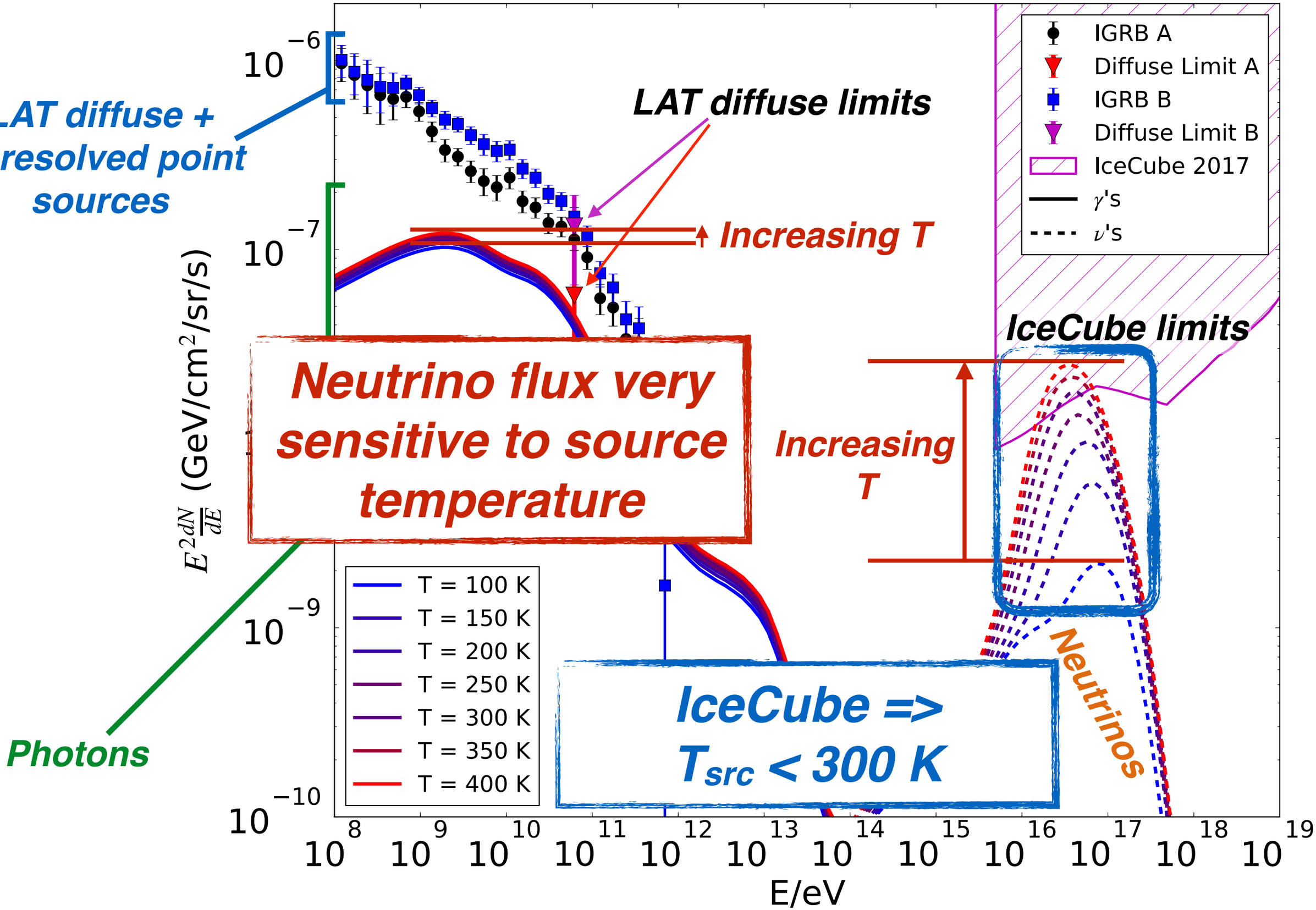
Constraints on Source Temperature



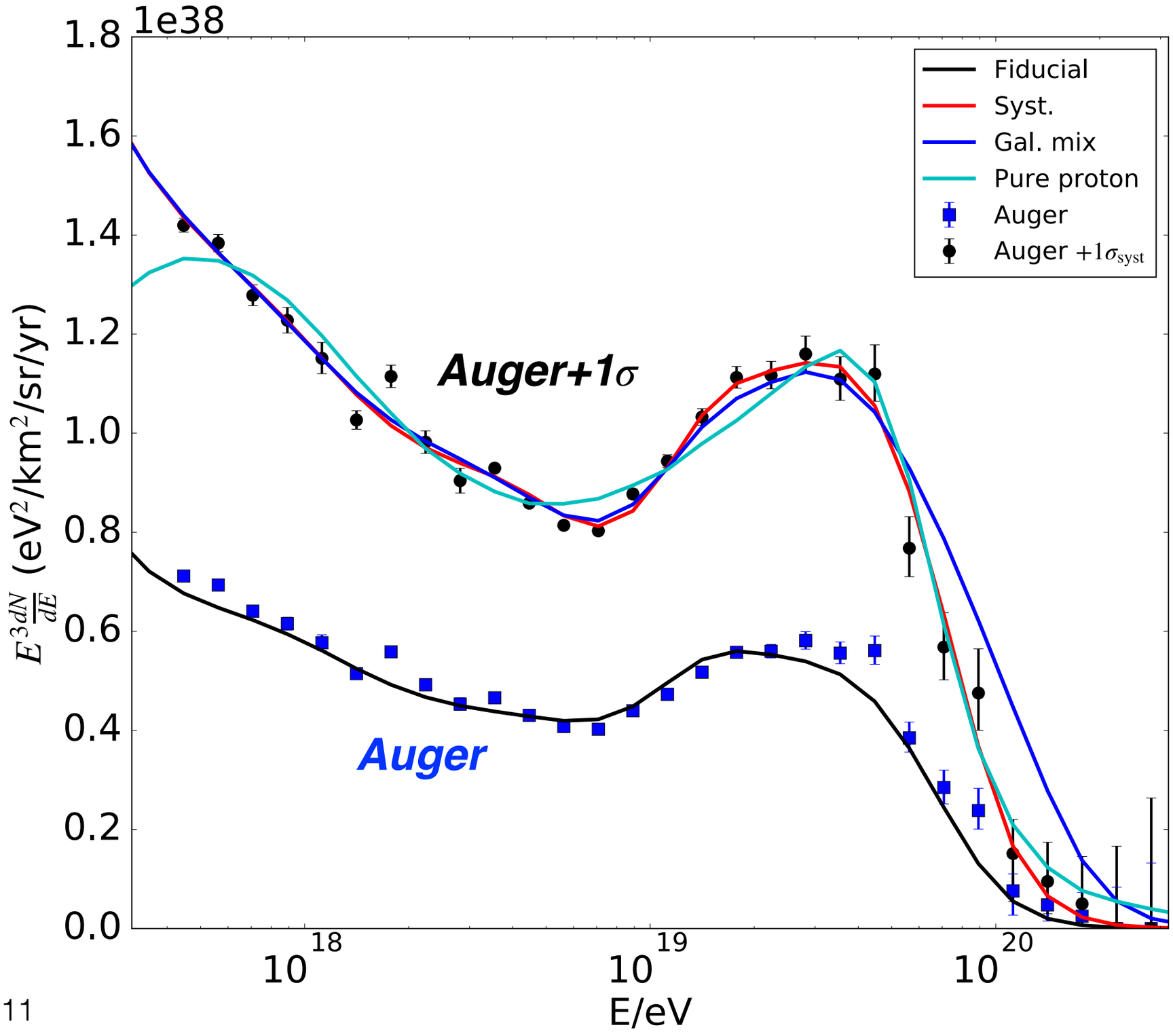
Constraints on Source Temperature

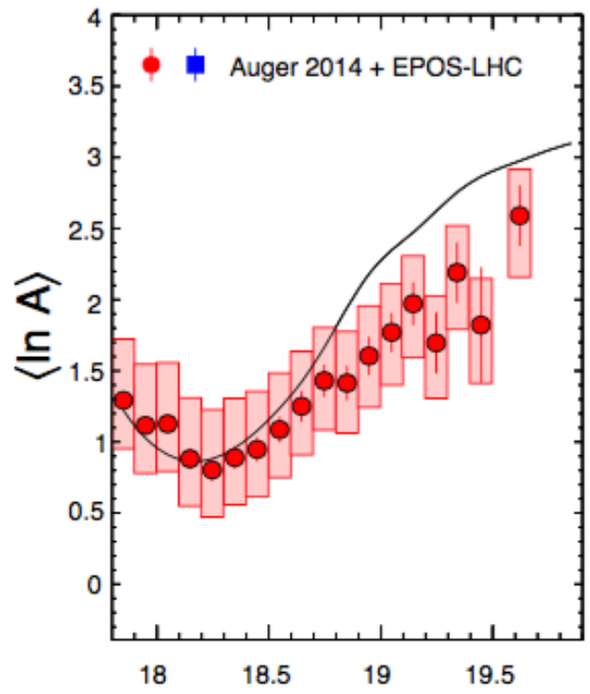


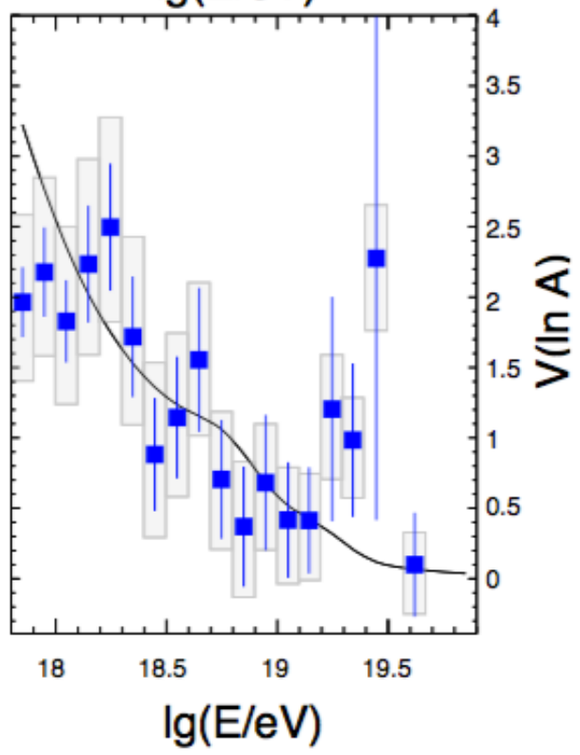
Constraints on Source Temperature



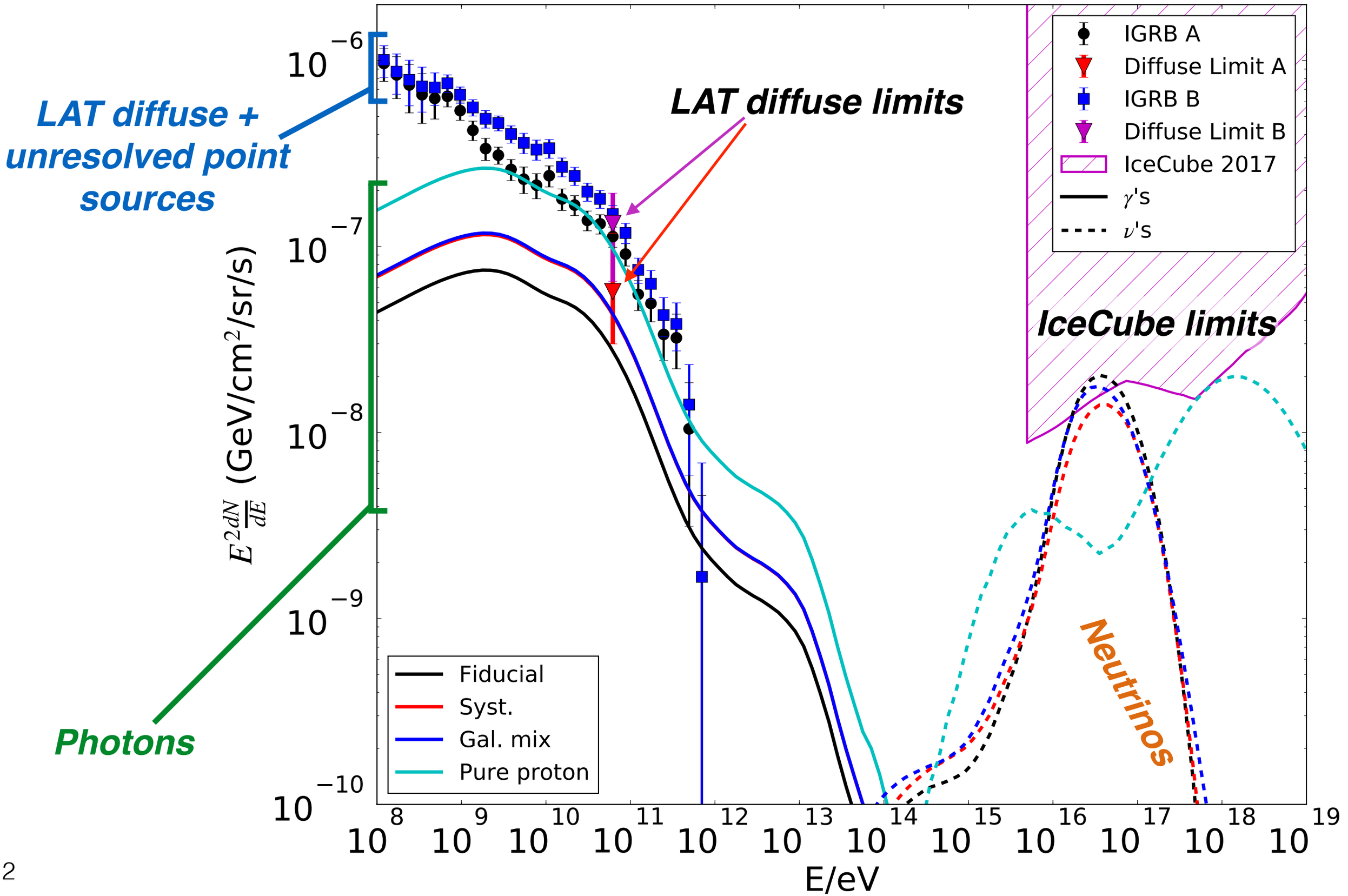
Several UFA variants give good fits to Auger spectrum + composition



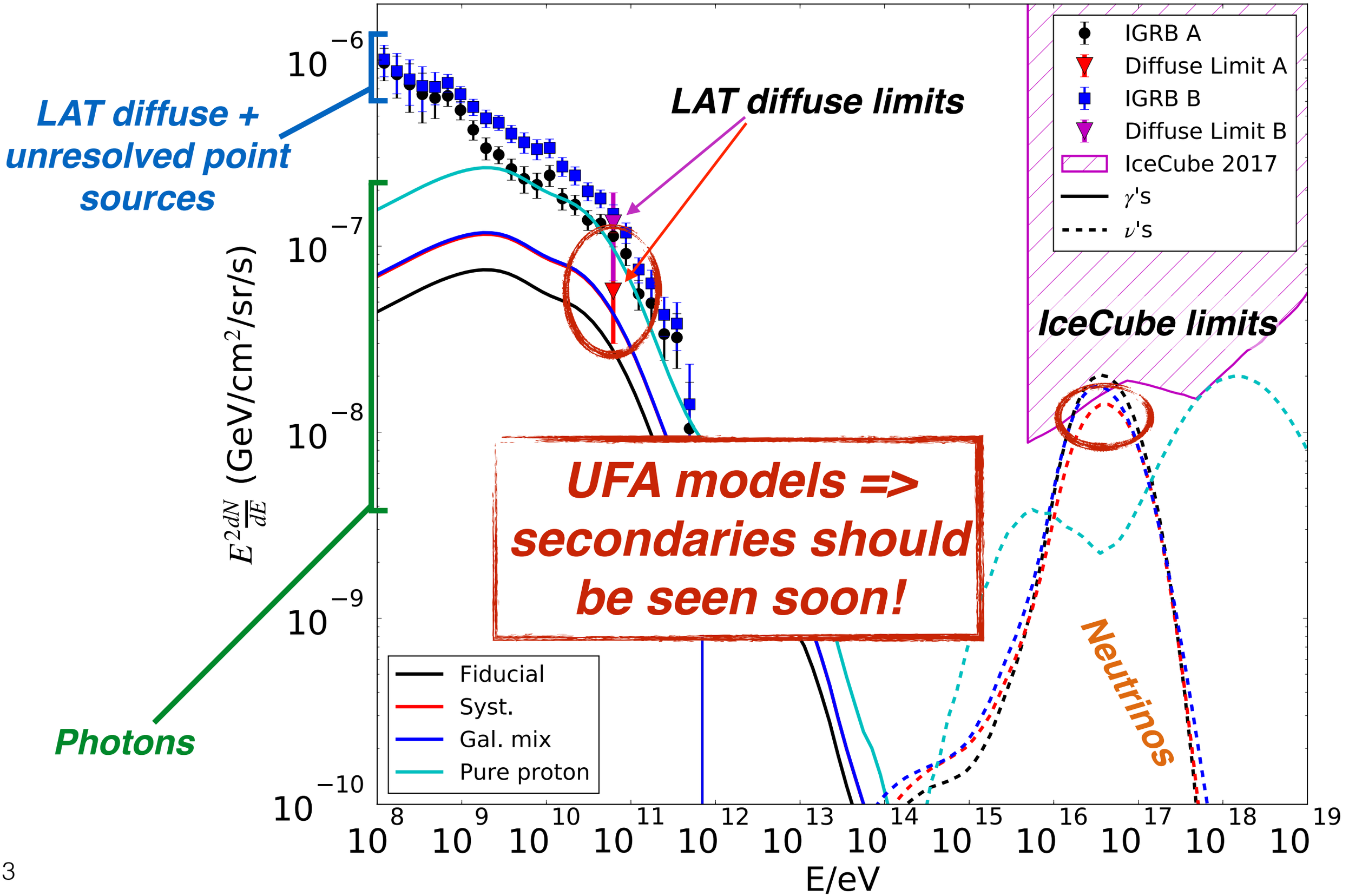




Can γ & ν's constrain UFAs?



Constraints on Benchmark UFAs



Summary

- Pure-proton models survive only in a narrow parameter space (and their UHECR fits are poor)

- Mixed-composition (UFA) models not yet constrained by secondary messenger limits

- Neutrino fluxes strongly constrain possible source temperatures

- UFA models:

  ✔ Auger spectrum

  ✔ Auger composition

  ✔ LAT compatible

  ✔ IceCube compatible