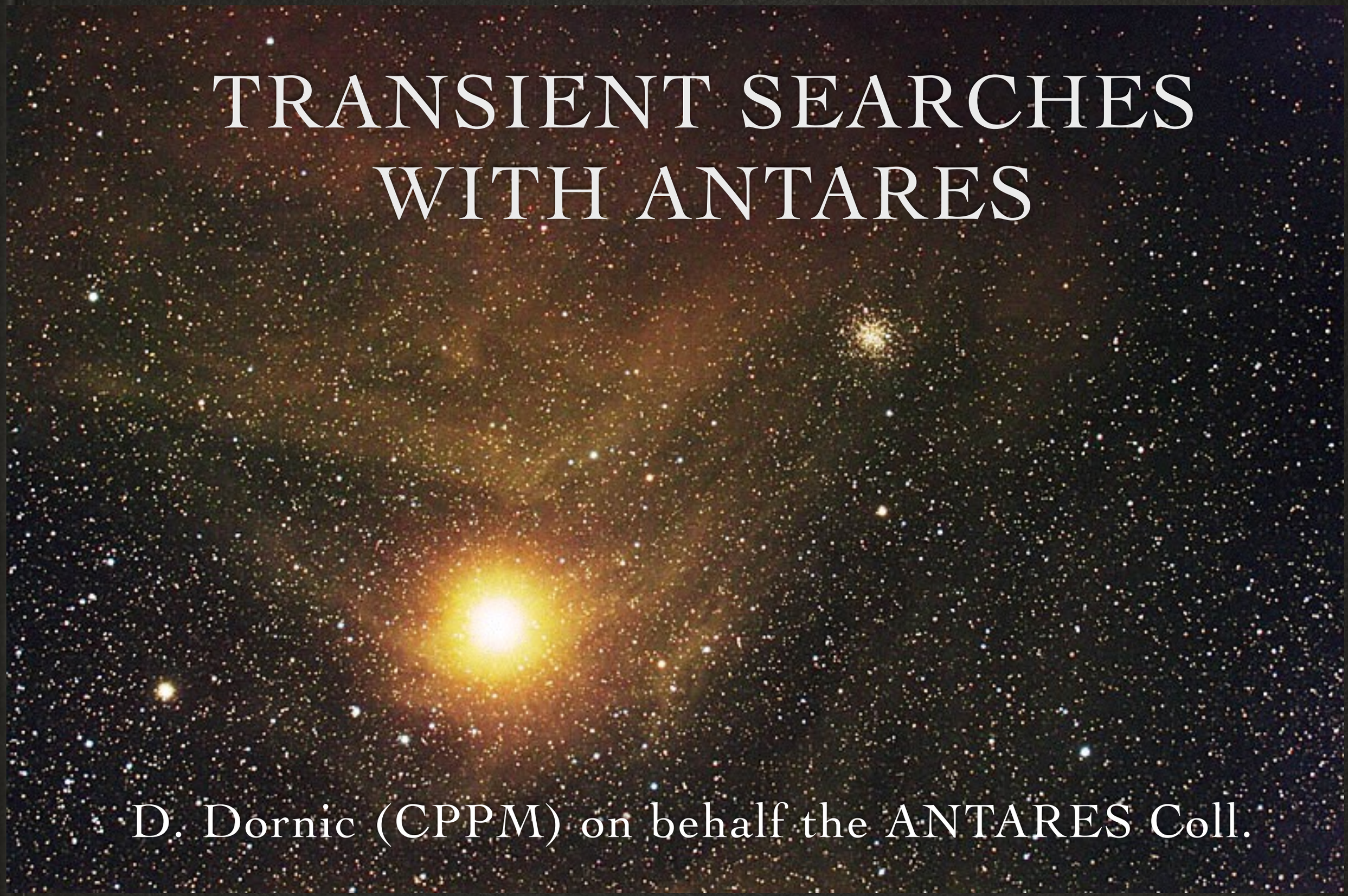
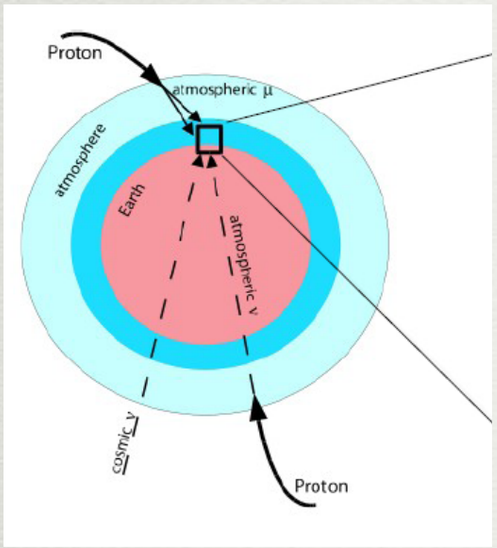
TRANSIENT SEARCHES WITH ANTARES



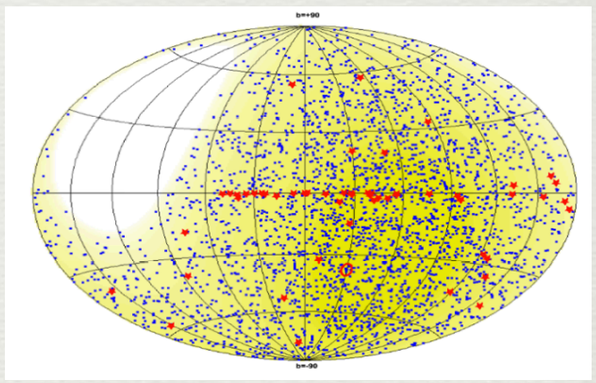
D. Dornic (CPPM) on behalf the ANTARES Coll.

Introduction



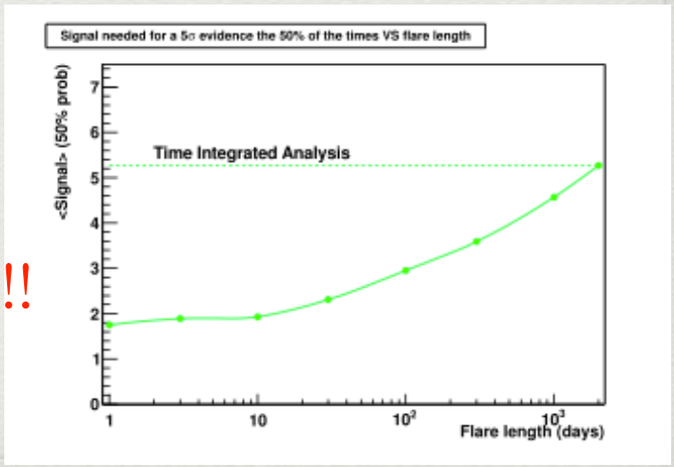
<u>ANTARES:</u> experiment dominated by the backgrounds: atm muon: 10/s, atm neutrino: 4-5/day, cosmic neutrino: 1-2/year (?)

=> Atm muons: quite easy to remove (zenith +quality cuts)
=> Atm neutrinos: irreducible isotropic background, low energy



<u>2 types of point-source analysis</u>:
All sky search: signif. cluster => 8-10 ν per source @ 5σ discov
Candidate list: 50 promising sources => 5-6 ν per source @ 5σ

Adding the time information:
=> 2-3 ν per source @ 5σ discov
=> Increase sensitivity by a factor 2-3



For a very short transient (GRB), only 1 ν per source is sufficient !!!

Analysis method

Unbinned method: minimization of a likelihood ratio
Applied to a subsample data in 2008–2012 (~1044 days live time)
Event selection optimized for the best 3σ model discovery potential

Likelihood: $$\log\left[L_{sg+bk}\right] = \sum_{i=1}^{N_{ev}} \log\left[n_{sg} \times P_{sg}(\alpha,\delta,E,t) + P_{bk}(\alpha,\delta,E,t)\right] - N_{ev}$$

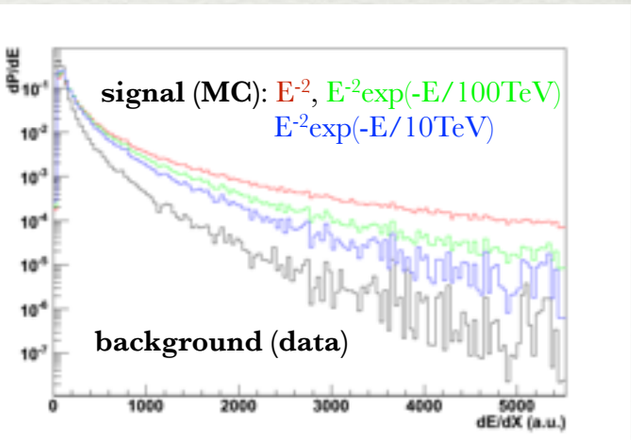
Test statistic: $$Q = \log\left[L^{\max}_{sg+bk}\right] - \log\left[L_{bk}\right]$$

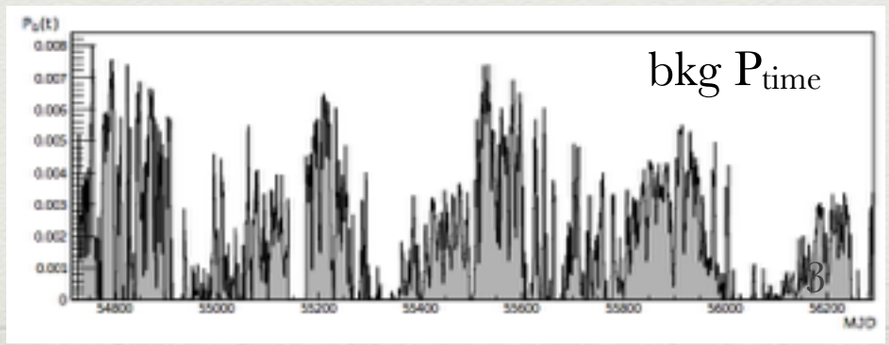
MC [$\nu_\mu + \nu_\mu{}^a$] γ–ray LC

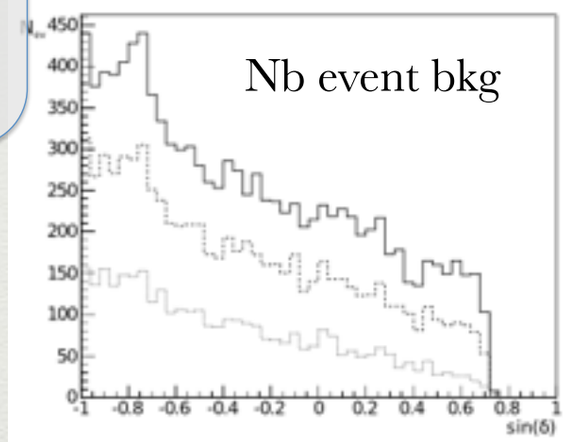
Signal: $$P_{sg}(\alpha,\delta,E,t) = P_{dir}(\alpha,\delta) \times P_{energy}(dE/dX) \times P_{time}(t+lag)$$

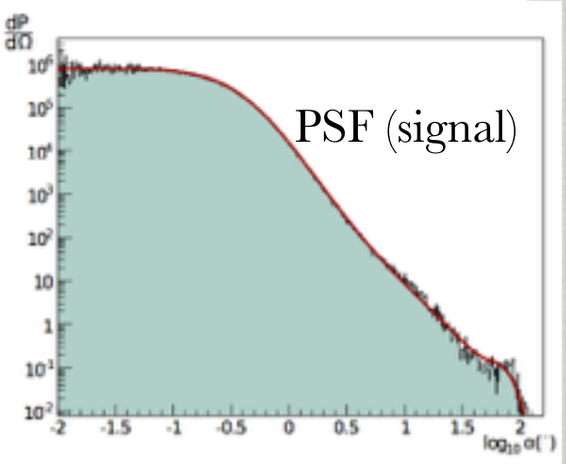
Noise: $$P_{bk}(\alpha,\delta,E,t) = (\Omega(\alpha,\delta))^{-1} \times P_{energy}(dE/dX) \times P_{time}(t)$$

Extracted from data





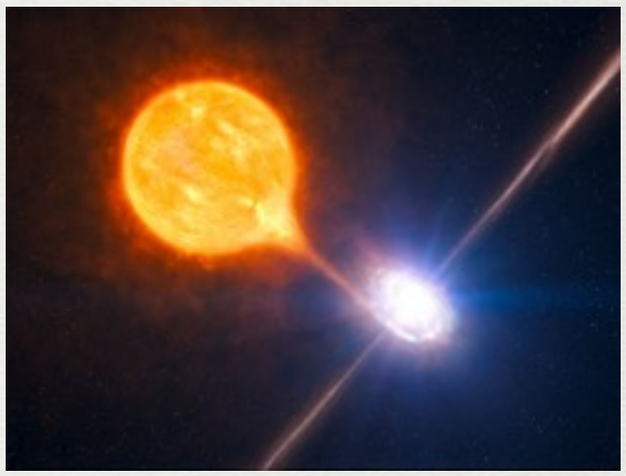




Transient searches

Galactic sources:

- Micro-quasars & X-ray binaries
- Crab
- Sagittarius A*



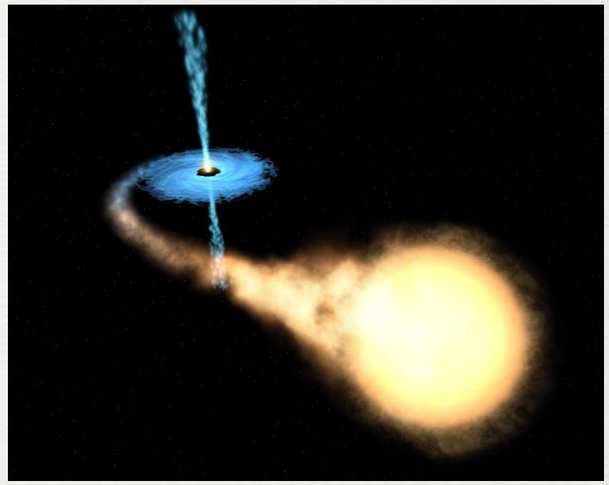
Extragalactic sources:

- Active Galactic Nuclei (Blazars)
- Gamma-Ray Bursts

Main hypothesis: gamma-rays and neutrinos are emitted in coincidence (or short delay)

X-Ray Binaries

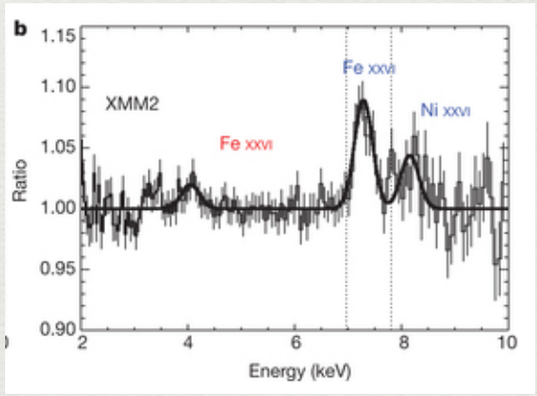
X-ray binary: binary systems formed
by a compact object (neutron star or black hole) +
companion star.
Traditionally, 2 categories: HMXB and LMXB
Very few cases with confirmed presence of jets
(detected with radio)



As usual only few indications of hadronic component in XRB, only 2-3 cases:
SS433, Cyg X-1 and 4U1630-472

SS433: Iron Emission Lines from Extended X-ray Jets in SS 433: Reheating of Atomic Nuclei S. Migliari, R. Fender, M. Mendez, Science, 297, 1673 (2002)

4U1630-472: Baryons in the relativistic jets of the stellar-mass black hole candidate 4U 1630-47 M. D. Trigo, J. C.A. Miller-Jones, S. Migliari, J. W. Broderick, T. Tzioumis, Nature, published online on 13/11/13



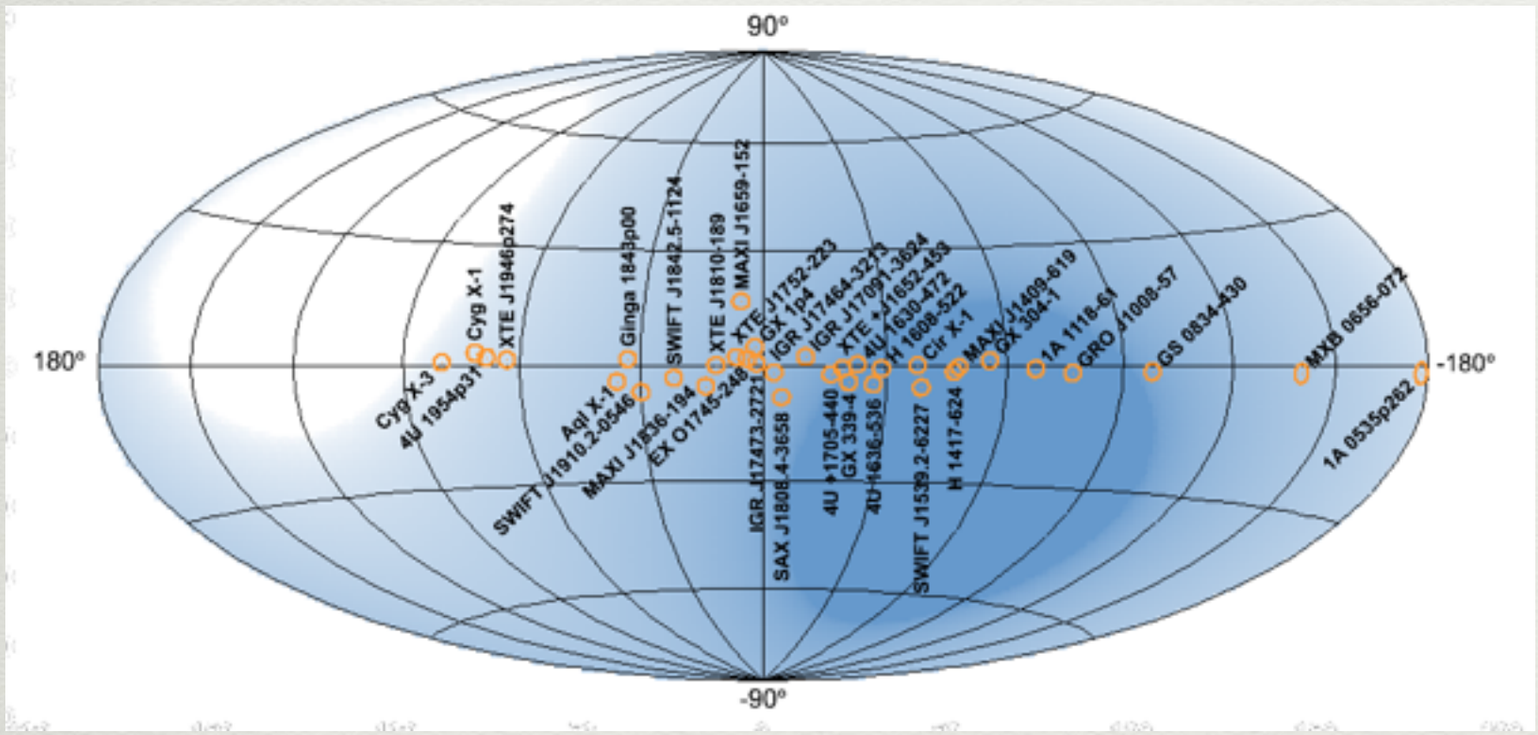
The non-thermal emission of the system is surely dominated by leptonic processes but a hadronic component could also be present. (not necessary to have jets)

X-Ray Binaries

Search for time/space correlations between neutrino and X-ray (or gamma) flares:

- Outbursts on 33 binary systems
- Transition state periods (TS) on 8 binaries (a-tels)

Analysis of the X-ray or gamma-ray light curves: look for significant outbursts and look for time/space correlation with ANTARES neutrinos



Results:

2 sources with events in coincidence with flares: GX 1p4 and IGR J17091-3624 (pre-trial 4.1% and 6.5%)

=> Compatible with background fluctuations

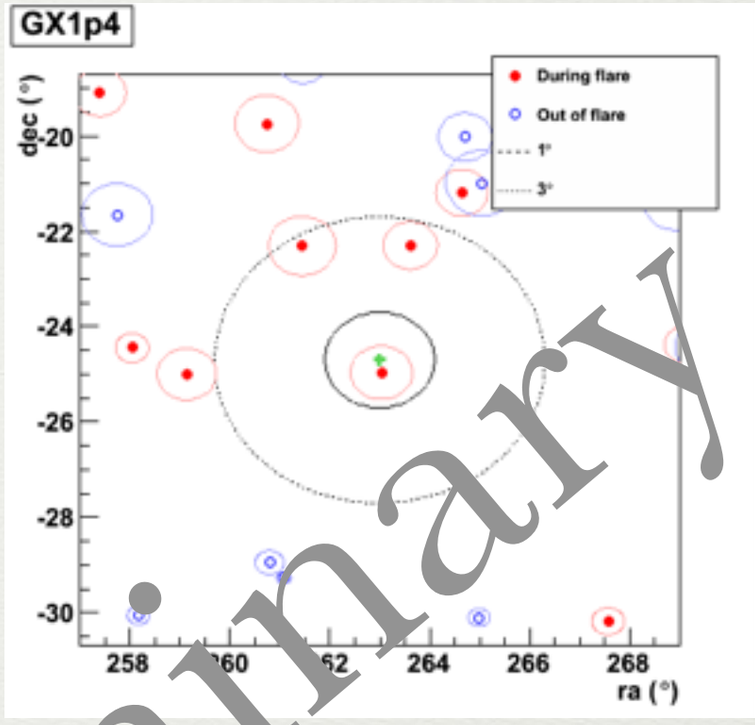
X-Ray Binaries

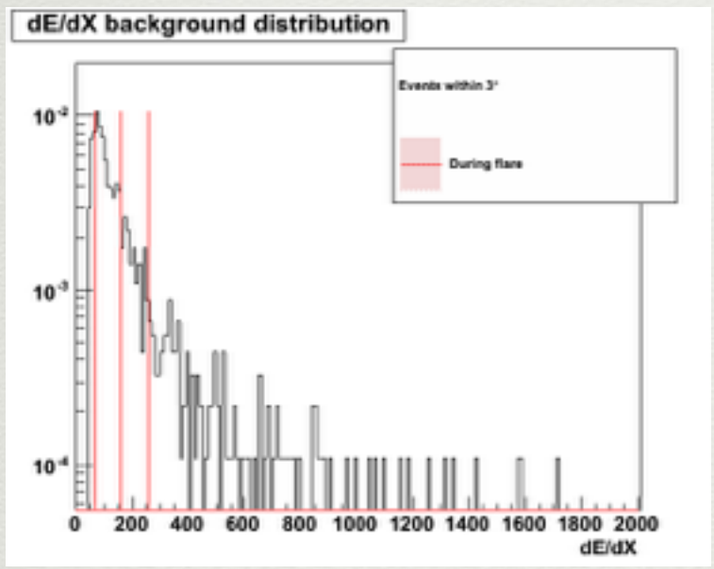
GX 1p4

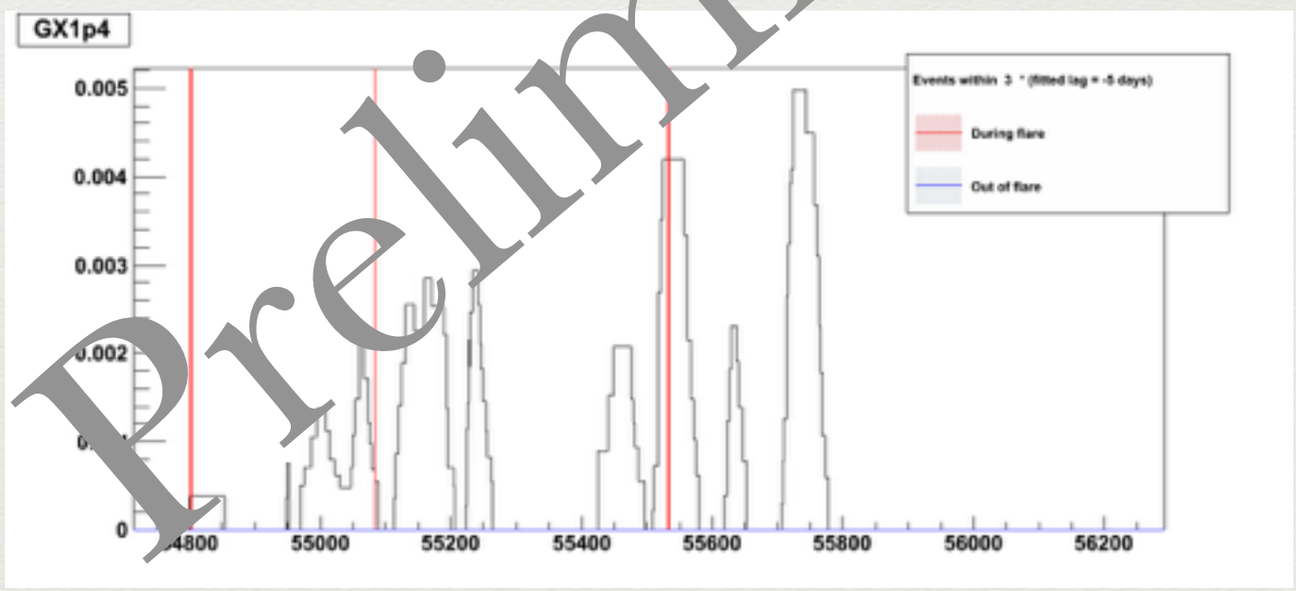
[DEC:-24.7|RA:263]

Flaring 557 days

p-value: 4.13% (post-trial: 72%)
n_{sig}: 0.69 (TS: 0.457)
lag: -5 days
Spectrum: "cutoff100TeV_costhetasup-0.15"
Lambda cut: -5.2

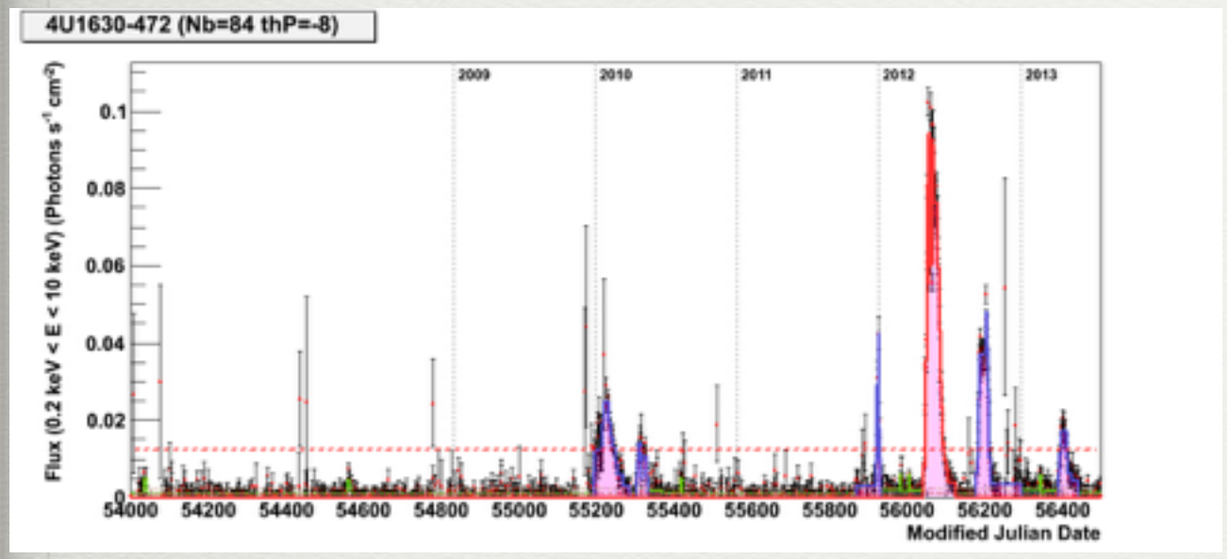


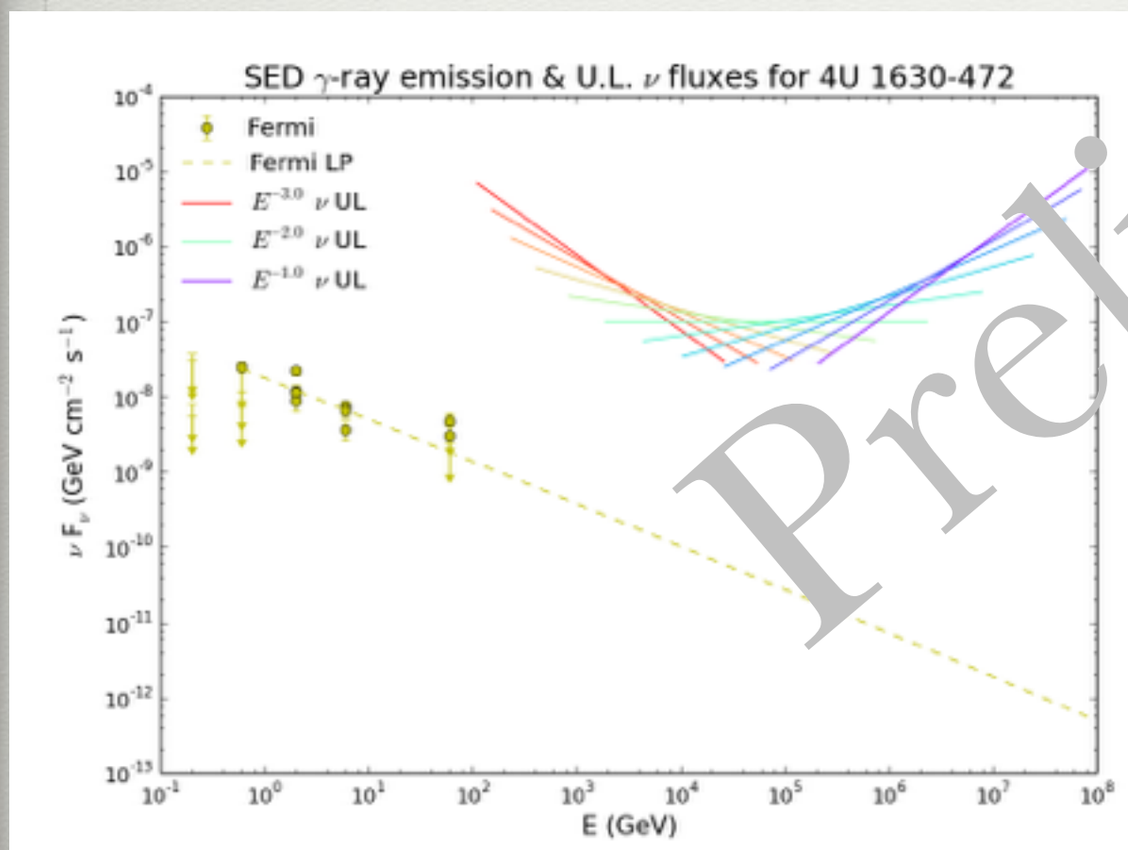




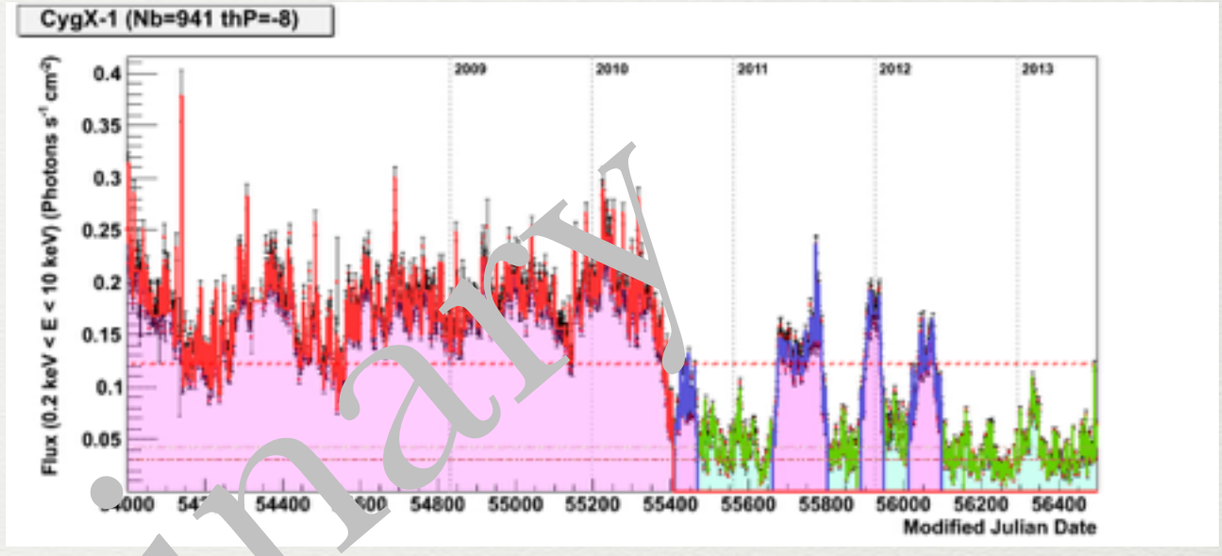
X-Ray Binaries

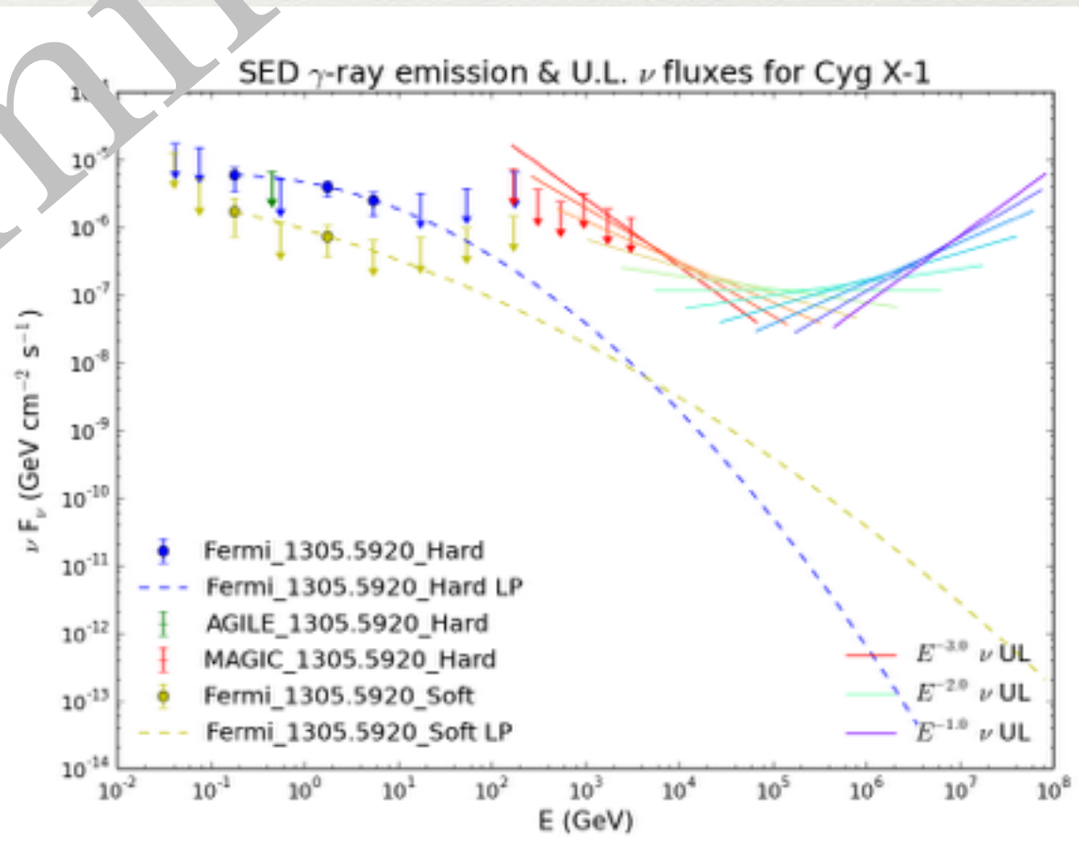
4U 1630-472





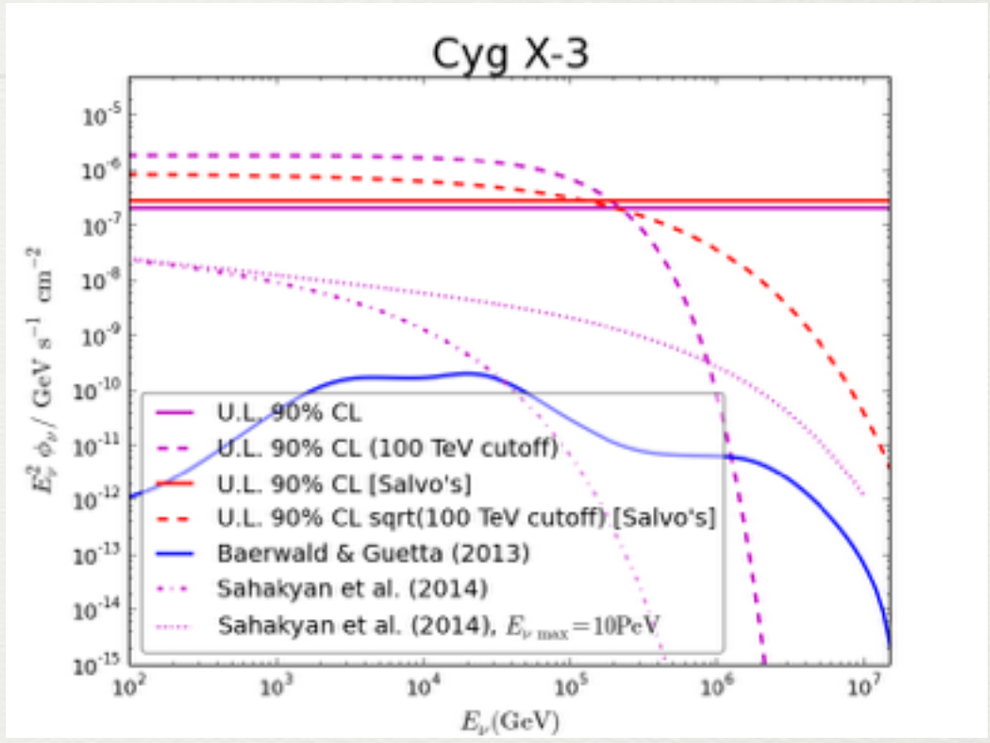
Cygnus X-1

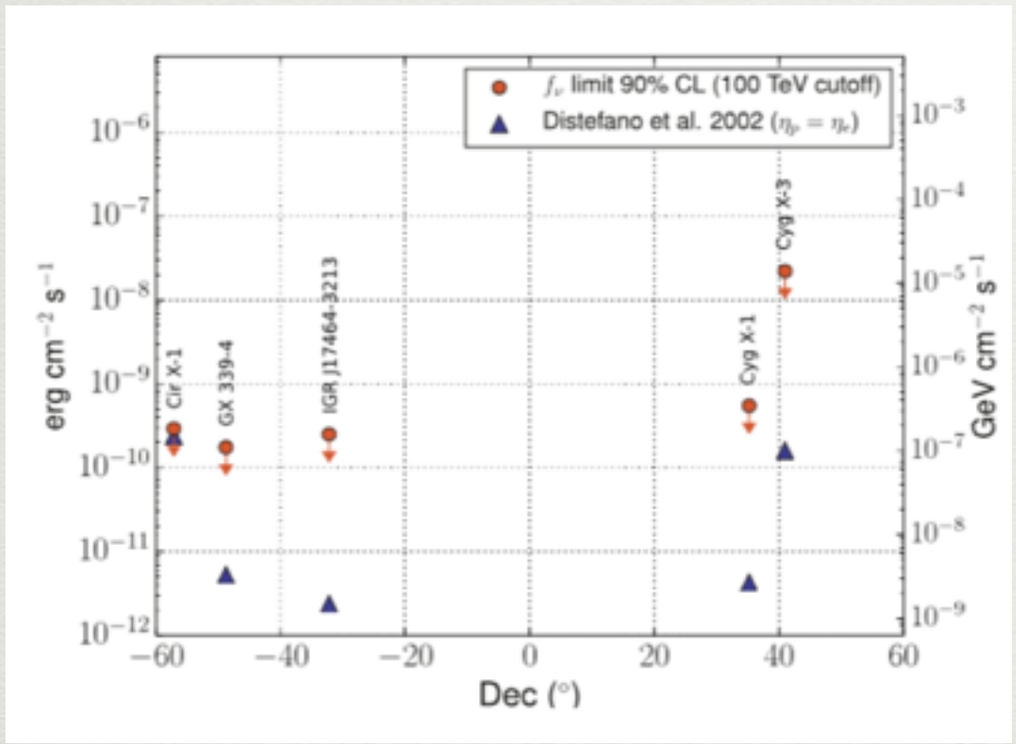


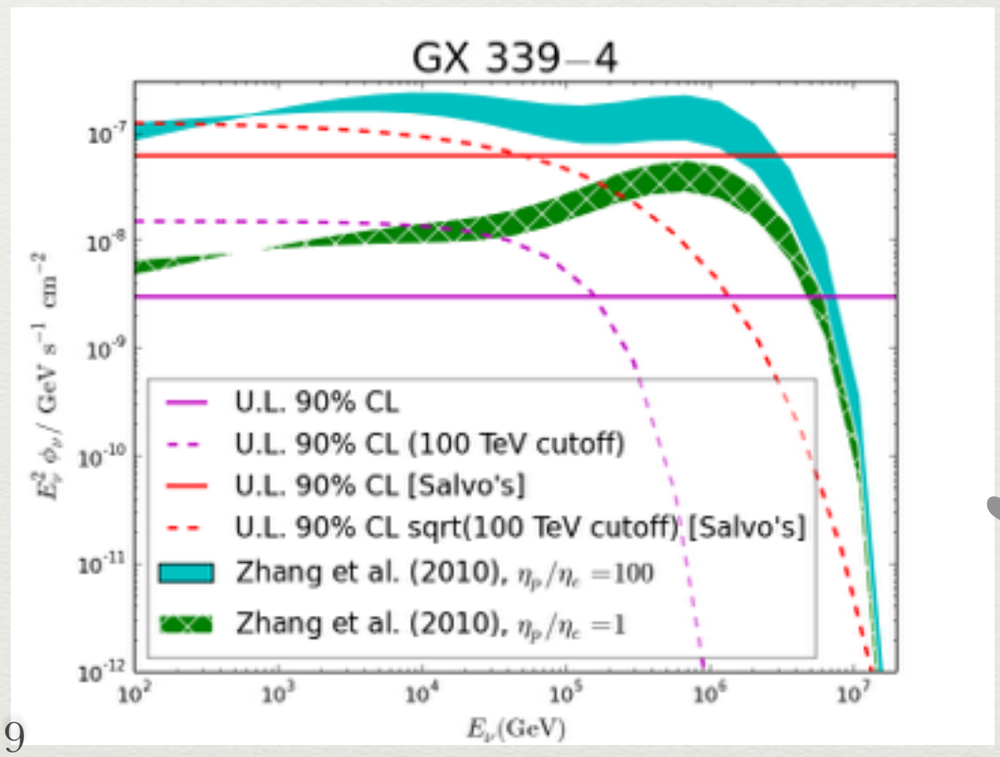


X-Ray Binaries

Comparison computed U.L. with model predictions





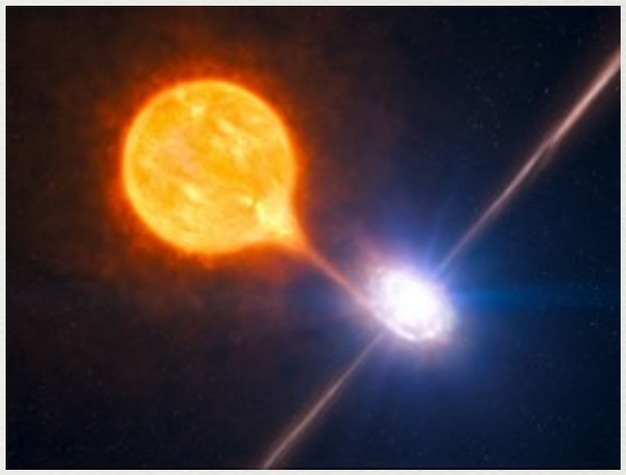


Preliminary

Transient searches

Galactic sources:

- Micro-quasars & X-ray binaries
- Crab
- Sagittarius A*

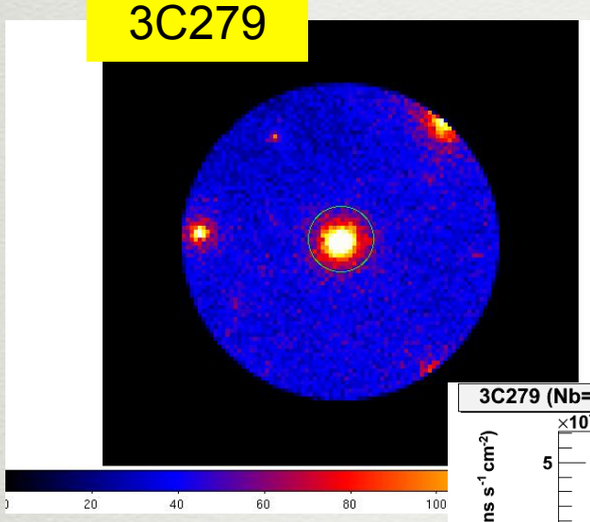


Extragalactic sources:

- Active Galactic Nuclei (Blazars)
- Gamma-Ray Bursts

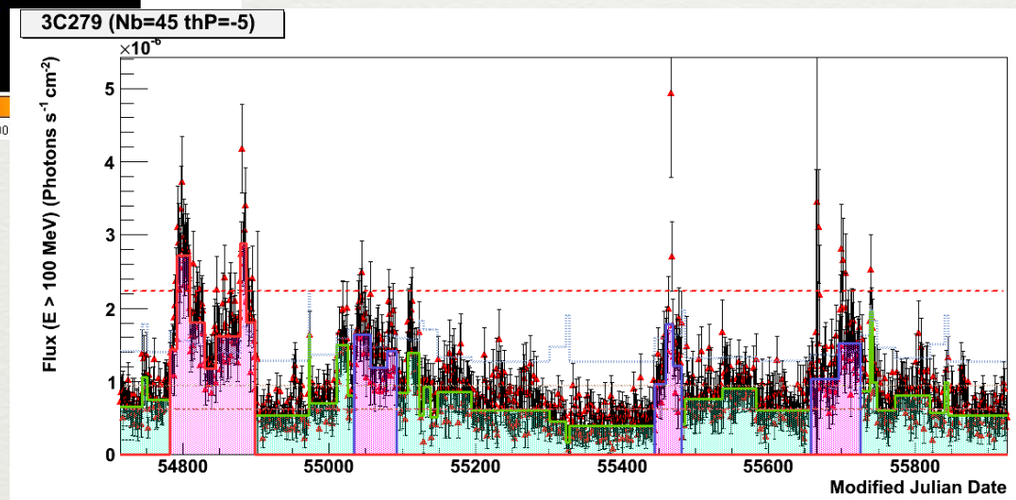
Blazars

3C279

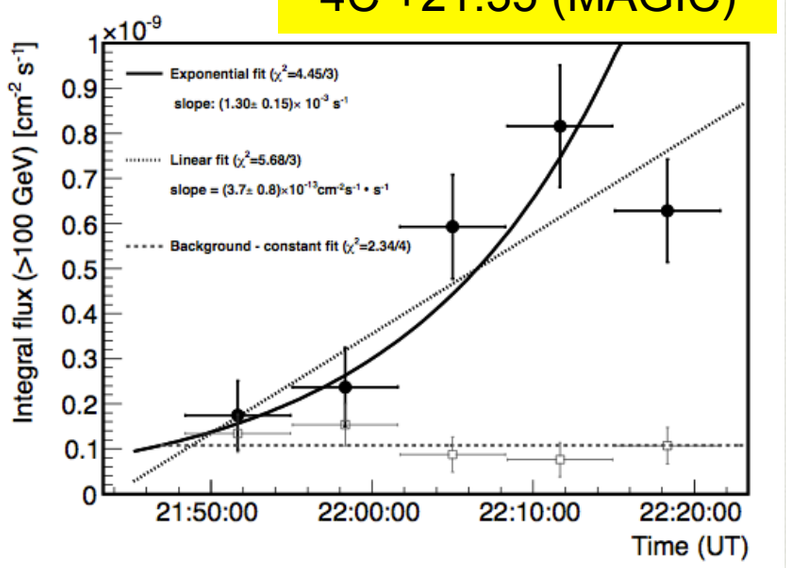


Analysis of Fermi data:

- *Counting map + ligthcurve (2deg)*
- *Denoising LC (Maximum Likelihood Block method)*
- *Selection of significant flares*



4C +21.35 (MAGIC)



First analysis: selection of 10 Fermi flaring blazars in 2008:

=> Astropart. Phys. 36 (2012) 204

Updated analysis: selection of 41 Fermi and 7 TeV sources in 2008-2012:

=> ICRC 2013 - JCAP in preparation

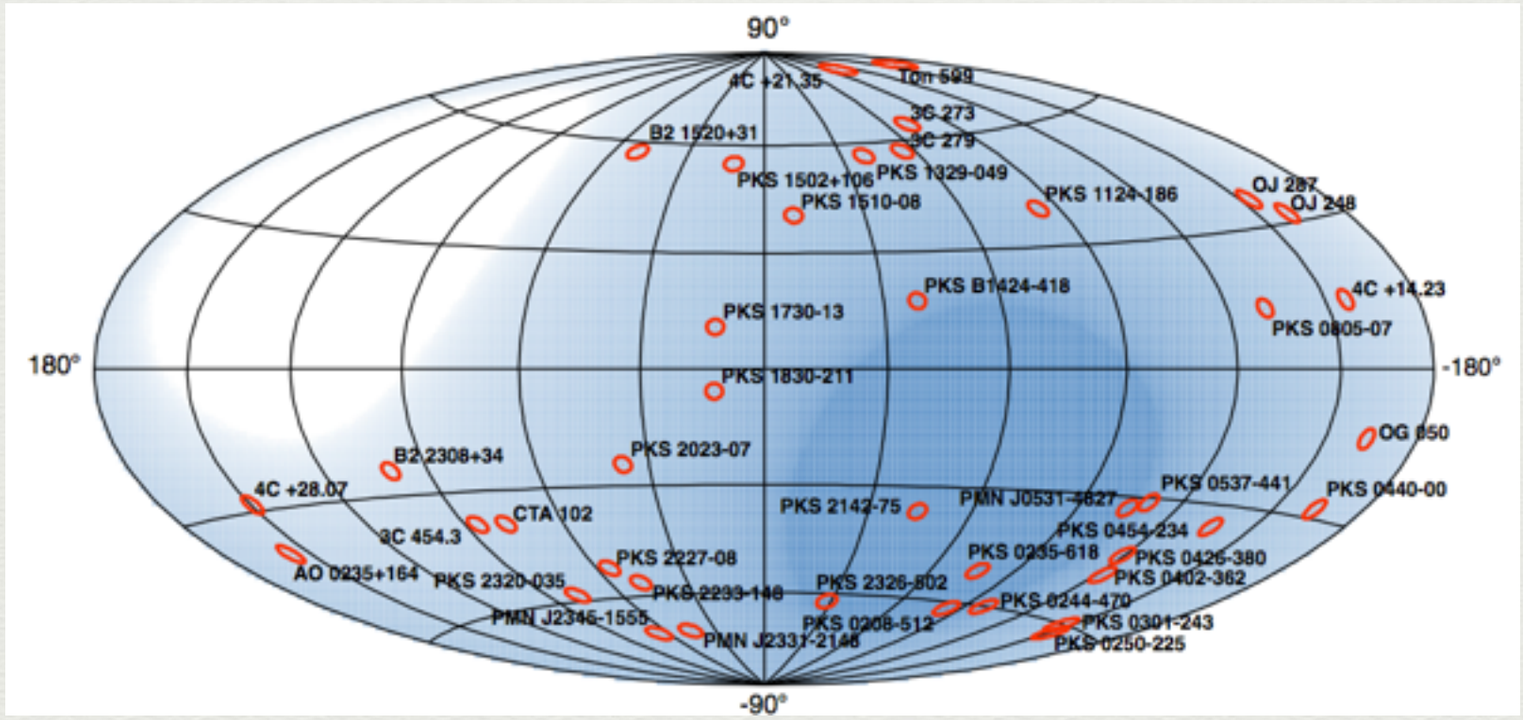
Blazars

Search for time/space correlations neutrino / gamma-flares from Blazars:

ANTARES 2008-2012 data

Blazars seen by FERMI: 41 candidate sources (average 135 flaring days)

Blazars seen by IACT: 7 candidate sources (average 12 flaring days)



Blazars

- From the 41 sources studied only 2 sources with fitted signal events (p-value$\lesssim$10%) in coincidence with gamma-ray flares:

3C 279, PKS 0235-618 and PKS 1124-186

Source	Flaring (days)	Λ_{cut}	n_{sig} 3σ@50%	n_{sig} Fitted	LAG Fitted	TS Fitted	TS Median	Sensitivity@90% (GeV cm^{-2} s^{-1})	**p-value**	post-trial	trial-factor	Spectrum
3C 279	279	-5.3	2.5	0.8	-4	0.13	9.5e-05	2.99e-07	**3.3%**	67%	21	E^{-2}
PKS 0235-618	25	-5.7	1.5	0.6	+5	0.[illegible]	1.1e-04	1.16e-05	**4.5%**	91%	20	$E^{-2}e^{-E/10\,TeV}$
PKS 0235-618	25	-5.7	1.8	0.7	+5	[illegible]50	1.3e-04	8.85e-05	**5.1%**	91%	18	$E^{-2}e^{-E/1\,TeV}$
PKS 1124-186	73	-5.4	3.1	[illegible]	+1	0.41	1.8e-04	2.03e-05	**5.9%**	94%	16	$E^{-2}e^{-E/1\,TeV}$
3C 279	279	-5.4	2.9	0.5	-4	0.14	1.6e-04	1.60e-06	**8.5%**	96%	11	$E^{-2}e^{-E/10\,TeV}$
PKS 1124-186	73	-5.4	2.5	[illegible]2	+4	0.019	1.0e-04	2.29e-06	**9.1%**	99%	11	$E^{-2}e^{-E/10\,TeV}$

- From the 7 sources studied only 1 source with fitted signal events (p-value$\lesssim$10%) in coincidence with gamma-ray flares:

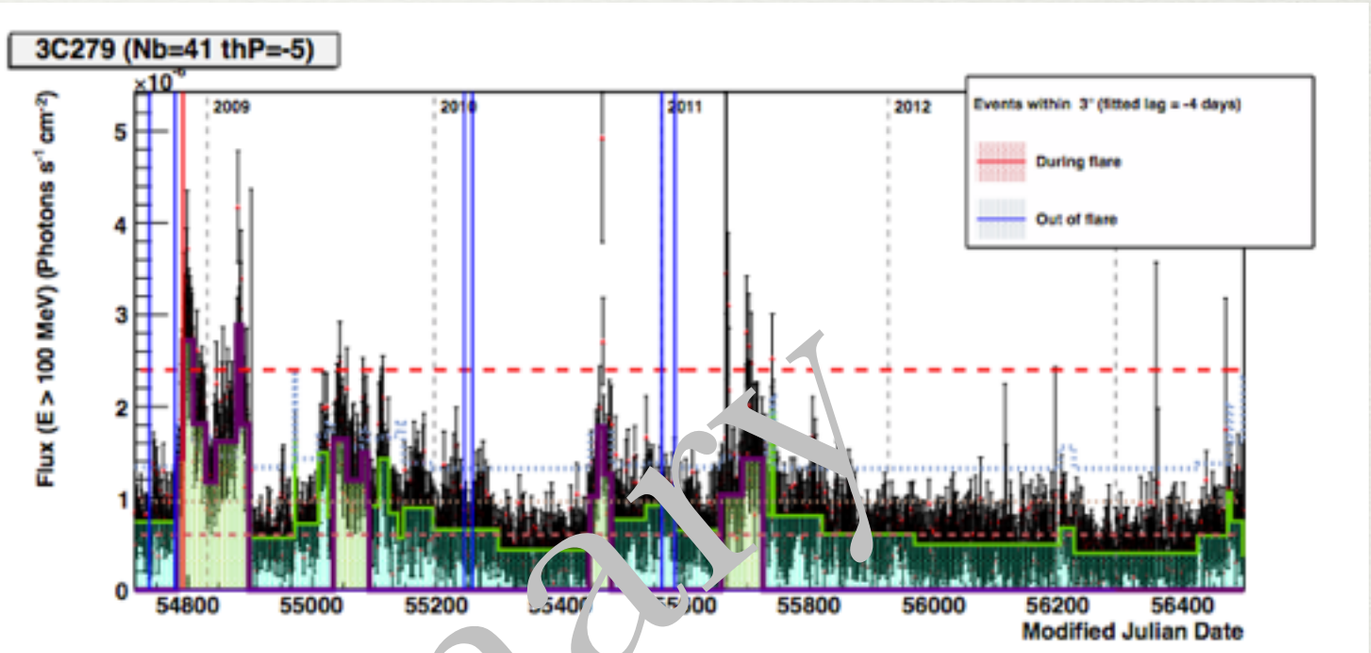
PKS 0447-439

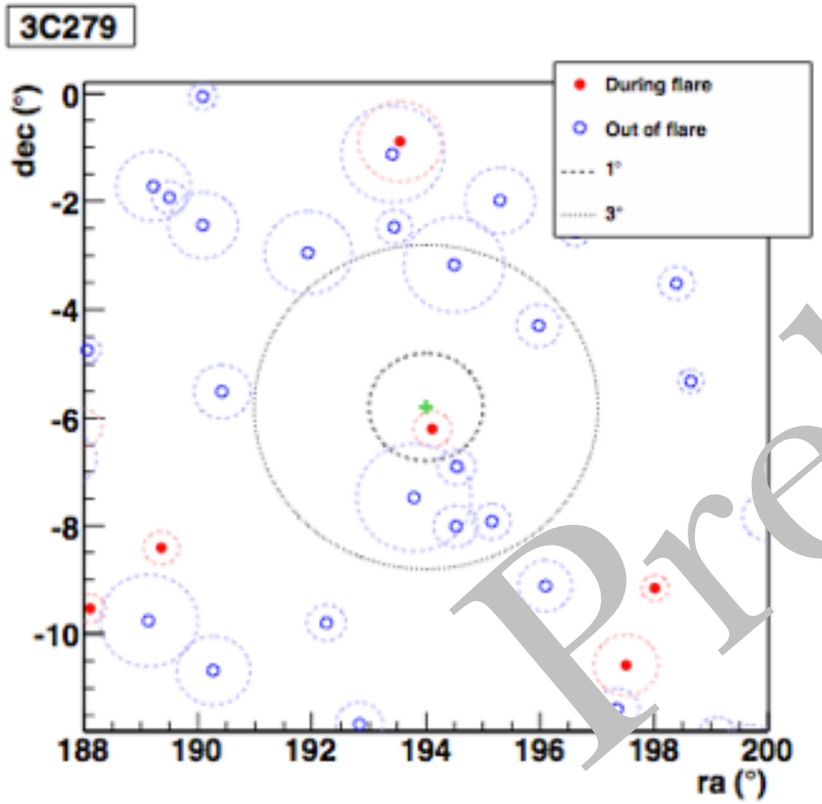
Sou[illegible]	Flaring (days)	Λ_{cut}	n_{sig} 3σ@50%	n_{sig} Fitted	LAG Fitted	TS Fitted	TS Median	Sensitivity@90% (GeV cm^{-2} s^{-1})	**p-value**	post-trial	trial-factor	Spectrum
PKS 0447-439	10	-5.4	1.75	0.10	5	0.0056	8.5e-05	1.10e-04	**10%**	54.8%	5.4	$E^{-2}e^{-E/1\,TeV}$

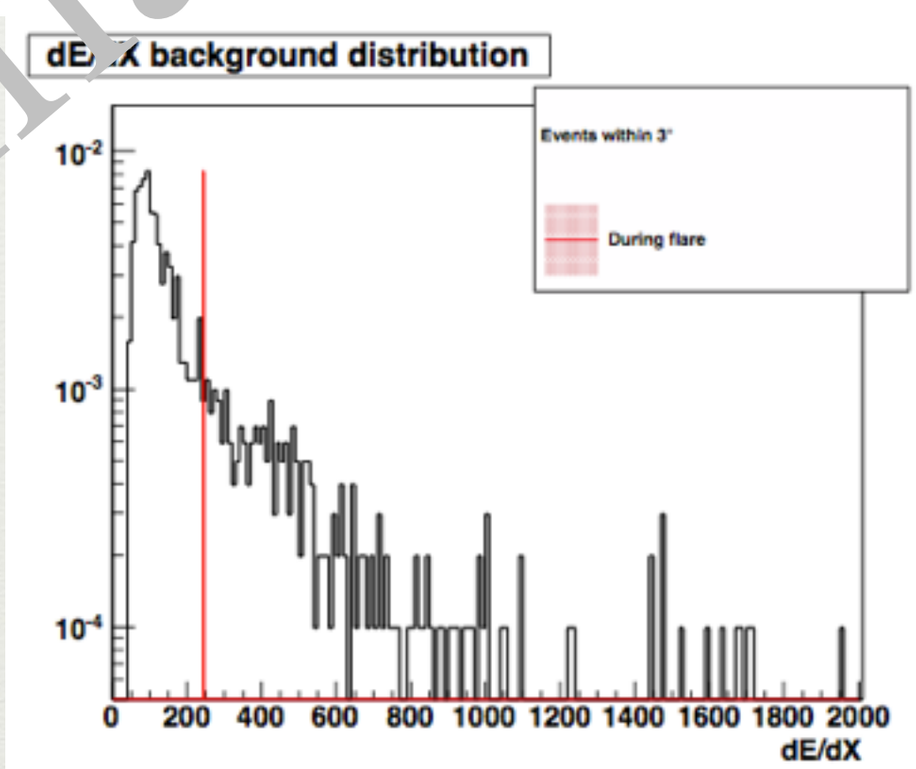
Blazars

3C 279 (279 flaring days)

BEST: 3.3% (67%) E^{-2}



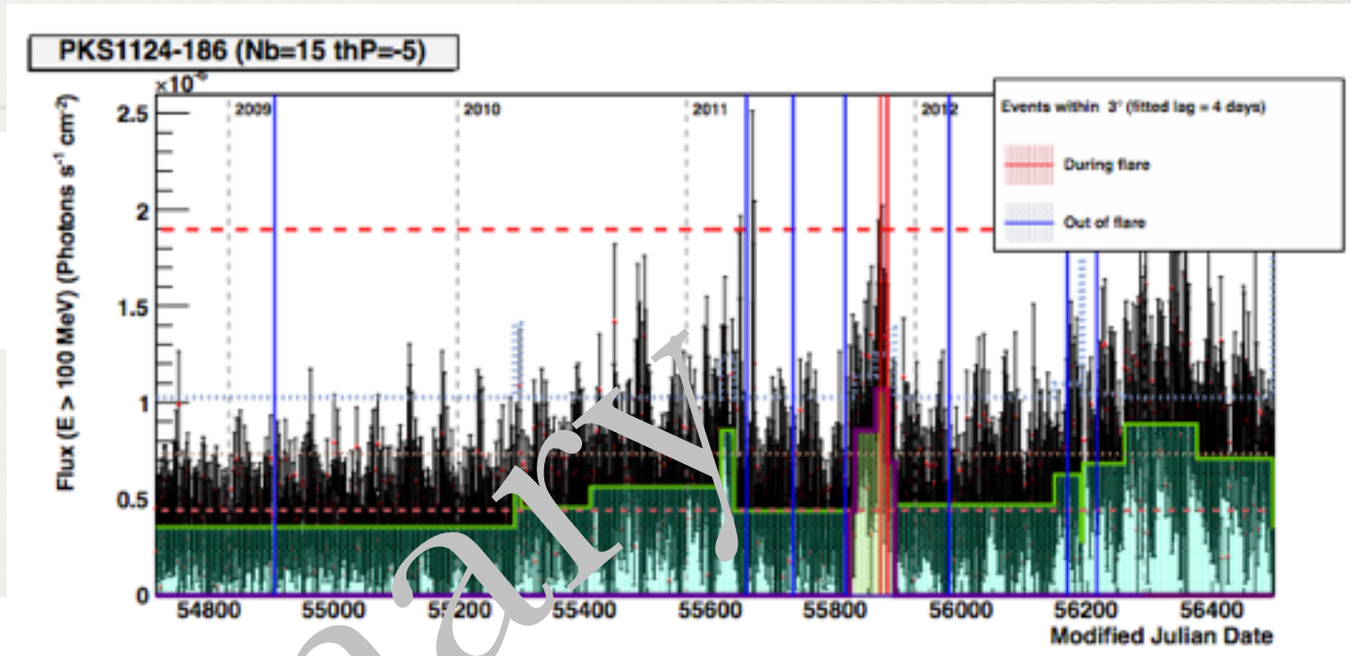


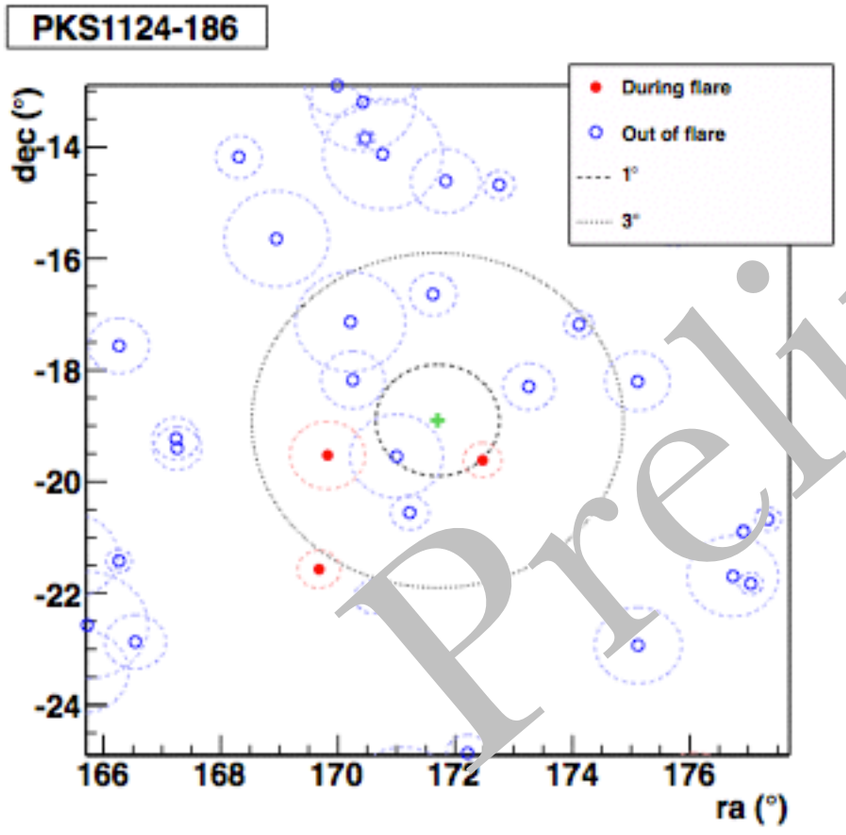


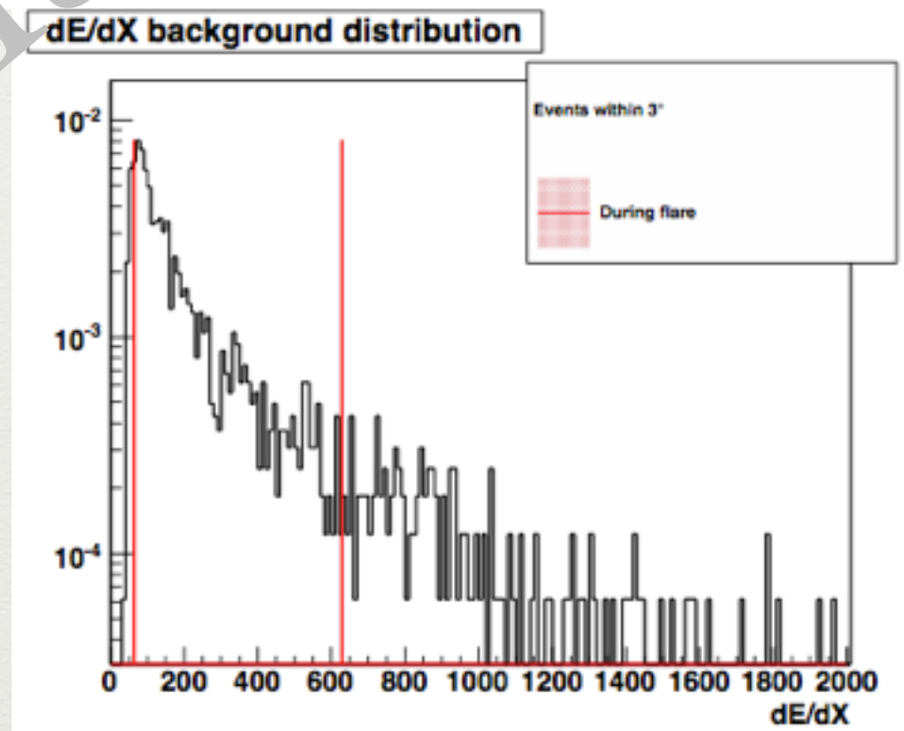
Blazars

PKS 1124-186 (73 flaring days)

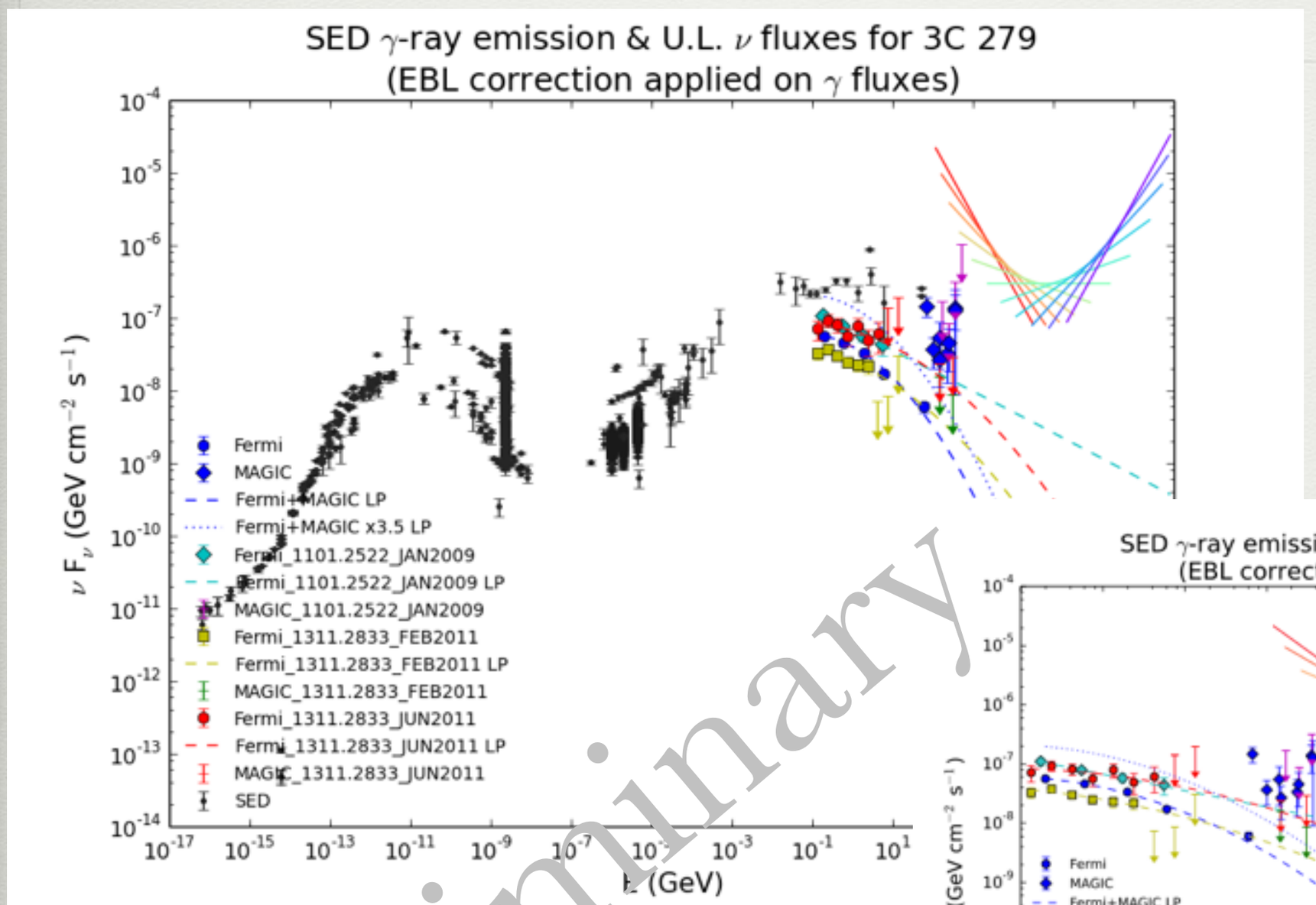
BEST: 5.9% (94%) $E^{-2}e^{-E/1TeV}$

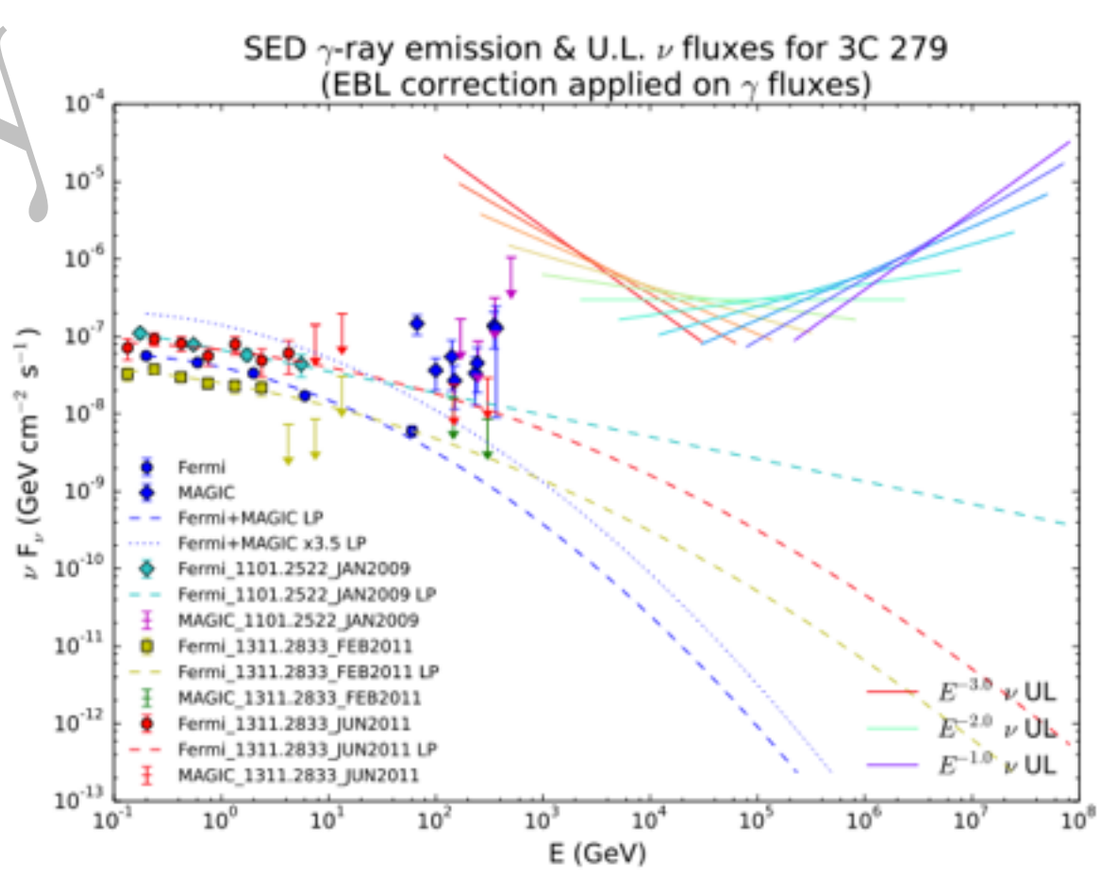




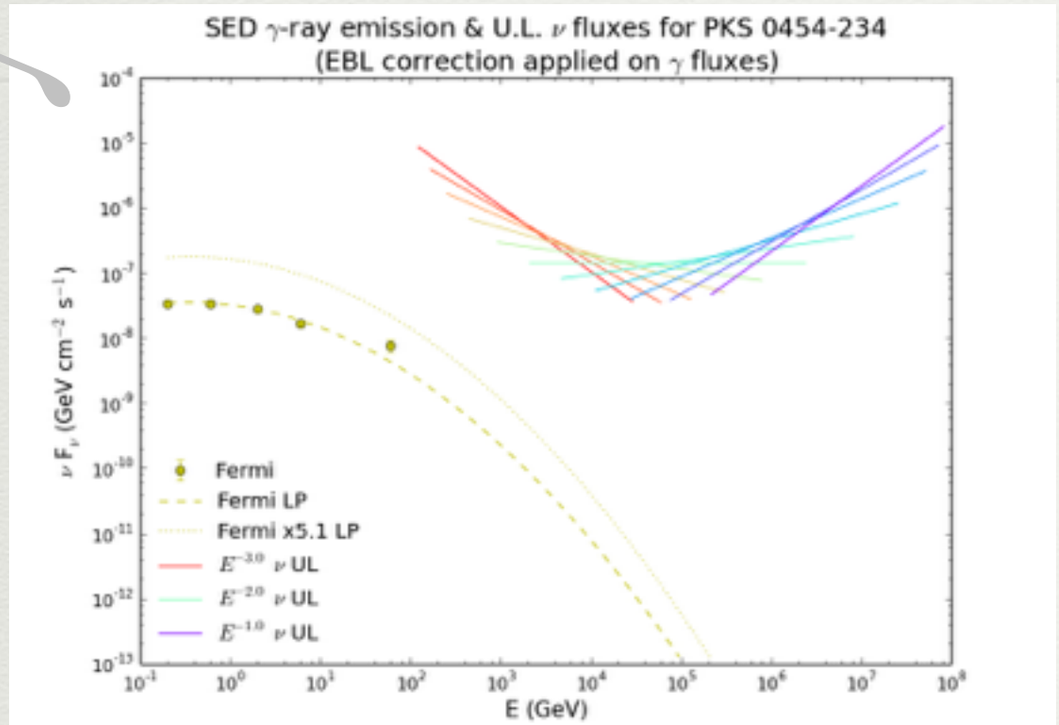


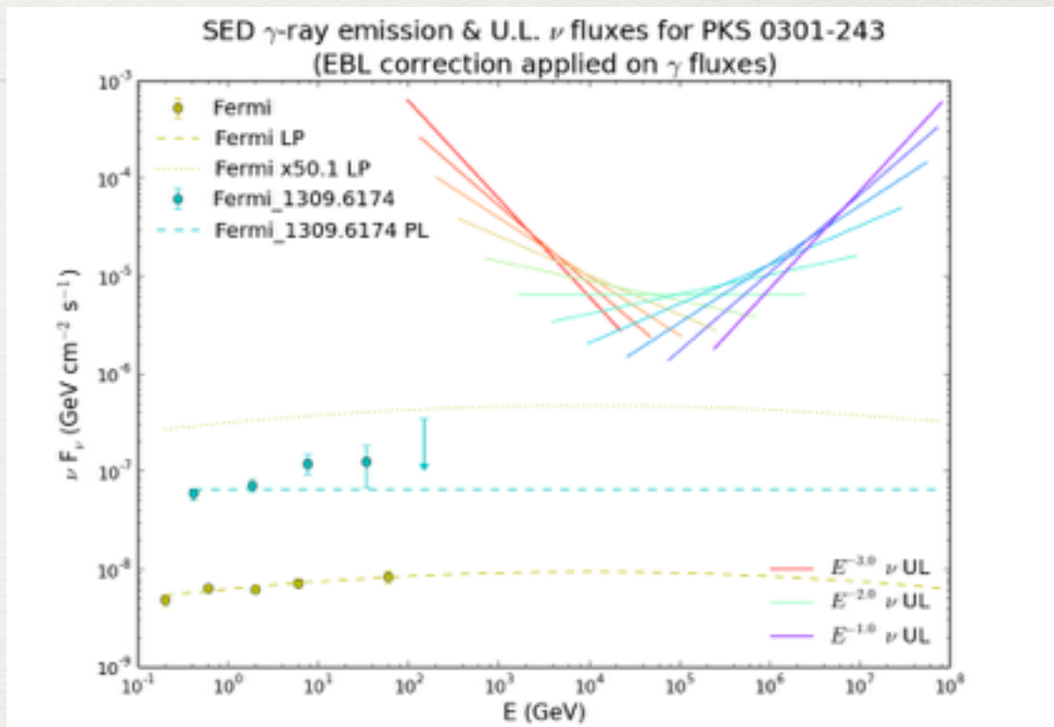
Blazars

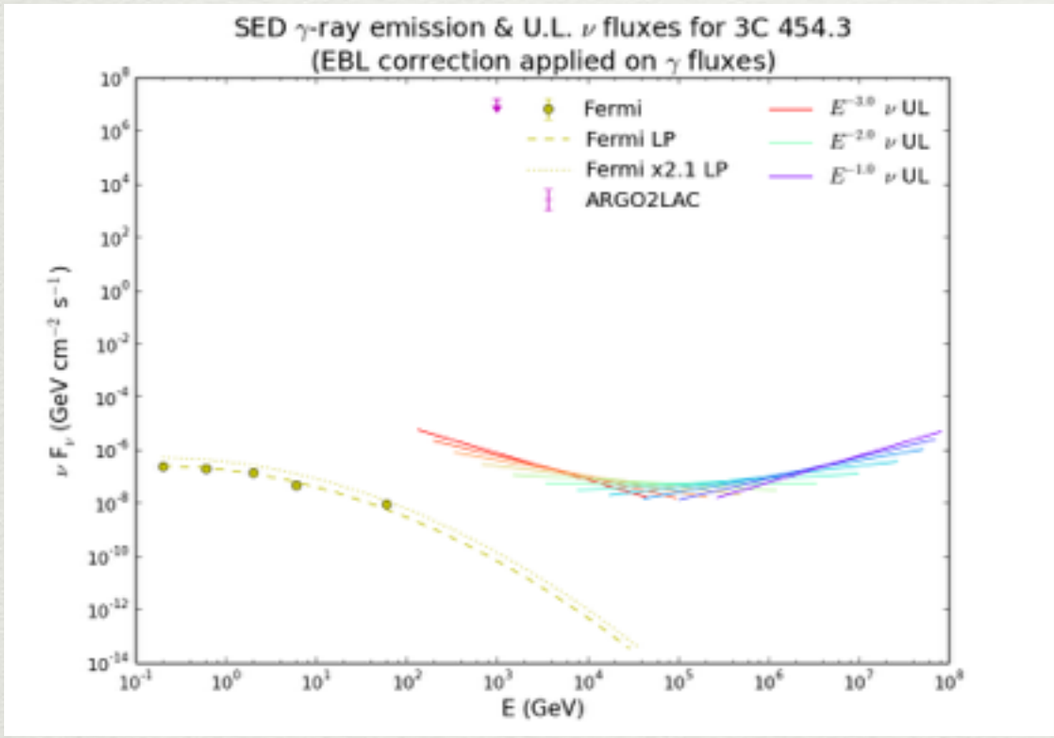


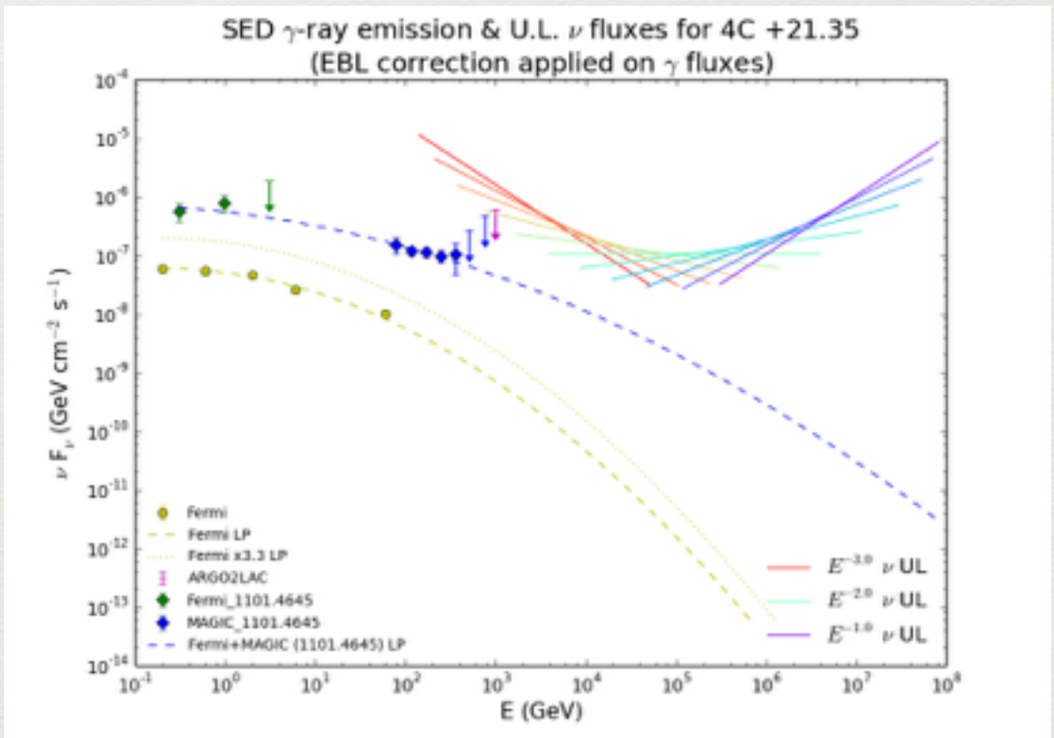


Blazars









Conclusion

ANTARES : Most sensitive neutrino telescope in the TeV-PeV range seeing the southern sky

No cosmic signal yet (but taking data until end 2016)

Transient searches offer the most sensitive method to look for a neutrino source since the backgrounds are significantly suppressed by the time correlation cuts.

Galactic X-ray binaries: search for 34 sources
=> no statistically significant excess

Extragal. Blazars: search for 41 Fermi sources and 7 TeV sources
=> no statistically significant excess