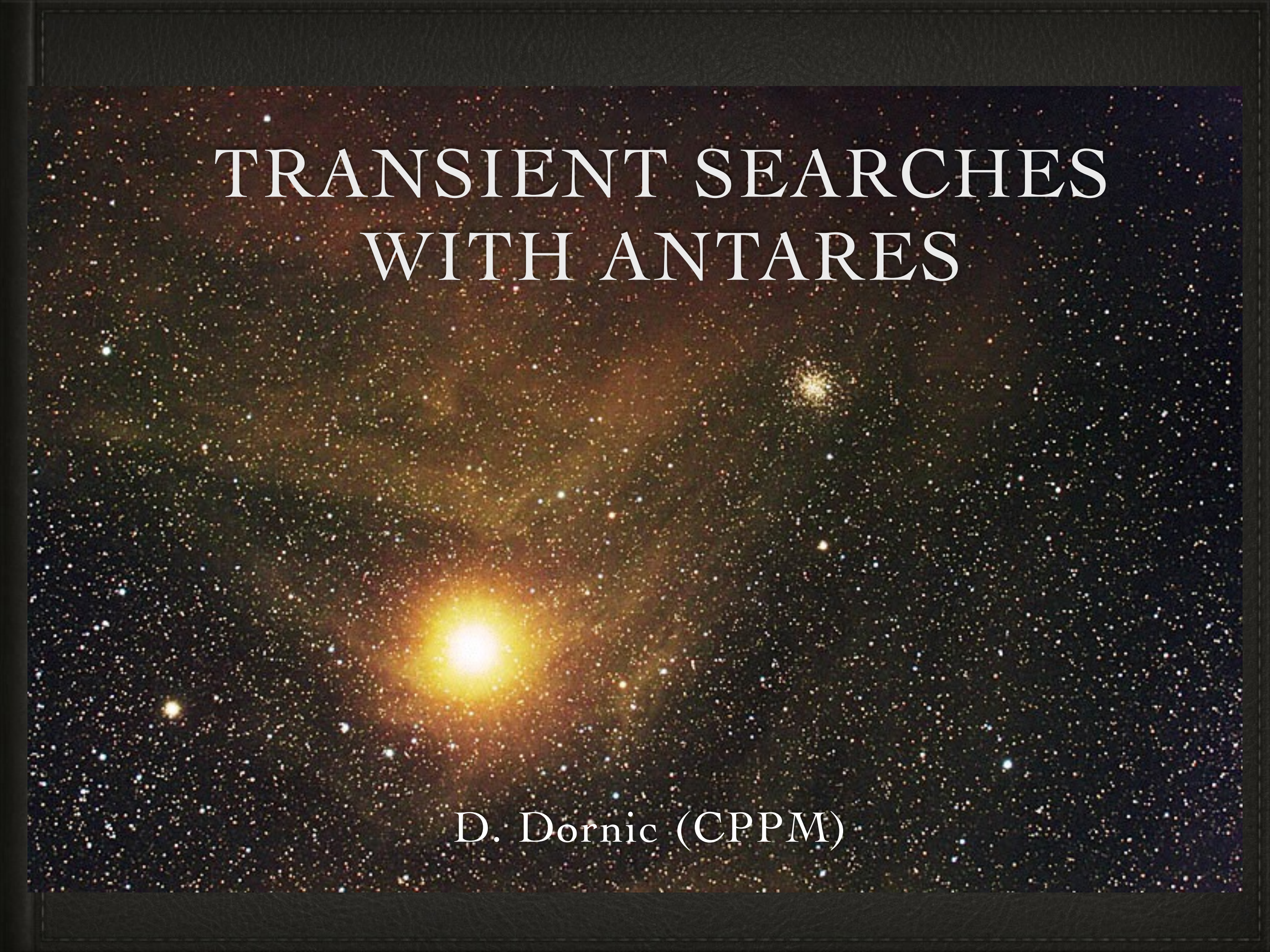
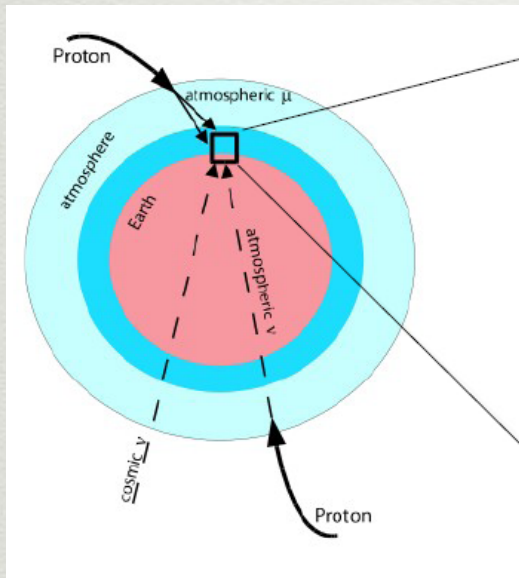


The background of the slide is a deep-field astronomical image showing a vast field of stars and distant galaxies. A prominent, bright yellow star is located in the lower-left quadrant, surrounded by a soft, glowing halo. In the upper-right quadrant, there is a faint, irregularly shaped galaxy or nebula. The rest of the image is filled with countless smaller stars of varying brightness and colors, set against a dark, almost black cosmic background.

# TRANSIENT SEARCHES WITH ANTARES

D. Dornic (CPPM)

# Introduction



**ANTARES:** 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

2 types of point-source analysis:

All sky search: signif. cluster => **8-10  $\nu$  per source @  $5\sigma$  discov**

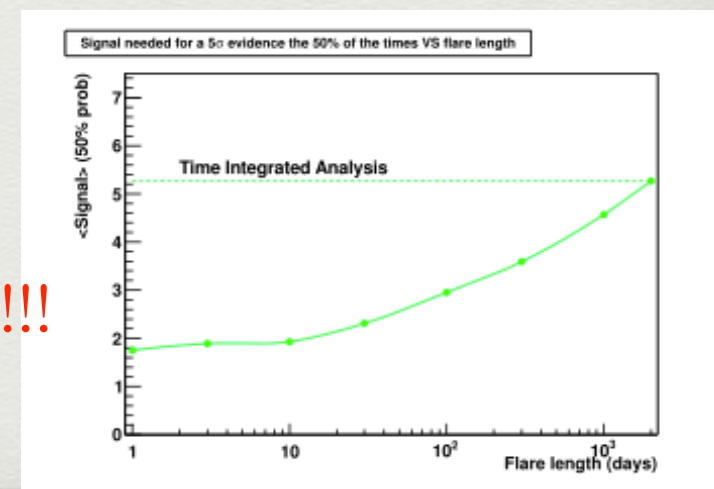
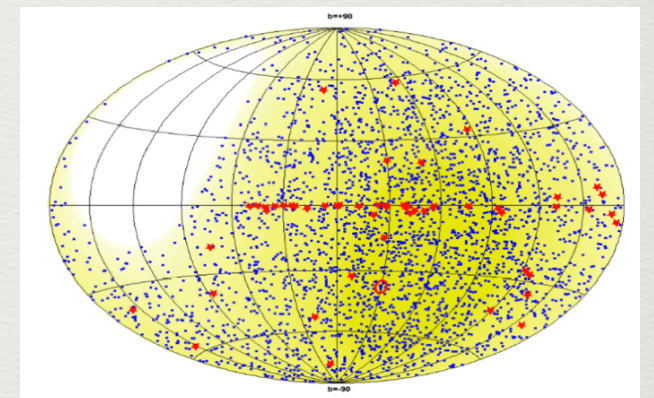
Candidate list: 50 promising sources => **5-6  $\nu$  per source @  $5\sigma$**

**Adding the time information:**

=> **2-3  $\nu$  per source @  $5\sigma$  discov**

=> Increase sensitivity by a factor 2-3

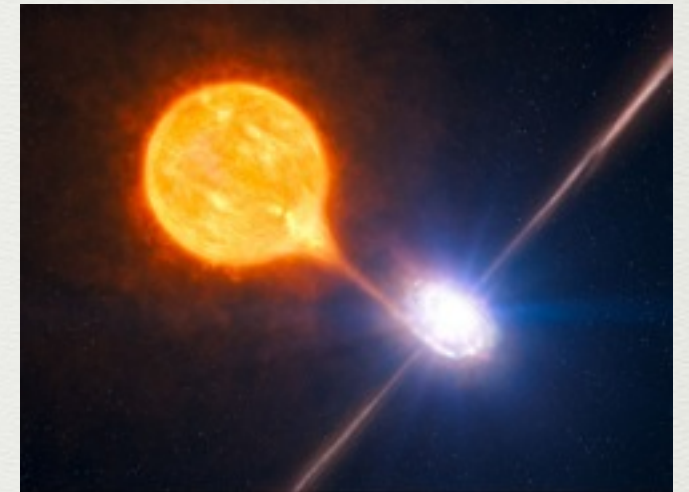
**For a very short transient (GRB), only 1  $\nu$  per source is sufficient !!!**



# Transient searches

## Galactic sources:

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



## Extragalactic sources:

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



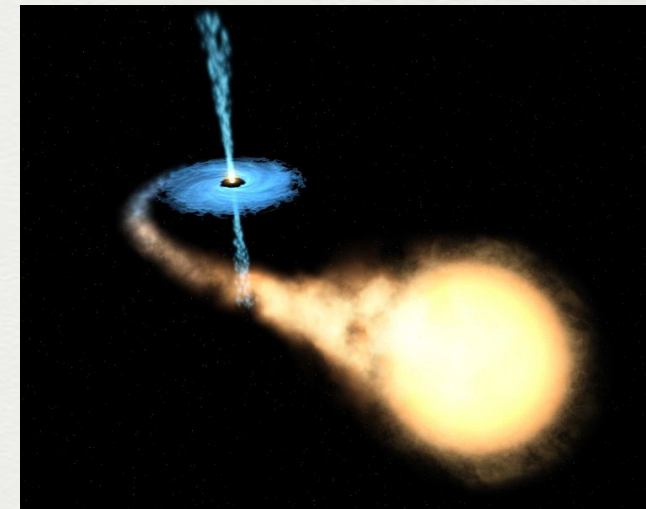
Main hypothesis: gamma-rays and neutrinos are emitted in coincidence (or short delay)

# 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

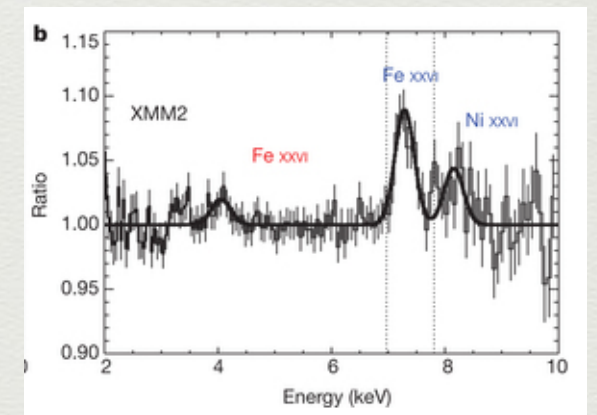
Very few cases with confirmed presence of jets  
(detected with radio)



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



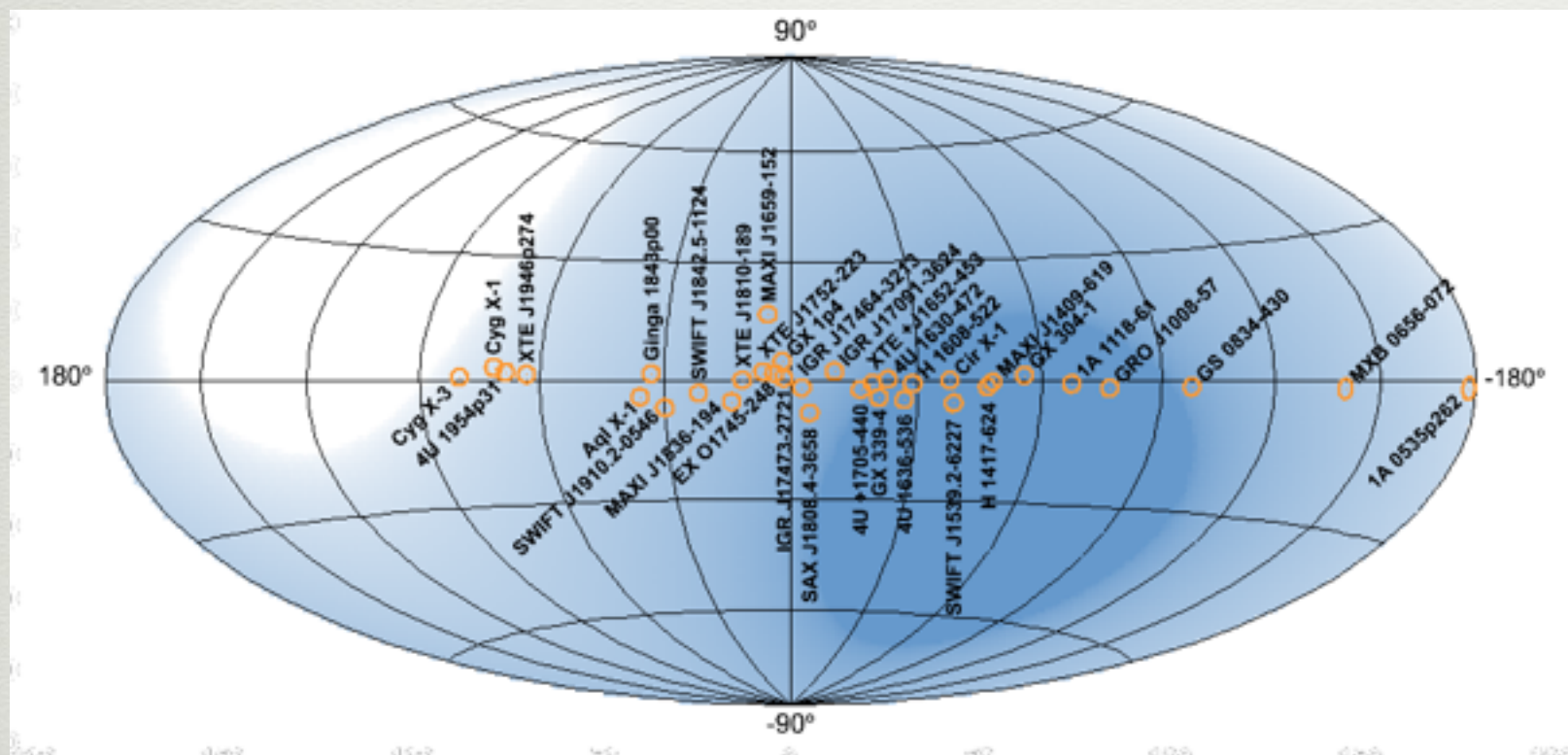
The non-thermal emission of the system is surely dominated by leptonic processes but a hadronic component could also be present. (not necessary to have jets)

# 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**

=> Compatible with background fluctuations

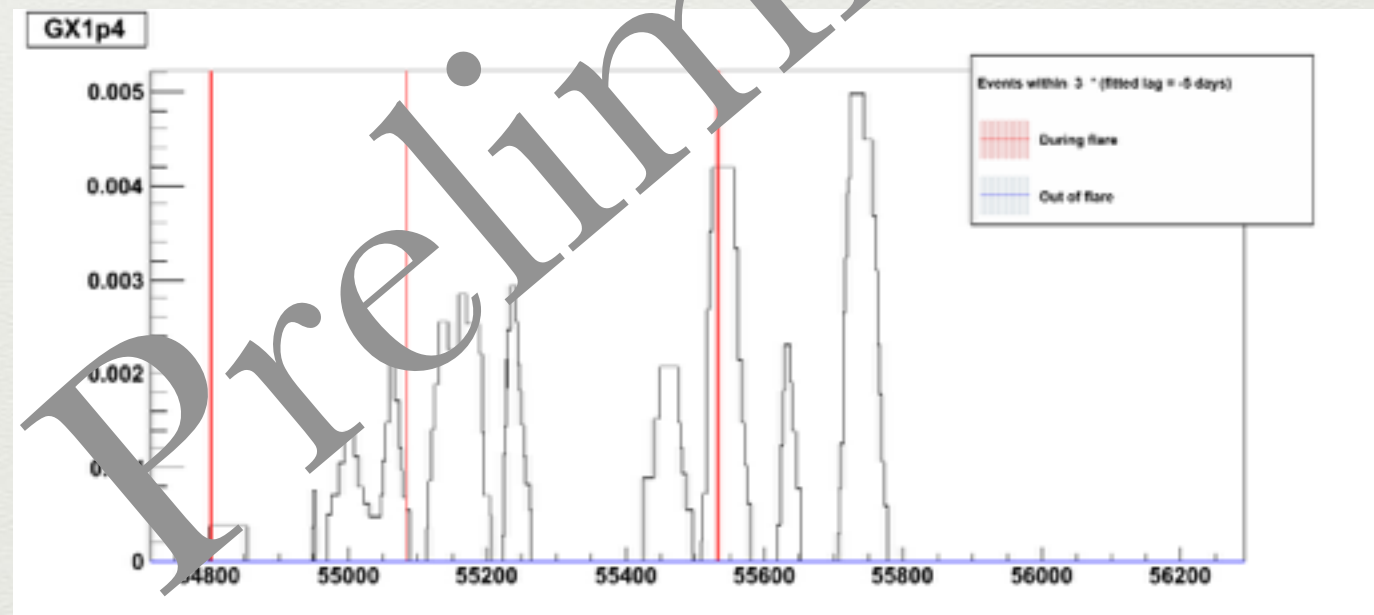
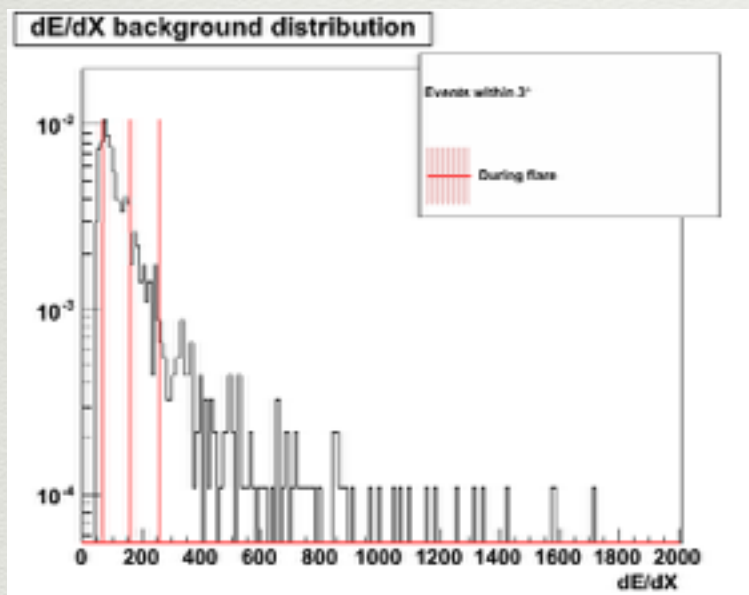
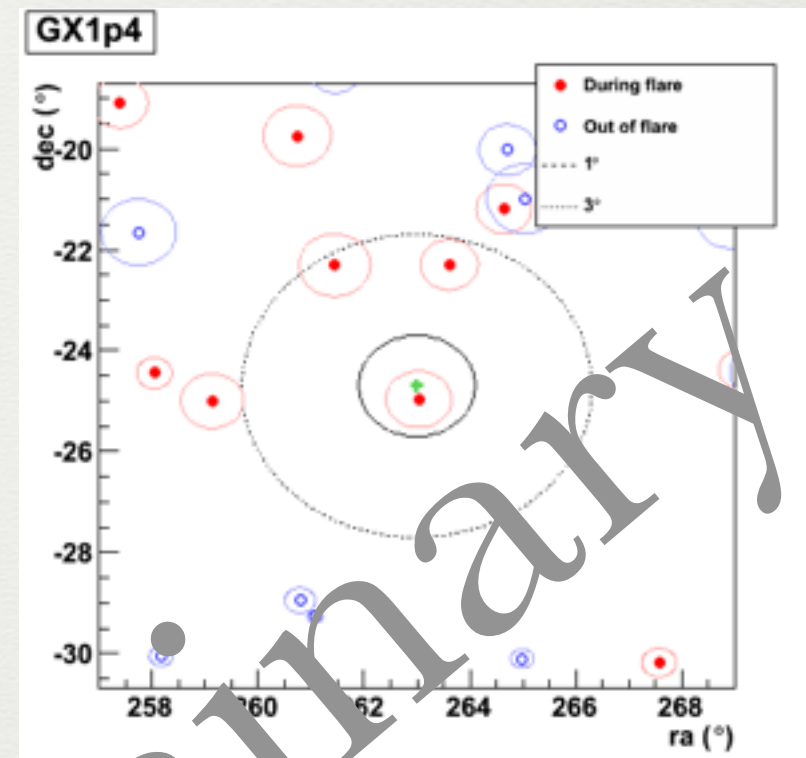
# X-Ray Binaries

GX 1p4

[DEC:-24.7|RA:263]

Flaring 557 days

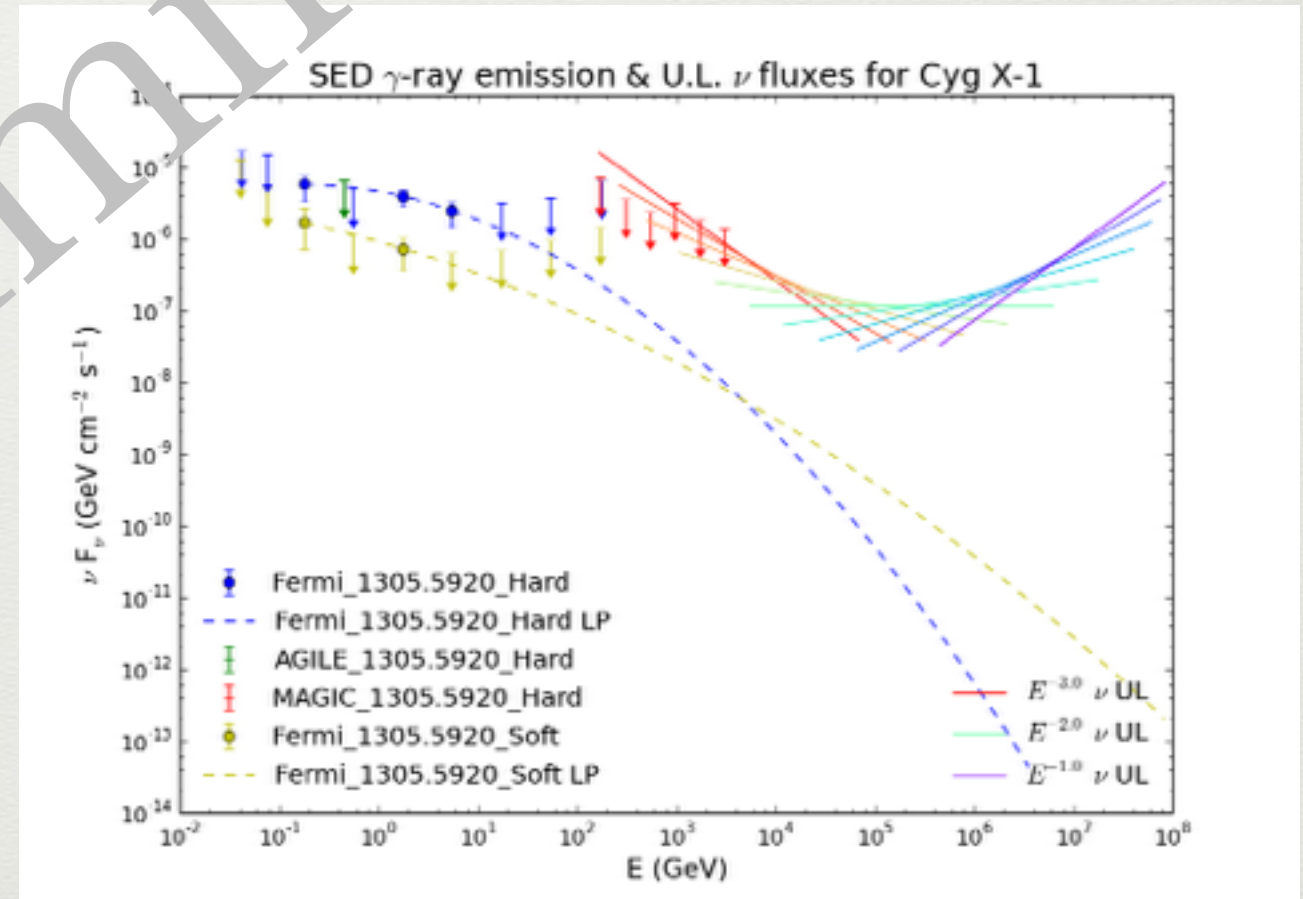
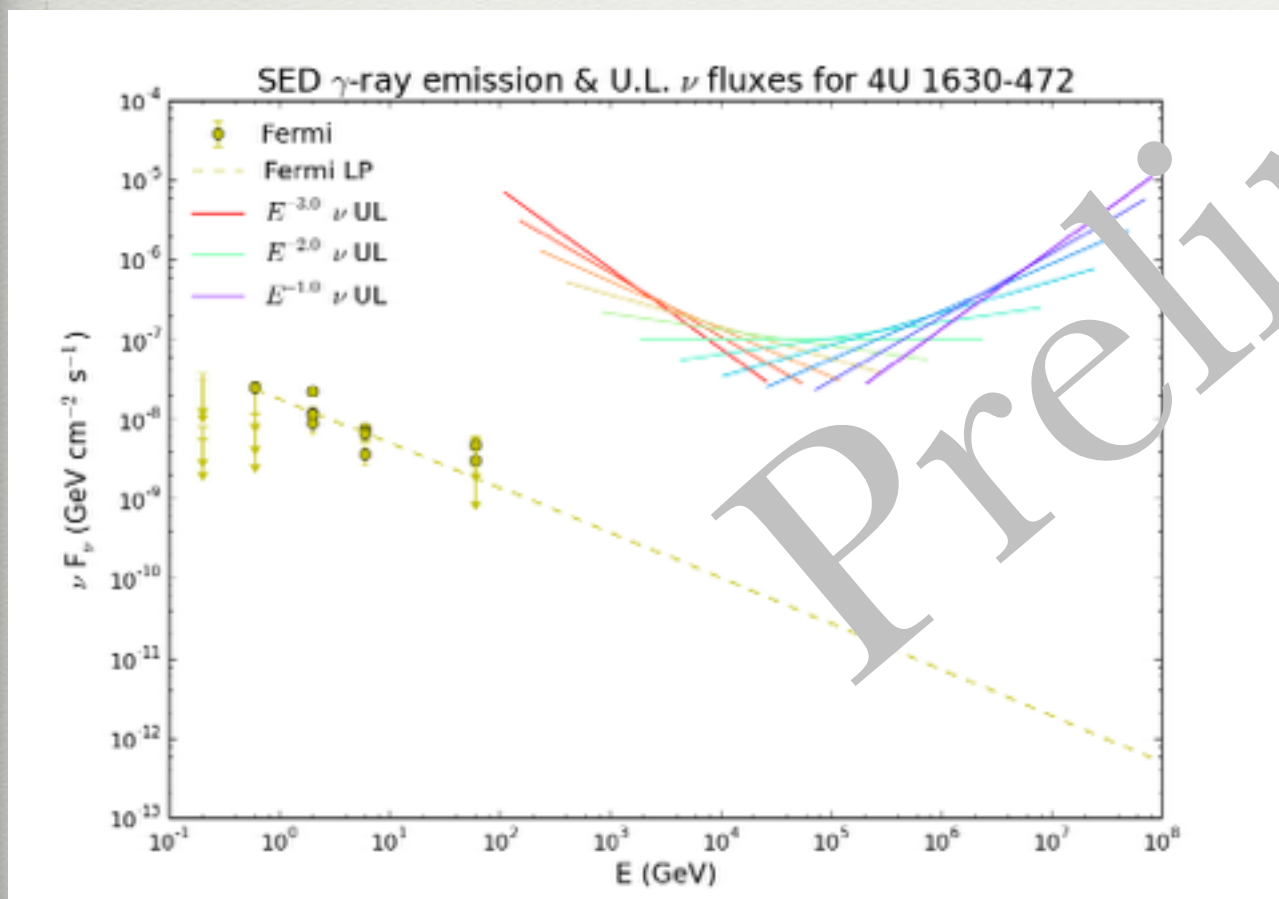
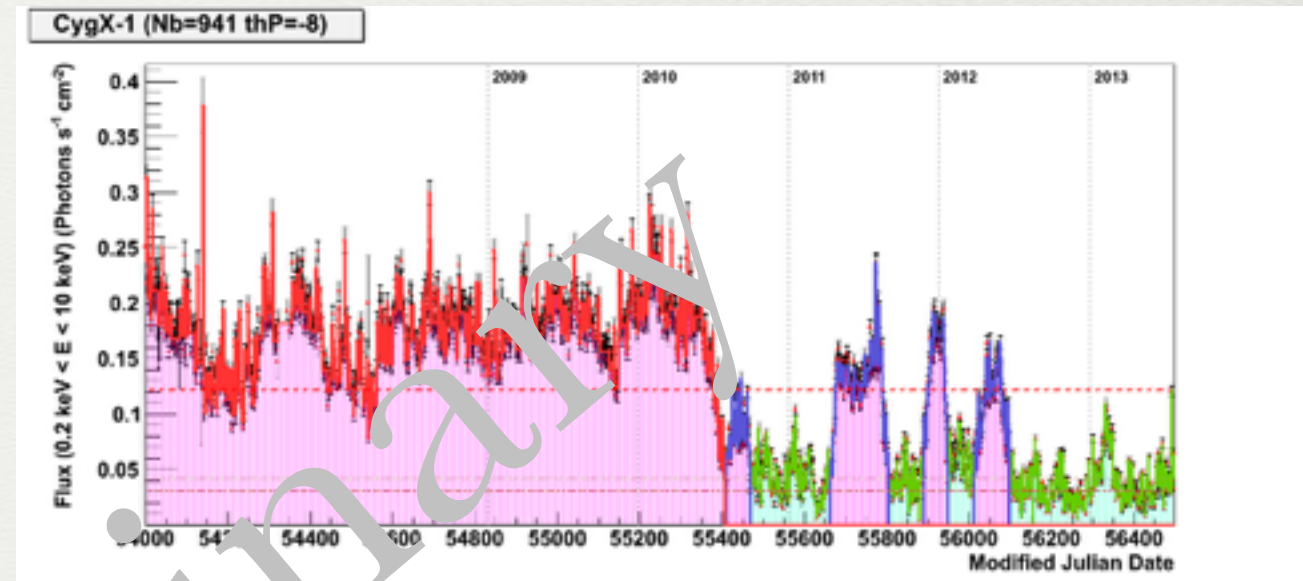
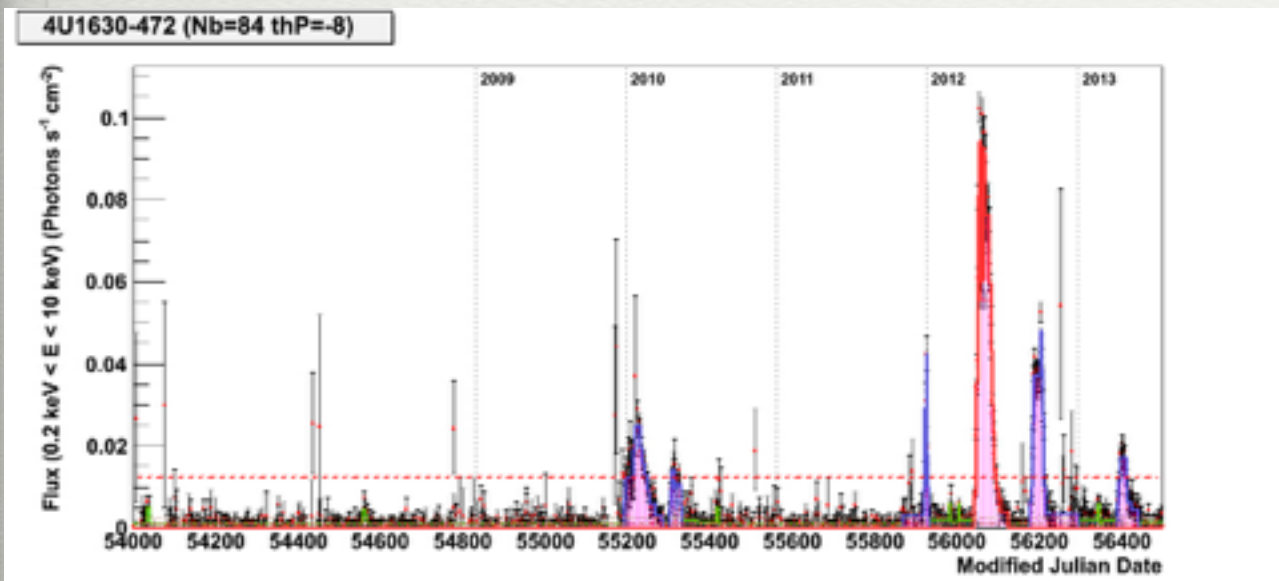
p-value: 4.13% (post-trial: 72%)  
 $n_{\text{sig}}$ : 0.69 (TS: 0.457)  
 lag: -5 days  
 Spectrum: "cutoff100TeV\_costhetasup-0.15"  
 Lambda cut: -5.2



# X-Ray Binaries

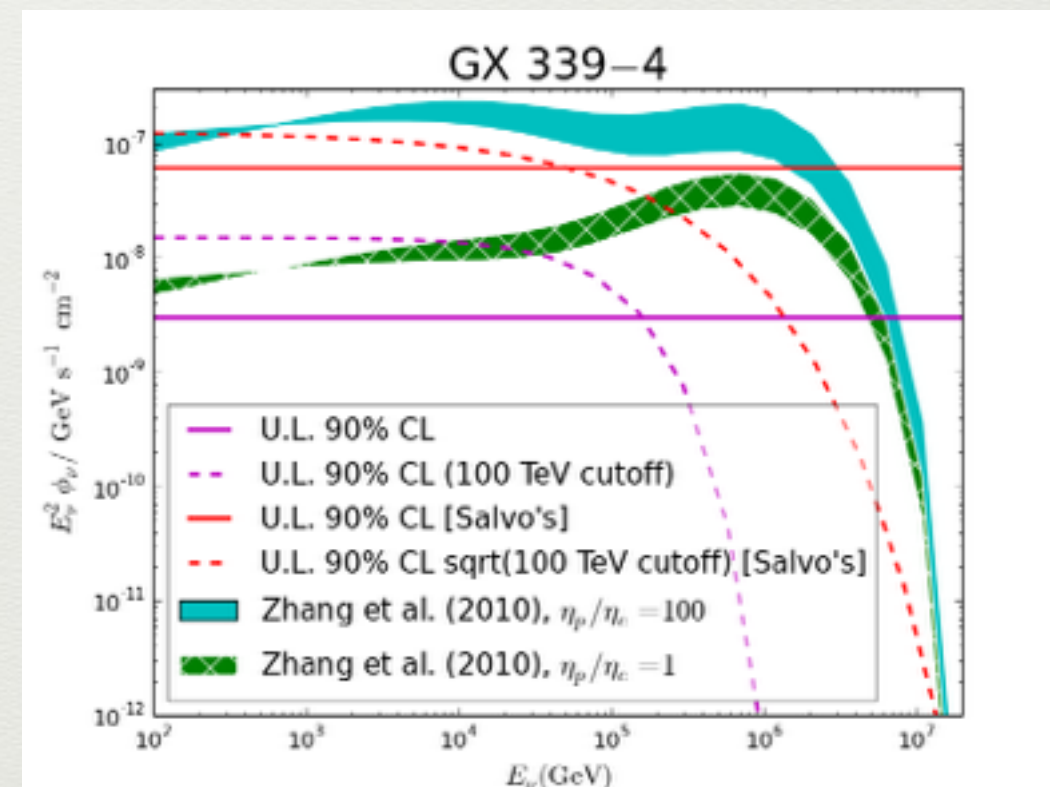
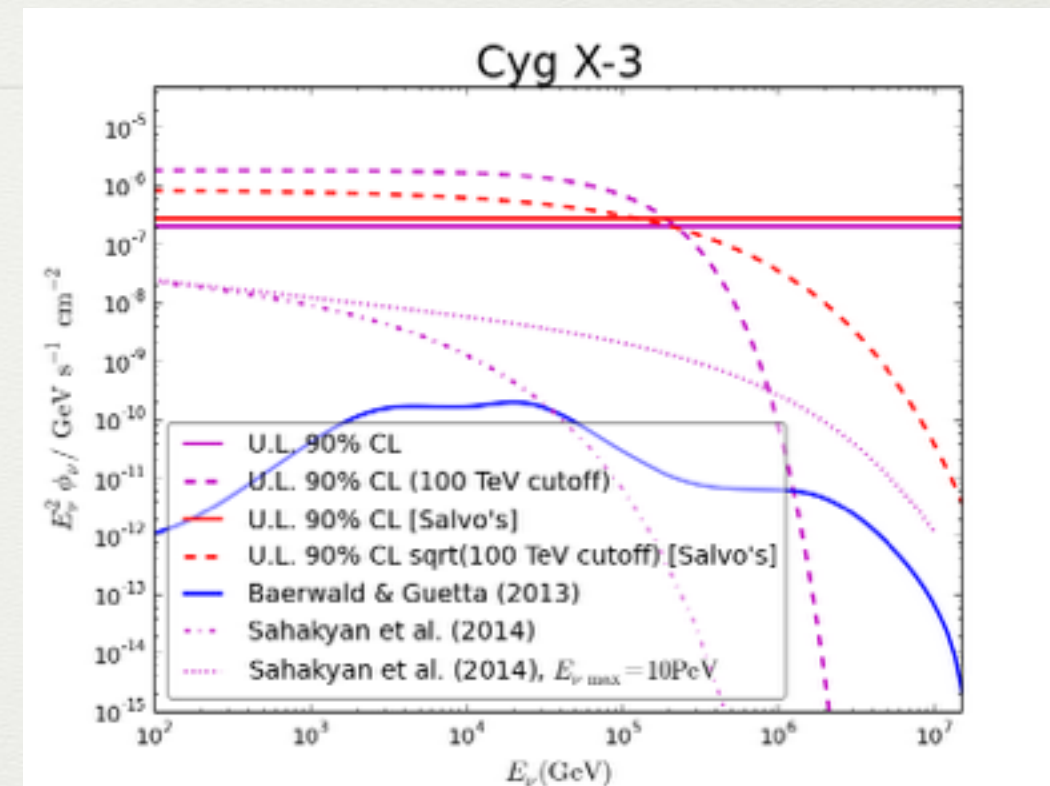
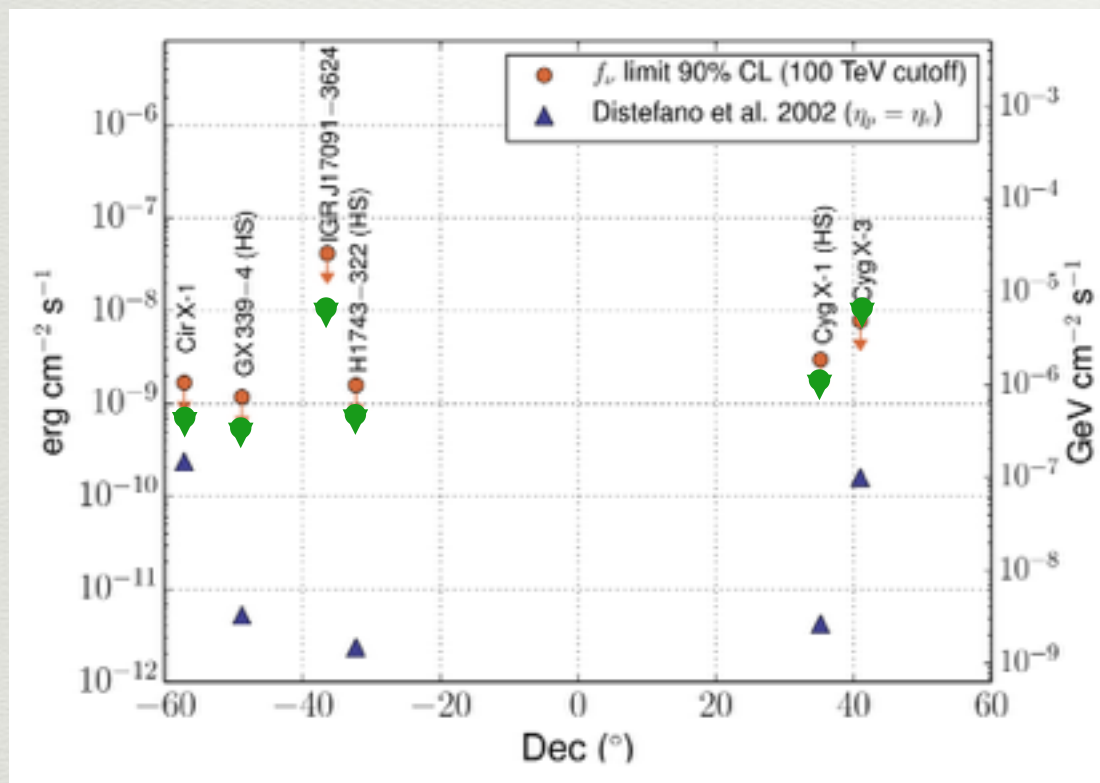
4U 1630-472

Cygnus X-1



# X-Ray Binaries

Comparison computed  
U.L. with model  
predictions

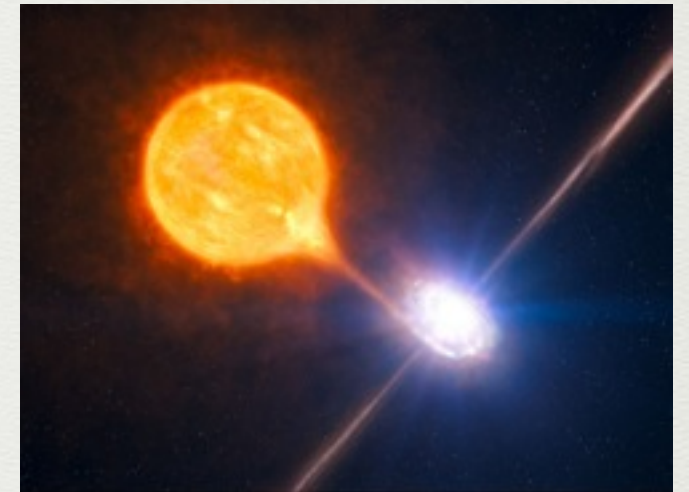


Preliminary

# Transient searches

## Galactic sources:

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



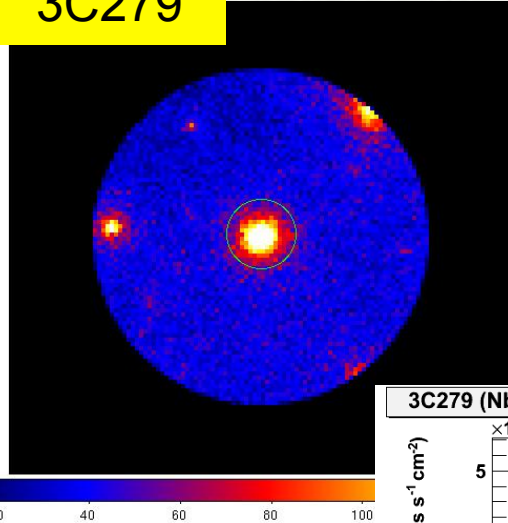
## Extragalactic sources:

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



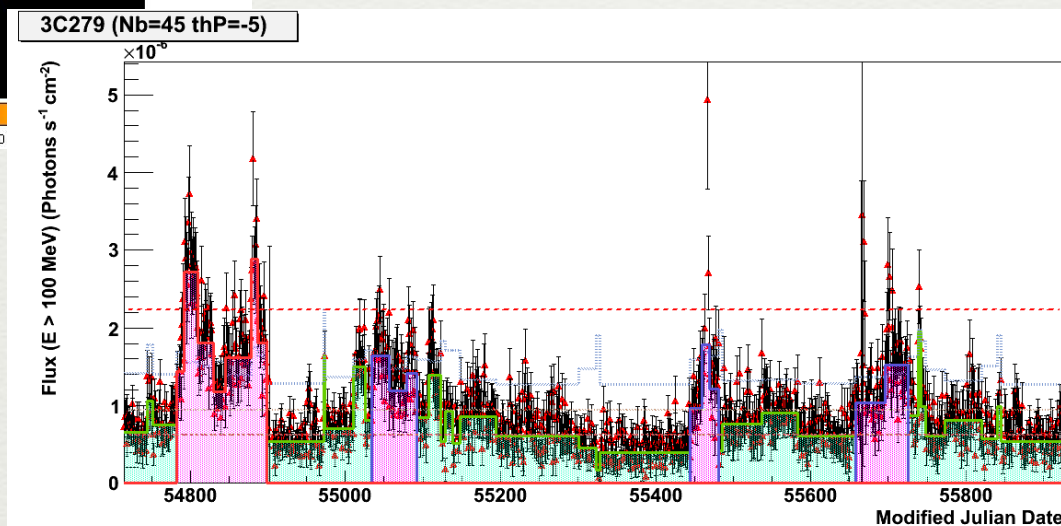
# Blazars

3C279

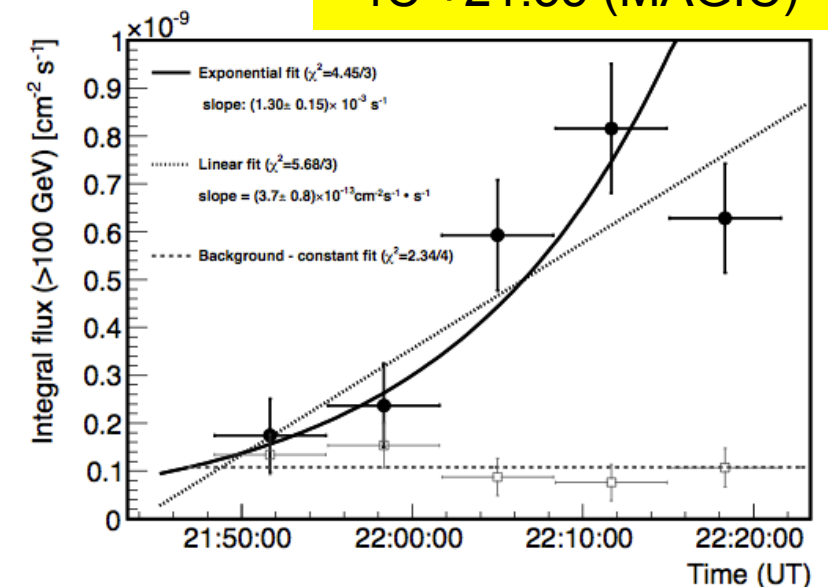


## Analysis of Fermi data:

- Counting map + lighthouse (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

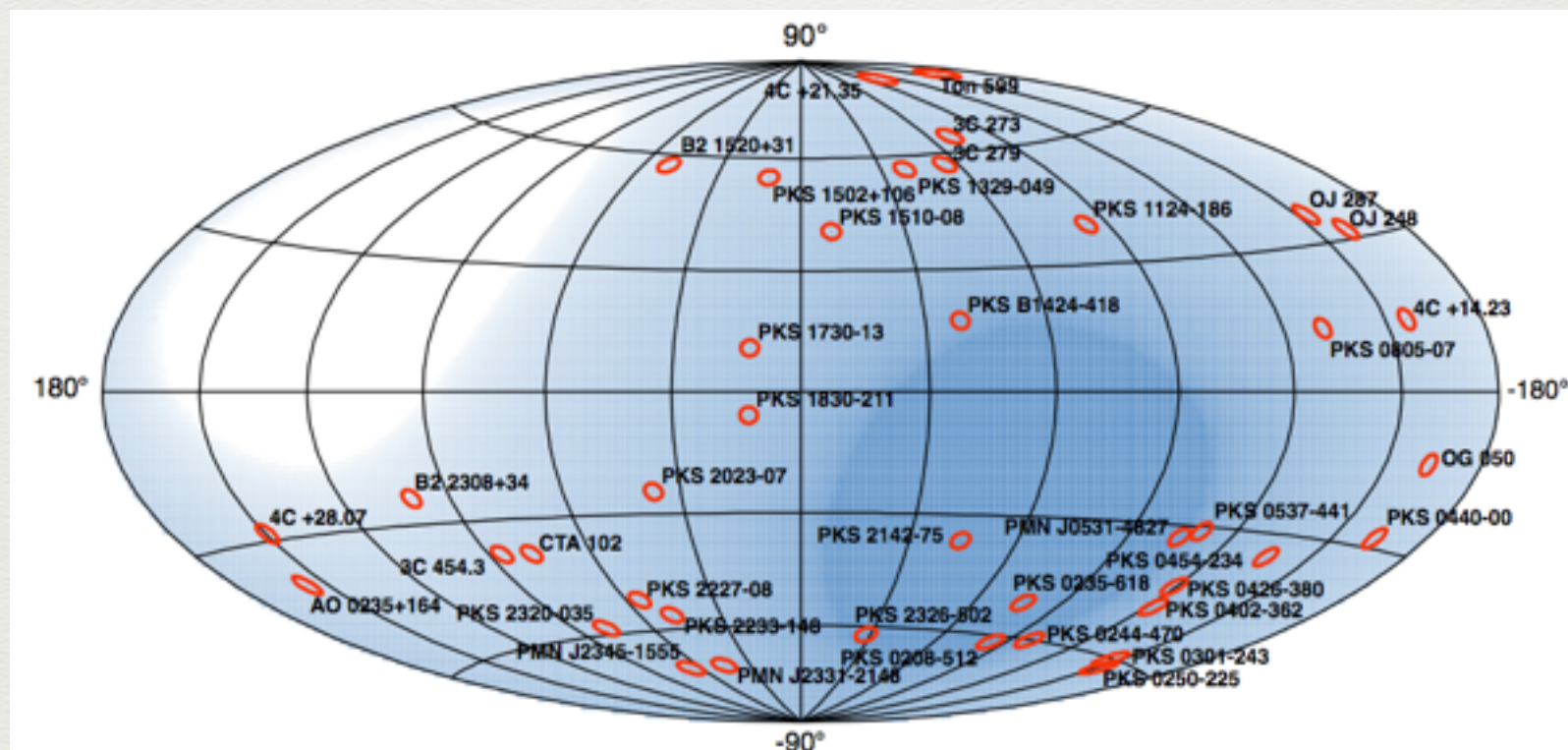
# Blazars

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 ( $p\text{-value} \lesssim 10\%$ ) in coincidence with gamma-ray flares:

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

| Source       | Flaring (days) | $\Lambda_{\text{cut}}$ | $n_{\text{sig}} 3\sigma@50\%$ | $n_{\text{sig}}$ Fitted | LAG Fitted | TS Fitted | TS Median | Sensitivity@90% (GeV cm <sup>-2</sup> s <sup>-1</sup> ) | p-value | post-trial | trial-factor | Spectrum                    |
|--------------|----------------|------------------------|-------------------------------|-------------------------|------------|-----------|-----------|---------------------------------------------------------|---------|------------|--------------|-----------------------------|
| 3C 279       | 279            | -5.3                   | 2.5                           | 0.8                     | -4         | 0.03      | 9.5e-05   | 2.99e-07                                                | 3.3%    | 67%        | 21           | $E^{-2}$                    |
| PKS 0235-618 | 25             | -5.7                   | 1.5                           | 0.6                     | +5         | 0.5       | 1.1e-04   | 1.16e-05                                                | 4.5%    | 91%        | 20           | $E^{-2}e^{-E/10\text{TeV}}$ |
| PKS 0235-618 | 25             | -5.7                   | 1.8                           | 0.7                     | +5         | 0.50      | 1.3e-04   | 8.85e-05                                                | 5.1%    | 91%        | 18           | $E^{-2}e^{-E/1\text{TeV}}$  |
| PKS 1124-186 | 73             | -5.4                   | 3.1                           | 0.5                     | +4         | 0.41      | 1.8e-04   | 2.03e-05                                                | 5.9%    | 94%        | 16           | $E^{-2}e^{-E/1\text{TeV}}$  |
| 3C 279       | 279            | -5.4                   | 2.9                           | 0.5                     | -4         | 0.14      | 1.6e-04   | 1.60e-06                                                | 8.5%    | 96%        | 11           | $E^{-2}e^{-E/10\text{TeV}}$ |
| PKS 1124-186 | 73             | -5.4                   | 2.5                           | 2                       | +4         | 0.019     | 1.0e-04   | 2.29e-06                                                | 9.1%    | 99%        | 11           | $E^{-2}e^{-E/10\text{TeV}}$ |

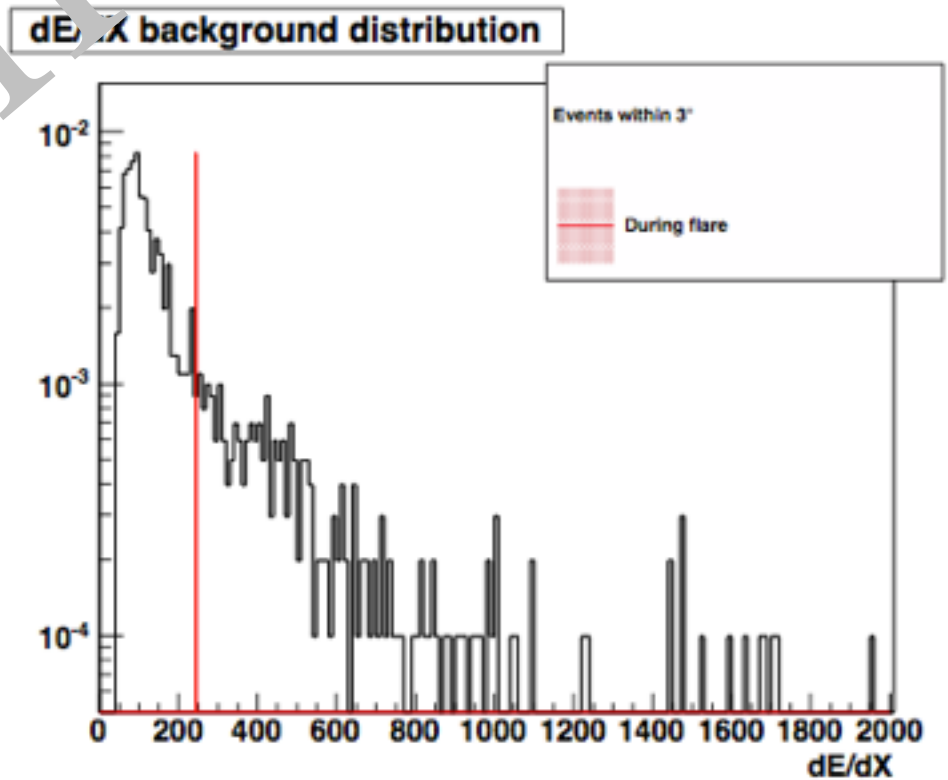
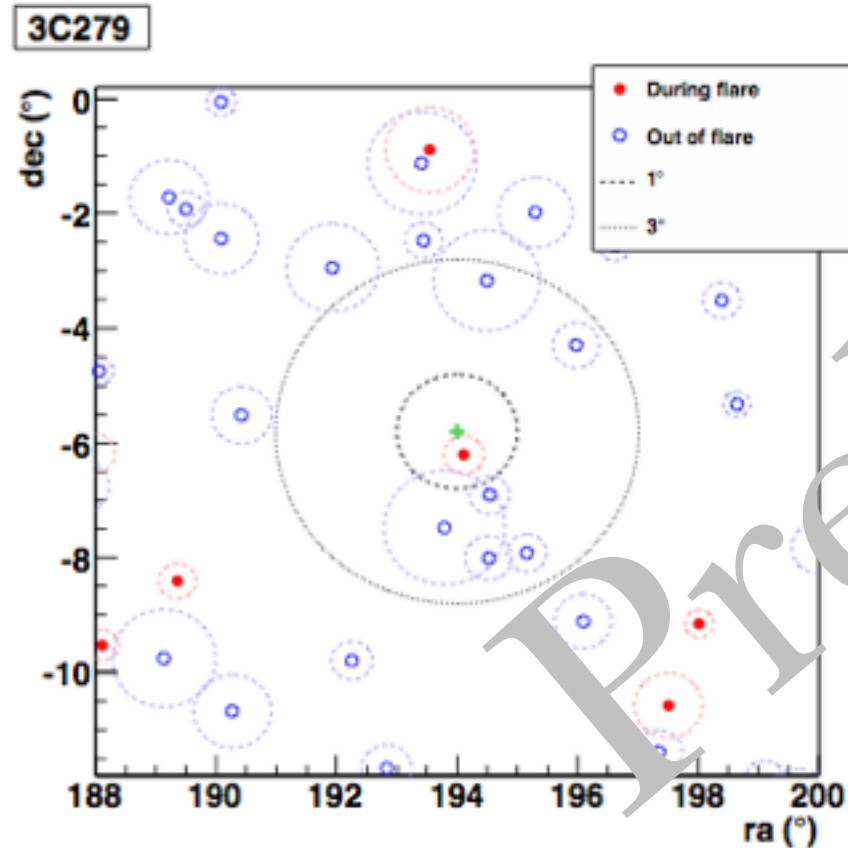
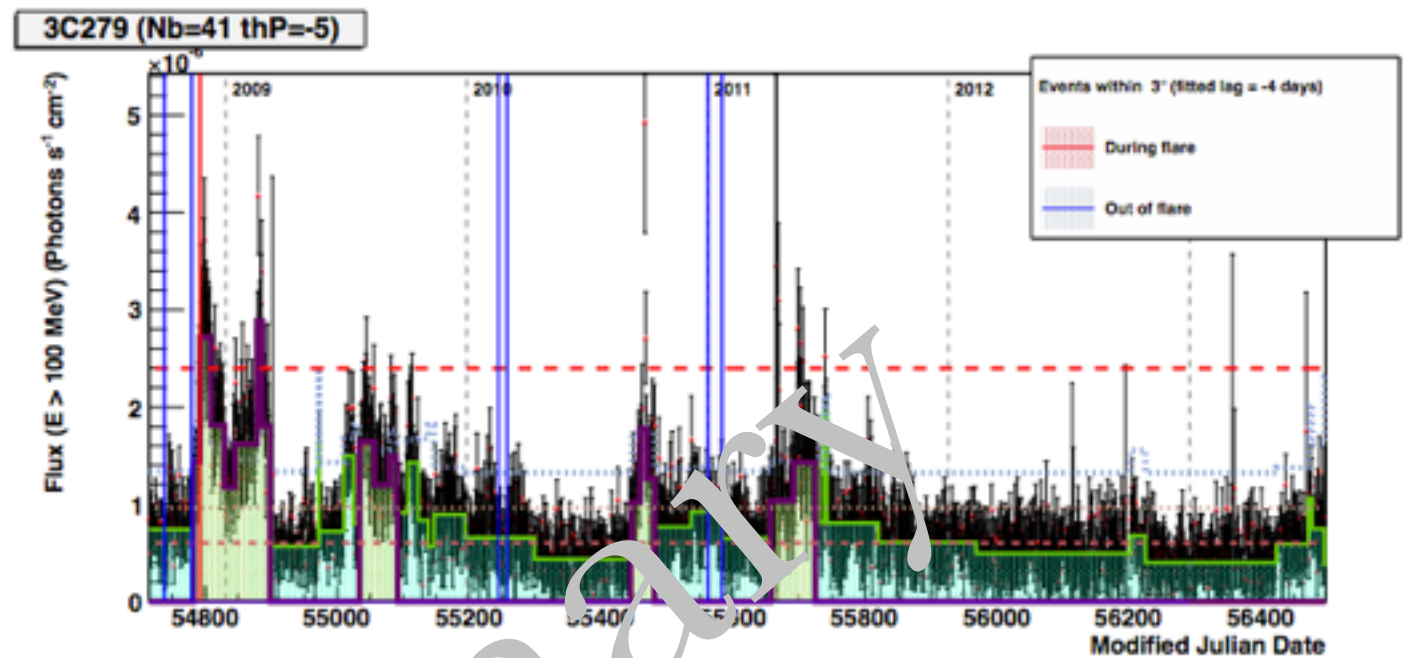
- From the 7 sources studied only 1 source with fitted signal events ( $p\text{-value} \lesssim 10\%$ ) in coincidence with gamma-ray flares:

**PKS 0447-439**

| Source       | Flaring (days) | $\Lambda_{\text{cut}}$ | $n_{\text{sig}} 3\sigma@50\%$ | $n_{\text{sig}}$ Fitted | LAG Fitted | TS Fitted | TS Median | Sensitivity@90% (GeV cm <sup>-2</sup> s <sup>-1</sup> ) | 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          | $E^{-2}e^{-E/1\text{TeV}}$ |

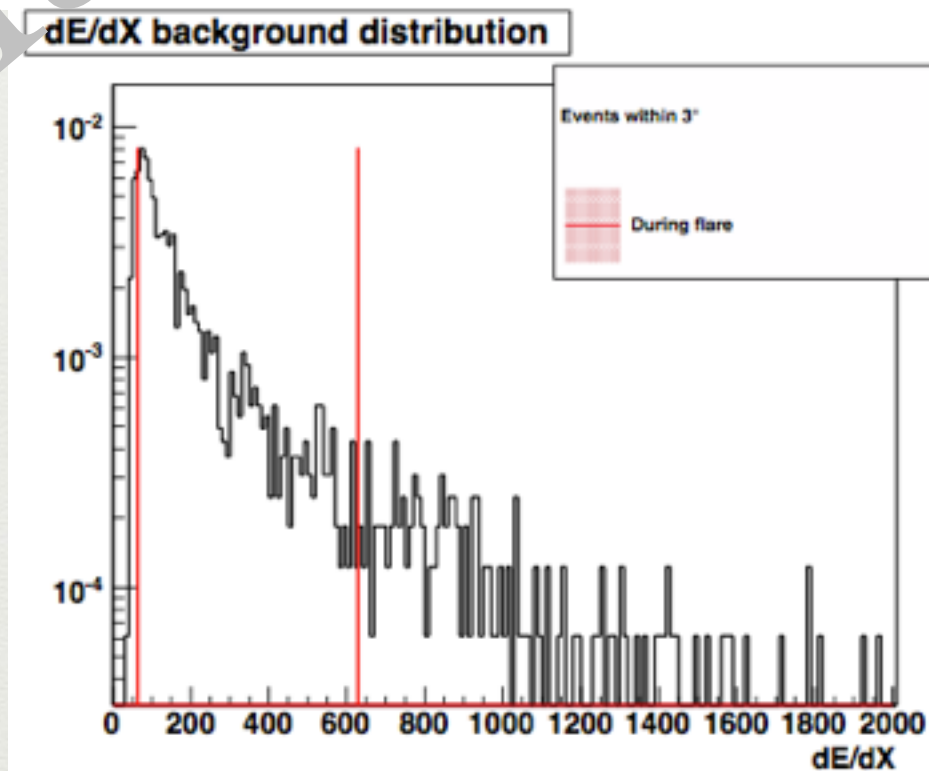
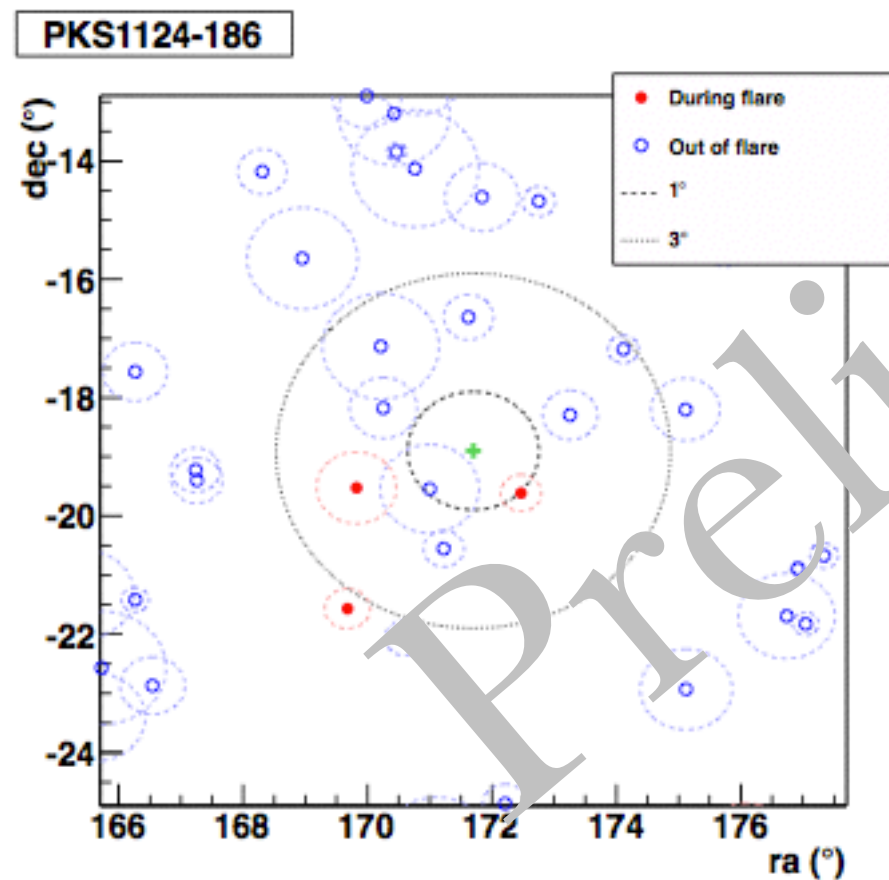
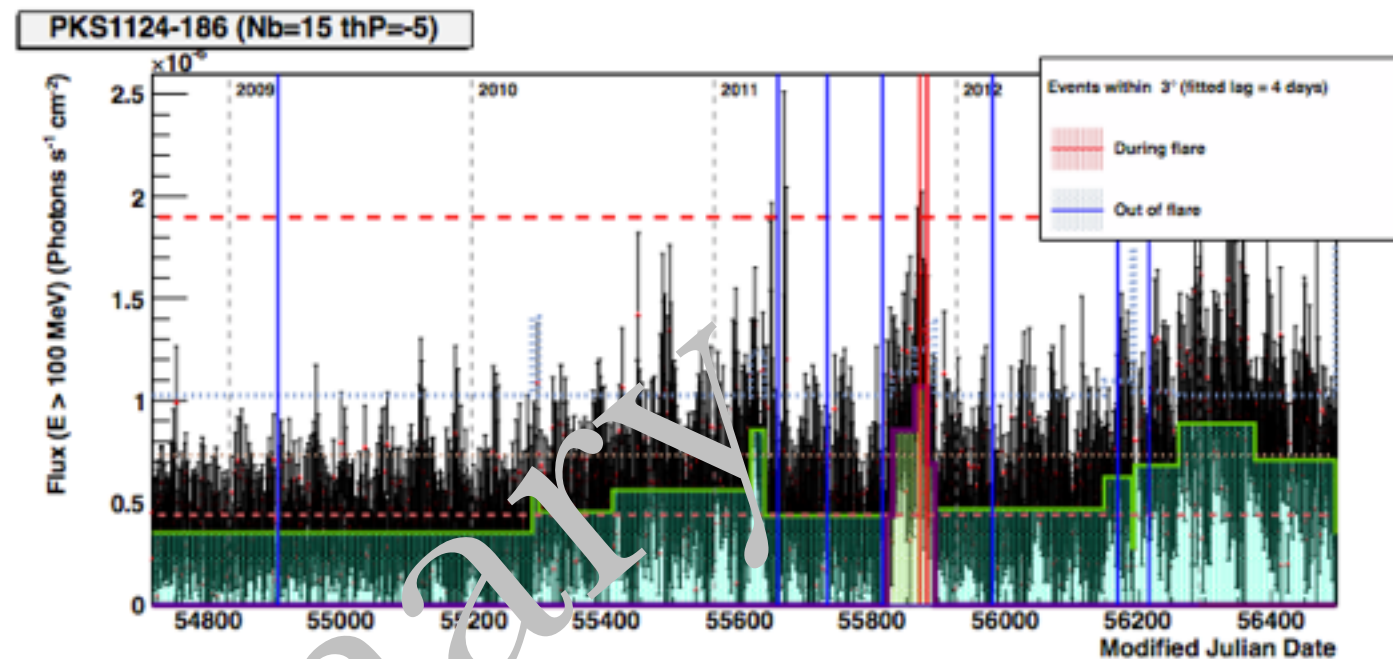
# Blazars

**3C 279** (279 flaring days)  
**BEST: 3.3% (67%)  $E^{-2}$**



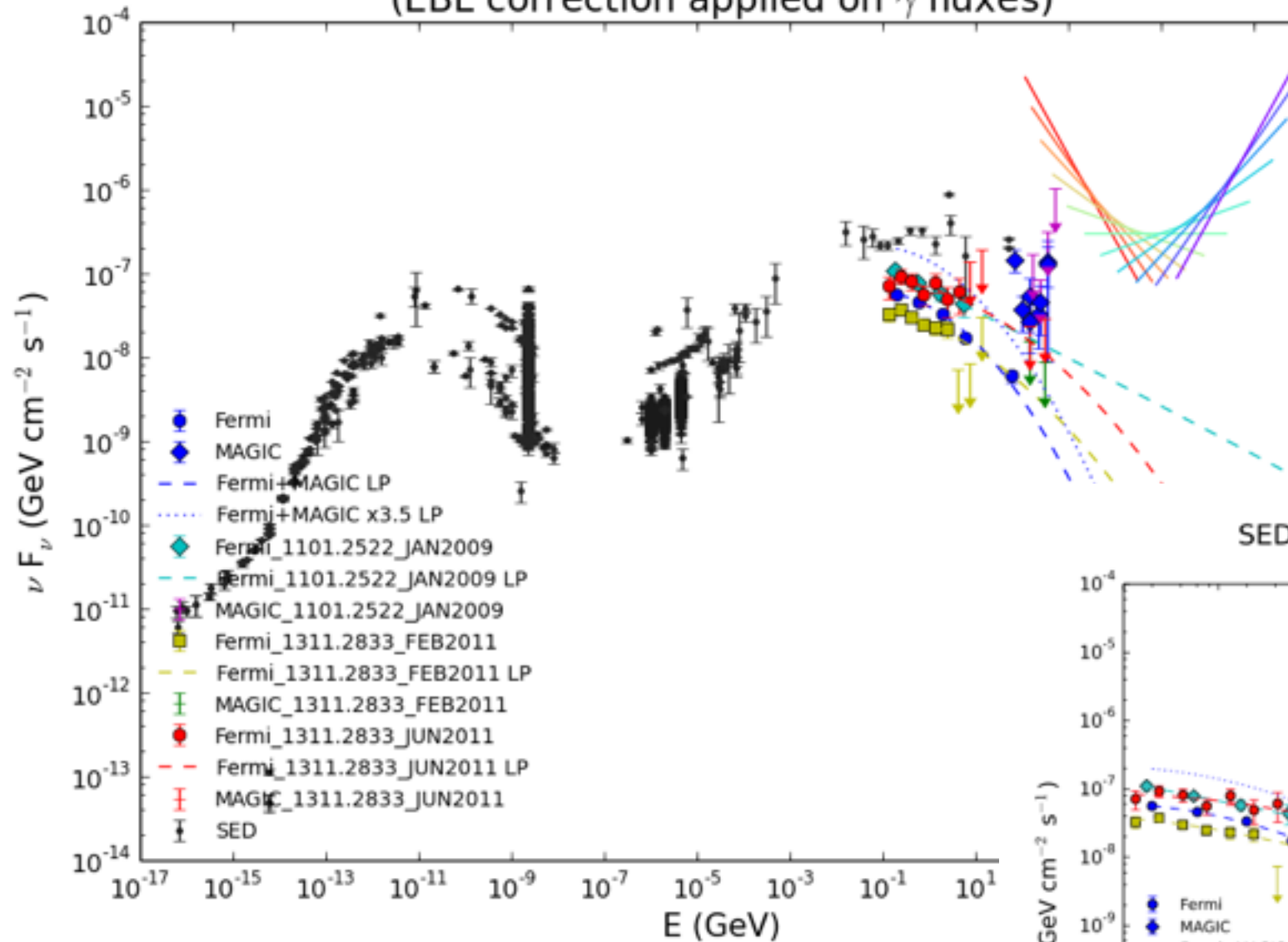
# Blazars

**PKS 1124-186** (73 flaring days)  
**BEST: 5.9% (94%)**  $E^{-2}e^{-E/1\text{TeV}}$

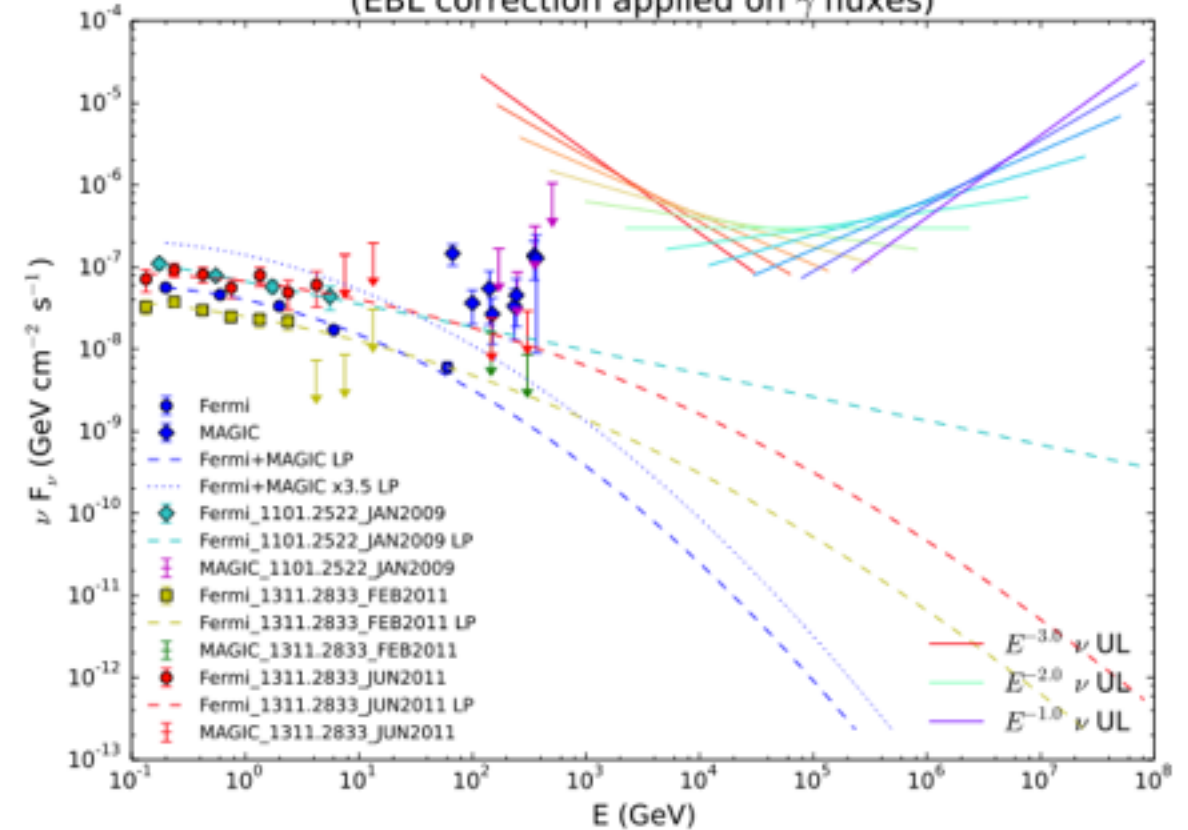


# Blazars

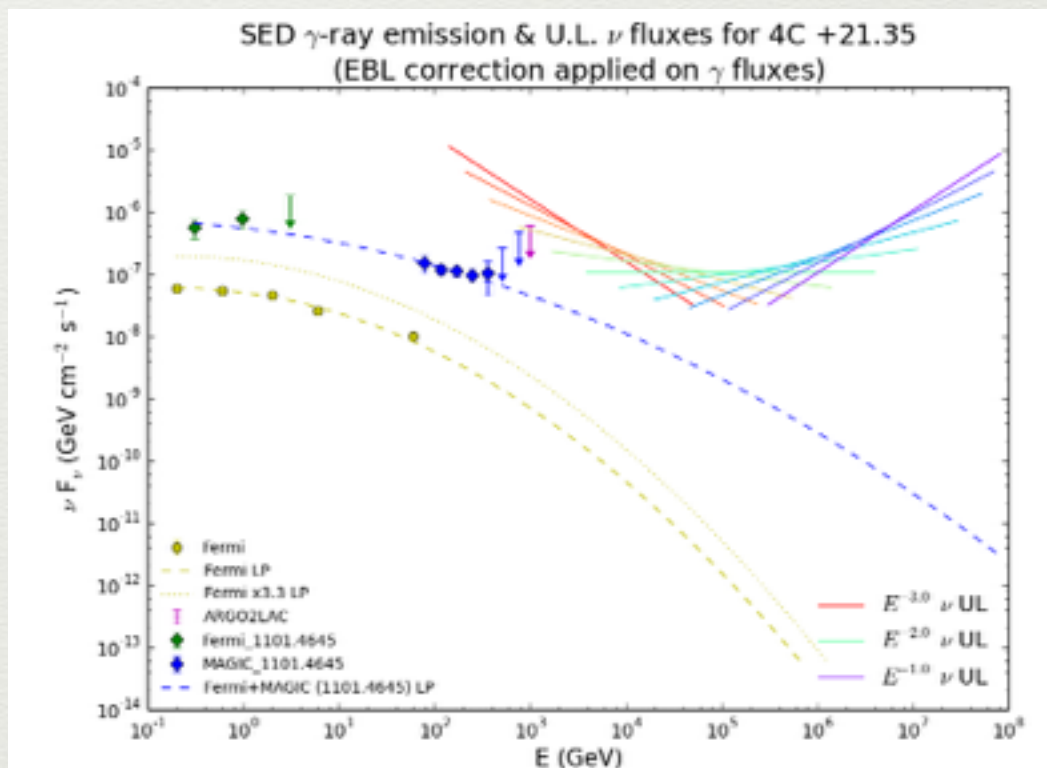
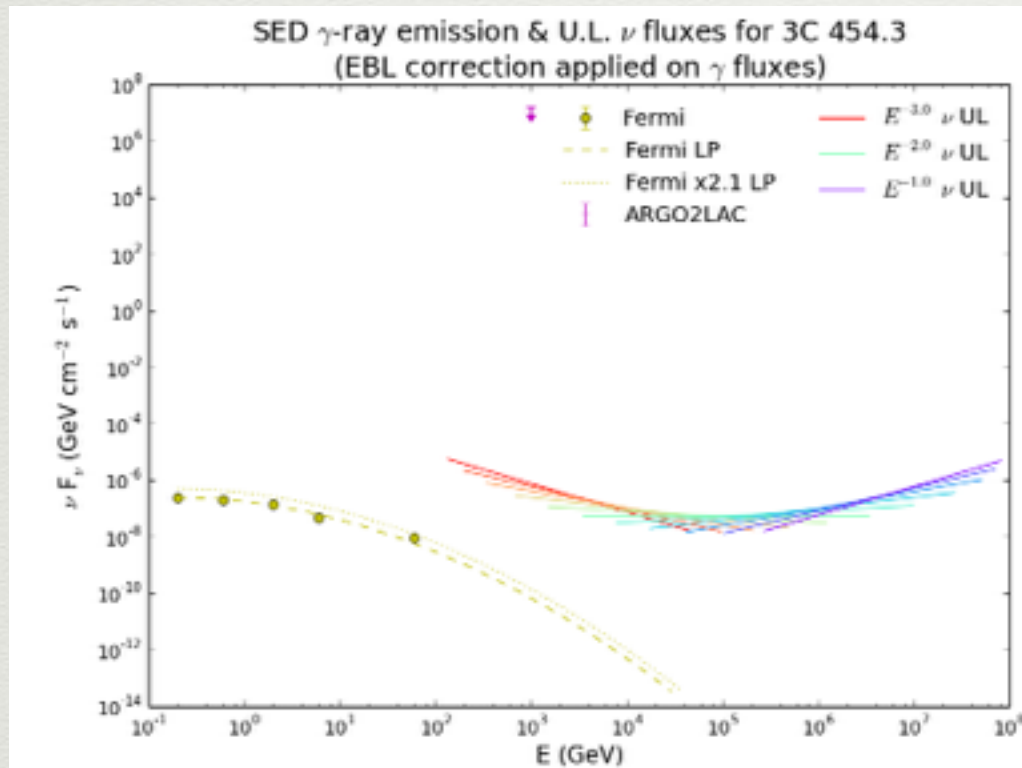
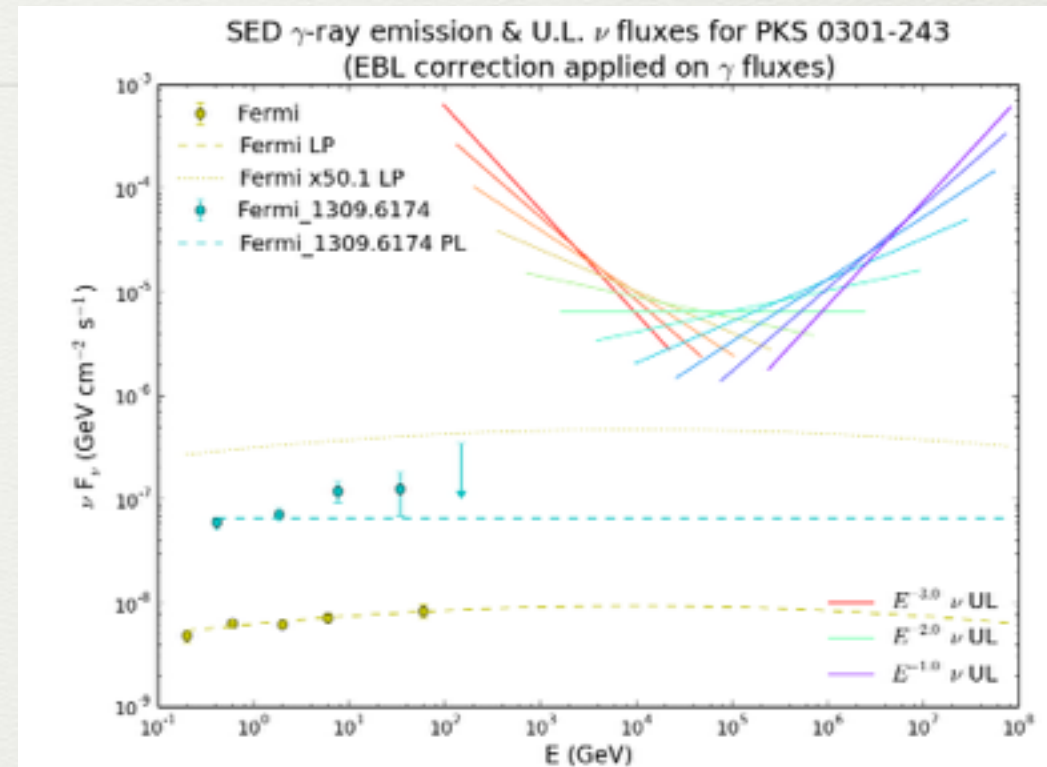
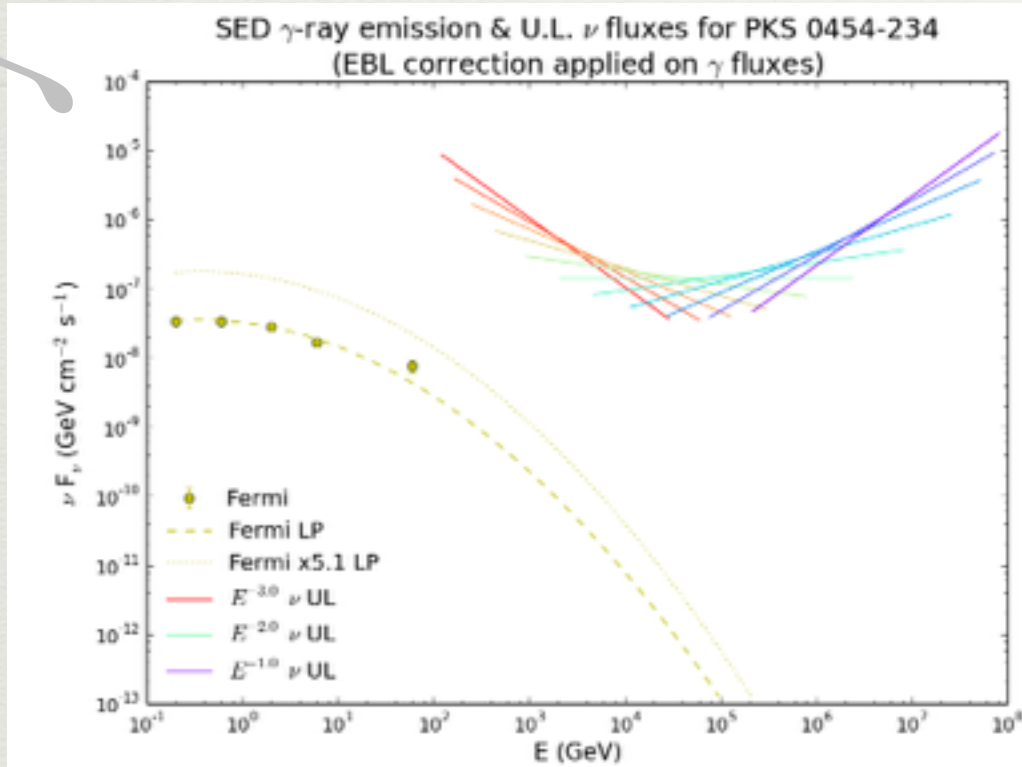
SED  $\gamma$ -ray emission & U.L.  $\nu$  fluxes for 3C 279  
(EBL correction applied on  $\gamma$  fluxes)



SED  $\gamma$ -ray emission & U.L.  $\nu$  fluxes for 3C 279  
(EBL correction applied on  $\gamma$  fluxes)



# 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)

IceCube has fixed the scale of the cosmic neutrino signal: we know that there are few cosmic events in the ANTARES sample.

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