

# Neutrino source search with Four year IceCube neutrino events.

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&

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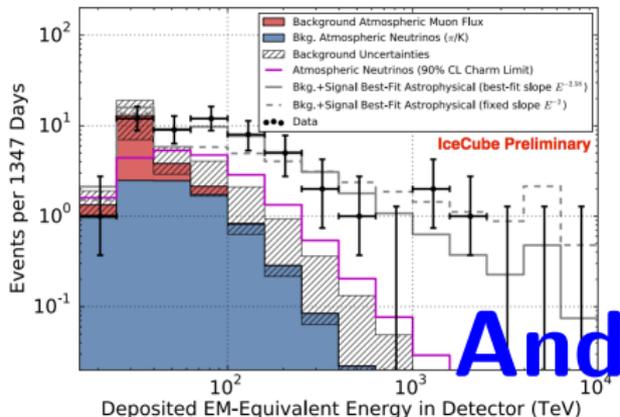
[University of Johannesburg]

TeVPA 2015, Kashiwa  
2015, Oct. 29

# IceCube results

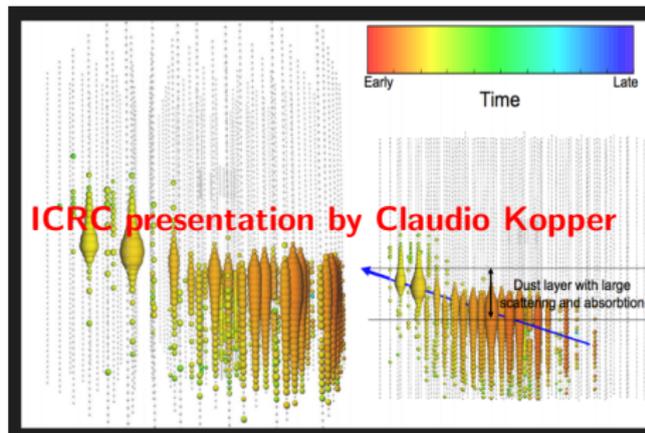
ICRC proceeding, 2015, M.G. Aartsen et. al., 2014, Aya Ishihara, TeVPA 2015

- Total 54 events, adding 6 tracks, and 11 cascades.
- Background expectation nearly 21.6. Rejecting only background with  $6.5\sigma$ .



ICRC proceeding, 2015

- Deposited energy  $2.6 \pm 0.3$  PeV.
- Direction:  $11.48^\circ$  dec,  $110.34^\circ$  RA.



*P. G. Tinyakov & I.I. Tkachev 2001*

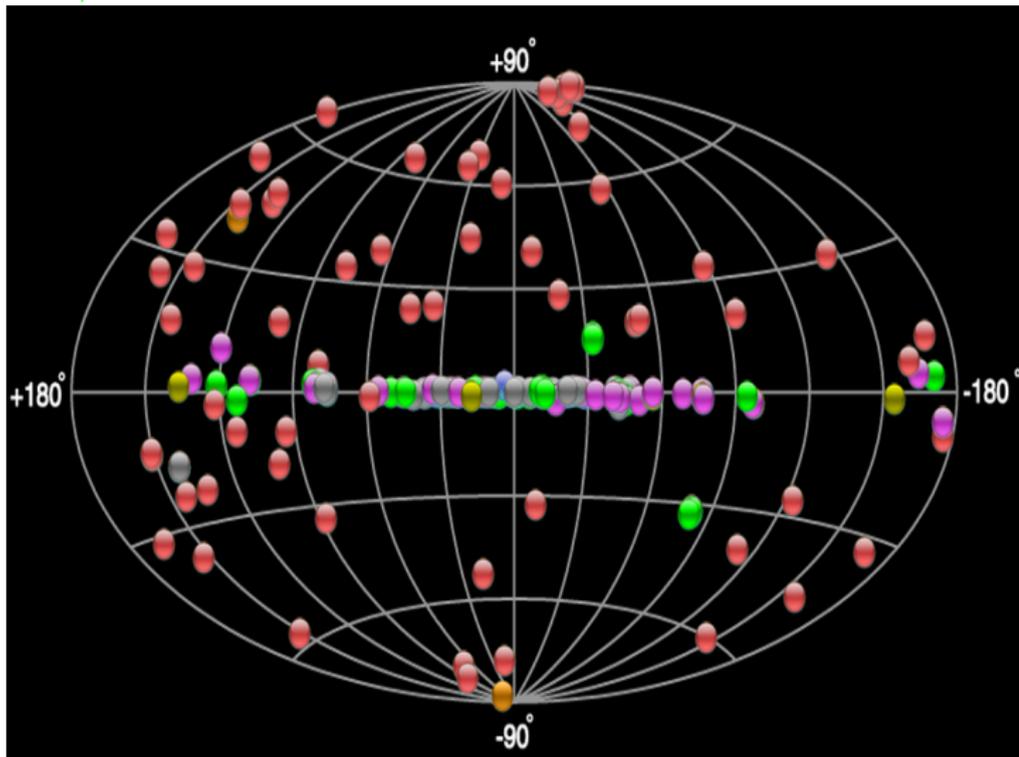
$$\gamma = \cos^{-1}(\hat{x}_{\text{neutrino}} \cdot \hat{x}_{\text{source}}),$$

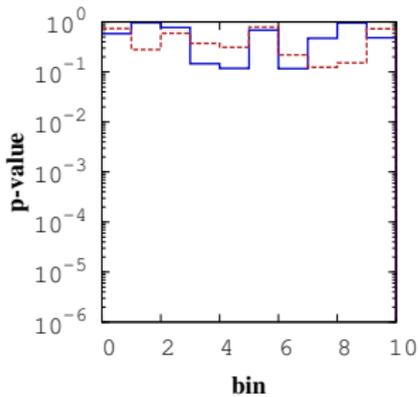
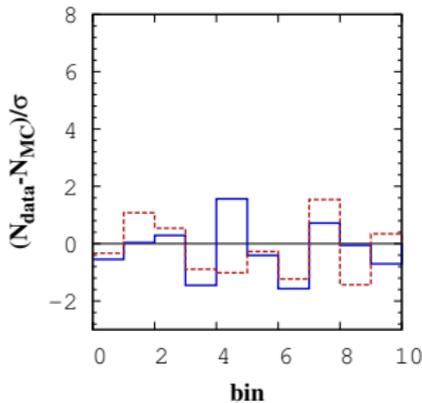
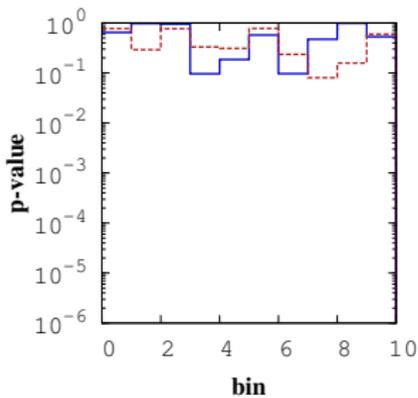
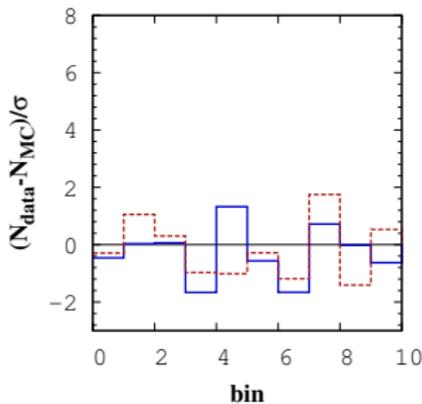
- Calculating the number  $N_{data}^i$  for which  $\gamma < bin$ , where  $bin$  are rings of  $0.1\sigma, 0.2\sigma, \dots$  till  $1\sigma$ .
- We repeat the same procedure for a large number (typically  $10^5$ ) of randomly generated sets of IceCube neutrino events for two null distributions, giving mean Monte-Carlo counts  $N_{MC}^i$  and variance  $\sigma_i$

$$\sigma_i^2 = \frac{1}{10^5} \sum_{i=1}^{10^5} (N_i^{MC} - N_p^i)^2,$$

- The relative excess  $(N_{data}^i - N_{MC}^i)/\sigma_i$  and minima of  $p$  with respect to each ring show the scales at which correlation is most significant.

175 TeVCat sources, AGNs, Starburst galaxies, PWN, UNID, Binary, SNR/Molec. Cloud.

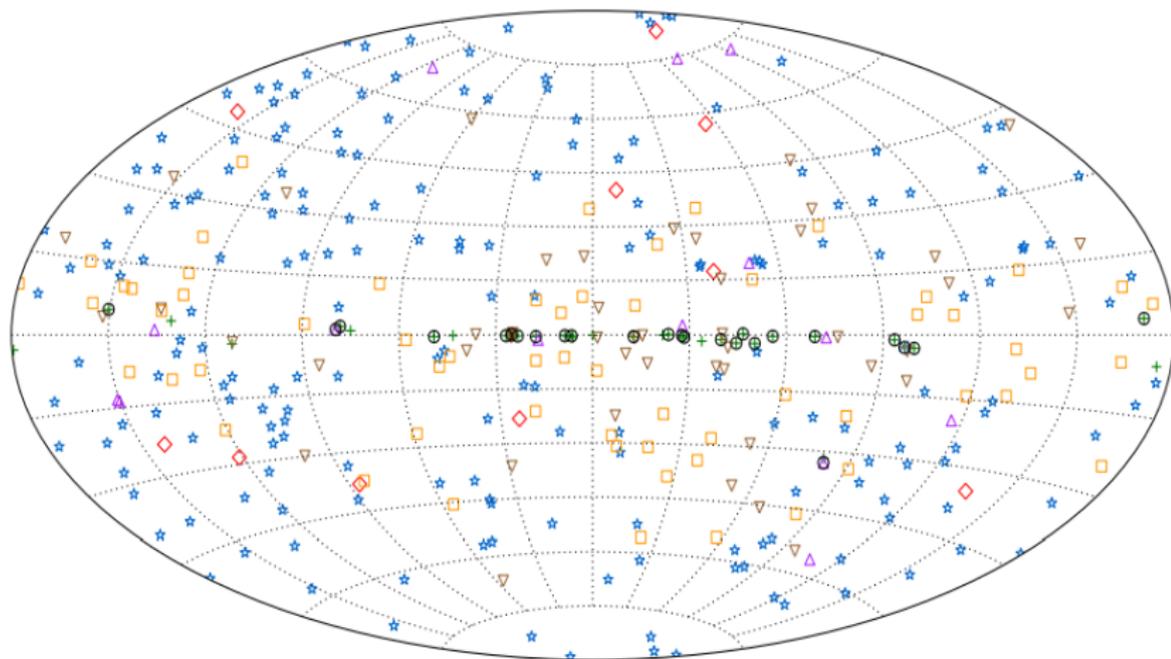




- 45 HBL 53.
- Randomizing IceCube neutrino events RA within range 0 to 360
- Randomizing both RA and Cos(dec) from -1 to +1.

## 2FHL catalog sources

(*M. Ackermann et., al, arXiv: 1508.04449*)



+ SNRs and PWNe

★ BL Lacs

□ Unc. Blazars

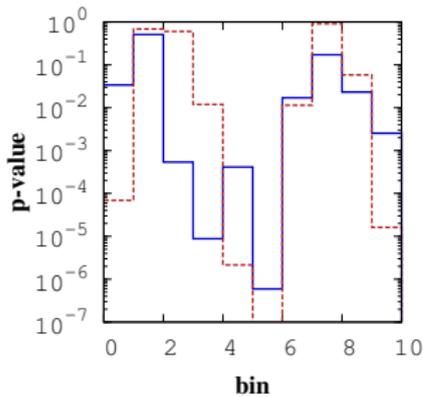
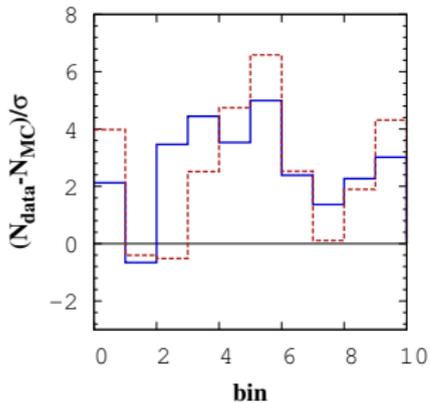
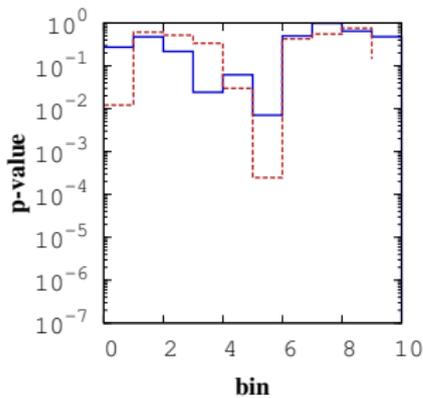
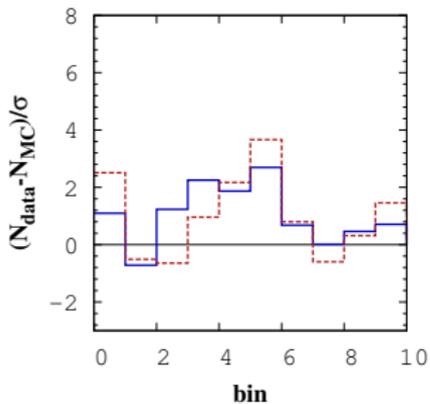
▽ Unassociated

× Pulsars

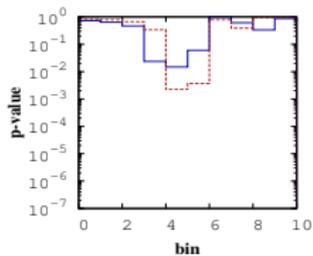
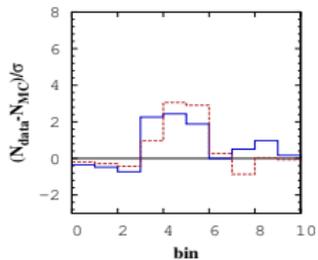
◇ FSRQs

△ Others

○ Extended

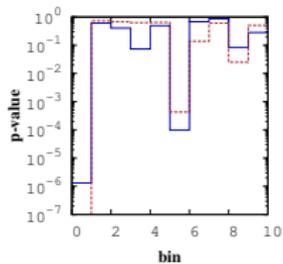
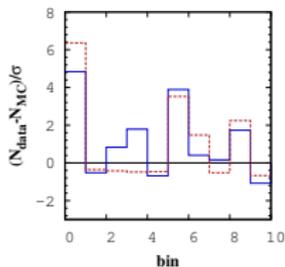
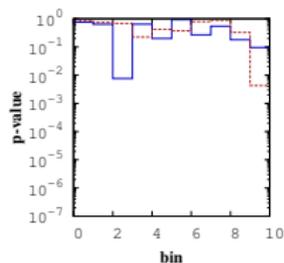
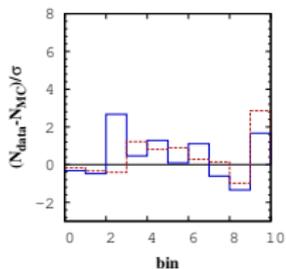


- 34 2FHL galactic sources.
- Randomizing IceCube neutrino events RA within range 0 to 360
- Randomizing both RA and Cos(dec) from -1 to +1.



13 2FHL supernovae remnants (SNRs)

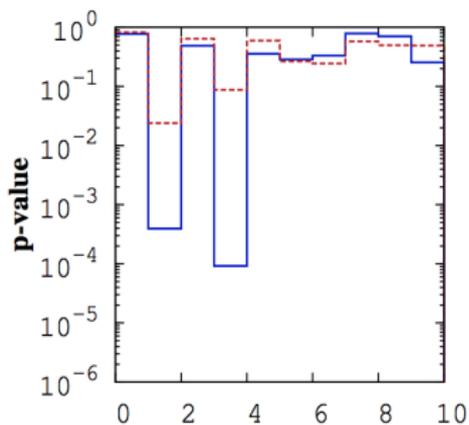
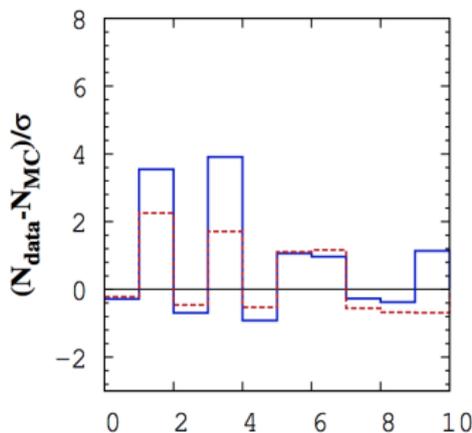
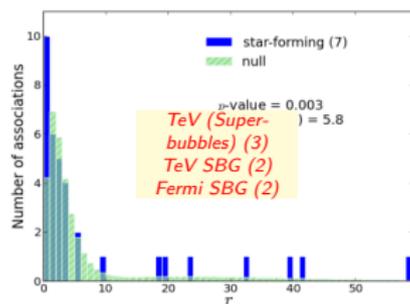
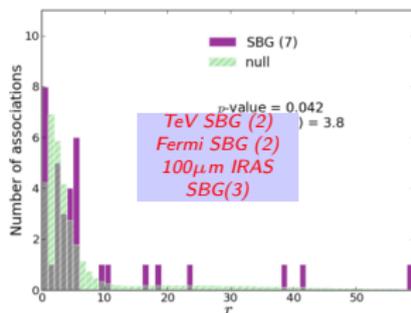
15 2FHL Pulsar wind nebulae (PWNs)



6 SNRs/PWNs from 2FHL source catalog.

# Star Burst galaxies and Super bubbles

(K. Emig, C. Lunardini & R. Windhorst arXiv: 1507.05711) R. Moharana & S. Razzaque, JCAP 2015

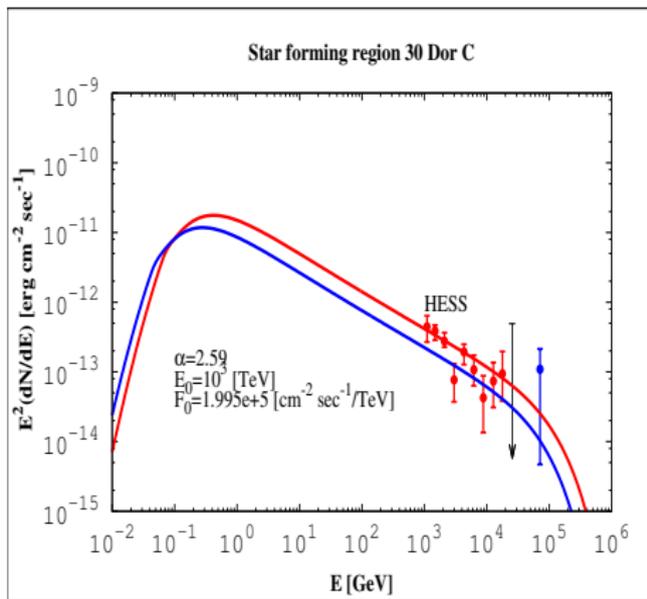


# Sources

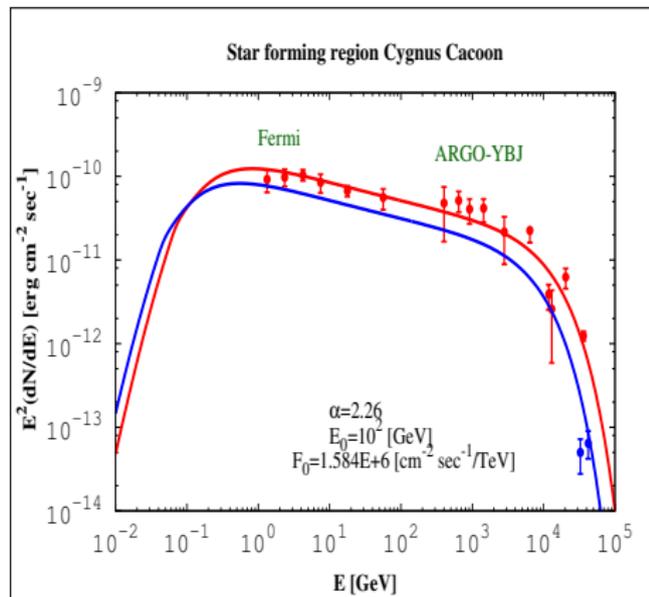
Source name	RA	Dec	Neutrino ID #	$E_\nu$ (TeV)
NGC253	6.8917	-25.2894	7,10,21	34.3,97.2,30.2
NGC1068	40.6792	-0.0258	1	47.6
IC342	56.7042	68.0961	-	-
30DorC	83.9792	-69.1861	19	71.5
M82	148.9708	69.6794	31	
NGC4945	196.3708	-49.4342	35	2.004 PeV
M83	204.2542	-29.8658	16,48	30.6, 104.7
W49A	287.6125	9.1903	25,33,34	33.5,385,42.1
CygnusCocoon	307.1708	41.1700	29,34	32.7,42.1
NGC6946	308.7167	60.1536	34	42.1

- To see further realistic view of these correlation study we need to see a fit of high energy gamma-rays as well with the neutrino events from pp channel.

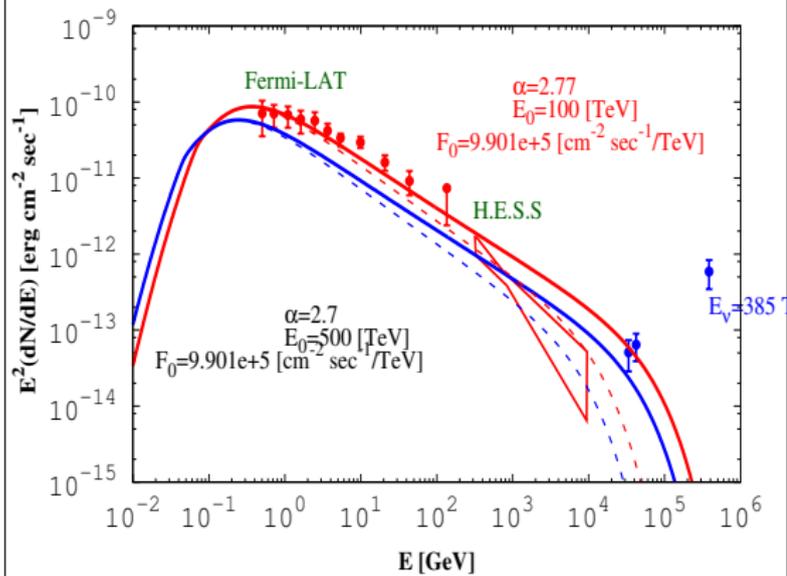
# High energy gamma rays and neutrinos from pp channel



$E_\nu=71.5$  TeV

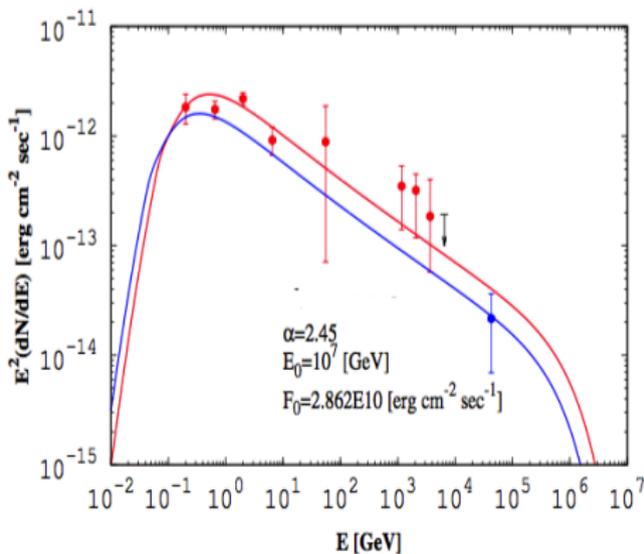


Star forming region W 49A



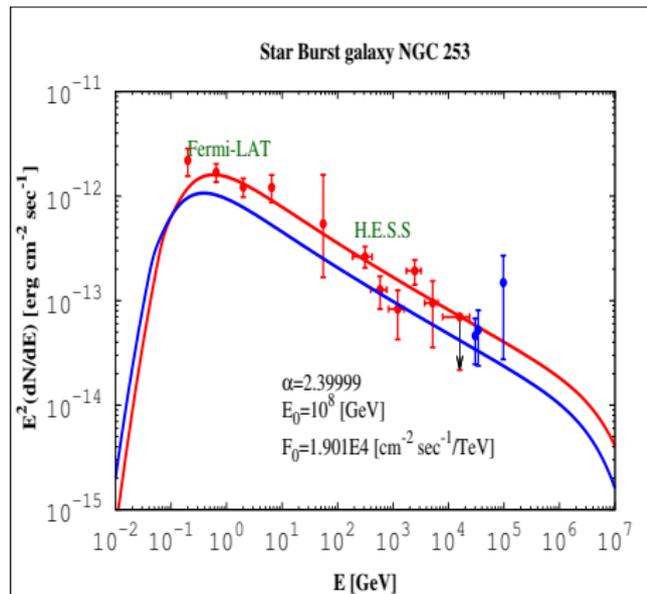
# Starburst Galaxy

Star forming galaxy M82

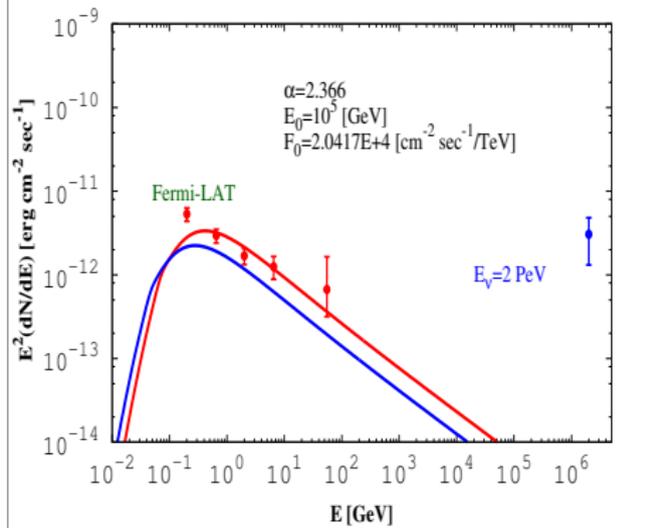


- 3.6 Mpc
- Gamma-rays detected by Fermi-LAT, H.E.S.S

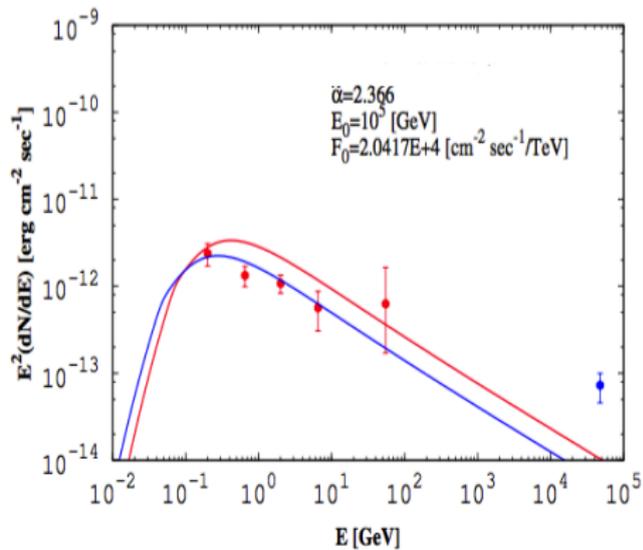
Star Burst galaxy NGC 253



Star Burst galaxy NGC 4945



Star forming region NGC 1068



$E_\nu=46$  TeV

# Summary

- Cross correlation method is used to find a correlation between different sources from catalog and the 4 yrs of IceCube neutrino events.
- Two randomization methods used for IceCube neutrino events.
- We found more than  $4\sigma$  correlation result for 2FHL "spp" sources and Starburst galaxies and Superbubbles.
- A multimessenger study is done for the SBG and superbubble.

**Thank you**