

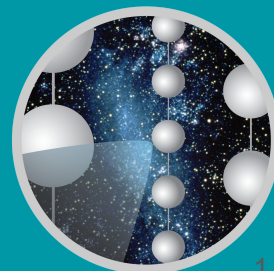


UPPSALA  
UNIVERSITET

# Testing blazar sky visible to IceCube

Adithya S  
13th October

**Project guide-** Ankur Sharma,  
Antonio Marinelli



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ICECUBE

*Name* : **Adithya S**

*Country* : India, Bangalore.

Integrated Master's Degree in **Physics** at Indian Institute of Science Education and Research - Thiruvananthapuram, Batch of 2021.

*Interests* - High Energy Physics , Astronomy.

*Courses taken* - HEP, QM I & II, GR, STR.

*Funding* - **INSPIRE Fellowship** (Dept. of Science & Technology, Govt. of India).

*Hobbies* - Ultimate Frisbee, Badminton, Coding.



सत्यमेव जयते  
Department of Science & Technology  
Govt. of India



Master's thesis was titled :

**“Correlated study of Right Handed Neutrino and W Prime Boson”** , under the guidance of **Dr. Tanumoy Mandal**, School of Physics at IISER TVM.

arXiv.org > hep-ph > arXiv:2109.09585

High Energy Physics - Phenomenology

*[Submitted on 20 Sep 2021]*

## **Testing left-right symmetry with inverse seesaw at the LHC**

Mathew Thomas Arun, Tanumoy Mandal, Subhadip Mitra, Ananya Mukherjee, Lakshmi Priya, Adithya Sampath

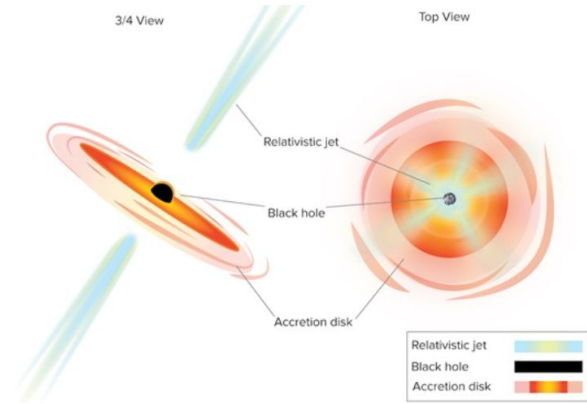
# Outline of Talk

- High Energy Neutrinos from Blazars
- Categories of Blazars
- Project Outline
- Methods to compute neutrino sed peak energy and expected neutrino flux
- A brief discussion on Catalogues
- Summary

# What are Blazars?

- AGN with the relativistic jets pointed towards the earth.
- Observations of gamma ray flaring of blazar TXS0506+056 coincides with high energy IceCube neutrino IC-170922A

- Jets - Broadband
- Broadline region- Optical, UV and soft X-rays



Sophia Dagnello, NRAO/AUI/NSF

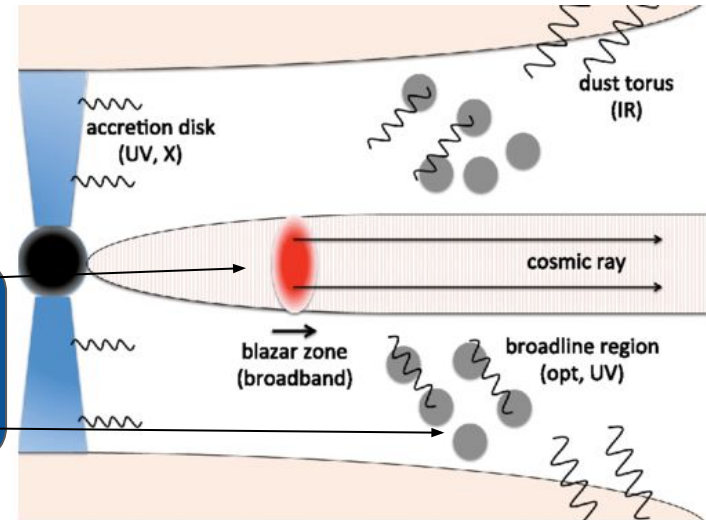
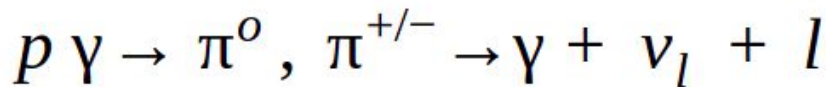
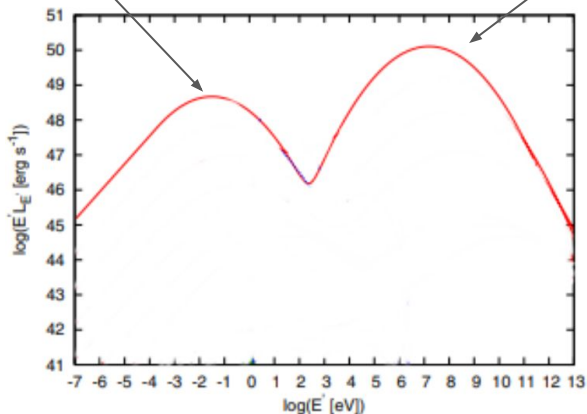


Image source - Murase et al, [Phys. Rev. D 90, 023007 \(2014\)](https://arxiv.org/abs/1402.0007).

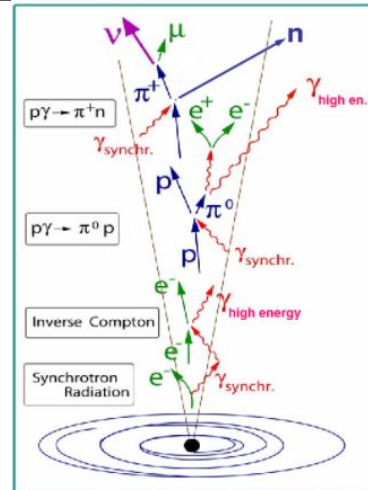
# Neutrino production in Blazars

- Blazar SED has 2 distinct peaks

Low energy peak is attributed to synchrotron emission of relativistic electrons



- Leptonic Models* - The second peak is attributed to synchrotron self compton emission(SSC) due to the electrons from the low energy peak
- Lepto-Hadronic Models*  
Photo hadronic interactions inside blazars lead to production of high energy neutrinos and gamma rays  
The second peak can have contributions from hadronically produced gamma rays
  - Target photons for  $p\gamma$  interactions can be internal or external to the jet



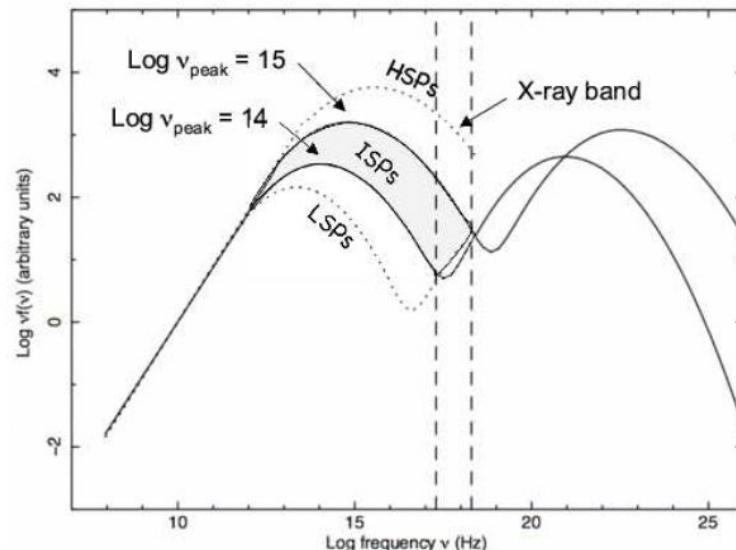
# Types of Blazars

Based on difference in **optical spectrum**

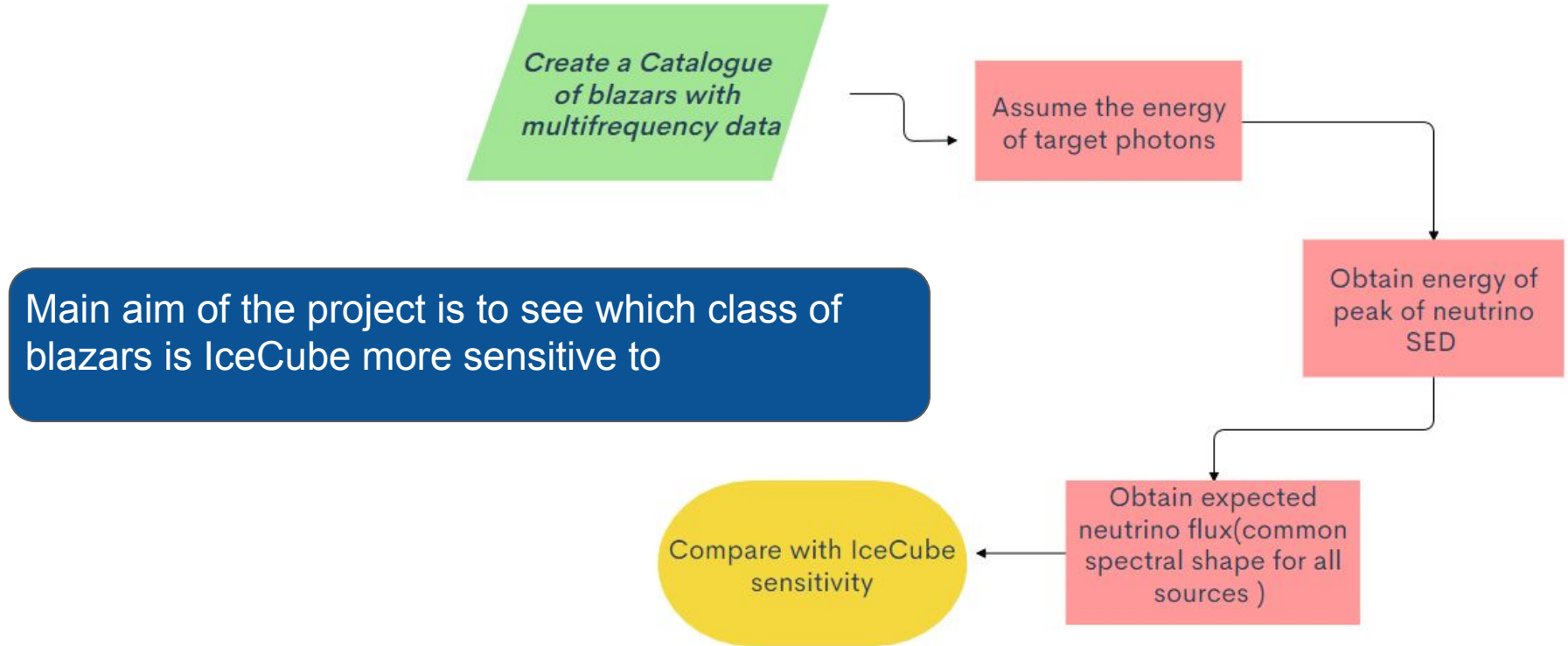
- BL Lacs - Weak emission lines in optical spectrum
- Flat Spectrum Radio Quasars (FSRQs) -  
Strong broad emission lines in optical spectrum

Based on location of **synchrotron peak position**

- LSP -  $\nu_{peak}^s < 10^{14} \text{ Hz} \mid < 0.4 \text{ eV}$
- ISP -  $10^{14} \text{ Hz} < \nu_{peak}^s < 10^{15} \text{ Hz} \mid 0.4 \text{ eV} < \nu_{peak}^s < 4 \text{ eV}$
- HSP -  $\nu_{peak}^s > 10^{15} \text{ Hz} \mid > 4 \text{ eV}$

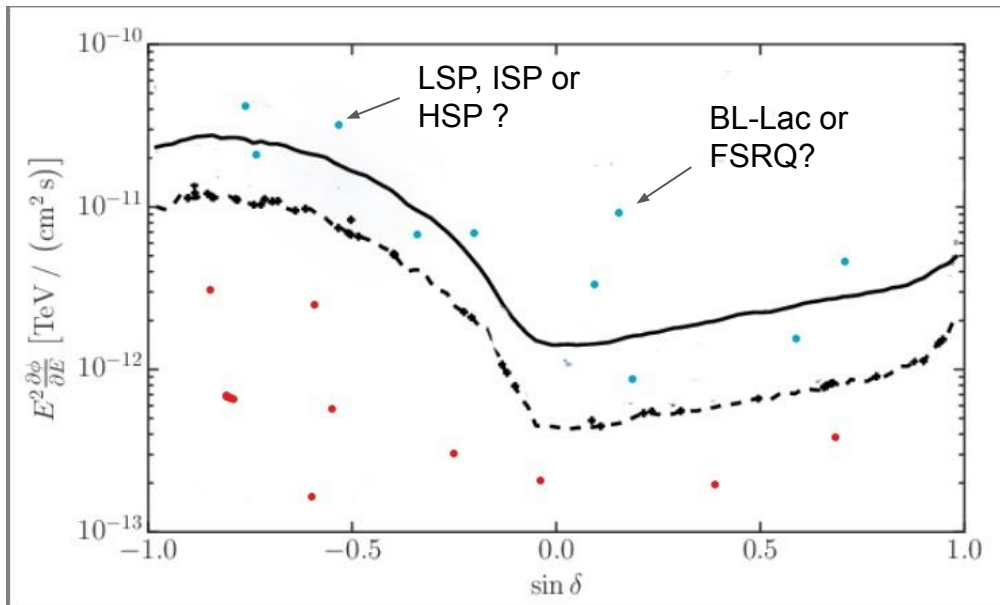


# Project Outline





# Predictions



- IceCube Sensitivity
- - 5 sigma discovery potential
- Sources detectable by IceCube
- Sources not visible to IceCube

- Compare the diff. sub-classes of blazars based on the position of their sync. peak to predict which class is more likely to be visible to IceCube
- Extend the prediction to higher energies by using IceCube Gen2 sensitivity

# Energy of neutrino SED peak

We plan to follow different methods and develop different pipeline for FSRQs and BL Lacs

## For BL Lacs

P.Padovani, et al. - <https://arxiv.org/abs/1506.09135>

$$E_{\nu,p}(\delta, z, \nu_{peak}^s) \approx \frac{17.5 \text{ PeV}}{(1+z)^2} \left(\frac{\delta}{10}\right)^2 \left(\frac{\nu_{peak}^s}{10^{16} \text{ Hz}}\right)^{-1}$$

Neutrino energy peak is obtained from synchrotron energy peak.

## For FSRQs

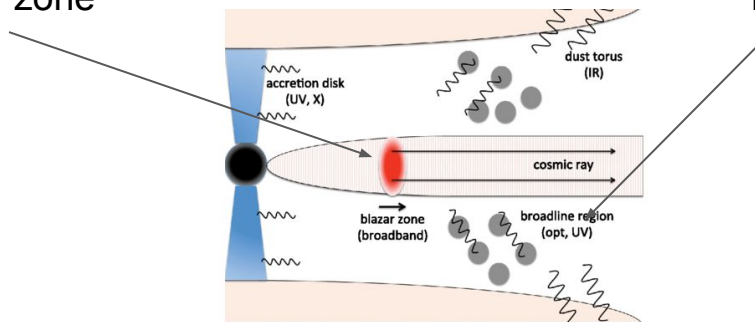
Murase et al, [Phys. Rev. D 90, 023007 \(2014\)](#).

$$E_{\nu}^{'b} \approx 0.05 E_p^{'b} \approx 80 \text{ PeV } \Gamma_1^2 (E_s'/10 \text{ eV})^{-1}$$

$$E_{\nu}^{'b} \approx 0.05 (0.5 m_p c^2 \bar{\epsilon}_{\Delta} / E'_{\text{BL}}) \approx 0.78 \text{ PeV}$$

Blazar zone

BLR - Broadline Region



# Neutrino flux estimation

- Obtain the neutrino flux corresponding to a single event at the energy of the neutrino SED peak, in  $\sim 10$  yrs of observation by convoluting with the effective area of IceCube
- Correlate the (GeV) gamma-ray flux to the neutrino flux assuming a linear correlation ( $Y_{\nu\gamma} = 0.1$ ).

**Is there a better way?? Suggestions?**

# Catalogues

Some useful parameters

- Optical to x-ray observational data
- Synchrotron peak frequency
- Gamma-ray data from Fermi-LAT (to estimate neutrino flux)
- Redshift
- Class of blazars

# Catalogues under consideration

## *3HSP blazar catalogue*

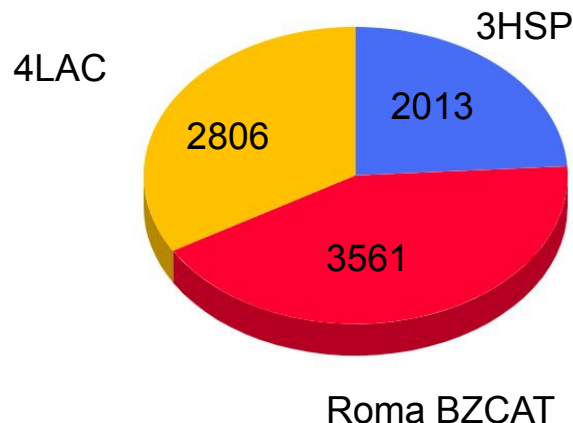
- Cross-matching studies between 2WHSP and IceCube neutrinos show HSP are potentially linked to neutrino events {[The 3HSP catalogue of extreme and high-synchrotron peaked blazars](https://aanda.org/)|(aanda.org)}
- Synchrotron peak , redshift and multifrequency data available

## *RomaBZCAT*

- A large catalogue with multi-frequency data available
- Blazars of all types are considered and are classified
- Synchrotron peak is not available

## *4LAC Catalogue*

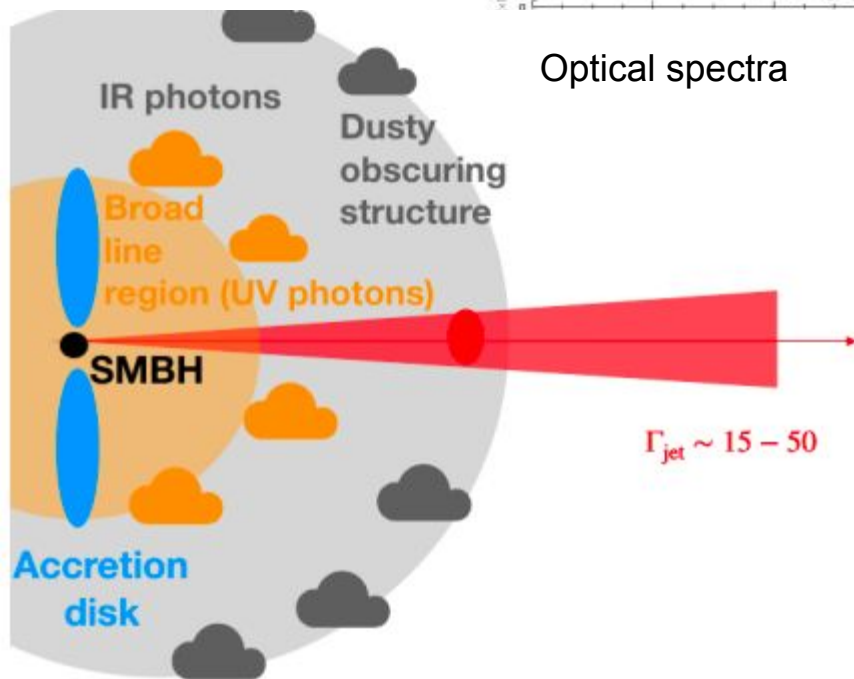
- Largest catalogue of blazars which emit in the gamma ray region
- We can estimate the neutrino flux from the gamma ray flux
- Synchrotron peak also available



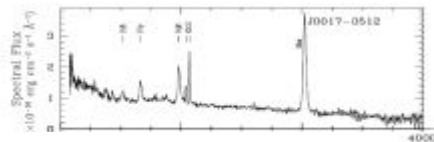
# Summary

- We look at different blazar classes and try to predict which is more likely to be visible to IceCube by making assumptions for target photon energies and neutrino fluxes and comparing to IceCube sensitivity
- Neutrino SED peak energy will be obtained from the sync. Peak frequency for BL Lacs (P.Padovani - <https://arxiv.org/abs/1506.09135>) and FSRQs (Murase - [Phys. Rev. D 90, 023007 \(2014\)](#).) separately
- Neutrino flux will be estimated from the gamma ray flux, or corresponding to 1 event in 10 years of IceCube observation
- Predictions for diff. spectral subclasses (LSP, ISP and HSP)
- Currently looking at multi-frequency AGN/blazar catalogs

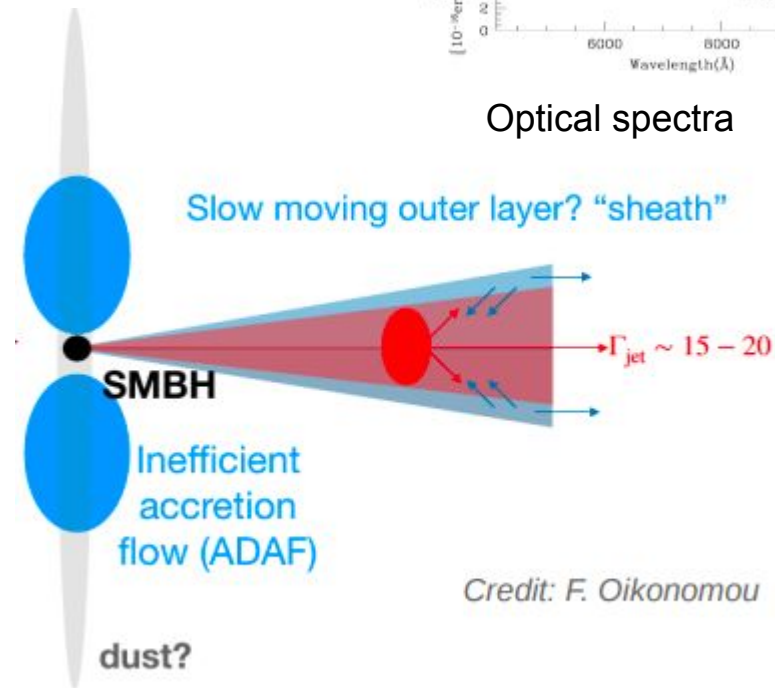
Thank you



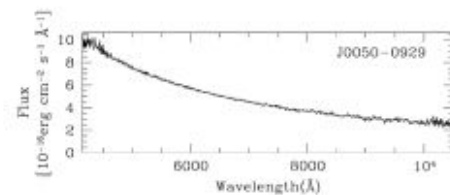
FSRQs



Optical spectra



BL Lacs



Optical spectra