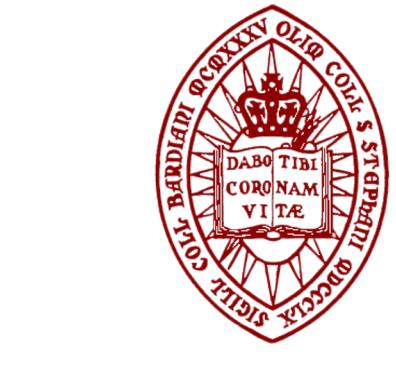




THE UNIVERSITY OF UTAH

Department of  
Physics & Astronomy

# Investigating the X-ray Spectrum of Candidate Neutrino Sources NGC 1068 and NGC 4151



Bard College

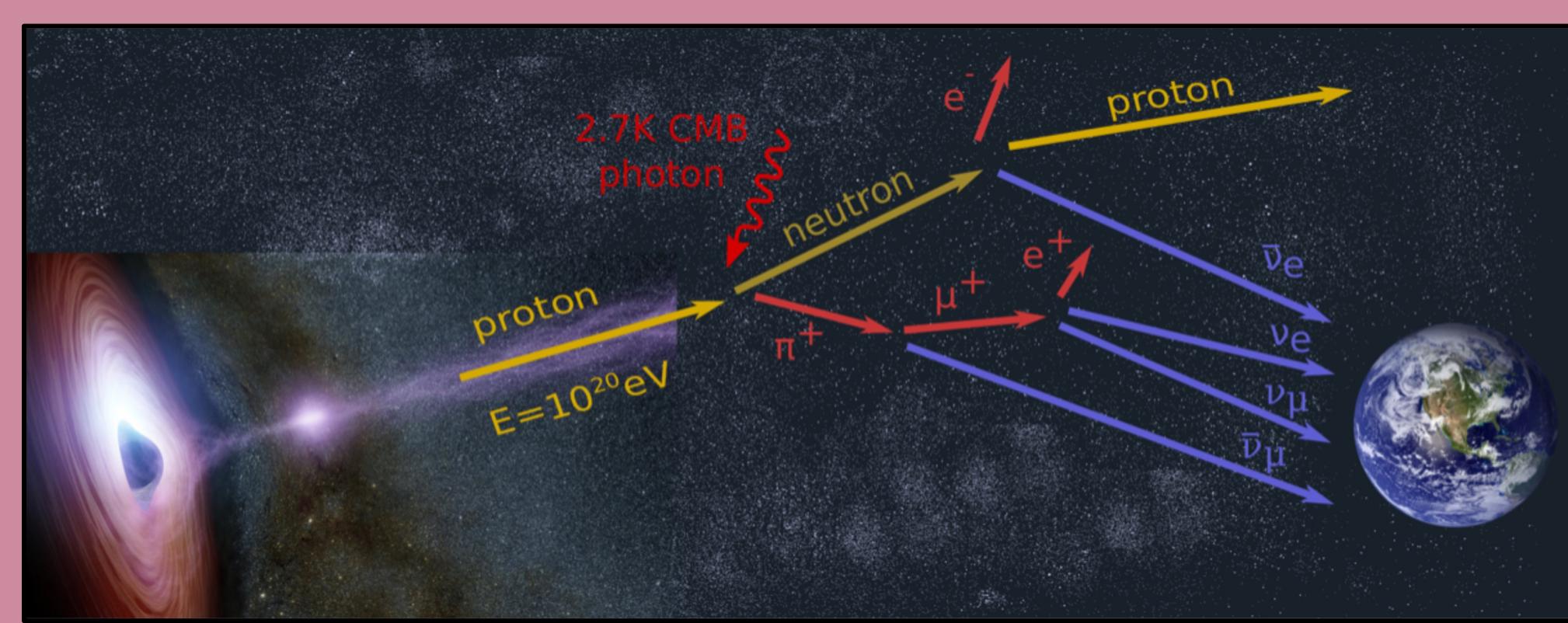


Chloe Dufeu • Qi Feng

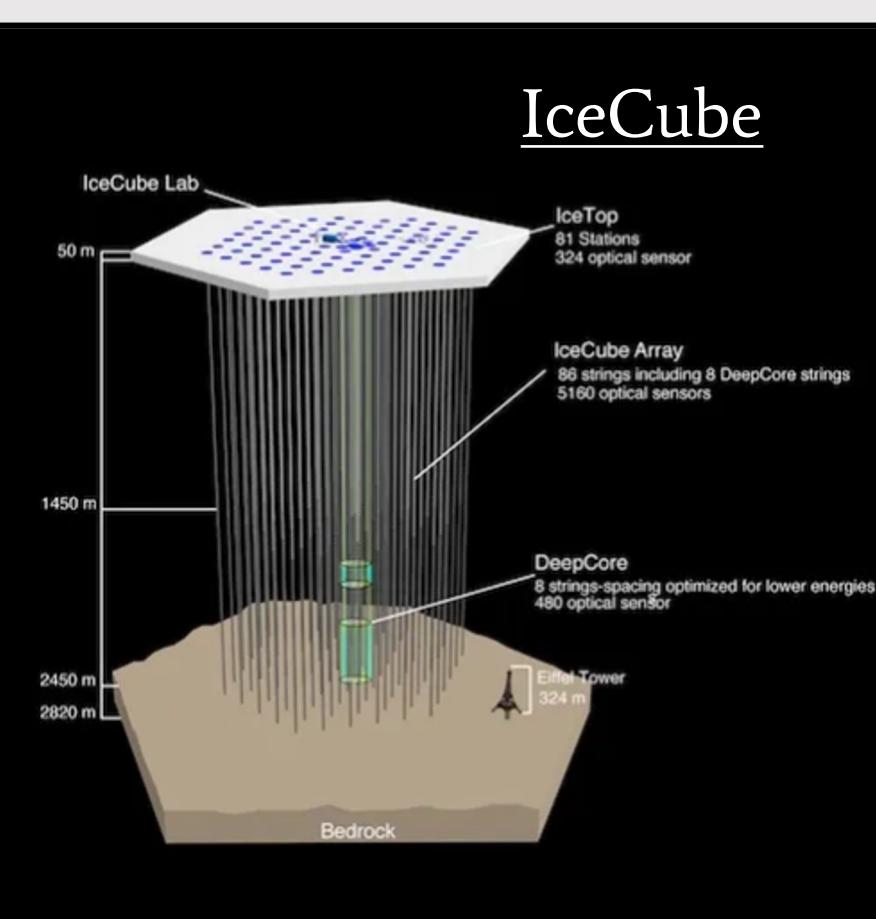
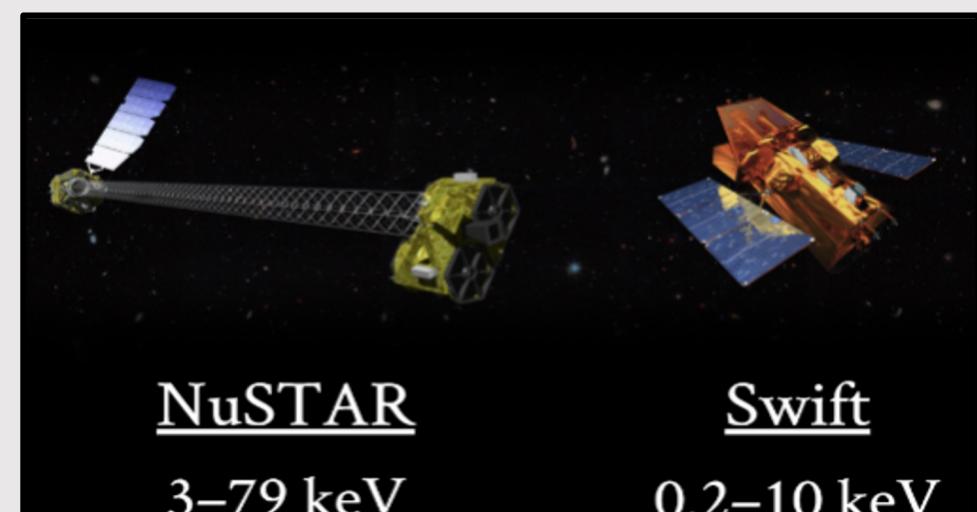
University of Utah, Department of Physics &amp; Astronomy

## Introduction

- Supermassive black holes can accelerate particles at relativistic speeds making them great candidates for neutrino production.
- Neutrinos are the most abundant particles with mass in the universe, yet we still know little about their origin.
- IceCube reported evidence for neutrinos from several Seyfert Galaxies including NGC 1068.
- The VERITAS observatory observed candidate neutrino sources NGC 1068 and NGC 4151.

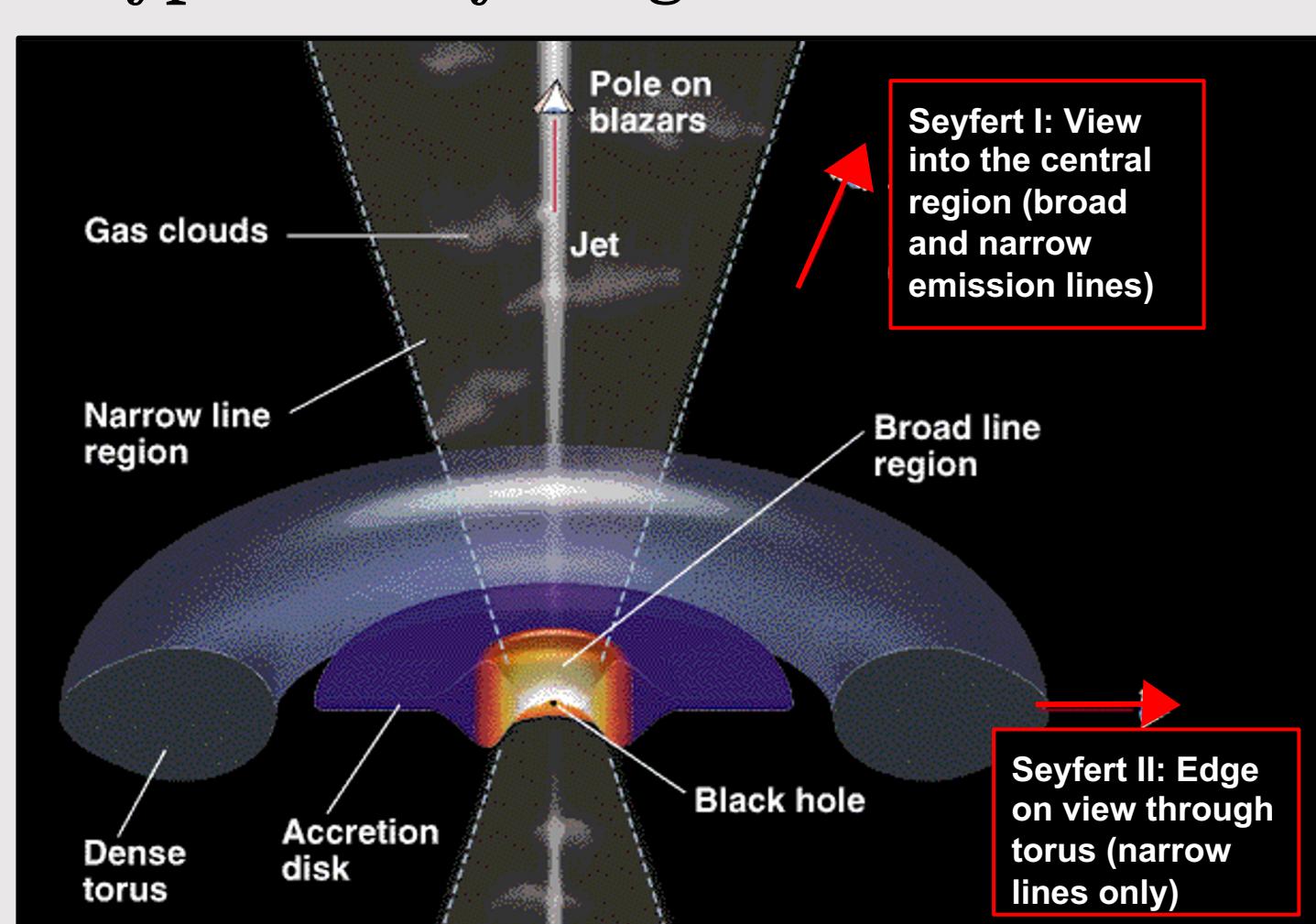


## Instruments



## Seyfert Galaxy

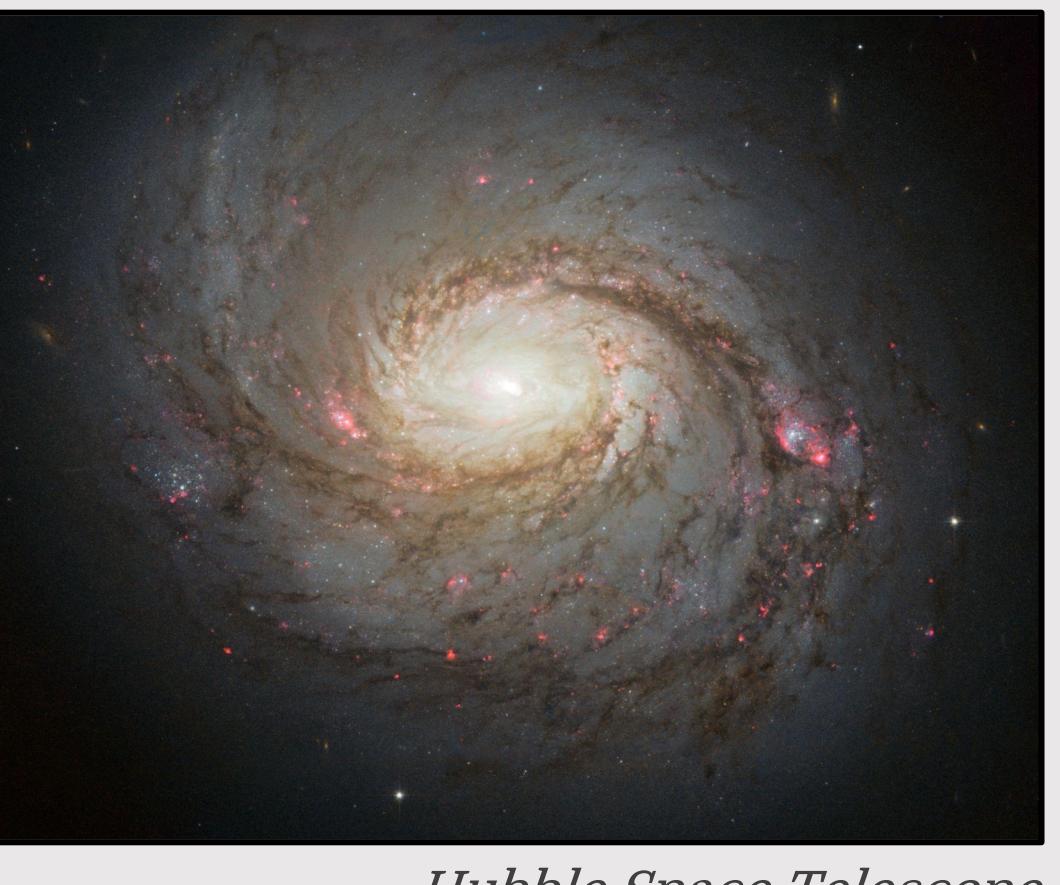
- A type of active galactic nuclei - powered by matter accreting onto black hole with a dense corona in the central region.
- Corona - region of hot gas surrounding accretion disk.
- Two types of Seyfert galaxies:



## NGC 1068

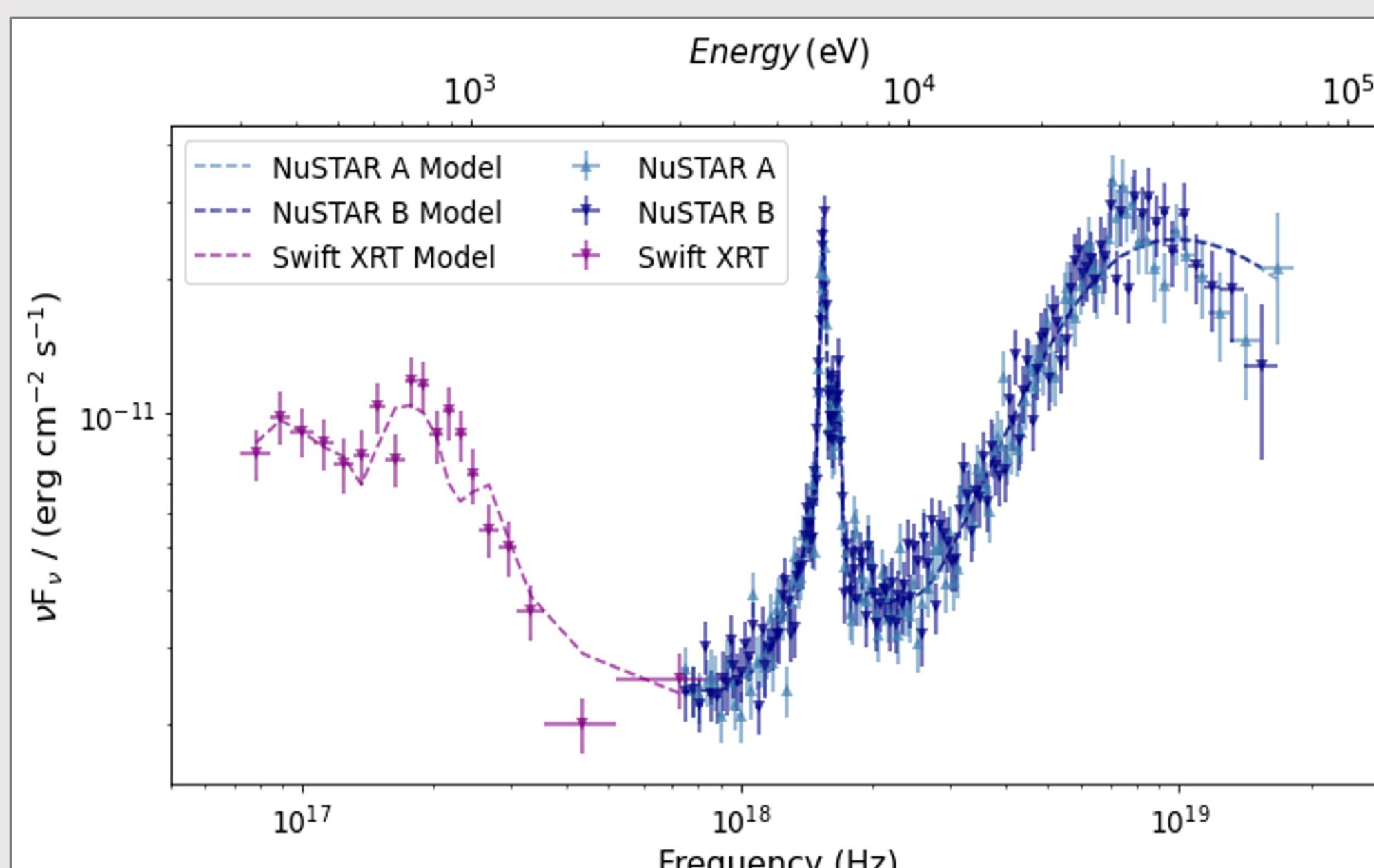
- NGC 1068 is a type II Seyfert galaxy.

- Has a jet of a kpc in length.
- Has a dense corona region.
- There is star formation in the spiral arms of the galaxy.



Hubble Space Telescope

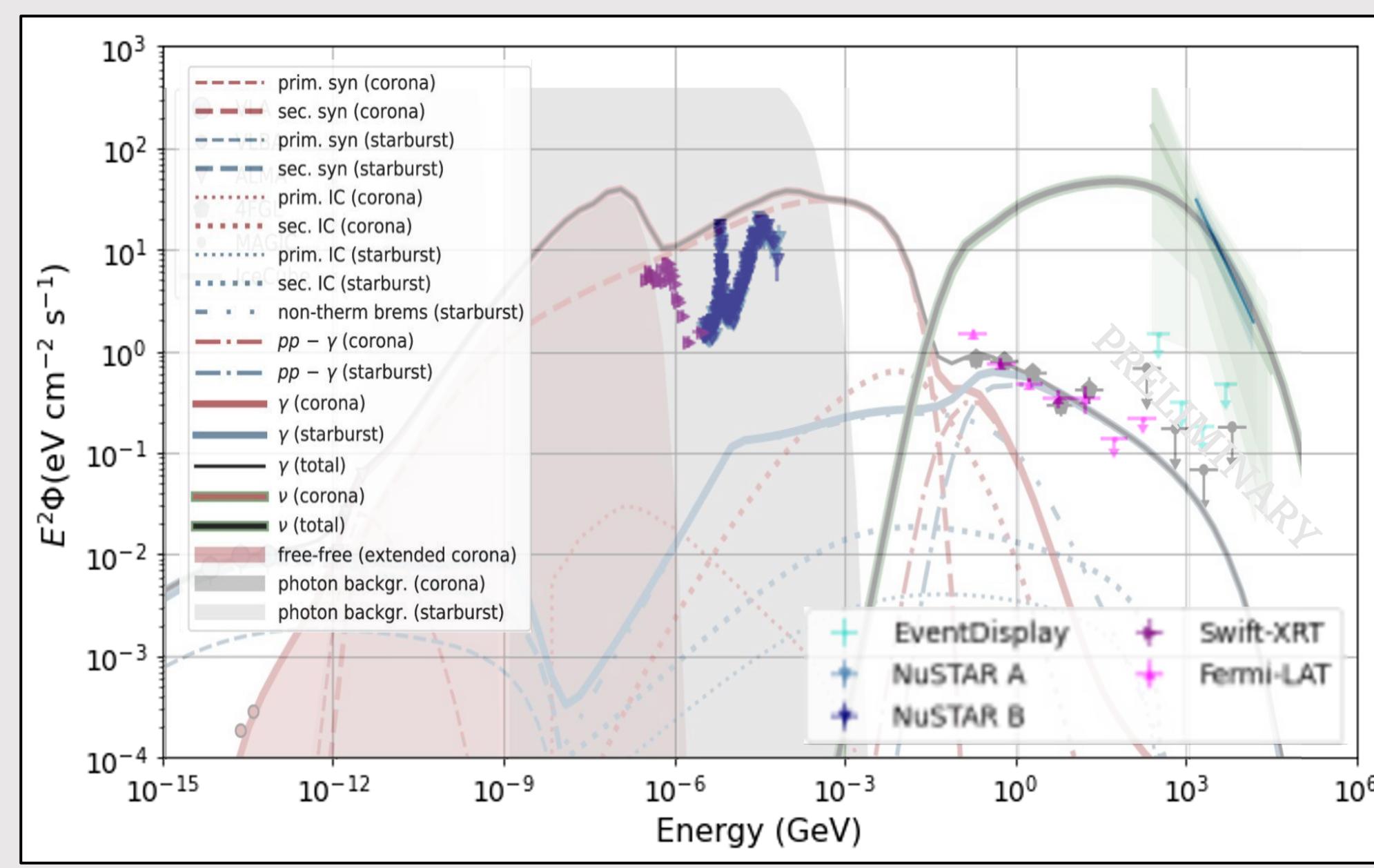
### NuSTAR and Swift-XRT Combined Spectra:



NuSTAR and Swift-XRT data observed on Jan. 23, 2024

- Model:** We used a disk-corona model with a relativistic reflection component, which takes in 29 parameters.

### Spectral Energy Distribution (SED):



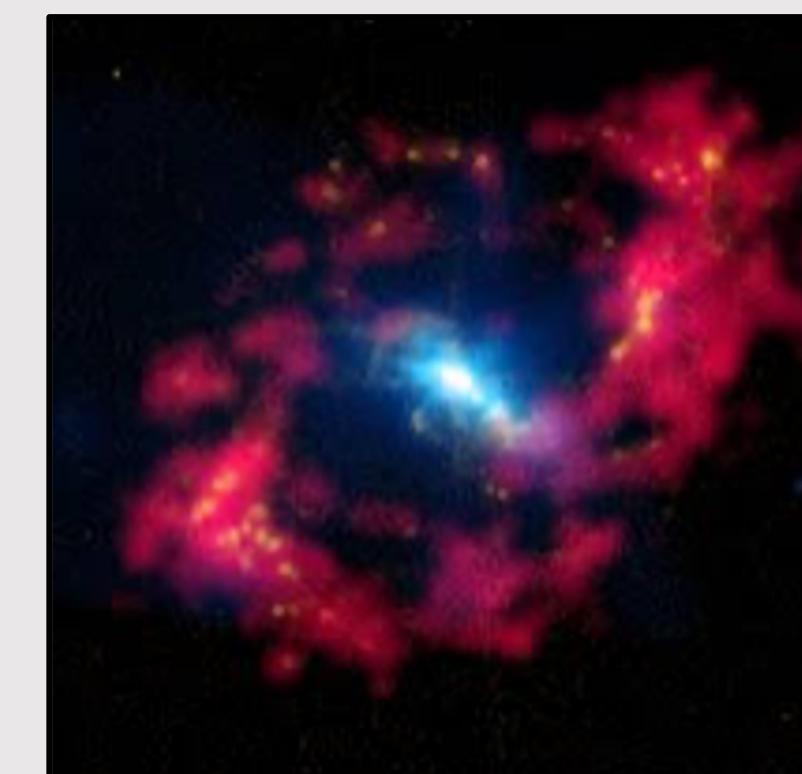
Eichmann et al. 2022

- The broadband SED including the NuSTAR and Swift-XRT spectra from this work and Fermi-LAT, VERITAS, and IceCube spectra.
- The high-energy neutrinos and the X-rays are both dominated by the corona emission and provide strong constraints on the corona model.

## NGC 4151

- NGC 4151 is a type 1.5 Seyfert galaxy.

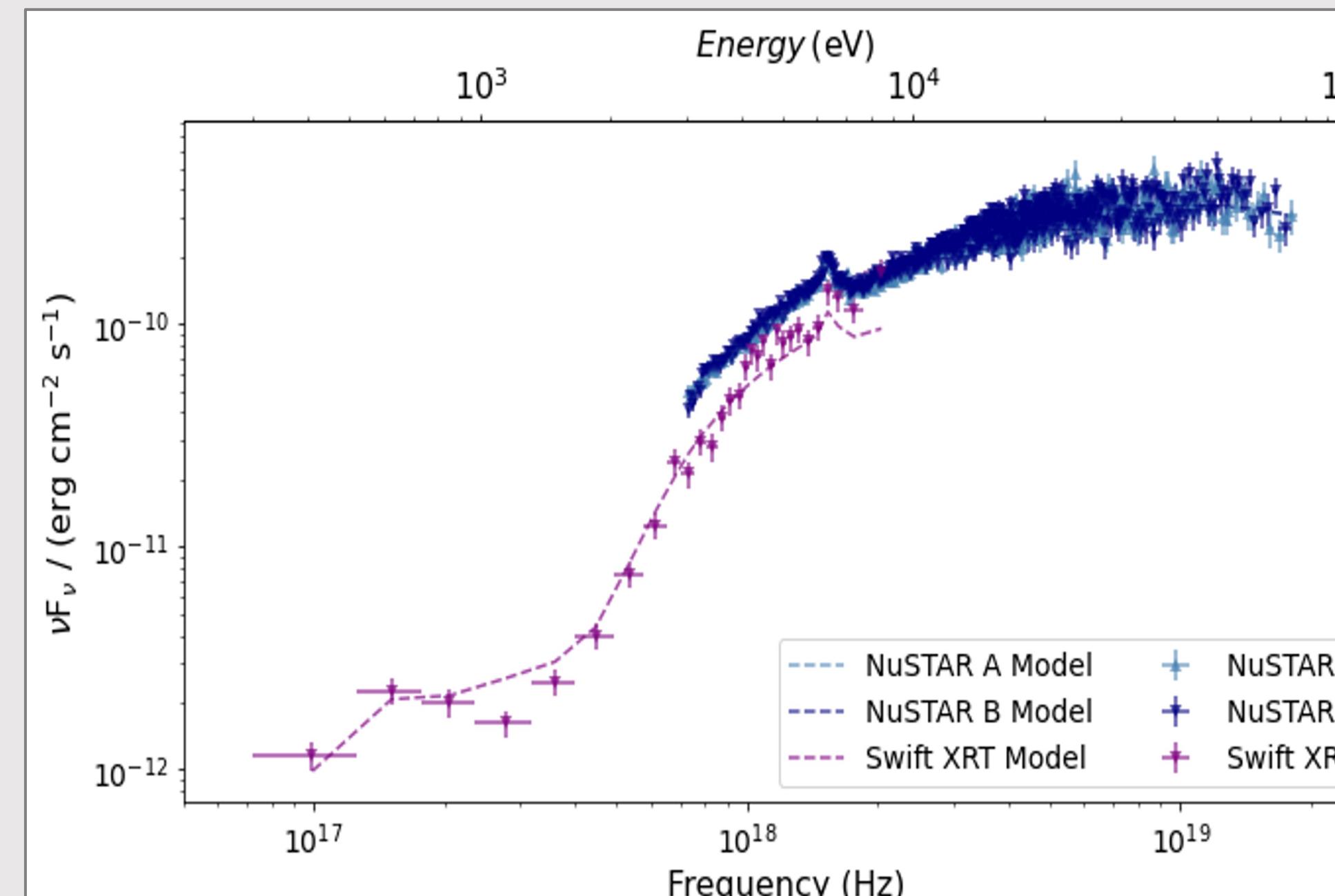
- Shows both broad and narrow emission lines, but the broad lines are less prominent than in Type I Seyfert.



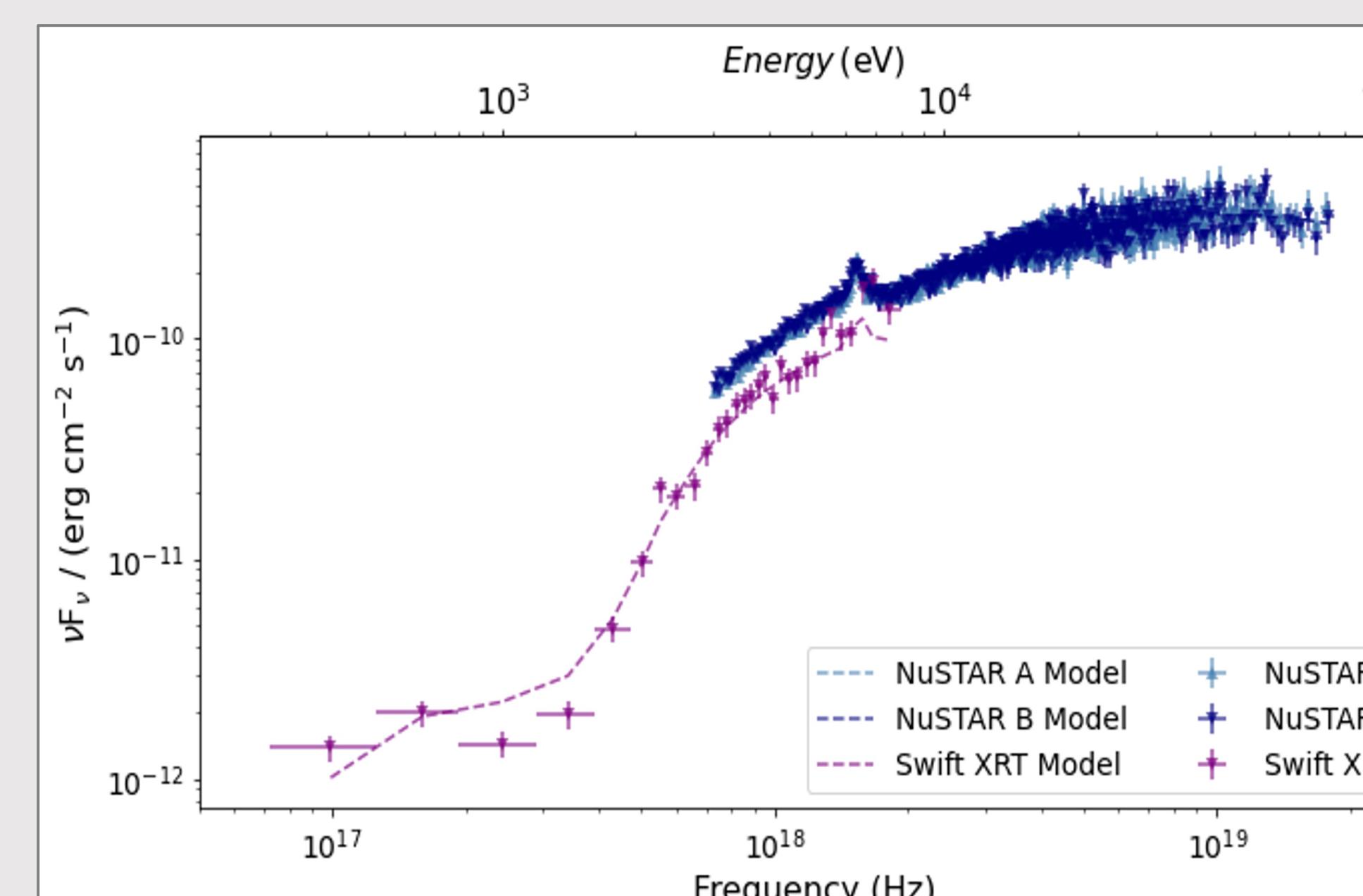
NASA/CXC/CFA/J.Wang et al.

### NuSTAR and Swift-XRT Combined Spectra:

- NGC 4151 is a variable source, so two different observations were analyzed.



Observation 1: NuSTAR data and Swift-XRT data observed on Jan. 10, 2020



Observation 2: NuSTAR data and Swift-XRT data observed on Jan. 23, 2020

- Model:** A very similar model to the one used for NGC 1068 was used to fit the NGC 4151 data.
  - Flux was measured for both observations and there is marginal evidence (~2 sigma) for 10% flux variability in the 13 day period.
- obs. 1:  $10^{-9.801 \pm 0.008}$  erg/cm<sup>2</sup>/s  
obs. 2:  $10^{-9.757 \pm 0.02}$  erg/cm<sup>2</sup>/s

## Conclusion

- X-ray data from NuSTAR and Swift-XRT for two candidate neutrino emitting Seyfert galaxies were analyzed.
- The data from both instruments were jointly modeled to provide a comprehensive view of the X-ray spectrum of the sources.
- A 29-parameter model was used to account for the complex innermost structure of Seyfert galaxies, which sufficiently agrees with the X-ray data.

## Future Plans

- The X-ray spectra and modeling in this work will be part of a VERITAS Collaboration publication, where TeV gamma-ray upper limits on NGC 4151 will be shown for the first time.
- The X-ray results will provide constraints on the interpretation of the emitting region and the underlying physics of these sources, and help understand the relation between the neutrinos, X-rays, and gamma rays.
- An estimate of the intrinsic X-ray spectra of NGC 1068 can also help constrain the theoretical model, which is above the observed X-ray spectrum.

## Acknowledgements

I would like to thank my advisor, Qi Feng, for giving me this opportunity and making this research experience so enriching. I also extend my appreciation to the U of U Physics and Astronomy program for making this possible. This project was funded in part by the National Science Foundation (NSF) award # 2349237.



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