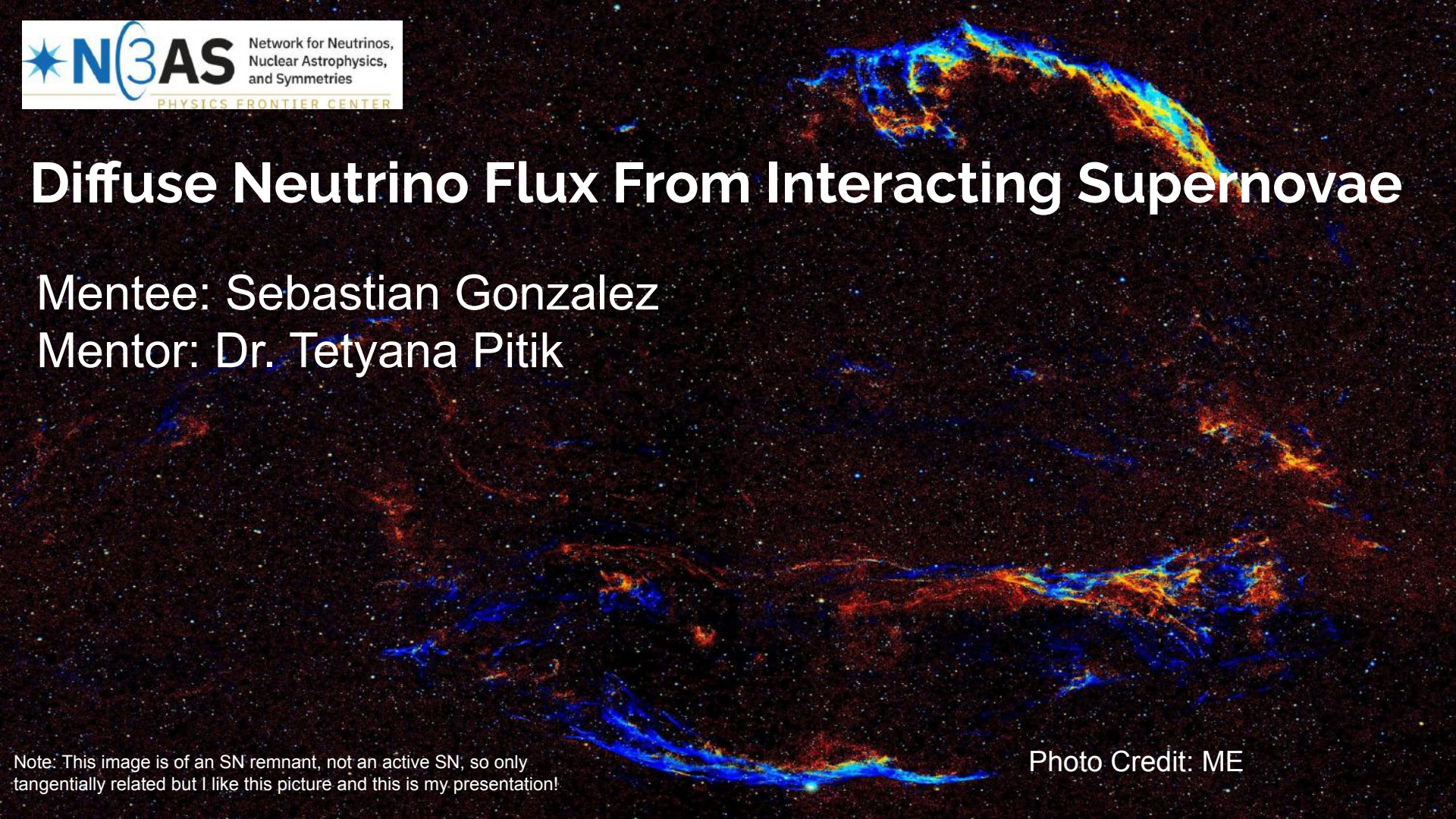


Diffuse Neutrino Flux From Interacting Supernovae

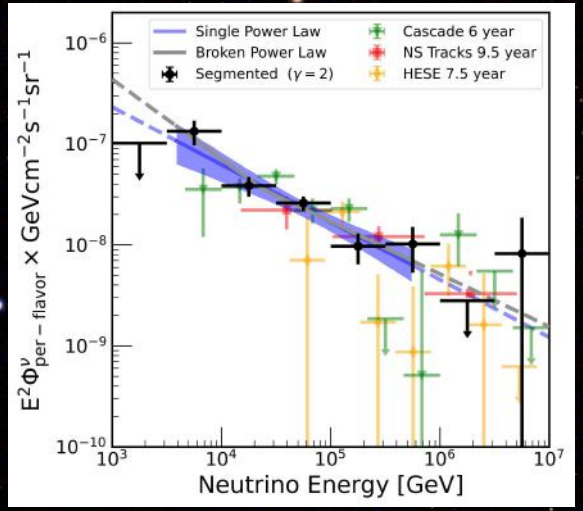
Mentee: Sebastian Gonzalez
Mentor: Dr. Tetyana Pitik

Note: This image is of an SN remnant, not an active SN, so only tangentially related but I like this picture and this is my presentation!

Photo Credit: ME

Motivation

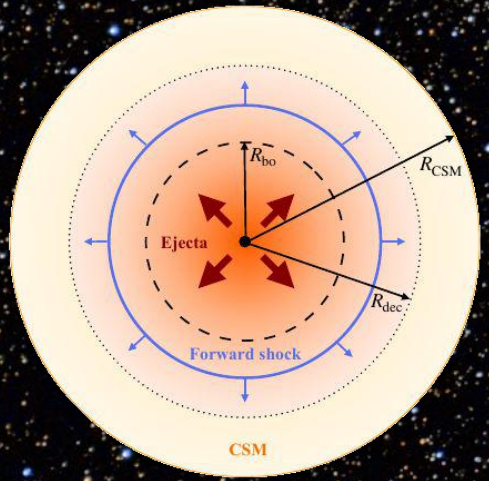
- Very massive stars unstable near end of life,create circumstellar material (CSM)
- Ejecta from Core-Collapse Supernovae (CCSNe) interact with CSM, strong extended interaction makes Type-IIn
- High-energy neutrinos and electromagnetic emission are produced by accelerated particles at shocks
- Large diversity in the parameters characterizing the ejecta and the CSM
- We build upon inferred parameters distribution to predict the emitted neutrino fluence over the history of the Universe



(Diffuse Neutrino Background from IceCube Collaboration)

Photo Credit: My hands, unfortunately not that relevant, but it would have been cool if it was because SN2023ixf happened in this galaxy, M101

Model for the Neutrino Production



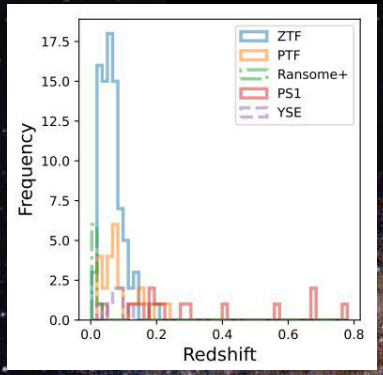
(From Pitik et al. 2022)

1. Shocks propagates through stellar envelope
2. Shock breaks out from the envelope (or optically-thick CSM)
3. Collisionless shock is decelerated by the CSM
4. Most loss is thermal, but some fraction of the energy goes into accelerating protons
5. Hadronic interaction of accelerated protons lead to the production of high-energy neutrinos

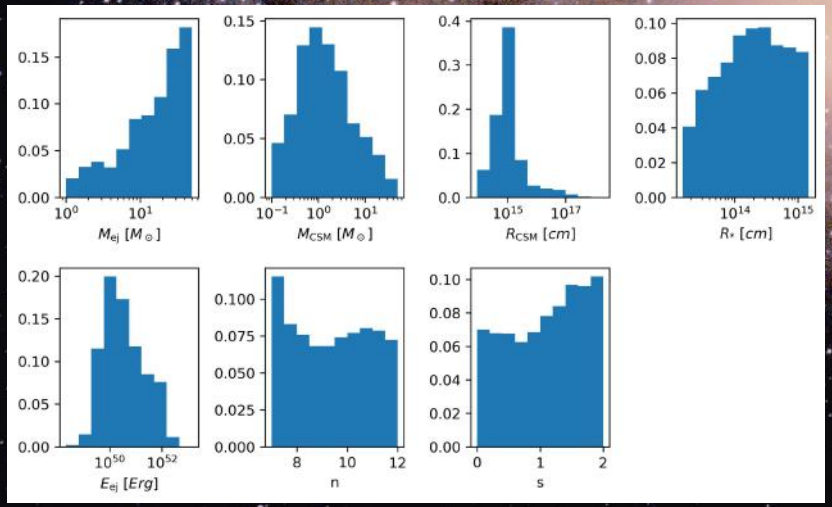
$$p + p \rightarrow X + N_\pi(\pi^+ + \pi^- + \pi^0)$$
$$\pi^\pm \rightarrow \mu^\pm + \nu_\mu(\bar{\nu}_\mu)$$
$$\mu^\pm \rightarrow e^\pm + \nu_e(\bar{\nu}_e) + \bar{\nu}_\mu(\nu_\mu)$$
$$\pi^0 \rightarrow \gamma + \gamma,$$

Photo Credit: Moi, a planetary nebula is almost like CSM, therefore the Dumbbell Nebula is relevant

Apply Model To Type-IIn SNe Population



(Figure from Ransome & Villar 2024)



- Input parameters drawn from MOSFIT samples constrained by 142 SNe (using DYNESTY) in Ransome & Villar (2024)
- Both ejecta and CSM properties are varied
- Currently only using a subset (10,000) of the 1,447,298 samples
- Special thanks to Numpy, Scipy, Cupy, and my GPU
- Parallel computing & mixed precision!
- Months -> Hours -> Minutes

Photo credit: Me again, Andromeda is relevant to stellar populations ok

SNe Event Rate

- Type-IIn SNe rate proportional to redshift dependent CSFR (cosmic star formation rate)
- $R_{IIn} = f_{IIn} \times k_{CC} \times CSFR$
- Scaling factors:
  - k_{cc}=0.0091 $M_{\odot}^{-1}$, CCSNe rate per solar mass formed (Strolger et al. 2015)
  - f_{IIn}=0.047, fraction of CCSNe that are Type-IIn (Cold & Hyorth 2023)
- f_{IIn} may vary with redshift
- CSFR produced by UNIVERSEMACHINE and constrained by observational parameters, from Behroozi (2019)

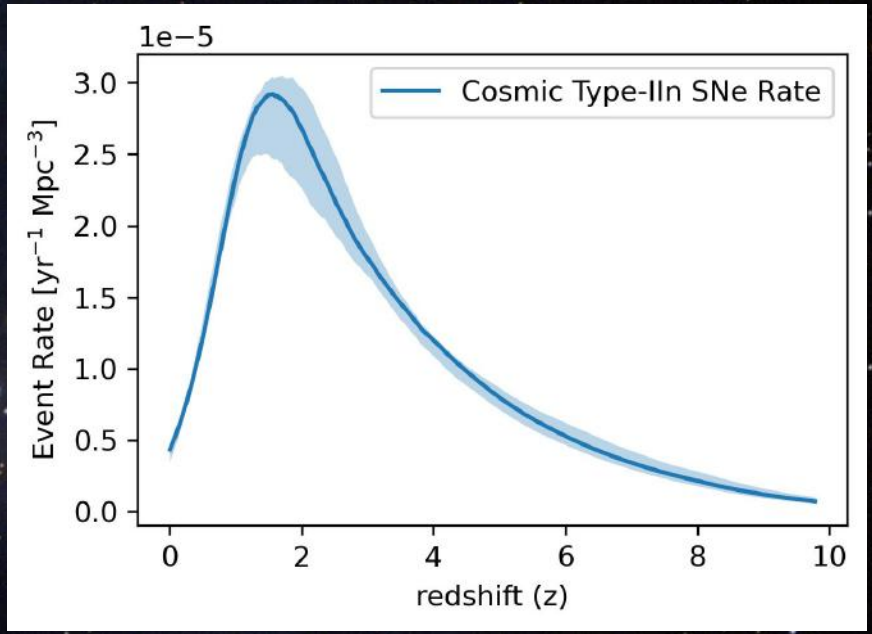
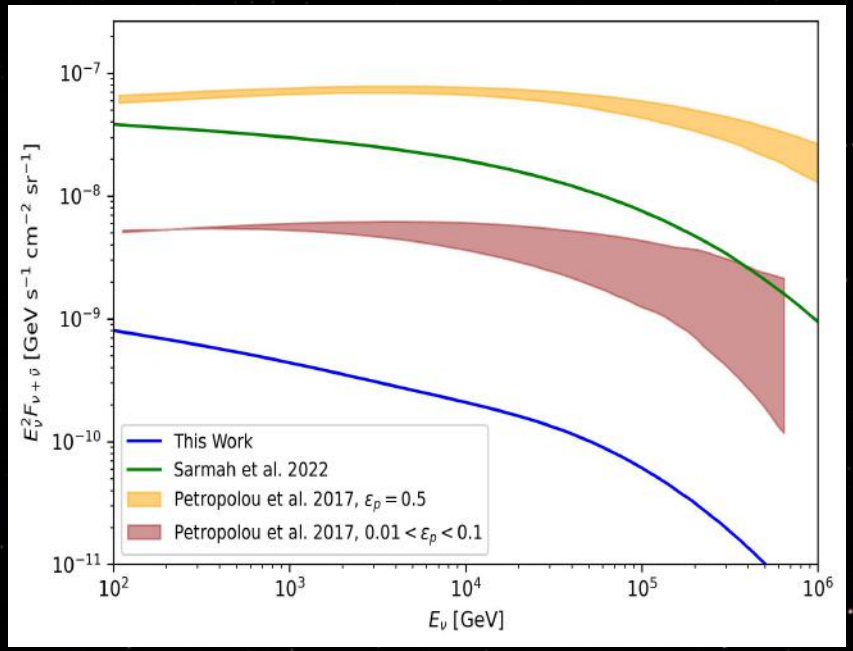


Photo Credit: Also me, this one is more related, the Orion Nebula (hidden in the background lol) is the closest star forming region to Earth

Results: Neutrino Diffuse Flux



$$E_\nu^2 F_{\nu+\tilde{\nu}} = E_\nu^2 \frac{c}{H_0} \int_0^{z_{\max}} dz \frac{R_{\rm IIn}(z) f_{\nu+\tilde{\nu}}(z, E_\nu(1+z))}{\sqrt{\Omega_\Lambda + \Omega_M (1+z)^3}} (1+z) d_c(z)$$

- R_{IIn}=density over comoving volume
- Lower estimate than previous works
- Possibly due to lower CSM radius and ejecta velocity estimates

Photo Credit: You will never guess who, galaxies are far, therefore the M81 group is relevant