SUPERNOVA NEUTRINO ESTIMATION FOR PRESENT AND FUTURE TELESCOPIC SURVEYS

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INTRODUCTION

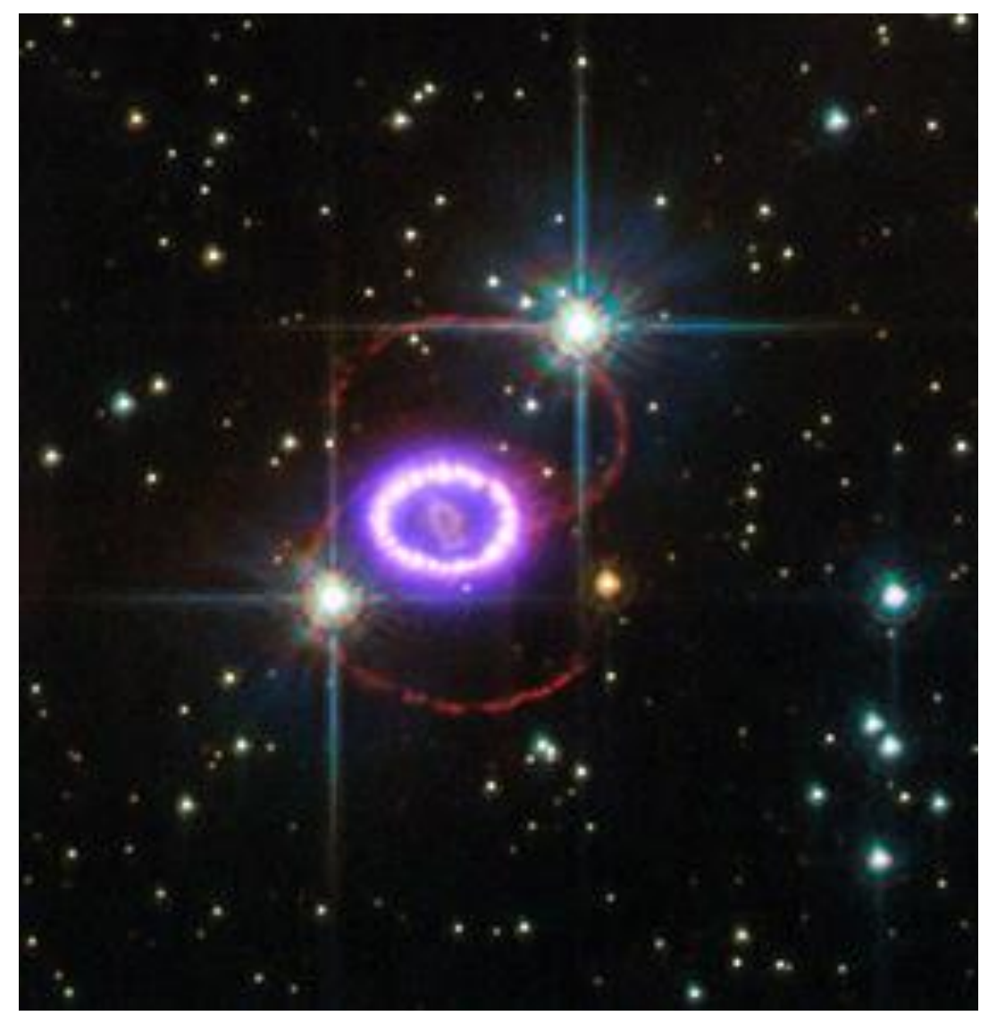

FIG. 1: SN1987A

Most massive stars will end their life with a violent explosion known as a core collapsing supernova. ~99% of the supernova's energy comes from neutrinos. These neutrinos will escape the core collapse before any photons and can give the time and direction of the explosion. Therefore, supernova neutrinos can serve as an early warning signal to astronomers. At present, there have only been approximately 20 neutrinos detected from supernovae, which all originated from SN1987A. Larger telescopes and detectors are currently being constructed that will increase the chance of finding neutrinos. Our goals of this project are to estimate the number of neutrinos from the All Sky Automated Survey for SuperNovae (ASAS-SN), and the Zwicky Transient Facility (ZTF) at the Hyper-Kamiokande (HK) detector, and predict the number of supernovae the Legacy Survey of Space and Time (LSST) will detect over a range of distances with the hopes of determining the best range of time and distance to find neutrinos.

CORE COLLAPSE

Core collapse supernovae are classified as types II, Ib, and Ic. A core collapse supernova happens when a star with a mass > 8 $M_\odot$ begins to fuse heavy elements in the star's core. Eventually, the core will try to fuse iron into heavier elements but will fail and cause the core to become so dense that it will collapse in on itself. During this process, thousands of neutrinos are produced through many ways such as **electron capture**.

$$p + e^- \rightarrow n + \nu_e$$

Neutrinos are then trapped and the core forms into a massive nucleus. This massive nucleus creates a shock wave that expands the core and releases neutrinos. Soon after the expansion, the shock wave will become stagnant, then turn into an accretion shock. During this phase, neutrinos react with protons and neutrons creating a massive amount of energy. This energy causes a shock revival, where the shock wave begins to expand outwards again. This shock wave results into a supernova.

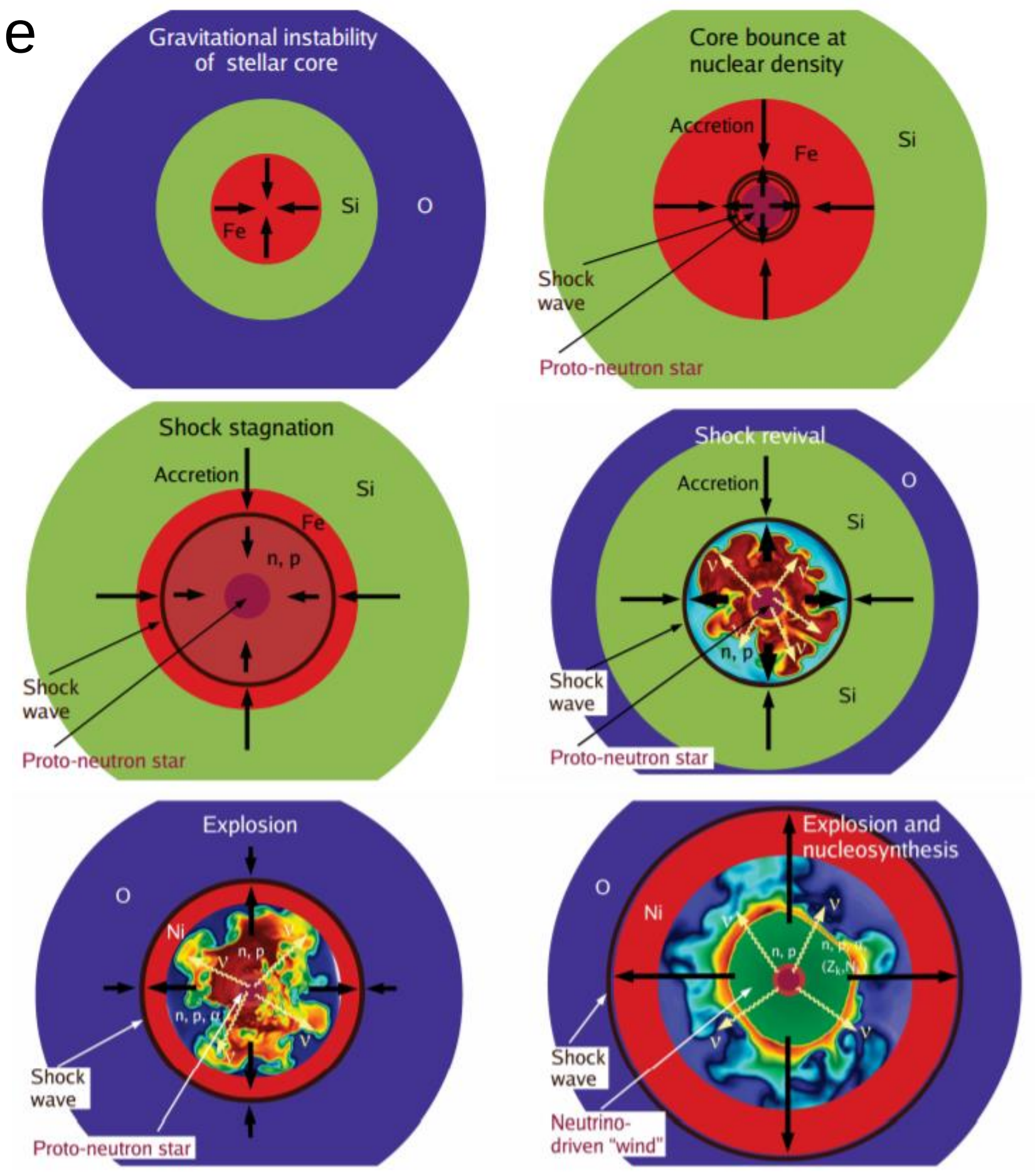

FIG. 2: Stages of a core collapse supernova explosion.

CURRENT SURVEYS

ASAS-SN and ZTF are on going surveys that look for new supernovae every day. We visualized the data from these surveys to gauge the importance of several factors.

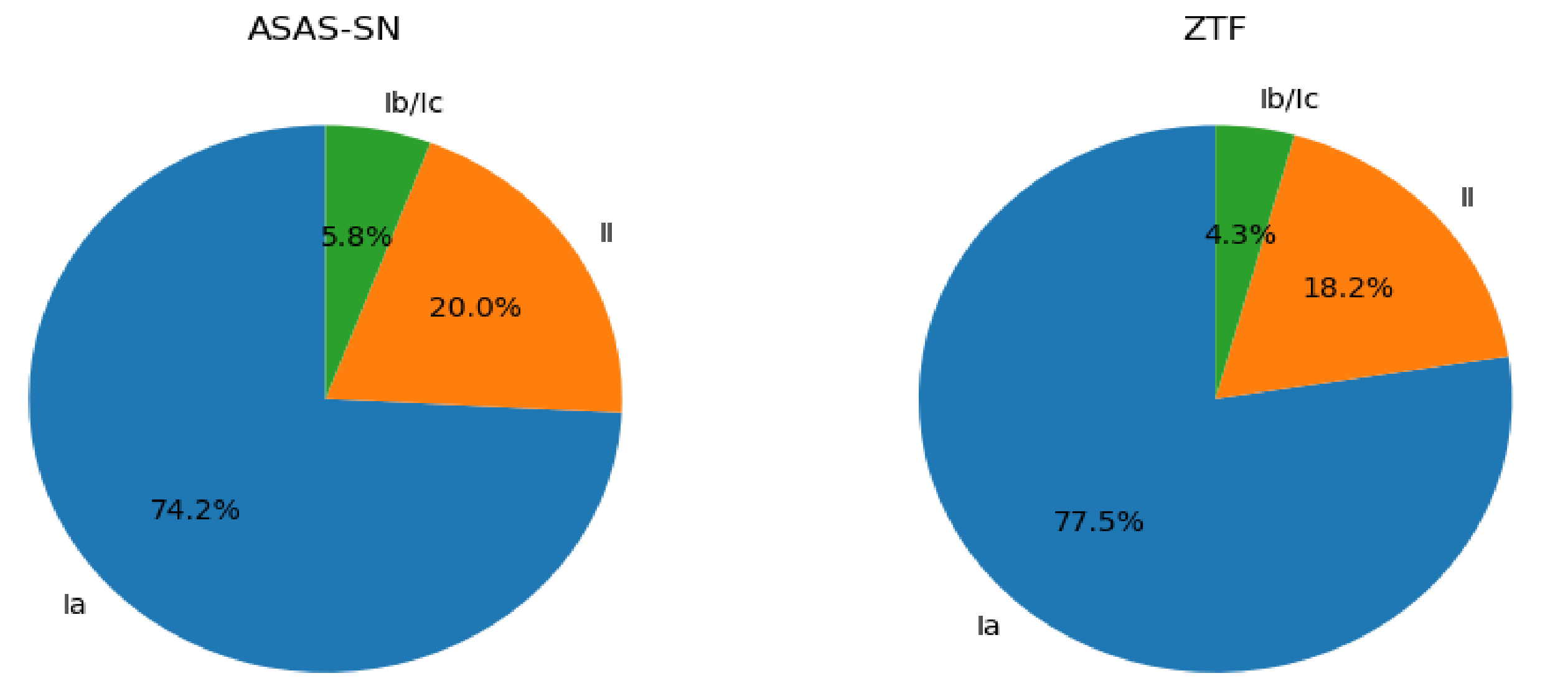

FIG. 3: Type breakdown of supernovae discoveries for both surveys

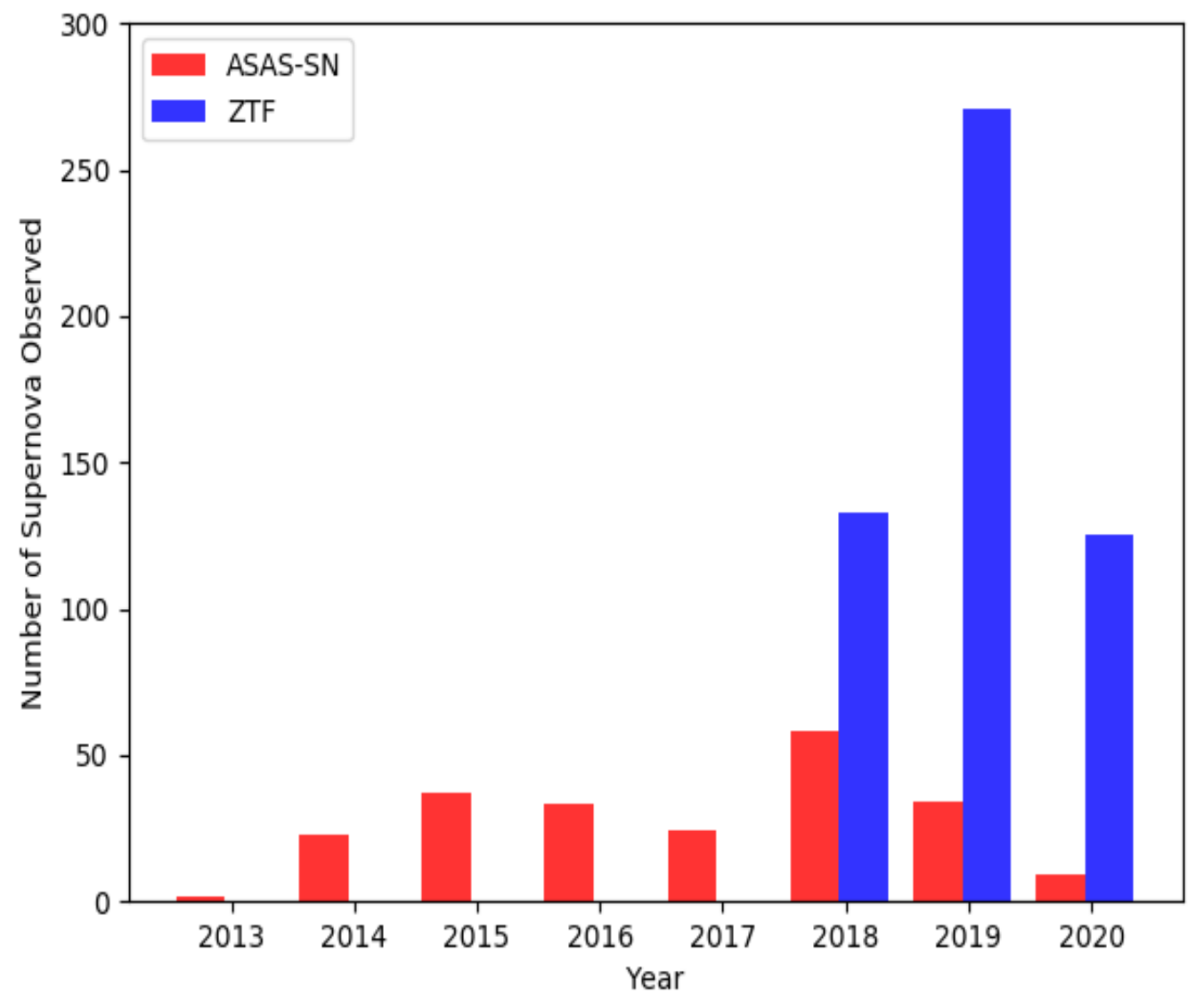

FIG. 4: Bar graph illustrating how many supernovae were discovered each year.

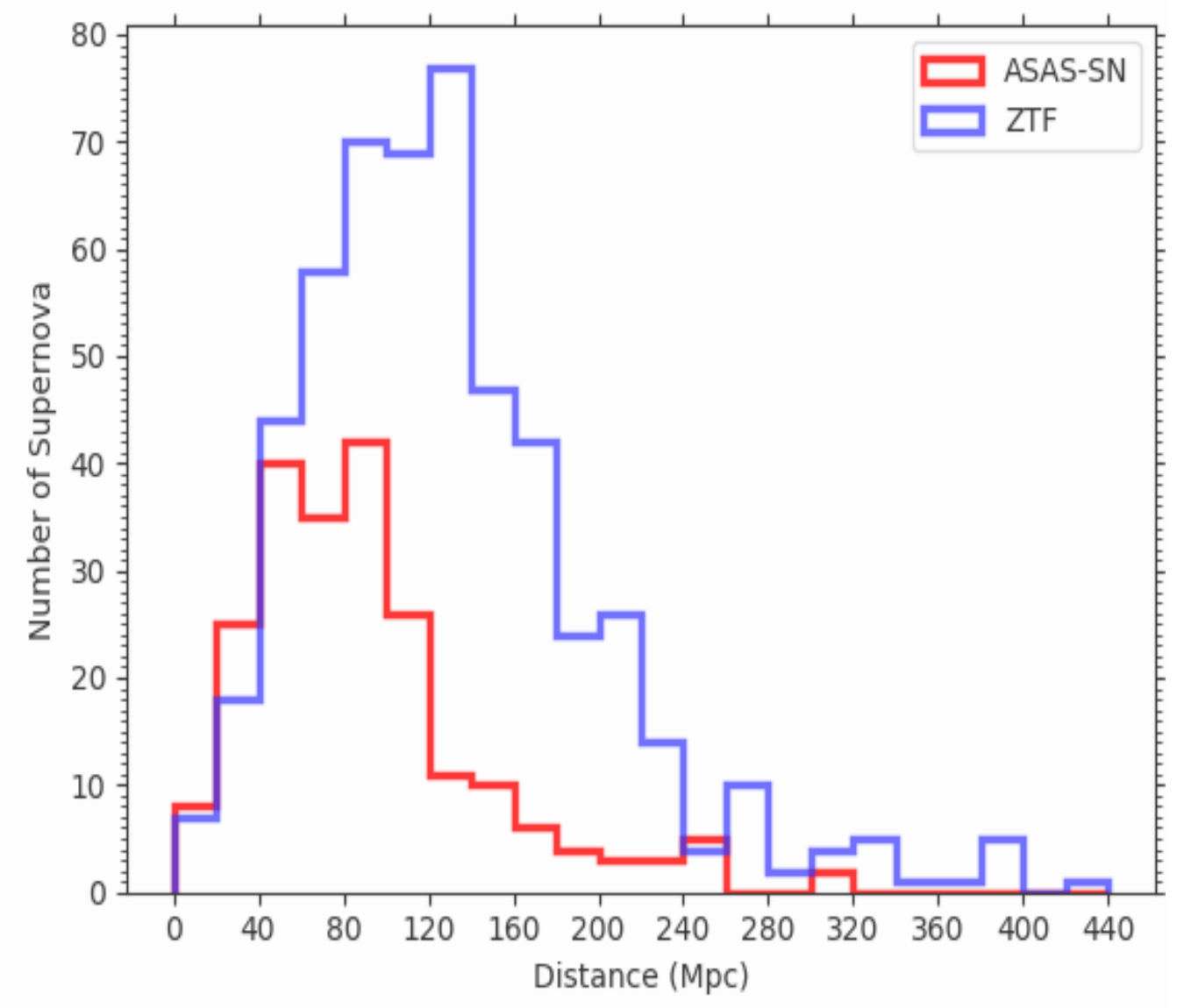

FIG. 5: Histogram with a bin width of 3 Mpc showing the distance distribution of the supernovae.

LSST

LSST is a future telescope survey that is predicted to be in full operations by 2022. The survey is planned to operate for 10 years at the Vera C. Rubin Observatory in Chile and will observe the entire sky every 3 nights. LSST is predicted to detect tens of thousands of supernovae every year, a huge improvement compared to current surveys.

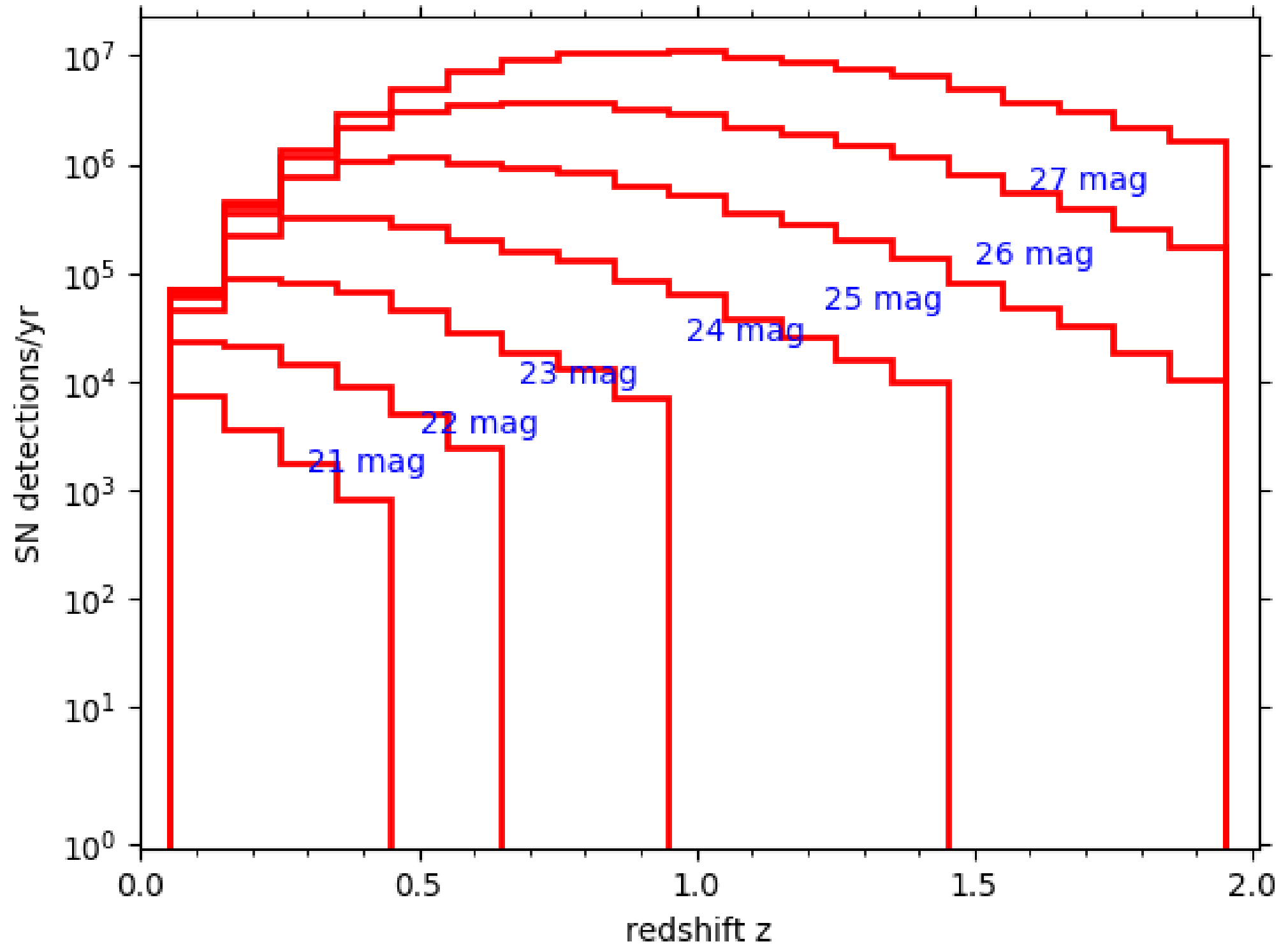

FIG. 6: Prediction of how many supernovae LSST will observe in one year over various limiting magnitudes.

BACKGROUND

HK is a detector that will be running soon and will be an order of magnitude larger than its predecessor Super-Kamiokande (SK). This larger size will allow it to be far more sensitive to neutrinos. These detectors also find various backgrounds. We have used the Diffuse Supernova Neutrino Background (DSNB) search at SK to estimate the background at HK.

ASAS-SN ID	Candence (days)	Background Events
ASASSN-16fq	4	2.62
ASASSN-19ml	3	1.97
ASASSN-16fp	6	3.93
ASASSN-16cc	2	1.31
ASASSN-18vc	4	2.62

TABLE 1: HK background rates for supernova that contributed the most to the neutrino rate. Data from SK-III was used.

RESULTS

The total number of neutrinos that could be detected at HK was 0.635 events from ASAS-SN and 0.649 events from ZTF. For LSST, we used a limiting magnitude of 24 and found that the total number of neutrino that could be detected in one year from HK was 12.2 events.

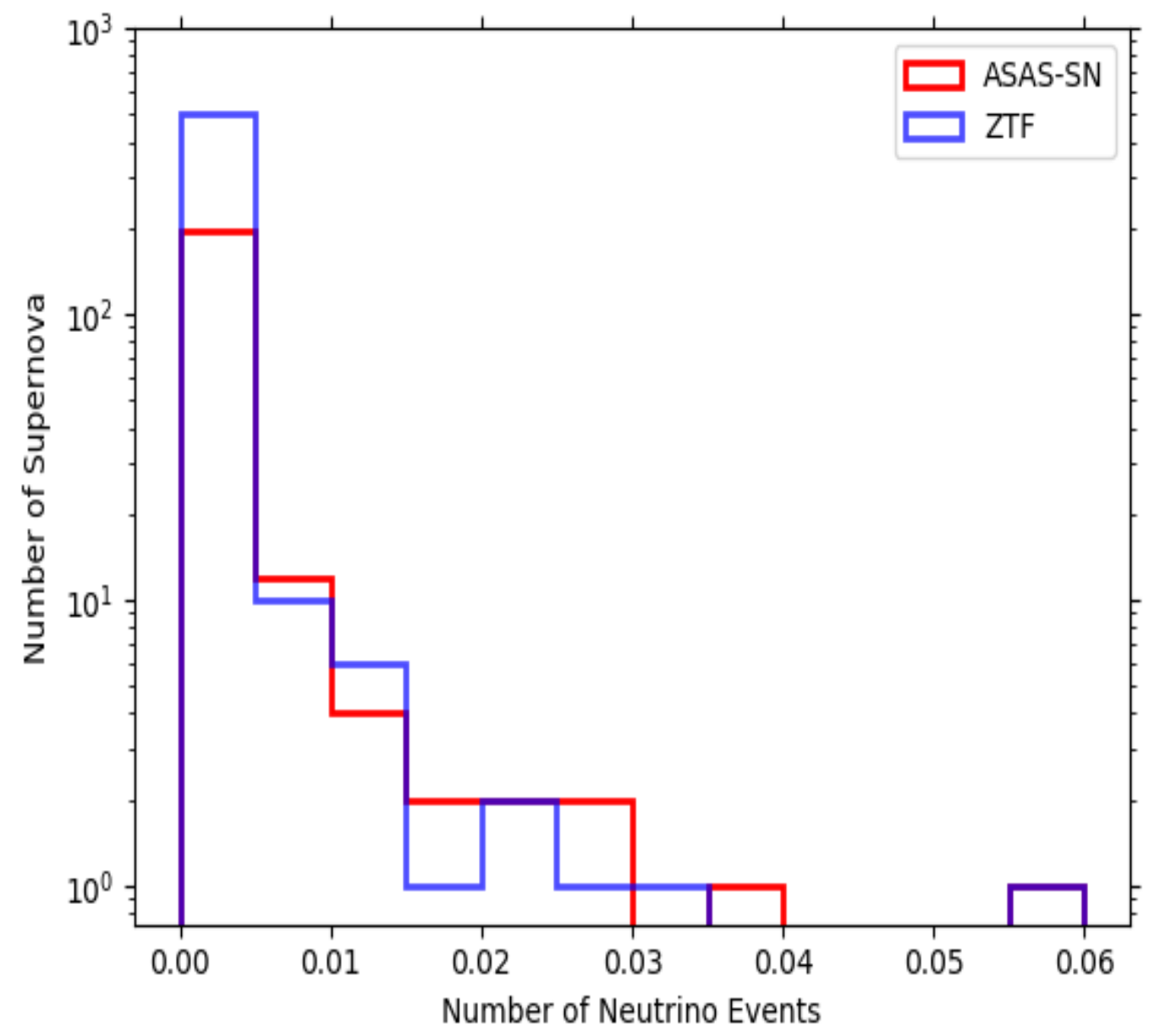

FIG. 7: Histogram illustrating neutrino event distribution from both on-going surveys with a bin width of 0.05 neutrino events.

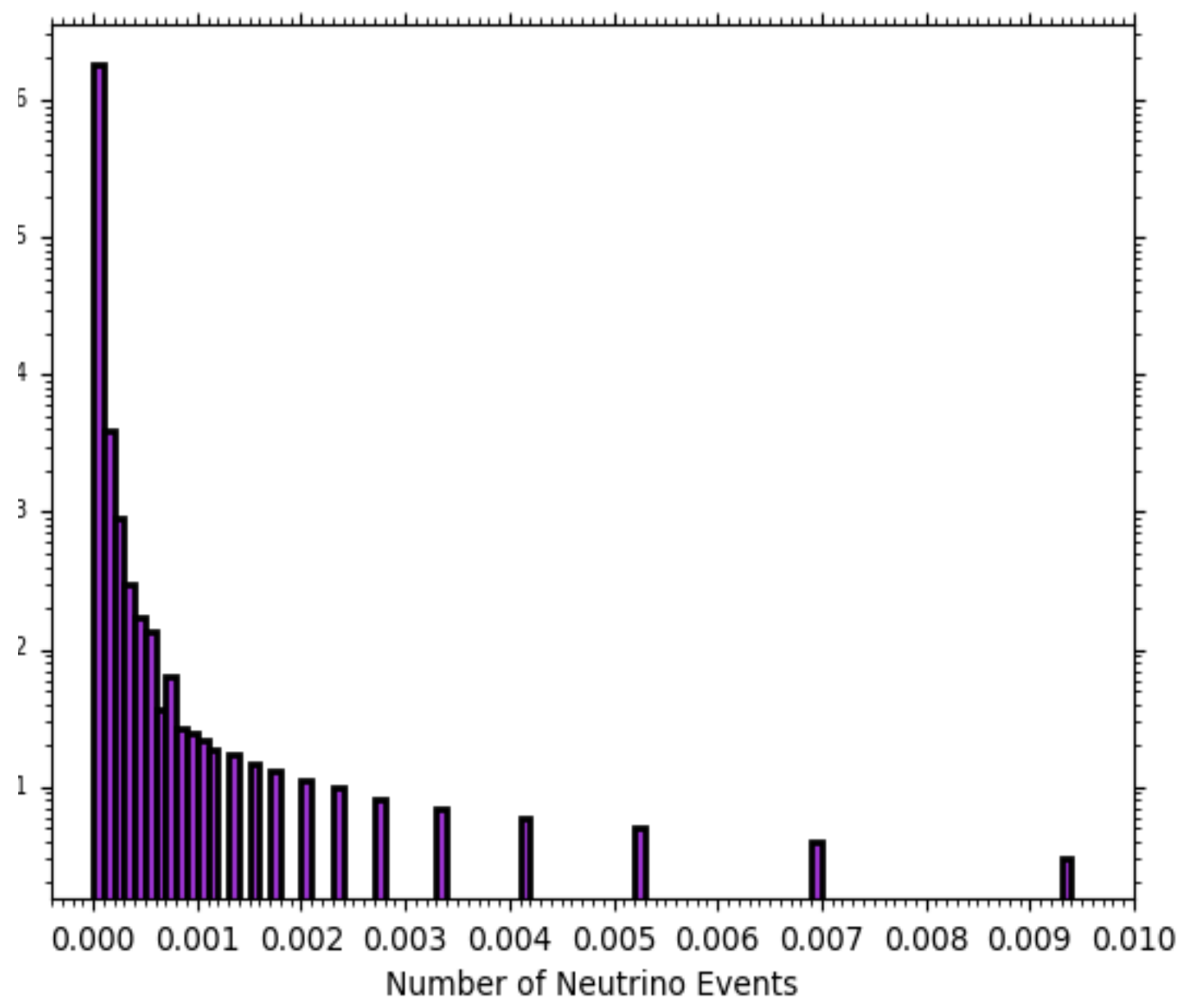

FIG. 8: Histogram illustrating neutrino event distribution for LSST with a bin width of 0.0001 neutrino events.

CONCLUSION

Our neutrino estimations for ASAS-SN and ZTF show promising outcomes because they are much higher than we anticipated. In the future, we hope to better estimate the number of supernovae LSST will detect each year, which will lead to better neutrino estimations. Furthermore, we want to better examine the neutrino background rate LSST would experience. This would lead to determining the best strategy to find neutrinos.

REFERENCES

[1] K. Bays *et al*. Supernova relic neutrino search at super-kamiokande.PhysicalReview D, 85:052007, 2012.
[2] Amy Lien and Brian D. Fields. Cosmic core-collapse supernovae from upcoming sky surveys. , 2009(1):047, January 2009.
[3] Kate Scholberg. Supernova Neutrino Detection.Annual Review of Nuclear and Particle Science, 62:81–103, November 2012.
[4] Kris Stanek. What is asas-sn?, Jan 2020.
FIG 1 image credit to X-ray: NASA/CXC/PSU/S.Park & D.Burrows.; Optical: NASA/STScI/CfA/P.Challis)
FIG 2 image credit to H. Thomas *et al*. Core-collapse supernovae: Reflections and directions, 2012.

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