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Nearby Supernova Rate Introduction

An area of interest that has developed recently is supernovae that form close to Earth, pioneering a new vein of research. Near-Earth Supernovae are ccSN (core collapse supernovae) that occur close to Earth, with the “kill distance,” the minimum safe distance for a supernova to explode from earth, being ~10 pc.

1. Why do we care?

Understanding how near-Earth supernovae occur and comparing them to other regions of the galaxy can give us an example of how real the supernova threat to Earth itself is, and how dangerous other parts of the galaxy are, i.e. the bad neighborhoods. It also tells us the uniqueness of Earth’s position in the galaxy, allowing researchers to understand whether our planet’s supernova situation is common or much more unique. Learning about our particular uniqueness gives insights into the uniqueness of the Local Bubble, the remnants of an unknown number of supernovae that form the cavity in the interstellar medium that the Earth is part of. Knowing the uniqueness of our location can tell us what we are likely to find in other areas of the galaxy. If we find that supernovae played a part in the development of life on Earth, calculating the rates in the other parts of the galaxies can give a contributing factor when mapping out the habitable zone of the galaxy, those locations where life is possible to have formed, narrowing down clues to where other lifeforms may exist.

Nearby supernova rates are important to Earth, as it is possible that near Earth supernovae may have played a role in the development of life on Earth, possibly depositing essential minerals on the planet that allowed life to form, or mutate into its current forms. It has been speculated that even for the lower limit of radiation from the supernova explosion, genetic mutations and deaths can result in species such as mice and other lab animals. Other animals may have been affected through radiation build up in fauna, as plants are the source of food for a great majority of animals, those prey animals affecting the predators through the radiation they consumed and so on (Krassovkjj, Sklovskjj 1958).

On the other hand, the same supernovae may have played a role in the mass extinctions on Earth. Although it was explained that a supernova most likely did not cause the extinction of the dinosaurs (Alvarez, Alvarez 1980), the Cretaceous-Palogene (KT) extinction may have been caused by a supernova. Studying the rates of near Earth supernovae can give insights into the history of earth, and ultimately the history of the galaxy. If a supernova explodes too close to Earth, the ozone layer could be wiped out, causing mass extinctions through the eradication of this essential layer, not even direct effects from the supernova itself. Supernovae as close as 15 pc can significantly damage the ozone layer, even increasing the cosmic ray influx by 40 times for 80 years. This can result in a rate of the Earth’s surface radiation increase of 1 [roentgen/yr]or 2.28x10-4 C / [kg\*yr]. The depletion of the ozone layer would cause increased mutations in deadly bacteria and airborne viruses infecting small insects and their hosts. However, this would have a larger effect on day species, as these are larger animals that would be exposed much longer to the unobstructed UV light, causing an increased Vitamin D production (Rudderman 1974).

1. Background from past works

Previously, rate calculations focused more on the whole galaxy, while ours narrows it down to specific areas in the galaxy, with the goal to make a roadmap of the supernovae that explode in the galaxy over time. The most general approach is to approximate the galaxy as a uniform disc, taking a small spherical volume away from the edges as the dV, volume of space that concerns the observer. In one such calculation, as indicated in Terry and Tucker’s 1968 calculation, the rate is based on the amount of neutral hydrogen that is involved in the supernova density curve, approximating that 1% of this is within the volume considering Earth. The rate of supernovae was found as: N(R, R0, t) = 2\*10-12 ft, where f is the frequency of 0.02 [yr]-1, and time is in years. This result indicates that one supernova explodes in the galaxy every 50 years. However, limitations for this rate calculations are quite extensive, as the parameters for these calculations were largely unknown. The frequency and radiation from the supernovae were both unknown, making this calculation highly errored. However, the method used was rather insightful, despite using estimates for the values (Terry, Tucker 1968), and it is possible to build more precise rate models for the near-Earth supernovae.

1. Influence of 60Fe

With the knowledge that the Earth does not naturally produce 60Fe, finding this metal on the surface of the planet can give an insight into previous supernovae whose remnants have been close enough to encounter Earth. Using samples from the ocean floor, layers of 60Fe can give insight into the supernova time scales. Like tree rings, counting the number of sediment layers can tell us how long ago the supernova occurred. 60Fe that has recently been discovered is giving researchers two spikes, in the data, indicating that two different supernovae had to have impacted Earth in the past. Using this knowledge, previous rate calculations are worth revisiting, since there is now a number to compare them to. Using more precise rate calculations, the next time a supernova will encounter Earth can be revisited.

1. Introducing more precision

Using the same starting point of approximating the galaxy as a disc and the affected area as the volume of a sphere, we found a rate of supernovae based on the global supernova rate of 3 SN/Myr depending on the radius of the sphere. We made the calculation more precise by including supernova clusters, with an average of 10 SN/cluster. Narrowing down the calculations for an inhomogeneous galaxy, using the double exponential distribution of stellar mass throughout the galaxy found in Adams et. al. 2013 is the next inclusion of precision into the calculation. Defining a rate density, that is, how the rate changes depending on the location in the galaxy and finding the supernova rate, ΓSN(D; R, z) inside a sphere of radius D, centered on the point (R,z) is the next step in our measurements.