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Why Should We Care About Exploding Stars?

This spring the attention of astronomers around the world has been focused on a *supernova* — an exploding star — that has become visible in one of the companion galaxies that accompany our own Milky Way. Now officially called *Supernova 1987A*, the explosion in the relatively small irregular galaxy called the Large Magellanic Cloud is the first supernova to be visible to the naked eye since the great astronomer Kepler saw one in 1604.

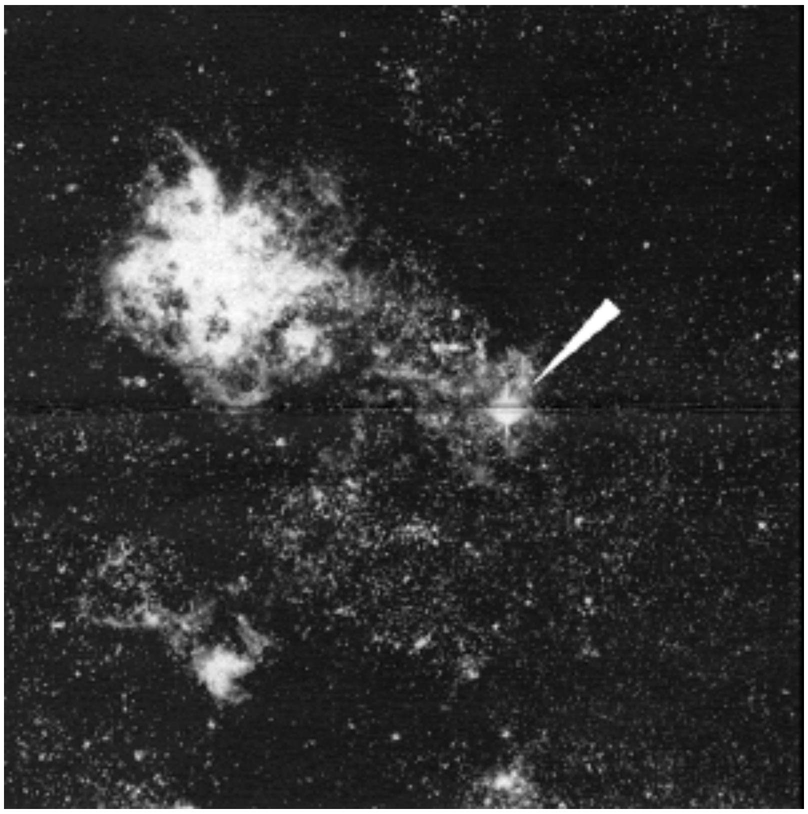
(The Large Magellanic Cloud is approximately 170,000 light years from us, which is an enormous distance in human terms, but really just the local neighborhood on the scale of the universe. It and its nearby companion, the Small Magellanic Cloud, are so named because Magellan and his crew were the first Northern Hemisphere inhabitants to record their existence. They are only visible from the Southern Hemisphere, which means the supernova cannot be observed by students or astronomy buffs in North America.)

While astronomers detect a number of supernovae in distant galaxies each year, 1987A is the first exploding star in modern times that is close enough, bright enough, and was caught early enough to permit detailed and intense scrutiny. Astronomers from around the world have flown to the Southern Hemisphere or adjusted telescopes aboard Earth-orbiting satellites to observe this long-awaited yet unpredictable event. Even the Voyager 2 spacecraft — on its way to a Neptune rendezvous in 1989 — has been instructed to make some measurements of 1987A.

Since this is a rapidly changing story, we cannot cover all the fast-breaking developments about the supernova in a quarterly newsletter like this one. (The Resource Corner in this issue does suggest where you can go for current and background information.) Instead, we would like to answer the question that many teachers and students are surely asking: why is such a fuss being made about a star that exploded so far away from the Earth and (because its light took some 170,000 years to reach us) so long ago?

Although the behavior of this supernova is already a bit different from what astronomers expected, it appears to be the sort of explosion that ends the life of a single star significantly more massive than our own Sun.

There are at least three reasons why scientists are so interested in these exploding stars and why "supernova'' should be a household word for any student who cares about cosmic history and the origins of humanity. Astronomers today believe that a large fraction of the atoms in our bodies were once inside stars that became supernovae, and that they were "launched'' into the universe when these stars exploded. Furthermore, we believe the explosions of supernovae have flooded the Galaxy with high-energy radiation that probably contributed to the radiation background that produces mutation and drives the evolution of life on Earth. Also, in recent years, we have found intriguing evidence that the formation of our own solar system may well have been triggered by a nearby supernova more than five billion years ago. Let's look at each of these connections in more detail.



Supernova 1987A on February 27, 1987, just four days after It was first seen. The supernova is the brightest star in the picture, just right of center (arrow). (The "rays'' emanating from it are not real; they are due to an optical effect in the telescope.) The large, wispy cloud to its left is the "Tarantula Nebula,'' a concentration of young stars and gas. (Photograph by and courtesy of the European Southern Observatory, La Silla, Chile.)

One of the great questions in modern science has always been the origin of the elements. All our theories about the origin of the universe predict that the cosmos should have begun with only the very simplest atoms. Where, then, did the more complex elements such as carbon? calcium, iron, and gold come from? The only sites in the universe where it is hot enough to *transform* light elements into heavier ones is in the centers of stars. Inside the Sun and other stars the temperatures can reach many millions of degrees. But just *producing* heavier atoms is not enough to explain their presence on Earth and elsewhere — the elements "manufactured'' inside stars must then have a way to reach the rest of the universe.

Here is where supernovae come in. Smaller stars like our own Sun live and die in relative peace. But the most massive stars become unstable at the end of their lives and explode in a sudden burst that can propel as much as 90% of their material out into space. The elements such stars make during their lives are thus "recycled'' into the cosmos and become part of the raw material available for making new stars, new planets, and, perhaps, even new astronomy students.

Furthermore, the violence of the supernova explosion can produce even heavier elements than the star was able to make during the quieter phases of its life. We believe that the heavier elements we take for granted on Earth — elements such as gold, platinum, or uranium — are all made during the brief, but intense cataclysm that destroys the most massive stars.

Because of the enormous violence of the supernova explosion, the material it produces — in the form of individual atomic nuclei — can be propelled into space at speeds approaching the speed of light. These particles travel onward and outward and over the eons can spread over vast distances. As billions of years pass and many millions of supernovae explode, each galaxy of stars (including our own Milky Way) begins to have a substantial "background'' of high-energy particles whizzing through every part of it. Before we understood where they came from, physicists gave these particles the somewhat misleading name *cosmic rays.*

Cosmic rays are thought to be — along with the radioactive rocks of the Earth — a main cause of *mutations*, the changes in the genetic code in living things that lead to the evolution of the species. By the law of averages, over the five-billion-year history of our solar system, a number of supernovae must have gone off in our Galaxy close enough to our location to flood the Earth with a larger than usual number of cosmic rays and high-energy radiation. The flow of these high-energy particles may well have accelerated the rate of change in living things and helped speed up our advent among the creatures that inhabit our planet.

Finally, just in the last few years, some intriguing evidence has accumulated that a nearby supernova may have helped "kick off'' the events that lead to the formation of our Sun and its planets. One of the unsolved problems in astronomy is the question of what induces a particular clump of cosmic raw material at some particular time to form a new star (and, we believe, sometimes an accompanying planetary system). One suggestion has been that the shock of an exploding star may compress raw material in its cosmic neighborhood and give it the extra little "kick'' it needs to collapse into new stars. If this theory is correct, and we can find some of the *primordial* (unchanged) material from which our solar system formed, we may be able to find in it traces of the explosion which gave it a push.

In the last decade, specialists in extraterrestrial chemistry have made very careful analyses of the composition of ancient *meteorites* — chunks of rock which fall to Earth from space and are thought to have formed at the beginning of our solar system. Much to their surprise, the scientists have found several unusual forms (or isotopes) of elements that are, in a sense, the fossilized fingerprints of supernova explosions. The abundances of these unusual elements seem to bear silent witness to the fact that a supernova must have gone off *quite close* to the cloud of raw material from which our solar system originated and only a few million years (a very short time in terms of star formation) before the cloud began to coalesce. It is interesting to speculate that this explosion may have provided the basic impetus for our Sun and planetary system to form.

In any case, it does seem clear that supernovae have an intimate connection with the conditions that led to life on Earth. The intensity with which astronomers are now studying the supernova in the Large Magellanic Cloud reflects more than an abstract interest in cosmic violence. It results from a well-justified fascination with how the universe provided the conditions necessary for our existence and a very human impulse to trace our "cosmic roots'' as far back in time as our intellect and instruments permit.

Watching Meteor Showers

As the Earth orbits around the Sun, our planet periodically "runs into'' streams of small bits of ice and rock which also orbit the Sun. These swarms of small particles are thought to be little pieces of comets which still follow their parent comets' orbits around our star. When Earth glides through such a swarm during our yearly path around the Sun, we experience a "meteor shower.''

What is A Meteor?

When small bits of natural interplanetary debris strike the highest layers of Earth's atmosphere, they burn up rapidly due to friction (since they are generally speeding along at tens of kilometers per second.) As they burn through the thin air, usually 60 to 100 kilometers above the ground, they create luminous streaks that we call **meteor**. (These are popularly called "shooting stars'' or "falling stars'' — but of course they're not stars at all.) Very rarely does a chunk that produces a meteor actually make it all the way to the ground without vaporizing completely; such rare remnants are called "meteorites''.

Under the ideal viewing conditions afforded by a clear, dark sky, a patient naked-eye skywatcher can generally see about seven randomly-scattered meteors per hour; these isolated events are due to random "vagabond'' small pieces of cosmic debris. However, when we swing through a stream of comet dust and experience a meteor shower, the average rate of visible meteors can approach one per minute.

What Does a Meteor Shower Look Like?

Even at a rate of one meteor per minute, such an event isn't exactly a sky show to rival the rededication of the Statue of Liberty. Instead, the meteors of a shower are generally swift, faint, silent streaks on the sky, lasting only a fraction of a second.

All of the bits of debris that make up a meteor shower speed along parallel to one another. This means that a meteor shower's trails (if extended backward in the imagination) will all appear to originate at one point on our sky. (In the same way, parallel railroad tracks or a flock of migrating geese appear to emanate from one point on the horizon.) Meteor showers are named after the constellation in which this apparent point of origin lies. For example, the major annual shower in August is called the "Perseids'', since if you trace its meteors' trails backward they appear to radiate from a point in the constellation Perseus.

In general, more meteors in a shower will be visible between midnight and dawn than during the more civilized — after sunset — hours of the night. The reason for this inconvenient circumstance is that as Earth swings through the stream of particles that makes up a shower, more "collisions'' (meteors) will happen on the "front'' of the planet (just as more bugs wind up on a car's windshield than on its back window). We are on the "front'' side of Earth during the morning hours.

The Best Meteor Showers

This table gives some characteristics of the four meteor showers that usually produce the year's richest crops of meteors:

Shower	Date of Next Maximum	Usual Number per Hour at Maximum	Moon Phase ('87-'88)
Perseids	August 12,1987	50	Full
Orionids	October 21, 1987	25	New
Geminids	December 14,1987	50	Last Quarter
Quadrantids	January 4, 1988	40	Full

The dates given in the table are for the mornings (pre-dawn, after midnight) on which the maximum occurs. Usually, meteors of a shower can be seen a day or two before and after the date of maximum, although at a lesser rate.

How To View A Meteor Shower

The key characteristic of most meteors in a shower is that they are *dim* — so the darker your sky is, the more meteors you'll be able to see. This means that you will want to be as far from city lights as you can. It also means that the Moon will play a significant role in how many meteors will be visible; if the Moon is in the sky and bright, its light will hide the dimmer meteors:

Moon's Phase	When Moon Is In Sky (nighttime)
New	Absent all night (ideal for watching meteors)
First Quarter	Sunset to midnight (look for meteors after midnight)
Full Moon	Up all night and very bright (very bad for meteor watching)
Last Quarter	Midnight to sunrise (look for meteors before midnight)

(The Moon's phases are usually chronicled in newspapers; many calendars keep track of them, too.)

The best instrument to use for viewing meteor showers is — the human eye! Since the meteors appear at random all over the sky, binoculars or a telescope would only restrict your field of view and make you miss most of them.

So, the best procedure for enjoying a meteor shower is to go to a clear, dark country location (usually after midnight, unless the Moon interferes). Take along a sleeping bag or other pad to keep you comfortable and dress *warmly.* When you reach your viewing place, lie down and just let your gaze wander across the sky — the swift motion of a meteor will generally draw your attention when it occurs, so you don't have to be staring right at the spot on the sky where it happens in order to see it.

Also, you should allow a good twenty minutes in darkness to allow your eyes to reach their maximum sensitivity to dim light — and don't expose them to bright light again until you're through (otherwise, you will just have to "dark adapt'' them all over again.) It's a good idea to take along a flashlight whose lamp has been covered by a heavy layer of red cellophane; the dim red light should be sufficient to help you find things once your eyes' pupils have dilated to adapt to the dark, but it won't be so bright that your night vision is impaired.

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