# Dangers to Earth from Ancient Supernovas

***Summary***
*This article is less about supernovas and star-mergers themselves, rather the possibility of matter ejected from them impacting the Earth. For the benefit of the general reader scientific terms are kept to a minimum and explained where necessary, or may be pursued in the suggested links. Astrophysical research papers are not usually written for the benefit of the general reader or even for the cross-disciplinary researcher, but for their specialist colleagues. It should not therefore be assumed that the present author fails to understand the terminology and equations in the cited sources; but neither should it be assumed that he understands all of them!*

In proposing a theory that the Earth's axis has changed in recent prehistory – be it either a pole-shift or a more extensive change to the obliquity or length-of-day – requires a mechanism to explain how it could happen; the question cannot be ducked. Even a giant asteroid impact like that which caused the extinction of the dinosaurs would not possess enough energy to significantly disturb the Earth's axis and rotation. This has long been sufficient cause for geologists and physicists to dismiss the entire subject of pole shifts and axis-tilts as pseudo-science. The historiography of this subject was discussed in my book ***Under Ancient Skies***. It is true; there have been many naïve pole-shift theories which do not acknowledge the vast energy that would be required.

Yet there are clues that something did disturb the Earth's rotation at the close of the ice-age and also again in the mid-Holocene (see: Raised Beaches and Submerged Forests - Curious Anomalies) To propose a theory of changes to the axis requires an external force that could significantly alter the Earth's angular momentum yet without leaving an obvious impact scar; and without causing a mass extinction event. As discussed in *Under Ancient Skies* there are three principal candidates that might offer an answer to this conundrum:

1) Small-fast meteors ejected by ancient supernovae, stellar mergers and active galaxies.
2) Gravity waves from mergers of compact stars in the close solar neighbourhood
3) As yet unknown physics: dark-matter; gravity leaking from parallel universes, etc.

Here we shall discuss only the first possibility. Since the 1990s there has been much discussion of the collision dangers from near-earth asteroids that we could detect. These might destroy cities and create dust-veils, but would not possess enough energy to significantly change the axis of rotation. Comets could strike with higher velocities up to 72 km/sec for a head-on collision – but while calamitous for all life, even this would not be enough to make the world wobble on its axis. Fast hyperbolic asteroids like *Oumuamua* that may have been ejected from other solar systems may travel even faster, but they still do not possess enough energy. Kinetic energy increases with mass, but with the *square* of the velocity ($E=1/2mv^2$) and so the real danger comes from small fast objects potentially ejected by ancient supernovas. To experiment with the scale of this you may like to try-out this useful calculator tool:

https://www.calculatorsoup.com/calculators/physics/kinetic.php

A little experimentation will show that the velocity of the comet would need to be travelling *at a significant fraction of the speed of light* to approach the kinetic energy of the Earth's rotation, calculated at $2.138 \times 10^{29}$ joules. Could a supernova or a stellar-merger send objects of such relativistic velocities in our direction? Might they reach us from even more distant active galaxies? The origin of the charged particles in cosmic-rays from such events is generally accepted, but the possibility of more substantial pieces of high-energy matter is more speculative. See for example:

https://www.sciencemag.org/news/2014/07/physicists-spot-potential-source-oh-my-god-particles

Astronomers identify two classes of stars that explode as supernovae. The first is 'core collapse' (types II, 1b and 1c); these are massive stars that leave a compact remnant of some kind, a pulsar or a black hole. Typical examples of this type would be the *Crab Nebula* in the constellation Taurus and its central pulsar; or *SN1987A* which exploded in the Large Magellanic Cloud in 1987; the most recent that has been observed in our Galactic neighbourhood. The Crab pulsar is observed to rotate 33 times per second, and the surrounding nebula is expanding at about 1500 km/s. Another example would be *Cassiopeia A*, a strong X-ray source, which should have been first-visible from Earth around 340 years ago but went unrecorded. The remnant is seen to be expanding away from a central pulsar at: "*up to 31 million miles per hour* [13800 km/s] *(fast enough to travel from Earth to the Moon in 30 seconds!*)". For more information about Cassiopeia A, including a Hubble photo, see:

https://svs.gsfc.nasa.gov/30951

The second class of supernova is a 'thermonuclear explosion' (type 1a); less powerful but likely to be more common. We may compare these to a vast nuclear bomb. They are believed to be white dwarf stars that have accreted a shell of matter, usually pulled from a close companion star. When they reach maximum size (Chandrasekhar limit) they must contract further to a neutron star but this can cause a thermonuclear runaway that completely disrupts the progenitor star. They leave no central remnant behind and by definition they should all be of a similar energy. Tycho's supernova SN1572 is one example, whose visible remnant has been variously calculated to be expanding asymmetrically at between 5,000 and 9,000 km/sec. [1]

https://www.nasa.gov/mission_pages/WISE/multimedia/gallery/pia13119.html

Kepler's supernova of 1604 may be another instance of this type of explosion within a close-binary system but its cause remains uncertain – a possible merger of two white dwarfs; see:

https://phys.org/news/2018-08-kepler-supernova-explosion-survivors-left.html

SN1604 is described by astronomers as having been 'unusually powerful'.[2] However, the estimated rate of expansion is comparatively low at 4200 km/s [3]. The recently discovered SNIa G1.9 + 03 may be another example of this type.

Astronomers observe that stars don't just explode without warning. Massive stars approaching their crisis will be surrounded by a dense planetary nebula ejected by novas in the later phases of their evolution. Within and beyond this will be the cloud of planetesimals, asteroids, meteors and comets that have circled the star ever-since it formed, equivalent to the Oort cloud around our Sun. These bodies are too small be detected but we know they must be present. Consider how many billions of icy comets and small asteroids orbit our own sun, completely unseen until one of them streaks through the sky as a comet.

A prime example of an 'overdue' supernova is the star *Eta Carinae*, which survived a nova explosion observed in 1843 (a supernova 'imposter'). The ejected matter is seen to be travelling at 32 million kilometres per hour! Astronomers cannot explain how the central star survived the nova as it is burning heavy elements in its core, its hydrogen fuel – long gone. It makes a startling image in the Hubble photographs.

https://www.universetoday.com/142734/hubble-has-a-brand-new-picture-of-the-massive-star-eta-carinae-it-could-detonate-as-a-supernova-any-day-now/
https://astronomynow.com/2018/08/03/astronomers-stunned-again-by-eta-carinae-the-star-that-will-not-die/
https://www.youtube.com/watch?v=cD0HshyLHdY

Fascinating as these spectacular examples are, it is probably the closer and less spectacular supernova remnants; those we can no longer see, which offer the more likely danger to us on Earth.

The final collapse of a massive star occurs within a fraction of a second as it exhausts its silicon and lighter elements and has only iron remaining in its core. This cannot release further energy from *nucleosynthesis* to support itself and can only collapse down to incredible density as the iron is crushed to a rapidly-spinning ball of neutrons – a neutron-star.

You may wonder how a collapse can cause an explosion. Various mechanisms are proposed and need not be discussed in detail here as we are more concerned with the remnant rather than the explosion. Most often discussed is that the collapsing matter 'rebounds' from the dense nucleus and collides with the in-falling matter triggering nuclear synthesis; and that the resulting burst of radiation and neutrinos would blow away the shell of the star. However another theory considers that the principle mechanism could be the rapid spinning-up of the core as it forms the central pulsar or black-hole; this throws-out the neutron-rich matter and the collapsing shell, in what is sometimes termed a 'sausage instability' (mass-shedding via outgoing spiral arms of matter). [4] Remember this all occurs within a fraction of a second! *A naive illustration would be to swing a string of sausages round your head – it is the fast-moving outer links that are most likely to fly-off at a tangent!* These ejecta collide with the in-falling stellar envelope and triggers further synthesis of heavy elements and vast release of radiation that we observe. The energy is carried away in a shock-wave that sweeps up everything surrounding the star and creates the visible nebula. The expansion of the ejected remnant then proceeds as the supernova fades.

We may propose that when the shocked ejecta reaches the outer shell of meteors, asteroids and icy-comets surrounding the exploding star then these would be disrupted into smaller fragments. Usually astronomers consider total disruption to gas and dust; and that the expansion ceases when the mass of the surrounding shell equals that of the unshocked interstellar medium. This may be so for most of the mass. However, bodies of optimum size and distance from the explosion may not be disrupted completely. If the explosion has enough energy to disrupt an asteroid then it must also be sufficient to propel away the fragments. Much depends upon how fast the collapsar is spinning. There is nothing in the interstellar vacuum of space that could then impede this shell of ejected meteors from expanding to infinity unless they encounter the gravity of another massive body (i.e. a star or planet).

[*A crude analogy for the non-astrophysicist: consider your garden blower as it easily blows-away the sand and leaves; the blower is strong and the leaves are light. However, if someone throws a pebble at you could you deflect it away with your leaf-blower? I don't think so! How strong would your blower need to be; and how small must be the projectile for the blower to have any effect? How hard would you need to blow to completely disrupt the pebble?*]

A further source of fast ejecta from a supernova may originate from neutron-matter expelled from the dense core as it spins-up. Astronomers theorise that such matter should very rapidly decompress to heavy nuclei (*r-process* elements) and iron. Again, these are likely to clump rather than persist as dust and gas. Sometimes trails can be observed within supernova remnants, which are interpreted as fragments from the core travelling through the gaseous remnant. For each of these there must be many smaller unobservable clumps. What is to impede these ejected pseudo-comets from escaping to great distances?

A complex collection of supernova remnants of various ages are found in the Vela nebula, revealed in a striking composite picture released by NASA.

https://apod.nasa.gov/apod/ap190110.html

You may also like to read:

http://blair.pha.jhu.edu/hstvela/hstvela.html

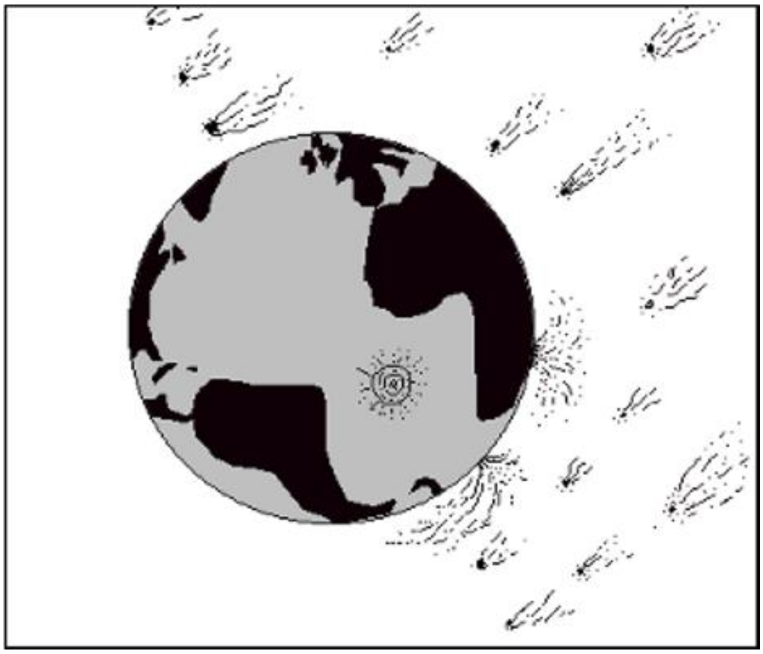
If we take as an example the paper by Loeb-et-al; the authors consider the V-shaped wakes observed within the Vela supernova remnant that are loosely estimated to be moving away at around 3000 km/s. [5] They demonstrate that these could not be the ejected former planets of the parent star, as these should be totally disrupted and would long-since have faded from view. At the point where the fragments cease to be observable, the professional astronomers lose interest; the planetary fragments are assumed to vanish into the supernova remnant. The disrupted planetary fragments, travelling at even a fraction of the remnant's expansion velocity, are still very fast compared to solar comets.

Rather, the authors consider that the observed high-velocity fragments are more likely to have been formed in the dense core and then ejected as the central remnant spins-up (an asymmetric gravitational collapse). The neutronic matter re-forms into heavy nuclei, principally iron and nickel – but unlike a solar iron meteorite these should also contain short-lived isotopes of heavy elements and iron-60. The authors consider that there must be "many more, smaller fragments" that we cannot detect. [6] Again the professional astronomer seems to lose interest if the bodies are too small to be detectable with telescopes. In fact, the diffuse shell must continue to expand long after the remnant has faded and they will one-day reach us. How many other expanding shells of older supernovas are out there, whose nebulae have faded from view? Their 'comets' are still on their way towards us, or have already passed through the solar system.

Until quite recently, astrophysicists believed that all the elements heavier than iron were created in supernova explosions. However, it is now accepted that even the high density of a supernova core-collapse is not dense enough for the *r-process* to create these elements. To produce these requires the merger of two neutron-stars, or perhaps a neutron star and a white dwarf. These events generate intense magnetic fields that fling jets of matter away from both poles of the collapsing star at near-relativistic speeds. These are also now believed to be the source of the *gamma-ray bursts* observed in distant galaxies; the bursts that are detected come from chance events where the polar jets are pointed directly at us. It is reasonable to expect that iron-rich meteor fragments might also be accelerated away by these intense magnetic fields.

The next problem to consider is how often we may expect to encounter the diffuse shells of fast-moving meteors and comets; and how may we observe them in order to prove their existence? In our historical records, visible supernovae have occurred about ever 300-500 years on average, the most recent being that observed by Kepler in 1604. In all, there should be about two events per century for the Milky Way galaxy, which would give the above average for our observable region. [7] Events on the far side of the galaxy should represent no danger to us. Therefore, the expanding shells of ancient ejecta should arrive at the solar system with a similar regularity to the observed supernova events. Between these episodes we are unlikely to encounter supernova ejecta and it may be that no such encounter has occurred since the advent of telescopic astronomy. In most events, they may be expected to rapidly pass through the solar system without hitting a planet. Therefore we may postulate a collision-event perhaps every few thousand years; really energetic axis-tilting events should be even less common by a multiple of 180. Without precise observational data to cite, the speculation flag will inevitably be raised!

When astronomers and popular commentators discuss the dangers from supernovas they tend to seek those that may explode within say, 500 light-years – the solar neighbourhood; such as the bright star *Betelgeuse* in Orion. The popular view is that as long as the supernova is more than say, 50 light-years away then we should be safe. The focus falls upon the gamma-ray burst or the intense flash of cosmic radiation and neutrinos that might reach us at the same time as we see its light; some others may consider the 'bubble' of charged particles, travelling typically at a fraction of light-speed that should reach us a few hundred years later. By contrast, many thousands of years may pass for the hyper-velocity solid ejecta to reach us from stellar explosions.



*A flux of small-fast-comets arrives at the Earth. This illustration was figure 10.1 of Under Ancient Skies*

However, we may get some advance warning. The charged particles from the supernova, travelling at a fraction of the speed of light, should reach us well in advance of the solid bodies; we should therefore observe a change in the background cosmic ray flux. Perhaps astronomers could then calculate their point of origin and predict when the dangerous 'comets' will arrive. Then what should we do?

We should also consider what the impact of a small-fast meteor on the Earth might look like; take as an example, a football-sized icy-comet, perhaps with a solid core, travelling at the ejected supernova velocities discussed above. The composition is irrelevant, ice would be just as destructive as iron; it is the velocity that supplies the kinetic energy not the mass. There is no ideal research to cite here as such impacts have not been much considered by specialists. The best one can suggest is that it would drill deep into the crust, more like a bullet-hole than an impact crater. The impact would throw-out behind it a tail of terrestrial rock far exceeding the small mass of the projectile, which would then dissolve deep within the earth. The best research we can consider would be the various theories for the formation of *tektites*, where we find strewn fields of these tiny impact-ejecta that are considered to be shocked glass formed from melted sedimentary rock as it re-enters the atmosphere. [8] Other than the tektites very little evidence would remain after a few thousand years; no crater, no tell-tale layer of Iridium, no evidence of a dust veil. We might however expect to find traces of heavy elements, and rare radioactive isotopes around the impact site – if we could find one!

The consensus seems to be that very special and seldom-encountered high-energy events are required to explain the composition of tektites. For further information, the reader may like to pursue the following links: a basic introduction plus a more scholarly article:

http://earthsci.org/space/space/tektites/tektites.html
http://www.jsg.utexas.edu/npl/outreach/tektites/

A high energy impact event therefore has the capacity to supply an *impulse* of kinetic energy in the direction of its travel. Depending upon the size, direction and velocity, this has the capacity to change the Earth's angular momentum; and to excite the *Chandler Wobble*. Without 'hard' evidence then all we should expect to see in the geological record of the recent-past is evidence of the transient wobble and a pole shift; perhaps: a change of obliquity and a glitch in the length of the day. We might expect these effects *to be of the order of arc-seconds or arc-minutes at most*, but enough to be noticeable. This would manifest as sea-level and climate oscillations in the recent geological record; and in transitions from one stable regime to another.

However, *it must be stressed again* that in order to change the Earth's angular momentum by any significant amount, say, measured in full degrees or arc-minutes of latitude, then the impactor must arrive at a very high velocity perhaps approaching half the speed of light; and it would also have to be very small were it not also to cause a mass extinction event. To create impactors of such high energy we may therefore narrow down the source to those smaller chunks of heavy elements and iron ejected from the core of a supernova or star-merger event during its collapse. The only other source powerful enough might be the relativistic jets ejected from the poles of the collapsar during its rapid contraction phase; and one would have to be pointing in our direction from an ancient event. If it were closer then we could not escape the even more destructive effects of the gamma-rays! If something like this did reach us during Earth's recent prehistory then astronomers should one-day be able to identify a candidate progenitor star, which should by now be detectable as a black-hole.

Unfortunately, evidence of sea level and climate oscillations in recent prehistory can also be explained by other causes; and so without a clear worldwide pattern the sceptical geologists and climate specialists will not be convinced of catastrophic events from space. Astrophysicists are more open-minded; they are accustomed to discussing hypothetical phenomena that they can't touch; but geologists: they study rocks and they drill holes; it can be difficult to persuade them to look upwards.

## References:


1) Pilar Ruiz-Lapuente et al (2018) Tycho's supernova: the view from https://arxiv.org/abs/1807.03593

2) Pilar Ruiz-Lapuente et al (2018) No Surviving Companion in Kepler's Supernova, *The Astrophysical Journal* DOI: 10.3847/1538-4357/aac9c4 https://phys.org/news/2018-08-kepler-supernova-explosion-survivors-left.html

3) Vink, J. (2008) *The Kinematics of Kepler's Supernova Remnant as revealed by Chandra* https://arxiv.org/abs/0803.4011

4) A. Loeb, F.A. Rasio, J. Shaham (1993) *Ejection of Fragments in Supernova Explosions*, page 3; https://arxiv.org/abs/astro-ph/9405071

5) ibid, page 1

6) ibid, page 6

7) Colgate, SA (1971) *The velocity and composition of supernova ejecta* , page 74 https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19720004110.pdf

8) Koeberl , C. (1994) *Tektite origin by hypervelocity asteroidal or cometary impact: Target rocks, source craters, and mechanisms.* in B.O. Dressler, R.A.F.Grieve, and V.L. Sharpton, eds., pp. 133–152, Large meteorite impacts and planetary evolution. Special Paper no. 293. Geological Society of America, Boulder, Colorado. https://www.univie.ac.at/geochemistry/koeberl/publikation_list/095-Tektite-origin-by-impact-GSA-SP293-1994.pdf

**Tags:** Ancient Astronomy, catastrophism, pole-shift, Chandler wobble, impact event, comet impact, Oumuamua, gravity wave, supernova ,remnant, stellar-merger

This article was originally published in 2018 as an interactive webpage at: https://www.third-millennium.co.uk/dangers-from-ancient-supernovas

**Citation:** Dunbavin, Paul (2020) Dangers to Earth from Ancient Supernovas, in *Prehistory Papers,* pp 1-12, Third Millennium Publishing, Beverley, ISBN: 978-0-9525029-4-4