Supernova Ejecta and the Dangers to Earth

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Summary: *As discussed in an earlier article 'Dangers to Earth from Ancient Supernovas' the risk of catastrophic collision with a comet or asteroid comes not just from objects orbiting our sun. There are other forces that may reach us from the galaxy or perhaps from the wider cosmos. While astronomers typically focus upon the objects that they can detect, optically or by any other method, the real danger may be from forces that we are unable to see or predict. In this article the focus should fall not on the stellar outbursts themselves rather upon their wider effects and the debris that they eject; and how these events could have caused catastrophic phenomena in Earth prehistory.*

It is not unreasonable to assume, given the advance of science and mensuration, that a day will arrive when astronomers can map every tiny asteroid and comet that orbits the sun, right out to the limits of the Oort cloud; and with the aid of supercomputers to predict their orbits far into the future. Those that might one day pose a threat could be watched and given a gentle 'nudge' to change their orbit and we may think ourselves safe again. The 'Domesday comet' is probably already on its way and will one day reach us. Perhaps in the meantime we may ponder how to divert it. But what about those visitors on a hyperbolic trajectory like *Oumuamua* and comet *Borisov* that originate from beyond our solar system?

When I first wrote about extra-solar comets and oblique impacts in the early 1990s, the suggestion that comets might strike the Earth was still a toxic subject – until the impact of comet Shoemaker-Levy-9 on Jupiter was witnessed on our TV screens. For most of the era of telescopic astronomy, keen amateur observers discovered solar asteroids and comets only when they passed close enough to be seen as tiny objects moving against the stellar background. There was what Stefan Michalowski called the 'giggle factor' attached to the possibility of impacts. [1] Eugene Shoemaker declared that the 'giggle factor' was gone when we witnessed a comet strike giant Jupiter. Sadly, denial has not gone away, because there remain other unseen dangers that could harm our planet, or have done so in the past. As astronomers probe the universe in new ways they discover many new phenomena: quasars, pulsars, dark-matter halos, rogue planets, gamma-ray bursts, gravitational waves; all unheard of half a century ago. What next?

Catastrophism in Earth history?

Many enigmas and possible catastrophic episodes may be cited during human prehistory that demand an explanation as to what could have caused them. The confirmation that an asteroid strike in Yucatan caused the ancient demise of the dinosaurs has set the norm and any suggestion of catastrophic phenomena in more recent Earth history founders on the reply: where is the crater? Even the colossal asteroid impacts that cause mass extinctions would not have sufficient kinetic energy to appreciably affect the Earth's axis or its orbit. This has long been sufficient for mainstream science to dismiss the idea of changes to Earth's obliquity and pole shifts during recent prehistory as pseudo-science. This has now become a serious blind spot in our understanding of the past.

Gradualist geology and climate science cannot explain the abrupt transitions between glacial periods, and at the end of the Ice Age; or the sharp transitions between stable climate regimes that have occurred during the Holocene. It cannot explain the rapid changes of sea level: the raised beaches and submerged forests that have transpired over the same period. It could not explain the references to astronomical phenomena described in various religious and mythological sources that suggest ancient pole shifts and axis tilts. Gradualist geology could not explain a possible change to the length of day since the earliest calendars. It could not explain climate and sea-level events, such as Joseph's famine, or Atlantis – or Noah's Flood. These examples from human prehistory demand a source of *high-energy* catastrophic events that do not leave an obvious impact crater. They were *survivable* events (i.e. they were not followed by a mass extinction) yet they possessed sufficient energy to have reset the rotation and climate of the Earth. Here are just a few suggestions based on the latest astronomy and physics.

Hyperbolic Exocomets

The appearance of comet *Oumuamua* passing close to us on its hyperbolic trajectory in 2017 has opened minds. Just two years later comet *2I/2019 Borisov* was observed with an even higher excess velocity. With two such discoveries within just two years we have to wonder how many earlier examples could have been missed. [*see note 1*] Astronomers have long been aware of hyperbolic comets with a small excess velocity; but these could be explained as solar comets ejected by a close encounter with one of the planets, only to fall back millions of years later. [2]

Oumuamua was a tiny object unnoticed until it was already on its way out of the solar system, most likely an asteroid ejected from its own star system. Its elongated shape (at most 1000 x 100 m) suggests that it is a fragment of a larger planetesimal torn-apart by whatever event projected it into interstellar space. Comet *Borisov* was somewhat larger and was enveloped in a coma more closely resembling a solar comet – apart from its excess velocity.

Just recently (2022) I have noted the possibility of impacts by exocomets mentioned by one of the 'television academics', together with another guest who ventured the possibility of oblique 'bouncing' impacts that would leave little trace on the Earth's surface. Such discussion could never have happened in earlier decades. When first I explored such matters in *The Atlantis Researches* back in the 1990s the concept of impact events was still derided as mere pseudo-science; one simply could not mention such things and be taken seriously.

Supernovas and Remnants

Astronomers regularly observe supernovas in distant galaxies although none have been observed in our own galaxy in the era of telescopic astronomy. An earlier article *Dangers to Earth from Ancient Supernovas* examined the question of what happens to the cloud of smaller bodies that must be orbiting a massive star before it goes nova. [3] These may comprise a range from planetesimal-sized objects down to meteorites small enough to hold in your hand. Pieces of the exploding star's iron and silicon core might also be flung-out by the rapid spin-up of a supernova as it collapses. If these are propelled-away rapidly enough then their kinetic energy would exceed any threat from a solar asteroid. By the time the expanding shell of high-energy meteors reached us it would be so dispersed that they would be millions of kilometres apart. They should arrive with about the same regularity as we observe local supernovae (so about every few hundred years) with impacts being even less frequent. We should only detect such meteors during the brief few days when the shell of solid ejecta passes rapidly through the solar neighbourhood.

Around every giant star there must be a region where planetesimals and asteroids orbit in a kind of perverse 'Goldilocks zone'. The lifetime of a supergiant star is just a few million years; not long enough for planets to coalesce. Before it explodes the star must pass through an expansive Wolf-Rayet phase that would envelop the planetesimals in its gas cloud. Close-in to the final supernova explosion the asteroids would be reduced to dust to become part of the visible remnant, eventually to cool and merge with the interstellar medium. Further out, the expanding shock wave would pass by the asteroids leaving them battered but still in orbit about the collapsed star. Between these two extremes there must lie a zone where the planetesimals are disrupted, yet are not reduced completely to dust; fragments of an optimal size would accelerated away by the wind of the supernova. Astronomers observe visible supernova remnants expanding at velocities of 1500 km/s (*Crab Nebula*) and even 13800 km/s (*Cassiopeia A*) Compare these to the relatively sedate orbital velocity of Halley's Comet at 55 km/sec or even the unbound Oumuamua at 87.3 km/sec.

One will often see, discussed in various astrophysical papers, the explanation that visible supernova remnants fade as they cool and expand until their density diminishes to that of the interstellar medium. This really amounts to a near-perfect vacuum colliding with an even more perfect vacuum; a strange concept! The meteorites that regularly strike the Earth have orbited in the solar wind since the formation of the solar system and have not been halted. If a supernova remnant contains swept-up solid ejecta then, at the hyper-velocities considered, there is nothing in the interstellar medium that could prevent the shells of meteors from expanding long after the visible nebula has faded.

Supernovae are not the only potential source of hypervelocity comets and asteroids that could reach the solar neighbourhood. Since the 1950s when Hoyle first proposed the theory of nuclear synthesis in stars the study of stellar collapse has been further refined. Physicists now recognise that even the high densities of a supernova core-collapse are insufficient to explain the abundance of the r- s- and p- process elements heavier than iron and nickel, such as gold, platinum and uranium. To form these heavy nuclei requires the high densities of a neutron star merger – themselves already collapsed supernova remnants. By inference, the presence of these heavy elements on Earth mandates that the primaeval solar nebula must have been preceded by a neutron-star merger.

Gamma Ray Bursts

Discovered accidentally in the 1960s by Vela satellites monitoring for nuclear tests, these were soon recognised as cosmic in origin; the product of explosions in distant galaxies. Two classes of gamma ray sources are now recognised: *long bursts* caused by implosion (hypernova) of high-mass luminous stars; and the *short bursts* attributed to the merger of neutron stars. Such collapses emit polar jets as the particles and radiation are channelled by the magnetic fields. The only reason we observe so many is that their magnitude is so bright that they are visible from the edge of the observable universe. Even then we only see that fraction whose jets are pointed directly towards us.

Gamma ray bursts are statistically rare, loosely estimated at a few per million-years in any galaxy; but consider that there must be 180 times this estimate for events where the polar 'beam' is not pointed in our direction. Some theories require that the remnant left behind would be a magnetar – a fast-spinning neutron star. Some theories even suggest that the Cambrian extinction some 488 million years ago was caused by a gamma ray burst in the solar neighbourhood. However, we need not dwell on the causal mechanism of such events (which is after-all only informed speculation by astrophysicists) rather to consider the solid ejecta and gravitational waves that they must release.

FBOTs

In 2018 astronomers discovered evidence in distant galaxies for a new class of supernova explosion. These have been termed Fast Blue Optical Transients (or FBOTs). Some have been given convenient nicknames; one explosion, known as "the Cow" was observed to be 10-times more powerful than any previously known supernova. [4] Another named "Koala" was almost as bright as a gamma-ray burst. [5] However, while gamma ray bursts may eject just a small mass of high-energy particles and radiation along the polar beams, the FBOTs may launch as much as 10% of our Sun's mass at relativistic speeds approaching even the speed of light.

Unlike a gamma-ray burst, the material ejected by an FBOT leaves the star in all directions. The name derives from the characteristic that the bright flash fades much more quickly than a normal supernova and they are hotter – the high temperature giving them their blue tint. Astronomers theorise that this new class of supernova needs a different mechanism to explain them. One suggestion is a black hole absorbing a white dwarf or a neutron star which then fades rapidly as the remnant falls within the event horizon; alternatively they may be examples of a core collapse producing a black hole, but in this case the polar 'beam' of gamma rays is not pointed directly at us.

The focus here has to be on the material expelled by the FBOT at relativistic speeds. Again, such ejecta must comprise small solid bodies, not just streams of hot gas. We may only speculate that the remnant, if we could observe one, would also fade more rapidly that any known remnant nebula. If such explosions can be observed in distant galaxies then it follows that they must have occurred in the Milky Way galaxy and their nebulae have long ago dispersed and faded – *but their shell of ejected meteors, travelling at relativistic speeds, continue to expand*.

If the supernova creates a central collapsar then its gravity may be enough to pull-back and retain much of the ejecta within the expanding remnant, but not when the parent star has been completely disrupted as in a Type I supernova. Ironically, the least powerful and most common class of supernova may present the greatest danger to us – and once the gaseous remnant has dispersed – totally undetectable by astronomers.

Unnovas

Another phenomenon related to the fast stars and FBOTs is the Unnova, sometimes misleadingly called a failed supernova. These are very far from failures; they are examples of the most massive stars (yellow hyper-giants of 20-60 solar masses) that try to explode by core-collapse but are too massive and are rotating relatively slowly, such that their light, or anything else, cannot escape from the event horizon. To our eyes the collapsing star would simply pop-out of existence. There are candidate stars that may be examples of this phenomenon; N6946-BH1 was observed to brighten and fade in 2009. The search for such stars has only come to the fore since the millennium as astronomers had been unable to find supernova remnants formed by the most massive supergiants.

Once again, we should expect that meteors and comets in just the right orbit might be whipped around such a collapsing star and thus be accelerated into the galaxy at relativistic velocities. This is really no different from the way that hyperbolic solar comets are ejected from our own solar system by close passage to Jupiter or Saturn – except that the velocities are so much higher.

We may have an example in one of our galactic neighbours: Cassiopeia A that exploded unnoticed in the mid-seventeenth century. Here astronomers observe not only the rapid expansion of the remnant at 21.6 million km/h, but also a region that is falling back at an equally impressive velocity of 6.9 million km/h; perhaps an indicator that it is under the intense gravitational pull of an invisible former companion star. [6]

Consider for a moment how long it might take for supernova ejecta to reach us. To take again the example of Cassiopeia A; if an ejected meteor were travelling at the observed rate of expansion, then at its distance of 10,000 light years it should reach us about 220,000 years from now. The immediate danger would therefore come from a similar supernova that exploded at this distance two hundred and twenty thousand years ago and whose ejecta would only now be reaching us. Of course, the fast meteors and exocomets could approach from various distances and velocities; and from any direction. There is little or no prospect of predicting such arrivals until humans become capable of interstellar travel.

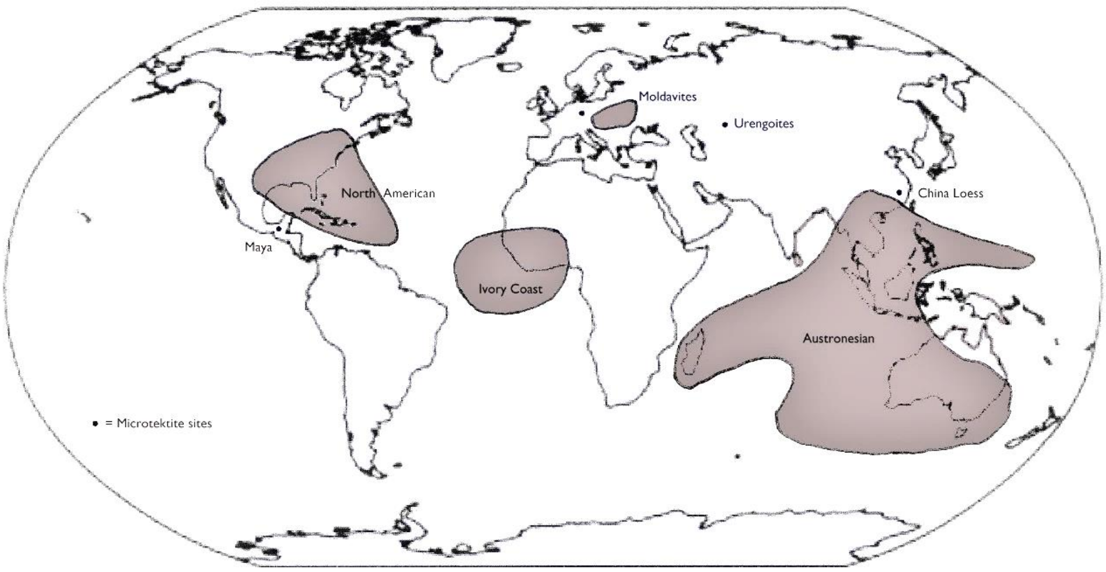
Rogue Stars and Planets

Other possibilities exist for sources of high-energy ejecta that could reach the earth. At the centre of our galaxy lies a supermassive black hole of 4 million solar masses called Sagittarius A-Star. We have all seen the excellent animations of the closest stars as they are observed to swing around it at velocities so fast that that they can be measured. In 2014 Sgr A* was observed to tear apart a gas cloud surrounding a small star. However, recent analysis would suggest that less than 1% of the matter orbiting the black hole actually falls within its event horizon; the rest is ejected into the galaxy. [7]

In 2019 one such fast-star S5-HVs1 was observed to be leaving the galaxy at a velocity of 1700 km/sec. Its track indicates that it has survived a close encounter with Sagittarius A-star. Again we should ask: how many smaller unseen rogue planets, comets and meteors are passing by us at comparable velocities? Answer: there could be billions. No longer is it mere science fiction.

Tektites

Should one of the hypervelocity fragments from an ancient supernova strike the Earth then what kind of physical evidence might we expect it to leave behind? Certainly not a crater, any more than you would expect a bullet from a gun to leave a crater in soft material. However the science of bolide ballistics does give us useful analogies. Most likely they would drill a hole deep into the mantle before being dissolved, or perhaps a ricochet scar from an oblique impact. The most likely hard evidence would be a strewn field of micro-tektites (impact glass) around the point of entry. We are considering here a football-sized body, or even smaller, travelling so fast that that they could penetrate to the mantle. We should expect the impact site to be inconspicuous and disguised by infill or volcanic extrusions. [8]



Tektite Strewn Fields. Most of the largest are millions of years old are linked to ancient craters. Examples of Holocene age are likely to be microtektite sites, too small to show on a large-scale map.

Prime locations to search for hard evidence would be the smallest tektite fields that are not associated with any known crater; and always bear in mind that three-quarters of all impacts must occur in the ocean leaving even less accessible evidence. It may be easier to find one on the Moon, where there has been less geology to conceal them. We shall see. Very little physical evidence would remain on the Earth's surface after a few hundred years but we may still detect short-lived radioactive isotopes that were synthesised in the parent supernova.

New Physics

If you wish then you can look into the more speculative and exotic phenomena that astronomers and physicists now consider possible.

Gravitational Waves

Long theorised but first detected in 2015, these are thought to be produced by the mergers of massive objects such as neutron stars and black holes. They must also occur when stars fall into Sagittarius A-star and when galaxies and supermassive black holes merge: a frightful concept! All the events so-far detected by the most sensitive gravitational wave detectors on earth result from mergers of collapsed stars in distant galaxies. Typically the amplitude of the waves is less than the width of a human hair and would go unnoticed – each of us has probably experienced numerous gravitational waves during our lifetime; it is no different to the radio waves and neutrinos that pass through us all the time.

A gravitational wave is a stretching and squeezing of the space-time fabric produced by high gravity events. Atoms and particles, as well as planets (which are merely large groups of atoms for this example) would alternately stretch and squeeze according to the wavelength. It is important to visualise that it is the spacetime structure that deforms not the matter that occupies it. Precisely what we would feel from a gravitational wave that originated much closer to us could only be speculation and imagination at this point.

Whatever else, the gravitational wave has a *point of origin* and a *direction*. It carries energy and it should affect the Earth in the same way as any other impulse. It would act to change the angular momentum of the planet, resulting in a nutation of the axis and could even alter the length of day. A change to the shape of the Earth (the squeezing and pulling) must also trigger a wobble and a pole shift. The real difference however, between this and the impulse delivered by an impact event, is that it should leave no crater or any other hard evidence on the surface.

A gravitational wave would not have to be spectacular to cause geological effects; a variation of perhaps a few millimetres might be enough to trigger worldwide earthquakes and flows of magma in the core and mantle, thus altering the shape of the geoid and its rotational balance. The rest is then just known geophysics.

Once again, it is important to appreciate that although physicists may talk as if they know what is going-on, they don't! No-one really understands gravity!

Mini-black-holes

The only known process by which a black hole could be created is by the gravitational collapse of a massive star at the end of its life, such that the core falls within its event horizon and the required escape velocity exceeds the speed of light. To form a stellar black hole, the collapsed core must be of a minimum of about 2 solar masses, commencing as a supergiant of 25+ solar masses, The resultant black hole would occupy a diameter of about 25 km. However, there is no minimum size limit so long as the required density could be achieved.

Scientists such as Jakub Scholtz and James Unwin propose that in the extreme conditions of the early universe, local unevenness could have created conditions where matter was clumped sufficiently for mini black holes to form. They suggest that the as yet unobserved Planet 9 could be a primordial black hole about the diameter of a tennis ball. [9] Some primordial black holes might be no bigger than fundamental particles. Once in existence, these would behave like any other massive object subject to gravity as the universe expanded; most falling into supermassive black holes and stars, or orbiting them. This raises the obvious question why are there not one or two orbiting the sun; are they the missing 'dark matter', etc.

Popular science-fiction would give us the notion that we would be sucked into such a black hole, but this is erroneous; from distance they would represent no more danger than a rock of similar mass. However, there is always the possibility that a close fly-by could produce tidal effects in the oceans and crust; and resultant catastrophism as has been proposed by other authors. The mini-black-hole theory is not one that that I favour but is listed here for completeness.

Gravity Leaks?

What is gravity? If you know then please tell the physicists. Modern astrophysicists can tell you how it behaves, building upon Einstein's relativity; they can even suggest that the newly-confirmed Higgs Boson confers mass; and it is the mass (whatever that is) that bends the space-time fabric; but this merely transfers the problem to a deeper level of unknown.

A stellar cast of physicists at LIGO sought to use gravitational waves as a way to probe whether gravity was 'leaking' from our universe into an adjacent parallel universe. They seem to be convinced that it does not; but what about gravity leaking into our universe from an adjacent one?

This conundrum derives from the multiverse theory, whereby an infinite series of parallel universes or 'branes' must exist in parallel, splitting-off at quantum level. These other universes would be 'stacked' adjacent to our own in a fourth dimension, each a Planck distance apart – rather like two-dimensional sheets of paper stacked in the third dimension. Gravity obeys an inverse square law; that is to say, it's strength is inversely proportional to the square of the distance from the source. Therefore it is reasonable to suggest that its influence in the higher dimensions would obey the same law. The gravity that we experience is therefore just a fraction of the total force, which could explain why it is so weak compared to the other fundamental forces.

This raises the possibility that the Earth may pass close to a source of mass (a planet or star) lying in an 'adjacent' universe and if it be close enough then its gravity would be felt in our own. These are the science fiction 'gravity anomalies' that you may see on an episode of *Star Trek* – gravitational pull emanating apparently from nowhere! Indeed it is such a difficult concept that there is not even adequate language to describe it.

All we really need to consider is that the gravitational effect of a mass in an adjacent universe should be similar to gravity from a mass in our own universe. However, such physics as is published would suggest that the body must approach extremely close – almost passing through us – in the higher dimension in order for us to experience its effects. Perhaps we should not worry about this idea until a physicist can explain what dark matter is and where it is.

Conclusions

If we observe exocomets then there must also be many more smaller exo-meteors. If we can watch high-energy phenomena occurring in distant galaxies then they must also occur in our own galaxy. Because we only see the rare phenomena during our short human timeframe we fail to perceive the long-term threat that they pose. It is rather like building your house close to a volcano and relying on the security that it has never erupted in your lifetime. We cannot do much about the future, but we can at least recognise the effect they might have had in the past and consider their effect on recent geology and human prehistory.

It is unfortunate that so much discussion of catastrophism in prehistory during the twentieth century was so unempirical that it could be easily demolished by scientists. This has led to a neglect and unwillingness by mainstream geologists to consider the question for fear of professional ridicule. It is a subject that must be considered. All of the phenomena suggested above could cause cataclysmic episodes on the Earth and yet they would not leave any hard evidence on the surface.

Let me pose you a troubling series of questions. How do you know that there is not a dark collapsar lurking, a few thousand light-years from earth, that 'exploded' millennia ago and sent a shell of meteors in our direction at unthinkable velocity? Is there a dark star awaiting discovery in our galactic locality, of just the right mass that may collapse further and send a gravitational wave in our direction disturbing our stable rotation as it passes through us? What would that feel like and what might its geological effects be? Is there a planet in an adjacent parallel universe that may pass close-enough in a higher dimension for its gravity to leak into our own? Are you waiting for a recognised 'expert' or professor to tell you whether such concepts are real or pseudo-science? Another definition of pseudo-science might be science that your expert has not yet thought of, or perhaps fears to mention lest their papers be rejected. Beware the giggle factor!

Note 1: *As this article was in preparation, evidence was released that a 0.45m diameter meteor estimated to be travelling at 210,000 km/h (58.33 km/sec) broke apart in the atmosphere over New Guinea in 2014. This discovery actually predated Oumuamua, but was awaiting conclusive verification of the data. As may be noted from the above discussion this velocity is still far below the maximum that could be generated by stellar phenomena, but well above the commonly observed velocities for meteorites of solar system origin. The authors suggest that the bolide came from the inner part of a planetary system in the disk of the Milky Way galaxy.* [10]

Relevant Hyperlinks

https://solarsystem.nasa.gov/asteroids-comets-and-meteors/comets/2I-Borisov/in-depth/
https://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1991JBAA..101..119H&defaultprint=YES&filetype=.pdf
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