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Journal
Berkeley Scientific Journal, 17(2)

ISSN
1097-0967

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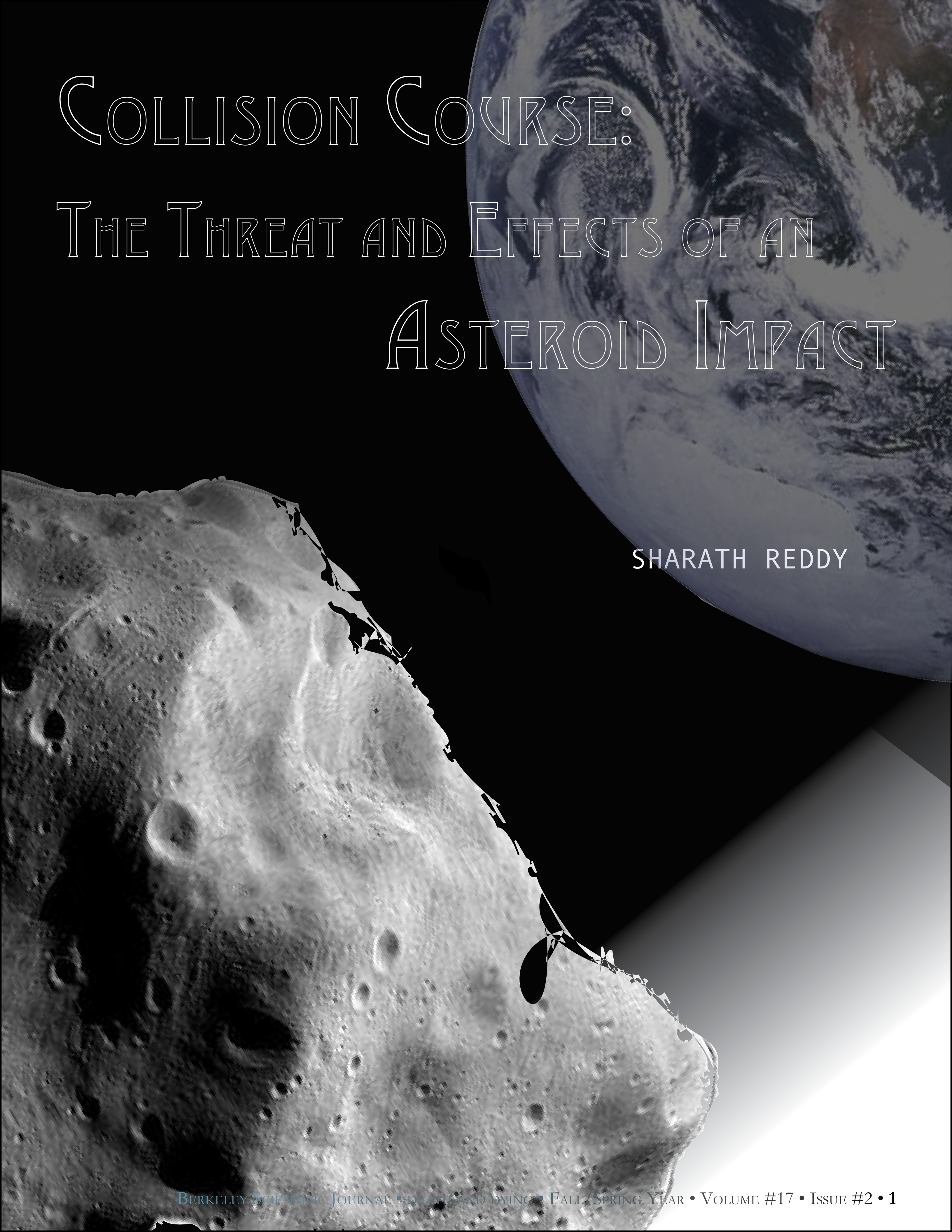
Publication Date
2013

DOI
10.5070/BS3172020099

Undergraduate



Collision Course: The Threat and Effects of an Asteroid Impact

SHARATH REDDY

In the winter of 2012, believers in the Mayan prophecy predicting the cataclysmic destruction of the Earth on December 21st, 2012 were disappointed when life continued on the 22nd. Although that may have been a "near miss" for the planet's inhabitants, a new threat is just upon the horizon: asteroids, comets, and meteoroids, all poised for a path dangerously close to our home.

With the recent Russian meteor impact on February 15th, 2013 (Wall, 2013), and a host of other nearby impact candidates, an asteroid impact is an important global threat that must be investigated. These asteroids, comets, and meteoroids which pose a significant threat to the Earth are collectively known as near-Earth objects (NEOs), defined as comets and asteroids that have been nudged by the gravitational attraction of nearby planets into orbits that allow them to enter the Earth's neighborhood (LSST 2003). Among these was asteroid 99942 Apophis, which in 2004 was predicted to collide with the Earth in the year 2029. NASA has since determined that there is no longer any significant probability of impact; however, considering the sheer number of NEOs in our solar system, investigating the possible threats and effects of such an impact is a necessity.

When an asteroid collides with another massive object (e.g. the earth), the kinetic energy of the asteroid is converted into heat and sound, creating pressure waves which travel radially outwards from the impact center, similar to that of an atomic bomb. However, an asteroid has the potential to be much more devastating than an atomic bomb: an asteroid just a few tens of meters across can yield the energy equivalent of ten to fifteen megatons of TNT (Institute of Physics). An asteroid of this size was the perpetrator of the 1908 Tungsuka event, during which an asteroid exploded midair in a sparsely populated region of Siberia, releasing pressure waves that felled trees for 30 miles, an impact which was more powerful than the atomic bomb dropped on Hiroshima (Phillips, 2008). Villagers living nearly 40 miles from the blast epicenter were eyewitnesses to the event, communicating what they saw to Russian geologists and astronomers. This effects of this impact resulted from an asteroid only a few tens of meters across. What NASA and other space agencies are searching for are asteroids which are a kilometer long, much larger than a few tens of meters. The destructive capabilities of such an asteroid are difficult to imagine, but there is at least one such impact which scientists have studied.

The archetypal example of an asteroid causing the extinction of entire species is the Cretaceous mass extinction, which occurred about 65 million years ago. Although fossils of dinosaurs had already been found in rock strata across the globe, the reason as to why they were there was not as well understood. Luis Alvarez, a physicist from UC Berkeley, and his son Walter (currently a professor at UC Berkeley), began studying rock strata using radioisotopes present in the different layers. While studying the layer of strata formed between the Cretaceous and Paleogene geological periods, they found levels of the element Iridium to be much higher than in regular rock strata.

Correlating this fact with the knowledge that asteroids were known to contain high concentrations of Iridium, Alvarez posited that an asteroid must have made impact between those periods depositing sediment containing high levels of Iridium on rock strata. Since fossils of dinosaurs were found only in Cretaceous strata (66 million years ago) and older, this led to the formulation of the Alvarez hypothesis, which theorizes that the cause of the extinction of dinosaurs was an asteroid impact. One valuable piece of evidence in support of this hypothesis is a large crater on the Yucatan peninsula of Mexico, Chicxulub that formed about 65 million years ago, precisely when the K-Pg (Cretaceous Paleogene) extinction occurred. Asteroid impacts are point events, which lead to a longer term effects such as a decrease in temperature and death of vegetation, which would eventually cause the extinction of dinosaurs (Alvarez, 1983). In more recent years, with the advent of radiometric dating, the formation of the Chicxulub crater has been placed to be within 33,000 years of the time of the K-Pg extinction. General acceptance of the Alvarez Hypothesis by the scientific community has also followed, cementing the notion of asteroids as the harbingers of mass extinction. An NEO such as that which collided with the Earth 65 million years ago poses just as great a threat to humanity as it did to the dinosaurs.

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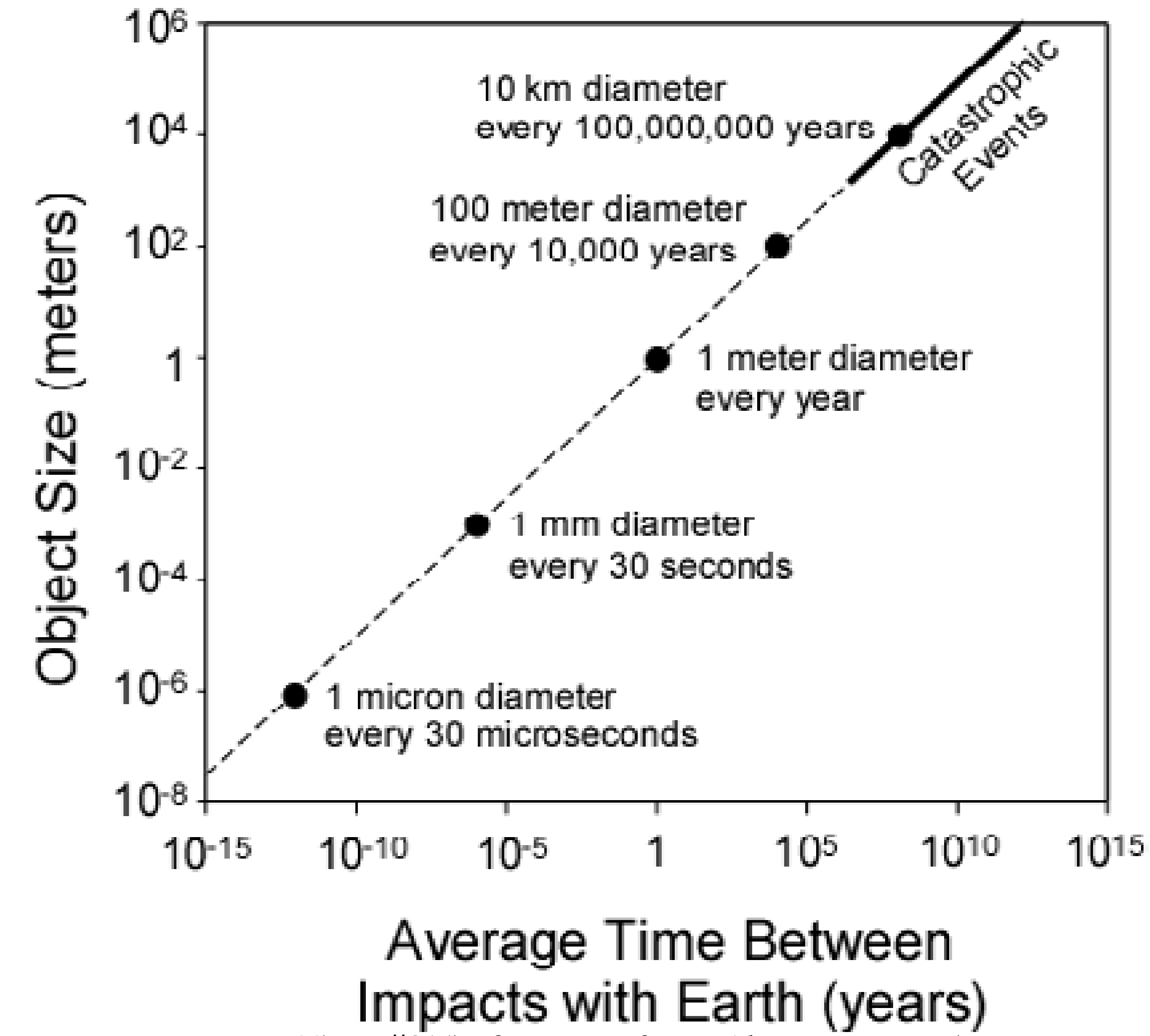
In order to visualize the threat an asteroid poses, we have to consider two things: magnitude of the event, and the probability of it actually occurring. Comparing the threat of an asteroid impact to the threat of other geological threats allows us to gain a better understanding of the relative threat an NEO poses. Megatsunamis caused by massive undersea earthquakes and volcanic supereruptions such as the Yellowstone Caldera comprise some such possible geological threats. Both supereruptions and megatsunamis occur much more frequently, about once every 50,000 years; the last major asteroid impact event was 65 million years ago, although smaller asteroids hit every couple decades (such as the Tunguska event and the recent Russian meteor). In fact, the earth is constantly bombarded by smaller particles originating in the asteroid belt. Objects a meter across impact on a yearly basis. However, more catastrophic events are much rarer, occurring tens of millions of years apart. (Image #2) Asteroid impacts would have a much larger range of devastation relative to a megatsunami or



Figue #2 The frequency of asteroid mpacts on Earth volcanic supereruption; for instance, the landslide of the La Palma island in the Atlantic Ocean could trigger a megatsunami which would devastate the eastern seaboard of the US, but few other places of the world would be affected. An asteroid a kilometer across would almost certainly have global effects (McGuire, 2006).

While a 1 kilometer asteroid impact only happens once every 600,000 years, the magnitude of the asteroid impact is very great compared to the other two possible geologic events. Even though impact rates have been stable for 50,000 years, the impact of an object greater than 1.5 kilometers in diameter would have a global effect, causing an estimated 1.5 billion deaths (Bland, 2005). Compared to the other possible geological threats the earth faces, an asteroid would affect the largest area and cause the most deaths. Furthermore, the statistical probability of dying due to an asteroid is 1 in 20,000; this relatively high number is due to the very high magnitude an impact would have. If an asteroid were to collide, even if it happens very rarely, you would have a higher chance of being killed. One reason the threat of impact is diminished is because discovery of a potentially dangerous near Earth object usually occurs a decade or more in advance, giving us ample time to mount a defense against such an impact. Considering all of these factors, the overall threat of an asteroid impact still comes out to be lower than a megatsunami or supereruption (Bland, 2006).

Although the probability of an NEO impact is small compared to other geologic catastrophes, the massive magnitude an impact would have calls for investigation and detection of these Near Earth Objects. Most NEOs come from the Kuiper belt, an icy area exterior to Pluto with abundant comets, and from the Asteroid belt, between Mars and Jupiter. NASA has been attempting to catalog the majority of the large NEO population in a reasonable amount of time, setting their initial estimates for about a decade (Pilcher, 1998). Following an increase in funding from only $1.5 million per year (1998) to $16 million (2012), the rate of discovery of new NEOs has increased exponentially (Image #1). Currently, there are multiple systems in place

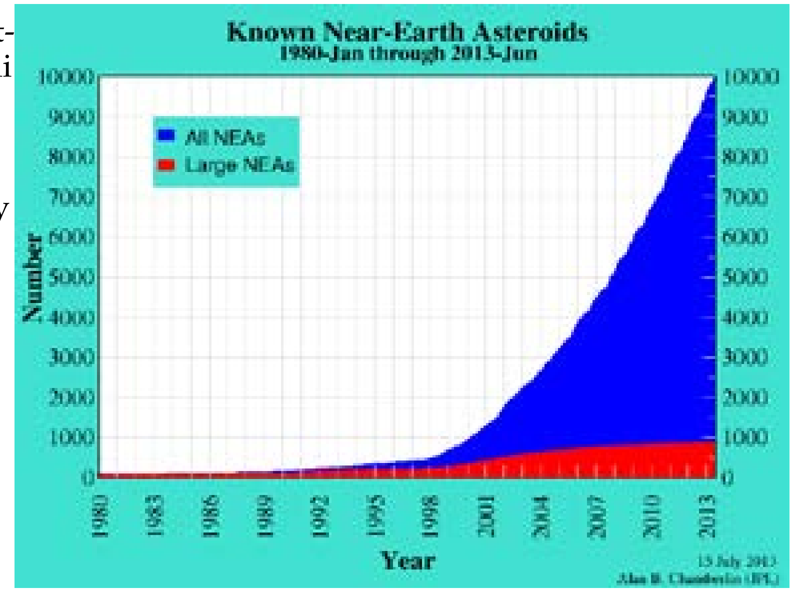


Figure #1 The discovery of known near-Earth asteroids.

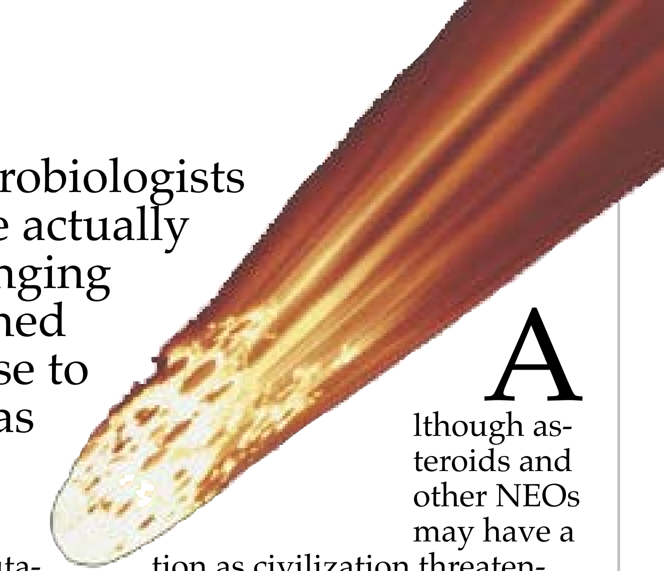
ranging from ground based optical telescopes to infrared space telescopes with the purpose of observing and predicting the movements of potentially hazardous asteroids and comets (LSST, 2003). Some are capable of predicting the orbital paths of an asteroid for the next century; some probes are being sent to already detected comets in order to collect samples (Evans et al., 2003).

A problem which persists, even with advanced asteroid detection technologies in place, is the recurring impact of smaller asteroids, like the one that recently hit Russia. They are too small to be detected by current technologies put in place to find NEO's, meaning they could continue to collide with the Earth with little to no warning (Wall, 2013). The NASA Near Earth Object Program is charged with finding only objects which are 1 kilometer or larger; the recent Russian impact was only 15 kilometers wide, yet it was still able to injure hundreds. Less than one percent of asteroids that are 40 meters or larger have been detected, meaning the vast majority are still out there without our knowledge (Wall, 2013).

Knowing the threat posed by NEOs allows astrophysicists to predict the effects of an impact. These effects are categorized by the Torino Impact Scale, which ranks impact candidates based on the kinetic energy and the probability of the impact. The global threshold size of an asteroid hitting the earth and causing a catastrophic fall in global temperatures (like during the Cretaceous mass extinction) is about 1 kilometer. At the impact site, multiple events will occur. First, a massive crater will form where the NEO collides, leading to a massive release of heat and sound in the form of a firestorm; this will lead to the complete obliteration of flora and fauna in the immediate impact area, which can be up to ten times the size of the actual asteroid. Wildfires around the impact site would lead to more loss of life and smoke blocking the sun. Earthquakes could also occur up to Richter magnitude 13, potentially altering the orbit of the Earth.

There would also be long-term effects on the climate: within hours of the impact, a global firestorm would start due to the reentry of ejecta back into the Earth's atmosphere (Nelson, 2011). Dust caused by the impact would block sunlight, leading to continual darkness, death of vegetation, food shortage, and death. The ozone would also be affected by a large impact, leading to increased exposure of UV radiation to Earth (Edwards, 2010). This is because an impact in the ocean would eject water vapor containing chlorine and bromine high into the atmosphere, leading to reactions similar to those caused by CFCs, resulting in the creation of a massive ozone hole. The depletion of ozone leads to another serious effect: global warming, possibly for centuries. This would affect not only the climates of areas, but also the flora and fauna that live there, possibly changing entire ways of life. Another possible consequence of an ocean impact is a large tsunami which could flood the interior of continents, causing devastating short term damage, but also long term changes on the populations that near these areas (Paine, 2011). Clearly, the threat and effects of an asteroid impact are very real, and have potentially disastrous consequences.

"For example, some astrobiologists hold that meteors were actually the vector of life, bringing microorganisms formed elsewhere in the universe to earth, a theory known as panspermia."



Although asteroids and other NEOs may have a reputation as civilization threatening, they also have life bringing capabilities. For example, some astrobiologists hold that meteors were actually the vector of life, bringing microorganisms formed elsewhere in the universe to earth, a theory known as panspermia. Furthermore, asteroids played a key role in the development of modern civilization and the rise of humans. As Luis and Walter Alvarez discovered, the impact of a large asteroid during the Cretaceous period led to the extinction of dinosaurs, allowing the rise of mammals as the dominant animal life form on the planet. This in turn would lead to the evolution of apes, and eventually humans (Institute of Physics). Of course, this doesn't really help out the current human population. However, steps are being taken to protect us from NEOs: the United Nations is currently discussing possible international defense systems and missions to predict and protect humanity from such a threat (David, 2013). And although there are thousands of other asteroids circling around the solar system,

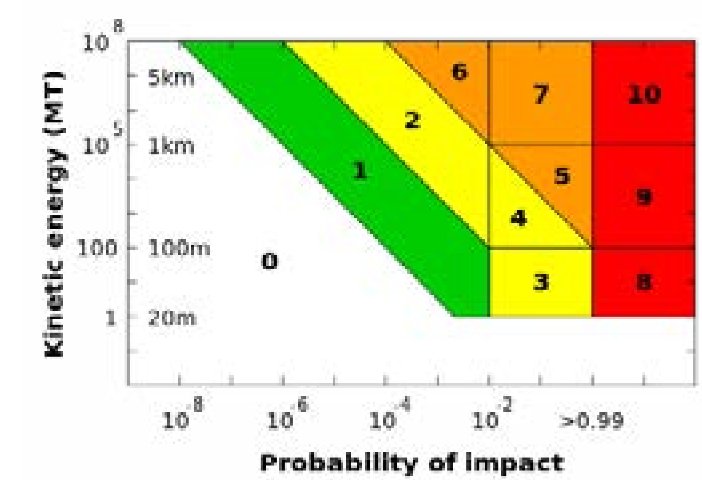


Figure #3. The Torino Scale is for categorizing the imact hazard associated with near-Earth Objects.

with the advent of new technologies to identify NEOs, we are giving ourselves more time to react in the case that an asteroid is headed straight for us, a collision which we'll be able to meet head on. Thus, the catastrophic effects an asteroid impact might have made them a global priority which is exactly what we need to face such a threat.

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