Hunting for killer asteroids:

The past, present and future of near–Earth asteroid surveys

A presentation by Dr Alan Harris (Space Science Institute, Colorado) delivered at the BAA Ordinary Meeting, 2007 May 30

Dr Harris opened his lecture by pointing out that as early as 1705 Edmund Halley was aware of the possibility of an impact of a cometary body with the Earth. The first planet-crossing asteroid, Eros, was discovered in 1898 and the first Earth-crossing asteroid, Apollo, in 1932. Fletcher Watson mentioned the likelihood of a collision in his book *Between the Planets* published in 1941. Evidence of impacts can be seen clearly on the surface of the Moon. Numerous impact craters have been found on Earth (Figure 1), some of the best examples of which are Manicouagan (Canada), Chicxulub (Mexico) and Barringer Crater (Arizona). The famous Tunguska event was an airburst leaving no crater on the ground. The Sikhote–Alin meteor fragmented to produce approximately 200 small craters. In 1992 a meteorite struck a car in Peekskill, USA. If the comet Shoemaker–Levy 9 had struck the Earth instead of Jupiter it would have caused a global catastrophe.

In order to place the impact hazard in the context of other natural disasters it is necessary to determine the frequency of impacts relative to the size of the impactor and the destruction caused. Multiplying the two latter terms gives the rate of destruction in deaths or dollars per year. The frequency vs size can be determined by counting and dating craters on the ground, or by counting discovered asteroids.

Early professional surveys dedicated to finding asteroids were photographic: the Shoemakers and Eleanor Helin at the Palomar Observatory from 1973 to 1995 and the Anglo-Australian NEO Survey at Siding Spring from 1990 to 1996. At the request of the US Congress the NASA NEO Detection Workshop issued the 'Spaceguard Survey' report in 1992. In 1998 NASA was directed by Congress to achieve the goal of 'Cataloging greater than 90% of all Earth-crossing asteroids larger than 1km in diameter within 10 years'. To achieve this aim a number of automated surveys were initiated: JPL NEAT, Spacewatch, LINEAR and the Catalina Sky Survey.

The present rate of discovery of near Earth asteroids with a diameter of >1km is approximately three per lunation, down from a peak of ten in 2000. The 1km diameter is assumed if the absolute magnitude of the asteroid is <18. The simplest and probably most accurate way to estimate total population in the largest size range, is to extrapolate the number discovered on a straight line (log scale), corresponding to a constant power law. The total population of asteroids in a given size range can also be calculated by comparing the ratio of redetections of known asteroids to all detections (new discoveries plus redetections). Computer models of current surveys indicate that it would take approximately ten years from the start of the survey to detect 80% of NEAs with a diameter of 1km.

Having calculated the numbers of NEAs for a given absolute magnitude or size range, we need to know the frequency of impacts vs. impact energy in order to evaluate the impact risk. Making assumptions about the velocity and density of the impactor the impact energy, E, is given by the equation $E = (70{,}0000 \times D^3)$ MT where D is the diameter of the impactor in km. Knowing the frequency of impacts of asteroids of a given size and the energy released by a single such impact the total impact energy can be calculated.

The area and severity of destruction is dependent on the size of the impactor and its velocity. For example we can expect an extinction event, caused by a 10km diameter asteroid, every 100 million years. With currently available technology, it is possible to discover and catalogue most NEAs larger than 1km in diameter. Thus it is economically feasible to determine if any one of the ~1000 NEAs capable of causing a global catastrophe is on a collision course with the Earth in the next century. The risk of death per individual from a mass extinction type asteroid impact is estimated to be 1 in 4,300,000 (USA figures). This lies between similar risks from food poisoning by botulism, and a shark attack. This raises the question 'Is it worth the investment of hundreds of millions of dollars to push the impact risk down still further, or should we simply declare 'mission accomplished' and move on?'.

Further automated surveys are planned (with implementation dates): VLT Survey Telescope (2008), Pan-STARRS 1 (2008), VISTA (2009, Figure 2), DST (2010) and LSST (2012). These telescopes are capable of detecting a larger proportion of faint objects than existing surveys. For example the LSST (Large Synoptic Survey Telescope) should be able to detect over 90% of asteroids of diameter 0.2km or greater over ten years of operation.

The 'Saga of NEA AL00667' demonstrates the difficulties of assessing and communicating the risk of an impact to the public. The object was

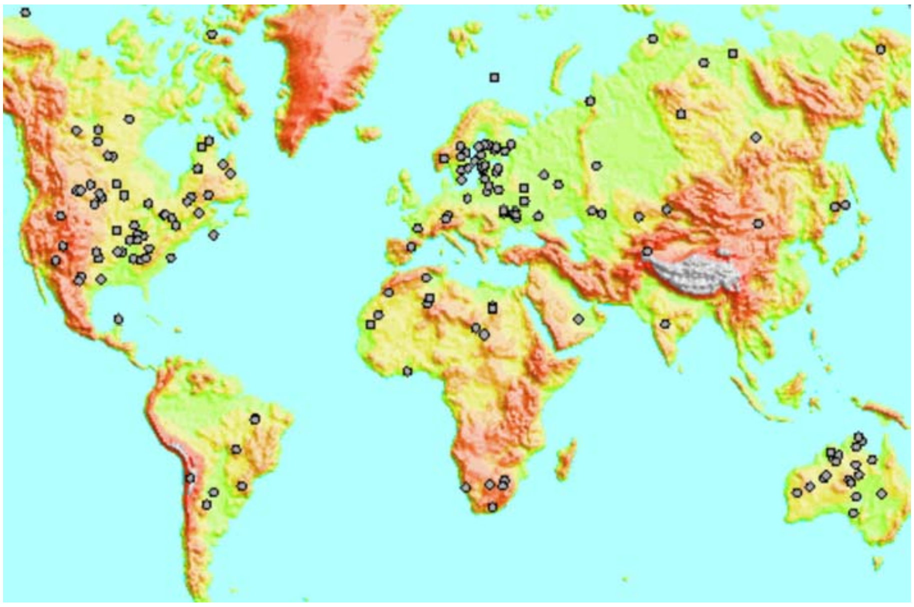

Figure 1. Identified impact structures on the Earth

Figure 2. VISTA, the Visible and Infrared Survey Telescope for Astronomy, is a joint UK/ESO development, installed at Cerro Paranal, Chile in 2008 April as part of ESO's Very Large Telescope facility. UK STFC/ESO

detected by the LINEAR survey on 2004 January 13 and details published on the Minor Planet Center's NEO Confirmation Page. Two amateur astronomers, BAA President Richard Miles and Reiner Stoss in Germany, observed that the object was brightening rapidly. Dr Harris then announced, via the Minor Planet Mailing List, that the ephemeris published by the MPC indicated an impact within 24 hours. The MPC calculated a new orbit which showed that the object would narrowly miss the Earth, and Steve Chesley, JPL, computed a range of positions of the object should it be on an impacting path.

However, the area in question was searched by experienced amateur Brian Warner and no object was found. Why the confusion? The apparent motion of an asteroid in the sky has two components: 'proper motion' due to the orbital motion of the asteroid and the Earth and 'parallactic motion' due to the offset of the observer from the centre of the Earth. In some cases it is not possible, over a short period of time, to distinguish one from the other of these two components, with interesting consequences.

The Torino Scale is used to communicate the risk of an impact and the associated destruction to the public. For example NEA 99942 (Apophis) scored 4 on the Torino Scale in 2004 December when it was predicted to have a 1 in 37 chance of hitting the Earth in 2029 April. This translates to 'A close encounter with a 1% or greater chance of a collision capable of causing regional destruction'. Radar tracking of Apophis over the next decade will very likely reduce the impact probability to zero. However should it still pose a threat then it may be possible to use a 'gravitational tractor', devised by astronaut Ed Lu, to deflect the asteroid.

Dr Harris concluded by stating that we should not build a deflection system unless a need is discovered, and that we should not make fools of ourselves and the rest of the astronomical community by publishing predictions that turn out to be, or appear to be, wrong.

In answer to a question from Nick James Dr Harris pointed out that new discoveries don't alter the long-term collision flux but do reduce the short-term risk as we know their orbits more accurately. Asked if the Earth passing through the tail of a comet could be harmful Dr Harris said no, but if such a close pass caused the comet to fragment it could cause problems at a later date. He also pointed out that cometary orbits cannot be accurately predicted over a long time period due to non-gravitational forces, and therefore we would not know until a few weeks or months beforehand whether an impact with an Earth-crossing comet was likely or not.

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