Colliding Asteroids with very Short Warning Time

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There are many collision asteroids approaching the Earth with very short warning time, and especially, when the asteroids approch the Earth from a blind celestial area surrounding the Sun (here, we tentatively define the area within 30° from the Sun), they can not be detected at all by ground-based observations because of bright sky-background brightness. Our estimation show that a percentage of the asteroids approaching from the blind area in the total asteroids approaching the Earth with the closest distance less than 0.01 AU is larger than 30% which is very dengerous situation.

Introduction

In July, 1994, many fragments of the comet Schoemaker-Levy 9 (SL-9) collided one by one with the Jupiter. Because of these big events, public people are given a deep understanding in possible comet and asteroid collisions with planets including our own Earth. There is an estimate that a collision probability of objects with a size of SL-9 with the Jupiter is onece a thausand year. Since a mass of the Earth is only one thausandth, its probability with the Earth is much smaller. However, there are certain evidences that collisions of asteroids with the Earth happened and there is a certain probability of the collisions in future. When an asteroid with a diameter larger than 1 km will collide with the Earth, a global catastrophie will follow.

When an asteroid is discovered at only a few weeks prior to its collision (we call it as a warning time), we have no way to escape a global catastrophie except bombing atomic bombs thrown by misiles on its surface. However, to proceed this certainly, we have to keep always misiles and atomic bombs at a stand-by condition. A big budget has to be uselessly payed during a period without its collision.

We discovered a large fraction of collision asteroids with very short warning time of a few days. These will be shown in this paper.

Asteroids approaching the Earth from Blind Drections

The space-guard project is a project to set up a network of 5 ground-based telescopes with an aperture of 2.4m. Because of ground-based telescopes there is a blind celestial area which is directions surrounding the Sun (here, we tentatively define the area within 30° from the Sun). We have to observe an asteroid approaching the Earth from the area only during a day-time and therefore can not detect it because of bright sky background. We found that a percentage of the asteroids approaching from the blind area in the total asteroids approching the Earth with the closest distance less than 0.01 AU is larger than 30 %.

Since 1988 when a detection observation of near-earth-asteroids(NEA) was started, using the space-watch telescope of the University of Arizona, a number of detected NEAs is a few tens per year and over 200 at the end of 1993. Most of them have relatively large values of an eccentricity different with those of asteroids distributing within the asteroid belt. Therefore, they cross an orbit of the Earth not only from the outer part but also from the inner part.

One of authors (MY) calculated orbital motions of many asteroids and analysed close encounters between asteroids and planets (Yoshikawa and Nakamura 1994, Yoshikawa 1994). Yoshikawa (1994) calculated positions of 188 NEAs detected till 1993 during a period from 1994 to 4600. In our study, we analyse close encounters between asteroids and the Earth using the results of Yoshikawa (1994).

Figure 1 shows motions of three typical asteroids relative to the Earth where X axis and Y axis are a direction of Sun-Earth line and its perpendicular direction, respectively. It is shown by dashed and dot-dashed lines for cases when the asteroids overtake the Earth. For both the cases, relative velocities between each asteroid and the Earth are small. For case shown by solid line when e is large, an orbit of the asteroid crosses that of the Earth, and it comes from a direction near the Sun.

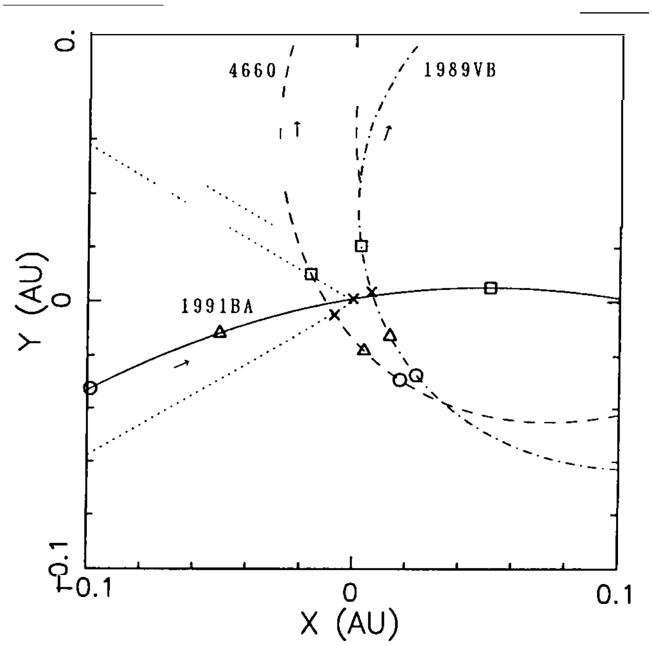

Figure 1. Motions of three asteroids near their closest approach relative to the Earth. X and Y axis are a directions of Sun-Earth line and its perpendicular direction. The Earth is at (X,Y)=(0,0). Positive values of X and Y are an anti-solar direction and an orbital direction of the Earth, respectively. Dotted lines are at 30° from the solar direction. Solid line is a case at the closest approach with a distance of 0.0011 AU on July 6, 2843, for the asteroid 1991BA with a semi-major axis, a, of 2.267 AU, an eccentricity, e, of 0.683, and an inclination, i, of 2.116°. Dashed and dot-dashed lines are cases at that of 0.0089AU on January 13, 3269, for the asteroid 4660 with a=1.520, e=0.370, and i=1.171° and at that of 0.0093AU on November 1, 4096, for the asteroid 1989 VB with a=1.856, e=0.460, and i=1.981, repectively. Circles, triangles, crosses, and squares show points at 10 days before the closest approach, at 5 days, at the closest approach and at 5 days after that, respectively.

It is clear that a ground-based observation can not detect asteroids at a direction of the sun and also surrounding the sun because of bright sky background. Considering that the asteroids near the sun are at low elevation at a time with dark sky background after sun-set and before sun-rise, we define a blind area for asteroid detection within 30° from the solar direction as a working condition.

Number of asteroids approaches the Earth during the given period from 1994 to 4600 depends on distances of the closest approaches. It is 6694 times for that of 0.1 AU, and 5689, 4702, 3799, 2918, 2146, 1469, 864, 378, 94 for that of 0.09 AU, 0.08 AU, 0.07 AU, 0.06 AU, 0.05 AU, 0.04 AU, 0.03 AU, 0.02 AU, and 0.01 AU, respectively. The number obtained by extrapolating this relation to 0.000043AU which is a radius (6400km) of the earth is onece 1.3×10^6 years which is a collision probability of 188 NEAs in the period. One should remind that this is for the detected 188 NEAs including asteroids with small radii about 10m.

Some NEAs cross the blind zone at their closest approaches to the Earth and stay there for only a few days. In those cases there is a possibility to detect the NEAs several days before their closest approaches. However, if an asteroid approaches the Earth directly from the blind zone, it stays in the zone more than 10 days prior to the the closest approach. Figure 2 shows two examples when each asteroid runs out from the zone. One can see that, for the case of asteroid No.1991BA, it will run out from the zone on the day at the closest approach. This leads to a conclusion that there is a possibility of asteroid collisions without a warning time.

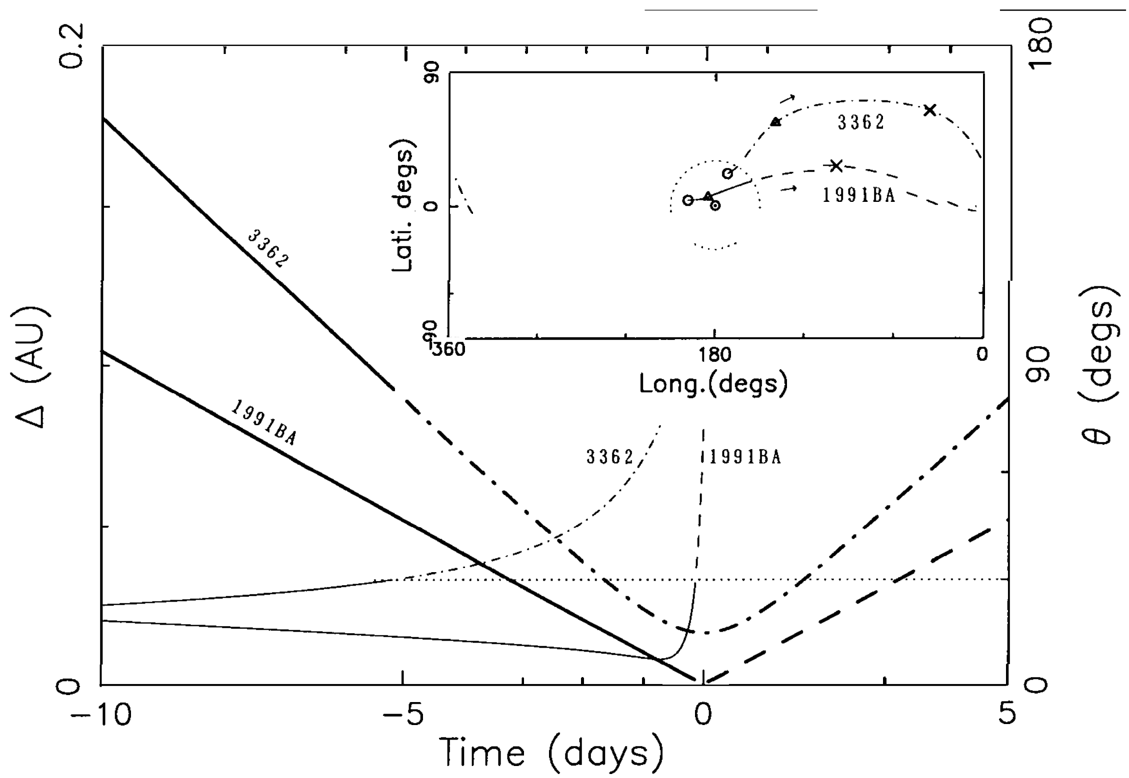

Figure 2. Distance variation of two asteroids depending on time where positive and negative values are after and before the closest approach, respectively. Left (corresponding to thick lines) and right (corresponding to thin lines) ordinates show a linear distance of asteroids from the Earth and an angular distance of asteroids from the Sun, respectively. Dotted line is given at the angular distance of 30°. Curves with dashed and dot-dashed lines are for asteroids of 1991BA and 3362, respectively. Each asteroid is inside the blind zone at a part of solid line on each curve. Superposed figure shows motions of two asteroids on a longitude and latitude plane relative to the Sun. The Sun is at 0° latitude and 180° longitude. Circles, triangles, and crosses are points at those days 10 days, 1 days, and 0 day before the closest approach, respectively.

A brightness of asteroids depends on those radius and albedo and also those distances from the Earth. Therefore, it is very difficult to detect the asteroids more than 10 days prior to those collisions or the closest approaches because of their faint magnitude. Although those detectability depends on their radius, here we define asteroids running out from the blind zone at a few days prior to the closest approaches as a dangerous one.

Numbers of asteroids running out from the zone at each day proior to the closest approaches ralative to the total number of close approch asteroids are shown in figure 3. A fraction of the dangerous asteroids is less than 3 % for the case of 0.1 AU, but is over 30 % for 0.01 AU. This means that a large fraction of colliding asteroids is a dangerous one. It is clear that even if powerful misiles and atomic bombs are kept to be at a stand-by condition we have no possibility to reject a collision of the dangerous asteroids.

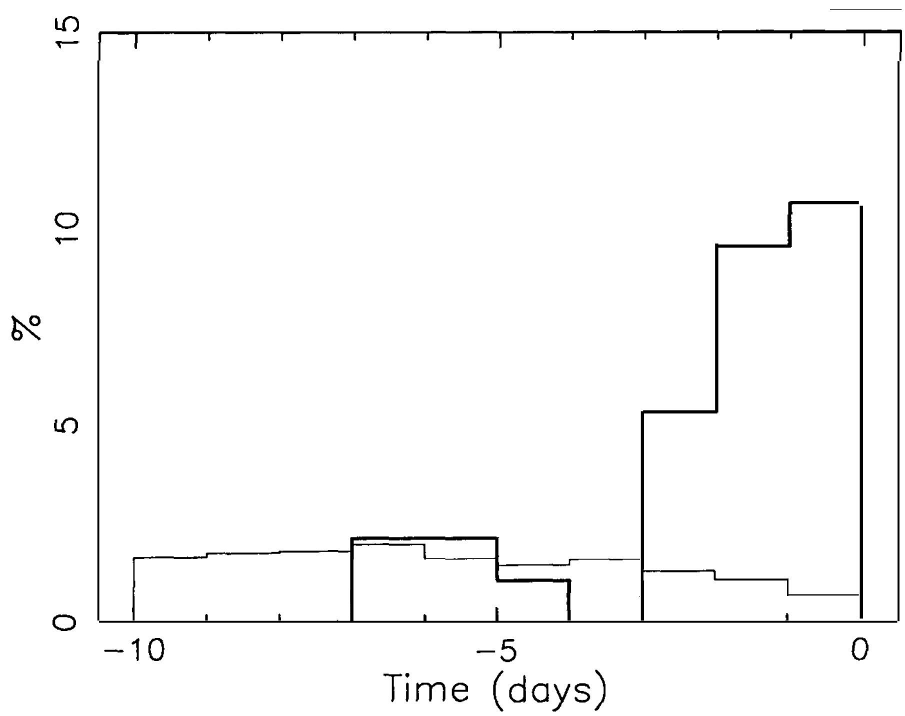

Figure 3. Number ratio of asteoids running out from the blind zone at each day prior to the closest approach out of the all asteroids approaching the Earth with the shortest distances less than 0.1 AU (thin line) and 0.01 AU (thick line), respectively.

The most effective way to escape the collision is to find all the NEAs and determine those orbits. The US spaceguard project is the one to aim this but only for asteroids with a radius larger than 1 km which certainly cause a global catastrophie and an extinction of human-beings. If an orbit of the dangerous asteroid is well determined many years prior to the collision, we can easily escape from the collision by giving only small additional velocity, for example, 1 cm/s, to the asteroid at a time of several ten revolution around the sun prior to the collision. This velocity change is produced by usual TNT bomb explosion on a surface of the asteroid and we are able to reserve enough to prepare launching a satellite carring the bomb.

Nessecity of Space-borne observations

The space-guard project is not a perfect one, because only 99 % of NEAs with a diameter larger than 1 km are planed to be detected and about 1 % will escape from a detection. Most of the NEAs with a diameter between 100 m and 1 km which will cause a catastrophie in a continental scale can not be detected.

Only one way to reject a collision of asteroids escaping from the detection by the space-guard project is an observation by telescopes located at places without terrestrial atmosphere where sky brightness is very dark only except to a direction of the sun. There are discussions to build a lunar-based station till a middle of 21st century under an international collaboration. If its project will be in reality, one should put the first priority to build there telescopes for a detection of the dangerous asteroids. To keep a warning time as long as we can do, one should develop a telescope watching an area of 1 steradian.

There is an estimate that a death probability of a human-being by asteroid collisions is nearly equal to that by air accidents in the total accidental death. We dare to say that an air accident makes only a fraction of those whole human-beings in the world but the human are able to live without any interuption. However, a collision of an asteroid with a diameter larger than a few hundred meter has a posibility to brings an extinction of the human as dinosaurs were extincted 65 million years ago.

Although it is not nessesary for us to be hurry to build the proposed lunar based telescopes for a detection of dangerous asteroids because of a low collision probability, the catastrophic asteroid collision will certainly happen with a certain collision probability. Therefore, considering the serious problems, human-beings should start to set up a system to escape the collison.

References

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