Asteroids, Comets, Meteors 1991, pp. 65–68
Lunar and Planetary Institute, Houston, 1992

Bias Correction Factors for Near-Earth Asteroids

G. K. Benedix (AMES Dept., UCSD; California Space Institute 0216, UCSD, La Jolla, CA 92093-0216)
L. A. McFadden (California Space Institute, UCSD, La Jolla, CA 92093-0216)
E. M. Morrow (AMES Dept., UCSD; California Space Institute 0216, UCSD, La Jolla CA 92093-0216)
M. N. Fomenkova (California Space Institute 0216, UCSD, La Jolla, CA 92093-0216; Space Research Institute, Profsoyuznaya 84/32, Moscow 117810, USSR)

ABSTRACT

Knowledge of the population size and physical characteristics (albedo, size, rotation rate) of near-Earth asteroids (NEAs) is biased by observational selection effects which are functions of the population's intrinsic properties and the size of the telescope, detector sensitivity, and search strategy used. The NEA population is modeled in terms of orbital and physical elements: a, e, i, ω, Ω, M, albedo, and diameter and an asteroid search program is simulated using actual telescope pointings of right ascension, declination, date, and time. The position of each object in the model population is calculated at the date and time of each telescope pointing. The program tests to see if that object is within the field of view (FOV = 8.75°) of the telescope and above the limiting magnitude (V=+16.5) of the film. The effect of the starting population on the outcome of the simulation's discoveries is compared to the actual discoveries in order to define a most probable starting population.

INTRODUCTION

The near-Earth asteroids (NEAs) are a population whose orbits approach or cross the orbit of Earth. Their proximity to Earth makes them a subject of curiosity and they may provide information about the origin and evolution of our solar system and perhaps life on Earth.

Where were the NEAs formed? How did they come to be in the region of space that they now occupy? Are they main belt asteroids, extinct comets, or a combination? What are they made of? How large is the true population? What is their true distribution of size and albedo? Do they contain carbon, water, and/or other life-forming elements?

The questions which motivate this study are dependent on accurate knowledge of the orbits, physical characteristics, and size of the true population. The term true population is defined as the total population of objects including the ones that have not yet been discovered or characterized. The term discovered population is used to refer to the approximately 200 NEAs with known orbital elements and some known physical properties (McFadden, et al., 1989). The nature and character of the true population is unknown because of biases due to observational selection effects, which have not been fully addressed. There are two types of biases, those intrinsic to the physical properties of the population, size, albedo and orbit, and those controlled by the parameters of the observing program. The relative availability of asteroids for discovery was addressed by (Shoemaker, et al., 1990), and (Luu and Jewitt , 1989) have demonstrated the existence of bias through study of the contribution of phase effects. The objective of this project is to define and quantify the bias factors that are associated with determining a true population of NEAs accounting for contributions from one of the search programs.

Our approach consists of creating different populations of NEAs with different orbital elements and physical characteristics and replicating the ground-based telescopic search program of the Palomar Asteroid Comet Survey (PACS) using the actual telescope pointings and an ephemeris program applied to our model population. The modeled discoveries are then compared to the number of real NEA discoveries, thus revealing a numerical bias correcting factor. In the process of determining bias factors, we are also studying the likelihood that various population characteristics might be real. This paper will serve as a progress report through August, 1991.

THE MODEL

Our model population consists of 2000 asteroids. This number was chosen in order to incorporate an estimate made by (Shoemaker et al., 1990) based on the cratering rates of asteroids with Earth. We doubled his estimate for a starting point. An asteroid is defined by eight parameters: six orbital elements, and two physical characteristics: albedo and H magnitude. Each parameter is represented by a random value generated in accordance with statistics given in Table 1. The diameter is derived from magnitude and albedo by the following equation:

$$D = 10^{(3.1295 - 0.5*\log(p) - 0.2*H)} \qquad (1)$$

where p is albedo, H is absolute magnitude, and 3.1295 is a constant which is dependent on wavelength. This equation is modified from (Bowell and Lumme 1979).

TABLE 1 Statistics of known NEAs on which model population is based.

Parameter	Mean	S	Distribution
a	1.92	0.66	Gaussian
e	0.50	0.16	Gaussian
i	0.00	19.60	Half-Gaussian
Ω	182.19	98.56	Uniform
ω	176.88	107.11	Uniform
M	167.85	106.52	Uniform
H	16.76	2.00	Power Law
p	0.14	0.08	Gaussian

Search Simulation

A computer program, called Search by D. Tholen, takes as input the position in the sky (right ascension and declination) and the date and time that an area of sky was searched. The limits of the telescope (field of view, limiting magnitude) are also specified. The program searches through a model population. The telescope pointings from the Palomar Asteroid Comet Survey (PACS) for the years 1984-1988 are used as input. Eugene and Carolyn Shoemaker use the 48 cm Schmidt telescope at Mt. Palomar for this program. To simulate the telescope and plate film, a limiting magnitude of 16.5 and a field of view of 8.75° are included as input parameters. The program takes each of the telescope pointings and determines if a modeled asteroid is in the field of view and below the limiting magnitude of the telescope at that time. If an asteroid is there, the program writes the "discovery" to an output file.

DISCUSSION and FUTURE DIRECTIONS

Table 2 shows the discoveries from 1984-1988 for both the real (column labeled NEA) and modeled populations for each model thus far created. The sky coverage for the 1986 telescope pointings is only half complete because the telescope was in exclusive use for another program. Model 1 and 2 are based on uniform distributions for all orbital elements with the difference between the two being the seed used to initiate the random number generator. The limiting magnitude is 18.0 in models 1-3. Models 3 and 4 use Gaussian distributions for a, e, i, p, and H, and uniform distributions for ω, Ω, and M. In model 4, we lowered the limiting magnitude to 16.5 and generated correlated distributions of a and e, and H and p. The number of simulated discoveries was reduced. In model 5, H and p are not correlated, H is expressed by a power law distribution, and p is Gaussian. Figures 1 and 2 show a versus e for the discovered and model 5 populations, respectively.

TABLE 2. Comparison of discovered asteroids: Real and modeled

Year	NEA	Model 1	Model 2	Model 3	Model 4	Model 5
1984	3	117	109	129	47	134
1985	5	152	162	140	98	67
1986	9	197	192	168	38	45
1987	11	145	151	114	47	52
1988	8	-	-	-	-	27

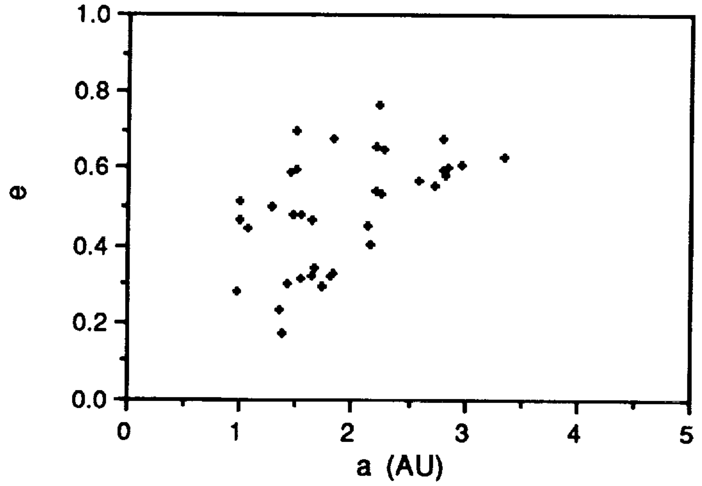

Figure 1. Semi-major axis (a) versus eccentricity (e) for the NEA population 1984-1988

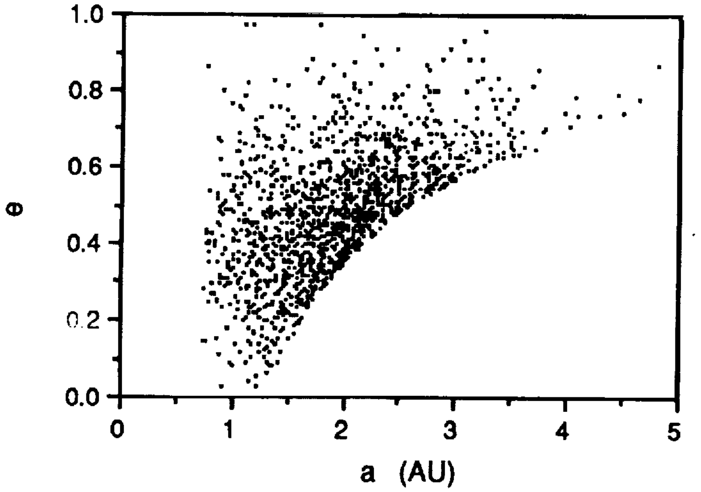

Figure 2. Semi-major axis (a) versus eccentricity (e) for model 5 population.

We believe that the number of simulated discoveries is much larger than the number of real ones because of two main reasons. First, albedos and magnitudes in our models are, on average, too high. The true population of NEA's is, probably, much darker. This indicates that the NEA's are not predominantly derived from the inner edge of the main belt which is dominated by bright asteroids. Rather they originated from the center or outer main belt where 60% of those asteroids >50 km are dark, or from comet nuclei, which are known to have very low albedos. Discovered NEA's are biased towards brighter objects that are easier to discover. Secondly, almost one hundred of the real NEA's were discovered before 1984. But as we don't have telescope pointings for the period of time earlier than 1984, those "already known" discoveries have not been accounted for in our model. This is a significant factor which we have not yet estimated.

We have concentrated on improving the accuracy of the physical model of the population and the constraints on the observing program. The starting populations based on diameters and albedo distributions rather than on albedo and magnitude distributions seems to be better connected with the existing hypothesis about the NEA's population and, hence, to provide better physical basis for our simulation. We should try two-dimensional Maxwellian distribution to simulate inclinations (as was suggested by J. Williams and J. Bhattacharyya). The effect of relative motion and film sensitivity have yet to be incorporated into calculations. These parameters combined select against the discovery of fast-moving, faint objects. The impact of plate edge effects, focus variations as a function of position on the photographic plate on discovery rates is minor, but have to be assessed.

We plan to create model asteroid populations which when tested by the search simulation program results in the best approximation of the NEA discovered population. Previously defined models of population distributions, such as (Wetherill, 1987) and (Wetherill, 1988) will also be run through the search simulation. The telescope search program conducted by Eleonor Helin and her colleagues at Jet Propulsion Laboratory will also be incorporated into the simulation.

REFERENCES

E. Bowell and K. Lumme (1979) Colorimetry and Magnitudes of Asteroids. In Asteroids (T. Gehrels, ed.), pp. 132-169. The University of Arizona Press, Tucson.

J. Luu and D. Jewitt (1989) On the relative numbers of C-types and S-types among near-Earth asteroids. Astron. J., 98, 1905-1911.

L.-A. McFadden, D. J. Tholen and G. J. Veeder (1989) Physical properties of Aten, Apollo and Amor asteroids. In Asteroids II (R. P. Binzel, T. Gehrels and M. S. Matthews, eds.), pp. 442-467. University of Arizona Press, Tucson.

G. W. Wetherill (1987) Dynamical relations between asteroids, meteorites and Apollo-Amor objects. Phil. Trans. R. Soc. Lond. A, 323, 323-337.

G. W. Wetherill (1988) Where do the Apollo objects come from? Icarus, 76, 1-18.