A CONCEPT OF HAZARDOUS NEO DETECTION AND IMPACT WARNING SYSTEM

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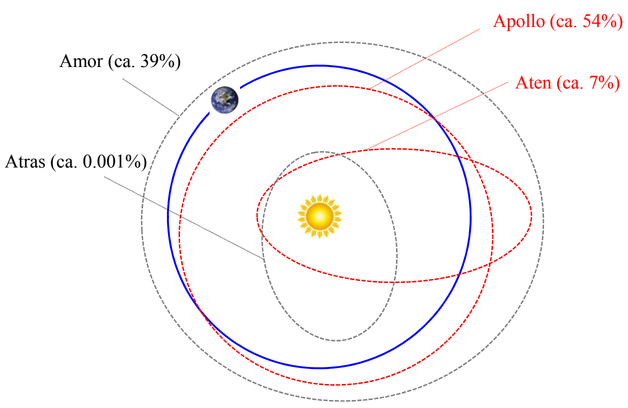
1. Introduction

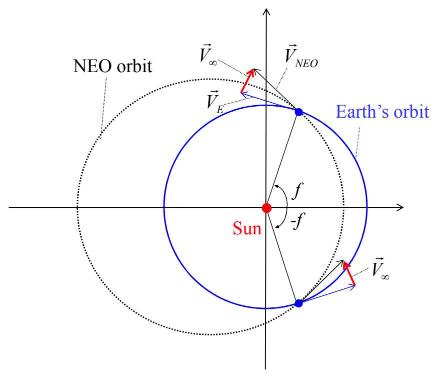
Tunguska: 30-50 m (1908/06/30)
http://science.nasa.gov/science-news/science-at-nasa/2008/30jun_tunguska/

Chelyabinsk: 20 m (2013/02/15)
https://www.newscientist.com/article/dn24542-csi-chelyabinsk-10-insights-from-russias-meteorite/

The threats by the impacts of NEOs are recognized from the past. The event of Chelyabinsk meteor reminded the mankind of the possibility of the hazard caused by NEO impact.



NEOs consist of four major types of asteroids. Apollos and Atens cross the Earth's orbit, which has potential of Earth impact.

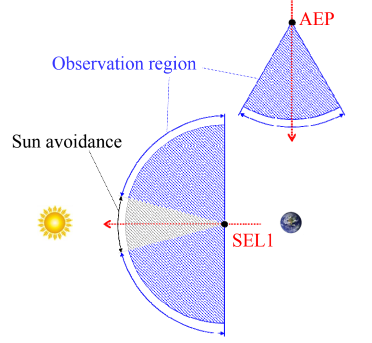


Two directions of NEO impacts depending on the impact points. Especially, it is difficult for ground observatories to detect NEOs incoming from the noon-side due to the Sun light.

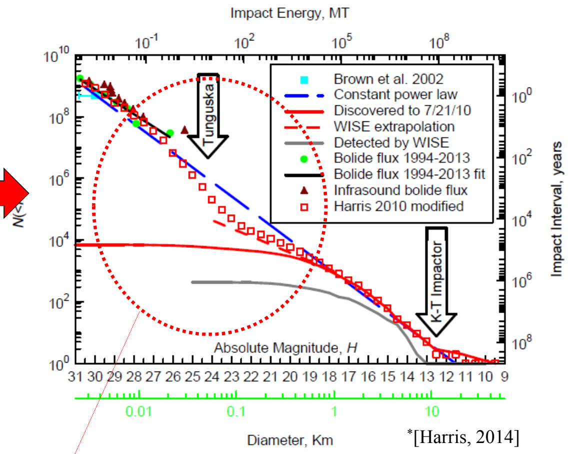
Chelyabinsk equivalent | Tunguska equivalent | Hiroshima atomic bomb = 0.017 MT

Type of Event	Diameter of Impacting Object	Approximate Impact Energy [MT]	Approximate Average Impact Interval [yr]	Absolute Magnitude
Airburst	25 m	1	200	26.26
Local scale	50 m	10	2,000	24.76
Regional scale	140 m	300	30,000	22.52
Continental scale	300 m	2,000	100,000	20.86
Below global catastrophic threshold	600 m	20,000	200,000	19.36
Possible global catastrophic	1,000 m	100,000	700,000	18.25
Above global catastrophic threshold	5,000 m	10 million	30 million	14.76
Mass extinction	10,000 m	100 million	100 million	13.25

*[National Research Council of the National Academies, 2010]



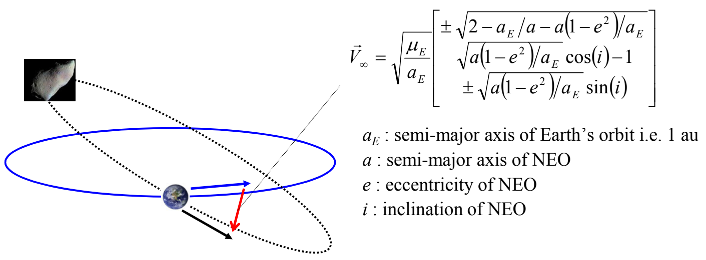
To overcome the difficulty, this study proposes a space-based telescope system dedicated to detect small size NEOs impacting on Earth.



*[Harris, 2014]

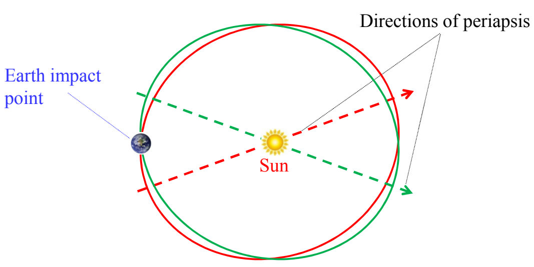
NEOs less than ca. 500 m are not fully discovered. Especially, most of Chelyabinsk class are not discovered. The proposed concept aims to ditect such small NEOs.

2. Virtual Impactors

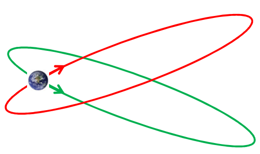


$$\vec{V}_\infty = \sqrt{\frac{\mu_E}{a_E}}\begin{bmatrix} \pm\sqrt{2 - a_E/a - a(1-e^2)/a_E} \\ \sqrt{a(1-e^2)/a_E}\cos(i) - 1 \\ \pm\sqrt{a(1-e^2)/a_E}\sin(i) \end{bmatrix}$$

a_E : semi-major axis of Earth's orbit i.e. 1 au
a : semi-major axis of NEO
e : eccentricity of NEO
i : inclination of NEO

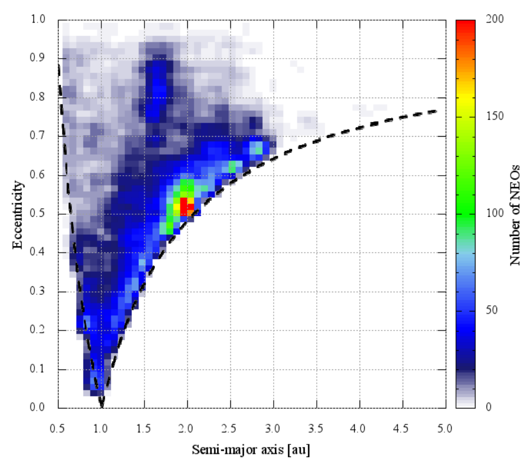


a) $V_{\infty x}$ difference



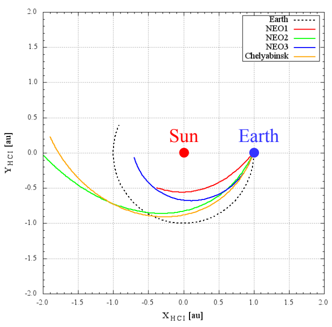
b) $V_{\infty z}$ difference

A combination of a, e and i determine VI's orbit. The ± signs of X component correspond to the directions of periapsis, and the signs of Z component determine descending or ascending at the impact.

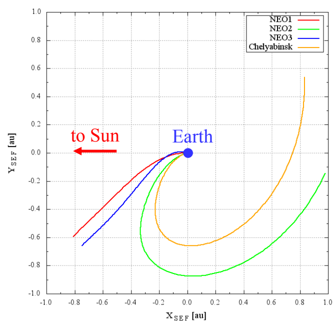


- Bottke model is applied to produce VIs.
- VIs concentrate on a = 2 au and e = 0.5.
- Black dashed line shows the boundary condition of the intersection of Earth's orbit as the follows:

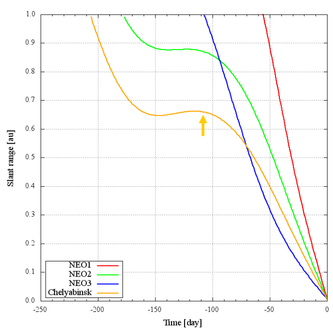
$$a(1-e) = 1\ au \quad \text{or} \quad 1\ au = a(1+e)$$



c) Inertial frame



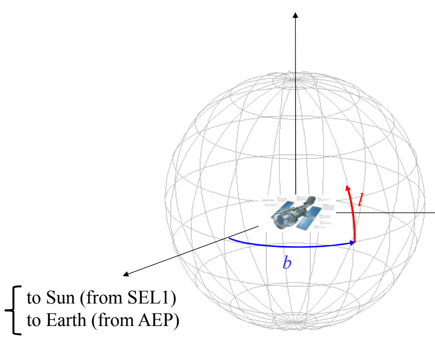
d) Sun-Earth fixed frame



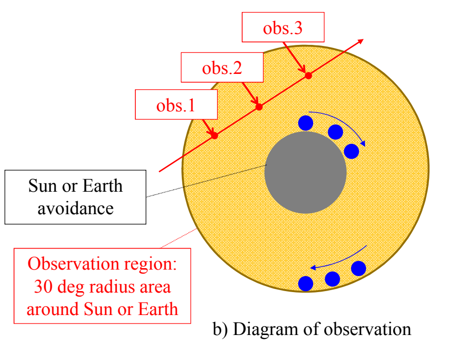
e) Range from Earth

- Figures show example VI orbits.
- Orange arrow in Fig. e) shows the point at which Chelyabinsk meteor comes into the noon-side from the night-side.
- The size of Chelyabinsk meteor was only 20 m, besides it was more than 0.6 au from Earth when it came into the noon-side, after which no ground observatory cannot detect it due to the Sun light.

3. Simulation of NEO Detection



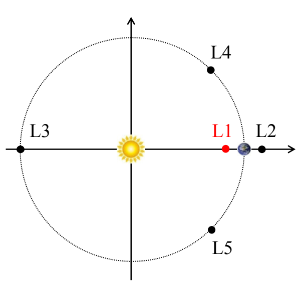
a) Definition of angles



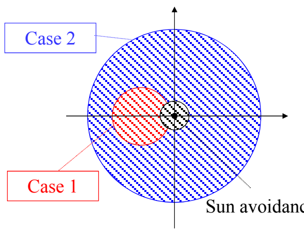
b) Diagram of observation

The assumed FOV is 2×2 deg^2. The telescope surveys the 30 deg radius region once per day. The integration time of each FOV is ca.120 seconds. Note J_1 is the detectable magnitude at 1 second integration.

➢ Detection from SEL1

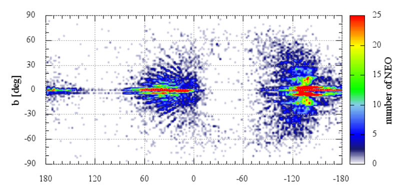


a) Location of telescope

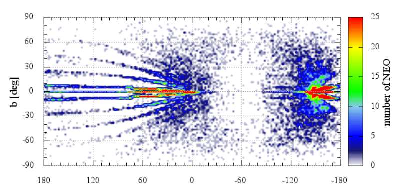


b) Observation schematic

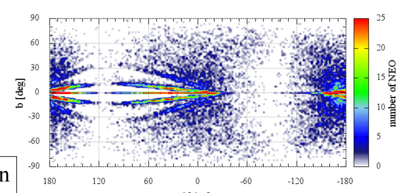
Space-telescope at SEL1 observes Sun direction. Case-1 observes 30 deg radius region while Case-2 observes half sky.



a) at 0.7 au



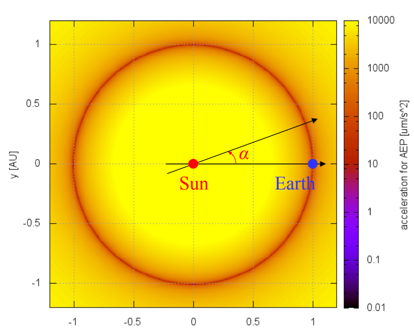
b) at 0.4 au



c) at 0.1 au

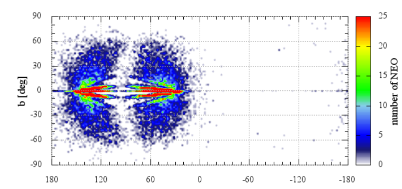
		25 m	50 m	140 m
Case-1	J_1 = 20	0.1%	0.7%	12.3%
	J_1 = 22	1.5%	10.0%	39.0%
	J_1 = 24	15.3%	39.0%	39.0%
Case-2	J_1 = 20	0.1%	0.1%	17.3%
	J_1 = 22	0.1%	14.7%	46.4%
	J_1 = 24	20.3%	40.7%	55.5%

➢ Detection from AEP

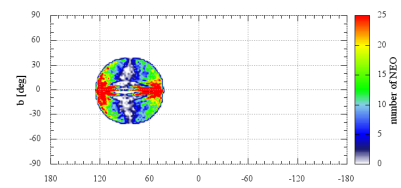


a) AEP acceleration map

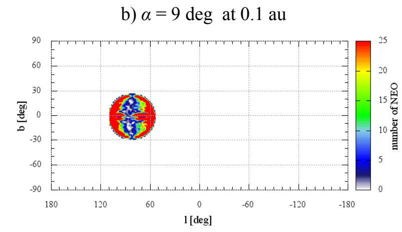
AEP (Artificial Equilibrium Point) is a stationary point in CR3BP by cancelling the residual acceleration. When VIs are shown from AEP, the VI cloud can be observed by the telescope. Right figures show the 0.1 au radius VI cloud around Earth as viewed in the telescopic view of the telescope on AEP.



a) α = 5 deg at 0.1 au



b) α = 9 deg at 0.1 au



c) α = 13 deg at 0.1 au

		25 m	50 m	140 m
$\alpha = 9$	J_1 = 20	0.4%	0.5%	46.0%
	J_1 = 22	6.1%	35.9%	50.6%
	J_1 = 24	47.8%	50.6%	50.7%
$\alpha = 13$	J_1 = 20	0.3%	1.5%	81.3%
	J_1 = 22	5.4%	61.6%	99.9%
	J_1 = 24	99.8%	99.8%	99.9%