EVALUATION OF AN NEO CLOSE APPROACH FREQUENCY INDEX FOR PUBLIC/MEDIA RELEASE PURPOSES

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NEO CLOSE APPROACHES IN THE MEDIA

Asteroid close approach: NASA gearing up as asteroid to pass closer than the Moon

NASA is on alert at
as a 'close approa
Moon.

DOOMSDAY DODGED Apophis 'God of Chaos' asteroid could hit Earth in over 100 years – as Nasa reveals it will 'miss' in 2068

Charlotte Edwards, Digital Technol
29 Mar 2021, 11:06 | Updated: 29 Ma

NASA has removed a huge

WHAT THE TRUCK Pickup truck-size ASTEROID came less than 250 miles from hitting Earth, Nasa reveals

Jon Lockett
17 Nov 2020, 19:28 | Updated: 17 Nov 2020, 19:33

TEROID the size of a pick-up truck has just skirted within 240 miles
th, NASA has revealed.

eek's very close encounter set a record for the nearest known space
o fly past the planet without actually hitting.

Skyscraper-sized asteroid travelling at 11,000mph will zip past Earth at a distance of 3.1 million miles this weekend

- The asteroid has been called 163348 (2002 NN4) and was first spotted in 2002
- It will make i
- The 1,870ft
- It poses no r

NASA WARNING Asteroid the size of the world's tallest building to zip past Earth at 56,000mph this week

Harry Pettit, Senior Digital Technology and Science Reporter
24 Nov 2020, 15:14 | Updated: 24 Nov 2020, 15:15

A GIGANTIC asteroid is set to zip past Earth this week, according to Nasa space debris trackers.

The rock is travelling at over 56,000 mph (90,000 kph) and at up to 820
metres (2
tallest bu

Asteroid news: A 1.2 mile rock to zip past Earth today - astronomers can already see it

AN ASTEROID big enough to be dubbed "potentially hazardous" but considered safe by NASA, has been photographed dashing through the solar system.

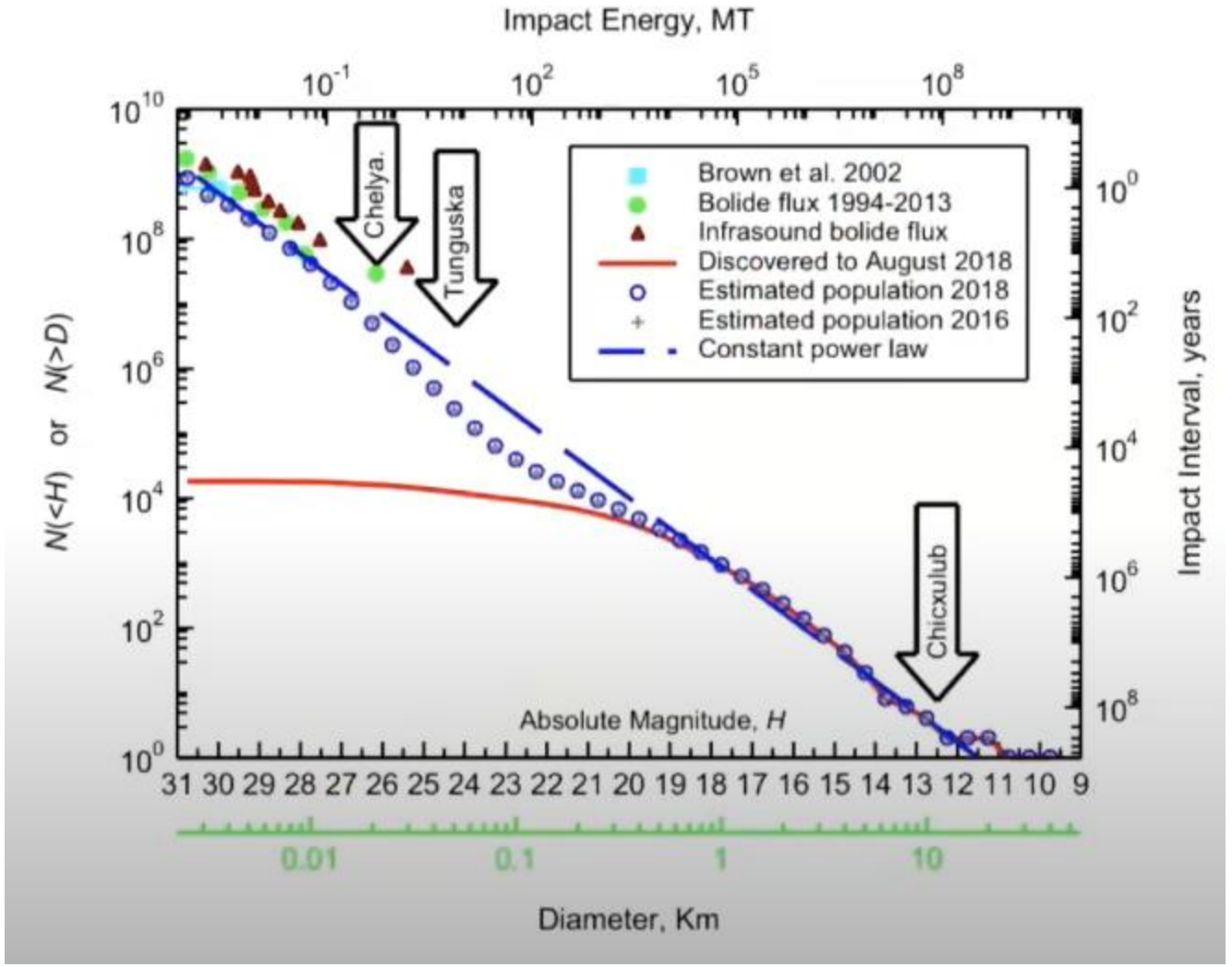
FREQUENCY OF A CLOSE APPROACH

- Given the close approach of an NEO to the Earth at distance d_{CA}, what is the frequency (or the period) of such event?
- A similar question has been responded in the past: the one associated to the NEO impact frequency

Why not extending such concept to the close approaches?

- Impact frequency has been extensively discussed in the literature in the last 50 yr
- The frequency is dependent on the NEO population distribution

IMPACT FREQUENCY VS POPULATION MODEL



Source: Harris, PDC-2019

There is a direct relation between a given population of NEOs and the impact frequency with Earth:

$$f_0 = k\,N$$

We need a function f_{CA} that allows the extension of the concept to any close approach conditions.

VARIABILITY WITH THE DISTANCE TO EARTH

- Assuming that the flux of NEOs is roughly uniform in the proximity of the Earth, the number of close approaches with the Earth will increase quadratically with the distance:

$$f_{CA}(N, b) = f_0(N)\left(\frac{b}{b_0}\right)^2$$

b is the b-plane impact parameter

- Taking into account the gravitational focusing due to the Earth:

$$f_{CA}(N, d, v_\infty) = f_0(N)\left(\frac{d}{d_0}\right)^2\left[\frac{v_{esc}^2 + v_\infty^2}{v_{esc0}^2 + v_\infty^2}\right]$$

d is the CA distance
v_∞ is the infinite CA velocity
v_{esc} is the Earth escape vel.

NEO POPULATION DISTRIBUTION MODEL

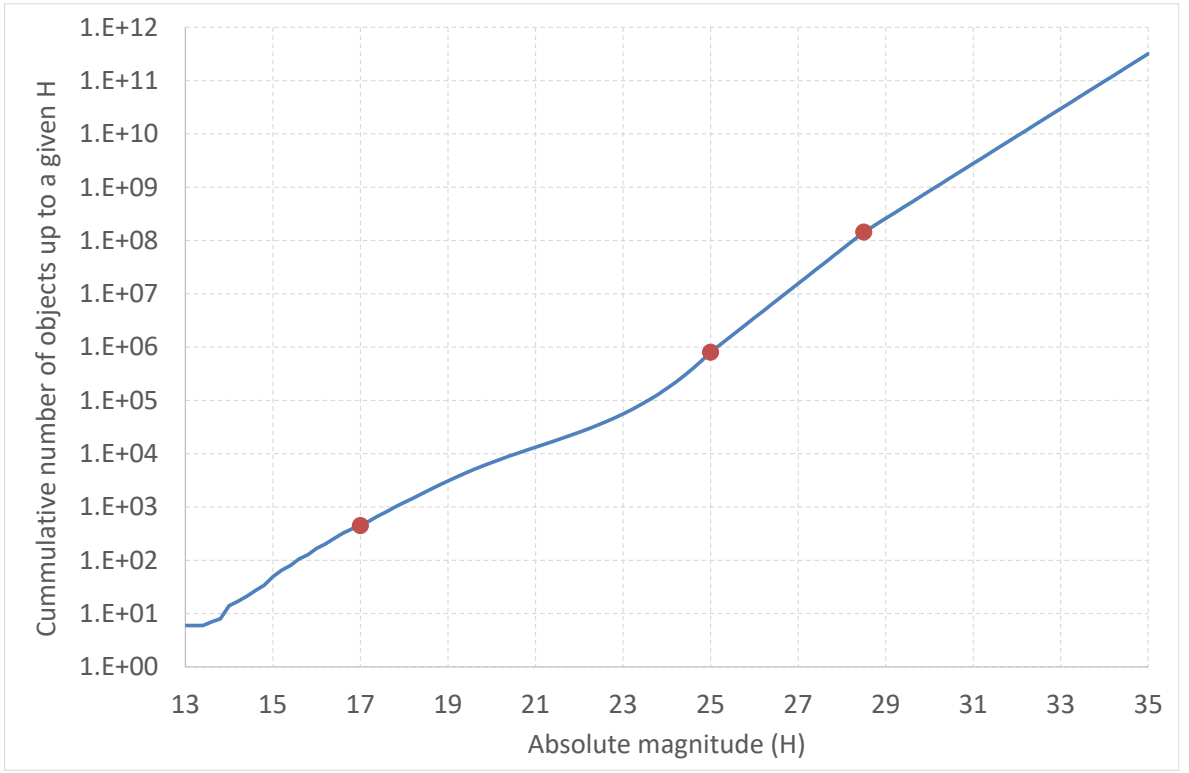
- Several NEO population models have been proposed in the last 25 years
- For our computations we decided to select:
  - The Granvik model (2018) for $H \leq 25$
  - A log-linear extrapolation of that model for $25 < H \leq 28.5$

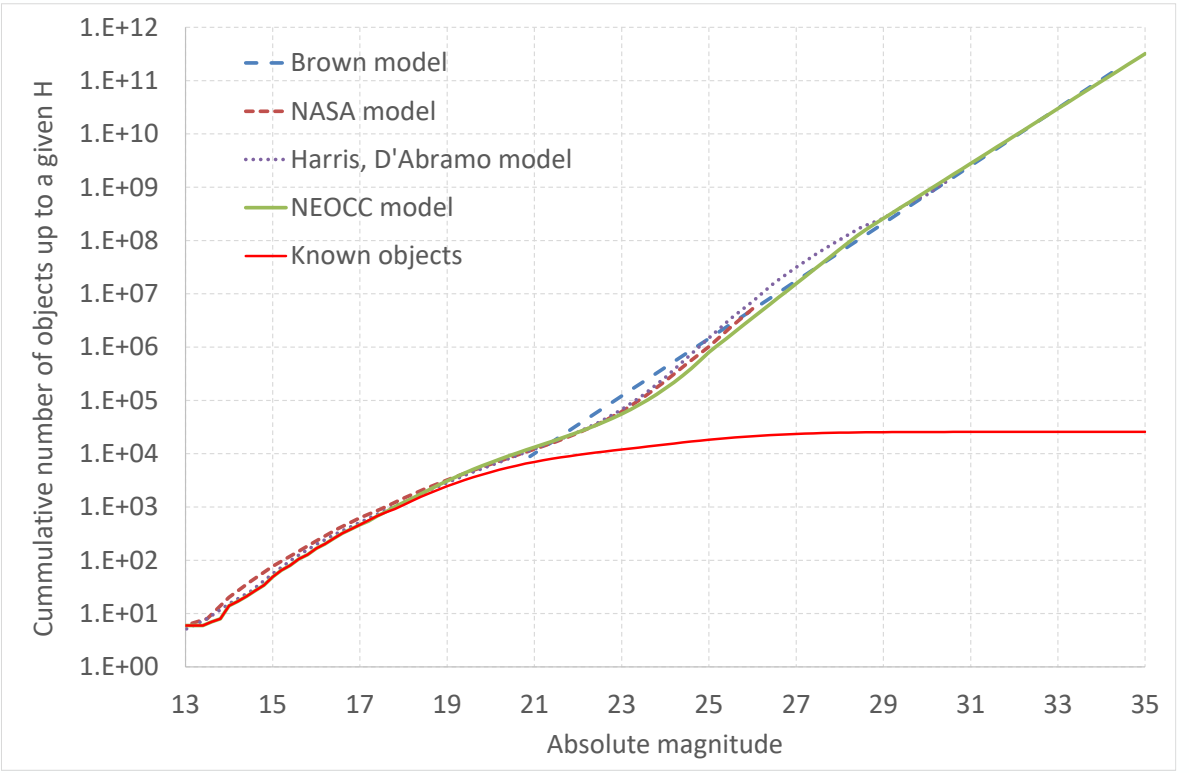
$$N(\leq H) = 802{,}404 \times 10^{\,0.6434\,(H-25)}$$

  - Another log-linear extrapolation with a slope better fitted to smaller asteroid fluxes for $H > 28.5$

$$N(\leq H) = 143{,}315{,}474 \times 10^{\,0.5151\,(H-28.5)}$$

NEO POPULATION DISTRIBUTION MODEL





THE IMPACT FREQUENCY CONSTANT

- Proposed values:
  - Shoemaker (1979): $k = \sim 2.5 \times 10^{-9} \ \ yr^{-1}$
  - Brown (2002): $k = 2 \times 10^{-9} \ \ yr^{-1}$
  - Tricarico (2017): $k = 4 - 6 \times 10^{-9} \ \ yr^{-1}$
  - NASA (2017): $k = 1.66 \times 10^{-9} \ \ yr^{-1}$
  - NEOPOP (2020): $k = 1.89 \times 10^{-9} \ \ yr^{-1}$
- We decided to use $k = 1.66 \times 10^{-9} \ \ yr^{-1}$, as it was computed over a much larger propagation time (tens of thousands of years)

THE CLOSE APPROACH INDEX

- In order to render the final values more manageable:

$$CAI = \log_{10}\left(f_{CA}(N, d, v_\infty)\right)$$

CAI > 1	Frequency larger than once per month	Very frequent event
0 < CAI ≤ 1	Frequency larger than once per year	Frequent event
-1 < CAI ≤ 0	Frequency larger than once per 10 years	Infrequent event
-2 < CAI ≤ -1	Frequency larger than once per 100 years	Rare event
CAI ≤ -2	Frequency smaller than once per 100 years	Very rare event

EXAMPLE: NEOCC CLOSE APPROACHES

- Evaluation of close approaches in the last month and in the next year, as provided in NEOCC's close approach list: https://neo.ssa.esa.int/close-approaches

Object designation	Absolute magnitude	Close approach date	CA distance (au)	Infinite velocity (km/s)	CA frequency (y^{-1})	Close approach index	Close approach ranking
2021 DM	26.1	2021-02-28	0.0327	10.2	1.82E+03	3.26	Very frequent event
2021 ET1	24.6	2021-02-28	0.0457	9.0	3.00E+02	2.48	Very frequent event
2021 EH2	26.2	2021-02-28	0.0456	5.8	1.92E+03	3.28	Very frequent event
2011 DW	22.7	2021-03-01	0.0361	13.6	3.05E+01	1.48	Very frequent event
2021 EU3	27.1	2021-03-01	0.0122	4.7	3.77E+02	2.58	Very frequent event
2021 EE	25.8	2021-03-02	0.0119	16.9	2.36E+02	2.37	Very frequent event
2011 EH17	24.9	2021-03-02	0.0342	16.6	4.90E+02	2.69	Very frequent event
2021 EE1	26.0	2021-03-02	0.0473	9.1	2.88E+03	3.46	Very frequent event
2021 EC	27.8	2021-03-02	0.0044	8.7	3.37E+02	2.53	Very frequent event
2021 EA	28.0	2021-03-02	0.0006	9.9	1.17E+01	1.07	Very frequent event
1999 RM45	19.8	2021-03-02	0.0196	20.0	1.58E+00	0.20	Frequent event
2016 DV1	24.8	2021-03-03	0.0053	18.3	1.06E+01	1.03	Very frequent event

And many more lines in the table…

EXAMPLE: NEOCC CLOSE APPROACHES

- Summary of results (cut-off on 2021-03-29):

Evaluation	Recent CAs	Upcoming CAs
Very frequent event	124	129
Frequent event	7	10
Infrequent event	1	5
Rare event	0	1
Very rare event	0	0
Total	**132**	**145**

EXAMPLE: NEOCC CLOSE APPROACHES

- Summary of results (cut-off on 2021-03-29):

Object designation	H	Close approach date	CA distance (au)	Infinite velocity (km/s)	CA frequency (y^{-1})	Close approach index	Close approach ranking
(231937) 2001 FO32	17.6	2021-03-21	0.0135	34.4	1.29E-01	-0.89	Infrequent event
2016 AJ193	18.7	2021-08-21	0.0229	26.2	9.53E-01	-0.02	Infrequent event
2019 XS	23.8	2021-11-09	0.0038	10.7	8.45E-01	-0.07	Infrequent event
(4660) Nereus	18.3	2021-12-11	0.0263	6.6	2.64E-01	-0.58	Infrequent event
(163899) 2003 SD220	17.7	2021-12-17	0.0363	5.6	2.26E-01	-0.65	Infrequent event
(7482) 1994 PC1	16.6	2022-01-18	0.0132	19.6	6.23E-02	-1.21	Rare event
(138971) 2001 CB21	18.4	2022-03-04	0.0328	12.0	9.34E-01	-0.03	Infrequent event
Apophis	18.9	2029-04-13	0.000254	7.42	7.03E-05	-4.15	Very rare event

SUMMARY

- We are proposing to the community to use an **objective index** to evaluate the **relative importance** of a given close approach
- Such index is based on the **current NEO population models**
- It expands from the concept of **impact frequency with the Earth**
- Uses the ***H*** of the object and the **close approach data**
- It yields **5 infrequent events and 1 rare event** in one year
- **Apophis close approach in 2029 will be a very rare event**
- We plan to include the evaluation of this index in **NEOCC's CA page**


THANK YOU!

ERROR ANALYSIS

- **Error in *H* / ΔH** = +0.1 magnitudes implies:
  - ΔCAI = +0.031 for H = 20
  - ΔCAI = +0.064 for H = 25
  - ΔCAI = +0.0515 for H = 30
- **Error in *N*:**
  - ΔN = +10% implies ΔCAI = +0.041
  - ΔN = +50% implies ΔCAI = +0.176
- **Error in CA distance** / Δd_{CA} = +50% implies:
  - ΔCAI = +0.299 for a d_{CA} = 0.0001 au
  - ΔCAI = +0.345 for a d_{CA} = 0.001 au
  - ΔCAI = +0.351 for a d_{CA} = 0.01 au