

Frequency of Close Earth Approaches by Near-Earth Objects

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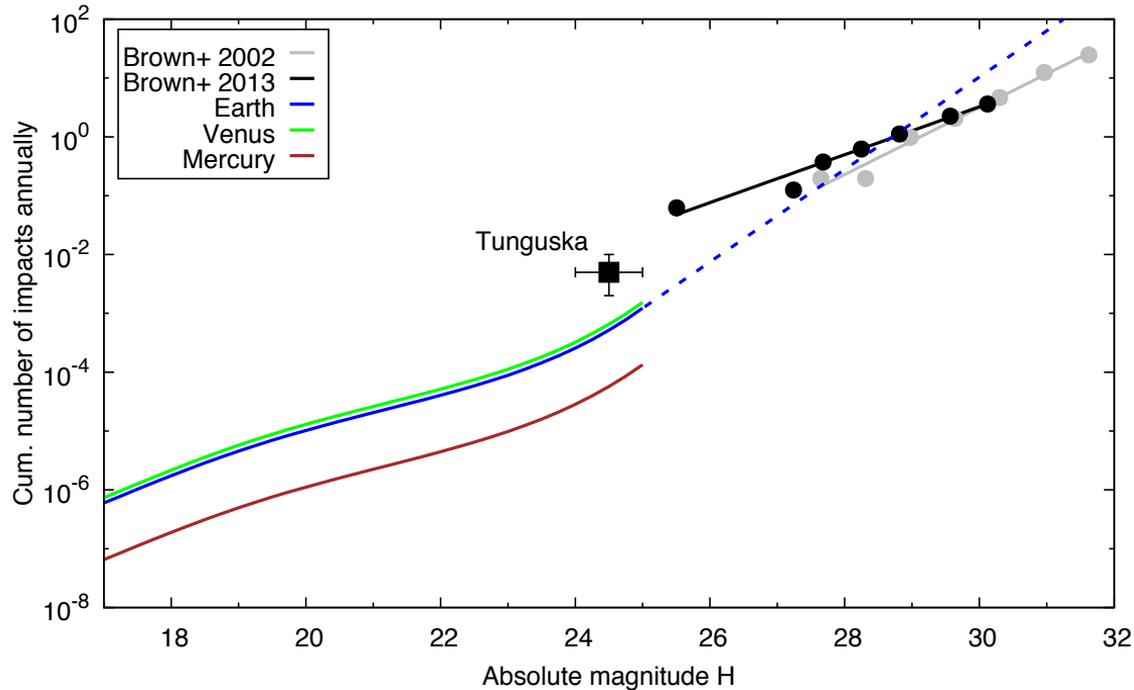
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Building on

Granvik, Morbidelli, Jedicke, Bolin, Bottke, Beshore,
Vokrouhlicky, Nesvorny, Michel, 2018. “Debiased orbit and
absolute-magnitude distributions for near-Earth objects”,
Icarus 312, 181–207.

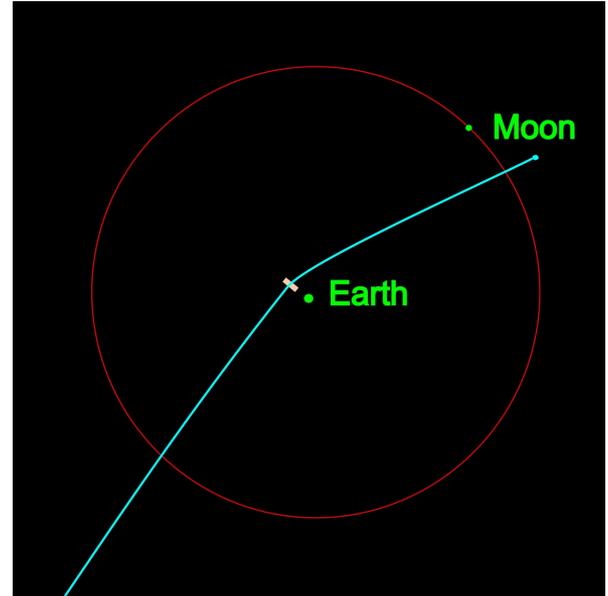
Predicted rate of impacts on the inner planets and comparison with bolides



Granvik+ (2018)

What is the frequency of encounters such as that by Apophis in 2029?

- Apophis has $H \approx 19.1$ and closest geocentric distance in 2029 is 0.00025 au.
- Frequency of Apophis-like encounters is once per 1000 yr according to casual statements – unclear where this number comes from.
- Frequency of Apophis-like encounters is once per 6500 yr according to Granvik+ (2018).



Can we rely on the Granvik+ (2018) prediction in terms of impact and close-encounter rates?

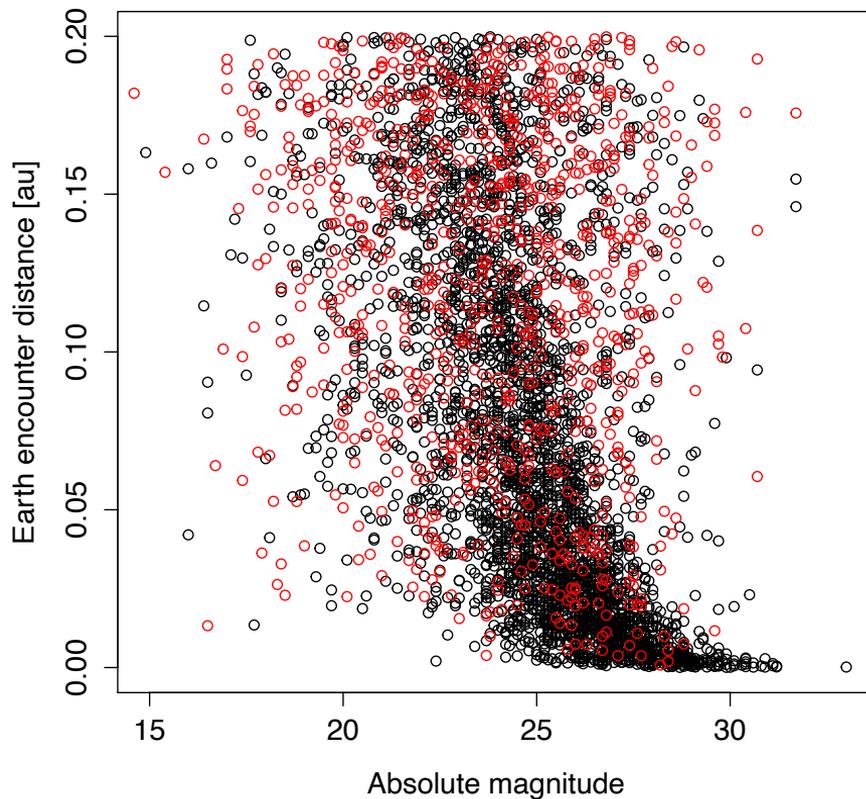
- The impact frequency in the size range of observed bolides appears to be in reasonable agreement with model prediction.
- A direct verification of the impact frequency for larger objects is, of course, impossible because impacts are rare and there is no observational data.
- We can make a direct comparison between the predicted and observed rate of close encounters, but need to use a reasonably unbiased sample to avoid being misled by observational biases.



The screenshot shows the NASA Jet Propulsion Laboratory (JPL) Center for Near Earth Object Studies (CNEOS) website. The main heading is "NEO Earth Close Approaches". Below the heading are navigation tabs: "Introduction", "Tutorial", "Data Table", "Comets (pre-1900)", and "Uncertainties". The "Data Table" tab is selected. Below the tabs is a section titled "Close Approach Data" with a brief description: "The following table shows close approaches to the Earth by near-Earth objects (NEOs) limited as selected in the 'Table Settings' below. Data are not available prior to 1900 A.D. nor after 2200 A.D. Data are further limited to encounters with reasonably low uncertainty." There is a link to a "brief video tutorial". Below this is a "Table Settings" section with three dropdown menus: "Near future (within 60 days)", "Nominal dist. <= 0.05au", and "no H limit". Below the settings is a "Show 10 entries" dropdown and a "Showing 1 to 10 of 31 entries" indicator. A search bar is located on the right side of the table. The table itself has columns for "Object", "Close-Approach (CA) Date", "CA Distance Nominal (LD) | au", "CA Distance Minimum (LD) | au", "V relative (km/s)", "V infinity (km/s)", "H (mag)", and "Diameter". Three rows of data are visible, each with a link to the object's page.

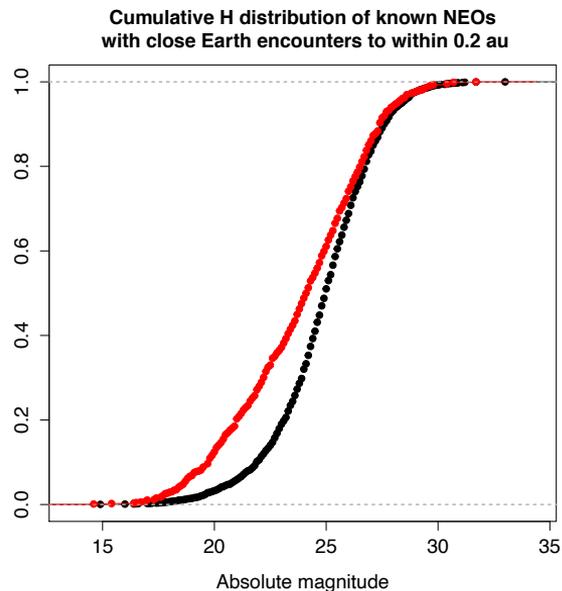
Object	Close-Approach (CA) Date	CA Distance Nominal (LD) au	CA Distance Minimum (LD) au	V relative (km/s)	V infinity (km/s)	H (mag)	Diameter
(2016 QE45)	2021-Apr-24 01:48 ± < 00:01	13.20 0.03391	13.20 0.03391	15.26	15.25	21.7	120 m - 270 m
(2021 HG 1)	2021-Apr-24 08:31 ± < 00:01	6.38 0.01639	6.36 0.01634	10.31	10.29	27.0	10 m - 23 m
(2021 FK3)	2021-Apr-24 17:45 ± < 00:01	15.73 0.04041	15.70 0.04035	14.05	14.04	22.4	89 m - 200 m

Close encounter data 2021-04-15 \pm 1yr from CNEOS

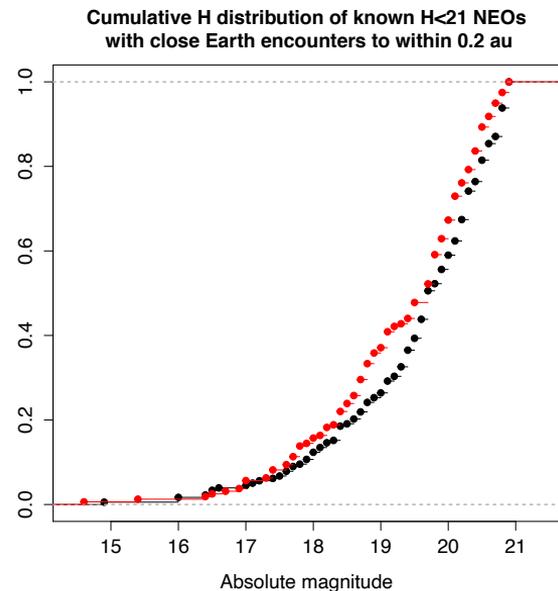
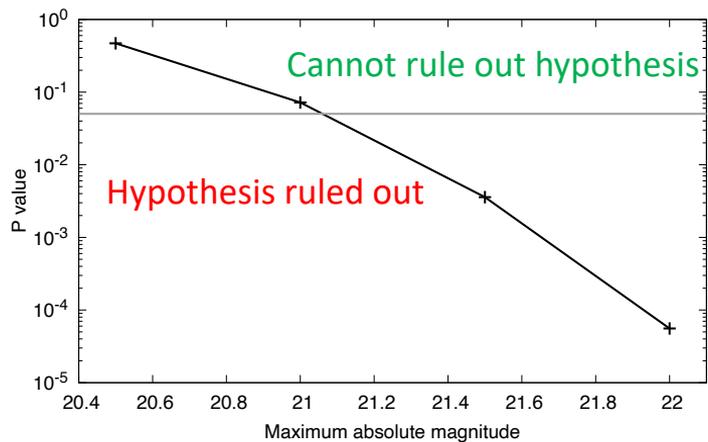


Past year ("observed")
Next year ("predicted")

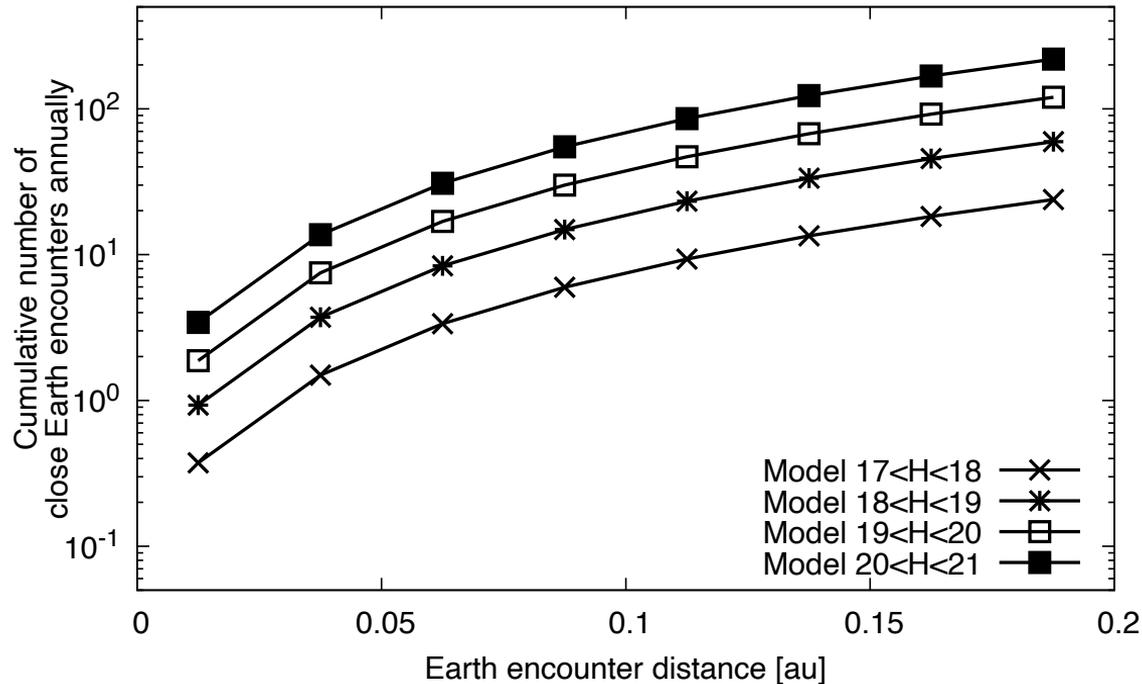
Unbiased close encounter data 2021-04-15 \pm 1yr



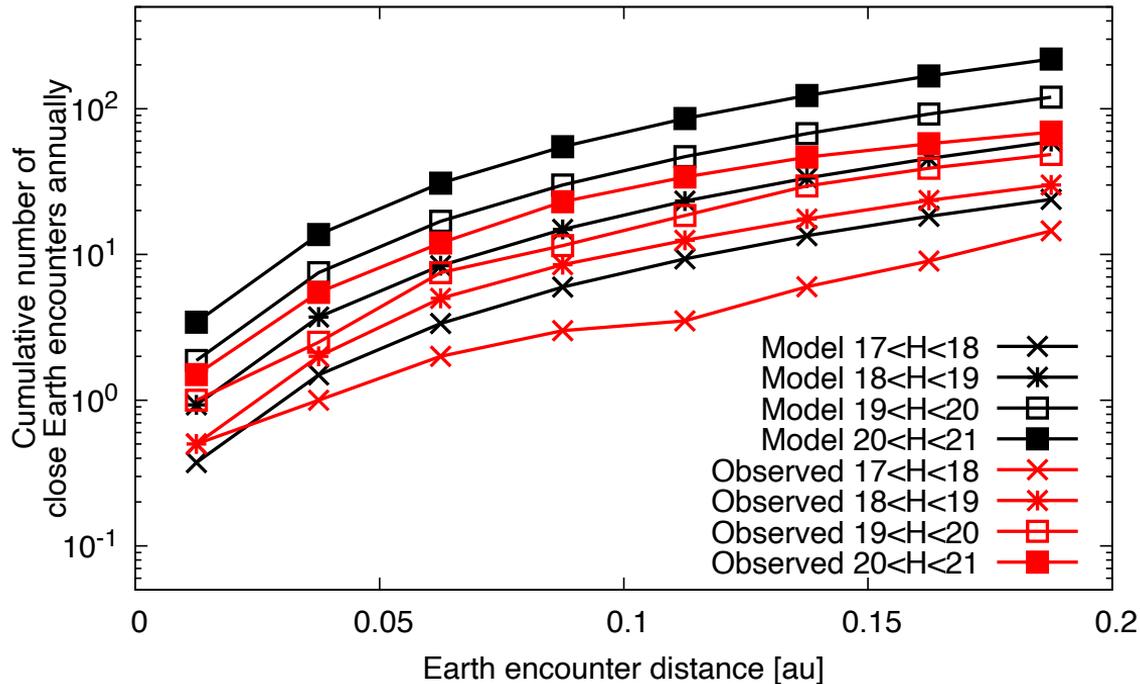
Null hypothesis for AD test:
Samples are drawn from
the same distribution



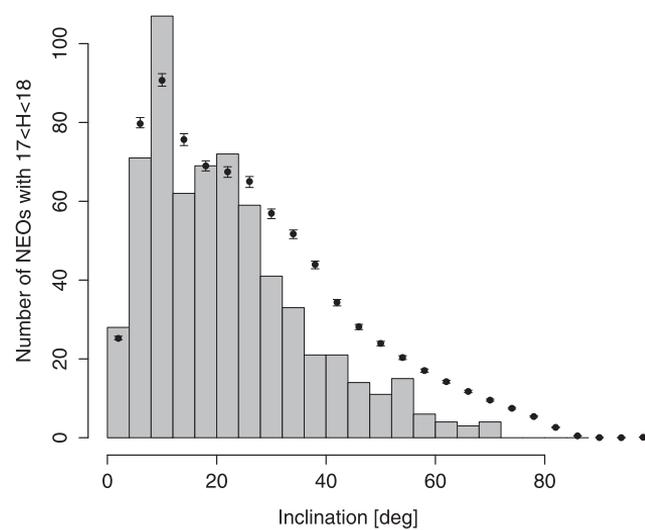
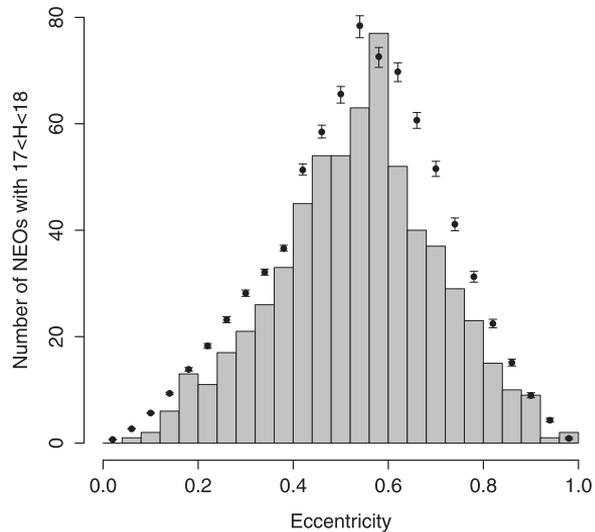
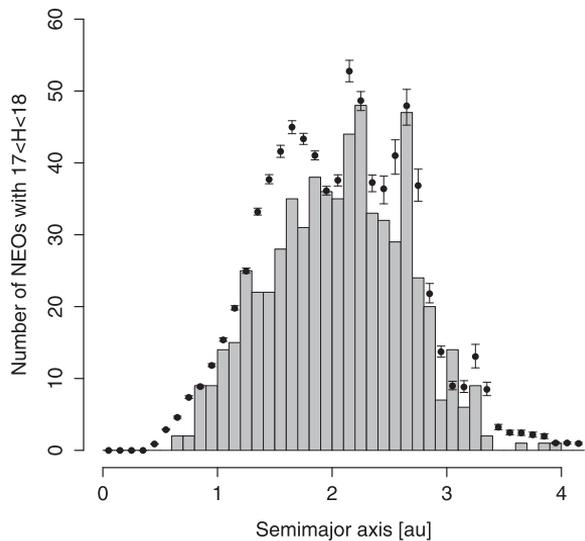
Model prediction for frequency of close encounters by large NEOs



Predicted frequency of close encounters is factor of few higher than observed frequency



Completeness of the $17 < H < 18$ NEO inventory in 2018



Granvik+ (2018)

Conclusions

- The observed frequency of close encounters for Apophis-scale objects is a factor of a few lower than the model predicts.
- The Apophis encounter in 2029 thus appears to be a once-in-20,000-yr event.
- The root cause for the disagreement between theory and observations is still not understood, but observational biases may be part of the explanation, in particular for smaller NEOs.

