The Viability of Small Gravity Tractors

Controlled deflection is possible for a significant
(perhaps ~2/3) of the 200 m NEA scenarios with
current technology

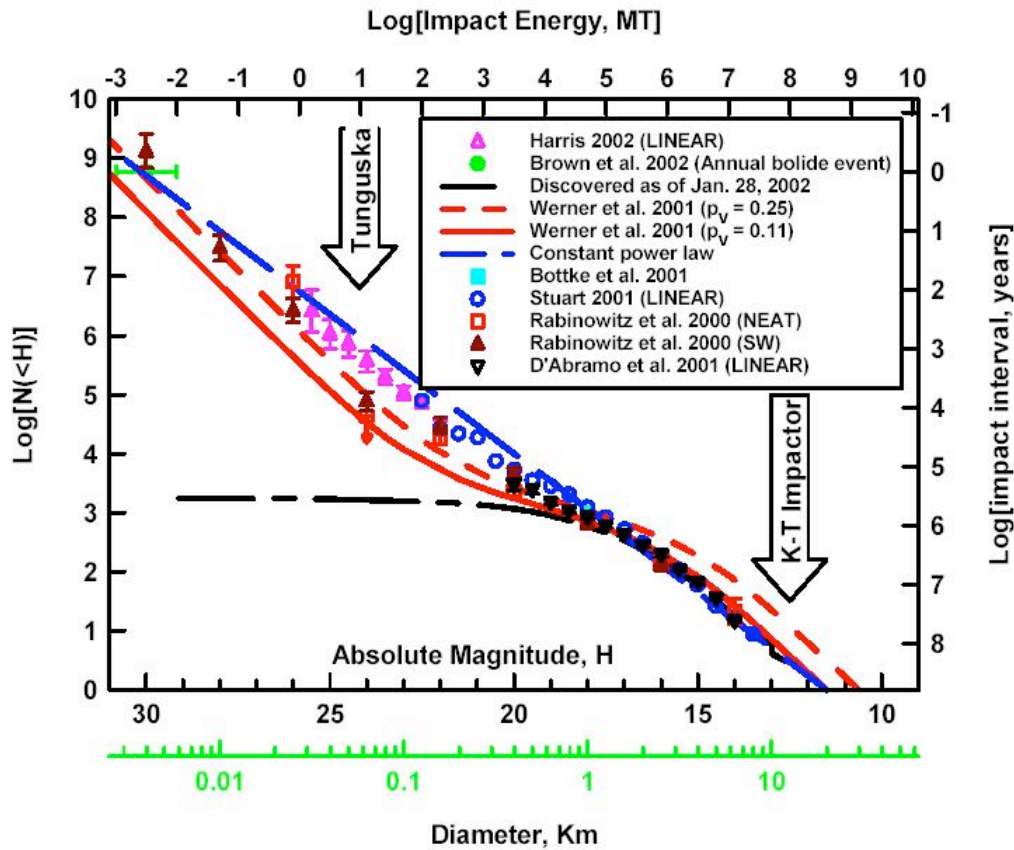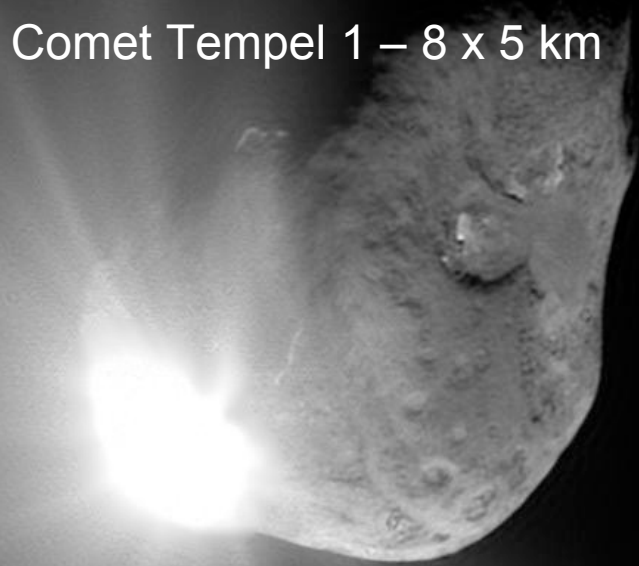Figure 2-3. The population of near Earth Asteroids

Of asteroids larger than Tunguska sized (10 Mton):

~90 percent are less than 200 meters

Why is Controllability Important?

Kinetic Impactor – ~500kg spacecraft at ~5 km/sec
~100 times Gravitational Binding Energy of Apophis
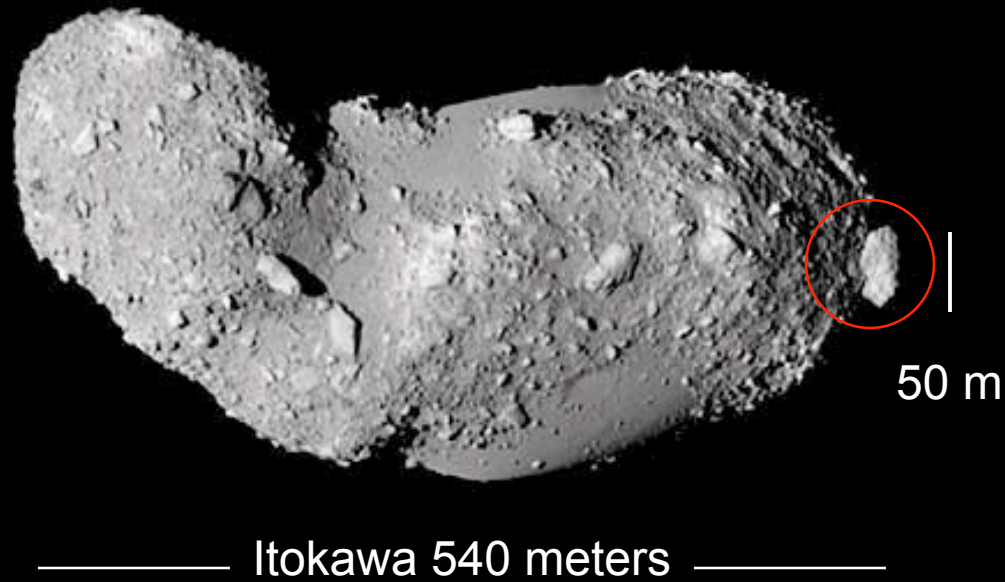
Comet Tempel 1 – 8 x 5 km

Apophis - ~250 meters

Many asteroids are rubble piles already on the verge of breakup

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Orbital Debris in Solar Orbit

50 m

Itokawa 540 meters

Meteor Crater ~40 m

Tunguska ~60 m

1. Will fragments break off?

2. How big will the fragments be?

3. Even if no fragments, how much deflection will you get?

Comet Schwassmann-Wachmann 3

Orbital Debris will spread downtrack-

crosstrack spreading is minimal (~100km max for escape velocity from 200m asteroid)

Even if no breakup: How much deflection?
Most of the deflection is due to ejection of material – extremely difficult to predict accurately

Problem: Lots of Keyholes

Apophis Keyhole Distribution
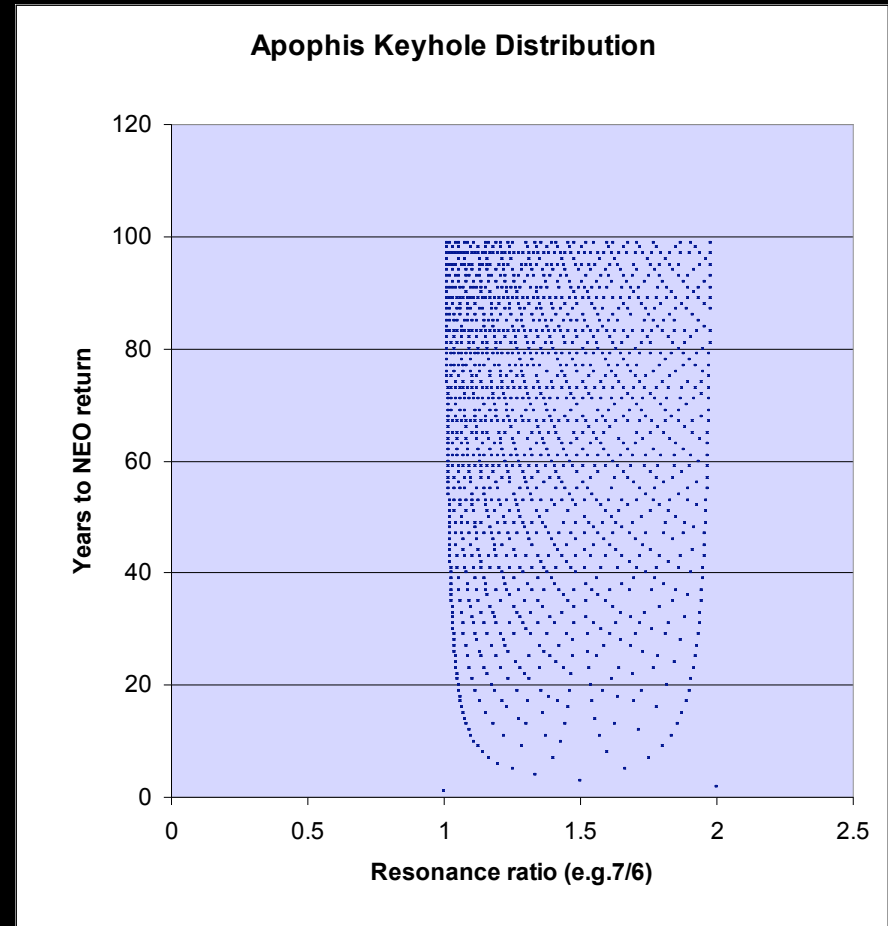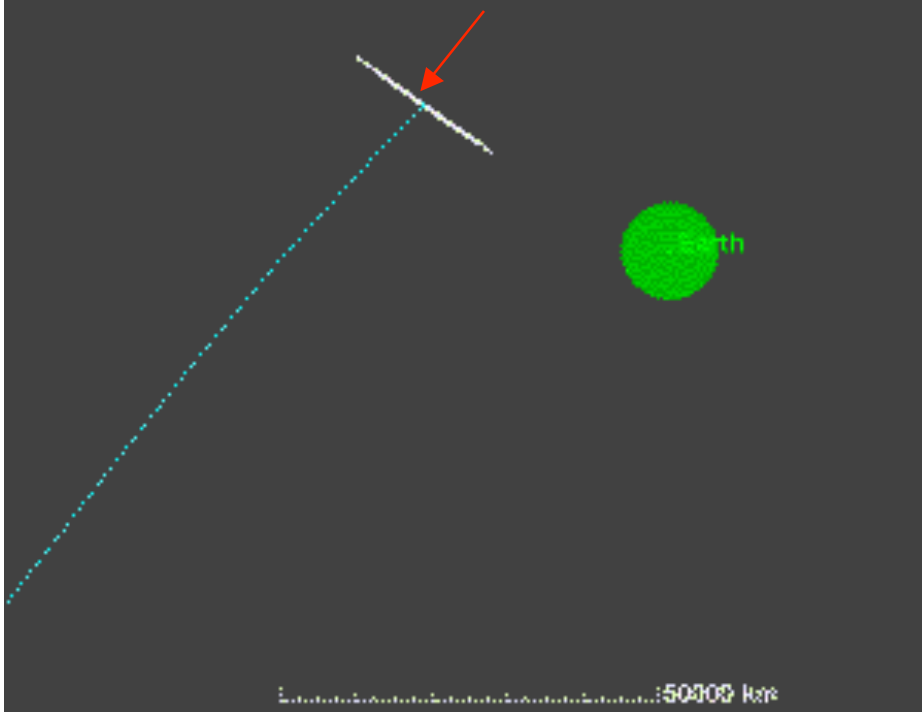
- **Another observer spacecraft needed to verify results**

- **What if it goes into another keyhole? Other spacecraft already launched and on standby?**
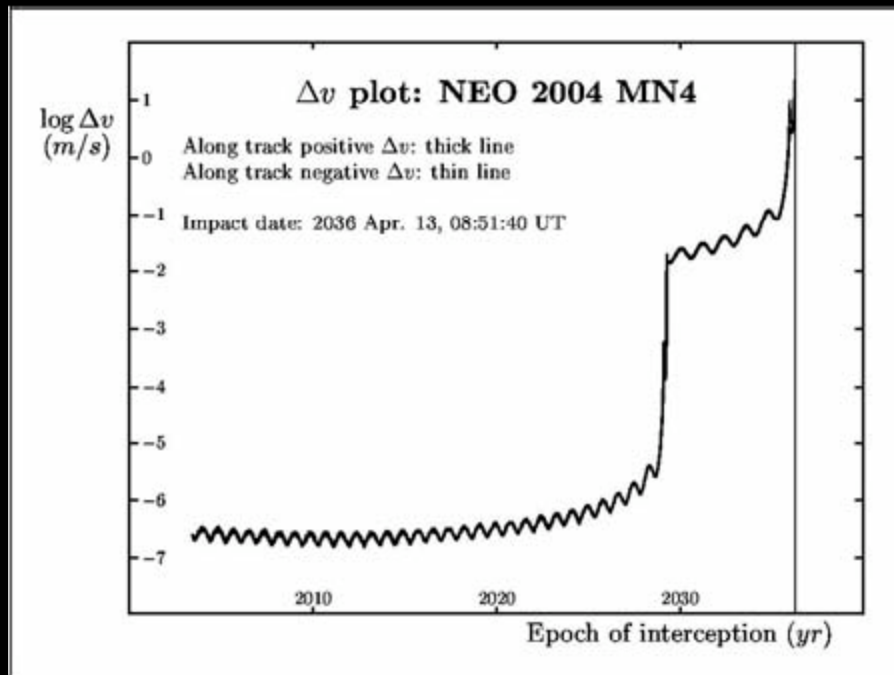
Gravity Tractor is controllable, but Δv is limited

Single spacecraft for orbit determination and towing

- A 2000 kg gravity tractor towing for 1 year results in a Δv = 2E-4 (200/d)**2 m/s

- assuming ISP=3500 s, fuel used/yr = 100 kg

- assuming 50% efficiency, power = 3kW

This is sufficient Δv for Apophis and VD17, but only because of intervening close approaches
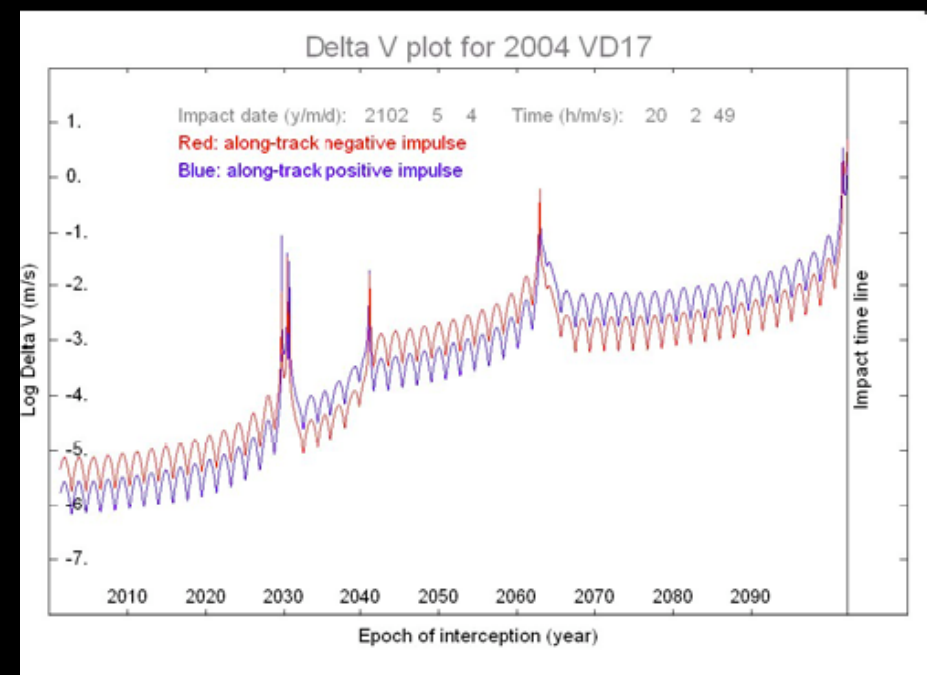
What is the effect of a close approach?

• Δv magnification scales roughly as (Hill Radius/b)**2 where b is the unperturbed distance of closest approach, and the Hill Radius = .01AU is the distance at which a solar orbiting object is equally affected by the Sun and the Earth
• A 400 meter asteroid can be deflected with the same Gravity Tractor as a 200 meter asteroid if it has half the close approach distance.

What percentage of threatening NEOs have an intervening close approach?

• Approximately 2/300 of the Earth's orbit is within .02 AU of Earth

• Therefore over a 100 year period, ~2/3 asteroids will have a close approach.

How does this hold up to the NEODyS data?

NEO	possible impact	close approach?
1. Apophis	2036	yes
2. 2004VD17	2102	yes, several
3. 2007DA41	2009	no
4. 2000QS7	2025	no
5. 2000SG344	2069	yes, also several ~.03 AU
6. 2006 QV89	2019	no

Proper way to calculate this is a Monte-Carlo simulation

Small (~2 ton) Gravity Tractor can deflect a significant number of asteroids

• ~2/3 of 200 meter asteroids can be deflected

• Magnification due to intervening close approaches can allow even large asteroids to be deflected

• Cases with close approaches also require higher accuracy orbit determination

• In such cases, Gravity Tractors have the advantage of being in principle fully controllable