THE INFLUENCE OF DWARF PLANETS ON THE STABILITY OF OBJECTS IN THE KUIPER BELT

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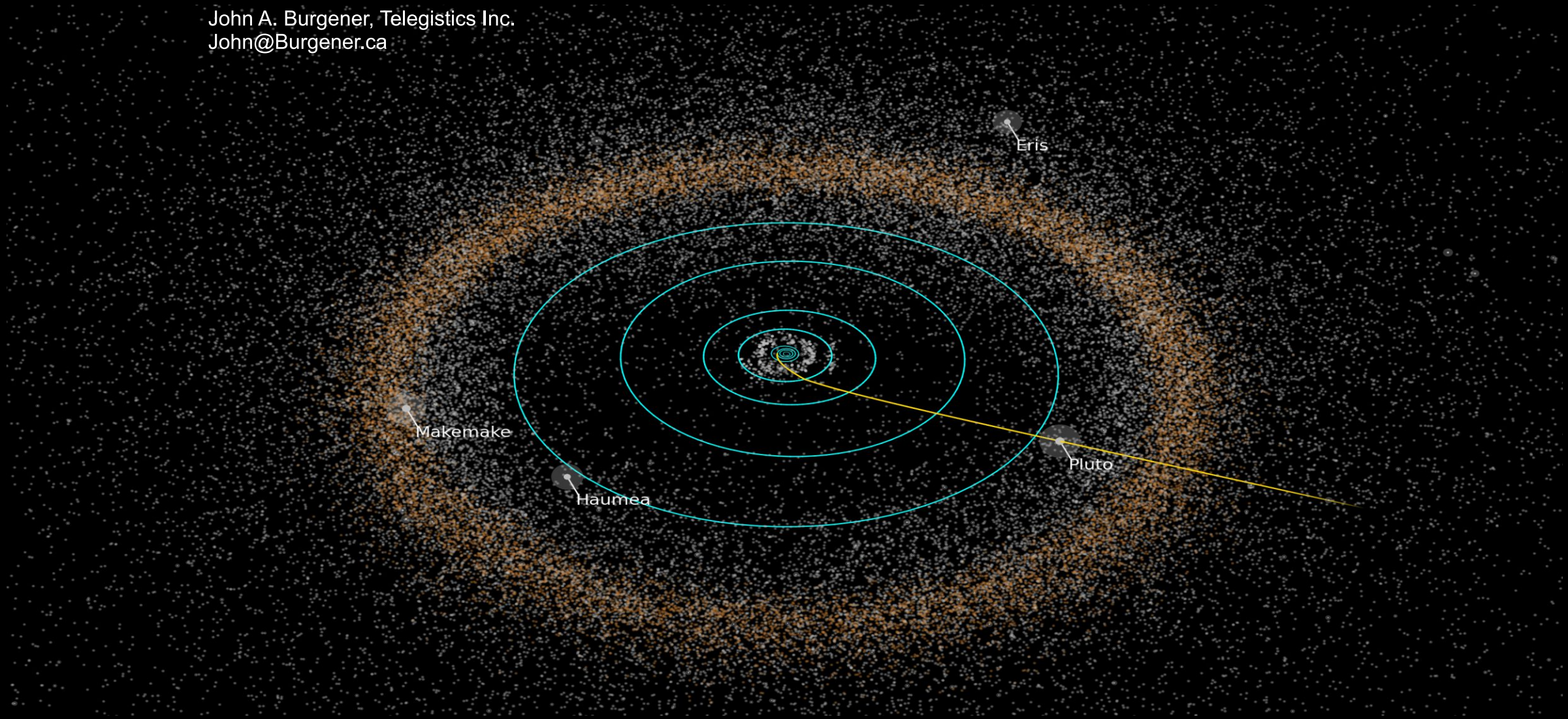


I believe that Earth is hit by comets often.

Often means:
every 400 - 800 years for 1 - 20 km comets,
every 3,000 - 12,000 years for 20 - 50 km comets, and
every 100 million years for 350 - 450 km comets.

This is not accepted by other geophysicists.
At present, it is believed that Chicxulub,
a 150 km crater caused by a 10 km asteroid,
killed the dinosaurs.

I propose that Chicxulub is too small.
The Amazon Basin is the right size.

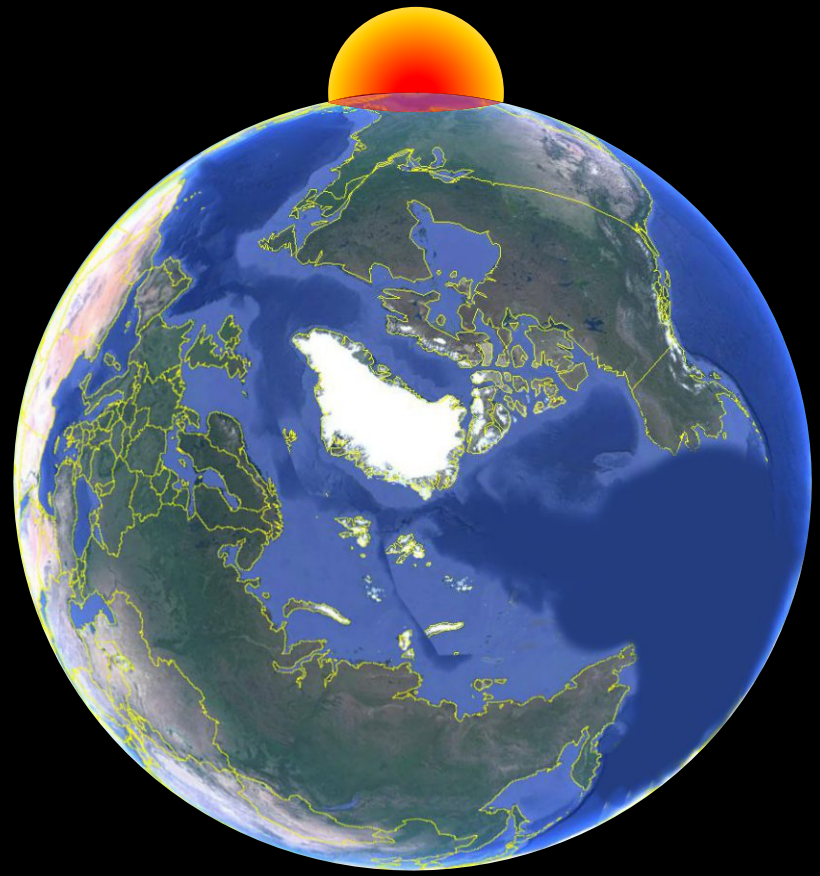
Chicxulub was caused by a 10 km diameter asteroid
It left a 150 km diameter crater.
The fireball was a tiny, local event.

Chicxulub can NOT be the dinosaur killer.

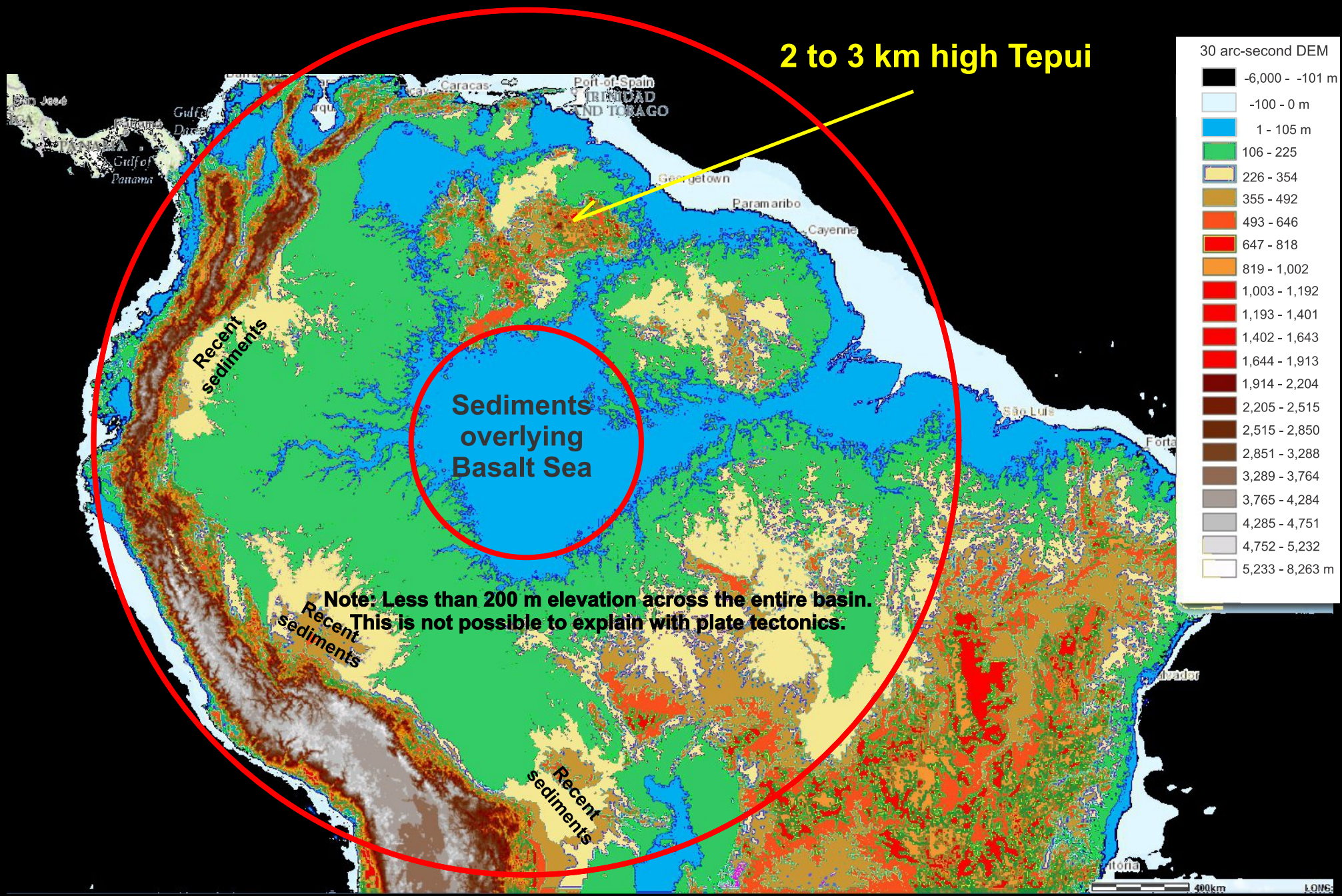
Its too small.

CHICXULUB:
12 km Asteroid, 20 km/sec
A Small
local event

1.2% of the planet
boiled or burned



Digital Elevation Map showing proposed Amazon Crater: 3,800 km diameter



An impact of this size
would have produced a fireball
that would cover 1/2 of the planet.

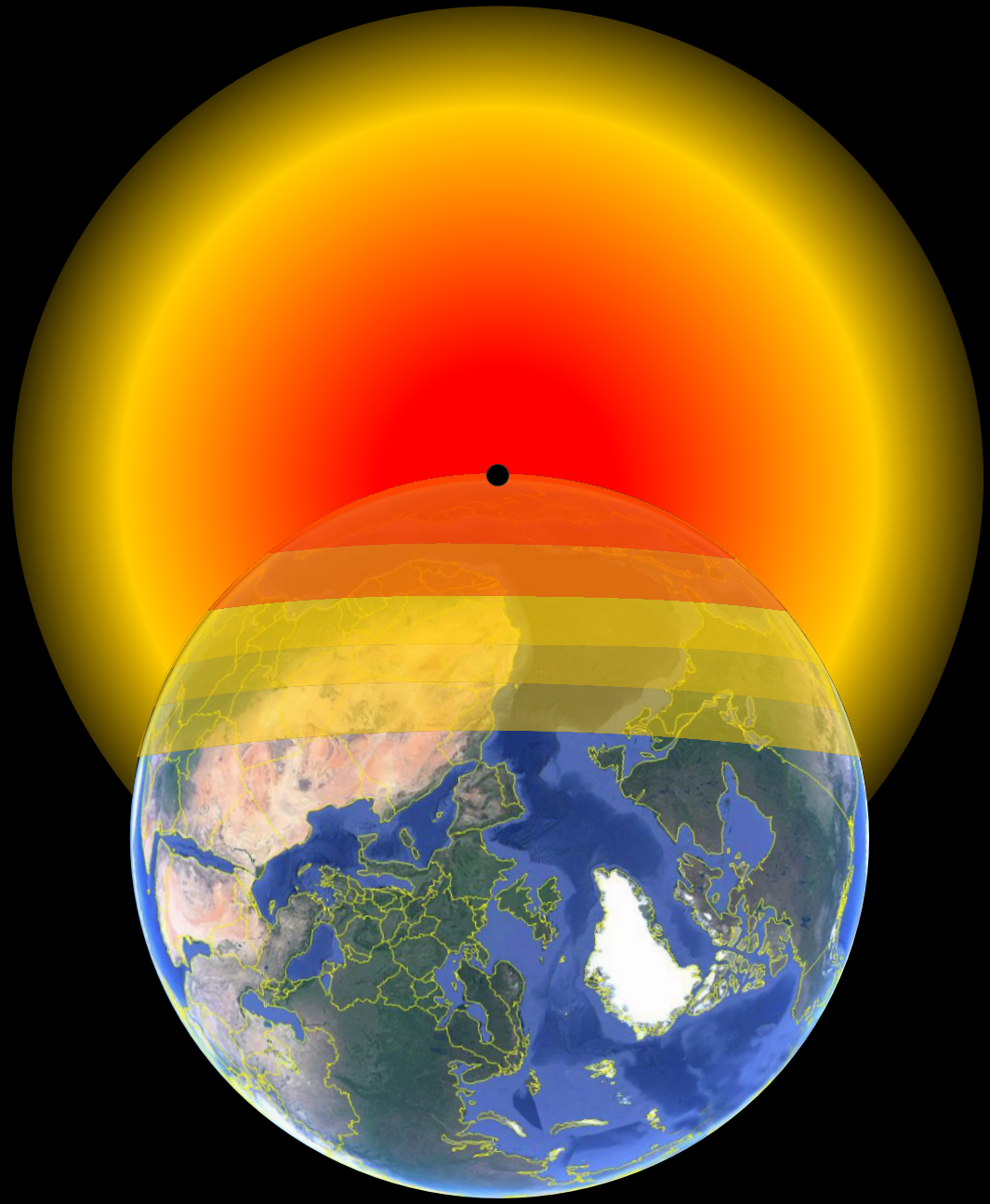
This would have caused
an extinction event.

AMAZON:
380 km Comet, 70 km/sec
A Planet
Devastation event

1/3 to 1/2 of the planet
boiled or burned

Fallout, Heat and
shock waves would
kill almost all large animals
in the remainder of the planet

An Extinction Event would clearly result.

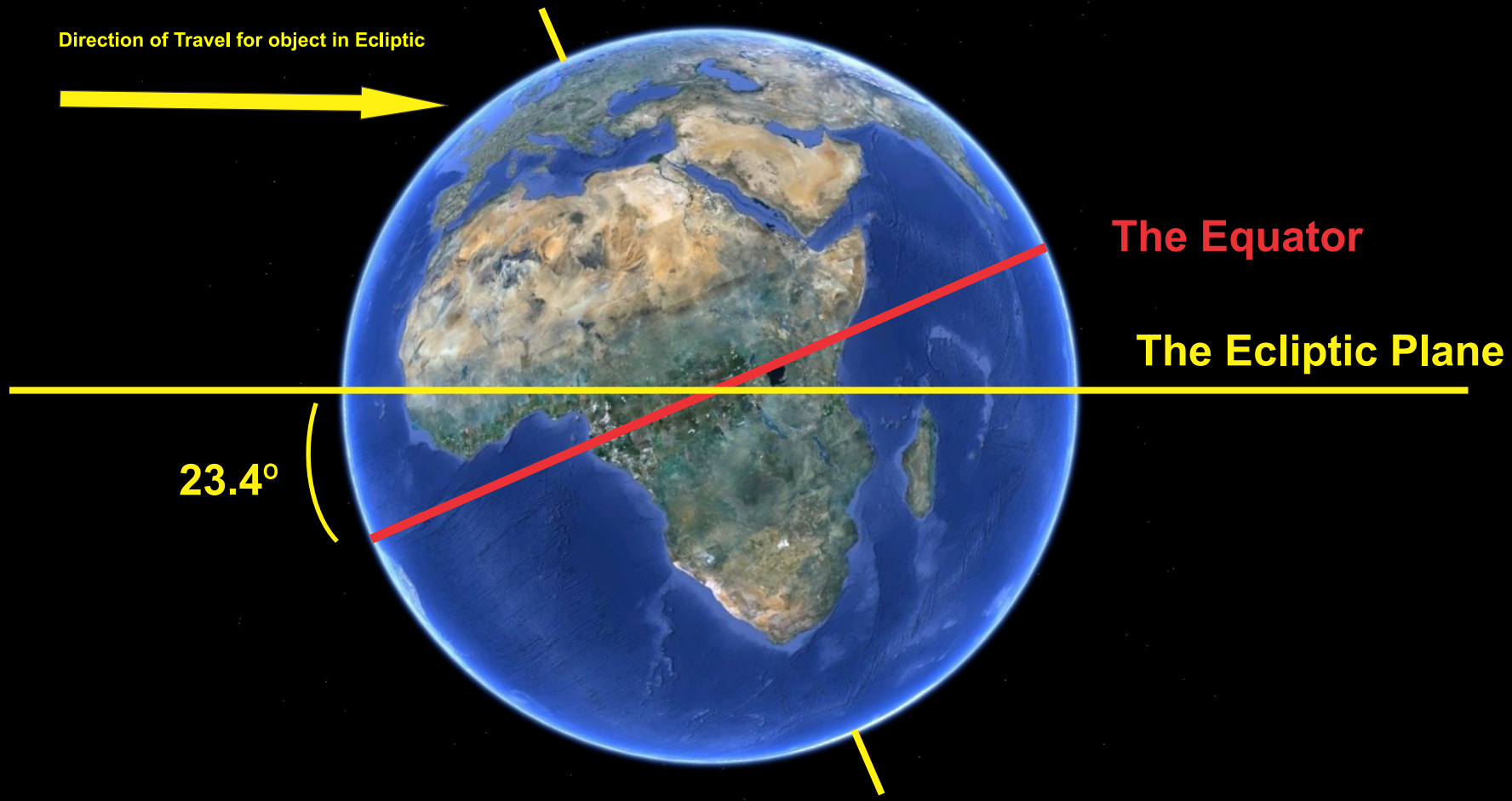


I propose that Lakes Ontario, Erie and Michigan
were caused by 10-30 km comet impacts 12,700 years ago.

I propose that the Carolina Bays
were caused by a comet forming Lake Michigan
and splashing a lot of ice.

To see why I think this makes sense, you need to know
how features orientated at 23.4^{o} relate to impacts.

The Earth is tilted 23.4° relative to the Ecliptic

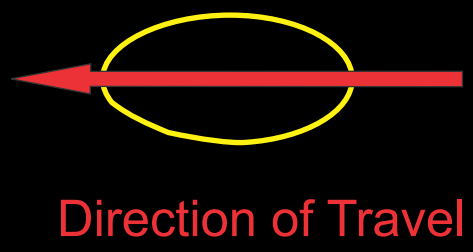


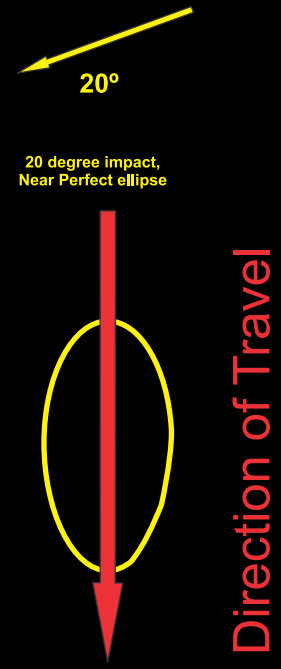
Low Angle Impacts form elliptical craters.

Direction of Travel effect on ellipsoidal craters:

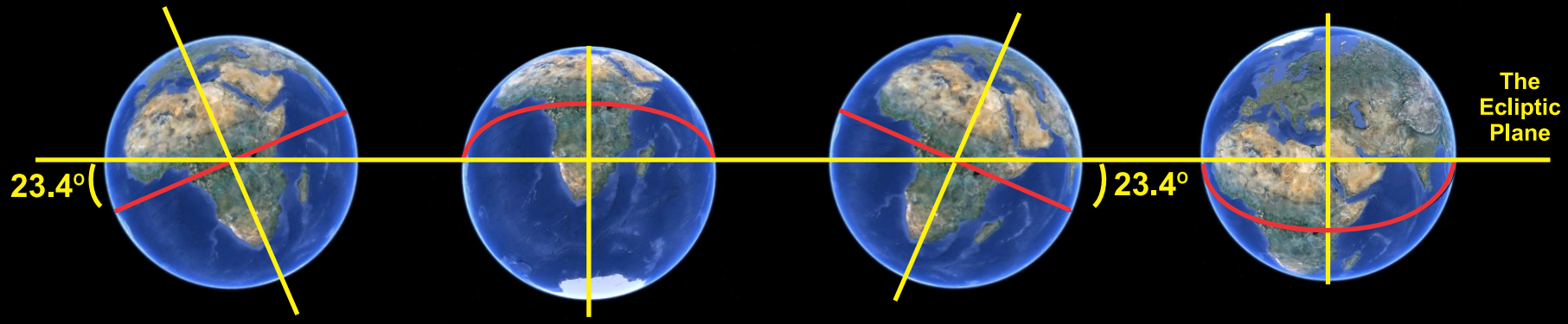
(Note that the Angle of Impact is 20° for all of these impacts.)

Results of pellet rifle shots into moist, soft clay. March 29, 2011





An impact from an object traveling in the Ecliptic can hit the Earth at any direction of travel angle between 0º and 23.4º relative to the Equator, depending on when and where it hits.



Ecliptic 23.4º clockwise
relative to the Equator

Ecliptic 0º
relative to the Equator

Ecliptic 23.4º counter clockwise
relative to the Equator

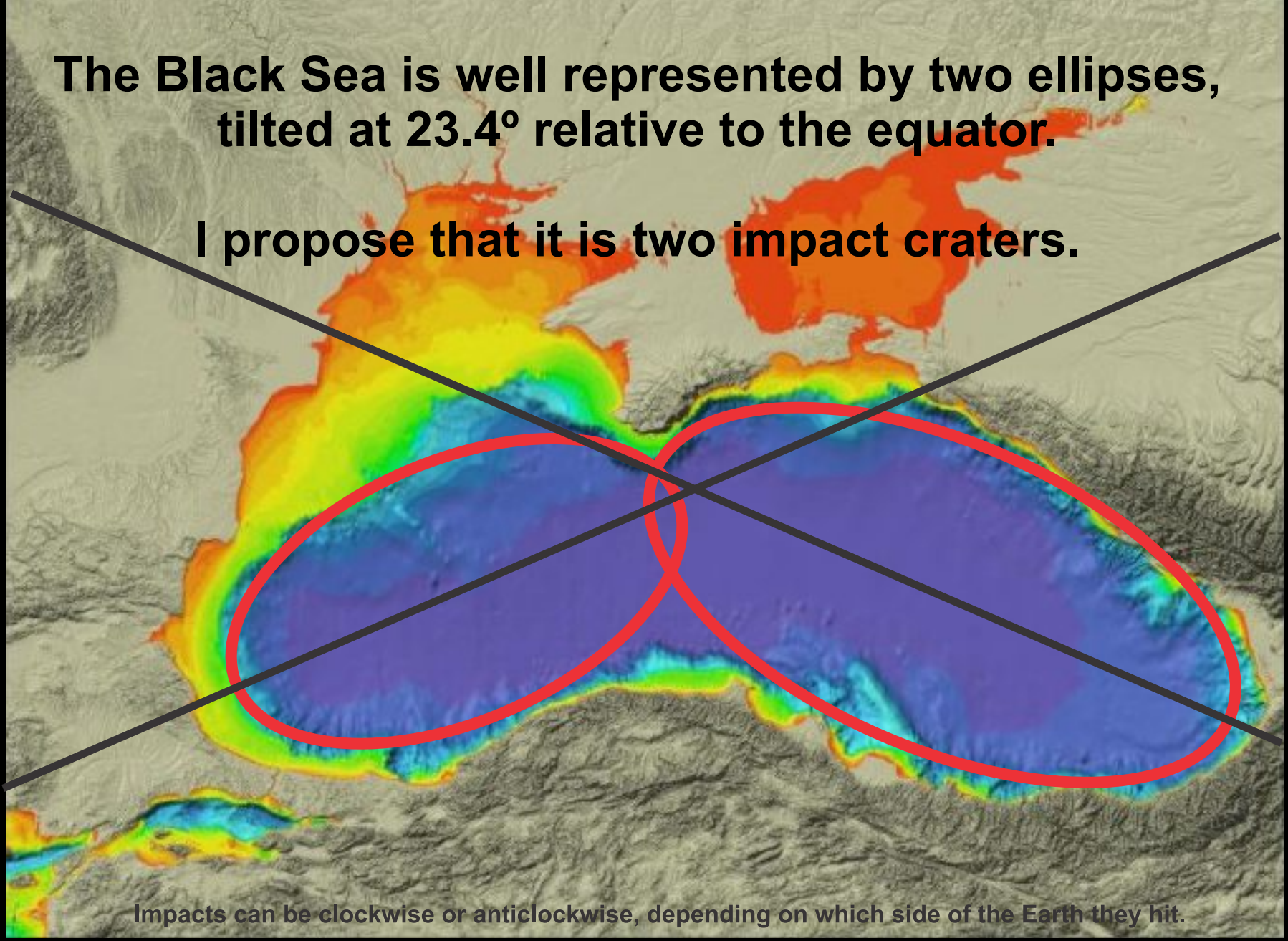
Ecliptic 0º
relative to the Equator

23.4º is not the only angle of travel possible,
but it is a unique angle that can only relate to an impact,
and not to tectonic processes.

A comet traveling in the Ecliptic can hit at either 23.4º Clockwise or 23.4º Counter-clockwise depending on which side of the Earth it hits.

Impact at 23.4º tilted Counter-clockwise

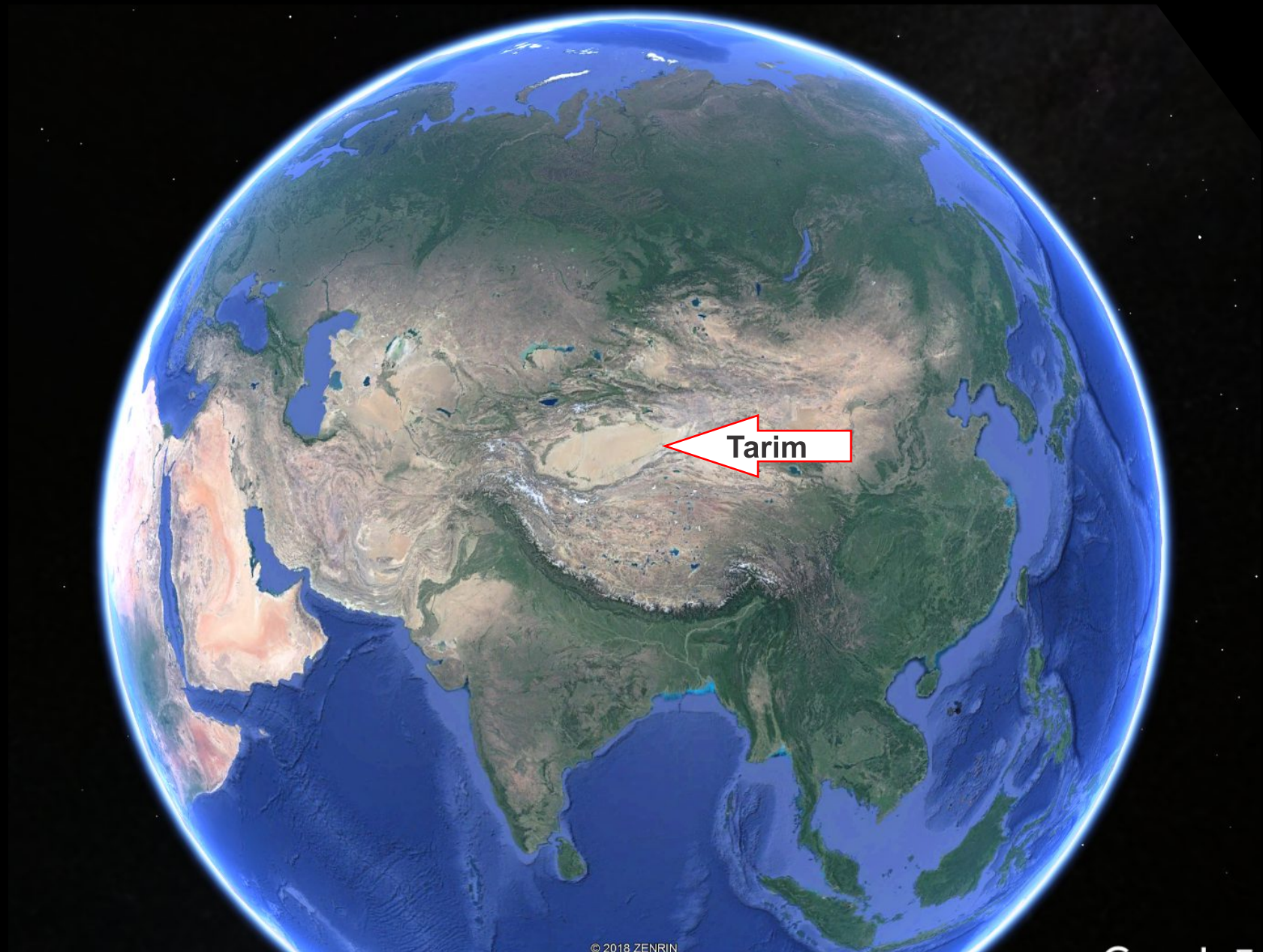
Impact at 23.4º tilted Clockwise



Depths of Black Sea indicated by color. Red is shallow, Purple deepest. Max depth 2,200 meters.

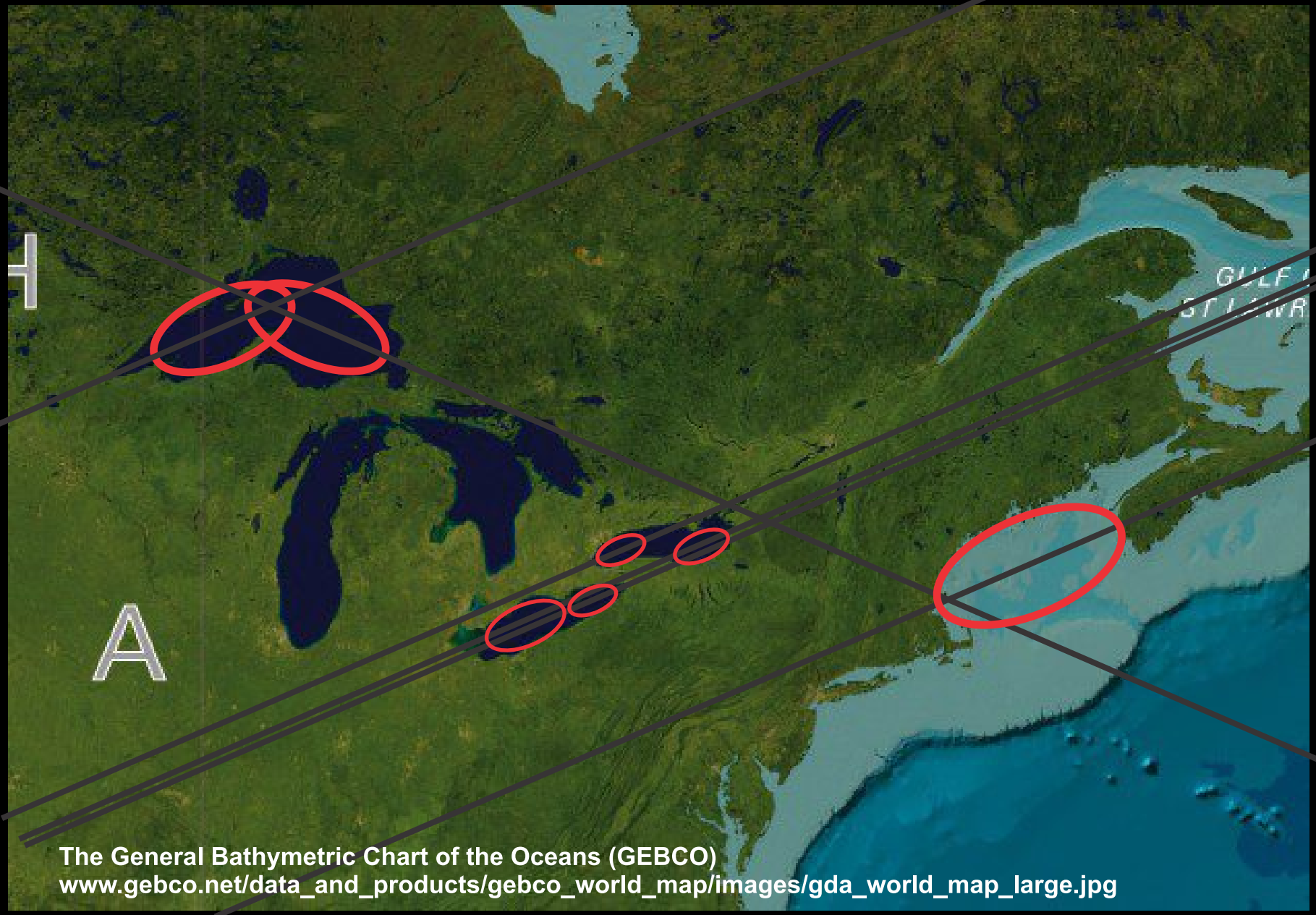
Image from GEBCO: http://www.gebco.net/data_and_products/gridded_bathymetry_data/gebco_08_update_history/version_20100927/

The Tarim Basin is a 900 km long ellipse tilted at 23.4º

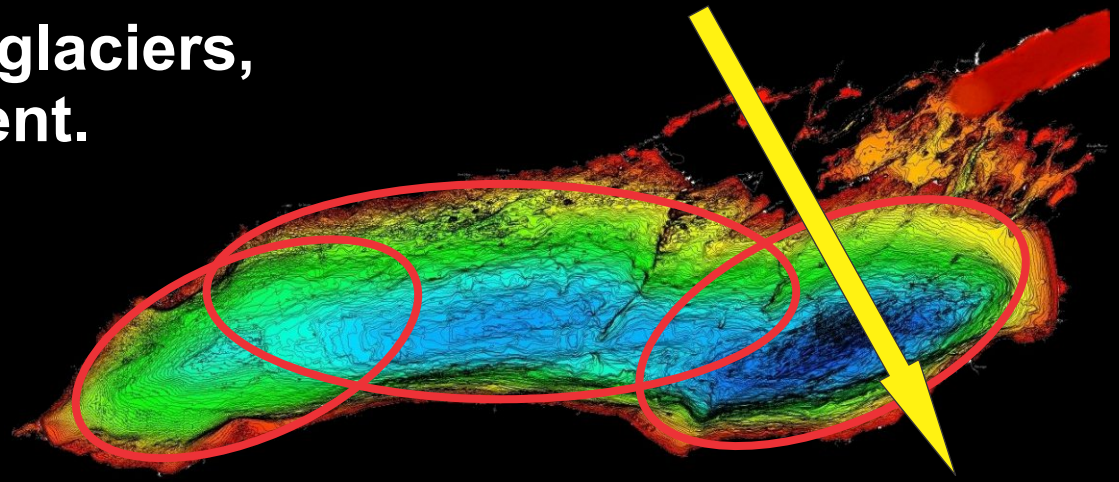



23.4°
Tarim

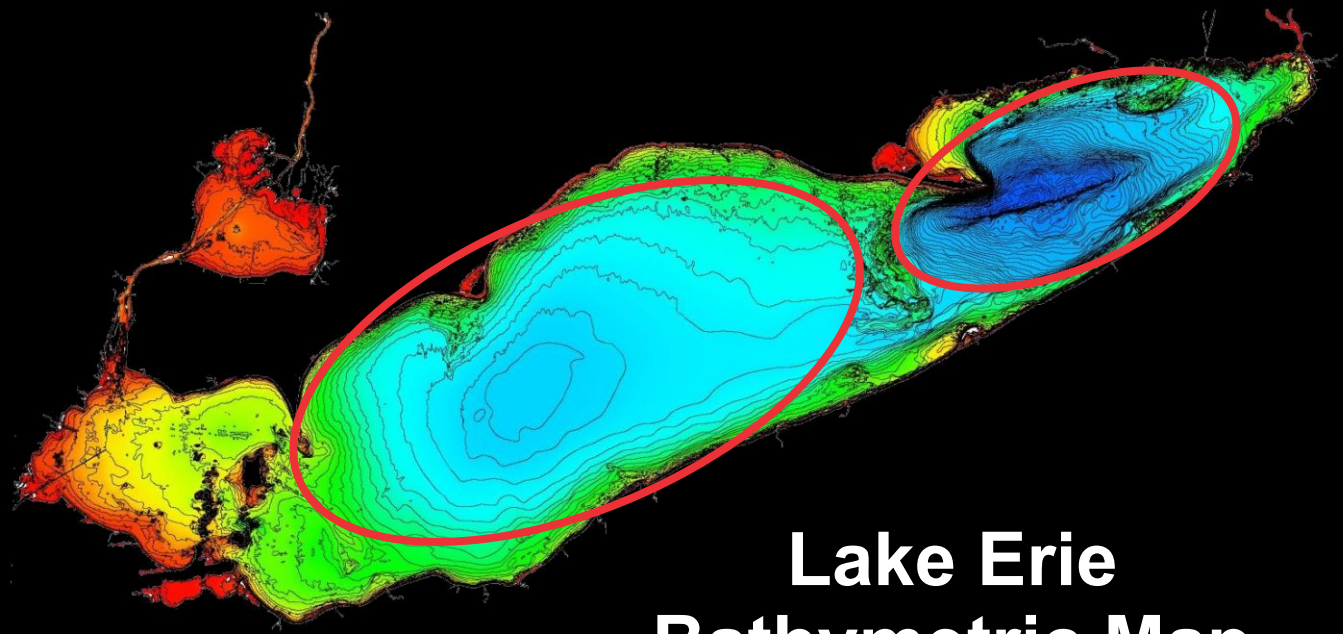
And North America has many 23.4º features:



The Great Lakes are distorted by glaciers, but the 23.4º features are prominent.

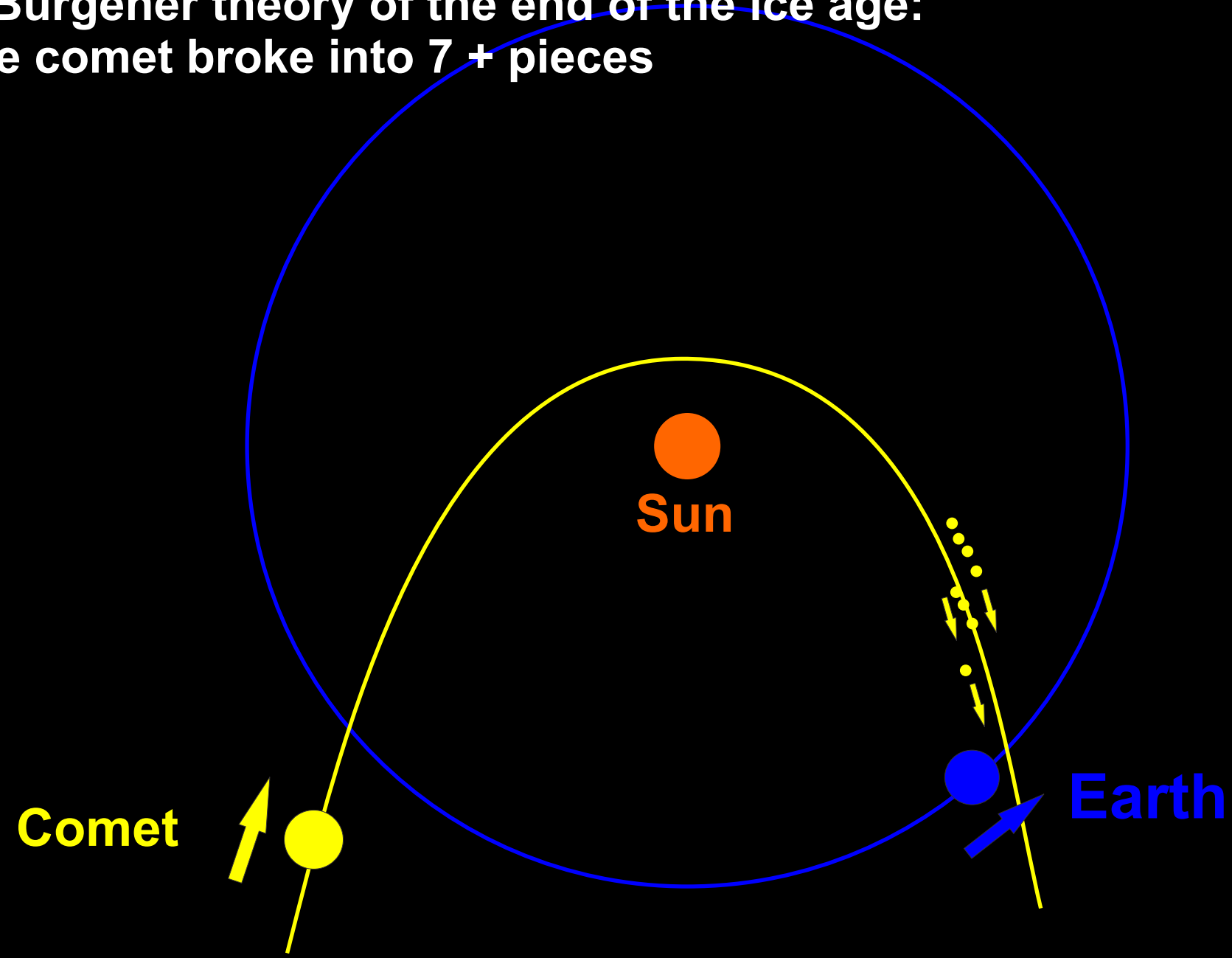


Lake Ontario Bathymetric Map



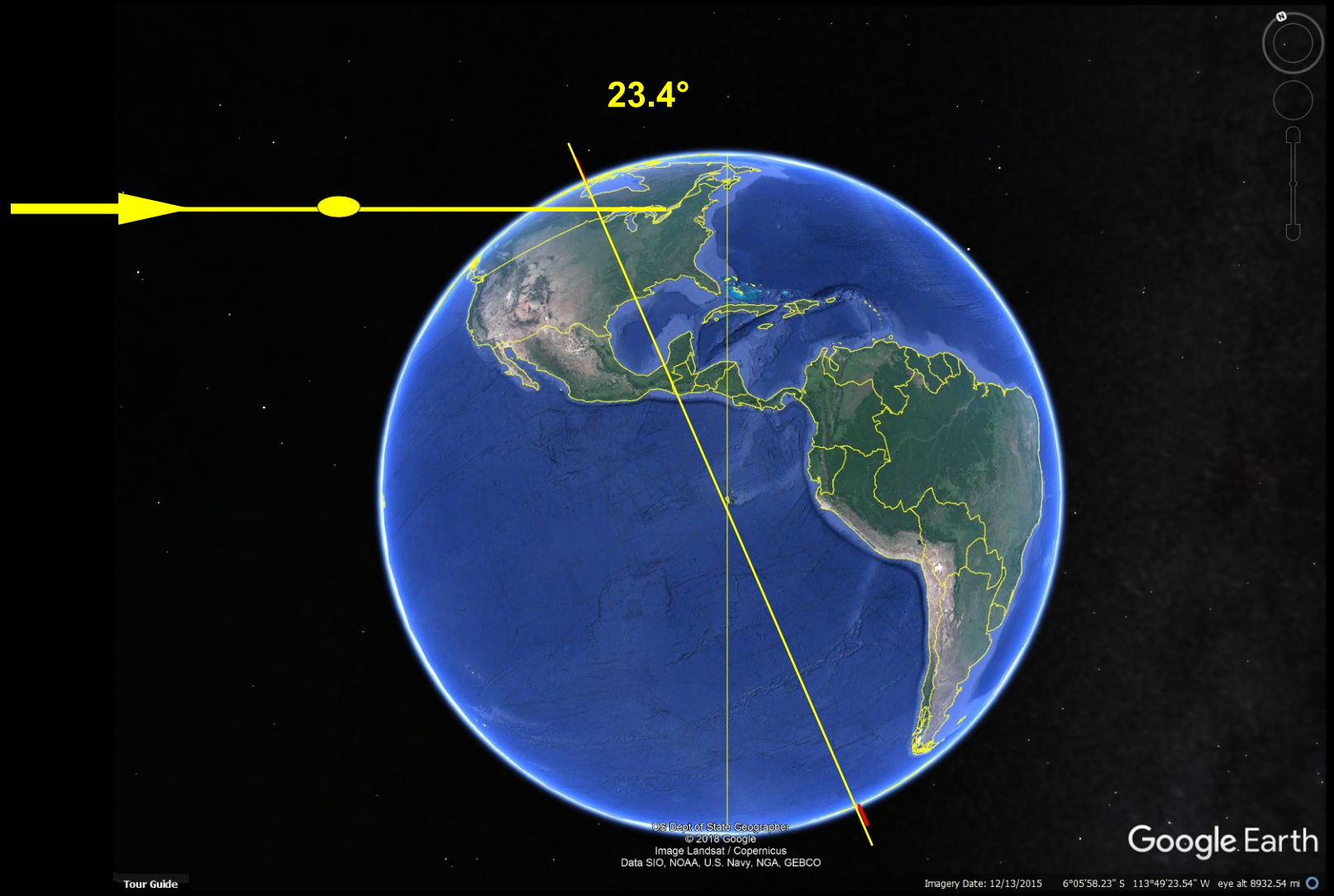
Lake Erie Bathymetric Map

John Burgener theory of the end of the ice age:
A large comet broke into 7 + pieces



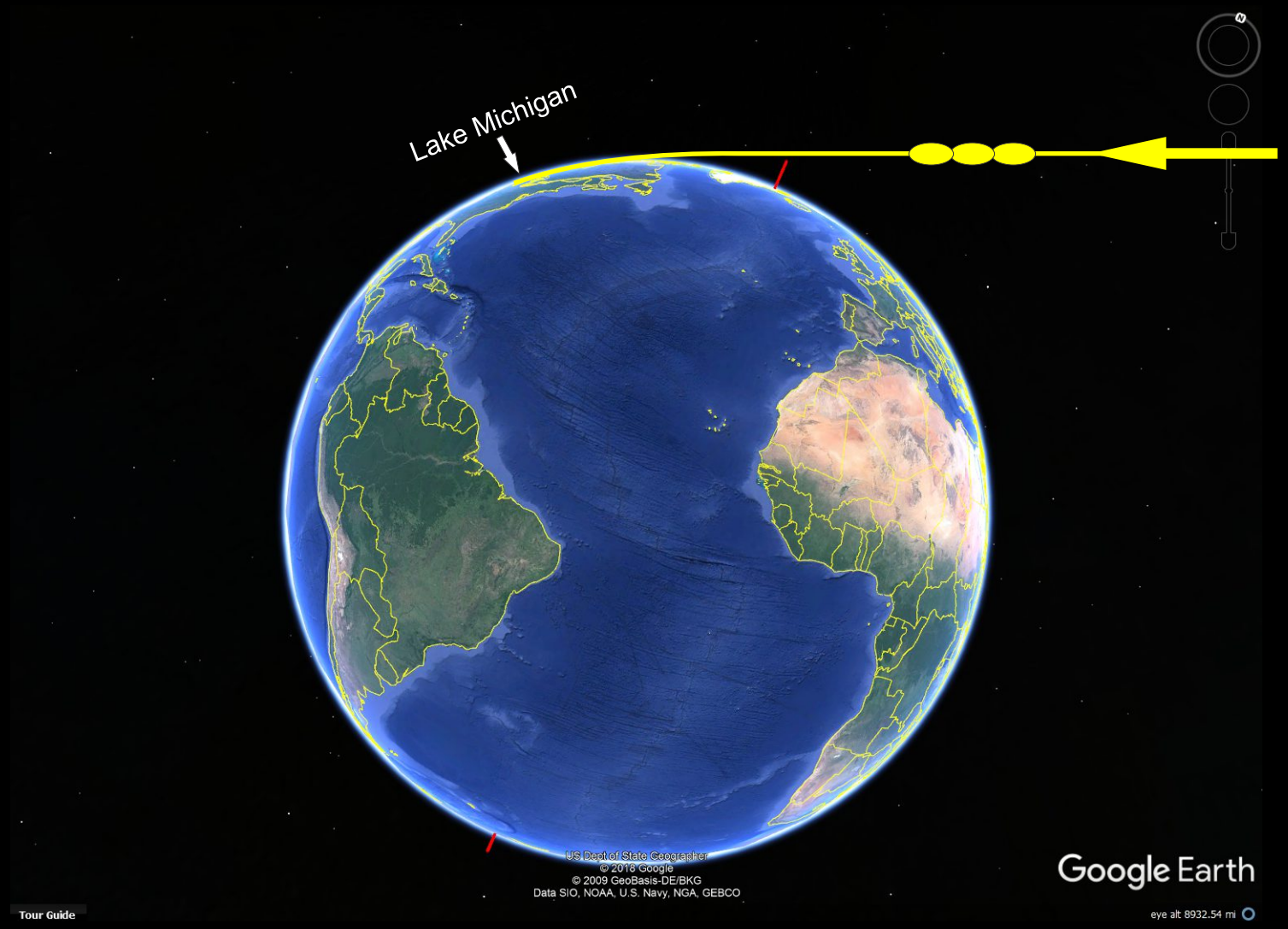
John Burgener theory of the end of the ice age:

1 hit Earth forming the Middle of Lake Ontario



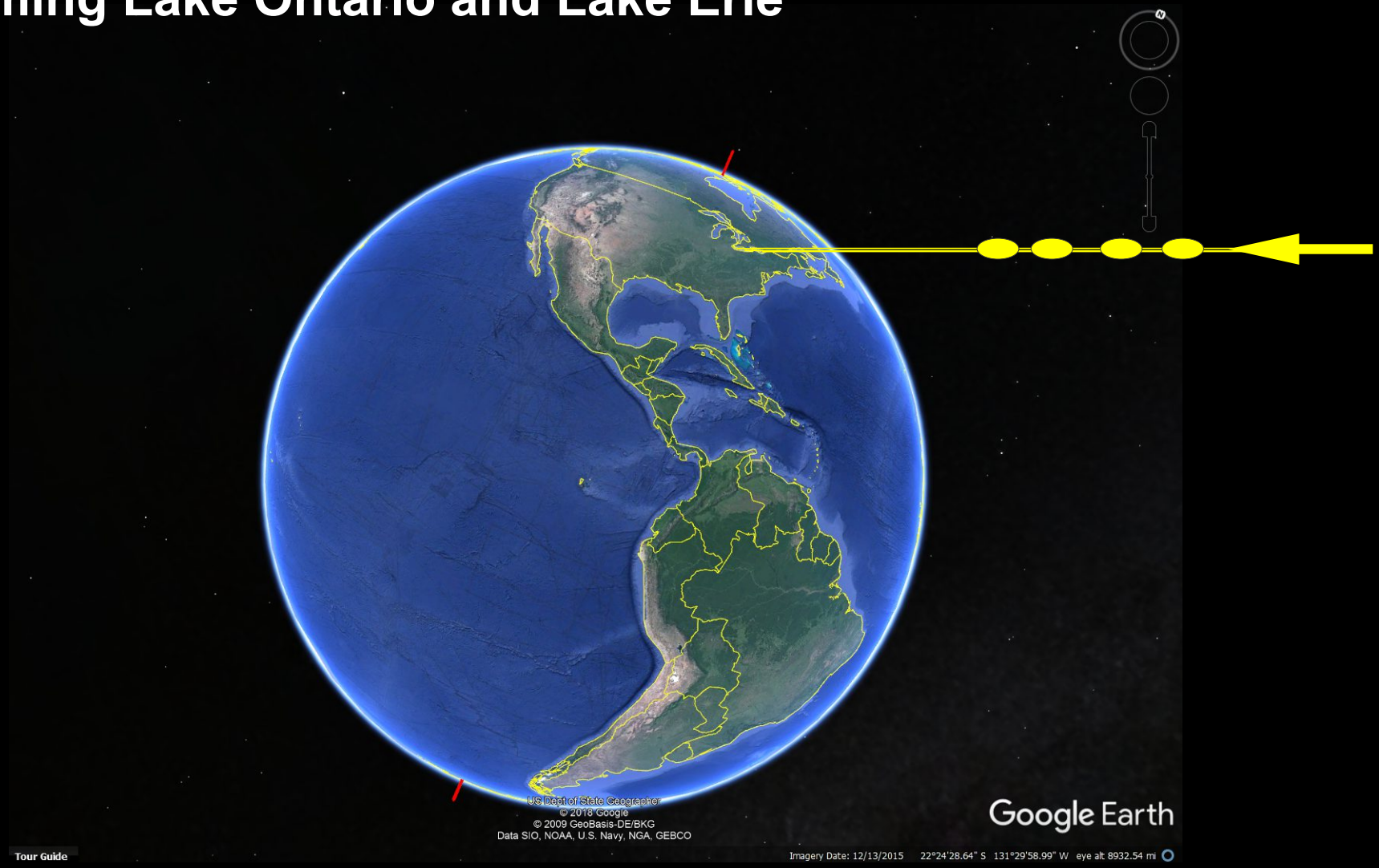
John Burgener theory of the end of the ice age:

6 hours later 3 hit Earth forming Lake Michigan

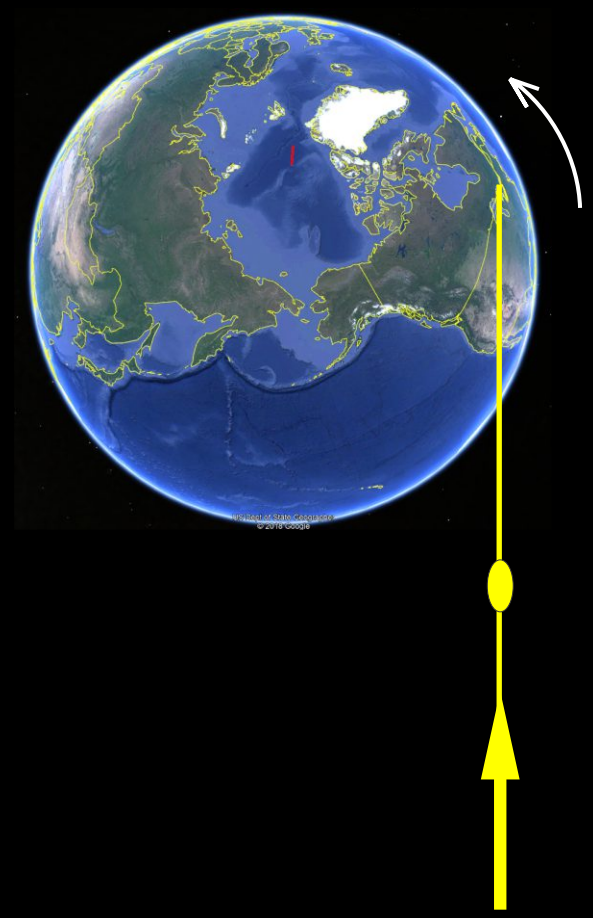


John Burgener theory of the end of the ice age:

6 more hours later 4 hit Earth forming Lake Ontario and Lake Erie



The view from above over 12 hours



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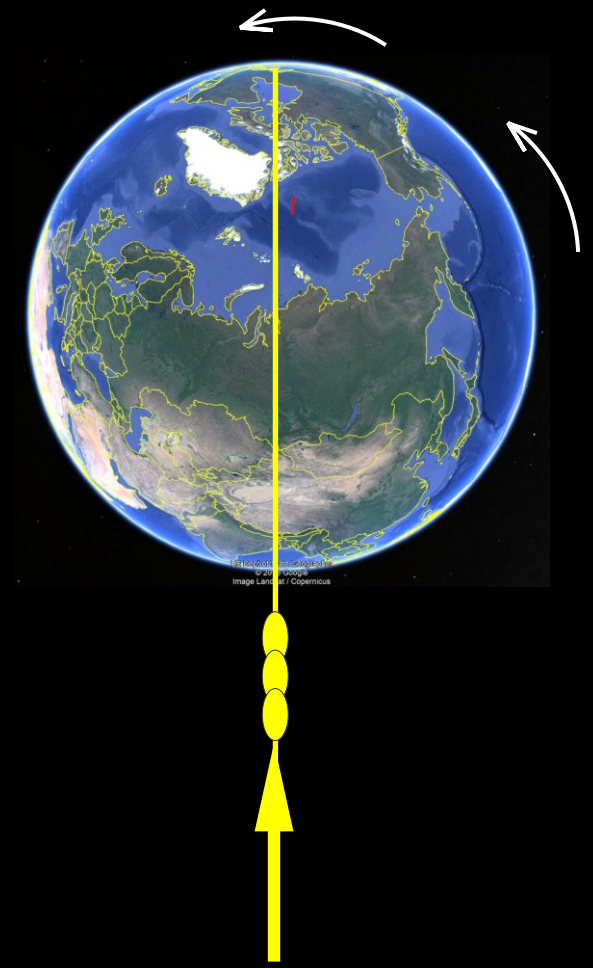
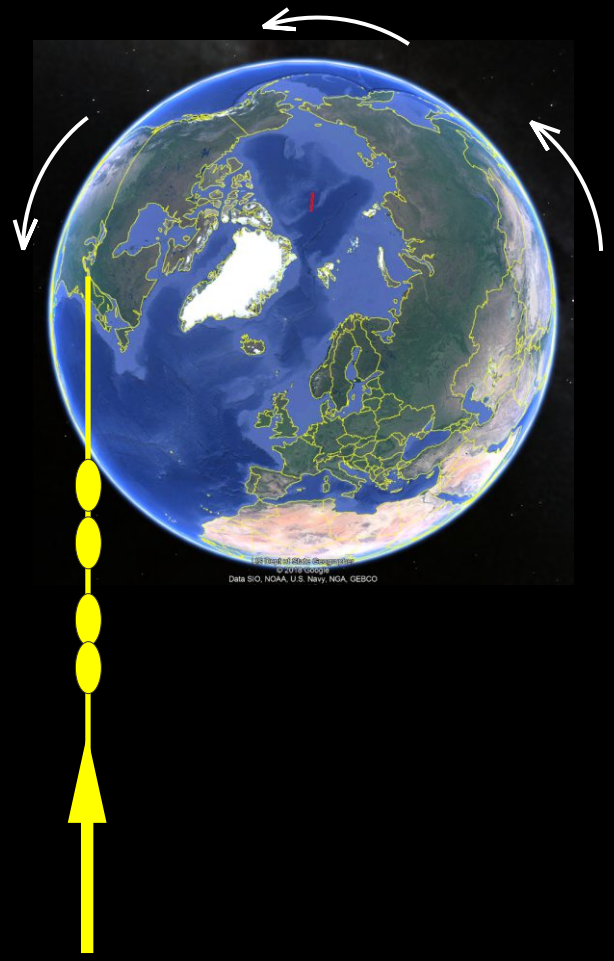
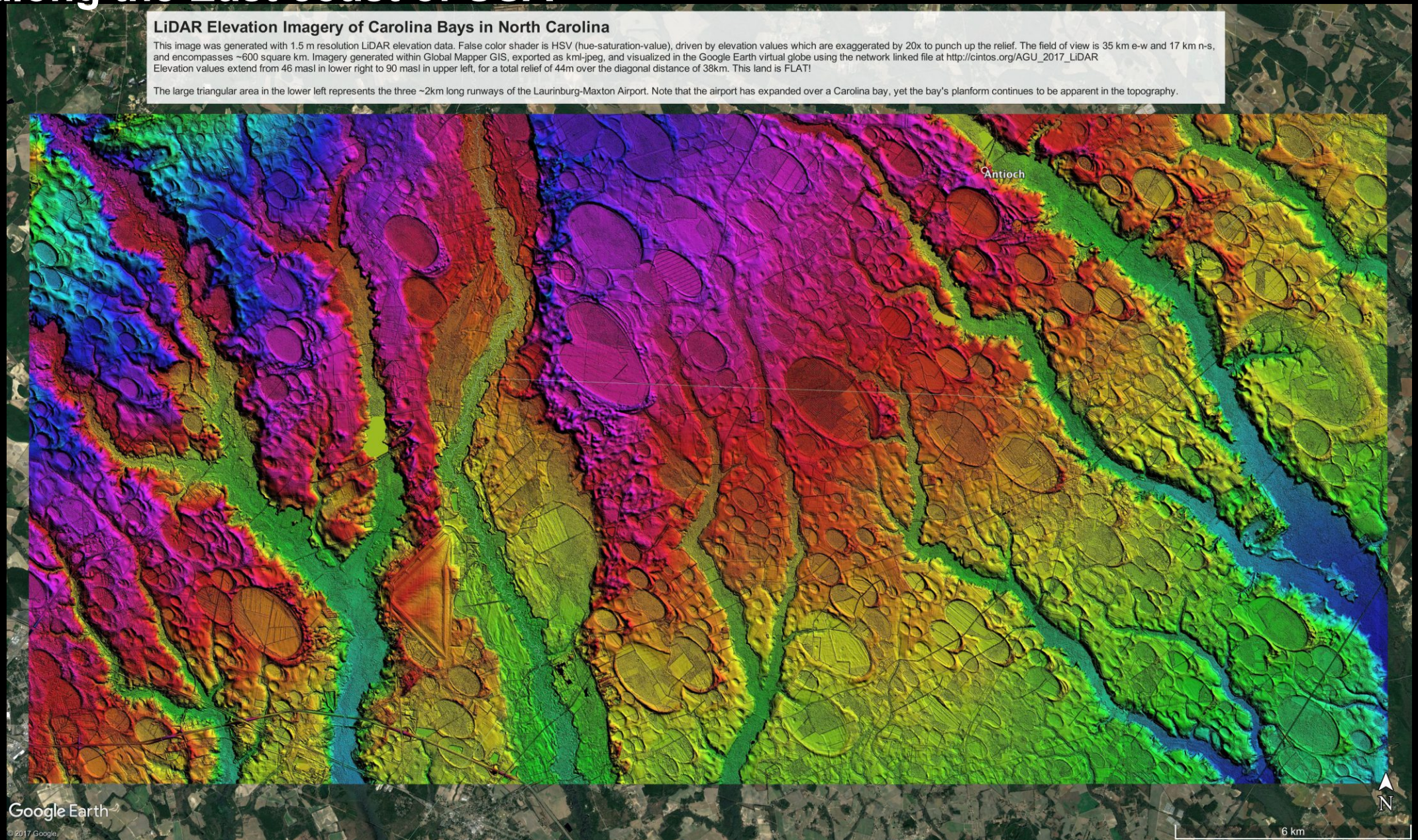


The view from above over 12 hours



The Carolina Bays are small oval depressions all along the East coast of USA



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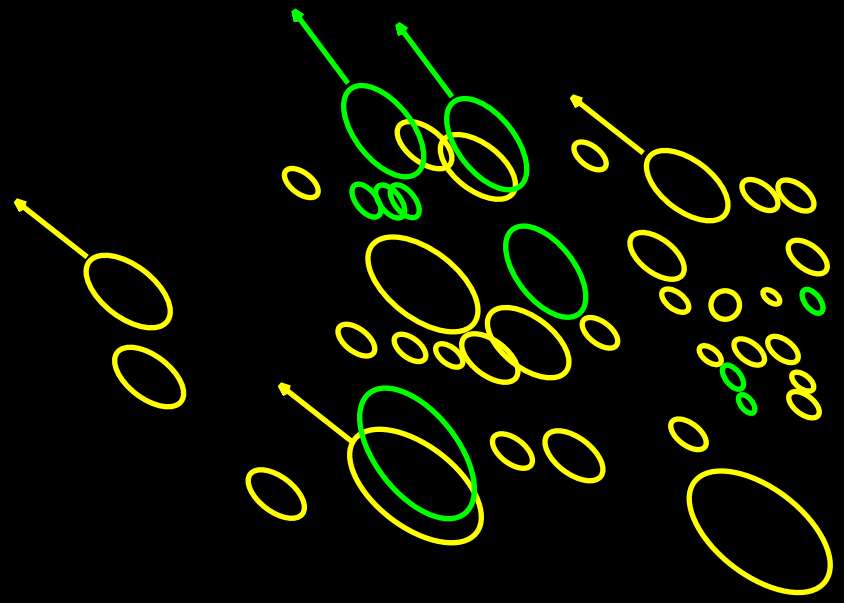
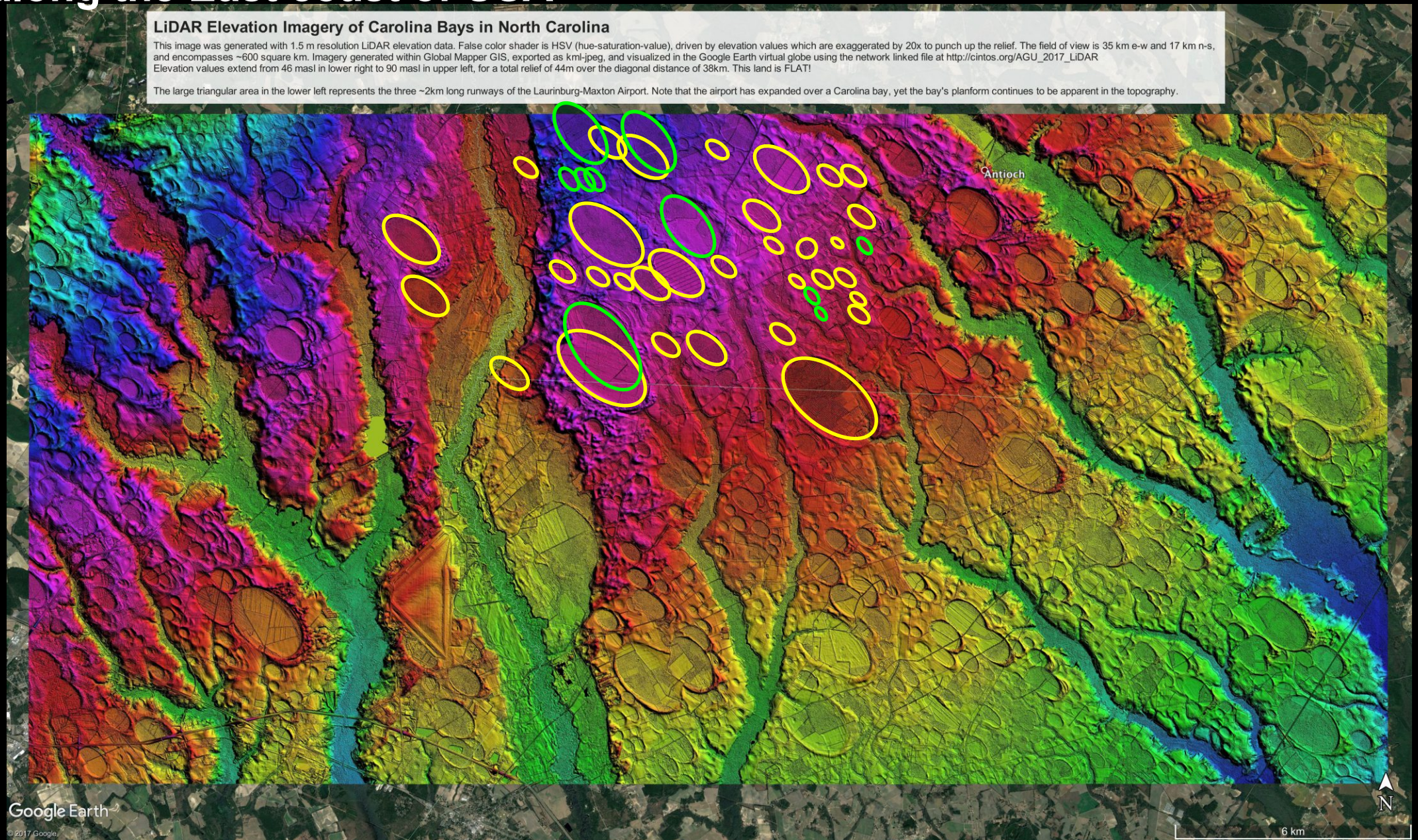


A Small section highlighted
showing two directions of travel

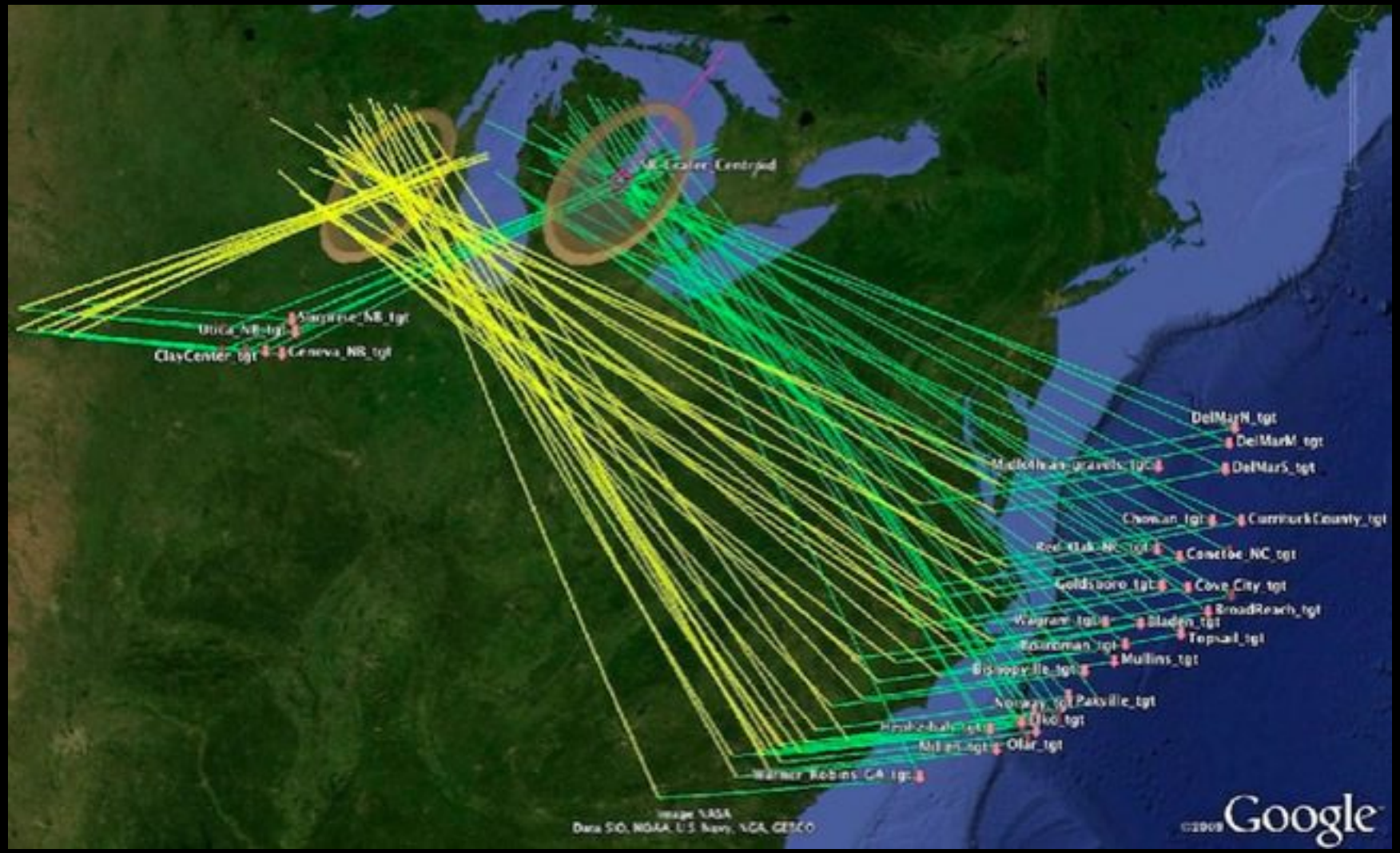
The Carolina Bays are small oval depressions all along the East coast of USA



Several Authors have tried to trace the origins of the Carolina Bays as splashes from impacts.

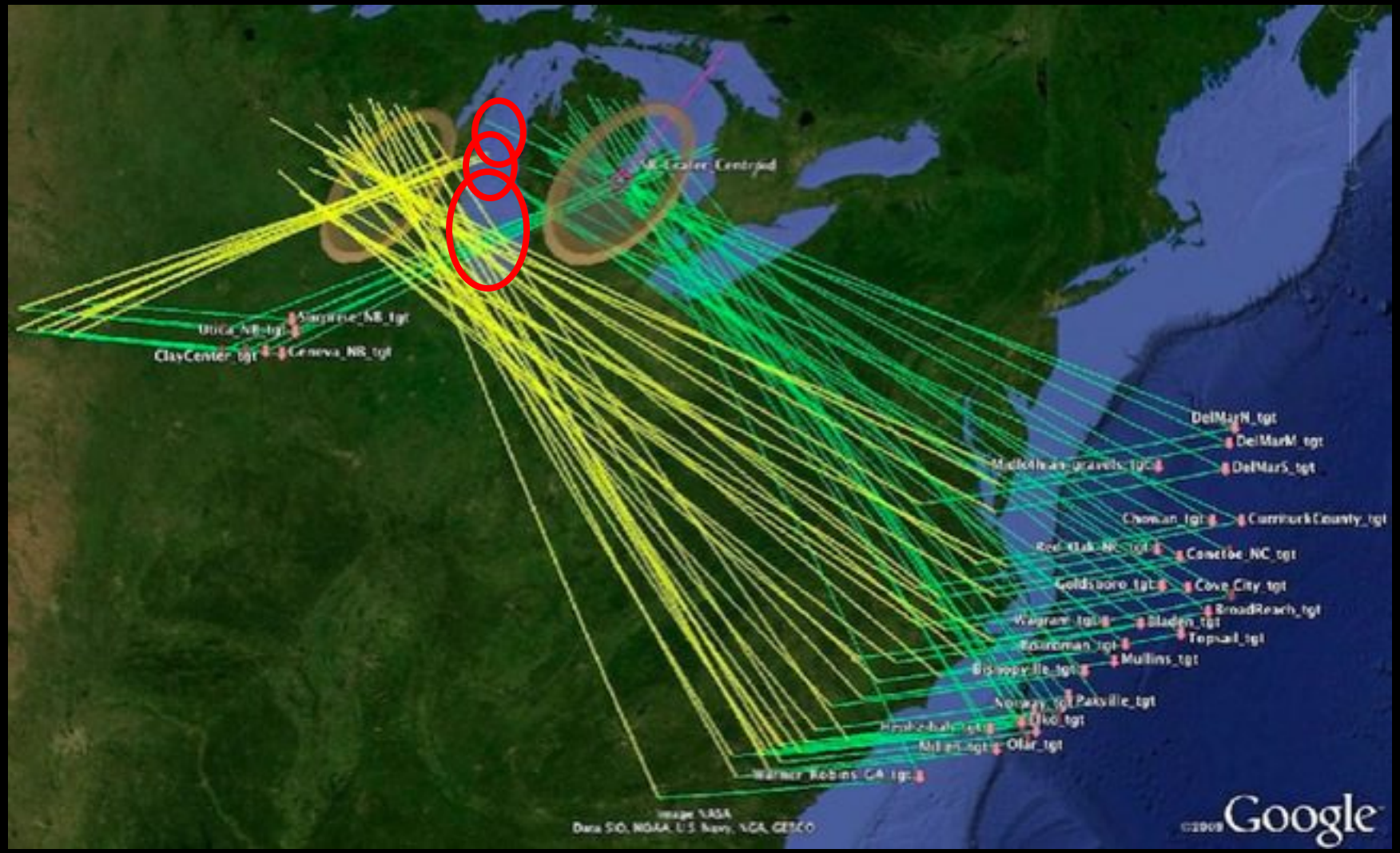
For Instance: "Correlating the Orientation of Carolina bays to a Cosmic Impact"

cintos.org/SaginawManifold/Introduction/index.html



My alternative is that an impact forming Lake Michigan is the source:

All of the lines lead to Lake Michigan



But many people have pointed out that comets are rare,
and NASA says that there are none of concern,

and that the Kuiper Belt,
which is believed to be the source of most short period comets,
is intrinsically stable and can not supply many comets.

But many people have pointed out that comets are rare,
and NASA says that there are none of concern,

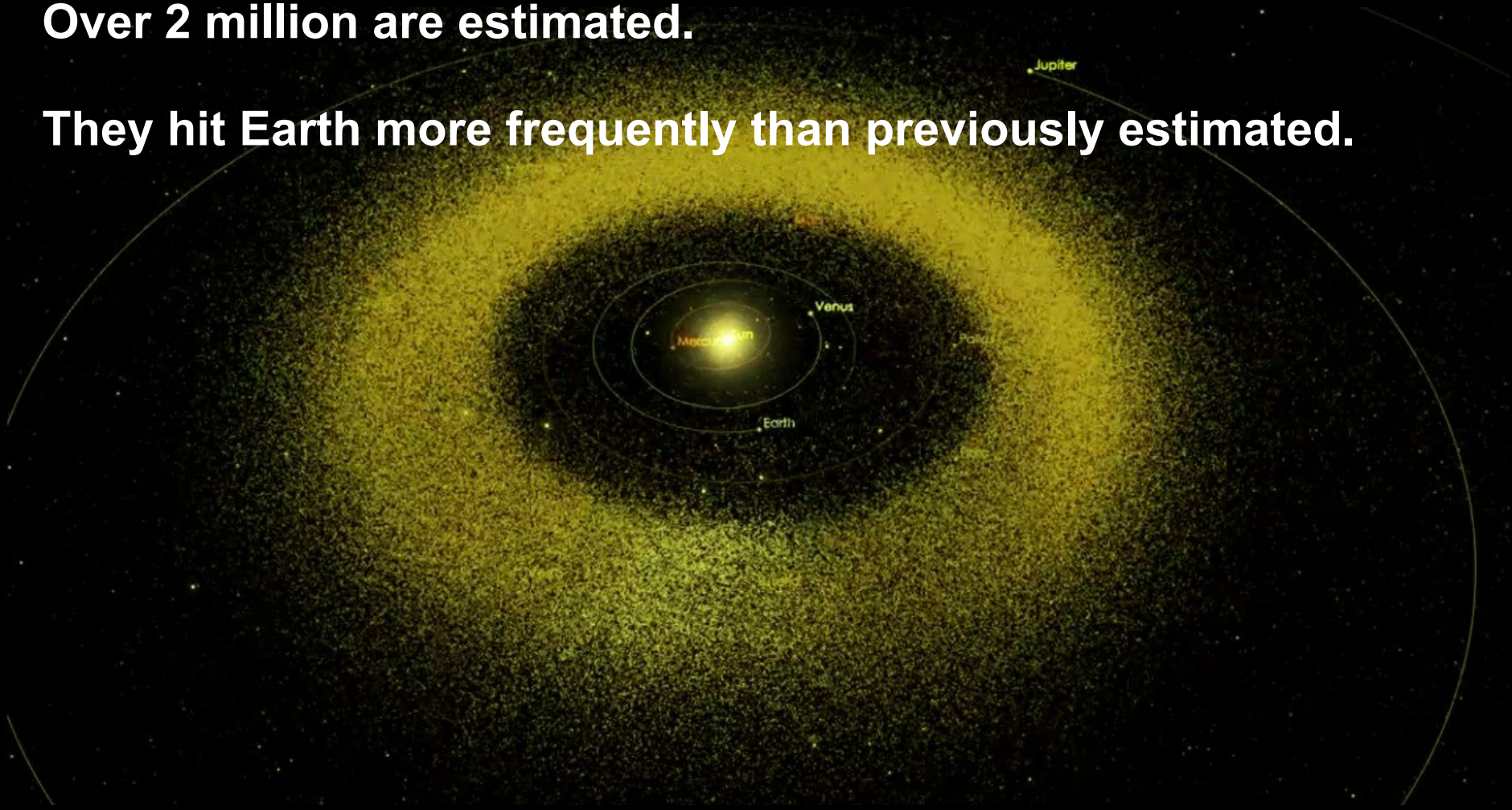
and that the Kuiper Belt,
which is believed to be the source of most short period comets,
is intrinsically stable and can not supply many comets.

Lets look at asteroids and comets.

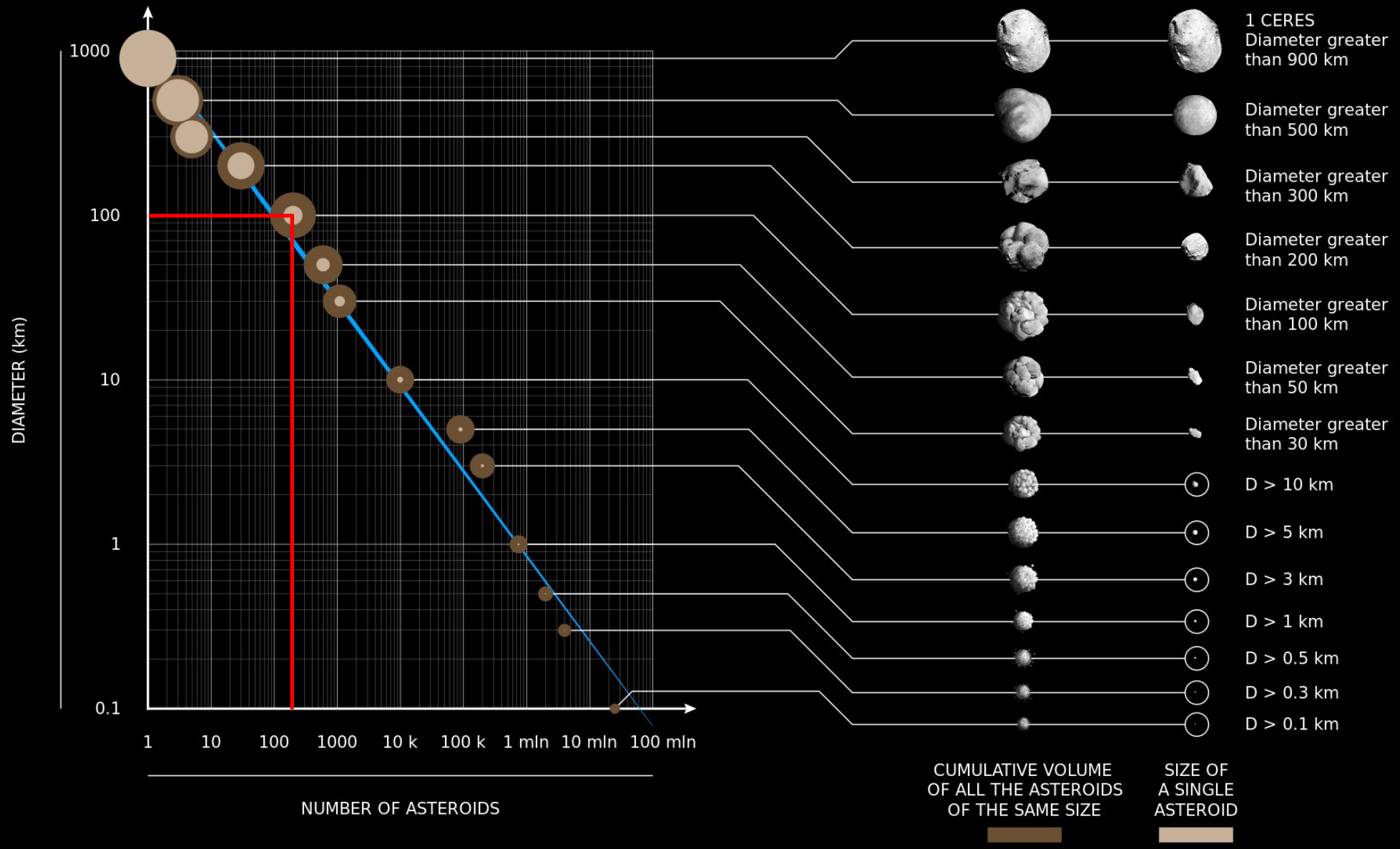
Comets and Asteroids are mainly on the Ecliptic.
When time between impacts was calculated
Less than 10,000 asteroids were known.

Today more than 600,000 have been identified.
Over 2 million are estimated.

They hit Earth more frequently than previously estimated.



Most asteroids are less than 10 km in diameter. About 10,000 are 10 km or larger, About 200 are over 100 km.



Most asteroids that hit Earth
will be much less than 1 km in diameter,

and their impacts will be devastating but local events.

Short period comets are from the Kuiper Belt, outside of Neptune's orbit.

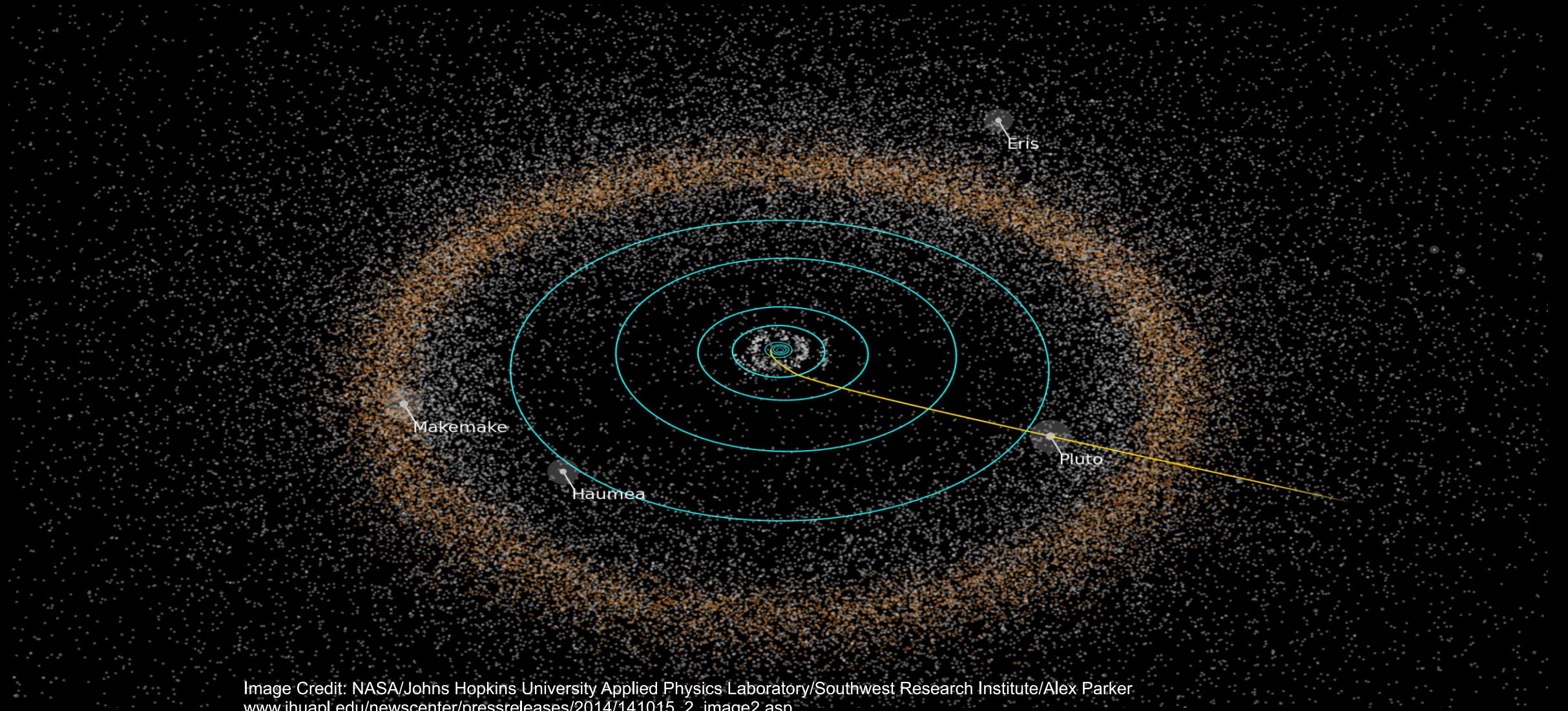


Image Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute/Alex Parker
www.jhuapl.edu/newscenter/pressreleases/2014/141015_2_image2.asp

It is estimated that there are over 100,000 objects (potential comets) more than 100 km in diameter in the Kuiper Belt

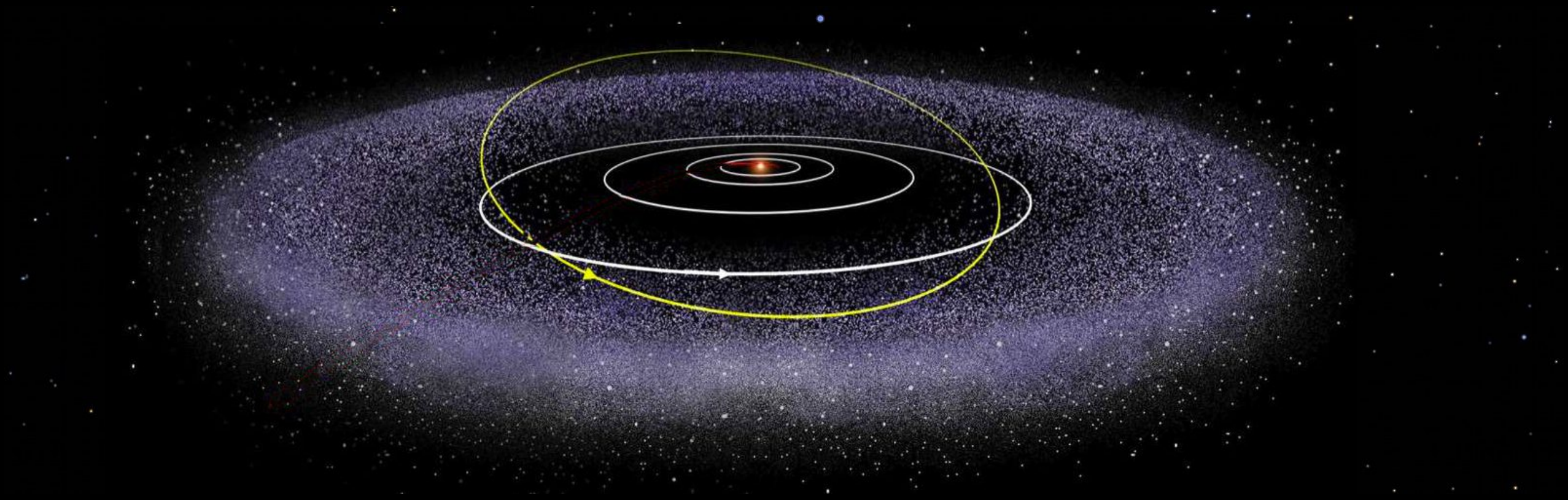


Image from NASA: https://solarsystem.nasa.gov/solar-system/kuiper-belt/overview/
Estimates of numbers of Kuiper Belt Objects from :
The Canada-France Ecliptic Plane Survey—Full Data Release: The Orbital Structure of the Kuiper Belt
J.-M. Petit et al. 2011 Astron. J. 142 131 doi:10.1088/0004-6256/142/4/131

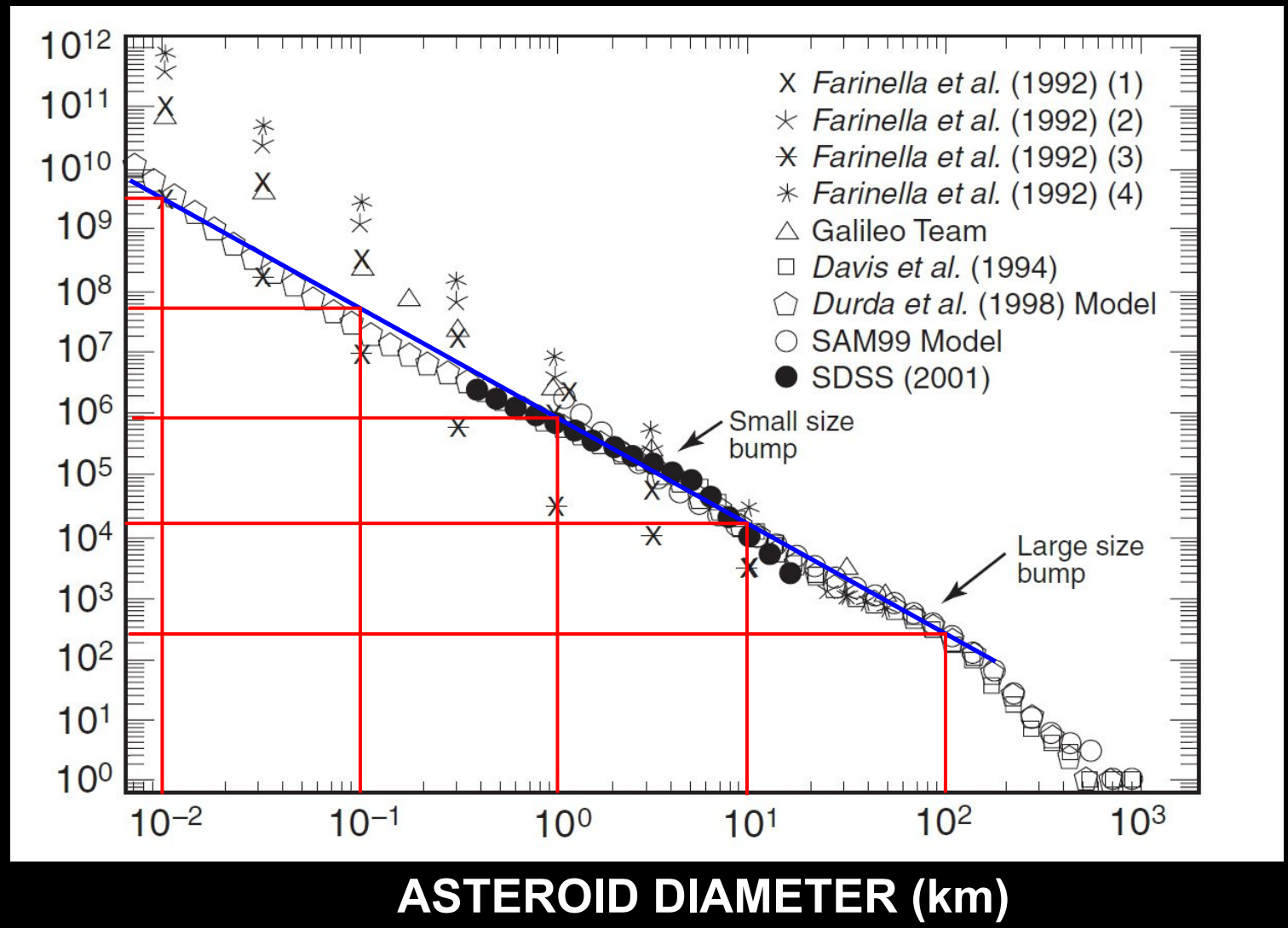
There are about 500 X as many comets as asteroids.

As Asteroid size decreases 10X, population increases by ~ 10^1.77

Asteroid Diameter km	# Asteroids
0.01	4 X 10^9
0.1	6 X 10^7
1.0	1 X 10^6
10	1.7 X 10^4
100	3 X 10^2

number $\propto \Delta$ Size^1.77

Comparison of Asteroid size distribution: Observations and Models



Collisional Evolution of Small-Body Populations (pp. 545–558)
D. R. Davis, D. D. Durda, F. Marzari, A. Campo Bagatin, and R. Gil-Hutton, a chapter in "ASTEROIDS III", Edited by William Bottke, Alberto Cellino, Paolo Paolicchi, and Richard P. Binzel, University of Arizona Press, 2002.

KBO in Kuiper Belt & Size Distribution

Assume that the KBO population size distribution is similar to the Asteroids

Present estimates of numbers of objects in the Kuiper Belt:
~ 100,000 objects > 100 km (Reference: Pitjev and Pitjev 2018)

Size distribution is ~proportional to ∆r^1.77, so the size distribution will be:

100+ km	**100,000**
10+ km	**6,000,000**
1+ km	**350,000,000**

"Mass of the Kuiper Belt", Pitjeva, E.V. & Pitjev, N.P. Celestial Mechanics and Dynamical Astronomy (Sept. 2018) 130: 57.
https://doi.org/10.1007/s10569-018-9853-5

Nesvorný et al 2017 estimate about 15 million 10Km size objects in the scattered disk,
so these numbers for the classical and resonate zones are appropriate.

For close approaches to Kuiper Belt Objects (KBO),
Dwarf Planets have a stronger gravitational pull
than Neptune or Jupiter.

It is desirable to define a Zone of Influence (ZOI)
in which the gravitational pull of a Dwarf Planet
is at least 10 X greater than the pull of Jupiter or Neptune.

The orbits of the KBOs effected by such a ZOI
should be significantly changed,
and many will move into the inner Solar System
to become Short Period Comets.

Show Video of Jupiter's pull here

Consider a KBO coming within the distance of a Dwarf Planet, eg Pluto, such that the Dwarf Planet's gravitational acceleration is 10X greater than the acceleration of Jupiter or Neptune.

$10 \text{ X } g_{Jupiter(48AU)} = 3.06X10\text{^-}11 \text{ km/s}^2$

Match 10 X Jupiter Acc to Pluto Acc:

$g_{Pluto} = GM_P/r_P^2 = 10 \text{ X } GM_J/r_J^2 = 3.06X10^{-11} \text{ km/s}^2$

$r_{Pluto} = 5{,}323{,}200 \text{ km}$

At 5,323,200 km, the pull of Pluto is 10 X greater than the pull of Jupiter

Gravity is a time dependant function.

Distance^2 and Time determine effect.

Jupiter's orbit is ~12 years, so assume 6 years of Jupiter's gravity has a significant effect on KBO orbits.

$\Delta v = g_{Jupiter}$ X 6 years = 3.06X10^-12 km/s ^{2} X 6 X 31,557,600 s

Δv = 5.794 X 10^-4 km/s **Jupiter Effect in 6 years**

Δv = The change in speed of a KBO due to Jupiter's gravitational pull for 6 years.

Definition of the Zone of Interaction (ZOI):

The volume of space effected by a Dwarf Planet so that the ∆v accumulated by a Kuiper Belt Object (KBO) is greater or equal to 10 X $\Delta v_{Jupiter\ @\ 48\ AU\ for\ 6\ years}$:

∆v = 5.794 X 10^-3 km/s 10X Jupiter Effect

Any combination of time and distance that provides this ∆v will be in the ZOI.

For Pluto to match 10 X ∆v of Jupiter:

r(km)	r^2	Time (sec)	Time (Years)	Speed
5,323,200	2.83 E13	188,877,117	6.00	0.04 km/s
2,200,000	4.84 E12	32,261,098	1.02	0.10 km/s
1,400,000	1.96 E12	13,064,411	0.41	0.15 km/s
1,000,000	1.00 E12	6,665,516	0.21	0.21 km/s
420,000	1.76 E11	1,175,797	0.04	0.50 km/s
380,000	1.44 E11	962,501	0.03	0.55 km/s
156,000	2.43 E10	162,212	0.01	1.35 km/s
97,000	9.41 E09	62,716	0.00	2.17 km/s
45,000	2.02 E09	13,498	0.00	4.67 km/s

Pluto's acceleration will match 10X Jupiter's acceleration for 6 years if object is at distance r for Time in above table.
Speed is how fast KBO can travel relative to Pluto to remain in that distance for that time.
Faster speed will allow less time so shorter distance for same acceleration.

For this distance, Pluto needs this much time, and needs to travel at this speed or slower to travel this distance in that time.

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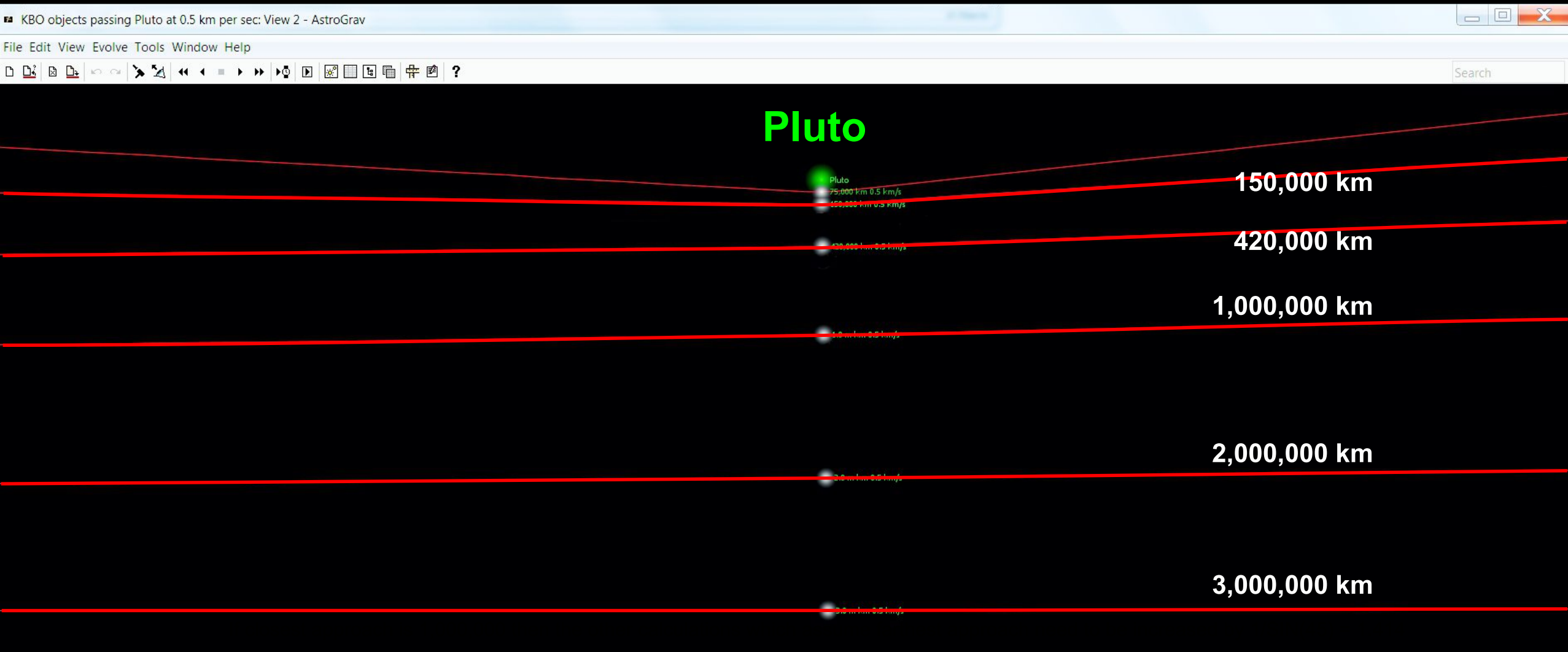
Pluto passes most KBO at speeds in the yellow highlighted zones

Orbit changes from close pass of Pluto at 0.5 km/s

Orbits drawn by AstroGrav (http://www.astrograv.co.uk)

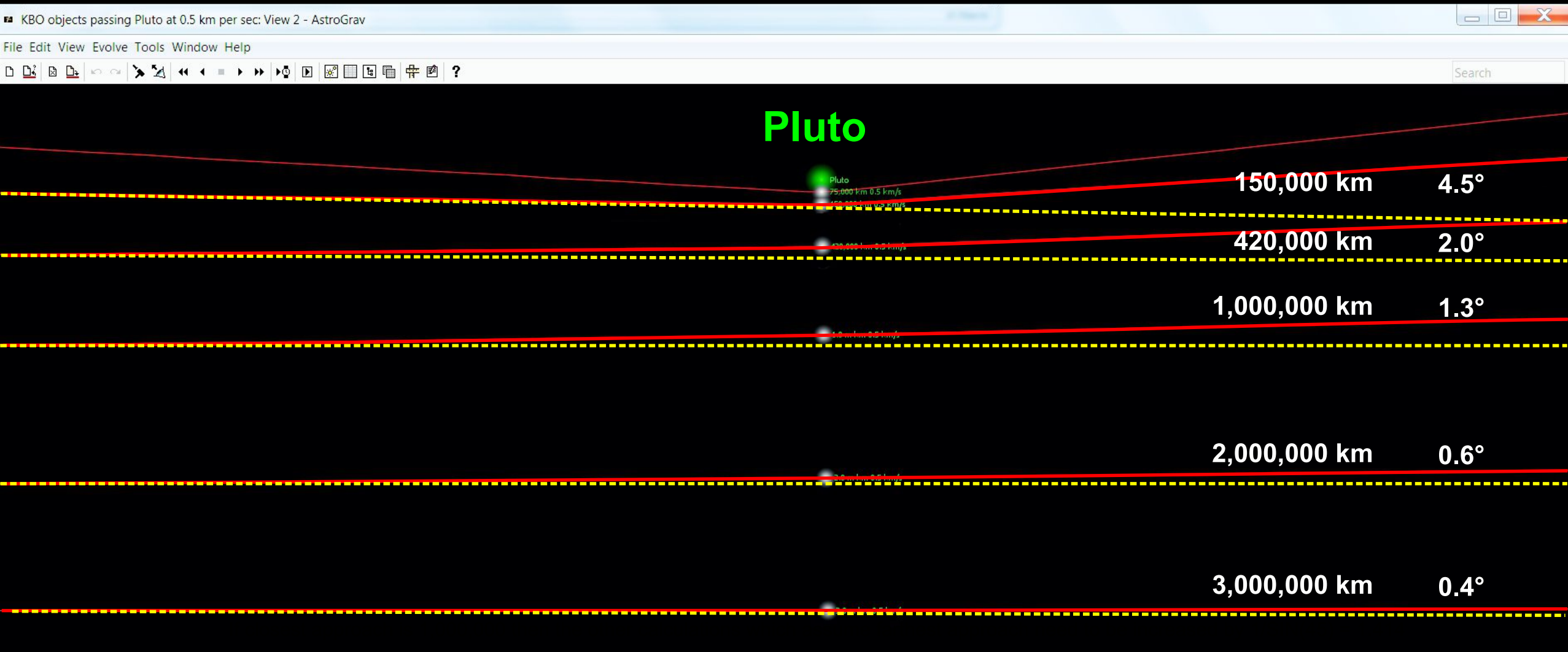


Orbit changes from close pass of Pluto at 0.5 km/s

(From AstroGrav)

Red Line = path with Pluto Influence

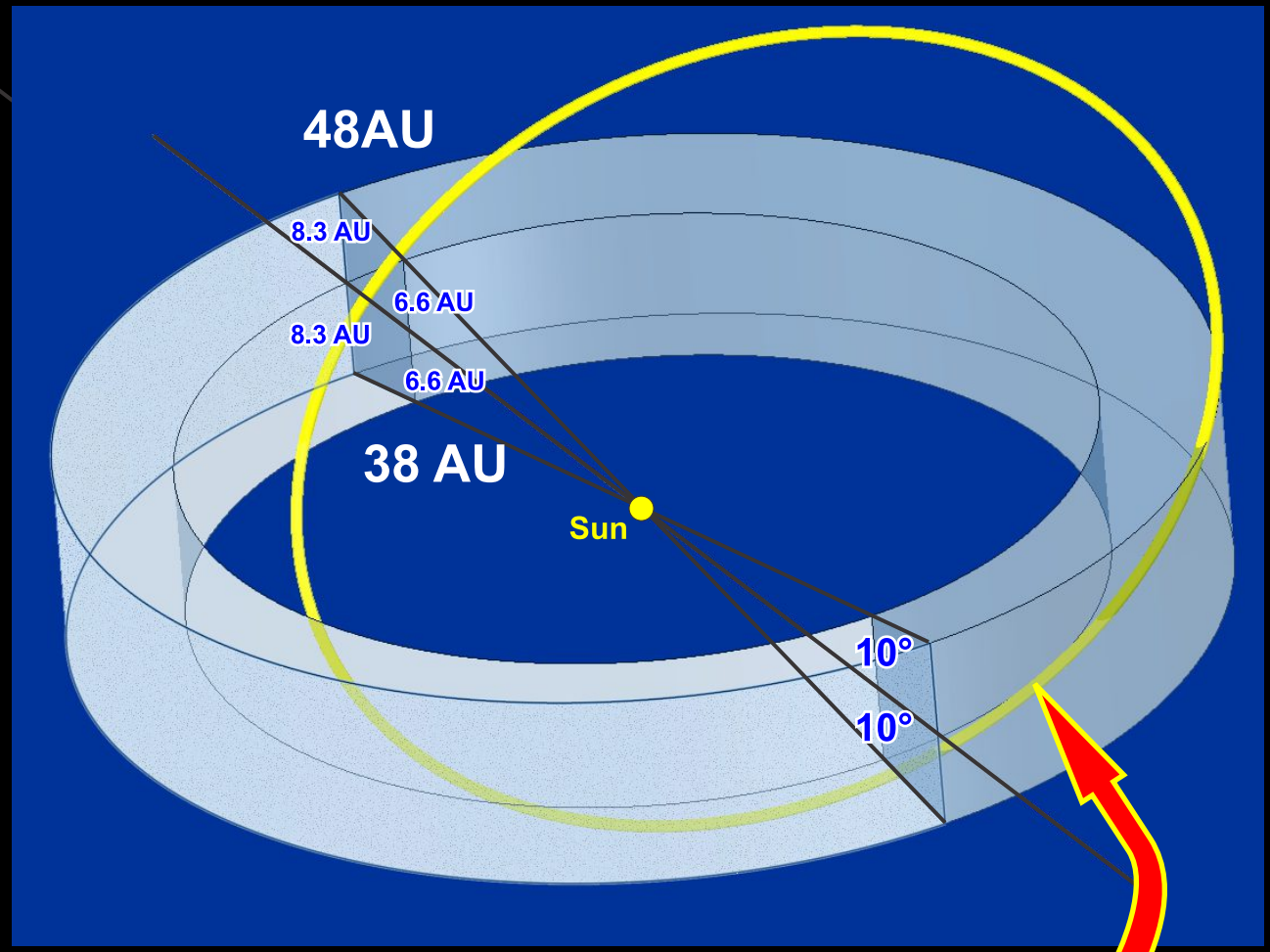
Yellow Line = path without Pluto Influence



Pluto's orbit

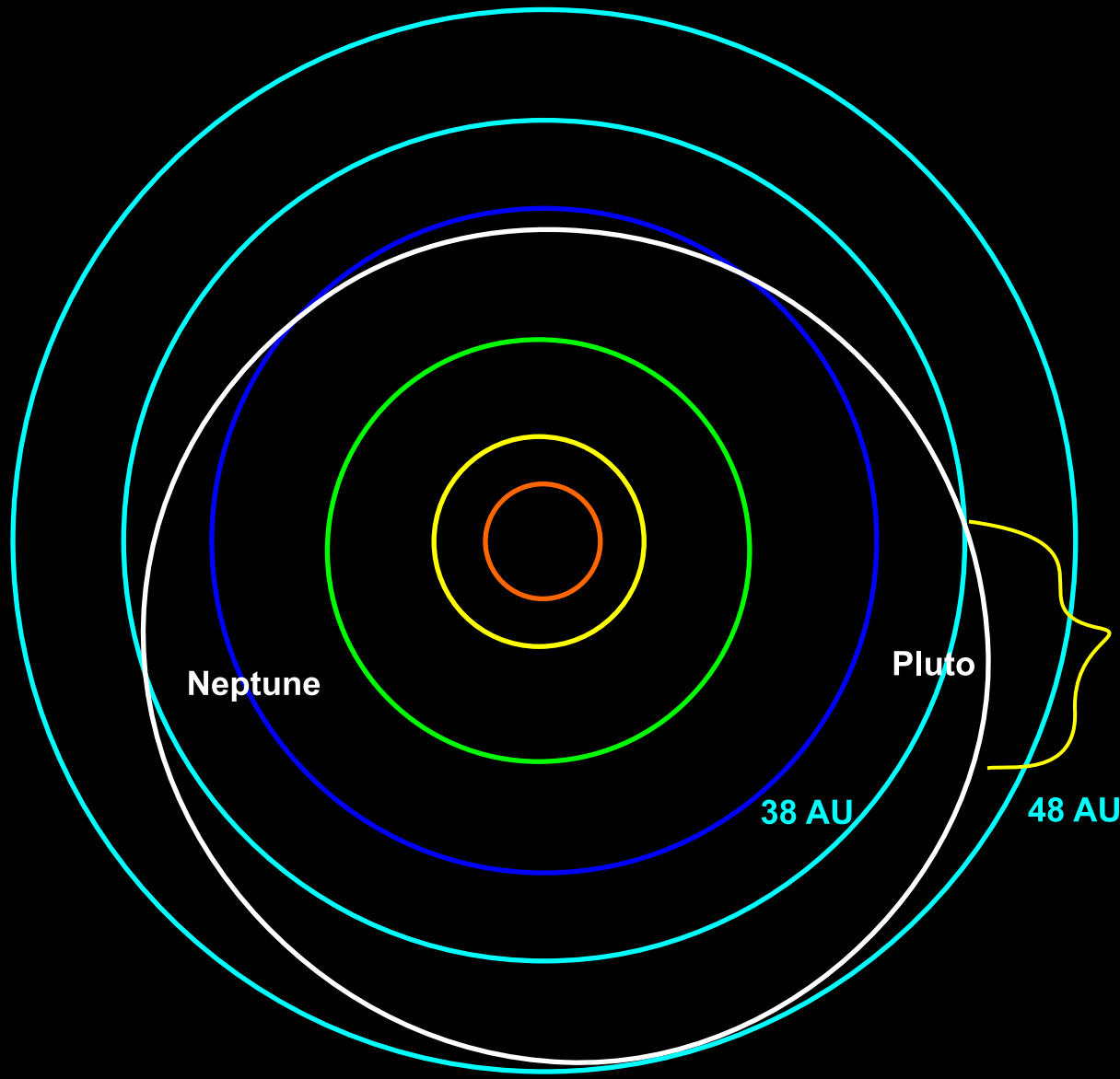
intersects the main KB zone
(includes classical and resonate zones)
for approx. 35 years,

ranging from 36 to 44 AU distance from Sun.



35 years in most densely populated part of KB

Pluto travels in the main KB Zone for approx. 35 years



Pluto in Classical KB Zone

Image from NASA JPL Small Body Database

Radius of Influence of Pluto's Path:

Pluto is inclined at 17°. KB main zone is +/- 10°

Range is from 17°-10° = 7° up to 17°

Horizontal speed difference is generally < 0.2 km/sec
Vertical difference ranges from 0.55 - 1.37 km/sec

From the 10 X ∆v Jupiter chart:
at speed of .55 km/s, Zone of Influence is 380,000 km radius
at speed of 1.365 km/s, Zone of Influence is 156,000 km radius.

For simplicity, use average of 200,000 km radius

Volume of Pluto's Path:

With the average of 200,000 km radius:

area of path = ¶ r^2 = 1.257E11 km^2

Pluto takes ~ 35 years to pass through classical portion of KB,

= 1.5E8 *35 = 5.25E9 km

Volume of Pluto Zone of Influence = 6.48 E20 km^3

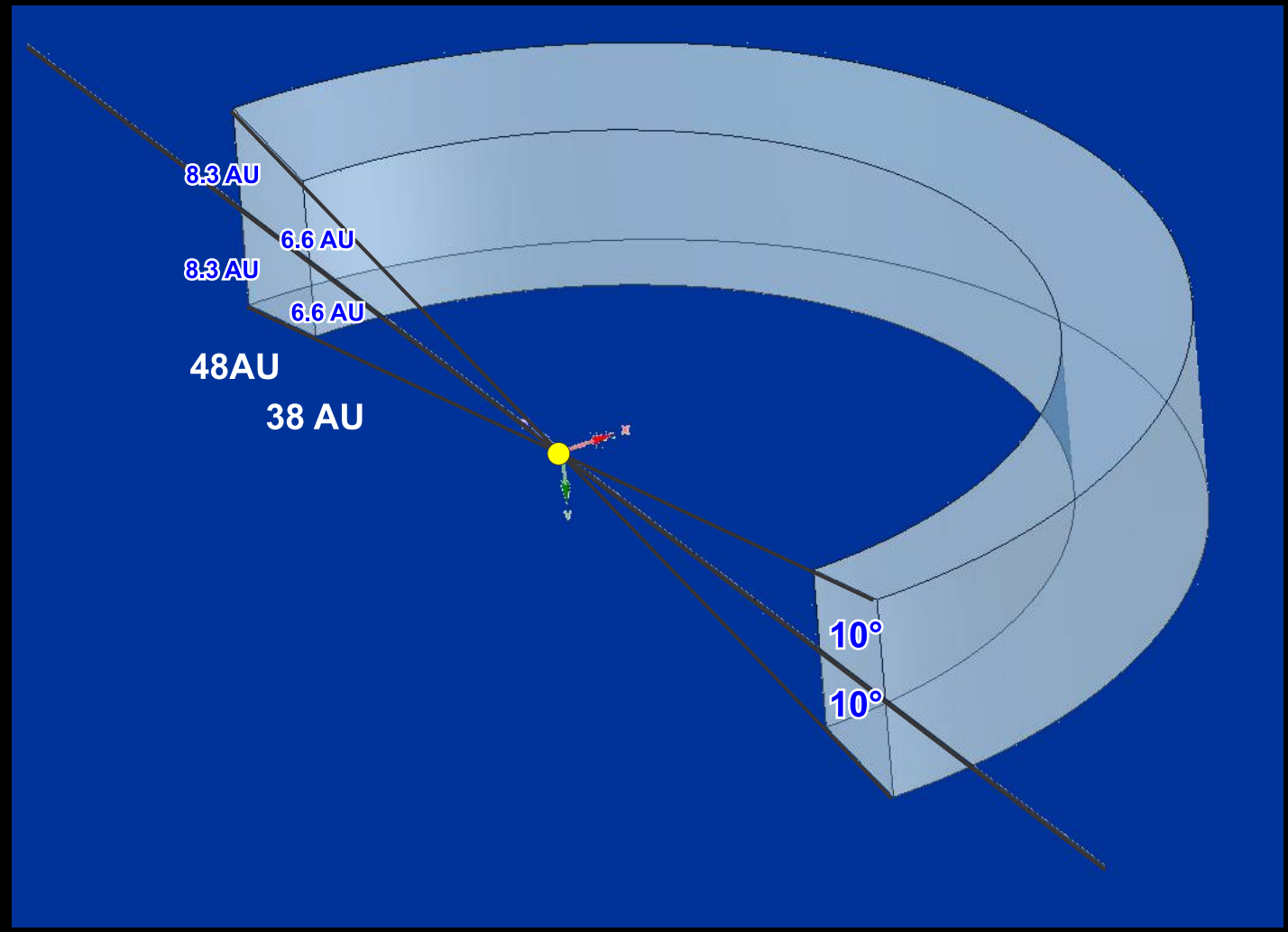
Classical & Resonant Kb

Volume of Kuiper Belt:

+/- 10 degrees, from 38 to 48 AU

Volume = 40,550 AU^3
Volume = 4.055E4 *1.49598E8^3 km^3

Volume = 1.3576 E29 km^3



Volume of cylinder = 3.14159 r^2 * h
= 3.14159 * 48 * 48 * 16.67 = 120,661
= 3.14159 * 38 * 38 * 13.19 = 59,835
Volume of cone 48 au = 1/3 Pi r^2 h = 40220
Volume of cone 38 au = 1/3 Pi r^2 h = 19945
Total Volume = (120,661 - 40,220) - (59,835 - 19,945) = 40,551 AU^3

Time required for Pluto to effect all of KB:

Volume of KB divided by Volume of Pluto ZOI

1.357E29 / 6.48E20 = 2.094 E8

= 209,400,000 orbits of 255 years each,

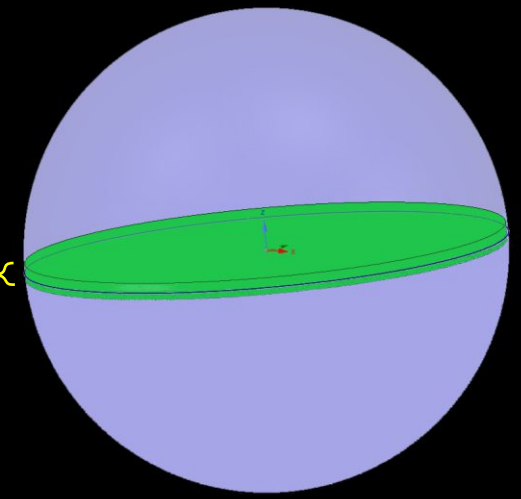
51,942,771,795 years to effect all of the Kuiper Belt

Which is 10X the age of the Solar system

Pluto's Effect on KBOs

Only a few will be pushed towards the Sun

+/-2°



The effected KBOs orbit will change in random directions

Some away from the sun, some towards, some to the Scattered Disk.

The KBOs with a change parallel to the Ecliptic Plane
will have their Perihelion closer to the sun,
and move into the influence of the inner planets.

Parallel to the Ecliptic +/- 2 degrees can become Earth Crossing.

+/- 2 degrees is 2/90 or 1/45 of the effected KBOs.

How many KBOs will be effected?

6 million over 10 km diameter
350 million over 1 km diameter

51,942,771,795 years to effect all KB, divided by 6 million:

8,738 years per 10 km KBO effected
148 years per 1 km KBO effected

1 in 45 eventually cross Earth Orbit:

389,571 years between 10 km diameter comets in Earth crossing Orbit.
6,678 years between 1 km diameter comets in Earth crossing Orbit.

50000 Quaoar

Match 10 X Jupiter Acc to Quaoar Acc:

$g_{Quaoar} = GM_Q/r_Q^2 = GM_J/r_J^2 = 3.06X10^{-11}$ km/s ^{2}

$r_{Quaoar} = 1{,}746{,}893$ km

Quaoar travels between 42 and 45.2 AU so it does not effect ALL of the belt.

For Quaoar to match 10 X Jupiter ∆v:

r (km)	r^2	Time (sec)	Time (Years)	Speed
1,747,000	3.05E12	189,273,187	6.00	0.01 km/s
1,000,000	1.00E12	62,023,555	1.97	0.02 km/s
500,000	2.50E11	15,505,890	0.49	0.05 km/s
250,000	6.25E10	3,876,472	0.12	0.09 km/s
100,000	1.00E10	620,236	0.02	0.23 km/s
50,000	2.50E09	155,059	0.005	0.45 km/s
35,000	1.22E09	75,979	0.002	0.64 km/s
5,000	2.50E07	1,551	0.000	4.51 km/s

Radius of Influence Quaoar's Path:

Quaoar is inclined at 7.99°. KB Classical zone is +/- 10°

Relative Range is from 0° up to 8°

Horizontal speed difference is generally < 0.2 km/sec
Vertical difference ranges from 0.0 - 0.63 km/sec

From the 10 X ∆v Jupiter chart:
at speed of 0.1 km/s, Zone of Influence is 250,000 km radius
at speed of 0.63 km/s, Zone of Influence is 35,000 km radius.

For simplicity, use average of 100,000 km radius

Volume of Quaoar's Path:

With the average of 100,000 km radius:

area of path = ¶ r^2 = 3.14 E10 km^2

Quaoar remains in KB main zone for the entire 288 year orbit:

= 1.5E8 *288 = 4.10 E10 km length

Volume of Quaoar Zone of Influence = 1.287 E21 km^3

Time required for Quaoar to effect all of KB:

Volume of KB divided by Volume of Quaoar ZOI

1.357 E29 / 1.287 E21 = 1.05 E8

= 105,440,000 orbits of 288 years each,

30,366,400,000 years to effect all of the Kuiper Belt

How many KBOs will be effected by Quaoar?

6 million over 10 km diameter
350 million over 1 km diameter

30,369,125,000 years to effect all KBO, divided by 6 million:

5,062 years per 10 km object effected
87 years per 1 km object effected

1 in 45 eventually cross Earth Orbit:

227,800 years between 10 km diameter comets in Earth crossing Orbit.
3,900 years between 1 km diameter comets in Earth crossing Orbit.

Dwarf Planet	Mass	Inclination	Years in Classical KB	Max Speed Difference km/s	ZOI	Years per Earth Crossing 1 km KBO
Quaoar	1.40 E21	7.99°	288	0.63	1.29 E21	3,905
Pluto	1.30 E22	17.16°	35	1.38	6.48 E20	6,678
Eris	1.66 E22	44.04°	20	2.39	9.80 E19	99,343
Haumea	4.01 E21	28.19°	43	2.14	4.83 E19	102,698
MakeMake	4.40 E21	28.98°	25	2.14	2.74 E19	197,035
Orcus	6.41 E20	20.58°	34	1.67	2.56 E19	168,491
2002 Ms4	6.00 E20	17.68°	78	1.39	2.21 E19	212,472
Ixion	4.00 E20	19.59°	45	1.59	1.90 E19	229,583
Varuna	3.70 E20	17.20°	100	1.34	4.49 E18	1,094,026
Salacia	4.38 E20	23.93°	93	1.87	2.71 E18	1,747,027
2007 OR 10	1.75 E21	30.90°	0	1.87	0	

KBO effected over a period of time

Dwarf Planet	ZOI	Years per Earth Crossing 1 km KBO	1 km Earth Crossing KBO / 10,000 years
Quaoar	1.29 E21	3,905	2.56
Pluto	6.48 E20	6,678	1.50
Eris	9.80 E19	99,343	0.10
Haumea	4.83 E19	102,698	0.10
MakeMake	2.74 E19	197,035	0.05
Orcus	2.56 E19	168,491	0.06
2002 Ms4	2.21 E19	212,472	0.05
Ixion	1.90 E19	229,583	0.04
Varuna	4.49 E18	1,094,026	0.01
Salacia	2.71 E18	1,747,027	0.01
	Total KBO / 10,000 years		4.47
	Years per new 1 km comet		2,236

KBO effected over a period of time

Dwarf Planet	ZOI	Years per Earth Crossing 1 km KBO	1 km Earth Crossing KBO / 10,000 years	10 km Earth Crossing KBO per 1,000,000 years
Quaoar	1.29 E21	3,905	2.56	4.39
Pluto	6.48 E20	6,678	1.50	2.57
Eris	9.80 E19	99,343	0.10	0.17
Haumea	4.83 E19	102,698	0.10	0.17
MakeMake	2.74 E19	197,035	0.05	0.09
Orcus	2.56 E19	168,491	0.06	0.10
2002 Ms4	2.21 E19	212,472	0.05	0.08
Ixion	1.90 E19	229,583	0.04	0.07
Varuna	4.49 E18	1,094,026	0.01	0.02
Salacia	2.71 E18	1,747,027	0.01	0.01
	Total KBO / 10,000 years		4.47	
	Total KBO / 1,000,000 years			7.67
	Years per new 10 km comet		2,236	130,439

KBO effected over a period of time

Dwarf Planet	ZOI	1 km Earth Crossing KBO per 10,000 years	10 km Earth Crossing KBO per 1,000,000 years	100 km Earth Crossing KBO per 100,000,000 years
Quaoar	1.29 E21	2.56	4.39	7.3
Pluto	6.48 E20	1.50	2.57	4.3
Eris	9.80 E19	0.10	0.17	0.3
Haumea	4.83 E19	0.10	0.17	0.3
MakeMake	2.74 E19	0.05	0.09	0.1
Orcus	2.56 E19	0.06	0.10	0.2
2002 Ms4	2.21 E19	0.05	0.08	0.1
Ixion	1.90 E19	0.04	0.07	0.1
Varuna	4.49 E18	0.01	0.02	0.0
Salacia	2.71 E18	0.01	0.01	0.0
Total KBO / 10,000 years		4.47		
Total KBO / 1,000,000 years			7.67	
Total KBO / 100,000,000 years				12.8
Years per new 100 km comet		2,236	130,439	7,826,337

Conclusions:

Dwarf Planets effect KBOs in the Resonate and Classical zones, moving some to become short period comets.

~ 1 km KBO into Earth Crossing Orbits every 2,200 years

~ 10 km KBO into Earth Crossing Orbits every 130,200 years

~ 100 km KBO into Earth Crossing Orbits every 7,825,000 years

Conclusions:

Dwarf Planets effect KBOs in the Resonate and Classical zones, moving some to become short period comets.

~ 1 km KBO into Earth Crossing Orbits every 2,200 years

~ 10 km KBO into Earth Crossing Orbits every 130,200 years

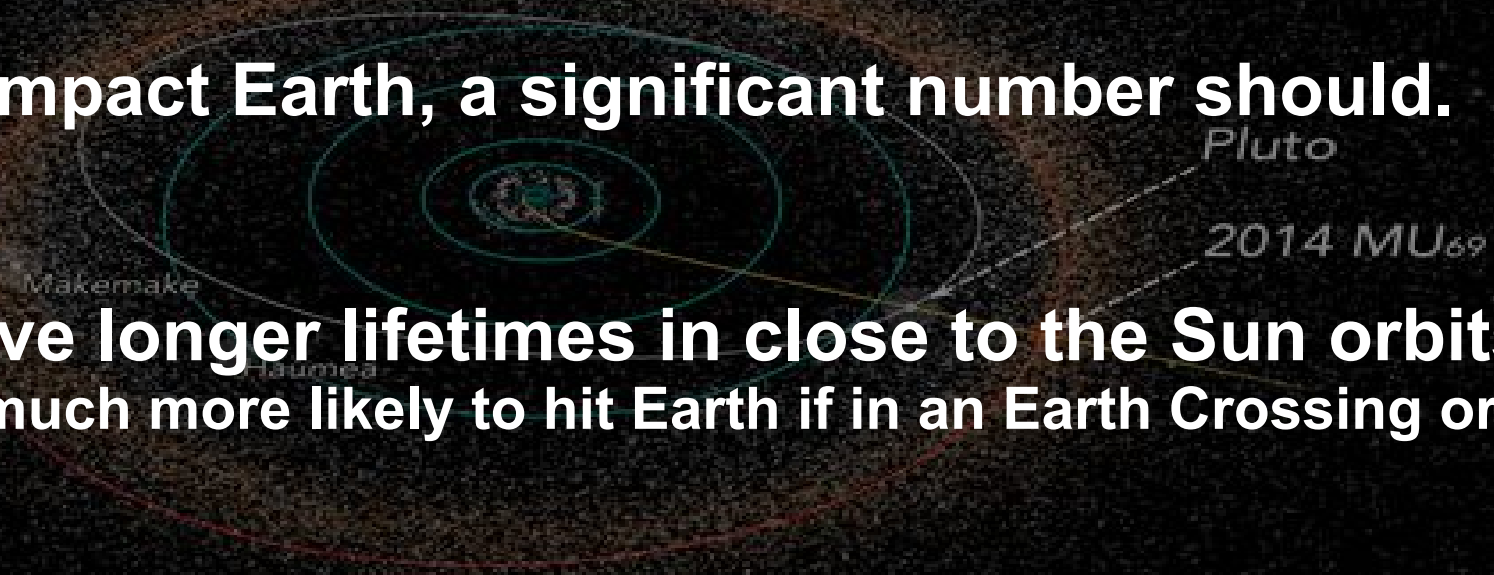
~ 100 km KBO into Earth Crossing Orbits every 7,825,000 years

These numbers are a MINIMUM.
The Zones of Influence have been set as small as possible.
The actual rate should be higher.

Conclusions:

If new 10 km KBOs go into Earth Crossing Orbit every 130,000 years, This implies that impacts from 10 km comets should happen much more frequently than once every 100 million years.

While not all will impact Earth, a significant number should.

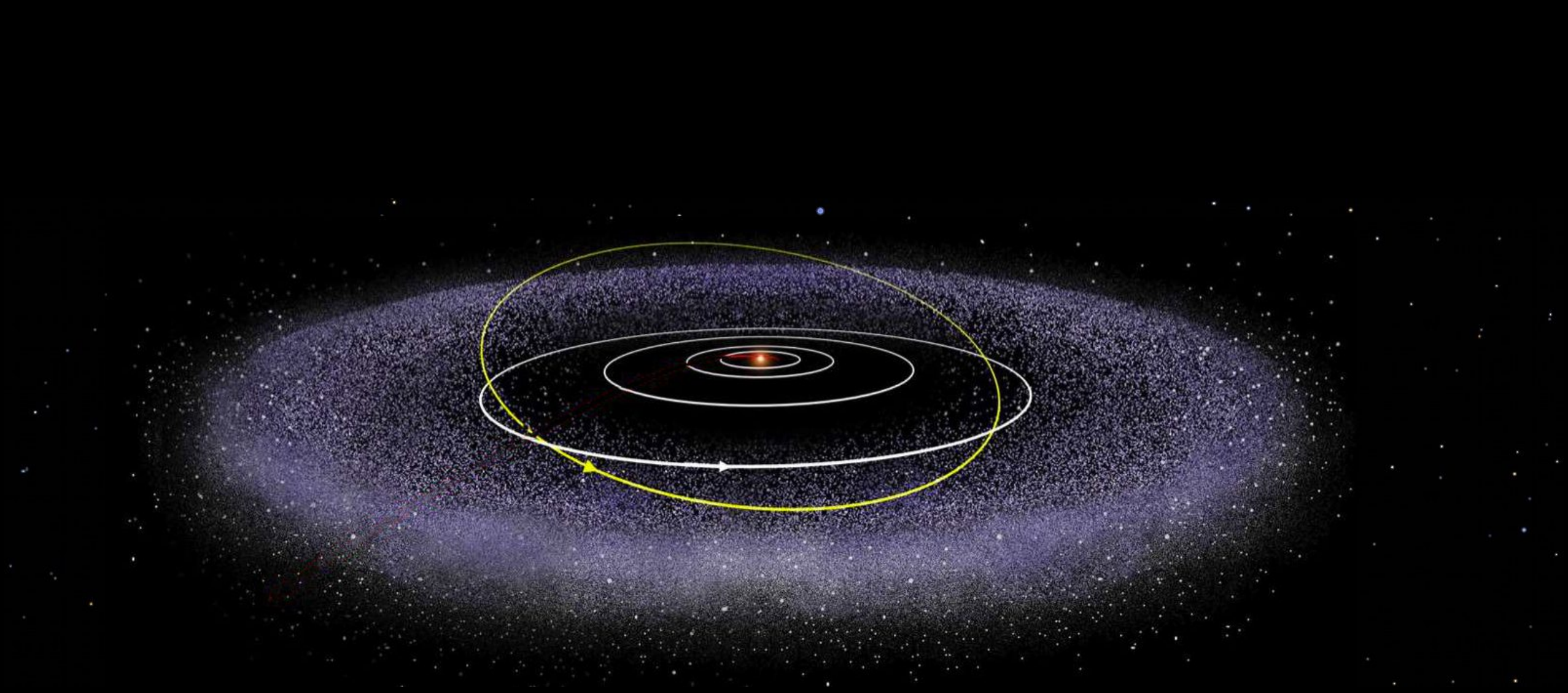


Larger comets have longer lifetimes in close to the Sun orbits,
so larger comets are much more likely to hit Earth if in an Earth Crossing orbit.

Conclusions:

It is apparent that comets must hit Earth much more often than presently believed.

The theory that large comets have hit Earth recently fits these calculations of how often Kuiper Belt objects are pushed out of their orbits.



Thank you for your attention.

Extra Notes if time permits:

Using the above calculations to explain The Late Heavy Bombardment

Musing on conditions at the beginning of the solar system:

1,000 X as many KBOs

+/- 5° for main zone instead of +/- 10°

Dwarf Planets in main zone of +/- 5°

Volume of KB Main zone: 20,368 AU^3 = 6.8187 E28 km^3

Pluto ZOI: +/- 2.5° max variation from KBOs
0.2 max vertical speed diff, near 0 min horizontal speed diff.
1 million km for 0.2, so go with 2 million as radius of ZOI
Quaoar ZOI: assume r = 500,000
Eris: same as Pluto: r = 2,000,000
etc.

Dwarf Planet	Mass	Inclination	Years in Classical KB	Max Speed Difference km/s	ZOI	10 km Earth Crossing KBO per 1,000,000 years
Quaoar	1.40 E21	2.5°	280	0.2	5.83 E21	40,712
Pluto	1.30 E22	2.5°	280	0.2	5.05 E23	3,526,556
Eris	1.66 E22	2.5°	280	0.2	8.02 E23	5,723,716
Haumea	4.01 E21	2.5°	280	0.2	4.77 E22	333,337
MakeMake	4.40 E21	2.5°	280	0.2	5.76 E22	402,131
Orcus	6.41 E20	2.5°	280	0.2	1.22 E21	8,534
2002 Ms4	6.00 E20	2.5°	280	0.2	1.07 E21	7,478
Ixion	4.00 E20	2.5°	280	0.2	4.76 E21	3,323
Varuna	3.70 E20	2.5°	280	0.2	4.07 E20	2,844
Salacia	4.38 E20	2.5°	280	0.2	5.71 E20	3,985
2007 OR 10	1.75 E21	2.5°	280	0.2	9.11 E21	63,612

Total KBO / 1 million years	10,116,227
# 10 km comets per year	10.1
% of KBOs removed per million years	0.17 %

Dwarf Planet	10 km Earth Crossing KBO per 1,000,000 years
Quaoar	40,712
Pluto	3,526,556
Eris	5,723,716
Haumea	333,337
MakeMake	402,131
Orcus	8,534
2002 Ms4	7,478
Ixion	3,323
Varuna	2,844
Salacia	3,985
2007 OR 10	63,612
	10,116,227
	10.1
	0.17 %

Total KBO / 1 million years

10 km comets per year

% of KBOs removed per million years

Attrition rate
0.17% / million years

Time	% removed
1 billion years	83%
2 billion years	98%
3 billion years	99.5%
4 billion years	99.92%