ULTIMA THULE – Probability of Gravitational (vs. Electromagnetic?) Formation

Dr. Raymond HV Gallucci, P.E. (ret.)

ABSTRACT. *The shape and rotational speed of the "contact binary," double-lobed, planetesimal Ultima Thule (renamed as 486958 Arrokoth) deep in the Kuiper Belt render a gravitational explanation for its formation, as espoused by mainstream astrophysics, while plausible, still unlikely. A probabilistic analysis of possible relative speeds between these objects prior to merger strongly suggests that gravitational forces would not have fused them together. Discussed is the Electric Universe Theory that electromagnetic forces, rather than gravitational ones, best explain Ultima Thule's formation, with gravity only now possibly playing a role in maintaining its structure.*

Key Words: Ultima Thule (Arrokoth), Kuiper Belt, gravity, electromagnetism, probability, comet

1. INTRODUCTION

The discovery of the "contact binary," double-lobed, planetesimal Ultima Thule (since renamed as 486958 Arrokoth) "on 26 June 2014 … using the Hubble Space Telescope" prompted mainstream astrophysicists to cite it as evidence for formation via "gravitational accretion." It was the object of the *New Horizons* space probe flyby on January 1, 2019, from which additional data were compiled. [1]

> *[Ultima Thule, renamed as] 486958 Arrokoth, is a trans-Neptunian object located in the Kuiper Belt. It is a 'contact binary,' … composed of two planetesimals …, nicknamed 'Ultima' and 'Thule' … With the New Horizons space probe's flyby … on 1 January 2019, Arrokoth became the farthest and most primitive object in the Solar System visited by a spacecraft … Arrokoth … [consists] of two lobes attached by a bright, narrow neck. The two lobes were likely once objects that had merged in a slow collision.*

The mainstream explanation of its formation is as follows: [2]

> *Ultima Thule coalesced from a cloud of rocky, icy material far from the sun. These smaller chunks first formed two larger objects, which then apparently orbited a common center of mass as a binary pair … These two bodies then slowly merged to form Ultima Thule … The [NASA] mission team has been able to put some 'speed limits' on that merger … [I]f the two lobes came together at about 22 mph (35 km/h), they likely would not have merged at all … A collision at 11 mph (18 km/h) would lead to a merger, but not one generating an object with two relatively intact lobes like Ultima Thule; there would be considerable distortion … [T]he result of simulations with a 5.5-mph merging speed 'is strikingly what we actually observe' …*

However, Electric Universe Theorists have postulated what they consider a much more likely explanation of its formation, as summarized by Wal Thornhill in the following: [3]

> *This discovery [of Ultima Thule], based on the double-lobed appearance, fits perfectly with the Electric Universe scenario … A fairly large number of Kuiper Belt Objects, or KBOs, … are binary objects … that are relative similar in size or mass that orbit around a shared center of mass that lies between them. Some binaries actually touch, creating a sort of peanut shape, … a 'contact binary' … [G]ravitational accretion didn't predict a double-lobed shape for planetesimals, asteroids or comets … [I]t has difficulty in keeping small colliding particles together, without some form of 'stickiness' or electrostatic 'clinginess' … [T]here's a problem removing angular momentum from closely orbiting bodies. It requires a number of smaller objects to be slung out of the system … The most difficult problem for the [gravitational] condensation theory to overcome is how such objects could form in the first place. The mean distance between small bodies in the vast volume of the Kuiper Belt is so great that collision and accretion has negligible probability … Then there's the problem of attaching*

and forming a neck between two bodies … Ice can be treated as rock at the very low temperatures at that distance from the Sun, and rocks don't fuse together when they collide at slow speed … [W]hy do we only ever see two objects fused together? … Ultima Thule has significant cratering which implies many high-speed collisions … despite the fact that they should be orbiting the Sun with low relative velocities and an infinitesimal probability of collision [g]iven their vanishingly small cross section in the unimaginable immensity of the Kuiper Belt … [T]his [formation via gravitational accretion] defies understanding because the model is wrong. Powerful long-range electromagnetic forces could form all condensed objects in the universe … Only after the electromagnetic forces have subsided, does gravity, the weakest force in the universe, take over …

2. GRAVITATIONAL FORMATION – IS IT PLAUSIBLE?

Let us first examine the plausibility of the mainstream explanation for formation, based on data compiled for Ultima Thule since the 2019 flyby. The relevant data are as follows: [1]

Equivalent mean radii of Ultima and Thule = 7950 and 6450 m, respectively
Semi-major orbital axis (average distance from Sun) = 44.6 AU = 6.69×10^{12} m
Rotational period = 15.9 h = 5.72×10^{4} s
Orbital period = 298 y = 9.40×10^{9} s
Volume = 3.21×10^{12} m^3

From these, we estimate the equivalent spherical volumes of Ultima and Thule as 2.10×10^{12} and 1.12×10^{12} m^3, respectively, which is essentially equivalent to the total volume cited above. To estimate the masses of each lobe, it is necessary to make an assumption regarding the density. Reference [1] provides some preliminary estimates:

Under the assumption that Arrokoth has a low comet-like density of around 0.5 g/cc, its internal structure is expected to be porous … A definitive mass and density estimate cannot be given as the two lobes of Arrokoth are in contract rather than orbiting each other … Under the assumption that both lobes … are bound by self-gravity, with the mutual gravity of the two lobes overcoming centrifugal forces that would otherwise separate the lobes, the entire body is estimated to have a very low density similar to that of comets, with an estimated minimum … of 0.29 g/cc …

Estimates of cometary density are also found in Reference [4], as follows:

Table 1. Properties of Some Comets

Properties of some comets

Name	Dimensions (km)	Density (g/cm^3)	Mass (kg)[40]	Refs
Halley's Comet	15 × 8 × 8	0.6	3×10^{14}	[41][42]
Tempel 1	7.6 × 4.9	0.62	7.9×10^{13}	[30][43]
19P/Borrelly	8 × 4 × 4	0.3	2.0×10^{13}	[30]
81P/Wild	5.5 × 4.0 × 3.3	0.6	2.3×10^{13}	[30][44]
67P/Churyumov–Gerasimenko	4.1 × 3.3 × 1.8	0.47	1.0×10^{13}	[45][46]

The cited values of 0.5 and 0.29 align well with these, the first being essentially the same as the listed minimum; the second corresponding to the average, i.e., 0.52 ≈ 0.5 g/cc. With these as candidate densities, we estimate

lower and higher masses for the two lobes to be: (1) Ultima = 6.10×10^{14} and 1.05×10^{15} kg, (2) Thule = 3.26×10^{14} and 5.62×10^{14} kg. Since the distance between the equivalent spherical centers of the two lobes is the sum of the radii (1.44×10^{7} m), the mutual gravitational force on each becomes: [1] $(6.67 \times 10^{-11}\ m^3/kg\text{-}s^2)(6.10 \times 10^{14}\ kg)(3.26 \times 10^{14}\ kg)/(1.44 \times 10^{7}\ m)^2 = 6.40 \times 10^{10}$ N, for the lower density estimates; [2] $(6.67 \times 10^{-11}\ m^3/kg\text{-}s^2)(1.05 \times 10^{15}\ kg)(5.62 \times 10^{14}\ kg)/(1.44 \times 10^{7}\ m)^2 = 1.90 \times 10^{11}$ N, for the higher density estimates.

To estimate the centrifugal forces on each lobe, we must first estimate their orbital speeds. Since the two lobes are of unequal mass, their mutual center of mass (barycenter) will lie the following distances from the center of each (since each lobe is assumed to have the same density, the values will be the same for either):

Ultima: $(7950\ m + 6450\ m)(3.26 \times 10^{14}\ kg)/(6.10 \times 10^{14}\ kg + 3.26 \times 10^{14}\ kg) = 5010$ m
Thule: $(7950\ m + 6450\ m)(6.10 \times 10^{14}\ kg)/(6.10 \times 10^{14}\ kg + 3.26 \times 10^{14}\ kg) = 9390$ m

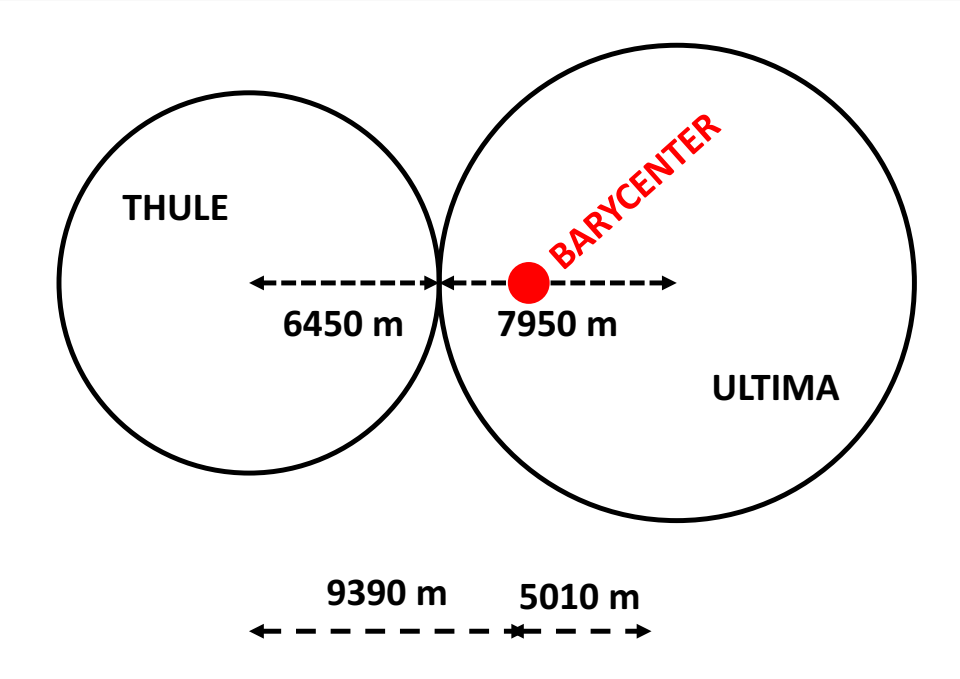


Figure 1. Schematic of Idealized, Equivalent Spherical Lobes for Ultima Thule

As expected (see Figure 1), the barycenter lies within the Ultima lobe, 5010 m from its equivalent spherical center. Given the orbital period of Ultima Thule, the rotational speeds of each lobe about the mutual barycenter become as follows:

Ultima: $2\pi(5010\ m)(5.72 \times 10^{4}\ s) = 0.550$ m/s
Thule: $2\pi(9390\ m)(5.72 \times 10^{4}\ s) = 1.03$ m/s

With these, we can estimate the centrifugal force experienced by each lobe and compare against the mutual gravitational force, as follows:

Ultima, lower density: $(6.10 \times 10^{14}\ kg)(0.550\ m/s)^2/(5010\ m) = 3.69 \times 10^{10}$ N, vs. gravitational force = 6.40×10^{10} N
Ultima, higher density: $(1.05 \times 10^{15}\ kg)(0.550\ m/s)^2/(5010\ m) = 6.36 \times 10^{10}$ N, vs. gravitational force = 1.90×10^{11} N

The results for Thule are the same. Therefore, for either density case, the mutual gravitational force exceeds the centrifugal force sufficiently to render it plausible that the two lobes will remain attached solely by gravity.

This confirms the mainstream finding that, even at a minimum density of 0.29 g/cc, "both lobes … are bound by self-gravity, with the mutual gravity of the two lobes overcoming centrifugal forces that would otherwise separate the lobes." [1] Therefore, gravitational formation for Ultima Thule remains plausible. However, is it probable?

3. GRAVITATIONAL FORMATION – IS IT PROBABLE?

At the risk of being accused of presenting a self-fulfilling prophecy, we shall at least attempt an "order of magnitude" examination of the probability of gravitational formation as the best explanation for Ultima Thule's appearance. The key to this is examining the previous mainstream conclusion from Reference [1] that "the result of simulations with a 5.5-mph merging speed 'is strikingly what we actually observe' … [as to how Ultima Thule gravitationally merged]."

We do not know the relative speeds among objects in the Kuiper Belt. However, to somehow guesstimate what these might be, we first note that Kuiper belt objects orbit the sun at an average speed of $2\pi(6.69 \times 10^{12}$ m)/$(9.40 \times 10^{9}$ s) = 4470 m/s, or 1.00×10^{4} mph. As a first step in the "order of magnitude" guesstimate, assume the average relative speed between any two KBOs is the square root of this average speed, or 100 mph. Let the standard deviation be the geometric mean between this and its next lower order of magnitude, i.e., $\sqrt{(100)(10)} = 31.6\,mph$. Let us bias the analysis in the sense that we choose a probability distribution that is skewed in a way to favor lower values without any becoming negative (see Figure 2).[1] One such candidate is the lognormal distribution, whose parameters become μ = 4.56 and σ = 0.309 and yield a probability of speeds 5.5-mph or less that is vanishingly small, i.e., essentially zero. Another candidate distribution with similar behavior as the lognormal is the gamma distribution, whose parameters become α = 10 and β = 10 and yield a probability of speeds 5.5-mph or less that is $< 1 \times 10^{-7}$ %. If we increase the uncertainty by allowing the standard deviation to equal the mean itself (i.e., a value of 100 mph), the probabilities of speeds 5.5-mph or less rise to the following: (1) lognormal – 0.11%, with μ = 4.26 and σ = 0.833; (2) gamma – 5.4%, with α = 1 and β = 100. Even in this case, with much greater uncertainty, the likelihood of gravitational formation of Ultima Thule peaks at only 5.4%.

However, perhaps assuming the square root of the average orbital speed as the mean relative speed between a pair of KBOs was not conservative enough. Let us take another square root, dropping the average speed between a pair of KBOs to 10 mph, with the standard deviation again as the geometric mean between this and the next lower order of magnitude, i.e., $\sqrt{(10)(1)} = 3.16\,mph$. Repeating our calculations for the two candidate distributions yields the following results:

Lognormal $\leq$ 5.5 mph = 3.7%, with μ = 2.25 and σ= 0.309
Gamma $\leq$ 5.5 mph = 5.4%, with α = 10 and β = 1

Again, as an extreme case, assume the standard deviation equals the mean. Now these probabilities rise as follows:

Lognormal $\leq$ 5.5 mph = 38%, with μ = 1.96 and σ= 0.833
Gamma $\leq$ 5.5 mph = 42%, with α = 1 and β = 10

However, even in this most extreme case with large uncertainty about a very low mean relative speed, the likelihood of gravitational formation for Ultima Thule remains below 50%.

---

[1] The use of the more common normal distribution would be appropriate only for those cases where there is not a significant contribution from its negative portion. This occurs for two of the cases: (1) mean (μ) = 100 mph, standard deviation (σ) = 31.6 mph. probability of speeds 5.5-mph or less ≈ 0.1%; (2) mean (μ) = 10 mph, standard deviation (σ) = 3.16 mph. probability of speeds 5.5-mph or less = 7.7%.

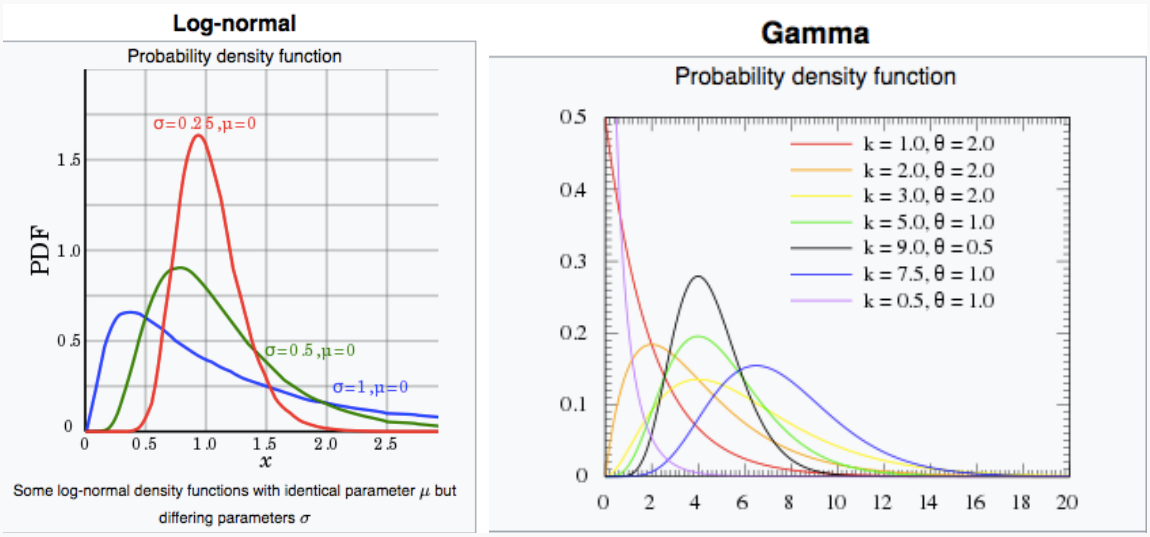


Figure 2. Typical Lognormal and Gamma Probability Distributions [5,6]

4. SUMMARY

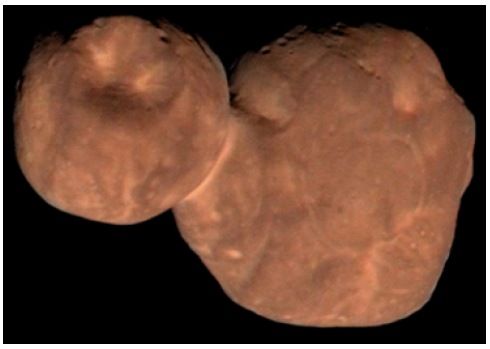
While our analysis indicates that gravity as the explanation for the formation of Ultima Thule remains plausible, at least an "order of magnitude" examination suggests that it is unlikely, with reasonable but conservative estimates of it being correct around 5% at best.[2] This lends support to the Electric Universe Theory that an electromagnetic explanation is the more likely. Again, as stated by Thornhill, "Powerful long-range electromagnetic forces could form all condensed objects in the universe … Only after the electromagnetic forces have subsided, does gravity, the weakest force in the universe, take over …" [3] This would seem to be an excellent fit for the appearance of Ultima Thule, in that only after its merger due to electromagnetic forces has gravity "taken over" to maintain it as a "contact binary," with the mutual gravitational force between the two lobes slightly exceeding the centrifugal forces from their mutual rotation about their barycenter that would try to break them apart.

5. REFERENCES

1. https://en.wikipedia.org/wiki/486958_Arrokoth
2. Mike Wall, "Ultima Thule's Mystery Mound Puzzle Scientists," April 25, 2019, https://www.space.com/ultima-thule-mystery-mounds-puzzle-scientists.html
3. "Wal Thornhill: Ultima Thule – Another Victory for the Electric Universe | Space News," January 16, 2019, https://www.youtube.com/watch?v=9x5_y3IZV_g
4. https://en.wikipedia.org/wiki/Comet
5. https://en.wikipedia.org/wiki/Log-normal_distribution
6. https://en.wikipedia.org/wiki/Gamma_distribution

[2] Even allowing the more generous 7.7% from the normal distribution as per the preceding footnote does not significantly alter this observation.

ULTIMA THULE: Probability of Gravitational (vs. Electromagnetic?) Formation



Dr. Raymond HV Gallucci, P.E. (ret.)

ULTIMA THULE

- A "contact binary," double-lobed, planetesimal (renamed 486958 Arrokoth) discovered "on 26 June 2014 … using the Hubble Space Telescope." It was the object of the *New Horizons* space probe flyby on January 1, 2019, from which additional data were compiled.
  - Mainstream astrophysicists cite it as evidence for formation via "gravitational accretion."
    - [Ultima Thule, renamed as] 486958 Arrokoth, is a trans-Neptunian object located in the Kuiper Belt ... composed of two planetesimals …, nicknamed 'Ultima' and 'Thule' … With the New Horizons space probe's flyby …, Arrokoth became the farthest and most primitive object in the Solar System visited by a spacecraft … Arrokoth … [consists] of two lobes attached by a bright, narrow neck ..., likely once objects … merged in a slow collision.

https://en.wikipedia.org/wiki/486958_Arrokoth

GRAVITATIONAL ACCRETION - MAINSTREAM

- *Ultima Thule coalesced from a cloud of rocky, icy material far from the sun. These smaller chunks first formed two larger objects, which then apparently orbited a common center of mass … then slowly merged …*
  - *The [NASA] mission team … put some 'speed limits' on that merger … [I]f the two lobes came together at about 22 mph (35 km/h), they likely would not have merged … A collision at 11 mph (18 km/h) would lead to a merger, but not one generating an object with two relatively intact lobes … [S]imulations with a 5.5-mph merging speed 'is strikingly what we actually observe' …*

Mike Wall, "Ultima Thule's Mystery Mound Puzzle Scientists," April 25, 2019, https://www.space.com/ultima-thule-mystery-mounds-puzzle-scientists.html

ELECTROMAGNETIC FORMATION – EU THEORY

- Electric Universe Theorists consider a much more likely explanation of its formation:
  - *… [T]he double-lobed appearance, fits perfectly with the Electric Universe scenario … A fairly large number of Kuiper Belt Objects, or KBOs, … are binary objects … that are relative similar in size or mass that orbit around a shared center of mass ... Some binaries actually touch, creating a sort of peanut shape, … a 'contact binary' … [G]ravitational accretion didn't predict a double-lobed shape … [I]t has difficulty in keeping small colliding particles together, without some form of 'stickiness' or electrostatic 'clinginess' … [T]here's a problem removing angular momentum from closely orbiting bodies. It requires a number of smaller objects to be slung out of the system …*

"Wal Thornhill: Ultima Thule – Another Victory for the Electric Universe | Space News," January 16, 2019, https://www.youtube.com/watch?v=9x5_y3IZV_g

ELECTROMAGNETIC FORMATION (cont.)

- *The most difficult problem for the [gravitational] condensation theory … is … [that] [t]he mean distance between small bodies in the vast volume of the Kuiper Belt is so great that collision and accretion has negligible probability … Then there's the problem of attaching and forming a neck … Ice can be treated as rock at the very low temperatures …, and rocks don't fuse together when they collide at slow speed … [W]hy do we only ever see two objects fused together?*
- *… Ultima Thule has significant cratering which implies many high-speed collisions … despite the fact that they should be orbiting the Sun with low relative velocities and an infinitesimal probability of collision [g]iven their vanishingly small cross section in the unimaginable immensity of the Kuiper Belt … Powerful long-range electromagnetic forces could form all condensed objects in the universe … Only after the electromagnetic forces have subsided, does gravity, the weakest force in the universe, take over …*

Thornhill (cont.)

GRAVITATIONAL FORMATION – PLAUSIBLE?

- Data compiled for Ultima Thule since the 2019 flyby: [*https://en.wikipedia.org/wiki/486958_Arrokoth*]
  - Equivalent mean radii of Ultima and Thule = 7950 and 6450 m, respectively
  - Semi-major orbital axis (average distance from Sun) = 44.6 AU = 6.69 x 10^{12} m
  - Rotational period = 15.9 h = 5.72 x 10^{4} s
  - Orbital period = 298 y = 9.40 x 10^{9} s
  - Volume = 3.21 x 10^{12} m^3
- The equivalent spherical volumes of Ultima and Thule become 2.10 x 10^{12} and 1.12 x 10^{12} m^3, respectively, which is essentially equivalent to the total volume above. To estimate the masses of each lobe, it is necessary to make an assumption regarding the density.

GRAVITY – PLAUSIBLE? (cont.)

- *Under the assumption that Arrokoth has a low comet-like density of around 0.5 g/cc, its internal structure is expected to be porous … Under the assumption that both lobes … are bound by self-gravity, … overcoming centrifugal forces that would otherwise separate the lobes, the entire body is estimated to have a very low density similar to that of comets, with an estimated minimum … of 0.29 g/cc …*

https://en.wikipedia.org/wiki/486958_Arrokoth

Properties of some comets

Name	Dimensions (km)	Density (g/cm^3)	Mass (kg)[40]	Refs
Halley's Comet	15 × 8 × 8	0.6	3×10^{14}	[41][42]
Tempel 1	7.6 × 4.9	0.62	7.9×10^{13}	[30][43]
19P/Borrelly	8 × 4 × 4	0.3	2.0×10^{13}	[30]
81P/Wild	5.5 × 4.0 × 3.3	0.6	2.3×10^{13}	[30][44]
67P/Churyumov–Gerasimenko	4.1 × 3.3 × 1.8	0.47	1.0×10^{13}	[45][46]

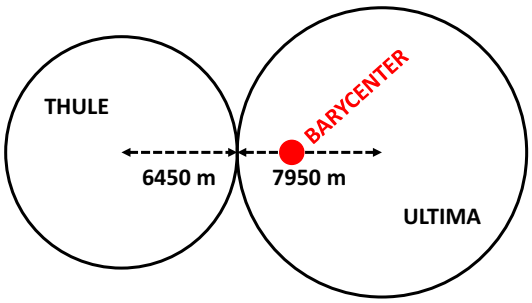
https://en.wikipedia.org/wiki/Comet

The cited values of 0.5 and 0.29 align well with these, the first being essentially the same as the listed minimum; the second corresponding to the average, i.e., 0.52 ≈ 0.5 g/cc.

GRAVITY – PLAUSIBLE? (cont.)

- With these candidate densities, the lower and higher masses become:
  - Ultima = 6.10×10^{14} and 1.05×10^{15} kg
  - Thule = 3.26×10^{14} and 5.62×10^{14} kg.
  - Since the distance between the equivalent spherical centers is the sum of the radii (1.44×10^{7} m), the mutual gravitational force becomes:
    - $(6.67 \times 10^{-11}\ m^3/kg\text{-}s^2)(6.10 \times 10^{14}\ kg)(3.26 \times 10^{14}\ kg)/(1.44 \times 10^{7}\ m)^2 = 6.40 \times 10^{10}$ N, for the lower density estimates
    - $(6.67 \times 10^{-11}\ m^3/kg\text{-}s^2)(1.05 \times 10^{15}\ kg)(5.62 \times 10^{14}\ kg)/(1.44 \times 10^{7}\ m)^2 = 1.90 \times 10^{11}$ N, for the higher density estimates.

GRAVITY – PLAUSIBLE? (cont.)



Schematic of Idealized, Equivalent Spherical Lobes for Ultima Thule

To estimate the centrifugal forces on each lobe, we must first estimate their orbital speeds. As expected, the barycenter lies within the Ultima lobe, 5010 m from its equivalent spherical center. Given the orbital period of Ultima Thule, the rotational speeds of each lobe about the mutual barycenter become :

Ultima: $2\pi(5010\text{ m})(5.72 \times 10^4\text{ s}) = 0.550\text{ m/s}$
Thule: $2\pi(9390\text{ m})(5.72 \times 10^4\text{ s}) = 1.03\text{ m/s}$

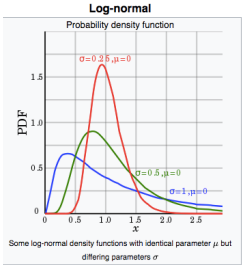
GRAVITY – PLAUSIBLE? (cont.)

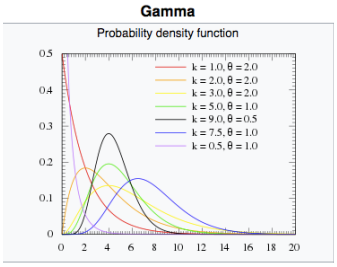
- Estimates of the centrifugal force experienced by each lobe vs. mutual gravitational force (the results for Thule are the same):
  - Ultima, lower density: $(6.10 \times 10^{14}\text{ kg})(0.550\text{ m/s})^2/(5010\text{ m}) = 3.69 \times 10^{10}\text{ N}$, vs. gravitational force = $6.40 \times 10^{10}\text{ N}$
  - Ultima, higher density: $(1.05 \times 10^{15}\text{ kg})(0.550\text{ m/s})^2/(5010\text{ m}) = 6.36 \times 10^{10}\text{ N}$, vs. gravitational force = $1.90 \times 10^{11}\text{ N}$
- For either density case, the mutual gravitational force exceeds the centrifugal force sufficiently to render it plausible that the two lobes will remain attached solely by gravity.
  - This confirms the mainstream finding that, even at a minimum density of 0.29 g/cc, "both lobes … are bound by self-gravity, with the mutual gravity of the two lobes overcoming centrifugal forces that would otherwise separate the lobes."
  - Gravitational formation for Ultima Thule remains plausible. However, is it probable?

GRAVITATIONAL FORMATION – PROBABLE?

- Attempt an "order of magnitude" examination of the probability that gravitational formation best explains Ultima Thule's appearance.
  - The key to this is the previous mainstream conclusion that "the result of simulations with a 5.5-mph merging speed 'is strikingly what we actually observe' … [as to how Ultima Thule gravitationally merged]."
- We do not know the relative speeds among objects in the Kuiper Belt. However, to somehow guesstimate what these might be, we first note that Kuiper belt objects orbit the sun at an average speed of 2π(6.69 x 10^{12} m)/(9.40 x 10^{9} s) = 4470 m/s, or 1.00 x 10^{4} mph.

GRAVITY – PROBABLE? (cont.)





Typical Lognormal and Gamma Probability Distributions

As a first step in the "order of magnitude" guesstimate, assume the average relative speed between any two KBOs is the square root of this average speed, or 100 mph. Let the standard deviation be the geometric mean between this and its next lower order of magnitude, i.e., $\sqrt{(100)(10)} = 31.6\ mph$. Let us bias the analysis in the sense that we choose a probability distribution that is skewed in a way to favor lower values without any becoming negative.

The lognormal with μ = 4.56 and σ = 0.309 yields a probability of speeds 5.5-mph or less that is vanishingly small, i.e., essentially zero. The gamma with α = 10 and β = 10 yields a probability of speeds 5.5-mph or less that is < 1 x 10^{-7} %.

Increase the uncertainty by allowing the standard deviation to equal the mean itself, the probabilities rise to: (1) lognormal – 0.11%, with μ = 4.26 and σ= 0.833; (2) gamma – 5.4%, with α = 1 and β = 100. Even in this case, with much greater uncertainty, the likelihood of gravitational formation of Ultima Thule peaks at only 5.4%.

GRAVITY – PROBABLE? (cont.)

- If assuming the square root of the average orbital speed as the mean relative speed was not conservative enough, take another square root, dropping the average speed to 10 mph, with the standard deviation again as the geometric mean between this and the next lower order of magnitude, i.e., $\sqrt{(10)(1)} = 3.16\ mph$. Repeating our calculations yields:
  - Lognormal $\leq$ 5.5 mph = 3.7%, with μ = 2.25 and σ= 0.309
  - Gamma $\leq$ 5.5 mph = 5.4%, with α = 10 and β = 1
- Again, as an extreme case, assume the standard deviation equals the mean. Now these probabilities rise to:
  - Lognormal $\leq$ 5.5 mph = 38%, with μ = 1.96 and σ= 0.833
  - Gamma $\leq$ 5.5 mph = 42%, with α = 1 and β = 10
  - However, even in this most extreme case with large uncertainty about a very low mean relative speed, the likelihood of gravitational formation for Ultima Thule remains below 50%.

SUMMARY

- While our analysis indicates that gravity as the explanation for the formation of Ultima Thule remains plausible, at least an "order of magnitude" examination suggests that it is unlikely, with reasonable but conservative estimates of it being correct around 5% at best. This lends support to the Electric Universe Theory that an electromagnetic explanation is the more likely.
  - Repeating Thornhill, "Powerful long-range electromagnetic forces could form all condensed objects in the universe … Only after the electromagnetic forces have subsided, does gravity, the weakest force in the universe, take over …"
  - This would seem to be an excellent fit for the appearance of Ultima Thule, in that only after its merger due to electromagnetic forces has gravity "taken over" to maintain it as a "contact binary," with the mutual gravitational force between the two lobes slightly exceeding the centrifugal forces from their mutual rotation about their barycenter that would try to break them apart.