

From: Avi Loeb <aloeb@cfa.harvard.edu>
Sent: Tuesday, October 4, 2022 1:32 PM
To: Abraham Loeb
Subject: [URL Verdict: Neutral][Non-DoD Source] "Down To Earth" Limits on Unidentified Aerial Phenomena in Ukraine
Attachments: arXiv_U.pdf
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The original scientific **paper** on which this essay is based, is available below and also at:
Caution-https://lweb.cfa.harvard.edu/~loeb/arXiv_U.pdf < Caution-https://lweb.cfa.harvard.edu/~loeb/arXiv_U.pdf >

The essay below is linked at:
Caution-<https://avi-loeb.medium.com/down-to-earth-limits-on-unidentified-aerial-phenomena-in-ukraine-6d8bb9f64f85> < Caution-<https://avi-loeb.medium.com/down-to-earth-limits-on-unidentified-aerial-phenomena-in-ukraine-6d8bb9f64f85> >

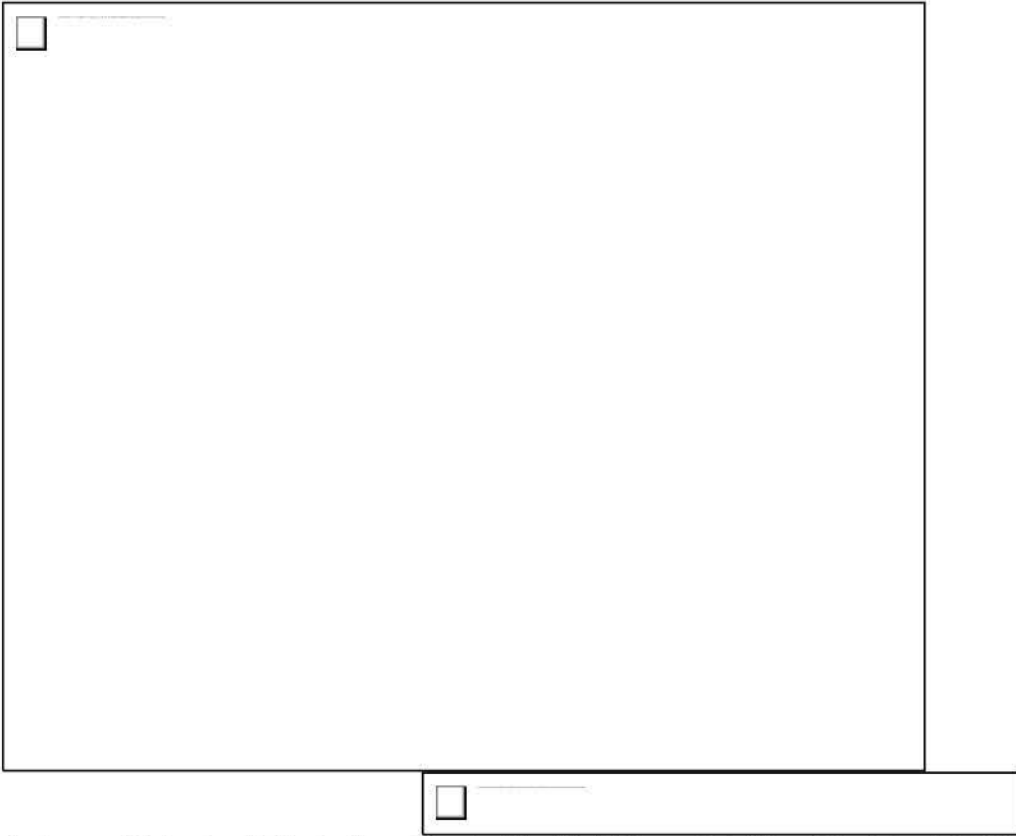
 < Caution-https://medium.com/@avi-loeb?source=email-adb0e108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8dd0_45f2_a372_00ef1d103e94-----c9de49b8ef2b >

Avi Loeb < Caution-https://medium.com/@avi-loeb?source=email-adb0e108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8dd0_45f2_a372_00ef1d103e94-----c9de49b8ef2b >

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“Down To Earth” Limits on Unidentified Aerial Phenomena in Ukraine



An image of “phantom” objects above Ukraine (Credit: Zhilyaev, Petukhov & Reshetnyk 2022)

Over the past two weeks I was bombarded by a dozen requests to read a new report < Caution-http://me.dm/r-qfQa1KrPLO?source=email-adboe108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8ddo_45f2_a372_0oef1d103e94-----c9de49b8ef2b > by astronomers on Unidentified Aerial Phenomena (UAP) in Ukraine. My response to all of these messages was the same: “I am not sure what to make of the report. Ukraine is in a military conflict with a lot of human-made activity in the sky. This must introduce a lot of noise for any search for objects that are not human-made. In science we aim to maximize the signal-to-noise ratio, and so Ukraine would be the last place on Earth where I would initiate UAP studies.”

But last evening I received a special request from a high-level official in the US government to summarize my thoughts on observable signatures of UAP and so this morning I checked the UAP report from Ukraine and wrote a paper < Caution-http://me.dm/r-f510scLH4J?source=email-adboe108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8ddo_45f2_a372_0oef1d103e94-----c9de49b8ef2b > about it a few hours later.

The Ukrainian paper < Caution-http://me.dm/r-qfQa1KrPLO?source=email-adboe108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8ddo_45f2_a372_0oef1d103e94-----c9de49b8ef2b > reports about two types of objects: luminous and dark. The dark objects with no visible emission were labeled as “Phantoms”.

They were characterized by a size of 3–12 meters and speeds up to 15 kilometers per second at a distance of up to 10–12 kilometers. If real, such objects exceed the capabilities of human-made aircrafts or rockets. I quickly realized that the distance of these dark objects must have been incorrectly overestimated by an order of magnitude, or else their bow shock in the Earth's atmosphere would have generated a bright fireball with an easily detectable optical luminosity.

The interest in UAP stems from their potential non-human origin. Extraterrestrial equipment could arrive in two forms: space trash, similar to the way our own interstellar probes (Voyager 1 & 2, Pioneer 10 & 11 and New Horizons) will appear in a billion years, or functional equipment, such as autonomous devices equipped with Artificial Intelligence (AI). The latter would be an ideal choice for crossing the tens of thousands of light years that span the scale of the Milky Way galaxy and could survive even if the senders are not able to communicate.

It is likely that any functional devices embedded in the Earth's atmosphere are not carrying biological entities because these would not survive the long journey through interstellar space and its harsh conditions, including bombardment by energetic cosmic-rays, X-rays and gamma-rays. Interstellar gas and dust particles deposit a kinetic energy per unit mass that exceeds the output of chemical explosives at the speed of tens of kilometers per second characterizing rockets. However, technological gadgets with AI can be shielded to withstand the hazards of space, repair themselves mechanically, or even reproduce given the resources of a habitable planet like Earth. With Machine Learning capabilities, they can adapt to new circumstances and pursue the goals of their senders without any need for external guidance.

As argued by John von Neumann in 1939, the number of such devices could increase exponentially with time if they self-replicate, a quality enabled by 3D printing and AI technologies. Physical artifacts might also carry messages, as envisioned by Ronald Bracewell in 1960.

In principle, the fastest gadgets could be launched by lightsails, pushed by powerful light beams up to the speed of light. Natural processes, such as stellar explosions or gravitational slingshot near black hole pairs, could launch objects to similar speeds. However, it would be difficult for relativistic payloads to slow down below the escape speed of Earth, smaller by 4.5 orders of magnitude than the speed of light, without having around the same facilities that generated their high initial speeds.

A better suited propulsion technique that was used in all space missions from Earth is chemical rockets. Since rockets carry their fuel, they can navigate to a desired planet and slow down near it.

The tyranny of the rocket equation, requiring that the fuel mass must increase exponentially with increasing terminal speed, explains why all human-made spacecraft reached a speed limit of tens of kilometers per second, 4 orders of magnitude below the speed of light. Interestingly, this speed is comparable to the escape speed from the Earth's orbit around the Sun, 42 kilometers per second, making it possible for humanity to launch probes to interstellar space by taking advantage of the motion of the Earth around the Sun at 30 kilometers per second. Chemical propulsion may not be sufficient for probes to escape from the habitable zone around dwarf stars, like the nearest star, Proxima Centauri.

In summary, chemical propulsion allows escape from the habitable zone of Sun-like stars and enables slowing down near a destination. The Ukrainian report suggests objects with comparable speeds of up to 15 kilometers per second.

Devices which need to refuel would favor a habitable planet where liquid water or combustible organic fuel are available. Planets can be identified from a distance as they transit their star or

through direct imaging. Once an Earth-like planet is targeted, an interstellar device can plunge into its atmosphere. In principle, a multitude of tiny devices can be released from a mothership that passes near Earth.

At a final speed of 30 kilometers per second, a probe would cross twice the distance of the Sun from the Milky-Way center within a time of half a billion years. The fraction of all Sun-like stars that host Earth-like planets in their habitable zone is in the range 3–100%. This implies that self-replicating probes could reach ten billion habitable planets around Sun-like stars in less than a billion years.

Since most stars formed more than a billion years before the Sun, it is possible that other technological civilizations predated ours by the amount of time needed for their devices to reach Earth. My paper < Caution-http://me.dm/r-f510scLH4J?source=email-adboe108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8ddo_45f2_a372_00ef1d103e94-----c9de49b8ef2b > points out that any supersonic motion of such devices through the Earth's atmosphere would inevitably be accompanied by optical emission.

I showed that an object with a frontal cross-sectional area of 10 square meters, moving at a supersonic speed of 10 kilometers per second must create a bow shock in the Earth's atmosphere and dissipate a mechanical power of 1.5 terra-Watt at an elevation of 10 kilometers. Data on meteors implies that about a tenth of the kinetic power which is radiated away in the optical band implying that the reported properties of the Phantom objects above Ukraine would result in a fireball of visible luminosity above 150 giga-Watt. For a path length 10 kilometers, the emission would last at least a second and cannot be missed.

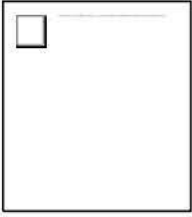
I concluded that the reported speeds and sizes of the ``Phantom'' objects would have generated fireballs of detectable optical luminosity at their suggested distances, and so these objects could not have appeared dark. However, if the Phantom objects are ten times closer than suggested, then their angular motion on the sky corresponds to a physical velocity that is ten times smaller, 1.5 kilometers per second and their inferred transverse size would be 0.3–1.2 meters, both characteristic of artillery shells.

The inferred fireball luminosity scales with distance to the 5th power, and is reduced to a modest level of a few MW if the distance is shorter by a factor of ten than suggested by the Ukrainian astronomers. If the artillery shells have a frontal diameter of only 10 cm, then the inferred fireball luminosity is merely 10 kilo-Watt, which at a kilometer distance would appear extremely faint like a 100-Watt light bulb at a distance of 100 meters.

The Ukrainian astronomers also identified a luminous and variable object at an altitude of 1,170 kilometers, which was detected through two-site observations above Ukraine. This object is likely a satellite.

Altogether “down to Earth” explanations can account for the reported UAP above Ukraine. But in salute to my colleagues in Ukraine, let me conclude with a quote < Caution-http://me.dm/r-HcuVx1MixB?source=email-adboe108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8ddo_45f2_a372_00ef1d103e94-----c9de49b8ef2b > from Oscar Wilde: “We are all in the gutter, but some of us are looking at the stars.”

ABOUT THE AUTHOR



Avi Loeb is the head of the Galileo Project, founding director of Harvard University’s—Black Hole Initiative, director of the Institute for Theory and Computation at the Harvard-Smithsonian Center for Astrophysics, and the former chair of the astronomy department at Harvard University (2011–2020). He chairs the advisory board for the Breakthrough Starshot project, and is a former member of the President’s Council of Advisors on Science and Technology and a former chair of the Board on Physics and Astronomy of the National Academies. He is the bestselling author of “*Extraterrestrial*: < Caution-http://me.dm/r-Ei84mwIx_w?source=email-adboe108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8dd0_45f2_a372_00ef1d103e94-----c9de49b8ef2b > *The First Sign of Intelligent Life Beyond Earth* < Caution-http://me.dm/r-Ei84mwIx_w?source=email-adboe108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8dd0_45f2_a372_00ef1d103e94-----c9de49b8ef2b > ” and a co-author of the textbook “*Life in the Cosmos* < Caution-http://me.dm/r-nVUotn4yw6?source=email-adboe108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8dd0_45f2_a372_00ef1d103e94-----c9de49b8ef2b > ”, both published in 2021.

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View story < Caution-https://medium.com/p/6d8bb9f64f85?source=email-adb0e108a94b-1664904268122-newsletter.subscribeToProfile-----5274e172_8dd0_45f2_a372_00ef1d103e94-----c9de49b8ef2b >

From: Avi Loeb <aloeb@cfa.harvard.edu>
Sent: Monday, October 3, 2022 10:18 AM
To: Kirkpatrick, Sean M HQE OSD OUSD INTEL & SEC (USA)
Subject: [URL Verdict: Neutral]Re: [Non-DoD Source] SALT New York | Avi Loeb: Are We Alone in the Universe? The Galileo Project

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Yes, Sean. I look forward to seeing you at 4PM today.

Here are some new essays from the last week:

*"Rogue Planets", Medium (October 3, 2022) < Caution-<https://avi-loeb.medium.com/rogue-planets-10066adcae36> >

*"Permanent Climate Change on Habitable Planets", Medium (October 2, 2022) < Caution-<https://avi-loeb.medium.com/permanent-climate-change-on-habitable-planets-858248925dbe> >

*"Do Astronomers Exist on Other Habitable Planets?", Medium (September 30, 2022) < Caution-<https://avi-loeb.medium.com/do-astronomers-exist-on-other-habitable-planets-b0f32b6549f7> >

*"An Extraterrestrial Resolution to the Absurdity of Life", Medium (September 28, 2022) < Caution-<https://avi-loeb.medium.com/an-extraterrestrial-resolution-to-the-absurdity-of-life-2ef70210b3e3> >

*"Understanding Ourselves Thanks to Sentient AI Systems", Medium (September 27, 2022) < Caution-<https://avi-loeb.medium.com/understanding-ourselves-thanks-to-sentient-ai-systems-3d73d6736400> >

Abraham (Avi) Loeb

Frank B. Baird Jr. Professor of Science

Director, Institute for Theory & Computation

Harvard University

Professional website < Caution-<https://lweb.cfa.harvard.edu/~loeb/> >

[List of Essays](https://lweb.cfa.harvard.edu/~loeb/Opinion.html) < Caution-<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> >

(b)(6)



On Mon, Oct 3, 2022 at 9:43 AM Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)

(b)(6)

Morning,
Still good for 4 this afternoon?
Best,
Sean

From: "Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)"

(b)(6)

Date: Wednesday, September 28, 2022 at 9:06:00 AM

To: "Avi Loeb" <aloeb@cfa.harvard.edu < Caution-mailto:aloeb@cfa.harvard.edu > >

Subject: RE: [Non-DoD Source] SALT New York | Avi Loeb: Are We Alone in the Universe? The Galileo Project

Thanks Avi. Looking forward to seeing you next week.

From: Avi Loeb <aloeb@cfa.harvard.edu < Caution-mailto:aloeb@cfa.harvard.edu > >

Sent: Wednesday, September 28, 2022 8:06 AM

To: Abraham Loeb <aloeb@cfa.harvard.edu < Caution-mailto:aloeb@cfa.harvard.edu > >

Subject: [Non-DoD Source] SALT New York | Avi Loeb: Are We Alone in the Universe? The Galileo Project

Caution-https://youtu.be/Yoy_7ZVImoM < Caution-https://youtu.be/Yoy_7ZVImoM >

Harvard astrophysicist Avi Loeb, Frank B. Baird Jr. Professor of Science at Harvard University, sat down with Alex Klokus, Founder & Managing Partner at Kyber Capital, to discuss Loeb's work heading The Galileo Project. They talk about the extensive research and writing Loeb has done around potential extraterrestrial life in the Universe. SALT is a global thought leadership and networking forum at the intersection of finance, technology and public policy. SALT New York, the first event held at the Javits Center Expansion, returned to Manhattan's west side September 12-14, 2022 for three days of collaboration focused on innovation.

From: Kirkpatrick, Sean M HQE OSD OUSD INTEL & SEC (USA)
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To: Avi Loeb
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Morning,
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Best,
Sean

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https://youtu.be/Yoy_7ZVlmoM

Harvard astrophysicist Avi Loeb, Frank B. Baird Jr. Professor of Science at Harvard University, sat down with Alex Klokus, Founder & Managing Partner at Kyber Capital, to discuss Loeb's work heading The Galileo Project. They talk about the extensive research and writing Loeb has done around potential extraterrestrial life in the Universe. SALT is a global thought leadership and networking forum at the intersection of finance, technology and public policy. SALT New York, the first event held at the Javits Center Expansion, returned to Manhattan's west side September 12-14, 2022 for three days of collaboration focused on innovation.

From: Avi Loeb <aloeb@cfa.harvard.edu>
Sent: Tuesday, September 20, 2022 6:27 PM
To: Kirkpatrick, Sean M HQE OSD OUSD INTEL & SEC (USA)
Subject: Re: [URL Verdict: Neutral][Non-DoD Source] Discovery of a Second Interstellar Meteor: Meter-Size Interstellar Objects Are Much Tougher than...

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For IM1, the error on the air density is negligible and the error on the velocity measurement is smaller than a few percent. Here is the complete information:

Original discovery paper: Caution-<https://arxiv.org/pdf/1904.07224.pdf> < Caution-<https://arxiv.org/pdf/1904.07224.pdf> >

Government confirmation Letter: Caution-<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> < Caution-<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> >

Material strength paper: Caution-<https://arxiv.org/pdf/2204.08482> < Caution-<https://arxiv.org/pdf/2204.08482> >

The fireball lightcurve: Caution-<https://lweb.cfa.harvard.edu/~loeb/lightcurve.pdf> < Caution-<https://lweb.cfa.harvard.edu/~loeb/lightcurve.pdf> >

NBC video: Caution-<https://www.cfa.harvard.edu/~loeb/NBCPNG.mov> < Caution-<https://www.cfa.harvard.edu/~loeb/NBCPNG.mov> >

NPR audio: Caution-<https://www.npr.org/2022/08/16/1117762211/an-astronomers-plan-to-trawl-the-ocean-floor-for-signs-of-extraterrestrial-life> < Caution-<https://www.npr.org/2022/08/16/1117762211/an-astronomers-plan-to-trawl-the-ocean-floor-for-signs-of-extraterrestrial-life> >

Overview: Caution-<https://avi-loeb.medium.com/the-first-interstellar-meteor-7d97bcb970cd> < Caution-<https://avi-loeb.medium.com/the-first-interstellar-meteor-7d97bcb970cd> >

What we know:

The meteor had a geocentric velocity vector:

$(v_x, v_y, v_z) = (-3.4, -43.5, -10.3)$ km s⁻¹, located at 1.3° S 147.6° E, at an altitude of 18.7 km, at the time of impact, 2014-01-08 17:05:34 UTC, as reported in the CNEOS catalog.

The above localization is within 10 kilometers; we need another significant digit. If you can find it for us, it would save us a lot of time in the expedition search area.

There are a million objects like IM1 at any given time within the orbit of the Earth around the Sun. But a thousand times more Solar system rocks.

Avi

Abraham (Avi) Loeb
Frank B. Baird Jr. Professor of Science
Director, Institute for Theory & Computation
Harvard University

Professional website < Caution-<https://lweb.cfa.harvard.edu/~loeb/> >

[List of Essays](https://lweb.cfa.harvard.edu/~loeb/Opinion.html) < Caution-<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> >

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On Tue, Sep 20, 2022 at 5:58 PM Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)

(b)(6)

That's very interesting. I'm not familiar with the air ram pressure estimate. What's the error bar on that estimate? 10%?

In your analysis, you assume a Gaussian distribution of the interstellar population for the naturally occurring events. Is there a situation in which a non-Gaussian distribution would come into play? Specifically an exploding supernova's geometric cross-section overlapping with the Solar System's orientation and distance? Are we certain the explosion is spherically symmetric?

With regard's to artificial spacecraft, am I correct in concluding that the release of probes, microsats etc, is based on the assumption that it is earth's atmosphere that triggers it? Have you thought about other planets near our Habitable zone?

In any event that's exciting to find two objects. I suspect there's more.

Sean

From: "Avi Loeb" <aloeb@cfa.harvard.edu < Caution-mailto:aloeb@cfa.harvard.edu > >

Date: Tuesday, September 20, 2022 at 5:31:26 PM

To: "Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)"

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Subject: [URL Verdict: Neutral][Non-DoD Source] Discovery of a Second Interstellar Meteor: Meter-Size Interstellar Objects Are Much Tougher than...

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PS. Here is some additional news from this afternoon.

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Note: The related scientific paper is attached below.

< Caution-Caution-https://medium.com/@avi-loeb?source=email-adb0e108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-https://medium.com/@avi-loeb?source=email-adb0e108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > >
Avi Loeb < Caution-Caution-https://medium.com/@avi-loeb?source=email-adb0e108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-https://medium.com/@avi-loeb?source=email-adb0e108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > >

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Discovery of a Second Interstellar Meteor: Meter-Size Interstellar Objects

Are Much Tougher than Solar System Rocks!

Figures from the new paper by Amir Siraj & Avi Loeb (September 20, 2022)

In a new paper < Caution-Caution-http://me.dm/r-t7rBQ5RzPo?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-t7rBQ5RzPo?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > with my student, Amir Siraj, we have identified a second interstellar meteor, IM2, in the CNEOS fireball catalog < Caution-Caution-http://me.dm/r-EoF8XWzfiT?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-EoF8XWzfiT?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > of NASA. The two interstellar meteors are meter-scale objects that collided with Earth from a trajectory that was gravitationally unbound to the Sun. In other words, the objects arrived to the Solar system from interstellar space and were moving faster than the escape speed from the Sun when they were collected by the “fishing net” of the Earth’s atmosphere.

Avi Loeb (left) and Amir Siraj (right) at Loeb’s Harvard office; Photograph taken on September 15, 2022.

The first interstellar meteor, CNEOS 2014–01–08 (IM1), that Amir and I discovered in 2019 < Caution-Caution-http://me.dm/r-BpgRCuSvgn?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-BpgRCuSvgn?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > , was confirmed at the 99.999% confidence level by a letter < Caution-Caution-http://me.dm/r-aqJrqFnn02?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-aqJrqFnn02?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > from the US Space Command to NASA. The second interstellar meteor we just discovered, CNEOS 2017–03–09 (IM2), was ten times more massive and roughly a meter in size. It was moving at a speed of 40 (compared to 60 for IM1) kilometers per second relative to the Local Standard of Rest < Caution-Caution-http://me.dm/r-u_4S4wS_6-?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-u_4S4wS_6-?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > , the local frame of reference of the Milky Way that averages over the motions of all the stars in the vicinity of the Sun.

Remarkably, both IM1 and IM2 disintegrated low in the Earth’s atmosphere despite their unusually high speeds. The air ram pressure, which is the product of the air mass density and the square of the meteors’ speed when they explode into fireballs, provides an estimate for the yield strength of their

material composition. The inferred material strengths of 194 Mega-Pascals (MPa) for IM1 and 75 MPa for IM2 imply that both were tougher than iron meteorites, which have a maximum yield strength of 50 MPa.

IM1 and IM2 ranked number 1 and 3 in the distribution of material strengths among all 273 meteors in the CNEOS catalog < Caution-Caution-http://me.dm/r-EoF8XWzfiT?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-EoF8XWzfiT?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > . The probability of drawing the material strength of the first and second interstellar meteors out of the familiar population of Solar system rocks is roughly the square of (3/273), or equivalently one part in 10,000. This means that the population of interstellar meteors is different from Solar system meteors at the 99.99% confidence level. This conclusion is corroborated by fitting the distribution of CNEOS meteors with a Gaussian shape in the logarithm of material strength. Both IM1 and IM2 lie on the far tail of the distribution, at 2.6 and 3.5 standard deviations away from the mean, making their combined likelihood less than a part in a million.

This tantalizing conclusion about the extremely rare material strength of IM1 and IM2, implies that interstellar meteors are not rocks from planetary systems like the Solar systems.

The Earth collides with interstellar objects along its orbit around the Sun. The simplest assumption to make is that these objects arrive into the Solar system on random trajectories in the Local Standard of Rest. Based on the detection rate of IM1 and IM2 in the CNEOS catalog, roughly once per decade, one can infer that about 40% of all refractory elements < Caution-Caution-http://me.dm/r-pDj2SdFiQo?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-pDj2SdFiQo?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > in the Milky-Way galaxy are locked in meter-scale interstellar objects. This extraordinarily high abundance again seems to defy a planetary system origin.

Interestingly, a paucity of refractory elements is observed in the gas phase in the interstellar medium, an observation which could potentially reflect refractory elements being locked in interstellar objects. Supernovae have been observed to produce iron-rich "bullets", which could be a possible origin of IM1 and IM2. In particular, X-ray imaging of the Vela supernova remnant revealed < Caution-Caution-http://me.dm/r-sWuuGF-wiY?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-sWuuGF-wiY?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > bow shocks from bullets flying out of the explosion site, a discovery that I attempted to explain < Caution-Caution-http://me.dm/r-wvfe-CIXZI?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-wvfe-CIXZI?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > three decades ago. It is possible that IM1 and IM2 were shot out of an exploding star.

But it is also possible that IM1 and IM2 move fast and are tough because they are artificial in origin, namely chemically-propelled interstellar spacecraft like our own interstellar probes < Caution-

Caution-http://me.dm/r-2EoVa9nljO?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----
-c9de49b8ef2b < Caution-http://me.dm/r-2EoVa9nljO?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----
3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > , but launched a billion years ago. One can also imagine a mother craft carrying CubeSats < Caution-Caution-http://me.dm/r-cfuFXPTq5B?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----
-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-cfuFXPTq5B?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----
-c9de49b8ef2b > > or micro-devices in its belly, which like Dandelion seeds automatically get released through friction with the atmosphere of a habitable planet.

The inferred abundance of interstellar objects could be smaller by 16 orders of magnitude < Caution-Caution-http://me.dm/r-vZ8ia_wRgB?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----
-c9de49b8ef2b < Caution-http://me.dm/r-vZ8ia_wRgB?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----
3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > for functional devices that are designed to visit the habitable regions of stars. This large factor is the ratio between the interstellar volume associated with the Sun (half-way to the nearest stars)—which would be uniformly populated by random trajectories, and the volume of the Sun’s habitable zone—which would be favored by targeted devices.

Altogether, interstellar meteors are anomalous relative to Solar system meteors. To gain a better understanding of the origins of IM1 and IM2, it is essential to retrieve their materials and analyze the composition and structure of their relics through expeditions to their landing sites. Plans < Caution-Caution-http://me.dm/r-1fbqhzvqgY?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----
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3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > for the first expedition < Caution-Caution-http://me.dm/r-m1rna1Rv4?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----
3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-m1rna1Rv4?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----
-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > to retrieve the fragments of IM1 near Papua New Guinea are underway. A second expedition for IM2 near Portugal will follow.

It is also important to keep in mind that a third interstellar object, `Oumuamua < Caution-Caution-http://me.dm/r-yHU2id2h37?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----
-c9de49b8ef2b < Caution-http://me.dm/r-yHU2id2h37?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----
3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > , which was discovered almost four years after IM1 and half a year after IM2, appeared anomalous. The effort to gather more data on interstellar objects based on their anomalies, received pushback from self-proclaimed experts and bloggers on social media.

But the data collected in a single Galileo Project < Caution-Caution-http://me.dm/r-B_AU4aCZkq?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-B_AU4aCZkq?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > expedition is worth a million tweets. Four centuries ago, Galileo Galilei < Caution-Caution-http://me.dm/r-COdZXF54hg?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-COdZXF54hg?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > was put in house arrest—the equivalent of being cancelled on social media today. Galileo’s experience suggests that intelligence is not manifested by authority, nor by popularity contests that insist on knowing the answer in advance and suppress alternative opinions. Instead, intelligence is exhibited by open-minded individuals seeking evidence for the nature of the unknown. In this spirit, the Galileo Project < Caution-Caution-http://me.dm/r-B_AU4aCZkq?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-B_AU4aCZkq?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > aims to understand empirically the origin of meter-size objects tougher than iron that fill up interstellar space.

The search is challenging but fun to carry out. Here’s hoping that our childhood curiosity will be guided by scientific papers like those mentioned above, and not suppressed by superficial comments from spectators. Basketball coaches often tell their team players: “Keep your eyes on the ball, not the audience.” My paraphrased recommendation to the expedition team is: “Keep your eyes on the fireball, not social media.”

ABOUT THE AUTHOR

Avi Loeb is the head of the Galileo Project, founding director of Harvard University’s — Black Hole Initiative, director of the Institute for Theory and Computation at the Harvard-Smithsonian Center for Astrophysics, and the former chair of the astronomy department at Harvard University (2011–2020). He chairs the advisory board for the Breakthrough Starshot project, and is a former member of the President’s Council of Advisors on Science and Technology and a former chair of the Board on Physics and Astronomy of the National Academies. He is the bestselling author of “*Extraterrestrial*: < Caution-Caution-http://me.dm/r-Ei84mwIx_w?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-Ei84mwIx_w?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > > *The First Sign of Intelligent Life Beyond Earth* < Caution-Caution-http://me.dm/r-Ei84mwIx_w?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b < Caution-http://me.dm/r-Ei84mwIx_w?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > >” and a co-author of the textbook “*Life in the Cosmos* < Caution-Caution-http://me.dm/r-nVUotn4yw6?source=email-

adboe108a94b-1663698644902-newsletter.subscribeToProfile-----
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nVUotn4yw6?source=email-adboe108a94b-1663698644902-newsletter.subscribeToProfile-----
-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----c9de49b8ef2b > >”, both published in
2021.

Respond on Medium < Caution-Caution-
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1663698644902-newsletter.subscribeToProfile-----
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https://medium.com/p/5b280fabaa6d?responsesOpen=true&source=email-adb0e108a94b-
1663698644902-newsletter.subscribeToProfile-----
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View story < Caution-Caution-https://medium.com/p/5b280fabaa6d?source=email-adb0e108a94b-
1663698644902-newsletter.subscribeToProfile-----
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https://medium.com/p/5b280fabaa6d?source=email-adb0e108a94b-1663698644902-
newsletter.subscribeToProfile-----3d24b676_ec62_41e0_b8d9_96bff40b5097-----
c9de49b8ef2b > >

Subject: Meet with Avi Loeb
Location: (b)(6)
Start: Mon 10/3/2022 4:00 PM
End: Mon 10/3/2022 6:00 PM
Show Time As: Tentative
Recurrence: (none)
Meeting Status: Not yet responded
Organizer: Kirkpatrick, Sean M HQE OSD OUSD INTEL & SEC (USA)

When: October 3, 2022 at 4:00:00 PM EDT

Where: (b)(6)

From: Avi Loeb <aloeb@cfa.harvard.edu>
Sent: Tuesday, September 20, 2022 5:28 PM
To: Kirkpatrick, Sean M HQE OSD OUSD INTEL & SEC (USA)
Subject: Re: [URL Verdict: Neutral][Non-DoD Source] Re: Discussion

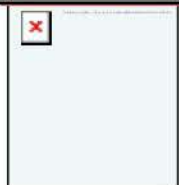
All active links contained in this email were disabled. Please verify the identity of the sender, and confirm the authenticity of all links contained within the message prior to copying and pasting the address to a Web browser.

Perfect. I reserved the time block on my calendar.
In my next message, I will share with you news from this afternoon.

Looking forward to seeing you on October 3 @ 4PM at my home.

Abraham (Avi) Loeb
Frank B. Baird Jr. Professor of Science
Director, Institute for Theory & Computation
Harvard University
Professional website < Caution-<https://web.cfa.harvard.edu/~loeb/> >
[List of Essays](#) < Caution-<https://web.cfa.harvard.edu/~loeb/Opinion.html> >

(b)(6)



On Tue, Sep 20, 2022 at 5:24 PM Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)

(b)(6)

Dear Avi,

That would be great. Let's say we meet at 4? That would give you time to get home and allow us an open ended opportunity to talk.

If it's alright with you, I will put it in my calendar and send you an invite. That will keep me from getting lost and on time.

I'm very much looking forward to it.

V/R
Sean

From: "Avi Loeb" <aloeb@cfa.harvard.edu < Caution-mailto:aloeb@cfa.harvard.edu > >

Date: Tuesday, September 20, 2022 at 4:40:17 PM

To: "Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)"

(b)(6)

Subject: Re: [URL Verdict: Neutral][Non-DoD Source] Re: Discussion

All active links contained in this email were disabled. Please verify the identity of the sender, and confirm the authenticity of all links contained within the message prior to copying and pasting the address to a Web browser.

Dear Sean,

Yes, October 3 would work for me. We could meet at my home address (a 20 minutes Uber drive from Cambridge). The address is: (b)(6) My home offers a noise-free environment where we can speak freely without interruption.

On Monday, October 3, I am available in the following time windows: before 11:30 AM; between noon-1 PM and anytime between 3:30-8PM. Let me know what works best for you.

Looking forward to meeting you.

Avi

Abraham (Avi) Loeb
Frank B. Baird Jr. Professor of Science
Director, Institute for Theory & Computation
Harvard University

Professional website < Caution-Caution-https://lweb.cfa.harvard.edu/~loeb/ < Caution-https://lweb.cfa.harvard.edu/~loeb/ > >

[List of Essays](https://lweb.cfa.harvard.edu/~loeb/Opinion.html) < Caution-Caution-https://lweb.cfa.harvard.edu/~loeb/Opinion.html < Caution-https://lweb.cfa.harvard.edu/~loeb/Opinion.html > >

(b)(6)

On Tue, Sep 20, 2022 at 4:20 PM Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)

(b)(6)

Dear Avi,

That's very kind of you. Thank you.

I was planning on coming up to Boston (b)(6) Would you be available on Oct 3rd at your convenience? I would be happy to meet in either location, and depending on your availability, I could see at least 1-2 hours, and perhaps more as we see how deep our conversation goes. There is much to discuss and I may have a challenge for you. I have the entire day of the 3rd available right now.

Looking forward to meeting with you,

Sean

From: Avi Loeb <aloeb@cfa.harvard.edu < Caution-mailto:aloeb@cfa.harvard.edu > < Caution-mailto:aloeb@cfa.harvard.edu < Caution-mailto:aloeb@cfa.harvard.edu > > >

Sent: Tuesday, September 20, 2022 11:05 AM

To: Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)

(b)(6)

Subject: [URL Verdict: Neutral][Non-DoD Source] Re: Discussion

All active links contained in this email were disabled. Please verify the identity of the sender, and confirm the authenticity of all links contained within the message prior to copying and pasting the address to a Web browser.

Dear Sean,

Wonderful to hear from you. I heard great things about your credentials (and noticed

some overlap between your scientific research described here < Caution-Caution-Caution-<https://media.defense.gov/2022/Jul/20/2003039076/-1/-1/1/DR-SEAN-M-KIRKPATRICK-BIOGRAPHY.PDF> < Caution-<https://media.defense.gov/2022/Jul/20/2003039076/-1/-1/1/DR-SEAN-M-KIRKPATRICK-BIOGRAPHY.PDF> > < Caution-Caution-<https://media.defense.gov/2022/Jul/20/2003039076/-1/-1/1/DR-SEAN-M-KIRKPATRICK-BIOGRAPHY.PDF> < Caution-<https://media.defense.gov/2022/Jul/20/2003039076/-1/-1/1/DR-SEAN-M-KIRKPATRICK-BIOGRAPHY.PDF> > > , and my SDI work in the 1980s).

I will be delighted to meet with you at my home or Harvard office if you are able to travel to the Boston area. Otherwise, I was invited to testify to the NASA Committee Study in DC on October 24, 2022. Originally I planned to come in and out of DC the same day, but I can extend the visit if helpful.

Let me know your preference regarding the timing and duration of our meeting.

By the way, you might enjoy my list of commentaries with recent updates at,

Caution-Caution-Caution-<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> < Caution-
<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> > < Caution-Caution-
<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> < Caution-
<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> > > < Caution-Caution-Caution-
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<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> < Caution-
<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> > > >

With kind regards,

Avi

Abraham (Avi) Loeb
Frank B. Baird Jr. Professor of Science

Director, Institute for Theory & Computation
Harvard University

Professional website < Caution-Caution-Caution-<https://lweb.cfa.harvard.edu/~loeb/> < Caution-
<https://lweb.cfa.harvard.edu/~loeb/> > < Caution-Caution-
<https://lweb.cfa.harvard.edu/~loeb/> < Caution-<https://lweb.cfa.harvard.edu/~loeb/> > > >

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<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> < Caution-
<https://lweb.cfa.harvard.edu/~loeb/Opinion.html> > > >

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On Tue, Sep 20, 2022 at 10:53 AM Kirkpatrick, Sean M HOE OSD OUSD INTEL & SEC (USA)

(b)(6)

Profession Loeb,

I have recently been named to standup and lead the office below for the Department of Defense, with support from the IC to address the UAP mission space. I was wondering if I could have some of your time for discussion on the topic area? I am happy to travel to wherever may be convenient.

V/R

Sean

Sean M. Kirkpatrick, Ph.D.

Director

All-domain Anomaly Resolution Office

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Universum mutatio est. Vita nostra est quod cogitationes nostra facere est.

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fall under FOIA exemption (b)(5)

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