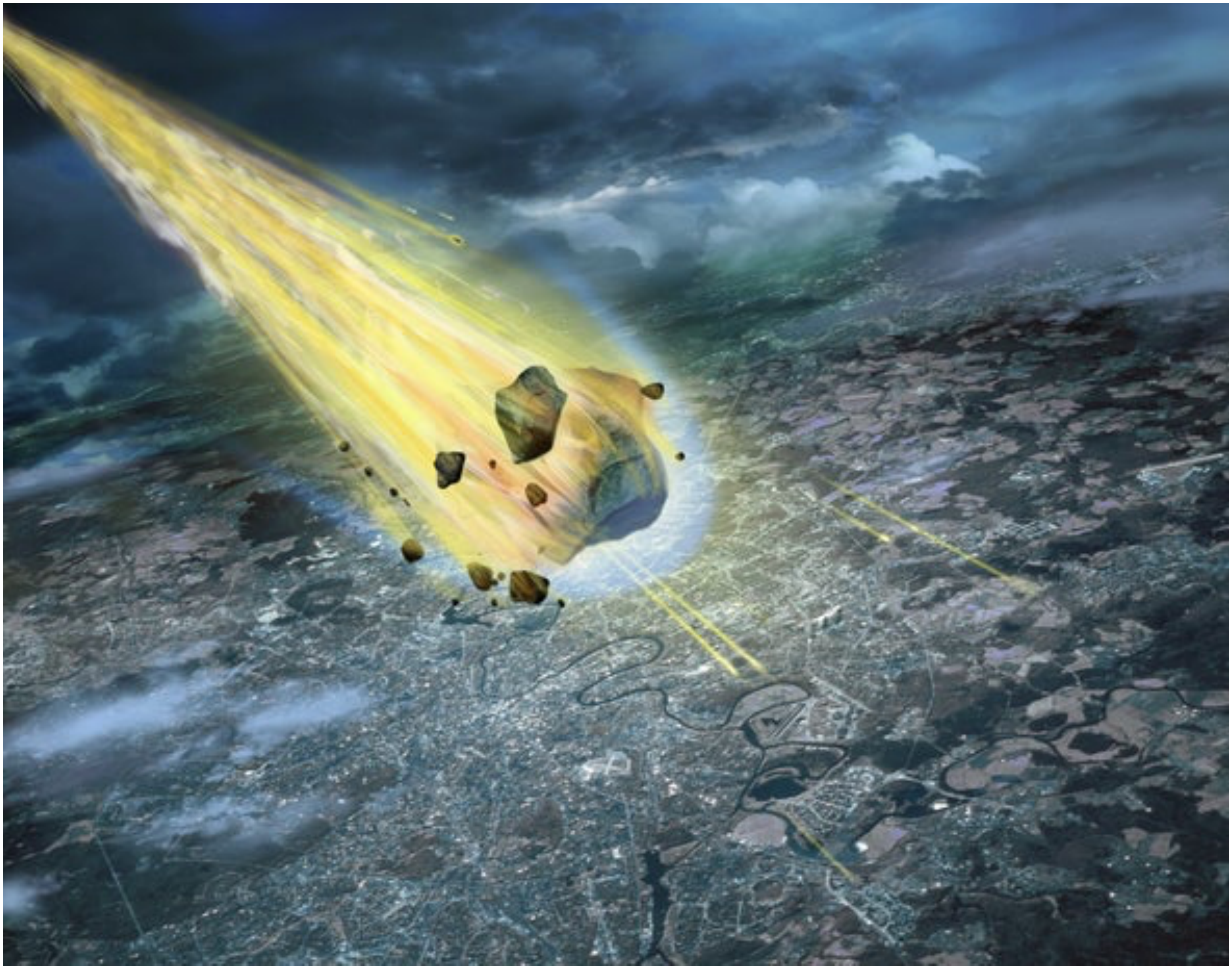
SPACE

For Asteroid-Hunting Astronomers, Nathan

Myhrvold Says the Sky Is Falling

The wealthy technologist claims some of the world's top experts on Earth-threatening asteroids are guilty of bad science

By Lee Billings on May 27, 2016



A new study from the wealthy technologist Nathan Myhrvold casts doubt on data from an asteroid-hunting NASA mission, suggesting that astronomers are in the dark about the magnitude of threats posed by potentially hazardous space rocks. Credit: Credit: Ron Miller

Nathan Myhrvold—wealthy former Microsoft technologist, current patent tycoon, classically trained chef, bestselling author, prize-winning photographer, PhD-holding physicist and gleeful scientific gadfly—has a new obsession: killer asteroids, or rather the researchers he suspects of botching their study.

Astronomers have found more than 14,000 potentially hazardous "near-Earth objects" (NEOs) that buzz our planet with alarming regularity, and estimate that hundreds of thousands more await discovery. Much of what we know about NEOs comes from a single spacecraft, NASA's Wide-field Infrared Survey Explorer (WISE), and its offshoot NEOWISE observing program. But according to a new 110-page paper Myhrvold has submitted to the journal *Icarus*, much of the NEOWISE catalogue is flat-out wrong. The NEOWISE team, he maintains, has wildly miscalculated the sizes and masses of many asteroids. Because bigger rocks make bigger booms when they strike Earth, Myhrvold's claims raise the chilling possibility that when and if another errant asteroid is found hurtling our way, no one will really know how dangerous it is—not even the supposed experts.

"Most of the asteroids that we know about are from NEOWISE," Myhrvold says. "The previous largest survey was 2,200 asteroids, and they have looked at more than 150,000. Hundreds of scientific papers have used these results, and those results ought to be replicable, but I haven't been able to do that. That is the short-term issue. The longer-term issue is that we must understand asteroids for more practical reasons, because they hit Earth all the time."

If confirmed, Myhrvold's work could turn the small, quiet field of asteroid studies upside down, throwing scientific textbooks, careers and plans for next-generation NEO surveys into turmoil. But NASA and the NEOWISE team say Myhrvold's critique is deeply flawed, and that the NEOWISE results are corroborated by data from multiple independent surveys and peer-reviewed studies. "Think of this paper as an alpha test version of Windows 2.0—not quite ready for prime time," says Ned Wright, the principal investigator for WISE at the University of California, Los Angeles. "It is too bad Myhrvold doesn't have Google's bug-finding bounty policy. If he did, I'd be rich."

Amy Mainzer, the principal investigator for NEOWISE at the Jet Propulsion Laboratory, says Myhrvold's paper is riddled with mathematical mistakes—including one as basic as confusing an asteroid's diameter with its radius, which results in dramatic miscalculations of some asteroids' sizes. As an example, Mainzer points to an asteroid called 295 Theresia, which Myhrvold's paper lists as having a diameter of roughly 660 kilometers—making it bigger than Vesta, the second-largest object in the Asteroid Belt. By contrast, data from WISE and another earlier space mission, the Infrared Astronomical Satellite (IRAS), pegs 295 Theresia's diameter at about 30 kilometers. "His math is just wrong," Mainzer says. "You can't get away with confusing diameter and radius—that's how you end up thinking a 30-kilometer asteroid is bigger than Vesta."

Myhrvold acknowledges that his paper contains some mistakes and says he is prepared to make revisions based on expert feedback, but insists that the NEOWISE team is cherry-picking cosmetic issues instead of addressing the most substantive criticisms he has raised, which he says involve fundamental misunderstandings of basic physics and statistics.

HOT ROCKS, MUDDLED MODELS

Myhrvold began analyzing the NEOWISE data last July after working on another paper, later published in the peer-reviewed *Publications of the Astronomical Society of the Pacific*, in which he estimated and compared the performance of several possible future asteroid-hunting telescopes. One of those was the Near-Earth Object Camera, or NEOCam, a nascent infrared space telescope meant to be a successor to NEOWISE. Proposed by Mainzer and other leaders of the NEOWISE team, NEOCam is one of five mission concepts NASA is considering for construction and flight as early as 2020 for a total cost of more than half a billion dollars.

To the human eye, most asteroids are dark as coal but they are much brighter in infrared wavelengths due to heating from sunlight. Generally speaking, the brighter an asteroid is at any wavelength the easier it is to detect—and paired with other measurements an asteroid's brightness can help astronomers pin down its size, mass and composition. For all these reasons, developing good thermal models of how asteroids absorb and emit heat is a vital part of hunting for them and measuring their sizes with infrared telescopes. Using such models the NEOWISE and NEOCam teams say they can estimate asteroid size with an uncertainty as minimal as 10 percent.

Myhrvold has said that last July, while looking at a thermal model supplied by the NEOCam team, he noticed they ignored a fundamental tenet of physics called Kirchhoff's law of thermal radiation—which dictates how differing wavelengths of light preferentially bounce off or penetrate a surface based on its reflectivity. According to Kirchhoff's law, darker objects radiate more heat whereas lighter, more reflective ones radiate less. Without accounting for Kirchhoff's law, Myhrvold says, NEOCam's models would confuse a fraction of the sunlight reflecting off an asteroid with emitted heat, drastically increasing the uncertainty of size estimates. Turning to NEOWISE's thermal model, Myhrvold said he found the same omission of Kirchhoff's law.

"So I started asking the NEOWISE team questions, and then they stopped corresponding with me," Myhrvold says. "It's possible if they had given me an answer I would have dropped the whole thing. Instead, I checked it out and I kept finding new problems with their work." According to Myhrvold, those problems included inappropriate extrapolations of small sample sizes to large populations as well as the use of unexplained ad hoc rules for finding statistical trends in data sets. Without more transparency from the NEOWISE team about their data analysis techniques, Myhrvold says, he could not replicate their results. But all together, he concludes that the problems he found push the size uncertainty for asteroids in the NEOWISE data as high as 300 percent, which translates to a nearly 3,000 percent uncertainty in estimates of an asteroid's mass.

Mainzer sees the situation differently. She readily admits that the NEOWISE and NEOCam thermal models, which are essentially identical, do not incorporate Kirchhoff's law and indeed treat all asteroids as idealized, half-illuminated spheres with spins perfectly perpendicular to the solar system's ecliptic plane. These models, which were last updated in 1998, crudely cram finer details like a shape, surface texture and heat capacity into a single parameter that comes nowhere close to capturing an asteroid's true complexity. And yet they seem to work surprisingly well. Peer-reviewed studies, Mainzer says, have validated that the models' estimated sizes closely match independent measurements of asteroids drawn from ground-based surveys as well as two older infrared space telescopes, IRAS and AKARI. "In an ideal world, we'd have a model that incorporated all of the factors that affect Kirchhoff's law," she says. "But we simply don't have that information about most asteroids."

As for the communication breakdown, in Mainzer's version of the story she and her colleagues became less responsive only after a lengthy period of fielding Myhrvold's extensive questions and providing feedback on early drafts of his paper. "After awhile it became clear that he wasn't incorporating any of our corrections," she says. "At some point we had to leave it to him to write his paper and send it through peer review."

THE HIGH-STAKES SEARCH FOR KILLER ASTEROIDS

The situation is now at an impasse, with each side accusing the other of, at minimum, flawed modeling and sloppy statistics—if not outright malicious intent. Myhrvold believes one reason for what he perceives as hostile stonewalling from Mainzer and her colleagues is the roughly $600 million at stake in NASA's decision on whether or not to green-light their proposed NEOCam mission.

The race to find killer asteroids before they strike is a key driver behind NASA's consideration of NEOCam. In 2005 Congress gave the agency until 2020 to catalogue 90 percent of the total population of midsized NEOs at or above 140 meters in diameter—objects big enough to devastate entire regions on Earth. NASA has already catalogued 90 percent of the NEOs that could cause planetary-scale catastrophe—those with a diameter of one kilometer or more—but is unlikely to meet the 2020 deadline for cataloguing midsize NEOs. NEOCam could be the agency's "better late than never" solution, offering a way for NASA to fulfill the congressional mandate in the early 2020s.

There is another option. The Large Synoptic Survey Telescope (LSST), an observatory under construction in Chile with a panoramic 8.4-meter mirror, will be an asteroid-discovery powerhouse when it begins its all-sky observations in 2020. The project is already fully funded, with roughly $650 million for the telescope's construction and an additional $400 million budgeted for a decade of operations. The billion-dollar effort could meet NASA's NEO-cataloguing mandate, too, LSST team members say—albeit a couple of years later than a notional NEOCam mission, and only by prioritizing NEO-surveying observations while delaying other science goals. Such tweaks would require an estimated $100 million of additional funding, and the project's leaders have suggested NASA might foot that bill. "LSST is very expensive but it is already being built, and it's going to find lots of asteroids," Myhrvold says. "Building another project to try to race it and find those asteroids two years earlier makes very little sense."

Even though he is now practically a pariah to the NEOWISE and NEOCam teams, Myhrvold is not without allies in the asteroid community. Some of the most helpful feedback he has received on his papers, he says, has come from University of Washington astrophysicist and LSST project scientist Željko Ivezić. "I cannot claim with certainty there is something wrong with NEOWISE," Ivezić says. "But if I had to bet money, I think it's more likely than not that Nathan is correct. There are errors people have spotted in his formulas, but his statistical methods are sound."

A QUESTION OF BIAS

Myhrvold's connection to LSST goes deeper than simply soliciting feedback from project members, however. Most of the funding for LSST comes from the National Science Foundation and the U.S. Department of Energy but a significant fraction comes from private donors—namely, a combined $30 million for the telescope's optics from former Microsoft titans Bill Gates and Charles Simonyi. Both Gates and Simonyi agreed to support LSST after being introduced to the project's leadership by Myhrvold.

Ned Wright, principal investigator of WISE and a senior member of the NEOCam team, believes Myhrvold's involvement with LSST is what drives his critiques. "Myhrvold is a big supporter of LSST, so he is motivated to find errors in the radiometric diameter method which is used by NEOCam, a potential competitor," Wright says. LSST will find lots of asteroids, Wright says, but because it observes in visible light from the ground rather than infrared from space like NEOCam, he estimates a full quarter of the midsize-NEO population will be far too dim for LSST to detect.

Myhrvold scoffs at allegations of bias, and notes that he has not donated any money to LSST. “Questioning my motivations is an odd thing to claim for people who are angling to get another $600 million or so of government money,” he says. “NEOCam does need to justify its existence because LSST will find most of the asteroids it would find.” To do that, Myhrvold says, the competing teams should collaborate on an open and transparent simulation making apples-to-apples comparisons of both projects’ performances.

Wright, Mainzer and other NEOCam team members say the ideal situation would be for both LSST and NEOCam to operate in tandem, combining their visible and infrared observations to find and study more asteroids than either could achieve alone. According to Mainzer, who is also a member of LSST’s Science Advisory Committee, “LSST and NEOCam are like chocolate and peanut butter, they work great together!”

Ivezic takes a more cautious view, opining that objectively establishing which project could better protect Earth from threatening asteroids—or whether they could productively work together at all—requires addressing Myhrvold's claims. "If, God forbid, we find an asteroid that will impact Earth, we will want to know whether we need to evacuate a city or a state or a region—and that depends on the size of the object," Ivezic says. "NEOWISE and NEOCam claim they can get sizes within 10 percent uncertainty, while LSST will get 50 or 60 percent uncertainty on diameters, so LSST alone looks much worse," he continues. "Now Nathan is saying, 'Wait a minute, NEOCam won't have 10 percent uncertainty, it will have 50 percent uncertainty, too.' If he is correct, the argument to have NEOCam in addition to LSST to better know the sizes of asteroids becomes much weaker. ... Some egos might be bruised

heart of science," he says. "But replication is hard, and I understand why. It's an incredible amount of work first of all, and second of all you become kind of a shit magnet. ... I'm going to be eating nails for breakfast for awhile, and if I'm wrong, I'll take it all back. But that's what science is about. This is me doing what I love."

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Credit: Nick Higgins