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# Dark matter and dinosaurs: meet Lisa Randall, America's superstar scientist

Harvard professor's radical theory of dark matter wiping out the dinosaurs and enigmatic research on extra dimensions has made her a true trailblazer It's a bright, chilly winter morning in Cambridge, Massachusetts, and in Peet's cafe, just around the corner from Harvard University, the coffee grinders are going hell for leather. Hunched over their laptops, students peer at seemingly never-ending dissertations while the edge is taken off their caffeine spikes by a soundtrack of soporific crooning.

I bag two chairs and wait for Lisa Randall to walk through the door. America's superstar scientist turns up a little late, negotiates the throng and perches her petite figure on a stool. But while the surroundings are humdrum, our discussion is anything but. Because Randall is here to talk about dark matter – and dinosaurs. Or, more precisely, how a putative disc of dark matter in our galaxy could potentially be responsible for dislodging lumps of rock from the distant Oort cloud which then hurtle towards Earth – possibly leading to events as catastrophic as the planet's fifth mass extinction – every 35 million years, or so. | | The first thing that strikes me is that's a lot of caveats – a factor some have been quick to point out. Randall is unimpressed. "I am fully aware that it is speculative," she says, her matter-of-fact tone, steely expression and languid drawl combining to remind me that you don't get to be one of the world's most cited theoretical physicists – or on Time's 100 list – by missing something as obvious as that. "Whether or not it turns out to be true, basically having an alternative [theory] makes you look at what you have more carefully," she adds.

But if there is one person likely to be unfazed by a panoply of uncertainties, it's Randall. Born and brought up in Queens, New York, she has dedicated her career to probing the abstract. "I guess I like to find unexplored corners," she says.

It's an approach that has paid off. With a prominent career in particle physics, she shot to fame for her work on extra dimensions with collaborator Raman Sundrum, work which explored among other things, she says, "why is gravity as weak as it is". Her seminal research focused on the idea that the world in which we live could be a three-dimensional spatial region within a system of "warped" extra dimensions. It was a stunning example of why many scientists have labelled her nothing short of a genius.

Since then, she has scooped a host of awards and honorary degrees, taken the chair opposite Jon Stewart on the Daily Show, appeared on Charlie Rose, the TV talkshow, and even made a cameo on the sitcom The Big Bang Theory. Although with papers like The Electromagnetic Penguin Contribution to the Epsilon-Prime/Epsilon for Large Top Quark Mass, it's hard to swallow her assertion that she chose to study physics over maths because "it is a little bit more sane and a little bit more connected to the world".

Lisa Randall's cameo in the Big Bang Theory. Randall is visible seated at a table behind Sheldon, but was instructed to be inconspicuous. Yet in some ways it is the Alice in Wonderland sound of her work that launched Randall into the public domain. Capturing the imagination with her enigmatic research and speaking with an authority born of its influence, she has featured in magazines ranging from Slate to Vogue and written a clutch of popular science books that have propelled her on to the New York Times bestseller list.

Not that communicating such scientific theories doesn't have its difficulties – indeed as Randall points out, many people find it hard to feel at home with the abstract. "What do you think when you're thinking about love – are you thinking in words or pictures?" she asks. "It is a concept. I think it is funny, there are certain things we'll be OK with, but [people] don't realise that there are lots of things that can fall into that in-between category."

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Indeed for Randall her carefully drawn analogies earn their keep for another reason. “Frankly, the analogies for you as a reader are about understanding the science but for me they are about getting to express my opinions on foreign affairs or social interactions,” she says. “I love using dark matter as the ignored mass of society.” And Randall is nothing if not direct. I ask whether she is concerned about the amount of money being poured into Cern and space missions. “What should we spend our money on?” she parries. “What will we remember 100 years from now – are we going to remember that we discovered the Higgs boson or are we going to remember some particular bombing of Syria? The expenses aren’t that different.” The Large Hadron Collider sets its sights on dark matter But she is blunt: projects, she says, must be about the scientific value. “You shouldn’t get me started on Mars,” she bristles when I bring it up, saying that while manned missions could bring technological advances, she believes the fervour to land humans on the red planet is also “an excuse not to face some of the problems that we do have [on Earth]”. Tellingly she recalls a moment when, at a gathering of scientists during the making of the Hollywood blockbuster Interstellar, “people asked all of us would you want to go to Mars and I was the only one who said no,” she says, adding that having gone camping in some pretty inhospitable places on Earth she’s nonplussed at the idea that anyone would set off on the mission. “I would rather explore Antarctica.”

For a moment I wonder what it must be like to be Lisa Randall – to be completely at ease with the unknown, to be familiar with enigmatic particles and to know more about “electromagnetic penguins” than that they probably aren’t part of the polar fauna. But then Randall, too, finds it hard to cross dimensions. “I can only appreciate how literally people take the [scientific] words when it is in a foreign language,” she says, adding that when she saw “field theory” rendered in French it wasn’t abstract ideas of electrons, photons and quarks that sprang to mind. “I thought of cows in a field,” she says.

Dinosaurs, by contrast, are undeniably tangible. Their huge bones are suspended in the atriums of museums the world over and few could claim to be unmoved by the knowledge that these otherworldly beasts once roamed the Earth.

Which is why linking their sticky end with dark matter – a substance as mysterious as it is intriguing – is the ultimate coup, a slam-dunk dream for the pop-sci publishing market. Elucidating on a paper released in 2014, Dark Matter and the Dinosaurs is Randall’s fourth book, although she is quick to point out that she didn’t set out to explain the fate of these extraordinary animals. “Actually we had not been thinking about it at all,” she says. Facebook Twitter Pinterest Lisa Randall at the Radcliffe Institute for Advanced Study at Harvard University. Photograph: Essdras M Suarez/The Boston Globe via The idea instead spun out from her work on dark matter. Despite making up about 85% of matter in the universe, we still haven’t worked out what it’s made of. What’s more, the fact that it neither absorbs nor emits light (hence the term “dark”) means we can’t tease apart its secrets directly through observations involving electromagnetic radiation.

One of the biggest clues to its existence comes from its gravitational effects in the galaxy: essentially the “tug” provided by dark matter means stars farther from the centre of the galaxy are moving faster than would be expected if only “normal” matter were exerting a pull. As dark matter expert Professor Gerry Gilmore of the University of Cambridge explains: “Our sun is travelling around the centre of the Milky Way at 220km per second. If there were no dark matter there, if there were just stars, we would be travelling at a ‘mere’ 150km per second.” Indeed it seems we are surrounded by the stuff. Current thinking suggests that the Milky Way lies inside a sphere, or “halo”, of dark matter that extends out far beyond the galaxy’s luminous region. Starwatch: What's the dark matter? But Randall thinks there’s more to it than that. “Why should dark matter be just one thing? After all, if you were people made of dark matter looking at our matter you would be very wrong if you said there was just one type of particle.” Gilmore agrees. “It is very, very likely that there are lots of types of dark matter and they will behave in

different ways," he says. Building on the idea, Randall and her collaborators have been working on the theory that a particular type of the dark matter, a fraction of what's out there, could exhibit interactions with itself other than gravity, ultimately leading it to collapse and form a thin disc within the midplane of the Milky Way.

And that's where the dinosaurs come in. As our solar system travels around the galaxy, it passes up and down through the galactic midplane – a motion a little like the bobbing of horses on a merry-go-round. As it does so, the gravitational tug experienced by the solar system varies. According to Randall and her collaborator, the extra gravitational pull of a dark disc would affect the period of this "bobbing" and, by increasing the magnitude of the variation in "tug" experienced by the solar system as it travels up and down through the galactic midplane, periodically oust weakly bound objects from the Oort cloud. In other words, the presence of a dark disc would explain the apparent 35m year or so periodicity in the formation of large craters on Earth. Why are dinosaurs extinct? You asked Google – here's the answer | Brian Switek The upshot, Randall believes, is that dark matter could have finished off the dinosaurs 66 million years ago.

If it sounds a little like a tottering house of cards, the flipside is that cold, hard data is in the offing. Launched in 2013, the Gaia satellite allows the distance and motion of more than a billion stars in the galaxy to be determined with unprecedented accuracy.

"Gaia is a big camera that keeps repeatedly imaging the sky," says Gilmore, who is a lead researcher on the mission. "If you measure [a star's] apparent motion across the sky and you know the distance you can turn that into a real speed – how many kilometres a second that star is moving." If a disc of dark matter exists, it could be detected by its influence on the motion of stars, in particular their vertical velocity. And we could soon have answers. "Over the next 10 years we are going to learn a great deal about how dark matter is distributed from Gaia and we are probably going to detect it in the Large Hadron Collider," he says confidently.

Gaia and the LHC aren't the only endeavours that could shed light on dark matter. Among other approaches, China's recently launched Dark Matter Particle Explorer is set to study the phenomena while Euclid – a new mission from Nasa and Esa set to launch in 2020 – will be designed to explore both dark matter and dark energy.

Yet despite an enthusiastic hunt, the response from the academic community towards the ramifications of a dark matter disc on the dinosaurs has been equivocal. Gilmore is unconvinced by the link while Coryn Bailer-Jones from the Max Planck Institute for Astronomy in Germany – a critic of the paper when it appeared – says he has yet to change his mind. "I remain rather sceptical. I see, from the methodological point of view, serious issues."

Among his concerns, he says, is the very low "likelihood ratio" reported in the 2014 paper – essentially a measure of how likely the theory is to yield current data compared to a model that assumes the rate of meteoroid impacts is uniform. He also says it is tricky to tell apart craters produced by objects hurled from the Oort cloud and those produced by rocks hailing from the asteroid belt. What's more, "for me the whole thing about periodicity and cratering is kind of dead," he says. But as Randall herself points out, she is fully aware of the speculative nature of the theory. "We said this is a question mark thing – let's figure out if we can make this into science."

Lisa Randall explains some of her recent theory of dark matter. Others, too, see the merit of informed conjecture. "This is a bit more off the wall but it is not completely unreasonable," says Dr Malcolm Fairbairn, a theoretical physicist at King's College London. "If everybody just gets stuck inside their own little valley and nobody tries to see what's over the nearest hill then things don't progress as quickly as they might do otherwise," he adds.

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Some scientists have even gone further. Professor Michael Rampino, a geologist at New York University who has long been a proponent of the idea that the solar system's movement through the galactic midplane is linked to a periodicity in impact crater formation on Earth, has recently suggested that clumps might exist within the 'dark disc' - and that these could accumulate in the Earth's core as our solar system passes through the disc. This, he says, could trigger a host of dramatic events, from volcanic activity to sea level changes. "As you pass through the [galactic] plane not only do you get the impacts/mass extinction story you might get this geological story where the geological activity of the earth is actually pulsing with the same period," he explains when I call, pointing out that the theory could help to explain the much discussed link between impacts and other events thought to contribute to mass extinctions. It sounds extraordinary, but Rampino is remarkably gung-ho about objections. "I am never bothered about controversy, the more controversy the better," he booms happily down the phone.

His enthusiasm for Randall's theory is not, however, reciprocated. "It's interesting to look for more connections and we appreciate his following our work. But this idea doesn't work I'm afraid," she shoots back when I quiz her by email. "He needs very dense dark matter to have a sufficient effect so he wants it in small dense objects. But they would be so small and dense that given the net amount of dark matter, there wouldn't be enough to have significant probability of one passing through the Earth." Fairbairn is also non-plussed while Bailer-Jones takes a moment to phrase his response. After a long pause, apparently searching for the right words, he settles on "It seems to be a bit of a what-if story."

Back in Cambridge MA, Randall is refreshingly detached about the debate her theory has provoked. "I think astrophysicists are rather conservative, as scientists should be in some ways, but sometimes you can be so conservative that you are missing things."

Ultimately, she later says, she isn't out to push a particular idea, viable though she believes it to be. "Do I want to be working on something that turns out to be the wrong path for the rest of my life? No – I'd rather find out the answer," she says. Science: Where are the women? | @GrrlScientist Indeed, although Randall admits to enjoying rock climbing, skiing and hiking, it is hunting for the truth, however peculiar and mind-bending that might be, that is her true passion. Which brings us on to a topic that has been lurking in the background throughout our interview: women in science. Randall is, after all, a pioneer – the first tenured female theoretical physicist at MIT (Massachusetts Institute of Technology), the first tenured female professor of physics at Princeton and, now, the first tenured female professor of theoretical physics at Harvard, her alma mater. She is, however, reluctant to talk about it. Last month she almost refused an interview with the Huffington Post in protest at its desire to talk about her gender. "There will be times [when] I'll have a five-minute interview to explain branes and [for] three minutes I have to explain being a woman in science," she fumes when I venture into the area. "And I think this is not fair – if I was a guy I wouldn't have to do that."

Not that Randall is dismissive of the problems facing women in science – she flags up concerns over a gender bias in private funding for a start – but generally she prefers her success to speak for itself, and inspire others. "It sounds crazy in a way but I am actually doing something out there in the world just by doing what I do, because there are so few women doing this," she says. And she doesn't feel the urge to "prove" herself at every turn, either. "Look, I have enough accomplishments under my belt that if people can't figure out that I am a reasonably smart person then what am I going to do?"

There is time for just one last question. What might her next book be? She emits a sharp, surprising explosion of laughter. "I am not thinking about it yet," she smiles. "I am really just thinking about doing my research." And with that she's back down the rabbit hole, off to explore a world of extra dimensions, intriguing particles and matter as elusive

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as the grin of the Cheshire cat. And electromagnetic penguins, of course.

Dark Matter and the Dinosaurs: The Astounding Interconnectedness of the Universe by Lisa Randall is published in the UK by The Bodley Head, £25.

FOUR OTHER US PHYSICISTS TO WATCH Facebook Twitter Pinterest Beloved US TV Physicist Neil deGrasse Tyson. Photograph: Supplied NEIL DEGRASSE TYSON

Often touted as the natural successor to Carl Sagan, astrophysicist DeGrasse Tyson achieved prominence for his role as director of the Hayden planetarium, his popular science books and his TV appearances - among them the reboot of Sagan's Cosmos series. Facebook Twitter Pinterest Brian Greene at the 2015 World Science Festival Spring Gala. Photograph: Desiree Navarro/WireImage BRIAN GREENE

A professor at Columbia University, New York, and a former classmate of Randall, Greene has made it on to the bestsellers list for his books on string theory and his appearance on PBS shows. He also co-founded the World Science Festival. Facebook Twitter Pinterest Kip Thorne at the premiere of Interstellar. Photograph: Kevin Winter/ KIP THORNE

Collaborator of Stephen Hawking and expert on general relativity, theoretical physicist Thorne was launched into the public consciousness for his work as an adviser on the smash hit Interstellar and the popular physics book he wrote to accompany the film. Facebook Twitter Pinterest Amy Mainzer speaks at a conference about near-Earth asteroids.

Photograph: Alex Wong/ AMY MAINZER

She gained public prominence through her appearances on TV science documentaries, but her day job is at Nasa's Jet Propulsion Laboratory where she heads projects on infra-red space telescopes and investigates minor planets.
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