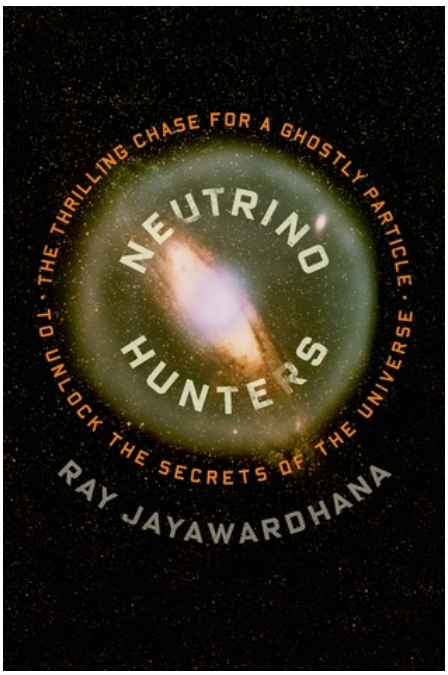

Neutrino Hunters: The Thrilling Chase for a Ghostly Particle to Unlock the Secrets of the Universe

Ray Jayawardhana

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Winner of the Canadian Science Writers Association 2014 Science in Society Book Award
A *Publishers Weekly* Top 10 Science Book of the Season
A Book to Watch Out For*, The New Yorker*'s *Page-Turner* Blog
A *Los Angeles Times* Gift Guide Selection
One of the Best Physics Books of 2013, Cocktail Party Physics Blog, *Scientific American*

Detective thriller meets astrophysics in this adventure into neutrinos and the scientists who pursue them

The incredibly small bits of matter we call neutrinos may hold the secret to why antimatter is so rare, how mighty stars explode as supernovae, what the universe was like just seconds after the big bang, and even the inner workings of our own planet.

For more than eighty years, adventurous minds from around the world have been chasing these ghostly particles, *trillions* of which pass through our bodies every second. Extremely elusive and difficult to pin down, neutrinos are not unlike the brilliant and eccentric scientists who doggedly pursue them.

In *Neutrino Hunters*, the renowned astrophysicist and award-winning writer Ray Jayawardhana takes us on a thrilling journey into the shadowy world of neutrinos and the colorful lives of those who seek them. Demystifying particle science along the way, Jayawardhana tells a detective story with cosmic implications—interweaving tales of the sharp-witted theorist Wolfgang Pauli; the troubled genius Ettore Majorana; the harbinger of the atomic age Enrico Fermi; the notorious Cold War defector Bruno Pontecorvo; and the dynamic dream team of Marie and Pierre Curie. Then there are the scientists of today who have caught the neutrino bug, and whose experimental investigations stretch from a working nickel mine in Ontario to a long tunnel through a mountain in central Italy, from a nuclear waste site in New Mexico to a bay on the South China Sea, and from Olympic-size pools deep underground to a gigantic cube of Antarctic ice—called, naturally, IceCube.

As Jayawardhana recounts a captivating saga of scientific discovery and celebrates a glorious human quest, he reveals why the next decade of neutrino hunting will redefine how we think about physics, cosmology, and our lives on Earth.

Neutrino Hunters: The Thrilling Chase for a Ghostly Particle to Unlock the Secrets of the Universe Details

Date	:	Published December 10th 2013 by Scientific American / Farrar, Straus and Giroux (first published 2013)
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Author	:	Ray Jayawardhana

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From Reader Review Neutrino Hunters: The Thrilling Chase for a Ghostly Particle to Unlock the Secrets of the Universe for online ebook

Nicole says

and the bartender says, we don't serve your kind in here!

....

a neutrino walks into a bar.

UPDATE at the halfway point:
So far I have to say that, while I am enjoying this and whizzing through it quickly, I could do with a lot more particle physics and a lot less anecdotal and biographical detail. Does this person not have an editor to tell him that it's neither necessary nor acceptable to add every random bit of information about everything as a subordinate clause? On the writing style more generally, Ray and I are going to have to agree to disagree (so. many. adjectives. OH GOD, the adjectives. Please make it stop.)

Maybe it's just me, maybe this is a strategy to make the physics accessible and entertaining for people, but I don't care which physicist wanted to be a rabbi as a boy, or whether or not they played stickball in the street. I don't care what the author was wearing in Antarctica (I hear it's like really cold there?) and I don't need to know that he yawned to clear his ears while descending a mile underground to visit a particle detector (so I'm guessing a mile underground is like really really deep?).

I would have liked a bit more explanation of what the different flavors of neutrino ARE, how they can be "associated with" another particle (what does that mean, associated with? are the other particles present? if not, then what? I don't get it, and I don't think it's because of me) and yet also change identity (and, apparently, mass, though this is not clear), what it means for them to oscillate, how their having mass changes the oscillation picture, and so on, you get the drift.

I guess I'm saying I want my neutrino book to be about neutrinos.

Does popular science writing really have to take out a bunch of the science in its effort to appeal to a lay audience?

FINAL UPDATE:
Okay, while I still love neutrinos, in fact, I love them more than ever, this was not a great book. The descriptions of the science are sloppy, especially for a physicist, and the last chapter appears to be a weird sour grapes rant against the LHC and the Higgs Boson team which suggests he doesn't really even support research in particle physics unless it's about neutrinos. I have no idea what's up with this, but I'm thinking it merits a one star docking in and of itself.

Jamie Barringer (Ravenmount) says

This book is a great popular science introduction to the topic of neutrinos, written with the general public in mind, clearly written, with more terms and concepts explained than one might see in books written for a professional physics audience, but not watered down or oversimplified. If only my undergrad physics courses had been this informative and interesting, I might have finished a physics degree after all. I did feel motivated after reading this book to participate in a citizen science project, helping hunt for supernovas (since those are neutrino sources and I liked the idea of being able to watch the neutrino signature of a supernova).

Erin Britton says

The Neutrino Hunters is Ray Jayawardhana's intriguing and informative concise history of both the highly elusive neutrino itself and of the peculiar, offbeat characters who made finding the least understood particle in physics their life's work. Jayawardhana has a gift for making extremely complicated topics digestible for the layman and his enthusiasm for astrophysics in general and, of course, neutrinos in particular, is infectious. While he clearly doesn't suffer from "neutrino fever" to the same extent of some of the real life mad scientists that he discusses, Jayawardhana vividly recounts what is currently known and neutrinos and convincingly postulates what further knowledge of the phantom particular could mean for science and humanity.

MystaryPi says

Pretty fun, but it was a little slow at some parts.

Ben says

Does a really impressive job distilling a complex concept into a readable text. Three favorite parts:

1) there's an undercurrent of resentment toward the big and expensive collider projects, which clearly get more money. Jayawardhana repeatedly talks about how much cheaper neturino hunting can be and how what they find is actually useful compared to CERN and things like that.

2) There's apparently a neutrino detection system at almost the South Pole, which consists of tubes buried really deep underground into essentially untapped water to try and measure neutrinos as they move through an area that's not disturbed by cosmic rays and other things.

3) I forget the country (Italy maybe?) but some scientists helped cover the excavation costs of this massive ship that went down a long time ago because some of the metal it was carrying that was lead that has decayed enough to not give off any particles that would mess up neutrino detection.

Sarah Pybus says

I received this book from a Goodreads Giveaway. This isn't just a Science book! It manages to weave in

human stories about Scientists with an interesting scientific narrative to make an absorbing read.

Helgi Hróðmarsson says

For those without an advanced degree in science jargon, neutrinos are elusive, tiny, tiny, tiny, tiny little particles who rarely interact with matter. MATTER of fact… *pause for laughter, followed by immense self-loathing*… trillions of neutrinos pass through the human body each second, and have done so every day from the moment we were born and will continue to the day we'll die. Alarmed yet? Don't be.

Neutrinos are byproducts of the nuclear reactions that fuel our sun (and the rest of the stars in the Universe) and they, like the neutron, have no charge. They are sort of like the Switzerland of atomic particles; small, neutral, and come in three flavors. (Wait, what?) Neutrinos are way smaller than other subatomic particles like the neutron or proton, but almost never interact with any matter, which, incidentally, is why we haven't noticed the approx. quintillion neutrinos that have passed through your body in your lifetime.

The Neutron Hunters in a superb mix of biography and science and covers the neutrino's history; how its existence was initially postulated, how it came to be detected and what can be learned from them. It's a massive subject but aptly abridged to approx. 200 pages and could have easily been longer. I seem to be finding it more and more as a fault with books that they aren't as long and detailed as I would have wished. (Maybe because I'm also reading Harry Potter and The Order of the Phoenix concurrently).

In his book, Jayawardhana visits massively ambitious laboratories built for the sole purpose of detecting neutrinos. These massive detectors are mostly built in abandoned mines where small, underground lakes are created; filled with various funny substances, such as dry cleaning fluid that neutrinos, on rare occasion, interact with to form new elements which are then detected. These neutrino events are few but give us nonetheless accurate depictions of their multitude as well as their origins.

We also travel to IceCube in Antarctica… which apparently is an actual place, where long steel cables with sensitive phototubes are buried deep into the ice to trace the paths of newly liberated neutrinos by observing other strange particles called muons. (Muons are 200 times heavier than electrons but way less abundant due to their lack of stability).

In my opinion, the most enjoyable passages in the book follow the exploits of Wolfgang Pauli and Bruno Pontecorvo, respectively. Pauli was a brilliant physicist who postulated the existence of neutrinos to account for the differences in masses of radioactive elements and the products of their decay. Pauli himself said that he had done a terrible thing. He had postulated a particle that couldn't be detected.

The story of Pontecorvo, however, is something straight out of a spy novel. He had theorized how to actually detect the shy neutrinos by an indirect observation. See, when a neutrino collides with a Chlorine atom (a rare event, but just so that we can observe a few of them), a radioactive Argon atom is formed. (Chlorine and Argon are next-door neighbors in the periodic table so if we change a neutron in a Chlorine atom to a proton, by colliding it with a neutrino, the Chlorine atom becomes an unstable Argon isotope that subsequently decays). By observing the radioactive decay of the Argon atom, we indirectly observe the work of the neutrino.

But Pontecorvo's story is much more elaborate. He flees the increasingly fascist regime in Italy to the U.S. There he is not trusted due to his socialist leanings. He then takes up a professorship in Liverpool, England,

but instead of returning there from holiday in Italy, he flies with his family to Stockholm, Sweden, then Helsinki, Finland. And that’s when he disappeared. Later, it was revealed that he defected to the Soviet Union. Like I said. Spy novel, only true.

The book is enjoyable and informative all throughout and through another of its countless anecdotes of scientists, it introduced to me an insult that I’m going to start taking up. “A spherical bastard”. I.e. a bastard seen from all sides. If anything, I’m going to start adding ‘spherical’ in front of all my name callings. E.g. spherical fart goblin, spherical demon toilet, etc.

Like I said, I would have liked some of the science-y parts of the book to be a little more elaborate, but this is a solid read for anyone interested in modern science in general, and especially, the hunt for neutrinos.

https://cosmicchemist.wordpress.com/2...

David says

I liked this book more for its up to date information (it was published at the end of 2013 and covers the latest developments) than for its explanations of some of the experiments. I understand that this is a book targeted at the layman, but sometimes a bit of detail will help in understanding some of the ideas. For instance, saying that an experiment will be improved by adding a bit of gadolinium without, at least, hinting at how this will be an improvement, is of limited use: you have some information, but remain without knowledge. Probably the best part of the book is the Notes chapter: it contains a large collection of text notes and web links that are useful in locating content mentioned in the book. In short, read it for the coverage of recent events. I must confess that I still prefer Frank Close's Neutrino, regarding the historical background.

Kate says

Excellent, lucid, engaging. The neutrino story is inherently fascinating to particle-physicist-manqué-me but the way Ray Jayawardhana handles the rhythms of the various theories, experiments and missteps -- not to mention his perfect pitch for just the most illuminating/winning anecdotes and quotations to share from a colourful cast of physicists -- should make this appeal to a much wider audience.

Read Ng says

This was a GoodReads giveaway.

I was not sure I really wanted to read this. I had my own struggles getting through college physics. Was I going to find this unpleasant? Well, it turned out that I quite enjoyed this telling. Of course modern physics is vastly different then, than it is today. And subatomic physics even more so. There is a great history of the development of subatomic theory that I was never really aware of. That's the problem when you study physics versus studying the history of physics. This story does not delve into heavy theory. But it does a good job of the developing chase. Perhaps I should have been a student of history instead of science?

Anyway, have a GoodReads.

Charlene says

If you are not already in love with the neutrino hunters who are spread all around the globe, trying to understand how matter came into existence, after this book, you will be. You won't be able to help falling in love with:

- The simple way in which Jayawardhana walks you through the science
- The wonderful history he provides of a few scientists (see end of review for his history of Paul Dirac**)
- His EXCELLENT explanations of the experiments going on right now (and making news!)
- And his ability to convey the implication of all of it -- the history, the science, the testing.

Neutrinos themselves might hold the answer to how everything we see today, every last bit of matter, might have come into existence. Neutrinos might have been the key regulator to ensure that you exist today to read this book. Often the articles, even the short blurbs from PopSci sites, require the reader to have at least some education in physics. Jayawardhana will give you all the prerequisite education you need to understand the new and exciting experiments that have been making the news as of late. I will post links to articles below.

**One of my favorite asides in the book was Jayawardhana's depiction of Paul Dirac, who won the Nobel Prize in Physics in 1933, but was so shy, he tried to refuse the award so he didn't have to go the ceremony. He hated personal attention that much.

Physicists seemed to appreciate his physics but were often annoyed because when they met with him in person, he would barely say anything. Colleagues coined the term "the Dirac" to define the fewest number of words a person could mutter per hour while still taking part in the conversation.

Loved this book!

Some supplemental material that is quite helpful in really emerging yourself in the world of neutrinos:

Articles:
http://www.symmetrymagazine.org/artic...

http://discovermagazine.com/2014/sept...

Video explaining the Nobel Prize:

http://www.bbc.co.uk/programmes/p034j...

Video explaining matter / antimatter imbalance (symmetry):
https://www.youtube.com/watch?v=fjkLj...

Megan Larsen says

Great for someone with a basic understanding of chemistry or physics who wants to go a bit deeper. A little dry at time because of the level of detail but overall a good read and great introduction to "quirky" science.

Sajith Kumar says

Only a few years back, a storm of protests broke out in the Indian state of Kerala over the proposed construction of a neutrino observatory on the state's border with Tamil Nadu. Politicians, including the then opposition leader of the state – who was uneducated – came on the scene amid much fanfare, extolling the dangers caused by neutrinos! Though the protests petered out in a few weeks, it was the first time ever in the world that neutrinos became controversial. It was projected out of all proportions by a section of the ignorant media who had no idea what they were talking about. 'The Neutrino Hunters' is a fine book that will alleviate all concerns a thinking person may normally have on what a neutrino is, and why it is incumbent on the scientific world to detect it. We are familiar with several byproducts of the research on nuclear physics that eventually made people's lives better. Neutrino research is still in its infancy, but exciting possibilities abound for its further development. Ray Jayawardhana was born and raised in Sri Lanka. After receiving his PhD from Harvard, he is now Dean of the Faculty of Science at York University. He has bagged many awards and authored several books on popular science. His primary research areas include the formation and early evolution of stars, brown dwarfs and planets.

The atom's nucleus is a storehouse of mysterious operations taking place spontaneously as if by magic. But don't be mistaken – all the activities are catalogued in fine detail by the rules of quantum mechanics. Neutrons in the nucleus are generally stable, but they sometimes undergo a transformation to change into a proton, which is also a constituent of the nucleus. In this process, a proton is thus formed, in addition to an electron, which is a beta ray. This process is called beta decay. When this phenomenon was discovered in the early-20th century, scientists found an anomaly, which was perplexing. If you tally the amounts of energies involved with the constituents which underwent change against the new particles which were formed, there was a minuscule shortage in the latter quantity. This is an apparent violation of the law of conservation of energy, which in physics is akin to blasphemy in a theocracy. Some scientists however, took the risk of claiming that beta decay doesn't obey the sacrosanct rule of nature. Wolfgang Pauli, of the Exclusion Principle fame, suggested a way out of this dilemma. He postulated that the missing energy may be of the form of a new kind of particle, having no charge, but a very small mass. Since the term 'neutron' was already around to denote a different particle, this new particle was named 'neutrino', or 'little neutron' in the Italian language. The mass of the neutrino being very, very small, and having no charge, Pauli hazarded a guess that it may not be physically possible to detect a neutrino in the lab. Science is an avenue where challenges are met with gusto, by pioneers in search. Immediately after the identification of the particle, the academic community started the search for it.

The search party was successful in the mid-1950s when nuclear reactors became a craze for developed countries. Fred Reines and Clyde Cowan were triumphant in detecting neutrinos emerging from nuclear test explosions and ordinary nuclear reactors. It was evident for scholars that neutrinos being very light, it passes through the earth without colliding with another corpuscle. Massive detectors are required to trap such particles. An ingenious way was developed to address this issue. When neutrinos hit a particle of water or carbon tetrachloride or any such material, a neutron is converted into a proton, along with release of a photon. This photon produces visible light of a light blue shade. So, if large number of phototubes is

arranged over a gigantic collection of such liquid, researchers may be able to detect the light flashes occurring rarely enough, even though trillions of neutrinos pass through the earth and each one of us every second. Scientists built massive detectors in mines, hundreds of meters down from the ground level, in order to avoid unwanted noise from neutrinos generated by atmospheric gases being hit by cosmic rays. Apart from this, the sun is the most abundant neutrino source on account of the nuclear reactions taking place in its core. John Bahcall made an estimate of the neutrinos produced normally in the sun which can be detected on earth. Another physicist, Ray Davis, set up a detector in Homestake gold mine in the U.S. Davis found only a third of the neutrinos predicted by Bahcall's theory. A controversy raged on the soundness of the theory and the methods of detection. Later, researchers showed that neutrinos come in three varieties or flavours as they are called – electron neutrino, muon neutrino and tau neutrino – which oscillate between the states midflight on its journey to earth. As the detector was able to trap only one kind of neutrinos, the count appeared to be one-third of the total predicted by theory. This shows the commendable level of understanding we have reached on what happens in the sun's core.

Neutrino bursts precede appearance of supernova events in the sky. Study of neutrinos is very relevant for understanding the processes going on inside stars during its origin, midlife, and end. In 1987, a supernova was seen suddenly on a cold February night in the Large Magellanic Cloud galaxy. Even though supernovae occur very frequently, one that can be seen by the naked eye is rare and was last observed way back in 1604. Naturally, astronomers were delighted to observe this phenomenon. It was also the time for neutrino hunters to jump in and take credit for their findings. Theory predicted that a neutrino stream generated in the supernova should have struck earth even before its visible light reached us. Don't think that neutrinos travel faster than light – it is only that visible light may be obstructed by gas or dust clouds, but neutrinos pierce through them with ease. All the world's leading neutrino detectors poured over their records and found that exactly such a stream had hit their instruments three hours before the celestial flare lit up the night sky.

Jayawardhana reserves the last chapter of the book to desperately enumerate the practical applications of neutrinos that are helpful to humanity. Even though we can wax eloquent at the dearth of funding insensitive politicians earmark for scientific research out of public funds, there is no denying that scientists have to show some benefits anticipated out of the new area of research for which money is being sought. Studying neutrinos is immensely helpful in learning more about the origin of the universe in its earliest seconds, the death throes of stars which spread the heavy elements essential for life in a supernova explosion and the processes going on inside the earth that maintains the temperature of its core. Moreover, as neutrinos are not hampered by any obstacles in its path, faster communication links can be developed out of an intense beam. The author's arguments are earnest, but seem to be a little too farfetched, considering the still early stage of the neutrino theory.

The book is nicely written, with scientific ideas conveyed in an accessible manner to all classes of readers. Jayawadhana's description of the 'IceCube' detector in Antarctica provides an exciting introduction to the narrative that follows. Also, his firsthand experience in visiting the Sudbury Neutrino Observatory (SNO) in Canada, by going more than a mile underground in a mine elevator is a fine example of the author's power to rivet the attention of the reader. The book includes extensive Notes for follow up reading and a helpful Index. A neat timeline of major events associated with neutrinos and an impressive glossary adds much utility to the book. A few monochrome photographs are also included, but lack correlation with the text. The book follows the standard pattern of including short biographical sketches of scientists mentioned in the text. If you are already familiar with them from other books, this may appear a bit dull.

The book is highly recommended.

Richard Needham says

I thought it would be good to know a little more about neutrinos, the elementary particles that pass through our bodies at a rate of billions per second and through the earth as if it wasn't even there. I knew a little about neutrinos (and antineutrinos) from college physics (they originate when a proton transforms to a neutron or vice versa during beta decay or nuclear fusion and solve the problem of why energy didn't seem to be conserved in that process; they were postulated by Wolfgang Pauli and named rather charmingly by Enrico Fermi as 'little neutrals'), but this nicely written and accessible book does an excellent job of explaining why they are among the most abundant particles in the universe, the history of their prediction and discovery (hard to discover since they rarely interact with matter, so how do you detect them?), and some fascinating recent advances which indicate that neutrinos have 'flavor' and therefore must have mass.

The many neutrino detectors now present throughout the world today are part of the well-told story, and how they each approach neutrino detection and analysis differently is presented (from the massive 'Ice Cube' detector in Antarctica to mile-deep caves in different countries to the KATRIN neutrino spectrometer in Karlsruhe Germany (see the photo on page 173 for this two-story alien-looking structure being squeezed between houses at the end of a 2000 mile sea journey when it was built only 250 miles away!). In short, this book presents the neutrino and its significance very engagingly, with no equations and few diagrams (I wouldn't have minded a little more of each) and with a nice historical perspective. Highly recommended for its timeliness and significance to modern day particle physics.

Steven Eisenberg says

Most books of this type are written from the theorists perspective. Not this. It's a wonderful history of the experimental approaches and future experiments.

As an experimentalist, I loved it. For the casual reader, it's very, very dense.
