Detecting Waves and Particles Around the World – and Beyond!

Gerald A Smith, PhD,
Professor Emeritus (Physics)

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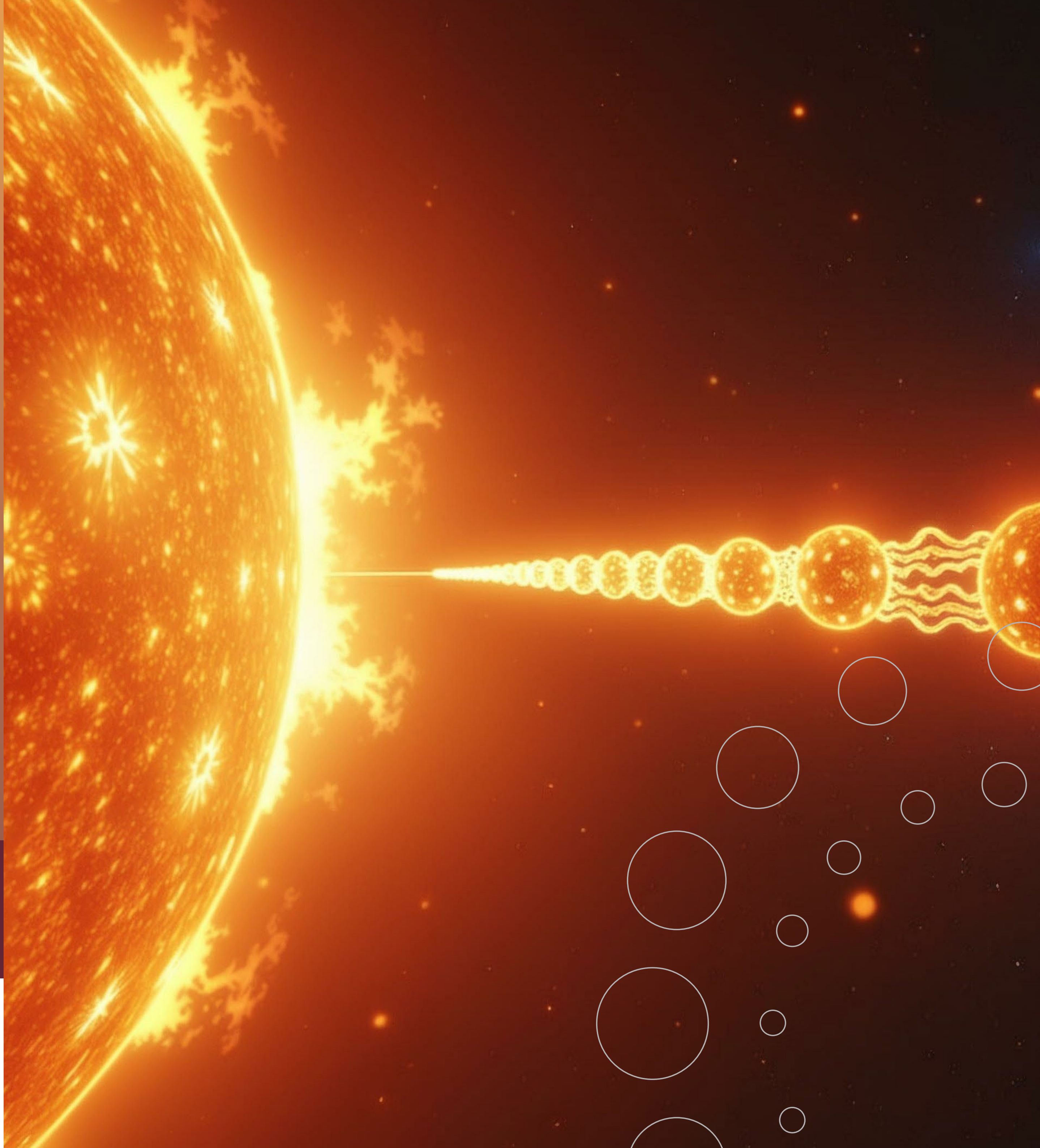
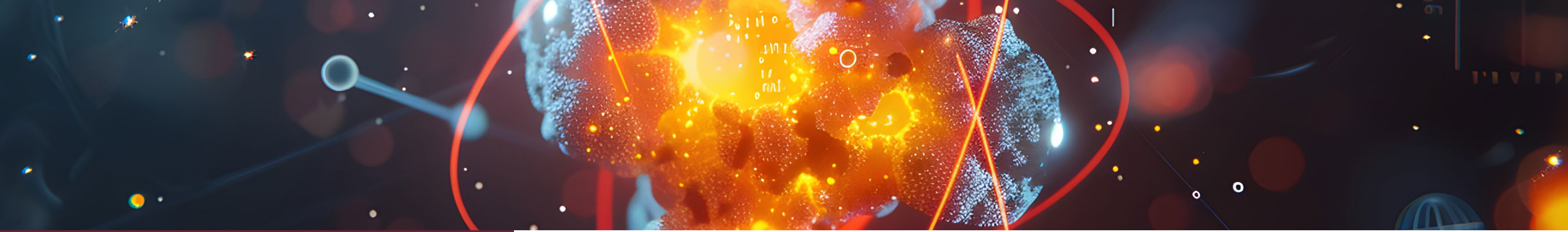




Detecting Waves and Particles Around the World – and Beyond!

The magnetic field around our planet, along with unique radioactive decay processes, can cause the generation of Alfvén waves. Dr Gerald Smith of Positronics Research LLC has been researching how we can observe these waves and the unique atoms formed in these processes. By looking at data locally and how these particle events are represented at telescopes and monitoring systems around the globe, Dr Smith observes their impacts and points to their potential in future interplanetary exploration.

Testing for Positronium States and Alfvén Waves

On Earth, our planet has its own weak magnetic field, and this magnetic field can impact particles around us. If the air around us is hydrated (containing more water vapour), a rare radioactive decay process can occur. Beta-plus decay (also known as positron emission) occurs when a radioactive material decays and emits an electron neutrino (a small, non-charged particle) and a positron. Positrons have the same mass as electrons, but the negative charge carriers that form part of the atom have a positive charge instead.

Positrons can form a rare system called positronium, which consists of an electron and a positron. Typically, this state is very unstable and has a short lifetime – the electron and positron usually quickly collide to produce gamma radiation. However, in unique conditions, such as the positronium being formed in a weak magnetic field, longer-lived positronium atoms called outer-well positronium atoms (OWPs) can be formed. These OWPs can form a type of wave called an Alfvén wave, where the oscillation occurs due to the small mass of the positronium and the force from the magnetic field.

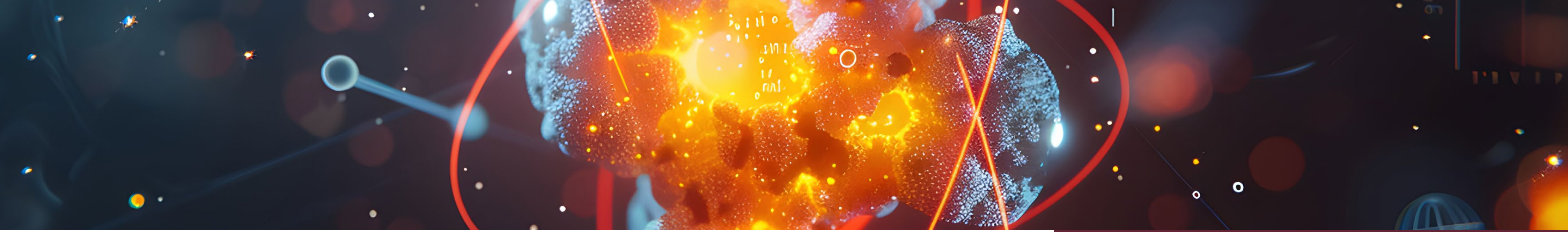
Dr Gerald Smith of Positronics Research LLC examines these fascinating phenomena with an experimental set-up consisting of an inflated rubber balloon placed between two Geiger counters, which detect and measure radiation. These counters form part of a circuit to identify coincidences, which, in simpler terms, means when both counters observe radiation simultaneously. A weakly radioactive source of sodium-22, which decays to emit positrons, is placed on top of the balloon, and two magnets are placed on opposite sides of the balloon to generate a magnetic field which acts as a trap for the positronium. This experiment takes place in Scottsdale, Arizona, on one of the Earth's circular magnetic field lines, where the field offers the possibility of generating OWPs.

Measuring Positrons and Alfvén Waves around the Globe

First, Dr Smith looks at the results for his trap in Scottsdale, showing how the coincidence measurements from his Geiger counter set-up agree with previous literature values, and showing that positrons can be trapped here for around 1.5 nanoseconds. He also suggests that the oscillations in the output data are Alfvén waves formed due to the collisions between electrons and positrons.

Dr Smith also considers how OWPs might travel along the Earth's magnetic field line between his experiment in Scottsdale and the Isla de Pascua Mataveri (IPM) magnetometer station on Easter Island, which can measure changes in the Earth's magnetic field. In Dr Smith's experiment, the conditions required to produce stable Alfvén waves are present, and the magnets are removed from his experiment to look at the Alfvén waves in Earth's magnetic field.

Both data from the experiment in Scottsdale and at Easter Island are considered. By using Earth's magnetic field, standing Alfvén waves are produced – a standing wave oscillates in time, but the peaks do not move in space, like the oscillation seen when we pluck a guitar string – and the reflections of these waves can be seen at each of the experimental stations. In Scottsdale, oscillations can be seen in the coincidence data. At IPM on Easter Island, magnetograms are recorded, which show how the magnetic field of the Earth varies over time. Once corrected for different contributions, such as from tidal activity, Dr Smith uses zero frequency limits (ZFLs) to identify potential OWPs. ZFLs are the time for the field to fall to zero and then return to the baseline reading. Due to the properties of the OWPs, they can be a cause of these intervals. By identifying these in the data, Dr Smith can calculate the lifetimes and probabilities of outer-well positronium atom events.



Impacts of OWPs and Alfvén Waves

During the time this data was being recorded, a coronal mass ejection occurred at the Sun – this occurs when the outer layer of a star expels magnetic field and plasma (matter that largely consists of particles with a charge). After this, there was a geomagnetic storm, causing a temporary disturbance in the magnetosphere, or the space around the Earth affected by its magnetic field. Dr Smith calculates how double helix pair annihilation could be capable of producing this kind of storm. Double helix pair annihilation occurs when two particles rotate around each other in a spiral pattern, similar to the double helix structure seen in DNA, before an annihilation process between the two particles, which could occur with OWPs.

Another interesting outcome of this experiment was the observation of fast radio bursts – these are radio waves but, again, have a double helix structure. These could be caused by outer-well positronium atom annihilation, and evidence of these was seen at the Australian Widefield Array (MWA) radio telescope, across the Pacific Ocean from Easter Island, and at the Chinese FAST radio telescope across from Scottsdale. The distances between MWA and Easter Island and between FAST and Scottsdale are similar. Both MWA and FAST recorded fast radio bursts at around the same times, with similar times between the pulses.

Excitingly, Dr Smith highlights how these Alfvén waves using positrons could be used in space, considering how these waves could be used to send transmissions between planets or to be used as a probe to discover more about our solar system. If these waves are launched at, for example, Jupiter or its surrounding moons, interactions and annihilations could occur between the OWPs and ionic nuclei from the planet or moon. The signatures we see from these interactions could tell us about different minerals that exist there or give insight into the compounds present at the beginning of life on Earth.

Overall, Dr Smith's work on OWPs and Alfvén waves shows how these positrons can be trapped and confined by magnetic fields, both in his lab in Scottsdale and using the Earth's magnetic field lines. From this, we can see signatures of these particles across the globe, from the IPM magnetographs on Easter Island to the radio telescope signatures at MWA and FAST. Dr Smith's work could also pave the way to learning more about our solar system, discovering more about rare minerals and even the compounds which led to life on Earth.

Article written by Imogen Forbes, MSci

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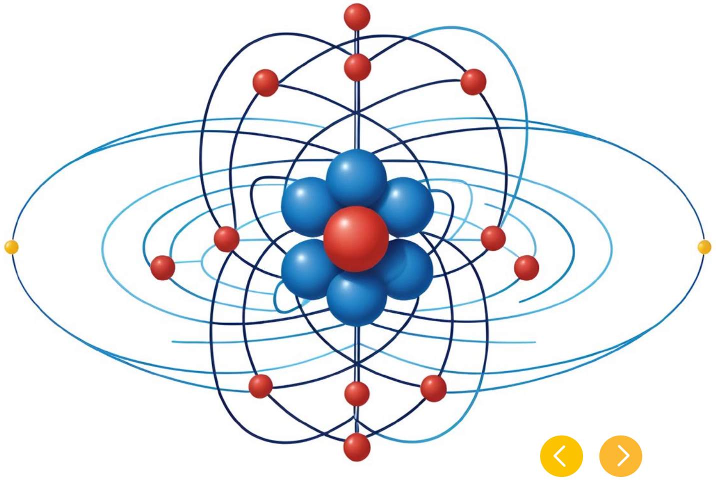
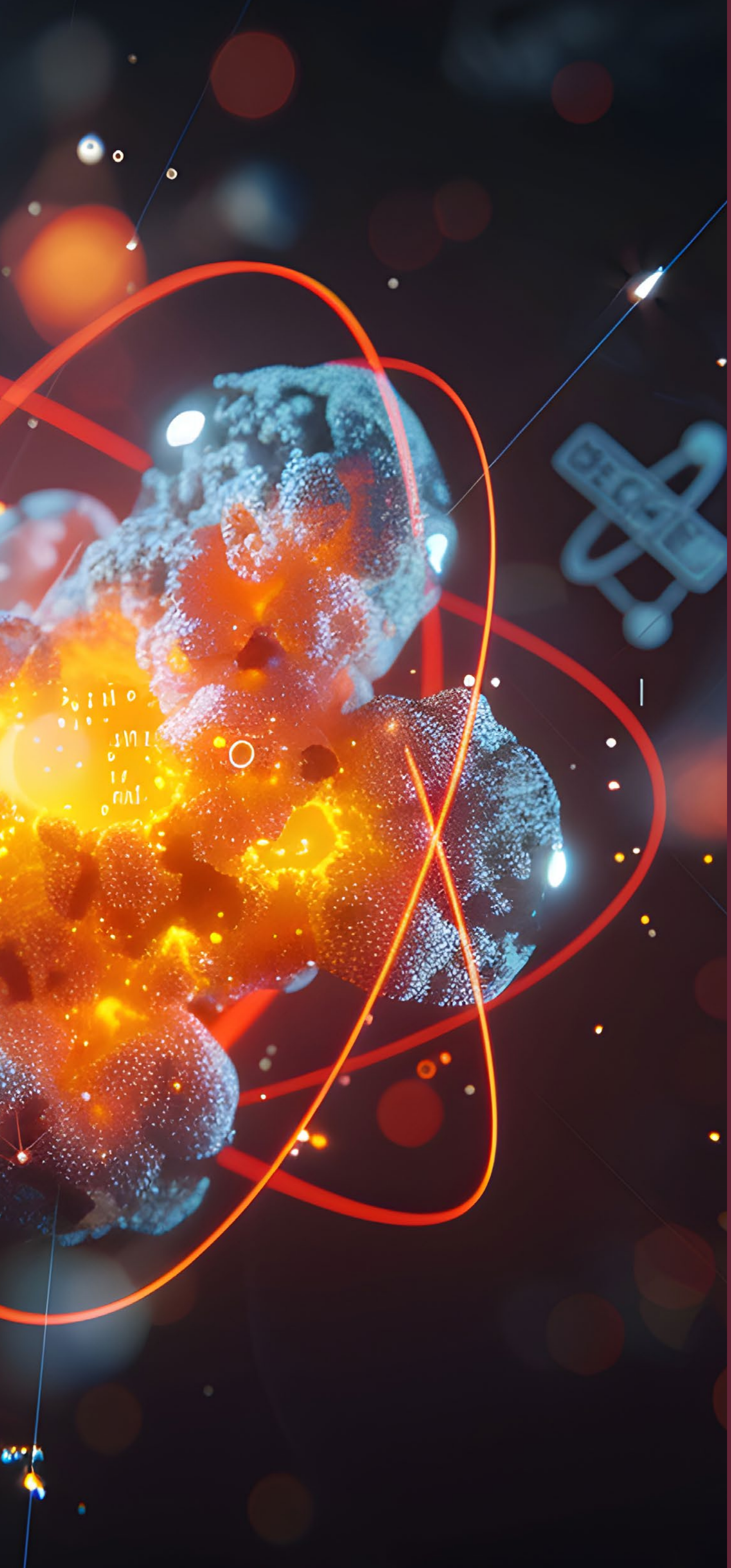


Simplified atomic model illustrating positronium with red positrons and blue electrons orbiting a central point.



MEET THE RESEARCHER

Gerald A Smith, PhD, Professor Emeritus (Physics)
Penn State University, Pennsylvania, PA, USA, Owner Positronics Research LLC,
Scottsdale, AZ, USA

Dr Gerald Smith grew up in Cuyahoga Falls, Ohio, and received his BA in physics (magnum cum laude) from Miami University (Ohio) in 1957. He received MS and PhD degrees from Yale University in 1958 and 1961. From 1961 to 1967, he was a lecturer and assistant professor in Nobel Laureate Luis Alvarez's research group at UC Berkeley, where he co-discovered several elementary particles using bubble chambers.

In 1968, he formed an experimental high-energy physics group at Michigan State University supported by the National Science Foundation. He was spokesman for one of the first experiments at the new Fermi National Accelerator Laboratory in Chicago from 1971 to 1972, followed by work at Argonne National Laboratory, Brookhaven National Laboratory, Stanford Linear Accelerator Center, and the Low Energy Antiproton Ring at CERN (Geneva, Switzerland). He also served as Associate Laboratory Director for High Energy Physics on leave from Michigan State at Argonne in 1978.

In 1983, he became Physics Department Head and Director of the Laboratory for Elementary Particle Science at Penn State University. His group continued antiproton work at CERN in meson spectroscopy, and later studied heavy quark formation in antiproton-proton annihilations at Fermilab and high-energy heavy ion collisions at Brookhaven. He developed portable antiproton traps for the NASA Jet Propulsion Laboratory and Marshall Space Flight Center. He became Professor Emeritus of Physics in 2000.

In 2000, he retired from Penn State and, in 2001, founded Positronics Research LLC in Santa Fe with support from the US Air Force. It developed solutions to space propulsion problems using novel positron devices. Clients included the USAF, DTRA, DARPA and NASA. Recent work involved material studies with Miami University for the Timken Company. During his career, he raised more than $20M of external research funding and has over 300 publications, 200 invited lectures, and eight patents. He is a Fellow of the American Physical Society.

✉ CONTACT

gerry@pr-llc.com
+1 (602) 315-9475