

The Oh-My-God Particle

by [John Walker](#)

January 4, 1994

Fly's Eye

The [University of Utah](#) operates a cosmic ray detector called the [Fly's Eye II](#), situated at the Dugway Proving Ground about an hour's drive from Salt Lake City. The Fly's Eye consists of an array of telescopes which stare into the night sky and record the blue flashes which result when very high energy cosmic rays slam into the atmosphere. From the height and intensity of the flash, one can calculate the nature of the particle and its energy.

On the night of October 15, 1991, the Fly's Eye [detected a proton](#) with an energy of $3.2 \pm 0.9 \times 10^{20}$ electron volts.[1,2] By comparison, the recently-canceled Superconducting Super Collider (SSC) would have accelerated protons to an energy of 20 TeV, or 2×10^{13} electron volts—ten million times less. The energy of the Oh My God particle seen by the Fly's Eye is equivalent to 51 joules—enough to light a 40 watt light bulb for more than a second—equivalent, in the words of Utah physicist [Pierre Sokolsky](#), to “a brick falling on your toe.” The particle's energy is equivalent to an American baseball travelling fifty-five miles an hour.

All evidence points to these extremely high energy particles being protons—the nuclei of hydrogen atoms. Recalling that the rest mass of the proton is 938.28 MeV—roughly 1 GeV, 1×10^9 eV, all of the rest of the particle's energy results from the kinetic energy resulting from its motion, which we can calculate according to basic formulæ of [special relativity](#). So let's crunch a few numbers.

Microbial Mass

First of all, noting that mass and energy are equivalent, we can calculate the rest mass equivalent of a 3×10^{20} eV particle to be about 5×10^{-13} grams. That doesn't sound like much until you recall that this is about 3×10^{11} daltons (chemists measure molecular mass in daltons, where 1 dalton is the mass of a hydrogen atom), just about the same as a single cell of the intestinal bacterium *E. coli* (5×10^{11} daltons). Thus this single subatomic particle had a mass-energy equivalent to a bacterium.

How Fast?

How fast was it going? Pretty fast. The total mass-energy of a particle is given in

Galactic nucleus	32,000	3.2 seconds
Andromeda galaxy	2,180,000	3.5 minutes
Virgo cluster	42,000,000	1.15 hours
Quasar 3C273	2,500,000,000	3 days
Edge of universe	17,000,000,000	19 days

Thus, if you [could accelerate yourself](#) to the speed at which the Oh My God particle was traveling, you'd be able to travel to the edge of the visible universe in a couple of weeks. Unfortunately, even assuming you found a source for the energy it would take and invented a means to accelerate yourself and Intergalactic Vessel [Omega Point](#) to this velocity, you wouldn't get far before being disrupted into subatomic goo due to interactions with photons in the ubiquitous cosmic microwave background radiation. Sokolsky has calculated that at 3×10^{20} eV, even a single proton could travel no farther than 10 megaparsecs, about the distance of the Virgo galaxy cluster, before losing energy in this manner.

Warp Factor Oh-My-God—Engage!

It is interesting to observe that a real particle, in our universe, subject to all the laws of physics we understand, is a rather better interstellar voyager than the best fielded in the 24th century by the [United Federation of Planets](#). Their much-vaunted Galaxy Class starships are capable of speeds slightly in excess of Warp Factor 9, an apparent velocity of 1516 cochranes (or 1516 times the speed of light).[4] At a velocity of $1516 c$, traveling to the centre of the galaxy would take, as perceived by the life forms on board, a little more than 21 years. By contrast, an observer on board the Oh-My-God particle would arrive at the nucleus of the Milky Way, according to his clock, just about 3 seconds after leaving Starbase Terra. That's more than 9,700,000 times faster than the starship. In the time the starship spends vacuum-whooshing and rumbling its way to the nearby star Aldebaran, the particle could travel to the edge of the visible universe.

Go Fast—Grow Thin

Finally, let's consider the length contraction in the direction of motion which results from the Lorentz transformation—objects in the direction of travel are seen to contract in that direction by a factor of:

$$\frac{l}{l_0} = \sqrt{1 - \frac{v^2}{c^2}}$$

And thus, paralleling the time dilation calculated above, in the frame of the particle, oncoming objects are seen as contracted by a factor of 3×10^{11} , three hundred billion times, in thickness. Thus, seen from the particle, the objects below will have

the following thickness.

Object	Rest Frame Thickness	Particle Frame Thickness
Earth's diameter	12,756 km	0.0399 mm
Solar system	80 AU	37 metres
Sun/Alpha Centauri	4.3 light years	127 km (79 miles)
Milky Way galaxy	30 kiloparsecs	2,895,000 km, about ten times the distance from the Earth to the Moon

But How?

How was such an extraordinary particle created? What cosmic process accelerated a mundane proton to a brick-on-the-toe-energy?

Nobody knows. A particle with such energy would be deflected little by galactic magnetic fields, and so its impact track should point right back at the source. [Astronomers see nothing unusual](#) in that direction.

Nature remains rich in mysteries.

References

1. Physical Review Letters, 22 November 1993.
2. G. Taubes, Science 262, 1649 (1993).
3. Ottewell, G. *The Astronomical Companion*. Greenville SC: Astronomical Workshop, 1979–1992. ISBN 0-93456-01-0.
4. Sternbach, R. and M. Okuda. *Star Trek: The Next Generation Technical Manual*. New York: Pocket Books, 1991. ISBN 0-671-70427-3.

Disclaimer

These calculations involve some elementary but easy to mess up algebra and some very demanding numerical calculations for which regular IEEE double precision is insufficient. If you'd like to double-check these results, be sure to use a multiple precision calculator with at least 30 significant digits of accuracy. I generally use [Mathematica](#) for symbolic work and Mark Hopkins' package C-BC for number crunching. It's entirely possible I've made one or more mistakes of order-of-magnitude or greater significance. But even so, (and please correct me!), this is, particle physics wise, a genuine Oh Wow event.

by *John Walker*