Phantom Particles Not of This World: Unparticles

By Mark A. Martinez II

In 2007, while contemplating what results the Large Hadron Collider (LHC) in Cern would produce and what new particles would be found, Harvard physics professor Howard Georgi came up with an astounding idea. What if no new particles were found? He theorized that this "stuff," which is completely unchanged if its momentum and mass are changed (scale invariant), has very little mass, but is not a photon (light). The closest analogue would be a neutrino, a very low mass particle, but even a neutrino is not truly scale invariant. What would one call this seemingly odd "stuff" that is clearly not a particle or a photon, but could possibly be a vital part of understanding physics?

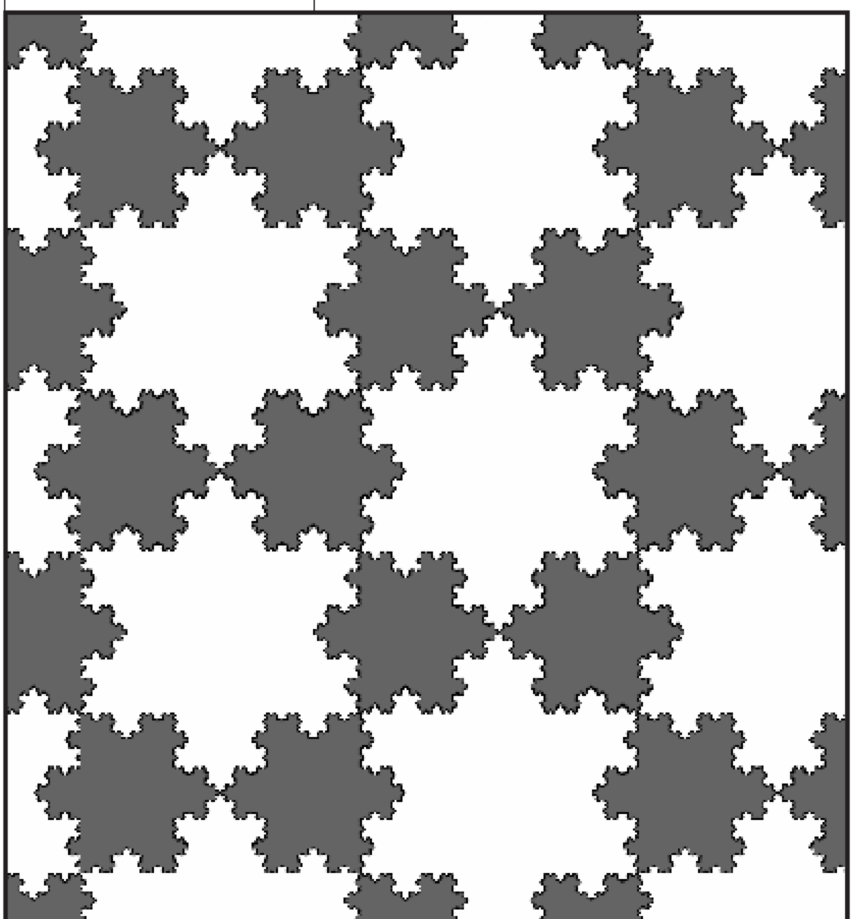
Unparticles of course!

Howard Georgi is not completely new in the field of theories of particles not existing. Before his publication of "Unparticle Physics" in 2007 in Physical Review Letters, he did research in Higgsless Theories (1). The Higgs-boson is what is strongly believed to be the particle that gives all other particles mass, but it has not been observed yet. However, this research did not turn out to be as fecund as initially hoped, with Georgi lamenting in his article that, "Sadly, I conclude, in agreement with previous analyses, that the promise of Higgsless theories is unlikely to be realizable, even in this more general class of theories. But I hope that the reader will find that this analysis is sufficiently unusual to justify the term "fun" in the title."

Unparticle Physics, by contrast, has created a storm of interest in physicists worldwide, with, at time of writing, 206 articles citing it since its initial publication (2)! Unparticles intuitively do not seem to make much sense; after all, there is nothing like them that has been observed yet. Georgi argues in his 2007 article that although finding new particles that the other theories of physics such as Super Symmetry suggest would be amazing, they would in the end just be new particles, but "unparticle stuff with nontrivial scaling would astonish us immediately."

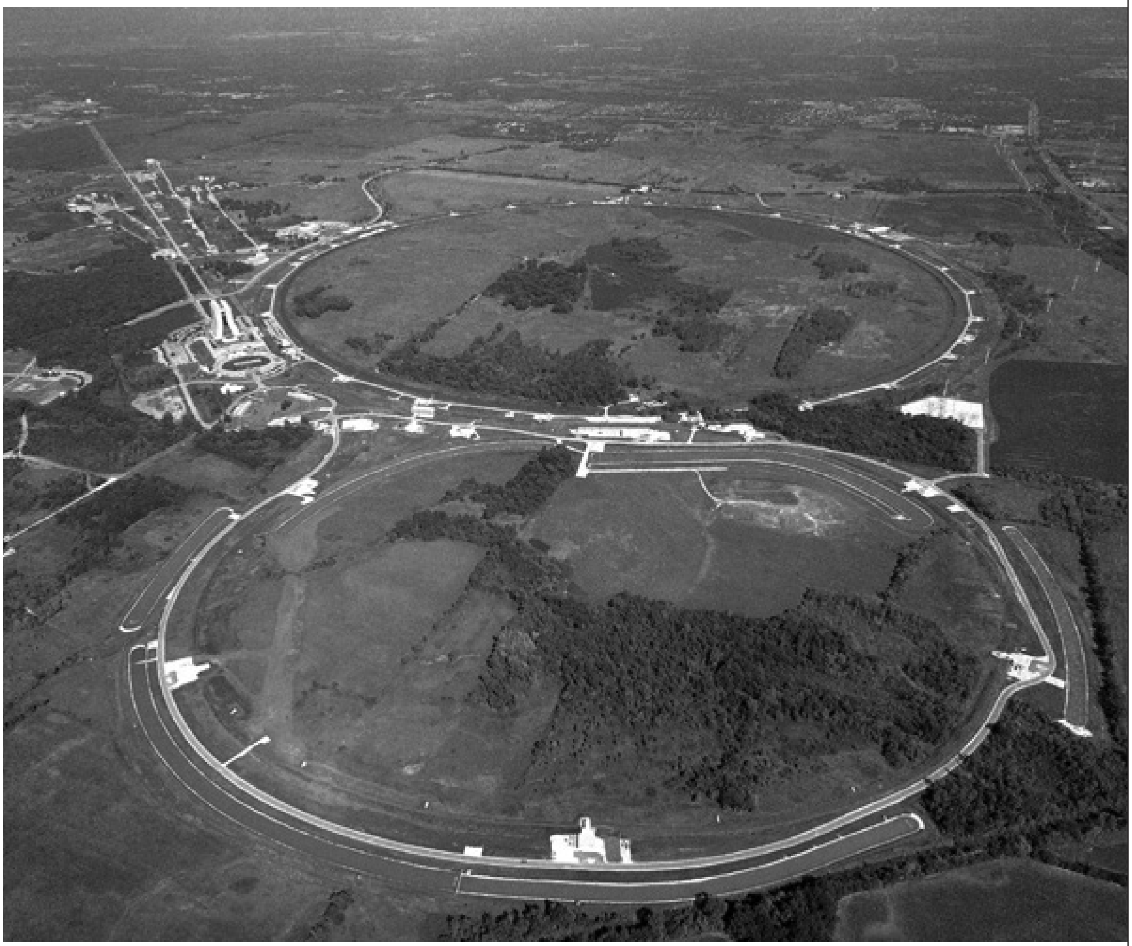
Unparticle Physics is an attempt to unite two fields of physics, The Standard Model and the Bank Zaks field. The two are normally mutually exclusive but that is only when dealing with particles. Bank Zaks fields do not interact with ordinary matter at low energies, but they would with unparticles which do not exhibit the same scale variance as particles (3). Scale invariance can also be thought of physically. The Koch Snowflake is the most common fractal.

No matter how much you were to zoom into one of the branches, the zoomed in por-



▲ **Figure 1.** This image gives possibly the most famous example of a fractal-the Koch Snowflake. A fractal is special because no matter how much one were to zoom into one of the edges of any snowflake, the image produced would be the exact same one as if it were not zoomed in.

Unparticles can be seen as analogous to fractals in this respect because they are constant under any change.



◀ **Figure 2.** This is a picture of an accelerator at Fermilabs in Batavia Illinois. This overview picture displays the size scale of particle accelerators.

tion would look exactly the same as the macroscopic portion. This property translates to unparticles. No matter what you change about it, the unparticle does not change at all.

Unparticles would not be able to be tested directly since they only interact with normal particles very weakly but instead would be detected by calculating missing energy. Because of the conservation of energy, energy is never destroyed but is only translated into other forms. By analyzing what would appear to be a deficit of energy in a collision reaction, it would be possible to see that some of the energy went into becoming an unparticle. Since the unparticles are so weakly interacting only a very strong collision, like one powered by the LHC, would exhibit the presence of these unparticles (4, 5).

Although no conclusion has been reached about if unparticle stuff actually exists and are a part of the physical model of the universe, a very large amount of theoretical research has already been done. It has been shown that when a collision does occur at the LHC, the presence of unparticles are large enough that they can be detected. But until then, unparticles will live in the realms of mystery that supersede mass and do not interact directly with particles of this world. H

—Mark A. Martinez II '14 is a Computer Science and Math concetrater in Adams House.

References:
1. Howard, Georgi. "Fun With Higgsless Theories" Phys. Rev.D71:015016,2005
2. Howard Georgi. "Unparticle Physics." Phys. Rev. Lett. 98, 221601 (2007)
3. Howard Georgi, Another odd thing about unparticle physics, Physics Letters B, Volume 650, Issue 4, 5 July 2007, Pages 275-278, ISSN 0370-2693, 10.1016/j.physletb.2007.05.037.
4. Kingman Cheung, Wai-Yee Keung, Tzu-Chiang Yuan. "Collider Signals of Unparticle Physics." Phys .Rev.Lett 99. 051803, 2007.
5. Tatsuru Kikuchi, Nobuchika Okada, Michihisa Takeuchi. "Unparticle physics at the photon collider." Phys. Rev. D 77, 094012 (2008)

credit: http://musicog.ohio-state.edu/Huron/Publications/huron.arch.text.html; musicmindandbrain.wordpress.com