







**Figure 2:** Ptolemy vs. Copernicus. Since a large number of epicycles of very convenient sizes and orientations need to be added to get the required accuracy in Ptolemy's model, we consider his geocentric theory to be fine-tuned and "unnatural." We thus prefer the much simpler heliocentric theory proposed by Copernicus.

reach by simply fiddling with their constants—and thus keep justifying their research (and their funding). These modifications make the theory more fine-tuned and thus less natural and elegant.

The trouble is that the concept of naturalness is purely human, and does not necessarily have anything to do with the universe we live in. Indeed, when there is no experimental evidence clearly falsifying one theory or another, the choice of which one to use often becomes a matter of taste. For instance, in discussing a possible modification to supersymmetry in his paper "The State of Supersymmetry after Run I of the LHC," author Nathaniel Craig, a physicist at the Institute for Advanced Study at Princeton University, evaluates the modified theory by noting that "there is no reason it can't be there, but it's fairly unsatisfying as a theory

of nature."<sup>8</sup> There is, however, no quantitative reason to reject a theory simply for being "unsatisfying."

On the other hand, historically, similar cases have demonstrated that the simpler theory is usually correct. For example, Ptolemy clung to the geocentric idea of the solar system by proposing that heavenly bodies moved around the earth in multiple nested circles called epicycles. By arbitrarily adjusting the number and size of epicycles in his model, he could make his theory as accurate as desired.<sup>10</sup> In contrast, Copernicus proposed a much simpler heliocentric model of the solar system, with Newton later providing the underlying physical explanation for this model. Despite the matching accuracy of both theories, Copernicus' more elegant heliocentric model of the solar system is what ultimately proved to be the more correct one. Be it theories of

the solar system or those of the expanding universe, scientists have had to develop new theories whenever the reigning ones have required overly contrived modifications.<sup>11</sup>

This dilemma leaves physics at an interesting crossroad, one in which the debate over the validity of a theory is, to a certain extent, philosophical rather than scientific in nature. Young researchers entering the field now have a difficult choice to make: continue efforts at justifying the absence of experimental evidence by fine-tuning—hoping that some evidence shows up sooner rather than later—or break away and explore radically different ideas. Which way should future research go? This debate, regardless of how it is resolved, will have an immense impact on the future of theoretical physics. It is indeed an exciting time to be a physicist.

## REFERENCES

1. Feynman, R., Leighton, R., & Sands, M. (1963). *The Feynman Lectures on Physics: Volume 1* (2nd Edition ed., Vol. 1).
2. Oerter, R. (2006). *The Theory of Almost Everything: The Standard Model, the Unsung Triumph of Modern Physics*: Penguin.
3. Shifman, M. (2012). Reflections and Impressionistic Portrait at the Conference "Frontiers Beyond the Standard Model," FTPI, Oct. 2012. Retrieved from <http://arxiv.org/abs/1211.0004>.
4. Was, Z. (1994). Radiative corrections (No. CERN-TH.7154-94). P00020602.
5. Wolchover, B. (2016, August). What No New Particles Means for Physics. *Quanta Magazine*. Retrieved from <https://www.quantamagazine.org/what-no-new-particles-means-for-physics-20160809/>.
6. Tata, X. (2015). Supersymmetry: Aspirations and Prospects. *Physica Scripta*, 90(10). doi:10.1088/0031-8949/90/10/108001.
7. Khalil, S. (2003). Search for supersymmetry at LHC. *Contemporary Physics*, 44(3), 196. doi:10.1080/001075103100077378.
8. Craig, N. (2013). The State of Supersymmetry after Run I of the LHC. Retrieved from <http://arxiv.org/abs/1309.0528>.
9. Baer, H., Barger, V., & Mickelson, D. (2013). How conventional measures overestimate electroweak fine-tuning in supersymmetric theory. *Physical Review D*, 88(9). doi:10.1088/0031-8949/90/6/068003.
10. Jones, A., (1998). Ptolemaic System. In *Encyclopaedia Britannica*. Retrieved from <https://www.britannica.com/science/Ptolemaic-system>.
11. Hawking, S., Mlodinow, L. (2010). *The Grand Design*: Bantam.