CP violation or new physics?

July 25 2016, by Lisa Zyga

This is the "South Pillar" region of the star-forming region called the Carina Nebula. Like cracking open a watermelon and finding its seeds, the infrared telescope "busted open" this murky cloud to reveal star embryos tucked inside finger-like pillars of thick dust. Credit: NASA

(Phys.org)—Over the past few years, multiple neutrino experiments have detected hints for leptonic charge parity (CP) violation—a finding that could help explain why the universe is made of matter and not antimatter. So far, matter-antimatter asymmetry cannot be explained by any physics theory and is one of the biggest unsolved problems in cosmology.

But now in a new study published in *Physical Review Letters*, physicists David V. Forero and Patrick Huber at Virginia Tech have proposed that the same hints could instead indicate CP-conserving "new physics," and current experiments would have no way to tell the difference.

Both possibilities—CP violation or new physics—would have a major impact on the scientific understanding of some of the biggest questions in cosmology. Currently, one of the most pressing problems is the search for new physics, or physics beyond the Standard Model, which is a theory that scientists know is incomplete but aren't sure exactly how to improve. New physics could potentially explain several phenomena that the Standard Model cannot, including the matter-antimatter asymmetry problem, as well as dark matter, dark energy, and gravity.

As the scientists show in the new study, determining whether the recent hints indicate CP violation or new physics will be very challenging. The main goal of the study was to "quantify the level of confusion" between the two possibilities. The physicists' simulations and analysis revealed that both CP violation and new physics have distributions centered at the exact same value for what the neutrino experiments measure—something called the Dirac CP phase. This identical preference makes it impossible for current neutrino experiments to distinguish between the two cases.

"Our results show that establishing leptonic CP violation will need exceptional care, and that new physics can in many ways lead to non-trivial confusion," Huber told *Phys.org*.

The good news is that new and future experiments may be capable of resolving the issue. One possible way to test the two proposals is to compare the measurements of the Dirac CP phase made by two slightly different experiments: DUNE (the Deep Underground Neutrino Experiment) at Fermilab in Batavia, Illinois; and T2HK (the Tokai to

Hyper-Kamiokande project) at J-PARC in Tokai, Japan.

"The trick is that the type of new physics we postulate in our paper manifests itself in the way in which neutrino oscillations are affected by the amount of earth matter through which the neutrino traverses," Huber said. "The more matter travelled through, the larger the effect of this type of new physics."

"Now, for DUNE, neutrinos would have to travel roughly 1300 km in the earth, whereas for T2HK they would travel only about 300 km. Thus one would find two different values for the Dirac CP phase in both cases, indicating a problem."

In order to be accurate, these experiments will require extremely high degrees of precision, which Huber emphasizes should not be overlooked.

"Of course, the same result could arise if for some reason either experiment was not properly calibrated and thus precisely calibrating these experiments will be extraordinarily important—a very difficult task, which I believe is not quite getting the attention it should."

More information: David V. Forero and Patrick Huber. "Hints for Leptonic CP Violation or New Physics?" *Physical Review Letters*. DOI: 10.1103/PhysRevLett.117.031801
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