Breaking Color Symmetry

Carla Farsi
Department of Mathematics
University of Colorado 395 UCB
Boulder, CO 80309-0395
Email: farsi@euclid.colorado.edu

Abstract

In this short paper I will describe my art work **"Breaking Color Symmetry,"** a short digital clip portraying **spontaneous color symmetry breaking**. This art work was inspired by Madame Wu's experiments with **spontaneous chiral symmetry breaking** of electron emissions in polarized Cobalt. We can define **color mirror symmetry** by using a color wheel, thus making complementary (i.e., opposite) colors correspond to **symmetric** mirror-reflecting pairs. In this theory, Magenta is the mirror-reflection of Green, and Blue of Yellow. Colors are an artistic representation of a particle's spin.

Madame Wu and Chiral Asymmetry

Chiral symmetry (also called *parity)* is the *symmetry* of spatial mirror-reflections. Surprisingly, this *symmetry* is violated in the physical world at both the microscopic and macroscopic level (i.e., in nature the right is differentiated from the left [G])! In this context, *spontaneous symmetry breaking* (roughly speaking, when no "obvious cause" for the *asymmetry* can be found) is perhaps the most intriguing type of *asymmetry* of all.

At the atomic level in physics, Madame Wu was one of the first researchers to demonstrate *chiral symmetry* violation. How this would happen had been theorized by Lee and Yang in [LY].

…The idea involved orienting cobalt nuclei with a strong magnetic field so that their spins are aligned in the same direction. Beta rays (electrons) are emitted at the poles of the nuclei. A mirror image of the system would also show beta rays being emitted from the poles of the mirror cobalt nuclei, the only difference being that the north and south poles of the mirror nuclei would be reversed since they spin in opposite direction of their real counterparts. Hence parity conservation demands that the emitted beta rays be equally distributed between the two poles. If more beta particles emerged from one pole than the other, it would be possible to distinguish the mirror image nuclei from their counterparts. Thus an anisotropy in the emitted beta rays would be tantamount to parity violation.

(Quotation above from [My].) On December 7, 1956, Madame Wu and Ernest Ambler succeeded in realizing an experiment with polarized Cobalt along the lines suggested by Lee and Yang. The results of this experiment supplied the decisive proof of the *chiral symmetry breaking* in weak interactions (i.e., interactions among fundamental particles).

Molecules too, take a well defined left- or right-handed spatial configuration, as first discovered by Pasteur. At the macroscopic level, in human bodies and embryos, *chiral symmetry* and *asymmetry* also play an important role. And *chiral symmetry* is also broken in the universe at large; a fundamental *chiral asymmetry* is perhaps at the origin of life [DK], [G].

Breaking Color Symmetry

I will now detail the theoretical and metaphorical structure underlining "Breaking Color Symmetry." The clip is an artistic rendering of one Madame Wu's experiments; it represents an oriented field of cobalt nuclei, together with the field's mirror image. In particular, each frame represents a nucleus, and its colors the particle's *spin*, or electrons emissions. Frame 1 is a still I took on a recent ski trip, and all of the other frames are generated from Frame 1 via Adobe Premiere 1.5 special effects as explained below.

Figure 1: F*rames100 and 101 of "Breaking Color Symmetry."*

As it can be seen by looking at a color wheel, all colors have a corresponding opposite color. For example, Magenta and Green, and Blue and Yellow, are color-opposite pairs. This defines a symmetry on the set of all colors. So, when a particle (i.e., a frame) is spatially mirrored, its *spin* (i.e., its colors) change[s] to its (their) opposite. Inspired by these ideas, I thus chose to generate my clip as follows. I performed on Frame 1 a spatial mirror-like reflection, together with a color symmetry. I also added some small random color and shape distortions to render the effects of the magnetic field. I thus obtained Frame 2. Then I repeated this process, replacing Frame 1 by Frame 2, to obtain Frame 3, and so on. For an example, look at Figure 1. To obtain Frame 101 from Frame 100, I mirror-reflected Frame 100, and changed each color into its opposite.
To render *spontaneity* I artificially produced a clip asymmetry by using frame repetitions. (In particular, the last 30 frames of the clip are all very similar to each other.) The biological side of *chirality* is manifested in the fact that my original picture (i.e., Frame 1) represents a group of people resting in the mountains.

I would like to thank Marek Grabowski for very stimulating conversations, and the referees for suggestions that very much improved the exposition of this short paper.

References

[DK] D. J. Durand and D. K. Kondepudi, *Chiral Asymmetry in Spiral Galaxies?* Chirality n. 7, pp. 351-6. 2001.
[G] M. Gardner, *The New Ambidextrous Universe,* W. H. Freeman Publishers, New York. 1990.
[LY] Lee, T. D., and C. N. Yang, Question of Parity Conservation in Weak Interactions, The Physical Review 104. 1956.
[My] K. Mynemi, *Symmetry Destroyed: The Failure of Parity,* http://ccreweb.org/documents/parity/parity.html