50 Years Ago

Individual plants of the amphibious buttercup species *Ranunculus flabellaris* Raf. are known to produce leaves of differing morphologies in response to different environments. Leaves produced in the aquatic phase are highly dissected, while terrestrially produced leaves are less dissected or simply trilobed. Bostrack and Millington have demonstrated that of the environmental variables to which the plants are normally exposed, changes in temperature produce the greatest changes in leaf morphology … Large, readily quantifiable, differences in leaf morphology are observed with a relatively small change in an ecologically significant environmental variable … [T]he relation between environmental change and morphological change is approximately linear over a wide range of temperatures … These suggest a relatively simple relationship between a change in environment and morphological change.

From *Nature* 24 June 1967

100 Years Ago

On the afternoon of June 4 I was mowing a heavy crop of grass with the scythe when I noticed a sharp crack occurring during the cutting strokes. The noise did not occur at every stroke, but was sometimes heard three times during a stroke. The noise exactly resembled a high-tension discharge, and I can think of no explanation other than that the blade became charged, due to the friction on the very dry grass … I may add that I am quite satisfied that the noise did not arise from the snapping of dry stems or from the scythe hitting stones, etc. I should be interested to hear if any of your readers have had a similar experience.

From *Nature* 21 June 1917

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more massive than helium)[4–8]. If confirmed, these signals could reveal valuable information about the properties of the early Universe. But writing in *Physical Review Letters*, the CMS Collaboration[9] reports a striking similarity between lead–lead and proton–lead collisions, which suggests that parity violation has not yet been detected.

Collisions of nuclei travelling close to the speed of light provide an opportunity to investigate the strong phase transition — the process in which fundamental particles called quarks and gluons become bound into protons and neutrons. The temperature achieved in such collisions is about 2×10^{12} °C (100,000 times hotter than the Sun's core)[10]. At this temperature, an unbound system of quarks and gluons called a quark–gluon plasma is expected to be produced in the overlapping region between the two colliding nuclei. Such a plasma would then expand and cool, causing the particles to become bound. The Universe itself underwent a similar phase transition about a millisecond after the Big Bang.

In heavy-ion collisions, parity violation could occur if the gluons form configurations that have a non-zero topological charge (a property akin to an electric charge that characterizes a system's topology). Interactions between these gluon configurations and the quarks of the quark–gluon plasma would then violate parity by creating an imbalance between the numbers of left- and right-handed quarks — a particle is right-handed if the direction of its intrinsic angular momentum (spin) is the same as its direction of motion, and left-handed if these directions are opposite. For example, in a region that has a negative topological charge, left-handed quarks would become right-handed, whereas right-handed quarks would be unchanged.

An extremely strong magnetic field (about 10^{19} times stronger than the magnetic field at Earth's surface) is also produced in heavy-ion collisions[11]. This field aligns the spins of positively charged quarks in the direction parallel to the field's orientation and the spins of negatively charged quarks in the opposite direction. The combination of this spin alignment and an imbalance in the numbers of left- and right-handed quarks would then result in a quark current, in which quarks of opposite electric charge move in opposite directions. Consequently, there would be a separation of charge in the direction of the magnetic field, perpendicular to the plane of the collision (Fig. 1). This phenomenon is called the chiral magnetic effect[12] (CME). Detecting such an effect would reveal details about the properties of primordial magnetic fields in the early Universe and the processes that led to the Universe having an excess of matter over antimatter.

The CME could be observed in heavy-ion collisions by detecting charge-dependent correlations between the particles produced in the collisions[13]. Such correlations have been measured by researchers at the Relativistic Heavy Ion Collider near New York City[4–6] and the Large Hadron Collider near Geneva, Switzerland[7,8], and are in qualitative agreement with theoretical expectations for the CME. However, charge-dependent correlations from other sources (backgrounds) can account for all or part of these observations.

The CMS Collaboration disentangled parity-violating effects from background contributions by measuring charge-dependent correlations in both lead–lead and proton–lead collisions at the Large Hadron Collider. The CME signal is expected to be much smaller in proton–lead collisions than in lead–lead collisions, because the direction of the magnetic field is randomly oriented with respect to the collision plane[14]. However, the authors found that the magnitude of the correlations is strikingly similar in these two types of collision when approximately the same numbers of particles are produced — the authors considered multiplicities of up to 300 particles. Their findings imply that the CME contribution to charge-dependent correlations is negligible for such multiplicities.

The results reported by the CMS Collaboration challenge the idea that parity violation has already been detected in heavy-ion collisions. However, to confirm this conclusion, a quantitative estimate of the CME contribution to charge-dependent correlations is needed over the entire multiplicity range (up to a few thousand particles), because the collision dynamics vary depending on the multiplicity. Various approaches are currently used, or have been proposed, to precisely determine whether and to what extent parity is violated in heavy-ion collisions. One suggestion[15] is to use collisions of isobaric nuclei — nuclei of different chemical elements that have the same atomic mass — to more easily distinguish the CME signal from background contributions. Another possibility is to vary the background contributions by selecting different shapes for the initial geometry of the collisions[16].

The ALICE Collaboration, also at the Large Hadron Collider, earlier this year reported measurements of charge-dependent correlations for different collision geometries. Combining these measurements with numerical simulations of the magnetic field, they set strong constraints on the CME contribution to these correlations (see go.nature.com/2sj9jhn). The search for parity violation in strong interactions therefore continues, and new insights into fundamental physics might be just around the corner. ■

Alexandru Florin Dobrin *is at the European Organization for Nuclear Research (CERN), CH-1211 Geneva 23, Switzerland.*
e-mail: alexandru.florin.dobrin@cern.ch

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