physics today

Macroscopic chiral crystals can segregate themselves

Johanna L. Miller

Citation: Phys. Today 66(10), 14 (2013); doi: 10.1063/PT.3.2133
View online: http://dx.doi.org/10.1063/PT.3.2133
View Table of Contents: http://www.physicstoday.org/resource/1/PHTOAD/v66/i10
Published by the AIP Publishing LLC.

says MPIR team member Heino Falcke. "But they can occur when the magnetic field is anchored in something other than the accreting gas itself. And this one might explain why Sgr A* is currently on such a starvation diet." Under some circumstances, super-equilibrium fields can inhibit accretion. The black hole's present accretion rate is only $10^{-8}\,M_\odot$ per year. At that puny rate it would have taken Sgr A* ten thousand times the age of the universe to reach its present mass.

Models that begin with negligible B at the periphery generally posit that dynamo mechanisms within the flow are sufficient to generate the strong B fields (of order 100 G) known from Sgr A*'s synchrotron radiation to prevail near the black hole's event horizon—its boundary of no return at a distance r of about half a light-minute.

"But now we know for the first time that there's already a dynamically significant magnetic field out where the accretion flow begins," says Falcke. "Naive $1/r$ scaling of the field we measured yields the requisite field strength near Sgr A*'s event horizon. We haven't excluded the dynamo mechanisms, but they're no longer urgently needed."

More to come

Only a tiny fraction of all radio pulsars are magnetars. So there are probably lots more radio pulsars waiting to be discovered and exploited in the immediate vicinity of Sgr A*. Magnetars, with their episodic flaring, may be the showiest, but they're not the most precise timers. "To test general relativity near Sgr A*'s event horizon," says Eatough, "we'd prefer an ordinary radio pulsar."

Meanwhile, the new magnetar, orbiting Sgr A* with a period on the order of 1000 years, might before long reveal interesting small-scale variations in the gas enveloping the black hole at the Milky Way's heart.

Bertram Schwarzschild

References

1. R. P. Eatough et al., *Nature* (in press), doi:10.1038/nature12499.
2. R. M. Shannon, S. Johnston, *Mon. Not. R. Astron. Soc.* (in press), doi:10.1093/mnrasl/slt088.

Macroscopic chiral crystals can segregate themselves

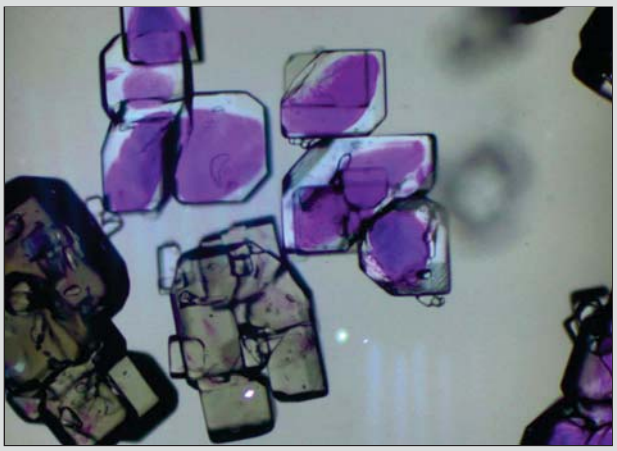
The molecular building blocks of life are nearly all chiral: They have a definite "handedness" and thus can't be superimposed on their mirror images. What's more, everywhere on Earth, biomolecules all have the same chirality, even though their left-handed and right-handed isomers are energetically identical. Somewhere along the line, something must have happened to break the left–right symmetry and induce the dominance of one chiral form over the other.

Inspired by the mystery of biohomochirality, Cristóbal Viedma, a geologist at Complutense University in Madrid, Spain, went looking for ways to break chiral symmetry in the lab. Rather than chiral molecules, his experiments use chiral crystals—achiral atomic and molecular ions arranged into a chiral lattice. He found that a fifty-fifty mix of left- and right-handed crystals of sodium chlorate ($NaClO_3$), suspended in aqueous solution, could be transformed into a single chiral form either by crushing and grinding the crystals[1] (see PHYSICS TODAY, April 2005, page 21) or by boiling the solution under a temperature gradient.[2] Common to the two methods is that as some crystals grow, others are broken down. In such a precarious environment, apparently, a tiny random imbalance that momentarily favors one chiral form can bring about complete chiral purity.

Viedma's attempt to reproduce the boiling experiment with a related compound, sodium bromate ($NaBrO_3$), failed, but in the process, he and a team of collaborators discovered another surprising effect. Shaking a suspension of millimeter-sized crystals of mixed chirality grew them into centimeter-sized aggregates. And each aggregate was almost entirely homochiral: all left-handed or all right-handed.[3]

It seemed impossible that the large, millimeter-scale chiral crystals could recognize one another. The interaction energy of two crystals brought into contact should be independent of their relative chirality, unless the crystal lattices somehow become perfectly aligned to within thousandths of a degree. And in actuality, the adjacent crystals in each aggregate were misaligned by 1–2°.

Could dissolution and recrystallization be responsible for the homochiral aggregation? Or could some crystals be reversing their chirality within the aggregates, perhaps by way of an amorphous intermediate? Those possibilities were ruled out by a further experiment: One of the chiral forms in the initial mix was dyed purple, and the other was left colorless. If the crystals dissolved, amorphized, or lost their handedness in any other way, the purple dye would be evenly distributed between both types of chiral aggregate. But as shown in the figure, that's not what happened. Instead, the initially dyed crystals all ended up in the same aggregates, joined by thin, colorless bridges of newly crystallized material.



Although the mechanism behind the effect remains a mystery, Viedma and company consider their results unambiguous. And they're keen to explore the implications for both achiral and chiral systems. If millimeter-sized crystals of like material can recognize one another and join together in near-perfect alignment, that could represent a new pathway for crystal growth, which may help to explain some of the large single crystals found in nature: It could be much faster for a crystal to grow millimeter by millimeter than atom by atom.

Johanna Miller

References

1. C. Viedma, *Phys. Rev. Lett.* **94**, 065504 (2005).
2. C. Viedma, P. Cintas, *Chem. Commun.* **47**, 12786 (2011).
3. C. Viedma et al., *Angew. Chem. Int. Ed.* (in press), doi:10.1002/anie.201303915.