In the Blink of Bird's Eye, a Model for Quantum Navigation

By Lisa Grossman

European robins may maintain quantum entanglement in their eyes a full 20 microseconds longer than the best laboratory systems, say physicists investigating how birds may use quantum effects to "see" Earth's magnetic field.

Quantum entanglement is a state where electrons are spatially separated, but able to affect one another. It's been proposed that birds' eyes contain entanglement-based compasses.

Conclusive proof doesn't yet exist, but multiple lines of evidence suggest it. Findings like this one underscore just how sophisticated those compasses may be.

"How can a living system have evolved to protect a quantum state as well — no, better — than we can do in the lab with these exotic molecules?" asked quantum physicist Simon Benjamin of Oxford University and the National University of Singapore, a co-author of the new study. "That really is an amazing thing."

Many animals — including not only birds, but some mammals, fish, reptiles, even crustaceans and insects — navigate by sensing the direction of Earth’s magnetic field. Physicist Klaus Schulten of the University of Illinois at Urbana-Champaign proposed in the late 1970s that bird navigation relied on some geomagnetically sensitive, as-yet-unknown biochemical reaction taking place in their eyes.

Research since then has revealed the existence of special optical cells containing a protein called cryptochrome. When a photon enters the eye, it hits cryptochrome, giving a boost of energy to electrons that exist in a state of quantum entanglement.

One of the electrons migrates a few nanometers away, where it feels a slightly different magnetic field than its partner. Depending on how the magnetic field alters the electron’s spin, different chemical reactions are produced. In theory, the products of many such reactions across a bird’s eye could create a picture of Earth’s magnetic field as a varying pattern of light and dark.

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However, these quantum states are notoriously fragile. Even in laboratory systems, atoms are cooled to near–absolute-zero temperatures to maintain entanglement for more than a few thousandths of a second. Biological systems would seem too warm and too wet to hold quantum states for long, yet that’s exactly what they appear to do.

Researchers led by University of California, Irvine physicist Thorsten Ritz (.pdf) showed in 2004 that, although robins had no trouble pointing their beaks toward Africa under the influence of Earth’s magnetic field alone, adding a second, shifting field destroyed their inner compasses. That second field was so weak — less than one-third of 1 percent of Earth’s field — that it could only have influenced a quantum-sensitive system.

“It shouldn’t be the case that the birds would even know that this had happened,” Benjamin said. “If someone changed the brightness of the scene that you’re seeing by a-third of 1 percent, you would struggle to know that it even happened. It certainly wouldn’t muck up your vision.

In a new paper in *Physical Review Letters*, Benjamin and colleagues built a mathematical model of Ritz’s experiment, including the Earth’s magnetic field, the slight secondary field, and the quantum systems that might make up the birds magnetic sense.

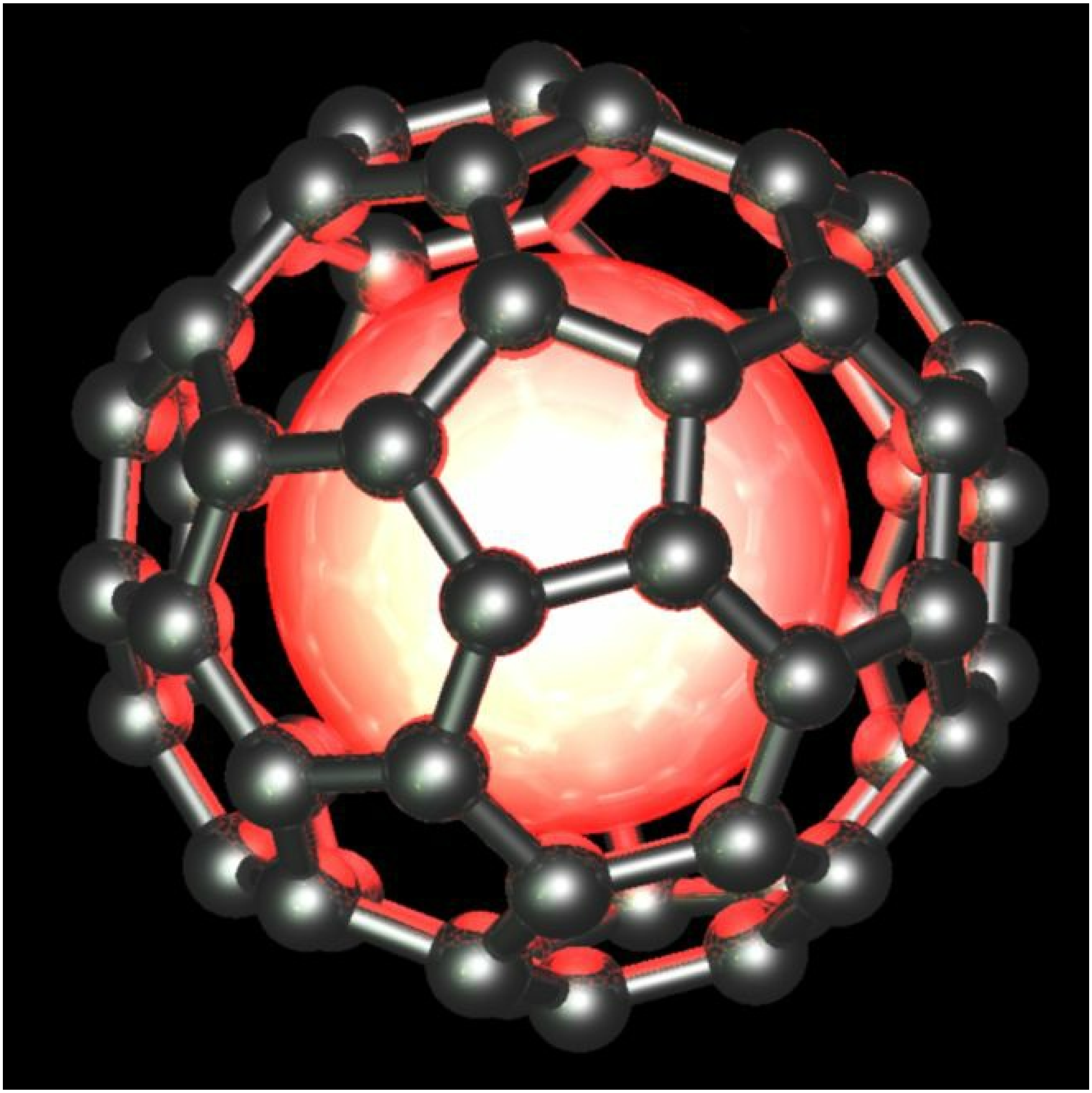
They calculated that, in order to be sensitive to such weak fields, entangled states in the birds’ eyes must last for at least 100 microseconds, or 0.0001 seconds.

To put this in perspective, Benjamin introduced an exotic molecule called N@C60, a geometric cage of carbon with a nitrogen atom inside. This molecule is one of the best-known laboratory systems for maintaining entanglement. “The cage acts to shield the atom, which is storing the information, from the rest of the world,” Benjamin said. “It’s considered to be quite a sexy, interesting, promising molecule.”

But at room temperature, even N@C60 only holds entanglement for 80 microseconds, or four-fifths of what birds appear to be doing.

“I think this is a very nice paper that attacks the problem from an interesting angle,” said Schulten, who was not involved in the work. “They use a hugely simplified model, but they make an interesting point. Entanglement could stay protected for tens of microseconds longer than we thought before.”

“The bird, however it works, whatever it’s got in there, it’s somehow doing better than our specially designed, very beautiful molecule,” Benjamin said. “That’s just staggering.”



Images: 1) The European robin. Courtesy Ernst Vikne/Flickr. 2) Schematic drawing of N@C60. Courtesy Simon Benjamin.

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