Abstractions

FIRST AUTHOR

How birds first got airborne remains an enigma. The puzzle is how a dinosaur forelimb could so completely change its function in the course of evolution. To try to answer this question, David Baier, a postdoc at Brown University in Providence, Rhode Island, and his colleagues used numerous lines of inquiry, including three-dimensional models of modern birds, fossil comparisons and force-balance metrics — modelling the forces acting on different animals' shoulder joints. Explaining the origin of flight eluded them, but they show on page 307 that a particular ligament in the shoulder was an important development in the evolution of modern bird flight.

Why is the origin of bird flight still not well understood?

Unfortunately, these are small animals with thin bones that are unlikely to be preserved. For much of the recent past, *Archaeopteryx*, a 150-million-year-old species, has been the only fossil available for analysis. Recently, a plethora of fossil information has come from China and around the world to drive further questions.

What hints do modern-day animals provide?

I had anticipated that once we had a better understanding of how the shoulder joint works in living birds, we'd need to examine modern birds' living relatives to understand how the joint evolved. As alligators are among modern birds' closest living kin, it made sense to use them to compare with and give context to the newer bird fossils found in China.

What were the key advances allowing you to better study living animals?

Using the force-balance approach was crucial. The muscles were insufficient to balance the joint, so I was very interested in knowing which forces — from ligaments, for example — were stabilizing. We modelled in three dimensions the structures that can balance the aerodynamic and muscle forces, and found that the acrocoracohumeral ligament is required to maintain stability at the joint and is a key structural component in flying birds.

What surprised you most about the findings?

It was a little surprising that the ligament was not associated with the origin of flight. It is a modification that developed later. This study became more of an investigation of the evolution of flight. We still don't know how the earliest birds flew and how they stabilized their forces — were they gliders or flappers? ■

MAKING THE PAPER

Richard Massey

Researchers use gravity to show the arrangement of dark matter.

Dark matter was first postulated in 1933 to explain the amount of gravity necessary to hold galaxies together, and constitutes about 85% of the matter in the cosmos. Because dark matter neither reflects nor emits light, it cannot actually be seen. Now, researchers at the California Institute of Technology (Caltech) in Pasadena, with collaborators from five other countries, offer the first glimpses of how this mysterious matter is arranged. It seems to crisscross the Universe like a massive scaffold, holding ordinary matter, such as planets and stars, in place.

The best method to locate dark matter is to study the way its gravity bends light from objects beyond it, a technique known as gravitational lensing. "We looked at ordinary galaxies behind the dark matter," explains Richard Massey, lead author of the study on page 286. "Their light has to pass through dark matter to be detected by our telescopes." Because during this process the light bends, the shapes of the galaxies are slightly distorted.

In a collaborative effort headed by Nick Scoville at Caltech, Massey and his colleagues collected images of half a million distant galaxies using the space-based Hubble Space Telescope (HST). The dense packing of galaxies provides abundant information and thus better resolution to see dark matter's structre. But only from the HST's perch above Earth's atmosphere is it possible to see such an enormous number of these distant, faint objects.

Before Massey and his colleagues could use the data they had collected, they had to tackle some unforeseen problems. As it orbits Earth, the HST travels in and out of Earth's shadow, contracting and expanding as it cools down and heats up again. "The Hubble Telescope effectively breathes as it orbits Earth," says Massey.

The breathing only changes the shape of the ~13-metre-long instrument by a few micrometres, but even this tiny change puts images out of focus. In fact, the shapes of galaxies are altered by an amount similar to that of the distortion caused by the dark matter.

To remove this artefact from the data, the scientists turned the HST on stars within our own Galaxy. As the precise shapes of the Milky Way's stars are known, the team was able to use them to calibrate the images of distant galaxies.

But they encountered other problems. For example, the electronic detector on the HST started to malfunction after years of being beaten by space particles. As a result, the scientists had to compensate for an increasingly blurred signal as data collection progressed.

After resolving each problem, Massey would return to his dark-matter map and refine it "until we got something that made sense". The picture that emerged, spanning an area equivalent in size to nine full moons, was one of long filaments of dark matter that meet at large structures marking the locations of galaxies. "On the whole, it is consistent with what we expected," says Massey. By and large, the map reinforces the theory that dark matter and ordinary matter coalesce at the same places because gravity pulls them together. Concentrations of dark matter should attract visible matter and, as a result, assist in the formation of stars and galaxies.

Gravitational lensing as a technique was first implemented just seven years ago, notes Massey, who wrote his PhD on the topic at the University of Cambridge, UK, before joining the Hubble project in 2004. "And now, at the start of 2007, we have mapped out the dark matter in the Universe," he says. "It's incredibly fast progress." ■

KEY CONTRIBUTORS

Evolutionarily, the chicken follows the more primitive shark, skate and sturgeon. However, a genetic technique for manipulating the avian egg has now provided clues about fin development in these earlier animals (see page 311).

When postdoc Randall Dahn joined Neil Shubin's evolution and development lab at the University of Chicago in Illinois, he brought with him a molecular-biology tool kit for manipulating chicken eggs. Dahn investigated how genetic tweaks affected the birds' development. "The goal was to link that to palaeontological and evolutionary standpoints," Shubin says.

They decided to study limb and fin development in more primitive organisms, following reports that sharks develop fins without *Sonic hedgehog* (*Shh*), a gene thought to be essential for the process in many organisms. Dahn used his tool kit on shark and skate eggs. "Randy treating shark like chicken was brilliant," says Shubin. Postdoc Marcus Davis did something similar to the eggs of sturgeon and other primitive fish.

They found that *Shh* does have a role in fin development in the organisms they studied. This shows that some *Shh*-related mechanisms are deeply conserved in vertebrates. And, they suggest, variations in *Shh* signalling among species could give insight into appendage evolution. ■