Smithsonian

Spotlight on Science at the Smithsonian

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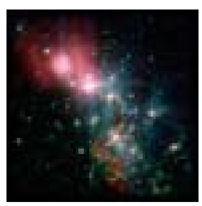

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- Dr. David Evans, Under Secretary for Science
- Theresa Mellendick, Editor, mellendickt@si.edu

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Introduction from the Under Secretary for Science

In this installment of Spotlight on Science we first visit the Smithsonian Environmental Research Center, where scientists study the ecological partnership between native orchids and soil fungi, and why it may be a key to understanding how orchids and other plants will fare in the face of climate change. Next, astronomers at the Smithsonian Astrophysical Observatory map magnetic fields in distant space. The shapes of these fields in interstellar dust clouds help us understand how stars like our Sun are born. And finally, scientists at the National Zoo take us to the tidal marshes of North America, an ecological treasure, and also a natural laboratory for understanding how species invade and adapt to new habitats.

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Goodyera pubescens is an orchid native to eastern North America. Like all orchids and most plants, it depends on soil fungi to extract nutrients from the soil.

Orchids and Fungi: A Marriage Meant to Last?

Every gardener knows that plants need more than just water and sunshine to thrive. They need to get the right mix of nutrients from the soil. But even this isn’t so simple. In order to absorb nutrients most plants need the help of certain fungi within the soil. In return for passing on nutrients to plant roots, the fungi get sugars and starches produced by the plant via photosynthesis.

As important as this relationship, known as mycorrhizal symbiosis, is for healthy plant growth, many of the details are still poorly understood by scientists. How specific are the associations? Do individual plants forge symbioses with more than one type of fungus at a time? Do the associations shift with changing environmental conditions? Answering these questions could be important for predicting the impact of climate change and other environmental stresses on plant communities.

Melissa McCormick, Dennis Whigham, and their colleagues at the Smithsonian Environmental Research Center study the importance of fungus for the largest and most diverse of plant families: orchids. Though often thought of as exotic tropical flowers, orchid species are found on every continent except Antarctica. The species studied by McCormick and Whigham, *Goodyera pubescens*, is native to forests in eastern North America.

Orchids are unusual in that their association with soil fungi appears to be a one-way affair: the orchids absorb nutrients from the fungi but give up nothing in return. In fact, in their early life stages orchids lack leaves and are incapable of photosynthesis and so produce no food of their own. These immature orchids, called protocorms, are completely dependant on their fungal partners.

The dust-sized seeds of orchids contain almost no stores of food for the embryonic plant, and so the connection between an individual orchid plant with its fungal partner must begin at germination. McCormick and Whigham found that this connection, once established, is exclusive and in most cases permanent. Orchids cannot “hedge their bets” by drawing nutrients from several fungal species or even several individual fungi of the same species. This means that environmental changes that threaten the survival of the mycorrhizal fungi also threaten the survival of the orchid plant.

But symbiosis is not a suicide pact. In a recent paper published in the journal *Ecology* the researchers present results of experiments that indicate that during situations of extreme environmental stress both protocorms and adult orchids can switch to a more viable fungal partner. Even so, mortality is high.

Reference

Melissa K. Mccormick, Dennis F. Whigham, Dan Sloan, Kelly O'malley, and Brendan Hodkinson, 2006. Orchid–fungus Fidelity: a Marriage Meant to Last? *Ecology*, 87(4), pp. 903–911.

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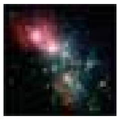

Orchids and other species in natural plant communities are increasingly challenged by global warming, competition from invasive species, and other environmental changes. How well they weather these changes will depend to a great extent on the fate of their invisible and still poorly-understood partners in the soil – mycorrhizal fungi.

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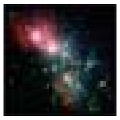

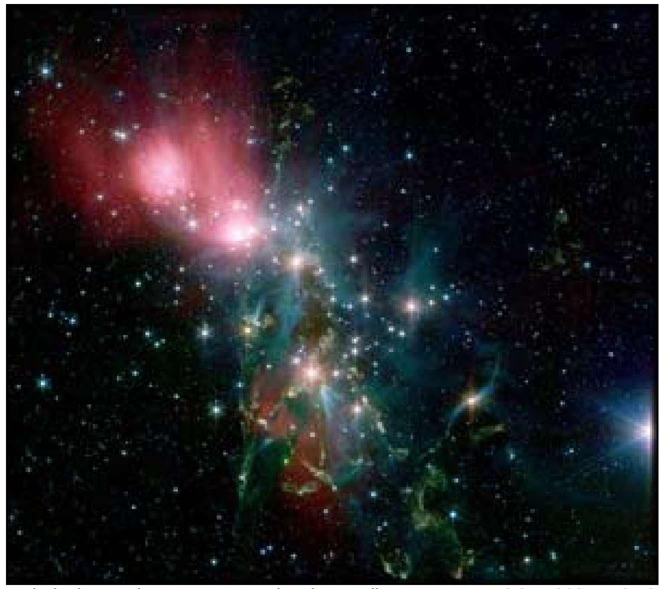
Nebulosity and young stars in the stellar nursery NGC 1333. SAO astronomers detected an hourglass-shaped magnetic field in the dust and gas surrounding one of the stars (between the rose and mint-colored regions of the image), confirming the role of magnetism in controlling the growth of stars. This image, courtesy of NASA and SAO astronomer Rob Gutermuth, was taken by the Infrared Array Camera on the Spitzer Space Telescope.

An “Hourglass” Magnetic Field

Astronomers have long known that the primal force in the creation of new stars is gravity. The gravitational attraction among the individual dust particles and gas molecules in interstellar clouds is incredibly minute, yet is enough to gather them from distant points in space and ultimately compress them into a massive glowing ball that we call a star.

While the role played by gravity in this process is clear enough, astronomers have been less certain about the role of another fundamental force: magnetism. Many of the particles within interstellar clouds are electrically charged, and so produce magnetic fields. In theory, the magnetic forces among the charged particles could oppose the gravitational forces, slowing down the contraction of the cloud. But magnetic fields in distant space are extremely difficult to measure, so astronomers have had no way of knowing whether the magnetic fields are strong enough to influence the rate of star formation or whether other factors such as turbulence within the cloud are more important.

But now astronomers at the Smithsonian Astrophysical Observatory have shed light on this question by mapping the magnetic fields surrounding an embryonic star some 1000 light years away. Ramprasad Rao, Daniel Marrone, and their colleague Josep Girart of the Institut de Ciènce de Espai in Spain were able to do this because particles within interstellar clouds align themselves along magnetic lines of force, much as iron filings align themselves around a magnet. Dust particles light years away in space cannot be individually observed, of course, but their collective alignment affects the way they polarize light — and this can be observed. Until recently, however, no instrument could measure the polarization with enough precision to resolve the structure of interstellar magnetic fields. But the Smithsonian’s Submillimeter Array of eight short-wavelength antennae near the summit of Mauna Kea in Hawaii, can measure polarization with unprecedented precision.

The study’s findings, published in August in the journal *Science*, was that the magnetic lines in the coalescing cloud pinched significantly inward near its massive center, indicating that the gravitational field had been able to compress the charged particles producing the magnetic field. This “hourglass” shape is what theorists predicted would be

Reference

J. Girart, R. Rao, and D. Marrone. 2006. Magnetic Fields in the Formation of Sun-like Stars, *Science*, 313, p.812-814.

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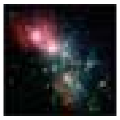

An “Hourglass” Magnetic Field

Evolution in Tidal Marshes

found if magnetism was indeed a significant factor in controlling the cloud’s condensation. If turbulence were important, the pattern would be more chaotic.

In our home galaxy, the Milky Way, interstellar dust aggregates at rate sufficient to produce one Sun-sized star per year. The results from the Submillimeter Array confirm that while gravity drives the process, magnetism has its foot on the brake, and stars like the Sun are born through the interplay of these two forces.

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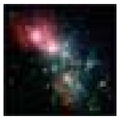

Located at the boundary between land and marine habitats, tidal marshes offer abundant food but impose strong selective pressures on resident terrestrial vertebrates such as birds, mammals, and reptiles. Image: U.S. Fish and Wildlife Service.

Evolution in Tidal Marshes

Reference

Russell Greenberg, Jesus Maldonado, Sam Droege, and M. V. Mcdonald. 2006. Tidal Marshes: A Global Perspective on the Evolution and Conservation of Their Terrestrial Vertebrates. *Bioscience*, 56(8), p.675-684

Each continent has its share of biological treasures: Africa has its Serengeti Plain; South America has its Amazonian rainforest; Australia its Great Barrier Reef. Among North America’s treasures are its tidal marshes. Though these salty or brackish wetlands occur in estuaries and low-lying coastlines worldwide, North America has by far the greatest concentration of tidal marshes, especially along the mid-Atlantic and Gulf coasts.

As a kind of environmental no-man’s land between marine and terrestrial environments, tidal marshes can be tough places for organisms to make a living. Water levels, temperature, and salinity are constantly fluctuating, which can be hard on any organism’s physiology. But those plant and animal species that can adapt to the rigors of tidal marsh life do very well, and tidal marshes are among the most productive ecosystems on earth.

Ecologists have long been fascinated by the high productivity of tidal marshes, and tidal marshes are natural laboratories for research on the basics of how ecosystems function. In a recent article published in the journal *Bioscience*, two researchers at the National Zoo point out that tidal marshes have a lot to teach us about the mechanisms of evolution as well. For land species adapting to the tidal marsh environment the abundant food but stressful conditions make a carrot and stick for rapid evolutionary change.

Russell Greenberg, director of the Migratory Bird Center, and Jesus Maldonado, of the Smithsonian Genetics Program, and their co-authors, cite the example of Song Sparrows in the San Francisco Bay area. Tidal marsh populations of these birds have differentiated into distinct subspecies in three different estuaries of the Bay. The evolutionary changes must have occurred quickly, not only because the marshes they inhabit are geologically young, just a few thousand years, but because their genetic differentiation from upland populations, as determined from DNA molecular clocks, is virtually nil. Overall, the number of land-based vertebrate taxa such as birds, mammals and reptiles that can maintain resident breeding populations in tidal marshes is small, but a large proportion of those that do are, like the sparrows, differentiated from upland relatives at the subspecies or even species level. This implies that the pressures of natural selection to adapt to conditions within the marsh habitat are indeed strong.

Greenberg and Maldonado also noted that North American tidal marshes are home to a far greater number of marsh-adapted land vertebrates than are marshes elsewhere. This is not simply a result of marsh abundance in North America, because salt marsh species and subspecies don’t necessarily occur in the same regions where the marshes are most extensive. A more likely explanation is that

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there is something about the geologic history or ecology of North American tidal marshes that has made them particularly suitable for evolutionary differentiation.

Whatever the answer is, North American tidal marshes, like those on other continents, are under threat from coastal development, climate change, and pollution. From an ecological and evolutionary standpoint, tidal marsh species are by definition survivors, but when the tidal marshes go, they will go, too.

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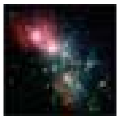

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