Phi Kappa Phi FORUM

A QUARTERLY PUBLICATION

Fall 2002

Big Space Little Space

WILLIAM A. HISCOCK

From Wormholes to the Warp Drive: Using Theoretical Physics to Place Ultimate Bounds on Technology

MICHIO KAKU

M-Theory: Mother of All Superstrings

GORDON KANE

Anthropic Questions

Peering into the Universe: Images from the Hubble Space Telescope

J-M WERSINGER

The National Space Grant Student Satellite Program: Crawl, Walk, Run, Fly!

Phi Kappa Phi FORUM

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The Honor Society of Phi Kappa Phi was founded in 1897 and became a national organization through the efforts of the presidents of three state universities. Its primary objective has been from the first the recognition and encouragement of superior scholarship in all fields of study. Good character is an essential supporting attribute for those elected to membership. The motto of the Society is *philosophia krateitō phōtōn*, which is freely translated as "Let the love of learning rule humanity."

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fall 2002

PHI KAPPA PHI FORUM, Volume 82, Number 4

Big Space Little Space

Letters to the Editor

Phi Kappa Phi Forum publishes appropriately written letters to the editor every issue when submitted. Such letters should be 150-300 words in length.
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Columns:

A Note from the Editor

James P. Kaetz

IN THIS ISSUE

Modern physics is mind-bending. Black holes, wormholes, quantum uncertainty, superstrings, the Big Bang, time travel, multiple worlds, multiple universes — the concepts discussed by our authors in this issue are sometimes almost impossible to accept, given that they often seem counter to our limited perceptions of reality. Even something as well-tested and experimentally proven as the fact that time slows the faster one travels is hard to grasp, especially for those of us who can never hope to understand the complex language of mathematical equations that physicists use every day.

Still I love to read about the discoveries that continue to revolutionize our view of the way reality works. In this issue we wanted to have our authors talk about both the large and the small of it: from cosmology on the grand scale to the search for the most fundamental way the universe works on the subatomic, quantum level, a level that we may never actually "see" at all. In truth, of course, one cannot separate "big" from "little" in physics, because the search for a Grand Unified Theory involves trying to marry the bizarre world of quantum physics with the slightly less bizarre world of the universe that we can see. Needless to say, any treatment of these fields can only scratch the surface of the astounding things that serious physicists are exploring each day. But we hope that this issue provides an interesting look into their explorations.

William Hiscock leads off by exploring the plausibility of some of our most cherished science fiction conceits: wormholes, warp drive, and time travel. Professor Hiscock shows how physicists use such extreme concepts to push their theories to their limits, to see just what is possible and what is not. His verdict? A definite maybe, though not likely, for most of our science-fiction fantasies.

Next, Michio Kaku helps us understand one of the most exciting recent developments in the quest for the Unified Theory: M-Theory. M-Theory is an extension of string theory, which has fallen in and out of favor with theoretical physicists for several decades now. As Professor Kaku explains, M-Theory may be able to unify the various competing versions of string theory, as well as other, similar theories, and at some point lead to the completion of our understanding of the way the universe works on its most fundamental level — if we are indeed clever enough to figure it all out.

Gordon Kane looks at some of the "anthropic" questions that people have been asking, in particular the idea that somehow the fact that we are here observing the universe means that it was designed to result in our existence, with the implication that some being or thing had to do the designing. Professor Kane discusses similar questions that have been answered by our expanding knowledge of the way everything works, and posits three questions that scientists are still exploring and hope to resolve some day.

Next, we present a visual treat: a photo spread of some of the amazing pictures captured over the past year or so by NASA's Hubble Space Telescope. With NASA's permission, we have included extended explanatory text with the pictures. For me, seeing these photographs always sparks a yearning to be able to visit the places that they record and makes me wish that "warp drive" were real.

J-M Wersinger then tells us about the National Space Grant Student Satellite Program, which involves students from the high school level through graduate school in the planning, fundraising for, building, and launching of satellites. The program's aim is to encourage these students to major in the sciences in an attempt to alleviate the shortage projected as many Baby Boom-generation technical professionals begin to retire. The program embodies the ideas that we as Phi Kappa Phi members value, and we are pleased to let our members know about it.

APPRECIATIONS

First, we want to thank Professor J-M Wersinger of the Physics Department here at Auburn University for sitting down with us to make some invaluable suggestions about topic areas and about possible authors for this issue. He also took the time to write about the student satellite program.

Also thanks go to Steve Roy of the Marshall Space Flight Center and to Ray Villard of NASA for information and permission related to the Hubble Space Telescope photos featured in the issue.

Most of all, thanks go to columnists Paul Trout, Eileen Kelly, Douglas Larson, and George Ferrandi for their wonderful work the past three years. In this issue they write their final columns, and we cannot possibly thank them enough for their efforts on behalf of the *Forum* and the Society itself. We will miss them all.

Enjoy the issue!

Forum on Education & Academics

Paul Trout

Smelly Little Orthodoxies

People who ideate or theorize for a living do not always understand the real world. So, even the most well-intended ideas and theories can have dreadful consequences.

That is why it is not anti-intellectual to have a healthy suspicion of the ideas and theories championed by academics and intellectuals. In fact, some intellectuals themselves have urged us to do so, such as Julien Benda (*The Treason of the Intellectuals*), Raymond Aron (*The Opium of the Intellectuals*), Alastair Hamilton (*The Appeal of Fascism: A Study of Intellectuals and Fascism 1919-1945*), John R. Harrison (*The Reactionaries: A Study of the Anti-Democratic Intelligentsia*), Garrett Hardin (*Filters Against Folly: How to Survive Despite Economists, Ecologists, and the Merely Eloquent*), Alain Finkielkraut (*The Defeat of the Mind*), Heather MacDonald (*The Burden of Bad Ideas: How Modern Intellectuals Misshape Our Society*), and Mark Lilla (*The Reckless Mind: Intellectuals in Politics*).

This is also the message of Theodore Dalrymple's *Life at the Bottom: The Worldview that Makes the Underclass* (2001). What sets this book apart is that it was written not by a member of the Theory Class, but by a physician/psychiatrist who works at a hospital and a prison located in one of Birmingham's worst slums. Decades of experience, both in England and Africa, have enabled Dalrymple to see how certain theories and ideas play out in the lives of real people.

The violence, crime, neglect and abuse of children, nihilism, and dumb despair that Dalrymple encounters day after day are not, to his mind, the effects of economic poverty. The English welfare state provides housing, food, medical care, and even entertainment (half of the London "poor" have satellite dishes).

Dalrymple argues that the peculiar squalor of the English underclass is more the result of bad ideas and policies trumpeted by the intelligentsia: "Like so many modern ills, the coarseness of spirit and behavior grows out of ideas brewed up in the academy and among intellectuals — ideas that have seeped outward and are now having their practical effect on the rest of society."

For Dalrymple the most toxic notion brewed up by academia is that of "relativism," the flattening of all distinctions, the programmatic refusal to judge or evaluate. A relativistic mindset now characterizes most social institutions, from education (where invented spelling is given as much status as correct spelling) and music (Mozart is placed on the same plane as Fatboy Slim), to the justice system (that is increasingly hesitant to blame immigrant Muslim fathers for abusing daughters who offend the faith).

Relativism is a particularly incapacitating doctrine for those with few resources to raise themselves other than willpower and good habits. If there is only difference, not better or worse, then there is nothing to choose between "good manners and bad, refinement and crudity, discernment and lack of discernment, subtlety and grossness, charm and boorishness." Aspiration is pointless because there is nothing better to aspire to.

Morally tolerant of all kinds of mischievous and self-destructive behavior, relativism provides a license for the pathologies that make underclass life so miserable — impulsiveness, violence, crime, sexual promiscuity, ignorance, and moral passivity. It encourages criminals to see their crimes not as the result of their bad decisions, but instead as the result of abstract and impersonal social forces that they are helpless to oppose. Violent male offenders demand that Dalrymple "do something" about their "anger-management syndrome," and then revile him when they again beat their girlfriends senseless. Because moral relativism enervates will, it condemns the underclass to material, mental, and spiritual misery. Ostensibly compassionate, relativism is really quite cold-hearted.

"Where knowledge is not preferable to ignorance and high culture to low, the intelligent and the sensitive suffer a complete loss of meaning. The intelligent self-destruct; the sensitive despair. And where decent sensitivity is not nurtured, encouraged, supported, or protected, brutality abounds." Decades of experience have convinced Dalrymple that cultural and moral relativism "is as barbaric and untruthful a doctrine as has yet emerged from the fertile mind of man."

Why can't academics and intellectuals who advance this fashionable doctrine see this for themselves? It is in part because they are too removed from those actually affected by such notions, and in part because they have little incentive to find fault with ideas that make them feel and appear idealistic, sensitive, and ideologically correct. Ideas have *us*, as much as we have ideas.

When cornered by the harsh realities of lived experience, intellectuals protect their sense of righteousness by resorting to the same strategies that others use to fend off uncongenial truths: wishful thinking, willful blindness, outright denial, tendentious historical comparisons, and distortion of the moral significance of what is before them.

Intellectuals, wrote Orwell, should point out obvious truths and expose the smelly little orthodoxies that contend for our souls. At the very least, they should be suspicious of their own

(continued on page 7)

Forum on Business & Economics

Eileen P. Kelly

Business Ethics — an Oxymoron?

Enron. Arthur Andersen. WorldCom. Global Crossing. Merrill Lynch. Recently a new business scandal seems to surface each day. The current volatility of the market reflects the apprehension, the sense of betrayal, and the lack of confidence that investors have in many large corporations and their managements. Massive accounting frauds and continuing restatements call into question the accuracy of financial statements of numerous public corporations and the corresponding veracity of stated revenues and profits. Even companies with sterling reputations are now often suspect.

DO BUSINESSES HAVE ETHICAL RESPONSIBILITIES?

A basic sense of trust and fair play is an essential cornerstone of any economic system, especially a free-market system. In the absence of such trust, chaos reigns. Clearly the ethical bankruptcy of some corporate leaders has caused considerable disruption in the markets. Fortunately, the fundamental soundness of our financial system has withstood the onslaught. The current wave of business scandals involves not only outright criminal activity, but also a grayer area in which companies met the letter of the law, while they breached the ethical expectations of many stakeholders.

The subject of business ethics is one that has a long history of debate in business, academic, and public circles. Views vary on the extent of ethical responsibility that businesses should exercise. The minimalist position, long espoused by Milton Friedman, holds that the only ethical responsibility a business has is to make a profit within the confines of the law. In a free-market society, this single-minded pursuit of profit making is ultimately in the best interest of society because market forces will maximize the economic well-being of society's members. Furthermore, Friedman argues that corporations are legal, not moral entities, and hence have no ethical obligations.

The opposing, and more prevalent, viewpoint holds that corporations do have a responsibility to act ethically beyond mere legal compliance. The modern world is a society of organizations, according to Peter Drucker. Organizations, especially large corporations, exercise enormous power that shapes the world and affects far more than those in a proximate relationship with the organization, for instance, employees, suppliers, creditors, and investors. Corporations owe an ethical responsibility to all of their stakeholders and have a duty to be good corporate citizens. Essentially, corporations derive their legitimacy from society. When they undermine that legitimacy by acting in ways contrary to the interests of society, they can lose that legitimacy and ultimately the business itself, as exemplified by Arthur Andersen.

PROMOTING ETHICAL BEHAVIOR

Modern businesses operate in a constantly changing and intensely competitive global environment. Furthermore, they face tremendous complexity and diversity in employees, customers, and markets. Given this complexity and diversity, ethical behavior probably will not occur spontaneously. The management of a business thus has a responsibility to foster the climate and conditions that are supportive of ethical behavior. An ethical corporate culture requires commitment, awareness, and oversight.

The commitment of top management is fundamental to the promotion of ethical conduct in an organization. Management must go beyond paying lip service to an official company code of ethics. The conduct of top management itself underscores the seriousness with which the rest of the company should take ethical behavior and sets the tone for a corporate culture that makes ethical behavior a key priority. Nothing sends a clearer message to employees than when top management itself engages in unethical behavior. Accountability and responsibility for promoting an ethical organization should rest in a top manager instead of being placed on the shoulders of a lower-level employee. A number of companies have instituted the role of Chief Ethics Officer at the upper-management level to address this issue.

While some areas of ethical transgressions in business are obvious, such as engaging in fraud, other areas are more ambiguous. Promoting ethical behavior necessitates making employees aware of ethical issues in the first place. Companies can do this by establishing an effective ethics program. Such a program makes supervisors and employees aware of the values of the business, its ethical expectations, and the repercussions of transgressions. Some companies have a written code of ethics in conjunction with policies and codes of conduct that are given to all employees. High-risk areas, such as purchasing or sales, may require even more detailed codes of conduct. However, written ethical guidelines alone are insufficient. Supervisors play a key role in interpreting and overseeing ethical policies in their areas. Additionally, formal ethical training in which employees are exposed to practical ethical dilemmas confronted in their respective areas of business — for example, vendors expecting kickbacks — can help clarify the company's expectations.

When implementing an effective ethics program, vigilance and oversight are essential. Periodic audit and compliance measures must be done by supervisors and others responsible for ethical oversight for the program to have any meaning. Disciplinary actions must be taken where necessary. If co-workers see colleagues, or worse yet management, violating the ethics code with impunity, the ethical climate will quickly disintegrate.

Ultimately businesses do not exist in a vacuum where economic forces alone prevail. Rather, they exist in society and must meet the needs of that society, economically and otherwise. If they do not, at best they warrant sanctioning by society and increased governmental regulation. At worst, the fundamental existence of the business is threatened.

In response to the title of this column, no, business ethics is not an oxymoron. Despite the current media scrutiny and the ethical bankruptcy of some corporations, clearly not all businesses, or even the majority of them, are engaging in criminal or unethical behavior. The entrepreneurial activity of business is an essential and noble pursuit. It provides the economic foundation and the fundamental basis of survival for society's members. In the modern world, business activity provides the means by which we feed, clothe, and shelter our families. It provides health care for our sick, entertainment for our leisure, and many other necessities of life. With that noble pursuit, however, comes a responsibility for businesses to operate in an equally noble manner.

Eileen P. Kelly is a professor of management in the School of Business at Ithaca College.

FORTHCOMING ISSUES

Winter 2003

CANCER RESEARCH

Spring 2003

PROFESSIONAL ETHICS

ECLIPSE

The moon, that pale porcelain drop
of timidity floating like a fragile
bubble through our history, has more
than one trick up its sleeve.

It can take heaven's glittering
hardware and submerge it in night,
blot out the sun and place shadow
where light once danced into a billion

varieties of green, and reminds us
time stands still for neither blades
of grass nor raging suns. This gentle
mirror knows how to have its way

with things — the sky transforms
in its hands, the good red earth
slumps into darkness, night creatures
waken when it should be day.

What deep lessons does this teach
the sea? Its tides are already giddy
from the pull of this light eater,
this surprise packed little celestial dot.

An eclipse is the kind of proof
a planet needs once its occupants
replace their need for wonder
with the quest for cold ready cash.

FREDRICK ZYDEK

Fredrick Zydek is the author of four collections of poetry: *Lights Along the Missouri*, *Storm Warning*, *Ending the Fast*, **and** *The Conception Abbey Poems*. **His work appears in** *The Antioch Review*, *The Hollins Critic*, *Michigan Quarterly Review*, *Poetry*, *Poetry Northwest*, **and other journals. Formerly a professor of creative writing and theology at the University of Nebraska and later at the College of Saint Mary, he is now a gentleman farmer when he is not writing. Most recently he has accepted the post as editor for Lone Willow Press.**

Forum on

Science & Technology

Douglas W. Larson

Tourism and the Road to Oblivion

We usually think of our national parks as unspoiled sanctuaries where natural wonders, hallowed ground, and historical artifacts are painstakingly preserved for present and future generations. As vestiges of an unbounded North American wilderness, many national parks evoke thoughts of tranquility, visual beauty, and nature in its primeval state. The author Edward Hoagland, writing about national parks on the National Park Service's seventy-fifth anniversary, called them "enclaves of greenery, history, and dignity."

But anyone who has visited a national park recently — in particular the more popular ones such as Yellowstone, Yosemite, Grand Canyon, and the Great Smoky Mountains — probably had an experience that he or she could just as easily have had in a densely populated urban environment. Conditions that were once completely foreign to national parks are now the norm: traffic gridlock, mobs of people, overcrowded park facilities, road rage, noise and air pollution, litter, crime, tacky souvenir shops, fast-food restaurants, diesel-spewing garbage trucks, shopping malls, and gun-toting security officers.

The problem of urban blight in national parks is attributable, in part, to the rising flood of park visitors. At Oregon's Crater Lake National Park, for example, the number of visitors rose from about 3 million during the park's first forty years of existence (1902-1941) to more than 8 million between 1970 and 1982. Visitation for all national parks, totaling around 300 million in 1990, is expected to exceed one-half billion by 2010.

But the problem cannot be blamed entirely on mere visitation. Lurking in the background are various interest groups whose sense of values about national parks is not consistent with the stated objective of the National Park Service, that is, to "conserve the scenery and the natural and historical objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them *unimpaired* [emphasis added] for the enjoyment of future generations." What these groups value most are money and political advantage. What they generally have in common is a willingness to turn priceless national treasures into cold hard cash. At Crater Lake, private enterprise charges exorbitant prices for overnight rooms in the park's newly renovated grand lodge; operates several fifty-passenger tour boats that prowl the lake, possibly damaging its rare and fragile limnological features; and pushes rubber tomahawks, fast food, and cheap trinkets at honky-tonk concession stands. Additionally, the park is pressured from all sides by relentless cultural expansion, including logging and mining operations, ski resorts, highways, real-estate developments, and "improvements" to commercial facilities inside the park.

Although Washington's Mount St. Helens National Volcanic Monument is not a national park, it was established by Congress in August 1982 with roughly the same purpose in mind: "to protect the geologic, ecologic and cultural resources . . . allowing geologic forces and ecological succession to continue *substantially unimpeded* [emphasis added]." The volcano's catastrophic eruption in May 1980 obliterated old-growth forests, triggered massive landslides and mudflows, and filled nearby lakes and rivers with giant logs and volcanic debris. As destructive as it was, the eruption also provided a once-in-a-lifetime opportunity to study the post-eruption recovery of forest, lake, and river ecosystems that had been suddenly and totally destroyed.

The monument, managed by the U.S. Forest Service, encompasses about 175 square miles comprising most of the volcano's blast zone. Congress directed the Forest Service to "permit the full use of the Monument for scientific study and research" and "prevent undue modification of the natural conditions of the Monument." The Forest Service itself proclaimed in its 1981 final environmental impact statement for the monument that "an unparalleled opportunity to study the dynamics of geological force and biological response was created by the eruption. Successive generations will witness the restoration of natural selection."

Shortly after the eruption, dozens of scientists fanned out across the volcano's blast zone, establishing long-term baseline-research sites to systematically measure and document ecological recovery in the wake of volcanic destruction. Since 1980, scientists have revisited the sites regularly to track revitalization. Of particular interest is the so-called Pumice Plain, a vast area of volcanic deposits lying between the mountain's crater and Spirit Lake (see photo on page 7). Here, scientists are studying the adaptive response of pioneer organisms capable of surviving in this seemingly uninhabitable environment. The research continues, with much yet to be learned.

Unfortunately, despite the explicit congressional mandate for scientific research, science has been largely brushed aside in favor of developing the monument for tourism and related economic development. Since 1982, the Forest Service has spent about $2 million on the monument's science program, nearly all of which went for administrative costs including salaries, travel, overhead, and vehicle expenses. Actual research received only a few thousand dollars per year. Most scientists obtained funding from other sources such as the National Science Foundation. Indeed, funds for lake research were so scarce that most of the work was done by volunteer scientists.

Meanwhile, as scientists struggled over the years to piece together the story about post-eruption ecological recovery, the Forest Service budgeted hundreds of millions of dollars for tourist facilities inside and around the monument. Visitor centers were constructed at Silver Lake, Coldwater Lake, and Johnston Ridge at a cost of nearly $30 million. These sites were linked to Interstate Highway 5 by a new highway (State Highway 504) costing more than $200 million. Another $100 million was spent on additional road construction, viewpoints, parking lots, and miscellaneous recreational facilities.

The monument has since become a theme park, attracting more than a million tourists per year. And they are treated to more than a glorious view of Mount St. Helens: Coldwater Lake is stocked with rainbow trout and open for angling. Concessionaires, operating out of trendy visitor centers, peddle food, souvenirs, books, videotapes, clothing, and trinkets molded from Mount St. Helens ash.

Recently, Governor Gary Locke of Washington approved a $350,000 study of a project to extend State Highway 504 across the entire monument. Seven miles long and costing about $20 million, the extended highway will be a constant source of air, water, and noise pollution in the vicinity of Spirit Lake. Worse, it will bisect the Pumice Plain, threatening the area's rare ecology and destroying precious baseline research sites.

The chief proponents of this highly controversial project include former and present commissioners of five counties surrounding the monument. The commissioners, none of whom apparently give a hoot about research of the monument's fragile and recovering ecosystems, view the road as a short-cut for tourists, log trucks, recreational vehicles, and 18-wheelers bound for the "timber-depressed rural areas" east of the monument.

The Washington Department of Transportation (WDOT), while trying to appear impartial, disingenuously listed four "potential benefits" of the highway extension: (1) Provide a new entry into the monument; (2) create new economic activity in timber-depressed rural areas; (3) improve response time by police, fire, and other emergency support agencies; and (4) save time and fuel for tourists and area residents. But the public, clearly troubled by the monument's commercialization, was not convinced: Responding to a WDOT request for public comment, more than 75 percent of the respondents expressed strong opposition to the highway project.

Thwarted by the lack of adequate financing, scientists now face the additional difficulty of protecting their research areas from disturbances created by construction activities and swarms of tourists. Human entry interferes with the natural process of ecosystem rehabilitation, damages or destroys research sites, and generally obstructs efforts to maintain long-term scientific databases that document ecological recovery.

But tourism, not ecological research, is where the money is, after all. Bulldozers will take care of the research sites, burying them under the road to oblivion.

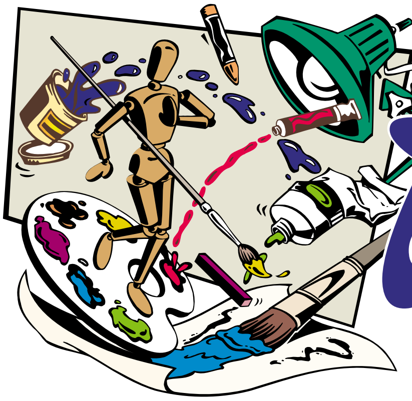
Douglas W. Larson is an adjunct professor in the Department of Biology at Portland State University and a water quality consultant. He spent fourteen summers conducting limnological research at Crater Lake National Park, and studied the limnological recovery of Spirit Lake and other blast-zone lakes at Mount St. Helens between 1980 and 1994.

Mount St. Helens, Washington, circa 1980. Spirit Lake (foreground) is partly covered with logs blown into the lake from surrounding old-growth forests. The Pumice Plain lies between the mountain and Spirit Lake, a distance of about five miles. Photo by Robert Heims, U.S. Army Corps of Engineers.

(continued from page 3)

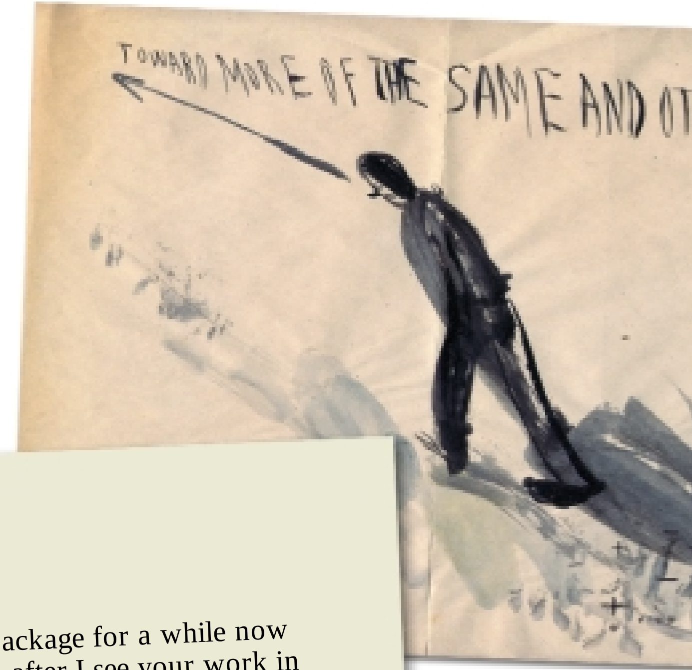
creedal passions and be tough-minded, as Dalrymple is, when analyzing ground-level realities. Because no wind tunnel exists for pretesting social policies, looking at consequences is the only way to determine what really flies.

Paul Trout, an associate professor of English at Montana State University-Bozeman, has published work in* The Chronicle of Higher Education, The Washington Times, *the* Christian Science Monitor, Change, Cresset, Soundings, Chronicles, *and elsewhere. He is the assistant editor of* The Montana Professor, *where he regularly publishes on higher education topics.



Forum on the Arts

George Ferrandi



Dear Chris Johanson:

I'm writing because I have wanted to send you a package for a while now — a package with the pictures and scribblings I make after I see your work in magazines or in galleries. But you are ever elusive — quite the slippery fish, you, with no permanent address and such fly-by-night wanderings from gallery to gallery.

So I invent you a mailbox here and put this note in it. Some things I would like to say:

1. You are one of my favorite artists. Does this seem big to you? It is big to me. I have been living in New York for one year now. One bruised and tender year. A very good year for trying to figure out what is important . . . .

2. Thank you for bringing your mountain to Manhattan Island. On my way to it, a little girl was asking her dad what was mother-of-pearl, anyway. I did not hear her — really hear her — until I had passed them on the street, taken a right into the gallery, and ducked into your cardboard mountain. Your shanty cardboard house of a mountain, dark brown like kids' cupcakes with a whitely painted peak. There were a few quiet drawings inside. One was an ink drawing of a star with lots of jaggy spokes. That was when I really heard her ask him. And I heard another girl then, too, from months before on the A-train coming from St. John's Cathedral, asking her dad another question. She was asking him what was infinity. He did not look up from the newspaper when he told her that was how much he loved her, so he never saw the sideways suspicion she was shooting at the abstractness of his answer. And then I heard myself talking to my own dad, also months before, telling him about the footprints of a chicken embedded in the sidewalk near my house in Brooklyn. I was trying to explain to him how surreal this seemed — such a rural residue in such a dramatically urban landscape. He said, "stupid chicken."

3. There is a story about a man who left a goodbye note to the world saying he would walk through his city, from his house to the bridge, and if a single person smiled at him or looked him in the eyes, he would not jump . . . .

We are implicated in each other's lives. We are responsible for each other's humanity. The delicate rawness of your drawings reminds us that we are each alone in here, right along with everyone else. We can make things go

either way. Your work talks about our tendency to arbitrarily divide the world into good or bad, odd or even, streets to park on or not to park on, and it makes us laugh at the ridiculousness of these — our own — ideas. It acknowledges the difference between what we say to each other, and what we know without saying.

4. I read that Chris Ware desires a deadness in his drawings so that the text has real work to do. I wonder if you want something like this, too, and if you would call it a "deadness." There is such an unchecked honesty in your words — in the voice of your text. I remember one scratchy figure, centered on the paper and facing forward. The words said something like "this is any person at any of many crossroads." And the simplicity of the image and the complexity of that idea collided in my head. I know that this is the way the very best cartoons work; the words and image depend on each other for completion in a way that makes the art exist even more in the mind of the viewer than it does on the actual page.

That piece exists and re-exists for me now, like much of your work, as I move around in the city. It exists especially in the places that people go on the train — not their physical destinations, but the alone-in-a-crowd places where their faces fall quiet and their eyes shift from the floor to the nothing just above the floor that happened to them yesterday. It exists in the vapor-thin lady with the tadpole-transparent skin and silver heels sharp as her eye shadow, and also in the European man with dreaming eyes, whose nose is made redder by the darkness of his hair. And in his girlfriend who, just as the doors suck shut, I notice has been noticing me noticing him. It is barely perceptible, in any describable way, but somehow still very much possible to tell who is happy and who is heartsick and who among them is at any of many crossroads.

Thank you for the drawing. I send good feelings to you, too.

George Ferrandi
georgeferrandi@hotmail.com

George Ferrandi is a multi-media artist and founding member of "Cloud Seeding: Circus of the Performative Object" (www.cloudseedingcircus.com). She is a former assistant professor at the University of Florida and is currently living and working in Brooklyn, New York.

Drawings by Chris Johanson, used by permission.

William A. Hiscock

From Wormholes to the Warp Drive: Using Theoretical Physics to Place Ultimate Bounds on Technology

"You cannot change the laws of physics, Captain."
— Lt. Commander Montgomery Scott, *U.S.S. Enterprise, Star Trek*

Wormholes. Time travel. The "warp drive." These staples of science fiction have today become subjects of serious study by theoretical physicists. Each of these concepts can be identified with mathematical solutions to the equations of Einstein's theory of general relativity — the modern theory of gravity, in which the phenomena of gravity are explained in terms of the geometry of curved spacetime. By studying these solutions in detail, theoretical physicists seek to better learn what bounds exist on the behavior of matter and geometry in our present physical theories. Such studies can yield new insights into the developing quantum theory of gravity, and can also help establish ultimate limits on technology — not based on the degree of scope or difficulty of an engineering challenge, but by compatibility with our core understanding of the fundamental laws of physics.

Three decades ago, adequate theories were first developed for three of the four fundamental forces of nature: the so-called "strong" and "weak" nuclear forces, which operate on subatomic scales, and the electromagnetic force, which is responsible for most of what we experience in everyday life: chemistry, biology, and technology (non-nuclear). The theoretical model of these three forces has been so successful in matching experiments that it has been termed the "Standard Model" of particle physics. Professor Howard Georgi of Harvard has testified to the robustness of the model in saying, "Everything anyone has ever seen can be explained in terms of the Standard Model." While there are some highly interesting aspects of the Standard Model in which new developments in particle physics are still taking place (for example, the study of neutrino properties), the development of the Standard Model of particle physics must rank as one of the premier scientific accomplishments of the twentieth century.

The fourth fundamental force in nature, the gravitational force, remains in many ways an enigma. Gravity was the first force for which a detailed mathematical theory was developed, by Isaac Newton, more than three hundred years ago. That theory is still adequate for us to be able to successfully navigate our planetary spacecraft, such as *Voyager 1* and *2*, around the solar system. Einstein developed our modern theory of gravity not because Newton's theory had been found to disagree with experiment, but because Newton's theory was mathematically incompatible with the dictates of Einstein's special theory of relativity, which requires that all observers measure the same value for the speed of light, c, regardless of their state of motion (this feature of nature has been overwhelmingly confirmed by experiment and observation). Einstein's new theory, completed in 1916, is usually called "general relativity," a name that unfortunately obscures the fact that it is actually a theory of gravitational interaction.

Einstein's theory is widely regarded as one of the most beautiful in all of science. It describes gravity in terms of the curved geometry of the four-dimensional (three space, one time) world that we inhabit. Physicist John Wheeler has beautifully summarized the content of general relativity in a sentence: "Matter tells space how to curve; space tells matter how to move." The first part of the sentence tells us the origin of spacetime curvature. Matter (in any form, including energy, as per Einstein's famous $E = mc^2$) is the source of gravity, causing the curvature of space (or "spacetime," a shorthand for our four-dimensional world). The second part of the sentence describes how matter behaves in this curved four-dimensional world, namely that it follows paths which are the curved-space generalization of "straight lines" — *geodesics*. The "great circle" route of an airplane flying from New York to Tokyo is an example of a geodesic; it is not a straight line (which would pass through the solid Earth), but is the shortest path connecting the two cities along the curved surface of the Earth.

UNRESOLVED QUESTIONS

Despite the great strides that have been made in understanding the behavior of matter and energy at the fundamental level, many unresolved questions still attract the attention of physicists. Perhaps the greatest of these is the search for an understanding of how gravity fits together with the other three fundamental forces. It is clear that a truly fundamental theory of gravity must be quantum in nature, and general relativity is not. The contrast between the Standard Model, which is built on the foundation of quantum field theory, and general relativity, which has been tested with a high degree of accuracy but is still inadequate because of its classical nature, has caused many to term the theory of quantum gravity to be the Holy Grail of theoretical physics. However, despite decades of effort, little is truly clear about the nature of quantum gravity. Should gravity be able to stand alone in a quantum theory, independent of the other fields that constitute nature, or can gravity be understood only in terms of a unified theory that attempts to handle all aspects of matter and its interactions at once? M-theory (sometimes called "the theory formerly known as superstrings") is a bold attempt at a theory of everything, solving the problem of the quantum theory of gravity by merging all matter and interactions into a single theory in which the fundamental objects are not point particles, but are higher-dimensional objects such as loops of "superstring."

In ordinary matter, quantum effects become quite evident when one reaches the atomic scale, at roughly 10^{-10} meters. Today's high-energy particle accelerators allow us to study the behavior of matter and energy at scales as small as 10^{-17} meters, where the existence of particles such as quarks, gluons, and W and Z bosons, which are completely invisible back up at the atomic scale, are evident. Quantum gravitational effects are expected to become important when one reaches the Planck scale, about 10^{-35} meters. If superstring theory describes nature, this is the size of a typical loop of superstring material. The large difference in scale between the Planck scale of superstrings and today's experiments — some eighteen orders of magnitude, a billion billion — is one reason why it is so difficult for physicists working on superstring models to make experimental predictions from their theory that can be tested with our present level of technology.

The even larger span between the scales at which quantum effects become evident in matter, and the Planck scale of quantum gravity, twenty-five orders of magnitude, is a realm in which the semiclassical theory of gravity may be a good tool to help us understand how gravity and quantum physics are to be married. In semiclassical gravity, the gravitational field is still treated classically, being described by the curved spacetime of general relativity. The matter that creates the spacetime curvature, however, is treated using quantum field theory. The resulting theory cannot be ultimately acceptable because it mixes classical and quantum physics, but it should be a valuable tool and an approximate description of the behavior of nature over length scales (and energy scales) that reach down towards the realm where string theory may provide an ultimate exegesis.

PUSHING THE LIMITS: BLACK HOLES AND WORMHOLES

Theoretical physicists expand their understanding of the strengths, limits, and behavior of a particular theory by "pushing" the theory to its limiting cases. For example, we understand general relativity much better by studying the properties of black hole solutions to the Einstein equations than we would if we restricted attention to the tiny differences between the predictions of Newtonian gravity and general relativity for, say, planetary orbits. These tiny differences provide valuable experimental tests of general relativity, given that we do not have any black holes in our near neighborhood that we can study in detail; but understanding the full range of behavior allowed by the theory is best enhanced by examining the nature of its predictions for situations that are far from "normal" — for instance, for black holes, and much more speculative solutions to the equations such as those called "wormholes," the "warp drive," and those which lead to the possibility of time travel.

Each of these concepts can be identified with particular spacetime geometries, and hence with mathematical solutions to Einstein's theory of general relativity. In fact, *any* four-dimensional geometry for a spacetime can be termed a solution of Einstein's theory — the question physics must answer is whether the matter necessary to curve spacetime into a particular "shape" is of a form compatible with nature as we understand it. If one postulates a spacetime geometry with some exotic property (for example, a wormhole), then it is likely that "exotic" matter is necessary to generate that geometry. By "exotic matter" we mean matter that has properties not usually seen in ordinary situations — such as negative mass or energy densities. Such properties are so far from those exhibited by normal matter that we must seriously ask whether such behavior is compatible with the quantum field theory description of matter in the Standard Model. This then provides a link between extreme quantum behavior of matter and exotic geometries, and hence insight into the possibilities of quantum gravity.

Next, one may ask whether the exotic geometry is *stable* — would small changes destroy the exotic structure, for example, by closing off a wormhole. In some cases, the small change necessary to drive the instability is provided by quantum mechanics, again providing a link between these exotic spacetime structures and quantum aspects of gravity. A pencil balanced on its point is an example of a mathematical solution of the laws of mechanics that is unstable; the smallest motion will cause it to fall in one direction or another. The goal is to continue to make the model of the geometry more realistic, adding more aspects of physics to its description and determining whether the original exotic geometry is compatible with this more realistic treatment. If physics rules the feature out, then no amount of clever engineering can hope to turn science fiction to fact; on the other hand, if no incompatibility with known physics is found, then it might be possible for future engineers to create such geometric structures in spacetime. It is important to note that the work of physicists does not aim to place limits on the potential scope of engineering, *except* where violations of well-tested and accepted laws of physics are involved. Simply because an engineering solution might involve energies and scales many orders of magnitude beyond what earthly technology can achieve today does not daunt the inquiring physicist at all.

An example of how such a study proceeds is provided by the story of how the present interest in these concepts largely began — surprisingly enough, with science fiction, namely the writing of the novel *Contact* by Carl Sagan. Sagan asked Kip Thorne, the Feynman Professor of Physics at Caltech, for advice to help ensure that the method chosen to transport the novel's heroine across the Galaxy would not be scientifically ludicrous. Thorne suggested replacing the notion of diving through a black hole as a portal to distant realms with the idea of using a wormhole.

A black hole is a spherical region of spacetime surrounded by an "event horizon," which functions as a one-way "gate." *Anything* that crosses the event horizon into the black hole — rocks, spaceships, light itself — cannot escape the black hole. In the simplest model of a black hole, where the black hole has no spin or electric charge, any matter falling into the hole is inevitably crushed into a spacetime *singularity*, where the gravitational tidal forces are infinitely strong. There is no escape. The notion that black holes might provide "tunnels to elsewhere" first arose in the 1960s, when physicists found that if a black hole had an electric charge, or if it was spinning, matter (for example, a spaceship) falling into the hole could avoid being crushed into a singularity and would eventually emerge from the confines of the hole into "another universe." This "other universe" might be identified with a distant region of our own universe, which led quickly to science fiction authors using black holes as interstellar shortcuts through spacetime.

However, the physics did not stop there: through the 1970s, work by a large number of physicists (including Nobel Laureate Subrahmanyan Chandrasekhar) showed that the "tunnel" structure inside such models of black holes is unstable, both classically and quantum mechanically. By including more physics in the model, we find that the tunnel is closed off, replaced by a singularity as in the simpler black hole case. Thus, by studying these exotic models of black-hole interiors in greater detail, the "science fiction" aspects were actually ruled out when nature was examined more closely.

For this reason, Thorne suggested that Sagan use a wormhole in his novel, rather than a black hole. A "wormhole" is, as the name suggests, a topologically distinct route between two locations which are the "mouths" of the wormhole (think of an actual wormhole which has two ends on the surface of an apple). A priori, the distance through the wormhole, from mouth to mouth, could be either longer or shorter than the conventional distance traveled through ordinary space (or over the surface of the apple). For the purposes of science fiction, wormholes that provide shortcuts through spacetime are of course preferred. Unlike a black hole, wormholes do not generally possess event horizons, so no "one-way gates" in spacetime are involved.

The serious study of wormhole geometries in general relativity began in the late 1980s when Thorne and his students, and subsequently many other theoretical physicists, showed that wormholes inevitably must involve "exotic matter." In order to hold the "throat" of the wormhole (between the two mouths) open, there must be some form of matter or energy present that has negative mass or energy. Every form of classical matter known to physics has positive mass, hence the term "exotic" for this alternate possibility. This is where the truly interesting research questions begin, for when one combines a quantum description of matter and energy with curved spacetime, it is known that situations involving negative mass can arise. This phenomenon has even been demonstrated in the laboratory, in the Casimir effect, a very weak attractive force that exists between two uncharged parallel plates made of electrically conducting material. This force exists due to the negative energy in the volume between the two plates, which is caused by the conducting plates eliminating some of the usual vacuum modes between them. While this is an example of how quantum effects can create an effective negative mass, it is a very weak effect — the negative mass is small in magnitude (much smaller than the mass of the plates) and occupies a very small volume of space.

For wormholes, the key question still being investigated today is whether any plausible configuration of quantum fields in curved spacetime could create sufficient negative mass to hold open a macroscopic wormhole — one large enough for a starship, a person, or even a single atom to pass through. So far, the evidence suggests that it is highly unlikely such structures could exist: strongly negative mass such as that required to hold a wormhole open has never been observed and is considered unlikely to exist (even antimatter has positive mass). The final word here has certainly not yet been written; our understanding continues to improve as new models incorporating more particle physics are examined.

Physicists are also interested in microscopic wormholes, much smaller than a proton, down at the scale of the Planck length. These might play an important role in quantum gravity, where spacetime is often viewed as a foaming sea of tiny wormholes, forming and disappearing every instant. Another significant problem for anyone enthusiastic about wormholes is the "worm" problem: how do you create a wormhole? Perhaps a small, quantum wormhole (if they exist) could be caught and expanded to useful size. This important question has not yet been addressed in any satisfactory manner.

WARP DRIVES

The "warp drive" is another example of an interesting geometry that is yielding new insights into general relativity. In 1994, Miguel Alcubierre, at the time a graduate student at the University of Wales in Cardiff, published a mathematical description of a spacetime geometry that embodies the properties usually associated in science fiction with a "warp drive." In this geometry, a "starship" can *apparently* travel faster than the speed of light, traversing interstellar distances of many light-years in an arbitrarily short time — both as measured by those on the starship, and those at the destination. I say "apparently," because the starship never exceeds the speed of light as measured by a local observer — thus, the basic tenet of Einstein's special relativity is not violated. The motion of the ship occurs because the spacetime in front of the starship contracts while that behind the starship expands, transporting the starship forward. Further study has shown that such solutions are probably all unphysical, for several reasons. The foremost difficulty was noted by Alcubierre in his original paper: such solutions inevitably involve a large concentration of negative mass, which appears to be just as implausible in this context as in the case of wormholes. Still, research continues in this area, as there are enough significant variations on Alcubierre's original idea to keep theoreticians busy for some time to come.

TIME TRAVEL

Is time travel possible? Ignoring the pedestrian everyday progression of time, the question can be divided into two parts: Is it possible, within a short time (less than a human life span), to travel into the distant future? And is it possible to travel into the past? Our current understanding of fundamental physics tells us that the answer to the first question is a definite yes, and to the second, maybe.

The mechanism for traveling into the distant future is to use the time-dilation effect of special relativity. Special relativity teaches us that time is not absolute and universal for all possible observers: a moving clock will appear to tick more slowly the closer it approaches the speed of light. This effect, which has been overwhelmingly supported by experimental tests, applies to all types of clocks, including biological aging. Departing from Earth in a spaceship that could accelerate continuously at a comfortable one *g* (an acceleration that would produce a force equal to the gravity we feel everyday at the earth's surface), one would begin to approach the speed of light relative to the Earth within about a year. As the ship continued to accelerate, it would come ever closer to the speed of light, and its clocks would appear to run at an ever slower rate relative to the Earth.

Under such circumstances, a round trip to the center of our Galaxy and back to the Earth — a distance of some 60,000 light-years — could be completed in only a little more than forty years of ship time. Upon arriving back at the Earth, the astronaut would be only forty years older, while 60,000 years would have passed on the Earth. (Note that there is no "twin paradox," because it is unambiguous that the space traveler has felt the constant acceleration for forty years, while a hypothetical twin left behind on an identical spaceship circling the Earth has not.) Such a trip would pose formidable engineering problems: the amount of fuel required, even assuming a perfect 100 percent-efficient conversion of mass into energy, greatly exceeds the mass of a planet. But nothing in the known laws of physics would prevent such a trip from occurring.

Time travel into the past is a much more uncertain proposition. Many solutions to Einstein's equations of general relativity exist, including some involving wormholes in motion, that allow a person to follow a timeline that would result in her encountering herself — or her grandmother — at an earlier time. The problem, as we have seen before, is deciding whether these solutions represent situations that could occur in the real universe, or whether they are mere mathematical oddities incompatible with known physics. Much work has been done by theoretical physicists in the past decade to try to determine whether, in a universe that is initially without time travel, one can build a time machine — in other words, if it is possible to manipulate matter and the geometry of space-time in such a way as to create new paths that circle back in time. The main possible roadblock to creating a time machine seems to be a quantum instability of the spacetime — any attempt to "turn on" a time machine would result in spacetime changing its geometry to prevent the machine's operation. This instability was first discovered by Deborah Konkowski of the U.S. Naval Academy and me in 1982. Once again, the question of the possibility of time travel remains an open and an active area of research; there are serious questions as to whether this quantum instability is truly strong enough to prevent time travel, and whether there are not special quantum states that avoid the instability altogether.

These concepts associated with science fiction continue to be useful areas of research for real, serious theoretical physics. By studying these solutions to Einstein's equations, we can gain new insights about the ultimate limits of gravity and its relation to quantum-field theory descriptions of matter.

William A. Hiscock, a professor of physics at Montana State University, is director of the Montana NASA EPSCoR Program as well as the Montana Space Grant Consortium. He has won numerous awards for his teaching and research, including the Wiley Research Award, the Phi Kappa Phi Fridley Outstanding Teaching Award, and the Cox Family Award for Academic Excellence in Teaching and Research. He has published pedagogical and public outreach articles in the ***American Journal of Physics*****,** ***Scientific American*** **(electronic version),** ***Discover*****,** ***Science Digest*****, and** ***Quantum*****.**

Suggestions for additional reading:

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PHYSICS PROFESSOR KILLED IN COFFEE SHOP

An old story, for all the new ways
of stringing out words in space.
You're in Starbucks. The instant
the cup is cool enough to lift to lip —
your mind on the structure
of the universe, say, nonzero constants,
the hypothetical symmetry between
fermions and bosons in the effort
to unify the electroweak and strong forces
into a single framework — just as you
purse your mouth, making an O,
darkness enters your soul, a car careens
through the wall and takes you out.
Since the Big Bang, that car and your need
for caffeine have been humming
through nothing. This is the way
the world works. You walk in the door,
take a seat, lift a steaming cup,
make thoughts beautiful or sordid,
and it comes — *out of control* the paper
will say next day, the octogenarian driver
at the end of her own rope, but
there's no way. You've proven again
the symmetry of the cosmos, matter
to energy, carom of fragile skull
off fatal headlight, the last thought
requiring no thought at all.

DAVID CITINO

David Citino teaches at Ohio State University. He is the author of twelve collections of poetry, including *The News and Other Poems* **(University of Notre Dame Press),** *The Invention of Secrecy*, *The Book of Appassionata: Collected Poems*, **and** *Broken Symmetry*, **named a Notable Book by the National Book Critics Circle. He writes on poetry for the** *Columbus Dispatch*, **and is the contributing editor of a book of prose,** *The Eye of the Poet: Six Views of the Art and Craft of Poetry* **(Oxford University Press).**

Michio Kaku

M-Theory: Mother of All Superstrings

Every decade or so, a stunning breakthrough in string theory sends shock waves racing through the theoretical physics community, generating a feverish outpouring of papers and activity. This time, the Internet lines are burning up as papers keep pouring into the Los Alamos National Laboratory's computer bulletin board, the official clearinghouse for superstring papers. John Schwarz of Cal Tech, for example, has been speaking to conferences around the world proclaiming the "second superstring revolution." Edward Witten of the Institute for Advanced Study in Princeton gave a spellbinding three-hour lecture describing it. The aftershocks of the breakthrough are even shaking other disciplines, such as mathematics. The director of the Institute, mathematician Phillip Griffiths, says, "The excitement I sense in the people in the field and the spinoffs into my own field of mathematics . . . have really been quite extraordinary. I feel I've been very privileged to witness this first hand."

And Cumrun Vafa at Harvard has said, "I may be biased on this one, but I think it is perhaps the most important development not only in string theory, but also in theoretical physics at least in the past two decades." What is triggering all this excitement is the discovery of something called "M-theory," a theory that may explain the origin of strings. In one dazzling stroke, this new M-theory has solved some long-standing puzzling mysteries about string theory that have dogged it from the beginning, leaving many theoretical physicists (myself included!) gasping for breath. M-theory, moreover, may even force string theory to change its name. Although many features of M-theory are still unknown, it does not seem to be a theory purely of strings. Michael Duff of Texas A&M is already giving speeches with the title "The Theory Formerly Known as Strings!" String theorists are careful to point out that this does not prove the final correctness of the theory. Not by any means. That proof may take years or decades more. But it marks a most significant breakthrough that is already reshaping the entire field.

PARABLE OF THE LION

Einstein once said, "Nature shows us only the tail of the lion. But I do not doubt that the lion belongs to it even though he cannot at once reveal himself because of his enormous size." Einstein spent the last thirty years of his life searching for the "tail" that would lead him to the "lion," the fabled unified field theory or the "theory of everything," which would unite all the forces of the universe into a single equation. The four forces (gravity, electromagnetism, and the strong and weak nuclear forces) would be unified by an equation perhaps one inch long. Capturing the "lion" would be the greatest scientific achievement in all of physics, the crowning achievement of 2,000 years of scientific investigation, ever since the Greeks first asked themselves what the world was made of. But although Einstein was the first one to set off on this noble hunt and track the footprints left by the lion, he ultimately lost the trail and wandered off into the wilderness. Other giants of twentieth-century physics, such as Werner Heisenberg and Wolfgang Pauli, also joined in the hunt. But all the easy ideas were tried and shown to be wrong. When Niels Bohr once heard a lecture by Pauli explaining his version of the unified field theory, Bohr stood up and said, "We in the back are all agreed that your theory is crazy. But what divides us is whether your theory is crazy enough!"

The trail leading to the unified field theory, in fact, is littered with the wreckage of failed expeditions and dreams. Today, however, physicists are following a different trail that might be "crazy enough" to lead to the lion. This new trail leads to superstring theory, which is the best (and in fact only) candidate for a theory of everything. Unlike its rivals, it has survived every blistering mathematical challenge ever hurled at it. Not surprisingly, the theory is a radical, "crazy" departure from the past, being based on tiny strings vibrating in ten dimensional space-time. Moreover, the theory easily swallows up Einstein's theory of gravity. Witten has said, "Unlike conventional quantum field theory, string theory requires gravity. I regard this fact as one of the greatest insights in science ever made." But until recently, there has been a glaring weak spot: string theorists have been unable to probe all solutions of the model, failing miserably to examine what is called the "non-perturbative region," which I will describe shortly. This is vitally important because ultimately our universe (with its wonderfully diverse collection of galaxies, stars, planets, sub-atomic particles, and even people) may lie in this "non-perturbative region." Until this region can be probed, we don't know if string theory is a theory of everything — or a theory of nothing! That's what today's excitement is all about. For the first time, using a powerful tool called "duality," physicists are now probing beyond just the tail, and finally seeing the outlines of a huge, unexpectedly beautiful lion at the other end. Not knowing what to call it, Witten has dubbed it "M-theory." In one stroke, M-theory has solved many of the embarrassing features of the theory, such as why we have five superstring theories. Ultimately, it may solve the nagging question of where strings come from.

PEA BRAINS AND THE MOTHER OF ALL STRINGS

Einstein once asked himself if God had any choice in making the universe. Perhaps not, so it was embarrassing for string theorists to have five different self-consistent strings, all of which can unite the two fundamental theories in physics, the theory of gravity and the quantum theory.

Each of these string theories looks completely different from the others. They are based on different symmetries, with exotic names like E(8)xE(8) and O(32).

Not only this, but superstrings are in some sense not unique: there are other non-string theories which contain "super-symmetry," the key mathematical symmetry underlying superstrings. (Changing light into electrons and then into gravity is one of the rather astonishing tricks performed by supersymmetry, which is the symmetry that can exchange particles with half-integral spin, such as electrons and quarks, with particles of integral spin, such as photons, gravitons, and W-particles.)

In eleven dimensions, in fact, there are alternate super theories based on membranes as well as point particles (called super-gravity). In lower dimensions, there is moreover a whole zoo of super theories based on membranes in different dimensions. (For example, point particles are zero-branes, strings are one-branes, membranes are two-branes, and so on.) For the p-dimensional case, some wag dubbed them p-branes (pronounced "pea brains"). But because p-branes are horribly difficult to work with, they were long considered just a historical curiosity, a trail that led to a dead-end. (Michael Duff, in fact, has collected a whole list of unflattering comments made by referees to his National Science Foundation grant concerning his work on p-branes. One of the more charitable comments from a referee was: "He has a skewed view of the relative importance of various concepts in modern theoretical physics.") So that was the mystery. Why should supersymmetry allow for five superstrings and this peculiar, motley collection of p-branes? Now we realize that strings, super-gravity, and p-branes are just different aspects of the same theory. M-theory (M for "membrane" or the "mother of all strings," take your pick) unites the five superstrings into one theory and includes the p-branes as well. To see how this all fits together, let us update the famous parable of the blind men and the elephant. Think of the blind men on the trail of the lion. Hearing it race by, they chase after it and desperately grab onto its tail (a one-brane). Hanging onto the tail for dear life, they feel its one-dimensional form and loudly proclaim "It's a string! It's a string!"

But then one blind man goes beyond the tail and grabs onto the ear of the lion. Feeling a two-dimensional surface (a membrane), the blind man proclaims, "No, it's really a two-brane!" Then another blind man is able to grab onto the leg of the lion. Sensing a three-dimensional solid, he shouts, "No, you're both wrong. It's really a three-brane!" Actually, they are all right. Just as the tail, ear, and leg are different parts of the same lion, the string and various p-branes appear to be different limits of the same theory: M-theory. Paul Townsend of Cambridge University, one of the architects of this idea, calls it "p-brane democracy"; that is, all p-branes (including strings) are created equal. Schwarz puts a slightly different spin on this. He says, "We are in an Orwellian situation: all p-branes are equal, but some (namely strings) are more equal than others. The point is that they are the only ones on which we can base a perturbation theory." To understand unfamiliar concepts such as duality, perturbation theory, and non-perturbative solutions, it is instructive to see where these concepts first entered into physics.

DUALITY

The key tool to understanding this breakthrough is something called "duality." Loosely speaking, two theories are "dual" to each other if they can be shown to be equivalent under a certain interchange. The simplest example of duality is reversing the role of electricity and magnetism in the equations discovered by James Clerk Maxwell of Cambridge University 130 years ago. These are the equations that govern light, television, X-rays, radar, dynamos, motors, transformers, even the Internet and computers. The remarkable feature about these equations is that they remain the same if we interchange the magnetic field B and electric field E and also switch the electric charge "e" with the magnetic charge "g" of a magnetic "monopole": $E \longleftrightarrow B$ and $e \longleftrightarrow g$ (In fact, the product "eg" is a constant.) This has important implications. Often, when a theory cannot be solved exactly, we use an approximation scheme. In first-year calculus, for example, we recall that we can approximate certain functions by Taylor's expansion. Similarly, since $e^2 = 1/137$ in certain units and is hence a small number, we can always approximate the theory by power expanding in e^2. So we add contributions of order $e^2 + e^4 + e^6$ and so on in solving for, say, the collision of two particles. Notice that each contribution is getting smaller and smaller, so we can in principle add them all up. This generalization of Taylor's expansion is called "perturbation theory," where we perturb the system with terms containing e^2. For example, in archery, perturbation theory is how we aim our arrows. With every motion of our arms, our bow gets closer and closer to aligning with the bull's eye. But now try expanding in g^2. This is much tougher; in fact, if we expand in g^2, which is large, then the sum $g^2 + g^4 + g^6$ etc. blows up and becomes meaningless. This is the reason why the "non-perturbative" region is so difficult to probe, since the theory simply blows up if we try to naively use perturbation theory for large coupling constant g. So at first it appears hopeless that we could ever penetrate into the non-perturbative region. (For example, if every motion of our arms got bigger and bigger, we would never be able to zero in and hit the target with the arrow.) But notice that because of duality, a theory of e (which is easily solved) is identical to a theory of large g (which is difficult to solve). Because they are the same theory, we can use duality to solve for the non-perturbative region.

S, T, AND U DUALITY

The first inkling that duality might apply in string theory was discovered by K. Kikkawa and M. Yamasaki of Osaka University in 1984. They showed that if you "curled up" one of the extra dimensions into a circle with radius R, the theory was the same if we curled up this dimension with radius $1/R$. This is now called T duality: $R \longleftrightarrow 1/R$ When applied to various superstrings, one could reduce five of the string theories to three. In nine dimensions (with one dimension curled up) the Type IIa and IIb strings were identical, as were the E(8)xE(8) and O(32) strings.

Unfortunately, T duality was still a perturbative duality. The next breakthrough came when it was shown that there was a second class of dualities, called S duality, which provided a duality between the perturbative and non-perturbative regions of string theory. Another duality, called U duality, was even more powerful.

Then Nathan Seiberg and Witten brilliantly showed how another form of duality could solve for the non-perturbative region in four dimensional supersymmetric theories. However, what finally convinced many physicists of the power of this technique was the work of Edward Witten and Paul Townsend. They caught everyone by surprise by showing that there was a duality between ten dimensional Type IIa strings and eleven dimensional supergravity! The non-perturbative region of Type IIa strings, which was previously a forbidden region, was revealed to be governed by eleven dimensional supergravity theory, with one dimension curled up. At this point, I remember that many physicists (me included) were rubbing our eyes, not believing what we were seeing. I remember saying to myself, "But that's impossible!"

All of a sudden, we realized that perhaps the real "home" of string theory was not ten dimensions, but possibly eleven, and that the theory wasn't fundamentally a string theory at all! This revived tremendous interest in eleven dimensional theories and p-branes. Lurking in the eleventh dimension was an entirely new theory which could reduce to eleven dimensional supergravity as well as ten dimensional string theory and p-brane theory.

DETRACTORS OF STRING THEORIES

To the critics, however, these mathematical developments still don't answer the nagging question: How do you test it? Because string theory is really a theory of Creation, when all its beautiful symmetries were in their full glory, the only way to test it, the critics wail, is to recreate the Big Bang itself, which is impossible. Nobel Laureate Sheldon Glashow likes to ridicule superstring theory by comparing it with former President Reagan's Star Wars plan, that is, they are both untestable, soak up resources, and siphon off the best scientific brains.

Actually, most string theorists think these criticisms are silly. They believe that the critics have missed the point. The key point is this: if the theory can be solved non-perturbatively using pure mathematics, then it should reduce at low energies to a theory of ordinary protons, electrons, atoms, and molecules, for which there is ample experimental data. If we could completely solve the theory, we should be able to extract its low-energy spectrum, which should match the familiar particles we see today in the Standard Model. Thus, the problem is not building atom smashers l,000 light years in diameter; the real problem is raw brain power: if only we were clever enough, we could write down M-theory, solve it, and settle everything.

EVOLVING BACKWARDS

So what would it take to actually solve the theory once and for all and end all the speculation and back-biting? There are several approaches. The first is the most direct: try to derive the Standard Model of particle interactions, with its bizarre collection of quarks, gluons, electrons, neutrinos, Higgs bosons, etc. etc. etc. (I must admit that although the Standard Model is the most successful physical theory ever proposed, it is also one of the ugliest.) This might be done by curling up six of the ten dimensions, leaving us with a four dimensional theory that might resemble the Standard Model a bit, then try to use duality and M-theory to probe its non-perturbative region, seeing if the symmetries break in the correct fashion, giving us the correct masses of the quarks and other particles in the Standard Model. Witten's philosophy, however, is a bit different. He feels that the key to solving string theory is to understand the underlying principle behind the theory.

Let me explain. Einstein's theory of general relativity, for example, started from first principles. Einstein had the "happiest thought in his life" when he leaned back in his chair at the Bern patent office and realized that a person in a falling elevator would feel no gravity. Although physicists since Galileo knew this, Einstein was able to extract from this the Equivalence Principle. This deceptively simple statement (that the laws of physics are indistinguishable locally in an accelerating or a gravitating frame) led Einstein to introduce a new symmetry to physics, general coordinate transformations. This in turn gave birth to the action principle behind general relativity, the most beautiful and compelling theory of gravity. Only now are we trying to quantize the theory to make it compatible with the other forces. So the evolution of this theory can be summarized as: Principle Symmetry $\longrightarrow$ Action $\longrightarrow$ Quantum Theory.

According to Witten, we need to discover the analog of the Equivalence Principle for string theory. The fundamental problem has been that string theory has been evolving "backwards." As Witten says, "string theory is twenty-first-century physics which fell into the twentieth century by accident." We were never "meant" to see this theory until the next century.

IS THE END IN SIGHT?

Vafa recently added a strange twist to this when he introduced yet another mega-theory, this time a twelve-dimensional theory called F-theory (F for "father") which explains the self-duality of the IIb string. (Unfortunately, this twelve-dimensional theory is rather strange: it has two time coordinates, not one, and actually violates twelve-dimensional relativity. Imagine trying to live in a world with two times! It would put an episode of *Twilight Zone* to shame.) So is the final theory ten, eleven, or twelve dimensional?

Schwarz, for one, feels that the final version of M-theory may not even have any fixed dimension. He feels that the true theory may be independent of any dimensionality of space-time, and that eleven dimensions only emerge once one tries to solve it. Townsend seems to agree, saying "the whole notion of dimensionality is an approximate one that only emerges in some semiclassical context." So does this mean that the end is in sight, that we will someday soon derive the Standard Model from first principles? I asked some of the leaders in this field to respond to this question. Although they are all enthusiastic supporters of this revolution, they are still cautious about predicting the future. Townsend believes that we are in a stage similar to the old quantum era of the Bohr atom, just before the full elucidation of quantum mechanics. He says, "We have some fruitful pictures and some rules analogous to the Bohr-Sommerfeld quantization rules, but it's also clear that we don't have a complete theory."

Duff says, "Is M-theory merely a theory of supermembranes and super 5-branes requiring some (as yet unknown) non-perturbative quantization, or (as Witten believes) are the underlying degrees of freedom of M-theory yet to be discovered? I am personally agnostic on this point." Witten certainly believes we are on the right track, but we need a few more "revolutions" like this to finally solve the theory. "I think there are still a couple more superstring revolutions in our future, at least. If we can manage one more super string revolution a decade, I think that we will do all right," he says. Vafa says, "I hope this is the 'light at the end of the tunnel' but who knows how long the tunnel is!" Schwarz, moreover, has written about M-theory: "Whether it is based on something geometrical (like supermembranes) or something completely different is still not known. In any case, finding it would be a landmark in human intellectual history." Personally, I am optimistic. For the first time, we can see the outline of the lion, and it is magnificent. One day, we will hear it roar.

Michio Kaku is professor of theoretical physics at the City University of New York. He is author of numerous books, including *Hyperspace* (1994), *Beyond Einstein* (1995), *Visions* (1997), and *Introduction to Superstrings and M-theory* (1999). His web site is www.mkaku.org.

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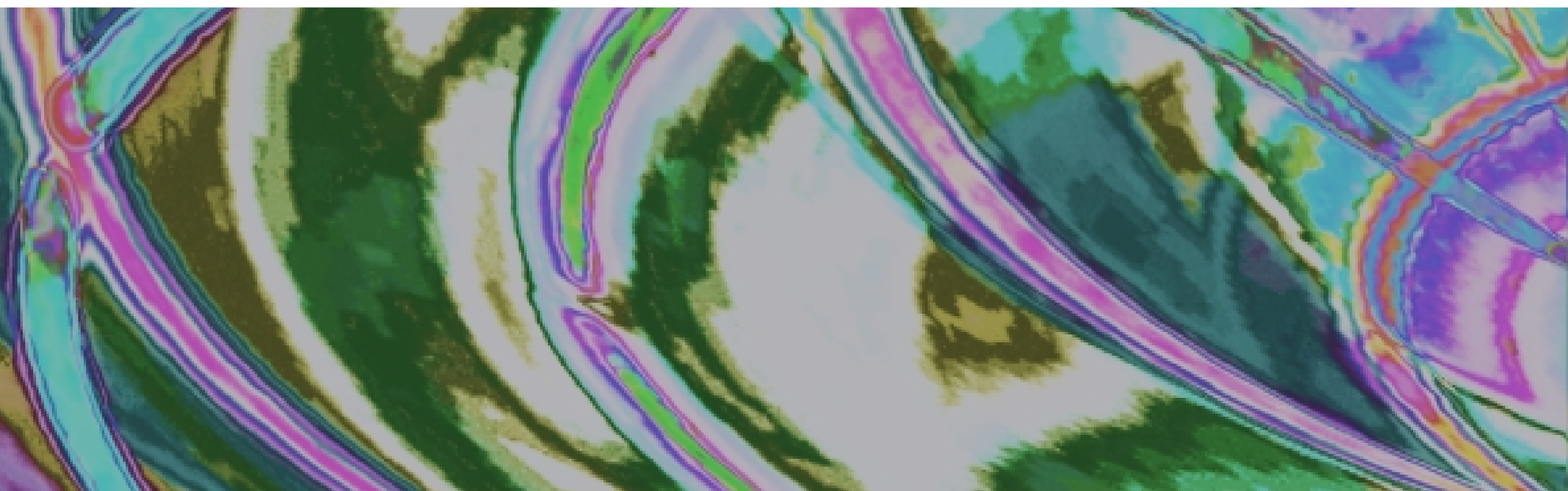


Gordon Kane

Anthropic Questions

The goal of science is to understand the natural universe as completely as possible. In the four hundred years since Galileo and Kepler and others began modern science, we have succeeded in understanding the physical world around us. We know the particles (electrons, and particles like electrons but with an extra interaction, called quarks) that make up all that we see, from flowers to people to stars. We know how the particles interact through the gravitational, electromagnetic, strong, and weak forces, according to the rules of quantum theory, to form the complexity and beauty of our world. We know the history of our planet, our sun, and our universe back to their beginnings. Our description is a fully mathematical theory that is very well tested and established. It incorporates the two Standard Models of particle physics and of cosmology (forgive the mundane names — the names arise as the phenomena are being studied, and then it is hard to change them). Now we would like to understand why it is that these particles exist and these interactions occur, and why they have the properties that they do, and to explain as much as possible about why the universe not only works as it does but even why it exists at all, and why we exist.

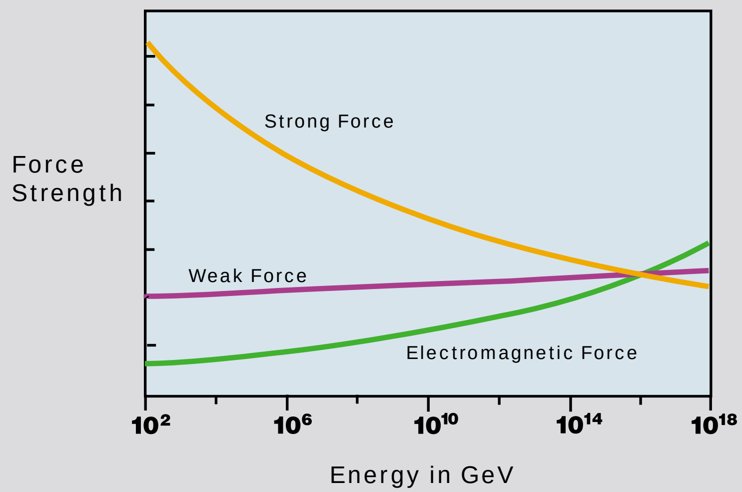
With the two Standard Models we can formulate such questions scientifically. We can work out how various quantities and forces affect the conditions for life. For example, we know that carbon and other heavier elements are necessary for our life. In the Big Bang, only helium and hydrogen were made in large quantities. Carbon and heavier elements are made in stars and then distributed throughout large regions when the stars die in supernova explosions after billions of years. That means life can arise only on the second- or third-generation planets that incorporate the heavy elements, after they have been formed in a first- or second-generation star. So we can basically understand a "why" question, "why is our universe so old as it is (about 13 billion years)?" It is because universes with life like ours have to be at least a few billion years old so that stars will have formed and died. We also understand why the universe is not very much older than it is because if it were, it would have expanded so much it would have such a small density in any region that solar systems with planets would no longer form.

Some aspects of how things work seem to have to be rather precise if life is to exist. One example is the strengths of the forces. Stars "burn" protons to make the light that provides energy for us to live. To give life time to evolve, stars need to live billions of years. The rate at which stars burn protons depends on a balance between the attractive strong force and the repulsive electromagnetic force. In the 1960s scientists realized that if the strong force were just a little stronger, only a few percent, stars would burn too fast and provide light for only a few years. Similar reasoning tells us that all the forces have to be about the strength that they are, or we would not exist. Can we explain why the forces have to be "just so," in astronomer Craig Hogan's phrase?

ANSWERING QUESTIONS

It turns out that such arguments are less constraining than they first seemed to be. Recently we have come to understand that the forces are not to be thought of independently. They can be unified in an extension of the Standard Model for which there is good indirect evidence, called the supersymmetric Standard Model, or in string theory. Assuming the forces are unified, if we imagine increasing the strong force, we must simultaneously increase the electromagnetic force. The increased attraction of the strong force is balanced by an increased repulsion from the electromagnetic force, and the amount of increase that allows life is significantly larger than if we treat them independently. Even then, though, the range of strengths that allows life is still limited — if the force strengths were very much larger than they are, the world would be much different. It is an interesting and legitimate question to ask if we can understand why the strengths of the forces are what they are.

I and many scientists think of these and similar questions about particle properties and other quantities as "anthropic questions" that we would like to answer. For one, we would like to understand why the force strengths are what they are. Other issues that need understanding are a complicated relationship between the masses of the up and down quarks and the electron, and a quantity that affects the curvature of the universe, called the "cosmological constant," whose actual value is much smaller than the value that simple calculations imply for it. If these quantities differed much from what they actually are, we would not exist. Although all the needed analyses have not yet been carried out, I think most of the anthropic questions that have to be "just so" in order for us to exist can be reduced to the three cited above, in today's unified theories.



This figure shows how the forces of nature (not including gravity) behave if they are extrapolated to high energies, or equivalently small distances. One can do the extrapolation since the forces and their effects are described by a mathematical theory. The strength of the forces is measured in experiments and shown at the left edge of the graph, and the strength they would have for increasing energy is then calculated. Remarkably, the forces become equal at very high energies, which implies that they can be interpreted as one basic force that apparently gives different effects at our low energies. Thus if one wants to ask about the effects of increasing the strength of one of the forces at our energies, one must move the whole set of lines up and simultaneously increase the others also (maintaining the unification).

In the past there were more anthropic questions; these questions have since been explained by normal physics, so an anthropic explanation for them is not needed. For instance, the universe probably went through a very early period of rapid increase in size called inflation, which culminated in the Big Bang expansion. The resulting universe would exist and expand a long time, so we have a likely explanation of why the universe is old. Another example is that the universe is made of matter but not antimatter. If there were equal amounts of each, life would not exist because matter and antimatter annihilate each other, leaving too little matter to form galaxies and stars. We do not yet know for sure how the universe evolved from an initial state with equal amounts of matter and antimatter to today's asymmetry (a universe dominated by matter, that is), but several possible explanations are being explored and tested. We expect one of them to be valid, so we think that we will understand this asymmetry. We do not know yet if all the anthropic questions will be explained, but the remaining three described above are all addressed by supersymmetric string theory, so we hope that they soon will be.

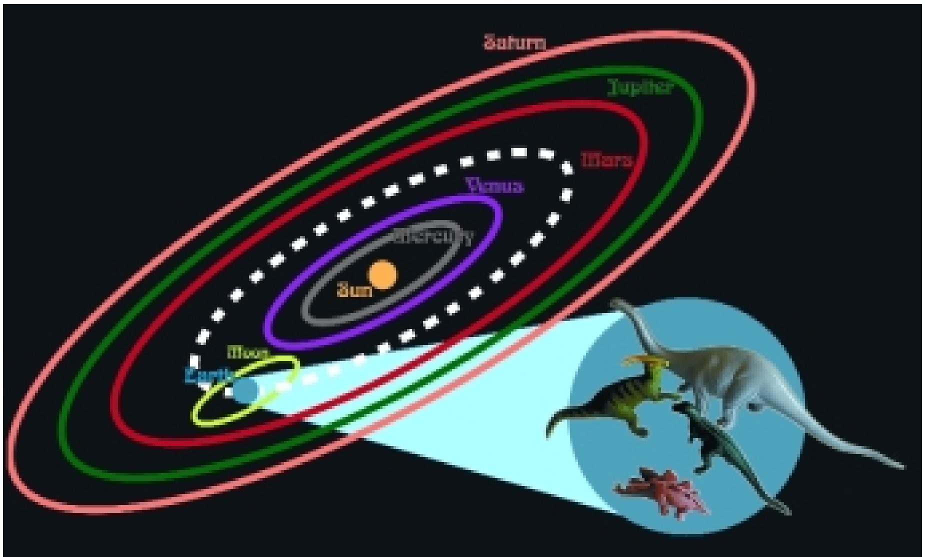
As people recognized the existence of anthropic questions during recent decades, a variety of reactions occurred. Some scientists are annoyed by them, basically saying that anthropic explanations (such as something is the way it is because if it were not, we would not be here to ask) are not explanations, and science can do better. Others, including distinguished leaders such as Vaclav Havel . . . reacted by saying the need for anthropic explanations puts us back at the center because the universe is arranged so that humans can exist.

As people recognized the existence of anthropic questions during recent decades, a variety of reactions occurred. Some scientists are annoyed by them, basically saying that anthropic explanations (such as something is the way it is because if it were not, we would not be here to ask) are not explanations, and science can do better. Others, including distinguished leaders such as Vaclav Havel (who have been unhappy that we learned in the past century that not only was the earth not the center of the universe, but it also was just one planet in one of a huge number of solar systems in one of a huge number of galaxies, and the particles that we are made of are not even the main form of matter in the universe), reacted by saying the need for anthropic explanations puts us back at the center because the universe is arranged so that humans can exist. That argument seems to be refuted by recalling that the conditions for life on earth led to a world dominated by dinosaurs for more than a hundred million years, until an accidental collision with an asteroid destroyed the dinosaurs and allowed mammals to evolve in new directions. Others have reacted by defining "anthropic principles" that are hypotheses for explaining anthropic questions. A widely accepted one is the reasonable Weak Anthropic Principle, which roughly says that the forces and particles and laws must be such as to allow the universe to contain intelligent life, because we know that it does. A number of other versions of anthropic principles exist, including stronger ones, but for science it is understanding anthropic questions (that is, "just-so" phenomena) that is relevant, not formulating principles that may lead us into missing some understanding.

MANY UNIVERSES?

Suppose one day we have a theory in which all anthropic questions are answered, in the sense that once the theory is written, calculations will correctly predict all the quantities that have to be "just so" for us to exist. Some people may still have an uncomfortable feeling, asking why the theory is one that leads to life instead of one that does not and considering the possible implications of that question. Such a question is illuminated and perhaps answered by another feature of recent theories — today's theories seem to imply the existence of many "universes." These results are not yet fully understood, so "universes" is in quotes because its meaning is uncertain. It may be that these universes are all to be thought of as domains of one inclusive universe, or as entirely separate ones.

Two paths at least lead to such ideas. One is inflation — inflation can happen repeatedly, even to



Are the laws of nature “just right“ for life to emerge on Earth?

small pieces of existing universes, with each patch that inflates turning in effect into another universe. The second is string theory. In science, theories provide equations or principles, and the behavior of actual phenomena are the solutions of the equations. A system will, most of the time, be in its state of least energy, the ground state, just as a ball will bounce down a hill to the bottom. A universe, like an atom, may form in any of many states, and it will eventually settle into its ground state. It turns out that string theory implies a large number of apparently equivalent ground states, all of which may lead to separate universes. Thus, both inflation and string theory may lead to multiple universes.

One aspect of our universe which we want to understand is that we live in three space dimensions. There is an anthropic explanation. About a century ago, we discovered that planetary orbits are not stable in four or more space dimensions, so if there were more than three space dimensions, planets would not orbit a sun long enough for life to originate. For the same reason, atoms are not stable in four or more space dimensions. And in one or two space dimensions, neither blood flow nor large numbers of neuron connections can exist. Thus, interesting life can exist only in three dimensions. Alternatively, it may be that we can derive the fact that we live in three dimensions because the unique ground state of the relevant string theory turns out to have three large dimensions (plus perhaps some small ones of which we are not normally aware). Or string theory may have many states with three space dimensions, and all of them may result in universes that contain life.

Each of the multitude of universes may have different laws of nature, or different values of quantities that determine how they behave, such as the speed of light or Planck’s constant (which determines the size of quanta in quantum theory). Some may be suitable for life, and some may not. All those suitable for life may have life develop. Sometimes life will evolve only into dinosaurs rather than something more intelligent. We cannot attach any meaning to the fact that a life form which could ask anthropic questions did develop in at least one universe. It is very much like a lottery. If you win the lottery, you may feel very grateful, but someone had to win, and no one selected who that was, except randomly. Just because a universe has a unique set of laws and parameters should not lead one to wonder whether that set was designed.

One might worry that the multiple-universe approach implies that we cannot hope to calculate and understand all the parameters of a physical theory from fundamental principles, because their values can differ from one universe to another. Hogan, for example, has argued that even a fully unified theory will not allow the calculation of all quark masses, in order to allow for different worlds that have different values for them. But from the string theory or inflation point of view, each world leads to its own full set of masses and other quantities and laws. In any of them that we could study experimentally, we might be able to learn to understand their laws and calculate their basic parameters.

At present, neither inflation nor string theory is understood well enough to calculate how many universes there are, or even whether the number is finite or infinite, or in what senses the laws of nature and the quantities that enter the equations can differ. So these arguments are informed speculation. But to many people it is exciting that these ideas are now finally the subject of basic physics research.

Gordon Kane is the Victor Weisskopf Collegiate Professor of Physics at the Michigan Center for Theoretical Physics, Randall Physics Lab, University of Michigan.

OCTOBER DRAGONFLY

The sweeping spiral of this gust of wind
skittering amber leaves above the silver pond
suggests the swirling shape of galaxies,
a template too for water draining down,
but what about the whorls of flesh tipping my fingers?
Are they too the residue of primal forces?
My eyes seeing in my flesh the very start of time?

A blur-quick dragonfly, so far out of season,
suddenly shares this patch of shoreline,
gliding over sunsplintered, wavering ripples
with the casual ease of owning the air.

If I'm the residue of primordial whirl
perhaps he's an arrow in sun-relentless motion
fired outward from that first climactic shudder
which birthed every atom of this huge mosaic.

He retreats to the shadow of overhanging boulders
even as the sun slips behind a gray cloud
some atoms of which perhaps can remember
that first wild moment of colliding spirals,
surging wind of birth made manifest as rock,
heat, shower, vision, eternity today.

LEE SLONIMSKY

Lee Slonimsky's work has appeared in *Connecticut Review*, *The Hiram Poetry Review*, **and other journals. A collection of his poems,** *Talk between Leaf and Skin*, **was published in 2001 by Sulphur River Literary Review Press of Austin, Texas. He is the manager of a hedge fund, Ocean Partners LP.**

Peering into the Universe: Images from the Hubble Space Telescope

The remarkable images that follow are all from NASA's Hubble space telescope. Originally a symbol of botched technology because of its flawed mirror, the Hubble, since it was repaired, has been a triumph for the space agency and for scientists all over the world. Its breathtaking images continue to startle and enlighten. The photos we have included are among the most recent, and were taken variously with the newly reactivated Near Infrared and Multi-Object Spectrometer (NICMOS), the Advanced Camera for Surveys (ACS), and the Wide Field Planetary Camera 2 (WFPC2). The text accompanying them is also from NASA's web site, http://oposite.stsci.edu/pubinfo/pictures.html, where you can find more extensive explanations, along with archived photos. We greatly appreciate NASA allowing us to use these images and text for this issue.

Omega Nebula

A watercolor fantasyland? No. It's actually an image of the center of the Omega Nebula, a hotbed of newly born stars wrapped in colorful blankets of glowing gas and cradled in an enormous cold, dark hydrogen cloud. This stunning picture was taken by the ACS.

The region of the nebula shown in this photograph is about 3,500 times wider than our solar system. The area represents about 60 percent of the total view captured by ACS. The nebula, also called M17 and the Swan Nebula, resides 5,500 light-years away in the constellation Sagittarius.

Like its famous cousin in Orion, the Swan Nebula is illuminated by ultraviolet radiation from young, massive stars, located just beyond the upper right corner of the image. Each star is about six times hotter and thirty times more massive than the Sun. The powerful radiation from these stars evaporates and erodes the dense cloud of cold gas within which the stars formed. The blistered walls of the hollow cloud shine primarily in the blue, green, and red light emitted by excited atoms of hydrogen, nitrogen, oxygen, and sulfur. Particularly striking is the rose-like feature, seen to the right of center, which glows in the red light emitted by hydrogen and sulfur.

Credit: NASA, H. Ford (JHU), G. Illingworth (USCS/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA

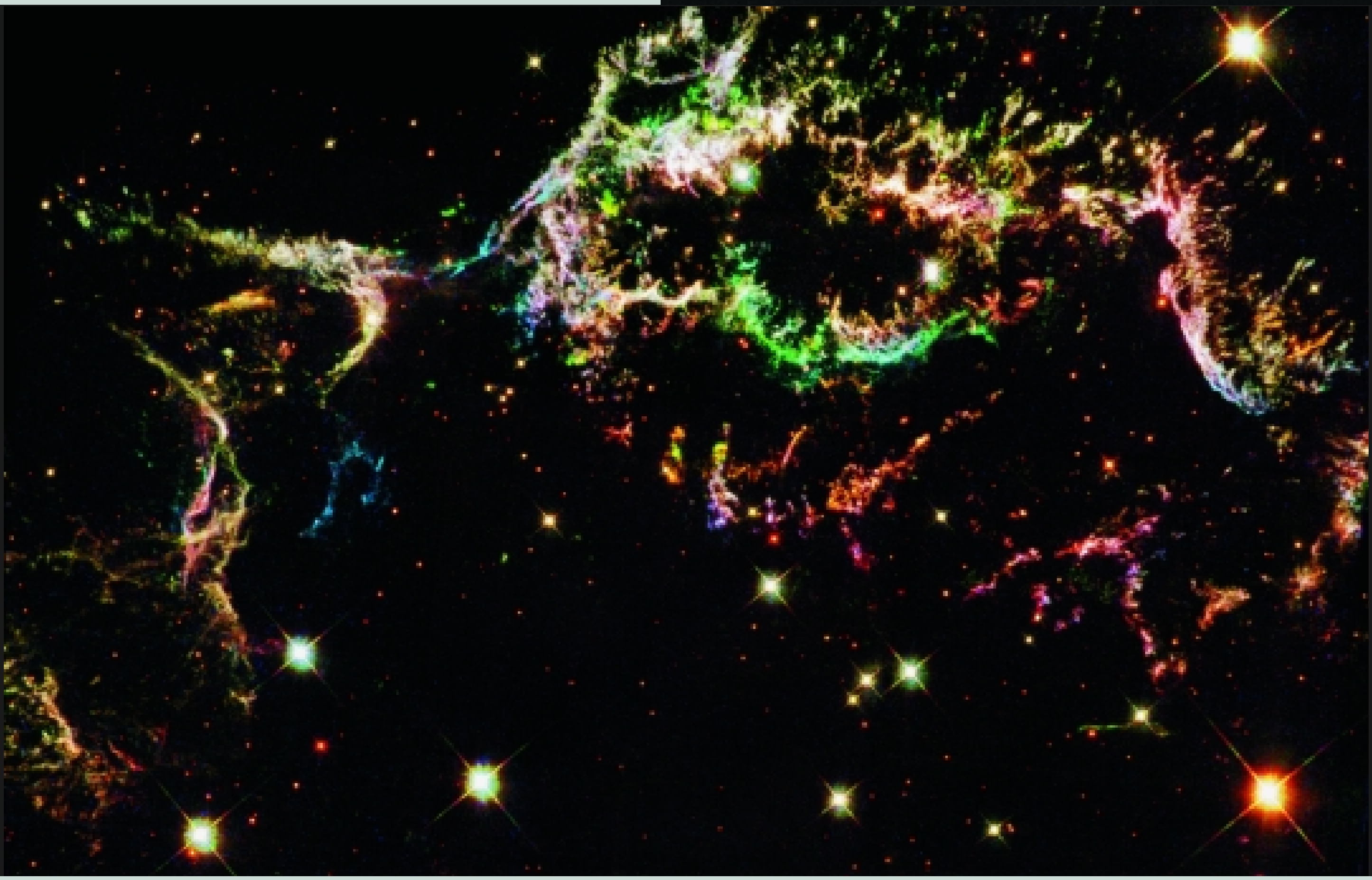
A Wheel Within a Wheel

A nearly perfect ring of hot, blue stars pinwheels about the yellow nucleus of an unusual galaxy known as Hoag's Object (after astronomer Art Hoag, who discovered it in 1950). This image captures a face-on view of the galaxy's ring of stars, revealing more detail than any existing photo of this object. The image may help astronomers unravel clues on how such strange objects form.

The entire galaxy is about 120,000 light-years wide, which is slightly larger than our Milky Way Galaxy. The blue ring, which is dominated by clusters of young, massive stars, contrasts sharply with the yellow nucleus of mostly older stars. What appears to be a "gap" separating the two stellar populations may actually contain some star clusters that are almost too faint to see. Curiously, an object that bears an uncanny resemblance to Hoag's Object can be seen in the gap at the one o'clock position. The object is probably a background ring galaxy.

Credits: NASA and the Hubble Heritage Team (STScI/AURA)

Acknowledgment: Ray A. Lucas (STScI/AURA)



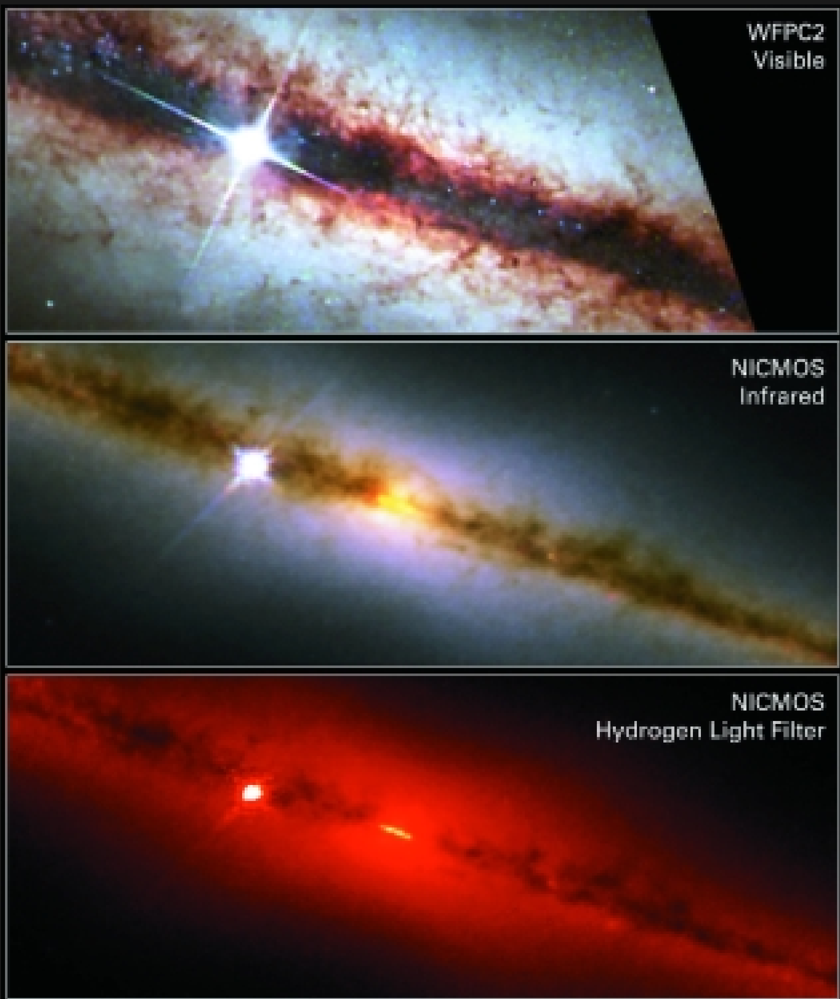
Cassiopeia A

Glowing gaseous streamers of red, white, and blue — as well as green and pink — illuminate the heavens like Fourth of July fireworks. The colorful streamers that float across the sky were created by one of the biggest firecrackers seen to go off in our galaxy in recorded history, the titanic supernova explosion of a massive star, about 15 to 25 times more massive than our Sun. The dead star's shredded remains are called Cassiopeia A, or "Cas A" for short. The light from the exploding star reached Earth 320 years ago.

Cas A is the youngest known supernova remnant in our Milky Way Galaxy and resides 10,000 light-years away in the constellation Cassiopeia, so the star actually blew up 10,000 years before the light reached Earth in the late 1600s.

Image Credit: NASA and The Hubble Heritage Team (STScI/AURA)

Acknowledgment: R. Fesen (Dartmouth) and J. Morse (Univ. of Colorado)



Galaxy NGC 4013

In another NICMOS shot, the Hubble has pierced the dusty disk of the edge-on galaxy NGC 4013 and peered all the way to the galactic core. To the surprise of astronomers, NICMOS found a brilliant band-like structure, which may be a ring of newly formed stars (yellow band in middle photo) seen edge-on.

In the visible-light view of the galaxy (top photo), the star-forming ring cannot be seen because it is embedded in dust. The most prominent feature in the visible-light image is the thin, dark band of gas and dust, which is about 500 light-years thick. The ring-like structure spied by NICMOS encircles the core and is about 720 light-years wide, which is the typical size of most star-forming rings found in disk galaxies.

The small ring is churning out stars at a torrid pace. The Milky Way Galaxy, for example, is more than 10,000 times larger than the ring. If the Milky Way produced stars at the same rate, it would be making 1,000 times more stars a year. The ring-like structure is seen more clearly in the photo at bottom. This picture, taken with a filter sensitive to hydrogen, shows the glow of stars and gas. Astronomers used this information to calculate the rate of star formation in the ring-like structure.

Credits for NICMOS images: NASA, the NICMOS Group (STScI, ESA), and the NICMOS Science Team (University of Arizona)

Credits for WFPC2 image: NASA, the Hubble Heritage Team (STScI/AURA) and ESA

Merging Galaxies: NGC 4676

The ACS here has captured a spectacular pair of galaxies engaged in a celestial dance of cat and mouse or, in this case, mouse and mouse.

Located 300 million light-years away in the constellation Coma Berenices, the colliding galaxies have been nicknamed "The Mice" because of the long tails of stars and gas emanating from each galaxy. Otherwise known as NGC 4676, the pair will eventually merge into a single giant galaxy.

The image shows the most detail and the most stars that have ever been seen in these galaxies. In the galaxy at left, the bright blue patch is resolved into a vigorous cascade of clusters and associations of young, hot blue stars, whose formation has been triggered by the tidal forces of the gravitational interaction. Streams of material can also be seen flowing between the two galaxies.

The clumps of young stars in the long, straight tidal tail (upper right) are separated by fainter regions of material. These dim regions suggest that the clumps of stars have formed from the gravitational collapse of the gas and dust that once occupied those areas. Some of the clumps have luminous masses comparable to dwarf galaxies that orbit in the halo of our own Milky Way Galaxy.

Credit: NASA, H. Ford (JHU), G. Illingworth (USCS/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA

Galaxy NGC 4622: Backward Spiral

To the surprise of astronomers, this galaxy, called NGC 4622, appears to be rotating in a direction opposite to what they expected. The image shows NGC 4622 and its outer pair of winding arms full of new stars (shown in blue).

Astronomers are puzzled by the clockwise rotation because of the direction in which the outer spiral arms are pointing. Most spiral galaxies have arms of gas and stars that trail behind as they turn. But this galaxy has two "leading" outer arms that point toward the direction of the galaxy's clockwise rotation. To add to the conundrum, NGC 4622 also has a "trailing" inner arm that is wrapped around the galaxy in the direction opposite to the one in which it is rotating. Based on galaxy simulations, a team of astronomers had expected that the galaxy was turning counterclockwise.

Astronomers suspect that NGC 4622 interacted with another galaxy. Its two outer arms are lopsided, meaning that something disturbed it. The Hubble image suggests that NGC 4622 consumed a small companion galaxy. The galaxy's core provides new evidence for a merger between NGC 4622 and a smaller galaxy.

Image Credit: NASA and The Hubble Heritage Team (STScI/AURA)

Acknowledgment: Dr. Ron Buta (U. Alabama), Dr. Gene Byrd (U. Alabama) and Tarsh Freeman (Bevill State Community College)

"Tadpole" Galaxy

Against a stunning backdrop of thousands of galaxies, this odd-looking galaxy with the long streamer of stars appears to be racing through space, like a runaway pinwheel firework. Galaxy UGC 10214, dubbed the "Tadpole," is unlike the textbook images of stately galaxies. Its distorted shape was caused by a small interloper, a very blue, compact galaxy visible in the upper left corner of the more massive Tadpole. The Tadpole resides about 420 million light-years away in the constellation Draco.

Seen shining through the Tadpole's disk, the tiny intruder is likely a hit-and-run galaxy that is now leaving the scene of the accident. Strong gravitational forces from the interaction created the long tail of debris, consisting of stars and gas that stretch out more than 280,000 light-years.

Numerous young blue stars and star clusters, spawned by the galaxy collision, are seen in the spiral arms, as well as in the long "tidal" tail of stars. Each of these clusters represents the formation of up to about a million stars.

The galactic carnage and torrent of star birth are playing out against a spectacular backdrop: a "wallpaper pattern" of 6,000 galaxies. These galaxies represent twice the number of those discovered in the legendary Hubble Deep Field, the orbiting observatory's "deepest" view of the heavens, taken in 1995 by the Wide Field and Planetary Camera 2. They are a myriad of shapes and represent fossil samples of the universe's 13-billion-year evolution.

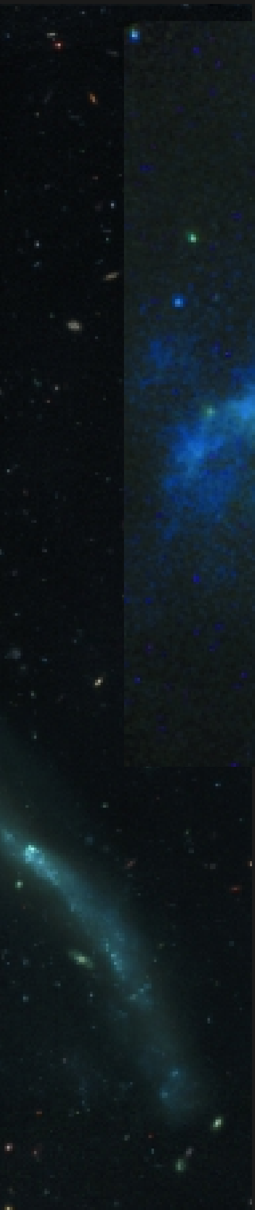
Credit: NASA, H. Ford (JHU), G. Illingworth (USCS/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA

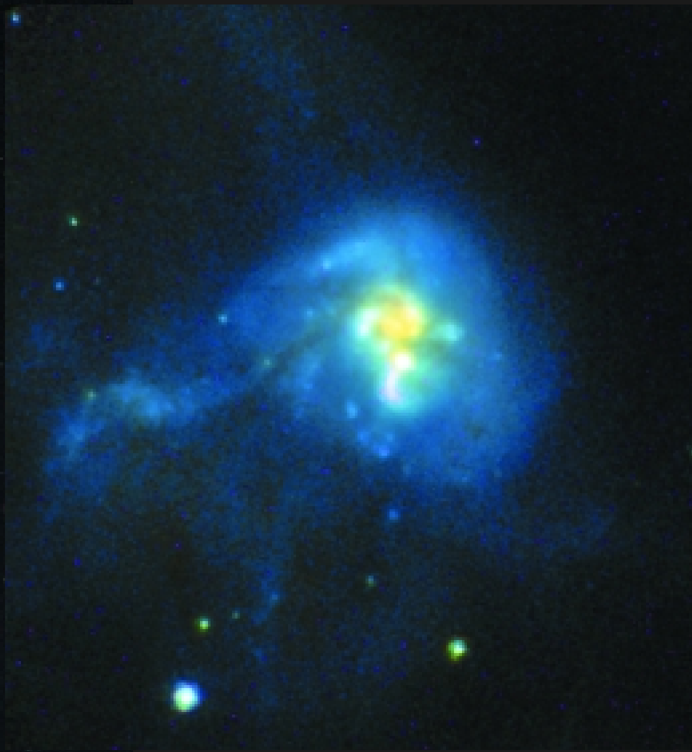
Gomez's Hamburger

Hubble has snapped a photograph of a strange object that bears an uncanny resemblance to a hamburger. The object, nicknamed Gomez's Hamburger, is a sun-like star nearing the end of its life. It already has expelled large amounts of gas and dust and is on its way to becoming a colorful, glowing planetary nebula. The ingredients for the giant celestial hamburger are dust and light. The hamburger "buns" are light reflecting off dust, and the patty is the dark band of dust in the middle. The reason why the star is surrounded by a thick, dusty disk remains somewhat uncertain. It is possible that the central object is actually a pair of stars. If so, then the star that ejected the nebula may be rapidly rotating, expelling material mostly from its equatorial regions.

Image Credit: NASA and The Hubble Heritage Team(STScI/AURA)

Acknowledgment: A. Gomez (Cerro Tololo Inter-American Observatory)





Collision of Four Galaxies

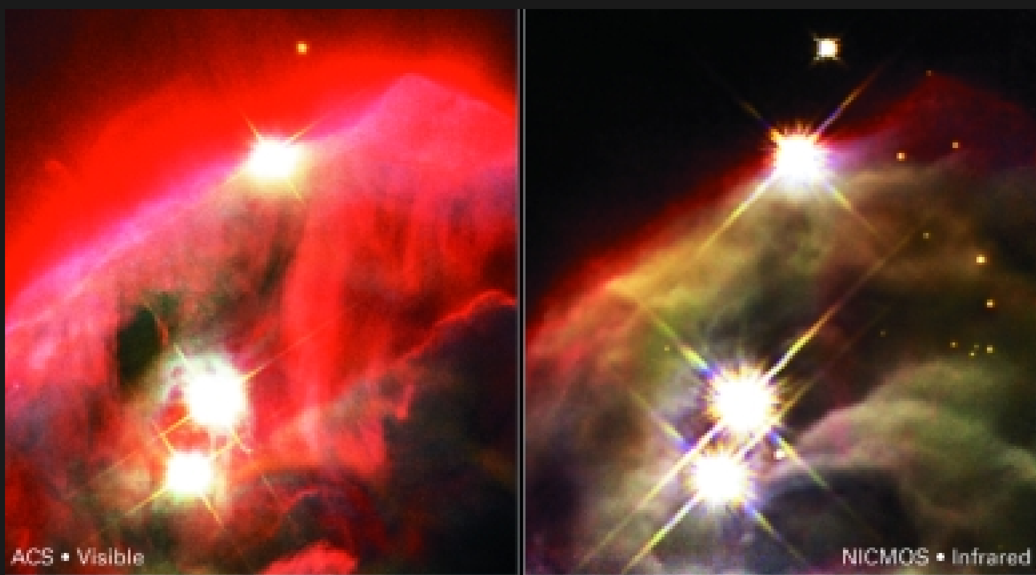
NICMOS and the ACS teamed up to capture the final stages in the grand assembly of galaxies. This photograph shows a tumultuous collision between four galaxies located one billion light-years from Earth. The galactic car wreck is creating a torrent of new stars.

The tangled up galaxies, called IRAS 19297-0406, are crammed together in the center of the picture. IRAS 19297-0406 is part of a class of galaxies known as ultraluminous infrared galaxies (ULIRGs). ULIRGs are considered the progenitors of massive elliptical galaxies.

ULIRGs glow fiercely in infrared light, appearing 100 times brighter than our Milky Way Galaxy. The large amount of dust in these galaxies produces the brilliant infrared glow. The dust is generated by a firestorm of star birth triggered by the collisions.

IRAS 19297-0406 is producing about 200 new Sun-like stars every year — about 100 times more stars than our Milky Way creates. The hotbed of this star formation is the central region (the yellow objects). This area is swamped in the dust created by the flurry of star formation.

Credits: NASA, the NICMOS Group (STScI, ESA), and the NICMOS Science Team (University of Arizona)



Cone Nebula

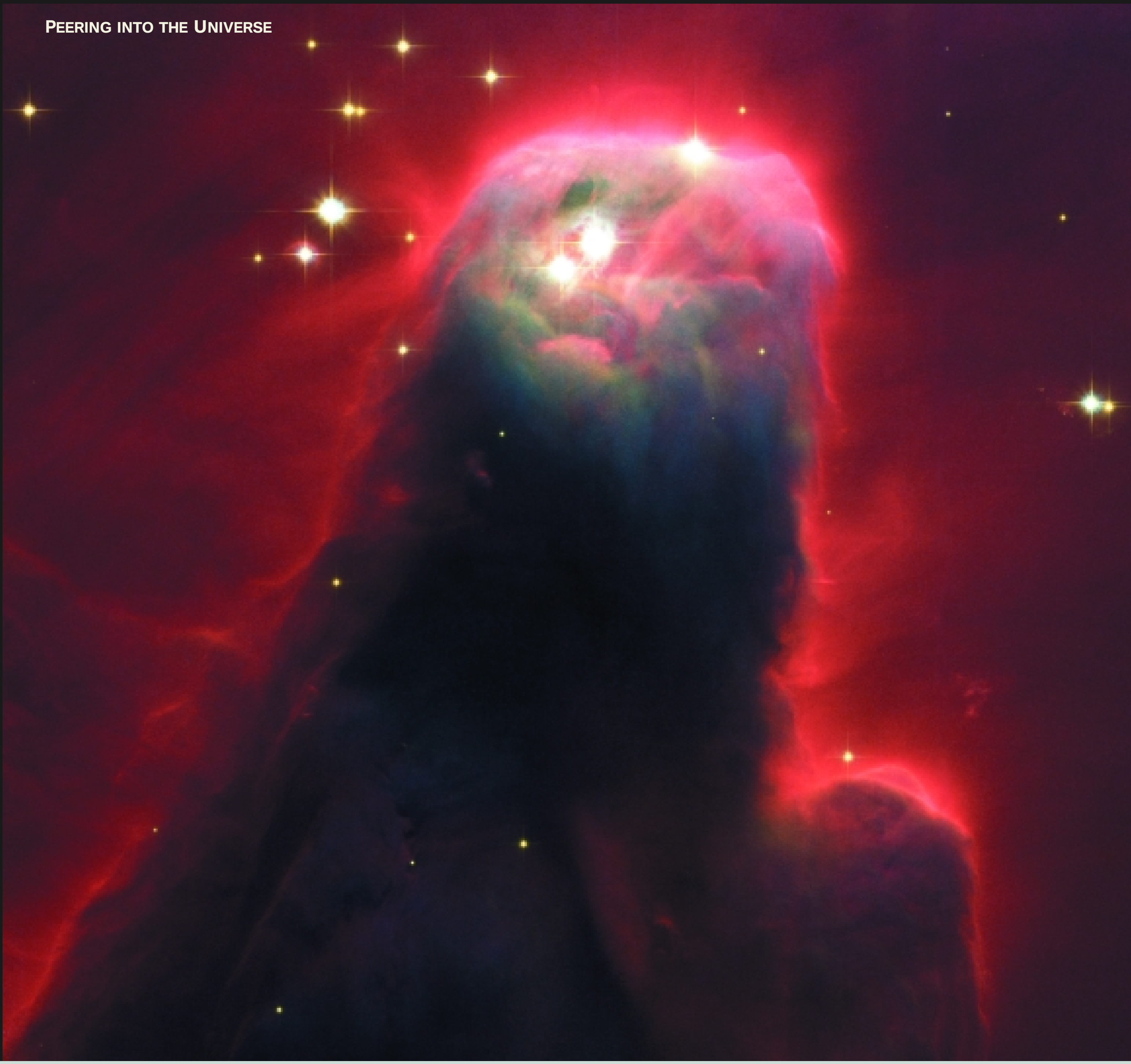
NICMOS has penetrated layers of dust in a star-forming cloud to uncover a dense, craggy edifice of dust and gas (image on the right in the paired photos).

This region is called the Cone Nebula (NGC 2264), so named because, in ground-based images, it has a conical shape. NICMOS enables the Hubble telescope to see in near-infrared wavelengths of light, so that it can penetrate the dust that obscures the nebula's inner regions. But the Cone is so dense that even the "near-infared eyes" of NICMOS can't penetrate all the way through it. The image shows the tip of the nebula, about half a light-year long. The entire nebula is 7 light-years long.

NICMOS has peeled away the outer layers of dust to reveal even denser dust. The denser regions give the nebula a more three-dimensional structure than can be seen in the visible-light picture at left, taken by the ACS. In peering through the dusty façade to the nebula's inner regions, NICMOS has unmasked several stars (yellow dots at upper right). Astronomers don't know whether these stars are behind the dusty nebula or embedded in it. The four bright stars lined up on the left are in front of the nebula.

Credits for NICMOS image: NASA, the NICMOS Group (STScI, ESA), and the NICMOS Science Team (University of Arizona)

Credits for ACS image: NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA



Dust Cloud in the Cone Nebula

Resembling a nightmarish beast rearing its head from a crimson sea, this monstrous object is actually an innocuous pillar of gas and dust in the Cone Nebula. This giant pillar resides in a turbulent star-forming region. This picture shows the upper 2.5 light-years of the nebula, a height that equals 23 million roundtrips to the Moon.

Radiation from hot, young stars (located beyond the top of the image) has slowly eroded the nebula over millions of years. Ultraviolet light heats the edges of the dark cloud, releasing gas into the relatively empty region of surrounding space. There, additional ultraviolet radiation causes the hydrogen gas to glow, which produces the red halo of light seen around the pillar. A similar process occurs on a much smaller scale to gas surrounding a single star, forming the bow-shaped arc seen near the upper left side of the Cone. This arc, seen previously with the Hubble telescope, is 65 times larger than the diameter of our solar system. The blue-white light from surrounding stars is reflected by dust. Background stars can be seen peeking through the evaporating tendrils of gas, while the turbulent base is pockmarked with stars reddened by dust.

Over time, only the densest regions of the Cone will be left. Inside these regions, stars and planets may form.

Credit: NASA, H. Ford (JHU), G. Illingworth (USCS/LO), M.Clampin (STScI), G. Hartig (STScI), the ACS Science Team, and ESA

J-M Wersinger

The National Space Grant Student Satellite Program: Crawl, Walk, Run, Fly!

Bringing Together University, Industry, Military, and Government Resources to Train America's Future Scientists and Engineers

The National Space Grant Satellite Program is opening a wide door of space opportunities for young people. Its "crawl, walk, run, and fly" strategy provides a chance to students from high school to graduate school to build, launch, and operate space hardware with increasing degrees of complexity and sophistication. The program's website announces that "Missions of growing complexity provide opportunities to acquire baseline skills and then to build on them. They range from the simple — building soda-can 'satellites' or small payloads for launch from small rockets or balloons — to building sophisticated satellites." The vision of the program's leaders is compelling: "to make aerospace history and send the first student-built satellites to Mars."

The National Space Grant Student Satellite Program (SG-SSP) comes as a blessing at a time when the aerospace community is facing a major crisis. The aerospace work force is getting old because fewer young people have been entering the pipeline. The Commission on the Future of the United States Aerospace Industry warns, "The impending retirement of the aging aerospace work force, the fact that young people are not choosing engineering as a career field, and a lack of qualified, skilled workers will result in a shortage of aerospace workers in the next decade." (Interim Report #3 – 2002) This is echoed by the new NASA Administrator, Mr. Sean O'Keefe: "We are coming up against critical shortages in the face of impending retirements." About half the NASA work force will reach retirement age within five years. In his address at Syracuse University on April 12, 2002, O'Keefe told the country, "America has a serious shortage of young people entering the fields of mathematics and science," adding that "our best and brightest are being drawn into other professions."

Whereas young people are very fond of space exploration, science, and technology in their preteen years, many lose this interest in their teen years and leave the mathematics, science, and technology pipeline between grades eight and the junior year in college. It is thus necessary not only to fill the pipeline with pre-teens but also to retain them during their teen years. A recent national commission report describes math and science teaching at the K–12 level as "nothing short of a national disgrace" (*Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century*, September 2000). In addition, in the first two years of college, students have very little motivation to pursue a career in the sciences or engineering, and the only hope committed students have is to reach the light at the end of the tunnel provided by the junior and senior years, when they will finally do something interesting. Others choose ostensibly greener pastures.

The National Space Grant College and Fellowship Program (Space Grant) is addressing this challenge head-on with its Student Satellite Program. The SG-SSP was launched by a group of Space Grant Directors with essential input from Professor Robert Twiggs of Stanford University, a veteran satellite builder and educator whose aim is to develop, build, and launch low-cost, small satellites within a short time. The SG-SSP gives students an opportunity to learn math, science, and technology by doing work with aerospace professionals, to participate in a project from inception to operation, to be engaged in a team effort, to have pride in their nascent skills, and to appreciate the value of the concepts that they learn. The program builds a "community of learners."

Hands-on, student-driven programs such as SG-SSP provide a welcome, unique, and very attractive learning experience that parallels and complements traditional learning formats. Students select and design their spacecraft, order parts, build and test components, integrate them into a functional whole, and finally ready the spacecraft for launch. In the process, students learn not only the technical aspects of building space hardware but also how to raise funds, write proposals, manage their program, work in teams, build websites, develop logos, and publish advertising brochures.

Until recently, student-built satellite programs have been developed in only a few states. This year the Space Grant Program has solicited work-force development proposals from its consortia. A total of $3.6 million was available. Many successful consortia proposed to establish a student satellite program in their states. We should thus see a significant development of these projects in many states and hundreds of new students across the country getting involved. Thanks to the Space Grant's national network of more than seven hundred affiliates, of which the majority are colleges and universities, there is widespread expertise and experience that the SG-SSP is eager to help share and spread to partner institutions.

Aerospace industries are strongly supportive of these programs. "Their engineers and scientists act as volunteer mentors to our students. Test facilities

About the Space Grant Program . . .

The National Space Grant College and Fellowship Program (Space Grant) is a nationwide network of more than seven hundred colleges, universities and other institutions that supports the National Aeronautic and Space Administration's education, research, and public service missions. It is a congressionally mandated public service program, instituted in 1988, and modeled after Sea Grant and Land Grant. Space Grant is comprised of fifty-two consortia, one per state plus the District of Columbia and Puerto Rico. Each consortium consists of a lead institution and affiliate member institutions, mostly universities but also industrial affiliates, state organizations, museums and planetariums, and other not-for-profit institutions. Consortia are funded by the Space Grant Office housed in the Education Division at NASA's Headquarters in Washington, D.C. Space Grant is probably best known for its scholarship and fellowship programs that have awarded support to more than 12,000 students since 1989. One of the central missions of Space Grant is to promote and help develop a skilled aerospace workforce. The National Space Grant Student Satellite Program will be a major thrust for Space Grant in 2003 as a tool for work force development.

and materials and even direct funding are made available for the student-built payloads. The companies are eager to move the students into employment as soon as they graduate," states the SG-SSP website.

The website then goes on to give the following examples:

- Within 24 hours of one state's first Space Grant Consortium student payload balloon flight, GSSL Inc., a NASA contractor, contacted the Consortium and offered to hire any student who had worked on the program.
- Since establishing the national CubeSat university email listserv, three aerospace companies sought to hire students who have worked on CubeSat programs.

Part of the interest stems from the fact that few NASA or aerospace-industry scientists and engineers ever take a project through the full mission cycle, whereas projects such as building CubeSats provide that opportunity, given the short one-year cycle for its completion from inception.

CRAWL

At the "Crawl" entry level, high school students and college undergraduates build and launch low-cost craft such as high-altitude balloons or model rockets that radio data to ground stations for analysis. High altitude balloons hover above 99 percent of the atmosphere, reaching altitudes of more than 100,000 feet — three times the altitude of commercial aircraft — where the roundness of earth and the blueness of the atmosphere are clearly visible. These near-space conditions are ideal for testing satellite components or for making astronomical and earth observations. When they reach their predetermined final altitude, the balloons are made to burst, and the equipment's descent is slowed by a parachute. A global positioning system (GPS) connected to a transceiver on board the craft reveals both the altitude and the latitude-longitude of the equipment during the entire experiment. Recovery is made by ground crews who follow the balloon experiment using their own GPS and ground receivers.

The Montana Space Grant Consortium's High-Altitude Balloon Program provides a near-space platform that can be used for student-led experiments. The Alabama Space Grant Consortium is developing AHAB, the Auburn High-Altitude Ballooning capability to launch science and technology experiments to the edge of space. Other Space Grant Consortia in states such as Arizona, Colorado, and Iowa have similar programs. A high-altitude ballooning capability can be established in a few months at the low cost of $4,000. Its very low launch cost — about $200 per launch — and its simplicity make this scheme very attractive to many entry-level student teams.

Model rocket programs have been developed in Arizona, California, New Mexico, and other states. Students develop, launch, operate, recover, and analyze data from soda-can-sized "spacecraft" launched from amateur rockets. The New Mexico Student Launch Project was developed to create scientific and engineering literacy in the area of launch technology. In California, high school students work on CricketSats, small telemetry experiments that measure temperature and other environmental conditions inside a can that can be launched by a model rocket or be part of a balloon experiment. These entry-level experiments provide the background, learning, and skills required to participate in increasingly complex space-flight missions.

WALK

Experiments at the "Walk" level take about a year to complete, require more funding, and are a notch higher in complexity than at the "Crawl" level. They include building and launching CubeSats into Earth orbit and designing and building experiments to be launched on board sounding rockets.

CubeSat was invented by Professor Twiggs. It is a small cube to be launched into earth orbit where it can perform science and technology missions. The SG-SSP website announces: "Under the leadership of Stanford University's Space Systems Development Laboratory and California Polytechnic State University, a number of Space Grant consortia are building small 1 kg and 10x10x10 cm Cubesats for launch to earth orbit. These small 'picosatellites,' capable of

Examples of CubeSat missions:

- Montana's first satellite, MEROPE (Montana Earth-Orbiting Pico Explorer), will measure radiation in the inner Van Allen belt around Earth.
- Auburn University's first satellite *AubieSat 1* will test communications with a tumbling satellite using patch antennae and will measure the tumbling rate of the satellite.
- The University of Arizona's *RinconSat* will measure its tumbling rate by measuring the currents from its solar panels.

carrying significant science and engineering payloads, can be designed, built, and launched on a much shorter timescale and are cheaper to build than standard satellites — major benefits for students and industry sponsors." A typical CubeSat costs between $5,000 and $10,000 (not including launch) and can be built, tested, and launched within a year. These features make it an ideal entry-level satellite that teams of undergraduate students in the sciences and engineering can design, build, test, launch, and operate. The Space Grant Consortia of Alabama, Arizona, Montana, and Pennsylvania are actively involved in supporting CubeSats at some of their affiliates. Many other Space Grant Consortia are expected to join the CubeSat club shortly. A number of universities in other states, such as California, Hawaii, and New Hampshire, are also actively involved in building CubeSats.

A typical CubeSat costs between $5,000 and $10,000 (not including launch) and can be built, tested, and launched within a year. These features make it an ideal entry-level satellite that teams of undergraduate students in the sciences and engineering can design, build, test, launch, and operate.

The single most difficult issue for CubeSats and other student-built satellites is to find an affordable launcher. A typical satellite launch costs millions of dollars, an amount that is obviously prohibitive for a student-satellite project. However, many rockets end up with extra cargo space that could be used for a secondary payload and that could be made available at a much lower cost. Expected launch costs should be in the $45,000-$70,000 range for a single CubeSat. Group launches could be arranged by SG-SSP with several CubeSats stacked together in so-called "P-Pods." The P-Pods would be released in space from the launching rocket when the primary payload has been safely put into proper earth orbit. Finally, a spring system would eject the CubeSats from the P-Pod. At a November 15, 2000, news conference, Bob Twiggs said that he could "envision some 100 to 200 of these small satellites being launched annually."

Another Space Grant-supported Walk-level program is the Alaska Student Rocket Program. Students at the University of Alaska at Fairbanks (UAF):

> work together as an interdisciplinary team to design, build, test, and launch sounding rocket payloads from the nearby Poker Flat facility. [Sounding rockets do not put payloads into orbit but provide telemetry data during a single flight. They are typically smaller and cheaper rockets that carry payloads of various weights to altitudes above 30 miles (48 km).] The goal of the program is to provide the students with an opportunity to apply their technical education to the solution of real-world engineering design problems. Equally important to the technical aspects of this program are the practical experiences gained in working as part of an interdisciplinary design team in an environment similar to what the students will encounter in industry. The Alaska Space Grant Program director serves as the primary faculty advisor and manager of this ongoing program (http://www.uaf.edu/asgp/asrp.htm).

The website adds that "The Poker Flat Research Range (PFRR) is the only university-operated sounding rocket range in the world." This facility could become a resource for a national Walk-level program under the auspices of the SG-SSP, allowing students from other universities to use it to launch their own space experiments.

RUN

Examples of "Run" level programs are nanosatellites. Nanosatellites are larger than CubeSats, more complex, take longer to design and build, cost more, and probably require graduate-student involvement. Several such satellites were built by students before the creation of the SG-SSP. For example: the "Six-kilogram nanosatellite *ASUSat 1* was successfully launched on January 26, 2000, from Vandenberg Air Force Base, on the first Air Force OSP Minotaur (Orbital Sciences). This event, culminating the efforts of countless individuals and corporate benefactors, provides testament to the potential in today's students — the space scientists and engineers of tomorrow — which can only be realized if provided the opportunity" (ftp://pirlftp.lpl.arizona.edu/pub/spacegrant/).

Another nanosatellite, *Citizen Explorer 1* (CX-1) is being designed, built, and operated by college students under the auspices of the Colorado Space Grant Consortium. It is a remote-sensing satellite that will take earth data from space and will involve K-12 schools all over the world as ground stations, bringing space one step closer to the classrooms. The CX-1 project combines the remote-sensing devices on board a satellite and ground observers using hand-held instruments to measure long- and short-term atmospheric events, especially changes in the ozone layers (http://citizen-explorer.colorado.edu/overview/science.php).

Finally, Arizona State University, the University of Colorado at Boulder, and New Mexico State University are joining efforts to develop *Three Corner Sat*, a set of three nanosatellites as part of the AFOSR/DARPA/AFRL/NASA GSFC/DoD STP University Nanosatellite Program. The three satellites will do formation flying in space to perform research and stereo-imaging and virtual formation operations, and to test innovative intersatellite communications, innovative command and data handling, and micro-propulsion. This constellation of three satellites will be launched in 2003 by the Air Force on the NASA Space Shuttle. The students actively participate in all the design and in Space Shuttle safety reviews. Moreover, the students are learning about the challenges of coordinating a program over long distances.

These are by no means the only examples of nanosatellites built by student teams. Other universities in the United States have student-satellite programs, some of them funded by NASA. Many student-satellite teams also have been established in other countries. Germany, Great Britain, Norway, and Japan have significant student satellite programs.

FLY!

"Crawl," "Walk," and "Run" projects will prepare us to "Fly!" announce the leaders of the SG-SSP, adding that this "may include visiting asteroids or the moon, or conducting sophisticated astrophysical or Earth Sciences missions — all with student-built satellites. Ultimately we plan to send a flotilla of student satellites, representing the 52 Space Grant consortia, to Mars." This bold concept was enthusiastically endorsed by Scott Hubbard, then NASA's Mars Program Director (and subsequently by his successor Orlando Figueroa), in a letter of support dated January 26, 2001: "I write . . . concerning sending 52 student-built 'CubeSats' to Mars under the auspices of the NASA Space Grant Program. Let me start by stating that the concept has a significant visionary aspect. It integrates NASA's Space Science and Education responsibilities into a program that adds substantially to both. If successful, the idea of launching 52 student-built CubeSats to Mars would constitute the first time student-built hardware has been launched beyond Earth orbit."

So far there are no student projects that fit this category, but the "Fly!" level is the pinnacle, the Holy Grail of student-satellite teams.

CONCLUSION

The National Space Grant Student Satellite Program offers young people a purpose and a road map. It is spurring many young space enthusiasts into action: to form teams, to select and design their spacecraft, to enlist the support of faculty members at their university, to contact the Space Grant Consortium in their state, and to request funding from their university, from Space Grant, from industry, and from the military. Since the end of the Moon Program, space enthusiasts have been looking for inspiring and committed leadership. Granted, we have sent instruments to explore the solar system and to probe the depths of the universe, and these instruments have provided us with a wealth of exciting information that has even forced us to rewrite the astronomy textbooks. We also have built a space station, and we have seen astronauts and cosmonauts orbit Earth and work in space.

But in the view of this author, we have not tried to push the envelope. We did not challenge ourselves to the point that we put a sparkle in the eyes of our younger generations. And the results are here: fewer young people interested in aerospace careers. This trend is now being changed. Young people have been given a challenge: learn to design, build, and launch small spacecraft that will explore the universe and our own planet from space. There is such enthusiasm, such a sense of direction, such hope in this program that we may well be on the road to exciting space exploration again, inspiring a new generation of explorers, as only NASA can.

J-M Wersinger is an associate professor of physics at Auburn University in Auburn, Alabama. He is the faculty mentor for the Auburn University Student Satellite Program's *AubieSat-1* and is the campus director for the Alabama Space Grant Consortium. He has been working with NASA as a Space Grant Faculty Fellow since 1994. His interests are in remote-sensing applications and in science outreach. He has helped initiate the Earth Grant Program, a joint NASA-USDA-NOAA effort to bring the benefits of remote-sensing applications to the states through the Land Grant Extension Network.

END OF SEASON

For some, it's an undulating flock linked
by a thread and fleeing a sudden cold snap,
or the gnarled hands of fallen leaves on the brink
of the tawny underworld, fingering a map.

For me, it's an autumn lightning bug that crawls,
dragging a belly of chilled luciferin,
no longer one of the syrupy stars, loosened
from a brilliant summer constellation. It stalls,

slowly raises the housing of its wings,
an old machine of wrought iron and dusky
tangerine, then launches itself, whirring,
into the agonizing stare of day.

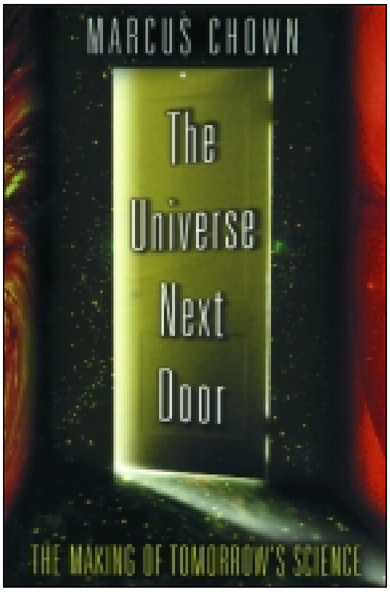
K.E. DUFFIN

K.E. Duffin's poems have appeared in *Poetry*, *Partisan Review*, *Ploughshares*, *The Sewanee Review*, *Verse*, **and many other journals. In 2001, she was a finalist for the National Poetry Series, the Walt Whitman Award, and the Colorado Prize. In recent years she has had residencies at The Millay Colony and Yaddo.**

Book Review

MARCUS CHOWN. *The Universe Next Door: The Making of Tomorrow's Science*. Oxford University Press, New York, 2002. 191 pages. $26.00

In this brief volume (actually only 158 pages of text, plus glossary and end materials), Marcus Chown presents the most entertainingly mind-boggling theories of the way the universe works on both the micro and macro level currently being discussed in the scientific community. Many of the ideas he covers are so contradictory to everyday experience that they seem ludicrous. Because of this issue's theme, I thought it would be worth summarizing *The Universe Next Door* briefly chapter by chapter to preview the theories that Chown covers.



Universe is divided into three major sections: "The Nature of Reality," "The Nature of the Universe," and "Life and the Universe." The book leads off with a chapter titled "Unbreak My Heart" in which Chown deals with the idea that somewhere in our universe the arrow of time might run backwards: shattered coffee mugs spring back together, elderly people grow younger and younger, civilizations fall, then rise. Chown points out that the arrow of time as we see it can be attributed to entropy and to the expanding universe. Cosmologists have long entertained the possibility of the "Big Crunch," in which the universe reaches a critical point in expansion and begins to contract, thus reversing the arrow of time. However, Lawrence Schulman of Clarkson University has created a computer simulation which shows that in localized areas of the universe, time already could be running backward, as long as these regions interact only weakly with our forward-running arrow of time. One explanation for these regions of reverse time is that they may be relics of an earlier era in our universe where a Big Crunch was occurring, and time was reversed.

In Chapter 2, "I'm Gonna Live Forever," Chown moves to the "Many Worlds" Theory, the idea that an infinite number of possible realities exist, realities in which our fates might be very different from the one that we perceive (including ones in which we might never die). The Many Worlds theory has been around for a number of years, based on the idea that one cannot observe phenomena at the quantum level without that observation affecting the thing being examined. In other words, "reality" is only potential until it is observed. Using the example of a quantum computer, which has the potential to do more calculations than there are particles in our universe, physicists argue that such a computer could overcome this limitation by interacting with and using the particles from other universes. Astounding though this idea may seem, many physicists are coming to embrace it as possible, if not probable. So take heart; if you failed to work up the nerve to ask Betty Jean or Brad to the prom in this universe, you might very well have succeeded gloriously in another.

With more serious implications for how the world is made, "Dividing the Invisible" covers the possibility that we may all be made up not of subatomic particles, but of waves. Humphrey Maris of Brown University argues that certain experiments using electrons trapped in super-cooled helium have shown that the supposedly indivisible electron can indeed be halved, with the implication being that the fundamental particles are literally waves, rather than particles that simply behave like waves under certain circumstances. Thus we are ultimately all composed of wave functions, a vaguely unsettling thought that plays with our illusion of our own solidity.

The next chapter takes quantum weirdness a step further by proposing that "All the World's a Time Machine." Chown begins this chapter by discussing the incompatibility between Einstein's Theory of General Relativity and quantum theory:

> Here then is the fundamental incompatibility between quantum theory and general relativity. General relativity, like every theory of physics before it, is a recipe for predicting the future. If a planet is here now, in a day's time it will have moved over there, by following this path. All these things are predicted by the theory with absolute certainty. Compare this with quantum theory. For an atom flying through space, all we can predict is its probable final position, its probable path. The very foundation stones of general relativity, such as the trajectory of a body through space, according to quantum theory, are a fiction (51).

Trying to reconcile these two incompatible theories is the current Holy Grail of physics. Physicist Mark Hadley proposes that quantum particles are actual time loops that exist in future, present, and past simultaneously. One of the paradoxes of quantum theory is that paired particles with reverse spins somehow "know" what each other's spin is. If one particle reverses its spin, the other particle instantaneously reverses its own, even if the particles are light years apart. This instantaneous reversal contradicts the law which says that nothing can travel faster than the speed of light. If Hadley's theory is correct, this phenomenon poses no threat to General Relativity because the particle simply receives the news outside of time. As Chown puts it, "There is . . . nothing to stop such a particle reacting to an event before it actually happens. According to Hadley, this is all that is happening when a particle reacts instantaneously to its partner flipping direction. It is simply reacting before news of the event arrives" (56).

In chapter 5, "Tales from the Fifth Dimension," Chown explores the concept of extra dimensions, beyond the four dimensions (three spacial dimensions plus time) that we can perceive. These dimensions, formed in the first milliseconds of the Big Bang, are "curled up" literally so small that they are beyond our current ability to detect them. Chown raises the possibility that the new Large Hadron Collider at CERN, scheduled to come on line in 2006, might be able to generate enough atom-smashing force to allow us to detect one or more of these tiny dimensions. String theory, the current best hope for the Grand Unified Theory, requires at least ten such dimensions, and having experimental evidence of them would begin to lend some credibility to that theory. In addition, knowledge of these extra dimensions would reveal a whole host of new subatomic particles and might also give us a clue about why matter came to predominate in our universe instead of antimatter.

In the next major section of the book, "The Nature of the Universe," Chown turns from the micro to the macro universe. He leads off with a chapter titled "The Holes in the Sky," in which he discusses the theory of Mike Hawkins, a Scottish astronomer, that much of the unknown "dark" matter, which cosmologists theorize makes up most of the matter in the universe, might be made up of countless refrigerator-sized black holes. Hawkins suggests that such black holes, small but tremendously dense, might account for 99 percent of all matter in the universe. By studying the gravitational lensing effect that makes quasars appear to fluctuate in their brightness, Hawkins decided that the fluctuation was caused not by the quasars themselves, but by countless very dense bodies passing in the line of sight between us and the quasars. If these countless black holes exist, they could account for enough mass to eventually put the braking motion on the universe's expansion and propel it toward a Big Crunch.

In "Looking-Glass Universe," the idea of a mirror universe existing along with our own is explored. This concept springs from a problem with symmetry. Nature seems to thrive on symmetry; as Chown puts it, "Nature, for reasons best known to itself, has chosen laws that exhibit the maximum possible degree of symmetry" (84–85). A problem arises, however, with the laws of physics. For example, neutrinos always "corkscrew" in a left-handed direction, never right. Where then are the right-handed neutrinos? To preserve symmetry, physicists have posited that there must be an invisible, "mirror" universe in which such particles exist.

Chapter 8, "The Universe Next Door," extends the mirror universe concept into the idea of the "multiverse," or an infinite number of possible universes. As Chown reveals, if certain fundamental forces that make up the universe were just fractionally stronger or weaker, the universe simply would not have formed, and we would not be here to witness it. Physicists find this "just-so" universe too perfect to be coincidental — it is almost as if it were designed, a concept anathema to many scientists (see Gordon Kane's article "Anthropic Questions" in this issue). As Max Tegnark asserts, "There are only two possible explanations . . . Either the universe was designed specifically for us by a creator, or there exists a large number of universes, each with different values of the fundamental constants, and not surprisingly we find ourselves in one in which the constants have just the right values to permit galaxies, stars, and life" (103).

In "Was the Universe Created by Angels," Chown presents the ideas of Edward Harrison, who takes the idea that the universe exists because we observe it a step further, positing that our universe was designed and created by super-intelligent beings in another universe in such a way that development of life was inevitable. Because these super beings are not gods, Harrison states that "the creation of the universe drops out of the religious sphere and becomes a subject amenable to scientific investigation" (114). The recipe for "making" a universe is not particularly complicated — it is simply far beyond our own current technical capabilities.

In the final major section, "Life and the Universe," Chown turns to the question of the origins of life. "The Worlds Between the Stars" covers the ideas of David Stevenson, a cosmologist at Cal Tech, about the possibility of Earth-sized solid planets (as opposed to gas giants such as Saturn) existing free in the depths of space, rather than orbiting a star. Many such planets may have been flung out of their originating solar systems by a close brush with a neighboring gas giant. Though isolated in the frigid cold of deep space, such planets could actually harbor life, warmed by their internal fires and insulated by a thick blanket of probably methane gas, not entirely unlike what astronomers speculate about Jupiter's moon, Europa. If such planets could be located free in space, they could be used as way stations for galactic exploration, though they would not necessarily be fit for human colonization.

In "The Life Plague," astronomer Chandra Wickramasinghe speculates that life on Earth originated in the icy comets that pass through our galaxy and occasionally make violent contact with the Earth. Wickramasinghe has found that interstellar grains of dust that permeate space absorb infrared light in precisely the same manner that dried bacteria do. He theorizes that this interstellar dust is thus made up of complex organic molecules, some of which could have been trapped by and flourished as life in the temporarily liquid centers of comets, and then survived the cometary deep-freeze for eons until they found a home on the newly hospitable Earth as it cooled and water appeared. Wickramasinghe freely admits that he does not know where these bacteria originated. His theory, however, might indeed be testable, using space craft on a close encounter with a comet.

To end the book, in "Alien Garbage," Chown presents the ideas of Alexey Arkhipov that we might find evidence of alien intelligence here on earth — in the form of random "space junk" that has crossed the Earth's path over the eons. Arkhipov, using calculations about the percentage of worlds in our galaxy that could have developed advanced civilizations and launched probes and spacecraft, estimates the number of alien space artifacts that have fallen to earth as between forty and four thousand pieces in our planet's four-and-a-half billion years of existence. With the forces of erosion and tectonic shift, the chances of such materials remaining intact enough to be recognized or even located are very small, but not zero. One suggestion is that a better place to find such artifacts might be on the Moon, because of the almost complete lack of erosion there. As Chown ends the chapter and his book:

> Somewhere in the world a puzzling artifact is lying in a museum. Perhaps nobody has noticed it for a century or more. Or perhaps, at this very moment, a curator is taking it out of a glass case, looking at it, and scratching his or her head in bafflement. Will the curator take it to be chemically analyzed? Or will the curator put it back in the case and forget about it forever? We can only hope that doesn't happen (155).

What to make of all this? Clearly many of these ideas and theories that Chown explores stretch one's credulity. Some of them seem to substitute one unknowable for another; for instance, the idea that super-intelligent beings created our universe in a way simply substitutes one "god" for another. Others are so fantastic that they seem to enter the realm of science fiction. Yet many aspects of Einstein's Theory of General Relativity were once seemingly outrageous, until they were experimentally demonstrated to be true. And the bizarre behavior of particles at the subatomic level, behavior that also seems against common sense, has been tested and demonstrated again and again. Thus it might be unwise to dismiss lightly even the most absurd-sounding theories in this volume.

Chown's real achievement in this book is not just in presenting these ideas, but in doing it so clearly that while the book is by no means a "quick read" (especially the earlier chapters), one can easily grasp the very difficult concepts with a little careful, patient reading. As a layperson who has spent a good deal of time wading through similar books on physics touted as "lucid" and "understandable," but which turned out to be quite opaque, I appreciate what Chown has accomplished. Even if you do not agree with the majority of what he presents, it is worth reading his book to know what serious scientists are proposing. After all, one never knows when some clever experimental physicist will devise a way to show that our universe actually does have more than four dimensions or that indeed quantum particles are tiny time machines, somehow enabling you to go back in time and ask Betty Jean to the prom after all. This is a fun book to read, one that stretches the imagination and revels in the wonders of our strange universe. It is well worth a look.

Pat Kaetz is editor of the *Phi Kappa Phi Forum*.

EINSTEIN'S CROSS

Toward Pegasus, light from
A quasar splits into four
Images in the shape of a cross,

A gravitational mirage to fool
The unwary but not
The theorist who predicted it.

Einstein didn't need to gaze
Into space. He could see
The images in his mind's eye,

The calculations a precise lens
By which light bent around
Stars aligned with Earth.

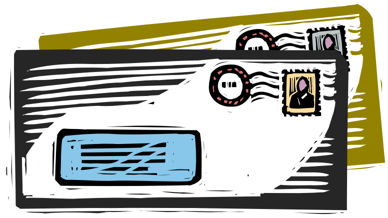
But what would Einstein say
About dark matter,
Which we can't even see,

Which makes up almost all
The universe's mass, and which
Is all around us?

PETER HUGGINS

Peter Huggins's books of poems are *Hard Facts*, Livingston Press/University of West Alabama, and *Blue Angels*, River City Publishing. *In the Company of Owls*, a novel for middle readers, is forthcoming from NewSouth Books. He is the president of the Alabama Writers' Forum and teaches in the English Department at Auburn University.

Letters to the Editor



A JUST CAUSE, NOT A JUST WAR

Howard Zinn's "A Just Cause, Not a Just War" ["Terrorism," Spring 2002] is disrespectful to all who serve in uniform. U.S. actions, at the cost of numerous American lives, have freed the Afghanis from the brutal al Qaeda-backed Taliban and have given the Afghans hope for a better future. The United States did not rush into this campaign. It took a decade of attacks (since the 1993 bin Laden-supported attack on U.S. forces in Somalia) before this country responded with force. The fact that the United States did not respond earlier, other than the "pinprick" 1998 cruise missile strike, emboldened bin Laden to think this country was weak, that he could attack with impunity.

It is overwhelming force alone that terrorists respect. The same was true in Vietnam; we struck fear into the North Vietnamese and brought them to the negotiating table only when B-52s and other aircraft, for eleven days and nights, rained destruction on Hanoi's military and industrial targets. The U.S. military is always very careful to avoid hurting civilians; there are exceedingly complex rules of engagement to prevent it. This was true in Vietnam also. In Iraq, Saddam placed civilians near military targets, making human shields of them.

No other country has done more to help suffering people throughout the world than the United States. The U.S. military has no "ambitions" other than protecting America. In Panama, Grenada, and elsewhere, the United States was trying to protect Americans and achieve other legitimate goals, such as ending drug trafficking and stopping Soviet/Cuban expansion. The United States has ever defended foreign peoples' freedoms. This was so in Vietnam, where the United States was trying to protect the South Vietnamese, and all of South Asia, from Communist aggression. The United States is protecting freedom — the war on terror is a good war.

Jeremy A. Mutz
Tallahassee, Florida

Thank you for publishing Howard Zinn's "A Just Cause, Not a Just War" in the Spring 2002 *Forum*. My heart winces every time I think of the people carried to their deaths on the flights crashing into the World Trade Center, into the Pentagon, and into the woods in Pennsylvania. Likewise, when I think of the people in those buildings, sitting down at their desks, reaching for a cup of coffee, or chatting with a friend, and imagine the walls crashing down on them, I want to cry out, "Why? Why, damn it? Why?"

Professor Zinn asks me to think of those civilians in Afghanistan killed by bombs dropped on them by my country in a similar manner. Children die equal deaths in both cases. How can their deaths be separated into unjust and just? How indeed!

Does he intend for us to equate the terrorist pilot and the military pilot? Innocent death results from the action of both. A dead baby is a dead baby. Does the label "collateral damage" make a baby less dead? This is the question that Professor Zinn asks me to ask myself. What is the answer? Do you know?

Many people do know the answer, don't they? President Bush apparently does; and I am confident that Vice President Cheney possesses that certain knowledge. But I suspect that Secretary of State Powell is still, in his heart of hearts, asking Professor Zinn's question. I surely hope so.

Thank you again for your decision to let the question be asked.

Miles Richardson
Baton Rouge, Louisiana

I am replying to the letter written by Mark Miller (Summer 2002 issue) in response to Professor Howard Zinn's article, "A Just Cause, Not a Just War." Professor Zinn's article contains little, if anything, with which I agree. Indeed, there is much to be said against the points made therein. (See, for example, Sam Snyder's letter in the Summer 2002 issue.) Mr. Miller's letter, however, disturbs me far more than Professor Zinn's article ever could.

Mr. Miller's letter embodies one of the very qualities that motivate the terrorist groups he rightly maligns — namely, an extreme expression of intolerance in the face of a divergent viewpoint. Least innocuous is Mr. Miller's implicit ad hominem attack by placing Professor Zinn's title in quotes. Far worse is the implication that anyone who does not favor war necessarily must support the terrorists.

Indeed, the fact that an opposing viewpoint causes Mr. Miller to experience "high blood pressure and anxiety" is a sad commentary on the current state of the values of freedom and tolerance upon which this great country was founded. I encourage Mr. Miller to recognize that *Phi Kappa Phi Forum* is precisely that: a forum for the presentation of views — some popular, some unpopular, some patriotic, some critical — but all worthy of expression.

Mr. Miller, I implore you to recognize that the greatness of our nation is, in part, grounded in the wide range of opinions held, and expressed, by members of our diverse population. I, for one, relish my ability and right to be exposed to those who do not see the world as I do.

Kevin D. Smith
Pittsburgh, Pennsylvania

In "A Just Cause, Not a Just War," Howard Zinn presents a condemnation of the United States for instigating the attack leveled upon it by the al Qaeda terrorists. In examining his jeremiad, I found his reasoning deeply flawed and his ignorance of military history total.

His piece does elicit certain questions. Why does Professor Zinn choose to live in a country that is so distasteful to him? What is holding him back from a move to Iraq, Syria, or any of the other "modest" peace-loving countries of the world?

Another question arises. Why do I continue to support an organization that is so relentlessly PC as Phi Kappa Phi?

Malcolm Muir, Jr.
Clarksville, Tennessee

HOW DID WE GET INTO THIS MESS? THE AUDITING DILEMMA

I am writing in regard to Professor Charles Davis's article in the "Business & Economics" column of the Summer 2002 journal ["Food & Culture"]. Professor Davis mentions the name Enron (he spells it with capital letters) several times but provides no evidence of what the topic of his article, IS audits, has to do with Enron's problems. I suspect the reason is that there is little, if any, relationship between the two. Information systems typically cover routine transactions — shipping and receiving, paying bills, and so forth. Enron's accounting trickery was not in how they accounted for day-to-day transactions; it was in legal structures that businesses and assets that were part of the company appear as if they were not. The only piece of more complicated transactions handled by systems are the booking, or not booking, of a few journal entries. Enron provides no evidence of a failed IS audit; it provides evidence of a failed audit of one-off type transactions.

The use of the word "Enron" to get an emotional response is a behavior that I expect from politicians anticipating mid-term elections or perhaps Gov. Gray Davis. I was shocked to see it in what is supposed to be a scholarly journal.

Judson A. Caskey

A special thanks is offered to "Business & Economics" columnist Charles K. Davis for the real protein he served up amidst all the gastronomy in your "Food & Culture" issue (Summer 2002). Davis provides convincing answers to puzzling questions about the causes of the current crisis in corporate fiscal reporting.

Davis's clear exposition about the computer-related difficulties faced today by auditing firms exemplifies the kind of incisive insight that causes the reader to pay it the compliment of regarding it as self-evident and deluding himself by thinking "of course — I should have realized that myself."

Technology has transformed or eliminated many professions — spearwright, teamster, publisher, and yes, we now see, thanks to Davis, auditor. I surmise that in each case the displaced establishmentarians have felt that the barbarians were at their gates. For example, even Davis categorizes the classical financial auditors as "highly polished . . . professionals" and the upstart information systems auditors as "quirky, nerdy computer jocks."

Fortunately, society as a whole, as well as some of the professional guilds, has proven more capable of acclimation to such change than has the typical individual guildsman. Though we no longer depend on literal horsepower, we utilize every day the mechanical horsepower of automotive transportation, with virtually total success. Though we no longer throw spears, we utilize whenever necessary the guided missiles which replaced them, with reasonable success. In each case, the skills required to become a guildsperson have undergone major revision.

The auditing dilemma which Davis's headline appropriately calls "This MESS" will eventually though painfully be solved in similar fashion. This too shall pass. The nerdy jocks will acquire an appreciation for public relations and will come to be regarded as highly polished professionals.

Ben B. Barnes
Florence, Alabama

THE PLEASURES OF COFFEE TOGETHER

They'll have to shoot me
if they shoot me down,
our colonel swore.

He leaned back, sipping,
and sighed: *I'd kill them all*
for coffee. How that man

could fly and teach a tight
formation, trying to save us
from rookies' mistakes

and missiles. Captured
when his luck ran out,
he lasted years in solitary,

beatings, bones never set.
After they dumped the corpse,
they shipped his dog tags back.

Now, past fifty,
I can't stand coffee at dawn
without my wife beside me.

I'd quit this habit without her.
God knows what I would do
if she were gone.

WALT McDONALD

Walt McDonald was an Air Force pilot and served as Texas Poet Laureate in 2001. His twenty books include *Climbing the Divide* **(University of Notre Dame Press, forthcoming, 2003),** *All Occasions* **(Notre Dame, 2000) and others from Harper & Row and university presses including Massachusetts, Ohio State, and Pittsburgh.**

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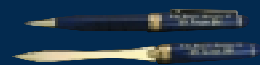

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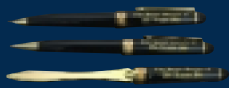

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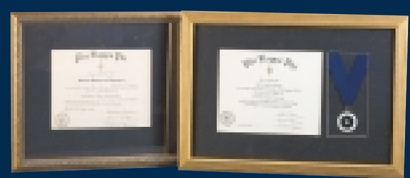

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