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Bruce Hendrickson and Hinke Osinga, co-chairs of the organizing committee for the 2013 SIAM Annual Meeting (San Diego, July 8–12), set out to create a program that would reflect as closely as possible the themes of Mathematics of Planet Earth 2013. They quickly realized that just about everything the SIAM community does falls in some sense under MPE. From the opening talk, by Lada Adamic on the ways in which information is shared (and transformed), through John Burns's plenary talk (joint with the control conference) on energy-efficient whole-building systems, to the sessions on the final day, speakers touched on issues and problems facing everyone on the planet. Hendrickson and Osinga also sought to keep the meeting vibrant right up to the end. They are shown below (at far left) with several of the people who helped them meet both goals: from left,

2013 SIAM Annual Meeting & Conference on Control and its Applications

Benjamin Santer, who titled his invited talk "The Search for a Human Fingerprint in the Changing Thermal Structure of the Atmosphere"; Chandrika Kamath and John Zack, co-organizers of a minisymposium on forecasting wind and solar power production (also the subject of Zack's invited talk); and Mary Silber, organizer and speaker in a session on tipping points.

As always, the prize lunch was a highlight of the meeting, with plenty of socializing as SIAM president Irene Fonseca had the pleasant duty of presenting a bevy of prizes and awards. (Some of the recipients are pictured here and on pages 2 and 3; others will be featured in future issues of *SIAM News*.) Lunch was followed by Stan Osher's John von Neumann Lecture; well attended even for the most venerable of SIAM's prize lectures, this one required the hasty addition of several rows of extra seats. Osher (at top right) did not disappoint, offering up big new ideas, and in some cases unexpectedly connecting old ideas with very up-to-date themes, in a lecture titled "What Sparsity and ℓ_1 Can Do for You."

Aptly, the 2013 W.T. and Idalia Reid Prize was awarded in San Diego to Tyrone Duncan, a control theorist (shown at right with Irene Fonseca). Cited by the prize committee for "fundamental contributions to nonlinear filtering, stochastic control, and the relation between probability and geometry," Duncan gave a prize lecture titled "Solvability for Stochastic Control Problems," which also found a receptive

audience. Fariba Fahroo and Wei Kang co-chaired the organizing committee for the control conference.

For 2013, SIAM members elected 33 new Fellows, on the basis of "outstanding con-

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Rethinking "Star Soup"

By Dana Mackenzie

One of the greatest mysteries in astrophysics these days is dark matter—an invisible form of matter that has been detected only through its gravitational effects. According to the latest estimates from the European Space Agency's Planck space telescope, dark matter accounts for 26.8% of the matter–energy in the universe. That is 5.5 times the amount of ordinary, or baryonic matter. (Both are dwarfed by "dark energy," but that's a subject for another article.)

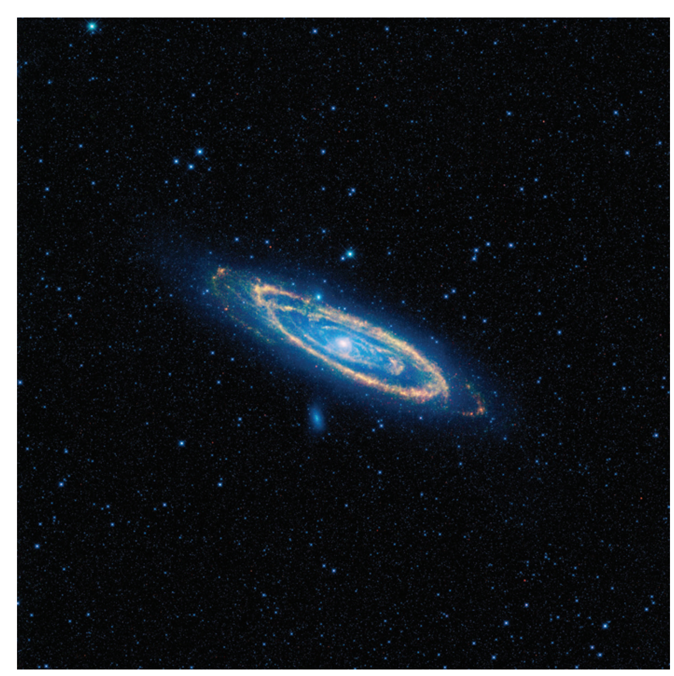
To date, nobody has ever actually seen a "lump" of dark matter. All the evidence for its existence depends on mathematical calculations—something that ought to make mathematicians happy. But Don Saari, a longtime specialist in celestial mechanics at the University of California at Irvine, is far from convinced.

At a standing-room-only lecture at this year's Joint Mathematics Meetings, Saari called into question a classical—in fact the earliest—method for estimating the amount of dark matter, which uses galactic rotation curves. "It's a mathematical computation, and that computation is not correct," Saari says.

The method, which was used by Vera Rubin in the 1970s to convince her fellow astrophysicists that dark matter was real, assumes that a galaxy can be approximated as what Saari calls a "star soup"—a uniform, homogeneous distribution of matter. Using this assumption and Newton's law of gravitation, it is easy to deduce a relation between the velocity of rotation $v(r)$ of a star at radius r from the center of a galaxy, and the total mass of the galaxy $M(r)$ that lies inside its orbit. The relation looks like this:

$$M(r) = \frac{rv(r)^2}{G},$$

where G is Newton's gravitational constant. In our solar system, for example, the masses of the planets are negligible compared to the sun. Thus, $M(r)$ is effectively constant beyond the sun's radius, and the rotation speeds of the planets drop off proportionally to $1/\sqrt{r}$. For a galaxy, which has a fuzzier edge than the solar system, we would not expect quite such a rapid decrease, but we would still expect $v(r)$ to decrease near the visible edge of the galaxy.



The Andromeda Galaxy, the first of many galaxies analyzed by Vera Rubin. Image courtesy of NASA/JPL-Caltech/UCLA.

But that's not the way galaxies behave. Rubin showed that the velocity of orbiting stars (and gas clouds) in a spiral galaxy remains constant out to the edge of the galaxy. If the velocity is constant, then $M(r)$ must increase proportionally to r. And this means there must be a vast amount of matter in the galaxy that we cannot see.

It's a simple argument that, according to Saari, has one big flaw: A galaxy is not a "star soup." To put it mathematically, the limit of billions of point masses will not necessarily behave like a continuum. In a galaxy of point masses, Saari points out, the masses are attracted much more strongly to nearby masses than to distant ones. This tugging can exaggerate local variations in velocity, and can lead to a "crack-the-whip" effect, with stars pulling their neighbors along, which is not permitted by the star soup approximation. This instability may be how galaxies get their spiral arms in the first place—a fascinating issue, Saari believes, for mathematicians to examine.

Central Configurations

What Saari has proved to date is that the standard method for estimating $M(r)$ produces extravagantly wrong answers for the total mass of special arrangements of stars called "central configurations." A symmetric configuration of point masses of this type rotates essentially as a rigid body under Newton's law of gravitation.

Certain central configurations are quite common. The most widely known is an equilateral triangle formed by three bodies: typically a large mass and two smaller masses that revolve around it in the same orbit, but 60 degrees apart. Such configurations were predicted mathematically by Joseph Louis Lagrange in 1772. One example consists of the sun, Jupiter, and the Trojan asteroids. Another consists of Earth, the moon, and a spacecraft, which could hypothetically be placed at either of two Lagrange points, one in front of and the other trailing the moon; these orbits are stable and would make excellent spots for fuel depots for interplanetary missions.

Another central configuration that can actually be found in the solar system is a ringed planet. In 1859, James Clerk Max-

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Honored in part for "his many contributions to serving and promoting applied mathematics" as director of the Institute for Mathematics and its Applications at the University of Minnesota, Doug Arnold received the 2013 SIAM Prize for Distinguished Service to the Profession at this year's SIAM Annual Meeting. A former president of SIAM (2009–10) and currently an active member of the SIAM Committee on Science Policy, Arnold is the McKnight Presidential Professor of Mathematics at Minnesota. As readers who heard his past-president's address (at the 2012 SIAM Annual Meeting) will know, he has directed much of his attention in recent years to troubling issues arising in scholarly publishing. Indeed, the prize committee commended him for taking "a leading role in discussions about citations and journal impact factors and in exposing unethical scholarly publishing behavior."

Arnold is the 13th recipient of the prize, which recognizes "distinguished contributions to the furtherance of applied mathematics on the national level"—a condition that he has easily satisfied at the international level as well. Despite the crowded agenda reflected by the prize citation, Arnold is an active researcher; his main current interest is finite element exterior calculus. His NSF/CBMS lectures on the subject, given at ICERM in June 2012, are slated to appear in the form of a SIAM book.

San Diego July 2013

Margaret Cheney (right) of Colorado State University and the Naval Postgraduate School, pictured here with AWM past president Jill Pipher, titled her 2013 AWM–SIAM Sonia Kovalevsky Lecture "An Introduction to Radar Imaging." According to the selection committee, Cheney has spearheaded "a broad line of research that is coupling disparate radar solutions in ways previously unrecognized. Her application of Microlocal Analysis to high-frequency radar scattering—a method largely unknown to the radar community—has proven to be especially relevant to the problems of radar target detection, tracking, and imaging. Using these tools, she has shown how the essential behavior of a wide variety of radar scattering scenarios can be isolated from secondary phenomena."

Cheney's unconventional approach has led to solutions to several longstanding problems in radar imaging that heretofore defied complete analysis, the committee concluded. She "has demonstrated how a class of important issues in modern radar can finally be addressed."

National Academies Release *The Mathematical Sciences in 2025*

By Mark L. Green and Scott T. Weidman

How healthy are the mathematical sciences today? What will the discipline look like in the coming years? How should the mathematical enterprise adjust? These questions are addressed in *The Mathematical Sciences in 2025*,* a recent report from the Board on Mathematical Sciences and Their Applications of the U.S. National Academies.

The study that led to the report was initiated and supported by the National Science Foundation's Division of Mathematical Sciences. BMSA assembled a broad, blue-ribbon committee to carry out the study, with members from core and applied mathematics, statistics, computational biology, computer science, finance, theoretical physics, industry, and university administration. The study was chaired by Thomas Everhart, president emeritus of the California Institute of Technology, with one of us (MLG) as vice-chair.

The study revealed three major themes:

■ The mathematical sciences enterprise is qualitatively different from the one that prevailed during the second half of the 20th century, and a different model is emerging—one of a discipline with a much broader reach and greater potential impact. The mathematical sciences are an increasingly integral and essential component of research in a growing array of areas in biology, medicine, social sciences, business, advanced design, climate, finance, advanced materials, and many other fields. All these areas are crucial to economic growth, national competitiveness, and national security.

■ Reflecting this expansion, the culture of the mathematical sciences needs to evolve and a serious rethinking of postsecondary mathematics education is needed.

■ Stresses that are beginning to affect all of higher education are likely to impact the mathematical sciences especially severely, and our community must be proactive in addressing these challenges.

The pervasive use of computing, the creation of massive datasets, and their widespread availability through the Internet have placed the mathematical sciences in a pivotal position. As a result, the study committee learned, the mathematical sciences reach into many other disciplines, and mathematically sophisticated research is being produced by a distributed community that extends well beyond the scope of most academic departments of mathematics or statistics.

Even as the mathematical sciences are broadening their reach, they are enjoying a period of striking accomplishments. As noted in the report,

> The opening years of the twenty-first century have been remarkable ones for the mathematical sciences. The list of exciting accomplishments includes . . . proofs of the long-standing Poincaré conjecture and the "fundamental lemma"; progress in quantifying the uncertainties in complex models; new methods for modeling and analyzing complex systems such as social networks and for extracting knowledge from massive amounts of data from biology, astronomy, the Internet, and elsewhere; and the development of compressed sensing.

Against this backdrop of accomplishments and broadening, the discipline has retained its unity and coherence, with ideas flowing freely between different areas and between the core and applications. The core of the subject is flourishing, as longstanding problems are solved and a steady supply of innovative ideas are pursued for internal reasons, but with benefits percolating ever more rapidly into other subjects. The health of the core is essential to the welfare of the mathematical sciences. Much of 21st-century science and engineering will be

See **Math 2025** *on page 7*

*National Research Council, National Academies Press, Washington, DC, 2013. Portions of this article replicate or paraphrase the wording in the report.

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San Diego

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tributions to fields served by SIAM"; the 15 who were at the meeting were recognized at the prize lunch and are pictured on this page.

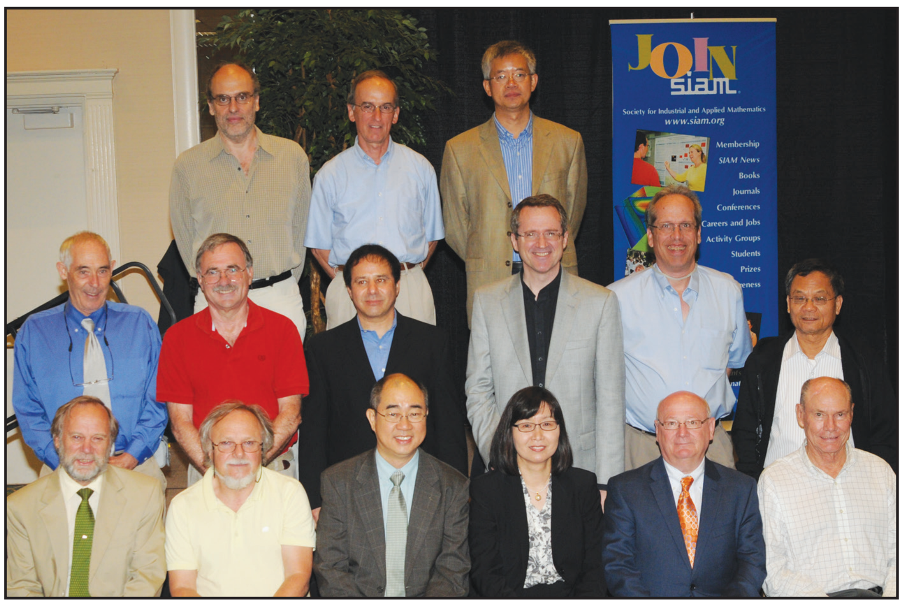
■ ■ ■

Nominations for the next (2014) class of SIAM Fellows are due November 4, 2013. A reminder to prospective nominators:

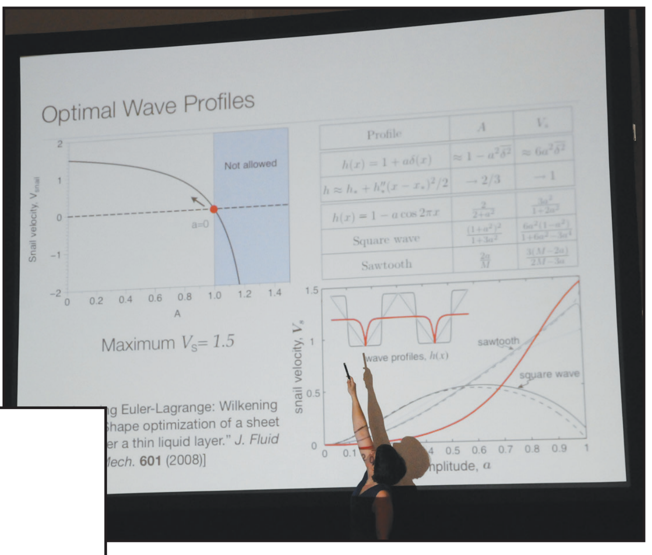
"Research excellence is one criterion for selection but it is not meant to be the only one. The Fellows program is also intended to recognize excellence in industrial work (that might or might not involve traditional research), excellence in educational activities that reach a broad audience, or other forms of excellence directly related to the goals of SIAM."

SIAM is clearly the home of many talented, productive mathematical scientists. Many of them are women, many live and work outside the U.S., and many are from groups underrepresented in the mathematical sciences. To date, SIAM's Fellows program has not honored members of these groups in proportion to their numbers in the membership. Correction of the imbalance begins with the nomination process!

Details can be found at http://www.siam.org/prizes/fellows/nomination.php.



2013 SIAM Fellows. *From left, top row: Oscar Bruno (California Institute of Technology), Benoit Couet (Schlumberger-Doll Research Center), and Qiang Du (Penn State University). Middle row: Michael Saunders (Stanford University), Randolph Bank (University of California, San Diego), Andrew Goldberg (Microsoft Research), Timothy Davis (University of Florida), C. David Levermore (University of Maryland, College Park), and Sze-Bi Hsu (National Tsing Hua University. Bottom row: Peter Turner (Clarkson University), Edgar Knobloch (University of California, Berkeley), Raymond Chan (The Chinese University of Hong Kong), Haesun Park (Georgia Institute of Technology), John Burns (Virginia Polytechnic Institute and State University), and Robert Plemmons (Wake Forest University).*
Not pictured: Kaushik Bhattacharya (California Institute of Technology), Jerry L. Bona (University of Illinois at Chicago), Andrew R. Conn (IBM T.J. Watson Research Center), Michael C. Ferris (University of Wisconsin–Madison), Christodoulos A. Floudas (Princeton University), Michel X. Goemans (Massachusetts Institute of Technology), Alan Hastings (University of California, Davis), Shi Jin (Shanghai Jiao Tong University and University of Wisconsin–Madison), David Kinderlehrer (Carnegie Mellon University), Marc Mangel (University of California, Santa Cruz), Hans G. Othmer (University of Minnesota), John Rinzel (New York University), Björn Sandstede (Brown University), Guillermo Sapiro (Duke University), Larry L. Schumaker (Vanderbilt University), Horst D. Simon (Lawrence Berkeley National Laboratory), Pauline van den Driessche (University of Victoria), and James A. Yorke (University of Maryland, College Park).



Anette (Peko) Hosoi of MIT, the 2013 I.E. Block Community Lecturer, gave a model lecture: interesting topics (appropriately connected to MPE 2013) and accessible mathematics, all clearly conveyed with irresistible enthusiasm. The lecture, "From Razor Clams to Robots: The Mathematics Behind Biologically Inspired Design," was followed by a lively community reception.

Anna C. Gilbert of the University of Michigan received the 2013 Ralph E. Kleinman Prize for her "creative and deep contributions to the mathematics of signal processing, data analysis and communications." Gilbert's "bold and interdisciplinary work," according to the prize committee, "combines techniques from computer science, harmonic analysis and probability in the best traditions of the Kleinman Prize."

Leading Eigenvalues and the Spread of Cholera

By Marino Gatto, Lorenzo Mari, and Andrea Rinaldo

Diarrheal waterborne diseases are caused by the consumption of pathogenic microorganisms in contaminated water (or food contaminated by water), and are thus directly or indirectly hydrologically controlled. The toll of these diseases is more than 2 million lives annually. Low-income countries and children account for most of the deaths.

Cholera, the best-known among lethal diarrheal diseases, is an infection of the small intestine caused by the bacterium *Vibrio cholerae*, discovered by Filippo Pacini in 1854 during an epidemic in Florence. The bacterium produces a toxin that can cause profuse diarrhea and death by dehydration. The World Health Organization has not yet released complete world statistics for 2012; for 2011, a total of 58 countries reported a cumulative total of 589,854 cases, including 7816 deaths (a case fatality rate of 1.3% and an increase of 85% over the number of reported cases for the previous year). The most recent large epidemic began in Haiti in October 2010, following the catastrophic earthquake that hit the poor Caribbean country at the beginning of 2010; the ongoing epidemic, according to the report of June 23, 2013, has claimed 8139 lives out of 661,468 recorded cases.

Efforts to understand, predict, and control epidemic outbreaks are crucial to improving the health of many people around the world. Mathematical models of epidemiology have an important role to play in achieving these goals. It was Daniel Bernoulli who, in 1760, proposed the first mathematical formulation to evaluate the effectiveness of inoculation against smallpox. Bernoulli was trained in both medicine and mathematics (a background shared by Sir Ronald Ross, recipient of the 1902 Nobel Prize in Physiology and Medicine, who developed differential equation models for malaria as a host–vector disease in 1911). Subsequently, A.G. McKendrick, another physician with a passion for mathematics, and W.O. Kermack, a biochemist, built on Ross's theory to develop the ancestor of all modern susceptible–infectious–recovered (SIR) models. They also obtained the first epidemic threshold results, a concept further clarified by George MacDonald in 1952. Working on malaria, MacDonald defined the basic reproduction number R_0 as the number of secondary cases one infectious individual, introduced into a completely susceptible population, generates on average over the course of his/her infectious period. If and only if $R_0 > 1$, the infection will be established in the long run.

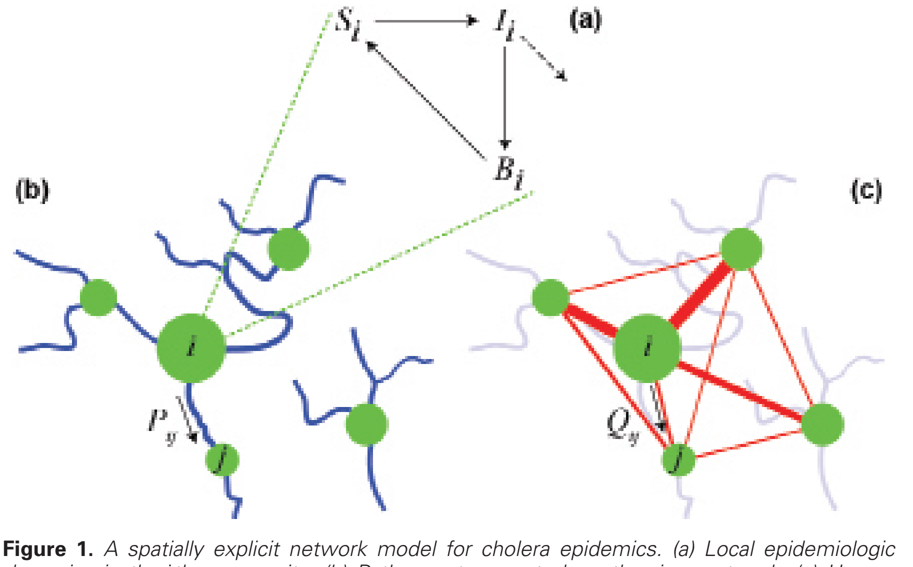


Figure 1. *A spatially explicit network model for cholera epidemics. (a) Local epidemiologic dynamics in the ith community. (b) Pathogen transport along the river network. (c) Human mobility network. Communities of different sizes constitute the nodes of the network model (green circles). Connections between nodes (specified by Markov matrices* **P** *and* **Q***) can represent hydrologic pathways and/or human displacement. Modified from [5].*

As for cholera, the seminal model was introduced in 1979 by Capasso and Paveri-Fontana [2], who studied the most recent epidemic in Italy (in Bari, 1973, a result of contaminated shellfish consumption). Their formulation was further developed by Codeço [3], who analyzed a system of ordinary differential equations that includes, in addition to susceptibles (S) and infectious (I), the population dynamics of bacteria (B) in water reservoirs (SIB model; see Figure 1a). Until recently, mathematical models of waterborne diseases did not explicitly

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A Game Theorist Reads Jane Austen

Jane Austen, Game Theorist. *By Michael Suk-Young Chwe, Princeton University Press, Princeton, New Jersey, 2013, 276 pages, $35.00.*

BOOK REVIEW
By Ernest Davis

When Frank Churchill rescues Harriet Smith from a menacing band of gypsies (Book III, Chapter 3, of Jane Austen's novel *Emma*), Emma Woodhouse, the heroine, wonders,

> "Could a linguist, could a grammarian, could even a mathematician have seen what she did, have witnessed their appearance together, and heard their history of it, without feeling that circumstances had been at work to make them peculiarly interesting to each other?"

To the best of my knowledge, this is the only mention of a mathematician in any of Austen's works. It is safe to say that it never crossed Austen's mind that any form of mathematics would be at all helpful in understanding her novels, still less that her novels would be a significant contribution to mathematics. However, Michael Chwe's new book *Jane Austen, Game Theorist* argues strongly for both of these claims, especially the latter. According to Chwe, himself a game theorist at UCLA, "Jane Austen systematically explored the core ideas of game theory in her six novels. . . . Austen is a theoretician of strategic thinking. . . . Austen's novels . . . are themselves an ambitious theoretical project, with insights not yet superseded by modern social science. . . . Austen's novels are game theory textbooks."

On the face of it, Austen seems a strange choice for game-theoretic analysis. Plots, plans, strategies, and manipulation play a central role in many literary works, from *Othello* to the *Harry Potter* series. (A complete game-theoretic analysis of the seven *Harry Potter* volumes would be a major undertaking.) By contrast, few of Austen's characters engage in sustained planning or plotting of any complexity.

The single major exception in Austen's major novels is the first third of *Emma*, which centers on Emma's attempts to create a match between Harriet Smith and Mr. Elton, the social-climbing village vicar. In some respects, however, this is an exception that proves the rule. First, Emma's plan is hopeless from the start, as there is no possibility that Mr. Elton will marry an illegitimate girl with no fortune. Second, Mr. Knightley, the voice of proper thinking throughout the novel, strongly disapproved of the plan, and Emma herself deeply regretted it, not merely because it failed, but because such games should not be attempted:

> "It was foolish, it was wrong, to take so active a part in bringing any two people together. It was adventuring too far, assuming too much, making light of what ought to be serious, a trick of what ought to be simple."

Chwe's analysis of the Austen novels accordingly focuses for the most part on comparatively small-bore manoeuverings. Unlike many who study applications of game theory to literature, Chwe does not expend much effort applying game-theoretic tools, such as preference matrices and decision trees, to the novels. A couple of such analyses serve as illustrations in an early chapter, but they are not very deep or enlightening. Rather, Chwe's primary concern is to argue that Austen herself was deeply engaged with fundamental concepts of game theory, such as choice, preference, and strategy; that she and her characters discuss these concepts in strikingly abstract and general terms; that Austen's view of these issues largely coincided with the standpoint taken in game theory; and that Austen had insights into these issues that, even now, have not been incorporated into the mathematical theory.

Chwe gives a detailed, careful analysis of many aspects of the novels. He studies the ways in which Austen's characters make choices, infer one another's preferences, resolve conflicting preferences, and construct plans. He compares choices based on the characters' preferred outcomes to choices driven by emotion, instinct, habit, rules, or social pressure, and argues that Austen consistently favors choosing according to preferences. He has a lengthy analysis of "cluelessness," the inability to realize that someone else might have different preferences; he considers this one of Austen's major conceptual advances. (Chwe takes the term from the movie *Clueless*, Amy Heckerling's adaptation of *Emma* to a 1980s southern California high school.) He discusses cases in which strategic planning is disadvantageous.

Chwe's very readable book is addressed to a general audience; it includes both an introduction to game theory and full synopses of the six major novels. He raises many diverse points of comparison, including strategic elements in folk tales, and strategic planning or cluelessness in international relations. He has extensive discussions of psychological and sociological studies that bear on the issues of game theory. His observations are often insightful and thought-provoking.

Chwe's readings of specific incidents often seem to me off-base, however. Two particular instances are from *Pride and Prejudice* (with which Chwe seems to have particular trouble, remarking himself that the novel fits his theory less well than the others). "In Austen's novels," he writes,

> "people calculate all the time without the slightest intimation that calculation is difficult, 'cold', or unnatural. . . . Since Mr. Collins is heir to Mr. Bennet's property, after he is engaged to her daughter Charlotte, Lady Lucas 'began directly to calculate, with more interest than the matter had ever excited before, how many years longer Mr. Bennet was likely to live.' The rapidity of her calculation is an expression of her joy."

This is not a good instance of Chwe's general point, that Austen does not disapprove of calculation. On the contrary, Lady Lucas's eager anticipation of the death of a friend and neighbor is contemptible, and Austen intends it to be so. To my mind, indeed, this is one of the few cases in which Austen lets satire get ahead of plausible characterization; such a thought would be appropriate to an intensely selfish character, but hardly to Lady Lucas, who otherwise seems harmless.

Second, and more seriously, Chwe suggests tentatively that the elopement of Elizabeth Bennet's sister Lydia might be an instance of successful strategic planning on Lydia's part. This reading is absolutely impossible. Austen clearly agrees with Lydia's entire family in considering her choice of Wickham as foolish in the extreme. What Lydia can reasonably expect is that Wickham will first seduce and then abandon her, leaving her in the status of a "ruined" woman, whatever exactly that entailed in that society at that time. The one extenuating circumstance, in Elizabeth's view, is that Lydia was genuinely fooled; otherwise, it would have been a "scheme of infamy." She is saved from ruin only because Darcy makes an extreme effort,

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Game Theory

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first to find Wickham, and then to bribe him into marrying her, which she has no reason to expect will happen.

Austen's view of choice and preference is also less well aligned with the axioms of game theory than Chwe supposes. Chwe makes much of Fanny Price's view (in *Mansfield Park*) that, in rejecting Henry Crawford's marriage proposal, it should suffice for her to say that she cannot like him; that is, her preference trumps every other consideration. Fanny's decision, however, is also motivated by Crawford's bad character. In other cases, it is not clear that personal preference should be the deciding factor. As Mr. Knightley says to Emma, "You would have chosen [a wife] for [Mr. Elton] better than he has chosen for himself." But there is no indication that Mr. Elton is at all unhappy with Mrs. Elton, still less that he would have preferred Harriet Smith. Mr. Elton's preference is viewed as faulty, not as absolute.

An even more telling quote from Mr. Knightley on the subject of choice and preference appears earlier in the book: "There is one thing, Emma, that a man can always do, if he chooses, and that is, his duty; not by manoeuvering and finessing but by vigor and resolution." Responsible choice, that is, cannot entirely follow personal preferences; one's duty is also a factor. Duty is not one of the competing factors in choice that Chwe considers as an alternative to preference. Chwe argues at one point that any such consideration can be integrated as an aspect of one's preferences. However, though that saves the game theory calculus, it throws out the entire argument that in Austen choice reflects personal preference rather than such other considerations as rules, emotion, and social pressure, as all of those can equally be incorporated into preference. One can view game theory as a neutral calculus that operates over preferences however they are defined, or one can view game theory as favoring certain kinds of considerations over others, but one cannot have it both ways.

Beyond these specific errors lies a more general and pervasive misunderstanding. In the final analysis, Austen places much more value on ethical behavior than on strategic planning. A vivid example is the character of Mrs. Jennings, a vulgar, silly woman, in *Sense and Sensibility*. At the beginning of the novel, Elinor, one of the heroines, has no use for Mrs. Jennings, and Marianne, the other, can't stand her. By the end of the novel, Mrs. Jennings is just as vulgar and silly (though she does get off a zinger against another character for cluelessness), but she has earned the love and respect of both sisters through her good heart and unfailing generosity. When it is important, she does the right thing, and she needs neither strategy nor insight nor sagacity to figure out what the right thing is.

Moreover, Austen's right-thinking characters often decry the use of strategies and cleverness in human interactions. I have already quoted Emma's repentant view of her own strategy and Mr. Knightley's disapproval of "manoeuvering and finessing." Here is Mr. Darcy: "Undoubtedly there is meanness in all the arts which ladies sometimes condescend to use for captivation. Whatever bears affinity to cunning is despicable."

Chwe's claim that Austen's purpose was to write a game theory textbook is far-fetched. If one does not accept this theory, he argues, "one would have to explain the inclusion of many particular and unnecessary details" relating to preferences, choices, and strategies. It seems to me that Chwe's argument reflects selection bias: This is what a game theorist notices in reading the novels. After all, one could assemble, as undoubtedly someone has, an equally impressive collection of quotations and incidents in which literature, music, and art are involved, with equally many "particular and unnecessary details"; one could then argue just as plausibly that Austen intended to write a textbook about the relation of the arts to character. Here Chwe perhaps falls victim himself to cluelessness; if *he* had written the novels, it would have been with the intention of writing a game theory textbook.

When an intelligent, knowledgeable reader with a new distinctive viewpoint engages intensely with a great work of literature, the results are usually worthy of attention. There is much that is valuable in Chwe's book. However, the central thesis is a half-truth; the issues considered in game theory are only a small part of Austen's rich, humane view of human interactions.

Ernest Davis is a professor of computer science at the Courant Institute of Mathematical Sciences, NYU.

Vogelius Is Next Director of DMS

Colleagues of Michael Vogelius helped him celebrate his 60th birthday earlier this summer at a conference titled Applied Analysis for the Materials Sciences, held at CIRM (Centre International de Rencontres Mathématiques) in Luminy, France. At the time Vogelius might have been thinking of a different way to mark the year, having put his name in play for the soon-to-be-open position of director of the Division of Mathematical Sciences at the National Science Foundation. As this issue of *SIAM News* went to press, NSF announced that Vogelius will become the new director of DMS in January 2014, succeeding Sastry Pantula, who steps down in September.

On arriving at NSF, he will join in planning for the fiscal year 2016 budget, which will then be in the very early stages. The FY 2015 budget will have been largely finalized, and Congress should have completed appropriations for 2014. The most important task, he says, will be to insure strong support for the core programs of DMS, while at the same time trying to motivate the mathematical community to participate in special initiatives considered of high national interest.

Vogelius joined the mathematics department of Rutgers University in 1989, and has been a Board of Governors Professor there since 1998. His work will be familiar to many in the SIAM community from his participation in the materials science conferences. A former editor of *SIAM Journal on Control and Optimization* (1994–2000), he is currently a member of the editorial board of *SIAM Journal on Mathematical Analysis.*

Changes to NSF's Grant Proposal Guide

To implement recommendations of the National Science Board, the National Science Foundation has announced recent changes to its Grant Proposal Guide.

The updated guide can be found at http://www.nsf.gov/pubs/policydocs/pappguide/nsf13001/gpg_index.jsp. Proposals that do not address the requirements in the updated guide will be returned without review.

Dark Matter

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well showed that a symmetric arrangement of masses in a circle around a central mass can rotate as if the masses were a rigid body. His intended application, the rings of Saturn, is a bit problematic because the rings are so wide that they cannot be considered particles in a single circle. A better example might be the very tenuous ring surrounding Uranus, which was unknown in Maxwell's day.

Saari has introduced a new central configuration, which is in fact a step toward a multi-ringed planet. What he envisions is a cosmic spiderweb, with equal spacing of the spokes, but not necessarily of the rings. A mass is placed at each intersection point of a ring and a spoke; all the masses on a given ring are equal, but the masses can differ from ring to ring. He has proved that if the spacing of the rings is chosen just right, the masses will orbit as a rigid body, which means that $v(r)$ grows linearly as a function of r. The usual argument would suggest, then, that the matter distribution $M(r)$ grows proportionally to r^3, a growth rate even more dramatic than that found in spiral galaxies. And yet the masses can actually be chosen in such a way that $M(r)$ is proportional to $\ln(r)$. This is a vast discrepancy: An astrophysicist would conclude that 99.999% (or more) of the spiderweb galaxy is dark matter—and yet there is none at all.

Saari argues that the reason for the discrepancy is the tugging from nearest neighbors that the "star soup" model ignores. In fact, the choice of spacing for the rings is very sensitive to this effect: Too far apart and there is not enough tugging, too close and there is too much.

Galaxy as Guinea Pig

The reaction to Saari's paper in the astrophysics community has so far been frosty: While referees have agreed that the mathematical argument is correct, the paper has been rejected by two astrophysical journals. Saari believes that the editors and referees missed the point. He views the spiderweb galaxy not as a configuration that is actually found in the universe, but as a test case to learn whether the method for computing $M(r)$ works, much like a guinea pig in a biological experiment. "If the guinea pig gets sick, then we would say there is a concern about the treatment," Saari says.

One reason that Saari may be fighting an uphill battle is that astrophysicists have by now gathered multiple independent lines of evidence that converge on roughly the same estimates for the cosmic ratio of ordinary matter (baryons) to dark matter. To begin with, the amount of matter in a galaxy can be estimated not only by rotation curves, but also by such methods as gravitational lensing. In this relativistic effect, two galaxies line up with the observer, and the light from the more distant galaxy bends around the closer one. This produces multiple images of the more distant galaxy, or sometimes even a complete ring. While such arrangements are rare, a few dozen of the billions of galaxies in the observable universe have an orientation that would produce lensing.

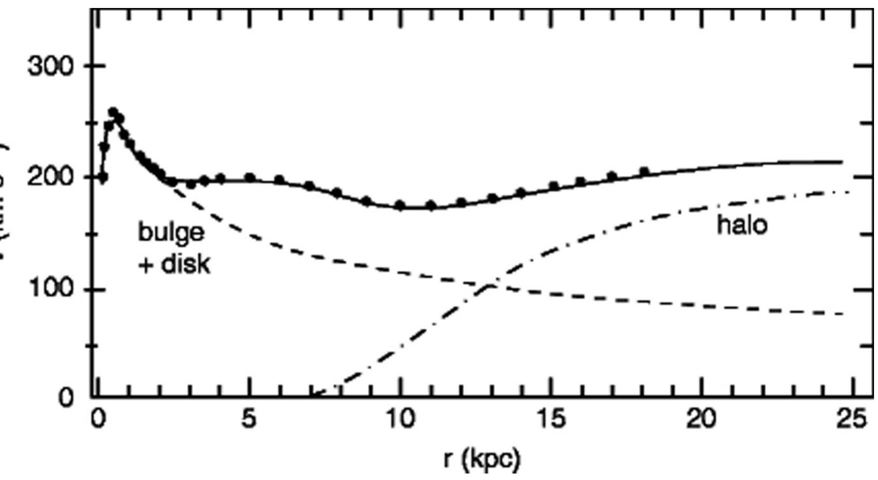
Another dark matter test is weak lensing, which occurs when the intervening matter is insufficient to produce multiple images but is abundant enough to distort the image of the distant galaxy in predictable ways—by shearing or bending, for example. Weak lensing has the advantage of being more or less ubiquitous, and it allows for the calculation of a distribution of matter in the nearer galaxy. These calculations consistently show baryonic matter concentrated in the center of a galaxy, with dark matter more abundant in the fringes. "There is now better agreement about the profile of the dark matter halo than the distribution of the central baryons!" wrote Richard Massey, Thomas Kitching, and Johan Richard in a 2010 survey article.

Finally, a different kind of evidence is provided by surveys of the cosmic microwave background, such as the one by the Planck telescope. These measurements allow astrophysicists to study the interaction of normal and dark matter *before* the formation of galaxies, in the era before space became transparent. At that time the universe was filled by a plasma of matter and photons that vibrated acoustically. The variations in temperature produced by these sound waves were "frozen in" when the universe became transparent, and the size of the variations provides a good clue to the amount of dark matter in the universe—just as the sounds of bells made of dense and light materials will be different.

Tremendous Opportunity for Mathematicians

Saari's argument does not address any of these other pieces of evidence for dark matter. In fact, he believes that dark matter most likely exists, although perhaps not in the amounts proposed by cosmologists. "I don't want to criticize astrophysicists," he says. "They can't wait for mathematicians to come up with a perfect model of a galaxy; they have to make simplifying assumptions. But there is a tremendous opportunity for mathematicians to look at those assumptions and see whether we believe them."

Among mathematicians, the reception to Saari's work has been warmer, although until the paper is subjected to peer review it can't be said definitively to be correct. "I do like the argument, and I think it needs



One of the first pieces of evidence for dark matter came from observations of the rotation speeds of stars in spiral galaxies, such as NGC3198 (shown here). The observed rotation speeds are nearly constant out to the very edge of the galaxy (data points). The rotation speeds predicted by the "star soup" model, assuming the galaxy has only visible matter, are shown by the dashed line. Astrophysicists interpreted the discrepancy to mean that there must be unseen dark matter. In fact, a model that combines the visible bulge and disk with a dark matter halo (solid line) matches the data very well. From Particles and Fundamental Interactions, *Chapter 13: Microcosm and Macrocosm, Sylvie Braibant, Giorgio Giacomelli, and Maurizio Spurio, Springer Netherlands, 2012; reprinted with permission from Springer Science+Business Media BV.*

to be countered," says Gareth Roberts, a celestial mechanics theorist at the College of the Holy Cross. "If I was interested in dark matter, I would want to get to the bottom of this."

Cédric Villani, a Fields medalist from the University of Lyon, who attended Saari's lecture, commented in an e-mail, "It may be a discrete-to-continuous issue, it may also have something to do with the inhomogeneity [of the mass distribution], or both. The only thing I can say is that one of the main arguments used for dark matter, viewed from an outsider's perspective, looks quite fragile, and Saari's counterexample showed this very well."

Dana Mackenzie, a freelance writer and a frequent contributor to SIAM News, *writes from Santa Cruz, California. He is the author of the 2012 book* The Universe in Zero Words: The Story of Mathematics as Told Through Equations.

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Institute for Advanced Study

School of Mathematics

The School of Mathematics at the Institute for Advanced Study, in Princeton, New Jersey, will have a limited number of one- and two-year memberships with financial support for research in mathematics and computer science at the institute for the 2014–15 academic year. The school frequently sponsors special programs; however, these programs comprise no more than one-third of the membership so that a wide range of mathematics can be supported each year. "The Topology of Algebraic Varieties" will be the topic of the special program in 2014–15. Claire Voisin, of the Institut de Mathématiques de Jussieu, will be the school's Distinguished Visiting Professor and lead the program. More information about the special program can be found on the school's homepage (http://www.math.ias.edu/).

Several years ago the school established the von Neumann Fellowships. Up to eight of these fellowships will be available for each academic year. To be eligible for a von Neumann fellowship, applicants should be at least five, but no more than 15, years after receipt of a PhD. Veblen Research Instructorships are three-year positions that were established in partnership with the Department of Mathematics at Princeton University in 1998. Three-year instructorships will be offered each year to candidates in pure and applied mathematics who have received a PhD within the last three years. Usually, Veblen research instructors spend their first and third years at Princeton University; these years will carry regular teaching responsibilities. The second year is spent at the institute and dedicated to independent research of the instructor's choice.

Candidates must have given evidence of ability in research comparable with at least that expected for a PhD degree. Postdoctoral applicants in computer science and discrete mathematics may be interested in applying for a joint (two-year) position with one of the following: Department of Computer Science at Princeton University, http://www.cs.princeton.edu; DIMACS at Rutgers, The State University of New Jersey, http://www.dimacs.rutgers.edu; or the Intractability Center, http://intractability.princeton.edu. For a joint appointment, applicants should apply to the School of Mathematics, as well as to one of the listed departments or centers, noting their interest in a joint appointment.

Applicants can request application materials from: Applications, School of Mathematics, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540; applications@math.ias.edu. Applications can also be found online at: https://applications.ias.edu. The deadline for all applications is December 1, 2013.

The Institute for Advanced Study is committed to diversity and strongly encourages applications from women and minorities.

Statistical and Applied Mathematical Sciences Institute

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The Statistical and Applied Mathematical Sciences Institute (SAMSI) invites applications for the position of deputy director, for a term of up to five years, beginning July 1, 2014. The deputy director will be a distinguished researcher who will provide scientific direction to the institute and oversight of the SAMSI grant, and who will work closely with the director on all aspects of the institute's oversight and program activities. The deputy director will also be strongly encouraged to pursue his/her personal research, in conjunction with the SAMSI programs or independently. The appointment will be made as a member of the research faculty at North Carolina State University. Rank and salary will be commensurate with the successful candidate's experience and qualifications. Education requirements are as follows: Applicants must have a minimum of a PhD in mathematics or statistics or equivalent. Qualifications and experience for the position include the following: Qualified candidates should be mathematicians or statisticians with excellent management skills and research records; proven administrative experience is an asset. Applicants should also have a strong interest in developing the programs of the institute. SAMSI seeks candidates who would intend to stay for at least two years.

SAMSI is one of eight mathematical sciences institutes funded by the National Science Foundation. The institute is managed by a directorate which comprises five members: the director, the deputy director, and three part-time associate directors. The director and deputy director form the executive side of the directorate and are responsible for the administration of programs, human resources and personnel issues, financial operations, and infrastructure. Together with the other members of the directorate, they also share the responsibilities of the selection, development, and implementation of SAMSI programs. More information on SAMSI is available via http://www.samsi.info/.

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Applications must be submitted online through: http://www.anl.gov/careers. Correspondence and supporting letters of recommendation should be submitted to Named-Postdoc@anl.gov. For more information, applicants should visit the Argonne Postdoc Blog at https://blogs.anl.gov/postdoc or contact the postdoc program coordinator, Kristene Henne, at khenne@anl.gov.

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THE UNIVERSITY OF TEXAS AT AUSTIN

Math 2025

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built on a mathematical foundation, and that foundation must continue to flourish, evolve, and expand. Many mathematical scientists remain unaware of the expanding role of their field, however, and this limits the community's ability to fully realize the benefits of the expansion.

One conclusion of the study is that the dramatic expansion in the role of the mathematical sciences "has not been matched by a comparable expansion in federal funding, either in amount or in the diversity of sources."

The number of students entering mathematics-intensive disciplines is inadequate to meet the opportunities of the future. The mathematical sciences community has a critical role to play in educating a broad range of students: those within the mathematical sciences; those pursuing degrees in science, medicine, engineering, business, and social science; and those already in the workforce who need additional quantitative skills. There is a need for multiple entry points and pathways, and for new courses, majors, programs, and educational partnerships with those in other disciplines, both inside and outside academe. Students would benefit from encounters with a variety of modes of mathematical and statistical thinking—including core mathematics, modeling and simulation, algorithms, probabilistic methods, and statistical inference—and should learn to deal with problems that are not precisely formulated. The widespread need for graduates with math-intensive career skills provides an opportunity for the mathematical sciences.

The traditional lecture–homework–exam format also needs re-examination. A large and growing body of research indicates that diversification of teaching methods can result in substantial improvements in STEM education. As part of this effort, it is essential that educators motivate students at all levels by explaining how the mathematical topics they are teaching are used and identifying careers that make use of them. Modest steps in this direction could lead to greater success in attracting and retaining students in mathematical sciences courses.

Cost pressures on universities and the advent of online education have the potential to elicit rapid change. The current business model of mathematical sciences departments, with its heavy reliance on lower-division service courses, may prove unsustainable. The mathematical sciences community should be proactive and engaged in discussions of institutional changes.

The market for mathematical talent is now global, the study found, and the U.S. is in danger of losing its global pre-eminence in the discipline; a brain drain from the U.S. is now a real threat. The report also recommends that every academic department in the mathematical sciences explicitly include recruitment and retention of women and underrepresented groups in the responsibilities of the faculty members in charge of the undergraduate program, graduate program, and faculty hiring and promotion, and it provides an extensive list of best practices.

The study committee recognized that the size of the pipeline of students preparing for careers that rely on the mathematical sciences is fundamentally limited by the quality of K–12 mathematics and statistics education. Although the study did not encompass K–12 education, this is an issue that should concern all mathematical scientists, especially in their role in the education of K–12 teachers.

A PDF of *The Mathematical Sciences in 2025* can be downloaded for free at www.nap.edu/catalog.php?record_id=15269. The study also produced an earlier report, *Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century*, which illustrates how the discipline is providing clear benefits for diverse areas of science and engineering, for industry and technology, for innovation and economic competitiveness, and for national security; a free PDF of that report can be downloaded at www.nap.edu/catalog.php?record_id=13373.

Mark Green, a founding director of IPAM, is a professor emeritus of mathematics at UCLA. Scott Weidman is director of the Board on Mathematical Sciences and Their Applications.

Cholera

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consider the spatial spread of pathogens that occurs primarily along hydrologic pathways, from coastal to inland regions or vice versa, and from inland epidemic sites to neighboring areas. Bertuzzo et al. were the first to integrate hydrology into epidemiologic models [1]. Another consideration is that infected individuals are often asymptomatic (as many as 80% in the case of cholera). While traveling or commuting, these individuals can spread the pathogen to communities other than those in which they were infected. Similarly, susceptible individuals can be exposed to pathogens and return as infected carriers to their home communities. The basis of our most recent analyses [4] and [5] is thus a spatially explicit nonlinear differential equation model that accounts for both the hydrologic (Figure 1b) and the human mobility networks (Figure 1c). Bacterial spread along the water network is described as a random walk on an oriented graph; human movements between communities obey a gravitation-like model.

We have studied the conditions under which a waterborne disease epidemic can start within a specific country and linked them to explicit demographic, epidemiologic, climatic, and socio-economic characteristics. We have shown that the key parameter for the spread of disease is the leading eigenvalue Λ_0 of a generalized reproduction matrix that accounts for the spatial distribution of human communities and for the connectivity networks. If Λ_0 is larger than 1, cholera can spread into the country; otherwise, it cannot. We note here that the condition that all the local R_0's be larger than unity is neither necessary nor sufficient for the outbreak of an epidemic—underscoring the importance of explicit introduction of the hydrologic and human mobility connections into cholera models to determine the fate of an initial infection. We have also demonstrated that the dominant eigenvector associated with Λ_0 can accurately describe the geography of epidemic outbreaks.

Our analysis is not only theoretical. The wide availability, via Geographic Information Systems, of spatial data on hydrology, road networks, population distribution, and sanitation makes these models applicable to the specific situations of different countries. Our network models have thus been used to study several cholera epidemics, most notably the one that continues to devastate Haiti. We have calibrated Haitian epidemiologic data for the period from November 2010 to May 2011 (Figures 2a and b); results of the analysis are shown in Figures 2c and d. In the Haitian case, Λ_0 = 1.08: The parameter is essentially insensitive to changes in pathogen movement rate l and average mobility distance D, and to increases of the human mobility rate m (Figure 2c), while it is quite sensitive to variations in the exposure and contamination rates ß and p, the pathogen mortality rate μ_B, and the recovery rate γ. Therefore, one effective way to prevent the cholera epidemic would have been to implement sanitation measures designed to decrease the exposure (or contamination) rate by more than 40%. The dominant eigenvector is a good indicator of the spatial distribution of recorded cases (Figure 2d), as demonstrated by the corresponding coefficients of determination (see caption for Figure 2). In a sensitivity analysis run to determine how the predictive ability of the dominant eigenvector and the value of Λ_0 change with parameter variations, the coefficients of determination exceed 75%, even for variations as high as 50%—an indication of robustness in the prediction of the spatial pattern [4].

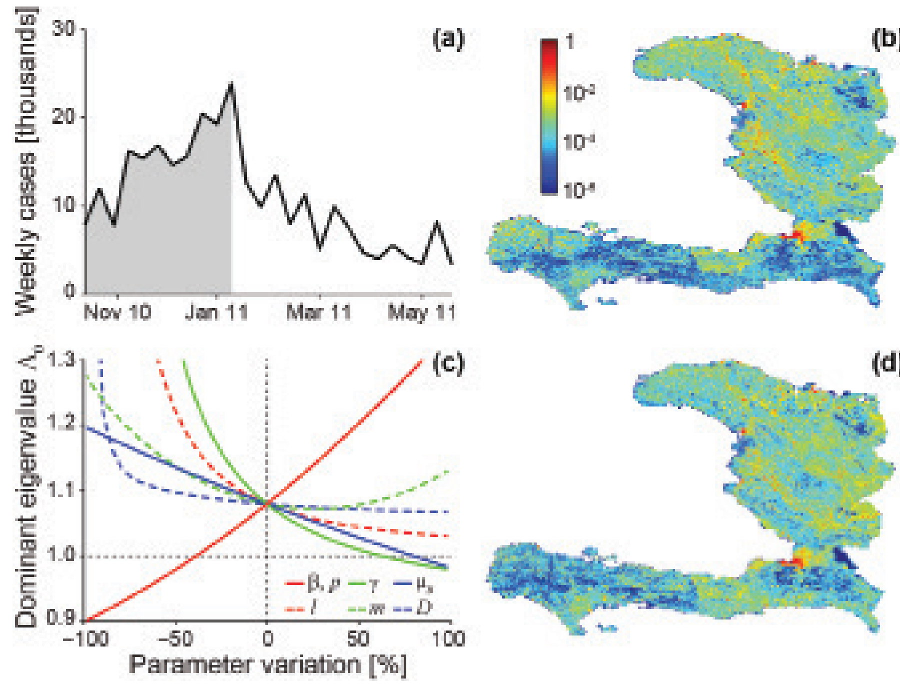

Figure 2. *Data and model predictions for the Haitian epidemic. (a) Total incidence data (weekly cases) from October 2010 to June 2011. (b) Fine-grained spatial distribution of cumulative recorded cases during the outbreak phase of the epidemic (defined as the period from beginning to peak, shown in gray in panel (a); cholera cases have been normalized). (c) Sensitivity to parameter variations of Λ_0, the dominant eigenvalue of the generalized reproduction matrix; the dotted horizontal line indicates the value below which the epidemic cannot start. (d) Fine-grained spatial distribution of cases as predicted by the dominant eigenvector; coefficients of determination for predicted vs. observed cases: R_0^2 = 0.92 (outbreak phase), R_1^2 = 0.95 (whole period). Parameter values are as in [5]; modified from [4].*

References

[1] E. Bertuzzo, M. Gatto, A. Maritan, S. Azaele, I. Rodriguez-Iturbe, and A. Rinaldo, *On the space–time evolution of a cholera epidemic*, Water Resour. Res., 44 (2008), W01424.

[2] V. Capasso and S.L. Paveri-Fontana, *A mathematical model for the 1973 cholera epidemic in the European Mediterranean region*, Rev. Epidemiol. Santé Publique, 27 (1979), 121–132.

[3] C. Codeço, *Endemic and epidemic dynamics of cholera: The role of the aquatic reservoir*, BMC Infect. Dis., 1:1 (2001).

[4] M. Gatto, L. Mari, E. Bertuzzo, R. Casagrandi, L. Righetto, I. Rodriguez-Iturbe, and A. Rinaldo, *Generalized reproduction numbers and the prediction of patterns in waterborne disease*, Proc. Natl. Acad. Sci. USA, 48 (2012), 19703–19708.

[5] A. Rinaldo, E. Bertuzzo, L. Mari, L. Righetto, M. Blokesch, M. Gatto, R. Casagrandi, M. Murray, S. Vesenbeckh, and I. Rodriguez-Iturbe, *Reassessment of the 2010–2011 Haiti cholera outbreak and rainfall-driven multiseason projections*, Proc. Natl. Acad. Sci. USA, 109 (2012), 6602–6607.

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