Mobility data reveals universal law of visitation in cities

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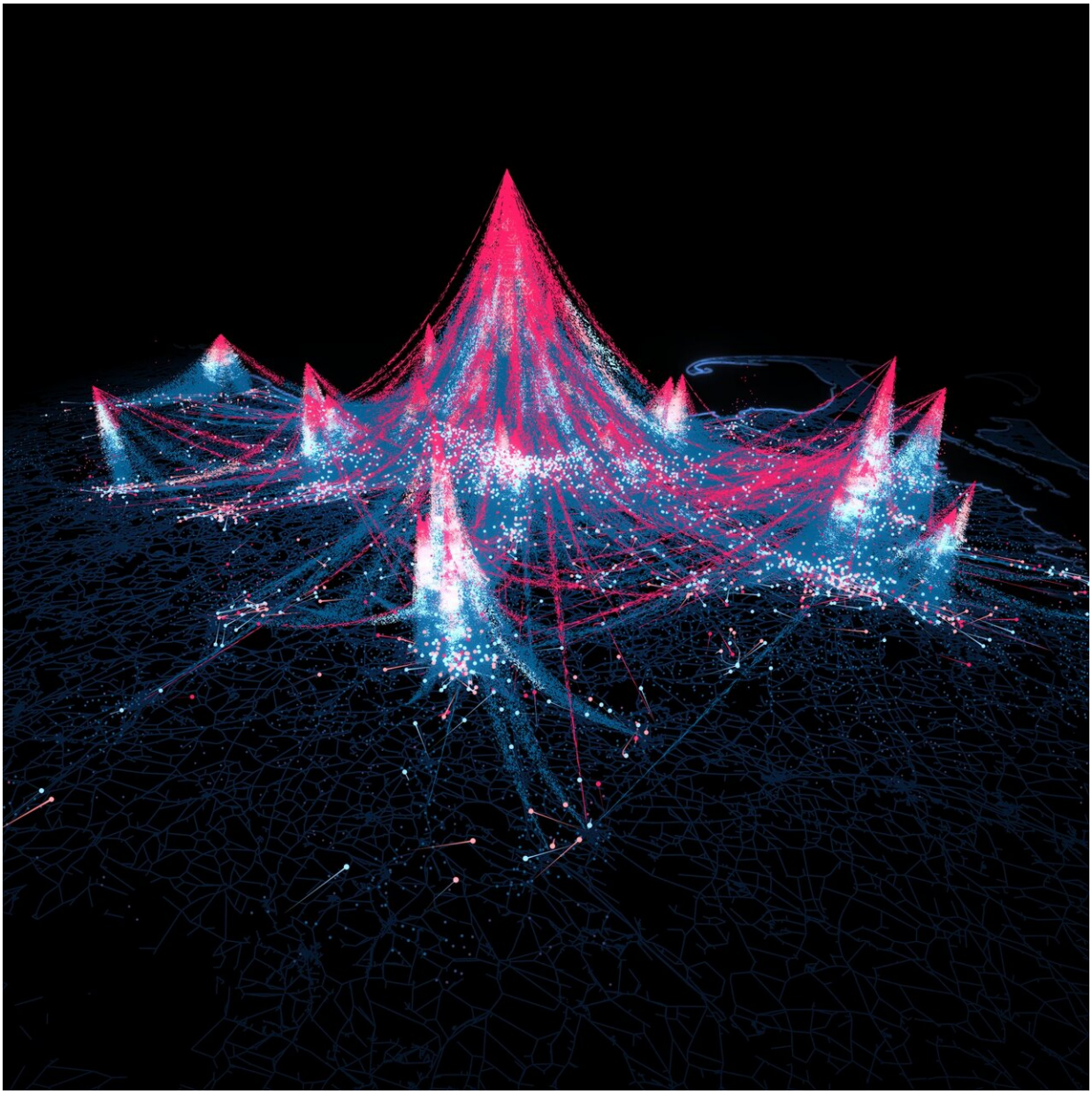


This image visualizes the flows of individuals across the Greater Boston area as lines (visiting frequency as the color, number of unique visitors as the width) that form spatial clusters of attractive places, with the height of mountains representing location-specific attractiveness. Credit: Guangyu Du.

New research published in *Nature* provides a powerful yet surprisingly simple way to determine the number of visitors to any location in a city.

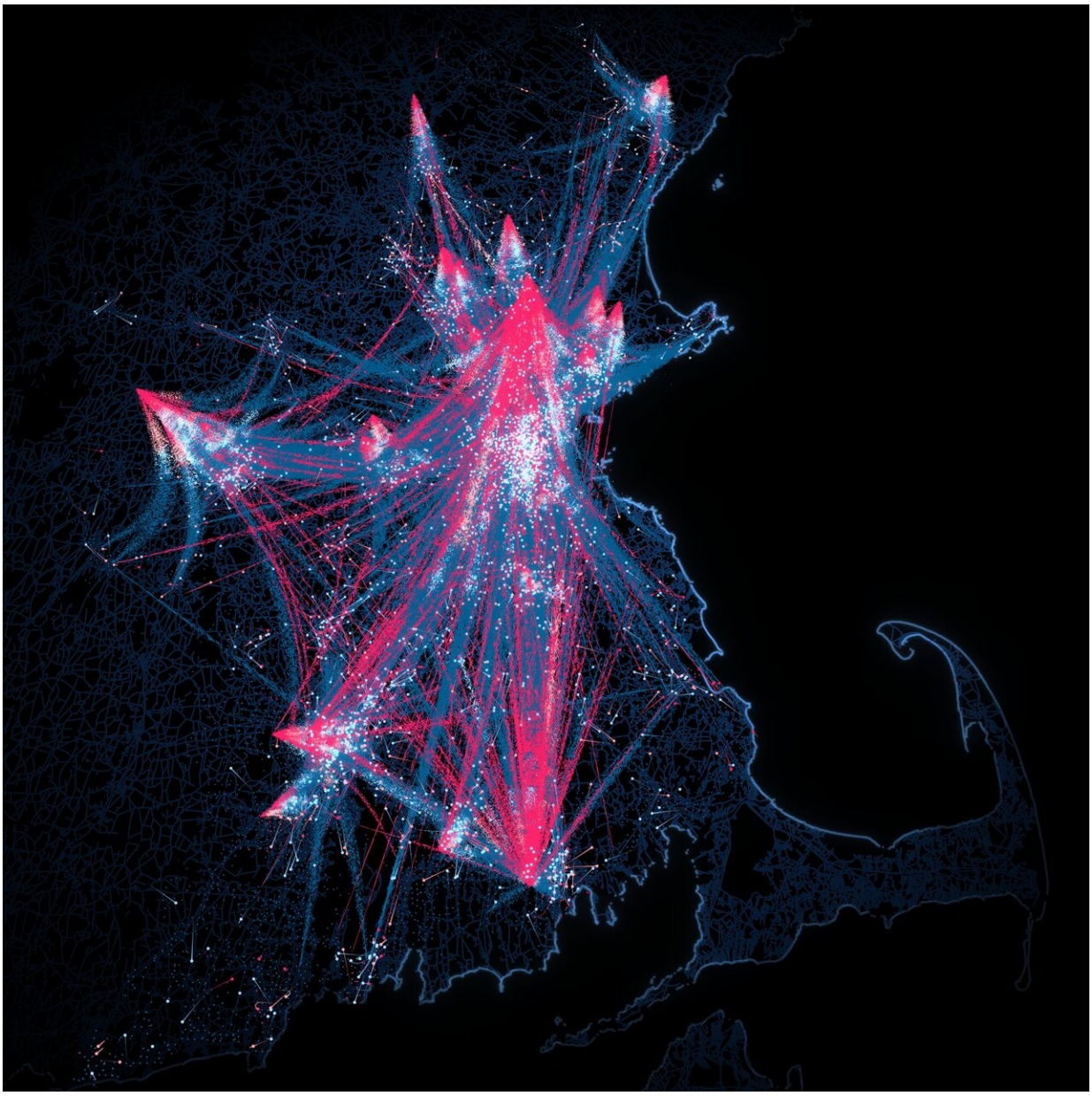
Scientists from the Santa Fe Institute, MIT, and ETH Zürich have discovered and developed a scaling law that governs the number of visitors to any location based on how far they are traveling and how often they are visiting. The visitation law opens up unprecedented possibilities for accurately predicting flows between locations, which could ultimately have applications in everything from city planning to preventing the spread of the next major pandemic.

"Imagine you are standing on a busy plaza, say in Boston, and you see people coming and going. This may look pretty random and chaotic, but the law shows that these movements are surprisingly structured and predictable. It basically tells you how many of these people are coming from 1, 2 or 10 kilometers away and how many are visiting once, twice or 10 times a month", says lead author Markus Schläpfer of ETH Zurich's Future Cities Laboratory. "And the best part is that this same regularity holds not only in Boston, but across cities worldwide."

The researchers' findings are a result of an analysis of mobile phone data from millions of anonymized cell phone users in highly diverse urban regions across the world, including Greater Boston in the United States, Lisbon in Europe, Singapore in Asia, and Dakar in Africa. Schläpfer began the analysis and development of the theory while he was a post-doctoral fellow at the Santa Fe Institute working together with senior

author Geoffrey West, a physicist who leads the Cities, Scaling, and Sustainability project. It was later extended to include researchers at the MIT Sensible Cities Laboratory under the leadership of the architect Carlo Ratti.

Universally, they found that the number of visitors to any urban location scales as the inverse square of both travel distance from home and the visitation frequency. Like the gravitational pull of a large planet, an attractive city plaza with fine museums and famous shops draws relatively more visitors from more distant locations, though less frequently than those coming from nearby locations, their relative numbers being predictably determined by the inverse square law. A further surprising consequence of this new visitation law is that the same number of people visit the location whether they are coming from, say, 10km away 3 times a week, or from 3km away 10 times a week.



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While previous research has used mobile phone data to study human

movement from the perspectives of individual people—where they go, when, and how often—this is the first systematic study to focus on the frequency of visits from the perspective of places, using mobile phone data to understand the relative attractiveness or utility of an urban area.

"There's an optimization problem going on here in terms of the amount of energy people are using, the distance they're travelling, and the number of trips they're making," says Geoffrey West. "When we travel for leisure we choose our destinations. During everyday life, those choices are more forced because we have to go to work, say, five times a week, pick up the kids two times, etc. But there's this remarkable conservation inherent in the visitation law—namely, the average amount of energy that people allocate to travel is the same whether they try to do it across different distances or at different frequencies."

Schläpfer says the new paper can give urban planners "a baseline for understanding which locations in their cities are over- or under-performing," in terms of the number of people they attract. It can inform planners about where to add amenities like parks and restaurants, or how much public transportation is needed for new urban developments.

The law of visitation joins a growing body of research in the science of cities, which SFI researchers and their collaborators have pioneered since 2007, when they first uncovered universal laws governing growth, innovation, and the pace of life in cities.

"All of the problems that we face, especially climate change are generated in cities because that's where the people are," West says. "So understanding cities, and how people move within them, plays into fundamental questions about the future of life on this planet."

More information: The universal visitation law of human mobility, *Nature* (2021). DOI: 10.1038/s41586-021-03480-9

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