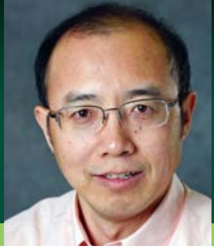

Jianliang Qian

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BIO SKETCH

Jianliang Qian has been at Michigan State University since August 2007, currently serving as a professor with a joint appointment in the Department of Computational Mathematics, Science and Engineering and the Department of Mathematics. He has published more than 50 journal papers, and has been the organizer or co-organizer of ten conferences, workshops, and seminars. His research is primarily supported by the National Science Foundation.

Prior to joining MSU, he was an assistant professor at Wichita State University (August 2005–July 2007), and served as a CAM assistant professor at UCLA (July 2002–July 2005). Dr. Qian earned his Ph.D. at Rice University, in Houston, TX, under the supervision of Prof. William W. Symes in May 2000. From August 2000 to July 2002, he was a postdoc fellow at the Institute of Mathematics and its Applications, at the University of Minnesota, where he was mentored by Prof. Bernardo Cockburn and Prof. Fadil Santosa. He received his B.S. from the Harbin Institute of Technology in Harbin, Heilongjiang, China.

RESEARCH INTERESTS

Fast algorithms for high-frequency wave propagation, fast algorithms for eikonal equations, Eulerian semiclassical analysis, Eulerian geometrical optics, Gaussian beams, kinetic inverse problems, photoacoustic computed tomography, ultrasound computed tomography, seismic imaging, and medical imaging

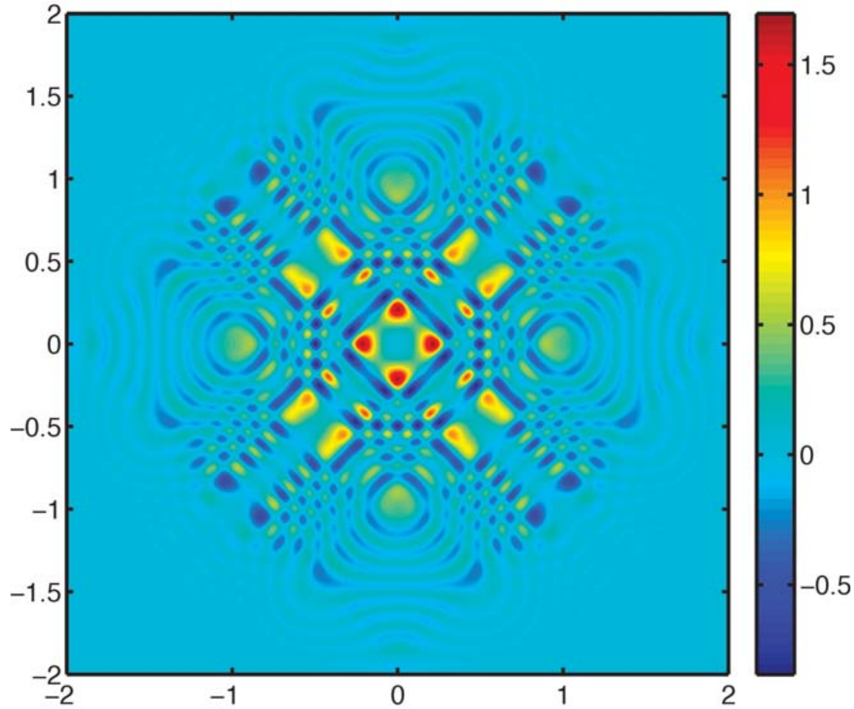

FIGURE 1. This figure illustrates quantum interference effects.

WEBSITE

http://www.math.msu.edu/~qian/

GROUP MEMBERS

POSTDOCTORAL RESEARCHERS: Dr. Wangtao Lu, Dr. Wenbin Li.
GRADUATE STUDENTS: Chao Song, Qinfeng Gao, Ali Algefary.

CURRENT RESEARCH FOCUS

The central theme of my research has been foundations and fast algorithms for computational geometrical optics (GO) and high-frequency waves, and applications to seismic imaging and medical imaging. Since 2005 I have been successful in obtaining funding to support my research. My research program on computational geometrical optics and high-frequency waves has been continuously funded by NSF since 2005.

Specifically, my research foci are in the following aspects: fast algorithms for eikonal equations, such as fast eikonal solvers for single-valued or multivalued traveltimes in exploration geophysics; fast algorithms for Eulerian geometrical optics, such as fast solvers for traveltimes and amplitudes in exploration geophysics, and applications to seismic modeling, migration, and inversion; fast single-scale and multi-scale Gaussian beam methods in both Lagrangian and Eulerian forms for high-frequency waves and applications in exploration geophysics; fast eikonal-based adjoint state methods for traveltime tomography; fast level-set methods for inverse gravimetry problems.

My first research direction is fast numerical methods for eikonal equations or Hamilton-Jacobi equations. The significance of this line of research is epitomized in the tremendous applications of this equation. Eikonal equations as a class of first-order nonlinear equations arise in a variety of applications: petroleum-exploration geophysics, wave propagation, classical mechanics, semi-classical approximation in quantum mechanics, image processing and computer vision, robotic path planning, and deep mantle tomography.

In petroleum-exploration geophysics, both traveltimes and amplitudes are critical for seismic imaging, such as true-amplitude migration and inversion. Therefore, we need to develop fast accurate solvers for both traveltimes and amplitudes. Since the amplitude function solving a transport equation depends on the second-order derivatives of traveltimes, high-order accurate eikonal solvers are essential in computing accurate amplitudes. The above considerations motivated me to develop fast algorithms for Eulerian geometrical optics. In particular we have developed the fast Huygens sweeping method for high frequency waves in inhomogeneous media, and this algorithm enjoys $O(N \cdot \log N)$ complexity for evaluating high-frequency waves for arbitrary high frequencies beyond caustics, where the number of points per wave length is fixed to be four to six points, and N is the

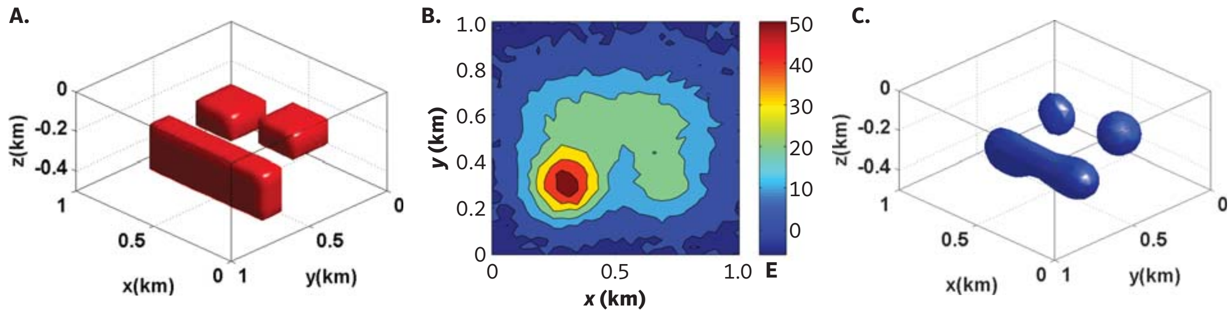

FIGURE 2. (A) The configuration of the target that we would like to find by solving the gravity inverse problem, (B) the gravity data that we have collected by flying an airplane over the targeted region, (C) the recovered target by solving the gravity inverse problem, which can be compared with the original target.

total number of sampling points. To the best of our knowledge, this is the best so far for computing Green functions of the Helmholtz equation in the high-frequency regime in inhomogeneous media.

One critical drawback of the traditional geometrical optics is that amplitude blows up at caustics, where ray tubes in the real space collapse in physical space. By making use of the symplectic structure hidden in the Hamiltonian system associated with an eikonal equation and complexifying the Riccati equation for the Hessian matrix of the eikonal equation, Gaussian beam methods yield single-ray based asymptotic solutions which are valid beyond caustics. Motivated by the tremendous potential applications of Gaussian beam methods, such as in exploration geophysics and semi-classical methods for quantum mechanics, we have developed the first Eulerian Gaussian beam method for Helmholtz equations.

One of the critical elements for a seimic migration method to succeed in imaging subsurface structure is an accurate velocity model, which is usually obtained through traveltime tomography or tomography based migration velocity analysis. Therefore, it is essential to develop reliable and robust traveltime tomography methods. To this end, we have made systematic efforts to develop eikonal-equation based fast first-arrival and multi-arrival traveltime tomography methods.

Inverse gravimetry consists of a class of inverse problems that aims at recovering mass distribution of the earth from measurements of gravity or gravity gradient data. Because the gravity potential satisfies the Laplace equation and thus is analytic outside the mass distribution, the inverse gravimetry problem is severely ill-posed. However, assuming that the density contrast of mass distribution is known, the inverse gravimetry problem can be reduced to a geometric domain inverse problem, which is known to have a unique solution under certain assumptions. To recover such geometric domains, we have proposed fast local level set methods for the inverse problem of gravimetry, and we have for the first time successfully processed a benchmark data set by using our level-set method.

RECENT PUBLICATIONS

J. Qian, L. Ying, "Fast Gaussian wavepacket transforms and Gaussian beams for the Schrodinger equation," *J. Computational Physics* 229: 7848–7873 (2010).

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J. Qian, S. Luo, R. Burridge, "Fast Huygens sweeping methods for multiarrival Green's functions of Helmholtz equations in the high frequency regime," *Geophysics* 80: T91–T100 (2015).