RTG Activities (2022-2023)

Organization

Meetings
The RTG PIs and Senior Personnel meet every 3 weeks. These meetings were organized by Jason Metcalfe (PI). The agenda for each meeting was shared in advance and the overall goal was to discuss the progress of the ongoing RTG activities, as well as plan future ones. These meetings guarantee that the RTG goals are met by promoting that the group acts in a cohesive and efficient manner.

Website
As planned, the RTG developed a website for disseminating its activities and results. The website URL is https://tarheels.live/waves/. It is updated weekly with information on ongoing activities and news.

Dissemination
Local activities are advertised via departmental email and are posted on a hallway board that is exclusively dedicated to displaying RTG activities. To advertise activities that are designed to reach a wider audience of students and faculty outside UNC-Chapel Hill, the RTG created an email list of about 150 faculty colleagues who work across the globe. Posters are created for each of these activities, and they are shared via email and posted on the RTG website. The posters can be found enclosed in the supporting pdf documents.

Participants and Mentoring

Participants
The RTG **postdocs** for the first year of the RTG were:
- Jian Wang. Mentors: Hans Christianson(co-PI) and Jeremy Marzuola (co-PI)

The RTG **graduate researchers** for the first year of the RTG were:
- Corbin Balitactac. Expected graduation: Fall 2026. Temporary mentor: Casey Rodriguez (co-PI)
- Benjamin Bechtold. Expected graduation: Fall 2024. Mentor: Jason Metcalfe (PI)
- Madelyne Brown. Expected graduation: Fall 2024. Mentor: Yaiza Canzani (co-PI)
- Sarah Carpenter. Expected graduation: Fall 2024. Mentor: Hans Christianson(co-PI)
- Jacob Folks. Expected graduation: Fall 2024. Mentor: Idris Assani (UNC faculty)
- Tim Van Hoose. Expected graduation: Fall 2026. Temporary mentor: Jeremy Marzuola (co-PI)
- Andrew Lyons. Expected graduation: Fall 2025. Mentors: Yaiza Canzani (co-PI) and Jeremy Marzuola (co-PI)
- Derrick Nowak. Expected graduation: Fall 2024. Mentor: Hans Christianson(co-PI)
- Jeremy Wall. Expected graduation: Fall 2025. Mentor: Arunima Battacharya (Senior Personnel)

The RTG **undergraduate researchers** for the first year of the RTG were:
- Yizhou (Josie) Gu. Graduation: May 2023. Mentor: Jason Metcalfe (PI)
- Xiao-Ming Porter. Graduation: May 2023. Mentor: Jason Metcalfe (PI)
- Ameer Qaqish. Graduation: May 2023. Mentor: Hans Christianson(co-PI)

- David Snider. Graduation: May 2023. Mentor: Mark Williams (Senior Personnel)

The RTG **high school researchers** for the first year of the RTG were:
- Liam Buttita. Mentor: Casey Rodriguez (co-PI)
- Zubin Narayan. Mentor: Jason Metcalfe (PI)

Mentoring

As planned, every term, each of the RTG postdocs and students went through a review of their Individual Development Plans (IDPs) and their dossier. These meetings took place with the mentor assigned to each participant and a second faculty member from the RTG grant.

The IDPs were created by Jason Metcalfe (PI) and are available to the public in the RTG website under "Scrolls".   The mentoring committee for overseeing the undergraduate student IDPs consisted of Jason Metcalfe (PI) and Yaiza Canzani (co-PI). The mentoring committee for overseeing the graduate student IDPs consisted of Hans Christianson (co-PI) and Jason Metcalfe (PI). The mentoring committee for overseeing the postdoc IDP consisted of Jeremy Marzuola (co-PI) and Jason Metcalfe (PI).

Incoming Postdoctoral Associates

The RTG hired its first cohort of RTG Postdoctoral Associates. The search committee consisted of Yaiza Canzani (co-PI), Jeremy Marzuola (co-PI), Hans Christianson (co-PI) and Jason Metcalfe (PI). The RTG hired James Rowan (University of California, Berkeley) and Daniel Weser (The University at Texas Austin), who will join the RTG activities on July 1, 2023. They were among the top four candidates in the short list for the job search. The job ad had a total of 120 applicants.

Proposed Activities

Developmental training groups

During the Fall 2022, the RTG ran the first year of the Developmental Training Group, designed and led by Yaiza Canzani (co-PI).
- The main activity consisted of weekly 2.5-hours meetings from August 17 to October 28, 2022, during which the participants designed and developed their materials to apply for an NSF GRFP. The materials included a CV, a research statement, and a personal statement. The program had 10 graduate student participants from all areas of mathematics, including 5 female students. Throughout the workshop, the students received feedback on their work from both peers and faculty. This led to eight applications for the NSF GRFP being submitted, which is more than double the average number of applications submitted in a typical year. One of the (female) students was awarded the NSF GRFP. The participating students were surveyed, and the program received unanimous praise.
- The RTG also organized a "First Academic Job Search" panel in which the panelists fielded questions from graduate students, including types of job positions, planning for job applications, how to prepare application materials, etc. The panelists were Yaiza Canzani (co-PI), Jason Metcalfe (PI) and Casey Rodriguez (co-PI). The meeting took place on September 29, 2022 and there were 22 graduate student participants.

Mini-Schools

The RTG ran the first PDE mini-school "Geometric singular analysis and black holes" on March 24-26, 2023. The school was organized by Yaiza Canzani (co-PI) and Jian Wang (Postdoctoral Fellow).

- It consisted of four main lectures taught by Peter Hintz (ETH) together with three satellite talks given by Katrina Morgan (Northwestern University), Ethan Sussman (MIT), and Lili He (Johns Hopkins).
- The mini-school had a total of 50 participants, including graduate students, postdocs, and faculty. The program funded 15 graduate students and 2 postdocs from 13 peer universities across the US. The RTG covered their lodging and transportation expenses. Three of the funded participants were US Citizens or permanent residents. The applicants were asked to submit a CV, a statement of purpose, and a letter of recommendation by their mentor.
- The mini-school had a reception dinner and four coffee breaks in between the talks and lectures to allow the participants to socialize and ask questions. The lecture notes and information for the participants of the mini-school were posted on the RTG website. The recorded lectures were added as materials to the RTG "Online Topics course collaborative". The school was advertised via email and a poster was created for this purpose.
- The participants were surveyed after the event ended. They conveyed overwhelming appreciation for the mini-school and expressed that they would like to participate in future events that the RTG may hold as well as apply for postdocs and professorship positions that the Analysis and PDE group at UNC may advertise.

Research Playground

The first year of the Research Playground was designed and run by Jeremy Marzuola (co-PI) and Casey Rodriguez (co-PI).

- During the Fall term of 2022, the activity gathered 7 junior graduate students interested in this research-based learning experience. The topic was "Stability theory for nonlinear equilibrium states, with an emphasis on equations from continuum mechanics". The students and faculty met once a week for a two-hour period. The students learned and presented material, mainly following the book "Differential equations and dynamical systems" by L. Perko.
- Once the term ended the students were surveyed and 4 of them expressed interest in starting a research project related to the material that they had learned.
- During the Spring term of 2023, the 4 continuing students and the faculty met once a week for a one-hour period. They started research on the stability of explicit equilibrium states computed in the article "On an elastic strain-limiting special Cosserat rod model." Math. Models Methods Appl. Sci. (33), 2023, p. 1-30. by K. R. Rajagopal and C. Rodriguez.

Undergraduate Analysis and PDE Seminar

During the Fall 2022 and Spring 2023 terms, the Undergraduate Analysis and PDE Seminar met on a monthly basis over Zoom. The organizers were Hans Christianson (co-PI) and Casey Rodriguez (co-PI).

- The attendance for each event averaged between 40 and 70 participants. The seminar was advertised via email and a poster for each event was created for this purpose.
- Each gathering consisted of two invited talks; one by an undergraduate student who is working on a research project, and one by a faculty member who is supervising undergraduate research. The invited leading faculty speakers were Tristan Collins (MIT), Thomas Witelski (Duke), Gigliola Staffilani (MIT), Betsy Stovall (UW-Madison), Eric Ling (University of Copenhagen), Kiril Datchev

(Purdue), and Svetlana Roudenko (FlU). Abstracts and schedules for the talks were regularly posted in the RTG website.

Asynchronous graduate courses
During Fall 2022, a graduate course on Harmonic Analysis was developed and taught by Jason Metcalfe (PI). This course is one of the three second-tier asynchronous courses proposed by the RTG with the goal that a broader selection of courses could be offered every year, without overtaxing the available faculty and teaching resources of the UNC Mathematics department. As planned, the course was first offered in a traditional format and was recorded for future online availability.

Online Topics course collaborative
The RTG started creating an online library of topics courses to help the training of the graduate students of the participating institutions by allowing them to learn key research methods in a structured manner. This RTG activity is led by Hans Christianson (co-PI). All the main lectures taught under the scope of this RTG have been recorded with the goal of adding them to the library. These include the course "Harmonic Analysis" (taught by Jason Metcalfe (PI)), the course "Stability of non-linear bound states in evolution equations" (taught by Jeremy Marzuola (co-PI)), the Brauer Lectures (taught by Carlos Kenig), the UNC PDE mini-school lectures (taught by Peter Hintz), and the special colloquiums (given by Daniel Tataru, Yannick Sire, and Jeff Cheeger).

Topic Courses
During Spring 2023, Jeremy Marzuola (co-PI) taught the topics course "Stability of non-linear bound states in evolution equations". The course had 6 graduate student participants. The material for this course has been recorded to be added to the "Online Topics course collaborative" RTG activity.

Analysis and PDE seminar
During the Fall 2022 and Spring 2023 terms the Analysis and PDE Seminar hosted a total of 18 speakers from institutions across the world. The organizers were Jeremy Marzuola (co-PI) and Casey Rodriguez (co-PI). On a weekly basis, the seminar gathered about 15 participants including a constant cohort of 10 graduate students. The speakers were: Tom Beck (Fordham University), Bjoern Bringmann (IAS), Ayman Said (Duke University), Katherine Zhiyuan Zhang (NYU), John Toth (McGill University), Ben Dodson (Johns Hopkins), Arunima Bhattacharya (SLMath), Jacob Shapiro (University of Dayton), Graham Cox (Memorial University), Gong Chen (Georgia Tech), Jonas Luhrmann (TAMU), Michael Taylor (UNC), Jacob Bernstein (Johns Hopkins, IAS), Mengxuan Yang (UC Berkeley), Cyril Letrouit (MIT), Demetre Kazaras (Duke), Zoe Wyatt (King's College), Marcelo Disconzi (Vanderbilt). The schedules and abstracts for the talks were regularly posted on the RTG website.

Special colloquiums and Events
- Brauer Lectures: Carlos Kenig (University of Chicago) delivered a series of three lectures on "Asymptotic simplification for solutions of nonlinear wave equations" on February 6-8, 2023. The event had about 60 participants and was organized by Casey Rodriguez (co-PI). The lectures were advertised via email and a poster was created for this purpose.
- Colloquium: Daniel Tataru (Berkeley University) delivered a talk on "Long time solutions for one dimensional dispersive flows" on November 10, 2022. The event had about 50 participants and was hosted by Jason Metcalfe (PI).

- Colloquium: Yannick Sire (Johns Hopkins University) delivered a talk on "Geometric variational problems: regularity vs singularity formation" on November 10, 2022. The event had about 45 participants and was hosted by Jeremy Marzuola (co-PI).
- Colloquium: Marcelo Disconzi (Vanderbilt University) provided a talk titled: "General-relativistic viscous fluids" on April 20, 2023. This was hosted by Casey Rodriguez (co-PI).
- Special Colloquium: Jeff Cheeger (New York University) delivered, on May 3, 2023, a special colloquium in honor of Michael Taylor's (Senior Personnel) retirement. The event had about 60 participants. The lectures were advertised via email and a poster was created for this purpose.

Research activities

Talks

Talks by faculty

- Arunima Bhattacharya (Senior Personnel)
  - Birthday Conference for Mikhail Safonov, Seoul, South Korea (June 20, 2023)
  - Differential Geometry/PDE Seminar, University of Washington (May 17, 2023)
  - Geometric Analysis Seminar, University of Oregon. (May 16, 2023)
  - Geometric and Analytic methods in PDE. Special session of AMS sectional meeting. (April 15, 2023.)
  - Gauge Theory, Geometric Analysis, and Low-Dimensional Topology. Special session of AMS sectional virtual meeting. (April 1, 2023)
  - Continuum Mechanics Seminar, University of Nebraska-Lincoln. (March 30, 2023)
  - Geometry and Topology Seminar, Duke University. (March 20, 2023)
  - Geometric Analysis Seminar, University of Chicago. (February 28, 2023)

- Yaiza Canzani (co-PI)
  - QMATH 15 at the University of California – Davis (September 12-16, 2022)
  - Colloquium at Northwestern University (October 5, 2022)
  - Chern-Weil Symposium at the University of Chicago (October 7-9, 2022)
  - Panelist for "Exploring a research landscape" at the GROW conference at Duke University (October 22, 2022)
  - Colloquium at Dartmouth University (October 29, 2022)
  - Münich-Aahrus-Santiago Seminar in Mathematical Physics. Virtual meeting. (December 5, 2022)
  - Geometria em Lisboa Seminar. Virtual meeting. (January 17, 2023).
  - Spectral Geometry in the Clouds Seminar. Virtual meeting. (March 6, 2023)

- Hans Christianson (co-PI)
  - SEARCDE Conference at North Carolina State University (November 12-13, 2022)

- Jeremy Marzuola (co-PI)
  - Workshop: "Nonlinear Waves and Dispersive Equations". Oberwolfach Institute for Mathematics (June 26-July 2, 2022)

- o Workshop: "At the interface between semiclassical analysis and numerical analysis of wave scattering problems". Mathematisches Forschungsinstitut Oberwolfach. (September 25- October 1, 2022)
  - o Applied math seminar at the University of North Carolina – Greensboro (October 3, 2022)
  - o SEARCDE Conference at North Carolina State University (November 12-13,2022)
  - o Analysis Seminar, Oklahoma University (February 13, 2023)
  - o Seminar, Purdue University (February 20, 2023)

- Jason Metcalfe (PI)
  - o Math Center Distinguished Colloquium, SUSTech International Center for Maths, Department of Maths, Southern University of Science and Technology, Shenzhen, China (virtual) (July 2022)
  - o Harmonic Analysis and Waves: A Conference Celebrating Hart Smith's 60th Birthday. University of Washington. (August 10-12, 2022)
  - o Analysis Seminar, University of New Mexico. Virtual meeting. (October 21, 2022)

- Casey Rodriguez (co-PI)
  - o Trends in Soliton Dynamics and Singularity Formation for Nonlinear Dispersive PDEs. Texas A&M University. (October 21-23, 2022)
  - o Workshop on Continuum Thermodynamics Analysis, Modeling, and Numerics, Prague. (December 1-4, 2022)
  - o Special Session, Spring Central Sectional Meeting of the AMS, University of Cincinnati. (April 15-16, 2023)

Talks by Graduate Students

- Maddie Brown
  - o Analysis Seminar at the University of New Mexico. (September 9,2022).
  - o Analysis Seminar, University of Rochester (September 30, 2022)
  - o Attended the Chern-Weil Symposium at the University of Chicago (October 7-9, 2022)
  - o Analysis Seminar, University of Wisconsin (October 18, 2022)
  - o Analysis and PDE Seminar, Johns Hopkins University (March 6, 2023)

Research

Articles by faculty

- Arunima Bhattacharya (Senior Personnel)
  - o Newly posted: J. Bernstein and A. Bhattacharya: Colding-Minicozzi Entropies in Cartan-Hadamard Manifolds

- Yaiza Canzani (co-PI)
  - o Y.Canzani and J.A.Toth. Lower bounds for eigenfunction restrictions in lacunary regions. arXiv:2207.05607

- o G. Berkolaiko, Y. Canzani, G. Cox, and J. Marzuola: Stability of spectral partitions and the Dirichlet-to-Neumann map. Calculus of Variations and Partial Differential Equations, to appear.
- o T. Beck, Y. Canzani, and J. Marzuola: Quantitative bounds on impedance-to-impedance operators with applications to fast direct solvers for PDEs. Pure and Applied Analysis, to appear.
- o Y. Canzani, J. Galkowski, and B. Keeler (former UNC graduate student): Asymptotics for the spectral function on Zoll manifolds.
- o Newly accepted: Y. Canzani and J. Galkowski: Weyl remainders: an application of geodesic beams. Invent. Math., to appear.

- Hans Christianson (co-PI)
  - o H. Christianson and D. Pezzi (former UNC undergraduate): Energy distribution for Dirichlet eigenfunctions on right triangles.

- Jeremy Marzuola (co-PI)
  - o K. Datchev, J. Marzuola, and J. Wunsch: Newton polygons and resonances of multiple delta-potentials.
  - o D. Baskin, J. Gell-Redman, and J. Marzuola: Price's law on Minkowski space in the presence of an inverse square potential
  - o G. Berkolaiko, Y. Canzani, G. Cox, and J. Marzuola: Stability of spectral partitions and the Dirichlet-to-Neumann map. Calculus of Variations and Partial Differential Equations, to appear.
  - o T. Beck, Y. Canzani, and J. Marzuola: Quantitative bounds on impedance-to-impedance operators with applications to fast direct solvers for PDEs. Pure and Applied Analysis, to appear.
  - o D. Baskin and J. Marzuola: The radiation field on product cones. Advances in Mathematics, to appear.
  - o M. Holst, H. Hu, J. Lu, J. Marzuola, D. Song, and J. Weare: Symmetry breaking in density functional theory due to Dirac exchange for a hydrogen molecule. Journal of Nonlinear Science, to appear.
  - o Z. Boyd, N. Fraiman, J. Marzuola, P. Mucha, and B. Osting: Escape times for subgraph detection and graph partitioning.
  - o L. Hillairet and J. Marzuola: Eigenvalue spacing for 1d Schrödinger operators, Asymptotical Analysis, to appear.

- Jason Metcalfe (PI)
  - o J. Metcalfe and A. Stewart: On a system of weakly null semilinear wave equations. Analysis and Mathematical Physics, to appear.
  - o M. Facci and J. Metcalfe: Global existence for quasilinear wave equations satisfying the null condition.. Houston Journal of Mathematics, to appear.
  - o K. Hepditch and J. Metcalfe: A local energy estimate for 2-dimensional Dirichlet wave equations. Involve, to appear.
  - o M. Facci, A. Mcentarrfar, and J. Metcalfe: An r^p-weighted local energy approach to global existence for null form semilinear wave equations. Involve, to appear.
  - o J. Metcalfe and T. Rhoads: Long-time existence for systems of quasilinear wave equations. Matematica, to appear.

- Casey Rodriguez (co-PI)
  - M. Bulíček, J. Málek, and C. Rodriguez: Global well-posedness for two-dimensional flows of viscoelastic rate-type fluids with stress diffusion. Journal of Mathematical Fluid Mechanics 24 (2022)
  - K. Rajagopal and C. Rodriguez: On evolving natural curvature for an inextensible, unshearable, viscoelastic rod. Journal of Elasticity, to appear.
  - K. Rajagopal and C. Rodriguez: On an elastic strain-limiting special Cosserat rod model. Mathematical Models and Methods in Applied Sciences, to appear.

- Michael Taylor (Senior Personnel)
  - X. Huang, C. Sogge, and M. Taylor: Product manifolds with improved spectral cluster and Weyl remainder estimates.
  - M. Taylor: Gauss-Green formulas on domains with non-rectifiable boundaries
  - M. Taylor: Introduction to Lie Groups, Open Math Notes, AMS.
  - M. Taylor: Short course on pseudodifferential operators, Open Math Notes, AMS

- Mark Williams (Senior Personnel)
  - Newly submitted: M. Williams: Reflection of conormal pulse solutions to large variable-coefficient semilinear hyperbolic systems.

Articles by Postdocs

- Jian Wang
  - J. Galkowski, P. Marchand, J. Wang, and M. Zworski: The scattering phase: seen at last.

Outreach

- Girls Talk Math: The RTG partially supported the "Girls Talk Math" program in Summer 2022. This is a free educational summer program that strives to make advanced mathematics accessible to students of underrepresented genders in STEM. Its founders, Katrina Morgan and Francesca Bernardi, are former UNC graduate students. GTM has expanded to sites at the University of Maryland and at Worcester Polytechnic Institute in addition to the original location at UNC.
- Hans Christianson (co-PI) taught a course at the Correctional Education Program on Summer 2022.   Christianson spent two nights a week teaching Math 118 at the Dan River Work Farm in Yanceyville.
- Madelyne Brown (Graduate student) volunteered as a mentor at the University of Michigan – Dearborn REU site where she led projects with Yunus Zeytuncu on Spectral Theory and CR-Geometry. (May 22- July 14, 2022)

Miscelanneous News

- Ph.D. students Collin Kofroth, Gary Moon, Grace Conte, and Taylor Rhoads all defended their Ph.D.'s in Summer 2022.
- Yaiza Canzani (co-PI) and Jeremy Marzuola (co-PI) participated in their last week-long SQuaRE (Structured Quartet Research Ensembles) at the the American Institute of Mathematics in San

Jose, CA (January 30 – February 3, 2023).   The two RTG members, along with their collaborators Greg Berkolaiko and Graham Cox began this journey in 2018, when their original collaborative proposal was approved by this NSF funded institute that specializes in bringing small groups together for focused collaboration