The Many Faces of Relativistic Fluid Dynamics

Report on the KITP program, May 22 - July 14, 2023

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1 Overview

Heavy-ion collision experiments at the Relativistic Heavy-Ion Collider (RHIC) and the Large Hadron Collider (LHC) have provided overwhelming evidence that quarks and gluons, the elementary particles within protons, can flow as a strongly interacting relativistic fluid over distance scales, not much larger than the size of a nucleus. Model-to-data comparisons have conclusively shown that the ultra-hot subnuclear matter formed in such collisions is not a “perfect fluid”, i.e., viscous effects are needed to describe experimental data, which inspired an entire field of research on relativistic viscous fluids. Meanwhile, with the dawn of the multi-messenger astronomy era marked by the detection of a binary neutron star merger, one must also consider the dynamics of extremely dense fluids made of nuclear matter in very strong gravitational fields. There are indications that viscous effects may be relevant in neutron star mergers, which may eventually lead to astrophysical observational consequences. The `relfluids23` program brought together theorists and experimentalists, gravity physicists, astrophysicists, string theorists, and mathematicians to explore the following topics:

- Mathematical formulations of relativistic viscous fluid dynamics;
- Fluctuations and effective field theories in relativistic fluids;
- Emergence of hydrodynamics from ab initio non-equilibrium dynamics;
- Relationships between hydrodynamics, holography, and black hole physics;
- Phenomenological applications and computational aspects of relativistic viscous hydrodynamics.

The number of applications significantly exceeded the number of available program slots. The program hosted both recognized leaders in the field and early- and mid-career scientists. The participants came from both “formal” and “phenomenological” backgrounds, which resulted in educational discussions. The program hosted 52 participants, 39 talks, and numerous discussions, both organized and informal, spontaneous discussions. This led to a large number of publications (more than 30 at the moment of writing the report, i.e. about 8 months after the program closed) [1–37], which illustrates how successful, thought-provoking, and important the program was.

2 Program organization

Our scientific activities during the program comprised formal talks and informal discussions. We had 39 talks during the program. A typical week would have 2 to 3 formal talks in the morning on Tuesdays, Wednesdays, and Thursdays. Additionally, on Mondays, we would have a Meet & Greet session where we would welcome the new participants, ensuring that all participants were properly introduced to each other. For the Meet & Greet sessions, we asked each participant to send a slide ahead of time before their arrival where they would briefly state what they were working on, what they hoped to learn from others in the program, the topics they wanted to be discussed in the program, and also what they liked to do during their spare time. The latter was important, as it helped us set up the program's social aspects (more on that below).

Informal discussions happened throughout the week. They were usually triggered by the program seminars and would continue through lunch and during the KITP coffee hour in the afternoon. Based on the input of the participants, we also scheduled an official time for discussions every week (on Thursdays or Fridays) to cover a variety of topics that could not be properly discussed by the seminar speakers due to time constraints or broad discussions about a single topic (for example, "What is the regime of applicability of relativistic fluid dynamics in heavy ion collisions?").

As mentioned above, lunchtime was also a time for further scientific discussions. All the participants would get together at the end of the last talk of the day (usually ending at 12 - 1 pm) and go to lunch around the campus. The organizers ensured that people from different areas (who may only have known each other by name or never met in person before) would go to lunch together to catalyze more interdisciplinary discussions. A similar situation also often occurred at dinner time. We also organized weekly women's lunches in collaboration with the other ongoing program (more details are given in Section 4).

One of our main social activities, which became very popular among participants, was a weekly barbeque at the residence (usually held on Thursday evening). This was a great activity, which further strengthened the connections (and friendship) among the participants. Other social events included hiking trips and playing sports (e.g., beach soccer) spontaneously organized among the participants.

3 Program goals and accomplishments

The main goal of the program was to bring together people from different communities that do not normally overlap and to form a lasting dialogue between communities targeting different corners of relativistic hydrodynamics. Based on the participants' input and the many new scientific papers published because of the KITP program, we believe we have largely succeeded. We received 33 exit reports (from our 52 participants), and below, we highlight a few of the scientific accomplishments triggered by the KITP program.

For example, the program fostered a new collaboration between Dr. Aniceto from the University of Southampton and Dr. Noronha from the University of Illinois Urbana-Champaign. Dr. Aniceto is a high-energy physicist who specializes in perturbation theory, non-perturbative phenomena in AdS/CFT, and the mathematics of exponential asymptotics and resurgence. In contrast, Dr. Noronha is a nuclear theorist who works on heavy-ion collisions and neutron star mergers. Their collaboration led to a new development in kinetic theory, which resulted in the paper [36]. Dr. Aniceto comments on this in her exit report: *"The discussions that prompted this collaboration with Dr. Noronha followed previous work on kinetic theory, in particular, the Boltzmann equation in the Relaxation Time Approximation. These discussions brought together different perspectives on the problem, and as a concrete outcome of this new collaboration, a manuscript is currently underway [36], with potential follow-ups being discussed. I can safely say that this collaboration and its outcomes would not have been possible without my participation in the KITP program. I believe that my research career will have directly benefited from my participation, with both a new vision of the breadth of the subject and the start of a new collaboration that will hopefully flourish beyond the outcomes mentioned above."*

The large breadth of our program and its ability to put together specialists in fluid dynamics from different areas (nuclear, particle, astro, gravity, computational, condensed matter) has been crucial for the recent development of an effective field theory description of fluid dynamics. For example, Dr. Lucas (a condensed matter theorist at the University of Colorado Boulder) put forward in his talk at KITP a new way to build a Wilsonian effective theory for non-thermal and active matter, which was published in [35]. Dr. Lucas directly benefited from the interdisciplinary environment of the KITP program, stating in his exit report: *"Our work is heavily inspired by recent effective field theories for thermal fluids, many of the inventors of which were present at the KITP program ... there were a large number of participants interested in EFTs for hydrodynamics who I had very valuable discussions with (Kovtun, Armas, Yarom, Jensen, Noronha, etc.). Based on the discussions at KITP, we have more carefully thought about the difference and discrepancy between KMS and time-reversal symmetry"*.

Other developments in the effective field theory of relativistic fluid dynamics appeared in [19] and [24], where new approaches were developed to describe causal and stable effective theories. The main authors of these papers were at KITP, and their papers greatly benefited from the discussions on this topic during the program.

The program has led to a very interesting collaboration between L. Yaffe (numerical simulations in gauge-gravity duality) and M. Luzum (numerical simulations of nuclear collisions). The purpose of this collaboration is to use holographic AdS/CFT simulations as an input to the initial state dynamics in hydrodynamic codes which simulate actual nuclear collisions. This has potentially significant implications for heavy-ion phenomenology; we expect the results to appear later this year.

A regular theme throughout the workshop was the idea of causality constraints that limit how far from equilibrium a relativistic fluid may be. The original works on this subject were presented in an afternoon discussion in the context of heavy-ion collisions. This led to several discussions and suggestions on ways to approach this problem from a theoretical and phenomenological perspective. Since the program, many groups have worked on understanding causality constraints. For instance, some participants (Denicol, Luzum, Shen) discussed how to apply the full non-linear causality condition for Israel-Stewart hydrodynamics in numerical simulations for relativistic heavy-ion collisions. They have come up with a new computational scheme that ensures causality conditions for all allowed inverse Reynold's numbers (this will be sent for publication soon).

One of the fundamental problems concerning the application of relativistic fluid dynamics in the physics of the quark-gluon plasma is the fact that, in such a system produced via the ultrarelativistic collision of nuclei, spatial gradients are parametrically large in the early stages of the collision. This implies that the Knudsen number Kn, the ratio between microscopic length scales (e.g., the mean free path) and the macroscopic scales associated with the variation of conserved currents, is such that $\mathrm{Kn} \gtrsim 1$ in the early stages of the collision. Given that fluid dynamics is usually understood as an effective theory for many-body systems in the regime where $\mathrm{Kn} \ll 1$, it is challenging to explain how fluid dynamics is so successful at describing both nucleus-nucleus collisions, and even the collisions between just two protons (investigated at ultrarelativistic energies at the LHC). This unreasonable effectiveness of fluid dynamics in heavy-ion collisions has driven several new developments (such as hydrodynamic attractors, new formulations of fluid dynamics, improved computational schemes, new experimental observables, etc), and it was a constant theme of discussion throughout the workshop.

By bringing together specialists in relativistic fluid dynamics from different areas, other scientists who were not originally working in nuclear theory are now aware of this fundamental question and can contribute towards its resolution. In fact, after the talk by Dr. Elias Most (computational astrophysicist at Caltech) in the program, it was realized that the weakly collisional plasmas near supermassive black holes also provide an example of this "unreasonable effectiveness of relativistic fluid dynamics". These low-luminosity black holes cannot accrete matter at a rate that balances dissipative effects such as viscosity, causing the plasma to heat up and expand into geometrically thick, though possibly optically thin, disks of hot, low-density charged particles. Additionally, the collisional Coulomb mean free path of such particles is expected to be orders of magnitude larger than the black hole horizon radius, implying that the plasma is approximately collisionless, with a (naïve) Knudsen number of the order of $\mathrm{Kn} \sim 10^5$. Yet, ideal general-relativistic magnetohydrodynamic (GRMHD) simulations (performed for example by the Event Horizon Telescope Collaboration) provide a very good description of experimental data. After the KITP program, it became clear that similar questions concerning the applicability of relativistic hydrodynamics are present not only in particle physics systems defined at 10^{-15} m (Fermi length) but also in plasmas surrounding supermassive black holes at the giga- to tera-meter scales. These discussions motivated the publication of [9], where theoretical tools used to study the applicability of hydrodynamics in nuclear collisions were employed, for the first time, to investigate a class of viscous GRMHD models used in state-of-the-art simulations of plasmas in M87 and SgA*.

Another interdisciplinary facet of the program were dynamical attractor phenomena in the context of pre-hydrodynamic evolution of quantum field theories: hydrodynamic and non-thermal attractors (also known as non-thermal fixed points).

The aforementioned unexpected applicability of relativistic hydrodynamics far away from local thermal equilibrium opened the problem of possible definitions of relativistic hydrodynamics without invoking truncated derivative expansions. Starting from 2015 dynamical attractor behaviour preceding applicability of hydrodynamics has been observed in theoretical models of nuclear collisions with increasing complexity. During the program, Dr. Mazeliauskas (who is a group leader at Heidelberg University in Germany) reviewed the field of hydrodynamic attractors and discussed their possible phenomenological applications to explain universalities in particle production patterns in nuclear collisions. The talk stimulated significant discussions regarding the precise definition and properties of hydrodynamic attractors. More along these lines and later in the program, Dr. Yan (who is an assistant professor at Fudan University in China) discussed very first efforts to implement the important effect of fluctuations on properties of hydrodynamic attractors. Significant discussions followed related to extending the regime of validity of the presented approach, which is the current of the ongoing collaboration between one of the organizers (Heller) and Dr. Spalinski and Dr.

Xin who for different reasons could not make it to the program despite being invited.

Regarding non-thermal attractors, these are dynamical attractor phenomena confining the dynamics to the vicinity of self-similar evolution in time. The program featured a single talk about this topic by Dr. Preis (who is still a PhD student at Heidelberg University and who was endorsed by one of the organizers (Kovtun)). Dr. Preis reviewed the state of the art, including experimental studies of non-thermal attractors in cold atom experiments, and presented then preliminary results of a collaboration with one of the organizers (Heller) and another participant (Dr. Mazeliauskas). The latter resulted in [16] with significant contributions done at KITP, which provided the first self-consistent theoretical description of slow dynamics akin to hydrodynamics, preceding the self-similar regime. This so-called prescaling phenomenon, in the form predicted in [16], was soon afterwards confirmed experimentally in cold atom experiments by a Cambridge-Heidelberg collaboration, which adds to the successes of the program.

Our program will have a long-lasting impact on the careers of young scientists in the field. For example, Dr. Gavassino (who is currently a postdoctoral scientist at the Mathematics Department of Vanderbilt University) published four papers that were directly influenced by discussions during KITP or arose from discussions at KITP [11–13, 33]. Our program also largely extended the network of young scientists, which is crucial for their further success and longevity in academia. Dr. Pinzani-Fokeeva (who is currently a postdoctoral scientist at the University of Florence working on string theory) stated in her exit report: *"I believe this workshop has already enhanced my existing network and has helped with new ideas and prospects on future directions of my research."*. A similar comment was made by Dr. Gavassino in his exit report: *"Besides opening the doors to new collaborations and projects, this workshop has allowed me to make new contacts, and to have a clearer idea of the actual point of view of the experts of the field on several matters. This will surely allow me to improve my scientific writing, since now I have a better idea of how the community "thinks". I also have a clearer picture of the open problems and future possible areas of investigation."* We also remark that Dr. Pinzani-Fokeeva later successfully led a proposal with other participants of the KITP program to organize a conference about relativistic fluids at the Galileo Galilei Institute in Florence in 2025. This proposal was accepted, and the conference will occur in the spring of 2025.

The program hosted several graduate students. The student participants wrote papers whose ideas were largely influenced by the discussions in the program: the paper [16] discusses non-thermal attractors; the paper [18] discusses causality in dispersion relations; the paper [33] discusses the regime of applicability of Israel-Stewart hydrodynamics. The authors of [33], both junior scientists, did not know each other before meeting at KITP.

Finally, it is clear from the overwhelmingly positive response we received that this program will have an impact also on the careers of established scientists from different areas. For example, Dr. Amos Yarom (a string theorist who is a professor at Technion Israel Institute of Technology) said: *"The program offered me many opportunities to get input on these topics from a wide variety of perspectives. In addition, I have been exposed to new ideas and open problems, especially in the context of the formulation of relativistic hydrodynamics. I feel that my participation in the hydrodynamics program has provided me with motivation and new ideas for the next few years. This will surely affect my future choice of research topics and research proposals."*. Similar comments were made also by mathematicians. Dr. Marcelo Disconzi (professor of Mathematics at Vanderbilt University) said in his exit report: *"I was exposed to many new perspectives on relativistic fluid dynamics which will undoubtedly broaden my understanding of the field and lead to new important questions and lines of research."*.

Our program was also instrumental in bringing to the spotlight the excellent work done by scientists in smaller research universities. For example, Dr. Sera Cremonini (a string theorist, faculty at Lehigh University, who was spending a sabbatical as a General Member at KITP during the program) said in her exit report: *"I came away from the program with new research projects, including on topics I wasn't familiar with before, and new collaborators. Such collaborations can make a significant impact on my research program and career, especially given that I am based at a very small university where we only have two faculty members (including myself) in the field of high energy theory, and no regular seminar series. In summary, thanks to the vibrant interactive atmosphere and the interdisciplinary nature of the program, my visit will leave a positive mark on my career, both in terms of new connections and new ideas that span a broad range of topics."*.

4 Efforts at achieving participation by groups underrepresented in physics

We made specific efforts to recruit women and underrepresented minorities, contacting several of them personally to encourage them to attend. We also advertised widely across multiple different communities. We accepted all the applications from women and underrepresented minorities (all were working directly in the field(s) involved in the workshop and had a strong body of work).

We found that the extra support for families specifically helped to attract women and participants with young families since several participants brought their children and spouses. We did have an issue finding local childcare for participants with very young children, which affected a few participants, who either could not attend or had to stay a shorter duration of time. A number of participants with older children used local summer camps, and it was even possible to organize carpools to Santa Barbara. However, there was an issue with our program starting a few weeks earlier than the local schools were out for the summer, so summer camps were not available in the first couple of weeks.

Of the participants who answered the demographic survey, 63% identified as white, 16% identified as Asian, and the remaining 20% identified either as another race or multiracial. We also had 14% of participants who identified as Latino/a. On gender, we had 14% women, with the rest of the participants identifying as men. We also took care to ensure that our schedule was representative of the demographics of our workshop. For example, 23% of the speakers were from underrepresented groups in physics (including white women, Latinos/as, and people of African descent).

Furthermore, during the program, we organized weekly women's lunches that were joined with the other ongoing program at KITP. These lunches were very well attended and well-liked by the participants. In fact, towards the end of the program, we set up an email to share everyone's email addresses so they could stay in touch. The lunches addressed several topics such as work-life balance, career advancement, discrimination and harassment, supporting other women, etc.

5 Suggestions

Our field has not had a KITP program for nearly 20 years. Thus, many of our participants were unfamiliar with the format, and that caused some confusion. For instance, in our field, it is standard that one also gives a talk when attending a workshop, and since that is not necessarily the point of a KITP workshop, this mistakenly led certain participants to believe that they were not invited to the workshop when they were. Our suggestion is to be clearer in emails about the format and possibly ask participants for an answer to an email following up to see if they agree with the format (just to ensure they have actually read the email).

As mentioned in the diversity section, one issue that we struggled with was finding local, short-term child care for participants. We are aware that other universities have on-site, subsidized, short-term child care available (for example, Heidelberg University in Germany) and would encourage KITP to look into such a possibility. This could set up a transformative example for the other top universities in the US.

Another issue we had to deal with was a large number of last-minute cancellations. As the cancellations were last-minute, the coordinators did not have enough time to organize visits by the participants on the waitlist, plus those on the waitlist had already made plans. In the future, this can be somewhat alleviated if KITP requires confirmations of participation a few months in advance, or perhaps the interested participants pay a small deposit which is refunded upon arrival at KITP.

6 Discussion of the program's success

The program `relfluids23` was quite unique. While conferences are standard in the field of hot and dense matter, extended programs are not; multi-week programs that bring together both formal theorists and phenomenologists with the aim of exchanging ideas have been non-existent in the field. We have been successful in bringing together people from different communities, and in making them talk to each other. This led to several new papers in the field that were either written and heavily influenced by the program or conceived during the program by scientists who met for the first time at KITP, including some already confirmed experimentally theoretical predictions. Discussion sessions at the end of each week were particularly notable for the intensity of collegial arguments among members of different communities, emphasizing various degrees of rigor and physical intuition. New conferences/workshops about the topic of our program are now being planned to take place in other centers throughout the world (for example, a new workshop that will take place at the Galileo Galilei Institute in Florence in 2025), to reproduce the fantastic atmosphere at KITP and make it a regular (bi-annual) event in the community.

Additionally, our program brought awareness to the wider field of heavy-ion collisions and the Quark Gluon Plasma about workshops at KITP. In fact, we known of another group of physicist in our field, one of which were participants in our workshop (Brewer) that are applying for another KITP workshop for the 2025/2026 academic year.

7 Manuscripts completed or in progress

The list of papers is given at the end of the report, see our references [1–37].

RELFLUIDS23 Program Talks

Speaker	Title	Date
Lorenzo Gavassino (Vanderbilt)	Slow non-hydrodynamic modes of neutron stars	May 23
Kristan Jensen (Victoria Univ.)	An invitation to hydrodynamics for systems with exotic spacetime symmetry (with applications to `fractons')	May 24
Gokce Basar (UNC)	Non-gaussian fluctuations in relativistic hydrodynamics	May 24
Luis Lehner (Perimeter Inst.)	Hydrodynamics for gravity and vice-versa	May 25
Dekra Almaalol (Univ. of Illinois)	Constraints on the hydrodynamic simulations of heavy-ion collisions	May 25
Dam Son (U. Chicago)	Exploding helium-3 nanodroplet	May 26
Ines Aniceto (University of Southampton)	The resurgent facet of hydrodynamic attractors	May 30
Aleksas Mazeliauskas (Heidelberg University)	What are hydrodynamic attractors (good for)?	May 31
Mikhail Stephanov (University of Illinois Chicago)	Maximum entropy freeze-out of fluctuations	May 31
Heinrich Freistühler (University of Konstanz)	Shock profiles in dissipative 5-field theories	June 1
Amos Yarom (Technion)	Comments on turbulence and holography	June 1
Pavel Kovtun (Victoria Univ.)	Meet & Greet	June 5
Amos Yarom (Technion)	Comments on turbulence and holography - Part II	June 6
Helvi Witek (University of Illinois Urbana-Champaign)	Lessons from gravity and hydrodynamics: PDE structure and well-posedness in higher derivative gravity and the gradient expansions in hydrodynamics	June 6
Natalia Pinzani Fokeeva (MIT & University of Florence)	Horizon symmetries, hydrodynamics, and chaos	June 7
Sera Cremonini (Lehigh University)	Comments on the temperature dependence of the shear viscosity in holography	June 7
Thomas Schäfer (North Carolina State University)	Simulating stochastic fluids	June 8
Derek Teaney (Stony Brook University)	Fluctuations, hydrodynamics, heavy ions, and the QCD critical point	June 13
Ulrich Heinz (Ohio State University)	Far-off-equilibrium hydrodynamics based on the Maximum Entropy principle for closing the kinetic moment hierarchy (ME Hydro)	June 13
Elias Most (California Institute of Technology)	Two fluid formulation of relativistic plasmas	June 14
Igor Shovkovy (Arizona State University)	Anomalous effects in the magnetar magnetospheres	June 14
Marcelo Disconzi (Vanderbilt University)	Causality, local well-posedness, and all that	June 15
Alex Buchel (University of Western Ontario)	From de Sitter hydrodynamics to dynamical fixed points	June 20
Andrew Lucas (University of Colorado, Boulder)	Wilsonian perspective for thermal or active fluids: generalizations of KMS and beyond	June 20
Jean-Francois Paquet (Vanderbilt University)	Heavy-ion phenomenology vs causality, attractors, non-hydro modes et al	June 21
Francesco Becattini (University of Florence)	Entropy current and entropy production rate in spin hydrodynamics	June 22
Gabriel Denicol (Universidade Federal Fluminense)	Hydrodynamics from an exact collision kernel	June 22
Thimo Preis (Heidelberg)	Universal dynamics around nonthermal attractors	June 27
Chun Shen (Wayne)	Applications of causality conditions in heavy-ion phenomenology	June 27
Alexandre Serantes (Barcelona)	The gradient expansion in relativistic hydrodynamics	June 28
Enrico Speranza (Illinois)	Comments on relativistic hydrodynamics with chirality and spin	June 28
Benjamin Withers (Southampton)	Bounds on transport from causality	June 29
Nabil Iqbal (Durham University)	Higher form symmetries, hydrodynamics, and the superconducting transition	July 3
Romuald Janik (Jagiellonian University)	Simplicity of domain wall velocities at strong coupling	July 3
Akash Jain (University of Amsterdam)	Approximate higher-form symmetries and topological defects	July 5
Matthias Kaminski (University of Alabama)	Ultraviolet-regulated theory of non-linear diffusion	July 5
Li Yan (Fudan University)	The emergence of hydrodynamic attractor in a noisy plasma	July 6
Lipei Du (McGill University)	Exploring Initial and Final Baryon Distributions in Heavy-Ion Collisions at Beam Energy Scan	July 11
Mauricio Hippert Teixeira (University of Illinois)	An action principle for stable and causal stochastic hydrodynamics	July 11
Laurence Yaffe (University of Washington)	Modeling pre-hydrodynamic evolution in QGP	July 12

RELFLUIDS23 Demographic Survey Summary

44 of 52 participants filled out the demographic survey. Of these:

- 6 identified as women, 38 as men, and none as another gender
- Race and Ethnicity:
  - 28 identified as white
  - 7 identified as Asian
  - 2 identified as another race
  - 5 identified as more than one race or ethnicity.
  - 2 identified as Hispanic or Latino; in addition, 4 of the respondents who identified as more than one race or ethnicity included Hispanic or Latino.
- 1 reported a disability.

RELFLUIDS23 Participants

Participant	Participation Dates
Dr. Dekrayat Almaalol (Univ. of Illinois)	May 22 - June 23
Dr. Ines Aniceto (Southampton)	May 22 - June 2
Dr. Jácome Armas (Univ. of Amsterdam)	June 19 - June 23
Prof. Gokce Basar (UNC)	May 22 - June 2
Prof. Francesco Becattini (Univ. of Florence)	June 19 - June 30
Dr. Jasmine Brewer (CERN)	June 12 - June 16
Prof. Alex Buchel (Western Univ.)	May 22 - June 23
Prof. Marcelo Disconzi (Vanderbilt)	June 12 - June 30
Dr. Travis Dore (Universitaet Bielefeld)	June 5 - June 23
Dr. Lipei Du (McGill Univ.)	July 5 - July 14
Prof. Heinrich Freistuhler (Univ. Konstanz)	May 22 - June 9
Dr. Lorenzo Gavassino (Vanderbilt)	May 22 - June 9
Prof. Blaise Goutéraux (CPHT, École Polytechnique)	June 5 - June 9
Prof. Ulrich Heinz (Ohio State)	May 22 - June 16
Prof. Michal Heller (Ghent Univ.)	June 26 - July 14
Dr. Mauricio Hippert Teixeira (Univ. of Illinois)	June 19 - July 14
Mr. Raphael Hoult (Victoria Univ.)	May 22 - July 14
Dr. Nabil Iqbal (Durham Univ.)	June 26 - July 7
Dr. Akash Jain (Univ. of Amsterdam)	July 2 - July 14
Prof. Romuald Janik (Jagiellonian Univ.)	June 26 - July 14
Prof. Kristan Jensen (Victoria Univ.)	May 21 - June 22
Prof. Matthias Kaminski (Alabama)	June 26 - July 14
Dr. Pavel Kovtun (Victoria Univ.)	May 22 - July 14
Dr. Luis Lehner (Perimeter Inst.)	May 22 - June 9
Mr. Ruochuan Liu (Victoria Univ.)	June 26 - July 14
Prof. Andrew Lucas (CU Boulder)	June 12 - June 23
Prof. Matthew Luzum (USP)	July 3 - July 14
Dr. Aleksas Mazeliauskas (Univ. Heidelberg)	May 22 - June 2
Dr. Elias Most (Caltech)	June 5 - June 15
Prof. Jorge Noronha (Univ. of Illinois)	May 22 - June 23
Prof. Jacquelyn Noronha Hostler (Univ. of Illinois)	May 29 - June 23
Prof. Jean Francois Paquet (Vanderbilt)	June 12 - June 23
Dr. Natalia Pinzani Fokeeva (CTP)	May 30 - June 16
Dr. Christopher Plumberg (PEPPERDINE/SEAVER CC	June 18 - June 23
Mr. Thimo Preis (Heidelberger University)	May 22 - June 30
Prof. Loganayagam Ramalingam (ICTS)	June 12 - June 30
Dr. Adam Ritz (Victoria Univ.)	May 22 - June 2
Dr. Thomas Schaefer (NC State)	May 29 - June 11
Dr. Alexandre Serantes (ICCUB)	June 19 - July 7
Dr. Chun Shen (Wayne State)	June 26 - July 7
Prof. Igor Shovkovy (Arizona State)	June 5 - June 23

RELFLUIDS23 Participants

Participant	Participation Dates
Prof. Gabriel Silveira Denicol (UFF)	June 19 - July 14
Dr. Dam Son (U. Chicago)	May 22 - May 26
Dr. Enrico Speranza (Univ. of Illinois)	June 19 - July 7
Prof. Mikhail Stephanov (UIC)	May 22 - June 2
Prof. Derek Teaney (Stony Brook)	June 5 - June 16
Mr. David Wagner (Univ. Frankfurt)	May 22 - June 2
Dr. Helvi Witek (Univ. of Illinois)	May 29 - June 9
Dr. Benjamin Withers (Southampton)	June 26 - July 14
Prof. Laurence Yaffe (Washington)	July 10 - July 14
Prof. Li Yan (Fudan Univ.)	July 3 - July 14
Prof. Amos Yarom (Technion)	May 22 - June 23

Manuscripts completed or in progress

[1] N. Abboud, E. Speranza, and J. Noronha, "Causal and stable first-order chiral hydrodynamics," arXiv:2308.02928 [hep-th].

[2] M. A. G. Amano, C. Cartwright, M. Kaminski, and J. Wu, "Relativistic Hydrodynamics under Rotation: Prospects & Limitations from a Holographic Perspective," arXiv:2308.11686 [hep-th].

[3] D. Areán, B. Goutéraux, E. Mefford, and F. Sottovia, "Hydrodynamics and instabilities of relativistic superfluids at finite superflow," arXiv:2312.08243 [hep-th].

[4] M. Baggioli, S. Cremonini, L. Early, L. Li, and H.-T. Sun, "Breaking rotations without violating the KSS viscosity bound," *JHEP* **07** (2023) 016, arXiv:2304.01807 [hep-th].

[5] G. Basar, J. Bhambure, R. Singh, and D. Teaney, "The stochastic relativistic advection diffusion equation from the Metropolis algorithm," arXiv:2403.04185 [nucl-th].

[6] F. Becattini, A. Daher, and X.-L. Sheng, "Entropy current and entropy production in relativistic spin hydrodynamics," *Phys. Lett. B* **850** (2024) 138533, arXiv:2309.05789 [nucl-th].

[7] A. Buchel, S. Cremonini, and L. Early, "Holographic transport beyond the supergravity approximation," arXiv:2312.05377 [hep-th].

[8] C. Chattopadhyay, U. Heinz, and T. Schaefer, "Fluid dynamics from the Boltzmann equation using a maximum entropy distribution," *Phys. Rev. C* **108** no. 3, (2023) 034907, arXiv:2307.10769 [hep-ph].

[9] I. Cordeiro, E. Speranza, K. Ingles, F. S. Bemfica, and J. Noronha, "Causality Bounds on Dissipative General-Relativistic Magnetohydrodynamics," arXiv:2312.09970 [astro-ph.HE].

[10] J. Cotler and K. Jensen, "Non-perturbative de Sitter Jackiw-Teitelboim gravity," arXiv:2401.01925 [hep-th].

[11] L. Gavassino and M. Shokri, "Stability of multicomponent Israel-Stewart-Maxwell theory for charge diffusion," *Phys. Rev. D* **108** no. 9, (2023) 096010, arXiv:2307.11615 [nucl-th].

[12] L. Gavassino, M. M. Disconzi, and J. Noronha, "Dispersion relations alone cannot guarantee causality," arXiv:2307.05987 [hep-th].

[13] L. Gavassino, "Mapping GENERIC Hydrodynamics into Carter's Multifluid Theory," *Symmetry* **16** no. 1, (2024) 78, arXiv:2311.10897 [nucl-th].

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