# Markus A.G. Amano

Research Statement

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**Rotating Plasmas** Quark Gluon Plasmas (QGP) produced at Brookehaven's RHIC (Relativistic Heavy Ion Collider) and CERN have been of interested to both theoretical and experimental communities. Heavy ions (like Au or Pb), collide to produce such a fluid. Head-on collisions have negligible voricity. Otherwise, collisions of center were found by the STAR collaboration to have the highest voricity in a natural phenomenon. It's well known that the QGP thermlizes quickly with respect to the time scale of the system.

With the AdS/CFT holographic duality, the we calculated transport coefficients of an analogous strongly CFT to that of QCD at finite temperature and voricity. The dual of a rotating CFT is a rotating blackhole in 5 dimensional AdS. This black hole is the so called five dimensional Myers-Perry AdS blackhole (5DMPAdS). Over the course of three papers, we find the three results. One, for the hydrodynamic regime, the measure of the effeciveness of hydrodynamical increases as extremality is approached. Two, locally, the transport coefficients of dual plasma equivalent to the transport of boasted relativistic fluid. Three, despite the lack of seperability out of time correlators (OTOC) were calculated along with the associated "chaos" transport - the lyapunov exponent and butterfly velocity.

In my first paper of the subject, we caluclated hydrodynamic and non-hydrodynamic transport related quatities of a rotating blackhole the case of small and larger temperature. We focused on the latter, large temperature case due to it's promise to qualatatively model hydrodynamic in rotating QGP. For the smaller temperature, we focused on calculating non-hydrodynamic transport as Quasinormal modes [1]. Furthermore about the gravitational background, foor 5D the number of independent planes of rotation is two, so the number of rotation parameters is two. Using the simply spinning configuration of the parameters (where they are set equal to eachother), we use the known fact that the background geometry has enhanced symmetry ($U(1) \times U(1) \rightarrow U(2)$). This enhanced symmetry allowed us to seperate the equations of motions of gravitational perturbations, such that we only had to solve ODEs instead of PDEs. Starting with the "small" temperature black hole (with a horizon of spherical topology), we calculated QNMs. On the dual theory, these QNMs correspond to expectation values of one point functions of the conformal stress energy temsor 4D theory. The horizon itself is dual to a non-zero temperature in the field theory. The rotation was scanned numberically analyze it effect on the dissipative and propagative properties of the 4D theory. We confirmed a previous result for large non-extremal rotation, the boundary becomes spacelike [2], and the background suffers from a linear instability since some of the QNMs' frequencies' imaginary parts become positive. We found discrimination between the direction the propagating gravitational modes which traveled with and against the direction of rotation. For large but finite temperature, we found Quasinormal Frequencies (QNF) could be approximated by a hydrodynamic expansion, despite such an expansion being ill-defined in the small temperature case.

For the other part of the paper of the we analyzed the large temperature limit where we scale the temperature and the holographic direction to be very large. This limit is also known as the "planar limit" since the resulting geometry of the dual field theory is planar (ie $\mathbb{R}^{1,3}$). In this limit, we calculated QNMs and hydrodynamic transport coefficients for three sectors (which decouple in the large black hole limit). We found that locally, the QNMs hydrodynamic sector was equivalent to a boast relativistic fluid as was already shown. As was shown in the previous section, the direction of the rotation discriminates modes that propogate parallel or anti-parallel to the rotation. The fluid was found to be as first order, hydrodynamically causal and and stable.

[1] QNMs are dissipative when the temperature is not zero.

[2] The boundary "spins faster than light".

**Sakai-Witten-Sugimoto Instantons** With the Sakai-Witten-Sugimoto duality, a promising method of doing tractable calculations on a strong coupled field theory with broken chiral symmetry is available. This field of modeling QCD with holography is simply noted as AdS/QCD where "AdS" means a spacetime that is negatively curved and locally, asympotitcally AdS. There are still questions to be answers nevertheless, about holographic models of QCD. The holographic models have the duality where bulk instanton as dual to skyrmions in the boundary theory (which represent the baryons of QCD). The number of baryons is topolotically protected and is mathematically the second chern class of the Yang-Mills field. In contrast to the flat duality, the the negative curvature naturally sets a size scale of bulk soliton/boundary skyrmion. Because of the negative curvature however, the size moduli of to be found instantons are zero. One can introduce a Chern-Simons to provide an repulsion to set the size of bulk solitons to a finite but fixed size.

The Sakai-Witten-Sugimoto model is an example of a top-down AdS/QCD model, derived from a string embedding of $D8-\overline{D8}$ branes in type IIA string theory. To use supergravity in such models, the 't Hooft limit is take where the number of colors and 't Hooft coupling, $\lambda$, is taken to be large. For large $\lambda$, size of the soliton can be said to be roughly inversely proportional to the size the soliton.

For large $\lambda$, soliton's size is small compared to the curvature scale of the bulk. So, for such a setup, it has been done where the soliton was approximated by flat space instanton.

The research is to analyze the moduli of such solitons which are then dual to the moduli of the baryons (skyrmions) on the boundary. This research is simular to the seminal works of Atiyah and others with flat space instantons.

Nevertheless, AdS-like bulks have a conformal boundary. This allows for boundary effects as seen in Atiyah-Patodi-Singer index theorem. For $SU(2)$, solitons in $\mathbb{R}^4$ flat space, the moduli is $8k-3$ where $k$ is the number of instantons and $-3$ are for setting the gauge. We believe, for negatively curved compated space, the moduli will be reduced to $6k-3$ where boundary takes away $k$ via boundary conditions and the negative curvature sets the scale to take away $-k$. For more boundaries, the number of moduli taken away is proportional to the number of disjoint boundaries.