Syllabus for learning seminar on Black Hole thermodynamics

Goal

To gain an up-to-date understanding about the filed of Blakc Hole thermodynamics.

Plan

1. Week 1-2: The four Laws of Black Hole mechanics: Bardeen-Carter-Hawking [2]. Area Theorem[6]. Wald Review [16]
2. Week 3: Black Hole entropy from microstates counting [12]
3. Week 4-5: Hawking Radiation [7] and Unruh effect [13]. Also [15, chapter 5, 6, 7].
4. Week 6-7: Information Paradox [5], Page curve [11], Uhruh-Wald information loss[14], Mathur review [10]
5. Week 8-11: Holographic principle and AdS/CFT. Maldacena [9], Witten [17]
6. Week 12-14: Quantum Information theory and Entanglement entropy. Witten note [18]. Replica Trick[3], Replica Wormhole [1], Casini-Huerta note [4]
7. Week 15-16: JT/SYK. Kitaev Lecture [8]

Other resources

- MIT open course by Hong Liu: `https://ocw.mit.edu/courses/8-821-string-theory-and-holographic-duality-f video_galleries/video-lectures/`
- Recorded lecture by Tom Hartman `http://www.hartmanhep.net/topics2021/`
- Recorded lecture by Edward Witten `https://phy.princeton.edu/academics/graduate-program/graduate-course-r`
- Haag, Rudolf. Local quantum physics: Fields, particles, algebras. Springer Science & Business Media, 2012.

References

[1] Ahmed Almheiri et al. "The entropy of Hawking radiation". In: *Reviews of Modern Physics* 93.3 (2021), p. 035002.

[2] James M Bardeen, Brandon Carter, and Stephen W Hawking. "The four laws of black hole mechanics". In: *Communications in mathematical physics* 31 (1973), pp. 161–170.

[3] Pasquale Calabrese and John Cardy. "Entanglement entropy and conformal field theory". In: *Journal of physics a: mathematical and theoretical* 42.50 (2009), p. 504005.

[4] Horacio Casini and Marina Huerta. "Lectures on entanglement in quantum field theory". In: *arXiv preprint arXiv:2201.13310* (2022).

[5] S. W. Hawking. "Breakdown of predictability in gravitational collapse". In: *Phys. Rev. D* 14 (10 Nov. 1976), pp. 2460–2473. DOI: 10.1103/PhysRevD.14.2460. URL: https://link.aps.org/doi/10.1103/PhysRevD.14.2460.

[6] Stephen W Hawking. "Gravitational radiation from colliding black holes". In: *Physical Review Letters* 26.21 (1971), p. 1344.

[7] Stephen W Hawking. "Particle creation by black holes". In: *Communications in mathematical physics* 43.3 (1975), pp. 199–220.

[8] Alexei Kitaev, Caltech and KITP, A simple model of quantum holography 1 and 2.

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[9] Juan Maldacena. "The large-N limit of superconformal field theories and supergravity". In: *International journal of theoretical physics* 38.4 (1999), pp. 1113–1133.

[10] Samir D Mathur. "The information paradox: a pedagogical introduction". In: *Classical and Quantum Gravity* 26.22 (2009), p. 224001.

[11] Don N. Page. "Information in black hole radiation". In: *Phys. Rev. Lett.* 71 (23 Dec. 1993), pp. 3743–3746. DOI: 10.1103/PhysRevLett.71.3743. URL: https://link.aps.org/doi/10.1103/PhysRevLett.71.3743.

[12] Andrew Strominger and Cumrun Vafa. "Microscopic origin of the Bekenstein-Hawking entropy". In: *Physics Letters B* 379.1-4 (1996), pp. 99–104.

[13] W. G. Unruh. "Notes on black-hole evaporation". In: *Phys. Rev. D* 14 (4 Aug. 1976), pp. 870–892. DOI: 10.1103/PhysRevD.14.870. URL: https://link.aps.org/doi/10.1103/PhysRevD.14.870.

[14] William G Unruh and Robert M Wald. "Information loss". In: *Reports on Progress in Physics* 80.9 (2017), p. 092002.

[15] Robert M Wald. *Quantum field theory in curved spacetime and black hole thermodynamics*. University of Chicago press, 1994.

[16] Robert M Wald. "The thermodynamics of black holes". In: *Living reviews in relativity* 4 (2001), pp. 1–44.

[17] Edward Witten. "Anti-de Sitter space, thermal phase transition, and confinement in gauge theories". In: *arXiv preprint hep-th/9803131* (1998).

[18] Edward Witten. "APS Medal for Exceptional Achievement in Research: Invited article on entanglement properties of quantum field theory". In: *Reviews of Modern Physics* 90.4 (2018), p. 045003.