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| **Introduction**  - You all heard …  - star -> black hole  - Kyriakos Papadodimas: observer falling…  - Equivalence principle?  **Gliederung**  - I will start with…  - short: QFT in curved spacetime  - Black holes  - short: Conclusion | **Massless scalar field**  - Only consider massless scalar field (most easy)  - Else analogue 🡪 will follow Birrell & Davies  - replace Min metric by spacetime metric  - Quantise according to normal procedure  **Problem of defining a vacuum:**  - normally: vacuum annihilated by all modes  - Problem: other system 🡪 other modes 🡪 not annihilate (mix pos & neg) 🡪 need to guess  - Static spacetime: intuitive way … (just a guess)  - observers: own system 🡪 what does he see? |
| **Greens function**  - answer that in a moment 🡪 first Greens function  - most important: Wightman function (expectation v)  - two more: Im and Re  - thermal: replace expectation v  - Im just a number, Re replace t -> t - iβn  **Unruh detector**  - Now answer what observer will see  - Idea goes back to unruh: detector model  - Perturbation theory 🡪transition rate splits…  - basically fouriertrafo of Wightman function  - Interpretation as particle population | **Minkowski space**  - To get feeling for this 🡪 Minkowski space  - Wightman function  - Important: reg. ε (sometimes drop it - simplicity)  - Static: (just getting older) 🡪 contour 🡪 poles shifted  - Inertial observer: vacuum is vacuum!  **Unruh effect**  - Accelerating observer: Hyperbola  - Compare to thermal Wightman function + static observer  - Accelerating observer 🡪 vacuum is a thermal state! |
| **Static spacetimes**  - this was intro 🡪basic plan: unruh detector around BH  - Before consider BH 🡪Some general properties  - Static spacetime: metric not time dependent  - positive frequency solutions + vacuum  - free to choose cords 🡪 normal coords (time dilation)  **Pole at x = 0**  - can apply this directly to pole at origin  - want to fouriertrafo 🡪 residue 🡪poles  - ε shifts pole to upper half  - drop pole and ε | **Other singularities**  - So ignore pole at zero 🡪 other poles?  - just basic idea (no mathematical proof)  - D follows wave equation, define A = 1/D  - pole: grad A lightlike -> lies on a lightlike surface  - pole at 0 🡪 singular on lightcone  - let’s assume one more singularity 🡪 continue lightray  - would encounter infinity at t = 0  - at least for us 🡪 no more singularities (on real axis)  - repeat for Im 🡪 D is real |
| **Static observers**  - Let’s turn to the observed spectrum 🡪 3 lemma  - don’t rely on vague arguments from before  - static: τ only in exp 🡪 delta = 0  - surprising: need to accelerate (e.g. BH)  **Killing vectors**  - even gets worse 🡪 movement along spatial killing  - complex condition 🡪A,B (velocites) & m,ω (eigenv)  - again: : τ only in exp 🡪 delta = 0  - example: circular orbit, k in ϕ, ω inf. Small  - surprising: geodesics with particles | **Killing vectors 2**  - explain that in a moment 🡪 apply on all observers  - Minkowski space 🡪 all inertial observers see nothing  - back to EP: holds only locally, this is globally  - fouriertrafo whole history of observer (start acc.)  **BH Black holes**  - now bothered you enough with technicalities  - now concrete: black holes  - consider star (Schwarzschild metric for simp.)  - After collapse: thermal state (not quite true!)  - spectrum before and after |
| **BH Solutions of Klein-Gordon**  - First we need Wightman function 🡪 need modes  - ansatz 🡪 this equation 🡪 far away 🡪 ignore  - spherical wave (but with r\_\*)  - fix prefactors 🡪 sine  **BH Wightman function**  - plug into formula  - run into 2 Problems:  - IR-divergence (ok, this happens often)  - more important: angular dependence only from one direction | **BH Intermezzo**  - to solve look at something we know 🡪 Minkowski  - instead of plane waves 🡪 use spherical modes  - far away: approx by sine  - Wightman function: same problems  - is solved by bessel functions: drop to 0  - idea: reverse approx. 🡪 replace sine by Bessel  - 🡪 Wightman function similar to Minspace  - check for static observer: same as Minspace |
| **BH Circular Observer**  - for circular observer shorten a bit  - plug in 🡪 small velocities find exponential spectrum  - high velocities: pole on real axis 🡪 approx. fails  - tried to figure out what goes wrong 🡪 Expansion  - only if …, difference < 10 % for r > 200  **BH After collapse summary**  - so far vacuum, no hawking radiation  - only 3 things left now | **BH Thermal Wightman function**  - so we need to calculate the thermal Wightman function  - recall from beginning … 🡪 split D  - thermal D + corrections  - static observers: Tolman relation – other analysis  - corrections from W: thermal + non thermal  **BH Determine temperature**  - During my research … people interested in shift  - Fit temperature over distance |
| **BH Determine temperature 2**  - Fouriertrafo: Plancherel 🡪 fit Wightman functions  - Small shifts 🡪 taylorexp. Around hawking temp  - in the end: calculate integral (numerically)  **BH Observers**  - finally we can look at our observers  - relative temp shift over radius (logarithmic)  - dotted line: r = 200  - static observer 🡪 benchmark  - errors: only numerical errors |  |
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