Explaining the essentials (Lecture 2)

1) The Book Keeping Problem. Completeness in QM
2) Completeness in BH
3) Finding all states
4) Fundamental input: all physical states can be written as
   a: a flat or curved space-time background, with
   b: elementary particles with momenta p_μ such that all components $|p| < M_{\rm Planck}$
5) The Penrose diagram slide 21

6) Consider time interval $t_{\rm out} - t_{\rm in} = \mathcal{O}(M_{\rm BH} \log M_{\rm BH})$.
Let a *given* in-state $|{\rm BH}_1\rangle_{\rm in}$ at $t = t_{\rm in}$ evolve into a *given* out-state $|{\rm BH}_1\rangle_{\rm out}$ at $t = t_{\rm out}$.

7) Now either add or remove one particle with momentum $\delta p^-_{\rm in}$

8) Calculate how *all* outgoing particles are shifted by a shift $\delta u^-_{\rm out}$

9) relation $\delta u^-_{\rm out} = f(\delta\theta)\delta p^-_{\rm in}$ is **linear**
$u^\pm$ and $p^\pm$ are coordinates *very close* to the horizon

10) $[u^\pm,\, p^\mp] = i\delta^2(\theta_1, \varphi_1,\ \theta_2, \varphi_2)$ generates simple algebra slide 16

11) Diagonalize this algebra using $Y_{\ell,m}$

12) At any given ℓ, m, get $\psi_{\rm in}(u^+) \rightarrow \psi_{\rm out}(u^-)$

13) Tortoise coordinates: $u = \pm e^{\varrho}, \quad = \sigma\, e^{\varrho}, \quad \sigma = \pm 1$

    when ϱ is very large, then ignore this particle (it is far from the BH), so the corresponding $p_{\rm in}$ or $p_{\rm out}$ can also be ignored. This justifies a posteriori the assumption that large $|p|$ can be ignored

14) plane waves in ϱ : $\psi(\sigma, \varrho) = \psi(\sigma) e^{-i\kappa\varrho}$

15) The role of regions *I* and *II*

16) Unitarity forces antipodal identification Consequences :

17) BH has no interior! It all happens at the horizon (surface): holography

18) and Hawking particles are entangled slide 5

PROBLEMS

19) $u^{\pm}(\theta, \varphi)$ CANNOT be second quantized. It is exactly one single "particle" going in, and one particle going out, *either* at θ, φ *or* at the antipodal point $\pi - \theta$, $\varphi + \pi$.
How to relate these particles with the 2^{nd} *quantized partices in Fock space of the SM?*
How to take SM quantum numbers into account?

Many elementary calculations still to be done!