The Chandrasekhar Mass Bound and Quantum Gravity

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CHANDRAYANA

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Solve Einstein eq $\mathcal{G}_{ab} = \frac{8\pi G}{c^4} T_{ab}$ with sph symm ansatz for perfect barotropic fluid $\longrightarrow$ Tolman-Oppenheimer-Volkov eq

$$\frac{dP}{dr} = -(P+\rho)\,\left[\frac{4\pi r^3 P + 2m}{r(r-2m)}\right]$$

where, $m(r) \equiv \int_0^r dr' 4\pi r'^2 \rho(r')$, $G = c = 1.$ Assuming uniform $\rho(r) = \rho_0 \Rightarrow m(r) = M_{core}(r/R)^3 \Rightarrow$

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Degenerate neutron gas : Fermi pressure

$$P_{deg} = \int_0^{p_F} n_{tot}(p)\, v(p)\, dp$$

where, $n_{tot}(p_F) \equiv \int_0^{p_F} \; n(p)\, dp = (8\pi/3\hbar^3)\; p_F^3$

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Contrast with std QG effects $\sim O(l_P)$!

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- Are QG effects guaranteed to be small ? No

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$\Rightarrow$ cond for instability wrt formation of **horizon** (null hypersurface with sp foliations being trapped 2-surfaces)

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Canonical Ensemble of (isolated) horizons (as sptm bdy) : States characterized by $A_n \sim n \, l_P^2$, $n \in \mathbf{Z}$ (LQG)

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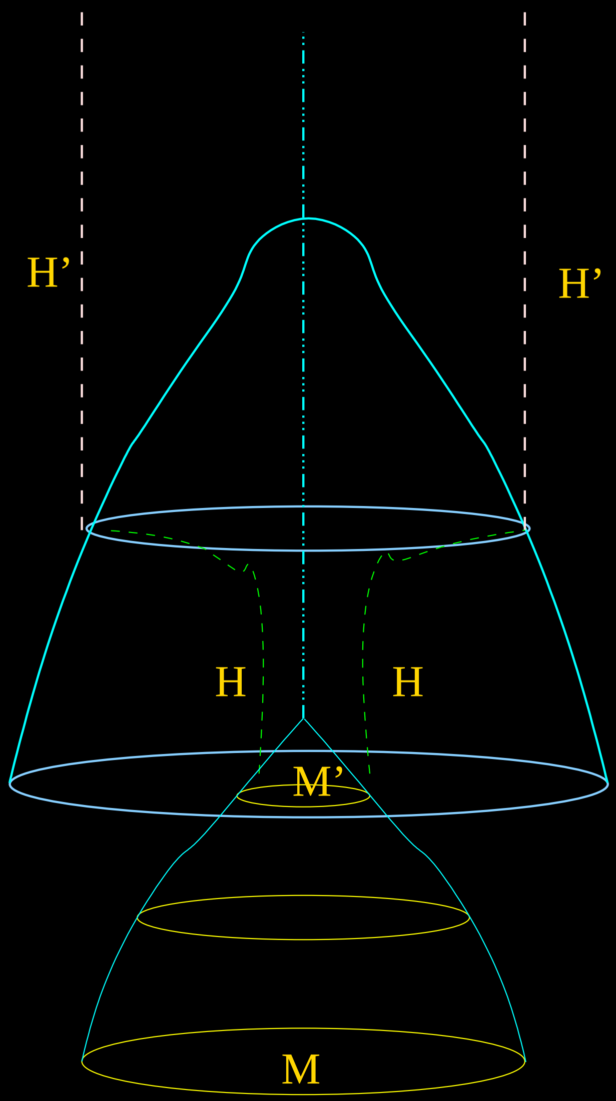
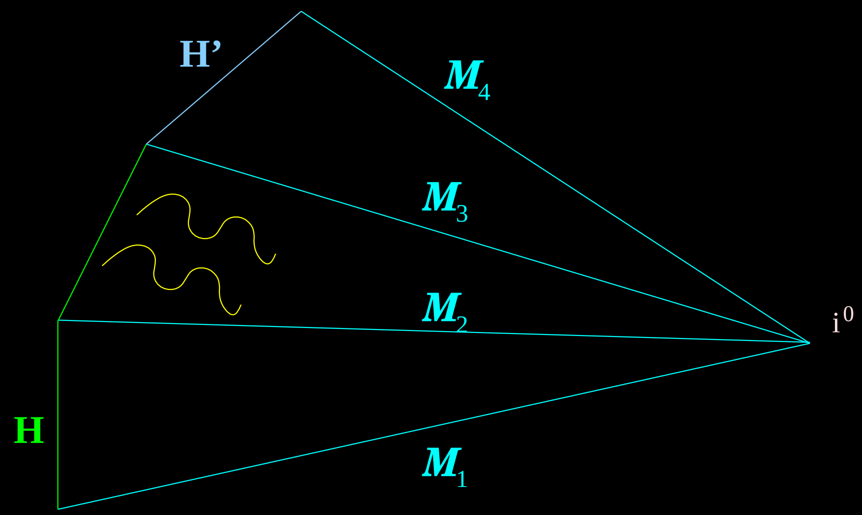
- Counting of horizon states ? Ashtekar et. al. 1997,2000; Kaul, PM 1998,2000; Das, Kaul, PM 2001


H'
H'
H
H
M'
M


H'
M_4
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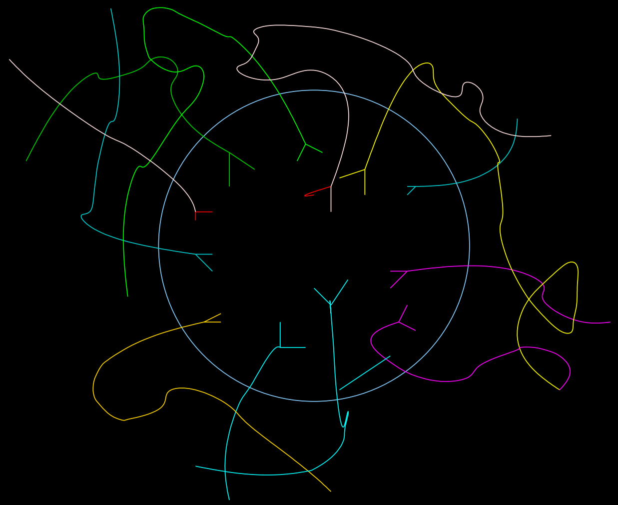
- **Gravity-gauge theory (topol) link derived**

Eff Quantum Horizon : Loop Quantum Gravity



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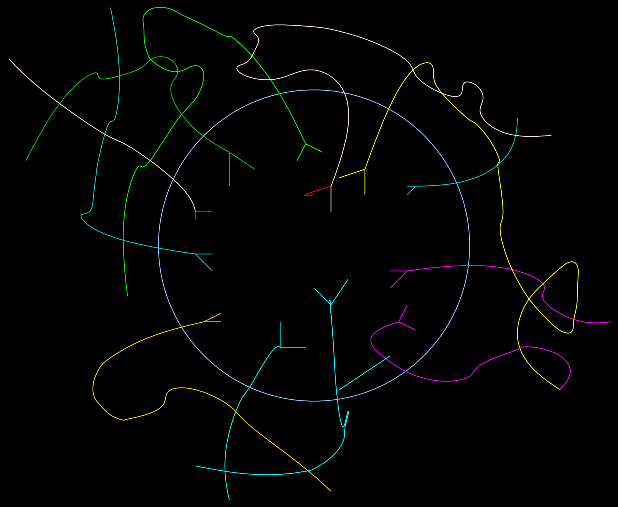

$$k_B^{-1}\,S = \frac{A_{hor}}{4l_P^2} - \frac{3}{2}\log\left(\frac{A_{hor}}{4l_P^2}\right) + O\left(\frac{4l_P^2}{A_{hor}}\right)$$

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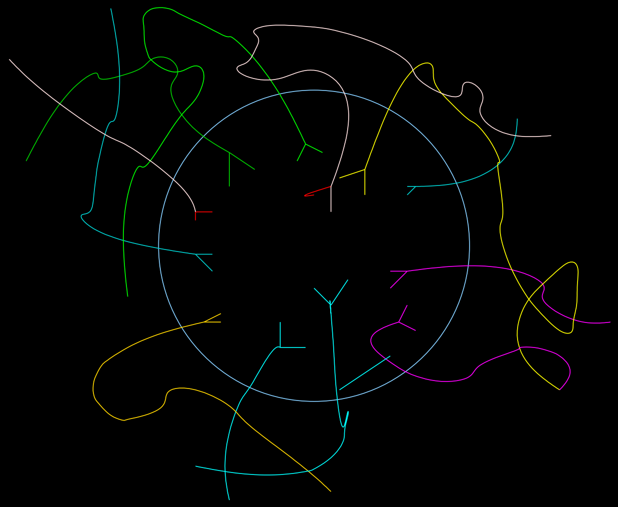

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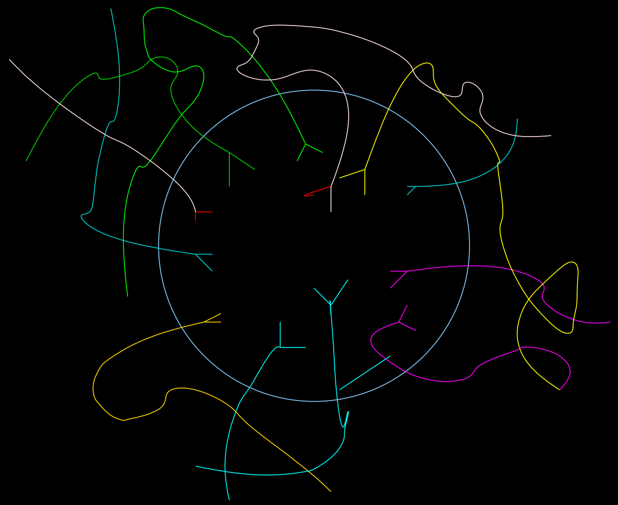

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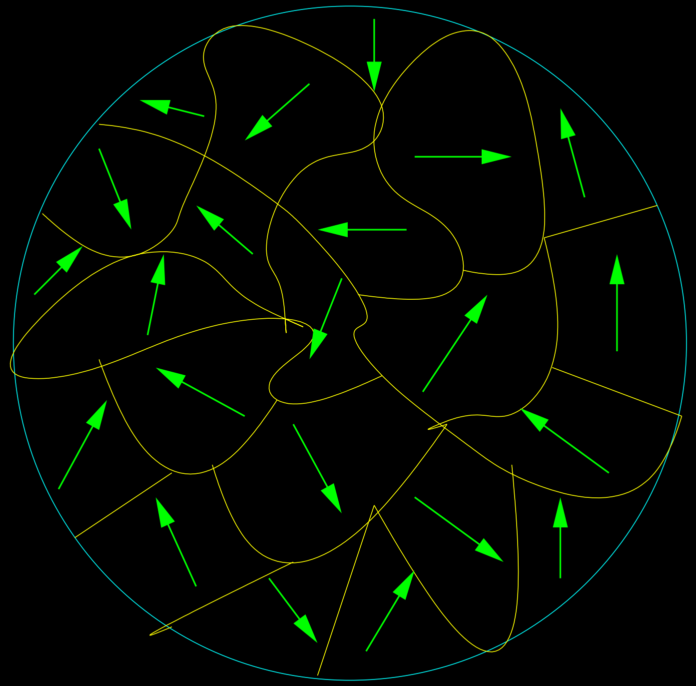
Corollary :

$$\beta = \beta_{Haw}\left(1 + \frac{6l_P^2}{A_{hor}} + \dots\right)$$

It from bit Wheeler 1992, ’t Hooft 1993



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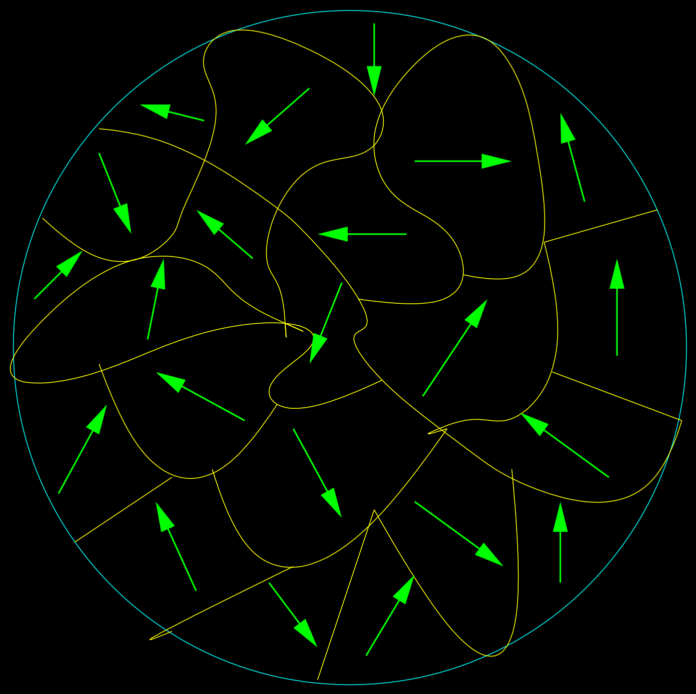

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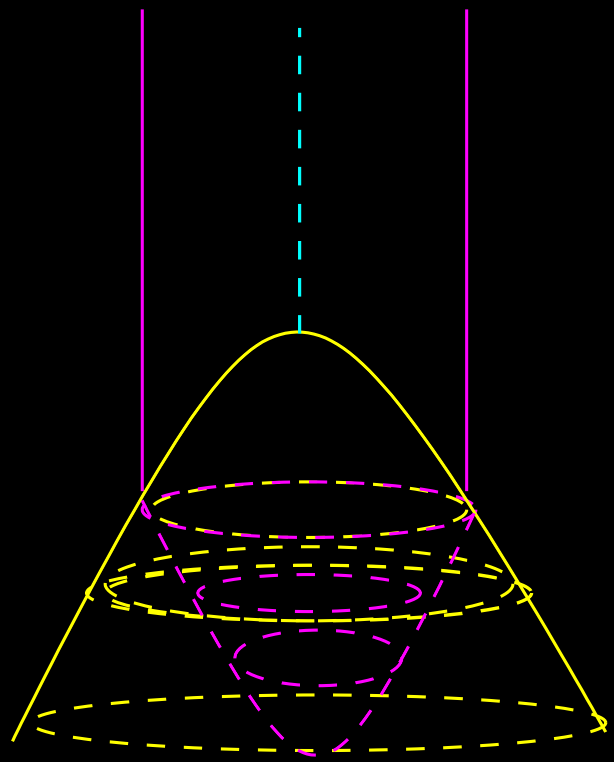
With Stirling approximation, replacing p in terms A_{hor}, obtain identical formula for $S(A_{hor})$.

Assume small energy loss during collapse to black hole



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$\Rightarrow M_{core} > M_{hor} = M(A_{hor}) \Rightarrow$

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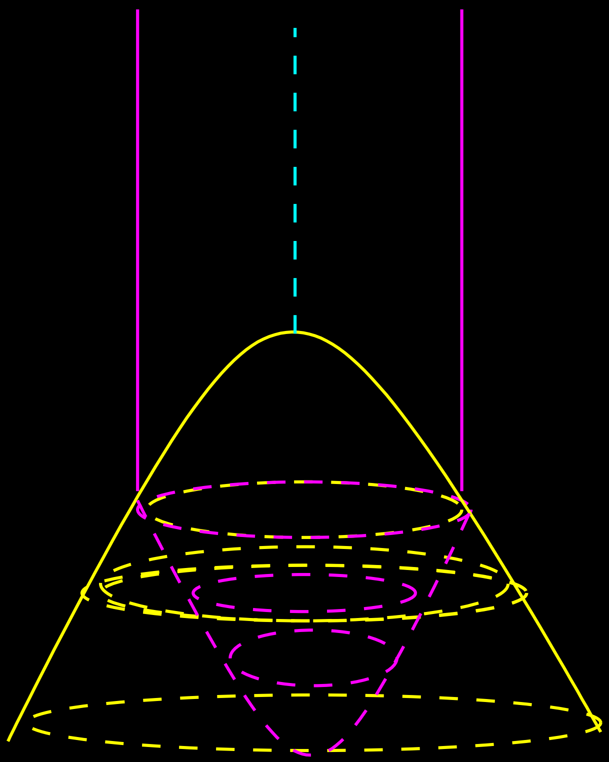

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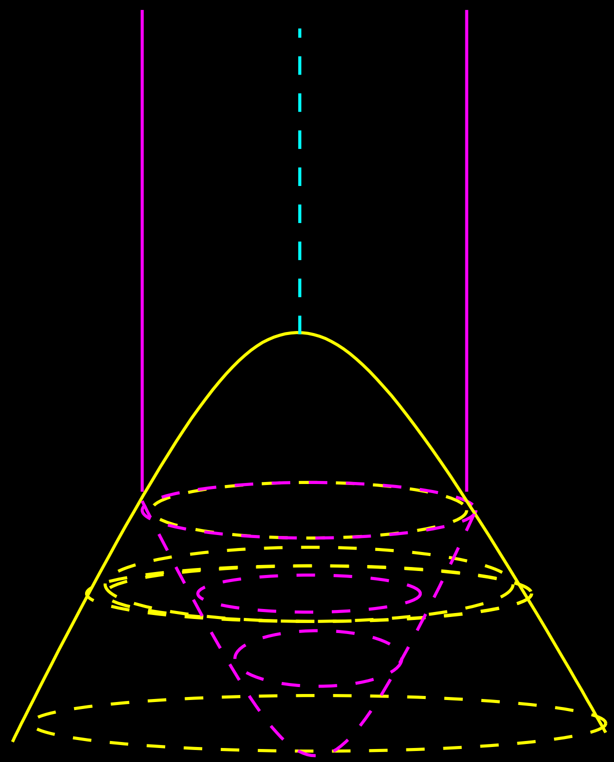

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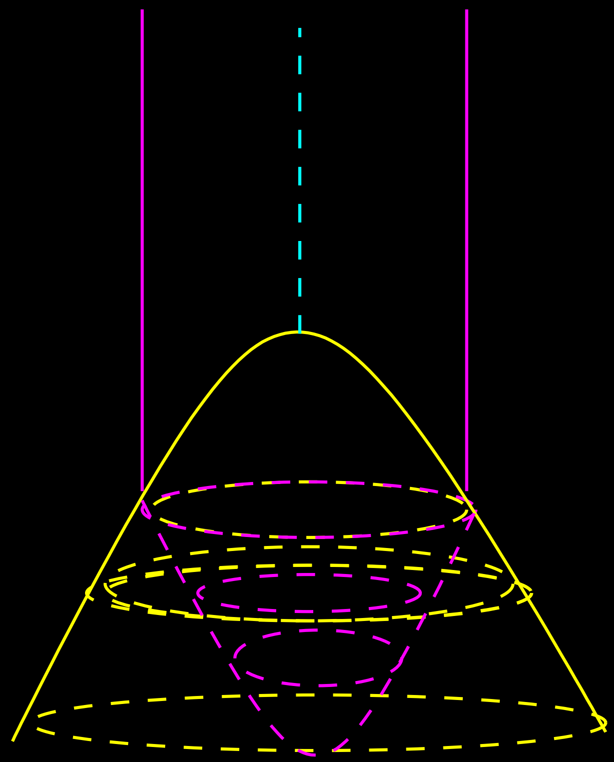

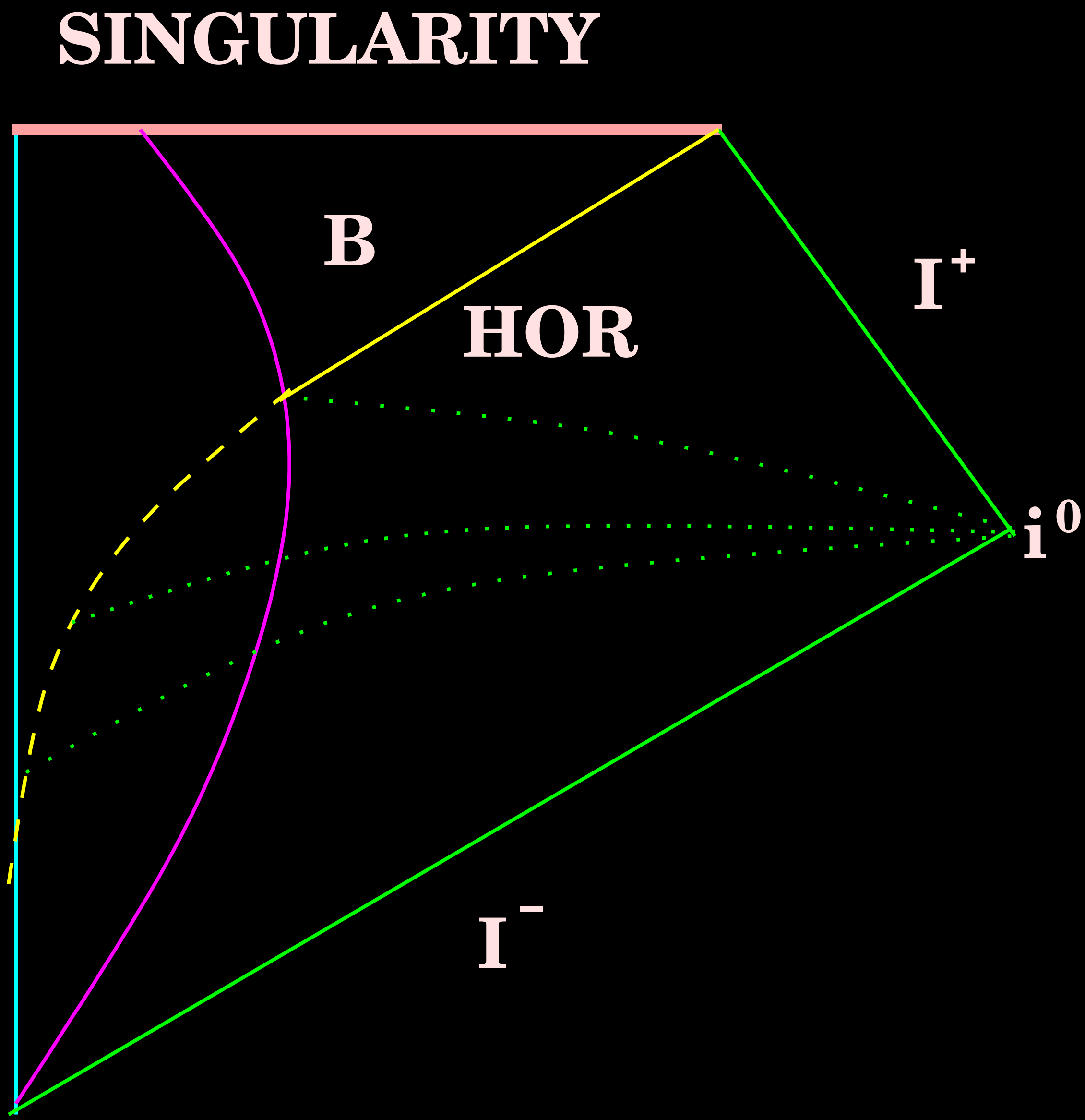
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Does such a hypersurface actually form in stellar collapse ? Test simple models : Oppenheimer-Snyder model of pressureless dust collapse (ongoing)

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- Need to go beyond effective quantum horizon : what exactly is a quantum horizon ?