Local data and black holes

Planck 2019

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Introduction

- The aim is to introduce a model to address an aspect of the black hole information problem
- A large amount of random information is released during decay, but this seems unrelated to the 'lost' information held by the collapsed matter
- Hawking radiation has $\lambda \sim R$
- This necessarily gives a very poor resolution image
- The photons are strongly biased to low angular momentum
- Emitted essentially GLOBALLY

Contd…

- Angular resolution of collapsed matter lost
- A model has to enable globalization as well as thermalization
- Attempts to preserve information near horizon do not address this
- New model uses string condensation to convert infalling matter to a globalized form
- Low information density
- Information stored like a delay line

Black holes and string condensate

- String condensate forms at Hagedorn temperature, as thermal scalar becomes massless
- Thermal scalar ϕ represents single winding mode in Euclidean time
- Solutions where BH has halo of condensate found by MH, Mertens Verschelde & Zakharov
- No direct evidence this contributes to information storage
- New model uses conjectured gravitational Meissner effect (MH 2016) to produce slow conversion of infalling matter to a globalized phase

2 questions about black holes

- WHY IS A BLACK HOLE BLACK?

A common answer is that particles are absorbed when they cross the event horizon.

BUT As a particle approaches a black hole a new horizon forms some distance from the old. We show below that this distance is at least

$4\sqrt{Mm}$ for a BH of mass M and a particle of mass m. This can be many Planck lengths in realistic cases.

…

- HOW CAN ANYTHING UNUSUAL HAPPEN WHEN CURVATURE NEAR THE HORIZON IS SMALL?

Our approach is based on a generalisation of the Penrose trapped surface concept, which does not rely on large curvature.

Unlike a horizon (3 dimensional) a trapped surface (2 dimensional) is defined locally. An additional global property (closed surface) implies singularity formation, subject to energy conditions.

The condition proposed for condensation (MH 2016) uses constant area critical gravity surfaces. These are a generalisation of marginal trapped surfaces, which are recovered in a limit where the Regge slope $\alpha' \to 0$

String condensation hypothesis

- Constant area critical gravity surfaces extend to 2+1 dimensions using timelike vector field with critical acceleration (Hagedorn Unruh temperature).
- This timelike vector normalized to E^0 the time component of a vierbein. This is used to define Wick rotation and the thermal scalar.

The hypothesis is that infalling matter that causes such surfaces to form will nucleate condensate formation.

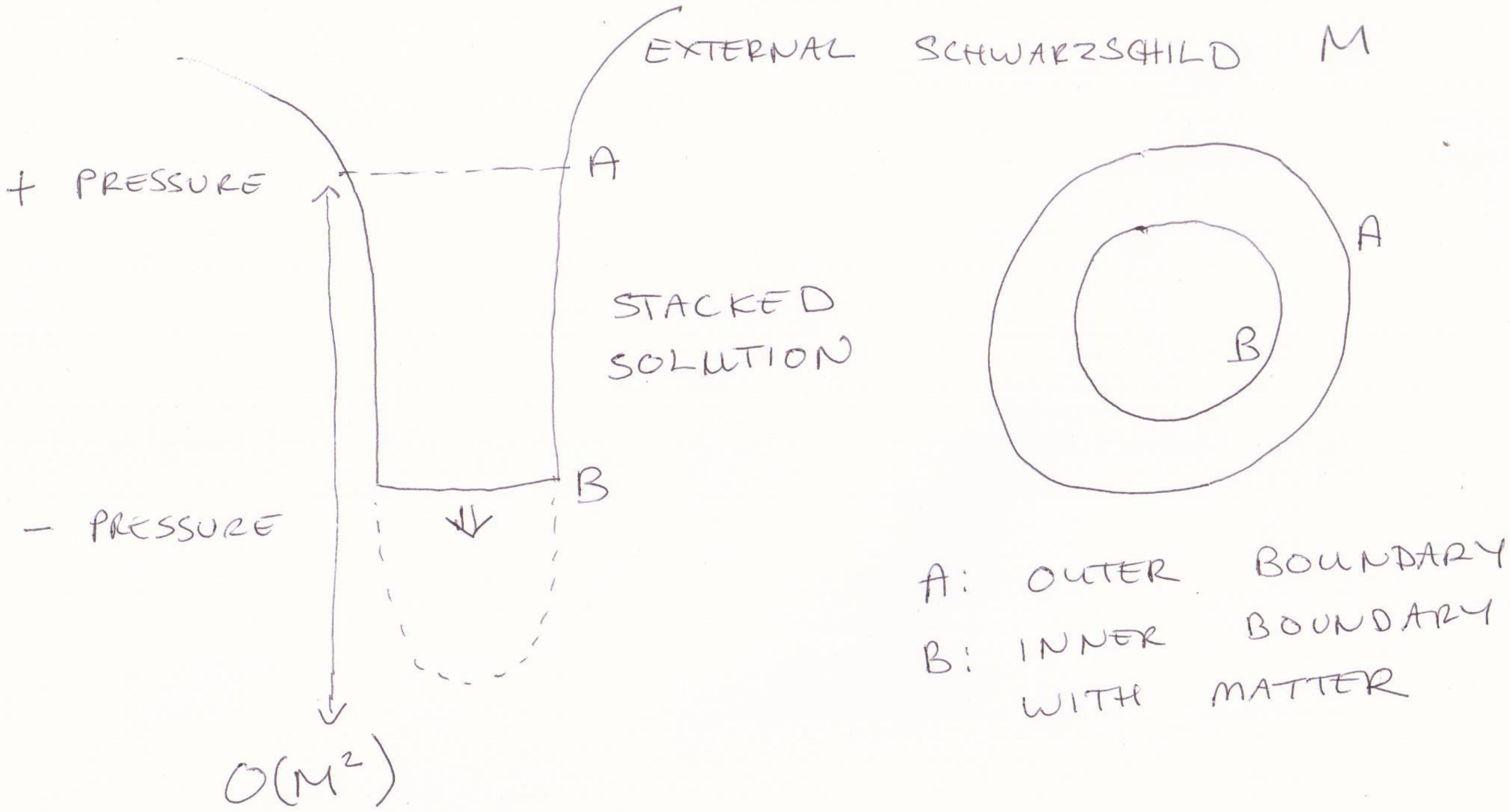
Meissner effect hypothesis

- T duality suggests that the boundary of the condensate expels gravitational fields (MH 2016)

- For the current model, this is realised by surface pressure around the boundary. This is positive on the outside and negative on the inside.

Summary of model

- Collapse generates an internal globalized cosmic string like solution
- The energy of the infalling matter is gradually exhausted, forming an internal region with length up to $O(M^2)$
- The interior carries globalized information which can be exchanged for Hawking radiation.


EXTERNAL SCHWARZSCHILD M
+ PRESSURE
A
STACKED SOLUTION
B
− PRESSURE
$O(M^2)$
A
B
A: OUTER BOUNDARY
B: INNER BOUNDARY WITH MATTER

EXTERNAL SCHWARZSCHILD SOLUTION

$(\hbar = c = G = 1)$

$$ds^2 = -\gamma^{-2} dt^2 + \gamma^2 dr^2 + r^2 d\Omega^2$$

$$\gamma = \left(1 - \frac{2M}{r}\right)^{-1/2} \qquad R = 2M$$

For $s \ll R$, $\gamma \to \frac{4M}{s} = \frac{2R}{s}$ (s measured from R)

A = area, $dA \sim 8\pi R\, dr$

$$\Delta A = \int dA = 2\pi \Delta s^2$$

$$\Delta A = 32\pi Mm$$

$\to s = 4\sqrt{Mm}$ to new horizon.

STACKED SOLUTION

$$\gamma_M = \frac{4M}{S_H}$$ HAGEDORN SURFACE AT S_H.

$$ds^2 = -\gamma_M^{-2} dt^2 + r^2 \left[\frac{4}{S_H^2} dr^2 + r^2 d\Omega^2 \right]$$

$a = r^2 \rightarrow$

$$ds^2 = -\gamma_M^{-2} dt^2 + \frac{1}{S_H^2} da^2 + a \, d\Omega^2$$

SURFACE PRESSURE

$$\mathbb{P} = \int p \, ds \quad \text{THROUGH BOUNDARY}$$

$$E_{LOCAL} = \gamma_M M = \frac{4M^2}{S_H}$$

$$\frac{E_{LOCAL}}{A} = \frac{1}{4\pi S_H}$$

$$\mathbb{P} = \frac{1}{2} \frac{E_{LOCAL}}{A} = \frac{1}{S_H}$$

$$\mathbb{P} = \frac{g}{32\pi} = \frac{1}{4} \sqrt{\mathbb{T}_S}$$

$\mathbb{T}_S$ = STRING TENSION, g = 4d COUPLING (e.g. E_8 GAUGE).

STRING RELATIONSHIPS

α_H = HAGEDORN ACCELERATION (UNRUH EQUIVALENT)

$$\alpha_H = \frac{2\pi}{\sqrt{\alpha'}} \quad , \quad S_H = \frac{\sqrt{\alpha'}}{2\pi}$$

$$T_H = \frac{\alpha_H}{2\pi} = \frac{1}{\sqrt{\alpha'}} = \frac{g}{8\pi}$$

$$\Delta A = \frac{16\pi}{g} \Delta S$$

$$\Delta S = \frac{\Delta A}{4} = \frac{4\pi}{g} \Delta S$$

ENTROPY

FOR STACKED SOLUTION

ANGLE DEFECT

GLOBALISED COSMIC STRING

TENSION $\mathbb{T}$

$$\Delta = 8\pi\mathbb{T}$$

$$\Delta = 4\pi \quad \text{(SPHERE CLOSURE)}$$

$$\rightarrow \mathbb{T} = 1/2.$$

FOR COMPARISON, STRING TENSION $\mathbb{T}_s = \left(\frac{g}{8\pi}\right)^2$

$$\frac{\mathbb{T}}{\mathbb{T}_s} = \frac{1}{2}\left(\frac{8\pi}{g}\right)^2 = \frac{8\pi}{\alpha}$$

$\uparrow$

"# STRINGS" — DEPENDS ON g, & $\therefore$ DILATON — NOT FIXED.

NUCLEATION LOCATION S_N

SPHERICAL FRONT

GLOBAL DENSITY (at ∞) $\rho_g = \dfrac{m}{16\pi M^2}$

$$S_N = 4\sqrt{Mm}$$

$$S_N^2 = 256\pi M^3 \rho_g$$

RESTRICTED FRONT : AREA a

$$S_N = 16\sqrt{\pi \rho_g M^3} = 16 M^{3/2}\sqrt{\frac{\pi m}{a}}$$

$\rightarrow$ NUCLEATION FURTHER OUT

FOR $a \gg Mm$ (APPROX. FLAT FRONT)

$$S_N = 16\sqrt{\pi}\, M^{3/2} \sqrt{\frac{m}{a}}$$

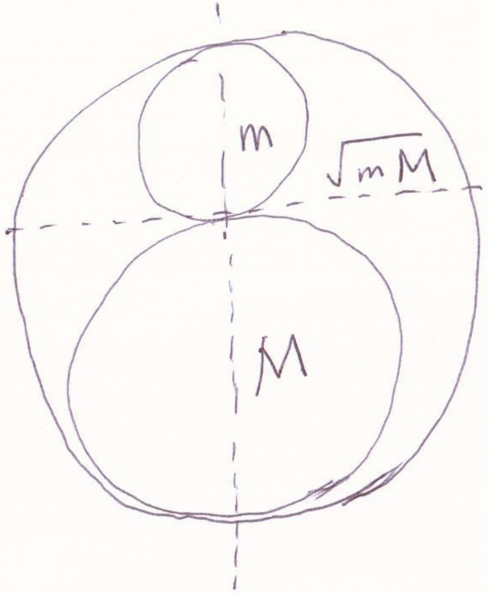
$$S_N \ll M^{3/2} \sqrt{\frac{m}{Mm}} \sim M \qquad \text{O.K.}$$

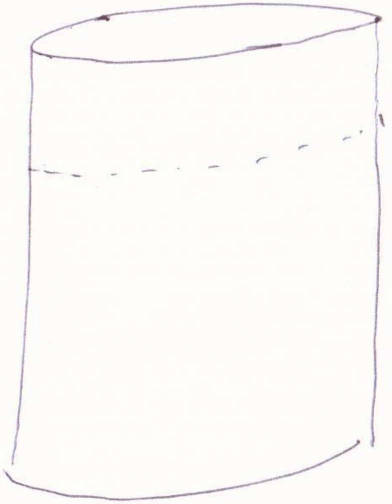
S_N ALWAYS BETWEEN $4\sqrt{Mm}$ and M.

FORCE ON m:

$$F = \left(\frac{d\gamma}{ds}\right)_{S_N} m = \frac{16\, m M}{S_N^2} = \frac{a}{4\pi R^2} = \Omega_a$$

* FORCE PROPORTIONAL TO SOLID ANGLE OF FRONT.

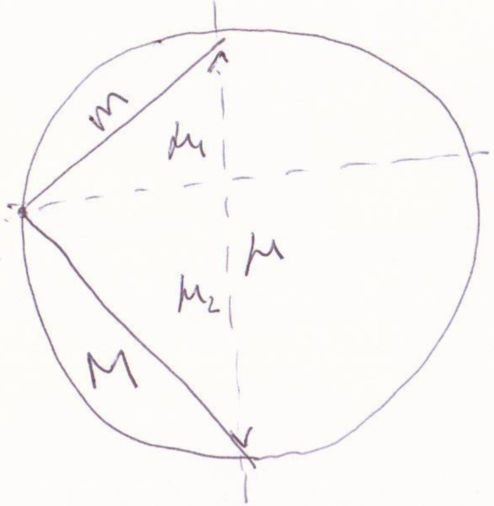


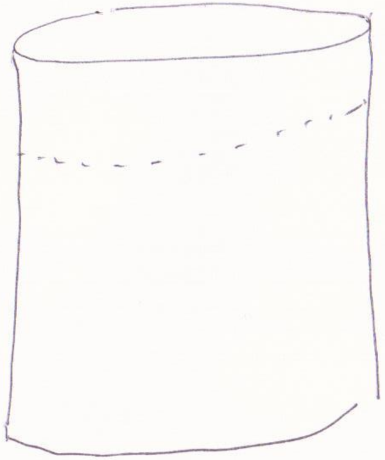


$2\pi m\,(M+m)$

$2\pi M\,(M+m)$

NO WORK: $\frac{1}{2\pi}\Delta A = 2mM$





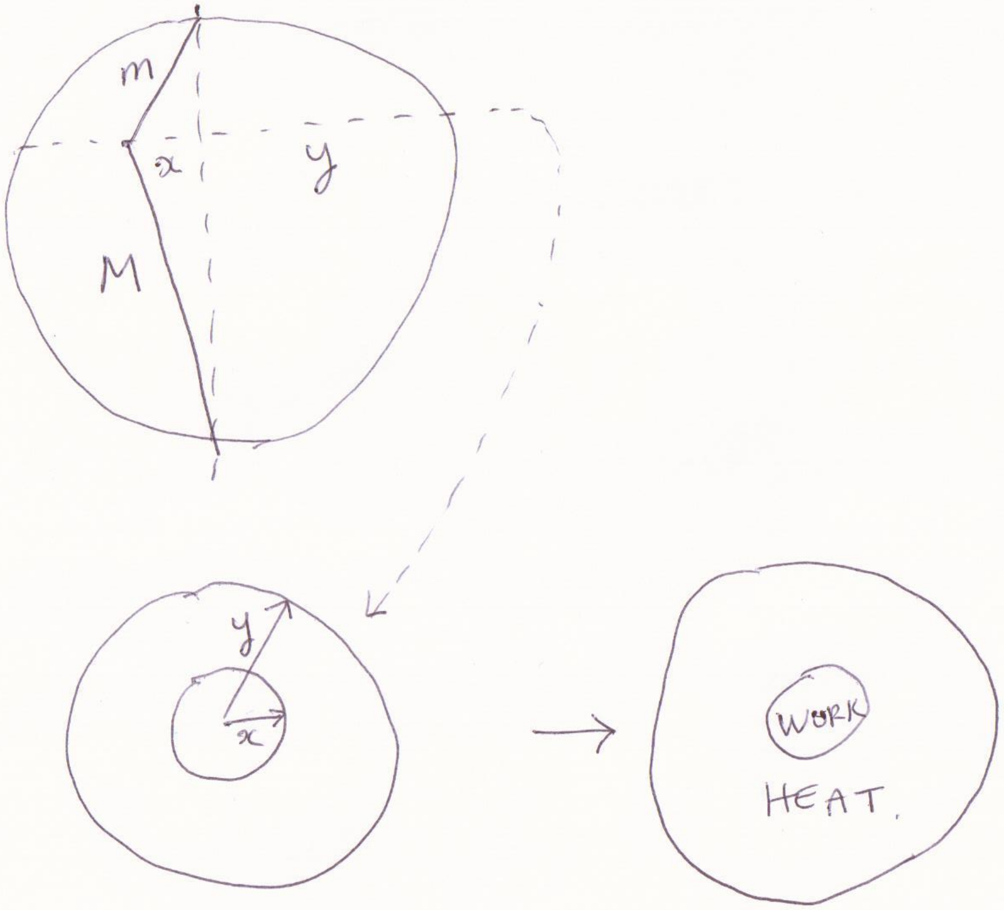
$2\pi\,\mu_1\,\mu = m^2$

$2\pi\,\mu_2\,\mu = M^2.$

('PONS ASINORUM')

MAXIMAL WORK $\Delta A = 0$

GENERAL CASE



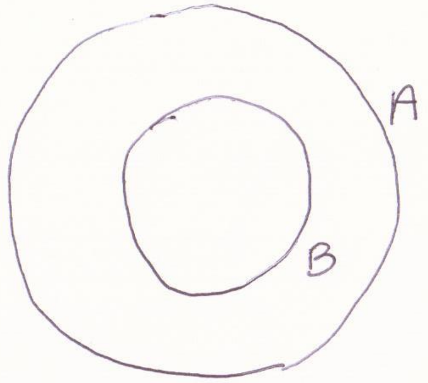
AREA OF CAP(i) = AREA OF SPHERE (i)
+ AREA OF 'HEAT' ANNULUS.

CAP (1) + CAP (2) = TOTAL.

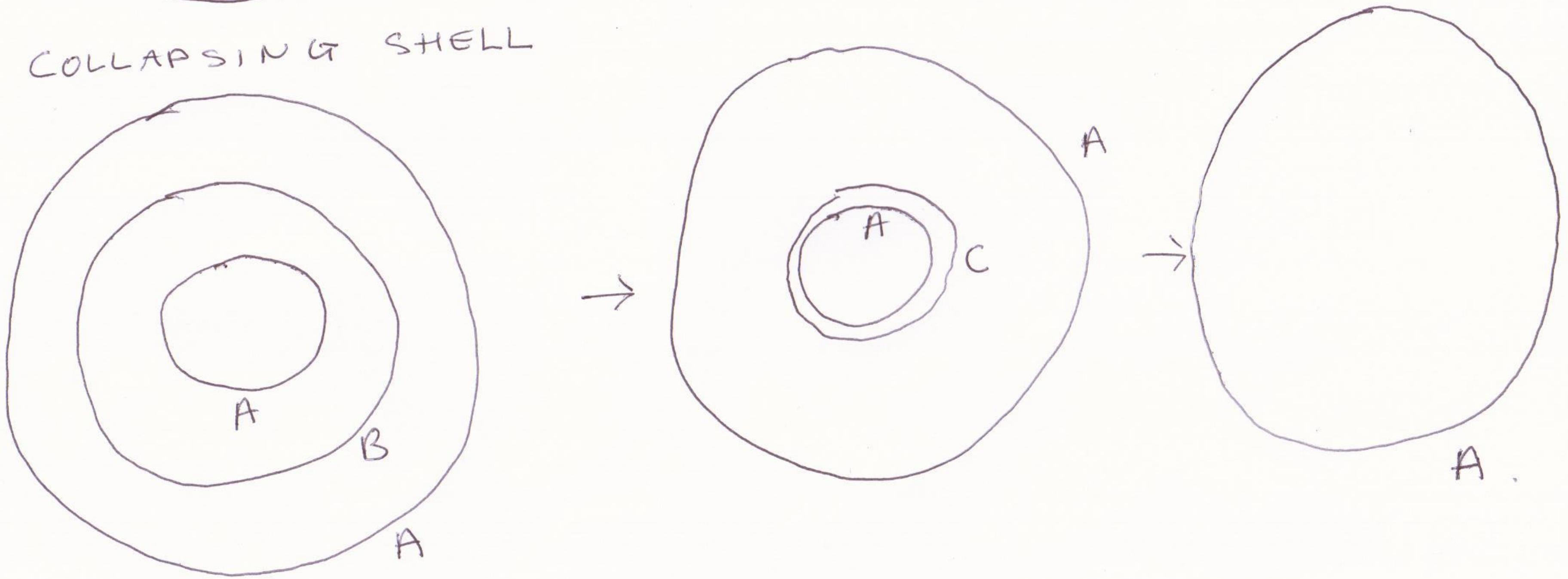
A: OUTER PRESSURE BOUNDARY

B: INNER PRESSURE BOUNDARY + MATTER (LORENTZ CONTRACTION!)

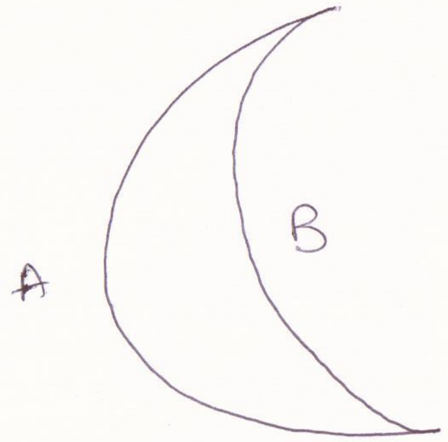
C: INNER PRESSURE BOUNDARY (LIMIT OF B).



COLLAPSING SHELL

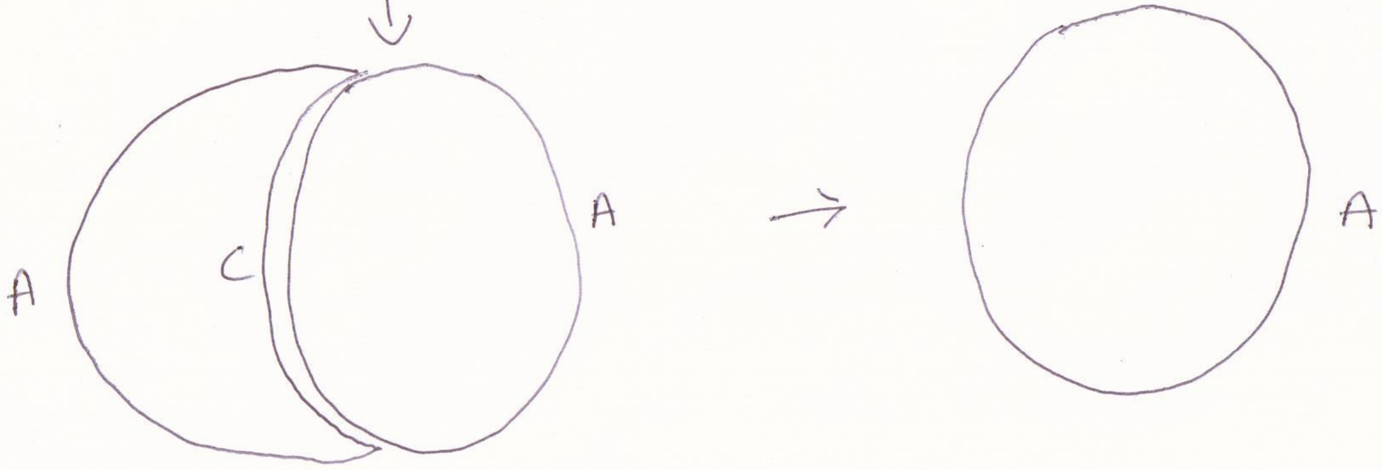


COLLAPSE OF SHELL ONTO EXISTING ϕ REGION.

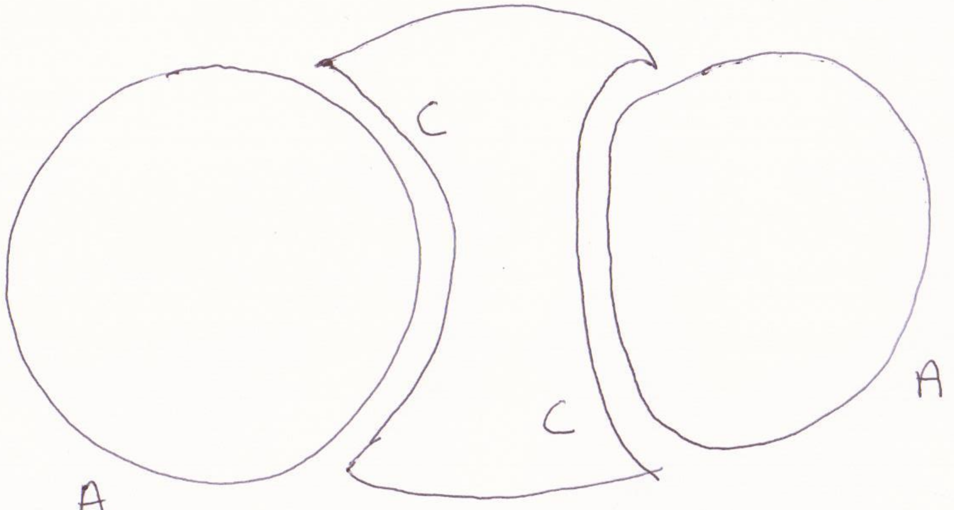


A, B HAVE COMMON TANGENT (PRESSURES CANCEL)

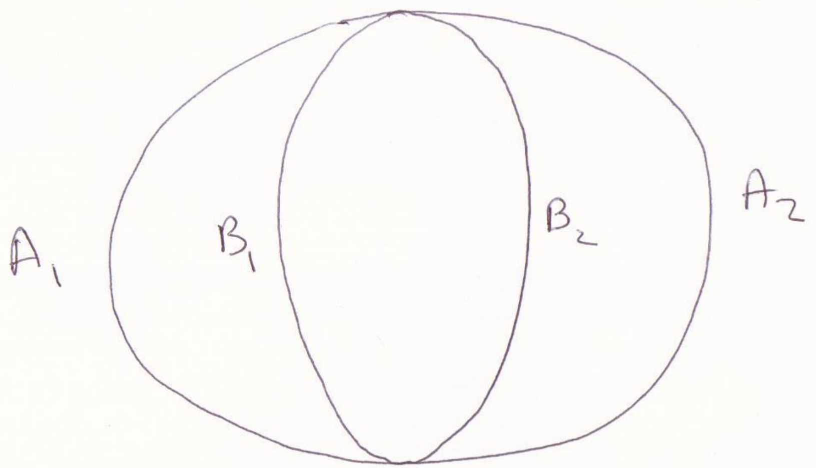
MATTER COLLAPSING ONTO REGION

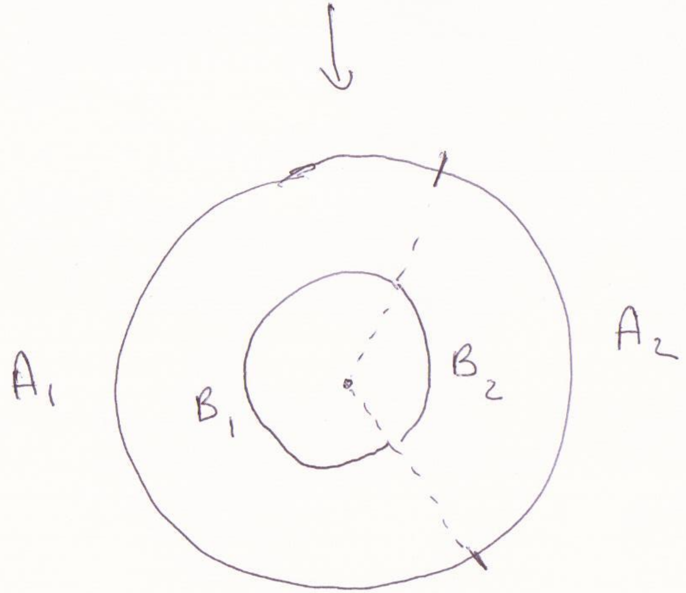


B → C AS IT APPROACHES A



NEW 'GHOST REGION'
ALLOWS MERGER.





PARTICLE COLLISION: SOLID ANGLE SHARED AS ABOVE.

Muchas gracias!