Dark Matter and Dark Energy: Cosmology of Spacetime with Surface Tension

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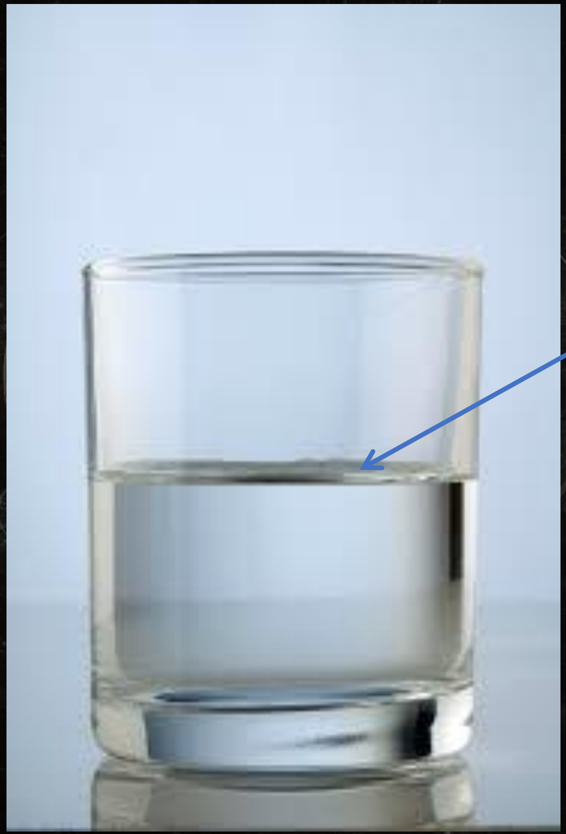
International Association of Relativistic Dynamics

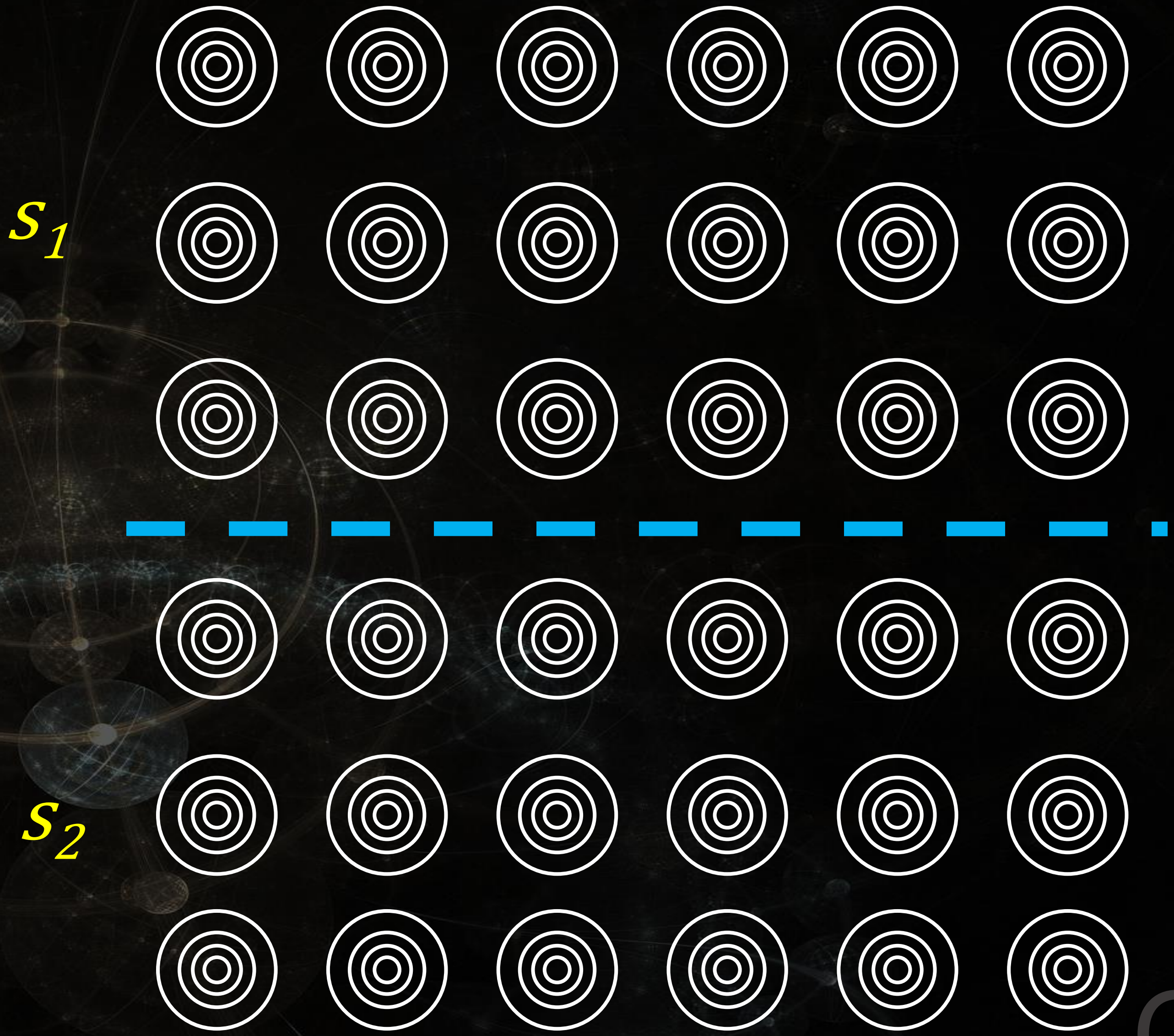
- If you were God’s engineer, how would you build the universe?
- Q: What do I have to work with?
- A: ….nothing except space and time.

Surface Tension



Membrane-Like
Behavior
at an Interface

Statistical Thermodynamics



Statistical Thermodynamics

Reduction in Multiplicity

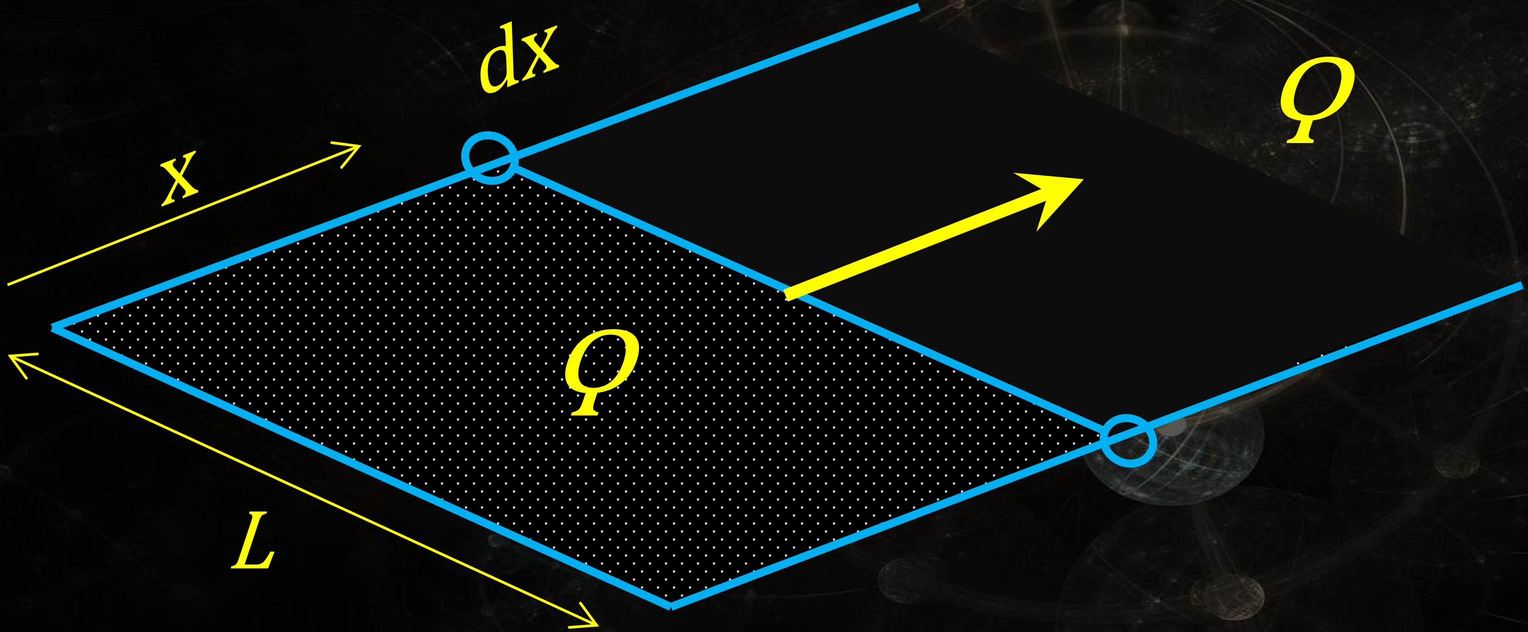
↓

Decrease in Entropy

↓

Requires Work

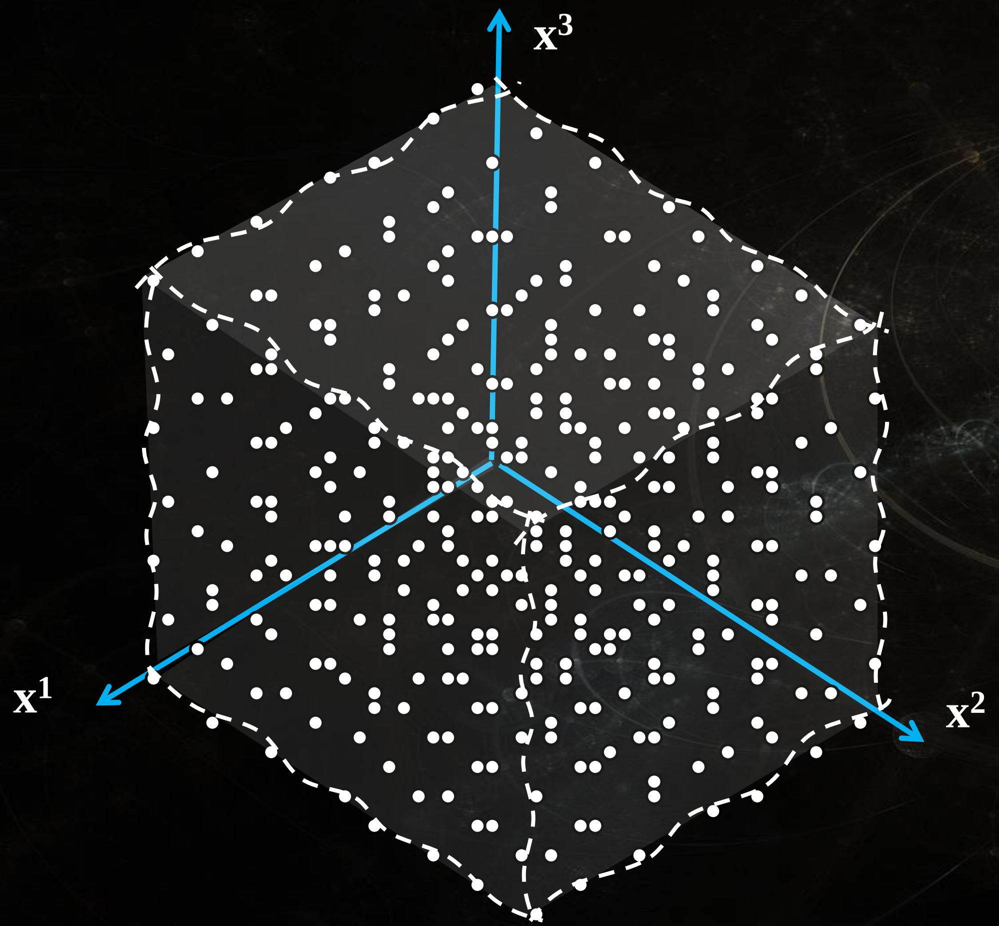
Surface Energy, φ → Surface Tension , φ

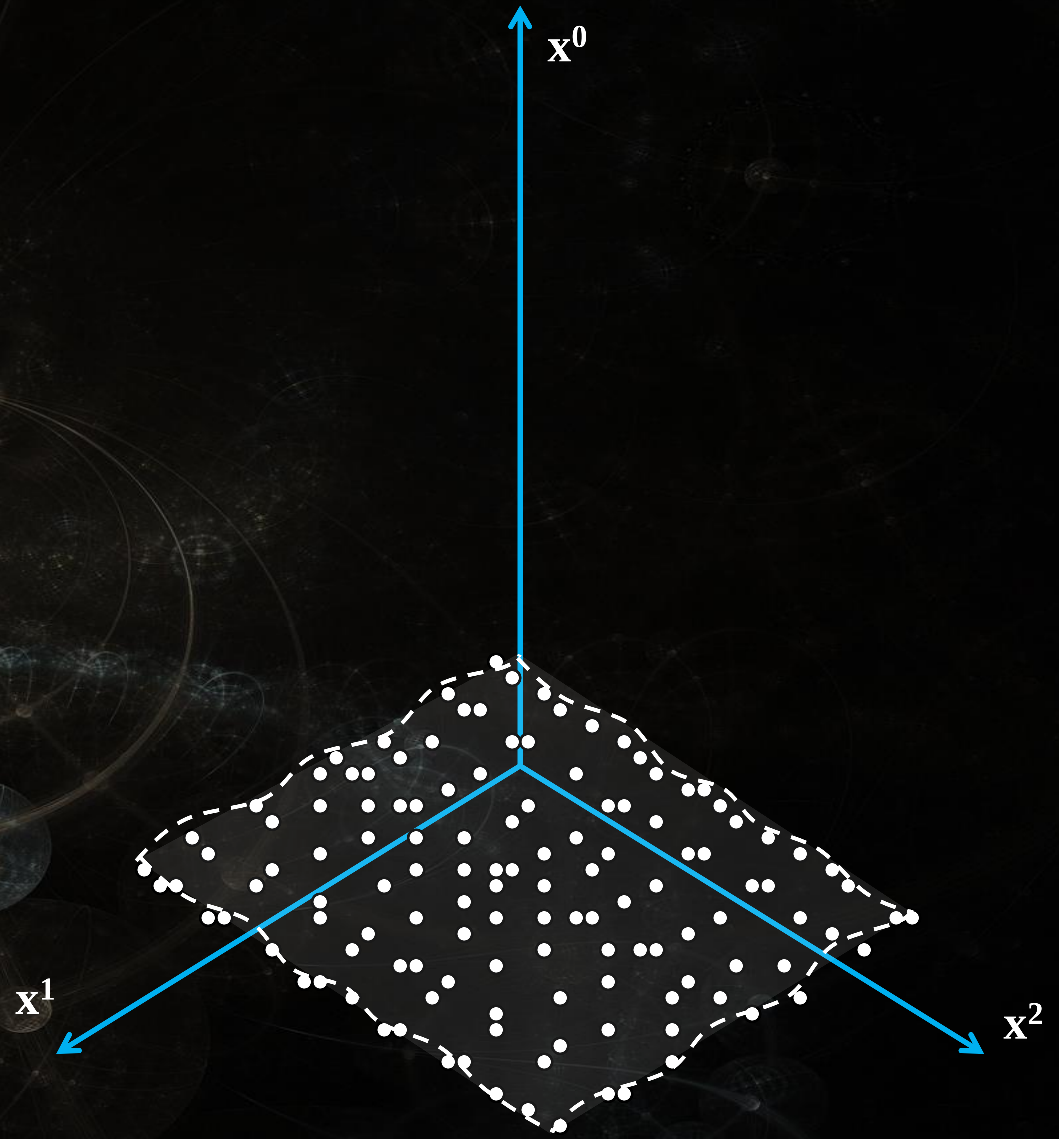


Work = $\varphi\, dA$

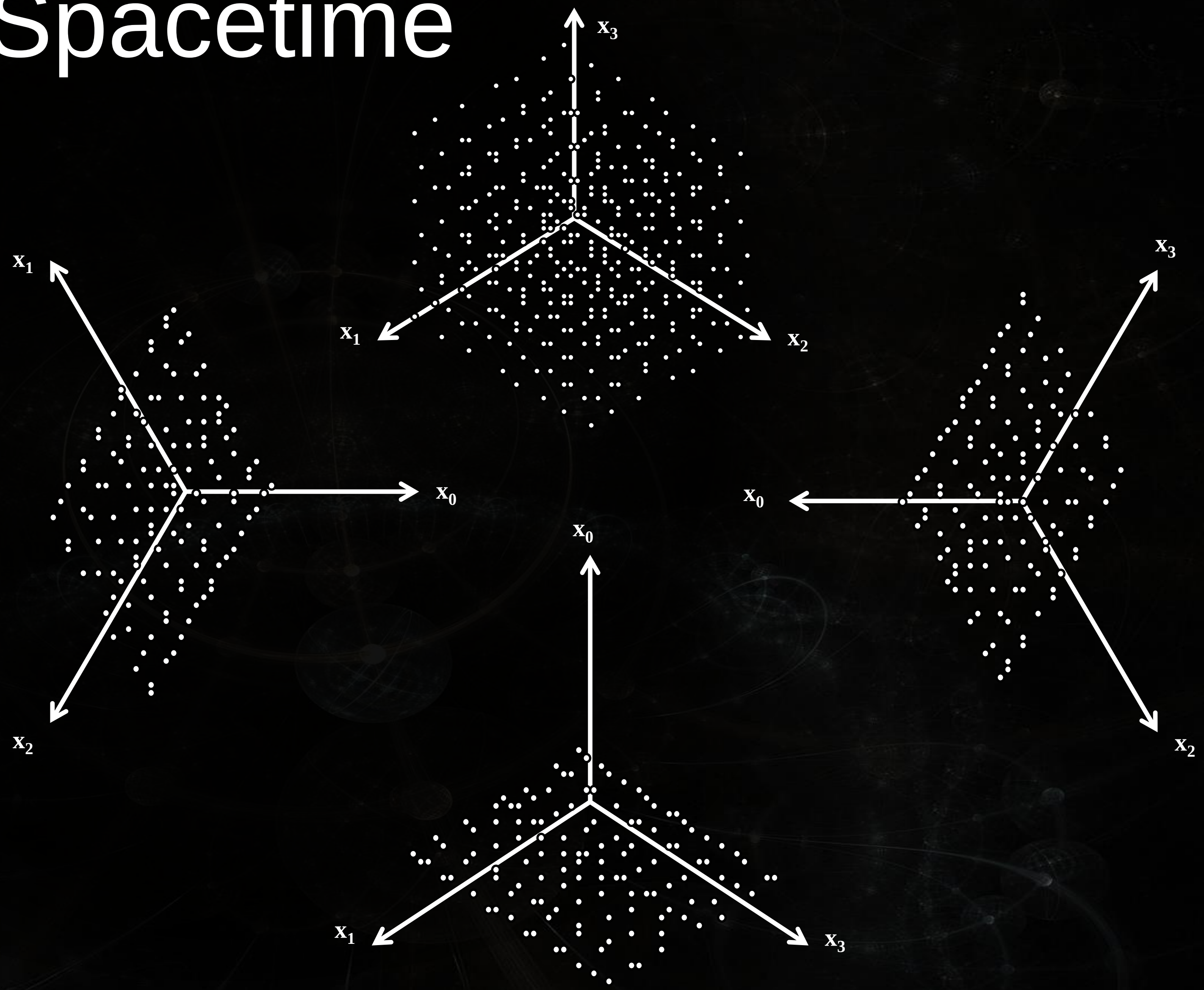
Work = $\varphi\, L dx$

Spacetime Diagram

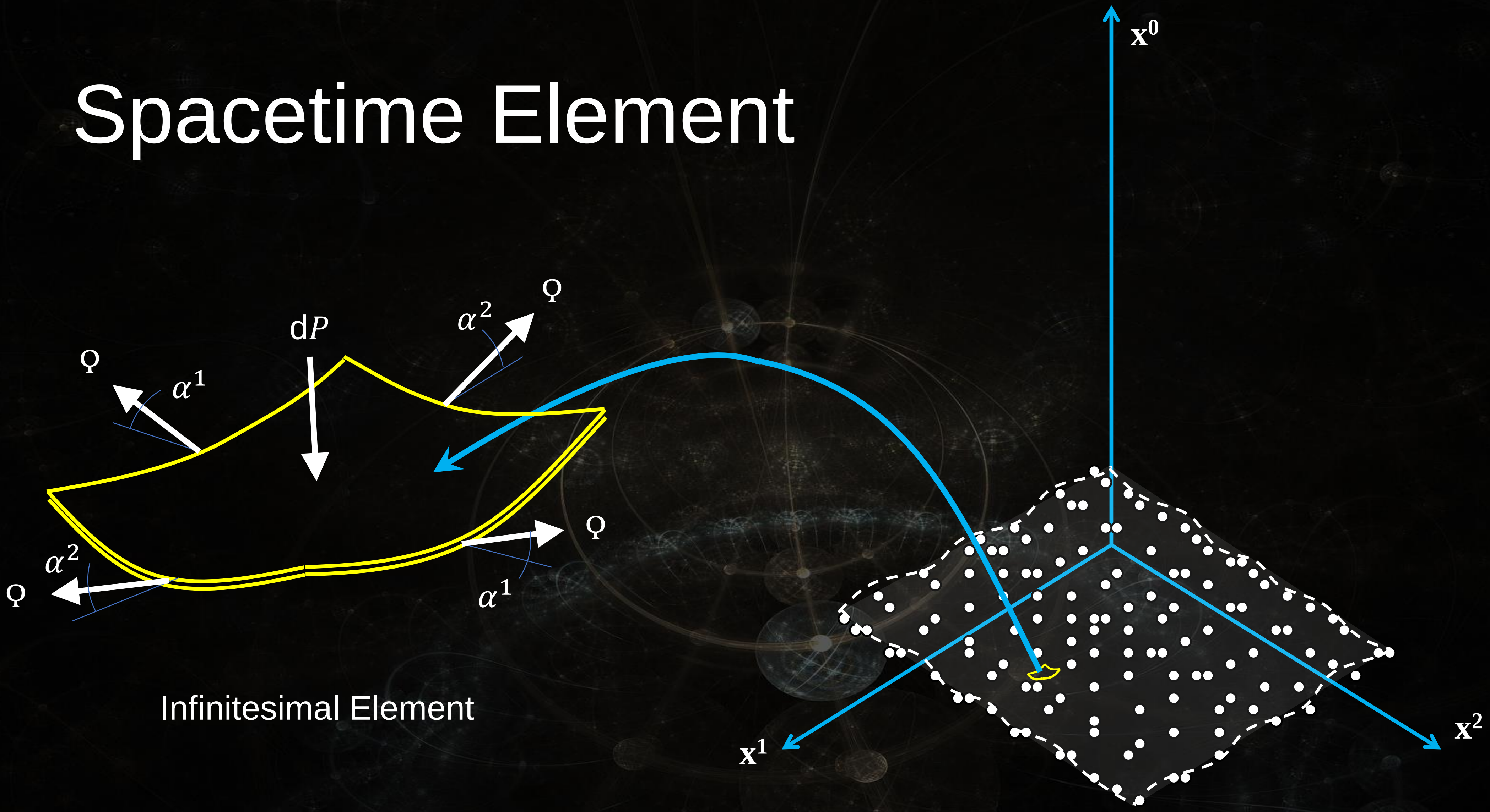




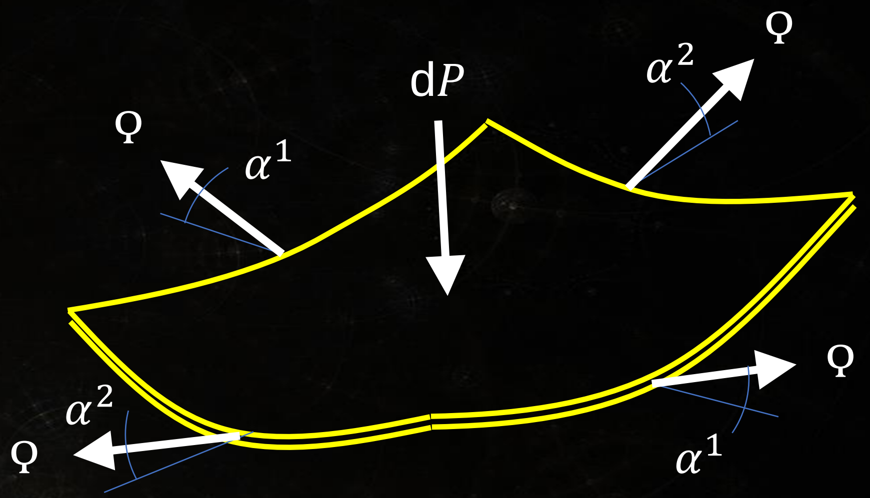
4D View of Spacetime



Spacetime Element

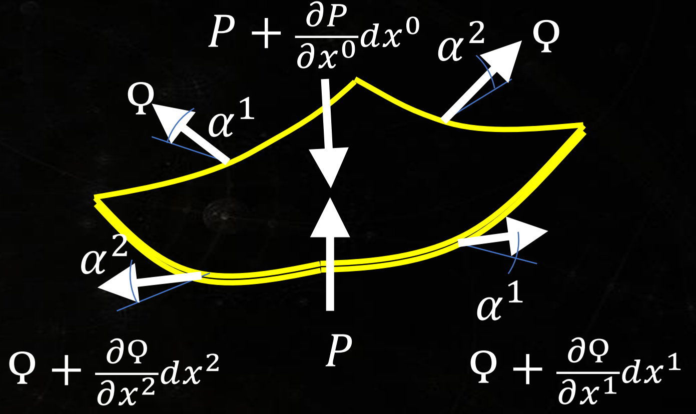


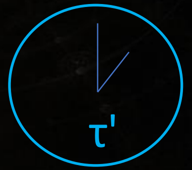
Stress Energy (Eq. 1)



$$T_{\mu\nu} = \begin{Bmatrix} dP & 0 & 0 & 0 \\ 0 & -\text{Ϙ} & 0 & 0 \\ 0 & 0 & -\text{Ϙ} & 0 \\ 0 & 0 & 0 & -\text{Ϙ} \end{Bmatrix}$$

Equations of Motion (Eq. 2)



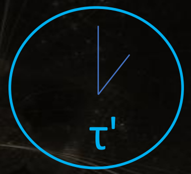


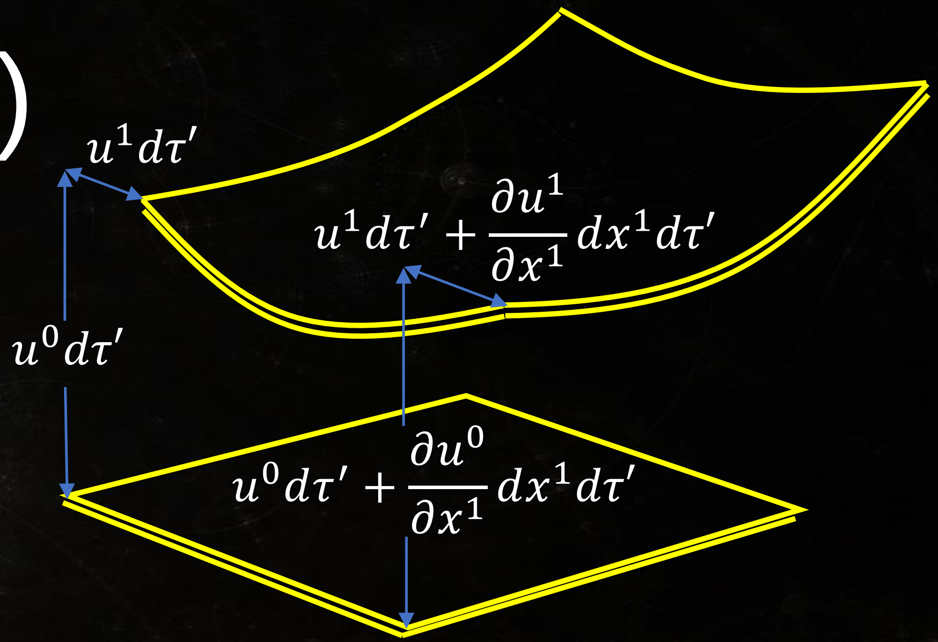
$\tau' = ic\tau \quad x^0 = ict$

$$
\begin{bmatrix}
\text{Ϙ}\left(\frac{\partial^2 x^0}{\partial {x^1}^2} + \frac{\partial^2 x^0}{\partial {x^2}^2} + \frac{\partial^2 x^0}{\partial {x^3}^2}\right) - dP & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^1} - dP\right) & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^2} - dP\right) & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^3} - dP\right) \\
\frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^1} - dP\right) & \frac{\partial \text{Ϙ}}{\partial x^1} & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^1} + \frac{\partial \text{Ϙ}}{\partial x^2}\right) & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^1} + \frac{\partial \text{Ϙ}}{\partial x^3}\right) \\
\frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^2} - dP\right) & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^2} + \frac{\partial \text{Ϙ}}{\partial x^1}\right) & \frac{\partial \text{Ϙ}}{\partial x^2} & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^2} + \frac{\partial \text{Ϙ}}{\partial x^3}\right) \\
\frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^3} - dP\right) & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^3} + \frac{\partial \text{Ϙ}}{\partial x^1}\right) & \frac{1}{2}\left(\frac{\partial \text{Ϙ}}{\partial x^3} + \frac{\partial \text{Ϙ}}{\partial x^2}\right) & \frac{\partial \text{Ϙ}}{\partial x^3}
\end{bmatrix}
$$

$$
= -\text{Ϙ}
\begin{bmatrix}
\frac{\partial u^0}{\partial \tau'} & \frac{1}{2}\left(\frac{\partial u^0}{\partial \tau'} + \frac{\partial u^1}{\partial \tau'}\right) & \frac{1}{2}\left(\frac{\partial u^0}{\partial \tau'} + \frac{\partial u^2}{\partial \tau'}\right) & \frac{1}{2}\left(\frac{\partial u^0}{\partial \tau'} + \frac{\partial u^3}{\partial \tau'}\right) \\
\frac{1}{2}\left(\frac{\partial u^1}{\partial \tau'} + \frac{\partial u^0}{\partial \tau'}\right) & \frac{\partial u^1}{\partial \tau'} & \frac{1}{2}\left(\frac{\partial u^1}{\partial \tau'} + \frac{\partial u^2}{\partial \tau'}\right) & \frac{1}{2}\left(\frac{\partial u^1}{\partial \tau'} + \frac{\partial u^3}{\partial \tau'}\right) \\
\frac{1}{2}\left(\frac{\partial u^2}{\partial \tau'} + \frac{\partial u^0}{\partial \tau'}\right) & \frac{1}{2}\left(\frac{\partial u^2}{\partial \tau'} + \frac{\partial u^1}{\partial \tau'}\right) & \frac{\partial u^2}{\partial \tau'} & \frac{1}{2}\left(\frac{\partial u^2}{\partial \tau'} + \frac{\partial u^3}{\partial \tau'}\right) \\
\frac{1}{2}\left(\frac{\partial u^3}{\partial \tau'} + \frac{\partial u^0}{\partial \tau'}\right) & \frac{1}{2}\left(\frac{\partial u^3}{\partial \tau'} + \frac{\partial u^1}{\partial \tau'}\right) & \frac{1}{2}\left(\frac{\partial u^3}{\partial \tau'} + \frac{\partial u^2}{\partial \tau'}\right) & \frac{\partial u^3}{\partial \tau'}
\end{bmatrix}
-
\begin{bmatrix}
u^0 \frac{\partial \text{Ϙ}}{\partial \tau'} & 0 & 0 & 0 \\
0 & u^1 \frac{\partial \text{Ϙ}}{\partial \tau'} & 0 & 0 \\
0 & 0 & u^2 \frac{\partial \text{Ϙ}}{\partial \tau'} & 0 \\
0 & 0 & 0 & u^3 \frac{\partial \text{Ϙ}}{\partial \tau'}
\end{bmatrix}
$$

Rate of Deformation (Eq. 3)





$$D^{\alpha}_{\beta} = \begin{bmatrix} \frac{\partial u^0}{\partial x^0} & \frac{1}{2}\left(\frac{\partial u^0}{\partial x^1} + \frac{\partial u^1}{\partial x^0}\right) & \frac{1}{2}\left(\frac{\partial u^0}{\partial x^2} + \frac{\partial u^2}{\partial x^0}\right) & \frac{1}{2}\left(\frac{\partial u^0}{\partial x^3} + \frac{\partial u^3}{\partial x^0}\right) \\ \frac{1}{2}\left(\frac{\partial u^1}{\partial x^0} + \frac{\partial u^0}{\partial x^1}\right) & \frac{\partial u^1}{\partial x^1} - \frac{1}{2}\left|\frac{\partial u^0}{\partial x^1}\right|^2 d\tau' & \frac{1}{2}\left(\frac{\partial u^1}{\partial x^2} + \frac{\partial u^2}{\partial x^1}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^1}\right)\left(\frac{\partial u^0}{\partial x^2}\right)\right| d\tau' & \frac{1}{2}\left(\frac{\partial u^1}{\partial x^3} + \frac{\partial u^3}{\partial x^1}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^1}\right)\left(\frac{\partial u^0}{\partial x^3}\right)\right| d\tau' \\ \frac{1}{2}\left(\frac{\partial u^2}{\partial x^0} + \frac{\partial u^0}{\partial x^2}\right) & \frac{1}{2}\left(\frac{\partial u^2}{\partial x^1} + \frac{\partial u^1}{\partial x^2}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^2}\right)\left(\frac{\partial u^0}{\partial x^1}\right)\right| d\tau' & \frac{\partial u^2}{\partial x^2} - \frac{1}{2}\left|\frac{\partial u^0}{\partial x^2}\right|^2 d\tau' & \frac{1}{2}\left(\frac{\partial u^2}{\partial x^3} + \frac{\partial u^3}{\partial x^2}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^2}\right)\left(\frac{\partial u^0}{\partial x^3}\right)\right| d\tau' \\ \frac{1}{2}\left(\frac{\partial u^3}{\partial x^0} + \frac{\partial u^0}{\partial x^3}\right) & \frac{1}{2}\left(\frac{\partial u^3}{\partial x^1} + \frac{\partial u^1}{\partial x^3}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^3}\right)\left(\frac{\partial u^0}{\partial x^1}\right)\right| d\tau' & \frac{1}{2}\left(\frac{\partial u^3}{\partial x^2} + \frac{\partial u^2}{\partial x^3}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^3}\right)\left(\frac{\partial u^0}{\partial x^2}\right)\right| d\tau' & \frac{\partial u^3}{\partial x^3} - \frac{1}{2}\left|\frac{\partial u^0}{\partial x^3}\right|^2 d\tau' \end{bmatrix}$$

Constitutive Relation (Eq. 4)

$$T_{\mu\nu} = C^{\beta}_{\mu\nu\alpha}\, D^{\alpha}_{\beta}$$

Coupling Constant

$$\cancel{T_{\mu\nu} = E\, D_{\mu\nu}}$$

$$C^{\beta}_{\mu\nu\alpha} = \frac{c\hbar}{2}\begin{bmatrix} \frac{1}{4\pi {l_p}^2} & 0 & 0 & 0 & \cdots \\ 0 & 1 & 0 & 0 & \cdots \\ 0 & 0 & 1 & 0 & \cdots \\ 0 & 0 & 0 & 1 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \end{bmatrix}$$

Gravitational Geometry

$$D_{\beta}^{\alpha} = \begin{bmatrix} \frac{\partial u^0}{\partial x^0} & \frac{1}{2}\left(\frac{\partial u^0}{\partial x^1} + \frac{\partial u^1}{\partial x^0}\right) & \frac{1}{2}\left(\frac{\partial u^0}{\partial x^2} + \frac{\partial u^2}{\partial x^0}\right) & \frac{1}{2}\left(\frac{\partial u^0}{\partial x^3} + \frac{\partial u^3}{\partial x^0}\right) \\ \frac{1}{2}\left(\frac{\partial u^1}{\partial x^0} + \frac{\partial u^0}{\partial x^1}\right) & \frac{\partial u^1}{\partial x^1} - \frac{1}{2}\left|\frac{\partial u^0}{\partial x^1}\right|^2 d\tau' & \frac{1}{2}\left(\frac{\partial u^1}{\partial x^2} + \frac{\partial u^2}{\partial x^1}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^1}\right)\left(\frac{\partial u^0}{\partial x^2}\right)\right| d\tau' & \frac{1}{2}\left(\frac{\partial u^1}{\partial x^3} + \frac{\partial u^3}{\partial x^1}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^1}\right)\left(\frac{\partial u^0}{\partial x^3}\right)\right| d\tau' \\ \frac{1}{2}\left(\frac{\partial u^2}{\partial x^0} + \frac{\partial u^0}{\partial x^2}\right) & \frac{1}{2}\left(\frac{\partial u^2}{\partial x^1} + \frac{\partial u^1}{\partial x^2}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^2}\right)\left(\frac{\partial u^0}{\partial x^1}\right)\right| d\tau' & \frac{\partial u^2}{\partial x^2} - \frac{1}{2}\left|\frac{\partial u^0}{\partial x^2}\right|^2 d\tau' & \frac{1}{2}\left(\frac{\partial u^2}{\partial x^3} + \frac{\partial u^3}{\partial x^2}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^2}\right)\left(\frac{\partial u^0}{\partial x^3}\right)\right| d\tau' \\ \frac{1}{2}\left(\frac{\partial u^3}{\partial x^0} + \frac{\partial u^0}{\partial x^3}\right) & \frac{1}{2}\left(\frac{\partial u^3}{\partial x^1} + \frac{\partial u^1}{\partial x^3}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^3}\right)\left(\frac{\partial u^0}{\partial x^1}\right)\right| d\tau' & \frac{1}{2}\left(\frac{\partial u^3}{\partial x^2} + \frac{\partial u^2}{\partial x^3}\right) - \frac{1}{2}\left|\left(\frac{\partial u^0}{\partial x^3}\right)\left(\frac{\partial u^0}{\partial x^2}\right)\right| d\tau' & \frac{\partial u^3}{\partial x^3} - \frac{1}{2}\left|\frac{\partial u^0}{\partial x^3}\right|^2 d\tau' \end{bmatrix}$$

$$D_{\beta}^{\alpha} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) + \frac{1}{2}\left|\left(\frac{\partial u_0}{\partial x_i}\right)\left(\frac{\partial u_0}{\partial x_j}\right)\right|$$

$$D_{\beta}^{\alpha} = \frac{1}{2} g^{\alpha\gamma} \mathcal{L}_{\sigma} \boldsymbol{g} + \frac{1}{2}\left|k_i k_j\right|$$

Multiply by $g_{\alpha\gamma}$

$$D_{\beta\gamma} = K_{3D\ \beta\gamma} + \frac{1}{2}\left|k_i k_j\right| g_{\beta\gamma}$$

$$D_{\beta\gamma} = R_{\beta\gamma} + \frac{1}{2} R g_{\beta\gamma}$$

(Eq. 5)

Quantum Geometry

Analogies

Klein-Gordon:
(0,0 Term – Eq. 2)

$$\frac{\partial^2 t}{\partial {x^1}^2}+\frac{\partial^2 t}{\partial {x^2}^2}+\frac{\partial^2 t}{\partial {x^3}^2}-\frac{dP}{ic\text{Ϙ}}=\frac{1}{c^2}\frac{\partial^2 t}{\partial \tau^2}$$

Schrödinger:
(i,i Term – Eq. 2, Substitute Eq. 3 into Eq. 2 per Eq. 4)

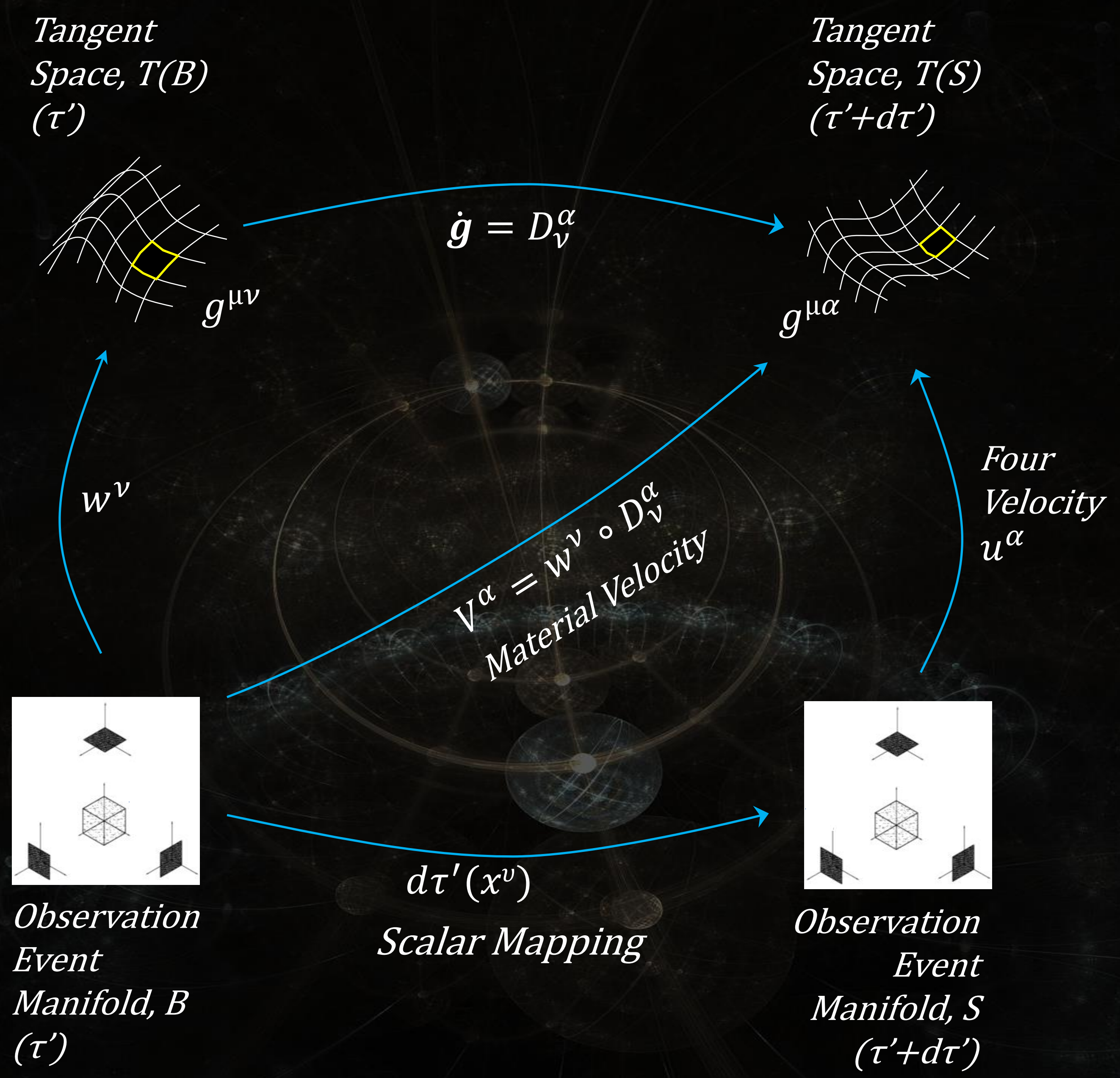
$$\frac{\hbar}{2}\frac{\partial^2 u^j}{\partial {x^j}^2}=-i\frac{\text{Ϙ}}{c^2}\frac{\partial u^j}{\partial \tau}$$

Weyl:
(i,j Term – Insert Eq. 3 & Eq. 1 into Eq. 4)

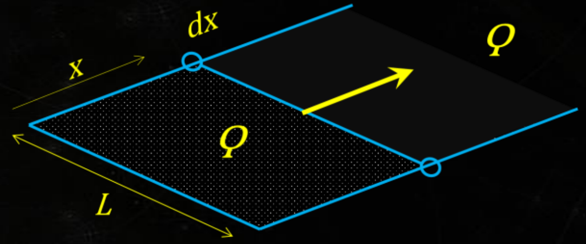
$$\frac{\partial u_1}{\partial x_2}+\frac{\partial u_2}{\partial x_1}-ic\left|\left(\frac{\partial u_0}{\partial x_1}\right)\left(\frac{\partial u_0}{\partial x_2}\right)\right|=0$$

Heisenberg:
(Eq. 4)

$$\frac{T_{jj}}{D^j_j}=\frac{c\hbar}{2} \Rightarrow d\text{Ϙ}\,d\tau=-\frac{i\hbar}{2} \Rightarrow d\text{Ϙ}^2 d\tau^2=\left(\frac{\hbar}{2}\right)^2 \Rightarrow (d\text{Ϙ}d\tau)^2 \geq \left(\frac{\hbar}{2}\right)^2$$


Tangent Space, T(B) (τ')
Tangent Space, T(S) (τ'+dτ')
$\dot{g} = D_\nu^\alpha$
$g^{\mu\nu}$
$g^{\mu\alpha}$
w^ν
$V^\alpha = w^\nu \circ D_\nu^\alpha$
Material Velocity
Four Velocity u^α
Observation Event Manifold, B (τ')
$d\tau'(x^\upsilon)$
Scalar Mapping
Observation Event Manifold, S (τ'+dτ')

Energy Relationships



$$T_{\mu\nu} = \begin{bmatrix} dP & 0 & 0 & 0 \\ 0 & -\text{Ϙ} & 0 & 0 \\ 0 & 0 & -\text{Ϙ} & 0 \\ 0 & 0 & 0 & -\text{Ϙ} \end{bmatrix}$$

The total energy, *W*, of a three-surface is,

$$W = \oiint_{\sigma} -\text{Ϙ}\,d\sigma \qquad (2)$$

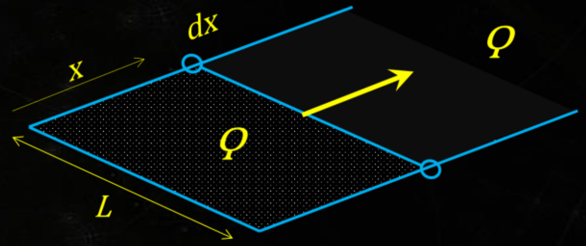
From the definition of work, the stored energy of a three volume is,

$$W = \oint_{V} dPdV \qquad (3)$$

When combined together through conservation of work and energy, (2) and (3) become,

$$\oiint_{\sigma} -\text{Ϙ}\,d\sigma = \oint_{V} dPdV \qquad (4)$$

Energy Relationships (Cont.)



$$T_{\mu\nu} = \begin{bmatrix} dP & 0 & 0 & 0 \\ 0 & -Ϙ & 0 & 0 \\ 0 & 0 & -Ϙ & 0 \\ 0 & 0 & 0 & -Ϙ \end{bmatrix}$$

According to the divergence theorem,

$$\oiint_{\sigma} Ϙ \, d\sigma = \oint_{V} (\nabla \cdot Ϙ) \, dV \qquad (5)$$

which means by direct comparison of (4) and (5),

$$\nabla \cdot Ϙ = -dP \qquad (6)$$

Differential temporal pressure (mass energy) is the spatial divergence of surface tension.

Dark Matter and Dark Energy Terms

$$T_{\mu\nu} = \left\{ \begin{matrix} dP & 0 & 0 & 0 \\ 0 & -\text{ϙ} & 0 & 0 \\ 0 & 0 & -\text{ϙ} & 0 \\ 0 & 0 & 0 & -\text{ϙ} \end{matrix} \right\}$$

$$T_{\mu\nu} = \left\{ \begin{matrix} dP + \text{ϙ} - \text{ϙ} & 0 & 0 & 0 \\ 0 & -\text{ϙ} & 0 & 0 \\ 0 & 0 & -\text{ϙ} & 0 \\ 0 & 0 & 0 & -\text{ϙ} \end{matrix} \right\}$$

$$T_{\mu\nu} = \left\{ \begin{matrix} dP + \text{ϙ} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{matrix} \right\} - \text{ϙ}\, g_{\mu\nu}$$

‘Newton’s Theory as a First Approximation’ – Revisited

$$-G\left(\frac{M}{R^2}+\frac{M}{16Rc^2}\right)=\frac{d^2x_\tau}{dt^2} \qquad (14)$$

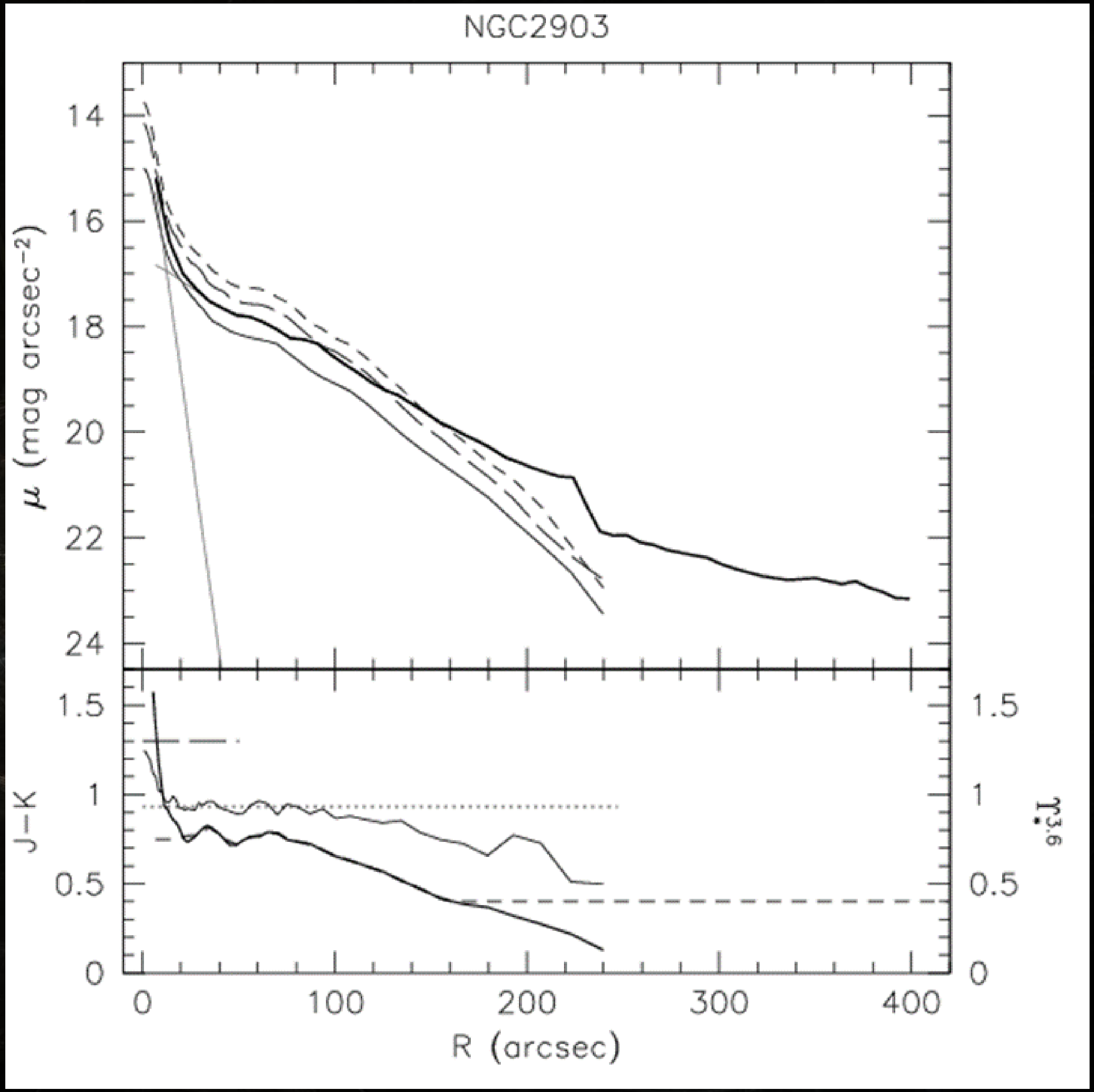
Orbital Velocity

$$v_r = \sin i \sqrt{GM\left(\frac{1}{R} + \frac{1}{16c^2}\right)} \qquad (16)$$

Properties of Select Galaxies

Galaxy	Diameter	Distance	Mass (CG)	Mass (ꝭ)	Inclination	Luminosity
	kpc	*kpc*	*Mo*	*Mo*	*deg*	*Lo*
2903	30	7600	7.10E+10	4.0E+08	62	3.87E+10
3198	35	13800	4.95E+10	2.4E+08	66	2.45E+10
M31	67	779	1.50E+12	2.7E+08	77	2.60E+10

Surface Brightness

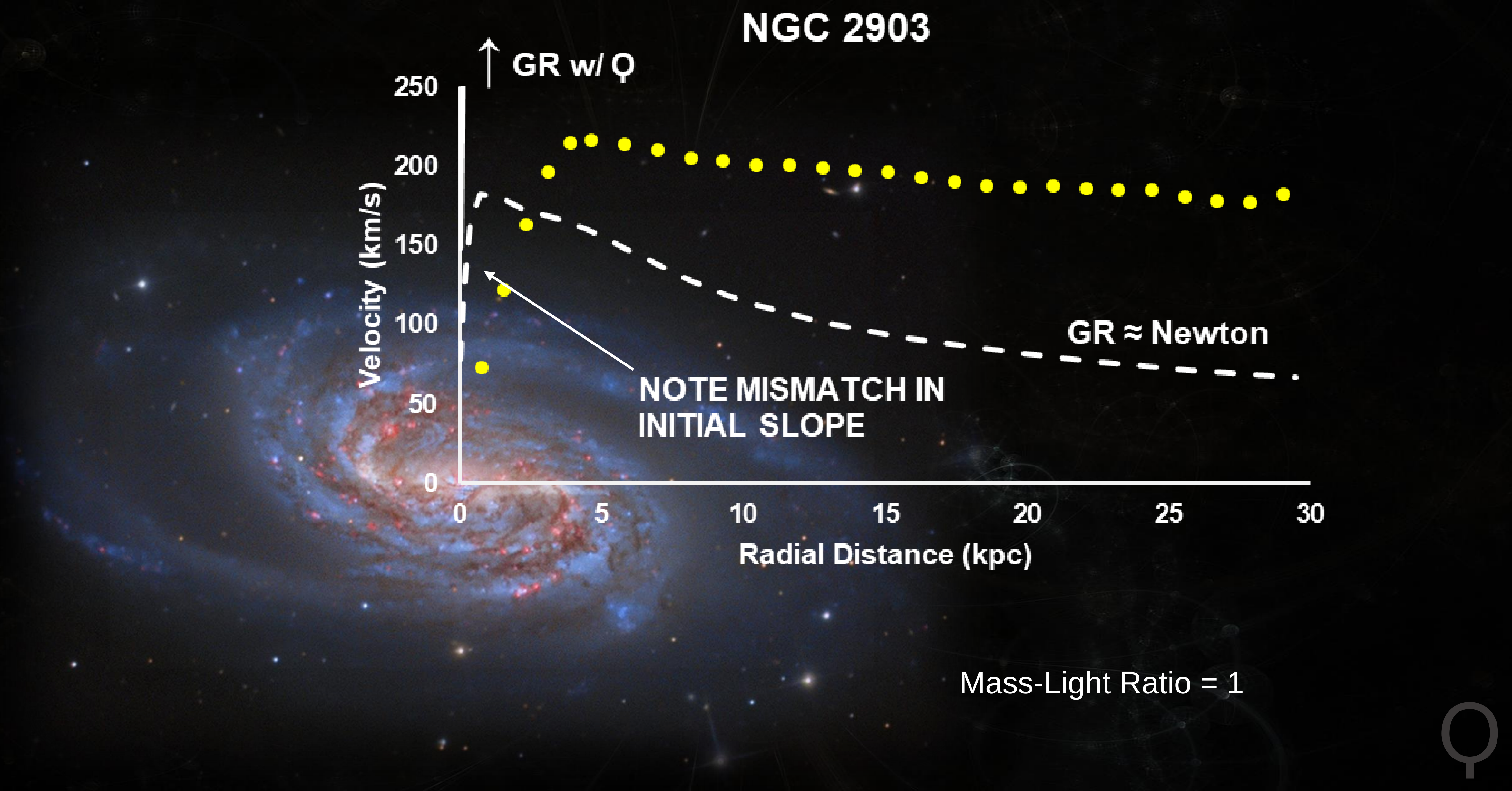


Mass from Surface Brightness

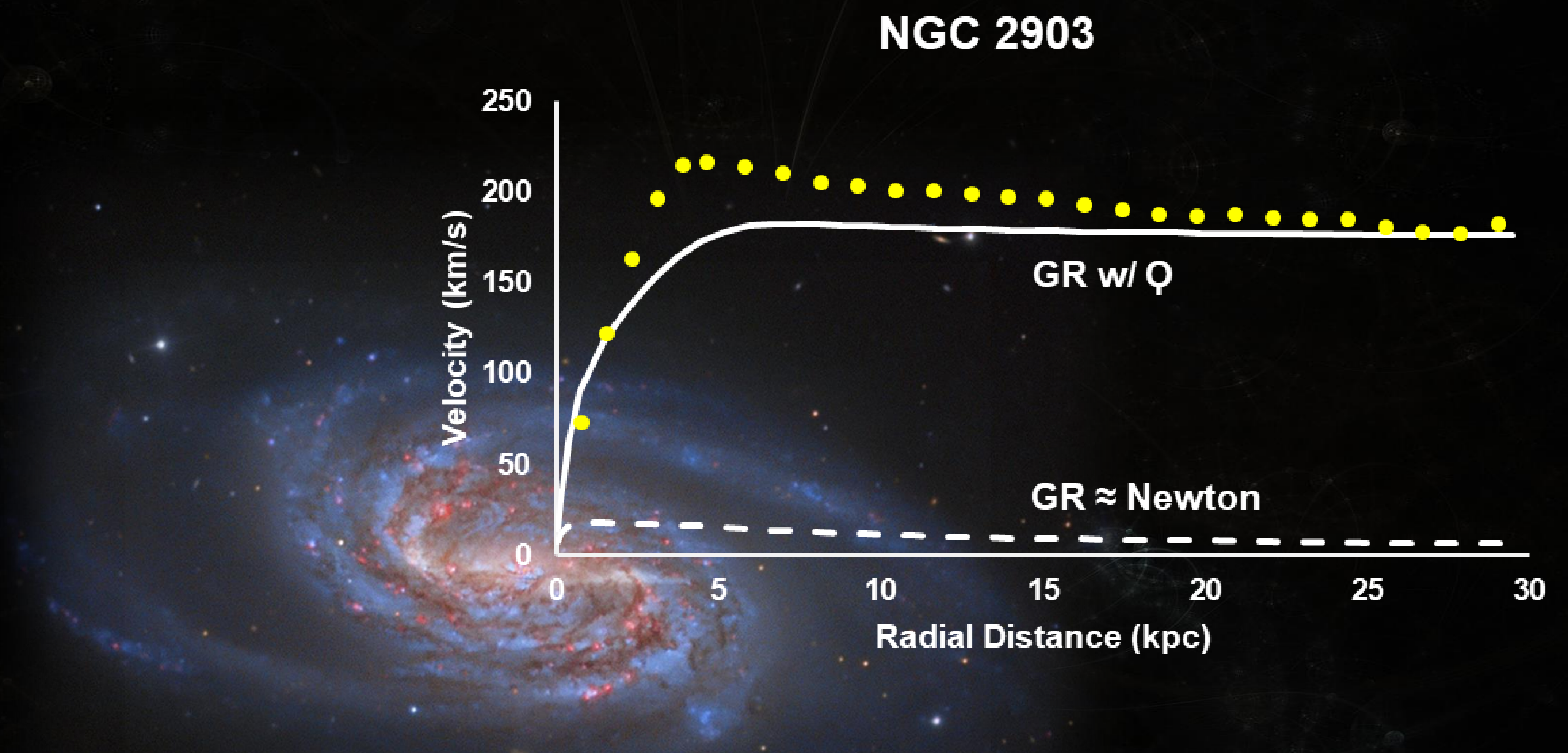
$$\mu - \mu_0 = -2.5\ \log_{10}(n) \qquad (17)$$

$$\mu_0 = 21.6 + M_0 \qquad (20)$$

$$M(R) = 2\pi\, \Upsilon M_{\odot} Cos\ i \int_0^R n(r) r dr \qquad (18)$$

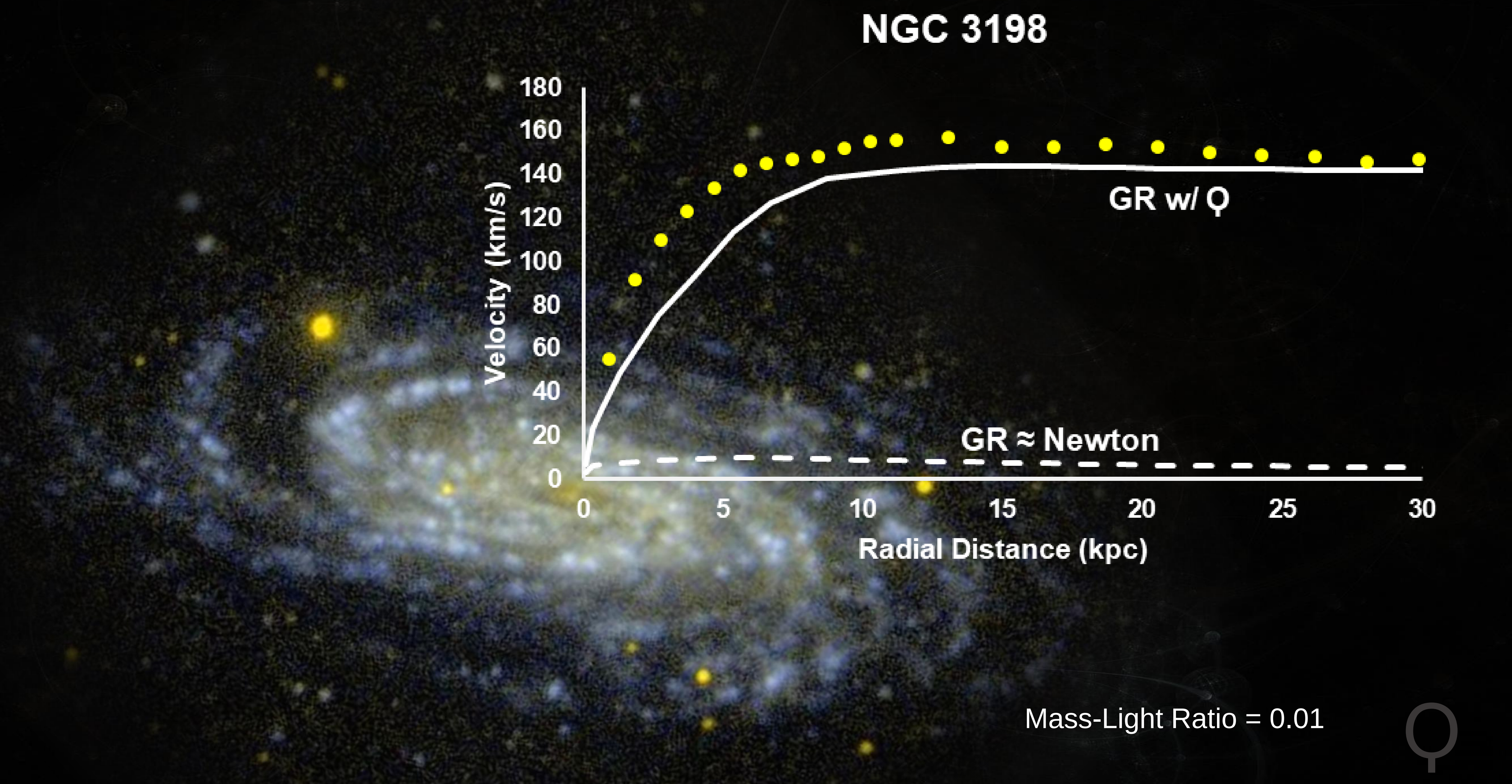


Galaxy Image ©Tony Hallas

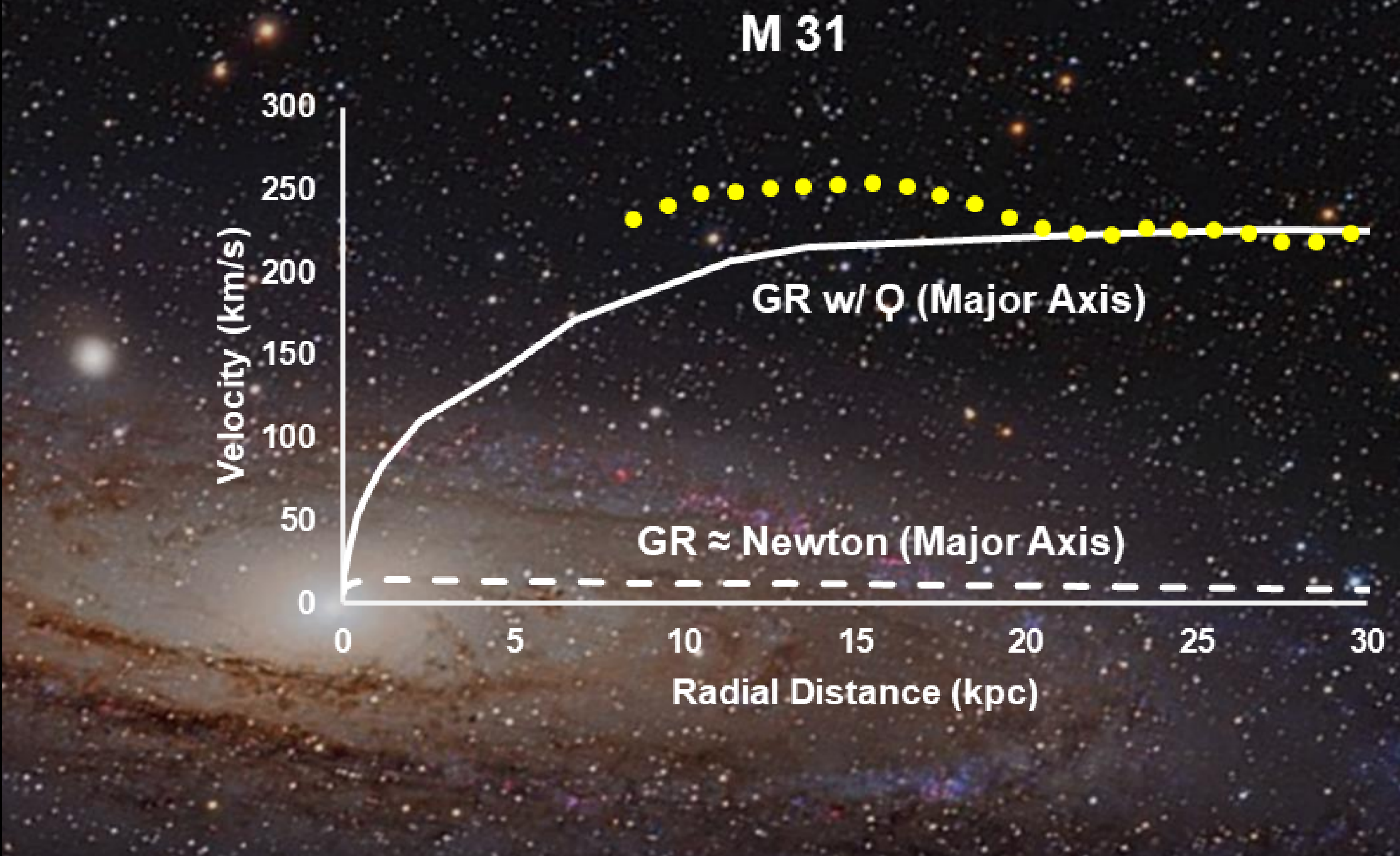


Mass-Light Ratio = 0.01

Galaxy Image ©Tony Hallas



Galaxy Image Courtesy of GALEX



Mass-Light Ratio = 0.01

Galaxy Image Courtesy of MONS.wikimedia.org

Conclusions

- The Model Consists of Stress Energy Tensor with Negative Terms in the Spatial Diagonal and a Proposed Anisotropic Coupling Tensor
- Spatial Terms in the Model Provide an Alternative ‘Quantum Mechanics’ in Geometry
- Temporal Terms in the Model Provide Gravitational Geometry that Reduces to Newton with Additional ‘Dark’ Terms
- The Additional ‘Dark’ Term is too Small to Affect Gravity at Scales of the Solar System but would Govern Galaxy Rotations
- Orbital Velocities Generated by the Model Compare Reasonably Well to Measured Galaxy Rotation Curves Provided M-L is 0.01

Next Steps

- Search for the Source of 0.01 M-L Correction
  - Is there an astrophysical reason why stars in the bulge are 100 times brighter by mass than the Sun?
  - Is there a scale correction factor that was missed in derivation of the model or its application?
- Compare Surface Tension Model to Tully-Fisher Relation
- Evaluate the Surface Tension “Dark Energy” Term in FRW Equations and Compare with Hubble Constant
- Continue to Develop and Apply the Surface Tension Model

Introducing surface tension to spacetime

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Abstract. Concepts from physical chemistry of surfaces and boundary mechanics are applied to spacetime. More specifically, matter and energy contained within an arbitrary moment in spacetime are shown to be analogous to a continuum held together by a multi-dimensional

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Gravitation in the surface tension model of spacetime

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Abstract. A mechanical model of spacetime was introduced at a prior conference for describing perturbations of stress, strain, and displacement within a metric of spacetime exhibiting surface tension. In the prior work, equations governing metric dynamics described by the model suggest

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Dark Matter and Dark Energy: Cosmology of Spacetime with Surface Tension [DRAFT]

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Abstract. A mechanical model of spacetime was introduced at a prior conference for describing perturbations of stress, strain, and displacement within a spacetime exhibiting surface tension. In the introductory presentation, it was shown that equations governing metric dynamics provide

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