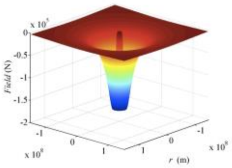
On a Heuristic Point of View Concerning the Mass of the Higgs Boson

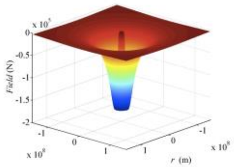
Réjean Plamondon
Département de Génie Électrique
École Polytechnique de Montréal



POLYTECHNIQUE MONTRÉAL

Research Hypothesis

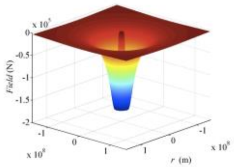
The basic hypothesis behind this talk is that if all the masses in the Universe have a common origin, through the interaction with a Higgs field, and if there is a way to bridge the gap between General Relativity and Quantum Mechanics, there must be some indirect manifestations of this phenomenon at different scales and may be some relationships could be pointed out between the different mass values as measured in this unifying representation.



POLYTECHNIQUE
MONTRÉAL

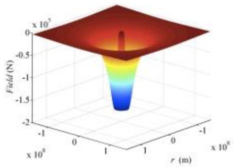
Topics

- Linking General Relativity and Quantum Mechanics
- Mass Definition and Measurement
- Predictions
- Conclusion



Topics

- Linking General Relativity and Quantum Mechanics
- Mass Definition and Measurement
- Predictions
- Conclusion

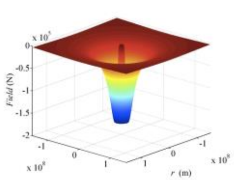


POLYTECHNIQUE MONTRÉAL

Interdependence principle

Spacetime curvature (S) and matter-energy density (E) are two inextricable information spaces defining the physically observable probabilistic universe (U); they must be mutually exploited to describe any subset U_i of this universe. The probability of observing a subset (U_i) is:

$$P(U_i) = P(S_i, E_i) < 1$$



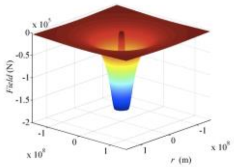
POLYTECHNIQUE
MONTRÉAL

Interdependence principle

Spacetime curvature (S) and matter-energy density (E) are two inextricable information spaces defining the physically observable probabilistic universe (U); they must be mutually exploited to describe any subset U_i of this universe. The probability of observing a subset (U_i) is:

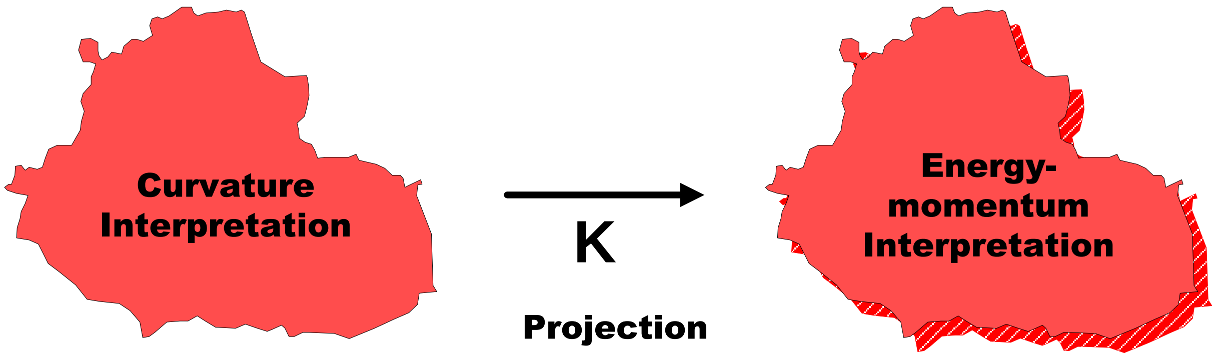
$$P(U_i) = P(S_i, E_i) < 1$$

A rephrasing of the Mach Principle

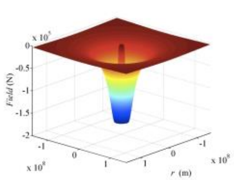


In terms of Bayes'law…

JOINT PROBABILITIES

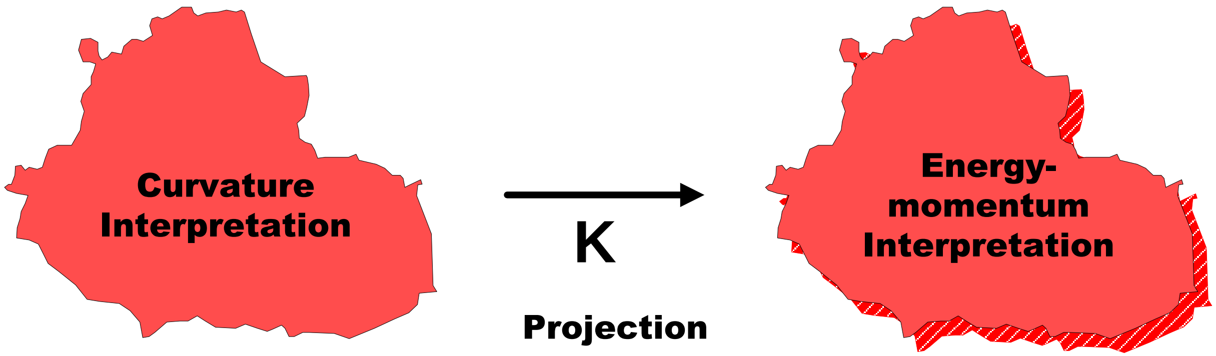


$$\mathrm{P}(U_i) = \mathrm{P}(S_i, E_i) = \mathrm{P}(S_i / E_i)\mathrm{P}(E_i) = \mathrm{P}(\mathrm{E}_i / \mathrm{S}_i) P(S_i)$$



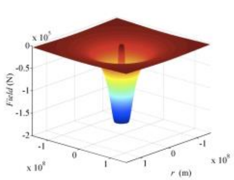
In terms of Bayes'law…

JOINT PROBABILITIES



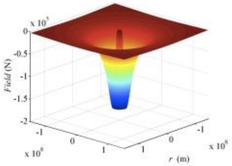
$$\mathrm{P}(U_i) = \mathrm{P}(S_i, E_i) = \mathrm{P}(S_i / E_i)\mathrm{P}(E_i) = \mathrm{P}(\mathrm{E}_i / \mathrm{S}_i)P(S_i)$$

$$G = K \ T \times f(E_i \ / \ S_i)$$



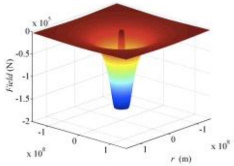
Building a star from scratch

- Adding numerous identical particles ($N \rightarrow \infty$), each one with its own wave function, density function and associated space-time, as seen from a locally flat tangent space.



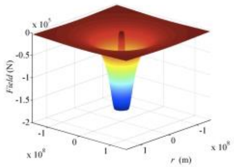
Building a star from scratch

- Adding numerous identical particles ($N \to \infty$), each one with its own wave function, density function and associated space-time, as seen from a locally flat tangent space.
- Making the convolution of their corresponding density functions.



Building a star from scratch

- Adding numerous identical particles ($N \rightarrow \infty$), each one with its own wave function, density function and associated space-time, as seen from a locally flat tangent space.
- Making the convolution of their corresponding density functions.
- The central limit theorem predicts that the ideal form of the global probability density will be a Gaussian multivariate function.



POLYTECHNIQUE MONTRÉAL

Emergence of the probability density

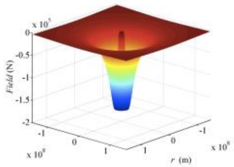
$$f(\bar{r}) = \frac{1}{4\pi^2\sigma^4}\exp\left(-\frac{\bar{r}^2}{2\sigma^2}\right) \Rightarrow \text{ External 4D Flat Space}$$

$\sigma \Rightarrow$ emergent parameter

$\sigma \Rightarrow$ intrinsic proper length of the system

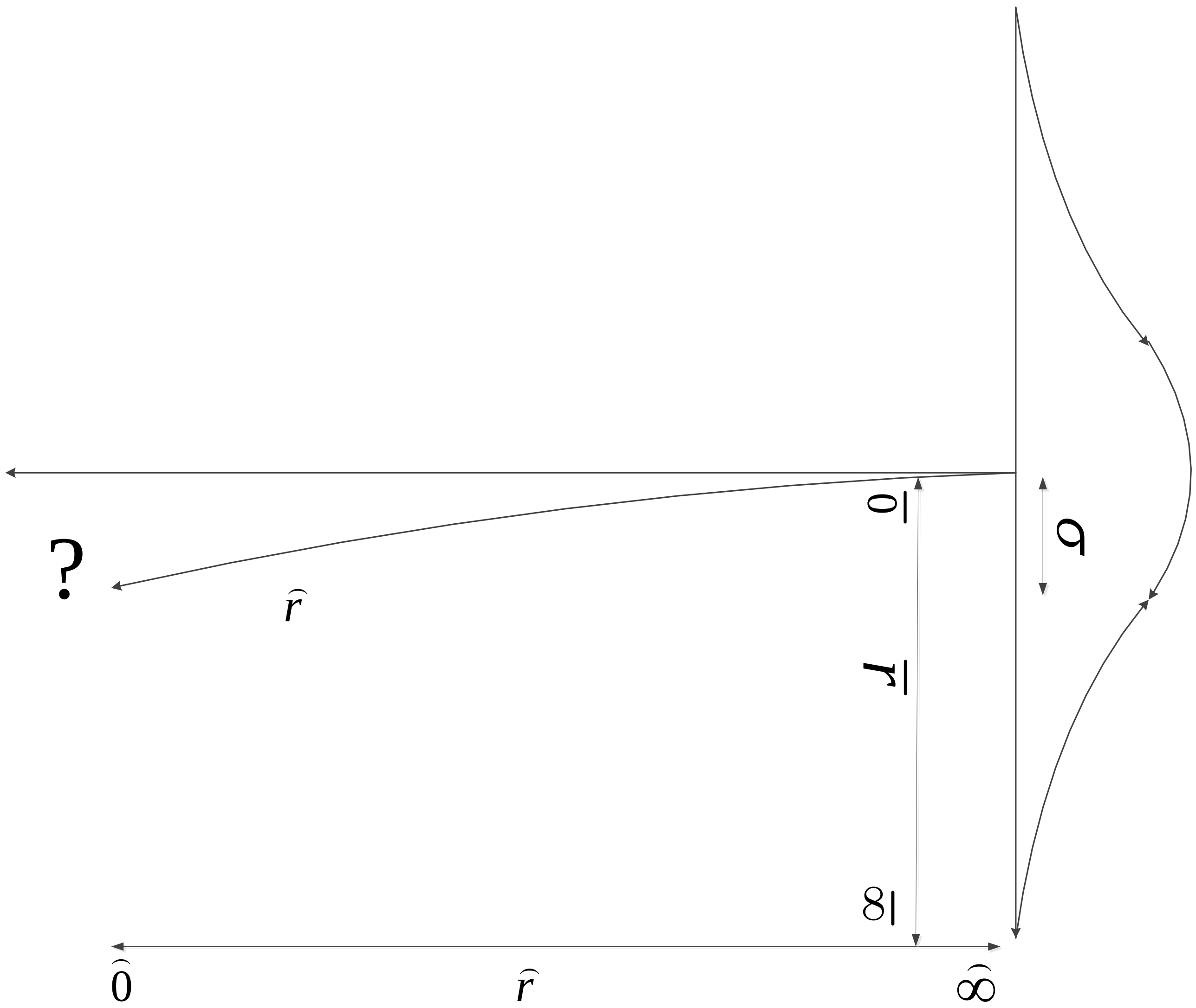
$\sigma \Rightarrow$ a range parameter, an anchor point

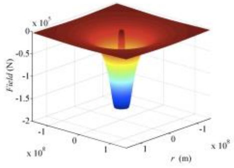
$f(\tilde{r}) \Rightarrow$ Internal curved space?



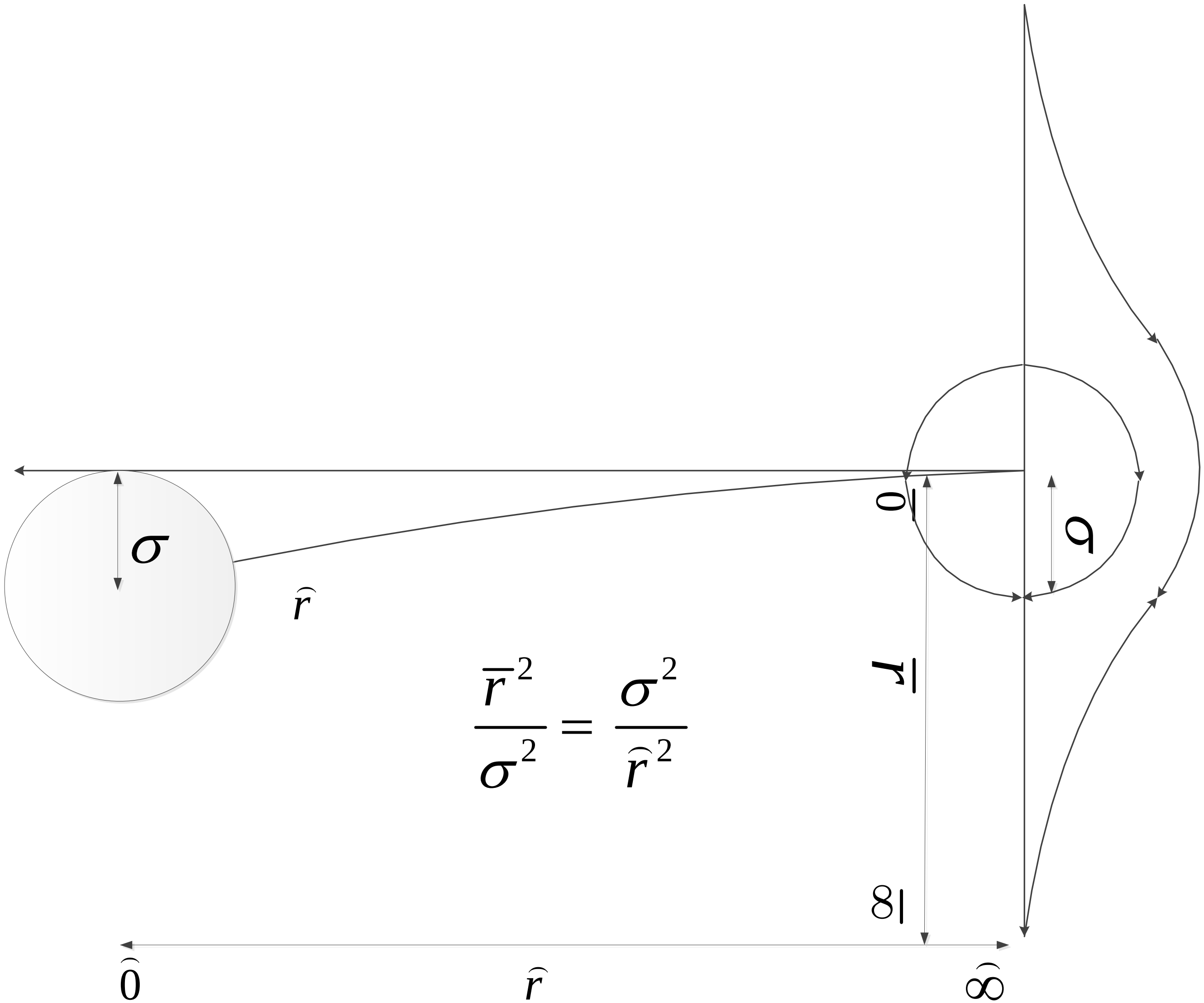
POLYTECHNIQUE MONTRÉAL

Curved vs flat space representations





Defining reference 2-spheres



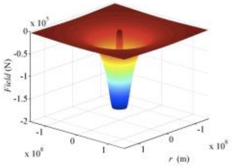
$$\frac{\bar{r}^2}{\sigma^2} = \frac{\sigma^2}{\hat{r}^2}$$

Invariance of the proper length

$$\frac{d\bar{r}}{\bar{r}} = -\frac{d\tilde{r}}{\tilde{r}}$$

$$\text{Mapping} \;\Rightarrow\; \frac{\bar{r}^2}{\sigma^2} = \frac{\sigma^2}{\widehat{r}^2}$$

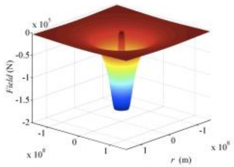
$$f(E_i / S_i) = \frac{1}{4\pi^2\sigma^2\widehat{r}^2}\exp\left(-\frac{\sigma^2}{2\widehat{r}^2}\right) \;\Rightarrow\; \text{Internal Curved Space}$$



Estimating the momentum- energy tensor

$$T_{00\;\bar{r}=\sigma} = T_{00\;\widehat{r}=\sigma} = \frac{M_{tot}c^{2}}{4\pi\sigma^{2}}$$

$$T_{00\;\widehat{r}} = \frac{M_{tot}c^{2}}{4\pi\sigma^{2}}\left(\frac{\sigma}{\widehat{r}}\right)^{3} = \frac{M_{tot}\sigma c^{2}}{4\pi\widehat{r}^{3}}$$



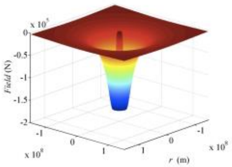
POLYTECHNIQUE
MONTRÉAL

Emergence of Newton's law of gravitation

$$R_{00} \cong \frac{1}{c^2}\nabla^2\Phi = \frac{1}{2}KT_{00}\, f(E_i \,/\, S_i)$$

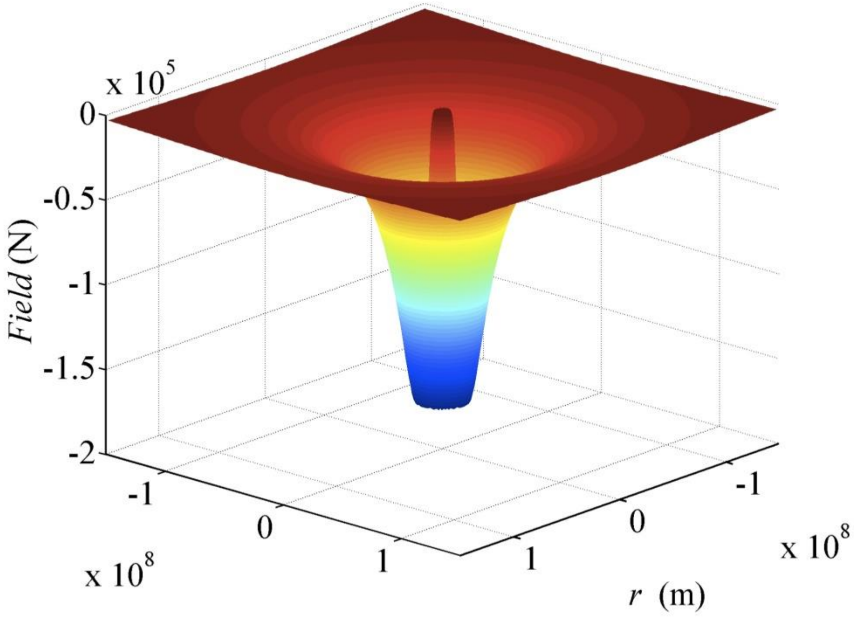
$$\nabla^2\Phi = \frac{2KMc^4\sigma^2}{4\pi\sigma^3 r^5}\exp\left(-\frac{\sigma^2}{2r^2}\right)$$

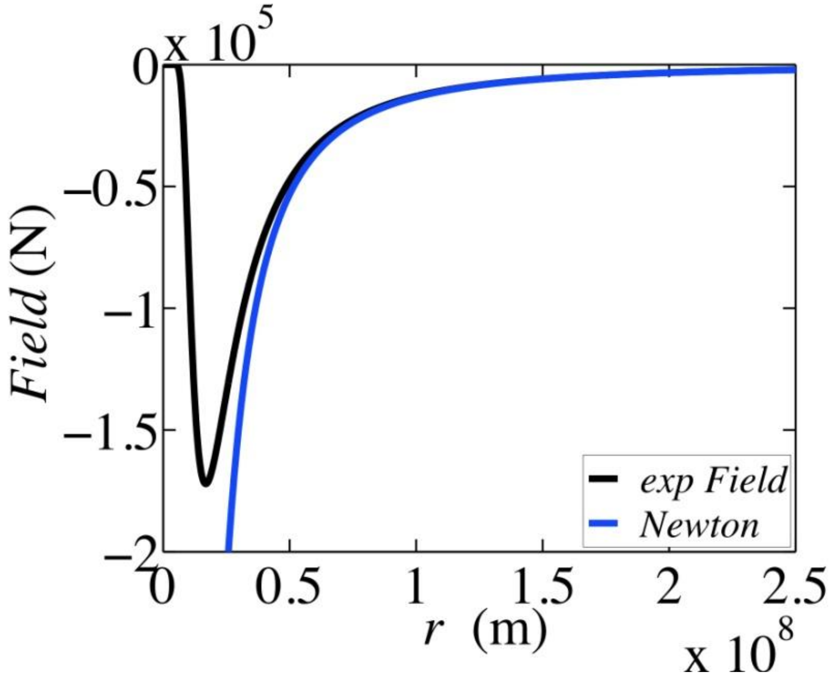
where from now on, the curved hat over the coordinate *r* is omitted.

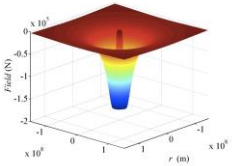


Emergence of a Modified Newton's law of gravitation

$$g(r) = -\left|\vec{\nabla}\Phi\ r\right| = -\frac{GM}{r^2}\exp\left(-\frac{\sigma^2}{2r^2}\right)$$

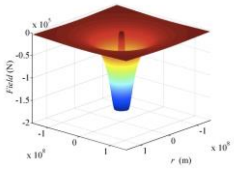




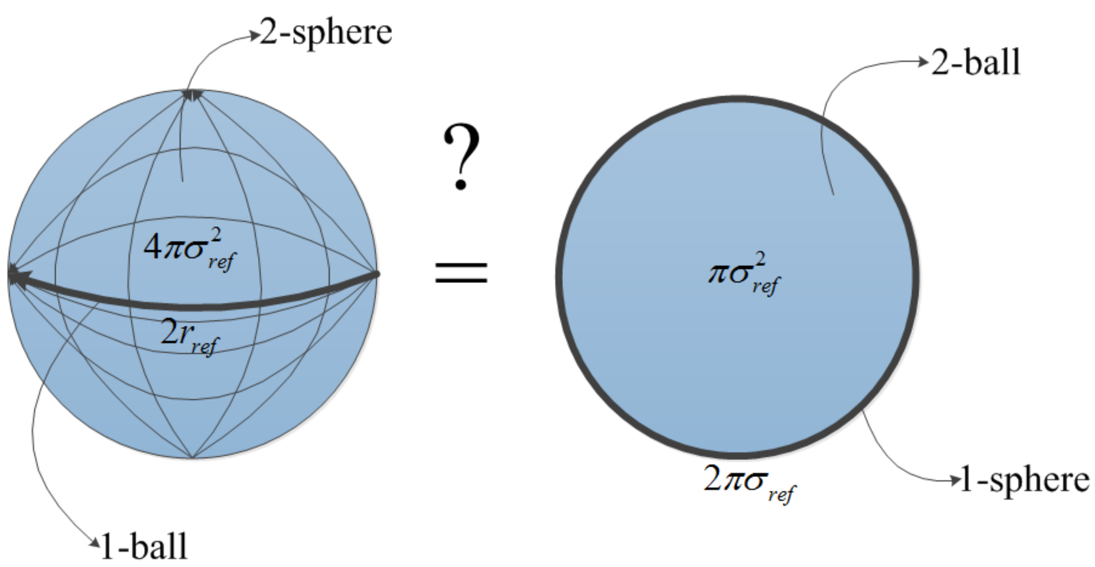


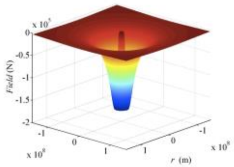
Topics

- Linking General Relativity and Quantum Mechanics
- Mass Definition and Measurement
- Predictions
- Conclusion

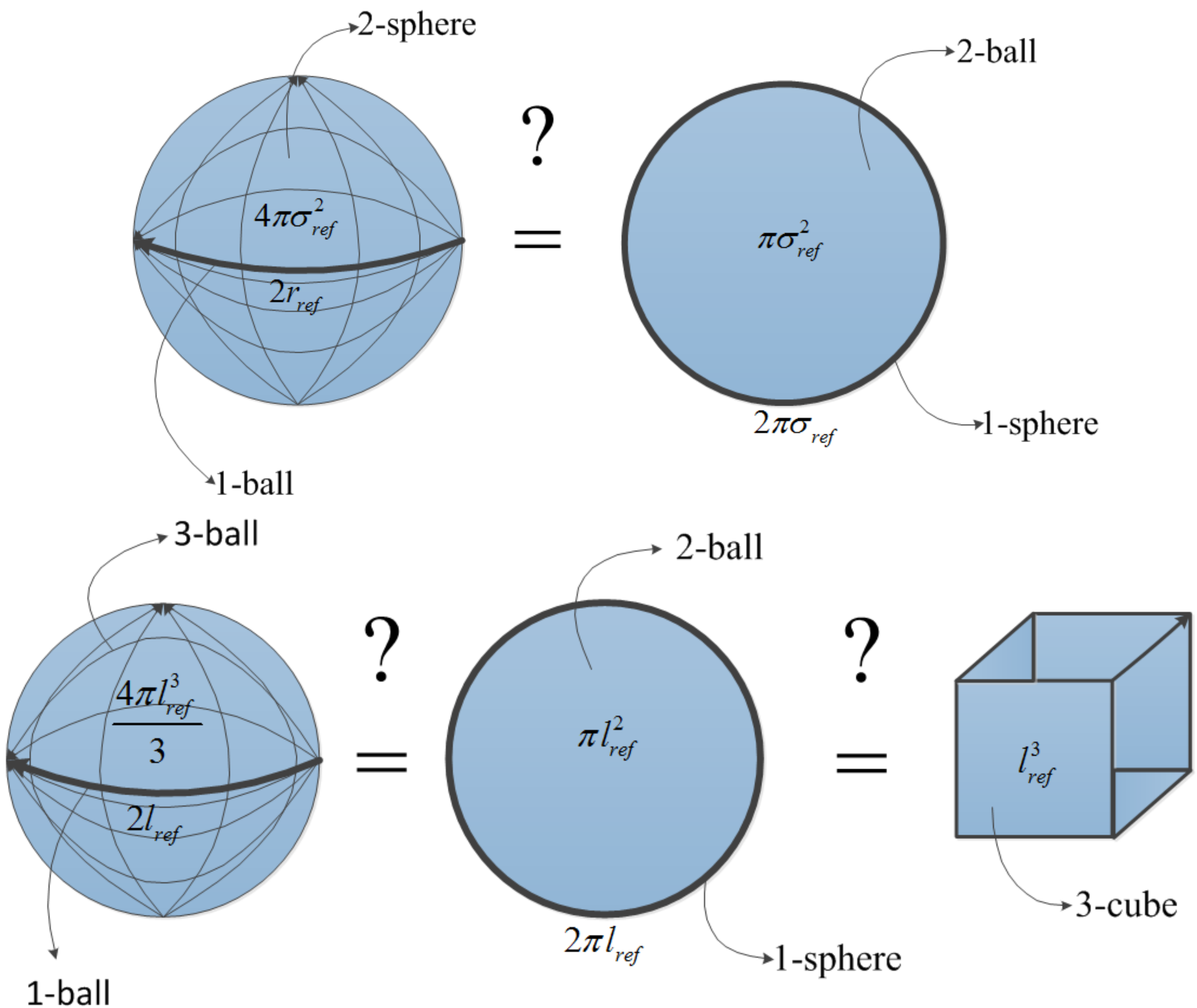


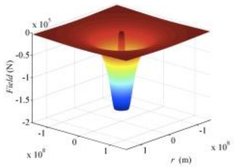
Challenges: keep coherent representations





Challenges: keep coherent representations





Once upon a time...

An observer living on a planet *P* orbiting a star, *S*, has defined a reference length unit l_{ref}

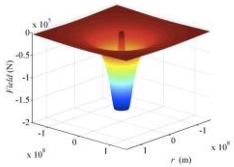
and has then used $(y\ l_{ref})^3$

to define a reference volume

in which he has poured into an amount *x* of a substance s_1,

to establish a macroscopic unit of inertial mass

$u_{im.}$



POLYTECHNIQUE MONTRÉAL

Macroscopic vs Microscopic

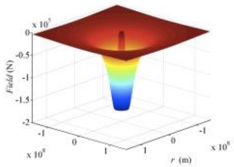
Moreover, on the same reference density basis, he has defined a microscopic unit of mass u from u_{im}:

$$u_{im} = wN_0\mathrm{u}$$

where w is a weighting factor that takes into account the plausible ratio between the arbitrary units u_{im} and u

and where N_0 is a numerical constant such that the specific mass of any substance s_x can be expressed in the macroscopic or microscopic scales using the same numerical value Z_x:

$$m_{s_x(u_{im})} = Z_x u_{im} = Z_x wN_0\mathrm{u} \Leftrightarrow m_{s_x(\mathrm{u})} = Z_x\mathrm{u}$$



Macroscopic vs Microscopic

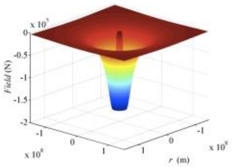
Moreover, on the same reference density basis, he has defined a microscopic unit of mass u from u_{im}:

$$u_{im} = wN_0\mathrm{u}$$

where w is a weighting factor that takes into account the plausible ratio between the arbitrary units u_{im} and u

and where N_0 is a numerical constant such that the specific mass of any substance s_x can be expressed in the macroscopic or microscopic scales using the same numerical value Z_x:

$$m_{s_x(u_{im})} = Z_x u_{im} = Z_x w N_0 \mathrm{u} \Leftrightarrow m_{s_x(\mathrm{u})} = Z_x \mathrm{u}$$



Units of volumetric mass density

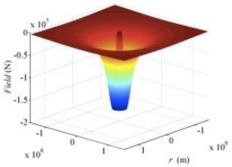
This calibration process also lead him to define a local volumetric mass reference density ρ_{ref} :

$$\rho_{ref} = \frac{u_{im}}{y^3 l_{ref}^3}$$

which de facto defined the global unit of volumetric mass reference density:

$$u_{\rho_{ref}} = \frac{u_{im}}{l_{ref}^3}$$

used in the present theory.

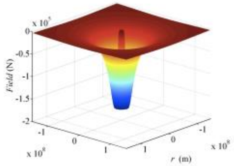


A first correction

Since this theory refers to volumes defined in $\left(l_{ref}^3\right)$, to find a mass m_1 in a system based on $\left(y^3 l_{ref}^3\right)$ will require respecting the following constraint:

$$\frac{m_1\big|_{l_{ref}^3}}{4\pi l_{ref}^2}\frac{1}{u_{\rho\ ref}} = \frac{m_1\big|_{l_{ref}^3}}{4\pi l_{ref}^2}\frac{l_{ref}^3}{u_{im}} = \frac{m_1\big|_{y^3 l_{ref}^3}}{4\pi y^2 l_{ref}^2}\frac{1}{\rho_{ref}} = \frac{m_1\big|_{y^3 l_{ref}^3}}{4\pi y^2 l_{ref}^2}\frac{y^3 l_{ref}^3}{u_{im}}$$

$$m_1\big|_{l_{ref}^3} = \frac{m_1\big|_{y^3 l_{ref}^3}}{y}$$

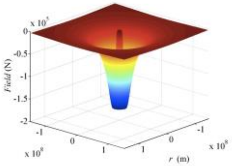


POLYTECHNIQUE MONTRÉAL

Global unit of volumetric mass density

The global unit of volumetric mass density can be recovered from any substance s_x of inertial mass expressed in u_{im} and volume expressed in l_{ref}^3 using:

$$u_{\rho_{ref}} = \frac{m_{s_x(u_{im})}}{V_{s_x(l_{ref}^3)}} \text{ with } \left|m_{s_x}\right| = \left|V_{s_x}\right| \text{ numerically}$$

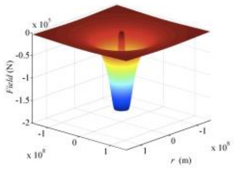


POLYTECHNIQUE MONTRÉAL

Mass relationships

In the context of the definition of the volumetric mass density unit $u_{\rho_{ref}}$ which is substance independent and based on any unitary inertial mass to volume ratio, various relationships among inertial masses measured in the star system can be pointed out:

$$u_{\rho_{ref}} = \text{constant} \Rightarrow m_{i1} = \frac{m_{i2} m_{i3}}{m_{i4}} \text{ if } \frac{V_1 V_4}{V_2 V_3} = 1$$



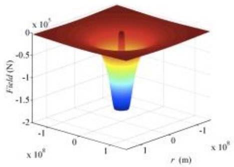
A Modified Gravitational Field

According to a recent Bayesian model, the observer's planet could be seen, in a curved spacetime representation, under low speed, weak field conditions, as attracted by a modified gravitation field:

$$\vec{g}_M = \frac{GM_{gS}}{r_{PS}^2} \exp\left(-\frac{\sigma_S^2}{2r_{PS}^2}\right)\vec{u}_r$$

where σ_S

is a range parameter representing the proper length of the star, that is the intrinsic scale of the star system.

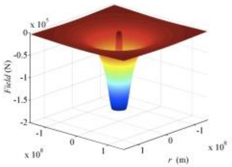


A mandatory correction

In this context, the interaction between a test mass m_1 and a source mass m_2 in both N and M representations will respect the following constraint:

$$m_{1gN} m_{2gN} = m_{1gM}\Big|_{\sigma_1=0} m_{2gM}\Big|_{\sigma_2=0}$$

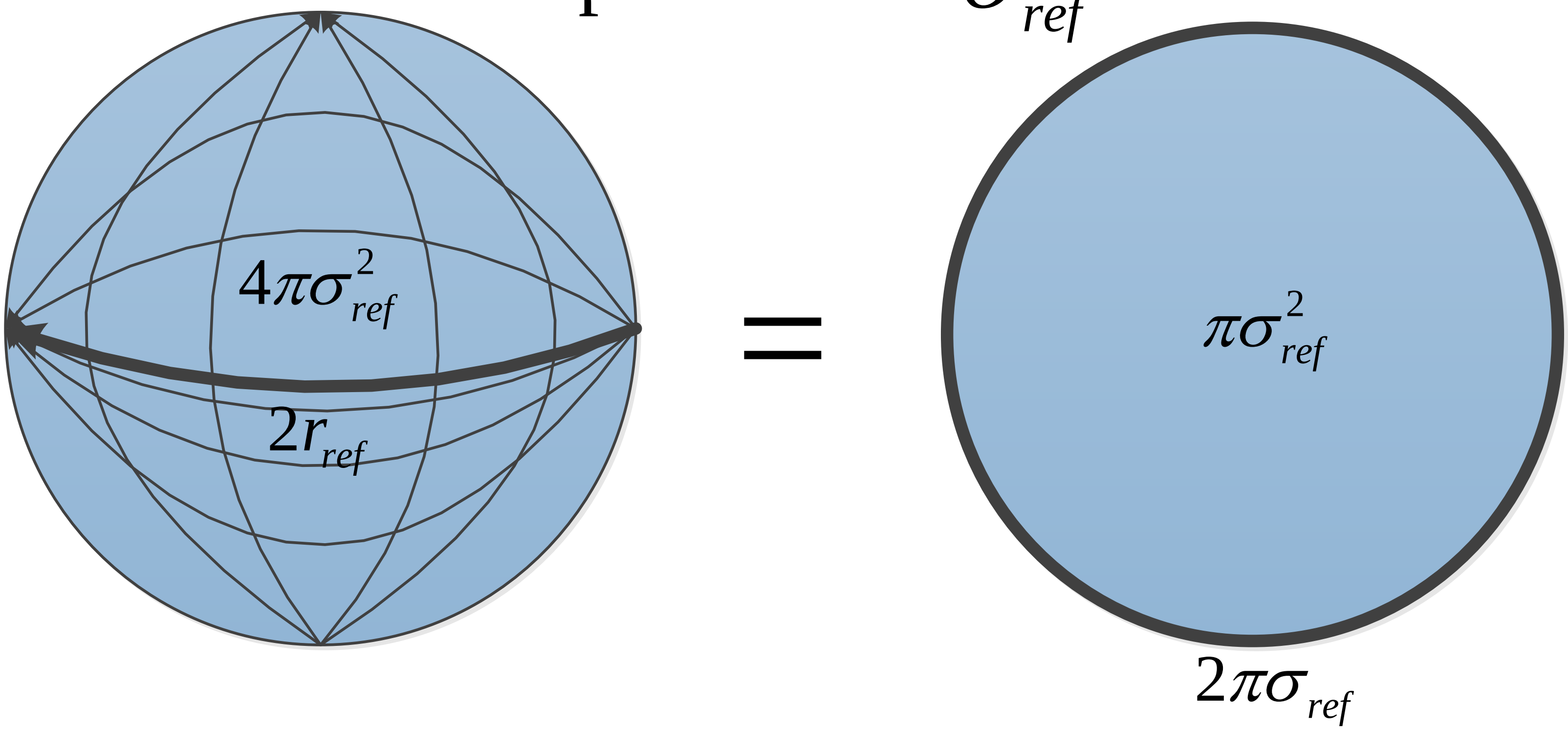
$$m_{1iN} m_{2iN} = m_{1gM}\Big|_{\sigma_1=0} \exp\left(-\frac{\sigma_1^2}{2r^2}\right) m_{2gM}\Big|_{\sigma_2=0} \exp\left(-\frac{\sigma_2^2}{2r^2}\right)$$



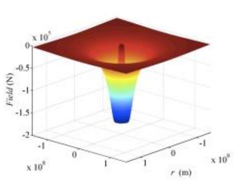
POLYTECHNIQUE MONTRÉAL

Heuristics

Define all inertial mass on the same relative scale, independent of σ_{ref}



$$\frac{2r_{ref}}{4\pi\sigma_{ref}^2} = \frac{2\pi\sigma_{ref}}{\pi\sigma_{ref}^2} \Rightarrow r_{ref} = 4\pi\sigma_{ref}$$



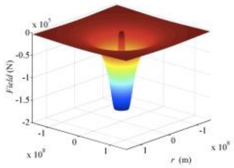
A mandatory correction

In this context, the interaction between a test mass m_1 and a source mass m_2 in both N and M representations will respect the following constraint:

$$m_{1gN} m_{2gN} = m_{1gM}\Big|_{\sigma_1=0} m_{2gM}\Big|_{\sigma_2=0}$$

$$m_{1iN} m_{2iN} = m_{1gM}\Big|_{\sigma_1=0} \exp\left(-\frac{1}{32\pi^2}\right) m_{2gM}\Big|_{\sigma_2=0} \exp\left(-\frac{1}{32\pi^2}\right)$$

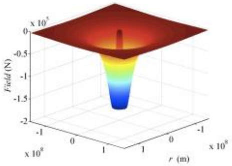
$$m_{2iN} = \frac{m_{1gN}}{m_{1iN}} m_{2gN} \exp\left(-\frac{1}{16\pi^2}\right)$$



Summary

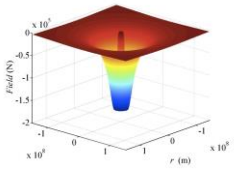
$$m_1\Big|_{l_{ref}^3} = \frac{m_1\Big|_{y^3 l_{ref}^3}}{y}$$

$$m_{2iN} = m_{2gN} \exp\left(-\frac{1}{16\pi^2}\right)$$



Topics

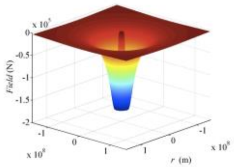
- Linking General Relativity and Quantum Mechanics
- Mass Definition and Measurement
- Predictions
- Conclusion



Basic premise

The whole *M* representation relies on a basic premise: the preservation of the volumetric mass density unit $u_{\rho_{ref}}$, throughout the various spacetime projections that are necessary to model and understand a physical phenomenon.

$$u_{\rho_{ref}} = \text{constant} \Rightarrow m_{i1} = \frac{m_{i2} m_{i3}}{m_{i4}} \text{ if } \frac{V_1 V_4}{V_2 V_3} = 1$$



P1: minimal reference test mass

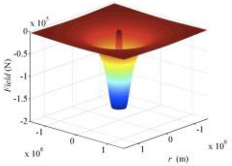
Fixing:

$$m_{i1} = m_{iref\ \min}\Big|_{l_{ref}^3} = \frac{m_{iref\ \min}\Big|_{y^3 l_{ref}^3}}{y}$$

$$m_{i2} = u_{im}$$

$$m_{i3} = m_{is1}$$

$$m_{i4} = M_{gS} \exp\left(-1/16\pi^2\right)$$



P1: minimal reference test mass

Fixing:

$$m_{i1} = m_{iref\,\min}\Big|_{l_{ref}^3} = \frac{m_{iref\,\min}\Big|_{y^3 l_{ref}^3}}{y}$$

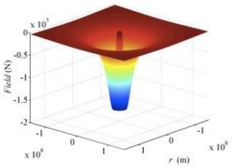
$$m_{i2} = u_{im}$$

$$m_{i3} = m_{is1}$$

$$m_{i4} = M_{gS}\exp\left(-1/16\pi^2\right)$$

one gets:

$$m_{iref\,\min}\Big|_{y^3 l_{ref}^3} = \frac{y u_{im} m_{is_1}}{M_{gS}\exp\left(-\frac{1}{16\pi^2}\right)}$$



POLYTECHNIQUE MONTRÉAL

To fix the ideas

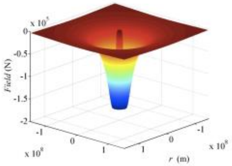
$$M_P = M_{Earth} = 5.98 \times 10^{24}\,\text{kg}$$

$$M_{gS} = M_{Sun} = 1.99 \times 10^{30}\,\text{kg}$$

$$m_{is_1} = m_{H_2O} = 18.01528\ \text{kg}$$

$$u_{im} = 1\text{kg} \Rightarrow w = 1\text{kg}/1\text{g} = 1000$$

$$y = 1dm / 1m = 0.1$$



To fix the ideas

$$M_P = M_{Earth} = 5.98 \times 10^{24}\,\text{kg}$$

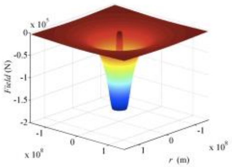
$$M_{gS} = M_{Sun} = 1.99 \times 10^{30}\,\text{kg}$$

$$m_{is_1} = m_{H_2O} = 18.01528\ \text{kg}$$

$$u_{im} = 1\text{kg} \Rightarrow w = 1\text{kg}/1\text{g} = 1000$$

$$y = 1dm / 1m = 0.1$$

$$m_{iref\,\min}\Big|_{y^3 l_{ref}^3} = 9.11(0562450) \times 10^{-31}\,\text{kg} \cong m_{electron}$$



P2: maximal minimal gravitational reference test mass

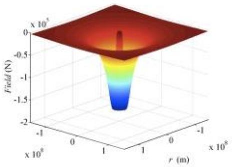
Fixing:

$$m_{i1} = m_{gref\,\max\min}\Big|_{y^3 l_{ref}^3}$$

$$m_{i2} = u_{mi}$$

$$m_{i3} = m_{iref\,\min}\Big|_{l_{ref}^3}$$

$$m_{i4} = M_{gP}$$



P2: maximal minimal gravitational reference test mass

Fixing:

$$m_{i1} = m_{gref\,\max\min}\Big|_{y^3 l_{ref}^3}$$

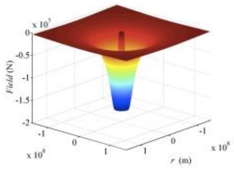
$$m_{i2} = u_{mi}$$

$$m_{i3} = m_{iref\,\min}\Big|_{l_{ref}^3}$$

$$m_{i4} = M_{gP}$$

one gets:

$$m_{gref\,\max\min}\Big|_{y^3 l_{ref}^3} = \frac{y^2 u_{im}^2}{M_{gP}}$$



P2: maximal minimal gravitational reference test mass

Fixing:

$$m_{i1} = m_{gref\ \max\min}\Big|_{y^3 l_{ref}^3}$$

$$m_{i2} = u_{mi}$$

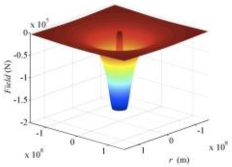
$$m_{i3} = m_{iref\ \min}\Big|_{l_{ref}^3}$$

$$m_{i4} = M_{gP}$$

one gets:

$$m_{gref\ \max\min}\Big|_{y^3 l_{ref}^3} = \frac{y^2 u_{im}^2}{M_{gP}}$$

$$m_{gref\ \max\min}\Big|_{y^3 l_{ref}^3} = 1.67(2240803)\times 10^{-27}\,\text{kg} \cong m_{proton}$$

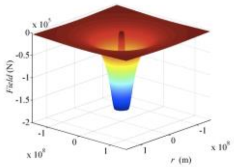


POLYTECHNIQUE MONTRÉAL

P3: maximal minimal inertial reference source mass

$$m_{iref\ \max\min M} = m_{gref\ \max\min M} \exp\left(-\frac{1}{16\pi^2}\right)$$

$$= \frac{y^2 u_{im}^2}{M_{gP}} \exp\left(-\frac{1}{16\pi^2}\right)$$

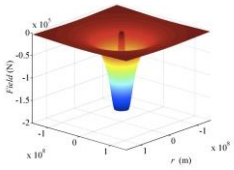


P3: maximal minimal inertial reference source mass

$$m_{iref\ \mathrm{max\,minM}} = m_{gref\ \mathrm{max\,minM}} \exp\left(-\frac{1}{16\pi^2}\right)$$

$$= \frac{y^2 u_{im}^2}{M_{gP}} \exp\left(-\frac{1}{16\pi^2}\right)$$

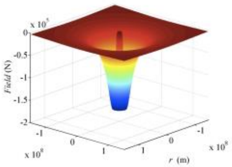
$$m_{iref\ \mathrm{max\,min}}\Big|_{y^3 l_{ref}^3} = 1.66(1684673)\times 10^{-27}\,\mathrm{kg} \cong \mathrm{u}$$



P4: invariant mass scale factor

Finally, since:

$$u = \frac{u_{im}}{wN_0}$$



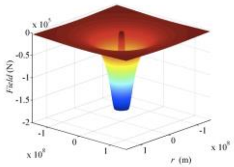
P4: invariant mass scale factor

Finally, since:

$$u = \frac{u_{im}}{wN_0}$$

This leads to:

$$N_0 = \frac{M_{gP}}{wy^2 u_{im}} \exp\left(\frac{1}{16\pi^2}\right)$$



POLYTECHNIQUE MONTRÉAL

P4: invariant mass scale factor

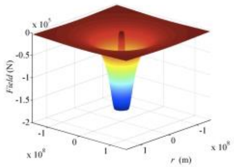
Finally, since:

$$\mathrm{u} = \frac{u_{im}}{wN_0}$$

This leads to:

$$N_0 = \frac{M_{gP}}{wy^2 u_{im}} \exp\left(\frac{1}{16\pi^2}\right)$$

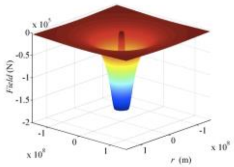
$$N_0 = 6.01(7988949) \times 10^{23} \cong N_A$$



The local reference mass?

Finally, the observer can presume the existence of a local mass reference $m_{iref\,.loc}$

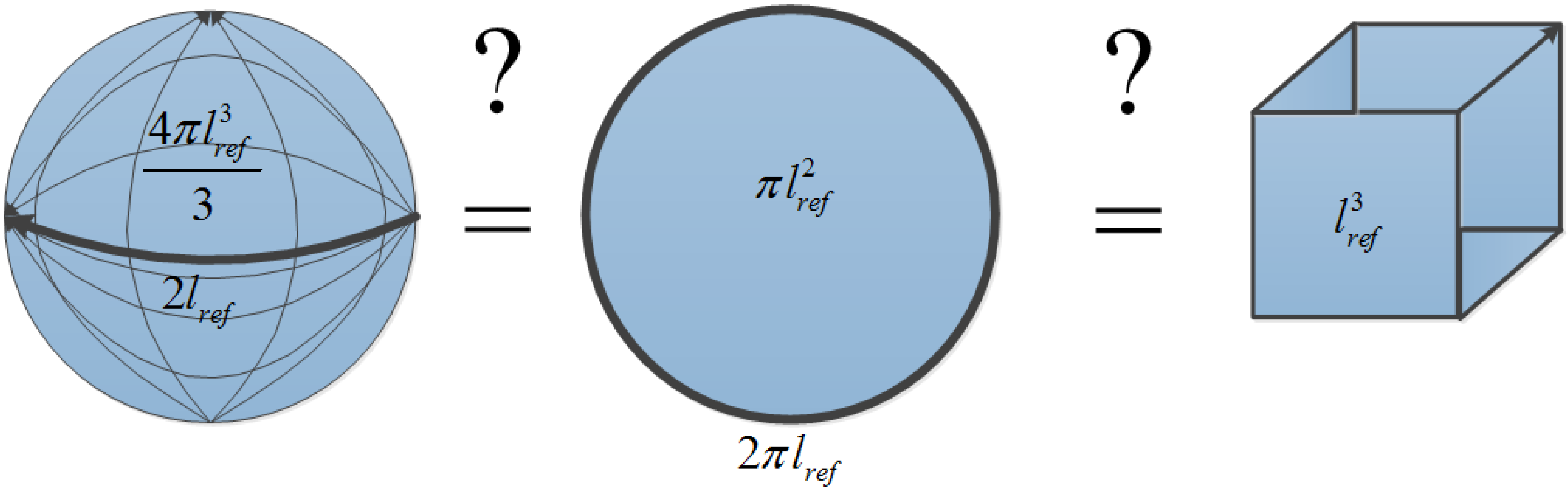
that can bring any mass measurements with respect to his own planet data considered as a source mass, once the proper projections between the 1D kinematic observation space and 3D mass densities, all expressed in u_{im} unit, are taken into account:



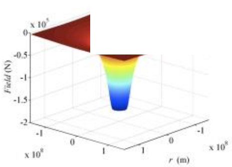
POLYTECHNIQUE MONTRÉAL

Heuristics

Maintaining a correspondence between the relative linear and volumic densities



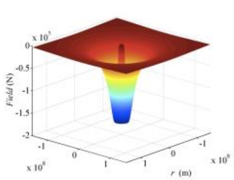
$$\frac{m_{iref.loc}}{2l_{ref}} \times \frac{2\pi l_{ref}}{u_{im}} = \frac{u_{im}}{l_{ref}^3} \times \frac{4\pi l_{ref}^3}{3M_{gP}\exp\left(-\frac{1}{16\pi^2}\right)}$$



P5: local reference mass

In other words, the local mass reference can be defined as:

$$m_{iref.loc} = \frac{4}{3} \frac{u_{im}^2}{M_{gP} \exp\left(-\frac{1}{16\pi^2}\right)}$$



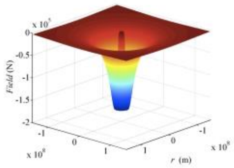
POLYTECHNIQUE MONTRÉAL

P5: local reference mass

In other words, the local mass reference can be defined as:

$$m_{iref.loc} = \frac{4}{3} \frac{u_{im}^2}{M_{gP} \exp\left(-\frac{1}{16\pi^2}\right)}$$

$$m_{iref.loc} = 2.24(381866) \times 10^{-25} \text{kg}$$



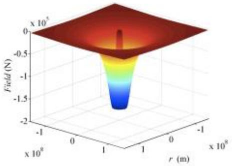
P5: local reference mass

In other words, the local mass reference can be defined as:

$$m_{iref.loc} = \frac{4}{3}\frac{u_{im}^2}{M_{gP}\exp\left(-\frac{1}{16\pi^2}\right)}$$

$$m_{iref.loc} = 2.24(381866)\times 10^{-25}\,\text{kg}$$

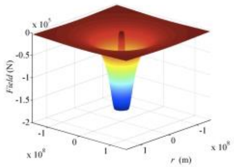
$$m_{iref.loc} = (125.869\,\text{Gev}) \cong m_{Higgs}$$



POLYTECHNIQUE MONTRÉAL

Concluding Remark

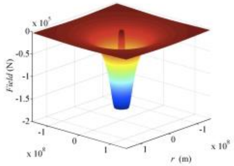
Using the modified gravitational model, derived from a potential link between General Relativity and Quantum Mechanics, and taking into account the various projections that are required to perform mass and density measurements respecting the star proper length , as well as considering the physical environment and the specific context in which these estimates are made, interesting numerical patterns among some mass references can be pointed out, which is in line with the hypothesis of mass common origin.



Concluding Remark

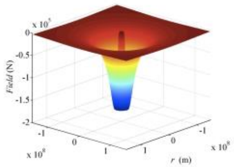
Once instantiated with the Sun-Earth data, these predictions seem to be quite consistent with the numerical values measured on Earth. Among other things, the mass of the Higgs boson appears as a condition that maintains the relative linear and volumic densities among the various mass definitions:

$$m_{Higgs} = \frac{4}{3}\frac{(1kg)^2}{M_{Earth}\exp\left(-1/16\pi^2\right)} = \frac{4}{3}\frac{m_{proton}}{y^2\exp\left(-1/16\pi^2\right)}$$



Concluding Remark

The overall process provides a practical criterion to evaluate the consistency of a system of mass units in a two body system, made up of a planet *P* and a star S:

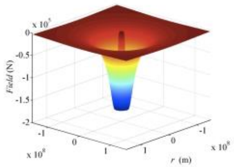


POLYTECHNIQUE MONTRÉAL

Concluding Remark

The overall process provides a practical criterion to evaluate the consistency of a system of mass units in a two body system, made up of a planet *P* and a star S:

$$\left[m_{gref\,\mathrm{max\,min}}\Big|_{y^3 l_{ref}^3} M_{gP} \right]^{1/2} = \frac{m_{iref\,\mathrm{min}}\Big|_{y^3 l_{ref}^3} M_S}{m_{s_1}} \exp\left(-\frac{1}{16\pi^2} \right) = yu_{im}$$



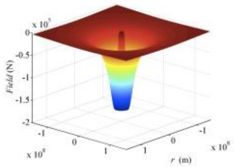
POLYTECHNIQUE MONTRÉAL

Concluding Remark

The overall process provides a practical criterion to evaluate the consistency of a system of mass units in a two body system, made up of a planet *P* and a star S:

$$\left[m_{gref\,\max\min}\Big|_{y^3 l_{ref}^3} M_{gP} \right]^{1/2} = \frac{m_{iref\,\min}\Big|_{y^3 l_{ref}^3} M_S}{m_{s_1}} \exp\left(-\frac{1}{16\pi^2}\right) = y u_{im}$$

which maintains the coherence between the macroscopic and microscopic description of the system.



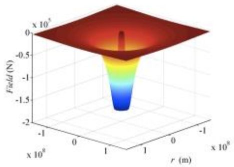
To investigate further…

A brief survey of the whole approach regarding emerging patterns:

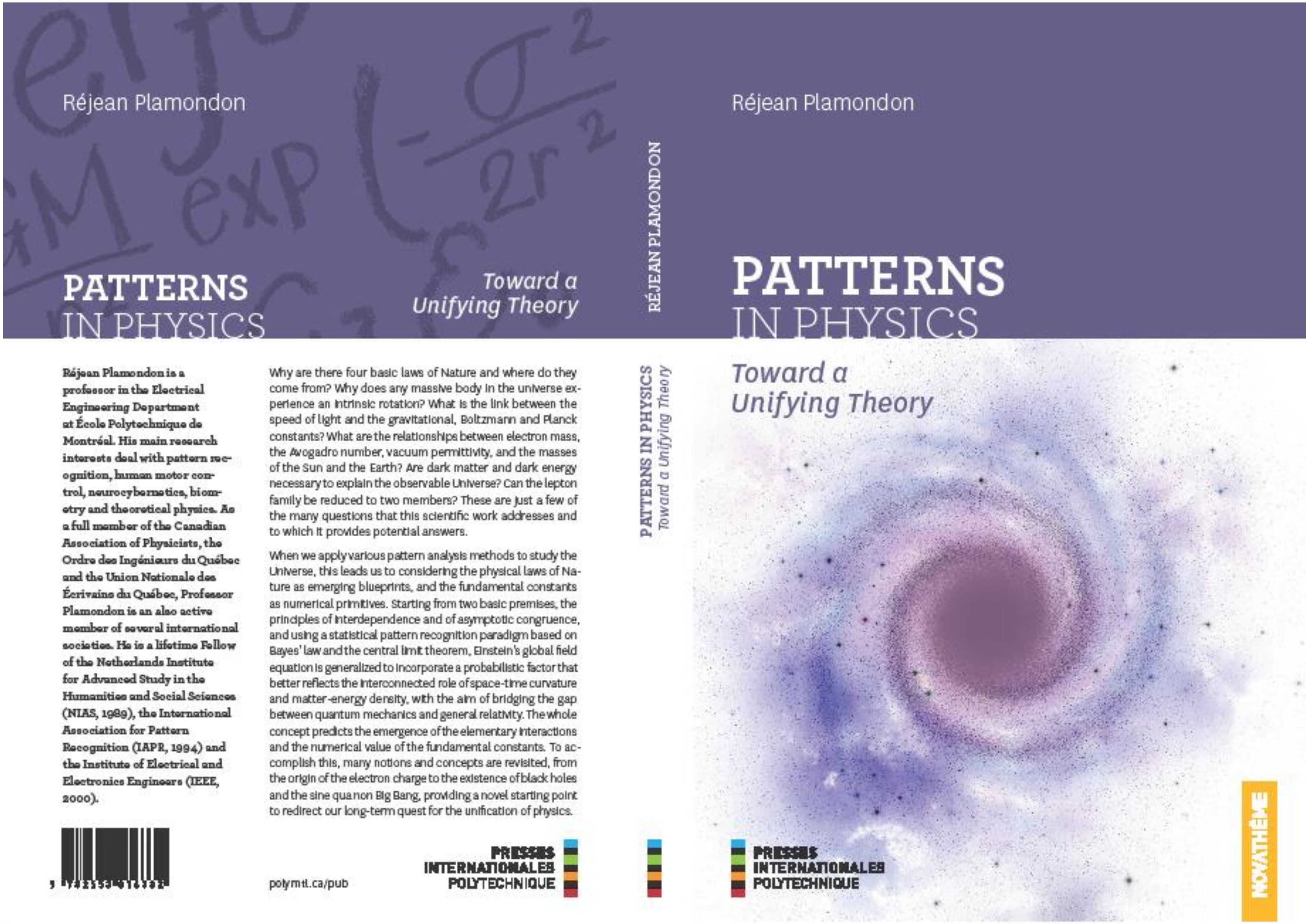
Pattern Recognition 47 (2014) 929–944

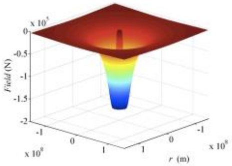
“Strokes against stroke—strokes for strides”

Réjean Plamondon, Christian O'Reilly, and Claudéric Ouellet-Plamondon.



To go deeper…





POLYTECHNIQUE MONTRÉAL

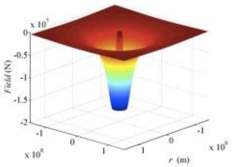
On a Heuristic Point of View Concerning the Mass of the Higgs Boson

Réjean Plamondon

Département de Génie Électrique

École Polytechnique de Montréal

Questions?



POLYTECHNIQUE MONTRÉAL