Primordial non-Dirac monopole gives first exact Geon with relevance to BICEP

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Abstract

Geons are particle-like electrovacua. Proposed as a proper first example is a 2-scale family $\mathcal{G}$ of (solitonic squashed-$S^3 \times \mathbb{R}$ pp-wave) monopole with primordial electric or magnetic Q/r^2 ($r \geq r_o$) field and higher moments, spin, NUT-like charge $\kappa|Q| = 2r_o$ as a diameter of elementary size, plus independently scaled mass. $\mathcal{G}$ cannot reduce to a Taub-NUT or to any Ricci-flat limit, neither have any (spacetime, Dirac-string, or $r_o = 0$) singularity, but Dirac's quantization condition reemerges. $\mathcal{G}$ geons (or $\mathcal{G}/2 = \mathcal{S}_Q$ with actual charge Q trapped on a round-$S^2[r_o]$ on $\partial\mathcal{S}_Q$, a physical singularity) could offer analytic models for dark-matter and early-galactic dynamics, or even for primordial gravitational pp-wave contributions to BICEP.

Introduction

A century-old interest on 'small particles' made of self-confined spacetime was alerted by Schwarzschild's 1915 solution and evolved all the way into the 50s with Einstein's own among widespread efforts to uncover non-singular particle-like vacua. Epitomized as geon by Wheeler, the concept still lacks a proper first example, namely a 'sufficiently' stable and asymptotically-flat exact non-singular solution of Einstein's gravity coupled to sourceless Maxwell fields.
Pure-vacuum geons would require exotic topologies, so the best we have to date is approximations to 4D geon electrovacua. Even Taub and NUT, found in much lesser adversity, took nearly two decades to be formulated as Taub-NUT almost-geon. This, as a pure vacuum, shares $\mathcal{S} = S^3 \times \mathbb{R}$ topology and metric type whithin our $\mathcal{G} = \mathcal{S}_- \vee \mathcal{S}_+$.

The $\mathcal{G}$-geon non-singular monopole

$$\mathcal{L} = \frac{1}{\kappa^2}\varepsilon_{\alpha}^{\ \beta}\,\mathcal{R}^{\alpha}_{\ \beta} - F\wedge *F\,, \tag{1}$$

with F primordial by $dF = d*F = 0,\ \partial\mathcal{G} = 0$

$$ds^2 = -\mathrm{L}_{\mathrm{o}}^2\left(g\ell^3 + 2du\right)\ell^3 + r^2 d\Omega^2\,, \tag{2}$$

in left $SU(2)$ ℓ^i, $d\Omega^2 := (\ell^1)^2 + (\ell^2)^2 = d\theta^2 + \sin^2\theta\ d\phi^2$,

$$R_{\alpha\beta} = \kappa^2\, T^{(\mathrm{em})}_{\alpha\beta}, \tag{3}$$

with $\quad T^{(\mathrm{em})}_{\alpha\beta} = \dfrac{E^2+B^2}{2}\ \mathrm{diag}[1,1,1,-1],$

$\mathcal{G}$ vs Taub-NUT

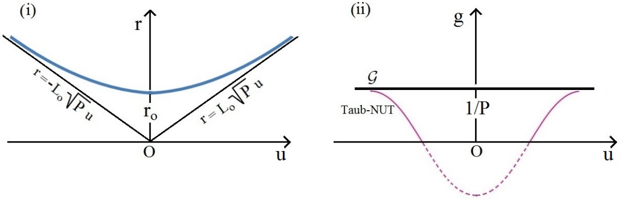

Figure: (i) Both have the same $r = r(u)$ function on $\pm \mathrm{L_o}\sqrt{P}u$ asymptotes and r_o minimum at $u = 0$, Planck-scaled in $\mathcal{G}$ as a $2r_o = \kappa|Q|$ NUT-like charge. (ii) $\mathcal{G}$ has constant $g(u) = 1/P$, thus L_3 is allways timelike $\forall u$.

$$r^2 = r_o^2 + \mathrm{L_o^2} P u^2 \,, \quad g = \frac{1}{P} \,, \qquad \left[2r_o = \frac{\mathrm{L_o}}{\sqrt{P}} = \kappa|Q| \right] , \tag{4}$$

Electromagneti content

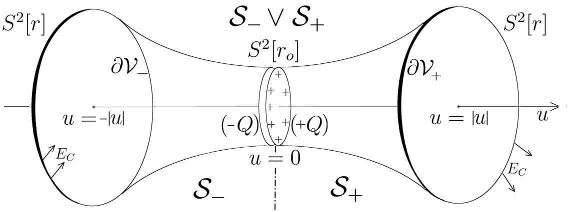

Figure: Round $S^2[r]$ sections along the $r = \pm \mathrm{L_o}\sqrt{P}u$ null-cone as (not shown) asymptote. (i) Disconnected $\partial\mathcal{V}_\pm$ boundary of $du = 0$ hypersurface $\mathcal{V}$ in $\mathcal{G}$. (ii) Via $S^2[r_o]$ and $S^2[r]$ on the right in $\mathcal{S}_+$ it is established that '$\mathcal{G}/2$' $= \mathcal{S}_Q$ carries actual Q charge on $S^2[r_o]$ of $\partial\mathcal{S}_Q$.

$$A^{(\mathrm{e})} \longrightarrow E^{(\mathrm{e})} = \frac{Q}{r^2} + O(r^{-4})\,, \quad B^{(\mathrm{e})} \sim O(r^{-3}), \qquad (5)$$

$$A^{(\mathrm{m})} \longrightarrow E^{(\mathrm{m})} \sim O(r^{-3})\,, \quad B^{(\mathrm{m})} = \frac{Q}{r^2} + O(r^{-4}). \qquad (6)$$

Topological confinement on $\partial\mathcal{S}_Q$, Asymptotic infinity, Causality and Stability of $\mathcal{G}$,$\mathcal{S}_Q$

$$\omega := *(v \wedge dv) = \frac{2r_o}{r^2}\,\theta^3 \qquad [\text{vorticity}] \tag{7}$$

Global t-time:

$$x^0 = t = 2r_o\psi + \mathrm{L_o}\sqrt{P}u = \pm\sqrt{r^2 - r_o^2} + 2r_o\psi \;\; [\text{mod } 8\pi r_o]\,, \tag{8}$$

Causality and Bogomol'nyi bound:

$$|Q| < \frac{r_{\text{sm}}}{\kappa} \quad \longrightarrow \quad r_o < r_{\text{sm}}, \tag{9}$$

$$m_G > \frac{|Q|}{\kappa} \quad \longrightarrow \quad P < 8\pi^4, \tag{10}$$

Conclusions and Applications

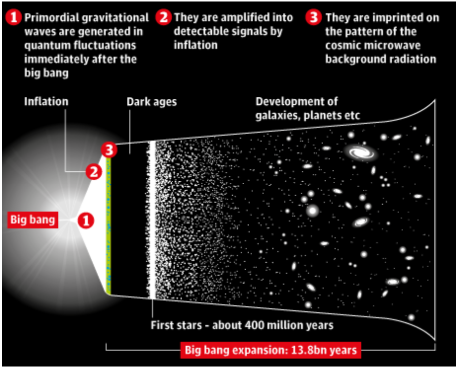

Figure: This, as $\mathcal{F}'$ model, includes accretion around $\mathcal{G}'_o$ geons in galactic dynamics during Dark ages. As $\mathcal{F}_{\rm bicep}$, it depicts $\mathcal{G}_{\rm bicep}$ geons as primordial gravitational pp-waves in ①, zooming through inflation ② toward asymptotic infinity in ③ (picture by courtesy of HSCA).