
Dynamical Timedomains From a Selfcoupling Scalar Field -

A theoretical Frame for localised and oscillating Eigentime- Structures including possible time-isolated and therefore time-neighbour shielded Points

Abstract:

Developed is a theoretical framework for localized, dynamic spacetime configurations, the defining characteristic of which is not primarily a spatial concentration of energy, but rather a locally altered proper-time structure. The starting point is a self-coupled real scalar field whose energy-momentum tensor generates a spherically symmetric spacetime curvature via the Einstein equations. The local proper time is determined by the time-dependent metric component (g_{tt}) . Examined then is both static and oscillating configurations, demonstrating that a harmonic evolution of the scalar field—comprising odd harmonic $s=s(\omega;3\omega;5\omega;\dots)$ —is naturally coupled to even harmonics of $h=h(0;2\omega;4\omega;\dots)$ of the metric. This provides a mathematically precise foundation for an oscillating "time bubble." The frequently encountered $(N=2n+1)$ structure is identified here as a harmonic structure, rather than being interpreted as an established quantization of proper time. The resulting problem is a nonlinear, self-consistent eigenvalue problem for the scalar field and the spacetime metric. The existence, stability, lifespan, and potential discrete spectrum of such solutions must be investigated numerically. In particular, a possible Planck-scale quantization of proper time is formulated as a testable spectral hypothesis.

Key-words:

Time-bubble; eigentime isolation state; harmonic-oscillations; discrete eigentime states; scalar-field; quantized proper/eigentime spectrum; discrete eigentime spectrum; dynamical state; harmonic evolution; curved spacetime metric.

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1. Introduction:

The standard description of a gravitational field [1.],[2.] employs a spatially varying potential or, in general relativity, a curved spacetime metric. A key physical consequence of this geometry is the variation in proper time elapsed along different worldlines connecting the same events. Here,

investigated is, whether a localized, dynamic field configuration can exist whose essential physical signature is a local proper time that varies spatially and—potentially—temporally. Referred is to such a hypothetical configuration as a time domain or time bubble. This term is not intended to denote an additional physical entity; rather, it represents a self-consistent solution to the Einstein-scalar field equations in which:

$$g_{tt} = -\alpha^2(r, t) c^2 \quad (1.1.)$$

deviates from its asymptotic value. The local proper time of an observer at constant (r, θ) and (ϕ) then is

$$d\tau = \alpha(r, t) dt \quad (1.2.)$$

A time bubble would thus be a localized region where

$$\alpha(r, t) \neq 1 \quad (1.3.)$$

(1.3.)

2. Theoretical Fundamentals:

Considered is the action of:

$$S = \int d^4x \sqrt{-g} \left[\frac{c^4}{16\pi G} R - \frac{1}{2} g^{\mu\nu} \partial_\mu \Phi \partial_\nu \Phi - V(\Phi) \right] \quad (2.1.)$$

Variation after the metric delivers:

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \quad (2.2.)$$

and variation after the scalar-field brings the result of:

$$\square_g \Phi = \frac{dV}{d\Phi} \quad (2.3.)$$

The energy-momentum - tensor then is:

$$T_{\mu\nu} = \partial_\mu \Phi \partial_\nu \Phi - g_{\mu\nu} \left[\frac{1}{2} g^{\alpha\beta} \partial_\alpha \Phi \partial_\beta \Phi + V(\Phi) \right] \quad (2.3.)$$

3. Spheric symmetric spacetime:

Used is a spacetime standard-form of:

$$ds^2 = -\alpha^2(t, r) c^2 dt^2 + a^2(t, r) dr^2 + r^2 d\Omega^2 \quad (3.1.)$$

Therefore follows for a worldline with constant spacelike radius:

$$d\tau = \alpha(t, r) dt \quad (3.2.)$$

The term of (α) ergo is the central variable for the local eigentime-structure. The radial metric function can be parametrized by a measuring function of: $m(t, r)$.

$$a^{-2} = 1 - \frac{2Gm(t, r)}{c^2 r} \quad (3.3.)$$

For a weak field there is the condition of:

$$\alpha \simeq 1 + \nu \quad (3.4.)$$

where the following term can be introduced as an effective time-potential:

$$\Psi_T = c^2 \nu \quad (3.5.)$$

4. Localised Scalarfield configuration:

Considered is a spheric symmetric, time dependent field-configuration.

$$\Phi = \Phi(r, t) \quad (4.1.)$$

Set and calculated for a symmetric field-sector is the Fourier-developement in the form of:

$$\Phi(r, t) = \phi_1(r) \cos \omega t + \phi_3(r) \cos 3 \omega t + \phi_5(r) \cos 5 \omega t + \dots \quad (4.2.)$$

The quadratic combinations of the field harmonics in comparison generate even harmonics.

$$T_{\mu\nu} = T_{\mu\nu}^{(0)} + T_{\mu\nu}^{(2)} \cos 2 \omega t + T_{\mu\nu}^{(4)} \cos 4 \omega t + \dots \quad (4.3.)$$

Therefore the metric possesses the same structure of parity.

$$\alpha(r, t) = \alpha_0(r) + \alpha_2(r) \cos 2 \omega t + \alpha_4(r) \cos 4 \omega t + \dots \quad (4.4.)$$

The fundamental field frequency generates therefore consequently a dynamical eigentime-structure containing a doubled ground-frequency.

5. Linear condition of localisation:

In the asymptotic area, where spacetime- and field- disturbance become rather small, the ground mode reduces to:

$$\phi_1'' + \frac{2}{r} \phi_1' + (\omega^2 - m^2) \phi_1 \simeq 0 \quad (5.1.)$$

For $\omega < m$ there is defined

$$\kappa = \sqrt{m^2 - \omega^2} \quad (5.2.)$$

Then the outer solution takes the form of:

$$\phi_1(r) \sim \frac{e^{-\kappa r}}{r} . \quad (5.3.)$$

Therefore the ground mode only is spacelike localized below the mass treshold.

6. Nonlinear Harmonics:

For a potential of:

$$V(\Phi) = \frac{1}{2} m^2 \Phi^2 + \frac{g_4}{4!} \Phi^4 + \dots \quad (6.1.)$$

the cubic term in the field-equation generates

$$V_\Phi = m^2 \Phi + \frac{g_4}{6} \Phi^3 + \dots \quad (6.2.)$$

a third harmonic.

Since

$$\cos^3 \omega t = \frac{3}{4} \cos \omega t + \frac{1}{4} \cos 3 \omega t , \quad (6.3.)$$

the third mode gets a radial equation of the form:

$$\phi_3'' + \frac{2}{r} \phi_3' + (9\omega^2 - m^2) \phi_3 = S_3(r) \quad (6.4.)$$

whereby (S_3) is a source, generated by the ground mode and and the gravitative backcoupling

For exponetial localisation of the third harmonic there must yield:

$$3\omega < m . \quad (6.4.)$$

Generally follows for the $(2n+1)$ -th harmonic the condition of

$$(2n+1)\omega < m \quad (6.5.)$$

This relation is the mathematical fundament for the appearing odd harmonic structure in the model but however it is no yet equal to a description of quantization.

$$\omega_n \propto 2n+1 . \quad (6.6.)$$

Such a quantization should be only demonstrated by deescribing the complete eigenwert-problem.

7. Gravitative Time-potential:

The time averaged energy-density of the ground-state mode approximately is:

$$\langle \rho \rangle = \frac{1}{4} [\omega^2 \phi_1^2 + (\phi_1')^2 + m^2 \phi_1^2] \quad (7.1.)$$

The enclosed mass fulfills:

$$M'(r) = 4 \pi r^2 \frac{\langle \rho \rangle}{c^2} . \quad (7.2.)$$

In the weak field limit therefore follows:

$$\nu_0'(r) \simeq \frac{GM(r)}{c^2 r^2} \quad (7.3.)$$

The static component of the time dilatation then is by that determined over the energy distribution of the scalar-field.

The oscillating component follows from the (2ω) part of the energy-momentum tensor:

$$\nu(r, t) = \nu_0(r) + \nu_2(r) \cos 2\omega t + \dots \quad (7.4.)$$

Therefore follows:

$$\frac{d\tau}{dt} \simeq 1 + \nu_0(r) + \nu_2(r) \cos 2\omega t$$

The time-bubble by that possesses both a static part as well as a dynamical one.

8. Timelines and Eigentime-Functional:

For a radial Worldline

$$r = r(t) \quad (8.1.)$$

follows from the metric:

$$d\tau^2 = \left[\alpha^2 - \frac{a^2}{c^2} \dot{r}^2 \right] dt^2 . \quad (8.2.)$$

Therefore follows:

$$\tau[\gamma] = \int \sqrt{\alpha^2(r, t) - \frac{a^2(r, t)}{c^2} \dot{r}^2} dt . \quad (8.3.)$$

The „timelines“ of the model then are timelike extremals of a dynamical spacetime. This description substitutes the original imagination of a pure spacelike potential-line by a geometric problem of well-defined worldlines.

9. Time-isolation:

Looked is at three space regions of A, C, B .

A local field configuration around (C) can generate a strong changing of

$$\alpha(r, t) \alpha(r, t) \quad (9.1.)$$

The eigentime of an observer in (C) then can strongly be reduced versus an outer observer.

$$\frac{d\tau_C}{dt} = \alpha_C(t) \quad (9.2.)$$

For two regions then is defined:

$$\Delta \tau_{AB} = \int_{t_1}^{t_2} [\alpha_A(t) - \alpha_B(t)] dt \quad (9.3.)$$

Such a configuration here is described, defined and named as **timelike isolated**, if its development of eigentime strongly differs or deviates from the evolution of neighboured regions. Timelike isolation thereby is not to be expressed or compared with an event horizon [3].

10. Coupling without Dimensioning:

A central dimensionless gravity strength is:

$$\Gamma = \frac{Gm^2}{\hbar c} = \left(\frac{m}{m_{PL}} \right)^2 \quad (10.1.)$$

Together with a dimensionless field amplitude of (A) the term determines the strength of gravity backreaction coupling. In the weak regime there is schematically:

$$\Gamma A^2 \ll 1 \quad (10.2.)$$

For

$$\Gamma A^2 \sim 1 \quad (10.3.)$$

the backreaction doesn't become perturbative any longer. The complete model then must be treated without weak-field approximation.

11. Eigenvalue-Problem:

The desired time domains are solutions of the coupled system.

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}[\Phi, g] \quad (11.1.)$$

and

$$\square_g \Phi = V_\Phi \quad (11.2.)$$

With the boundary conditions of:

$$\phi_n'(0)=0 \quad , \quad \phi_n(\infty)=0 \quad , \quad (11.3.1./11.3.2.)$$

$$\alpha(\infty,t)=1 \quad , \quad a(\infty,t)=1 \quad (11.4.1/11.4.2.)$$

the frequency (ω) becomes an eigenvalue.

Therefore can be written:

$$\omega = \omega(A, \Gamma) \quad (11.5.)$$

The complete numerical solution then yields the description-terms of:

$$(\Phi_n(r, t), \alpha_n(r, t), a_n(r, t), M_n, R_n, \omega_n) \quad . \quad (11.6.)$$

12. Effective Radius:

Since the field does not have a sharp edge, the size of the time domain is defined by its energy distribution .With:

$$E(r) = 4\pi \int_0^r \rho(s) s^2 ds \quad (12.1.)$$

and

$$E_\infty = E(\infty) \quad . \quad (12.2.)$$

For example,

$$E(R_{50}) = \frac{1}{2} E_\infty \quad (12.3.)$$

can be used as the characteristic radius.

Similarly, R_{90}, R_{99} , etc., are possible.

The total mass is:

$$M_T = \frac{E_\infty}{c^2} \quad (12.4.)$$

13. Stability:

A solution found is not physically relevant simply because it exists mathematically. It also must be investigated whether small perturbations grow or decay like:

$$\Phi \rightarrow \Phi + \delta \Phi \quad (13.1.)$$

The linearized problem schematically has the form of:

$$\delta \ddot{\Phi} + L[\Phi, g] \delta \Phi = 0 \quad (13.2.)$$

The eigenvalues of this perturbation problem determine its stability or instability. A stable or long-lived time domain would be characterized, in particular, by:

$$\Im \Omega_{pert} \approx 0 \quad (13.3.)$$

14. Possible losses of radiation:

If a harmonic exceeds the mass threshold,

$$(2n+1)\omega > m \quad (14.1.)$$

it can no longer decay exponentially asymptotically. Instead it becomes a propagating mode. This allows energy to be transported outwards. The time domain would then not be an exactly stationary state, but a long-lived, slowly decaying state of:

$$E(t) \simeq E_0 e^{\frac{-t}{\tau_{life}}} \quad (14.2.)$$

The lifetime (τ_{life}) thus becomes an additional physical observable.

15. Planck-Scaling as a Hypothesis:

A possible original hypothesis of the model is:

$$\Delta \tau_n = (2n+1) \tau_{PL} \quad (15.)$$

However, this relationship does not follow automatically from the equations derived so far. It must be treated as a spectral hypothesis. The numerical eigenvalue problem should therefore test whether a sequence of solutions (B_n) exists whose characteristic proper times $\Delta \tau_n$ exhibit such a structure. Alternatively, another discrete relation could be obtained.

16. Relationship to the original potential concept:

The original image of a spatial potential is replaced by the metric in the present formalism.

Defined then is:

$$\Psi_{T(r,t)} = c^2 \ln \alpha(r, t) \quad (16.1.)$$

For weak fields, there is assumed:

$$\Psi_T \equiv c^2(\alpha - 1) \quad , \quad (16.2.)$$

thus establishing a direct connection to the ordinary gravitational potential.

The crucial difference is the possible time dependence:

$$\Psi_T = \Psi_T(r, t) \quad . \quad (16.3.)$$

The theory therefore does not describe an ordinary static potential field, but rather a dynamic proper-time geometry.

17. Interpretation of the “time-bubble”:

In this model, a time bubble is not introduced as an additional dimension or as an independent medium. It is defined as:

$$B = \{(r, t) : \alpha(r, t) \neq 1 ; \Phi(r, t) \neq \Phi_{vac}\} \quad (17.1.)$$

Its properties are characterized by four quantities:

$$(R_T ; M_T ; \omega ; \alpha) \quad . \quad (17.2.)$$

This allows the theory to be tested numerically in principle.

18. Open Mathematical Questions:

The present construction does not yet answer the question of whether such solutions actually exist. In particular, the following questions must be investigated:

- 1. Do regular, asymptotically flat solutions of the complete Einstein scalar field system exist?**
- 2. For which potentials $V(\Phi)$ do localized oscillating solutions exist?**
- 3. What frequency (ω) corresponds to a given central amplitude?**
- 4. Are there discrete radial eigenstates?**
- 5. Are these states stable or metastable?**
- 6. Which harmonics can remain localized?**
- 7. Which solutions exhibit strong eigentime dilation?**
- 8. When does a horizon emerge?**
- 9. Is there a natural Planck scaling of the eigentime?**

10. Does the eigenvalue problem actually result in a $N=(2n+1)$ -structure of the eigenstates or merely of the Fourier-harmonics?

19. Conclusion:

A self-consistent theoretical framework for localized and oscillating proper time structures has been formulated. The central mechanism consists of the feedback loop of:

$$(\Phi \rightarrow T_{\mu\nu} \rightarrow g_{\mu\nu} \rightarrow \tau \rightarrow \Phi) \quad . \quad (19.1.)$$

The local proper time is determined by:

$$\tau = \alpha(r, t) dt \quad (19.2.)$$

A time-dependent scalar field configuration generates a time-dependent spacetime metric via its energy-momentum tensor. For a symmetric field configuration, natural odd harmonics appear in the field and even harmonics in the metric:

$$\Phi: (1\omega; 3\omega; 5\omega; \dots) \quad (19.3.)$$

and

$$g_{\mu\nu}: (0; 2\omega; 4\omega; \dots) \quad (19.4.)$$

The resulting structure represents a possible mathematical basis for an oscillating time bubble. However, the derivation so far does not prove a quantization of proper time in units of

$$t_n = (2n+1)t_{PL} \quad . \quad (19.5.)$$

It represents a testable hypothesis whose validity must be determined from the complete eigenvalue spectrum. The next necessary step therefore is a numerical solution of the coupled Einstein scalar field eigenvalue problem. Only from this can statements about existence, stability, mass, radius, lifetime and a possible discrete time bubble spectrum be derived.

20. Research Program:

The theory can be decomposed into five consecutive numerical problems:

I. Flat eigenvalue problem,

II. Nonlinear harmonics,

III. Weak gravitational feedback,

IV. Complete Einstein scalar field solution,

V. Stability and spectral analysis.

Only after completing these five steps it can be determined whether the concept of a dynamic time bubble is merely a useful mathematical model or an independent class of self-consistent spacetime solutions. This is therefore a usable preliminary draft, but deliberately not yet a "finished" physics theme in the sense of a proven result: The crucial numerical proof of existence and stability is still missing. The next step would now be very concrete: Derived can the actual numerical system of

equations for the lowest approximation $(\phi_1; \phi_3; \nu_0; \nu_2; a_0; a_2)$ from the paper and derived a shooting/relaxation algorithm from it. Then there would be no longer just only the theory on paper, but a way to compute the first concrete time bubble solution.

21. References:

[1.] --- Einstein, A. (1916). Die Grundlage der allgemeinen Relativitätstheorie. Annalen der Physik, 49, 769–822. DOI: 10.1002/andp.19163540702.

Content: Einstein's mathematical formulation of the general theory of relativity and the gravitational field equations. Utility: The theoretical foundation for describing spacetime and black holes.

[2.] --- Schwarzschild, K. (1916). Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie. Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, S. 189–196. Content: One of the first exact solutions to Einstein's field equations for the gravitational field of a spherically symmetric mass. Significance: The basis for the Schwarzschild metric and the Schwarzschild radius of a non-rotating black hole.

[3.] --- Kokkotas, K. D., & Schmidt, B. G. (1999). Quasi-Normal Modes of Stars and Black Holes. Living Reviews in Relativity, 2, 2. DOI: 10.12942/lrr-1999-2. Springer Nature.

Content: Theory of quasinormal modes (QNMs), perturbations of black holes, and their mathematical description. Application: Particularly relevant for the damped oscillations following a black hole merger and for the analysis of gravitational waves.

22. Non-scientific comment:

--- Blowing bubbles in the air. --- Clark Sisters.

23. Verification:

This paper definitely is written without support from an AI, LLM or chatbot like Grok or Chat GPT 4 or other artificial tools. It is fully, purely human work in every universe

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