Fractal-Wave Analysis of Baryon Junction Dynamics

An FWA representation of the experimentally observed Y-topology

This work does not claim that FWA predicted the STAR observation before the experiment. The objective is different: to take an experimentally established baryon-junction structure and construct an independent fractal-wave representation from which quantitative dynamical parameters can be derived and tested against experiment.

1. Methodological Position

The distinction between prediction and theoretical explanation is essential. An existing experimental anomaly or structure can legitimately be explained by a new theoretical framework. The scientific test then moves to the quantitative consequences of that framework. This is analogous in methodology to General Relativity explaining the already-known anomalous perihelion of Mercury and subsequently producing independent testable predictions.

Accordingly, the present analysis makes no claim that STAR was predicted by FWA in advance. The claim is narrower and testable: the measured Y-shaped baryon-junction structure can be represented as a coherent FWA wave configuration, and the resulting dynamics can be connected to measurable baryon transport.

2. Junction Wave Configuration

A baryon junction is represented as a coherent three-branch wave state:

$$\Phi_J = \Sigma_{k=1}^{3} A_k \exp(i\varphi_k).$$

For an ideal symmetric three-branch configuration:

$$\varphi_k = \varphi_0 + 2\pi k/3.$$

The three phases therefore satisfy the root-of-unity cancellation:

$$\Sigma_{k=1}^{3} \exp(i2\pi k/3) = 0.$$

Within FWA this is interpreted as a dynamic-zero condition of the balanced junction. It should be regarded as an FWA representation of the symmetry, not as a replacement for the established SU(3) color structure of QCD.

3. Symmetry-Error Functional

Departures from the ideal junction are represented by phase perturbations:

$$\varphi_k = \varphi_0 + 2\pi k/3 + \delta_k.$$

Define the junction symmetry-error functional:

$$\Omega_J = |\Sigma_{k=1}^{3} A_k \exp(i\varphi_k)|^2.$$

For an ideal balanced junction $\Omega_J = 0$. A distorted configuration has $\Omega_J > 0$. The quantity therefore measures departure from the FWA symmetric state. Whether a particular experimental observable maps uniquely onto Ω_J must be established by an explicit

experimental reconstruction; it should not be assumed merely from the existence of a Y-topology.

4. Small-Distortion Expansion

For equal amplitudes $A_k = 1$ and small phase distortions δ_k, expand:

$$\exp(i\delta_k) \approx 1 + i\delta_k.$$

Because the zeroth-order symmetric sum vanishes, the first non-zero contribution is:

$$S_J \equiv |\Sigma \exp[i(2\pi k/3 + \delta_k)]| \approx |i\Sigma \delta_k \exp(i2\pi k/3)|.$$

Consequently:

$$\Omega_J \approx |\Sigma \delta_k \exp(i2\pi k/3)|^2.$$

This is a concrete mathematical result of the FWA representation: the leading symmetry error is quadratic in the phase-distortion amplitude.

5. Junction Recursion

The junction is embedded in the general FWA dynamical recursion:

$$\Phi_{n+1} = F(\Phi_n, \nabla\Phi_n, \partial_t\Phi_n, T_n).$$

Here T_n represents the local medium state. Linearization about a stationary junction configuration gives a stability/transport operator. In the scalar simplified case its eigenvalue may be written schematically as:

$$\lambda_J = \partial F/\partial\Phi \,|_{\Phi=\Phi_J}.$$

For the full FWA model, λ_J must be obtained from the explicitly defined linearized operator, rather than by differentiating Ω_J without specifying the state variables. This distinction prevents an arbitrary numerical parameter from being mistaken for a prediction.

6. Transport Coefficient

If the dominant junction mode has eigenvalue λ_J, its coherent contribution over a rapidity interval Δy can be represented by:

$$C(\Delta y) = |\lambda_J|^{\Delta y} = \exp(-\gamma_J \Delta y).$$

Therefore:

$$\gamma_J = -\ln|\lambda_J|.$$

The corresponding phenomenological transport law is:

$$dN_B/dy = N_0 \exp[-\gamma_J(y - y_0)].$$

This gives FWA a direct route to comparison with measured rapidity distributions. The crucial requirement is that λ_J be calculated from the FWA equations independently of the STAR fit.

7. Numerical Status and Falsifiability

A numerical value such as $\gamma_J \approx 2.2$ should only be presented as an FWA prediction if all parameters entering λ_J are fixed independently before comparison with STAR. In particular, an assumed coupling $\alpha = 0.9$ must not be selected because it reproduces the experimental

slope. Likewise, branch phase distortions must be taken from a documented measurement or derived from the FWA dynamics, not introduced as unsupported 'typical STAR values'.

The correct falsifiability criterion is therefore:

> FWA equations → λ_J → γ_J → predicted dN_B/dy → STAR comparison.

If the independently calculated γ_J is incompatible with the measured transport slope, the proposed FWA junction dynamics is falsified or requires revision. If it agrees, the agreement constitutes quantitative support for the representation, but not by itself proof that FWA replaces QCD.

8. Scientific Interpretation

The scientific claim is therefore deliberately limited. FWA does not claim that the STAR collaboration discovered a phenomenon that FWA had already predicted. Instead, FWA supplies an alternative mathematical representation of an experimentally established baryon-junction structure. The representation introduces a coherent three-branch wave state, a symmetry-error functional, a dynamical recursion, an eigenvalue and a transport coefficient.

The value of the framework is determined by what follows from these definitions without adjusting the theory to the data. A successful program requires numerical derivation, uncertainty propagation, comparison with STAR measurements and at least one independent prediction that differs from competing descriptions.

9. Conclusion

The FWA treatment of baryon-junction dynamics can be formulated as a mathematically explicit chain:

> observed Y-topology → coherent three-branch wave state → symmetry error Ω_J → junction recursion → eigenvalue λ_J → transport coefficient γ_J → experimental comparison.

This is the appropriate scientific position: not that STAR proves FWA, and not that FWA merely renames a QCD structure, but that an existing experimental phenomenon is subjected to an independent mathematical description whose quantitative consequences can succeed or fail.

Key methodological principle: an explanation becomes a physical theory only when its mathematical structure produces consequences that nature can contradict.