

Symmetric Projection Attractor Reconstruction as a Cardiac Attractor: Structural Parallels with the Attractor Framework

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Abstract

The attractor framework proposes that persistence under perturbation is a fundamental marker of reality, with corrective permeability (κ) serving as a proposed multi-dimensional measure of a system's capacity to return to its attractor after perturbation. Bonet-Luz et al. (2020) developed Symmetric Projection Attractor Reconstruction (SPAR), a patented mathematical method that reformulates the entire electrocardiogram (ECG) waveform into a bounded, symmetric, 2-dimensional attractor and extracts quantitative features from it. Applied to mice with an *Scn5a*^{+/-} mutation linked to Brugada syndrome, SPAR features achieved 96% classification accuracy—substantially outperforming standard ECG intervals and amplitudes. This paper identifies structural parallels between SPAR's attractor-based analysis and the attractor framework. The SPAR attractor is a concrete, computable attractor derived from a physiological signal, and a provisional mapping is proposed between specific SPAR

features and proposed components of κ . The parallels are post-hoc and do not constitute independent validation of the framework. The framework's κ remains qualitatively defined; this mapping is offered as a contribution to its ongoing development.

1. Introduction: Attractor-Based ECG Analysis

The attractor framework (Galida, 2026a, self-published May 2026 at fantasyattractor.com; no DOI) proposes that dissipative attractors—stable configurations toward which systems converge and from which they resist displacement—are the fundamental units of persistent organization across physical, biological, cognitive, and social domains. Corrective permeability (κ) is a proposed multi-dimensional measure of a system's capacity to return to its attractor after perturbation. The framework distinguishes between the attractor (the invariant set of states toward which the system converges) and the basin (the set of initial conditions that converge to that attractor). In the present paper, we use “attractor” in the standard dynamical systems sense and note where the framework's usage aligns or diverges.

In 2020, Bonet-Luz, Aston, Nandi, and colleagues published a study in *Heart Rhythm* 02 (Elsevier) applying Symmetric Projection Attractor Reconstruction (SPAR) to murine electrocardiograms (Bonet-Luz et al., 2020). SPAR is a patented mathematical method that reformulates the entire ECG waveform into a bounded, symmetric, 2-dimensional attractor, preserving all available waveform morphology rather than extracting only a few fiducial points. The method was applied to distinguish wild-type mice from those carrying an *Scn5a*+/- mutation linked to Brugada syndrome, a hereditary condition associated with sudden cardiac death.

The study did not cite the attractor framework and was conducted within the established traditions of biomedical signal processing, nonlinear dynamics, and machine learning. This paper identifies structural parallels between SPAR's attractor-based analysis and the attractor framework. The parallels are post-hoc and do not constitute independent validation.

2. The SPAR Method

SPAR generates a 2-dimensional attractor from approximately periodic signals such as ECG, blood pressure, or photoplethysmogram waveforms. The method determines an average cycle length from the signal, sets a time delay parameter as one-third of that cycle, and plots the data in a bounded box using a symmetric projection. The resulting attractor is a compact, easily visualized representation of the entire waveform morphology, overlaid with a density map indicating which regions are visited more or less frequently. The method factors out changes in heart rate and baseline variation to concentrate on waveform morphology.

For murine lead I and II ECG signals, the SPAR attractor typically exhibits 3 long arms predominantly representing the R peak, with deep S peaks and sometimes deep Q peaks producing shorter arms in the opposite direction, yielding an attractor with up to 6 arms in total (Figure 1 of the original paper). The central core region reflects T-wave and P-wave morphologies.

From this attractor, Bonet-Luz et al. extracted 74 manually defined features relating to the density, size, and symmetry of the attractor, along with the average heart rate and a vertical normalization scaling factor. These features were used in a k-nearest neighbors classifier ($k=3$) with leave-one-

animal-out cross-validation.

The dataset comprised ECG recordings from 42 anesthetized mice (39 lead I, 39 lead II) of varying genotype (wild-type vs. *Scn5a*+/-), sex, and age. Each signal was divided into 13 non-overlapping 10-second windows, yielding 1,014 records for classification. Standard ECG intervals (7) and amplitudes (6) were also extracted for benchmarking. It is important to note that the effective sample size for the classification is 42 animals, not 1,014 windowed records, and the 96% classification accuracy has not yet been independently replicated in a separate cohort.

3. Results Summary

The SPAR features alone achieved 87.2% classification accuracy for genotype (majority vote), outperforming ECG intervals (74.3%) and intervals plus amplitudes (85.9%). The highest accuracy (96.2%) was obtained by combining all features—SPAR, intervals, and amplitudes. For sex and age classification, SPAR features similarly outperformed standard measures.

The machine learning algorithm selected 16 SPAR features out of 20 in the combined model, with the remaining 4 being the ST height, P and R amplitudes, and the PR interval. The density distribution and symmetry in the arm regions of the attractor were the most discriminative SPAR features. The ST height—a known marker for Brugada syndrome—was selected in both feature groups that included amplitudes.

The authors concluded that the ECG carries sufficient information to detect the *Scn5a*+/- mutation, but that enhanced analysis techniques are required to extract it. Standard interval and amplitude measures fail to capture the relevant signal because the mutation's effects are distributed across the entire waveform morphology, not concentrated at isolated

time points.

4. Structural Parallels with the Attractor Framework

4.1 The SPAR Attractor as a Cardiac Attractor. The SPAR method generates a bounded, stable 2-dimensional attractor from the ECG signal. This attractor is a compact representation of the cardiac system's dynamical state—a region in state space toward which trajectories converge and around which they organize. In the attractor framework's vocabulary, this is an **attractor** generated by a dissipative system (the beating heart, maintained by continuous metabolic energy input). The attractor's density distribution, arm structure, and symmetry reflect the stability and structural coherence of this configuration.

4.2 SPAR Features as Candidate Proxies for Corrective Permeability (κ). The framework proposes κ as a multi-dimensional measure of a system's capacity to return to its attractor after perturbation. A healthy heart with normal ion channel function has a deep, stable attractor—it responds to perturbations and returns rapidly to its baseline rhythm. The Scn5a+/- mutation degrades sodium channel function, making the cardiac tissue more vulnerable to arrhythmia. This degradation manifests as measurable changes in the SPAR attractor.

A provisional mapping between specific SPAR feature categories and proposed components of κ is offered below. This mapping is hypothetical and has not been formally derived; it is presented as a structural analogy to be tested in future work. The κ component labels in this table are introduced here for exploratory purposes and are not yet formalized in the primary framework document (Galida, 2026a); they are subject to revision pending formal axiomatization of κ .

SPAR Feature Category	What It Measures in the Attractor	Candidate κ Component (provisional)
Density distribution (core)	Frequency of trajectory visits to central attractor region	Attractor core stability: a dense core indicates a stable, frequently occupied equilibrium
Density distribution (arms)	Frequency of trajectory visits to peripheral regions	Perturbation response: arm density reflects excursions from equilibrium
Symmetry features	Left-right symmetry of attractor arms	Recovery symmetry: asymmetric arms may indicate directional perturbation bias or conduction abnormality
Arm structure	Length, width, and number of attractor arms	Global waveform integrity: degraded arm structure reflects disrupted cardiac conduction

The 96% classification accuracy (pending independent replication) demonstrates that these attractor-derived proxies capture diagnostically relevant information that standard interval measures miss. Whether this information corresponds specifically to κ , or to more general signal properties, cannot be determined without a formal derivation of κ from the framework's axioms.

4.3 Multi-Dimensional Feature Combination. The framework proposes that κ is multi-dimensional—no single measure fully captures a system's corrective permeability. The SPAR results are consistent with this principle: combined features outperformed any individual feature set. However, this result is also expected under standard machine learning practice, where feature combination typically improves classification performance. The result is therefore consistent with the framework without uniquely supporting it. The specific finding

that SPAR features (16/20) dominated the combined model suggests that attractor-derived measures carry more discriminative information than point-based measures for this particular mutation. Whether this dominance generalizes to other perturbations and other physiological systems is an open empirical question.

4.4 Normalization as Signal Isolation. The SPAR method normalizes the signal to factor out changes in heart rate and baseline variation, concentrating on waveform morphology. In the framework's terms, this is a methodological step that isolates the attractor's structural properties from confounding variables. Heart rate is influenced by autonomic tone, physical activity, and respiratory cycle-perturbations that can obscure the measurement of the attractor's intrinsic stability. SPAR's normalization yields a cleaner representation of the attractor. However, this normalization step is standard practice in many signal processing methods and does not constitute a distinctive parallel with the framework.

5. Limitations

This mapping is post-hoc. The parallels identified here are structural analogies, not independent evidence for the framework. The provisional κ -proxy mapping in Section 4.2 is hypothetical and has not been formally derived from the framework's axioms. The κ component labels used in the provisional mapping table (e.g., "attractor core stability," "recovery symmetry," "global waveform integrity") are introduced in this paper for exploratory purposes and are not yet formalized in the primary framework document (Galida, 2026a). They are subject to revision pending formal axiomatization of κ .

The framework's κ remains qualitatively defined. A formal derivation specifying the state variables, the attractor geometry, and the perturbation response function is required before the SPAR feature mapping can be evaluated as more than a structural analogy.

The 96.2% classification accuracy was obtained from a single study of 42 mice (effective $N=42$, despite 1,014 windowed records). Independent replication in a separate cohort has not been performed. The accuracy figure should be interpreted with appropriate caution.

The SPAR method was developed for approximately periodic signals and has been validated on cardiovascular waveforms. Its applicability to the non-periodic attractors the framework describes in cognitive and social domains is unknown.

The attractor framework is self-published and has not undergone independent peer review.

6. Falsifiability Conditions

The following observations would weaken or invalidate the parallels drawn here:

- **Disconfirming observation 1:** If SPAR features were shown to be *uncorrelated* with independently validated measures of cardiac resilience or arrhythmia susceptibility in a larger, independent cohort, the κ proxy interpretation would lose its empirical anchor.
- **Disconfirming observation 2:** If the SPAR attractor's classification accuracy for the *Scn5a*^{+/-} mutation were shown to derive primarily from features unrelated to attractor geometry (e.g., heart rate alone or predominantly heart rate), the attractor interpretation

would be substantially weakened.

- **Disconfirming observation 3:** If alternative signal processing methods with no attractor reconstruction component achieved equal or higher classification accuracy using the same data, the attractor interpretation would not be uniquely supported.

Affirmative predictions:

- **Primary prediction:** If the provisional κ -proxy mapping in Section 4.2 captures genuine components of corrective permeability, then pharmacological interventions that improve cardiac ion channel function (e.g., sodium channel modulators) should produce measurable shifts in specific SPAR features—density, symmetry, arm structure—toward the wild-type baseline. Conversely, interventions that degrade ion channel function should shift these features away from the baseline. This prediction is testable using pre- and post-intervention ECG recordings with the same SPAR methodology.
 - **Secondary prediction:** If attractor-derived features are more sensitive to κ -relevant perturbations than point-based measures, then SPAR features should show *greater* sensitivity to these pharmacological interventions than standard ECG intervals and amplitudes. This secondary claim is more speculative; failure of the secondary prediction while the primary prediction holds would suggest that SPAR features track relevant physiological changes without uniquely capturing κ as distinct from other measures.
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7. Conclusion

The SPAR method developed by Bonet-Luz et al. (2020) generates a mathematically defined attractor from ECG signals that encodes diagnostically relevant information about cardiac stability. A provisional mapping between SPAR features and proposed components of corrective permeability (κ) has been offered, along with primary and secondary affirmative predictions. The 96% classification accuracy for a disease-causing mutation demonstrates that attractor-based features capture information about system integrity that standard point-based measures miss. These parallels are structural analogies, not independent validation. The framework remains a self-published, preliminary research program. This mapping is a contribution to its ongoing development.

References

- Bonet-Luz, E., Lyle, J. V., Huang, C. L.-H., Zhang, Y., Nandi, M., Jeevaratnam, K., & Aston, P. J. (2020). Symmetric Projection Attractor Reconstruction analysis of murine electrocardiograms: Retrospective prediction of Scn5a+/- genetic mutation attributable to Brugada syndrome. *Heart Rhythm* 02, 1(5), 368–375. <https://doi.org/10.1016/j.hroo.2020.08.007>
- Galida, R. (2026a). *Persistence Under Perturbation: The Eternal Skeleton and the Transient Dance*. Fantasy Attractor. Published May 2026.