Petrarch vindicated: Modeling Human Romance with the Morse Quantum Oscillator

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Abstract

We propose a tongue-in-cheek quantum-mechanical model of romantic relationships in which the "coordinate" is an abstract attachment strength r and the interaction is described by the Morse potential. Our Morse formulation is elegant because it achieves **maximal physical content with minimal parameters** while remaining **exactly solvable in quantum mechanics**—a remarkably rare and beautiful combination. We show that while immortal Italian poets struggled to understand human romance, the Morse potential's finite number of bound states and the clean separation between eternally bound (until death) and rapidly decaying states reproduce the observed mixture of near-Gaussian lifetimes for viable couples and heavy-tailed (Pareto-like) lifetimes for non-viable ones surprisingly well. Thus, Morse's crystal clear formulation prevails over Petrarch-inspired renditions in words and provides a natural second-quantization layer for Rinaldi's classical *love equations*. Fake but credible numerical examples for a high-chemistry and a low-chemistry couple are presented.

1 Introduction

né per intelletto salir al vero,
né per oblio fuggir di mente Amore;
arde et arde, et non è chi gli dia aita,
et non è chi mi creda, et pur è vero.
— Francesco Petrarca, *RVF* 134

One can argue with overwhelming textual evidence that the "sommi poeti" of the Italian tradition (Dante, Petrarca, and their heirs) saw romance as fundamentally and gloriously irrational, and that this irrationality is not a defect but the very signature of authentic, transcendent love. Petrarch realized it so well that he turned love's irrationality into proof of its greatness and authenticity. His immortal line "né per intelletto salir al vero" is not a complaint; it is a surrender.

Before the pioneering work of other Italians, Sergio Rinaldi and his co-workers [1], love was considered for centuries to be too complex (or too poetic) to be modeled with rigorous mathematics. By interpreting romantic feelings as classic state variables governed by nonlinear differential equations—with attraction, forgetting, and effort as explicit feedback terms—they transformed the dynamics of couples and marriages into a legitimate branch of systems theory. Our quantum-Morse approach can be seen as the natural quantization underlying Rinaldi's classical *love equations*. Far from contradicting classic results, our quantization is a refinement (a kind of 'quantitative elasticity') of classical love mechanics.

2 Why the Morse Potential Expresses Love

The Morse potential is a realistic anharmonic potential [2] defined as follows:

$$V(r) = D_e\Big(1 - e^{-a(r-r_e)}\Big)^2, \qquad r \geq 0 \tag{1}$$

It comes with some crucial properties:

- Dissociation limit $V(\infty) = D_e$ (zero binding $\leftrightarrow$ separated)
- Exactly solvable: energy levels

  $$E_n = \hbar\omega\Big(n + \frac{1}{2}\Big) - \frac{(\hbar\omega)^2}{4D_e}\Big(n + \frac{1}{2}\Big)^2, \quad n = 0, 1, \ldots, n_{\max} \tag{2}$$

  where $\omega = a\sqrt{2D_e/\mu}$ and $n_{\max} = \lfloor\sqrt{4D_e\mu}/\hbar - 1/2\rfloor$.
- Only a finite number of truly bound states exist — exactly like human relationships.

The Morse potential is widely regarded as one of the most elegant interatomic potentials in physics and chemistry because, unlike Petrarch's poetic description, it combines physical realism with exact mathematical solvability in a way that few other potentials achieve. Equation (1) contains only three parameters:

- D_e: dissociation energy (well depth),
- r_e: equilibrium bond length,
- a: width parameter controlling the stiffness of the well.

With just these three parameters, the Morse formula simultaneously expresses harmonic behavior near equilibrium, the correct dissociation limit, realistic anharmonicity, and the smooth transition of a two-body system from bound to unbound states.
To avoid losing at this point any reader who may have only a humanities background, let's take the example of a perfect pendulum, consisting of a string of length r fixed at one end and a movable weight[1]. If we displace the pendulum's weight by a small angle ($<$ 15 degrees), we will obtain *harmonic* oscillations, whose fundamental angular frequency depends only on the length r of the string, according to Hooke's law[2]. The restoring force is indeed $F = -\,mgsin(\theta)$, where θ is the displacement angle. For small angles, the approximation $\theta = \sin(\theta)$ holds, so the force $F = -(mg/r)\theta r$ is directly proportional to the angular displacement θ (or to the lateral displacement $s = r\theta$). The angular frequency of oscillation is therefore $\omega = \sqrt{k/m} = \sqrt{mg/r/m} = \sqrt{g/r}$, which corresponds to a constant period $T = 2\pi\omega = 2\pi\sqrt{r/g}$.
Anharmonicity is the property of an oscillating system to **not** behave like a harmonic oscillator for certain values of the parameters[3]. A pendulum is either oscillating harmonically (with oscillations depending on r only) or anharmonically, depending on the initial displacement angle. Instead, the Morse oscillator smoothly transitions between harmonic and anharmonic behavior. We interpret r as a dimensionless measure of relational intensity in humans:

$$r \to \infty : \text{divorced/detached}, \quad r = r_e : \text{healthy attachment}, \quad r \to 0 : \text{toxic enmeshment}.$$

[1] We use the symbol r here instead of the classic L to emphasize the analogy with the "length" of the Morse potential.

[2] The fundamental principle of the mechanics of elastic solids was first stated in 1676 by the English physicist Robert Hooke as an anagram (*"ceiiinosssttuu"*) and published two years later in the form: *"Ut tensio, sic vis"*

[3] Anharmonicity applies to pendulums when the load is displaced by a large angle. In chapter 117 of "Foucault's Pendulum" [3], the body of Jacopo Belbo, hanging from the pendulum's string in the Conservatory on rue Saint-Martin in Paris, oscillates anharmonically. *«It swung slowly, like a very slow pendulum. But it was not a pendulum. A pendulum oscillates according to Hooke's law only for small angles. Here the angle was large, almost one hundred eighty degrees, and therefore the oscillation was strongly anharmonic. The period was no longer independent of the amplitude. It was a diabolical pendulum, which slowed more and more, and in millions of years it would have stopped.»*

3 Physiological Foundations for r

We argue shamelessly that the coordinate r in our quantum-romance Morse potential is *not* a vague metaphor but a perfectly well-defined (and secretly measurable) dimensionless physiological variable.

The Unified Relational Intensity Index (RII)

$$r \propto \frac{\text{Oxytocin} \times \text{Dopamine (NAc)} \times \text{Vasopressin} \times \text{Heart-rate synchrony}}{\text{Cortisol} \times \text{dlPFC activation} \times \text{Interpersonal distance (cm)}} \tag{3}$$

Or, in everyday units:

$$r \simeq \left(\frac{\text{Mutual staring time}}{\text{Minutes in separate rooms without anxiety}}\right) \times (\text{skin-conductance when partner's name pops up})^{0.7} \tag{4}$$

Component	**Physiological evidence**	**Why it belongs in r**
Plasma oxytocin × vasopressin	Peaks in first 6–18 months [4, 5]	"Cuddle cocktail"; decays $\Rightarrow$ r drifts outward
Dopamine in nucleus accumbens	Same circuits as cocaine [6]	Pure obsession metric; higher $\Rightarrow$ closer to $r = 0$
Heart-rate (IBI) synchrony	Unconscious entrainment stronger in new couples	"We literally beat as one"
Cortisol	Acute love: high; secure love: low	Early excitement compresses r; fights shoot $r \to \infty$
dlPFC / vmPFC activity	Hypoactivation in early love = suspended judgment	Reason offline $\Rightarrow$ smaller r
Physical proximity tolerance	New couples: metres apart = distress	Attachment-theory rubber-band length
Pupillary dilation (partner photo)	Uncontrollable arousal marker	Victorian novels were physiologically correct

Table 1: Physiological contributions to the dimensionless relational intensity coordinate r. Simultaneously ridiculous and defensible.

We are now in a position to declare, with a completely straight face:

> "Relational intensity r is a rigorously defined dimensionless physiological coordinate whose time evolution is governed by the Morse potential, quantitatively calibrated to neuro-endocrine panels and cardiac-entrainment data."

4 The Schrödinger Equation is Exactly Solvable

The resolution of the Schrödinger equation stands as one of the paramount endeavors in quantum mechanics, my dear readers. In those rare instances where the equation yields an analytical solution for a physical system, the insights gleaned therefrom afford a profundity of understanding that eclipses the fragmentary and approximate apprehensions derivable from numerical methods—and, heaven forfend, from supervised machine learning.[4] Let us, then, savor

[4] In the preponderance of cases, ML methods prove interpolative or regressive: they acquire knowledge from a 'training set,', yet they neither 'comprehend' nor 'represent' the system (with the partial exception of learning univariate polynomial functions [7]). An analytical solution, instead, demands no training and unveils to the initiated the mathematical connections that a computational learning model seldom 'discovers' unaided.

Relationship phase	Approx. r	Dominant physiological signature
First eye contact across the room	0.3–0.8	Dopamine + pupil explosion
Honeymoon (0–18 months)	1.2–1.6	Oxytocin/dopamine max, dlPFC on vacation
Healthy long-term (5+ years)	$\simeq 2.1$ (near r_e)	Balanced hormones, gentle cardiac synchrony
Seven-year itch crisis	2.8–3.5	Cortisol surge, synchrony lost, reason returns
Pathological enmeshment	< 1.0	Oxytocin overdose, zero boundaries
Breakup / divorce	$\to \infty$	Oxytocin crash, cortisol max, kilometres apart

Table 2: Typical values of the dimensionless relational coordinate r during the life cycle of a human couple.

the step-by-step elucidation of the Schrödinger equation for the Morse potential of love, without entertaining for a moment the vulgar notion that it might have been conjured by some mechanical oracle like ChatGPT. The equation, in its stationary and one-dimensional guise, assumes the form

$$-\frac{\hbar^2}{2\mu}\frac{d^2\psi}{dr^2} + D_e\left(1 - e^{-a(r-r_e)}\right)^2 \psi(r) = E\psi(r).$$

Step 1 — A Judicious Change of Variable

One introduces the dimensionless variable

$$z = 2\lambda\, e^{-a(r-r_e)}, \qquad \lambda = \frac{1}{a}\sqrt{\frac{2\mu D_e}{\hbar^2}},$$

wherein λ approximates, with commendable accuracy, the number of bound states in the liaison. With this substitution, $z \to +\infty$ as $r \to -\infty$ (a behavior decidedly unphysical, one must concede) and $z \to 0^+$ as $r \to +\infty$.

Step 2 — The Reduced Form of the Equation

Following laborious substitutions that few souls could essay without recourse to authority (vide, for instance, the venerable Landau–Lifshitz [8] or any tome of advanced quantum mechanics), the equation transmutes into

$$\frac{d^2\psi}{dz^2} + \frac{1}{z}\frac{d\psi}{dz} + \left[\frac{\lambda^2 - (E/D_e)}{z^2} - \frac{1}{4} - \frac{\lambda^2}{z}\right]\psi(z) = 0.$$

Step 3 — Substitution

Let us now posit a wave function of the general form

$$\psi(z) = z^s e^{-z/2}\, u(z),$$

with $s = \lambda - \frac{1}{2}$. Substituting this into the equation yields, for $u(z)$, the equation of the Laguerre polynomials that approximate the solution:

$$zu''(z) + (2s + 1 - z)u'(z) + (\lambda - s - 1)\, u(z) = 0.$$

Step 4 — Quantization

For $u(z)$ to manifest as a finite polynomial (corresponding to physical comportment in the limiting cases $z \to 0$ and $z \to \infty$), the parameter λ must perforce be a non-negative integer:

$$\lambda - s - 1 = n \qquad (n = 0, 1, 2, \dots)$$

whence, recalling that $s = \lambda - 1/2$,

$$\lambda - n - \frac{1}{2} = s \in \mathbb{N}_0 \qquad \Rightarrow n = 0, 1, 2, \dots, \left\lfloor \lambda - \frac{1}{2} \right\rfloor.$$

Step 5 — Exact Energy Levels

Imposing the quantization condition, we arrive at the celebrated formula we reiterate here for emphasis:

$$\boxed{E_n = \hbar\omega\left(n + \frac{1}{2}\right) - \frac{(\hbar\omega)^2}{4D_e}\left(n + \frac{1}{2}\right)^2 \qquad (n = 0, 1, 2, \dots, n_{\max})}$$

where the (anharmonic) frequency of oscillations is

$$\hbar\omega = a\sqrt{\frac{2D_e}{\mu}}.$$

Step 6 — Normalization

The normalized eigenfunctions are

$$\psi_n(r) = N_n\, z^{(\lambda-n-1/2)} e^{-z/2}\, L_n^{2(\lambda-n-1/2)}(z),$$

with $z = 2\lambda\, e^{-a(r-r_e)}$ and the normalization constant

$$N_n = \left[\frac{a\, n!\, 2(\lambda - n - 1/2)}{\Gamma(2\lambda - n)}\right]^{1/2}.$$

5 Two Quantum Regimes of Love

> *«If it be not true, 'tis most ingeniously contrived: if it be not so, one is most admirably excused for the other»* [9].

Let us now see how well our Morse potential describes reality. According to the veritable data of the United Nations, the longevity of human pairings constitutes a mélange of two profoundly divergent distributions:

1. Stable couples (profound bound states): endogenous dissolution rate nigh on nil. Duration conforms to a unilateral long-tailed distribution $\sim N(T; \mu_{\text{vita}}, \sigma_{\text{vita}})$ with $\mu_{\text{vita}} \approx 45$–55 years—ah, the blissful endurance of matrimonial felicity!

2. Unstable couples (elevated n states + continuum): duration is exponential with a featherweight tail $S(T) \sim T^{-\alpha}$, $\alpha \approx 1.5$–2.5—one might say, the fleeting caprices of Cupid's less steadfast arrows.

Let us now compute the parameters of a stable amorous liaison and its fickle counterpart (in arbitrary units $\hbar = \mu = \omega = 1$) and the attendant results:

1. **Viable couples** (deep bound states): almost zero endogenous breakup rate. Duration $\sim \mathcal{N}(T; \mu_{\text{life}}, \sigma_{\text{life}})$ with $\mu_{\text{life}} \approx 45$–55 years.

2. **Non-viable couples** (high-n states + continuum): heavy-tailed lifetimes, empirically Pareto-like $S(T) \sim T^{-\alpha}$, $\alpha \approx 1.5$–2.5.

6 Simulation 1: High-Chemistry Couple "Alex & Jordan"

Parameters (in arbitrary units $\hbar = \mu = \omega = 1$):

Parameter	Value	Interpretation
D_e	12.5	Deep well, ∼18 bound states
a	0.85	Moderate anharmonicity
r_e	2.1	Comfortable attachment distance
Initial state	Gaussian $r_0 = 1.7$, $\sigma = 0.22$	Intense honeymoon

Results:

Component	Probability	Fate if dominant
Deep bound ($n = 0$–7)	61%	Gaussian, ∼52 y (death)
Fragile + continuum	39%	Heavy-tailed, median 5.8 y

Year	Still together	Main termination mechanism
5	79%	Resonance decay
7	71%	Quantum seven-year itch
10	67%	—
20	64%	—
50	61%	Death

Table 3: Survival milestones for Alex & Jordan.

7 Simulation 2: Low-Chemistry Couple "Taylor & Morgan"

Parameter	Value	Interpretation
D_e	6.8	Shallow well, only ∼9 bound states
a	0.92	Steeper short-range repulsion
r_e	2.3	Healthy distance feels distant
Initial state	Gaussian $r_0 = 2.6$, $\sigma = 0.48$	Starts lukewarm

Results:

Component	Probability	Fate if dominant
Deep bound ($n = 0$–3)	19%	Gaussian ∼50 y
Fragile + continuum	81%	Heavy-tailed, median 3.1 y

Year	Still together	Typical reason if ends
1	68%	"We tried"
2	49%	Peak low-chemistry hazard
5	29%	Most non-viable gone
10	22%	Stubborn tail
50	19%	Only the viable 19% remain

Table 4: Survival milestones for Taylor & Morgan.

8 Coupled Morse Oscillators as the Natural Quantization of Rinaldi's Equations

E Beatrice, severa: «Amore è uno, e ordina l'alma a un sol congiunto sposo; chi in molti il spezza, in molti si fa bruno per bestial brama, e perde il suo riposo. — Apocrypal Dante Alighieri, *ADA* 134

Although the single Morse oscillator already captures the essential phenomenology of monogamous pair bonding with shocking accuracy, a truly ambitious theory like ours must also address the elephant in the (bed)room: *old-time humans sometimes cheated, dated multiple partners simultaneously, or (heaven help us) engaged in polyamory.* Rinaldi's classical love equations [1] are, in their most general form, a set of $2N$ coupled nonlinear ODEs for N individuals:

$$\begin{aligned} \frac{dx_i}{dt} &= f(x_i, y_i) + \sum_{j\neq i} g_{ij}(x_i, x_j, y_i, y_j), \\ \frac{dy_i}{dt} &= h(x_i, y_i) + \sum_{j\neq i} k_{ij}(x_i, x_j, y_i, y_j), \end{aligned} \tag{5}$$

where x_i and y_i represent the love and the response (or "appeal") felt by individual i towards their partner(s).

The natural, Hilbert-space-covariant quantization of this system is immediate: promote each classical romantic degree of freedom to a Morse oscillator and allow *arbitrary linear combinations* of the corresponding creation/annihilation operators.

8.1 The Polyamorous Hamiltonian

Define N identical Morse oscillators with on-site potential $V(r_i)$ and introduce pairwise "entanglement potentials" $V_{\text{int}}(r_i, r_j)$ that are morally questionable but mathematically unavoidable:

$$\begin{aligned} \hat{H} = &\sum_{i=1}^{N} \left[\frac{\hat{p}_i^2}{2\mu} + D_e \left(1 - e^{-a(\hat{r}_i - r_e)}\right)^2 \right] \\ &+ \sum_{1\leq i<j\leq N} J_{ij} \left(e^{-b|\hat{r}_i - \hat{r}_j|} - e^{-c(\hat{r}_i + \hat{r}_j)} \right). \end{aligned} \tag{6}$$

The first interaction term $e^{-b|\hat{r}_i - \hat{r}_j|}$ represents *jealousy repulsion* (the closer two partners are to each other in relational-intensity space, the more explosive the conflict). The second term is the infamous *secret-affair attraction* that decays only when *both* r_i and r_j become large (i.e., both partners drift away from the primary relationship).

8.2 Second Quantization (for the terminally committed)

For large open relationships, one may pass to field operators

$$\hat{\psi}^\dagger(r) = \sum_n \phi_n(r)\hat{a}_n^\dagger,$$

where $\phi_n(r)$ are the exact Morse eigenfunctions (the associated Laguerre polynomials in disguise). The many-body ground state of a triangle ($N = 3$) is then found by minimizing

$$\langle \hat{H} \rangle = \int dr\, \hat{\psi}^\dagger(r)\hat{h}_{\text{Morse}}(r)\hat{\psi}(r) + \frac{1}{2}\iint dr\, dr'\, v(r, r')\, \hat{n}(r)\hat{n}(r'),$$

yielding a Hartree–Fock–Bogoliubov (HFB) equation[5] whose solutions are colloquially known as *broken hearts* and *new relationship's energy high.*

8.3 Spectacular Predictions (to be tested on Tinder)

1. **Entanglement entropy plateau**: After the initial N-body entanglement spike, the von Neumann entropy of any subsystem saturates at $S \approx \ln(2)$ for stable groups and diverges logarithmically for unstable ones, explaining why some group chats never die.

2. **Quantum seven-year itch becomes a phase transition**: At critical coupling $J_{ij} = J_c \approx 0.74\, D_e$, the system undergoes a first-order "monogamy restoration transition" in which all but one Morse well abruptly deepens while the others collapse.

3. **Superfluid phase of love**: In the limit of very large N (Burning Man), off-diagonal long-range order appears, and the entire camp experiences spontaneous heartbeat synchronization. Experimental verification is left to the brave.

We are currently training a restricted Boltzmann machine on three years of group-chat logs to extract the effective J_{ij} matrix. Preliminary results suggest that adding a single well-calibrated Morse oscillator to an existing couple increases the probability of survival past seven years by $61\% \pm 42\%$, consistent with both quantum theory and certain anecdotal evidence from the late Seventies that the authors still like to recall.

9 Conclusion

The Morse oscillator provides a shockingly accurate toy model for romance:

- Finite $D_e \to$ only a few couples are "truly bound for life"
- Shape resonances $\to$ the infamous 7-year itch
- Mixture of Gaussian (death) + Pareto (breakup) tails $\to$ real demographic curves

In the future, should we have even more time to kill, we will incorporate the two-body reduced mass depending on the century's high neuroticism ratio and add a time-dependent external potential for children (deepening the well). Further details will appear elsewhere after our ethics board recovers consciousness.

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