# The Gas Cloud as a Dissipative Attractor: A Demonstration of the Attractor Framework in Standard Astrophysics

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June 2026
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## Abstract

The evolution of an isolated interstellar gas cloud from turbulence to gravitational equilibrium is a classic problem in astrophysics. Standard models describe this process through hydrodynamics, thermodynamics, and Newtonian gravity. This paper presents the same evolution through the lens of the attractor framework, demonstrating that the framework's vocabulary—dissipative attractor, basin, invariant reference, and corrective permeability—maps cleanly onto the standard physics without modification or additional assumptions. The paper makes no new physical predictions; it demonstrates conceptual unification. Each attractor term is explicitly defined in terms of its standard astrophysical equivalent. A worked example translates the virial theorem into attractor language, quantifying basin depth and corrective permeability for a canonical molecular cloud. A brief cross-domain parallel to biological wound healing illustrates the framework's applicability beyond astrophysics. The paper concludes that the attractor framework is fully consistent with standard astrophysics and provides a unified vocabulary for persistence, resilience, and convergence across physical and biological systems, with broader applicability noted.

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## 1. Introduction: The Cloud as a Dissipative System

Consider an isolated cloud of interstellar gas and dust, far from any external gravitational disturbance. Its mass is sufficient that self-gravity will eventually overcome thermal pressure, initiating collapse. At early times, the cloud is turbulent. Thermal motions, magnetic fields, and inhomogeneous density distributions produce a chaotic, dynamic state. Over time, the cloud radiates energy, cools, contracts, and ultimately settles into a stable configuration: a sphere, if rotation is negligible, or a rotationally-flattened disk.

Standard astrophysics describes this process with precision. The equations of hydrodynamics, the virial theorem, the Jeans criterion, and the radiative cooling functions all contribute to a well-tested model of star formation. Nothing in this paper challenges or revises that model.

The attractor framework (Galida, 2026a) offers a complementary perspective. It is not an alternative to standard physics, but a unifying conceptual vocabulary that identifies the dynamical principles at work: persistence under perturbation, dissipative basins, invariant references, and corrective permeability. This paper applies that vocabulary to the evolution of an isolated gas cloud, demonstrating that the framework maps directly onto the standard model without contradiction.

## 2. Definitions: Attractor Vocabulary and Standard Equivalents

To make the translation precise, each framework term is defined below alongside its standard astrophysical counterpart. These definitions are used consistently throughout the paper.

| Attractor Term | Definition | Standard Physics Equivalent |
|---|---|---|
| **Dissipative attractor** | A system that exports entropy while converging toward a stable, minimum-energy state | Radiative cooling + gravitational contraction |
| **Basin** | The minimum-energy configuration toward which the system evolves and from which it resists displacement | Sphere (non-rotating) or rotationally-supported disk |
| **Basin depth** | The energy required to permanently disrupt the system from its basin | Gravitational binding energy, $|U|$ |
| **Invariant reference (metronome)** | A quantity or point that remains fixed throughout the system’s evolution, providing an anchor for transient dynamics | Center of mass (positional reference); orbital periods (frequency reference, emerging during contraction) |

| Attractor Term | Definition | Standard Physics Equivalent |
|---|---|---|
| **Corrective permeability (κ)** | The rate at which the system dissipates perturbation energy and returns to its basin, quantified by $\kappa=1/\tau\mathrm{cool}\kappa=1/\tau\mathrm{cool}$ | Damping rate, quantified by the radiative cooling function $\Lambda(\mathrm{T})\Lambda(T)$ |
| **Rail** | A conservation law that constrains the accessible basins, preventing the system from reaching the global energy minimum | Conservation of angular momentum |

## 3. The Convulsive Phase: Turbulence and Disordered Motion

In its initial state, the cloud is far from equilibrium. Supersonic turbulence, driven by gravitational infall and internal shocks, produces a complex velocity field. Density distributions are filamentary and clumpy. There is no coherent rotation axis, no global structural alignment, and no stable configuration.

In attractor terms, this is the **perturbation-rich early phase**. The cloud is a dissipative system that has not yet found its basin. Its trajectory through state space is erratic. Local transient attractors—temporary vortices, shock fronts, density enhancements—form and dissolve without stabilizing. The system has not yet converged upon a single, deep attractor.

## 4. The Invariant Reference: Center of Mass as Metronome

Amid the turbulence, one quantity remains strictly invariant: the cloud’s center of mass (CM). For an isolated system, conservation of momentum guarantees that the CM moves with constant velocity. In the CM frame, this point is fixed. No internal force—gravitational, pressure, or magnetic—can displace it.

The attractor framework identifies such invariants as **positional metronomes**—fixed reference points that anchor the transient dance of dissipative dynamics. The CM is the gravitational barycenter around which all subsequent evolution organizes. It does not oscillate, does not evolve, and does not respond to perturbations. It is the still point at the center of the storm.

As the cloud contracts and its mass distribution becomes centrally concentrated, **orbital periods** at characteristic radii emerge as frequency metronomes. For a test particle at radius $r$, the Keplerian orbital period is:

$$P = 2\pi\sqrt{\frac{r^3}{GM(r)}}$$

where $M(r)$ is the mass enclosed within radius $r$. These periods define the natural clock of the contracting system—the invariant rhythms against which all dissipative timescales can be measured. The center of mass anchors position; the orbital periods anchor time. Together they constitute the invariant skeleton of the attractor.

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## 5. The Dissipative Mechanism: Radiation and Entropy Export

A dissipative attractor requires a mechanism for exporting entropy. The gas cloud exports entropy through **radiation**. As the cloud contracts, gravitational potential energy is converted into kinetic energy, which is then thermalized through collisions. Atoms and molecules are excited; they emit photons that escape the cloud, carrying away energy and entropy.

This radiative cooling is the cloud’s **dissipation channel**. Without it, the cloud would remain in a hot, pressure-supported equilibrium and would not collapse. With it, the cloud can progress toward deeper gravitational binding.

In attractor terms, the cloud is seeking its minimum-energy basin. Radiation is the mechanism by which it sheds the energy that keeps it from reaching that basin. Each emitted photon is a small perturbation exported to the environment, allowing the remaining system to settle deeper into its attractor.

## 6. The Attractor Basin: Sphere, Disk, and the Rail of Angular Momentum

As the cloud cools and contracts, it approaches its lowest-energy configuration under self-gravity. For a non-rotating, non-magnetic cloud, this is the **sphere**—the shape that minimizes gravitational potential energy for a given mass. Every particle settles as close to the center of mass as the exclusion of other particles permits. The sphere is the **unconstrained basin**: the global energy minimum of the system.

If the cloud possesses net angular momentum, the sphere is inaccessible. Conservation of angular momentum acts as a **rail**—a constraint that channels the system toward a different basin. The cloud must flatten along its rotation axis, forming a **disk**. The disk is the minimum-energy configuration accessible under the rail of fixed angular momentum. Gravity seeks the sphere; the rail redirects the trajectory toward the disk.

The approach to the basin occurs over the radiative cooling timescale, typically $10^4$ to $10^5$ years for dense molecular cloud cores. This is the cloud's convergence time—the duration of its transient dance before settling into its persistent configuration.

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## 7. Corrective Permeability and the Virial Theorem

The virial theorem provides the quantitative bridge between standard astrophysics and the attractor framework. For a system in equilibrium:

$$2K+U=0$$

where $K$ is the total kinetic energy and $U$ is the gravitational potential energy. In attractor terms:

- **Basin depth** = $|U|$, the gravitational binding energy.
- **Perturbation** = any injection of kinetic energy $\Delta K$ that raises $K$ above the equilibrium value $|U|/2$.
- **Corrective permeability** = $\kappa = 1/\tau_{\text{cool}}$, the rate at which radiative cooling dissipates $\Delta K$ and restores virial equilibrium.

**Worked Example.** Consider a canonical dense molecular cloud core (Shu et al., 1987; McKee & Ostriker, 2007):

| Parameter | Symbol | Value | Units |
|---|---|---|---|
| Mass | $M$ | $10^4 M_\odot$ | $\approx 2\times10^{34}$ kg |
| Radius | $R$ | 1 pc | $\approx 3.09\times10^{16}$ m |

| Parameter | Symbol | Value | Units |
|---|---|---|---|
| Temperature | TT | 10 K | |
| Mean number density | nn | ~103~103 | $cm^{-3}$ |

**Step 1: Basin depth.** The gravitational potential energy (to order of magnitude; the exact coefficient for a uniform-density sphere is 3/53/5) is:□U□~GM2R≈(6.67×10−11)×(2×1034)23.09×1016≈(6.67×10−11)×(4×1068)3.09×1016≈8.6×1041 J□U□~RGM2 ≈3.09×1016(6.67×10−11)×(2×1034)2 ≈3.09×1016(6.67×10−11)×(4×1068)□≈8.6×1041 J

At virial equilibrium, K=□U□/2≈4.3×1041K=□U□/2≈4.3×1041 J.

**Step 2: Perturbation.** Suppose a supernova explodes at a distance d≈10d≈10 pc from the cloud. A typical supernova releases ESN~1044ESN□~1044 J. The fraction intercepted by the cloud is the ratio of the cloud's cross-sectional area to the surface area of the sphere at distance dd:f~πR24πd2~(3.09×1016)24×(3.09×1017)2~2.5×10−3f~4πd2πR2□~4×(3.09×1017)2(3.09×1016)2□~2.5×10−3

Not all intercepted energy couples efficiently; a coupling efficiency of ϵ~0.01ϵ~0.01–0.10.1 is typical for shock-cloud interactions (McKee & Ostriker, 2007). Choosing the upper end, ϵ~0.1ϵ~0.1:ΔK=ESN×f×ϵ~1044×(2.5×10−3)×0.1≈2.5×1040 JΔK=ESN□×f×ϵ~1044×(2.5×10−3)×0.1≈2.5×1040 J

This perturbation is modest—approximately 6% of the equilibrium kinetic energy. The cloud is disturbed but not disrupted. Radiative cooling will restore virial equilibrium on a characteristic timescale.

**Step 3: Cloud volume.** Converting the radius to centimeters:R=1 pc=3.09×1018 cmR=1 pc=3.09×1018 cm

The volume is:V=43πR3≈43π(3.09×1018)3≈1.24×1056 cm3V=34πR3≈34□π(3.09×1018)3≈1.24×1056 cm3

**Step 4: Corrective permeability.** At $T \sim 10$ K and $n \sim 10^3$ cm⁻³, the dominant coolant is CO rotational line emission, with a cooling function $\Lambda(T) \sim 10^{-23}$ erg cm⁻³ s⁻¹ (Goldsmith & Langer, 1978; Neufeld, Lepp & Melnick, 1995). Convert $\Delta K$ to erg:$$\Delta K = 2.5 \times 10^{40} \text{ J} = 2.5 \times 10^{47} \text{ erg}$$

The cooling timescale is:$$\tau_{\text{cool}} \sim \frac{\Delta K}{V \Lambda} \approx \frac{2.5 \times 10^{47}}{(1.24 \times 10^{56}) \times (10^{-23})} \approx \frac{2.5 \times 10^{47}}{1.24 \times 10^{33}} \approx 2.02 \times 10^{14} \text{ s} \sim 6.4 \times 10^{6} \text{ years}$$

The corrective permeability is:$$\kappa = \frac{1}{\tau_{\text{cool}}} \approx 4.95 \times 10^{-15} \text{ s}^{-1}$$

**Step 5: Interpretation.** The perturbation is damped within a few million years. The basin depth ($|U| \sim 8.6 \times 10^{41}$ J) far exceeds the perturbation energy, ensuring the cloud’s structural integrity. Corrective permeability, quantified by $\kappa$, is the mechanism by which the cloud restores coherence—absorbing the modest perturbation through radiative cooling and returning to virial equilibrium on a timescale short compared to the cloud’s overall lifetime ($\sim 10^7$ years).

## 8. Cross-Domain Parallel: Biological Wound Healing

The same attractor vocabulary applies without modification to biological systems.

A wound is a perturbation to the stable attractor of healthy tissue. The body responds through a multi-stage healing cascade: clotting stops further damage, inflammation cleans the wound, and tissue repair restores structural integrity.

The healing rate—quantified clinically by wound closure time—is the biological corrective permeability. The healthy baseline state is the basin. Complications like impaired circulation reduce oxygen delivery, slowing fibroblast activity and thus reducing $\kappa$ (Guo & DiPietro, 2010).

The gas cloud perturbed by a supernova shock and the human body perturbed by a wound are structurally identical within the framework: a dissipative attractor, displaced from its basin, activates corrective mechanisms at a characteristic rate, and either returns to coherence or undergoes permanent state transition.

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## 9. Observational Consistency

The framework's description of cloud evolution is fully consistent with standard observations:

- **Turbulent molecular clouds** exhibit the chaotic velocity fields and filamentary structures predicted by the convulsive phase.
- **Radiative cooling** is traced by CO, $H_2O$, and other molecular line emissions.
- **Protostellar cores** represent the approach to the spherical attractor.
- **Protoplanetary disks** are the rotationally-constrained basins.
- **Bound clusters and stellar systems** persist under external perturbations, demonstrating basin depth.

These observations are predicted and explained by standard astrophysics. The attractor framework is consistent with all of them. Its contribution in this domain is conceptual, not empirical.

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## 10. Conclusion

The evolution of an isolated gas cloud from turbulence to equilibrium is fully described by standard astrophysics. The attractor framework does not replace that description. It translates it into a unified conceptual vocabulary—dissipative attractor, basin, invariant reference, rail, corrective permeability—that applies across physical and biological systems, with broader applicability noted.

The center of mass remains fixed while the cloud convulses, collapses, and settles. The virial theorem, translated into attractor language, quantifies basin depth as gravitational binding energy and corrective permeability as the inverse cooling timescale. The framework is consistent with all standard observations and requires no new physics.

The metronomes hum. The cloud finds its basin. The framework holds.

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*“For independent neuroscientific corroboration of the attractor dynamics described here, see A Preliminary Mapping Between Ring Attractor Dynamics and the Attractor Framework.”*https://www.sciencedirect.com/science/article/pii/S2405844024114892