

The Tensile Fracture Cascade Model of Stellar Collapse: Explaining Supernovae, Neutron Stars, and Black Holes

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1. Core Premise

Black hole formation during stellar collapse is typically modeled as a largely uniform, symmetric gravitational process where core mass exceeds degeneracy pressure limits, leading to singular collapse. However, this model proposes that:

- The internal structure of massive stars is highly inhomogeneous both materially and dynamically.
 - Mechanical fracture physics interacts with gravitational collapse in non-trivial ways.
 - Localized collapse into micro-black holes initiates a competitive and dynamically complex internal cascade.
 - The final outcome (neutron star — potentially stable or metastable — or black hole) depends not just on total mass but on the evolving internal mechanical stability of high-density material.
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2. The Multi-Stage Conditioning and Collapse Process

2.0 Fracture Seeding Through Shell Collapse Cascades

- Long before final core collapse, massive stars undergo multiple shell burning stages, each progressively fusing heavier elements as prior fuels are exhausted.
- As upper shells exhaust their fuel, they fall inward due to gravity, colliding with denser burning shells beneath them.
- These infalling shells partially rebound, producing repeated momentum-driven bounce cycles that transfer kinetic energy outward while further compressing inner layers.
- Each bounce contributes to the creation of fracture planes, alloy inhomogeneities, and stress redistribution within the stellar interior.
- The star's observed expansion during red giant phases results not only from radiation pressure but also from accumulated outward momentum transfer through repeated partial rebounds.

- Thermal pulses observed in certain late-stage stars may be surface manifestations of these repeated bounce cycles.
- By the time iron core fusion ceases, the star's structure is deeply pre-conditioned — filled with fracture planes and internal heterogeneity that prime it for the Tensile Fracture Cascade that follows.

2.1. Pre-Collapse Layered Structure

- As stars exhaust nuclear fuel, fusion occurs in stratified shells of progressively heavier elements.
- Heavier elements (iron-group nuclei) sink toward the center due to gravitational stratification.
- Late-stage red giants develop a complex, non-uniform structure: similar to a dense, irregular bread with layers of partial voids, bubbles, and "veins" of different material compositions and tensile strengths.
- Momentum-Driven Shell Expansion
 - In addition to standard radiation pressure effects, this model proposes that much of the red giant's outer expansion arises from repeated momentum transfers during shell infall cycles.
 - As outer shells collapse inward and rebound off deeper fusion-active layers, some kinetic energy is redirected outward, steadily driving the star's radius outward in multiple episodic stages.
 - This mechanism helps explain observed layered expansion, episodic mass ejections, and pre-collapse thermal pulses.
- Due to inhomogeneous material properties, certain high-tensile "veins" act like ropes pulling surrounding layers inward faster.

2.2. Progressive Momentum Build-Up

- Infalling layers gain momentum, as elements fuse down into heavier ones, but fall down with each failed fusion stage.
- This increasing momentum becomes the key parameter: not simply mass, but mass-in-motion, determining the force exerted at collapse.

2.3. Micro-Black Hole Nucleation

- At certain localized points where falling dense material exceeds critical momentum thresholds, micro-black holes form.
- These micro-black holes appear prior to global collapse, seeded in high-density, high-momentum micro-environments.
- The structural threads present around the micro-black holes create preferential corridors feeding certain micro-black holes preferentially.

2.4. Fracture-Induced Mechanical Shockwaves and Supernova as an emergent phenomenon

- As these structural threads break, mechanical shockwaves propagate outward, temporarily reducing the inward gravitational acceleration of surrounding material.
- These partial bounces around the micro-blackholes create temporary surfaces where matter rearranges and halts in-fall momentarily.
- Even though there is nothing below this layer – this is very close to the core and the only thing underneath the falling material is the event horizon of the micro-black hole: It is the emergence of these temporary surfaces that provides material for the upper layers, still in motion to bounce against. This emergent bounce is what is observed as a supernova.
- Reframing the Supernova
 - In this model, the event we observe as a supernova is not fundamentally different from the many prior momentum-driven rebounds that occurred during the star's layered evolution.
 - Rather, it represents the final, most energetic bounce — where the cumulative momentum of all previous collapses and fusions concentrates into one ultimate shock.
 - The massive outward explosion of a supernova is the natural consequence of this aggregated internal momentum finally encountering collapse conditions it can no longer redistribute, releasing its energy outward in a single powerful event.

2.5. Competition and Pocket Formation

- Micro-black holes begin to compete for matter as they grow.
- This creates localized low-density pockets as matter fractures internally.

2.6. Selective Growth and Hierarchical Merging

- Based on the inhomogeneous distribution of material around Micro-black holes, some might create stable pockets void of material unable to feed on any further while some might experience further growth (due to preferential feeding corridors).
- If, depending on the type of material in the region of nucleation, most of the micro-blackholes stabilize, the star would not collapse any further and stabilize into a neutron star configuration; others would continue their collapse further based on the growth of the micro-blackholes within.
- Growth is not instantaneous or uniform. Instead, micro-black holes feed preferentially from nearby material corridors rich in loosely bound matter.
- As some black holes grow larger, their gravitational cross-section increases, allowing them to dominate local spacetime and gravitationally attract nearby smaller black holes.
- Over time, hierarchical mergers occur as larger black holes absorb smaller ones in a cascade-like process, further accelerating collapse dynamics.

3. The Final Fate: Competing Outcomes

- If micro-black holes coalesce through preferential feeding and hierarchical mergers, they may eventually form a singular macro-black hole.
 - If tensile fractures and slowed accretion dominate, collapse halts, producing neutron stars.
 - This creates a time-dependent phase space where black hole formation is not simply mass-determined but driven by mechanical and dynamical feedback.
 - The micro-black hole nucleation, competition, and hierarchical merger processes described in the preceding sections occur during the rapid final collapse of the star, typically unfolding over seconds to minutes as the system races toward one of its possible end states.
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4. The Deferred Collapse Extension

4.1. Post-Supernova Black Hole Formation Possibility

- In stars near the critical mass threshold, a supernova may occur without immediate black hole formation.
- Residual micro-black holes may survive within the newly formed neutron star.
- Over extended timescales, further feeding from rotational slowdown, internal alloy phase changes, or additional accretion may allow these micro-black holes to eventually merge and collapse the neutron star into a black hole.

4.2. Post-Supernova Black Hole Formation via Residual Micro Black Hole Growth (Feeding Limited Process)

- In stars near the critical mass threshold, even after a supernova, residual micro-black holes may survive inside the neutron star.
- Over extended timescales, continued feeding — via rotational slowdown, internal accretion, or phase changes — allows these seeds to slowly merge into a full black hole.

4.3. Fracture-Stabilized Over massive Neutron Stars (FS-ONS): Collapse Limited by Mechanical Integrity

- In certain cases, stars may reach total masses traditionally expected to cross the black hole formation threshold, yet avoid immediate collapse due to internal fracture mechanics and heterogeneous material distribution.
- These over-massive neutron stars temporarily stabilize because structural inhomogeneities redistribute stress, allowing localized fracture planes to absorb infall momentum without immediately triggering global collapse.
- Micro-black hole nucleation may occur but remain insufficiently fed due to limited preferential feeding corridors.
- Statistically, such fracture-stabilized neutron stars would exist for shorter durations compared to lighter neutron stars, as higher mass increases gravitational stress on structural integrity.
- Over time, as rotation slows, internal alloy phase transitions occur, or fracture planes weaken, these stars become increasingly vulnerable to collapse via resumed hierarchical mergers.
- This predicts the existence of a transient class of neutron stars occupying mass ranges beyond the canonical Tolman-Oppenheimer-Volkoff limit.

- **Observational Implications:**
 - The limited lifetime of fracture-stabilized over-massive neutron stars offers a unique observational window.
 - Statistically, such objects should undergo collapse into black holes on much shorter timescales than traditional neutron stars, increasing the likelihood of capturing real-time collapse events.
 - Targeted surveys of neutron stars near or slightly exceeding the classical TOV mass limit could yield candidates for imminent collapse, producing gravitational waves, FRBs, or unexpected transient signatures.
 - The model predicts that some of these FS-ONS objects may serve as real-time laboratories for studying late-stage gravitational collapse dynamics.

4.4. Early Empirical Hints

- While this model is primarily conceptual, several emerging observations offer tantalizing indirect support for its framework:
 - **Massive neutron stars like PSR J0740+6620** (~ 2.1 solar masses) approach or exceed classical TOV limits, hinting at possible fracture-stabilized over-massive states.
 - **Fast Radio Bursts (FRBs)** have been hypothesized as potential signatures of sudden neutron star collapse events, possibly linked to the delayed collapse pathways described here.
 - **Certain gravitational wave events** reveal mergers involving compact objects whose masses straddle the upper edge of expected neutron star masses, consistent with transitions between FS-ONS states and full black hole formation.
 - These observations may represent early glimpses into the fracture-modulated collapse dynamics this model predicts and provide natural observational targets for future validation.
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5. Future Observation Possibilities

- In the future, if we develop probes capable of entering and transmitting data from within red giants, we may be able to detect the internal structure and potential micro-black hole mergers occurring within.
 - Alternatively, advancements in spacetime curvature detection or exotic radiation signatures may allow us to directly observe stable micro-black holes embedded inside neutron stars, even before full collapse occurs.
 - Sensitive future gravitational wave detectors may also pick up unique signals from micro black hole mergers occurring within collapsing stellar interiors.
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6. Why This Model is Distinct

- Introduces mechanical fracture physics into stellar collapse models.
 - Suggests competitive micro-black hole nucleation and hierarchical merger cascades as the true initial phase of a supernova and introduces black hole formation as one of the possible results.
 - Explains both black hole formation thresholds and why some stars stabilize into neutron stars while others continue collapsing into black holes.
 - Proposes that fracture-induced mechanical shockwaves are not just side effects but may serve as key contributors to supernova explosion mechanics, providing an alternative or complementary mechanism to neutrino-driven models.
 - Predicts a time-dependent delayed collapse pathway, not often accounted for in standard models as a possible result of the collapse process: formation of temporarily stable neutron stars that undergo a collapse in future.
 - Predicts the existence of fracture-stabilized over-massive neutron stars (FS-ONS) that temporarily resist collapse, offering testable observational opportunities.
 - Proposes potential future detection methods for internal micro black holes.
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7. Future Research Directions

- High-resolution 3D simulations incorporating fracture mechanics in stellar cores.
 - Exploration of high-density alloy and phase transitions under extreme gravity.
 - Modeling of hierarchical merger cascades in gravitational collapse.
 - Searching for observational evidence of delayed neutron star collapses.
 - Targeted searches for fracture-stabilized over-massive neutron stars and tracking their collapse probabilities.
 - Development of advanced detection techniques for micro-black holes inside stars.
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8. Closing Reflection

This Tensile Fracture Cascade Model proposes that black hole formation may not be a clean, singular threshold phenomenon, but rather a dynamic competition between gravitational momentum and material structure. By blending astrophysics with geologically-inspired fracture mechanics, it offers a fresh framework to explore both stellar death and cosmic birth.