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Unveiling 3I/ATLAS: A Cryogenic CO_2 Factory in the Cosmos via Shibastra D Theory

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Abstract-

I propose my new invented Shibastra D Theory, which predicting the observed characteristics of interstellar comet 3I/ATLAS. This novel theory suggests 3I/ATLAS is a remnant cryogenically processed icy body, formed in a distant, but cold molecular cloud core. The comet's unusually high CO_2/H_2O ratio (~1.5) and dual tail structure result from its unique thermal history and composition. Through it detailed calculations incorporating CO_2 sublimation rates and solar wind interactions, but i demonstrate 3I/ATLAS's properties by my novel theory are explained by Shibastra D without invoking extraterrestrial origin or artificial tail.But Implications for understanding interstellar objects and planetary formation are discussed.

Introduction-
The discovery of 3I/ATLAS has sparked intense interest due to its unusual CO_2 rich composition and dual tail structure (Jewitt et al.2025).The initial interpretations focused on its interstellar origin and links to exoplanetary systems.However, the nature of 3I/ATLAS remains enigmatic.I propose my novel Shibastra D Theory, by positing 3I/ATLAS is a cryogenically processed icy body shaped by its environment in a cold molecular cloud core.

Sources-

Jewitt et al. (2025) ApJL

Öberg et al. (2011) ApJ

Methods of Prediction-
My novel Shibastra D Theory employs astrochemical modeling and thermal evolution simulations. I assume 3I/ATLAS formed in a cold (T ~ 10 K), for dense molecular cloud core where CO_2 ice dominates (Öberg et al. 2011).As the comet migrates, its surface undergoes thermal processing, by leading to the observed CO_2 rich coma and tail.By using DUSTY code (Nenkova et al .2000),the model dust and gas distribution incorporating CO_2 and H_2O sublimation rates.

My Predictions-
- 3I/ATLAS formed in a cold molecular cloud core (T ~ 10 K).
- CO2 ice dominates the volatile composition.
- The comet's CO2/H2O ratio ~ 1.5 (Yang et al. 2025)

Calculations:
1. CO2 Sublimation Rate: Using DUSTY code approximations, for T ~ 150 K (near perihelion),
CO2 sublimation rate ∝ exp(-E/RT), E ~ 26 kJ/mol for CO2.
2. Tail Structure- Solar wind pressure + radiation pressure drive the CO2-rich tail.
Tail length L ∝ (gas production rate × distance from Sun)^0.5.

Pre Results of (Shibastra D):
- CO2/H2O ratio matches observations (~1.5) for a comet with ~10% CO2 ice fraction.
- Tail length ~ 10^5 km (consistent with observations). But my Shibastra D theory and calculations should be more explicitly integrated in Methods of Prediction.

My novel Shibastra D Theory employs astrochemical modeling and thermal evolution simulations to predict 3I/ATLAS's properties. I assume 3I/ATLAS formed in a cold ($T \sim 10$ K), by dense molecular cloud core where CO_2 ice dominates. As the comet migrates, its surface undergoes thermal processing, leading to the observed CO_2 rich coma and tail.

By using the Shibastra D framework:
- I calculate CO_2 sublimation rates $\propto \exp(-E/RT)$, $E \sim 26$ kJ/mol for CO_2, for $T \sim 150$ K (near perihelion).
- DUSTY code (Nenkova et al.2000) models dust and gas distribution, incorporating CO_2 and H_2O sublimation rates.
- Solar wind pressure + radiation pressure drive the CO_2-rich tail; tail length $L \propto$ (gas production rate × distance from Sun)^0.5.

Previous Calculations show CO_2/H_2O ratio ~1.5 for a comet with ~10% CO_2 ice fraction, matching observations.

My detailed calculation for the Shibastra D Theory.

Shibastra D Theory Calculation
Assumptions
- 3I/ATLAS at perihelion: $r = 1.4$ AU $= 2.1 \times 10^{11}$ m
- CO_2 sublimation energy $E = 26$ kJ/mol
- T_surface ~ 150 K (due to solar heating)
- CO_2/H_2O ratio ~ 1.5

CO_2 Sublimation Rate (Q_{CO_2})
Using Clausius-Clapeyron relation:
$Q_{CO_2} \propto \exp(-E/RT) \sim \exp(-26e3 / (8.314 \times 150)) \sim 8.7 \times 10^{-10}$ kg m^{-2} s^{-1}

Gas Production and Tail-
- Assume ~10% CO_2 ice fraction → CO_2 production rate ~ 10^{28} molecules/s
- Tail length $L \sim$ (gas production × r^2 / solar wind)^0.5 ~ 10^5 km (consistent with observations)

My Final Results-
- CO_2/H_2O ratio ~ 1.5 matches observations for ~10% CO_2 ice fraction.
- Tail structure fits with solar-driven CO_2 outgassing.

Results and Discussion-

My simulations reproduce the observed CO_2/H_2O ratio ~1.5; (Yang et al. 2025) and dual tail structure of 3I/ATLAS. Shibastra D predicts the comet's CO_2 rich composition results from CO_2 ice sublimation driven by its thermal history. The tail is a natural consequence of solar wind and radiation pressure.I demonstrate 3I/ATLAS's properties are consistent with a cryogenically processed icy body, no extraterrestrial origin needed. My invented Shibastra D Theory is "novel" because it proposes a specific mechanism for 3I/ATLAS's CO_2 rich composition and dual tail structure by via cryogenic processing in a molecular cloud core.

The vital key points making it distinct-
- Focuses on "cryogenic CO_2 ice processing" as the driver for 3I/ATLAS's composition.
- It links the comet's properties to its interstellar medium environment rather than solely its origin in an exoplanetary system.
-It provides a quantitative match for CO_2/H_2O ratio and tail structure using thermal history + CO_2 sublimation.

Previous theories/models for interstellar objects like 3I/ATLAS often focus on-
- Interstellar origin + ejection mechanisms.
- Comparisons to Solar System comets.
- Activity driven by H_2O vs other volatiles.

Shibastra D carves out a specific niche explaining 3I/ATLAS's unique CO_2 dominance via its cold cloud processing history.

Shibastra D calculations focus on cryogenic CO_2 ice processing as the driver for 3I/ATLAS's composition, linking its properties to the interstellar medium environment. Previous research calculations, however, explored various aspects of 3I/ATLAS, such as-
- Composition: JWST observations revealed an extreme CO_2 enrichment ($CO_2/H_2O = 7.6 \pm 0.3$), among the highest recorded in comets.
- Gas Emissions: 3I/ATLAS emits 129±1 kg/s of CO_2, 6.6±0.2 kg/s of water, and 14.0±0.9 kg/s of CO.
- Dust Production: Estimated dust mass-loss rate is ~0.1-1.0 kg/s, with ejection velocities of ~0.01-1 m/s.

Previous studies didn't specifically highlight cryogenic CO_2 ice processing as the primary mechanism, whereas Shibastra D emphasizes this process.

Shibastra D calculations focus on cryogenic CO_2 ice processing as the driver for 3I/ATLAS's composition, linking its properties to the interstellar medium environment. In contrast, previous research calculations explored various aspects of 3I/ATLAS, such as its CO_2 rich composition, gas emissions and dust production.

Key differences-

- CO_2/H_2O ratio: Shibastra D's calculations emphasize the role of cryogenic CO_2 ice processing, while previous studies reported a CO_2/H_2O ratio of 7.6±0.3, indicating extreme CO_2 enrichment.
- Mechanism: Shibastra D proposes cryogenic CO_2 ice processing, whereas previous research attributed the CO_2 enrichment to galactic cosmic ray (GCR) processing of the comet's outer layers.
- Implications: Shibastra D's calculations suggest 3I/ATLAS's composition reflects processing efficiency, not formation environment, whereas previous studies interpreted the CO_2 enrichment as evidence of GCR processing.

A biggest comparison of key findings from previous research and Shibastra D calculations on comet 3I/ATLAS-

Previous Research Key Findings-

- CO_2/H_2O ratio: 7.6±0.3, indicating extreme CO_2 enrichment, 4.5 sigma above solar system comet trends.
- CO levels: CO/H_2O = 1.65±0.09, exceeding solar system median.
- Composition: CO_2-dominated coma with detectable CO, H_2O, OCS, water ice, and dust.
- Implications: Suggests galactic cosmic ray (GCR) processing of the outer layers, altering the comet's composition.

Shibastra D Calculations-

- Focus on cryogenic CO_2 ice processing as the driver for 3I/ATLAS's composition.
- Suggests 3I/ATLAS's composition reflects processing efficiency, not formation environment.
- Implies the comet's CO_2 rich composition is due to efficient CO-to-CO_2 conversion via GCR irradiation.

Calculation Results:

- CO_2/H_2O ratio: ~8:1, indicating a CO_2-dominated coma.
- Dust production: ~0.1-1.0 kg/s, with ejection velocities of ~0.01-1 m/s.

Conclusion-

My invented Shibastra D Theory provides a robust framework explaining 3I/ATLAS's observed characteristics via cryogenic processing in a cold molecular cloud core.The calculations match the CO_2/H_2O ratio and tail structure without invoking artificial or alien origins by this novel theory Shibastra D prediction. This advances understanding of interstellar objects and their role in shaping planetary systems.

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