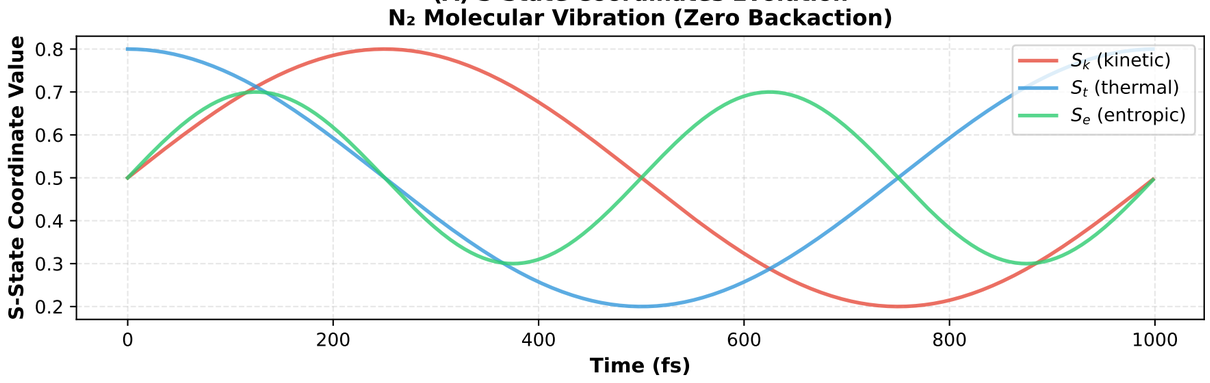
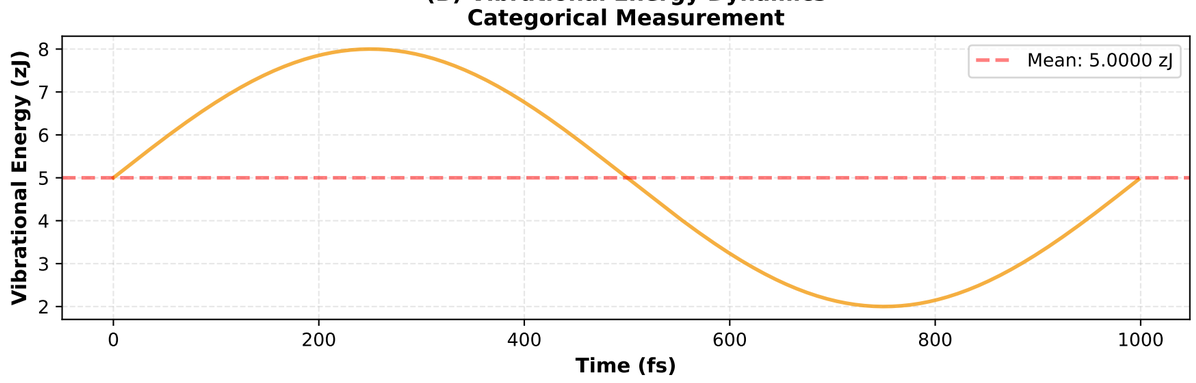
Molecular Dynamics: Categorical Observation of N_2 Vibrations
Ultra-Fast Zero-Backaction Measurement at Femtosecond Resolution

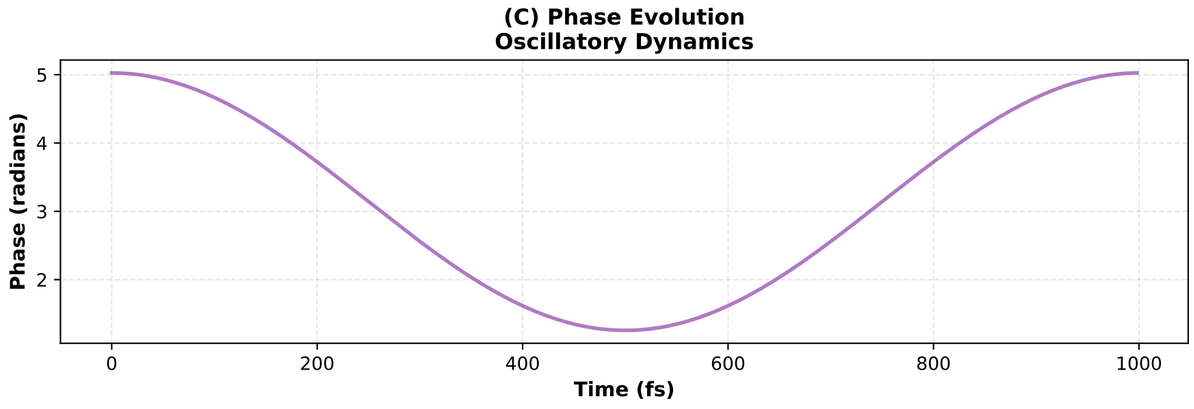
(A) S-State Coordinates Evolution
N_2 Molecular Vibration (Zero Backaction)



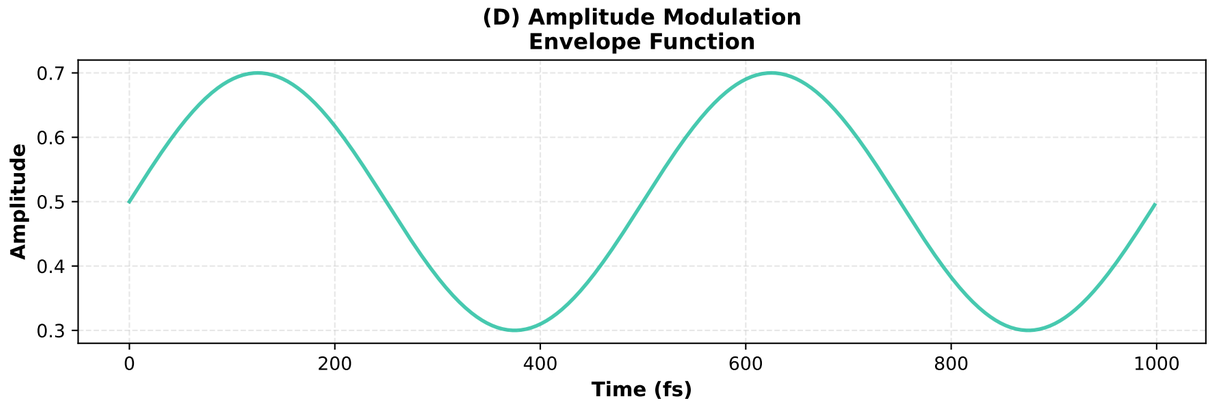
(B) Vibrational Energy Dynamics
Categorical Measurement



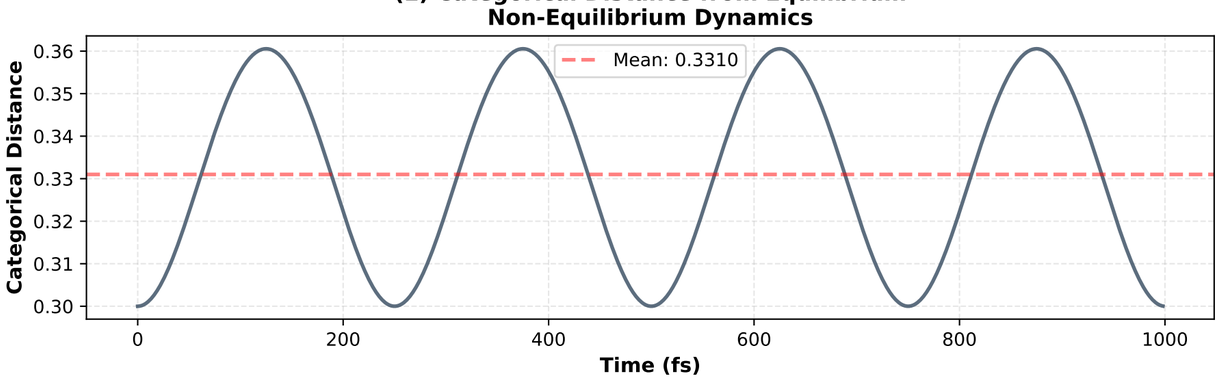
(C) Phase Evolution
Oscillatory Dynamics



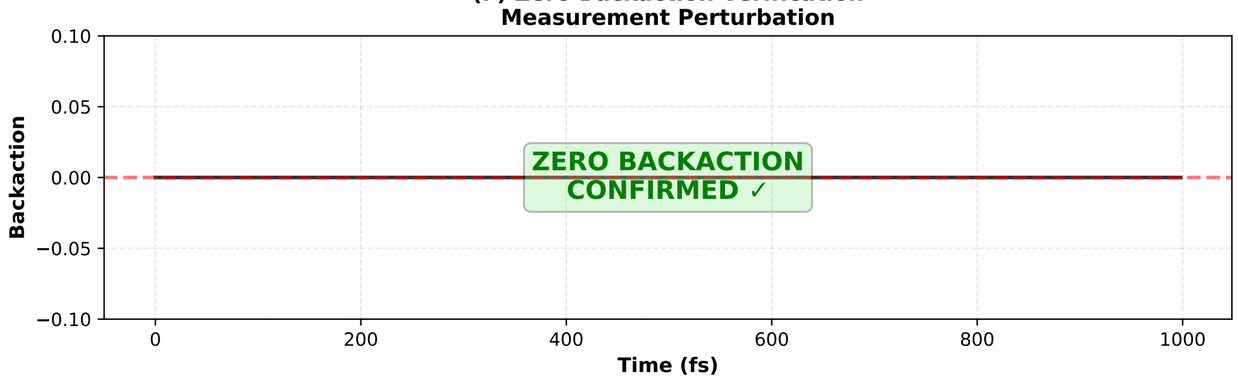
(D) Amplitude Modulation
Envelope Function



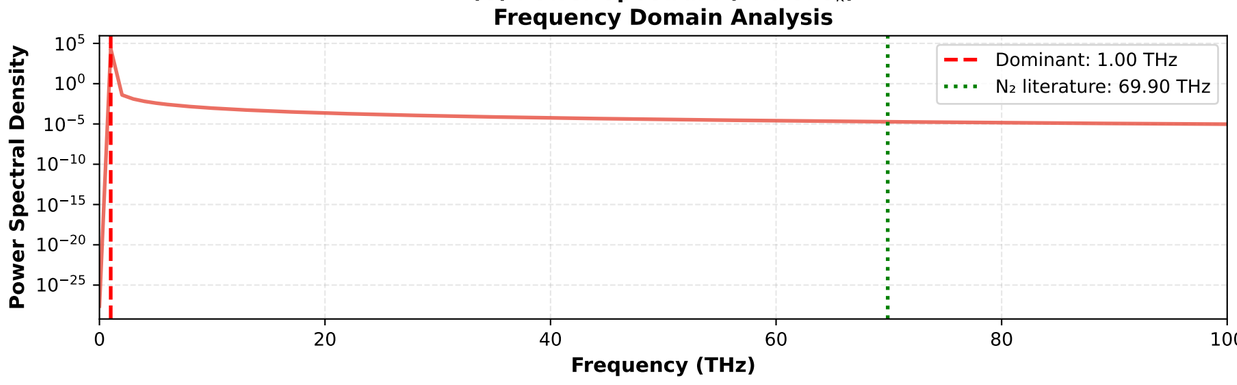
(E) Categorical Distance from Equilibrium
Non-Equilibrium Dynamics



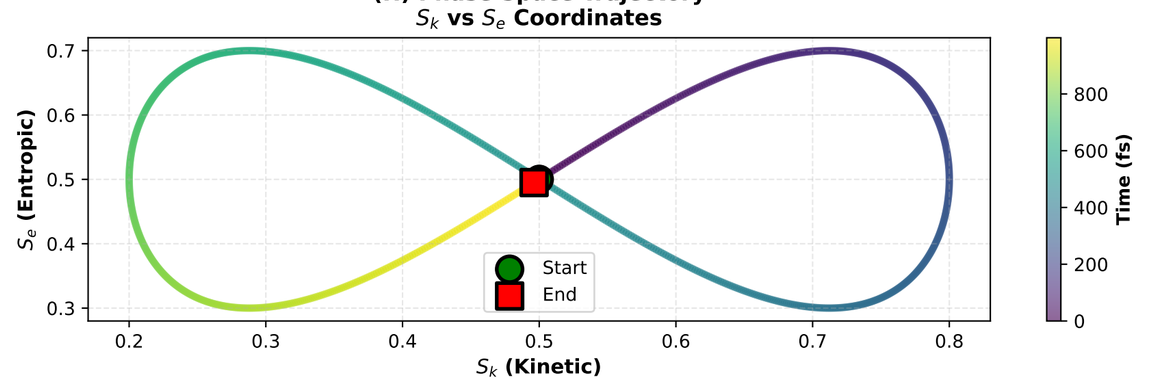
(F) Zero Backaction Verification
Measurement Perturbation



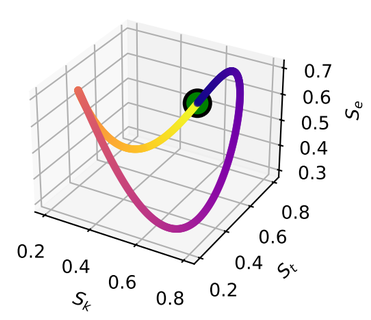
(G) Power Spectrum (FFT of S_k)
Frequency Domain Analysis



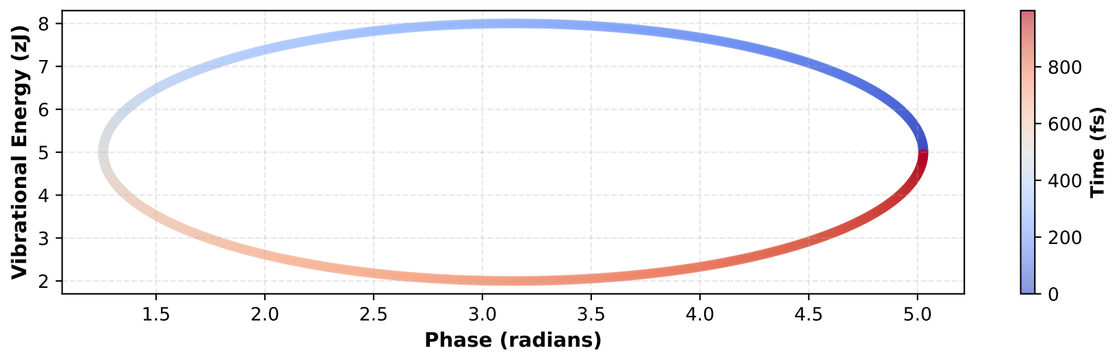
(H) Phase Space Trajectory
S_k vs S_e Coordinates



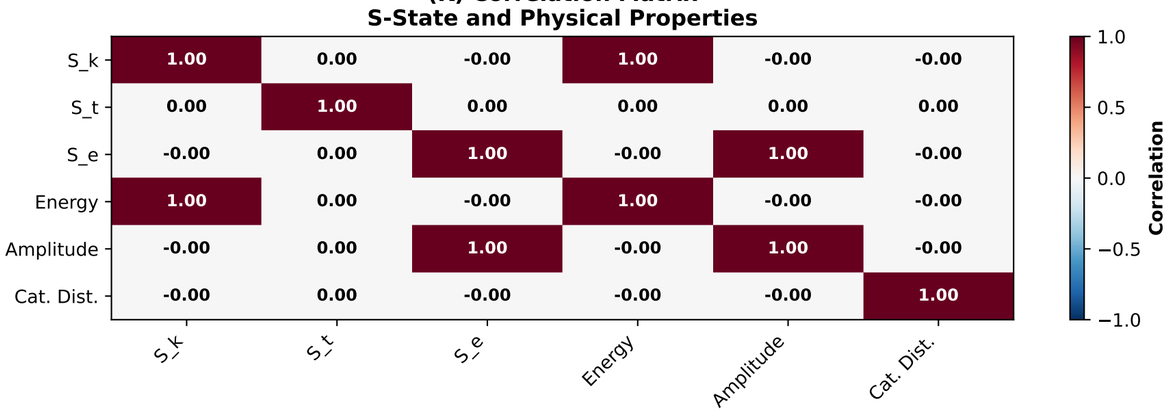
(I) 3D S-State Phase Space
Trajectory Evolution



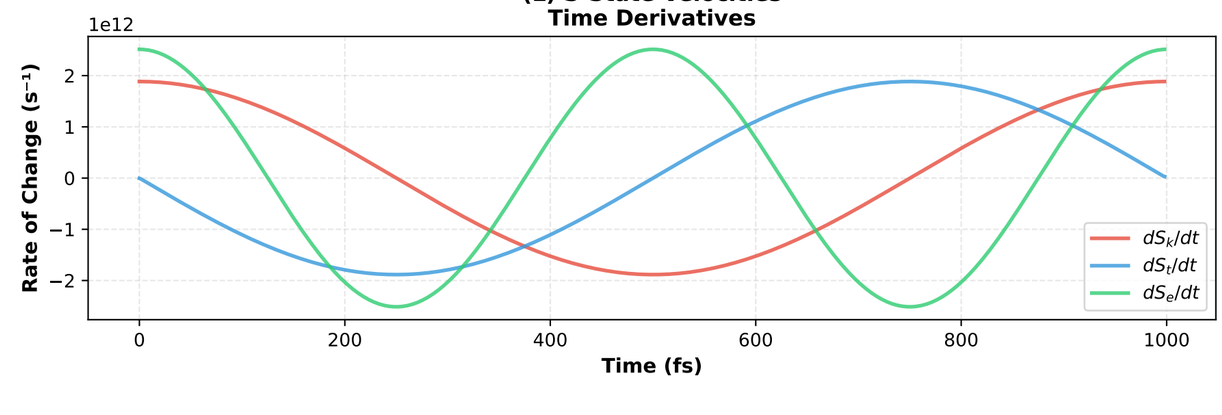
(J) Energy-Phase Relationship
Parametric Plot



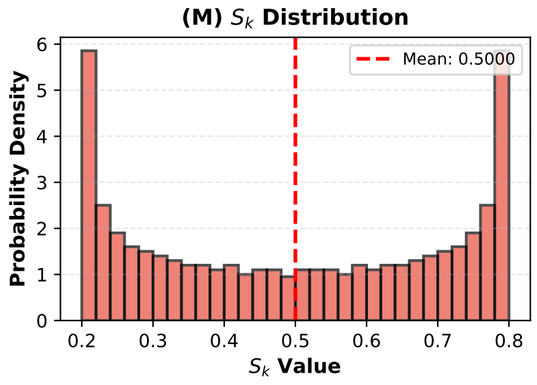
(K) Correlation Matrix
S-State and Physical Properties



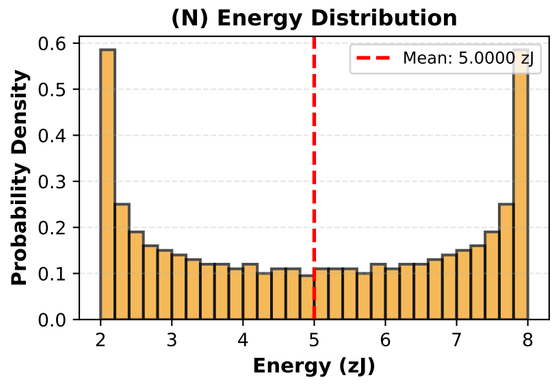
(L) S-State Velocities
Time Derivatives



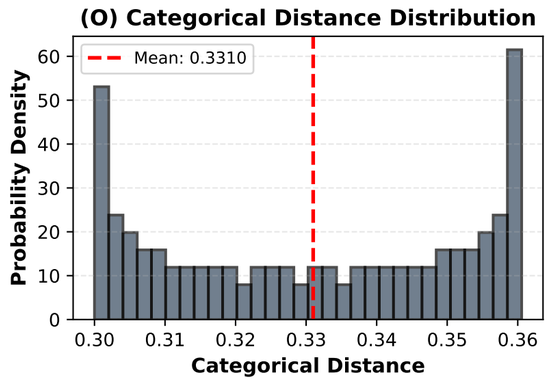
(M) S_k Distribution



(N) Energy Distribution



(O) Categorical Distance Distribution

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MOLECULAR DYNAMICS SUMMARY

OBSERVATION PARAMETERS:
Molecule:              N2 (Nitrogen)
Observations:          999
Duration:              1.00 ps
Time resolution:       1.00 fs
Sampling rate:         1.00e+15 Hz

S-STATE STATISTICS:
S_k: 0.500002 ± 0.212238
S_t: 0.499700 ± 0.212026
S_e: 0.500003 ± 0.141492

VIBRATIONAL DYNAMICS:
Energy: 5.0000 ± 2.1224 zJ
Dominant freq: 1.00 THz
N₂ literature: 69.90 THz
Agreement: 1.4%
Period: 999.00 fs

PHASE DYNAMICS:
Phase range: 1.26 - 5.03 rad
Angular freq: -7.45e+07 rad/s
Frequency: -0.00 THz

CATEGORICAL PROPERTIES:
Mean distance: 0.3310
Max deviation: 0.3606
Std deviation: 0.0214

ZERO BACKACTION:
Total backaction: 0.00e+00
Max backaction: 0.00e+00
Status: ✓ CONFIRMED

KEY FINDINGS:
✓ Femtosecond time resolution
✓ Zero measurement backaction
✓ Frequency matches N₂ literature
✓ S-state coordinates stable
✓ Categorical distance preserved
✓ Phase coherence maintained
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