Information Leaving Its Owner

Does Local Entropy Production Shift Transition Frequencies? A Pre-Experimental Protocol for a Dual-Comb Spectroscopic Test in Reacting Flows

Erkan Bayar

Version 1.0 · 29 October 2026
DOI: 10.5281/zenodo.23781810
Companion to Time-Gel Theory v12.1, doi:10.5281/zenodo.23106516
and to the ice clock protocol, doi:10.5281/zenodo.23724281

Abstract

In a flame, a sheet less than a millimetre thick turns fuel into products. Almost all of the flame's entropy is produced inside that sheet, and the record of what happened there does not stay: light escapes, products flow away. In the ice clock protocol the owner of the information was born from within the water. Here the information leaves its owner as fast as it is made.

Time-Gel Theory (v12.1) says a local clock slows with the local density of irreversible interaction, ρ_I. Under the rate reading, adopted as primary in the companion ice protocol, $\rho_I \equiv \sigma/k_B$, the local entropy production rate. In the reaction zone of an ordinary laboratory flame ρ_I is about 10^{29} $\mathrm{s^{-1}m^{-3}}$, three to four orders of magnitude more than in freezing water. If the theory holds with ρ_{crit} near today's soft bound of 10^{33} $\mathrm{s^{-1}m^{-3}}$, every transition frequency of every molecule inside the sheet is lowered by the same fraction, about 4×10^{-5} to 2×10^{-4}: some 9 to 35 GHz on a water line near 1.4 µm, larger than the line's own width.

We found no published measurement that rules this out. Flame spectra are taken in burnt gas above the sheet, or calibrated against lines in the same flame, or differenced between two beams. Each of these removes a shift common to all lines. This protocol measures absorption line centres inside the reaction zone against an outside frequency reference, with an entropy-matched control without reaction and a burnt-gas control without entropy production. Its sharpest signature is universality: Time-Gel predicts the same fractional shift, with the same sign, on every line of every species, while collisional shifts differ from line to line.

The protocol is pre-registered in structure and blinded. A null result sets the bound $\rho_{\mathrm{crit}} \gtrsim 10^{35}$–$10^{37}$ $\mathrm{s^{-1}m^{-3}}$, two to four orders of magnitude above the present one. No measurement has been made. Every number here comes from a definition or an order-of-magnitude estimate.

01 // How to read this document

Every claim carries one label. The labels are the method, as in the ice protocol [2].

[MEASURED]	Established by experiment in standard physics.
[MODEL]	Calculated from Time-Gel's equations or definitions.
[HYPOTHESIS]	A Time-Gel claim that this experiment can test.
[DECISION]	A choice made by the author of the theory, recorded before any data.
[OPEN]	A point the theory has not settled.
[INTERPRETATION]	A reading offered by this document. It may contain a hypothesis, but it is not yet one.
[ANALOGY]	An image. Not a physical claim.

Record first, interpret later. No sentence in this document carries the label [MEASURED] for a flame quantity that this protocol is meant to measure.

02 // The chain of thought

1. **Spark.** A premixed methane–air flame burns in a thin front, the reaction zone, a few tenths of a millimetre thick at atmospheric pressure [MEASURED]. Temperature rises from 300 K to about 2000 K across it.
2. **Change.** Inside the sheet, bonds break and form at a high rate. Heat is released at 10^{8}–10^{10} $\mathrm{W\,m^{-3}}$ [MEASURED, ORDER OF MAGNITUDE]. This is where almost all the flame's entropy is produced.

3. **The record leaves.** Ice keeps its record: the crystal holds as long as it is cold. A flame keeps nothing. Light leaves at once; products are carried downstream within milliseconds. Above the sheet the gas is hot, full of products, and almost at rest in entropy terms [INTERPRETATION].
4. **The clock.** Every molecule is a clock: its transition frequencies are its ticks. If time runs slow inside the sheet, the lines of the molecules inside it move to lower frequency, as seen by an outside reference [MODEL].
5. **What separates the readings.** Under the rate reading, the shift follows entropy produced: largest in the sheet, near zero in the burnt gas. Under the stock reading it would follow the record that is present, and in a flame the record is mostly gone.

The experiment's question: inside a flame's reaction zone, measured against an outside reference, do all lines move together to lower frequency?

03 // Who is the owner

In the ice protocol the source and the state builder coincided: the owner was born from within. In a flame they part at once.

Role	In this experiment	Reversible?	Measurable counterpart
Source	Fuel and oxygen molecules	No, once burned	Unburned composition
Carrier	Heat flow and radicals diffusing ahead of the front	Yes	Temperature and radical profiles
Processor	Elementary reactions in the sheet	No	Heat release rate, chemiluminescence
State builder	Product molecules (H_2O, CO_2)	No, but they leave	Burnt-gas composition
Meaning-giver	An observer who reads the flame	—	None [OPEN]

The record is made and immediately carried away. This is the opposite end from ice [INTERPRETATION]. Ice asks whether keeping a record costs time; the flame asks whether making one does.

04 // Time-Gel in one page

04.1 The flow law [MODEL]

Time-Gel v12.1 writes the local clock rate as

$$\frac{d\tau}{dt} = \frac{\sqrt{\max\left(0,\, 1-\rho_I/\rho_{\mathrm{crit}}\right)}}{1+\beta\Phi/c^2} \;\approx\; 1+\frac{\Phi}{c^2}-\frac{\rho_I}{2\rho_{\mathrm{crit}}}, \qquad \beta=-1. \tag{1}$$

The gravitational term is identical for every point of a table-top flame. Existing optical-clock data give the soft bound $\rho_{\mathrm{crit}} \gtrsim 10^{33}\ \mathrm{s^{-1}m^{-3}}$ [2].

04.2 What the clock looks at [DECISION]

As decided in the ice protocol [2], the clock looks at the change, not at the result:

$$\rho_I \equiv \frac{\sigma}{k_B} \qquad \text{(local entropy production rate per unit volume, } \mathrm{s^{-1}m^{-3}}\text{)}. \tag{2}$$

04.3 From clock to line [MODEL]

A transition of frequency ν_0 in a region whose time runs at $d\tau/dt$ is seen by an outside reference at $\nu = \nu_0\, d\tau/dt$. The fractional shift is therefore

$$\frac{\Delta\nu}{\nu} \;=\; -\frac{\rho_I}{2\rho_{\mathrm{crit}}}. \tag{3}$$

Three properties follow, and they are the signature of the effect:

- **Sign.** Always negative: lines move to lower frequency. The square-root law allows no speed-up.

- **Universality.** The same fraction for every transition of every species in the same volume. A water line, a CO line and an OH line move by the same $\Delta\nu/\nu$.
- **Locality.** It follows σ along the beam: present in the reaction zone, near zero in the burnt gas.

Ordinary collisional (pressure) shifts have none of these properties together: their size and sign differ from line to line and from species to species.

04.4 The rival reading [HYPOTHESIS]

In the stock reading the clock follows records that are present. In a flame the record is not well defined [OPEN]. If product molecules count as records, their density in burnt gas is at most about 2×10^{25} bit/m^3 (heat of reaction per methane molecule divided by $k_BT\ln2$, about 70 bits, Appendix A), and the shift would be largest in the burnt gas, not in the sheet. If only records that stay where they were made count, a flame holds almost none and nothing shifts. Either way the stock reading predicts no shift that peaks in the reaction zone. The ice protocol is the place to test it; this protocol only records its predictions.

05 // How big is the effect

05.1 Rate reading [MODEL]

A one-dimensional premixed methane–air flame at 1 atm, with a heat-release sheet about 0.2 mm thick and a peak heat release $q_{\max}$ between 10^9 and 10^{10} W m^{-3}, gives (chemical term q/T plus heat conduction $\lambda|\nabla T|^2/T^2$, Appendix A):

$$\bar{\rho}_I^{\,\text{zone}} \approx 0.8\text{–}3\times10^{29}\ \text{s}^{-1}\text{m}^{-3}, \qquad \rho_I^{\,\text{peak}} \approx 1.5\text{–}7\times10^{29}\ \text{s}^{-1}\text{m}^{-3}. \tag{4}$$

At $\rho_{\text{crit}} = 10^{33}$ the fractional shift averaged over the zone is 4×10^{-5} to 1.7×10^{-4}. On a water line near 7000 cm^{-1} ($\nu\approx2.1\times10^{14}$ Hz) that is 9 to 35 GHz to the red. The Doppler-plus-collision width of the same line at 2000 K and 1 atm is about 2 GHz [MEASURED, ORDER OF MAGNITUDE]. The predicted shift is larger than the line itself.

For scale: during the growth of ice in the companion protocol the fractional slowdown is about 3×10^{-8} [2]. The flame is three to four orders of magnitude stronger. Under the rate reading, the ice protocol was not expected to improve the atomic-clock bound. This one is.

05.2 What a null would mean [MODEL]

If line centres in the zone agree with the reference to within δ, then

$$\rho_{\text{crit}} \gtrsim \frac{\bar{\rho}_I^{\,\text{zone}}\,\nu}{2\,\delta} \approx \begin{cases} 3\times10^{35}\text{–}1\times10^{36} & \delta = 30\ \text{MHz} \\ 9\times10^{35}\text{–}3.5\times10^{36} & \delta = 10\ \text{MHz} \\ 9\times10^{36}\text{–}3.5\times10^{37} & \delta = 1\ \text{MHz} \end{cases} \text{s}^{-1}\text{m}^{-3}. \tag{5}$$

These assume that the beam samples the zone with full weight. A beam thicker than the zone, or one that crosses it only over part of its path, weakens the bound by the fraction of absorbers it sees inside the zone.

06 // What the literature already says

We looked for published flame spectra that could already test the prediction. None we found can [INTERPRETATION], for three reasons.

- **Place.** Measurements are made in burnt gas, a few millimetres above the burner, where $\sigma\approx0$. A comb-based water line list at 1950 K, for example, was recorded 2.5 mm above a flat flame [3].
- **Calibration.** Frequency axes are often calibrated against lines in the same flame [3]. A shift common to all lines disappears into the calibration. Universality, the effect's main signature, is exactly what such a calibration removes.
- **Differences.** Velocity measurements subtract two beams crossing the same gas [5]. A common shift cancels.

One measurement shows what the burnt-gas control can reach. In a non-reacting flow at 500–900 K, single-beam dual-comb absorption referenced to GPS reproduced line centres to about 2×10^{-4} cm^{-1}, roughly 6 MHz, after the database's own uncertainty [4]. That is the sensitivity class assumed above. The reaction zone itself, against an outside reference, appears not to have been measured [OPEN: THE SEARCH WAS NOT EXHAUSTIVE].

07 // Distinguishing predictions

Situation	Rate reading (primary)	Stock reading (rival)	Conventional
A · Reaction zone	Red shift, same $\Delta\nu/\nu$ on all lines	No zone peak	Line-dependent collisional shifts only
K1 · Same σ, no reaction	Same as A	Zero	Collisional only
K2 · Burnt gas, $\sigma \approx 0$	Zero	Zero, or largest if products count	Collisional only
C · Dose (vary σ)	Shift $\propto \sigma$	No dependence on σ	No common shift
D · Many lines, two species	One common fraction	—	Scatter in size and sign

The decisive comparison is the common fractional shift in A, against K2 in the same flame and against an outside reference. K1 separates entropy from chemistry.

08 // The experiment

08.1 Flame

A water-cooled flat-flame burner (McKenna type) with premixed methane and air. The flame is a flat sheet parallel to the burner surface, so a horizontal beam at the height of the reaction zone travels its whole path inside it. A low-pressure version (tens of millibar) thickens the zone to millimetres and makes it easy to resolve, at the cost of a lower σ per volume [OPEN: TRADE-OFF TO BE COMPUTED].

08.2 Probe

- **Tier 1.** A tunable diode laser near 1.4 µm, scanned across several water lines. A room-temperature water-vapour reference cell and a wavemeter in the same beam give the outside reference. The GHz-scale prediction needs no comb.
- **Tier 2.** Dual-comb absorption referenced to GPS, covering many water lines and, with a second band, CO or OH. This is the instrument named in the title; it is needed to test universality at the MHz level.

The beam is narrower than the zone and is scanned in height from the burner surface into the burnt gas. Counter-propagating passes cancel residual Doppler shift from the slow vertical flow.

08.3 Arms

Arm	What happens	What it controls
A · Reaction zone	Beam through the sheet; height scan	Test arm
K2 · Burnt gas	Same flame, beam several mm higher	Temperature, products, collisions, at $\sigma \approx 0$
K0 · Reference	Room-temperature cell and wavemeter or comb	The outside clock
K1 · Entropy-matched	Inert gas seeded with water, heated in a thin sheet to the same σ without reaction, by laser absorption or a shock front	Reaction versus no reaction at equal σ [OPEN: FEASIBILITY]
C · Dose	Equivalence ratio, dilution and pressure varied to change σ at similar temperature	Does the shift scale with σ?
D · Universality	Many water lines; a second species	Common fraction versus line-dependent shifts

09 // Measurement plan and analysis

The analysis is written and sealed before any data arrive. Data are unblinded once. The result is published whatever its sign.

1. **Pre-registration.** Reading under test: rate (primary). Sign rule: $\Delta\nu/\nu \leq 0$. Threshold, stopping rule and exclusion criteria fixed and timestamped.
2. **Calibration rule.** The frequency axis is never calibrated against lines in the flame. Only the outside reference (K0) is used.
3. **Quantities.** For each height and line: centre, width and area by line-shape fit; temperature from line ratios; $\sigma(h)$ from a flame model fixed before unblinding and checked against measured temperature and OH^* profiles.
4. **Systematics model.** Collisional shifts are measured line by line in K2 and in heated cells over the same temperature range, and fixed before test data are inspected. Their known dependence on temperature and partner gas is propagated through the zone.
5. **Blinding.** Software adds a secret common offset to all line centres and hides the height labels until the analysis is frozen.
6. **Model.** For line j at height h,

$$\frac{\nu_j(h)-\nu_{j,0}}{\nu_{j,0}} = s_j(h) + a\,w(h) + \varepsilon_j(h), \qquad a = -\frac{\bar{\rho}_I^{\,\text{zone}}}{2\rho_{\text{crit}}}, \tag{6}$$

   where s_j is the line-dependent collisional term, $w(h)$ the pre-computed σ-weighted overlap of beam and zone, and a is one number shared by all lines. The null is $a = 0$.
7. **Statistics.** Likelihood ratio against the null; one-sided 95% upper limit on $|a|$, converted to a lower bound on ρ_{crit}.
8. **Replication.** If an effect appears, raw spectra and code are released and a second laboratory repeats it with a different laser and reference. One laboratory's result never earns the label [MEASURED].

10 // Rival explanations

Rival	What it produces	How it is separated
Collisional shifts in the zone	Line-dependent shifts, tens to hundreds of MHz at flame temperature	Differ in size and sign between lines; a common fraction does not
Unusual collision partners (radicals)	Extra line-dependent shift in the zone only	Same: not universal; checked in arm D
Temperature gradient along the beam	Distorted, asymmetric line shapes	Height scan; flat flame; asymmetric profiles fitted
Doppler shift from flow	Shift $\propto v/c \approx 10^{-8}$ for 3 m/s	Beam perpendicular to flow; counter-propagating passes
Refractive-index gradients	Beam steering, etalons	Do not shift frequency; baseline fitted
Wavemeter or cell drift	Slow common offset	Reference measured with the flame off before and after each run
Experimenter expectation	False positive	Pre-registration, blinding, replication

11 // What would count as what

Support (only all together): a common negative fractional shift in A, above threshold, the same on every line and in both species; absent in K2; scaling with σ in arm C; present in K1 if K1 can be built; replicated elsewhere.

Not support, not falsification: no common shift within sensitivity. The bound on ρ_{crit} rises by the factors in Section 5.2.

Falsifies this form of the theory:

- A significant, replicated common shift to *higher* frequency.
- A common shift in A but none in K1 at equal σ: the effect follows chemistry, not entropy, and the rate reading is wrong.
- A common shift that does not scale with σ in arm C.

The limit of this test. Time-Gel gives ρ_{crit} only a lower bound [OPEN]. As long as no upper bound is written, no null result can refute the theory as a whole. It can only show that, if the effect exists, it is smaller than this.

Inconclusive: if collisional shifts in the zone cannot be modelled below the sought limit, or a result appears in one laboratory only.

12 // Feasibility

Tier 1 can be built in a university combustion laboratory with present equipment in a few months. It answers the question at the level the theory currently allows: tens of GHz. Tier 2 needs a dual-comb spectrometer, which several combustion groups operate [4,5]. Arm K1 needs development [OPEN].

What still does not exist: a reaction-zone measurement against an outside reference; a K1 arm with verified σ; an upper bound on ρ_{crit} from the theory.

13 // Interpretation: the record that leaves

This section is not tested by the experiment.

- **Three ends of one question** [INTERPRETATION]. In ice the owner is born from within. In DNA repair [6] the owner arrives from outside and searches. In a flame the information leaves its owner as fast as it is made. If the clock follows the change, the flame is where it should be easiest to hear.
- **Light as a messenger** [ANALOGY]. The photons a flame emits are its record leaving. The photons it absorbs are the outside world asking what time it is there.

A comment that names how it could be wrong has become a hypothesis. Until then, it is honest to call it a comment.

14 // Open problems

1. An upper bound on ρ_{crit}. Without it, a null only pushes the bound.
2. How to build K1: equal σ without reaction, in a sheet thin enough to probe.
3. The definition of a record in a flame, which decides what the stock reading predicts.
4. Collisional shifts with radicals at flame temperature, which limit the universality test.
5. The low-pressure trade-off between resolving the zone and keeping σ high.

Appendix A. Calculations

- Flame model: $T(x)$ rises from 300 to 2200 K over 0.4 mm (tanh profile); heat release $q(x) = q_{\max} e^{-(x/0.1\,\mathrm{mm})^2}$; $\lambda = 0.026\,(T/300)^{0.75}\ \mathrm{W\,m^{-1}K^{-1}}$; $\sigma = q/T + \lambda|\nabla T|^2/T^2$; $\rho_I = \sigma/k_B$. Zone average over $|x| < 0.2$ mm: 8.4×10^{28} ($q_{\max} = 10^9$) and $3.3 \times 10^{29}\ \mathrm{s^{-1}m^{-3}}$ ($q_{\max} = 10^{10}$). Burnt gas ($x > 1.5$ mm): $\sim 10^{16}$.
- Shift at $\rho_{\mathrm{crit}} = 10^{33}$: $\bar{\rho}_I/(2\rho_{\mathrm{crit}}) = 4.2 \times 10^{-5}$ to 1.65×10^{-4}; times 2.1×10^{14} Hz gives 8.8 to 35 GHz.
- Bounds: $\bar{\rho}_I \nu/(2\delta)$ with $\delta = 1, 10, 30$ MHz.
- Stock-reading record density (upper estimate): heat of reaction 8.9×10^5 J/mol per CH_4; per molecule 1.48×10^{-18} J; divided by $k_B T \ln 2$ at 2200 K: about 70 bits. Burnt-gas number density at 1 atm, 2200 K: $3.3 \times 10^{24}\ \mathrm{m^{-3}}$, of which about 1 in 10.5 molecules corresponds to one burned CH_4: $\rho_{\mathrm{rec}} \approx 2.2 \times 10^{25}$ bit/m^3.
- Ice for comparison: fractional slowdown during growth $\approx 3 \times 10^{-8}$ at $\rho_{\mathrm{crit}} = 10^{33}$ [2], i.e. $\rho_I \approx 6 \times 10^{25}$; the flame zone is 1.4–5.5 $\times 10^3$ times larger.

All values are order-of-magnitude estimates. A live version of this calculation runs at `https://timegeltheory.org/flame-clock-live.html`.

Appendix B. Provenance

The author wrote a two-page Turkish outline of a flame test in October 2026 with AI assistance. On 29 October 2026 Claude (Anthropic) reviewed it against Time-Gel v12.1 and the ice protocol. The outline's exponential clock law, undefined ρ_I, predicted emission oscillations and photon-count (Fano factor) test did not follow from the flow law, and the outline had no controls; they are not used here. Claude computed the size of the effect, surveyed published flame spectroscopy, proposed the universality signature and the K1 and K2 arms, and drafted this English version around the observable the ice protocol had already named: a shift of transition frequencies. The ice protocol [2] cites this work under an earlier identifier that was never issued (10.5281/zenodo.23122235); the identifier on this page is the correct one. Decisions are the author's. AI agreement is not independent validation.

References

[1] E. Bayar, *Time-Gel Theory: Time as the Fundamental Medium — A Falsifiable Framework*, v12.1, Zenodo (2026). doi:10.5281/zenodo.23106516.

[2] E. Bayar, *Information Looking for Its Owner: A supercooled-water clock test that separates two readings of Time-Gel*, v1.0, Zenodo (2026). doi:10.5281/zenodo.23724281.

[3] L. Rutkowski, A. Foltynowicz, F. M. Schmidt, A. C. Johansson, A. Khodabakhsh, A. A. Kyuberis, N. F. Zobov, O. L. Polyansky, S. N. Yurchenko, J. Tennyson, An experimental water line list at 1950 K in the 6250–6670 cm^{-1} region, J. Quant. Spectrosc. Radiat. Transf. (2018). doi:10.1016/j.jqsrt.2017.10.016; arXiv:1712.09406.

[4] D. Yun, S. C. Egbert, A. T. Frymire, S. C. Coburn, J. J. France, K. M. Rice, J. M. Donbar, G. B. Rieker, Single-beam velocimetry with dual frequency comb absorption spectroscopy, arXiv:2403.01377 (2024).

[5] D. Yun, N. A. Malarich, R. K. Cole, S. C. Egbert, J. J. France, J. Liu, K. M. Rice, M. A. Hagenmaier, J. M. Donbar, N. Hoghooghi, S. C. Coburn, G. B. Rieker, Supersonic combustion diagnostics with dual comb spectroscopy, Proc. Combust. Inst. (2023). doi:10.1016/j.proci.2022.07.103; arXiv:2205.04891.

[6] E. Bayar, *Information Looking for Its Owner in DNA Repair*, v1.0, Zenodo (2026). doi:10.5281/zenodo.23725581.

[7] L. S. Rothman et al., HITEMP, the high-temperature molecular spectroscopic database, J. Quant. Spectrosc. Radiat. Transf. 111, 2139 (2010).

[8] C. M. Will, The confrontation between general relativity and experiment, Living Rev. Relativ. 17, 4 (2014).