

Ultrametric Engine: Deploying a 20-Principle p-Adic Discovery Worker

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Abstract

The theoretical framework developed in P1-P5 requires computational infrastructure to make ultrametric (p-adic) analysis accessible to experimentalists. We specify and deploy an ultrametric discovery engine — a Cloudflare Worker implementing 20 principles from the proven Ask QWAV production system. The Worker provides 27+ API endpoints including Bruhat-Tits tree construction, p-adic ranking via 3-phase discovery, dendrogram visualization data, and spectral analysis (Tate, Amice, intrinsic Amice transforms). Deployed on Cloudflare's edge network with D1, R2, and Vectorize bindings, the engine enables experimentalists to compute Gromov δ for their Majorana systems, classify ZBW transition graphs as ultrametric or Archimedean, and validate the ZBW Z_2 invariant predictions from P2-P3.

Keywords: Ultrametric engine, Cloudflare Workers, Bruhat-Tits tree, p-adic discovery, Gromov hyperbolicity, p-adic time clusters

1. Architecture

1.1 20-Principle Stack

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1.2 Cloudflare Bindings

Binding	Type	Purpose
PAPERS_DB	D1	Paper corpus storage
DB	D1	Audit + state
VECTORIZE_INDEX	Vectorize	Semantic paper search
PAPERS_R2	R2	Tree JSON + title index
AI	Workers AI	Text analysis
cron trigger	Every 30 min	Tree regeneration

1.3 Wrangler Configuration

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2. Core Algorithms

2.1 3-Phase Discovery Engine

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2.2 Ultrametric Tree Builder

2.3 p-Adic Cache TTL

3. API Endpoints

3.1 /health

3.2 /did-you-mean?q=quantm

3.3 /gromov-delta?graph_id=<id>

Computes Gromov δ for a user-provided graph:

3.4 /spectral-analysis?paper_id=<id>

Returns Tate, Amice, and intrinsic Amice transforms:

4. Deployment Verification

4.1 Verification Checklist

- [x] /health returns *papercount*, *chunksin_vectorize*
- [x] /did-you-mean?q=quantm returns discoveries (cluster neighbors beyond word matches)
- [x] /ultrametric-tree includes all 19 statistical fields
- [x] /spectral-analysis includes *intrinsicAmice* (Principle #20)
- [x] Tree persists across cold starts via R2 (<100ms restore)
- [x] Gromov δ endpoint operational for external graph analysis

4.2 Integration with P3 Readout Protocol

The /gromov-delta endpoint directly supports P3 Protocol C: experimentalists upload their Majorana system's transition graph and receive a Gromov δ value with ultrametricity verdict. This enables:

1. Classification of ZBW signals as ultrametric vs. Archimedean
2. Comparison of δ_{Dirac} vs. δ_{Majorana} across different platforms
3. Validation of the ZBW Z_2 invariant prediction ($\delta_{\text{Majorana}} < \delta_{\text{Dirac}}$)

5. Limitations and Future Work

1. **Cold starts:** Worker cold starts add ~80ms latency on first invocation
 2. **Tree size:** Current 451-paper tree is 1.2MB; scaling to 10,000+ papers would require D1-based incremental updates
 3. **Gromov δ computation:** $O(n^4)$ for naive implementation; currently sampling 10,000 triples for speed
 4. **p-adic time clusters:** Requires 30+ paper corpus with timestamps for meaningful clustering
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Changelog

- v2.0.0: Adversarial audit revision. Fixes: no substantive corrections required.

References

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