VACUUM: From your head down to your shoes (©Buddy Guy)

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SCaLe 21x

EDB

Self introduction

- PostgreSQL Major Contributor
- Responsible for the PostgreSQL RPM repos (Red Hat, Rocky, AlmaLinux, Fedora and SLES)
- Fedora and Rocky Linux contributor
- PostgreSQL community member
- Postgres expert @ EDB
- London, UK.

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Nowadays:

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Agenda

- MVCC: The basics
- Data snapshots
- VACUUM
- VACUUM processing
- FREEZE
- VACUUM tuning
- VACUUM FULL

“*”

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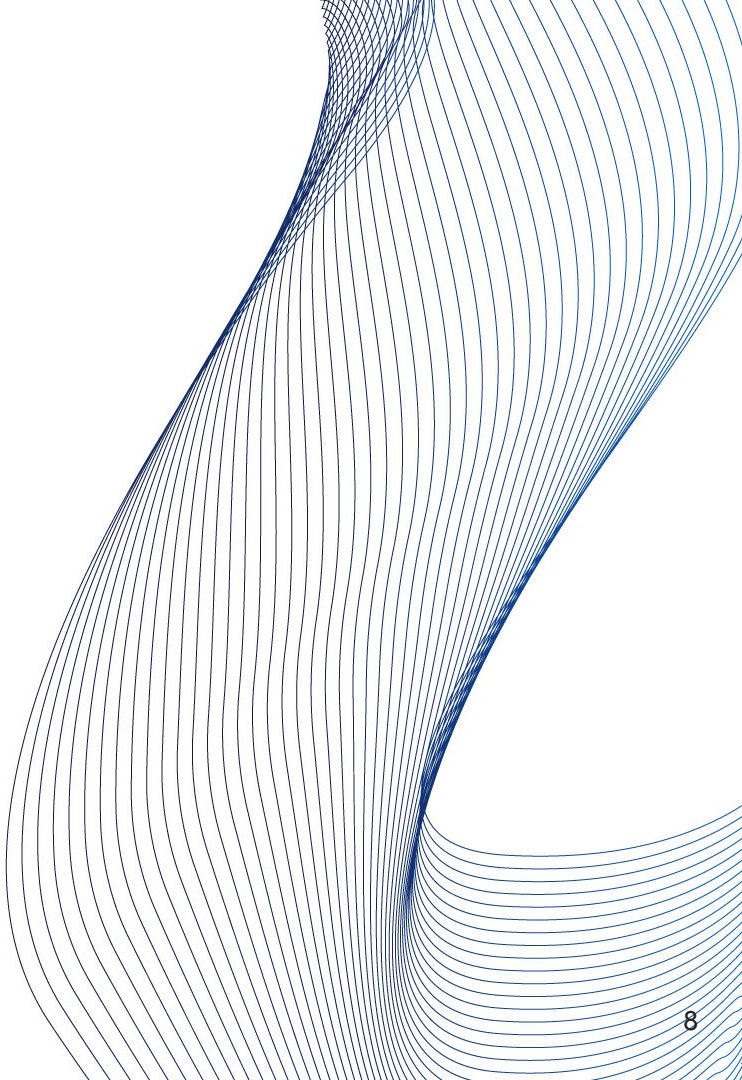
- Basic question first ;)
- What does * sign represent in **SELECT * FROM t1**;

What is MVCC?

MVCC

- Multi Version Concurrency Control
  - Implementation of concurrency in Postgres
  - Snapshot isolation



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  - New versions are created during updates
  - Uncommitted transactions
  - Dead tuples (see next slides)

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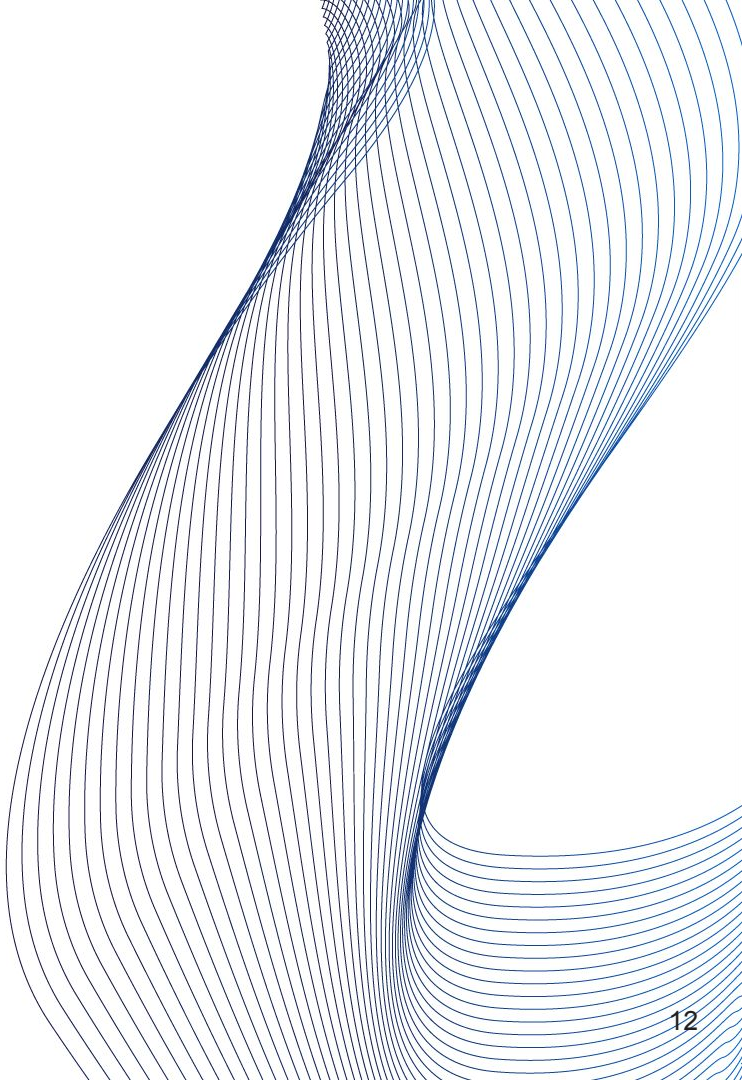
  - Dead tuples (see next slides)
- Side effect: VACUUM
  - We will get there ;)

Transaction id

- “txid”



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  - “Circle”
    - 2 billion in the past, 2 billion in the future
  - 3 special (reserved) txids
    - 0: Invalid
    - 1: Bootstrap
    - **2: Frozen**

Transaction id

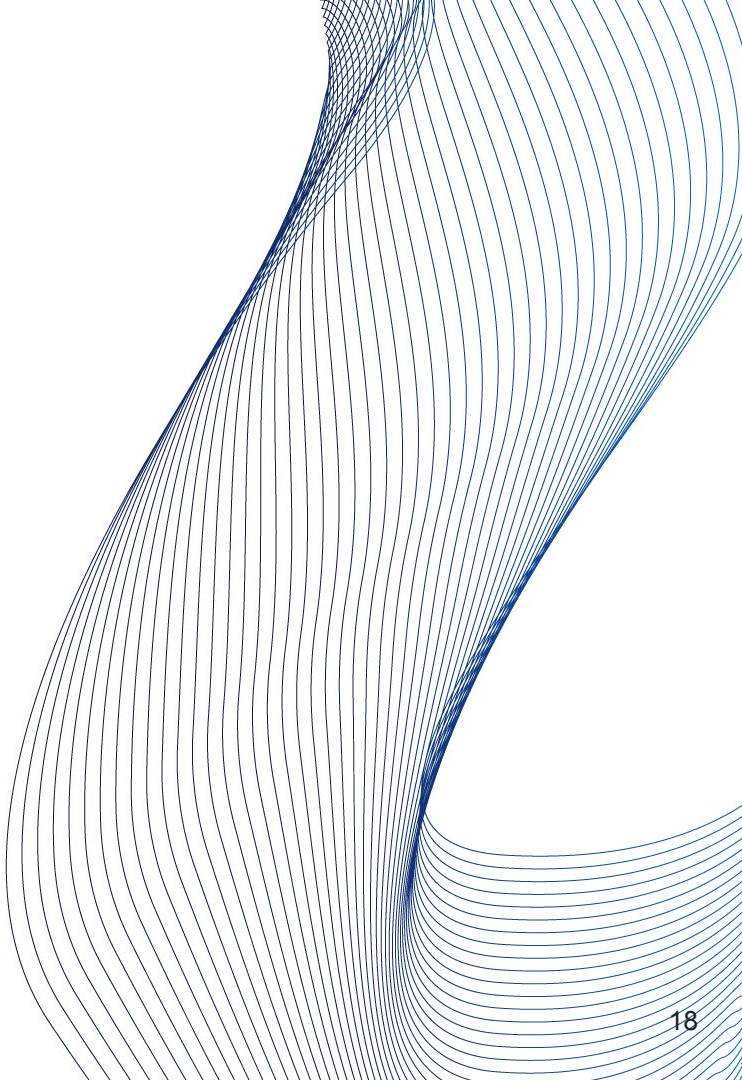
- SELECT
  - Utilizes “virtual txid”
    - txid_current_if_assigned()

Transaction id

- SELECT
  - Utilizes “virtual txid”
    - txid_current_if_assigned()
- Stored in the header of each row
  - xmin: INSERT
  - xmax: UPDATE or DELETE
    - (0, when this not apply)

INSERT, DELETE and UPDATE

- INSERT
  - Insertion is done to the first available space
    - xmin: set to the txid
    - xmax: 0



INSERT, DELETE and UPDATE

```
[postgres] # CREATE TABLE t1 (c1 int);
CREATE TABLE
[postgres] # INSERT INTO t1 VALUES (1),(2);
INSERT 0 2
[postgres] # INSERT INTO t1 VALUES (3);
INSERT 0 1
[postgres] # INSERT INTO t1 VALUES (4);
INSERT 0 1
[postgres] # SELECT cmin, cmax, xmin, xmax, ctid,* FROM t1;
 cmin | cmax |  xmin  | xmax | ctid  | c1
------+------+--------+------+-------+----
    0 |    0 | 161031 |    0 | (0,1) |  1
    0 |    0 | 161031 |    0 | (0,2) |  2
    0 |    0 | 161032 |    0 | (0,3) |  3
    0 |    0 | 161033 |    0 | (0,4) |  4
(4 rows)
```

INSERT, DELETE and UPDATE

- DELETE
  - Logical deletion
  - Long lasting transactions?
  - xmax is set to the txid
  - → **dead tuple!**

INSERT, DELETE and UPDATE

First session:

```
[postgres] # BEGIN ;
BEGIN
[postgres] # DELETE FROM t1 WHERE c1=1;
DELETE 1
[postgres] # SELECT cmin, cmax, xmin, xmax, ctid,* FROM t1;
 cmin | cmax |  xmin  | xmax | ctid  | c1
------+------+--------+------+-------+----
    0 |    0 | 161031 |    0 | (0,2) |  2
    0 |    0 | 161032 |    0 | (0,3) |  3
    0 |    0 | 161033 |    0 | (0,4) |  4
(3 rows)
```

INSERT, DELETE and UPDATE

Another session:

```
[postgres] # SELECT cmin, cmax, xmin, xmax, ctid,* FROM t1;
 cmin | cmax |  xmin  |  xmax  | ctid  | c1
------+------+--------+--------+-------+----
    0 |    0 | 161031 | 161034 | (0,1) |  1
    0 |    0 | 161031 |      0 | (0,2) |  2
    0 |    0 | 161032 |      0 | (0,3) |  3
    0 |    0 | 161033 |      0 | (0,4) |  4
(4 rows)
```

INSERT, DELETE and UPDATE

- UPDATE:
  - “Expensive” operation
  - INSERT + DELETE
  - Dead tuple (as a part of deletion)

INSERT, DELETE and UPDATE

```
[postgres] # BEGIN ;
BEGIN
[postgres] # UPDATE t1 SET c1=20 WHERE c1=2;
UPDATE 1
[postgres] # SELECT cmin, cmax, xmin, xmax, ctid,* FROM t1;
 cmin | cmax |  xmin  | xmax | ctid  | c1
------+------+--------+------+-------+----
    0 |    0 | 161032 |    0 | (0,3) |  3
    0 |    0 | 161033 |    0 | (0,4) |  4
    0 |    0 | 161035 |    0 | (0,5) | 20
(3 rows)
```

INSERT, DELETE and UPDATE

Another session:

```
[postgres] # SELECT cmin, cmax, xmin, xmax, ctid,* FROM t1;
 cmin | cmax |  xmin  |  xmax  | ctid  | c1
------+------+--------+--------+-------+----
    0 |    0 | 161031 | 161035 | (0,2) |  2
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```
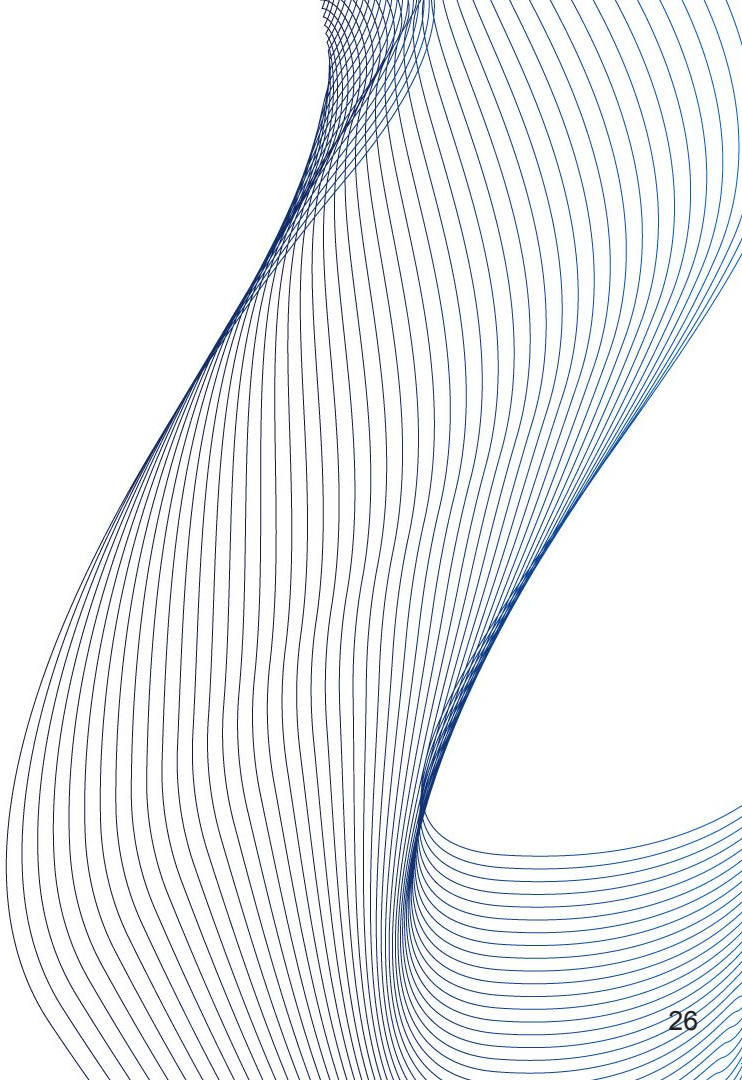

INSERT, DELETE and UPDATE

- Consider huge side effects of excessive DELETEs (and UPDATEs)



Comboid, cmin, cmax

- pre-8.3: cmin and cmax were separate
- Per comboid.c:
  - To reduce the header size, cmin and cmax are now overlayed in the same field in the header. That usually works because you rarely insert and delete a tuple in the same transaction, and we don't need either field to remain valid after the originating transaction exits.

```
0 |    0 | 208611 |    0 | (0,4) |  4
0 |    0 | 208612 |    0 | (0,5) |  5
2 |    2 | 208612 |    0 | (0,7) |  7
4 |    4 | 208612 |    0 | (0,8) |  8
```

https://doxygen.postgresql.org/combocid_8c_source.html

Data snapshots

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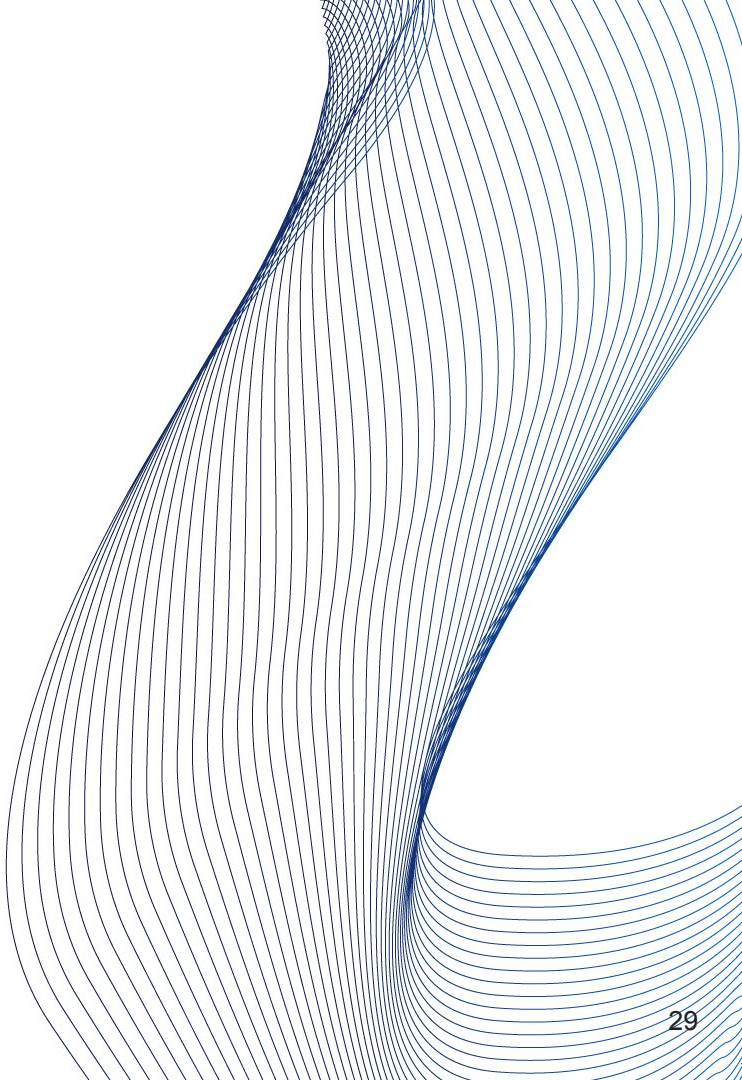
  - Not a physical snapshot



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- Data snapshots
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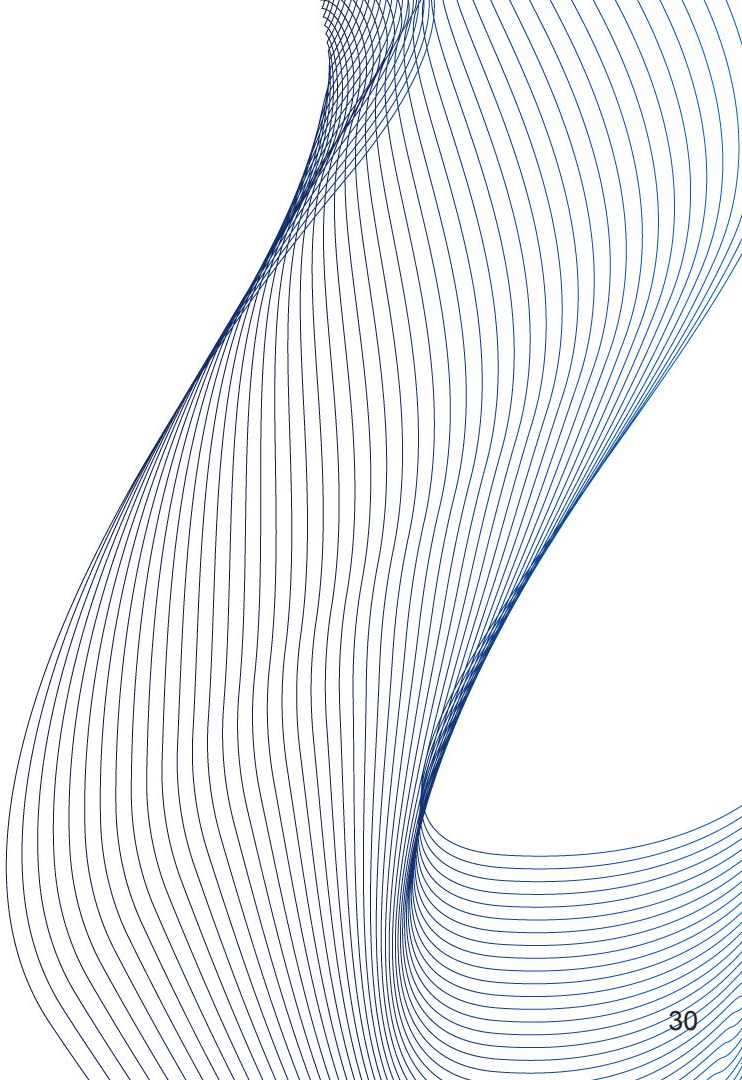
- Isolation
  - Created at the beginning of the transaction
  - Contains committed data
  - Uncommitted data is ignored.



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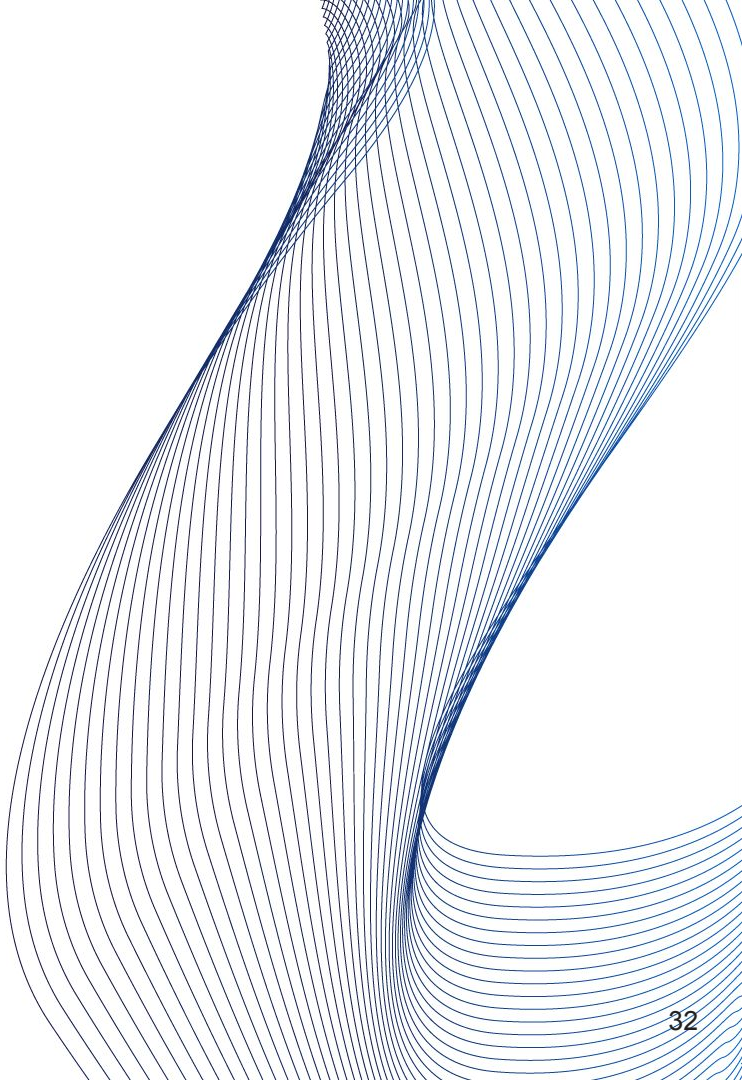
- Also determines *VACUUM-able* rows or *non-VACUUM-able* rows

Data snapshots

- Long running transactions
  - pg_dump



Data snapshots

- Long running transactions
  - pg_dump
- Some parameters:
  - idle_in_transaction_session_timeout (disabled by default)
  - old_snapshot_threshold (disabled by default)

Visibility

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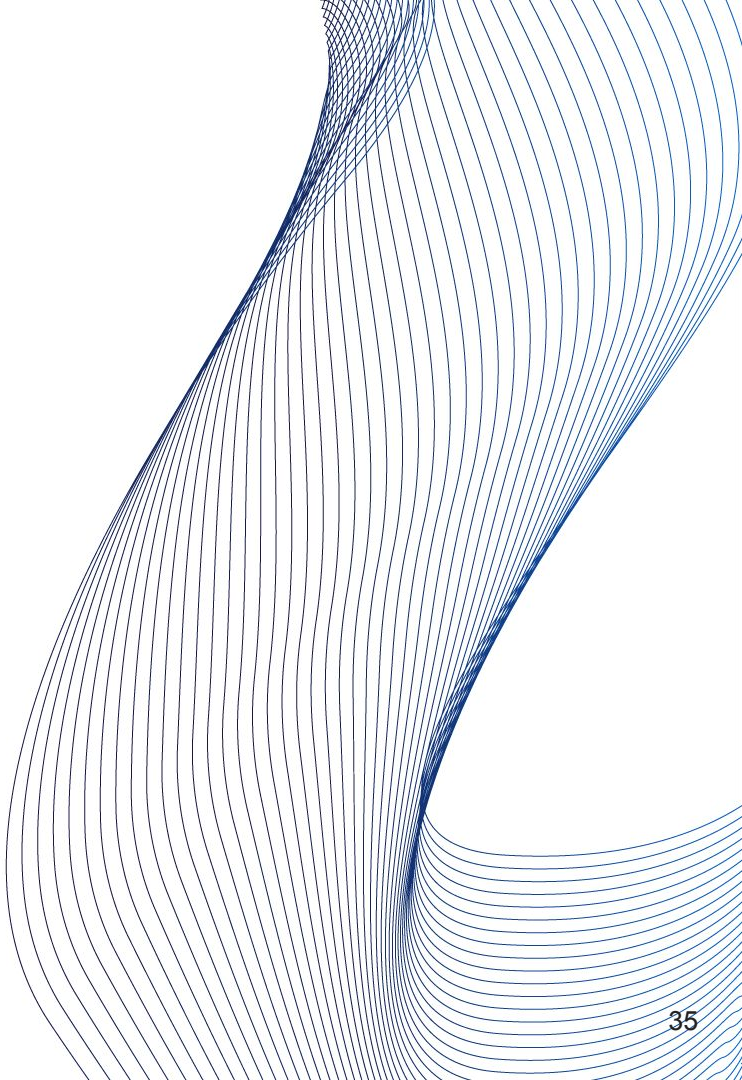
- Tuple visibility
  - xmin,xmax



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- Tip: Commit time is not stored.
- Tip: Rollback segments are not available in PostgreSQL
  - No chance for seeing a past consistent state (lively).

VACUUM

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- Two main tasks:
  - Removing dead tuples
  - Freezing transaction ids

VACUUM

- Does **not** block most of the queries
  - Concurrent vacuums to the same table is not allowed
  - Cannot create index (concurrently or regular)
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- I/O
  - Creates I/O (we will get there)

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- Update statistics (optional)

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- NOTE: Dead tuple cleanup is not done at this phase.

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  - Maintenance_work_mem
    - Can also be set per-session
    - VACUUM can utilize up to 1 GB
      (matches on-disk data file size limit)

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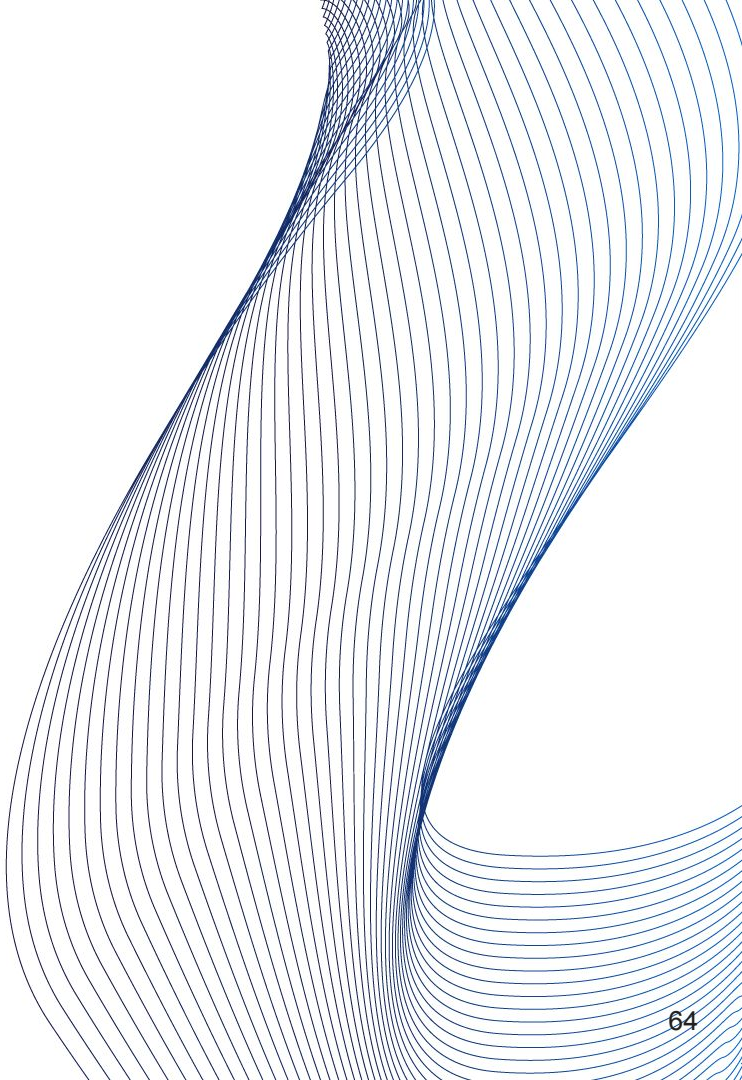
VACUUM: Second phase

- Removal of dead tuples



VACUUM: Second phase

- Removal of dead tuples
- FSM and VM are updated (per page)

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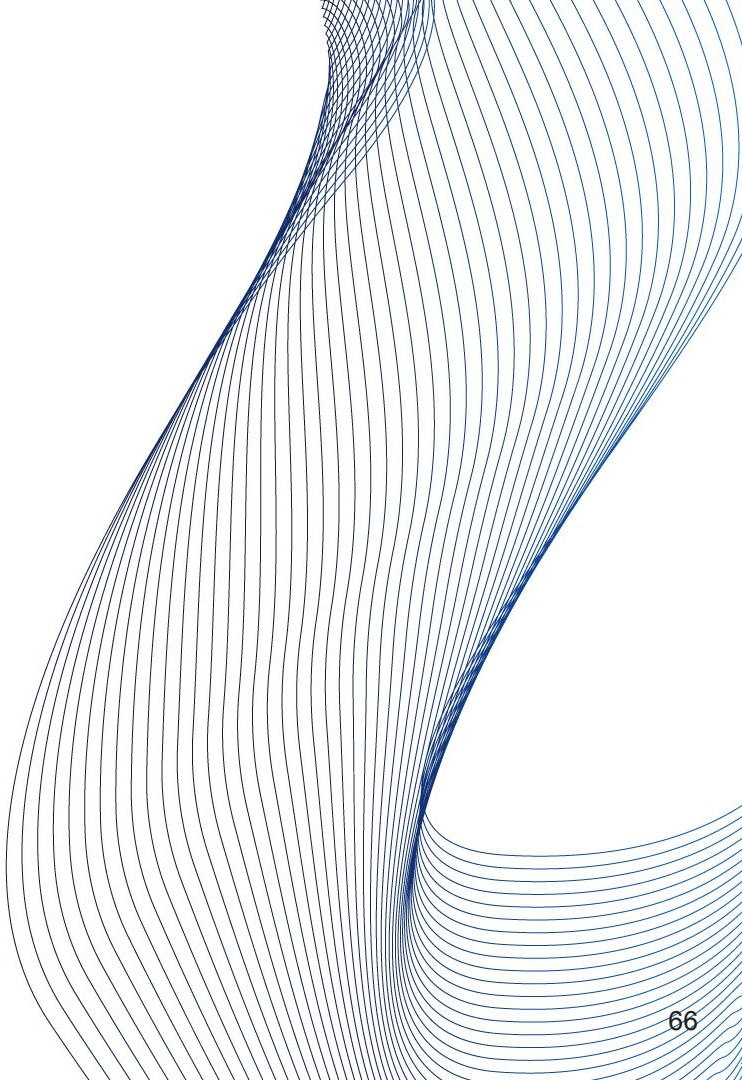
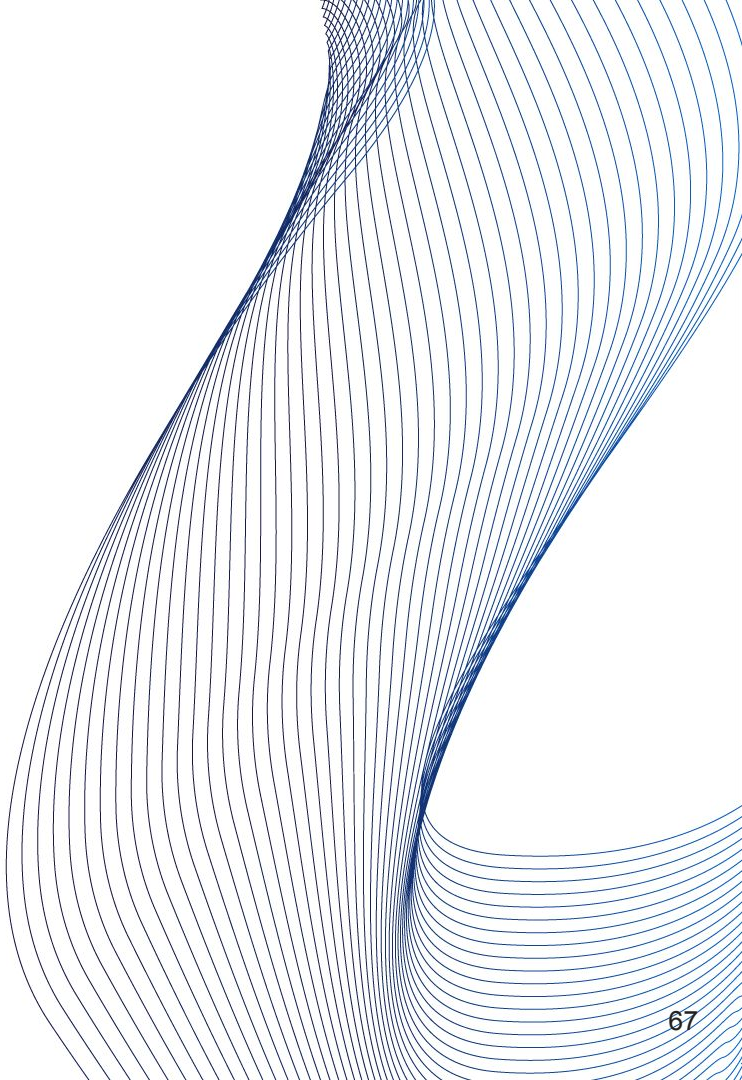
- FSM and VM are updated (per page)
- Repairs fragmentation (per page)



VACUUM: Third phase

- Final phase



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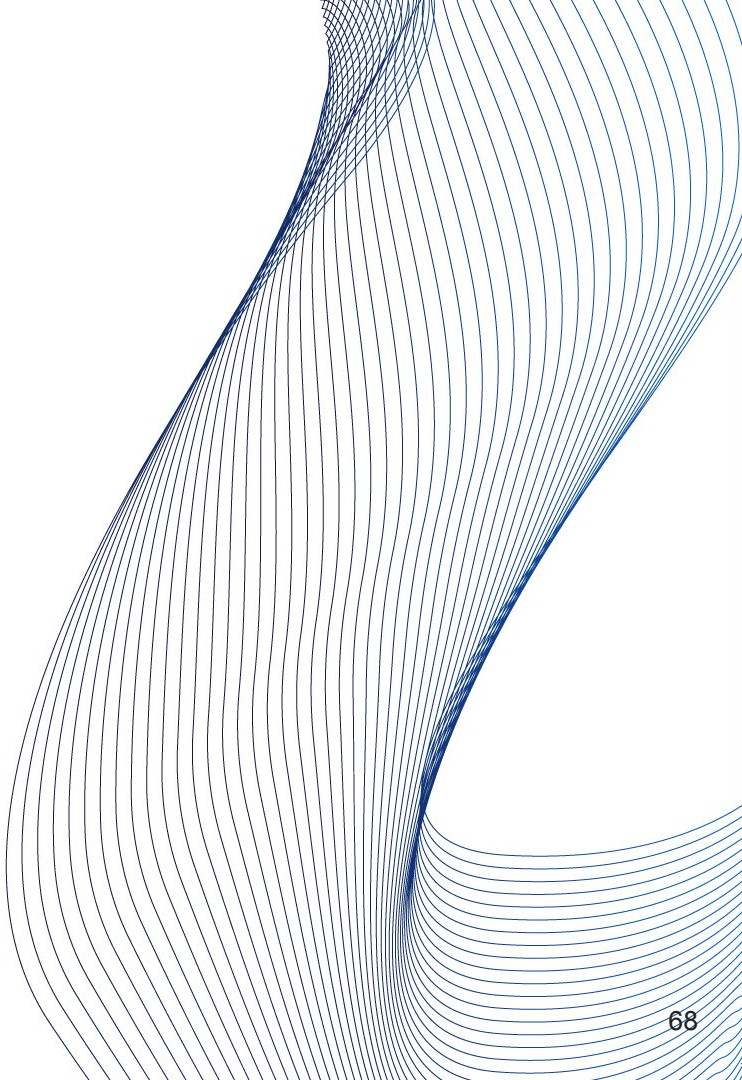
- Index cleanup



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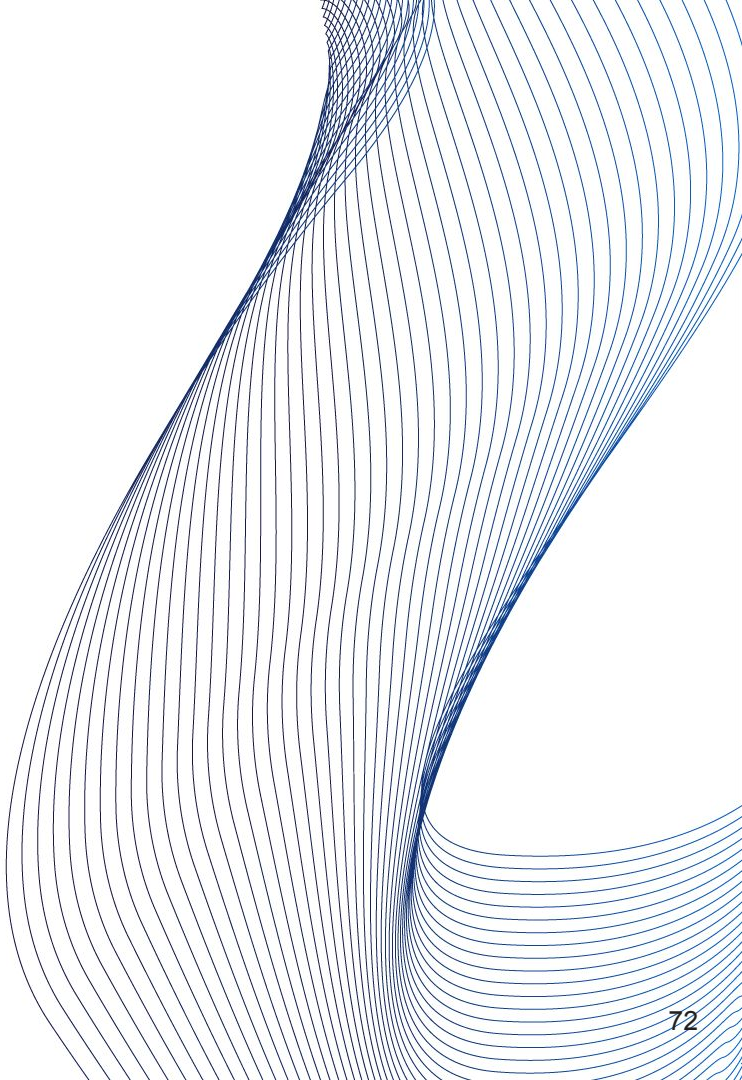
- Truncation (if applicable)

VACUUM: Ring buffers

- Buffer Access Strategy (as of v16+)
  - saves shared_buffers
  - Uses them circularly
  - https://www.postgresql.org/docs/current/glossary.html#GLOSSARY-BUFFER-ACCESS-STRATEGY
- Pre-16: Does not use buffer pool
  - temporary
  - small
- Helps keep shared buffers “hot”
- 256 kB
  - Per docs (src/backend/storage/buffer/README):
  - “For sequential scans, a 256 KB ring is used.
    That's small enough to fit in L2 cache,
    which makes transferring pages from OS cache
    to shared buffer cache efficient.”

VACUUM: FREEZE

- “Transaction ID wraparound problem”
  - Time to recall “circle”
  - A must-avoid problem



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- vacuum_freeze_min_age

VACUUM: FREEZE

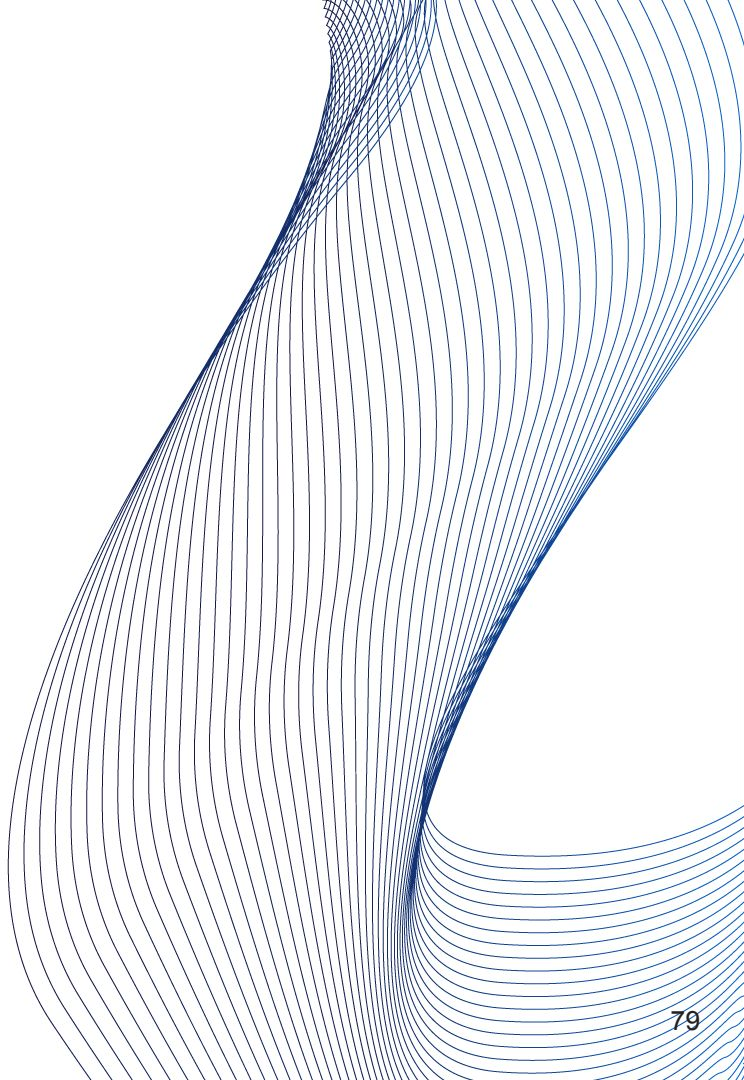
- “ Limited number (N = 2^32) of XID's required to do vacuum freeze to prevent wraparound every N/2 transactions.
- This causes performance degradation due to the need to read and rewrite all not yet frozen pages tables while being

(Extracted from 64-bit xid patch)

VACUUM parameters

VACUUM parameters

- FULL [boolean]
- FREEZE [boolean]
- VERBOSE [boolean]
- ANALYZE [boolean]
- DISABLE_PAGE_SKIPPING [boolean]
- SKIP_LOCKED [boolean]
- INDEX_CLEANUP { AUTO | ON | OFF }
- PROCESS_MAIN [boolean]
- PROCESS_TOAST [boolean]



VACUUM parameters

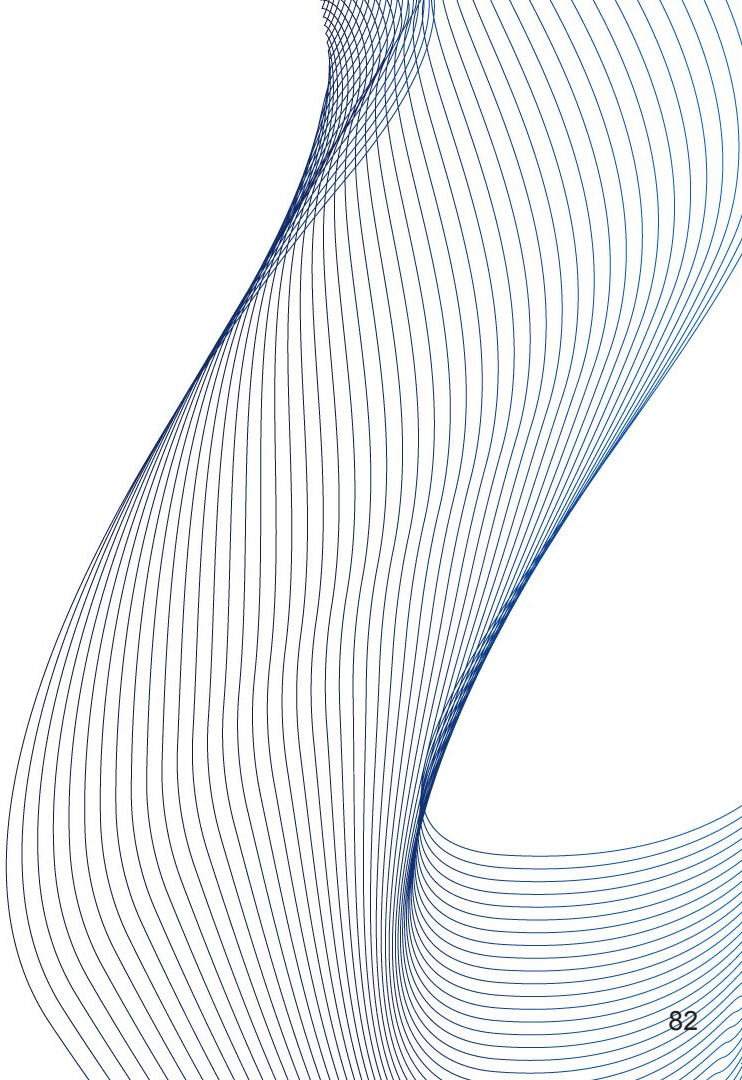
- TRUNCATE [boolean]
- PARALLEL integer

- v16+:
- SKIP_DATABASE_STATS [boolean]
  - skip updating the database-wide statistics about oldest unfrozen XIDs
- ONLY_DATABASE_STATS [boolean]
  - Just update database statistics
- BUFFER_USAGE_LIMIT size
  - vacuum_buffer_usage_limit
  - Max 16 GB

VACUUM and WAL

WAL

- Logging of transactions



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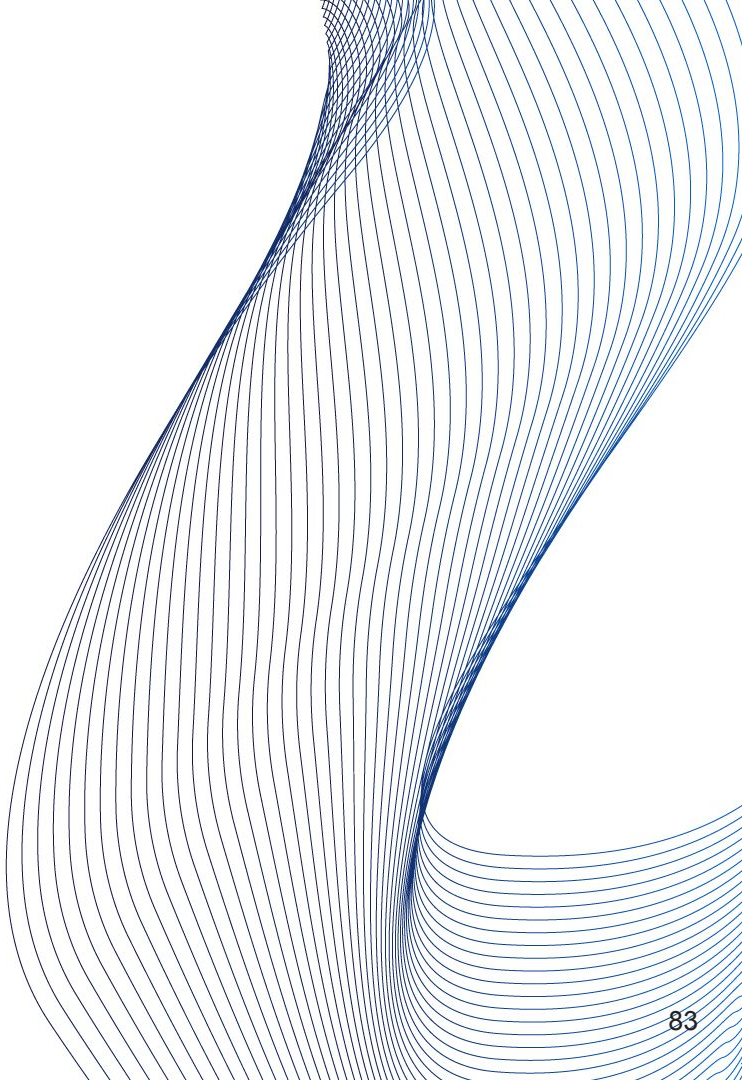

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  - backups!

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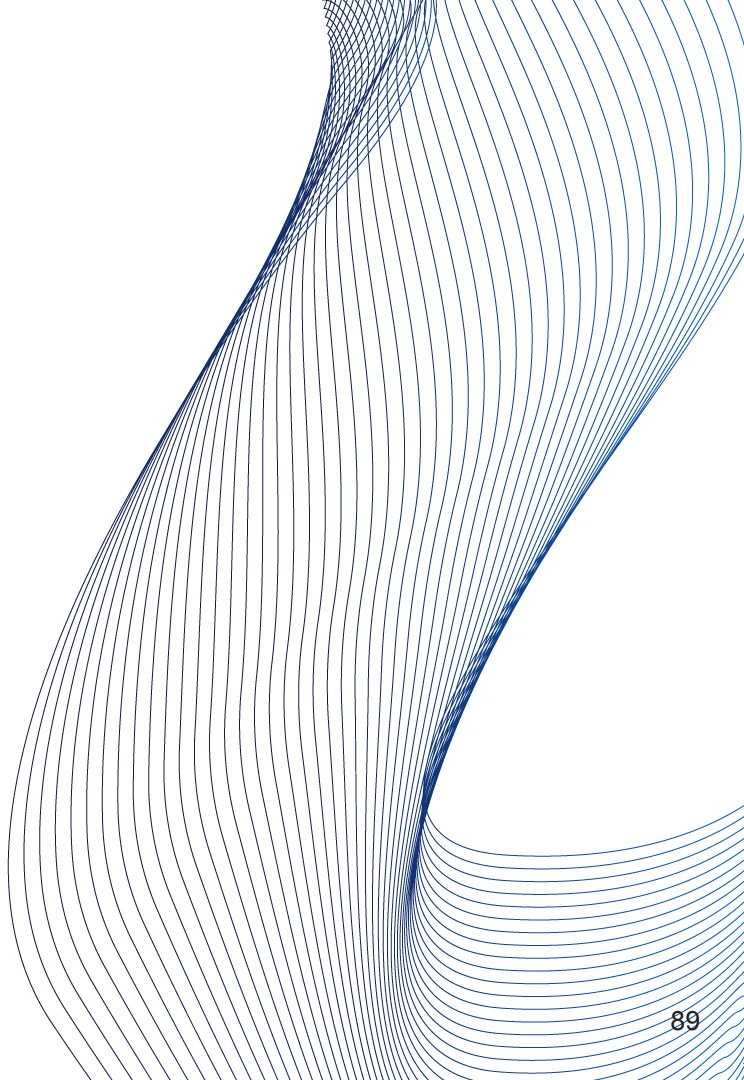

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- Long running (SELECT) queries on standby
- Row is / rows are modified on primary
- VACUUM kicks in
- Standby: “ERROR: canceling statement due to conflict with recovery”
- Parameter: hot_standby_feedback
- Side effect: VACUUMs will delay, bloat will increase.

VACUUM performance

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- vacuum_cost_delay (0, disabled by default)

VACUUM performance

- vacuum_cost_delay (0, disabled by default)
- vacuum_cost_page_hit (1 by default)

VACUUM performance

- vacuum_cost_delay (0, disabled by default)
- vacuum_cost_page_hit (1 by default)
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- vacuum_cost_page_hit (1 by default)
- vacuum_cost_page_miss (2 by default)
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- vacuum_cost_limit (200 by default)

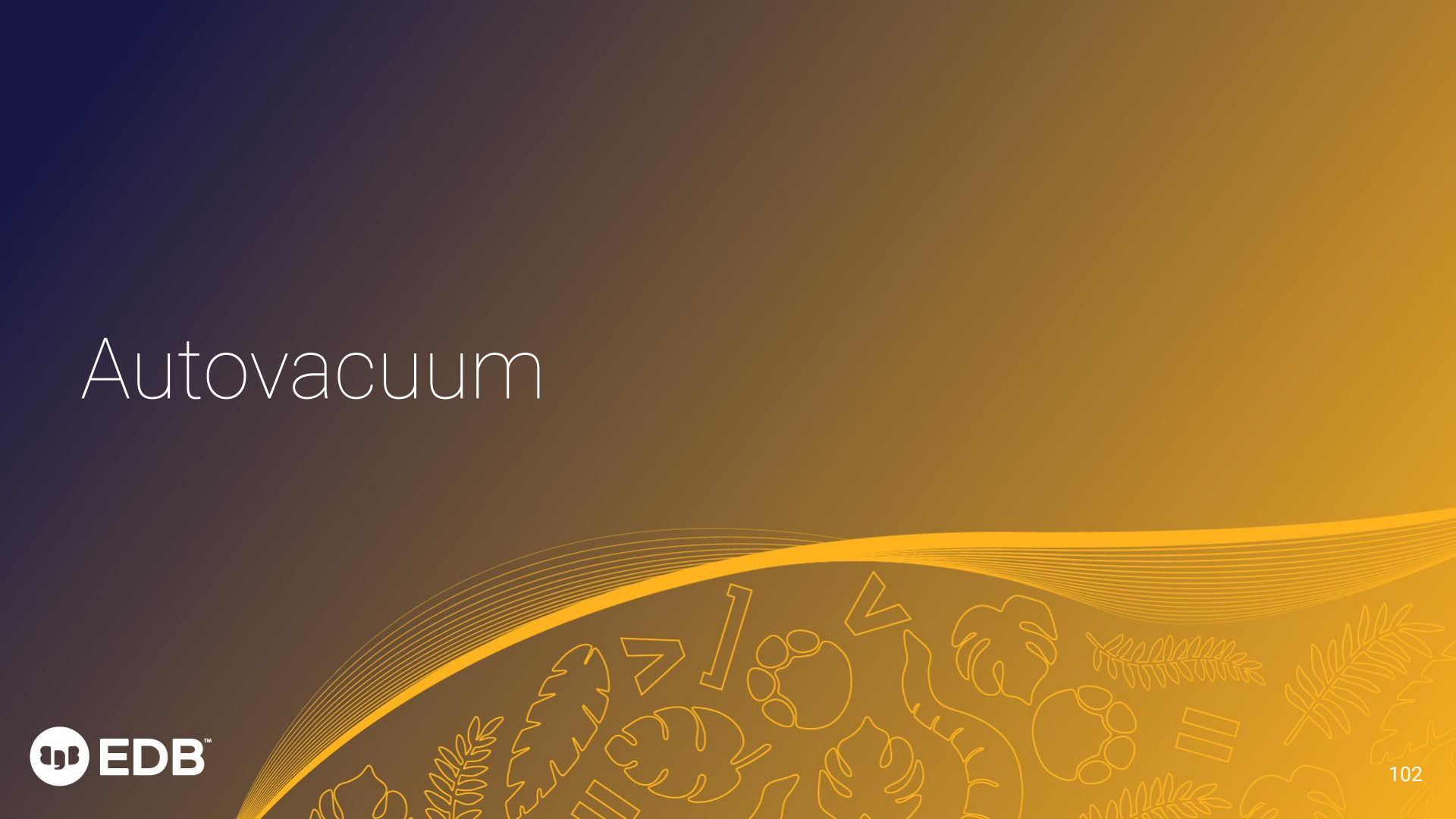
VACUUM performance

- Changing vacuum_cost_delay will result in less I/O over the time, but then VACUUM will take longer.

VACUUM performance

- Changing vacuum_cost_delay will result in less I/O over the time, but then VACUUM will take longer.
- This is the way to throttle VACUUM process.

Autovacuum



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- Kicks off autovacuum/autoanalyze, per parameters.
- Kicks off to prevent transaction ID wraparound.
- On by default.
  - Do not turn it off!

AUTOVACUUM: Is everything cool?

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- No.
- Murphy rule: Autovacuum will kick of during peak hours
- May / will prioritize busy tables
  - Some tables may / will be untouched
- Anti-wraparound vacuum cannot be stopped.
  - Will start even if autovacuum is turned off.

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AUTOVACUUM: Is everything cool?

- More workers -> more I/O
- More workers -> more RAM usage (maintenance_work_mem)
- Cancels itself when a higher lock level is required by another transaction
    - Some tables may never be autovacuumed.

AUTOVACUUM: parameters

- autovacuum_work_mem = -1
- log_autovacuum_min_duration = 10min
- autovacuum = on
- autovacuum_max_workers = 3
- autovacuum_naptime = 1min
- autovacuum_vacuum_threshold = 50
- autovacuum_vacuum_insert_threshold = 1000
- autovacuum_analyze_threshold = 50

AUTOVACUUM: parameters

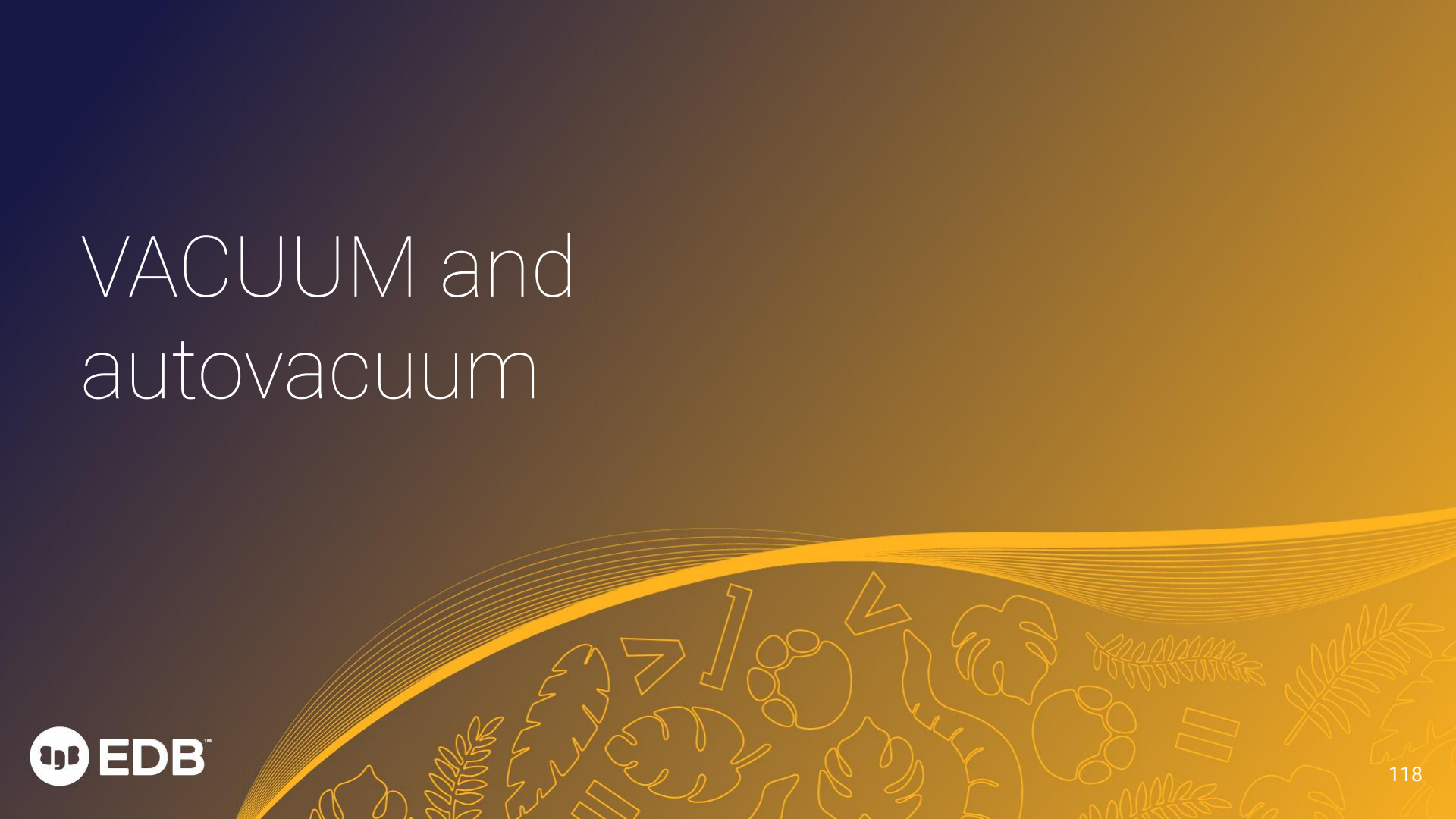
- autovacuum_vacuum_scale_factor = 0.2
- autovacuum_vacuum_insert_scale_factor = 0.2
- autovacuum_analyze_scale_factor = 0.1
- autovacuum_freeze_max_age = 200000000
- autovacuum_multixact_freeze_max_age = 400000000
- autovacuum_vacuum_cost_delay = 2ms
- autovacuum_vacuum_cost_limit = -1

Autovacuum: Tuning per table

```
ALTER TABLE t1
 SET (autovacuum_vacuum_scale_factor = 0.05,
     autovacuum_vacuum_threshold = 200000,
     autovacuum_analyze_scale_factor = 0.1,
     autovacuum_analyze_threshold = 200000);
```

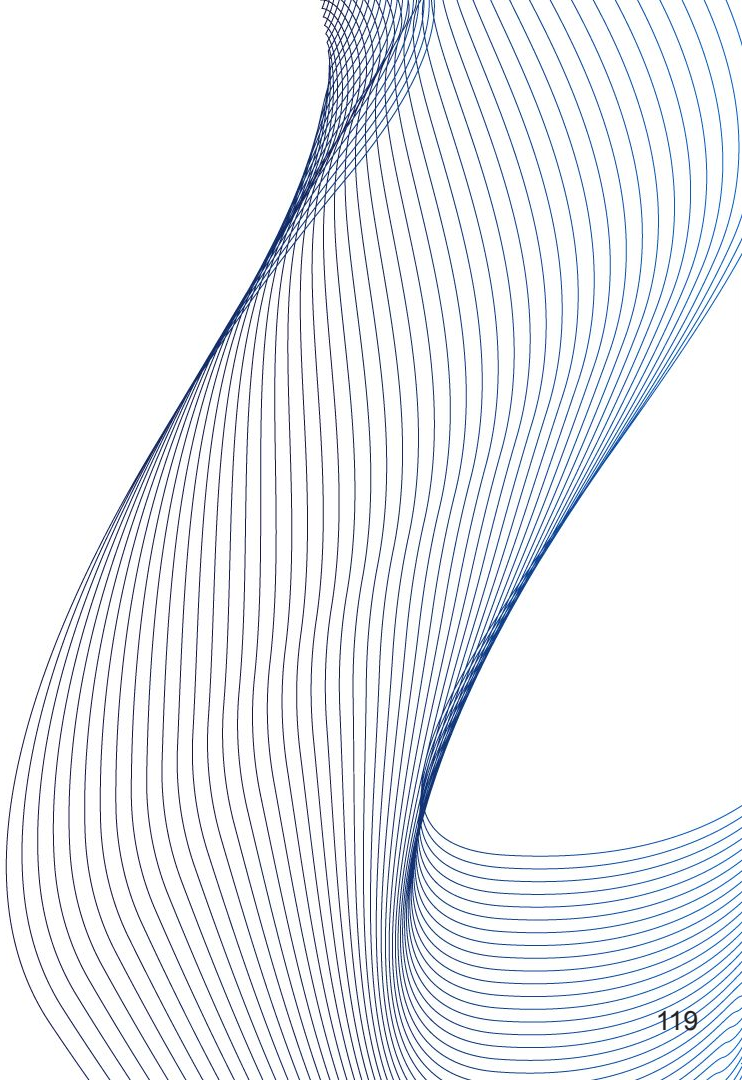
- Can be used to customize autovac settings for some tables

VACUUM and autovacuum



VACUUM and autovacuum

- Can live together.



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- Can live together.
- Tuning both of them will help overall performance.
- We suggest using cron-based VACUUM.
  - This will very likely prevent peak-time autovacuum accidents.

VACUUM FULL

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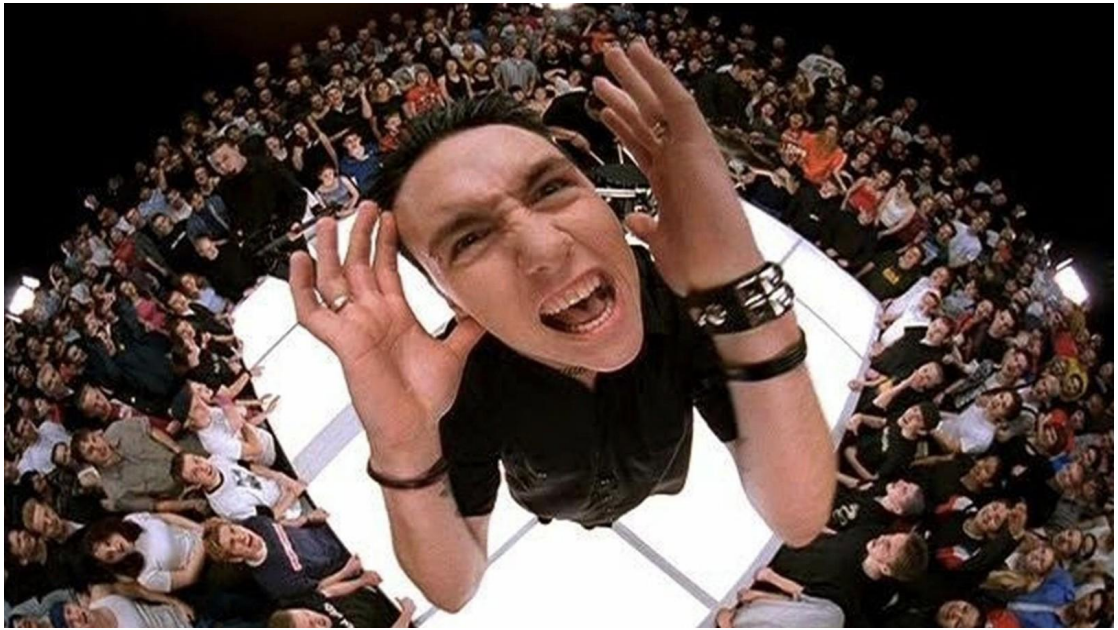

VACUUM FULL

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- Rewrites the table
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  - The only transaction that runs against the table
- Requires disk space similar to the table size.
- Downtime!

VACUUM FULL: Non-blocking Alternative

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VACUUM FULL: Non-blocking Alternative

- Some alternatives exist
  - pg_repack
  - pg_squeeze (cron!)

VACUUM VERBOSE

- INFO: finished vacuuming "onlinedps.pg_toast.pg_toast_20508": index scans: 0
- pages: 0 removed, 0 remain, 0 scanned (100.00% of total)
- tuples: 0 removed, 0 remain, 0 are dead but not yet removable
- removable cutoff: 30184655, which was 3 XIDs old when operation ended
- new relfrozenxid: 30184655, which is 30180246 XIDs ahead of previous value
- new relminmxid: 16, which is 15 MXIDs ahead of previous value
- index scan not needed: 0 pages from table (100.00% of total) had 0 dead item identifiers removed
- I/O timings: read: 0.051 ms, write: 0.000 ms
- avg read rate: 32.150 MB/s, avg write rate: 0.000 MB/s
- buffer usage: 19 hits, 1 misses, 0 dirtied
- WAL usage: 1 records, 0 full page images, 188 bytes
- system usage: CPU: user: 0.00 s, system: 0.00 s, elapsed: 0.00 s

pg_stat_progress_vacuum

pid	18303
datid	19323
datname	foobar
relid	19870
phase	scanning heap
heap_blks_total	370044
Heap_blks_scanned	13443
heap_blks_vacuumed	0
Index_vacuum_count	0
max_dead_tuples	107682804
num_dead_tuples	149101

THANK YOU

Now it is time for questions!

VACUUM: From your head down to your shoes (©Buddy Guy)

Devrim Gündüz
Postgres Expert @ EDB

14 March 2024
SCaLe 21x

EDB