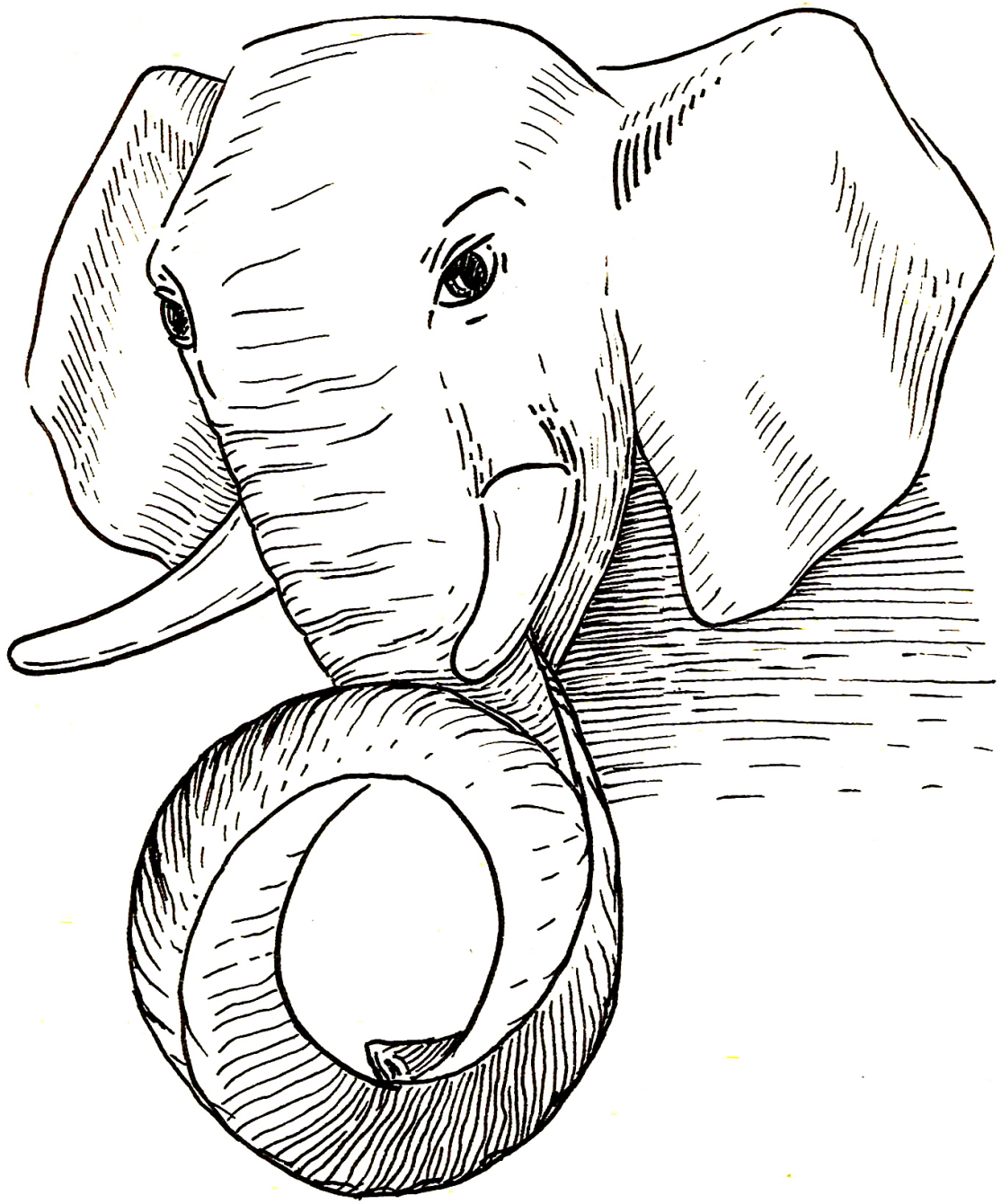


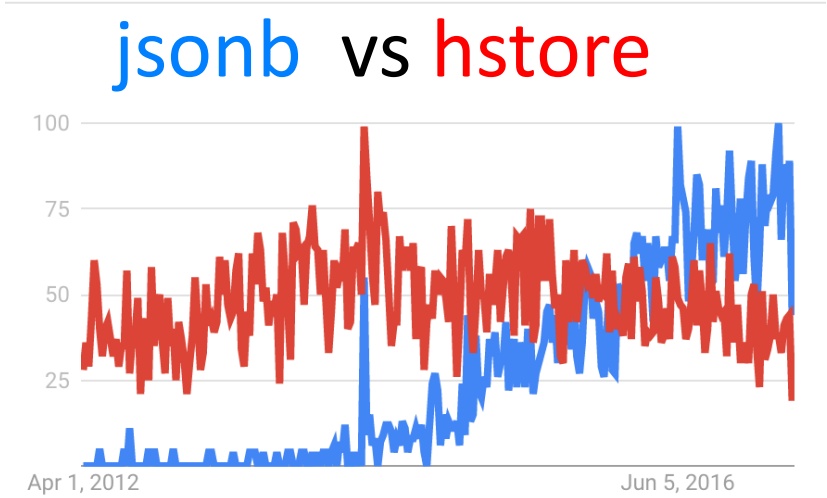
NoSQL Postgres

Oleg Bartunov
Postgres Professional
Moscow University

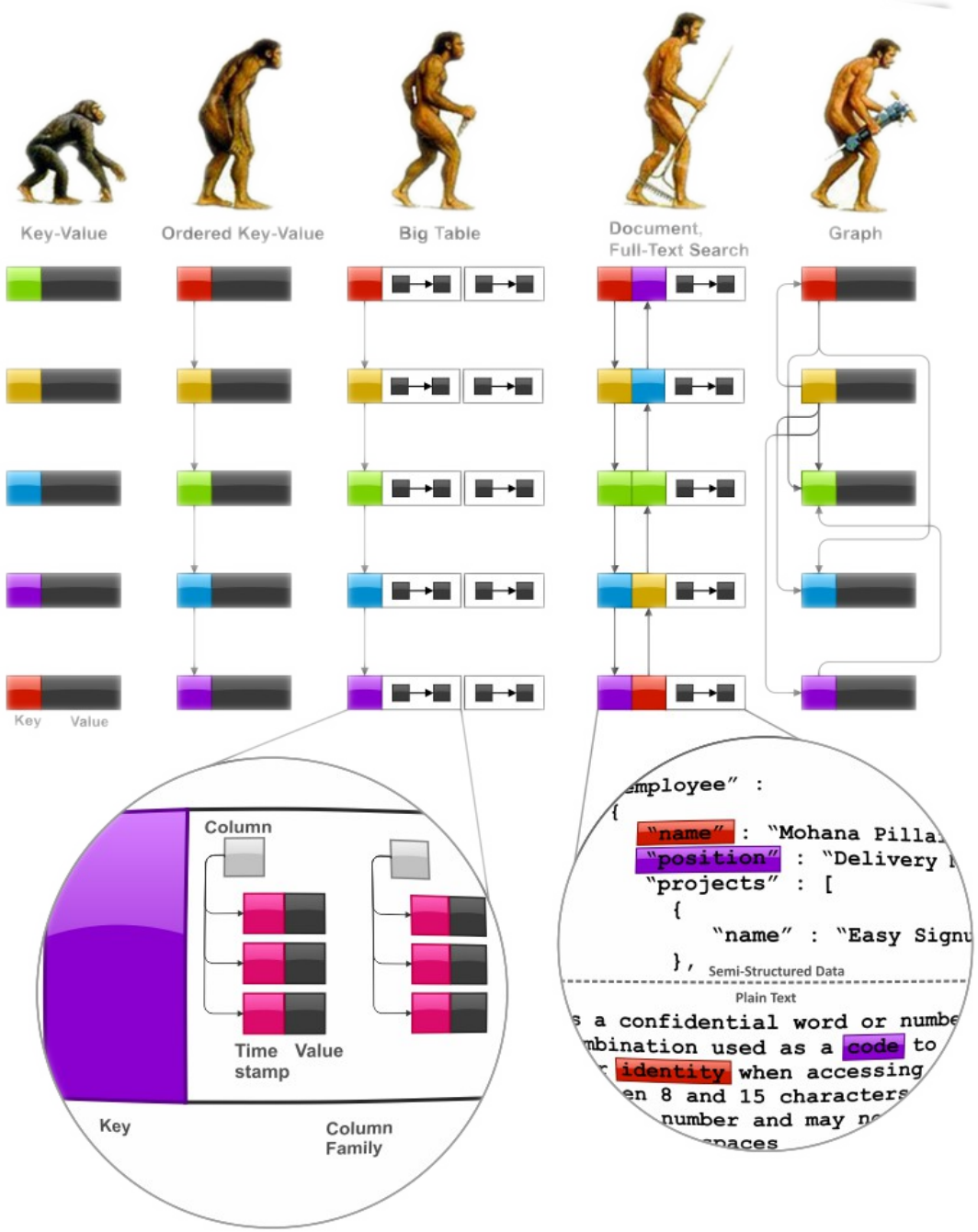
Stachka 2017, Ulyanovsk, April 14, 2017

NoSQL Postgres briefly

- 2003 — hstore (sparse columns, schema-less)
- 2006 — hstore as demo of GIN indexing, 8.2 release
- 2012 (sep) — JSON in 9.2 (verify and store)
- 2012 (dec) — nested hstore proposal
- 2013 — PGCon, Ottawa: nested hstore
- 2013 — PGCon.eu: binary storage for nested data
- 2013 (nov) — nested hstore & jsonb (better/binary)
- 2014 (feb-mar) — forget nested hstore for jsonb
- Mar 23, 2014 — jsonb committed for 9.4
- Autumn, 2018 — SQL/JSON for 10.X or 11 ?



PROFESSIONAL Postgres



PostgreSQL 9.4: NoSQL on ACID

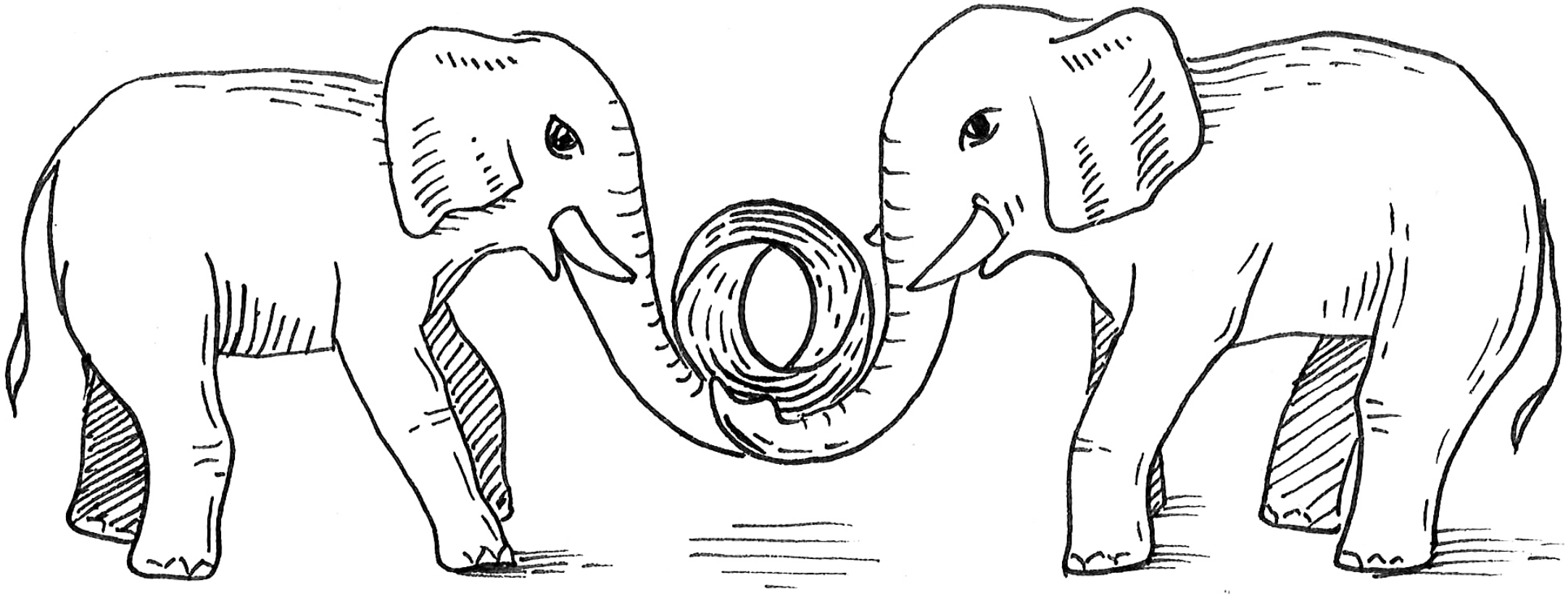
JSONB - 2014
- Binary storage
- Nesting objects & arrays
- Indexing

JSON - 2012
- Textual storage
- JSON verification

HSTORE - 2003
- Perl-like hash storage
- No nesting
- Indexing

PROFESSIONAL Postgres

Two JSON data types !!!

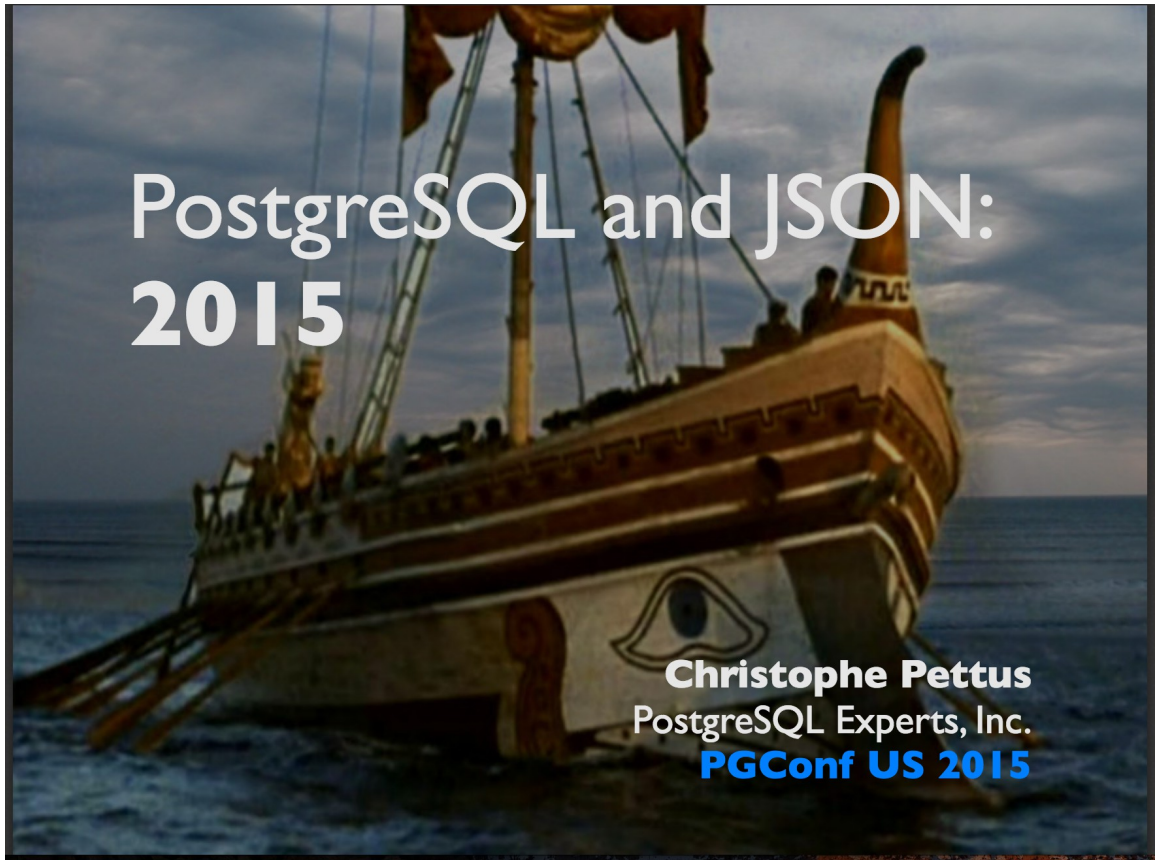


Jsonb vs Json

```
SELECT j::json AS json, j::jsonb AS jsonb FROM
(SELECT '{"cc":0, "aa":  2, "aa":1,"b":1}' AS j) AS foo;
                json                |           jsonb
------------------------------------+----------------------------
 {"cc":0, "aa":  2, "aa":1,"b":1} | {"b": 1, "aa": 1, "cc": 0}
(1 row)
```

- json: textual storage «as is»
- jsonb: no whitespaces
- jsonb: no duplicate keys, last key win
- jsonb: keys are sorted by (length, key)
- jsonb has a binary storage: no need to parse, has index support

Very detailed talk about JSON[B]



http://thebuild.com/presentations/json2015-pgconfus.pdf

Postgres PROFESSIONAL

JSONB is great, BUT

No good query language —

jsonb is a «black box» for SQL

Find something «red»

```
      Table "public.js_test"
 Column |  Type   | Modifiers
--------+---------+-----------
 id     | integer | not null
 value  | jsonb   |

select * from js_test;
 id |                                        value
----+-----------------------------------------------------------------------
  1 | [1, "a", true, {"b": "c", "f": false}]
  2 | {"a": "blue", "t": [{"color": "red", "width": 100}]}
  3 | [{"color": "red", "width": 100}]
  4 | {"color": "red", "width": 100}
  5 | {"a": "blue", "t": [{"color": "red", "width": 100}], "color": "red"}
  6 | {"a": "blue", "t": [{"color": "blue", "width": 100}], "color": "red"}
  7 | {"a": "blue", "t": [{"color": "blue", "width": 100}], "colr": "red"}
  8 | {"a": "blue", "t": [{"color": "green", "width": 100}]}
  9 | {"color": "green", "value": "red", "width": 100}
(9 rows)
```

Find something «red»

- VERY COMPLEX SQL QUERY

```
WITH RECURSIVE t(id, value) AS ( SELECT * FROM
js_test
 UNION ALL
    (
      SELECT
        t.id,
        COALESCE(kv.value, e.value) AS value
      FROM
        t
        LEFT JOIN LATERAL
jsonb_each(
CASE WHEN jsonb_typeof(t.value) =
'object' THEN t.value
          ELSE NULL END) kv ON true
        LEFT JOIN LATERAL
jsonb_array_elements(
          CASE WHEN
jsonb_typeof(t.value) = 'array' THEN t.value
          ELSE NULL END) e ON true
        WHERE
          kv.value IS NOT NULL OR e.value IS
NOT NULL
     )
)
SELECT
  js_test.*
FROM
  (SELECT id FROM t WHERE value @> '{"color":
"red"}' GROUP BY id) x
  JOIN js_test ON js_test.id = x.id;
```

```
 id |                                                                value
----+-------------------------------------------------------------------------
  2 | {"a": "blue", "t": [{"color": "red", "width": 100}]}
  3 | [{"color": "red", "width": 100}]
  4 | {"color": "red", "width": 100}
  5 | {"a": "blue", "t": [{"color": "red", "width": 100}], "color": "red"}
  6 | {"a": "blue", "t": [{"color": "blue", "width": 100}], "color": "red"}
(5 rows)
```

Find something «red»

```
WITH RECURSIVE t(id, value) AS ( SELECT * FROM
js_test
 UNION ALL
    (
      SELECT
        t.id,
        COALESCE(kv.value, e.value) AS value
      FROM
        t
        LEFT JOIN LATERAL
jsonb_each(
CASE WHEN jsonb_typeof(t.value) =
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          ELSE NULL END) e ON true
        WHERE
          kv.value IS NOT NULL OR e.value IS
NOT NULL
     )
)
SELECT
  js_test.*
FROM
  (SELECT id FROM t WHERE value @> '{"color":
"red"}' GROUP BY id) x
  JOIN js_test ON js_test.id = x.id;
```

- **Jsquery**

```
SELECT * FROM js_test
WHERE
value @@  '*.color = "red"';
```

https://github.com/postgrespro/jsquery

- A language to query jsonb data type
- Search in nested objects and arrays
- More comparison operators with indexes support

JSON in SQL-2016

JSON in SQL-2016

- ISO/IEC 9075-2:2016(E) - https://www.iso.org/standard/63556.html
- BNF https://github.com/elliotchance/sqltest/blob/master/standards/2016/bnf.txt
- Discussed at Developers meeting Jan 28, 2017 in Brussels
- Post -hackers, Feb 28, 2017 (March commitfest)
  «Attached patch is an implementation of SQL/JSON data model from SQL-2016 standard (ISO/IEC 9075-2:2016(E)), which was published 2016-12-15 ...»
- Patch was too big (now about 16,000 loc) and too late for Postgres 10 :(

SQL/JSON in PostgreSQL

- It‘s not a new data type, it‘s a JSON data model for SQL
- PostgreSQL implementation is a subset of standard:
  - JSONB - ORDERED and UNIQUE KEYS
  - jsonpath data type for SQL/JSON path language
  - nine functions, implemented as SQL CLAUSEs

SQL/JSON in PostgreSQL

- **Jsonpath** provides an ability to operate (in standard specified way) with json structure at SQL-language level
  - Dot notation — $.a.b.c
  - Array - [*]
  - Filter ? - $.a.b.c ? (@.x > 10)
  - Methods - $.a.b.c.x.type()

```
SELECT * FROM js WHERE JSON_EXISTS(js, 'strict $.tags[*] ? (@.term ==
"NYC")');

SELECT * FROM js WHERE js @> '{"tags": [{"term": "NYC"}]}';
```

SQL/JSON in PostgreSQL

```
SELECT JSON_EXISTS(jsonb '{"a": 1, "b": 2}', '$.* ? (@ > $x && @ < $y)'
            PASSING 0 AS x, 2 AS y);
 ?column?
----------
 t
(1 row)

SELECT JSON_EXISTS(jsonb '{"a": 1, "b": 2}', '$.* ? (@ > $x && @ < $y)'
            PASSING 0 AS x, 1 AS y);
 ?column?
----------
 f
(1 row)
```

SQL/JSON in PostgreSQL

- The SQL/JSON **construction** functions:
  - JSON_OBJECT - serialization of an JSON object.
    - json[b]_build_object()
  - JSON_ARRAY - serialization of an JSON array.
    - json[b]_build_array()
  - JSON_ARRAYAGG - serialization of an JSON object from aggregation of SQL data
    - json[b]_agg()
  - JSON_OBJECTAGG - serialization of an JSON array from aggregation of SQL data
    - json[b]_object_agg()

SQL/JSON in PostgreSQL

- The SQL/JSON **retrieval** functions:
  - JSON_VALUE - Extract an SQL value of a predefined type from a JSON value.
  - JSON_QUERY - Extract a JSON text from a JSON text using an SQL/JSON path expression.
  - JSON_TABLE - Query a JSON text and present it as a relational table.
  - IS [NOT] JSON - test whether a string value is a JSON text.
  - JSON_EXISTS - test whether a JSON path expression returns any SQL/JSON items

SQL/JSON examples: Constraints

```
CREATE TABLE test_json_constraints (
       js text,
       i int,
       x jsonb DEFAULT JSON_QUERY(jsonb '[1,2]', '$[*]' WITH WRAPPER)
       CONSTRAINT test_json_constraint1
              CHECK (js IS JSON)
       CONSTRAINT test_json_constraint2
CHECK (JSON_EXISTS(js FORMAT JSONB, '$.a' PASSING i + 5 AS int, i::text AS txt))
       CONSTRAINT test_json_constraint3
CHECK (JSON_VALUE(js::jsonb, '$.a' RETURNING int DEFAULT ('12' || i)::int
       ON EMPTY ERROR ON ERROR) > i)
       CONSTRAINT test_json_constraint4
              CHECK (JSON_QUERY(js FORMAT JSONB, '$.a'
WITH CONDITIONAL WRAPPER EMPTY OBJECT ON ERROR) < jsonb '[10]')
);
```

Find something «red»

- ```
  WITH RECURSIVE t(id, value) AS ( SELECT * FROM
  js_test
   UNION ALL
      (
        SELECT
          t.id,
          COALESCE(kv.value, e.value) AS value
        FROM
          t
          LEFT JOIN LATERAL
  jsonb_each(
  CASE WHEN jsonb_typeof(t.value) =
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            ELSE NULL END) kv ON true
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  jsonb_array_elements(
            CASE WHEN
  jsonb_typeof(t.value) = 'array' THEN t.value
            ELSE NULL END) e ON true
          WHERE
            kv.value IS NOT NULL OR e.value IS
  NOT NULL
       )
  )
  ```

```
SELECT
  js_test.*
FROM
  (SELECT id FROM t WHERE value @> '{"color":
"red"}' GROUP BY id) x
  JOIN js_test ON js_test.id = x.id;
```

- Jsquery

```
SELECT * FROM js_test
 WHERE
 value @@  '*.color = "red"';
```

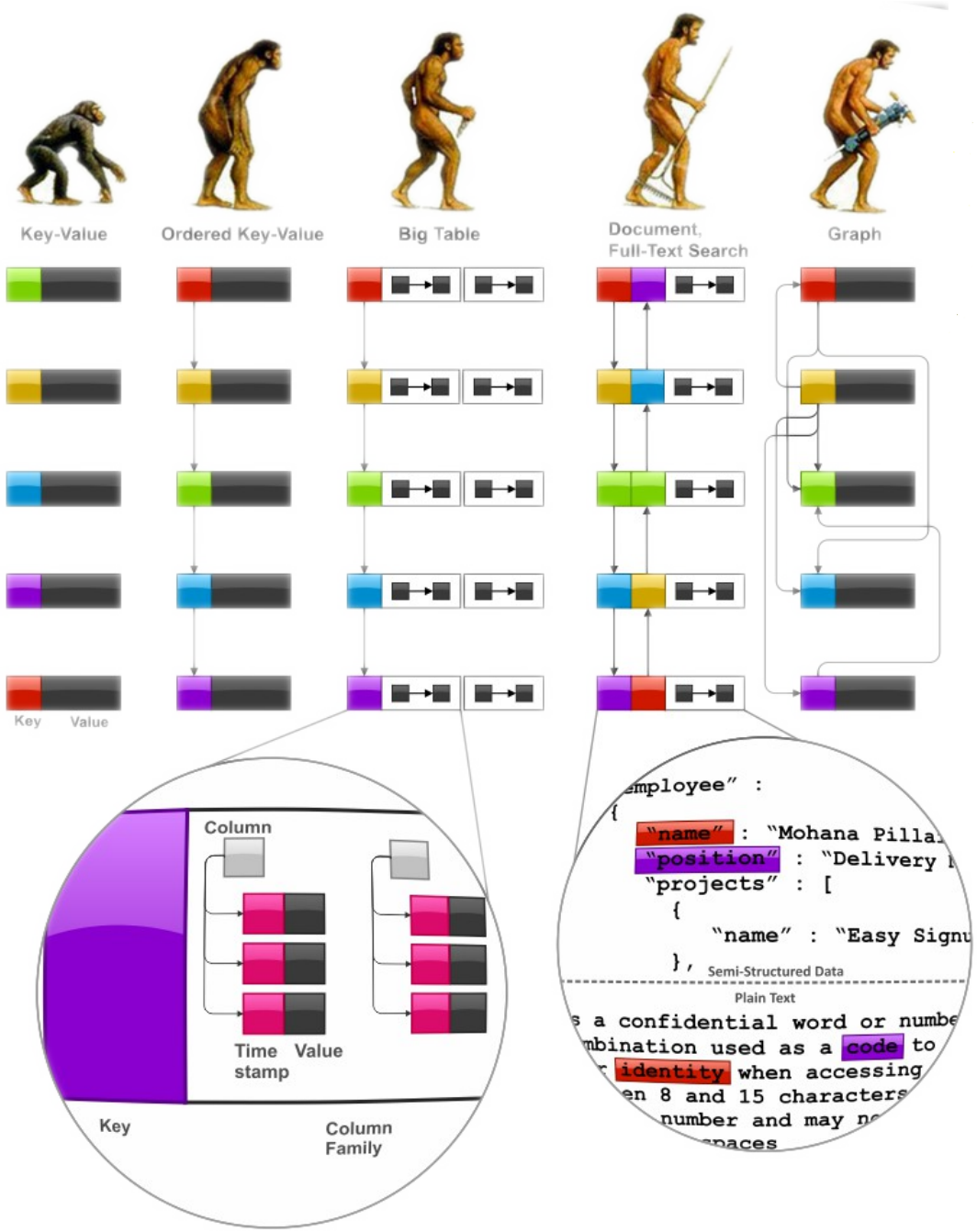
- **SQL/JSON 2016**

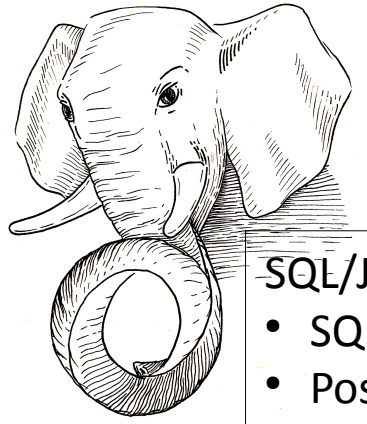
```
SELECT * FROM js_test WHERE
JSON_EXISTS( value,'$.**.color ?
(@ == "red")');
```
```

SQL/JSON availability

- Github Postgres Professional repository
  https://github.com/postgrespro/sqljson
- SQL/JSON examples
- WEB-interface to play with SQL/JSON
- BNF of SQL/JSON
- We need your feedback, bug reports and suggestions
- Help us writing documentation !

PROFESSIONAL Postgres





SQL/JSON - 2018
- SQL-2016 standard
- Postgres Pro - 2017

JSONB - 2014
- Binary storage
- Nesting objects & arrays
- Indexing

JSON - 2012
- Textual storage
- JSON verification

HSTORE - 2003
- Perl-like hash storage
- No nesting
- Indexing

PROFESSIONAL Postgres

JSONB COMPRESSION

Transparent compression of jsonb

+ access to the child elements without full decompression

jsonb compression: ideas

- **Keys replaced by their ID in the external dictionary**
- Delta coding for sorted key ID arrays
- Variable-length encoded entries instead of 4-byte fixed-size entries
- Chunked encoding for entry arrays
- Storing integer numerics falling into int32 range as variable-length encoded 4-byte integers

jsonb compression: implementation

- Custom column compression methods:

```
CREATE COMPRESSION METHOD name HANDLER handler_func

CREATE TABLE table_name (
      column_name data_type
      [ COMPRESSED cm_name [ WITH (option 'value' [, ... ]) ] ] ...
)

ALTER TABLE table_name ALTER column_name
      SET COMPRESSED cm_name [ WITH (option 'value' [, ... ]) ]

ALTER TYPE data_type SET COMPRESSED cm_name
```

- attcompression, attcmoptions in pg_catalog.pg_attributes

jsonb compression: jsonbc

- **Jsonbc** - compression method for jsonb type:
  - dictionary compression for object keys
  - more compact variable-length encoding

- All key dictionaries for all jsonbc compressed columns are stored in the pg_catalog.pg_jsonbc_dict (dict oid, id integer, name text)

- Dictionary used by jsonb column is identified by:
  - sequence oid – automatically updated
  - enum type oid – manually updated

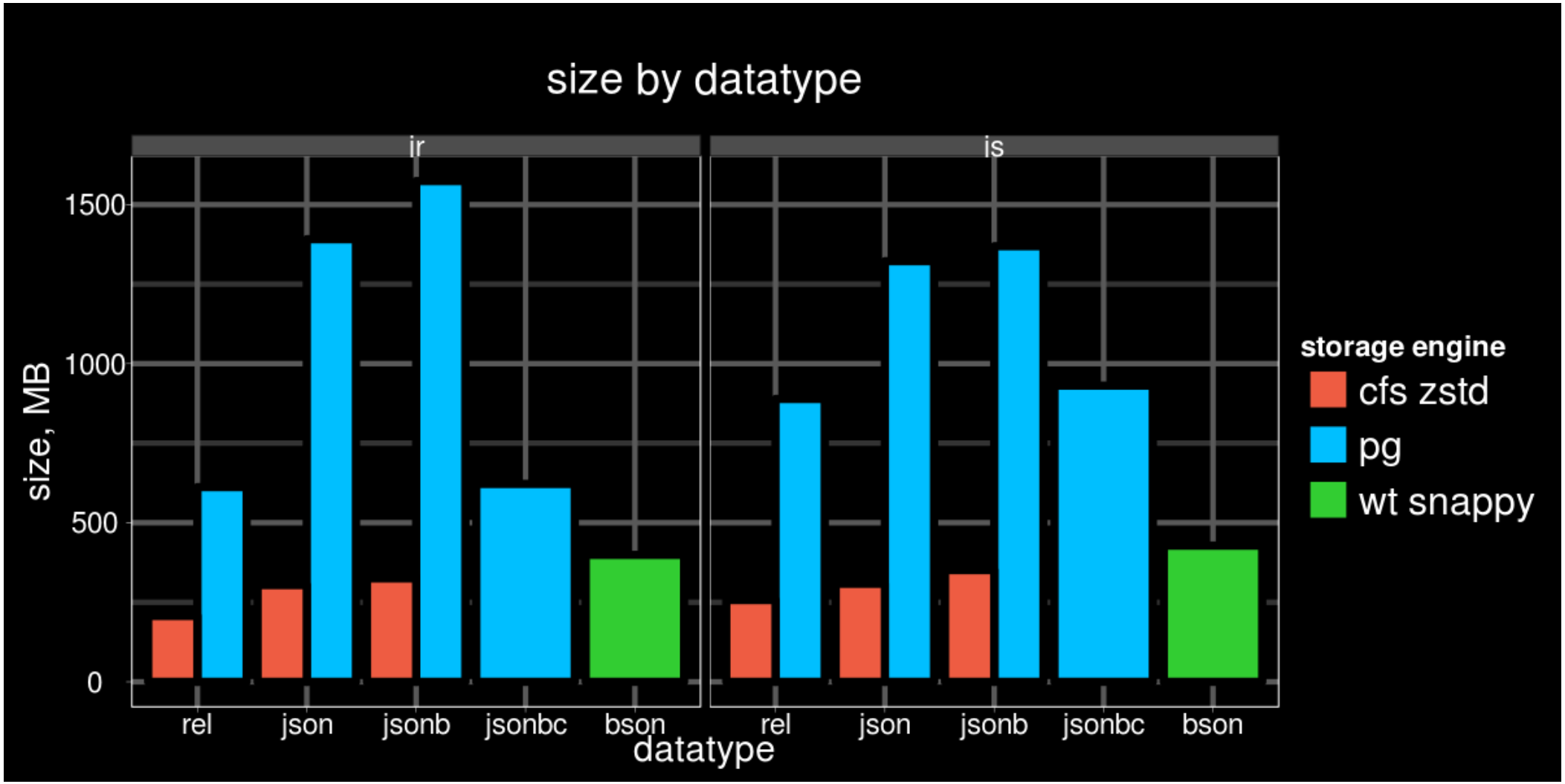
jsonb compression: results

Two datasets:

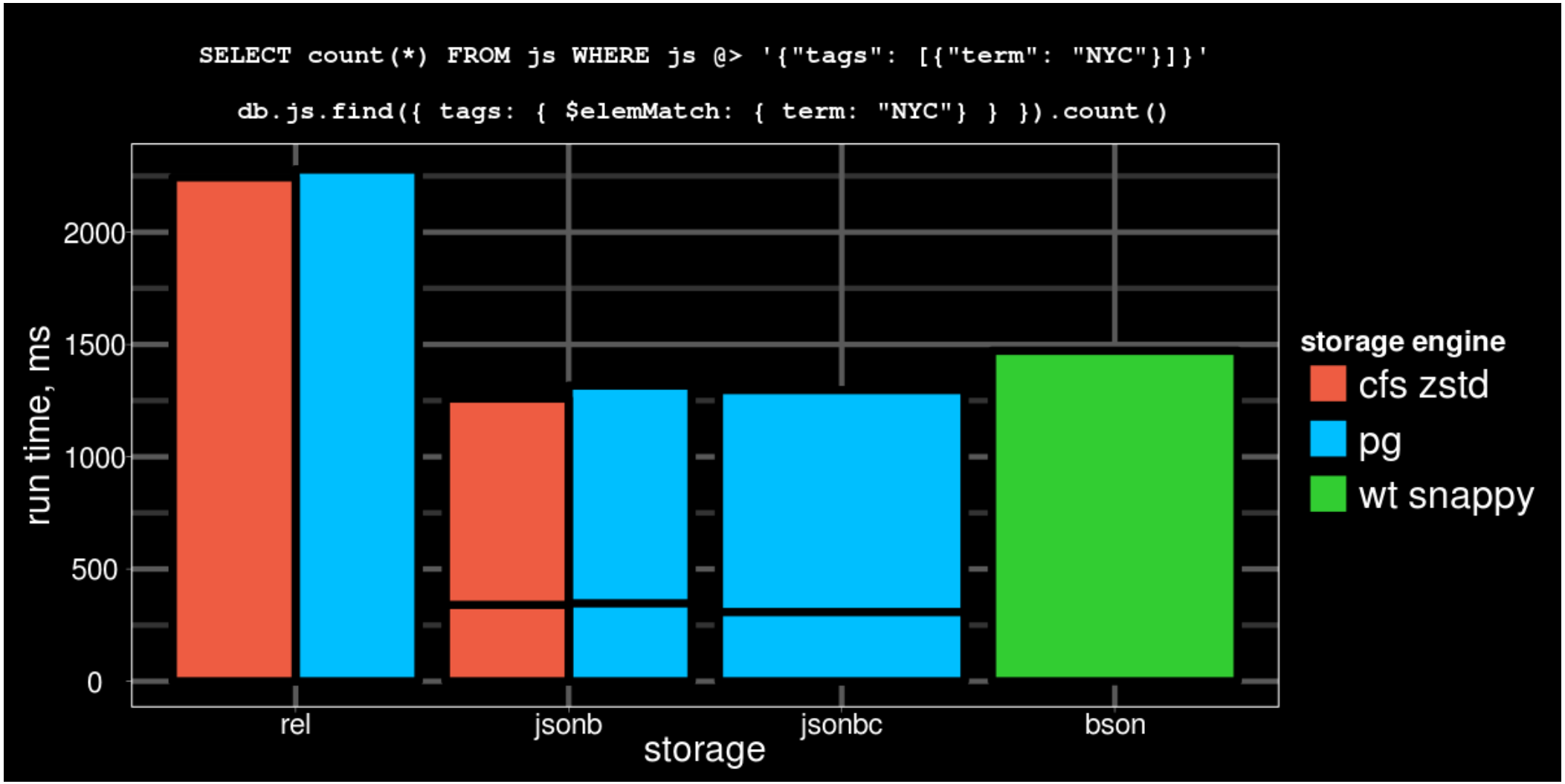
- js – Delicious bookmarks, 1.2 mln rows (js.dump.gz)
  - Mostly string values
  - Relatively short keys
  - 2 arrays (tags and links) of 3-field objects
- jr – customer reviews data from Amazon, 3mln (jr.dump.gz)
  - Rather long keys
  - A lot of short integer numbers

Also, jsonbc compared with CFS (Compressed File System) – page level compression and encryption in Postgres Pro Enterprise 9.6.

jsonb compression: table size



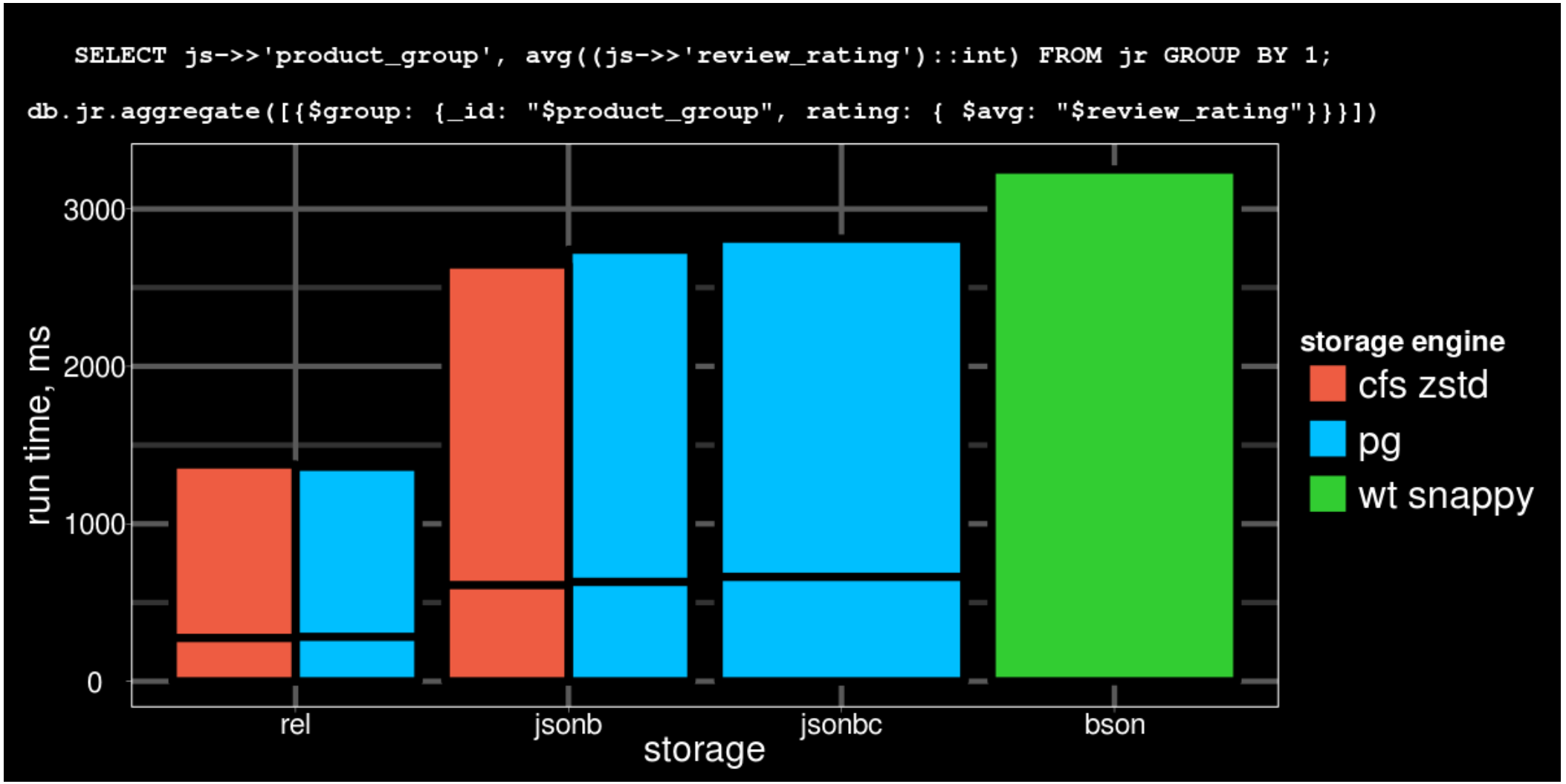
jsonb compression (js): performance



jsonb compression (jr): performance

```
SELECT js->>'product_group', avg((js->>'review_rating')::int) FROM jr GROUP BY 1;

db.jr.aggregate([{$group: {_id: "$product_group", rating: { $avg: "$review_rating"}}}])
```



jsonb compression: summary

- jsonbc can reduce jsonb column size to its relational equivalent size
- jsonbc has a very low CPU overhead over jsonb and sometimes can be even faster than jsonb
- jsonbc compression ratio is significantly lower than in page level compression methods
- Availability:

  https://github.com/postgrespro/postgrespro/tree/jsonbc

JSON[B] Text Search

- tsvector(configuration, json[b]) in Postgres 10

```
select to_tsvector(jb) from (values ('
{
     "abstract": "It is a very long story about true and false",
     "title": "Peace and War",
     "publisher": "Moscow International house"
 }
'::json)) foo(jb);
                                    to_tsvector
-------------------------------------------------------------------------------
'fals':10 'hous':18 'intern':17 'long':5 'moscow':16 'peac':12 'stori':6 'true':8 'war':14
```

```
select to_tsvector(jb) from (values ('
{
     "abstract": "It is a very long story about true and false",
     "title": "Peace and War",
     "publisher": "Moscow International house"
 }
'::jsonb)) foo(jb);
                                    to_tsvector
-------------------------------------------------------------------------------
 'fals':14 'hous':18 'intern':17 'long':9 'moscow':16 'peac':1 'stori':10 'true':12 'war':3
```

JSON[B] Text Search

- Phrase search is [properly] supported !

```
select  phraseto_tsquery('english','war moscow') @@ to_tsvector(jb) from (values ('
{
     "abstract": "It is a very long story about true and false",
     "title": "Peace and War",
     "publisher": "Moscow International house"
 }
'::jsonb)) foo(jb);
 ?column?
----------
 f
```

```
select  phraseto_tsquery('english','moscow international') @@ to_tsvector(jb) from
(values ('
{
     "abstract": "It is a very long story about true and false",
     "title": "Peace and War",
     "publisher": "Moscow International house"
 }
'::jsonb)) foo(jb);
 ?column?
----------
 t
```

- Kudos to Dmitry Dolgov & Andrew Dunstan !

PROFESSIONAL Postgres

BENCHMARKS:
How NoSQL Postgres is fast

First (non-scientific) benchmark !

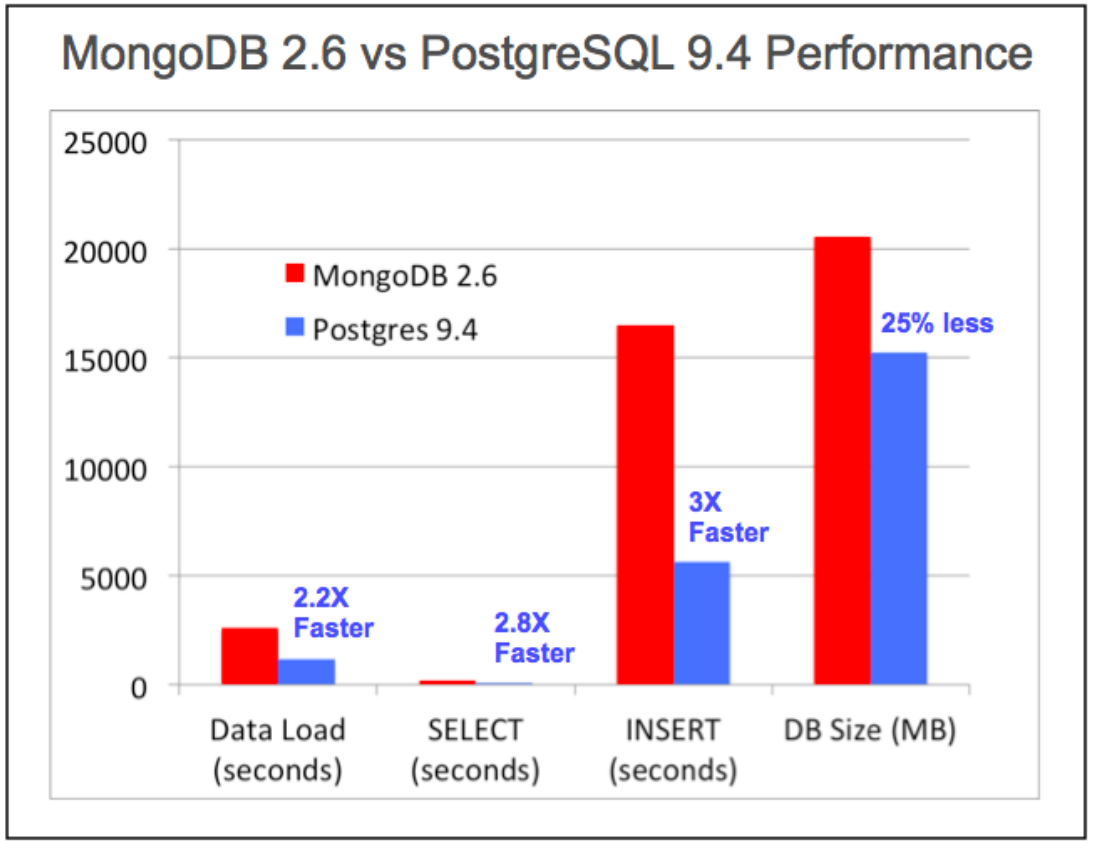
Summary: PostgreSQL 9.4 vs Mongo 2.6.0

- Search key=value (contains @>)
  - json : 10 s seqscan
  - jsonb : 8.5 ms GIN jsonb_ops
  - **jsonb : 0.7 ms GIN jsonb_path_ops**
  - mongo : 1.0 ms btree index
- Index size
  - jsonb_ops - 636 Mb (no compression, 815Mb)
    jsonb_path_ops - 295 Mb
  - jsonb_path_ops (tags) - 44 Mb USING gin((jb->'tags') jsonb_path_ops
  - mongo (tags) - 387 Mb
    mongo (tags.term) - 100 Mb

- Table size
  - postgres : 1.3Gb
  - mongo : 1.8Gb
- Input performance:
  - Text : 34 s
  - Json : 37 s
  - Jsonb : 43 s
  - mongo : 13 m

Engine Yard™

EDB NoSQL Benchmark

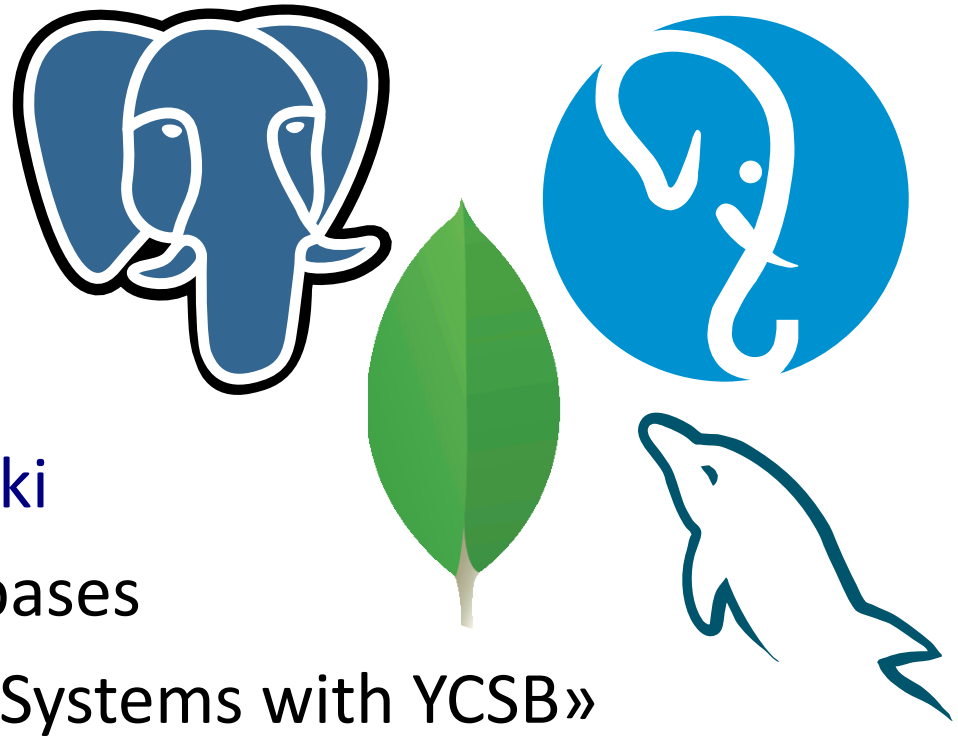


https://github.com/EnterpriseDB/pg_nosql_benchmark

Benchmarking NoSQL Postgres

- Both benchmarks were homemade by postgres people
- People tend to believe independent and «scientific» benchmarks
  - Reproducible
  - More databases
  - Many workloads
  - Open source

YCSB Benchmark



- Yahoo! Cloud Serving Benchmark - https://github.com/brianfrankcooper/YCSB/wiki
- De-facto standard benchmark for NoSQL databases
- Scientific paper «Benchmarking Cloud Serving Systems with YCSB» https://www.cs.duke.edu/courses/fall13/cps296.4/838-CloudPapers/ycsb.pdf
- We run YCBS for Postgres master, Postgres Pro Enterprise 2.0, MongoDB 3.4.2, Mysql 5.7.17
  - 1 server with 24 cores, 48 GB RAM for clients
  - 1 server with 24 cores, 48 GB RAM for database
  - 10Gbps switch

YCSB Benchmark: Core workloads

- Workload A: Update heavy - a mix of 50/50 reads and writes
- Workload B: Read mostly - a 95/5 reads/write mix
- Workload C: Read only — 100% read
- Workload D: Read latest - new records are inserted, and the most recently inserted records are the most popular
- Workload E: Short ranges - short ranges of records are queried
- Workload F: Read-modify-write - the client will read a record, modify it, and write back the changes
- All (except D) workloads uses Zipfian distribution for record selections

YCSB Benchmark: details (1)

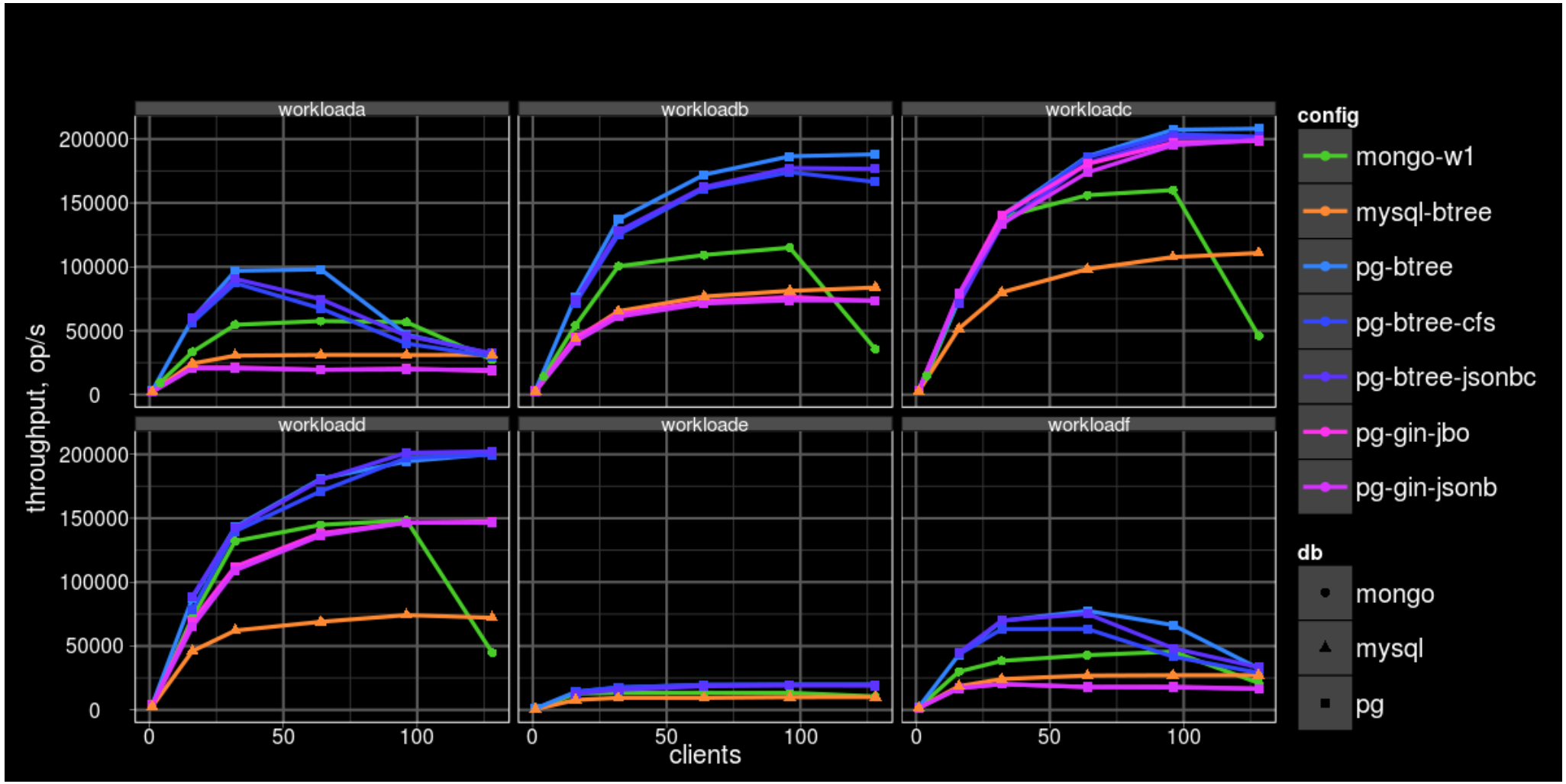
- Postgres (9.6, master), asynchronous commit=on
  Mongodb 3.4.2 (w1, j0) — 1 and 5 mln. rows
- Postgres (9.6, master), asynchronous commit=off
  Mongodb 3.4.2 (w1, j1) — 100K rows
- MySQL 5.7.17 + all optimization
- We tested:
  - Functional btree index for jsonb, jsonbc, sqljson, cfs (compressed) storage
  - Gin index (fastupdate=off) for jsonb, jsonb_build_object
  - Mongodb (wiredtiger with snappy compression)
  - Return a whole json, just one field, small range
  - 10 fields, 200 fields (TOASTed)

YCSB Benchmark: details (2)

- Client machine load:
  - Postgres <= 30%
    Mongodb <= 55%
- Server machine load:
  - Postgres — 100%
  - MySQL — 100%
  - MongoDB — 70%

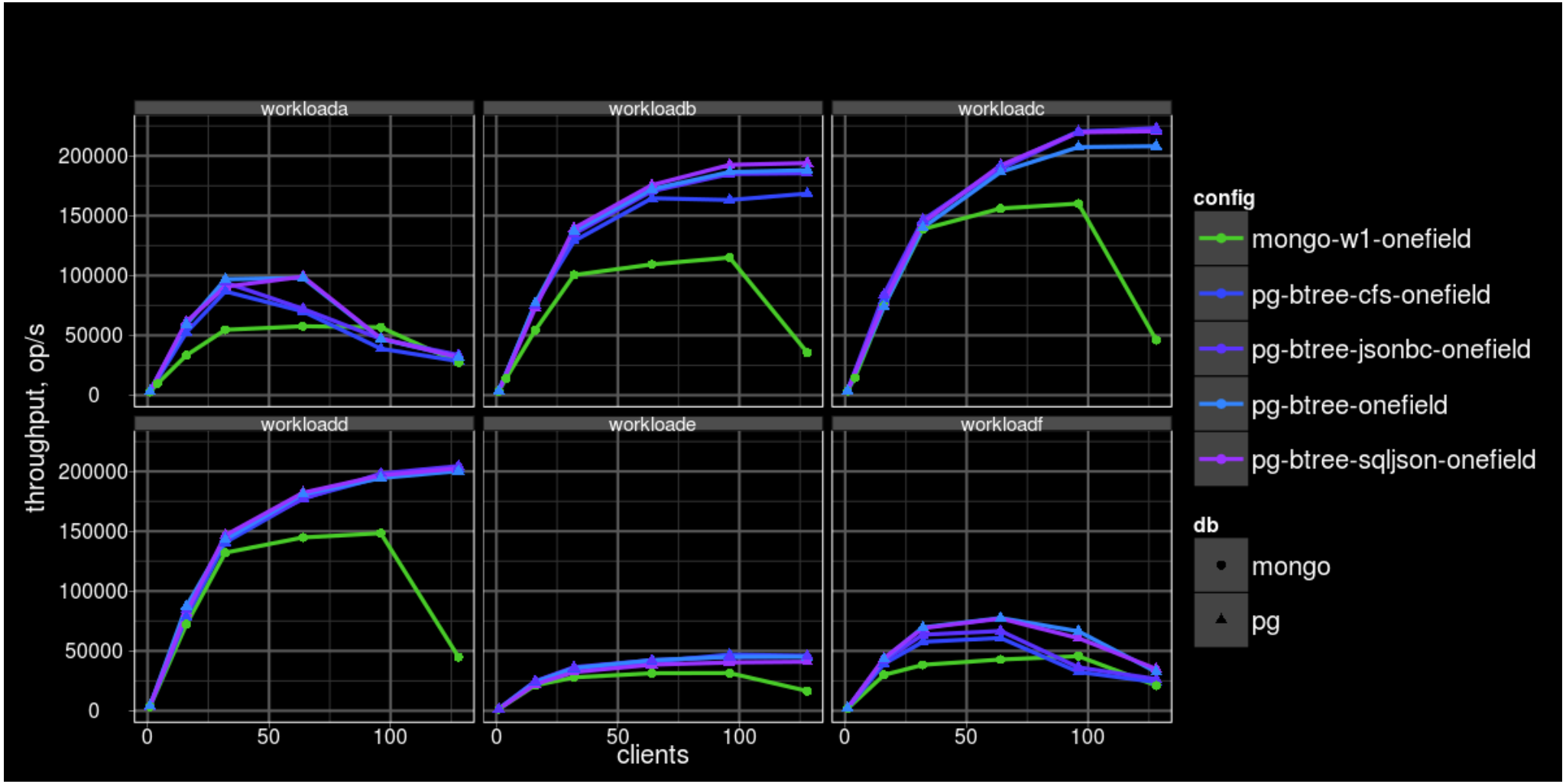
1 mln rows, 10 fields, select all fields

- Postgres is better in all workloads !
- All jsonb variants are the same for most read workloads
- Gin, jsonbc and jsonb(cfs) are not good for updates



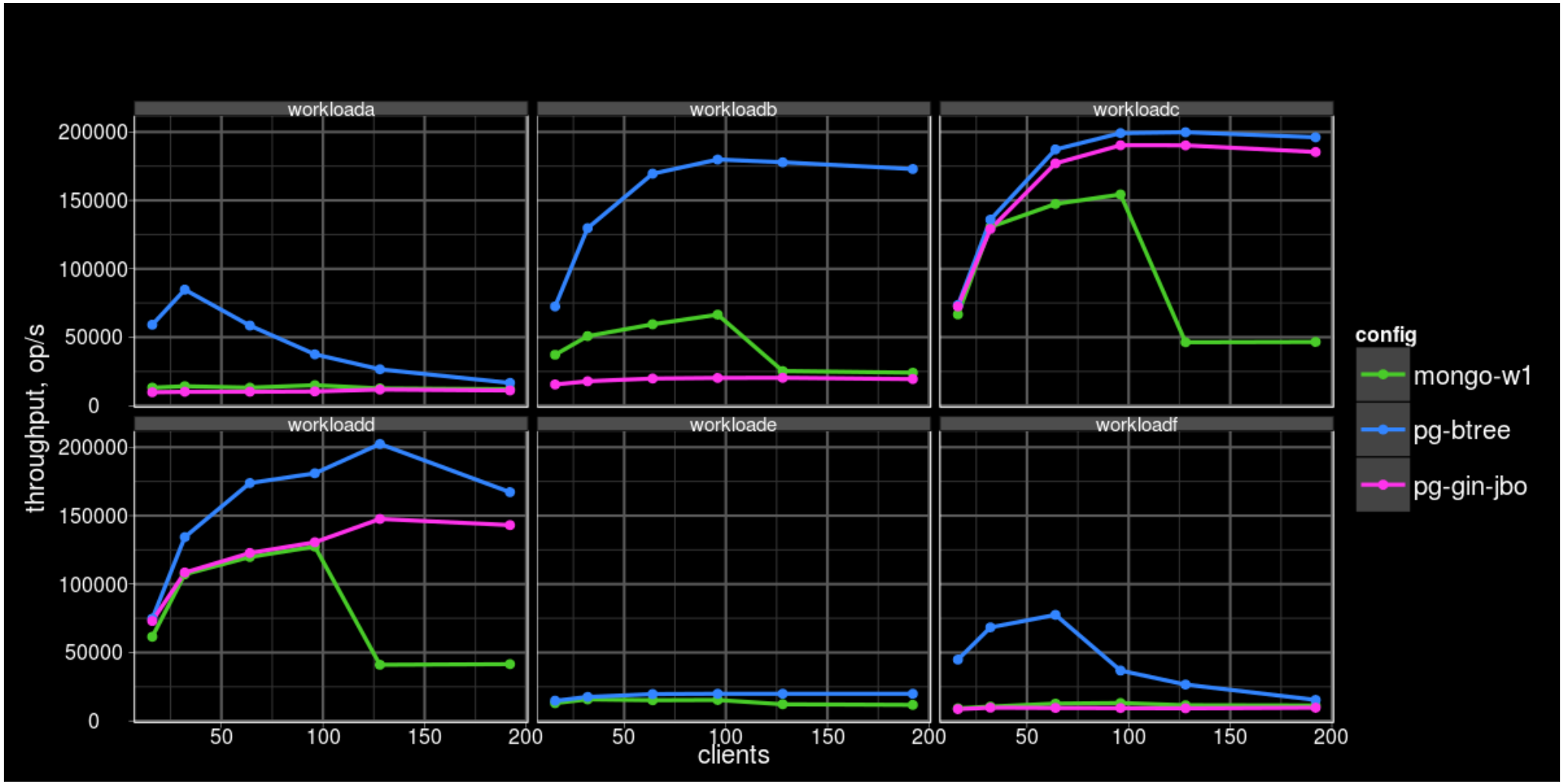
1 mln rows, 10 fields, select one fields

- Postgres is better in all workloads !
- Jsonb ~ jsonb(cfs) ~ Jsonbc ~ sqljson for most read workloads
- Jsonbc and jsonb(cfs) not good for updates



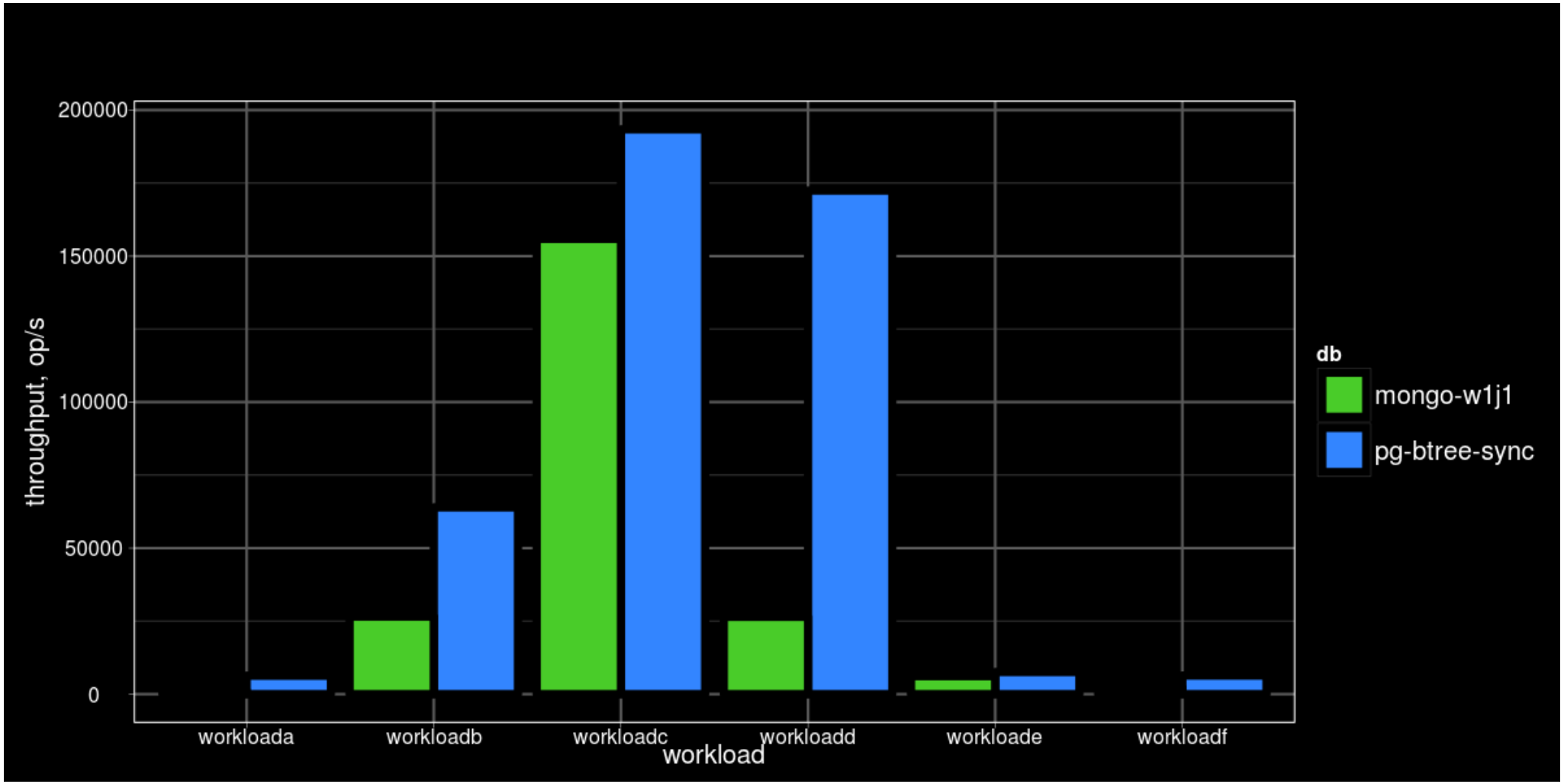
5 mln rows, 10 fields

- Postgres is better in all workloads !
- Gin is not good for updates



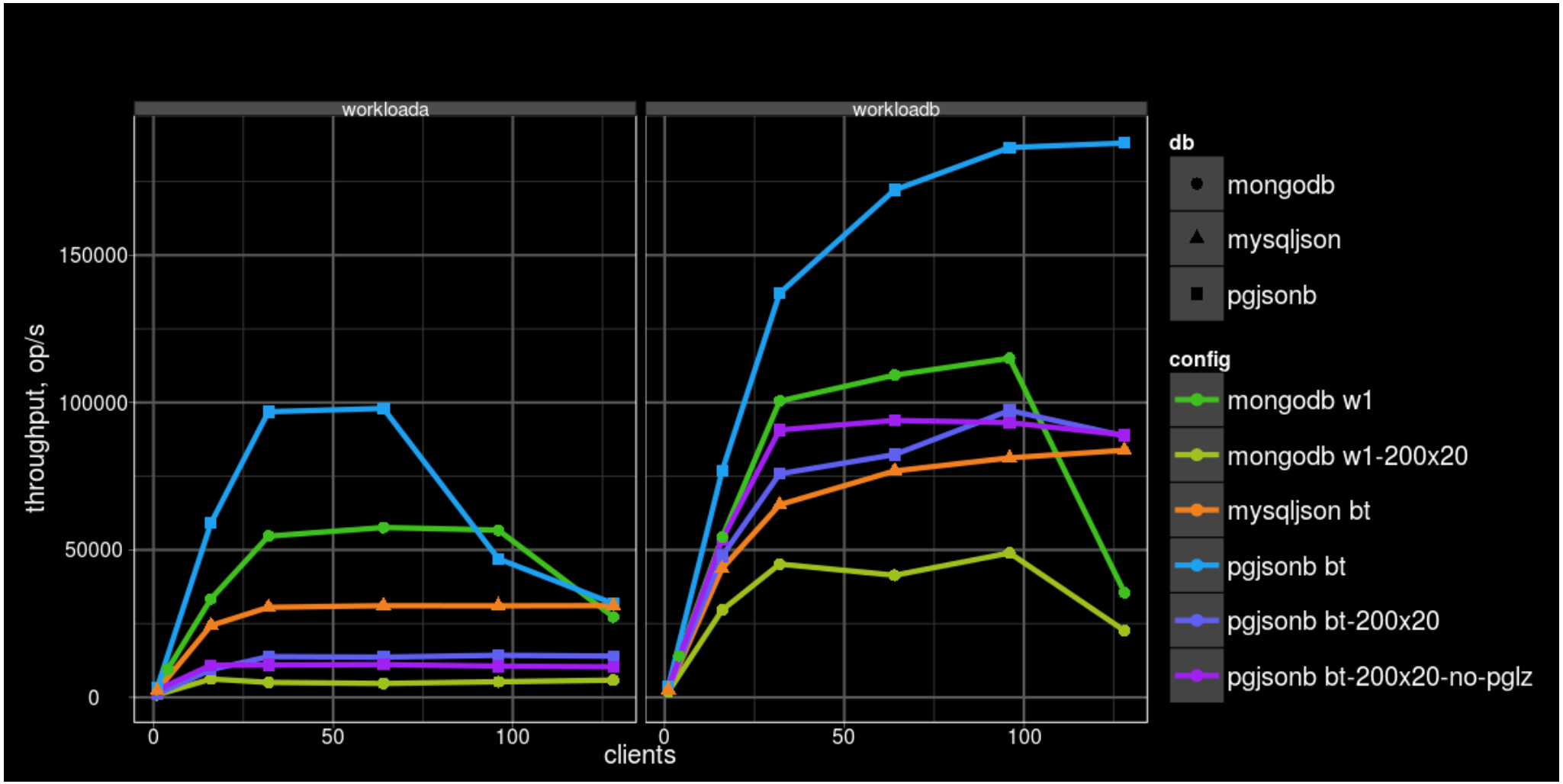
100K rows, 10 fields, journal on disk

- Mongo — j1
  Postgres - async.commit is on
- Postgres is better in all workloads !



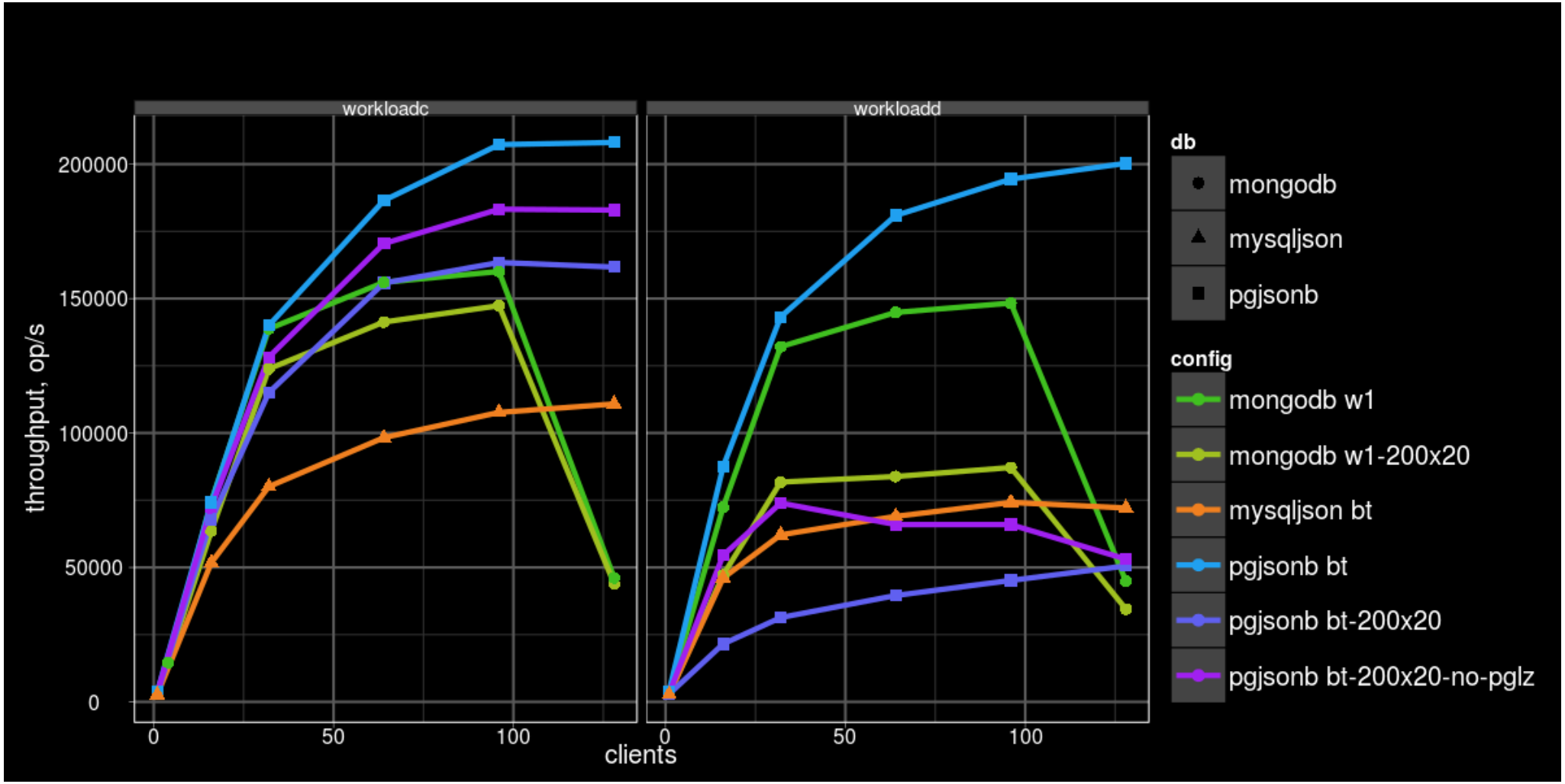
1mln rows, 200 fields, workloads a,b

- Postgres is better !



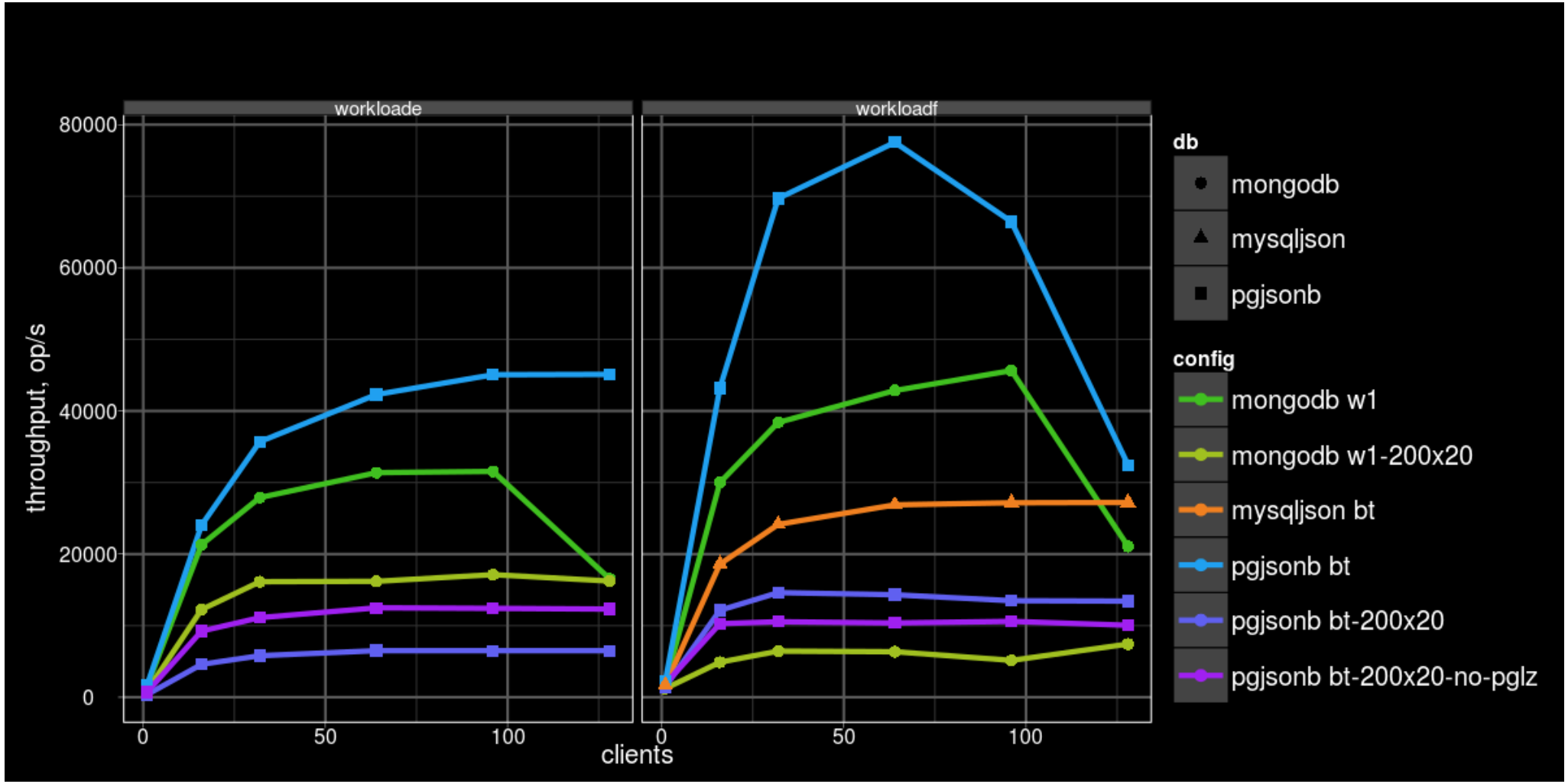
1mln rows, 200 fields, workloads c,d

- MongoDB is better in workload D
- Postgres is better in workload C



1mln rows, 200 fields, workloads e,f

- MongoDB is better in workload E
- Postgres is better in workload F

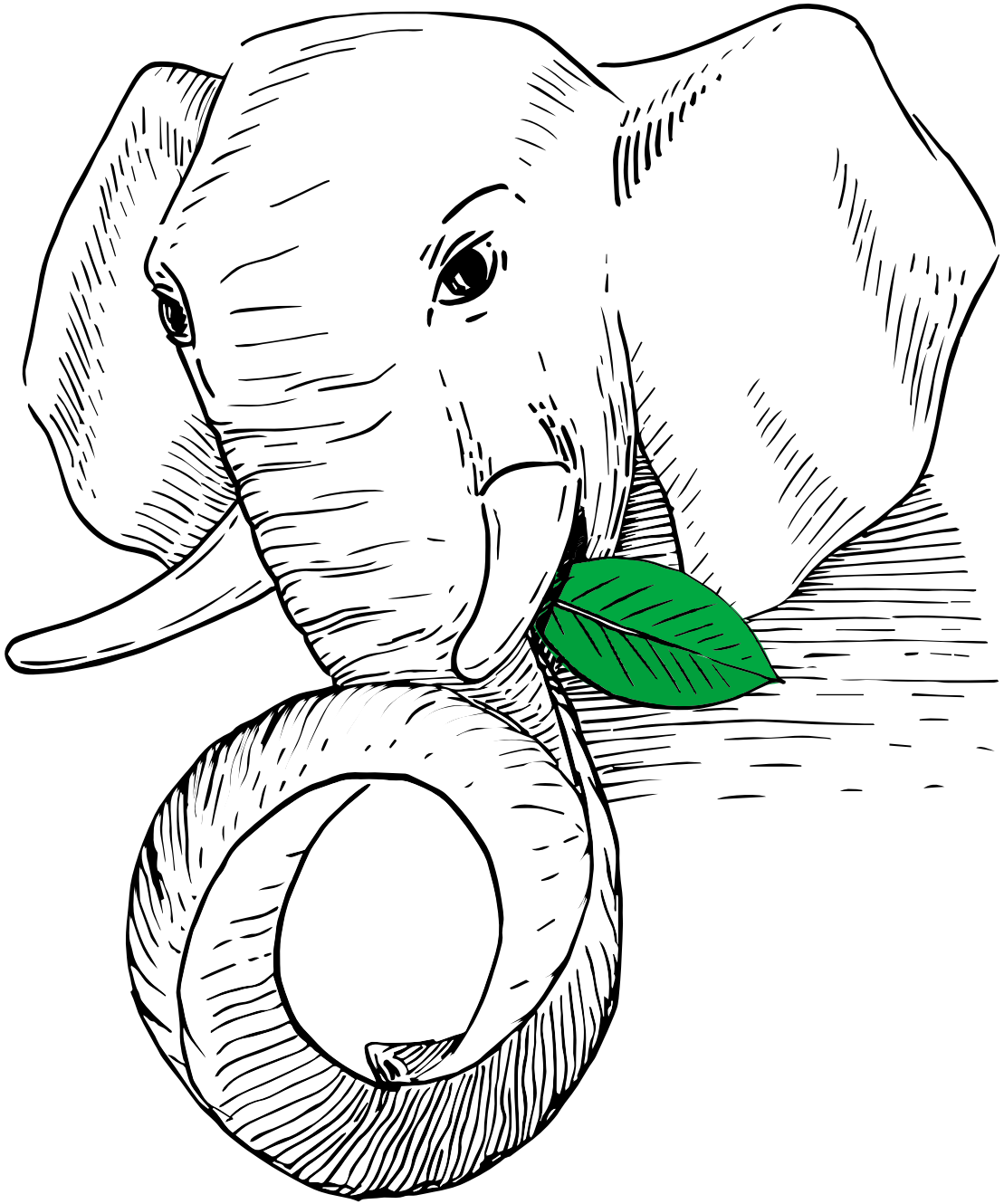


Postgres PROFESSIONAL

PostgreSQL

beats

MongoDB !



PROFESSIONAL Postgres

Still need more tps ?

Use partitioning

- Upcoming version of pg_pathman supports partitioning by expression
- Delicious bookmarks dataset — 5 partitions

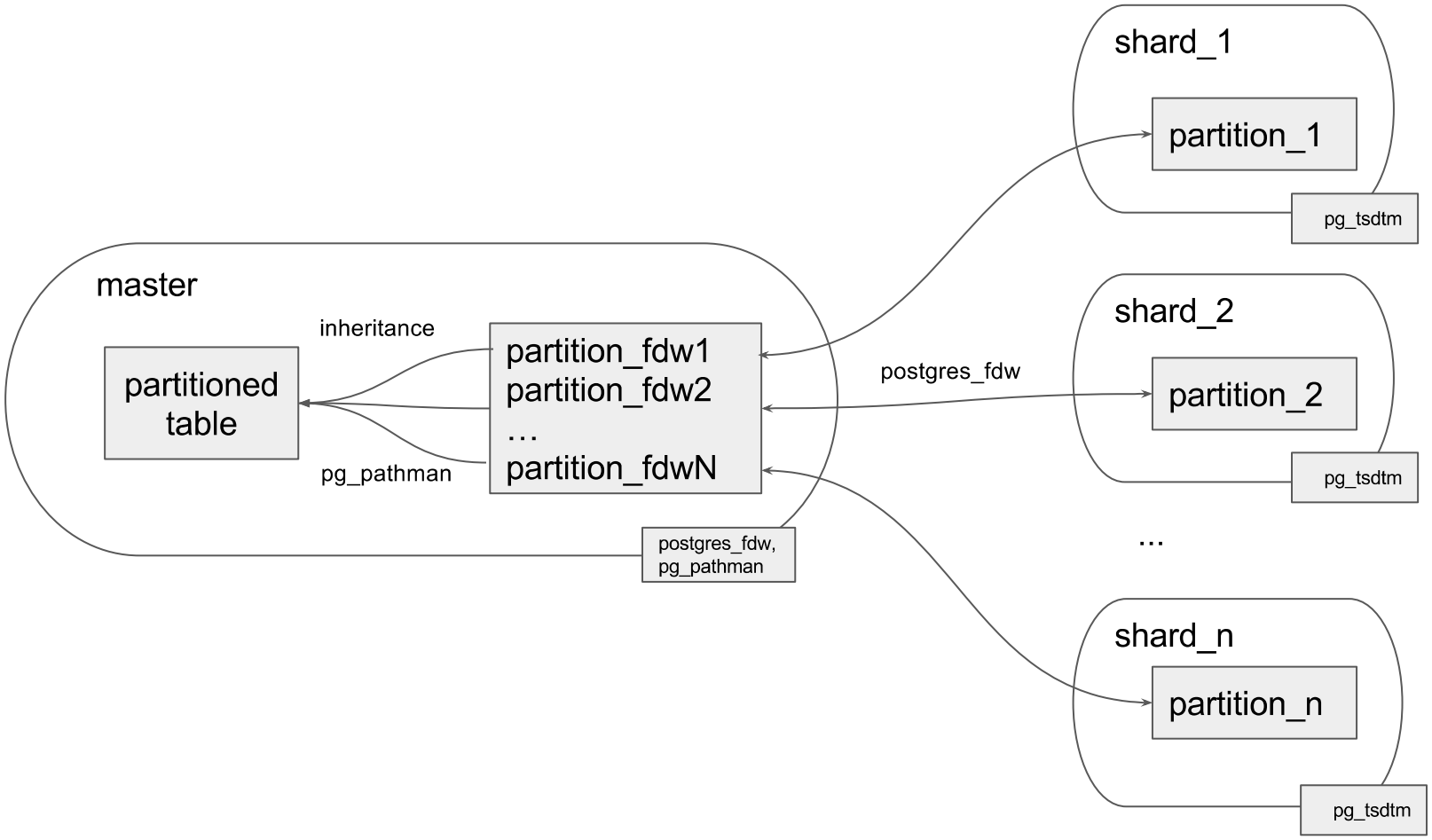
```
SELECT pathman.create_hash_partitions('jb', 'jb->>''id''', 5);
 create_hash_partitions
------------------------
                      5
(1 row)

SELECT * FROM jb
WHERE (jb->>'id') = 'http://delicious.com/url/c91427110a17ad74de35eabaa296fa7a#kikodesign';
```

  - Vanilla 9.6 - 818, 274 (parallel) +pg_pathman - 173, 84 (parallel)
- Delicious bookmarks dataset — 1000 partitions
  - Vanilla 9.6 — 505 ms (27 ms) + pg_pathman — 1 ms (0.47 ms) !

Still need more tps ?

Use sharding !



Sharding with postgres_cluster

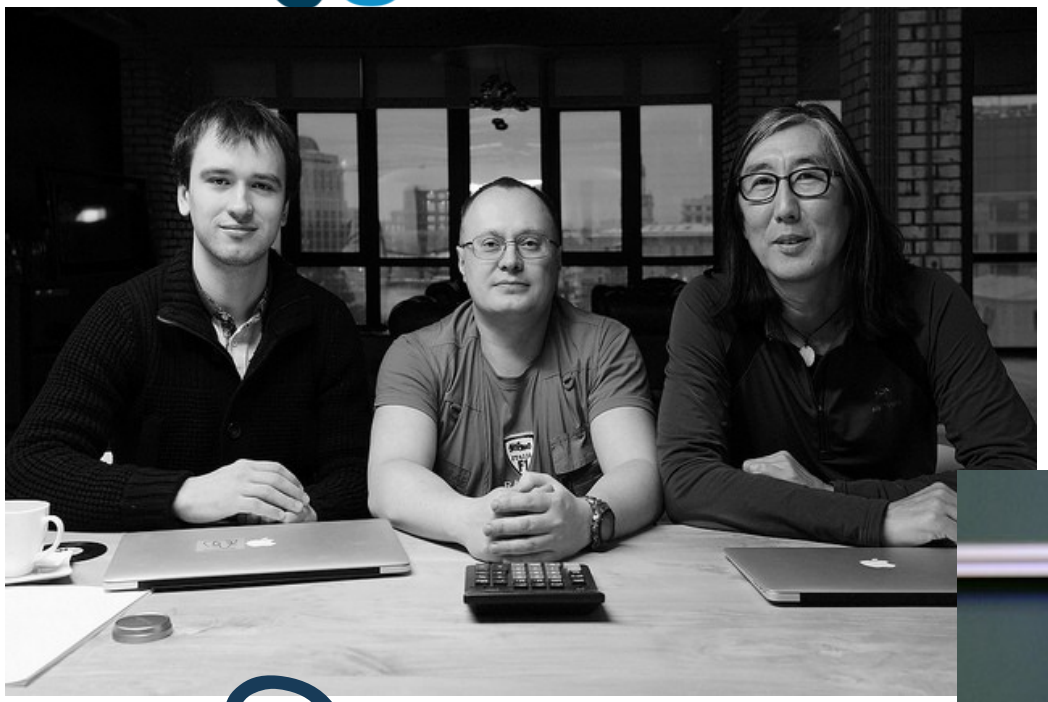
- Master: fork postgres_cluster
  https://github.com/postgrespro/postgres_cluster
- Shards: pg_tsdtm
  https://github.com/postgrespro/pg_tsdtm

Суббота, 15 апреля, 16:00, «Советская школа»
От создателей pg_pathman туториал
«Распределенное секционирование (шардинг)»

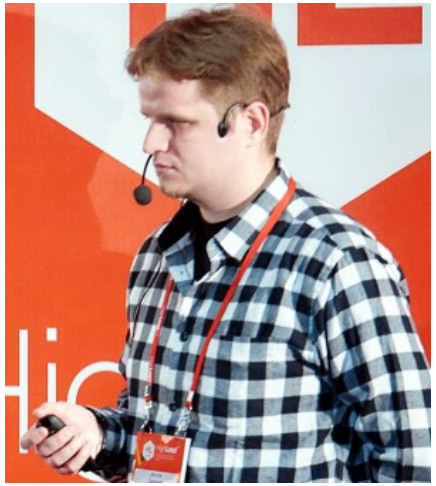
Summary

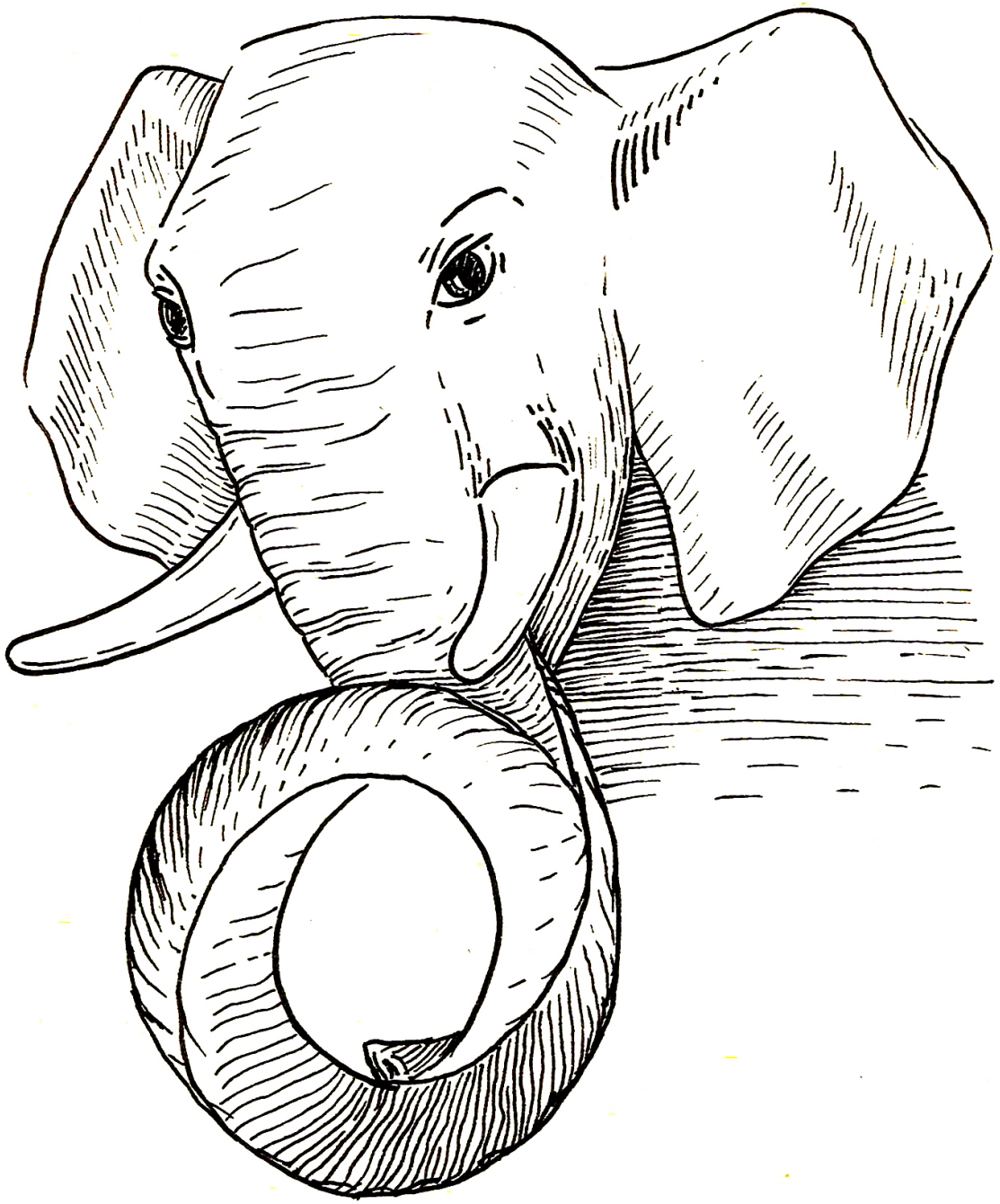
- Postgres is already a good NoSQL database + clear roadmap
- Move from NoSQL to Postgres to avoid nightmare !
- SQL/JSON will provide better flexibility and interoperability
  - Expect it in Postgres 11 (Postgres Pro 10)
  - Need community help (testing, documentation)
- JSONB dictionary compression (jsonbc) is really useful
  - Expect it in Postgres 11 (Postgres Pro 10)
- Postgres beats Mongodb and MySQL in one node configuration
  - Next: YCSB benchmarks in distributed mode
- Full version of this talk:
  http://www.sai.msu.su/~megera/postgres/talks/jsonb-stachka-2017-full.pdf

PEOPLE BEHIND JSON[B]



Nikita Glukhov





Thanks !