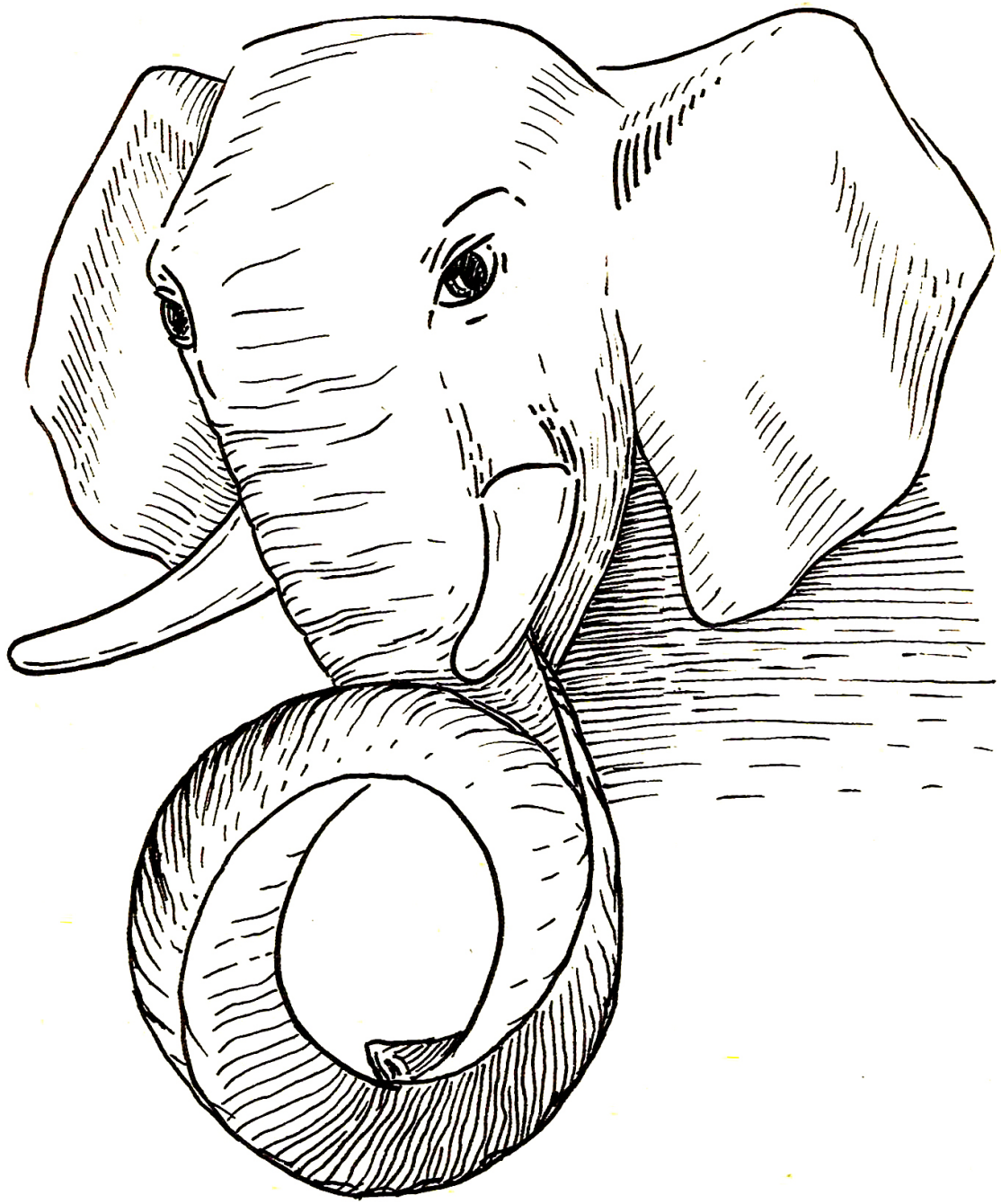


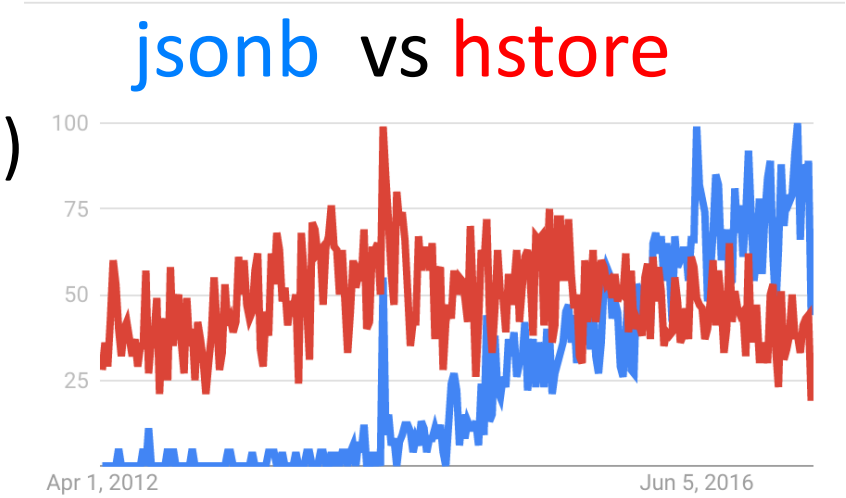
JSON in Postgres - The present and Future

Oleg Bartunov
Postgres Professional
Moscow University

PGConf US 2017, Jersey City, US March 28 - 31, 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: 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 ?



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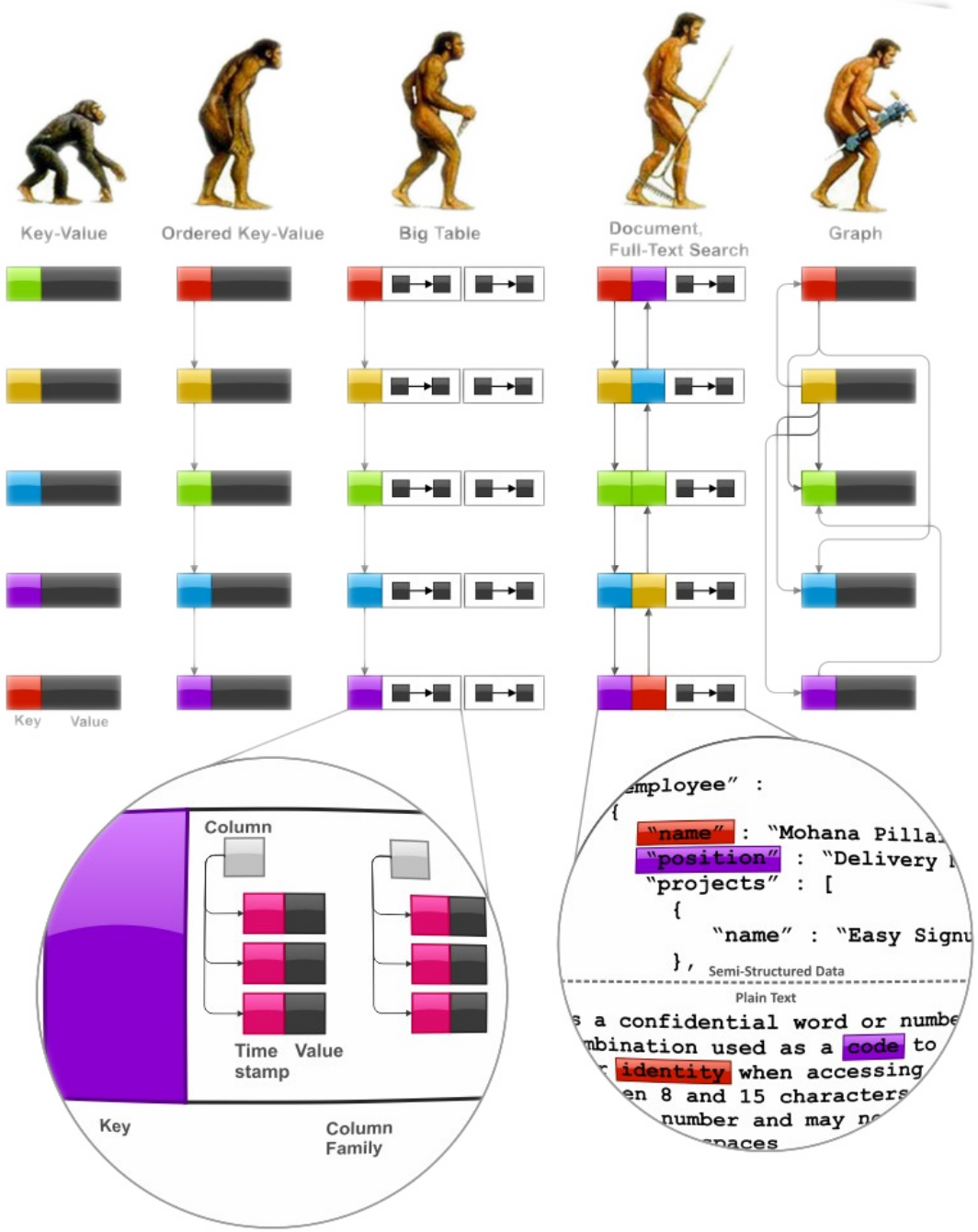


PostgreSQL 9.4: NoSQL on ACID

JSONB - 2014

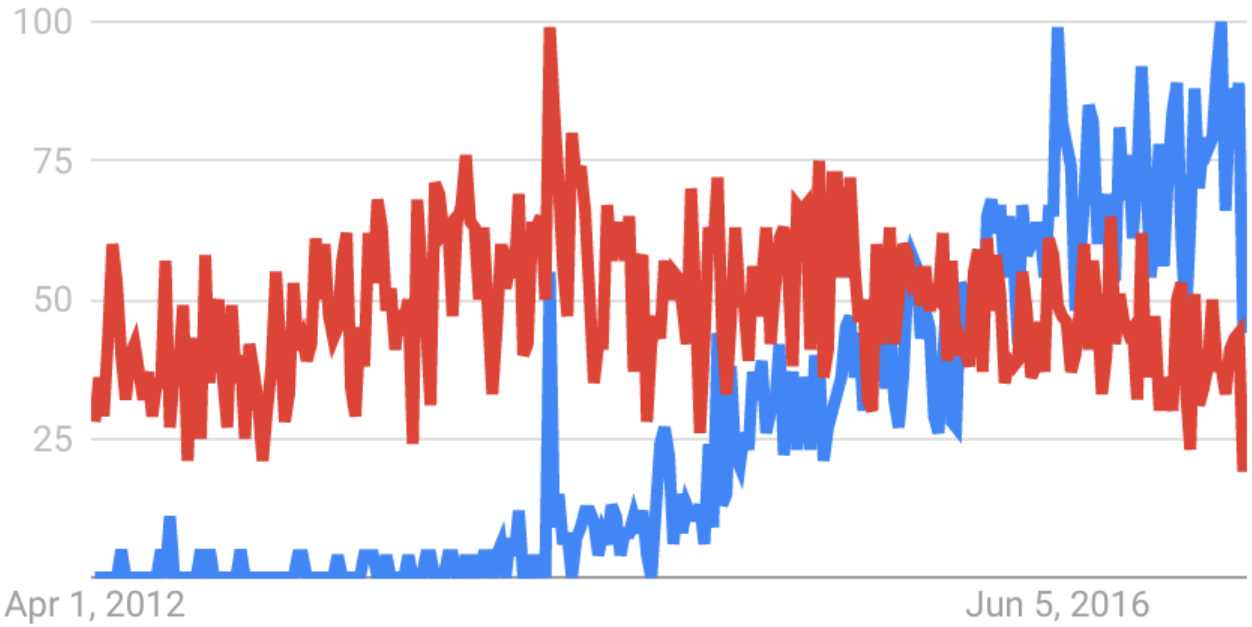
- Binary storage
- Nesting objects & arrays
- Indexing

HSTORE - 2003

- Perl-like hash storage
- No nesting
- Indexing

PROFESSIONAL Postgres

Google trends: jsonb vs hstore



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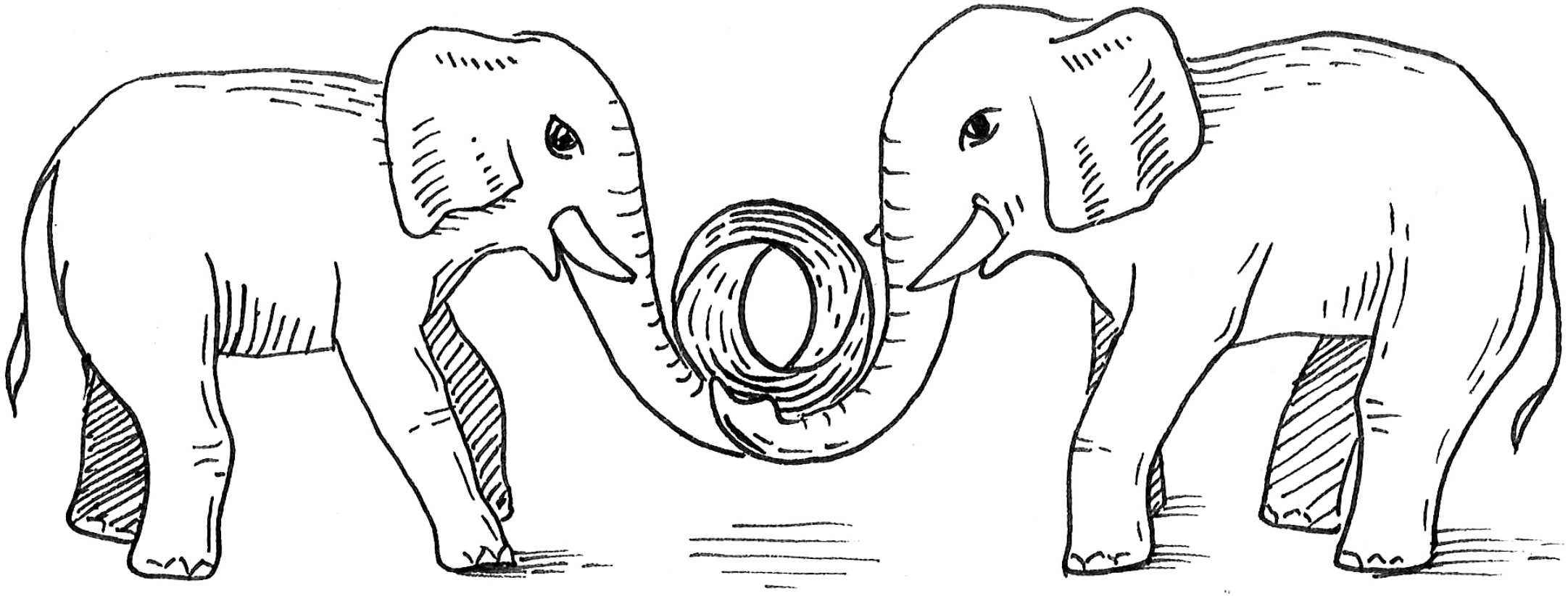
Two JSON data types !!!

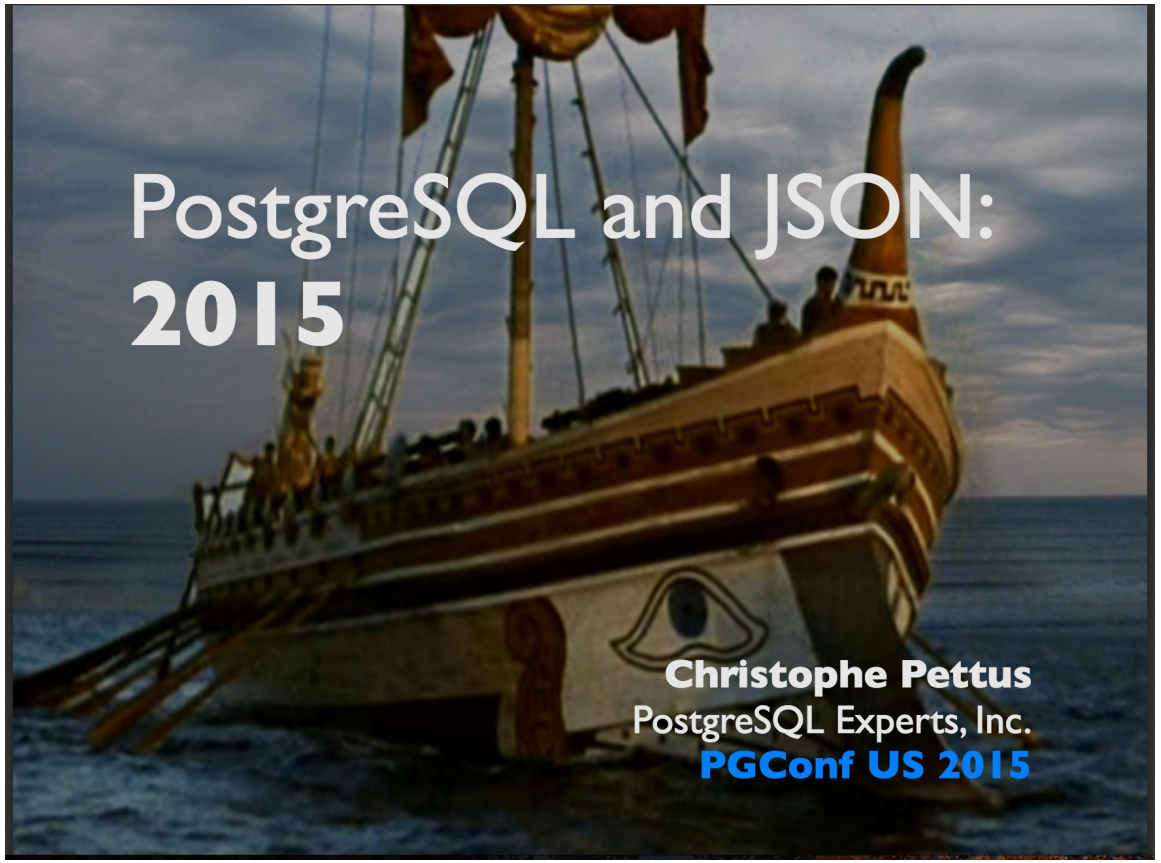


Jsonb vs Json

```
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)
```

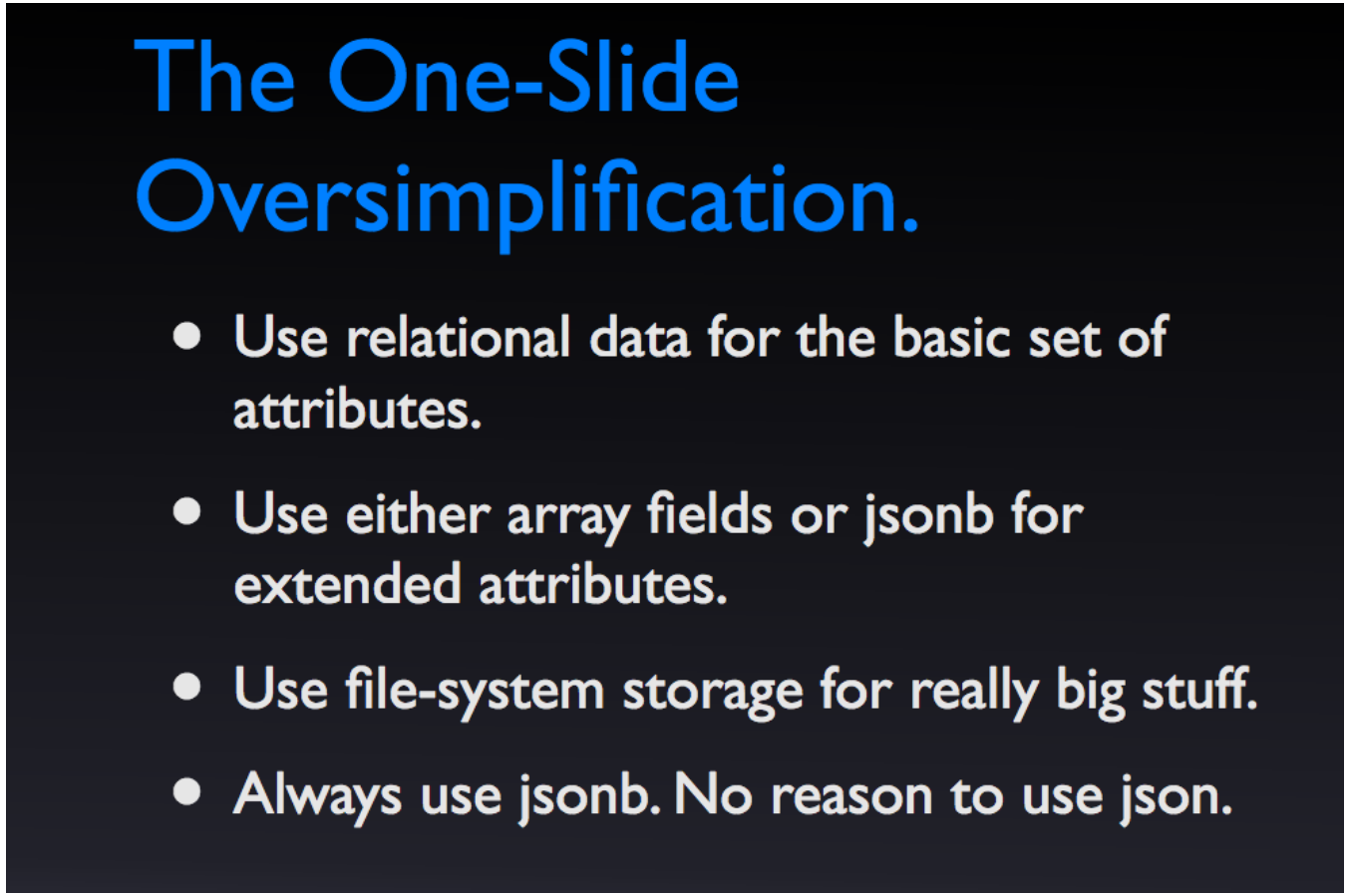
- json: textual storage «as is»
- jsonb: no whitespaces
- jsonb: no duplicate keys, last key win
- jsonb: keys are sorted by (length, key)
- jsonb has a binary storage: no need to parse, has index support

Very detailed talk about JSON[B]



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

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»

```
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;
```

- **Not easy !**

PROFESSIONAL Postgres

PGCon-2014, Ottawa

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) =
'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;
```

- **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);
```

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: JSON_VALUE

```
SELECT
x,
JSON_VALUE(
jsonb '{"a": 1, "b": 2}',
'$.* ? (@ > $x)' PASSING x AS x
RETURNING int
DEFAULT -1 ON EMPTY
DEFAULT -2 ON ERROR
) y
FROM
generate_series(0, 2) x;
 x | y
---+----
 0 | -2
 1 |  2
 2 | -1
(3 rows)
```

SQL/JSON examples: JSON_QUERY

```
SELECT
        JSON_QUERY(js FORMAT JSONB, '$'),
        JSON_QUERY(js FORMAT JSONB, '$' WITHOUT WRAPPER),
        JSON_QUERY(js FORMAT JSONB, '$' WITH CONDITIONAL WRAPPER),
        JSON_QUERY(js FORMAT JSONB, '$' WITH UNCONDITIONAL ARRAY WRAPPER),
        JSON_QUERY(js FORMAT JSONB, '$' WITH ARRAY WRAPPER)
FROM
        (VALUES
                ('null'),
                ('12.3'),
                ('true'),
                ('"aaa"'),
                ('[1, null, "2"]'),
                ('{"a": 1, "b": [2]}')
        ) foo(js);
```

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]')
);
```

SQL/JSON examples: JSON_TABLE

- Creates a relational view of JSON data.
- Think about UNNEST — creates a row for each object inside JSON array and represent JSON values from within that object as SQL columns values.
- Example: Delicious bookmark
- Convert JSON data (1369 MB) to their relational data

```
                Table "public.js"
 Column | Type  | Collation | Nullable | Default
--------+-------+-----------+----------+---------
 js     | jsonb |           |          |
```

Delicious bookmarks


```
{                                                                                +
    "id": "http://delicious.com/url/b5b3cbf9a9176fe43c27d7b4af94a422#mcasas1",   +
    "link": "http://www.theatermania.com/broadway/",                             +
    "tags": [                                                                    +
        {                                                                        +
            "term": "NYC",                                                       +
            "label": null,                                                       +
            "scheme": "http://delicious.com/mcasas1/"                            +
        }                                                                        +
    ],                                                                           +
    "links": [                                                                   +
        {                                                                        +
            "rel": "alternate",                                                  +
            "href": "http://www.theatermania.com/broadway/",                     +
            "type": "text/html"                                                  +
        }                                                                        +
    ],                                                                           +
    "title": "TheaterMania",                                                     +
    "author": "mcasas1",                                                         +
    "source": {                                                                  +
    },                                                                           +
    "updated": "Tue, 08 Sep 2009 23:28:55 +0000",                                +
    "comments": "http://delicious.com/url/b5b3cbf9a9176fe43c27d7b4af94a422",     +
    "guidislink": false,                                                         +
    "title_detail": {                                                            +
        "base": "http://feeds.delicious.com/v2/rss/recent?min=1&count=100",      +
        "type": "text/plain",                                                    +
        "value": "TheaterMania",                                                 +
        "language": null                                                         +
    },                                                                           +
    "wfw_commentrss": "http://feeds.delicious.com/v2/rss/url/b5b3cbf9a9176fe43c27d7b4af94a422"+
}
```


```
SELECT
    jt.*
FROM
    js,
    JSON_TABLE(
        js, '$' AS root
        COLUMNS (
            id text,
            link text,
            author text,
            title text,
            NESTED PATH '$.title_detail' AS title_detail COLUMNS (
                base text,
                title_type text PATH '$.type',
                value text,
                language text
            ),
            updated timestamptz PATH '$.updated.datetime("Dy, DD Mon YYYY H24:MI:SS TZHTZM")',
            comments text,
            wfw_commentrss text,
            guid_is_link boolean PATH '$.guidislink',
            NESTED PATH '$.tags[*]' AS tags COLUMNS (
                tag_term   text PATH '$.term',
                tag_scheme text PATH '$.scheme'
            ),
            NESTED PATH '$.links[*]' AS links COLUMNS (
                link_rel  text PATH '$.rel',
                link_href text PATH '$.href',
                link_type text PATH '$.type'
            )
        )
        PLAN (root INNER ((tags UNION links) CROSS title_detail))
    ) jt;
```

SQL/JSON examples: JSON_TABLE

- Example: Delicious bookmark
- Convert JSON data (1369 MB) to their relational data (2615 MB)

```
                        Table "public.js_rel"
     Column     |            Type             | Collation | Nullable | Default
----------------+-----------------------------+-----------+----------+---------
 id             | text                        |           |          |
 link           | text                        |           |          |
 author         | text                        |           |          |
 title          | text                        |           |          |
 base           | text                        |           |          |
 title_type     | text                        |           |          |
 value          | text                        |           |          |
 language       | text                        |           |          |
 updated        | timestamp with time zone    |           |          |
 comments       | text                        |           |          |
 wfw_commentrss | text                        |           |          |
 guid_is_link   | boolean                     |           |          |
 tag_term       | text                        |           |          |
 tag_scheme     | text                        |           |          |
 link_rel       | text                        |           |          |
 link_href      | text                        |           |          |
 link_type      | text                        |           |          |
```

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) =
  '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;
```

- 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
- More examples (thousands !)

  https://github.com/postgrespro/sqljson/blob/sqljson/src/test/regress/sql/sql_json.sql
- BNF is available
  https://github.com/elliotchance/sqltest/blob/master/standards/2016/bnf.txt#L370
- We need your feedback, bug reports and suggestions
- Help us writing documentation !

JSON Roadmap

- Push SQL/JSON to Postgres 11 (Postgres Pro 10)
- Dictionary compression to Postgres 11 (Postgres Pro 10)

PROFESSIONAL Postgres

JSONB COMPRESSION

Transparent compression of jsonb

+ access to the child elements without full decompression

jsonb compression: motivation

- Long object keys repeated in each document waste a lot of space
- Fixed-size object/array entries overhead is significant for short fields:
  - 4 bytes per array element
  - 8 bytes per object field
- Numbers stored as postgres numerics which have a quite long representation for the short integers:
  - 1-4-digit integers – 8 bytes
  - 5-8-digit integers – 12 bytes

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_attributes

jsonb compression: jsonbc

- **jsonbc** is a compression method for jsonb type using dictionary compression for object keys and more compact variable-length encoding.

- All key dictionaries for all jsonbc compressed columns are stored in the single catalog relation pg_jsonbc_dict:

```
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

json compression: jsonbc dictionaries

Examples:

```
-- automatical test_js_jsonbc_dict_seq creation for generating key IDs
CREATE TABLE test (js jsonb COMPRESSED jsonbc);

-- manual dictionary sequence creation
CREATE SEQUENCE test2_dict_seq;
CREATE TABLE test2 (js jsonb COMPRESSED jsonbc WITH (dict_id 'test2_dict_seq'));

-- enum type as a manually updatable dictionary
CREATE TYPE test3_dict_enum AS ENUM ('key1', 'key2', 'key3');
CREATE TABLE test3 (js jsonb COMPRESSED jsonbc WITH (dict_enum 'test3_dict_enum'));

-- manually updating enum dictionary (before key4 insertion into table)
ALTER TYPE test3_dict_enum ADD VALUE 'key4';
```

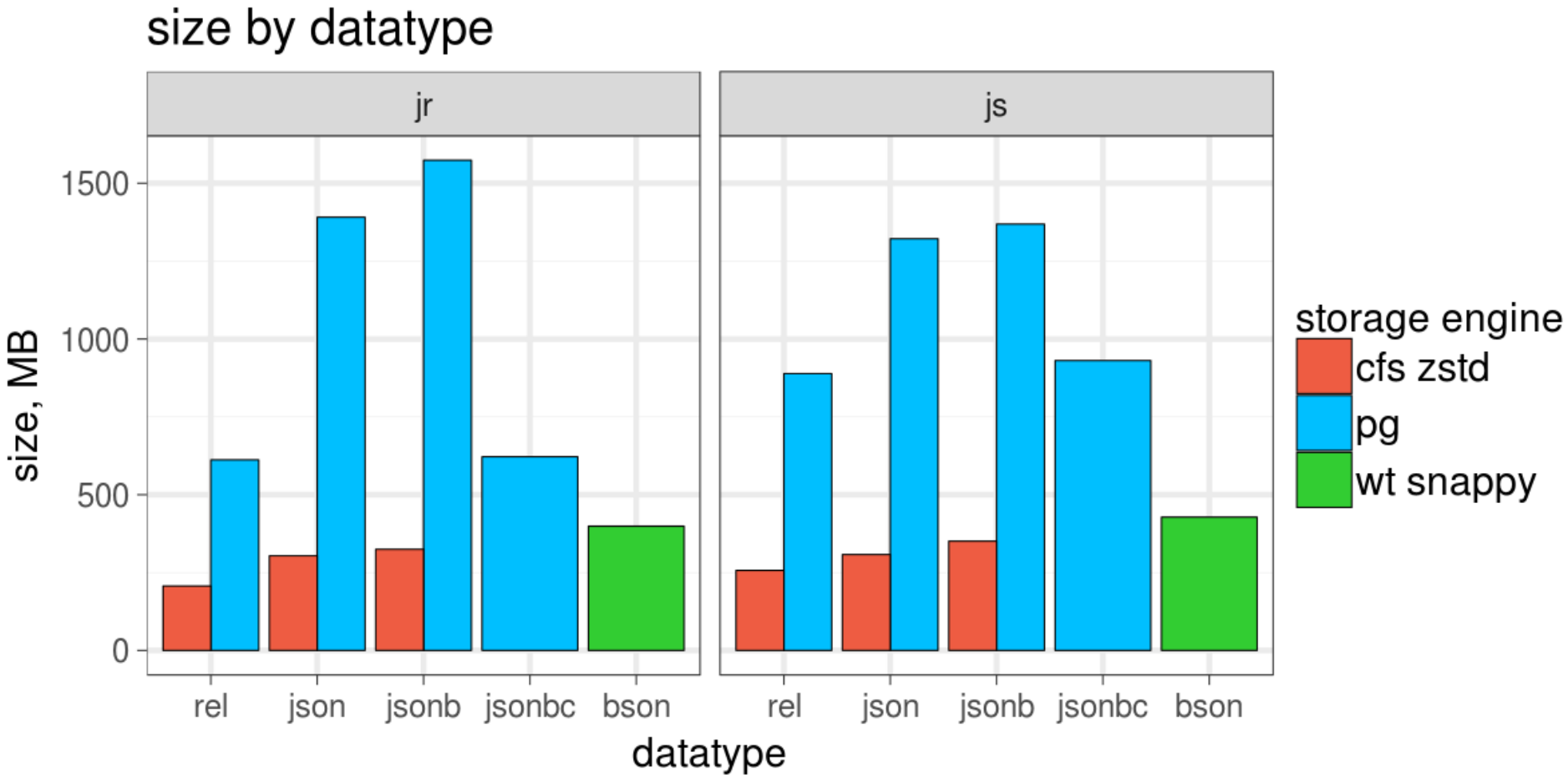
jsonb compression: results

Two datasets:

- js – Delicious bookmarks, 1.2 mln rows
  - Mostly string values
  - Relatively short keys
  - 2 arrays (tags and links) of 3-field objects
- jr – Citus Data dataset: customer reviews data from Amazon, 3mln
  - 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.

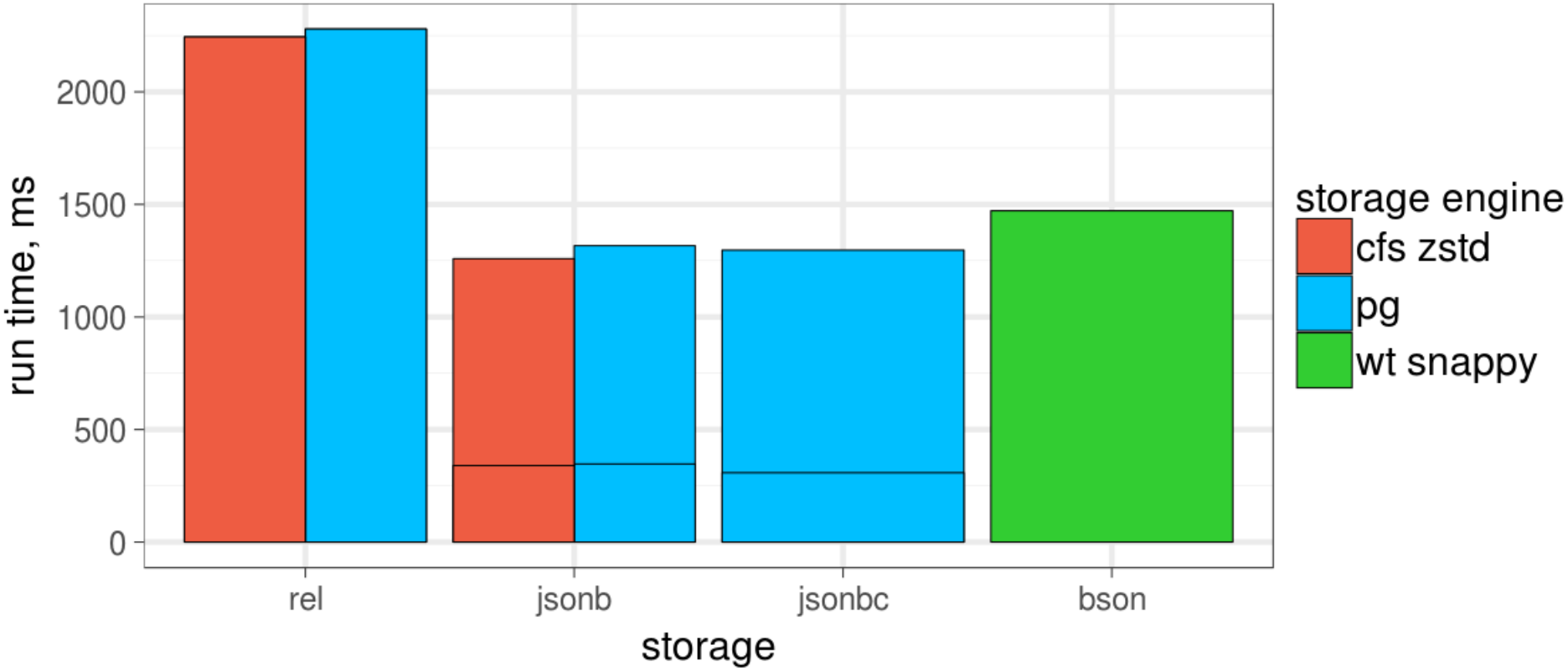
jsonb compression: table size



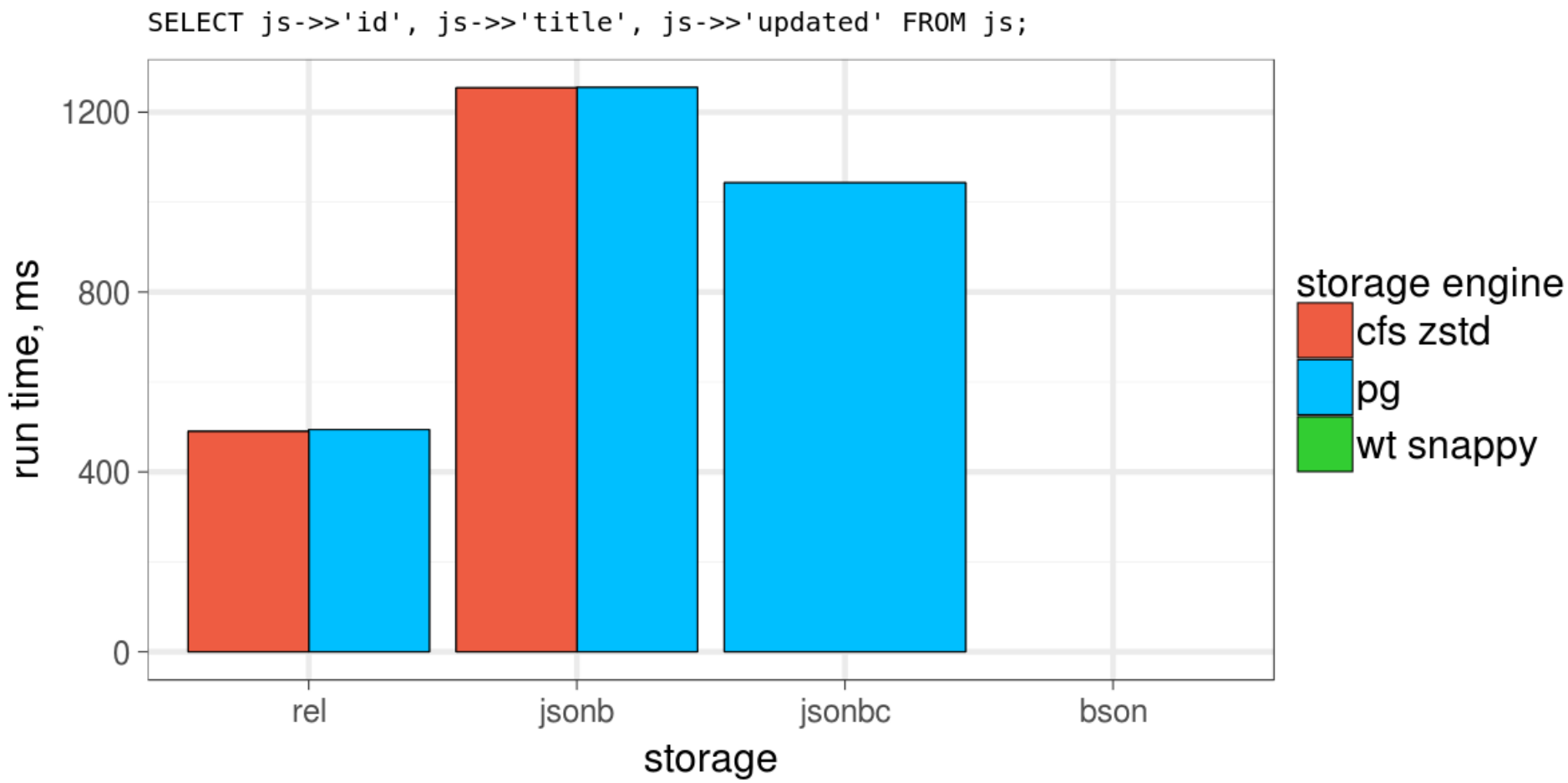
jsonb compression: performance

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

db.js.find({ tags: { $elemMatch: { term: "NYC"} } }).count()
```



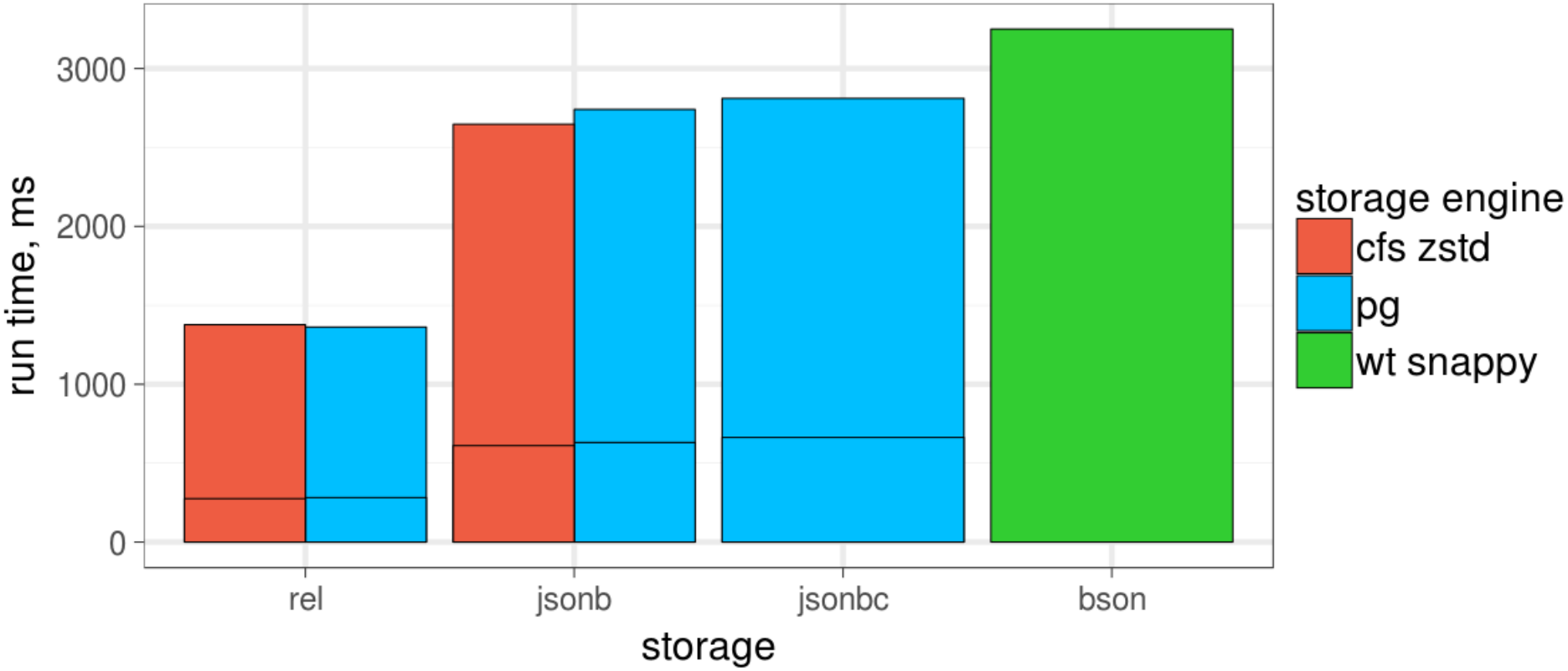
jsonb compression: performance



jsonb compression: 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: jsonbc problems

- Transactional dictionary updates

  Currently, automatic dictionary updates uses background workers, but autonomous transactions would be better
- Cascading deletion of dictionaries not yet implementing. Need to track dependency between columns and dictionaries
- User compression methods for jsonb are not fully supported (should we ?)

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 even can be faster than jsonb
- jsonbc compression ratio is significally lower than in page level compression methods
- jsonbc still needs some work
- Availability:

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

PROFESSIONAL Postgres

BENCHMARKS:
How NoSQL Postgres is fast

First (non-scientific) benchmark !

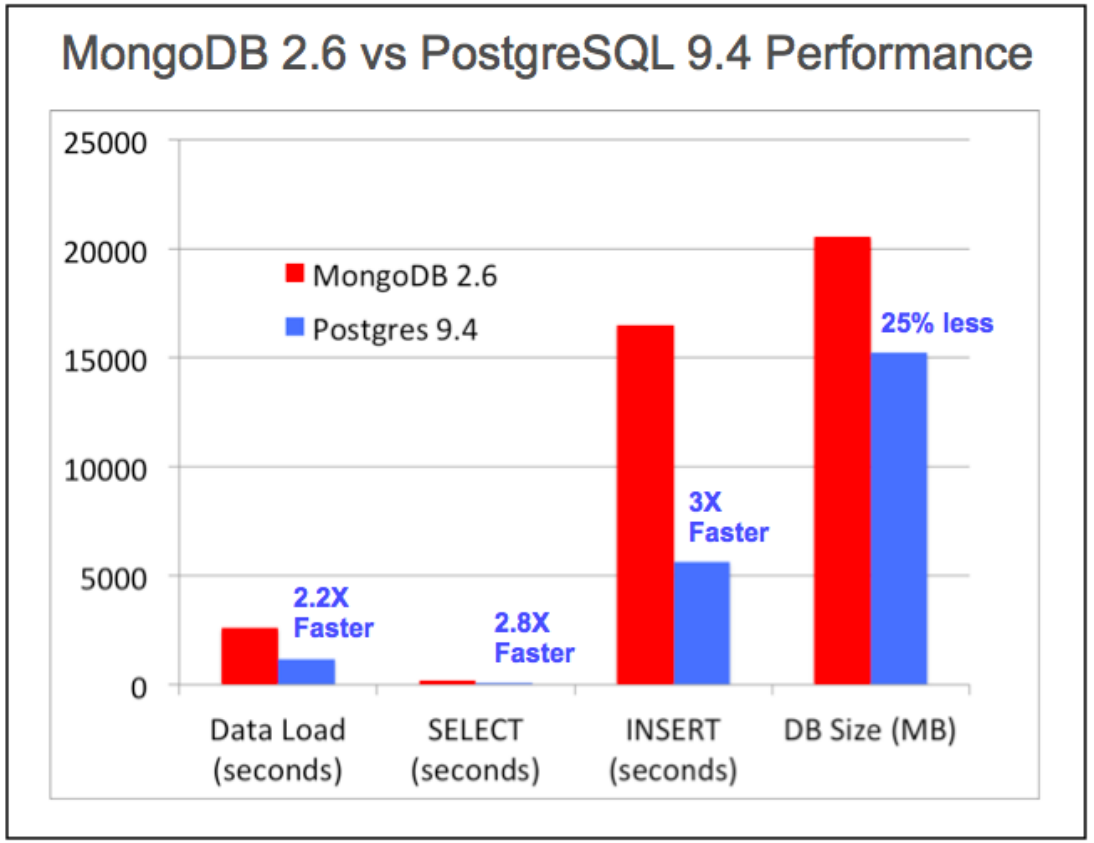
Summary: PostgreSQL 9.4 vs Mongo 2.6.0

- 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 are 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 and MongoDB 3.4.2
  - 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

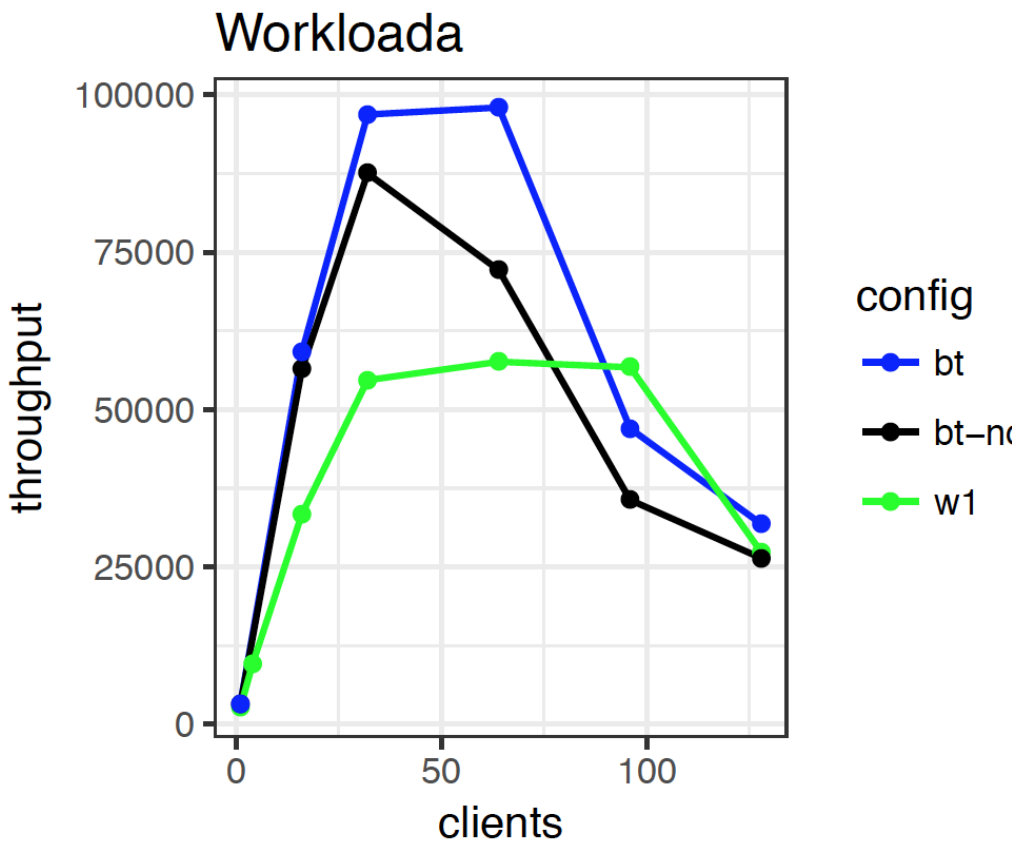
- Workload A: Update heavy - a mix of 50/50 reads and writes
- Workload B: Read mostly - a 95/5 reads/write mix
- Workload C: Read only — 100% read
- Workload D: Read latest - new records are inserted, and the most recently inserted records are the most popular
- Workload E: Short ranges - short ranges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

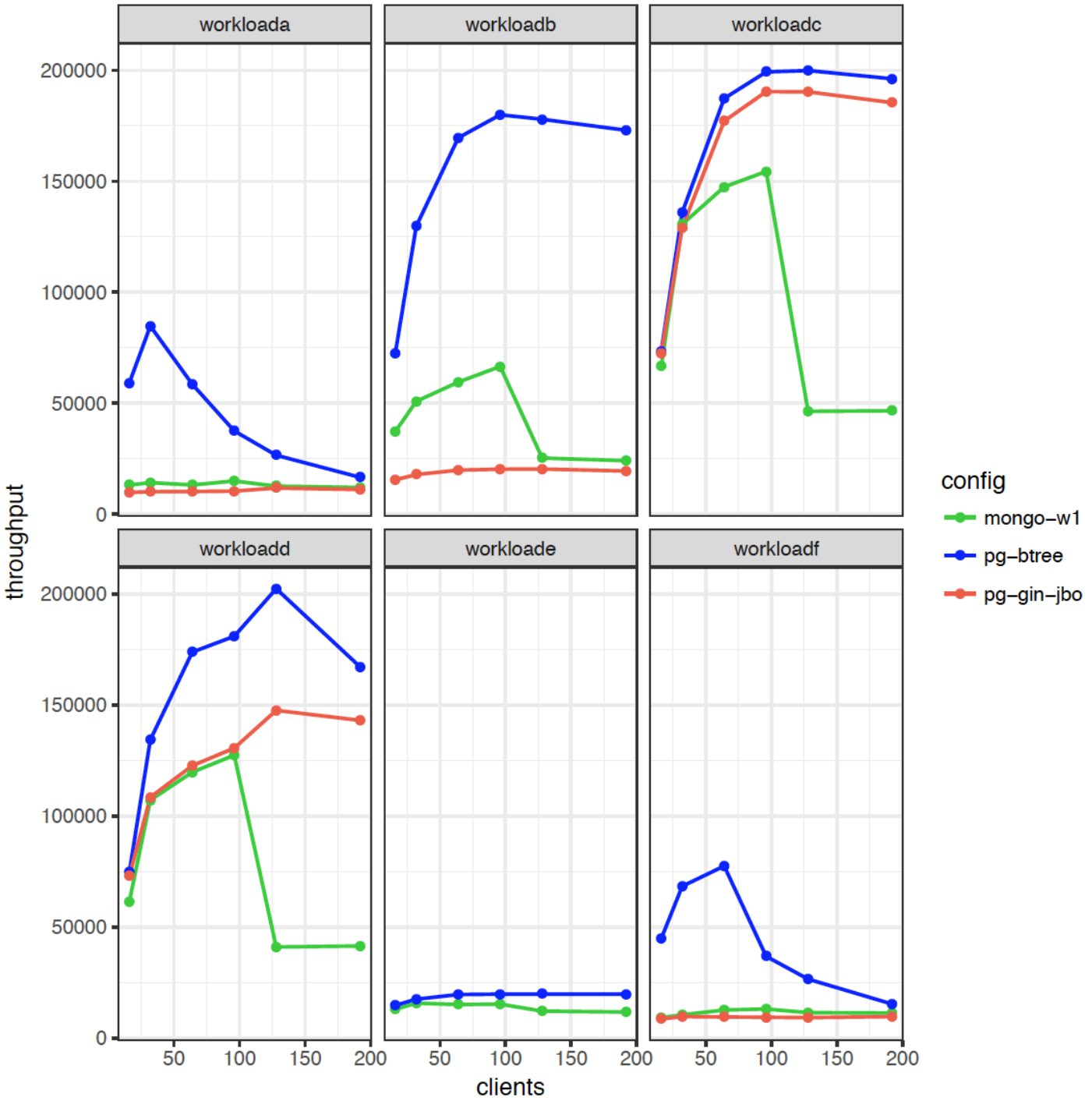
YCSB Benchmark: details

- 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 (Mongo is too slow !)
- fastupdate=off for GIN index
- We tested:
  - functional btree index for jsonb, jsonbc, sqljson
  - Functional btree index for jsonb on cfs (compressed)
  - Gin index for jsonb, jsonb_build_object
  - Mongodb (wiredtiger with snappy compression)
  - Return a whole json, just one field
  - 10 fields, 200 fields (TOASTed)

PROFESSIONAL Postgres

HOT upda

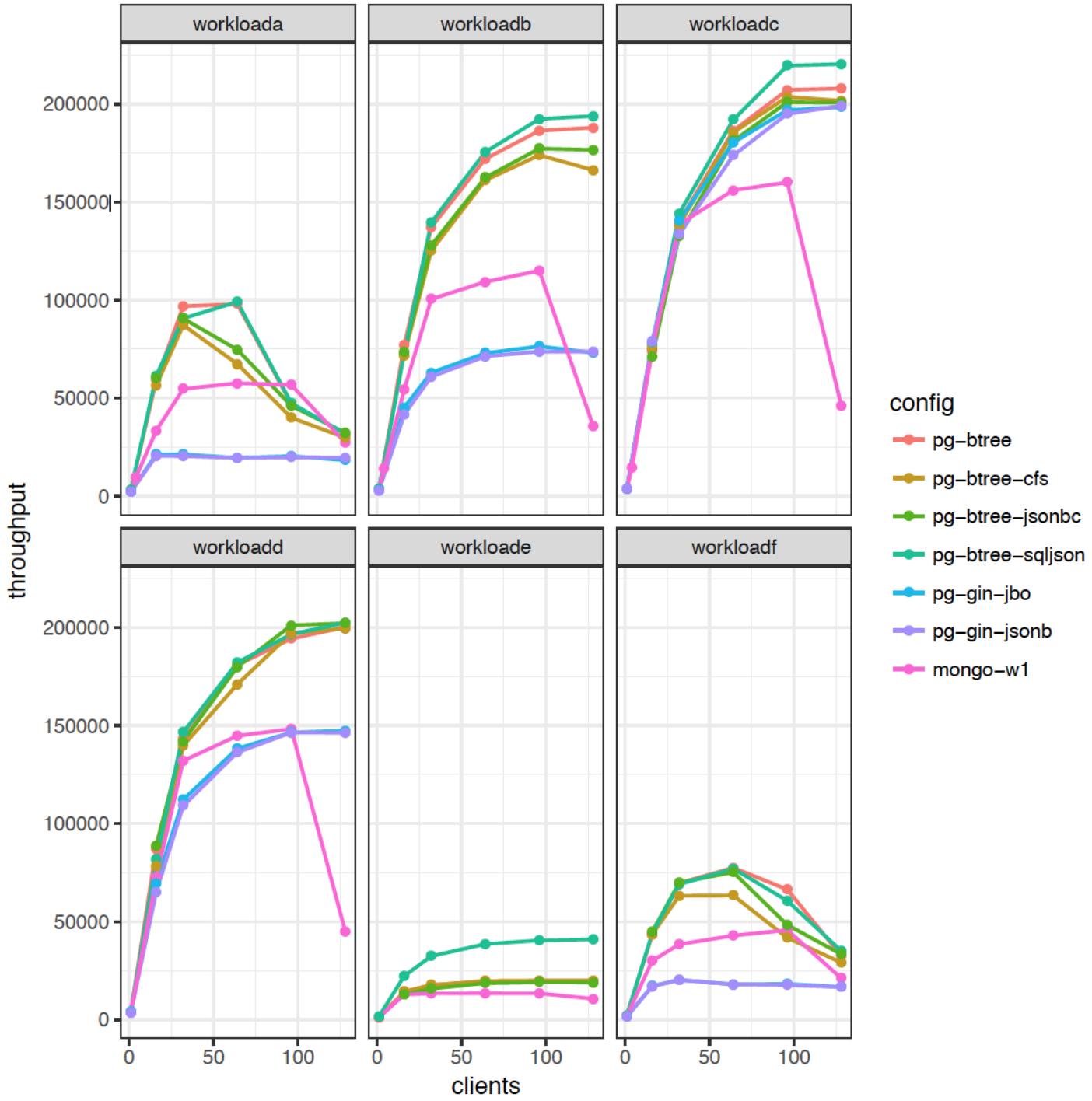




PROFESSIONAL Postgres

1 mln rows, 10 fields

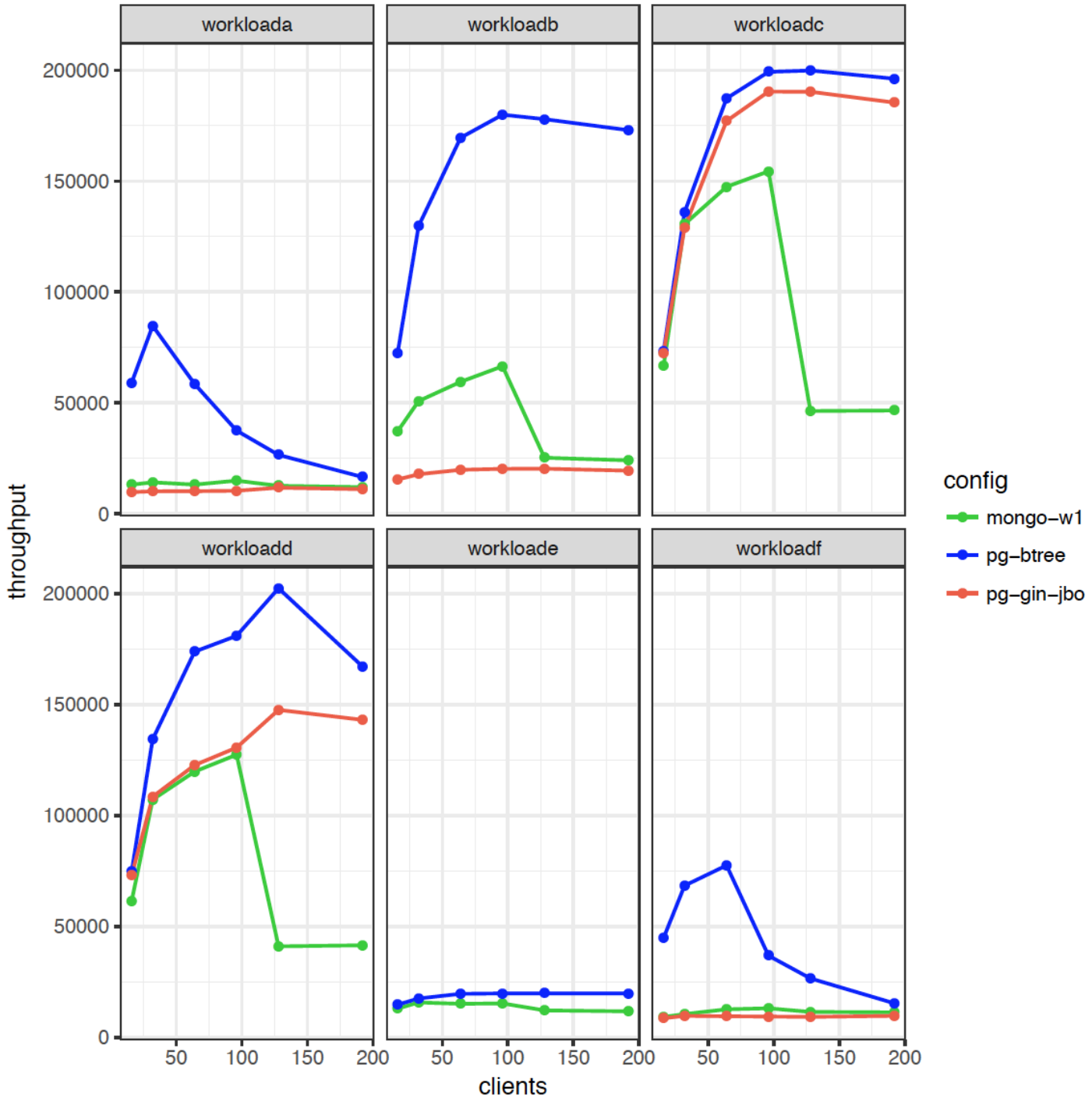
- Postgres is better in all workloads !
- Jsonb ~ jsonb(cfs) ~ Jsonbc ~ sqljson
- Gin is not good for updates



PROFESSIONAL Postgres

5 mln rows, 10 fields

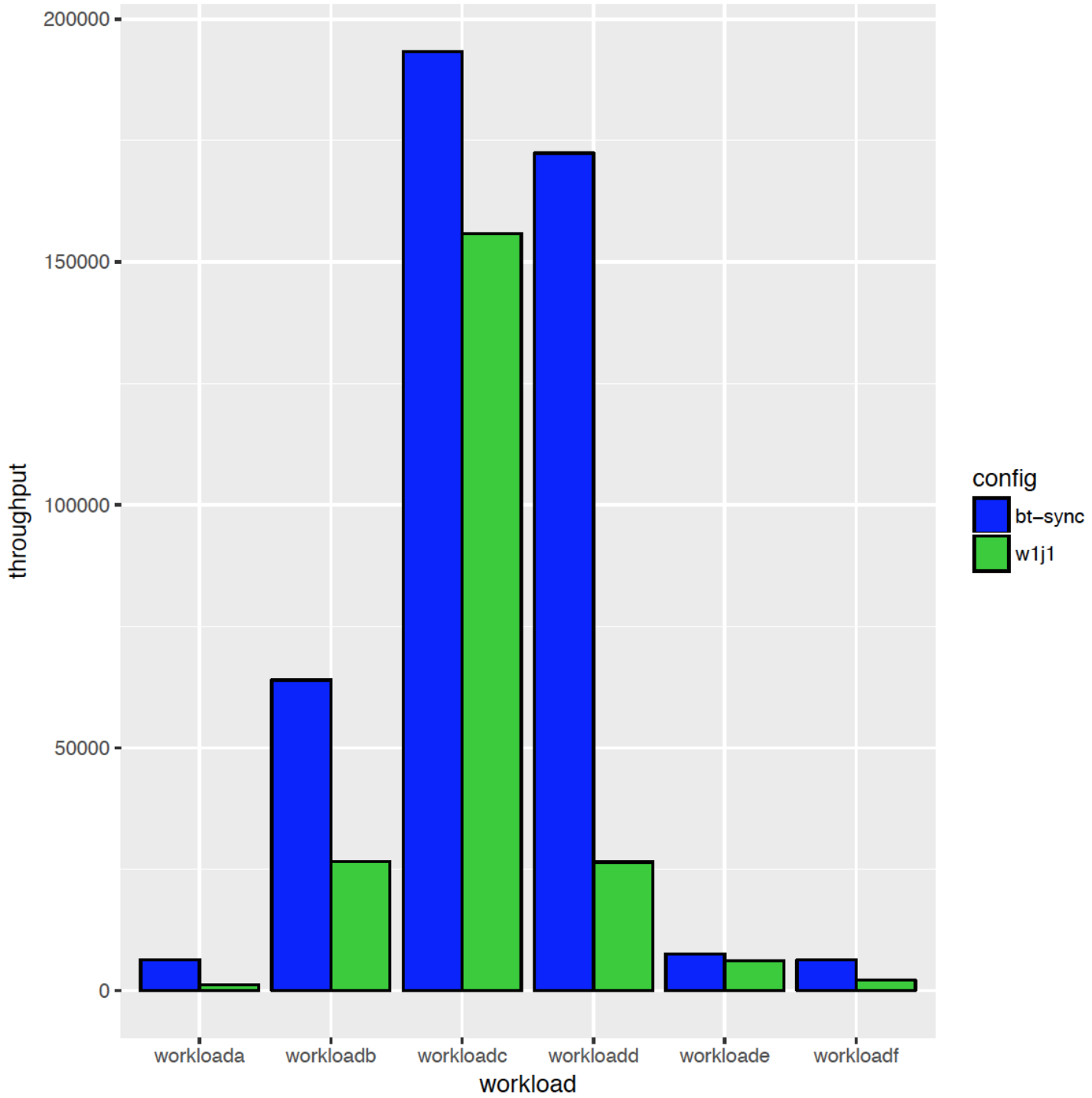
- Postgres is better in all workloads !
- Gin is not good for updates



PROFESSIONAL Postgres

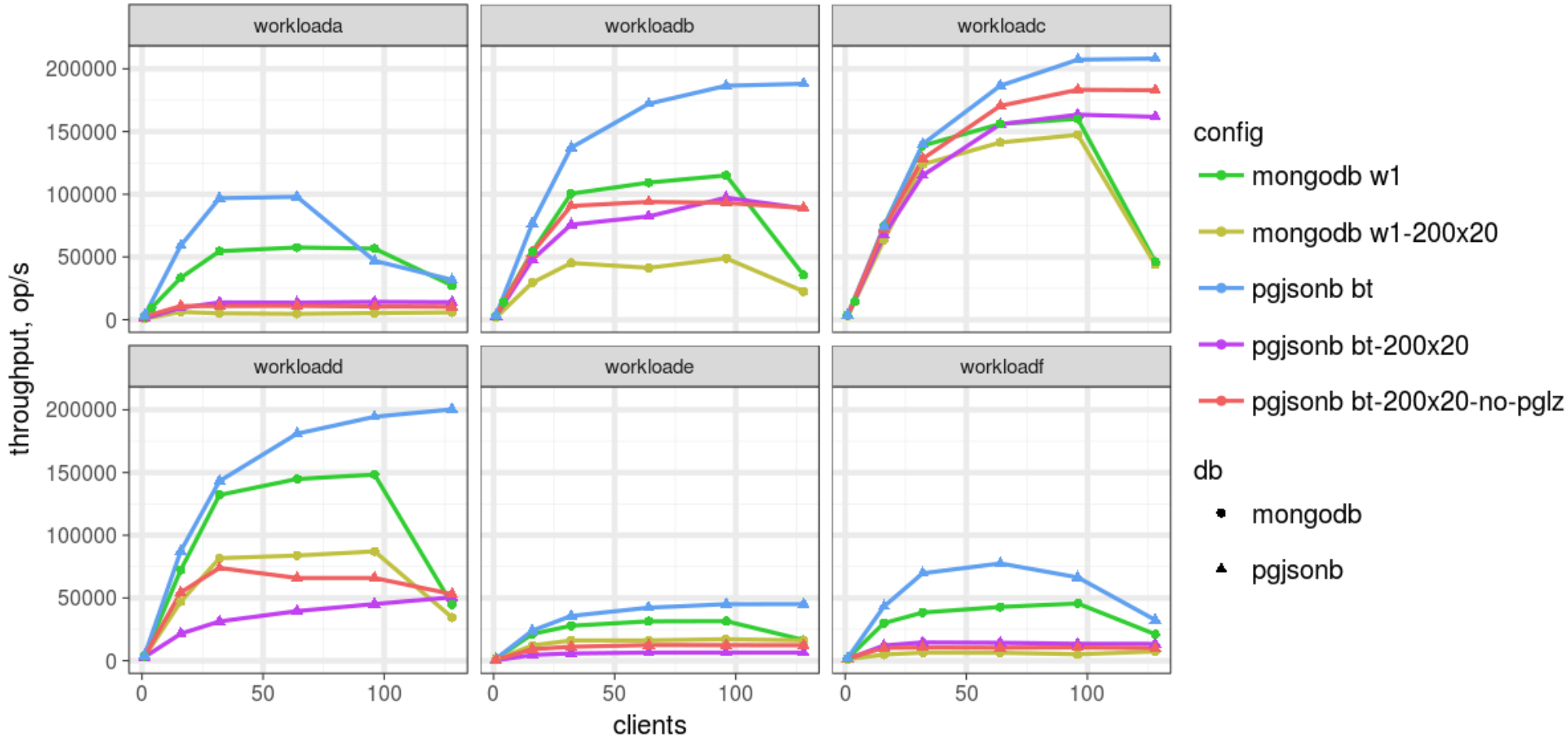
1 mln rows, 10 fields, (journaled to disk, asynchronous_commit off)

- Postgres is better in all workloads !



1mln rows, 200 fields (TOASTed)

MONGODB is better on some workloads.



PROFESSIONAL Postgres

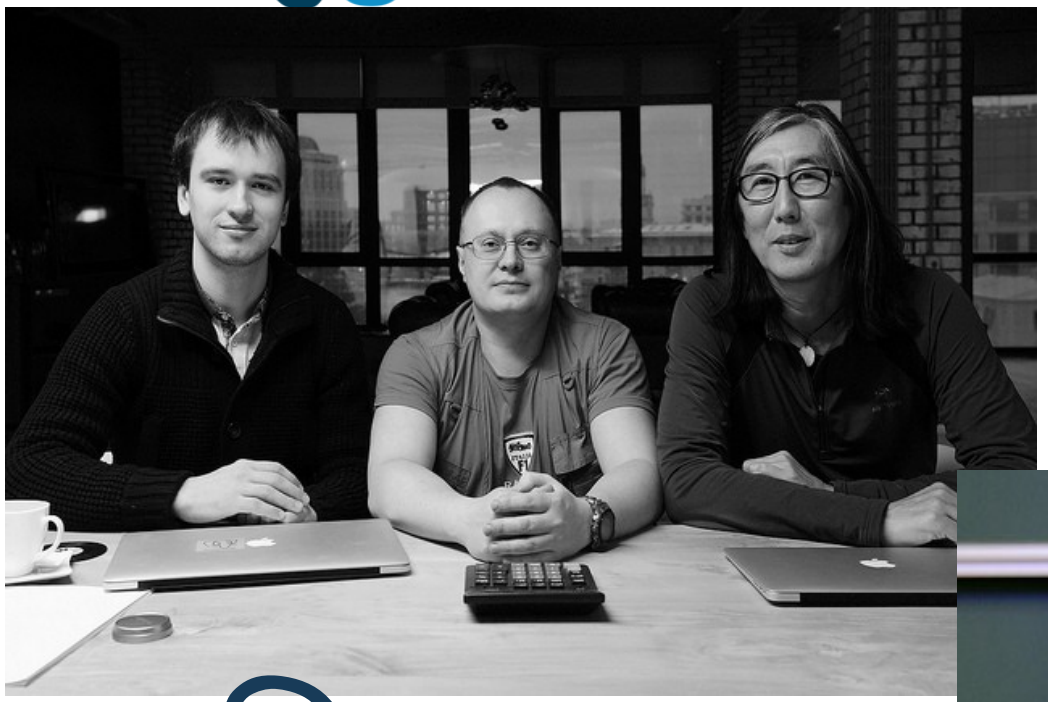
PostgreSQL still beats Mongodb !

on one server

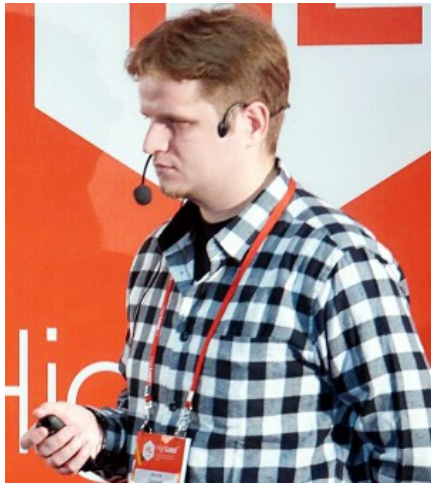
Summary

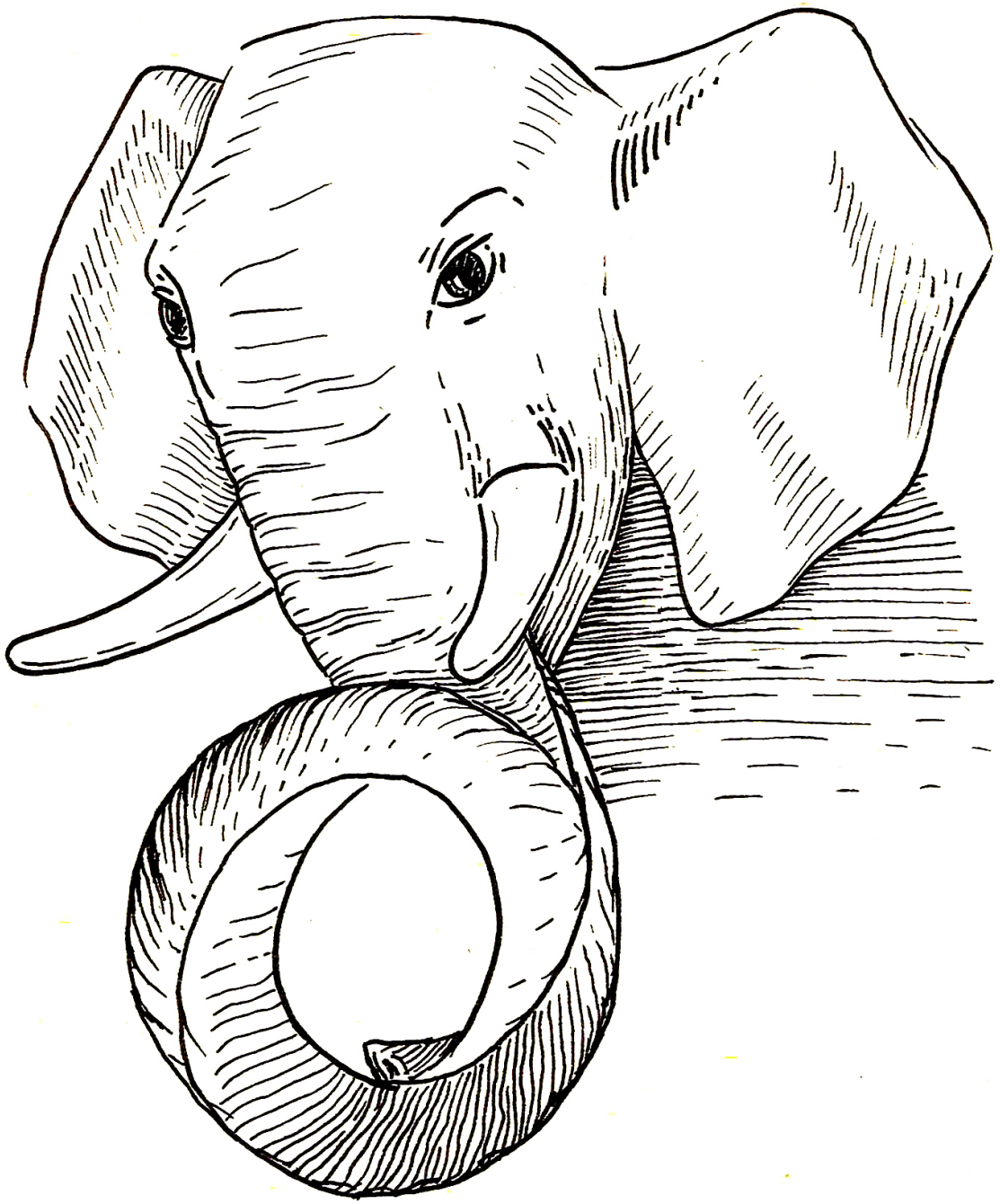
- Postgres is already a good NoSQL database
- SQL/JSON will provide better flexibility and interoperability
  - Expect it in Postgres 11 (Postgres Pro 10)
  - Need community help (testing, documentation)
  - What“s about index support ?
- JSONB dictionary compression (jsonbc) is really useful
  - Expect it in Postgres 11 (Postgres Pro 10)
- Postgres beats Mongodb in one node configuration
  - HOT for JSONB, type specific compression
  - YCSB benchmarks in distributed mode (Citus ?)
- Postgres will help NoSQL users to avoid nightmare
  - Need sharding, community is working on it. Expect in 2-3 years !

PEOPLE BEHIND JSON[B]



Nikita Glukhov





Thanks !