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Rewrite Your Complex MySQL Queries for Better Performance

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Introduction to Subqueries

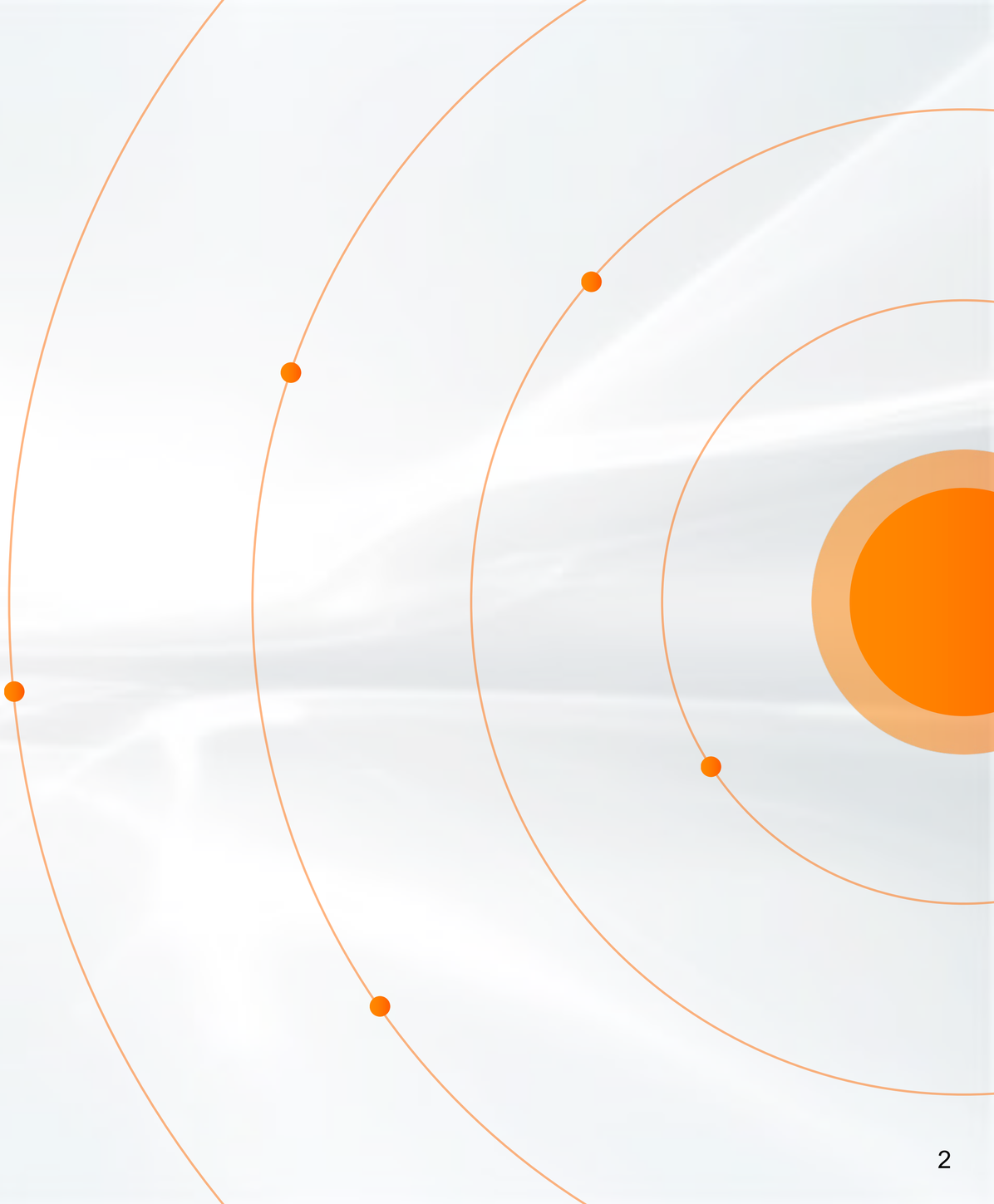
Derived Tables

Scalar Subqueries

IN/EXISTS subqueries

Use Window Functions

Optimizer Hints



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Types of Subqueries

- Scalar subqueries
  - Returns maximum one row
  - May be used most places where a value can be used
  - Examples:

```
SELECT a1, (SELECT AVG(b2) FROM t2) FROM t1;

SELECT a1 FROM t1 WHERE a1 < (SELECT AVG(b2) FROM t2);
```

- Non-scalar subqueries
  - May return multiple rows
  - Examples:

Derived Table

```
SELECT b1, avg_b2 FROM (SELECT b1, AVG(b2) avg_b2 FROM t2 GROUP BY b1) dt;

SELECT a1 FROM t1 WHERE a1 IN (SELECT b2 FROM t2);
```

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Correlated Subqueries

- Subquery refers columns of outer query
- Examples

```
SELECT a1, (SELECT b2 FROM t2 WHERE b1 = t1.a1) FROM t1;

SELECT a1 FROM t1 WHERE a1 < (SELECT AVG(b2) FROM t2 WHERE b1 = t1.a1);

SELECT a1 FROM t1 WHERE NOT EXISTS (SELECT 1 FROM t2 WHERE b1 = t1.a1);

SELECT t1.a1, dt.b2 FROM t1, LATERAL (SELECT b2 FROM t2 WHERE b2 = t1.a1) dt;
```

New in MySQL 8.0.14

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Nested Subqueries

TPC-H Query 20: Potential Part Promotion Query

```
SELECT s_name, s_address
FROM supplier, nation
WHERE s_suppkey IN (
        SELECT ps_suppkey
        FROM partsupp
        WHERE ps_partkey IN (
                SELECT p_partkey FROM part WHERE p_name LIKE 'dodger%' )
          AND ps_availqty > (
                SELECT 0.5 * SUM(l_quantity)
                FROM lineitem
                WHERE l_partkey = ps_partkey AND l_suppkey = ps_suppkey
                  AND l_shipdate >= '1994-01-01'
                  AND l_shipdate < DATE_ADD('1994-01-01', INTERVAL '1' YEAR))
      )
  AND n_name = 'INDIA'
ORDER BY s_name;
```

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Execution of Subqueries

- Naïve approach
  - Execute subquery for each row of the outer query
  - May use indexes to speed up correlated queries
  - Example: `SELECT a1 FROM t1 WHERE a1 < (SELECT AVG(b2) FROM t2 WHERE t2.b1 = t1.a1);`
- Optimizations / Query transformations
  - Merge subquery into outer query
  - Materialization of non-correlated subqueries
  - Semi-join/Anti-join for (NOT) IN/EXISTS
  - Rewrite to MIN/MAX for queries like *<CompOp> ALL/ANY (SELECT …)*

    ```
    SELECT a1 FROM t1 WHERE a1 > ALL (SELECT b2 FROM t2);
    ```
  - New query transformations in 8.0

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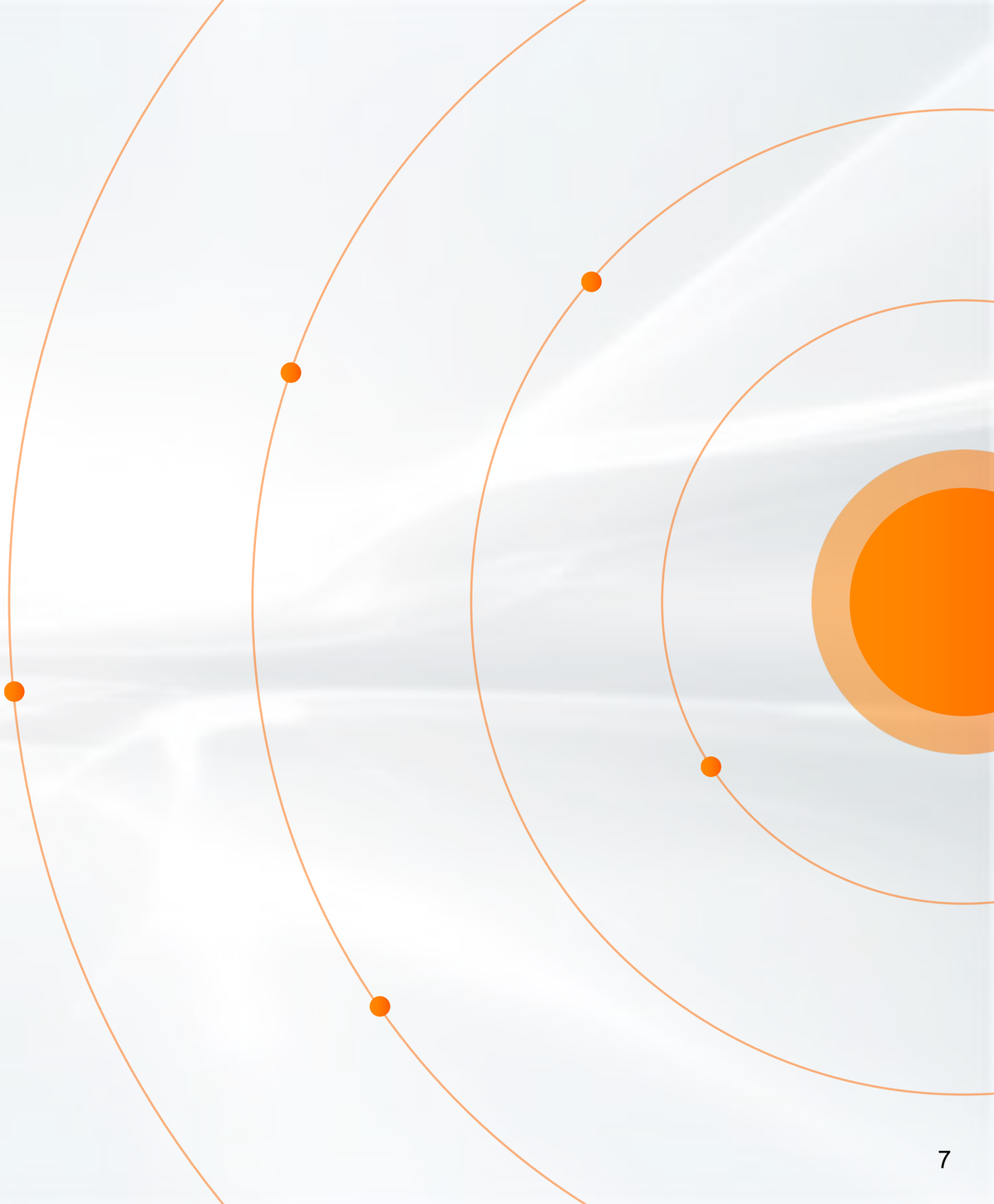

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Execution of Derived Tables

- Materialization

```
SELECT b1, avg_b2 FROM (SELECT b1, AVG(b2) avg_b2 FROM t2 GROUP BY b1) dt;
```

1. Store the result of the subquery in a temporary table (may create indexes on temporary table if useful)

```
CREATE TEMPORARY TABLE dt AS (SELECT b1, AVG(b2) avg_b2 FROM t2 GROUP BY b1);
```

2. Execute the main query using the temporary table

```
SELECT b1, avg_b2 FROM AS dt;
DROP TEMPORARY TABLE dt;
```

- Merge into outer query (MySQL 5.7)
  - Handle derived tables the same way as views
  - Not supported for queries that contain aggregation functions, GROUP BY, LIMIT, UNION, DISTINCT, …

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Materialized Derived Tables

Do not SELECT more data that needed by outer query

```
mysql> SELECT AVG(o_totalprice) FROM
            (SELECT * FROM orders ORDER BY o_totalprice DESC LIMIT 100000) dt;

+--------------------+
| AVG(o_totalprice) |
+--------------------+
| 398185.986158      |
+--------------------+
1 row in set (24.65 sec)

mysql> SELECT AVG(o_totalprice) FROM
            (SELECT o_totalprice FROM orders ORDER BY o_totalprice DESC LIMIT 100000) dt;

+--------------------+
| AVG(o_totalprice) |
+--------------------+
| 398185.986158      |
+--------------------+
1 row in set (8.18 sec)
```

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Materialized Derived Tables

Move conditions into derived table

```
SELECT b1, avg_b2
FROM (SELECT b1, AVG(b2) avg_b2 FROM t2 GROUP BY b1) dt
WHERE b1 < 10;

SELECT b1, avg_b2
FROM (SELECT b1, AVG(b2) avg_b2 FROM t2 WHERE b1 < 10 GROUP BY b1) dt;


SELECT b1, avg_b2
FROM (SELECT b1, AVG(b2) avg_b2 FROM t2 GROUP BY b1) dt
WHERE avg_b2 > 90;

SELECT b1, avg_b2
FROM (SELECT b1, AVG(b2) avg_b2 FROM t2 GROUP BY b1 HAVING avg_b2 > 90) dt;
```

WL#8084: Condition pushdown for materialized derived tables (MySQL 8.0.22)

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Materialized Derived Tables

MySQL 8.0.22: Condition pushdown for materialized derived tables (and views)

```
EXPLAIN FORMAT=TREE SELECT b1, avg_b2
FROM (SELECT b1, AVG(b2) avg_b2 FROM t2 GROUP BY b1) dt
WHERE b1 < 10;
```

8.0.21 (1.22 ms):

```
-> Filter: (dt.b1 < 10)
    -> Table scan on dt
        -> Materialize
            -> Table scan on <temporary>
                -> Aggregate using temporary table
                    -> Table scan on t2  (cost=103.65 rows=1024)
```

8.0.22 (0.85 ms):

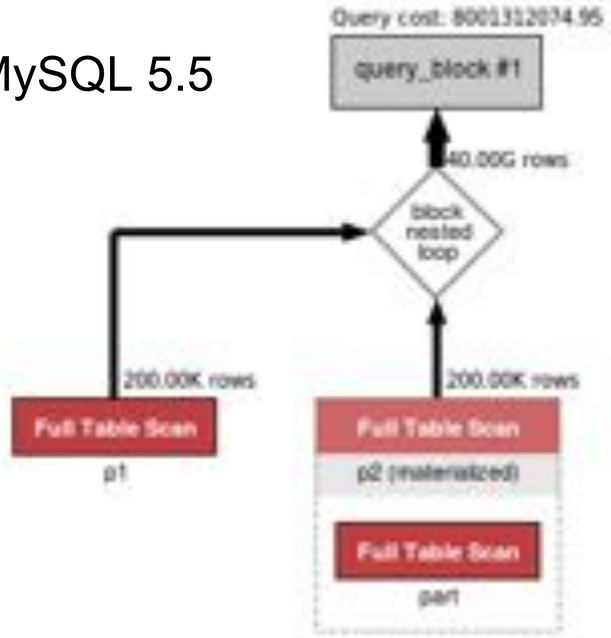
```
-> Table scan on dt  (cost=40.86 rows=341)
    -> Materialize
        -> Table scan on <temporary>
            -> Aggregate using temporary table
                -> Filter: (t2.b1 < 10)  (cost=103.65 rows=341)
                    -> Table scan on t2  (cost=103.65 rows=1024)
```

Merged Derived Tables

Not always optimal

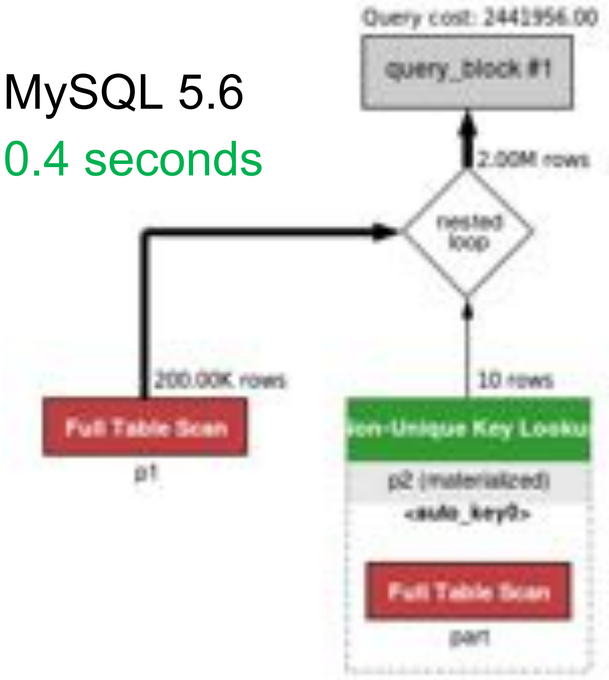
```
SELECT *
FROM part p1
JOIN (SELECT * FROM part WHERE p_type LIKE '%STEEL%') p2 ON p1.p_name = p2.p_name
WHERE p1.p_type LIKE '%COPPER%';
```

MySQL 5.5



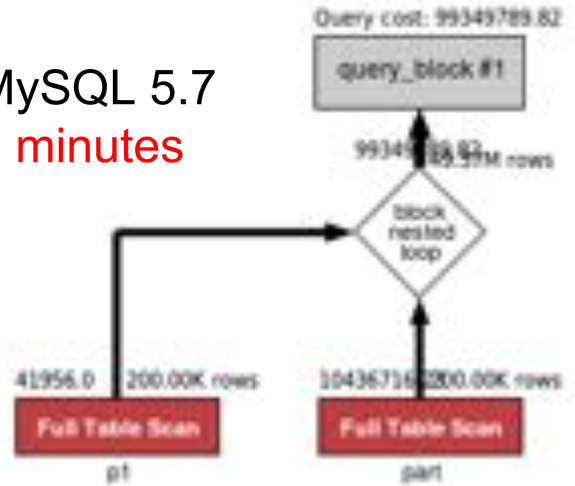
MySQL 5.6

0.4 seconds



MySQL 5.7

6 minutes



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How to Prevent Merging of Derived Tables

- MySQL 5.7
  - Rewrite derived table so it can not be merged

```
SELECT *
FROM part p1
JOIN (SELECT * FROM part WHERE p_type LIKE '%STEEL%' LIMIT 1000000) p2 ON p1.p_name=p2.p_name
WHERE p1.p_type LIKE '%COPPER%';
```

- MySQL 8.0
  - Use NO_MERGE hint

```
SELECT /*+ NO_MERGE(p2) */ *
FROM part p1
JOIN (SELECT * FROM part WHERE p_type LIKE '%STEEL%') p2 ON p1.p_name = p2.p_name
WHERE p1.p_type LIKE '%COPPER%';
```

  - MySQL 8.0.18: Not necessary since using hash join is 35% faster.

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Use Common Table Expressions

MySQL 8.0

- Derived tables:

```
SELECT *
FROM (SELECT a, b, SUM(c) s FROM t1 GROUP BY a, b) AS d1
JOIN (SELECT a, b, SUM(c) s FROM t1 GROUP BY a, b) AS d2 ON d1.b = d2.a;
```

- Common Table Expressions (CTE):

```
WITH d AS (SELECT a, b, SUM(c) s FROM t1 GROUP BY a, b)
SELECT * FROM d AS d1 JOIN d AS d2 ON d1.b = d2.a
```

- Improved Readability
- CTE is only materialized once

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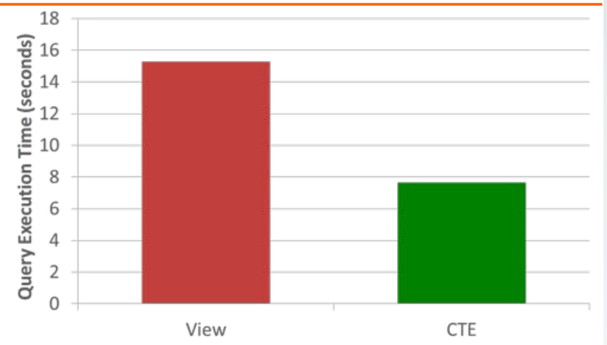
Better Performance with CTEs

TPC-H Query 15: Top Supplier Query

```
CREATE VIEW revenue0(supplier_no , total_revenue) AS
    SELECT l_suppkey, SUM(l_extendedprice * (1 - l_discount))
    FROM lineitem
    WHERE l_shipdate >= '1996-07-01'
      AND l_shipdate < DATE_ADD('1996-07-01', INTERVAL '90' DAY)
    GROUP BY l_suppkey;

SELECT s_suppkey, s_name, s_address, s_phone, total_revenue
FROM supplier, revenue0
WHERE s_suppkey = supplier_no
  AND total_revenue = (SELECT MAX(total_revenue) FROM revenue0)
ORDER BY s_suppkey;
```

```
WITH revenue0 AS (…)
SELECT s_suppkey, s_name, s_address, s_phone, total_revenue
FROM supplier, revenue0
WHERE s_suppkey = supplier_no
  AND total_revenue = (SELECT MAX(total_revenue) FROM revenue0)
ORDER BY s_suppkey;
```



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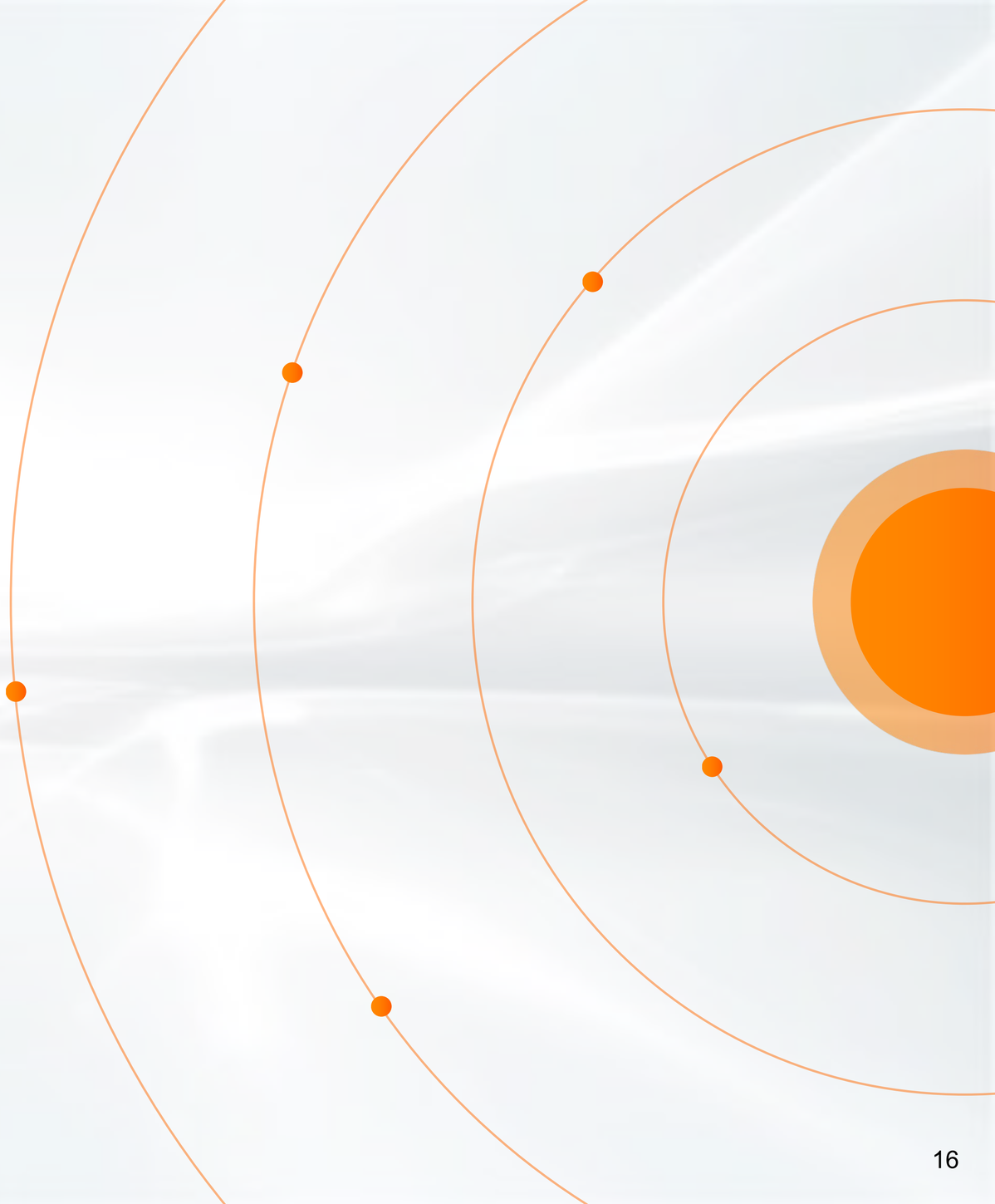
Optimizer Hints



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Rewrite Scalar Subquery to Derived Table

(Or CTE in MySQL 8.0)

Q1

```
SELECT SUM(l_extendedprice) / 7.0 AS avg_yearly
FROM lineitem JOIN part ON p_partkey = l_partkey
WHERE p_mfgr = 'Manufacturer#1'
  AND l_quantity
        < (SELECT 0.2 * AVG(l_quantity) FROM lineitem WHERE l_partkey = p_partkey);
```

Q2

```
WITH pq(avg_qty, pk) AS (SELECT 0.2 * AVG(l_quantity), l_partkey
                         FROM lineitem GROUP BY l_partkey)
SELECT SUM(l_extendedprice) / 7.0 AS avg_yearly
FROM lineitem JOIN part ON p_partkey = l_partkey JOIN pq ON pq.pk = p_partkey
WHERE p_mfgr = 'Manufacturer#1' AND l_quantity < pq.avg_qty;
```

Q3

```
WITH pq(avg_qty, pk) AS (SELECT 0.2 * AVG(l_quantity), l_partkey
                         FROM lineitem JOIN part ON p_partkey = l_partkey
                         WHERE p_mfgr = 'Manufacturer#1' GROUP BY l_partkey)
SELECT SUM(l_extendedprice) / 7.0 AS avg_yearly
FROM lineitem JOIN pq ON pq.pk = l_partkey
WHERE l_quantity < pq.avg_qty;
```

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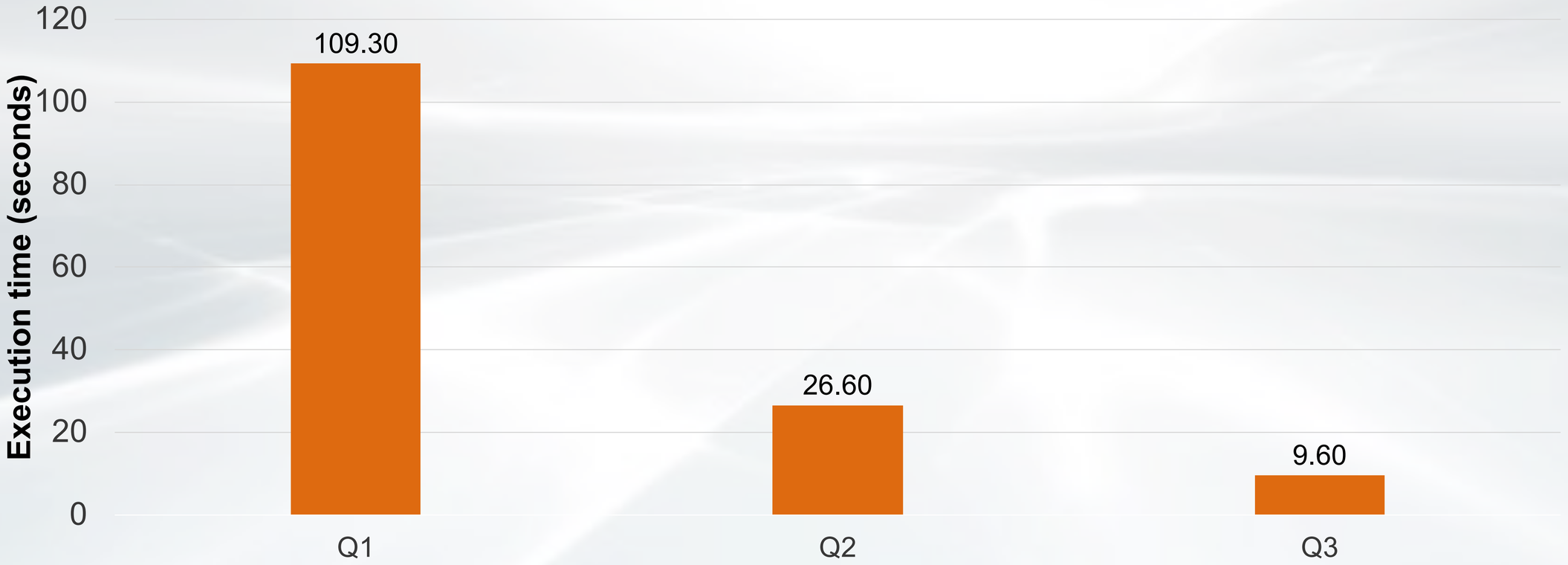
Rewrite Scalar Subquery to Derived Table

Comparing Execution Times



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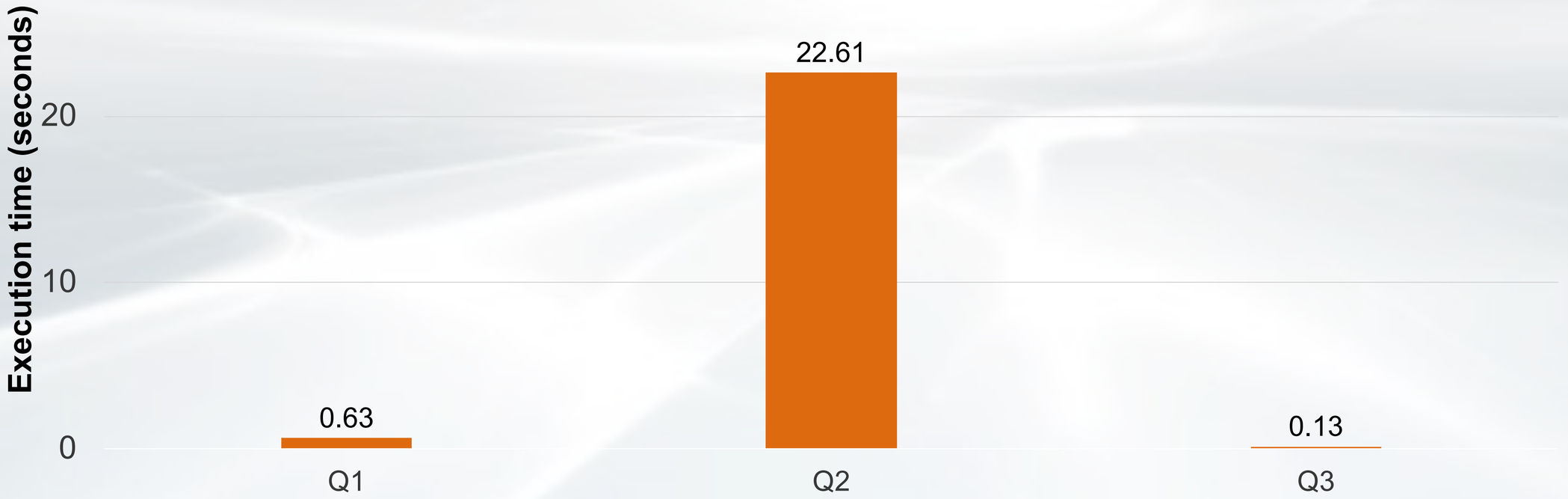
Rewrite Scalar Subquery to Derived Table

Not always optimal

```
SELECT SUM(l_extendedprice) / 7.0 AS avg_yearly
FROM lineitem JOIN part ON p_partkey = l_partkey
WHERE p_brand = 'Brand#11' and p_container = 'SM CAN'
  AND l_quantity
          < (SELECT 0.2 * AVG(l_quantity) FROM lineitem WHERE l_partkey = p_partkey);
```



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Automatic Rewrite of Scalar Subqueries to Derived Tables

MySQL 8.0.21

- Only supported for non-correlated scalar subqueries
- Off by default, to enable:

```
SET optimizer_switch='subquery_to_derived=on';
```

- Not cost-based, may give worse performance than scalar subqueries

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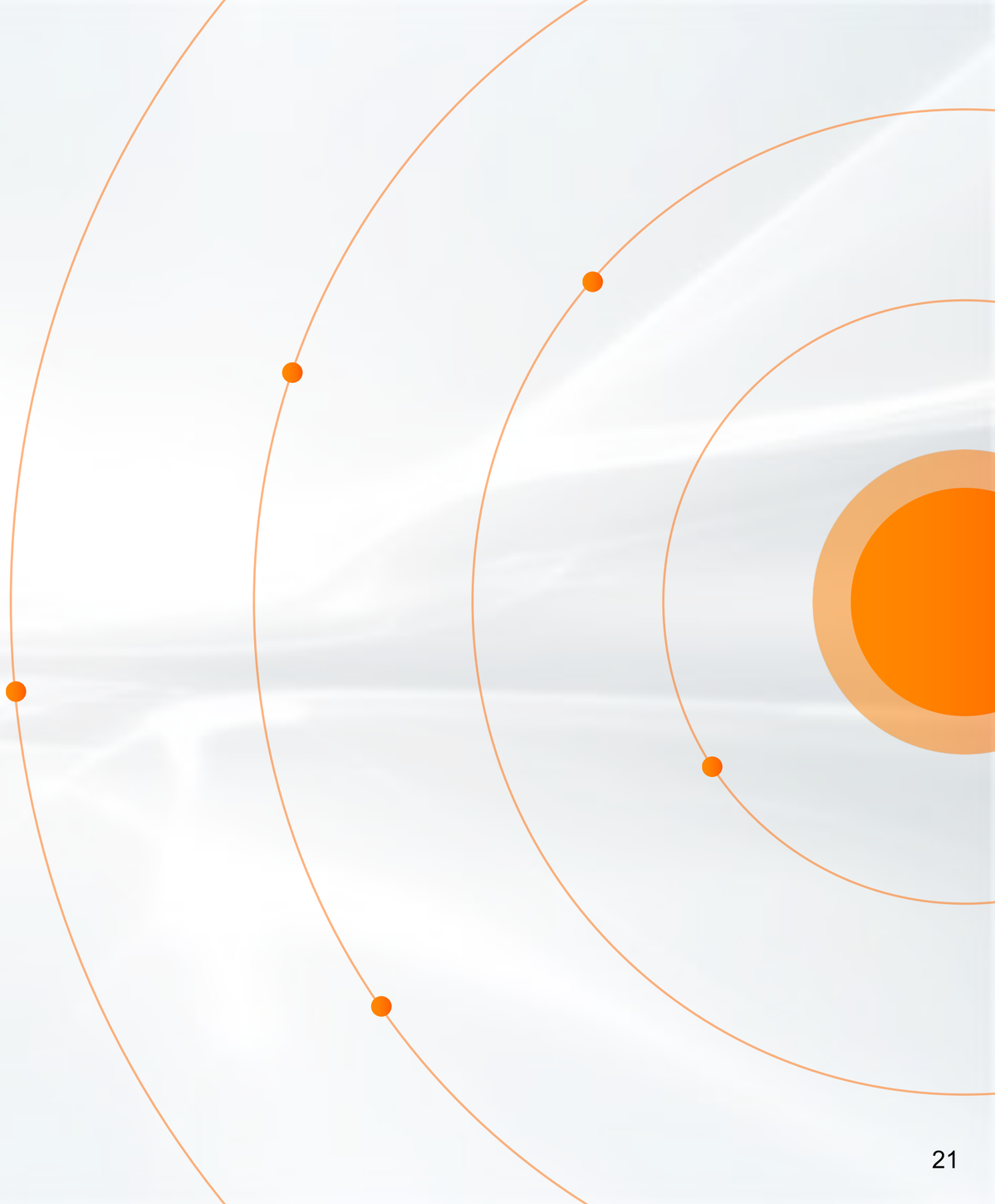

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IN-subqueries

```
SELECT o_orderdate, o_totalprice FROM orders
WHERE o_orderkey IN (SELECT l_orderkey FROM lineitem WHERE l_shipDate='1996-09-30');
```

- Semi-join
  - Introduced in MySQL 5.6
  - Inner Join + Duplicate removal
  - Opens up for more optimal ”join orders”, may process inner tables before outer tables
  - Can not be used if subquery contains UNION or aggregation
- Prefer IN over EXISTS

```
SELECT o_orderdate, o_totalprice FROM orders
WHERE EXISTS (SELECT 1 FROM lineitem WHERE l_shipDate='1996-09-30' AND o_orderkey = l_orderkey);
```

- MySQL 8.0.16: Automatic conversion from EXISTS to IN

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Rewrite IN-Subquery to Derived Table

TPC-H Query 18: Large Volume Customer Query

Subquery SELECTs and GROUPs by **`l_orderkey`**, so it will not produce any duplicates:

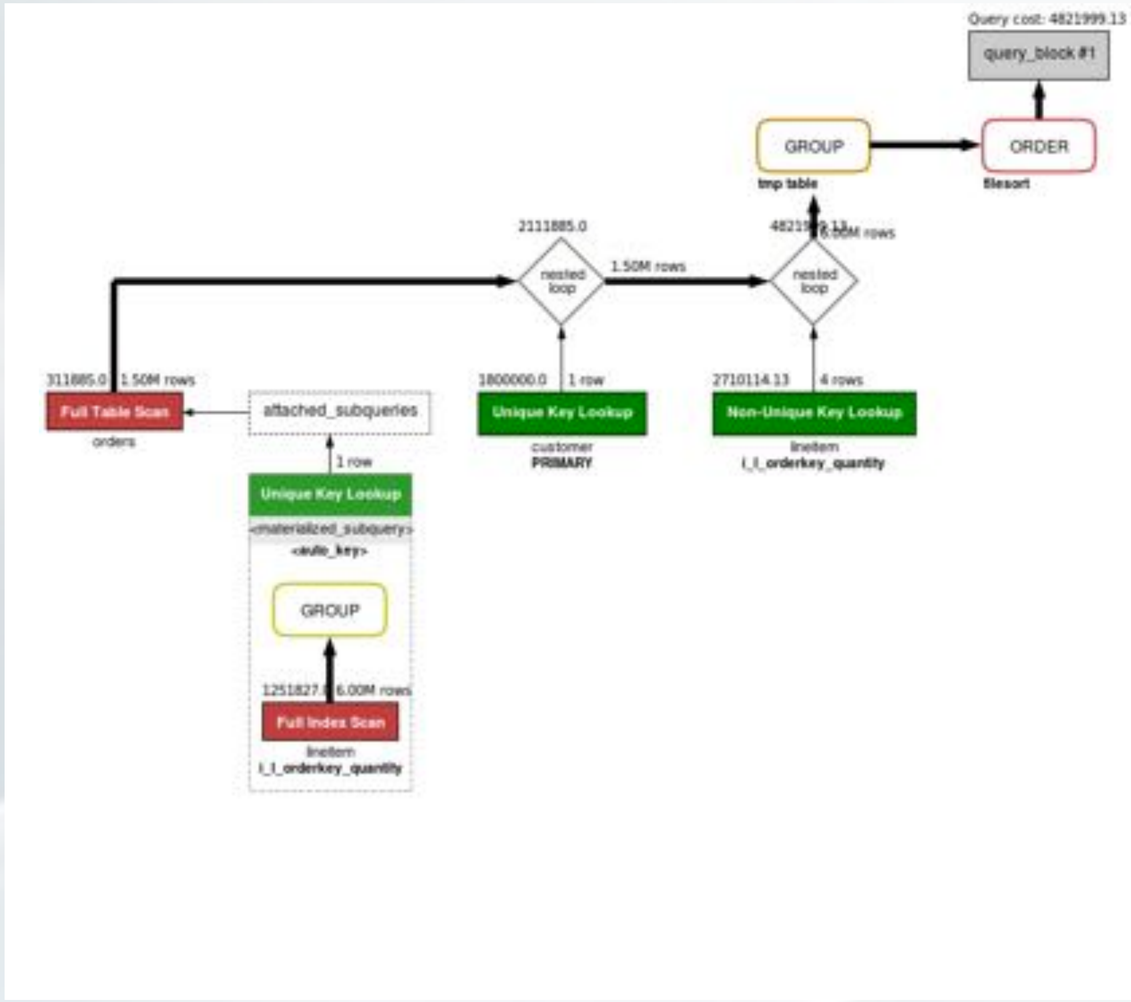
```
SELECT c_name, c_custkey, o_orderkey, o_orderdate, o_totalprice, SUM(l_quantity)
FROM customer JOIN orders ON c_custkey = o_custkey
              JOIN lineitem ON o_orderkey = l_orderkey
WHERE o_orderkey IN ( SELECT l_orderkey FROM lineitem
                      GROUP BY l_orderkey HAVING SUM(l_quantity) > 313 )
GROUP BY c_name, c_custkey, o_orderkey, o_orderdate, o_totalprice
ORDER BY o_totalprice DESC, o_orderdate LIMIT 100;
```

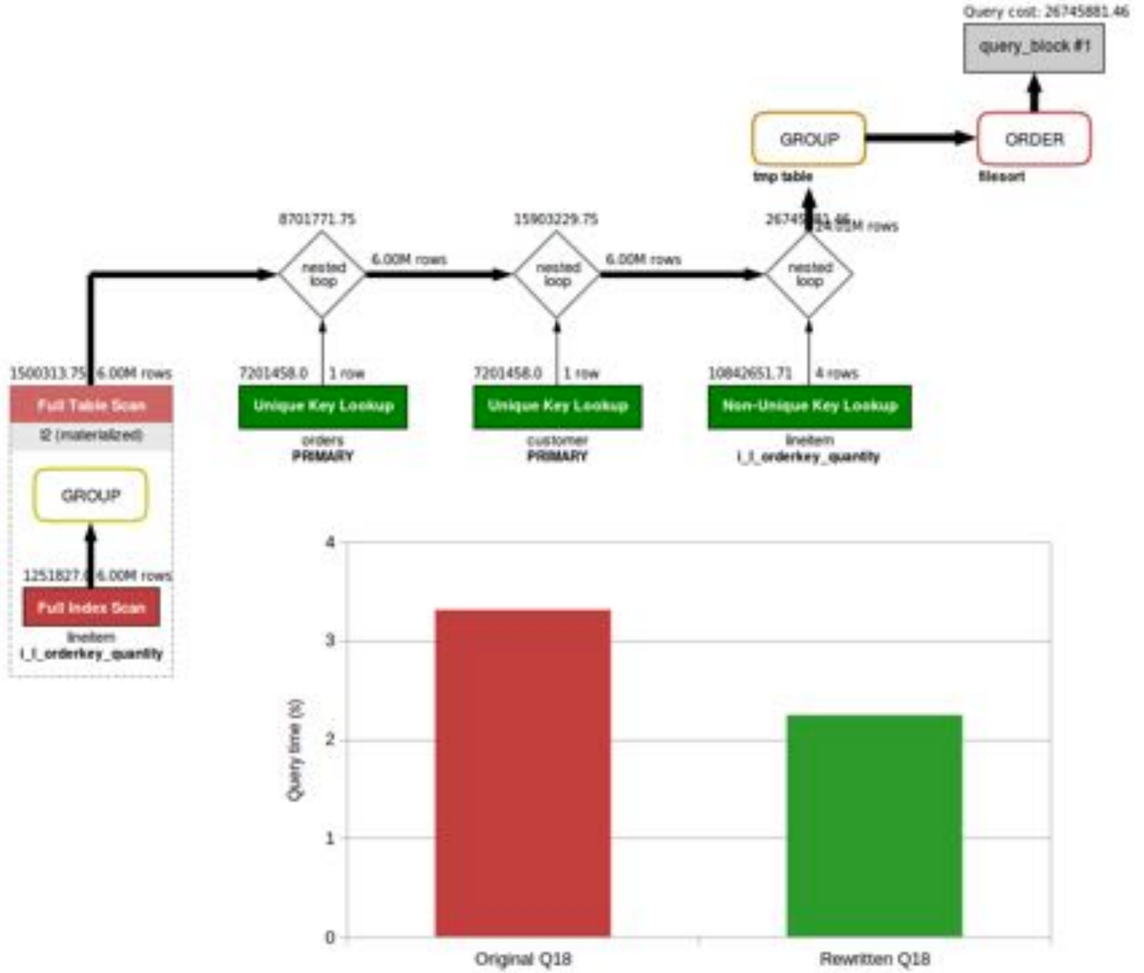
Since no duplicate removal is needed, we can rewrite to use INNER JOIN:

```
WITH l2 AS (SELECT l_orderkey FROM lineitem
            GROUP BY l_orderkey HAVING SUM(l_quantity) > 313 )
SELECT c_name, c_custkey, o_orderkey, o_orderdate, o_totalprice, SUM(l_quantity)
FROM customer JOIN orders ON c_custkey = o_custkey
              JOIN lineitem ON o_orderkey = lineitem.l_orderkey
              JOIN l2 ON o_orderkey = l2.l_orderkey
GROUP BY c_name, c_custkey, o_orderkey, o_orderdate, o_totalprice
ORDER BY o_totalprice DESC, o_orderdate LIMIT 100;
```

Rewrite IN-Subquery to Derived Table

Improved performance with JOIN





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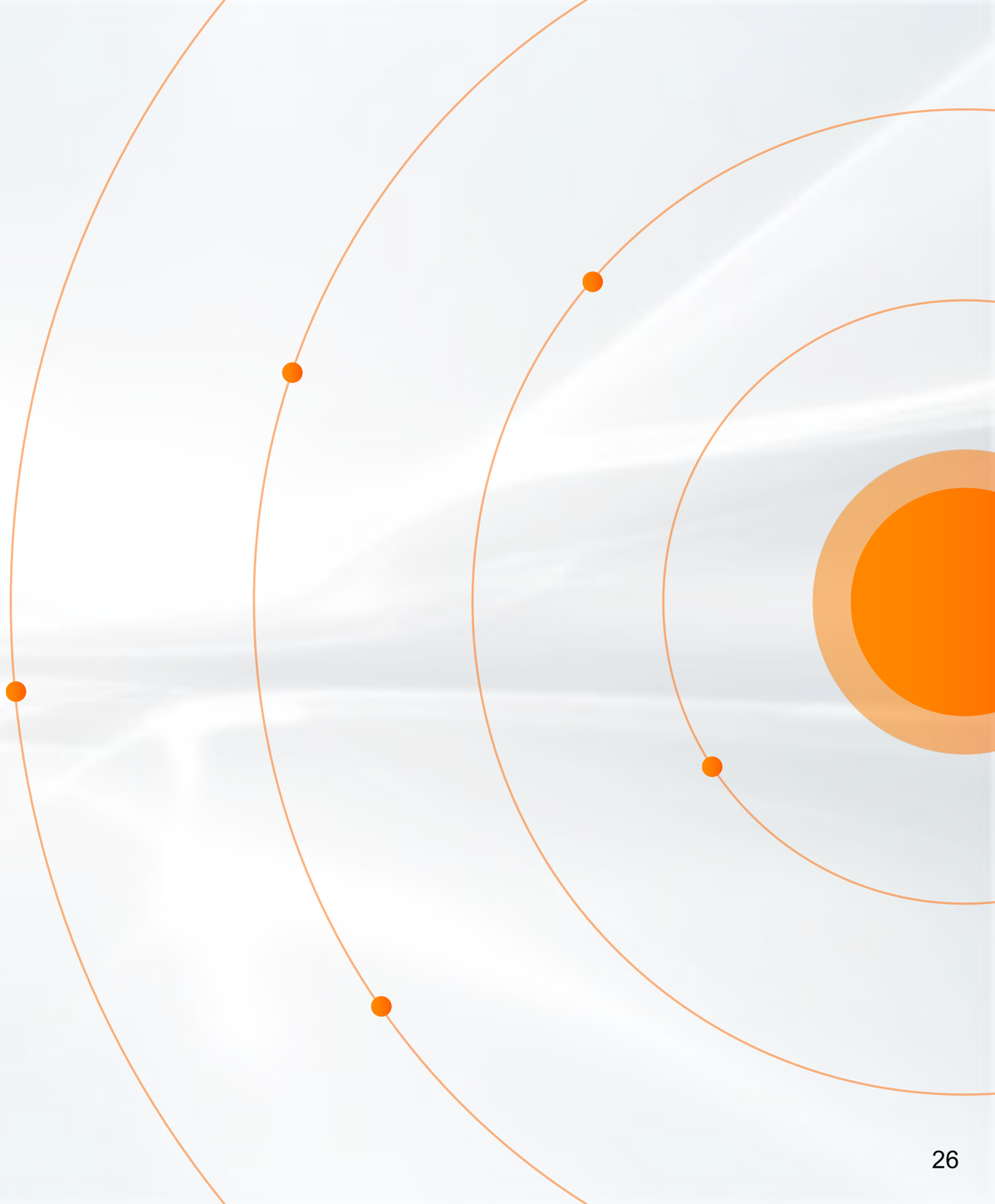

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Use Window Functions Instead of Subqueries for Aggregation

TPC-H Query 17: Small-Quantity-Order Revenue Query

```
SELECT SUM(l_extendedprice) / 7.0 AS avg_yearly
FROM lineitem, part
WHERE p_partkey = l_partkey AND p_brand = 'Brand#11' AND p_container = 'SM CAN'
  AND l_quantity
          < (SELECT 0.2 * AVG(l_quantity) FROM lineitem WHERE l_partkey = p_partkey);
```

```
WITH win AS (
    SELECT l_extendedprice, l_quantity,
           AVG(l_quantity) OVER (PARTITION BY p_partkey) avg_l_quantity
    FROM lineitem, part
    WHERE p_partkey = l_partkey AND p_brand = 'Brand#11' AND p_container = 'SM CAN'
)
SELECT SUM(l_extendedprice) / 7.0 AS avg_yearly
FROM win
WHERE l_quantity < 0.2 * avg_l_quantity;
```

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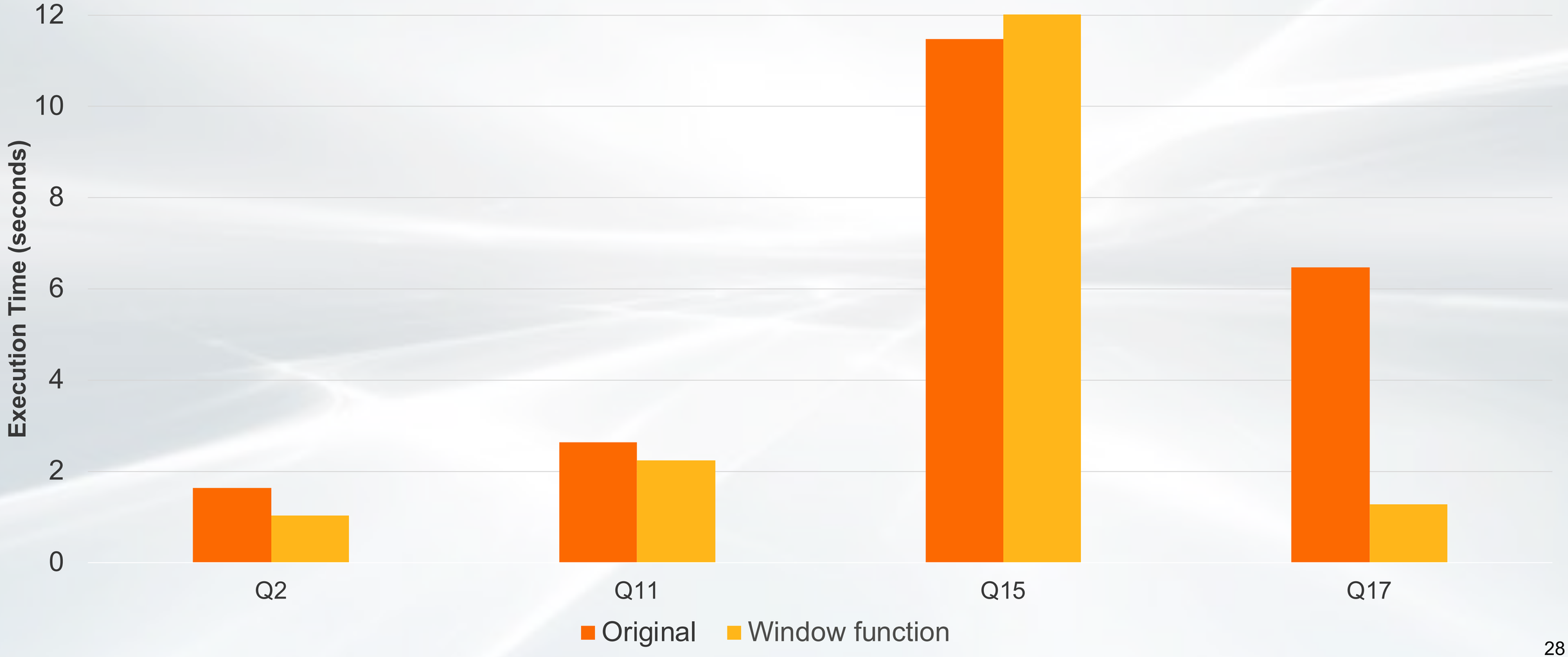
Window Functions Instead of Subqueries for Aggregation



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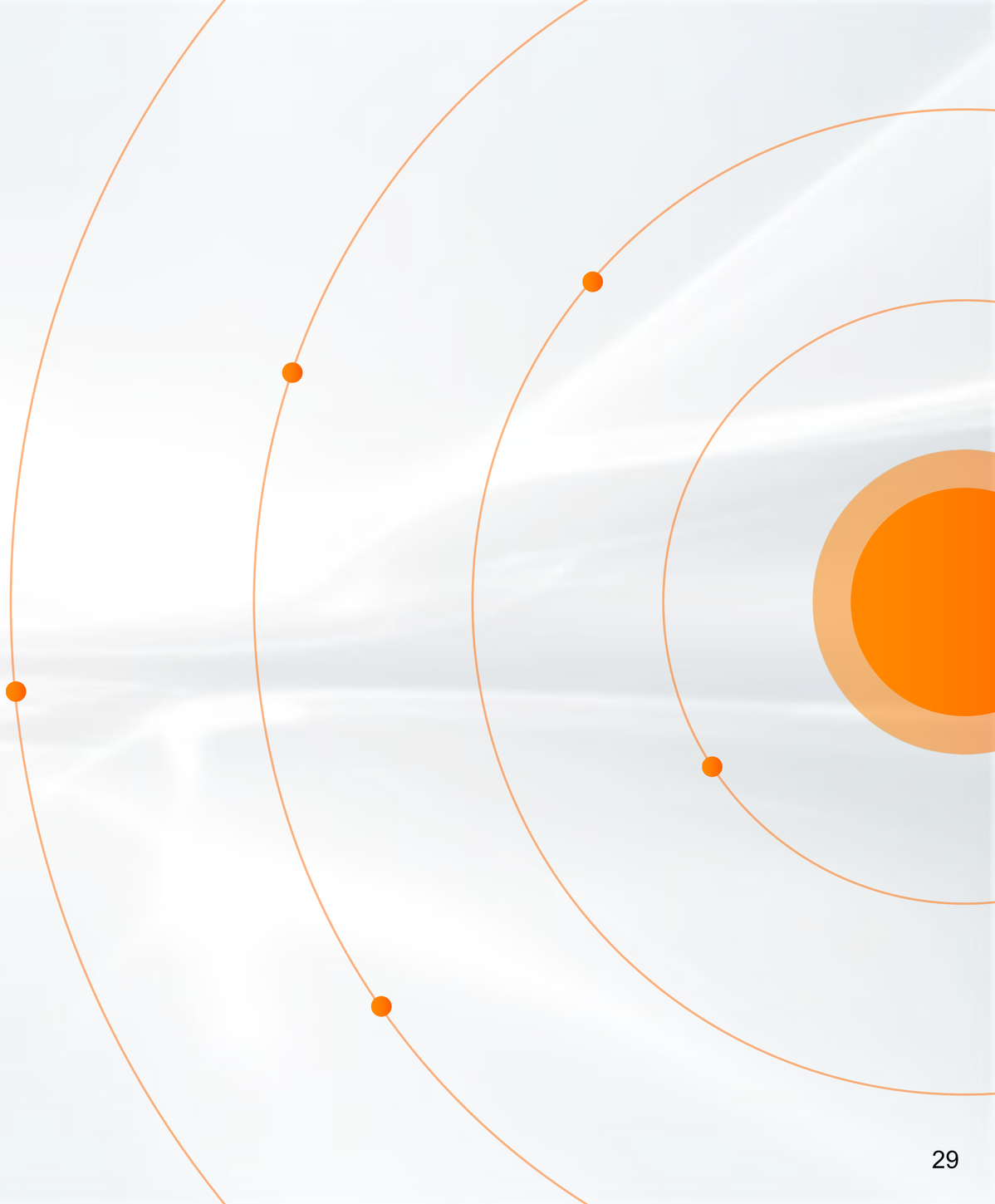

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Optimizer Hints

- Syntax: **`SELECT`** `/*+ hints */ ...`
- Subquery hints:
  - MERGE(), NO_MERGE(): Merge derived table/View/CTE? (MySQL 8.0)
  - SEMIJOIN(), NO_SEMIJOIN(): Whether to use semi-join, and which strategy to (not) use
  - SUBQUERY(): Which subquery strategy to use for non-correlated subqueries (Materialization or not)
  - DERIVED_CONDITION_PUSHDOWN(),NO_DERIVED_CONDITION_PUSHDOWN() (MySQL 8.0.22)
- Other very useful hints:
  - JOIN_PREFIX(), JOIN_ORDER(), JOIN_SUFFIX(): Affect join order (MySQL 8.0)
  - INDEX(), NO_INDEX(): Which index to use (MySQL 8.0.20)

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Query Rewrite Plugin

- Rewrite problematic queries without the need to make application changes
  - Add hints
  - Rewrite queries
- Add rewrite rules to table:

```
INSERT INTO query_rewrite.rewrite_rules (pattern, replacement ) VALUES
("SELECT * FROM t1 WHERE a > ? AND b = ?",
 "SELECT /*+ INDEX(a_idx) */ * FROM t1 WHERE a > ? AND b = ?");
```

- Pre- and post-parse query rewrite APIs
  - Users can write their own plug-ins

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Summary

- Do only select columns in derived table that will be used by outer query
- Push conditions into subqueries
- Be aware that sometimes the automatic merge of derived tables is not optimal
- MySQL 8.0: Use Common Table Expressions (CTEs) instead of derived tables.
- Scalar subqueries may be rewritten to derived tables, but will not always improve performance.
- Prefer IN over EXISTS
- If semijoin does not apply, check if IN-subquery can be replaced by derived table.
- MySQL 8.0: Use window functions to avoid referring the same table twice.

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Thank you