ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Spark SQL

Big Data Analysis with Scala and Spark

Heather Miller

Relational Databases

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But it's a pain in the neck to connect big data processing pipelines like Spark or Hadoop to an SQL database.

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- to get all of the optimizations we're used to in the databases community on Spark jobs?

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Wouldn't it be nice...

- if it were possible to seamlessly intermix SQL queries with Scala?
- to get all of the optimizations we're used to in the databases community on Spark jobs?

Spark SQL delivers both!

Spark SQL: Goals

Three main goals:

1. Support **relational processing** both within Spark programs (on RDDs) and on external data sources with a friendly API.

Sometimes it's more desirable to express a computation in SQL syntax than with functional APIs and vice a versa.

Spark SQL: Goals

Three main goals:

1. Support **relational processing** both within Spark programs (on RDDs) and on external data sources with a friendly API.
2. High performance, achieved by using techniques from research in databases.
3. Easily support new data sources such as semi-structured data and external databases.

Spark SQL

Spark SQL is a component of the Spark stack.

- It is a Spark module for structured data processing.
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- **`DataFrames`**
- **`Datasets`**

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Three main APIs:

- **SQL literal syntax**
- **`DataFrames`**
- **`Datasets`**

Two specialized backend components:

- **Catalyst**, query optimizer.
- **Tungsten**, off-heap serializer.

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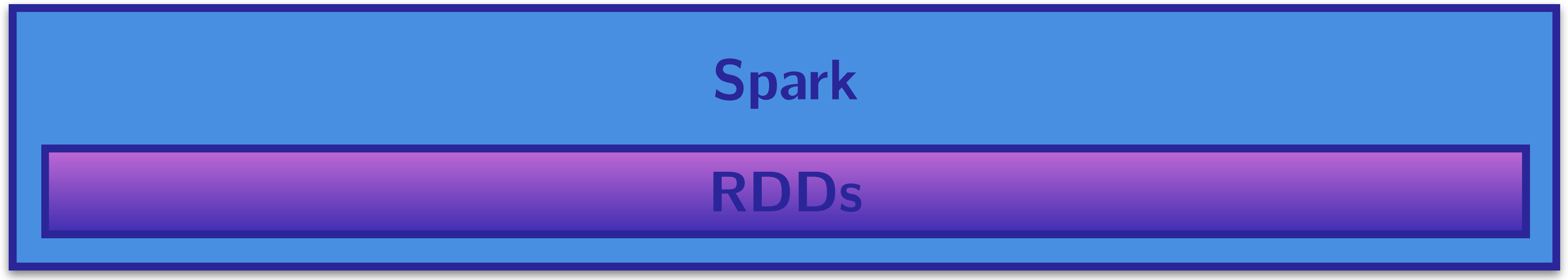
Visually, Spark SQL relates to the rest of Spark like this:



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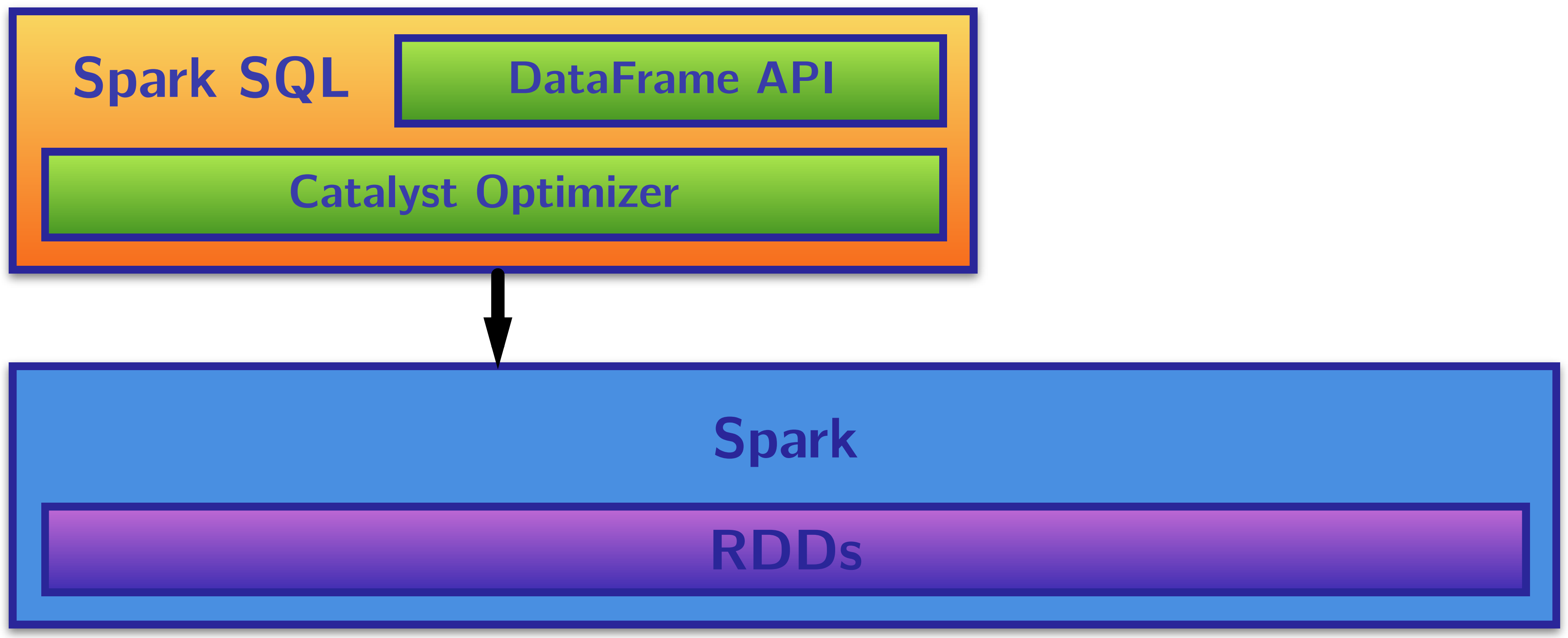

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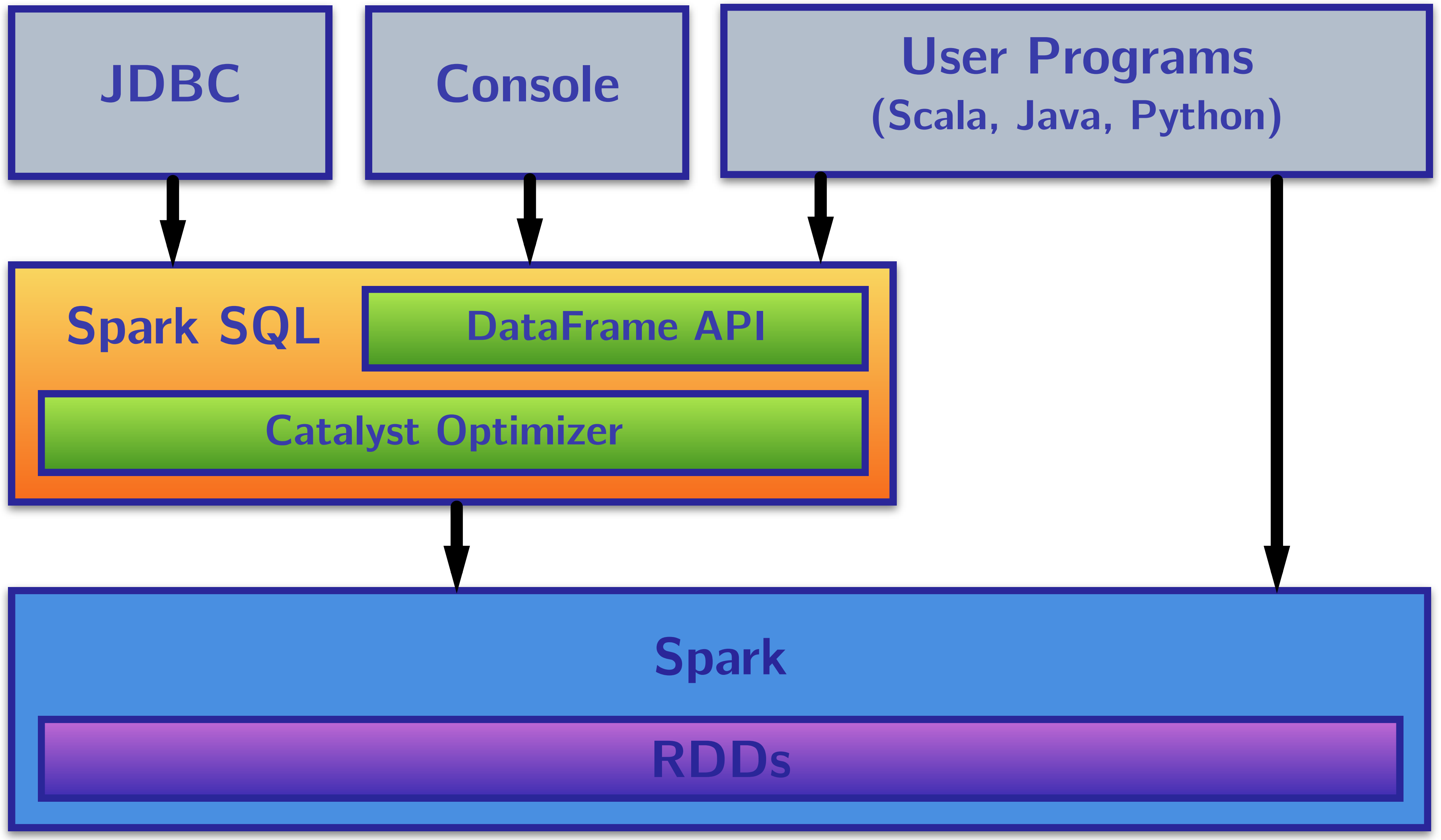

Relational Queries (SQL)

Everything about SQL is structured.

In fact, SQL stands for *structural query language*.

- There are a set of fixed data types. `Int`, `Long`, `String`, etc.
- There are fixed set of operations. `SELECT`, `WHERE`, `GROUP BY`, etc.

Research and industry surrounding relational databases has focused on exploiting this rigidness to get all kinds of performance speedups.

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Let's quickly establish a common set of vocabulary and a baseline understanding of SQL.

Relational Queries (SQL)

Data organized into one or more **tables**

Customer_Name	Destination	Ticket_Price
"Weitz"	"Luzern"	53.20
"Schinz"	"Zürich"	32.40
"Dubois"	"Neuchâtel"	12.50
"Hug"	"Basel"	32.10
"Strub"	"Winterthur"	9.60
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"Smith"	"Genève"	12.70
"Weitz"	"Bern"	21.40

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- Tables contain ***columns*** and ***rows***.

columns

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SBB customers dataset

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A *relation* is just a table.

Attributes are columns.

attribute

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A *relation* is just a table.

Attributes are columns.

Rows are *records* or *tuples*

record /tuple

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Spark SQL

`DataFrame` is Spark SQL's core abstraction.

Conceptually equivalent to a table in a relational database.

`DataFrame`, *is a table, sort of.*

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DataFrames are, *conceptually*, RDDs full of records with a known schema

distributed collection of rows/records.

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Unlike RDDs though, DataFrames **require** some kind of schema info!

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DataFrames are **untyped**! !! !!

That is, the Scala compiler doesn't check the types in its schema!

DataFrames contain ***`Row`s*** *which can contain any schema.*

`DataFrame`, *is a table, sort of.*

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RDD[T]

DataFrame

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Transformations on DataFrames are also known as **untyped transformations**

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SparkSession

To get started using Spark SQL, everything starts with the `SparkSession`

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```
import org.apache.spark.sql.SparkSession

val spark = SparkSession
    .builder()
    .appName("My App")
    //.config("spark.some.config.option", "some-value")
    .getOrCreate()
```

Creating DataFrames

`DataFrames` can be created in two ways:

1. From an existing RDD.
   Either with schema inference, or with an explicit schema.
2. Reading in a specific **data source** from file.
   Common structured or semi-structured formats such as JSON.

Creating DataFrames

(1a) Create DataFrame from RDD, schema reflectively inferred

Given pair RDD, `RDD[(T1, T2, ... TN)]`, a `DataFrame` can be created with its schema automatically inferred by simply using the `toDF` method.

```
val tupleRDD = ... // Assume RDD[(Int, String String, String)]
val tupleDF = tupleRDD.toDF("id", "name", "city", "country") // column names
```

Note: if you use `toDF` without arguments, Spark will assign numbers as attributes (column names) to your `DataFrame`. _1 _2 _3

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Note: if you use `toDF` without arguments, Spark will assign numbers as attributes (column names) to your `DataFrame`.

If you already have an RDD containing some kind of case class instance, then Spark can infer the attributes from the case class's fields.

```
case class Person(id: Int, name: String, city: String)
val peopleRDD = ... // Assume RDD[Person]
val peopleDF = peopleRDD.toDF
```

(1b) Create `DataFrame` from existing RDD, schema explicitly specified

Sometimes it's not possible to create a `DataFrame` with a pre-determined case class as its schema. For these cases, it's possible to explicitly specify a schema.

It takes three steps:

- Create an RDD of `Rows` from the original RDD.
- Create the schema represented by a `StructType` matching the structure of `Rows` in the RDD created in Step 1.
- Apply the schema to the RDD of `Rows` via `createDataFrame` method provided by `SparkSession`.

Given:

```scala
case class Person(name: String, age: Int)
val peopleRdd = sc.textFile(...) // Assume RDD[Person]
```

(1b) Create `DataFrame` from existing RDD, schema explicitly specified

```
// The schema is encoded in a string
val schemaString = "name age"

// Generate the schema based on the string of schema
val fields = schemaString.split(" ")
  .map(fieldName => StructField(fieldName, StringType, nullable = true))
val schema = StructType(fields)

// Convert records of the RDD (people) to Rows
val rowRDD = peopleRDD
  .map(_.split(","))
  .map(attributes => Row(attributes(0), attributes(1).trim))

// Apply the schema to the RDD
val peopleDF = spark.createDataFrame(rowRDD, schema)
```

Creating DataFrames

(2) Create `DataFrame` by reading in a data source from file.

Using the `SparkSession` object, you can read in semi-structured/structured data by using the `read` method. For example, to read in data and infer a schema from a JSON file:

```
// ‘spark‘ is the SparkSession object we created a few slides back
val df = spark.read.json(”examples/src/main/resources/people.json”)
```

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Semi-structured/Structured data sources Spark SQL can directly create DataFrames from:

- JSON
- CSV
- Parquet
- JDBC

To see a list of all available methods for directly reading in semi-structured/structured data, see the latest API docs for `DataFrameReader`: `http://spark.apache.org/docs/latest/api/scala/index.html#org.apache.spark.sql.DataFrameReader`

SQL Literals

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Given:

A `DataFrame` called `peopleDF`, we just have to register our `DataFrame` as a temporary SQL view first:

```
// Register the DataFrame as a SQL temporary view
peopleDF.createOrReplaceTempView(”people”)
// This essentially gives a name to our DataFrame in SQL
// so we can refer to it in an SQL FROM statement
```

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// SQL literals can be passed to Spark SQL's sql method
val adultsDF
  = spark.sql("SELECT * FROM people WHERE age > 17")
```

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The SQL statements available to you are largely what's available in HiveQL. This includes standard SQL statements such as:

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- `SELECT`
- `FROM`
- `WHERE`
- `COUNT`
- `HAVING`
- `GROUP BY`
- `ORDER BY`
- `SORT BY`
- `DISTINCT`
- `JOIN`
- `(LEFT|RIGHT|FULL) OUTER JOIN`
- Subqueries: `SELECT col FROM ( SELECT a + b AS col from t1) t2`

Supported Spark SQL syntax:
https://docs.datastax.com/en/datastax_enterprise/4.6/datastax_enterprise/spark/sparkSqlSupportedSyntax.html

For a HiveQL cheatsheet:
https://hortonworks.com/blog/hive-cheat-sheet-for-sql-users/

For an updated list of supported Hive features in Spark SQL, the official Spark SQL docs enumerate:
https://spark.apache.org/docs/latest/sql-programming-guide.html#supported-hive-features

A More Interesting SQL Query

Let's assume we have a `DataFrame` representing a data set of employees:

```scala
case class Employee(id: Int, fname: String, lname: String, age: Int, city: String)

// DataFrame with schema defined in Employee case class
val employeeDF = sc.parallelize(...).toDF
```

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```

Let's query this data set to obtain just the IDs and last names of employees working in a specific city, say, Sydney, Australia. Let's sort our result in order of increasing employee ID.

What would this SQL query look like?

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val sydneyEmployeesDF
  = spark.sql("""SELECT id, lname
                  FROM employees
                 WHERE city = "Sydney"
              ORDER BY id""")
```

registered "employees"

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Pretty simple.

A More Interesting SQL Query

Let's visualize the result on an example dataset.

Given:

```
val employeeDF = sc.parallelize(...).toDF

// employeeDF:        "employees"
// +---+-----+-------+---+--------+
// | id|fname|  lname|age|    city|
// +---+-----+-------+---+--------+
// | 12|  Joe|  Smith| 38|New York|
// |563|Sally|  Owens| 48|New York|
// |645|Slate|Markham| 28|  Sydney|
// |221|David| Walker| 21|  Sydney|
// +---+-----+-------+---+--------+
```

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```

Result

```
// employeeDF:                              sydneyEmployeesDF:
// +---+-----+-------+---+--------+         +---+-------+
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// +---+-----+-------+---+--------+
```

Note: it's best to use Spark 2.1+ with Scala 2.11+ for doing SQL queries with Spark SQL.