Catalytic Compilation

A modern take on safe Spark

APACHE
Spark
TM

APACHE Spark™

SQL

- Distributed relational engine since 2014
- Scala's Killer App
- Large ecosystem : data sources, languages

```sql
SELECT s.name, r.timestamp, r.temperature
FROM weather_stations s
JOIN weather_readings r ON s.id = r.station_id
WHERE r.temperature > 30.0
ORDER BY r.temperature DESC
```

SQL String

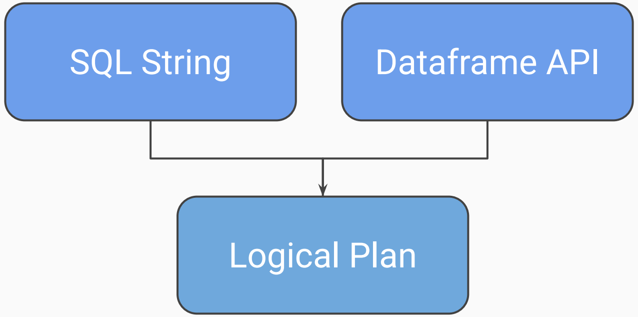
Dataframe API

```
val df = spark.sql:
  """
  SELECT s.name, r.timestamp, r.temperature
  FROM weather_stations s
  JOIN weather_readings r ON s.id = r.station_id
  WHERE r.temperature > 30.0
  ORDER BY r.temperature DESC
  """
```

SQL String

Dataframe API

```
stations
    .as("s")
    .join(readings.as("r"), stations.col("id") === readings.col("station_id"), "inner")
    .where(col("r.temperature") > 30.0)
    .select(
      col("s.name").as("name"),
      col("r.timestamp").as("timestamp"),
      col("r.temperature").as("temperature")
    )
    .orderBy(col("r.temperature").desc)
```

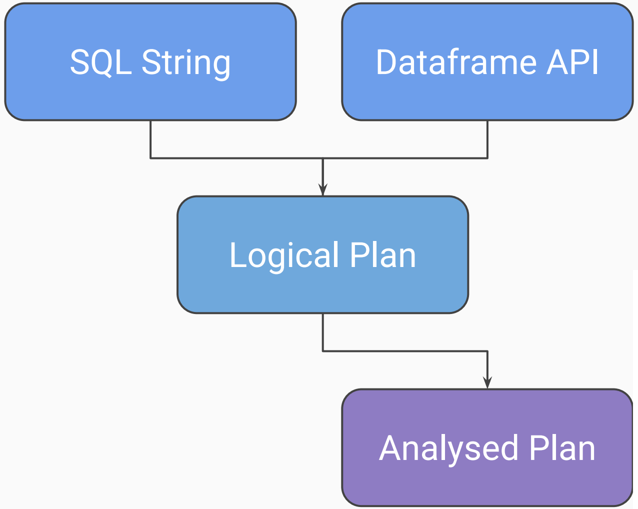


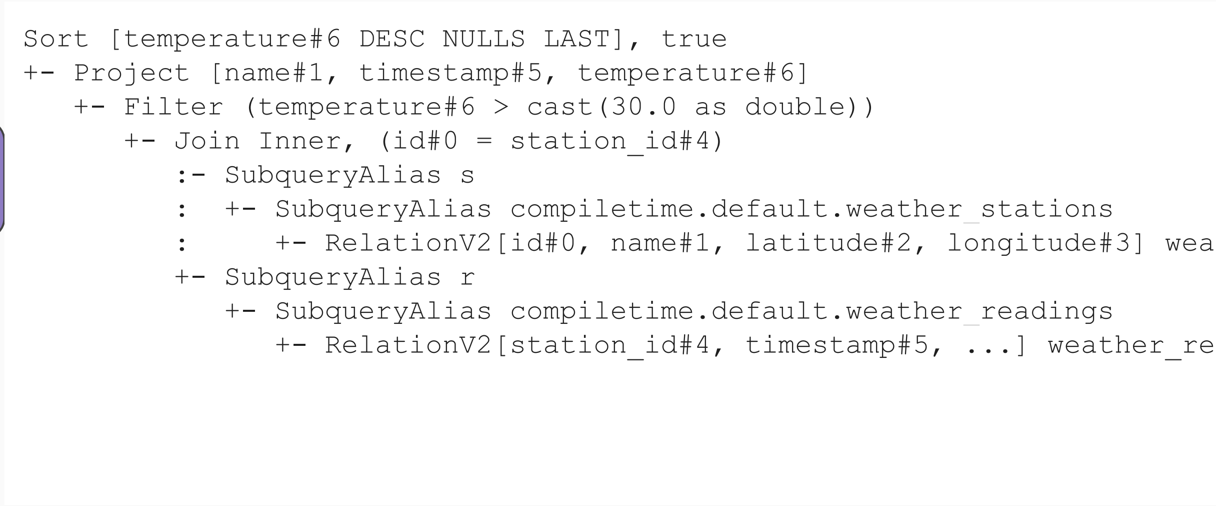
SQL String

Dataframe API

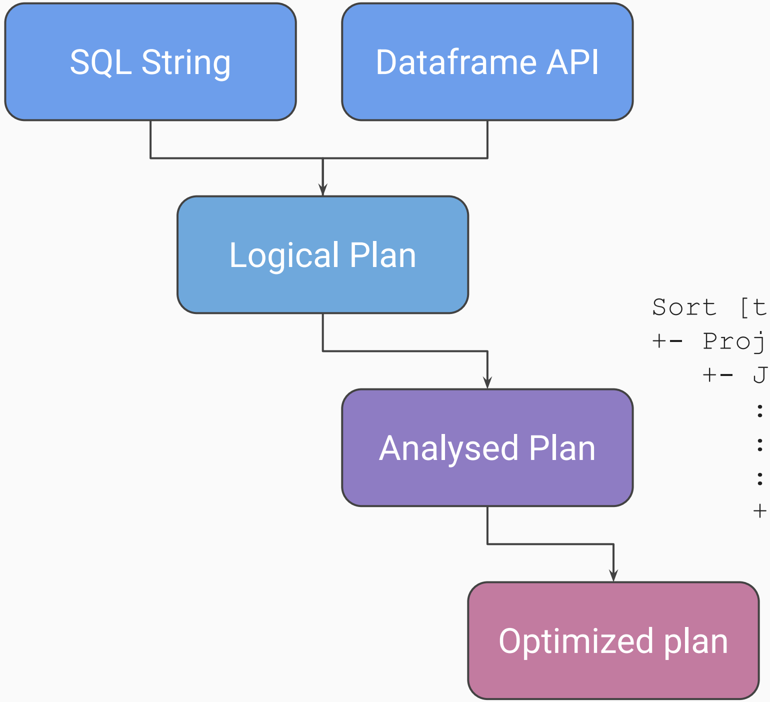
Logical Plan

```
'Sort ['r.temperature DESC NULLS LAST], true
+- 'Project ['s.name, 'r.timestamp, 'r.temperature]
  +- 'Filter ('r.temperature > 30.0)
     +- 'Join Inner, ('s.id = 'r.station_id)
        :- 'SubqueryAlias s
        :  +- 'UnresolvedRelation [weather_stations], [], false
        +- 'SubqueryAlias r
           +- 'UnresolvedRelation [weather_readings], [], false
```

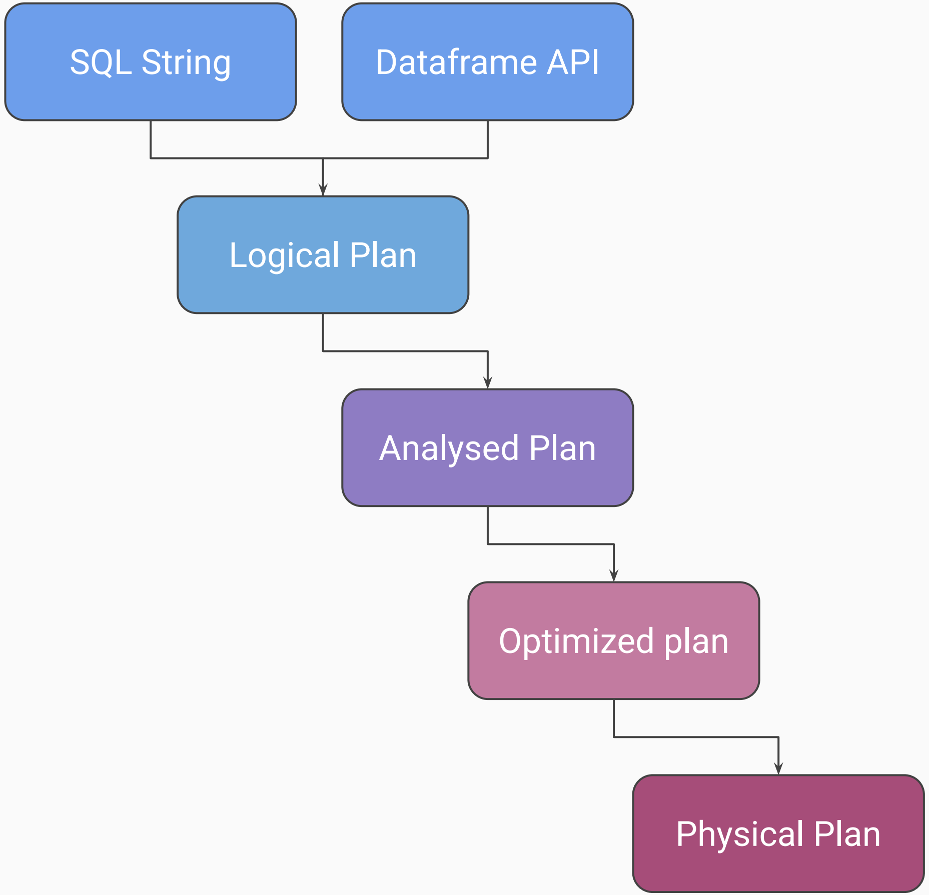




```
Sort [temperature#6 DESC NULLS LAST], true
+- Project [name#1, timestamp#5, temperature#6]
   +- Filter (temperature#6 > cast(30.0 as double))
      +- Join Inner, (id#0 = station_id#4)
         :- SubqueryAlias s
         :  +- SubqueryAlias compiletime.default.weather_stations
         :     +- RelationV2[id#0, name#1, latitude#2, longitude#3] wea
         +- SubqueryAlias r
            +- SubqueryAlias compiletime.default.weather_readings
               +- RelationV2[station_id#4, timestamp#5, ...] weather_re
```



```
Sort [temperature#27 DESC NULLS LAST], true
+- Project [name#11, timestamp#28, temperature#27]
   +- Join Inner, (id#8L = station_id#26L)
      :- Project [id#8L, name#11]
      :  +- Filter isnotnull(id#8L)
      :     +- Relation [id#8L,latitude#9,longitude#10,name#11] json
      +- Project [station_id#26L, temperature#27, timestamp#28]
         +- Filter ((isnotnull(temperature#27) AND (temperature#27 > 30
                     AND isnotnull(station_id#26L))
            +- Relation [humidity#24,pressure#25,station_id#26L,tempera
                         timestamp#28] json
```



SQL String

Dataframe API

Logical Plan

Analysed Plan

Optimized plan

Physical Plan

```
AdaptiveSparkPlan isFinalPlan=false
+- Sort [temperature#27 DESC NULLS LAST], true, 0
   +- Exchange rangepartitioning(temperature#27 DESC NULLS LAST, 200), ...
      +- Project [name#11, timestamp#28, temperature#27]
         +- BroadcastHashJoin [id#8L], [station_id#26L], Inner, BuildLeft, false
            :- BroadcastExchange [params…]
            :  +- Filter isnotnull(id#8L)
            :     +- FileScan json [id#8L,name#11]
            :                 Batched: false,
            :                 DataFilters: [isnotnull(id#8L)],
            :                 Format: JSON, Location: InMemoryFileIndex(1 paths)[file],
            :                 PartitionFilters: [],
            :                 PushedFilters: [IsNotNull(id)],
            :                 ReadSchema: struct<id:bigint,name:string>
            +- Filter (filters...)
               +- FileScan json [station_id#26L,temperature#27,timestamp#28]
                           Batched: false,
                           DataFilters: [filters],
                           Format: JSON,
                           Location: InMemoryFileIndex(1 paths)[file],
                           PartitionFilters: [],
                           PushedFilters: [filters],
                           ReadSchema: struct<station_id:bigint,temperature:double,timestamp:string>
```

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SQL

Catalyst is just a compiler

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Spark™
SQL

Catalyst is just a compiler *in a runtime*

APACHE Spark™

SQL

Catalyst is just a compiler *in a runtime* ***without tooling***

Strongly typed pipelines ?

```
val df = spark.sql:
  """
  SELECT s.name, r.timestamp r.temperature
  FROM weather_stations s
  JOIN weather_readings r ON s.id = r.station_id
  WHERE r.temperature > 30.0
  ORDER BY r.temperature DESC
  """
```

Strongly typed pipelines ?

```
[PARSE_SYNTAX_ERROR] Syntax error at or near '.'.(line 2, pos 30)

== SQL ==

 SELECT s.name, r.timestamp r.temperature
------------------------------^^^
 FROM weather_stations s
 JOIN weather_readings r ON s.id = r.station_id
 WHERE r.temperature > 30.0
 ORDER BY r.temperature DESC
```

Strongly typed pipelines ?

```
stations
   .as("s")
   .join(readings.as("r"), stations.col("id") === readings.col("station_id"), "inner")
   .where(col("r.temperature") > 30.0)
   .select(
     col("s.name").as("name"),
     col("r.timestamp").as("timestamp"),
     col("r.temprature").as("temperature")
   )
   .orderBy(col("r.temperature").desc)
```

Strongly typed pipelines ?

```
[UNRESOLVED_COLUMN.WITH_SUGGESTION] A column or function parameter with name `r`.`temprature` cannot be
resolved. Did you mean one of the following? [`r`.`temperature`, `r`.`pressure`, `r`.`humidity`,
`s`.`latitude`, `s`.`longitude`].;
'Project [name#11 AS name#61, timestamp#28 AS timestamp#62, 'r.temprature AS temperature#63]
 +- Filter (temperature#27 > 30.0)
    +- Join Inner, (id#8L = station_id#26L)
       :- SubqueryAlias s
       :  +- SubqueryAlias weather_stations
       :     +- View (`weather_stations`, [id#8L,latitude#9,longitude#10,name#11])
       :        +- Relation [id#8L,latitude#9,longitude#10,name#11] json
       +- SubqueryAlias r
          +- SubqueryAlias weather_readings
             +- View (`weather_readings`, [...])
                +- Relation [humidity#24,pressure#25,station_id#26L,temperature#27,timestamp#28] json
```

Stringly typed pipelines !

Why did pyspark succeed ?

```python
from pyspark.sql.functions import col

stations = spark.table("weather_stations")
readings = spark.table("weather_readings")

df = (
    stations.alias("s")
    .join(
        readings.alias("r"),
        col("s.id") == col("r.station_id"),
        "inner"
    )
    .where(col("r.temperature") > 30.0)
    .select(
        col("s.name").alias("name"),
        col("r.timestamp").alias("timestamp"),
        col("r.temperature").alias("temperature")
    )
    .orderBy(col("r.temperature").desc())
)
```

```scala
import org.apache.spark.sql.functions.*

val stations = spark.table("weather_stations")
val readings = spark.table("weather_readings")

val df =
  stations.as("s")
  .join(
     readings.as("r"),
     stations.col("id") === readings.col("station_id"),
     "inner"
  )
  .where(col("r.temperature") > 30.0)
  .select(
    col("s.name").as("name"),
    col("r.timestamp").as("timestamp"),
    col("r.temprature").as("temperature")
  )
  .orderBy(col("r.temperature").desc)
```

Why did pyspark succeed ?

APACHE Spark
APACHE Spark
Corporate needs you to find the differences between this picture and this picture.
They're the same picture.
imgflip.com

The issue with Spark SQL

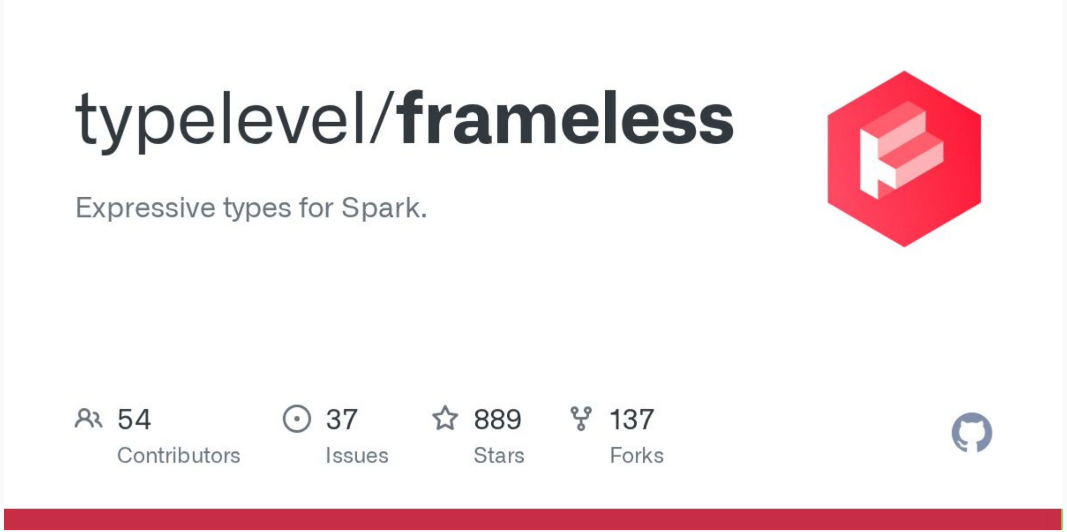
- Scala add **little to no value** in term of correctness

- Scala compiler do not understand table and rows

- All checks are deferred until runtime (or tests)

And then ?

What if there was a better way ?



typelevel/**frameless**

Expressive types for Spark.

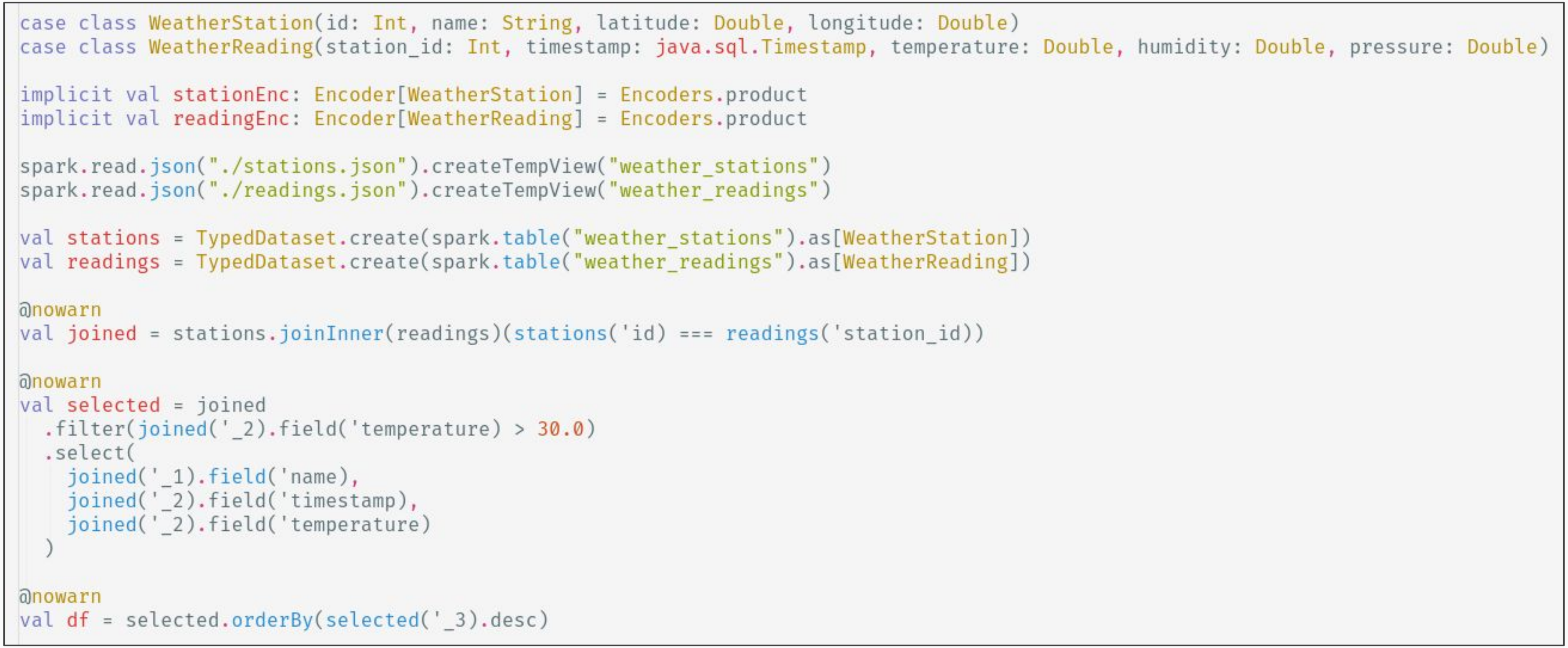
54 Contributors

37 Issues

889 Stars

137 Forks

Frameless



```scala
case class WeatherStation(id: Int, name: String, latitude: Double, longitude: Double)
case class WeatherReading(station_id: Int, timestamp: java.sql.Timestamp, temperature: Double, humidity: Double, pressure: Double)

implicit val stationEnc: Encoder[WeatherStation] = Encoders.product
implicit val readingEnc: Encoder[WeatherReading] = Encoders.product

spark.read.json("./stations.json").createTempView("weather_stations")
spark.read.json("./readings.json").createTempView("weather_readings")

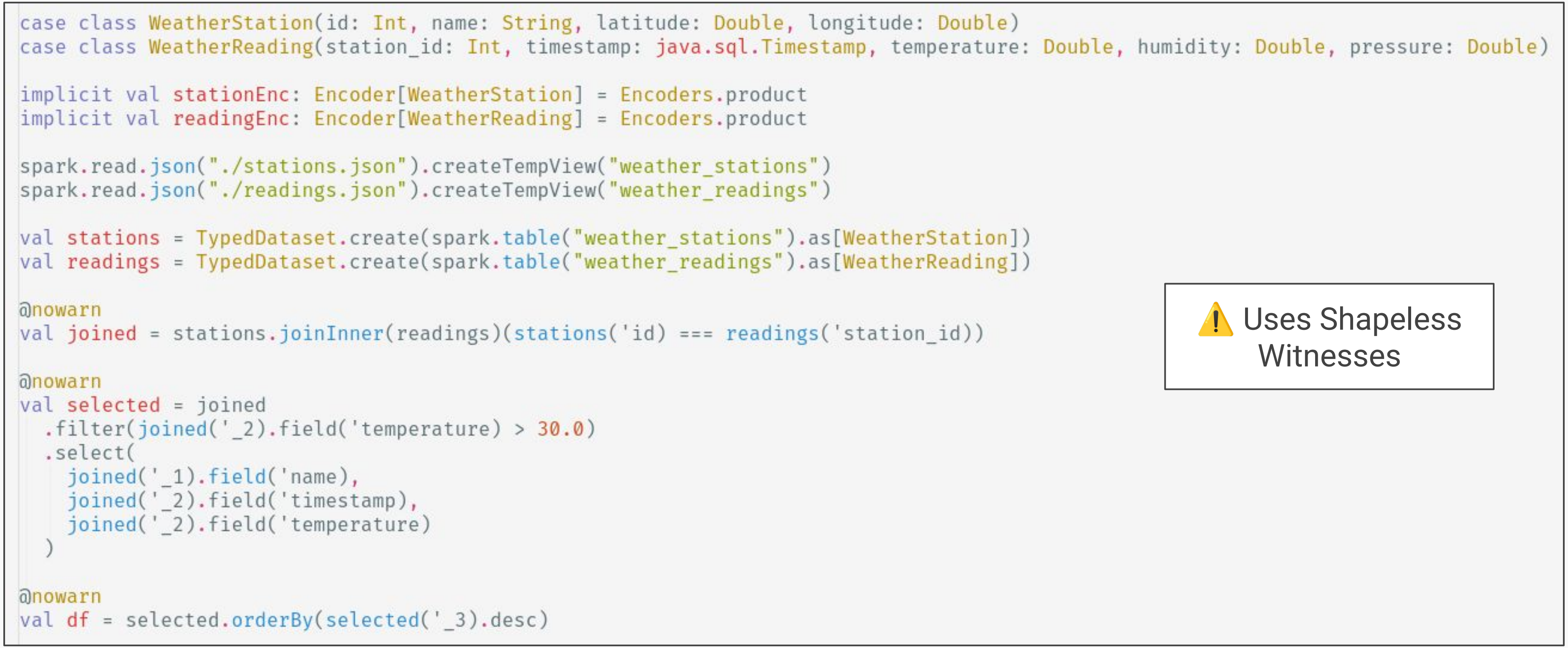
val stations = TypedDataset.create(spark.table("weather_stations").as[WeatherStation])
val readings = TypedDataset.create(spark.table("weather_readings").as[WeatherReading])

@nowarn
val joined = stations.joinInner(readings)(stations('id) === readings('station_id))

@nowarn
val selected = joined
  .filter(joined('_2).field('temperature) > 30.0)
  .select(
    joined('_1).field('name),
    joined('_2).field('timestamp),
    joined('_2).field('temperature)
  )

@nowarn
val df = selected.orderBy(selected('_3).desc)
```

Frameless



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case class WeatherStation(id: Int, name: String, latitude: Double, longitude: Double)
case class WeatherReading(station_id: Int, timestamp: java.sql.Timestamp, temperature: Double, humidity: Double, pressure: Double)

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val readings = TypedDataset.create(spark.table("weather_readings").as[WeatherReading])

@nowarn
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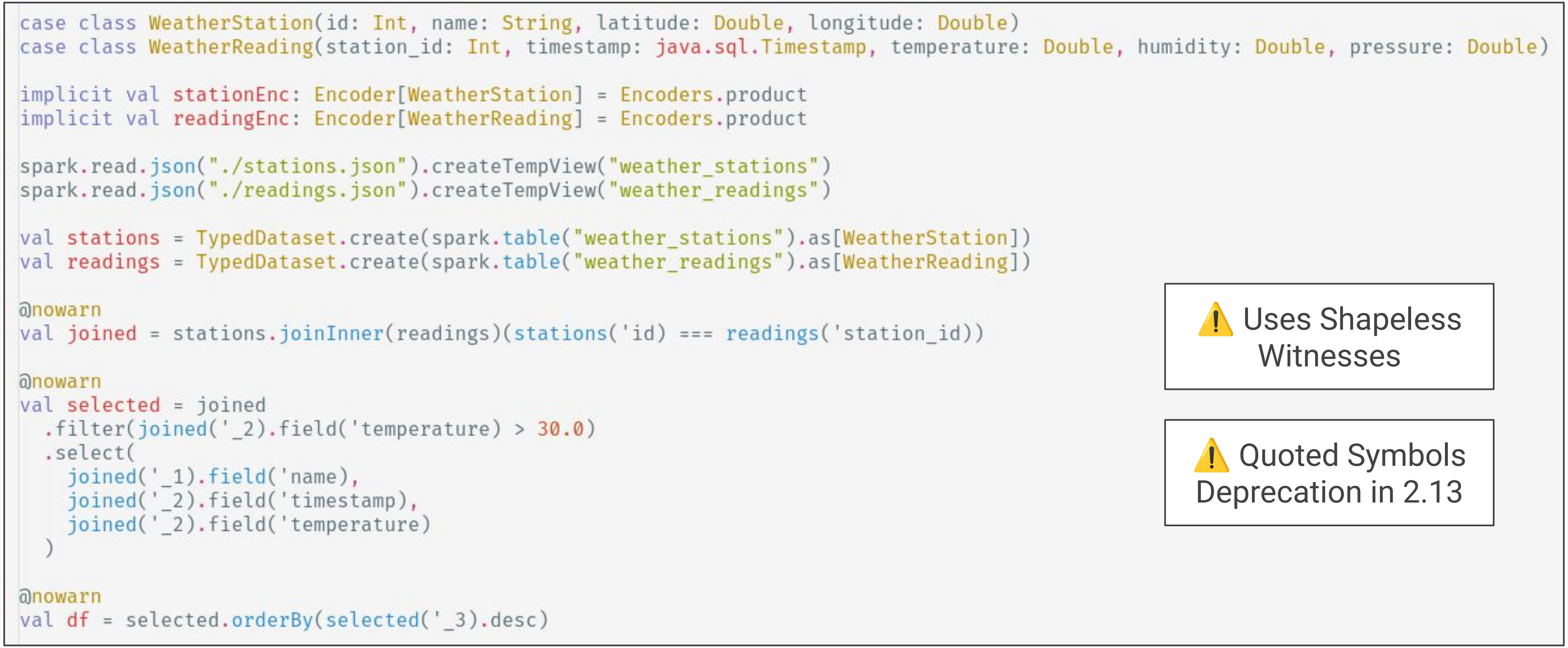
@nowarn
val selected = joined
  .filter(joined('_2).field('temperature) > 30.0)
  .select(
    joined('_1).field('name),
    joined('_2).field('timestamp),
    joined('_2).field('temperature)
  )

@nowarn
val df = selected.orderBy(selected('_3).desc)
```

⚠️ Uses Shapeless Witnesses

Frameless



```scala
case class WeatherStation(id: Int, name: String, latitude: Double, longitude: Double)
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implicit val stationEnc: Encoder[WeatherStation] = Encoders.product
implicit val readingEnc: Encoder[WeatherReading] = Encoders.product

spark.read.json("./stations.json").createTempView("weather_stations")
spark.read.json("./readings.json").createTempView("weather_readings")

val stations = TypedDataset.create(spark.table("weather_stations").as[WeatherStation])
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@nowarn
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@nowarn
val selected = joined
  .filter(joined('_2).field('temperature) > 30.0)
  .select(
    joined('_1).field('name),
    joined('_2).field('timestamp),
    joined('_2).field('temperature)
  )

@nowarn
val df = selected.orderBy(selected('_3).desc)
```
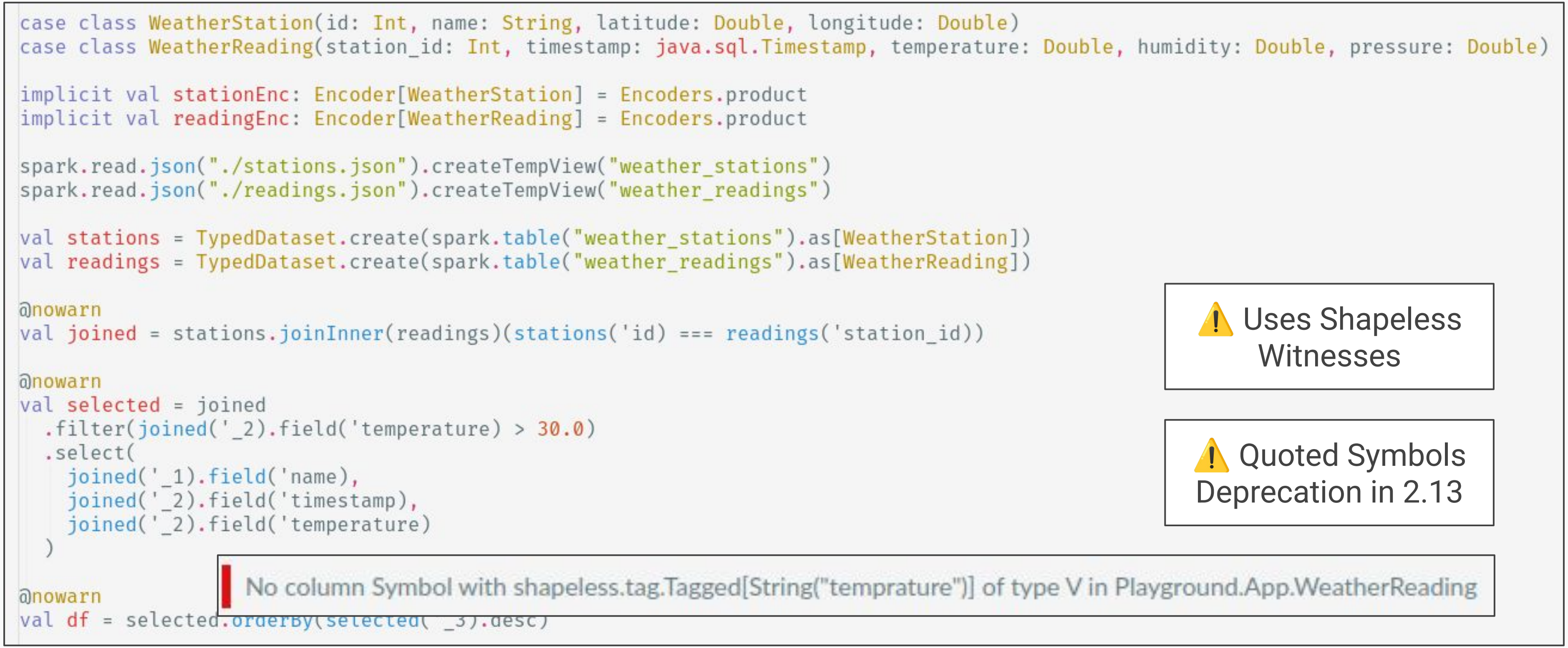

⚠️ Uses Shapeless Witnesses

⚠️ Quoted Symbols Deprecation in 2.13

Frameless



```scala
case class WeatherStation(id: Int, name: String, latitude: Double, longitude: Double)
case class WeatherReading(station_id: Int, timestamp: java.sql.Timestamp, temperature: Double, humidity: Double, pressure: Double)

implicit val stationEnc: Encoder[WeatherStation] = Encoders.product
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spark.read.json("./stations.json").createTempView("weather_stations")
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val stations = TypedDataset.create(spark.table("weather_stations").as[WeatherStation])
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@nowarn
val selected = joined
  .filter(joined('_2).field('temperature) > 30.0)
  .select(
    joined('_1).field('name),
    joined('_2).field('timestamp),
    joined('_2).field('temperature)
  )

@nowarn
val df = selected.orderBy(selected('_3).desc)
```
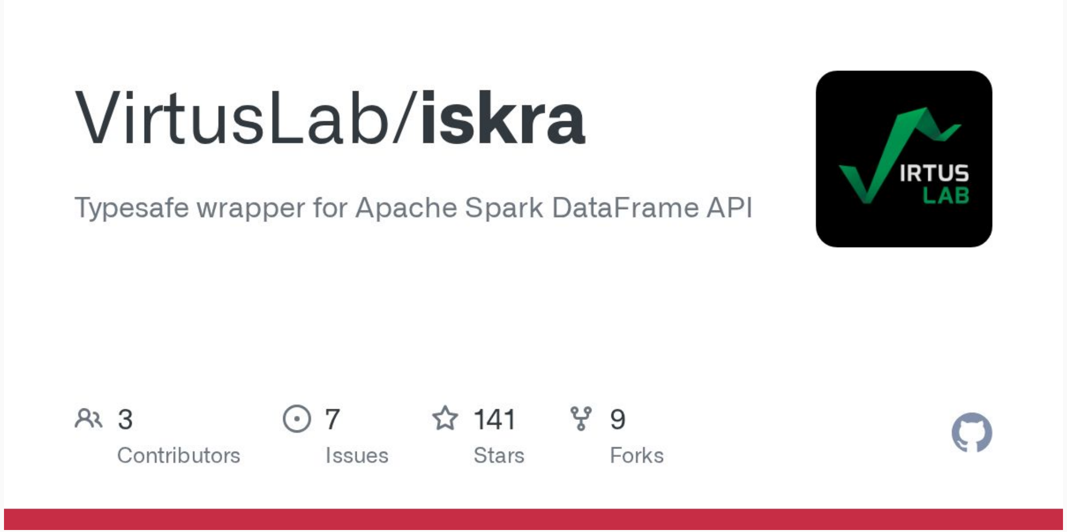

No column Symbol with shapeless.tag.Tagged[String("temprature")] of type V in Playground.App.WeatherReading

⚠️ Uses Shapeless Witnesses

⚠️ Quoted Symbols Deprecation in 2.13

And then ?

What if there was a better way ? (season 2)



VirtusLab/**iskra**

Typesafe wrapper for Apache Spark DataFrame API

3 Contributors

7 Issues

141 Stars

9 Forks

Iskra

```
// no iska encoder defined for java.sql.Timestamp

 case class WeatherStation(id: Int, name: String, latitude: Double, longitude: Double)
 case class WeatherReading(station_id: Int, timestamp: Long, temperature: Double, humidity: Double, pressure: Double)

 spark.read.json("./stations.json").createTempView("weather_stations")
 spark.read.json("./readings.json").createTempView("weather_readings")

 val stations = spark.table("weather_stations").typed[WeatherStation]
 val readings = spark.table("weather_readings").typed[WeatherReading]

 val df = stations
   .innerJoin(readings)
   .on($.stations.id === $.readings.station_id)
   .where($.readings.temperature > lit(30.0))
   .select(
     $.stations.name,
     $.readings.timestamp,
     $.readings.temperature
   )
 // .orderBy($.readings.temperature.desc)
```

Iskra

```
// no iska encoder defined for java.sql.Timestamp

 case class WeatherStation(id: Int, name: String, latitude: Double, longitude: Double)
 case class WeatherReading(station_id: Int, timestamp: Long, temperature: Double, humidity: Double, pressure:
Double)

 spark.read.json("./stations.json").createTempView("weather_stations")
 spark.read.json("./readings.json").createTempView("weather_readings")

 val stations = spark.table("weather_stations").typed[WeatherStation]
 val readings = spark.table("weather_readings").typed[WeatherReading]

 val df = stations
   .innerJoin(readings)
   .on($.stations.id === $.readings.station_id)
   .where($.readings.temperature > lit(30.0))
   .select(
     $.stations.name,
     $.readings.timestamp,
     $.readings.temperature
   )
 // .orderBy($.readings.temperature.desc)
```

⚠️ Some rough edges

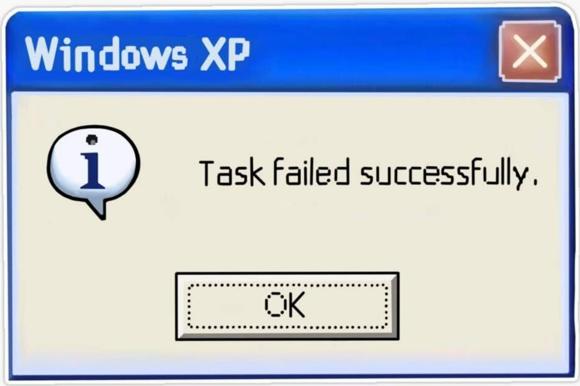
Iskra

```
// no iska encoder defined for java.sql.Timestamp

 case class WeatherStation(id: Int, name: String, latitude: Double, longitude: Double)
 case class WeatherReading(station_id: Int, timestamp: Long, temperature: Double, humidity: Double, pressure: Double)

 spark.read.json("./stations.json").createTempView("weather_stations")
 spark.read.json("./readings.json").createTempView("weather_readings")

 val stations = spark.table("weather_stations").typed[WeatherStation]
 val readings = spark.table("weather_readings").typed[WeatherReading]

 val df = stations
   .innerJoin(readings)
   .on($.stations.id === $.readings.station_id)
   .where($.readings.temperature > lit(30.0))
   .select(
     $.stations.name,
     $.readings.timestamp,
     $.readings.temperature
   )
 // .orderBy($.readings.temperature.desc)
```

⚠️ Some rough edges

⚠️ Use its own Codecs

And then ?



Task failed successfully.

Brute forcing the problem

- High migration costs
- Everything needs to be modeled
- The ORM syndrome : another tool to learn

And then ?

What if there was a better way ? (season 3)

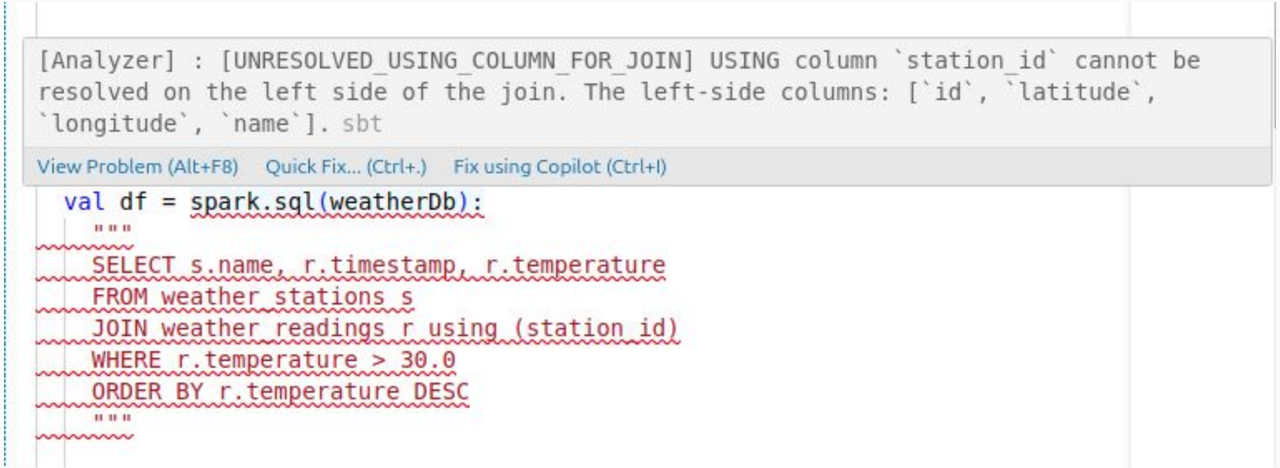
And then ?

Let's put spark into the compiler !

And then ?

Live demo

Spark Compiletime

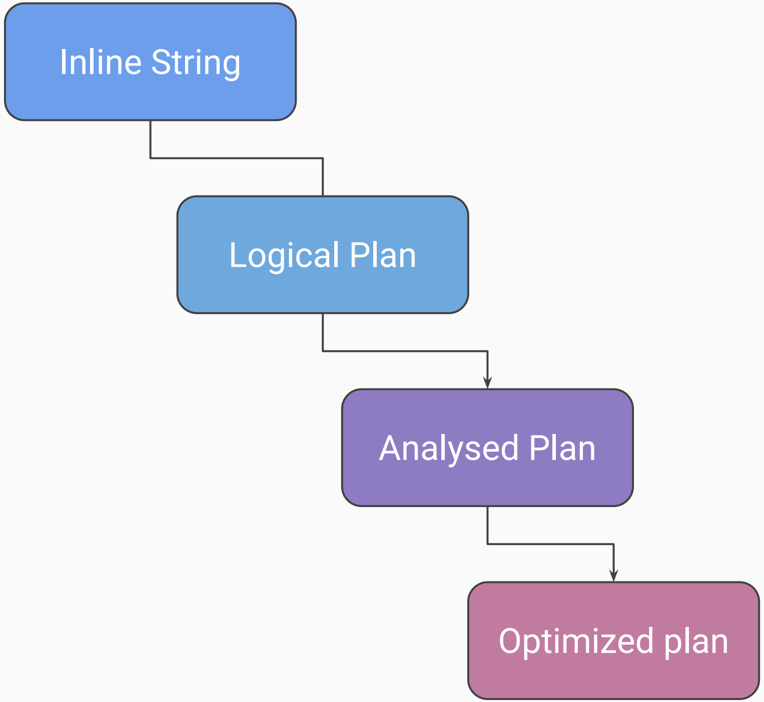


```
[Analyzer] : [UNRESOLVED_USING_COLUMN_FOR_JOIN] USING column `station_id` cannot be
resolved on the left side of the join. The left-side columns: [`id`, `latitude`,
`longitude`, `name`]. sbt
```

```
  val df = spark.sql(weatherDb):
    """
    SELECT s.name, r.timestamp, r.temperature
    FROM weather_stations s
    JOIN weather_readings r using (station_id)
    WHERE r.temperature > 30.0
    ORDER BY r.temperature DESC
    """
```

Using macros, Catalyst itself is parsing and optimizing the query

How does it work ?



- Type level catalog using mirrors
- Table mirrors are derived from their creation query
- Macros runs lightweight catalog (no SparkSession)

Why tables mirrors

Table mirrors : from inlines ...

```scala
trait TableMirror:
  type DB <: String
  type Name <: String
  type Schema <: String
  type Query <: String

  inline def db: String           = TableMirror.db[this.type]
  inline def name: String         = TableMirror.name[this.type]
  inline def schema: StructType   = TableMirror.schema[this.type]
  inline def schemaString: String = TableMirror.schemaString[this.type]
  inline def query: String        = TableMirror.query[this.type]
```

Table mirrors : to macros ...

```
object TableMirror:

  inline def query[T]: String =
    ${ macros.queryImpl[T] }

// other implementations
```

Table mirrors : to type matching

```
def queryImpl[T: Type](using Quotes): Expr[String] =
 import quotes.reflect.*
 Type.of[T] match
   case '[TableMirror { type Query = query & String }] =>
     Expr(utils.stringFromType[query])
```

Table mirrors : to AST handling

```
def stringFromType[T: Type](using Quotes): String =
 import quotes.reflect.*
 TypeRepr.of[T] match
   case ConstantType(StringConstant(label)) => label
   case _                                   =>
     report.errorAndAbort(s"expected a constant string, got ${TypeRepr.of[T]}")
```

Table mirrors : to AST handling

```
def typeFromString(name: String)(using Quotes): Type[?] =
  import quotes.reflect.*
  ConstantType(StringConstant(name)).asType
```

Table mirrors : materialization

```
val dbType     = utils.typeFromString(tableName.namespace().mkString("."))
val nameType   = utils.typeFromString(tableName.name())
val schemaType = utils.typeFromString(tableSchema.toDDL)
val queryType  = utils.typeFromString(sql)

(dbType, nameType, schemaType, queryType) match
  case ('[db], '[name], '[schema], '[query]) =>
    '{
      new TableMirror {
        type DB     = db     & String
        type Name   = name   & String
        type Schema = schema & String
        type Query  = query  & String
      }
    }
  case unreachable                           =>
    report.errorAndAbort(s"Unexpected types: $unreachable")
```

Toward the future

- Table mirrors are only extractable from SQL statement
  - Other sources could be used : avrodl, DB schemas, Hive catalogs
- No concatenation / interpolators
- API is rough while interacting with datasets / dataframes

Conclusion

- Embrace SQL as your relational data manipulation DSL
- Scala macros are super fun to use !
- Scala shines at making compiler extensions
  - ideas: Apache calcite, datalog, or more (CoQ?)

Thank you !