Introduction to data.table

Fast data handling and concise syntax in R

Jorrit Mesman
University of Geneva / Uppsala University

August 2021

Workshop Outline

- Introductory presentation (15 min.)
  - What is data.table and why should you use it?
- Questions (5 min.)
- Walkthrough script – Part 1 (15 min.)
- Break (10 min.)
- Walkthrough script – Part 2 (15 min.)
- Questions & Try it out yourself! (15 min.)

What is data.table?

- CRAN R package
  - Main developer: Matt Dowle
  - First release: 2006
  - Active development
- Extension to data.frame
- Fast data handling
  - Main focus of the package
  - Reading, writing, selecting, joining, etc.
- Consistent and concise syntax

Website: https://rdatatable.gitlab.io/data.table/
Twitter: @MattDowle, #rdatatable

Why this workshop?

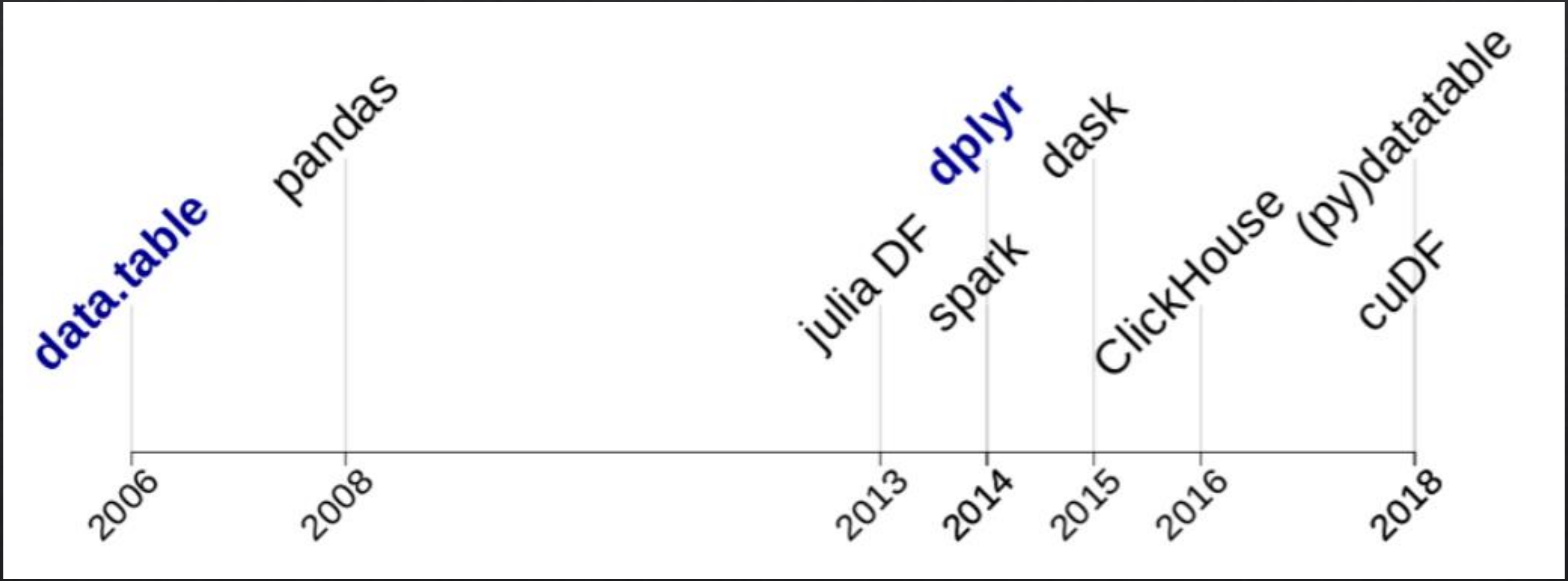
- One of the main packages in R, but little advertised
- Can help you write clearer code and faster scripts
- Faster data handling is particularly useful for GLEONites!
  - High-frequency data and long-term datasets
  - Modelling
  - Global analyses

Performance of data.table

- It is often said that R is slow
- Whether speed is relevant depends on the size of your data and how often you will call your function
  - Single use:
    - Small datasets (<10MB), speed is not so important
    - Large datasets (hundreds of MB), speed matters a lot
  - Repeated analyses:
    - Even small improvements in performance can save you hours

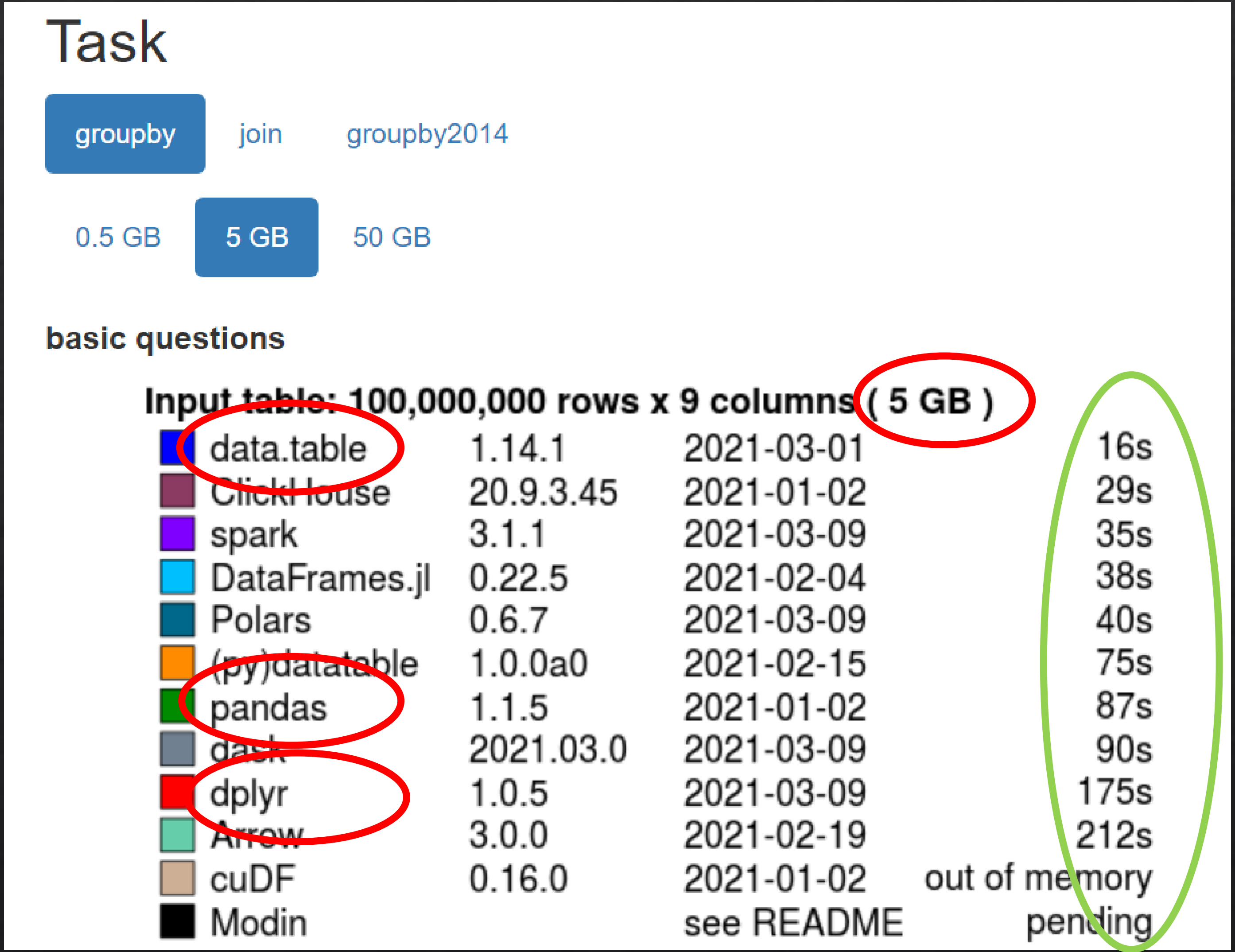
Indication of file sizes:
13 years of water temperature data, text format, 12 distinct depths
- Hourly: 11 MB
- 10 minutes: 85 MB
- 2 minutes: 387 MB

Performance of data.table



Source: Jan Gorecki, 2019

Performance of data.table



Task

groupby | join | groupby2014

0.5 GB | 5 GB | 50 GB

basic questions

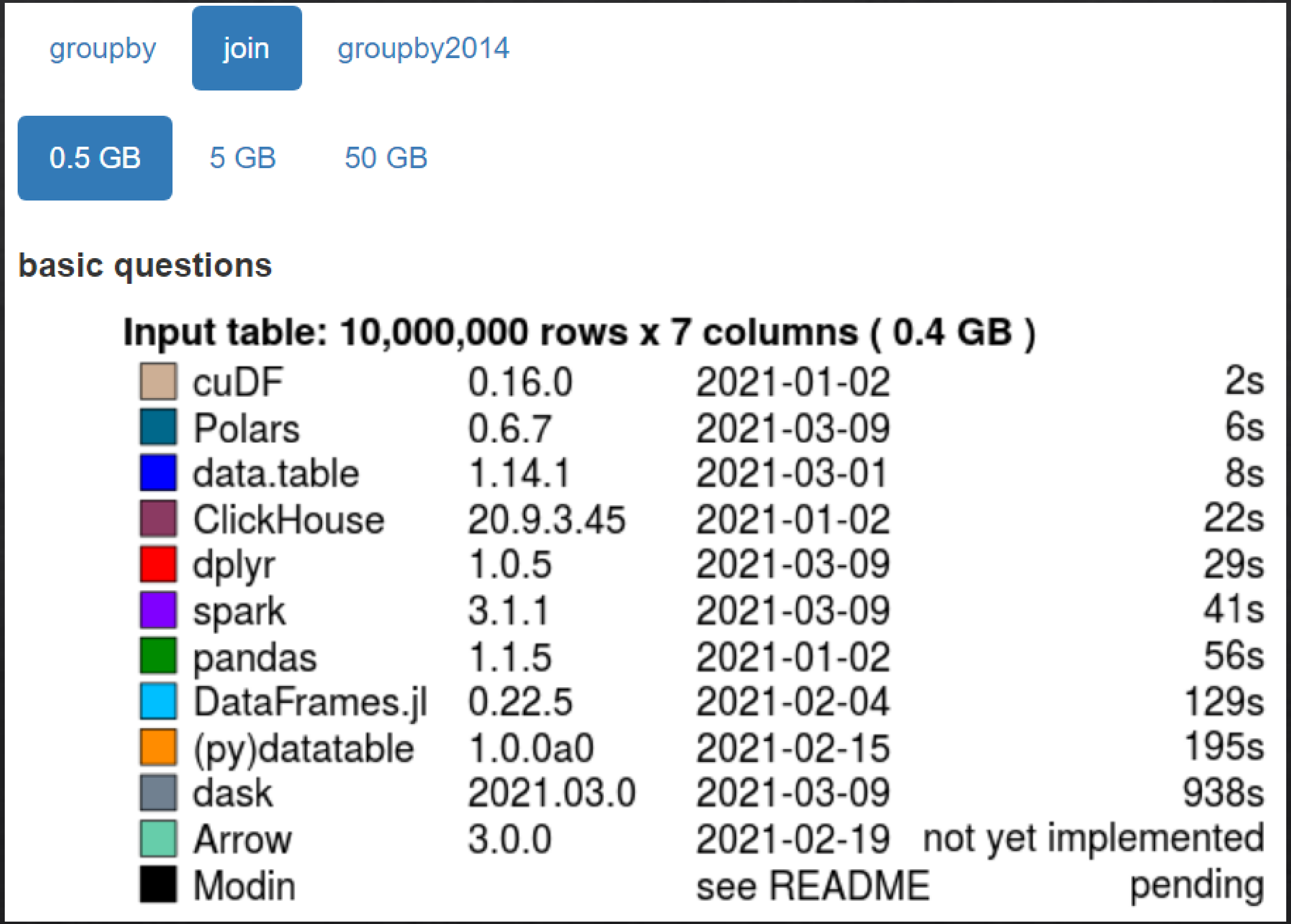
Input table: 100,000,000 rows x 9 columns (5 GB)

🟦	data.table	1.14.1	2021-03-01	16s
🟪	ClickHouse	20.9.3.45	2021-01-02	29s
🟪	spark	3.1.1	2021-03-09	35s
🟦	DataFrames.jl	0.22.5	2021-02-04	38s
🟦	Polars	0.6.7	2021-03-09	40s
🟧	(py)datatable	1.0.0a0	2021-02-15	75s
🟩	pandas	1.1.5	2021-01-02	87s
⬜	dask	2021.03.0	2021-03-09	90s
🟥	dplyr	1.0.5	2021-03-09	175s
🟩	Arrow	3.0.0	2021-02-19	212s
🟫	cuDF	0.16.0	2021-01-02	out of memory
⬛	Modin		see README	pending

Data.table can be multiple factors faster than alternatives, even those in other languages!

https://h2oai.github.io/db-benchmark/, 2021-03-15

Performance of data.table


groupby | join | groupby2014

0.5 GB | 5 GB | 50 GB

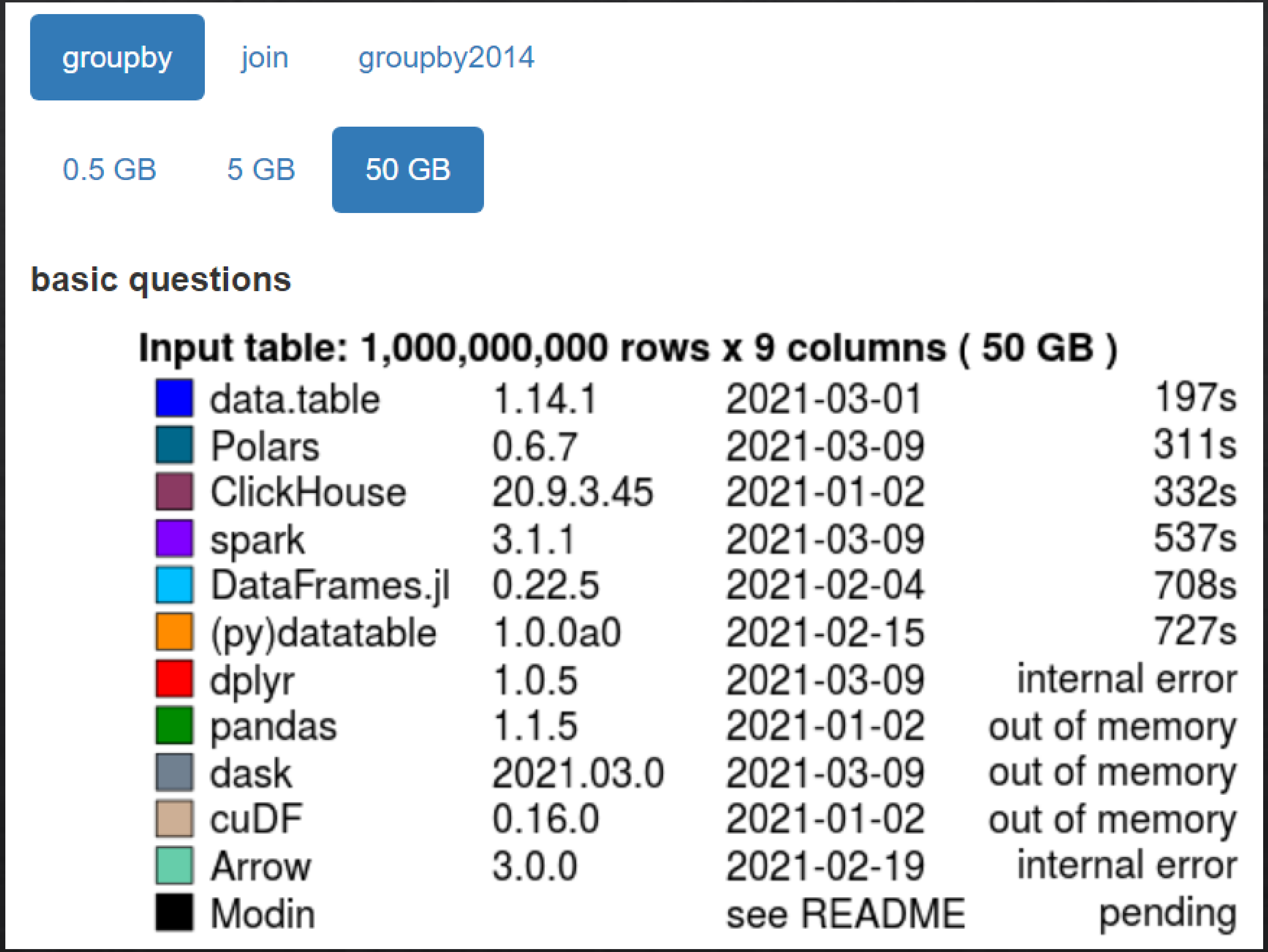
basic questions

Input table: 10,000,000 rows x 7 columns (0.4 GB)

🟫	cuDF	0.16.0	2021-01-02	2s
🟦	Polars	0.6.7	2021-03-09	6s
🟦	data.table	1.14.1	2021-03-01	8s
🟪	ClickHouse	20.9.3.45	2021-01-02	22s
🟥	dplyr	1.0.5	2021-03-09	29s
🟪	spark	3.1.1	2021-03-09	41s
🟩	pandas	1.1.5	2021-01-02	56s
🟦	DataFrames.jl	0.22.5	2021-02-04	129s
🟧	(py)datatable	1.0.0a0	2021-02-15	195s
⬜	dask	2021.03.0	2021-03-09	938s
🟩	Arrow	3.0.0	2021-02-19	not yet implemented
⬛	Modin		see README	pending

https://h2oai.github.io/db-benchmark/, 2021-03-15

Performance of data.table


groupby | join | groupby2014

0.5 GB | 5 GB | 50 GB

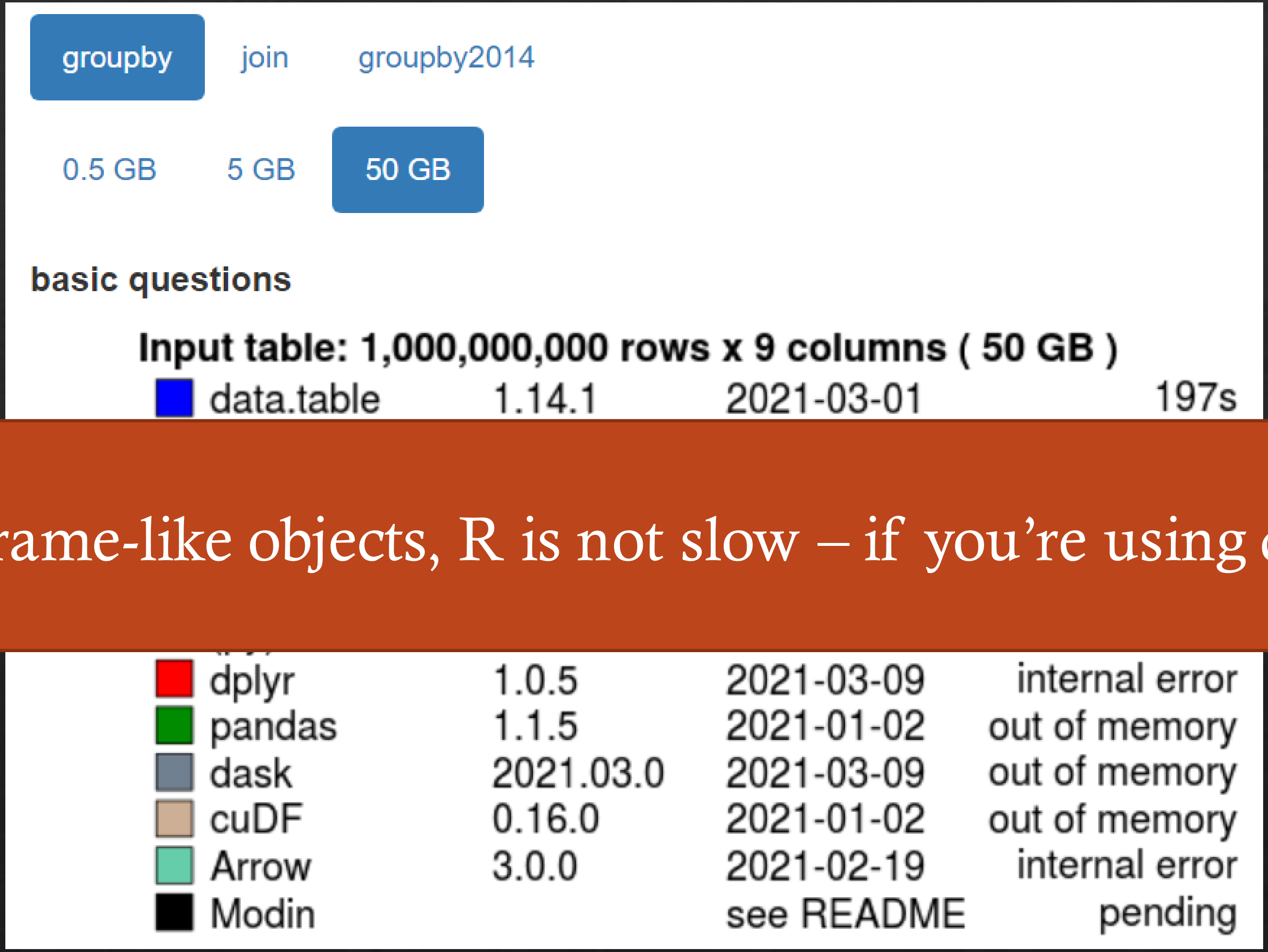
basic questions

Input table: 1,000,000,000 rows x 9 columns (50 GB)

🟦	data.table	1.14.1	2021-03-01	197s
🟦	Polars	0.6.7	2021-03-09	311s
🟪	ClickHouse	20.9.3.45	2021-01-02	332s
🟪	spark	3.1.1	2021-03-09	537s
🟦	DataFrames.jl	0.22.5	2021-02-04	708s
🟧	(py)datatable	1.0.0a0	2021-02-15	727s
🟥	dplyr	1.0.5	2021-03-09	internal error
🟩	pandas	1.1.5	2021-01-02	out of memory
⬜	dask	2021.03.0	2021-03-09	out of memory
🟫	cuDF	0.16.0	2021-01-02	out of memory
🟩	Arrow	3.0.0	2021-02-19	internal error
⬛	Modin		see README	pending

https://h2oai.github.io/db-benchmark/, 2021-03-15

Performance of data.table



basic questions

Input table: 1,000,000,000 rows x 9 columns (50 GB)

🟦	data.table	1.14.1	2021-03-01	197s
🟥	dplyr	1.0.5	2021-03-09	internal error
🟩	pandas	1.1.5	2021-01-02	out of memory
■	dask	2021.03.0	2021-03-09	out of memory
■	cuDF	0.16.0	2021-01-02	out of memory
■	Arrow	3.0.0	2021-02-19	internal error
⬛	Modin		see README	pending

for data.frame-like objects, R is not slow – if you're using data.table!

https://h2oai.github.io/db-benchmark/, 2021-03-15

What makes data.table so fast?

- Speed has been the main focus of data.table during its whole development
- Efficient algorithms (C code)
- Internal structure of data.tables
- Less in-memory copying
- Low-level multi-threading

- When using data.table, most of this will happen internally, so you can code “normally” and still achieve a high efficiency

Not just fast, a clear syntax as well!

- Data.table has a syntax that is different from base R
- “Come for the performance, stay for the syntax” – Elio Campitelli, R blogger
- Concise
- Consistent
- DT[i, j, by]
  - i: what rows
  - j: what to do
  - by: by what groups
- More on this in the walkthrough…

Not just fast, a clear syntax as well!

- Tidyverse also offers an alternative syntax to base R
  - Verbose
  - Verbs as functions
  - Pipes
- Data.table
  - More alike query languages such as SQL
  - Closer to base-R
- Which one is "better" ultimately comes down to preference, but to get optimal performance, you'll have to use at least some of the data.table syntax
- dtplyr package (https://cran.r-project.org/web/packages/dtplyr/index.html)

Short comparison syntax of data.table and tidyverse

Tidyverse	data.table
`DF %>% group_by(z) %>% summarise(sum(y))`	`DT[, sum(y), by = z]`
`ans <- DF %>% group_by(z) %>% mutate(y = cumsum(y))`	`DT[, y := cumsum(y), by = z]`
`DF %>% filter(x>2) %>% group_by(z) %>% summarise(sum(y))`	`DT[x > 2, sum(y), by = z]`
`ans <- DF %>% group_by(z) %>% mutate(y = replace(y, which(x > 2), cumsum(y)))`	`DT[x > 2, y := cumsum(y), by = z]`

https://stackoverflow.com/questions/21435339

Short comparison syntax of data.table and tidyverse

Tidyverse	data.table

```
diamondsDF %>%
  filter(cut != "Fair") %>%
  group_by(cut) %>%
  summarize(
    AvgPrice = mean(price),
    MedianPrice = as.numeric(median(price)),
    Count = n()
  ) %>%
  arrange(desc(Count))
```
	```
	diamondsDT[
	  cut != "Fair",
	  .(AvgPrice = mean(price),
	    MedianPrice = as.numeric(median(price)),
	    Count = .N
	  ),
	  by = cut
	][
	  order(-Count)
	]
	```

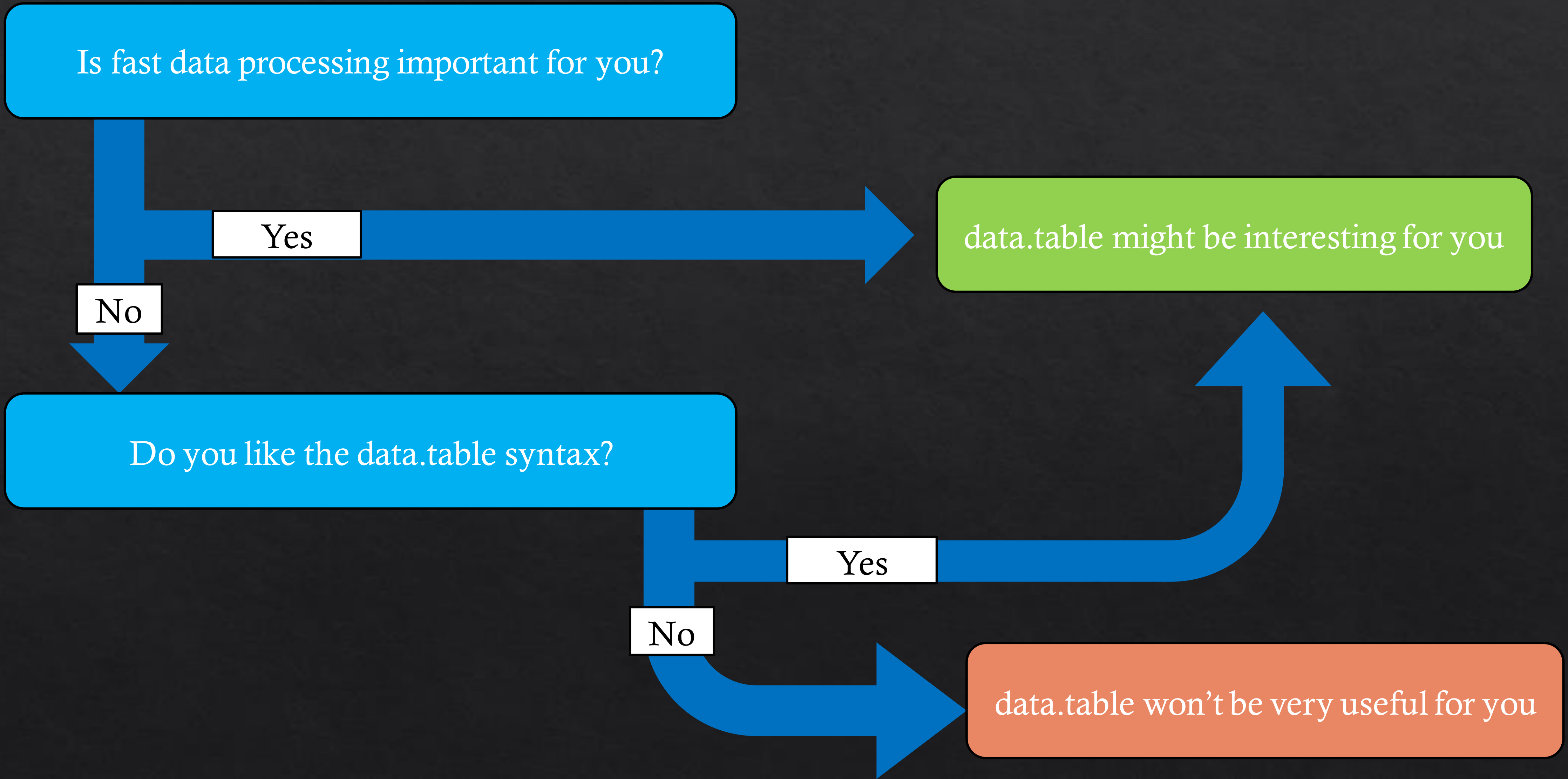
https://stackoverflow.com/questions/21435339

But combinations are possible!

data.table with pipes

```
library(magrittr)
library(ggplot2)
temperature %>%
   .[level == 1000] %>%
   .[, mean(air), by = .(lat, lon)] %>%
   .[lat > 0] %>%
   ggplot(aes(lon, lat)) +
   geom_raster(aes(fill = V1), interpolate = TRUE)
```

Should you use data.table?


Is fast data processing important for you?
Yes
No
data.table might be interesting for you
Do you like the data.table syntax?
Yes
No
data.table won't be very useful for you

In summary

- data.table is very fast on especially large datasets
  - Significantly faster than many alternatives
  - File size needs to be large to notice difference
- Consistent and concise syntax
  - We'll learn how to work with this during the walkthrough
- To the hands-on part!

Outline

- What is data.table (extension to data.frame) Package creator Matt Dowle. Website link. Already in R for a long time.
- Why this presentation: I like data.table a lot, helped me write better code, not advertised that much. But especially the speed argument may be very relevant for GLEON!
- First presentation (15 min.), then walkthrough R script, then questions/exercises
- Speed! Internal optimisation, update by reference. R still has the reputation of being a slow language, but actually…
- Show benchmark website (faster than base R, Python, tidyverse…) Now the speed argument is important, but realise that you need to have data >100MB to actually notice anything, or many repeated operations.
- Syntax (come for speed, stay for syntax) (quick comparison with tidyverse; concise and consistent vs. Verbose and accessible to non-coders) -> Comes down to preference

Outline

- Syntax is consistent, as it is always i, j, by (some additional arguments possible)
- Some like it, some prefer base R or tidyverse, and in that case, the syntax is a burden when you would like to use the fast computation of data.table. I hope that my walkthrough would in that case help (also consider dtplyr if you like the tidyverse syntax; not as fast as data.table, but it comes a long way)
- Additional upsides: stable, rigorous testing, large community, updates
- I like it a lot, but this is not a sales pitch; essentially, if you need the speed, check it out. If you like the syntax, also check it out.
- I hope that my walkthrough script can simultaneously act as a "cheat sheet" when using data.table for the first time.

- Speed is good, but you should focus on the bottlenecks