GraalVM FastR

Mixed interactive debugging of R and native code with FastR and Visual Studio Code

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GraalVM™

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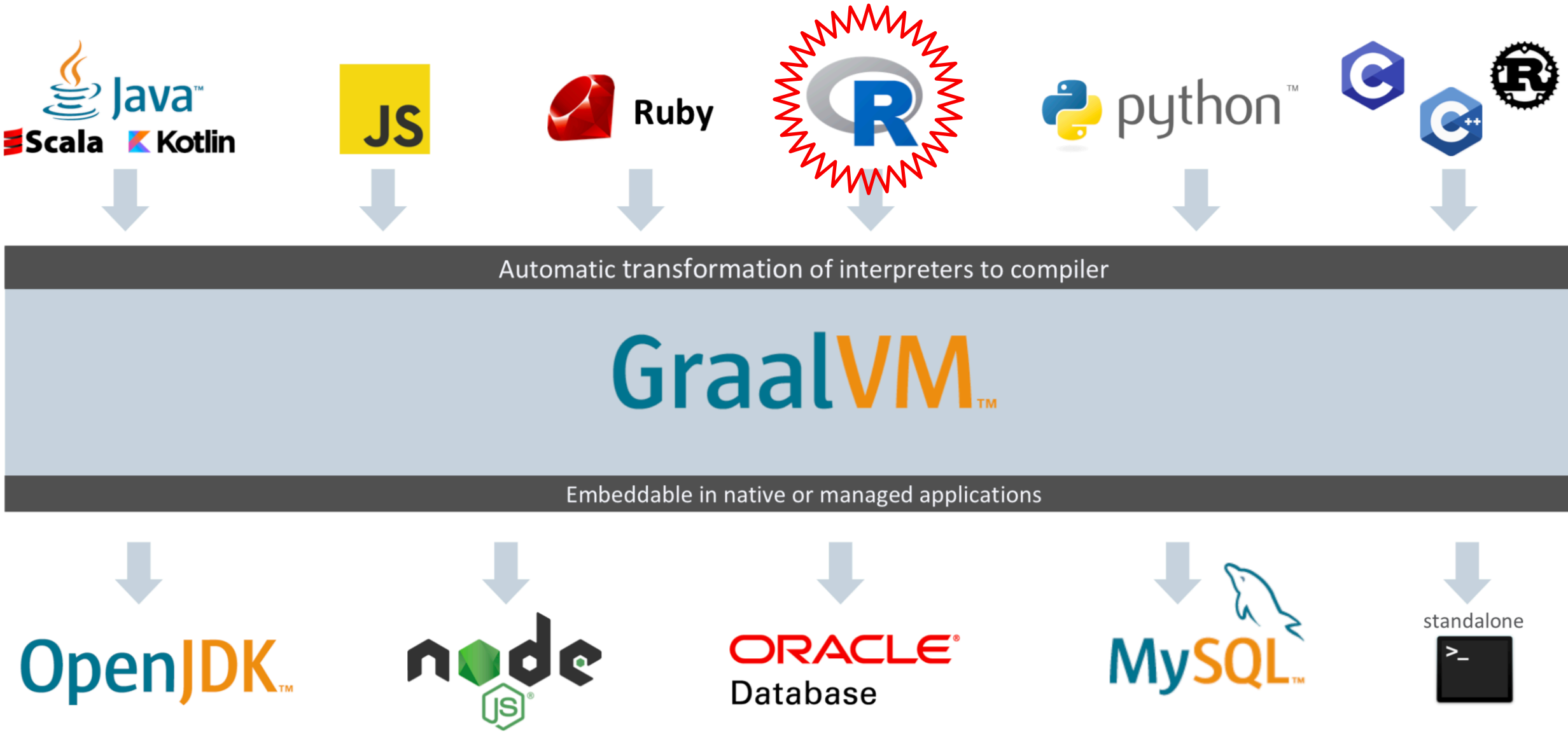
Agenda

- Quick Intro to GraalVM
- FastR Overview
- Debugging Native Code Examples
- Conclusion
- Q&A



Top 5 Things To Do With GraalVM

1. High-performance modern Java (just-in-time mode)
2. Low-footprint, fast-startup Java (ahead-of-time mode)
3. Combine JavaScript, Java, Ruby, Python and **R**
4. Run native languages (e.g. C, Fortran) via LLVM
5. Tools that work across all languages (**debugger**, profiler …)

- *To learn the **Top 10 Things**, visit a comprehensive article by Chris Seaton on https://medium.com/graalvm/graalvm-ten-things-12d9111f307d*

What's FastR?

- An R implementation running on **GraalVM**
- Mature, but still in the **experimental** stage
- Goals
  - Efficient
  - Polyglot
  - Compatible
    - https://www.graalvm.org/docs/reference-manual/compatibility/
  - Embeddable
- Licence: GPLv3

GraalVM Debugger

- GraalVM supports debugging of guest language applications
- Implements ChromeDev Tools protocol
- GraalVM applications can be debugged using, e.g.:
  - Chrome Developer Tools
  - **Visual Studio Code**
- Visit https://www.graalvm.org/docs/reference-manual/tools/

Native Code Debugging Examples - Prerequisites

- GraalVM installed
- FastR installed in GraalVM
- Visual Studio Code installed
- VSC R Plugin installed
- Debugging examples cloned from GitHub
- The examples folder added to VSC workspace
- Visit **fastr-mixed-debug** in https://github.com/graalvm/examples repository for detailed information

Example 1: Debugging Simple Native Code

- Agenda
  - How to debug a **simple R and C code** using FastR and GraalVM debugger
  - How to use **Visual Studio Code** and the **R plugin** to debug the code
  - How to use FastR's **LLVM backend** to debug native code
  - How **FastR objects** are displayed when debugging **native** code
  - https://youtu.be/xc9mS09B7Fk

Debugging Simple Native Code

`lapplyNative.c`

```c
#include <R.h>
#include <Rdefines.h>

SEXP lapplyNative(SEXP list, SEXP fn, SEXP rho) {
    int n = length(list);
    SEXP R_fcall, ans;

    R_fcall = PROTECT(lang2(fn, R_NilValue));
    ans = PROTECT(allocVector(VECSXP, n));
    for(int i = 0; i < n; i++) {
        SETCADR(R_fcall, VECTOR_ELT(list, i));
        SET_VECTOR_ELT(ans, i, eval(R_fcall, rho));
    }
    setAttrib(ans, R_NamesSymbol,
        getAttrib(list, R_NamesSymbol));
    UNPROTECT(2);
    return ans;
}
```

`lapplyNative.R`

```r
lapplyNative <- function (x, fun, env = new.env()) {
    .Call("lapplyNative", x, fun, env)
}
```

```
R CMD SHLIB -o lapplyNative.so lapplyNative.c
```

```
> dyn.load("lapplyNative.so")
> source("lapplyNative.R")
> x <- list(a = 1:5, b = rnorm(10))
> lapplyNative(x, sum)
$a
[1] 15

$b
[1] -1.45445
```

Source: https://cran.r-project.org/doc/manuals/r-release/R-exts.html#Named-objects-and-copying

Debugger Activation in FastR

- Launch FastR with this additional argument
  - `--inspect` — activates the GraalVM debugger

Enable LLVM Debugging in FastR

- To debug **native** code, FastR must be instructed to use the **LLVM** version of **shared** libraries
  - The LLVM bitcode is **bundled** with a shared library during **compilation**
  - Native code is compiled by the **GraalVM LLVM toolchain** (clang)
  - The **LLVM** bitcode is **interpreted** just as another GraalVM language
- Use these **LLVM-related** additional arguments
  - `--R.BackEndLLVM` — to instruct FastR to use the LLVM version of libs
  - `--R.DebugLLVMLibs` — to enable debugging of the LLVM bitcode

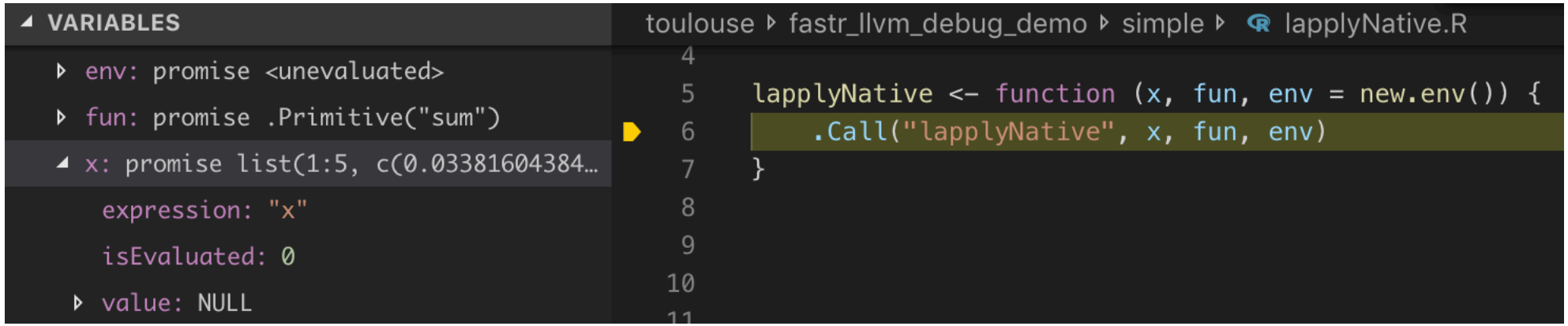
Attaching Visual Studio Code to GraalVM Debugger

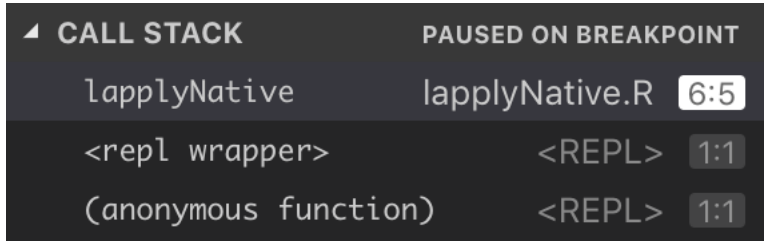
```
bash-3.2$ R --inspect --inspect.Suspend=false --R.BackEndLLVM --R.DebugLLVMLibs
Debugger listening on port 9229.
To start debugging, open the following URL in Chrome:
    chrome-devtools://devtools/bundled/js_app.html?ws=127.0.0.1:9229/1fbc7afb-2f50d632a8171
```

Note: The URL can be copied and pasted to Chrome to start debugging in DevTools

Debugging in Visual Studio Code

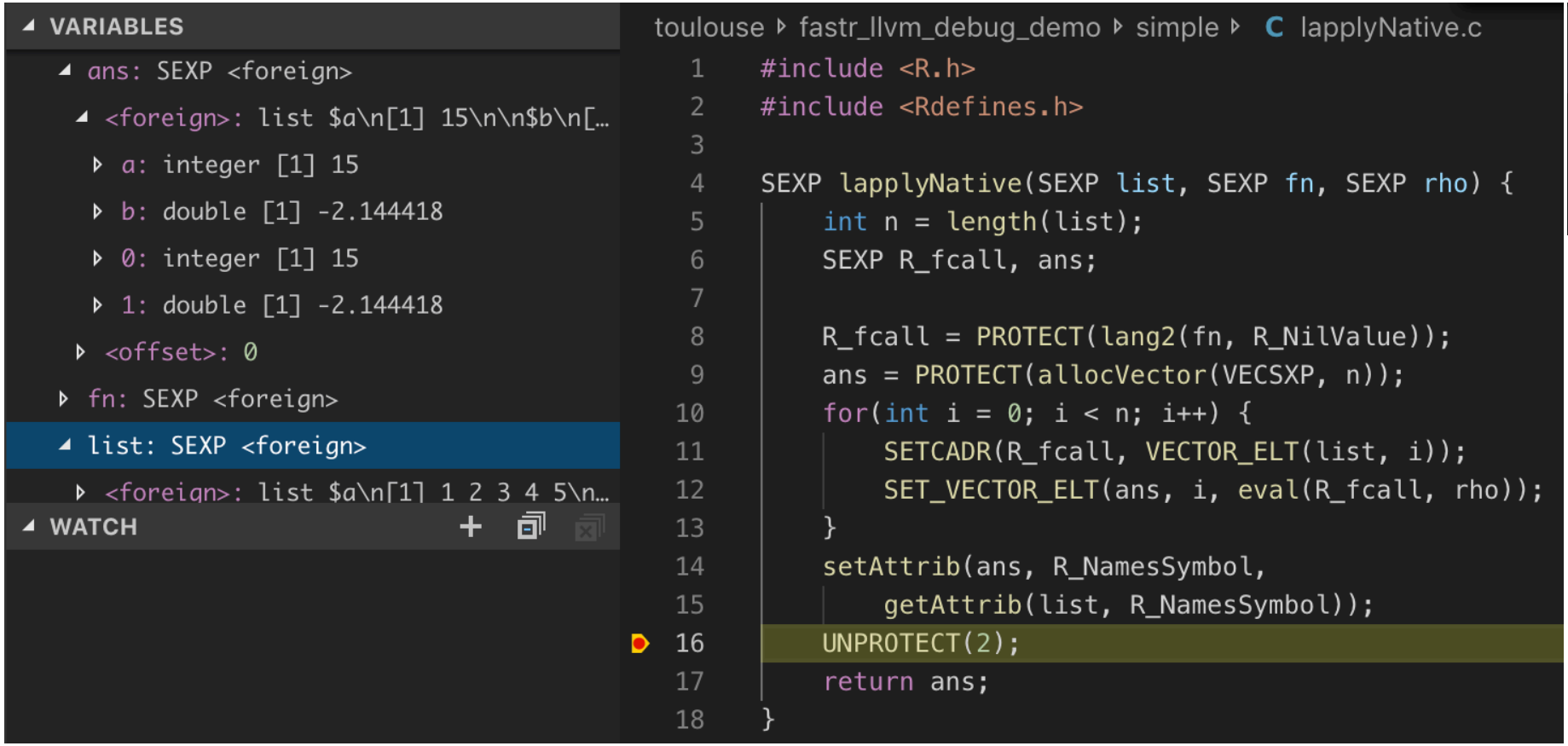
- Locate `lapplyNative.R` in VSC Explorer and toggle a breakpoint in the `lapplyNative` function
- Execute `lapplyNative` again

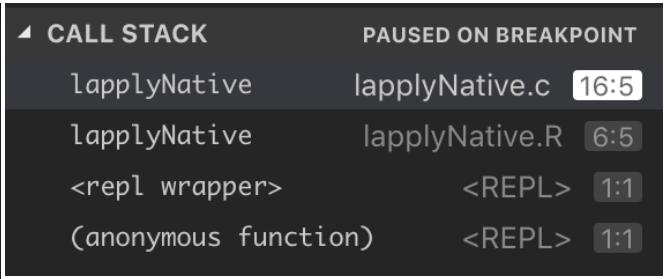




Debugging in Visual Studio Code

- Locate `lapplyNative.c`, toggle a breakpoint and press F5





Example 2: A Package With Rcpp Code

- Agenda
  - Debugging a package containing **Rcpp** code
  - Stepping into and debugging **Rcpp functions**
- Prerequisites
  - Rcpp 1.0.0 installed from the unpacked **source tarball**
    - `R CMD INSTALL package-sources/Rcpp`
  - The **gibbs** sampler example installed
    - `R CMD INSTALL ./gibbs`
    - `http://adv-r.had.co.nz/Rcpp.html#rcpp-package` by Hadley Wickham

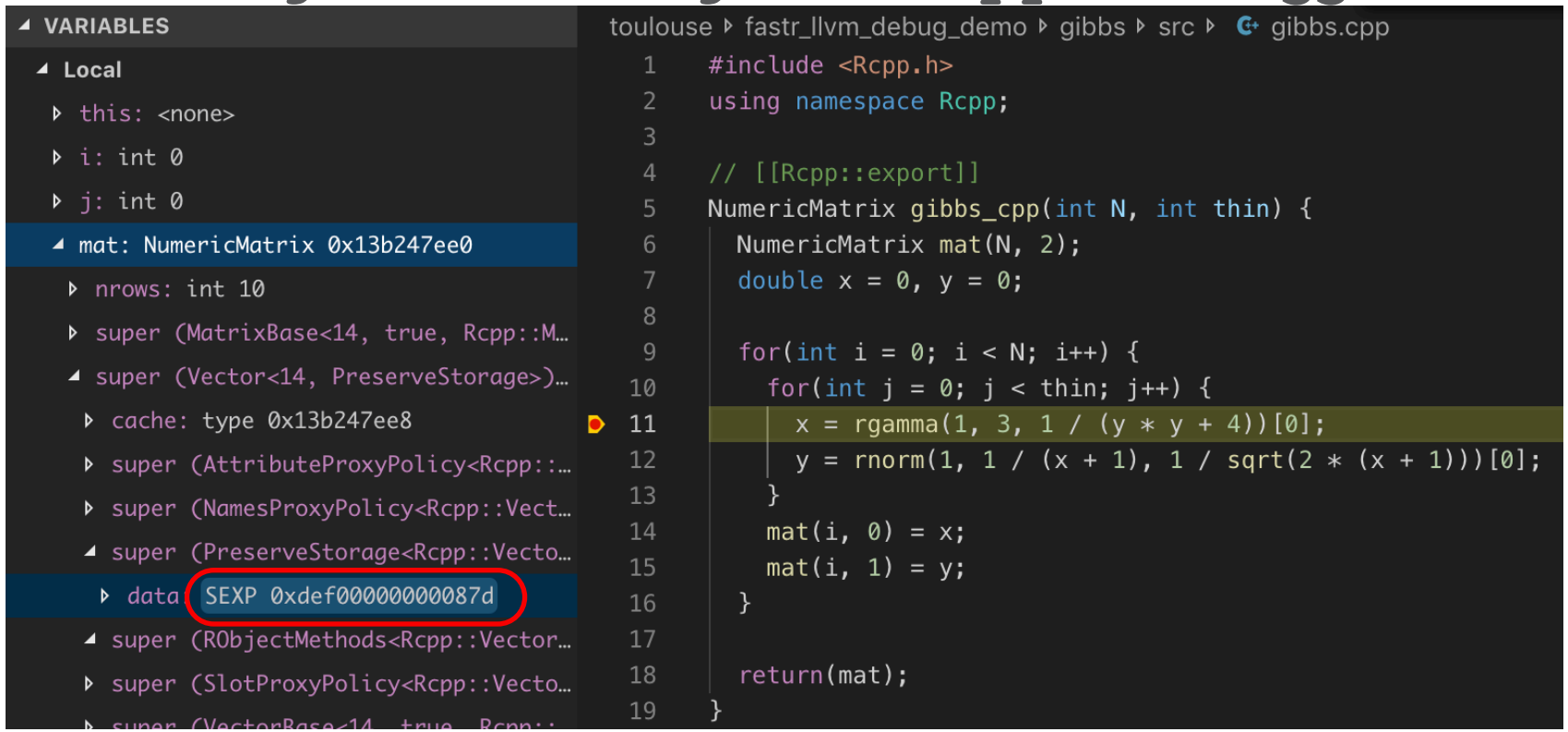
Debugging Rcpp Code

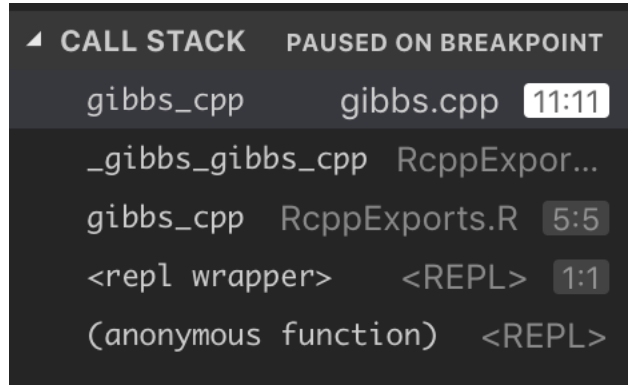
- Launch FastR in debug mode
- Load the gibbs package and execute `gibbs_cpp(100, 10)`

```
> library(gibbs)
> gibbs_cpp(10, 10)
           [,1]      [,2]
 [1,] 0.4922806 0.9848679
 [2,] 0.3332298 0.7986238
 [3,] 0.1811279 2.3413093
 [4,] 0.2363802 2.0305358
 [5,] 0.6196257 0.8939006
 [6,] 0.4226072 0.8424776
 [7,] 0.4207100 0.2881861
 [8,] 0.5958476 0.6877602
 [9,] 0.3973855 1.0024997
[10,] 0.9245635 0.8350409
```

Debugging Rcpp Code (cont.)

- Switch to VSC and attach to the GraalVM debugger
- Locate `gibbs/src/gibbs.cpp` and toggle a breakpoint

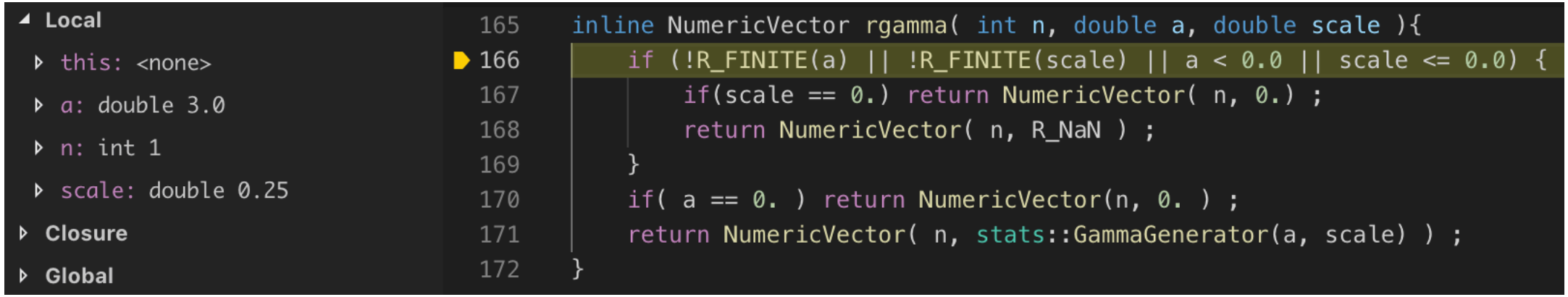


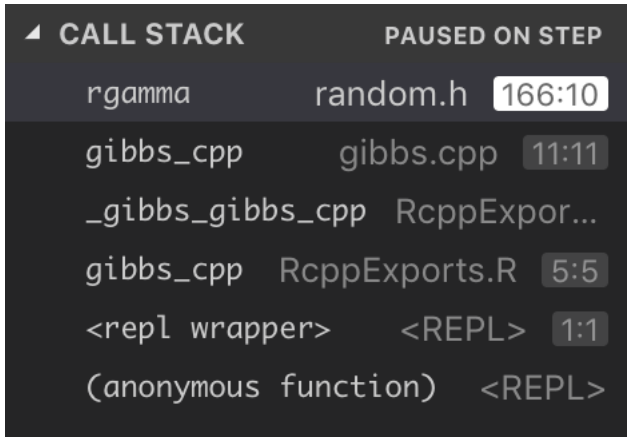


Source: http://adv-r.had.co.nz/Rcpp.html#rcpp-package

Debugging Rcpp Code (cont.)

- Step into the `rgamma` Rcpp function (F11)





Conclusion

- FastR as part of GraalVM provides an advanced support for **mixed debugging** of **native** and **R** code
- **Visual Studio Code** provides a comfortable debugger UI that can be used in tandem with **FastR/GraalVM**

- TODO
  - Completeness of LLVM implementation
  - Displaying “nativized” R objects (esp. Rcpp ones)
  - A better source-paths management for packages installed from CRAN

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Website
http://www.graalvm.org/

Github Repository
https://github.com/oracle/graal
https://github.com/oracle/fastr
https://github.com/graalvm/examples

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Other Links

FastR overview:
https://medium.com/graalvm/faster-r-with-fastr-4b8db0e0dceb

GraalVM compatibility (can be used to check the status of a package):
http://www.graalvm.org/docs/reference-manual/compatibility/

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