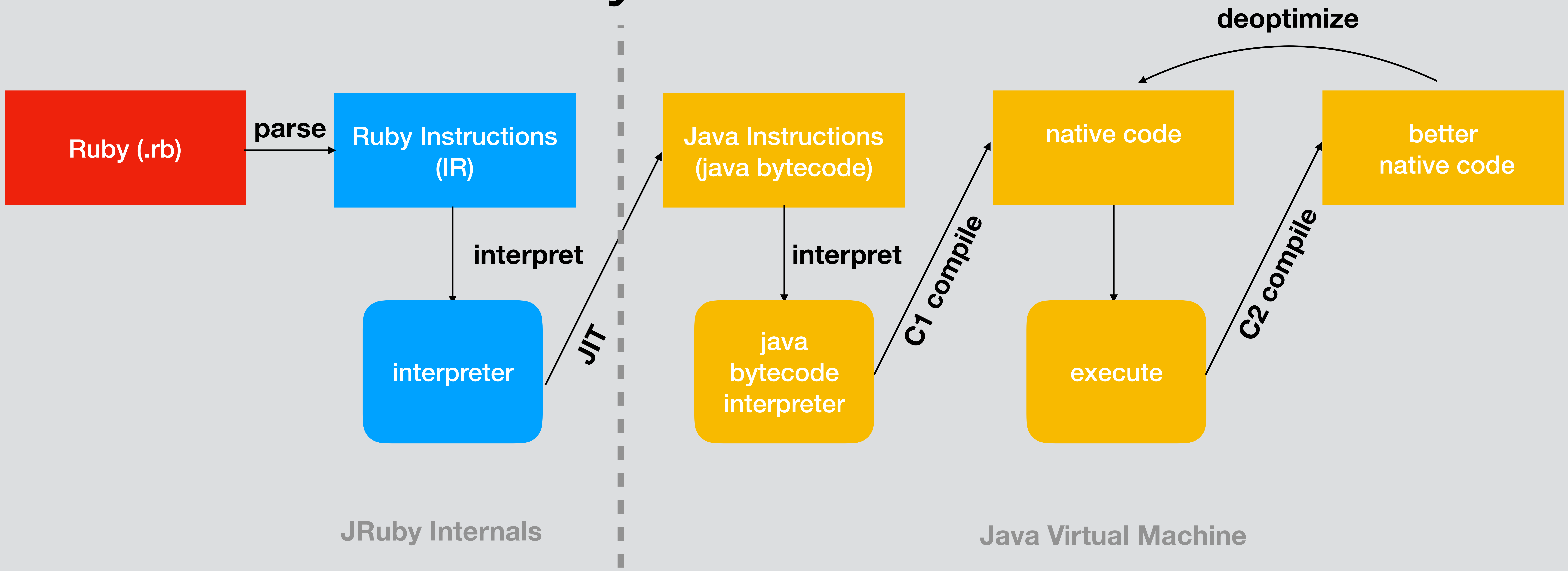
JRuby on Graal

Performance and Startup Experiments

JRuby Review

- Ruby for the **JVM**
  - Two-way integration with Java, fitting into ecosystem
  - We are a Ruby implementation, but also a JVM language
- Core classes largely written in Java
- Parts of core and most of standard library in Ruby
- Distribution like CRuby or as jars/wars, embedded into apps
- No support for CRuby extensions, on purpose

JRuby Architecture



JRuby Challenges

- Java bytecode is a narrow vocabulary
    - InvokeDynamic helps but adds complexity
- Object boxes are too expensive
- Lambda-style code optimizes poorly
- Startup time, memory footprint are crucial for adoption
- Two FTEs barely keeps up with compatibility, user issues

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eazyBI
NASA
IBM
loggly
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JRuby and Graal

History

- Experimented with Maxine back in the day
- Collaborated with TruffleRuby early on
- Investigating JRuby performance on Graal
  - Playing with compiler passes
  - Studying compiler IR, assembly code for opportunities

Today

- JRuby on Graal straight-line performance
  - Microbenchmarks up to small web services
- JRuby native with GraalVM
  - Working POC
  - Plans going forward

Performance

It's a Hard Problem

- Heavy use of invokedynamic
  - Method calls, constants, globals, instance variables, ...
- Limited specialization
  - Object shaping, flattened arrays, frame elimination, splitting
- Looking for new opportunities
  - e.g. "truly final" final fields

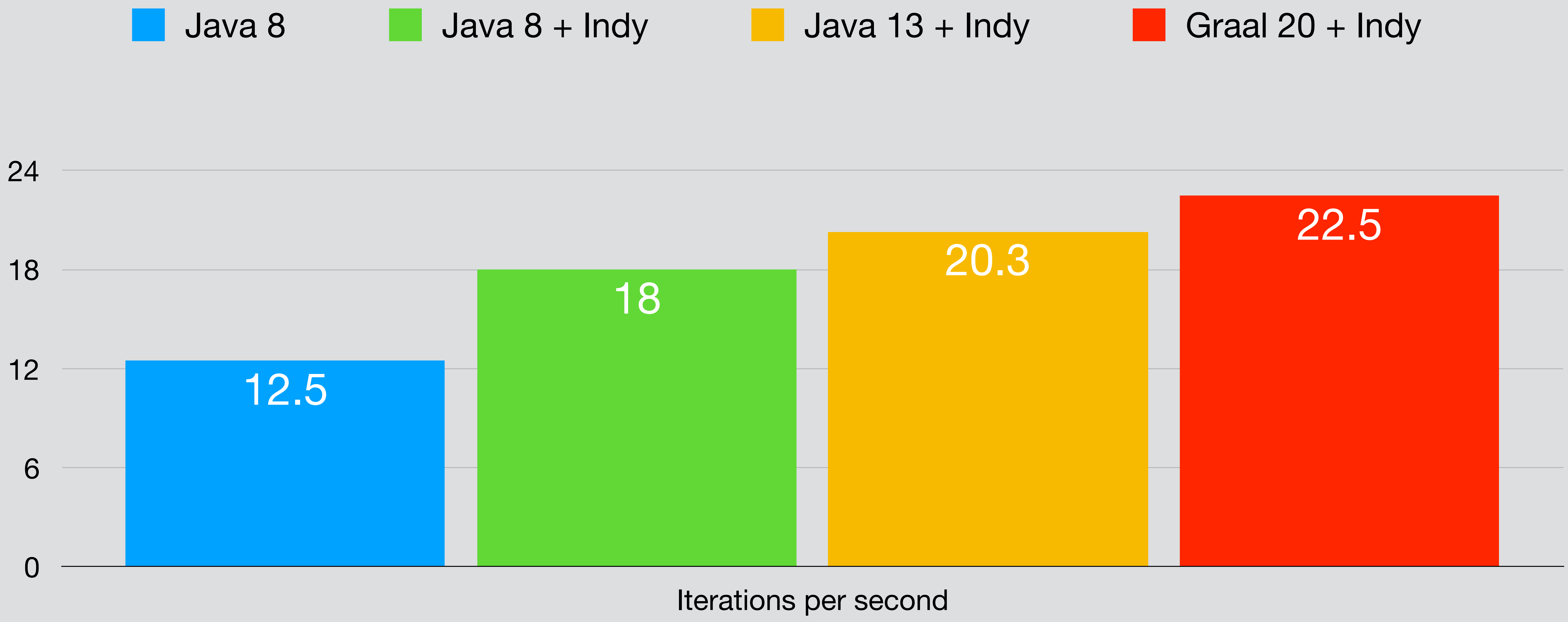
General Notes

- Java 8, Java 13, GraalVM 20
  - Invokedynamic, fixnum caching options
  - Java 13 using -XX:+UseParallelGC
- Iterations or requests per second (higher is better)
- Force compilation to JVM bytecode (no interpreted phase)

Integer Loop

- Simple while loop from zero to 10M
  - "nanobenchmark"
- Small method, simple integer math, conditional looping

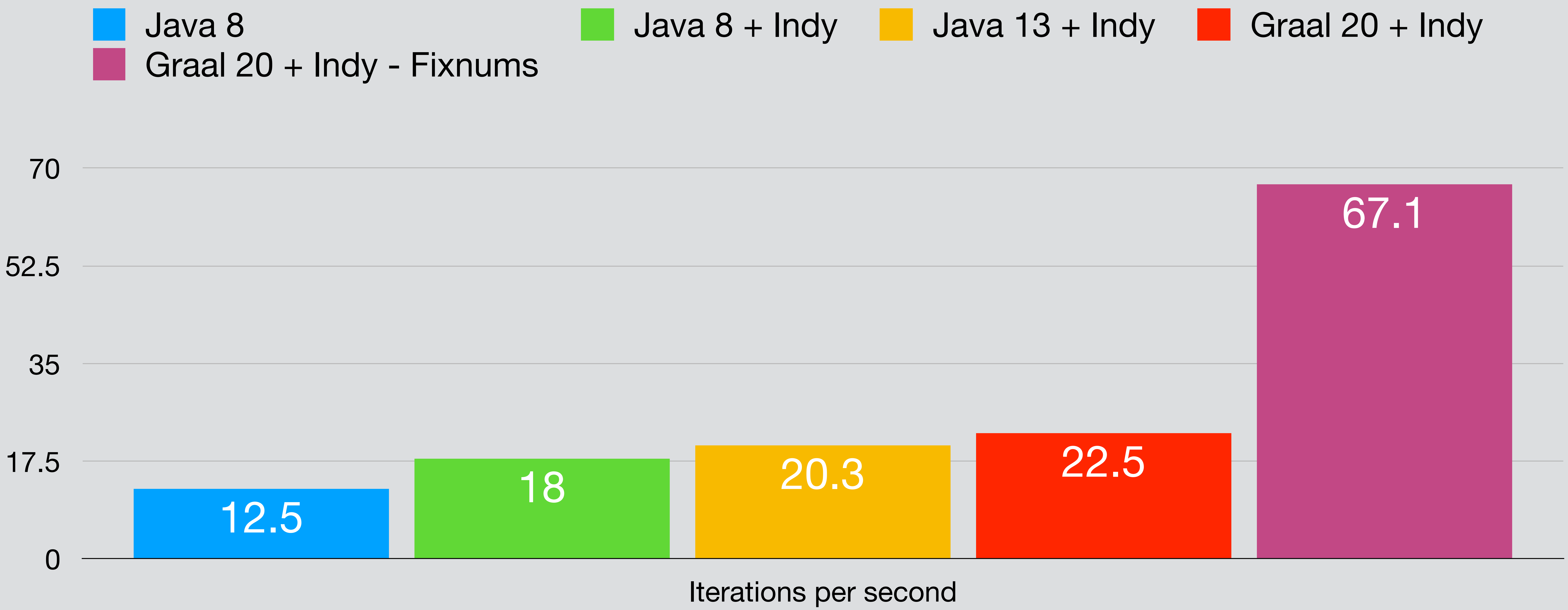
Integer Loop



Helping Graal

- Make more state final
  - Fewer loads, more constant propagation
- Avoid caching elidable objects
  - Mixing real and virtual objects seems to cause problems
  - Added a flag to disable Fixnum cache (like Integer.valueOf)

Integer Loop

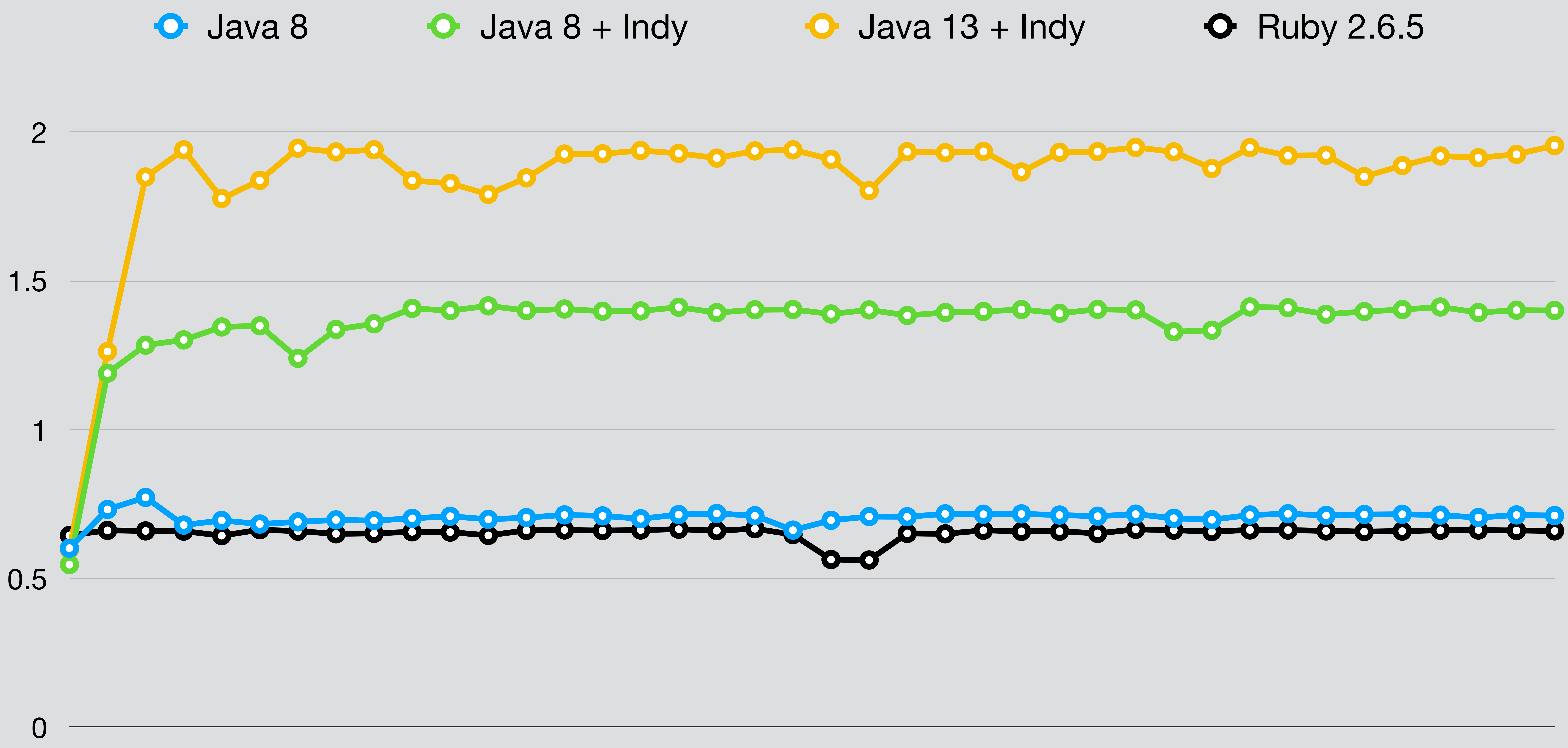


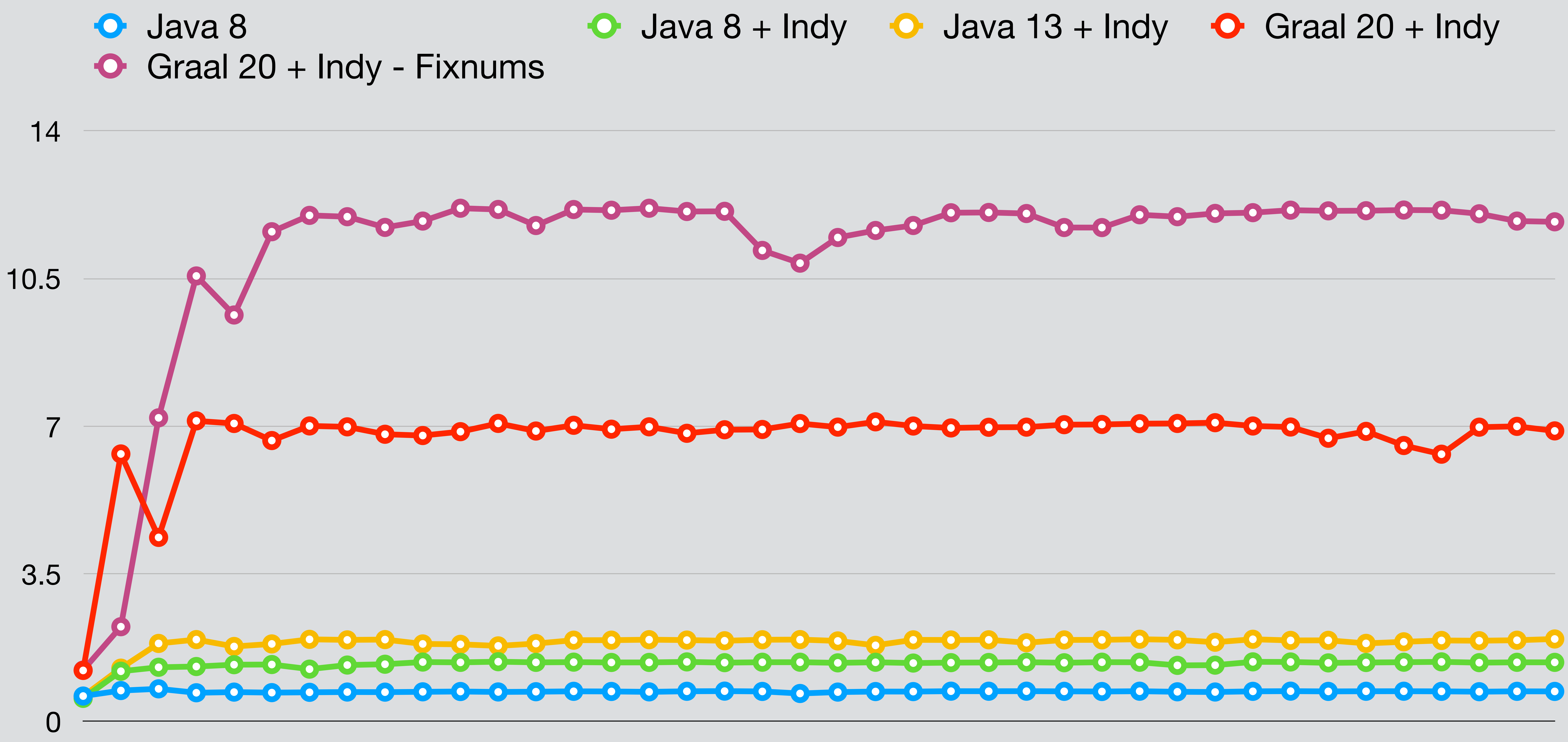
Mandelbrot

- Microbenchmark: one moderately-sized method
- Nearly all numeric computation
  - Reasonable baseline for numeric algorithm performance
- Worst case for JRuby on most JVMs
  - 100% boxed numerics
  - Allocation rather than GC is the bottleneck

Mandelbrot Optimizations

- Final references to Boolean objects, core classes
- Keep literal numerics as primitives
- Avoid caching Fixnum objects

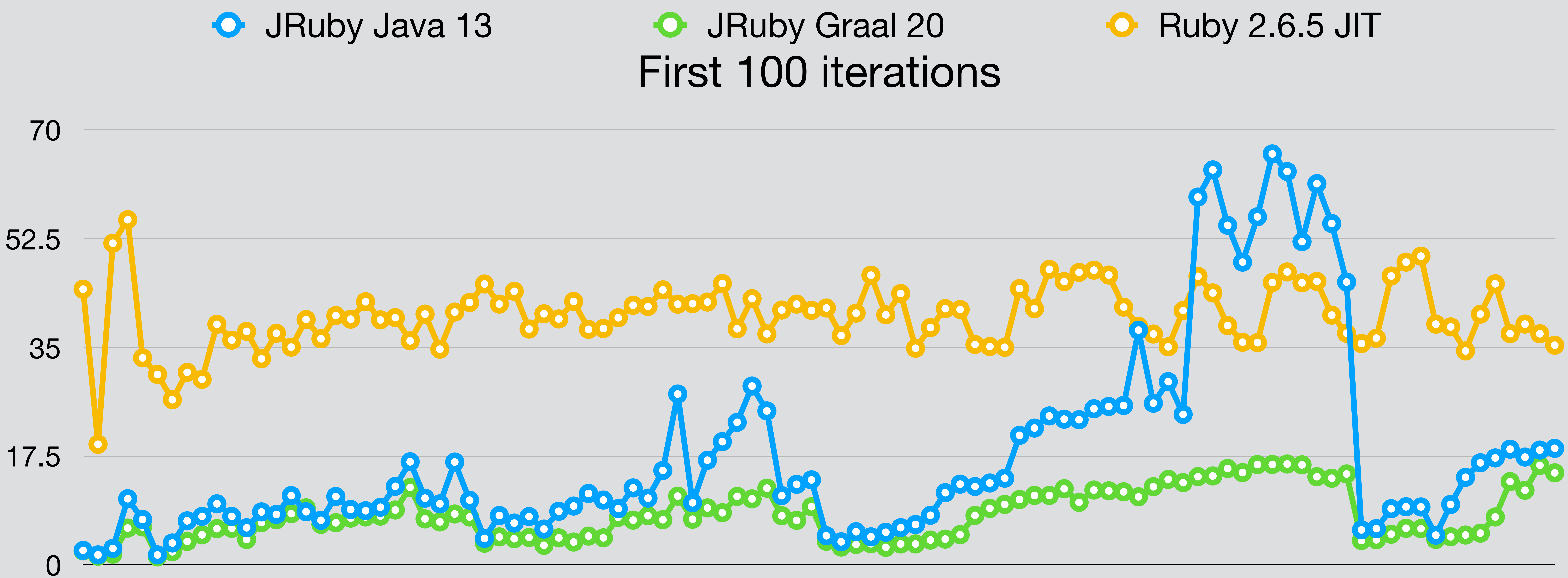

Java 8
Java 8 + Indy
Java 13 + Indy
Ruby 2.6.5
2
1.5
1
0.5
0


Java 8
Java 8 + Indy
Java 13 + Indy
Graal 20 + Indy
Graal 20 + Indy - Fixnums
14
10.5
7
3.5
0

Optcarrot

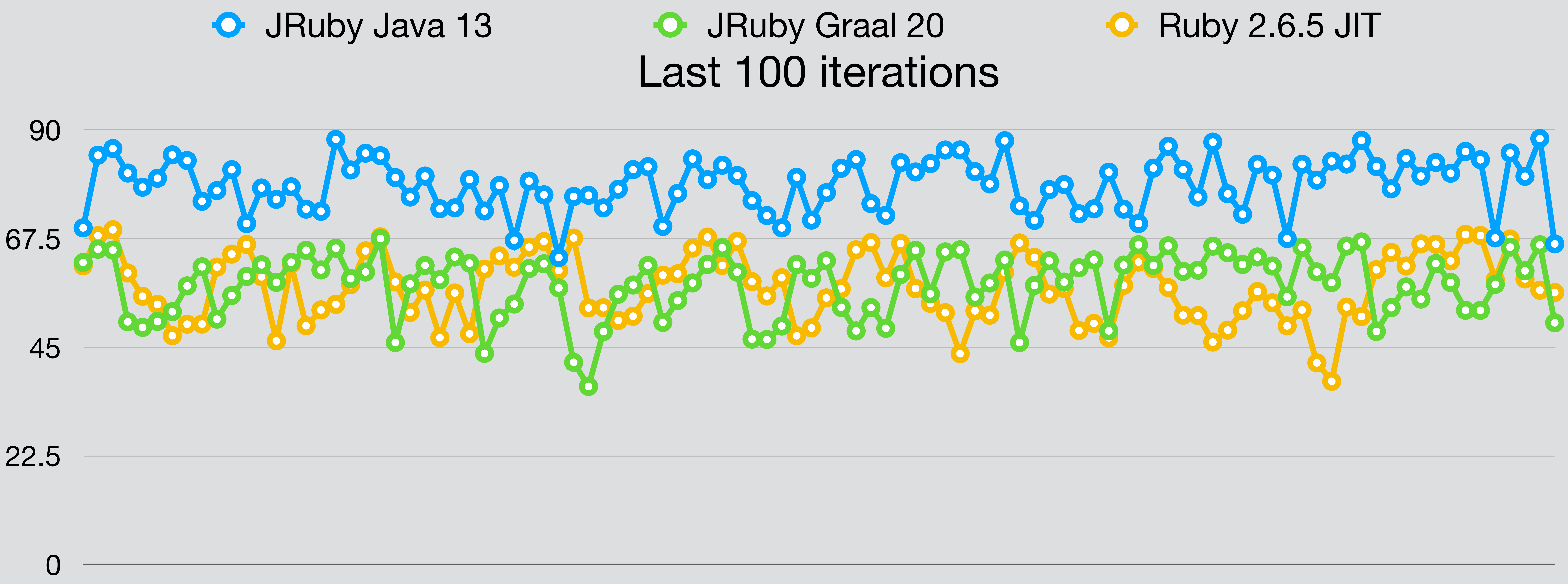
- Nintendo Entertainment System emulator in pure Ruby
- Heavy use of simulated memory (integer arrays), dynamic dispatch
- Very little optimization work on JRuby side

Optcarrot



JRuby Java 13
JRuby Graal 20
Ruby 2.6.5 JIT
First 100 iterations
70
52.5
35
17.5
0

Optcarrot



JRuby Java 13
JRuby Graal 20
Ruby 2.6.5 JIT
Last 100 iterations
90
67.5
45
22.5
0

Applications

- Roda
  - Microservice-style web framework
- Rails
  - Heavily dependent on ActiveRecord performance
- CRuby vs JRuby, JRuby + Graal

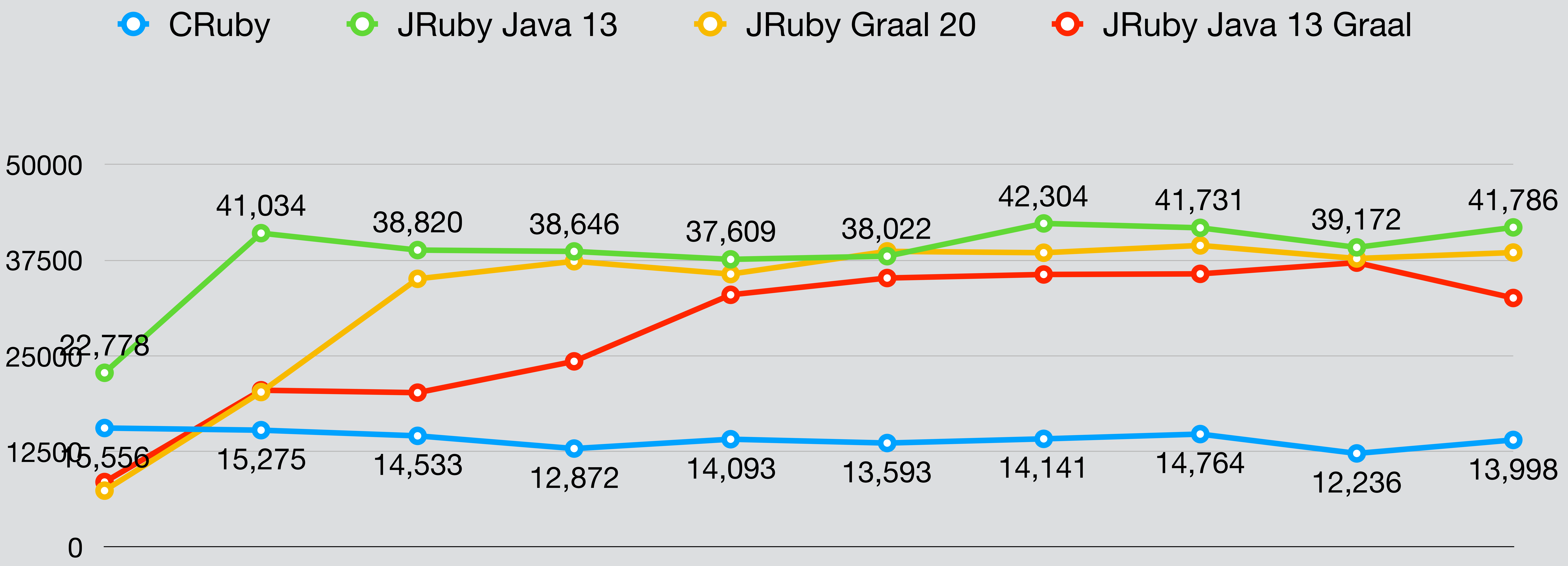
Roda

- Small, well-supported service framework
  - Many production users at large scales
- Very simple example with no database
  - Benchmarking request routing mostly
- Good indicator of small app performance

Setup

- CRuby: 8 processes
- JRuby: 8 threads
- Driver: wrk with 16 connections, 2 reactor threads

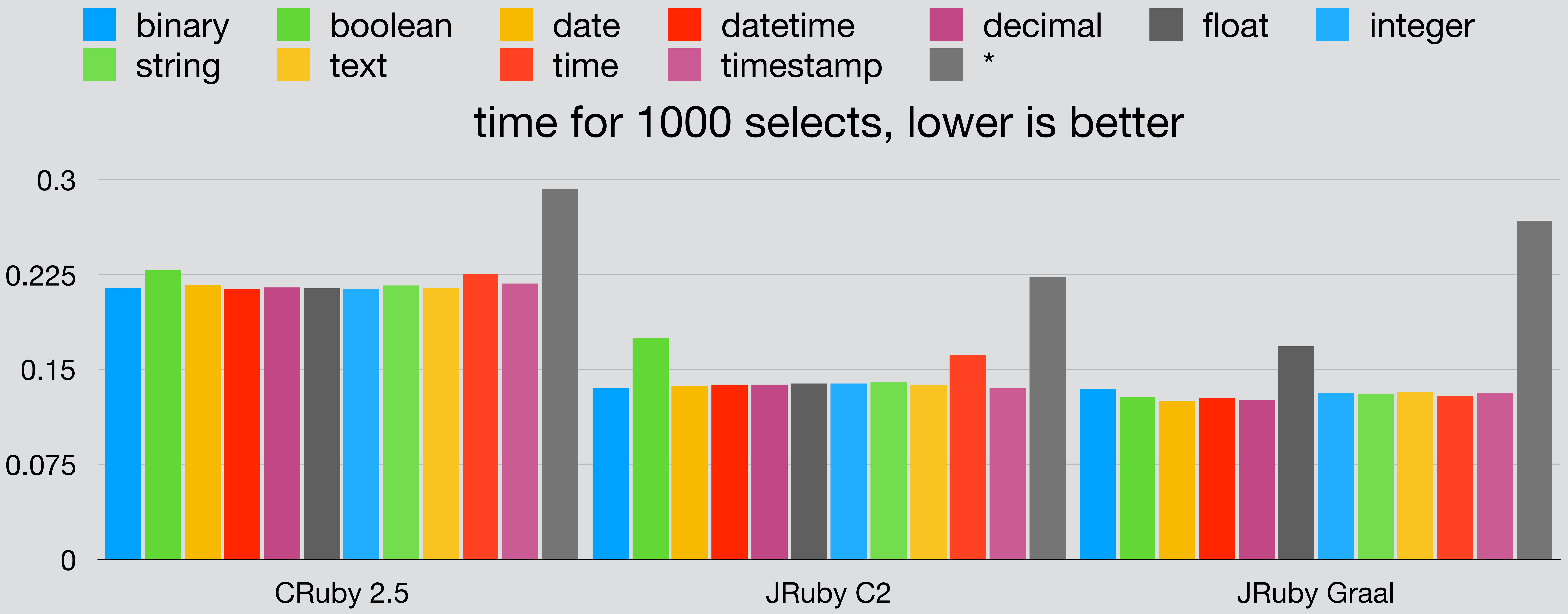
Roda Full Concurrency



ActiveRecord Performance

- Rails apps live and die by ActiveRecord
  - Largest CPU consumer by far
  - Heavy object churn, GC overhead
- Create, read, and update measurements
- CRuby 2.5.1 vs JRuby 9.2 on JDK11

ActiveRecord Selects

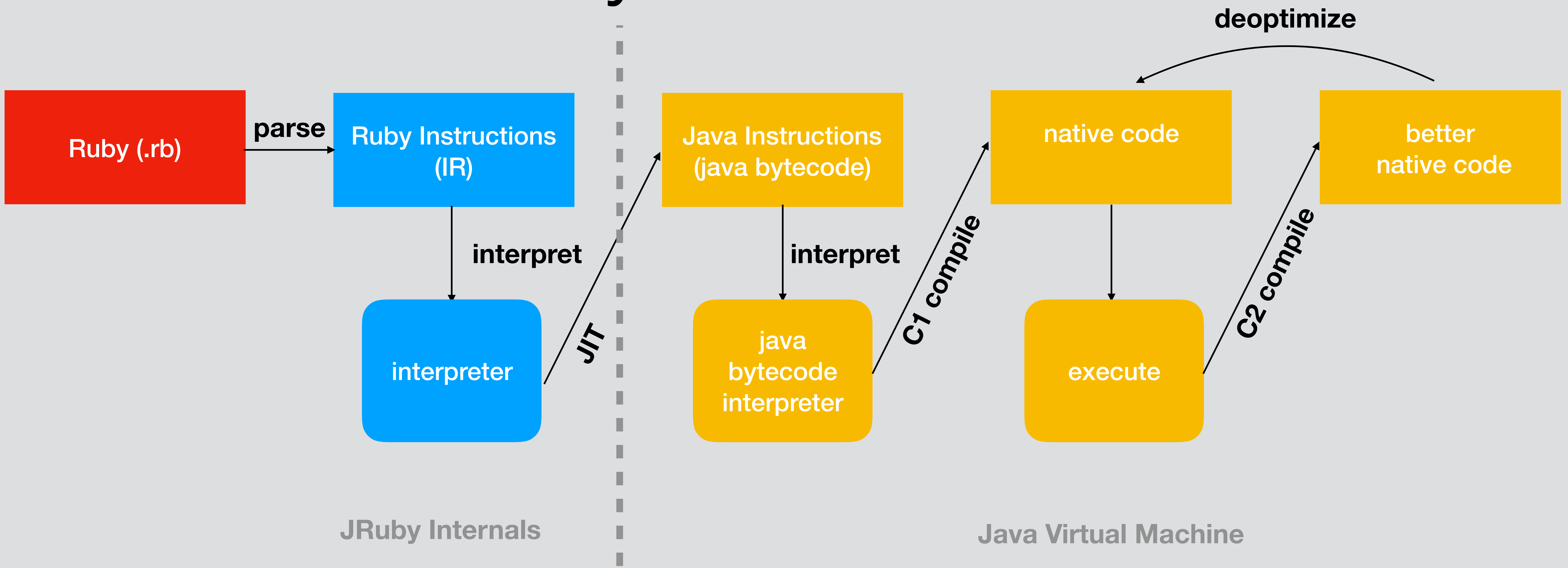


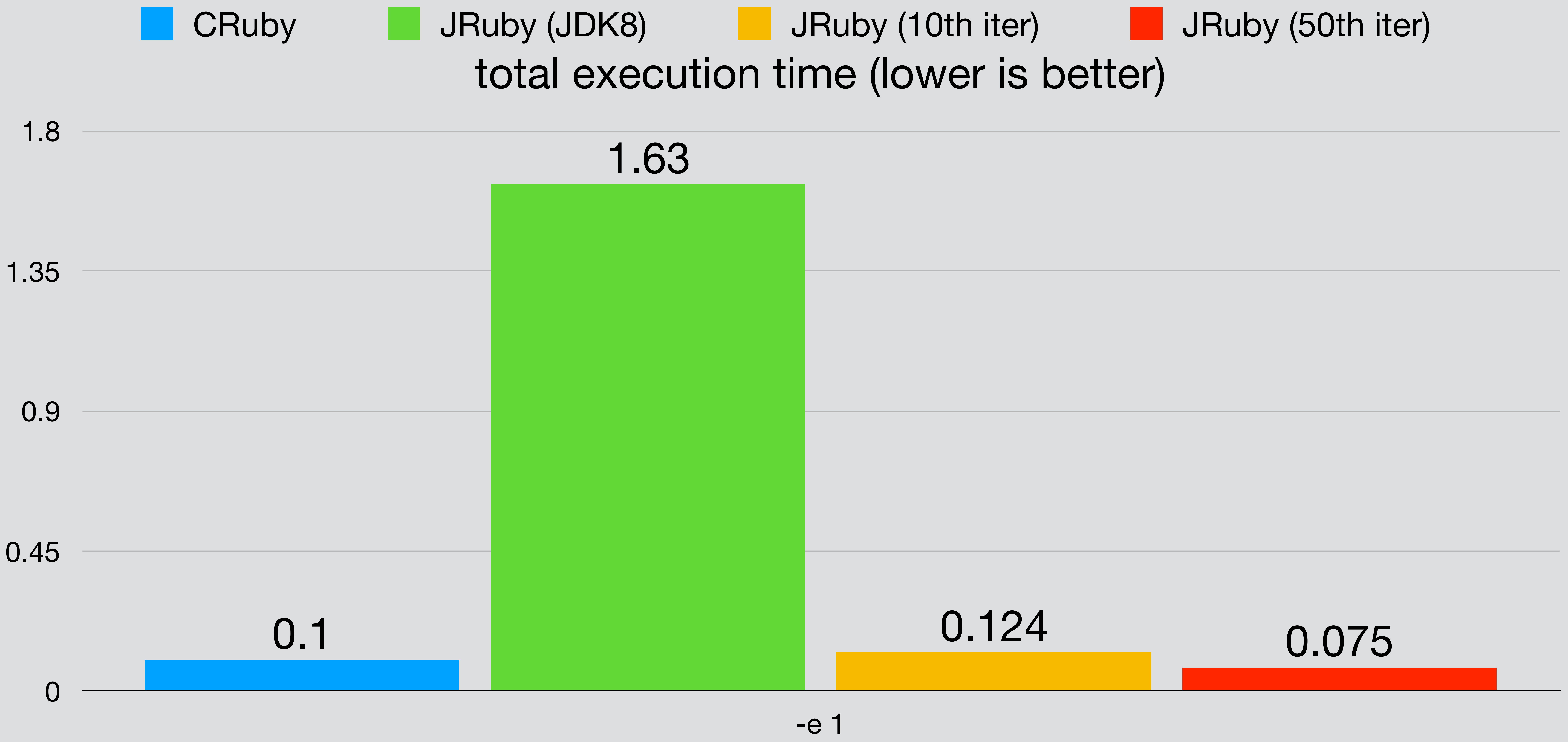
JRuby + Graal

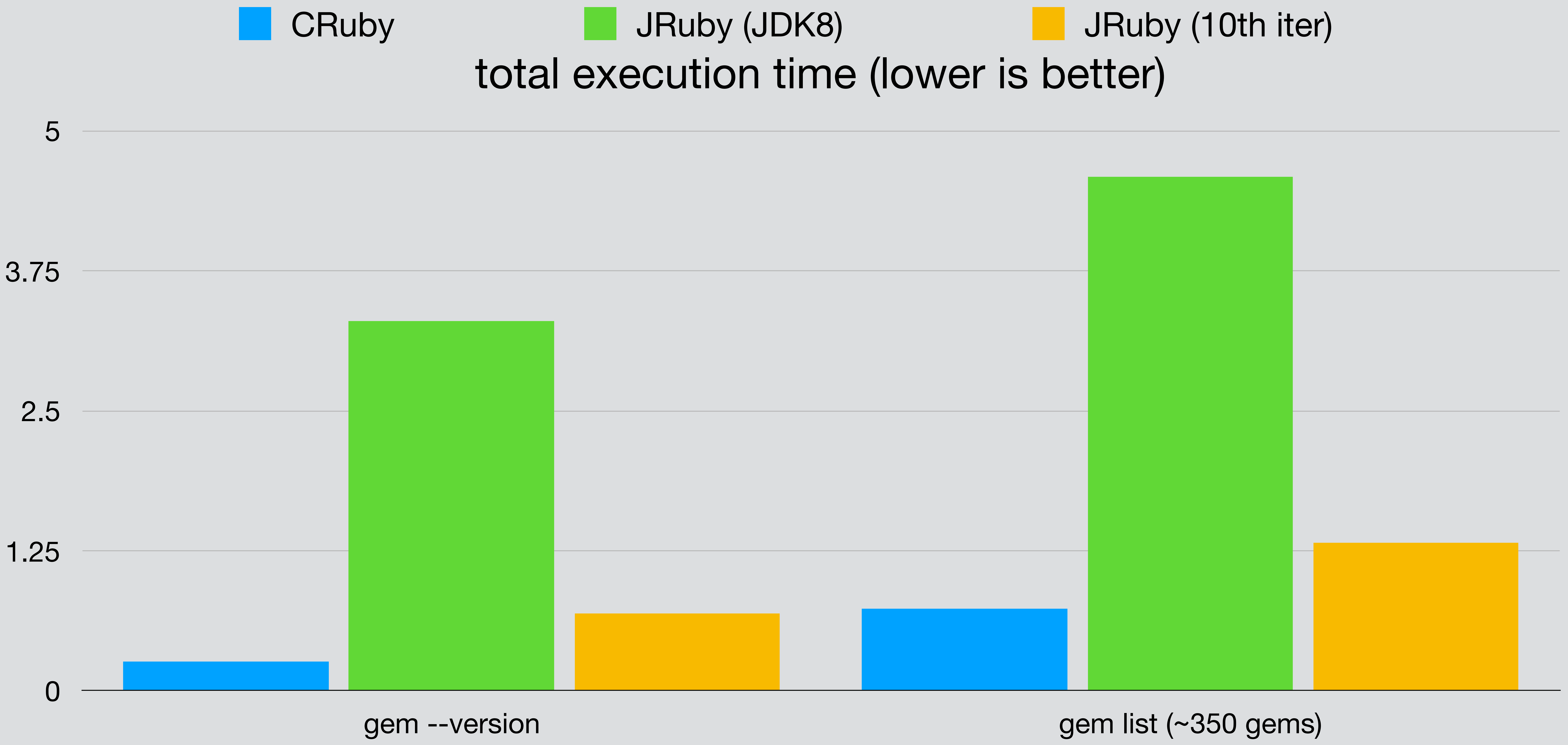
- Clear wins for small, object-heavy benchmarks
- Larger applications are a mixed bag
  - Need to dig deeper and see why
- Potential to be the fastest way to run JRuby
  - Applicable to other languages and libraries on JVM

Startup

JRuby Architecture




CRuby
JRuby (JDK8)
JRuby (10th iter)
JRuby (50th iter)
total execution time (lower is better)
1.8
1.35
0.9
0.45
0
1.63
0.1
0.124
0.075
-e 1



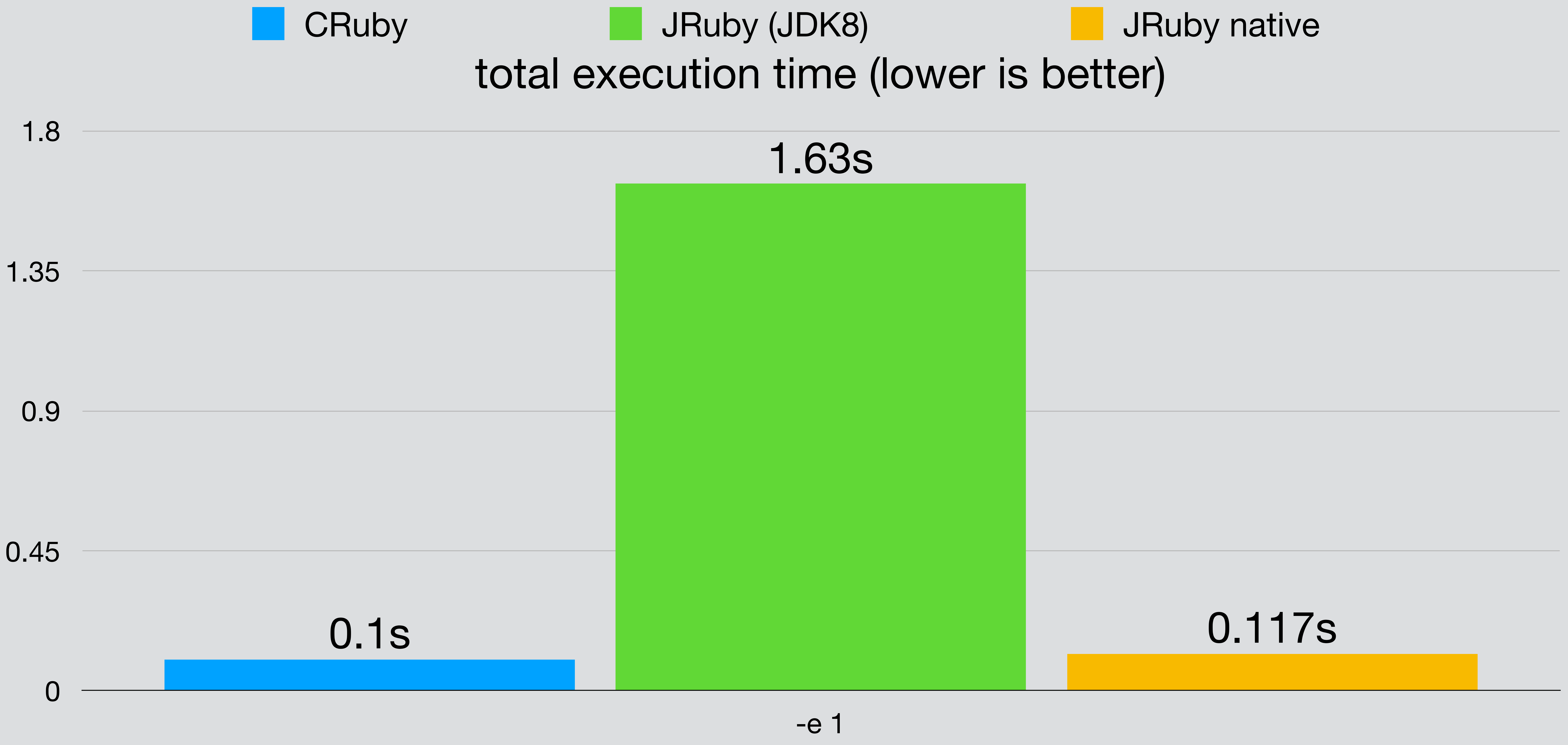
CRuby
JRuby (JDK8)
JRuby (10th iter)
total execution time (lower is better)
5
3.75
2.5
1.25
0
gem --version
gem list (~350 gems)

Startup Experiments

- Preboot or reuse JVM process
- Save parse results, compiled IR
- Precompile to native

GraalVM Native Image

- Compile all of JRuby to native (working POC)
  - Build times in 2-3min range... not bad
- Many limitations
  - No invokedynamic, limited reflection, no dynamic classloading, ...
- Eventual goal: fully native Ruby apps (no startup or warmup)
  - Compile Ruby to bytecode, and then to native
  - Good for tools, microservices


CRuby
JRuby (JDK8)
JRuby native
total execution time (lower is better)
1.8
1.35
0.9
0.45
0
1.63s
0.1s
0.117s
-e 1

Bytecode AOT Mode

- AOT mode: No indy at all
  - A bit more bytecode generated
  - Only direct method handles or LambdaMetaFactory objects
- Cold bytecodes reduced vs normal precompile

Next Steps

- Compile Ruby app + library sources to native
  - Needed bytecode AOT to proceed
- Static optimizations
- Remove unneeded parts of JRuby
- Probably limited to small services, command line tools
  - libjruby?

Thank you!

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