Go GC:
Prioritizing Low Latency and Simplicity

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My Codefendants: The Cambridge Runtime Gang

https://upload.wikimedia.org/wikipedia/commons/thumb/2/2f/Sato_Tadanobu_with_a_goban.jpeg/500px-Sato_Tadanobu_with_a_goban.jpeg

Go: A Language for Scalable Concurrency

Lightweight threads (Goroutines)
Channels for communication
GC for scalable APIs
Simple Foreign Function Interface

Simplicity: The Key to Success

Go: A Language for Scalable Open Source Projects

Do Less, Enable More

- Learning
- Implementation
- Tooling
- Reading
- Understanding

Sharing

Go: A Runtime for Scalable Applications

This is the story of Go's garbage collector

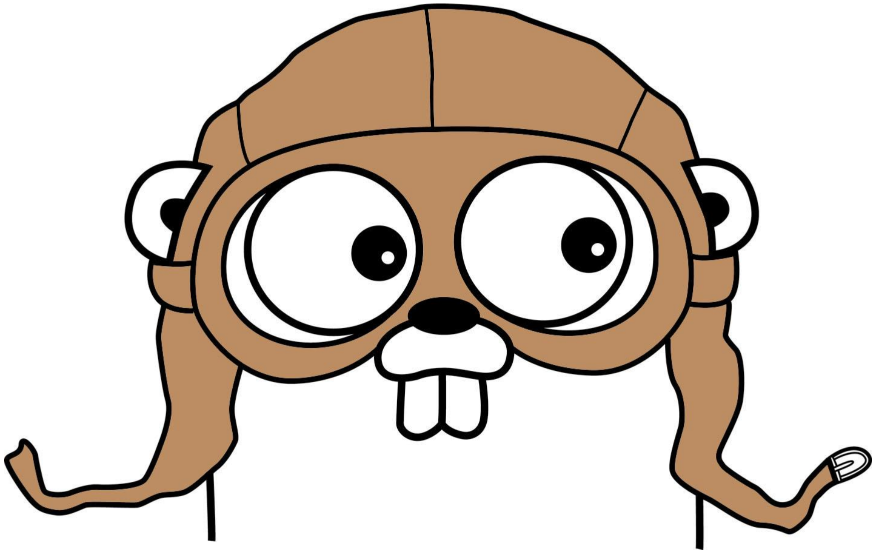


Image by Renee French

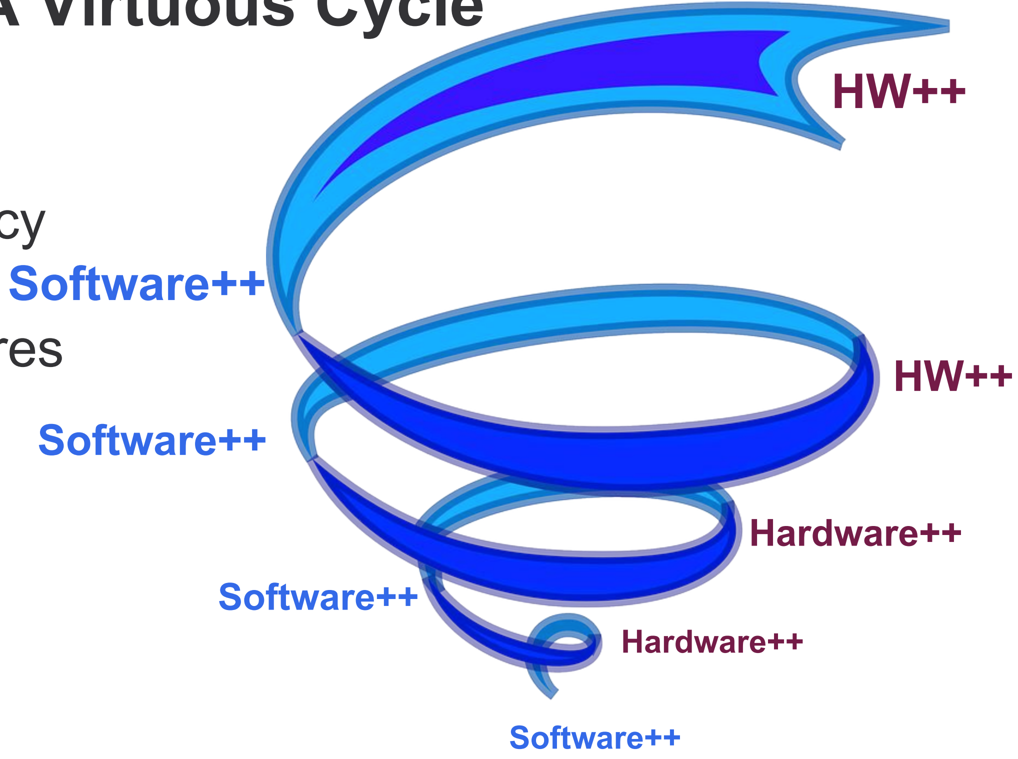
Making Go Go: Establish A Virtuous Cycle

News Flash:
- 2X Transistors != 2X Frequency

More transistors == more cores
- Only if software uses more cores

Long term
- Establish a virtuous cycle

Short term
- Increase Go Adoption

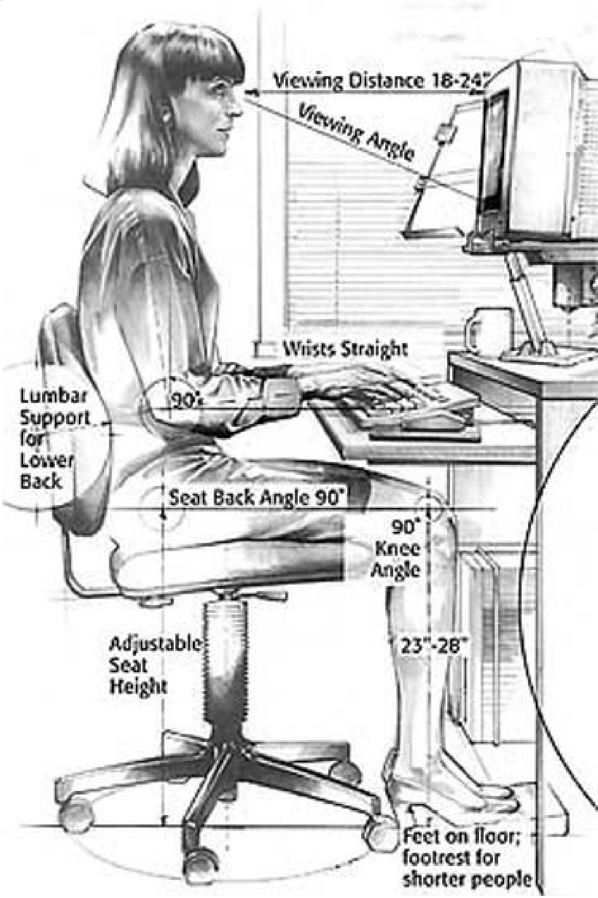


#1 Barrier: GC Latency

When is the best time to do a GC?

When nobody is looking.

> Using camera to track eye movement
> When subject looks away do a GC.



https://upload.wikimedia.org/wikipedia/commons/3/35/Computer_Workstation_Variables.jpg

Pop up a network wait icon

https://commons.wikimedia.org/wiki/File:WIFI_icon.svg#globalusage

Or

Trade A Little Throughput for Reduced GC Latency

Latency

Nanosecond

1: Grace Hopper Nanosecond 11.8 inches

Microsecond

5.4: Time light travels 1 mile in vacuum

Millisecond

1: Read 1 MB sequentially from SSD

20: Read 1 MB from disk

50: Perceptual Causality (cursor response threshold)

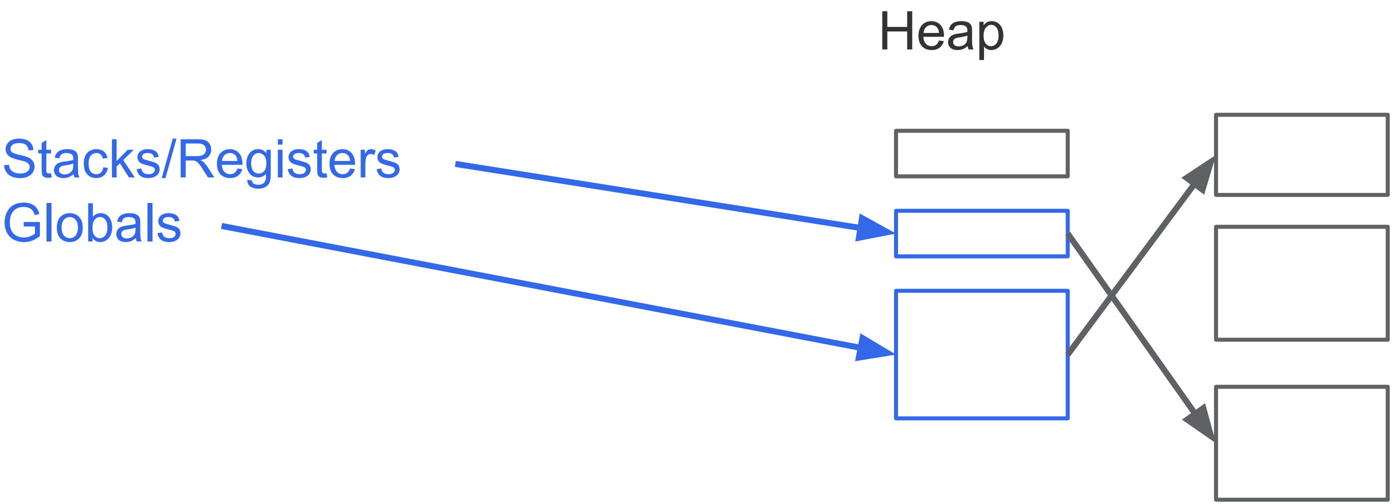
50+: Various network delays

Saccades (ms)
30 Reading
200 Involuntary

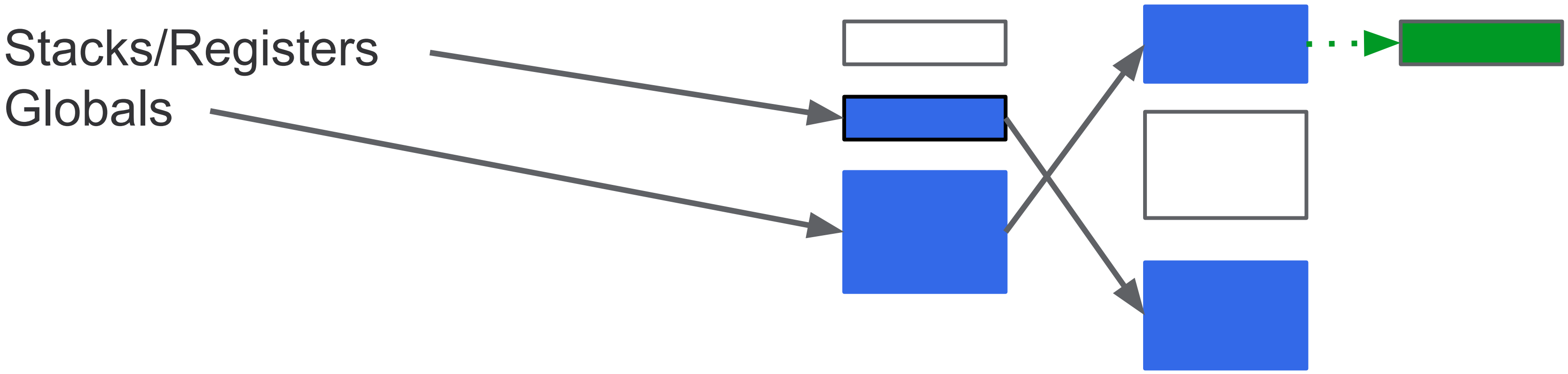
Eye Blink
300 ms

GC 101

Root Scan Phase



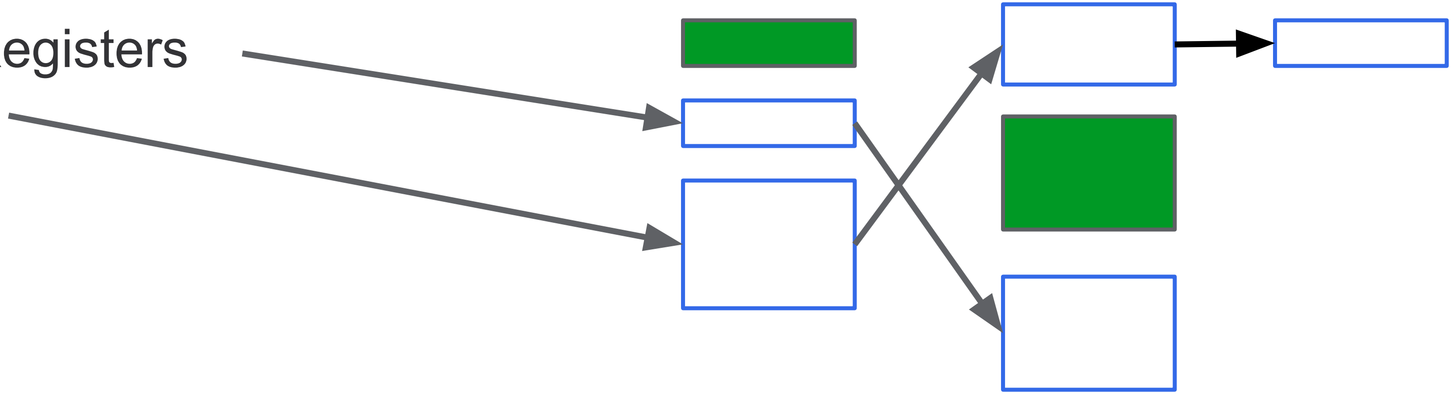
Mark Phase



Righteous Concurrent GC struggles with Evil Application changing pointers

Sweep Phase

Stacks/Registers
Globals

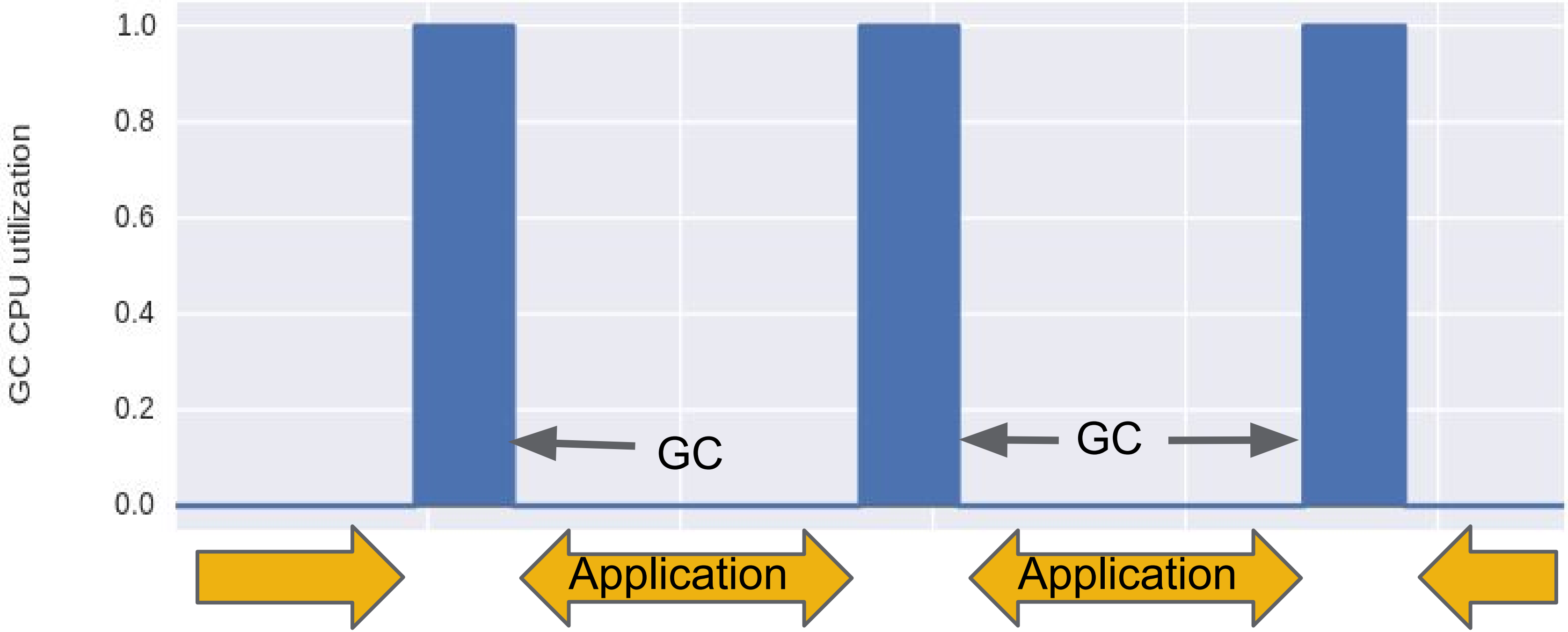


Go isn't Java: GC Related Go Differences

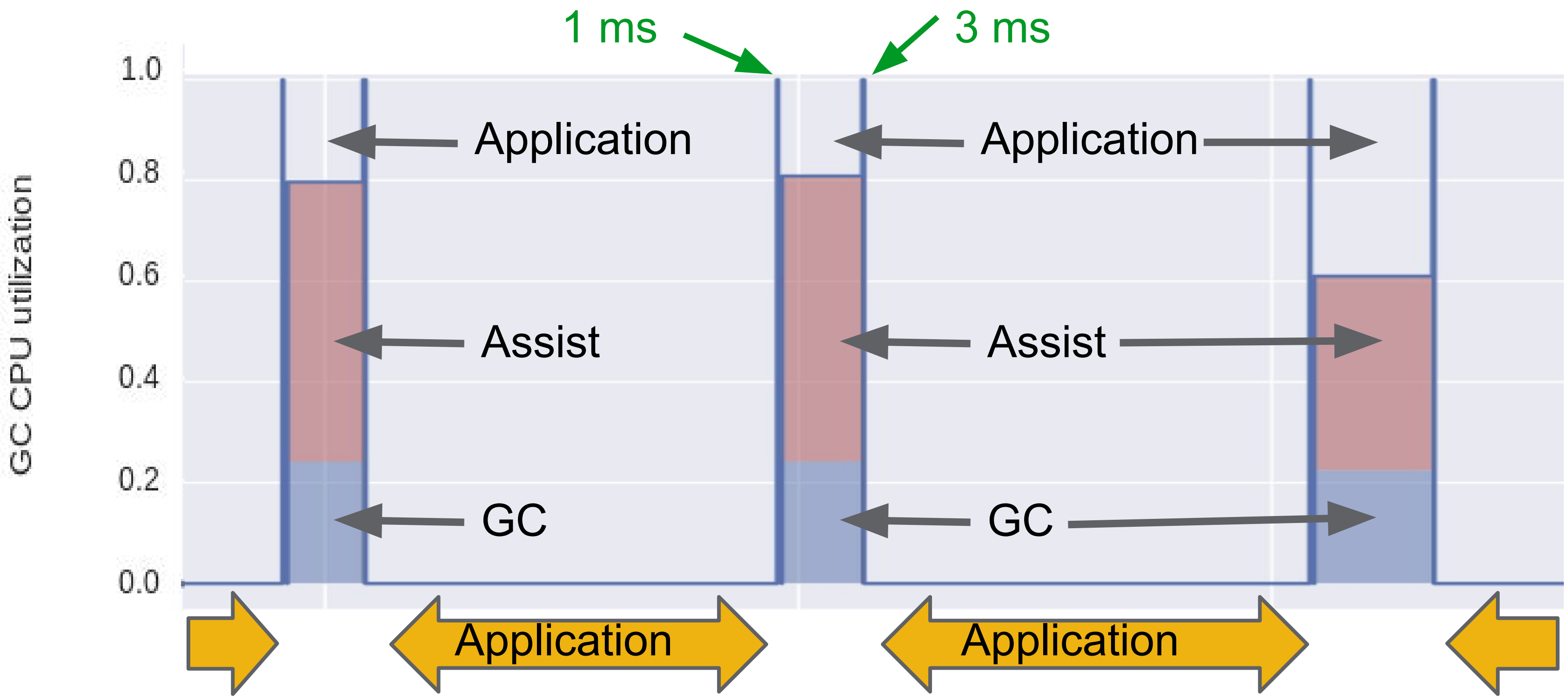
Go	Java
Thousands of Goroutines	Tens of Java Threads
Synchronization via channels	Synchronization via objects/locks
Runtime written in Go	Runtime written in C
Leverages Go same as users	
Control of spatial locality	Objects linked with pointers
Objects can be embedded	
Interior pointers (&foo.field)	
Simpler foreign function interface	

Let's Build a GC for Go

1.4 Stop the World



1.5 Concurrent GC



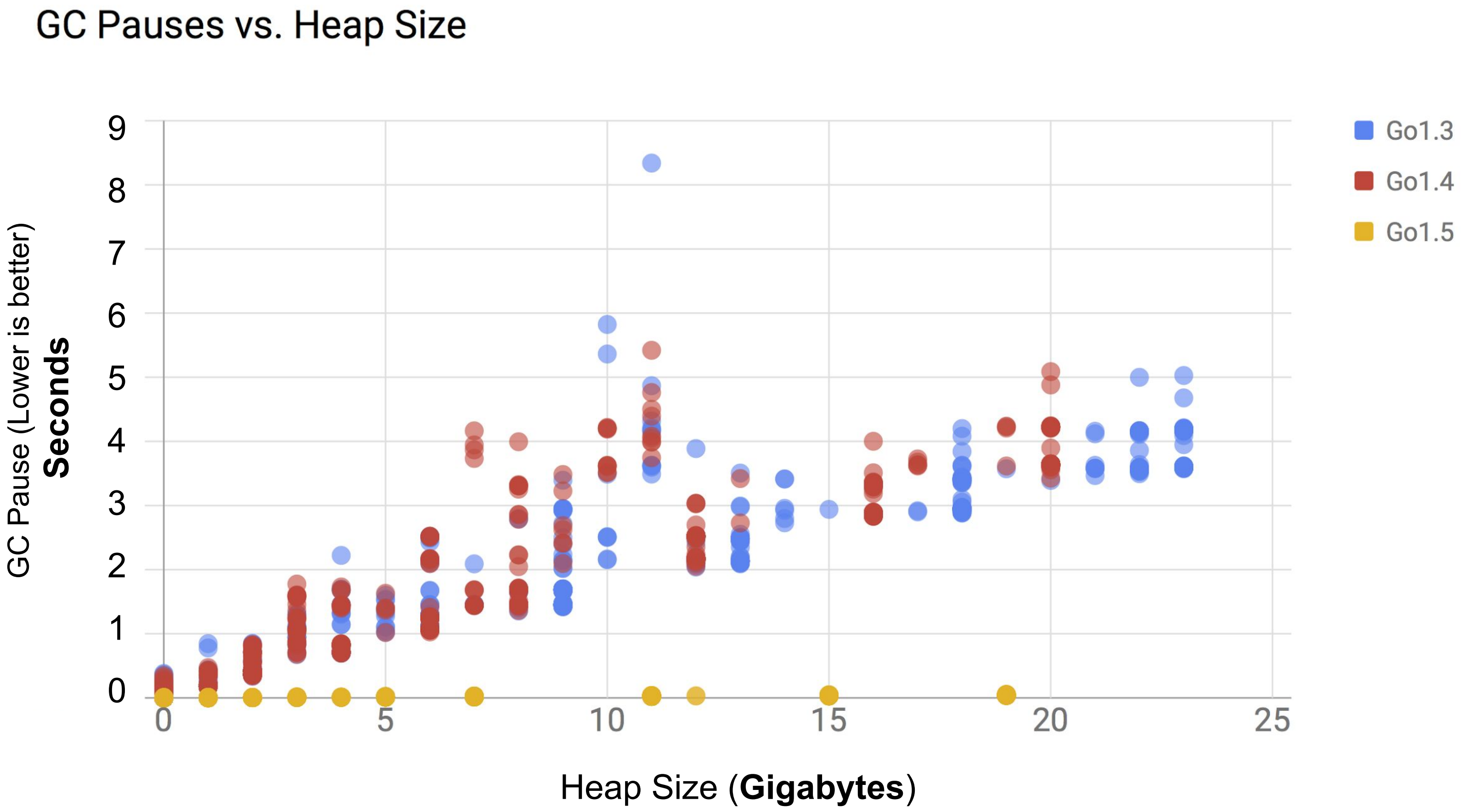
GC Algorithm Phases

Phase			Description
Off			GC disabled Pointer writes are just memory writes: *slot = ptr
Stack scan			Collect pointers from globals and goroutine stacks Stacks scanned at preemption points
Mark	WB on		Mark objects and follow pointers until pointer queue is empty Write barrier tracks pointer changes by mutator
Mark termination		STW	Rescan globals/changed stacks, finish marking, shrink stacks, … Literature contains non-STW algorithms: keeping it simple for now
Sweep			Reclaim unmarked objects as needed Adjust GC pacing for next cycle
Off			Rinse and repeat

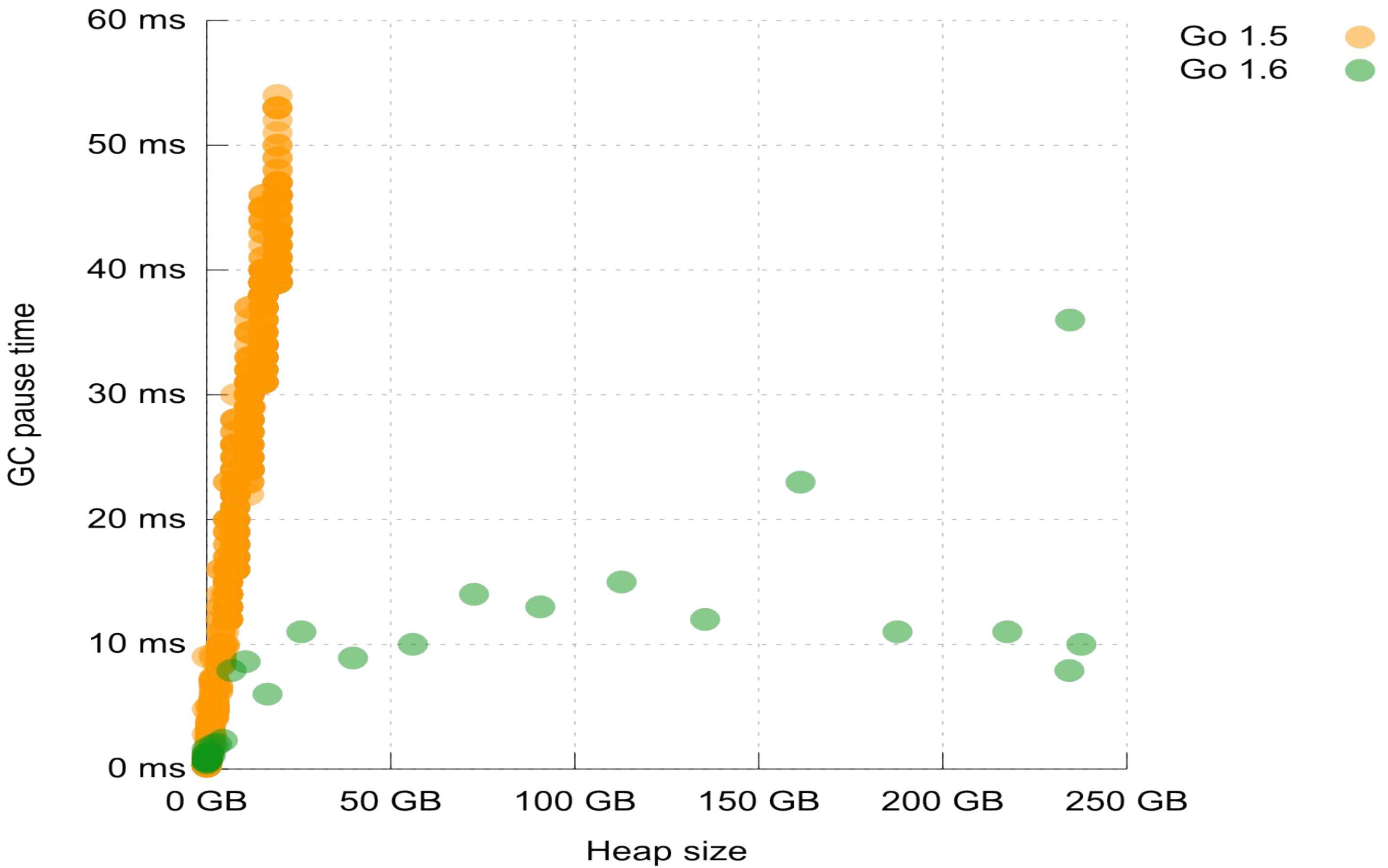
Correctness proofs in literature (see me)

Google

Garbage Benchmark



Garbage Benchmark



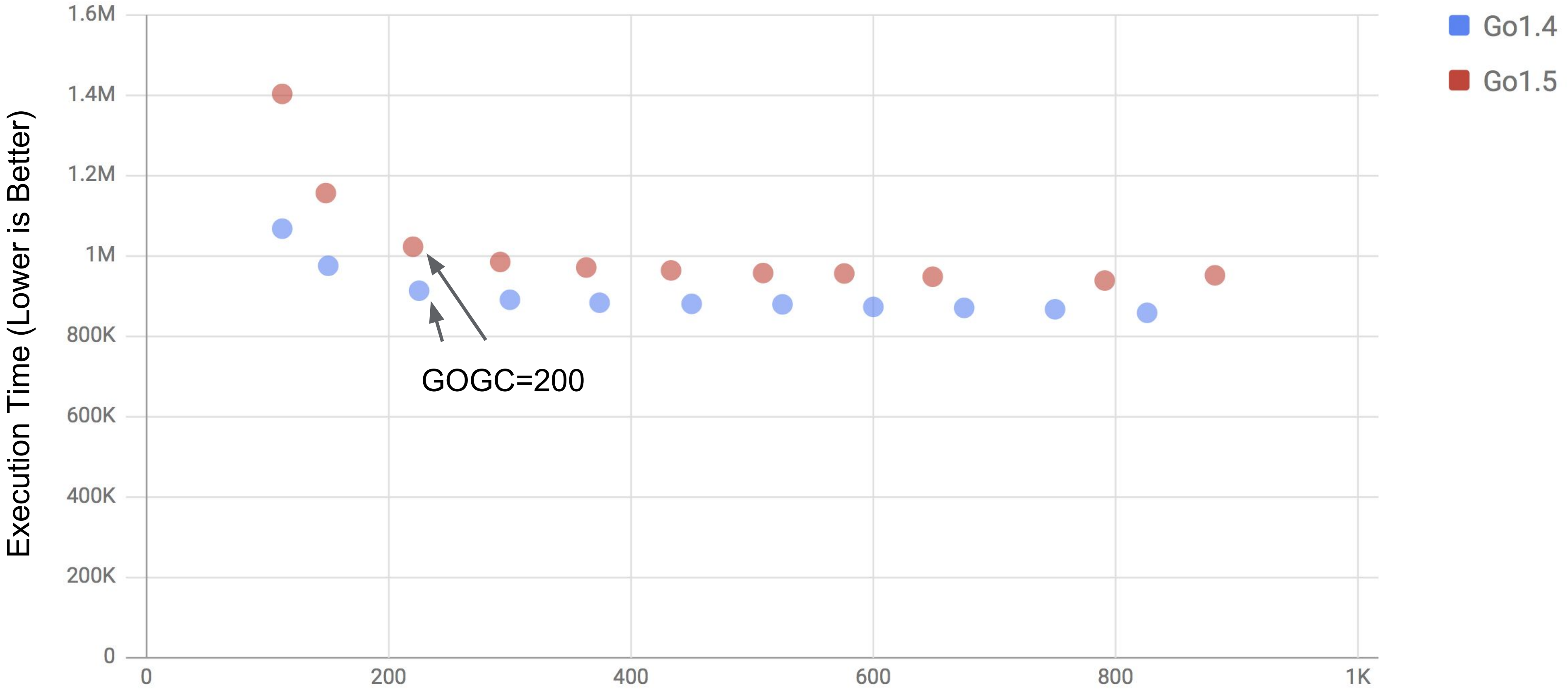
2x Live heap size

GOGC knob: Space-Time Trade off

More heap space: less GC time, and vice-versa

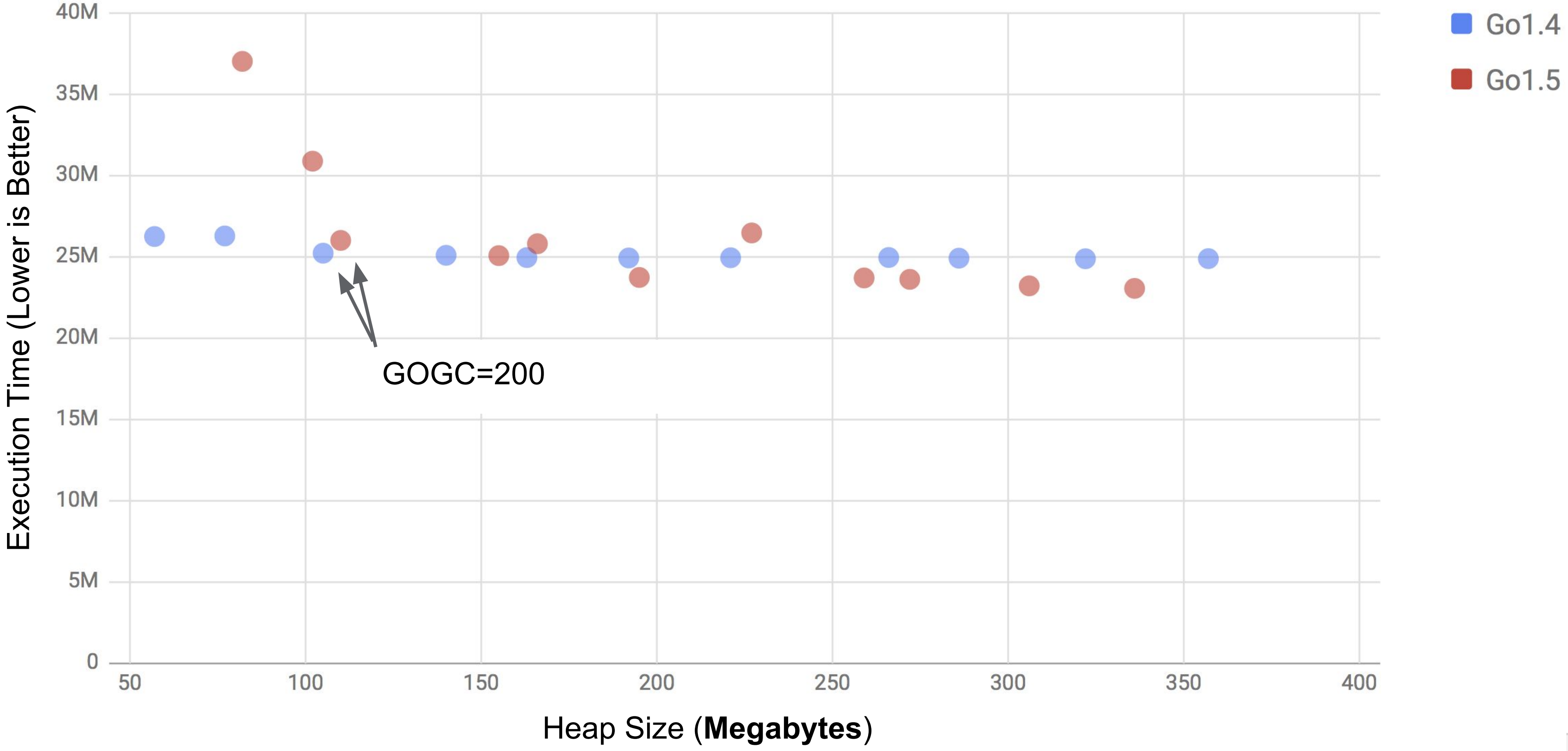
Implementing a one knob GC is a challenge

Splay: Increasing Heap Size == Better Performance



Heap Size (**Megabytes**):
Live heap kept constant

JSON: Increasing Heap Size == Better Performance



Onward: We're not done yet….

Tell people that GC latency is not a barrier to Go's adoption

Tune for even lower latency
    higher throughput
    more predictability
Tune for user's applications
Fight devils reported by users

Increase Go Adoption
Establish Virtuous Cycle

Questions