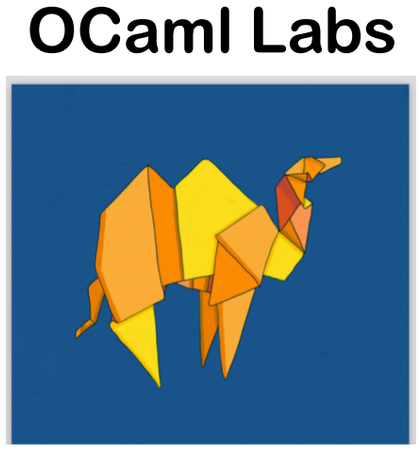
Retrofitting Parallelism onto OCaml

KC Sivaramakrishnan, Stephen Dolan, Leo white, Sadiq Jaffer, Tom Kelly, Anmol Sahoo, Sudha Parimala, Atul Dhiman, Anil Madhavapeddy



Industry

ahrefs

Jane Street

docker

FACEBOOK

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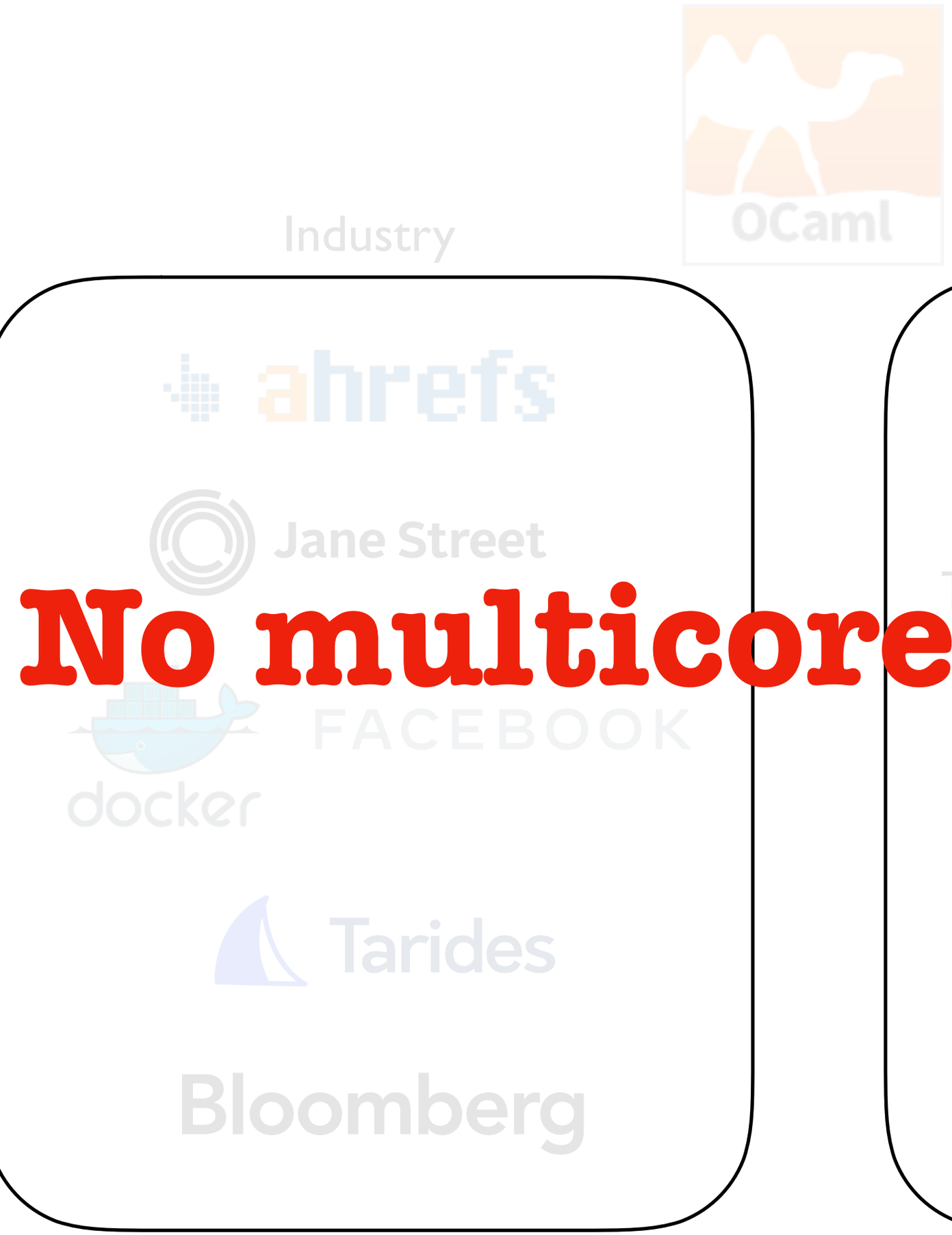
Projects

The **Astrée** Static Analyzer

COMPCERT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Multicore OCaml

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- Focus of this work is *parallelism*
  - ✦ Building a multicore GC for OCaml
- Key parallel GC design principle
  - ✦ *Backwards compatibility before parallel scalability*

Challenges

- Millions of lines of legacy code
  - ✦ Weak references, ephemerons, lazy values, finalisers
  - ✦ Low-level C API that *bakes in* GC invariants
  - ✦ Cost of refactoring sequential code itself is prohibitive

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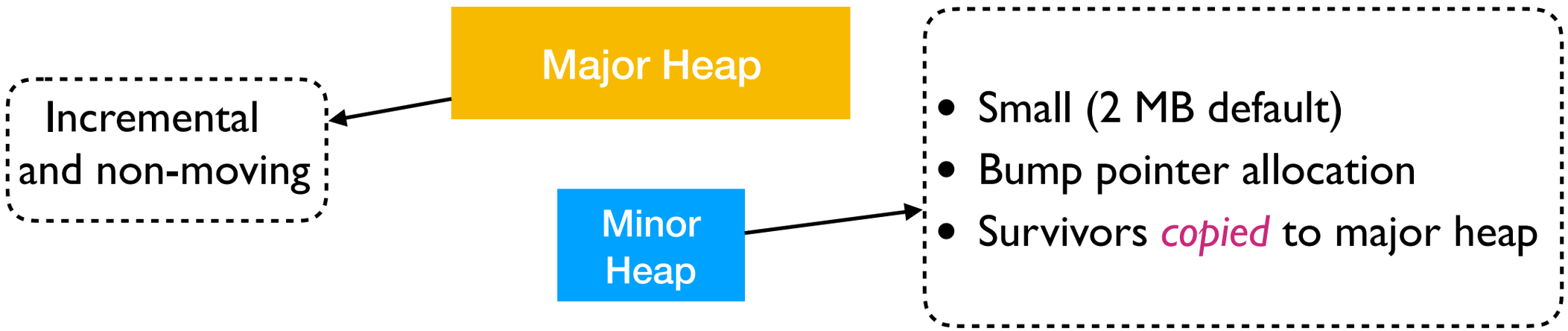
- Low-latency and predictable performance
  - ✦ Thanks to the GC design

Stock OCaml GC

- A generational, non-moving, incremental, mark-and-sweep GC



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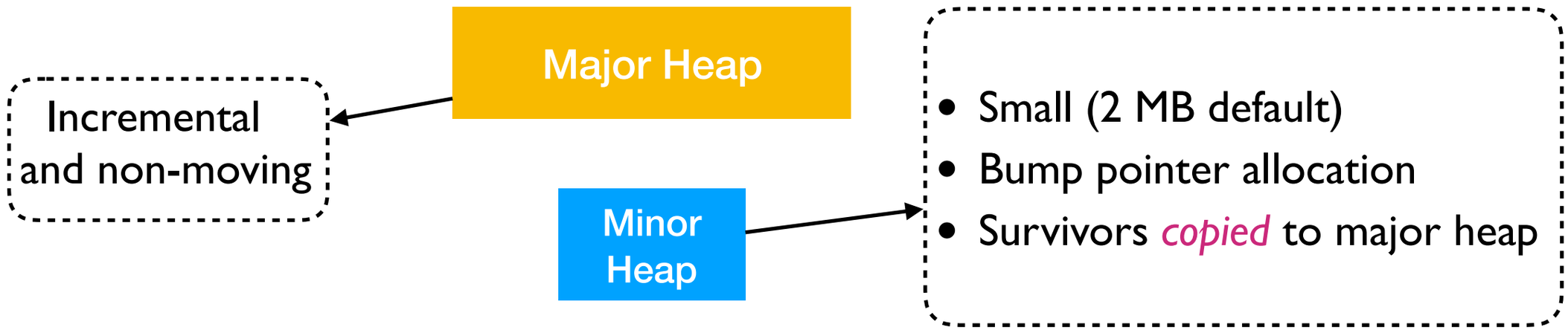

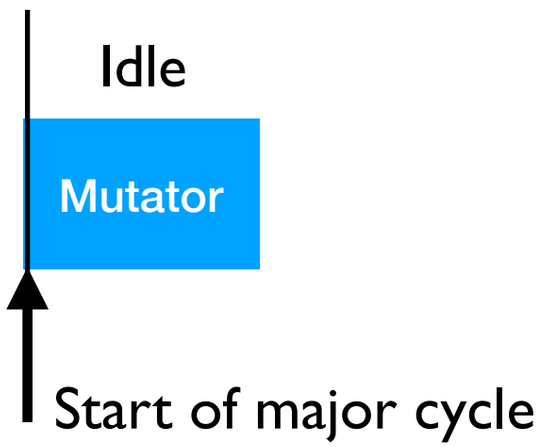

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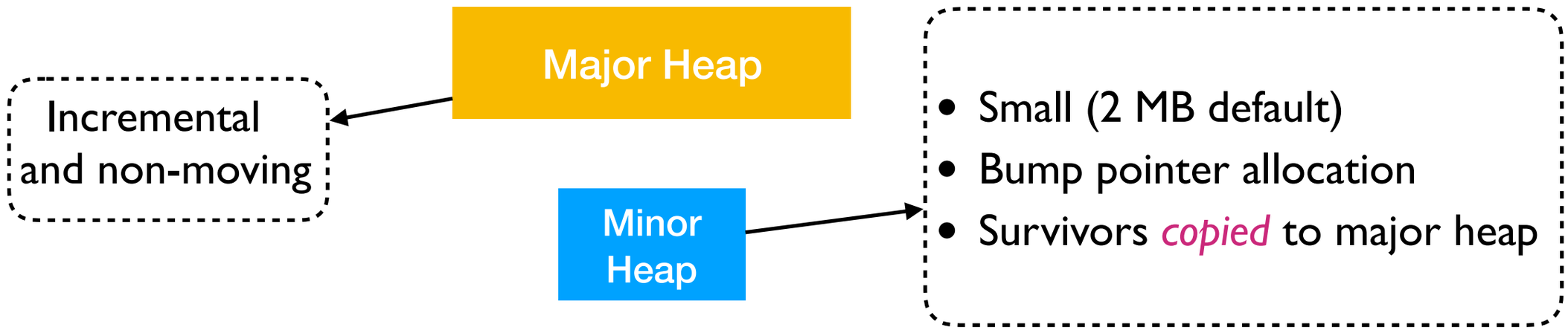

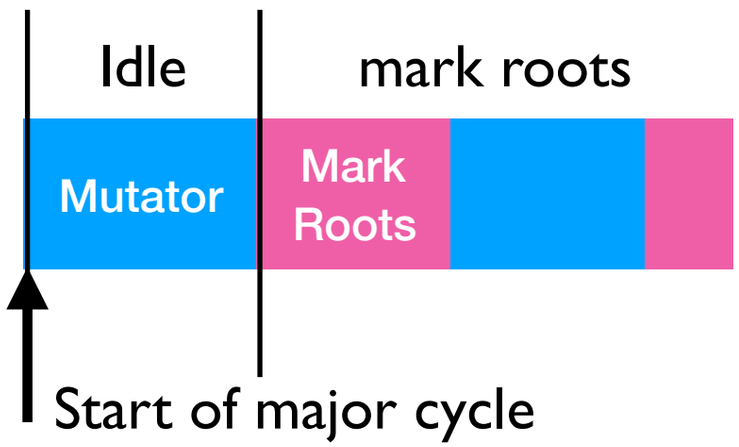

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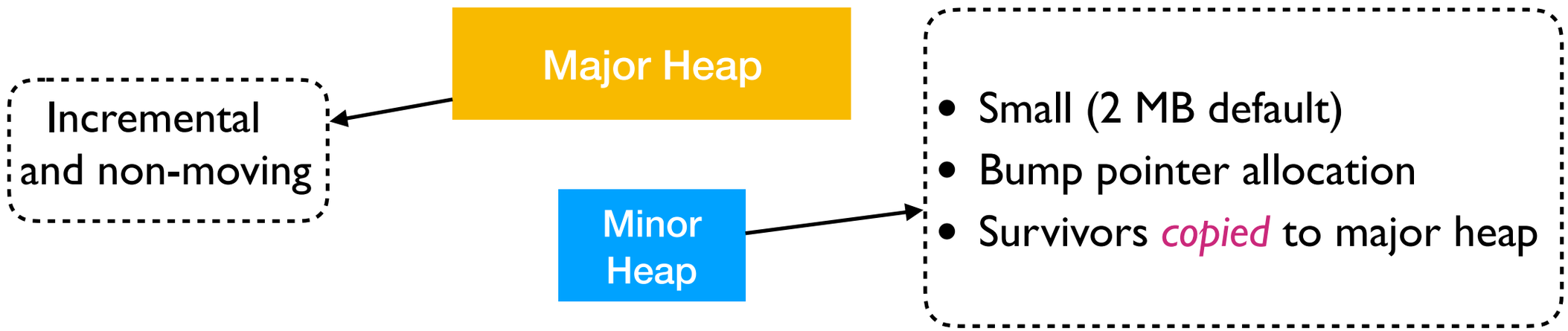

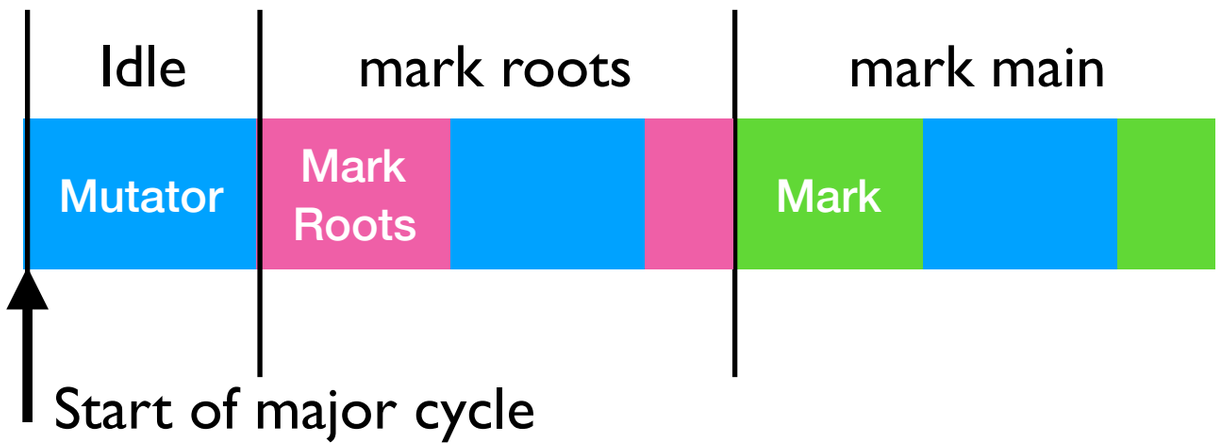

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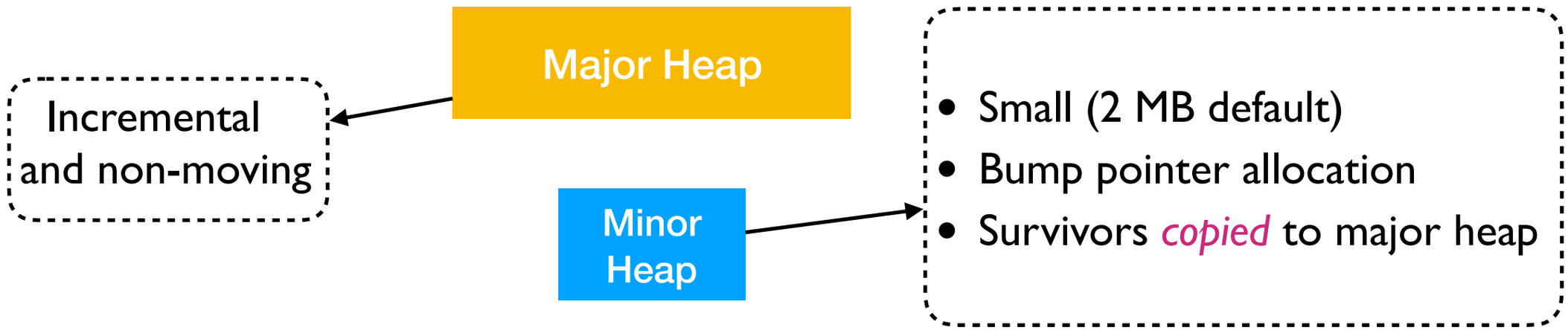

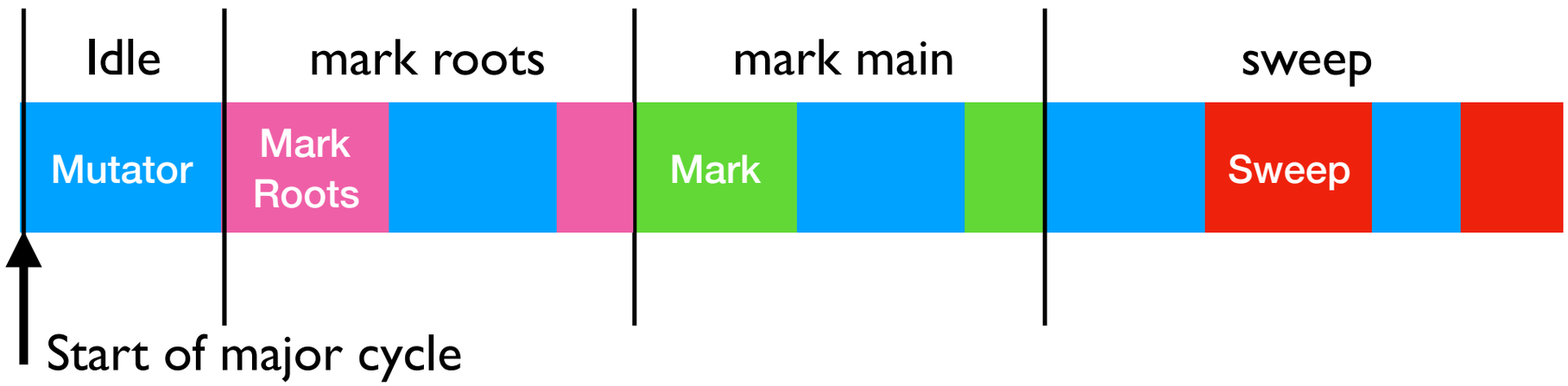

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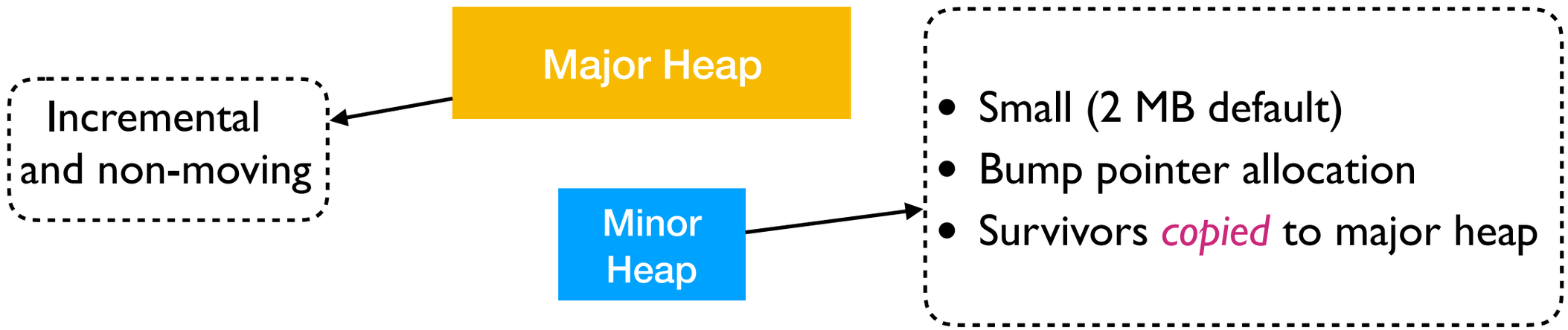

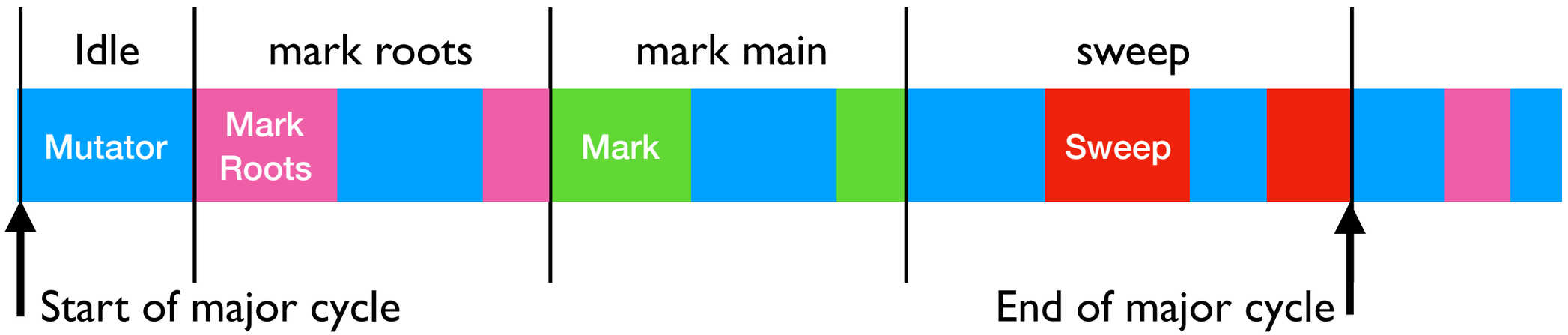

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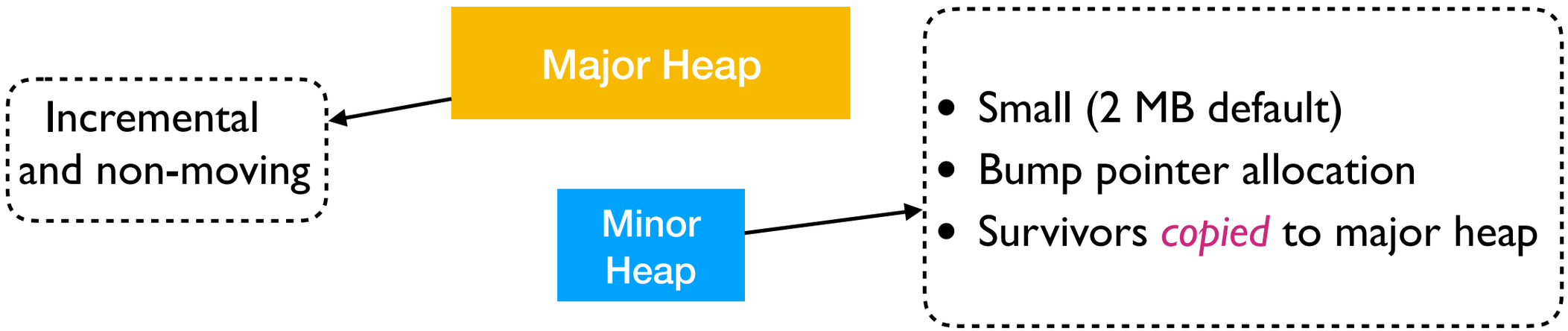

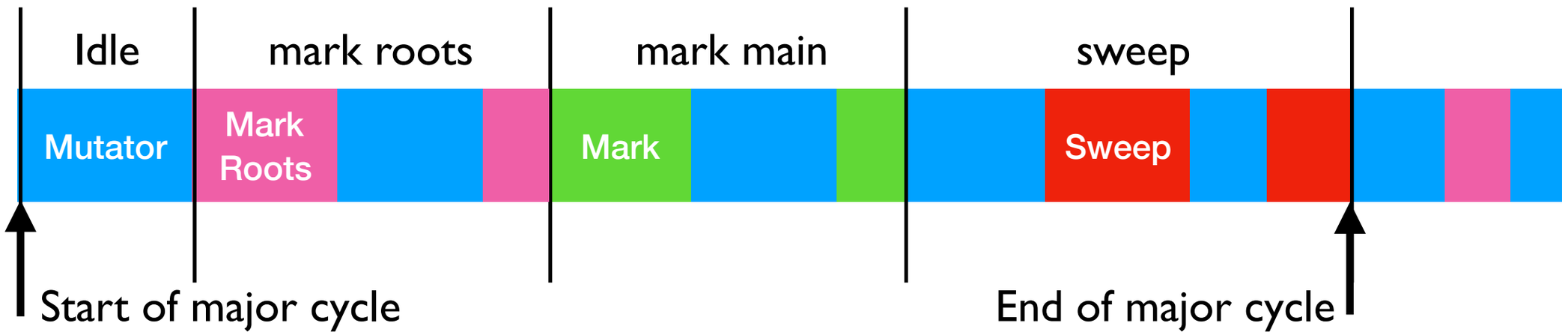

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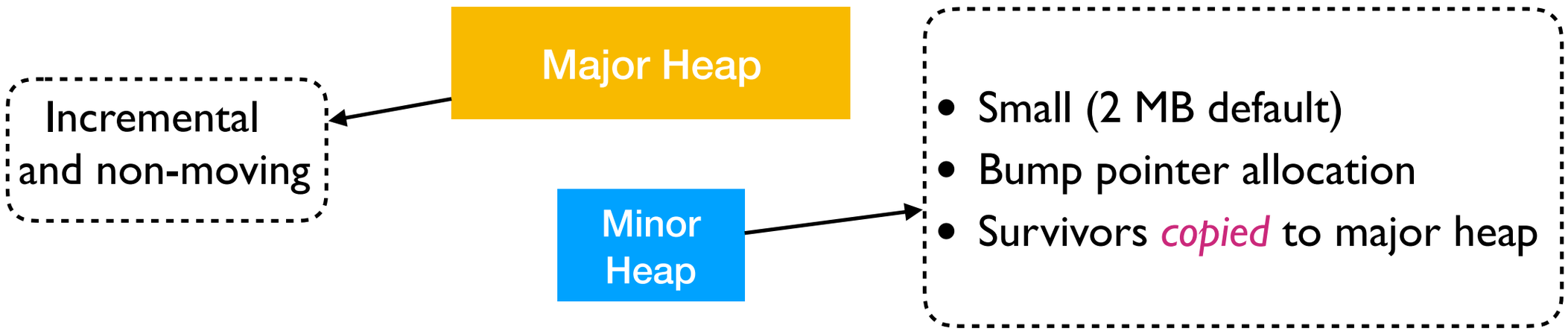

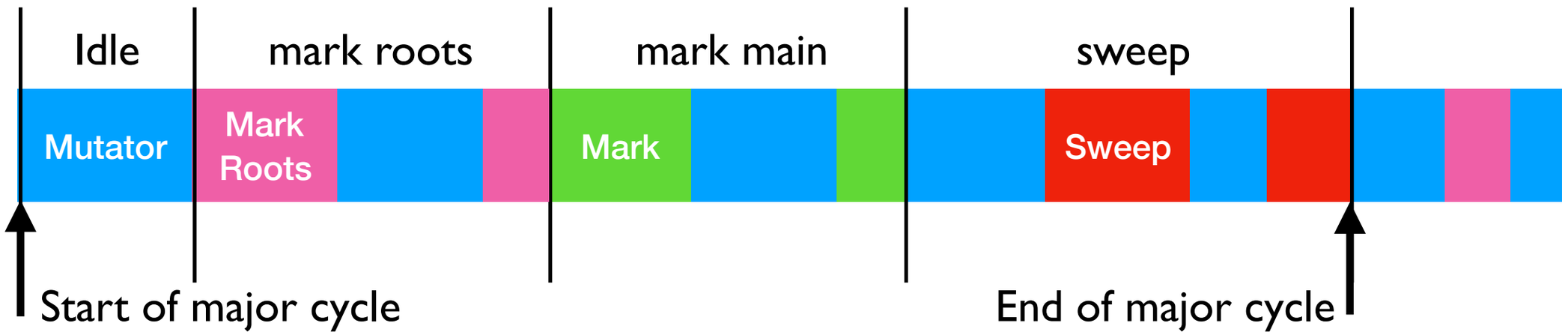

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- Max GC latency **< 10 ms**, 99th percentile latency **< 1 ms**

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3. **Parallel responsiveness and scalability**
   - Parallel programs remain responsive
   - Parallel programs scale with additional cores

Multicore OCaml: Major GC

- Multicore-aware allocator
  - ✦ Based on Streamflow [Schneider et al. 2006]
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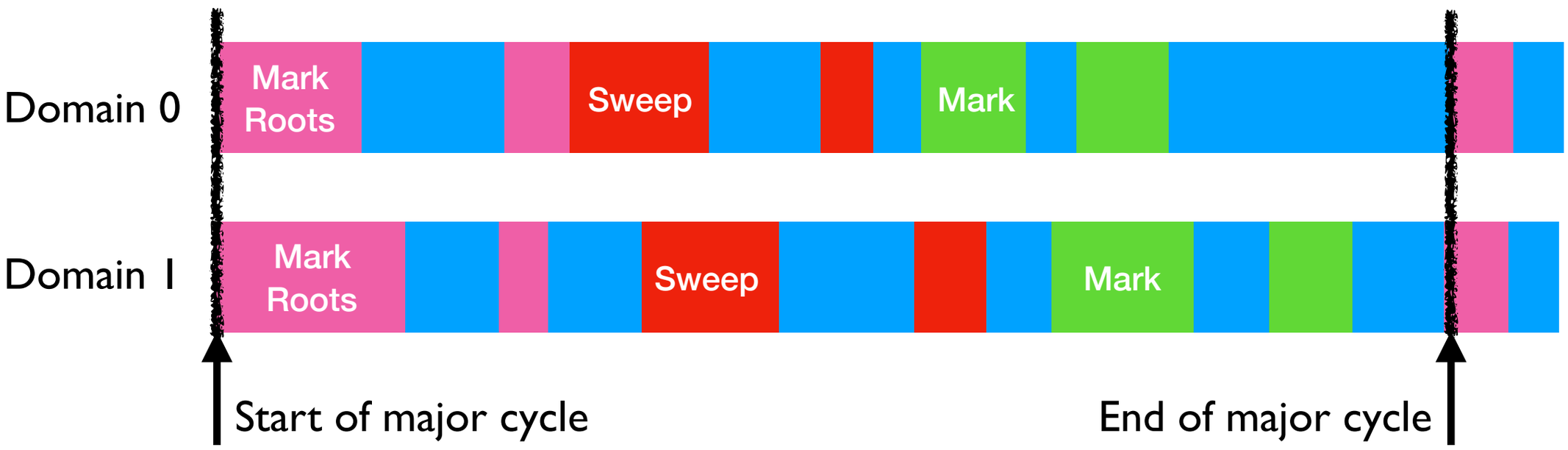

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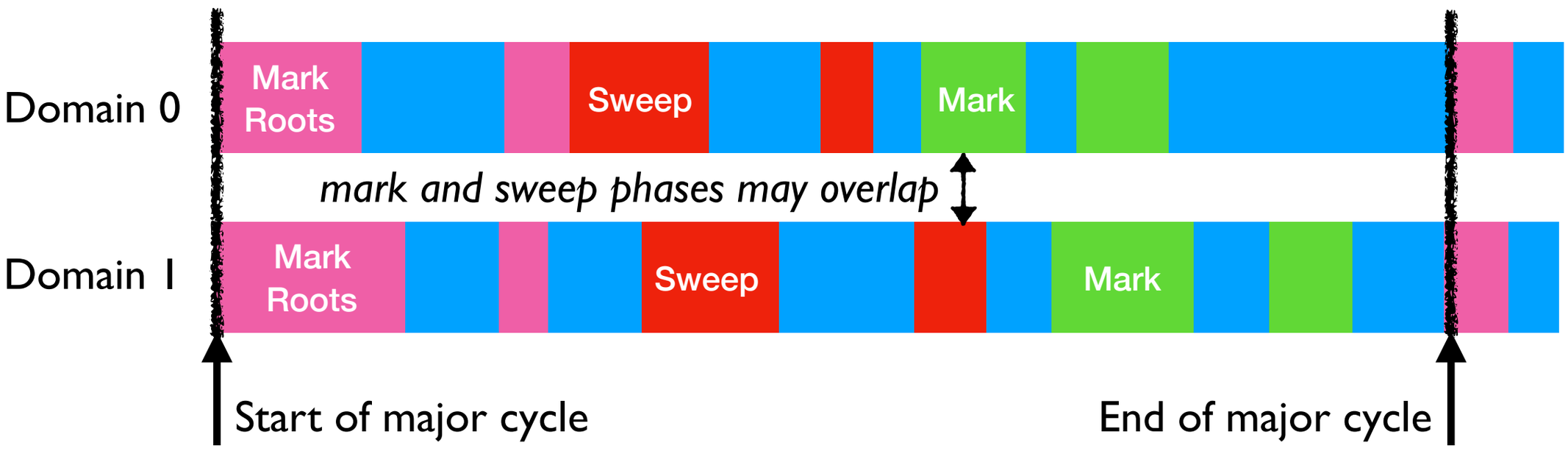

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  - ✦ A generalisation of weak references
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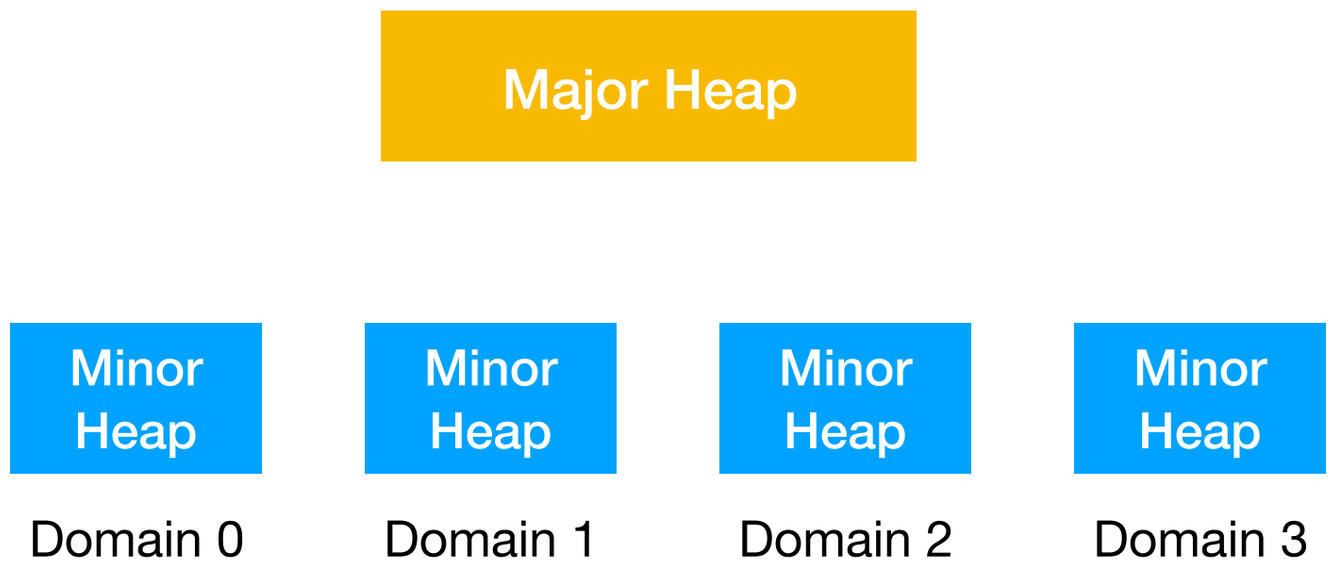

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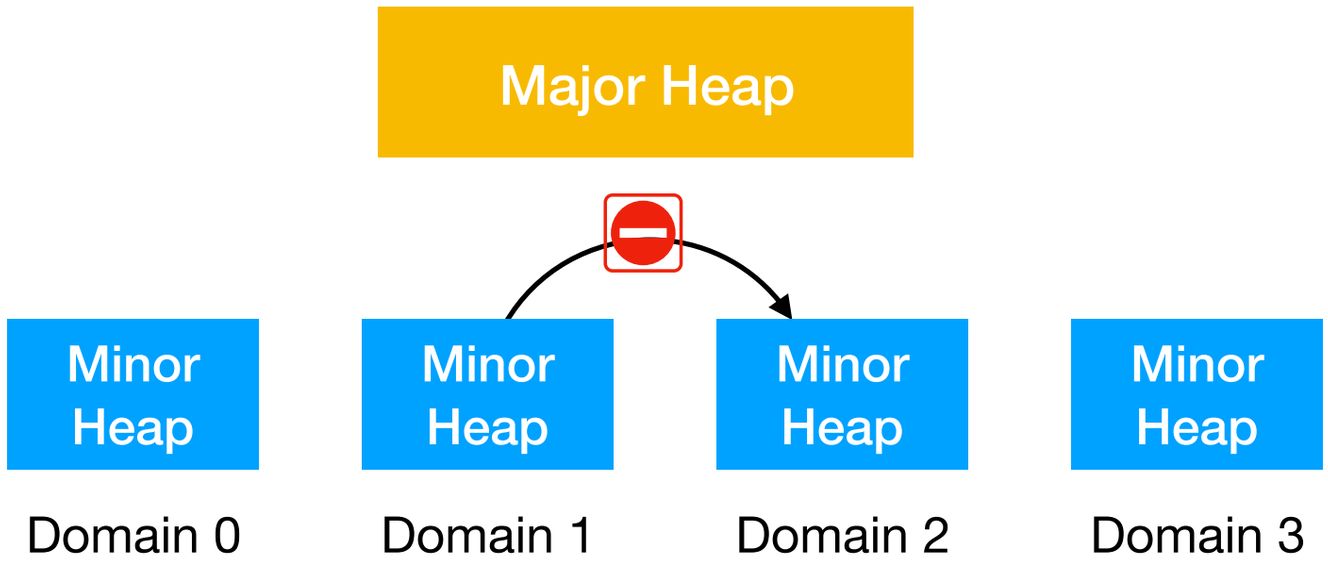

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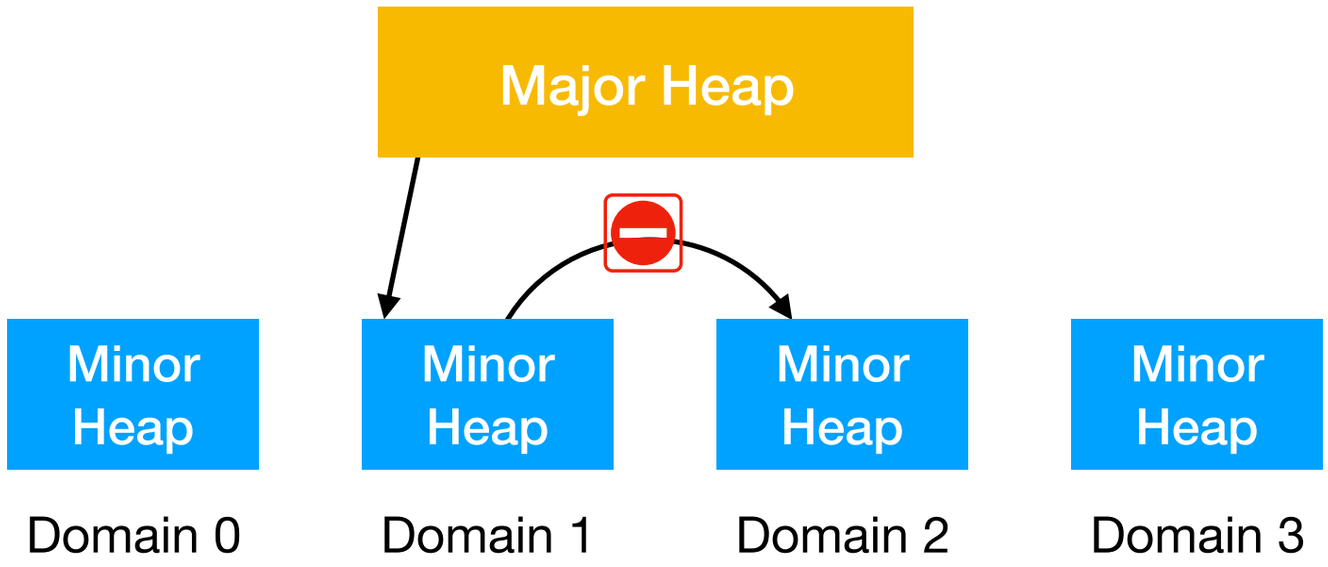

- Each domain can *independently* collect its minor heap
- Major to minor pointers allowed
  - ✦ *Prevents early promotion & mirrors sequential behaviour*
  - ✦ *Read barrier required for mutable field + promotion*

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- *3 instructions in x86* - VMM + bit-twiddling tricks
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- Unfortunately, read barriers *break the C API* (feature backwards compatibility)

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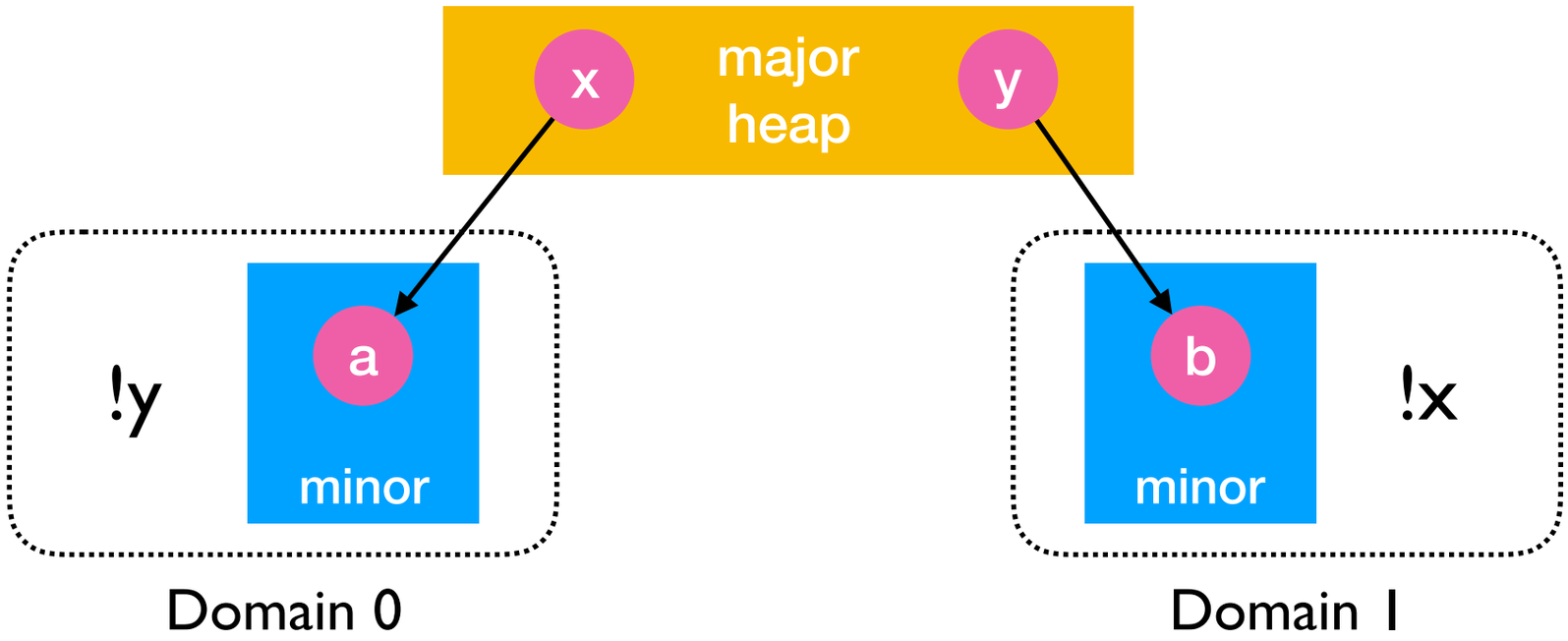

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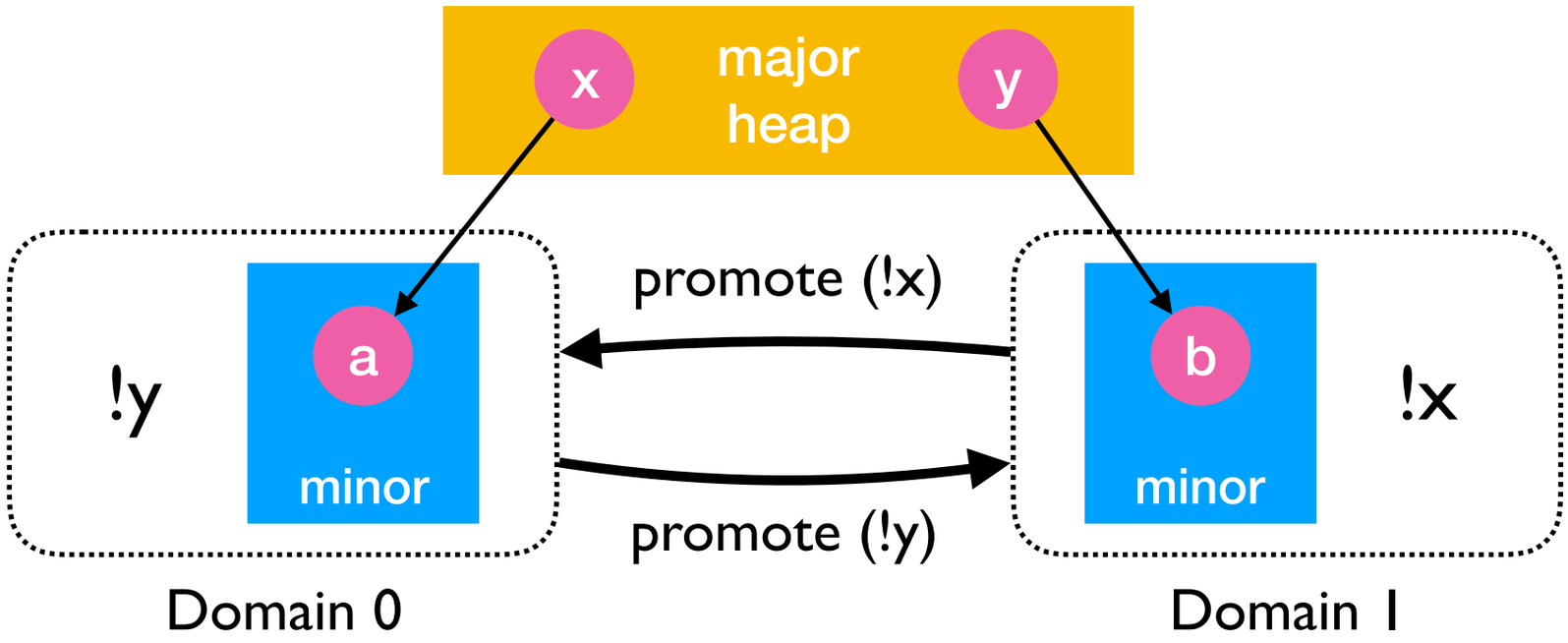

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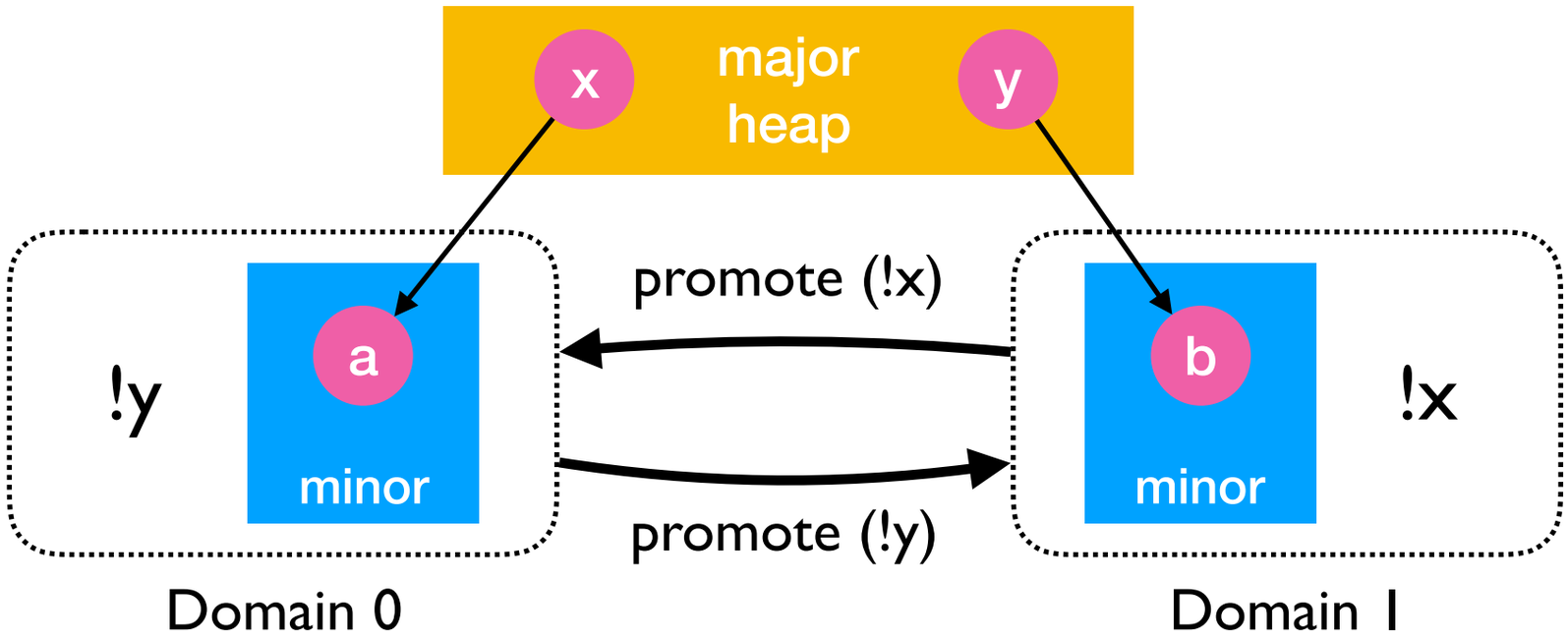

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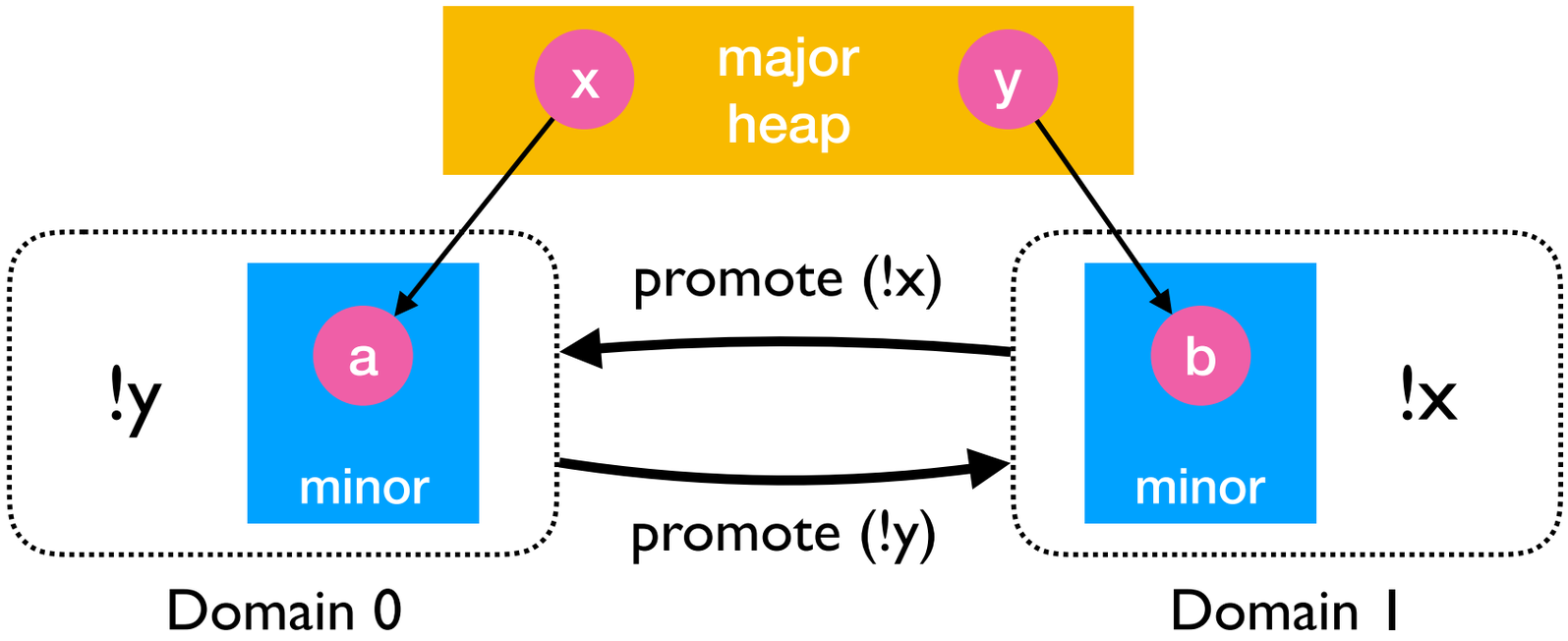

- Service promotion requests on read faults to avoid *deadlock*
  - ✦ *Mutable reads are GC safe points!*
- C API written with explicit knowledge of when GC may happen
  - ✦ *Need to manually refactor tricky code*

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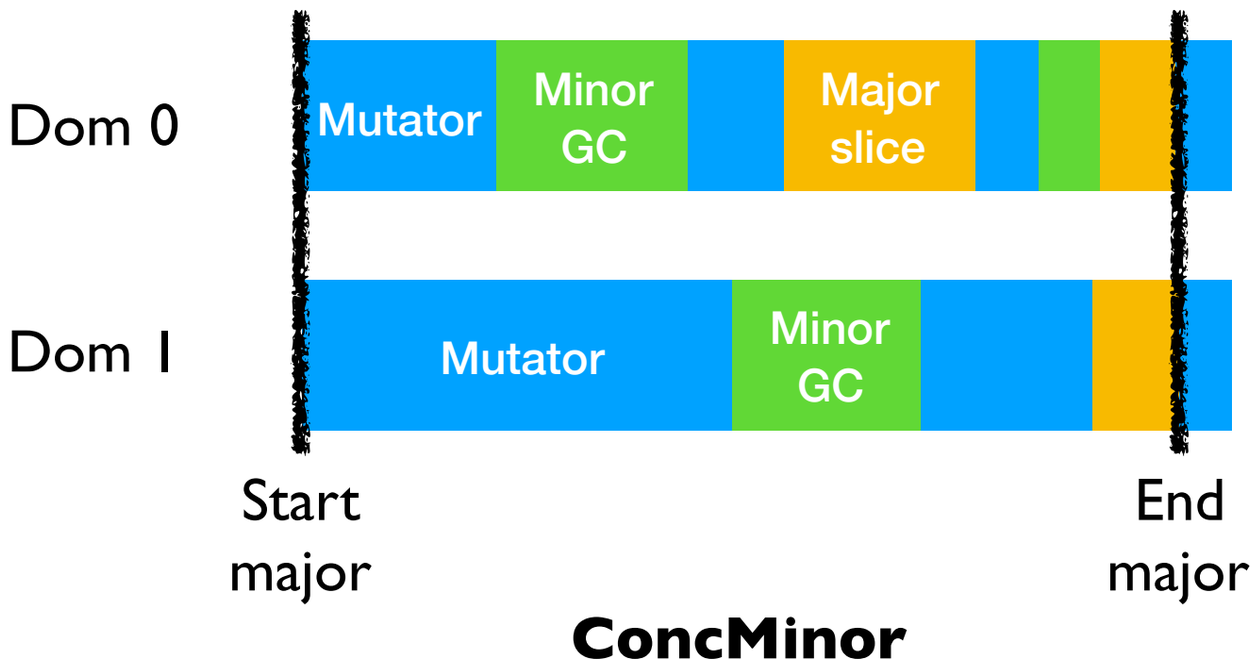

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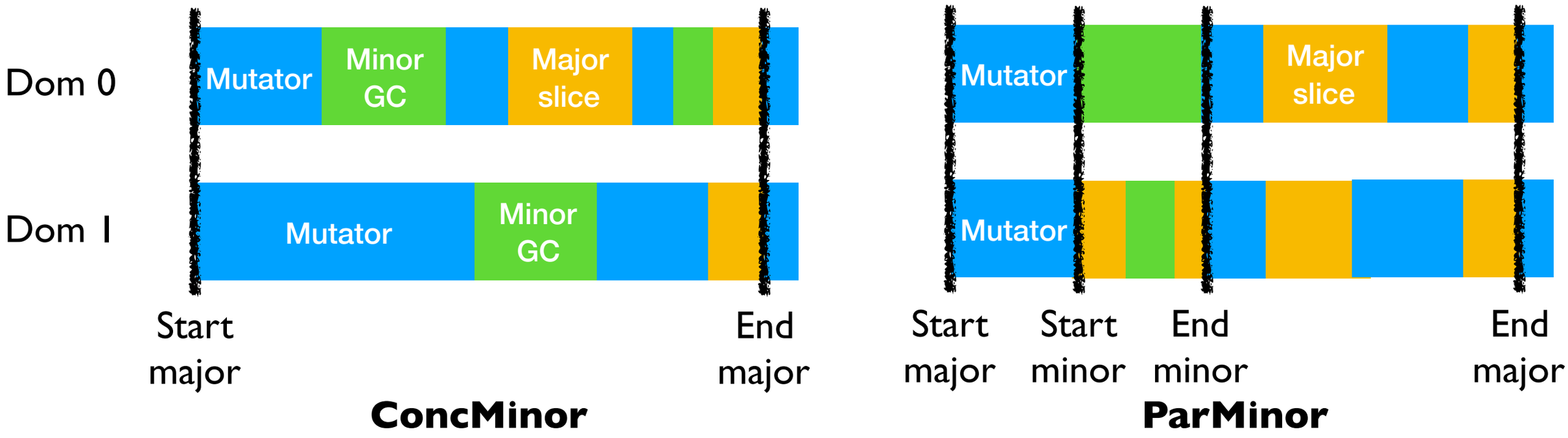

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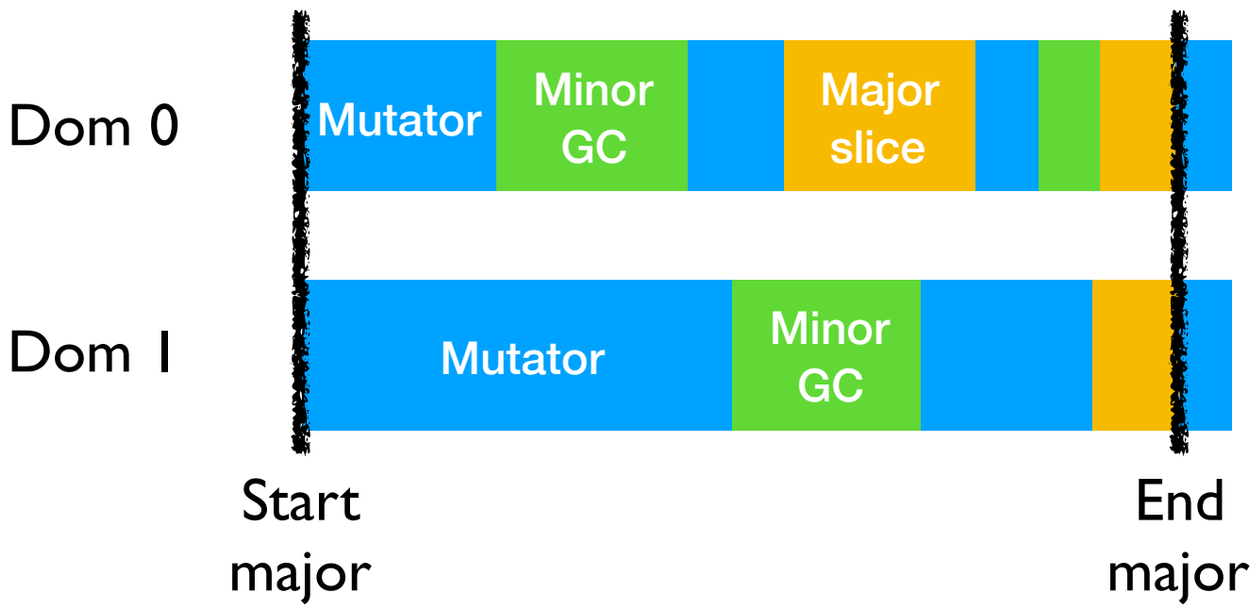

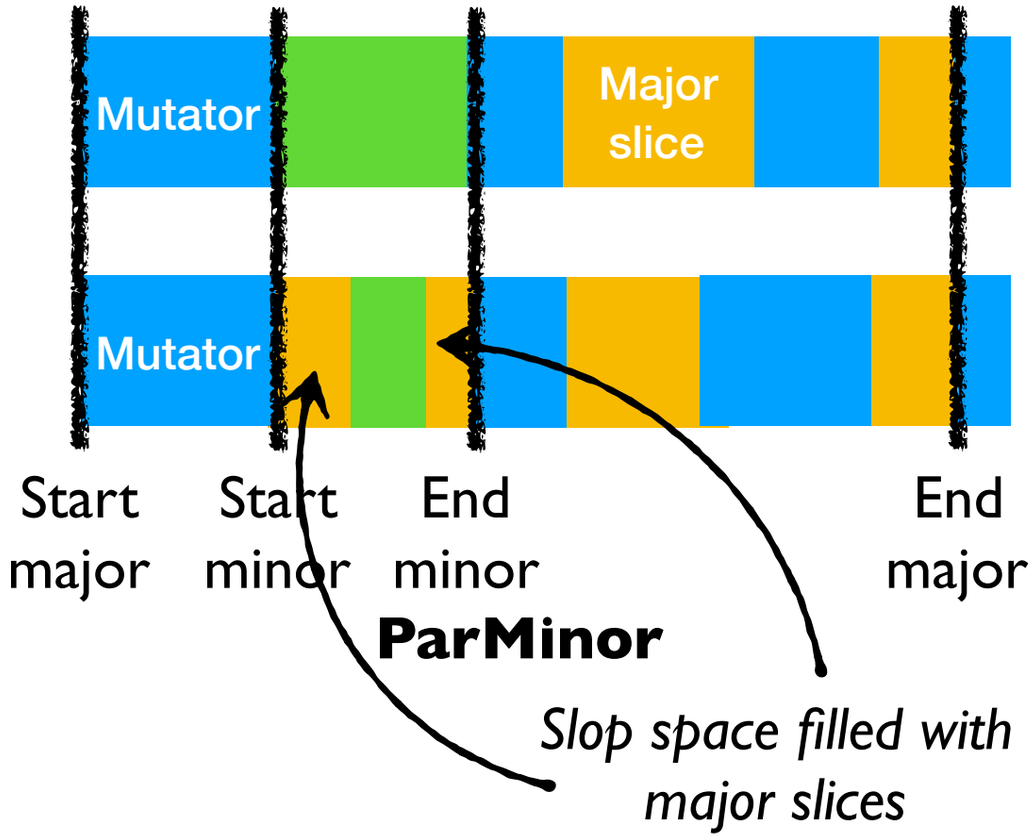

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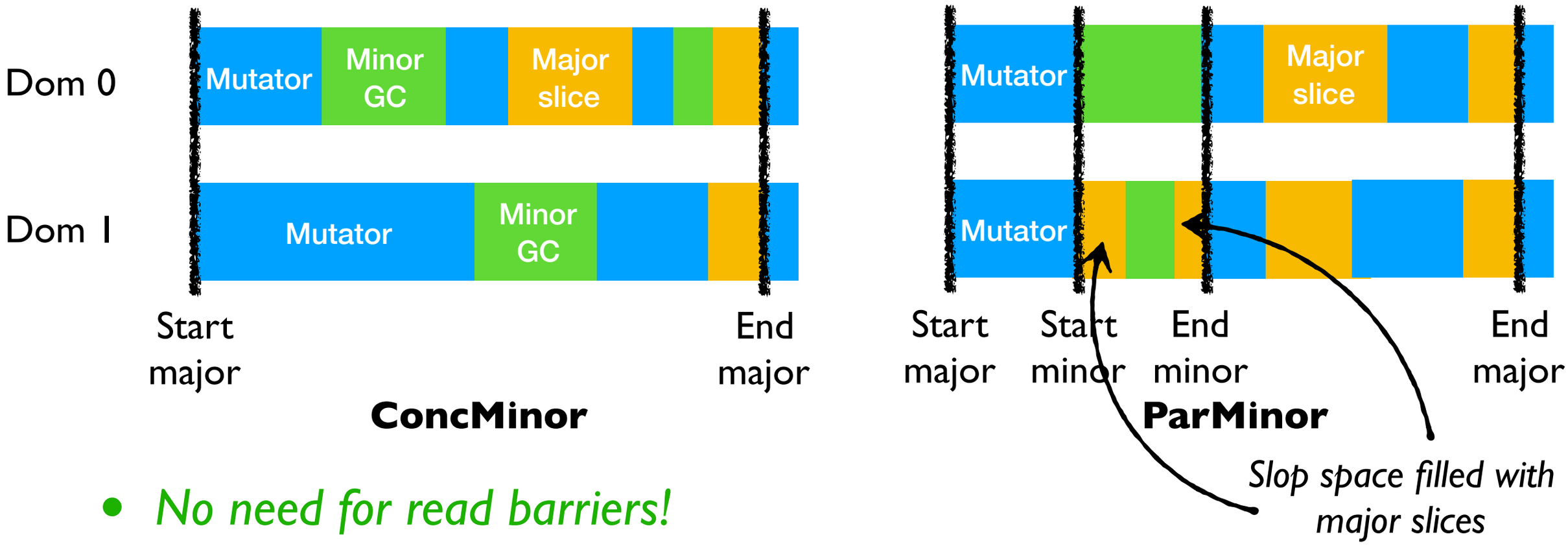

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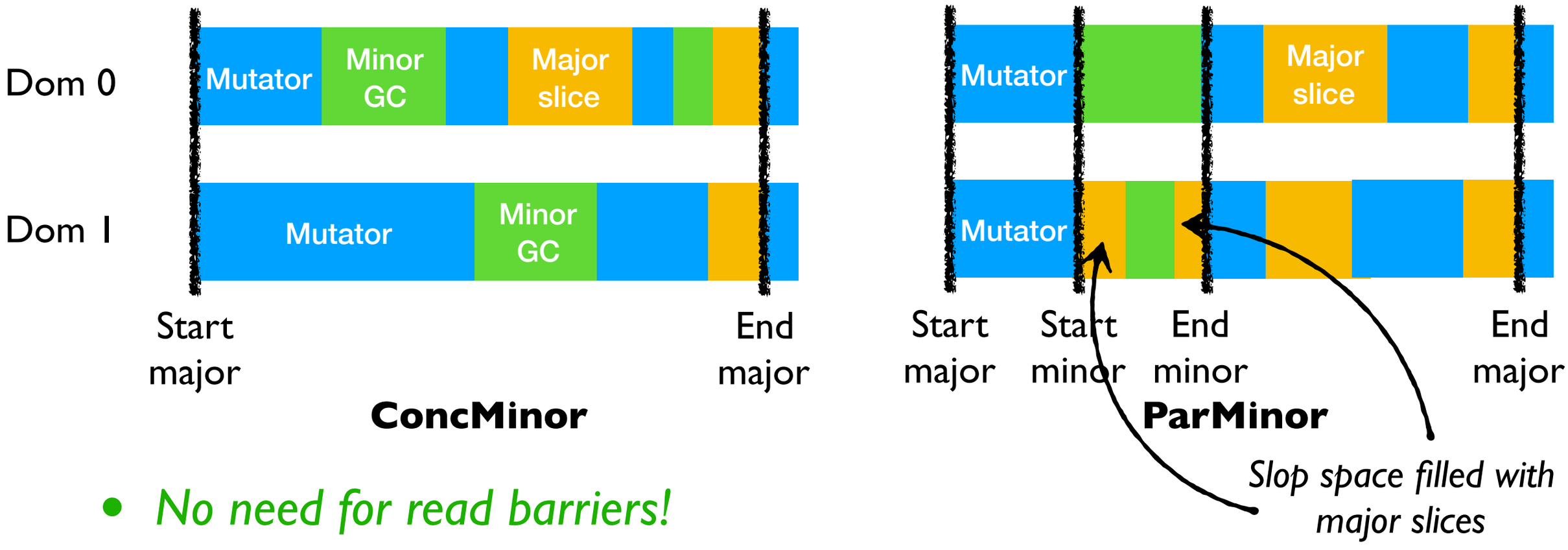

- *No need for read barriers!*
- Quickly bring all the domains to a barrier
  - ✦ Insert poll points in code for timely inter-domain interrupt handling [Feeley 1993]

Evaluation

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  - ✦ ConcMinor 4.9% slower and ParMinor 3.5% slower
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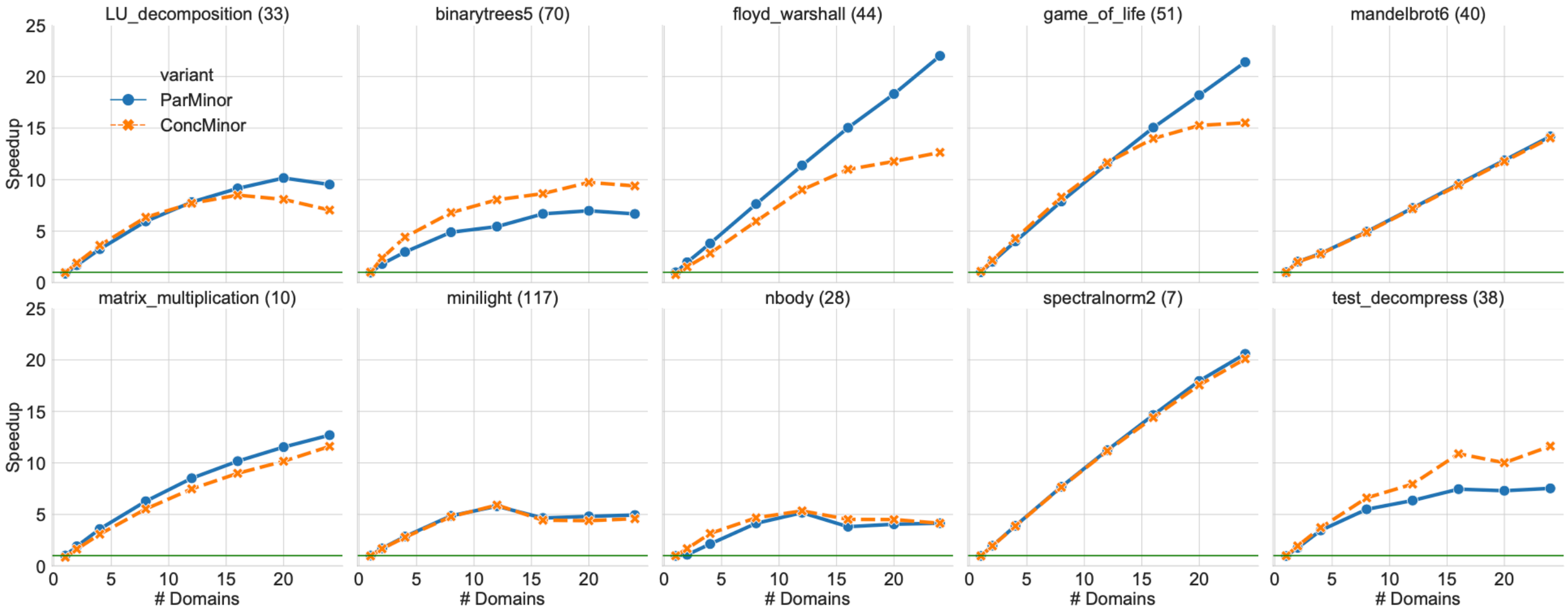
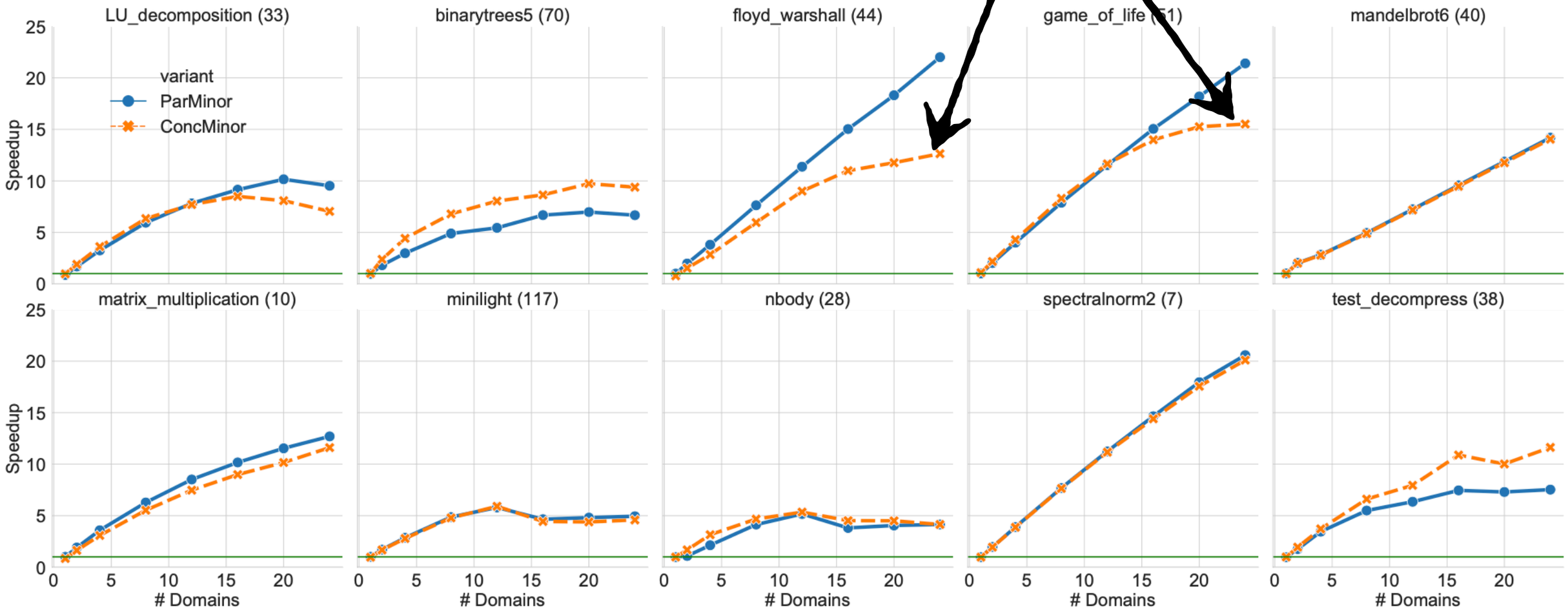
- Sequential GC pause times on par with stock OCaml

Parallel Scalability



Parallel Scalability

ConcMinor suffers due to read faults



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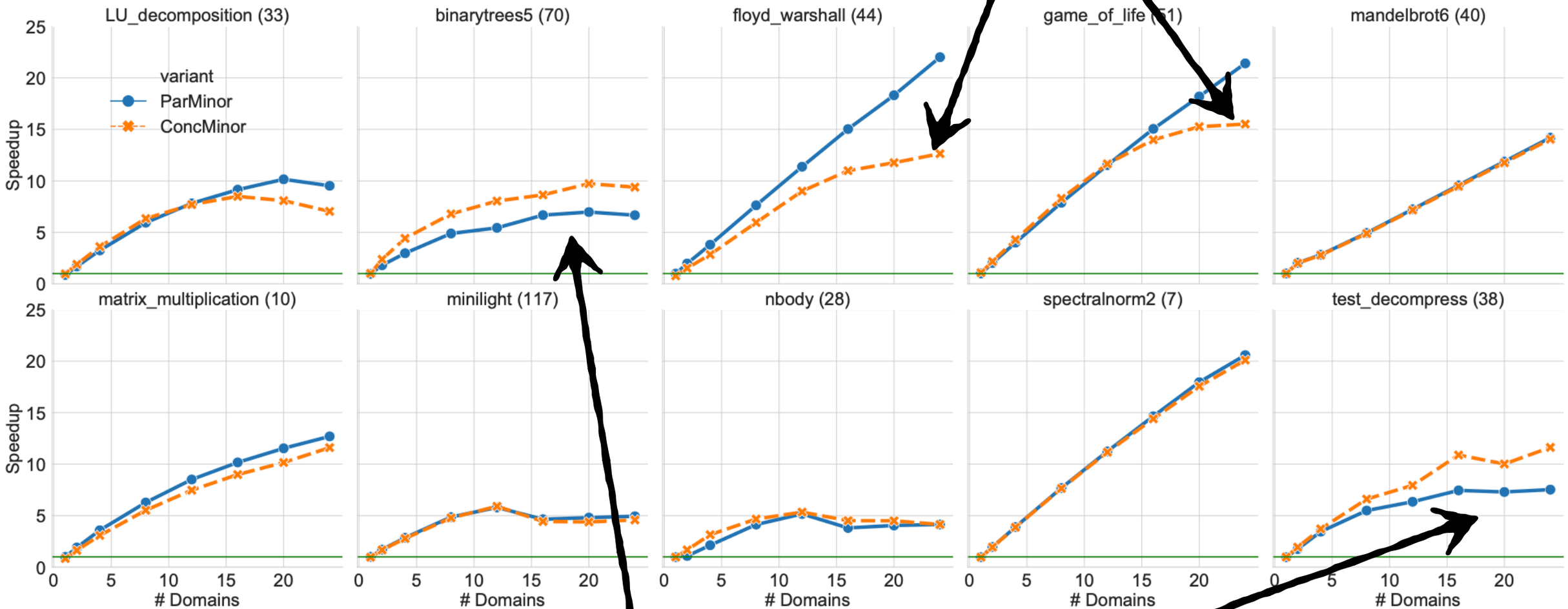

Unbalanced allocation leads to inopportune minor GCs in ParMinor

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- ParMinor wins over ConcMinor
  - ✦ Does not break the C API
  - ✦ Performs similarly to the ConcMinor on 24 cores
- **OCaml 5.00** will have multicore support and use ParMinor
  - ✦ May revisit ConcMinor later for manycore future

Thanks!

- Multicore OCaml
  - ✦ https://github.com/ocaml-multicore/ocaml-multicore
- Sandmark — benchmark suite for (Multicore) OCaml
  - ✦ https://github.com/ocaml-bench/sandmark/
- SPIN models
  - ✦ https://github.com/ocaml-multicore/multicore-ocaml-verify
- Parallel Programming with Multicore OCaml
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