Visualization in Testing a Volatile Memory Forensic Tool

By

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The Digital Forensic Research Conference

DFRWS 2011 USA New Orleans, LA (Aug 1st - 3rd)

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Digital Forensic Research Workshop (DFRWS 2011)
August 1st, 2011

Visualization in Testing a Volatile Memory Forensic Tool

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Follow Along

- Paper on page S42
- Flickr: http://doiop.com/dfrws2011

Volatile Memory Analysis

- Study growing rapidly since 2005 DFRWS memory challenge
- String search/carving
- Tools such as PTFinder, Volatility allow reconstruction (for Windows)
- Growing disk sizes, use of encryption motivate its increasingly important role
- No tool on Macs since OS X 10.4

Current Imaging Techniques

- Hardware
  - Cards
  - Firewire
- Software
  - Windows: mdd, win32dd, dumpmmf
  - Linux: /dev/mem, /dev/crash
    - Broken by design
  - OS X: 10.0-10.4 (PPC)
    - Broken by design
    - kmem=1 will create broken /dev/kmem, /dev/mem

Mac Memory Reader (mmr) on OS X

- Implemented as a Kernel Extension (kext)
- Supports >= 10.4 (ppc, i386, x64)
- Creates two devices
  - `/dev/pmap` – physical memory map
    - same format as `showbootermemorymap` debug macro
  - `/dev/mem` – physical memory device
- Userspace utility outputs as Mach-o dump file
  - dd also supported

Memory Imager Properties

4 metrics for evaluation

1. Speed – Copy memory fast for consistency
2. Completeness – Copy all of physical memory
3. Accuracy – Copy memory accurately
4. Non-Interference – Don't overwrite memory

Testing our /dev/mem

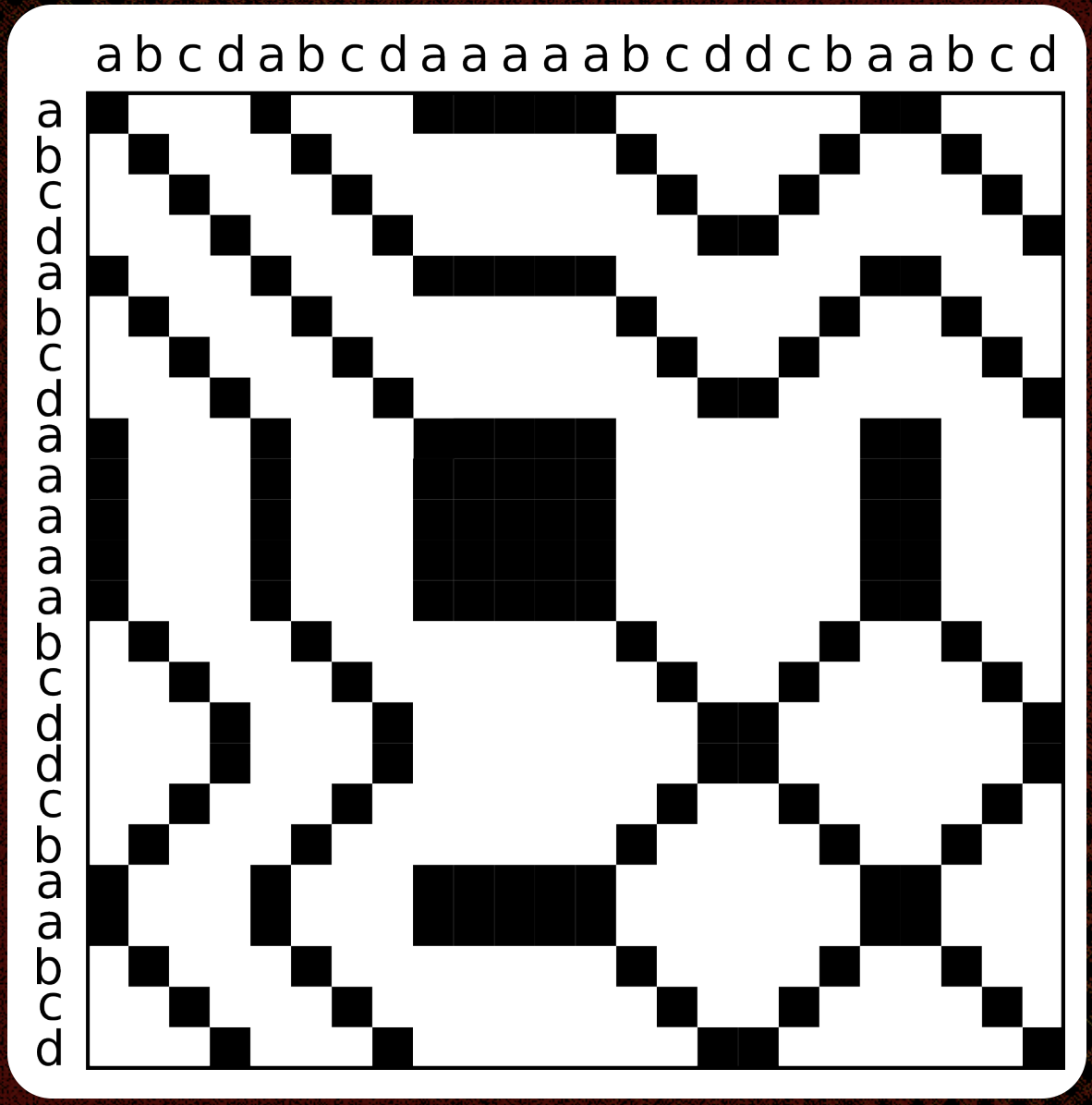
comparison against dd

1. Speed: 14.2 secs (mmr) vs 16.4 secs (dd)
2. Completeness: 131072 (mmr) vs 131072 (dd)
3. Accuracy: 93% similar (using netcat)
4. Non-interference:
   - Average similarity after 5 runs
     - mmr: 97%
     - dd: 32%

Testing our /dev/mem
Finding our bug

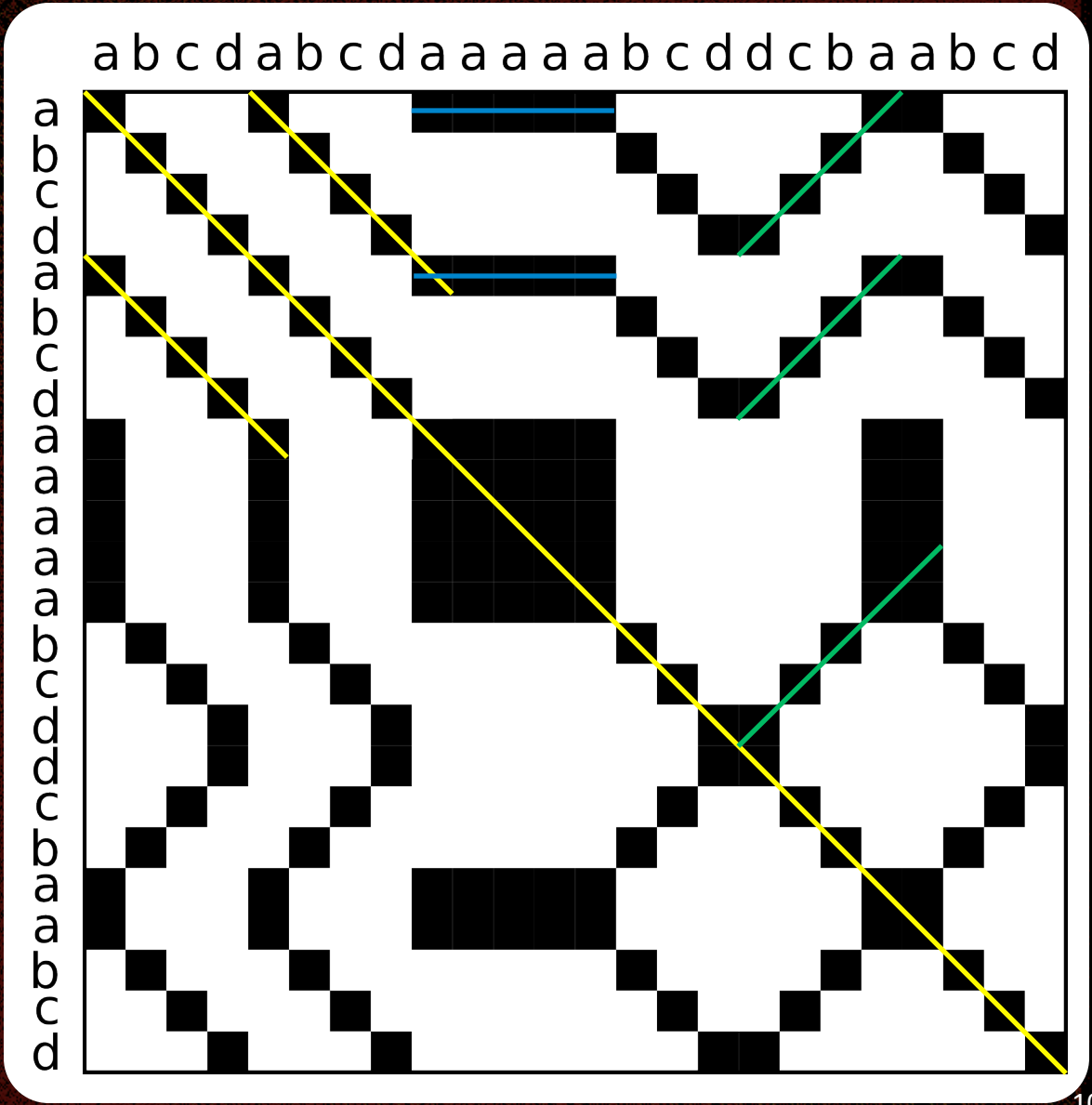
- Using debug info to check symbols
- String injection
  - Inject kext with known unique string
  - Look for it in image file
  - Multiple copies?
    - Disk cache, user space applications, kernel
- String extraction found large identical sequences of pages ☹

Dotplots



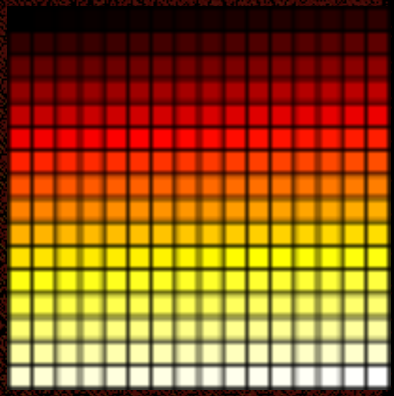
Dotplots

- Forward Similarity
- Retrograde Similarity
- Duplication

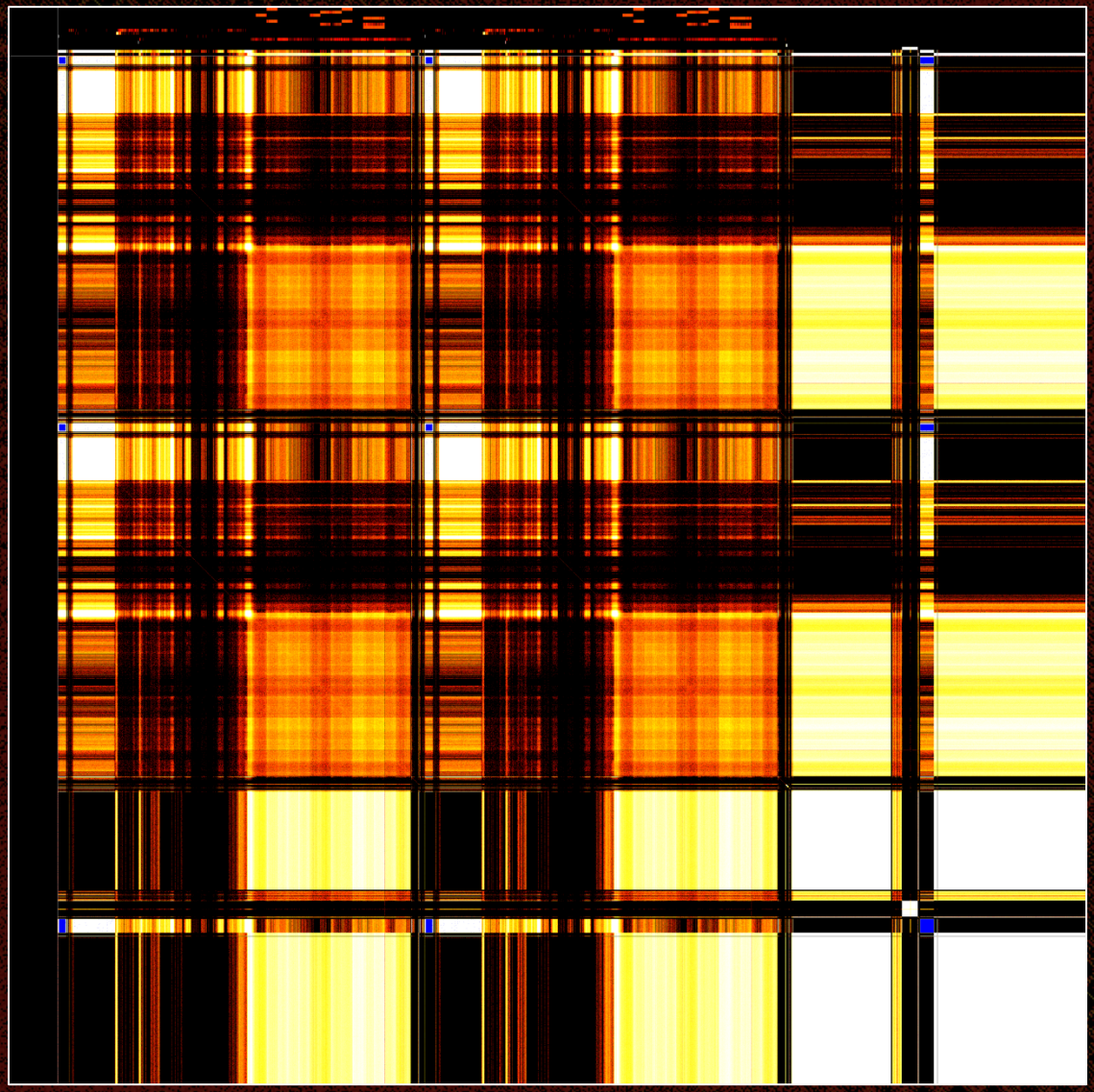


Physical Memory Dotplots

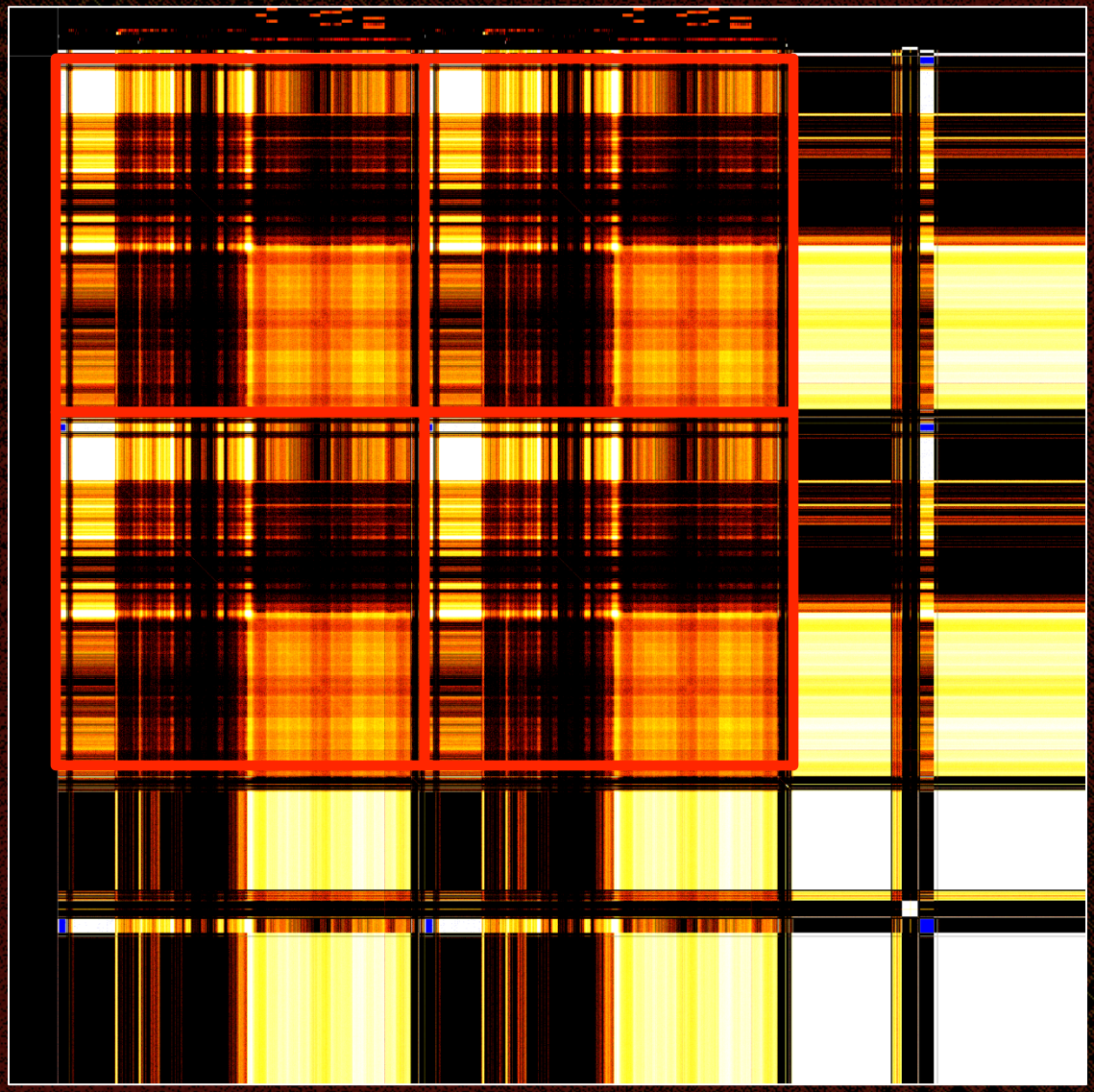
- Each page (hash) is a symbol
- Many pages per pixel (page window)
- Blackbody radiation palette
  - Black – no similarity
  - White – all pages identical
  - Blue – all pages are the zero page
- Sampling reduces runtime



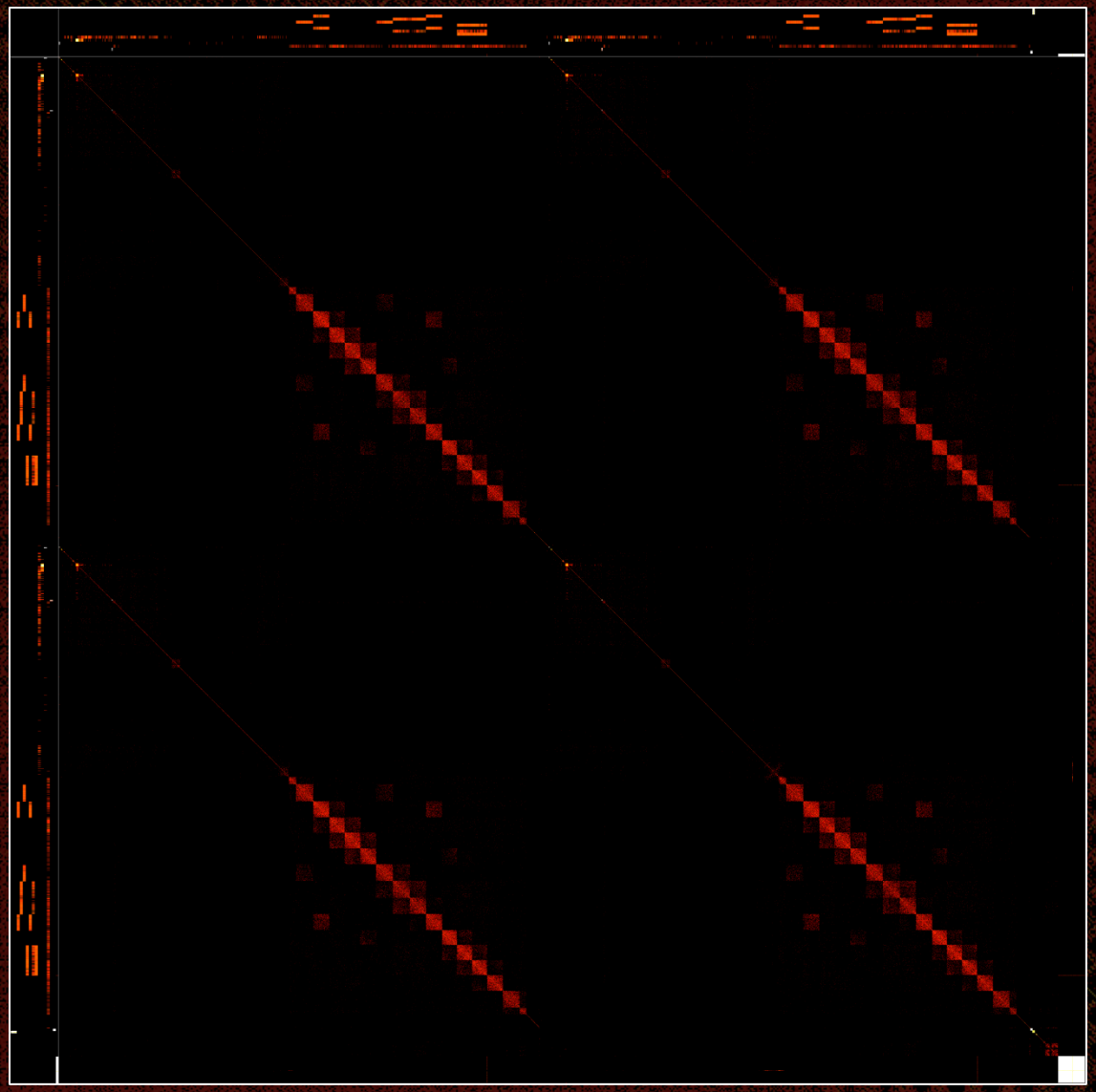
Visualizing our bug



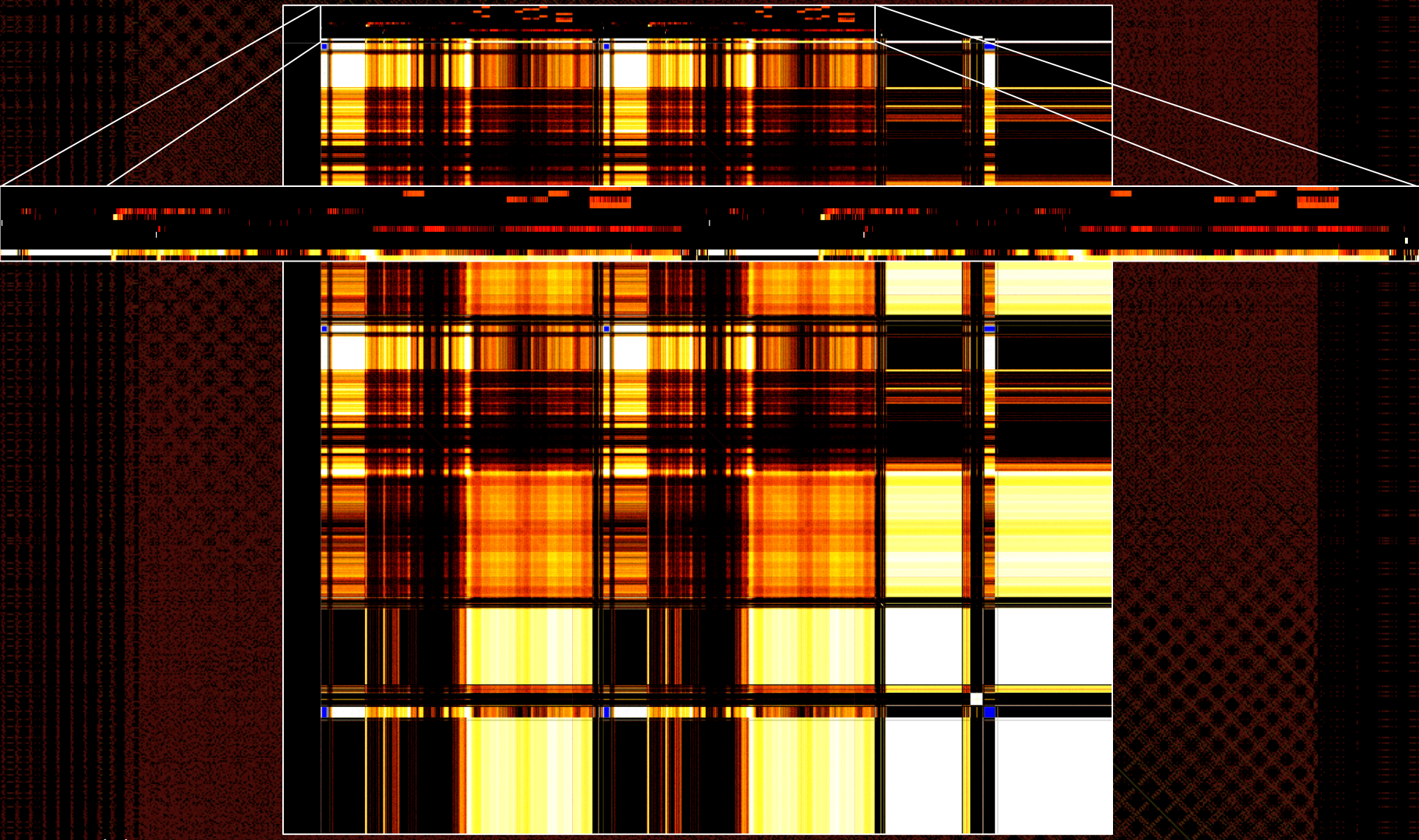
Visualizing our bug



Visualizing our bug: No Zero Pages

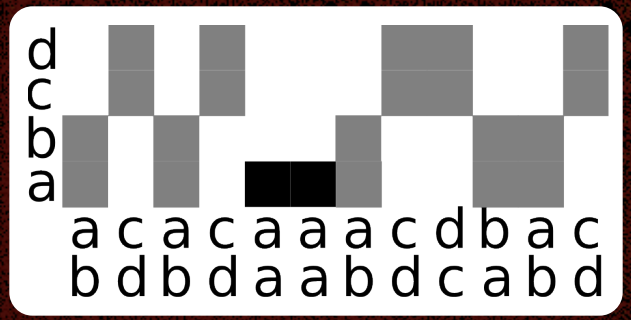


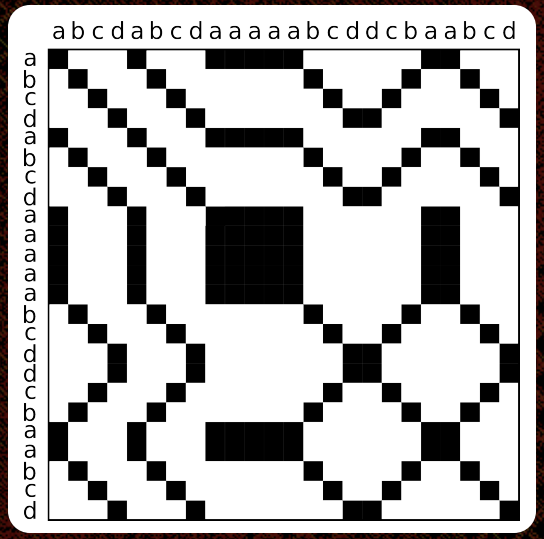
Visualizing our bug: Density Plots



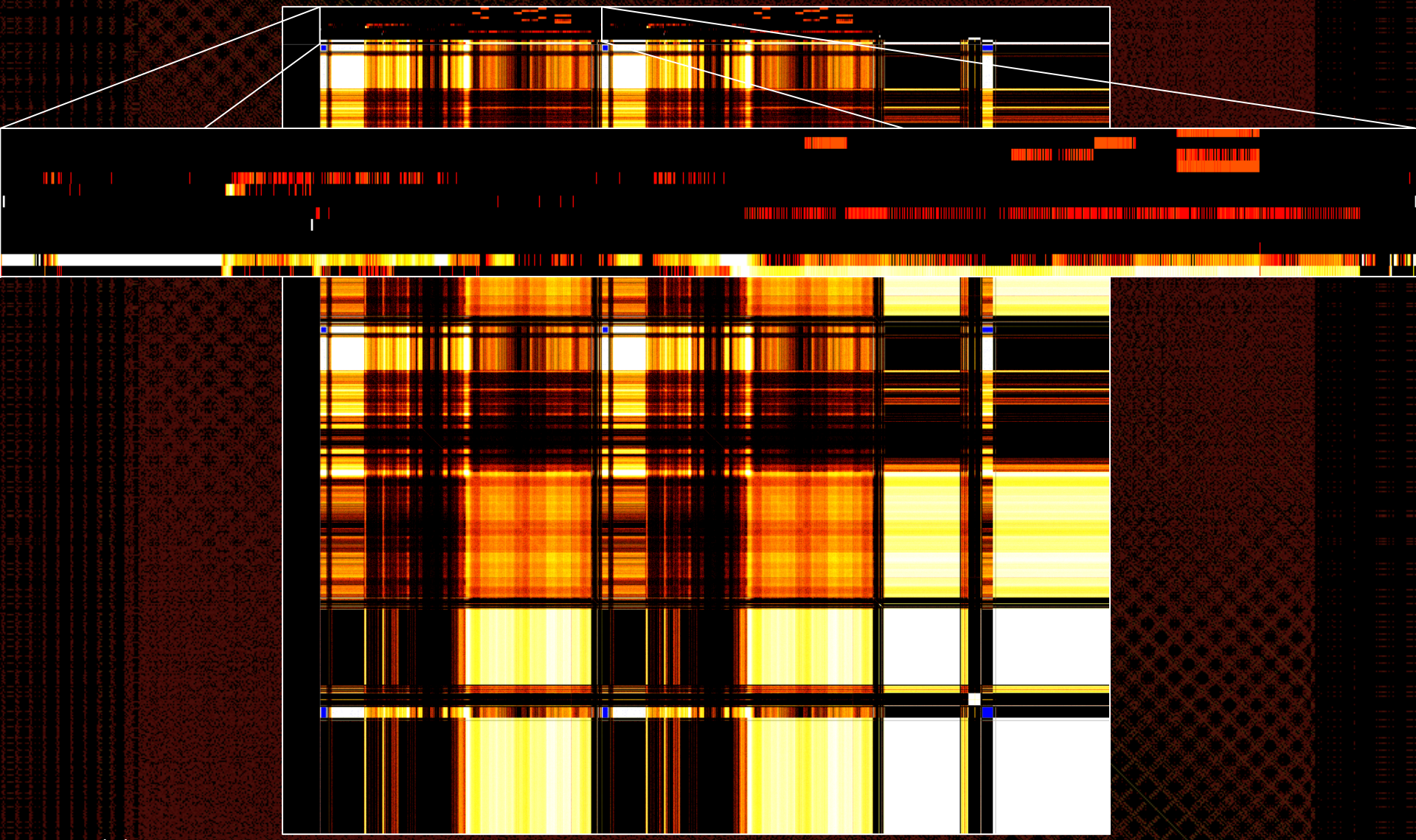
Density Plots

- Calculate ordered list of page frequencies
- Plot density of *n* most frequent (we chose *n*=8) against each page window.





Visualizing our bug: Density Plots



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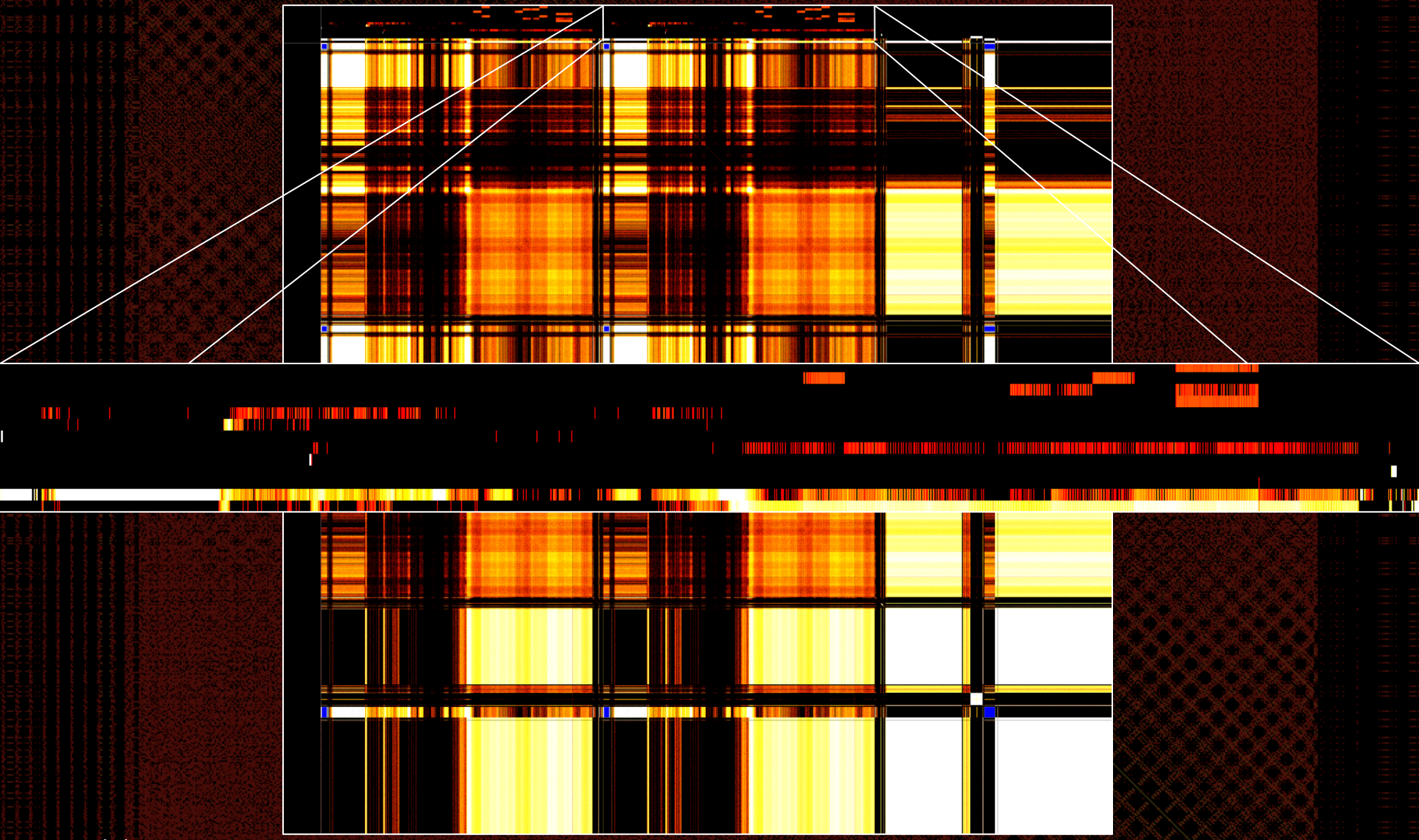
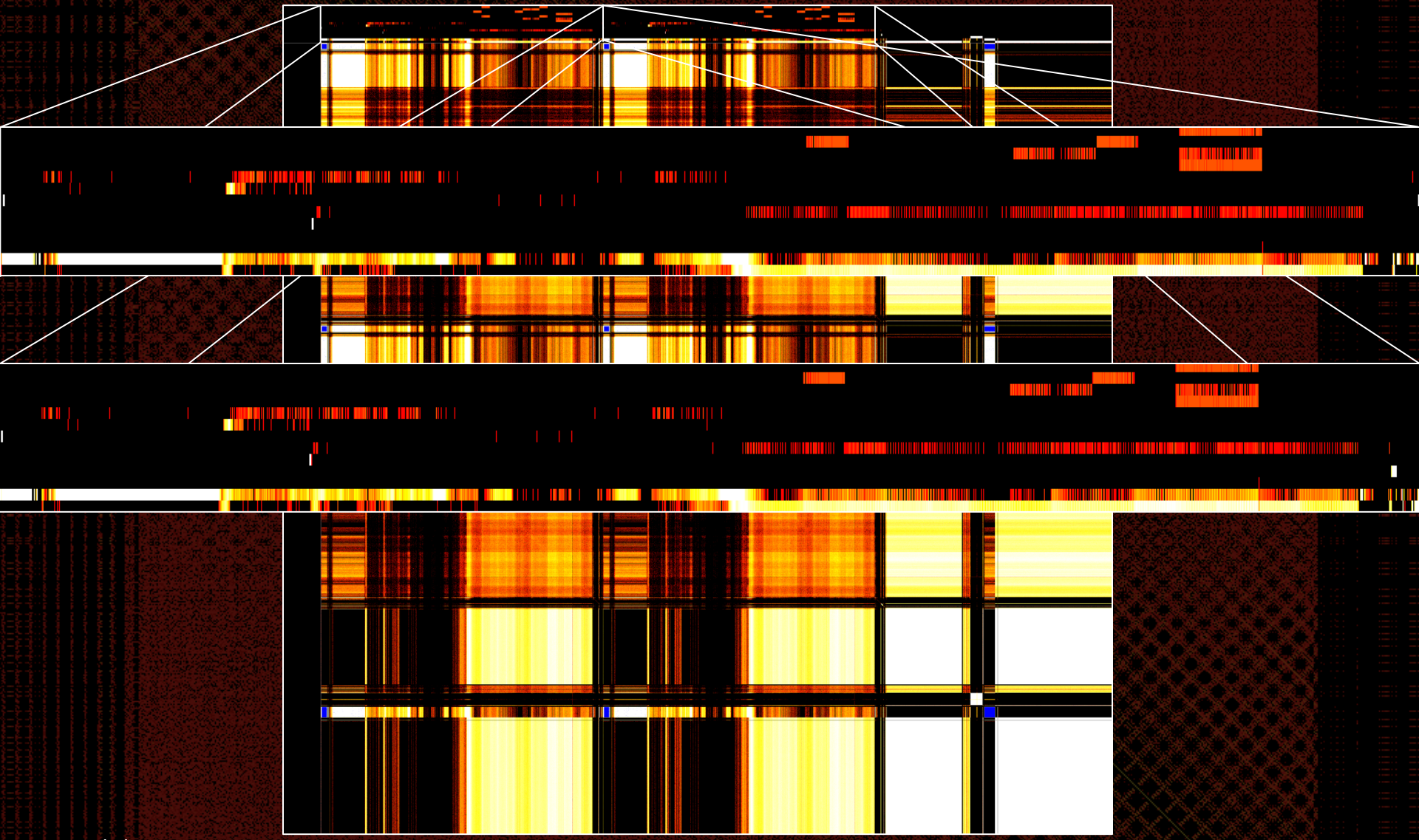
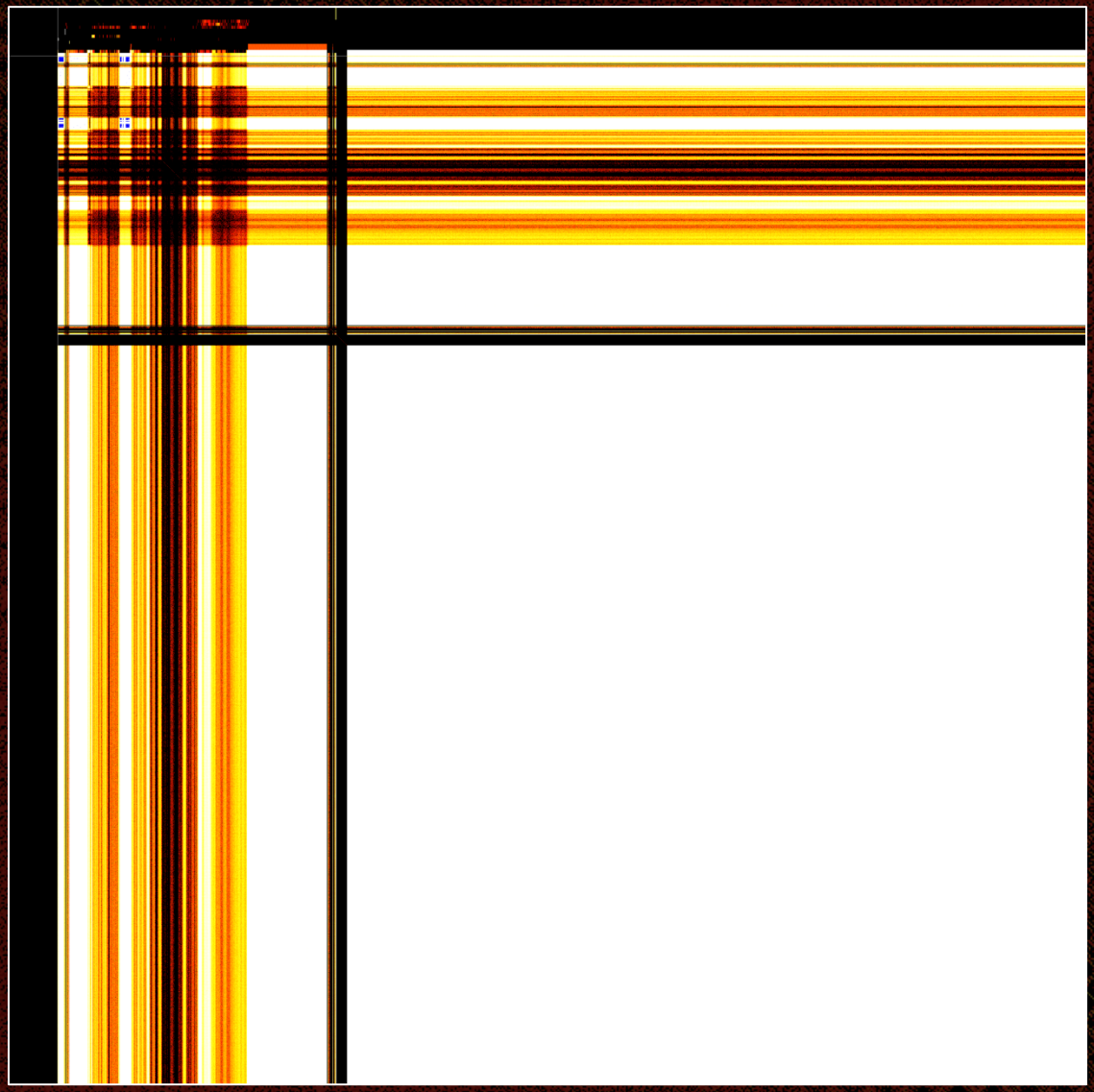


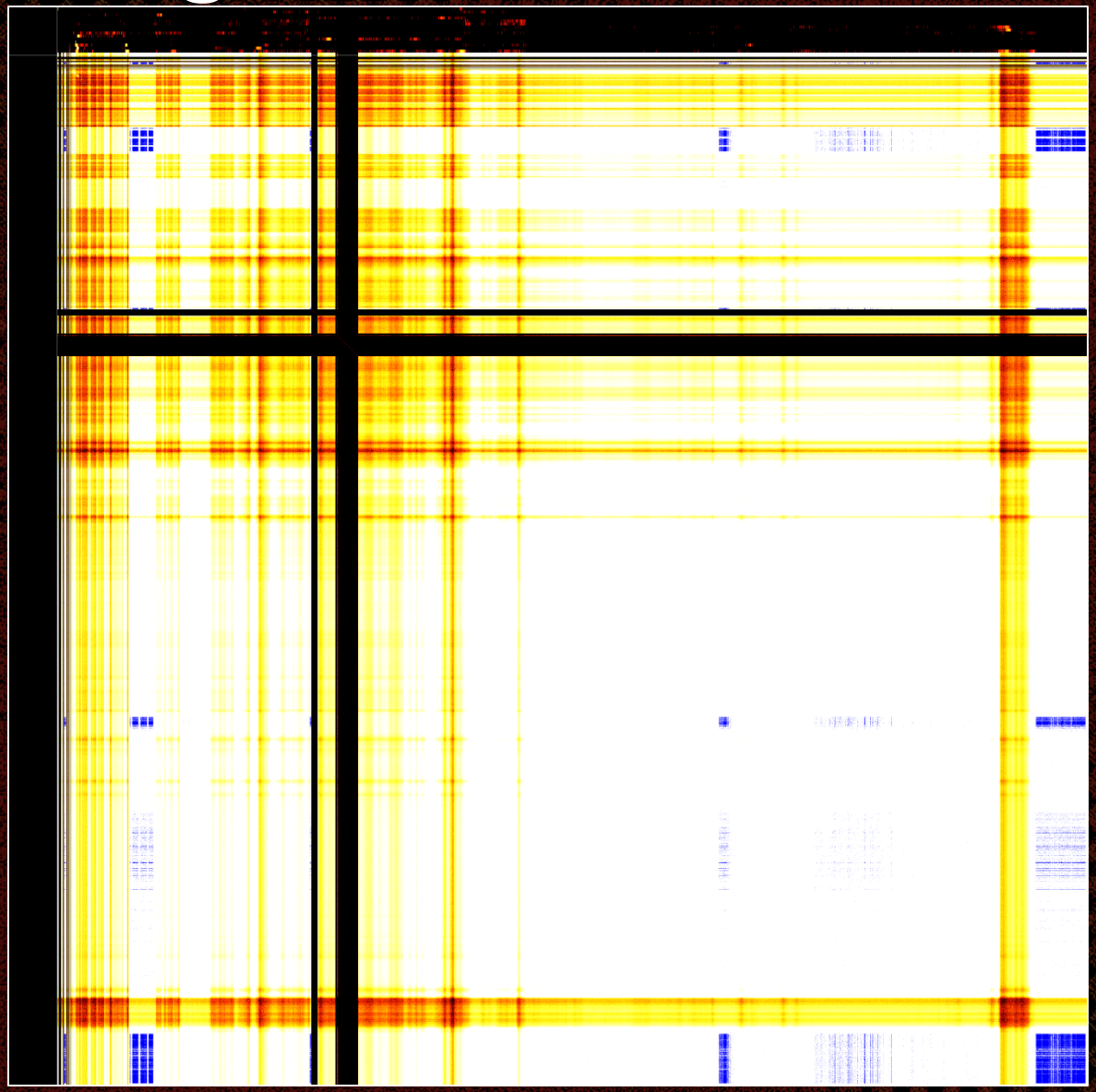
Visualizing our bug: Density Plots



Visualizing our bug: Non-Buggy Plot



Using the Hibernation File



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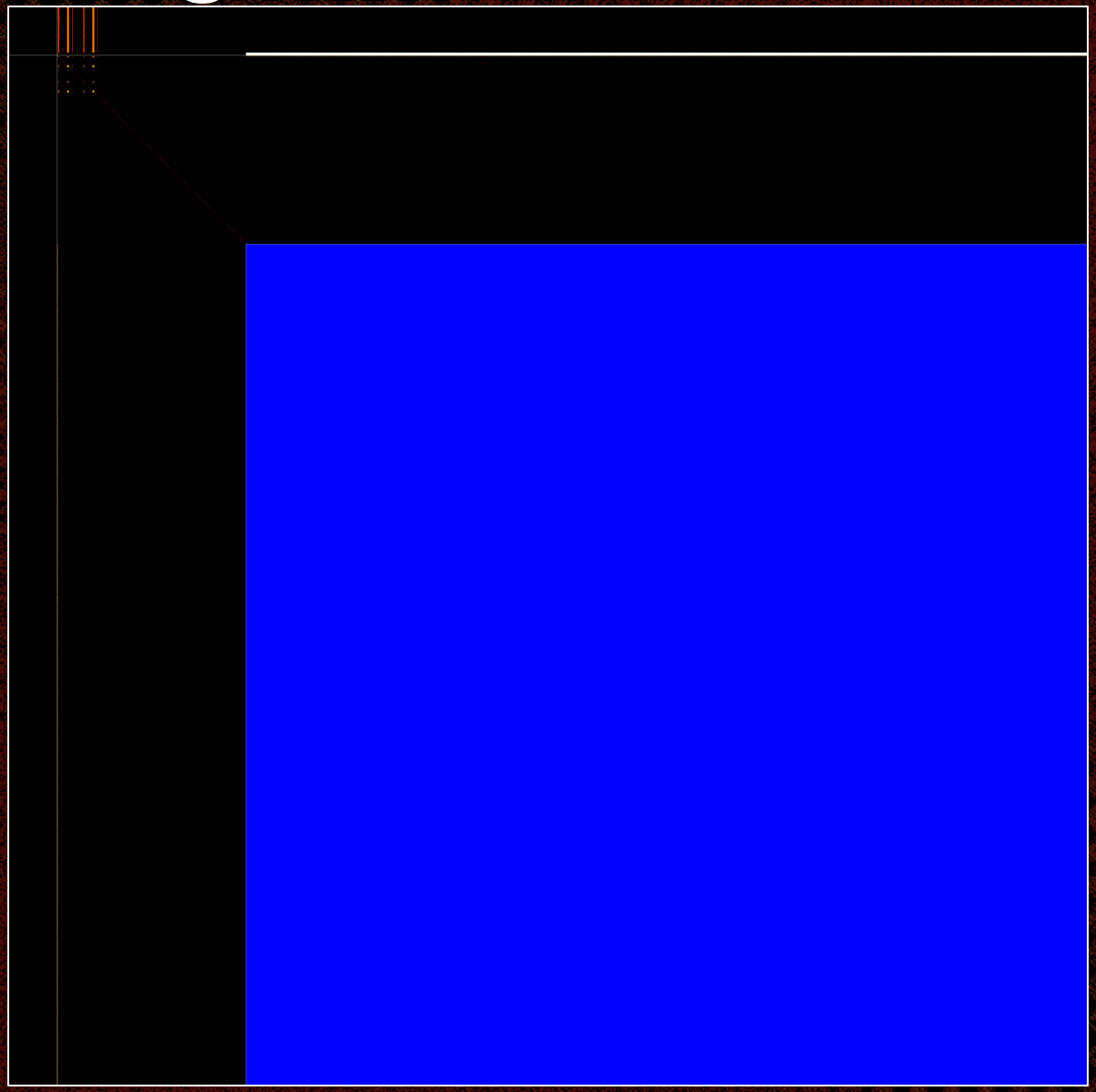
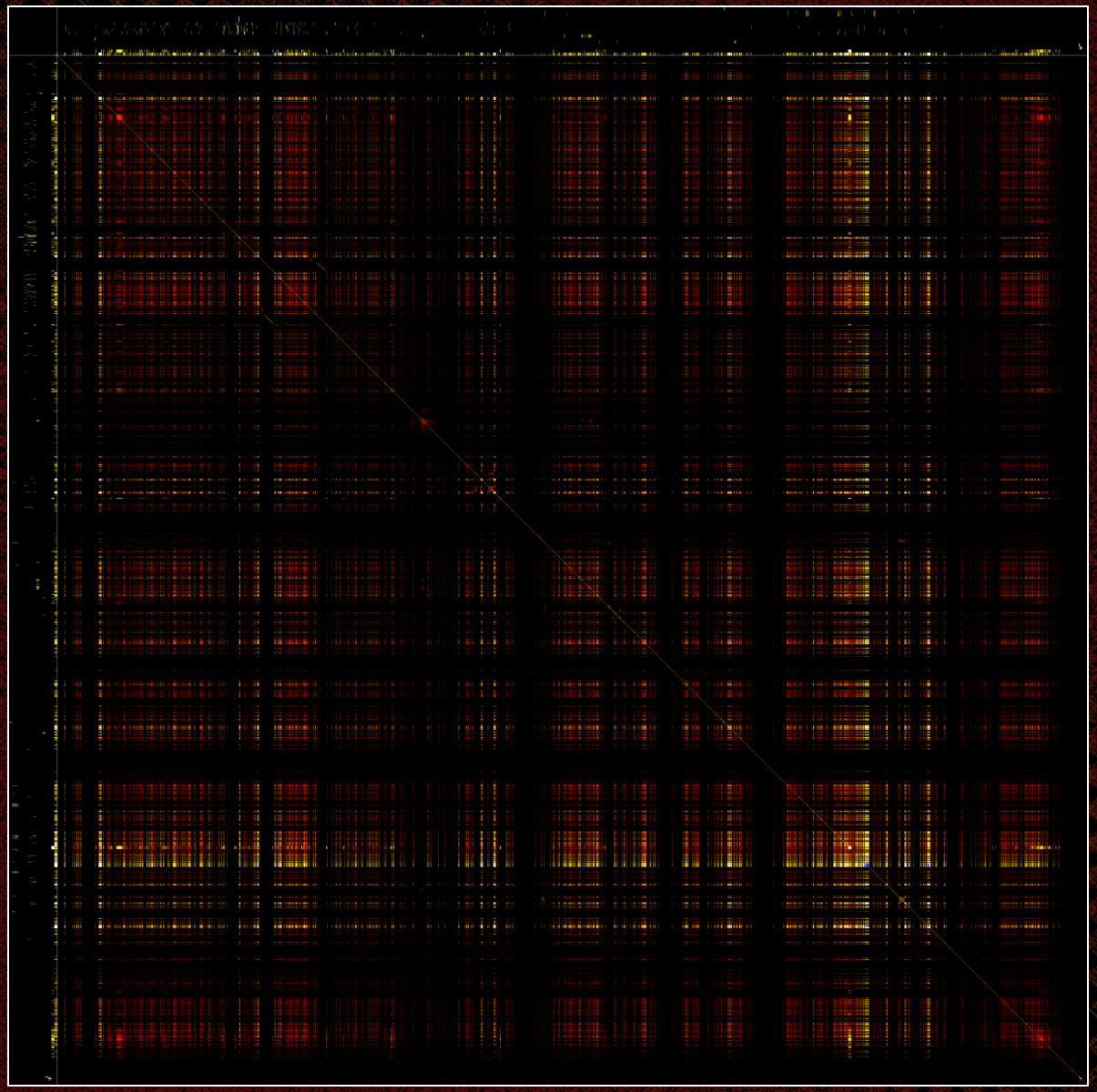


Comparing OS X /dev/mem to MMR



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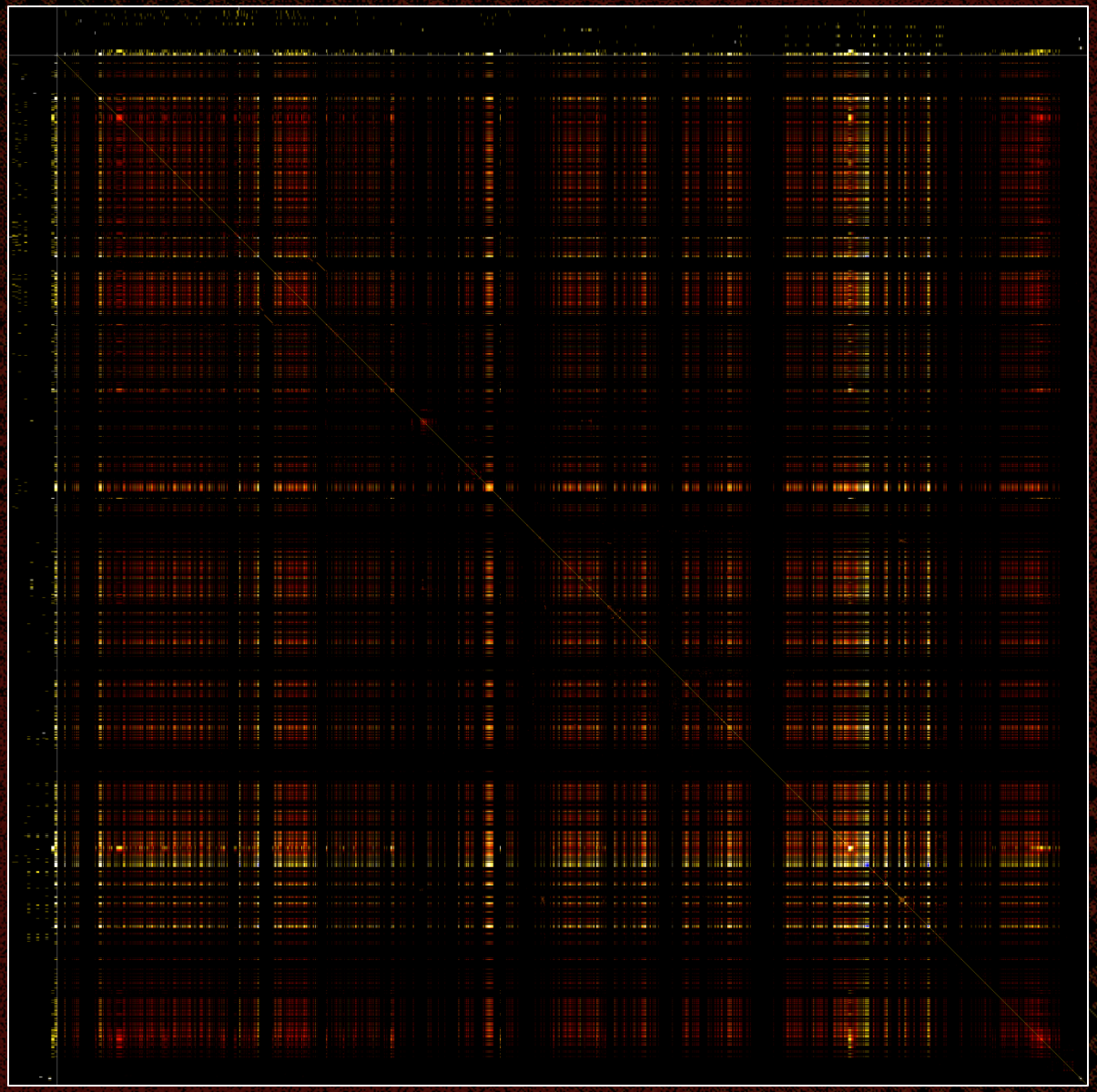

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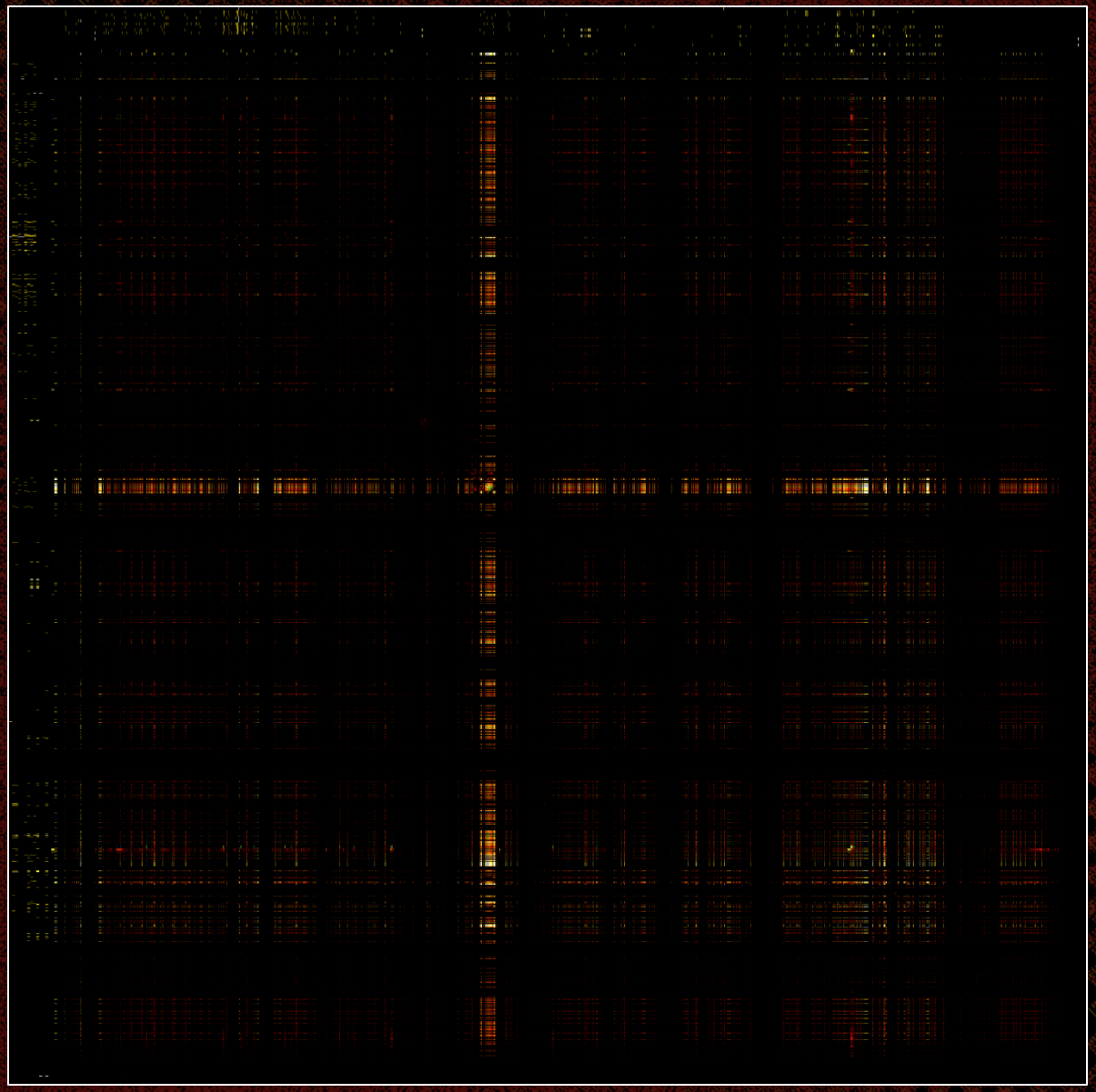

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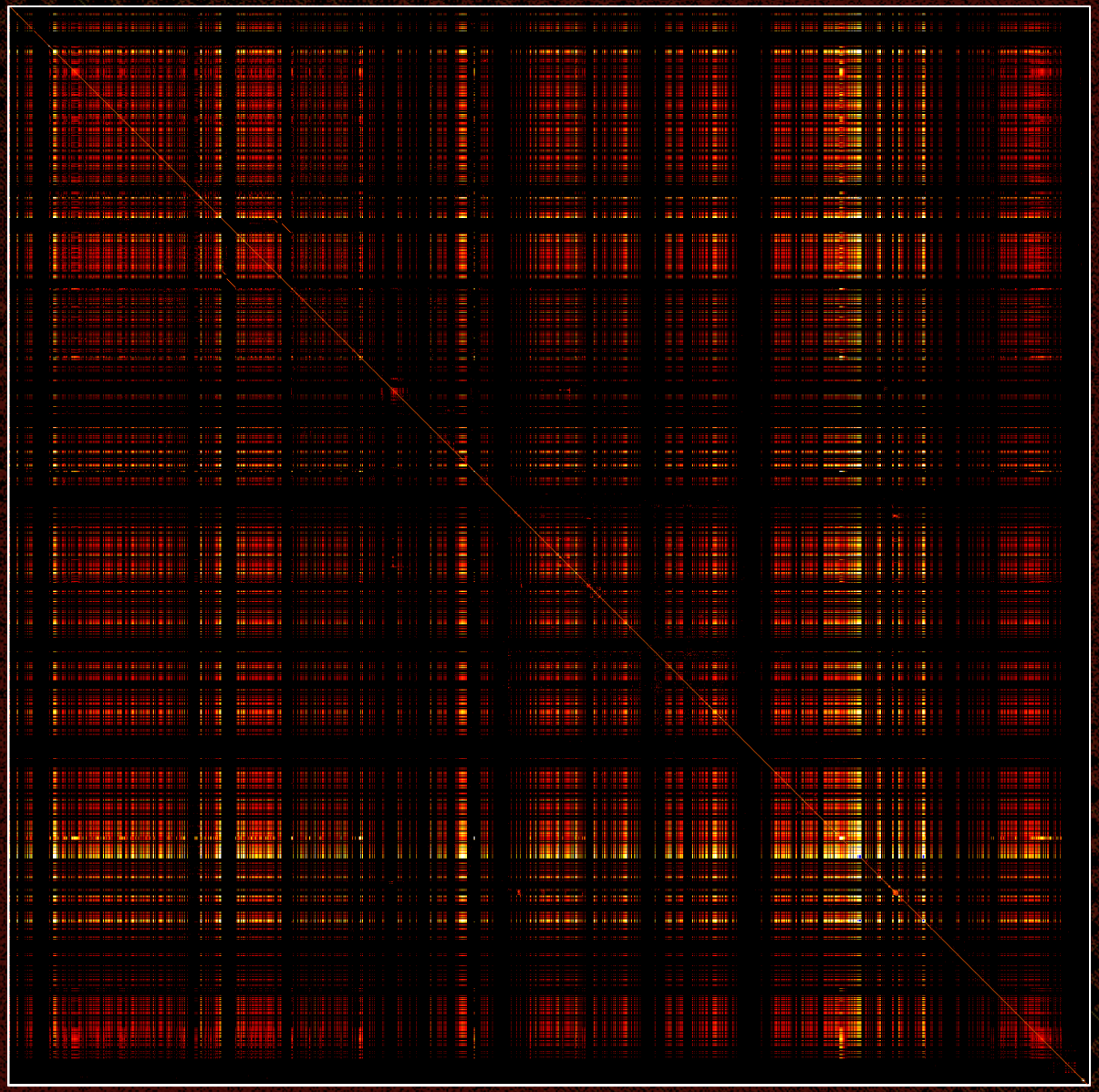
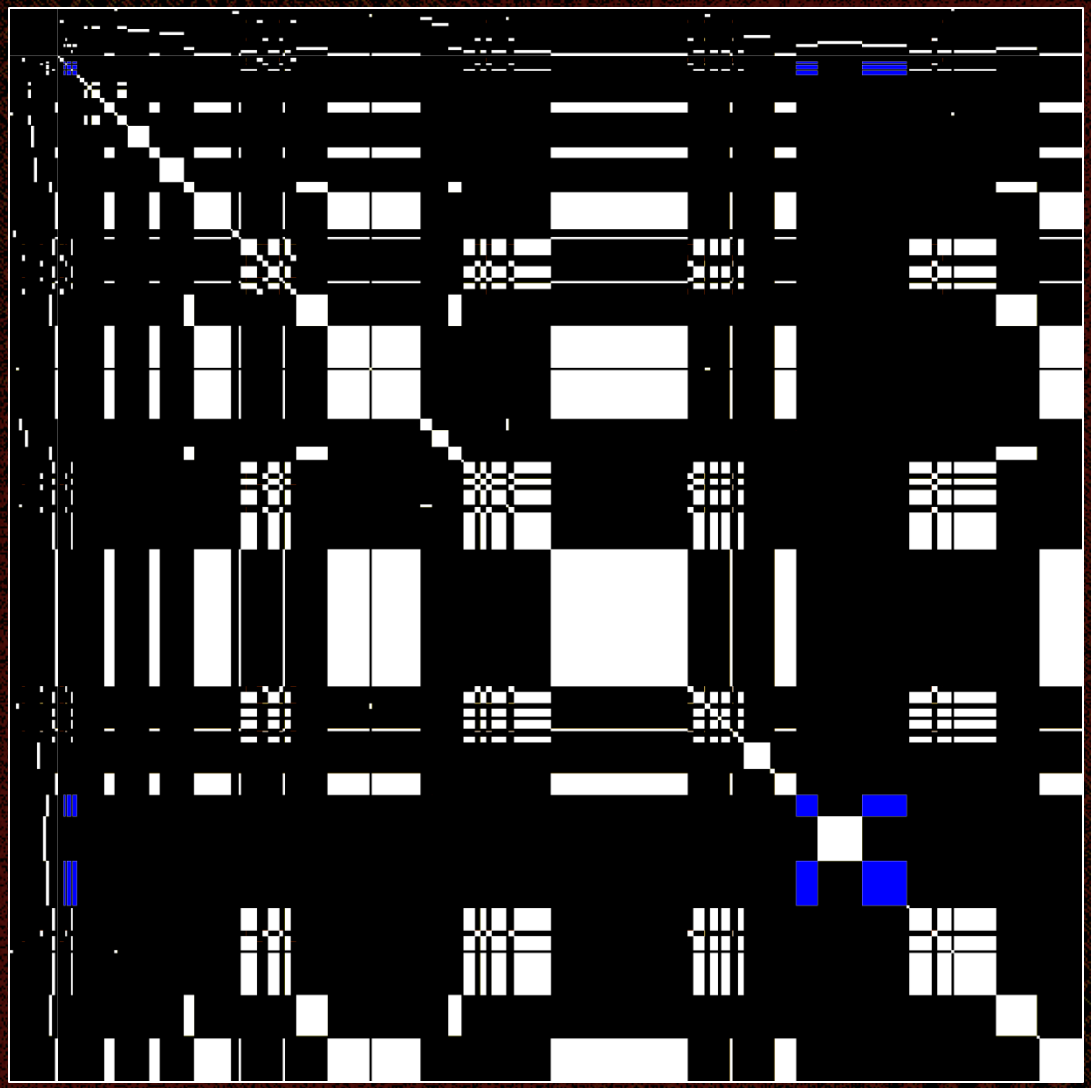


Apple's /dev/mem
(on Intel)



OS X **dd** to Disk

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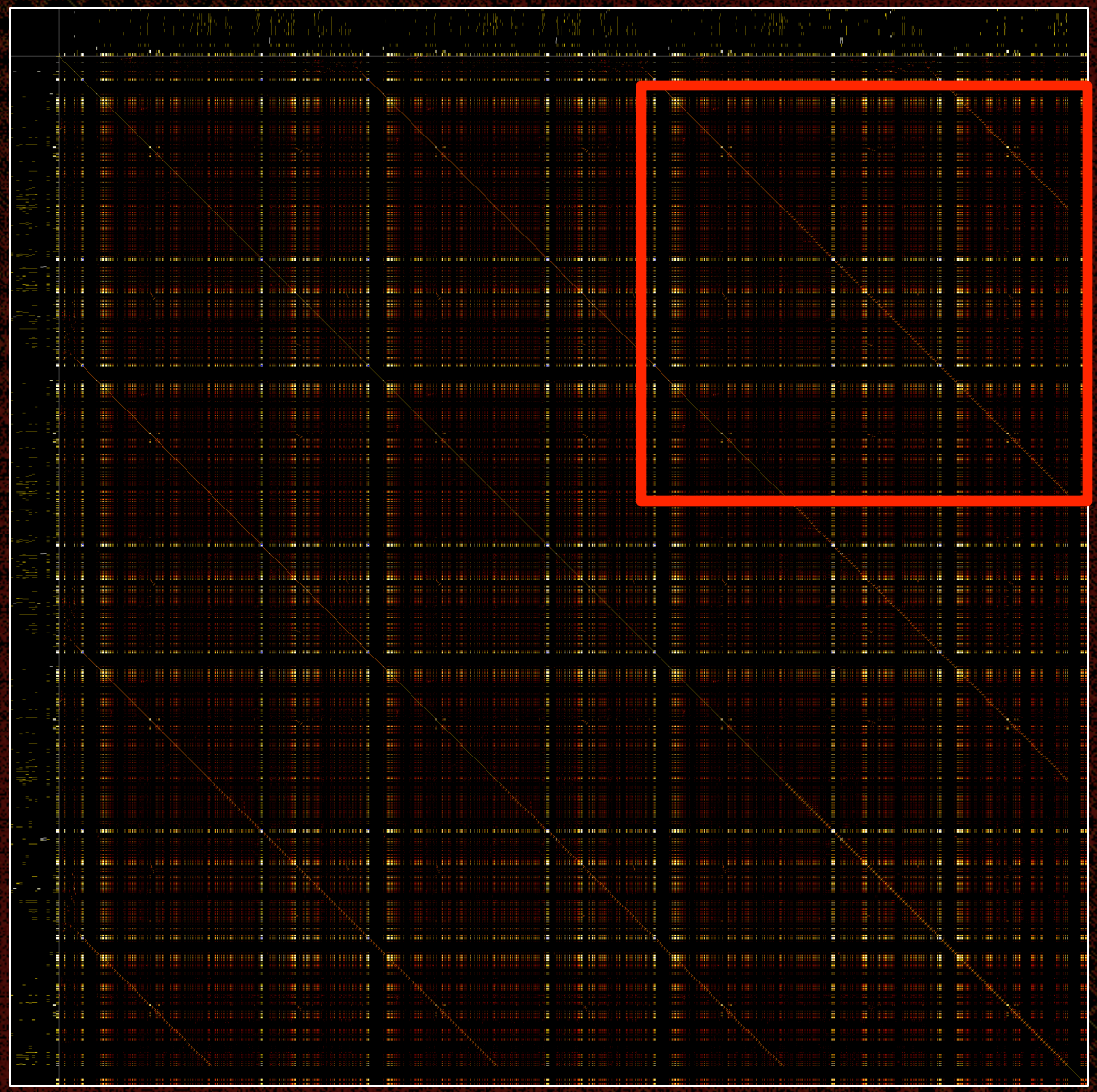

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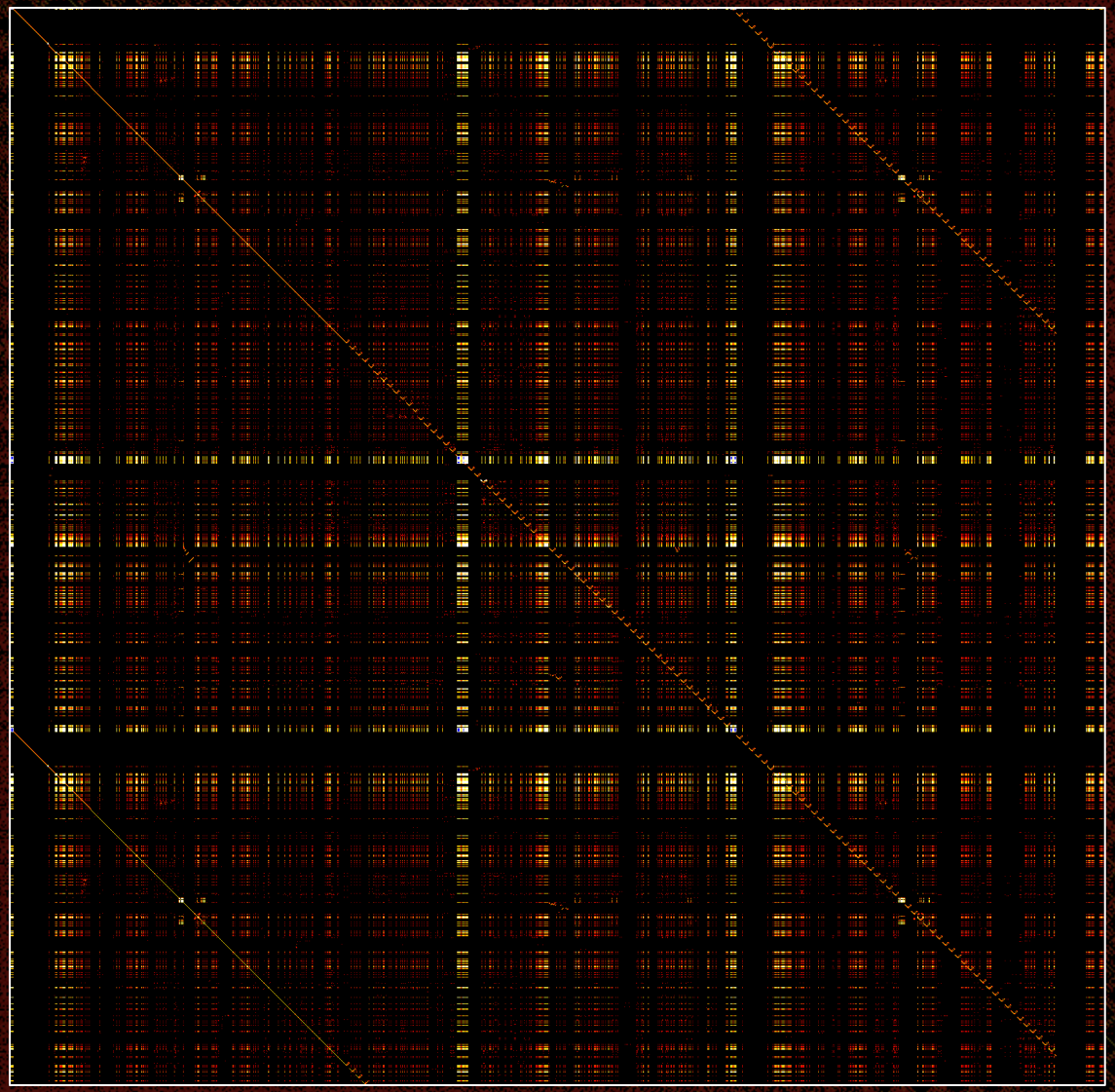
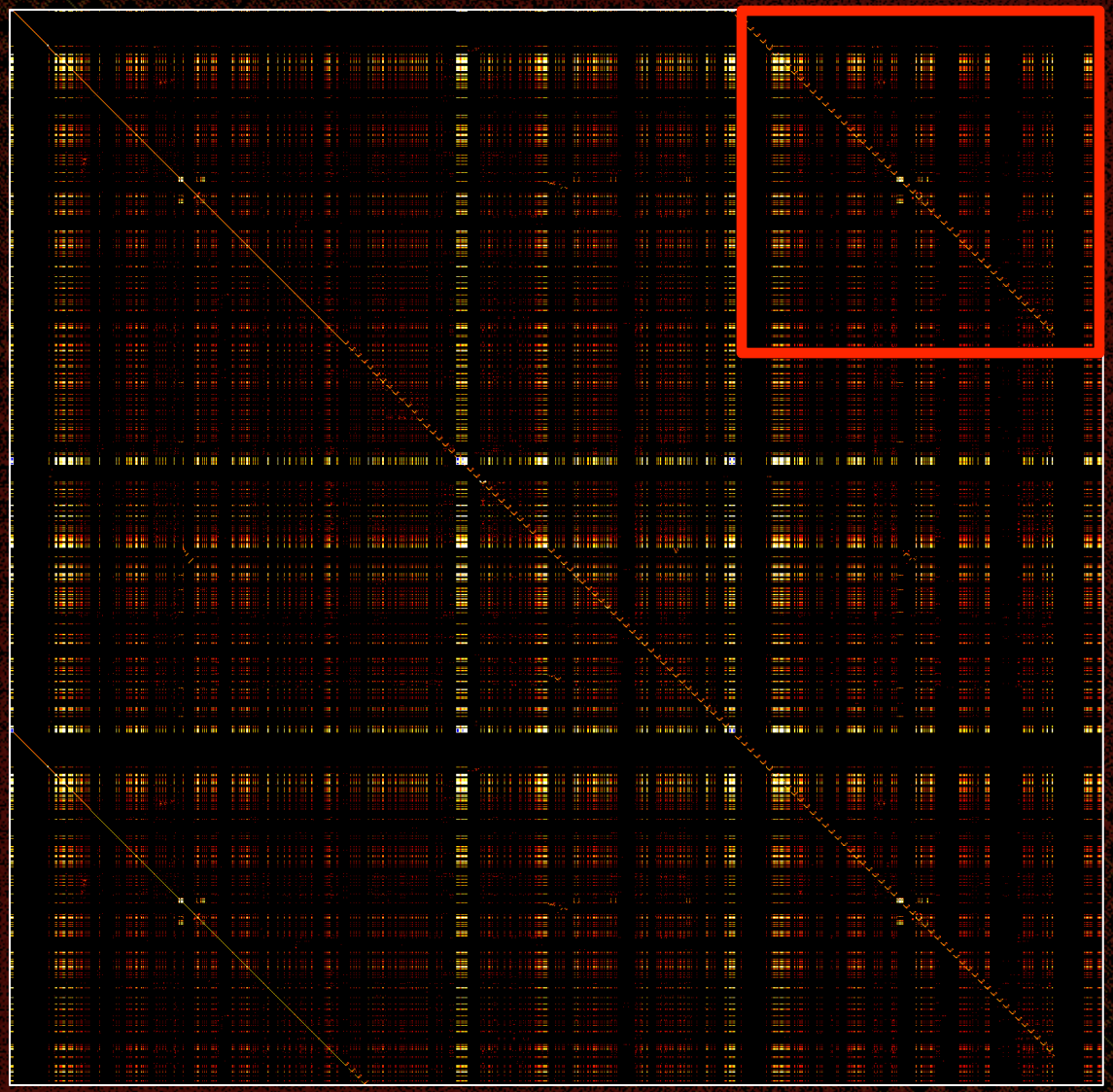


OS X **dd** to Disk



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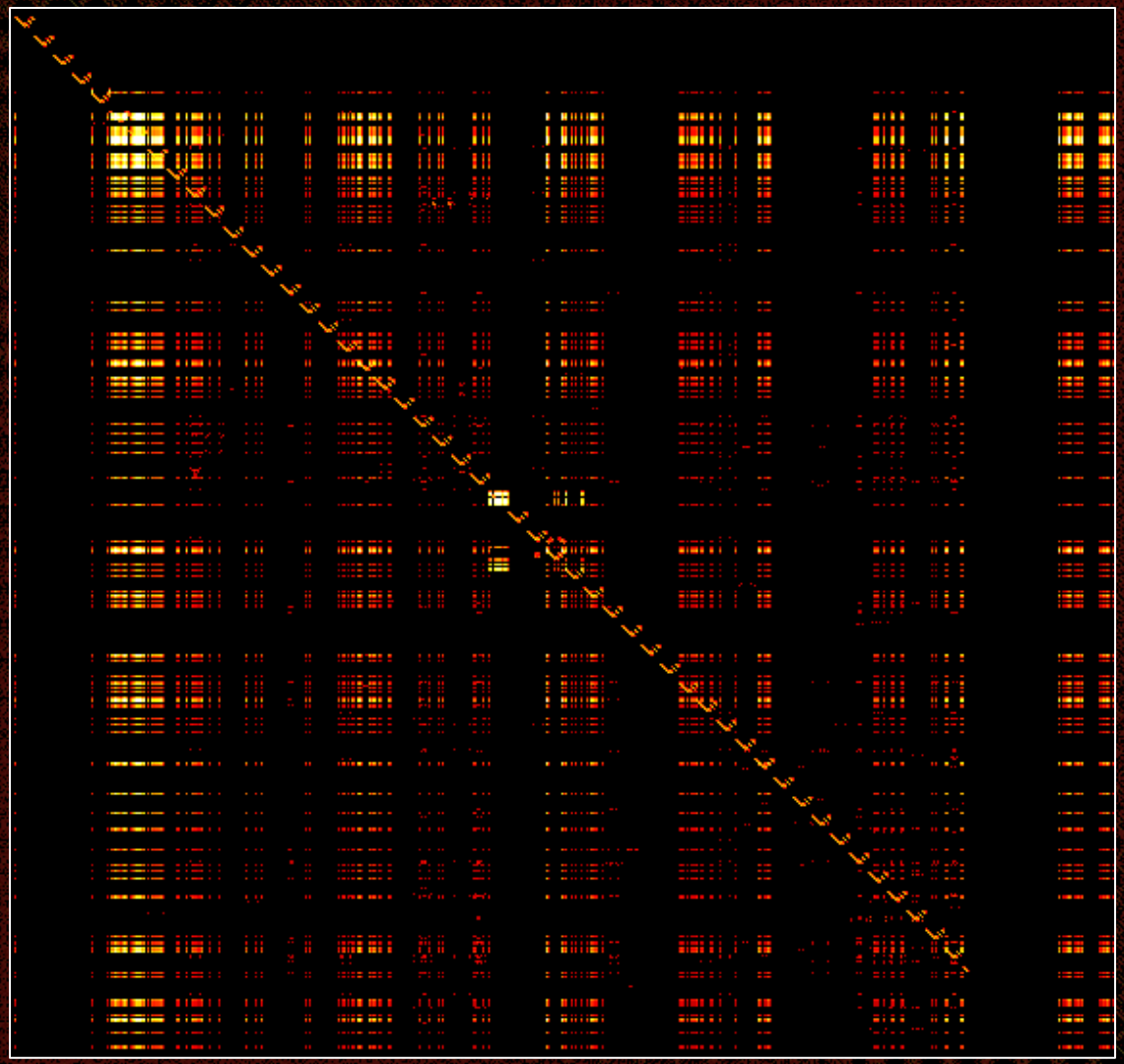
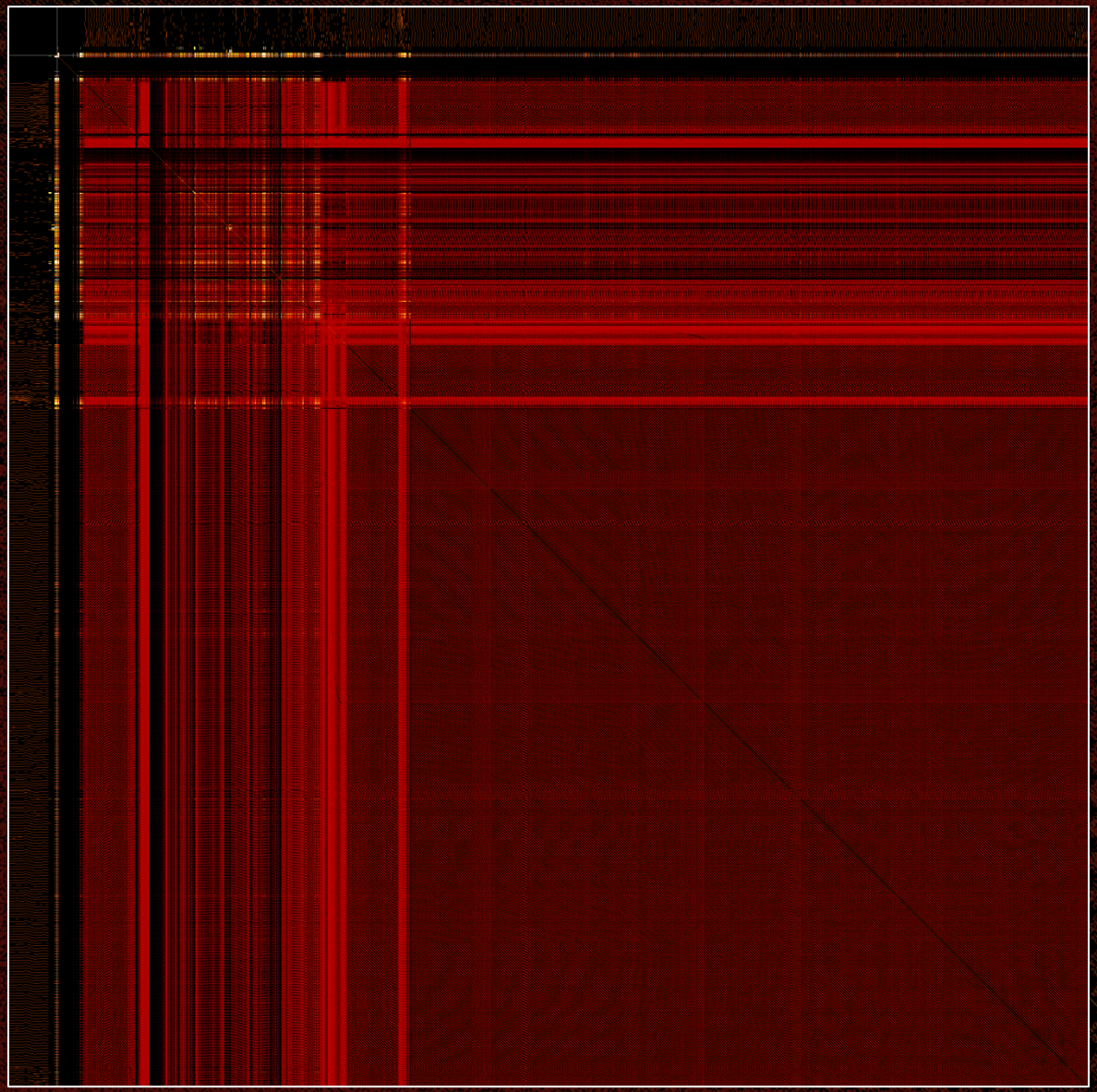
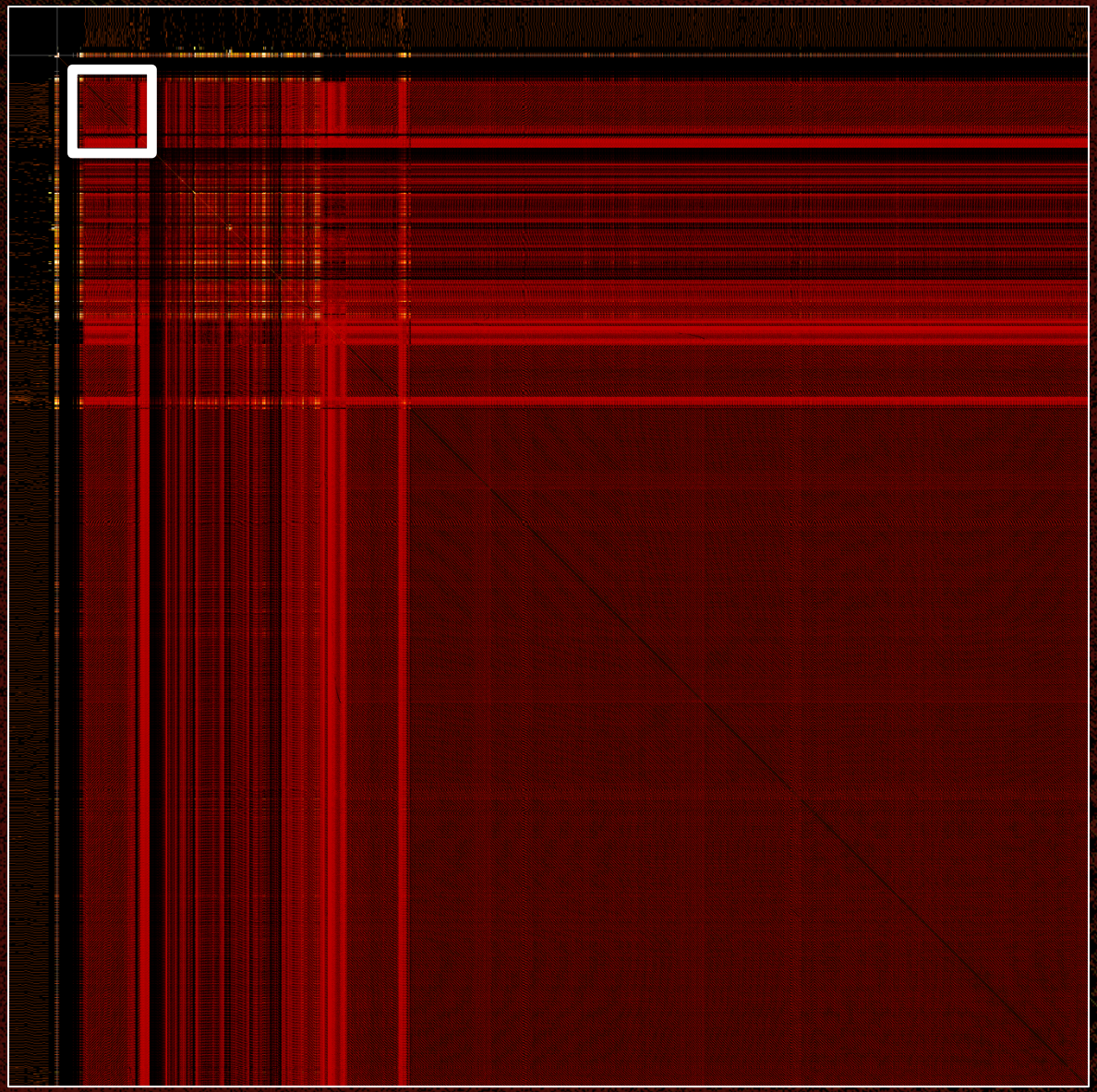


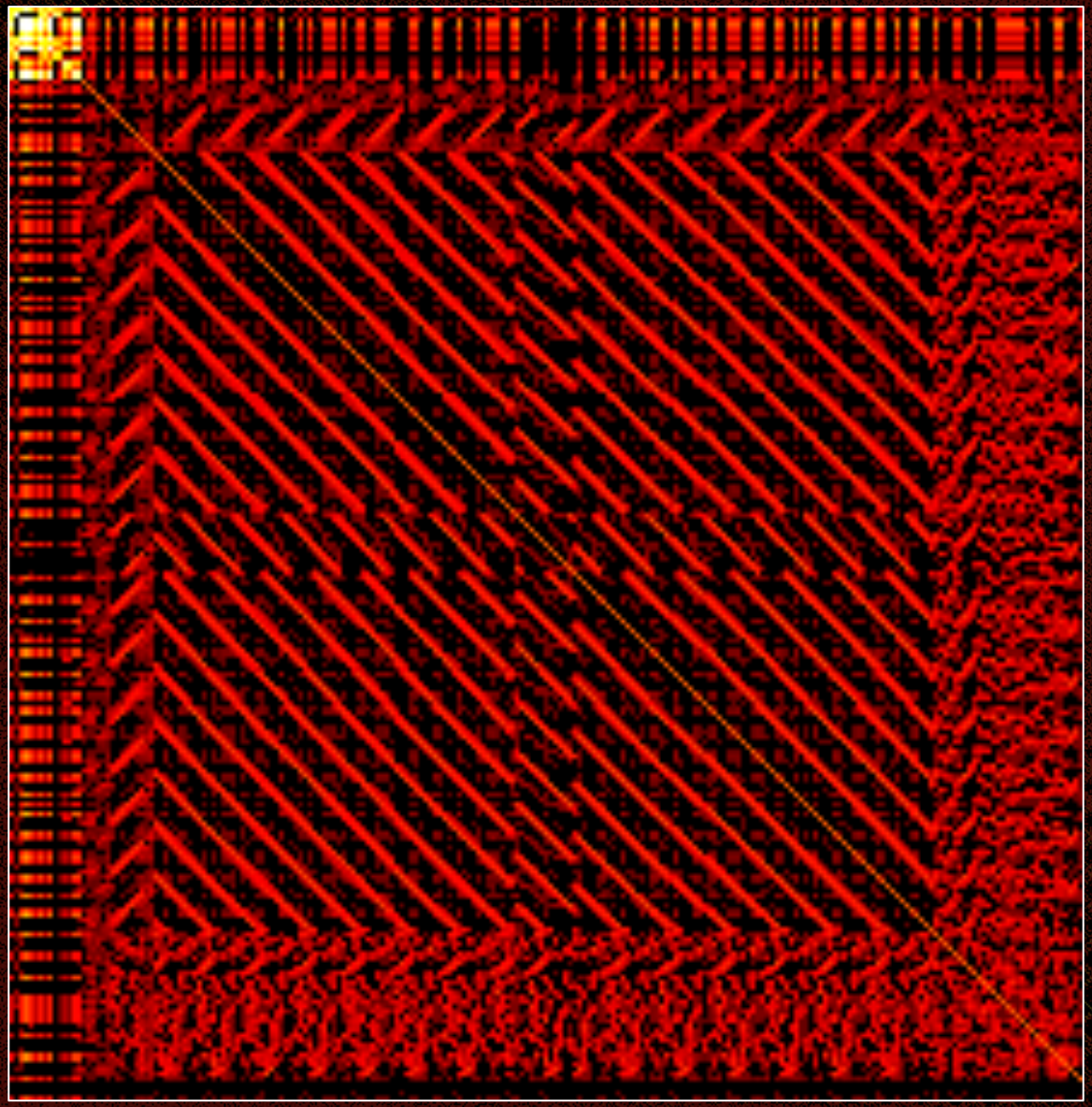
String Injection



String Injection



String Injection



Conclusion

- Implemented a physical memory imager for OS X
- Established metrics for imaging:
  - Speed, completeness, accuracy, non-interference
- With no ground truth, testing is difficult
  - Tools produce different results
- Visualization can help:
  - dotplots
  - density plots
- OS X:
  - Don't record dd to disk
  - Don't rely on the hibernation file
  - Mac memory reader available at: www.cybermarshal.com/index.php/cyber-marshal-utilities/mac-memory-reader

Future Work

- Mac Memory Reader for Lion (OS X 10.7)
  - Released July 28th
- Analysis
  - Matthieu Suiche – Blackhat Paper: Mac OS X Physical Memory Analysis
  - Kyeong-Sik Lee - Volafox
  - Our own tools are forthcoming

Questions

(How was the background image generated?)