PySKI:
THE PYTHON SPARSE KERNEL INTERFACE

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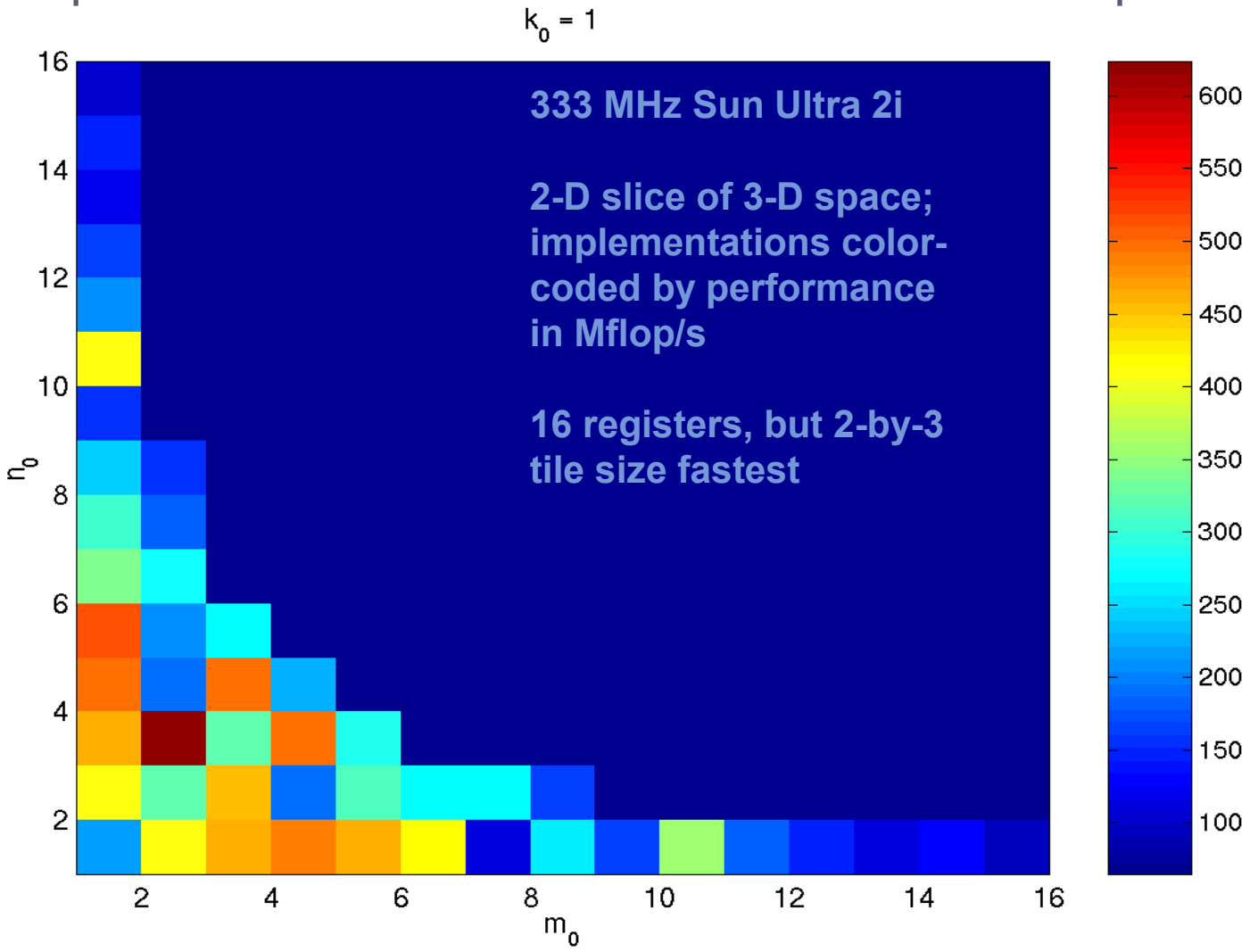
THE NEED FOR AUTO-TUNING

Mflops/s for Various Block Sizes in MatMul Operation



WHAT IS OSKI?

- “Optimized Sparse Kernel Interface”
- C Library used in solver libraries
- BLAS-style interface
  - SpMV, SpTS, etc.
- Automatically tuned computational kernels on sparse matrices
  - Optimal tuning choices are often non-obvious
  - 3 Types of Tuning
    - Static tuning (based on system)
    - implicit dynamic tuning (performance monitoring)
    - explicit dynamic tuning (workload hints)

PYSKI MOTIVATION

- Productivity code: express computation in the easiest way possible
- Efficiency code: tuning and other implementation choices to get best performance
- C/OSKI code conflates the two
  - When to change representation of a matrix?
  - When to do expensive "unmarshal" of a representation?
  - When to tune and re-tune?
    - Setting explicit tuning hints

EXAMPLE: TUNING WITH EXPLICIT HINTS

```
oski_matrix_t A_tunable = oski_CreateMatCSR( … );

/* Tell OSKI we will call SpMV 500 times (explicit workload hint) */
oski_SetHintMatMult(A_tunable, OP_NORMAL, α, x_view, β, y_view, 500);

/* Tell OSKI we think the matrix has 8x8 blocks (structural hint) */
oski_SetHint(A_tunable, HINT_SINGLE_BLOCKSIZE, 8, 8);

/* Ask OSKI to tune */
oski_TuneMat(A_tunable);
```

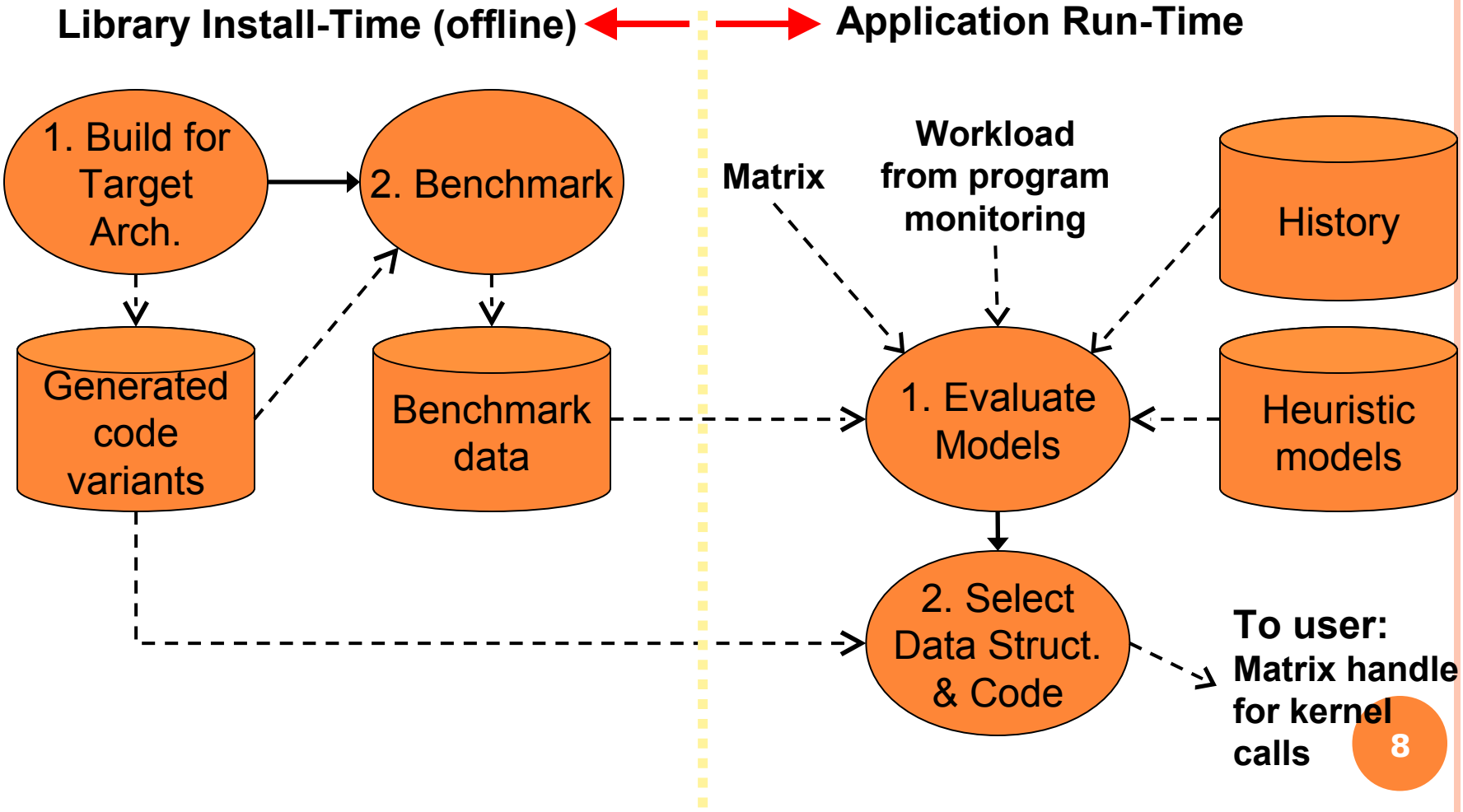
```
for( i = 0; i < 500; i++ )
   oski_MatMult(A_tunable, OP_NORMAL, α, x_view, β, y_view);
```

PYSKI SEPARATES TUNING FROM COMPUTATION

- Provide Python bindings for OSKI via scipy.sparse
  - OSKI maintains data structures plus "shadow" data structures for tuning
  - Abstract datatypes wrap pointers to these structures
- Expose higher-level abstract datatypes & methods to productivity programmer
  - low-level OSKI objects become invisible to mainline computation
- Idea: separate tuning hints into another file
  - changes to policy don't contaminate source
  - *policy experimentation can proceed in parallel*

BACKUP SLIDES

HOW OSKI TUNES (OVERVIEW)



Extensibility: Advanced users may write & dynamically add “Code variants” and “Heuristic models” to system.

SUMMARY OF PERFORMANCE OPTIMIZATIONS

- Optimizations for SpMV
  - **Register blocking (RB)**: up to **4x** over CSR
  - **Variable block splitting**: **2.1x** over CSR, 1.8x over RB
  - **Diagonals**: **2x** over CSR
  - **Reordering** to create dense structure + **splitting**: **2x** over CSR
  - **Symmetry**: **2.8x** over CSR, 2.6x over RB
  - **Cache blocking**: **2.8x** over CSR
  - **Multiple vectors (SpMM)**: **7x** over CSR
  - And combinations…
- Sparse triangular solve
  - Hybrid sparse/dense data structure: **1.8x** over CSR
- Higher-level kernels
  - $\mathbf{A \cdot A^T \cdot x}$, $\mathbf{A^T \cdot A \cdot x}$: **4x** over CSR, 1.8x over RB
  - $\mathbf{A^2 \cdot x}$: **2x** over CSR, 1.5x over RB
  - $[A \cdot x, A^2 \cdot x, A^3 \cdot x, \ldots, A^k \cdot x]$