Reduction

Parallelizing problems of limited parallel nature

Examples of reduction algorithms

Extracting small data from larger

- Finding max or min
- Calculating median or average
- Histograms

Common problems!

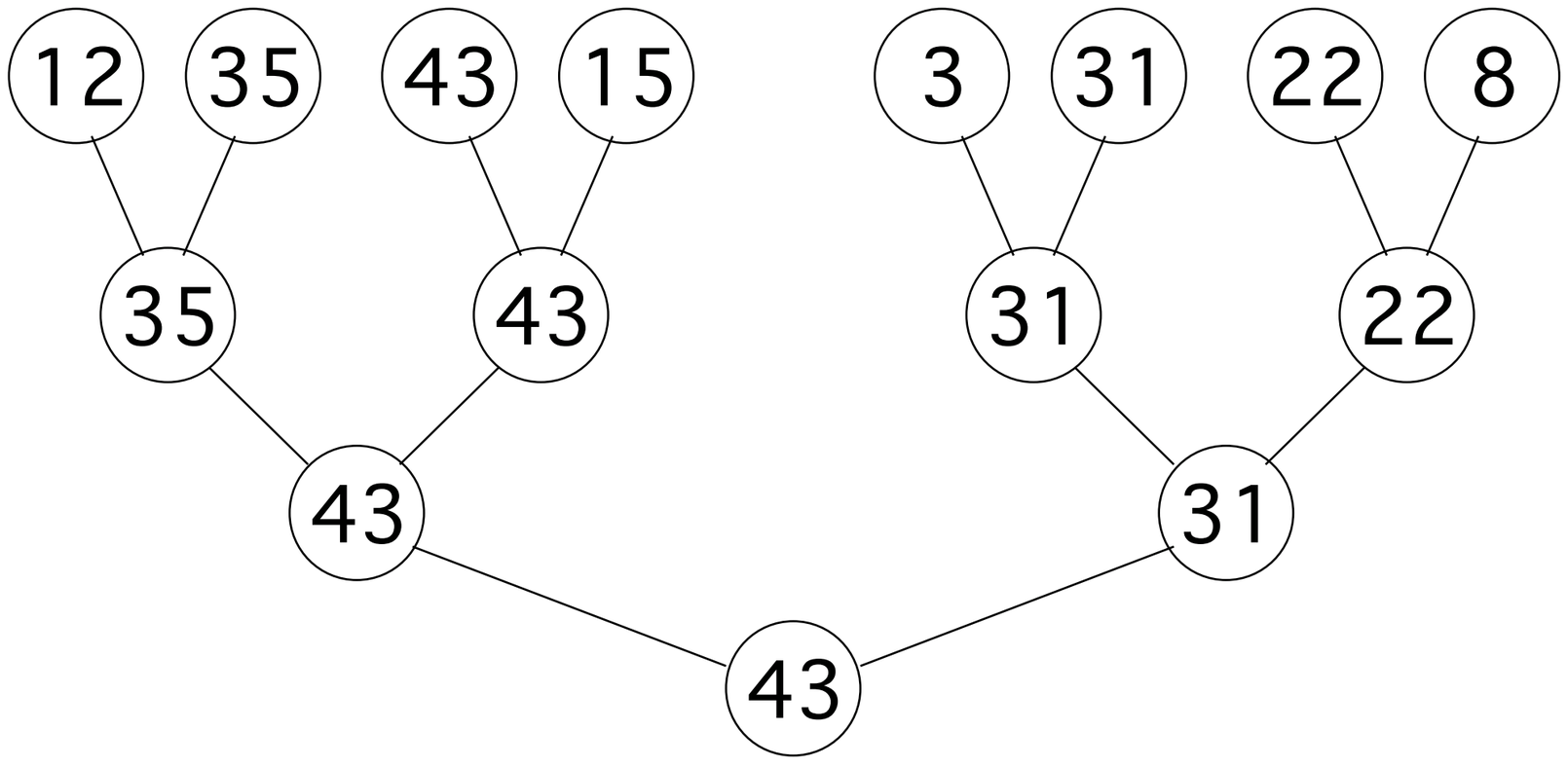
Sequentially trivial

Loop through data

Add, min/max, accumulate results

Fits badly in massive parallelism!

Tree-based approach

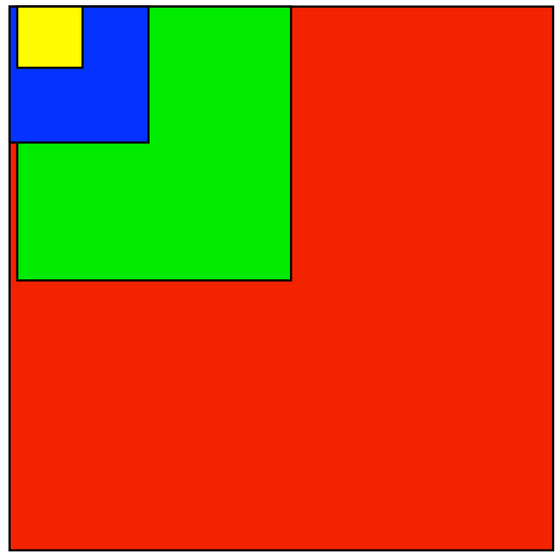


In 2D, typically 4-to-1 per level

Pyramid hierarchy

47	2	3	57	5	12	7	8
10	20	6	13	14	15	16	17
19	11	21	22	23	68	25	26
38	29	64	31	32	33	35	34
37	28	39	49	53	42	41	52
46	1	48	40	61	51	44	43
55	71	4	58	69	62	50	60
30	65	66	67	24	59	70	56

47	57	15	17
38	64	68	35
46	49	61	52
71	67	69	70

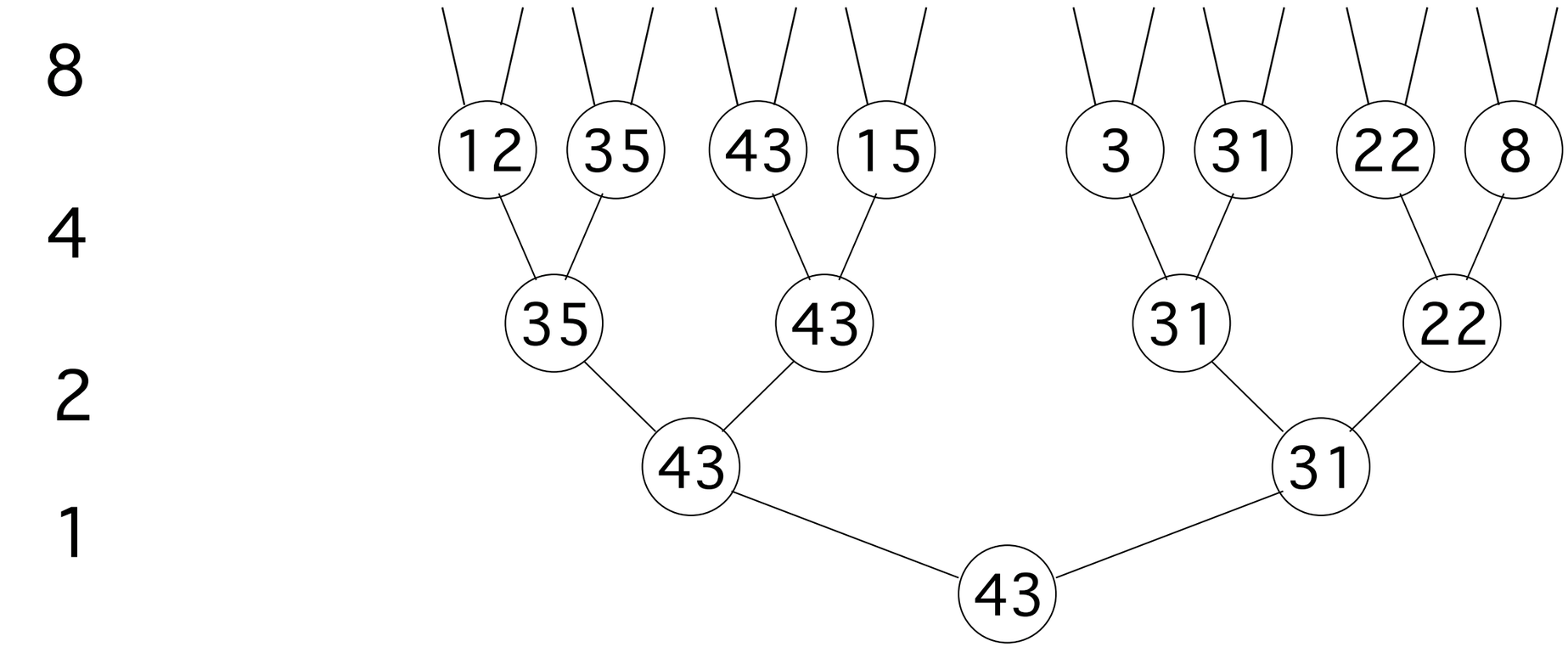


Tree-based approach

Each level parallel! Can be split onto large numbers of threads

but

the parallelism is reduced for each level, and the results need to be reorganized to a smaller number of threads!


etc
16
8
4
2
1
12
35
43
15
3
31
22
8
35
43
31
22
43
31
43

Multiple kernel runs for varying size!

For n = k downto 0 do
Launch 2^n kernels

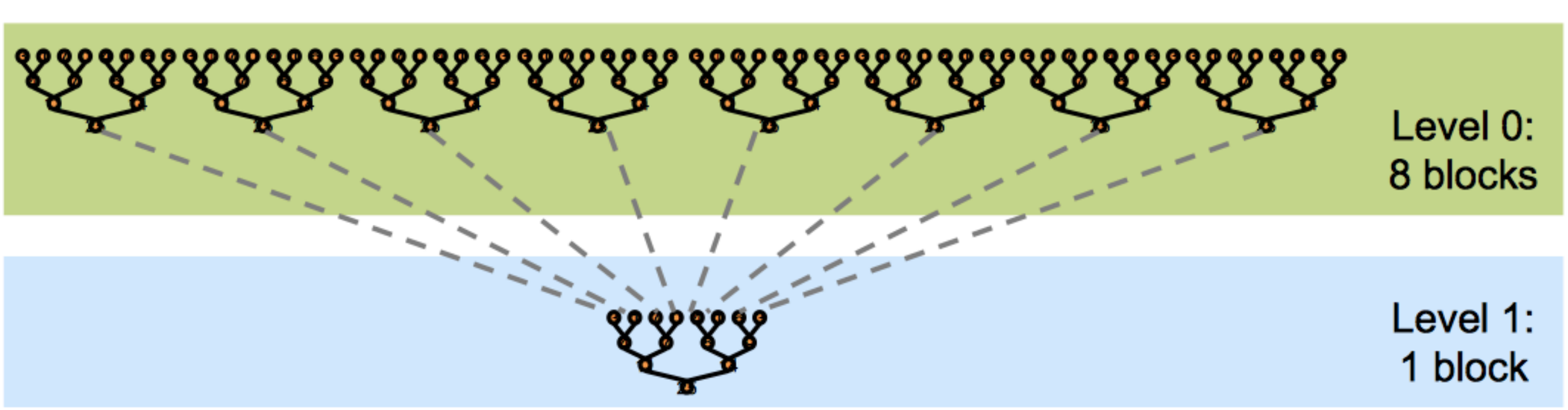
Multiple levels can be merged into one - but not all of them!

Important note: You can not synchronize between blocks!

Why?

- Complex hardware
- Risk for deadlock between blocks that are not simultaneously active

Multiple levels per kernel run for avoiding overhead



(Picture by Mark Harris, NVidia)

Many important optimizations:

- **Avoid "if" statements, divergent branches**
- **Avoid bank conflicts in shared memory**
- **Loop unrolling to avoid loop overhead (classic old-style optimization!)**

Huge speed difference reported by Harris

	Time (2^{22} ints)	Bandwidth	Step Speedup	Cumulative Speedup
Kernel 1: interleaved addressing with divergent branching	8.054 ms	2.083 GB/s		
Kernel 2: interleaved addressing with bank conflicts	3.456 ms	4.854 GB/s	2.33x	2.33x
Kernel 3: sequential addressing	1.722 ms	9.741 GB/s	2.01x	4.68x
Kernel 4: first add during global load	0.965 ms	17.377 GB/s	1.78x	8.34x
Kernel 5: unroll last warp	0.536 ms	31.289 GB/s	1.8x	15.01x
Kernel 6: completely unrolled	0.381 ms	43.996 GB/s	1.41x	21.16x
Kernel 7: multiple elements per thread	0.268 ms	62.671 GB/s	1.42x	30.04x

(Picture by Mark Harris, NVidia)

Conclusions:

- **Multiple kernel runs for varying problem size**
- **Multiple kernel runs for synchronizing blocks**
- **Optimizing matters! Not only shared memory and coalescing!**