

# Parallelism Inherent in the Wavefront Algorithm

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- ▶ Particle transport code using wavefront algorithm
  - Primarily used for benchmarking
- ▶ Coded in Fortran 90 and MPI
  - Scales to thousands of cores for large problems
- ▶ Over 90% of time in one kernel at the heart of the computation

Outer iteration

Loop over energy groups

Inner iteration

Loop over sweeps

Loop over cells in z direction

Loop over cells in y direction

Loop over cells in x direction

Loop over angles (only independent loop!)  
work (90% of time spent here)

End loop over angles

End loop over cells in x direction

End loop over cells in y direction

...

...

Loop over cells in z direction

Possible MPI\_Recv communications

Loop over cells in y direction

Loop over cells in x direction

Loop over angles (number of angles too small for MPI)  
work

End loop over angles

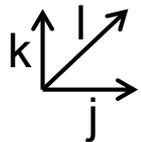
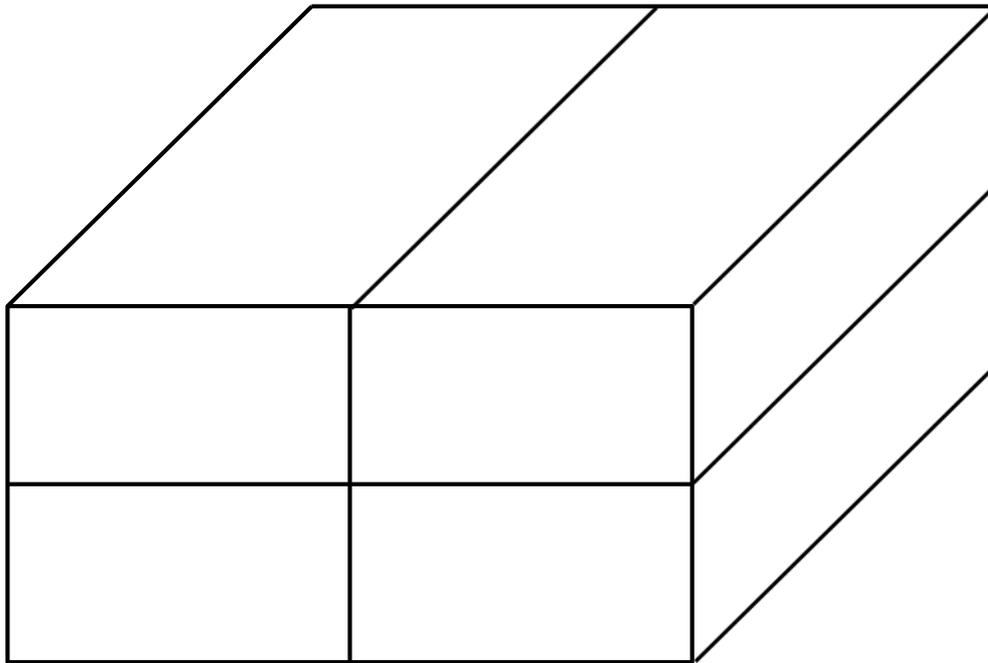
End loop over cells in x direction

End loop over cells in y direction

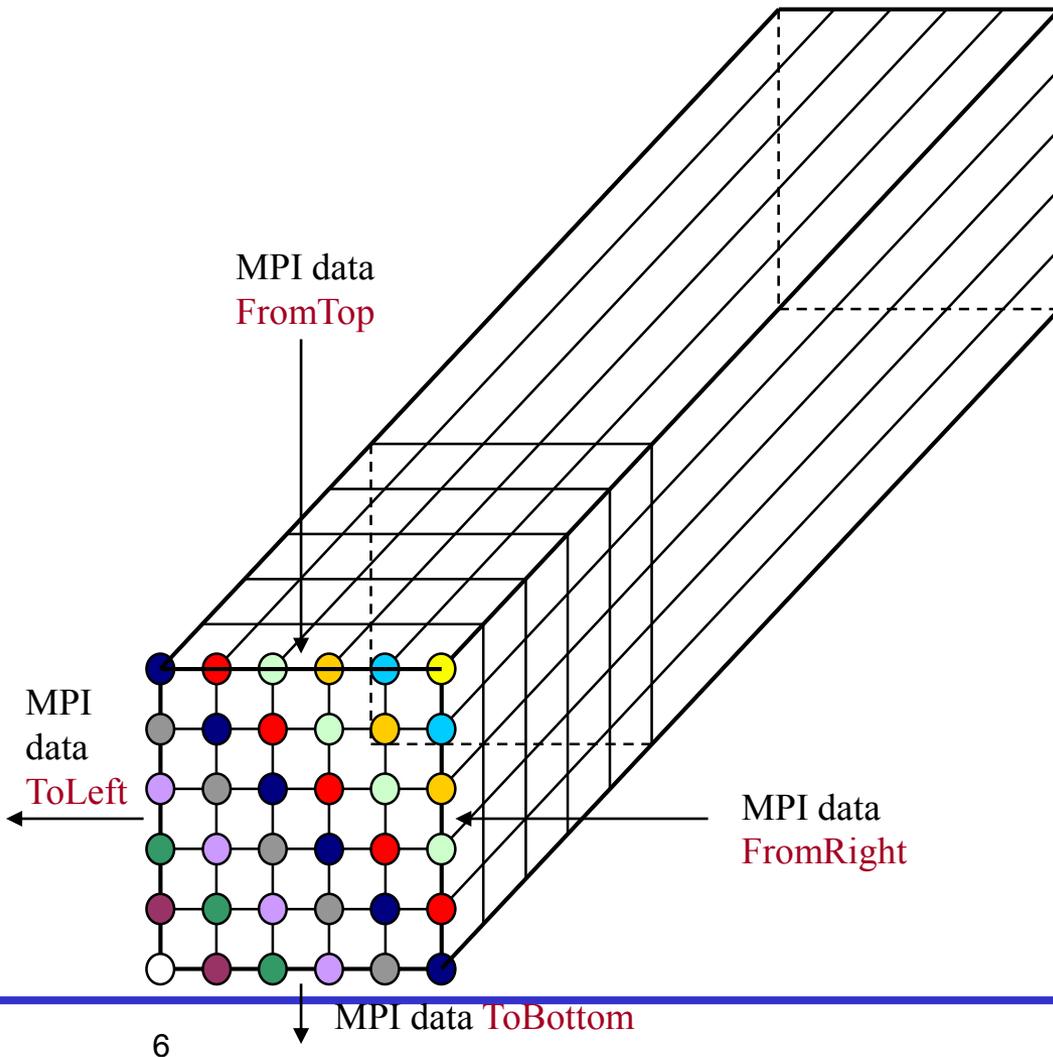
Possible MPI\_Ssend communications

End loop over cells in z direction

...

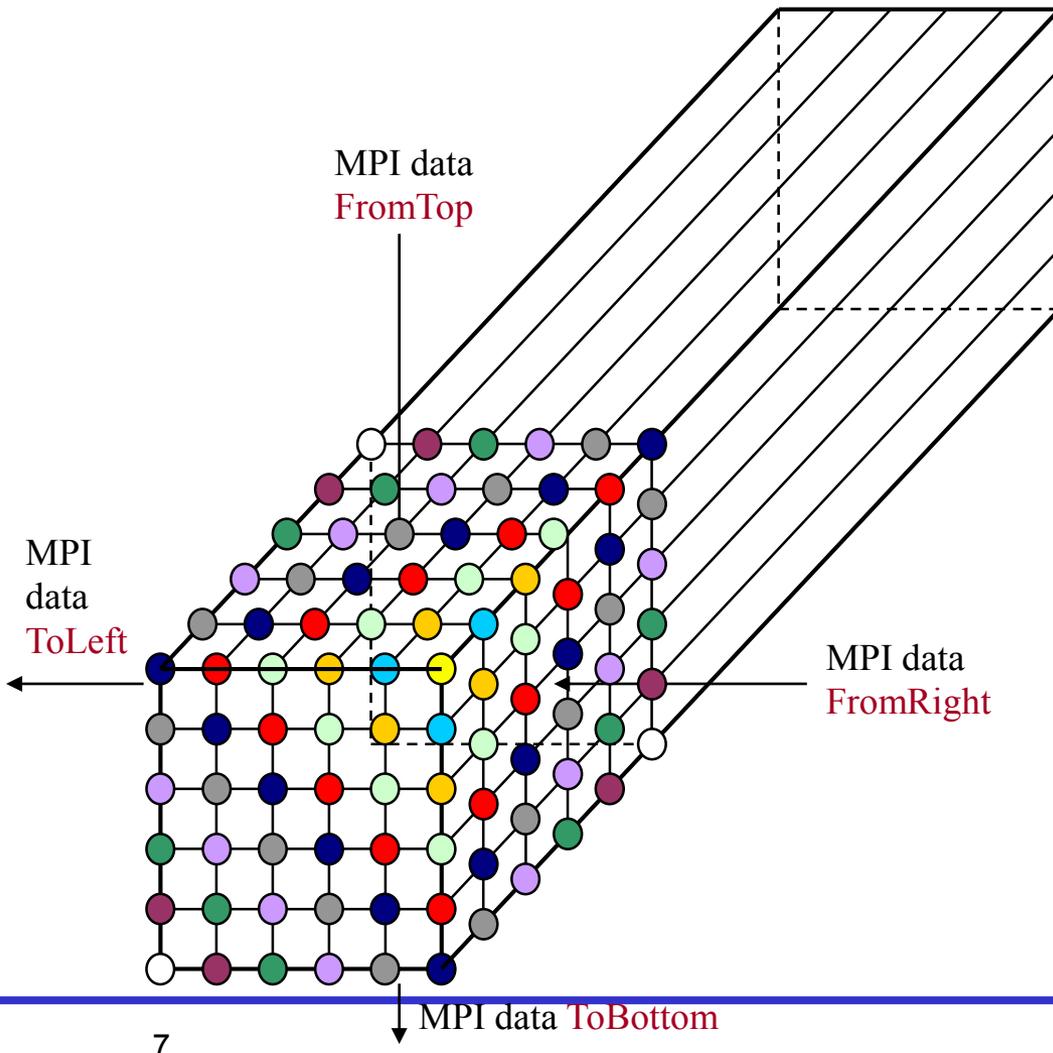


- ▶ MPI 2D decomposition is 2D decomposition of front x-y face.
- ▶ Figure shows 4 MPI tasks

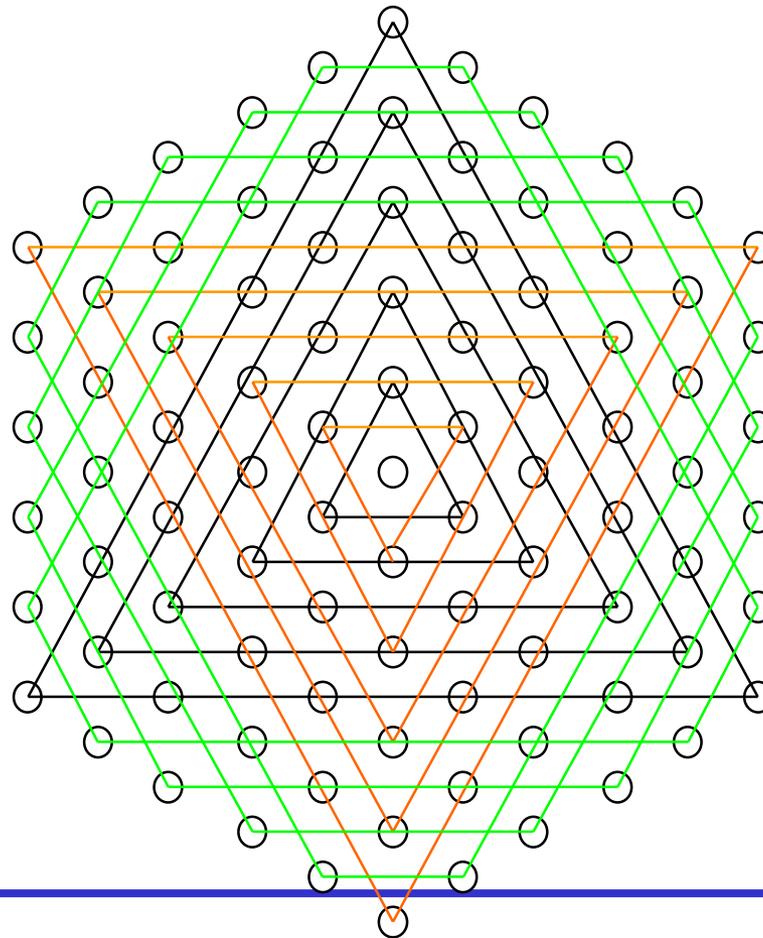


▶ This diagram shows **the domain of one MPI task**

▶ A cell cannot be processed until all cells “upstream” have been processed.



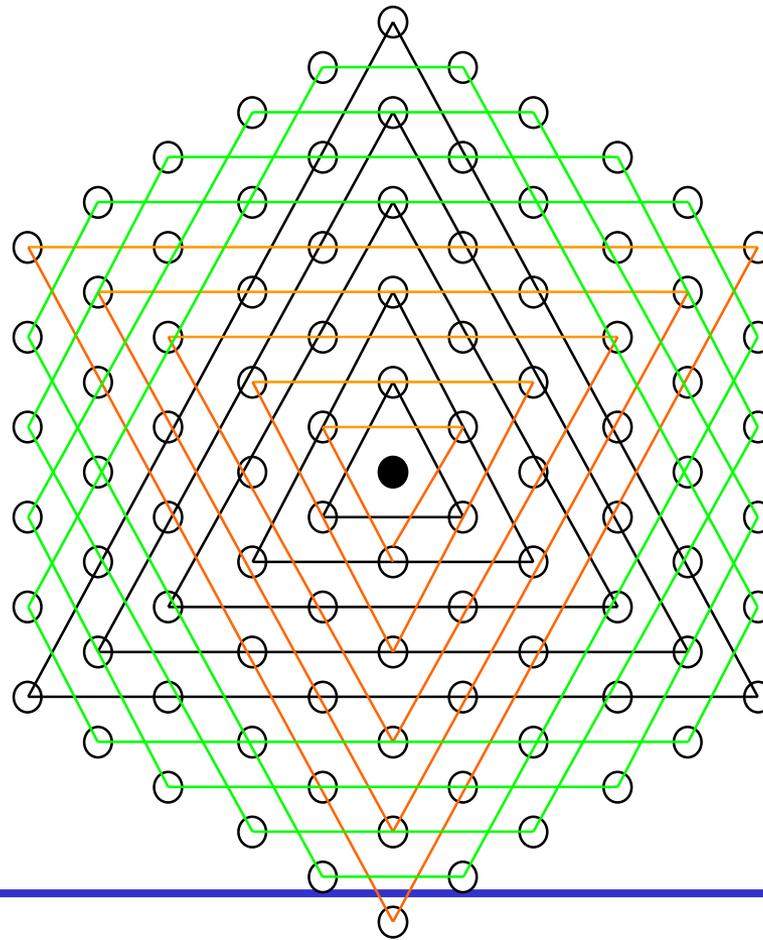
**Cells of the same colour are independent and may be processed in parallel once preceding slices are complete.**



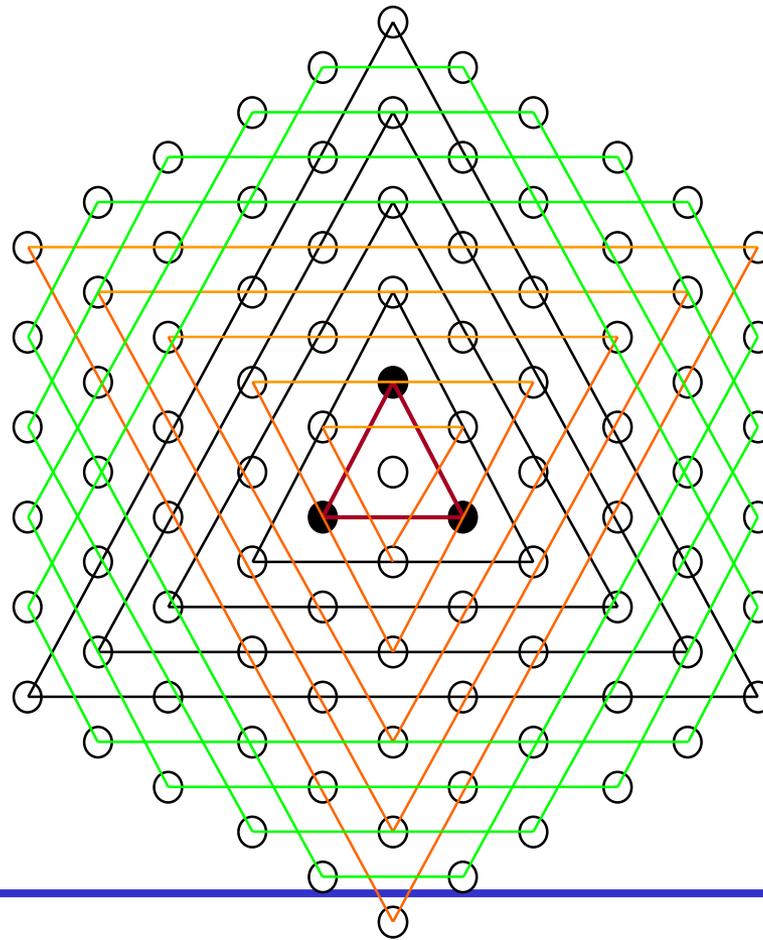
Increasing triangles

Then transforming  
Hexagons

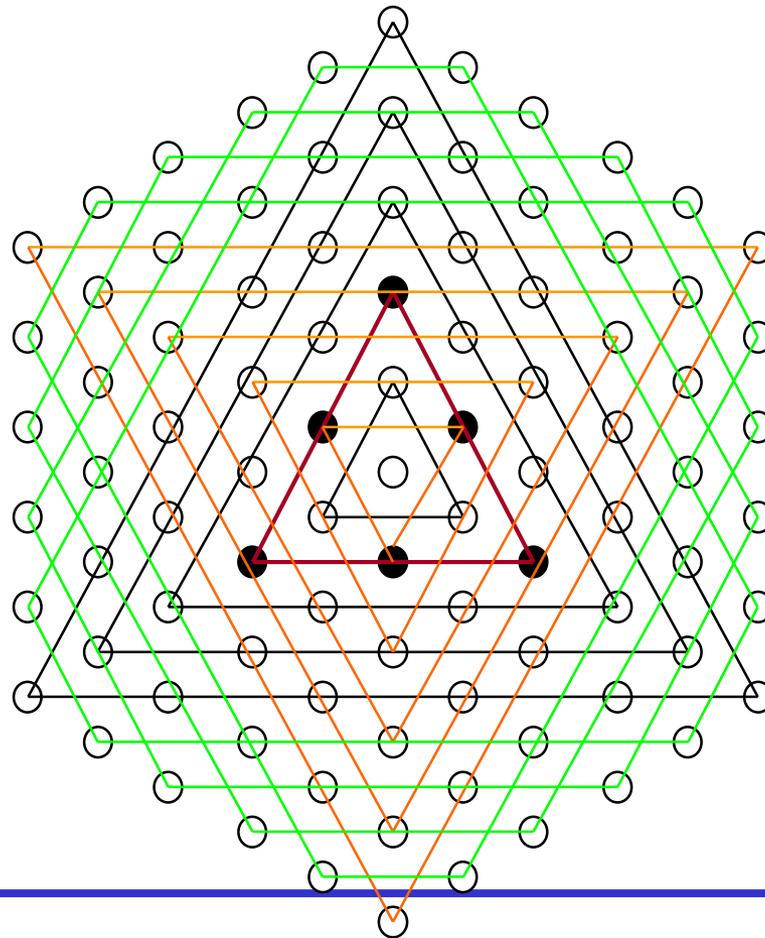
Then decreasing (flipped)  
triangles

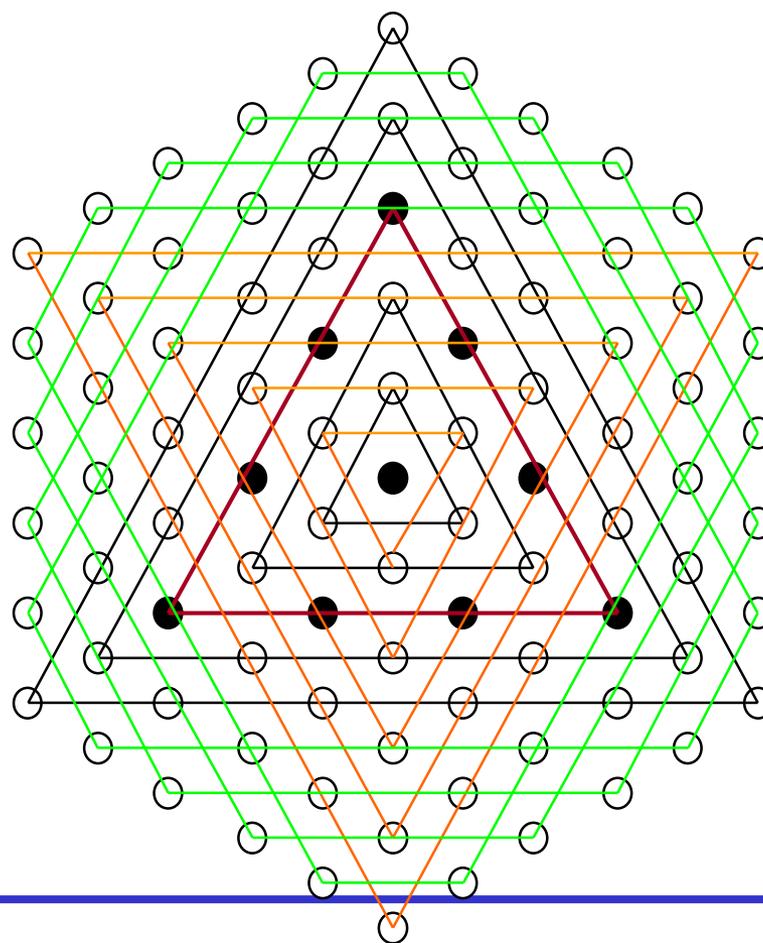


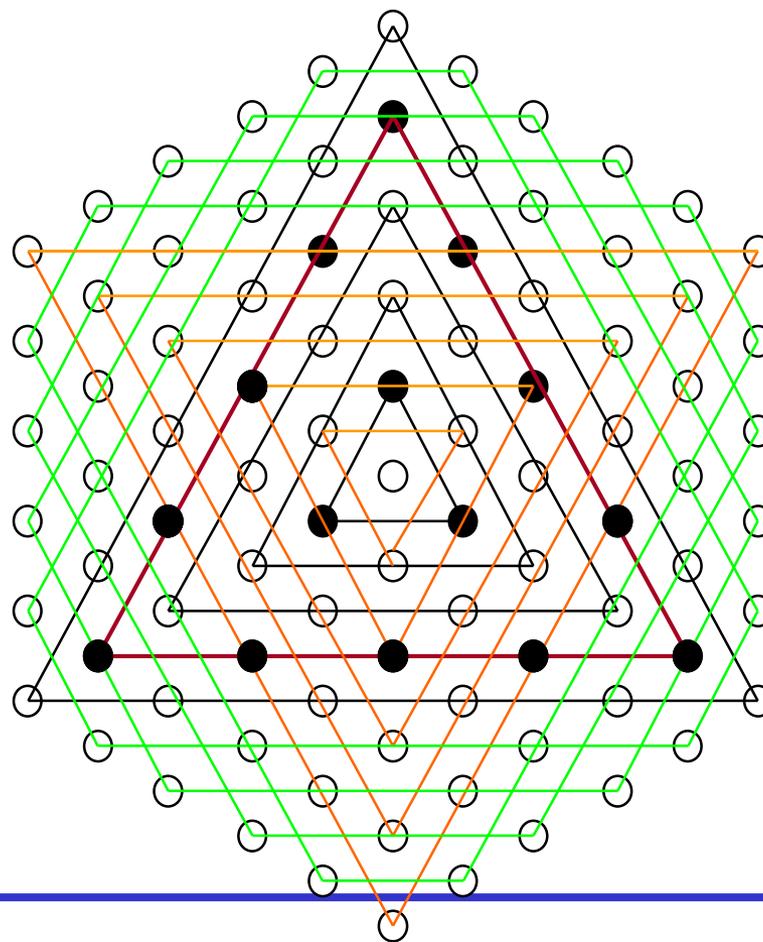
Cell nearest the  
viewer

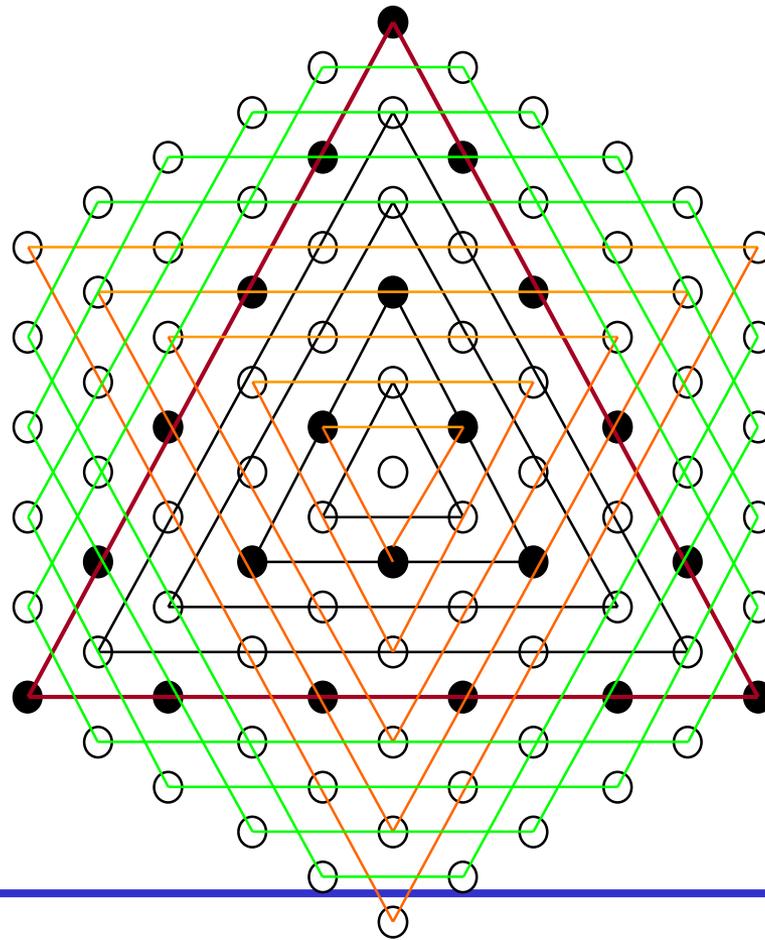


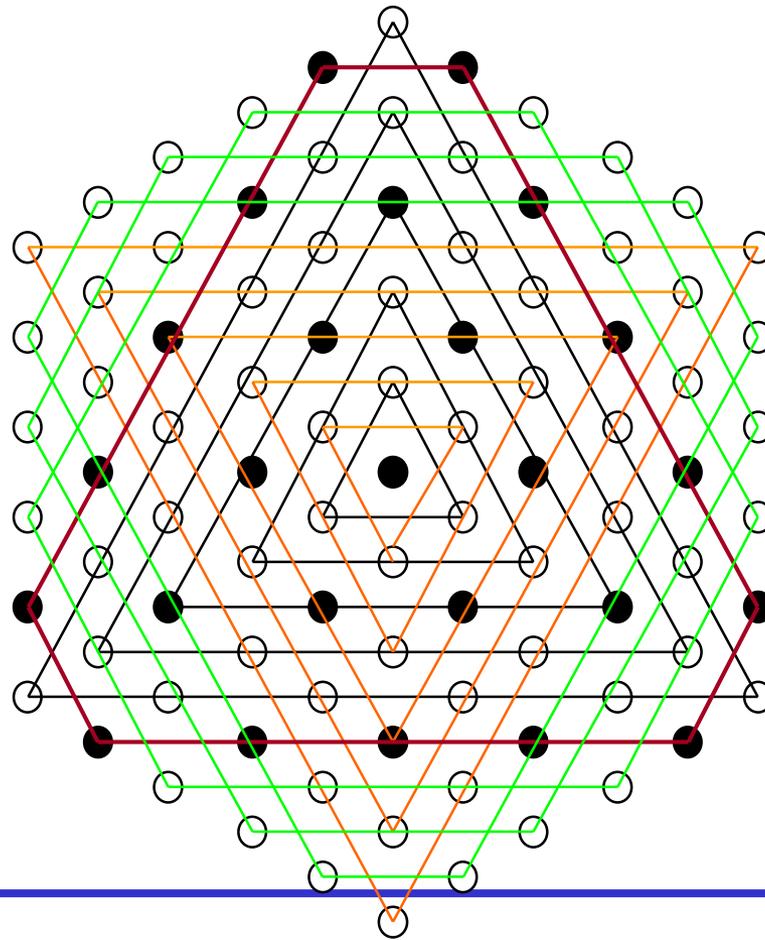
Moving down  
away from  
viewer

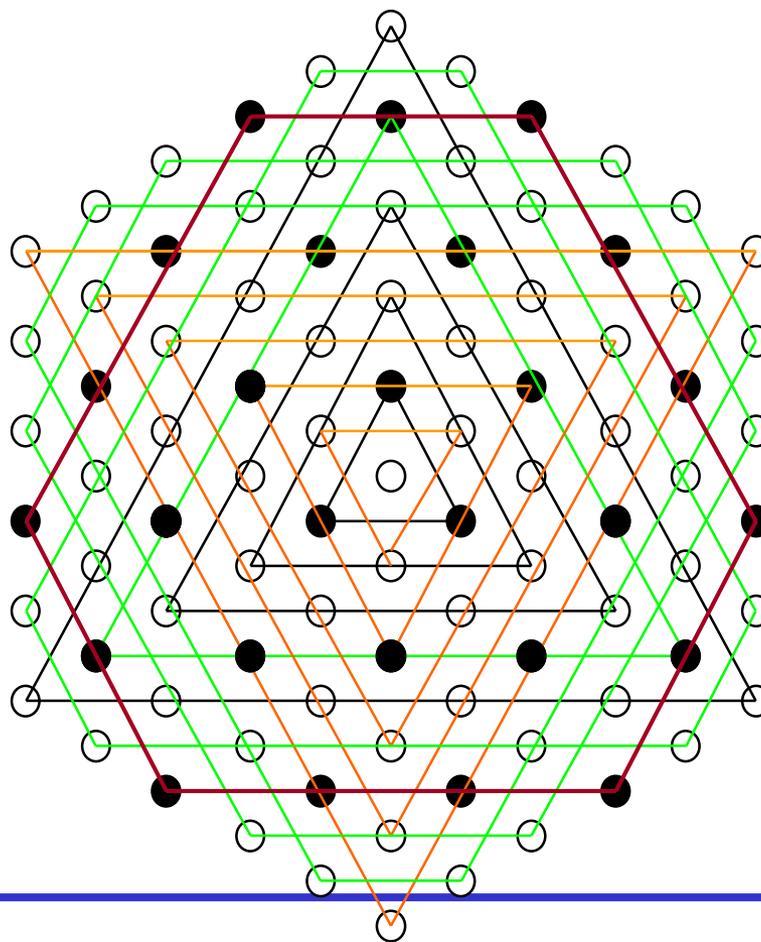


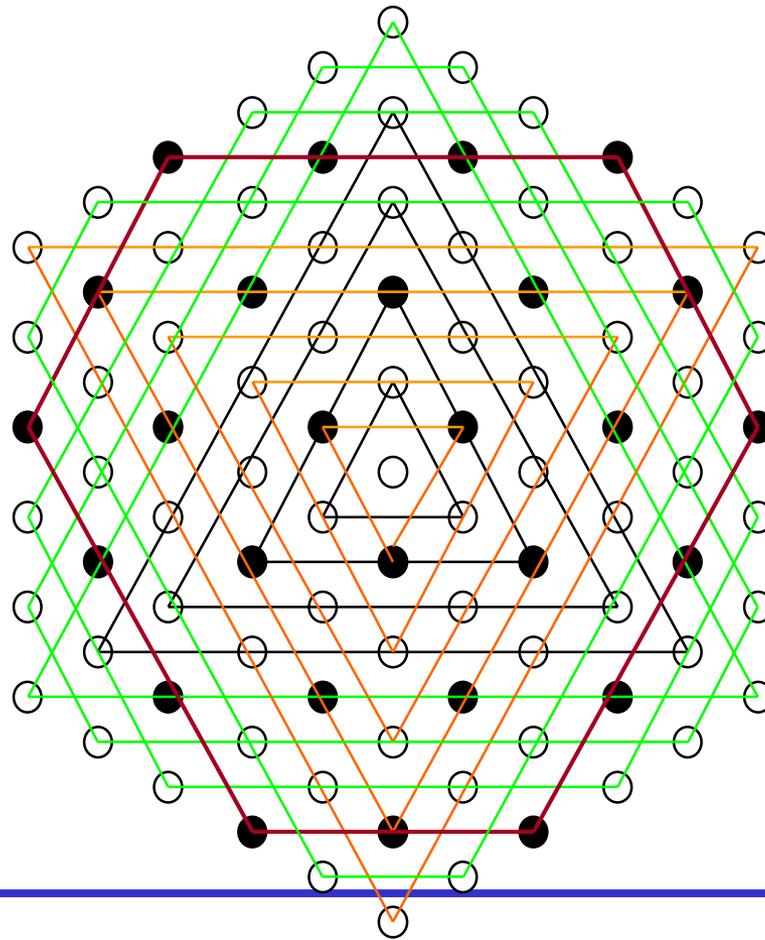


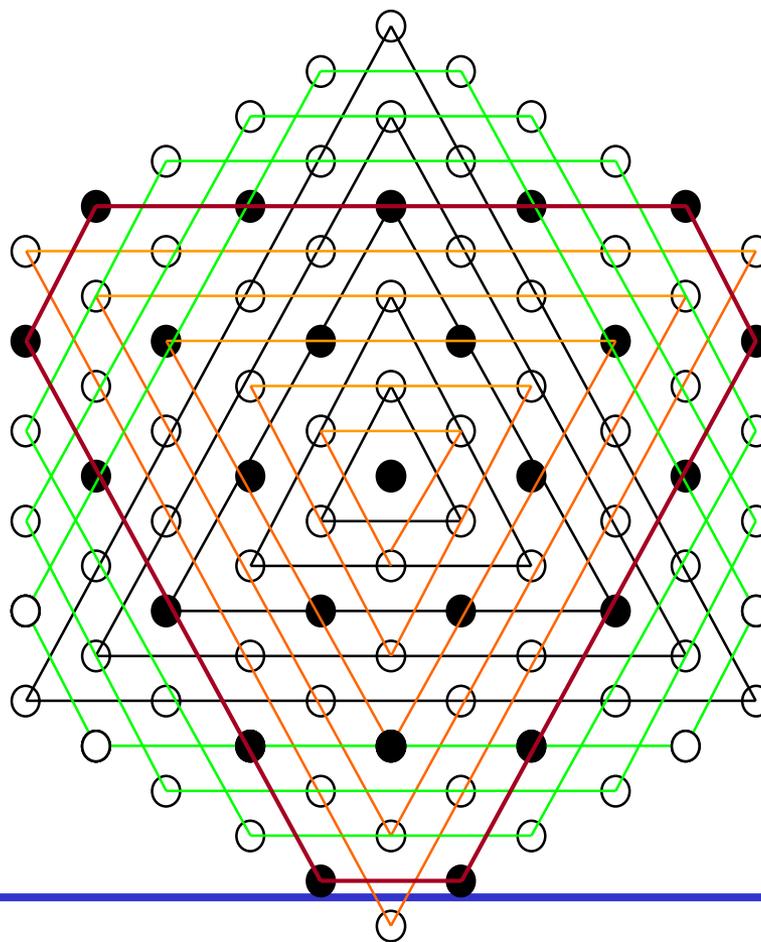


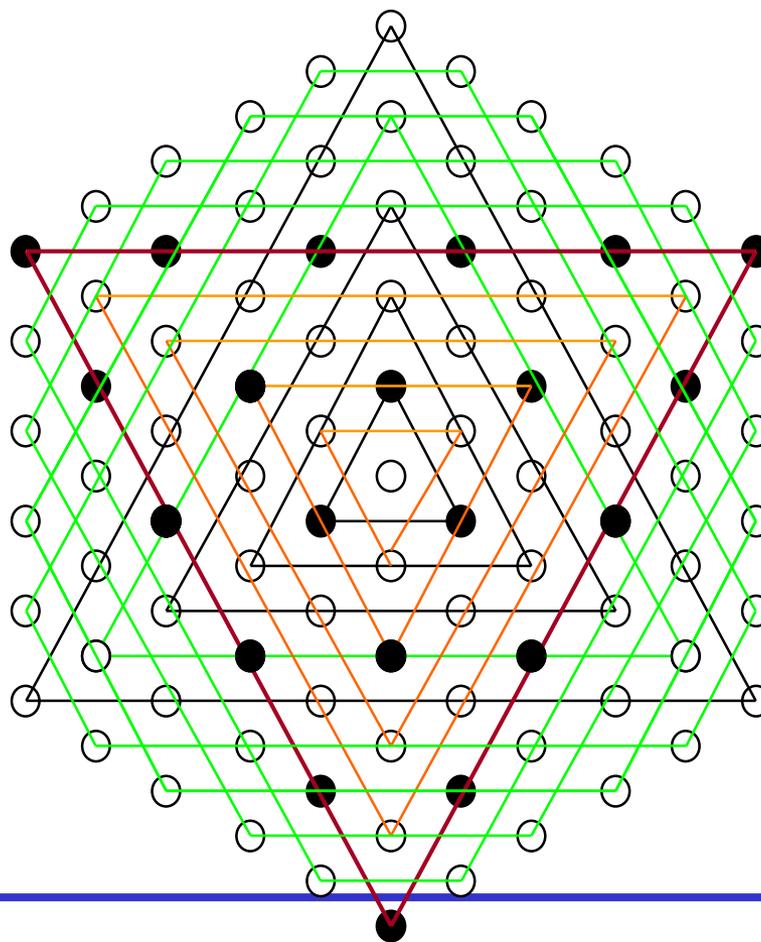


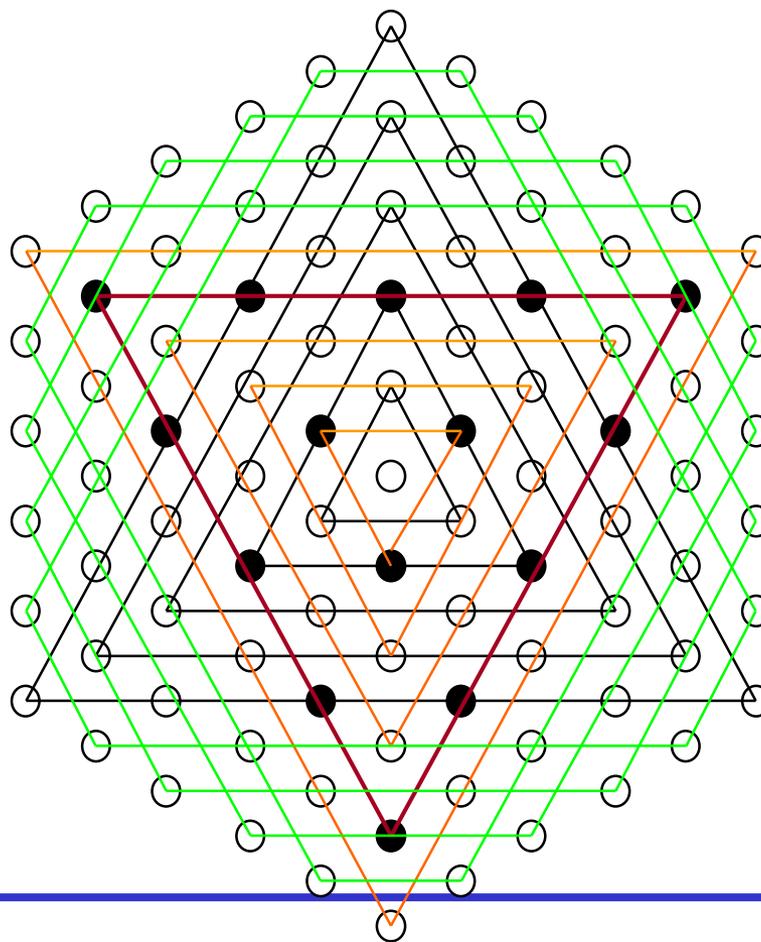


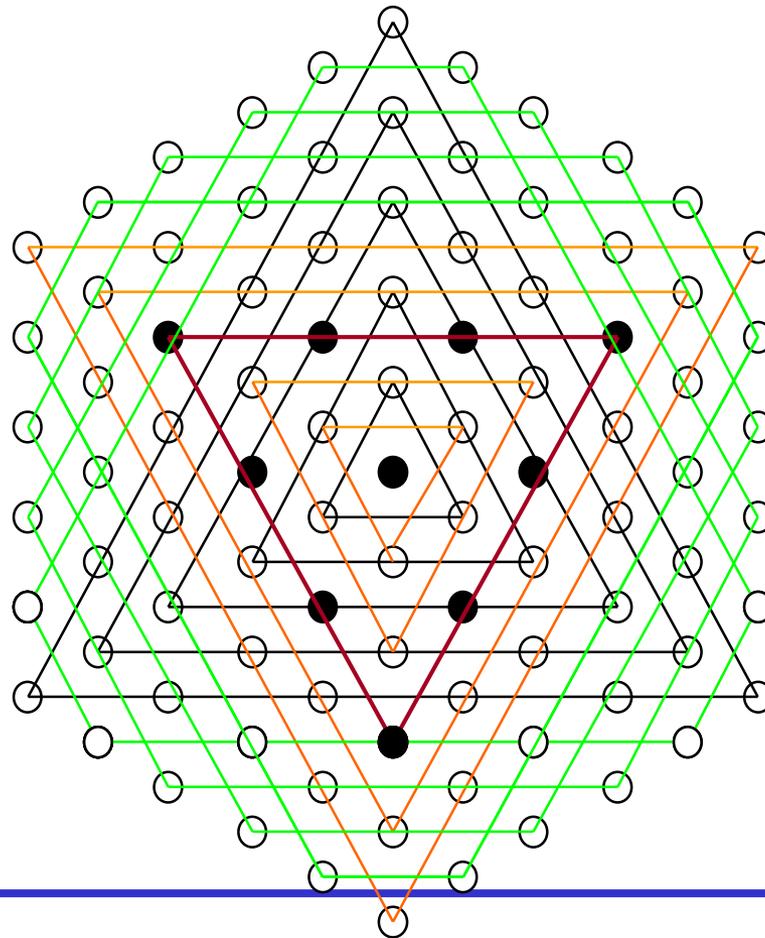


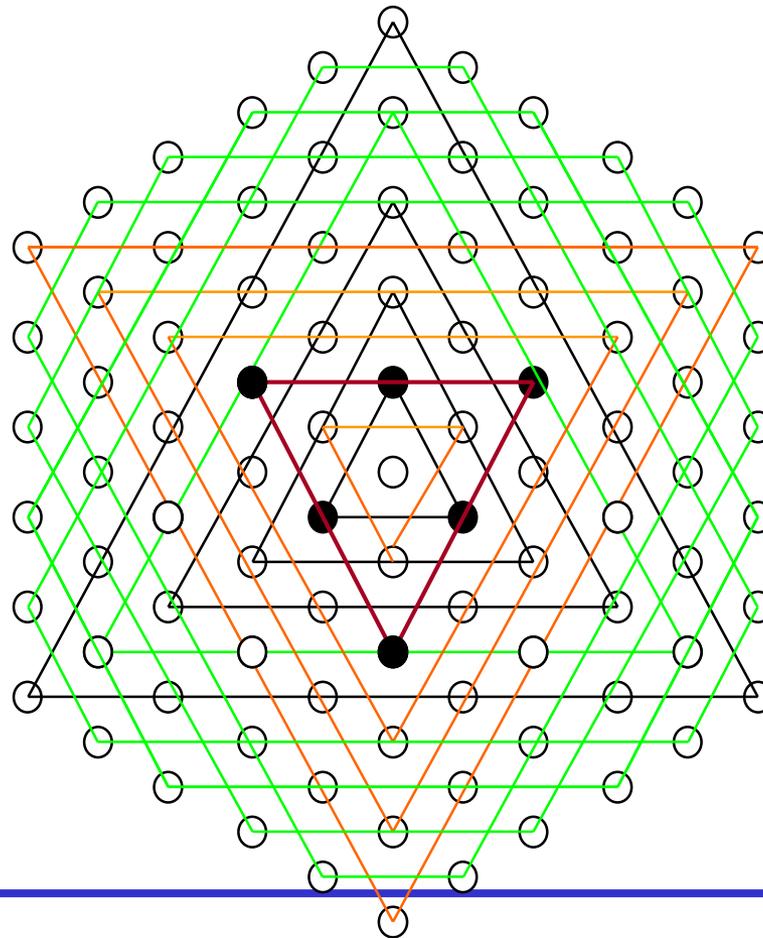


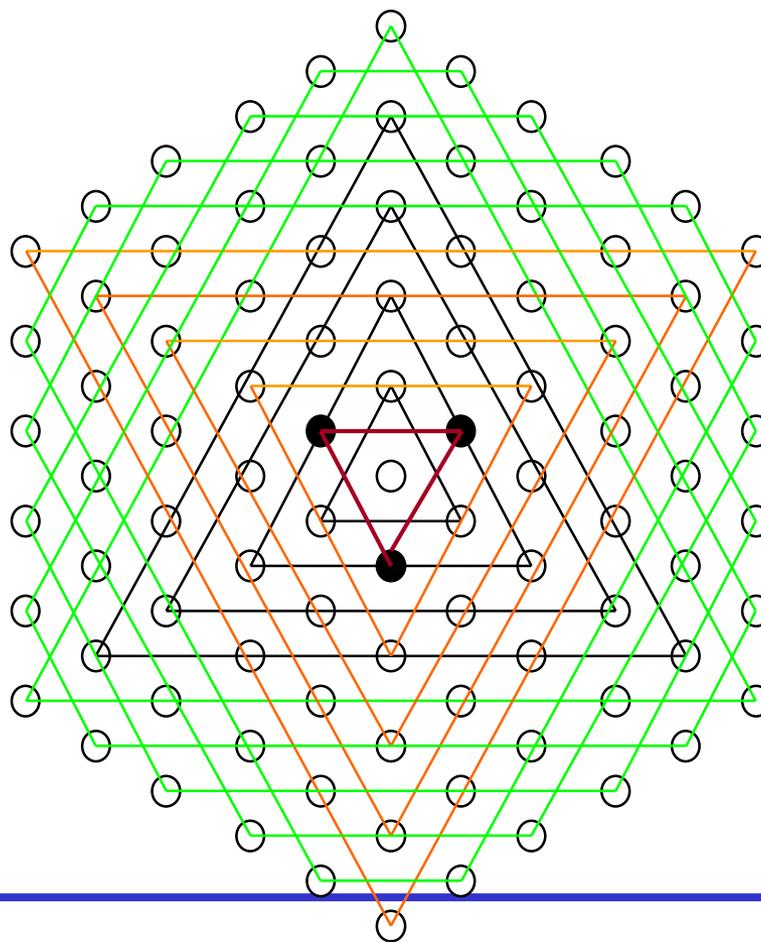


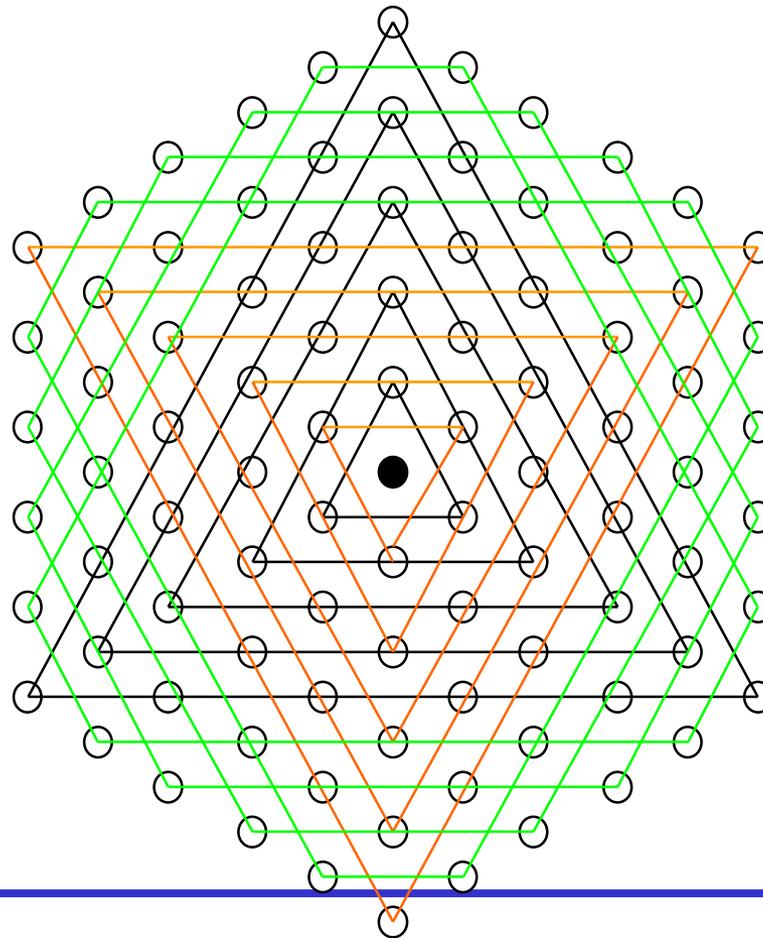












Point furthest  
from viewer

...

Loop over cells in z direction

Possible MPI\_Recv communications

Loop over cells in y direction

Loop over cells in x direction

Loop over angles (number of angles too small for MPI)  
work

End loop over angles

End loop over cells in x direction

End loop over cells in y direction

Possible MPI\_Ssend communications

End loop over cells in z direction

...

...

Loop over slices

Possible MPI\_Recv communications

OMP DO PARALLEL

Loop over cells in each slice

OMP DO PARALLEL

Loop over angles

work

End loop over angles

OMP END DO PARALLEL

End Loop over cells in each slice

OMP END DO PARALLEL

Possible MPI\_Ssend communications

End loop over slices

...

Outer iteration

Loop over energy groups

Inner iteration

Loop over sweeps

Loop over slices

Possible MPI\_Recv communications

OMP DO PARALLEL

Loop over cells in each slice

OMP DO PARALLEL

Loop over angles

work

End loop over angles

Etc

- ▶ Initially, each energy group calculation used a previous energy groups results as input
- ▶ Decoupling the energy groups has two outcomes
  - Execution time is greatly increased
  - Energy Groups are now independent and can be parallelised
- ▶ Often seen in HPC
  - Modern algorithms can be inherently serial
  - An older version may be parallelisable

- ▶ If all the tasks take the same time to compute
  - Block distribution of tasks
  - Cyclic distribution of tasks
    - “dealing cards”
- ▶ else if all tasks have different execution times
  - If length of tasks are unknown in advance
    - Cyclic distribution of tasks
  - else
    - Order tasks: longest first, shortest last
    - Cyclic distribution of tasks
  - endif
- ▶ Endif

Outer iteration

MPI Task Farm of energy groups

Inner iteration

Loop over sweeps

Loop over slices

Possible MPI\_Recv communications

OMP DO PARALLEL

Loop over cells in each slice

OMP DO PARALLEL

Loop over angles

work

End loop over angles

Etc

- ▶ Other wavefront codes have the loops in a different order
- ▶ Loop over energy groups can occur within loops over cells and might be parallelised with OpenMP
  - Must be decoupled

- ▶ Any questions?
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