HP-SEE USER FORUM

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REFLECTIONS ON PARALELIZATION OF GRAVITY INVERSION

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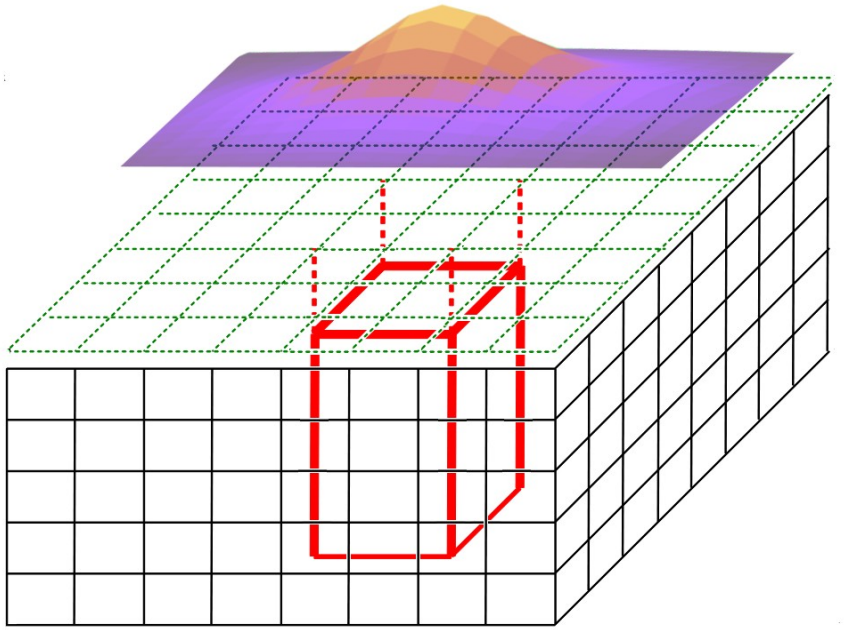
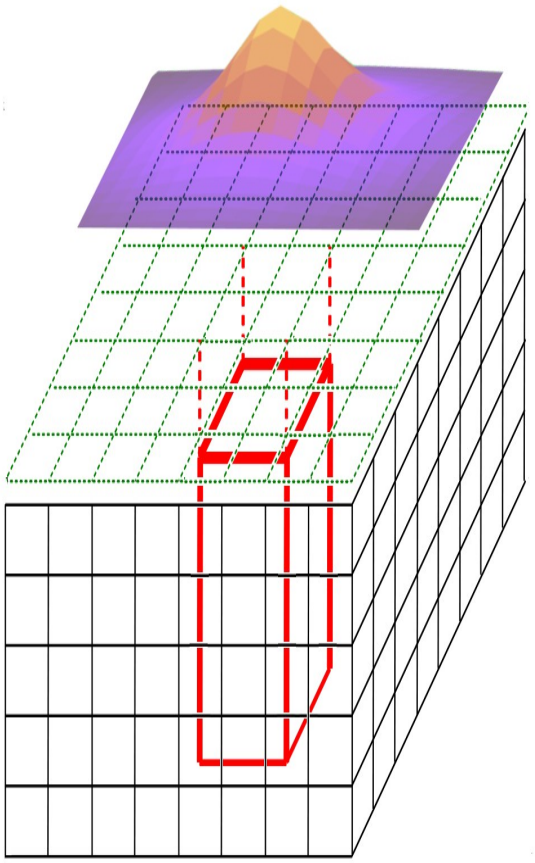
Gravity Inversion Problem

- Typical ill – posed problem
- Extrapolation from 2D array => 3D array
- Decades of R&D and continues ...



Proposed Solution - "*CLEAN*"



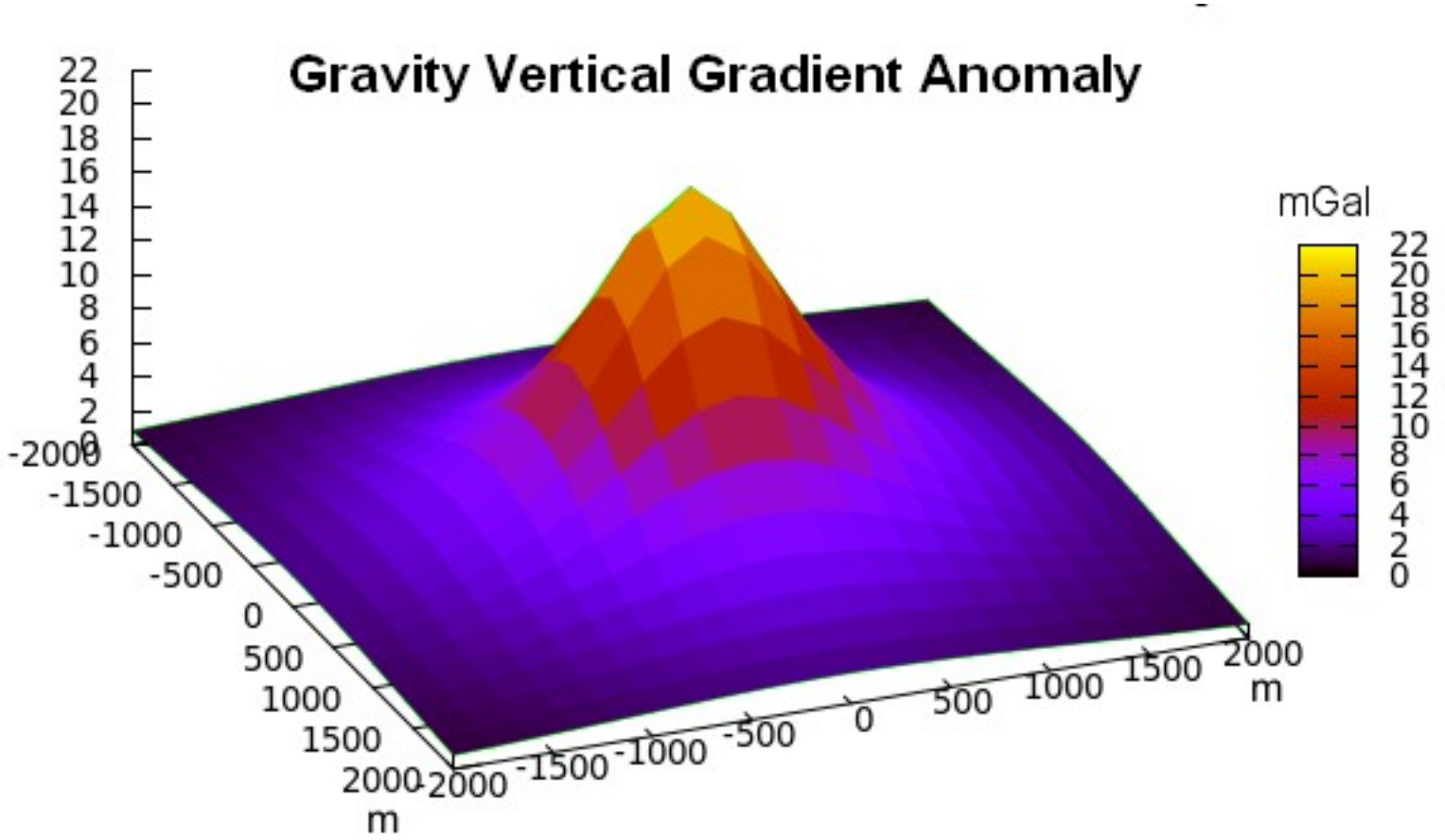
- Iterative approach
  - Scan 3D array
    - Each 3D node: calculate the 2D effect
    - Select best 3D node
    - Modify mass density of best node
    - Update the 2D anomaly
    - Repeat until …
- Complexity O(N^8)
  - N ~ linear size of arrays
  - 3D x 2D / (3D mass density step)

Parallelization Schema

- Started in SEE-GRID-2
- In each iteration
  - Split the 3D array in chunks
  - Scan each chunk in separate thread / process
  - Integrate results
- Software used
  - OpenMP
  - MPI
  - Future for GPU ? For multi-cluster grid ?

Typical Results - Anomaly

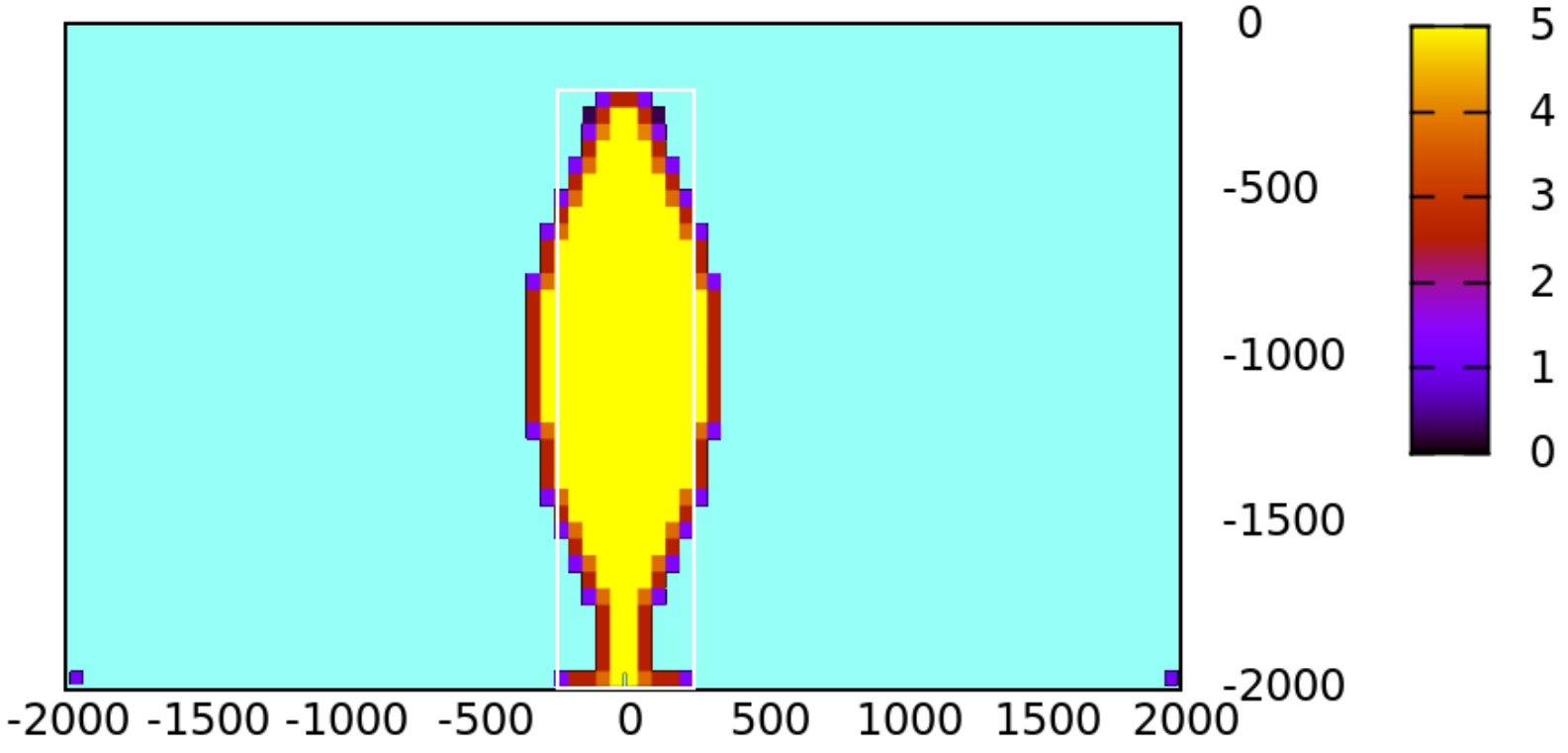
Effect of a prismatic body of higher mass density



Typical Results - Inversion

Maximal mass density and contrast :-)

Prismatic approximated by round shaped body



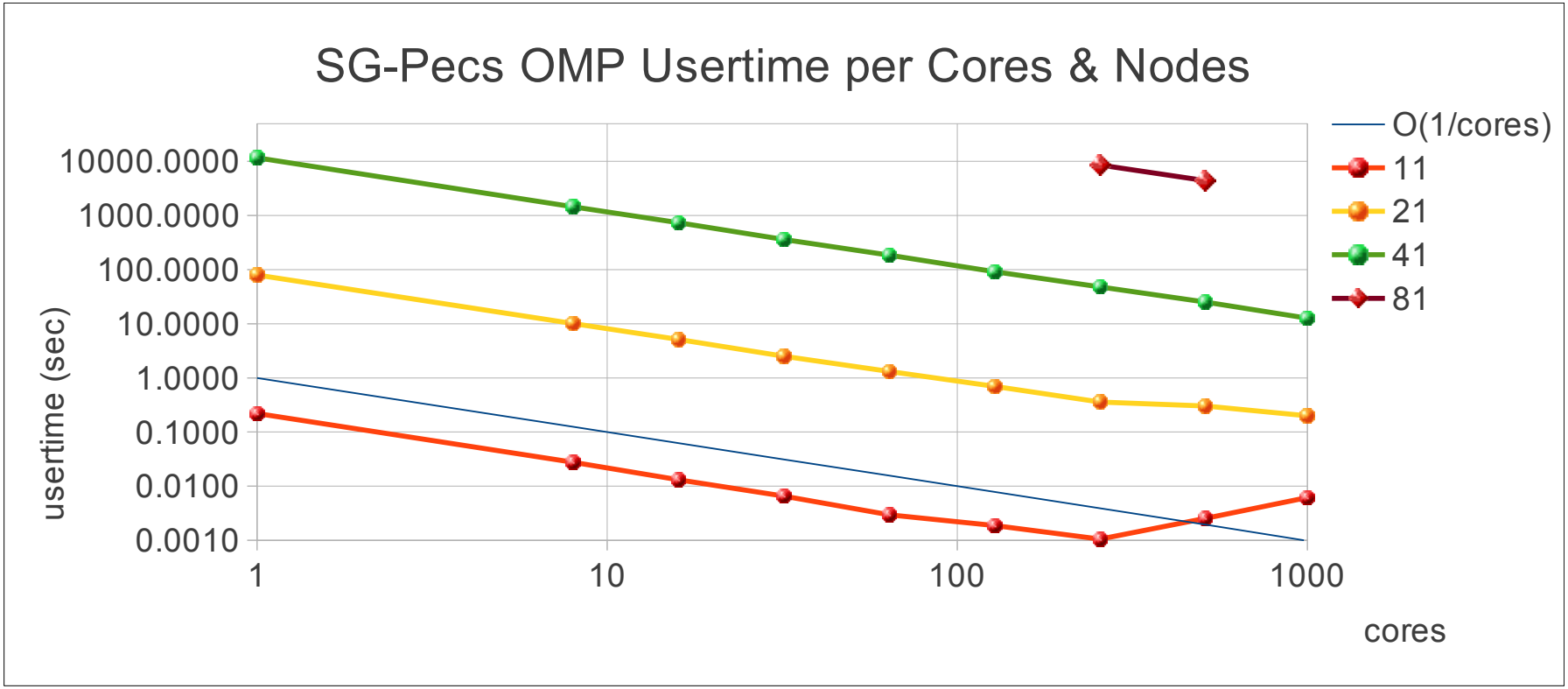
Using OpenMP

- Easy programming
- Difficult to find platforms
  - Need for shared memory
  - Most HPC are clusters
    - Offer 4 – 8 – 16 parallel [hyper]threads
    - First tests in HPCG of IICTP-BAS
  - Succeeded in NFII Pecs SGE
    - Up to 1000 cores / parallel threads

OpenMP in Pecs SGE

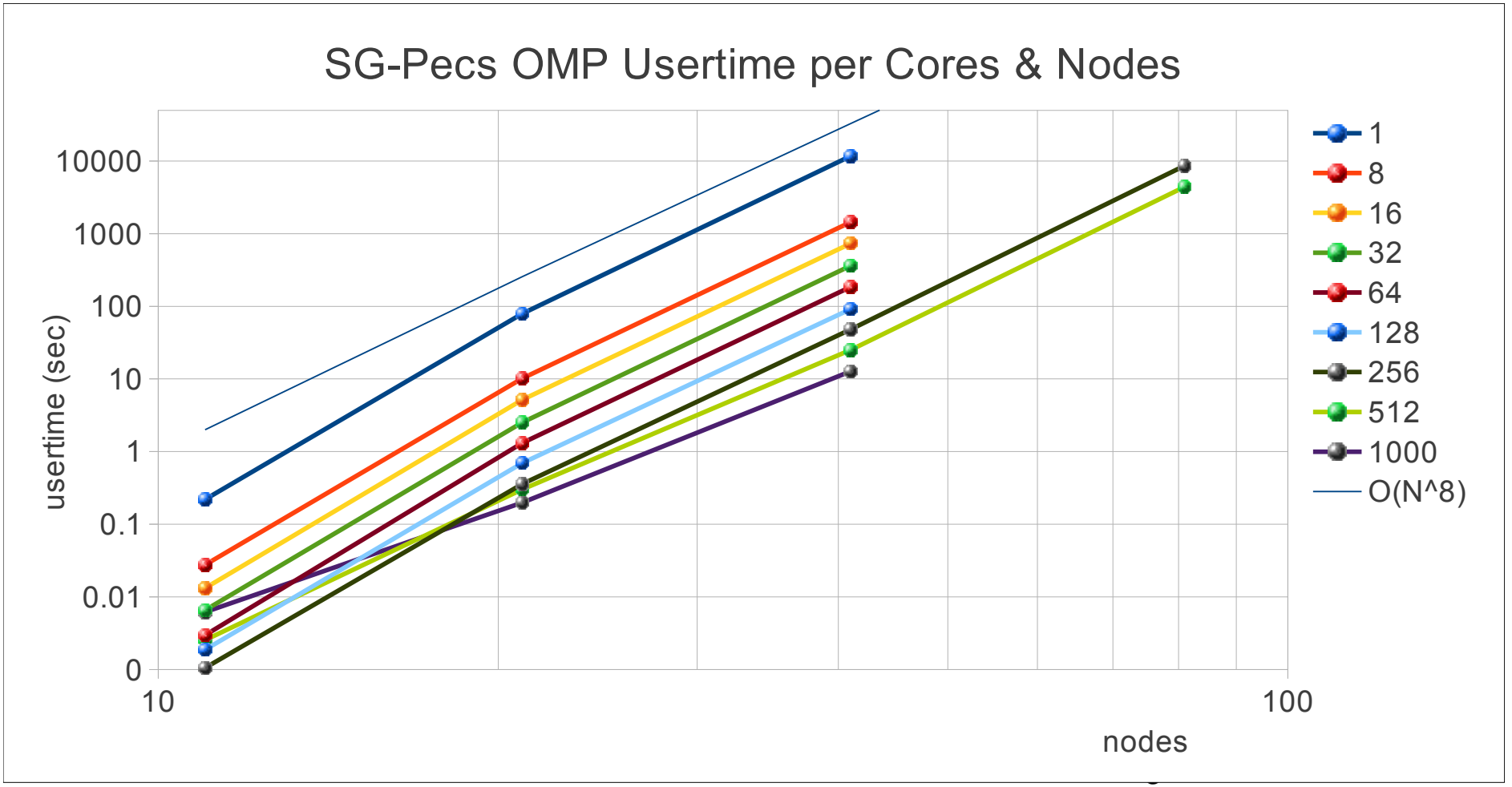
Scalability by number of cores O(1/cores)

Degeneration of scalability for small size / cores



OpenMP in Pecs SGE $_2$

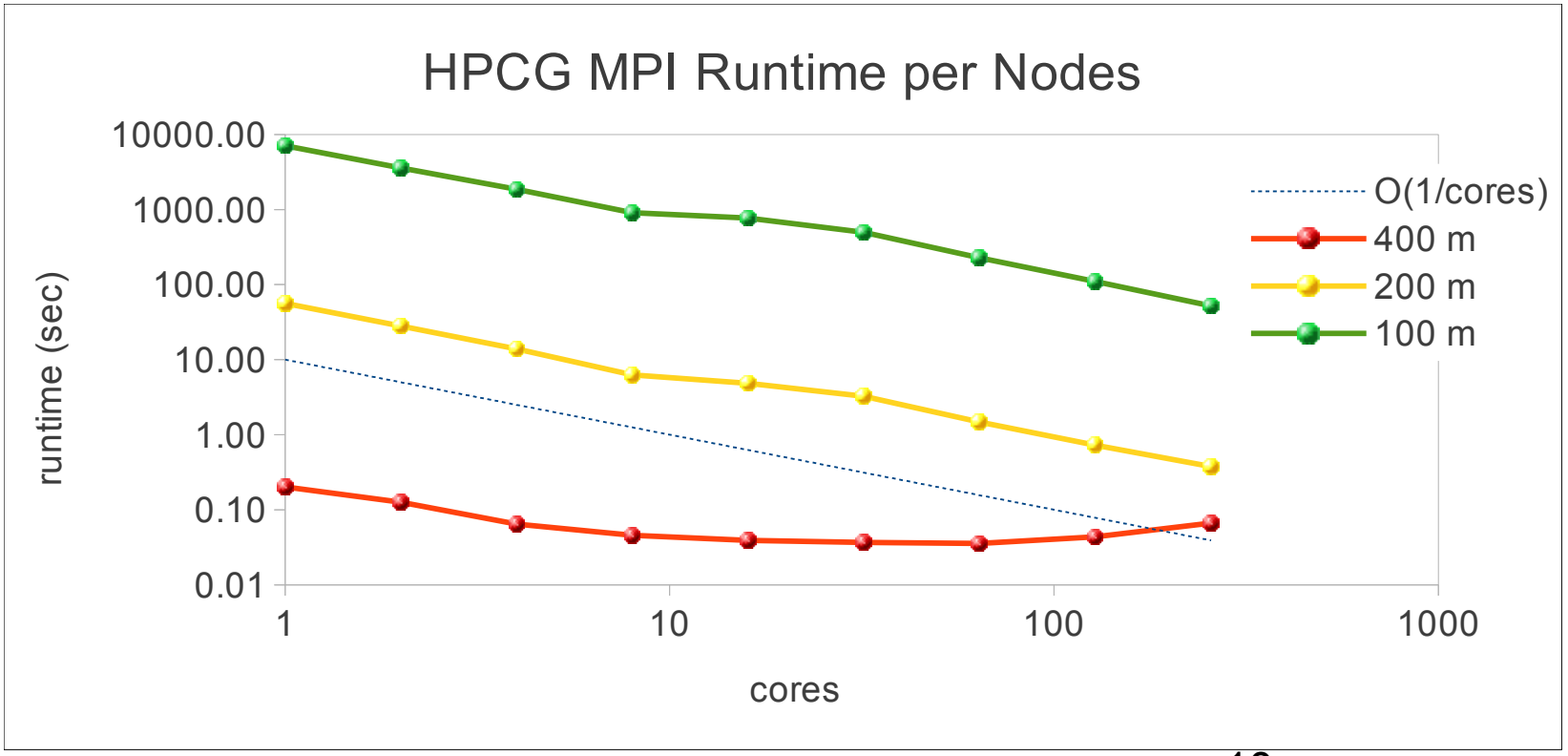
Scalability by model size O(N^8)



MPI in Sofia HPCG

Scalability by cores O(1/cores) + *shift*

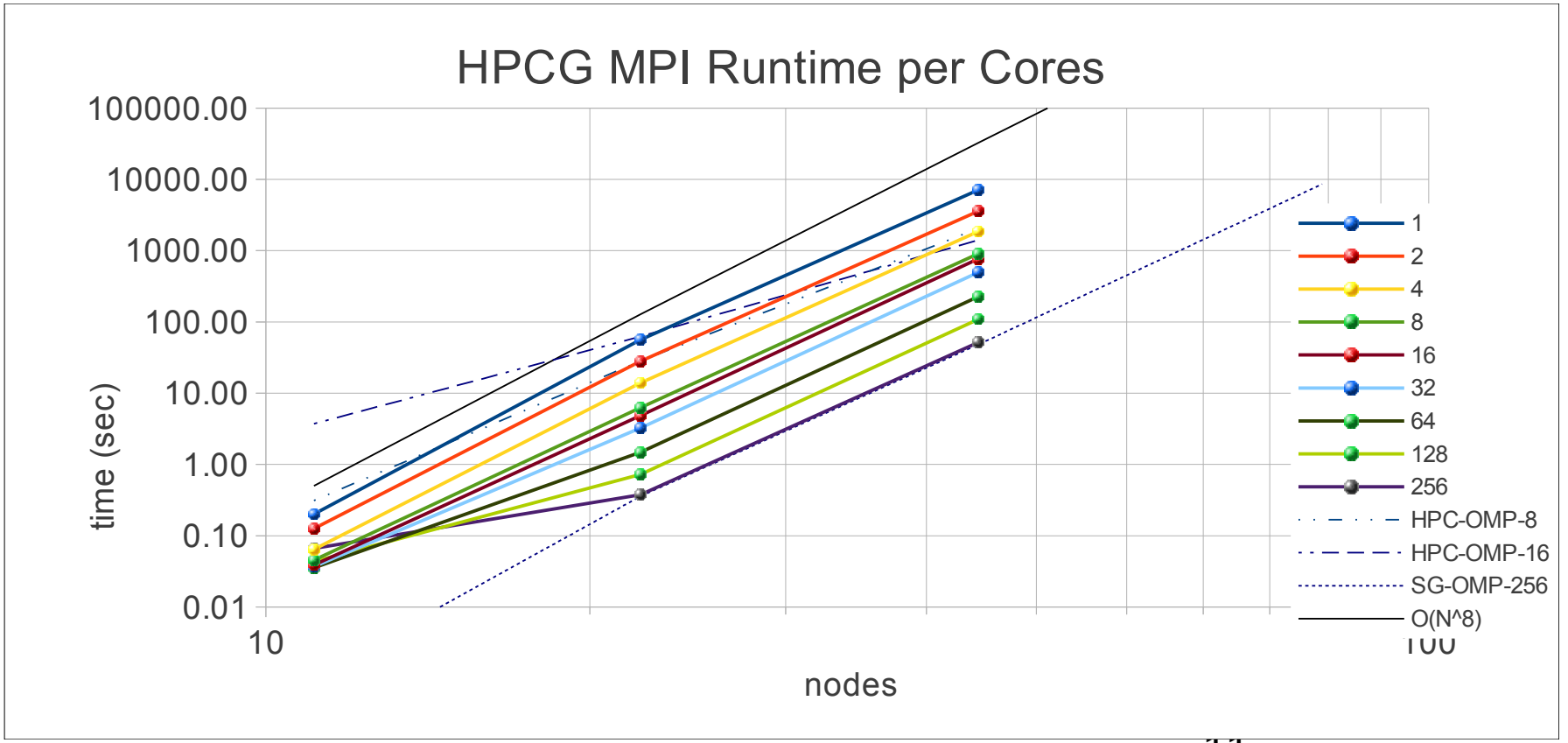
Degeneration for small size / cores



MPI in Sofia HPCG $_2$

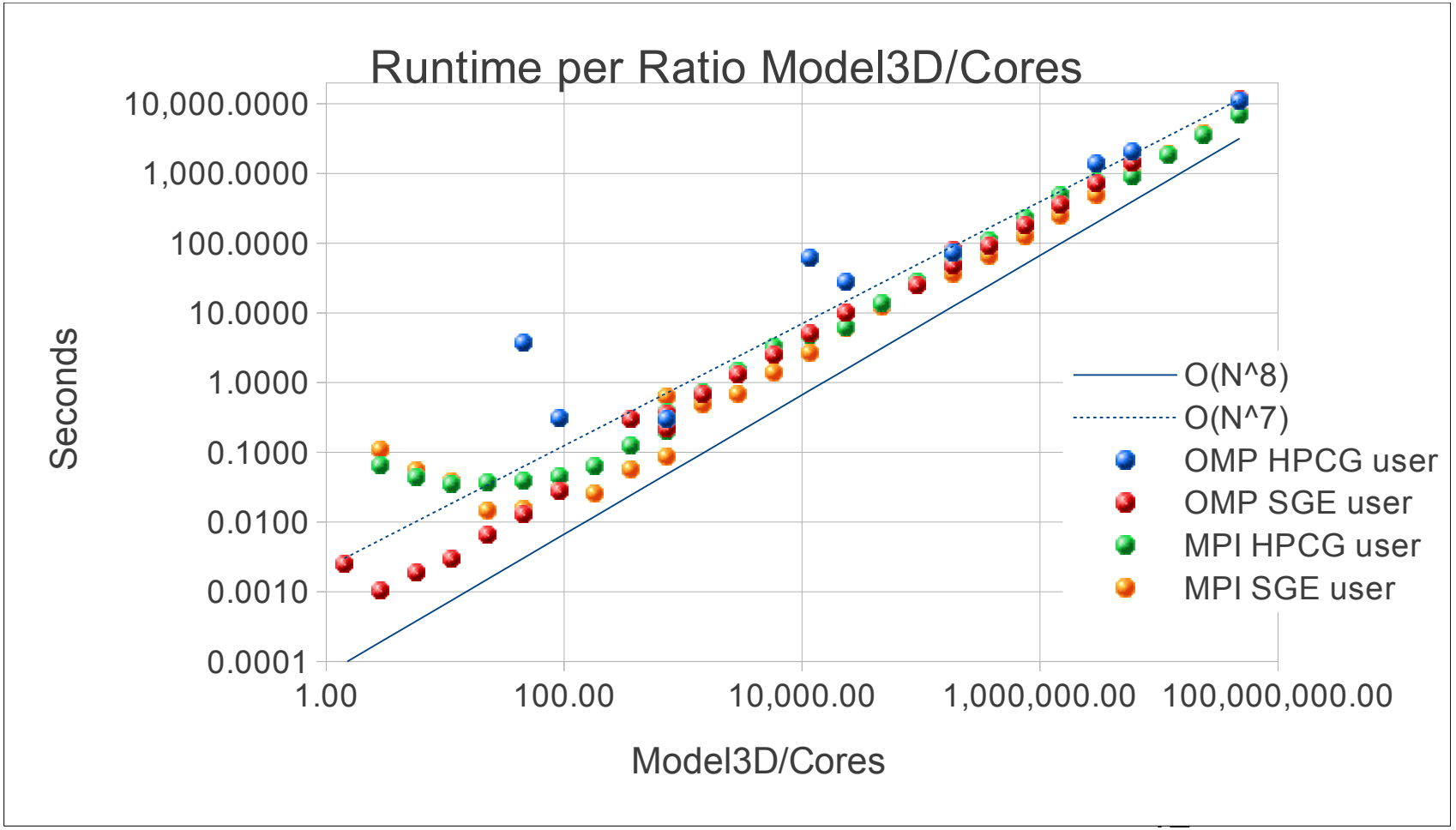
Scalability by model size O(N^8)

Hypertheads offer better scalability O(N^7)



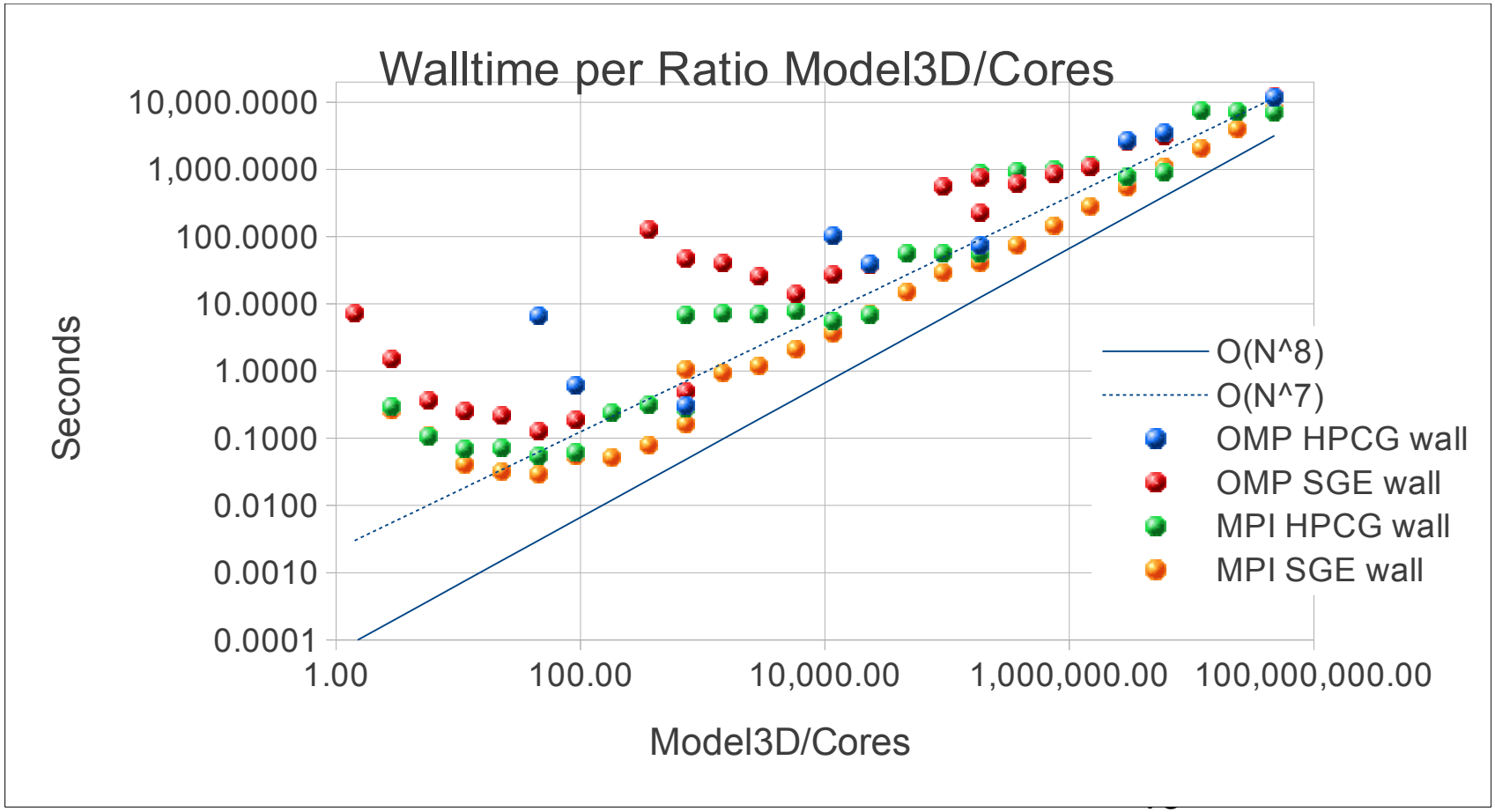
Integration of Results - Runtime

Normalization using *3D_size / cores*



Integration of Results - Walltime

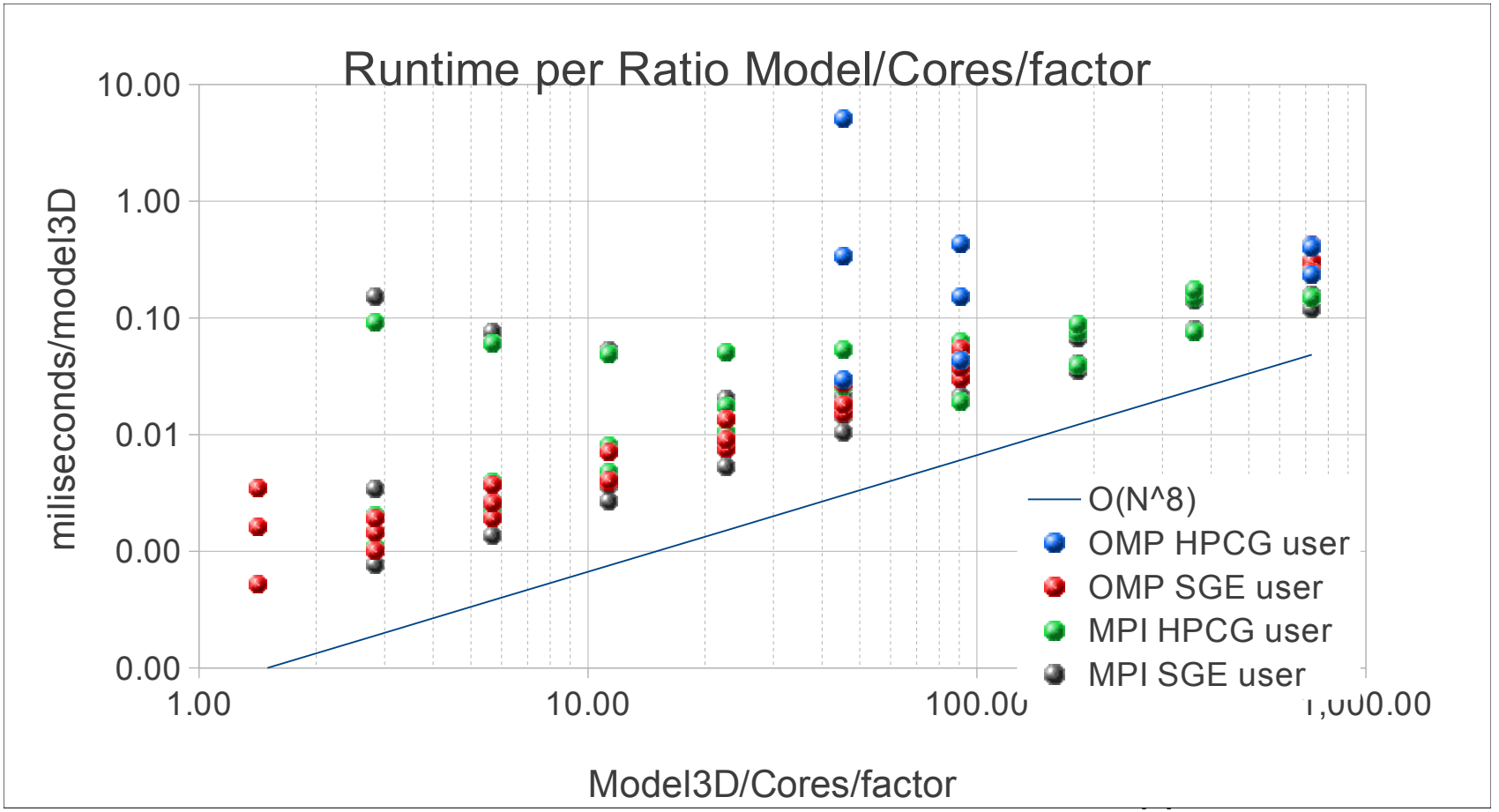
Walltime performance improved for big models



Degeneration of Runtime

Normalization by model increase factor

Degeneration for model/cores<100 with MPI

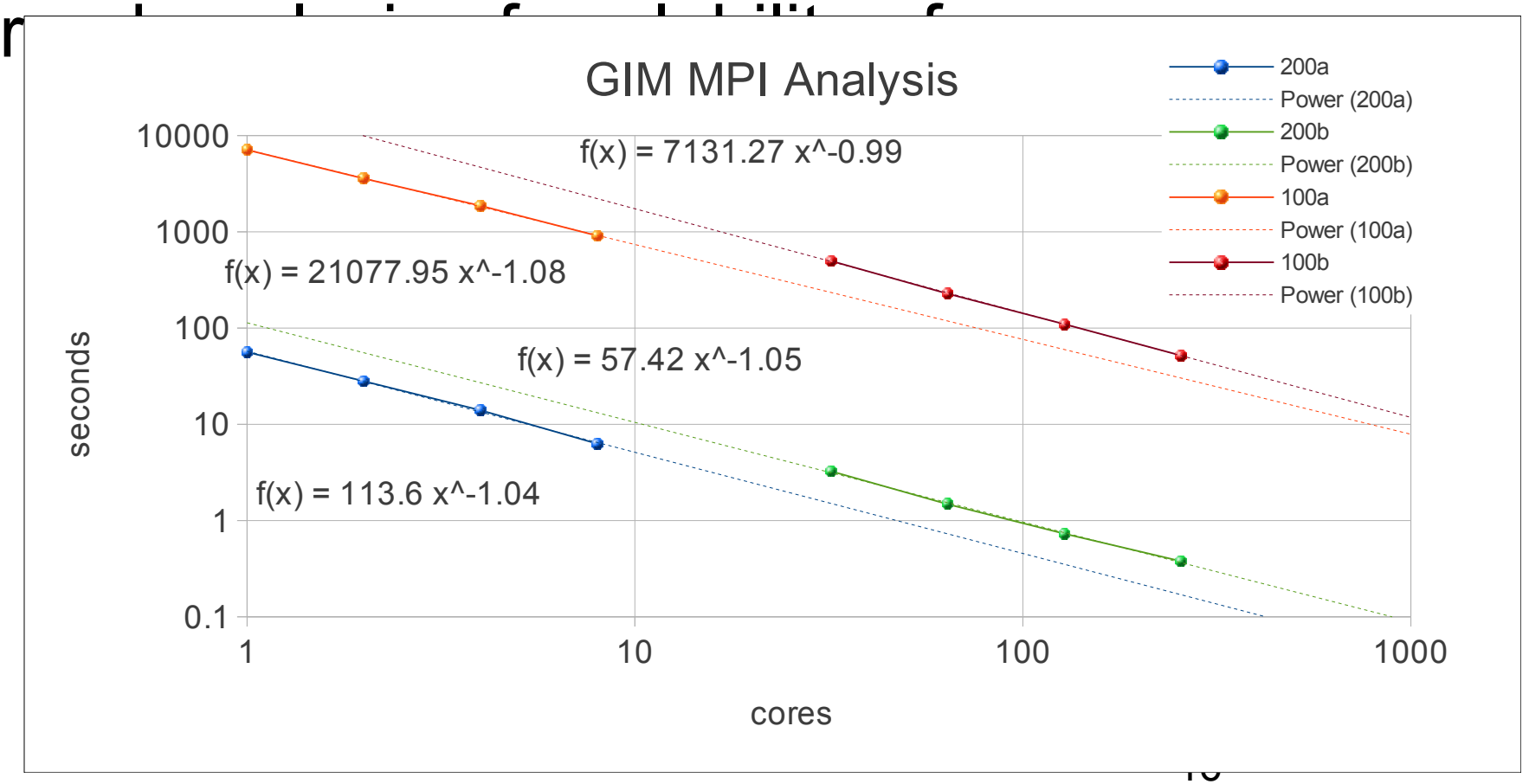


Prognosis for Details

- Model size 81x81x41 3D array
  - Spatial step 50m
  - Runtime ~ 27 hours in 1000 cores
- For a model of 161x161x81 3D nodes
  - Spatial step 25m
  - Runtime expected ~ one year in 1000 cores
- May we think about multi-cluster grid ?
  - Over 10^4 cores ?

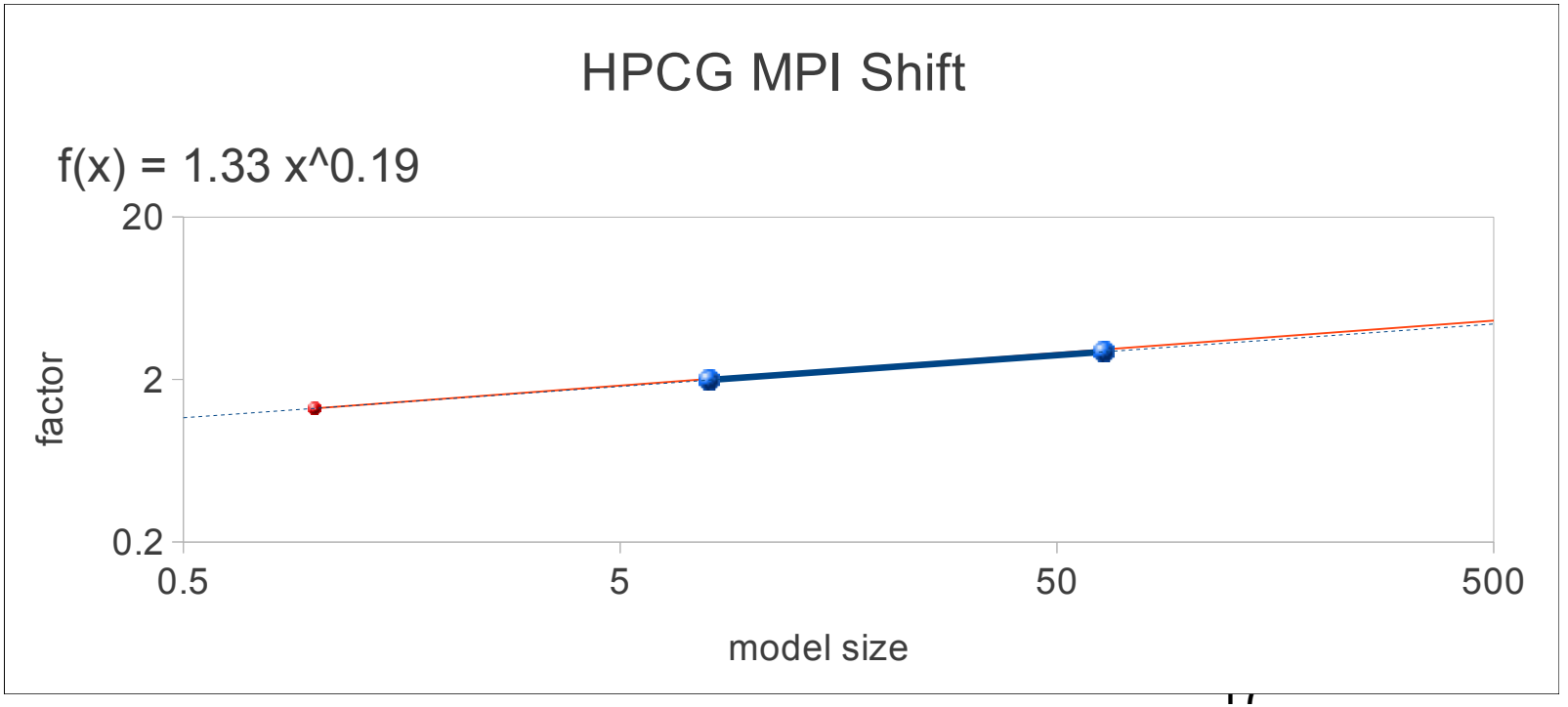
Time Shift Effect with MI in HPCG

- Inter-process communication between processes
- Tr



Extrapolation of Time Shift Effect

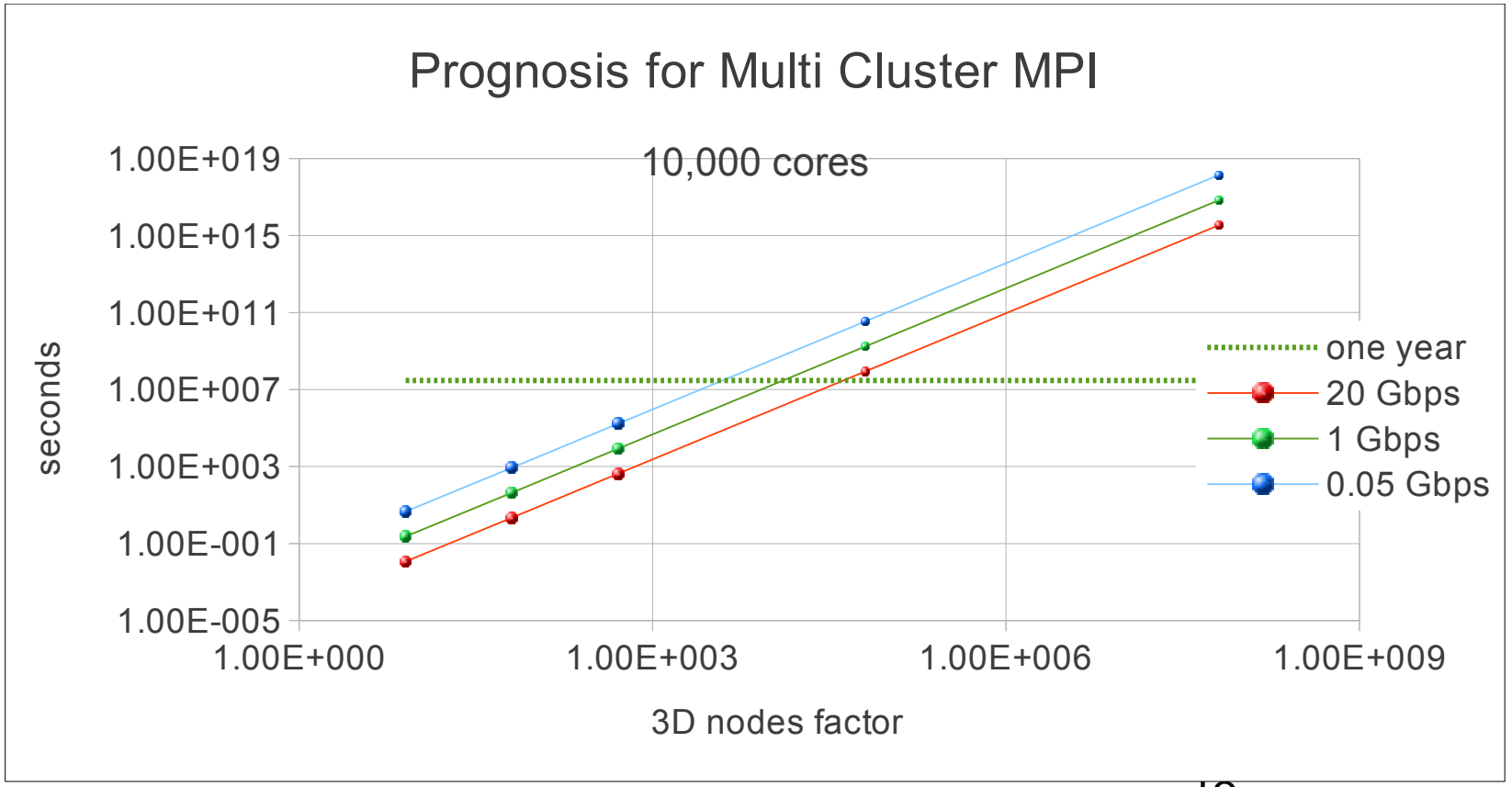
- Inter-process communication between processes
  - Case of HPCG: 20 Gbps
  - Time shift factor ~ 1.33x^0.19
    - X = model size factor



Extrapolation of Time Bottleneck

Extrapolated time bottleneck from HPCG data

time_delay = 26.2 (nodes^0.2) / bus_bandwidth



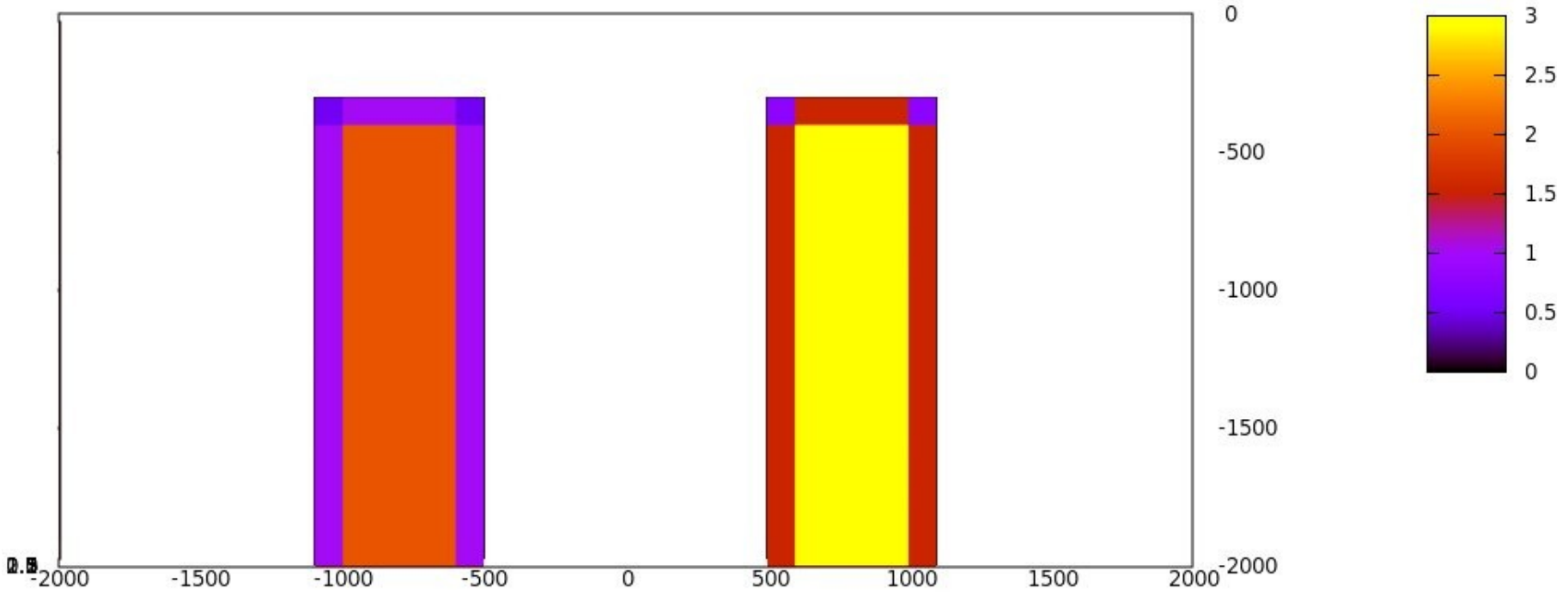
Extrapolation Conclusions

- Interprocess communication in each iteration penalizes the time-reduction effect from increase of cores in a multi-cluster system
- Inversion of huge models (alias metric scale) requires multi-years of runtime
- Applicability for regional studies
  - New tricks necessary for engineering works

Geophysical Correctness – Model

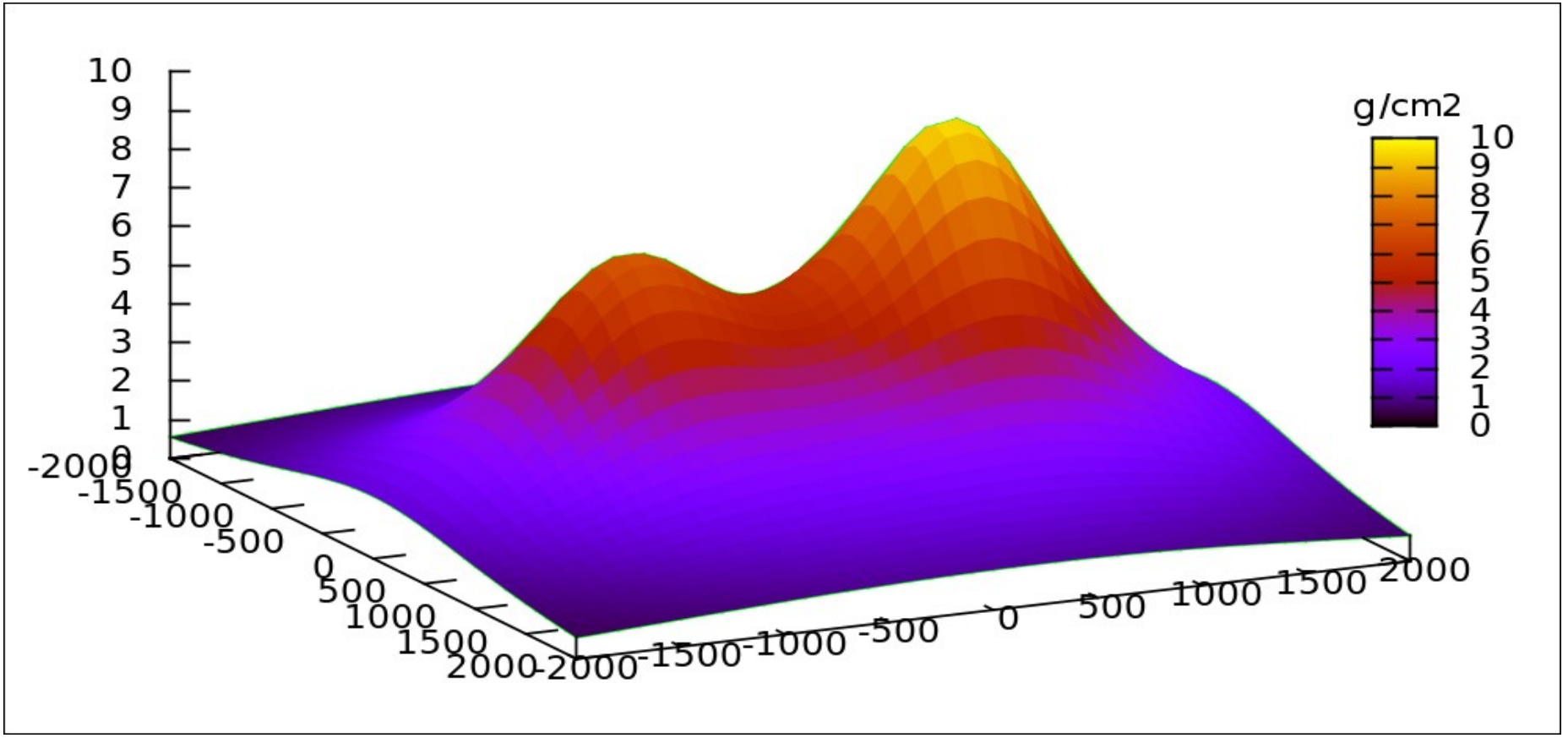
Case of one body – OK

Case of two bodies ???



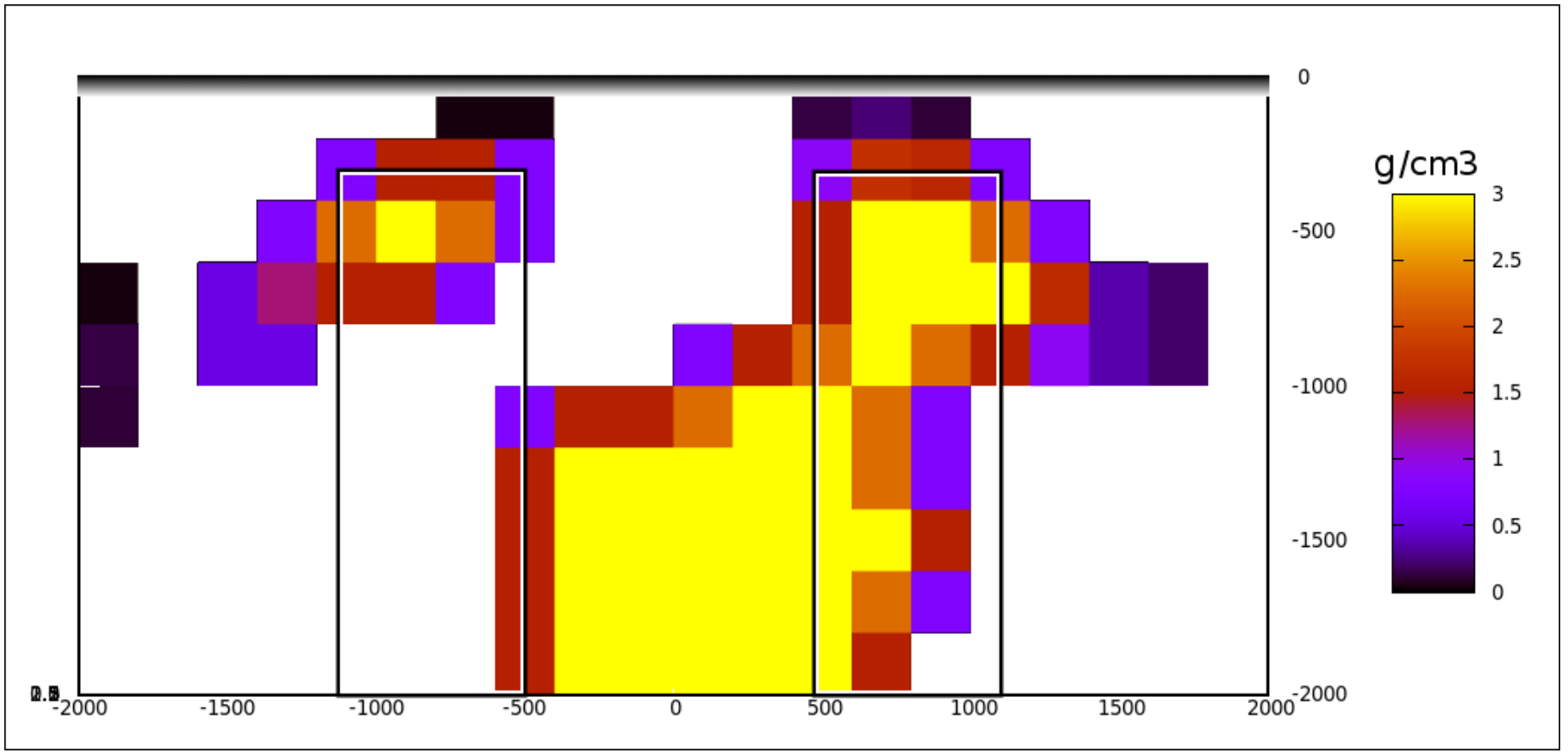
Geophysical Correctness – Anomaly

A bi-modal anomaly



Geophysical Correctness - Inversion

"*Micky Mouse*"



Geophysical Correctness - Meaning

Intuitively correct interpretation for ill-posed problem

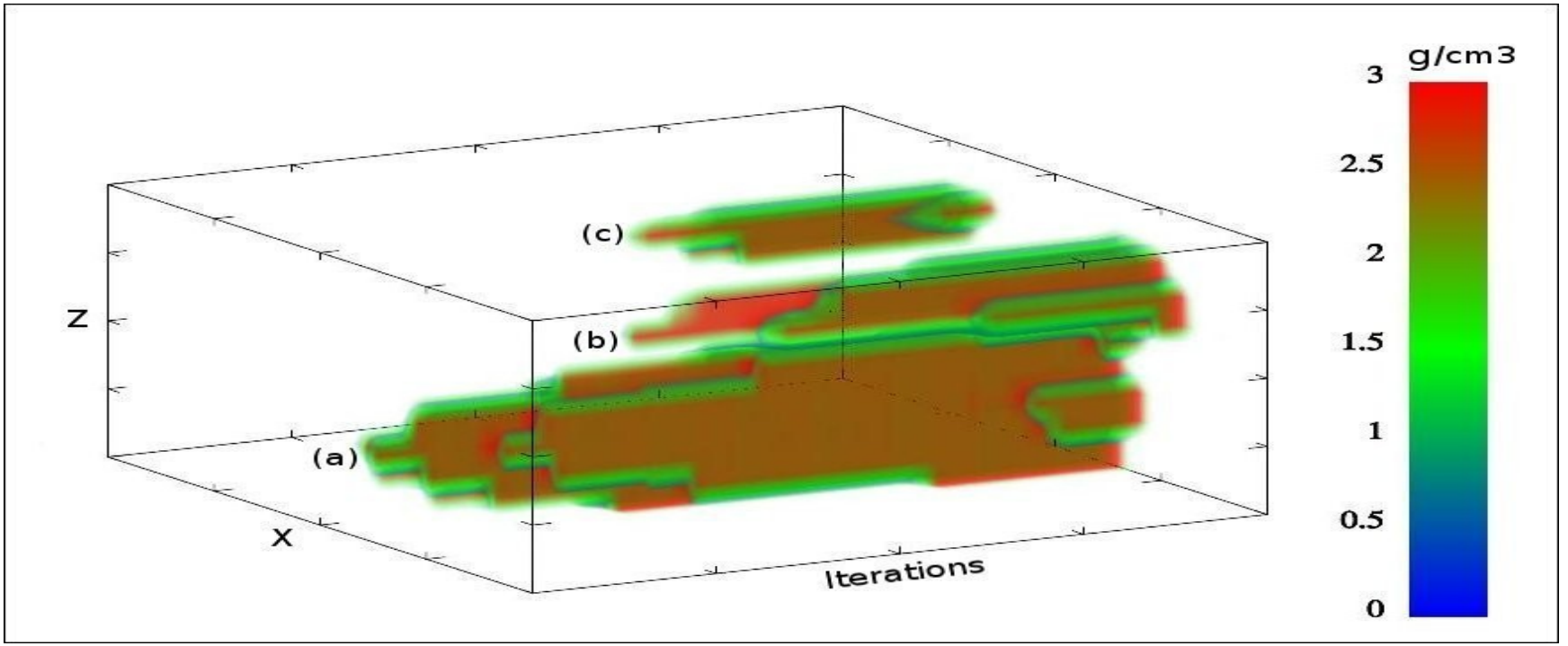


Fig. Development of central anomalous geostructure cross-section by Iterations

Tasks for the Future

- Experimentation of Monte–Carlo for delineation of initial multi–bodies solution
- Experimentation in GPU combined with MPI

Thank You

Q & A